A DATABASE SYSTEM CONCEPT TO SUPPORT FLIGHT TEST - MEASUREMENT SYSTEM DESIGN AND OPERATION

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ABSTRACT

Information management is of essential importance during design and operation of flight test measurement systems to be used for aircraft airworthiness certification. The reliability of the data generated by the realtime- and post-processing processes is heavily dependent on the reliability of all provided information about the used flight test measurement system. Databases are well fitted to the task of information management. They need however additional application software to store, manage and retrieve the measurement system configuration data in a specified way to support all persons and aircraft- and ground based systems that are involved in the design and operation of flight test measurement systems. At the Dutch National Aerospace Laboratory (NLR) a "Measurementsystem Configuration DataBase" (MCDB) is being developed under contract with the Netherlands Agency for Aerospace Programs (NIVR) and in cooperation with Fokker to provide the required information management. This paper addresses the functional and operational requirements to the MCDB, its data-contents and computer configuration and a description of its intended way of operation.

KEY WORDS

Database system, measurement system operation, data reduction support

INTRODUCTION

Flight tests with prototype civil aircraft are carried out mainly for airworthiness certification purposes. In order to perform these tests the aircraft is equipped with a measurement or instrumentation system to measure the required (raw) data, to process part of the data in realtime and to record all data for postflight processing and analysis. The nature of the airworthiness certification process demands the flight test results to

be reliable and traceable. As these results are obtained by processing the measured data on the basis of information pertaining to the flight test measurement system used, this formation should also be reliable and traceable. Fokker and NLR have developed an integrated "Measuring, Recording and Processing System" (Dutch: acronyrn MRVS) to support the activities occurring in the certification process. The MRVS covers the complete range of hardware- and software systems and procedures used in Fokker flight test programs. Medio 1990 a decision was taken to develope an upgrade of the MRVS, called MRVS90. The upgrade appeared to be mandatory because ageing of the current hardware systems used in MRVS and the ever increasing numbers of parameters (up to 10,000) to be measured and processed caused problems to guarantee reliability, traceability and acceptable turn around times of the flighttest results. Part of the upgrade of MRVS comprises a new database system supporting the flight test measurement system design and operation: the Measurementsystem Configuration DataBase (MCDB). This paper presents the environment in which the MCDB is to be used, the functional and operational requirements to the system and the data-contents and computer configuration of it. As a conclusion the intended way of operating the MCDB within the design and operation of flight test measurement systems is presented. The paper actually describes the results of a "definition study" which was carried out as the first stage of the MCDB development.

THE DESIGN AND OPERATION OF A FLIGHT TEST MEASUREMENT SYSTEM AT FOKKER/NLR

To provide a better insight in the required functions and characteristics of MCDB a global description of the design and operation of a flight test measurement system at Fokker/NLR will be given in this section.

In figure 1 the global steps carried out during the process of flight testing are presented. Generally the process is initialized by a flight test order which leads to the following activities:

1. Composing a list of parameters to be measured and/or processed, and specify the required ranges, accuracy levels, frequency etc. The list may contain 50 - 10,000 parameters, dependent on the specific flight test at hand.
2. Designing a measurement system configuration to measure the specified parameter.
   The designer use the parameter list from step 1 as a specification of the measurement system to be designed. Furthermore they need information on the available instruments. This information is provided by the instrument- and calibration management database. During the design

process a description of the future measurement system is created and has to be properly stored and managed. Several measurement systems can be in the design phase at the same time. The design process is considered not to be time-critical.

3. Building and testing the designed measurement system configuration and implementing it into the aircraft (w.i. "making it operational").
4. Maintenance: During ground periods of the aircraft between the actual flight tests the measurement system has to be maintained: e.g. replacing instruments, cables etc.
5. Operating the measurement system:
   During this phase of the flight testing process the measurement system is actually being used for flight testing. This involves the following activities:
   a. System set-up: Initializing the measurement system, related aircraft- and ground based realtime and quick-look systems for a specific measurement task.
      This is a very time-critical activity: in the Netherlands the weather needed for a specific flight test may change rapidly and last minute changes in the measurement system configuration have to processed into the set-up data before take-off, otherwise the system would not be properly initialized.
   b. Inflight operation: Inflight acquisition, multiplexing, decommutating, processing, recording and telemetering data.
   c. Inflight control: Monitoring and controlling the measurement system.
      Errors or changes to the set up of the measurement system configuration that occur during the flight test are controlled and logged in a journal.
6. postflight processing and analysis of the measured data.

Activity 1 and 6 can be seen as input and output of the process of designing and operating a flight test measurement system. The main activities during the design and operation are described by 2-5. The design and test occur only once in the lifetime of a measurement system. Maintenance and operational activities however have a repetitive nature and can be carried out for several prototype aircraft at the same time at different places, even abroad. These activities require the support of an appropriate database system to manage the information used in the mentioned processes and to provide a reliable means of communication for it. This environment and required support leads to the functional and operational requirements to MCDB as described in the next section.

FUNCTIONAL AND OPERATIONAL REQUIREMENTS

The functional and operational requirements follow from the main purpose of MCDB and from the activities it should support. In this section both the main purpose and related support are considered.

The main purpose of MCDB is to provide a reliable repository for (the most up-to-date) flight test measurement system configuration data. Furthermore it should provide all persons and systems involved in the design and operation of flight test measurement systems with the tools to determine, store, manage and retrieve the configuration data in the format they need for proper functioning, with proper timing. This imposes some general functional requirements on MCDB:

- MCDB should always contain and provide reliable and consistent configuration data
- The data-contents of MCDB should always to users (in time).

From the described purpose it can also be derived which activities, as considered in the previous section, should be supported by MCDB. In figure 2 the activity scheme of figure 1 is redrawn showing the position of MCDB in it. It can be seen that MCDB supports all involved activities, except the parameterlist composition. Regarding the general purpose and the characteristics per activity the functionally required formation and the operational requirements to MCDB can de derived. They will be given per activity:

1. Support the design of the measurement system configuration.
MCDB should contain and provide the following measurement system design information:

- the parameter list specifications for the design.
- instrument data to be used in the design to meet the specification.
- the configuration lay-out of a measurement system design from sensor to recording device.
- the description of the data-streams to be used in or produced by the measurement system.
- the coupling between designed measurement channels and parameters to be measured.

The operational requirements are:

- the database should support the parallel design of several measurement systems.
- measurement system design data should not interfere with data on operational measurement systems.
- the lay-out of the measurement system design should be presented in a user-friendly format.

2. Support the building, testing and implementation of the measurement system.
Functionally the MCDB should contain and provide configuration information on:

- the actual implementation data of the designed measurement system, e.g. the actual instruments used, the basic settings of the measurement system and calibrations functions.
- the status of the measurement system (e.g. "design", "test", "operational").

An operational requirement to MCDB for this activity is that is should present the lay-out of the measurement system design in a user-friendly format.

3. Support the maintenance of the operational measurement system.
When an operational measurement system is not actually being used for flight testing it is still possible that the configuration data might change. For instance due to maintenance of the measurement system instruments might be replaced causing calibration functions for parameters to be changed. Furthermore it might be necessary to adjust the gain or offset of a measurement channel of the system. When these changes occur between two flight tests these activities are time-critical. For the pulse of reliable and consistent configuration data, these changes should be stored into MCDB too. These characteristics do not lead to new functional or operational requirements.

4. Support the operation of the measurement system.
In figure 2 it can be seen that support is needed in several sub-activities. Figure 3 presents it more in detail. Actually there is no active inflight support required but only pre-flight and post-flight support (MCDB is a ground-based system). MCDB is functionally required to provide the following configuration data:

- the initialization of aircraft- and ground-based systems. This comprises the set-up data for the commutation- and decommutation equipment, realtime data-processing and presentation, and inflight telemetry of measurement results. For the aircraft-based systems this data is transferred to the Instrumentation Control System (ICS) which actually loads the set-up to the measurement system and other aircraft-based systems.
- guarantee of data-consistency in the several dataflows occurring shortly before a flight test; Associated aircraft- and ground based systems may need to contain exactly the same information. For instance the onboard telemetering system has to be provided with the same telemetry stream format data as the ground based telemetry station, otherwise it would not be possible for the ground station to decommutate the datastream received via the telemetry link.
- guarantee of data-integrity: because of the time pressure operators of MCDB may easily make mistakes while entering data into MCDB in an interactive

way. MCDB should provide online constraint-checking to protect the operator from entering wrong data.
- the tool to store the changes to the measurement system as logged (by the ICS) inflight, to be able to reproduce the measurement system configuration at any time during the flight test.

The operational environment for flight testing at Fokker/NLR is a very dynamic one and the flight tests are under a constant time-pressure. So all mentioned activities are time-critical. Therefore some harsh operational requirements are imposed on MCDB. It should be possible to:
- store the last-minute (pre-flight) configuration changes to the measurement system in MCDB up to 10 minutes before the flight test is scheduled. This means that the retrieval from MCDB of the complete set of set-up data for the aircraft-based systems, which is a large amount of data, should take less than 10 minutes. (It should also be easy to change the stored implementation data).
- to support the operation of several measurement systems at different places at the same time.
- to protect all data stored in MCDB related to a particular flight test from being changed after MCDB has provided the ICS with its data-set, until the flight log is fed back.

5. Support of postflight processing and analysis.
Shortly after the flight test MCDB should have processed all inflight-changes to the measurement system configuration data because this data is to be transferred to the postflight processing system. MCDB does not directly support the postflight processing and analysis. This is done by another database called 'Historical Configuration DataBase' (HCDB). In this database configuration data on all historically used measurement system configurations is stored to support postflight data-processing and to guarantee traceability and reproducability of flight test results for over 10 years.

These functional and operational requirements have resulted in a development of MCDB according to the concept described in the next section.

THE DATA-CONTENTS AND COMPUTER CONFIGURATION OF MCDB

The concept of MCDB to meet the functional and operational requirements described in the previous section will be considered in this section. The MCDB-concept consists of two parts: the relevant data to be contained by MCDB and its computer configuration.

MCDB contains measurement system configuration data from the design - to the operational phase of a measurement system. This includes:

- administrational information (e.g. the name of the project and aircraft in which the measurement system is used).
- parameter information (parameter names, engineering units, ranges, resolution etc.).
- description of the measurement system; in database terms: description of logical connections between the devices used in a measurement system and the logical coupling of parameters to measurement channels. (figure 4).
- format and description of the data-streams occurring in the measurement system (PCM-, ARINC-, multiplexed ARINC- and serial streams).
- calibration information on all measurement channels to transform measured data into engineering units.
- set-up data for the instruments (gains, offset, PCM-stream definition)
- set-up data for the realtime processing and display systems (parameter selections for several output devices, calibration- and processing algorithms, PCM-stream definitions etc).
- status data on all contained information ('design', 'test', 'operational').
- constraints on measurement system configuration data (e.g. possible functional position of an instrument in the description of the measurement system, maximum amount of parameters to be coupled to a specific device).

The hardware configuration of MCDB can be described as follows: A database on a central computer is used to support the design- and testing activities: MCDB-central. A database on a local workstation situated near the prototype aircraft is used to support the implementation and operational activities per measurement system: MCDB-local. The configuration is presented in figure 5. The two computers are coupled by an online data-link to guarantee the required communication between the two databases.
The design activities are supported by MCDB-central because of the fact that in the design phase of a measurement system much communication is needed between MCDB and the instrument- and parameter management databases. A 'central' Fokker-NLR computer network will provide a reliable means for the mentioned communication. Anaother reason for MCDB-central is the fact that the design of measurement systems is a 'central activity' as opposed to the actual operation.

The actual operation is a local activity taking place in the neighbourhood of the aircraft which could be tested almost anywhere. Therefore these activities where chosen to be supported by a local database. So several MCDB-locals belonging to different prototypes can be independently active at the same time at different places. All local databases will contain configuration data of one measurement system only.

This has the advantage that the measurement system configuration data to be used to support the flight test operation can be stored near the aircraft they belong to and can be locally managed and retrieved. The purpose of this database configuration is to guarantee the different MCDB-locals to have the required quick and predictable response to for instance the time critical request for the setup data for the aircraft- and ground based systems shortly before a flight test.

The online data-link will be used to download the configuration data of a designed and tested measurement system from MCDB-central to the concerning MCDB-local. It will also be used for reasons of backup: the measurement system configuration data stored at the MCDB-local will be sent to MCDB-central at a certain update rate, for instance after every flight test. This backup copy can be used when the configuration data of MCDB-local have been lost for instance due to a disk crash of the local workstation. The backup copy can also be used to update the Historical Configuration DataBase that is also resident on a central computer. An online data-link might not be available, for instance when MCDB-local has to be operated abroad or due to a defect. In this case the MCDB-local can be operated stand-alone for it provides all locally required configuration data and database functions.

OPERATING MCDB

In this section the intended way of operating MCDB during the design and operation of a fligh test measurement system is considered. Again the different activities as described in the previous sections will be used as a guideline (figure 6).

During the design of a measurement system configuration MCDB-central is providing the tools to create, manage and store several measurement system layout designs. It therefore contains the parameterlist specifications which were extracted via an automatic mechanism from the parameter management database. It provides the tools to define and present a logical measurement system: the way in which measurement channels in logical devices (sensor, signal conditioner, data-acquisition unit, realtime data-processing unit and recorder) are connected to form the measurement chain for a specific parameter (figure 4). Furthermore the designers will define the datastreams to be commutated and decommutated by resp. the data-acquisition units and the realtime data-processing unit. When the design is ready and checked thouroughly the designers will change the status of the measurement system configuration data from 'design' to 'test' and will replace the logical devices used in it by representative-codes for the physical instruments that are to be used in the building, testing and implementation phase of the measurement system. All relevant information about the instruments, such as actual possible gains, offsets and calibrations is automatically extracted from the instrument- and calibration management database. MCDB-central now contains

the configuration data of the actual measurement system and can therefore support the integration and test of the physical measurement system in the laboratory. The purpose of the tests is to check whether the measurement systems can perform its operational tasks and whether MCDB contains the correct data to support it. Therefore MCDB-central provides the same functionality during these tests as MCDB-local does in the operational phase of the measurement system.

Before the implementation activities are started the configuration data of the concerning measurement system data are copied from MCDB-central to the concerning MCDB-local situated near the prototype aircraft. At MCDB-central the original is kept to be the basis of the future backup copy, but it is protected from other changes than initiated by the backup mechanism. When the measurement system is implemented and found to be properly functioning the status of the measurement system can be changed to 'operational'. At this stage the operational phase is started.

During this phase MCDB-local has to support the actual operation of the measurement system. It only contains data on the measurement system configuration which is related to that specific prototype aircraft to guarantee independence of comparable activities with other measurement systems. Again: because of this independence and because of the relatively small dataset contained by MCDB-local the performance of it in supporting time-critical activities is guaranteed.
Shortly before a flight test the data-extractions for the systems involved in the concerning test are made from one source: MCDB-local. The latter to guarantee data-consistency in the occurring measurement system configuration-data flows to the aircraft- and ground based systems. As MCDB-local is providing these systems with all (setup) data for the scheduled flight test(s) it can stay on the ground and be 'locked' during the actual flight test to protect it from 'unauthorized' changes. After the flight test the logged changes to the measurement system configuration will be fed back to the MCDB by the Instrumentation Control System. When MCDB-local eventually has updated its contents to the most actual status of the measurement system, all configuration data (changes) are transferred to MCDB-central and thereby to HCDB. The transfer of data from MCDB-local to -central will be done by the online data-link when it is available. In the case of operations abroad without data-link, the updates can either be stored locally (only for a short period) or be sent to MCDB-central on for instance a 1/4" tape.

CONCLUSION

A database system can be used to provide the required information management during the design and operation of a flight test measurement system to be used for aircraft airworthiness certification.

At Fokker/NLR the Measurementsystem Configuration DataBase (MCDB) is being developed for this purpose. Additional application software and computer infrastructure to support MCDB-functions are considered in the development on the basis of functional and operational requirements. These requirements to MCDB follow from the nature of airworthiness certification night tests. MCDB should be a reliable repository for configuration data on a flight test measurement system, such as parameter information, measurement system description, processing-algorithms and consistency-constraints. It should always provide consistent configuration data in the required format at the proper time. To meet the requirements a database on a central computer will support the design activities and data-transfer to the Historical Configuration DataBase (HCDB) while the operational activities will be supported by a database on a local workstation (one workstation per measurement system) which is connected to the central computer by an online data-link for backup purposes.

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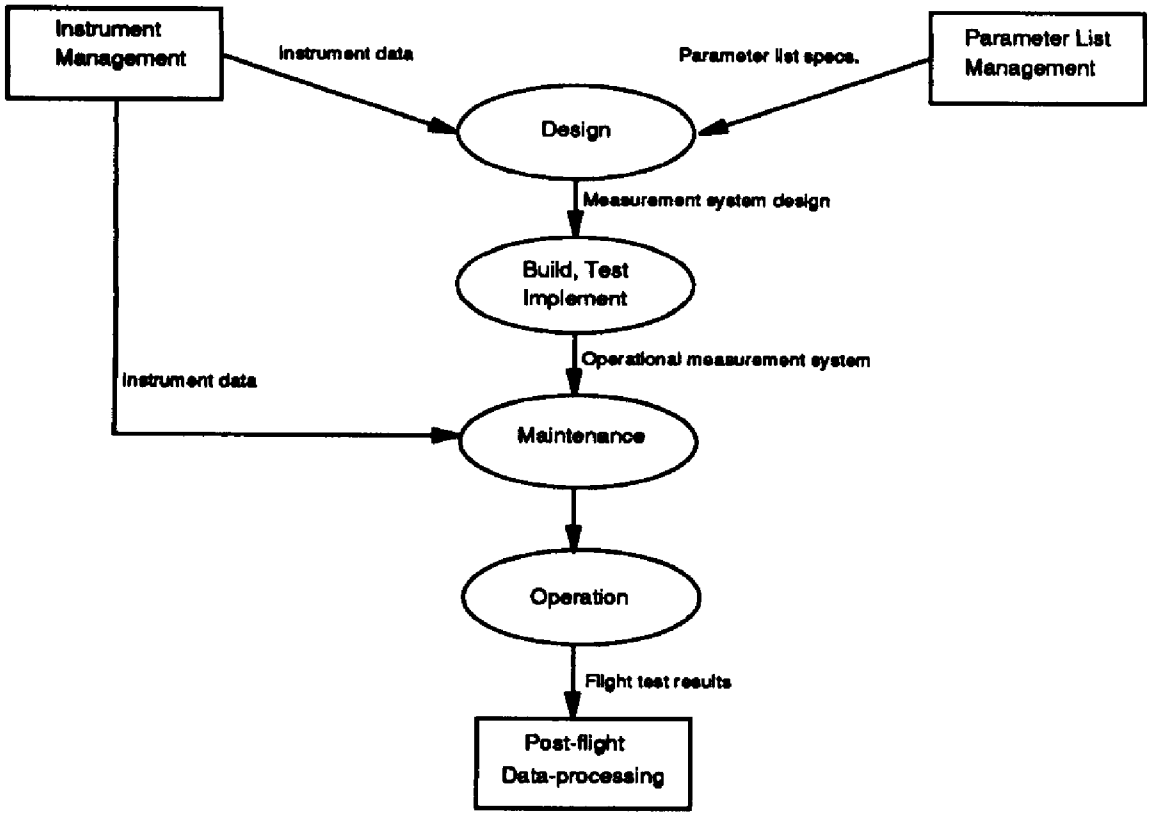

Figure 1: Activities during design and operation of a flight test measurement system at Fokker/NLR.

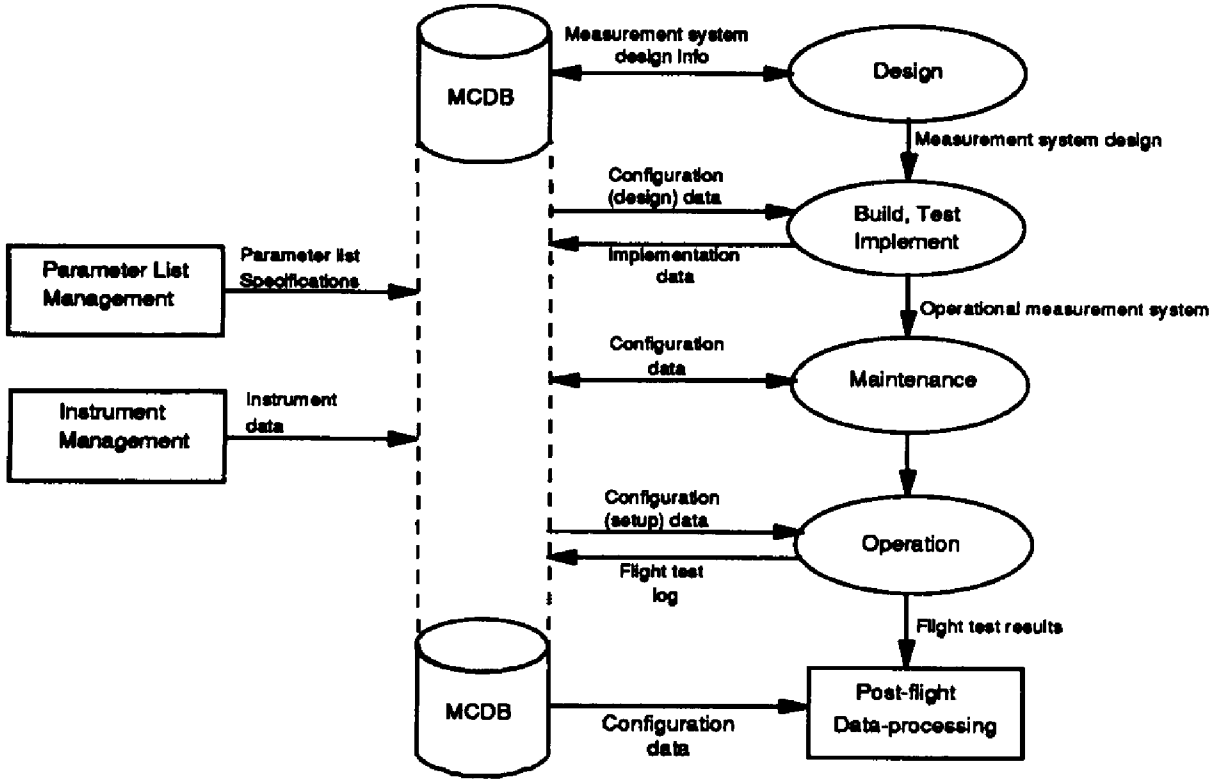

Figure 2: Required MCDB-support to design and operational activities of a flight test measurement system at Fokker/NLR

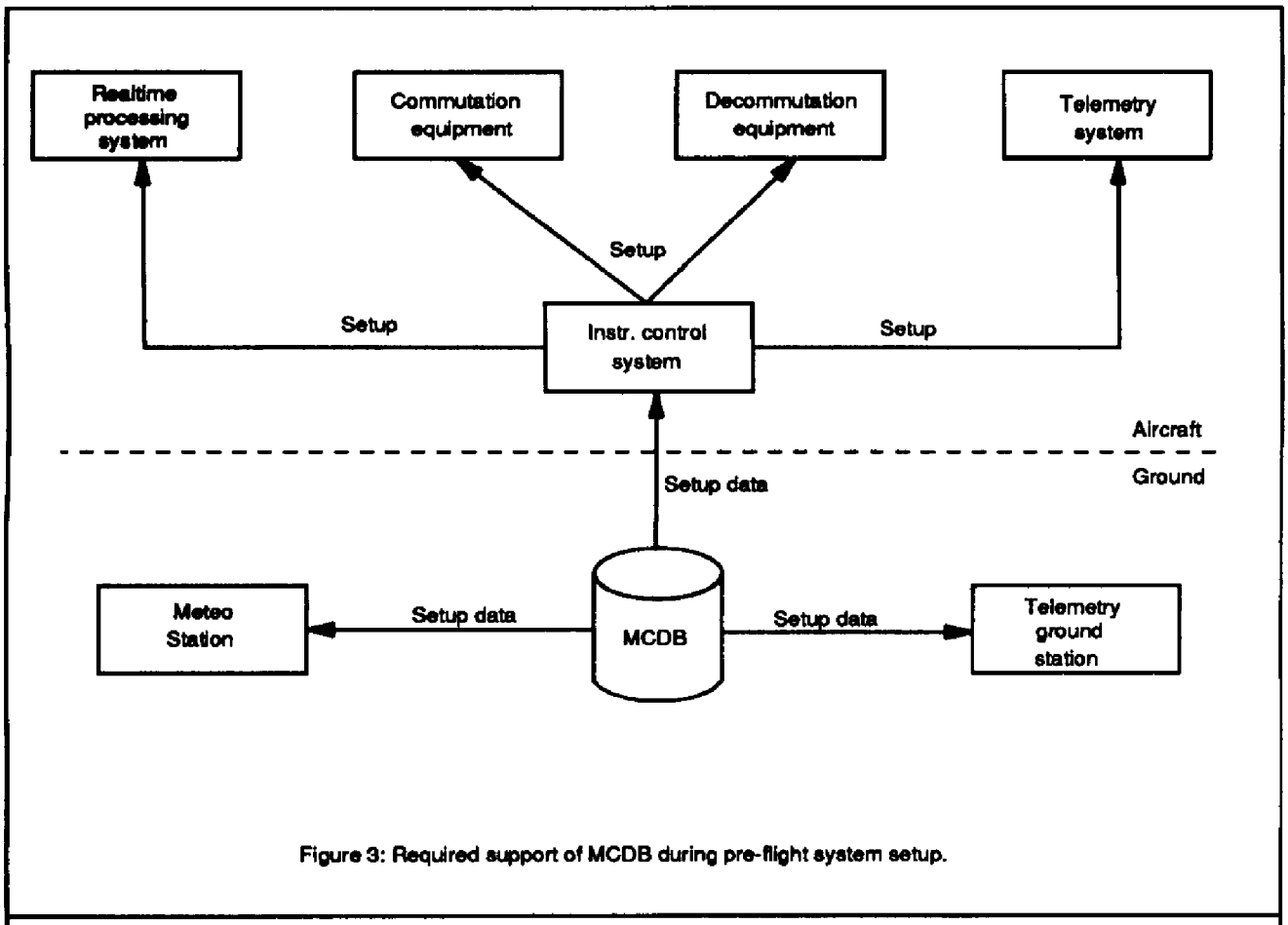

Figure 3: Required support of MCDB during pre-flight system setup.

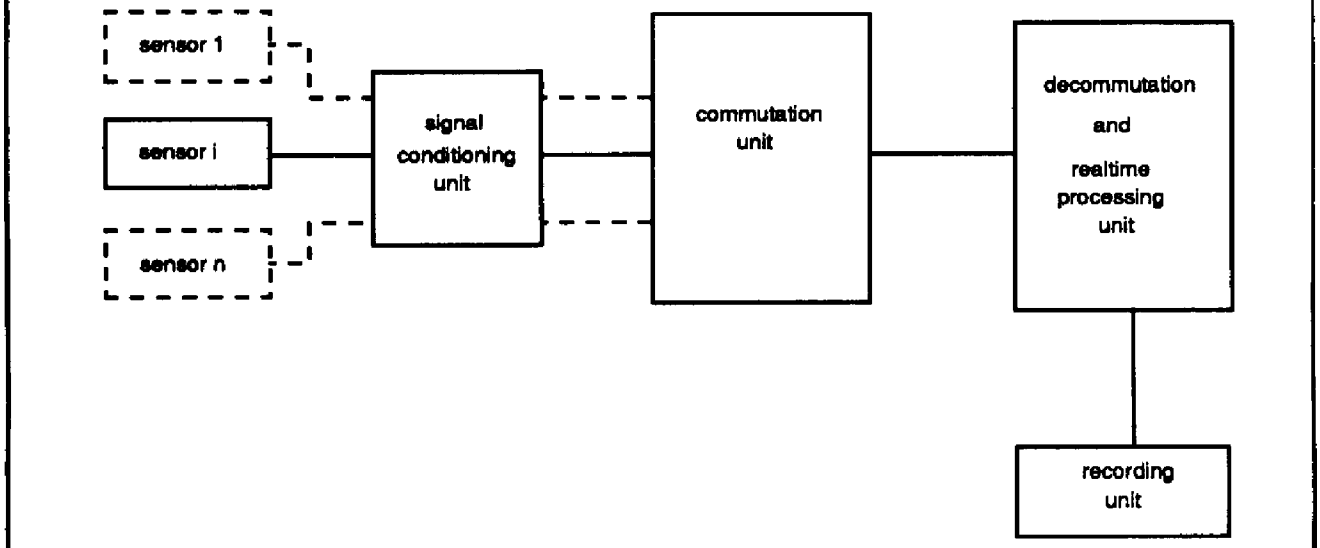

Figure 4: Logical representation of a measurement system in MCDB.