LINKING DATA REDUCTION SOFTWARE
TO
AIRBORNE DATA ACQUISITION SOFTWARE

By
William F. Trover
Associate Director of Advanced Systems
Teledyne Controls
Los Angeles, California

ABSTRACT

With the incorporation of microprocessors providing dynamic control capability in flight test data acquisition and telemetry systems, software is now becoming a critical part of the airborne data system. Software importance generally appears to be underestimated by many users of the airborne systems, as until now they have only had to worry about programming a PCM data cycle map into EPROMs and plugging them into the airborne hardware. With newer programmable systems using microcomputers with E^{2}PROM and RAM to provide a realtime EU display and control capability, airborne software can become a critical link in scheduling. Programming requirements for realtime data display and control in these data acquisition systems now makes it essential that there be software configuration control and a software (firmware) link between the data reduction software residing in the ground station and the data acquisition software in the aircraft. This paper addresses one solution to this new class of problem in flight test.

INTRODUCTION

Most current airborne PCM systems are stored program units offering the user the option of prestoring in EPROM one or more PCM data cycle maps, selectable dynamically during a flight. Most ground station data processing software however is presently not flexible enough to use this capability of dynamic reconfiguration of the airborne data cycle map. Because EPROMs are physically bothersome to reprogram, little effort has been expended to use the programmability features of the airborne hardware on a day to day basis. Most software links to the airborne system are limited to programming the EPROMs via a PROM programmer connected to the PCM ground station or by a large GSE cart. Since changes in a given test aircraft's sampling program are seldom made (except GPA gain/scale factor changes early in a test program), software configuration control has not been a big concern. Until recently airborne systems typically did not have integral

computers and realtime processing/control and EU data display capability so company organizational lines also divide flight hardware responsibilities (with no software except data cycle maps) from ground data processing responsibilities.

Newly developed PCM systems have integral microcomputers and in conjunction with on-board computer controlled display units and download control capability offer much more PCM system flexibility and usefulness. They also however require software support to successfully use this capability, and this invokes a need for integration (both functionally and organizationally) of the airborne software with the ground station software. The ability for several people (instead of one or two) to change and update the software to match changing test requirements and conditions brings forth the need for software configuration control which must be as rigidly enforced as it is in hardware configuration changes. The emergence of software as a key dynamic element of the airborne flight test system, until just recently limited to large transport type aircraft testing, will cause re-thinking of both processes and organizational responsibilities. This paper will only attempt to address the former.

IMPACT OF NEW PCM SYSTEM ARCHITECTURE

The advent of E^2PROM memory and low cost/low power microcomputers have changed the architecture of current PCM system design, providing smart systems with realtime display/control capability and the attendant need for software support. This change in system architecture is complimented by the fact flight test efficiency has proven to be increased (with attendant lowering of test costs), when test pilots can be given derived parameter energy management profiles in realtime[1] and pilots and test engineers can have access to realtime EU data displays of basic or derived parameters in the cockpit.

The use of "smart" modules in the airborne data acquisition system provides several new flight test capabilities:

1. The ability to quickly and easily load and test different sampling maps into the PCM system during aircraft preflight test opens up new techniques for sensor calibrations and the handling of PCM tapes.

2. The ability to dynamically modify the memory contents of selected time slot locations in the data cycle map permits the addition of analog and discrete/digital command output cards to the data acquisition system so realtime control functions can be implemented.

3. The download capabilities between the on-board Computer Controlled Display Unit [CCDU] and the Remote/Multiplexer Demultiplexer Unit [RMDU] also permit

on-board EU converted realtime display parameters to be inserted dynamically into preassigned dummy time slot locations in the data cycle map so the same data presented to the flight crew can be displayed on the ground (through the telemetry link) in realtime as well as being recorded on the PCM tape.

The command output capability of the smart airborne data acquisition system can be used to drive special test instruments in the cockpit with derived parameters, while insertion of realtime display data into the PCM stream lets more people have concurrent access to critical data so there is less of a chance for human misinterpretation.

AU of these new features and capabilities however require the creation of software and planning to implement the functions. The advent of significant software in the airborne system and the flexibility of the smart airborne hardware opens up new opportunities to improve test procedures by greater integration of the airborne and ground station software. Figure 1 is a functional block diagram showing the software programs which must flow between the PCM ground station computer system and major elements of the flight test activity.
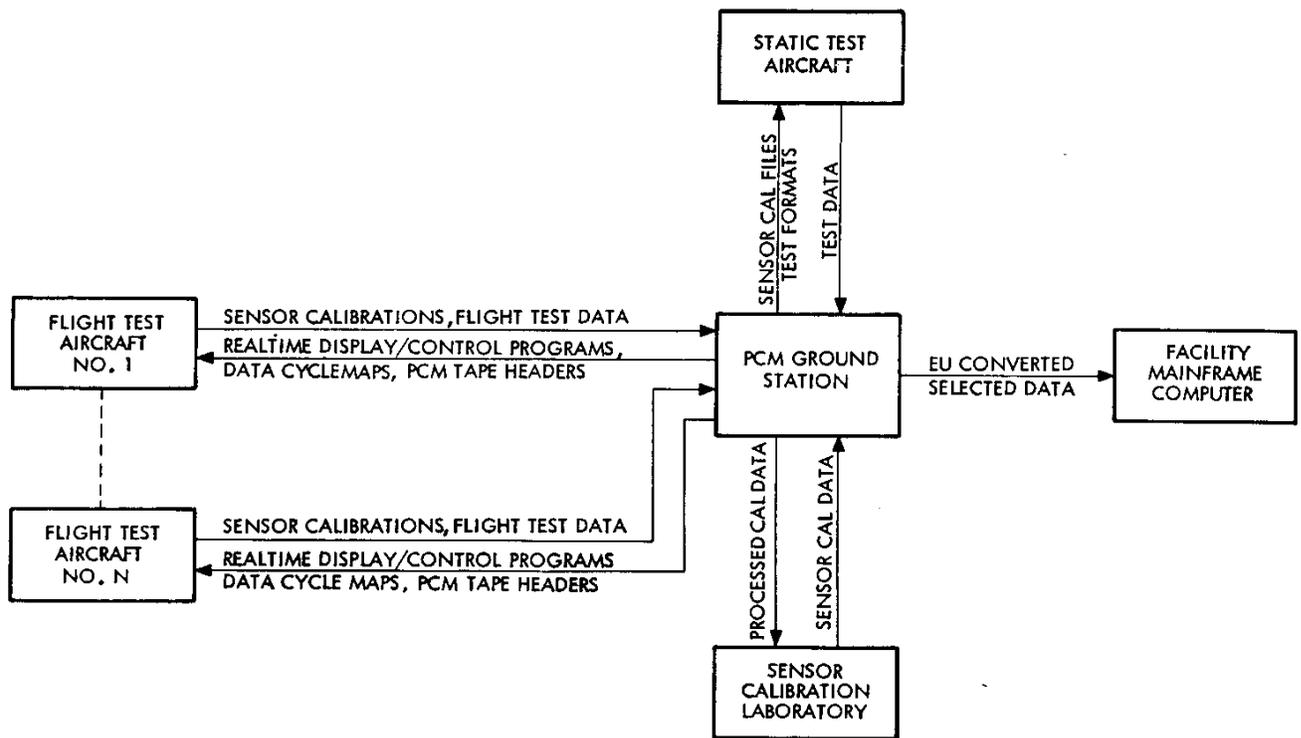
TC15481

Figure 1. Software Program Flow Throughout The Test Activity

Sensor calibration is one area where software integration speeds up the test process. This is achieved by using an airborne multiplexor (a subset of the airborne system) in the sensor calibration laboratory so that calibration data is sent via the PCM stream to the ground station and the processed data is presented in realtime to the operator's remote CRT in the cal lab. In this manner, the same procedures and software can be used for in-situ calibrations of sensors in the aircraft as are used in the cal lab. With precision internal calibration channels the airborne multiplexer with a 12-bit accuracy can be a secondary standard. Therefore, using the same hardware for all sensor calibrations will reduce error uncertainties from the calibration processes, and the semiautomatic calibration process will tend to minimize errors introduced by manual entry of cal data into the computer.

Another application where software integration can simplify data processing procedures is the use of tape headers on airborne PCM tapes. E^{2}PROM memory in the airborne PCM system permits loading of a PCM tape header map prior to loading the flight test map. The tape header map is a constant size data cycle map containing all characteristics of the flight test map for that flight. The tape header format is recorded for a few seconds on the PCM flight tape before the flight test map is loaded into the RMDU system and tested. In this manner a default program on the ground with a special function key to "Read PCM Tape" will automatically configure the ground station to read the PCM header (all headers have the same word length, sync pattern, frame length, etc) which in-turn reconfigures the ground station by setting up the decomm, calling appropriate sensor cal files and setting up flight scenarios for realtime processing of test data from the remainder of flight PCM tape (following the header).

In summary, the use of smart data systems generates several categories of airborne softare where there was none before. These include, data acquisition software, PCM tape header software, sensor calibration software, control software and display software. The best solution to controlling this new software, and minimizing its effect on the flight test activity is to integrate it with the ground station software and generate all flight test programs from the same database. For example, in many instances the algorithms used to generate on-board data displays are the same as those used in ground station realtime displays (true Mach, true, center of gravity, gross weight, stall speed, etc). Also, the same sensor calibration files or thermocouple lookup tables must be used for the on-board processing as are used in the ground station. In order to eliminate errors and minimize programming costs, the integrated approach should be taken so that only one set of algorithms are developed and in a high level language in the ground station. This high level programming capability is supported by cross assemblers, compilers and debuggers in the ground station for assembly and checkout of the airborne microcomputer software plus a simple non-volatile transfer media for program migration from the ground station to the airborne data acquisition/ display system.

TECHNIQUES FOR INTEGRATING THE SOFTWARE

There are several techniques which can be used to link the airborne PCM system and the sensor calibration laboratory to the PCM ground station where the common data base for all flight test activities must be maintained. The main need is to have a non-volatile media for the physical transfer media between the ground station and the flight test aircraft (the sensor cal lab, the static test airframe and the mainframe computer can be interconnected via hardware/software networks). The three generally accepted media are disks, tape, E^2PROMs. The former two have been used up to now where any link existed because E^2PROMs only became multisource available recently. They do however represent a compact, nonvolatile media which by use of an airborne computer/display unit at the ground station means there is no special load hardware required at or on the test aircraft. This eliminates the need for a large mobile PCM test unit for preflight/postflight testing as the small on-board Computer Control/Display Unit [CCDU] can function both as the ground test unit and the airborne test computer system.

Figure 2 is a functional block diagram of one configuration of a distributed airborne data acquisition and processing system depicting how programs and data flow between the test aircraft, the ground station and the sensor calibration laboratory. The CCDU in this application is the common (hardware) interface for software transfers between the test aircraft and the ground station with its small, pluggable E^2PROM Program Load Module being the non-volatile physical transfer media. Since the different PLM programs for the aircraft; sensor calibration, PCM tape header, flight data cycle and realtime application displays are used at different times during the test process the CCDU can be used as the MMIF for loading/testing and using each program. In-situ sensor calibrations are performed inbetween flights, the PCM tape header is generated as the first part of the pre-flight activity followed by PCM system checkout (of the flight data cycle map). Finally the realtime application display program is loaded and tested as the final part of the pre-flight test.

AIRBORNE COMPUTER CONTRO/DISPLAY UNIT [CCDU]

The CCDU is a multifunction microcomputer system that interfaces with the serial PCM stream (with clocks) of an airborne PCM system and provides realtime decommutation, processing and data display capabilities. It is an airborne unit that can be mounted in either a 19" rack panel for ground station applications, its own portable carrying case with handle, or in an ARINC standard 4.75 inch wide avionics control panel mount located in a cockpit. A photograph of the CCDU is presented in Figure 3. The pluggable Program Load Module (PLM] of the CCDU functions as the non-volatile transportable load media to carry programs from the PCM ground station or data processing system to the aircraft. The CCDU is also used as a PCM system tester in either the aircraft or in the laboratory as
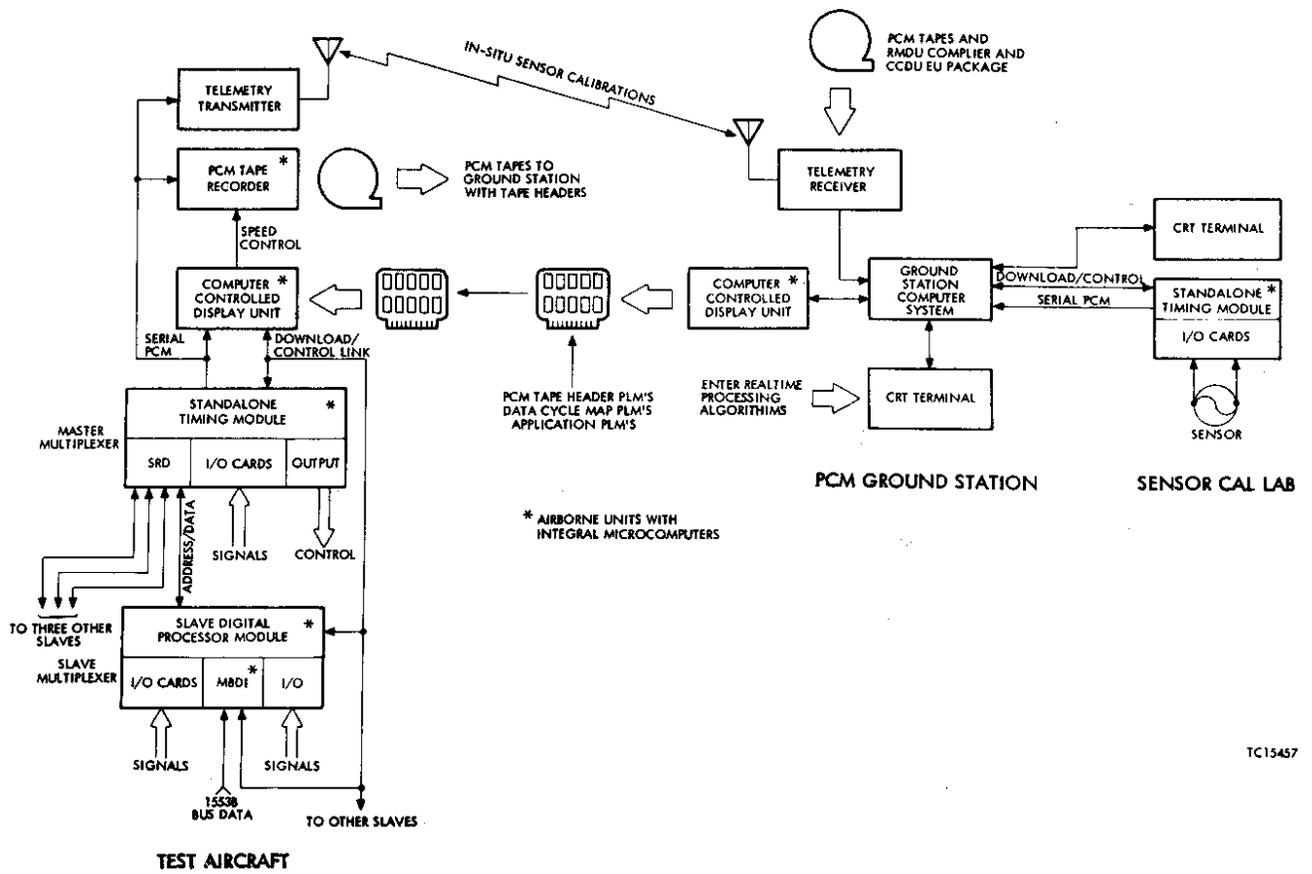
Figure 2. Program and Data Flow Within and Between Test Aircraft and Ground Facilities
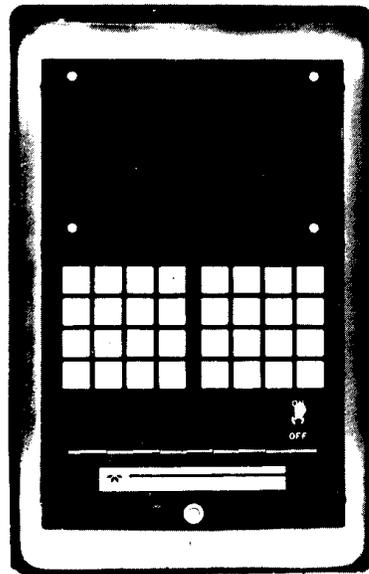

Figure 3. Computer Control Display Unit [CCDU]

well as an in-light data display unit. In summary, the CCDU provides the following basic flight test system functions:

1. Ground computer to aircraft interfaces

2. Portable memory load unit for the PCM system

3. A portable PCM system test unit

4. A documentary data entry unit for each test flight

5. A preflight or pretakeoff go/no-go tester of system performance

The CCDU can be remotely located with only a data display panel in the cockpit or if it is installed in the cockpit (or at the test engineers console or larger aircraft) it provides an interactive man-machine interface to the flight test data acquisition/control systems. Figure 4 is a simplified functional block diagram of the CCDU. Software to support the CCDU and the airborne multiplexer (RMDU) system is divided into two major areas:

1. Software resident in the host computer (PCM ground station or data reduction computer) which interfaces with the CCDU.

2. Standalone software which resides in PLMs located in the CCDU to permit it to perform its various functions.

One host resident software package for the CCDU is a Fortran program identified as an RMDU compiler. Its task is to interface with files in the host computer defining each time slot of the data cycle map. The files consist of an ASCII string of characters divided into a header and a data cycle map definition. The compiler identifies the header string which specifies the aircraft type, serial number, flight number, test number date and characteristics of the data cycle map (frame length, subframe [cycle] depth, word size, sync pattern, etc.). The ASCII string of data cycle map time slot identifiers defines the characteristics of each parameter (RMDU no., card no., chan no., gain, offset, etc.). The compiler converts these ASCII strings into the binaries for loading into the RMDU sampling map memories of the airborne system. The top level data cycle map is divided into pages for loading into the up to eight different RMDU module memories Master RMDU (SAT-M), Slave RMDU (S-PDP-M), I/O Module (1553B MBDI) which can be included in a given system configuration. These pages are downloaded to the CCDU and the CCDU in turn loads them into the PLM E^2PROMs and performs a memory verify.
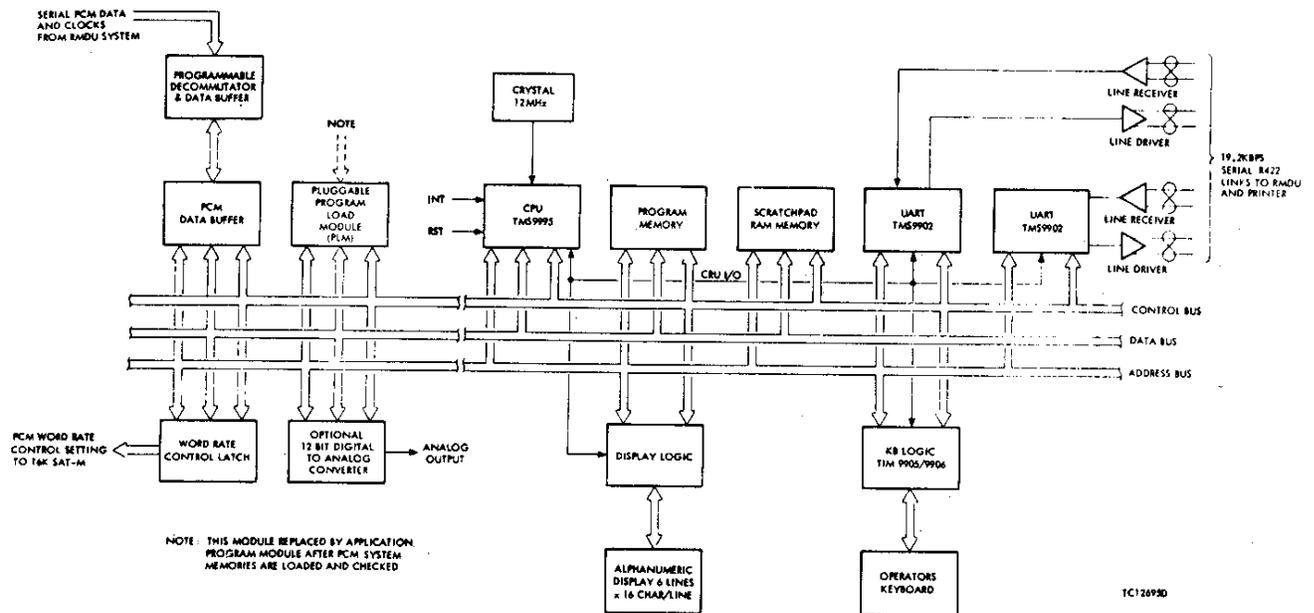
Figure 4. CCDU Simplified Functional Block Diagram

The CCDU download and RMDU system test software package provides the following functions:

1. Reads PLM memories and downloads sampling map contents to RCA1805 CPUs in SAT-M, S-DDP-M and MBDI modules

2. Verifies RMDU system downloaded program accuracy

3. Calls up and displays any RMDU system memory address contents (up to 8 D/L modules per system)

4. Permits (via password) modification of any RMDU system memory location with automatic incrementation of the configuration control word value in master data cycle map

5. Static display which acquires any six parameters from a data cycle map and displays the data in sign-magnitude or binary raw format (updating the display 2 times/ second)

6. A dynamic display which accepts complete frames (or data cycles) up to 2048 words and presents raw data in scrolling format six parameters at a time

7. Outputs complete frames (or data cycles) through its RS-422 serial port to a printer or CRT terminal

Because the CCDU can write directly to SAT-M memory, documentary data such as aircraft serial number, flight number, pilot, date, etc. can be written into the data cycle map as an overhead words(s) the same as frame synchronization patterns. This eliminates the need for conventional thumbwheel switches, hardwire in parallel to a discrete multiplexer card.

Standalone software resident in the CCDU is divided into the following categories:

1. Receipt and storage in PLMs of download programs for the test aircraft from the host CPU in the ground station

2. Uploading of aircraft test program changes made by an operator in the test aircraft (from the PLM)

3. Downloading and verification of PCM tape header and sampling map programs from the CCDU (PLM) to the loadable modules in the airborne RMDU system

4. Configuration control/monitoring of the flight test program during on-board modifications or changes

5. Preflight testing and hardcopy output of the flight test program

6. Checkout and execution of the realtime display/control programs

The bootstrap program in the CCDU and the download, modify and test programs are the only permanent programs. Application programs for realtime control/display are entered from PLMs generated in the PCM ground station.

PCM TAPE HEADERS

Another CCDU program developed in the ground station but used in the aircraft is the PCM tape header program. This program is a special PCM data cycle map which is compiled from the completed ground station realtime processing program produced for each test flight of a given aircraft. The PCM tape header program is a simple main frame only PCM map which always has the same sync pattern and contains the same information in each word (or group of words in the frame). This data defines the data cycle map characteristics of the flight test map, which sensor cal files are to be pulled from the data base for realtime processing and which Scenarios are to be used to process the data. This map is down loaded to the CCDU for loading into a PLM in the same manner as the flight data cycle map.

If there is an RMDU in the PCM ground station for realtime processing of dynamic data from an FM multiplex or in the sensor calibration laboratory, then PCM tape headers can be generated in the ground station and the blank flight tape with its pre-recorded tape header which is generated on the ground stations PCM tape recorder is carried to the aircraft and installed in the airborne recorder.

The choice of selecting which location it is best for recording of the PCM header on the flight tape is a function of many things many of which may be unique to a given test facility. One solution is to generate the tape header in the ground station before the blank tape is installed in the airborne tape recorder. Probably the safest place is to write the header in the aircraft after the blank tape is installed on the airborne recorder. In this manner the proper header (aircraft serial no., flight no and date) can be verified on the CCDU in the aircraft before it is recorded on the flight tape. This procedure should minimize the possibility of human error, however no system or procedure is totally impervious to human errors.

REALTIME DISPLAY/CONTROL PROGRAMS

Realtime EU data displays and control output programs for in-flight execution by the CCDU are generated in the PCM ground station. The software package to generate the realtime application programs is identified as the EU conversion package and it resides in the ground station.

The EU conversion package for the CCDU is composed of two software packages. The first is a set of services within the CCDU which allows the users to write general purpose algorithms in the ground station in the TI 9995 assembler language and have them execute in the CCDU. The services allow for extraction of any of up to 2048 PCM words from the serial PCM stream and presentation of results by using the CCDU displays. The second package is a simple compiler (which is written in ANSI 77 Fortran for portability) which allows the user to define data from the PCM stream, manipulate the data using the four arithmetic operations (+, −, x, ÷) and present the results on the CCDUs display.

Both the TI 9995 assembler and the Teledyne compiler allow the user to enter his own EU conversion polynomial coefficients or lookup tables, as well as derived parameter algorithms. The resident CCDU EU software has the following services:

- Software Floating Point
  24-bit fraction, 8-bit exponent

- Hardware Integer
  16-bit two's complement

- Raw Data Extraction
  Mainframe word number and subframe word number and the bit length of the PCM word (10-, 11- or 12-bit) must be input to this service

- Mask, Shift and Word Assembly operations to allow extraction of discretes and assembly of multi-word parameters

- Data Display
  The value and its format - fixed or floating must be provided

- Insert a derived parameter in the PCM Stream
  If a Teledyne RMDU is used in the airborne system a derived parameter may be inserted into the PCM stream. The user must define the SAT-M map location of the derived parameter

Programs which are produced by the EU conversion software packages are transmitted from the host CPU to the CCDU by an asynchronous RS-232-C communication link using printable ASCII characters. The CCDU buffers the program and then loads it into the E^2PROM in its Program Load Module [PLM].

In addition to the normal flight test data system support functions, application programs generated for the CCDU could provide the test pilot with unique EU data that must normally be extracted from the Pilot's Flight Manual or manually computed during flight. Applications of the CCDU in this area include; pre-takeoff go/no-go testing of the data acquisition system, display interactively the pilot's takeoff check list, aircraft acceleration (go/no-go indications) on takeoff, calculate V_1 (line speed), V_2 (rotation speed), V_{10} versus gross weight/altitude/ OAT, calculate/display dynamic gross weight and/or center of gravity (as a % of mean aerodynamic chord), display climb speed versus flap position, display approach, flare and stall speeds (versus flap position, gross weight and altitude), display surface flutter onset, calculate/display true thrust of engine, display system operating times of flaps, landing gear, spoilers, trim tabs, calculate and display engine acceleration/deceleration times and display roll/pitch/yaw response rates.

Other application programs for the CCDU include using the realtime computational capability to generate derived parameters which can be downloaded to the RMDU and outputted as analog and/or digital command signals for closed loop control functions. These can include generation of the servo control signal for a flutter vane operation. The realtime control program can monitor the amplitude of key accelerometers and reduce the amplitude of the servo signal (or stop it) when the structural accelerations reach predetermined levels. Other analog output functions could include the display of special flight test parameters on analog instruments mounted in the cockpit (other than normal

flight instrumental). These instruments, driven by an analog output card in the RMDU can present test data such as true angle of attack, sideslip angle, control surface position, etc. Discrete outputs from the RMDU could be used to drive alarm lamps in the cockpit as a function of analog limit exceedances of test parameters such as airspeed, flap position, g-loads, vibration amplitudes etc.

Open or closed loop control programs use both the CCDU computer and the microcomputer of the Down-loadable Standalone, Timing Module (D/L SAT-M) in the master RMDU. The data sources for the control algorithms executed in the CCDU are any of the analog or discrete inputs (or 1553B mux bus parameters) sampled by the PCM system's data cycle map during the test flight. Since the 1553B Mux Bus Data Interface [MBDI] module can extract any word or message from the bus in realtime and buffer it for sampling by the PCM map, it is possible to present comparisons in realtime of data from any of the avionics systems (sensors) with data from separate flight test sensors.

Figure 5 is a simplified block diagram showing the CCDU/RMDU and the data flow paths for both data acquisition and open/closed loop command functions in realtime. The power on bootstrap program in the SAT-M computer inspects the E^2PROM steering memory contents and offloads the card select address of those channels representing control channels (output cards) into RAM memory (up to 16-channels control can be processed at one time). The hardware starts stepping through the MF/SF contents of the E^2PROM PCM map memory. Whenever a control channel address is next, the address generator reads from the proper location in RAM instead of E^2PROM. By storing command channel addresses in RAM instead of E^2PROM the control byte (LSB) of the address can be dynamically notified by the CCDU.

The PCM stream is decommutated by the programmable decomm and buffer in the CCDU and the PCM words selected for the realtime control program are passed from the two 2048x16 ping pong buffers in the decomm section to the CCDU computer for processing. Command words computed by the realtime control program are downloaded via the 19.2 kbps serial download link to the SAT-M computer which loads them into the proper RAM locations) representing the output channel locations in the data cycle map.

The command word represents the LSB 12-bits of the RMDU address (the first four bits are the card select bits which are programmed in the data cycle map to represent the RMDU card slot in which the output card is located in the chassis). The four bits after the card select bits are for channel demultiplexing on the output card. The least significant eight bits are the output command word value. Since two bytes are required for each analog output command, up to 12-bit DACs may be used on the AOC for conversion to analog outputs. In realtime operation, the SAT-M computer only has to accept command words from the CCDU and route them into the proper RAM destinations. The address
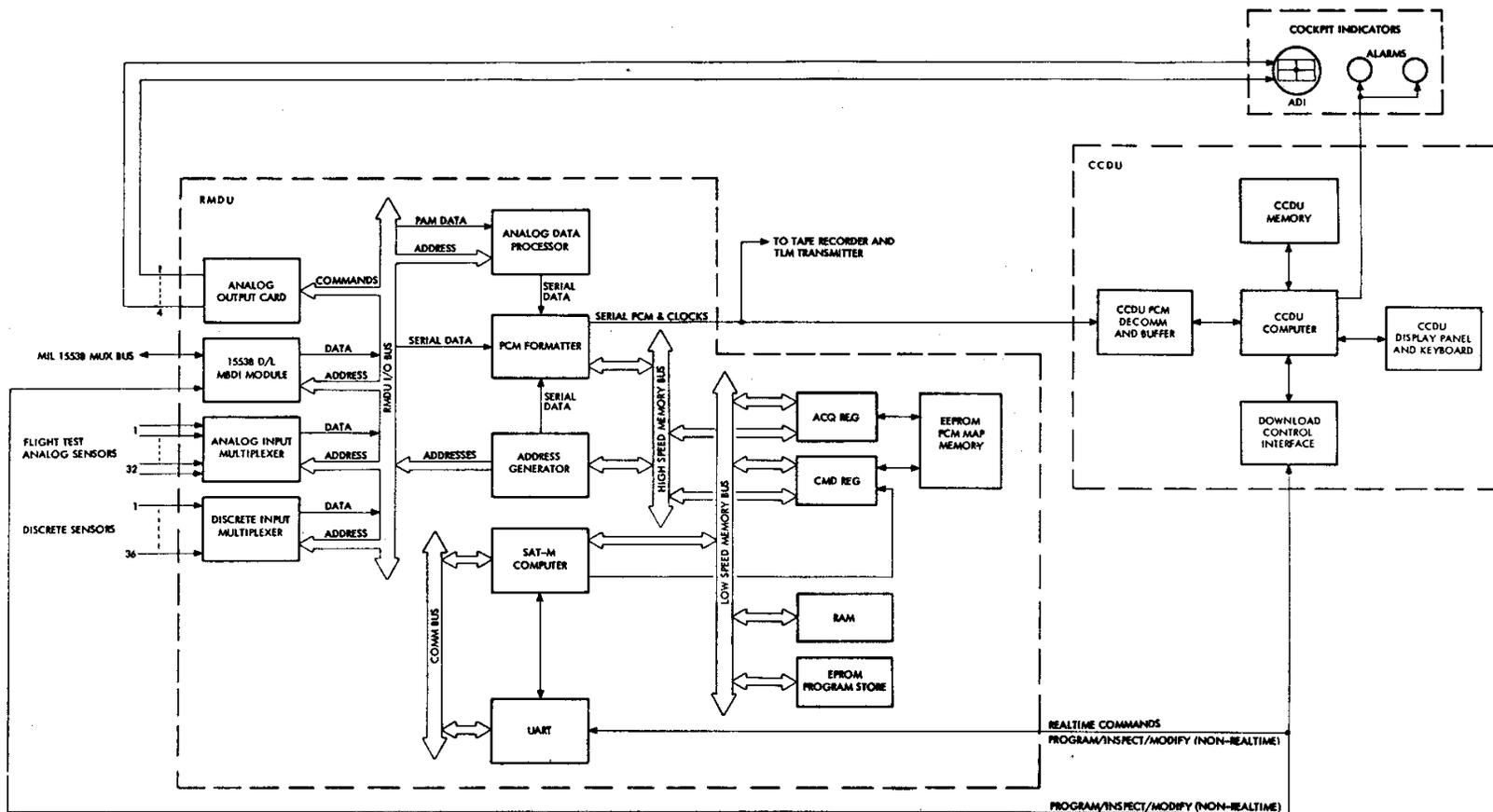
Figure 5. Open/Closed Loop Control Data Flow

generator permits a sampling format memory location to be routed through a two word shift register to the output PCM formatter as well as being decoded and applied to the RMDU I/O bus. In this manner overhead words such as frame sync patterns and computed parameters downloaded from the CCDU can be inserted in the PCM stream in the same manner as analog or digital data sampled from input cards. Since there is no input data from an output card when it is addressed in the format, the same channel/data value field that is sent to the output card is automatically inserted in that time slot of the data cycle map. In this manner all command channels executed by output cards in the RMDU to drive on-board instruments or lamps are also sent to the ground station via the telemetry link.

Each command parameter downloaded to the RMDU can also be displayed in A-N format on one line of the CCDU display surface concurrent with its execution as an output command by the RMDU. Here however, the realtime A-N display is limited to the 6-line capacity of the CCDU display panel (as opposed to the 16-channel realtime control capacity of the SAT-M in the RMDU).

SENSOR CALIBRATIONS

Sensor calibrations fall into three categories; (1) sensors which must be calibrated in the test aircraft (such as position sensors, pitot/static sensors, etc.), (2) sensors calibrated in the calibration laboratory and (3) sensors which must be calibrated by the sensor manufacturer with the cal data entered manually into the ground station data base. Each sensor in the test facilities inventory must be identified by a Descriptor whose contents include:

- Sensor Log Identifier [ID]
- Sensor Mnemonic
- Sensor Type
- Serial Number
- Manufacturer
- Range [EU]
- EU Measurement Units (i.e., psi, ft, lbs, degrees)
- Full scale voltage
- Calibration ID
- Calibration Number

In order to minimize calibration accuracy uncertainties and speed up the calibration procedures, software for sensor calibrations has been designed so the calibrations can be run end-to-end through the PCM system.

For sensor calibrations in the cal lab it is only necessary to have an RMDU system with a DC bridge multiplexer card, a discrete multiplexer card and a presample filter card plus a CRT terminal and keyboard connected to the ground station (the serial PCM data lines and the download control line of the SAT-M in the RMDU are connected respectively to the PCM decomm and the CCDU in the computer system). The sensor is connected with temporary clip leads to the signal conditioner card in the RMDU to provide it with excitation power and a signal load in the same manner it is connected in the test aircraft (i.e. for non-filtered channels use a low level multiplexer input and filtered channels use a presample filter input with appropriate GPA gains). A sensor calibration data entry panel unit (see Figure 6) is connected to the discrete multiplexer in the RMDU. This panel permits the operator to dial in on thumbwheel switches the physical data value (± XXXXX x 10 to X) of each calibration point. The three sensor number switches define which parameter (sensor) in the data cycle map is being calibrated. The data valid discrete is depressed by the operator when a stable physical value of the calibration point is obtained.
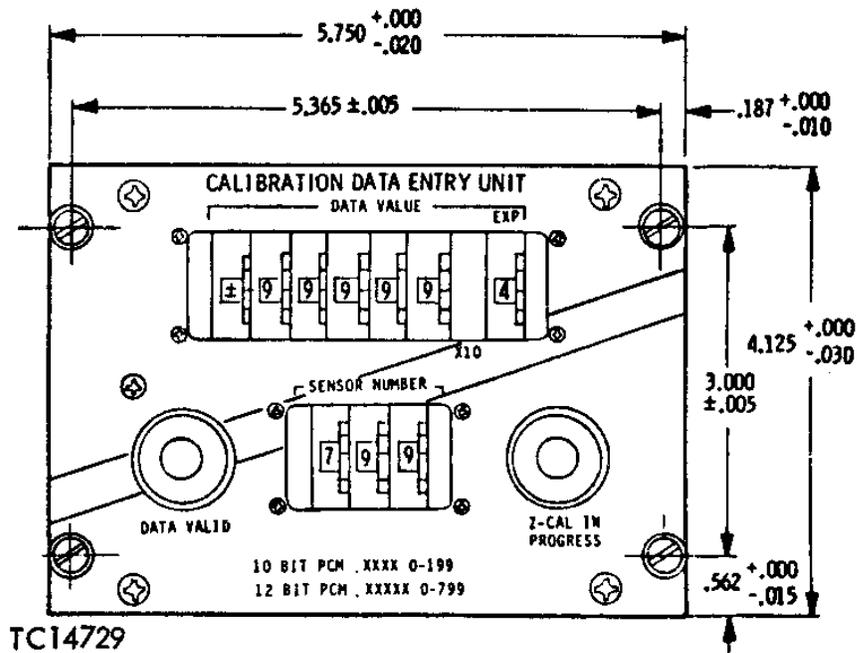

Figure 6. Sensor Calibration Data Entry Panel Unit

The data processing software downloads via the CCDU the flight sampling map to the RMDU. With the proper thumbwheel settings, when stable data is achieved, the data switch is depressed. The ground station reads the discrete words from the sensor calibration data entry panel and determines which sensor is being calibrated. The limit exceedance software monitors the data valid status and when it goes "high" the computer takes 100 samples of the analog PCM word representing the sensor being calibrated. It discards any wild points (the wild point window is user selectable) and averages the remaining samples and downloads the average to the CRT terminal in the cal lab for

display along with the absolute data value and the error value. The average is displayed in both counts and volts (mV).
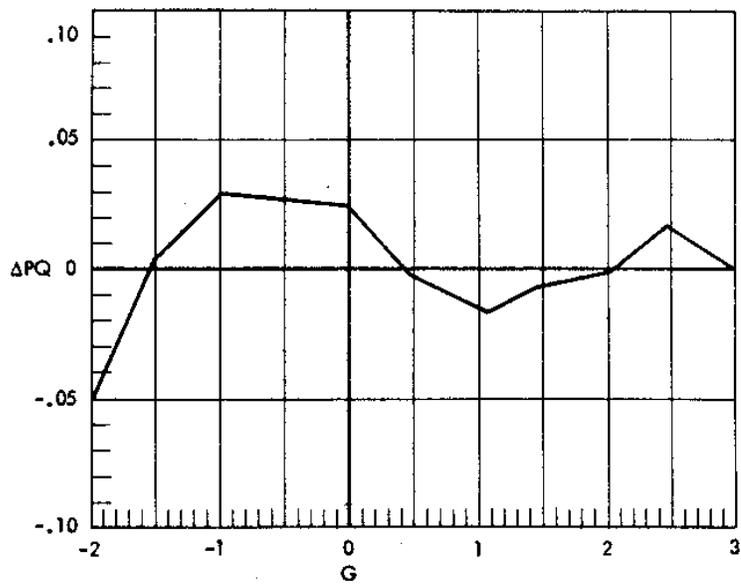
When the operator has stepped through each of the physical calibration points he can ask for any of three curves; (1) a plot of physical value vs volts (Figure 7), (2) a plot of physical value vs counts (Figure 8) and. (3) as shown in Figure 9 a plot of actual vs ideal physical quantities (ΔP_Q). These plots can be reduced to hard copy along with a tabular presentation of the data (Figure (10) providing four "A" size sheets representing each sensor's calibration. The error curves will assist the test engineer in deciding which degree of polynomial to use for realtime data processing. When all data has been reviewed and verified by the calibration engineer the data can be automatically entered into the ground station data base.
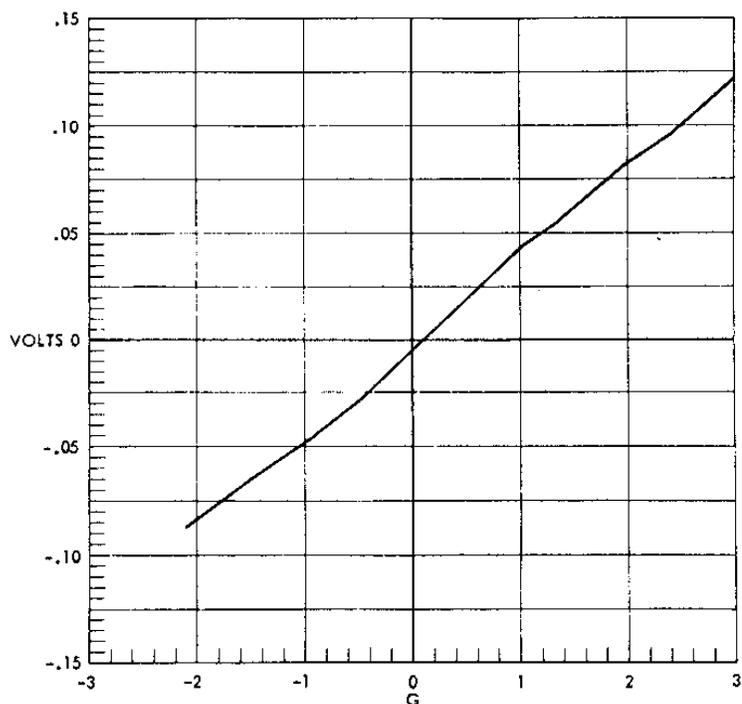
SENSOR LOG ID:
CALIBRATION ID:
CALIBRATION NUMBER:
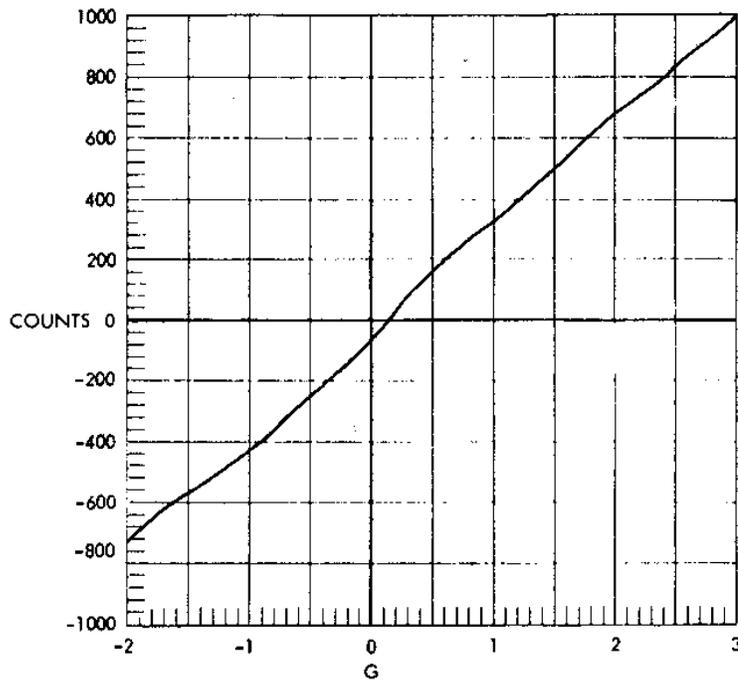CALIBRATION DATE:
CALIBRATION TIME:

TC14511

Figure 7. Acceleratometer Output vs Acceleration Input

Figure 8. Accelerometer Input vs Counts Output

Figure 9. Accelerometer Error vs Input

Figure 10. Transducer Calibration Tabular Data

Since all test data systems have at least one discrete multiplexer connector where the discrete signals are normally connected. The test unit can be located where the operator is calibrating the sensor. The same procedures previously described are used for each calibration point. However, since there is no CRT terminal at the test aircraft (unless it is within reasonable cable distance from the ground station) either the ground station to test aircraft radio voice link must be used or the test must be run with no realtime feedback to the operator (assuming the telemetry link is the realtime link into the ground station). If there is no telemetry link then the procedure is to record a few seconds on the PCM tape at each valid calibration point and then process the "cal" tape later in the ground station.

In any case, the same procedures, hardware and software are used for calibrations of sensors in the test aircraft as are used for sensor calibrations in the cal laboratory. Data is automatically recorded on PCM tape for a backup until the data is determined to be acceptable and via operator request is automatically entered into the data base. By running the RMDU recorder at low data rates (approx. 1 7/8 ips) a one hour sensor calibration run even if recorded continuously (instead of in snapshots as earlier described) could be played back through the ground station in less than 2 minutes (at 60 ips or 32 times record speed) so as not to tie up the decomm long for sensor calibrations.

AUTOMATIC GENERATION OF DATA CYCLE MAPS

With software control of most features of the flight test program there are still some areas that are best left to manual implementation. One of these, and certainly one to be considered controversial is design of the flight test data cycle map itself. Automatic data cycle map designs can be done by the computer but the physical restrictions become significant, especially when the data processing software is flexible and can handle any size of data cycle map within IRIG limits.

It is easy enough for the computer to count the number of channels at each defined sampling rate so as to determine how many subframe columns to generate when the highest sampling rate is picked as the mainframe rate and all other parameters are subcommutated (the first restriction). If there is a 4:1 to 10:1 or higher ratio between the second highest sampling rate and the highest sampling rate then the decisions become more complex and it is usually better to use supercommutation. However if the number of channels at the highest rate is a large number (typically more than 5% to 10% of the number of channels at the next highest sampling rate) then the main frame becomes long and complex. Here again to keep the auto-format program reasonable in size and complexity another limitation must be invoked as supercommutation can produce lower total word rates but usually at the expense of fewer spare time slots (channels).

As depicted in Figure 11 a simple data cycle map using supercommutation and Figure 12 the same map without supercommutation each solution has its own advantages and disadvantages. The supercommutated map has the lowest PCM word rate (25% lower than without supercommutation) but it only has two spare mainframe slots for system growth. The map without supercommutation has 31 spare time slots for system growth (44% more channel capacity for only 25% more PCM bandwith). This simple example is complicated enough when the highest to next highest sampling rate ratio is only two to one. If it is three to one or higher the problem is more complicated for at 3:1 another 12 words must be added to the frame length (seven words for the supercomm interval plus the 5 supercomm channels). Under these conditions (3:1 ratios) supercommutation would generate a PCM word rate of 36 kwps with no more spare time slots while the non-supercommutated map could be shortened to a 13 word frame but made 96 frames deep to provide the 125 sps and 62.5 sps rates. This would produce 39 kwps, a slightly higher word rate (approx. 8%) but it would increase the spare channel capacity to 225% (158-chan). If the highest to next highest sampling rate ratios were 4:1 (4000 sps vs 1000 sps) the frame length could be shortened to 12 words (48 kwps) for non-supercommutation while still achieving the same word rate as the map with 4X supercommutation of the 5-chan at 4000 sps/chan.

The main point to be made is that reasonable tests for automatic use of supercommutation can be made but there are many restrictions and the best tradeoff of spare channel capacity vs PCM word rate cannot be automated. Suffice it to say that several years ago three smart programmers spent about 18 man months developing an automatic data cycle map design software program for NASA-DFRC under a 6 man month fixed price contract. When it was completed there were so many restrictions that NASA has not used the program for the design of data cycle maps for day to day flight tests. The format generation software has been restricted to automatic generation of sample map codes from data cycle maps designed by the test engineer and entered into the computer manually.
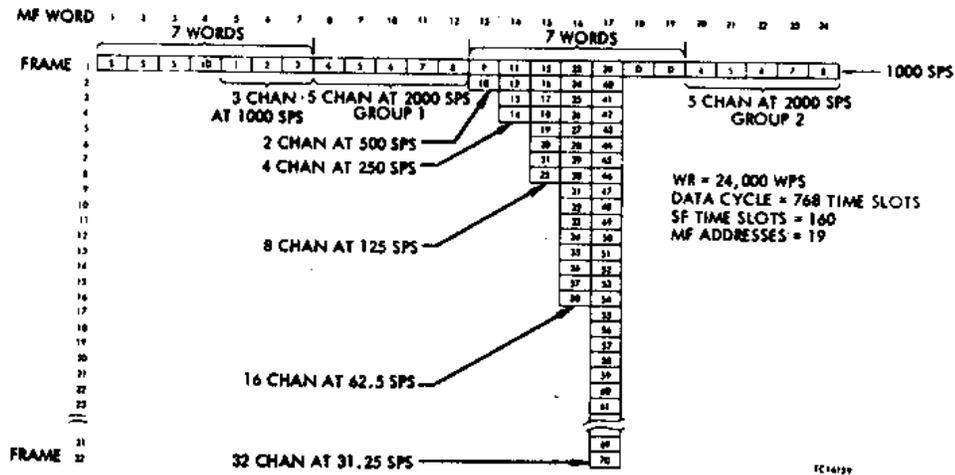
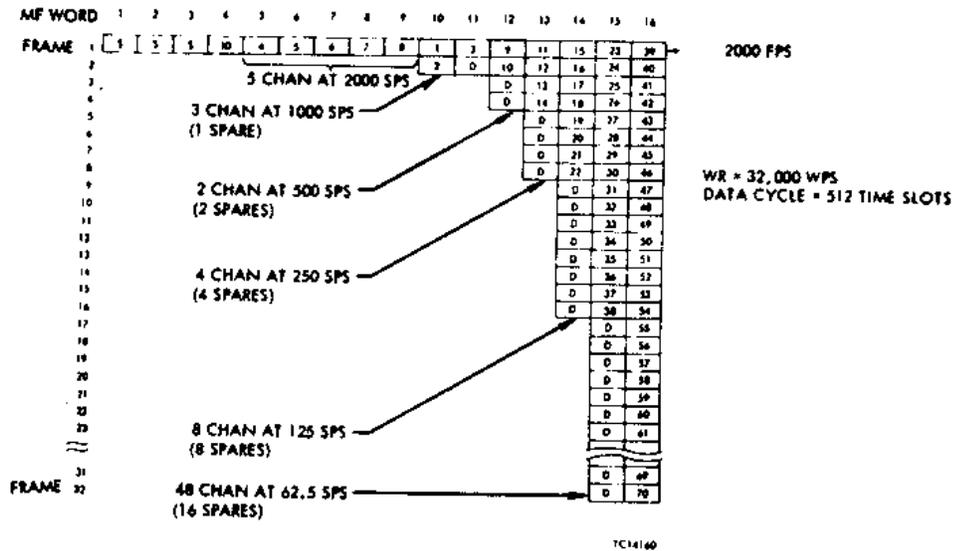**Figure 11. 70-Chan Data Cycle Map with 5-Chan of Supercommutation**

Figure 12. 70-Chan Data Cycle Map Without Supercommutation

CONFIGURATION CONTROL

With more hardware under software control and with realtime processing in the test aircraft, software configuration control becomes a critical item. In order to reduce test costs by not having to go back to the PCM ground station to make a minor change in a data cycle map between flights (such a changing the GPA gain on one or two analog channels) it is necessary to permit the operator to inspect and modify sampling map memory contents from the CCDU in the aricraft.

A password precludes the possibility of anyone but authorized personnel to make these changes, but there still is always the possibility that the flight test engineer may make a change in the aircraft and for some reason not carry that change back to the ground station (via a PLM or manually). To raise a configuration control flag at the ground station, the CCDU modify software has been designed so that a software configuration control word must be located in the last time slot of a data cycle map before a modification can be made to any memory location in any downloadable module. This time slot is an overhead word and when sampled by normal data cycle map execution the memory contents go directly via the dual shift registers to the PCM formatter in the same manner as frame sync codes and other documentary data words.

Before any memory location is modified by an operator download change from the CCDU keyboard, the software reads the memory contents of the configuration (last) timeslot, ensures that it is a configuration word (no card slot address) and increments the stored number represented by that memory address by one, and downloads the revised configuration control number at the same time any other memory locations are changed.

The data reduction software which automatically generated the airborne data cycle map from the data reduction image of the map, also generated the original configuration control number for that program. When the realtime data reduction process starts, the software inspects the configuration control number in the airborne data cycle map and compares it with the number originally generated for that flight. If the numbers are not the same, an alarm is generated and displayed on all of the ground station CRT terminals and logged on the printer.

This configuration control technique cannot prevent problems of this nature but when the test is made as part of the airborne system end-to-end preflight test (via the telemetry link to the ground station) the problem will be detected and with only a few people having access to the CCDU password it should be possible to quickly close the loop and correct the problem.

REFERENCES

(1)   AIAA-83-2747
      Real-time Pilot Guidance System for Improved Flight Test Maneuvers R.R. Meyer Jr. and Cdr. E.T. Schneider, NASA Dryden Research Facility, Edwards AFB, CA