The Concept of a Flight Data Recording System for Sailplanes

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1. Introduction – Problem Presentation

At the institute for flight mechanics of the Technical University of Munich, the problems of data recording in flight are being dealt with in the following way:

For reasons of cost and personnel limitations the flight tests should be effected with light aeroplanes and sailplanes. In these cases there is still a market gap compared with industry, which either mainly works on bigger projects or cannot afford them (for instance, the sailplane industry).

Through the flight tests both performance and handling (flight stability and control) should be examined. In the first place primary flight stability and control of sailplanes are going to be examined.

Hitherto the equipment shown in Fig. 1 has been used in the work of the Akafliegs and good results were achieved.

Manoeuvres are flown according to the agreed test programme. Means for recording the measured data comprise:

1. Knee-pad for note keeping
2. So-called "Phi-psi-theta" for the determination of bank angle ∅ and changes in Azimuth and pitch angles.
3. Tape measure for control stick position determination, and
4. Force measuring spring-balance.

Quick and good evaluations can be made with these alone, but if one wants to describe the whole system aircraft more exactly, more precise recording and a larger quantity of data are needed. For a computer based evaluation, control inputs as well as aircraft responses have to be determined as exactly as possible as functions of time.

Fig. 2 shows such a recording. The time behaviour of the following during a flight on a DO 28 is shown.

1. η (measured electrically)
2. α taken with a Dornier incidence vane in front of the fuselage
3. ρ speed of rotation of pitch
4. θ pitch attitude

Our first aim is to obtain such time behaviour for many (8 or 16) parameters almost automatically.

2. Requirements for Recording and Processing

In order to be able to specify recording and plotting equipment, we have compiled the main requirements within light aeroplane and sailplane limitations.

2.1 The Aircraft recording system

With regard to the recording we will not here consider in detail the sensors (transmitters, transducers) which form a specialist sphere. Thus we make the following provisions:

(1) Small and light for sailplanes
(2) Small power consumption because of lack of generation
(3) Flexibility of the inputs, i.e. different input sensibilities for an optimum sensor adaptation
(4) Selection of different scanning rates from 30–50 Hz for flight path data to approximately 1 kHz for structural examinations and others
(5) Duration of recording approximately 1–2 hours for flight path data on tape, as telemetry equipment requires too many personnel
(6) High resolution, 12 bit
12 bit 4096 grades, i.e. at H = 4096 m
1 m resolution in the ideal case (no background noise, optimum evaluation of the range).
Through the resolution of 12 bit one obtains also a high dynamic range
(7) Easy to install the whole equipment into other aircraft.

2.2 The calculating equipment

After the data have been recorded in the aircraft they should be ready for subsequent processing as soon and well-presented as possible. This demands the following:

(1) Sorting of the test data for further digital processing with input to the computer
(2) The language used for the processing is FORTRAN
(3) Graphical representation of the data (time behaviours) scaled
(4) Eventual smoothing of faulty data
(5) Easy handling of a complete programme (dialogue)

2.3 Selection of the system

As the input to the computer with Fortran routine was especially important, and the sub-routines were to have been supplied by the computer manufacturer, we decided on the PCM-system of a firm in Munich. Frequency

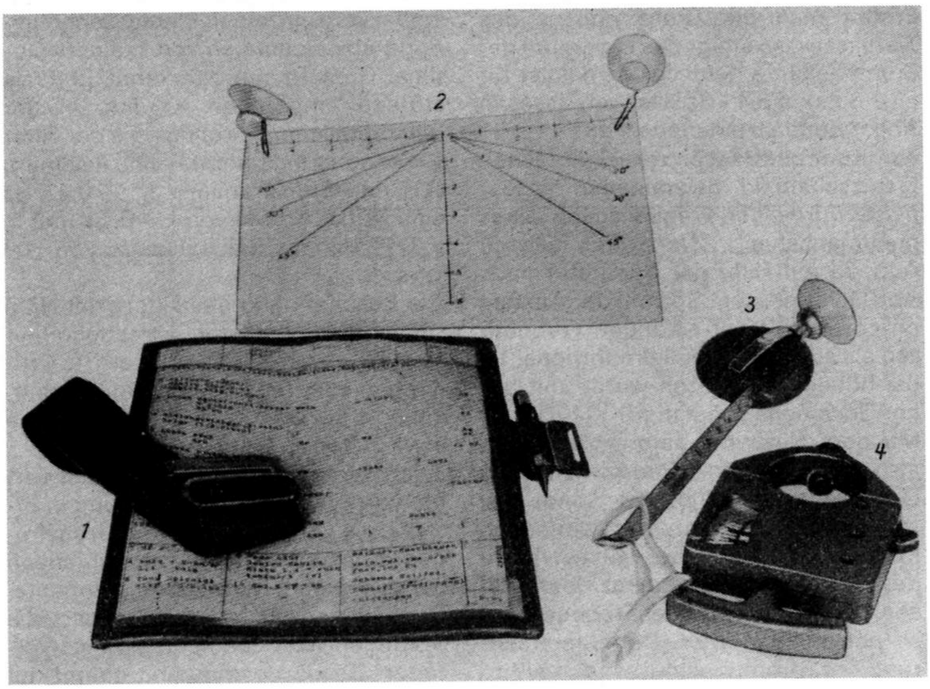

Fig. 1. Usual auxiliary means for the quick evaluation of sailplanes.

1. The Knee-pad
2. The "Phi-psi-theta"
3. The tape measure
4. The spring-balance

modulation was ruled out because of the costly and heavy tape machines.
Concerning the ground equipment, the data recording equipment consists of the computer, which was already available, the DMA-Interface and the so-called demodulator (Fig. 3), which prepares the data for the computer. In addition the signal is prepared as an analogue signal in the demodulator so that the data can also be represented on an oscillograph or a multichannel recorder without using the computer.
For the aircraft a PCM-modulator and a tape recorder were purchased (Fig. 4).

3. On-board Hardware

Fig. 5 shows the block diagram of the on-board recording equipment, which consists of the measuring sensors, central unit, accumulators, modulator, tape recorder and control unit.

3.1 PCM-modulator

Data:
2×8 channels of each 12 bit resolution
13th bit for marking
time code generator with day, hour, minute and second
5 selectable scanning rates of 92 to 740 Hz for all channels
5 input sensitivities of ±0.5 volt to ±10 volt adjustable according to the channel
diode display for operation, time code operation, tape speed and overmodulation
weight approximately 7 kg

3.2 Tape recorder

The tape recorder possesses 4 PCM-tracks and an additional sound track. In addition there is a facility for external power supply and sound control for the start/stop operation. It has 5 tape speeds and a weight of 5 kgs.

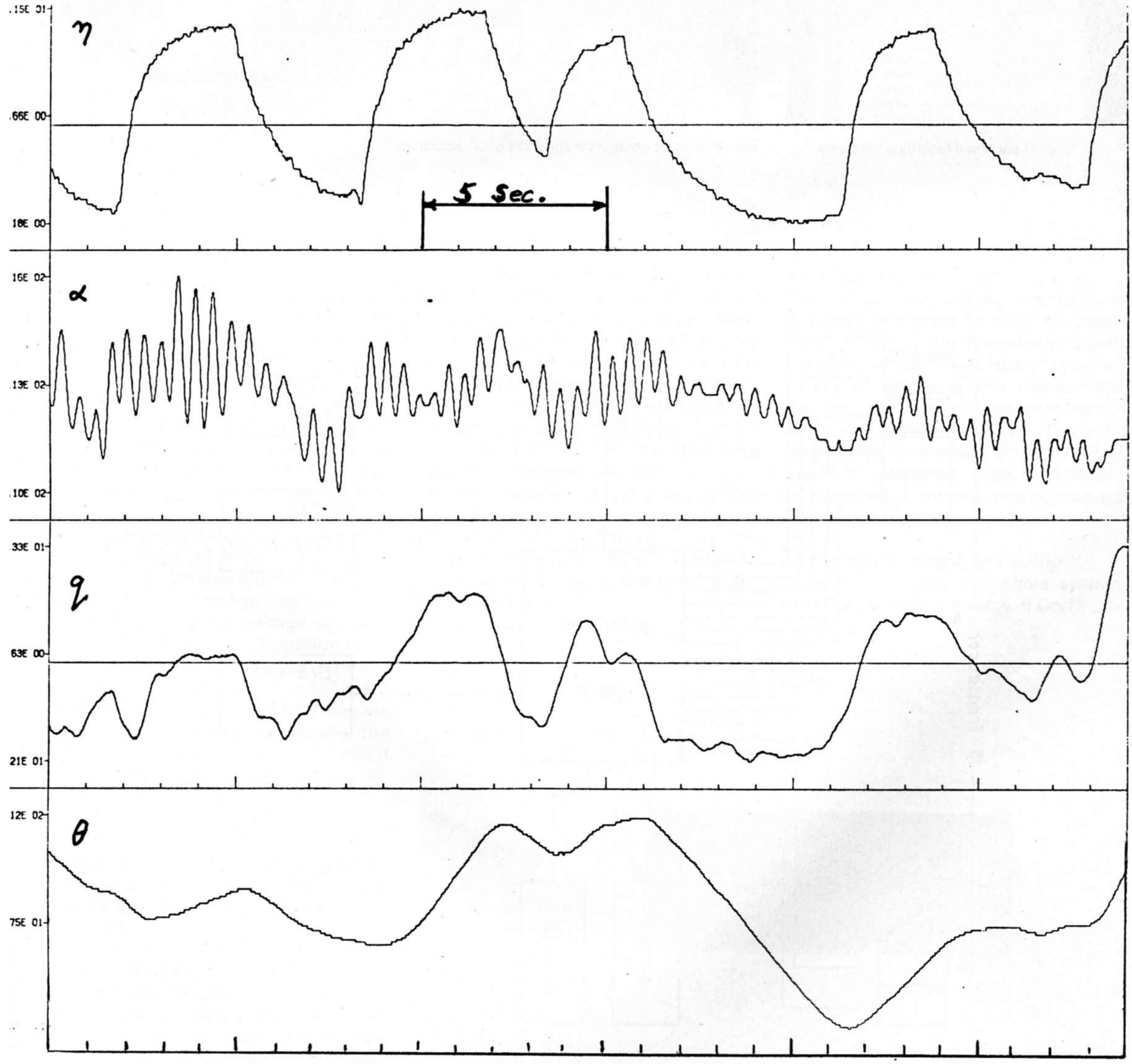

Fig. 2 Desired presentation of test data.

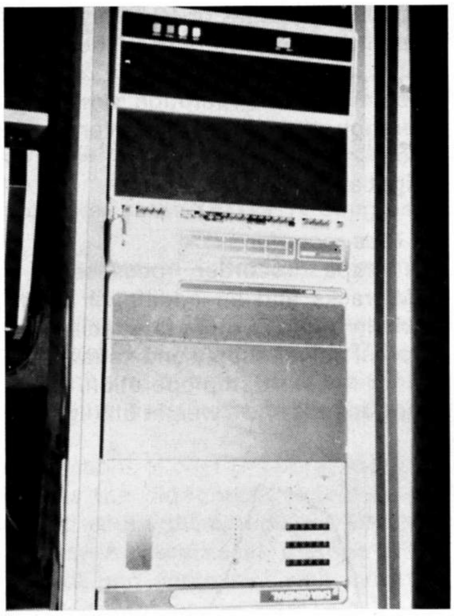

Fig. 3. Ground concerned recording hardware.

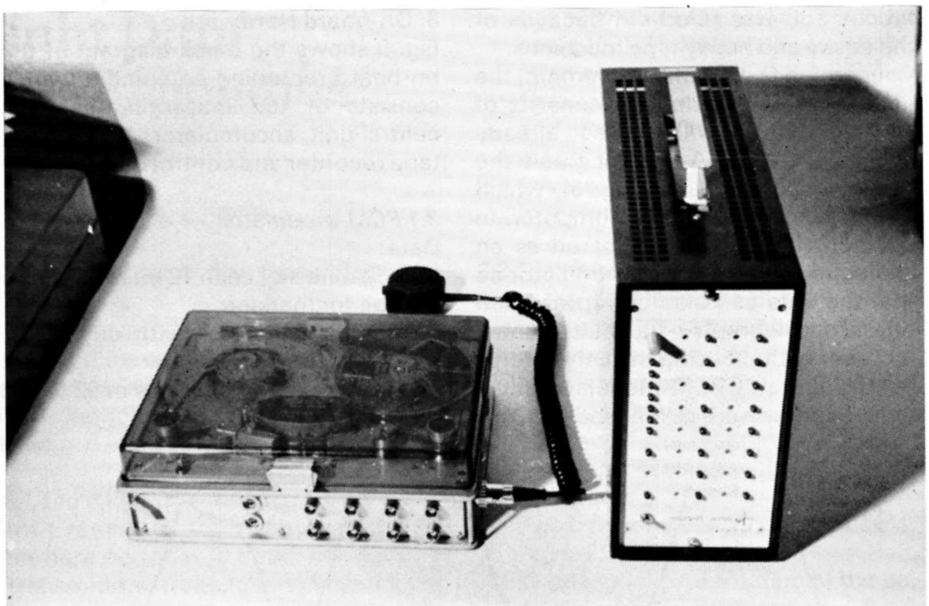

Fig. 4. Aircraft equipment for PCM-data-recording.

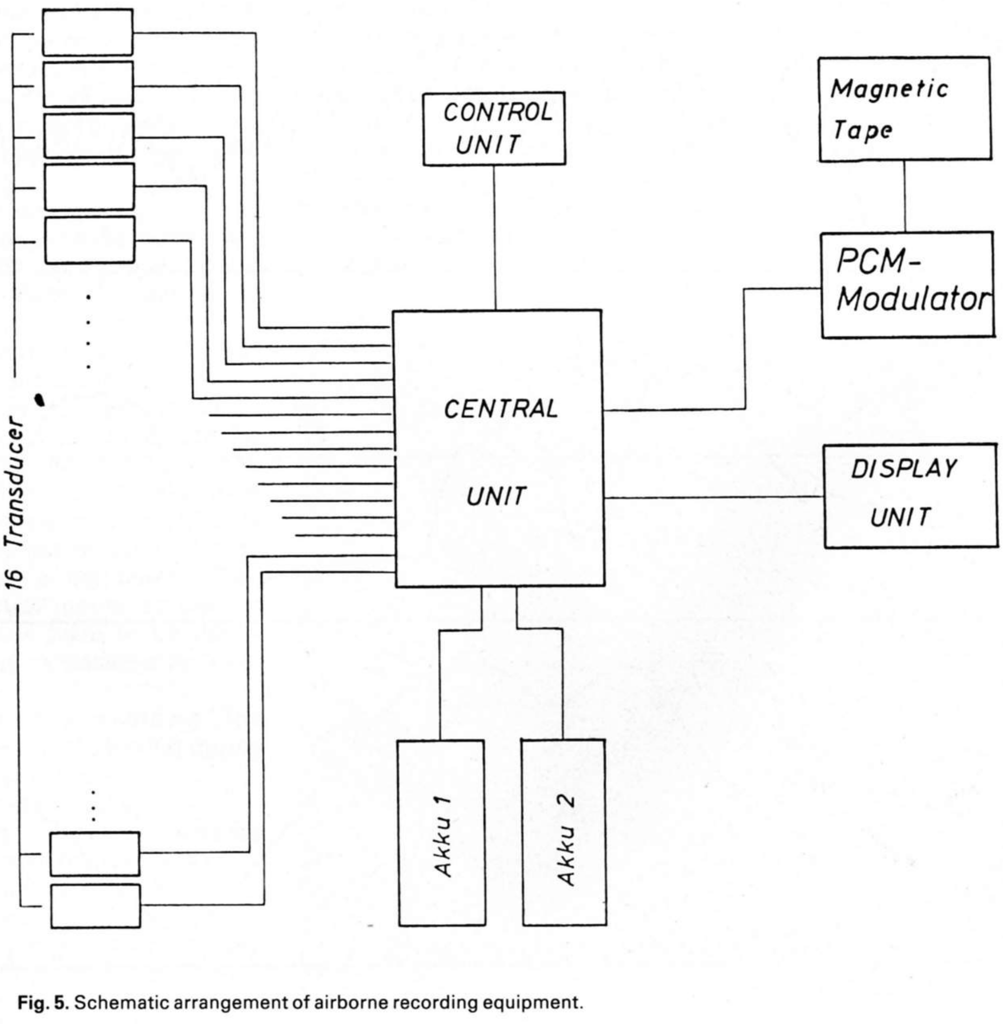

Fig. 5. Schematic arrangement of airborne recording equipment.

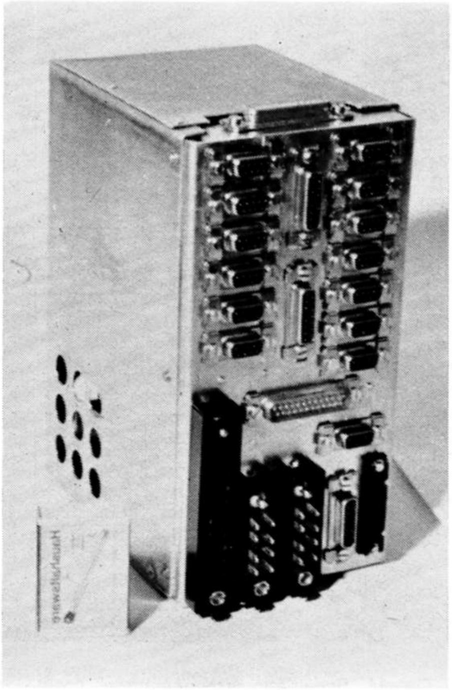

Fig. 6. Central unit.

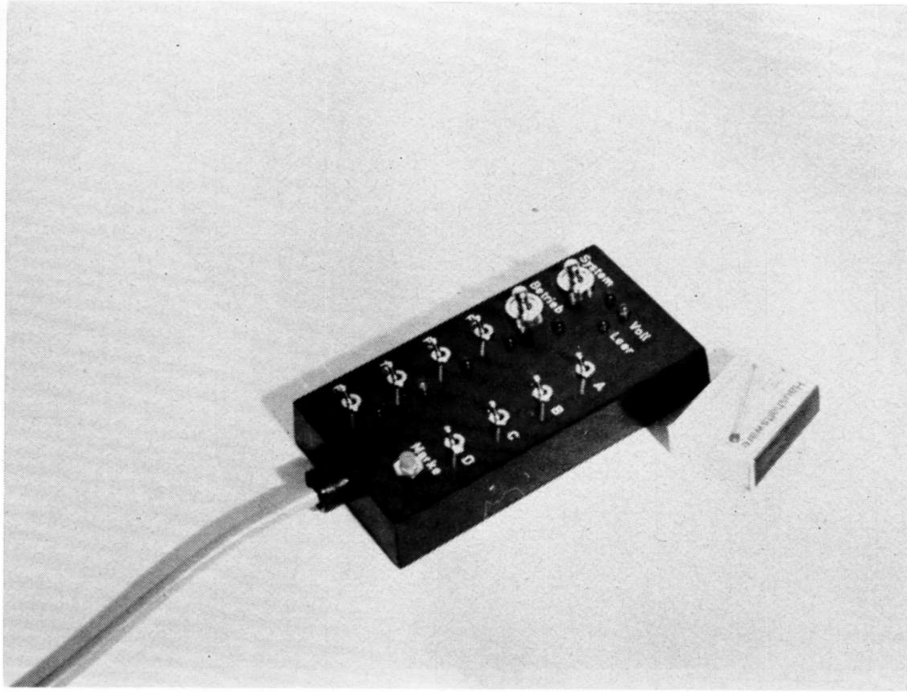

Fig. 7. Control unit.

3.3 The central unit
In order to assemble the separate devices into a complete system, one needs a central unit which connects all modules together.
Fig. 6 shows this central unit.
It has 16 inputs for the measuring sensors. For the signals of the measuring sensors there is the possibility of adapting the signal to the PCM-modulator by means of an integrating amplifier.
The measuring sensors are fed with supply voltage ±5 V or ±15 V by the central unit. For this purpose the central unit has voltage transformers which distribute the voltage supplied by the accumulators and stabilize it.
We can see from Fig. 5 that all connections run from the central unit. Thus it is possible to charge the batteries via the central plug without undoing the other connections. This is important if they have to be recharged without being taken out.

3.4 Control unit
The only parts of the complete equipment which are important for the pilot are the control unit and the display unit.

3.4.1 Control Unit
Fig. 7 shows the control unit. The pilot fastens it to his thigh. After switching on the main switch "system" one can see the state of charge of the display diodes. Now the voltages ±5 V and ±15 V exist and the supply voltage for the modulator is produced. The switch "operation" switches additional operating voltages on the sensor side, for instance, for gyroscopes. It is the main switch for eventual additional functions which can then be switched separately with switches F1 and F2 and A to E. Switch "TB" is the start/stop switch for the tape recorder.
With pushbutton "mark" it is possible to short-circuit the input of the integrating amplifier. Through this the supplementary voltages of the amplifier can be evaluated and marks set for the evaluations.

3.4.2 Display unit
Fig. 8 shows the display unit which is attached in the pilot's field of vision, for instance to the instrument panel. For both display lines there is the possibility of choosing the represented channel. The channel number is shown through a luminous display. The indicated value is received at the outlet of the PCM-modulator. Thus the indicated value is the same that is registered on the digital tape.

3.5 The power supply and wiring
In order to supply the whole system with the necessary energy, 6 Dryfit-ac-

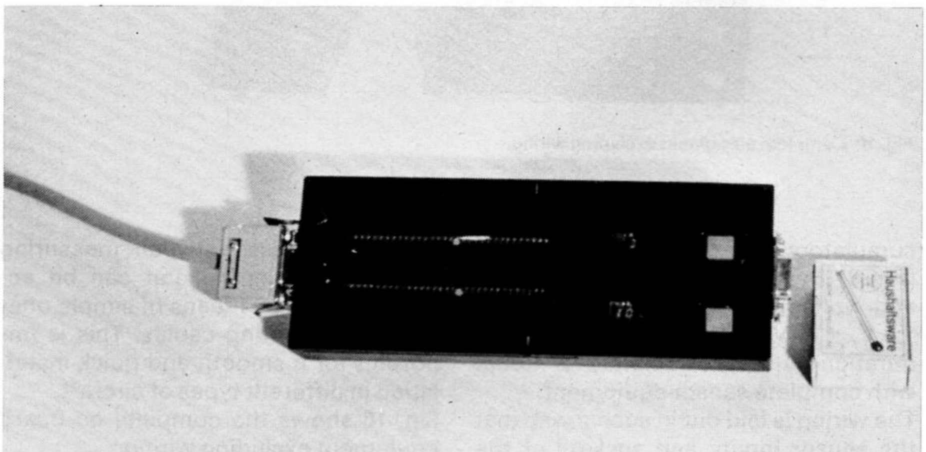

Fig. 8. Display unit.

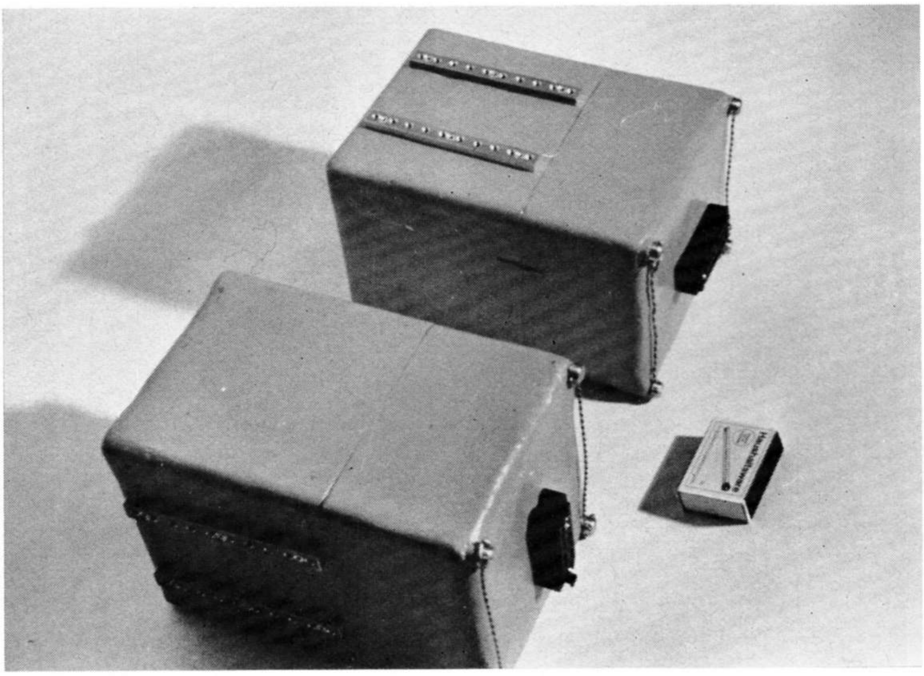

Fig. 9. Accumulators.

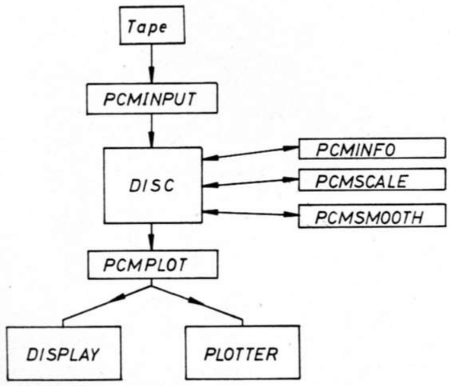

Fig. 11. Schematic arrangement of basic software.

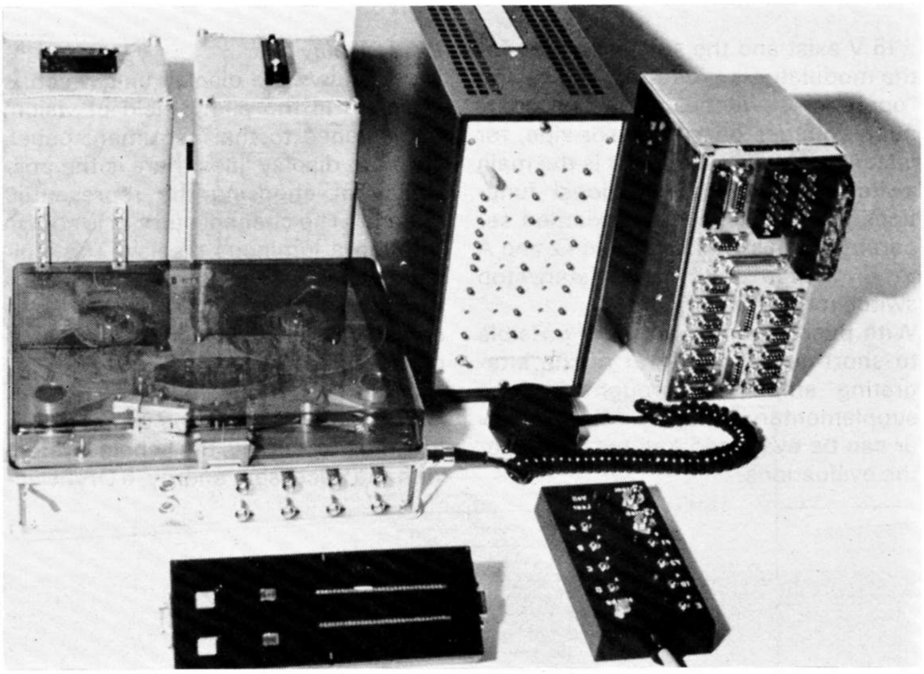

Fig. 10. Complete equipment excluding wiring.

cumulators 6 V 6.7 AH are available (Fig. 9). By means of different pick-ups and voltage regulators one obtains ±5 V, ±15 V and 36 V. The measuring duration is approxiamately 2 hours with complete sensor equipment.

The wiring is laid out in such a way that the sensor inputs and sockets of the central unit and the outlet of the measuring sensors are plugs of the same type and covering. By this means different distances between measuring sensors and central unit can be accommodated by means of simple one-to-one connecting cables. This is important for a smooth and quick installation in different types of aircraft.

Fig. 10 shows the complete on-board equipment excluding wiring.

4. Plotting with the Computer

The data should be processed in the simplest way possible in a digital computer. First of all a PCM-demodulator and a DMA-Interface are needed. With this hardware and corresponding software, supplied by the manufacturers as a complete system, a Fortran compatible data takeover is possible. Now only an easily handled software packet has to be provided for the data processing.

4.1 Take-over and organisation of data

For the data take-over the digital tape is connected by a simple coaxial cable to the demodulator. In the dialogue all necessary information, for example, test number and place, channel covering and scanning rate are annotated. As also the time of the test is recorded on the tape (no additional track) the taking-over can be effected after a certain time or after a certain mark which was set during the test (see control unit).

At the beginning of the data sentence is the information that was administered in the dialogue. This leads to a continuous identification possibility of the taken-over measurement. Afterwards the measuring channels follow in a suitable order.

The data are not changed in the processing, so remain always available,

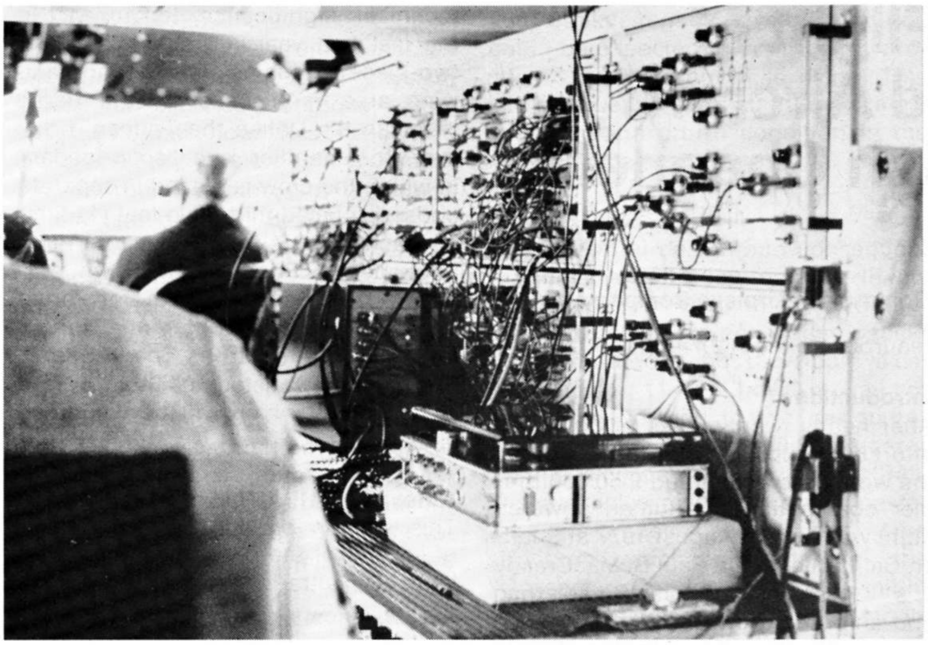

Fig. 12. PCM-equipment in a Do 28.

Fig. 13. Data recording system in an ASK 13.

which is important for the filtering, smoothing and scaling. In this way possible processing mistakes will not mean the loss of the measurement.

4.2 Representation of the data and software system

First it is important to represent the time behaviour of the original data. Fig. 2 shows a measurement of η, α, ρ and θ. The represented plot shows already scaled data, i.e. the disposable width for a measured value is taken advantage of by the curve. For this 80% of the plotting width is used for the range between the maximum and minimum measured value of the time range being shown. The result is a clear optical separation between the different parameters. Maxima and minima are noted on the left margin.

Fig. 11 shows a survey of the plotting software in the most simple stage of development.

4.3 Software programmes

For the further processing of the test data the following programmes have been developed so far.

Filter programmes for the elimination of sensor oscillations (see Fig. 2, channel 2)

Calculation and representation of the speed and drag polars

Two-value diagrams, for example, stick force F over the stick travel s

Aircraft motion

Determination of the derivatives.

5. Installation Examples and Future Prospects

The equipment has so far been installed in two aircraft. Fig. 12 shows the equipment in a Do 28. Fig. 13 shows the equipment in an ASK 13. In the latter case the luggage space is just large enough.

The first big project that is being undertaken with the equipment is the Mü 27 of the Akaflieg Munich. The entire flight testing for this aircraft with Fowler wings, two seats and a wingspan of 22 m is going to be recorded. When this has been completed it will be possible to make a comprehensive statement on the possibilities, limitations and costs of this equipment.