TRADEOFFS TO CONSIDER WHEN SELECTING AN AIRBORNE DATA ACQUISITION SYSTEM

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ABSTRACT

Selecting an airborne data acquisition system involves compromises. No single data acquisition system can be at the same time, lowest cost, smallest, easiest to use and most accurate. The only way to come to a reasonable decision is to carefully plan the project, taking into account what measurements will be required, what are the physical environments involved, what personnel and resources will be needed and of course, how much money is available in the budget? Getting the right mix of equipment, resources and people to do the job within the schedule and the budget is going to involve a number of tradeoffs. A good plan and a thorough knowledge of available resources and equipment will allow you make the necessary decisions. Hopefully, this paper will offer some suggestions that will aid in preparing your plan and give some insight into available system alternatives.

KEY WORDS

Data acquisition, signal conditioning, digital data bus, data acquisition system software, calibration, common bus, flight test.

INTRODUCTION

Airborne data acquisition systems come in many flavors and sizes. How do you select the system that meets your particular needs and fits into your instrumentation budget? The first objective to address is probably the most complex, what data must the new system acquire in order to provide all of the information needed by the many disciplines involved in a modern flight test program? The next factor to be considered is size and weight. Unless the system can be integrated into the test vehicle without adversely affecting its performance, it can't gather the required data. Finally, what will the system cost, keeping in mind any additional costs involved in installing and servicing the system?

Obviously, many additional issues must be discussed before we are through, but the first three, 1) Capacity, 2) Size and 3) Cost are the most critical. Factors such as ease of use, support, programmability, accuracy, and other considerations must be addressed after the first three are satisfied. Unless you have an unlimited budget and limitless space there will be compromises involved in your selection. One thing to keep in mind throughout this selection process, **the data must be made available when requested and it must be an accurate representation of the physical parameter being measured**.

CAPACITY

The first step in this process is the generation of a measurement list. This can only be done after consulting with all of the users of the acquired data. This list should contain a complete listing of all measurement parameters including the details of how they are to be acquired and what the range of measurement must be. Typical measurement types would be temperature, pressure, displacement, shock, vibration, flow, computer data, TSPI data, etc. These data parameters can be acquired as Analog inputs, Strain gauge inputs, Discrete inputs, Avionics bus inputs, Accelerometer inputs, Thermocouple inputs, Pressure inputs, Serial data inputs, RTD inputs, Frequency inputs, Synchro resolvers, Time code inputs, LVDT inputs and many more specialized inputs.

Table 1.1 is an example of a measurement list including enough information to at least start the process. **The measurement list will provide the basis for determining the capacity of the data acquisition system needed for your project**.

Figure 1-1 is an example of a large system capable of measuring thousands of parameters and using several different types of data acquisition units. Figure 1-2 is an example of a much smaller system that could be used when the data requirements are not so extensive.

SIZE

The next issue to address is the physical size constraints that will be placed on your system components. As a general rule **the larger the physical size of the system components the less they will cost, especially on a per channel basis**. Before you can even consider the cost however, you will need to determine where the components will need to be physically located. In many cases there will different size areas that need to be instrumented within the same vehicle. If it can be determined that all areas can accommodate large system components you are in luck because you will then have the largest selection of low cost components to chose from. Unfortunately, this is not always the case. To guarantee that the collected data will not be contaminated with noise the data acquisition system components must be placed as near as possible to the sensors.

It is possible to use a variety of data acquisition units of varying sizes and capacities within the same system as long as they can share a common bus. This feature allows the selection of large high capacity units where the physical room exists, and smaller (and usually higher cost) units where necessary. Specialized units for groups of temperature or pressure sensors are available that can be located in hostile environments such as engine compartments and external pods. Figures 1-3 and 1-4 show such system configurations.

COST

Costs for data acquisition systems are driven by several factors. Size is a major factor, and as a general rule, the smaller the unit the higher the per channel cost.

Another important factor is environmental ruggedness. Perhaps overlooked sometimes, another critical cost driver is accuracy. Unless the measurements accurately reflect the true conditions occurring during the test, false or contradictory conclusions will result. If a test must be repeated because of inaccurate measurements the cost savings resulting from selecting inferior equipment is lost very quickly. The selection of components used and the amount of testing required affect the cost of accuracy and ruggedness.

The ability to select off the shelf equipment is another primary factor when considering costs. Obviously, new developments raise costs and add risks to both schedule and performance. Sometimes this added cost is justified because of specific program requirements, or, in some cases, the actual total cost can be reduced because a new development can allow the use of less equipment or less manpower to accomplish the program goals. In most cases however, **proven off the shelf equipment will substantially lower costs.** The cost of a failed attempt to gather data can easily outstrip the original cost of the equipment. As with any product, the lifetime cost of ownership must be considered not just the original purchase price.

Once the main issues of size, capacity and cost have been addressed, other considerations such as ease of use, accuracy, programmability and support should be taken into account.

EASE OF USE

Ease of use means different things to different users, however the primary areas of concern are:

Equipment Installation
Mission creation
System checkout
Calibration

EQUIPMENT INSTALLATION

Long lead lengths between the sensors and the signal conditioning is the major cause of noisy, unreliable measurements. Ideally, all long wire runs should be done using a digital data bus. Low level analog signals such as those output from most common sensors are particularly susceptible to noise contamination and their lead lengths should be kept as short as possible. To accomplish this ideal, remote data acquisition units are placed as near as possible to the sensors. The remote units are then connected to the master data acquisition unit via a digital data bus. This digital bus can be normal copper wire for runs of up to 10 or 20 meters. For longer runs fiber optical cabling can be used with the added advantage of much better EMI characteristics.

MISSION CREATION

After the measurement list has been completed, the task of creating a viable means of collecting the required data is the next hurdle that must be overcome. All of the necessary information to do it is contained in the measurement list. A critical step after selecting the transducers and other data sources, is to verify that the signal conditioning can easily interface to these sources. A list of the necessary signal conditioning modules must be compiled and the modules distributed among the various data acquisition units (generally referred to as remotes) according to the location of the sensors. The software package used for this task should be easy to use and intuitive. Each measurement must be assigned to a specific channel of one of the signal conditioning modules. Each channel must then be programmed for the appropriate gains, offsets, filtering, etc. required to condition the measurement signal assigned to it.

Once the hardware parameters have been programmed, a format must be created that assigns each measurement to a specific slot or slots within the format. Again, all the information needed is contained in the measurement list. A single format will be generated that gathers data from all components of the data acquisition system. The critical part of this task is assigning a synchronous sampling rate that meets or exceeds the minimum rate defined for each parameter in the measurement list, while keeping the overall bandwidth as small as practical considerations allow. Many attempts have been made to define and/or automate this task but in the end their success is debatable. Automated software to accomplish format generation generally uses some sort of expert or artificial intelligence programming techniques and will usually completely redo the entire format each time a change is made no matter how small the change. This results in a different frame map each time the format is compiled. Each user will complete this task in whatever way he is most comfortable.

The format that ultimately results must be compiled into a set of instructions that can be used by the data acquisition system and then downloaded into the actual system. **Downloading should be easily accomplished via some sort of standard interface such as a serial RS-232 link between the data acquisition system and a standard PC**. This link should also allow the data to be read back for verification. Only one unit of the entire system should be used to provide the download link, this unit is generally referred to as the Master while any other system components are Slaves.

SYSTEM CHECKOUT

After the new format has been downloaded into the data acquisition system, it must be tested to verify that all the hardware is operational and that the data being collected is valid and meets the users requirements. A portable ground checkout system is usually used for this task. The same PC used to generate and download the format to the data acquisition system can be used for this function if it can be supplied with the necessary hardware such as a decommutator and a bit synchronizer. The same format downloaded into the airborne data acquisition must be programmed into the ground checkout system. **A file generated by the data acquisition system software should be used to program the ground checkout system**. The use of the same file assures that the formats are compatible and makes the checkout task much faster and easier to accomplish.

CALIBRATION

Before each mission, the data acquisition system should be calibrated to ensure that all measurements collected during the mission are within established parameters. Also, whenever a measurement falls outside of its expected boundaries it must be determined whether the problem lies with the test equipment or the unit under test. In either case, the initial calibration is done by substituting a known input to the signal conditioning module or, in some cases, to the sensor so that the correct gains, offsets, etc. can be applied to normalize the data. Subsequently, the system can be checked for range and accuracy by substituting the same inputs used in the initial calibration and comparing the results with the initial results. **As conditions change and equipment ages, the system must be re-calibrated to maintain consistent and accurate measurements. The data acquisition system must have some convenient way of substituting a known input to the signal conditioning modules**. This can take the form of a voltage substitution, a shunt resistor substitution or simply grounding the input. Often the system installation doesn't permit easy access to the measurement inputs and thus the calibration inputs must be built in or system calibration would not be possible, or at least very practical.

Measurement sensors are not necessarily linear and so a calibration algorithm must be used to do a conversion to engineering units. Ideally, calibrations should include multiple points to establish slope and intercept. A set of calibration coefficients is used to do a best-fit function to linearize the data. The calibration coefficients are generally obtained by testing the sensor itself and are provided to either the data acquisition system or the ground checkout system for engineering unit conversion capability.

ACCURACY

The accuracy of a data acquisition system is affected by many factors. One of the most important is the selection of the D/A converters used to digitize the analog data. The more digital bits used to represent the data the better the system resolution. The more resolution available the more accurate the data can be represented. Keep in mind that more bits also means higher bit rates and more bandwidth. Resolution alone however, does not guarantee accuracy. **Resolving a measurement down to extremely fine increments means nothing if the data being resolved is incorrect**. This is the old garbage in, garbage out syndrome.

To take advantage of the resolution gained in going from a 10 bit system to a 12 bit system the analog data must accurately reflect the physical parameter being measured. This means that the sensor must be capable of converting the physical phenomenon (Movement, pressure, temperature, position, etc.) into an accurate electrical change (voltage, current, resistance) with enough resolution to be measured. The resulting analog signal from the sensor must then be conditioned before it can be converted to a digital representation. If this low level analog signal is contaminated with noise before it can be conditioned any effort to get an accurate result is futile. There are many ways to mitigate the effects caused by long lead lengths but the best remedy is to avoid them.

The signal conditioning circuitry in the data acquisition system is critical in attempting to get accurate measurements. Proper impedance matching, low noise instrumentation amplifiers and good filtering are required to get accurate results. Any attempt to cut costs at this level will probably result in less accurate data.

PROGRAMMABILITY

Programmability allows a data acquisition system to be much more flexible without requiring any physical changes. Without programmability a system will need to be removed from the vehicle or weapon being tested and altered by changing components, wiring, jumpers or modules. A programmable system can be modified by downloading new software. Gains, offsets, filters, data selection criteria, sampling rates, etc. can be changed by downloading a new format or simply changing a single module's setup parameters via a link to an external controller. It is possible to switch between previously loaded formats by activating discrete control inputs. Systems vary widely in programmable features.

Programmability is another tradeoff between system cost and the cost of labor to make physical changes if required. Often the price of programmability is a reduction in channel density but this is not always the case.

SUPPORT

System support is something of an intangible. One factor is the actual size of the vender of the system. Obviously, **the ability of a vender to support a customer is contingent on the availability of personnel to provide the support**. The availability of parts, modules, test equipment and test personnel is critical when an emergency repair is needed. Worldwide support is not possible if any of these requirements cannot be made available. This is another initial cost versus long term cost tradeoff that must be considered. An inoperable test system can be extremely costly if not quickly returned to operation.

Training is another necessary activity that is often overlooked. Qualified instructors and useful training materials are required if a training program is to be successful. **If problems can be resolved by a user's own people, a significant amount of time and money can be saved**. This can only happen if the customer's on-site personnel are thoroughly familiar with the systems.

				Range						Transducer					
Measurement No	Category	Measurement Description	Meas Type	Minimum	Maximum	Eng Units	Ctr Freq (HZ)	Accuracy (%FS)	Sampling Rate	Excit.	Output	Mfg.	Model	Location	Remarks
PR001	PROP	FUEL PUMP INLET PRESSURE	PRESS	0	300	PSIA	30	3	250	5V	0-55mv	KULITE	BM-20P-1000-300A	ENGINE	LODM 10/10/96
AC001	FLUTTER	TAIL BOOM	ACCEL	-10	10	G	100		500			KISTLER	8304A20	COCKPIT	
CP001	CPU	CPU EVENT #1	DISCRETE	0	1	DISCRETE									
FR001	PROP	ROTOR RPM	FREQ	0	12000	RPM	200	0.04	1000					ENGINE	
SG001	STRUCTURE	ENGINE SUPPORT	STRAIN	50	400	LBS	60	4	250	10V	0-20mv			PYLON	
TP001	HYDRO	HYDRAULIC TANK TEMPERATURE	T/C	0	300	DEG F	15		60			OMEGA	TJ36-CAIN-18(U)-4-CC		TYPE K CrAl

TABLE 1-1

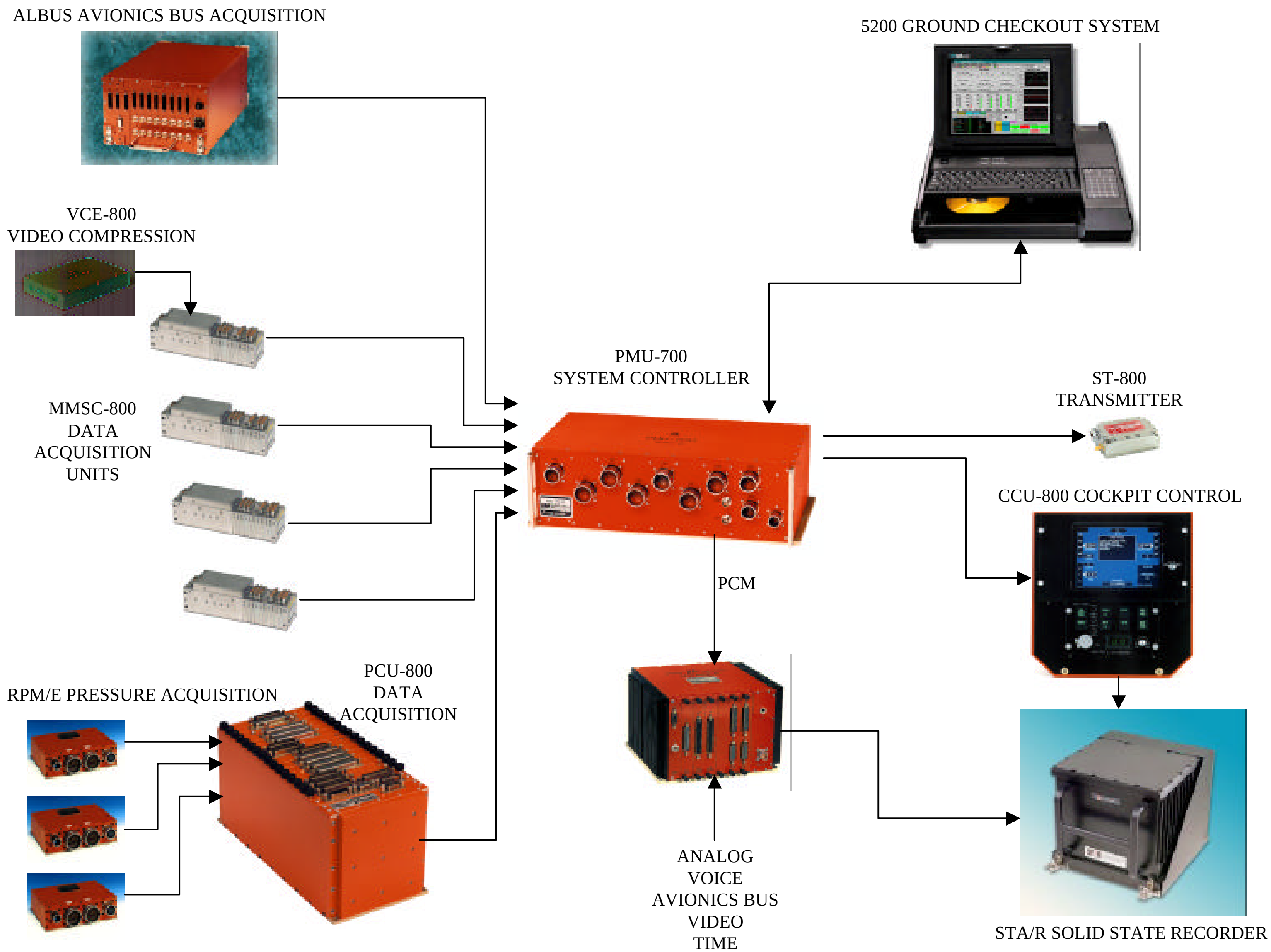
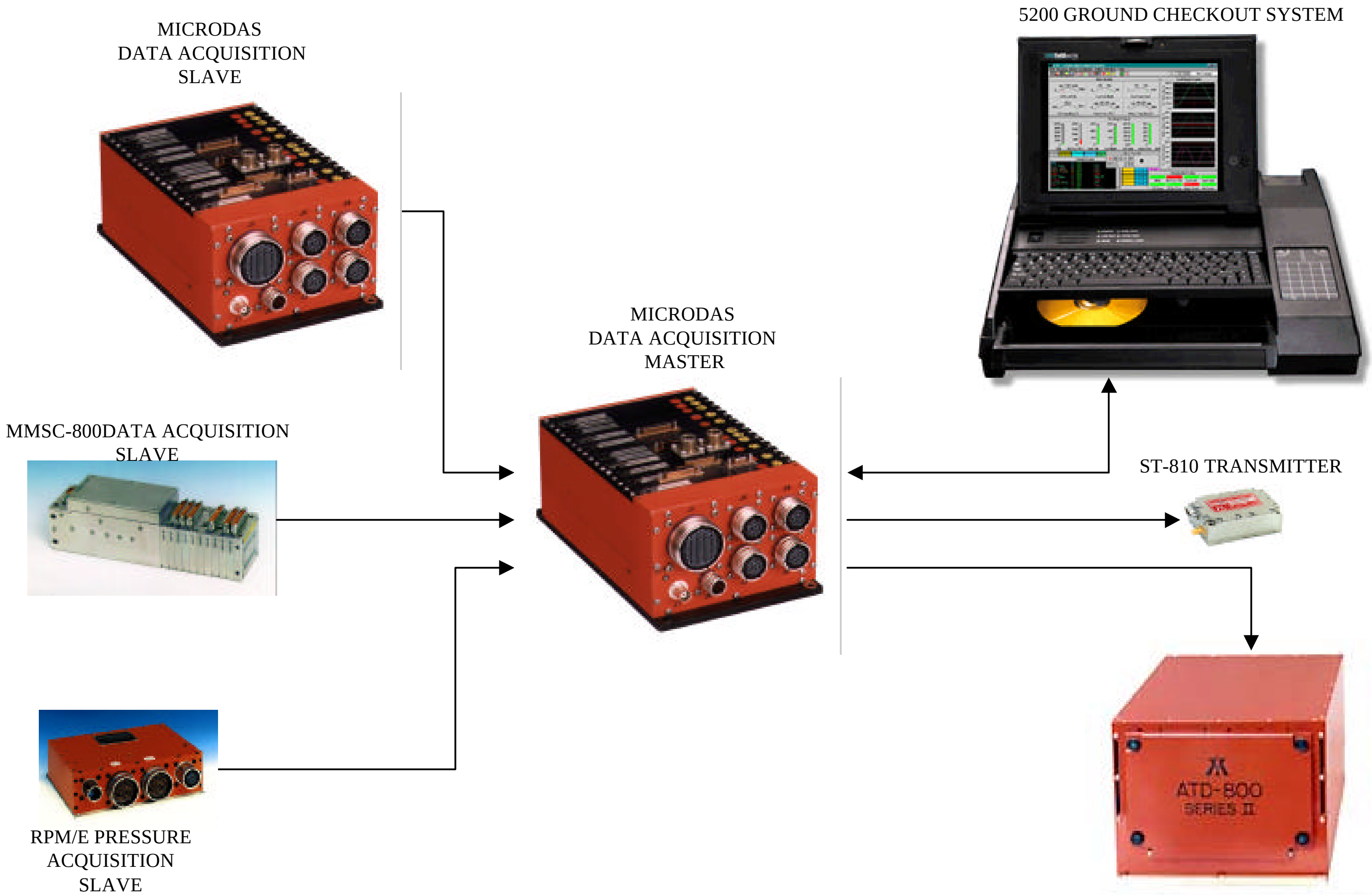

ALBUS AVIONICS BUS ACQUISITION
5200 GROUND CHECKOUT SYSTEM
VCE-800
VIDEO COMPRESSION
PMU-700
SYSTEM CONTROLLER
ST-800
TRANSMITTER
MMSC-800
DATA
ACQUISITION
UNITS
CCU-800 COCKPIT CONTROL
PCM
PCU-800
DATA
ACQUISITION
RPM/E PRESSURE ACQUISITION
ANALOG
VOICE
AVIONICS BUS
VIDEO
TIME
STA/R SOLID STATE RECORDER

Figure 1-1



MICRODAS
DATA ACQUISITION
SLAVE
5200 GROUND CHECKOUT SYSTEM
MICRODAS
DATA ACQUISITION
MASTER
MMSC-800DATA ACQUISITION
SLAVE
ST-810 TRANSMITTER
ATD-800
SERIES II
RPM/E PRESSURE
ACQUISITION
SLAVE
ATD-800 DATA RECORDER

Figure 1-2

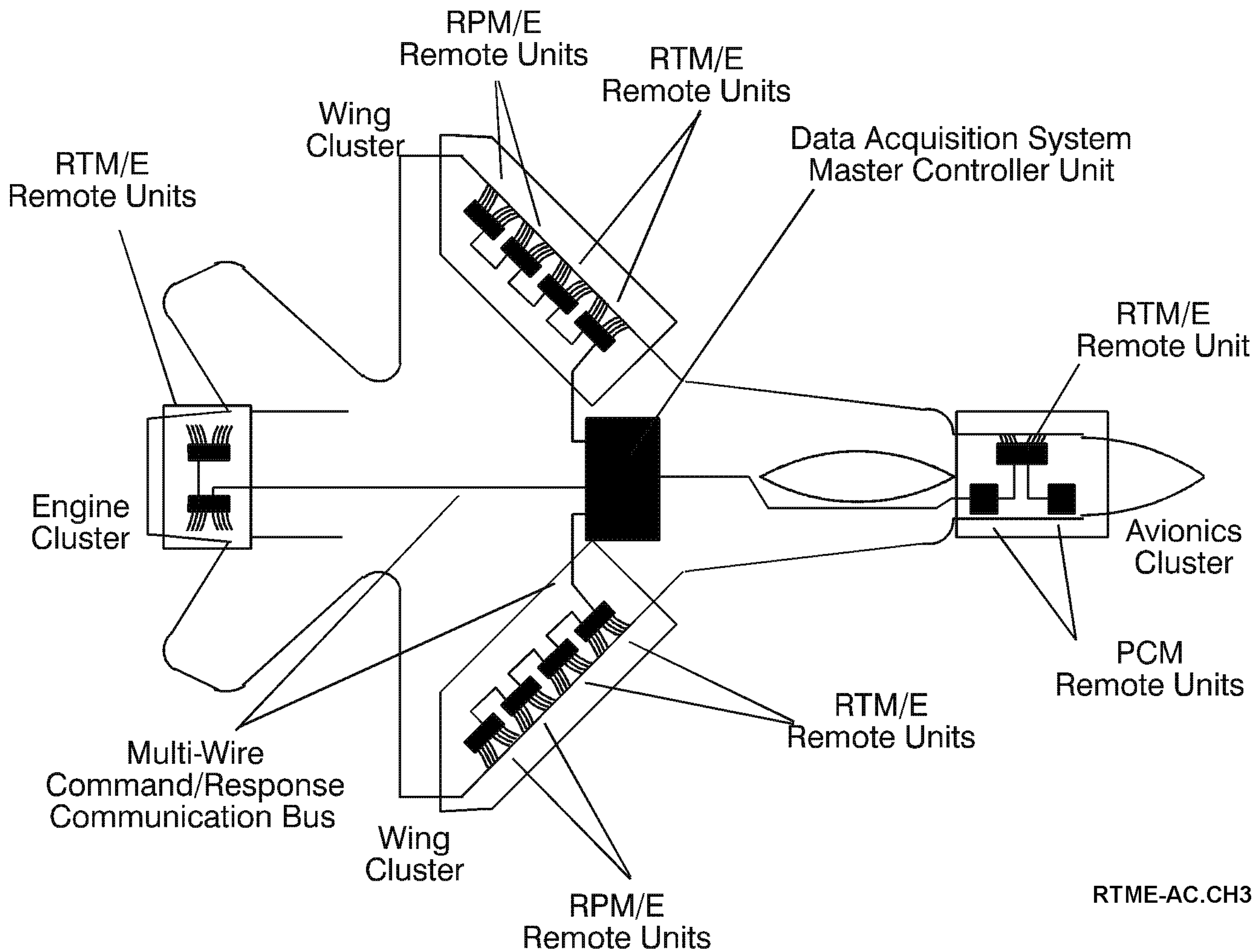
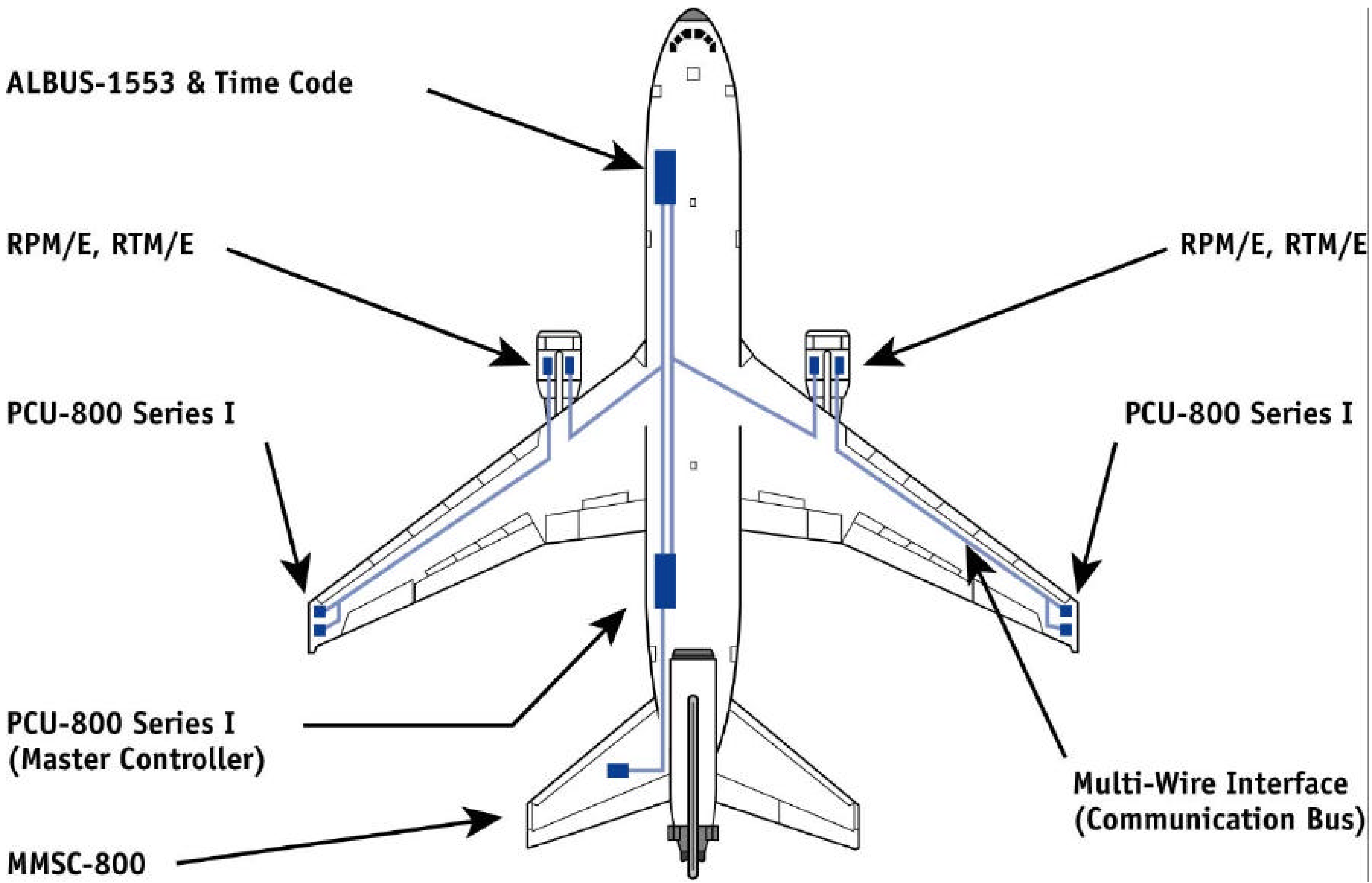

RPM/E
Remote Units
RTM/E
Remote Units
Wing
Cluster
RTM/E
Remote Units
Data Acquisition System
Master Controller Unit
RTM/E
Remote Unit
Engine
Cluster
Avionics
Cluster
PCM
Remote Units
RTM/E
Remote Units
Multi-Wire
Command/Response
Communication Bus
Wing
Cluster
RPM/E
Remote Units
RTME-AC.CH3

Figure 1-3



ALBUS-1553 & Time Code
RPM/E, RTM/E
RPM/E, RTM/E
PCU-800 Series I
PCU-800 Series I
PCU-800 Series I
(Master Controller)
Multi-Wire Interface
(Communication Bus)
MMSC-800

Figure 1-4