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OFFICE OF THE DEAN OF ENGINEERING

April 22, 1935

Dr. Warren Weaver  
Rockefeller Foundation  
49 West 49th Street  
New York, N. Y.

|     |            |             |
|-----|------------|-------------|
| WW  | APR 23 '35 | Noted<br>PK |
| Am  | APR 27 '35 | M.7         |
| FBH |            | FBH         |
|     |            | WW          |

Dear Dr. Weaver:

In accordance with our telephone conversation I am sending enclosed a proposal for the design of an improved Differential Analyser. If this is not in the form in which you would like to have it do not hesitate to send it back for revision. I have kept the main proposal brief, but have appended lists of published papers and the like to indicate the scope of the work.

As Dr. Compton is in Washington I have not sent with this the letter from him stating that the proposal has his approval, but this will be sent shortly if he has not already sent it directly from Washington.

In making out the budget on page 6, which is at the present time a rough estimate only, I left out the salary of the Assistant Professor who would act as supervisor, as the Institute is ready to carry this cost with its other overhead. I did however include a summer fee to Professor Caldwell. However if this also should be left out on the basis that it is part of the supervision, please delete it. It is a small item in any case.

I hesitated for some time in making out this budget for the first year, as I would have liked to include some provision for precision tools. However the man-power on design appears to me to be much more important for the first year, and I accordingly left it in that form. However this is all tentative and it might be changed about in this respect if our plans so develop in the next month or two that a change is indicated.

Dr. Weaver -2-

I think I have brought in all the points which you stated over the telephone that you wished me to cover, but if I have left some out, just let me know.

Very truly yours,

A handwritten signature in dark ink, appearing to be 'V. Bush', written in a cursive style.

V. Bush

VB.E



OFFICE OF THE DEAN OF ENGINEERING

April 22, 1935

To the Rockefeller Foundation

PROPOSAL

for the  
DESIGN OF AN IMPROVED DIFFERENTIAL ANALYSER

V. Bush

Massachusetts Institute of Technology

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Object

The object of the proposed research is the production of designs for an improved differential analyser, with initial points in the design experimentally investigated.

The differential analyser is a device for the mechanical solution of differential equations. It bears much the same relation to scientific analysis that a computing machine bears to arithmetical work. It facilitates the application of certain branches of mathematics, notably differential equations, by greatly reducing the labor involved, and by solving equations which are prohibitively complex, when treated by ordinary methods. It thus enables analysis to be more freely and effectively employed in all scientific investigation where differential equations describe the phenomena investigated, and this includes widely diverse fields of science. The object

of this proposal is to design an improved device of this nature.

### History

The present differential analyser has been notably successful. The broad concept of utilizing mechanical aids in the application of higher mathematics is as old as Leibnitz. The first concrete proposal for thus handling differential equations was made by Kelvin. A practical machine for the purpose was produced at the Massachusetts Institute of Technology after a development extending over eight years, and involving the construction of three successive models. The present model has been in continuous use on a wide range of problems for four years. In view of its success it has been reproduced elsewhere with the aid of the Institute group of investigators, and with such improvements as experience indicated, but without radical departure in design. The University of Manchester, England, and the University of Pennsylvania have recently put such units into operation, the former primarily for use in atomistics by Professor Hartree. Another unit is under construction at the Astrophysical Institute at Oslo, where it will be used by Professor Rosseland and his colleagues on studies of variable stars and other problems.

The unit at M.I.T. has produced important results on studies concerned with cosmic rays, geophysics and seismology, continuous structures, electrical machinery, acoustics,

atomistics, radiation and the like. An appendix to this proposal gives photographs of the present unit and of the unit at Manchester, and a list of problems on which solutions have been made.

Why an improved analyser is proposed.

The opportunities for constructive service in the development of this research tool are by no means exhausted. The present devices having proved exceedingly useful, it is opportune to now take a radical step forward. The present devices in their field may be compared to hand operated keyboard calculators in the field of arithmetic. These latter have been developed into punched-card machines of notable power for facilitating statistical analysis. Similarly the differential analyser may be developed into a far more powerful implement for the furtherance of analysis.

It is proposed that the new differential analyser shall be a step forward in three aspects: improved precision, higher speed of operation, and increased scope of applicability. A comparison for a typical case will render this clear. Consider that, for the purposes of a research, it is necessary to obtain twenty solutions of a given differential equation. To obtain these, in a typical instance, would require several months' work by a mathematician with ordinary computing aids. The present device may be placed in condition for making solutions



by one day's work by a mechanic. It will then produce a solution every fifteen or twenty minutes. These may be depended upon for a precision, typically, of a fraction of one percent. Many interesting problems cannot however be placed on the present machine because of its limitations as to the number of elements available. The new machine would have little such limitation in regard to scope. It could be prepared to solve a new problem in a few minutes. It would then produce the twenty solutions in perhaps two hours, and be ready for the next problem. Its precision would be improved, it is hoped by a factor of ten. It would thus have many times the capacity of the present machine, which experience has shown is needed, and it would be able to handle more difficult problems with greater accuracy. It should not be concluded from this that merely a bigger and better device of the same characteristics is contemplated. The new device will open whole new regions of scientific research to rapid analysis.

General Program of which this is a Part

This is not the only analytical aid being developed at the Massachusetts Institute of Technology; but it forms the most important and highly developed portion of a general program of mechanical analysis. The results of this program are just beginning to be felt. Application has been so far in the fields where mathematical analysis is most readily and freely

employed. The final result of a successful program will be to further analysis in fields where it is now prohibitively laborious because of the inherent complexity of the problems studied. Such a field is that of mathematical biology, illustrated by the work of Haldane, where the common experience is that equations may be formulated, but means of solution are not available. Another similar and striking field is that of econometrics. The Institute contemplates carrying forward the entire program as rapidly as funds allow.

#### Present Status.

Much rough design on the improved differential analyser has already been made. Experimental work, necessary for the design, has been continuous. It is now essential to proceed with final investigation and design of the principal features. This includes primarily the design and construction of a high precision integrator and of an amplifying transmission device. Preliminary work has been done on both of these.

Fortunately both of these projects are such that their accomplishment would be of value in other ways than for differential analyser use alone. A precise integrator is much to be desired for many purposes. The type of transmission being studied will be of service in various types of automatic controls. Hence these two problems may be separated and attacked with the assurance that, if contingencies should then interrupt the work, the accomplishment will not have been futile.

Program

This proposal contemplates a program of investigation and design beginning July 1, 1935 and extending for one year, with expenditures, excluding overhead costs, not to exceed \$10,000.

The Massachusetts Institute of Technology will furnish space, overhead costs, and supervision. For this latter it is proposed to utilize about half the time during the academic year of an assistant professor of its staff. The writer of this proposal intends to devote considerable time and energy to the matter.

The out-of-pocket expenses are budgeted as follows:

|                              |               |
|------------------------------|---------------|
| Designing draftsman          | \$ 2,100✓     |
| Expert machinist             | 2,000✓        |
| Research assistant           | 1,440✓        |
| Detailed draftsman           | 1,200✓        |
| Assistant                    | 1,200✓        |
| Summer fee to Prof. Caldwell |               |
| on design                    | 300✓          |
| Supplies and purchases       | <u>1,700✓</u> |
|                              | \$ 9,940.     |

This is a tentative distribution, and may be altered as the program proceeds. A portion of the personnel may be added in the middle of the year. On the other hand more provision for purchases may be desirable. The key men proposed are available.

The Institute has facilities, in the form of precision tools and laboratory apparatus, sufficient for this purpose. It would be highly desirable to add several machine tools of




great precision, but the work at least in connection with this present proposal, can with careful planning be adequately carried on without them.

### Conclusion

The Institute has always made its entire program on analysing devices available to scientific workers everywhere, both by making the use of its own machines for their purposes conveniently possible, and by aiding them by publication and counsel to obtain their own devices. This policy will be continued in connection with the present proposal. A list of publications on the differential analyser and its applications is appended, together with a copy of one of the principal publications.

This proposal is for the accomplishment of one part of a broad program for creating means whereby analysis in scientific fields may be extensively furthered, through a center of such accomplishment at the Massachusetts Institute of Technology. As such I submit it for your consideration in the hope that the Rockefeller Foundation may find it possible to cooperate in its furtherance.

  
V. Bush