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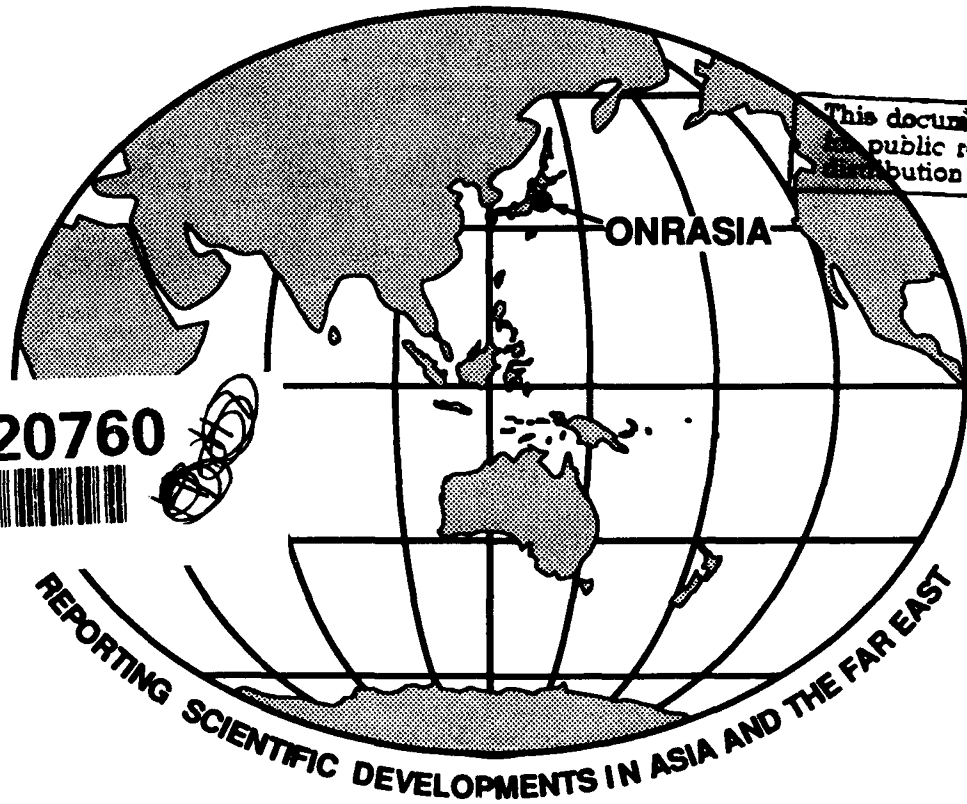

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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONRASIA, with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest. This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large. It is available free of charge to approved members of the DoD scientific community. Send written request describing DoD affiliation to: Director, Office of Naval Research, Asian Office, Unit 45002, APO AP 96337-0007.

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Scientific Information Briefs

Preliminary Benchmark Figures from Hitachi S3800 and NAL Numerical Wind Tunnel, 23 July 1993

This week, 19-23 July 1993, the Association for Computing Machinery (ACM) International Conference on Supercomputing and the Workshop on Benchmarking and Performance Evaluation in High-Performance Computing were held at Waseda University, in central Tokyo. There were many western attendees, and several have agreed to help write detailed summaries of the two meetings. I hope that these will be available in August 1993. This short note is to alert readers, and to provide a few data points about two Japanese computers, which might be of general interest.

Professor Y. Oyanagi reported joint work with W.F. Wong and E. Goto on the result of running six benchmarking problems on the new Hitachi S3800, which was recently installed at the computer center at the University of Tokyo. I have reported on this machine earlier. It is a four processor, 2ns, 32 GFLOP (4 X 8 GLOP) successor to Hitachi's S820 series supercomputer, and has been up at the University of Tokyo since the early spring of 1993. Oyanagi and colleagues studied the following algorithms.

- Congruential random number generator (both portable and vendor provided versions),
- Elementary functions (provided by the vendor),
- FFT (source from Numerical Recipies),
- Dense matrix operations (Livermore loops, Linpack, and Householder transformations),
- 3-D Nearest Neighbor (rule-specified) matrix operations,
- List-vector operations.

Some detailed tables are provided in their paper; other data were shown during the presentation. Oyanagi emphasized that many of their results were quite preliminary, and needed further checking and tuning. (There was a discussion as to whether better algorithms might be available for random numbers and FFT.)

In the case of Linpack, the 100 X 100 figures are 394 MFLOPs for one processor (there is no multiprocessor data available yet), and 5.7 GFLOPs for "best effort." The latter is a new single processor record, but as a percentage of the S3800's 8 GFLOP peak, it is lower than might be expected. Oyanagi speculates that somewhat more than 6 GFLOPs should be possible with more tuning.

CFD benchmarks on the National Aerospace Laboratory's Numerical Wind Tunnel were presented in a paper by T. Iwamiya and M. Fukuda. Two CFD programs were tested, NS3D (a NS solver without turbulence by using TDV and IAF), and TVDSD (which includes algebraic turbulence), and also FFT3DX, which executes three univariate FFTs, and a great deal of data movement. For NS3D they report 108 GFLOPs with 128 PEs on a 64 X 128 X 128 grid, and 116 GFLOPs with 140 PEs on a 512 X 420 X 280 grid; the latter is reported as about 190 times the speed of a Fujitsu VP400. TVDSD, which is used to simulate viscous flow around an aircraft has a significant amount of data transfer, so the authors do not report floating point performance, but actual running time; 18 min for 2000 iterations on 50 PEs with a 1001 X 100 X 50 grid, 37 min for 2000 iterations on 100 PEs with a 1001 X 100 X 100 grid. They estimate that the 5 million point problem would have run for about 50 h on the VP400 if that machine had sufficient memory (it does not). For FFT3DX, communication time is the dominant performance limiter, a 512^3 computation is done in about 0.3 sec on 128 PEs.

Dongarra reports that the NWT "best effort" figures are 112 GFLOPs with 128 PEs (Nmax=27600), and 124 GFLOPs with 140 PEs (Nmax=31900); the figures presented by Iwamiya and Fukuda are consistent with these data. -- *David K. Kahaner, ONRASIA*

*****

Third International Conference on Artificial Reality and Tele-existence (ICAT), 6-7 July 1993, Tokyo, Japan

This report on ICAT '93 was submitted by:

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Readers of the following report are forewarned that the article has been written by someone who did not actually attend the meeting. The report was written after discussions with a limited number of attendees. A second note of caution: this is an English report on Japanese reports about a workshop held in English here in Japan. In short, facts and details about the workshop have been passed through several unusual filters so that the output may be slightly distorted or skewed in perspective. Many thanks to Dr. David Kahaner for his kind words of encouragement, "epsilon.gt.0"; indeed I hope that this limited report is better than none. [Readers may want to review last year's conference, "icat.92", 5 Aug 1992, DKK.]

The report consists of four sections:

- Administrative Information and Conference Program
- ICAT '93 Proceedings: Table of Contents
- ICAT '93 Video (review and comparison with the video: Virtual Reality '93 (JTTAS))
- Impressions and Tidbits on the Conference

Official papers and documentation will be covered in the following parts 1 and 2. I will pretty much limit discussion in parts 3 and 4 to impressions and trends sensed by attendees rather than technical details. Interested readers are requested to directly contact speakers and/or the organizing committee regarding purchases of the proceedings, technical content, and details.

1. Administrative Information and Conference Program

Sponsors:
- Japan Technology Transfer Association JTTAS)
  2-11-2 Nagata-cho, Chiyoda-ku, Tokyo 100
  Japan
  Tel:03-3597-8220; Fax:3597-8224
- The Society of Instrument and Control Engineers
- Nihon Keizai Shimbun, Inc.

Organizing Chair:
Prof. Susumu Tachi,
RCAST, University of Tokyo
Research Center for Advanced Science and Technology (RCAST)

Organizing Co-Chair:
Prof. Michitaka Hirose, University of Tokyo

International Organizing Committee:
Steve Ellis, NASA Ames Research Center
Yukio Fukui, Agency of Industrial Science and Technology (AIST), MITI
Hiroshi Harashima, University of Tokyo
Toyohiko Hatada, Tokyo Inst. Polytechnics
Katsura Hattori, Asahi Shimbun
Takayuki Itoh, NHK
Hiroo Iwata, Univ. of Tsukuba
Robert Jacobson, World Design, Inc.
Myron W. Krueger, Artificial Reality Corp.
Carl Loeffler, Carnegie Mellon Univ.
Taro Maeda, Univ. of Tokyo
Ryo Mochizuki, Media Int'l Corp.
Warren Robinett, Univ. of N. Carolina
Makoto Sato, Tokyo Inst. of Technology
Thomas B. Sheridan, MIT
Robert Stone, Nat'l Advanced Robotics
Gen Suzuki, NTT Human Interface Laboratory
Haruo Takemura, ATR Communication Systems Research Laboratory
David Traub, Compec

I have not listed the program since it is a subset of the table of contents of the Proceedings given below. The conference consisted of two days of talks, demos, and a panel discussion with lunch and coffee breaks, breaks at comfortably spaced intervals. Keynote lectures by Loeffler (7/6), Harashima (7/7), and Ellis (7/7) kicked off both days of the meeting. General talks were given in three technical sessions:

- Virtual Reality Communication and Control,
- Virtual Environment Construction,
- Force Display and Shape Modeling.

In addition to the technical program, there was the first Inter Collegiate Virtual Reality Contest (ICVRC '93) and a Beer Party on the evening of the 6th. A high registration fee and length (2 weekdays) were enough to make corporate managers think carefully about the number of researchers to send to the meeting. One estimate put the number of attendees at somewhat over 100.

2. ICAT '93 Proceedings: Table of Contents

Marks:

K = Keynote Speech
1 = Technical Session I: Virtual Reality Communication and Control
2 = Technical Session II: Virtual Environment Construction
3 = Technical Session III: Force Display and Shape Modeling
O = Other Papers without Presentation

I find the Proceedings to be an excellent and interesting source of information. It is not a real book; it is a set of photocopies of A4-size papers, which have been heat-bound. (Note: SIAM Japan and other Japanese organizations use the same type of binding.)

3. ICAT '93 Video (review and comparison with the video: Virtual Reality '93 (JTTAS))

In addition to the proceedings, the conference package contained a video of some of the VR, Tele-existence and artificial life systems described in the papers. Some of the topics overlap with those that appear in the video: VIRTUAL REALITY '93 (VR '93) distributed by the Japan Technology Transfer Association. Although the clips from the two videos emphasize different aspects in the same laboratories, they are similar enough to make one regret the purchase of both. The contents of both are compared and outlined below.

ICAT '93 Video:

The ICAT '93 video is, as advertised, a video supplement to the usual printed proceedings. It shows the movements and inner workings of some of the tools described in the papers, and is a valuable plus to the reader. The quality of the clips in the ICAT '93 video however vary quite a bit. At the risk of sounding overly critical and somewhat disrespectful, I offer the following notes of caution (for those who may be contemplating a purchase):

- Clips 1, 2, and 5 are too long and could use some streamlining and/or editing.
- Some clips suffer from poor audio recording.
- All of the narrations may be a little difficult to understand by those who are not used to listening to non-native speakers.
- Although the music in the fourth clip helps to pick up the pace, it becomes very distracting when combined with an Indian accent.

Contents: ICAT '93, Video Proceedings (About 18 min)

1. Susumu Tachi, Kenichi Yasuda (RCAST, Univ. of Tokyo)
   Evaluation Experiments of Tele-Existence Manipulation System (narration by Japanese male)
   Tele-existence is defined and a method for quantitative comparison of tele-existence systems is proposed. The ability to complete tasks under different operating conditions is studied. Results are listed below in order from best to worst.

   - Binocular (Stereo) Vision + Head Mount Display (HMD)
   - Non-stereo (1-Camera) Vision + HMD
   - Robot Mounted Camera, no HMD
   - Outside (Remote) Camera, no HMD

   The ability of Robots to handle complex situations, e.g., moving fragile objects (eggs) is shown. (Note: Same system appears in VR '93 video, similar egg scenario)

2. Hiroo Iwata, Hiroaki Yano
   (Institute for Engineering Mechanics, Univ. of Tsukuba)
   Artificial Life in Haptic Virtual Environment (no narration)

   Artificial life is illustrated through the example: plant growth.
   Contents: Examples of growth and reversal of plants
   Examples of modified ramification frequency branching
   Chopping off branches by user

3. Juli Yamashita, Yukio Fukui
   (National Institute Bioscience and Human Technology, AIST, MITI)
   A Direct Deformation Method of Free Forms for CAD Interface (narration by Japanese female)

   The clip shows how DDM methods and tools may be used by direct manipulation, freeing the user from mathematical details. Close-up/zoom and reduction features are also demonstrated. Future work on DDM + 3-D input devices is discussed using a 3-D wire-mesh graph.
   (Note: Same system appears in VR '93 video)

4. Masahiro Ishii, Makoto Sato
   (Precision and Intelligence Lab., Tokyo Inst. of Technology)
   A 3-D Interface Device with Force Feedback for Pick-and-Place Tasks
   (narration by Indian male)

The SPIDAR systems are shown.
(Note: Same system appears in VR '93 video)

5. Martin Buss, Hideki Hashimoto
(Inst. of Industrial Science, Univ. of Tokyo)
Intelligent Cooperative Manipulation Using Dynamic Force Simulator
(narration by Japanese female)

Shows how robot hand is trained in two phases:
1. Skill acquisition phase: a human manipulates a hand with sensors and the movements are recorded.
2. Skill transfer phase: the movements recorded in phase 1 are transferred to a robotic hand. The results appear on a CG screen.

Virtual Reality (VR)'93 Video:

VR '93 consists of short interviews with professors managing the laboratory followed by narrations describing various tools in the laboratories. It is more of a tutorial and/or a show (e.g., a Carl Sagan drama or NOVA episode) than a scientific research document. There is no hardcopy documentation or even a pamphlet to accompany the tape. Again, at the risk of sounding overly critical and/or disrespectful, I noted that most scientifically inclined viewers seemed to find the first few chapters of VR '93 to be excessively long, drawn-out, and uninspiring. Many felt that the interesting material could have been covered in about 10 min; something to keep in mind when considering the purchase of this video. VR '93 is distributed by JTTAS and is expensive: Japan¥10T (covers postage and delivery for domestic orders, i.e., within Japan.) Details about costs for postage and handling for overseas orders may be discussed on a case-by-case basis via surface mail or FAX with Mr. Hara at:

Japan Technology Transfer Association (JTTAS)
2-11-2 Nagata-cho, Chiyoda-ku, Tokyo 100 Japan
Tel: 03-3597-8220;
Fax: 3597-8224

Please note that the JTTAS recently moved to a new location so that the address and numbers are different from those posted in a recent information bulletin by Dr. Kahaner ("vr-video.93", 25 May 1993.) Phone inquiries should be made in Japanese.

If your inquiries elicit no response, please note my experience: it took me four phone calls and three fax promises over a six week period to obtain a copy of VR '93. I then received a double billing.

Contents: Virtual Reality '93, Vol. 1 (30 min)

Introduction (00:00-00.30)

Chapter 1 (00.30-06:43) Prof. Michitaka Hirose, Dept. of Mechano-Informatics, University of Tokyo

Contents: introduction to VR devices, e.g., virtual dome, see-through HMDs, force feedback, air flow display, handling objects in virtual space

Chapter 2 (06:44-11.12) Dr. Makoto Sato, Precision Machinery and Electronics, Tokyo Inst. of Technology

SPIDAR, SPIDAR III, POWER SPIDAR systems are shown.
(Note: Same system appears in ICAT '93 video)

Chapter 3 (11.13-16:37) Dr. Hiroo Iwata Inst. of Engineering Mechanics, Tsukuba University

A desk-top and desk-side force display, a texture display, and a walk-through simulator are shown. It is puzzling that the walkthrough system actually requires a person to walk on an exercisetype machine when a simpler device, e.g., a mouse could be used for input.

(Note: Hiroo contributed Haptic Life clip to ICAT'93 video)

Chapter 4 (16:38-21:04) Dr. Yukio Fukui Info. Factors Laboratory, Human Environment Systems Dept., AIST, MITI

A force-feedback device using an XY recorder, a system for direct manipulation of form & curved lines and surfaces, a multimodal integrative mouse, and sensor glove are shown.

Chapter 5 (21.05-30:00) RCAST, University of Tokyo
Contents: a clip on a tele-existence mater-slave

system a clip on tele-existence in a virtual environment
(Note: Same system as in ICAT '93 video, same example with egg.)

4. Impressions and Tidbits on the Conference.

The two topics that dominated the conference were: Virtual Reality and tele-existence. Most of the material could be classified as either software or hardware (robot, input or display). The tele-existence category pretty much equalled Tachi's work. The video clips are indispensable to fully appreciate the research at RCAST. Regarding the hardware: the input device category was dominated by the Japanese with their haptic, camera, and wand devices. Again, they are best described through their video clips rather than by text. Unfortunately, one that does not appear is the wand, a magic device that allows the user to create a world with a flick of a switch. A poetic researcher commented, "wand-do de pick-ku shite, VR no sekai ni ire-te--iku". In the display category, three head-mounts were presented: EyeGen3, SONY Vizer Tron, and Olympus. All claimed to have 370,000 pixels and a 30° view range. I only received feedback on the EyeGen3 and SONY devices. The 30° angle seems to be too small to give the user a feeling of being immersed in a different world. The EyeGen3 system had a poor screen image and was slow in reacting to movements. SONY VT had a better screen image and faster response time.

CMU's Distributed VR presentation was appreciated by the Japanese as a realistic and inexpensive idea. ATR presented an interesting Virtual Space Teleconferencing System (all Japanese Denki-makers seem to be developing or trying to develop one.)

Ellis's investigations on the head movements (3° of freedom with a 60° range) inspired some interesting informal discussions after the conference. Will the results of the study only be relevant to Americans? Are there body-size, cultural or racial differences in movements? Harashima's work on facial expressions was also well received, even by some skeptic-types.

Although the hardware experts revealed a number of interesting tools and gadgets, software undoubtedly stole the show. Michael Zyda's real--time graphics game dazzled the attendees, including our local graphics experts at IBM. For those lucky graphics and war game buffs who plan to attend this summer's SIGGRAPH, rumor has it that Zyda will have a demo booth in sunny Anaheim. The game lives in a set of high end Silicon Graphics Systems and allows up to 500 players to shoot at each other. Here in Japan, where unusually high proportions of children and adults love amusement parks, pachinko parlors, and video games, it was not surprising that a heated discussion on business opportunities with a modified version of Zyda's system began during a coffee break. One clever Japanese corporate manager noted that the profits from a DoD start-up venture might be used to eliminate the U.S. deficit. Discussion about the game also inspired scientists to dream up new approaches to many new problems for connecting 10,000 players (or more!) in one system. For instance, the development of an efficient message passing mechanism, and space alone poses challenging new questions. Seamless, or real-time display without delay or hesitation poses another challenge.

Panel Discussion: (with Ellis, Hirose, Tachi, Zyda, Iwata)

Listed below are some tidbits from attendees,

- Ellis commented that VR is not a completely new subject; studies on the relationships between man and machine have been developing over many years. Costs and benefits of VR technologies will undoubtedly influence and will be influenced by potential applications.
- Hirose commented that the introduction of powerful and inexpensive systems, such as the US$5T IRIS system to be introduced next month in Japan, will open new doorways for the imagination. Young and small users will likely conjure up breathtaking new and innovative applications.
- Zyda's game as well as administrative abilities impressed one attendee who noted that Zyda serves on the National Academy of Sciences committee on Virtual Reality. His key words: Hypermedia, Info. Node and Warp also seem to have caught people's imagination.

Perhaps the Japanese are all too familiar with Iwata and Tachi to have been left with a powerful new impression after the panel discussion. An interview with a foreign attendee would undoubtedly have given an interesting and different view of the same panel discussion. -- *Dr. Mei Kobayashi, IBM Tpkyo, Japan.*

*****

Higuchi's Laboratory at Tohoku University (Sendai), Multivalued Logic Chips, 20 May 1993

As part of a visit to the city of Sendai to see a demonstration of their fuzzy-controlled subway system ("fuzzy5.93", to be released soon), I visited the laboratory of Tatsuo Higuchi at Tohoku University.

Sendai is 350 km north of Tokyo (2 hours by fast train) on the Pacific coast. It is a lovely city of about 900,000 population with many trees and other greenery. Many Japanese and Westerners alike prefer it to the more congested cities of Tokyo, Osaka, etc., and also prefer its climate, which is similar to that in New England. Sendai is the site of Tohoku University, one of Japan's National Universities. It was founded in 1907 as the Tohoku Imperial University with 5,200 faculty and staff, and about 13,000 students of which 550 are foreign students and 100 foreign researchers on five campuses. This report makes no attempt to summarize the university research, but it focuses only on one specific laboratory.

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On the day of our visit, Prof. Higuchi was unavailable. Our host was Prof Masayuki Kawamata (KAWAMATA@HIGUCHI.ECEI.TOHOKU.AC.JP).

I was accompanied by:

Dr. Michael F. Griffin
Visiting Researcher, Dept. of Systems Science, Tokyo Inst. of Tech. and also with United Technology Research Center in the United States of America,
Dr. Anca Ralescu
Laboratory for Internat Research in Fuzzy Engineering (LIFE), Yokohama, and also the Univ. of Cincinnati,
Prof. Hung Nguyen
Tokyo Inst. of Technology
and also New Mexico State University.

This report is jointly authored by the scientists listed above and myself.

We visited the Electronic Control Systems (ECS) Laboratory at Tohoku University in Sendai, Japan, to assess the status of Professor Higuchi's research in Multiple-Valued Logic (MVL). Members of this laboratory, led by Professor Tatsuo Higuchi, include Associate Professors Tatsuo Uchida and Michitaka Kawamata, a Research Associate Shoji Kawahito, and approximately 20 graduate students. Professor Higuchi and his group are internationally recognized for their work in multiple-valued logic.

MVL research at ECS is one of four major research areas titled "Post-Binary Electronics." The other three are "Robot Electronics," "Ultra Highly Parallel VLSI System," and "Physical Characteristics of Liquid Crystals and Their Applications." During the visit, however, Professor Kawamata and one of his graduate students discussed and demonstrated only their work in MVL and Multidimensional Digital Signal Processing (M-DSP). It wasn't clear, however, under which category M-DSP belongs.

The robot electronics research area includes the study of practical high-performance VLSI processors for visual information processing, path planning, coordinate transformations, and digital control. In addition to MVL, Post-Binary Electronics research area includes bimolecular computing research. Ultra Highly Parallel VLSI System research area focuses on highly parallel VLSI systems based on neural network algorithms and distributed cellular hardware algorithms for fault tolerance. Finally, the research in physical characteristics of liquid crystals focuses on new ferroelectric liquid crystals and side chain liquid crystal polymers for high-quality color displays, 3-D displays, high-speed optoelectronic devices, optical parallel logic devices, and highly stable and high-density optical memory devices.

The main idea for using MVL is to design chips with more high-speed arithmetic logic units (ALUs) than currently possible. Adding ALUs using current (binary) technology increases the number of interconnections and associated complexity. Chip size and performance are increasingly related to wiring, and pins, rather than to devices. MVL, in principle, can provide a means of increasing data processing capability per unit chip area. The basic idea is very simple and certainly not new (IEEE already had a technical committee on MVL in the 1980s). Rather than using traditional voltage states (hi, low) for representing information, MVL uses current levels for digit values, and current flow direction for digit sign, e.g., multiple level signals are used inside the chip for internal encoding of the data, and is transparent to the user. (Thus the term bidirectional, current mode circuits.) For such circuits to be effective, not only must they be fabricated to be reliable and economical, but also arithmetic algorithms need to be developed to take advantage of them, in the same sense that binary arithmetic is specific to traditional binary circuits. (Binary arithmetic is much more troublesome than decimal for people, primarily because of the large number of digits places needed to represent numbers.)

One approach to making use of MVL is to use higher-radix number systems. There is a variety of possibilities such as ordinary weighted, symmetrically weighted, signed digit, and symmetrical residue number systems. (Residue arithmetic for computer applications dates at least to the 1960s. It represents a technique by which computation time of common arithmetic operations in a signed number system can be reduced by representing a large integer as several smaller integers where arithmetic on each smaller integer is independent of each other. The final integer result is obtained from the individual parts by use of the Chinese Remainder Theorem. Because of the lack of "carries", residue arithmetic is highly parallel; it is also inherently fault tolerant.) Professor Higuchi's group has designed and fabricated several chips using current-mode MVL. One such chip is a 32x32-bit signed digit multiplier fabricated in CMOS. Another chip that the laboratory has designed is a modulo 7 residue arithmetic adder. Work at the laboratory on MVL has been going on since the early 1980s, with at least one chip fabricated in 1984. The key to success of this approach will clearly be the cost; however I am not knowledgeable about device fabrication to comment on this aspect.

Another generalization of MVL is to Set Valued Logic (SVL), which is being studied for bimolecular computing. The researchers on this project, however, were not available during our visit, so we simply make a few general comments here. The laboratory has been working on bimolecular switching devices based on the use of enzymes and their specificity in their choice of reactants (substrates). In this model, reactants are broadcast (in solution) from a source. They diffuse with random molecular motion and carry information by their presence or absence in solution. At a destination site, an enzyme-based biosensor selectively detects the released substrates and then triggers a specific bimolecular switch in the solution. In a sense this data transmission is interconnection-free. Because such bimolecular data transmissions are slow, they cannot compete with electronic systems (which are orders of magnitude faster) in this regard. But they are highly parallel, because enzymes are highly specific and spatially configured to fit the appropriate substrate exactly (like a key in a lock) and operate almost independently of each other. Due to this selectivity, enzymes can serve as switches that can recognize specific molecular information. Building a logical system from these ideas depends upon the fact that set-theoretic union [illegible]ial to implement by simple mixing corresp[illegible] substrates in solution. SVL realizes pr[illegible]ct-type functions (intersections) by designing a basic building block as an inhibitor, i.e., a device that generates molecules if it does not detect specific molecules. A very well written paper (in English) by the Sendai group on this topic describes a potential image processing system using these ideas (see referenc[illegible] below).

Professor Kawamata is also quite interested in the digital signal processing and M-DSP, in particular. His current research is in the design of multidimensional digital filters for HDTV and image processing applications. He is currently interested in the design of a M-DSP filter using Genetic Algorithms (GAs). His students demonstrated a GA designed filter where only the magnitude response was of interest. To design a 1-D digital filter with as close to ideal passband characteristics, the GA algorithm required 24 h of compute time on a SUN workstation. A 2-D digital filter with approximately 2Oth-order finite impulse response passband characteristics took approximately three days to be executed on the SUN. When asked why they didn't use the University's supercomputer for processing, they said it was too expensive. The Institute for Materials Research at Tohoku University is the likely site for a new supercomputer, so perhaps some of Kawamata's models can be run there in the future. (The University Computing Center currently has a NEC SX/3, and the University's Institute of Fluid Science has a Cray Y-MP8.)

Kawamata and his students have built a 32-processor systolic array for image processing algorithms. Each of the processor boards are approximately 2 ft^2, and are separated by 1 in. A NEC personal computer serves as the host machine.

There is also work going on in the laboratory on parallel computing using optical wavelength multiplexing, and an optical half adder as well as complement gate have been implemented in prototype form (see reference below).

Professor Higuchi in cooperation with Tohoku University are sponsoring the 1993 IEEE International Workshop on Intelligent Signal Processing and Communication Systems, scheduled for October 27-29, 1993 in Sendai, Japan. For more information contact Kawamata at the address given above. -- *David K. Kahaner, ONRASIA*

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Japanese Databases (in English) Associated With S&T in Asia, 7 June 1993

The following is a list of some Japanese databases giving access to information about science, technology, and economics in Asia, but mostly concerning Japan. No attempt is made to be complete, but I would appreciate information from readers on missing services.

Name: ASAHI
Type: Full-text, newspaper
Subject: News, general
Producer: Asahi Shimbun,
Asahi Evening News Editorial Dept.,
3-2, 5-chome, Tsukiji,
Chuo-ku, Tokyo, 105, Japan
Tel:+81 3 5540-7641;
Fax:+81 3 3542-6172
Language: English
Content: The Asahi News Service is produced by a special editorial team of the Asahi Shimbun, Tokyo's leading daily newspaper. Each day, from Monday to Friday, some half dozen articles of international interest are selected and translated from Asahi Shimbun or edited from its sister publication, the English-language Asahi Evening News. These articles are transmitted as a newswire for publication in other parts of the world. The file carries the full text of each day's newswire transmission, with headlines added by PROFILE. About seven to eight items are added each day. Stories are normally on-line 24 hours after transmission. The file covers events in Japan and the Far East, with particular emphasis on Japanese policy and international relations, trade, telecommunications, computers, electronics, pharmaceuticals, medicine, and agriculture.
Sources: ASAHI SHIMBUN, ASAHI EVENING NEWS
Time Span: 1982/08-present
Updates: Daily

Name: JAPIO
Type: Bibliographic
Subject: Patents
Producer: Japan Patent Information Organization,
Bansui Bldg., 1-5-16, Toranomon,
Minato-ku,Tokyo 105, Japan
Tel:+81 3 3503-6181;
Fax:+81 3 3580-7164
Language: English
Content: Contains citations, with abstracts, to more than two million unexamined Japanese patents.
Sources: PUBLISHED UNEXAMINED PATENT APPLICATION
Time Span: October 1976 to present
Updates: Monthly

Name: JAPINFO
Type: Full-text
Subject: S&T
Producer: Eurobrokers Sarl,
BP 2761, L-1027 Luxembourg;
Tel:+352-439097;
Fax:+352-433259
Language: English
Content: Information on a wide range of Japanese S&T fields including electronics, communications, biology, biotechnology, engineering, energy, aerospace, automotive industry, and computer science.
Sources: Unspecified
Time Span: Unspecified
Updates: Unspecified

Name: JAPI (JAPINFO Japanese Information on S&T Topics)
Type: Bibliographic, abstracts
Subject: S&T
Producer: Eurobrokers Sarl,
BP 2761, L-1027 Luxembourg;
Tel:+352-439097;
Fax:+352-433259
Language: English
Content: JAPINFO presents Japanese S&T information translated into English. It provides abstracts

of high-level S&T "gray literature" published in Japan. Abstracts are produced by automatic translation.

Sources: Over 80 sources, including: Institute of Electronics Information and Communication Engineering; Laboratory of Nuclear Science; Institute of Space and Astronautical Science; National Research Institute for Metals; Science and Technology

Time Span: 1987-present

Updates: Monthly

Name: JGRIP

Type: Bibliographic

Subject: S&T

Producer: Japanese Science Information Center, 2-5-2, Nagata-cho, Chiyoda-ku, Tokyo 100, Japan Tel:+81 3 3581-6411; Fax:+81 3 3593-3375

Language: English

Content: Ongoing and completed S&T projects carried out by government-supported research organizations.

Sources: Annual surveys

Time Span: 1990-present

Updates: Annually

Name: JICST

Type: Bibliographic

Subject: S&T

Producer: Japanese Science Information Center, 2-5-2, Nagata-cho, Chiyoda-ku, Tokyo 100, Japan Tel:+81 3 3581-6411; Fax:+81 3 3593-3375

Language: English

Content: Information on scientific R&D carried out in Japan.

Sources: Japanese government documents, journals, periodicals, dissertations.

Time Span: 1985-present

Updates: Biweekly

Name: JPCO (COMLINE JAPANESE CORPORATE DIRECTORY)

Type: Directory, profiles

Subject: Company, biotechnology, advanced materials

Producer: COMLINE Business Data, 1-12-5, Hamamatsu-cho, Minato-ku, Tokyo 105, Japan Tel:+81 3 5401-4567; Fax:+81 3 5401-2345

Language: English

Content: JPCO is a directory of companies in the chemical and materials, biotechnology, medical technology and pharmaceutical industries of Japan. It includes every Japanese company quoted on the Japanese Stock Exchange and information on the computing, electronics, telecommunications, transport and industrial automation industries is in preparation. Company listings are enhanced with detailed description, product range, and SIC-code information. Company information in the directory is complemented by daily-updated business and industrial news on-line in the Japanese newswire service JPNW.

Sources: Verified direct information from companies and ministries.

Time Span: Unspecified

Updates: Monthly

Name: JPNW (JAPAN NEWS WIRE: COMLINE)

Type: Bibliographic, abstracts

Subject: Business, S&T, mechanical engineering, telecommunications, environment

Producer: COMLINE Business Data, 1-12-5, Hamamatsu-cho, Minato-ku, Tokyo 105, Japan Tel:+81 3 5401-4567; Fax:+81 3 5401-2345

Language: English

Content: JPNW provides detailed information on corporate, industrial, financial, economic affairs as well as information on high-technology developments and research and development. JAPAN NEWS WIRE is the only English language daily business and technical news service from Japan. Subjects covered include: electronics, physics, computers, telecommunications, industrial automation, transportation, agriculture, environment, economy, defense, and construction.

Sources: Thirty major Japanese financial and industrial newspapers, and 60 trade journals

Time Span: 1986-present

Updates: Daily

Name: KYOP (Kyodo News Service)

Type: Full-text, press agency

Subject: News, general, business
Producer: Kyodo News Service Kaigai-Bu, 2-2-5 Toranomon, Minato-ku, Tokyo 105, Japan Tel:+81 3 3584-4111; Fax:+81 3 3505-6630
Language: English
Content: This is the English-language edition of Japan's news wire service. KYOP concentrates on Japanese business and financial data, e.g., stock market news, investment reports, company intelligence, new products, industry and product performance figures, etc. It covers developments in computers, robotics, biotechnology, and other high-tech industries, as well as government policies and decision making.
Source: Kyodo News Wire articles
Time Span: 1986/06-present
Updates: Daily -- *David K. Kahaner, ONRASIA*

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Computer Related Activities at Nippon Kokan Company-Nippon Steel Tubing (NKK), 30 September 1993

In a recent report ("commp.93" 14 Sept 1993) I commented that Japanese steel companies, which are among the world's largest, have considerable expertise in computing because of their heavy investment in automating steel plants. But steel is seen as an industry that is not going to experience significant growth during the next few decades. At the same time, computing, or generally more information technology, is viewed as a growth industry. Thus it is natural that steel companies, trying to capitalize on their strength in people, would make every effort to move into computer related fields. One general evidence of this trend is the fact that among the dozen or so current partners of Japan's Real World Computing Partnership, one finds the Japan Iron and Steel Foundation along with more expected participants such as NEC and Hitachi. This is clearly seen more as a learning activity than anything else, but it indicates the level of commitment to this technology.

It was with this in mind that I visited NKK's research laboratories south of Tokyo. What follows is a brief overview of NKK's general research situation in outline form, and then in more detail about their computer research.

My host at NKK was:

Dr. Chiaki Ouchi
General Manager, No.1 Materials Research Dept.
Materials & Processing Research Center
NKK Corp.
1-1 Minamiwatarida-cho
Kawasaki-ku, Kawasaka, 210 Japan
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[Dr. Ouchi is a well known materials scientist, not an expert in computation, but he graciously accompanied me through all the computer laboratories, and for this I am very grateful. Ouchi showed me his own laboratories also, focusing on titanium and aluminum; however, I am not qualified to comment on these. He also displayed a titanium wok that he claims is extremely popular with Chinese chefs because of its light-weight and excellent heat-conduction properties. DKK]

NKK (Nippon Kokan in Japan, Kokan means Steel Tubing), was Japan's first privately owned steelmaker, founded more than 70 years ago and now the country's second largest. Currently it has more than 22,000 employees and sales of over Japan¥1.3T (about US$13B). It is a different company, and completely independent from Nippon Steel Co. NKK it has six major divisions, as follows,

- Steel division
- Engineering division
- Electronics division
- Urban development division
- LSI division
- New business division

(Computing research is mostly done in the Electronics division.)

Steelmaking will obviously be the cornerstone of NKK's business even into the next century, with an emphasis on advanced steel products such as high-tensile steel, surface treated sheet steels, etc. But at the same time the company is rapidly moving into associated areas such as advanced materials, related electronic devices (semiconductors), and computing, as mentioned above and exemplified below. General engineering services including construction, urban development, residential and urban projects, environmental activities (waste treatment, clean manufacturing, reduced energy consumption, and double hull oil tankers, etc.). To show NKK's determination to move beyond steel, the company has set the year-2000 as the goal for only 50% steelmaking, 23% engineering, and 20% new fields, for sales revenue. There is also an aggressive effort to make international tie-ups. For example, NKK recently purchased 70% of the U.S. National Steel. More interestingly for this readership is the decision to become partner with Convex Computer in the United States on the development of parallel processing software (more below).

NKK R&D (outline).

There are four research centers, as follows,

- Applied technology research center
  - Biotechnology (organic synthesis toward new pharmaceuticals)
  - Control engineering (sensing, characterization, image processing, and optical system)
  - Civil and building research (CE, building tech, aerodynamics, structures, constructional inorganic materials, etc.)
  - Human life technology
  - Materials characterization (organic and inorganic)

- Materials & processing research center
  - Raw materials
  - Ironmaking, steelmaking
  - Ceramics, slag
  - Magnetic materials
  - Alloy steel
  - Aluminum, titanium
  - Surface engineering, corrosion, joining
  - Organic synthesis, polymers, paints, plastics
  - Steel products (sheet, galvanized, coated, and tubing)

- Engineering research center
  - Combustion engineering
  - Fluid & thermal engineering
  - Pipeline engineering
  - Aqua-technology, eco-technology
  - Quantum equipment technology
  - Amusement technology
  - Marine hydrodynamics
  - Ice & snow engineering
  - Marine structures
  - Non-destructive inspection
  - Fabrication technology
  - Materials & corrosion

- Electronics research center
  - Devices and processing
  - Hybrid microelectronics
  - Electronics design
  - Computer design
  - Operating systems
  - Human interface

The last two items are = Computer systems R&D

Below I list a variety of R&D activities and their results. For most of these I have no personal association—comments are made on those few that I can evaluate.

- Steel products
  - Can materials
  - Steel sheets for automobiles
  - Sheet products and coated products
  - Improved H-beams (Excel-beams)
  - Composite steel-concrete composite columns
  - Colored stainless steel

- Functional steel products
  - Vibration-damping composite steel sheets
  - 6.5% Si steel sheet
  - Invar for shadow masks
  - Damping alloy steel made with aluminum and silicon

- Iron & steel processing
  - Direct Iron Ore Smelting reduction process
  - Application of EM force to control the solidification process in continuous casting
  - Hot strip mill technologies
  - Blast furnace technologies
  - Electroplating technologies

- Nonferrous metals
  - Superplastic titanium alloy
  - Colored titanium panels
  - Plating of titanium, alloys, ceramics in vacuum
  - Aluminum alloy sheet for auto bodies

- Polymers, chemical products & ceramics
  - Fiber reinforced plastic tank (200atm) for natural gas

- Stampable sheet for bumper beams (ther moplastic resin reinforced with glass mat)
- 50 liter synthesis unit for research (mono mers of functional polymers, and intermedi ates of fine chemicals)
- Parts for 300 KW ceramic gas turbine

• Electronic materials & devices
  - Large diameter silicon single crystals grown by Czochralski process
  - Extra fine, double sided polishing machine
  - High performance cleaning line for silicon wafers
  - IC simulation systems
  - Focused ion beam for IC development
  - Wafer and multichip packaging technology (deep submicron)

• Environmental
  - Water purification by micro-organisms
  - Cyclone melting furnace for sewage sludge (1400C)
  - Fluidized bed waste incinerator
  - Electron beam irradiation process for HCI, NOx, SOx exhaust gas treatment
  - Soil improvement technology based on blast furnace slag

• Civil engineering, construction, shipbuilding, offshore structures
  - Long span bridges (wind, aerodynamic, vibration damping analysis)
  - High tensile steel with low yield ratio (superior seismic resistance)
  - Off-center propeller ship (NOPS)
  - Linear capsule tubular distribution center for use with linear motor car

• Pharmaceutics & medical equipment
  - Superconducting cyclotron
  - Automated chemical module for PET radio compounds
  - Mammalian cell cultures
  - Cell isolation technology
  - Drug synthesis research

• Measurement, control & analysis
  - Unmanned, multi-robot (14) system for bridge panel fabrication
  - Ultraprecise positioning technology (plus/minus 20 nm)
  - Noncontact 3-D measuring system using image processing
  - Hand-held ellipsometer for online measurement of coated thin film and oxide thin film for semiconductors
  - Microbeam analytical techniques at nano meter level
  - Inductively coupled plasma mass spectrometry accurate to parts per trillion

• Leisure & living environments
  - Wave pools
  - Snow melting tank
  - Indoor ski facilities
  - Landscape river walls
  - Landscape characterization system

• Computers, CAE, Simulation
  - Networking
  - CAD software
  - Integrated office system & pen based computer
  - Molten steel simulation
  - CAE system integrating finite element computation and experimental data
  - Merging tank and CFD for simulation of 50 knot submerged foil vessel

NKK has had a long interest in shipbuilding, and built Japan's first ice-breaker. This led to the study of ice and water-waves, which resulted in a variety of unusual projects. A large wave-pool (Wild Blue Yokohama) provides up to 3-m high waves in an indoor "beach" setting in Yokohama. Using wave making technology plus urban waste heat, a commercial snow melting tank is available for use in heavy snowfall areas. A new indoor ski facility is perhaps the most unusual result, it recently opened near Tokyo's Disneyland. This huge facility, which from the outside looks like a monster covered ski jump, is constructed by using NKK steel struts and panels. Inside, new technology snow making machinery generates powdered flakes of depths of 50 to 60 cm. This snow machine is claimed to be much more natural than the usual icy snow used in conventional ski runs. (Incidentally this facility operates summer and winter.)

COMPUTING RESEARCH

The Computer Systems R&D division, which is part of the Electronics research center (see above) is composed of about three dozen staff. There are also about 25 researchers in NKK's LSI division, and about 10 researchers working on a joint project with Convex on parallel processing software. Work at CSRD began in the late 1980s when the company speculated that main-frame hosts would be replaced by distributed computing in Japan by the mid 1990s.

There is one major development project and several smaller projects. The former goes under the heading of NOW for NeoOpenWorld, which is a general concept for a distributed computing environment in offices. NOW has three parts; Net Keeper, NOWAssistant, and XT&T.

Net Keeper

This is a network management support system designed for use in office network environments by system administrators with little experience in managing and operating distributed software. There is a kernel (Net Keeper Kernel) that manages and controls distributed computing resources. The kernel includes a manager (network scheduling, fault recovery, and security) and associated software operating in a client-server model. At the user level is a network management support system with a GUI, all controlled by the kernel. I am told that Net Keeper is used (experimentally) at NKK's R&D facility and will soon be put into production use.

NOWAssistant is a set of software packages that allow offices to mesh their particular business software (via a GUI) if they are not already linked. Currently available packages are for control and filing (desktop, signature, name-information, and name card), communication (schedules, room-booking, multi-communication), document preparation, and various repetitive tasks such as linking with databases and other routine forms. Of course, these are integrated into Net Keeper also and meant to be used in this environment.

XT&T is the most interesting (and also most speculative) activity, an entirely NKK developed X-window terminal. Looking like a large laptop standing up rather than flat, the front panel folds down to become a standard keyboard that faces an upright flat panel display. But the display also can rotate down over the keyboard and then functions as a pen-based input device. Character recognition is via an NKK designed ASIC, claimed to have recognition time of less than 0.3 s. This chip employs, in hardware, a set of recognition algorithms developed by NTT. The display is b/w 640x480 8-grey shade, made by Wacom with 192x144 mm display area. The central processor is a 20 MHz R3000 (actually a 79R3051E). Internally, there is up to 16MB of DRAM, a built-in Kanji ROM (compatible with 16, 24, and 32 dots), an Ethernet controller, modem. I tried the pen system briefly; it appeared to function at least as well as others I have used. At the time of my visit to NKK, final pricing for this had not been announced-my thought was that it might be a bit expensive, but it is a fascinating project nevertheless.

Two smaller projects in CSRD are the development of expert systems, and an AI-board computer (Forbrain). There are also several engineering design activities including building CAE and CAM software (CIDAS) and a system for understanding drawings.

Pen-based computers and parallel processing software, quite a different world from steel tubes! -- *Daivd K. Kahaner, ONRASIA*

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Computer-assisted Materials Design and Process Simulation (COMMP '93), Tokyo, 6-9 September 1993

In the remarks below, I wish to acknowledge the assistance of

Mr. Jan Terziyski
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COMMP'93 was sponsored by the Iron and Steel Institute of Japan. The Chairman was:

Dr. Kazuyoshi Nii
Director-General
National Research Institute for Metals (NRIM)
Tsukuba Laboratories
1-2-1, Sengen, Tsukuba-shi, Ibaraki 305
Tel:+81 298-51-6311: Fax:+81 298-51-4556

[The National Research Institute for Metals is moving from Tokyo to Tsukuba, readers should be aware of the new address. DKK]

I wanted to attend portions of this conference primarily to get a sense of the impact of computing on material-science activities in Japan, however COMMP'93 may not have been a perfect choice since its orientation was toward heavy steel. Approximately 150 participants from 30 countries listened to 100 papers and posters. Speakers representation was as follows. The counts are not exact because of multiple affiliations.

Although several well known researchers from the United States attended, overall I was surprised at the relatively low U.S. participation. Reasons given to me were

- as a first of its kind conference in a chain that is to take place in the near future, COMMP-'93 was not heavily advertised and had somewhat of an invitational flavor,
- the emphasis was placed on steelmaking, which is seen as a fading industry by many in the West, and

	University	Industry	National Laboratories
Germany	2	1	2
Japan	39	30	69
Canada	2	-	2
US	2	4	6
Israel	-	1	1
PR China	2	-	2
Norway	2	1	3
Sweden	4	1	5
Mexico	1	-	1
France	-	1	1
UK	2	1	3
Korea	1	-	1
TOTALS	57	40	96

- The scientists from the United States may feel that they are more advanced than the Japanese in computational materials design.

Steel-making is a complex scientific and engineering activity. The largest steelmaking companies in the world are located in Asia, including Japan and Korea. Sweden, and Germany; they are also large producers, and this clearly accounts for their interest. Computers have been used for years in various ways within the steel industry, from ordering the raw materials to scheduling and distributing finished products. During the operation of the mills, computers monitor complex real-time systems, check and adjust parameters associated with the blast furnaces and rolling mills. Thus steel companies have a great deal of experience and manpower tied up in computerization. They have been early users and continue to be users and developers of expert systems, knowledge bases, and AI techniques in many phases of steelmaking. There are plenty of examples of applications of new techniques such as neural networks and fuzzy theory, especially in the Japanese steel companies.

The steel companies are also heavy users of computing for finite element analysis and fluid dynamics as simulation tools. Analysis of flows of gas, liquid, solid, cracks, and even chemical reactions are common. At this conference I noticed more 2-D than 3-D models, although there are a few well thought-out efforts to build general modelling software. I also noticed a significant number of simulations that use molecular dynamics techniques, but (with one exception noted below) there was no indication of any special algorithms used to take advantage of parallelism.

Material properties are strongly dependent on microstructure, i.e., grain size, morphology, distribution, etc. There were about a half dozen papers in which this microstructure was modelled by using what is called the "vertex method," which in two dimensions tracks the motion of the grain vertices (assuming polygonal grain edges) using classical equations of motion.

The simulations I heard about were usually done on large-scale computers or fast workstations, but not necessarily done on top-end supercomputers. Some, but by no means all within this community, would like more computational power. Mr. Terziyski disagreed about this and states that "I think the process simulation should make the analysis available for most of the users and the hardware they can access. The metalworking processes are to be simulated fast, simply, and as automatically as possible. Besides, a simulation done overnight is OK to reduce the cost of tryouts and human labor, and this approach was defended in previous presentations in Japan even by people from Livermore Lab."

In the Japanese steel community there is plenty of computer expertise in what would be called processing (rolling, quenching, blast furnace characteristics, etc), and modelling, which is easily confirmed by scanning the list of titles appended below, or my remarks about them. (COMMP'93 was to focus on process simulation, materials design, and fundamental properties, but I felt that the majority of the papers covered the first area.) However, there appeared to be much less Japanese work in the design of materials by computer. Perhaps it does occur, but not as much within the steel industry and hence was not represented here. I put the question to

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Professor Doyama (retired from the University of Tokyo) gave the opening lecture from the Japanese side, (there was also a speaker from Germany, Canada, and the United States.) He has also been involved in computational aspects of materials science since the 1960s, including a very early stint at Argonne National Laboratory. He agreed that in Japan, materials design by computer is very much behind that in the West. (His talk was a survey of applications of computing to material science, much of it historical. He emphasized, as did several other speakers, that there is no point in precise calculations based on inaccurate theory. But he went on to say that it was better to start with simple models and do something reasonable than to wait for perfect theory.

On the basis of the participants at this conference it was difficult to dispute Doyama's assertion that materials design by computer was less advanced in Japan. Perhaps it was because many Japanese attending were metallurgists, but it was clear that a great many were unsophisticated about computing. The U.S. speaker at the opening lecture was M. Koszykowski from Sandia Laboratories, Livermore. His discussion, laced with references to grand challenges, FDDI, C++, X-window widgets, and his attempted distinctions between class libraries and toolkit approaches to software architecture, was well recognized by the audience, but it might have been better understood at a conference on supercomputers or communications than at this one. Another U.S. participant, M. Baskes (Email: BASKES@CA.SANDIA.GOV), who is also the Editor in Chief of the Modelling and Simulation in Materials Science and Engineering Journal, agreed that Western scientists are significantly ahead in this area. Although many Japanese companies now have access to powerful computers, they are still lacking in the sophisticated infrastructure where supercomputers are coupled with workstations, graphics devices, and other tools in a easy to use web. (A common remark from scientists here is that, yes they can make color graphics based on computer output, but no, it is not easy and may even require assistance from other people or use of a special remote facility.)

The Japanese government is working to do something about this in the area of materials. Doyama pointed out that in 1987 STA predictions for future technology, the topic of materials design, as well as the science and control on the atomic and molecular level were mentioned as important technologies. In STA's most recent prediction, 1992, molecular structural control and evaluation were again mentioned as key technologies. (This has translated into the Atomic Scale Engineering project, sometimes called the nano-technology project. But Japanese participants at COMMP'93 felt that the thrusts of that were different from computer related materials design.) Nevertheless, given the expertise in Japanese steel industry, in computer processing, and model building, it is just a matter of time before explicit materials design gets to a par with that in the West.

Mr. Terziyski considered the conference slightly off, relative to his interests in CAD, CAM, and CAE systems, and pointed out that the main objectives of CAD in the materials area are (among others) the following.

1. Assist die design and process development
   a. Conduct metal flow simulation
      - prevent flow induced defects
      - avoid exceeding forming limits, so that failures are prevented
      - achieve desired grain flow and product properties that are usually nonuniform throughout the part
   b. Predict and attempt to control the temperature in the material and die during forming

2. Improve shape quality and reduce forming cost
   a. Predict and improve grain flow and microstructure
   b. Reduce die try-outs
   c. Reduce rejects and improve material yield

In this context, he felt that the presentations were heavy in the topic of nondestructive material evaluation and properties prediction. And powerful techniques to predict material characteristics like acousto-sonic evaluation were really the subject of science fields different from process simulation and design by computers. Along with this, he felt that much more attention was paid to the tools for computer processing rather than hardware tools for process simulation, investigation, and improvement. Also, "the mathematics of the problems being analyzed could be subject to a separate meeting or even some post-conference proceedings." However, he admits that "it is extremely difficult to combine the interests of all steel-making and processes-developing companies, institutes, and universities in four days. I think a large-scale survey on state-of-the-art simulators and technologies should take at least a week, with longer presentation time [for each paper]. Also, the poster session could be displayed during the entire length of the conference in the entrance hall. However, we should recognize the best organization by ISIJ who made the conference possible and did well."

A list of papers is given below. First, I make some brief remarks on (Asian-authored) papers that were of particular interest to me.

"Bright," a blast furnace model, fairly complete, but only in 2-D (Suqiyama, et al.).

Electromagnetic braking, both duct and jet flows are studied (Okazawa, et al.).

Chaotic dynamics applied to nonperiodicity in blast furnace, with very good predictive capabilities (Gao, et al. from PR China). In one paper, (Tojima, et al.) used neural nets to classify graphite shapes in cast iron.

Basic studies of validity of k-e turbulence model in studying the flow fields of continuous casting molds, using Flotran, a commercial product (Takeuchi, et al.).

Three-dimensional casting solidification analysis, using the SOLDIA code (Ohnaka). In shape casting, the author notes the need for an unstructured 3-D mesh generator as well as improved algorithms for such meshes, especially when applied to free surface problems. Simulation of absorption and entrapment of gas, and solid-liquid two phase flow. Turbulent flow with free surfaces. Simulation of casting defects. Microscopic modeling for microstructures, pore nucleation, microsegregation.

HEARTS, a 3-D FEM program for heat treatment simulation (Inoue, et al.), which also includes an easy to use pre/post processor, for carbon diffusion, phase transformation kinetics, heat conduction, and stress/strain. Some examples performed on a workstation are shown with 3-D graphics.

An overview of difficulties with current FEM algorithms applied to powder forming (Matsumoto). One interesting aspect is that the developed stiffness matrix is nonsymmetric, if classical plasticity theory is used.

Elegant models for metal injection molding (Iwai, et al.), and forging (Terziyski, et al.), both 3-D. We also note a more theoretical model (Kawasaki et al.) of textured surfaces such as soap froth.

A new friction model that uses molecular dynamics, leads to a state called superlubricity, in which frictional forces exactly vanish in the limit of the sliding velocity going to zero (Hirano, et al.). The authors have performed some experiments by using two contacting muscovite mica. These experiments have confirmed that the friction forces become smaller as the experimental conditions approach those for the appearance of the superlubric state. They are further planning experiments using well-defined surfaces under a high vacuum of 10^{-10} Torr.

A variety of techniques that include molecular dynamics and Monte Carlo have been applied to thin-film simulation (Sasajima et al.). Monte Carlo is also applied to microstructural evolution (Nogami, at al.).

For readers reference, I note the paper by Fujita & Noda on nuclear material design and selection. The authors explain that a pilot information system for nuclear materials is being developed. Moreover, they note that for about three years, the National Research Institute for Metals, the Japan Atomic Energy Research Institute, and the Power Reactor and Nuclear Fuel Development Corporation have been cooperating in the development and creation of a "Data-Free-Way" for accessing materials-related data.

The one Japanese paper on parallel computing (Ohno, et al.), began with a Monte Carlo algorithm for simulation of star-polymers, which the authors vectorized on an NEC SX-2, and then rewrote in Fortran 90 for a DEC mppl2000, with 4K processors (currently succeeded by DECmpp 12000/SxM200). Their results are interesting, but the computational model is quite simple, only about one page, in either Fortran 77 or Fortran 90.

There were also several papers on database and knowledge-base techniques and applications. These ranged from rather conceptual, the Virtual Production Line (Iwata) or KIND an integrated materials database (Kawazoe, et al.), to specific, such as strength and life prediction (Monma), or case-based reasoning applied to quality in steel plates (Omura, et al.). The KIND project, which began more than 5 years ago at the Institute for Materials Research at Tohoku University, stores more than 30,000 papers on opto-magnetic disks, concentrating on intermetallic compounds, and superconducting materials, although there is recent work in amorphous materials. Queries can be made via a standard SQL using keywords, up to 4KB in length, and some multimedia capability is also available.

One paper did not relate to computer modeling, but rather to image processing, (Furukimi, et al.). The authors used Dr. Image, a package developed by Kawasaki Steel, to process a pair of 8° offset images provided from a scanning electron microscope to obtain 3-D data.

Although not Asian, I want to call attention to the survey of the Swedish Consortium for Computer Assisted Materials and Process Development (CAMPADA), building software and databases (Sundman, et al.). In addition, it is worth noting the paper of E.Wimmer, representing the BIOSYM company in France. Wimmer's paper is an excellent survey of quantum mechanical calculations for materials design, and also includes a brief discussion of their potential economic impact. -- *Jan Terziyski, University of Tokyo*

Computational Mathematics and Related Activities in Australia, 25 August 1993

Two Australian conferences, Computational Techniques and Applications Conference (CTAC'93) Canberra, and Chaotic Numerics, Geelong, held in July 1993, are described, as well as some other observations on computing in Australia.

David K. Kahaner

I attended two conferences in early July in Australia. In each case, participants have been kind enough to prepare a summary and to allow me to use it. Modified versions of these are included below along with my comments. In an accompanying report ("ctac93.abs", 23 Aug 1993) I have provided abstracts for almost all the papers, including authors names and addresses. I also have most of the papers, in preprint form.

My general impression, which I formed during an earlier visit to Australia and reinforced by this trip, is that the scholarship level and research capabilities of Australian scientists are really top-notch, beyond that of most other Pacific-Rim countries of comparable or even larger population. Readers will get a sense of this by going through the reports below and by examining the abstracts. The main difficulties in Australia relate to infrastructure problems caused by a large country with a small population, unemployment hovering at 10% or more, and an industrial base that has historically been extraction-centered. The challenges for the Australian government are to get the country's industry operating on a higher level of technology, and to take advantage of the expertise that is available at the universities and government laboratories. This problem is well known, and there have been significant efforts to industrialize high technology, but it is not clear to me that they have yet born fruit in terms of technologically-based economic growth. One sign of this was the almost complete lack of industrial attendees at CTAC. I was told by several participants that industrial participation has been episodic in the past and hopefully will be better next year. But, it was nevertheless disappointing to most of the academic and government scientists who were in attendance. Concerning high performance computing specifically, things seem in somewhat better shape than on my last visit, about two years ago. The Australian government appears to be paying increased attention to this topic, and there is a growing (but still small) body of researchers at government and university sites with experience on advanced computing platforms, which are slowly permeating into the country's infrastructure. Industry is still far behind, however, and one service bureau that existed at the time of my last visit to provide Cray cycles, has gone out of business.

Concerning government efforts, it is not possible here to describe these in detail, but several are worth special mention. About three years ago the Australian government launched a program that set up 50 cooperative research centers (CRCs), 34 initially and 17 at the end of 1992, to undertake collaborate research and education in natural science and engineering, with a strong focus on applications. Total resources available to the CRCs amount to A$872M as follows. A$618M, National government; A$170M, Business; A$183M, Universities; A$178M, Commonwealth departments and agencies, including CSIRO; A$85M, State departments and agencies; A$2M, Medical research institutes.

Center support is focused in six major areas:

- Manufacturing technology
- Information & Communications technology

- Mining and Energy
- Agriculture & Rural-based manufacturing
- Environment
- Medical science and technology.

In the second category there are five established CRCs and three new ones as of Dec 1992, a total of 17 new CRCs established at that date. The established ones are the following

- Intelligent Decision Systems (Melbourne) A$6.3M
  Dr. M. Georgeff
  1 Grattan St.
  Carlton, Vic 3053
  Tel: +61 3 663-7922;
  Fax: +61 3 663-7937

Topics:
  Intelligent control techniques (real time systems),
  Planning and scheduling methods,
  Intelligent databases,
  Machine interpretation techniques,
  Distributed intelligent systems,
  High performance computing.

- Robust and Adaptive Systems (Canberra, Sydney, Adelaide) A$7.7M
  Dr. R.R. Bitmead
  Dept of Systems Eng
  Australian National Univ
  Mills Road, Acton ACT 2601
  Tel: +61 6 249-2849;
  Fax: +61 6 249-2698

Topics:
  Signal processing,
  Adaptive systems,
  Feedback control systems,
  Adaptive beamforming,
  Robust control,
  Hidden Markov models,
  Spectrum estimation,
  Tracking.

- Distributed Systems Technology (Brisbane, Gold Coast, Adelaide, Melbourne, Sydney) A$12.OM
  Mr. R. Cook
  General Purpose South Bldg.
  Research Road
  Univ of Queensland QLD 4072
  Tel: +61 7 365-4321;
  Fax: +61 7 365-4399

Topics:
  Distributed architectures & databases,
  Management security and performance of distributed systems,
  Distributed software tools.

- Australian Photonics (Sydney, Melbourne, Canberra) A$26.7M
  Dr. M. Sceats
  Madsen Building F09
  University of Sydney
  Sydney NSW 2006
  Tel: +61 2 692-4670;
  Fax: +61 2 692-4671

Topics:
  Photonics,
  Optical fibre materials characterization,
  Fibre fabrication and design,
  Optical fibre amplifiers,
  Photonic systems and networks,
  Optical fibre sensing technology,
  Advanced waveguide technology.

- Sensor Signal and Information Processing (Adelaide, Melbourne, Brisbane) A$12.4M
  Prof. H.A. d'Assumpcao
  SPRI Bldg. Warrendi Ave
  Pooraka SA 5095
  Tel: +61 8 302-3477;
  Fax: +61 8 302-3124

Topics:
  Signal processing,
  Information processing,
  Radar systems,
  Sonar systems,
  Shape inference,
  Artificial neural networks,
  VLSI design,
  Target tracking,
  Target recognition.

In the category of Information and Communications Technology the three new CRCs are as follows,

- Broadband Telecommunications and Networking A$11.6M
  Prof A. Cantoni
  Australian Telecommunications Research Inst
  Curtin Univ of Tech
  GPO Box U1987
  Perth WA 6001
  Tel: +61 9 351-3239;
  Fax: +61 9 351-3244

Topics:
R&D to support the creation of an Australian design infrastructure in broadband telecommunications and networking.

- Advanced Computational Systems A$13.OM
  Prof. M. McRobbie
  Center for Information Science Research
  Australian National University
  Acton ACT 2601
  Tel:+61 6 249-2035;
  Fax:+61 6 249-0747

Topics:
Establish an internationally competitive research capability in high performance advanced computational systems for the benefit of Australian industry through strategic alliances with industry, government, and research organizations through focused demonstrator systems in visualization of complex data, hypermedia for large scale multimedia databases, and command support.

- Research Data Network A$13.OM
  Prof. M. McRobbie
  Center for Information Science Research
  Australian National University
  Acton ACT 2601
  Tel:+61 6 249-2035;
  Fax:+61 6 249-0747

Topics:
Conduct research and education in areas relating to communications network technologies, applications, and services, support network infrastructure development and upgrading of the Australian Academic and Research Network (AARN).

In addition to the CRCs most readers are aware from my earlier reports that CSIRO, the Commonwealth Scientific and Industrial Research Organization, is the country's largest and most influential distributed government science facility. CSIRO, with a staff of more than 7,000 and a budget of A$620M deserves a report of its own. Here I only wish to remark that CSIRO has recently been tasked to generate about one third of its funding from outside sources and thus is under significant pressure to work in areas of interest to other organizations. CSIRO is divided into six large institutes. Divisions of the information science institute are also shown.

- Information science and engineering
  Contact:
  Dr. R.H. Frater
  105 Delhi Road
  North Ryde NSW 2113
  Tel:+61 2 887-8220; Fax:+61 2 887-2736

  - Information technology
  - Mathematics & statistics
  - Radiophysics
  - Australian telescope national facility
- Industrial technologies
- Minerals, energy, and construction
- Animal production and processing
- Plant production and processing
- Natural resources and environment

The divisions have further suborganizations in many cases. For example, the Division of Mathematics and Statistics has a specific Applied and Industrial Mathematics Program.

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Dr. Barton has provided me with a great deal of material on the math and statistics activities in CSIRO, for which I am very grateful, but space does not allow me to review this in the current report. I should mention, however, that CSIRO has a long history of attempting to provide mathematics expertise to industry. For example (only one of many), Robert Anderson, CSIRO DMS, GPO Box 1965, Canberra ACT 2601, Fax: +61 62 815 555, has written many articles on this topic, see for example "Linking Mathematics with Applications: The Comparative Assessment Process," Math & Computers in Simulation, 33 (1992) pp 469-476.

As might be expected in any science organization that finds itself under very tough budget pressures, there is ample finger pointing that the government is going about this all wrong. Julian Cribb, the S&T writer for the newspaper "Australian" has accused the Science Minister of guerrilla tactics involving merging ANSTO (Australian Nuclear S&T Organization) with CSIRO, and also for attempting to remove oceanography, fisheries, and atmospheric research from CSIRO to build a stand alone National Institute for Marine Science. These and related actions have led to public protests by researchers, and has caused Cribb to state that the country's scientific community is becoming "increasingly demoralized." I do not have enough information to take a position in this matter, but feel that Western scientists who are interested in the furtherance in what has been a very outstanding Australian science establishment, should communicate with their down under colleagues to try to get as much sensible input as possible.

CTAC93: Computational Techniques and Applications Conference

by Prof. Mike Osborne
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CTAC93 was held at the Australian National University, 5-9 July 1993. Some 130 registrants braved uncharacteristic wet conditions that appeared to do no harm at all to their attention spans. The meteorological records were not so lucky—July 1993 proved to be the wettest on record. On the first three days they were treated to six invited talks with 90 contributed talks in three parallel sessions. During the final two days, workshops were held in CFD and plasma computations, in developments in optimization and variational inequalities, and in problem solving on distributed memory multiprocessor computers.

The invited talks spanned an unusual range of modelling approaches. David Green (ANU, Email: GREEN DQLAPLACE.ANU.EDU.AU), speaking about new paradigms in biological computing, introduced techniques based on discrete systems and syntactic rules. He also gave details of the ANU Bioinformatics Hypermedia Service, which he is developing. Joe Monaghan (Monash, Email: JJMQVAXC.CC.MONASH.EDU.AU) stressed the problem solving power of his particle based SPH (smoothed particle hydrodynamics) methods in which particles carry physical quantities, and field quantities are obtained analytically from formulae that refer only to particle properties.

[Particle methods were invented by Frank Harlow at Los Alamos in the late 1950s under the name Particle in Cell (PIC). Monaghan, whose background is in astrophysics, described SPH almost 20 years later in a paper with R.Gingold, although the technique was developed independently of PIC to solve 3-D astrophysics problems. SPH is a true Lagrangian method, in that no grid is necessary; particles carry physical quantities, and spatial derivatives are calculated analytically from approximate interpolation formula which refer only to particle properties. Both PIC and SPH are alive and well today, with many refinements. SPH is the method of choice for elastic fracture problems leading to breakup, and for astrophysical problems with wide length and timescale ranges. Monaghan expects further improvements in both algorithms (for more general kernels) and in their parallel implementation, DKK.]

Steve McCormick (Colorado, Email: SMCCORMIQCOPPER.DENVER.COLORADO.EDU) demonstrated the advantages of multigrid in solving the equations that arise in the discredization of field equations in continuum modelling. But the talks stressed also innovation and technique. Tony Cooper (Lausanne, Email: COOPER@CRPPSUNI.EPFL.CH) described the Cray Prize program TERPSICHORE for the linear stability analysis of 3-D plasmas. Here the aim is to explore parameter space to identify configurations that demonstrate attractive potential as fusion reactors. Charles Elliott (Sussex, Email: MMFC8QSYMA.SUSSEX.AC.UK) discussed the solution of the Cahn-Hilliard and related equations for the modelling of phase field problems including the development of fingering at interfaces. Andreas

Griewank (Argonne/Dresden, Email: GRIEWANK-QANTARES.MCS.ANL.GOV) described recent applications and problem areas in his work on computational (automatic) differentiation. An application to the optimal design of lifting surfaces provided a spectacular illustration of what is becoming possible with effective implementations of these techniques.

The contributed talks reflected the usual CTAC bias towards scientific computation and engineering applications. Approximately one third of the talks were directly aimed at the development of computational techniques. These covered such topics as sparse matrix computations, PDE solvers, boundary integral methods, and inverse problems. In the applications area most of the emphasis was placed on things that flow rather than things that crack, break, or move in a controlled or even chaotic fashion. The use of particle methods was well in evidence as were reports of experience with the CSIRO Fastflo package for finite element modelling and visualization. In the fluids area, a range of applications was covered in the papers presented, which included the modelling of transient flow in shock tubes, discussions of a variety of metereological phenomena, and several papers were concerned with the modelling of flow and the dispersal of pollutants in the sensitive Spencer Gulf area.

[The latter includes a tidal modelling program developed over ten years at the University of Adelaide by John Noye and colleagues (Email: JNOYEQ-SPAM.MATHS.ADELAIDE.EDU.AU). I was also interested in the work by Songping Zhu (Wollongong, Email: S.ZHU@UOW.EDU.AU) on a new boundary element method for combined wave diffraction and refraction that was applied to wave oscillations in harbors with very good results, DKK]

[Fastflo is a project used to develop computation CFD software by using finite element methods with unstructured meshes in 2-D and 3-D. The main objective is to produce a fast central module based on operator splitting, with a variety of application modules built around it and suitable for commercialization. The three year (1991-1994) A$600K project is being done in Melbourne, Sydney, and Canberra by scientists at CSIRO, with contributions from BHP Research, a major Australian mining and resources company. More than 15 staff years of work have already been put into this research. Currently, they have developed an 8K-line finite element engine with no explicit physics built in. Physical modelling is via Fastalk, which provides a higher level interface and can be run either interactively or through an input macro file. Fastalk has a variety of interesting capabilities oriented toward solving linear boundary value PDEs, including global sparse vector/matrices, time marching, triangular and tetrahedral mesh generation, as well as manipulation, postprocessing, and graphics. Mooney (CSIRO, EMAIL: JOHNM-QCBR.DMS.CSIRO.AU) has a very interesting paper on the use of Fastflo for problems in natural convection; and Nick Stokes, the project PI described its use in a project to model the cooling of steel from 1500C. Stokes commented that Fastflo is very versatile, but still demanding for users. Work is continuing on free surface, flows with magnetohydronamic body forces, solidification, chemical reacting flows, two phase flows, and non-Newtonian flows. This is a very ambitious project that amply takes advantage of the strong analytic skills of the team members. For further information contact the following.

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DKK.]

[Many of the CTAC papers gave global perspectives on a variety of applied mathematics and computation related topics. See for example A.Andrew's work on inverse eigenvalue problems (Email: MAT-ALAQLURE.LATROVE.EDU.AU), Osborne and Mahmood's paper on collocation for boundary value problems, Osborne and Cleary's paper on eigenvalue solvers for large problems, and Brent's paper on parallel algorithms in linear algebra. Of particular mention in this context was the invited paper by J.J. Monaghan already mentioned, which reviews particle methods for the solution of PDEs, DKK.]

The workshops that concluded the meeting provided opportunities for speakers to talk about their material in greater depth. Tony Cooper, Steve McCormick, and Joe Monaghan took part in the workshop on CFD and plasma, as did several of the speakers attending a further plasma meeting the following week. Charles Elliott and Andreas Griewank contributed to the Optimization workshop that also included speakers detailing new work on nonsmooth optimization and interior point methods. The third workshop had to do with programming distributed memory multiprocessors. Presentations on basic techniques and HPF were followed by papers by Terry Bossomaier and Heinz Schmidt who described their work on C** and data parallel Sather, both of which introduce the object oriented paradigm. In contrast, Richard Brent (ANU, Email: RPBQCSLAB.ANU.EDU.AU) showed what has been possible to do on the Fujitsu AP1000 prototype, when all that was available initially was C and a raft of message passing routines.

[See especially, Brent & Strazdins, "Implementation of the BLAS Level 3 and Linpack Benchmark on the AP1000", Fujitsu Sci Tech J., 29(1), pp 61-70, March 1993. More generally, Fujitsu has an on going significant collaboration activity with ANU in the area of algorithms for high performance computers. For example, they have asked ANU scientists to develop eigenvalue solvers, especially for tridiagonal systems for use on Fujitsu machines such as their new VPP crossbar parallel computer. Further, Fujitsu has made a major effort to conduct a variety of R&D at centers in Australia including the following.

- FAST (Fujitsu Australia Software Technology Center):
  R&D on new system software and fine tuning of existing (Japan-produced) software.

- SERC (Systems Engineering Research Center):
  Development of system engineering tools (for systems engineers and customer installations).

- CRISP (Center for the Release of International Systems Products):
  A product development center for installation, connection, and implementation of new company products.

- There is also Fujitsu collaborative activity at ANU as mentioned above, at ANSTO (where another VP2000 system is installed), and at the Telecommunications R&D Center in Melbourne where work is done on synchronous transmission and central office switching.

However, Fujitsu is not the only large company seeking to exploit Australian scientific talent. For example, NCR has recently signed a A$47M agreement to fund local R&D to develop products in networking, including wireless communications, parallel computers, and electronic funds transfer.

CTAC also revealed that Australian scientists are getting more experience with a variety of supercomputers, for example David Harrar's paper (ANU, Email: DLHQGALT.ANU.EDU.AU) comparing a preconditioned conjugate gradient solver on the CM-5 and VP2200, or Rob May's paper (Royal Melbourne Institute of Technology, Email: ROBQRMIT.EDU.Au) describing performance of several well known iterative methods on a DEC 1200, or Linda Stals computations (ANU, Email: LINDAQMATHS.ANU.EDU.AU) using multigrid on the AP1000, or the paper by Daniel Ralph (Melbourne, Email: DANNY@MUNDOE.MATHS.-MU.OZ.AU) on parallel methods for discrete time control problems with implementation on an Intel iPSC/860 hypercube. A final example is given by the paper by Brent and Zhou on a parallel implementation of the singular value decomposition, specifically designed for tree architectures, with comments about its applicability to the CM-5 (this is to be presented at the 22nd Int. Conf. on Parallel Processing, St. Charles, IL 8/93), DKK.]

Sponsors of CTAC93 included the School of Mathematical Sciences of the Australian National University, the British Council that supported Charles Elliott's visit, Cray Research (Australia) that supported the visit of Steve McCormick, Fujitsu Australia, and TMC Australia. A refereed proceedings of CTAC93 will be published by World Scientific.

It was confirmed that CTAC95 will be held in Melbourne. Alan Easton will be the Director, and it is expected that the venue will be Swinburne Institute of Technology. Principal officers of the CTAC special interest group for the next two years are: Chairman, Mike Osborne; Secretary, Steve Roberts; Treasurer, Manmohan Singh; Committee, Jerard Barry, and Alan Easton (ex oficio), Clive Fletcher, Kerry Landman, Bob May, and John Noye. There was a tentative agreement that CTAC97 be held in Queensland and be directed by Kevin Burrage.

[In addition, a public lecture was held in conjunction with the CTAC93 meeting. It was presented by Trevor Robinson whose extensive computing industry insights have been augmented recently through significant "behind the scenes ' political influence in the area of information technology. Trevor provided a perspective of computing in Australia culminating in suggestions of what might (and might not) happen in the way of government support for supercomputing and fast data communications in the next few years. The text of this lecture is given below. It begins by reviewing the idea of supercomputing by giving a brief history as seen from Robinson's CDC perspective. A variety of application areas are mentioned, all of general interest to nonspecialists. More valuable, in my opinion, were Robinson's comments about what is happening and needed now in Australia, focusing on infrastructure, and particularly on networking with optical fiber as a national priority. He called supercomputing both a productivity enhancement tool and a turbocharger of technology. He concludes, and I agree, that Australia has exceptional talent but has been slow to exploit it, especially with regard to industry. He also comments that a more targeted government policy encouraging supercomputing in government laboratories, academic and industrial sites is needed. DKK]

[In connection with material of interest to those in the high performance computing community but not associated with CTAC, I would like to point out a lecture "From FLOPS to Breakthroughs, The Promise of Supercomputing" that was presented by Prof. Paul Pritchard, Head, School of Computing and Information Technology, Faculty of Science and Technology, Griffith University, Queensland 4111 Australia. This lecture has been published in a small booklet (ISBN 0 86857 411 2) available from the author. This is somewhat more technical than Robinson's, but still a very readable discussion of developments in supercomputing, including parallel computing and potential applications for simulation, a brief description of grand challenge applications, especially environmental and molecular modelling and scientific visualization. Also included are comments on the implications to the university and the community of high performance computing. I thought that the latter part of Pritchard's comments were interesting enough to include them here as follows.

Pritchard's remarks (partial)

"Whether or not numerical simulation quite gains the same status as theory and experimentation, it is clear that, as its technological underpinning, supercomputing will be an increasingly important tool for R&D across a very broad spectrum of science and engineering, and its use will spread to other areas. Just as a serious broad research effort in chemistry is infeasible without NMR spectrometers and X-ray crystallography equipment, so will be research in science and advanced engineering without supercomputing infrastructure, which pace the older universities (currently reacting to unaccustomed competition with a sort of reverse noblesse oblige), will be a better indicator of commitment to research excellence than a medical school.

But money can't buy everything—supercomputing infrastructure, including visualization facilities, high-speed networking, and support staff, are necessary but not sufficient. Most important of all is a genuine commitment to interdisciplinary and multidisciplinary research and teaching. The international supercomputer centers, notably the four funded by the NSF in the United States, have all assembled sizable teams of computer scientists, numerical analysts, and visualization specialists to work with experts in particular applications areas. It is hard to imagine funding for such an independent center, particularly being found in Australia. Then, where would these strong centers have the best prospect to emerge out of the existing organizations? Here's the shopping list:

- Critical masses of first-rate scientists and/or engineers in important application areas for supercomputing.
  (Concentration on a very few areas will be necessary to be internationally competitive.)
- Expertise in parallel computing, because parallel machines will soon dominate, and they require new programming paradigms.
- Expertise in applied numerical mathematics, because the main use of supercomputers is numerical simulation.
- Expertise in scientific visualization.
- An organization with all of the above requirements in a single location, and, cru-

cially, committed to bringing all together in cooperative interdisciplinary efforts.

- A supercomputing facility with a MIMD parallel supercomputer and a networked visualization laboratory being the essential items.

- Local industry that can benefit from supercomputing.
(Support from industry will emerge as the benefits become evident.)

- A source of graduates educated in computational science to help spread the exploitation of supercomputing by industry and government.

- Government that is sufficiently visionary and decisive, and, preferably, that presides over a healthy economy.

This is a tall order, certainly, but not an impossible one. It is with great personal satisfaction that I can truthfully tell you that my university, Griffith University, has it in spades.

My own School of Computing and Information Technology (at Griffith University) has one of the largest such groups among Australian universities. The school has strategically recruited to build a Parallel Computing Unit that will be recognized as the leading group in the area of research in the country, with prominent senior researchers providing bridging expertise in applications to high-performance computing and in scientific visualization." The school played the leading role in the Queensland Parallel Supercomputing Initiative, with a successful proposal to the Australian Research Council to deliver a parallel supercomputer to support research in seven Queensland universities.

The Parallel Computing Unit will leverage the university's acknowledged strengths in various areas of science and in environmental modelling and engineering, to mount concerted multidisciplinary research efforts supported by the parallel supercomputer. This process is underway and is concentrating on molecular modeling for rational drug design (in conjunction with the Queensland Pharmaceutical Research Institute), nd on various aspects of environmental modelling (in conjunction with colleagues in the Faculty of Environmental Sciences.)

Griffith University is distinctive for being designed to encourage interdisciplinary and multidisciplinary research and teaching, and real problem-oriented collaborations are a continuing feature. Importantly, applied numerical mathematicians have long been part of the relevant Faculties, especially Environmental Sciences and Science and Technology.

As for the other items in our shopping list, I cannot speak with the same authority. The Queensland government is presently in the process of deciding whether to follow the recommendations of its own Information Policy Board's strategic plan, and help in funding a major supercomputer center in Brisbane. (The suggested location is the Mt. Gravatt Research Park.) This talk has (I think appropriately) focussed on the role of supercomputing in university research. The case for government funding to put its universities in a strong position to redress the current imbalance in federal R&D funding, and to exploit the universities' initiatives for the long-term benefit of Queensland's industries and environment is compelling, and I have been putting considerable effort into it, but this is not the place to mount it. It is sufficient to say that there are strong supporters of supercomputing in government, and if the Leading State Initiative is not to be empty rhetoric, they must be heard.

But let us end on a more positive note, in harmony with the palpable excitement building in this university, for which supercomputing will be a vitalizing force, capitalizing on its leading areas of research strength and its distinctive structure, quintessentially in keeping with its focus on the future, and contributing to the scientific, educational, economic, and environmental well-being of the greater community. We have worked hard to put everything in place, and our momentum is now irresistible. Let the Good Times Roll!" DKK]

Readers should not get the impression that this is the only high performance computing activity at the Australian universities. Two other examples are indicative, but by no means exhaustive. I have already remarked on significant work at ANU (Australian National University) in Canberra. There is also

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Professor Fletcher has been heavily involved in aerodynamic design and related computational problems. In fact, he and colleagues organized a CTAC-following workshop on the calculation of gradients for aerodynamic design problems. I expect to visit C-ACES on my next Australian trip.

Chaotic Numerics, 12-16 July 1993, Deakin University

Prof. David Stewart
School of Mathematical Science
Australian National Univ,
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Email: desQthrain.anu.edu.au

Prof. Timothy D. Sauer
Dept. of Mathematical Science
George Mason Univ,
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As both Professors Stewart and Sauer have provided me with summaries, I have integrated them as well as merged in my own remarks. To avoid interrupting the flow I have not annotated which of us said what, but I take responsibility for any errors. On the week after the CTAC93 and annual Australian Mathematical Society meetings, there was a week- long conference at Deakin University, Geelong, which was organized by Peter Kloeden on "Chaotic Numerics." A co-organizer was Ken Palmer (University of Miami, Florida). Geelong is a small coastal city about one hour south-west of Melbourne. A total of 61 participants turned up for the conference. However, just what was meant by "chaotic numerics" was never made entirely clear. Peter opened the conference saying that that was one of the reasons for holding it. Nevertheless, there were a range of interesting talks ranging from the theoretical side to reports of some new pieces of software.

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Kloeden is well known for his work in dynamical systems, and the current meeting was subtitled, "Approximation and Computation of Complicated Dynamical Behavior." Kloeden is currently writing a book on Metric Spaces of Fuzzy Sets, coauthored by P.Diamond, to be published by World Scientific. Papers presented at Chaotic Numerics will be published in the AMS Contemporary Math Series in the Spring of 1994. Electronic copies, in LaTeX form, are being sent to Kloeden, so interested readers can contact him for this material.

The topics covered by the talks included the problems of approximating attractors, tracking invariant manifolds (such as for periodic orbits), numerically computing the branches in a bifurcation, reconstruction of dynamics or "chaotic time series", shadowing numerical trajectories with true trajectories, computing Lyapunov exponents, spurious chaos from numerical methods, backward error results for dynamical systems, numerically finding homoclinic orbits (which generate chaos), chaotic control, and numerous applications to physical and biological systems. There were nonparallel sessions, which was a relief in one way (should I go to hear my friend's talk, or to another I'm really interested in?) but it meant that you knew who stayed away...

The speakers came from not only Australia, but also from America, Germany, Spain, England, and Japan; but several people came from South Africa, and one came from the new republic of Slovenia. Meanwhile the Victorian weather couldn't make up its mind as to whether it wanted to be good or bad. Most of us, however, found consolation in the small bistro at Deakin, which served such good food (and free carafes of wine!) that it was only on the last possible night that many of us tried the Geelong restaurants.

Each of the four keynote speakers presented two hours of lectures during the week. Wolf Beyn (Universitat Bielefeld, Germany) presented one hour of numerical techniques for the computation of homoclinic phenomena in dynamical systems, and numerical methods for analyzing and cataloging bifurcations was addressed. He stressed the importance of finding well-posed unfoldings of homoclinic orbits to stabilize the resulting computations. A second hour focused on stable computation of local and global bifurcation orbits.

Included amongst the speakers were well known figures in the area of dynamical systems such as Jack Hale and Shui-Nee Chow of Georgia Tech.

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Professor Chow presented research on lattice equations, including the complicated spatial organization of a particular type of steady-state solutions called mosaic patterns. In a second hour, he described work done by a few groups on the shadowing of computer-generated pseudo-trajectories, which involves rigorous (and in general computer-assisted) proofs of the existence of nearby true trajectories, in spite of the exponential growth of errors.

Professor Hale spent the first hour surveying results of computer-assisted proofs in differential equations, including computational verification of a homoclinic intersection in the Mackey-Glass delay differential equation, and the recent work of Mischaikow and Mrozek on the proof of the existence of a two-shift (horseshoe dynamics) in the Lorenz equations. In the second hour, he discussed the effects of discredization errors in approximation of solutions of PDEs. As spurious solutions for space discredizations are ubiquitous phenomena, requirements on numerical schemes and the PDE are needed to ensure the upper semicontinuity of attractors as a function of discredization size.

The fourth keynote speaker was Jens Lorenz (University of New Mexico), who discussed the numerical aspects of locating the precise position of global attractors and invariant manifolds of dynamical systems. A particular case involves the computation of invariant tori for forced dissipative systems, and continuation methods for following the tori as a parameter varies.

Tim Sauer (George Mason University) discussed numerical techniques for reconstructing dynamics of attractors from experimental data, and showed how estimates of "fractal" dimensions could be misleading. He surveyed relevant theorems on embedding and discussed methods for predicting nonlinear time series and distinguishing stochastic processes from low-dimensional deterministic processes using prediction. This theme was also taken up by Aneta Stefanovska (Ljubljana University, Slovenia) who talked on the analysis of blood microcirculation through time series data. Keith Briggs (Adelaide University) spoke on a nonlinear optimization method for fitting parameters in global mappings, by using chaotic time series.

J.M. Sanz-Serna (Valladolid University, Spain), known for his work on symplectic methods for Hamiltonian systems, spoke on "modified equations," which is a sort of backward error analysis for numerical methods for ODEs. Given a vector field and a numerical method depending on a step size, the goal is to find a new vector field whose differential equation matches the numerical method applied to the ODE to as many powers of the step size as it is reasonable. Modified equations can be used to give better error estimates than Taylor methods, and can be designed to conserve quantities such as energy for Hamiltonians. Robert Corless (Western Ontario University) used the ideas of modified equations to explain why numerical methods "usually" succeed, and proposed the use of defect control methods for long simulations of dynamical systems. G. Turner (LaTrobe University, Bundoora) showed how to construct integrators for reversible maps and flows, by making symmetric products of low-order integrators. D. Stewart (Australian National University, Canberra) used multigrid multilevel spectral AIM algorithms to approximate inertial manifolds of PDEs.

Hussein Kocak (University of Miami) gave an informative survey of computer-assisted methods for proving the existence of shadowing trajectories for dynamical systems, and reported on a new method for the shadowing of autonomous ODEs, which present a special problem because of the nonhyperbolicity along the direction of flow. He showed how to get guaranteed bounds on how far a true trajectory might be from a numerically computed one without making untestable assumptions about the nature of the system such as "hyperbolicity".

Peter Tsen (National Chiao Tung University, Taiwan) talked about the estimation of the distance of the true shadowing trajectory from the computed trajectory. Erik Van Vleck (Simon Fraser University) described a new method for the stable computation of Lyapunov exponents for ODEs, when the equations are known. The method succeeds by following a continuous QR-factorization of tangent directions by solving the differential equations for the orthogonal matrix Q.

Charles Elliott (University of Sussex, England) talked about spatio-temporal model of binary alloy evolution, and gradient systems that come from phase transition problems. Special cases of the general form are the Cahn-Hilliard and Allen-Cahn equations, with and without viscosity. Important issues are the complex morphology of interfaces, solidification rates, phase transitions, and pattern formation. Asymptotic numerical solutions compared well qualitatively with experimental results of chromium-iron alloys, which were displayed. He also talked about mean-field equation for the Isinq model.

Spurious solutions, a major theme of the workshop, are solutions of the discretization that are not solutions of the original equation. Helen Yee (NASA Ames, California, Email: YEE@WK79.NAS.NASA.GOV) showed many pictures of spurious numerical solutions for nonlinear differential equations. She focussed on examples of spurious attractors and basins of attraction, primarily for large step-size. Stephen Cox (Adelaide University) found spurious solutions in a doubly diffusive (heat/salinity) PDE that are artifacts of the number of modes followed by a spectral method. The use of more than 15 modes results in the correct behavior, while using fewer modes exhibits the period-doubling route to chaos. Arnold Dikansky (St. John's University, N.Y.) talked on the interpretation of Galerkin approximations of reaction-diffusion equations, and in particular gave conditions under which it can be inferred that certain solutions of the true problem exist. Connie Schober (University of Colorado) showed that there are large regions in the parameter space of the nonlinear Schrodinger equation where inherent instabilities are computationally unavoidable, even though the equation is integrable. Xinghuo Yu (University of Central Queensland, Email: YUX@T-OPAZ.UCQ.EDU.AU) talked about discredization effects on a discontinuous system that arose from a switching problem designed for control. Greg Ovenden (Witwatersrand University, South Africa) reported on spurious solutions of linear multistep methods applied to ODEs.

A. Pokrovskii (Russian Academy of Sciences) showed how to use an interval-arithmetic version of stochastic matrices for the discredization of 1-D maps. He argued that to really understand chaotic systems, they should be turned into random ones! He derived theorems on the metric distance between the correct and computed invariant measures. Mathias Gundlach (Bremen University, Germany) discussed the spatiotemporal phenomena of coupled map lattices. H. Tanaka (Waseda University, Japan) gave a singular point analysis from the integrable case to investigate a chaotic neural network. Xue-Zhong He (Flinders University, Adelaide) exhibited conditions for the existence of a unique attracting fixed point for neural networks with a nonzero delay transmission time. L. Debraux (Technical University, Compiegne, France) described a numerical technique for following invariant circles from a discrete Hopf bifurcation. W.H. Steeb (Rand Afrikaans University, South Africa) discussed symbolic computation and object-oriented programming for the simulation of chaotic systems.

R. Huilgol (Flinders University, Adelaide, Email: RAJ@IST.FLINDERS.EDU.AU) studied the kinematics of a mass suspended from an overhead crane, using a Melnikov analysis to prove the existence of a transversal homoclinic intersection under certain conditions. John Christie (Flinders University, Adelaide) applied Melnikov analysis to a system of 30 ODEs representing a chemical reaction. Hal Smith (Arizona State University) explained theoretical results on asymptotically autonomous semiflows.

Two engineering-oriented talks explored hardware applications of chaos. Takeshi Yamakawa (Kyushu Technical Institute, Japan), is very well known for his work on fuzzy controllers and runs the Fuzzy Logic Systems Institute in Kyushu. He described a conception of a "postbinary" computer, which will contain aspects of fuzzy logic, neural computation, and chaos. Professor Yamakawa made an interesting distinction between digital, fuzzy, neural, and chaotic systems in terms of their distinguishability and redundancy. For example, 64 bits allows about 10^{19} distinct states with no redundancy, a fuzzy system has high redundancy and low distinguishability (in the labels and membership functions), a neural system also has high redundancy and intermediate distinguishability in the weights and thresholds, and a chaotic system (via nonlinear difference equations) has intermediate redundancy and distinguishability, where memory space is obtained at the expense of read-out speed (time to generate parameters associated with nonlinear difference equations). I must admit that some of this was fuzzy to me too, but nevertheless very thought provoking.

Yamakawa demonstrated a prototype chaos chip, which is a circuit implementing a nonlinear 2-D map with parameters that can be easily set by the user. The chip implements a discrete nonlinear map x(n+1)=f(x(n)), where f is a three-segment piecewise linear function with shape externally controlled. The chip has but three elements, a nonlinear delay, a linear delay, and a summing element. Very complicated systems can be built from these by combining these simple building blocks. The prototype is implemented by a 3μ-m double polysilicon CMOS process. The package is approximately 3.5mm^2 with 28 pins. Yamakawa gave three simple application areas for a chaos chip,

(1) a basic educational tool for studies of chaotic behavior,
(2) a research tool because it is easy to use and inexpensive, and
(3) a verification tool for industry.

In the latter case he pointed out the interest in the consumer electronics community, for devices that have variations in characteristics, for example temperature stability. He mentioned that in Korea, Goldstar had already developed a prototype washing machine that uses an external chaotic circuit to ensure that there are no periodicities in the wash or rinse cycles, and the company claims that this significantly reduces the amount of clothing tangles. Yamakawa commented that he has been discussing the possibility of Goldstar incorporating his ideas in a simple (internal) circuit that would add very little to the cost of such a product. In 1988 Yamakawa produced a fuzzy chip, so one must take very seriously his ideas on a related topic.

Through a multimedia demonstration, Prof. Yamakawa convinced most attendees at the workshop that the "jukebox of the future" is already within our grasp, by plotting the phase space of trajectories while changing the map parameters according to the intensity of rock-and-roll music. Those of us who remember the light-boxes of the 1960s and '70s were impressed with the progress that has been made in this field.

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Tom Vincent (University of Arizona) demonstrated the advantages of chaos for control applications with a mechanical double pendulum with electric motors at the pivots. Using the fact that chaotic trajectories often explore large regions of phase space, he showed how to target an unstable steady state (the lower pendulum standing straight up, parallel to the upper pendulum) and force the system into that state by using small pushes from the motors.

In listening to papers and speaking to some of the attendees who were not actually presenting papers, it was clear to me that there were really two groups of individuals present at this workshop. First, a significant number of internationally known researchers (many described above), who were describing high-class research to their colleagues—in a sense this is what a workshop is all about. But the second group, less well informed, came to learn about a subject that they knew very little of, initially. I doubt if this group was particularly well served by the papers presented here. It might have been better for the organizers to be clearer in the workshop description concerning who should attend and how they might benefit, and then keep those goals in mind when soliciting papers and attendees. DKK]

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From:
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For the last several months our research group has been involved in a series of experiments to evaluate the relative performance characteristics of the currently available CM5 programming paradigms. A major area of recent work has been exploring the low-level programming of the CM5's vector hardware through the assembly language DPEAC. This has largely involved a consideration of how efficient algorithms specific to the hardware configuration of the CM5 may be designed and issues involved in implementing these algorithms.

A technical report describing this recent work is now available for anonymous ftp from ftp.cs.adelaide.edu.au in the directory pub/cm5reports as exper-cdpeac.ps.Z. The report is entitled "Experiences with CDPEAC: Vectorising a Laplace Iteration" and has the following abstract:

Abstract

We motivate and describe an algorithm we have designed to perform an efficient Laplace iteration on the CM5 using a synchronous message passing paradigm and programming the vector processing hardware directly. Some notes on the implementation of the algorithm and some performance statistics are included. These show our implementation to be more efficient than the equivalent program written with higher level paradigms like CM Fortran.

Also available from the same site and directory is an extended diagrammatic example of the operation of the algorithm presented in the report. This example appears as exper-example.ps.Z in the pub/cm5reports directory.

Any comments concerning this work are naturally welcomed.

"Supercomputers: Essential Tools or Expensive Toys" E.T. Robinson CTAC'93 Lecture, Australian National University, 6 July 1993

First let me say that I was pleasantly surprised to be invited to address an audience that includes some of our leading mathematicians and supercomputing experts.

Although it is over 30 years since I was involved in computer design, I did have the good fortune to work with Control Data for many years and thus had an opportunity to watch the development of leading-edge machines of the time such as the CDC 3600, 6600, 7600, 8600, STAR and the promising but ill-fated ETA series.

The saga of high-performance computing (perhaps like high-performance anything else!) has been, and continues to be fascinating. As we shall see, it has added a totally new approach to scientific investigation and perhaps brought us closer to knowing the mind of God, to use Stephen Hawking's famous phrase.

Much has been written on the place of computation in the field of mathematics. It comes as something of a shock to learn that there are such areas of interest as computational algebra and that computers can have a place in such abstruse areas as theorem proving. Advances in hardware speeds and memory size, coupled with new systems software, new approaches and ingenious algorithms have transformed a whole field of science that only came into existence 50 years ago. And, it is leading us to a new idea—computational science; those intellectual ideas in science and engineering that exploit supercomputing as an essential tool. Computational science is not computer science—to quote from a paper given at the Supercomputing Conference in Melbourne last year by Gary M. Johnson and John S. Cavallini of the U.S. Department of Energy: "In computer science, computers are the end objective. In computational science, computers are a means to accomplish other scientific and engineering objectives". One of the essential tools of computational science is the supercomputer. What is a supercomputer and in what way does it differ from a computer that isn't a supercomputer?

To answer, we need to go back 50 years to the beginning of electronic computing. We won't dwell on the abacus, Napier's bones, the legendary Charles Babbage or others who laid the foundations; people like Boole, Shannon, Turing, von Neumann, Atanasoff and Zuse, because time is short. Suffice to say that when World War II broke out in 1939, the necessity to compute artillery tables, break codes in a hurry, and similar imperatives fathered the invention of the earliest digital computing devices. The first electronic stored-program machine, ENIAC, was completed in 1945 in the United States after the War ended. It weighed 30 tons, was 80 feet long, had a complement of nearly 20,000 valves and ran at about 1/100,000th the speed of today's personal computer.

Progress during the 1950s was rapid. Computational speeds increased by three orders of magnitude, the transistor replaced the themonic valve or vacuum tube, and the IBM Company realized that the computer was more than a scientific tool—it was also a business machine. The first commercial computer (the Remington Rand UNIVAC) appeared in 1952. It was joined by the IBM 704 in 1956, but IBM was soon in the ascendancy—in both scientific and commercial markets.

In that year Control Data Corporation, a Univac spinoff, produced its 6600 computer designed by the then relatively unknown Seymour Cray. In simplistic terms, this was a branch point; IBM, although it has never deserted the scientific and engineering market, went off to totally dominate the commercial market and leave Seymour Cray as the Colossus of scientific computing for the next 30 years, with Control Data until 1972 and subsequently with his own companies.

The CDC 6600 is generally regarded as the first supercomputer, but the appellation was not coined until much later and was not used in the literature until 1978. In retrospect, it would seem fair to describe the fastest machine of the day as a supercomputer. According to one worker in the field (Carl Ledbetter), the identification of the 6600 as the first supercomputer marks the bifurcation of scientific and commercial computing. Commercial data processing and scientific computing call for different kinds of specialization—like living things, the two species have evolved along different branches.

So, what is a supercomputer? There is no consensus quantitative definition, the term is restricted to that class of computers with the current best capability of handling numerically intensive problems. That reduces to a definition that identifies supercomputers as computers that solve super problems. Super problems are problems that need to be solved within some desirable time—weather prediction is a good example.

There are other tongue-in-cheek definitions, all of which contain a grain of truth. One attributed to Seymour Cray defines a supercomputer as any machine that costs U.S.$10M. Translated to the dollar value of today that is substantially accurate. Another definition stipulates "A supercomputer is a computer that turns a compute-limited job into an input/output-limited job" And, cynically perhaps, "A supercomputer is a computer that is only one generation behind the requirements of the user.

Computing speed is a necessary feature of a supercomputer, but adequate memory is required for sufficiency in the case of a single von Neumann processor. Seymour Cray, while restricting himself to proven components, showed his genius in his packaging and his hardware tricks (such as pipelining) that removed bottlenecks. But there are practical limits to hardware artifices in a single processor machine.

It should be noted here that Cray, although dominant, has never had the field entirely to himself, his major competitor in the 1970s and 1980s was Control Data, followed in the 1980s by three Japanese companies, Fujitsu, Hitachi and NEC. IBM also reappeared with up to six attached vector processors on their large-scale 3090s. More recently, Convex Computer Corporation (a U.S. company) entered the ranks to join the Japanese companies in challenging Cray's dominance of the market.

The Japanese supercomputer industry should not be underestimated. Aware of the crucial part that supercomputing plays in both national development and national security, the Japanese Ministry of International Trade and Industry has directly supported major computer manufacturers. Fujitsu, with more than 160 supercomputers installed worldwide, last year announced the new VP500 series with a peak performance of 355 gigaflops and upwards compatibility from the VP200 series. The VP500 uses up to 222 processors in a concept Fujitsu calls Vector Parallel Processing. Meanwhile both Hitachi and NEC are offering extremely competitive systems. At present, these three companies have about 35% of the world market; they expect that share to grow to 50% by the end of the decade.

The way out of the single processor limitation is parallelism. In fact, this had been demonstrated on the ILLIAC IV in the late 1960s. This machine had 64 processors that shared the data on which each instruction operated simultaneously—a single-instruction multiple-data (SIMD) machine, as distinct from the type of parallel machine where each processor operates independently on its own data—a multiple-instruction multiple-data (MIMD) machine.

In recent years the vector machines have gained throughput by adding processors.

For instance, Cray computers have used multiple processors increasing from 2 to 4, 8, 16, soon to 32 and foreseeably to 64. Of course overall processing speeds do not increase linearly with processor numbers but it is a successful architectural ploy that is being exploited in a new class of machine—the massively parallel computer.

In 1971 Intel Corporation succeeded in putting an entire computer on a chip—the microprocessor. This development, which spawned the era of the personal computer, also provided supercomputer designers with a low-cost, reliable, off-the-shelf component for this new type of machine. Wiring the processors together was easy; programming them was difficult. Nevertheless, progress has been rapid. The number of microprocessors has jumped from 64 to the binary thousands—the Thinking Machines Corporation's CM-2, for instance, has 64K processors.

All the recognized supercomputer manufacturers in the United States, Europe, and Japan (including Cray and Convex) are bringing out massively parallel machines, but it should be borne in mind that the great bulk of the world's 600 or so supercomputers are single or dual processor machines, such as the Cray X-ND. The situation is well summarized by Kaufmann and Smarr in their excellent book "Supercomputing and the Transformation of Science." "Although the vector multiprocessor computers are no longer the fastest machines or those with the largest memories, they will still be considered supercomputers for some years to come. They will retain their status as long as most third-party application codes to perform engineering, chemistry, or biology simulations; they are only available on the vector machines. Because of the high risk and small installed base of the massively parallel machines, it will take several years to develop a set of application software for these new architectures that will rival that already available on vector machines."

What of supercomputer speeds and supercomputer costs? Supercomputer speeds are measured in flops—floating point operations per second. A million flops is one megaflop, a billion is one gigaflop and a trillion flops is one teraflop, achievable perhaps by 1995. One measure of a supercomputer's capacity to solve problems is peak speed, but there are other equally significant factors, such as memory size, and there are also "horses for courses". In a particular case the ideal machine to solve a problem is unlikely to be the fastest scalable massively parallel machine available—on the other hand it could be—it all depends on the nature of the problem and available software.

This graph tells the extraordinary story of how speeds have increased. Note that the vertical scale is logarithmic and points to an increase in peak speeds by a factor of a trillion in 56 years. But it should be remembered that average speeds are usually only 5% to 10% of peak values.

[The figure is omitted, but it is a fairly standard plot of improvements in computing speed over time, DKK.]

The second issue is cost. Seymour Cray's whimsical definition translates to about $30 million, and that's about the cost of a Cray C90, a machine with 16 processors and a peak speed of 16 gigaflops. There are entry-level Crays costing less than a million dollars and other so called mini-supercomputers, but generally speaking we are talking about machines in the range of A$10 to 40M, although there is some hope of improved cost/performance ratios as new generation machines embodying massive parallelism, shared memory, and enhanced vector capabilities become available.

It is pertinent to ask whether cost can become a barrier to further use; is there some figure that is so high that it is no longer tolerable to the agencies and corporations that make up the user base for top-end machines?

According to some vendors, there is such a barrier and it is being approached. One could, for instance, speculate on the price of the future 64-processor CRAY Triton-X. If a 16 processor machine costs US$45M, could a 64-processor development cost less than US$150M? The top-of-the-line Fujitsu VP500 supercomputer, offering 355 peak gigaflops, is reportedly priced at US$150M. Will organizations pay US$150M or more for a supercomputer? The answer is almost certainly "yes" if the benefits outweigh the costs. The issue is well illustrated by the situation with the Ford Motor Company. Ford paid US$45M for a CRAY C-90. That was a heavy cost but the benefit to Ford was enormous; the model development cycle was halved thus presenting the company with a competitive advantage as well as reducing other costs. Ford's Board, incidentally, was so pleased that they authorized the purchase of a second C-90.

There are similar cost-benefit considerations applicable to intelligence gathering and national security in general, but as a practical issue, I think we have to accept that there are limits to what the ordinary research supercomputer user can pay. It is interesting to note the connection between supercomputing and intelligence agencies worldwide. For some time it has been no secret that a prolific source of intelligence, in both war and peace, is the interception and decryption of radio and telecommunications traffic. It is no exaggeration to state that computing began in this environment. Intelligence has been a generous supporter over the years and continues to be the major investor in this technology. The largest, fastest, most sophisticated, and expensive supercomputers in any advanced country are to be found in the intelligence agencies.

When we combine the "horses for courses" guideline with the expense issue, it becomes obvious that supercomputers must be networked. The United States has established a pattern that we in Australia are emulating in a suitably modified way to accommodate our slimmer checkbook and smaller population albeit in a country of similar geographical size. In the United States the Government has established four National Computer Centers (at San Diego, Cornell, Pittsburgh, and Champaign-Urbana near Chicago). Each of these has a selection of 4 to 6 supercomputers that are connected over a broadband network and together constitute the "National Machine Room."

These centers are supported by the U.S. Government under a long range plan called the High Performance Computing and Communications (HPCC) Initiative. Its scale can be judged by the cost—US$700M in 1991 rising to more than US$1.4B in 1996.

In an ideal case, within such a network, a scientist, or an oil geologist, or a drug designer, or automobile engineer can sit at his workstation or PC, run his problem on an appropriate supercomputer of his choice, get the results back on his PC, and, in a few iterations, solve the problem.

The modern scientific age began when Galileo looked through his telescope in 1604. In the last 400 years, scientific and technological progress has been based on two mainstream activities sometimes called the roads to discovery or the two modes of science. One has been based on observation and experiment epitomized by Galileo himself, and others exemplified by perhaps, Rutherford's work on the atomic nucleus and Florey's on penicillin. The other route to scientific discovery has been theory. Maxwell's work on the electromagnetic field and Einstein's on relativity are two remarkable examples. But, both methodologies have limitations—experimentally the phenomena may be too fast, too small, or impossible to examine directly, while many theoretical approaches can deal only with the simplest, idealized situations.

Computer simulation has proved to be a third powerful methodology, which has not only advanced the boundaries of science but has also done much for technology. We can now simulate on a supercomputer experiments that are too expensive, too dangerous, too complicated to perform in real life, or just physically impossible. Into this category comes the simulation of nuclear explosions, thunderstorms, star formation, and collisions between galaxies. At a more practical level we have the design of drugs, aircraft wings, and automobiles. In the latter case safety can be improved by simulating rather than physically crashing cars.

John Rollwagen, Cray's CEO, tells a story of how the supercomputer wind tunnel group at NASA in no way impressed their colleagues on the real wind tunnel with the accuracy of their simulations until they demonstrated the true story—what happened when the walls of the wind tunnel were removed. This simulation told a different story; aircraft fly in free air, not along tunnels.

The economic and social significance of this third mode of discovery cannot be overestimated. Accurate predictions of the weather, (particularly of cyclones, hail, frost and snow) can save billions of dollars through timely warnings. An issue of significance to us all is global warming; we can only do the actual experiment once and that may be too late. Supercomputer simulation is the obvious way to tackle this problem. These methods are widely applicable in the oil industry to both exploration and recovery, and so it can be no surprise that the major oil companies are among the pioneer users of industry.

Finally, on simulation, let me quote from a book by John McLeod and John Osborn. "...in real life mistakes are likely to be irrevocable. Computer simulation, however, makes it economically practical to make mistakes on purpose. If you are astute, therefore, you can learn much more than they cost. Furthermore, if you are at all discreet, no one but you need ever know you made a mistake".

Failure analysis is another supercomputer application. It has been pointed out that the Challenger space shuttle disaster need never have happened. After the event some 1500 hours of supercomputer time were used doing 3-D analyses on the 0-rings that exposed the failure mode unrevealed by earlier 2-D analyses. And, last Friday the Financial Review repeated a Business Week item on the problem of Boeing 747s shedding engines on two or three occasions because of failure of the fuse-pins. These had been designed originally as part of the wing structure in which the wing was subjected to a 10,000 node finite element analysis. Boeing recently carried out an ll-h, 34,000-node analysis on the fuse-pins alone that revealed unacceptable stresses on the pins at takeoff. Needless to say the pins have been redesigned and the 948 747s in service have had the new pins fitted. This story drives home the point that supercomputers are, in yet another way, part of our life-support system.

Triumphs in medicine, biology, engineering, construction, particle physics, and cosmology are unfolding in what we can expect to be a never-ending sequence. For instance, recent developments in the understanding of the influenza virus at the Biomolecular Research Institute in Melbourne were made possible by a supercomputer—in this case a Convex. And progress in new areas of chaos theory and complexity, particularly as they affect economic theory, may bring significant results. The computational mode of discovery has certainly earned its place beside experiment and theory as the third way to discovery.

So now I hope we have settled the issue between expensive toys and essential tools. Supercomputers are indeed essential tools—one might add essential economic tools, and they are certainly not toys. They are, however, expensive.

Like all sophisticated modern devices, supercomputers require infrastructure. The institutions and companies that use these machines need the help of experienced analysts, programmers, maintenance engineers, communications experts, and, of course, the researchers themselves. That is the human resource side.

What are the other infrastructure elements? I mentioned earlier the need for a broadband network to enable distance working of supercomputers. Plainly, a nation of 17 million people must use the few machines it can afford in an optimal way. The transmission of large volumes of data and other imperatives (such as visualization) require the facility of the broadband network mentioned earlier. Australia was given a head start by Telecommunications which has not only girdled Australia with optical fibre but has interconnected capital cities and major centers. The completion of the optical fibre network to businesses, tertiary institutions, and, in a limited way, to homes would not only be a boom to productive computation, but would go a long way toward establishing the foundations for a "clever country". We shall return to this subject a little later.

It goes without saying that finance is the ultimate underpinning infrastructure element. With the exception of the Adolph Basser Foundation at the University of Sydney Australia's earlier (pre-1990) high-performance computing facilities were all taxpayer financed. Even now, there is only a handful of supercomputers in industry—an entry-level Cray at BHP in Newcastle, several Convexes doing mostly seismic analysis, and one or two under temporary arrangements with vendors. These are steps in the right direction but at first glance the performance of industry seems to be disappointing. However, we must bear in mind that our largest companies are small compared with their counterparts in the United States, Japan, and Europe. Their need and their ability to pay for expensive computing facilities is also considerably less. Some of you will have heard Alan Bell's analysis of this issue at the 1992 Supercomputer Conference in Melbourne. He pointed out that enabling technologies take time before they bite, so we should be patient. Bell suggested that supercomputing partnerships between industry and the appropriate tertiary institutions will provide an eventual answer and in that he is almost certainly correct, but it would seem most unlikely that direct Government intervention along the lines of the United States' High Performance Computing and Communications Initiative will occur in the foreseeable future.

There are several issues here. Michael Porter, in his much-quoted "Competitiveness of Nations" suggested that Governments, in general, should restrict their commercial activities to catalyzing initiatives like supercomputing—they should encourage and cajole but stay out of the heavy action such as managing and financing. I believe it can be fairly said that the Commonwealth Government still sees supercomputing as a big R research activity with a small d for the development component rather than viewing it as yet another tool available across a fairly wide range of industries to improve productivity and thereby raise GDP to boost our flagging standard of living. However, in spite of the fact that there are no specific policy settings for supercomputing as in the United States, France, United Kingdom, and Japan, the Government has supported supercomputing through some of its agencies. The CSIRO, in particular, can point to a history that goes back to the CSIRAC of Trevor Pearcey, a CDC 3600 in the 1960s, CDC 7600 and 205 and then a CRAY-XMP with Leading Edge and now a CRAY-YMP as well as two Maspars and a CONVEX. Government is also visible though ANSTO's Fujitsu VP-2200, through the Bureau of Meteorology with 2 CRAYs, and the BMR (now the Australian Geological Survey Organization) with a CONVEX.

But we are being too hard on the Government. The major Australian universities, beginning with Sydney in the late 1950s, have contributed tremendously to the promotion and practice of high-performance computing in Australia. This audience is well aware of the wide range of computing and networking resources available, including the supercomputing facilities here at the ANU. These are all, indirectly, financed by the taxpayers. The problem with supercomputing in Australia does not reside in the research institutions or with Government funding through the universities and CRCs as R&D agencies. It lies with industry, (which has yet to realize that time is money), and with those parts of the bureaucracy reluctant to accept that supercomputers ought to be included in the set of technological tools that this country can use to improve its GDP. To quote a trivial example: CAT-scanning hardwood logs (which would involve the use of a relatively low-cost, available, massively parallel supercomputer) would, as estimated by the timber industry, save Australia A$200M a year in imports. This is because CAT-scanning would permit a proportion of the hardwood that is now pulped to be selected for construction or veneering—another example of the smart use of technology, but again, one to be financed by the tax dollar.

When I was at Control Data I shared some of the pain, as well as some of the joy associated with the 3600, the 6600, the 205 vector machine at CSIRO and Control Data's Cybernet Bureau. One lesson stands out; managing a high- performance bureau to profitability is a difficult commercial challenge. That was certainly true in the 1960s and 1970s and more so in the 1980s. I don't expect that it is getting any easier. There is perhaps a second lesson for Government- don't make the taxpayers pay the capital cost of supercomputers and then try to recover that cost from the users who, for the most part, are themselves taxpayer-funded. It has been pointed out ad nauseam that supercomputing is an enabling technology and should be seen as such. There is no community expectation of recovering the cost of medical research or the Australian Telescope; we should have the same attitude toward taxpayer investment in supercomputing.

Supercomputing is just one of the technologies underpinning the clever (or intelligent) country concept. Better access to knowledge, to reasoning and computing tools, at the level of the individual (not just for institutions and corporations) can give this country a competitive edge it badly needs. One avenue is through completing the optical fibre network with which Telecom has criss-crossed Australia at a cost of some A$10B or so. Connecting this network to provide appropriate bandwidth into Australia's 6 1/2 million institutions, businesses, and homes will cost A$4B or more, but as a national project that can realize some of our more worthwhile aspirations, it may be a small price to pay. Unfortunately, this initiative, although it has been acknowledged in the Prime Minister's preelection Policy Statement, is now part of the Pay-TV controversy. Although Pay-TV is part of that scene, as first-cab-off-the-rank and as a revenue provider, it is not the central issue. As has happened so often before (plain-paper copying, aircraft "black-boxes" and computer networking, for example) Australia is in the van with broadband, but we seem to be facing a slowdown. By contrast, Japan, as part of a $625 billion program to build a broadband national network will spend US$138B on the optical fibre network alone. If Australia continues to dither over the $5 billion needed to adequately use our existing network, (and which can at least be partly funded by private investors), supercomputing will be but one of the losers.

We must not, however, forget the Research Data Network CRC with its US$13M in funding over the next five years, its very capable participants, its association with the Australian Vice-Chancellor's Committee, its responsibility to upgrade AARNet and to fund access to broadband facilities such as the proposed AOTC Experimental Broadband Network at some ten sites. The CRC's four research programs are all related to the escalating need to move data around the country in greater volumes and at higher speeds. Along with the Photonics CRC it is a good thing.

Where is supercomputing going in Australia? Although we tear our hair out and complain to the heavens, things are not that bad. Last year we had Greg McCrae out here with the Warren Center; this was a very commendable effort and one had to be impressed by his zeal, his enthusiasm, and his belief in the capabilities of his compatriots. But will it and similar initiatives get industry off the starting blocks?

We have been discussing the use of supercomputers as scientific and industrial tools. Could Australia be involved in the development of these devices? Hardware development might be beyond our resources, but there could be possibilities on the systems software side. Where might an Australian effort fit?

There have been past attempts at what might be called systems involvement. The first (and most notable) was undoubtedly the CSIR Mark I (CSIRAC) but there have been others—the DAD operating system at CSIRO and the CDC (for Control Data Canberra) designed hardware system, both rejected by Control Data, to give just two examples. There have, of course, been others. The fact of the matter is that computer systems design is a very private activity with a high NIH (Not Invented Here) component; joint ventures even between compatriots are unusual so the likelihood of international joint undertakings seems unlikely. I mention this because suggestions have been made that Australia might have such an opportunity in Japan.

As the Chairman of ISR Group, although small, now has its own Japanese subsidiary. I might note that our Japanese are not entirely convinced of our dedication to deadlines—failure to deliver the crayfish and abalone to royal weddings on time can have unusual side effects!

For all that, such an arrangement would be a good thing, if it can be brought to fruition.

What of future progress? Competition has never been more intense and it is no secret that many (if not almost all) supercomputer suppliers are finding it difficult to make money. We can expect new products featuring enhanced performance for both the parallel vector machines such as Cray's forthcoming 32-processor Triton and for the massively parallel machines. Published projections are hard to come by, but the Japanese Electrotechnical Laboratory has stated objectives of 200 gigaflops by 1995 or thereabouts, 50 teraflops in 1998 and 3,200 teraflops by the year 2002. They are looking at a new architecture and the trend line, advisedly, is dotted. Prediction is a dangerous business—as that American politician said: "The future lies ahead of us"—but there is no reason to anticipate any slowdown in the rate of progress.

In the immediate future, supercomputer users will be offered seamless access through workstations, a wider applications base and scalable massive parallelism with vector capability and shared memory. For example, next year, Convex will release "an air-cooled, production-ready, stand-alone system that will support an easy-to-use shared memory programming model and familiar (Hewlett Packard) user interfaces, on which] customers will be able to run more than 4,000 applications".

Supercomputing shares a problem with many other leading edge technologies—it is but another node in a complex network which includes basic research, lateral inventiveness, intellectual property definition, product development, and finally the ingestion of the resulting products and services into the community. When things get as tough as that, there is always a temptation to run to the Government crying for help. But governments have a problem with very advanced technology when it comes to lavishing support on one particular element such as supercomputing. It is not easy to find a sympathetic Minister or broadly based understanding in the bureaucracy. Nor is it easy to find an influential champion who can carry the day for the large sums of money involved when there are so many competing issues and when the Government's first three priorities are, in order, jobs, jobs, and then jobs. And I don't think any of us want to disagree with that.

It will not have escaped your notice that I have meandered from issue to issue but let me now try to draw a few conclusions from what has been said about supercomputinq. In summary:

- supercomputer capabilities continue to develop rapidly;

- the ability to use supercomputers (computational science) parallels the developments in hardware and software;

- accessibility to supercomputing facilities through broadband networking and the seamless interfacing of workstations is being greatly improved

- Australia has a good deal of experience and no lack of talent in the use of supercomputers;

- supercomputers and their support infrastructure are expensive. Accelerating progress in technology calls for frequent replacement, which means high continuous expense;

- national security is dependent to a large and little known degree on supercomputing usage in the field of intelligence gathering;

- developments in chaos and complexity theory, as they affect economic theory are likely to become of national importance;

- the usage of supercomputers in the leading economies is a good indicator of the standard of livinq trend lines in those countries;

- Australian industry appears to be slow off the mark in exploiting supercomputing, and

- Government policy and programs aimed at encouraging supercomputing as a productivity-enhancing tool for industry do not appear to be well enough targeted or focussed.

What should be done about it? I remarked earlier that Australia would be unlikely to adopt the U.S. High Performance Computing and Communications initiative, which on a per capita comparison would cost us about US$100M a year. Apart from the fact that we couldn't afford it, our circumstances are quite different, particularly when it comes to industry. And because the sums of money involved are so large, only the Government is in a position to make the necessary moves.

Looking across CSIRO, the Universities, and involved Government agencies there is a good deal of activity but by no stretch of the imagination could it be regarded as mobilized to contribute to the economy in any direct way. Curiosity-led research is admirable; when Australia was a rich country we could afford to indulge ourselves but now we have to make a livinq as well as play.

There can be little doubt that supercomputing could contribute. What we need is a Government policy recognizing this followed by the establishment of a coordinating authority. As in the United States, this would include those organizations with an existing involvement and/or an emerging interest. Obvious choices would be:

- CSIRO, the Australian Vice-Chancellors' Committee, and involved Commonwealth departments:
  - Defense
  - Industry, Technology and Regional Development
  - Transport and Communications
  - Education, Employment and Training
  - Environment
  - Prime Minister and Cabinet.

This authority would be chartered to establish national programs in high-performance computing targeted on four goals:

- Industry development programs to encourage industry in
  - import replacement and exports
  - improved productivity,

- Coordination of AOTC, Optus, the telecommunications companies, and the concerned CRCs to provide optimal levels of access to supercomputers;

- Academic programs to
  - develop intellectual property for export
  - export supercomputer expertise and computational science through the training of foreign students either locally or in their own countries
  - carry out research and development into computational science, and

- With the assistance of Austradc nurture selected Australian companies to market the products of academia directly into appropriate export markets, particularly in the Pacific Rim countries that have the need, the means to pay, and perhaps more respect for our technological capability than we ourselves display.

The opportunities are there; we should not ignore them! Thank you.

Alpha-flow Activities and Status, 21 May 1993

Current status and prospects for the computational fluid dynamics project, "Alpha-flow", in Japan are addressed in this report

David K. Kahaner

I have written several reports on a major Japanese R&D activity to develop capability in computational fluid dynamics (CFD). See for example, "alphal92", 25 Feb 1992, and "alpha", 6 May 1991 where this project is described in detail. The present report is an update and assessment.

Briefly, the project attempts to make use of the latest techniques in both numerical analysis and artificial intelligence to build a modular, easy to use, efficient suite of software for CFD. Although the primary objective of the project was to develop general use CFD software, it was also hoped that the efforts would establish maintenance frameworks for other large-scale scientific software. A subsidiary benefit is to use the project as an educational tool. Thus CFD specialists could learn how to develop general purpose engineering software, and at the same time engineers would have a tool to use in the production of fluid and thermal engineering.

Mostly the project was funded by companies that are users of CFD, e.g., supercomputer manufacturers, research institutes, universities, software development companies. The project budget was J¥1.3B (about US$10M) to be distributed over four years (ending in March 1992), from the member companies of the Association for Large Scale Fluid Dynamics Analysis Code, which was the organizational entity set up to coordinate the project. The Association is composed of 15 main companies and another 30 companies that provide lesser support. In addition, the Japan Key Technology Center is also financing the project through one of its member companies, and provides advice and coordination. While MITI seems to have had only a minor active role, its leadership (through JKTC) was important to get the member companies to commit (a small amount of original MITI seed money was repaid by the member companies). An Alpha-flow developer's association was created after the project ended last year, primarily for dealing with business problems. A user's association will be initiated soon.

Although this Association is the nucleus of the development project, there are various technical committees and technical working groups, including participation from university faculty. In addition, the actual software writing was done by the Fuji Research Institute Corp (FRIC), one of the member companies. I have visited their facilities several times over the past two years to follow the work. The current report also reflects the opinions of Dr. David Keck of Convex Computer Corporation, who also visited FRC with me.

The basic design goals have been to build a package that is easy to use even by nonexperts, is tuned to vector supercomputers, and becomes a standard for reliability. To this end, the designers wanted to make good use of workstations to help with the man-machine interface, and also to introduce expert systems to make it easy for nonexperts to handle fluid dynamics problems. Other goals were to develop a data management system (using a standard file format, SFF) that allows computational results and input data to easily flow between modules, and generally to emphasize modularity at every stage, including libraries and multiple programs.

OVERALL SYSTEM CAPABILITIES

The system is designed as a set of modules. It is assumed that Unix is the operating system; X-windows is used for the windowing software and PHIGS for the graphics. Modules for input, data management, expert systems, interactive post processing, and control are thought of as existing on the man-machine interface side of the system, whereas modules for solvers are on the other side. Between them is a gateway module that is essentially responsible for reading and writing files, and for maintaining a standardized file format. The solver modules consist of about 400,000 lines of Fortran; the man-machine interface modules consist of almost as many lines of C. Solvers exist for incompressible flows (heat transfer in solids and mass transfer), incompressible flows with free boundaries, chemically reacting flows, and compressible flows.

Each solver module, except the heat transfer and mass transfer modules, are independent of all others. The heat transfer and mass transfer modules can be incorporated into any other solver module and used in combination. The gateway module helps to keep other modules independent as well as helps modification and makes addition of new functions relatively easy. Also, the analysis modules represent a type of library that allows addition of a variety of new modules depending on the need. When a module is added, it simply has to match the interface of the gateway module, so it is fairly easy to incorporate existing user codes into Alpha.

Some of the modules have interesting capabilities. Some examples follow.

The input module has the following functions

- Generation of 3-D configurations: Generation of primitives, local and global transformation operations can be done interactively. Free surfaces can be generated.

- The computational grid can be generated either in Cartesian and cylindrical coordinates, or in Boundary Fitted Coordinates (BFC). In the latter case, various domains can be combined.

- Specifying data for analysis, initial conditions: This can be done interactively by using an X-window format.

Analysis Modules

The incompressible flow module is in two parts, one for Cartesian and cylindrical coordinate systems and one BFC, although the analysis in both are basically the same.

The main incompressible analysis model is as follows: The basic equations are the Navier-Stokes, continuity and energy conservation equations. The turbulent flow model can be either k-epsilon or LES (Large Eddy Simulation). The difference in the scheme for the convection terms can be first order, third order upwind differencing, second order or fourth order central differencing, or QUICK (Quadratic Upstream Interpolation for Convective Kinematics) schemes. (Like other Japanese CFD software, Alpha uses finite difference, finite volume methods not finite element. Keck felt that this was just a trend, with no particular significance.) Time integration is by the simplified marker and cell method. Solving the linear equations can be done via Modified Incomplete Cholesky Conjugate Gradient or Scaled Conjugate Gradient. Quite general boundary conditions are allowed.

An incompressible flow module that allows free surfaces is available, but not by using BFC. This module can handle flow containing a number of air bubbles and flow in which surface tension cannot be neglected, in addition to ordinary free surface flow. In determining the position of the free surfaces, the volume-of-fluid method is used.

The purpose of the compressible flow analysis module is to analyze high-velocity viscous compressible fluid. The basic equations can be either the Euler or the Thin-Layer equations. The coordinate system is BFC, and the turbulence module is the Baldwin-Lomax model. The differencing of the convection terms can be TVD (Total Variation Diminishing), fourth order central + artificial viscosity, or third order upwind differences. Integration over time is by IAF (Implicit Approximate Factorization). To capture shock waves accurately, an Adaptive Grid method is incorporated.

In the module for flows, including combustion and chemical reactions (subsonic reactive flow), the basic equations are the Navier-Stokes, conservation of mass, mass of chemical species, and energy conservation. Cartesian or cylindrical coordinates are permitted. Turbulence is calculated by using the k-epsilon model, and turbulent combustion is via Magnussen's eddy current dissipation model. This module can also handle radiation between wall surfaces.

The combustion model incorporates models of spray combustion and solid particle combustion. Boundary conditions can be freely established by the user.

Convection term differencing can be first order upwind or QUICK. Integration over time is by the SIMPLE (Semi-implicit Method for Pressure-Linked Equations). Simultaneous linear equations are solved by using the MICCG method and the

ILUCGS (Incomplete LU Conjugate Gradient Squared).

The heat transfer analysis module performs heat transfer analysis of solids. Its main purpose is to analyze heat transfer where heat and flow are highly coupled. Analysis can be performed by using Cartesian, cylindrical, or BFC.

The mass transfer module analyzes cases where a trace amount of a material is mixed with the fluid. It can be used independently or coupled with the fluid analysis module. The trace material can be a gas, liquid, or aerosol. Up to ten types of material can be analyzed simultaneously.

STATUS AND FUTURE PLANS

The project has officially ended, but the staff at Fuji Research are still active in supporting the software they have developed. Source versions of the package have been delivered to the Association member companies. Of the latter, four (NEC, Hitachi, Fujitsu, and Fuji Research) have announced plans to sell the software. For example, NEC is now promoting Alpha-flow as a general purpose fluid dynamics analysis system on their SX-3 series supercomputers. NEC's version is claimed to be faster than the original and also has some additional and improved features. (Alpha implementation generally is for the highly vectorized multipipe, multifunctional unit, Japanese supercomputers.) NEC states that the system has application to a variety of fields, including architectural and civil engineering, mechanical engineering, aeronautics, automotive design, chemical industry, environmental analysis, and basic research. However, staff from Fuji Research told us that a major target of the software is in the civil engineering field, for example to model flow around buildings, and that six of the "supporting member" constructions companies have adopted the Fuji version for their design engineering departments. This seems to be the main commercial version other than those provided by the Japanese computer companies (all of which are principal members). These Japanese vendors have not been able to make all of the "Western" commercial CFD codes available on their machines (one issue being market size). There are five customers other than those original members (for the FRIC version). Currently, Fuji Research has about 20 people working on the software. As far as use of the software within the member companies, we were told that it is considered important that Japanese engineering companies have access to the source of an engineering code. This is much less so in the West where source licences are atypical, and shrink-wrapped binary is typical. (A reasonable price for a source license accounts for one of the reasons for the success of STREAM in Japan.)

Scientists at Fuji who are working on the project felt that its functionality was okay, and about the same as the popular Star-CD commercial software. Further, they felt that it would be a top level package in about three years with continued development. Keck and I were shown a brief demonstration of the system and its user interface. I had already seen this before and, in fact, had arranged for a research exhibit of the project at Supercomputing '91 in Albuquerque. The interface is almost entirely in Japanese, so it was difficult to study this aspect carefully. Fuji staff felt that it could be rewritten in English in several months, but they have been hesitant to start because their own English skills were weak. (Is there possible collaboration here with a group from the West? It seems that foreign firms could license the software, but this was not completely clear to us. Source licenses cost about US$500K to new customers. One Fuji researcher explained a typical Japanese company view: "Why pay US$50 to 100K/year license fee for a binary when you can buy source for US$500K?") NEC has already developed an English interface for their version. During our brief demo, we discovered that the system only permits structured meshes (unstructured meshes are to be added later), and that as expected relocatable adaptive meshes have limited success. Also we were surprised that the communication between modules was not much smoother—this should have been point and click. At the moment the user has to exit one module by writing a file and then read the file in after starting another module; however, this seems to be a minor point that can easily be cleaned up.

Keck was also concerned about the commercialization potential of the package. He felt that the market for such software may not be growing rapidly and that for Alpha to succeed, Keck will have to take customers away from other existing packages—a difficult task. Concerning CFD software market potential, Keck makes the following admittedly subjective comments.

The growth of the CFD market is currently limited only by its ability to become a standard and cost effective design/analysis tool in production of fluid and thermal applications (meaning that it is usable by design engineers and not just CFD experts and researchers.) This has been more the case with structural analysis, for instance.

I think that the market size is potentially larger than that for structural analysis, (e.g., even beer brewinq benefits from CFD) but not yet realized. The CFD vendors currently are a little more concerned with limited market growth than the structural software vendors. However, a large (but unknown) percentage of CFD usage is related to in-house codes (often research oriented and used by the code authors). But CFD problems are nonlinear in nature, so getting good solutions may take some user expertise, thus the expert system approach may be critical to market growth.

Use of Alpha in Japan does provide the benefit of large customer service staff, Japanese interface and documentation, expert system, and source availability. The program is generally near the state of the art, but not at the level of FLUENT, FIDAP, and the soon to be released SPECTRUM. So Alpha popularity may grow. However, over the last year there were five new Alpha licensees compared with my estimate of 40 new "Western" CFD licensees in Japan (e.g., FLUENT, FIDAP, STAR-CD etc.). Another trend to notice is that the most successful engineering software in Japan is related to the size of the technical support staff regardless of worldwide trends. MARC is most popular in Japan, but ABAQUS is more popular worldwide, FLUENT is the most popular Western CFD code in Japan by far, while worldwide FLUENT and FIDAP are in a much closer race. PAMCRASH is dominant in Japan, whereas worldwide the race among LS-DYNA, PAMCRASH, and RADIOSS is much closer. As we all know, commitment to the Japanese market is the key.

[DKK] My feeling is that there is still a very large market potential for easy to use software CFD, so I see room to grow. We were told that currently there are about 100 users, with about half from the developing Association, and this seems fairly good to me, especially if these are actually sales. We are not aware of any U.S./European CFD software that has implemented a Japanese user interface or provided documentation in Japanese. There are several commercial Japanese CFD codes including Nagare from the Institute for CFD, STREAM, and SCRYU from Software Cradle. STREAM has been reasonably successful.

One very interesting aspect of this project is the follow-up, Beta project. The conceptual design of Beta is finished and documented (in Japanese). It will also be a four-year project, of approximately US$10M. It will have some of the same worldviews, but will attempt to build two-phase flow software. (Alpha-flow is restricted to single phase flow.) Plans are to develop capabilities in vapor-liquid, solid-vapor, and solid-liquid solution techniques.

When I first wrote about Alpha, I commented that it had to be judged on its long range approach. Beta appears to be a reconfirmation of that opinion.

I wish to thank,

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for the many helpful discussions about Alpha, and also for his frank opinions on the state of Japanese computing.

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11th Aircraft Computational Aerodynamic Symposium, NAL, Japan, 10-11 June 1993

This is a report of the 11th Symposium on Aircraft Computational Aerodynamics, which was held on 10-11 June 1993, at National Aerospace Laboratory Headquarters in Jindaiji-Higashi, Chofu-shi, Japan.

David K. Kahaner

In an earlier report, "nwt.93" of 27 May 1993, I described a very powerful parallel computer that has been recently installed at the National Aerospace Laboratory (NAL), outside Tokyo. I visited NAL to have a look at the Numerical Wind Tunnel (NWT) during the 11th Symposium on Aircraft Computational Aerodynamics, held 10-11 June 1993. The details of NWT are presented in the aforementioned report; here I will briefly summarize my observations during that visit.

The 140 processor NWT represents, on paper, one of the worlds most powerful computers. Each processor has a peak performance of 1.7 GFLOPs that allows a potential peak performance of 236 GFLOPs. NWT is situated in a room that also contains a Fujitsu VP2600 that is also a powerful 5 GFLOPs (peak) supercomputer, but that functions as a front end for the NWT. There are no operators in this room, they are in another building along with some tape units.

User jobs, which are almost always in Fortran with compiler directives, are submitted to the VP and, if necessary, transferred to the NWT. Users can request various numbers of processors on the NWT, up to 128. At the moment, the VP runs Fujitsu's own operating system that is IBM-like, and NWT runs a version of Unix. Job directives as well as data files need to be converted (which is done on the VP) before sending them to the NWT. Such conversions have caused problems according to our host,

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and there were early software problems. Things are going more smoothly now. However, Dr. Hirose feels that it will take a number of months before the system is really humming. Nevertheless, he stressed that almost all the problems have been software related, and that the hardware has been functioning very reliably. The system uses a great deal of power, about 300 KW, and this was a consideration (along with budget) in the decision to purchase 140 processors. The NWT is water cooled, with an in/out temperature gradient of about 10°C.

At the moment, usage is low, and in fact when I visited there were no users on the NWT (many scientists were participating in the Symposium, although in principle the NWT, via the VP, is accessible to others beyond NAL on Japanese networks). Hirose explained that the system is capable of bringing itself down if there is no work, and then coming back up on demand. I asked about usage, and Hirose explained that he was not too knowledgeable about this, but that a significant fraction of the month's time is allocated to Fujitsu for their own purposes. NAL's main problem has been the user community inexperience with the system. Most of the scientists have had no training in parallel computing techniques; many are still grappling with understanding Unix, and Fortran was the common application language. However, users can request a single CPU from the NWT and get at least as much production as from the shared memory VP, which is busy multitasking jobs from a large community. Multiple CPU usage has been confined to SIMD computations, which are easy to set up. As far as Hirose could tell, there have not been any significant efforts to use the NWT in MIMD mode. Thus it is really much too early to predict the type of performance that the system can give.

From my perspective, the most interesting thing about NWT at NAL was the lack of what in the West we would call "computer science" expertise among the staff. As far as I could tell, everyone associated with the project was trained in some aspect of aerodynamics or a related science. Hirose mentioned no groups exploring new tools, languages, graphics, networked applications, or the usual potpourri of systems level research that would exist at virtually every Western laboratory with a machine as advanced and expensive as NWT. There is a graphics activity, but it was (according to Hirose) significantly behind in similar work in the West. For example, there is no automated slide or film production facility, and while expert help was available, users had to go to the graphics area rather than submit jobs from their local workstation. On the other hand, we were shown a very well produced computer graphics video describing NAL and NWT, proving that excellent results can be obtained in this manner. We did see a variety of advanced graphics hardware, film recorders, and graphics workstations, but these did not appear to be significantly networked.

Research is highly directed toward aircraft applications driven and led by experts in these fields rather than by those with specific background in parallel processing. This is consistent with many of my other observations examining advanced computing in Japan, where the research tends to be led by field-specific-trained scientists who know a great deal about their application and whose computing expertise is built up by experience (sometimes over many years) rather than by formal training. I meet scientists with the latter training very infrequently, and wonder to what extent they can influence applications development. This is quite different from the situation in the West. However, younger Japanese scientists with good university training in parallel computing are beginning to be seen (see for example, "jspp.93", 2 June 1993) and I expect that their knowledge will be integrated into the applications at laboratories in a natural way.

I believe that the current Japanese approach is less likely to result in techniques that can be used by the wider community. However, it also means that applications expertise can be applied directly to help modify, select, and tune methods, and that users have the first and last say in many important decisions. For example, Hirose explained that NAL scientists worked for several years with Fujitsu to define the kind of architecture that they wanted in NWT. NAL's approach to this type of computing is also reflected in the Symposium papers, the titles of which are given below. Readers will find that almost all titles are highly focused around the physical application being studied.

All the papers were presented in Japanese, except for one invited speaker, Dr. W. Kordulla of Goettingen AVA, DLR, Germany, which described computational activities at DLR (German Aerospace Research Establishment). This year, as in the recent past, non-Japanese contributions seems to be EC centered, with Americans nowhere to be seen.

For translations of the Symposium titles, I wish to acknowledge the work of Mr. Scott Johnston [JOHNSTON@CARDINAL.STANFORD.EDU], who has been working in Japan for some time after finishing his MS at Stanford University. I also wish to thank Dr. Hirose for his efforts to open NAL research to the international science community.

Numerical Wind Tunnel at Japan's National Aerospace Laboratory, 22 July 1993

Overview of Japan's National Aerospace Laboratory Numerical Wind Tunnel is given in this report.

David K. Kahaner

I ha 'e written several reports on NAL's Numerical Wind Tunnel.
Recentiy,

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who has been my host for repeated visits to NAL, wrote a long overview of the project providing much amplification and correcting some errors that I made because of mainly my translation difficulties. I am grateful for his efforts in making this contribution. He also commented to me that he hopes to see many Western visitors at the 5th ISCFD, to be held in Sendai, 31 August through 3 September, and that these people are welcome to visit NAL.

Introduction to NAL Numerical Wind Tunnel An Observation from a CFD User at NAL (This view is purely personal and does not reflect the official view of NAL.)

12 July 1993
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In Kahaner Report: file named "nwt.93", 27 May 1993 and file named "nal-symp.93", 15 June, 1993,(anonymous FTP from host cs.arizona.edu, directory japan/kahaner.reports) Dr. Kahaner reports on Numerical Wind Tunnel at National Aerospace Laboratory, Chofu, Tokyo, Japan. I, Dr. Naoki Hirose, of Aircraft Aerodynamics Division, NAL, invited Dr. David Kahaner and Mr.Scott Johnston (visiting research scientists to MITI Research Institute, Tokyo) to visit NAL and to attend the 11th NAL Symposium on Aircraft Computational Aerodynamics (llth SACAD). They and Dr. Wilhelm Kordulla of DLR Goettingen, Germany, who is the invited speaker of the symposium were guided to the facility tour of the newly installed computer system "Numerical Simulator II" and its computation engine "Numerical Wind Tunnel (NWT)". Dr.Kahaner's reports are based on this visit.

Dr. Kahaner kindly reported our system in detail to the netnews readers, however, I found there are several lines that might lead to misunderstandings of NAL computer system development. Although I and our staff tried through our best efforts to explain the system in English as precisely as possible, translation seems to fail to work perfectly. As wise readers may understand, we, in Japan, speak Japanese and not English.

The following explanations are prepared for the netnews readers so that they can understand correctly the history of and the present Numerical Simulator II. Several people, including myself from NAL, have reported about our Numerical Simulator and Numerical Wind Tunnel Project on many occasions including at the past SACAD Symposia and international meetings in the past*. Therefore the historical part of this article may not be new to some of the readers. They may skip to the latter part of this article. I added its recent status description after the new system became operational last February 1, 1993. I tried to describe the system based on the open information as accurately as possible from the standpoint of one CFD user at NAL. Therefore, the view here is my personal one and does not necessarily reflect the official view of NAL authority.

(* Hirose, 3rd ISNaS Symposium, NLR, The Netherlands, Sept 1991; Wada, 5th ISNaS Symposium, NLR, The Netherlands, Nov. 1992; Iwamiya, Parallel CFD 93, Paris, France, May 1993.)

I. BACKGROUND — History of NAL Computer System

[NH comments: The following portion originally from "Numerical Wind Tunnel Project and Computational Fluid Dynamics at National Aerospace Laboratory, Japan" by Naoki Hirose was presented to the Third ISNaS Symposium, 19-20 September 1991, NLR (National Aerospace Laboratory) Noordoostpolder, the Netherlands. with additional comments.]

NUMERICAL SIMULATOR

History of NAL Computer System

NAL was established in 1955 to promote aeronautical engineering technology, and it is part of the Science and Technology Agency. Wind tunnels were build to serve at the national facility. Computers were brought in as part of data processing machines for 2m X 2m Transonic Wind Tunnel. When machine time was available, it served as the calculator for theoretical fluid dynamics that includes transonic flow problems.

Since then, the role of computers at NAL has been changed significantly, just like sister organizations in other countries. Table 1 shows the time chart of the NAL computer system and its major applications. The history making decision was made in 1974, when NAL and Fujitsu Co. started a joint development of the first Japanese supercomputer FACOM 230-75-AP (Array Processor). NAL was the only institute that correctly evaluated the significance of numerical simulation such as CFD and the needs for supercomputers. The experience of using 75-AP resulted in the start of the Numerical Simulator Project in 1979.

Three major companies: Fujitsu, Hitachi, and NEC began to sell commercial models of supercomputers in the early 1980s. Universities installed these models competitively. NAL's Numerical Simulator Project was not realized until 1987. During this period, experimental STOL plane "ASKA" development had been made, and the budget for computers was limited.

Numerical Simulator - Present System

In 1987, the Numerical Simulator (NS) facility began its operation. NS consists of Fujitsu VP-400, VP-200, and M-780. VPs are back end vector processors for CFD, M-780 manages job scheduling and TSS as the front end processor. Since 1991, VP-2600 replaced VP-200 and hard disc capacity was increased. In 1989, Numerical Wind Tunnel (NWT) feasibility study started to seek the next step. Major features of the system are shown in Table 2.

[NH additional comment: This was the system until January 1993.]

Table 1 — History of NAL Computer System

Year	Machine	Major Applications
1960-1966	Burroughs DATATRON 205	TWT data processing theoretical fluid dynamics
1967-1974	Hitachi HITAC 5020 (32kw)	TWT data processing fundamental CFD researches
1968-1974	HITAC 5020F (65kw)	FEM for structure mechanics
1974-1975AP	Joint Development of first Japanese Supercomputer	
1975-1981	Fujitsu FACOM 230-75	2D-Euler and 3D potential
1977-1981	CFD2CPU(640kw,3.5MIPSx2) FACOM 230-75-CPU+APU	2D-NS solver development FEM for structure mechanics (1OOOkw,22MFLOPS) TWT data processing
1979	Start of Numerical Simulator Project	
1982-1986	FACOM M380+M180IIADx2 (44MB/HD9GB, 27MIPS)	2D-NS code for YXX design, 3D-NS solver development
1985 Oct.	Exp.STOL"ASKA"maiden flight	
1987-1990 for	Numerical Simulator Facility(24Hr Operation) FACOM VP-400 (1GB, 1.14GFLOPS) FACOM VP-200 (128MB, 0.57GFLOPS) FACOM M-780 (128MB, 45MIPS / SSD 32MB/ HD 90GB/ OptD 180GB)	 3D-NS code(wing,wing-body) YXX, HOPE, SP etc. 3D-NS code development for complicated geometry reactive flow code
1989 June	Numerical Wind Tunnel Feasibility Study Started	
1991-	VP-2600 replaced with VP-200, reinforced HD (512MB, 5GFLOPS)	LAN(Ethernet)

Table 2 — Numerical Simulator, Present System

Processors		
VP-2600	5 GFLOPS	512 MB
VP-400	1.14 GFLOPS	1 GB
M-780	45 MIPS	128 MB
External Storage		
Solid State Disk		64 MB
Magnetic Hard Disk		125 GB
Magneto-Optical Disk		180 GB
High-Speed Network		
Ethernet Type LAN		10 Mbit/s
Channel Interface		3 MByte/s
CCP Interface		64 Kbit/s
NTT network links to Chofu Branch, Kakuda Branch, MHI, KHI, FHI and IHI		

Graphics Tools

Graphics hardware is listed in Table 3. Most of these terminals are nonintelligent type and linked to FEP by channel to obtain high-speed data transfer. A total of 60 personal computers, FMR-60HX and TSS/GD terminals, are located at various buildings and linked with FEP using Ethernet type NAL-LAN. 2-D color graphics monitoring can be made at these terminals as well as at 48 TSS/GD terminals.

Recently, work station type terminals are increasing in number. But the major owners of WS are not CFD researchers yet. Some people are testing how to use WS at the present circumstances, especially for local handling of postprocessing graphics. Titan 3000, 750, IRIS and SUN are used for this purpose. But most CFD users remain in the world of mainframe. There may be several reasons for this.

[NH additional comment: 1993 status has changed quite a lot, as work stations are used by many people. Fujitsu-6683 emulator and unix interface are used to access the system; this is 1991 status.]

Since the unified graphic software can be used regardless of hardware types, Graphic Control Package Library; GCP was developed at NAL. CFD users need only to call GCP subroutines in its FORTRAN program. By specifying the library of Graphic Hardware at linkage, the user can output graphic data from any device in batch or TSS jobs. For example, only TSS command:

[GLIB GRIP CR]

is needed when TSS session on 3-D-GD(COMTEC) is opened.

Work Stations — Titan 3000, Titan 750, IRIS, SUN etc., were recently introduced.

Job Classes

Since the NS was introduced for large-scale CFD simulations, priority of large jobs are made. Table 4 shows present job classes. To process these large jobs, the NS operates 24 h every day.

Table 3 — Graphic Hardware

NEXUS 6410 X 1 set
20" 3D-image display
512 x 480 resolution, 24 bit colors
nonintelligent terminal with film recorder
(35 mm, Polaroid), VTR, optical disk, digitizer

FIVIS F6510 X 3 set
20" 3D-image display 1280x 1024 resolution,
24 bit colors nonintelligent terminal with
film recorder (35 mm, Polaroid), hard copy,
16mm movie camera

COMTEC DS351B X 8 set
20" 3D-image display 1280x 1024 resolution,
24 bit colors local-handling terminal with
film recorder (35 mm, Polaroid), hard copy,

TSS/GD F6683 X 48 set
14" 2D-display 960 672 resolution,
3 bit colors nonintelligent TSS terminal
with graphics with hard copy,

TSS/PC FMR-60HX X 50+10 set
14" 2D-display 960 X 672 resolution,
3 bit colors nonintelligent terminal.

FMR can monitor graphics using F6680 Emulator*

* most popular NEC-PC9800 cannot handle graphics.

Table 4 — Job Classes of Present System

SHP2 (VP-2600)

Job Class	Memory Max Size	CPUT Max
SHRT	45OMB	5 min
MIDL	5OMB 30 min	
LONG	45OMB	100 min
HJOB	45OMB	300 min

SHP1 (VP-400)

Job Class	Memory Max Size	CPUT Max
SMAL	5OMB 60 min	
LARG(shrt)	968MB	3 min
LARG(long)	968MB	100 min
HUGE	968MB	300 min

FUTURE DEVELOPMENT: NWT (Numerical Wind Tunnel)

Our Estimation of Requirements

As the significance of CFD's use as a design tool for the aerospace development became to be recognized, the need for CFD research and computer demands both at NAL and by other government agencies are increasing. Even before the NS was installed, such needs were strong. The achievement of NS enhanced these requests. We came to a conclusion therefore that a new computer with reasonable performance and cost should be introduced to replace the present system in a few years.

Opinions and needs of CFD researchers and aerospace industries were collected, and the following is the resulting requirement estimation.

1. Main Memory Size Estimation

a. Grid points:

(1) for full configuration analysis with engine, flap, SRB, etc.
5 - 15 x 10exp6 grid points

(2) for practical application of LES
150 x 10exp6 grid points

b. Data:

conventional TANS analysis
(perfect gas, algebraic turbulence model, steady flow)
30 - 50 data/grid point
high level TANS analysis
(real gas, refined turbulence model)
twice as above

c. Data accuracy:

4 - 8 Byte
(4 B for primitives, 8 B for works)

Result:

(a) 15 X 10 exp 6 X (200-400 B) -> 3 - 6 GB
(b) 150 X 10 exp 6 X (200-400 B) -> 30 - 60 GB

Total memory size of at least 30 GB is required.

2. Processing Speed Estimation

a. Typical CPUTime on VP-400
TANS analysis with 106 points... 10 h
Stiff problems such as real gas takes 2-3 times longer.
average/peak speed ratio in highly vectorized
FORTRAN code is 0.5 - 0.3

b. Data Productivity Requirement
at NASA, NAS is:
practical application: 10 min/data point
research computation: 1 h/case
at NAL, it will be:
practical application: 1 h/data point
research computation: 10 h/case

Result:
Effective speed should be: 150 X VP-400 average speed.

Numerical Wind Tunnel (NWT)

To realize NWT with the above requirements, RFP for feasibility study was released in 1989. RFP was opened to foreign computer makers as well as to Japanese makers. It was found that no commercially developed machine could fulfill our requirements and could replace VP-400 within 2 to 3 years. Therefore, if we did not develop one by ourselves, we could not have been able to realize the NWT. A study of how to realize the NWT was continued by research staff of the Computational Sciences Division and CFD user scientist group.

[NH additional comment: The end of reference from Third ISNaS paper]

[NH additional comment: The RFP for the Feasibility Study was released officially on 12 June 1989, and was made available to the potential computer makers: Fujitsu, NEC, Hitachi, CRAY, IBM and UNISYS.]

II. NUMERICAL SIMULATOR II — Development of Present System

NAL NWT Project Development

The Numerical Wind Tunnel Project officially started from the feasibility study in 1989, although in-Lab studies have been started long before. The feasibility study revealed that NWT, which has speed performance of more than 100 times of effective

CFD code rate of VP400 and main memory on the order of 30 GB, can be realized within the circumferential constraints at NAL, such as budget, electric power availability, and housing. It also became clear that there is no commercial product available in the first quarter of 1993 that can satisfy these requirements. The target date came from time schedules of numbers of national aerospace development projects.

[NH additional comments: Hajime Miyoshi writes in his paper "Computer Requirements for Future CFD Development," at 8th NAL Symposium (SACAD), 25 June 1990. The feasibility study reports are also presented on the same Symposium by NEC, Hitachi, and Fujitsu. All of those reports are included in the proceedings of 8th SACAD, NAL SP-13, Sept. 1990. The proceedings are available at NAL upon request.]

The construction of NAL NWT satisfying NAL's specifications was put to tender in FY 1990. Joint research and development of the software system was contracted with the bidder to realize the system as it exists without available software for NWT beforehand. *Only one manufacturer*, Fujitsu, bid and was selected as contractor, and the construction started. Fujitsu build the hardware and softwares and delivered it to NAL.

The reader may want to know if NAL NWT is Fujitsu VPP-500. VPP-500 was announced by Fujitsu last September 1992, and the first machine will be made by next September. NAL NWT project started long before Fujitsu planned this commercial machine. NWT originated from purely CFD needs at NAL and national aerospace needs. This is just like a large scale wind tunnel construction for the national aerospace developments. There is no commercial product of wind tunnel. Large wind tunnels in the world are all custom made. In the world of computers, this kind of custom development is rare, but the first parallel computer of then-supercomputer level, ARPA ILLIAC-IV Computer System, was developed and built by ARPA and was housed in Building N-233 at NASA Ames.

[NH additional comment: see p.91, NASA TM-X-69411 Ames Research Facilities Summary 1974.]

Burroughs Corporation was the contractor that built the skeleton machine, but the official name does not have the company's name. NASA Ames further planned a more high-performance custom machine called NASF. Feasibility studies were contracted with Burroughs and CDC.

[see NASA CP-2032 Future Computer Requirements For Computational Aerodynamics, 1978.]

Burroughs proposal was the prototype machine that later became Burroughs Scientific Processor (BSP) and CDC proposal later became STAR100; both are commercial products. Unfortunately, before NASF Project realized, a new star commercial machine called CRAY-1 was developed by genius Seymore Cray, the designer of CDC7600. Los Alamos and NCAR at Denver purchased the first two machines circa 1976. Ames lost the reason for developing custom machine, therefore they changed to purchase commercial machines. Ames changed the project name to NAS. Also, Burroughs and CDC's commercial version machines were not successful from a commercial point. In aerospace industry, often a company develops commercial products based on custom model ordered by the government. USA-DOD development of the first jet-tanker KC135 turned out to be Boeing 707. DOD large-scale transport aircraft request resulted in Boeing 747, Lockheed L1011, and Douglas DC10. Fighters such as F15, F16, F18 and F5 are sold to other countries as commercial products. Space-launchers: Atlas, Titan, Thor-Delta now used as commercial space launchers by private companies, look exactly like USAF ICBM and IRBM.

[NH additional comments: RFP for Joint Research was publicized on Government Official Gazette and Results of Joint Research with Fujitsu: "Development of NWT" has been reported to the public at each occasion of SACAD Symposium. 9th and 10th SACAD meetings, held in 1991 and 1992, include details of system, OS, software of NWT development. These are available on NAL SP-16 and 19, the proceedings of the symposia. If people have been watching carefully from the start, they should know the project, since all of these announcements are opened to the public.]

From my personal point of view, it may be understandable that Fujitsu planned to design commercial machine such as VPP-500 based on their effort on NAL NWT and with modification and improvements so that it has commercial sales points.

In the beginning, commercial product plan didn't exist even in the minds of computer makers, and only custom development could build such machine. In this sense it can be said that NAL NWT development affected strongly Fujitsu to develop commercial machine similar to NAL NWT. In other words, NAL NWT may be considered as a one of prototype machine to VPP500.

[NH additional comment: Kahaner writes "NWT sounds exactly like VPP500" (quotation by NH). In fact, it is the opposite, "VPP500 sounds like NAL NWT." I do not know the details of VPP500 and can not compare it with NWT. I guess VPP is not pinpointed only to CFD. If so, it does not bring profit. I imagine the commercial product VPP500 should have high-quality stability and reliability and no bugs on hardware and software.]

[NH additional comment: All of the following information is from open literatures available from NAL.]

Numerical Simulator II System

NS II System Configuration

NWT is defined as the computing engine working in the background of the NAL NUMERICAL SIMULATOR II (NS II) since 1 February 1993. The NS II consists of Front End Processor: Fujitsu VP2600/10, NWT and Large-Scale External Storages, High Speed Network etc. VP2600 has 512 MB memory and 5 GFLOPS speed. External storages consist of Magnetic Disk 210 GB and Magneto-Optic Disk 500 GB. The Network is the same as that of the previous NS I system, i.e., Ethernet Type LAN Interface 10 Mbit/s and Channel Interface 4.5 Mbyte/s. TSS full-screen terminals, FMR PC's with 6683 Emulator and TCP/IP EWS's, graphic WS's, remote I/O stations (with graphics), wind tunnel data processing stations (minicomputers) that are connected to the network. The network is not connected to outside networks such as Internet except by private network connections to remote stations located at airframe and aeroengine manufacturing companies. This usage is limited to the joint research and contract works only. VP2600 is connected to NWT through System Storage Unit (SSU). SSU is 8 GB and its performance is 1200 MB/s for read, and 800 MB/s for write.

[NH additional comment: Dr.Kahaner writes NWT is accessible through network. This is not true. (I was shown a network diagram that included the NWT as part of larger net connecting many researchers in Japan. Dr. Hirose has subsequently told me that this plan is not realized. DKK) He writes that Fujitsu uses NWT for its purpose. This is misinterpreted. NAL provides the use of NWT to Fujitsu engineers to conduct cotracted works such as the development of utilities, debugging of hardware and softwares, and parallelization of cfd codes. They are not allowed to use it for their own purposes.]

NWT Configuration

NWT is a parallel computer system of distributed memory architecture composed of vector processors. NWT consists of 140 Processing Elements (PE), two Control Processors (CP), and a Crossbar Network. That is, each PE is a vector supercomputer similar to VP400. Each PE has 256 MBytes of memory and peak performance of 1.7 GFLOPS. PE has Vector Unit, Scalar Unit, and Data Mover that communicates with other PEs. PE is 50% faster than the standard VP400 and has the same size of memory. CP has 128 MB of memory. CP manages NWT and communicates with VP2600 through SSU. CPs do not execute real computation of CFD code.

Cross-bar Network has 421 MByte/s X 2 X 142 performance between each processor. The total performance of NWT is 236 GFLOPS and 35 GB main memory. The electricity power required for using NWT is 1000 KVA.

[NH additional comments: Kahaner writes 300 KW and this is the reason to purchase 140 PEs. The purchase limitation comes from the yearly budget allocated for the computer facility at NAL. Of course, power consumption is increasing extraordinarily as the performance is increased. NS I system required 300 KW.]

The specific feature of NWT is that it only pursues the efficiency and performance of CFD codes. The architecture is intended to satisfy to get maximum efficiency in this target only. Each PE can execute a large scale CFD computation with fewer data exchanges with other PEs. Commercial MPP type machine has deficiencies in this aspect, as each load is small granularity. Commercial machines may not be able to concentrate into CFD purpose only, even if they become available early this year. Only special order can realize this kind of development.

[NH additional comment: Evaluations of CFD codes on parallel architectures are reported in SP-13.]

The system configuration is shown in the following Fig. 1.

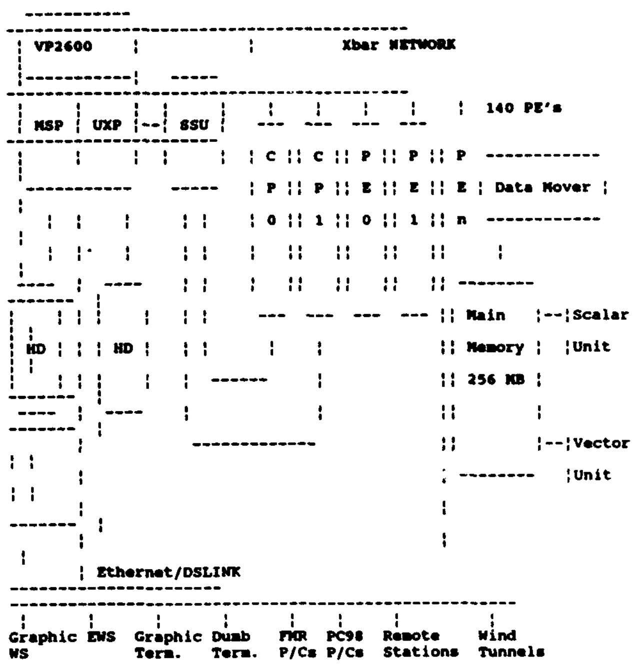

Fig. 1 NWT System Configuration

Software

Userview of NWT

FEP: VP2600 is dually operated by Fujitsu MSP-OS (IBM-type mainframe OS) and Fujitsu UXP (Unix based OS). NWT is under NWT-OS, a Unix based OS. Userview is only MSP. Users are familiar with MSP since they have been using it on previous machines for nearly 20 years. CFD users at NAL have been using MSP and TSS environment for developing CFD codes. There are quite many accumulation of center utility resources and user files. On the other hand, the users nor operating staff are at all familiar with Unix OS. Unix has very poor capabilities on file and user access security. NWT FORTRAN is an extension of fortran77 with parallel processing capabilities. CFD users have no previous experience on parallel algorithm and coding. Considering these factors, MSP was chosen as the only user interface. UXP is not visibly chosen by the users. A user can submit batch jobs just similar to the previously used method of jcl description and commands. NWT executes only batch jobs in the background. All of the TSS jobs, front end processing (including compile and linkage) of batch jobs, file management and maintenance, post processing of printer outputs and graphics, network processes, are executed on FEP. FEP also executes vector batch jobs and scalar batch iobs.

[NH additional comment: Dr.Kahaner writes that many users are grappling with understanding Unix. As I wrote above, users remain within the old world of MSP. Knowledge of Unix is not required at this moment. Probably in the future, as Unix EWS users are increasing, cfd users will have to learn Unix.

FEP(VP2600) Job Class

The following are the job class list of FEP.

(VP-2600)

Job Class	Memory Max Size	CPUT	Max Multiplexity
Scalar Job Class (Virtual Memory Addressing)			
SERV	16MB	5 min	2 jobs
DATA	16MB	5 min	1
HANJ	2lMB	30 min	1
FJOB	3OMB	300 min	1
Vector Job Class (Real Memory Addressing)			
SHRT	10MB	10 min	1 job
MIDL	3OMB	30 min	1
LONG	50MB	300 min	1

FEP shuts down automatically for the weekend when NWT stops, and FEP jobs are finished.

NWT Job Class

The following are the job class lists of NWT. Primary NWT job class Cnnn shows the numbers of PEs, nnn, and subclass stands for CPU time limit.

Nonparallel vector program written by FORTRAN77EX/VP with less memory size of 230MB runs as job class C001 (nonparallel 1 PE job).

(NWT)

Job Class	Subclass 10min	60min	120min	300min	multijobs daytime	PE's (nighttime)
H001	---	---	---	huge	1(1)	1(1)
C001	short	midle	long	---	8(4)	8(4)
C002	"	"	"	---	4(1)	8(2)
C004	"	"	"	---	3(2)	12(8)
C008	"	"	"	---	1(1)	8(8)
C016	"	"	"	---	1(1)	16(16)
C032	"	"	"	---	0(1)	0(32)
C064	"	"	"	---	0(1)	0(64)
C094	"	"	"	---	0(1)	0(94)
C102	"	"	"	---	0(1)	0(102)
C128	"	"	"	---	0(1)	0(128)
C140	"	"	"	---	0(1)	0(140)
H001	---	---	---	huge		

Memory Max size for one PE is 230MB.

Job class requesting more than 16 are tentatively run by advanced request and manual job scheduling. Job start priority is "First In First Out" based on priority setting:

shrt>middle>long>huge.

The daytime shift executes H001, C001 to C016 job classes using 53 PEs. The nighttime shift executes all job classes using 140 PEs.

NWT shutdowns automatically FOR THE weekend, when all jobs are finished.

NWT Job Process Flow

NWT jobs are submitted by \NSUB command in TSS session (MSP-OS). Front end process of submitted batch job is made on MSP-OS. This process converts catalogued procedures into NWT/F commands, and does file format conversion of MSP user files to NWT/F-OS (UXP-OS on VP2600) intermediate work files, and code conversion between EBCDIC and ASCII.

NWT/F-OS executes FEP batch request (NWT FORTRAN compile, linkage-editor) and sends to NWT/B-OS (NWT-OS on NWT-CP). Compiler options are single PE vector compile (default), single PE scalar compile, and parallel vector compile.

NWT/B processes NWT batch request (go step) on NWT.

NWT read/write IEEE-expression binary data and ascii code text data. MSP binary files are MSP (IBM-like)-expression and text file are EBCDIC code. Input data file format and binary expression are converted automatically by JCL interpreter (actual conversion takes place at the go step). The output data file format and binary expression ARE also automatically converted to MSP form. When the output data file is used as the input data file of the next job, no conversion is required as it is written in IEEE-expression and can be used as the next input file. IEEE-expression data can also be sent to work stations for postprocessing without conversion.

[NH additional comment: For details see M. Tuchiya, et al., "A Method of User Interface for NWT," NAL SP-19, pp.259-264, 1992.]

Sample NWT JCL

A simple batch job JCL will be as follows. This job uses 32 P's.

```
//XOIXXXX NJOB C032
// EXECNFORTC,SF='NAL.TEST.FORT77',-
      PARAM='-Ps -Pd
-Wp',ELM='TEST1'
// EXEC NLIED,PARAM='-Wp'
// EXEC NGO,TIME=30,PARAM='-Wl,-C'
 3  10.0   2.5   8.0
 4   3.0  12.0   6.5
// EXPANDNUSDKR,RNO=50,FILE='NAL.-
      TEST.INPUT',TYPE=B
//EXPAND NUSDKW,RNO=60,FILE='NAL.-
      TEST.OUTPUT',TYPE=B
//
```

This JCL example shows that JCL is the same as that of MSP. Parameter options are the only changes.

NWT-FORTRAN

[NH additional comment: The following is a summary of the papers by Fukuda, Yoshida, Nakamura et al., in SP-16 and 19. I have not tryed to run my code on NWT yet. So, these give only a brief image of nwt-fortran.]

FORTRAN based language is used on NWT. FORTRAN77 is extended to perform efficiently on distributed memory type parallel processor NWT. The extension is realized by compiler directives. The requirements for CFD program, typically 3D-Navier-Stokes Implicit Approximate Factorization schemes as well as the explicit codes, and respective solutions are:

1. Global data

Requirement: 5 to 10 arrays that store variables Q, metrics, etc. are global data accessed from many subroutines. These global data accesses should be transparent to the programmer, and they should also be distributed among the PEs to avoid access conflicts.

Solution: Virtual Global Memory that is accessible from any PE and physically distributed among PEs.

2. Parallel Executing of Do loop

Requirement: Core of CFD code consists of triple do loops (for 3-D directions,x,y,z). Some do loops have parallelism in three directions. The rest have parallelism in two directions and no parallelism in the other direction. These parallel portions have a large amount of granularity and parallelism (do loop numbers) is high. Parallelism for do loop in necessity.

Solution: Spread-Barrier Execution of parallel operation. This consists of spread mode, where do loop is executed in parallel on each PEs, Barrier mode, i.e., synchronization of all PEs is made, and a redundant execution mode on all PEs.

3. Partitioned Allocation of Data

Requirement: Data allocation by partition to PEs should be made so that data transfer among PEs should be minimum when the computation is made for a particular computation region. Computation region usually coincides with array partition in CFD codes.

Solution: Specification of computation region and array partition is specified by the program.

These solutions are realized by procedure partition, data partition, and data transfer. NWT-FORTRAN uses compiler directives to specify these functions.

Data partition:

"PROCESSOR" specifies number of PE's.
"INDEX PARTITION" describes partition of one-dimensional index.
"GLOBAL" declares global data. Other data are local data on each PE.

Procedure partition:

"PARALLEL REGION" and "END PARALLEL" indicates start and end of parallel execution.
Other portion of source is executed only on one PE.

Parallel execution consists of Do index partition and multidomain partition.
"SPREAD DO" and "END SPREAD" indicates do loop partition (SIMD type execution).
"SPREAD REGION", "REGION" and "END SPREAD" divide the specified portion of program into multidomain procedures(MIMD type execution).
"SPREAD MOVE" specifies data transfer among PE's.
This is made asynchronously.
"BARRIER", "POST/WAIT", etc. are used for synchronization.

An example of NWT-FORTRAN program image using directives will be:

```
PROCESSOR P(8)
....A...
PARALLEL REGION /P
....B...
  SPREAD REGION /P(1:2)
  ...C...
  REGION /P(3:8)
  ...D...
  END SPREAD
  ...E...
  SPREAD DO /(P)
  do 10 i=l,n
  ...F...
  10 continue
  END SPREAD
  ...G...
END PARALLEL REGION
  ...H...
```

Here this code uses 8 PEs from PE0 to PE7. Block...A... is done on PE0. Block B is done redundantly on PE0 to PE7. Block C is done on PE0 and PEl while Block D is done on PE2 to PE7 at the same time. Block E is done redundantly on PE0 to PE7. Block F is distributed to PE0 to PE7. Do loop is made for respective index regions on each PEs. Block G is done on PE0 to PE7. Block H is done on PE0. Barrier synchronizations are given at

END SPREAD and END PARALLEL REGION if necessary.

The data partition and do loop can be more easily described by the following example. Global declaration of Q(1000,100) is spread among PE0 to PE3. The second index j is partitioned. Do loop for j is partitioned as in the figure.

```
PROCESSOR F(4)                         Q 1 j  25     50     75    100
COMMON Q(1000,100)                      1---------------------------
GLOBAL Q(:,/(F))                      i  |      |      |     |      |
....                                  1000----------------------------
....                                         GLOBAL Q(:,/(F))
SPREAD DO /(F)                                      |
  do  j=1,100                                      \ /
    do i=1,1000                        -------------------------------
    calculation on Q(i,j)  |  Global memory                          |
    end do                 | Q1-----  Q2-----  Q3----  Q4-----        |
  end do                   | | 1:25 | | 26:50| |51:75| |76:100|      |
END SPREAD                 |  ------   ------   -----   ------        |
....                        -------------------------------------
....                          do j=    do j=    do j=    do j=
                              1,25     26,50    51,75    76,100
                             \                                 /
                              --------- SPREAD DO /(F) ------
```

4. Performance

a. Performance Estimation

[NH additional comment: The following data are from papers by Yoshida, et al., NAL SP-19, 1992.]

Performance of NWT was first evaluated on desk using CFD that are used in real aerodynamic application computations by NAL researchers. One code, SD, uses single computational grid domain. The other code, MD, uses two grid domains. Code is 3-D Time-average Navier-Stokes solver based on IAF algorithm and Baldwin-Lomax turbulence model. SD used grid numbers of 501 X 140 X 280 and 401 X 140 X 140. This grid number uses the maximum size of 140 PEs. VTAP, a software simulator for vector processing of vector computer, which was used to evaluate the performance of each PEs. The result shows 50.7 GFLOPS. This is 117 times faster than on VP400 (assuming 123 X 29 X 30 + 71 X 36 X 20 grid points computation is made on single VP400, VP400 gives 434 MFLOPS). SD simulation gives 62.O GFLOPS. This is 158 times faster than VP400 for a typical original 91 X 33 X 24 grid point computation (391 MFLOPS).

On the desk estimation shows NWT can attain the target of 100 faster than VP400 in real computation of cfd codes.

b. Measured Performance on NWT

[NH additional comment: This is from a paper by Nakamura, et al., Abscract of 11th SACAD, 10 June 1993. Proceedings will be due at the end of the year as NAL SP.]

After NWT was installed at NAL, performance was investigated on a real machine. Two codes were used. NS3D: one test case uses maximum grid point number of 50.5M on 128 PEs. The second case used grid number of 64 X 128 X 128 (lM points) which can be put into single PE job. NS3D is written presuming parallelism efficiency. TVDSD: this code does not assume parallelism as this is the actual research code. This code uses a number of work arrays that may cause data transfer among PEs high and less operation numbers on each grid point. The grid number of 5 Million is the actual application data.

The measured results are,

Code	Number of PE	Grid Numbers	Operations	Performance
NS3D	128	50.5 M	582.5 G	108 GFLOPS
TVDSD	50	5.0 M	11.35 G	19.9 GFLOPS

The reason of low speed in TVDSD comes from the above code description.

Test case 2 of NS3D shows the rate of speed-up when PE number is increased.

Number of PEs:	2	4	8	16	32	64
Rate:	1.89	3.72	7.49	14.96	29.77	57.65
Efficiency:	0.95	0.93	0.94	0.93	0.93	0.90

Here the total operation number is 11.5 GFLOP. Rate is CPUTime on single PE / parallel CPUtime. Efficiency is rate / PE numbers.

Case 2 type of computation increases overhead on data transfer as PE number is increased and data size is reduced. CPU time linearly decreases proportional to number of PEs.

Nakamura, et al., conclude the excellent performance was obtained in actual application codes of 3-D NS codes using IAF. They write that they will evaluate other types of CFD codes such as unstructured grid cfd code, direct method and other types of repetitive solution algorithms.

As benchmarking test strongly dependent on the cfd code. This test intends to confirm the performance of NWT only and has no intention of comparison with other machines. For such purpose, there will be other standard programs. The present results will be published on the proceedings of the meeting as NAL SP later.

Concluding Remarks

The NAL NWT project has been developed entirely by the leading efforts of NAL, especially by the people at the Computational Sciences Division, and by CFD researchers. The efforts of Fujitsu to build this machine also should be counted. The NAL staff evaluated CFD code vectorization, parallelization to design best architecture for CFD codes. User interfaces are designed by the staff. Graphics packages that are device-independent were developed by the staff. Although we do not have a so-called "computer science expertise" as defined in the West, the staff has been engaged in the development of high performance computers for 20 years. Their power exceeds the so-called "computer science expertise." This is a cultural tradition of social systems in Japan. I believe that only the customer can realize this kind of project. NAL NWT status is only at the beginning at this time. Various researches must be made before we can use its fullest performance in parallelism and vector processing. But, I do not expect data transfer overhead to overwhelm the net cfd computations unlike other machines called MPP. This design best fits the CFD.

Experiences of a Summer Student at the National Aerospace Laboratory, 8 September 1993

Experiences of a Ph.D. candidate, W. Jones, Dartmouth College while using Japan's National Aerospace Laboratory's Numerical Wind Tunnel (NWT) parallel computer.

David K. Kahaner

During the summer of 1993, two graduate students from the United States worked at Japan's National Aerospace Laboratory (NAL), Mr. Wesley Jones of Dartmouth College and Ms. Mary L. Hudson of North Carolina State University. During that time they used NAL's large parallel processor, the Numerical Wind Tunnel (see my reports on the topic, such as "nal.793", 19 July 1993). Jones' supervisor, Dr. Naoki Hirose, who has contributed material on NAL several times in the past (Email: WILDWOOD@MAYBELLE.AEROSPACE-LAB.GO.JP) asked Mr. Jones to write a short summary of his summer's experiences. Dr. Hirose's brief introduction is below, and it is followed by Jones' report.

[Mr. Wesley B. Jones is a plasma physics Ph.D. candidate at the Department of Physics and Astronomy, Dartmouth College, New Hampshire. He visited and spent several weeks this summer at the National Aerospace Laboratory, Tokyo, Japan, under "the Summer Institutes in Japan Program" sponsored by the Science and Technology Agency of Japan and National Science Foundation of the United States of America. He had a chance to run his code on NAL's newly developed parallel vector processor: NAL Numerical Wind Tunnel as one of two first American Scientists.

He contributes this report by the request of his NAL supervisor, Dr. Naoki Hirose, Aircraft Aerodynamics Division. He was faced with twofold difficulties that Western students encounter in Japan: Nihongo (Japanese) environments in computers and office, and main-frame IBM-like computer environment. He was lucky to have the assistance of an English-speaking supervisor. He straightforwardly expresses his impression here as a typical American student. Naoki Hirose, AAD, NAL. August 13, 1993.DKK]

Japan's National Aerospace Laboratory Numerical Wind Tunnel: a Foreigner's Perspective.

Wesley Jones

I have been working at the National Aerospace Laboratory (NAL) in Japan for about a month. I have been using their Numerical Wind Tunnel (NWT) parallel vector supercomputer to run a pseudo-spectral Fourier-Chebyshev Naviers-Stokes fluid code. Based on my experience here, my host has asked me to write a short article for the news. I have been using supercomputers for only two years, so my knowledge is still quite limited, and most of what I report should be taken as an opinion rather than fact. A full description of the Numerical Simulator II (NSII) project including the NWT is given in an article by Dr. Naoki Hirose "Introduction to NAL Numerical Wind Tunnel", in the newsgroup comp.research.japan, July 12, 1993. Message-ID: <2lt8e2$ikiQoptima.cs.arizona.edu>, [or essentially equivalent report mentioned above, DKK].

In short, the NWT is the computational engine of the NSII and is composed of 140 vector processing elements linked in parallel by a cross-bar network. The peek speed and main memory for a single processor are 1.7 GFLOPS and 256 MB respectively. A Fujitsu VP2600 vector supercomputer serves as the front end, NWTFEP, for the NWT.

NAL is the only research institute in Japan with daily needs that include GFLOP computer speed and Gigabytes of main memory and storage for many users. Therefore they needed to contract to Fujitsu Corporation to build a new type of machine with this capability. The machine has attained these goals of speed, memory, and storage, but it is still under development to make its use easier for the operator, both in terms of code development and production run use.

I used the computer for a month but, because I was not familiar with the Japanese operating system, I was not able to start a production run until a week before the computer was shutdown for O-bon, a national holiday. I will try to give a description of the environment where I worked at NAL, and I will include comments that are relevant only if you have read the articles on the NWT by Dr. Hirose.

The main computer environment at NAL centers around the the NWT and NWTFEP with direct connections to PCs, printers, and graphics output devices. Most of these are located in one building, while the NWT itself is located in a separate building. In general, access to the NWTFEP is via a personal computer that is connected through a high-speed network to NWTFEP. You are allowed one TSS or log session at a time, although this will increase to three in the near future and will be much more convenient for the user. In the office where I was working I had use of a terminal connected to a Unix workstation and used an mwm environment. I generally telneted to NWTFEP via a local ethernet and used the XTERM6683 developed by Fujitsu Corporation for access to the NWTFEP and use of MSP operating system. This, however, is still under development and it was necessary to use the PC to cancel the session sometimes when trouble arose. Internet access is planed for the Spring of 1994.

The Unix operating environment at NAL is also still undergoing development. Although there are roughly 100 Unix workstations at NAL, only a few CFD researchers have Unix workstations from a variety of manufacturers. They are all loosely connected by ethernet. Unfortunately, there are almost no Unix experts at NAL (mostly self-taught experts) and no systems manager for all of the machines. Thus, each group that has a machine is forced to develop its own unique environment and rely on telephone calls to the manufacturer, although there is a lot of shared access via rsh. Ftp was used to transfer files back and forth between the NWTFEP and the Unix environment. In the Unix environment program debugging and graphical output were much less tedious than on the NWTFEP or NWT.

Because there are only a few Unix workstations located at NAL, Unix is not popular. The NWT and VP2600 have Unix operating systems, but another operating system MSP, with which the researchers at the lab are more familiar, is used as a frontend. Unfortunately, this contributes to a long job turn-around time. Because all files must be converted from ascii or IEEE format to another format associated with the MSP operating system, this is a nontrivial time-consuming operation. Job turnaround and foreground response time are further slowed because the VP2600 is still used as a supercomputer for large CFD codes. Unfortunately, I could find no real break from the heavy load on the computer. Because of Japanese lessons I could not come in the early morning, and the NWT stops accepting jobs on Friday evening so that the machine can be shutdown for the weekend. Due to file conversion, job turnaround time can run into the hours for a five minute job, if you are not careful about the size of your output. Also the queing system and job priorities are not tuned yet. Some of the priority setting as well as submission of jobs using more than 16 processors is still done manually. Generally, not more than eight processors are available for general single processor use.

To create files that are larger than your quota limit, the files must be allocated/created before the job is submitted and have "SMWORK" included as part of their name. Files are always referred to by their full path name. All jobs are submitted in background to the NWT and are controlled by a job control file (JCL). All files that you will write to must be opened in a job control file before the job is run via special commands. Thus, the standard Fortran OPEN and CLOSE statements are not used.

High-quality graphics output is available, but it is still quite time consuming. A consultant has been hired who helps produce output by using equipment available at NAL. An easily accessible user friendly graphics program is not available, although this is bound to change as the use of Unix workstations increases. I believe they are planning to buy a high-end graphics workstation in the near future.

Manuals for the use of the NWT exist but they are still developing. Unfortunately, for those that cannot read Japanese no manuals can be obtained at NAL, although I hypothesize that English manuals for the MSP operating system do exist somewhere in the Fujitsu corporation. English manuals for the NWT should not be expected, since the NWT is a one of a kind Japanese machine. Online help is usually in Japanese. The PFD program for file manipulation is an exception and has an English terminal option making access easy for the English user once he/she gets familiar with the commands. Unfortunately, NWTFEP, or maybe just the TSS session and PFD program, have no keyboard buffer, so one must wait upon entry of each command and cannot type in a blind string of commands, resting while waiting for the slow user response. One may also get online help in English by telneting to NWTFEP and choosing a terminal other than the specially prepared XTERM6683, but these terminals are not yet well supported and online help seems quite limited and incomplete, even in Japanese.

My jobs were run on one PE only, so I only tinkered with the Parallel Language that consists of Fortran compiler directives. The Parallelism of the NWT focuses around the parallelizing over an index/direction of a "DO" loop over an array and vectorizing over another index/direction. The cross-bar network allows for rapid transfer/rotation of arrays so that Parallelism over different indices/directions is done by transferring/rotating the whole array to a new physical location. For SIMD type operation over "DO" loops in CFD type codes, this leads to straightforward parallel directives, although it is still time-consuming. MIMD type operations are also possible, but the codes that I saw used SIMD type operations to parallelize the "DO" loop.

The last paragraph is most definitely incomplete, and my lack of knowledge of parallel machines inhibits proper analysis of the current situation. However, if I am to conform to American tradition, I must present my views and ardently defend them in spite of their validity. Much of the recent focus in supercomputer technology in the United States has centered around the development of massively parallel processor computers (MFP) and the development of algorithms that minimize communication because communication between processors is the bottleneck for most programs. In general, this is quite difficult and requires a lot of expertise and time to code. The NWT project has taken a different approach based upon the general structure of CFD algorithms (i.e., granularity) and the use of vector supercomputers for the basic processing element. The granularity ensures that each step of the algorithm can be done (almost) in parallel across at least one index of an array that will many times have three indices. However, different steps must be done in parallel across different indices of the array. Thus, with a distributed memory system the physical location of the array must be changed for different steps of the algorithm. On the NWT this is done by using the cross-bar network.

As an example, for the 3-D fast-Fourier transform, an MPP machine with distributed memory will usually do two directions on individual processors then develop algorithms to do the butterfly bit-reversal and summation in the third direction to minimize communication and memory usage. On the NWT a 3-D fast-Fourier transform has been written to do the two directions on individual processors. The array is then physically rotated so that elements of the third index of the array are located on individual processors and the fast-Fourier transform in the third direction is done on individual processors and the code is parallel over another direction. This is the general procedure used on the NWT and is applicable to many of the operations that one performs for typical CFD codes. Due to the large size and structure of CFD codes, this seems to be a quite powerful technique while we wait for MPP type systems to develop and write appropriate algorithms for each individual step of a code.

The NWT is quite an ambitious project and specifically designed to handle CFD type codes. As the usage increases and user access is made easier, the combination of large main memory, high-speed cross-bar network, and vector supercomputer technology should prove to be quite powerful.

Experiences of Second Summer Student at NAL STA Fellowship Program, 15 September 1993

Experiences of Ph.D. candidate M. Hudson (North Carolina State University) gained in Japan at the National Aerospace Laboratory (NAL) by using the Numerical Wind Tunnel (NWT) parallel computer. Description of the Science and Technology Agency's Fellowship Program, and the Summer Institute in Japan (SIJ) program.

David K. Kahaner

In a recent report "nal.993" of 8 September 1993, the experiences of W. Jones, Ph.D. candidate at Dartmouth College, gained at the National Aerospace Laboratory's Wind Tunnel parallel computer were described. This report contains a short excerpt from the final report of the second summer student, Mary L. Hudson, who has finished her second year of graduate studies in aerospace engineering at North Carolina State University. In addition, it also contains a description of the Science and Technology Agency (STA) Fellowship Program, under which NAL operates as a host institution.

From the Final Report of Mary L. Hudson, North Carolina State University, Email: HUDSONQJUPI TER4.MMRC.NCSU.EDU

I spent the summer of 1993 living and working in Japan. This was my first visit to Japan, and although I had been to other countries, Japan was initially even more foreign than I expected. This was probably because of the very different written language and culture. Following are some of my impressions after 56 days of living, working, sight-seeing, and being in Japan, which now does not seem foreign at all.

Last fall, during my second year of doctorate studies in aerospace engineering at North Carolina State University (NCSU), I happened to see an announcement for the National Science Foundation 1993 Summer Institute in Japan program for graduate students in science and engineering. I applied and was one of sixty lucky students selected nationally to spend the summer in Japan. We arrived in Japan in late June. Our first impressions were aptly described by a quote on the bus to Tokyo "this isn't Kansas, Toto!" Forty students were located in Tsukuba, a town just outside Tokyo, while the rest of us lived and worked in Tokyo. During the summer, even Tokyo commuting became routine for me due to the efficient Japanese transportation system, my helpful hosts, and my increasing understanding of the Japanese environment. Living in a city with 11 million people was an experience by itself for a kid from a small town in New Mexico. My 56 days in Japan were spent in the areas of technical work and professional visits, language study, and cultural events, and travel.

Technical

I was doing my technical work at the National Aerospace Laboratory (NAL). Dr. Ishiguro (woman researcher) and Dr. Ogawa in the Computational Sciences Division kindly hosted me. Two aspects should be considered when working in a new environment:

- the technical work itself, and
- the new background including laboratory customs and relations.

Researchers at NAL are solving equations for nonequilibrium hypersonic flows almost exactly as we do at NCSU with the exception of the numerical scheme. They use a TVD (Total Variational Difference) higher order scheme. NAUs application for these computations is Japan's hypersonic HOPE (H-II Orbiting Plane) which is an unmanned shuttle vehicle. Like some of America's space programs, HOPE is currently on hold because of funding. The computer system at NAL consists of personal computers (plus I saw one MacIntosh), workstations, and the 5 GFLOPS vector processor, VP2600, built by Fujitsu. The new hardware at NAL is a Fujitsu-built prototype Numerical Wind Tunnel (NWT) parallel computer consisting of 140 processing elements, each with 1.7 GFLOPS performance. Researchers at NAL are working hard to develop the new parallel computer hardware and software.

I was one of the two first foreign researchers to use NAL's new NWT
[W. Jones was the other, see report mentioned above, DKK].
Learning to use NWT was an exercise in communication. Computer manuals and on-line help either did not exist or were in Japanese, as should be. The best source of information was from Japanese researchers who were most helpful. I successfully ran three jobs on NWT. Each run exercised various options in my code, which modeled hypersonic flow of pure nitrogen in thermal and chemical nonequilibrium over a sphere-cone at 0-degree angle of attack. Using only one processor, the NWT cpu time was 4.37 h for 2000 iterations on a 111 X 199 grid resulting in four orders of magnitude reduction in the residual. There were three types of graphics postprocessing: a quick-look graphics and main frame graphics both of which required problem-specific coding, and the complex AVS (Application Visualization System) package. I think a general postprocessing interactive graphics code (like TECPLOT) was needed at NAL. However, graphics workstations were currently being evaluated for purchase. For word processing, they used LaTeX at NAL which is also popular at many American companies.

[Language study and cultural remarks deleted, DKK]

Science and Technology Agency (STA): Fellowship Programs at The National Aerospace Laboratory 10 September 1993.

by:

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[Portions of this text are modified sections of the report "nwt.93", 27 May 1993, DKK.]

STA Fellowship Program

The National Aerospace Laboratory (NAL), an institute under STA, is one of the host institutes for the STA Fellowship Program. The Science and Technology Agency (STA), an administrative organ of the Government of Japan, established the STA Fellowship Program in 1988 to offer opportunities to promising young foreign researchers in their fields of science and technology to conduct research at Japan's national laboratories and public research corporations. This program excludes universities and university-affiliated institutes.

NAL is promoting CFD research in various fields of aerospace science such as applied aerodynamics, aerodynamics, fluid dynamics (turbulence simulation, turbulence modeling etc.) and internal flow problems.

NAL has recently started operation of new high-speed computer called NAL Numerical Wind Tunnel (NWT). NWT is a vector parallel computer consisting of 140 Processing Elements. Each PE has a peak performance of 1.7 GFLOPS and a main memory of 256 MB. The total peak performance is therefore 236 GFLOPS with 35 GB of main memory. The architecture is a distributed memory architecture. A single PE is similar to the Fujitsu VP400 but is 50% faster. Highly vectorized CFD codes can run on a single PE (if size is less than 230MB) or run on multiple PEs, up to 140, provided memory size is less than 35GB. Use of multiple PEs is realized by using simple compiler directives. The benchmark test using an actual application research CFD code for 3-D Navier-Stokes equations showed a performance of 108 GFLOPS with 128 PEs. The maximum number of grid points is 50.5 million. The usage of fortran for NWT is very easy for CFD researchers who are accustomed to vector processing of their codes when compared with unfamiliar (at least in Japan) MPP type computers.

The use of this new system is opened to everyone who conducts research work on CFD and other disciplines at NAL, which would include a STA fellow. We hope to offer an opportunity for CFD research at NAL internationally through scientist exchange programs such as the STA Fellowship. The topics covered are in the field of aerospace science and engineering, but CFD in other disciplines may be included depending upon the proposal and availability. The availability of the supercomputer at NAL to CFD scientists may be one of the best among the research institutes in the world as the number of users are few.

Anyone who is interested in doing CFD research on NWT is encouraged to contact: (within United States of America)

Ms. Janice M.Cassidy
Japan Programs
Division of International Programs
National Science Foundation
1800 G Street, NW., Washington, D.C. 20550
Tel: 202-653-5862; Fax: 202-653-5929
Email: JCASSIDY&NSF.GOV

or directly to: (other countries)

Research Development Corporation of Japan (JRDC)
Department of International Research Exchanges
5-2, Nagata-cho 2-chome, Chiyoda-ku,
Tokyo 100, Japan
Tel: +81-3-3507-3024;
Fax: +81-3-3581-1486

They will provide the researcher with a brochure "STA Fellowship in Science and Technology. The Fellowship is similar to the NRC Associateship in the United States. The applicant may contact a NAL research scientist. The applicant must possess a doctor's degree in science or engineering, and there is an age limit of 35 in principle. The fellowship supports round-trip airline ticket and a monthly living allowance of J¥270,000, family allowance of J¥50,000, initial allowance, and housing. The details are in the brochure.

The application deadline for FY 1993 has already passed. Next year's application procedure starts soon and contact should be started right now.

Summer Institute in Japan Program

There is another exchange program called Summer Institute in Japan (SIJ). This program is for younger research students in graduate school. SIJ provides graduate students with an opportunity to do research during the summer season (July to August) at national institutes in Japan. NAL is also a member of this program. This summer we are hosting Mr.Wesley Jones of Dartmouth College, NH, and Ms. Mary Hudson of North Carolina State University. Mr.Jones will be the first American who has a chance to run his code on NWT. Mr.Jones's address is <Wesley.Jones@Dartmouth.edu>.

Graduate students who are interested in this program are encouraged to contact Ms. Cassidy of NSF.

Plans and Confusion, re: Japan's Optical Communications Infrastructure, 5 September 1993

The status of Japanese efforts in building a broadband integrated services digital network (B-ISDN) and associated jurisdictional disputes are described in this article.

David K. Kahaner

The following article appeared in the Journal of Japanese Trade and Industry, No 4, 1993, pp 40-42. It was written by Maeno Kazuhisa of the Mainichi Shimbun. Readers who were confused about the aspects of Japanese telecommunications activities will find this report very interesting, but they will also appreciate that their confusion stems from similar crossed signals from within Japan.

Information Superhighway, Japanese Style

Japan is currently engaged in a heated debate over a plan to establish a next-generation communications network. This fervor revolves around how best to construct a telecommunications system for the 21st century.

There is a common saying: "When the United States sneezes, Japan catches a cold." Earlier this year, U.S. President Clinton stated, "We endorse the appreciation of the yen," which amounted to an endorsement of a depreciation of the dollar. With an exchange rate around 110 yen to the dollar, the yen has never been so strong.

[The current rate is closer to 105 yen, DKK].

Economically Japan has become a power that is on the par with the Unite States, yet this common saying about the United States and Japan is still very much alive. Likewise, in Japan's scheming for a next-generation communications network, the same pattern is being followed.

The plan for Japan to build this network stems from a proposal that U.S. Vice President Albert Gore made shortly after taking office. His plan is "... to build, by 2015, a high-speed telecommunications highway that would connect the states across the United States in an information transmission network for the next generation." For an agricultural/industrial society, the circuit commonly used for transporting commodities has been highways. But for the upcoming information society, information as a commodity will be transported via telecommunications networks.

American interstate highways, it is said, were first proposed by Vice President Gore's father who, at the time, was a senator. Gore, following in his father's footsteps, called for building highways for the information society, e.g., and "interstate information superhighway." The plan calls for building a broadband integrated services digital network (B-ISDN) across the United States by using optical cables.

Japan was ahead of the United States in establishing a nationwide ISDN system, the most updated system in telecommunications. The transmission used for conventional communications systems is an analog format that involves transmitting data through copper cables. In the ISDN system, data is numerically transmitted by laser, using fiber-optic cables made of fiber glass, through digital exchanges. B-ISDN, unlike the analog system that requires separate communications lines for telegraph, telephone, fax, and data communications, provides for an integrated communications network that uses a single channel of fiber-optic cables. And, because it is said to be capable of transmitting color images (video), the system can also be used for color TV telephones.

[As I have stated in earlier reports, grey ISDN-capable public telephone booths are common sights in Tokyo and other cities in Japan, DKK.]

Japan, in the days of Nippon Telegraph and Telephone Public Corporation, started building the ISDN system using the name Information Network System (INS). In the main cities on the Japanese archipelago, arterial networks were laid, and since 1988 the company has been providing Japan with circuit lines called INS Net 64 and INS Net 1500. One theory has it that the popularization of telecommunications services must be in proportion to a particular nation's GNP, and for the upcoming information society the telecommunications network is an indispensable infrastructure that provides the technical basis for the new society.

Because Japan uses the N-ISDN (narrowband integrated services digital network) system, Vice President Gore suggested the B-ISDN system, which is 1,000 times more powerful in data transmission and reception, can transmit TV broadcasts via the same circuits.

Meanwhile, in Japan, as a means to pump-prime the sluggish economy, Mori Yoshiro, minister for the Ministry of International Trade and Industry (MITI), suggested that "Japan should build a nationwide fiber-optic system as a next-generation communications network." As for funding, he stated at a press conference that "it should come from construction bonds." With the combined-recession, sales of telecommunications and data processing related products have been slow. While Minister Mori's view is in compliance with the wishes of the Communications Industry Association of Japan, his statement became the spark plug that started a heated dispute between political, financial, and administrative circles.

As mentioned before, Vice President Gore proposed the use of publicly-raised funds to construct optical cable networks across the United States. While the building of telecommunications systems is accepted in the United States as a public works project, the situation is different in Japan. Projects eligible for construction bonds, according to guidelines set by the Ministry of Finance (MOF), are limited to future-generation projects that are semi-permanent. It follows that the main targets are public works such as highways and sewerage. The development of a telecommunications network is not eligible for public funds since it is not considered a public works project. (This goes to show how backward the Japanese government is.)

Officials at the Ministry of Posts and Telecommunications (MPT), responsible for the development of telecommunications, are familiar with the hitherto attitude of the Finance Ministry. However before they could propose that the telecommunications plan should be included in construction bonds, MITI beat them to it. Since telecommunications come under the jurisdiction of the MPT, the officials there, in a big flurry, decided at the last minute in mid-March to refer to the Telecommunications Council, an advisory panel to the industry, a recommendation on what should be the 21st century telecommunications system and how such a system can be established.

This marked the beginning of MPT's counterattack. In the past, MPT and MITI have been in constant disagreement. And today, over fiber-optic networks, the two ministries are again engaged in a dispute. As will be mentioned further on, to MPT, ever since the privatization of Nippon Telegraph and Telephone Public Corporation in 1985, Nippon Telegraph and Telephone Corporation (NTT) is nothing more than one of many private telecommunications companies.

[NTT is the world's largest corporation, with market capitalization of about US$150B. ATT is second, at about US$80B, DKK.]

Worse yet, the company has been plagued by competition from newcomers in the market and is suffering from an unfavorable business climate. MPT feels that they cannot trust to NTT the building of a next-generation telecommunications network, a system that will play a decisive role in the 21st century economy of Japan.

MPT launched a plan to organize a public corporation to be in charge of the entire project and have NTT and other telecommunications companies compete in the supply of cables for the network. This plan has been met with keen opposition from MITI, which openly argues that the privatization of NTT had been a painstaking effort. Organizing a public corporation will only defeat the purpose of the privatization reform aimed at improving business effectiveness. But the ministry's true motive, as is widely discussed among people involved, is in trying to prevent a MPT-influenced public corporation from being organized, as the existence of such an organization will only intensify its dispute with MPT. Meanwhile the Finance Ministry is also against MPT's proposal, saying that the plan to organize a public corporation will only dig further into tax revenues and governmental bonds. This, MOF fears, may lead to a crisis in the nation's finances.

At the juncture NTT came out and announced, "As long as there is capital, we can do it with our own hands just as we have always done." NTT's business performance has declined since the New Common Carriers entered the telecommunications market. Because NTT had applied for a price-hike with MPT earlier, the ministry looked at the company's gesture merely as an excuse to open up the issue again.

Following the liberalization of the telecommunications market in 1985, breaking the monopoly held by the then Nippon Telegraph and Telephone Public Corporation, new enterprises, one after another, entered the market. Three newcomers have entered the long-distance telecommunications business: "Daini-Denden Inc. (DDI), founded by Kyocera, Sony and three other companies; Japan Telecommunications, in which the now defunct Japanese National Railways was a major shareholder; and Nippon Kosoku Tsushin (Teleway Japan), backed by the Japan Highway Public Corporation and automobile manufacturers.

NTT's long-distance telephone charges are higher than those in the United States. MPT's tactic in the privatization process was to allow new firms to enter the market and bring prices down through competition. MPT initiated this competition by setting the starting rate at about 30% cheaper than that of NTT. The result was that within seven years phone charges have decreased four times. For example, a three-minute call between Tokyo and Osaka, while NTT charged 400 yen seven years ago, now it only charges 200 yen. The new firms started at 300 yen, and now charge 180 yen for the same service. For telephone users this is indeed a big plus.

However, business began to deteriorate for NTT. For service between Tokyo and Osaka, which is a major money maker, the New Common Carriers are now in possession of as much as 53% of the business shares. For fiscal 1992, NTT closed its accounts with a Japanese¥102.7B shortfall in current profits, which originally had been projected at Japanese¥351B.

NTT went to MPT saying that the company's telephone billing system has been such that profits gained in long-distance phone billing are used to cover deficits incurred for local telephone bills. Owing to a drop in profits in long-distance calls, NTT requested a price hike in local calls to adjust for this imbalance. But MPT rejected the request, saying "... deterioration in your long-distance phone business is due to taking too much profit over the years, this cannot be a reason for your price hike. Why don't you develop new services to make up for your declining business?"

In Japan the (average) length of time used telephoning per line per day is a little less than 12 minutes—one third of that in the United States. Although the number of telephones has increased to 55 million, they are left idle for 23 hours and 48 minutes per day; a great loss to the nation. While MPT maintains that NTT should "diversify services and try to make people use the phone more as a way to raise profits," NTT retorts with "local phone bills must be raised for business improvement." MPT then charged NTT with lobbying aggressively among Diet members, trying to influence the Liberal Democratic Party's Post and Telecommunications "clan"—people who are influential in the administrative affairs of MPT. The ministry and NTT became even more antagonistic and the former insists that it will not grant NTT its wishes to raise local phone bills.

The Finance Ministry and MITI have now added fuel to the fire. MOF holds two-thirds of NTT's shares and this ministry, partially motivated by a desire to raise share prices, is eager for NTT to raise phone prices. Meanwhile, MITI feels strongly that NTT should be in charge of building the next-generation communications network. The result is a complicated situation where interests of the involved ministries are intertwined.

While the dispute over the selection of a main builder for the next-generation communications network continues, so far the issue on how the communications circuit should be used is being completely ignored. Because B-ISDN is capable of transmitting enormous quantities of data, the circuit can be used not only for transmissions of telephone and communications, but also transmissions and receptions of color TV broadcasts via the existing air waves.

MPT began its telecommunications administration by making a distinction between communications and broadcasts. Communications is defined as "limited, small volume of communications" whereas broadcast is "unlimited transmissions of large quantities of data." Because MPT treats the two as different kinds of communications, the ministry has set up two separate organizations, the Communications Policy Bureau and the Telecommunications Bureau, to deal with the category of communications. The result is that for satellite TV broadcasts, the broadcasters often have to make use of two different kinds of satellites—a communications satellite and a broadcasts satellite—for their transmissions. Consequently, broadcast subscribers have to buy two separate antennas.

Ten years ago, when the first broadcast satellites were launched, reception was poor and there was the need to specify that broadcast satellites must be more powerful than communications satellites. Now, with the advance of technology, it is believed that it is no longer necessary to distinguish between communications satellites and broadcast satellites.

In addition, facsimile transmissions once could only be used on a one-to-one basis with the receiving party restricted to one fixed location. Now technology has improved to such an extent that one fax machine can be used to send transmissions to several hundred parties. In other words, communications is increasingly moving towards the forms of broadcast. As mentioned before, because B-ISDN can be used to transmit animated color TV images via fiber-optic networks, the belief is that the time has come for MPT to review its policy of treating communications and broadcasts as separate entities.

That is the reason MPT has decided to bring up the issue to the Telecommunications Council. Recommendations are to be submitted to the council by next March (1994). In Japan there is the high probability that a new communications legislation will be drafted similar to the one in the United States. In America, the Federal Communications Commission (FCC) has already granted permission for a new service called Video Dial Tone that uses telephone circuits to broadcast TV. It looks like Japan will again follow suit.

International Systems Research (ISR) Workshop, 8 September 1993

ISR's High Performance Computing & Networking Workshop was held in Tsukuba, Japan, 27 September 1993.

David K. Kahaner

ISR, originally called the Institute of Supercomputing Research, when it was part of the Recruit company, has had a research laboratory in Tokyo for several years. Several western scientists have been involved in collaborative research there. For example, Dr. H.Wasserman from Los Alamos, and others have worked there. ISR also published the Vector Register, a useful newsletter of activities in Japanese high performance computing. Also, ISR has had well received annual workshops on high performance computing for the past five years (see for example, "workshop.isr", 27 Sept 1990).

However, Recruit Co. has decided that high-performance computing does not fit with their other business interests, and, during the past year, the facility has been transformed into a multimedia development center. ISR's Director, Dr. Raul Mendez, has recreated ISR as a private organization, International Systems Research, without ties to Recruit. In this activity he is joined, on the United States side, by Mr. Craig Lund, who runs Local Knowledge from Durham, NH. Their initial activities will be associated with system integration, with particular interest in the short term, on the 11 supercomputer systems that are to be purchased and installed by April 1994 at Japanese government laboratories as part of the economic stimulus package.

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Last month, ISR ran its annual workshop in Tsukuba. But in keeping with the new organization's charter, the emphasis was on bringing users and potential users together with vendors. As distinguished from past ISR workshops, this was not a research forum. Instead, six speakers gave tutorials or overview talks. In addition, there was a small exhibition where five vendors were represented ; NEC, Cannon-KSR, IBM, HP, and Matsushita-Parsytec. (On the Japanese side, it was very interesting to see NEC's material on the Cenju-3, a multistage net connected parallel machine with up to 256 50 MFLOP VR4400SC processors.) The workshop was also cosponsored by the Ministry of Education's Science in Education Research Foundation. Supporting organizations included the U.S. Embassy and the journal Parallelogram.

Approximately 100 actual participants (excluding vendors) were present. ISR did a good job of getting representation from all the 11 government sites planning supercomputer purchases. In the past years, a large conference and exhibition, Japan Supercomputing 199x, was held, but the 1993 conference was cancelled and I am told that the planned 1994 conference is also likely to be cancelled due to the high costs. Thus, the ISR workshop was one of the few opportunities for potential users to come together and hear about systems. Although there were a few participants who were very well versed in supercomputing, clearly many were here to learn, and in that sense they were well served and the workshop should be deemed a success.

Below I have included summary material on the Japanese presentations. (Two presentations, in English, were overviews of activities in the United States on clustered workstations and High Performance Fortran.) Of these, the most interesting for me, and perhaps for Western readers, was the overview of NTT's networking and service strategy, called by the company VI&P (Visual, Intelligent and Personal Communications). This is related to applications of (Integrated Services Digital Network) ISDN. As I have written on this topic several times before, here I will only summarize the latest activities, what NTT calls Phase II. (For associated material, both narrowband and broadband ISDN, see the reports "j-comm.93" 5 Sept 1993, "isdn.93" 25 Feb 1993, and "isdn.92" 6 May 1992.) At the ISR workshop, the NTT presentation was made by:

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Since April 1991, NTT has been conducting comprehensive experiments related to VI&P services, NTT's service vision for the 21st century at its company's laboratories. B-ISDN and FTTH (Fiber to The Home) are important and basic items for the VI&P concepts, and are being developed at the NTT laboratories. Existing ISDN experiments at NTT have focused on optimizing the use of current N-ISDN (called by NTT, INS-Net). Beginning this fiscal year, the company is concentrating on experiments for new services and applications for the time when higher bandwidth becomes available. This past summer, NTT released information about their work in two general areas,

- multimedia and
- high-speed computer communications.

Multimedia

NTT's Yokosuka R&D center, which is located at about one hour South of Tokyo, is connected by an optical subscriber transmission system to a "house" about 4 km away. The system can multiplex-transmit data at speeds of several Mbps, up to several hundred Mbps, on a single optical fiber. The environment in the house is supposed to simulate a real home or office situation, so in addition to sophisticated issues, NTT is also studying optical fiber cable wiring questions such as the installation of optical cables, mainly applied indoor. NTT plans to install FTTH in Japan by year 2015. Experiments in the house are related to simultaneous use of multiservices and applications of superhigh definition, (SHD) (see below) images. Specific applications include electronic newspaper transmission and transmission of photomicrographs of cellular tissues or X-ray data for medical diagnosis.

Experiments related to simultaneous multiple services involve the use of a video telephone and 60 channels of TV (including some HDTV) on a single optical fiber using the optical subscriber transmission system mentioned above. SHD applications (see next paragraph) in the office are envisioned to include such things as fabric databases, high-definition images from libraries and museums, CAD, etc.

NTT's SHD is a system that will transmit and display images with four time HDTV data capacity (claimed to be about the resolution of 35 mm film). Using 150 Mbps (B-ISDN) and this system, NTT can transmit a still image in less than one second. Using 600 Mbps lines, a high-quality moving picture can be transmitted in real time.

High-speed computer communications

The Yokosuka R&D center is also connected to NTT's Musashino R&D center via ATM links connected to a 100 km 2.4 Gbps optical transmission line. (Musashino is west of Tokyo.) The centers will also be connected by analog NTSC and digital 156 Mbps satellite links in 1993 and 1995 respectively. The idea is to study problems associated with various applications including latency and error effects. FDDI LANs are installed within each center. There is also a supercomputer at Musashino that generates computer graphics image data sent to an HDTV quality display at Yokosuka. There are multimedia system experiments such as PC-based multipoint desktop video conferencing using ATM-LAN developed at the NTT laboratories.

[Remark: Readers of my reports will doubtless get the impression that there is some disarray in Japan's activities with regard to ISDN. For example, the report "j-comm.93" 5 Sept 1993, suggests that financial pressures may retard the completion dates of the FTTH project. The Japanese economy is not nearly as strong as in the past, competition is intense within the communications industry, and there are many governmental "turf wars," nevertheless, forward progress is evident. DKK]

Simulation Supercomputer Center at National Institute for Fusion Science Kunihiko Watanabe, NIFS

This talk described the newly created supercomputer center at the National Institute for Fusion Science in Nagoya. Their "Simulation Analysis System" is centered on an NEC SX-3 24R supercomputer that a small number of users share. (The decision to obtain this machine instead of a Cray caused front page headlines here several months ago.) The basic concept is to try to advance the understanding of fusion physics by increasing the computational resources dedicated to numerical simulation. The NIFS system is unique in several ways (even by Japanese standards). For instance, it is designed for handling 4 GByte, 2-hour jobs in single user mode. Notable features of the system are its use of mass storage (1.5 TByte, 10 MByte/sec throughput) as disk space, and its use of a 160 Gbit RAID disk system as a buffer from which data are transferred to mass storage after job execution.

Amateur's Experiences on a Highly Parallel Computer, A Large Scale Numerical Simulation on AP-1000 (QCD-TARO Project). Atsushi Nakamura, Faculty of Education, Yamagata University

This talk described the author's experience with parallel processing on the Fujitsu AP-1000, a distributed memory system based on the Sparc RISC chip. The AP-1000, a 2-D mesh (or more precisely a torus), is the parallel processor with the largest number of users in Japan. This talk was a kind of user's log of experiences porting QCD applications to the AP. The mapping from the physical domain to the topology of the AP as well as load balancing in QCD applications were discussed in detail. (TARO stands for Thousand cell Array processor for Omnipurposes.)

The Emerging Workstation Cluster Craiq Lund, ISR America, Durham NH

HPF: Why, Where, and How Larry Meadows, The Portland Group, Wilsonville OR Benchmarking, Past, Present, and Future S. Sekiguchi, ETL, Tsukuba Japan

This talk surveyed the performance of supercomputer systems. First a review was given of the various attempts at establishing a methodology for measuring performance. The author emphasized that benchmarks should be used for the performance estimation or prediction, when users purchase new machines or when designers develop new machines. Thus, one of the important features of a benchmark is that it must cover the perspectives of both applications and architectures. Of course, "performance" is supposed to be a function of computing something, and hence, once an application has been run, the output should contain the data necessary for evaluation.

The PERFECT, NAS, SLALOM, SPLASH, Euroben, and several other benchmarks were discussed. These varied from the hierarchical approach, proceeding from simple vector operations, to kernels, advancing to subroutines, and reaching up to full application programs. There are mutual interactions among benchmark's hierarchical levels.

Sekiguchi also stated that MITI is planing to start an academic project for research on computers' performance modeling and its theory.

NEURAL NET APPLICATIONS IN SIGNAL PROCESSING CONFERENCE, SINGAPORE, 17-20 AUGUST 1993

Neural Network Applications to Signal Processing (NNASP'93) Conference was held 17-20 August 1993 in Singapore, and it is here summarized. A few miscellaneous comments about networking activities in Singapore are also included.

David K. Kahaner

The conference, Neural Network Applications to Signal Processing (NNASP'93), was held 17-20 August 1993 in Singapore. These four days included four half-day tutorials on the first day, and a technical program composed of about 90 papers in two concurrent tracks and two panels during the remaining three days. NNASP'93 was sponsored by the Singapore section of the IEEE, and the general chairman was

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I have a copy of the proceedings and will attempt to provide requestors with photocopies of individual papers. For additional information contact

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The tutorials given at the NNASP conference were about standard topics, except for the "Sensor Data Fusion for Military Surveillance Systems" by Professor Leonard Chin Nanyang, Tech. Univ. School of Electrical & Electronic Engineering, Nanyang Ave, Singapore 2263, Tel: +65 799-5442; Fax: +65 791-2687.

Professor Chin, who worked for the United States Department of Defense for many years and also was head of Radar Systems for Magnavox, gave a very interesting overview of the target tracking issues, and contrasted missile threats of today to those expected by the year 2000.

	Today	Year 2000
Radar crossection	2.Om^2	0.2m^2
Highest altitude	2Okm	2Okm
Lowest altitude	15m	5m
Speed	30Om/s	60Om/s

Professor Chin also described fundamental problems that command and control systems must resolve for the target association and tracking needs.

- Random measurement errors from multiple sensors in position, velocity, and intensity
- Process noise (unobserved influence and target maneuvers)
- False alarms
  - Target too close to be resolved
  - Sensor noise
  - Background clutter
- Inaccurate handoff estimates (from one system to another)
- Jamming
- Target intensity variations
- Target entering and leaving field of view
- High target density
- Unknown number of targets
- Target stage/phase transition

Professor Chin's major research activity concerns dealing with the fusion of data from many different sensors (for example, several different radar systems) to maximize the probability of detection and its range, while minimizing the probability of false alarms and time-to-decide. He presented a table of systems used for data fusion and the basic processing technique, e.g., estimation, templating, bayes estimates, fuzzy sets, expert systems, clustering, and evidence reasoning. In his list, most systems used expert system technology.

Professor Chin gave an overview of all these topics but emphasized the area of research at his university, which is to associate multiple measurements with multiple target threats to establish correct tracts in the face of maneuvering targets with abrupt dynamics.

According to Professor Chin, conventional multitarget tracking relies heavily on Kalman filtering for state estimation (joint probability data association filter, JPDAF). Chin claims to have developed a new approach, which combines a neural net with a Kalman filter to incorporate learning, and which is said to significantly reduce trackinq errors, at least in simulated experiments.

The technical conference was mainly applications oriented. No major new theory on neural networks was presented. But, as expected, there were many interesting applications of neural nets in signal processing; speech and sound recognition, classification, medical (MRI, ECG, cell-microscopy, tomography, etc), sensor data fusion, coding and communications, image compression, handwriting analysis, tool-wear diagnosis, robot manipulation, etc. Many of these papers involved modifications of known theory, or combinations of several techniques such as neural plus fuzzy, adding delays to neural net learing, optical neural nets, etc.

My general impression is that there is a high level of understanding of the basic mechanics of neural networks at the universities and labs in Singapore, and that was evident in the presentations made at NNASP. These scientists are pushing the development of new applications, some in very innovative ways. However, there was no indication of fundamental breakthroughs or even really deep theoretical work.

Among some specific examples of excellent application groups in Singapore, the most interesting is under the direction of

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Dr. Patterson and his colleagues presented papers on a variety of topics such as military and commercial image recognition, traffic motion detection, time series forecasting. This is clearly one of the most active groups in the region.

A few especially interesting presentations are highlighted below.

B.Widrow (Stanford) gave a fascinating historical treatment of his involvement, which started with the LMS algorithm (Widrow & Hoff) in 1959. Widrow presented a variety of examples such as cardiography and beamforming, and the use of LMS and ADALINE in adaptive noise cancelling with one or two sources.

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Dr. Furui discussed neural network examples in speech recognition at NTT, particularly his work on the Hidden Markov Model for this problem.

Sato, et al. (Yamatake-Honeywell and Hokkaido University) described a 2-D color sensor system that uses a combination of neural nets and fuzzy sets. The experimental application is to identify different kinds of bottle caps. Earlier color sensor systems fail when light conditions change with time. The new approach seems to work better, but still fails when there are discontinuous input changes.

Teow, et al. (NUS) discussed truth value flow inferencing using neural nets. TVFI is an inferencing process for fuzzy sets that requires no aggregation (as does Mamdani's method). The authors presented an elementary experiment relating to the perfect gas equation, PV=nRT.

Zhang et al. (NUS) discussed processing of video camera for traffic data. The system detects and extracts moving vehicles from TV camera data, tracks their motion, and identifies one of five types of vehicles (truck, car, bus, etc) in real time. The system uses a separate algorithm for each extraction, tracking, and classification; the latter uses a neural net. This system appears to work fairly well, although more work is needed to process shadows caused by moving objects.

A very interesting application to cervical cytology was presented by Tien et al. (Ngee Ann Poly, Singapore, Email: AR569@PO.CWRU.EDU.) Cervical cancer is a major problem worldwide, and it is the fifth most common cancer occurring in women. It is easily detected and treated in its early stages, and screening programs are widespread. Unfortunately, examining glass slides manually is very tedious because in the early stages there are only three to four abnormal cells per 60K on a slide. Because of fatigue, the error rate is very high with manual screening, but thus far, attempts to automate the process have not been successful. This paper discusses the use of a multilayer perception (using back-prop). Results indicate that 70% classification is reasonable with almost no care in the choice of the network or problem parameters; however, getting 80% classification was more difficult. This seems like a very promising approach, but obviously much more work is needed.

A pure application paper by Lau et al. (NUS) compared different neural network architectures against handwritten databases from Canada, Center for Pattern Recognition & Machine Intelligence at Concordia University, and the United States, National Institute of Standards and Technology. This was interesting to me because the characteristics of the digits in the two databases are very different, and lead to quite different conclusions about the successful recognition rates of the various approaches.

Another application (Jia et al., Nanyang) compared seven different data coding approaches (binary, BCD, Grey code,) to see if coding can affect neural net training.

Patterson et al. (NUS & Nanyang) discussed the use of neural nets to forecast time series. What made this particularly interesting to me was their choice of series, which were generated by numerical integration of a differential equation (Mackey-Glass) or iteration of a the Henon equation. They have also studied Standard & Poors and exchange rate series. It goes without saying that if the authors had really cracked this problem they would no longer be university professors.

In another paper, Patterson et al. (NUS & Nanyang) experiment with modifications to improve the performance of BAM (bidirectional associative memory) by using the Hamming distance as an association metric, and by subdividing the input image into parts. The experimental application is to 32^2 pixels from the binary image of digits. This appears to be a reasonable technique, but it requires much more experimentation than has been presented in the current paper.

Qi et al. (NUS), who are also associates of Patterson have been applying neural nets to container ID verification at the Port of Singapore, which is one of the world's largest container ports (millions of containers per year). The issue here is the need for extremely high recognition accuracy, beyond 99.5%, based on image data taken from the containers under a variety of lighting conditions. The main focus of the present paper is to discuss the improvements that have been made to a working Container Number Recognition System (CNRS), such as using grey-level rather than binary images, expanding the character training database to about 20,000 individual characters, integrating character segmentation and recognition rather than performing these operations sequentially, and adding a feature based recognizer to the (back prob) neural net recognizer. I liked this paper a great deal because it illustrates that in designing a workable recognition system, engineering and sweat are more likely to be needed than theory.

Among many classification papers one specific application to using neural net (multilayer perception) to process the power spectrum of ship noise is worth noting (Donglei, NW Poly Univ, China). The results improve with the number of hidden units (the more the better, i.e., no theory, just do it) giving over 90% recognition in realistic cases that appear to be perfectly practical.

Work by Zhou et al. (NUS) provided yet another application of neural networks, i.e., to on-line diagnosis of tool wear. The neural network was trained in using the standard back-propagation. But instead of using actual experimental data to train the network, equations describing the tool wear state were derived off-line, and training data were "artificially" generated by using these equations. The results appear promising and show improved performance over neural-network methods trained on actual experimental data (because of inconsistency in some of the data). Improved performance over standard least-squares estimation was also seen.

A growing interest seems to be apparent in using radial basis functions (RBF's) as the nonlinear activation functions in neural networks. Tan's (NUS) paper uses them for system identification. The advantage of RBF's is that convergence can be guaranteed when using Lyapunov based techniques (from Control Theory). As Widrow mentioned, convergence of neural networks is very hard to prove, but with RBF's, it makes the problem tractable. It, however, inherits the current limitations of neural networks, that is, how does one know how many RBF's (neurons) are needed?

PANELS

A most interesting aspect of NNASP were the two panels, one on forecasting with neural nets and a second on future directions in neural net research. The forecasting panel dwelt on financial issues. The key ideas in the future direction are summarized below.

FUTURE DIRECTIONS IN NEURAL NETS PANEL

Widrow: Admits to having a bad prediction record, but emphasized that in the absence of war, typically 25 years were needed for sound ideas to get into general practice. Neural nets appear to be simple, practical, and useful, but there is still a lack of general theory in the neural net field. However, he felt that theoretical ideas come from solving practical problems. Key point—patience is needed.

Furui: His emphasis was clearly on speech, in which field he has several decades of experience. Both theory and applications are needed, but although there are many theories, we still don't understand what is really going on. The four areas in the speech field are

(1) language modelling,
(2) speaker independent recognition,
(3) large vocabulary, and
(4) real field tests as opposed to demos in labs.

There are problems associated with environment, speakers, input equipment, and that the really tough problem is continuous speech recognition. Furui emphasized that neural nets alone seem inferior to statistical techniques, but perhaps used together, some parameter optimization can be done.

Sririvasan (National University of Singapore): He emphasized his optical background and wanted to draw the analogy between a hologram and an associative memory, and the use of an optical control link to back prop. Also, he felt that neural nets would be faster than expert systems.

The panelists agreed that the main interesting properties of neural nets relate to nonlinearity and the storage of information in a distributed way. There was also general agreement that a great deal of neural network was experimenting with black boxes. While there was a recognition that such things are nice for students, often they do not generate fundamental understanding or increase knowledge. This point came up several times in discussing the difference between neural nets and optimal statistical methods. A neural net can be seen as a black box that is trainable (i.e., it learns) and works in parallel. With a statistical method one has to know the model and the phenomenological statistics. When both are applicable, it is normal to have neural network performance no better than statistical methods in most cases. Dr. Widrow pointed out that success usually comes to those who believe in their approach (this latter in the context of Dr Furui's comments that he was somewhat less comfortable with neural nets than with statistical approaches).

There was an interesting side discussion about the relation between neural net and fuzzy technology. Many commercial products were showed that used fuzzy logic, especially in Japan, such as washing machines, air conditioner compressors, variable speed AC motors; in this area, Japan was seen to be very far ahead of the United States. But while fuzzy gives people another way of thinking about practical problems, the panel felt that in most cases the problems were quite simple and could be solved by a variety of different methods such as neural nets, fuzzy logic, and statistics, with the main aim to introduce some control into such simple machines. The point was made that for the fuzzy washing machine the major advances were obtained because the use of a tremendous amount of sensor information rather than the explicit fuzzy rule-set. Comparing fuzzy logic with neural nets shows that both deal with nonlinear mappings, but not in the same way. For fuzzy, one has a set of rules, and the mapping is done without explicit learning, whereas with neural, one is working with a set of examples and the mapping is determined by some kind of learning. Both fuzzy and neural are able to use a combination of known rules when a new situation occurs. Of course this is not true with traditional expert systems.

ASSOCIATED SINGAPORE SCIENCE NOTES.

As usual, during my visits to Singapore, I remained impressed with the country's efforts to grow by using information technology. On this trip I noticed major efforts to move both the construction and real estate industries into the IT world by the use of Corenet (Construction & Real Estate Network). This activity was announced at the International Conference on Management of IT for Construction, held in Singapore in August. The idea is to enable architects and engineers to electronically submit various development permit applications and design drawings to different government agencies simultaneously. Designers would be able to access up-to-date product specifications and a standard library of symbols. Also, current building codes, planning guidelines, valuation and bidding information, and material prices would also be accessible.

In addition to Corenet, there is a major initiative in connecting Singapore's Construction Industry Development Board and Germany's Siemens to jointly develop strategic IT technologies and joint training. The first step is a US$3M R&D project on concurrent engineering in building design, focusing on simultaneous design and testing. This is a three year project. Siemens, both in Germany and Singapore on one side, and Nanyanq Tech. Univ. (Gintic Inst of Manufacturing Tech) on the other.

Four smaller projects associated with IT in construction were also mentioned.

(1) Graphics interchange standards,
(2) Construction management information systems,
(3) Expert systems for evaluating building plans (taking building drawings and checking compliance with building regulations), and
(4) VR for 3-D architectural rendering and walk-troughs.

In a related development, Singapore (with the help of its National Science Technology Board), has set up "Technet" which is a Singapore-wide computer network that links to tertiary institutions. In addition, all companies involved in some kind of R&D are allowed computer accounts into Technet. Through it, local companies can have access to Internet and Bitnet for global connectivity (e-mail, news, etc.).

Teleview is another computer network facility that is geared more towards domestic users. Each household can apply for a computer account on Teleview. A computer is needed to access the network, but access is possible via modem, or through the air (UHF) by using a tuner card for the PC. There are e-mail facilities among Teleview services as well as shopping and banking services. There may be plans to link Teleview with Technet.

I also want to call attention to the very readable quarterly Journal, "Engineering & Technology," from Singapore Technologies. The Vol.3 No. 2 (April-June 1993) issue is quite typical. Usually contains four to six descriptions of engineering applications with excellent graphics.

"Structural Analysis of a Helicopter Horizontal Stabilizer" (Lee Chong), describes the use of Nastran and other structural analysis packages for studying one part of an aluminum 2-ton helicopter.

"Aircraft Grid Generation Using Interactive Environment" (Ong Lih Yenn, Lee Kuok Ming) describes the development of a C-language grid generator for using Silicon Graphics GL library primitives and its use in the analysis of an unspecified fighter aircraft.

"Vibration Environmental Qualification of an Electronic Package" (Pang Seng Tuong), describes a vibration analysis study of an electronic display unit installed in a fighter aircraft. Some finite element modeling of the printed circuit board, corrosion study, and a significant amount of experimentation are discussed.

"Multiperiod Short-Term Job Assignment Model (MSJAM)" (Lim Mui Hong), describes a linear network flow problem using public domain relaxation software published by Bertsekas & Tseng in Annals of Operations Research in 1988. The current author also developed an easy to use preprocessor.

"Improving the Calibration Test Rigs Through Computational Simulation" (Lim Kay Leong), describes simulation of the elevation-range curve for a variety of projectile launchers, and comparison with experimental data.

Concerning these articles, if readers are expecting to do academic research or even new engineering techniques, this publication is not the place to look. They will, however, find perfectly acceptable journeyman type articles describing real physical problems, to which traditional solutions are being applied with care.

Joint Symposium on Parallel Processing (JSPP'93), 17-19 May 1993, Tokyo, Japan

Summary of the 1993 Joint Symposium on Parallel Processing (JSPP'93), held at Waseda University, 17-19 May 1993, Tokyo, Japan

David K. Kahaner

Two major regularly scheduled meetings are held in Japan on the topic of parallel computing, the Joint Symposium on Parallel Processing (JSPP), which is held each spring in Tokyo, and the Summer Workshop on Parallel Processing (SWoPP). JSPP is fairly conventional, whereas SWoPP is an informal workshop. The participants of the workshop are housed together for a week each summer, dormitory style, and engage in relaxed discussions in a resort--type setting. Japanese is the language used in both JSPP and SWoPP. JSPP usually has a few English participants, SWoPP does not. About 100 papers were presented at this year's JSPP'93, and after being reviewed, these were down to about 50 presentations in three parallel sessions over three days. The symposium was held in a new and very spacious conference facility at Waseda University, which is a large, private university in central Tokyo.

JSPP is essentially a conference about systems building, both hardware and software. Applications, including a few interesting ones associated with numerical computation, were mostly tossed in on the last day. Also, as JSPP is about parallel computing, there were no papers dealing with large scale vector processors (C90, SX-3, etc.).

This was the best JSPP ever held. The quality of the papers was very high. While the number and variety of papers is still not quite what one would expect at a comparable Western conference, JSPP'93 indicates that there has been a significant improvement in the state of research on parallel computing in Japan. Why? One reason is simply maturation of the field, but mostly, there are now significant numbers of parallel systems available in Japan for researchers to use. Not only the United States and the European Community (transputer) systems, but a growing number of Japanese products, either experimental, prototype, or preproduction. This includes systems developed at company labs and also at government and university labs. Of the Japanese, NEC, Matsushita, Toshiba, and especially Fujitsu are now making a number of systems available for use within the research community. Hitachi is developing applications software, in particular DEQSOL, to run on parallel systems—their will probably be a product that is being developed using HP's PA-Risc chips. The Real World Computing project has two large United States systems, and RWC is already generating a great deal of work, especially from the researchers who are or have been at ETL, on new versions of dataflow computers. They described their plans to develop an MPP (RWC-1) with 1K PEs by 1995, and subsequently systems of 16-64K PEs that will emphasize rapid interprocessor communications. (Their paper compared message passing time on the EM-4 as 10 mu-s, less than either iPSC/860 or CM-5.) I have previously discussed work on various PAX systems at the Universities of Tsukuba and Tokyo, and that is also being used for some real computations—more examples of opportunities for experience building with parallel computing.

ICOT was also represented by several papers on PIM systems, and some theoretical papers on logic programming; but the emphasis, at this conference, has clearly shifted from ICOT to RWC. Simulations, while still strongly in evidence, are now more and more being replaced by actual experimentation. Furthermore, more papers now contain references to Western benchmarks, Linpack, Shallow, and even

High Performance Fortran, regardless of what one thinks of their relevance; the fact that they are being studied is a good sign.

Many university contributions are evolving from those that have been described in earlier conferences (such as Waseda University's OSCAR, or the Reconfigurable Machine that began at Kyushu University under Prof Tomita and is now in version II at Kobe University). There is also a plan to design and build a large distributed shared memory system by Hiraki and others at U-Tokyo. Language, design, and simulation are still strong at the universities, such as a discussion on issues of locality in garbage collection by A.Yonezawa and students at U-Tokyo. Overall, I could not tell much about quality difference between the best Japanese papers and those from the Western participants. There is also some excellent theoretical work being done at the corporate labs, such as NTT's M.Takesue's work on network transformations, as one example.

Fujitsu's AP1000 is still the front runner in terms of getting a system out the door. Fujitsu has announced this as a product, and is currently beefing up the individual CPUs for better numerical performance, and also frame buffers for better performance in graphics applications. NEC's Cenju, which began as a 64 node system for SPICE-type calculations, is now being developed as Cenju3. This will have 256 VR4400 CPUs and a multistage interconnection network. NEC's Nobuhiko Koike tells me that Cenju3 will also be a product. Matsushita's ADENART will have an improved interconnection network (two hops) as well as new superscalar PEs. As part of RWC, Toshiba has proposed a Teraflop system TS/1 with 250MFLOP (multithreaded) vector processors that will use high bandwidth DRAMs in a 3-D high-bandwidth network. Toshiba states that a 64 node prototype will be built by 1995 and a lK system by 1996. IBM Japan has several papers discussing use of their TOP-1 system, but this seems more like a research facility than some of the others.

Along with the lack of real application papers, there was no evidence, yet, that parallel computing has been accepted as a production tool in industry. Similarly, I still sense a concern among the Japanese computer vendors as to the commercial feasibility of parallel systems. While many are moving forward, to me this seems with some trepidation. Parallel computers have arrived at the research labs, but are only just beginning to enter the profit making divisions of most organizations.

The proceedings contain printed copies of all the papers. With the exception of the Western speakers, almost all papers are written in Japanese, but they also include an English abstract that is given below. Because Japanese was the conference language the few Western participants were in attendance during their session but rarely otherwise. There were ample opportunities for informal discussion during the breaks, and as Peter Sellers learned, "being there" also has many benefits.

For the abstracts given below I wish to acknowledge the assistance of members of the JSPP organizing committee, and especially

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I have included an email address for almost all of the papers, but not always a complete mailing address. Readers who are unsuccessful in communicating with the authors can contact either me or Professor Nakashima.

JSPP'93 Program

May 17 (Monday) - 19 (Wednesday), 1993

Center for Scholarly Information, Waseda University, Tokyo, Japan Compiling HPF for A Cluster of Workstations

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High Performance Fortran (HPF) is an emerging de facto standard language aiming at data-parallel programming for various parallel machines. Ease of parallel programming by simple data placement annotations to Fortran 90 is particularly attractive to end users. Success of HPF approach, however, depends on innovation of new compiler technology. The HPF compiler is responsible for generating efficient, scalable Single Program Multiple Data (SPMD) code for reasonable speedup on the target parallel machine. This paper will present a basic

compilation strategy and our preliminary results on a cluster of workstations.

Data Transfer Rate Required for Permuting Data on a Massive Parallel Processor

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A massively parallel processor with multilevel shared memory is modelled to find a memory bandwidth between PEs (processor elements) so that it does not give rise to a data-transfer bottleneck. Focusing on concrete data-permuting problems, this paper also gives a parallel algorithm whose processing time is the lower bound of a single-processor time cost times the inverse of the number of PEs. Interlevel data-transfer rate of the hierarchical memories and the capacity of memory at each level are derived to maximize the CPUs computing power.

Evaluation of Latency Hiding on a Fine-grain Parallel Processor

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Latency associated with memory accesses and process communications are one of the most difficult obstacles in constructing a practical massively parallel system. An instruction-level data-driven computer is an ideal testbed for evaluating these latency hiding methods because prefetching and multithreading are naturally implemented in an instruction-level data-driven computer as unfolding and concurrent execution of multiple contexts. This paper evaluates latency hiding methods on SIGMA-1, a dataflow supercomputer developed in Electrotechnical Laboratory. As a result of evaluation, these methods are effective to hide static latencies but not effective to hide dynamic latencies.

Effect of Message Communication on Distributed-Memory Parallel Computer Performance-Overlapping Communication with Computation and Direct Message Receiving

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The performance of message-passing applications depends on CPU speed, communication, and message handling overhead. In this paper we investigate the effect of applying techniques to reduce message handling overhead on the execution efficiency of ten different applications. Using a message level simulator setup for the architecture of the AP1000, we showed that overlapping communication with computation and transferring received messages directly to a user area improves performance. In particular, the speedup of overlapping computation with message reception is almost double, because this reduced message handling overhead and idle time.

Data Distribution Management for Distributed Memory Machines in Parallel Programming Environment PCASE

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This paper presents data distribution management and communications generation techniques for distributed memory machines in parallel programming environment PCASE, under development at NEC. PCASE automatically converts a sequential FORTRAN program into a parallel program with communications and synchronizations for the target machine. We carried out performance measurement on a 16 node Cenju2, with two VR3000 RISC microprocessors and 64MB memory per node,using 3-D Poisson solver program(60 x 60 x 60) based on SCG method. In this experiment, we achieved 11 times speedup as compared with executing on one node.

A Study of a High-level Numerical Simulation Language DEQSOL and its Translation Technique for Distributed Memory Parallel Processors

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Parallel computers have been proved efficient for numerical simulation of PDE (Partial Differential Equation) problems, but it is very time consuming to develop simulation programs for them. It is because current programming languages require the programmer to specify a problem to be solved at a low level of abstraction. An alternative approach is to specify the problem to be solved at a high level. DEQSOL (Differential Equation Solver Language) is a high-level programming language specially designed for PDE problems to improve programming productivity. This paper describes the parallelization technique of DEQSOL program to enable high performance of parallel computers.

Automatic Paralleling Compiler for Distributed Memory Parallel Computers-New Algorithms to Improve the Performance of the Inspector/Executor

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In this paper, we focus on paralleling compiler techniques that generate SPMD codes for distributed memory computers. Parallelization of loops with indirect accesses with index arrays causes irregular access patterns. For such codes, a technique to generate inspector/executor code has been proposed. In this technique, however, the inspector must perform all-to-all global communications. Furthermore, codes, to which this method is applicable, are restricted. To resolve these drawbacks, we propose two inspector algorithms, inverse index method, and exhaust inspection method. We evaluated the effectiveness of these methods on the highly parallel computer AP1000.

An Application of an OR-Parallel Prolog System with a Priority Control Mechanism to Search Problems

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We implemented an OR-Parallel Prolog system with a priority control mechanism on a tight-coupled multiprocessor machine. This paper presents its application to searching problems. The priority mechanism enables us to describe the A* algorithm in OR-Parallel environment. By applying it to the inference of molecular phylogenetic trees, a maximum of 40-fold (super-linear) speedup was attained on 26 processors.

New Results in Finite Algebra by a Parallel Model Generation Theorem Prover

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This paper reports some new results in finite algebra by MGTP, a parallel theorem prover developed at ICOT. The heuristics and OR-parallelization that we introduced to MGTP worked well for proving new existence and nonexistence theorems of quasigroup. It should be noted that MGTP is a general-purpose theorem prover not at all designed for quasigroups in mind.

Transitive Closure Evaluation of Database Relations on Massively Parallel Computer MasPar MP-1

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Transitive closure evaluation of database relations is important to recursive query processing. It is intrinsically expensive in both computation and communication. In this paper we study the performance of three parallel transitive closure algorithms using the double-hash data distribution on massively parallel computer MasPar MP-1. Relations with up to one million tuples are tested on the SIMD mesh of 4,096 processors. Our results show that it is a promising direction to improve database performance by exploring massively parallelism.

Parallel Processing on a Multiparadigm Massively Parallel Teraflops Machine - Interprocessor Chaining and Its Applications

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The massively parallel Teraflops machine TS/1 is going to be developed by Toshiba under the project of Real World Computing Partnership (RWCP). TS/1 will have thousands of 250MFLOPS single chip multithreaded vector processors with the mechanisms for chaining between remote FIFO vector registers (Interprocessor chaining) and for new generation high-bandwidth DRAMS, which are connected by high-bandwidth network using 3-D packaging technologies. The effect of the interprocessor chaining is evaluated by estimating the performance of TS/1 with typical applications. The result shows that TS/1 has extremely higher performance than commercial supercomputers for communication constrained applications (Matrix multiplication and LU decomposition with pivoting) and memory bandwidth constrained application (2-colored SOR).

Basic Features of a Massively Parallel Computer RWC-1

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The authors are now studying and developing a massively parallel computer consisting of tens of thousands of processing elements (PEs). This paper presents the basic features of it. It proposes the following innovative concepts and technologies:

(1) RICA (Reduced Interprocessor Communication Architecture): architectural fusion of communication and computation,
(2) Superthreading: optimization of thread creation and thread execution,
(3 fast interconnection network with extra facilities, and
(4) support for the massively parallel operating system.

RWC-1, the first prototype, will be operational with 1024 PEs by 1995, and a platform system consisting of 16K to 64K PEs will successively be developed.

A Hierarchical Macro-dataflow Computation Scheme of OSCAR Multigrain Compiler

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This paper proposes a hierarchical macro-dataflow computational scheme that exploits the coarse grain parallelism inside a macrotask like a subroutine or a loop hierarchically. This paper especially describes a hierarchical definition of macrotasks, parallelism extraction scheme among macrotasks defined inside an upper layer macrotask and a scheduling scheme that assigns hierarchical macrotasks on hierarchical processor clusters. Also, a performance of the hierarchical macro-dataflow computation is evaluated on a multiprocessor system OSCAR.

Parallelism Detection Scheme with Execution Conditions for Loops

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Thus far, the coarse grain parallelism detection scheme, which represents the parallelism as Execution-Start-Conditions with the restriction that the flow-graph of macrotasks has no cycle, has been proposed. In this paper, the way to remove the restriction is discussed.

Near Fine Grain Parallel Processing without Synchronization using Static Scheduling

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The near fine grain parallel processing scheme using static scheduling algorithms has been proposed to process a Fortran basic block in parallel on a multiprocessor system. However, the scheme suffers from relatively large synchronization overhead since synchronization codes must be inserted into a parallel machine code to satisfy precedence constraints caused by data dependences among tasks. To cope with this problem, this paper proposes a parallel code generation scheme that removes all synchronizations by optimizing or scheduling, execution timing of every instruction in a machine clock level. Furthermore, it reports performance of the parallel processing without synchronization evaluated on an actual multiprocessor system OSCAR, which is designed to support the proposed scheme.

Barrier Synchronization Models - Proposing Taxonomy and New Models, and Evaluating Performance -

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Barrier synchronization is an important method for coordinating parallel processors; therefore, many barrier synchronization models have been proposed in the literature so far. This paper proposes a taxonomy that classifies these existing models well and also suggests new possible models. This paper also gives a performance formula for each classification of barrier synchronization models, and then evaluates their performance quantitatively.

Compiling Technique based on Dataflow Analysis for Functional Programming Language Valid

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In this paper, we present a compiling method to translate a functional programming language Valid into an object code executable on a commercially available shared memory multiprocessor (a Sequent Symmetry S2000). Since the cost of process management is very high in such a machine, we exploit coarse-grain parallelism at function application level, and the function application level parallelism is implemented by fork-join mechanism. The compiler translates Valid source programs into controlflow graphs based on dataflow analysis and then serializes instructions within graphs according to flow arcs such that function applications which have no data dependency with each other are executed in parallel. We report results of performance evaluation of the compiled Valid programs on Sequent S2000 and discuss usefulness of our method.

A Breadth-First Method for Automatic Vectorization and Parallelization of Recursive Procedures

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A method for automatic vectorization and parallelization of recursive procedures by a compiler is proposed. 'Breadth-First' method utilizes the parallelism between 'environments' that are dynamically generated by the recursive calls. This method is particularly effective for the procedures that are implementations of various divide-and-conquer algorithms. The method has been implemented on our automatic vectorizing compiler V-Pascal. Experimental results show that a procedure which treats a tree-structured data is accelerated about 10 times in ideal cases.

WASMII: A Data Driven Machine on a Virtual Hardware

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Virtual hardware is a technique with which to realize a large digital circuit with a small real hardware by using an extended Field Programmable Gate Array (FPGA) technology. Several configuration RAM modules are provided inside the FPGA chip, and the configuration of the gate array can be rapidly changed by replacing the active module. Data for configuration are transferred from an off-chip backup RAM to an unused configuration RAM module.

A new computation mechanism called the WASMII, which executes a target dataflow graph directly, is proposed on the basis of the virtual hardware. A WASMII chip consists of the FPGA for virtual hardware and the additional mechanism to replace configuration RAM modules in the data driven manner. Configuration data are preloaded by the order that is assigned in advance with a static scheduling preprocessor. By connecting a number of WASMII chips, a highly parallel system can be easily constructed.

A Reconfigurable Machine: RM-II

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This paper presents a Reconfigurable Machine-II (RM-II) based on the concept of Reconfigurable Machine, capable of efficiently implementing a wide range of computationally complex algorithms on its flexible architecture combining FPGAs and memories. RM-II has been built to offer higher flexibility and large capacity than the first prototype: RM-I. RM-II incorporates 10 FPGAs, one of which can be used to provide flexible interconnection between other FPGA's. A cross-bus is employed for data exchange among FPGAs without using additional external pins. RM-II has been applied to image processing and logic diagnosis, the results have shown its effectiveness for accelerating applications.

An Interconnection Network Simulator for Massively Parallel Computers

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This paper presents an interconnection network simulator to evaluate the performance of various interconnection networks toward realization of massively parallel computers. This interconnection network simulator provides salient features to investigate the desired interconnection network description - language which specifies the characteristics of the interconnection network such as its topology, flow control method, and so on. Furthermore, it can estimate the performance of an interconnection network by simulating on it some communication patterns obtained from actual parallel programs. A torus network was simulated, and its communication performance was evaluated.

Transfer Mode and Deadlock-Free Message Routing on Parallel Computer ADENARTx

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This paper describes the design and the implementation of the interconnection network called HX-net for parallel computer: ADENARTx. As the maximum distance between PEs is two in HX-net, it covers wide range of applications. A deadlock-free message passing method based on wormhole routing is proposed and its implementation into two VLSIs is considered. Using the simulation, the optimized performance of all-to-all dedicated communication is estimated.

A Reconfigurable Torus Network

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Independent subgroups of a hypercubic or mesh DMPP may be accessed simultaneously by multiple users. However, partitioning of a torus network is complicated by having to deal with wraparound paths. In this paper, we present a new architecture for a dynamically reconfigurable torus. Our design arises from geometrically folding the torus and interspersing switches between appropriately designated partitions. We avoid excess additional wiring and switching complexity and allow subgroups of processors to be used independently by different users. We describe our routing algorithm and show that efficient global reduction and broadcast can be performed by using network switches.

EM-C: A Parallel Programming Language for the EM-4 Multiprocessor,

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We present a parallel programming language, EM-C, designed for the EM-4 multiprocessor whose dataflow architecture efficiently integrates communication into computation. EM-C allows a programmer to use dataflow mechanism as a set of basic operations for fast thread creation and synchronization. We introduce the notion of a global distributed address space to distribute data structures and access them by using remote memory operation by the dataflow mechanism. New parallel constructs are provided to support for executing threads dependent on the data distribution and exploiting relatively coarse-grain parallelism to tolerate the data-dependent remote operation latency.

On Linda Tuple Management Protocols on LAN

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Linda is one of the programming languages used to program in parallel distributed environment realized on computers connected by LAN. In this environment, tuple access latency is among the performance hindrances for a Linda program. In this paper, we propose a method to reduce tuple access latency by exploiting tuple access pattern information provided by the programmer and show the effectiveness of the method through the result on the implementation on Sun SS2.

An OR-Compositional Semantics of Guarded Horn Clauses

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We propose an OR-Compositional declarative semantics of GHC (Guarded Horn Clauses) by extending the semantics constructed in [Murakami. A declarative semantics of Flat Guarded Horn Clauses for perpetual processes. '90] using the idea of OR-Compositional semantics of pure logic program constructed in [Boss, et al., Contributions to the Semantics of Open Logic Programs. '921.

A Parallel Selection Algorithm on the Mesh of Buses

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In this paper, we present an $O((\text{loglog } n)^2)$ algorithm for the selection problem. This problem is to find d_i which is the closest to a target integer d_0 from n^2 integers $d_1, d_2, \ldots d_{n^2}$ each of which is given originally in each of n^2 processors. An O(loglog n) optimal algorithm on PRAMs is known. Compared to this, our present algorithm is fairly competition. Note that it is not possible to develop algorithms running in time faster than log n on cube-connected networks.

An Efficient Butterfly Communication Algorithm for Multiport Boolean Cubes

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The objective of the work is to support high-speed butterfly communications on multiport boolean cube computers.

The butterfly communication is widely used in parallel processing. It is a primitive upon which to build almost any aggregate array operation, e.g., scan, reduction, and permutation. It is also found in a variety of numerical algorithms, such as FFT and bitonic sort; and other important communication patterns can be transformed into butterfly communications as well.

The multiport communication system, where communication occurs concurrently on all ports of every processor, is one of the most valuable resources for a massively parallel computer. Although butterfly communication has been optimally mapped to boolean cubes in previous work, the algorithms used communication links along only one of n available dimensions. In other words, (n-1)/n of the peak capability of the multiport system is wasted.

In this paper we show that butterfly communications over n independent data sets can be performed simultaneously, and a large data set can be partitioned into n related data subsets to narrow down the gap between sustained performance and peak performance; therefore our work implements one of the most general communication pattern efficiently on the most attractive communication mechanism.

We also show the conceptual and performance advantages of our solution as compared to the well-known pipeline approach. Our algorithm has been implemented on the TMC's CM2 machine, and the benchmarks support our performance analysis.

Relationships between Typical Networks

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This paper presents clear relationships between pairs of typical networks: the omega network, the shuffle exchange network, the hypercube, and the cube-connected-cycles. A relationship between networks is represented by a graph transformation, expressed by a composition of primitive operations, that changes a network into a form that is isomorphic to another network. A structure or an algorithm embedded in one network is efficiently embedded in another network by mechanically transforming the structure according to the relationship between the two networks. For example, a complete binary tree in the omega network can be routinely transformed and embedded in the hypercube. In this transformation, a node of the tree is mapped (intuitively) to an edge of the hypercube. A tree of (2^{m+1}-1) nodes can thus be embedded in the hypercube of 2^m nodes, and the Fetch & Add combining operation - an important operation for parallel processing -, for example, then has the same performance in each kind of network.

Research on Parallel Algorithms — Its Motivation, Fascination and Importance

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Japanese abstract

Global Virtual Virtual Memory for "Fluid", A Massively Parallel Operating System

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In this paper, we propose Global Virtual Virtual Memory(GVVM) as a virtual memory system for massively parallel distributed memory systems. GVVM is intended to realize load balancing of memory in a system by page borro[illegible] and system wide LRU. The results of prelin[illegible] evaluation using a simulator shows that the [illegible]VM attains higher performance than ordinary virtual memory system.

Distributed Shared-Memory Architecture Using Memory Based Processors

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This paper proposes a high-performance large-scale distributed shared-memory system. To construct the shared-memory system, a memory-processing-dedicated fine-grain processor called Memory-Based Processor (MBP) is introduced. The processor performs activities that have no locality to memory accesses in themselves, and is attached to each memory bank on the lowest memory hierarchy. MBP receives command messages that are originally issued from main element processors (conventional microprocessors) as main memory operations, and operates its memory-modules quickly and directly. MBPs are responsible for data transmissions among memory banks, management of the consistency of the cache system, various memory-based synchronization mechanisms, page management of virtual shared memory, management of contexts of element-processors, and so forth. The distributed shared-memory system and its cache system are characterized as follows:

(1) Per-page directory scheme using TLBs is used as the loweR cache hierarchy of per-block (per-line) snooping scheme.
(2) Fully virtual distributed shared memory is implemented with two-stage address translation scheme.
(3) In directory cache scheme among clusters, while per-page directory scheme is adopted, the unit of data transmission is the size of a block.
(4) Performance of maintaining consistency among clusters is improved by caching information of directories.
(5) Both the structure of an entry of the directory and the manner of collecting acknowledgments from clusters correspond to the structure of the hierarchical broadcasting mechanism.
(6) Per-page protocol switching is governed by static information of data accesses pattern.

Memory Consistency Models — Proposing New Models and Performance Evaluation —

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The choice of memory consistency model largely determines the performance of a shared-memory multiprocessor, and therefore several different consistency models have been proposed in the literature. This paper proposes a new consistency model, called Less Protective Consistency (LPC), which improves the degree of pipelining memory accesses further than any conventional models. The paper then evaluates the performance attainable by three conventional models (Sequential Consistency, Weak Consistency, and Release Consistency) and the LPC, and concludes that the LPC outperforms these conventional models.

Unifying Control — and Data-Parallelism in an Object Oriented Language

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PSather is a parallel extension of the existing object-oriented language Sather. It offers a shared-memory programming model that integrates both control and data-parallel extensions. This integration increases the flexibility of the language to express different algorithms and data structures, especially on distributed-memory machines (e.g., CM-5). This paper describes our design objectives and different kinds of language extensions. Then an example is presented with performance figures on the CM-5 using various degrees of optimization. The reasonable performance of PSather and its relative ease of use supports our optimism that it serves as a practical platform for parallel programming.

Modula-3*: an Efficiently Compilable Extension of Modula-3 for Problem-Oriented Explicitly Parallel Programming

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In this paper we present the programming language Modula-3* and machine-independent optimization techniques for its compilation. We consider Modula-3* to be a promising new framework for problem-oriented explicitly parallel programming that aims at high performance on a variety of architectures and machines. By proposing a large collection of effective optimizations we illustrate the feasibility of efficient Modula-3* compilation. We ensure portability of the compiler by formulating most optimizations as source-to-source transformations in the intermediate high-level language Modula-3\pi, an extension of Modula-3*, especially designed for this task. Incorporating Locality Management into Garbage Collection.

Incorporating Locality Management into Garbage Collection in Massively Parallel Object-Oriented Languages*

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This paper discusses how locality between objects affects the performance, and proposes a software architecture for enhancing locality while keeping load-balance reasonable at the minimum sacrifice of runtime overhead. Objects are created locally by default, and long-lived objects are selectively migrated during garbage collection. By enhancing locality, message passings are likely to be local, and objects are likely to be referred to from only local objects, thus they are quickly reclaimed when becoming garbage. By integrating migration process into garbage collection, load-balance is achieved, and information useful for migration (e.g., reference counting) are collected at a low cost during garbage collection.

Efficient Multiprocessor Scheduling Based on Bidirectional Complement Hypothesis and Building Block Hypothesis

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The problem of multiprocessor scheduling is stated as finding a schedule for a general task graph to be executed on multiprocessor systems, so that the schedule length can be minimized. This problem is known to be NP-complete, and methods based on heuristic search have been proposed. This paper proposes a scheduling method that attains an efficient parallel search based on the building block hypothesis in a framework of genetic algorithms. Good solutions can be expected even in the first population, because generation of the first population is based on the bidirectional complement hypothesis in this method. This paper also shows that a better schedule for the problem of the robot inverse dynamics computations can be generated by this method than one by a branch and bound type scheduler.

Lower Bound on Time for Typed Task Systems with Communication Costs

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This paper presents a lower bound on the completion time of task systems with communication costs for a set of processors of different types. On the calculation of the lower bound, both dependence constraints and execution delays are appended to the sets that consist of tasks of identical type, respectively, and then the lower bounds on time of these sets are calculated, the maximum of which is used as the lower bound on time of the given typed task system. The new lower bound is sharper than the known values, because the delay time due to the execution influence of tasks of different types is evaluated.

On Scheduling Task Trees on Multiprocessors to Minimize Makespan

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Tree task structures occur frequently in many applications where parallelization may be desirable. We present a formal treatment of scheduling task trees on distributed memory multiprocessors and show that

(1) the problem of scheduling a task tree in absence of any inter-task communication on a fixed number of processors, and
(2) the problem of scheduling a task tree with inter-task communication on an unbounded number of processors at NP-complete.

We also present an optimal algorithm to schedule task trees, that satisfy certain conditions.

A Register File Architecture for Instruction Level Parallel Processing and its Evaluation

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We propose a new register configuration for RISC processor, named "Queue Register." Queue Register assists compiler realizing "Modulo Scheduling," that is a kind of software pipeline technique.

Performance of conventional RISC processor is kept high by using cache memory. On the other hand, programs for large scale numerical applications handle many data. Most of such data cannot stay in cache memory, so a processor must read many data from main memory, which results in performance degradation. Modulo scheduling can improve performance of conventional RISC processor by operating memory access and other operations simultaneously. Modulo scheduling needs many registers. Queue Register can support that. In Queue Register, every logical register has plural registers and consists of data queue. In the case of processing Livermore 14 Kernel, Queue Register can increase performance of RISC processors by 1.5 to 2.63 times.

High-Bandwidth Data Cache Memory for a VLSI Superscalar Processor — Performance Evaluation and Memory Latency Effects —

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A superscalar microprocessor, OHMEGA, that has been developed as a PE (Processing Element) for a next generation massively parallel computer system ADENARTx employs a high bandwidth data cache memory to decrease the performance degradation caused by disadvantage of lower data bandwidth. In this paper, we describe the feature and hardware organization of the high bandwidth data cache memory employed by OHMEGA microprocessor, and we estimate the sustained performance by using the simulation results of the Linpack and Livermore Kernels.

Parallel Gridless Router Using Time Warp

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Japanese abstract

Parallel Wirec-Routing by Competing Processors Approach—Improving quality of wiring by rip-up—

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In our previous research into automated wire routing by parallel computation the "Competing processor and net assignment" algorithm was developed. Although this algorithm displayed significant speedup, the quality of the routing result was not as good as that obtained by sequential algorithms. In this paper we propose a new approach to parallel wire routing by introducing a random rip-up procedure to our algorithm to improve the quality of the result. The effectiveness of this algorithm is then evaluated on a MIMD multicomputer, Coral-68K.

Dataflow Graph Optimization for Dataflow Architectures — A Dataflow Optimizing Compiler —

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In general, graphs for which it is difficult to optimize quality are those used for branches (conditionals) and loops. Although a number of dataflow graph transformation schemes have taken these into account, they do not compare the quality of graphs produced with that of hand-written optimized graphs. In this paper, dataflow graph transformation and optimization schemes performed by the DPC compiler, a dataflow optimizing compiler developed by the authors, are described, and the results of an evaluation of the degree of optimization achieved by the DPC compiler are presented.

Dynamic Load Balancing Mechanism and Multilevel Dynamic Scheduling Scheme on Datarol Machine

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In this paper, we propose dynamic scheduling scheme and load balancing mechanism on Datarol machine, which is an optimized dataflow machine.

In the scheduling scheme, we control function level parallelism according to the availability of hardware resources, and instruction level parallelism in accordance with the load of processor. In the load balancing, a processor dynamically determines whether or not to dispatch processes according to the minimum load information transmitted by network. We evaluate the proposed scheme by software simulation.

Evaluation of Automatic Load Balancing Method on the Parallel Inference Machine PIM/P

Hiroyoshi Hatazawa, Susumu Arai,
Fujitsu and ICOT

We evaluate the automatic load balancing method on the parallel inference machine, PIM/p. Interprocess communications through the "stream" is improved not to use shared bus so often. It is concluded that the efficiency of a random load balancing method is not so good because of the low data locality, the large bus traffic, and the increasing number of instructions executed by multiple PEs. But static analysis of the KL1 programs and our improvements applied to the stream communications may better the efficiency.

A Diffusional Load Balancing Scheme on Loosely Coupled Multiprocessors =LLS-G

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A dynamic load balancing scheme called LLS-G (Local Load Spreading method using Generation Information) is proposed for large scale loosely coupled multiprocessors. In this scheme, each processor exchanges with its neighbors information on the predicted workload derived from the number of subtasks generated, and distributes tasks to lower loaded processors. The interval of load balancing is also managed according to the degree of the workload. Evaluation on the parallel inference machine, PIM/m, shows better performance and speedup than other dynamic load balancing schemes.

Evaluation of Snoop Cache Efficiency Under a Multiuser Operating System

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The performance of snoop cache is affected not only by the data-sharing characteristics of an application program, but also by the algorithm of virtual machine abstraction on which the program runs. This paper discusses the effects of the operating system on snoop cache performance, using the results of actual measurements taken with the OSF/1 operating system on the TOP-1 multiprocessor. It is shown that in the two kinds of snoop protocol supported by TOP-1, namely, the update protocol and the invalidate protocol, the former can easily suffer a loss in performance because of excess data-sharing caused by the abstraction mechanism.

Evaluation of Nonlinear Deformational Analysis by Finite Element Method on the Parallel Machine Cenju2

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When using the finite element method for nonlinear deformation analysis, like shock analysis, there are two main stages: calculating a stiffness matrix and solving a linear equation. In this paper, we present a method of paralleling the two stages, and evaluation of it on the parallel machine Cenju2.

Since Cenju2 architecture differs from Cenju, the original Cenju method did not achieve good speedup on Cenju2. Therefore we suggest a new method using block transfer primitives which is implemented by hardware in Cenju2. For the calculation of the stiffness matrix, we attain 14 times speedup using 16PEs. While in the solution of the linear equation, we gained 8 times speedup.

Parallelization of the Multigrid Preconditioned Conjugate Gradient Method

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A multigrid preconditioned conjugate gradient method (MGCG method) that uses the multigrid method as a preconditioner of the PCG method, converges rapidly even for the problems that the original multigrid method does not converge effectively. This paper considers parallelization of the MGCG method and proposes the MGCG method with high parallelism and high efficiency. There are various problems when the multigrid method is parallelized, however in the case of the MGCG method, these problems can successfully be settled. Next implementation of the MGCG method on the Fujitsu multicomputer AP1000 is performed and the most efficient MGCG method is studied. Then it is evaluated by comparing with the Scaled CG method that is often used on the multicomputers.

FFT Parallel Processing on Multiprocessor

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High-speed FFT computation has been executed by an array processor using a pipeline processing. However, with the advance of VLSI, a parallel computation on multiprocessor systems is an interesting and challenging problem. The parallel FFT computation is performed on a tree machine. First, typical parallel multidimensional FFT algorithms are surveyed. Second, to efficiently perform the parallel FFT algorithms on multiprocessors, relationships between the multiprocessors and the parallel FFT algorithm are analyzed. An optimal multiprocessor architecture and its characteristics are presented. Finally, parallel FFT algorithms are implemented on the tree machine. Efficient data communication methods are presented. High-performance results of the parallel 2-D FFT computation are shown on the tree machine.

Debut-L: Programming Filters and Recognizers in a Parallel Debugger

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This paper describes Debut-L, a language for programming filters and recognizers in an event-based debugger for parallel and distributed systems. The debugger (DEBUT) puts emphasis on the distributed aspect or external behavior of processes of debugging. This is useful to find synchronization and communication errors. When the application makes a call to the operating system or an user-defined function an event is generated. To reduce the huge amount of events, filters are applied. Filtering is a means to make the stream of events more manageable. Recognizers recognize behavior of a parallel or distributed program and offer higher levels of abstraction to the programmer. They may be used in several ways:

(1) summarize behavior by defining high level events;
(2) interact with the application;
(3) detect incorrect behavior.

Examples are given in the paper. Filters and recognizers are programmable by means of a language with similarities to regular expressions. For reasons of efficiency, filter definitions first are compiled and then loaded into the filters. The same is true for recognizer definitions. Filters can only be applied at the lowest level in the system; each filter processes events that all originate from the same processing node. Recognizers may be used at all levels in the system. They can process events from different processing nodes, correlate them and act upon them.

Interactive Compilation and Performance Analysis in a Percolation Scheduling Environment

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Automatic paralleling compilers seem to produce generally good results. However, for time-critical applications, general purpose scheduling approaches may not be able to extract enough parallelism from programs to achieve the high performance required by the applications while satisfying the physical constraints of the target architecture. In this paper, we present a graphical interface to a paralleling compiler that allows the user to interactively control the parallelization process by providing decisions and directives to the system based on problem specific knowledge, human intuition, and quantitative and visual feedback provided by the system at intermediate stages of the parallelization process.

Research and Development of a Massively Parallel Computing System in RWC Tsukuba Research Center

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Japanese abstract

Use of the Processor Array PAX

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Japanese abstract

Basic Design of a Massively Parallel Processing Architecture

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Japanese abstract

What parallel computer does attract me?

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Japanese abstract

Application of Massively Parallel Computers to Computational Mechanics

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Japanese abstract

Computational Physics Parallel Computer, CP-PACS, 21 May 1993

Plans for a 300GFLOP, 48 GByte memory, 500GByte disk parallel computer for computational physics is described in this report. This is the result of experience gained over 15 years of constructing Japanese parallel computers for QCD calculations.

David K. Kahaner

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has provided me with the following description of a new parallel computer project to be undertaken for the purpose of building a capability for computational physics research. The complete article is published in Nuclear Physics B(Proc. Suppl.) 30 (1993) 299-300 North Holland. The paper was presented at the International Symposium on Lattice Field Theory Amsterdam, the Netherlands, 15-19 September 1992.

New Parallel Computer Project in Japan Dedicated to Computational Physics

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A new project is underway in Japan for construction of a parallel computer dedicated to lattice QCD and other problems of computational physics. This project is formed by a collaboration of lattice gauge theorists, physicists of other disciplines, and computer scientists. The basic design is currently being worked out with a tentative design target of at least 300 GFlops for theoretical peak performance for 64 bit arithmetic and 48 GBytes of main memory with an interconnecting network suited to local data communication and a distributed disk system.

Introduction

In this talk we give a brief report of a new project in Japan for construction of a parallel computer dedicated to lattice QCD and other problems of computational physics. The project, named CP-PACS (Computational Physics by Parallel Array Computer System), is formed by a collaboration of lattice gauge theorists, physicists of other disciplines and computer scientists with a current total of 21 members currently. [A complete list of the members is given at the end of this report. DKK]

With the experience gained in the QCDPAX project at University of Tsukuba, it became clear that a massive parallel computer is a key tool to solve difficult problems such as those in lattice QCD and that we need a much more powerful machine to get reliable results for those problems. With this background, we made a proposal for the project to the Ministry of Education, Science and Culture in February 1991 [1].

The project formally started in April 1992 with the Japanese Government approval and will span the period of 1992 through 1996. A special grant of about Yen1.5B in total will be provided. The leader of the project is Y. Iwasaki and the subleader for hardware design and construction of the machine is K. Nakazawa. The full-scale machine is scheduled to be completed by early 1996.

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More than 15 years ago T. Hoshino and T. Kawai initiated the PAX (Processor Array experiment) project [2]. With an increasing number of collaborators they have built several parallel machines. The QCDPAX dedicated to QCD simulation was the fifth of the PAX series [3]. The CP-PACS project will draw heavily on the lessons learned in the QCDPAX project. [I have described PAX and related research in a series of reports, see for example, "jhpc-pp.92, 28 June 1992. DKK]

The CP-PACS Project

Design Targets

The target of the CP-PACS parallel computer is a peak speed of at least 300 GFlops in 64 bit arithmetic with more than 48 GB main memory totally and about 500 GB of distributed disk space. The MIMD architecture is adopted. The design of the machine is currently being worked out in close collaboration with Hitachi Ltd., and the details finalized in March 1993. [It is recently reported that Hitachi will produce a general purpose parallel computer using PA Risc technology. Officially, there is no relation between that and the CP-PACS project. DKK]

Processing Units

We plan to adopt a RISC chip for CPU of the processing units (PU) with some modifications that are needed for high capability of floating point operations. Since simple data cache is not effective for large scale simulations, various possibilities are explored for a more efficient way for data I/O. In particular we are studying a pseudo-vector processor based on register-windowed superscalar pipeline. Since the effective performance severely depends on the data transfer speed between the memory and the CPU, main memory should have high bandwidth and low latency. The number of PUs will be from one thousand to two thousands depending on the speed of a PU [4]. [Prof Nakazawa will present further ideas on the "shift window" at the upcoming International Conference of Supercomputing, July 1993 in Tokyo. DKK]

Interconnection

The PUs of PAX computers are interconnected in a toroidal 2-D nearest-neighbor-mesh. This architecture has proven to be useful for various problems in different fields. However, the structure of 2-D torus made a strict restriction on the size of lattice that could be simulated on the machine. This is a serious drawback. In lattice QCD, studies of finite-size scaling behavior, which have become an important tool in many ways, require simulations on a number of lattice sizes. Furthermore, in various problems of computational physics, communications that are more nonlocal than in QCD are necessary. For these purposes a flexible communication network with a worm-hole routing might be favorable. Based on these considerations we consider a 3-D hypercrossbar network as a strong possibility of the machine. The array of PUs will be made dividable.

Distributed Disks

With the speed and memory size of the CP-PACS machine, the intermediate results of calculations become huge. Therefore distributed disks will be installed to store intermediate data and snapshot dump. One disk will be installed for about ten PU's with about 500 GB in total.

Language

At least for the first stage we use the 'nodal' language. We program instructions for each PU together with message passing (communication) and synchronization. Such "nodal" programming is simple and user-friendly for regular static models like QCD. We plan to install Fortran and C compilers together with the assembly language (for hand optimization of codes). The library for communication and synchronization will be developed. We are also considering the possibility of developing a global language such as HPF (High Performance Fortran) to facilitate the use of the machine.

Time schedule

Details of the architecture of the CP-PACS machine and the design of PU were fixed in March 1993. Now, a detailed logic design will be made. We plan to have a prototype composed of 16—64

PUs by 1994, and the full-scale machine by early 1996.

(For further details, contact Prof Iwasaki at the address given above.)

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Fifth Generation Computer System (FGCS) Summary, 1 June 1993

A summary of the Fifth Generation Computer System Project and planned follow on project are described in this report

David K. Kahaner

I have written several reports about the Fifth Generation Computer System (FGCS) Project, sometimes also called the ICOT project, see for example "icot.kll", 28 Feb 1992; "icot.692", "fgcs.toc", 22 June 1992, and 4 June 1992; especially the last for my general evaluation. However, I still receive many questions. A recent issue of the Japan Computer Quarterly, No 93, March 1993, contains an excellent English summary of the project; it was written by Prof. Koichi Furukawa of Keio University. JCQ is published by:

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and individual copies of this issue can be obtained by contacting the address above.

Below, I extract some key details and some summary information. Mr. Yuji Yamadori, JIPDEC's Director for Research & International Affairs presents a brief description of the project from the Japanese Ministry of International Trade and Industry's (MITI) viewpoint and a very general discussion of the future. This is followed by an overview by Prof. Furukawa, and budgets are also included. I have omitted the details about the specific research results, which have been frequently reported. Finally, Prof. Furukawa gives some additional details on future plans.

Yamadori.

The word "generation" is frequently used to express progress made in the computer field, especially in relation to hardware. In other words, in accordance with the elements used to build computers, computers using vacuum tubes were called the first generation, those based on transistors and diodes the second generation, those adopting ICs the third generation, and those built by using LSIs the third and a half generation. Since today's computers use VLSIs as elements on a large scale, it is said that computers have now entered a fourth generation. Computers have developed rapidly ever since the announcement of the first general purpose computer using a built-in program system, and processing speed has also increased considerably along with innovations in element technology. However, conventional computers have all been based on the von Neumann theory, and theory has essentially followed in its footsteps, even up to the present.

MITI has implemented various measures to improve computer technology in Japan. In the mid-1970s, MITI requested JIPDEC to carry out a basic investigation into the research and development of an epoch-making computer that would mark a significant departure from past theory and technology. To do this, JIPDEC decided to carry out investigations and research for a three year period starting in 1979 with cooperation from industry, academia, and government. For this investigation, JIPDEC established a research committee composed of researchers and specialists from universities, governmental and industrial laboratories, and users, and held active discussions in a wide range of fields, such as basic technical theory, the conditions of the social environment and computer architecture. With expectations for the advent of a new generation computer, this computer was called the next generation computer, that is, the "Fifth Generation Computer". The results of this three-year investigation were reported to the government and were made public at an international symposium to an audience of Japanese and overseas specialists. The results were evaluated highly by the government, and in 1982 the government decided to establish an "Institute for New Generation Computer Technology (ICOT)" through joint investment with private enterprise to promote this project. The Fifth Generation Computer Project was established as a long-term plan extending over a period of about 10 years. The project had achieved the desired objectives to a certain extent by the end of March 1992, and was brought to a close in March 1993, after one year of final unification, evaluation, and improvement work.

Japan learned many things from the major industrialized countries at the dawn of the computer age, and today's Japanese computer technology fostered based on this knowledge. Making a contribution internationally through the execution of this new kind of project was an important role for Japan. Therefore, at the start of the Fifth Generation Computer Project, MITI widely appealed to overseas research institutes for involvement in the project. At the same time, interim results from the project were made public externally by holding international symposiums as necessary. To promote smooth execution of the project, JIPDEC dispatched many engineers to ICOT to offer their cooperation. AI played an important role in this project in the research of basic theory. Regarding AI, trial introduction of expert systems has become popular in private enterprise, but it has been pointed out that AI cannot be expected to spread further because development techniques have not yet been established. Therefore, ICOT and JIPDEC established an ICOT-JIPDEC AI Center in 1986 to investigate, study, and disseminate AI technology. Its specific accomplishments include the publication of "The AI Vision", and "The AI White Paper", and the sponsorship of various lectures and seminars.

The research and development phase of the Fifth Generation Computer Project was completed at the end of March 1993, but the propagation of its results will continue to be important from now on. Therefore, for a period of two years starting in April 1993, JIPDEC will make efforts to disseminate the parallel knowledge processing technology fostered in the project.

The history of research and development of the project, an outline of its results, and the prospects for the future will be introduced in this issue to commemorate the completion of the Fifth Generation Computer Project. In drawing up this summary, we received full cooperation from ICOT. We would like to use this opportunity to acknowledge this support, and we hope this report will be of help to our readers.

Furukawa.

Overview of the FGCS Project

1. Preliminary Study Stage for the FGCS Project

The circumstances prevailing during the preliminary stage of the FGCS Project, from 1979 to 1981, can be summarized as follows:

Japanese computer technologies had reached the level where they are now among the most up-to-date overseas computer technologies.

The change in the role of the Japanese national project for computer technologies was being discussed whereby there would be a move away from improvement of industrial competitiveness by catching up with the latest European computer technologies and toward worldwide scientific contributions through the development of leading computer technologies with all its inherent risks.

Regarding this situation, MITI began study on a new project—the Fifth Generation Computer Project. This term expressed MITI's commitment to developing leading technologies that would progress beyond the fourth generation computers that are due to appear in the near future and which would anticipate upcoming trends.

The Fifth Generation Computer Research Committee and its subcommittee were established in 1979. Not until the end of 1981 did they decide on target technologies and a framework for the project.

Well over one hundred meetings were held with a similar number of committee members participating. The following important near-future computer technologies were discussed:

- Inference computer technologies for knowledge processing
- Computer technologies to process large-scale data bases and knowledge bases
- High-performance workstation technologies

- Distributed functional computer technologies
- Supercomputer technologies for scientific calculation

These computer technologies were investigated and discussed from the standpoints of international contribution through the development of original Japanese technologies, the important technologies of the future, social needs and conformance with Japanese government policy for the national project. Through these studies and discussions, the committee decided on the objectives of the project by the end of 1980, and continued future studies of technical matters, social impact, and project schemes.

The committee's proposals for the FGCS Project are summarized as follows:

a. The concept of the Fifth Generation Computer: to have parallel (non-Von Neumann) processing and inference processing using knowledge bases as basic mechanisms. To possess these mechanisms, the hardware and software interface is to be a logic program language.

b. The objectives of the FGCS project: to develop these innovative computers that are capable of knowledge information processing and to overcome the technical restrictions of conventional computers.

c. The goals of the FGCS project: to research and develop a set of hardware and software technologies for FGCS, and to develop an FGCS prototype system consisting of a thousand element processors with inference execution speeds of between 100M LIPS and 1G LIPS (Logical Inferences Per Second).

d. R&D period for the project: estimated to be accomplished within ten years, divided into three stages.

- 3-year initial stage for R&D of basic technologies

- 4-year intermediate stage for R&D of subsystems

- 3-year final stage for R&D of total prototype system

MITI decided to launch the FGCS project as a national project for new information processing, and made efforts to acquire a budget for the project. At the same time, the international conference on FGCS '81 was prepared and held in October 1981 to announce these results and to hold discussions on the topic with foreign researchers.

2. Stages and Budgeting in the FGCS Project

The FGCS project was designed to investigate a large number of unknown technologies that were yet to be developed. Since this involved a number of risky goals, the project was scheduled to take place over a relatively long period of ten years. This ten-year period was divided into three stages.

- In the initial stage (FY 1982 - 1984), the purpose of R&D was to develop the basic computer technologies needed to achieve the goal.

- In the intermediate stage (FY 1984 - 1988), the purpose of R&D was to develop small to medium subsystems.

- In the final stage (FY 1989 - 1992), the purpose of R&D was to develop a total prototype system. The final stage was initially planned to last three years. After reexamination halfway through the final stage, this stage was extended to four years to allow evaluation and improvement of the total system in FY 1992. Consequently, the total length of this project has been extended to 11 years.

Each year the budget for the following years of R&D activities is decided. MITI made strenuous efforts in negotiating each year's budget with the Ministry of Finance. The budgets for each year, which are all covered by MITI, are shown in Figure 2 [I omit this, as it is given in the text that follows, DKK]. The total budget for the 3-year initial stage was about ¥8B. For the 4-year intermediate stage it was approximately ¥22B. The total budget for 1989 to 1991 was around ¥21B. The budget for

1992 is estimated to be ¥3.6B. Consequently, the total budget for the ll-year period of the project will be about ¥54B.

3. Summary of the Project Research Results

In the FGCS Project, two main research targets were pursued: knowledge information processing and parallel processing. Logic programming was adopted as a key technology for achieving both targets simultaneously. At the beginning of the project, we adopted Prolog as our vehicle to promote the entire research of the project. Since there were no systematic research attempts based on Prolog before our project, there were many things to do, such as the development of a suitable workstation for the research, experimental studies for developing a knowledge-based system in Prolog, and investigation into possible parallel architecture for the language. We rapidly succeeded in promoting research in many directions.

From this research, three achievements are worth noting. The first is the development of our own workstation dedicated to ESP (Extended Self-contained Prolog.) We developed an operating system for the workstation completely in ESP.

The second is the application of partial evaluation to meta programming. This enabled us to develop a compiler for a new programming language by simply describing an interpreter of the language and then partially evaluating it. We applied this technique to derive a bottom-up parser for context-free grammar given a bottom up interpreter for them. In other words, partial evaluation made meta programming useful in real applications.

The third achievement was the development of constraint logic programming languages. We developed two constraint logic programming languages: CIL and CAL. CIL is for natural language processing and is based on the incomplete data structure for representing "Complex Indeterminates" in situation theory. It has the capability to represent structured data like Minsky's frame and any relationship between slots' values can be expressed by using constraints. CIL was used to develop a natural language understanding system called DUALS. Another constraint logic programming language, CAL, is for nonlinear equations. Its inference is done by using the Buchberger algorithm for computing the Grobner Basis that is a variant of the Knuth-Bendix completion algorithm for a term rewriting system.

We encountered one serious problem inherent to Prolog, and that was the lack of concurrence in the fundamental framework of Prolog. We recognized the importance of concurrence in developing parallel processing technologies, and we began searching for alternative logic programming languages with the notion of concurrence.

We noticed the work by Keith Clark and Steve Gregory on Relational Language and of Ehud Shapiro on Concurrent Prolog. These languages have a common feature of committed choice nondeterminism to introduce concurrence. We devoted our efforts to investigating these languages carefully and Ueda finally designed a new committed choice logic programming language called GHC, which was simpler syntax than the above two languages but still has similar expressiveness. We recognized the importance of GHC and adopted it as the core of our kernel language, KL1, in this project. The introduction of KL1 made it possible to divide the entire research project into two parts: the development of parallel hardware dedicated to KL1 and the development of software technology for the language. In this respect, the invention of GHC is the most important achievement for the success of the FGCS project.

Besides this language oriented research, we performed extensive fundamental research in the field of artificial intelligence and software engineering based on logic and logic programming. This includes research on nonmonotonic reasoning, hypothetical reasoning, abduction, induction, knowledge representation, theorem proving, partial evaluation, and program transformation. We expected that this research would become important application fields for our parallel machines by the affinity of these problems with logic programming and logic-based parallel processing. This is now happening.

In this article, we first describe the research and development of the sequential inference machine PSI. Then, we present our research results on constraint logic programming. Finally, we discuss our research activities in the field of parallel inference from both hardware and software aspects.

[Sections that are omitted detail the PSI-I (Personal Sequential Machine), Constraint Logic Programming, Parallel Inference System and features of PIM modules, KL1, and PIMOS operating system, and finally, Concurrent Logic Programming, DKK].

FGCS Follow-on Project & Forecasts

1. FGCS Follow-on Project

As described above, the FGCS Follow-on Project is a two year project that runs from the beginning of FY 1993 until the end of FY 1994. A major role of the FGCS Follow-on Project is to promote a diffusion of parallel knowledge processing technologies that have been developed in the FGCS Project.

Much of the KL1 software that aims at the provision of the new infrastructure for advanced computer research has been developed for research on parallel knowledge processing technologies in the FGCS Project. Moreover, the major software has been released as IFS. However, a sequential inference machine, PSI, or parallel inference machine, Multi-PSI or PIM, is required to execute the software. Though a "Pseudo Multi-PSI," that is, a pseudo parallel system for KL1 software, has been released as IFS, a PSI-III is required to execute it. A "PDSS", that is a KL1 programming environment on UNIX machines, has also been released as IFS; there are some limits to its efficiency and functions for executing KL1 software on it. Thus, although the PDSS system is suitable for learning KL1 language, it cannot be used to execute large KL1 software released as IFS. Therefore, it is difficult to execute the KL1 software released as IFS at hand.

In the FGCS Follow-on Project a series of KL1 programming environments, including a KL1 language processor and a parallel operating system, PIMOS, shall be ported onto sequential and parallel UNIX machines so that they can be used easily at any site. These UNIX based KL1 programming environments shall be designed as machine-independent as possible. They are also planned to be released as IFS.

An experimental version of the UNIX based KL1 programming environment is currently under development for evaluating an implementation scheme. Although we plan to release it as IFS in April 1993, this version is for language implementation experts and is not suitable for application users, since it lacks some important features for application users, such as debugging aids.

The first version for application users is planned to be released in September 1993. This version shall provide reasonable software development functions, including debugging and performance analyses. This system shall be ten times faster than the PDSS, although it is for single processor UNIX machines.

The release of a KL1 programming environment for parallel UNIX machines is planned for the second quarter of 1994. It shall be designed avoiding the use of machine-dependent functions. Various improvements are planned after these releases.

2. Forecasts for Some Aspects of 5G Machines

LSI technologies have advanced in accordance with past trends. Roughly speaking, the memory capacity and the number of gates of a single chip quadruple every three years. The number of boards for the CPU of an inference machine was more than ten for PSI-I, but only three for PSI-II, and a single board for PIM.

The number of boards for 80M bytes memory was 16 for PSI-1, but only four for PSI-11, and a single board for PIM(m).

Figure 1 shows the anticipated trend for board numbers for one PE (processor element: CPU and memory) and the cost of one PE based on the actual value of inference machines developed by this project. [This figure is omitted. Details are summarized in the text that follows, DKK.]

The trend reveals that by the year 2000 approximately ten PEs will fit on one board, around 100 PEs will fit in one desk side cabinet, and 500 to a 1,000 PEs will fit into a large cabinet. This trend also shows that the cost of one PE will halve every three years.

Figure 2 shows the performance trends for 5G machines based on the actual performance of inference machines developed by this project. [Similarly omitted, see below, DKK.]

The sequential inference processing performance for one PE quadrupled every three years. The improvement in parallel inference processing performance for one PE was not as large as it was for sequential processing, because PIM performance is estimated at around two and one half times that of multi-PSI. Furthermore, Figure 2 shows the performance of one board for both sequential and parallel processing, and the performance of a conventional microprocessor with CISC and RISC technology. In this figure, future improvements in the performance of one PE are estimated to be rather lower than a linear extension of past values would indicate because of the uncertainty of whether future technology will be able to elicit such performance improvements. Performance for one board is estimated at about 20M LIPS, which is 100 times faster than PIM. Thus, a parallel machine with a large cabinet size could have lG LIPS. These parallel systems will have the processing speeds needed for various knowledge processing applications in the near future.

Several parallel applications in this project, such as CAD, theorem provers, and genetic information processing, natural language processing, and legal reasoning were described previously. These applications are distributed in various fields and aim at cultivating new parallel Processing application fields.

We believe that parallel machine applications will be extended to various areas in industry and society, because parallel technology will become common for computers in the near future. Parallel application fields will expand gradually according to function expansion by the use of advanced parallel processing and knowledge processing technologies.

Parallel Artificial Intelligence in Japan, 3 June 1993

A summary of AI activities in Japan, especially those associated with parallel computing are given in this report

David K. Kahaner

Professor J. Hendler, University of Maryland, spent two months in Japan last year. Below he describes several of the projects that he found most interesting. Over the past few years I have written about many of these projects, and for those cases Hendler's report is an important follow up. Readers looking for additional details or background can refer to those earlier reports, which are cited. In addition, please refer to the recent report, "jspp.93", 2 June 1993, which describes the Joint Symposium on Parallel Processing, held in Tokyo, 17-19 May 1993.

Massively Parallel AI research in Japan, by:

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One major emphasis of the Japanese 5th Generation Project was to develop parallel support for the development of large scale AI and knowledge base efforts, the follow on "Real World Computing" project focuses on massive parallelism and includes AI among the areas intended to be worked on. In this report, we discuss these and other Japanese research efforts, from the point of view of the newly growing field of "massively parallel AI" (MPAI). Under sponsorship of the Office of Naval Research, I spent November and December 1992 in Japan, visiting universities and industries with an interest in the development of massively parallel computers and MPAI. In this report I summarize some of the more interesting projects and their results. A more detailed description of Japanese and United States efforts in MPAI will be included in an article in the book "Massively Parallel Artificial Intelligence" which I am editing with Dr. Hiroaki Kitano (NEC and CMU) expected to be out late in 1993 (AAAI/MIT Press). (This book will be one of the more concrete results of the developments encountered during this sponsored research trip).

[NOTE: I have tried to provide names and references to allow interested researchers to contact appropriate Japanese colleagues. I apologize for the misspellings and inaccuracies that inevitably result from language differences.]

The Ministry of Education "Super Parallel Computer" Project

Perhaps the most interesting of the many projects I saw and heard about is the "Super Parallel Computer" Project that is being sponsored by the Japanese Ministry of Education. This project's funding level is about ¥700B (about US$5.5M) over a 3 to 5 year period. The project is being conducted at universities, by over 30 faculty members involved at a number of different schools. The faculty researchers are divided into four main subgroups:

- Modeling and Applications, chaired by Dr. Muraoka (Waseda Univ.)
- Language Design, chaired by Dr. Amamiya (Kyushu Univ.)
- Control mechanisms/OS, chaired by Dr. Saito (Keio Univ.)
- Hardware Architecture, chaired by Dr. Tomita (Univ. Kyoto)

The goal of this project is to develop and produce a general purpose, massively parallel supercomputer for use by university groups. Ideally, the project focuses on developing a powerful machine for supporting basic research, and providing copies of this machine to all the universities involved (the majority of the major universities in Japan.)

To date, the project is focuses on producing a machine with several thousand of relatively powerful individual processors, thus combining the best of SIMD and MIMD. The prototype machines are expected to have 1,000-2,000 processors to start, with the maximum size being of about 16,000 processors. The hope is to provide virtual shared memory among the machines, thus allowing separate physical memories (for SIMD or SPMD computing) with an illusion of shared memory where necessary (the idea of a fast "virtual" shared memory is relatively common among Japanese researchers, although not as prevalent in the United States.)

The language being designed is an object-oriented C, with parallel extensions. (I was not able to meet with Dr. Amimaya, and therefore I do not have details.) The applications targeted for this machine include modeling and finite element computations (as in US HPCC project), but also (MP)AI. The modeling projects include particle problems and also simulations (including a simulation of economic systems being developed in cooperation with the United States Brookings Institute.) The AI projects currently underway include natural language translation and speech processing, support for human-computer interfaces (an interesting integration of rule-based and pattern-matching techniques), and AI-based visualization and animation programs.

A symposium of participants in this project is held twice a year (the second such meetings was held in March, 1993.) A Japanese Proceedings of the symposium has been prepared, and is available to interested parties. I don't have details on how to obtain a copy, but I was told that any of the four subcommittee chairs could provide more information.

[COMMENT. In a series of reports on parallel computing (6 Nov 1991), H.T.Kung and myself remarked that in the past, university parallel computing projects in Japan were heavily into system building, and that the scale of the projects tended to be modest, especially compared to activities in industry. This project has the potential to be larger. For associated work presented at JSPP'93, see papers by Hiraki, "Distributed Shared-Memory Architecture Using Memory Based Processors"; Tomita, "A Reconfigurable Machine: RM-II"; Amamiya, "Compiling Technique Based on Dataflow Analysis for Functional Programming Language Valid" and "Dynamic Load Balancing Mechanism and Multilevel Dynamic Scheduling Scheme on Datarol Machine"; DKK.]

Real World Computing Project/ ETL

In recent reports (rwc-3.93, 12 April 1993; rwc-3.93a, 17 April 1993), Dr. Kahaner has provided details of the organization and mission of the Real World Computing Project. From an AI perspective, this project includes among its goals the creation of real-time information systems, supporting significant speech and translation projects, and integrating neural network and symbolic computing. In this section, I will briefly supply some of the technical details of the hardware platform and these applications.

My visit to Tsukuba was jointly hosted by RWC and ETL; I met with a number of researchers including Drs. Sakai, Ishikawa, Shimada, Sato and Toda.

The RWC machine is based largely on the EM-4 dataflow parallel machine developed by ETL. The development route is apparently for this machine to be further developed and extended (into the EM-X) by ETL, while being also explored in other ways by RWC. In addition, the CODA machine, a fast MIMD system (target: 128 50MIPS Processing Elements), also under development at ETL, is envisioned as a contributor of many ideas. Thus, both cross-fertilization and shared development are expected to result.

The EM-4 has been operational since late in 1990 and can perform close to a billion IPS (peak and sustained). The machine is a multistrategy, dataflow-based architecture (multithreaded dataflow) with a very fast network (the setup times for a message are about 9x faster than a CM5). A "Reduced Interprocessor Communication Architecture" (RICA) that is supposed to be to routing what RISC is to microcoding, is at the heart of this speed. Using this routing, the hope is to develop a 1000 processor, 1 TeraFlop machine by 1995, and a 16,000 processor, 10 TeraFlop, machine by late 1997 (This latter machine depends on the project being extended for two extra years. This is something that is too early to predict since it is a project that started so recently.) One important factor about the machine is that it is expected to allow virtual processors on the physical processing units (as the CM-5 does), thus allowing SPMD algorithms to be tried with quite large numbers of processors (roughly one million virtual processors are expected from the 1000 processor machine.)

The languages that are being developed for this machine are largely C-based. The current system uses a C++ language with extensions for massive data parallelism as well as control level parallelism for the physical processors. The language views the EM machine as, essentially, a collection of lightweight threads that can be named (i.e., via ports, thus allowing asynchronous, buffered message passing and remote memory accesses) or simple (via forking operations). The compiler for this language extends C to include global arrays and pointers that include named ports. A multiuser OS, allowing dynamic configuration of the machines, time sharing and space sharing, is currently under development using this language; a first version is expected to be released with the 1995 machine.

For more details about the EM-4 and RICA see Sakai et al., "Design and Implementation of a Versatile Interconnection Network in the EM-4" (Proceedings of ICPP, 1991) or Sakai et al., "Principles of a Massively Parallel Computer" (Technical Report of the Institute of Electronics, Information and Communication Engineers (IEICE), December 1992). For more on the language and operating system see Shaw et al., "Data-Parallel Programming on the EM-4 Dataflow Parallel Supercomputer" (Proceedings Frontiers '92). [NOTE: At JSPP'93, see paper by Sato, "EM-C: A Parallel Programming Language for the EM-4 Multiprocessor", DKK].

Another interesting project at ETL is the processor that is being developed by Dr. Higuchi. Higuchi's IXM2 Parallel Associative Processor is a machine that has been used as a special purpose associative memory for AI work, particularly including machine translation work at ATR (see below). The IXM2 has 64 PEs each with a 4KW Associative memory. This allows for the development of very fast special purpose processing of certain AI operations. (For some tests, the IXM outperformed the CM2 by a considerable margin (about 30 times), but it is a far less general machine. The IXM2 has been used for the work in machine translation and also in the area of Genetic Algorithms.

Political note about the RWC!

[I HAVE PARAPHRASED THIS SECTION. DKK. Hendler points out that United States researchers are currently restricted in their ability to participate in most parts of the RWC project, including those parts that are related to AI, Neural networks, etc. ([NOTE: I have already mentioned that Germany joined the RWC Partnership quite early. I am now told that Singapore, Sweden, and the Netherlands have also been admitted as foreign partners. DKK]) Hendler, along with many other U.S. researchers believe that RWC is a potential source for important United Ssates-Japanese interaction, a viable source of funds for U.S. researchers interested in these areas, and a potentially exciting path for scientific collaboration. Regardless of the original reasons for the U.S. research restriction, it is worthwhile to re-examine the topic to see if they remain valid.]

The ATR laboratories (Kyoto)

The most impressive use of parallelism in the direct support of AI that I saw in Japan was the work at the ATR Interpreting Telephony Research Laboratory, where mv visit was hosted by Dr. Iida. This work was in tne .ea of machine translation.

One area in which Japan has done significant high-quality research and applications is in the area of machine translation. This MT work includes both textual translation (rendering of Japanese texts into English or other languages) and the translation of spoken speech (recognition coupled with translation). In the textual realm, Japanese companies have developed some huge bilingual dictionaries including the 300,000+ word EDR (Electronic Dictionary Research) project (see below) and the NEC translating editor, which includes tens of thousands of words in separate "technical" dictionaries. There are two main approaches to MT: transfer based and interlingual. The first does translation based on either statistics or examples with no "meaning" analysis, the second is based on an analysis of the word meanings and by "understanding" the meaning of the text and translating according to these meanings. The statistics based approach has been explored in the United States (particularly in the CANDIDE system of IBM) as have the interlingual and KB-based approaches. The example-based approach, in its modern incarnation, was proposed by Dr. Makoto Nagao (Univ. Kyoto) and has been primarily done in Japan. [See S. Sato, "Example-based Machine Translation," Doctoral Dissertation, Kyoto Univ., 1991. Dr. Sato is now at JAIST-East.] While the most used commercial MT system in the world is the U. S. Systrans system, the Japanese efforts are both large scale and effective. (For a detailed discussion of machine translation in Japan see the 1992(?) JTEC study on Japanese MT.)

Dr. Sumita and others at ATR are pushing the example-based approach (based on the work of Nagao and Sato) with a particular interest in using massively parallel algorithms to perform the work effectively. A number of impressive experiments on serial machines (including experiments with a 17,000 sentence corpus), aspects have been tested on Dr. Higuchi's IXM machine (described above). In addition, ATR has recently acquired a CM5 to continue this work. The work on the IXM machine has used example based techniques to translate a particular set of very common noun-phrases that are apparently very difficult to translate from Japanese to English (and that have been a stumbling block for a number of the other Japanese-English MT projects). Using a newer version of the IXM machine, a base of 1000 examples was encoded in 4KW of IXM memory. Time to find the best example was 22 microseconds (not milliseconds, as I first thought they must mean, but microseconds!), significantly faster than either CMs or other special purpose KR chips have performed. A project to use larger associative memories to couple the IXM with the larger corpus, and to move much of the corpus-based work to the CM-5 are currently underway. [See also the report, atr.92, 7 Feb 1992 for a general overview of ATR. Also note the following two conferences.

(1) Fifth International Conference on Theoretical and Methodological Issues in Machine Translation (TMI'93), 14-16 July 1993, Kyoto, Japan, TMI'93 Secretariat HS Bldg. 7-1-9 Nishi-gotanda, Shinagawa-ku, Tokyo 141 Japan
Tel: +81 3 3494-1869;
Fax: +81 3 3495-2405
Program: Yuji Matsumoto: matsu@pine.kyoto-u.ac.jp

(2) Fourth Machine Translation Summit (MT Summit IV), 19-22 July 1993, Kobe, Japan, MT Summit IV Secretariat, c/o AAMT Akasaka Chuo Mansion 305 7-2-17 Akasaka, Minato-ku, Tokyo 107 Japan
Tel: +81 3 3479-4396;
Fax: +81 3 3479-4895
DKK]

The Electronic Dictionary Research Institute

Although not currently exploiting parallelism, the Japanese EDR Institute is doing some very interesting work in the development of Very Large Knowledge Bases (VLKBs) and examining the possibility of the use of parallel AI in the future. Largely supported by MITI, the EDR was created to develop and eventually market and distribute a large bilingual Japanese-English dictionary and sentence base that could be used in Machine Translation projects around the world. The first phase of the project, slated for completion in March 1995, resulted in the development of a set of machine readable dictionaries and tools that could be easily used for a wide variety of purposes. This led to the development of several important corpora—a machine readable dictionary of 200,000 general terms (English and Japanese versions), one of 100,000 technical terms, and a 300,000 word co-occurrence dictionary (containing, for example, information on which nouns co-occur with which verbs) with English and Japanese versions. Perhaps more importantly from an AI/MT viewpoint, they also provide a "concept classification" dictionary that contains a superclass/-subclass ontology with over 400,000 entries. This latter is one of the largest knowledge bases developed in the world to date, rivaling the MCC CYC project (depending on how one perceives size.)

The next goal of the EDR project is to extend the techniques used in the current project to develop a huge, knowledge base consisting of common knowledge about many items and events (similar in principle to the motivation behind CYC). This is envisioned as a seven-year plan, starting in 1993, which has a two-year basic research phase (1993-1995), followed by a three-year research and prototyping stage (1995-1998), and a two year development, improvement and expansion phase (1998-2000). This project is being funded in part by the Economic Research Institute, the Japan Society for the Promotion of Machine Industry (JSPMI), and the Systems Research and Development Institute of Japan. In addition, significant international involvement is sought.

For more information on the EDR dictionaries see "An Overview of the EDR Electronic Dictionaries" (Japan Electronic Dictionary Research Institute Ltd, TR-024, April 1990). There is also a 1992 document entitled "A Plan for the Knowledge Archives Project" (distributed by the JSPMI.) [Also see edr.92, 27 Mar 1992, DKK.]

EDR, with the support of MITI and a number of other organizations will be hosting a conference on "The building and Sharing of Very Large Knowledge Bases" in Tokyo, December 1993. NSF is likely to sponsor a grant to pay partial support for this conference for U.S. researchers with papers accepted. (U.S. researchers can contact me for more information.)

SONY CSL

In an earlier report, Dr. Kahaner described in detail a visit to SONY CSL and the research there (sony-csl.93, 24 April). This organization, led by Dr. Mario Tokoro, is also doing some interesting AI research as well as the research mentioned in Dr. Kahaner's report. In particular, they are looking into Distributed AI (DAI) models, and into the use of AI in interfaces and applications. While the bulk of this work is not in MPAI, the DAI work is intended to scale to the very large number of "intimate computers" (see Kahaner's report) that SONY CSL envisions to exist someday (i.e., very large numbers of small mobile personal machines.) This view of MPAI merging with "massively distributed AI" is currently being explored in a few U.S. laboratories as well (particularly the work of Carl Hewitt at MIT) but Sony CSL is clearly doing some of the groundbreaking research in this area.

Fujitsu's AP1000

To promote technical exchange and provide research access to massively parallel machines to a number of Japanese (and foreign, see below) researchers, Fujitsu has made several of its parallel machines available for research use. The AP1000 machine, developed for this purpose, consists of a host machine and 16-1,000 "cells". Each cell is approximately equivalent to a Sparc class processor (25 Mhz) with 128 Kbyte cache and 16 M DRAM. Machines that are currently available include 64, 128 and 512 cell machines. Three different networks coexist among the processors allowing point-to-point, broadcast, and synchronized (tree structure) communication. These machines support both SPMD and MIMD processing, somewhat similar to the CM-5. While not as fast as the CM-5, these machines do achieve impressive performance (600 MFlops on the Linpack benchmark with matrix order = 1000, on the 512 cell machine.)

The AP1000s are made available over the internet to researchers in Japan and abroad, including U.S. university researchers (Iowa, OSU and Utah). Application forms are available from Fujitsu (contact Dr. Saito, head of the project) although they need Japanese government approval. Foreign researchers (primarily from the EC currently), are also welcome to visit Fujitsu and use the machines for research projects. These machines seem to be widely used by Japanese university researchers. In fact, most of the prototyping for the Super Parallel Computer Project (see above) is being done on these machines.

For more information on the AP1000 see Ishihata et al., "Third Generation Message Passing Computer AP1000" (Proceedings International Symposium on Supercomputing, Kyusu, November 1991). [See also jhpc-pp.92, 29 June 1992, At JSPP'93 several applications developers made use of this machine, see for example the paper by Tatebe (Parallelization of the Multigrid Preconditioned Conjugate Gradient Method). The access to AP1000 that Prof. Hendler mentioned is mostly at Fujitsu's new Parallel Processing Research Center. AP1000 systems with 512, 256, 128, and 64 nodes are available there and a 1024 node AP will be brought up this summer. About 150 member organizations have access to the Center including, as was mentioned, a few from the West. DKK.]

ICOT

Anyone interested in ICOT (the 5th Generation Computing Project) should read the Special Section of the March 1993 CACM (Volume 36(3)) entitled "The Fifth Generation Project: Personal Perspectives" edited by Ehud Shapiro and David Warren. In a series of "position statements," for lack of a better term, a number of researchers involved with ICOT describe what occurred and discuss the strengths and weaknesses of the results. In their epilogue, Shapiro and Warren sum up their perspective by stating:

> In summary, it can be said that ICOT has built a bridge between parallel computers and AI applications. However, with the two ends of the bridge being (perhaps temporarily) out of favor,

and the bridge itself being weaker than it might be, it is perhaps too soon to expect the inauguration of the bridge to be greeted with great acclaim.

This is similar to my own opinion, although as can be seen from the bulk of my report, a number of other bridges, some much stronger, were being built at the same time.

Scientifically, the basic flaw of ICOT's choice of logic programming as the bridge between AI and parallelism has a lot to do with the current state of each. Logic Programming has not yet been extended neatly to deal with complex numeric computation to handle large structured data or knowledge-bases, or to exploit locality of reference. On the other hand, it is exactly those things that massively parallel models seem best at exploiting. As such, the SPMD model, which has provided the greatest speedups to AI approaches to date, was not highly applicable to LP approaches. ICOT did an impressive job of speeding up the logic programming (although peaks of lGLips have been reported, I find the sustained 1.4 MLips reported by ICOT more believable.) However, they were working with one hand tied behind their backs, compared to those of us who could exploit massive parallelism, and particularly the SIMD processors just then becoming available.

The strength of ICOT, on the other hand, seems to me largely to be reflected in the gains to the infrastructure of parallel computing in Japan. A number of companies started looking seriously at it during that project, and many are building architectures that CAN exploit the very things that ICOT couldn't. Repeatedly, during my visits, I discovered that the scientists I was talking to had either been involved in the ICOT project or were working with those who had. In addition, researchers in industrial laboratories in Japan often seemed to know much about the work being pursued by their colleagues at other companies. By contrast, university researchers were often surprised to hear about work going on at other universities in Japan (and occasionally even with work at their own institution). When I asked about this, several of the company employees opined that they had all met through ICOT. In the ofttimes insular Japanese culture, the mixing of ideas that resulted from ICOT seemed to have greatly strengthened the ties between these researchers.

Also interesting is the often overlooked two year extension to the ICOT project. Although scaled back from the original design, a number of researchers continue to work on the project in two new "laboratories." Hosted by Dr. Nitta of ICOT, I visited the Second Laboratory, where some applications were developed and intended to show that the results of the 5th Generation project can be used to solve hard problems. The systems being developed included work in protein structure (part of the Japanese counterpart of our Human Genome project), legal reasoning (extending ideas in case-based reasoning), Computer-Aided Design, and playing Go (which generates incredibly large search spaces beyond the capability of even the special purpose sort of machines developed for computer chess). One of the important aspects of this work is that these projects bring in experts from beyond the companies originally involved in ICOT and target applications these experts are interested in.

At the time I visited, much of this was just starting, and it is difficult to guess what sort of impact the results of this new research effort will engender. My best guess at this point is that nice, and maybe even potentially useful, programs will result from this effort. However, still handicapped from exploiting the fastest results currently available in MPAI, I personally believe these projects will fail to scale the way the work described in the previous sections is likely to. [See also the reports icot.692, 4 June 1992, and fgcs.93, 1 June 1993, as well as papers at JSPP'93, DKK.]

JSAI - Special Interest Group on Parallel Processing and AI

The Japanese counterpart of the American Association for AI (AAAI) is the Japanese Society for AI (JSAI). This scientific society has about 4,000 members, and supports a yearly conference, a journal, and a number of special interest groups. The most recently formed special interest group is the SIG on Parallel Processing in AI (SIG-PPAI).

A symposium on massively parallel AI was held in a Sony-owned conference center outside of Tokyo in December, 1993. One of the purposes of this meeting was to help launch the new SIG. Interest in the group was high, and the group was recognized as an official JSAI SIG soon thereafter. Since my return to the United States, I've been informed that the SIG is doing well and is expected to be an important organization in the collection and dissemination of Japanese results in this area. In particular, SIG-PPAI is publishing workshop notes on the most current parallel AI research in Japan. Some of the articles (and all the figures) in these reports will be in English. For more information on obtaining these reports, contact Hiroaki Kitano (kitanoQcs.cmu.edu).

Personal Perspectives

This trip was quite an eye opener for me. As with most stereotypes, I discovered that many of my preconceived notions of Japanes society and science seemed true at first glance, but rapidly proved to be facile as I learned more. Below, in no particular order, I reflect on two of the pervasive myths I'm asked about as I talk with colleagues in the United States:

(1) MYTH: The quality of Japanese Computer Science Research lags well behind that of the United States.

I think this missimpression comes from a different emphasis in what the computer science community focuses on in each country. In Japan, I was struck by the fact that many computer scientists in Japanese Universities would be in departments of computer engineering, as opposed to computer science, as is in the United States. These researchers often seemed more concerned with chip design, architectural issues, and the building of machines, than with software and applications. Their hardware research is impressive (for example, I understand that some of the wafer scale work in Japan is leading the technology). In software, where there has been less emphasis, there's been less work—thus less publication, publicity, etc. However, in those areas where an emphasis on software is necessary (such as machine translation), Japanese work is clearly on par with U.S. research. In AI, this year two of the four best papers at the International Joint Conference on AI are from Japanese researchers, and a Japanese researcher, Hiroaki Kitano, has been chosen to receive the prestigious "Computers and Thought" award, presented by IJCAI to one outstanding young AI scientist every other year. Clearly, at least in AI, we see major research results coming out of Japan, helping put to lie this myth.

(2) MYTH: The top results in Japan are generally based on U.S. research.

I think there is some truth to this, but it is not because the U.S. research is somehow superior; rather, the Japanese seem far less susceptible to the NIH "Not Invented Here" syndrome then are U.S. scientists. In the United States, a company will rarely base a research program on a result developed elsewhere. In Japan, an exciting idea will often be explored and exploited, regardless of whether it was invented in that company, in Japan, the Pacific Rim, the EC, the United States, or anywhere else for that matter. I was quite pleased, for example, to discover that some of my early work —not terribly influential in the US—had been explored by the Japanese and was found to be a useful technique for certain computations. The technique has been integrated into a couple of different projects, serving as a testimony to Japanese willingness to explore and improve upon ideas from elsewhere.

What did became obvious to me as I traveled, was that the Japanese typically improved upon and extended the techniques developed elsewhere, and often integrated these with techniques developed by themselves, thus improving the utility of the results. Throwaway U.S. research results (like my own) were thus turned into useful technology or used as the bases of work that went far beyond the original. In addition, I think the proportion of ideas from outside that are being exploited is probably declining. Some of the work going on in Japan, particularly at research centers such as SONY CSL, seems to me to be taking a lead, and like anyone else, the Japanese are happier basing their work on the more accessible results printed in their own language, than on foreign research.

United States researchers who feel comfortable ignoring the results of Japanese laboratories, based on the myths above, run a risk of missing out on important new results. This can be difficult since there is often little incentive for Japanese researchers to publish in English, and thus many of these results are hard to obtain. I believe that Japanese researchers will be forced to live under the two myths, despite winning best paper awards etc., until more Japanese conferences, journals, etc. translate (at least their best papers) into English which, for better or worse, tends to be the major language used internationally for scientific communication. [NOTE: I certainly agree with this. One small step toward better communication of Japanese research results would be for Japanese conference committees to put more effort into providing (English) abstracts, etc., in machine readable form. This situation is getting better, but it is still uncommon. DKK]

Summary

I spent two months in Japan and came home very impressed with Japanese research in parallel architectures and in AI. The Japanese are probably not major contenders for replacing companies like Thinking Machines Inc. as leaders in selling parallel computers, but this is in part because they seem more geared up for producing small numbers of special purpose devices, rather than for producing and selling a large number of big machines. However, the emphasis on parallelism, the educational incentive to make "super parallel" computing available to all Japanese universities, the number of companies making special purpose highly parallel computers, and the national resources going into the RWC projects, all show that Japan is very serious about being a major scientific player in the arena of supercomputing in general, and MPAI in particular. U.S. researchers (and politicians) should pay attention to Japanese research in this area, and be aware of a number of exciting projects such as those discussed above.

[COMMENT: Regardless of their future potential, parallel computers are not profitable (or barely profitable) now, in my opinion. Japanese vendors are well aware of this, as we are in the West. However, there is no question that Japanese scientists in industry, government, and academia are working hard to develop their expertise in parallel computing. DKK]

Acknowledgements

I want specially to thank Dr. Hiroaki Kitano for the time he spent helping me arrange these visits, helping me find my way to the various sites, and the time spent discussing what I'd seen. In addition, I wish to thank the many Japanese researchers, too numerous to list by name here, who took time out of their busy schedules to tell me about their work. I also wish to thank David Kahaner for taking the time to talk with me on several occasions during my visit, and to Andre Van Tilborg and the Office of Naval Research for making this trip possible.

All of the opinions expressed herein are my own, and do not necessarily reflect those of the University of Maryland, my American or Japanese colleagues, or anyone else.

Comment on JSPP'93 by E.A. Heinz (Karlsruhe, Germany), 11 June 1993

Further comments on Joint Symposium on Parallel Processing (JSPP'93) were made by E.A.Heinz, University of Karlsruhe, Germany, 2 June 1993

David K. Kahaner

In my recent report on the 1993 Joint Symposium on Parallel Processing, held in Tokyo, 17-19 May 1993, I made the following statement.

"This was the best JSPP ever held. The quality of the papers was very high. While the number and variety of papers are still not quite what one would expect at a comparable Western conference, JSPP'93 indicates that there has been a significant improvement in the state of research on parallel computing in Japan."

Another Western attendee

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sent me the brief comments given below. Heinz presented a paper on Modula-3* at JSPP'93 and, following the conference, spent two weeks visiting Japan and some Japanese computing research facilities. Also attached to this note is a slightly corrected version of Heinz's JSPP'93 abstract that was given in my earlier report.

"All researchers I talked to during my JSPP'93 attendance were well informed and highly skilled in the field of parallel processing. Considering the large number of talks with interesting titles—held in Japanese, though, such that I could not always follow—under this former aspect, I think that the quality of JSPP'93 and of research in parallel processing in Japan as a whole is quite high. My later talks at Kyoto University further supported this impression. I really wonder if the rest of the world can truly estimate Japan's know-how in the parallel processing field.

As for business, all big Japanese information technology companies seem to be eager to jump onto the massively parallel train if they have not already done so. Other supercomputer vendors have to watch out for them!

My visit and talk at Kyoto University were particularly interesting because the groups lead by Prof. Tomita, Prof. Nakashima, and Prof. Kunieda showed strong interest in our Project Triton and also in real collaboration. Furthermore, Prof. Tomita and Prof. Nakashima introduced the concepts of their new D-Machine and their involvement in a nationwide new project to me."

The corrected version of the abstract of the paper presented at JSPP'93 follows,

MODULA-3*: An Efficiently Compilable Extension of MODULA-3 for Problem-Oriented Explicitly Parallel Programming

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In this paper we present the programming language Modula-3* and machine-independent optimization techniques for its compilation. We consider Modula-3* to be a promising new framework for problem-oriented explicitly parallel programming that aims at high performance on a variety of architectures and machines. By proposing

a large collection of effective optimizations, we illustrate the feasibility of efficient Modula-3* compilation. We ensure portability of the compiler by formulating most optimizations as source-to-source transformations in the intermediate high-level language Modula-3\pi, an extension of Modula-3*, especially designed for this task.

Real World Computing Summary by Nikkei Computer, 19 July 1993

A popularized description of the Real World Computing Program (RWC) from the 5 May 1993 issue of Nikkei Computer, translated and updated by Dr. Thomas Hagemann of the (German) GMD. GMD is one of the participants in the RWC Partnership.

David K. Kahaner

Nikkei Computer (1993.4.5) Special Feature: The following article was translated and updated by

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Readers of my reports will find that much of the basic material on the Real World Computing Program (RWC) as well as information about ETL (Electrotechnical Laboratory) research and its relationship to RWC has already been described. However, this overview is very well written and brings together a great many details that had been reported sequentially. In addition, details of industrial activities related to RWC are much more fully presented here. Worthy of note are that both Sweden and Singapore have now joined RWC. Also several Japanese steel companies, while admittedly not contributing much in terms of basic research, have joined for the insights that the program will give to their research staff. This report concludes with a related article on Optoelectronic Interconnections by Jun'ichi Shimada, Director of Research, and Director of Optoelectronics Department, Real World Computing Partnership.

I have deleted the figures to allow electronic transmission, and also because I did not find them essential for understanding.

The Challenge of Soft Information Processing, The Real World Computing Program Gets Underway

- MITI's new large-scale project, the Real World Computing (RWC) Program, also known in Japan as the 4-Dimensional (4-D) Computer Project, has commenced research activities. The project aims at realizing human-like "soft" information processing functions for the 21st century.
- The emphasis of the RWC program is to produce new basic research for the whole world rather than developing just a machine. It is the first large-scale project in which a framework has been created for research cooperation with academia and overseas research institutes.
- In striving for leading-edge basic research, a range of many different elemental technologies will be tackled. The final goals of the project will be set gradually while monitoring the progress of the research. Here we explore the vision of the computer that Japan is hoping to give birth to (by Atsushi Senda).

In his speech at the March 8, 1993 inaugural reception for the Real World Computing Program, Minister of International Trade and Industry Yoshiro Mori said, "This project will be a great undertaking to open the 21st century, and I have high hopes for its success. I am not sure I understand what it is about (laughter), but after looking over the materials a little while ago, it sounds like the project aims to create another brain for humans."

The Real World Computing Program (RWC) got fully underway in April. Its aim is to realize a computer that can process the diverse types of information used in the real world based on the soft, or flexible, information processing capabilities of humans. RWC will pursue this vision through research until FY 2001.

In the 1960s and 1970s, Japan conducted national R&D projects that targeted the performance of American-made computers, and built strength in general-purpose machines and supercomputers sufficient to compete with the world's best. In the 1980s, through the Fifth Generation Computer Project, the nation tried its hand at developing parallel inference machines based on the originally European concept of logic programming, and achieved some measure of success.

Now, in the 1990s, Japan aims through the RWC Program to originate the basic technologies of the 21st-century computer and to diffuse these to the rest of the world. Here we investigate what kind of vision of computing Japan has tackled, and trace the first steps in research taken in pursuing this.

[Photo (omitted) The inaugural reception for the Real World Computing Partnership held in March 8 at the Tokyo Prince Hotel (MITI Vice Minister Tanahashi teleconferencing with German Federal Ministry of Research and Technology's Director General Gries).]

Realizing Human-like, Soft Information Processing with Right Brain Functions

The key words of the overall Real World Computer program are "soft information processing." Very simply, this is research on ways to make computers perform the equivalent of human information processing.

Present-day computers can process only numerical values or symbolic information. The processing is entirely dependent on algorithms provided by humans.

In the real world, however, there are large quantities of pattern-like information such as speech and moving images. There are also many real-world problems for which no algorithm is known, and the only way of dealing with them is to check all the conceivable solutions. In the real world, the environmental conditions change with time. The real world often cannot wait until a solution is found.

Humans are capable of organizing pattern-like information (for example, the shape of a frog), as symbolic information (such as by spelling out the word f-r-o-g), and processing information in the world of symbols logically (by inferring that if it is a frog, it is an amphibian). Humans are also able to respond in the flow of real time to deal with problems that cannot be solved logically, using their intuition to obtain a "probably" sort of solution that, while vague, is nevertheless useful. Humans can evaluate the worth of their solutions by themselves and develop their information processing abilities through the experience called "learning."

If we use the human brain as a metaphor for computers, up to now computers have specialized in left-brain logical thought. One would expect that if right-brain intuitive thought could be reproduced, and if both were integrated, it would be easier for humans to use the computer— a good partner. This is the challenge of the Real World Computer program.

Massive Parallelism and Optical Connection as Building Block Technologies

Another theme of the RWC program is the development of a computing platform to execute these types of human-like information processing functions. In concrete terms, this means a massively parallel computer. The only platform that is now capable of executing soft information processing is the human brain, which is made up of approximately 14 billion neurons—a massively parallel system. To process the large quantities of information in the real world, and to do it in real time, would require a machine many times more powerful than the existing computers: an ultraparallel supercomputer.

As the building block technologies for such a machine, RWC participants will research optical interconnections. It is fundamentally impossible to connect tens of thousands of processors by using existing electrical circuits. What is needed is the technology to make connections by using light, which makes possible great parallelism and flexible changing of interconnections.

Another name for the Real World Computer Program, used only in Japanese, is the 4-D Computer project. This signifies a computer that can process real space (3-D) data in real time (the 4th dimension).

But RWC is not merely a plan to develop a high-performance massively parallel computer. According to Professor Takemochi Ishii of the Faculty of Environmental Information at Keio University, who was Chairman of the Survey Research Committee from FY 1989 through FY 1991, "The age when we made development of a single machine a national project is over. It may even be unnecessary for the RWC program to produce a computer itself."

Budget Projected at ¥70B Over 10 Years

Before we introduce the RWC research themes, let us first analyze its organization and structure.

The RWC Program is a large-scale project led by MITI, with a projected total government budget of ¥70B for 10 years, which started in FY 1992 (the year ending March 31, 1993). Following the 3-year preparatory survey research period from FY 1989, approximately ¥880M was apportioned for the official starting year in FY 1992.

However, FY 1992 ended up as a preparatory phase of the program. A technology research association called the New Information Processing Development Institute, also known as the RWC Partnership, was commissioned to conduct research for the project and its establishment was approved in July 1992. The project's Central Research Laboratory, which is located in Tsukuba, Ibaraki Prefecture, that is also called the Tsukuba Research Center (TRC), was opened in October, and the real delineation of research themes finally started at about that time. Actual research activities will start in FY 1993.

RWC research is being entrusted by the government to the RWC Research Partnership (RWCP) and ETL of MITI's Agency of Industrial Science and Technology in Tsukuba. As for the basic division of labor between these two, according to a MITI spokesman, "ETL's main responsibility will be advanced basic research," but in practice both may be viewed as a single entity. If one looks at the staff of the RWCP, everyone from departmental research directors on up through the Director of the entire laboratory is on loan from ETL. The purpose of locating the RWC Central Research Laboratory in Tsukuba was to allow for close ties with ETL. The FY 1993 budget allotted to ETL for RWC is ¥120M out of a total request of ¥3.6B for the project.

Table 1 — Members of the RWC Partnership: 20 Corporations and Industry Groups, 1 April 1993.

Fujitsu	Sumitomo Electric
NEC	Furukawa Electric
Hitachi	Fujikura
Toshiba	Nippon Sheet Glass
Oki Electric	NTT
Mitsubishi Electric	Mitsubishi Research Institute
Sanyo Electric	Japan Iron and Steel Federation
Sharp	German National Research Center for Computer Science (GMD)
Matsushita Research	

Organizations that joined on 24 May 1993:

Stichting Neuronale Netwerken (SNN)
Swedish Institute for Computer Science (SICS)
Institute of Systems Science (ISS), National University of Singapore

Parallel Research at Tsukuba Research Center (TRC) and Corporate Research Projects

Initially, 12 corporations and groups joined the RWC Partnership, these were followed by Nippon Telegraph and Telephone (NTT) and GMD, the German National Research Center for Computer Science. On 8 March, three Japanese corporations were added, and on 24 May, three foreign organizations also joined (Table 1).

Research will be conducted in parallel by five research groups at TRC and at 32 [plus 3 new foreign] distributed research groups within each RWCP member organization. At present there are more than 20 TRC researchers including assignees from the ETL and member companies, and the plan is to increase this to about 40 in the future. The distributed research groups consist of about 3 to 5 researchers each.

[Fig. 1 - Organizational Chart of the Real World Computing Partnership (as of April 1993). (omitted)]

These research groups are organizationally equal in relation to one another. In principle, the distributed research groups are responsible for elemental basic research, and TRC is responsible for integrated substantiating research.

Creation of a Framework for Cooperative R&D with Academia and Overseas Research Institutes

Since the RWCP is a partnership, in principle the research achievements are the property of each member corporation or group and the country that commissioned the research. The Management Board, shown in Fig. 1, that decides operating policies, the Affairs Committee that decides personnel and salaries, and the Research Committee that decides themes and assignees are all organized so that each member of the RWC Partnership has one representative within.

However, the RWC Program does have a mechanism for open cooperative research with outsiders other than partnership members. Funding will be provided to universities and overseas public research institutes for cooperation in "subcontracted research."

About one-tenth of the RWC budget is expected to be provided to overseas participants, and about half that amount to research commission fees for academia. Adding in the operating costs for common use of the research network (described below), about one-third of the budget will be directed to external cooperative research of this kind. Among large-scale projects relating to computers, RWC is the first to have a system for public cooperation with academic and foreign participants. Proposals for sub-contracted research themes are being collected now so that decisions can be made in or around May. [More than 10 Japanese universities and three foreign research labs (Europe, Australia) are candidates for sub ontracts.]

In addition to the above, international cooperation in RWC includes a joint U.S. and Japanese project to facilitate supply of optical device prototypes to researchers (see below). MITI is also said to be preparing liberal rules for foreign researchers to visit and have access to the RWC Partnership.

The TRC has installed two parallel computers for development, and is constructing a network that can be used jointly by any of the distributed research groups. Participating universities and foreign research institutes will also be able to have access and use this network.

In Europe, there are plans to connect the RWC network to a network linking European research institutes called the EBONE, with GMD as the central node (Figure omitted).

Steel Industry Group Participates as User

The majority of RWC Partnership members are computer makers and optical fiber or optical device makers. An exception among these is the Japan Iron and Steel Federation that is headed by Chairman Hiroshi Saito, President of Nippon Steel.

Tetsuren established a research committee in 1990 and drew up requirements from the standpoint of users for a computer of the future that would be used in production processes. The final description was close to the concept of "soft information processing," so the Federation participated in the preliminary RWC survey work that was being conducted simultaneously. This led to the Federation's joining the RWC Partnership as well. The six blast furnace steelmakers (Nippon Steel, NKK, Kawasaki Steel, Sumitomo Metals, Kobe Steel, and Nisshin Steel) all agreed to send two researchers each to TRC and continue to explain user requirements. However, according to Yasuhito Uchida, Assistant Section Chief of the Federations Technology Control Section, "Basically, we (the Federation participants) will most likely be students of RWC research."

Parallel Research of Numerous Technologies: Not a Straight Line Toward a Single Goal

In the Real World Computing Program, Japan aims at pioneering basic new computer technologies on its own. To that end, the research schedule has features unlike any previous large-scale project.

Until the Fifth Generation Computer Project, all the large-scale projects established a single, clear development goal at the outset. The research progressed towards this goal directly as in the "Climbing Mt. Fuji" metaphor.

In contrast, RWC has adopted for itself the metaphor of "Climbing the Eight Peaks," derived from the mountain chain "Eight Peaks" in central Japan, as opposed to the famous one-peak-only Mt. Fuji. Initially, individual basic technology fields will be researched in parallel. At the middle stage of the project, the feasibility of the elemental technologies in each area will be re-evaluated, and the themes gradually narrowed as the project proceeds toward the final stage. Multiple research groups will start working in parallel on the basis of their own distinct theories and principles to pursue identical goals, such as optical interconnection technologies and the integration of pattern and symbolic information, and explore the possibilities thereof.

TRC and the distributed research groups finally drew up their research themes for FY 1993 in the first part of March (Table 2). This does not represent the entirety of the RWC Program, and the research themes will be reviewed every fiscal year, with commissioned research by universities and overseas participants broadening its scope. Partly to invite exploration of a range of possibilities, the interrelations among and ranking of the various research themes described below are not being defined yet. Be that as it may, let us now introduce the approaches to "climbing the mountain" that each RWC lab is tackling in the following sequence:

(1) Theory and Novel Functions;
(2) Massively Parallel and Neural Systems; and
(3) Optical Interconnections and Computing.

Table 2 — FY 1993 Laboratory Research Themes in the RWC Program (In random order within groups, organized by Nikkei Computer)

- Theory and Novel Functions Research Department

– Theory

Computational Learning Ineory of Probabilistic Knowledge Representations (NEC)
Statistical Inference as a Theoretical Foundation of Genetic Algorithms (GMD)
Group Information Processing Software Model (Fujitsu)
A Vision Processor in Neural Architecture (Mitsubishi Electric)

– Novel Functions

Information Integration Interactive Systems (TRC Information Integration Lab)
Integration of Symbol Information Processing and Pattern Information Processing (Mitsubishi Research Institute)
Cooperative Problem Solving based on Heterogeneous Knowledge (Oki Electric) Multimodal Human Interface (Sharp)
Information Integration Technology for Applying Sign Language Recognition (Hitachi)
Vision Sensor (NEC)
Self-organizing Information Base (Mitsubishi Electric)
Parallel Information Processing and Attention Mechanisms in the Brain (NTT)
Real World Adaptive Autonomous Systems (TRC Active Intelligence Lab)
Learning and Growth Functions for Autonomous Mobile Robot (Fujitsu)
Vision-based Autonomous System (Sanyo Electric)

- Massively Parallel and Neural Systems Research Department

– Massively Parallel Hardware and System Software

Massively Parallel Execution Model and Architecture (TRC Massively Parallel Architecture Lab)
Massively Parallel Computation Model, OS, Prog. Language, and Environment (TRC Massively Parallel Software Lab)
Massively Parallel Machine with Optical Interconnection (Toshiba)
Adaptive Massively Parallel Systems (NEC)
Resource Management in Massively Parallel Computers (Sanyo Electric)

– Massively Parallel Development Environments

Design and Implementation of a Process-oriented Programming Language (Mitsubishi Research Institute)
Development, Implementation, and Evaluation of a Programming Model for Massively Parallel Systems (GMD)
Massively Parallel Object-oriented Model (Mitsubishi Electric)

– Neural Systems

Adaptive and Evolutionary Computers (TRC Neural Systems Lab)
Pattern Recognition based on Structured Neural Networks (Toshiba)

- Optoelectronics Research Department

– Optical Interconnection

Optical Interconnection by Wavelength Domain Addressing (Fujitsu)

3-D Optoelectronics Interconnection Technology (Oki Electric)
Optical Interconnection and Signal Processing via Optical Frequency Addressing (Hitachi)
Multifunctional Surface Element for Space-multiplexed Optical Interconnections (Toshiba)
Parallel Optical Interconnection by Optical Fibers (Sumitomo Electric)
Optical Bus Interconnection System (Nippon Sheet Glass)
Spatial Light Deflector (Fujikura)
Electrophotonic Processor Network (NEC)
3-D Integrated Stacked Optical Devices for Optical Computing Systems (Sanyo Electric)
Wavelength-tunable Surface Emitting Laser Diode Array (Furukawa Electric)

- Optical Neurocomputers

Optical Neurocomputers (Mitsubishi Electric)

- Optical Digital Computers

Stacked Optical Computing System (Matsushita Research)

Theory and Novel Functions Laboratory Integration of Pattern and Symbolic Information: (Key to the Treasure-house of Soft Information Processing)

The Theory and Novel Functions Laboratory will develop basic theory and techniques to achieve "soft information processing," and then proceed to test these through a variety of sample applications. Most of the research themes being considered at present aim at techniques for the "integration of pattern and symbolic information," with man-machine interface as the sample problem. There are four distributed laboratories choosing topics on the basic theory side, but for now it appears that most of these will rely on ETL advances and academic research. The Neural Systems Laboratory, discussed below, will pursue studies approaching fairly basic research.

Humans Learn, Grow, and Deal with Ambiguous Information

Research on aspects of basic theory will be started from almost a clean slate. Shun'ichi Amari, Professor of Computational Engineering at Tokyo University, says, "Up until now, computers have been constructed based on the solidly logical structures of theory, computation, and algorithms within the realm of symbolic processing. But information processing by humans involves processing of pattern information, and we supplement the inaccuracies of this in the realm of logic. To achieve this with computers, a new theoretical system of computation will probably have to be built."

Such a new theoretical system must be able to demonstrate various functions modeled on those of the human brain. One issue is how to express real world information that contains characteristics related to likelihood, such as ambiguity, noise, and the concept of "probably." Another issue will be how to give computers the capability to learn and self-organize information: given a small set of information, the rest is organized on the basis of its own skill and knowledge and classified. This process is akin to growth (i.e., intellectual development), or the process by which a child gradually learns to talk.

In the brain, there are regions responsible for vision and others for hearing. Within the vision regions, smaller regions that respond only to specific shapes or objects that move in specific directions process sensory information in parallel and are linked with one another. To process information in real time, it is thought that one must modularize the system in stages in the same way as the brain mechanism and realize functions to generate modules autonomically when data is added.

Academia and ETL Workshops to be Mainstays of Basic Theoretical Research

Two approaches to integrating these theoretical seeds seem to exist: the experimental approach of extending and expanding neural networks, and the top-down approach of tempering symbolic inference theory with probabilistic and statistical viewpoints. In general, the former is represented by the work of Professor Amari of Tokyo University, and the latter by that of RWC Chief Researcher (and Director of the Intelligent Information Section of ETL; see below) Nobuyuki Otsu. However, both approaches are alike in that they are aiming for an integrated theory, and from first principles are not necessarily incompatible.

According to Ryuichi Oka, Director of the Theory and Novel Functions Laboratory, this theoretical research will be conducted primarily in workshops linked to but independent of RWC, rather than within the RWC Partnership. Eventually a theoretical laboratory may also be started at the RWC Tsukuba Research Center, but until then we will place an emphasis on novel functions." These workshops will be organized with academics and ETL members forming the nucleus, and will start work on five themes in April:

- Integration of symbolic and pattern processing;
- Acquisition of probabilistic knowledge;
- Image understanding;
- Voice and natural language understanding; and
- Situational inference and dialogue.

Development of "Genetic Algorithms" is Main Topic of Theoretical Research at Distributed Labs

Four distributed laboratories will work on theoretical themes. Of these, the Mitsubishi Electric Laboratory is rather close to applications, so we shall cover it in the section on new functions. The three remaining laboratories are still in the conceptual stages, but they share the common goal of expanding genetic algorithms (GA).

Genetic algorithms are a method of finding the optimum solution from among a vast number of conceivable candidates. Starting with a multitude of initial parameters, the low-quality solutions are eliminated (selection), and parameters are generated in the vicinity of good solutions (mutation). Alternately, parameters are generated by exchanging part of those parameters for good solutions (cross-over) through repetitions and the best solution is sought. These algorithms are said to be suited to processing by massively parallel machines.

To improve the efficiency of genetic algorithms, the German GMD has introduced the concept of a Breeder. By advancing this concept and combining it with statistical inference theory, new algorithms will be developed.

The NEC theme, which is similar to GMD's, is to construct a theory of learning reflecting the concepts of probability as an advanced form of genetic algorithm research. Fujitsu is also working on an expansion of genetic algorithms with the theme of developing a theory for "interactive yet self-organizing group mechanisms." The aim is to establish a theoretical foundation to support learning, growth, and response to changing problems.

From Understanding of Gestures and Conversation to Mobile Robots

In parallel with the theoretical research, there is a body of research being conducted on "novel functions" to demonstrate the theory. First we shall consider the research themes of the two laboratories working in this area at TRC.

The Information Integration Laboratory began research on four topics during the last fiscal year [(Figure 3) omitted]:

- Understanding of Moving Images;
- Understanding of Spoken Conversation;
- Self-organizing Databases; and
- Autonomically Operated Systems.

Understanding of Moving Images will encompass research in technology for recognition of human body and hand gestures and recognition of environment on a mobile camera image as it pans horizontally. ETL research on gesture recognition is fairly advanced. Several types of gestures have been recorded, and a demonstration is already possible in which the start and finish of actions can be grasped in real time from a stream of inputted images.

However, according to Oka, the laboratory director, "Many difficult problems remain, such as recognition of subtle facial expressions, or whether a finger is bent or straight." (Translator's note: such gestures are used on the trading floor.)

[Figure 3 - Research Themes in the Information Integration Laboratory of the Real World Computing Partnership]

In Understanding of Spoken Conversation, RWC researchers will tackle the problems of understanding sentences containing hesitations or broken speech and restatements in order to recognize natural human conversation. Here again, the ETL has completed a demonstration system that recognizes, in real time, a limited vocabulary and speaker-independent voice in context (with automatic recognition of sentence beginnings and endings). In addition to this technology, there are plans to develop a system that not only converts speech input to characters, but also understands the context and expresses it in images.

Reorganizing Large Volumes of Symbolic Information as Patterns

The Self-organizing Databases research group will target research on processing of databases, such as those of newspaper articles, for which large-volume searches are difficult. Researchers will develop techniques for extracting patterns from such large bodies of symbolic data, automatically initiating searches, classification, and structuring. Conventional pattern recognition extracts symbolic information from pattern information, so this will be technology to go in the opposite direction. According to Oka, "This will constitute a challenge of new research areas to find out what kinds of regularities are hidden in real-world symbolic information, and how humans learn these regularity-detection techniques."

The Autonomically Operating System will involve experimentation to integrate these elemental technologies. Researchers will modify commercial robots with mobile capabilities, equip them with various input and output devices, and have them operate while processing moving image data and performing speech recognition in real time.

Most Distributed Laboratories Tackle Man-Machine Interface

Most of the Novel Functions distributed laboratories will work on the problem of integrating pattern and symbolic information. The themes for the Mitsubishi Research Institute (headquarters in Tokyo; Hisaya Nara, President) and Oki Electric are not yet decided, but will involve research in areas involving pattern processing-oriented principles such as neural networks based on symbolic inference systems.

The NEC research theme is recognition of moving objects by integration of information from moving image (video) and other sensors.

Hitachi's theme is understanding of sign language. The research team will develop technology to recognize images of hand movements and facial expressions and supplement this with contextual and semantic understanding of ambiguous portions using symbolic inference.

Sharp will undertake construction of a more elaborate man-machine interface integrating recognition of hand and body gestures and expressions, voice input, virtual reality usable for output, and an environment in which one can converse with the computer by using gestures and expressions just as one could with another human being. It would be fair to call this theme the most representative of "soft information processing" in the whole RWC Program.

Mitsubishi Electric will work on a self-organizing type database, the same topic being researched at the Tsukuba Research Center. The company will also study the theme of visual processing using neural networks as a theoretical topic. The idea will be to process in parallel features extracted from image data, such as "relationships" or "appearance" as preliminary processing modules while also tying together high-order processing modules such as "unitary solid objects" and "movement." The recognition output would be used as feedback to make the camera follow or zoom up on the object.

NTT's theme, which stands out from the others in this area, is to observe human brain activity with high resolution using electromagnetic sensors and research responses to sound and noise.

The theme that Toshiba will be tackling in its Neural Systems distributed laboratory - character recognition - is also close to those of the Novel Functions projects. The company will aim to integrate conventional theoretical techniques with neural network-based recognition techniques to distinguish structural features of letters.

Investigating Action Understanding Through Research on Intelligent Robots

According to Hiromasa Inoue, Professor of Mechanical and Information Engineering at Tokyo University, "In order to realize a robot in the true sense of the word, one has to enable it to see, feel, hear, and communicate with other robots and humans and respond in real time. The goal of RWC is not the development of an intelligent robot, but this would be an excellent means of integrating and proving the technologies developed by the project."

Robots are also a theme of the TRC Active Intelligence Laboratory, another in the Theory and Novel Functions Research Department. However, while the Information Integration Laboratory is working from research on individual functions towards their integration in a robot as a model, the Active Intelligence Laboratory is targeting the realization of intelligent robots themselves and seeking out the necessary elemental technologies. The Active Intelligence Laboratory hopes to develop robots that can work in cooperation with humans in a human environment. Thus, the core research theme is Understanding of Actions.

As the Director of the Active Intelligence Laboratory, Takeshi Suehiro , notes, "The first thing is to understand human actions. Without knowing what the person is trying to do, you cannot figure out how to help the robot. The next problem is to understand the actions of the robot itself. It needs to have the capability to understand the purpose of its own actions, try again when it decides that it has failed, and think about the reasons and learn on its own."

Robots Working in Cooperation with Humans in a Human Environment

Related to this, research will also be conducted on breaking down work and skills into "meaningful" units, and having the robot learn these. Almost all present-day robots are positional control robots that move objects to specified locations. The RWC researchers will create a system in which one can provide instructions to robots in meaningful work units, such as putting the cap on a pen. They will also work on technologies for robots to observe human patterns of action, and recognize and learn the skills involved.

The actual sample problems that the Active Intelligence Laboratory will use to pursue this research are undecided, but the present direction is toward taking up arm-type robots, in contrast to the initial focus on mobile robots at the Information Integration Laboratory. According to Suehiro, "It may be interesting to look at topics such as working in collaboration with humans, for example, cleaning up a desktop. The ultimate goal is robots that help without getting in the way in an environment with humans. But it will be difficult to complete this within the project timeframe."

Sanyo and Fujitsu to Study Robots at Distributed Laboratories

Two companies will also do research at their distributed laboratories. Sanyo Electric's research theme is very similar to that of the Active Intelligence Laboratory: "Sanyo will develop real-world recognition technologies and technologies for robots to understand the purpose of tasks and operate with dexterity," says the company. However, there are no definite plans to build an actual robot.

Fujitsu selected the problem of mobile robots. Specifically, the goal is to develop a robot for use in an office, which would avoid humans and do things such as collect trash containers. According to Fujitsu, "We would like to integrate three basic technologies: autonomy, learning, and ability to grow in knowledge. As part of our previous research on neural networks, we went as far as integrating autonomy and learning through our work on problems like follower robots and unicycles. But the hard problem is how to integrate these with the ability to grow. We won't restrict ourselves to neural network technology."

Massively Parallel and Neural Systems Research Department Developing Massively Parallel Machines with Original Processors; Working on Theories for Modeling Living Organisms

The Massively Parallel and Neural Systems Research Department is responsible for developing the hardware, operating systems, and languages that will form the environment for implementing soft information processing. The initial basic plan, released in May 1992, called for development of a massively parallel system with a one million or more processors and a neural system with a million or more nodes in the final stages of the RWC program. At present, however, the plan to develop such large-scale hardware is up in the air. Instead, the goal is to develop the basic technologies needed to realize such hardware.

TRC Neural Systems Lab Concentrates on Basic Theory of Life-Form Modeling

For the time being, the Neural Systems Laboratory of the Tsukuba Research Center plans to deepen its research on fundamental theory rather than developing hardware systems. Tatsumi Furuya, Director of the Massively Parallel and Neural Systems Research Department and Director of the Neural Systems Laboratory (see below), explains, "Our topic is not only neural systems but information processing techniques as a whole that are modeled after life forms. We would like to experiment with a broad range of possibilities while watching world research trends." Furuya's lab will attempt to construct a theory of "mechanisms for adaptation and evolution" and "associative capability" to respond to vague or partial input, as in neural systems.

16K-Processor Experimental Platform for Massively Parallel Computation to be Completed in 1998

Meanwhile, fairly concrete plans to develop systems have emerged in the Massively Parallel Architecture Laboratory and the Massively Parallel Software Laboratory. Since this system will be a demonstration and experimental platform for the Theory and Novel Functions Laboratory, the development plans were fleshed out at an early stage.

As shown in Fig. 4, the schedule calls for development of a 1024-processor RWC-1 in the next three years (by spring of 1996), and of a RWC-2 with about 16,000 processing elements in five years (1998). Each processor is expected to process 64 bits and operate at a frequency of about 100 MHz. The operating system and languages for these machines are to be developed within a year of the hardware implementation.

[Figure 4 (omitted): Projected Specifications and Component Technologies of the RWC-1 and RWC-2 Research Prototypes (to be developed by the Massively Parallel Architecture Laboratory and the Massively Parallel Software Laboratory of the Real World Computing Partnership)]

The foremost characteristic of the planned systems is the use of an original architecture for the processing elements. Shuichi Sakai, Director of the Massively Parallel Architecture Laboratory, explains, "To keep costs low, the massively parallel machines currently being commercialized use general-purpose microprocessors for computational processing sections, and separate processors for interprocessor communication functions. In the RWC program, however, we have to respond to the demands that will emerge from the theory and novel functions research for flexibility and high performance. That means we will be constructing an architecture premised on a truly massively parallel machine, one that integrates processing and communications at a high level."

A portion of this architecture has been realized in the EM-4 parallel machine being developed at ETL. According to Sakai, however, "Unlike the EM-4, which emphasizes performance for its own sake, the RWC-1 and RWC-2 will be built with the idea of practicality. Features such as virtual memory, multiuser capability, and fault-tolerance will be necessary."

The RWC-2 will be designed with an architecture that can support a 64,000-processor configuration. An architecture that can support a one-million processor machine that will be developed in the second part of the project, but whether or not such a machine can be built "depends on the budget," notes Sakai.

High-level Languages to be Developed for Operating Systems and OS Description Language

The Massively Parallel Software Laboratory will develop operating system software, a base language to describe it, and a high-performance functional language. Development of the base language, prototyping of high-performance functional languages, and design of the operating software are planned in FY 1993.

According to Yutaka Ishikawa, Director of the Massively Parallel Software Laboratory, "By using C++ as the base language we made it possible to support real-time and description for parallel processing. The operating system will be one that can be used as a stand-alone system, and be practical for multiple users." As for the high-level language, "It will probably have to be parallel object-oriented and be capable of reflection (supporting expansion and description of the language functions in the same language). But we will decide while keeping the balance with performance in mind," says Ishikawa.

Distributed Laboratories: Toshiba to Research Opto-Interconnected Parallel Machines

Toshiba, which runs one of the distributed laboratories doing research on massively parallel systems, will attempt to construct a large-scale system. Unlike the Tsukuba Research Center, Toshiba has adopted the approach of employing general- purpose reduced-instruction-set computer (RISC) processors and external communications processors. In the first half of the project, the company will operate a system with several thousand processors using electrical connections and confirm the effectiveness of an architecture premised on optical interconnections. In the second half, Toshiba will undertake demonstration with optical interconnections. As for software, there is the intention to share elements with the software developed at the TRC, but the details are undecided.

In addition to Toshiba, NEC will study architectures that can support changes in processing methods according to the purpose. Sanyo Electric will conduct research on the more theoretical aspects of architecture, such as memory management and fault-tolerance. Introducing the concept of "inter-object distance" to object-oriented processing, Mitsubishi Electric will investigate processing models and languages for efficient distribution with parallel machines. Mitsubishi Research Institute will research extensions of object-oriented languages for massively parallel machines.

From 1984 to 1989, GMD arranged collaborative research with industry and universities in the development of the 256-processor SUPRENUM parallel computer and produced the prototype. Drawing on this experience, GMD will develop a language compiler for automatic load distribution in massively parallel computers. This compiler will also be based on an object-oriented model. GMD says that a new computational model designed to handle the three elements of computation, communications, and synchronization independently will make it easier to program massively Parallel machines.

Optoelectronics Research Department Main Thrust in Optoelectronic Interconnection Technology; Will Also Research Opto-neural and Opto-digital Systems

There are three research areas for the Optoelectronics Research Department:

- Optoelectronic interconnection,
- Optoelectronic neurocomputers, and
- Optoelectronic digital computers.

The majority of research themes studied in FY 1993 are related to achieving links among processors in massively parallel machines using optoelectronic interconnection.

The Optoelectronics Research Department is starting out with no laboratories of its own at the Tsukuba Research Center (see also remarks by Jun'ichi Shimada, below). In the area of optoelectronic interconnection, the distributed laboratories of the computer makers are seeking flexible and mutual connections among the processors inside massively parallel computers. NEC is developing a light-emitting element called VSTEP that can control the amount of light generated by an optical input signal, and will research processor connections using this device. Fujitsu has made both an optical laser and a light-receiving optical device with the ability to select wavelengths like those of a TV channel. Using these, it will study the theme of achieving transmission from one specific processor to another via an optical bus that looks like a glass plate.

Oki Electric will study a similar optical bus method for transmission paths, but is targeting technology for bonding and connecting each device to the wafer using what it considers the optimum materials for each purpose: silicon for the processors, gallium arsenide for high-speed conversion to optical signals, and indium and phosphorous, respectively, for the optical emitter/receptor devices. Hitachi is also researching technology to change connections at will by selecting frequencies. Rather than controlling it with light-emitting devices as Fujitsu is attempting to do, Hitachi will concentrate on a technique for intervening with a device to change the frequency midway through transmission.

Sumitomo Electric will develop technology for large-volume transmission between systems. The company's researchers will produce a solid connector made up of layers of semiconductor lasers and optical receptor devices and connect it to a fiber optic cable containing approximately 1,000 individual strands.

Opto-neural and Opto-digital Research Aims at Instantaneous Video Input and Real-time Processing

Mitsubishi Electric is directing a small number of researchers working on optical neurocomputer systems. The company has been researching optical neurocomputing since 1986, and in 1990 completed a prototype opto-neural integrated circuit. For the RWC program, Mitsubishi will combine a specialized opto-neural artificial retina device for image recognition with a conventional logic-processing computer. The aim is to develop a system that can perform

(1) feature extraction of image relationships and moving parts via the artificial retina, and
(2) recognition via links between the opto-neural and logical processing sections.

Matsushita Research, a member of the Matsushita Electric Industry Group (with headquarters in Kawasaki, Kanagawa Prefecture; Masaya Nakajima, President), is taking on the challenge of developing an optical digital computer (Fig. 5) [omitted]. Researchers will construct an image processing system using components such as a spatial light modulator that alters the reflectivity of the backplate when images are input to the surface, a functional optical connection device that can diffract or combine light, and a fiber plate (composed of fiber optics bundled together and then cut into a very thin ring) to facilitate positioning of optical interconnections.

Both of the systems being investigated by Matsushita and Mitsubishi are aimed at execution of real-time image processing. In current image recognition, video cameras are used for input; the field of view is scanned and data stored in memory. As a result, it takes time to input, and there is the risk of not being able to follow real-world movement; hence the need for direct, total input and processing of images in parallel.

[Figure 5 - Concept of Matsushita's "Layered-type Optical Computing System" Research Theme. The system would be able to perform feature extraction in real time from image data input. (omitted)]

United States—Japan Cooperative "Broker" System to Supply Optical Devices to Researchers at Low Cost

Optoelectronics technology is the only area of the RWC Program at this time in which there exists a structure for U.S.-Japan cooperation: the "broker/foundry" system (Fig. 6) [omitted]. This is a proposed way for optical device makers (foundries) to supply devices that are being developed and represent the leading edge of technology at a low cost to optical computer system developers. Simply put, this is a mechanism in which a wholesaler (or broker) acts as a go-between organizing the requirements for prototypes and making them easier to mass-produce. If the system developer negotiates directly with the foundry, it ends up revealing its technological development in progress and risks its intellectual property. With the interceding of a broker, however, these problems can be avoided.

[Figure 6 - Japan-U.S. cooperation in the Real World Computing Program: the Optical Device Broker/Foundry System (omitted)]

The same kind of mechanism was implemented in the United States in the 1980s to supply metal-oxide film semiconductor (MOS) chips to researchers. The MOSIS system, as it was called, was said to be a success. In the RWC Program, an auxiliary organ of MITI, the Optoelectronics Industry and Technology Development Association (whose Chairman is Koji Kobayashi, Honorary Chairman of NEC Corporation) has been commissioned by the RWC Partnership as a broker.

The Need for Understanding of the Visionary Challenge

The Real World Computing Program has just started, but already there are those who raise criticisms. For example, the budget cannot be said to be adequate for the number of research topics. Including all the corporate participants, the average amount disbursed for distributed laboratory projects in FY 1993 is said to be less than ¥50M. If the demonstration systems end up being small-scale and limited by conditions, they may slow down basic research.

There are also some problems with the openness of the research structure. The current selection of research themes was essentially the work of a Promotion and Evaluation Committee composed of 18 university professors and ETL researchers. This may be good in the sense of links with academia, but because this committee is a collection of the key persons from each field in academia, there tends to be a lack of neutral (disinterested) university research subcontractors.

There are intellectual property problems in cooperation with foreign participants. According to MITI, "Recognition of patent rights to research results has been greatly expanded to a maximum of 50 percent. As for copyright of software, the plan is to make anything over the network freely useable." MITI says, these represent great improvements. But a sense of danger on the part of foreign research institutes has not disappeared due the fact that it is not legally explicit that results may be freely used.

The greatest problem is that in order to take on the challenge of the very forefronts of research, the project participants must "think about the goals while running." This may be said to be the real significance of the Real World Computer Program, and it is necessary for observers to have the understanding of this point. In the case of the Fifth Generation Project, it seemed that the researchers considered their goal to be the "development of a parallel inference machine," and that is in fact what they accomplished. But because the gap between this accomplishment and what had been proposed before starting the project as the project concept (which is actually fairly close to that of RWC) was so large, the mass media labeled the project a "failure" in its final stages.

Perhaps reflecting on the experience of the Fifth Generation Project, those involved in the Real World Computing Program seem to want to concentrate on their research quietly instead of loudly publicizing their project. But they must also seek public understanding of the importance of pursuing, without fear of failure, a visionary challenge.

Human Information Processing Explained as "Probabilistic Inference" (Remarks by Nobuyuki Otsu, Chief Researcher, Real World Computing Partnership.)

The Electrotechnical Laboratory has been working on "soft logic" research for some time. It is safe to say that humans formed their logical structures out of the hazy, unrefined pattern-like information of the real world. To do research in soft logic is the same as to explain the process of going from recognition to forming concepts, representing them symbolically, and thinking abstractly in the world of logic. This is the background for the "soft information processing" of the Real World Computing Program.

I started out doing research in pattern recognition. Pattern recognition is the theory of extracting features from redundant information and converting them into symbolic information. Through this research, I learned that some techniques of analyzing unrefined redundant data were shared in common with other fields.

For example, the technique of multivariate analysis, which is used to analyze and predict questionnaire results in the area of sociology, corresponds to the example of a curve with a special shape from the viewpoint of "nonlinear feature extraction" in pattern recognition. Similarly, neural networks have a special nonlinear pattern and can be explained as a slight expansion of the multivariate analysis technique.

Then I realized that this nonlinear feature extraction could actually be interpreted as a special form of "symbolic inference incorporating probabilistic factors." With this realization it became possible to explain both redundant or ambiguous information processing and symbolic information processing using the common theory of probabilistic inference (Fig. 7) [omitted].

To make an analogy, if the theory that has up until now been the foundation of computer science is like Newtonian physics, then the theoretical foundation of soft information processing would be something like Einstein's relativistic theory. Although the theory of the world of symbolic logic has been taken almost to its utmost limits, computers are still hard to use. Soft information processing, the theory that will provide the solution, is thus an urgent area of research.

[Figure 7 - The new principle of information processing to support real world computing (RWC) may be "probabilistic inference" (omitted)]

The Historical Significance of Integrating Pattern and Symbolic Processing (Remarks by Ryuichi Oka, Director of Theory and Novel Functions Department, and Director of Information Integration Laboratory, Real World Computing Partnership.)

This is probably the only research project in the world with the theme of integrating pattern and symbolic information processing. Right now it is almost all talk, but Japan has already established its strength in the field of pattern recognition. In view of the expectations that Japan will be able to show its individuality and that this will become universal technology in the future, I believe this challenge will turn out to have historical significance.

An integrated technology to process patterns and symbols will require two fundamentals: representation of information, and algorithms. Representation is paradigms, frameworks, and theory. In physics, it corresponds to quantum theory or relativity. Algorithms, on the other hand, are like the Schroedinger wave equations, things that lead to actual solutions. Research on massively parallel machines to run these algorithms will also come into play for representation.

The Theory and Novel Functions Research Department will be responsible primarily for discovering and testing new algorithms. For example, by using neural networks, we are not going to try to solve everything with neural systems that approach "soft information processing." Our goal is rather to develop new algorithms that can be linked with the fruits of theoretical research.

Progress in Neural Systems is Fast - Initial Emphasis on Theory, not Hardware (Remarks by Tatsumi Furuya, Director of Massively Parallel and Neural Systems Department, and Director of Neural Systems Laboratory, Real World Computing Partnership.)

At the preliminary survey stage of this project, neural systems was chosen as a fairly new and challenging field that would provide a different angle of attack from symbolic information processing. Recently, however, information processing theories modeled after living organisms, such as genetic algorithms and artificial life forms, have started to appear on the periphery of the field.

Each of these theories is based-on a model in which small components exhibit independent action based on local information with the result that the system as a whole responds to changes in its environment (i.e., learns). We feel that such theories have great future potential for the purpose of realizing a flexible response to the real world and the demand that the systems be implemented on massively parallel machines. However, we must watch future world research trends to see which of these takes off. That is why we made the overall theory that takes life forms as its model, and not just neural systems, the subject of our research.

Research is advancing rapidly, so at this point we are holding back on the nuts-and-bolts step of making some "thing," and are concentrating on generating lots of ideas. There is a possibility that we will build some small-scale hardware to prove theory in the second period of the project, but we are not aiming for a large-scale neurocomputer with a million nodes.

Tackling 2nd-Generation OEICs for Optoelectronic Interconnection (Remarks by Jun'ichi Shimada, Director of Research, and Director of Optoelectronics Department, Real World Computing Partnership.)

We are now at the stage when the themes for every laboratory have finally been settled, so one might say that FY 1993 is still a study period for the Real World Computing Program as a whole. The subcontracts for overseas and university research were supposed to be decided by the end of 1992, but now we are targeting May. That's why I don't want people to think that the collection of individual themes that have been named at this time will cover the entire program.

When one thinks about the future of computer technology, one realizes that it is the problem of the connections between processing elements rather than the computational elements themselves whose relative importance has been increasing. Likewise, in optoelectronics research within this project, the foremost topic that we need to work on right now is optoelectronic interconnection. By using optical technology for the most important connection parts, we will have realized an "optical computer." We hope to conduct a small-scale packaging demonstration in the final stage of the project and actually make something that could be called the first optical computer in history.

In a large-scale project on optoelectronic device technology conducted from about 1980, in which I myself was involved as a project leader, we succeeded in producing an optoelectronic integrated circuit (OEIC) by integrating transistors and semiconductor lasers. This device has been widely used in optical telecommunications, but it was not something that could meet the requirements of computer system developers. For example, a single laser needed to have high output for telecommunications. However, in order to apply optoelectronics to computers it is necessary to integrate compactly multiple lasers, and the challenge is the opposite one of attaining technology to realize low output and low-power consumption.

The Optoelectronics Department started before there was a central RWC laboratory at the Tsukuba Research Center. In the research field of applying optical interconnection to systems, we had a narrow lead over the United States. For that reason, there were those on both sides of the Pacific that were saying that we should build a central research laboratory in the United States and develop device technology under a system-oriented leader; but so far we are still watching quietly. The issue will probably be resolved in another one or two years.

Japanese University Massively Parallel Processing Project (JUMPP), 7 September 1993

This report gives a description of the Japanese University Massively Parallel Processing Project (JUMPP), a US$7M-3-year project, April 1992-March 1995

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For information about JUMPP, many thanks to

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Readers of my reports will know that there are many projects on parallel computing associated with Japanese universities. But, in the past most of them have been primarily educational activities. By this I mean that they are small, often only parts of complete systems, with limited staff and budget, hence moving forward at a modest pace. To see really meaningful activities, one needs to go either to industrial laboratories or to a government laboratory such as ETL. There are certainly exceptions. For example, the QCDPAX project and its follow on CP-PACS, which is at Tsukuba University where Professor Nakazawa leads the group. This has certainly resulted in a usable system that is actually doing physics.

Japanese university professors are well aware of the difficulties. Typical research grants from the Ministry of Education (Mombusho) are very small and focused on individual, uncoordinated projects. The Japanese University Massively Parallel Processing Project (JUMPP) is an attempt to use a different model for research activity, which involves a larger project coordinated among several different universities. By United States funding standards the project is large but not huge, about Yen700M (about US$7M) over three years, April 1992 through March 1995. As Japanese university faculties are considered government employees, the budget figure above is independent of salaries. There are specific project goals, which are given below, but an unstated supplementary goal is to build a cooperative research attitude among staff at many different universities. The scientists I spoke to about JUMPP are excited by the general opportunities this provides but are also realistic about what they want to accomplish—this is clearly a research activity for the Japanese university computer science and computer systems research community rather than an industrial prototype.

The general goals of JUMPP are as follows.

- To establish a framework for general purpose massively parallel computing systems.
- To develop a total (working) system in prototype form.
- To show feasibility of new software and architectural schemes for use in massively parallel processing.

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Because the D group under Prof. Tomita is responsible for the architectural design, the informal name for the computer system that is being designed is the "D Machine."

I asked Prof. Hiraki, why, if the goal was to develop expertise on the use of parallel systems, didn't the group buy an existing parallel computer? There are two TMC CM-5s within the university system, a 32 node system at the Medical Institute of the University of Tokyo, and a 64 node system at the Japan Advanced Institute of Science and Technology (JAIST), Hoiuriku. Also, the development of the MP-1 system is being done at Tokyo University's Roppongi campus, the Institute of Industrial Science. Several Fujitsu AP-1000 systems that are available to the research community at Fujitsu are newly established parallel processing research center in Kawasaki. Hiraki explained that, given their budget, a CM-5 was simply too expensive and the AP-1000 did not have sufficiently attractive memory management capabilities for the computer scientists. But more than anything else, it was necessary to have their own project to learn on and to develop as researchers.

Although research is being emphasized, JUMPP is not a paper project. A variety of prototypes are to be built. In that sense there are real deliverables. Specific prototypes are as follows.

A prototype MPP system (D-machine) is to be delivered to Kyoto University in March 1995. A prototype operating system will run on it. In addition, several languages for MPP use (NCX, V, etc.), database, functional programming, object oriented, are to be delivered. Specific demonstration programs will also be running. These include some numerical computations, graphics, robot behavior simulation, and simulation of human behavior.

What follows is a summary of plans for the machine architecture. Thanks to Prof. Hiraki for his contribution.

The D-machine is supposed to be a general purpose massively parallel processor, designed for the university research community, which should not only be capable of dealing with applications but also acceptable to software researchers, and be a testbed for new software applications, languages, operating system concepts. Of course, it is being built to also evaluate the feasibility of a new architecture. Work is being shared by six universities: Tokyo, Kyoto, Keio, Kyushu, Kyushu Institute of Technology, and Kobe. The architecture of the project has one fourth the total budget, Yen150M, quite small. Of course, this size budget is not expected to cover the building of a full-size system, but the design is for 16K processors, and a prototype implementation of IK processors will be built. It is also expected that as much as possible latest technology will be commercially available and will be used.

The D-machine design is hierarchical; four processors constitute a cluster, and clusters are connected to an interconnection network. Within each cluster there are four RISC processors (off the shelf for coarse grained parallelism). Thus the protype to be delivered to Kyoto in 1995 will consist of 256 clusters. Each processor has an on-chip primary (level-1) cache (16KB) for speed as well as an off-chip (level-2) cache (IMB). The processors are connected by a shared bus and two memory based processors, MBP, which are custom designed for fine grained parallelism. The memory based processor is connected to a cluster memory bank that functions as a level-3 cache and main memory. Each cluster is connected to an I/O interface as well as the interconnection network via the MBP that functions as a global synchronization mechanism. This is to be a distributed shared memory system with local execution by the individual processors and nonlocal execution by the memory based processors, thus giving the system a mixture of data-driven as well as control-driven parallel processors. In keeping with the desire for applications to graphics, the network adaptor will connect to a high-resolution video input system and an HDTV display system.

The MBP, which is based on the research of Prof. T. Matsumoto (Univ. of Tokyo), is a key ingredient in making the D-machine efficient, as it provides not only memory management and data transfer between memories but consistency management, active thread control, and memory based synchronizations.

The interconnection network is also very interesting and unique. From the application side certain requirements were evident that the network should have a small diameter (few hops from one end to another) and high throughput that a variety of popular existing topologies should be easy to emulate (mech, cube, shuffle, etc), and that broadcast and multicast capability be included. Based on the research of Prof. H. Amano (Keio Univ.), a recursive diagonal torus (RDT) was selected. This allows a diameter of 8 for a 4K system and 12 for a 64K system, along with good redundancy and simple routing.

Remark: JUMPP incorporates a number of new ideas in parallel processing. The project is challenging and ambitious, but not so overwhelming as to be unfeasible. It is a good test case for the Ministry of Education to see if so many distributed university researchers can cooperate effectively while satisfying their own diverse scientific needs.

Cray User Group Conference, Kyoto, Japan, 20-23 September 1993

The 1993 (semi-annual) Cray User Group Conference, held in Kyoto, Japan, 20-23 Sept 1993, is summarized in this report.

David K. Kahaner

The Cray User Group (CUG) meets twice each year. This fall, 1993, the CUG conference was held in Kyoto, Japan, for the first time in a number of years. This is an international conference and representatives from any CUG sites can participate, but not surprisingly Japanese representatives accounted for a large portion of the approximately 200 participants. Other participants were from the United States, France, United Kingdom, Germany, Australia, Belgium, and Korea. Participation might have been even more numerous, but CUG is self supporting. Japan is an expensive country, and this was reflected in the registration fees and accommodation charges. Cray Research Inc. (CRI) was exceptionally well represented with about 75 CRI'ers in evidence from the United States, France, United Kingdom, Germany, and of course Japan. CRI is an important part of CUGs, but they are participants not organizers. Local arrangements were coordinated by Century Research Corporation (CRC) Research Institute. CRC was the first Japanese organization to obtain a Cray (XMP) at their service bureau south of Tokyo, and they are still active in selling both software and engineering services that make use of supercomputing.

As usual, at such user meetings many talks were given by members of CRI about new or enhanced products and services, and also a great many talks were given by the users about the "operational" side of supercomputing, e.g., management of resources and experiences with the latest version of various software. Attendees were especially interested to hear about CRI's new parallel machine T3D (officially announced on 27 September, 1993,) plans for the future, and other corporate activities. Tutorials were also given, "Birds of a Feather" sessions, CRI product demos, and a few posters. Most talks were well prepared, but I felt that a few lacked significant content and had clearly been put together quickly. Because of my own and my readers' interests, I focused on applications presentations, and I will limit my summary to discussion of those. The participants that I spoke with, also felt that the applications sessions were exceptionally interesting, and one among the most exciting aspects of the conference. The general feeling was that real user applications should be a major part of all CUGs.

A proceedings will be written, and readers who wish to have more information about that or related issues should contact

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A few overall summary points are worth making.

First, all the applications people from Japan that I spoke to are very interested in parallel computing. They are already sophisticated users of existing supercomputing, often for many years. However, these people are working in companies that are making products or providing services. There seemed very little enthusiasm (from them) to experiment with lines of inquiry that would not lead rapidly to results useful to their company's main business products. Definitely one got the impression that they were quite happy to have government laboratories and universities investigate new architectures and tell them when stable applications were available.

This leads to the second point. I saw relatively little interest within the Japanese applications groups toward writing code. The excitement for PVM, HPF, Fortran 90, C++, or other languages seemed to me to be rather low compared with the desire to run packaged software such as Nastran and Gaussian. Much more interest was apparent in integrating such packages smoothly into a unified computing environment than in developing new difference schemes or vectorizing/parallelizing an existing one. However there were several very interesting exceptions as noted below. I suspect that the first vendor that is able to market a parallel machine with a useful set of known applications will be the big winner. Performance and cost need to be reasonable but need not be either fastest or cheapest.

Two final points at a finer level of detail. There was a repeated complaint about the human time necessary to prepare mesh and related data for input to engineering applications. We were given examples of problems requiring a few tens of hours on a large Cray, but which required days or weeks of grid generation time beforehand. While this is an active research topic, much more needs to be done, especially as wall clock time for computation decreases with emerging parallelism.

Also, Japanese companies are producing practical engineering application packages with significant capabilities in structural analysis, thermal analysis, CFD, etc. However, there is still a heavy dependence on the use of western commercial application software, although most have Japanese language interfaces.

Detailed summaries of a few selected presentations follow

The keynote was by

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Yagawa's background is in continuum mechanics, and his group is currently using a lK NCUBE2. His talk, rather general, emphasized four future application areas for supercomputing.

1. Safety & Economics

   Including automotive collision analysis, nuclear safety, seismic design, typhoon prediction, and global warming.

2. Comfort

   Including design to quiet the inside of a car, etc.

3. Evolution/Revolution

   Including new materials such as a golf ball that can travel further, etc.

4. Realtime

   Including nuclear accident prevention, realtime typhoon and earthquake prediction, robotics, flight simulation, virtual manufacturing and the virtual factory.

He posed the question of how to perform supercomputing, and concluded that in the next decade the only way will be through parallel processing, although he included in that everything from shared memory vector processors and MPPs with hundreds or thousands of processors to workstation clusters, and noted that paralleling compilers are not mature yet.

Moving closer to his technical research area, he mentioned that work in parallel matrix computations are now giving way to domain decomposition methods and related these to network oriented algorithms that he felt were very promising. At the same time he realizes that the bottleneck is communication, therefore he urges work to be done on algorithms to reduce this. He hopes to see the ability to compute a 5M DOF nonlinear finite element analysis in about 10 hours, or perhaps 1 hour for a linear problem, and remarked that we definitely do need TFLOP computing. He is looking for automatic mesh generators for tetrahedral and hexahedral elements, and he was the first of many speakers to note that mesh generation time is often ten times computation time.

Finally, he noted that it is important to combine traditional numerical computation with what he termed AI, specifically fuzzy, neural, and genetic algorithms. I liked this comment because it reflects my own opinion that these aspects of computation are (relatively) more emphasized in Japan than in the West.

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The Institute for Fluid Science (IFS) is composed of 12 research groups in addition to the Shock Wave Research (SWR) Center, and of course, Tohoku's large supercomputer center. Professor Takayama presented an overview of shock wave research at SWR, which he runs. Work there is about 70% basic research. He only mentioned two projects going on in this research: hypervelocity impact studies, and inertial confinement related to the interface between shocks and gas.

In the area of applied research Takayama mentioned three major problems.

- Blast wave associated with volcanic eruptions.
- Extracorporeal shock wave lithotripsy (ESWL) used to decompose kidney and gallstones.
- Tunnel-exit sonic booms caused by high speed trains in tunnels.

In this context Takayama mentioned that Japan's Shinkansen (bullet train) projects cost, roughly, as much as the U.S. Apollo Project; listeners were left to form their own impression about comparative societal value.

Takayama felt that 2-D shock problems can be computed (most of us would agree), but there is still much to be done about 3-D, including a great deal of not-yet-understood physics. For the future, he wants SWR to focus on 3-D shock wave flow by combining supercomputer computations with real experimental data taken from optical measurements, perhaps in real time (I have not heard about similar work in this area before.)

There were several networking presentations, including one about the Japanese NREN (National Research and Educational Network) by Mr. Sugihara (SUGIHARA@CRAY.COM) and another about the KREONET, the Korean Research and Educational Network by Mr. Kisong Yoon. Most of this material was not new to me except for updates, and has already been covered in earlier reports, see for example, "inet.92", 26 June 1992; "japan.net", 16 July 1992; "isdn.93", 25 Feb 1993; and "ntt-r-d.993", 19 Sept; among others for Japan, and "korea.392", 13 Mar 1992. The main networking emphasis in Japan is the move toward ISDN, which has been discussed here several times. (CUG's venue, the Kyoto International Conference Center, was amply supplied with 64 Kbps ISDN public telephones.) Sugihara made several interesting contrasts between the United States and Japan which are worth repeating.

High speed networking testbeds: US-five sites, Japan-NTT only
Products: US-LAN oriented, emphasizing switches from Japan
Attitude: US-software and marketing, Japan-hardware
Industry: US-technical ventures, standardization, Japan-big companies follow standards, but each company does everything by itself

With respect to Korea, I was interested to hear that now about 60 institutions are connected to the backbone hierarchical KREONET, that currently independent research and educational networks will probably be combined, that a 128 Kbps link to the EC will be connected soon, that a metro-area network in the science town of Daeduk is planned for 1994 and connected by a T-3 line to Seoul, and that there are plans for some kind of supercomputer network.

Associated with the last comment, there was also a presentation by

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on the status of supercomputing in Korea. There are a total of six supercomputers (Cray Y-MPs) in Korea (Kia Motors, Hyundai Motors, Samsung, SERI, Kyeong-buk University, and one associated with the Korean military.) The country could benefit from more high- performance computing resources, but networking and telecommunication infrastructure are also very important. SERI was the first to purchase a Cray-2 in 1988. (This is now going to be replaced by a 16 processor C-90.) Kia and Hyundai obtained machines after getting experience at SERI. Kia's is used mostly for crash simulation; Samsung's has been used for semiconductor design but more recently is also being used for automotive design. SERI's machine is heavily used for mechanical engineering and CFD (37%), followed by chemistry (22%), physics (7%), production engineering (6%), and weather (3%). Miscellaneous computing occupies the remaining 25% of cpu time. There are about 325 user accounts from 60 organizations including 27 universities, 14 research institutes, and 16 companies.

As mentioned, the C-90 will replace the Cray-2 in Nov 1993. During the subsequent two years an effort will be made to install a scientific visualization system and high-speed networks including a HIPPI channel. At the end of this period some MPP will be purchased. In response to my question, Mr. Choi acknowledged that although there are several MPP projects in Korea, these are all prototypes. Currently a MasPar is on loan to SERI for studying and for benchmarking.

I see many similarities between SERI's activities and those at the National Center for High Performance Computing in Taiwan (see report, "nchc.93", 28 April 1993). Both have a lead role in educating scientists on the use of supercomputing in their countries. Both have very pragmatically resisted any temptation to build a new computer or even design new system software, and will instead concentrate on providing resources, both cycles and application expertise for the engineering and science communities.

In terms of general purpose software two presentations standout

Ms. Kunie Shimada from Toshiba described a new 3D FFT done in what looks like an obvious way, making a n^3 long l-D array. The 3-D FFT can be done with a single l-D FFT and two matrix transpositions. Although there is no way to reduce the absolute number of multiplications, it does effectively increase the array lengths, and thus on a vector machine like a Y-MP this can significantly reduce execution time. Shimada presented run times of 1/l0th, 1/15th that of IMSL and even 1/4th that of CRI's SCILIB for short vectors, with no examples requiring more time.

This seems very appropriate for certain kinds of partitioned problems. Even the CRI staff were impressed. As one key software person told me, "why didn't I think of it?"

CRI's Qasim Sheikh (QSQCRAY.COM) gave a presentation (third in an ongoing series) related to iterative solvers, based on fundamental research by Alex Yeremin and colleagues at the Institute of Numerical Linear Algebra of the Russian Academy of Science. The approach here is to discredit boundary integral equations and then take advantage of knowledge about both the matrix structure as well as the desire to solve problems with more than one right hand side. There were more general applications too, but it was impossible for me to evaluate these from Sheikh's overview. Nevertheless, he presented some astonishing performance figures including a 100 fold speedup over LAPACK on a 20 K system in ship-hull free surface interactions, and predicts that existing computers will be able to handle dense systems of over 100 K and perhaps even as large as 300 K. Work on this topic is one of CRI's submissions for the 1993 Gordon Bell Prize, which will be presented at Supercomputing 1993 in November. The results certainly appear to be very impressive.

Papers were given by representatives from three automotive companies; Daihatsu, Mazda, and Nissan. Work varied from CFD for aerodynamic analysis, CFD inside engines, and crash simulation. The auto industry has been an early and enthusiastic user of supercomputing, so it isn't surprising that the level of science there is quite high. As sales of Japanese cars drop (from 13M to 12M to llM and below) it will clearly be more important than ever to reduce costs by shortening cycles, performing additional simulations, etc.

Mr. Yoshida from Daihatsu described tests of several difference schemes to model air flow inside cylinders and to redesign intake/exhaust to achieve better mixing. He concluded that the so-called "smart" difference scheme, while producing a little more accuracy, was also much slower, and hence not practical compared to a hybrid (lst & 2nd order) scheme. He also described work on a grid generation package that has reduced preparation time from five to two days.

Mr. Takiguchi from Mazda surveyed activities at his company. Mazda produces about 1.3M vehicles at its Hiroshima plant (17 automotive and 7 commercial models) based on three engine types. Research is done at four R&D centers (a large center in Yokohama, two in the United States and one in Germany). The company has three supercomputers, two Cray Y-MPs and a NEC SX-2A. One of the Crays is used exclusively for crash analysis (PAM_CRASH, MADYMO, etc), the second for structural analysis and some crash simulation, while the NEC is primarily for aerodynamic analysis. For example, a 2M grid point problem now takes about 20 CPU hours, and the company's goal is to reduce this an order of magnitude or more. Grid generation is also very troubling, now taking from 1 to 40 days. Again, with preprocessing, it is hoped that this can be reduced to a maximum of about 10 days. Postprocessing of simulation/analysis output now takes 1 to 2 days, and a goal is to get this down to a few hours. Generally speaking, CAE applications fall in the following categories, among others.

- Crash analysis
- Aerodynamics
- Structural analysis
- Noise and vibration analysis
- Heating
- Kinematics
- Injection shielding

the first being the most important. Currently there is a great deal of simulation of side-impact crashes. New areas of interest are related to fuel savings, for example weight and drag coefficient reduction and combustion efficiency. Workstation usage is growing very rapidly and there is interest in parallel computation, but for the latter only if commercial software is available.

Mr. Himeno from Nissan spent most of his time discussing air flow simulation around car bodies. Much of this appeared fairly standard, but Himeno commented that Nissan's 240 SX was the first automotive model to use CFD airflow simulation to replace much of the traditional wind tunnel testing. He also showed a video. Because of the very high quality rendering and tape length (15 minutes or more) everyone (including normally jaded experts from western laboratories) was extremely impressed by the quality and the amount of computer time required. Himeno graciously gave me a copy of this tape, and I will lend it to interested readers.

In a somewhat surprising paper, Yoshinari Fukui, also from Toshiba, discussed the possibility of using a simulation language, such as ACSL, on a parallel machine for solving transient analysis problems, e.g., initial value problems for ordinary differential equations. His argument was that the syntax of these languages allows more natural parallelization of physical problems than more traditional languages such as Fortran. Typical modular software separates integration and model description (the latter refers to evaluation of the right hand sides of the equations) with the integration of the easier part to vectorize. ACSL or its equivalent is claimed to make the model calculation easy to parallelize. Fukui has credibility as he has produced one of the most highly vectorized and efficient versions of SPICE.

Among newly developed software packages three from CRC are specially worth noting.

- MAGNA/FIM, an electromagnetic field analysis calculation package that combines finite elements and boundary integral equations (hence the acronym, finite integral method) and is used by 170 companies.

- HEARTS, a finite element package for temperature, metallic structure, and stress/strain in heat treatment processes, which is said to be especially useful for phase transformations, deformation, quenched parts, etc. The algorithm is based on theoretical work of Bathe at MIT and Inoue at Kyoto University. CRC has developed a Fortran 77 package with 35K lines and 200 subroutines. One specific application mentioned was modelling the transition of austenite to pearlite to martensite in molten steel.

- MANJUSRI-3D, for space debris hypervelocity impact simulation onto perforating bumper plates. The author discusses the issue of mesh distortions and techniques that he experimented with to stabilize Lagrangian computational meshes, including adding artificial "antitangle" forces, ALE (arbitrary Lagrangian and Eulerian mesh), etc. He is interested in shock heating and resulting vaporization. While acknowledging the importance of the topic, I was a little surprised to see CRC working on such a code, but the author commented that they are selling software services.

Finally, modifications to the GSMAC-FEM package (generalized simplified marker and cell FEM) from Nippon Sheet Glass for unsteady incompressible viscous flow analysis. The application here (a very nice one too) is to model the cooling of molten glass that needs to be perfectly flat to be useful in flat panel displays. The company has also developed an automatic mesh generator.

NINETEENTH SYMPOSIUM ON NAVAL HYDRODYNAMICS

Latest in the series, the Nineteenth Symposium on Naval Hydrodynamics was held in Seoul, Korea from 23 to 28 August 1992

Edwin P. Rood and James A. Fein

The Nineteenth Symposium on Naval Hydrodynamics was held in Seoul, Korea, 23-28 August 1992. This is the latest symposium in the series and was organized by Dr. Edwin P. Rood, Office of Naval Research; Mr. Lee M. Hunt, National Research Council Naval Studies Board; and Prof. Jong Heul Hwang, the Society of Naval Architects of Korea, Seoul National University. The series of symposia was established in 1956 as an international forum for the exchange of ideas and research results in the field of ship hydrodynamics and in related fields of fluid dynamics. During the past three and a half decades, the series has become *the* premier international meeting in this field of research. The Symposium is held every two years alternately in the United States and one of the several countries heavily involved in hydrodynamics research.

The Nineteenth Symposium was attended by 205 participants from the United States and from 12 countries in Europe and the Far East. A total of 48 papers were presented and discussed. The preprints of the papers and the discussions and replies are in the process of being edited before their publication as Proceedings of the Nineteenth Symposium on Naval Hydrodynamics. This report highlights the information, presented in the papers, that is sufficiently important for the advancement of predictive capability and that warrants broad dissemination.

The technical sessions were divided into seven topical areas

- nonlinear ship motions,
- viscous ship hydrodynamics,
- hydrodynamics in ship design,
- wave/wake dynamics,
- cavitation and bubbly flows,
- propulsion hydrodynamics/hydroacoustics, and
- frontier experimental techniques.

Because of the large number of papers submitted to the symposium, those papers that contained only numerical techniques without a discussion of comparison to physical observation or of useability in an application were referred to the Sixth Conference on Numerical Ship Hydrodynamics held at the University of Iowa, Iowa City, Iowa, USA in August 1993. Collectively, the papers provide state-of-the-art understanding of results from physical experiments in naval hydrodynamics. Because the symposium did not directly address numerical techniques, the papers are not a comprehensive state-of-the-art collection for computational fluid dynamics. They are, however, representative of the state-of-the-art of the application of computational methods to the prediction of ship hydrodynamics.

As reported at the symposium, experiments that used model ships have demonstrated that previous numerical predictions of nonlinear motions were qualitatively accurate. A. Nayfeh presented towing tank measurements that showed the conditions under which coupled pitch and heave motions produced by head and stern seas lead to excitations in roll. These results demonstrate that nonlinear interactions between degrees of freedom can cause energy to flow from one motion to another. J.F. O'Dea, et al., presented additional towing tank measurements showing that the acceleration response of a model ship experiencing either very low or very high encounter frequencies is dominated by cubic effects. In this case, the nonlinearity is in the amplitude of the primary motion. Together, these two papers empirically document conditions under which nonlinearities in mode and/or amplitude should be expected. The significant finding is that nonlinear ship motions may be sufficiently important that they need to be included in design criteria.

These experiments were complemented by several papers reporting on efforts to develop numerical methods to predict ship motions. Two of the papers are of special note, one by B. Maskew and the other by J. Pawlonski. These papers, discussed below, show that advanced numerical prediction capability for ship motions has reached a high level of sophistication.

Time-domain panel codes for potential flow predictions of a surface-piercing body were shown by B. Maskew to be almost routine calculations in spite of the flow complexity and the required computational resources. The paper presented results for flare variations and modelled the effects of deck wetness. Nonlinear free-surface effects and the interference of the towing tank are also included in the calculations. The prediction method includes some provision for boundary layer calculations and the convection of the wake. Maskew summarizes his paper as follows: "Encouraging progress on the development of a general nonlinear numerical method for wave/hull interaction problems is presented. [Validation data] presented here for a sphere case in large amplitude motion is in good agreement with published results, at least for the first harmonic loads. Discrepancies in the . . . higher harmonics will be investigated as the study proceeds. Initial results for a frigate application in large amplitude motion and in the presence of large amplitude wave encounters look promising for future stages of the ongoing study aimed at comparisons with experimental data on the model in steep head waves." Maskew clearly demonstrated the importance of computer graphics and numerical flow visualization to communicate the results from flow studies involving complex geometries. The data were presented as real-time video displays of the time-dependent motions of the ship and the water.

J. Pawlonwski, in the other paper, showed that the analytic formulation of nonlinear boundary value problems of ship hydrodynamics has been brought to an advanced stage, where all the variations for specific conditions can be derived from one systematic formulation. Various approximations to the formulation permit solutions for specific conditions. The constraints are in the perturbation solutions and the weak scatterer hypothesis that are applied to the solution of the formulated problem. The technique is particularly suited for computations on small computers and gives reasonable results.

The two papers by Maskew and Pawlonwski represent the state-of-the-art for mostly inviscid ship hydrodynamics. On the one hand there is an advanced computationally intensive numerical approach, and on the other hand a sophisticated analytic/numerical approach suitable for low-cost implementation on a personal computer.

J.H. Park and A.W. Troesch discussed the numerical stability involved with predictions of motions for non-wallsided bodies. The problem presented by the logarithmic singularity at the water-hull intersection is described as having global effect on numerical computations. Linear stability analysis is shown to be an appropriate basis for the investigation of nonlinear stabilities. It is concluded that the linear stability estimate is good for obtaining stable discretization in numerical computations.

The papers on viscous ship hydrodynamics revealed an advanced level of capability for numerical predictions of the flow around ships. S. Abdallah, et al. presented turbulent flow predictions for double-hull configurations (rigid full-slip water surface); however, the technique has yet to be empirically validated. Fully nonlinear laminar free-surface flow predictions are routinely made for two-dimensional (2-D) surface-piercing bodies (R. Yeung and P. Ananthakrishnan; M.-S. Shin, et al.), but they have yet to predict three-dimensional (3-D) flow. The application to 3-D bodies, which produce surface-normal vorticity, in the laminar flow case, and the incorporation of free-surface turbulence models for any conditions remain the primary challenges. The inclusion of turbulence models modified to account for wall conditions by a two-layer approximation is apparently satisfactory for some complex vortical flows (W.J. Kim and V.C. Patel) but the computations have not been shown to be valid for more general flows such as the flow around a ship.

The papers on hydrodynamics of ship design demonstrated the usefulness of supercomputers in the design process where the complicated flow detail around ships is required to be known. The new computer programs are very sophisticated in the representation of complex geometry, the incorporation of full nonlinear effects of the free-surface, and the suitability of turbulence models to reproduce the viscous features of the flow. However, the levels of sophistication are not equally distributed among the various components of any one computer program, and there is no single computer program that includes appropriate representation of all aspects of the ship hydrodynamics problem including the nonlinear free-surface, the turbulent flow, the hull, and the propeller. Inviscid predictions (H. Raven) capture nonlinear free-surface features, but do not include the important effects of turbulence. Turbulence is qualitatively included (S. Ju and V.C. Patel) in some computer programs, but the presence of the free-surface is not. Complex geometries are described in detail to capture the flow interactions (C.-W. Lin, et al.), but the hydrodynamics is not adequately included. As a result, new nonconventional ship designs (K.S. Min) rely on traditional design methods based on an empirical database supported by crude approximations for flow coefficients and geometry representation such as polynomial fits to the hull.

The conclusion drawn from these papers is that the naval architecture field has yet to incorporate the various pieces of a surface ship hydrodynamics prediction method into one computer code, although the pieces exist. Certainly there is a problem in that the applications side of the field has proprietary interest in protecting any such computer programs that exist, but the gap between newly emerged techniques and the use of these techniques in technology is wide. This statement does not indicate that the flow around surface ships has been solved. Clearly matters of turbulence modelling and grid generation for complex geometry, a deforming free-surface, and the inclusion of time dependence remain formidable challenges. However, there is substantial capability available to develop a computer code for application and to guide future research into the aspects that most need investigation.

The papers on wave/wake dynamics were the most fundamental from a fluid dynamics perspective. Turbulent free-surface wakes were studied in several papers. This topic is an exciting relatively new research area for ship hydrodynamics. Research in this area is motivated by remote sensing problems for which an understanding of the underlying free-surface hydrodynamics is required. Research interest in this difficult area has been stimulated by new capabilities in numerical and physical experiments. Investigations are underway to understand the role of the nonlinear turbulent free surface around a ship in determining the vehicle motions and the effective wake inflow to the propulsor. The fundamental mechanism underlying vortex interactions with a free-surface is the "disconnection" event. An archival experiment documenting the phenomena is the collision of a vortex ring with the free surface (M. Song and G. Tryggvason). This interaction exhibits primary vortex disconnection as well as the secondary vorticity effects arising from surface tension gradients. The mechanism of disconnection is experimentally defined (M. Gharib, et al.) to consist of both vorticity flux, associated with free-surface acceleration, and diffusion to secondary flow. These laminar flows define the fundamental mechanism of vortex disconnection, which is to free-surface turbulence as hairpin vortex generation is to no-slip boundary layers.

A naval need in wave/wake dynamics is to understand free-surface turbulence, including the full spectrum of vorticity scales from the large eddies observed by eye to the small scales making up the dissipation. A turbulent tip vortex interacting with the free-surface is a generic flow that contains both the deterministic features of a primary vortex as well as the chaotic eddies characteristic of turbulence. T. Sarpkaya showed that the interactions of a turbulent vortex and a free surface produce multiple disconnections of the secondary vorticity, and that the disconnection events produce an apparent 2-D turbulence at the free surface joined to a 3-D turbulence beneath the free surface. This finding may have important consequences for a turbulence model that must address both the decay of 3-D turbulence and the growth by amalgamation of 2-D turbulence. An investigation of a more complex free-surface turbulent flow was made using measurements of the features of a free-surface jet (D. Anthony, et al.). It was found that the turbulence is characterized by an outward surface current at low Froude numbers, and that the surface current diminished at high Froude number, in which case the vortex structures were observed to distort the free-surface to produce waves. This investigation indicates that the turbulence Froude number may be important in scaling turbulent wakes.

Other papers addressing wave/wake interactions considered inviscid, irrotational flows approximating the effects of vortex interactions with waves, the generation of inner-angle wave packets for a Kelvin wave system attributed to ship motions, and the effect of wave-making by a large object in a narrow tank. These papers demonstrated the continuing usefulness of potential flow approximations for solving real problems, to which viscous flow effects are secondary and can be neglected.

Several papers reported on experimental and computational investigations of cavitation inception, bubble dynamics, and acoustics from bubble collapse. The investigations studied the details of viscous effects, bubble fission, and bubble interaction for inception and for noise production. For the flow cases studied, the understanding of the complexities of the flow led to the observation that the inclusion of details in the models of inception and noise would produce less conservative estimates than obtained by simple approximations (Y. Kuhn de Chizelle, et al.; D. Furman, et al.; G. Chahine, et al.). This conclusion seems to indicate that design estimates for inception and noise production may safely use current techniques, but that more understanding of the mechanisms is required if methods are to be devised to control cavitation. A model predicting broadband noise produced by the collapse of sheet cavitation has been developed (J. Matusiak) using existing empiricism and intuitive techniques. The calibrated predictions were observed to agree with the experimental data. The method is remarkable for its systematic incorporation of several mechanisms occurring simultaneously in this complex flow.

Numerical methods to predict the unsteady loads on marine propellers continue to achieve higher levels of sophistication as more physics are included in the problem. Turbulence ingestion (C.W. Jiang, et al.) has been shown through correlation analysis to contribute to a broadband background as well as to low- frequency blade-rate humps in the force spectrum for a propeller. This numerical investigation is a very sophisticated approach to understanding the role of turbulence in blade and shaft forces. Viscous flow predictions are now being routinely made for propellers (K. Kaoyama), although problems with turbulence models and gridding remain challenges to practicality. Unsteady cavitation (S. Kinnas and N. Fine) and lift (G.Q. Wang, et al.) are also routinely calculated using boundary element and vortex lattice methods. Panel methods have been improved to include the thickness of the blade in the calculations. As these numerical methods reach new levels of sophistication, there is a need to provide equally sophisticated physical measurements on propellers to validate and guide the numerical research. There was no reported effort to obtain physical measurements. It is anticipated that in the future results will be reported of experiments underway with an unsteady lifting surface (J. Kerwin) at MIT for validation of time-dependent Reynolds Averaged Navier-Stokes computer programs.

New particle image velocimetry measurement techniques (Fu, et al.) that capture the instantaneous flow in a plane were described. This capability is important because, for example, it permits the measurement of vorticity and vortices in situations where the core of the vortex meanders. The paper reports on the use of PIV to understand the vortices associated by maneuvering bodies in which it is desired to control the downstream evolution of the vortices and their interaction with a solid structure. The development of "whole flow field" measurement techniques has taken a giant stride forward with the advent of advanced computers that permit on-site high-volume high-speed data acquisition and analysis.

A general conclusion from the symposium is that supercomputers are permitting very rapid advances in computational ship hydrodynamics, and that new measurement techniques are permitting insights into detailed flow structure. There is movement toward truly complementary physical and numerical investigations.

The proceedings of the symposium are being published by the National Academy of Science. Each conference registrant will receive a copy, as will selected institutions. A limited number of additional copies will be available for distribution to other institutions involved in ship hydrodynamics who submit a written request to the National Academy of Science, Naval Studies Board, 2101 Constitution Ave., Washington DC 20418 ATTN: Susan Campbell.

There seems to be a worldwide movement toward a computational capability for the turbulent wavy free-surface flow around a ship. The current efforts are directed toward integration of such separate computational capabilities as grid generation and deformable free surfaces. Apparently there is minimal effort underway to develop turbulence models accounting for the anisotropy in the flow along the ship hull and at the free-surface. Such phenomena as breaking waves have yet to be incorporated in ship hydrodynamics. In the United States there is emphasis on the physics of the flow whereas in other countries the emphasis seems to have turned to applications for commercial advantage.

An impression derived from the symposium is that the foreign commercial sectors are not providing funding for basic research, and that only a small amount of basic research is sponsored by the universities. The United States seems to be the leader in basic research. However, there are "pockets" of good specialized research underway in other countries which are important complements for the research in the United States. The CFD Workshop SRI 1994 to be held in Tokyo, 22-24 March 1994, will provide an important measure of the state of ship computational hydrodynamics. This workshop has focussed an international effort on the prediction of turbulent wavy free-surface flow around surface ships. The results of the various computational efforts will be discussed along with the problems associated with basic flow studies in general.

Edwin P. Rood is the Program Manager (Acting) for the ONR Fluid Dynamics Program. Dr. Rood is responsible for sponsored research in the areas of ship hydrodynamics, hydroacoustics, and wake/ocean interactions. He received his B.S. (1968) and M.S. (1971) degrees in physics from Virginia Polytechnic Institute and from American University. In 1984, following a long period in the applied research environment at the David Taylor Model Basin, he received his Ph.D. in fluid mechanics from Catholic University. Prior to joining ONR in 1987, Dr. Rood was head of the Special Systems Branch at the David Taylor Model Basin.

James A. Fein graduated from the University of Michigan in 1969 with a B.S.E. in Engineering Mechanics and obtained an M.S.E. in Mechanical Engineering from the University of Maryland in 1972. He was employed from 1969 to 1988 at the David Taylor Model Basin where he specialized in the dynamics of advanced ships such as air cushion vehicles and SWATH. During 1984-1985 he was detailed to the Office of the Assistant Secretary of the Navy (Research, Engineering and Systems) in the Research and Advanced Technology Office. Since 1988 he has been the Program Manager for Applied Hydrodynamics at ONR.

OCEAN DISPOSAL OF CARBON DIOXIDE

The Second International Workshop on Interaction between C02 and Ocean 1-2 June 1993, Tsukuba Center of Institutes, Tsukuba, Japan

Difficult economic questions were asked about energy costs of disposal as well as difficult scientific and engineering considerations were posed on the validity and feasibility of proposed disposal techniques. Progress is needed in the understanding of the carbonate system, with a liquid phase, interacting with natural marine bottom sediments and their impacts on the resident biota. Much work must be done to truly evaluate the feasibility and the desirability of this concept. However, a good start has been made on an international scale.

Pat Wilde

INTRODUCTION

The international concern over the environment and "Global Warming" in particular has lead the Central Research Institute of the Electric Power Industry (CRIEPI) of Japan to consider a variety of strategies to ameliorate the environmental consequences of power generation by fossil fuels. As the "Global Warming" issue is based on the projected rise in the level of carbon dioxide gas in the atmosphere, and the consequent greenhouse effect rise in global atmospheric temperatures, CRIEPI has focused on ways to reduce carbon dioxide emissions to the atmosphere by power plants. Scrubbing carbon dioxide from the stack emissions, an obvious primary solution, creates the secondary problem of disposal of the residual carbon dioxide to prevent it from reentering the atmosphere. Natural sinks for carbon dioxide involving biological processes include plant material produced by photosynthesis as calcium carbonate seen in vast limestone deposits and as coral reefs. There are programs in Japan to investigate both enhanced biological storage as plant material and in coral reefs. This type of "storage" involves biological growth or farming and may be energy intensive enough to negate any storage benefit.

One proposed inorganic solution is to store carbon dioxide in the ocean directly in some quasi-stable form. Ocean disposal is apparently attractive, as

- the ocean at depth is vastly undersaturated with respect to calcium carbonate and
- deep and intermediate circulation in the ocean is slow that even if the stored carbon dioxide escapes, it will not reach the atmosphere for hundreds to thousands of years.

Accordingly, CRIEPI and other agencies are sponsoring various research programs investigating the feasibility and consequences of direct ocean disposal of carbon dioxide.

The first workshop specifically related to carbon dioxide disposal in the ocean was held in Amsterdam in March 1991, proceedings will be published by Elsevier; it focused on the physical - chemistry of the carbon dioxide water system. This second workshop focused on the interaction of the carbon dioxide system with the ocean, including environmental concerns. The program was organized by CRIEPI, with the co-operation of the Geological Society of Japan, the Japan Society of Energy and Resources, the Japan Society of Environmental Science, the Chemical Society of Japan, the Ecological Society of Japan, the Geochemical Society of Japan, the Meteorological Society of Japan and the Oceanographical Society of Japan, it is a status report on the ongoing international research in ocean disposal of carbon dioxide. Eleven technical papers and 11 comment presentations, in English, were presented on the topics of

- Direct ocean disposal (3 papers, 2 comments);
- Technical aspects (3 papers, 4 comments);
- Physicochemical Properties of the Carbon dioxide-seawater system (3 papers, 3 comments); and
- Deep-sea Biological Activity and Environmental Concerns (2 papers 1 comment).

Speakers were from

- Japan (14),
- United States (4),
- Australia (1),
- Canada (1),
- Norway (1), and
- United Kingdom (1).

OVERVIEW OF DIRECT OCEAN DISPOSAL OF CARBON DIOXIDE

The lead-off paper was on "Disposal Options in View of Geochemical Cycle of Carbon Dioxide" given by Dr. Takashi Ohsumi (CRIEPI, Japan), who was the chief organizer of the conference. The discussion centered on natural analog of carbon dioxide flux that are disposal of from carbon dioxide commercial wells and natural carbon dioxide emanations from volcanoes. Reinjection into rock storage aquifers poses the safety problem of overpressure related explosions. The natural analog was the outgassing of Lake Nyos in Africa in 1986 resulting in 1700 deaths. The geochemical cycling of carbon dioxide has been combined with other elements in the BLAG (Berner, Lasaga, and Garrels) model that relates the ocean, atmosphere, land reservoirs of C, S, O, Ca, and Si and their various common mineral phases. The disposal pathway for C as carbon dioxide involves carbonate species and the ultimate mineral phase calcium carbonate with an intermediate "weathering" step of the reaction of carbon dioxide with calcium silicate producing calcium carbonate and silica. For ocean disposal, reaction with the water column would involve the carbonate species. However, if the disposed carbon dioxide is as a "heavy" or bottom sitting clathrate or liquid carbon dioxide or in a sub-bottom aquifer, the weathering reaction with the sediments could occur. The question to be answered, besides safety, is the residence time with, obviously, a long cycling time preferred. Geologic residence times for the carbonate system are

- tens to hundreds of years for land based aquifers;
- hundreds to thousands of the years for the deep ocean water column;
- up to millions of years in geologic rock sinks.

W. G. Ormerod (coauthors: I.C. Webster, H. Audus and P.W.F. Riemer), of the IEA (International Energy Agency) Greenhouse Gas Research and Development Programme at Cheltenham, Gloucestershire, United Kingdom spoke on "Developing the Concept of Ocean Disposal of C02 within the Framework of an International Agreement." He discussed the initial three-year program on mitigation strategies of the effects of carbon dioxide emissions for all options, not just ocean disposal. This program is sponsored by 15 countries, chiefly European, but also the United States, Canada, Australia, and Japan. The concept now is to evaluate the total fuel cycle not just that from burning. That is to consider such inputs as methane release during mining operations. A major goal of the study is to assess the cost of carbon dioxide removal in terms of a new total energy cost. The problem is that it takes energy to dispose of carbon dioxide that, in turn, generates carbon dioxide. One such energy intensive process is compression of the gas to a liquid for pipeline transport to the disposal site. Estimated disposal costs for various options are:

- Ocean Disposal, for 100 km pipeline and injection at 500 m in the ocean: $5/ton Carbon;
- Terrestrial Disposal, solidification: $45/t C;
- Aquifers: $79/t C;
- Exhausted Gas Wells, on shore: $14/t C;
- Exhausted Oil Wells, on shore: $14/t C;
- Enhanced Oil Recovery: $0/t C;
- Global Forest Management, no capture: $3.5/t C.

However if the total energy costs (scrubbing, compression etc.) are included values as high as $282/t C can be expected. Ocean disposal appears to be one of the least expensive options given no cost delivery of the liquified gas. It is clear that the economics of the total fuel cycle with treatment and disposal costs must be considered to get realistic figures on the impact of carbon dioxide removal on energy costs to the consumer.

C.S. Wong (coauthor R. Matear) of the Institute of Ocean Sciences, Canada, discussed "Fate and Effects of Disposed C02 for Scenarios in the North Pacific Ocean." They proposed four criteria for the evaluation of ocean disposal sites:

1. High dilution capacity;
2. Amount of acid neutralizing (buffering) sediments (chiefly calcium carbonate oozes);
3. Isolation
4. Long residence time of the water mass to extend recirculation time to the surface.

The North Pacific generally meets these criteria, except for the low amounts of neutralizing sediments there. For disposal below 3000 m, 0.25 Gt of Carbon per year would be acceptable in the North Pacific. For special cases and higher quantities, basin with carbonate sediment such as the Philippine, Caroline in the Western Pacific, and the Guatemala Basin in the Eastern Pacific are suggested. Basins with depths below 3000 m are found in the Subarctic in the Sea of Okhotsk and in the Bering Sea. Outside the Pacific, the Arctic Basin, although it does not have the carbonate sediments, it has long residence times, stratified water column, and high capacity due to cold temperatures. A model study using the Hamburg-Broecker five layer box model suggests that disposal of 0.25 Gt carbon per year for 200 years into the North Pacific deep waters would not affect the atmospheric content of carbon dioxide.

Two general comments followed the main presentations. C. Goyer of Woods Hole gave a brief description of the Monterey Bay Aquarium Research Institute (MBARI) carbon dioxide sensing buoy deployed off Central California. At that site preliminary results show absorption of carbon dioxide from the atmosphere. It is suggested that more such buoys should be deployed to get some real values on the geographical capacity of the upper ocean to exchange carbon dioxide. The present theoretical models have no real time series or geographical coverage. N. Suginohara of the University of Tokyo described briefly a circulation model of North Pacific Intermediate Waters that is different from the Stommel-Arons model. This model showed a short 80-year resident time for this water mass.

An open discussion followed, and several legal and procedural points were explored. First, what are the rules governing Ocean dumping (London Convention on Ocean Dumping)? Second, to whom would you submit a dumping permit request? There seems to be no definitive answer to these questions given the nebulous status of "International Law" and no generally agreed to "Law of the Sea" treaty.

TECHNICAL ASPECTS

This session was chaired by K Yamada of the University of Tokyo.

P. Haugan, coauthor H. Drange, of the Nansen Environmental & Remote Sensing Center, Norway, presented a paper on "Disposal Options in View of Ocean Circulation." The discussion in the paper summarized existing model approaches and previous attempts to evaluate the oceanic carbon cycle. The procedures here focused on the Hamburg circulation model and the Broecker world ocean conveyer belt concept of carbon dioxide flux. For disposal, one must consider the problem of "neutral surfaces" compared with potential density profiles. Another consideration is vertical diffusivity. Accordingly, they suggest that disposal should be below the maximum depth of surface convection (avoid areas of strong upwelling), and site on abyssal plains should be preferred to more rugged bathymetries.

This paper was followed by a comment by K. Cole of the Science Applications International of Seattle, Washington. She discussed modelling of carbonate clathrates noting clathrate formation about carbon dioxide bubbles. As expected they noted a large change in outgassing with depth (pressure).

Eric E. Adams (coauthors: D. Golomb, University of Massachusetts, and X.Y. Zhang and H.J. Herzog, Massachusetts Institute of Technology, gave an engineering discussion on "Confined Release of C02 into the Ocean" based on their extensive laboratory and modeling studies of discharge plumes and discharge orifices. Basically, he proposed that the optimum design for discharge was for a confined release into a specially designed chamber. Inside the chamber the effluent carbon dioxide was cleverly mixed with seawater via a manifold to produce a clathrate seawater mixture that is denser than seawater. This mixture is then discharged and will continue down slope until it finds its neutral density within the water column. Such a system, if deployed in a confining canyon can greatly reduce the cost of the effluent pipeline. As noted above, discharge depths below 3000 m are considered optimal. However, the cost of a pipeline to such depth is astronomically expensive and may not even be technically feasible at this time.

"Technical View on CO Transportation and Dispersion at Intermediate Depths" was presented by N. Nakashiki (Coauthors T. Ohsumi (CRIEPI), M. Ozaki and Y. Suetake (Mitsubishi Heavy Industries Ltd.). This paper outlined the various innovative schemes proposed by the Japanese researchers to transport and dispose liquid carbon dioxide derived from burning. He evaluated, from best to worst, various discharge configurations from a transporting ship including

(1) floating pipe;
(2) pipe from a semi-submersible;
(3) pipes from an injection ship; and
(4) pipe from a tension leg platform.

Discharge strategies for liquid carbon dioxide, were also evaluated. They concluded that the best method was by spraying into seawater at depth or scattering by towing the discharge pipe. A possible technique would be to dilute at a barge at the discharge site. Less acceptable to unacceptable would be dilution at the site through either eductor orifice or a screw type orifice. An unacceptable method would be dilution on land before transporting to sea. The volumes required are too large for economical transport to the disposal site.

Y. Kobayashi of Nagoya University gave a brief comment on a survey of storage of carbon dioxide as a solid (dry ice). He noted that liquid carbon dioxide is both sterile and anaerobic so that bottom organisms certainly would be affected if liquid carbon dioxide remained on the seafloor. This comment was followed by a discussion on the use of models by P.C. Lund, who is a visiting scientist at the National Institute for Materials and Chemical Research, Japan.

PHYSICOCHEMICAL PROPERTIES OF CARBON DIOXIDE-SEAWATER SYSTEM

This session was chaired by H. Sakai, Yamagata University.

The first paper of this session was by M. W. Wadsley, Monash University, Australia, on the "Thermodynamics of Multiphase Equilibria in the C02 - Seawater System." This paper was a detailed discussion of the phase equilibria in the C02-Water system. Much of the initial work on the system was the result of studies for enhanced oil recovery technology and is found in the chemical engineering literature. The pure system has been studied extensively. However, Professor Wadsley suggests that there is much to be learned from the possible associated mineral phases that do not occur in the hydrocarbon systems, but occur as bottom sediments at proposed disposal sites. He indicates that there may be significant stability fields for sodium bicarbonate and calcium bicarbonate solids at high partial pressures of C02, which would occur near any liquid C02 pools on the seafloor. The formation of carbonate hydrates at the oceanic pressure at proposed disposal sites may also precipitate calcium sulfate (Gypsum). For seafloor disposal, the possibility of interaction with silicate phases must also be considered, particularly in areas with little or no carbonate sediments such as the North Pacific.

This theoretical paper was followed by an experimental paper "Ocean C02 Sequestration" by H. Komiyama (Tokyo University), T. Hakuta (National Institute for Materials and Chemical Research), Y. Yanagisawa (Harvard University), Y. Fujioka (Mitsubishi Heavy Industries Ltd.) and Y. Shindo (National Institute for Materials and Chemical Research, Japan) who gave the talk. Experiments were done in a chamber at pressures of 28 and 35 MPa, and at a temperature of 3°C simulating pressure-temperature conditions at oceanic depth at approximately 2800 and 3500 m. A droplet of liquid carbon dioxide was ejected into the chamber. A thin layer of hydrate is formed by diffusion of water into the droplet. A pH sensitive dye shows the presence of carbonic acid formed by the gradual solution of the hydrate accompanied with the gradual shrinkage of the drop. Another experimental paper on "Laboratory Experiments of C02 Injection into the Ocean" was presented by S.M. Masutani (Coauthors: C.M. Kinoshita, G.C. Nihous, T. Holl, L.A. Vega and Y. Mori) of the Pacific International Center for High Technology Research, University of Hawaii at Manoa, U.S.A. Their experimental apparatus tested plume behavior from the injection of liquid carbon dioxide into a pressurized cylinder filled with seawater. Depth simulation was only to about 600 m compared to the previous work at several thousand meters. In addition, laser Raman was used to determine the various chemical species developed during the tests. During the tests, the stream separated into an array of droplets, substantiating results from prior modeling efforts. High-injection velocities produced smaller droplets. During the runs of approximately 5 to 15 min, no evidence of clathrate formation was observed visually. However, solids were observed at the top of the chamber when it was depressurized. As these solids floated, they seemed to be lighter than water, which is contrary to the expected density of the clathrates of 1.112 or denser than seawater. In addition, Raman spectroscopy was done over a range of pressure up to 50 MPa or about a depth of 5000 m in a separate chamber, but at 20°C, much warmer than ambient temperatures for oceanic depths. No bicarbonate and carbonate ion bands were detected.

Three comments followed these experimental papers. H. Chiba, Kyushu University, showed a video tape of the carbonate clathrate chimneys found in the Okinawa Trough at 700 m. Bubbles from the chimneys collected in tubes by a submersible, seemed to produce a coating on the tube, which did not fill the tube. I. Aya of the Ship Research Institute, Japan, described an experimental pressure facility (30 MPa or 3000 m depth) to produce clathrates. M. Nishio, Mechanical Engineering Laboratory of Japan, discussed a 50 MPa (5000 m depth) apparatus to study the absorption of C02 into the ocean.

DEEP-SEA BIOLOGICAL ACTIVITY AND ENVIRONMENTAL CONCERN

The final formal session was chaired by M. Takahashi, University of Tokyo.

"Environmental Impact Study caused by Deep-Sea Mining" given by K. Tsurusaka, National Institute for Resources and Environment, Japan, was an example of the type of environment studies that may be required at carbon dioxide disposal sites. Y. Sirayama, Ocean Research Institute, University of Tokyo, gave a talk entitled "An Experimental Approach to the Deep-Sea Ecosystem Research." He noted the lack of foraminifera (a carbonate secreting protista) in the area near the carbonate chimneys in the Okinawa Through. The suggestion was that the pH was lowered sufficiently so that the shell could not form. However, no evidence of abnormally low pH was observed at the site. He noted that deep-sea organisms are energistically different from well observed surface and near-surface groups and suggested a series of experiments to develop some data for the proper assessment of the impacts of ocean disposal, and particularly the potential presence of a liquid carbon dioxide pool on the deep sea floor.

Two brief comments followed. A. Taniguchi, Tohoku University, proposed possible nutrification of the deep sea as if one adds carbon dioxide; it should be balanced by appropriate additions in the proper proportions of nitrogen and phosphorous. Because of the absence of J. Kasahara of the Earthquake Research Institute at the University of Tokyo, and since there was an earthquake swarm in the Izu Peninsula during the conference, Dr. T. Ohsumi of CRIEPI presented Dr. Kasahara's viewgraphs. He proposed the use of an abandoned submarine cable to act as a data link for C02 and other parameter monitoring between Japan and Guam. There is a proposal to the Science and Technology Agency (The Venus project) to set up an undersea network of sensors that could be useful in assessing the environmental conditions for carbon dioxide disposal and for planning other assessment strategies.

GENERAL OBSERVATIONS

The Second International meeting on Carbon Dioxide disposal in the Oceans served a useful purpose in laying the groundwork for a more scientific and practical (economic) assessment of the feasibility of the concept. Very severe economic restrains of actual energy costs of disposal must be addressed. These include costs of scrubbing the gas from power plants, compressing it to a transportable liquid, delivering the liquid to the disposal site either by specialty refrigerated ships or pipelines, and monitoring the discharge into the ocean as well as pre-disposal monitoring. Professor Adams has demonstrated a reasonable approach to the techniques for the actual disposal of the liquid, which in turn could reduce the cost of a pipeline from shore in areas where submarine canyons come close to the shore in industrialized areas. However, the design depth of 3000 m for "non returnable" disposal seems prohibitive for ship borne transfer of liquid C02 to the disposal site except for countries like Japan with deep trenches close to shore. An area where much progress can be made is determining exactly what happens to a pool of liquid carbon dioxide at oceanic depth. It is apparent that even simple information such as the density of the clathrate is still uncertain. Unquestionably there is very little real data on the potential impact on deep sea life; although, it must be assumed that an environment such as a pool of liquid carbon dioxide is not very conducive to existing life forms. As in many projects, the studies developed as proof of concept may be more valuable in the long term than the actual concept itself or will have lasting relevance even if the concept is proven unworkable or uneconomic. The Central Research Institute of the Electric Power Industry of Japan is to be congratulated for organizing this meeting with a very international makeup. It is hoped that the funding will continue to permit some answers to the real difficult questions posed here.

Dr. Pat Wilde is an oceanographer-marine geologist currently serving as liaison scientist for Ocean Science and Engineering for the U.S. Office of Naval Research Asian Office in Tokyo. He is concurrently, a lecturer in Ocean Engineering at the University of California, Berkeley.

Dr. Wilde received his B.S. in Geology (Magna cum Laude) from Yale University in 1957. He worked for the Exploration Division of Shell Oil Company from 1957 to 1959 as a geologist. In 1959, Dr. Wilde returned to academia receiving his A.M. in Geology in 1961 and his Ph.D. in Geology in 1965 from Harvard University. While at Harvard, he also was a Graduate Research Geologist at the Scipps Institution of Oceanography working on the sedimentology of deep-sea fans. In 1964, Dr. Wilde joined the Engineering Faculty of the University of California, Berkeley and was Chairman of the Ocean Engineering Program from 1968 to 1975. In 1975, he joined the Lawrence Berkeley Laboratory and from 1977 to 1982 was Head of the Marine Sciences Group, whose major task was the environmental studies associated with the Ocean Thermal Energy Conversion program of the Department of Energy. In 1989, he received the Humboldt Foundation Senior Prize and spent a year in residence at the Institute of Geology and Paleontology at the Technical University of Berlin, Germany.

Tectonic Framework and Energy Resources of the Western Margin of the Pacific Basin Kuala Lumpur, Malaysia November 29-2 December 1992

The vast and growing oil and gas potential in South East Asia was emphasized at a four day meeting held in resource-rich Malaysia. Besides conventional informational papers on specific oil and gas fields or regions, there were many papers relating the occurrence of petroleum to global plate tectonic events. This unifying thread not only explained some of the complex structures that heretofore had been the subject of much conjecture and controversy, but also provided a framework for predicting the structural occurrence and development of both new fields and extensions to known areas. Emphasis, as expected, was on offshore developments and prospects.

Pat Wilde

Introduction

The Geological Society of Malaysia and Circum-Pacific Council for Energy and Mineral Resources sponsored a four-day symposium with 62 oral presentations, 16 posters, and an accompanying exhibition and display booths for various government agencies and private firms. The joint sponsorship reflected the dual nature of the meeting focusing chiefly on the petroleum provinces in Malaysia and neighboring countries but in the context of a the broader perspective of the geology of the Western Pacific. The meeting dealt primarily with the marine geological influence on the energy resources and their development in South East Asia.

The meeting was organized around five major themes:

- Geology and Tectonics of East and Southeast Asia - Regional; Malaysia; Indonesia; Philippines; and Indochina, Thailand, China and Japan.
- Petroleum-Bearing Basins and Potential of Southeast Asia - Regional; Malaysia and Philippines; and Indonesia and Andaman Sea.
- Australia, New Zealand and the Pacific.
- Geothermal Energy.
- Coal.

Each half-day session during the three days of formal presentations was introduced by a Keynote Address. The six Keynote speakers were:

- David G. Howell (U.S. Geological Survey): Plate Tectonics and Petroleum Habitats
- Charles D. Masters (U.S. Geological Survey): World Petroleum Resources—where and how much?
- Charles S. Hutchinson (University of Malaya): Tectonic Framework of the Southeast Asian Tertiary Basins.
- David A. Falvey (Australian Geological Survey): Evolution of the island arc and marginal basins of the Western Pacific

- M.G. Johnson (Exxon Exploration Co.): 3-D Seismic benefits from exploration through development: An Exxon Perspective.
- Richard Sinding-Larsen (Institute of Technology, University of Trondheim): Regional Data Processing and analysis as a basis for co-operative resource assessment.

The unifying theme of the conference was the major influence of plate tectonics in the formation of the energy resources in the region. As such, there was more emphasis on structure, stratigraphy and sedimentology; and less emphasis on the climatic, chemical, and biological influence on source rock. The following is a reorganization of the papers along more conventional topics: Geophysics, Reserves and Resources, Stratigraphy and Sedimentology, Tectonics.

Geophysics

1. Paleomagnetic evidence to define a stable East Asia and Sundaland: Robert MCCabe*, Steven Harder*, Vivat Paijitprapapon** Nguyen Giang***, Eko Lumadyo****, *Dpt. of Geophysics, Texas A&M University, College Station, Texas 77843, U.S.A.; **Geologic Div., Dpt. of Mineral Resources, Bangkok, Thailand; ***Geophysics Society of Vietnam, Hanoi, Vietnam; ****Unocal Indonesia, Jakarta, Indonesia.
2. The nonlinear inversion of paleogeothermal evolution: example from the North part of South China Sea: Xue Aimin, The Institute of Geophysics, Chinese Academy of Sciences, Tatun Rd., Beijing 100101, P.R. China.
3. Fission track analysis of Khorat Group sediments, Khorat Plateau, Thailand: Charlie Bristow, Dpt. of Geology, Birkbeck College, Malet St., London WCIE 7HX, England.
4. The Bouguer gravity variation over South East Asia as derived from satellite altimeter data: Clive A. Foss & John Savage, Ark Geophysics.
5. Thermal studies in oil basinal areas of Indonesia: Sandjojo Subono & Siswoyo R&D Centre of Oil and Gas Technology, "LEMIGAS", P.O. Box 1089/JKT, Jakarta, Indonesia.
6. The role of advanced seismic interpretation in development planning for the Kinabalu Main Field, offshore NW Borneo: Christian F.W. Hocker, Sabah Shell Petroleum Co. Ltd.
7. Australia-Philippines cooperative marine seismic and sniffer survey in four Philippine offshore sedimentary basins: Chao-Shing Lee*, Doug Ramsay*, Freddie Rellira**, Malcolm Galloway* & David Baladad**, *Bureau of Mineral Resources, GPO Box 378, Canberra, ACT 2601, Australia; **Office of Energy Affairs, Merritt Rd., Fort Bonitacio, Makati, Manila, Philippines.
8. A new investigation of some continental scale gravity lineaments in Australia: Cathy Elliot Dpt. of Geology, School of Earth Sciences, University of Melbourne, Parkville, 3052 Australia.
9. Heat flow distribution in the western margin of the Pacific: Osamu Matsubayashi*, Toshiyasu Nagao** & Seiya Uyeda***, *Geological Survey of Japan, Tsukuba, 305 Japan. Now at CCOP Technical Secretariat, Bangkok, Thailand; **Kanazawa University, Kanazawa, 902, Japan; ***Texas A&M University, College Station, TX 77843-3114, U.S.A. & Tokai University, Shimizu, 424 Japan.
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Observations

Mike Halbouty, one of the grand old men of Petroleum Geology remarked, at one of the luncheons, that it was interesting to see that a vast majority of the young geologists were Asian, far in excess of what one would have seen at a similar meeting even held in Asia just a few years ago, which would have been dominated by Western faces. He also commented that at this meeting there was still a spirit of progress and a sense of a future. This was lacking in any Petroleum Geology or even Geology meeting in the U.S. in the past several years. Unquestionably, the economic miracle of Singapore has spread to Malaysia, with Indonesia and Thailand waiting in the wings. Thus, the technical pool for even such a small field as geology is now becoming local. Today, the centers of advancement thinking in geology are still in the West. However, with declining enrollments in the United States and presumably Europe coupled with increased technical opportunities in areas such as South East Asia and China, one wonders how long it will be before the intellectual center shifts also.

Micromachine Technology Center and National Project, 28 May 1993

Japan's Micromachine Technology R&D Project and associated Micromachine Center are described in this report.

David K. Kahaner

The following description was presented at the Second International Symposium on Measurement and Control in Robotics (ISMCR'92), 15-19 November 1992, at the AIST Tsukuba Research Center, Tsukuba Science City, Japan.
(We are preparing a full listing of the papers presented at this conference and will distribute this when it is complete.)

Outline of Micromachine Technology R&D Approach of Micromachine Center

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Abstract

The Micromachine Center was established for advancing the research, development, and dissemination of micromachine technology. The organization of the Center and its activities are described here. Also, an overview is given of the aims and substance of the Micromachine Technology R&D Project launched in FY 1991 by the Agency of Industrial Science and Technology as one of its Large-Scale Projects.

Introduction

Micromachine systems is composed of a number of small-sized function elements that are expected to produce far-reaching changes in various fields of technology. As micromachine R&D is still in its infancy, the establishment of micromachine technology will involve heavy funding, high risk and a long periods of time. Because of these requirements, the Ministry of International Trade and Industry (MITI) embarked on the Micromachine Technology R&D Project as one of its large-scale projects in FY 1991 [1], and authorized the establishment of the Micromachine Center as a nonprofit foundation in January 1992.

The Micromachine Center and the Micromachine Technology R&D Project launched by the Agency of Industrial Science and Technology (AIST) are described in this paper.

Micromachine Center

Purpose

Micromachine technology will make possible to realize advanced maintenance systems for use in the confined and contorted spaces within electric power plants and jet engines, as well as in production systems with reduced energy and material requirements, multifunction home electric appliances, home robots, and highly advanced medical instruments.

Because of the short history of R&D in this field, however, putting micromachine technology to practical use will require solutions to a wide range of problems. These include the development of various functional microelements, methods for fabricating these elements, energy supply methods, and system control methods. The participation and exchange of technical information among many companies, universities, and public institutes will be indispensable in this work. The Micromachine Center was established as the core organization for effectively promoting this R&D over the long term, as well as for disseminating the results achieved. Table 1 shows the types of Micromachine Center members. The current membership includes about 30 companies, foundations, and other organizations.

Table 1 - Types of Supporting Members in Micromachine Center

Type	Description
1. General supporting member	Involved in activities related to micromachine (except those of type 2 and 3)
2. Research supporting member	Conducts Micromachine Technology R&D delegated to Micromachine Center by NEDO (except type 3)
3. Group supporting member	Foundations, universities, or the equivalent. Involved in activities related to micromachines.
4. Special supporting member	Involved in activities other than the above.

Organization

Under the Micromachine Center's board of directors are an administrative committee, technical committee, international committee, and working committee. These committees plan the various activities of the Center and evaluate the results. The activities decided by the board of directors are carried out by individual departments.
[Figures illustrating the organization are omitted from this distribution. DKK.]

Activities

The Micromachine Center promotes the following activities aimed at accelerating micromachine technology R&D and dissemination of the results.

(1) Survey and research activities

Promotion of "Micromachine Technology R&D Project". The New Energy and Technology Development Organization (NEDO) has commissioned the Micromachine Center to conduct "Micromachine Technology R&D". This work is carried out by the research members of the Center listed in Table 2.

(2) Survey on current state of micromachine technology R&D.

The Micromachine Center reviews the reports on the technology presented at research conferences held in Japan and abroad, as well as patents and other sources of information on the current state of the technology. The Center also conducts feasibility studies on various kinds of application systems using micromachine technology.

(3) Collecting and supplying technology information.

The results of the survey on current micromachine technology R&D are kept on file for supply to related organizations through various media, including the Center's own magazine and other publications.

(4) Exchange and cooperation relating to micromachines with organizations.

To encourage joint-research among company, government and academia, and international exchanges of micromachine technology. The center supports the change of researchers, international conferences, and basic research related to the technology.

(5) Standardization of micromachine technology.

Micromachine technology is interdisciplinary. It is therefore important for researchers in various fields of science to have an understanding of the technical terms and measurement methods used in the field. The Center promotes standardization in those areas.

(6) Disseminating information on micromachines.

The Center publishes bulletins and holds seminars and symposiums relating to micromachines.

Table 2 - Research Supporting Members

Mitsubishi Electric Corporation
Fuji Electric Corporate Research and Development, Ltd.
Sumitomo Electric Industries, Ltd.
Matsushita Research Institute Tokyo, Inc.
Murata Mfg. Co. , Ltd.
Yaskawa Electric Corporation
Fanuc Ltd.
Kawasaki Heavy Industries, Ltd.
Omron Corporation
Mitsubishi Material Corporation
Mitsubishi Heavy Industries, Ltd.
Nippondenso Co., Ltd.
Meitec Corporation
Toshiba Corporation
Fujikura Ltd.
Yokogawa Electric Corporation
Sanyo Electric Co., Ltd.
Olympus Optical Co.,Ltd.
Seiko Instruments Inc.
Hitachi, Ltd.
Mitsubishi Cable Industries, Ltd.
Terumo Corporation
Aisin Seiki Co., Ltd.
Japan Power Engineering and Inspection Corporation

Micromachine Technology R&D Project

Need for R&D

The mechanisms and systems of large-scale machines are complicated. This increases the importance of enhancing the reliability and lowering the maintenance costs of such systems. At electric power plants, for example, there is a strong need for the technologies enabling inspection and repair to be conducted without disassembling the facilities. In the medical field, the development of sophisticated instruments that can reduce the physical and mental pain of surgery patients is desired.

Having concluded that micromachine technology has the potential to respond to those social needs, MITI decided in FY 1991 to pursue R&D into micromachine technology under a large-scale R&D program, and budgeted about ¥25M for development of such technology over a ten-year period.

Research and Development Plan

The aim of the project is to establish micromachine technology to realize micromachine systems that can move in confined spaces, such as inside a pipe in an electric power plant or inside a living organism, for autonomous carrying out inspection or medical treatment. Micromachine technology consists of a number of basic element technologies, as shown in Table 3.

Before anything else, micromachine technology needs functional microelements, such as minute actuators, mechanisms, sensors, and ICs, and the various materials and micro-machining technologies required for fabricating these elements. Also needed is assembly technology for using the various microelements to build highly integrated multifunctional devices and modules. Of particular importance is the development of manipulators with a high degree of freedom.

Second, it is necessary to develop technology for supplying micromachines with the energy they need to operate. This includes technology for using light, electromagnetic waves or the like for supplying energy from the outside, and electric energy storage technology in the machine. Third, control technology for operating micromachine systems has to be developed. This includes, among others, distributed, cooperative control technology, and human interface technology. Fourth, it is important to establish technologies for measuring and evaluating the characteristics of functional microelements and devices.

This project envisions the development of a high-performance maintenance system and medical treatment system composed of several kinds of functional modules. The R&D on various functional modules in the first phase of the project (FY 1991--1995) shown in Table 4, is aimed at establishing the basic technologies mentioned above. These include, for example, various functional microelements, fabrication methods, energy supply methods, system control methods, and so on. R&D during the second phase (FY 1996-2000) has not been planned in detail yet, but it will focus on the advancement and systematization of micromachine technology through development of various functional devices, modules, or systems.

Table 3 - Basic Element Technology Items on Micromachine

Item	Content
Technology for functional microelements	1. Actuators (electrostatic, solenoid, shape-memory alloy,) motion transfer mechanisms, sensors (visual, tactile,) and others. 2. Micro-machinings (IC-process, electro discharge machining, electron beam machining,) & fabrications (3-D manipulator.)
Energy supply technology	1. External energy supply (fiber optics.) 2. Internal energy supply (electric dynamo, photo cell, battery.)
System control technology	Information Processing, communication, cooperative control, human interface
Evaluation technology	Measurement and evaluation methods for the characteristics of functional microelements and microdevices.

Table 4 - Schedule of Micromachine Technology R&D

	R&D item	1991	First phase 1992 - 1995	Second phase 1996 - 2000
1.	Advanced Maintenance Microcapsule Mother ship Inspection module Repair module	System Survey on micro machine technology	R&D on basic technologies and functional micro devices	(R&D on devices, modules, and and systems)
2.	Advanced Medical Instrument System			
3.	Total systems	Feasibility of the systems		

R&D Subjects

• Micromachine system envisioned

— Industrial micromachine system

An advanced maintenance system for electric power plants envisioned by this project is shown in the figure. This system is composed of four kinds of micro devices: the microcapsule, mother ship, inspection module and repair module. [The figure is omitted in this distribution. It shows a microcapusle less than 10mm in diameter and a mother ship inside a pipe approximately 25 mm in diameter.]

The microcapsule is carried through the pipe by a water stream at a relatively high speed. It detects cracks and scale in the pipe and informs the operator of the defect-detected location. The mother ship carries inspection modules and repair modules near the place where the microcapsule detected the defects. It then supplies energy to the modules and maintains communication between these modules and the operator. The inspection module moves to the detected defect and examines the crack or scale in detail. The module is supplied with energy from the mother ship without physical connection. The repair module repairs the crack or removes scale based on the information ascertained by the inspection. The module receives energy from the mother ship by an electric wire or optical fiber.

— Medical micromachine system

An advanced medical instrument system for diagnosis and treatment envisioned by this project is shown in the figure [omitted, a general cartoon]. This system comprises a flexible active catheter with a diameter of less than lmm and a multifunctional diagnosis and treatment head attached into the tip of the catheter. The catheter is inserted into a small blood vessel, pancreatic or cystic duct or other afflicted member and the multifunctional head diagnoses and treats the morbid part. Treatment of aneurysms, cancers and the like are envisioned.

- Research and Development subjects

This R&D project focuses on two types of application systems outlined above. Micromachine technology will be established by the R&D into the various kinds of functional devices that the systems need, and their fabrication technology. Table 5 shows the main subjects to be developed by the project.

Table 5 - Main Subjects of R&D Subjects

Actuator and Mechanism	Motion devices (Electrostatic, Magnetic, PZT, mechanisms,) SMA manipulator, Photo-thermal driving units, Hydraulic clamping unit.
Sensor	Ultrasonic device, Optical devices (CCD, Image fiber, Photo spectroscopy,) Gyroscope and accelerator unit.
Communication	Signal transmission (PZT composite material,) Communication network.
Energy supply	Dynamo (Electromagnetic.) Photo-electric conversion units, Microwave transmission unit, Battery (Hydrogen absorption alloy.)
Control	Dynamical motion control, Coordinate control, group control Teleoperation.
Machining and assembly	1. IC process (Multisource sputter, Laser assisted etching FIB, RIE, 3-D dry etching, Injection molding (Metal, Ceramic) Photo enhanced electrolytic 3-D process, Electro discharge machining. 2. Bonding (Surface activation, multilayer, Laser welding, anodic,) 3-D packaging. 3. 3-D manipulators.

Conclusion

The recently established Micromachine Center and MITI's Micromachine Technology R&D Project were described. Micromachine technology is a very young technology. For the unrestrained use of the technology, it will be necessary to nurture the technology seeds that are found, positively and persistently over a long period of time. The Micromachine Center will be dedicating itself to this end.

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Micromachine Examples, 7 June 1993

Specific examples of micromachine technology applications in Japanese research laboratories (from newspapers).

David K. Kahaner

TOSHIBA DEVELOPS WORLD'S SMALLEST ELECTROMAGNETIC MOTOR

Denki Shimbun, in Japanese, 25 Sep 1992 pp 13

Coil and Magnet Placed in Tandem: Various Applications for Micromachines Expected

Toshiba Corporation announced on 24 October 1992 that it has succeeded in developing the world's smallest electromagnetic motor of 0.8 mm in diameter. The smallest electromagnetic motors in the world so far, have been of 2 mm in diameter and have been developed by a company, another of 1 mm in diameter has been developed by a university. Toshiba has succeeded in reducing the diameter of the motor by arranging the coil and the magnet in a tandem position. Toshiba plans to use it as a prime mover for micromachines.

There are two types of motors: electromagnetic and electrostatic. Although an electromagnetic motor has an advantage because it is easy to control the motor power by controlling the current supply, it seems that it would be structurally difficult to miniaturize it, as it needs a coil to generate a magnetic field.

The key of Toshiba's success in miniaturization is the arrangement of the coil and magnet in tandem with an axial gap between them instead of the conventional method of coil and magnet arranged concentrically with a radial gap between them. Furthermore, they have succeeded in:

- winding 0.03 mm diameter wire around the steel core of O.l mm in diameter with 20 turns to form a 0.25 mm diameter coil, based on the coil winding technique used for the video head;
- applying the wire electro-discharge machining method to do micron order machining on components where sparks were discharged from a fine tungsten wire, while the wire was kept swinging back and forth.

Toshiba plans to use this motor for such micromachines as pipe inspection robots to detect internal damage in pipes of small diameter in nuclear plants, ultrasmall manipulators for medical applications, and miniature robot hands for bioengineering applications.

METROPOLITAN UNIVERSITY GROUP DEVELOPS OPTICAL MICRO-ENGINE

Nikkan Kogyo Shimbun, in Japanese, 25 Sep 1992 pp 7

Rotates Vane-Wheel in Vacuum Using Thermal Motion of Gaseous Molecules

Masahiro Ohta, a researcher at the Tokyo Metropolitan University, and a colleague have developed an optical microengine based on the thin gaseous effect and have succeeded in crating an actual rotation, paving the way to its application as an actuator for micromachines, and in the space science. The engine has a vane-wheel with four aluminum vanes, each of which is separated by 90° and is covered with soot on one side. When a light beam is cast on these vanes in a vacuum chamber, it generates a rotating power because of the heat drop between the front and back sides of the vanes, according to the principle of a thin gaseous body regarding the thermal motion of each gaseous molecule. It can be developed into a practical optical engine by proper selection of vane material, a coating with polymers, and using a laser light. The result of this development will be reported at the National Convention of the Japan Society of Mechanical Engineers which is scheduled to be held at the Shinshu University.

Aimed at Micromachines

In today's scientific fields at the cutting-edge of technology, such as in the fields of microelectronics and micro-mechanics, which are based on microscopic technology, analyses based on thin gas dynamics are critical. Thin gas dynamics can be applied when the average free depth (the average distance a gaseous molecule can fly before it hits another molecule, which becomes longer as it approaches vacuum) of a particular gas is in the same order with the typical length of the field (for example, the vane of the optical engine). The ratio of the two is called the Knudsen number. Since the Knudsen number of a gas vs. objects on the Earth's surface is small, the gas can be dealt as a continuous substance, but the Knudsen number becomes large in the space, for example, so that a gas has to be dealt with as a group.of molecules.

When a microscopic object is placed in a vacuum, the free depth of a gaseous molecule becomes greater and the length of field is small so that the Knudsen number becomes larger (ratio: 1 - 10:100), making an optical engine realizable. Its principle is as follows: When a gas molecule hits a solid body, the molecule bounces off of the solid body with a speed relative to the energy corresponding to the temperature of the body surface; therefore, the vane wheel rotates if there is a temperature difference between the front and back sides of the vanes due to the difference in the energies they provide.

In this experiment, the four vanes made of aluminum (10 mm wide square, 0.08 mm thick) were coated with soot on one side, and the vane wheel was placed in a vacuum chamber and illuminated by a 500 W flood light from one side. The temperature on the soot side became 36°C, and 26°C on the exposed aluminum side, causing a temperature difference of 100°C. Although the wheel did not turn in the atmosphere, it started to turn with increasing speed and torque as the gas pressure was reduced. The speed was about 300 rpm and the torque was 10^{-2} Newton per m^2 when the vacuum was 10^{-2} torr (Knudsen number = 0.5-1). Mr. Ohta, et al., believe that the motion was caused primarily by force according to the thermal creep flow when the Knudsen number is small and by force according to the free molecule flow when it becomes larger. They are hoping to work out the dynamical analysis by using computer simulation in the future.

NTT APPROACH TO MICROMACHINE TECHNOLOGY DETAILED

NTT Gijutsu Janaru, in Japanese, Aug 1992 pp 68-70

World of Micro Machines - Innovations They Create: Significance of Micromachines and Their Applications

[Author: Hiroki Kuwano, Research Fellow, Optomechatronics Dept., NTT Interdisciplinary Research Laboratory]

A machine is generally defined as an object that transports, measures, or transforms other objects by some physical or chemical process. Jumbo jets and super tankers are machines of gigantic sizes that are created to transport large quantities of cargo or people and are equipped with prime movers to propel them.

On the opposing end of the spectrum, there is a technological concept of compacting various functions into a tiny space to make it easier to handle and transport. Portable tape recorders and camcorders are the products based on this concept. Micromachines can be considered as an extreme case of this miniaturization concept. However, micromachines will not be limited only to the miniaturized versions of existing machines, rather they will provide us with something that was once impossible and unthinkable, creating a wide range of applications that will profoundly affect our lives.

The figure [not reproduced here] shows application fields where miniaturization is expected to be particularly effective. In the areas of equipment maintenance and inspections, micromachines may remove the need for overhauls and expensive works, as micromachines can enter narrow spaces such as aircraft engines, cooling pipes of nuclear plants, telephone cables, and conduct maintenance and inspections. In the medical field, micromachines will enable the use of microsurgeries or microcapsules to deliver pin-point cures to specific areas of infections or damage, thus making it unnecessary to open large areas of the body to get to small affected parts.

Micromachines will eliminate many unnecessary works and burdens for human beings, because they can function within extremely small spaces. The smallness of their physical size means that they affect the environment less since they need only small amounts of materials to be produced and small amounts of energy to be manufactured, transported, and operated.

Micromachines Being Created

What makes these micromachines closer to reality is the recent advancement in micro-machining technology, integrated circuit technology, material sciences, and software technology. The micro-machining technology is needed in the miniaturization and integration of electrical circuits.

The benefit of semiconductor micro-machining technology is the economy of being able to produce a large number of patterns consisting of elements less than 1 μ in size by means of photolithography, thus entirely eliminating the need to assemble. By using this semiconductor micro-machining technology, various micromachine components such as micro gears, cranks, sliders, an electrostatically driven motors of about 100 μ in diameter, and micro tweezers have been produced on the laboratory level since late in 1980. Various institutions have been particularly interested in the development of micromechanical sensors lately, as the forerunners of micromachines.

Research Objects for Micromachines

Micromachines comprise sensors, actuators, transfer mechanisms, communication components, and energy sources. To complete a micromachine, we have to study their structures, materials, manufacturing methods, and surface mounting methods. The studies and development works on sensors and actuators have just began.

Several basic differences exist between micromachines and conventional machines in that the traditional engineering is not necessarily applicable to micro machines, thus leaving several areas to be investigated. For example, the effect of the surface area becomes relatively larger due to the miniaturization. In other words, the forces related to the surface area such as friction, viscosity, and electrostatic force are more detrimental to the nature of the particular machine than the forces related to volume such as inertia and magnetic force. Consequently, the control of those surface-related forces becomes an important object of research. Other important objects of research are the control method of an entire micromachine, the method of energy supply, and the method of controlling communications.

Projects Conducted at NTT Interdisciplinary Research Laboratory

In our laboratory, we are currently working on the studies of micromachine parts, their manufacturing methods, design method, measuring method, control method, and material engineering, as a part of general research programs on communication switches and information sensing.

As an example, a micro-valve [K. Yanagisawa, A. Tago, T. Ohkubo and H. Kuwano. Proceedings IEEE, Micro Electro Mechanical Systems, pp 123-129] which operates on a small electromagnetic force with a small dead space intended for semiconductor process. A swastika-shaped spring made of NiFe thin film is formed as a soft magnetic material on the surface of silicon substrate, and a valve of 20 μ in diameter is formed in the center by photolithography. A magnetic slope generated by a microscopic coil placed around this microscopic swastika spring opens and closes the valve. High-speed response capability with a resonance frequency of 33 kHz and a minimum displacement of 0.2 nm (1 nm = 10^{-3} μ) are achieved.

Another example is a micro-encoder [R. Sawada, H. Tanaka, O. Ohguchi, J. Shimada and S. Hara. ibid. pp 233-236] which is a typical sensor for detecting position, displacement, angle, and speed. By forming a microlens and a polygon laser in one piece on a Ga-As substrate by photolithography, we realize a resolution of 10 nm, despite the fact that it is 1/100 of the previously available device (0.5 mm^2).

Other projects we are working on include a method of high-accuracy positioning of single mode optical fibers [Kikutani, Hirano, Koyabu and Ohhira. Proceedings of Institute of Electronic, Information and Communication Engineers, 1991, C-160], microactuator based on electrostatic force and micro-switching devices for various types of communications.

Conclusion

The above is a brief introduction of micromachines studied at our laboratory, a technology that is expected to result in a wide range of innovations in various technological fields, such as telecommunications, environment, medical, and various other industrial fields.

Micromachines will be able to respond to the current demands of society, particularly to global environmental concerns and our desires for a more comfortable life.

Micromachine Activities in Japan, 2 July 1993

Micromachine activities in Japan, the Micromachine Center (MMC), Yaskawa Electric, the University of Tokyo's Institute of Industrial Science (IIS), and MITI's Mechanical Engineering Lab (MEL) are reported here.

David K. Kahaner

Japanese research in micromachine technology has been discussed in several earlier reports. The last report presented a description of the Japanese Micromachine Center (MMC), in Tokyo, as well as the Micromachine Technology R&D Project (¥25B) that began in 1991, under MITI's Agency of Industrial Science and Technology, (AIST). Recently, I visited at MMC with

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Professor Ro and I would like to express our appreciation to the many Japanese scientists who graciously spent time with us, often on short notice. This is particularly true for scientists at the Micromachine Center, Yaskawa Electric, and MITI's Mechanical Engineering Laboratory. Names of specific individuals and their contact addresses are given in the text below.

Some of the material that I reported on earlier was repeated to us, other aspects were new. Our hosts at MMC were

Mr. Takayuki Tsunemi
Managing Director & Chief of Secretariat
Micromachine Center
3F Sanko Bldg.
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and Dr. Tokio Kitahara, General Manager of the Research Department.

In the following paragraphs I provide additional details, mostly made available through documents from the MMC staff. Because these are written in English, I have decided to use them with only minor changes, adding my comments when necessary.

Objectives of the Micromachine Center (MMC)

Micromachines, only a few millimeters in size, can conceivably perform complex microscopic tasks. As a consequence, many people, worldwide, want to use these minute devices to cope with the increasing demand for advanced maintenance technology to be used in plants and machinery, and in medical techniques that use complex and precise mechanical systems.

Micromachines have many potential uses. In industry, the devices could provide sophisticated and delicate maintenance in many kinds of industrial plants and machinery. In medicine, micromachines would cause minimal discomfort to patients undergoing advanced medical techniques. These and other uses of micro-machine technologies should have far-reaching effects.

[Two applications were described and focused on

- advanced maintenance systems used in power plants, and
- intraluminal diagnostic & therapeutic systems.

Seemingly the project with the clearest specific subtasks were:

- a microcapsule about 2 mm in diameter,
- a mother "ship" 10 mm in diameter,
- an inspection module of 2.5 mm in diameter operating without wire, and
- a wired operation module of 2.5 mm in diameter.

The idea is as follows,

a. A group of microcapsules would be introduced into a tube of a power plant and make a rough inspection of the condition of the thermo-conduction tubes.

b. A mothership with wireless inspection and operation modules would be sent in the vicinity of any potential problems ("unusuals") that were indicated by the microcapsule.

c. At the vicinity of unusuals, the wireless inspection module would be sent out from the mothership and would perform a precise inspection. After that, the wired operation module would be sent out from the mothership and would extract samples or perform repairs.

The ten year project was envisioned to be divided into two five-year phases with an evaluation period to end in 1995 for the first phase, and then again in 2000 for the second phase.

The medical applications are conceived as remote controlled diagnostics and therapy such as pancreatic & biliary ducts, aneurysms, blood vessels, and alimentary canal, although there is much less detail associated with these.

Both of these projects are described in more detail in the text below, DKK.]

However, prior to realizing micromachines' potential applications, many basic technologies must be developed, including methods for processing the microscopic and intricate parts of these devices and for providing energy supply and control mechanisms.

Another urgent task is to prepare a forum for international exchanges of new micromachine developments overseas. Information exchanges are important for the development of micromachines and for ensuring the establishment of a central role for this technology as it spreads into the economic and social sectors. People from industry, government, and academia should interact with ease as the research and development of micromachines accelerates at corporations, universities, and research institutions.

The Micromachine Center (MMC) was established on 24 January 1992, with the approval of the Ministry of International Trade and Industry (MITI). Its purpose is to conduct R&D into micromachines, collect and provide information, and foster exchanges and cooperation with organizations in Japan and abroad. In this way, the center will establish basic micromachine technology and disseminate micromachines in society, thereby contributing to the development of domestic industry and the international community.

Organization of MMC

MMC was established on 24 January 1992, with an endowment of an estimated ¥700M by the end of FY 1992, and a staff of 26 directors, 2 auditors, and 34 companies and organizations as supporting members.

[These companies and organizations were listed in my earlier report. All but three are Japanese companies. The three non-Japanese are IS Robotics (United States) research into behavioral control, SRI (United States) research into artificial muscle, and Royal Melbourne Institute of Technology (Australia) research into magnetic bearing. The MMC is encouraging other organizations to become general supporting members for an initiation fee of ¥4M and an annual fee of ¥2M. This permits participation in surveys, research, study groups, use of databank, results and receipt of publications. Various international delegations visit MMC (French and British were explicitly mentioned), but there is not much to see there, as the Center is the administrative arm of the project, with research actually taking place within the associated organizations. In that context Professor Ro and I asked to be shown some representative research organizations. Mr. Tsunemi obliged us by arranging short visits to one company, Yaskawa Electric, also to MITI' Mechanical Engineering Laboratory, both in Tsukuba. See below for descriptions. DKK]

Activities of MMC

To establish basic technologies and lead the dissemination of micromachines in economic and social sectors, the Micromachine Center mainly

A. Investigates and researches micromachines
B. Collects and provides information on micro machines
C. Engages in exchanges and cooperation relating to micromachines with organizations in Japan and abroad
D. Promotes micromachine standardization
E. Provides and disseminates education on micromachines.

A. Investigation and research activities

The New Energy and Industrial Technology Development Organization (NEDO) has entrusted MMC with a large-scale project known as "Micromachine Technology" the 10-year project begun in 1991 by MITI's Agency of Industrial Science and Technology (AIST). The MMC's role is to investigate and conduct research on micromachines.

NEDO delegated micromachine R&D to the MMC under the National Research and Development Program (Large-Scale Projects). The MMC conducts its R&D with 23 domestic companies, one domestic organization, and three overseas members.

- R&D objectives

The need for micromachines is gr[illegible] These minute devices can quickly and eas[illegible]ntain increasingly advanced and complex industrial systems and can be used in the sophisticated medical techniques to minimize discomfort to patients.

Responding to this need, MITI's AIST began a R&D project on micromachines in FY 1991, as part of the agency's Large-Scale Projects.

The micromachine project consists of researching and developing devices that can move in very fine tubing to inspect and repair complex systems, such as power generation stations, and that can examine or operate inside the human body.

- R&D period

Five years from FY 1991 (10 years for the entire plan)

- R&D funds

About ¥10B (gross budget: ¥25B)

- R&D areas

- Microcapsule R&D - The MMC studies element technology for floating type wireless micromachines as well as systematization technology. Based on the progress of these technologies, the MMC studies applications to conduct R&D on capsule type micromachines, which can function as independent modules or as parts of a group of devices.

- Mother ship R&D - The MMC undertakes R&D on element and systematization technologies for micromachines that serve as mother ships, which transport inspection and operation modules and provide a communications link between the micromachines and outside controllers.

- Inspection module R&D - The MMC performs R&D on element and systematization technologies for wireless micromachines that move inside tubes. Wireless micromachines are composed of multiple modules capable of environmental recognition, movement, energy supply, and communications.

- Operation module R&D - The MMC does R&D on element and systematization technologies for cabled micromachines, which have units that can inspect, repair, diagnose, or carry out medical treatment.

- Total system research - In addition to defining complete micromachine systems, the MMC investigates and researches valuable ways for using micromachines.

- Long-term development plans

- Studies of the trends of micromachine R&D in Japan and abroad — The MMC studies organizations capable of micromachine development and the state of development in Europe, the United States, and Japan.

- Studies on materials — The MMC studies the needs for material technology in the fields in which micromachines are to be introduced and conducts experimental studies on the feasibility of applying this material technology to micromachines.

- Studies of industrial ownership rights — The MMC investigates industrial ownership rights on micromachines in Japan and abroad.

- Joint research facilities — The MMC studies the establishment of joint facilities for micromachine research and the provision of these facilities to researchers.

B. Activities to gather and provide micromachine information

The MMC collects information and data on micromachine technology from universities, industry, and public organizations in Japan and abroad. It also catalogs reference materials on its own studies and makes all materials in its library available to participants.

C. Exchanges and cooperation relating to micromachines with organizations in Japan and abroad

To keep up with international development of micromachines, the MMC plans international exchanges and joint studies among industry, government, and academia. To encourage cooperation on micromachines science, the MMC implements the following technology exchange and research support activities:

- Aid for micromachine technology R&D
- Aid for international exchanges among micromachine technology researchers
- Symposia on micromachine technology and participation in symposia held in Japan and abroad
- Workshops on micromachine technology and participation in workshops held in Japan and abroad
- Dispatch of missions to the United States, Europe, and other countries, thereby fostering exchanges and tie-ups with universities, research laboratories, and other institutions.

D. Promotion of micromachine standardization

The MMC works with relevant organizations to promote the standardization of the terms, units, and measurement methods for micromachines.

E. Provision and dissemination of micromachine information

The MMC engages in the following activities to provide and disseminate micromachine information:

- Periodically publishes and distributes a public relations document about micromachines
- Holds annual seminars on micro machines in Tokyo and other places
- Holds exhibitions on micromachines once a year, and a symposium is scheduled for April 1994

Worldwide Research & Development
of Micromachines
Yoshitaka Tatsue
Director Engineering Lab
AIST, MITI

Introduction

Since micromachine R&D is being vigorously conducted worldwide by researchers and engineers enthusiastically supported, this new publication is an appropriate way to follow the zealous, long-term development of this technology and to promote information exchanges.

[Mr. Tatsue is referring to MMC's newsletter, "Micromachine", the first issue of which (Feb 1993) contains his remarks, as given above. This newslet ter can be obtained by writing to MMC at the address listed at the beginning of this report, DKK.]

Presently, while micromachine R&D should be done as freely as possible, it is important to accurately document in a timely manner who is researching, what, and where. Here, I would like to frankly express my impressions and understanding of the current status of micromachine R&D, and I look forward to an article in the future issues that will present the R&D in detail.

Status of micromachine R&D

All R&D challenges the unknown, but usually the basic topography of the research area is known to some extent. However, I say without exaggeration that micromachine R&D has started with a blank map. From now on, we must earnestly construct the framework for researching this technology.

Research subjects tend to be taken up with relative ease in most countries. Yet, no established research pattern exists for micromachines that is similar to the earlier example of conventional machinery for which the basic ideas were conceived in Europe, developed in the United States, and commercialized and matured in Japan. However, Japan, Europe, and the United States, though technologically advanced, have not established vectors for the development of a technology specific to each area.

Therefore, I believe that it is important to introduce in this technology series the status of micromachine R&D in Japan and abroad.

Moreover, since the image of micromachines differs depending on the understanding and interpretation of each individual concerned with this technology; a willingness to "try everything" emerges. This attitude is natural because micromachine researchers must construct a technological system comparable to that established for machinery by the sublimation of previous technology and the creation of new technology.

Micromachine R&D subjects will vary from sensors and simple actuators (soon to be realized) to energy sources, control mechanisms, and whatever is being seriously studied henceforth. Basic research efforts will also cover broad technologies for materials, design, and processing and assembly.

To perform this wide range of research, we must make full use of the existing advanced mechanical, electronic, optical, and biological technologies and know-how. We must not rely only on industrial research, but we must also emphasize creative scientific research.

Again, let me emphasize that many people in Japan and abroad are engaged in various kinds of R&D work, including micromachines, to foster their dreams. The situation is like bamboo shoots sprouting everywhere.

Except for a few technologies like the semiconductor and LIGA processes, micromachine research is doable to a considerable extent by using comparatively small-scale facilities. At the laboratory level, broad research areas can be covered quickly and interesting study themes emerge in rapid succession. In extreme cases, research work that attracts attention today may be regarded differently tomorrow.

Micromachine technology will certainly not be established in one day, so to speak. As micromachines pass through the development and application stages, their concepts and basic structures will be established, and their design, manufacturing, and application technologies will accumulate steadily.

While it is difficult to accurately assess how micromachine R&D is conducted in Japan and abroad, typical examples of the starting point technologies and related research situations are shown in the table below. The general classifications of mechanism, processing, and system and control are for convenience only. Also, included in each category are common technologies; technologies that are apparently the same but, in fact, differ substantially; and other unclassified technologies, because, at present, no interdisciplinary boundaries exist.

[The table lists institutions in Japan, United States, and Europe where micromachine work is ongoing, and is clearly not meant to be exhaustive, DKK.]

Mechanism-related technology: Sensors, Actuators, Energy Sources, Designs.

Japan:	Tohoku University, Tokyo Institute of Technology, University of Tokyo, Nagoya University, Kyushu Institute of Technology, MITI's Mechanical Engineering Laboratory, MITI's National Research Laboratory of Metrology, and many companies.
United States:	University of California, Berkeley; MIT; University of Utah; Stanford; AT&T; NOVA.

Europe: Fraunhofer Institute, University Twente, Philips, LETI, Siemens.

Process-related technology: Addition, Reformation, Removal, and Assembling.

Japan: University of Tokyo, Tohoku University, Mie University, Seikei University, MITI's Mechanical Engineering Laboratory, many companies

United States: MIT, University of Wisconsin

Europe: Fraunhofer Institute, Messerschmidt, KfK, STEAG, Imperial College.

System and Control Related Technology: Autonomous Distribution, Telemetry, Cooperative Control

Japan: University of Tokyo, MITI's ETL, MITI's Mechanical Engineering Laboratory

United States: University of Michigan, MIT, IBM

Europe: University of Neuchatel.

Yaskawa Electric, Tsukuba Japan

Yaskawa is primarily a robot manufacturer. Sales, in 1992, amounted to about US$1.7B. Mechatronics (robots, inverters, and servos) account for about half the company's business. Heavy electrical products (induction motors and generators) account for about 27% and most of the balance in systems products (integration and facilities). The company trademarked the term Mechatronics in 1976 and claims to have produced 56% of the world's industrial robots, mostly under the name "Motoman." Yaskawa staff is of almost 5,000 employees, although only about 200 are associated with research. The company has four research laboratories. We visited the Tsukuba laboratory that opened in 1991, with a staff of about 40 researchers. As with MITI's Mechanical Engineering Laboratory, the focus of the visit was on micromachine activities and not on a full examination of the company's research projects.

Our hosts were

Drs. Seishi Kudo
Manager of Tsukuba Research Lab
Yaskawa Electric Corp
5-9-10 Tokodai
Tsukuba Ibaraki Japan 300-26
Tel: +81 298 47-0751;
Fax: +81 298 47-0765
Email: KUDOQYASKAWA.CO.JP

as well as Mr. Kawabe, Matsuzaki, and Dr. Futami (FUTAMI@YASKAWA.CO.JP).

Af'er a short video (in Japanese) we were taken to see three research projects.

- Flagellar Motor — This was Dr. Kudo's project, and both Prof. Ro and I agreed that this has to be one of the most unusual long--term research project to be performed in a company of this type. Kudo has recently come from an ERATO research project on Cell and Information and he carries that interest with him to Yaskawa. His basic goal is to understand how bacteria rotate their flagella and develop a machine that can convert the technique to a machine capable of doing directed work. He admits that presently there are no applications in sight. One aspect of particular note is the use of a dark-field microscope to study moving flagellar. Kudo explained that the rotor and tail dimensions (50 and 20 $\times 10^{-9}$ m resp.) make this a very difficult size for STM use and thus the dark-field approach. An early description of this work was published in "Abrupt Changes in Flagellar Rotation Observed by Dark-Field Microscopy", S.Kudo et al., Nature V346, No. 6285, pp 677-680, 16 Aug 1990. A bit more recent publication is "Rapid Changes in Flagellar Rotation Induced by External Electric Pulses", N.Kami-ike et al., Biophys J, V60, pp 1350-1355, Dec 1991.

- Micromachine and Micromotor — This was Mr. Matsuzuki's project and focuses on fabricating and evaluating motors of 1.5 to 2.5 mm in diameter. This includes both pancake-type electromagnetic and cylindrical-type electrostatic motors. Their experiments involve torque measurements and comparisons with calculations and comparisons between motor size and torque. At the moment, they have fabricated prototype motors of about 5 mm in diameter, but their conclusions indicate that electrostatic motors are more effective (with respect to torque) than electromagnetic motors of diameters below 1.5 mm. In a related development, Nippondenso recently displayed an electromagnetic motor driven car, 4.8 × 1.8 mm, which was claimed to be the world's smallest moving car (Tom Thumb's car).

- Predictive-learning — This is a technique used in the robot and machine tool field in those situations when repetitive motion is required, and when better tracking precision and/or speed is desired. One basic approach, increasing the control loop gain, decreases system stability. Other approaches involve learning control and predictive control. Learning control requires that a reference input is repeated with a known period. Tracking error of the previous iteration is used to modify the control input of the next iteration (sometimes the error derivative is used). This approach requires a system model, either state space or transfer function. Predictive learning attempts to minimize some cost function of estimated future errors, calculated on the basis of the system dynamics. Again, an identified model is required. Mr. Nakamura's project combines these into one algorithm for repetitive motion improvement, using the step function of the system, but without requiring either its state-space or transfer function. He has applied this to a positioning controller for a DC servo motor. Similar approaches are also being used in the West.

REFERENCE

"Predictive Learning Control and Application to Servo System of DC Motor", H. Nakamura et al., Proc. 1989 IECON, Philadelphia, PA.

UNIVERSITY OF TOKYO INSTITUTE OF INDUSTRIAL SCIENCE (IIS)

IIS, University of Tokyo's third campus is located in the Roppongi area of central Tokyo. (IIS recently held an open house that will be reported on separately.) There is a research group working on aspects of Micromechatronics with seven main projects.

The Group Leader and point of contact for information is

Prof. Hiroyuki Fujita
EE Dept., Institute of Industrial Science
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Professor Fujita describes the overall activities as follows.

The purpose of the micromechatronics research is to integrate micromachines and microelectronics into a complete mechatronics system called MEMS, microelectromechanical systems, in the United States and micro systems, in Europe, which works in the micro world. The research projects cover from micromachining technologies using both semiconductor processes and extremely fine mechanical machining to micro motors and actuators based on new principles. Ultraprecision control down to atomic dimensions and intelligent motion control using advanced sensing scheme are also investigated. The prospective application includes biomedical engineering, micro robots, micro optics, micro fluidic systems, and information storage and retrieval devices.
The subprojects and their principal investigators are as follows.

MICROMACHINING

T.Masuzawa Laboratory — [Email: MASUZAWAQIIS.U-TOKYO.ACJP]

Our main interest is in micro machining with conventional machining methods such as EDM and cutting. Peripheral techniques such as measurement and assembly of micro parts are also included. Some examples from our subjects are:

- Machining of micro pins and micro tools by WEDG (wire electrodischarge grinding).

- Machining of micro holes, cavities and convex shapes by EDM, drilling, milling, and punching.
- Fabrication of micro nozzles by a combined system with WEDG, EDM and electroforming.
- Measurement of micro 3-D shapes by VS (vibroscanning) method.
- On-the-machine machining/assembly system for micro parts production.

MICROELECTROMECHANICAL SYSTEMS BY IC-PROCESSES

H. Fujita Laboratory — [Email: FUJITA@IIS.U-TOKYO.ACJP]

Micro mechanisms and actuators that are 10-100/mu-m in size are studied. Micro fabrication technologies based on IC-compatible processes are also investigated. The research goal is to build a smart micro system through the integration of moving mechanisms, sensors, and electronics on a chip.

Current research projects are as follows:

Electrostatic micro actuators and micro motors
Fabrication technologies based on IC-compatible processes
Parallel cooperative MEMS
Superconductive or piezoelectric materials for MEMS
Application of MEMS to scanning probe microscopes
Micromechanoptics (optical MEMS)

NANOTECHNOLOGY APPLIED TO SCIENTIFIC INSTRUMENTATION

Kawakatsu Laboratory — [Email: KAWAKATSU QIIS.U-TOKYO.ACJP]

- Application of crystalline lattices to metrology with a scanning tunnelling microscope (STM).
- Positioning control with lattice spacing as the scale reference.
- Laser guided magnetic suspension systems for vacuum, clean-rooms and hostile environments.
- Multidegrees of freedom force control in atomic force microscopy.
- Use of surface acoustic waves to displacement measurement.
- Manipulation and surface modification with AF/STM.

ACTIVE MICRO LEVITATION

Hannes Bleuler Laboratory — (Toshiba Chair of Intelligent Mechatronics)

From natural scaling laws it follows that with miniaturization, mechanical wear, and friction (surface force) become dominant compared to weight and inertia (volume force). The aim of our projects is to overcome friction problems by realizing active contact-free levitation and bearings for micromachines.

- Micro-magnetic bearing-stepper motor
- Micro-magnetic bearing-induction motor
- Position-sensorless magnetic bearing

MAN-MACHINE INTERFACE IN THE MICRO ENVIRONMENT

H. Hashimoto Laboratory — [Email: HASHIMOTO QIIS.U-TOKYO.ACJP]

Realization of complicated performances of the robot or mechanical systems in the micro environment are studied. The artificial reality is applied to the man-machine interface to complete the micro tasks. We are now developing the system that can extract the skill from the human performances and then let the skill be realized in the micro environment by micro robot hands.

- Study on the mathematical expression of skill
- Study on sensor glove to extract the skill from human performances
- Study on Dynamic Force Simulator to realize physical world Development of multidegrees of freedom robot hands.

MICRO SENSORS FOR ADVANCED CONTROL

R. Luo Laboratory — Toshiba Chair of Intelligent Mechatronics

My current research activities related to MEMS area are focused on two projects, micro proximity sensor and micro tactile image array sensor using micro machining technology. In the first project, we first derive the mathematical modeling of a fringing capacitance based proximity sensor and identifying all the necessary physical parameters. This sensor can measure the proximity distance in the range of selection from 10 μ to mm for both conducting and nonconducting objects. The second project involves design and fabrication of a micro tactile image array sensor. This tactile image array sensor consists of a matrix of micro-size force sensing element with overall size 50 μ-m × 50 μ-m. The force sensing element has a unique structure that consists of a micro capacitive proximity sensor and a membrane. This type of tactile image array can detect a variety of object properties through "sensing by touch" such as shape, force, texture, and pressure force distribution incorporating with dexterous robot hand.

Professor Luo is currently on leave from North Carolina State University, where he will return in September 1993. Address for correspondence after 1 September 1993 is as follows.

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ULTRAFINE MECHATRONICS

T. Higuchi Laboratory — [Readers may recall that Professor Higuchi was the Project Leader for a related project that I described in the "kast.93" report mentioned earlier. DKK]

Higuchi laboratories at the University of Tokyo and KAST are engaged in the study on Mechatronics. Current topics related to micro mechatronics are as follows

- Electrostatic film actuators,
- Precise positioning by piezoelectric element,
- Micro robot,
- Machining center and flexible manufacturing system for micromachines,
- Micro drilling,
- Precise positioning by using STM image as a scale,
- Micro ultrasonic motor,
- Micro manipulator for cell operation, and
- Micro slicer for 3-D image observation of micro creatures.

Professor Higuchi also belongs to KAST (Kanagawa Academy of Science and Technology) as a project leader.

MECHANICAL ENGINEERING LABORATORY (MEL), TSIKUBA JAPAN

MEL is one of a number of MITI laboratories in the science city of Tsukuba, outside Tokyo. Our host was

Mr. Hitoshi Maekawa
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Mr. Maekawa is also involved in robotics activities and showed us his own research project (see third project described below). The Director of the Research Planning Office is Dr. Toshio Kojima (Email: KOJIMAQMELINFO4.MEL.GO.JP). Readers will remember that he is also in charge of the STEP Center in Tokyo (see "step.792", 3 Aug 1992). Also, Dr. Kojima coordinated our visit but was not available on that day.

MEL is a very important Japanese laboratory, but surprisingly small, with a staff of only 250, and 207 researchers. In fact, the numbers have been decreasing in recent years in line with the government's plans to outsource research. However, the actual number of researchers may be somewhat greater because of students and industrial collaborators. MEL's R&D budget for FY 1993 is about ¥1.6B.

Mr. Maekawa gave us a general overview of MEL and also showed us an excellent English language video. Although this was about two years old, I thought that it was extremely well done and he was kind enough to give me one copy. He emphasized that no duplication from the tape is permitted, but I can provide it on brief loan to any interested reader who contacts me.

Since the purpose of our visit was to focus on the micromachine activities, I simply summarize some of the other research activities that Mr. Maekawa presented to us. Except for the three projects described in detail below we were unable to see any other research activities.

MEL's General Director is Dr. Ken-ichi Matsuno; his Deputy is Dr. Yoshinori Nakazawa, who is also in charge of the Materials Engineering Department.

Scientifically, MEL's organization comprises six departments and two extra groups, as follows.

- Applied Physics and Information (Science Department — Dr. Kiyofumi Matsuda)

  Optical Engineering Division
  Instrumentation and Control Division
  Computer Science Division
  Biomechanics Division
  Machine Intelligence Division

- Machinery Department
  (Mr. Yoshitaka Tatsue)

  Design Engineering Division
  Machine Elements Division
  Machine Dynamics Division
  Vehicle Engineering Division
  Advanced Technology Division
  Senior Researcher

- Materials Engineering Department
  (Dr. Yoshinori Nakazawa)

  Material Properties Division
  Materials Design Division
  Plasticity and Forming Division
  Tribology Division

- Manufacturing Systems Department
  (Dr. Hideo Inoue)

  Machining Technology Division
  Energy Processing Division
  Joining Technology Group
  Machine Tool Division
  Manufacturing Information Division

- Energy Engineering Department
  (Dr. Kazuo Kontani)

  Thermal Engineering Division
  Fluid Engineering Division
  Combustion Engineering Division
  Energy Conversion Division
  Environmental Engineering Division
  Senior Researchers

- Robotics Department
  (Dr. Taketoshi Nozaki)

  Mechanism Division
  Cybernetics Division
  Autonomous Machinery Division
  Biorobotics Division

- Biomechanical Engineering Research Group
  (Dr. Tetsuya Tateishi)

- Micromachine Engineering Research Group
  (Mr. Yoshitaka Tatsue)

MEL DESIGNATED RESEARCH

(Long range, large research projects in several departments)

Industrial Science and Technology Frontier Program

- Advanced Material Processing and Machining System

  - Ultraprecision Machining System*
  - Forming Technology of Advanced Metal Forming*
  - Beam Assisted Hybrid Machining*
  - Evaluation of Mechanical Properties of Beam Processed Material*

- Super/Hyper-Sonic Transport Propulsion System

  - Evaluation Techniques for Machine Elements in Extremely High Temperature Gas Generator*

- Underground Space Development Technology

  - Robotic Underground Excavation Technology

- Measurement of Human Perception

- Artificial Reality for Evaluation of Human Perception*
- Noninvasive Measurement System for Stress-Related Factors and its Metabolism*

• Micromachine Technology

- Evaluation of Micro Motion Mechanism*

• Ecofactory Technology

• Medical and Welfare Apparatus

- Ambulatory Apparatus with Weight Bearing Control
- Next Generation Oral Device Engineering System
- Optical Tomographic Imaging System

• Welfare Apparatus Technologies

- Design and Transfer Support System for Wheel Chair

• Development of High Performance Materials for Severe Environments

- Stirring Synthesis for Intermetallic Compounds
- Development of Advanced Intermetallic Compounds

• R&D on Carbon-Carbon Composites for Efficient Power Generator

- Damage Tolerance Characterization of High Performance Materials for Severe Environments*

• New Models for Software Architecture

- Framework of Agent-Based Systems for Machine Design

New Sunshine Program

• Hydrogen Energy

- Fundamental Research on Hydrogen-Oxygen Combustion System
- Surface Reactions in Hydrogen-Oxygen Combustion*
- Evaluation of Hydrogen-Oxygen Combustion Turbine*

• Comprehensive Research

- Wind Energy Conversion System
- Best Mix Strategy for Energy Utilization
- Development of Large-Sized Wind-Energy Power-Generation System*

• Geothermal Energy

- Analysis and Evaluation on Measurement Methods*

• Solar Energy

- Analysis of Silicon Single Crystal Growth Process for Photovoltaic Substrate*

• Broad Area Energy Utilization Network System

- Thermal Energy Utilization System Analysis Based on Second Law of Thermodynamics
- Advanced Thermal Energy Utilization Reactors for Energy Transport*
- Active Fouling Prevention and Microscale Thermal Storage Control*
- Heat Cycle Using Ultimate Heat Source*

• Superconducting Technology for Electric Power Apparatuses

- Evaluation of Structural Integrity for Superconducting Generator*

• Ceramic Gas Turbine (CGT)

- Aerodynamic Components for Ceramic Gas Turbine
- C/C Composite Rotor for Ceramic Gas Turbine*
- Combustor for Ceramic Gas Turbine*
- Regenerator for Ceramic Gas Turbine*
- Impact Damage by Small Particles*
- Evaluation Technology of CGT*

• Leading and Basic Technology for Energy Conversion

- Multifuel Small Otto Engine

- R&D of Technologies Related to Global Environment

- Study on C02 Fixation in Deep Sea

Human Frontier Science Program

- Perception, Recognition and Motion-Behavior Control

- Behavioral Modulators in the Brain

Specific Regional Technology Development System

- Technology of Structural Control for Functional Composite Materials

- Laser Applied Advanced Processing System

*= Funded by Special Account for Electric Power Development Promotion Policy

MEL SPECIAL RESEARCH

(Approximately 5 year, ¥6-15M/year, projects)

- Technology for Measurement and Standardization

- Development of Optical Information Processing Using Novel Optical Devices
- Wide Band Precision Surface Profile Generation

- Bionics

- Biomechanical Study on Promotion of Bone Formation and Replacement of Bone

- New Materials Technology

- Processing Technologies of Super-Lattice Materials
- Application of Damping Alloys

- Application of System Engineering

- Whole Arm Manipulation
- Dynamic Modeling of World for Autonomous Vehicles
- Dynamic Skill
- Intelligent Control for Machining

- Space Development Technology

- High Precision Position and Attitude Control in Space
- Robot Programming through Virtual Environment

- Technology for Establishment of Industrial Foundation

- A High Efficient Propulsion Technology for Airships
- Absolute-Stationary Stage System Using a Magnetically Supported Control Method
- Manufacturing Technique of High-Performance Metal Material Sheets
- Ecology-Harmonized Technology for Manufacturing Process
- Fluid Dynamics of Turbo Pumps for Artificial Hearts

- Interdisciplinary Research

- Production Technologies for the Future Manufacturing Systems
- Integration Technology for the Future Manufacturing Systems

- Specific International Joint Research Project

- Special Purpose Optical Elements for Precision Shape Measurement

- Technology for Small and Medium-Sized Enterprises (Small and Medium Enterprise Agency)

- A Study on Advanced Complex Arc Welding System

- Atomic Energy Engineering for Peaceful Use (Science and Technology Agency)

- Noncontact Remote Monitoring Technology on Atomic Energy Components

- Pollution Protection Technology (Environment Agency)

- Air Pollution Control of Automobile Exhaust Gas in Urban Road Tunnels
- Regenerable Filter Trap Oxidizer for Diesel Particulate Control
- Exhaust Clarification of Diesel Engines by Activating Middle and Late Stage of Combustion
- A Noise Reducing Method of Tires
- Low Emission Diesel Engine by Using Low Cetane Fuel Combustion

- Institute for Transfer of Industrial Technology

- High Performance Metal Matrix Composite Materials
- Study of Surface Machining/Modification

- Research Information Processing Systems

- Development of Design and Manufacturing Database System for Advanced Materials with Artificial Intelligence (AI)

MEL ORDINARY RESEARCH

(Fairly short, about 3 years ¥2-6M/year projects, within a department)

- Applied Physics and Information Science Department

- Method to Measure Flat Mirror with Large Aperture by Holographic Optical Element
- Advanced Control Method for Mechanical Systems
- Interfacial Phenomena of Fluids
- Random Data Processing in Mechanical Engineering
- Challenge for Advanced CAE
- Damage and Repair Process of Bone and Connective Tissues
- Specimen Preparation for Cutting and Polishing of Embedded Neuron Fibers
- Lateral and Longitudinal Control of an Autonomous Vehicle
- Measurement of Car Behavior Near a Yellow Traffic Signal for Prediction of Accidents

- Machinery Department

- Characteristics of Power Transmission Elements
- Surface Fracture in Rolling-Sliding Contact
- Mechanical Components with Phase-Changeable Fluids
- Source Localization Technique for Impact Noise
- Active Noise Control of 3-D Structure-Born Sound Field
- Friction Materials of Nonsteel Fibers
- A Research Study on Dynamics of the Vehicle-Driver System
- Concept of Comfortable Machinery
- Laser Control of Discharge Position in Electrical Discharge Machining

- Materials Engineering Department

- Evaluation Technique of Impact Properties
- Mechanical Properties of Uni-Directional Oriented Polymeric Materials
- Superplasticity of Single Phase Stainless Steel
- Improvement in Quality of Blanked Products
- Application of Isostatic Pressure to Metal Forming
- Development of Core Forging Technology and Low Noise Forming Machinery
- Microtribological Aspects of Sliding Surfaces
- Study of Functional Inorganic Allotrope
- Study of Super Advanced Tribo-System

- Manufacturing Systems Department

- Basic Study for Ultraprecision Grinding of Brittle Materials
- High-Quality Grinding of New Composite Materials
- Thermo-Chemical Machining of Nonconducting Ceramics
- Advanced Technology in Joining and Surface Modification
- Improvement for Ultraprecision Machining and Processing
- Characterization of Element Interfaces in Machine Tool
- Advanced Human Interface Technology for Machine Tools

- A Study of Representation and Inference for Machining Know-How

- Energy Engineering Department

- Thermo-Acoustic Effect and its Application to Cryogenic Engineering
- Numerical Analysis of Turbulent Flow
- Fundamental Study on the Structure of Turbulent Combustion
- Closed Cycle MHD Power Generation System
- Measurement of Diesel Exhaust Particulates
- Research of Low Temperature Aqueous Solution

- Robotics Department

- Model-Free Robotics
- Cooperative Robotics
- Basic Elements of an Autonomous Robotic System
- The Advising Systems for the Conceptual Design
- Basic Study of Sensor and Motion Integration

Some assorted projects are also supported by other agencies and jointly supported by companies. These follow.

COORDINATION FUNDS FOR PROMOTING SCIENCE AND TECHNOLOGY (Science and Technology Agency)

- Encouragement of Basic Researches at National Research Institute

- Basic Study on Tribological Control of Electrorheological Fluids for Machine Elements
- Wavelength Scanning Interferometer for Shape Measurement
- Study on the Transport Mechanism in Polymer Complex

- Promotion System for Comprehensive Research and Development Project

- Quantitative Nondestructive Evaluation of Materials-Acoustic and Photoacoustic Microscopy
- NIR Measurement of Living Bodies (Development of NIR Optical-CT Imaging Instrument)
- Evaluation of Biocompatibility under Dynamic Conditions
- Wear Testing and Evaluation Methods
- Construction of Active Motile Materials by Biomimetic Chain Reactions

GLOBAL ENVIRONMENT RESEARCH PROGRAM

- Environment Agency

- Physics of Stratospheric Aerosols
- Preparation of Systems for Adequate Charge and Operation
- Analysis and Evaluation of Product Design Modification for Waste Reduction and Recycling

JOINT RESEARCH

- With companies

- Application of Logic Programming System to Knowledge-Based Machinery Design/ Manufacturing
- Scanner for Low Temperature Acoustic Microscope
- Formal Implementation Method of CAD/ CAM Data Exchange System
- Trial and Strength-Analysis of Axially-Layered C/C Rotor
- Regeneration Technique of Diesel Particulate Filter
- Construction of Next-Generation Processing System
- Machining by High-Speed Projectile Impact
- Materials for Micro-Fabrication
- Steering Control for Autonomous Locomotion Vehicle
- LPG Fueled Diesel Engine

Mr. Maekawa emphasized to me that about joint research with companies, MEL only exchanges researchers and information. There is no financial flow between MEL and private companies.

The brief lab tour at MEL consisted of two projects on micromachines and control and a project on robot hand.

The first project was on high-stiffness torque control of a DC motor that uses an acceleration controller. The use of a torque sensor reduces the structural stiffness of the motor system because of the compliance of the sensor. The work in essence uses an advanced control scheme that uses acceleration feedback to increase the stiffness as well as the bandwidth of the control system. This particular work did not have a direct link with the micromachine effort; however, the stiffness improvement of a conventional DC geared system makes it possible for a miniature version of these motors for micro robotics in general. A micro-order torque control is expected to be constructed by applying this method.

The second project was directly linked to the micromachines effort in that its main object was to develop a micro gripper that can manipulate an object of the size of a micron. A prototype has been built in which two fingers manipulate a tiny object. The concept can be extended to further miniaturize the fingers for in vivo manipulation of biological objects. The heart of each finger rests on a parallel link mechanism with two circular planes whose relative orientations are controlled by a set of six miniature PZT stacks. A thin glass tube is attached to the upper plane whose position and orientation can be manipulated. Using two sets, representing two fingers, of these mechanisms, the motion of the tips can be controlled for grasping or to perform other functions.

The third project was on robotic hand with three fingers. These fingers are equipped with force sensors for compliance control in a wide-range of compliance for varied grasping purpose. The ultimate goal is to develop dexterity that is comparable to that of human hands, even though this may seem a bit far-fetched at this point. The mechanism used for finger actuation is cable driven with tension controlled by strain gages. Also, an effort in tactile sensing for the fingertips is on going. The tactile sensor is developed based on the scattering of totally internally reflecting light (using white light source through fiber optics) when the tip, consisting of a hemispherical optical waveguide, is disturbed by external touch. This scattering intensity is transmitted to the detector that then processes the information to the computer. The experimental setup works impressively well with a reasonably fast processing time. The tactile sensing is another aspect of on-going effort to emulate human fingers.

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(3) K. Kaneko et al., "Accurate Torque Control for a Geared DC Motor based on an Acceleration Controller", Proc. IECON'92, San Diego CA, 9-13 Nov. 1992, pp. 395-400.

(4) H. Maekawa et al., "Development of a Finger--shaped Tactile Sensor and its Evaluation by Active Touch", Proc. IEEE Int. Conf. on Robotics & Automation, Nice France, 12-14 May 1992, pp. 1327-1334.

(5) H. Maekawa, "Stable Grasp and Manipulation of 3D Objects by Multifingered Hands", Proc. ISMCR'92, Tsukuba Japan, 15-19 Nov. 1992, pp. 335-342.

(6) T. Arai et al., "Micro Hand Module Using Parallel Link Mechanism", Proc. Japan-USA Symp. on Flexible Automation, ASME Book No 10338A, 1992, pp. 163-168.

(7) "Kinematic Optimization of a Chopsticks-type Micromanipulator, ibid, pp. 151-157.

(8) "A Six-degree-of-freedom Micro-Manipulator Using a Piezoelectrically Driven Parallel-Link Mechanism", ibid, pp. 173-174.

MEL has an active scientist exchange program. In FY 1992 about 100 Japanese were sent abroad, and 35 foreign scientists were working at MEL. Interestingly, of the latter, almost twice as many were from Western Europe, the rest was from North America. There are a variety of cooperative research programs, especially in the area of advanced materials.

Overview of Research and Development at NTT, 19 Sept 1993

An overview of the Research and Development direction at NTT is presented in this report

David K. Kahaner

I have already written about some networking issues and related interdepartmental disputes, see "j-comm.93", 5 Sept. 1993. On the latter topic, one reader from Japan pointed out that our Trade & Industry is published by MITI and emphasizes their viewpoint as opposed to that of MPT. NTT, as readers will recall, was a spun off from the Japanese government in 1985.

I doubt if non-Japanese can really understand the details of these issues, but today, the annual market for telecommunications equipment and services in Japan is about J¥7T (about US$70B) for Type I carriers (operators who own their own circuit facilities), J¥1T for Type II carriers (operators who lease their facilities from Type I carriers), and J¥1.5T for terminal equipment vendors. Some government estimates project 400% increase of the telecommunications market by the year 2015.

NTT (with market capitalization worth US$150B) has financial problems, as the earlier report mentioned, but in 1993 it is planning to add more than 78,000 INS-Net 64 circuits (N-ISDN, 64 kbit/s), and 1,200 INS-Net 1500 (N-ISDN, 1.5 Mbit/s) circuits. (B-ISDN has variable bit rate transmission, up to 622.08 Mbit/s). With so much activity, it is essential to keep track of this huge company's activities. The following report is by a key NTT R&D manager. While naturally expressing a very positive view, it clearly states the directions NTT is headed.

Following this report, titles are presented from the English language NTT Review, 5(3-4, (1993).

Overview of R&D at NTT

Noboru Miyawaki
Executive VP & Senior Executive Manager
Research & Development Headquarters, NTT
From: NTT Review, 5(3), (May 1993)

INTRODUCTION

The telecommunications industry in Japan is fiercely competitive, which makes it more important than ever for NTT to conduct research and development to maintain its competitive edge. Yet at the same time, NTT operates the nation's public-switched telephone network, one of society's most crucial infrastructures. The company is thus under a special obligation to provide the very best telecommunications services possible with fail-safe reliability. This is NTT's corporate mission, and extensive R&D plays a role in every facet of the company's operations to fulfill this mission. For example, major R&D outlays serve to create enticing new services that are more visual, more intelligent, and more personal, to upgrade operations technologies so that services can be provided smoothly and reliably; and to conceive, design, and control better integrated and more efficient network architectures. Moreover, telecommunications networks are built on a rapidly progressing technological foundation of network elements, terminal equipment, and other assorted hardware. NTT therefore devotes extensive R&D to provide the technological underpinning to support these essential products.

As Japan's flagship public carrier, NTT aspires to contribute to the advancement of telecommunications technology in Japan and at the same time promoting the well-being of society at large within the regulatory framework of Japan's Telecommunications Business Law. This is a commitment to something larger than just short-term profitability, and it motivates NTT's work on basic science and ground-breaking new technologies with the potential to radically reorient the course of telecommunications. Moreover, NTT discloses the results of this research in print and in public forums, and thereby makes a substantial contribution to the advancement of world science and technology.

This paper is an interim report and update of R&D conducted at NTT. I have especially sought to highlight work that contributes to NTT's futuristic vision of services for the 21st century that are more visual, more intelligent, and more personal.

Telecommunications Services in the 21st Century

Telecommunications evolve, and as they come to be used in new and different ways, the industry applies R&D in a constant effort to create new service offerings that people will find useful and appealing. At NTT we conducted a careful inquiry to ascertain the future communications needs of diverse segments of society, and we identified three salient needs. We found that people are longing for services that are more visual, more intelligent, and more personal. We have thus taken these three concepts and created the acronym VI&P as our watchword and vision of customer services for the 21st century, and much of NTT'S R&D effort is focused on converting this vision into reality.

"More visual" means breaking, with the long history of voice-oriented telephone to open up a whole new visual dimension to add life and vitality to voice. New and innovative uses of telecommunications will quickly multiply with systems in place that can integrate computer data and interactive video for simultaneous delivery with voice.

"More intelligent" means a profusion of smart new services that are able to unobtrusively anticipate what people want and respond accordingly. And with intelligence distributed in the network, it will be possible to access network resources without extensive network expertise or resorting to complicated procedures. Intelligence in the network opens also the way to customer networking—giving customers greater control over their own services so, for example, they can manage and operate their own corporate wide-area networks.

Finally, "more personal" means services that are tailored to the needs and preferences of individuals, such as personal phone numbers that are assigned to people, rather than to telephones that are anchored in a fixed location. The combination of personal phone numbers with lightweight, pocket-sized communicators will at last bring communications into line with our more mobile life-styles, so that subscribers can be reached anytime anywhere.

Migration to a VI&P Service—Ready Network Architecture

NTT's network architecture will undergo a profound transformation over the next ten years to make it ready for the profusion of advanced new VI&P services that we will be making available. Here, I will review the key technologies that will implement this transformation.

First, the network must be upgraded to an intelligent network architecture to support the rapid and easy provisioning of the many advanced services that we have in mind such as customer control and personal communications services.

Second, the network will migrate to broadband ISDN (B-ISDN) in the latter half of the 1990s to meet the demands of business for high-speed, variable-bit-rate multimedia applications. The B-ISDN environment proposes Asynchronous Transfer Mode (ATM) for cell-based switching over Synchronous Digital Hierarchy (SDH) transport systems. ATM allows the SDH payload to be flexibly allocated to a wide range of applications with varying bandwidth needs.

Third, turning to the local loop plant, digital multiplex systems have been introduced as ISDN penetrates the network. Moreover, large business customers have been in the first wave to exploit Fiber-to-the Office (FTTO) systems as the primary-rate INS-Net 1500 service. Indeed, demand for FTTO has grown much faster than we anticipated to meet the insatiable demand of business customers for high-speed digital communications. Fiber-to-the-Home (FTTH) is still some years off, but optical fiber will move into the local loop very quickly in response to increasing demands for visual communications such as entertainment video once it reaches cost parity with the copper narrowband ISDN (N- ISDN) loops.

While these are the most fundamental driving forces to transform the network, there are in addition a host of technologies that must be addressed at the same time. The most important among these are

(1) network, operations, and transmission technologies to establish a viable network infrastructure;

(2) media processing and security technologies to establish a viable service provisioning platform; and
(3) photopic, nanoelectronic, and intelligent information processing technologies that hold the potential to radically transform the network of the 21st century.

In the rest of this article I will briefly review the status of NTT's research and development in each of these key areas.

[Fig. 1: (omitted) "Evolution of Networks and Key Technologies." I have omitted this figure. It shows conventional systems fading shortly after the year 2000, SDH use fading very slowly, but being replaced by ATM, with growth, but still small use of FTTO and B-ISDN, DKK]

Network Infrastructure Trends

Network Technologies

Above all else, network technologies must be based on a sound network architecture that gives network operations the ability to monitor the functional performance and operational status of services that are made available to end users. The network must also be resilient to accommodate the dynamic fluctuations in traffic that are characteristic of multimedia transport.

At NTT we seek to optimize network design work by feeding back actual network data to be incorporated into the design process, and to enhance operations by using knowledge base systems containing decades of accumulated experience and know-how. To further smooth the design process, our researchers recently developed a high-performance network design support tool that features a graphical user interface. The system has already paid off in the form of better quality network designs, which has also helped to hold down costs. This and other innovations in this area will smooth NTT's transition to full deployment of B-ISDN sometime before the turn of the century.

Operations Technologies

Enhancement of operations-related technologies is of paramount importance for the smooth provisioning of telecommunications services. Although NTT is now concerned with cost-cutting and streamlining its operations, the company is nevertheless aiming to provide comprehensive service support to its customers.

Many routine operational procedures have already been converted to on-line systems including billing calculations, switching, operations, and circuit status monitoring. The next step in facilitating easier operations and efficiency will be to tie all of these operational procedures together in a fully integrated operations environment. Adding urgency to this work is the growing demand for customer networking, which essentially means giving customers limited operational control over their own services.

Our engineers are working on a common solution that can resolve both of these issues, i.e., integration of operational procedures and enhanced customer control, at once. Specifically, this will involve assembling operations systems so they are interchangeable and interconnectable by using a uniform data manipulation of expressions on a common platform (Fig. 2). In parallel with this, R&D is also focused on implementing a vendor—independent architecture and developing enhanced network security.

[Fig. 2 (omitted) Operation technologies, shows a very high level view of this integrated operation vision, DKK.]

Data Transmission Technologies

ATM Switching

Implementation of ATM switching requires high-speed switch processing of cells, dynamic traffic control, and advanced interface protocol processing. We have succeeded in demonstrating an ATM switch with a throughout of 300 Gbit/s. But, to realize a viable broadband switch that can handle the same number of circuits as our current narrowband switch, cross-the-board improvements in LSI (large scale integration) technology will be required: downscaled features to enhance speed performance and more compact realization. We have now succeeded in implementing a very dense ATM switch as an 8 X 8 multichip module that supports a throughout of 156 Mbit/s. This makes the part only about 1/4 the size of its predecessor.

As we are working on the hardware implementation of an ATM switch, NTT is also an active participant in international standardization efforts. Consensus has now been reached on aspects pertaining to basic connectivity. This should open the way to wide-area high-speed digital communications and multimedia applications for large business enterprises. We hope to accelerate work on ATM-related technologies so it can penetrate to the household subscriber level by the turn of the century.

Lightwave Technologies for Fiber-Optic Networks

Turning to long-haul lightwave communications, great interest is now focused on speeding up optical transmitters and detectors, and on direct amplification by using erbium-doped fiber amplifiers. Unlike conventional repeaters that have to convert light into electricity, amplify it, and then convert it back into light, fiber amplifiers boost the light signal directly and thus do not interrupt the light as it propagates through the fiber. This allows transmitters to be independent of the transmission clock rate. To assess the feasibility of fiber amplifiers and other technologies for long-span systems, a field trial was conducted on a 1,260 Km commercial cable running between Tokyo and Hamamatsu. With 19 erbium-doped amplifiers deployed along the route, an impressive transmission throughput of 10 Gbit/s was achieved.

Meanwhile, with the goal of transmitting even more information at faster rates over longer distances, NTT engineers are working on other technologies that exploit the inherent wave nature of light. Wavelength division multiplexing (WDM), which involves the simultaneous transmission of multiple wavelengths of light down a single strand of fiber, offers one such approach. NTT recently demonstrated a system that supports 100 densely packed stable channels over a single fiber with a per-channel throughput of 600 Mbit/s. This technology that will be perfected over the next decade, will support terabit-order throughput capacities by the dawn of the 2lst century.

Fiberizing the Local Loop

For the local loop, we are evaluating an approach that would deliver a multiplexed signal over a single line to a pedestal serving a cluster of residential subscribers. By the way costs are falling, we anticipate that cost parity with copper N-ISDN loops will be reached within a few years.

And, if regulatory restraints can be cleared out of the way so that telecommunications companies can deliver entertainment video and other applications over the same line with voice, this will eliminate the redundancy of multiple lines and drive costs down even more. Multiplexed signals have to be directly amplified to make up for losses incurred in the delivery, but, here again, fiber amplifiers should provide a cost-effective solution.

Once these technologies are fully established and costs fall to where it is economically viable to retire copper in favor of fiber in the local plant, then fiber will move into the local loop very quickly. Fiber in the local loop will provide a viable broadband platform to deliver multimedia applications in line with the needs and expectations of subscribers.

Intelligent Network Architecture

The intelligent network architecture makes a functional separation between the creation and control of services on the one hand and the physical switching of networks on the other hand.

The main advantage of this approach is that services can be rapidly introduced and customized in response to market opportunities without perturbing the underlying switching fabric. We also aim to simplify the service creation process by implementing service procedure descriptions for the various hierarchical layers at a higher level than in the past.

The technical content and functional allocation to the different layers has now been mapped out, and we are working on a prototype deployment of personal communications services (PCS), generally considered to be the leading intelligent network service. In the prototype architecture, action scenarios that control switching (corresponding to switching in existing switching offices) are separated into network control scenarios used by the network provider to implement basic common services and service scenarios used by subscribers to create and customize their own services.

This service-independent architecture will make it much easier to create and deploy revenue-producing new services in a timely fashion. In fact, if current estimates are reliable, it should take only one-half to one tenth the time and effort it has taken in the past to bring out new service offerings. We are also developing a scenario language that will give users the ability to define many detailed aspects of their own personal communications services relating to connection, transmission, and automatic answering.

Multimedia and Human Interface Technologies

Endowing the network with distributed intelligence and broadband capabilities is thus the key to establish a robust, service-ready platform to support multimedia applications. Besides these basic infrastructure upgrades, there are other important issues that also have to be addressed, such as devising efficient means of creating multimedia information, developing user-friendly systems that support cooperative work from remote sites over the network, and evolving simple means of controlling diverse services.

This actually entails a number of interrelated R&D themes. First, we are developing the technology that will allow workstations and personal computers to simultaneously handle audio, computer graphics, and video images extracted from media received from multiple locations over ATM switched lines. Second, media conversion capability is an essential prerequisite in a multivendor environment in order to freely exchange data between different vendors' equipment with different functional and performance capabilities. Other areas on NTT's R&D agenda include voice and image recognition to extract logical data from patterns, and voice and image synthesis to recreate a sense of presence and markedly enhance the human interfaces.

Exemplifying NTT's work in the multimedia area is a terminal developed by the company that synchronizes audio and video for application to computer-supported cooperative work. Even though people participating in a cooperative project are scattered among several remote locations, their desktops can be superimposed as semitransparent overlays on one another's screens thus creating a common visual space. The system flexibly accommodates just about any medium that a participant in the work might prefer to use—including virtually any wordprocessing program, a stylus pen, printed materials, and gestures. The system provides a high-performance conferencing environment and is so intuitive that users can start using the system with little or no special training.

Security

One advantage of digital technology penetrating to the level of terminal equipment is that this makes it easier to implement security features. This is important, because as society conducts more and more activities over accessible public networks—televoting, electronic fund transfers, and so on—this increases the need for enhanced security and greater personal privacy of communications. Also, as customers assume greater direct control over their own services, measures must be taken to ensure that the security and reliability of the network is not in any way compromised.

Concern for security has prompted NTT to explore encryption technologies for application to the public network. The main emphasis is on verifying the cryptographic strength of algorithms—even to the extent of inviting attack by outside cryptographers as a challenge—and on developing more secure ciphers. Many of the futuristic VI&P services that NTT plans to make available will also involve security-related technologies, including a reliable system of digital signatures, fail-safe procedures for managing and distributing encryption keys, and custom LSIs specifically designed for encryption applications.

For example, if we change over entirely to electronic verification of financial transactions, business orders, and so on, then we will need a reliable electronic surrogate for seals and signatures. This led NTT to develop a sophisticated electronic signature system that, for example, provides assurance that electronic mail actually comes from the purported sender (and also prevents the sender from later disavowing that he sent the message) and also ensures that the message was not tampered with en route or forged. These capabilities have been implemented in software on an IC card. The device is now in the final testing stage and should be available for commercial application in the near future.

Breakthrough Technologies

Photonics

Nowhere has progress been so rapid or the potential benefits so great as in the area of photonics. The availability of optical frequency division multiplexing and free-space digital optics that exploit the massive parallelism and enormous bandwidth potential of light should enable ATM switching of tens of thousands of circuits at data throughputs in the terabit range across spans of hundreds of kilometers. In effect, this will permit the delivery of video to subscribers on demand for roughly the same cost as delivering the ordinary telephone service today. And recent work on ultra stable solitons (waves that do not broaden or weaken as they propagate through a defect-free fiber holds out the prospect of transport across unrepeated spans measuring thousands of kilometers.

Meanwhile, interconnections between chips, between broads, and between devices have emerged as a performance bottleneck as chip sizes have increased and gate speeds have been accelerated by downscaling VLSI feature sizes. Here again, photonics hold the solution in the form of optical interconnections at all levels of the interconnect hierarchy. Farther down the road, emerging free-space photopic technologies including holography and optically addressed spatial light modulators hold out enormous promise for the storage and manipulation of images.

While the potential is clearly there, fully unlocking it will have to await further maturation of optoelectronic integrated circuits (OEIC) which, as the name suggests, combine optical elements with electronic circuits on the same chip. NTT is at the forefront in this field and recently demonstrated an OEIC that monolithically integrates photodiodes (which convert light into electricity) with field-effect transistors (which amplify the detected signal). The device transfers data at a rate of 10 Gbit/s and exhibits unparalleled sensitivity.

The tempo of advances in the field of photonics is evolving very rapidly with diminishing cycle times from initial exploratory work in the laboratory to actual deployment in the field. For example, NTT is now developing a practical optical interconnection module for ATM switching systems and planar photopic switching arrays that use light to control light.

Nano-electronics

Widespread penetration of VI&P services cannot be achieved without enhancing the performance of all the underlying hardware. To give large-scale ATM switches and broadband multimedia-capable terminals the ability to handle the prodigious amounts of data and the complex high--speed processing demanded by future services, they must be realized more compactly and economically.

This, to a great extent, depends on techniques for patterning ever finer design rules on VLSI chips.

NTT has had a compact synchrotron in operation since 1989, but only recently succeeded in integrating the main production steps—collimating the soft X-rays, transferring the pattern on the mask to the wafer, and carving the mask itself into one continuous process. NTT is now positioned to explore ULSI technologies with printed features as small as 0.2 μ. This calls for processing precision down to several tens of nanometers, and thus represents the first tentative step into the new realm of nanometer scales. This order of device miniaturization will open the way to one gigabit (one billion bits) random access memories and immense-scale ATM switches for telecommunications.

As chip geometries edge into the deep submicron region, designing and testing such devices becomes increasingly difficult. To meet this challenge, NTT is working on an intelligent design system that will in advance verify the design and provide assurance that the chip will actually function as it is supposed to.

When device dimensions fall below 100 nm, quantum effects begin to appear that are satisfactorily explained using the wavelike nature of particles. One type of device that NTT researchers are currently exploring that deliberately exploits quantum effects is the resonant-tunneling transistor. The underlying principle of this device is the quantum well, an ultrathin layer of semiconductor sandwiched between two 1-nm-thick cladding barriers of higher band-gap material that confine electrons in the well. A practical version of this device would have a huge impact on communications, for it would permit switching speeds at least an order of magnitude faster than the today's fastest speed of 0.1 ps.

Intelligent Information Processing

Great strides have been made in applying computer-aided instruction (CAI) and other design-support tools incorporating expert knowledge in the area of intelligent information processing. For example, by applying these expert systems techniques to the management of services, network resources, and operations, it is possible for network managers without extensive expertise to develop fairly sophisticated management control procedures. The availability of these user-friendly tools should also help to alleviate a particular problem associated with advanced services, that of feature interaction. Feature interaction crops up when services become so complicated that they begin to impinge and interfere with each other.

Looking further out on the horizon, we envision services that could handle much more complicated tasks such as smart communications surrogate that could handle our communications for us when we are away by screening calls, taking messages, or forwarding calls from particular people. Before services such as these can be made available, however, considerable work remains to be done in developing more user-friendly human interfaces and much smarter systems that can recognize ordinary conversation and written input.

Going beyond expert systems, research is also being concentrated on applications of artificial intelligence (AI). This cannot be divorced from a general inquiry into the way humans perceive and process information. Therefore efforts are being made to accumulate a store of theoretical knowledge about the way people learn and communicate.

For example, valuable insights might be gained by investigating how the minute magnetic field patterns outside the head that reflect neural activity of the brain are perturbed in response to audio stimulation. Accumulated knowledge in this area of human information processing will undoubtedly lead to fresh perceptions relating to speech processing and conversational cognition.

CONCLUSIONS

Progress toward the target VI&P service-ready network will be paced by how quickly we address the R&D themes reviewed in this paper. We have now reached the point where we are ready to pull all the disparate technologies together into an integrated system and begin trial services to assess their technical and economic viability. To this end, we constructed a high-speed broadband testbed network between NTT's Musashino and Yokosuka R&D Centers that incorporates ATM switching, fiber-optic transmission, and enhanced intelligent capabilities. First, we will evaluate broadband transmission and fiber in the local loop as a viable platform for supporting broadband delivery. In terms of services, we will assess N-ISDN multimedia delivery first. After the infrastructure proves to be dependable, we will proceed to evaluate B-ISDN services.

The network will be upgraded in-a series of progressive enhancements as customer needs and technological capabilities continue to evolve. Here I will briefly trace how the migration to the target architecture is likely to unfold into the 21st Century.

[Fig. 3 (omitted): 21st Century Network, which illustrates the remarks detailed below, DKK.]

First, the network will be upgraded to support ubiquitous multimedia wide-area communications including high-speed digital transport. To meet these needs, the network must be invested with high-speed, variable-bit-rate capabilities based on ATM switching and lightwave transmission technologies—capabilities that push the network toward full-scale B-ISDN. Multinational and other large business enterprises will feature prominently in the first wave of ISDN customers with their prodigious multimedia and high-speed networking needs. After that, fiber will be extended to the home to meet the demand of residential subscribers for multimedia services; this will open the way to ubiquitous deployment of B-ISDN.

Meanwhile, in the same time frame, the network will be upgraded to an intelligent architecture that will support the rapid deployment of diverse advanced voice and data services. This will also open up more ubiquitous access to the network through personal phone numbers (independent of a network address) and a host of other innovative services tailored to the needs and preferences of individuals. One implication is the need for faster common channel signaling, which again underscores the need for ATM switching. In a parallel development, network management and operations functions will be further integrated, and this will facilitate customer networking—that is, giving customers greater discretionary control over their own services.

Multimedia wireless systems will also be enhanced to provide wireless access via satellite and access in sparsely populated areas that lack a reliable terrestrial infrastructure.

These will certainly be the key developments transforming the network, but they may be in sooner than projected. NTT's commitment to fundamental research in photonics and nano-electronics leaves open the possibility of a major breakthrough speeding up transformation of the network.

NTT is striving to deploy a robust VI&P service--ready infrastructure that will meet the increasingly network-oriented needs of society in the 21st century. To achieve this goal, NTT remains firmly committed to the pursuit of research and development across the entire spectrum of telecommunications-related science and technology and also to the pursuit of robust vendor-independent standards.

3rd International Symposium on Large Spatial Databases and the Far East Workshop on Geographic Information Systems, June 1993, Singapore

The 3rd International Symposium on Large Spatial Databases (SSD'93), and the Far East Workshop on Geographic Information Systems (FEGIS'93) held in Singapore, June 1993, are reviewed. Some additional remarks about computing activities in Singapore are included.

David K. Kahaner

During the week 21-25 June 1993 the main topic of the Far East Workshop at Singapore was the Geographic Information Systems (GIS) and associated database technology. The two-day workshop on GIS, the Far East Workshop on Geographic Information Systems (FEGIS'93) was held at the plush Oriental Hotel with the assistance of local corporate sponsorship. Following the three-day international conference, Large Spatial Database (SSD'93) was held on the campus of the National University of Singapore.

GIS are essentially computerized decision support systems that involve the integration of spatially referenced data. Applications are wide and multidisciplinary, such as cartography, environmental protection, surveying, hydrology, forestry, urban & regional planning, transportation planning, and navigation. Geographic data includes maps but also many other objects in relation to objects in space. One general definition of GIS (O'Callaghan) presents it as a system for capturing, manipulating, analyzing, and displaying data that are geographically-referenced to the Earth. Here, geographic refers to human scale, i.e., mountains rather than molecules, in which the user envisions moving around within the data rather than moving the data objects.

Early GIS concentrated on capabilities for data capture, manipulation, and mapping in the general sequence,

capture-->manipulation-->analysis-->display.

The interest in GIS has been, and continues to be a significant within the military community, and it is clear that the parallel processing implementations for rapid military intelligence are being pursued in several countries. However, GIS has also been heavily associated with database (DB) technology because of the large volumes of data that are traditionally associated with geographic information.

Early GIS incorporated separate facilities for managing geographic data and attribute (either numeric or factual) data. The early GIS systems were built on existing relational database packages. There is still research in the area of building sensible GIS query systems that then are converted to SQL queries on ordinary DB systems, or developing such queries by using conventional DB languages. More recently, the trend has been to merge all types of data with the use of more flexible DB systems, in particular with Object-Oriented databases (often using the C++ language) that seems extremely well suited to geographic issues. These have the potential to include multiple formats such as video, image, graphics, voice, and text. Query capabilities are also improving, they are much less structured queries with the ability to support browsing and navigating.

As DB capabilities have improved so have the GIS. Also, as capture (digitizing) and storage of geographic data has become more automated, there has been more time and motivation to focus on the high-end parts of the process, as well as a trend toward making them less sequential and more interactive. One SSD'93 participant commented that currently 90% of GIS costs are related to data generation and gathering, and that much more work needs to be done on user interfaces that still remain weak. Better user interfaces, including multimedia and interaction, as well as more sophisticated and faster DB storage and query techniques have immediately been put to use by the GIS community; in fact, many GIS researchers could be classified as DB researchers and conversely. Although end-user requirements are not well understood, the current trend is to move GIS from a specialist tool used by a technical group to an integrated decision making tool that will be used for spatial and temporal data management of complex phenomena at various levels within organizations including operations, logistics, and executive. In other words, to become part of information systems services, active document (paperless) systems, enterprise systems, etc. In particular, as industry becomes more distributed and global, the use and need for geographical information is also increasing. (Several speakers mentioned industrial applications related to tracking of equipment, packages, personnel, etc., by using GIS in conjunction with global positioning systems.)

GIS are not as widely used in Asia as they are in the West. However, over the past few years many large GIS projects have been initiated as the economies of these countries pick up steam. Every country that I have visited in Asia has a very high level of interest in GIS. Usually major projects exist that are supported at the top levels of government. The potential applications of GIS are easy to describe and demonstrate and invariably enthuse both politicians and bureaucrats who can preconceive the benefits. Because many Asian countries are just now beginning to grapple with problems of agriculture, planning, environmental assessment, etc., GIS are seen as a potentially invaluable tool. Intergraph, a company that provides software and related GIS services, illustrated examples of their products in use in Singapore, Hong Kong, Australia, Philippines, New Zealand, Thailand, etc.

Some fundamental research in GIS and related DB topics is occurring in Asia, but many of the papers presented at the FEGIS'93 workshop were detailed applications of GIS to a specific city, country, or regional needs. These examples were provided by speakers from Indonesia, Pakistan, Taiwan (oceanic info system), Australia, Bangladesh, Malaysia, Vietnam, and Singapore. Thus the workshop provided many "case studies". One very interesting short paper showed the variety of possible applications for satellite data in China and the need for integration and standardization. The workshop provided opportunities for people who wanted to learn about GIS, for practitioners who could describe specific implementation/development projects that they were working on, and for vendors who displayed products at the associated exhibit. A few papers were clearly marketing opportunities. (I have no objection to such talks as they often convey useful information, but feel that the speaker's affiliation and position should be clearly indicated in the program to allow participants to make sensible judgements—especially in the case of parallel sessions.) While many papers would not be classified as pure "research," some were very interesting nonetheless. In the following I have summarized several of the papers that were of special interest to me. A complete list is attached to this report. In addition, the proceedings have been published as follows.

GIS: Technology and Applications
Proceedings of the Far East Workshop on
Geographic Information Systems
Eds: Hongjun Lu & Beng Chin oOi
World Scientific Publ Co Pte. Ltd
PO Box 128 Farrer Road, Singapore 9128
(US Address: Suite lB, 1060 Main St.,
River Edge, NJ 07661)
ISBN 981-02-1445-6 (1993)

In terms of general vision (within the Asian community) I should point to remarks by Australia's CSIRO Division of Information Technology under John O'Callaghan, whose keynote speech clearly showed that GIS will spread toward organization-wide services. He gives an example of a water utility that "could use the DB of its reticulation network to support not only planning and design of the network but also activities concerned with network maintenance, emergency services, and marketing. Information on these activities could be made available as map-based documents, able to be interrogated as appropriate throughout the utility."

CSIRO appears to be one of the largest Asian centers of research in GIS and related technology. Callaghan's IT Division has a staff of more than 100 persons with a budget of about A$9M at three sites (Sydney, Canberra, and Melbourne), and 20 professionals working at the Canberra laboratory on Spatial Decision Support Systems (distributed databases, systems integration, real time spatial information systems). [Email: JOHN.OCALLAGHAN@CSIS.DIT.CSIRO.AU].

Two very interesting research papers were given by Singaporians. Professor Beng Chin oOi from the National University of Singapore [Email: ooibcQiscs.nus.sg] described fundamental work in knowledge discovery (done jointly with colleagues at Simon Fraser University. Dr. Jian Kang Wu [Email: JIANKANGQISS.NUS.SG] at the Institute of Systems Science described a large knowledge-based GIS that he designed and implemented while at the University of Science and Technology in PR China based on remote sensing data. This was the first GIS software system in China and we were told that this is now in the stage of product development.

A number of papers were concerned with implementing 0-0 ideas into GIS typically with implementation in C++ (Wang & Lee), and data structures for dealing with the special characteristics of geometric data (Kim & Bae). Sometimes data structures and user interface are considered together (Nakamura, Abe, & Ikeda). Position uncertainty is a common problem (digitized maps or plat plans often have errors)—Shibasaki discusses the relationship between data structures (point, line, polygon) that allow for such errors using a probabilistic approach in one paper and fuzzy inferencing in another. Several speakers commented on the use of real-time positional satellite information for navigation and to reduce surveying errors, and Frank even suggests that future surveyors will wear VR type glasses. When an object in the glasses (computer data) appears to be out of place in relation to its physical entity (a pipe is displaced a few meters), the surveyor will use a data glove to move the computer entity to correspond to its proper position, and the GIS will appropriately update the internal data representation. Frank points out that it takes 7 to 8 years for research laboratories results to get into the marketplace; thus, he views the turn of the century as the most likely time for today's laboratory work to be commercially viable. Or to say this in another way, "very little will reach the market in 10 years, which is not yet studied in a research laboratory." O'Callaghan feels that GIS will become more integrated into business systems and that communications will be the key technology to make that happen. Integration is already occurring in some places. Madhav (Singapore) describes the integration of GIS with workflow management. Also, see my remarks below about Singapore's data hub project.

The Large Scale Database conference (SSD'93) which occurred immediately after FEGIS'93 was essentially an international conference that just happened to be held in Singapore. By that I mean that there were only two or three papers from Asian institutions, Singapore, Taiwan, and Australia. Generally, Singaporians were listening and learning. A widely available Proceedings has been published,

Advances in Spatial Databases
Third International Symposium, SSD'93,
Singapore, June 1993
Eds: David Abel & Beng Chin Ooi
Lecture Notes in Computer Science # 692
Springer Verlag, Berlin
ISBN 0-387-56869-7, 1993.

SSD'93 had about 170 participants from all the major countries as well as from several smaller ones (Saudi Arabia and Libya). A list of titles and authors is attached to this report. I will concentrate on only two points that I felt were particularly interesting, and I will allow readers to refer to the Proceedings for details on the other international contributors.

At the opening of SSD'93 there was a speech by Mr. Tan Chin Nam, chairman of Singapore's National Computer Board, and managing director of the Economic Development Board. I felt that his remarks were particularly insightful and I have included large sections of them below, with the caveat that there may have been some alterations in his speech that I missed. Please note particularly the four items considered to be essential for GIS in Singapore—support for distributed databases, standards for data exchange, ease of use, and training.

"Whilst spatial information technology has been applied in many areas such as CAD/CAM, multimedia, imaging, visualization, one of the most promising applications is Geographic Information System. I would like to make some comments on this particular application.

Singapore is a small island of about 640 Km² with about 3 million people. Land is a precious resource. Singapore's physical and intrastructural development is driven by the needs of a growing economy and, more and more, by the changing aspirations and expectations of an increasingly affluent society. Hence, it is of critical importance that we do the best job in managing the usage of our land resources, implementation of telecommunication and utility lines, construction of roads and buildings, and urban planning. That is why we have begun to exploit geographic information systems.

In Singapore, GIS is widely used in the public sector. The Integrated Land Use System (ILUS), Singapore's first large-scale GIS project, is being developed to support the city planning, development and building control, and road planning functions of the Ministry of National Development.

The Public Utilities Board is using GIS to manage the utility lines, Singapore Telecommunications to manage the telecommunications lines, and the Ministry of the Environment to manage the drainage and sewerage system. The Ministry of Law uses the technology to manage the legal boundaries of land parcels and to produce the Singapore street directory.

A key success-factor of these GIS projects is the availability of relevant data. Often, geographic data collection is an enormous task requiring substantial effort because the data reside in many different government agencies. In Singapore, a Land Data Hub was set up in 1990 to administer land data and to coordinate land data sharing in the public sector. Using GIS, the Land Data Hub integrates vast volumes of data scattered among 12 public organizations. With the hub, a wealth of spatial and textual data can be exchanged and shared. Currently 23 Government departments and statutory boards subscribe to the services.
[See also remarks about this hub below, DKK].

GIS applications are not restricted to land management, urban planning, facilities management, automated mapping and resource management. An application that could make good use of GIS is site selection by retail outlets. By studying market profiles in a certain locality could help a businessman decide on the actual site for a retail outlet, products to be carried, and the kind of targeted promotion programs to launch. More applications could be made in the transportation sector. With GIS, we could have a smart road infrastructure that would permit on board vehicle navigation. Such a system could help us, as drivers or passengers, to select the best route to the office or other places of interest, taking into account on-the-spot traffic conditions. Businesses that move goods on land can reduce their cost by optimizing their distribution routes. In an emergency, traffic could be diverted automatically and routes cleared for emergency vehicles. The minutes saved could mean a difference between life and death. The potential of GIS is vast.

Even President Bill Clinton used GIS to help himself in determining how his campaign resources could be best deployed in the 1992 presidential election. His staff used GIS extensively to show voting trends and voter profiles throughout the country, identifying areas where elections had been close in the past. The information helped the campaign tremendously in targeting media advertising and in determining where to send the candidates. It even helped with the drawing of the Clinton-Gore bus route through the Midwest after the Democratic convention. This resource targeting strategy worked and also helped save money for the 1992 Democratic presidential campaign.

The opportunities for using GIS are plentiful, and the benefits to be reaped from it appear to be tremendous. However, for the technology to be exploited on a large scale, four issues need to be addressed.

First, there is a need to support distributed spatial databases. Often, data that support the spatial analysis of business functions are stored in different databases at different locations. Open standards for heterogeneous spatial database environments need to be established so that the databases can "talk" to one another.

The second issue concerns the establishment of a national or even an international graphic interchange standard for effective and efficient data exchange. As spatial information technology is multidisciplinary, the data tend to be different in formats and models. A common data exchange format and model for the entire spectrum of users does not fully exist yet. In Singapore, graphic interchange standards is one of the priority areas that our national standards committee is actively looking into.

The third and an important issue is the ease of use of the system. No matter how powerful the computer hardware and software are, it means little if the average office worker or in the case of a public transport system, the average commuter cannot use it. Also, it needs to be made affordable and as commonplace as personal computer wordprocessing and spreadsheet packages.

Finally, we need a workforce that is trained to use spatial technology. I understand that the National Institute of Education in Singapore has acquired GIS packages to teach geography. Also, I have been told that most current computer science curricula already include courses on computer graphics, database applications, and multidimensional data structures at the undergraduate level. However, it would be desirable to have more advanced courses, perhaps at the postgraduate level, to train specialists in spatial information technology.

I would like to take this opportunity to urge the government organizations, spatial technology experts, and the industry end-users to work together to help accelerate the development and exploitation of this powerful tool.

A talk was given by Ms Yuk-Wah Tang-Kwong, who is the manager of the 17 person Land Systems Support Unit, the operational arm of the Singapore Land Data Hub. The outlines of this were described above. Here I will add that there are plans for a truly national integrated DB. Work on the hub began in the early 1980s with existing DBs for land and people, and that it has been significantly expanded (although still not complete). About 92% of the cadastral land lot boundaries are included, and the remainder are scheduled to be added by the end of 1993. Gas, water, electricity, drainage and sewer networks have been imported into the hub. The hub will eventually contain proposed and existing graphic outlines and related textual data for buildings constructed by the government and private contractors. Three of four agencies responsible for road construction have supplied road outlines to the hub, with road center line information based on 1:5000 topography maps. These maps, which also show roads and tracks, outlines of buildings and other structures, hydrographic features, footpaths, etc., are also mostly entered into the hub. Other categories include the Singapore Street Directory, lot base information, and government building data.

The obvious benefits, as mentioned, are integration, consistency, and quality improvements in existing services, with opportunities for new applications. Institutional, rather than technical issues have proved to be the major challenges, although data sharing between organizations has not been a problem. Large amounts of effort are expended on fixing discrepancies, vertical and horizontal integration (does detailed data from one source agree with higher level data from other sources, etc.), data harmonization and related quality aspects.

There is a central copy of common sharable data (although providers have their own copies), a corporate data manager for spatial and nonspatial data, semiautomated updating, and map replacement.

Major challenges are related to the comments by Mr. Tan Chin Nam, ease of use, distributed model, low cost, as well as the additional item of data security. The next step is to merge the hub with telecommunications data exchange services to further integrate Singapore's databases (100% of Singapore's telephone network information is now being digitized, and it will probably be the first to be 100% fiber to the home).

(One Western participant asked "how did you get people to agree to share data—we have many difficulties with this." The speaker admitted that she did not know why it was easy to get cooperation—my own feeling is that she should have responded rhetorically, "why is it so difficult for you, when the benefits for all are so clear?")

One unusual paper (Williams & Woods) on expectations in spatial information was related to the problem of building a tactical military intelligence processing system. An interesting problem, yet many attendees were clearly uncomfortable with the topic.

M. Stonebraker (Berkeley, CA) described the objectives of the SEQUOIA 2000 project, which has the goal to build a better computing environment for global change researchers, a topic that he felt was the key science issue for our generation. The paper presented at SSC'93 (included in the Proceedings) is an excellent readable summary of the plans. The project has substantial funding from a variety of companies (including DEC, HP, etc.), U.S. science agencies (ARPA, NSF, ARO, NASA, USGS), as well as funding from California's Department of Water Resources. A key aspect of this project was the performance required—high performance I/O on terabyte data sets, high-speed networking, powerful visualization tools, etc. I mention this because I was surprised that during the five days of papers at both SSD and FEGIS, large scale performance issues did not seem to play a major role. My thought is that, especially in Asia, the emphasis is on GIS systems that run on workstations (mostly singletons, but a very few distributed systems) and PCs. The typical organizations that are using GIS in this part of the world do not yet have access to really powerful computational platforms. Nevertheless, with the availability of high-performance workstations and servers, GIS can now be implemented by using a client-server approach. In this, the server handles the data retrieval and storage, while the clients run individual application programs on their workstations.

SSD'93 ended with a panel addressing the question "Are We on Track?" Stonebraker presented a list of issues that needed to be worked on as well as those that (he felt) were settled.

Work needed on:
Visualization tools
Abstracting
Lineage
Uncertainty in data
Object oriented GIS and DB design tools
Data mining
Integration of visualization, DBMS, models (for steering)
Classification functions
DBMS extension mechanisms
Multitype operators (such as joins) over heterogeneous types and DBs

Work not needed on:
Spatial access methods
Geographic SQL

The topic of spatial access provided the only area where there were major disagreements among participants. Spatial access refers to data structuring techniques for describing complicated geographic data. The key issue here is rapid access, and a variety of tree-traversal techniques have been developed (R trees, quadtrees, pyramid, BSP trees, K-d trees, etc.). Several variants were presented at either the workshop or SSD'93. One of the world's experts in this topic is H. Samet (University of Maryland), and he strongly disagreed with Stonebraker's view that enough had been done. Samet remarked that many GIS users are in government organizations where costs and efficiency are not a major issue. But within industry the situation is very different. Companies using efficient access methods are reluctant to talk about this for fear of giving away an economic advantage. He commented specifically on a parcel delivery service in the United States, which was vitally interested in efficiency.

Other points made during the panel were similar to those made during individual papers presentation, the need to interoperability, better visualization, scale transformations, growth of O-O technology, etc. There was also the re-emphasis on the need to educate users and several comments that for GIS uses, political issues dominated technical ones.

In response to questions about how additional research funding could be generated, Stonebraker and other "successful" researchers remarked that it was important that GIS researchers had "customers" whose needs they kept in mind, as opposed to traditional academic research projects. As an indication of the need to link to other scientists, SSD'93 participants were reminded that there were no interdisciplinary papers presented.

Singapore: Additional remarks.

As I have written in several earlier reports, Singapore is hard at work trying to make itself the technology capital of the Pacific rim—the Intelligent Island concept. The computer part of this is called IT2000, which is being implemented by the National Computer Board. I will have more details about the general plans in the future, but here I should mention some progress that was evident even during a brief visit.

The second phase of the country's science park has just opened, and should be completed by 2001. (This was modelled on St John's Innovation Center in Cambridge University, United Kingdom.) The first tenants are to be the Institute of Microelectronics and the Information Technology Institute. The existing section has a variety of R&D organizations, including many government agencies. There are some unusual ones too; Reuters software occupies one of the largest and most elaborate building within the science park.

Singapore is making a major effort to be the conference center of the region. English language conferences are in progress virtually nonstop all year; I cannot keep track of them all, and could only attend a very small fraction. This is a friendly and effective way to learn about advanced technology as well as a mechanism for sharing technical ideas. To the extent that Singaporian participation is mostly passive, information flow is basically inward, but as the level of local expertise increases, such conferences are useful for all attendees. Conference fees and hotel charges are relatively high, so this is probably a significant commercial activity too.

National University of Singapore (NUS) Computer Science (CS) and Math Depts.

In addition to hosting SSD'93, many CS members were participating in the conference that was held in the same building as most Department offices.

I had a brief introduction to the Department's activities by

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Professor Leong (Ph.D. Illinois) works in the general area of fundamental algorithms with specific application to VLSI design automation. He is coordinating the Department's Algorithms and Design Automation Laboratory that has six faculty members and seven junior faculty (some faculty also belong to other research laboratories). Very recent papers (jointly with a Ph.D. student) include the following.

C.P. Low & H.W. Leong, Probabilistic Analysis of Memory Reconfiguration in the Presence of Coupling Faults, Proc. IEEE Intl WS on Defects & Fault Tolerance in VLSI Systems, 4-6 Nov 1992, Dallas TX.

C.P. Low & H.W. Leong, Efficient Algorithms for Reconfiguring Memory Arrays in the Presence of Coupling Faults, Proc. IEEE Asia-Pacific Conf. on Circuit and Systems (APCCAS'92), 8-12 Dec. 1992, Sydney Australia.

C.P. Low & H.W. Leong, On the Reconfiguration of Degradable VLSI/WSI Arrays, Submitted to DFT'93, Venice Italy.

Some of his algorithms have been implemented on an RS/6000 department workstation. There seemed to be an adequate number of workstations and related facilities for general purpose research.

I also met briefly with

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to discuss the status of NUS's computational science program. I wrote about this just as it was beginning, about two years ago. Professor Chong remarked that the first group of students would graduate soon, so it was still too early to determine the actual success of the program. However, enrollment was increasing and the program seems to be well accepted. Professor Chong with other scientists in Singapore are now working on a plan to upgrade the high-performance computing capabilities available (see below) to the country's S&T community. (There is a significant amount of engineering and other activity in Singapore that could make good use of high-performance computers. Currently there is an SX-1 that clearly needs to be either replaced or updated.) It is my opinion, which is shared by many in Singapore, that significant additional capacity is seriously needed. Without it, scientists will naturally restrict the kinds of problems they tackle, which alters their worldview. It is a feedback loop that is counterproductive.

INSTITUTE OF SYSTEM SCIENCE

While SSD'93 was at the National University, I also visited the Institute of System Science (ISS) which is across the campus. I have reported on this before but my return visit reaffirmed that this is an impressive place that is getting significantly stronger. ISS is working in the information technology arena, with particular emphasis on four topics.

- Human interface technology
- Machine intelligence
- Networking and information architectures
- Parallel architectures and algorithms.

There are subtle, but real differences between research at ISS and that conducted at NUS. This can be summed up by making the analogy between a Western university CS department and an associated university laboratory. ISSs research is project oriented and managed by project managers with activities grouped by teams, and explicitly intended to fulfill the vision proposed by the country's National Computer Board toward making Singapore a more high tech community. ISS has a combination of talented staff, excellent facilities (more than 100 Unix workstations and associated equipment housed in a new US$15M building) in an on-campus location, project oriented research, good links with industry (Apple and IBM are conspicuous), in a fully English language environment that is relatively open.

It is not appropriate to describe in this report the research going on here in detail, except to mention several new members of the staff. Dr. Raghu Raghavan from Wisconsin, Ph.D. in Physics, who has worked in the United States in automata, pattern recognition, and real-time parallel computing is leading work on multi-computing over high-speed networks. I have invited Dr. Raghavan to participate in the Supercomputing Around the World Minisymposium to be held as part of Supercomputing '93 in Portland, Oregon (Nov 1993), where he will describe Singapore's plans and projects for high-performance computing. [Email: RAGHU@ISS.NUS.SG]. Dr. Timothy Poston, from Warwick, Ph.D. in Mathematics, who has written texts in Differential Geometry and Catastrophe Theory, is working in medical imaging issues related to computer vision, neural networks, the geometric structure of the human brain, and also in human computer interfaces. I met Dr. Poston first in Korea; an eclectic, he has published in physics, biology, mathematics, and archeology [Email: TIM@ISS.NUS.SG]. Dr. Wu Jian Kang, from the University of Tokyo, Ph.D. in computer science, is also a full professor at the University of Science and Technology in the PR China. I mentioned his work on GIS earlier (see above). Dr. Wu has recently been working on a system for facial image retrieval with identification and inferencing capabilities by using both neural nets and fuzzy sets; he will present a paper on the topic at the ACM Multimedia Conference in Anaheim CA in Aug 1993.

Institute for Future Technology, 28 June 1993

The Institute for Future Technology activities, especially with respect to lunar base plans, are discussed in this article.

David K. Kahaner

Much of the information contained herein was provided to me by:

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Mr. Hiroo Hieda (Manager, Research Division) and Mr. SungJoon Roh (Senior Fellow) were also very helpful.

The Institute for Future Technology (IFTECH) was founded in 1971, as a nonprofit corporation, to promote research on issues related to S&T. Activities focus on trends in science and technology and future problem areas in the social economy. IFTECH's founding was prefaced by a team visit to the U.S. think tanks in 1969, and the resulting decision was that a technologically oriented think tank should be established in Japan. It is currently a foundation under the Science and Technology Agency (STA), which is a part of the Prime Minister's Office. Currently it is staffed by about 70 people; 42 full time, 28 two-year temporaries, plus 10 to 15 part-time. IFTECH is commissioned mostly by Japanese Government agencies and affiliated organizations, plus municipal and other public organizations to perform about 70 project studies yearly; over 600 contracts since its founding.

Major areas of study are:

- Science policy and new energy systems
- Space development
- Technology forecasting and technology assessment
- Human science frontiers
- Telecommunications and information processing
- Social systems and urban development, environment
- Disaster management and social safety
- Structural changes in industry and the economy

Mr. Fujioka estimates that Telecommunications is the largest effort (30-40%), Science policy (15%), and other fields using the balance. IFTECH stimulated the start of the STA's Technology Forecast Survey (see my report, "sta.93", 8 June 1993).

One of my interests in IFTECH centered on the Institute's literature, which mentions "studies of cognitive science and AI to discover the human mechanisms of recognition and learning, and to apply these mechanisms to a new computer system and the brain mechanism," as well as "investigation for a promotion program of the AI industry," and "investigation of AI applications in space development." However, Mr. Fujioka stated that very little work has been done in these areas recently, so they are not discussed further in this report.

I was also interested to hear about IFTECH's conception of a lunar base. This is a futuristic project that involved a study group of 200 scientists in a long term plan for lunar exploration. The study proposed a lunar penetration in 1996, moving on from there to a fully manned permanent lunar base. An Executive Summary in the English language, "Report of the Moon Base and its Resources, Exploratory Study," was released about two years ago. It was done by the study group mentioned above with input and collaboration from Western scientists, and in particular was published shortly after "America's Space Exploration Initiative" was completed in 1991. Also see below.

The report proposed a five phase program as follows.

Fundamental Concept

The fundamental aims for developing the Moon base will be:

1. Scientific observation from the Moon,
2. The establishment of an outpost for Conducting various technical experiments to explore the other planets, particularly Mars, and
3. The extraction of fusion fuel, specifically, helium-3.

The base that is to be built on the Moon needs to have a steadfast operation ability and a housing facility. The subjects we embodied in our project during the process of consideration are;

1. Scientific observation of the universe, solid planetary science, and in-space physics,
2. A life-support system,
3. Energy,
4. Base construction,
5. A system to utilize resources,
6. A transportation system,
7. A social system,
8. An information and communications system, including robotics, and
9. Loqistics to the other planets, particularly Mars.

In our project we have created a five-phase increment model. In the process of formulating the phases of the model, the main consideration was to whether the mission was to be manned or unmanned, the size ofthe manned missions, time required for the use of space resources, the size of the particular science observation, and an available operational site on the Moon.

The success of the development of the activities on the Moon is totally dependent upon the mission objective and the incorporation of technology infrastructure (technological advancement). We have considered both in establishing the time of the activities. The required cost schedule for the project has not been determined.

The size of the Moon base will depend on the number of residents, the location of the base, the targeted depth of the science observation, the estimated amount of the resources that will be needed, and the amount of energy that will be required.

Phase One

Phase One will consist of precursor missions with the absence of human presence on the moon. The main objective is scientific observation, including data collection to be used in preparation for the construction of the Moon base, which will come at a much later phase. The scientific area of the mission will include; small optical interferometer placement, pre-investigation for observation in the next phase, observations of the geomagnetosphere and balanced infrared rays, and the collection of surface composition samples for analysis on Earth. In other areas, the satellite-mounted remote sensors and robot rover(s) on the surface will investigate the Moon base site and attempt to analyze the regolith by conducting on-site investigations and by collecting samples for analyzation on Earth. Surface mapping and mapping of the location of resources will also be attempted.

Transportation from Earth to the Moon will be provided by our H-2 rocket. The H-2 can carry the substantial payload of the satellite and the Moon Lander to the Moon's surface. The Space Station Freedom project, behind its originally scheduled completion date, may be able to offer assistance to the project. The rover(s) and the robot on the Moon's surface will have a self-decision making device embodied in them, as well as being remote-controlled from the Earth station. The power required, which is estimated at approximately 20 kW, will be supplied by a solar power generator.

Phase Two

In Phase Two, the missions will be manned. The main objective of Phase Two is to prove that men are able to live and stay on the Moon for a few days to prepare for the base expansion that will come in a later phase. We propose to place a group of eight people on the Moon for a few Moon days. This will occur in the first part of this phase, and will increase to a few days and nights in the second or last part of the phase, with the location being either on the Moon's equator or an adjacent site on the surface. These are two preselected spots, and one will be chosen at a later date.

The science area of the mission will begin to provide a weather forecast of the Moon, an infrared ray assisted all-weather survey, and other observations that will be made with a small-size infrared optical telescope. The emplacement of the Very-Long Baseline Interferometer (VLBI) between the Moon and Earth will demonstrate its higher resolution capability.

In the field of solid planetary science, emphasis will be placed on the Moon's heat flow rate, gamma ray surveys, soil physics, and a wider range of the study of geostatics (earthquakes). However, most of the science observation in this phase may be shifted to Phase Three, if the main objective needs more attention than the science area.

Construction components for a high quality life support system, similar to the one embodied in the space station Freedom, will be transported from Earth along with an experiment module, a logistics cartridge, and a vegetable module. The food and other nutrients will be transported from Earth: the vegetable module will only be in the experimental stage in this phase. It will not provide products for consumption at this time. The Moon soil will shield the modules to protect them from a variety of radiation and heat. To provide the power required to operate the base, a solar heat generator, including its fuel cells, will provide 35 kW electricity.

In the second part of the phase, a small, surface nuclear power plant will start to generate 300 kW electricity. This will start the power plant's ten-year, non-refueled operation. As noted, in the second part of Phase Two, the men will experience Moon nights, test the resource pilot plant, and collect information about the resource site, including observations about the selected location. In this phase, the volume of the mass of the payload to be transported to the Moon is estimated to reach 100 metric tons. A transportation network system that includes a number of fuel stations between Earth and the Moon must be formulated. The vehicles used in this phase include a Higher Load Launch Vehicle (HLLV) similar in concept to the Advanced Launch Vehicle in the United States, and a new generation launch vehicle to be developed from our H-2 rocket. Its concept will be represented in Shuttle-C and Energia, the Moon lander, and a series of rovers, attended or unattended by man. These will be used for construction and transportation of robots. More autonomous function will be placed in the unmanned rovers and robots besides their remote-controlled operations.

Phase Three

In Phase Three, the number of people on the Moon will possibly increase to thirty-two. These people will be separated into groups occupying two or three bases; however, they will be connected by an extensive communication system. In this phase, the people will stay on the Moon continuously for three months. The main objective of Phase Three is to provide a practical and conclusive assessment of the Moon's resources, and emphasis will be placed on technical verification of helium-3.

In the area of scientific observation, an increased number of experts will be involved in operating medium-sized infrared optical telescopes, operating the interferometer to observe submillimeter waves, mapping gamma rays, and attempting to identify neutrinos. Studies of the soil and crust composition, and a geological survey of the surface are also going to be conducted. Regarding resources processing, oxygen production is expected to start at 1 ton per year, and it will reach 200 tons per year in the second half of this phase.

Experiments on metal smelting will identify the most feasible method to provide products used in space activities. We have estimated that the volume of cargo that will have to be transported between Earth and the Moon for satisfactory operation of the Moon base will amount to hundreds of tons. The transportation network may be required to establish a space station that orbits the Moon, in addition to the above noted network. The employment of the reusable orbiter may be advantageous, considering its ability of aerobraking. This may also help us create an efficient method for the Moon landing.

Phase Four

In Phase Four, the number of experts on the Moon will increase to a minimum of 64 and possibly to a maximum of 125. These experts will be spread among two to three diversified habitation centers. The habitation areas may be located underground for protection from the falling meteoroids. The main objective of Phase Four is to accomplish the creation of an extraction system for Helium-3. A medium-size production factory will demonstrate its capabilities by processing the lunar soil into glassware and blocks.

Phase Five

In this phase, the infrastructure of the Moon will become self-sufficient, similar to a country on Earth. A variety of products will be produced and manufactured on the Moon for export to Earth and consumption on the Moon. Helium-3 production may result in the generation of electric power up to 1000 MW or more on the Moon. The study of planetary science will be promoted to the fullest extent.

(Please contact either me or Mr. Fujioka for copies.)

To support the plan (which is still very much a paper project) the Lunar and Planetary Society was formed in 1992; Mr. Shigebumi Saito is the Chairman. Its founding is premised on the idea that after the turn of the century the effort in the direction of development and exploration of the Moon and Planets will become a core part of the space activities in Japan, in particular that "exploration of an abundant resource deposited in the Moon and in space that can be used for the Earth's alternative energy source." The Society hopes to "start an international endeavor that focuses on the lunar exploration and development, well balanced in the priorities between manned and unmanned portions. Furthermore, we need to continue a number of plans to explore Mars and beyond." To that end, a series of conferences and workshops have been held. For example,

> 15-17 July 1992 (Tsukuba)
> Future Space Activity Workshop/Lunar Base Workshop '92, for which a detailed proceedings (in Japanese) is available.

and

> 21-22 January 1993,
> Workshop on Scientific Aspects in Planetary Exploration

Mr. Fujioka explained that details on the most recent workshop can be obtained from Dr. Hitoshi Mizutani (Tel:+81 427 51 3911), but he emphasized to me that there is no government approval for major lunar projects at this time. However, a three-year paper study developed by Dr. Tsutomu Iwata (Tel:+81 298 52 2250) is waiting for a decision by the Japanese government.

The 1991 plan is the latest that IFTECH has published. However, five study groups within the Lunar and Planetary Society have been working on the project, and five additional reports (in Japanese) will be completed in August 1993. The study groups will report on the following.

- Lunar and Planetary Architecture
- Nuclear Power Propulsion
- Lunar Observatories
- Utilization of Micromachines on Lunar & Planetary project
- Utilization and control for "microbes".

Budget estimates have not been prepared formally. Earlier estimates are probably inaccurate. Mr. Fujioka acknowledges that some rough estimates have recently been developed, based on worldwide space activity budget trends. (I have not seen these.) The Japanese government, through MITI, with NASDA and ISAS are involved in the planning; MITI through AIST the Agency of Industrial Science and Technology, and ISAS (Institute of Space and Astronautical Science) mostly associated with environmental activities from space. MITI will begin a feasibility study of lunar resource utilization in FY 1996. IFTECH and the Lunar and Planetary Society cooperates with MITI in planning activities.

Space related activities surface in many Japanese organizations. I will have some follow-up reports on a few of these, in particular from ISAS.

Space Efforts in Japan, 1 July 1993

History and outlook of Japanese space efforts are described in this article.

David K. Kahaner

The article "History and Outlook for Japanese Space Efforts" was written by:

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The original article on this subject appeared in "Kokusai Koku Uchu Symposium" (in Japanese), 1 December 1992. Subsequently, Dr. Akiba provided me with many updates, additions, and corrections. I wish to acknowledge his efforts as well as those of Ms. Takemi Chiku (Office of External Relations, ISAS.)

History to Advent of "Ohsumi"

Japan's activities in the field of space development began with scientific observation and have been marked from the first by peaceful goals. The pencil rocket was first planned by Professor Itogawa of the Production Technology Research Institute of Tokyo University Institute of Industrial Science and other volunteers from university and government as an engineering research project following the resumption of aeronautical research. But just three months before the experiment was conducted, something happened that had a great impact on the course of space research in Japan. This was the decision to participate in the International Geophysical Year (IGY) events with a domestic sounding rocket.

What was of great technological significance up until that point was the adoption of solid rockets. At the time, it was conventional wisdom throughout the world that in order to attain high altitudes, a rocket should be a liquid-propellant rocket in the tradition of the V-2, and that solid rocket technology, on the surface of things, appeared to offer little potential future. However, in conducting research toward the goal of achieving the capability of reaching altitudes of 100 km, as required for the IGY, the problems that had to be faced as the project progressed were greater than anybody expected. It should be emphasized, however, that there was some prospect for success. The factor that contributed the most in achieving such goal, despite the prevailing situation, was the development of composite propellants. Even though, in the end, the 100 km altitude could not be achieved, the K-6 rocket was capable of reaching 60 km and was used in the final six months of the IGY for high-altitude air temperature and wind observations. This was the first time Japan contributed to the international society with the use of sounding rockets.

Building on the achievements during the IGY, the development of sounding rockets proceeded steadily, and eventually matured so that the feasibility of launching artificial satellites now was being studied. Against this background and with the demand by space scientists all over Japan, the Institute of Space and Aeronautical Sciences (ISAS) was founded as part of Tokyo University in 1964. This institute was to be used as a joint research institute for the purpose of achieving space observations by using space carrier vehicles. It is true that some bitter setbacks were to be encountered before the first satellite was launched, but eventually Japan's first artificial satellite, "Ohsumi," was launched in 1970.

Meanwhile, for a time in the latter half of 1960, much attention was focused on the use of space in the fields of communications and meteorological observations. This had an impact on the direction of space research in Japan, thus resulting in a flurry of activity to set up a central organization to handle space development in application fields, which finally resulted in the establishment of the National Space Development Agency (NASDA) in 1969.

History of Satellite and Launch Vehicle Projects

It was natural that, with the founding of the National Space Development Agency, studies would be done to come up with a basic government policy on how, in the future, to handle the scientific satellite projects that had been conducted at Tokyo University. As a result, the scientific and application fields were separated, and as we see today, with these being handled respectively by the Institute of Space and Aeronautical Sciences (ISAS) at Tokyo University and the National Space Development Agency (NASDA), they are coordinated by the Space Activities Commission. Under the increasing influence of large-scale applications programs, which began later, scientific satellite programs gradually produced results and had successes commensurate with the capabilities of Japanese rockets. With this background, the scientific satellite program, in response to the demand by space scientists, started to make steady progress toward more advanced observations.

Let us list here the scientific satellites that up until the early 1980s made the most lasting impression: "Shinsei" and "Taiyo", which carried out the observation of ionospheric anomaly associated with anomalies in the terrestrial magnetism over South America; "Kyokko", which succeeded in photographing UV images of the aurora; "Jikiken", which conducted comparative observations of magnetospheric plasma phenomena and aurora activities; "Hakucho" and "Tenma, which observed X-ray stars using the modulation collimator; "Hinotori", which contributed to the X-ray observation of the sun during periods of high activity; and "Ozora", which was successful in the remote observation of the atmosphere at mid-altitude. All of these satellites were small, but nevertheless they produced outstanding results that attracted the attention of space scientists all over the world.

When founded, the National Space Development Agency was charged with the mission of placing satellites of appropriate size into stationary Earth orbits. Since it was judged impractical to quickly move to the practical stage with only domestic efforts, NASDA decided, pursuant to the exchange of notes between Japan and the United States in 1969, to import technology. Thus development work began on the N-series rocket that was based on transferred technology of Delta-series liquid-fuel rockets. The Japan-United States Exchange Communique pertained not only to rockets, but was an agreement concerning the acquisition of technology related to a broad range of space equipment, and contained items that restricted the transfer of such technology to a third nation. As a result, very great restraints remained as we entered the era of space commercialization, and the pros and cons of this communique are still being debated. In any case, the U.S. technology transfer enabled NASDA to acquire liquid-fuel rocket technology in a relatively short time frame, and in 1977 Japan successfully launched the geostationary engineering testing satellite "Kiku-II" with the third N-I rocket. However, NASDA was still far from obtaining the launch capability to meet the demands of those application satellites between 300-350 kg in mass. Therefore NASDA had to commission two satellite launches to the United States before the next generation N-II vehicle was ready to go up in 1981.

Before this (1978) the Space Activity Commission formulated the Space Fundamental Development Policy Guidelines. The importance of promoting the development of rockets using Japanese technology was stressed in this document, and thus bringing Japanese space activities to another turning point. It was at this time that the development of the H-I, with its cryogenic second stage, and the H-II, with its cryogenic first and second stages based solely on Japanese technology, were initially conceived.

Age of Internationalization

In the past 10 years, the Japanese prowess in space development has very quickly gained recognition internationally. Naturally, this is due in part to the overall advance achieved by Japanese industry. But another large factor has been that both the United States and Soviet Union slowed the pace of their space development for different reasons.

First, in the field of space science, the probe to Halley's comet, which approached our sun in 1986, was in many respects epoch-making. On the domestic front, it was this development that enabled the founding of the Institute of Space and Astronautical Science. Concurrently, Japan participated with the United States, Soviet Union, and European nations in this project with two probes, and successfully achieved its goals. This led not only to the development of the probe vehicles, but also to major improvements in the M rocket launch vehicle. The M-3SII rocket that resulted, is still the primary launch vehicle used for scientific satellites. On the international front, U.S.-Soviet antagonism was still quite severe, and it was little short of amazing that the U.S., European, Soviet, and Japanese organizations could all cooperate and conduct projects successfully. This was regarded around the world as an ideal example of international cooperation. Since then, international cooperation was also achieved with the participation of Japanese and foreign scientists in the projects involving the satellites that the Institute of Space and Astronautical Science subsequently launched, namely the "Ginga," Akebono," "Hiten," and "Yohkoh," despite their small scale. Moreover, in July of this year, the magnetospheric observation satellite "Geotail" was launched from Cape Canaveral in a collaborative program with NASA.

In the practical field, the H-I rocket was completed at about the same time. This vehicle was used to launch application satellites used for such diverse purposes as communications, broadcasting, meteorology, and ocean and land observations. This allowed Japan to gain more confidence in its indigenous technology. However, the impact of globalization in application fields is even more complicated. One of the problems is the demand by the United States to open the satellite market for government procurement concerning communication satellites and others. Such demand was made under the Super 301, a part of the Omnibus Trade and Competitiveness Act of 1988, which is often referred to in reference to U.S.-Japan trade imbalance. Japan fully accepted the U.S. demand, and as a result, it has been agreed that the government budget can cover only those satellite projects for the demonstration of new technology or for noncommercial and scientific research purposes. For the time being, the largest international cooperative program in space is the Space Station Freedom. The United States seems determined to implement this project as a matter of national pride, and there can be no doubt but that this project will have an extremely large influence on the future of the applications field. In any case, steady efforts are being directed toward use of the space environment, and the manned space experiments conducted this past September (1992) in the space shuttle Endeavor are still fresh in our memories.

One example of the use of space environment is the joint project SFU undertaken by the Institute of Space and Astronautical Science (ISAS), Ministry of International Trade and Industry (MITI), and National Space Development Agency (NASDA). The field of Earth observation has become of interest in recent years from the perspective of environmental preservation. In this International Space Year, in particular, we are seeing a lot of international activity that has been organized under the banner of "Mission to Planet Earth." In this field Japan is also contributing internationally with the launches of MOS-la and b, and JERS. This field is also of interest to the so-called nonspace nations in terms of remote sensing and is being carried out with wide participation by researchers and agencies all over the world.

Perspectives

Now, in Japan, two rocket vehicles are under development, namely the M-V and the H-II. The M-V is designed to launch scientific satellites, and the H-II to launch application satellites. The M-V can place a payload of up to two tons into low Earth orbit, and will be used in the future for small missions to the Moon and the planets and for small to medium-sized earth missions. The H-II, on the other hand, is capable of placing about two tons into geostationary orbit, and will be used in the future for commercial launches.

Space research is becoming increasingly diverse and advanced; however, the scope of activities is likely to remain in the area covering from the near-Earth to the planets. Therefore, the development of M-V does not immediately lead to larger probes and satellites. The fields of infrared millimeter wave astronomy, VLBI astronomy, and lunar and planetary probes, including sample-return missions employing robots are expected to develop rapidly in the future. In the field of engineering, a future space transportation system is the research theme of major concern. Projects currently underway include the MUSES-B, which involves space VLBI tests, PLANET-B in which the interrelationship between the martian atmosphere and solar winds is being studied, and LUNAR-A, which will send a lunar seismograph to the moon.

In the practical field, development of a winged space shuttle "Hope" is targeted for the purpose of transporting products from the Space Station, as a part of the efforts to establish the infrastructure for space operations. Stimulated by the finding of new merits of small satellites, the development of J-1 with only solid stages is being carried out, combining the solid booster of H-II and the upper stage of M-3SII. Robot engineering test satellites are also planned to establish the technology required for on-orbit rendezvous and docking techniques, and the "Comets" satellites for developing new technology oriented toward future communications needs. A great deal of developmental work is being focused on making Earth observation satellites more functionally sophisticated with higher precision, while the completion of the overall observation system is certainly one of the major objectives, as it is reflected in the proposal of WEDOS.

Sending a manned probe to Mars is, of course, a very attractive project. The dominant view is that this should be pursued as a joint international project. The present writer has no desire to argue against this view, except to register my skepticism on the feasibility of implementing such a project in the context of international cooperation. I say this because of the difficulty I have in envisioning a scenario in which the sum of the cost is estimated at the global total, and then, the necessary funding is somehow raised in ways that coincide with each nation own projects. But let us suppose, for argument's sake, that this is all possible. Such a project is still of dubious significance unless it lasts forever. Therefore, we would first have to increase the scale of space utilization and to implant by various means the sound consciousness of the usefulness of space activities in the mind of the general public.

The solar power generating satellite is drawing attention as being a future means with which to provide a nonpolluting power source that lasts forever. However, this task would be of enormous scale. It would, therefore, require a lot of technological development, thus making it difficult to estimate its full cost. Currently, there is no climate for supporting a global approach to this project. According to forecasts based on global models, however, after recognizing that we have already used up half of our subterranean oil reserves, it is said that the environment will deteriorate in the early 2000s, because of the increase in carbon dioxide and other pollutants in the environment, as a result the world population will begin to decline. In other words, the retrogression of modern civilization will be staring us in the face if we do not alter our present course. The only way to avoid such an embarrassing eventuality is to abandon our oil-dependent civilization. It is in this context that the costs of solar power satellites should be debated, and not on the basis of current electric power costs. In any event, what we need to do now is, in the first place, to steadily develop the requisite technology for a future solar power satellite project and, in the second, to take every opportunity we can to demonstrate developed technologies as much as possible so that the general public could be convinced that it is feasible and so that a solid support base can be formed. The Institute of Space and Astronautical Science, albeit on a small scale, is steadily making efforts in this direction. ISAS has organized researchers nationally, and early in 1994 plans to conduct microwave electric power transmission tests in the ionosphere by using a sounding rocket, as part of the activities of the International Space Year (ISY) sponsored by the International Astronautical Federation (IAF). The importance of the development of a low-cost mass-transport vehicle such as the space plane can surely be emphasized from this perspective.

Attempts on the moon would have slightly different meaning compared to a manned Mars project. In the examinations at the international level, too, the major significance of the lunar activities was found in scientific observations or in building bases of experiments for many purposes including scientific observations. Much knowledge has been gained on the moon through the Apollo Program, and lunar activities are included in the scope of near-Earth activities. It is not too much to say that the moon is another Antarctic. Taking into consideration that a number of problems still remain to be solved to be able to adapt man to outer space environment, the effects of developing manned activities on the Moon would be beyond one's expectation. In our country, the Institute of Future Technology is playing a key role in conducting technological investigations related to the establishment of lunar base by private companies (see also the report "iftec.93", 28 June 1993). The precondition for building the lunar base is the development of an effective transportation system. Unfortunately, such scenario is likely to be considered unrealistic, since our country still does not have such ambitious manned projects. It is my strong wish that scientists evaluate the effectiveness of lunar activities from the right and broad perspectives. Also, under the current circumstances, it is said that the one that will have the highest demand in space is space tourism. The value of the Moon as the resource for tourism should be worth considering.

I believe that, in due course, space operations will become closely linked to our daily lives and bring us many wonderful benefits.

AUTHORS

SUBJECTS

ORGANIZATIONS/RESEARCH FACILITIES

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