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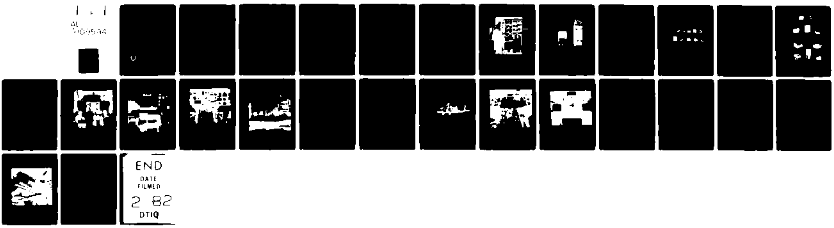

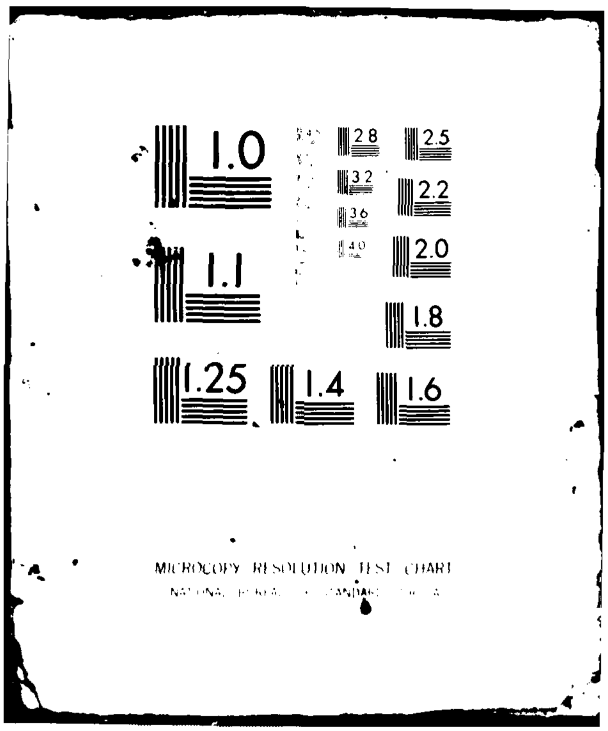
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AVRADCOM

Technical Report-81-E-4

INTEGRATION OF CONTROLS AND DISPLAYS IN U.S. ARMY HELICOPTER COCKPITS

J. A. DASARO
C. T. ELLIOTT
US ARMY AVIONICS RESEARCH & DEVELOPMENT ACTIVITY

NOVEMBER 1981

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1. REPORT NUMBER AVRADCOM TR-81-E-4	2. GOVT ACCESSION NO. AD-A109 544	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Integration of Controls and Displays in U.S. Army Helicopter Cockpits		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dr. J. A. Dasaro Mr. C. T. Elliott		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Headquarters US Army Avionics R&D Activity ATTN: DAVAA-F Fort Monmouth, NJ 07703		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS Headquarters US Army Avionics R&D Activity ATTN: DAVAA-F Fort Monmouth, NJ 07703		12. REPORT DATE November 1981
		13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Avionics	Displays	Microprocessors
Controls	Multiplexing	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Integration of controls and displays in Army helicopter cockpits has become mandatory because of increasing demands on the aircrew and constraints imposed on the aircraft cockpit designers. Expanded missions such as anti-armor, night surveillance, and air-to-air, coupled with the survivability requirement of nap-of-the-earth flight, dictate a radical new approach to cockpit design. This approach must apply the latest technological innovations in the areas of controls, displays, multiplexing, and microprocessors to unburden the pilot. Space, weight and cost constraints placed on the cockpit system designers must also (Contd)

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30. ABSTRACT - Contd

be satisfied. The U.S. Army has recently completed its first full scale engineering development program in the area of cockpit integration, and is currently involved in a more ambitious exploratory development effort. This report presents an overview of these efforts to integrate the helicopter cockpit, including results of simulation experiments and operational flight tests.

The U.S. Army helicopter fleet consists of gunships, scout, utility, and cargo aircraft which use dedicated controls and displays for each crew function. The need for a radical new approach to cockpit design became apparent during a 1975 aircraft review at which time the addition of required equipment to enhance the capability of a gunship was prevented by the lack of panel space in the cockpit. As a result of this, the U.S. Army embarked on a digital avionic program with the immediate goal of developing an integrated avionic system which would eliminate all dedicated communication, navigation, and identification (CNI) control and display units (CDU's) from the cockpit. The CNI equipments were viewed as a well defined set whose control and display functions could be integrated at minimal risk. After in-house government experiments, which provided the expertise needed to prepare a functional specification, the Army made a major investment in cockpit integration hardware. This effort resulted in the AN/ASQ-166 Integrated Avionics Control System (developed by Rockwell Collins and Grumman Aerospace). The integrated CDU developed can be used to in-service or developmental aircraft to alleviate space problems, reduce pilot workload, and increase CNI capability.

The next step was the initiation of an exploratory effort to determine to what extent the integration concepts used successfully in the CNI area could be applied to the remaining cockpit functions. A four-phase effort consisting of design, hardware fabrication, system integration, and testing was established. A cockpit was synthesized for the BLACK HAWK helicopter in which all crew functions were accomplished using multifunction interactive controls and displays. The results of this effort (performed by Sperry Flight Systems and Bell Helicopter) are presented, together with the status of the hardware currently in fabrication and the Army's plans for bench and flight testing. This exploratory effort is called the Army Digital Avionic System (ADAS).

NOTE: The information contained in this report was presented as a paper at the NATO AGARD 32nd Symposium of the Guidance and Control Panel, 5-8 May 1981, Stuttgart, Germany.

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FIGURES

1. INTRODUCTION

The idea for integrating controls and displays in Army helicopter cockpits was first considered at Fort Monmouth in the early 1970's. At that time the Army was conducting experiments in night nap-of-the-earth flight using a variety of sensors (night vision goggles, forward looking infra-red, rotor blade radars, etc.). Early in these experiments it became evident that crew workload was approaching undesirably high levels. In addition, many of these sensors required new dedicated cockpit displays and controls to be added to the already overcrowded cockpit. In this era, the helmet mounted display became an attractive alternative to an instrument panel mounted display for pilot night vision (FLIR, L^3TV) and flight information. While the helmet mounted display provided some relief for the cockpit real estate problem in the area of pilotage, the need for cockpit space for displays and controls for other new equipment (target acquisition designation systems, aircraft survivability equipment, etc.) continued to grow causing a concomitant growth in crew workload.

In 1974, an experimental program was conducted in-house to investigate the feasibility of integrating the controls and displays of the four communication radio functions normally required in Army helicopters (two VHF-FM, one VHF-AM, and one UHF-AM). The program was structured to capitalize on the emerging technology not only in the control/display area, but also in the areas of digital processing and time division digital multiplexing. Figure 1 shows the control/display unit fabricated under this effort. In addition to providing a centralized means of control and display for the four functions, the system provided up to 20 pre-set channels for each radio (a function not contained in the standard radios of the 1970's). Making the pre-sets available together with the centralized control and display was intended to reduce crew workload. No attempt was made in this preliminary effort to solve the problem of reading electronic displays under bright sunlight conditions.

After bench demonstrations at Fort Monmouth, the unit was used in demonstrations to Army helicopter pilots at Fort Rucker, Alabama, helicopter program managers in St. Louis, Missouri, at Bell Helicopter, Dallas, Texas, and Hughes Helicopter, Culver City, California.

As a result of this effort and the demonstrations, it was concluded that pilot acceptance could be obtained for integrated control/displays provided major human factors requirements such as ease of operation, sun light readability, and night vision goggles compatibility could be achieved. From a program manager, airframe developer viewpoint it was apparent that the cockpit space savings, as illustrated in Figure 2, had to be more dramatic. Impetus for further effort in this area of integrating cockpit controls and displays surfaced in late 1975 after it was determined during a helicopter gunship program review that required additional equipment could not be physically installed into the already over-crowded cockpit. With the impetus thus provided, the Army Avionics Research and Development Activity (AVRADA) embarked on a series of efforts which will result in a fully integrated cockpit being evaluated in the Fort Monmouth laboratory this year.

2. INTEGRATION OF CNT: THE FIRST STEP

In early 1976, a digital avionic program was established in the Advanced Systems Division of AVRADA which had two goals. The first goal was to apply

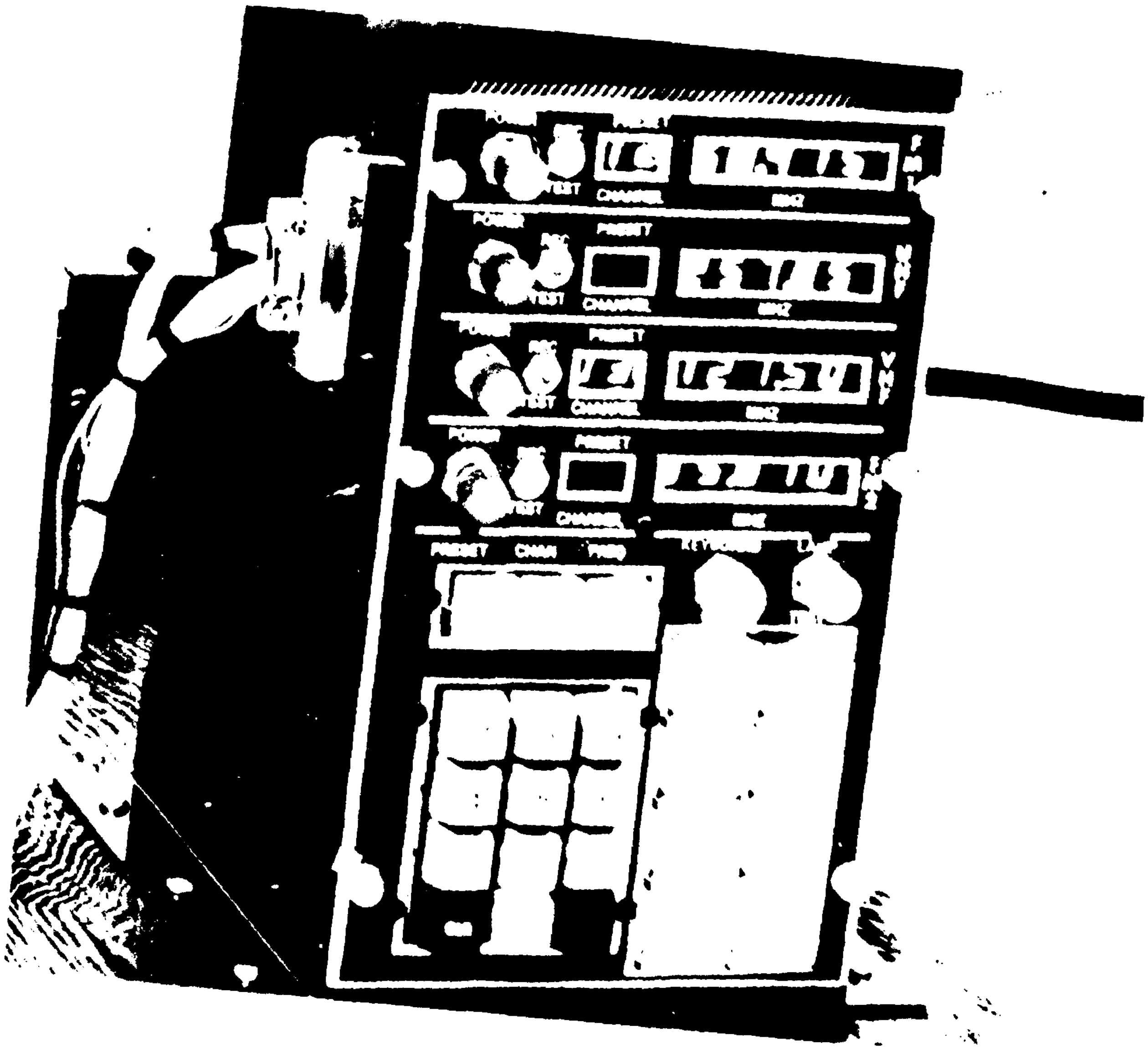

Figure 1. Experimental Control/Display Unit for Communications

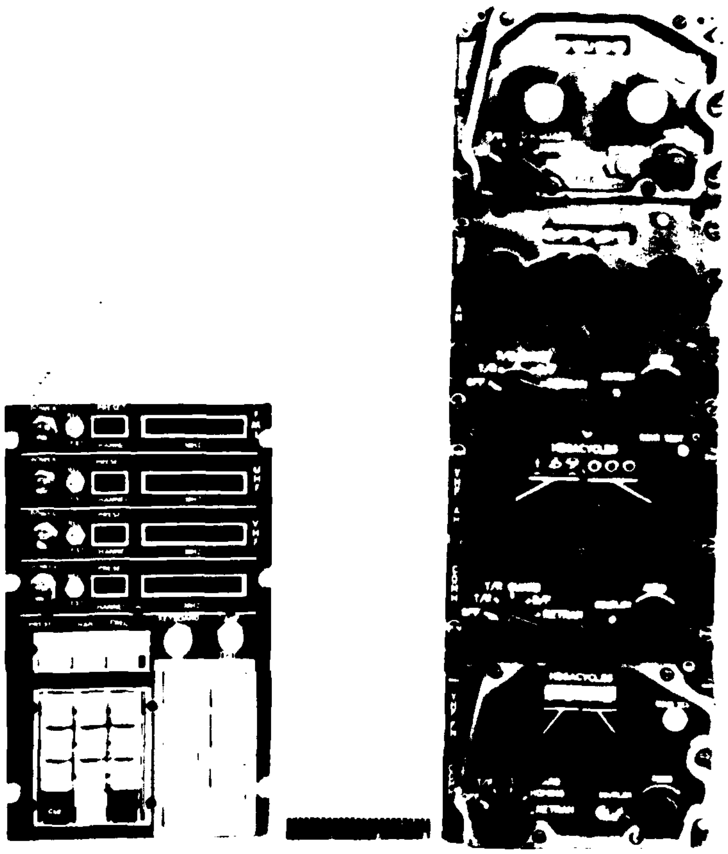

Figure 2. Experimental Control/Display Unit Versus Four Dedicated Equipments

the concept of integrated controls and displays demonstrated in the aforementioned experimental hardware to a subset of functions common to all Army helicopters, the controls and displays of which could be integrated at minimal risk. The integration of this subset would provide an immediate avenue of relief to in-service helicopter which were becoming limited in the area of mission capability improvements due to lack of cockpit panel space and would also be available for new helicopter systems. The second goal was to develop a longer term exploratory program to investigate the feasibility of integrating all remaining cockpit management functions.

To meet the first goal, all functions in the area of communication, navigation, and identification were examined. These functions were common across the fleet and risk is minimized since, for the most part, only switching functions are involved rather than true computation. The final subset arrived at consisted of all the communication radios, the VOR, ILS, marker beacon, ADF, IFF, doppler radar navigation system, and the communication security devices. Integration of the control/display functions for these devices would, on the average, eliminate from the cockpit the equipments shown in Figure 3. Typically, the avionic functions in this subset require approximately 260 square inches of cockpit panel space. By applying control/display integration concepts, the above functions can be accomplished in as little as 40 square inches.

An intense effort was then undertaken in AVRADA to develop a specification which functionally described an Integrated Avionic Control System (IACS) from both a cockpit control/display perspective and an electronic architecture perspective. A joint working group was established which included representatives of the combat elements. From this group a number of requirements in the cockpit area were developed. Of significance were the requirements that:

a. the integrated system be fault tolerant in the sense of no single point of failure (this applies to both the electronic architecture, including processing, and the cockpit control/display elements),

b. the cockpit displays be readable in bright sunlight up to an intensity of 10,000 foot-candles,

c. the cockpit displays be dimmable to levels compatible with airborne night vision goggles,

d. a capability to switch from one pre-set frequency to another or one pre-set destination to another be provided which does not require the crew member to look at the display,

e. a single one line optional status panel be provided which could be mounted near the top of the instrument panel to inform the crewmember as to what frequency would be transmitted if the keying switch were activated and the state of the security equipment, and

f. automation of emergency functions, such as zeroize and guard channel activation be provided to the greatest extent possible.

Decisions were then made in the Department of the Army to solicit industry for an engineering development effort and award two contracts to provide for competition.

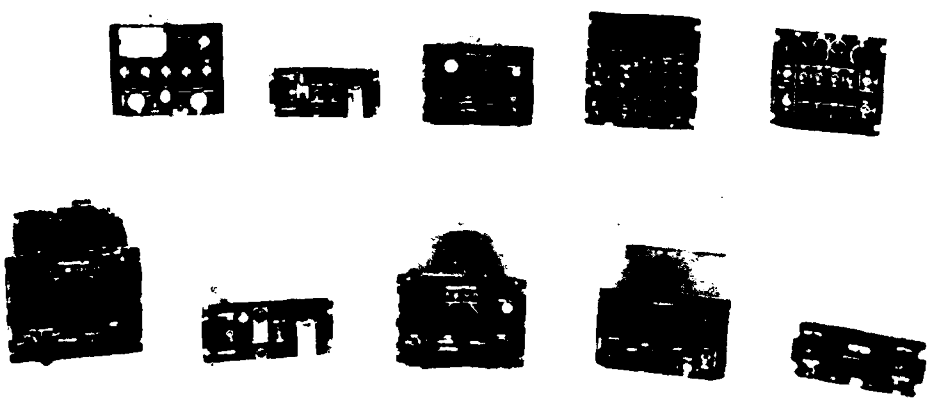

Figure 3. Typical Army Helicopter CNI Controls/Displays

The results of the competitive developments which were conducted by Rockwell Collins and Grumman Aerospace are shown in Figures 4 and 5.

While the contractors used slightly different technologies to accomplish the objectives, the results were essentially the same. In each case a primary control panel (shown in center of Figures 4 and 5) was developed from which all the CNI and associated security equipments could be operated. The cockpit designer had the option of specifying either two primary control panels or one primary control panel and one secondary control panel (shown left front of Figures 4 and 5) as a function of crew size or fault tolerance requirements. As specified, the secondary control panel was to provide a minimum capability for emergency situations. The specification requires it to control one VHF-FM radio, one VHF-AM radio, and the ADF as a minimum. Both contractors, however, expanded the capability to include practically all of the functions of the primary. The essential difference is in the one line of alpha-numeric display versus the multi-line capability of the primary. The status panel (shown right front of Figures 4 and 5) is a small one line display which provides frequency and mode status information of the active radio. All goals for the system, previously mentioned were achieved. A typical Integrated Avionic Control System installation is depicted in block diagram form in Figure 6. Note that all interface between the cockpit and equipment bay is via the standard (MIL-STD-1553) time division serial data bus which is dual redundant. Thus only two twisted shielded pair wires are required to interconnect the cockpit with the equipment bay. The interface units (shown in rear of Figures 4 and 5) are used primarily to interface with the controlled equipments.

The development of the primary control panel established a common set of operational rules which the crew can learn in order to operate a wide variety of avionics functions. Previously, as can be seen in Figure 3, each equipment had a different method for entering essentially the same kind of data. The displays (CRT in the Collins design and fiber optic incandescents in the Grumman) are sun-light readable, are red for night-time viewing, are compatible with night vision goggles, and are legible in a vibration environment, such as encountered in rotary wing flight. Both designs use an interactive or paging technique[1].

Both contractors delivered systems to the Army during 1979. The testing of the Integrated Avionics Control System consisted of a functional verification on the AVRADA hot bench, engineering verification in a UH-1H helicopter at Fort Monmouth, and an operational verification in a UH-1H at Fort Rucker, Alabama.

To facilitate installation of the system, pallets were prepared for each contractor's hardware. Figure 7 shows the hot bench set-up. In addition to functional verification, the hot bench set-up was used for pilot training. Figure 8 shows the Grumman system installed in the hot bench cockpit and Figure 9 shows the Collins system installed in the UH-1H helicopter. After engineering checkout in the UH-1H at Fort Monmouth, the aircraft was flown to Fort Rucker, Alabama to undergo operational tests. On arrival at Fort Rucker in early 1980, an instrumentation pallet containing a fixed mounted camera, a video tape recorder, and a time code generator was installed (see Figure 10).

The test objectives at Fort Rucker were to assess (1) the operational feasibility and military utility and (2) the operational advantage over the

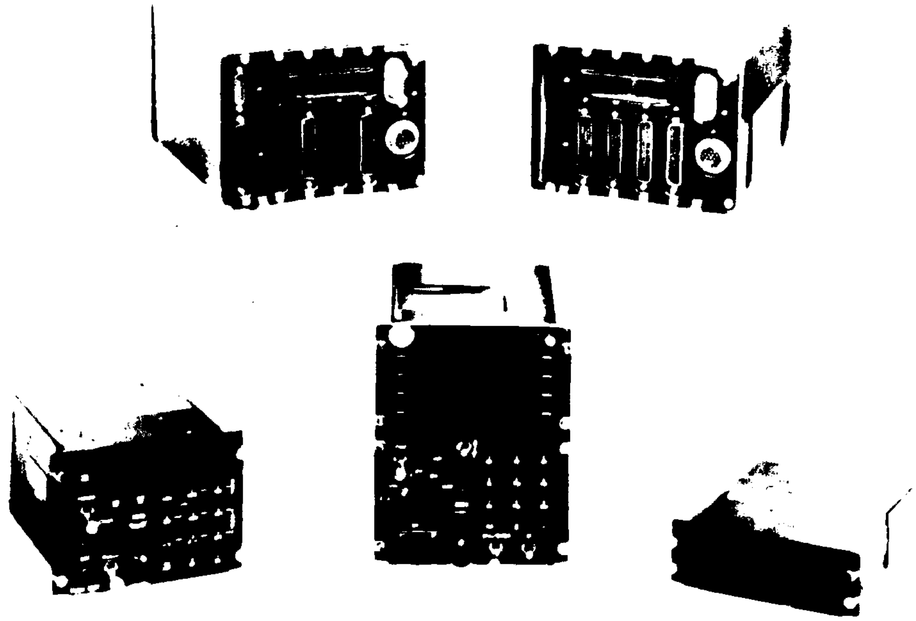

Figure 4. Collins Integrated Avionics Control System, AN/ASQ-166 (XE-2)

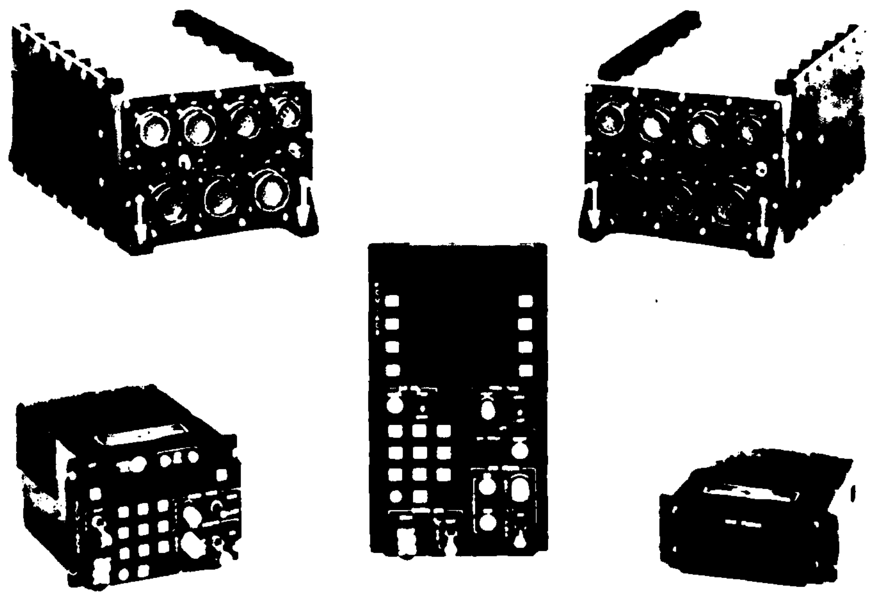

Figure 5. Grumman Integrated Avionics Control System, AN/ASQ-166 (XE-1)

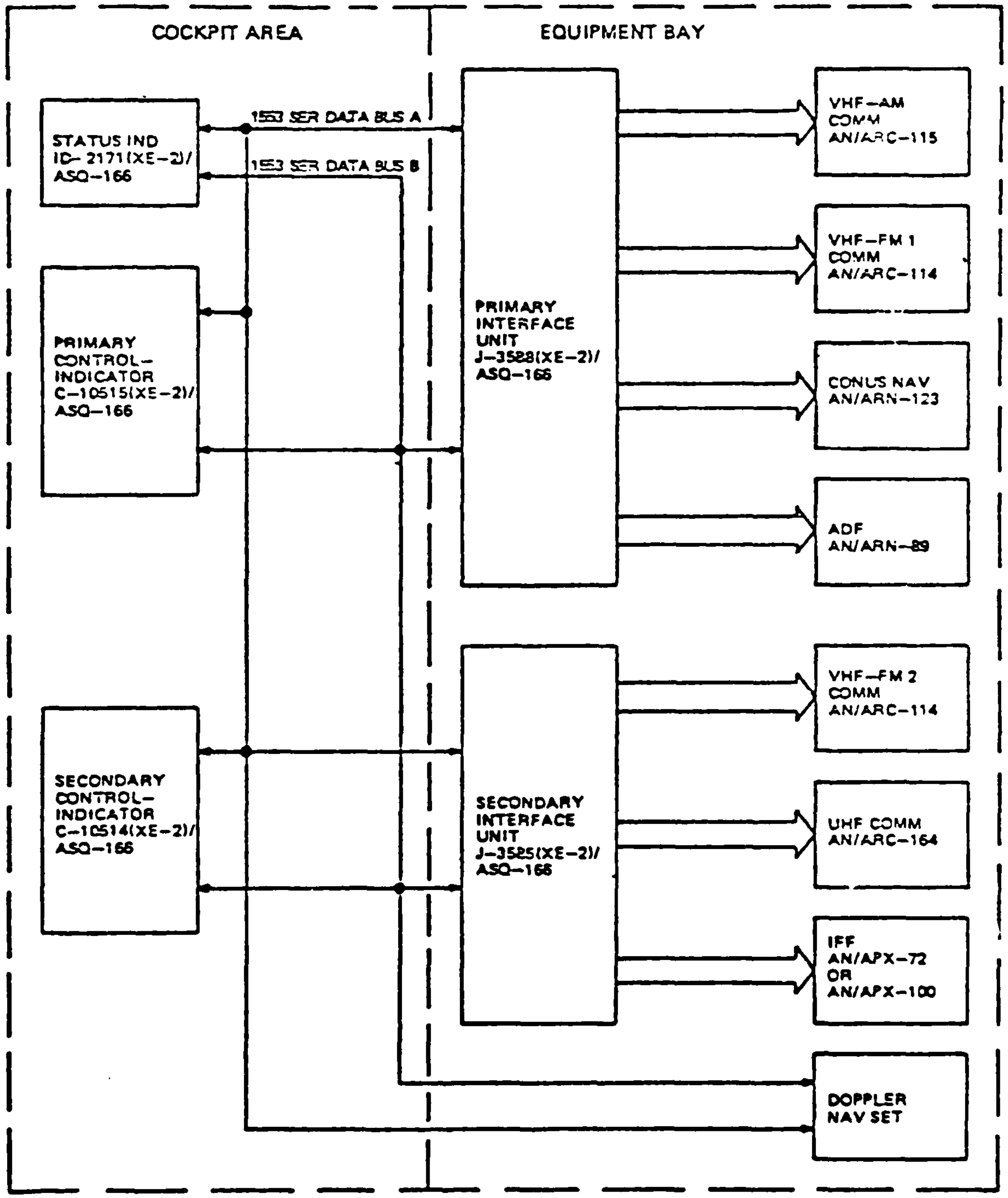

Figure 6. Integrated Avionics Control System, AN/ASQ-166

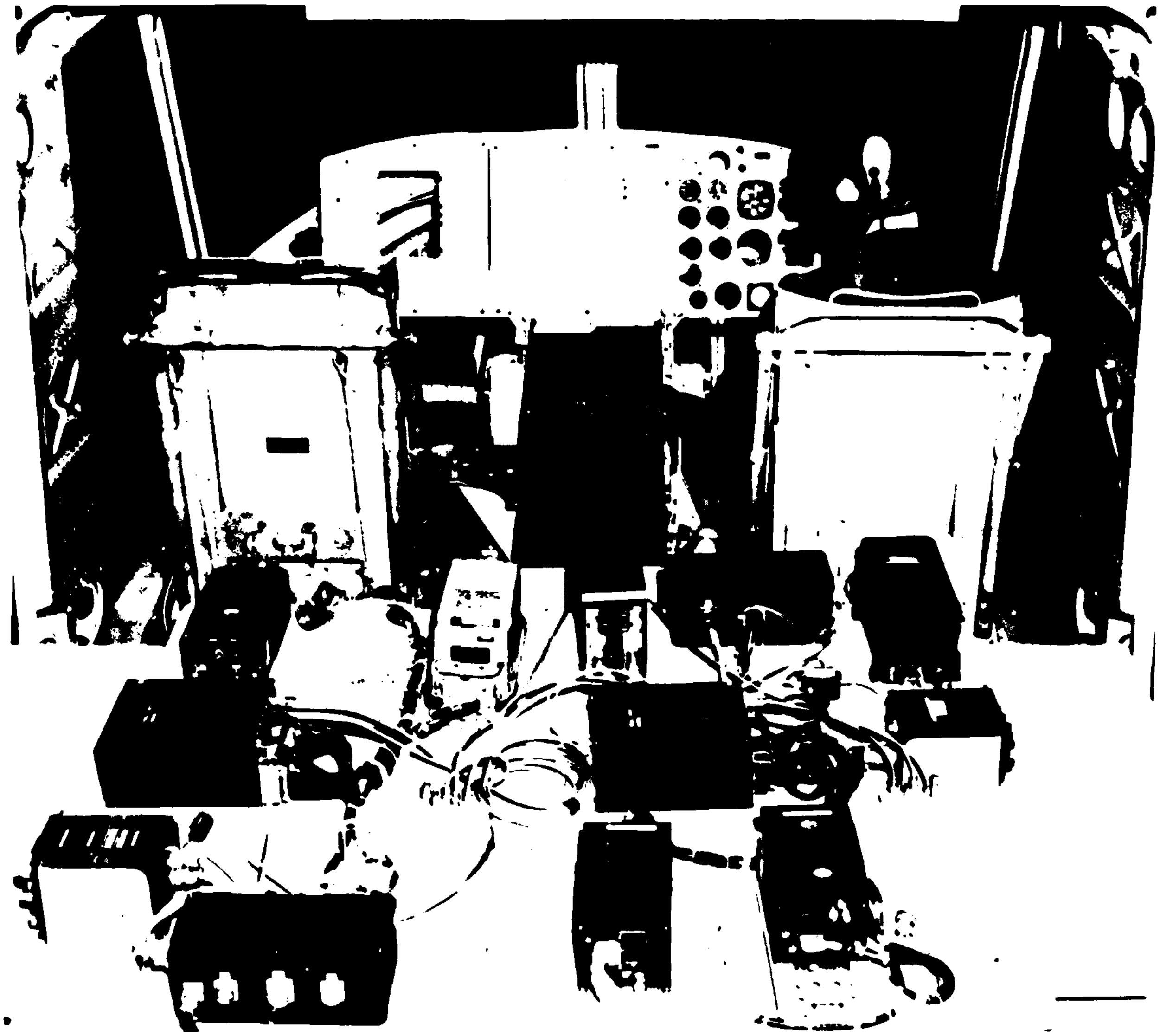

Figure 7. Integrated Avionic Control System Hot Bench

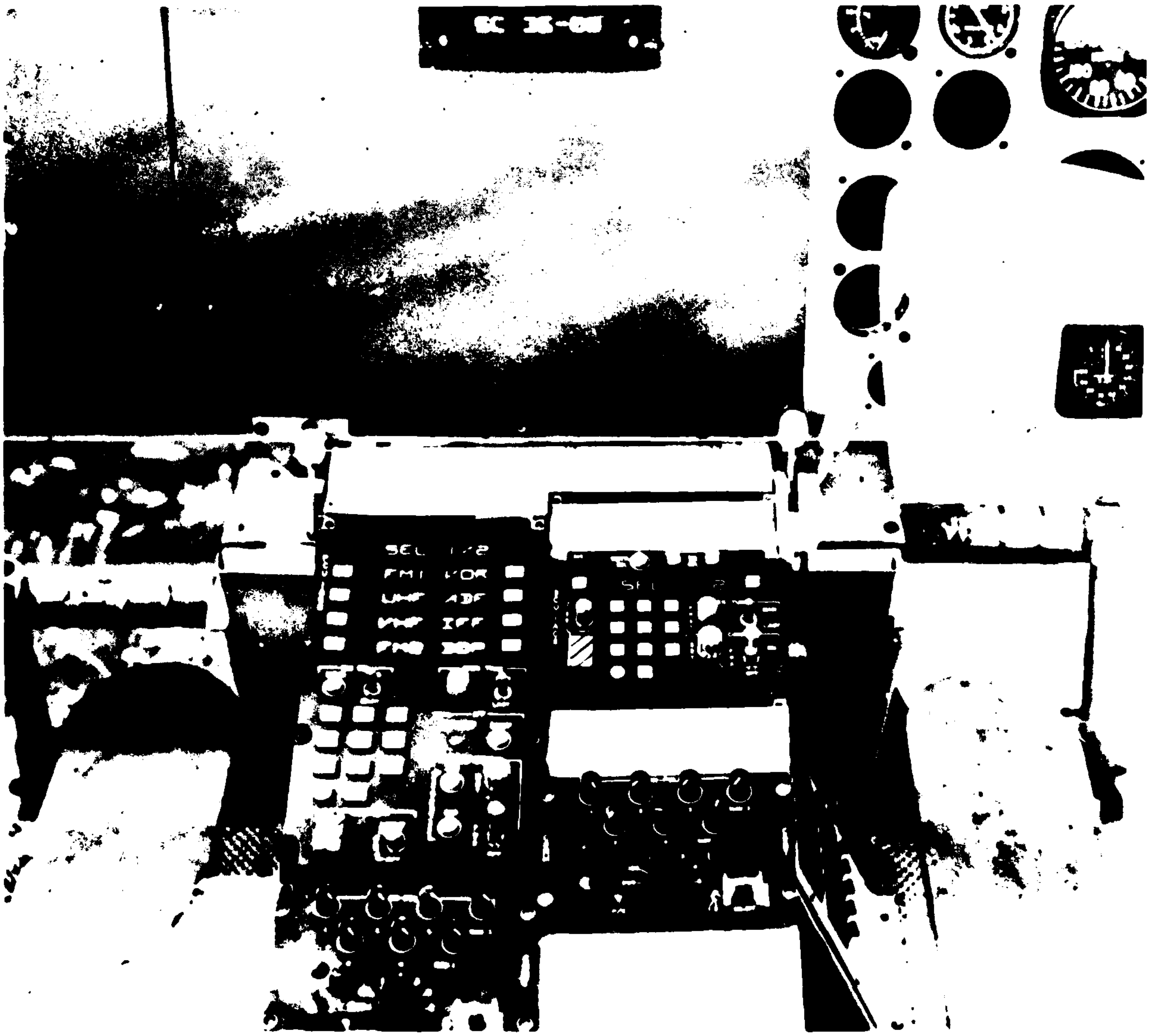

Figure 8. Grumman System in Hot Bench Cockpit

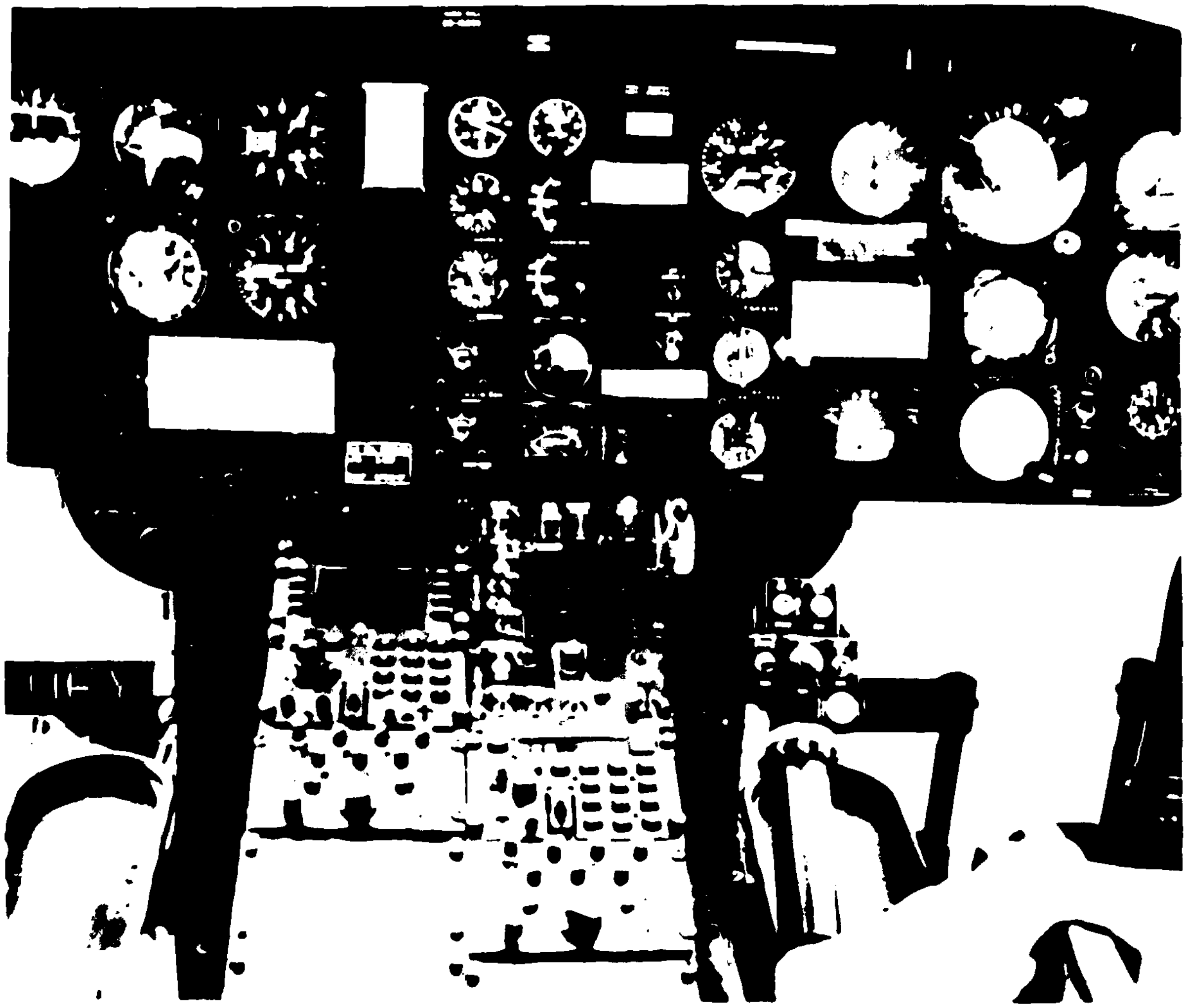

Figure 9. Collins System in Army UH-1H

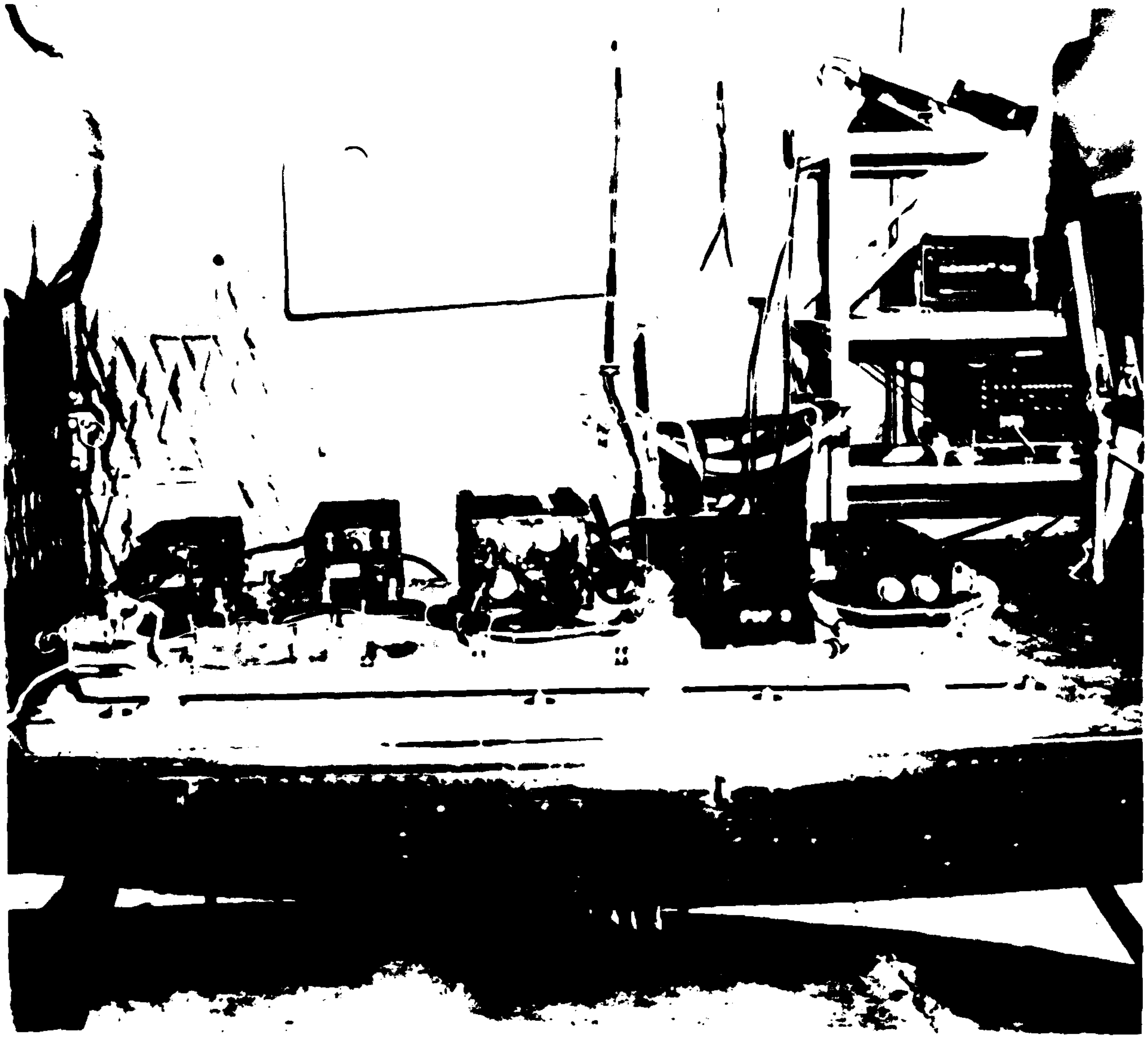

Figure 10. UH-1H with Integrated Avionic Control System (One of Two Pallets) and Fort Rucker Instrumentation Rack

present avionics configuration. To attain the second objective, a baseline in a conventional UH-1H cockpit had to be established.

The methodology used in this operational flight test[2] depended on player questionaires and time-motion studies to conduct the required assessment. Twelve player pilots were used. All twelve flew the standard UH-1H to establish the baseline, then six flew the Collins system and six flew the Grumman System. A 90-minute typical attack mission was used consisting of three 30-minute phases. The first phase was administrative, flown at 1,000 feet altitude. The second phase was low-level flight, at 25 to 50 feet above ground level. The third phase was nap-of-the-earth, flown as close to the earth as terrain and vegetation permitted. Each pilot was assigned 12 tasks per phase. Each pilot performed 6 manual tasks and 6 present tasks with the integrated system, and 12 manual tasks with the standard system. Night flights were conducted using all the controlled avionics and comparisons made (via a subjective questionnaire only) to the standard system.

Assuming time to be a valid measure of pilot workload, the time motion studies (day flight only, 90-minute flights, 36 trials) indicated a significant decrease in workload using the full capability (including pre-sets) of the integrated system. The mean response time to complete a required task for the integrated system (18 trials for each contractor's version) was 3.88 seconds as compared to 6.72 seconds for the standard system. When tasks were performed manually (no pre-sets), no significant increase or decrease in work-load was measured. The subjective workload data indicated that all pilots (100) felt that crew workload was lessened by use of the integrated system in both day and night flight.

As a result of the operational tests, the United States Army Aviation Test Board concluded:

"The Integrated Avionics Control System provides the pilot a cockpit management system that reduces pilot workload. All avionics can now be controlled from one central location. By spending less time inside the cockpit programming different radios, the pilot is able to perform the demanding tasks associated with (NOE) flight more safely and efficiently."

3. THE ARMY DIGITAL AVIONICS SYSTEM (ADAS)

The next step toward integration of controls and displays in Army helicopter cockpits was to determine to what extent the integration concepts used successfully in the CNI area could be applied to the remaining cockpit functions. In late 1978, a four-phase effort consisting of design, hardware fabrication, system integration, and testing was initiated. For approximately 1 year, the design effort concentrated on applying integration concepts to the UH-1H helicopter. Sperry Flight Systems of Phoenix, Arizona was competitively selected to lead the effort and Sperry chose Bell Helicopter Textron, Dallas, Texas to provide assistance in the area of cockpit design. The Bell cockpit design effort had as its goal the definition of a new integrated Army cockpit responsive to both crew and mission requirements using advanced multiplex and display techniques. The previously developed Integrated Avionic Control System was to be incorporated as a fully integrated avionic subset; however, the multiplex data bus architecture would allow for information interchange between any element of the avionic subset and the entire system. The cockpit configuration synthesized by Bell[3] for the UH-1H relied on detailed functional requirements analyses, information transfer analyses, workload assessments, and a survey of Army pilots. The Army Human Engineering Laboratory, Aberdeen, Maryland, provided a detailed mission scenario and also provided information in the area of operational requirements. After an intensive effort lasting approximately 1 year, a cockpit was synthesized which incorporated on a total system basis many of the concepts previously used in integrating the CNI subset. As the results of this synthesis were being assessed and reviewed in the Army, a decision was made to re-orient the effort from the UH-1H to a new production UH-60A BLACK HAWK. The UH-60A is the Army's newest utility helicopter and would provide for a testbed with more weight carrying capability. The new BLACK HAWK was named STAR (System Testbed for Avionics Research) and is now performing the role as a testbed aircraft for the Advanced Systems Division of the research activity. Figure 11 shows the STAR helicopter. Phase 1 of the effort was then extended to reflect the change in helicopter. As expected, the cockpit integration concepts were portable and the differences between the helicopters were readily accomodated by the ADAS.[4] The standard production UH-60A cockpit is shown in Figure 12. A mock-up of the ADAS cockpit is shown in Figure 13. Two 6.8-inch by 6.8-inch cathode ray tube displays will be mounted on each side of the cockpit to handle flight, interactive control/display, and navigation display functions. The flight display will be used to present basic flight information in an integrated format, along with required caution/warning alarms and procedures.

Normally, the flight display function will be presented on the display directly in front of the crew member selecting the function (outer displays in Figure 13). However, the flight display function can be presented on any of the four main displays under reconfiguration conditions. This fault tolerance is a key feature of the digital avionic architecture. The inner CRT's in Figure 13 have line select units mounted *immediately* adjacent on each side. When used with these line select units and the keyboard terminal unit (one each side of center console in Figures 13 and 14). The two inboard CRT displays can be used to present procedures (normal, test, and emergency), engine and fuel status, transmission and rotor status, secondary systems status and control, advisory/caution/warning information, aircraft survivability equipment status, navigation status and mode control and a number of other functions such as command instrument system status and control, aircraft performance guides, and communication operating instructions.

The navigation display function will be used to present navigation/map and status information to the aircraft flight crew. Normally, the navigation display function will be presented on the CRT display directly in front of the crew member selecting the function; however, the navigation display function may also be presented on any of the cockpit CRT displays under reconfiguration conditions.

All CNI control/display functions are performed in the Integrated Avionics Control Systems primary control panel located on either side (top) of the center console. The one line status panel is provided for each crew member. At the bottom of the center console (each side) is an intercommunication control system. The remaining cockpit items whose functions were not integrated are: the aircraft control panel (center bottom of console), a digital clock, and from left to right a copilot's stabilator indicator, a standby airspeed indicator, a

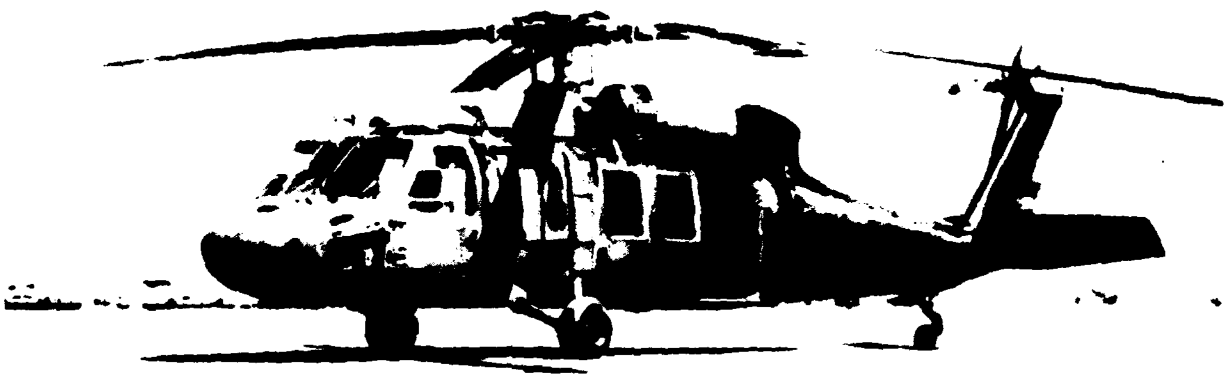

Figure 11. UH-60A STAR (System Testbed for Avionics Research)

Figure 12. Standard UH-60A BLACK HAWK Cockpit

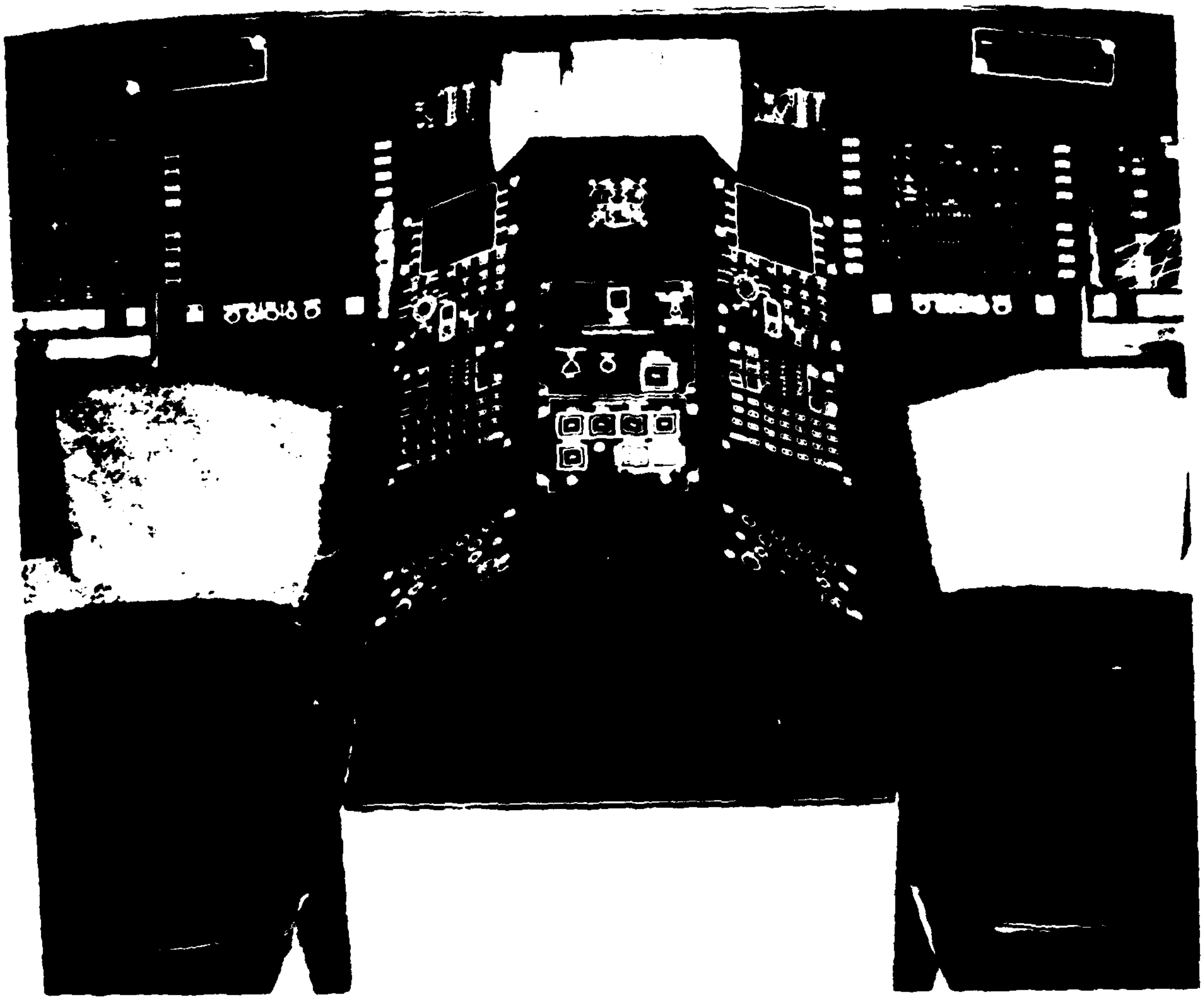

Figure 13. Army Digital Avionic Syster ADAS) Cockpit

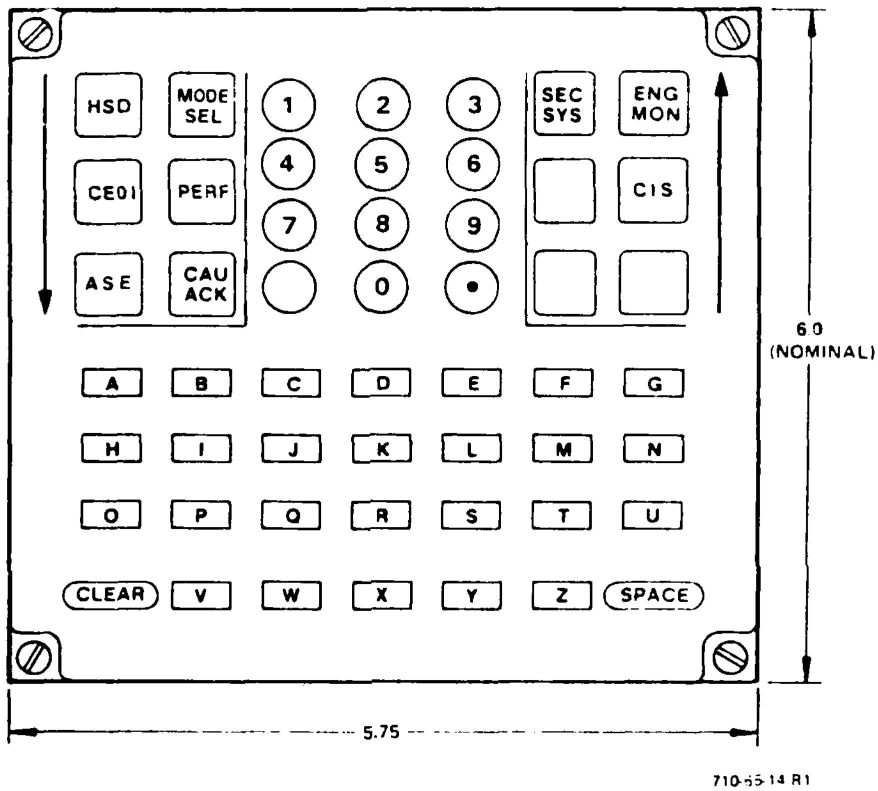

Figure 14. Keyboard Terminal Unit

standby attitude indicator, a standby altimeter and the pilot's stabilator indicator. Not shown in Figure 13 but to be included is a standby compass and a radar signal detector indicator. Figure 15 illustrates what information typically would be displayed on each CRT during cruise flight.

The production UH-60A overhead console (partially shown in Figure 16) will be reduced to the overhead console illustrated in Figure 17.

At this time ADAS is undergoing hardware fabrication (Phase II) by Sperry Flight Systems. Delivery to the AVRADA hot bench is scheduled for the fall of this year. At that time hot bench system testing (Phase III) will be initiated by AVRADA. The key objective of this hot bench testing will be to perform a functional validation to insure that all functions required can be performed. AVRADA engineers will be able to change software as required via a software development station in the hot bench facility. Due to the flexibility of the ADAS architecture, any changes in information format required as a result of the hot bench phase will be able to be incorporated by software modification. At the end of the hot bench evaluation (approximately 1 year), AVRADA will begin installation of an ADAS system into the UH-60A STAR.

During Phase IV, ADAS will be flight tested in the UH-60A STAR. The AVRADA hot bench will remain configured with the ADAS cockpit to provide a flexible system integration tool whereby future subsystems can be first integrated into the ADAS on the hot bench prior to integration and flight test on the STAR. In the near term systems such as the Army night navigation pilotage system[5] and the Army multifunction coherent CO_2 laser radar[6] will be integrated with the ADAS. In the far term, it is envisioned that much of the cockpit hardware will evolve as control and display technology advances (e.g., monochromatic CRT to full color flat panel, etc.) and new cockpit subsystems (such as voice recognition and synthesis) will be added to further reduce crew workload. The ADAS (both hot bench and aircraft) provides the U.S. Army Avionics Research and Development Activity with a digital avionic structure for the entire aircraft system which allows for growth and technology advances in all of the various subsystems.

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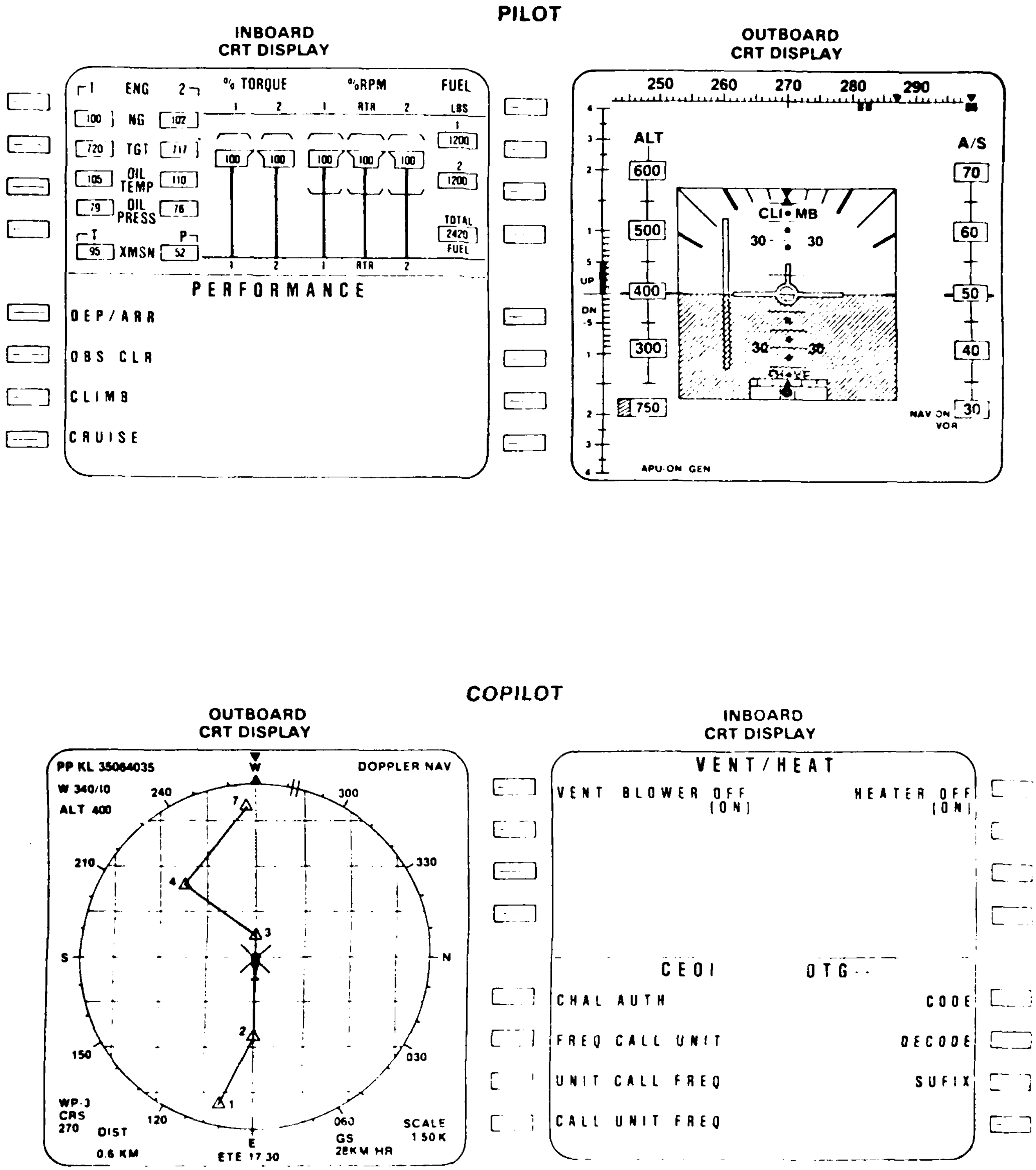

Figure 15. Typical Information on CRT Displays During Cruise

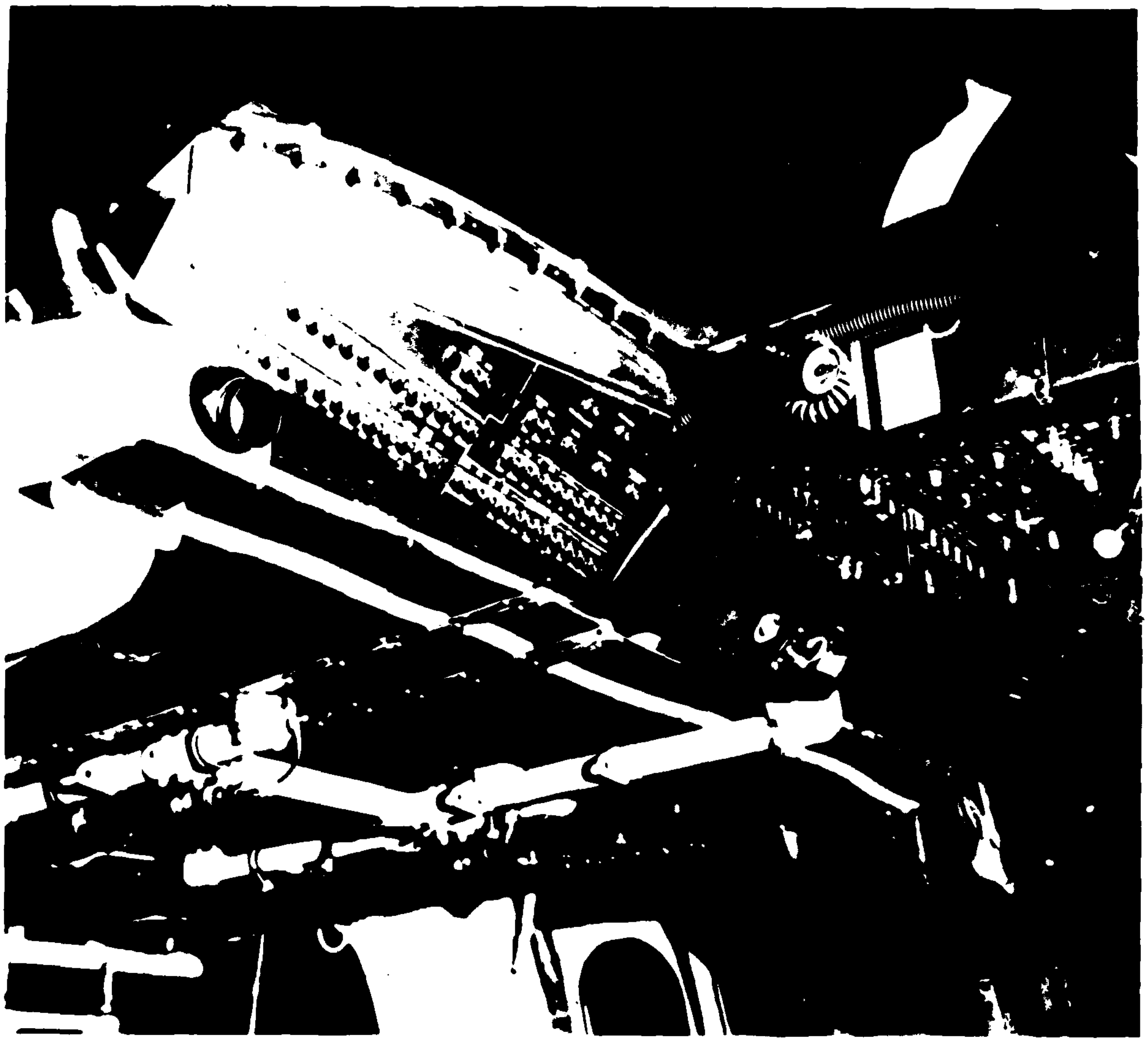

Figure 16. Production UH-60A BLACK HAWK Overhead (Pilot Side)

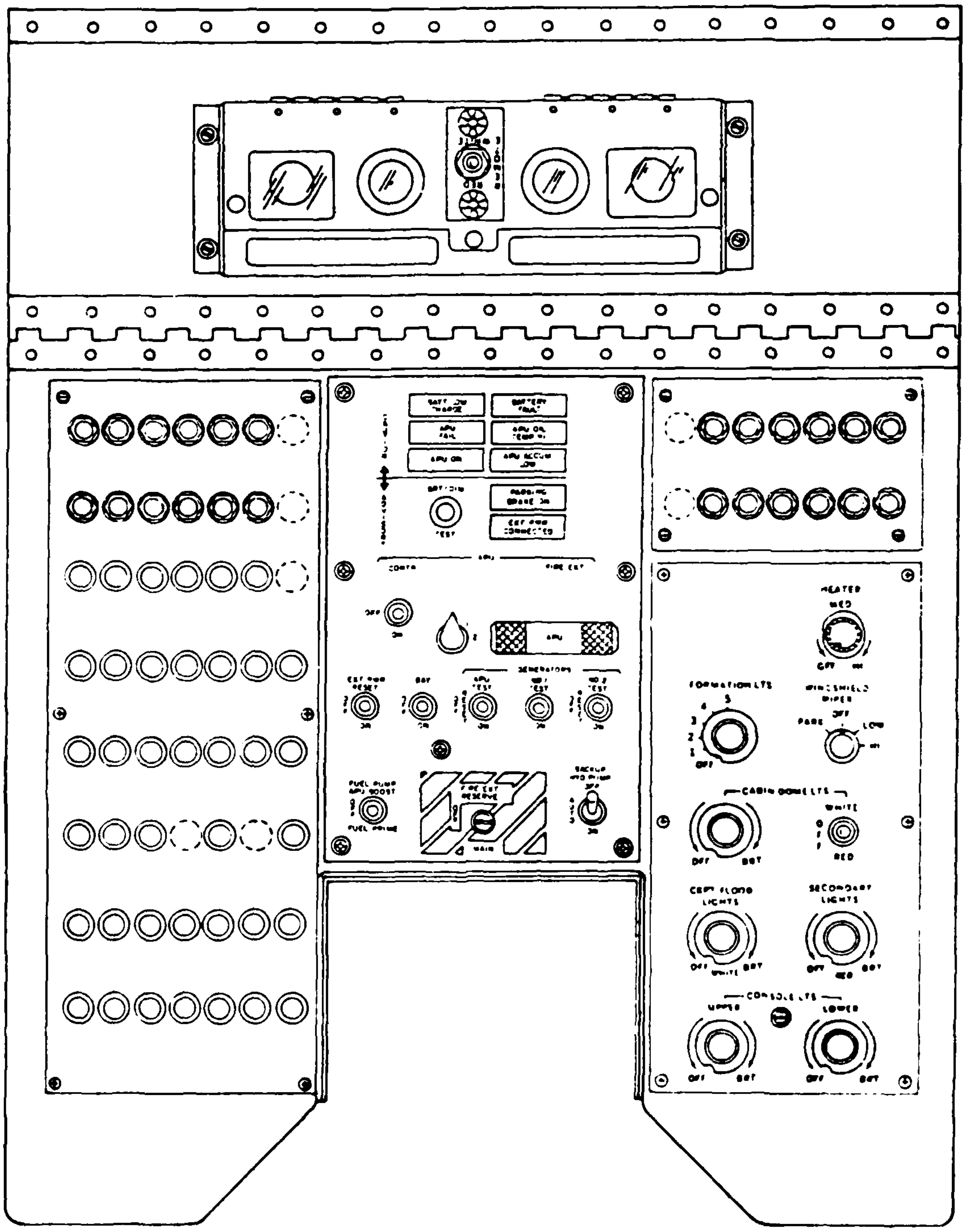

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Figure 17. ADAS Overhead Console

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