CONFERENCE

DATA PROCESSING AND AUTOMATIC COMPUTING MACHINES

OPENING ADDRESS

by

B.G. Gates, Acting Chief Scientist
Research and Development Branch
Department of Supply, Melbourne, Victoria

LADIES AND GENTLEMEN : It was hoped, when this Conference was planned, that the Minister of Supply and Defence Production, The Honorable Mr. Howard Beale, would have been able to address you at the opening stage. Unfortunately he has found it impossible to be present, but he has asked me to deliver to you the following message:

> "I very much regret that I am unable to be present at the opening session of the W.R.E. Conference on Data Processing and Automatic Computing Machines. However, I would like to extend a warm welcome to all our visitors from U.K., U.S.A., and Australian Industry, Universities, Federal and State Government Departments, and other instrumentalities. I have no doubt that you will find the equipment and methods used by W.R.E. of great interest, and feel sure that you will agree with my view that a very high degree of skill and ingenuity has been shown by all who have been concerned with the development of the very advanced types of equipment now in use at W.R.E. This equipment has led to immense savings in time and effort in the processing of the enormous amount of data obtained from trials. I consider that the warmest praise for their most valuable achievements is due to all who have contributed.
> I am confident that both you and W.R.E. will profit by the papers and discussions which will be dealt with during the forthcoming proceedings, and wish the Conference every success."

In the absence of the Minister, it has become my pleasant duty to deliver the opening talk at this Conference, and therefore I would like to add to the Minister's remarks my own welcome on behalf of the Department of Supply to all attending this Conference.

During the proceedings taking place this week you will receive fully detailed information on the methods in use at W.R.E. in data handling, but I think in this address I might try to explain the background which has led up to the development of a variety of data handling equipment at W.R.E., and to outline for you the objectives which the establishment has sought to obtain.

I believe that many of you may not be familiar with work on guided weapons, the general method by which such weapons are tested and the problems arising from dealing with the data obtained in such tests. Therefore I hope that those already initiated will forgive me if I spend a little time in giving a brief description of guided weapon trials methods.

First of all, a guided missile is a very expensive and complex piece of equipment and, moreover, it is also part of an even more complex weapon system comprising missile preparation facilities, launchers, guidance equipment, and target acquisition radars. Therefore each trial must be so planned as to collect the maximum amount of information from it on the behaviour of all these items, although careful consideration is always given to avoiding over-elaboration, demands for excessive accuracy and so on, which can only be provided at the expense of reliability. Further, when a flying target is used, such as the Jindivik pilotless aircraft, data on the relative paths of target and missile must also be obtained. The speed of most missiles is very high and they travel over considerable distances. It is therefore necessary to collect information at a very rapid rate, both from within the missile itself and from a number of widely scattered observation posts. When the test is over, all this information must be collected, calibrated and evaluated numerically, in order to provide data for further tests or for variations in design and development. The sort of information required falls broadly into two classes - external and internal.

Let us first consider the components of the missile from which internal information is required. In the main, a guided missile consists of an airframe adapted to withstand high accelerations and for travel at high supersonic speeds. This airframe is fitted with lifting and control surfaces arranged in some cases in one plane, as in an aircraft, and in others, in a cruciform arrangement in two planes, at right angles. Inside this airframe we have first of all the propulsion system which in the majority of cases is some kind of rocket motor, often in two parts, namely a high thrust boost motor and a low thrust sustainer motor. Next we have the stabilising system comprising gyroscopes, accelerometers and associated electronics, hydraulics and pneumatics etc., arranged for stabilisation in roll, pitch and yaw. Associated closely with these is the internal guidance system which collects information about the position of the target, either directly or via a ground radar or radio link. Finally, in an operational weapon, there is the warhead, and frequently the proximity fuze. In W.R.E. trials at Woomera the warhead is replaced by ancillary test apparatus for telemetry and internal recording and also in many instances, parachute and/or break-up devices to permit missile recovery after flight.

In the planning of a trial, a selection is made of the performance parameters relating to the above items on which data is required and this choice usually has to be limited by practical considerations to a number of the order of two dozen. Transducers are then arranged in the missile to convert these desired parameters into electrical quantities, and these in turn are applied usually in time sequence to modulate a small radio transmitter carried in the missile which passes on the data to a suitable ground receiver. Sometimes in addition a few parameters are arranged to operate internal recorders from which results can only be obtained after the missile has been recovered.

We can now turn to the devices yielding external information. First, for the majority of missiles, there is some form of base guidance system either on the ground, for ground to air missiles, or carried in the launching aircraft in the case of air to air weapons. During a trial, data are recorded from the guidance system of all essential parameters required to compare the actual flight performance of the missile with the behaviour which the guidance system directed it to carry out. Next the trajectory and attitude of the missile in space are observed by a number of kinetheodolites suitably located along the length of the trials range and also by high speed cine-cameras. In addition to tracking by optical methods, the missile is also tracked by radar and by highly refined long range direction-finding apparatus. Further, in order to check any errors which may arise in differentiating position measurements to obtain velocity and acceleration, direct velocity measurements are made by radio-doppler methods.

Finally, when a target aircraft is used as is frequently the case, the movements of this must also be recorded and, in addition, accurate information is required on the relative paths of the missile and the target during the period in which they are in close proximity.

All of the above devices produce large quantities of records, and in the original conception of guided missile trials practically all such records were obtained photographically. This meant that from each trial many hundreds of feet of cinematograph film and large numbers of telemetry and doppler traces had to be examined visually and measurements scaled off from them by manual methods. From these measurements calculations were made using desk machines to obtain data directly useful to the missile designer.

It very rapidly became apparent that this method would reach saturation at a very low level of activity, far below what would be required to meet impending programmes. Very early in the piece, punched card computing aids were employed, the cards being punched by manual methods. This method too was found to be quite inadequate, and the next step was to obtain means for the direct transfer to punched cards of information from kinetheodolite films and telemetry and doppler records, and this was done by means of film and record readers automatically coupled with card perforators. These film and record readers worked by projecting the magnified image of the kinetheodolite picture or telemetry trace on a screen in front of an operator who moves cursors over the image to intersect over the point under examination. In the case of kinetheodolite films, the operator also reads off figures recorded on the image giving time and elevation and azimuthal angles of the camera axis. In the case of telemetry records, allowance has to be made for the calibration curves of the transducers etc. The movement of the cursors is automatically recorded on punched cards supplemented by the other information inserted by the operator.

However, useful as these devices were, they gave insufficient relief in the solution of the problem of data reduction. An obvious avenue for exploration was the use of a high speed digital computer, but it was clearly seen that the major difficulty in the application of such a computer would reside in the rapid extraction of data from the trials records and its conversion into a form suitable for input to the computer. It was decided, after discussion with overseas workers on similar problems, to investigate the possibility of utilising magnetic recording for telemetry and doppler data in order to avoid manual operation in the extraction of such data. It was considered that if the data was expressed as a frequency modulation and that if suitable precautions were taken against the effects of tape speed variation, noise etc., this data could be automatically digitised in a form suitable for use in a high speed electronic digital computer.

This line of attack did not assist in reducing the work required from kinetheodolite film readers but these readers could readily be adapted to prepare punched tapes also in a form suitable for use in a high speed computer. Thus the kinetheodolite records could be made to fit in with the overall scheme without difficulty, even though the rate of output of the film readers would still be a limiting factor.

However, before embarking on the heavy expense which would be incurred by the purchase of a high speed digital computer, an analysis was made of the anticipated load of calculation which was likely to fall upon the Establishment in the foreseeable future. Such a survey was made in 1953 and the information then obtained showed how great the problem was likely to become. For example it was estimated that for the two years 1955 and 1956 the programme would call for -

(a) Computations totalling 400,000 points (or 800 points per day), for trajectory, velocity, attitude and target interception data.

(b) Large numbers of computations, some of considerable length involving aerodynamic derivatives and missile characteristics; and

(c) Calibration of some 6 million telemetry points.

In addition to these trials requirements, it was expected that there would be a number of essential problems in the research and development field requiring solution on a high speed computer and the possibility of a still more intense programme of trials subsequent to 1956 had to be faced.

It was estimated that it would take 200,000 man hours to obtain results from missile trials for the years 1955 and 1956, even if 100 percent efficiency were assumed. As this was unlikely to be the case, owing to such things as machine faults, inability to maintain an even firing rate, leave and sickness etc., it was estimated that it would be necessary to have 100 to 120 women computers with supervising and administrative staff, two sets of punch card equipment and four complete units of telemetry data reduction equipment, and even these might still prove inadequate. It was felt that the recruitment of sufficient computing staff to do this work was not practicable, nor would the organisation, if set up, be sufficiently flexible to cope efficiently with an uneven missile firing rate. In addition to the computing problem, there would be the need to process annually between 1 million and 2 million feet of film.

Having regard to the immensity of the problem, approval was given to embark on the project of purchasing a high speed computer and of developing the necessary magnetic tape recording and digitising equipment. In addition to these, plans were made for the procurement of suitable output equipment in the form of high speed printers and curve plotters.

The magnetic recording and digitising methods and equipment were developed here in the W.R.E. laboratories. A great deal of effort was devoted to ensuring that the equipment used was both reliable and accurate. Having regard to the great expense of carrying out guided missile trials, no chances could be taken with the possibility of abortive trials arising from unsatisfactory trials records. The main problems which have had to be solved include satisfactory conversion of records containing a considerable noise component and the devising of a method of parameter measurement independent of tape speed variation. While dealing with these and other scientific problems, much thought and care was given to ensuring the highest degree of reliability both in the recorders employed at the range and in the data converter here at Salisbury.

The high speed computer itself and the associated output converter and high speed printer were developed and manufactured by Messrs. Elliott Brothers Limited in the United Kingdom to specifications prepared by W.R.E., and throughout the work the closest liaison was maintained between this firm and W.R.E. by interchanges of visits.

All the equipment described has been installed, has been nursed through its inevitable teething troubles, and is now in full operation. You will have ample opportunity during the course of this Conference to study it in detail.

As an example of the time saved by the installation of automatic equipment, the following figures will be of interest. In 1952 it required 120 man hours work to calibrate and make the necessary calculations associated with ten thousand telemetry points using desk calculators.

With semi-automatic punch card equipment, this time was halved. With the modern equipment now in use, the time has been reduced to 40 minutes for the same amount of work. It may be said, therefore, that the problem of dealing with records of the telemetry type is well on the way to being satisfactorily solved. However, the evaluation of kinetheodolite films is still a relatively slow process and involves manual scanning of the film records. Much thought is being given to the development of photo-electric methods of scanning such films in order to obviate the human operator, but owing to the variable quality of the missile image which at great ranges is marginal in visibility, no satisfactory solution to this approach has yet been obtained.

When all this data has been prepared in tabular or graphical form, it is handed over to the appropriate contractor for examination and he makes use of it to plan further development and further trials. However, in addition to this, W.R.E. has undertaken to carry out evaluation work on trials results in parallel with the contractors in order to assist them in planning new trials in a manner likely to extract the maximum amount of useful information at the minimum cost in missiles and range time. This work is done in the W.R.E. Systems Assessment Division where they have set up simulators which are in fact analogue computers of various kinds. You will see during the course of this Conference the AGWAC computer which has been used for this purpose for some little time, and has already shown its value.

Other applications of the WREDAC computer have been exploited outside the field of guided missiles. For example, it has already been applied to a variety of calculations arising in aerodynamics and aircraft structures, and now the possibility of its use for business calculations is under consideration. An officer of the Public Service Board has spent some time here studying the WREDAC in order to report to the Board on the possible applications of high speed digital computers in Government Departments. W.R.E. itself has arranged a demonstration, which will be shown to you during this Conference, on the preparation through WREDAC of a payroll for several hundred employees and also of a system of inventory control.

To sum up, it can be said that the work of W.R.E. during recent years on data handling for guided missile trials has led to a notable advance in this technique, and that for the time being they are able to handle, with reasonable expedition, the trials results emanating from the Woomera range.

Coming now to the Conference agenda, I note from the list of papers to be presented that a very wide variety of subjects will be covered. These include descriptions of high speed computers in use in other organisations, the application of such computers in various fields including the challenging problems of linguistics, and many papers on programming mathematics and computer components. So great is the material which has come forward in discussion that it has been found necessary as you know, to split the proceedings into two parallel sessions, and also to hold evening sessions.

It is most gratifying to note the wide interest which this Conference has attracted, and I am sure that W.R.E. will benefit very much, not only from the discussions arising from these papers, but also from individual talks with the many visitors which we are so glad to receive.

I conclude by saying once more how very welcome you all are to this Conference, and to express the hope that it will prove to be of value both to you and to W.R.E. in the development of the fields of data handling and high speed computation.