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MULTIPLEX SYSTEM FOR A LIGHT ATTACK HELICOPTER

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ABSTRACT

This multiplex system provides an integrated approach to aircraft system management for light attack helicopters, and features a combination of centralized data handling with MIL-STD-1553B and distributed data processing using strategically located microprocessors. The initial system function is to replace aircraft wiring between systems and between installation areas of the aircraft. This includes replacing various special-purpose control and display devices with a multiplexed control and display unit (CDU) in each cockpit.

The system has access to the majority of all data in the aircraft which facilitates the integration of flight control, stores management, fault detection, and location within the system.

Overall workload reduction is a prime advantage of this multiplex system. Automated checklists and control of new functions such as automatic start and continuous system performance monitoring free the pilot and gunner from numerous housekeeping tasks, releasing them to perform supervisory activities and direct the aircraft as effective weapon managers. The system is designed to provide automatic reconfiguration to improve survivability in the event of battle damage or system failure.

I. INTRODUCTION

In the broadest sense, multiplex is the concept of using a single conducting medium to carry many signals rather than providing point-to-point wiring for each signal. The need for multiplex in aircraft has become clear as aircraft instrumentation becomes more integrated and more digital. The original multiplex concept was to provide a practical means of interconnecting digital systems in an organized and structured manner to save aircraft wiring weight. Today, however, multiplexing is recognized as a powerful aircraft integration tool that offers a degree of sophistication and flexibility that was only dreamed of in the past. The concept is so important that many aircraft in the U.S. Army inventory are being considered for a multiplex system, using MIL-STD-1553B as the multiplex standard.

The use of multiplex dictates an integrated approach to avionics system design. Communication between avionics components is established in a centralized manner. On the other hand, control and computation may be distributed throughout the system. This distribution need not be functional, but may be topological, as best fits the aircraft configuration. These key considerations lead to significant advantages.

- Pilot and gunner capabilities are enhanced - the multiplex system allows an integrated approach to control and display. This approach also allows maximum use of human factors principles to reduce operator workload.

- Weight is reduced - an original goal of multiplex is achieved in reduced wiring weight and, more importantly, in reduced special-purpose panels and displays.

- Survivability is increased - the combination of centrallized communication and distributed control permits the system to automatically reconfigure and select reversionary modes of operation in case of failures or battle damage. In many cases the reconfiguration will be accomplished without any performance degradation.

- Flexibility to match mission - the integrated systems design approach, coupled with enforced communication standards, will allow new equipment to be installed without any major aircraft rewiring.

- Multiplex reduces development risk - the distributed processor approach to control changes many system parameters from hardware consideration to software. On the other hand, multiplexed systems design must take into consideration other effects such as failure modes which do not exist in conventional systems. For instance, failure modes analysis must be performed to ensure graceful degradation of performance in the event of system component failures.

This paper describes a system designed for a light attack helicopter. The system was designed using experience gained on the advanced Attack Helicopter (AH-64) multiplex system. The A129, built by Agusta (Construzioni Aeronautiche Giovanni Agusta S.p.A.) was used as the host vehicle for this configuration study. The multiplex system described is a baseline system which would be optimized with trade studies during a development program. Performance improvement and survivability are the key elements of design for the example system. There are no competitive compromises in this example. Multiplex remote terminals are positioned to exact complete redundancy for flight-critical items. This requirement dictates more terminals and interface hardware than used in a single-string architecture.

Functions included in the system are:

- Flight control/guidance, including automatic stabilization

- Stores management

- Navigation

- Communication/navigation/identification control

- Aircraft power train management

- Electrical power system management

- Fault detection and location

- Airframe management

The aircraft configuration is shown in Figure 1. Aircraft mission equipment is assumed to include: a laser rangefinder, Doppler navigation, helmet display, and FLIR. Weapons include the TOW missile and rockets.

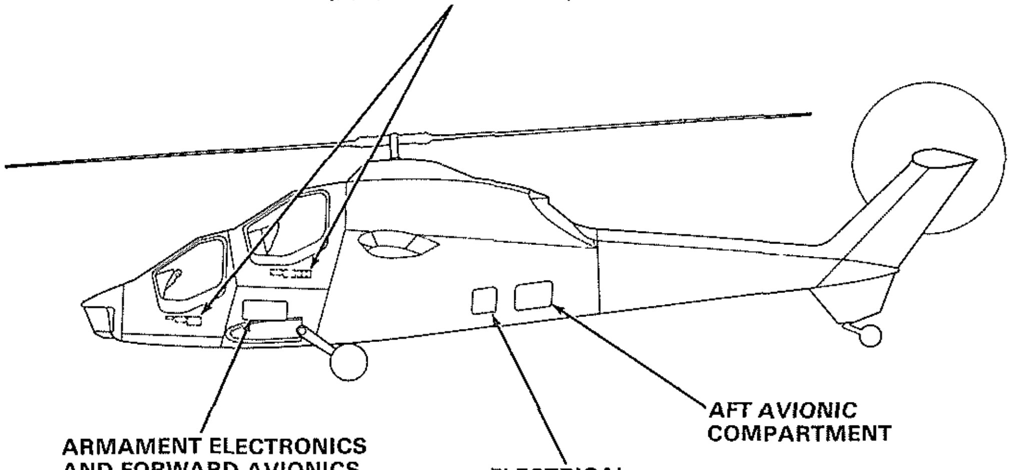

Figure 1: Aircraft Configuration

II. SYSTEM DESCRIPTION

The criteria for system design are:

1) The system must provide fail operational reliability for critical functions - this dictates the core system design which satisfies this first criteria with a dual data bus structure with primary and back-up bus control functions. Each multiplex remote terminal has a single-string internal construction; redundancy requirements for critical signals are satisfied with signal cross-strapping between remote terminals.

2) The helicopter must remain flyable when the entire multiplex system is inoperative - this dictates certain dedicated instrumentation in parallel with the multiplex system.

The signal characteristics of each area in the aircraft were analyzed as a first step in the study. Table 1 summarizes this investigation and contains signals sufficient to provide redundant paths for flight-critical signals. This table was used to size the remote terminal requirements for each area in the aircraft.

Assignment of remote terminal functions in the aircraft is an iterative process which must allow for sufficient circuit volume in each terminal for the required signal conditioning. It also must consider system failure modes. In some cases it is necessary to assign two remote terminal functions to a specific area of the aircraft which provide redundant signal paths for critical signals or allow separation of functionally critical signals. For example, attitude data from primary and backup attitude gyroscopes must not interface with the system

TABLE 1: Signal Characteristics

	Copilot Gunner	Pilot	Forward Avionics	Right Wing	Left Wing	Engine	Aft Avionics	Total
Discrete and Switch Input	56	54	20	6	6	36	19	197
Discrete and Switch Output	12	21	45	-	-	26	28	132
DC Analog Input	-	1	-	-	-	43	3	47
DC Analog Output	9	10	4	-	-	4	-	27
AC Analog Input	4	4	-	-	-	4	-	12
Synchro Input	-	-	3	-	-	2	3	8
Synchro Output	5	3	-	-	-	-	5	13
Serial Digital In/Out	1	4	7	-	-	-	3	15
Tachometer Input	-	-	-	-	-	12	-	12
Lamp Drive	10	10	-	-	-	-	-	20
Fuze Drive	-	-	-	26	26	-	-	52
Squib Drive	-	-	-	30	30	8	-	68
DC Power Control	12	20	12	2	2	44	14	106
AC Power Control	5	2	6	-	-	2	1	16
Total	114	132	97	64	64	181	76	725

through a single remote terminal. Therefore, remote terminals in immediately adjacent areas of the aircraft were allowed to assume the role of redundant interface, if required.

As a result of this study, one terminal was found necessary in each of the copilot, pilot, forward avionics and wing areas. Three terminals were assigned to the combined engine and aft avionics areas. Signal cross-strapping is provided among the three terminals in the forward area and the three in the aft areas. No redundancy is required for signals which interface with the two terminals in the wing area.

The system must contain two bus controllers to satisfy redundancy requirements of the core system. The role of the bus controller is to direct data from terminal to terminal throughout the system. Military Standard 1553B allows four modes of communication:

- Controller to remote terminal or "receive" command
- Remote terminal to controller or "transmit" command
- Terminal-to-terminal data transfer command
- Controller to all terminals or "broadcast" command

A signal bandwidth study was conducted for the example system which revealed that only a small part of the data bus capacity (48,000 data words per second) is required for the system in normal operation, using only the first two communication modes. The system design was therefore restricted to these two modes to avoid the integration and hardware specification complications of terminal-to-terminal and broadcast modes.

The bus controller must contain sufficient programmed intelligence to sort and repackage data messages for each terminal in the system. In some cases this function will change with system mode or with system configuration. Within the system, other programmed intelligence must supply data scaling and computation for flight control, navigation, aircraft management, etc. For this system, the bus controller and data processing functions are combined and are hereafter referred to simply as the bus controller.

Under normal operations either bus controller has full bus control capability. It is not, however, mandatory or even desirable that all data processing functions be duplicated in each bus controller. This system is configured so that the second bus controller can be accessed the same way as any other remote terminal by the bus controller in command. This configuration is significant for the following reasons:

- The in-command bus controller may exercise and test the backup bus control function over the data bus without transfer of full control to the second processor.
- The second bus controller can be used as a system data processor, thereby doubling the available data processing facility of the system in normal operation.
- Transfer of the system state vector is accomplished over the data bus to reduce transient effects when bus control responsibility is exchanged.

The system is configured so that data processing functions are independent of actual bus control and are divided between the two bus control processors. Where data processing functions must be redundant (such as for automatic stabilization), instructions are carried in both processors. In the event of a processor failure, the data processing roles of the failed processor are assumed by the remaining unit. The redundant data processing need not be identical. Therefore, it is possible to incorporate dissimilar redundancy within the software of the system. This overall configuration allows for maximum flexibility during system development and for future system evolution and growth.

The processor selected for this multiplex system is the Sperry SDP 175 which is capable of over 600,000 operations per second. It is a 16-bit, single-precision processor with 96 basic instructions. Memory addressing includes base relative and register indirect modes. Twenty-four thousand words of read-only memory, two thousand words of random access scratchpad memory, and one thousand words of electrically alterable nonvolatile memory are included within each processor. A special microprogrammed sequencer provides for data bus control of the processor.

This data processor was originally designed to provide aircraft flight control for fighter aircraft fly-by-wire systems. A memory size and timing analysis for the light attack helicopter multiplex system indicated that this processor configuration can handle all data processing for the tasks listed in the introduction and provide room for 50 percent growth.

The bus control function can be collocated with any terminal in the system. The choice for this system is one bus controller with the forward avionics remote terminal and one in the engine remote terminal. This choice was made to equalize the chassis requirements among the components of the system. The chassis and construction of the remote terminal and bus control hardware were found to be available directly from the components and hardware now used in the AH-64 multiplex equipment. A remote terminal with collocated bus controller is shown in Figure 2.

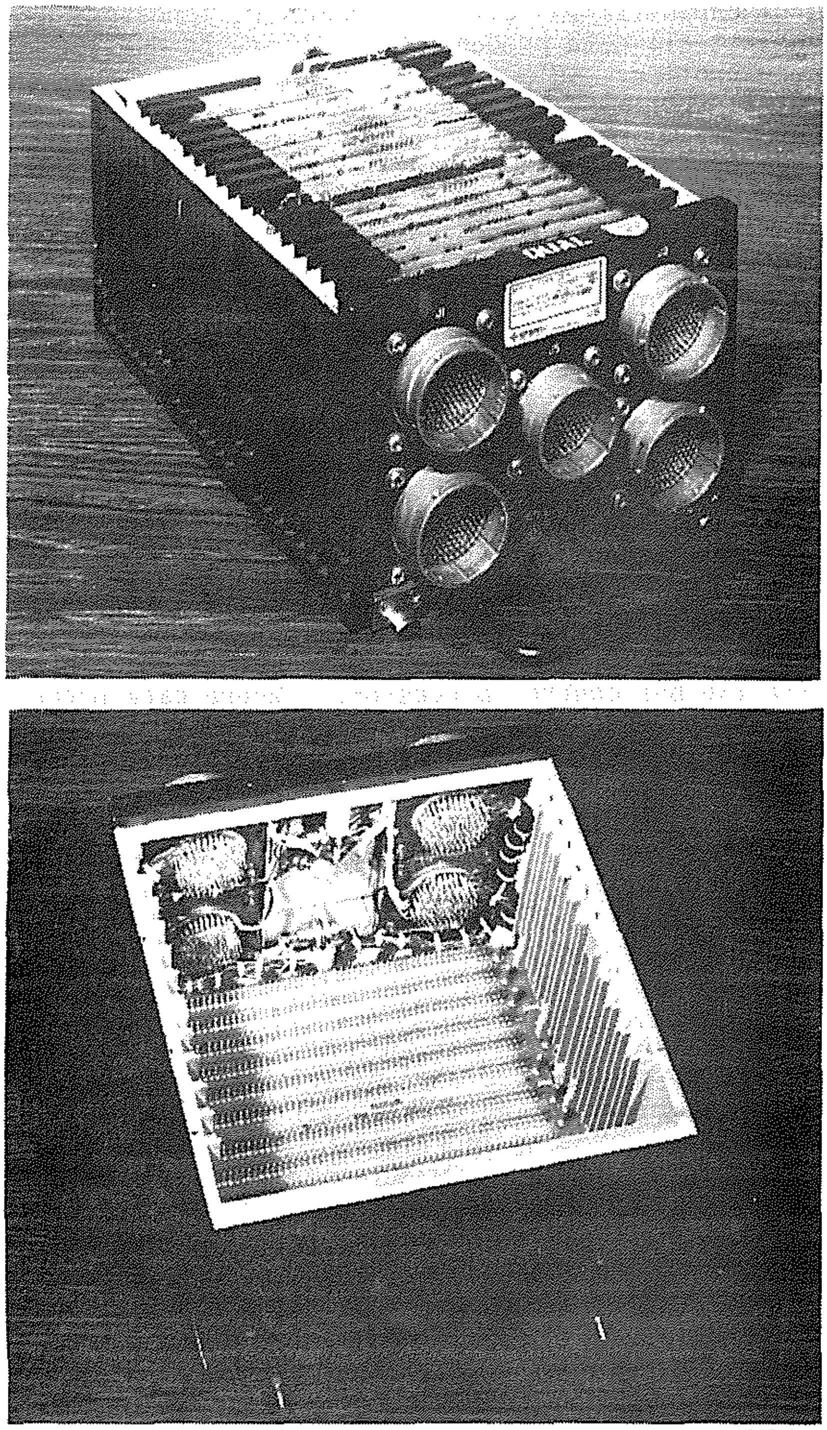

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Figure 2: Remote Terminal with Bus Control

The physical characteristics of the various components of the multiplex system, including controls and displays, are shown in Table 2.

TABLE 2: Physical Characteristics

Item	Where Used	H x W x D (inches)	Weight (lbs)
Remote Terminal Type I	Copilot, left wing, right wing, aft avionics	5 x 7 x 7.4	10.0
Remote Terminal Type III	Pilot, forward avionics, engine, aft avionics	5 x 7 x 10.25	12.5
Keyboard Remote Terminal and Video Display	Pilot, copilot	5.75 x 9 x 10	18.0
Remote Frequency Display	Pilot, copilot	5.75 x 1.25 x 3	.6

This equipment list was compared to the list of equipment required for the example aircraft configured without multiplex. The study indicated that a conservative weight savings well over 100 pounds could be achieved with mutliplex. The bulk of this savings is a result of the deletion of dedicated control and display devices in the cockpit.

The system configuration shown in Figure 3 is the starting point for analysis of system failure modes and required signal and functional cross-strapping.

III. CONTROLS AND DISPLAYS

The implementation of multiplexed signal interconnect in an aircraft does not mandate integrated control and display. However, the greatest system advantages are realized when conventional instrumentation and dedicated controllers are abandoned in favor of integrated electronic control and display units. For this aircraft, the basic cockpit configuration uses conventional vertical and horizontal situation displays with an integrated control and display unit (CDU) replacing dedicated controllers. The CDU function is provided by a keyboard remote terminal and video display. The CDU provides the aircraft system management function with access to all avionics and electrical devices. An additional numeric display is included for radio frequency display.

The ability of the pilot to effectively interact with the system is of prime importance in an integrated aircraft. In particular, the keyboard and video display are a focal point of the pilot's mode selection, data entry, and data display transactions in this multiplex system which requires annunciated pushbuttons and operator-prompting to effect an improved cock-

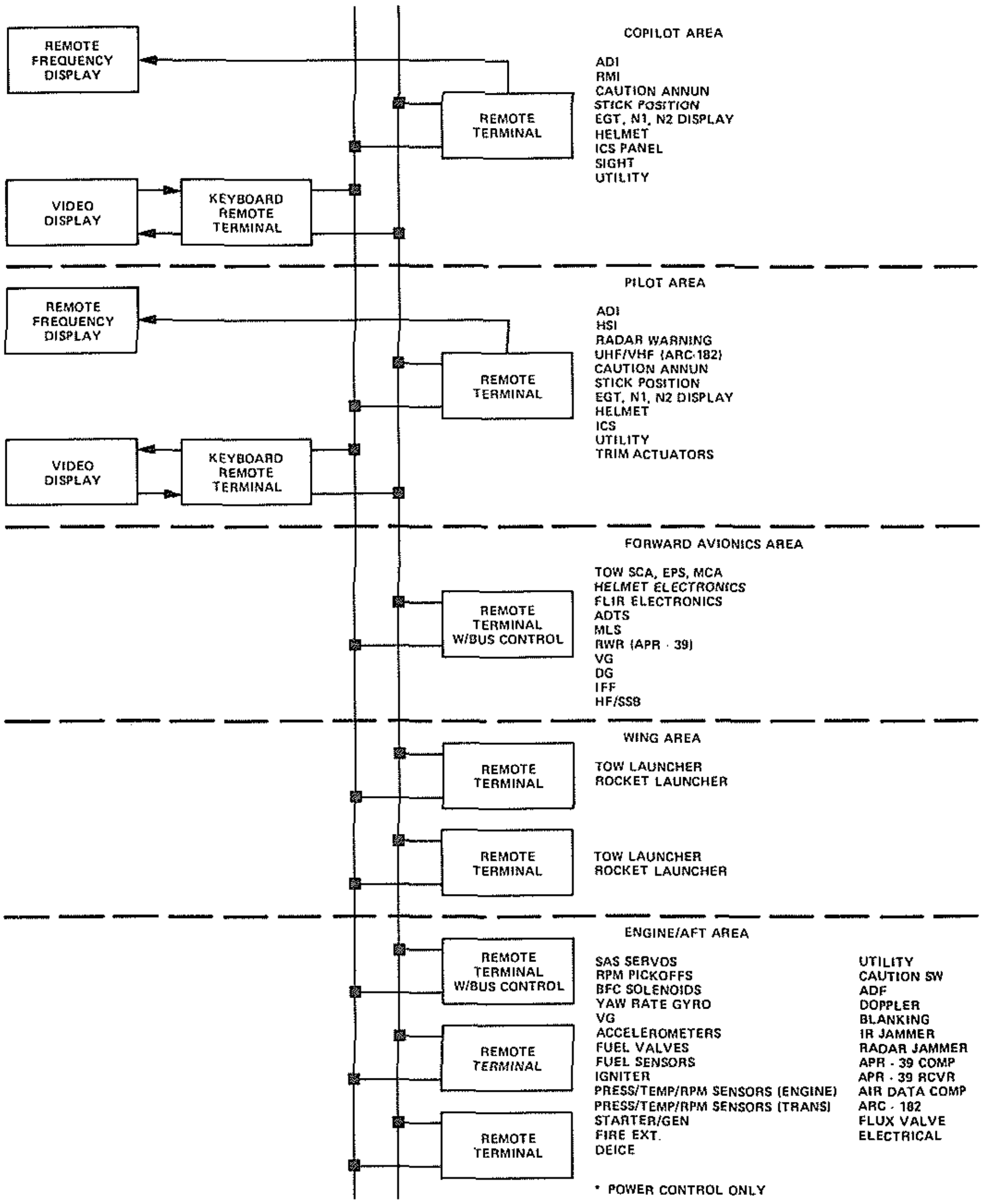

Figure 3: System Configuration

pit environment. The keyboard panel shown in Figure 4 features full alphanumeric data entry. All controls are functionally separated by barriers between adjacent functions keys.

This control and display unit is constructed with a video subassembly which may be separated from the keyboard remote terminal for additional cockpit flexibility. The video signal generation is contained within the keyboard remote terminal. Thus, it is possible to install the video display remote from the keyboard. It is also possible to change the size of the display to meet cockpit layout requirements. Since this is a raster display, the data may be exchanged with other video data in the cockpit.

The CDU shown uses the smallest display considered practical for the functions of this system.

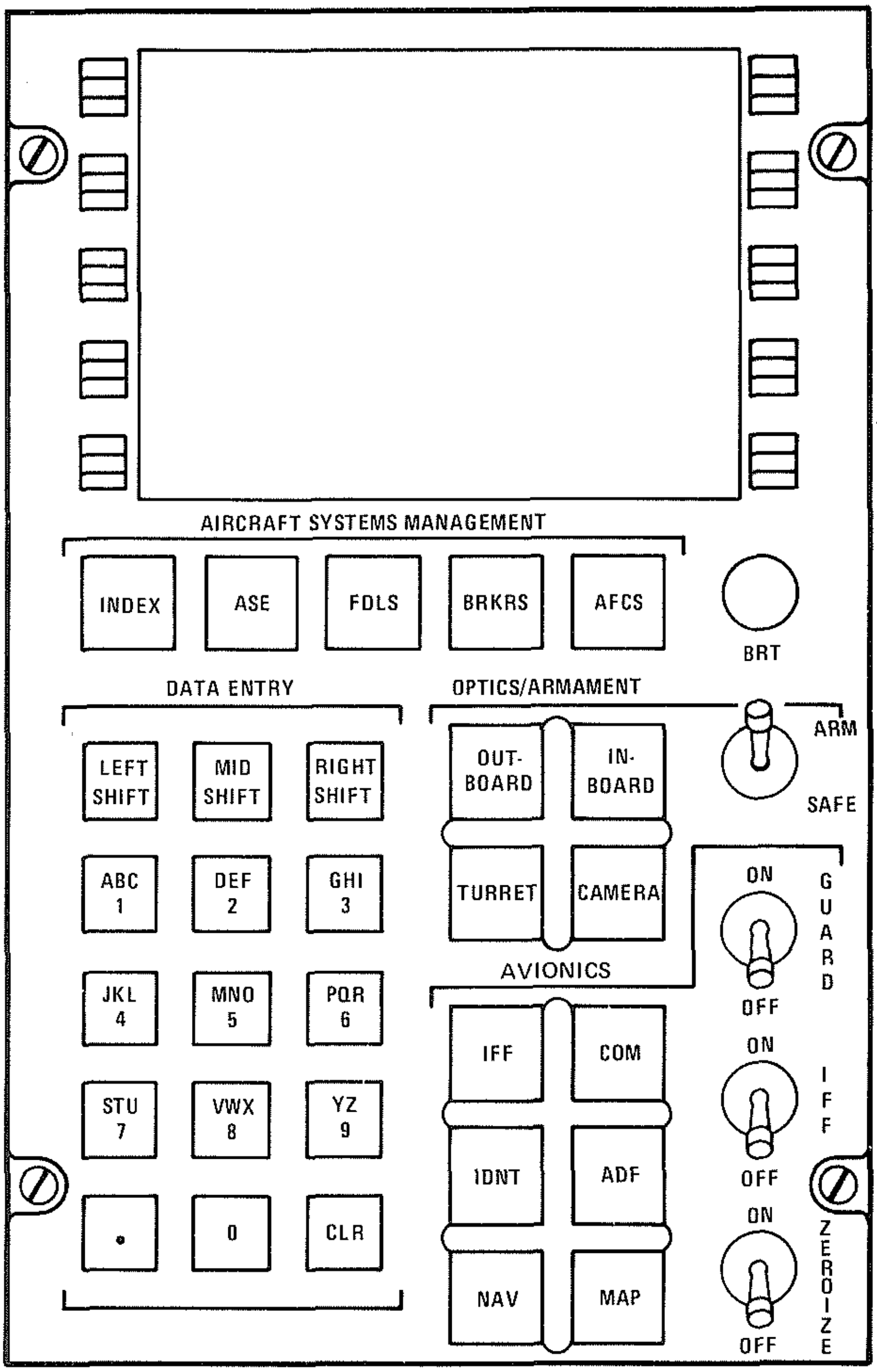

Figure 4: Control and Display Unit

The system controls and displays are expandable to include other dedicated display functions. For example, the incorporation of an electronic attitude director indicator function is immediately available to the system. All data required for the display is already available in the multiplex system. Symbol generation and electronic display actually reduce some of the input/output requirements of the system. Cockpit layouts were done for both the pilot and copilot gunner stations, using this concept. An example configuration shown in Figure 5 demonstrate a practical level of aircraft display integration for a light attack helicopter.

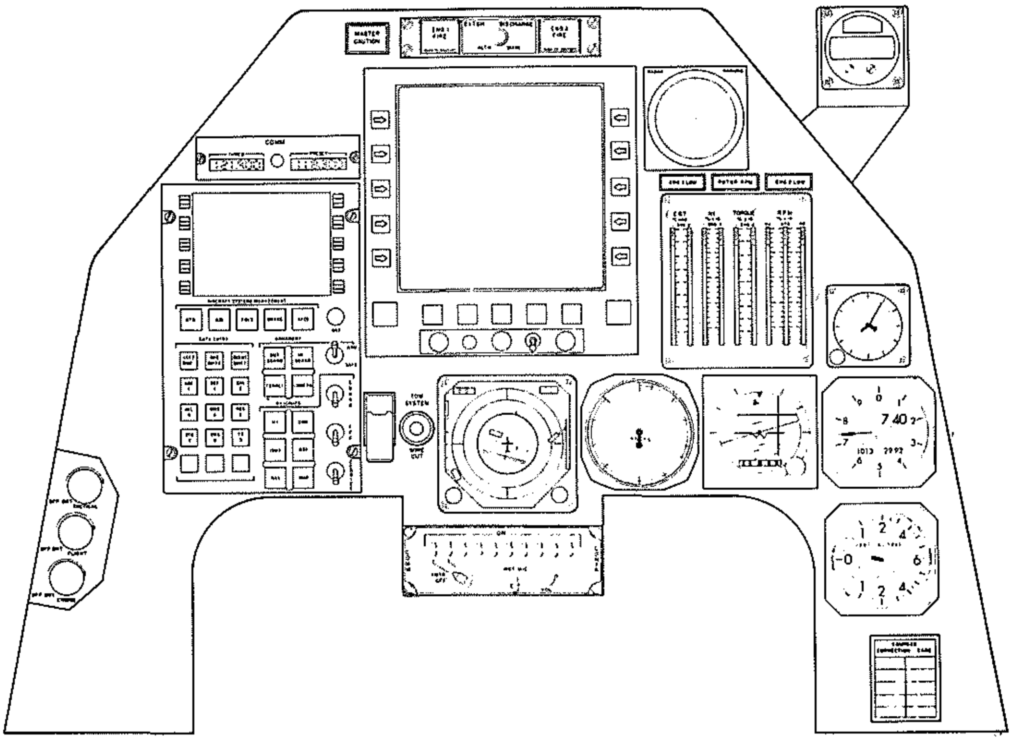

Figure 5: Pilot's Crew Station

The CDU performs aircraft systems management. This function is available to either pilot. The central multifunction display offers integrated attitude displays and displays for radar or synthetic maps, or it may act as backup for the CDU display. Again, the displays are available in both cockpits. Dedicated displays and backup instruments complete the layout.

IV. SYSTEM OPERATIONS

All system management by the operator is through the keyboard and video display. One master breaker engages the system which automatically initiates in the mode engaged at system shutdown. Normal startup begins with a checklist. The system automatically sequences through the prestart checklist, and prompts the operator each time pilot action is required (for example, to connect shoulder harness or close door). Communication frequencies are requested by the system. If they have not changed since last entered, the operator need not reenter since they are retained by the system.

When the system reaches the point in the start checklist where the crank is to begin, the pilot is told to initiate start. During the crank, the system monitors the start for malfunctions or pending hot-start conditions. Such conditions are then reported to the pilot for action. Here, as in all other system modes, the system provides advisory data to the pilot, but will not initiate corrective action without pilot authorization.

The checklist sequence is an excellent example of selective control and display. The checklist for the front cockpit is concerned only with functions and controls which are accessible to the copilot, while those on the back display concern only the pilot. Even though the displays are identical, specific messages are under control of the bus control processor, and are addressed to the correct display station. Once the start is complete, the system display automatically advances to an index page for mode selection by the operator. In normal operation the mode of each display is selected by that operator. Thus, the pilot may select a checklist mode while the copilot manipulates communication frequencies or navigation parameters. The system will advance the mode of the CDU to the next logical mode at the end of each significant mode. The index mode is the obvious default condition when the next mode is not apparent.

Caution and fault monitoring is displayed on a priority basis. Thus, a particular fault detected by the system will be reported with an urgency commensurate with the current system status. For instance, consider a circuit breaker fault to the microwave landing system. If such a fault occurs while the gunner has a weapon delivery mode engaged and the pilot is in a tactical communication mode, the breaker light will illuminate on both control panels. The fault is low priority in this situation. However, should the fault occur while the pilot has an autoland mode engaged, the breaker annunciators would flash in both cockpits, demanding immediate attention.

This example also highlights one of the main features of the multiplex system: constant attention to system monitoring and housekeeping tasks. The system continuously surveys the entire aircraft to identify and report faults or out-of-tolerance conditions to the pilot. Further, routine calculation can be readily performed within the system. A key point is that the system continues to provide monitoring and reporting throughout all flight modes. In addition, critical conditions, such as overtorque, are recorded in nonvolatile memory for use by maintenance crews when the aircraft returns to home base. The approach in this system is to free the pilot and copilot from housekeeping tasks, allowing them to perform system supervisory activities and direct the aircraft as effective weapons managers.

Normal display modes of the system include startup, cruise navigation, tactical navigation, weapon delivery, and fault/emergency. Functional modes include index, fault detection/maintenance, electrical system (breakers) and autoflight control. Within index, there are several functional modes such as communication, navigation, and weapons. The display and selection of each mode is entirely programmable. Access to any CDU function used inflight can be achieved with a maximum of two key strokes. Each cockpit also contains a remote frequency display that shows the tuned frequency and one preset frequency. These frequencies can be exchanged with one keystroke at any time.

Abnormal operation of the system falls into several categories:

- Operator role-switching

- Aircraft subsystem fault due to loss of a component not in the multiplexed system

- Fault due to loss of a multiplex component

The ability of the operators to switch roles is greatly enhanced by the multiplex system. Total system management is available to either pilot. In conventional systems, circuit breaker panels, Doppler navigation panels, compass system controllers, weapon delivery panels etc, must be selectively placed in one cockpit, and are inaccessible to the other operator. The multiplex CDU places all functions within easy reach of either operator.

Aircraft subsystem faults, such as a gyro or instrument failure, are more readily accepted by a multiplex aircraft. If the system determines a fault through data comparison or from equipment status discretes (built-in-test), the system is programmed to automatically provide data substitution or alert the pilot to the fault. Although the organization of automatic reconfiguration can become very complicated, the degree to which it is implemented is a matter of system software.

Multiplex component failures are the most difficult to handle. Once again, the system is capable of automatic reconfiguration. The program must allow for the failure of each multiplex component in the system and either provide data substitution for each affected function or advise the pilot of the appropriate action to be taken.

V. CONCLUSION

The keypoints of the introduction were addressed in the study and found to be achievable within the framework of a light attack helicopter. Multiplexed wiring and control and display of aircraft subsystems can be achieved with a very significant weight savings. At the same time, the new system is programmable for flexibility during development and able to meet various missions. The integrated approach to control and display has the potential for reduced workload and increased mission-capability through operator prompting and computed performance display. Finally, the survivability of the aircraft is improved through planned reconfiguration of the system in response to component failures.