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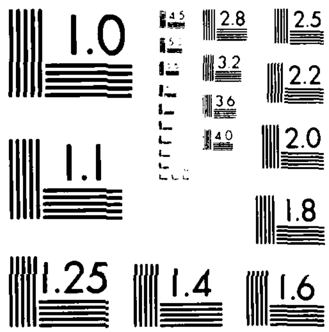

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JASON

Infinite Computing

H. Abarbanel
P. Banks
C. Callan
K. Case
A. Despain
D. Eardley
C. Max
W. Press
O. Rothaus
J. Vesecky

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JASON
The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, Virginia 22102

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This report presents ideas on what might be done if one had infinite computing capability. Infinite is arbitrarily defined as 100-1000 Cray-1's. The ideas are intended to be suggestive rather than definitive.

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We were asked to contemplate what we would do in the form of additional efforts, both continuations of present programs and initiation of new ones, if an infinite amount of computing power were made available. First we agreed among ourselves that "infinite" would mean that 100 to 1000 Cray-1's would be representative of the word infinite here. Then we agreed to have a far ranging discussion of the various things we would contemplate doing, whether or not they lay within our professional competence. Thus what follows is a record of a variety of topics we discussed at varying degrees of depth. Some we feel quite confident are important issues for DARPA to be involved in; others are much more speculative. Our goal was not a program, but an outline of interesting and important topics. Many of them are surely known to DARPA, but a longer shopping list is what we sought.

Before we launch into our list, a few general remarks are in order. First, as a sobering thought about how little we really know about what we would do with 100 Cray-power we note the advice of a senior professor to one of our group circa 1970:

> The time it takes to do a computing job will always be limited by the time it takes to read in the cards.

Second, we were in general agreement that the availability of powerful hardware would not create significant opportunities without accompanying high quality software, communications and general support of the user. For example, the presence on each person's desk of a Cray-PC would soon become an albatross if there were not some efficient way to have the software updated and modified, perhaps by an inexpensive high-bandwidth link to a "file server" center where full time professionals would maintain the software base for the desktop users.

Third, much of what one would do with the suggested additional computing power would be to discover, among all the fields and subjects soon to be listed, things that cannot be done. The example we discussed to help us reflect on this was that of the enthusiasm for using computers for the prediction of weather. It was the advent of the computing power itself that has been responsible for the present general agreement that one will not be able to predict the weather more than a few days in advance, whatever the number of Cray-units available. In other words the computers themselves led to the undoing of the high hopes of the pioneers.

Now we turn to our list of items. These are not in a priority order, instead we hope they will be stimulating rather than restrictive. Furthermore, this is a mixed bag of items. Some of them require extensive software to go along with the additional computer power, some of them are things we know how to do now, are doing at a paltry rate, and simply need more megaflops to do well, and some of them are things we desire to do and simply don't know how to do yet. Falling in the latter category would be some of the Artificial Intelligence issues of great importance.

(1) Physics

(A) Partition Function calculations in lattice gauge theories of high energy physics and in statistical physics. With the N (100-1000) fold Crays available one should be able to determine the static properties of the elementary particles and the condensed matter states described by the theories. Dynamic calculations would require yet more power.

(B) Fluid Turbulence. (i) Calculate the dimension and asymptotic distribution functions of the strange attractors arising in fluid flows. From this calculate the turbulent transport coefficients for these flows. This is a do-able problem with more megaflops, but surely holds surprises. (ii) Make direct calculations of the states of fluids in their transition to turbulence. This is difficult and to learn something from this we'd need to have enhanced display capabilities (see below). (iii) Calculate the statistical properties of fully developed turbulence. This also is surely do-able, though a computing problem of some considerable magnitude. Although this latter point is conventional in the sense that people have been trying to do it for years, the rewards are enormous in succeeding.

(C) Scattering Cross sections from fundamental theory. This is the next logical step in the exploration of gauge theories after the particle spectrum has been calculated. This is a much more useful set of calculations since reaction rates of the sort one would evaluate are essential in a large set of practical arenas.

(D) Colliding Black Holes. This is generic of relativistic calculations involving many particles or many degrees of freedom. Speed and memory are presently the limiting factors for this type of work, so a "simple" increase in computing power by two or more orders of magnitude will immediately make an impact here.

(E) Solid State or Condensed Matter Physics. (i) Calculate material properties from first principles. For example, the design of new semiconductros or other new materials could take place in digital form along with or before lab work. (ii) In the field of superconductivity one could design new superconductors from conventional materials and such speculative materials as "heavy electron" materials.

(F) Evolution of Globular Clusters. Calculate the dynamics of large numbers of stars (order of 10^6). This seems to be almost possible with three orders of magnitude increase in the amount of Cray power.

(G) Magnetic Reconnection Problems. Large scale computing problems having application in solar physics studies and in the fusion program.

(H) Particle Codes in Plasma Physics. These are simulations of plasma dynamics which treat the individual particle motion and interaction as accurately as possible. This form of calculation is essential for low density situations and is as computationally demanding as the globular cluster calculations above.

2. Chemistry

(A) Calculations in surface chemistry and catalysis. Rather clear topic of importance in many applications.

(B) Biochemistry. (i) Use the calculating power as a design tool for living things. This would use the computer as a digital experimental test bed. (ii) Use the machine as a laboratory to calculate the "non-carbon" analogs of biochemical structures. (iii) Simulate testing of new drugs. One of the problems in testing new drugs is the sample size required and the time needed to carry out the tests. Computation will never totally replace the actual testing of new drugs, but much efficiency may be gained by doing digital testing when possible.

3. Theory of the Brain

Use the enhanced computing ability to build and test models of the brain as they are presently understood from neurophysiology. Use this model to simulate and stimulate laboratory experiments. Begin with as detailed a model of the actual neurons as is possible and refine it in a digital environment.

4. Molecular Computing

(i) Calculation of the interaction and energy transport by solitons in long molecular chains. (ii) Calculation of electron tunneling effects in complex molecules. (iii) Calculation of electrical conducting and superconducting properties of molecular chains such as $(SN)_x$.

5. Natural Language Translation

Extend the systems now in use, namely, SYSTRAN. Especially useful for improved translations of scientific and engineering documents where syntax and subtlety are not so essential. From the enlarged base one can go on to really complex problems.

6. Library Enhancements

Using the additional computing and retrieval power expected one can, in effect, replace the libraries we presently use. Browsing, now hard since individiual local libraries cannot bear the e[illegible]lly increasing costs of housing the volumes available, would become possible again. Books could be delivered by electronic mail and hard copies, if needed, would be available by local facilities. Large scale "associative searches" of enormous data bases would become possible without local space or dollar resources being exhausted. On line electronic storage will replace the extensive and inefficient physical space usage now required.

7. Medical Diagnosis

Using a broad base of basic medical diagnoses one could store and search this base from local emergency rooms both in peacetime and from a battlefield. One needs the central database to be accessible from remote locations and good database software as well as powerful and fast hardware to be available at the remote locations. Even the diagnosis of simple illness from the home would become possible. We have in mind in this idea that physicians would not be replaced, but that the lore which is used for the first or second passes at diagnosing common illnesses would become available on line and the basic culling out of incorrect leads could be done remotely from large hospitals with the expertise of those hospitals still available.

8. Cryptography

This is a pretty obvious use of enhanced computational power and, indeed, may be one of the driving forces behind its inception. One must note that increasing the availability of computational power helps both the offense and the defense in this problem. Furthermore, the enhanced computational power we are talking about here could very well kill the utility of DES and public key encryption.

9. Improved Displays

One of the limiting factors in using the computational power now available, much less the many orders of magnitude increases we are talking about here, is the ability to display in a useable form the output. Computer graphics and "windowing" have made large strides lately riding on the back of cheap, fast VLSI circuitry. We anticipate that the improvement of display technology will have to come hand in hand with significant computational power increases if there is to be a real qualitative change in the way computers become useful to society. Large, long number crunching applications, which we consider important but not especially imaginative, will go forth without this, but most of the items on our list will need this display enhancement to be viable.

10. Computer Algebra and Symbolic Manipulation

We expect one of the very fruitful applications of the enhanced level of computing we are considering to be the growth by orders of magnitude in the power and availability of programs such as MACSYMA, REDUCE, SMP, and their relatives and progeny. It is hard to guess what the ability to analytically invert 15x15 matrices, say, will do for scientific computing. The software for that does exist, but the machine time at present cpu rates is usually prohibitive. An important application of symbolic computing techniques will be the investigation of suspected conserved quantities in the investigation of integrable nonlinear dynamical equations. One can often guess the structure of these important quantities, but the algebra involved in proving them constants of the motion is often unacceptable. Enlarging the category of known integrable systems is then an achievable goal.

11. Arms Control

Significant contributions to the geophysical issues of arms control would be made by the many time

Cray power being considered. The computation of systhetic seismograms and the attendant improvement in our knowledge of the properties of the earth at all seismic frequencies would enormously enhance the ability we have to discriminate between explosive and earthquake sources. If discrimination at high frequencies (>5 Hz) becomes important, extensive calculation will be indispensible and since we now know how to do the calculations, enhanced computational power and speed will immediately make a big difference in this problem.

12. Mathematics

We anticipate an increased use in the use of computers in mathematics in the form of producing counterexamples for indicating theorems which might be true and thus leading one in the correct direction toward proving them. With the exception of special cases, which will be interesting in themselves, we do not anticipate the actual proof of the theorems to result from better computing power.

We will end our list here though we do not wish to portray it as exhaustive. We not only discussed many other topics not reported here, but have no illusions that we have anticipated all or even a fraction of the potential benefits which would accrue from the kind of increases in computing power envisioned. We have made some effort in this shopping list of anticipated improvements to distinguish between things we know how to compute but don't have enough megaflops to do efficiently--some of the symbolic manipulation problems or partition function calculations come under this heading--and, much more interestingly, those things we desire to do but really don't now know how to program. Among the latter might come the natural language translation improvements and the modeling of the brain and the "design" aspects of improvements in biochemical capabilities.

DISTRIBUTION LIST

Dr. Henry D.I. Abarbanel
1110 Crest Road
Del Mar, CA 92014

Dr. Marv Atkins
Deputy Director, Science & Tech.
Defense Nuclear Agency
Washington, D.C. 20305

National Security Agency
Attn RS: Dr. N. Addison Ball
Ft. George G. Meade, MD 20755

Prof. Peter M. Banks
928 Casa Nueva Place
Stanford, CA 94305

Dr. Charles Buffalano
DARPA
Deputy Director for Research
1400 Wilson Boulevard
Arlington, VA 22209

Dr. Curtis G. Callan, Jr.
Department of Physics
Princeton University
Princeton, NJ 08540

Dr. Kenneth M. Case
The Rockefeller University
New York, NY 10021

Dr. Robert Cooper [2]
Director, DARPA
1400 Wilson Boulevard
Arlington, VA 22209

Defense Technical Information [2]
Center
Cameron Station
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Dr. Alvin M. Despain
1192 Grizzly Peak Boulevard
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CAPT Craig E. Dorman
Department of the Navy, OP-095T
The Pentagon, Room 5D576
Washington, D.C. 20350

CDR Timothy Dugan
NFOIO Detachment, Suitland
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Washington, D.C. 20390

Dr. Douglas M. Eardley
618 Miramonte Drive
Santa Barbara, CA 93109

Dr. Craig Fields
DARPA/DSO
1400 Wilson Boulevard
Arlington, VA 22209

Director [2]
National Security Agency
Fort Meade, MD 20755
ATTN: Mr. Richard Foss, A05

Dr. Larry Gershwin
NIO for Strategic Programs
P.O. Box 1925
Washington, D.C. 20505

Dr. S. William Gouse, W300
Vice President and General
Manager
The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, VA 22102

Dr. Howard Greyber
4301 Suitland Road
Suitland, MD 20390

DISTRIBUTION LIST (Cont'd.)

Dr. Edward Harper
SSBN, Security Director
OP-021T
The Pentagon, Room 4D534
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Mr. R. Evan Hineman
Deputy Director for Science
& Technology
P.O. Box 1925
Washington, D.C 20505

Mr. Ben Hunter [2]
1917 Westmoreland Street
McLean, VA 22101

The MITRE Corporation [25]
1820 Dolley Madison Blvd.
McLean, VA 22102
ATTN: JASON Library, W002

Dr. Robert E. Kahn
DARPA/IPTO
1400 Wilson Boulevard
Arlington, VA 22209

Dr. Sherman Karp
DARPA/STO
1400 Wilson Boulevard
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Mr. John F. Kaufmann
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Washington, D.C. 20500

MAJ GEN Donald L. Lamberson
Assistant Deputy Chief of Staff
(RD&A) HQ USAF/RD
Washington, D.C. 20330

Dr. Donald M. LeVine, W385 [3]
The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, VA 22102

Mr. V. Larry Lynn
Deputy Director, DARPA
1400 Wilson Boulevard
Arlington, VA 22209

Mr. Robert Lyons
DARPA/IPTO
1400 Wilson Boulevard
Arlington, VA 22209

Mr. John McMahon
Dep. Dir. Cen. Intelligence
P.O. Box 1925
Washington, D.C. 20505

Dr. Claire E. Max
617 Grizzly Peak Boulevard
Berkeley, CA 94708

Director
National Security Agency
Fort Meade, MD 20755
ATTN: William Mehuron, DDR

Mr. Carl Miller
CIA
Washington, DC 20505

Dr. Marvin Moss
Technical Director
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

Dr. Julian Nall [2]
P.O. Box 1925
Washington, D.C. 20505

Director
National Security Agency
Fort Meade, MD 20755
ATTN: Mr. Edward P. Neuburg
DDR-FANX 3

Prof. William A. Nierenberg
Scripps Institution of
Oceanography
University of California, S.D.
La Jolla, CA 92093

Mr. Gordon Oehler
Director CIA/OSWR
P.O. Box 1925
Washington, DC 20505

Mr. Ronald Ohlander
DARPA/IPTO
1400 Wilson Boulevard
Arlington, VA 22209

Mr. C. Wayne Peale
Office of Research and
Development
P.O. Box 1925
Washington, DC 20505

Dr. William H. Press
Harvard College Observatory
60 Garden Street
Cambridge, MA 02138

The MITRE Corporation
Records Resources
Mail Stop W971
McLean, VA 22102

Mr. Alan J. Roberts
Vice President & General Manager
Washington C^3 Operations
The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, VA 22102

Los Alamos Scientific Laboratory
ATTN: C. Paul Robinson
P.O. Box 1000
Los Alamos, NM 87545

Mr. Richard Ross [2]
P.O. Box 1925
Washington, D.C. 20505

Dr. Oscar S. Rothaus
106 Devon Road
Ithaca, NY 14850

Dr. Phil Selwyn
Technical Director
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217

Dr. Eugene Sevin [2]
Defense Nuclear Agency
Washington, D.C. 20305

Mr. Robert Shuckman
P.O. Box 8618
Ann Arbor, MI 48107

Dr. Joel A. Snow [2]
Senior Technical Advisor
Office of Energy Research
U.S. DOE, M.S. E084
Washington, D.C. 20585

Mr. Stephen Squires
DARPA/IPTO
1400 Wilson Boulevard
Arlington, VA 22209

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COMD William O. Studeman
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Navy Department
Washington, DC 20350

Mr. Alexander J. Tachmindji
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The MITRE Corporation
P.O. Box 208
Bedford, MA 01730

Dr. Vigdor Teplitz
ACDA
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Room 4484
Washington, D.C. 20451

Dr. Al Trivelpiece
Director, Office of Energy Research, U.S. DOE
M.S. 6E084
Washington, D.C. 20585

Dr. John F. Vesecky
Center for Radar Astronomy
233 Durand Building
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