

FINAL REPORT

CONTRACT NUMBER: Nonr 1358- (04)  
AUTHORITY : Office of Naval Research,  
Electronics Branch  
NR-NUMBER : NR-374-583/3-16-56  
CONTRACTOR : The Institute for Advanced Study  
Electronic Computer Project,  
Princeton, New Jersey  
PERIOD COVERED : 15 June 1956 - 30 June 1957  
DATE OF ISSUE : 31 August 1957  
AUTHOR : Hans J. Maehly  
Acting Project Director

## INTRODUCTION

This report has been prepared in accordance with the terms of contract Nonr 1358-(04) and constitutes the Final Report, called for under the terms of that contract, and covering the period from 15 June 1956 to 30 June 1957.

Said contract between the Institute for Advanced Study and the Department of the Navy, Office of Naval Research, was entered on 16 March 1956 for the purpose of operating and maintaining the electronic digital computer at the Institute for Advanced Study in continuation of our work under Contract DA-36-034-ORD-1646 with the Department of the Army. These two contracts were overlapping in time. From 15 June 1955 to 31 December 1956 the Navy Contract paid for about 10% of the cost of maintenance and operation while the Army Contract still carried 90% of the burden. Therefore, the results obtained during this period have been described in our Final Report on Contract DA-36-034-ORD-1646 where the contribution of the Navy is mentioned in the preface.

In 1957, Contract Nonr 1358-(04) has been the only contract supporting maintenance and operation of our machine, but another Navy Contract, Nonr 1358-(03) has supported "analysis and development of methods for high-speed automatic computing". Both contracts terminated by 30 June 1957 when the machine and its staff were separated from the Institute of Advanced Study and became a part of Princeton University.

The technical information given in this report is therefore limited to the results obtained in the first six months of the year 1957.

## SUMMARY OF WORK SUPPORTED BY CONTRACT Nonr 1358-(04)

### 1. FLINT (Floating-Point Interpretive Subroutine)

Originator : Hans J. Maehly  
Coders : Several, see text below  
Described in : ref. (2), 11.0 - 11.9  
Status : Improved

The FLINT code has been in operation during the whole period covered by this report and has been used by several coders. Some of these have suggested and actually incorporated various improvements. We list the more important ones:

(i) James Cooley coded a faster output routine especially suited for "bulk output", such as tables (cf.ref.(2), 22.54).

(ii) Mrs. Barbara Weymann changed the read-in procedure to the effect that the FLINT code is normally stored on that part of the magnetic drum on which "writing" can be prohibited by setting of a switch. The code will thus be read in from the drum to the Williams memory, rather than from IBM cards, which saves time and avoids some card handling.- Another change concerns drum references while running the FLINT code.. These "Drum-to-Williams" transfers have always been checked but an error would cause the machine to stop. This has been changed to an automatic repetition.

(iii) In the original version of FLINT, codes for use with the interpretive routine had to be punched in binary form, which was bothersome for the beginner, especially since binarily punched codes cannot be tabulated. Richard E. Heitman has written a routine for converting such "pseudo codes" from decimal to binary.

It would have been desirable to make some further changes both to facilitate coding and to speed up the running of FLINT. However, such changes would require a completely new version of FLINT, for which, in fact, some planning has been done prior to 1 July 1957. Coding of this new version is progressing while this report is being written.

## 2. SASSY- A SYMBOLIC ASSEMBLY PROGRAM

Originator and Coder : Irving N. Rabinowitz  
Described in : cf. text  
Status : Completed

Asymbolic assembly routine is useful for taking the burden of address assignment, cross referencing between subroutines and translating orders into the particular numerical code of the machine used. Furthermore, the existence of a symbolic assembly routine permits the construction of a library of subroutines which may be used for a variety of programs. Such a routine has been written for our machine with special emphasis on flexibility and ease of application. Work on this project was begun in January 1957 and completed in May 1957. A technical report is now being written and will be submitted as soon as SASSY is fully checked.

## 3. MAGNETOHYDRODYNAMIC THEORY OF SOLAR SPICULES

Originator and Coder : Reimar Lüst  
Described in : ref (2), 21.30-21.37  
Status : Completed

Spicules or jets are relatively small (6" of arc) disturbances of the solar chromosphere which are characterized by an increasing rate of outward propagation and a short lifetime of the order of two minutes. It is believed that they transport a substantial amount of energy to the corona. The differential equations governing the propagation of these spicules are complicated and non-linear. A fast machine and extensive storage facilities are needed for the numerical solution of these equations, which, together with the computational methods and some first results, have been described in our last report (2). A considerable amount of machine time was spent in the period covered by the present report to complete these computations. A paper describing the results is now being prepared and will be submitted to the Astrophysical Journal.



#### 4. NUMERICAL EXPERIMENTATION ON STELLAR EVOLUTION

Originator and Analyst : Martin Schwarzschild  
Coder : Mrs. Hedvig Selberg  
Described in : ref. (2), 21.10-21.16  
Status : Continued

Work on this long and complicated code was begun in 1954 and a great number of valuable numerical results were obtained up to January 1957. This work has been continued in 1957, but it was hampered by the fact that this code required an amount of reliability -- i.e. error-free running -- of the machine which in the period covered by this report could not be achieved by the drastically reduced engineering staff. Several additional checking and automatic repeat routines were added, therefore, in order to get reliable results in spite of this situation. Technical details of this work are described in our Monthly Progress Reports (3)(1). It is planned to prepare Technical Reports and/or papers for a scientific journal (presumably the Astrophysical Journal and/or its Supplementary Series) whenever an important phase of this work has been finished.

#### 5. INTERNAL EQUILIBRIUM OF DENSE COLD STARS

Originators : J. A. Wheeler, K. Harrison, and M. Wakano  
Coders : M. Wakano and Mrs. B. Weymann  
Described in : presumably Physical Review or Astrophysical Journal, 1958  
Status : Completed

The gravitational equilibrium of matter in stars has been investigated assuming (i) zero absolute temperature (ii) catalysis to the endpoint of thermonuclear evolution. The equations of hydrostatic equilibrium, based on the theory of general relativity, for a mixture of nuclei and electrons were numerically integrated for a variety of values of the central pressure. The results seem likely to have a significant bearing on the theory of very dense stars and of gravitational energy sources. A paper will be submitted to one of the scientific journals mentioned above.

## 6. THE ORIGIN OF HIGH VELOCITY STARS

Originator and Analyst : Uco van Wijk  
Coder : Donald Morton  
Described in : cf. text  
Status : Debugged

This program is intended to test the hypothesis that stars are formed with an isotropic Maxwellian velocity distribution. As by-products we can expect information concerning the location of the origin of high-velocity stars, which should contribute to our understanding of the evolution of these stars, and information concerning the structure of our galaxy.

A similar program of very limited scope was carried out with a desk computer. The results have been published in the *Astronomical Journal* 61, 277 (1956) where the whole problem is described in detail. The present program uses the same equations but is designed to give much more detailed information which will facilitate comparison with observational data. The results will be submitted to a scientific journal, presumably to the *Astronomical Journal*, 1958.

## 7. NUMERICAL CALCULATIONS OF THE ANGULAR DISTRIBUTIONS FOR DEUTERON - PROTON AND SIMILAR REACTIONS

Originator : William Tobocman  
Analyst : Hans J. Maehly  
Coders : Sonja Bargmann and Patricia Eberlein  
Described in : ref (1) 2/55, 12/55, 3/56, 5/56, 11/56  
ref. (2) 22.30  
Status : Continued

Work for this code was begun in the summer of 1955 with an extensive study of the various mathematical problems. Programming and coding was done through the year 1956.

During the first six months of 1957, about 90% of the code was debugged and several test runs were made in order to check the mathematical procedures employed to generate Coulomb Wave Functions and to integrate their products. These experiments in general confirmed previous theoretical error estimates.

Some minor changes were made to further reduce the errors in special cases. As soon as the methods used in the second part of the code, viz. for computing associated Legendre polynomials and vector addition coefficients, have been adequately tested, we shall prepare a Technical Report to the Office of Naval Research describing all mathematical procedures -- as far as they are not standard -- and all coding features -- as far as they would also apply to other fixed point machines -- together with the results of various test runs. We hope to be able to issue our Technical Report before the end of 1957.

#### 8. MOLECULAR INTEGRALS

Originators	: R. C. Sahni and J. W. Cooley
Analyst and Coder	: J. W. Cooley
Described in	: ref. (2) 22.50-22.54
Status	: Continued

The computation of certain molecular integrals has been continued in the period covered by this report. A table of one-electron overlap integrals was completed while the potential and kinetic energy integrals are now being prepared for computation. The results will be published together as a Technical Report for Contract NAW 6514 (between the National Advisory Committee for Aeronautics and New York University), by which all mathematical analysis and programming has been supported.

#### 9. ELASTIC SCATTERING OF 17 Mev PROTONS BY NUCLEI

Team Work by	: W. Aron, J. H. Bigelow, J. S. McIntosh and G. Schrank
Described in	: ref. (3)
Status	: Testing completed

This code has been written for the analysis of scattering experiments with 17 Mev protons on various nuclei. The model employed is based upon a complex well with a phenomenological spin-orbit term. From this potential, wave functions are calculated, phase shifts determined, and cross sections obtained. This computation was planned and written prior to the initiation

of this contract. Some testing and improvements, however, have been made during the contract period.

10. PROTON ORBITS IN A 3 Bev SYNCHROTRON

Originator : C. J. Tsao  
Coder : V. Korenman and C. J. Tsao  
Described in : ref. (4)  
Status : Partially debugged

In view of the high cost of big acceleration machinery, it is highly desirable to make preliminary studies of the efficiency and the design parameters of the new Synchrotron by computation rather than by experimentation. The aim of the present study is to find an optimum arrangement for extracting protons after they have been accelerated to the final energy. A pseudo code using the floating-point interpreter FLINT has been written and at the close of Contract Nonr 1358-(04) was in the process of being debugged. This work will be continued and reported under A.E.C. Contracts.

11. AUTOMATIC ADJUSTMENT OF PARAMETERS FOR RATIONAL APPROXIMATIONS

Originator : Hans J. Maehly  
Coder : Mrs. Patricia Eberlein  
Described in : ref. (5), 5 & 6/57  
Status : Preliminary testing

The numerical results obtained so far have shown that our method will yield rational approximations for transcendental functions which compare very favorably with truncated power series and even with best fit polynomials.

It is planned to continue this work under a new ONR contract and to issue a Technical Report as soon as more extensive results have been obtained.

12. HISTORICAL EPHEMERIS FOR THE YEARS -600 to 0

Originators : O. Neugebauer and A. Sachs  
Analyst and Coder : Bryant Tuckerman  
Described in : ref. (2), 23.70; cf. text below  
Status : Discontinued

A first version of the code for computing the historical ephemeris was



completed early in June 1957. This first version was a simplified one inasmuch as it did not include certain small corrections -- due to the mutual interactions between the planets -- which would be relevant only for the most accurate of the historical (Babylonian) observations. A short table (covering the period from -300 to -230) has been produced before the close of this contract.

At that date, Dr. Tuckerman left our project and joined IBM, with the understanding that he would be permitted to rewrite the code, including the perturbations mentioned above, and produce the full table on a 704 computer.

It is anticipated that this final ephemeris will be published by a scientific society as a monograph of about 300 pages of tables with accompanying text explaining the method of computation.

### 13. STUDENT USE OF THE MACHINE JANUARY-JUNE 1957

Originator : Forman S. Acton  
Coders : Princeton University Students

From January to June 1957 small amounts of machine time were used by several students taking a course, "Applications of Digital Computers", at Princeton University. These projects were quite varied in subject matter, but had the unifying purpose of exploring the difficulties attendant upon communicating with a digital computer.

Frank Poage designed a program to permit the easy evaluation of the frequency response of an electrical circuit directly from its schematic diagram. The user need only punch a group of cards, one for each circuit element, in a simple conventional fashion in order to be provided with the set of equations describing the behavior of the circuit. The solution of these equations assumes the availability of a routine for solving simultaneous linear algebraic equations with complex coefficients. The work was undertaken to explore the logical difficulties encountered in coding an essentially geometric problem -- i.e., the description of a formal circuit diagram in numerical terms.

William Ridgway outlined two problems: one, an alpha-numeric input-output translation routine for the binary machine which permits -- among other things -- the efficient storage of plain English text, as well as intermixed

alphabetical and numerical symbols such as might be encountered in a symbolic coding language. The utility of such a routine and the problems to be encountered are obvious; and two, the simulation of a destroyer-submarine warfare game. This second problem was undertaken in order to gain some experience in coding essentially geometric problems and also in learning how to treat problems involving random elements.

Other members of the class worked on various phases of the problems involving complex arithmetic, symbolic assembly of an external language, general routines for the integration of ordinary differential equations, and studies of air traffic control problems. None of these other projects reached a stage where more than an hour or two of machine time was used.

#### 14. ION EXCHANGE IN TERNARY SYSTEMS

Originator and Coder : J. S. Dranoff  
Status : Code debugged

A small amount of machine time was spent by J. S. Dranoff, graduate student in chemical engineering at Princeton University, for debugging a code (in FLINT language) which represents a simplified model of his chemical experiments. By the so-called "method of characteristics" \*) a system of two partial differential equations with two unknowns can be reduced to two ordinary differential equations which are then solved by standard methods.

It is anticipated that a full description of the problem and the final results will be submitted for publication to "Industrial and Engineering Chemistry" early in 1958.

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\*) Acrivos A., Industrial and Engineering Chemistry, 48, 706 (1956)

### References

- (1) Monthly Progress Report on Contract No. DA-36-034-ORD-1646  
Project No. TB3-0538.
- (2) Final Report on Contract No. DA-36-034-ORD-1646, Part II (Computer  
Use), May 1957.
- (3) Physical Review 99, 629 (1955).
- (4) Princeton-Pennsylvania Accelerator Project, Contract A.E.C. AT (30-1)-  
1916, Internal Report CJT-7, Ching J. Tsao, Jump-Target Ejector.
- (5) Monthly Progress Report on Contract Nos. Nonr 1358-(03) and 1358-(04),  
May/June 1957.