Paper R-206

CHARLES BABBAGE — SCIENTIST AND PHILOSOPHER

January 31, 1952

DIGITAL COMPUTER LABORATORY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CHARLES BABBAGE -- SCIENTIST AND PHILOSOPHER

Excerpts describing his Work on Mechanical
Computation and his Reflections on Human Behavior

Edited by
Robert R. Rathbone

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FOREWORD

Over 100 years ago, Charles Babbage of London made public his plans for the construction of a large-scale digital computer. This machine, called the Analytical Engine, never went beyond the drawing-board stage because its inventor lacked the funds for continuing the venture privately and encountered only indifference on the part of the British Government in sponsoring such an "engine" (although the feasibility of the project had been clearly demonstrated by the mechanical perfection of the completed sections of his Difference Engine No. 1).

But Mr. Babbage was not entirely discouraged by this setback. Although he abandoned hope of ever seeing his Analytical Engine completed, he continued to work on new improved mechanisms and on new tools and methods for their construction.

Of this phase, his great-grandson, Mr. Richard H. Babbage of Montreal, wrote the following in a letter to Mr. Jay W. Forrester:

"In all that has been published about C. B.'s Difference and Analytical Engine, I think insufficient reference has been made to the formidable difficulty he surmounted in contriving tools and tool-holders to put his ideas in metal."

A guess as to the number and nature of these obstacles is possible if one bears in mind all the variety of motions which had to be propagated simultaneously throughout the machine, and the newness and apparent impossibility of the scheme to the skilled workmen upon whom Babbage had to depend. His invention of a practical plan of mechanical notation to overcome some of these difficulties bears proof to his resourcefulness and foresight.

Although Charles Babbage wrote very little on the actual operation of his calculating engines, others have recorded most of the missing details. His son, H.P. Babbage, to whom he left all his drawings and notations, in 1889 compiled a large volume of existing writings entitled "Babbage's Calculating Engines." Excerpts from four of the articles in this book will be found on succeeding pages.

The second section of this paper contains excerpts from Charles Babbage's "Passages from the Life of a Philosopher." It is a long book, dealing with a multitude of subjects, but it is written with force and imagination and is not without numerous touches of humor. If, due to editing, the selected portions do not stimulate the curiosity of the reader, perhaps the following quotation from the Ferranti Mark I Brochure will:

"The possibility of making such a machine was first suggested over a hundred years ago by Charles Babbage . . . . It is clear that he had a more profound understanding of the principles and possible applications of these machines than anyone else until a few years ago."

Thanks are due Mrs. Eleanore Galant for obtaining the original volumes and Charles Adams for suggesting certain selected passages.

Robert R. Rathbone

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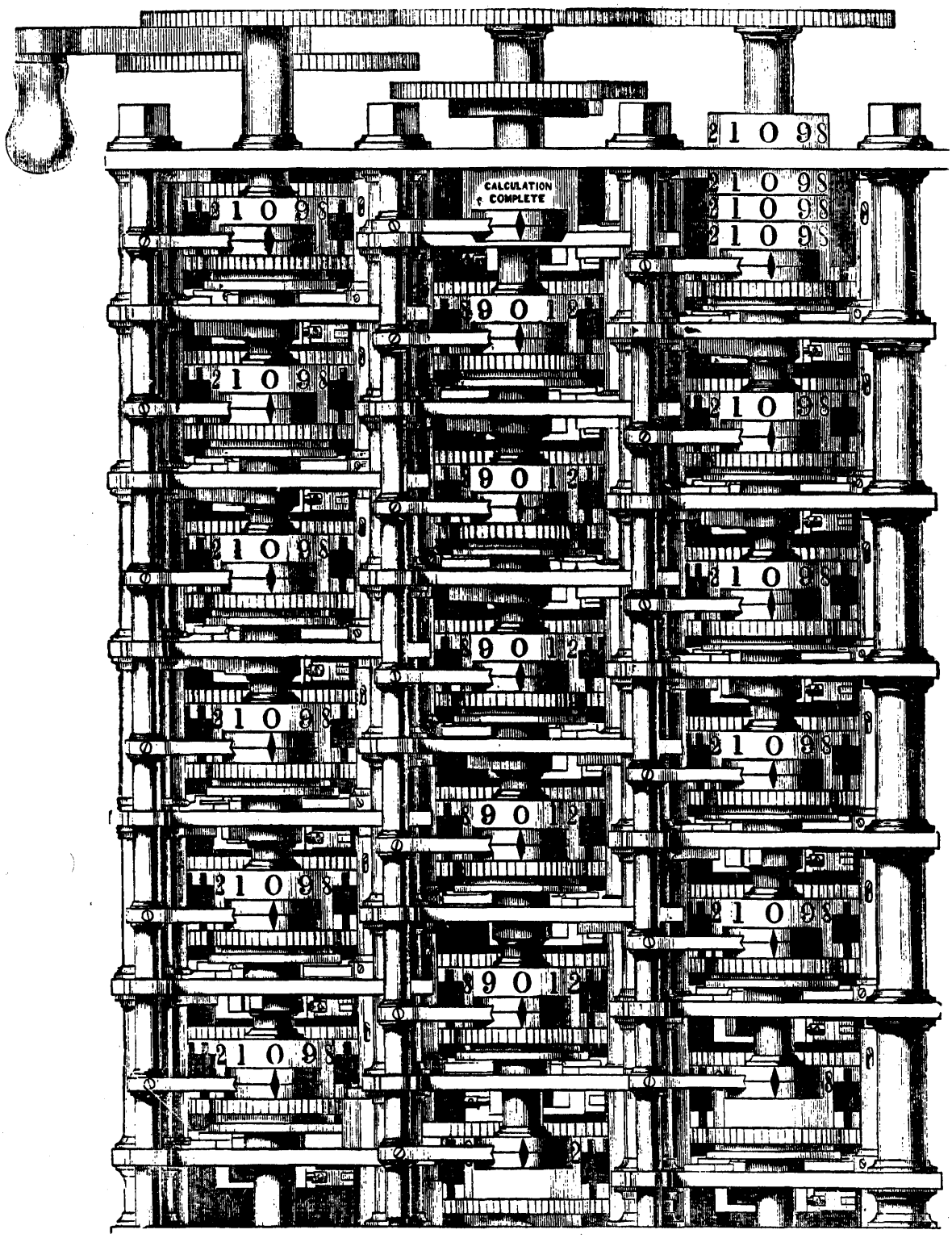
BABBAGE'S

CALCULATING ENGINES.

BEING

A COLLECTION OF PAPERS RELATING TO THEM;
THEIR HISTORY, AND CONSTRUCTION.

LONDON:
E. AND F. N. SPON, 125, STRAND.
1889.



B. H. Babbage, del.

Impression from a woodcut of a small portion of Mr. Babbage's Difference Engine No. 1, the property of Government, at present deposited in the Museum at South Kensington.

It was commenced 1823.
This portion put together 1833.
The construction abandoned 1842.
This plate was printed June, 1853.
This portion was in the Exhibition 1862.

"STATEMENT OF THE CIRCUMSTANCES ATTENDING THE INVENTION AND CONSTRUCTION OF MR. BABBAGE'S CALCULATING ENGINES"

by

L. F. Menabrea, of Turin, Officer of the Military Engineers

(From the Philosophical Magazine, Sept. 1848, p. 235.)

Much misapprehension having arisen as to the circumstances attending the invention and construction of Mr. Babbage's Calculating Engines, it is necessary to state from authority the facts relating to them.

In 1823, Mr. Babbage, who had previously invented an Engine for calculating and printing tables by means of differences, undertook, at the desire of the Government, to superintend the construction of such an Engine. He bestowed his whole time upon the subject for many years, refusing for that purpose other avocations which would have been attended with considerable pecuniary advantage. During this period about £17,000 had been expended by the Government in the construction of the Difference Engine. A considerable part of this sum had from time to time been advanced by Mr. Babbage for the payment of the workmen, and was of course repaid; but it was never contemplated by either party that any portion of this sum should be appropriated to Mr. Babbage himself, and in truth not one single shilling of the money was in any shape whatever received by Mr. Babbage for his invention, his time, or his services, a fact which Sir Robert Peel admitted in the House of Commons in March 1843.

Early in 1833 the construction of this Engine was suspended on account of some dissatisfaction with the workmen, which it is now unnecessary to detail. It was expected that the interruption, which arose from circumstances over which Mr. Babbage had no control, would be only temporary. About twelve months after the progress of the Difference Engine had been thus suspended, Mr. Babbage discovered a principle of an entirely new order, the power of which over the most complicated arithmetical operations seemed nearly unbounded. The invention of simpler mechanical means for exacting the elementary operations of that Engine, now acquired far greater importance than it had hitherto possessed.

In the Engine for calculating by differences, such simplifications affected only about a hundred and twenty similar parts, while in the new, or Analytical Engine, they might affect several thousand. The Difference Engine might be constructed with more or less advantage, by employing various mechanical modes for the operation of addition. The Analytical Engine could not exist without inventing for it a method of mechanical addition possessed of the utmost simplicity. In fact it was not until upwards of twenty different modes for performing the operation of addition had been designed and drawn, that the necessary degree of simplicity required for the Analytical Engine was ultimately attained.

These new views acquired great additional importance from their bearings upon the Difference Engine already partly executed for the Government; for if such simplifications should be discovered, it might happen that the Analytical Engine would execute with greater rapidity the calculations for which the Difference Engine was intended; or that the Difference Engine would itself be superseded by a far simpler mode of construction.

Though these views might, perhaps, at that period, have appeared visionary, they have subsequently been completely realized.

To have allowed the construction of the Difference Engine to be resumed while these new views were withheld from the Government would have been improper; yet the state of uncertainty in which those views were then necessarily involved, rendered any written communication respecting their probable bearing on that engine a matter of very great difficulty. It therefore appeared to Mr. Babbage that the most straightforward course was to ask for an interview with the head of the Government, and to communicate to him the exact state of the case. Various circumstances occurred to delay, and ultimately to prevent that interview.

From the year 1833 to the close of 1842, Mr. Babbage repeatedly applied to the Government for its decision upon the subject. These applications were unavailing. Years of delay and anxiety followed each other, impairing those energies which were now directed to the invention of the Analytical Engine. This state of uncertainty had many injurious effects. It prevented Mr. Babbage from entering into any engagement with other Governments respecting the Analytical Engine, by which he might have been enabled to employ a greater number of assistants, and thus to have applied his faculties only to the highest departments of the subject, instead of exhausting them on inferior objects, that might have been executed with less fatigue by other heads. It also became necessary, from motives of prudence, that the heavy expense incurred for this purpose should be spread over a period of many years. This consideration naturally caused a new source of anxiety and risk, arising from the uncertain tenure of human life and of human faculities, -- a reflection ever present to distract and torment the mind, and itself calculated to cause the fulfilment of its own forebodings.

Amidst such distractions the author of the Analytical Engine has steadily pursued his single purpose. The numberless misrepresentations of the facts connected with both Engines have not induced him to withdraw his attention from the new Invention; and the circumstance of his not having printed a description of either Engine has arisen entirely from his determination never to employ his mind upon the description of those Machines so long as a single difficulty remained which might limit the power of the Analytical Engine. The drawings, however, and the notations have been freely shown; and the great principles on which the Analytical Engine is founded have been explained and discussed with some of the first philosophers of the present day. Copies of the engravings were sent to the libraries of several public institutions, and the effect of the publicity thus given to the subject is fully proved by its having enabled a distinguished Italian Geometer to draw up from these sources an excellent account of that Engine.

Throughout the whole of these labours connected with the Analytical Engine, neither the Science, nor the Institutions, nor the Government of his Country have ever afforded him the slightest encouragement. When the Invention was noticed in the House of Commons, one single voice* alone was raised in its favour.

During nearly the whole of a period of upwards of twenty years, Mr. Babbage had maintained, in his own house, and at his own expense, an establishment for aiding him in carrying out his views, and in making experiments, which most materially assisted in improving the Difference Engine. When that work was suspended he still continued his own inquiries, and having discovered principles of far wider extent, he ultimately embodied them in the Analytical Engine.

The establishment necessary in the former part of this period for the actual construction of the Difference Engine, and of the extensive drawings which is demanded, as well as the formation of those tools which were contrived to overcome the novel difficulties of the case, and in the latter part of the same period by the drawings and notations of the Analytical Engine, and the experiments relating to its contruction, gave occupation to a considerable number of workmen of the greatest skill. During many years in which this work proceeded, the workmen were continually changing, who carried into the various workshops in which they were afterwards employed the practical knowledge acquired in the construction of these machines.

To render the drawings of the Difference Engine intelligible, Mr. Babbage had invented a compact and comprehensive language (the Mechanical Notation), by which every contemporaneous or successive movement of this Machine became known. Another addition to mechanical science was subsequently made in establishing principles for the lettering of drawings; one consequence of which is, that although many parts of a machine may be projected upon any plan, it will be easily seen, by the nature of the letter attached to each working point, to which of those parts it really belongs.

By the means of this system, combined with the Mechanical Notations, it is now possible to express the forms and actions of the most complicated machine in language which is at once condensed, precise and universal.

At length, in November 1842, Mr. Babbage received a letter from the Chancellor of the Exchequer, stating that Sir Robert Peel and himself had jointly and reluctantly come to the conclusion that it was the duty of the Government, on the ground of expense, to abandon the further construction of the Difference Engine. The same letter contained a proposal to Mr. Babbage, on the part of Government, that he should accept the whole of the drawings, together with the part of the Engine already completed, as well as the materials in a state of preparation. This proposition he declined.

The object of the Analytical Engine (the drawings and the experiments for which have been wholly carried on at Mr. Babbage's expense, by his own draftsmen, workmen and assistants) is to convert into numbers all the formulae of analysis, and to work out the algebraical development of all formulae whose laws are known.

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* That of Mr. Hawes, Member for Lambeth

The present state of the Analytical Engine is as follows:--

All the great principles on which the discovery rests have been explained, and drawings of mechanical structures have been made, by which each may be carried into operation.

Simpler mechanisms, as well as more extensive principles than were required for the Difference Engine, have been discovered for all the elementary portions of the Analytical Engine, and numerous drawings of these successive simplifications exist.

The mode of combining the various sections of which the Engine is formed has been examined with unceasing anxiety, for the purpose of reducing the whole combination to the greatest possible simplicity. Drawings of almost all the plans thus discussed have been made, and the latest of the drawings (bearing the number 28) shows how many have been suspended, and also, from its extreme comparative simplicity, that little further advance can be expected in that direction.

Mechanical Notations have been made both of the actions of detached parts and of the general action of the whole, which cover about four or five hundred large folio sheets of paper.

The original rough sketches are contained in about five volumes.

There are upwards of one hundred large drawings.

No part of the construction of the Analytical Engine has yet been commenced. A long series of experiments have, however, been made upon the art of shaping metals; and the tools to be employed for that purpose have been discussed, and many drawings of them prepared. The great object of these inquiries and experiments is, on the one hand, by simplifying as much as possible the construction, and on the other, by contriving new and cheaper means of execution, at length to reduce the expense within those limits which a private individual may command.

EXCERPTS FROM

"SKETCH OF THE ANALYTICAL ENGINE INVENTED BY CHARLES BABBAGE, ESQ."*

by

L. F. Menabrea, of Turin, Officer of the Military Engineers

* From the "Bibliothèque Universelle de Genève", No. 82, October, 1842. Translated by Lady Lovelace, Ada Augusta, only child of Lord Byron.

EXCERPTS FROM

"SKETCH OF THE ANALYTICAL ENGINE INVENTED BY CHARLES BABBAGE, ESQ."

by

L. F. Menabrea

The chief drawback hitherto on most . . . machines is, that they require the continual intervention of a human agent to regulate their movements, and thence arises a source of errors . . . .

But if human intervention were necessary for directing . . . partial operations, nothing would be gained under the heads of correctness and economy of time; the machine must therefore have the additional requisite of executing by itself all the successive operations required for the solution of a problem proposed to it, when once the primitive numerical data for this same problem have been introduced. Therefore, since, from the moment that the nature of the calculation to be executed . . . have been indicated to it, the machine is, by its own intrinsic power, of itself to go through all the intermediate operations which lead to the proposed result, it must exclude all methods of trial and guess-work, and can only admit the direct processes of calculation. [1]

It is necessarily thus; for the machine is not a thinking being, but simply an automaton which acts according to the laws imposed upon it . . . .

To understand how the machine can now go through its functions according to the laws laid down, we will begin by giving an idea of the manner in which it materially represents numbers. Let us conceive a pile or vertical column consisting of an indefinite number of circular discs, all pierced through their centers by a common axis, around which each of them can take an independent rotatory movement. If round the edge of these discs are written the ten figures which constitute our numerical alphabet, we may then, by arranging a series of these figures in the same vertical line; express in this manner any number whatever. It is sufficient for this purpose that the first disc represent units, the second tens, the third hundreds, and so on. When two numbers have been thus written on two distinct columns, we may propose to combine them arithmetically with each other, and to obtain the result on a third column. In general, if we have a series of columns[2] consisting of discs, which columns we will designate

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[1] This must not be understood in too unqualified a manner. The engine is capable, under certain circumstances, of feeling about to discover which of two or more possible contingencies has occurred, and of then shaping its future course accordingly. -- Note by Lady Lovelace, Translator.

[2] called the storehouse

as V_0, V_1, V_2, V_3, V_4, etc., we may require, for instance, to divide the number written on the column V_1 by that on the column V_4, and to obtain the result on column V_7. To effect this operation, we must impart to the machine two distinct arrangements; through the first it is prepared for executing a division, and through the second the columns it is to operate on are indicated to it, and also the column on which the result is to be represented. If this division is to be followed, for example, by the addition of two numbers taken on other columns, the two original arrangements of the machine must be simultaneously altered. If, on the contrary, a series of operations of the same nature is to be gone through, then the first of the original arrangements will remain, and the second alone will be altered. Therefore, the arrangements that may be communicated to the various parts of the machine may be distinguished into two principal classes: . . . that relative to the operations and that relative to the variables . . . .

The Analytical Engine contains two principal species of cards: . . . Operation cards, by means of which the parts of the machine are so disposed as to execute any determinate series of operations, such as additions, subtractions, multiplications, and divisions . . . and cards of the Variables, which indicate to the machine the columns on which the results are to be represented.

EXCERPTS FROM

"TRANSLATOR'S NOTES TO M. MENABREA'S MEMOIR."

The operating mechanism of the Analytical Engine . . . might act upon other things . . . whose mutual fundamental relations could be expressed by those of the abstract science of operations . . . and the operating notation and mechanism of the engine. Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent . . . .

The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform. It can follow analysis, but it has no power of anticipating any analytical relations or truths. Its province is to assist us in making available what we are already acquainted with . . . .

It is obvious that, in the invention of a calculating engine, these two branches of the subject [the mechanical and the analytical] are equally essential fields of investigation, and that on their mutual adjustment, one to the other, must depend all success. They must be made to meet each other, so that the weak points in the powers of either department may be compensated by the strong points in those of the other . . . .

"PART OF CHAPTER VIII, 'NINTH BRIDGEWATER TREATISE' "

by

Charles Babbage, Esq.

Let the reader suppose himself placed before the Calculating Engine, and let him again observe and ascertain, by lengthened induction, the nature of the law it is computing. Let him imagine that he has seen the changes wrought on its face during the lapse of thousands of years, and that without one solitary exception, he has found the engine register the series of square numbers. Suppose now, the maker of that machine to say to the observer, "I will, by moving a certain mechanism, which is invisible to you, cause the engine to make one cube number instead of a square, and then to revert to its former course of square numbers;" the observer would be inclined to attribute to him a degree of power but little superior to that which was necessary to form the original engine.

But, let the same observer, after the same lapse of time -- the same amount of uninterrupted experience of the uniformity of the law of square numbers, hear the maker of the engine say to him -- "The next number which shall appear on those wheels, and which you expect to find a square number, shall not be so. When the machine was originally ordered to make these calculations, I impressed on it a law, which should coincide with that of square numbers in every case, except the one which is now about to appear; after which no future exception can ever occur, but the unvarying law of the squares shall be pursued until the machine itself perishes from decay." Undoubtedly the observer would ascribe a greater degree of power to the artist who had thus willed that event which he foretells at the distance of ages before its arrival.

If the contriver of the engine then explain to him, that, by the very structure of it, he has power to order any number of such apparent deviations from its law to occur at any future periods, however remote, and that each of these may be of a different kind; and, if he also inform him, that he gave it that structure in order to meet events, which he foresaw must happen at those respective periods, there can be no doubt that the observer would ascribe to the inventor far higher knowledge than if, when those events severally occurred, he were to intervene, and temporarily to alter the calculations of the machine.

If, besides this, the contriver were so far to explain the structure of the engine that the observer could himself by some simple process, such as the mere moving of a bolt, call into action those apparent deviations whenever certain combinations were presented to his eye; if he were thus to impart a power of predicting such excepted cases, dependent on the will, though in other respects beyond the limits of the observer's power and knowledge, -- such a structure would be admitted as evidence of a still more skilful contrivance . . . .

When the construction of the [Analytical] engine was first attempted, I did not seek to give it the power of making calculations so far beyond the reach of mathematical analysis as these appear to be. I had determined to invest the invention with a degree of generality which should include a wide range of mathematical power; and I was well aware that the mechanical generalisations I had organised contained within them much more than I had leisure to study, and some things which will probably remain unproductive to a far distant day.

PASSAGES

FROM

THE LIFE OF A PHILOSOPHER.

BY

CHARLES BABBAGE, ESQ., M.A.,

F.R.S., F.R.S.E., F.R.A.S., F. STAT. S., HON. M.R.I.A., M.C.P.S.,

COMMANDER OF THE ITALIAN ORDER OF ST. MAURICE AND ST. LAZARUS,

INST. IMP. (ACAD. MORAL.) PARIS CORR., ACAD. AMER. ART. ET SC. BOSTON, REG. ŒCON. BORUSS., PHYS. HIST. NAT. GENEV., ACAD. REG. MONAC., HAFN., MASSIL., ET DIVION., SOCIUS. ACAD. IMP. ET REG. PETROP., NEAP., BRUX., PATAV., GEORG. FLOREN, LYNCEI ROM., MUT., PHILOMATH. PARIS, SOC. CORR., ETC.

"I'm a philosopher. Confound them all—
Birds, beasts, and men; but no, not womankind."—*Don Juan.*

"I now gave my mind to philosophy: the great object of my ambition was to make out a complete system of the universe, including and comprehending the origin, causes, consequences, and termination of all things. Instead of countenance, encouragement, and applause, which I should have received from every one who has the true dignity of an oyster at heart, I was exposed to calumny and misrepresentation. While engaged in my great work on the universe, some even went so far as to accuse me of infidelity;—such is the malignity of oysters."—*"Autobiography of an Oyster" deciphered by the aid of photography in the shell of a philosopher of that race,—recently scolloped.*

LONDON:

LONGMAN, GREEN, LONGMAN, ROBERTS, & GREEN.

1864.

DEDICATION.

TO VICTOR EMMANUEL II., KING OF ITALY.

SIRE,

IN dedicating this volume to your Majesty, I am also doing an act of justice to the memory of your illustrious father.

In 1840, the King, Charles Albert, invited the learned of Italy to assemble in his capital. At the request of her most gifted Analyst, I brought with me the drawings and explanations of the Analytical Engine. These were thoroughly examined and their truth acknowledged by Italy's choicest sons.

To the King, your father, I am indebted for the first public and official acknowledgment of this invention.

I am happy in thus expressing my deep sense of that obligation to his son, the Sovereign of united Italy, the country of Archimedes and of Galileo.

I am, Sire,
With the highest respect,
Your Majesty's faithful Servant,

CHARLES BABBAGE.

Yours truly
C. Babbage

FROM A PHOTOGRAPH TAKEN IN 1860

EDITOR'S NOTE

The following excerpts from Charles Babbage's book "Passages From the Life of a Philosopher" have been chosen to introduce the reader to Babbage the scientist and Babbage the man, but in only a small way can they recreate the intimate details and personal flavor of the original. To those who may wish to pursue the work in its entirety, a single copy is available for examination at the Hayden Library in the Derr rare-book collection. This copy is also on microfilm at the Digital Computer Laboratory.

Robert R. Rathbone

Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts
January, 1952

EXCERPTS FROM "PASSAGES FROM THE LIFE OF A PHILOSOPHER"

by
Charles Babbage, Esq.

Circumstances Connected with the Exhibition of the Difference Engine No. 1 in the International Exhibition of 1862

. . . On Mr. Gravatt applying to the Commissioners for space, it was stated that the Engine must be placed amongst philosophical instruments, Class XIII.

The only place offered for its reception was a small hole, 4 feet 4 inches in front by 5 feet deep. On one side was the only passage to the office of the superintendent of the class. The opposite side was occupied by a glass case in which I placed specimens of the separate parts of the unfinished engine [Difference Engine No. 1]. These, although executed by English workmen above thirty years ago, were yet, in the opinion of the most eminent engineers, unsurpassed by any work the building of 1862 contained. The back of this recess was closed in and dark, and only allowed a space on the wall of about five feet by four on which to place the whole of the drawings and illustrations of the Difference Engine. Close above the top of the machine was a flat roof, which deprived the drawings and the work itself of much light.

The public at first flocked to it; but it was so placed that only three persons could conveniently see it at the same time . . . and he [Mr. Gravatt] was continually interrupted by the necessity of moving away in order to allow access to the numerous persons whose business called them to the superindendent's office.

I was myself frequently asked why I did not employ a person to explain the Difference Engine . . . but my greatest difficulty was with foreigners; no explanation I could devise . . . appeared at all to satisfy their minds . . . . That the nation possessing the greatest military and commercial marine in the world--the nation which had spent so much in endeavouring to render perfect the means of finding the longitude--which had recently caused to be computed and published at considerable expense an entirely new set of lunar tables should not have availed itself at any cost of mechanical means of computing and stereotyping such tables, seemed entirely beyond their comprehension . . . .

Of the Analytical Engine

. . . In order to carry out my pursuits successfully, I had purchased a house with above a quarter of an acre of ground in a very quiet locality. My coach-house was now converted into a forge and a foundry, whilst my stables were transformed into a workshop. I built other extensive workshops myself, and had a fire-proof building for my drawings and draftsmen. Having myself worked with a variety of tools, and having studied the art of constructing each of them, I at length laid it down as a principle--that, except in rare cases, I would never do anything myself if I could afford to hire another person who could do it for me . . . .

Such works could not be carried on without great expenditure. The fluctuations in the demand and supply of skilled labour were considerable. The railroad mania withdrew from other pursuits the most intellectual and skilful draftsmen. One who had for some years been my chief assistant was tempted by an offer so advantageous that in justice to his own family he could scarcely have declined it. Under these circumstances I took into consideration the plan of advancing his salary to one guinea per day. Whilst this was in abeyance, I consulted my venerable surviving parent. When I had fully explained the circumstances, my excellent mother replied: "My dear son, you have advanced far in the accomplishment of a great object, which is worthy of your ambition. You are capable of completing it. My advice is -- pursue it, even if it should oblige you to live on bread and cheese". . . .

This advice entirely accorded with my own feelings. I therefore retained my chief assistant at his advanced salary.

The most important part of the Analytical Engine was undoubtedly the mechanical method of carrying the tens . . . . Twenty or thirty different plans and modifications had been drawn. At last I came to the conclusion that I had exhausted the principle of successive carriage. I also concluded that nothing but teaching the Engine to foresee and then to act upon that foresight could lead me to the object I desired, namely, to make the whole of any unlimited number of carriages in one unit of time . . . . [See plate X1, p. 20.]

This new and rapid system of carrying the tens when two numbers are added together, reduced the actual time of the addition of any number of digits, however large, to nine units of time for the addition, and one unit for the carriage. Thus in ten's units of time, any two numbers, however large, might be added together. A few more units of time, perhaps five or six, were required for making the requisite previous arrangements . . . .

The Analytical Engine consists of two parts:--

1st. The store in which all the variables to be operated upon, as well as all those quantities which have arisen from the result of other operations, are placed.

2nd. The mill into which the quantities about to be operated upon are always brought.

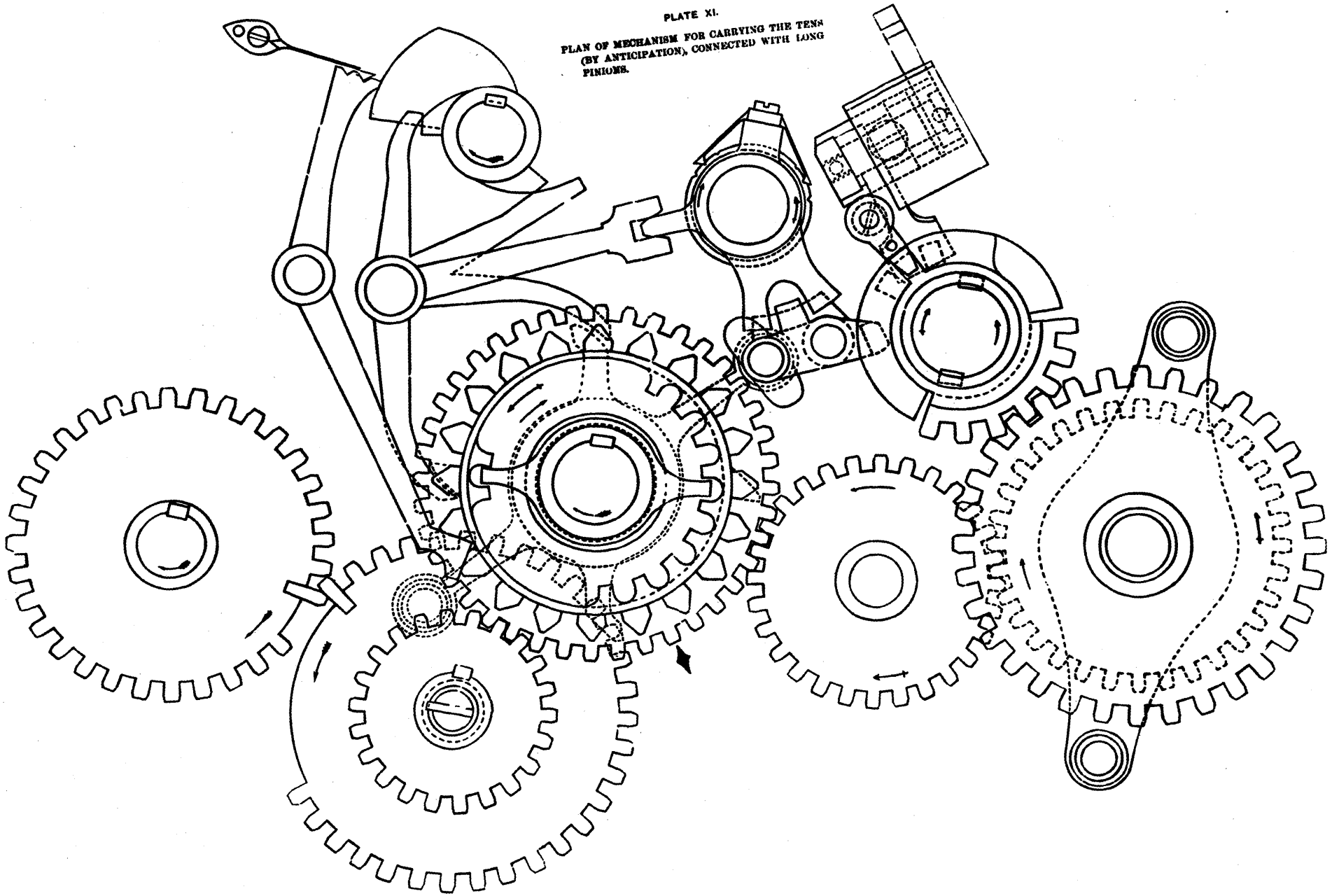
Every formula which the Analytical Engine can be required to compute consists of certain algebraical operations to be performed upon given letters, and of certain other modifications depending on the numerical value assigned to those letters.

There are therefore two sets of cards, the first to direct the nature of the operations to be performed -- these are called operation cards: the other to direct the particular variables on which those cards are required to operate -- these latter are called variable cards . . . .

The Analytical Engine is therefore a machine of the most general nature. Whatever formula it is required to develop, that law of its development must be communicated to it by two sets of cards. When these

PLATE XI.

PLAN OF MECHANISM FOR CARRYING THE TENS (BY ANTICIPATION), CONNECTED WITH LONG PINIONS.



have been placed, the engine is special for that particular formula. The numerical value of its constants must then be put on the columns of wheels below them, and on setting the Engine in motion it will calculate and print the numerical results of that formula.

Every set of cards made for any formula will at any future time recalculate that formula with whatever constants may be required. Thus the Analytical Engine will possess a library of its own . . . .

Besides the sets of cards which direct the nature of the operations to be performed . . . there is another class of cards called number cards .... Any number which the Analytical Engine is capable of using or producing can, if required, be expressed by a card with certain holes in it . . . .

The Analytical Engine will contain,

1st. Apparatus for printing on paper, one, or, if required, two copies of the results.

2nd. Means for producing a stereotype mould of the tables or results it computes.

3rd. Mechanism for punching on blank pasteboard cards or metal plates the numerical results of any of its computations . . . .

The Analytical Engine I propose will have the power of expressing every number it uses to fifty places of figures. It will multiply any two such numbers together, and then, if required, will divide the product of one hundred figures by number of fifty places of figures.

Supposing the velocity of the moving parts of the Engine to be not greater than forty feet per minute, I have no doubt that

Sixty additions or subtractions may be completed and printed in one minute.

One multiplication of two numbers, each of fifty figures, in one minute.

One division of a number having 100 places of figures by another of 50 in one minute . . . .

There are, however, methods by which any machine made for a given number of figures may be made to compute the same formulae with double or any multiple of its original number . . . .

Games of skill that can be played by an Automaton

I have already stated that in the Analytical Engine I had devised mechanical means equivalent to memory, also that I had provided other means equivalent to foresight, and that the Engine itself could act on this foresight.

In consequence of this the whole question of making an automaton play any game depended upon the possibility of the machine being able to represent all the myriads of combinations relating to it. Allowing one hundred moves on each side for the longest game at chess, I found that the combination involved in the Analytical Engine enormously surpassed any required, even by the game of chess.

As soon as I arrived at this conclusion I commenced an examination of a game called "tit-tat-to," . . . . I ascertained what number of combinations were required for all the possible variety of moves and situations. I found this to be comparatively insignificant. I therefore easily sketched out mechanisms by which such an automaton might be guided . . . . A difficulty, however, arose of a novel kind . . . . When the automaton had to move, it might occur that there were two different moves, equally conducive to his winning the game. In this case no reason existed within the machine to direct his choice: unless, also, some provision were made, the machine would attempt two contradictory motions.

The first remedy I devised for this defect was to make the machine keep a record of the number of games it had won from the commencement of its existence. Whenever two moves, which we may call A and B, were equally conducive to winning the game, the automaton was made to consult the record of the number of games he had won. If that number happened to be even, he was directed to take course A; if it were odd, he was to take course B.

Deciphering

Deciphering is, in my opinion, one of the most fascinating of arts . . . . I practised it in its simplest form when I was at school. The bigger boys made ciphers, but if I got hold of a few words, I usually found out the key. The consequence of this ingenuity was occassionally painful: the owners of the detected ciphers sometimes thrashed me, though the fault really lay in their own stupidity . . . .

One of the most singular characteristics of the art of deciphering is the strong conviction possessed by every person, even moderately acquainted with it, that he is able to construct a cipher which nobody else can decipher . . . .

In a conversation on that subject with the late Mr. Davies Gilbert, of the Royal Society, each maintained that he possessed a cipher which was absolutely inscrutable. In comparison, it appeared that we had both imagined the same law . . . .

This cipher was arranged upon the following principle:-- Two concentric circles of cardboard were formed, each divided into twenty-six or more divisions.

On the outer were written in regular order the letters of the alphabet. On the inner circle were written the same twenty-six letters, but in any irregular manner.

In order to use this cipher, look for the first letter of the word to be ciphered on the outside circle. Opposite to it, on the inner circle, will be another letter, which is to be written as the cipher for the former.

Now turn the inner circle until the cipher just written is opposite the letter a on the outer circle. Proceed in the same manner for the next, and so on for all succeeding letters.

Theatrical Experience

I was never particularly devoted to theatrical representations . . . . I did, however, occasionally, in one or two rare instances, assist in a tableau . . . .

On one occasion having joined a party of friends in their box at the opera 'Don Juan', I escaped, by half a second, a marvellous adventure. Somewhat fatigued with the opera, I went behind scenes to look at the mechanism. One of the scene-shifters . . . offered to take me all over the theatre . . . .

After a long rambling and descending endless steps, I found myself in a vast dark and apparently boundless area . . . . Suddenly a little bell rang -- the signal for my scene-shifting friend to take his post . . . . Instantly my friend became invisible in the surrounding gloom.

My first step when thus suddenly abandoned, was to mount on a large oblong platform about six feet above the floor . . . . Suddenly a flash of lightening occurred. On looking up, high above my head, I saw an opening as large as the platform on which I stood. All there was brightness. Whilst I was admiring this new light, and seeking my way to the upper and outer world, two devils with long forked tails jumped upon the platform . . . .

"What do you do here?" said Devil No. 1.

Before I could invent a decent excuse, Devil No. 2 exclaimed.

"You must not come with us."

This was consolatory and reassuring, so I replied--

"Heaven forbid."

During this colloquy, the table, the philosopher, and the devils, were all slowly moving upward to the open trap-door of the stage above. Seeing a beam some six feet higher . . . I inquired whether it was fixed and would bear my weight . . . .

"Yes," said Devil No. 1.

"But you cannot reach it at a jump," added Devil No. 2.

We had now reached the level of the desired beam, though not near enough for a jump. However, still ascending, we passed it: then stooping my head and bending my body to avoid the floor of the stage . . . I sprang down on the beam . . . . My two Missionary companions continued their course to the world above in order to convey the wicked Juan to the realms below . . . . I soon rejoined my companions who congratulated me on what they represented as my 'undeserved escape:' kindly hoping that I might be equally fortunate upon some further occasion.

Mastership of the Mint

In 1846 the Mastership of the Mint became vacant. In former days it was held by Newton. I had pointed it out in "The Decline of Science" as one of those offices to which men of science might reasonably aspire. A complete acquaintance with the most advanced state of mechanical science, which the demands of my own machinery had compelled me to improve, added to a knowledge of the internal economy of manufactories, appeared to me to constitute fair claims to that office.

In the event of my succeeding, I had proposed to let the whole of my salary accumulate, so that at the end of ten or twelve years I might retire from the office, and be enabled, with the 20,000£ thus earned, to construct the Analytical Engine . . . .

The appointment remained for a short time in abeyance; but it was found necessary to detach Sheil from O'Connell, and the appointment was therefore given to Sheil . . . .

In 1849, on the promotion of Sheil, the Mastership of the Mint again became vacant. I thought my own claims sufficiently known to the public; but I had no political interest. My friend Sir John Herschel was more fortunate, and he received the appointment.

After a few years, the office again became vacant by the resignation of Sir John Herschel. The Government had now for the third time an opportunity of partially repairing its former neglect. I had, however, no political party to support me, and the present Master of the Mint, Mr. Graham, then received the appointment.

Motives for Being on a Committee

. . . At all elections some few men . . . do all the difficult and real work of the committee. The committee itself is, for several reasons, generally very numerous.

All who are supposed to have weight are, of course, put upon it.

Many who wish to appear to have weight get their names upon it.

Some get put upon it thinking to establish a political claim upon the party.

Others because they like to see their names in the newspapers.

Others again, who, if not on his committee, would vote against the candidate.

There are also idlers and busybodies, who go there to talk or to carry away something to talk about, which may give them importance in their own circle.

Young lawyers . . . are very numerous, possessing acute perceptions of professional advantage.

A jester and a good story-teller are very useful . . . .

Occasionally, a few simply honest men are found upon committees. These are useful as adjuncts to give a kind of high moral character to the cause; but the rest of the committee generally think them bores, and when they differ upon any point from the worldly members, it is invariably whispered that they are crotchety fellows.

Street Nuisances

During the last ten years, the amount of street music has so greatly increased that it has now become a positive nuisance to a very considerable portion of the inhabitants of London. It robs the industrious of time; it annoys the musical man by its intolerable badness; it irritates the invalid; deprives the patient, who at great inconvenience has visited London for the best medical advice, of that repose which, under such circumstances, is essential for his recovery, and it destroys the time and energy of all the intellectual classes of society by its continual interruptions of their pursuits.

Instruments of torture permitted by the Government to be in daily and nightly use in the streets of London:

Organs	Bagpipes
Brass bands	Accordians
Fiddlers	Halfpenny whistles
Harps	Tom-toms
Harpsichords	Trumpets
Hurdy-gurdies	Shouting out object for sale
Flageolets	Religious canting
Drums	Psalm-singing

I have very frequently been disturbed by such music . . . after twelve o'clock at night. Upon one occasion, a brass band played, with but few and short intermissions, for five hours.

Encouragers of street music

Tavern-keepers	Ladies of doubtful virtue.
Public-houses	
Gin-shops	Occasionally titled ladies;
Beer-shops	but these are almost
Coffee-shops	invariably of recent
Servants	elevation, and deficient
Children	in that taste which their
Visitors from the country	sex usually possess.

Conclusion

. . . [The reader] may reasonably ask what peculiarities of mind enabled me to accomplish what even the most instructed in their own sciences deemed impossible.

I have always carefully watched the exercise of my own faculties, and I have also endeavored to collect from the light reflected by other minds some explanation of the question.

I think one of the most important guiding principles has been this:--that every moment of my waking hours has always been occupied by some train of inquiry. In far the largest number of instances the subject might be simple or even trivial, but still work of inquiry, of some kind or other, was always going on.

The difficulty consisted in adapting the work to the state of the body. The necessary training was difficult. Whenever at night I found myself sleepless, and wished to sleep, I took a subject for examination that required little effort, and which also had little influence on worldly affairs by its success or failure.

On the other hand, when I wanted to concentrate my whole mind upon an important subject, I studied during the day all the minor accessories, and [returned to work at] two o'clock in the morning . . . . [Only then did I find repose from] the nuisances of the London street . . . .

I believe my early perception of the immense power of signs in aiding the reasoning faculty contributed much to whatever success I may have had. Probably a still more important element was the intimate conviction I possessed that the highest object a reasonable being could pursue was to endeavor to discover those laws of mind by which man's intellect passes from the known to the discovery of the unknown.

This feeling was ever present to my own mind, and I endeavored to trace its principle in the minds of all around me, as well as in the works of my predecessors.

EXCERPTS FROM
"THE WORK OF CHARLES BABBAGE" *

by
Richard H. Babbage

. . . [Charles Babbage's] main purpose was to reproduce in mechanism the human faculties of memory and foresight so as to free mankind from the heavy brain drudgery which accompanied prolonged calculation of intricate mathematical tables. Our modern "Electronic Numerical Integrator and Computer" [the ENIAC] is more marvelous than Babbage's "Analytical Engine" because of the speed at which it delivers results. But the application of machinery to perform the functions of memory and foresight were successfully accomplished more than 110 years ago in [his] two great calculating machines . . . .

About the beginnings of his mechanical adventures [Charles Babbage] makes this observation:

"When the first idea of contriving mechanical means for the calculation of all classes of astronomical and arithmetical tables occurred to me, I contented myself with making simple drawings, and with forming a small model of a few parts. But when I understood it to be the wish of the Government that a larger engine should be constructed, a very serious question presented itself for consideration, namely: Is the present state of the art of making machinery sufficiently advanced to enable me to execute the multiplied and highly complicated movements required for the Difference Engine?

"After examining all the resources of existing workshops, I came to the conclusion that, in order to succeed, it would be necessary to advance the art of construction itself . . . . "

[In addition to the many mechanical difficulties which Charles Babbage encountered in designing his Analytical Engine, another obstacle, of an amusing nature, is worthy of note.]

"The fourth of the apparent impossibilities to which I have referred concerns the kind of objections that my countrymen make to inventions. Propose to any Englishman any principle or any instrument, however admirable, and you will observe that the whole effort of the English mind is directed to find a difficulty, a defect, or an impossibility in it. If you speak to him of a machine for peeling a potato, he will pronounce it impossible; if you peel a potato with it before his eyes, he will declare it useless because it will not slice a pineapple. Impart the same principle or show the same machine to an American or to one of our Colonists and you will observe that the whole effort of his mind is to find some new application of the principle, some new use for the instrument."

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* A paper delivered at the Symposium on Large-Scale Digital Calculating Machinery at Harvard University, January 7, 1947, and published in its "Proceedings."

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