A PROPOSAL FOR THE STUDY OF

COMPUTER CONTROL OF EXTERNAL DEVICES

AND AN AUTOMATED BIOLOGICAL LABORATORY

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10-15-64

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draft of

INTRODUCTION

This proposal is presented jointly by two research groups at Stanford University, namely the Exobiology Group in the Genetics Department and the Artificial Intelligence Group of the Computer Science Division.

We intend to collaborate in research in several connected areas, namely:

1. The design of an automated biological laboratory
2. Computer control of experiments in chemistry, biology, physiology and medicine.
3. Computer control of external devices in general
4. Artificial intelligence

For this purpose we need a laboratory the core of which will be a large general purpose computer suitable for very sophisticated control processes, but which will also contain other apparatus such as an artificial eye consisting of a TV camera and storage tube that will permit the computer to look at the outside world; a mechanical hand operated by the computer; and connections to laboratory apparatus such as a mass spectrometer.

The remaining sections of this proposal, are the following:

a) Motivation

b) Immediate Projects

c) Long-range Goals

d) Equipment Plans

e) Budget

f) Personnel

g) Appendices

Motivation

The three motivations to be considered are those of the Artificial Intelligence Group, the Exobiology Group, and NASA.

The Artificial Intelligence Group of the Computer Science Division find the problem of control of external devices and, specifically, the automated biological laboratory an excellent focus for many of its efforts. It also needs a computer that has potentially a very large memory on which to focus its programming work. Appendix A gives a general description of the goals in artificial intelligence. Some additional sources of motivation are given in Appendix B.

The Exobiology Group believes that the most effective way of studying the state of evolution of a planet is with an automated laboratoy. It also believes that automated laboratory techniques will prove effective and even necessary for carrying out biochemical analyses and syntheses of the complexity required to study the complete structure of chromosomes and proteins.

For the reasons given at length in Appendix C, we believe that an automated biological laboratory in which a computer controls experimental apparatus according to programs that can be revised on earth is the key to the biological study of Mars. The effectiveness of this laboratory will depend in a large measure on how much "intelligence" we can program into it. It is therefore to NASA's advantage to support basic research and development in computer control of biological instruments and in artificial intelligence.

Immediate Projects

Three projects will be undertaken immediately:

1. Computer programmed eye-hand co-ordination. This has many applications to the automated biological laboratory, and its effectiveness will affect strongly what the laboratory can be programmed to do. It is also a key problem from the point of view of artificial intelligence. The work on this will mainly be carried on by the Artificial Intelligence Group.

2. Computer control of a mass spectrometer.

3. Computer controlled wet chemistry

The Artificial Intelligence Group will also take the responsibility for the programming support of the computer.

Long-range Goals

The long-range goals of the Computer Science Division are to establish the Computer Control Laboratory described in Appendix B. We also want a computer with a large core memory because we believe this is necessary for artificial intelligence work.

The Exobiology Group

We both want to continue research aimed at the Automated Biological Laboratory for Mars, but we are not proposing to assume responsibility for flyable hardware at this time.

Equipment Plans

The equipment planned here is based frankly on the amount of support we were told we can hope for. It is a minimal plan in the following respects:

1. It will not provide enough memory for work in artificial intelligence for several years. This will force the Artificial Intelligence Group to divide its programming systems efforts between the IBM 7090 at the Computation Canter and the PDP-6 in our new laboratory. This will also limit the sophistication of the control programs that can be written.

2. Not enough memory or secondary storage is provided for a time-sharing system. Therefore, the machine can easily be jammed when several people have large programs to debug.

3. The system places extensive reliance on the already heavily committed time-shating system of the Computation Center. Delays and breakdowns there will cause the project to lose time.

On the other hand, our plans do provide for a fast computer with good real-time interaction capability and which is expandable to meet the deficiencies mentioned above.

We plan the following computer equipment based on the PDP-6 computer manufactured by the Digital Equipment Corporation of Maynard, Massachusetts:

1.	Arithmetic processor type 166. This is a 36 bit word length single address binary computer with a 2 microseconal memory	$146,100
2.	Core memory type 163. 16384 words	126,000
3.	Paper tape punch	5,500
4.	Paper tape reader	9,000
5.	Data control type 136. For attaching external devices	10,000
6.	Display monitor and control	40,000
		$336,600

Besides this equipment purchased from the manufacturer, we shall need a connection to the Stanford time-sharing system, the cost of which we estimate at $10,000 for a transmission rate of 1200 bits per second and two teletypes connected to that system at $3,000 a piece. Thus, the computer equipment totals $352,600 to which must be added 4% sales tax of $14,104, about $3,000 shipping cost and $3,000 installation. These figures add up to $372,104. For the first experiments planned we shall need the TV system estimated at $40,000 and a simple hand estimated at $10,000. Thus, the hardware costs come to $422,104. There is some possibility of a discount of not more than 20% from D.E.C. on the computer, but this cannot be regarded as highly probable because of the government's "most favored customer" rules.

We can rent the equipment at 1/30 of the purchase price per month with 75% of what is paid in the first year applicable to purchase. We may have to do this to sqyeeze by.

If we can place a fairly firm letter of intent by January we can expect delivery in July.

We estimate the minimum personnel costs at $15,000 in fiscal 1965 and $75,000 per year thereafter. This estimate is based on supporting the principal investigators from other present contracts. However, for the for the direct support of the installation, we shall need the following personnel:

2 Systems programmers	$20,000
2 Applications programmers	20,000
1 Electrical engineer	10,000
1 Secretary	5,000
4 Graduate research assistants (including summers)	20,000
Total Personnel	$75,000

If as indicated we can hope for $100,000 this year (before June 1965) and $350,000 per year thereafter with the first $350,000 coming in August 1965, we must compare the $450,000 income with an expected expenditure of $512,104 (not counting overhead) in the first year. The discrepancy can be met by renting part of the equipment for the first year at a cost of losing 25% of the rental when we convert to a purchase.

We are hoping that NASA will be able to provide more than first indicated, and we also hope for support from other government agencies. If additional support were available we would probably spend it in the following ways:

Capital Equipment

1. $20,000 more on the eye-hand for a more workmanlike job

2. $21,400 for a microtape system for local storage of programs and data.

3. $20,000 for a data communication system and 4 more teletypes

4. $126,000 for 16384 more words of core

5. $30,000 for fast memory to speed up the computer

6. $110,000 for a magnetic drum system that would permit a time-sharing system

7. $252,000 for 32,768 more words of core. This would permit a transfer of the artificial intelligence work from the IBM 7090.

8. $180,000 for a second processor that would permit simultaneous

real-time and time-shared operation

9. $30,000 for a line printer

10. $100,000 estimated for a disk file.

At this point we would be independent of the Computation Center.

11. Still more core

If we could plan a large system soon we would have a better bargaining position with respect to the manufacturer. A system that would permit an effective simulation of all functions of the proposed automated biological laboratory might cost $3,500,000 for the computer including two processors, 256 K of core, a time-sharing system, a multi-console display system, and facilities for controlling a number of experiments. Other apparatus might come to $1,000,000 and personnel costs might run $500,000 to $1,000,000 per year. We believe that the prompt support of such a laboratory would increase the probability of a successful biological landing on Mars and would make a substantial contribution to the art of controlling experiments by computer.

Budget

<u>Income</u>

Fiscal 1965	$100,000
Fiscal 1966	350,000
Total	$450,000

<u>Expenditures</u>

Personnel (fiscal 1965)	$ 15,000
Personnel (fiscal 1966)	75,000
Personnel overhead	
Equpment costs	422,000
Total	
Discrepancy	62,000 + overhead

This discrepancy is to be made up by leasing part of the equipment.

Personnel

Computer Science Division

John McCarthy, Professor of Computer Science

Edward Fergenbaum, Associate Professor of Computer Science

Harry Ratchford

Raj Reddy

Gary Feldman

Stephen Russell

Harold Gilman

Exobiology

Joshua Lederberg

Elliot Levinthal

Appendix A

General description of AI

Appendix B

Computer control lab proposal

(expurgated of speculation about people's intentions)

Appendix C

AB2 draft