# INTRODUCTION TO THE WRE DATA PROCESSING SYSTEM

by

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## 1. INTRODUCTION

In this short introductory talk I will indicate how the WRE Automatic data processing system operates, what equipments are being used and how such an integrated system has saved us many man hours of time.

## 2. ORGANISATION

At the Weapons Research Establishment one group is responsible for handling and processing all data from trials carried out at the Woomera Rocket Range and the functions of this group can be seen from Figure I. When a contractor desires to launch a test vehicle or missile he prepares an Instruction which sets out his intentions, the facilities he requires, some details of his missile, the allocation of telemetry channels and the information that he wishes to obtain from the trial. This is co-ordinated by a Projects Group at WRE and a copy of this co-ordinated Trials Instruction comes to the Mathematical Services Group which is responsible for processing the data.

There are five operations to be considered in data processing, they are : Recording, Assessment, Reduction, Computing, Display. Automatic real-time recording is used throughout a trial and the information is displayed on film from such equipments as kinetheodolites, tracking cameras, airborne cameras, radars and direction finding systems and on magnetic tape from doppler and telemetry. The cameras operate at various speeds and the magnetic tape units operate at 75 inches per second for telemetry and 7.5 inches per second for doppler, and record information on any one or more of three channels of a four channel quarter inch tape with a constant frequency of 100 kc/s on the fourth channel. To avoid errors introduced by different recording and playback speeds, the 100 kc/s signal is used to correct and digitize the data as it passes through the converters and also to give a continuous elapsed time count.

When they arrive at Salisbury these range records pass through a clerical records section in the Mathematical Services Group to various project officers in the Assessment Section of the Group. Each of these officers is allocated definite projects so that he always deals with the same contractors and the same type of information. The main function of these officers is to examine the primary range records to determine the particular records or portions of records which are required to be reduced, the computations which are necessary to provide the information called for in the Trials Instruction and to issue appropriate orders for this reduction and computing to be done. It is usual to assess the film records by visual observation and to mark elapsed time on the film manually, which of course is tedious and time consuming, but it has not yet been made automatic. The magnetic tape is at present monitored on the Cathode Ray tubes of the converters, although special monitors consisting of tape transports with variable speed of tape motion and a rotating scanning head are on order. With this type of monitor, it will be possible to obtain a stationary picture of a small section of the tape or a succession of elements rather like a moving picture.

After the initial assessment has been completed, the information on the records is converted into a binary form suitable for input to a high speed digital computer (WREDAC) in the following manner :

The films are passed through film readers which are semi-automatic in-so-far as certain automatic functions are performed by the readers under human control, but the operator is required to exercise his supervising intelligence in nearly every phase; however, the output is through Creed teleprinter equipment, which records the data automatically and thus provides the secondary records for the Computer. The degree of automation involved in these readers will be evident from the description of the equipment.

The first equipment I would like to describe is the Boscar, a unit which is used for reading Askania and Contraves theodolite films. In the equipment the theodolite film is magnified and projected onto a ground glass screen whence details of the information can be supplied to the output, and a keyboard on the console enables the operator to transfer the azimuth and elevation dial readings to punched paper tape. A light spot which can be placed on the missile image by joy stick control gives the x and y tracking correction readings, and when the spot is so placed read-out on punched paper tape is automatic when a button is pressed. Our operators can read about three frames a minute, which of course is slow when compared with a fully automatic reading system, but as this speed has been taken into account in the design of the whole system, it is not a real holding factor. If the operator is good the editing of the secondary tapes is not a long process, however for inexperienced readers this editing can take a considerable time. The tapes are passed through a Page Printer and checked for gross errors, such as incorrect punching, signs, spaces etc., and a correct tape is prepared using a reproducer. This corrected tape then becomes the secondary tape for the WREDAC. The operational precision of the Boscar readers should be about 6 seconds of arc for contraves theodolites, but this is of course slightly variable dependent on operator ability and quality of record.

The Telereader is a general purpose film reader used for measuring x and y co-ordinates from a previously fixed datum. We have used this equipment very successfully in the past for reading telemetry histogram records onto punched cards at a rate of 1000 points per hour. The equipment has now been modified to record on punched paper tape as well as the cards and this tape can be used with the high speed computer, after it has been edited. The reader also has a rotating arm for measuring angles, and this has proved a useful facility for much of our work. In this equipment there is a continuous transport of film or paper up to 12 inches wide and a back projection system equipped with three different magnifications (viz. 2, 4, 11). The angle measuring unit generates 10 pulses for each degree of rotation. The mechanical precision of the system is 400 x m units per inch on the record using the cartesian system (m = magnification), but the operational precision varies with image quality and type. It is usual for records to be read to within 3 to 4 counts when a high speed of output is maintained. More accurate measurements are possible if this speed is reduced.

Certain types of trials and experiments require oscillograph traces, which are recorded on film, to be calibrated and then plotted on a linear scale. For this work we use an Oscar which basically measures distances along two axes, but which in addition allows the operator to apply linear and non-linear calibrations by means of a perspex overlay.

The output from the Oscar can be recorded on an electric typewriter, or as a graph using an Electroplotter which can accept the data directly from the Oscar, or it can be recorded on punched cards or punched paper tape for use with the Computer. The Electroplotter can also accept data from punched cards and can display it as a graph. It also has a keyboard input, and in time will be able to accept a punched paper tape input.

The magnetic tape from doppler and telemetry instrumentation is passed through data converters which have been designed and built at the Weapons Research Establishment. The technical details of these equipments will be discussed at length during the conference, and I propose to mention only the function of these equipments in our system.

The main telemetry system installed at Woomera is a frequency modulated time multiplexed 24 channel system with one synchronising channel and 23 information channels. The function of the converter is to identify the synchronising pulse and separate out the 23 data channels from this pulse, to measure the data frequency by means of the fixed reference frequency which is recorded on the primary magnetic tape at the same time, to record it in binary code on the secondary output magnetic tape and to accumulate the reference frequency in a binary counter to give a coded measure of elapsed time, which can also be transferred to the secondary tape in place of the synchronising channel. Since it is unlikely that all the information recorded from the telemetry sender will be required in digital form a low speed photographic record of all the uncalibrated channels is available as well as the tape record, and this plot enables the contractor to obtain an overall picture of the flight in an easily understandable and compressed form and he can then say which parts of his record he requires to have accurately processed in digital form. It is possible to programme the converter to digitize and to record on the secondary record only relevant data and this reduces the length of the tape needed to read into the computer, and thus saves valuable time.

The doppler converter changes the signals from a doppler system into digital form in much the same way as the Telemetry converter does for the telemetry system. To make certain that good signals are fed into the equipment the original records pass through a narrow tracking filter to remove the unwanted noise on the doppler signal. The output from this converter is the time required for a pre-determined number of doppler cycles and this digital information is recorded on a secondary magnetic tape suitable for use on the computer.

When the Reduction Section has completed the work according to their instructions the magnetic tape and punched paper tape secondary records are passed to the Computer Section who have by this time received their computing instructions.

This Computing Section is responsible for the preparation of all the programmes for the WREDAC and for processing trials data through the computer. Some examples of these programmes are computations of trajectory and its derivatives, correction and calibration of Telemetry, the first-stage analysis of a complicated guided missile system etc. The input to the machine is either 5 hole punched paper tape or magnetic tape and the output is either paper tape or magnetic tape. Whatever the form of this output it is useless until it can be converted into an intelligible form. The paper tape of course can be passed through a page printer and the information on the tape can be tabulated but this is a slow process when a large quantity of data is to be displayed.

In order to enable information to be displayed at the same rates as it is reduced and computed it was necessary for us to specify a fast display unit to form part of the integrated data processing system.

The function of the unit is to provide graphical and/or printed displays from the tertiary magnetic tape record which is the output from the computer. When the "start" switch is pressed, the action of the converter thereafter is to read the number of words required from the magnetic tape records, transform them into an appropriate code and then store these records in serial registers via selection plugboards. These selected numbers are then supplied automatically to the display units, after which a new block of numbers is read in and the action is repeated.

A Bull line printer is used for the tabular display and operates at 2 lines of 92 characters per second or at a slower rate if desired.

There are four graphing units each of which is a modified Mufax picture receiver, and two points can be plotted on up to 16 graphs each second.

The last stage in the cycle is to have the displayed data examined by the Assessment Section, probably in conjunction with the Contractor's representative, to see if it meets the requirements of the specification, and if so, to arrange for publication and distribution without further delay.

## 3. THE EFFICIENCY OF THE SYSTEM

From the records which we have kept we know that we can rely on the semi-automatic readers being available for useful work for 80-90% of the time and the computer for 70-80%. The data converters have not yet been used continuously but we have had little trouble with them and they have always been available when called on to do work for us.

After that rather brief introduction to the system some general comments on such a data processing system seem to be appropriate at this stage.

The main objects of such a system are to produce data continuously so that no backlog of work is built up, in time for it to be used effectively, in a form suitable for immediate use or for further analysis, and at a reasonable cost in money and manpower. For if a system should require a large number of highly skilled operators and technicians and highly qualified engineers and scientific staff to operate and maintain the equipment in the system the whole system could fail because this class of person is not readily available or the cost of such an automatic installation is too high.

In order to produce completed data continuously each stage of the data processing system must be completed in approximately the same absolute time. This fact was taken into account in the design of our data converters, the input and output equipment for the Computer and the display equipment, and the results so far show that the original estimates of time are correct. For instance, Figure 2 shows what we thought would happen in the processing of 10,000 points from a telemetry record. Although this estimate and diagram are 2 years old, in actual fact 10,000 points were processed recently in 45 minutes without any panic or undue haste, and this could have been reduced to 40 minutes.

For film records we are not so well off. Film processing takes approximately 2 days, the initial assessment and preparation of check points takes $1\frac{1}{2}$ days, the reading on Boscar semi-automatic viewers takes another day, computing on the WREDAC including waiting time to put it on the machine is $1\frac{1}{2}$ days and publication about $\frac{1}{4}$ day. This adds up to approximately 7 days for a trial on the average. This I do not think is good enough and our next thoughts will be on how we can cut down the quantity of film and use more tape, e.g. multi-station doppler for positional information instead of kinetheodolites, how we can use the semi-automatic reader more efficiently, e.g. shift work and more skilled operators; how we can reduce the assessment time and let the WREDAC do more sorting and checking, and also to let it go to 3 full shifts to cut waiting time; and

finally, we must examine whether it is really worthwhile considering a fully automatic system.

One of the greatest problems in any automatic system is the use of non standard instrumentation and techniques and in some trials these non standard methods are more in number than the standard ones and are not suitable for automatic reduction. It must be appreciated therefore that the figures I quote are for a system which is amenable to automatic methods, and it must be appreciated by the sponsors who organise the trials that if they fall in with our scheme they will obtain information quickly, if they do not it will take very much longer. It is possible, sometimes, to make our system fit a non-standard technique by some slight modification to some of the equipment and we have done this, but we do not usually recommend it. However if we can process most of the data quickly, we have achieved much of what we set out to do.

Although there is still a need to improve the time for the processing of film recorded data, the statistics show that in 1955 and early 1956 before the WREDAC came into operation and when manpower was somewhat scarce, it took anything up to 40 days to provide basic data for a normal type of trial, and rarely was this reduced below 15 working days or 3 weeks. Towards the latter end of 1956 when the WREDAC did come into operation partially the average time was about 10 days. In 1957 so far the average time for major trials is about 6 days. We hope to reduce this to 4 days.

In 1955 film delivery was 2 to 3 days, distribution time, which included typing, checking and duplicating, was another 4 to 5 days, and cost was approximately £2 per standard data point where this standard was taken as the time to compute the cartesian co-ordinates of a point from 2 kine-theodolites.

In 1957 distribution of completed data has been cut to a few hours and the cost per standard data point is now reduced to a few shillings, and will be reduced still further to a fraction of a shilling when some of the film handling problems I mentioned earlier are overcome. The reasons for this improvement can be explained by our change in thinking on the whole problem. Four days for publication was not significant in 40 days, but it certainly is in 6 days, hence our outputs are now in a form immediately available for reproduction and these reproduction units are in our own building and controlled by the Group, hence it is only a matter of hours to have a number of copies ready for distribution. The saving in money is mainly due to the reduction in working days to produce the information and also in the reduction in the number of people required to obtain the solutions, and in the organisation of data handling in the Group.

The establishment for computing staff has not been increased since 1952 but the capacity to do trials data processing has increased by a factor of at least 10 and will increase even more when additional shifts are worked on the computer. In 1953 there were 14 professional officers and 60 computers in the Mathematical Services Group, today, May 1957 there are 15 professional officers and 50 computers for data processing and mathematical research problems and three engineers and 11 technical and industrial staff for maintenance. The increase is negligible. If, however, it had been necessary to do our work without a data processing system we would now require an additional 100 computers, some additional officers for supervision together with additional desk calculating machines and film reading equipment. This latter idea of course was untenable as this additional staff does not exist in the Australian labour market.

The fact that a digital computer is available for research problems has brought in additional work that we did not budget for in 1953 although we knew it would come when the power of such a tool as a computer was known, hence we do in fact need an increase in mathematical staff to cope with these problems, which are additional to the trials data processing work.

To sum up, therefore, we can say that most trials information can be made available to the customer within 6 to 10 days of a launching without any increase in staff but with an increase in trials work by a factor of at least 10, and the cost of producing this information has been reduced by a factor of approximately 20. We hope by the end of 1957 to make data available within 4 to 6 days and to reduce the cost still further by more streamlined methods. We hope to increase the programming staff so that additional and necessary research problems can be undertaken without interfering with the processing of trials work, and finally we know that when peak loads occur, we shall be able to clear the data without undue delays.

# DATA PROCESSING AT W. R. E.

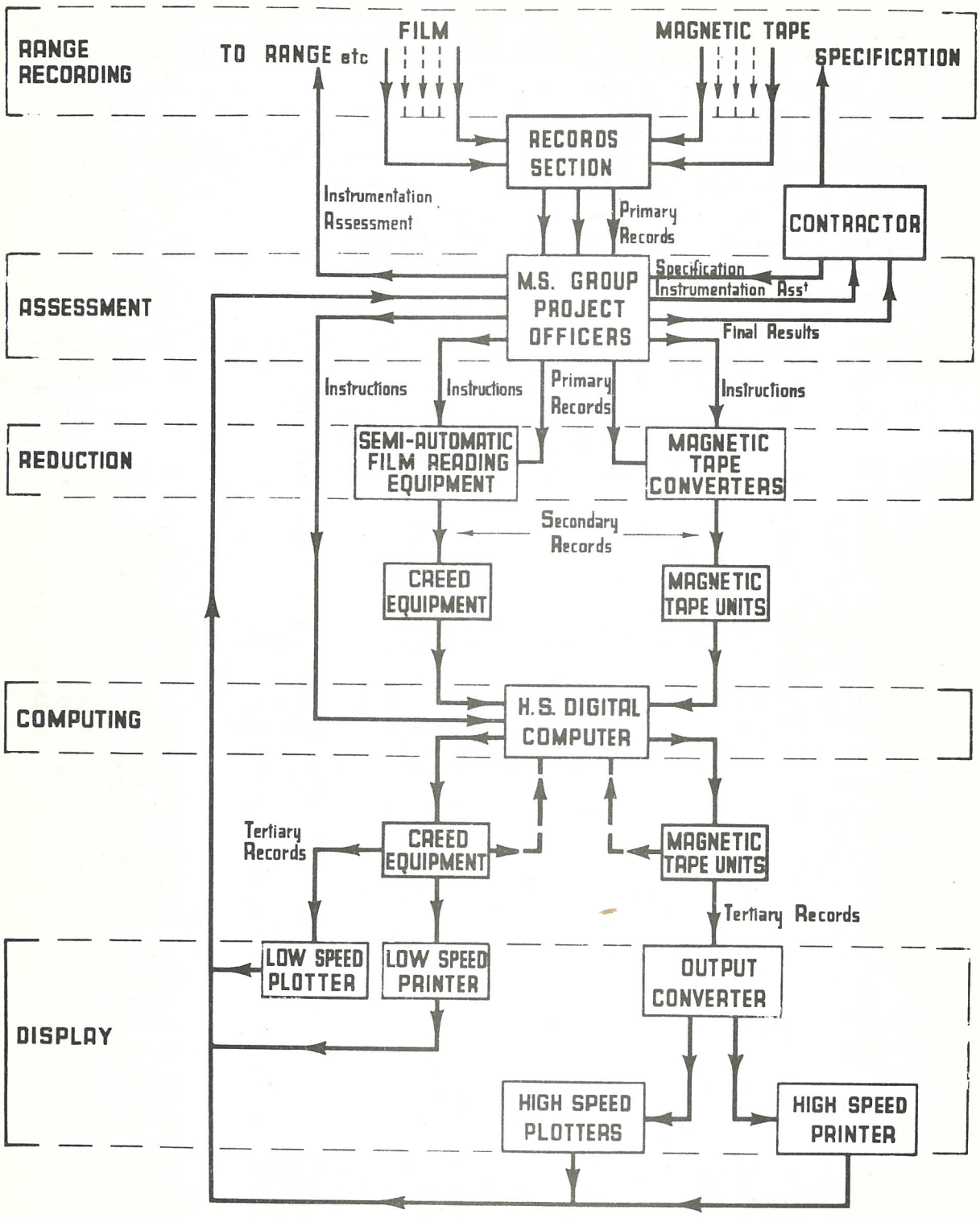


Figure 1.

# Figure 2. W.R.E DATA PROCESSING SYSTEM.

TELEMETRY

COMPARATIVE TIMES FOR THE PROCESSING OF 10,000 POINTS OF DATA.