

**Avionics System Design Requirements
for the
United States Coast Guard HH-65A Dolphin**

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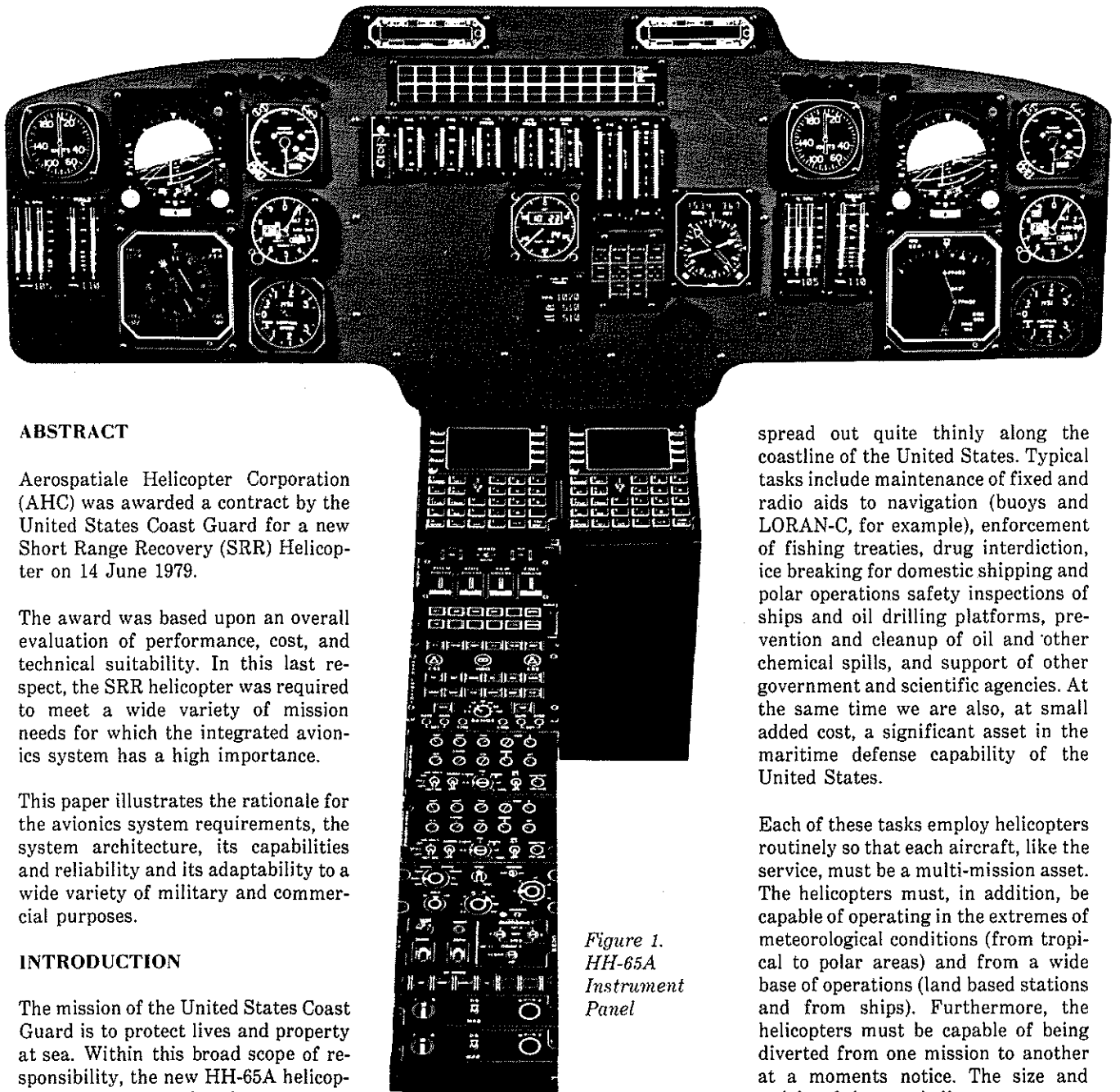


Figure 1.
HH-65A
Instrument
Panel

ABSTRACT

Aerospatiale Helicopter Corporation (AHC) was awarded a contract by the United States Coast Guard for a new Short Range Recovery (SRR) Helicopter on 14 June 1979.

The award was based upon an overall evaluation of performance, cost, and technical suitability. In this last respect, the SRR helicopter was required to meet a wide variety of mission needs for which the integrated avionics system has a high importance.

This paper illustrates the rationale for the avionics system requirements, the system architecture, its capabilities and reliability and its adaptability to a wide variety of military and commercial purposes.

INTRODUCTION

The mission of the United States Coast Guard is to protect lives and property at sea. Within this broad scope of responsibility, the new HH-65A helicopters, being procured under a recently awarded contract to Aerospatiale Helicopter Corporation (AHC), will find a variety of applications for a service which prides itself on its adaptability and multi-mission service to the public. This paper briefly discusses how the HH-65A avionics system requirements relate to these missions, the system architecture, reliability aspects, and specific capabilities.

The most well known activity of the Coast Guard is its search and rescue role. While it may be the most demanding, from the standpoint of equipment, manning, and reliability requirements, our resources must be consistent with several other roles. The majority of Coast Guard forces are

spread out quite thinly along the coastline of the United States. Typical tasks include maintenance of fixed and radio aids to navigation (buoys and LORAN-C, for example), enforcement of fishing treaties, drug interdiction, ice breaking for domestic shipping and polar operations safety inspections of ships and oil drilling platforms, prevention and cleanup of oil and other chemical spills, and support of other government and scientific agencies. At the same time we are also, at small added cost, a significant asset in the maritime defense capability of the United States.

Each of these tasks employ helicopters routinely so that each aircraft, like the service, must be a multi-mission asset. The helicopters must, in addition, be capable of operating in the extremes of meteorological conditions (from tropical to polar areas) and from a wide base of operations (land based stations and from ships). Furthermore, the helicopters must be capable of being diverted from one mission to another at a moments notice. The size and weight of the new helicopter was constrained by the types of production

helicopters available and the requirement to operate from small ships.

THE AVIONICS ARCHITECTURE

The development of the Avionics System Specification for the HH-65A helicopter was influenced by the Coast Guard's desire to reduce the intense air crew duties during a search and rescue flight. Since the visual search and mission management are best handled by the crew, the routine functions of flight control, navigation, power train management and even routine communications should be relegated to an automatic mode as much as possible.

These desires and the foregoing operational requirements resulted in the following avionics equipment and architecture specification. Certain equipments are Coast Guard furnished to preserve commonality with standard Navy and Coast Guard systems. Other systems were specified on a commercial brand-name-or-equal basis or purely on a functional basis relying on ARINC or FAA TSO specifications. It was recognized early in the program that aircraft performance (including that of its installed avionics equipment) is the important end product and that such "fly-away" performances are the important parameters to specify. Therefore, FAA certification is the rule, where applicable, and includes Category II IFR approach capability, area navigation precision to the standards of FAA Advisory Circular 90-45A, and all of the attendant safety of flight criteria. Environmental conditions for particular equipment are not specified except that they must be commensurate with the flight condition envelope of the aircraft as a whole. The prospective aircraft manufacturers could, therefore, protect equipment from temperature or other environmental extremes or "harden" them if exposed. In fact, a combination of these two procedures was proposed by AHC.

Appendix 1 is a list of the principal avionics systems to be installed. An immediate reaction to this list might be that it would be impossible to accommodate all of the control heads to operate the equipment. The dilemma which faced the Coast Guard is obvious. The requirement for a large suite of avionics equipment with the practical constraints of weight and volume imposes the necessity to use extraordinary means to make all this equipment fit. Yet, the fleet size of 90 helicopters cannot support a large development cost. The Coast Guard also did not wish to equip itself with aircraft or installed equipment which are peculiar to itself and therefore difficult to support in later years.

Furthermore, it was recognized that not all equipment is required for all missions. The Coast Guard design philosophy, therefore, was predicated upon the following basis:

FLEXIBILITY - The system must be able to accommodate growth and change (possible additions or replacements would be a microwave landing system, FLIR, or NAVSTAR/GPS receiver). Electronic interfaces must be standardized.

ADAPTABILITY - The system must lend itself to removal of equipment in a snap-on/off manner to adapt to particular missions or bases of operations. For example, it must be possible to remove certain equipment (such as one or more VOR receivers, LORAN-C receivers, IFF, Loudhailer, Voice Scrambler, VHF-FM transceiver), depending on their mission utility, to increase payload without changing the cockpit configuration.

In consideration of these factors, the Coast Guard specified a system architecture implemented in a manner which:

1. Provides complete redundancy in all primary and most secondary capacities

2. Combines all navigation and communication control and displays functions in the Central Control Display Units (CDU's), Horizontal Situation and Video Displays (HSVD's), and HSVD Control Panel - all of which are dual redundant

3. Utilizes a MIL-STD-1553B multiplex data bus system to integrate individual components

The HH-65A Avionics System which resulted from the competitive procurement is a very integrated and adaptable one. From the pilot's point of view, the cockpit panel and console layout (Figure 1) is very clean and compact. The underlying system architecture bears some examination, however, to appreciate its features.

The heart of the system operation is the Flight Management System (FMS). It interconnects and operates with the navigation sensors, the communication radios, the flight guidance equipment, and special sensors such as the radar, power train sensors and air data equipment. Although the HH-65A avionics system is not completely digital, the multiplex data bus system is essential to the light-weight, efficient operation of the FMS. In its most simplistic form, the data bus system can be depicted as shown in Figure 2.

In this case a single multi-function control-display unit (CDU) transmits and receives data, on a time shared basis, through a shielded, twisted pair of wires called a bus. The content and control of this data, generated at a rate of one million bits per second, is managed by the Bus Controller which contains all the bus control logic, memory, and timing circuits. There may be certain equipment, dedicated to communication, navigation, armament or displays which operate directly on the bus. In this case the CDU communicates directly to these equipments to change modes or frequencies. Other data, in turn, is returned to the CDU or Navigation display for readout to the pilot.

The immediate advantage of a multiplex data bus system becomes apparent when one considers all of the wires for tuning, mode control, and analog data which would be otherwise required to be routed throughout the aircraft. This problem compounds itself as additional communication, navigation, sensor and display equipment is added.

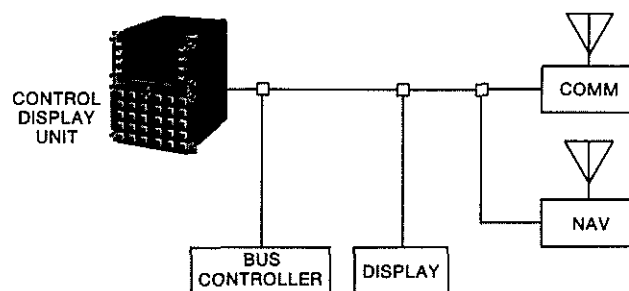


Figure 2. Simplified Data Bus Structure

Equipment which will connect directly to a multiplex data bus is still rare and it is necessary to provide the proper interface to existing equipment. As a practical matter, it is easiest to combine interface adapters with the bus controller into one unit (which we call a Systems Coupler Unit or SCU). Figure 3 shows how such a unit is added.

In this case, digital control commands from the CDU are converted into, for example, a typical set of "2 out of 5" tuning discrettes plus mode discrettes to control a VOR receiver. While the analog VOR data might be reconverted to digital data on the bus, it can be wired directly to any electro-mechanical display which also has no bus interface.

The system as shown is obviously not adequately reliable since a failure of either the CDU, the SCU (or its internal bus controller) or the bus itself would cause a complete failure of the whole avionics system. In addition, the CDU is, at any one time, devoted to one control or display function as is the navigation display. To solve this problem, the system is reconfigured as shown in Figure 4.

Another CDU has been added. This allows independent yet redundant control and display of all units. A failure of one CDU does not affect system operation except, for example, that a simultaneous control display of radio frequency and navigation functions is not then possible. The additional parallel data bus, navigation display, and SCU (which includes another bus controller) provide a high mission completion reliability with independent and simultaneous control and display capabilities for two pilots.

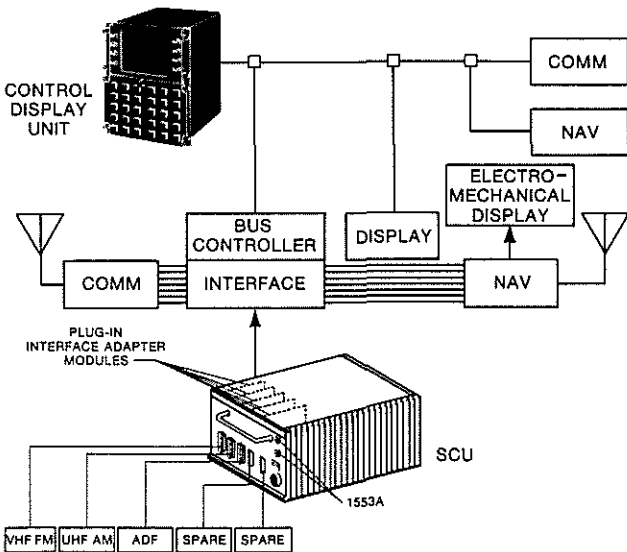


Figure 3. Data Bus with Systems Coupler Unit

A new item, the Mission Computer Unit (MCU) provides specialized services to all other systems on the bus. These services include LORAN-C, VOR and TACAN coordinate conversion, through a Kalman filtered position estimator, into geographic coordinates, RNAV flight plan management (including generation of search patterns), engine and power train condition monitoring and recording, and performance and fuel alert calculations. In addition, the MCU retains a data base consisting of navigation waypoints, listings of local rescue resources, and engine trend data.

This, then, describes the architecture of what the Coast Guard terms a Flight Management System (FMS). Figure 5 is the face of the CDU showing one typical function, communication radio control, in use.

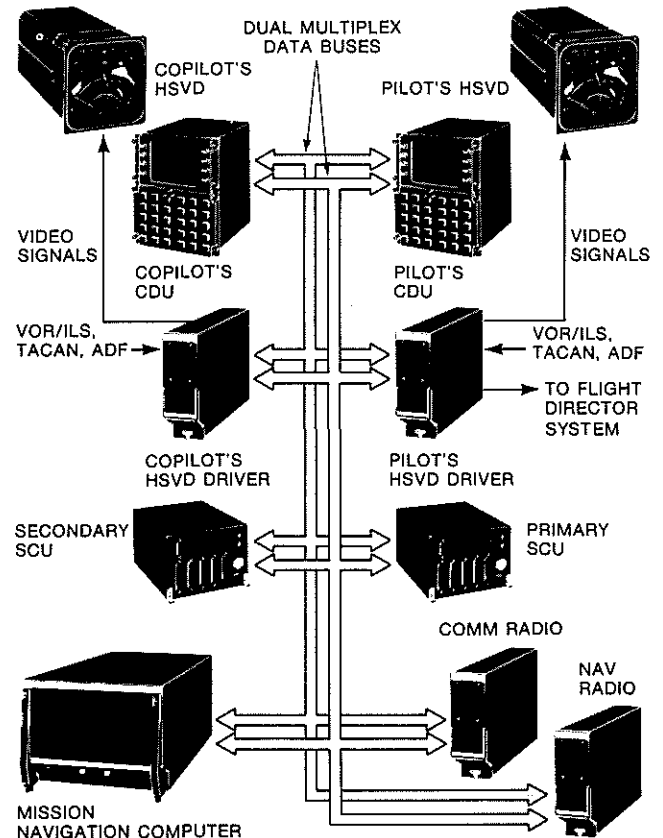


Figure 4. Dual Data Bus Structure

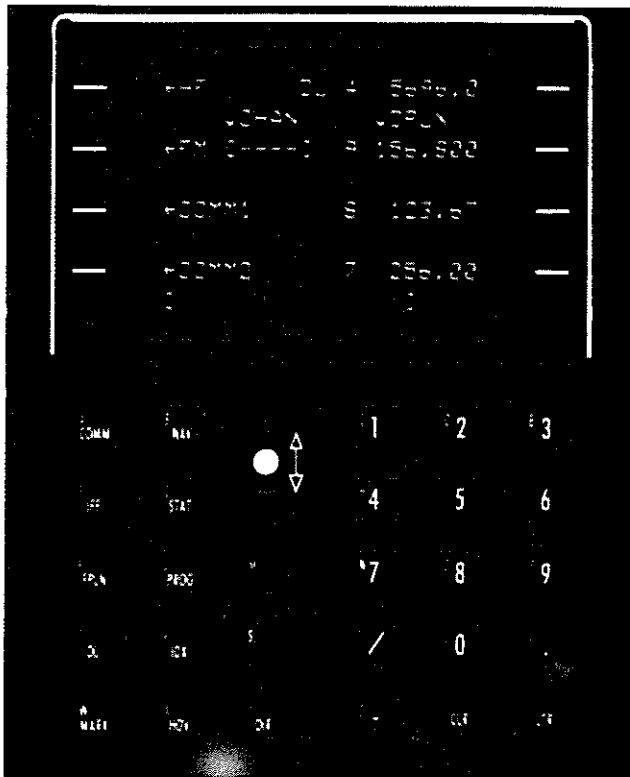


Figure 5. Flight Management System CDU

AUTOMATIC FLIGHT CONTROL SYSTEM

The pilot's effectiveness is much higher if he is not concerned with the helicopter's stability, especially in a low altitude hover at night. The HH-65A Automatic Flight Control System (AFCS) provides hands-off attitude and heading retention, stability/command augmentation for manual flight, automatic trim in all axes, and full coupling to the navigation systems through the flight director. The entire mission can, in fact, be flown automatically through the various flight director modes.

The AFCS uses a combination of limited authority series servos (for high frequency stability augmentation) and full authority parallel servos (for trim and "outer loop" guidance functions). In order to meet Coast Guard requirements for safety, the AFCS is fail-passive: Whenever a failure occurs it causes (1) no perceivable control motion, and (2) positive disengagement and alerting of the pilot. To meet our requirements for mission reliability, each AFCS axis engages individually to permit continued operation of the non-failed axes.

FLIGHT DIRECTOR SYSTEM

The navigation equipment (mission computer, VOR and TACAN) provide flight guidance information to the AFCS through the Flight Director System (FDS). The FDS accepts these inputs and computes pitch, roll, and collective steering commands according to the selected mode, as shown in the following table.

FLIGHT DIRECTOR MODES

HDG SEL	Heading Select
NAV	Navigation (VOR/LOC/BC/RNAV/TACAN)
APPR	Approach (VOR/ILS/BC/RNAV/TACAN)
IAS	Airspeed Hold/Beep
VS	Vertical Speed Hold
ALT	Baro-Altitude Hold
IAS/VS	Airspeed and Vertical Speed Hold (Pitch and Collective)
HOV AUG	Hover Stability Augmentation (Accelerometer Input to Coupled Mode)
T-HOV	Transition to Hover
GA	Go-Around/Auto-Takeoff

These commands are provided to the AFCS for coupled operation and, in addition, they are displayed on the Attitude Director Indicators (ADI's), shown in Figure 6. If any or all of the AFCS axes fail to operate, the pilot may revert to manual flight using these displayed steering commands with little additional workload. This is a reversionary procedure which contributes to mission reliability.

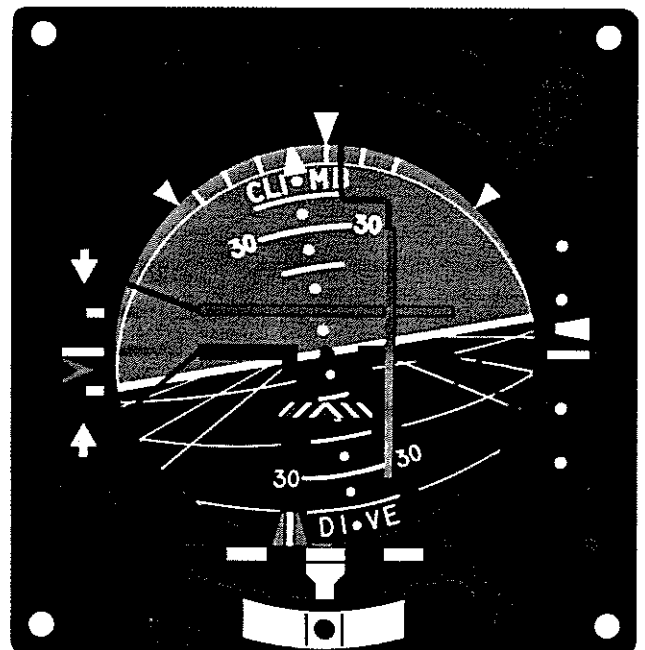


Figure 6. Attitude Director Indicator

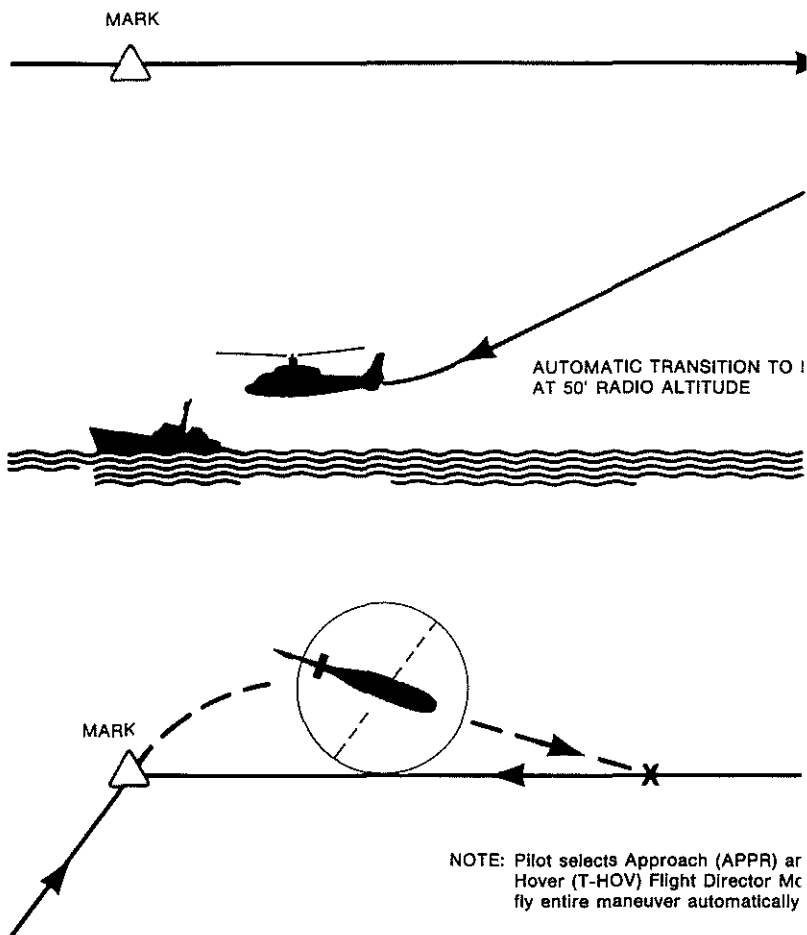


Figure 7. Transition to Hover.

The most interesting of these flight director modes is the "T-HOV" or Transition to Hover mode. The pilot selects the Approach (APPR) mode to fly an ILS or RNAV approach in a fairly typical fashion. The FDS provides cyclic and collective commands to capture and follow the approach path at an approach speed which can be modified throughout the approach. "Armed" while in the APPR mode, the T-HOV mode "captures" at 100 feet radio altitude and commands a deceleration to approximately zero groundspeed at 50 feet above the surface of the runway or water. Figure 7 is a profile of the T-HOV mode of approach.

SPECIAL SYSTEMS

The HH-65A will incorporate other equipment which, while not technically new in military systems, is integrated into this system in a unique way.

The aircraft's power train instruments are vertical, electro-optical instruments which are commercial versions of those which are installed in the Army Blackhawk (UTTAS), Navy Seahawk (LAMPS) and Army Advanced Attack Helicop-

ters. The Coordinating System available in the aircraft analyzes the aircraft's power train checks; it also monitors the amount of wind. The ECM system provides additional

The radar system for high altitude turns employs a dual turn clutch on the H

The requirement to display multiple navigation sensor information, flight plan data, and search sensor video, along with a need to keep the instrument panel as small as possible for search visibility, resulted in the specification for a HSVD. This CRT device supplies the navigation and tactical situation and sensor data needed by the crew for each mission phase. Seven display modes and three navigation sources are independently available to each pilot. The display modes include not only a conventional HSI format, but radar, map, and a special hover display which is useful for low altitude, low airspeed, close-in navigation to a spot. It is this hover display which is used to present low range, omnidirectional airspeed from the Pacer LORAS to the pilots.

Provisions for the display of Forward Looking Infra-Red (FLIR) video have been provided so that this equipment can be added to the helicopter in the near future with a minimum of retrofit difficulty. The combined radar-map display, Figure 8, is representative of the flexibility this device has.

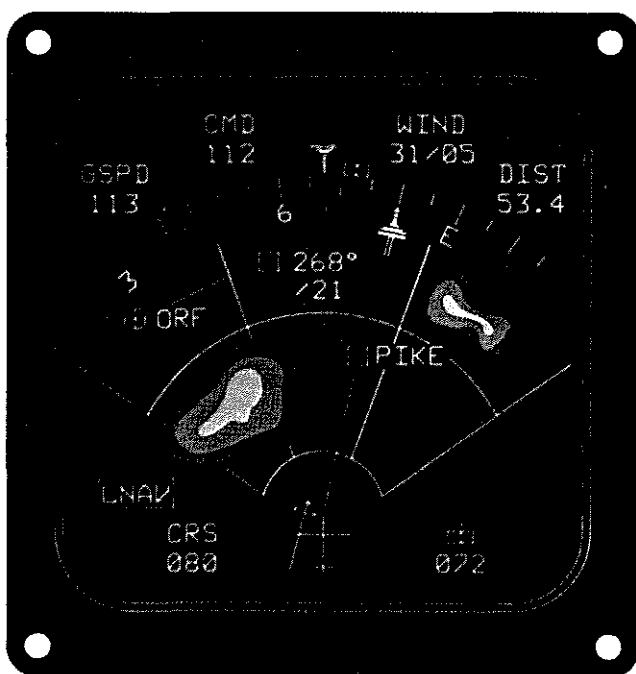


Figure 8. HSVD Radar-Map Mode

CERTIFICATION

The Coast Guard will depend upon the FAA certification process as an acceptance criteria for the aircraft and the avionics system. This means that except for certain military items (such as the TACAN, voice scrambler) all equipment must meet FAA TSO's and must be installed and certified under the aircraft's Type Certification (TC) or a Supplementary Type Certification (STC).

Although the HH-65A avionics system is a synergistically integrated set of individual subsystems, these multiple subsystems will be individually STC'd. With a system such as this, there is a built-in flexibility which will allow other users to select from a large menu of qualified new products depending on their specific requirements. The operator must only determine what capabilities he requires: single or dual pilot IFR operation, area navigation, special instrument approaches, two or three cue flight director, collective assist in the AFCS. . . and most of this adaption is possible with little apparent change in the cockpit. In fact a fleet of differently equipped helicopters can retain the same cockpit configuration - even as new systems, such as satellite navigation and microwave landing systems, are introduced.

The HH-65A will become operational in the spring of 1982. The Coast Guard has specified a helicopter and an avionics system which is planned to have a long service life. From all appearances, these expectations will be fulfilled, despite changes in missions and technology, for many years.

**APPENDIX 1
INSTALLED EQUIPMENT LIST**

COMMUNICATIONS:	
HF Transceiver, 2-30 MHz	Collins 718U-5
VHF/UHF Transceiver	ARC-182 (dual)
VHF-FM Transceiver	Wulfsburg RT-9600
Transponder	APX-100
Voice Scrambler	VP-II
Public Address System	AEM 400
Emergency Locator Transmitter	CIR-11
Acoustic Beacon	Dukane N15F210B
Intercomm System	Pilot, Copilot, Crewmembers
NAVIGATION:	
VOR/ILS/MB	ARN-123 (dual)
TACAN	ARN-118
LF-ADF	COLLINS DF-60
VHF/UHF ADF	COLLINS DF-301
LORAN-C	NSI ADL-82 (dual)
Radar Altimeter	HONEYWELL HG-7502
Air Data	PACER LORAS-1000
FLIGHT GUIDANCE:	
Flight Director	Collins HFCS-800
AFCS	Collins HFCS-800
DETECTION:	
Radar	BENDIX RDR-1300 derivative
FLIR	Display provisions
INSTRUMENTATION AND DISPLAYS:	
ADI	3 cue (dual)
HSI	Collins MFD-80 multifunction display system
BDI	Collins BDI-36
Engine Instruments	Canadian Marconi 730 series vertical-scale electro-optical
Various Others	As required for FAR 29, dual pilot instrument flight
COMPUTER:	
Navigation, LORAN-C coordinate conversion, waypoint memory, engine condition monitoring, fuel alert, mission computer, data link	Collins CAPS-5