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Data Acquisition and Processing in a Large Aerodynamic Test Center

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Today, a data acquisition and processing system in a large aerodynamic test center must fulfil a number of functions, which are enumerated and analyzed here. These functions, along with the expected performance and the particular location of the test center under consideration, dictate the configurations of the best systems and the choice of hardware and software. As an example, the system utilized in the Modane and Le Fauga Centers of ONERA is described. It concerns two continuous and one intermittent wind tunnels at Modane and one low-speed pressurized wind tunnel at Le Fauga, about 600 km distant from Modane. The detailed description of the data acquisition and processing systems of these two centers is presented and discussed.

Introduction

FOR the past quarter century, aerodynamic testing facilities have greatly contributed to the advance of the aerospace sciences and techniques. During the same period of time these facilities, which are quite often concentrated in large specialized centers, have evolved as a function of both the test requirements and the new potentials offered by scientific and technical advances. Progress in physics, and particularly in electronics and computers, has greatly influenced the nature and the performance of the data acquisition and computation systems used in such centers.

In France, the Office National d'Etudes et de Recherches Aérospatiales, ONERA (National Institute for Aerospace Research) operates several wind tunnels in its two large Aerodynamic Test Centers (Modane and Le Fauga), where new data acquisition and processing equipment will be utilized shortly.The design and implementation of such a costly system has been the result of two simultaneous occurrences: on the one hand the Modane center, with its very large (8-m-diam) sonic S1 wind tunnel, operational for over twenty years, its supersonic continuous tunnel S2, its supersonic blowdown tunnel S3, its hypersonic tunnel S4, and its various other facilities, had to have its data acquisition and processing system renewed according to the new concepts; and on the other hand a new center was being built at Le Fauga, in the Toulouse region, some 600 km away from both Modane and Châtillon, the ONERA headquarters, with the construction of a large pressurized subsonic wind tunnel, called F1. It was felt that this situation offered a unique opportunity to devise a coherent system that should, with possible minor adjustments, serve efficiently for a number of years. The paper describes this new equipment and shows the successive steps followed for selecting such a new system, without entering into the detail of the various solutions retained for the wind tunnels themselves.

Definition and Requirements

The data acquisition and processing system in a wind tunnel consists of the whole set of instrumentation for measuring pertinent physical parameters, calculating the results of the tests, and presenting and storing these results for later use. The means for actually measuring the pertinent physical parameters is beyond the scope of this paper and will not be discussed here. Thus, the various operations to be performed are as follows: signal conditioning and amplification, signal filtering, analog-to-digital conversion, storage and computation of the digital values, and test control and monitoring.

Signal Conditioning and Amplification

A transducer provides an electric signal whose amplitude is dependent on the amplitude of the parameter to be measured. According to the nature of the transducer, this signal may take different forms: current variation, voltage variation, resistance variation, etc. Generally speaking, the level of this signal is low and needs to be amplified in order to be processed, but amplifiers act only on the voltage applied at their input. For this reason, it is necessary to turn the output signal of the transducers into a voltage variation if it is not already so. It is the signal conditioner which fulfils this function.

Signal Filtering

During the test, the useful signal representing the measurement is disturbed by the presence of noise signals which may have either an electric cause or, in some wind tunnels, an aerodynamic cause. In order to improve the accuracy of the measurements, filters are used to attenuate these noise signals.

Analog-to-Digital Conversion

The amplitude of the analog output signal of an amplifier or a filter represents the value of the measured parameter. For computational flexibility, this value must be expressed in digital form.

Storage and Computation of the Digital Values

The numerical values resulting from this conversion must be stored in order to be processed. This processing deals with more or less sophisticated equations that lead to the desired aerodynamic parameters.

Test Control and Monitoring

A test includes a number of stages which must be connected with one another. These connections, which may be more or less automated, are dependent upon previous results. These may be directly input by a control system, or indirectly by a human operator. This latter case entails decisions which require a thorough knowledge of the phenomena coming into

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play during the tests. In order to make a decision, the human operator needs to have the necessary results at his disposal, and these must be properly presented.

Historical Account: Past Evolution of Data Acquisition and Processing Systems

With a view toward satisfying the needs of the users, data acquisition and processing systems have been considerably improved during the last thirty years. Without going into detail, but considering the development as a whole, we can say that in about a quarter of a century the measuring instruments have changed from the liquid manometers to the electrical transducers with their associated electronics, and, as regards calculations, from the slide rule or the desk computing machine to the present-day powerful computer.This evolution results, on the one hand, from the evolution of the wind-tunnel testing techniques themselves, and on the other hand from the progress made in the field of instrumentation, electronics and computers.

The wind tunnels had to adapt themselves gradually to tests utilizing greater Mach numbers, and do it at a nonprohibitive cost; this goal has been reached through consideration of both initial investment and testing efficiency. The reduction of the initial investment was obtained by a reduction of the size of the test section and often by a drastic limitation of the duration of the run. The efficiency of the tests was improved by increasing the number of measuring channels, the rate of the data acquisition, the degree of automation applied to the test control and monitoring, the number and the rapidity of verifications to be done over the whole data acquisition instrumentation, the rapidity of the data processing, and the performance and number of units for presentation of the test results. It is easy to show that this improvement of test efficiency was made possible by the sustained progress made in the field of measuring instrumentation and data acquisition and processing.

The measurements to be performed in the wind tunnels deal with pressures, forces, and thermal phenomena. In terms of the number of the processed numerical values, pressure measurements dominate. The most important evolution was the replacement of the liquid manometers by electric transducers. Indeed, when the parameter to be measured is represented by an electric signal it can be very easily transmitted, measured, and stored.

At the beginning, when the pressure measurements were made by liquid manometers, the numerical value of the height of the liquid column was directly read on a graduated ruler by the experimeter, who accomplished the analog-to-digital conversion himself. As the wind-tunnel tests demanded the simultaneous measurement of numerous pressures, the liquid manometers have been juxtaposed in instruments called multimanometers. These consisted of a set of tubes set side by side behind transparent graduated rulers, so that the different heights of the liquid columns were easily read.The aerodynamicists had acquired a great experience with the multimanometers, and the general appearance of the different liquid columns heights was most often a distinctive sign of the proper development of the test. In order to reduce the duration of the tests, a photograph of the multimanometers was taken for every special test configuration. The photographs were then shown on a screen and the heights of each column recorded.

The development of wind tunnels with very short run durations, incompatible with the use of liquid manometers, contributed to both the improvement of the electric manometers and to the change of the habits of the aerodynamicists. Improvements in other aspects of instrumentation have been more gradual, and the various stages were marked by smaller discontinuities. We shall comment on these stages rapidly, proceeding from the transducer to the final presentation.

Signal conditioning is typically undertaken where the signal level is the lowest. That is why one must be very careful in the design and construction of the conditioning apparatus, so that any electrical noise which may be induced there is as low as possible. The transducers, which use strain gages as sensing devices, must first be provided with bridge voltage supplies and bridge balancing impedances. For a long time these elements were provided either separately or integrated within the channel amplifiers. Today, one can find a broad choice of commercially available signal conditioning devices which provide high-quality measurements and are easy to handle.

Signal amplification took general advantage of all of the technical progress made in the field of electronics. If we consider the use of amplifiers in wind-tunnel measurement channels we can note the general and continuous improvement in measurement capabilities (noise level, stability, common mode rejection, frequency pass-band, etc.) and the volume reduction of the amplifiers, thanks to the use of transistors and, to a smaller extent, to the important scale of integration.

The filtering problem to eliminate disturbing signals is not simple, and it seems that it has not been safisfactorily solved for a long time. The electric noise signals can generally be reduced to a reasonable level by analog electric filters incorporated within the amplifiers, but the same can't be said for disturbing signals of other origin. Indeed, the spectrum of this noise is generally situated in a frequency band lower than the lowest filtering limit of the amplifiers. In order to reduce the level of these disturbing signals to a value consistent with the desired accuracy, two solutions can be pursued: either the introduction of an analog, very low pass filter in each measuring channel or the application of filtering algorithms to the acquired digital data.

The analog solution, despite its drawbacks, had no alternative solution for many years, since we had not at our disposal the processing means necessary to implement the digital filtering. The two main drawbacks of the analog solution are high unit cost and difficult use in large facilities needing numerous measuring channels. The high cost stems, on the one hand, from the previously mentioned spectrum which implies the use of expensive components and, on the other hand, from the necessity of obtaining as nearly identical phase characteristics as possible on the different channels.

The difficulty of use arises from the large response time of the filters to transient signals. For example, to proceed with the calibration of a channel we must wait a long time before we can obtain the final value with sufficient accuracy. Today, the means necessary to proceed to numerical filtering in real time exist in the form of specialized processors, and it is possible to incorporate these in the data acquisition and processing system. For the analog-to-digital converters, the required qualities are accuracy, rapidity, and reliability.

The force measurements in the wind tunnels are generally obtained by means of balances using strain gages as sensing elements. For a long time, the output voltages of the strain-gage bridges were measured at ONERA by means of servopotentiometers in which the analog-to-digital conversion was made by a contact encoder directly mounted on the potentiometer shaft. The accuracy of these devices was satisfactory, but the mechanical components demanded important maintenance work, and such a converter could only be used for very low frequency phenomena. So the great progress made in the field of analog-to-digital conversion resulted from the availability of electronic converters with blocking samplers. Since their appearance, these converters have been gradually improved, and today they make a measurement in 50 ns and convert it within $2\mu s$ with an accuracy of about 10^{-4}. These achievements are very satisfactory, but reliability remains uncertain.

Generally speaking, the converters are associated with multiplexers which allow the conversion of signals from several measuring channels successively. The most appreciated qualities of the multiplexers, from the point of view of their use in wind tunnels, are reliability and switching rapidity, the latter allowing a large number of successive measurements to be taken on different channels and yet be considered as simultaneous. The stages of the progress in this field were 1) the use of unreliable and slow telephone relay switches; 2) the use of the Reed relay switches (nickel-iron contacts in a chamber filled with neutral gas) which permit 10^3 switching operations per second and are fairly reliable. They are still used today for the switching of low level signals (thermocouples); and 3) the use of MOS-FET switches with integrated circuits, which allow a rate of 10^5/s and are reliable.

The different stages reached during the evolution of the devices used to store and to process the digital data have been very closely linked to the evolution of the computers and their input capabilities. For a long time the data input was performed by means of a punched paper tape, and the acquisition systems had to produce such perforated tapes which included, as well as the data, the whole set of codes necessary for their processing by the computer. In their simplest configuration these data acquisition systems included transcoders, memory for storage, logic circuits, and a paper tape puncher as an output peripheral. The technology used at first was similar to that used in telephone equipment (relays, selectors, switch boards). As time went on, this technology has improved and the telephone-type equipment has been replaced by electronic circuits. This type of acquisition system, with only a paper tape puncher as an output unit, was very limited in speed and incompatible with use in wind tunnels, where it was necessary to read a great number of measures in a short time. For the wind tunnels in the ONERA centers, the tests were recorded on an analog magnetic tape which was processed off-line. The reading speed, even if much lower than the recording speed, led to a data delivery rate superior to that of the paper tape punch, and consequently demanded an intermediate storage on a digital magnetic recorder of start-stop type. Then the progress of standardization allowed use of the digital magnetic tape directly on a peripheral digital magnetic reader of the computer.

Finally, the advent of the minicomputer was fairly important to the progress of the acquisition systems since, in addition to the data acquisition itself, they made possible test management and control, direct transmission to the processing computer, and local presentation of partial results.

Example of a Data Acquisition and Processing System in a Large Aerodynamic Test Center

The choice of a data acquisition and processing system for use in a large aerodynamic test center results from a study including both technical and economic considerations. These considerations are dependent on both the test center and the time when this choice is being made. Since it is difficult to write about this selection problem without being specific, this section will deal with the systems chosen by the ONERA for its Modane and Le Fauga Centers. This presentation provides the opportunity for making some comparisons with the solutions selected by other organizations for other centers.

The ONERA solution concerns three wind tunnels of the Modane Center: 1) a continuous subsonic and transonic wind tunnel S1-MA (Mach 0.03 to Mach 1.02; test section diameter

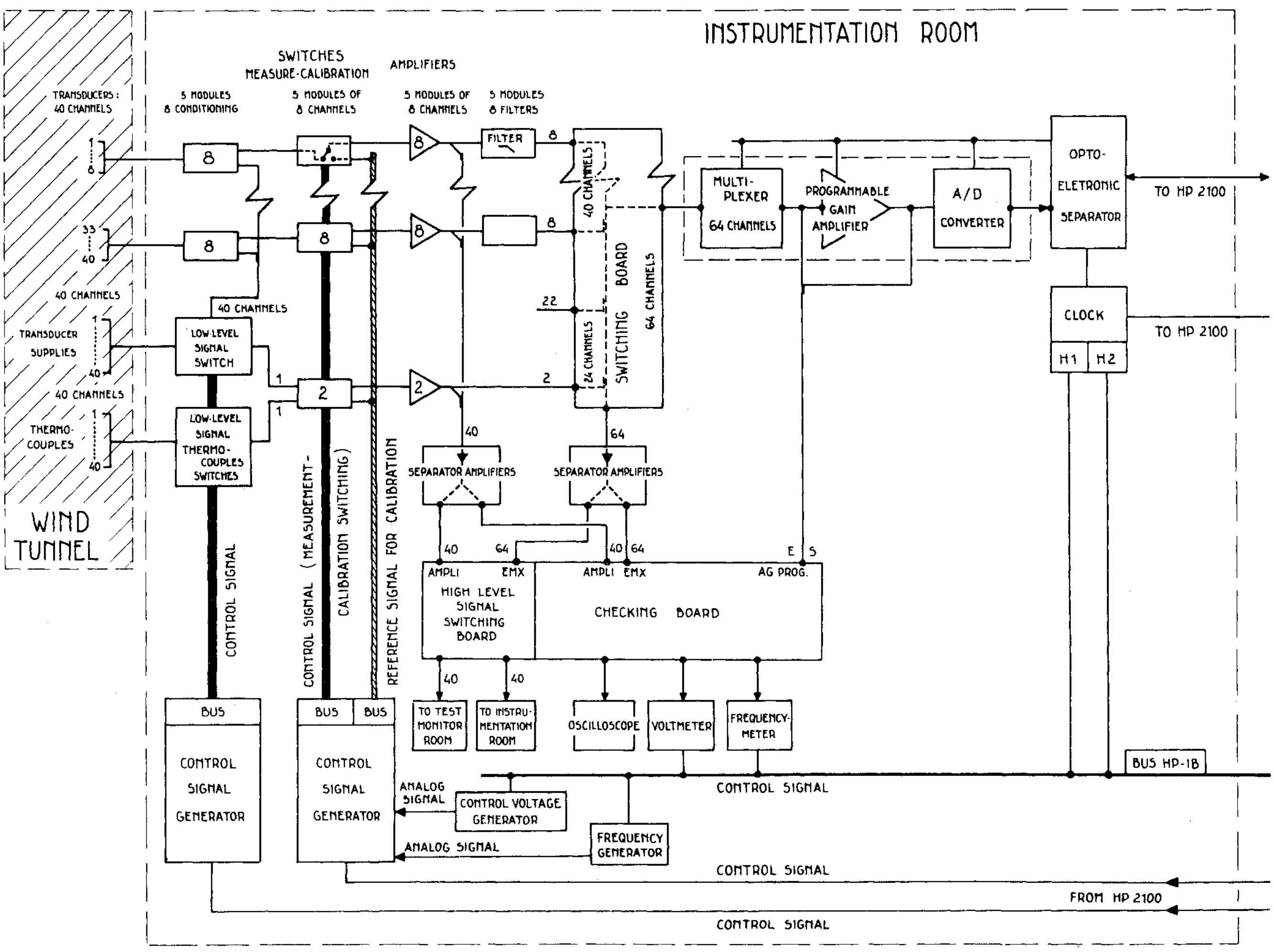

Fig. 1 Analog portion of the acquisition system.

8 m); 2) a continuous subsonic and supersonic wind tunnel, S2-MA (Mach 0.2 to Mach 2.8; test section 1.85×1.75 m); and 3) a blowdown wind tunnel, S3-MA, used as transonic and supersonic wind tunnel up to Mach 4.5 (test section 0.8×0.76 m), and a low-speed wind tunnel, pressurized at 4 bar (test section 4.5×3.5 m; velocity 10 to 70 m/s) of the Fauga Center. The data acquisition and processing equipment are about the same in the Modane and Le Fauga Centers.

Analog Equipment

The structure of the analog portion of the data acquisition channels is represented on Fig. 1. The different units that constitute these channels are made both of commercially available equipment and of equipment specially manufactured according to ONERA specifications.

The conditioning, amplification, and filtering functions need to be achieved in a similar way in many research centers. That is why it is possible to find excellent commercially available equipment, to fulfil these functions. On the other hand, the operations of interconnecting, of switching, and of control must be adapted to local conditions, and it is generally better to develop specific equipment in order to fulfil them. That is what was done for the wind tunnels of the Modane and Le Fauga Centers. As far as the analog part of the acquisition system is concerned, three different geographical localization systems must be considered for each wind tunnel: 1) the wind tunnel itself, where the transducers have to be located; 2) the instrumentation room where the measuring signal conditioning, amplification and filtering equipment are concentrated; the personnel in charge of instrumentation handling work in this room; and 3) the test monitoring and control room, in which the test crew works.

It was assumed that, during the preparation and the progress of a test, it is necessary to be able to monitor constantly a certain number of analog measuring signals, either in the instrumentation room or in the monitoring and control room. Two switching units, respectively called "high level distributor" and "checking unit," allow this monitoring to occur. In order to make sure that the monitoring does not disturb the signal quality, the necessary connections are made through decoupling amplifiers of unity gain. The amplification of a measuring channel signal is achieved with the help of two amplifiers, one with a gain adjustable from 1 to 2500, the other with a programmable gain.

There are as many adjustable gain amplifiers as measuring channels, but only one programmable gain amplifier for each wind tunnel. This amplifier, situated between the blocking sampler and the A/D converter, is successively connected to each measuring channel by the multiplexer. The gain of the amplifier belonging to each channel is adjusted before the test to a value depending on the level of the expected input signal. This level can vary within a broad range during the test. It is the programmable amplifier gain which provides a satisfying output signal at any phase of the test, because it uses a gain which was programmed according to the expected evolution of the input signal on each channel.

The amplifier of each channel includes a low-pass filter with adjustable cutoff frequency. The lowest value of this frequency is 10 Hz. For the transonic wind tunnel S1-MA where disturbing signals at lower frequencies exist, low-pass filters with a cutoff frequency of 0.1 Hz had to be utilized.

The number of channels for each wind tunnel was limited to 40 for the Modane Center. For Le Fauga Center, it was decided to provide 64 channels for use during the test run and 64 channels for use during the test preparation. These numbers are sufficient in most cases, but some tests in Modane may require a greater number of channels; so a 40-channel mobile unit, quite similar to those of each tunnel, has been made available. The A/D converter of this mobile unit can be easily connected to the acquisition minicomputer of the wind tunnel. Also, the possibility of connecting a second mobile unit, which will be specially adapted to the data acquisition of unsteady tests, has been provided for.

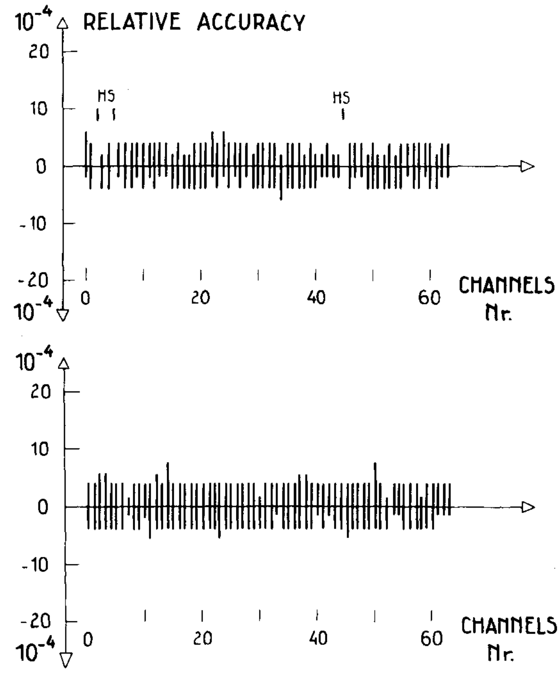

Fig. 2 Examples of accuracy of analog units.

The overall accuracy of the analog equipment results from the accuracy of the calibration and from the stability of the channel units. The calibration of a channel consists of introducing a calibrated input voltage and of converting the corresponding output voltage into a digital value. A voltage generator can produce a standard voltage with 10^{-5} accuracy and the A/D converter gives a 10^{-4} accuracy. The performance stability is more difficult to obtain because one observes drifts which depend on time, temperature, and temperature gradients.

In order to give an idea of the actual accuracy, the acquisition channels of the Fauga F1 wind tunnel were submitted to several 4-h tests taking place in the following conditions. The standard voltage "calibration" (see Fig. 1) was given by the standard voltage generator via an attenuator. The attenuation was adjusted in order to compensate exactly the amplifier gain so that the voltage obtained at the channel output might be equal to the voltage given by the standard voltage generator. During the 4-h test, eight measuring "cycles" have been achieved, each cycle consisting of the application of 20 voltage values equally distributed over the whole measuring range. Figure 2 shows the scattering of the measures for each 64-channel unit with amplifier gain equal to 1000 and passband 100 Hz. The measures' discrepancies from the theoretical values are within the $\pm\ 4\times10^{-4}$ interval for most of the channels.

Digital Equipment

General Considerations

The experimenter responsible for performing a test in the wind tunnel must be able to judge its progress and the validity of the results obtained. It is the digital part of the data acquisition and processing system which provides him with this information in an appropriate form. This equipment should be utilized in such a fashion so as to increase test efficiency by allowing as much data as possible to be obtained as swiftly as possible, and by minimizing the probability of unnecessary test repititions. In addition, it must be versatile enough to adapt itself to the different types of tests liable to take place in the facilities, and be reliable enough not to delay or stop the progress of the test programs.

Efficiency increase and suppression of unnecessary repetitions can be obtained if the results provided to the experimenter are presented in a format which is capable of

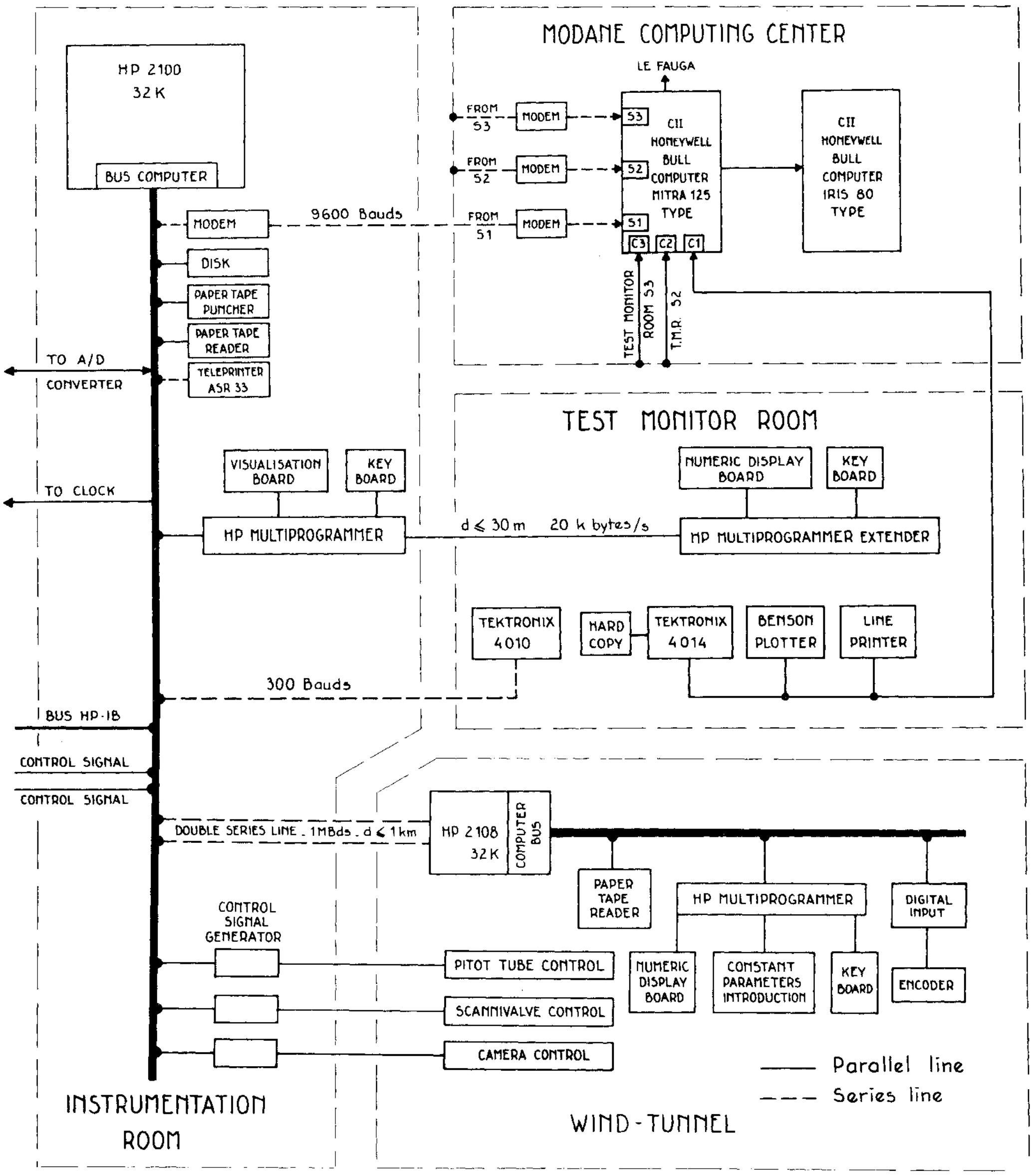

Fig. 3 Data acquisition and processing system at each wind tunnel.

quick and easy interpretation. To satisfy these requirements, computers have taken a part which has become more and more important during the two last decades. First used for processing of the test results in deferred time, they are now more and more used on-line in quasi-real-time. Although the prices of the computers, for the same power, have constantly decreased, their part in the overall investment in the wind tunnels has not stopped increasing. That is why it is essential that their choice in an aerodynamic test center should depend on a thorough analysis. However this choice may be made difficult by the existence of equipment of different ages in the same center. Indeed, a new piece of equipment added to old equipment may create connection and compatibility problems. Besides, there is a risk that the old equipment might not be simultaneously modernized for financial reasons. In this case, a general solution may be studied and its application may be scheduled over several years, but then the chances taken by the center are of two types: either the suppliers cannot follow their "line of products" and the implementation of the solution stops before the end or, during the implementation time, new equipment which performs much better is commercialized and one must give up either the original solution or the improvement at one's disposal. So, for an aerodynamic test center, it is desirable, whenever it is financially possible, to plan an overall solution which simultaneously involves all of the equipment, but not so long that it compromises in the long run the international competitiveness of the center. Today, a 5-6 year time frame seems to be a reasonable compromise.

This is the solution chosen by ONERA for its Modane and Le Fauga Centers. According to the information given by John W. Davis at the 48th STA meeting, it is also the solution chosen by NASA for its Ames Research Center. When such a solution is possible, there is the problem of the degree of centralization which should be adopted for the computers, one extreme being a unique central computer for the whole center; at the other extreme, no central computer but, at the level of each facility, a specific computer powerful enough to assume the whole of the tasks which are assigned to this facility. Both of these extremes have had their strong supporters, but today this quarrel between "centralizers" and "decentralizers" seems outdated and the present thinking seems to favor an intermediate solution which eliminates or attenuates the main reproaches made to both extreme solutions. Indeed, this quarrel could be justified when the computers worked off-line in batch processing or from a slow terminal unit. Today, the tasks requiring real-time processing are more and more numerous, and the restraints pertaining to some of these tasks are such that they justify the existence of a local computer or of a specialized processor. So, it appears that there are two levels of tasks to execute: 1) a primary level, before the data gathering; it is the real-time level in close connection with the test equipment; it is at this level that the A/D conversion, the control of the data acquisition and the data reduction occurs; and 2) a secondary level, after the data gathering; it is the execution level of the more sophisticated calculations, of the program storage, of the data and results banks; this can be centralized. Between these two levels it is necessary to have an intermediate level in order to insure their connection, to effect temporary storage, or to drive some input-output peripherals.

Some solutions with several levels were accepted in the following large aerodynamic test centers: Ames Research Center, NASA (USA), Aerodynamics Department, Royal Aircraft Establishment (England),[1] National Lucht-en Ruimtevaart Laboratorium - NRL (Netherlands),[2] Modane and Le Fauga Centers - ONERA (France). They all try to make the data acquisition at a high rate; to drive the data acquisition system and the test in progress by use of adequate software; to make some type of calculations possible in real time; to present to the experimenter results from the test in progress or from previous tests; and to make the test development possible in an interactive way.

As explained previously, ONERA decided to undertake the simultaneous modernization of the data acquisition and processing systems of the major facilities of the Modane Center and to do it about at the same time when the pressurized wind tunnel of the Fauga Center was put into operation. This simultaneous modernization allowed selection of identical solutions for both centers, with standardized hardware and software. This standardization is very favorable to cost reduction and improvement in efficiency.

Cost Reductions. For the hardware it is possible to group the purchases in order to obtain good price conditions, to decrease the importance of the spare equipment, and to obtain better conditions for the maintenance contracts. For the software, the whole compatibility of the software permits a unique conception and realization for all of the facilities, which decreases the extent of the whole investment.

Improvement in Efficiency. The fact that several units of the same type are put into operation at the same time justifies the organization of a thorough training program for the personnel. Before we examine the choices made at each of the previously defined computer levels, let us examine the nature of the installations of the digital portions of the data acquisition and processing system. There are four of them: the wind tunnel itself, the instrumentation room, the monitoring and control room, and the central computer room.

Data Acquisition Level

The computer chosen to drive the data acquisition system of each wind tunnel is an HP 2100. Taking into consideration the size of the tasks to execute at this level, each computer has been provided with the largest main memory capacity (32 k-words) and with a disk of 5 M-bytes. This computer is located in the instrumentation room, but there are some peripherals or some systems in the wind tunnel as well as in the monitoring and control room, which exchange data or logical orders with it. There can be problems with these exchanges either because of their timing or because of the distances involved. However these problems have been solved by commercially available equipment for the Modane and Fauga Centers.

The diagram of Fig. 3 shows the general structure of the data acquisition and processing system at the level of each wind tunnel. One sees on this diagram that the links between the data acquisition computer and the wind tunnel concern: the various digital encoders (angular positions, etc.), the numerical values introduced by operators through keyboards, the video displays of some digital values coming from the computer, and the logical orders related to devices such as scanivalves, cameras, etc.

The great distance which sometimes exists between the data acquisition computer and the wind tunnel, and the high rates of the exchanges of information have led to the introduction of a second HP 2100 computer in the wind tunnel. Without any peripheral such as paper tape reader, it drives the link between some of the elements located in the wind tunnel and the acquisition computer. The existence of this second HP 2100 provides extra reliability and permits data acquisition in deteriorated conditions when the network of other computers is totally out of order.

The links inside the instrumentation room raise no particular problem. These links concern the numerical information coming from the measuring channels and the logical orders necessary to insure the management of the data acquisition and the control or calibration of the measuring channels. The links between the data acquisition computer and the monitoring and control room concern the introduction of numerical values specific to the test and the display of results acquired on an alphanumeric terminal (4010 Tektronix). Finally, the link between the acquisition computer and the central computer room concerns exchanges of data and programs.

Processing Level

The different ONERA centers, spread over the French territory, are located relatively far from one another. The main building is at Châtillon, in the Paris area, whose Computing Center was equipped in 1973 with a CII-Honeywell-Bull computer of IRIS 80 type. This computer, which should be operational until 1982, changed in 1976 from a monoprocessor configuration to a dual processor configuration. The operation of this computer proved to be satisfactory and its characteristics are well adapted to test data handling. For this reason we decided to equip each of the Modane and Le Fauga Centers with a computer of this type. In order to satisfy the needs of these centers, simpler configurations than the Châtillon one have been chosen. However, one had to take the following elements into account: at the Modane Center, three wind tunnels are liable to operate simultaneously; at the Fauga Center, it is possible to have a test running in the pressurized test sections and at the same time a test in preparation outside the test section. In addition, it was planned that the computer of this center should operate in batch processing via a 9600-baud line for the benefit of the Châtillon computer.

The Intermediate Level

The intermediate computer has to fulfil the following functions: driving of the link, temporary data storage, driving of the monitoring and control room peripherals, and dispatching of data to the correct computer according to previously defined criteria.

Network

In these conditions, with computers of the same type existing at Modane and Le Fauga, it is possible to realize a network (see Fig. 4) which considerably improves the overall reliability of the system. The unavailability or failure of one of the two connected processing computers does not imply cessation of the processing in the corresponding center, since this can be accomplished via a 9600-baud line on the computer of the other center.

The Software

It has been shown in Ref. 3 that the cost of the programs increases exponentially with the percentage of the computer storage capacity. Consequently, this cost can be reduced considerably if a powerful computer is used. It was also shown[3] that the percentage of software cost in the total investment increased monotonically between 1955 and 1975. Today this percentage is about 75%, which points out the obvious advantage of using the same software for as much of the equipment as possible. This can be done at ONERA, as hardware of the same type has been installed simultaneously in both centers.

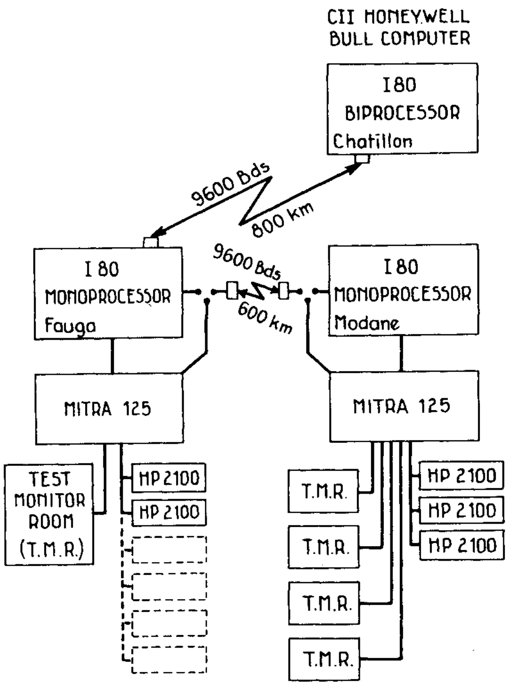

Fig. 4 Network formed by the three centers

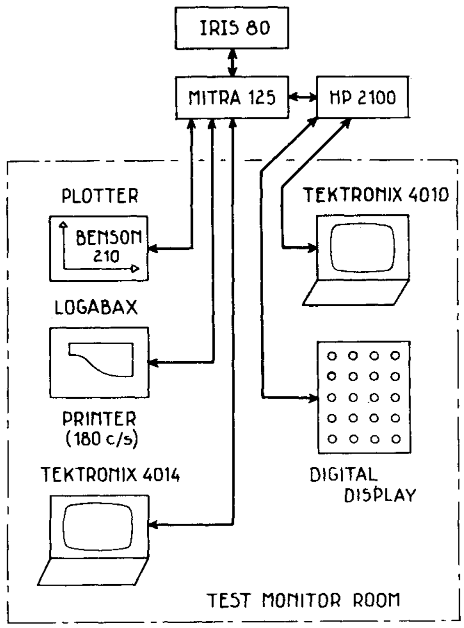

Fig. 5 Peripheral at the user's disposal.

At the level of the processing computer, the software must fulfil three functions: 1) to handle the acquired data, 2) to make calculations on these data, and 3) to display and edit some of the data and the results of the tests. Fulfilling these functions utilizes three levels of software: 1) the level corresponding to the system developed, and provided by the manufacturer of the computer (zero level); 2) the level which defines and executes the tasks related to the kind of tests and calculations (level 2); and 3) a level which insures the connection between the two (level 1). Only levels 1 and 2 had to be developed; level 2 was developed at ONERA, and level 1 by the computer manufacturer. Level 2 was the subject of a precise definition from the experimenters. At present it is still being written and will be gradually put into operation during the first semester of 1978. It should reduce the duration of the whole test preparation, be an efficient test tool, especially as it permits self-adaptive control, and insure continuity in the responsibility of the experimenter, obviating the systematic dependence upon a expert programmer. Figure 5 shows the peripherals at the experimenter's disposal during the tests.

Conclusion

A large aerodynamic test center can play an important part in the development of aeronautical programs. If a failure of the data acquisition and processing instrumentation jeopardizes the development of the most critical tests related to a large national or international program, the cost due to this delay can be considerable, much larger, in fact, than the cost of the instrumentation involved. The choice of efficient and reliable facilities is thus of great importance, and recent progress in electronics, instrumentation, processors, and computers makes it possible to define and purchase adequate hardware.

The choice of analog equipment does not raise any special difficulty and, with certain exceptions, the measurement accuracy does not seem to be limited by the performance of this equipment, but rather by transducer performance and by the control and calibration operations. The choice of digital equipment and of software is more difficult because of the consequences it implies. Indeed, for a large center it is necessary to have a general and consistent policy, and the application of this policy constrains the devices brought into use in the center for a period of time of 4 to 8 years.

We expressed the idea that the best possible policy consists in a simultaneous modernization of all of the equipment of the center. In this case, it is possible to find a satisfactory technical solution. In the present state-of-the-art, the solution accepted by most of the existing centers consists in bringing into operation a hierarchical network of processors and computers working on two or three different levels. This solution permits data acquisition and processing in real time or quasi-real-time thanks to a very powerful processing computer and several processors or computer systems specialized in data acquisition and in operational control.

The evolution brought about by the next step in technology seems to point toward more and more specialized processors, monitored by a minicomputer connected to a powerful computer, which would also allow all of the calculations in quasi-real-time, and display the results on adequate peripherals. Since the cost of such computers is likely to diminish considerably in the next years, it is reasonable to think that one will be allocated to every wind tunnel; thus, isolated facilities would enjoy the same advantages as today's large aerodynamic centers.

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