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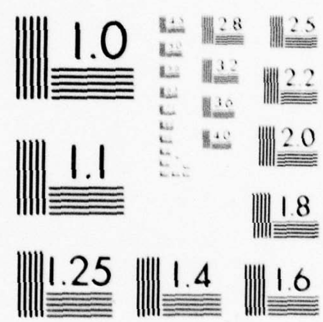
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LEVEL II

AVIONIC SYSTEM ARCHITECTURE INVESTIGATION (AVSAR II)

TECHNICAL REPORT

20 MARCH 1979

Contract No. DAAB07-78-C-2445

U.S. Army Avionics R&D Activity
U.S. Army Aviation Research and Development Command
Fort Monmouth, New Jersey 07703

(14)

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TECHNICAL REPORT

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D. D'AVINO
R. MEREDAY
M. MINNICH
R. NOBLE
L. SORENSON

Prepared by:

SEMCOR
Strawbridge Lake Office Building
Moorestown, New Jersey 08057
Contract No. DAAB07-78-C-2445

Prepared for:

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The objective of the Avionic System Architecture Investigation (AVSAR II) was to investigate the extent to which multiplex technology and integrated control/display techniques could be applied to the AH-1S Night Cobra (Step 4). The primary purpose of the study was to determine if the integration of a multiplex data bus system would have a significant impact on aircraft system weight. Secondary objectives were to determine whether a reduction of crew workload and a reduction of cockpit real estate requirements could be effected through implementation of the new architecture.

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Abstract (Continued)

This technical report describes the system analysis, system definition, and system integration considerations that resulted in a Step 4 Night Cobra avionic system with integrated controls/displays and a multiplex data bus.

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LIST OF ACRONYMS AND ABBREVIATIONS

A	Ampere(s)
Acq	Acquisition
A/D	Analog-to-Digital
ADF	Automatic Direction Finder
ADI	Attitude/Direction Indicator
ADS	Air Data System
AGL	Above Ground Level
ALT	Airborne Laser Tracker
Alt.	Altimeter
AM	Amplitude Modulation
ATDS	Airspeed Transducer and Direction Sensor
Aux.	Auxiliary
AVRADA	Army Avionic Research and Development Activity
AVRADCOM	US Army Research and Development Command
AVSAR II	Avionic System Architecture Investigation
Az	Azimuth
BALT	Barometric Altimeter
BC	Bus Controller
BIT	Built in Test
CCU	Central Control Unit
CG	Center of Gravity
CKT	Circuit
CLK	Clock
CNI	Communication, Navigation, and Identification
Comm.	Communication
Cont.	Control (also Contr)
CONUS	Continental Limits, United States
Coor.	Coordinate(s)
CRT	Cathode Ray Tube
CW	Command Words
D/A	Digital-to-Analog
Det.	Detection
DF	Direction Finder
Disc.	Discrete(s)
DNS	Doppler Navigation System
Dyn.	Dynamic
DT	Data Terminal
EAHD	Electronic Attitude and Heading Display
ECP	Engineering Change Proposal
ECS	Environmental Control System
EIA	Electronic Interface Assembly
EL	Elevation
EM	Electromagnetic

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

Emerg.	Emergency
Eng	Engine
EPS	Electronics Power Supply
EPU	Electronic Processor Unit
ESM	Electronic Warfare Support Measures
Ext.	External
FAARP	Forward Area Rearm/Refuel Point
FACTS	FLIR Augmented Cobra TOW Sight
FC	Fire Control
FCC	Fire Control Computer
FEBA	Forward Edge of the Battlefield
FLIR	Forward Looking Infrared
FM	Frequency Modulation
FMD	Flight Management Display
FOV	Field of View
G	Gunner (Copilot)
Ga	Gauge
GCP	Gunner's Control Panel
GHS	Gunner's Helmet Sight
HARS	Heading and Attitude Reference System
HDG	Heading
HERO	Hazards of Electromagnetic Radiation to Ordnance
HMS	Helmet Mounted Sight
HP	Horse Power
HSI	Horizontal Situation Indicator
HSIU	Horizontal Situation Indicator Unit
HSS	Helmet Sight System
HUD	Head-Up Display
Hyd.	Hydraulic
IACS	Integrated Avionic Control System
ICS	Intercommunication System
IFF	Identification Friend or Foe
IGE	In Ground Effect
ILS	Instrument Landing System
IMG	Intermessage Gap
IR	Infrared
IRCM	Infrared Counter Measures
Jam.	Jammer
Jett.	Jettison
LH	Left Hand
LHG	Left Hand Grip

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

LLLTV	Low Light Level Television
Loc.	Locator
LOS	Line of Sight
LRF	Laser Range Finder
LRU	Line Replaceable Unit
LTL	Left Tow Launcher
LTG	Lighting
LWS	Left Wing Store
Mag. Comp.	Magnetic Compass
MCA	Missile Command Amplifier
MFD	Multiformat Display
MUX	Multiplex
Nav.	Navigation
NOE	Nap of the Earth
OGE	Out of Ground Effect
OSD	Operational Sequence Diagrams
P	Pilot
PCP	Pilot's Control Panel
PDR	Preliminary Design Review
PHS	Pilot's Helmet Sight
PMD	Projected Map Display
PP	Present Position
RADHAZ	Hazards from Electromagnetic Radiation
RALT	Radar Altimeter
RH	Right Hand
R&M	Repair and Maintenance
RMI	Radio Magnetic Indicator
RMS	Rocket Management System
RPM	Revolutions per Minute
RT	Remote Terminal
RTL	Right Tow Launcher
RWI	Radar Warning Indicator
RWS	Right Wing Store
SCA	Stabilization Control Amplifier
SCAS	Stabilization Control Augmentation System
SDP	Software Development Plan
SHC	Sight Hand Control
SP	Status Panel
SU	Signal Unit
SW	Status Word(s)
TA	Target Acquisition
TACH	Tachometer

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

TAS	True Airspeed
TBD	To Be Determined
TGT	Turbine Gas Temperature
TOW	Tube Launched, Optically Tracked, Wire Guided
TSU	Telescopic Sight Unit
UHF	Ultra High Frequency
UTS	Universal Target System
VA	Voice Annunciation
VD	Drift Velocity
Vel.	Velocity
VH	Horizontal Velocity
VHF	Very High Frequency
VLS	Vertical Line of Sight
VOR	Visual Omnidirectional Range
VV	Vertical Velocity
WEAPTRIG	Weapon Trigger
XMSN	Transmission

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SEMCOR thanks staff members of the U.S. Army Avionics Laboratory at Fort Monmouth, New Jersey, especially, George Chandler, Anthony Santanelli, and Larry Youngblood, and William B. Debellis of the Human Engineering Laboratory at Aberdeen Proving Grounds, Maryland, for their comments and suggestions throughout this study.

1. EXECUTIVE SUMMARY

a. Introduction. Historically, avionics system architectures have been described as an amalgamation of nearly autonomous subsystems, the subsystems being segregated along functional lines, such as navigation, communications, fire control, etc., each having an independent sensor, processor, control, and display. This situation has led inevitably to several system-level problems, the more serious of which include the decrease in reliability of avionics systems, despite an increase in reliability of individual components, due to increased system complexity and sophistication; the increase in aircraft crew workloads to unacceptable levels caused by the requirement to control and monitor increasing numbers of sensors and displays; and the reduction in cockpit spare real estate to near-zero levels. Other problems have been the difficulty of reconfiguring aircraft avionics systems to meet changing mission requirements or to take advantage of new technology and the high costs arising from the proliferation of functionally similar, but noninterchangeable, subsystems.

Digital technology, particularly in the LSI and microprocessor areas, has now evolved to the point where these operational problems are amenable to solution through application of digital integration techniques at the system level. The new type of avionics system architecture resulting from this approach is characterized by the use of a multiplex data bus to interconnect sensors, controls, and displays, integrated programmable controls and displays, and the widespread application of microprocessors at the subsystem level.

The objective of the Avionic System Architecture Investigation (AVSAR II) was to investigate the extent to which this new type of architecture could be applied to the AH-1S Night Cobra (Step 4). The primary purpose of the study was to determine if the integration of a multiplex data bus system would have a significant impact on the aircraft system weight. Secondary objectives were to determine whether a reduction of crew workload and a reduction of cockpit real estate requirements could be effected through implementation of the new architecture.

b. Methodology. The following presents an overview of the engineering approach SEMCOR applied in performing the AVSAR II study.

SEMCOR initiated the study by evaluating the Modernized AH-1S Cobra (Step 3) system and functionally dividing this system into generic subsystems for the purpose of further analysis. Step 4 requirements were integrated into the generic subsystems, as applicable, to provide a baseline Step 4 Night Cobra configuration. Each subsystem was then further subdivided into equipment lists, and each item of equipment was characterized by its electrical interface.

In addition, the Night Cobra mission requirements were analyzed from a human factors viewpoint. Operational sequence diagrams depicting the mission were generated and further broken down into time lines for critical mission segments. Based on this information, data requirements and data priorities were determined for both the pilot and gunner during each mission segment. These requirements and priorities were then used to postulate a new cockpit layout for both crewmembers, using a mix of existing equipment and equipment yet to be developed.

The baseline equipment list was then adjusted based on the results of the control and display analysis. SEMCOR evaluated this information to determine the viable candidate equipment for multiplexing. The candidate multiplex equipment list was then used to establish remote and embedded terminal locations, develop the data bus architecture, and compute bus loading requirements. This process involved the continuous evaluation of candidate equipment against various criteria in an effort to define a totally integrated Night Cobra system.

Finally, the system was analyzed in terms of weight, cost, crew workload, and cockpit real estate savings.

c. Summary of Results. The electronic system for the Night Cobra consists of the electronic subsystems and assemblies needed to perform the functions of communications, navigation, identification, target acquisition, fire control, electrical power control, aircraft self-protection, and aircraft system management. In addition, the electronic system encompasses the equipment units required to integrate the various subsystems into an efficient system configuration; these "system-level" equipment units include a multiplex data bus subsystem, an integrated central display subsystem, and an electrical power control/distribution subsystem.

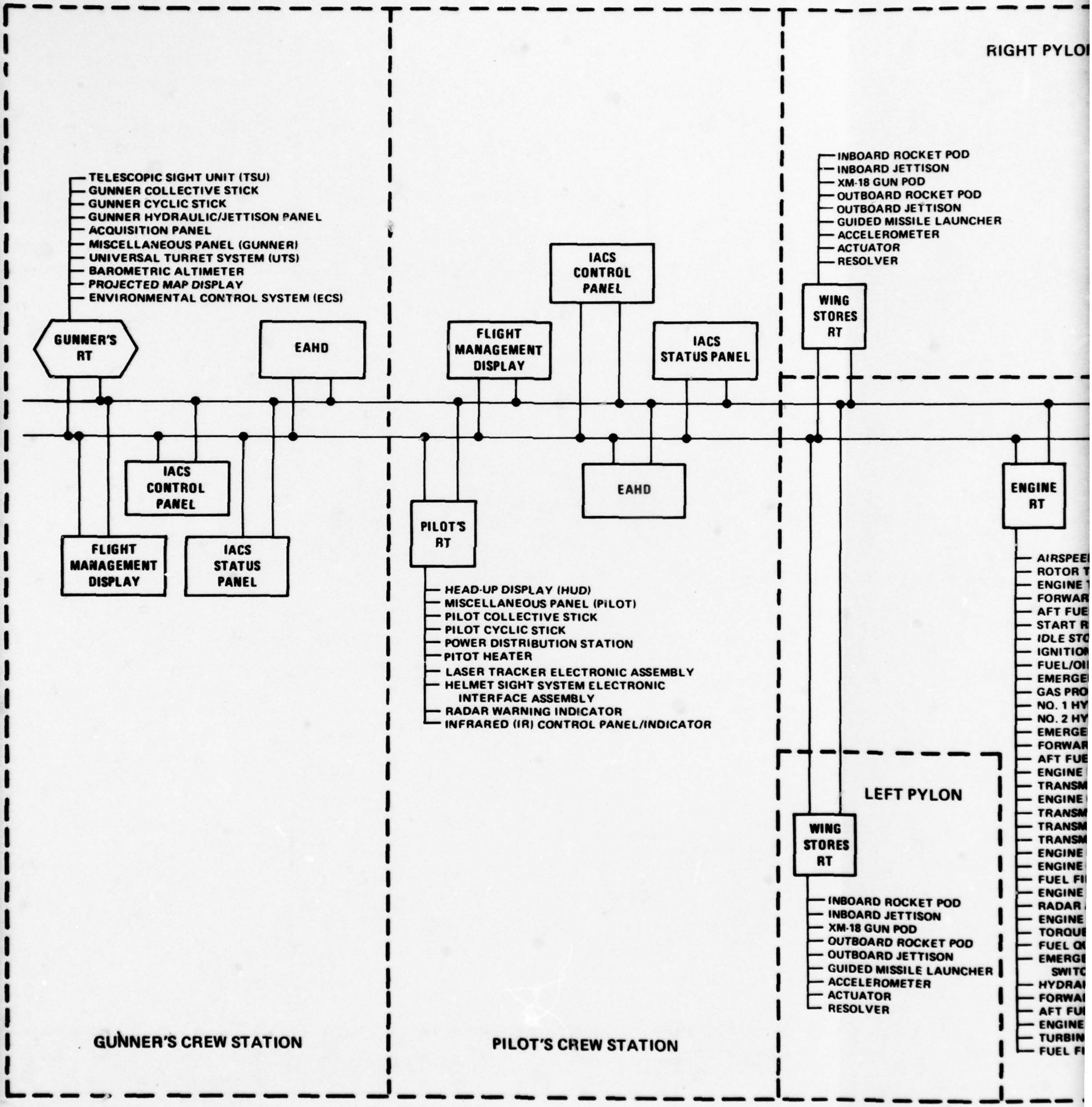
The Night Cobra electronic system is configured as shown in Figure 1, structured around a dual redundant MIL-STD-1553B data bus. This data bus constitutes the primary means of communication between electronic subsystems; hardwired signals are kept to a minimum. Equipment includes six remote terminals located as shown in the figure; the primary bus controller resides in the gunner's remote terminal, and the secondary (backup) bus controller resides in the aft remote terminal. Electronic subsystems/equipment units communicating with the data bus through the remote terminals are identified in Section 5.1. Additional equipment connected directly to the bus includes the following:

(1) AN/ASN-128 doppler navigation system

(2) AN/ARC-164 radio

(3) AN/ARC-186 radio

(4) Fire control computer



RIGHT PYLON
INBOARD ROCKET POD
INBOARD JETTISON
XM-18 GUN POD
OUTBOARD ROCKET POD
OUTBOARD JETTISON
GUIDED MISSILE LAUNCHER
ACCELEROMETER
ACTUATOR
RESOLVER
WING STORES RT
TELESCOPIC SIGHT UNIT (TSU)
GUNNER COLLECTIVE STICK
GUNNER CYCLIC STICK
GUNNER HYDRAULIC/JETTISON PANEL
ACQUISITION PANEL
MISCELLANEOUS PANEL (GUNNER)
UNIVERSAL TURRET SYSTEM (UTS)
BAROMETRIC ALTIMETER
PROJECTED MAP DISPLAY
ENVIRONMENTAL CONTROL SYSTEM (ECS)
GUNNER'S RT
EAHD
IACS CONTROL PANEL
FLIGHT MANAGEMENT DISPLAY
IACS STATUS PANEL
IACS CONTROL PANEL
FLIGHT MANAGEMENT DISPLAY
IACS STATUS PANEL
EAHD
PILOT'S RT
HEAD-UP DISPLAY (HUD)
MISCELLANEOUS PANEL (PILOT)
PILOT COLLECTIVE STICK
PILOT CYCLIC STICK
POWER DISTRIBUTION STATION
PITOT HEATER
LASER TRACKER ELECTRONIC ASSEMBLY
HELMET SIGHT SYSTEM ELECTRONIC INTERFACE ASSEMBLY
RADAR WARNING INDICATOR
INFRARED (IR) CONTROL PANEL/INDICATOR
ENGINE RT
LEFT PYLON
WING STORES RT
INBOARD ROCKET POD
INBOARD JETTISON
XM-18 GUN POD
OUTBOARD ROCKET POD
OUTBOARD JETTISON
GUIDED MISSILE LAUNCHER
ACCELEROMETER
ACTUATOR
RESOLVER
GUNNER'S CREW STATION
PILOT'S CREW STATION

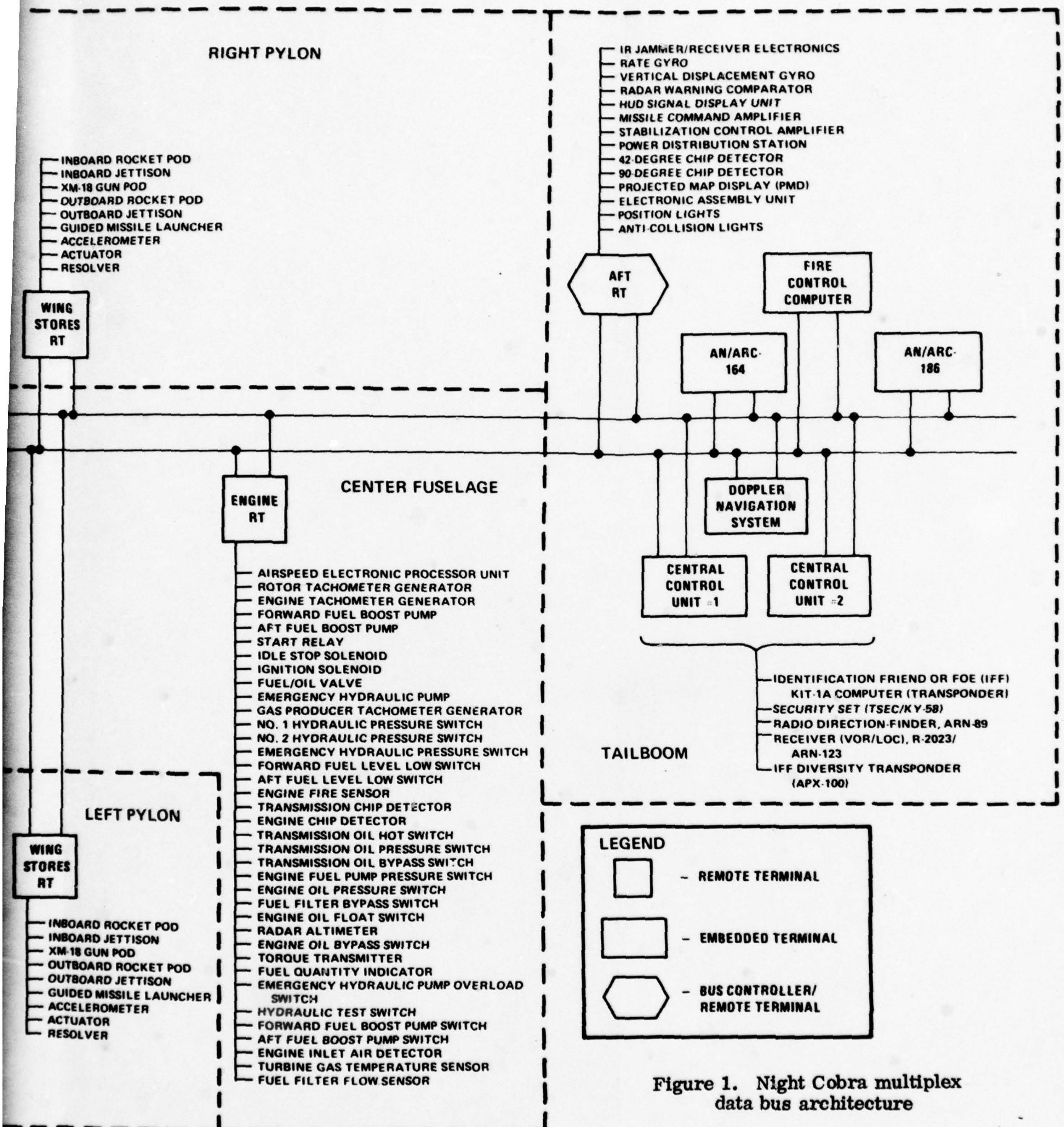


Figure 1. Night Cobra multiplex data bus architecture

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(5) Integrated Avionic Control System (IACS) central control unit, J-3588/ASQ-166, J-3585/ASQ-166 (2)

(6) IACS primary control panel, C-10515/ASQ-166 (2)

(7) IACS status panel, ID-2171/ASQ-166 (2)

(8) Electronic attitude/heading display (EAHD) (2)

(9) Flight management display (FMD) (2)

The integrated control/display subsystem for each crewmember consists of the following:

(1) FMD

(2) EAHD

(3) IACS primary control panel

(4) IACS status panel

(5) Intercom/communications/navigation selection control panel

(6) Helmet-mounted sight

In addition to the displays described above, the pilot's cockpit contains the following:

(1) Head-up display

(2) Radar warning indicator

(3) Laser tracker panel

(4) Miscellaneous jettison panel

(5) Clock

Additional displays in the gunner's cockpit are as follows:

(1) Telescopic sight unit (TSU)

(2) Projected map display (PMD)

(3) Magnetic compass

(4) Hydraulic/jettison panel

(5) Laser range panel

(6) Acquisition panel

Electrical power control and distribution will be accomplished using solid-state power controllers per MIL-P-81653, which are installed in two power distribution stations connected to the data bus through the pilot remote terminal (RT) and the aft RT. Any intelligence required for the electrical power control function will reside in the power distribution stations rather than their associated remote terminals.

The configuration will provide a weight savings of approximately 46.7 kg (103 lb) over a Step 4 hardwired configuration, while providing increased functional capability. In addition, the integration of controls and displays results in a reduction in complexity of approximately 52 percent.

d. Recommendations. Recommendations based on the AVSAR II investigation are summarized below:

(1) A dual redundant MIL-STD-1553B multiplex data bus should be used to effect the required architecture.

(2) Dual redundant bus controllers should be used to control the data bus.

(3) An integrated control/display approach, as described in Section 1.3, can provide crew workload reduction and increased cockpit real estate at a low technological risk for the 1982 time frame.

(4) Additional control/display integration techniques, as described in Section 6.1, should be investigated for possible application in later Night Cobra updates.

(5) The software development cycle should be closely monitored and documented, as described in Section 6.2; in addition, a life cycle plan should be written for the Night Cobra software.

(6) The Night Cobra multiplex architecture should be evaluated in terms of the effect of survivability.

(7) An investigation into providing a data bus test set for ease of maintenance should be initiated.

(8) The AN/ARC-164 should be relocated, and a 1553B compatible interface should be provided.

(9) The AN/ARC-114 and AN/ARC-115 should be replaced with a 1553B compatible AN/ARC-186.

(10) Preparation of Prime Item Development Specifications for the Night Cobra RT's should be initiated.

(11) Development programs should be initiated to provide 1553 interfaces for major aircraft LRU's, such as the FCC, air data system, rocket management system, and so forth.

2. INTRODUCTION

a. Baseline System. The baseline system for the AVSAR investigation consisted of the avionics equipment suite aboard the AH-1S Step 3 Cobra. This equipment suite was to be supplemented in Step 4 by the addition of the following avionics systems: FLIR Augmented Cobra TOW Sight (FACTS), NOE Communication, Projected Map Display (PMD) AN/ASN-99, and IACS.

b. Methodology. SEMCOR initiated the AVSAR investigation by evaluating the baseline Step 3 Cobra system and functionally dividing this system into generic subsystems as follows:

1.0	Communications	9.0	Self-Protection and Warning
2.0	Navigation	10.0	Display and Control
3.0	Air Data	11.0	Electrical (ac and dc)
4.0	Flight Control	12.0	Engine Control and Monitoring
5.0	Target Acquisition	13.0	Data Transfer
6.0	Fire Control	14.0	Weapon and Armament
7.0	Stores Management	15.0	Lighting
8.0	Environmental		

This functional division provided the basic framework for an analysis of the Cobra system; the next step in the process was to assign Step 3 equipment to a subsystem as applicable. The result was a functional representation of the Step 3 Cobra. Step 4 requirements were subsequently integrated into the Step 3 equipment list, providing a baseline Step 4 Night Cobra.

Each item in the baseline equipment list was then characterized by its electrical interface, with consideration given to bandwidth, signal type, voltage, impedance, resolution, update rate, and wire type.

While this characterization was in progress, SEMCOR analyzed the Night Cobra mission requirements from a human factors viewpoint. Operational sequence diagrams were generated and time lines were prepared for various critical mission segments. This analysis allowed the determination of data priorities and data requirements for both the pilot and gunner during each mission segment. These requirements and priorities were then used to postulate a new cockpit layout for both crew members, using a mix of existing equipment, equipment added for Step 4, and equipment to be developed.

The results of the control and display analysis were then used to adjust the Step 4 equipment list to reflect the integration of controls and displays and the application of multiplex technology. The equipment list was then subjected to a set of multiplex criteria designed to provide a design that effectively used multiplex techniques. This process resulted in a candidate multiplex equipment list. Equipment not on this list would remain hardwired in the Step 4 Night Cobra.

The candidate multiplex equipment list was then used to establish remote and embedded terminal locations, develop the data bus architecture, and compute bus loading requirements. Once terminal locations were established and tentative terminal-to-equipment assignments were made, the candidate multiplex equipment list was reviewed again. As the system design progressed, information flow requirements were defined, additional information from the control/display analysis was provided, and inputs were made available from several system studies. This iterative process involved the continuous evaluation of candidate multiplex equipment against multiplex criteria and engineering tradeoffs in an effort to define a totally integrated Night Cobra system.

Finally, the system was analyzed in terms of weight, cost, crew workload, and cockpit real estate savings.

c. Report Format. The remainder of this report is divided into the following sections:

(1) Section 3. System Definition. The multiplex criteria used in the definition of the Step 4 equipment suite is addressed. The initial considerations in the development of the data bus architecture are described.

(2) Section 4. System Analyses. A detailed description is provided on the analysis performed in the areas of wire weight, control/display weight, moment, bus loading, bus controller loading, and critical signals.

(3) Section 5. System Integration. The assignment of equipment to remote terminals is described, the integration of controls and displays is addressed, and methods of information transfer on the data bus are investigated.

(4) Section 6. Future Considerations. Control and display integration techniques and technologies which are candidates for future study are described and a guide to tools and documents required in the procurement of software is provided. A weight and cost summary for the implementation of the recommended multiplex data bus system is provided.

(5) Appendices. Appendices are included as needed.

d. Assumptions. The validity of the technical approach and engineering work on the AVSAR study was predicated on a baseline set of assumptions, as described in the following paragraphs.

(1) Airframe. The host airframe for the Night Cobra multiplex system was the modernized AH-1S Cobra. The placement and sizing of equipment were constrained by the limits of this existing airframe. The tandem cockpit configuration was also defined by this airframe.

(2) Baseline System. The baseline system for the study was the avionics suite contained in the modernized AH-1S Cobra Step 3.

(3) New Development Systems. The following systems, currently in development or production, were to be integrated into the Night Cobra multiplex system: FLIR Augmented Cobra TOW Sight (FACTS), NOE Communication, Projected Map Display (PMD) AN/ASN-99, IACS, and 2000 HP T53 Engine. These systems were to be integrated as defined by U.S. Army Aviation Research and Development Command (AVRADCOM).

(4) Weight. The baseline weight for the Step 4 Night Cobra was given as follows:

AH-1S, Step 3	10,184 lbs
FACTS	64
NOE Communication	62[1]
PMD	57
IACS	45
2000 HP T53 Engine	16
AH-1S, Step 4	10,428 lbs

(5) Mission. The Night Cobra mission was defined in documentation provided by AVRADCOM.

(6) Standardization. Standard avionics equipment was to be used in replacing or supplementing existing equipment. In cases where standard equipment was not

[1] If NOE Communication (improved FM) is utilized the weight will be 13 lbs.

available or not functionally sufficient, new equipment could be proposed, based on the following philosophy:

> Standardization of equipment for fleet-wide application is a primary design goal. Therefore, Night Cobra specific functional requirements should not be imposed on existing standard equipment without sufficient and stringent justification.

(7) Technology. The proposed Night Cobra design must be technologically feasible in the 1982 time frame. Alternatives not feasible within this time frame could be recommended for further study.

(8) Display Symbology. Display symbology to be used in the Night Cobra was provided by AVRADA.

(9) Drawings. The modernized AH-1S Cobra drawings provided by AVRADCOM represented the baseline Step 3 system.

(10) Communications Equipment. The AN/ARC-164 and AN/ARC-186 were assumed to be configured with MIL-STD-1553B interfaces.

3. SYSTEM DEFINITION

a. Multiplex System. The Step 3 Cobra system is a hardwired system; interfaces between equipment are via wire. One area of the AVSAR study involved applying multiplex techniques to the hardwired Cobra system and designing a hybrid hardwired/multiplexed system for implementation in the Step 4 Night Cobra. Therefore, it is important that the advantages of a multiplex system are understood.

A multiplex system, in the most general sense, is any system capable of transferring more than one signal over a given channel. The channel may be a twisted pair, a coaxial cable, a radio link, an optical fiber, or any other link over which information may be transmitted.

For most systems where moderate to large amounts of data must be transferred, a multiplex system can:

(1) Reduce the number of wires and connection points needed, reducing system weight and cost, and increasing system reliability, maintainability, and availability

(2) Provide redundant data paths, increasing system availability and survivability

(3) Provide data path commonality, facilitating reconfiguration

(4) Provide a single system performance monitor point, facilitating fault detection and diagnosis, and increasing system maintainability

A minimum multiplex system consists of a multiplexer (transmitter), a single data transmission channel, and a demultiplexer (receiver). The multiplexer receives data from the various sources and performs the operations necessary to transmit them over the multiplex channel. The demultiplexer monitors the channel, performs the operations necessary to decode the signals from the channel, and distributes the reconstituted signals to their respective destinations.

The introduction of a multiplex system invariably reduces the number of wires and connection points, simply because each multiplexed bus carries many signals. In many cases, active components such as signal conditioners and line drivers may be simplified or eliminated. In a multiplexed system with a large number of signals, system complexity, documentation, layout engineering, and individual connections and wires lowers the cost and weight of the system, while improving reliability, maintainability, and availability. The important point to remember here is that, although a multiplex system is conceptually more sophisticated than dedicated wires and drivers, it has fewer components in practice.

The fact that numerous signals are sent over the same multiplexed data path makes reconfiguration of the system much easier. In a dedicated-wire system, adding a new piece of equipment requires running new wires between the added unit and any other equipment with which it must exchange data. In a multiplexed system, it is only necessary to make a single connection to the multiplex bus.

Another advantage of a multiplexed data transfer system is that it makes it possible to connect a monitor unit at any convenient point on the bus and be able to monitor all data transfers on the bus. This monitor is usually capable of identifying errors and isolating faults and often actively performs tests on the equipment. In a dedicated-wire system, each individual wire would have to be tapped and routed to the monitor unit to provide this capability.

The likelihood that these advantages could be derived from applying multiplex technology to the Night Cobra was a driving force in the AVSAR study.

b. Equipment Definition. The equipment (Baseline, Step 3) aboard the Night Cobra has been assigned a generic subsystem name and number. The subsystems are as follows:

1.0 Communications

2.0 Navigation

3.0 Air Data

4.0 Flight Control

5.0 Target Acquisition

6.0 Fire Control

7.0 Stores Management

8.0 Environmental

9.0 Self Protection and Warning

10.0 Display and Control

11.0 Electrical (ac and dc)

12.0 Engine Control and Monitoring

13.0 Data Transfer (Step 4 only)

14.0 Weapon and Armament

15.0 Lighting

Table 1 presents a breakdown of the generic subsystems into the actual equipment aboard the Step 3 Cobra. This equipment list, therefore, defines the candidate equipment suite to be considered in applying multiplex technology. A description of each item of equipment has been listed with its designation or AN nomenclature, if known.

Functional Signal Types. Once this list was compiled, each of the items of generic subsystem equipment was then analyzed to determine its functional signal type (input/output). The function signal types considered were:

(1) Radio Frequency[2]

(2) Discrete

(3) Dc Analog

(4) Ac Analog

(5) Synchro

(6) Video

(7) Serial Digital

(8) Parallel Digital

(9) Dc Power and Control

(10) Ac Power and Control

(11) Pulse

(12) Voice[3]

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[2]Not candidate for multiplexing because of system bandwidth limitations. Once defined, signals with these characteristics were immediately excluded from further consideration within the study.

[3]Not candidate for multiplexing in this study in order to preserve red/black separation.

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 1 of 20)

1.0 COMMUNICATION

Item	Description	Designation/AN Nomenclature
1.1	Radio Set (UHF-FM)	RT-1167/ARC-164
1.2	Antenna (UHF)	AT-256A/ARC
1.3	Radio Set (VHF-FM)	AN/ARC-114A
1.4	Antenna (FM Homing)	AS-3205/ARC
1.5	Radio Set (VHF-AM)	AN/ARC-115
1.6	Antenna (VHF)	AS-3204/ARC
1.7.1	Pilot Control Interphone	C-10414( )/ARC
1.7.2	Gunner Control Interphone	C-10414( )/ARC
1.8	IFF Diversity Transponder	RT-1157( )/APX-100
1.9	IFF Mounting	MT-4811( )/APX-100
1.10.1	IFF Antenna Bottom Boom	AT-884( )/APX
1.10.2	IFF Antenna Top Tail	AT-741( )/APX
1.11	High Pass Filter (ARC-164)	HPF-40-017
1.12	Bandpass Filter (ARC-115)	BFF-40-03P
1.13	Low Pass Filter (ARC-114)	LPF-40-02B
1.14	IFF Mark-XII Computer (Transponder)	KIT-1A/TSEC w/mount
1.15.1	Security Set	TSEC/KY-28 w/mount
1.18	FM Communication Antenna	209-077-202
1.19	Audio Threshold	MD-( )/A

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 2 of 20)

2.0 NAVIGATION

Item	Description	Designation/AN Nomenclature
2.1	Automatic Direction Finder (ADF) Receiver Set	R-1496A/ARN-89A
2.2	ADF Antenna	AS-2108A/ARN-89A
2.3	ADF Amplifier/Impedance Match	AM-4839A/ARN-89A
2.4	Receiver (VOR/LOC)	R-2023/ARN-123
2.5	Mount (VOR/LOC)	MT-4980
2.6	Antenna (VOR/LOC)	AS-1304( )/ARN
2.7	Antenna (Marker Beacon)	AT-640/ARN
2.8	Antenna (Glideslope)	AS-3188/ARN
2.9	Doppler Nav. Rec./TW/Antenna	RT-1193/ASN-128
2.10	Converter, Signal Data (Doppler Nav. Comp.)	CV-3338/ASN-128
2.11	Radar Altimeter (Transceiver)	RT-1115/APN-209
2.12	Radar Altimeter Antenna (2 each)	AS-2595/APN-194( )
2.13	Gyro Compass	CN-998/ASN-43
2.14	Transmitter, Remote Compass	T-6/ASN/CN-403/ASN
2.15	DF Sense Antenna	209-030-133
2.17	Altimeter (P/O Barometric Alt.)	AAU-31/A
2.18	Attitude Gyro	
2.19	Rate Gyro Transmitter	
2.20	Vertical Gyro	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 3 of 20)

3.0 AIR DATA

Item	Description	Designation/AN Nomenclature
3.1	Air Data System	
3.1.1	Airspeed Transducer and Direction Sensor (AADS)	
3.1.2	Airspeed Electronic Processor Unit (EPU)	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 4 of 20)

4.0 FLIGHT CONTROL

Item	Description	Designation/AN Nomenclature
4.1	Pitch Hydraulic Solenoid Valve	
4.2	Roll Hydraulic Solenoid Valve	
4.3	Yaw Hydraulic Solenoid Valve	
4.4	Pitch Transponder	P/N 570-074-84
4.5	Roll Transponder	P/N 570-074-84
4.6	Yaw Transponder	P/N 570-074-84
4.7	SCAS Sensor Amplification Unit	P/N 570-074-010
4.8	Pylon Compensation Unit	
4.9	Aft Pylon Transducer	
4.10	Control Tube Assembly (Fore-Aft Cyclic)	
4.11	Control Tube Assembly (Antitorque)	
4.12	Control Tube Assembly (Lateral Cyclic)	
4.13	Antitorque Mag Brake RH Side	
4.14	Lateral Mag Brake RH Side	
4.15	Lateral Mag Brake LH Side	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 5 of 20)

5.0 TARGET ACQUISITION

Item	Description	Designation/AN Nomenclature
5.1.1	Pilot Helmet Sight Subsystem (HSS)	227716-01
5.1.2	Gunner Helmet Sight Subsystem (HSS)	227716-02
5.2	Telescopic Sight Unit (TSU)	3234-001-TBD
5.3	Laser Tracker Electronics Assembly	AN/AAS-32
5.4	Laser Rangefinder (LRF)	
5.7	Laser Tracker Receiver	
5.8	Laser Electronics Units	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 6 of 20)

6.0 FIRE CONTROL

Item	Description	Designation/AN Nomenclature
6.1	Fire Control Computer (FCC)	
6.2 (14.8)	Missile Launcher Command Amplifier (MCA)	209-071-131-3
6.3 (14.9)	Electronic Power Supply (EPS)	209-071-131-3
6.4	Interface Control Unit (Right Side)	
6.5	Helmet-Mounted Sight (HMS) Gunner Linkage Assembly	
6.6	HMS Pilot Linkage Assembly	
6.7	HMS Fire Control Electronics Interface Assembly (EIA)	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 7 of 20)

7.0 STORES MANAGEMENT

Item	Description	Designation/AN Nomenclature
7.1	Left Hand Inboard Rocket Signal Unit (SU)	
7.2	Right Hand Inboard Rocket Signal Unit (SU)	
7.3	Left Hand Jettison Inboard	
7.4	Right Hand Jettison Inboard	
7.5	Left Hand XM18 Gun SU	
7.6	Right Hand XM18 Gun SU	
7.7	Left Hand Outboard Rocket SU	
7.8	Right Hand Outboard Rocket SU	
7.9	Left Hand Jettison Outboard	
7.10	Right Hand Jettison Outboard	
7.13	Terminal Boards	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 8 of 20)

8.0 ENVIRONMENTAL

Item	Description	Designation/AN Nomenclature
8.1	Boom Compartment Blower (TOW)	
8.2	Fire Detector Amplifier/Control Unit	
8.3	Engine De-Ice	
8.4	Pitot Heater (Air Data)	
8.5	Environmental Control System (ECS)	
8.6	Engine Compartment Heat Sensor	
8.7	Miscellaneous	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 9 of 20)

9.0 SELF-PROTECTION AND WARNING

Item	Description	Designation/AN Nomenclature
9.1	Radar Warning Receiver (2 each)	RT-1838( )/APR-39
9.1.1	Radar Warning Receiver Aft	RT-1838( )/APR-39
9.1.2	Radar Warning Receiver Forward	RT-1838( )/APR-39
9.2	Radar Warning Comparator	CM-440( )/APR-39
9.3	Radar Warning Antenna (LH) (2 each)	AS-2891( )/APR-39
9.4	Radar Warning Antenna (RH) (2 each)	AS-2892( )/APR-39
9.5	Radar Warning Blade Antenna	AS-2890( )/APR-39
9.6	IR Jammer/Transmitter	T-1364( )/ALQ-144
9.7	Radar Jammer	RT-1149( )/ALQ-136
9.8	Radar Jammer Transmit Antenna (LRU-2T)	AS-3007( )/ALQ-136
9.9	Radar Jammer Receiver Antenna (LRU-2R)	AS-3007( )/ALQ-136

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 10 of 20)

10.0 DISPLAY AND CONTROL

Item	Description	Designation/AN Nomenclature
10.1	Automatic Direction Finder Control	C-7392A/ARN-89A
10.2	VOR/ILS Nav. Facility Control	C-10048/ARN-123(V)
10.3	Doppler Nav. Computer Display Unit	CP-1252/ASN-128
10.4	Radar Warning/Control	C-9326( )/APR-39
10.5	Radar Warning Indicator	ID-1150( )/APR-39
10.7	Gunner ICS Control Panel	C-6533( )/ARC
10.8	Pilot ICS Control Panel	C-6533( )/ARC
10.9	HUD Signal Display Unit	
10.10	Laser Tracker Control Panel	
10.16.1	Turbine Gas Temp. Indicator (Gunner)	
10.16.2	Turbine Gas Temp. Indicator (Pilot)	
10.17	Dc Volt/Amp. Meter	209-075-659-3
10.18	Turn/Slip Indicator	
10.19	Engine Transmission Temp. Indicator	209-075-658-1
10.20	Gunner Attitude Indicator	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 11 of 20)

Item	Description	Designation/AN Nomenclature
10.21.1	Gunner Torque Indicator	209-075-663-7
10.21.2	Pilot Torque Indicator	209-075-663-7
10.22	ECS Control Panel	
10.23	IR Control Panel and Indicator (Jammer)	
10.24	Search Night Control (See 10.58)	
10.25	Governor Control (See 10.60, 10.84)	
10.26	Emergency Hydraulic System Boat	
10.27	Barometric Altimeter (Pilot)	AAU-31/A
10.28	IFF Control	C-10009( )/APX-100
10.29	Security (Comm.) Control	C-8157/ARC
10.30	Radar Alt. Indicator	RT-1115(ID 1917)/APN-209
10.32	Pilot Master Armament Control Panel	
10.33	SCAS Control Panel	
10.35	Fuel Quantity Indicator	
10.36.1	Gas Producer Tachometer (Gunner)	209-075-653-9
10.36.2	Gas Producer Tachometer (Pilot)	209-075-653-9
10.37	Heads-Up Display (HUD)	
10.38	Radar Jammer Control Indicator	C-9576( )/ALQ-136
10.39	Compass Controller	C-6347( )/ASN-43

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 12 of 20)

Item	Description	Designation/AN Nomenclature
10.40	Horizontal Situation Indicator (HSI)	ID-2103
10.41	HSI Display Control Panel	
10.42	Force Trim Switch Pilot (ECP)	
10.43	Force Trim Switch Gunner (ECP)	
10.44	Pilot Attitude Indicator	ID-2104/A
10.45	Gunner Radio Magnetic Indicator (RMI)	ID-2105/A
10.46	Engine Oil Temperature Indicator	209-075-656-1
10.47	Pilot Clock	
10.48.1	Engine/Rotor RPM (Dual Tachometer)(Gunner)	229-075-665-5
10.48.2	Engine/Rotor RPM (Dual Tachometer)(Pilot)	229-075-665-5
10.49.1	Airspeed Indicator (Pilot)	209-075-666-1
10.49.2	Airspeed Indicator (Gunner)	209-075-666-2
10.51	Barometric Altimeter (Gunner)	AAU-31/A
10.52.1	Vertical Airspeed Indicator (Pilot)	209-073-663-1
10.52.2	Vertical Airspeed Indicator (Gunner)	209-073-663-2
10.53	Laser Range Control Panel (Gunner)	
10.54	TOW Control Panel	209-071-129
10.55	Sight Hand Control (TSU)	209-071-132
10.56	RMS Control and Display Panel	
10.57	Ac Circuit Breaker Panel	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 13 of 20)

Item	Description	Designation/AN Nomenclature
10.58	Dc Circuit Breaker Panel	
10.59	Power Control Panel	
10.60	Engine Control Panel (Pilot)	
10.61	Pilot Miscellaneous Panel	
10.62	Collective Stick (Pilot)	
10.63	Cyclic Stick (Pilot)	
10.64	Collective Stick (Gunner)	
10.65	Cyclic Stick (Gunner)	
10.66	Armament Control Panel (Gunner)	209-075-719-1
10.67	Radio Control Panel	ARC-115
10.68	Radio Set Control	ARC-164
10.69	Radio Set Control	ARC-114
10.70	Pilot Caution Panel	
10.71	Pilot Master Caution Indicator	
10.72	Fire Warning Indicator	
10.73	Pilot Instrument Dimming	
10.74	Pilot External Light Control Panel	
10.75	Gunner Hydraulic/Jettison Panel	
10.76	Gunner Caution Panel	
10.77	Gunner Master Caution Indicator	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 14 of 20)

Item	Description	Designation/AN Nomenclature
10.79	Acquisition Panel	
10.80	Standby Compass	
10.81	Pilot Pedals (Right and Left)	
10.82	Gunner Pedals (Right and Left)	
10.83	Gunner Telescopic Sight	3234001-TBD
10.84	Gunner Miscellaneous Panel	
10.86	Pilot Steering Control Indicator	
10.88	Gunner Armament Status Indicator	
10.89	Rocket Control Panel	
10.93	Electric Power Control Panel	
10.94	Sight Support	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 15 of 20)

11.0 ELECTRICAL

Item	Description	Designation/AN Nomenclature
11.1	Alternator (10 kVA)	
11.2	Battery	BB-649A
11.3	Transformer/Rectifier Unit	209-075-999
11.4	Inverter 750 VA	MS17406-3
11.5	Starter Generator 300 A	
11.6	Relay Box	
11.7	Voltage Regulator	
11.8	Alternator Control Unit	
11.9	Ac Circuit Breaker, TOW	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 16 of 20)

12.0 ENGINE CONTROL AND MONITORING

Item	Description	Designation/AN Nomenclature
12.1	RPM Warning Unit	
12.2	Rotor Tachometer Generator	GEV-7/A
12.3	Engine Tachometer Generator	
12.4	Forward Fuel Pump	
12.5	Aft Fuel Pump	
12.6	Start Relay	
12.7	Idle Stop Solenoid	
12.8	Ignition Solenoid	
12.9	Fuel/Oil Value	
12.10	Emergency Hydraulic Pump	
12.11	Gas Producer Tachometer Generator	
12.13	No. 1 Hydraulic Pressure Switch	
12.14	No. 2 Hydraulic Pressure Switch	
12.15	Emergency Hydraulic Pressure Switch	
12.16	Forward Fuel Level Low Switch	
12.17	Ignition Switch	
12.18	Aft Fuel Level Low Switch	
12.19	Engine Fire Sensor	
12.21	Oil Bypass Valve	
12.22	Chip Detector — 42^{o}	
12.23	Chip Detector — 90^{o}	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 17 of 20)

Item	Description	Designation/AN Nomenclature
12.24	Chip Detector — Transmission	
12.25	Chip Detector — Engine	
12.26	Aft Fuel Boost Switch	
12.27	Transmission Oil Hot Switch	
12.28	Transmission Oil Pressure Switch	
12.29	Transmission Oil Bypass Switch	
12.30	Engine Fuel Pump Pressure Switch	
12.31	Engine Oil Pressure Switch	
12.32	Fuel Filter Bypass Switch	
12.33	Engine Oil Float Switch	
12.34	Engine Oil Bypass Switch	
12.36	RPM Actuator Motor	
12.37	Fuel Valve Motor	
12.38	Torque Transmitter	
12.39	Fuel Quantity Transducer	
12.40	TOW Hydraulic Solenoid	
12.41	System 1 Hydraulic Bypass Solenoid	
12.42	System 2 Hydraulic Bypass Solenoid	
12.43	Emergency Hydraulic Pressure Solenoid	
12.44	Emergency Hydraulic Return Solenoid	
12.45	Emergency Hydraulic Pump Solenoid	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 18 of 20)

Item	Description	Designation/AN Nomenclature
12.46	Emergency Hydraulic Pressure Overload Switch	
12.47	Hydraulic Test Switch	
12.48	Armament Hydraulic Solenoid	
12.49	Forward Fuel Boost Pump Switch	
12.50	Aft Fuel Boost Pump Switch	
12.51	External Power	
12.52	Engine Inlet Air Detector	
12.53	Turbine Gas Temperature Sensor	
12.54	Fuel Filter Flow Sensor	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 19 of 20)

14.0 WEAPON AND ARMAMENT

Item	Description	Designation/AN Nomenclature
14.1	TOW Launcher (4 each)	3234008-110
14.2	Universal Gun Turret (XM28)	
14.3	Gun Control Box	
14.4	Universal Turret Control Box	
14.5	Launcher Servo Electronics Control Unit	
14.6	Missile Launcher Hydraulic Servo (2 each)	
14.7	Stabilization Control Amplifier (SCA)	209-071-129-3
14.8 (6.2)	Missile Command Amplifier	209-071-138
14.9 (6.3)	Electronic Power Supply	
14.10	Aft Test Connector	
14.11	Forward Test Connector	
14.12	Midship Test Connector	
14.13	Accelerometers (2 each)	
14.14	Actuators (2 each)	
14.15	Resolvers (2 each)	
14.16	Launcher Test Switch	
14.18	Electronic Control Assembly	
14.20	Left Ammunition Box Assembly	
14.21	Right Ammunition Box Assembly	

TABLE 1. AH-1S STEP 3 BASELINE EQUIPMENT LIST (Sheet 20 of 20)

15.0 LIGHTING

Item	Description	Designation/AN Nomenclature
15.1	Search Light	
15.2	Right Wing Position Light	
15.3	Left Wing Position Light	
15.4	Right Tail Position Light	
15.5	Left Tail Position Light	
15.6	Anticollision Light	
15.7	Caution Light	
15.8	Instrument Panel Power Supply (Pilot)	
15.9	Instrument Panel Power Supply (Gunner)	
15.10.1	Pilot Cockpit Light	
15.10.2	Gunner Cockpit Light	
15.11	Flasher	
15.12	Pilot Console Light	
15.13	Miscellaneous	
15.14	Navigation Printed Circuit Boards	
15.15	Transmission Oil Level Light	

Interface Signal Lists. In order to document each piece of equipment studied, a set of AH-1S Subsystem Interface Signal Listings (see Appendix A) was created. The factors considered in the study are:

(1) Signal name by function

(2) Origin of signal with connector pins listed (to-from)

(3) Intermediate destination — terminal board connections or fan out

(4) Ultimate destination — sink or source with signal termination

(5) Bandwidth/frequency responses

(6) Signal type as defined in the functional signal type list

(7) Voltage — ac or dc voltage of signal under consideration

(8) Impedance — source/sink defined

(9) Resolution — if multiplexed, approximately how many bits are required to define the signal

(10) Update rate — if multiplexed, how frequently shall the signal be strobed

(11) Wire type/gauge — present wire size and type (used in weight calculation)

(12) Remarks — additional information discovered during the study

The definition, study, and documentation of the Step 3 Cobra equipment suite, as outlined above, provided a baseline system; this system provided the framework from which an integrated Night Cobra multiplex system would eventually evolve.

Development of Multiplexing Criteria

(1) Elimination of Wiring. The driving force of the study has been weight reduction. Therefore, one of the first items to be considered is: how much wire can be saved if a line-replaceable-unit (LRU) is tied to the multiplex bus. The length of wiring between LRU's has been studied and defined. Where it has been found that the distance between LRU "A" and LRU "B" is less than 3 feet, no appreciable weight saving may be realized by tying to a multiplex bus, and the interface would remain hardwired. If the LRU's are not located in the same proximity, they would become candidates for multiplexing.

(2) Relocation. Some of the equipment on-board the Step 3 model is to be relocated in different parts of the aircraft. Although it may not be a candidate for multiplexing in the Step 3 configuration because of the elimination of wiring criteria, the equipment becomes a candidate for multiplexing when relocation occurs. Relocation of equipment is desirable in an attempt to eliminate ballast.

(3) Redesign. Certain items of equipment undergoing development or redesign will include 1553B compatibility (imbedded terminals). These items, by their own nature, will be multiplex candidates. Examples are the ARC-186, ARC-164, and the IACS.

Control and Display Redesign. The pilot's area has 40 prospective candidates for multiplexing, the gunner area has 24. Some of these candidate LRU's have been incorporated into IACS. Of the remaining LRU's, some will remain hardwired and others will be multiplexed and integrated into bus compatible control/display units.

Critical Signals. Several signals aboard the aircraft are critical signals; a certain amount of care must be exercised when sending them. For example, the command signals used to fire the weapons must be handled in a manner that ensures that the weapons do not fire inadvertently, but only on command. These signals may be candidates for multiplexing if care is exercised in the structure of the data word or message commanding such action. The critical signal paths may not superficially appear to be candidates for multiplexing; however, further investigation has revealed that they are candidates if special care is exercised when integrating them into a multiplex system. Techniques that ensure the proper handling of the critical signals shall be employed.

Summary of Multiplexing Criteria

(1) Eliminate excess wire — save weight

(2) Relocate equipment — eliminate ballast, change moments

(3) Redesign equipment — IACS, other bus compatible equipment

(4) Redesign Control and Display — eliminate meters, display LRU's, etc.

(5) Critical signals

c. Multiplex Versus Hardware.

Candidates for Multiplexing. The equipment listed in Table 1 (baseline, Step 3) represents all of the equipment on-board the aircraft. Not all of this equipment is a candidate for multiplexing. During the investigation, some of this equipment was immediately eliminated from further consideration because of the multiplex system bandwidth limitations. Signals creating transmission frequencies above 400 Hz were excluded from consideration. The criteria developed have been applied to the remaining equipment to determine whether it remains hardwired or becomes integrated into the multiplex system. Tables 2 to 6 list all of the candidates for multiplexing with the results of their disposition after the multiplexing criteria have been applied. The equipment listed in the tables has been organized with respect to its physical locations. The generic subsystem breakdown is no longer of importance here. Each piece of equipment has been studied, and the determination has been made that several candidates will remain hardwired. The IACS multiplexed subsystem will handle the item listed via the pilot's control panel (PCP) and/or the gunner's control panel (GCP). A flight management display (FMD) will be one of the control and display LRU's connecting or interfacing several of the listed items. Some of the remaining equipment will be controlled by the electronics attitude and heading display (EAHD). Several of the Step 3 control and display LRU's will remain within the respective compartments. These items are listed as multiplexed without integrated displays. They are not a part of IACS, the FMD, or the EAHD.

Hardwire Considerations. The majority of the equipment candidates have been deemed capable of being multiplexed and will not remain hardwired. The items that will remain hardwired have been found to either communicate with equipment in their close proximity or are integral to the aircraft. Where information from the integral equipment is required for the multiplexed system, special transducers are required. Certain controls, such as instrument dimming control potentiometers, have remained hardwired for simplicity. They could be integrated into the multiplexed system, but the additional hardware and software requirements would not be cost effective. There are other LRU's that must be hardwired because the multiplex system has to be activated via these hardwired paths. The ignition switch, for example, should be hardwired to an LRU that initiates a series of actions resulting in an operational aircraft.

Multiplexed Equipment. The equipment from the baseline suite that is integrated to the multiplexed system gets attached to the bus via several different ports or black boxes (embedded terminal devices, remote terminal devices, but controller devices, etc.).

(1) IACS. The communication, navigation and identification (CNI) equipment listed in Step 3 will be integrated into the multiplexed system via IACS. Two control and display units (PCP and GCP) shall be placed aboard the aircraft in their respective compartments. In addition, each compartment will also have an IACS status panel. The standard control/display LRU's for this equipment will no longer be needed and have been deleted from the Step 4 equipment list.

(2) Integrated Displays. Two integrated display units (FMD and EAHD) are planned to replace a large number of the control and display LRU's. Each compartment, pilot and gunner, will have one of each type located therein. The displays will be capable of providing access to or displaying mission essential information and will

TABLE 2. PILOT COMPARTMENT (STEP 3 TO STEP 4) (Sheet 1 of 3)

Item Description		Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
5.3	Laser Tracker Electronics Assembly				X
6.7	Helmet Mounted Sight System Electronic Interface Assembly				X
10.1	Automatic Direction Finder Control Panel		PCP		
10.2	VOR/ILS Navigation Facility Control		PCP		
10.4	Radar Warning Facility/Control			FMD	
10.5	Radar Warning Indicator				X
10.8	Intercommunication Control Panel (Discretes)				X
10.10	Laser Tracker Control Panel	X			
10.16.2	Turbine Gas Temperature Indicator			FMD	
10.17	Dc Volt/AMP Meter			FMD	
10.18	Turn/Slip Indicator			EAHD	
10.19	Engine Transmission Temp. Indicator			FMD	
10.21.2	Torque Indicator			FMD	
10.22	Environmental Control System (ECS)				X
10.23	IR Control Panel & Indicator				X
10.24	Search Light Control	X			
10.27	Barometric Altimeter			EAHD	
10.28	IFF Control Panel		PCP		
10.29	Security Control Panel (KY-58)		PCP		

TABLE 2. PILOT COMPARTMENT (STEP 3 TO STEP 4) (Sheet 2 of 3)

	Item Description	Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
10.30	Radar Altitude Indicator			FMD	
10.32	Master Armament Control Panel			FMD	
10.33	SCAS Control Panel			FMD	
10.35	Fuel Quanity Indicator			FMD	
10.36.2	Gas Producer Tachometer			FMD	
10.37	Heads-Up-Display (HUD)				X
10.38	Radar Jammer Control Indicator	X			
10.39	Compass Controller Panel				X
10.40	HSI Indicator (Gyro Heading)			EAHD	
10.41	HSI Display Control Panel			FMD	
10.44	Attitude Indicator (Turn/Bank) ADI			EAHD	
10.46	Engine Oil/Temp/Press			FMD	
10.47	Clock	X			
10.48.2	Engine/Rotor RPM (Dual Tachometer)			FMD	
10.49.1	Airspeed Indicator			EAHD	
10.52.1	Vertical Speed Indicator			EAHD	
10.56	Rocket Management System Panel			FMD	
10.57	Ac Circuit Breaker Panel			FMD	
10.58	Dc Circuit Breaker Panel			FMD	
10.59	Power Control Panel			FMD	

TABLE 2. PILOT COMPARTMENT (STEP 3 TO STEP 4) (Sheet 3 of 3)

Item Description		Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
10.60	Engine Control Panel			FMD	
10.61	Miscellaneous Panel				X
10.62	Collective Stick (Discretes)				X
10.63	Cyclic Stick (Discretes)				X
10.67	Radio Set, VHF-AM AN/ARC-115		PCP		
10.68	Radio Set, UHF-AM ARC-164		PCP		
10.70	Caution Panel			FMD	
10.71	Master Caution Indicator			FMD	
10.72	Fire Warning Indicator			FMD	
10.73	Instrument Dimming	X			
12.17	Ignition Switch	X			

TABLE 3. GUNNERS COMPARTMENT (STEP 3 TO STEP 4) (Sheet 1 of 2)

Item Description		Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
5.2	Telescopic Sight Unit (TSU)				X
8.4	Pitot Heater				X
10.3	Doppler Nav. Sys. Display Unit		GCP		
10.7	Interphone Control Panel (Discretes)				X
10.16.1	Turbine Gas Temp Indicator			FMD	
10.20	Attitude Indicator (Turn/Bank)			EAHD	
10.21.1	Torque Indicator			EAHD	
10.36.1	Gas Producer Tachometer			FMD	
10.45	Radio Magnetic Indicator (RMI)			FMD	
10.48.1	Engine/Rotor RPM (Dual Tachometer)			FMD	
10.49.2	Airspeed Indicator				
10.51	Barometric Altimeter			EAHD	
10.52.2	Vertical Speed Indicator				
10.53	Laser Range Control Panel	X			
10.54	Tow Control Panel			FMD	
10.64	Collective Stick (Discretes)				X
10.65	Cyclic Stick (Discretes)				X
10.66	Armament Control Panel			FMD	
10.69	Radio Set, VHF-FM AN/ARC-114		GCP		
10.75	Hydraulic/Jettison Panel				X

TABLE 3. GUNNERS COMPARTMENT (STEP 3 TO STEP 4) (Sheet 2 of 2)

	Item Description	Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
10.76	Caution Panel			FMD	
10.77	Master Caution Indicator			FMD	
10.79	Acquisition Panel				X
10.80	Standby Compass	X			
10.84	Miscellaneous (Instrument) Panel				X

TABLE 4. ENGINE COMPARTMENT (Sheet 1 of 3)

Item Description		Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
2.11	Radar Altimeter				X
3.1.2	Airspeed Electronic Processor Unit				X
12.2	Rotor Tachometer Generator				X
12.3	Engine Tachometer Generator				X
12.4	Forward Fuel Boost Pump				X
12.5	Aft Fuel Boost Pump				X
12.6	Start Relay				X
12.7	Idle Stop Solenoid				X
12.8	Ignition Solenoid				X
12.9	Fuel/Oil Valve				X
12.10	Emergency Hydraulic Pump Switch				X
12.11	Gas Producer Tachometer Generator				X
12.13	No. 1 Hydraulic Pressure Switch				X
12.14	No. 2 Hydraulic Pressure Switch				X
12.15	Emergency Hydraulic Pressure Switch				X
12.16	Forward Fuel Level Low Switch				X
12.17	Ignition Switch	X			
12.18	Aft Fuel Level Low Switch				X
12.19	Engine Fire Sensor				X
12.21	Oil Bypass Valve	X			

TABLE 4. ENGINE COMPARTMENT (Sheet 2 of 3)

Item Description		Remains Hardwired	Multiplexed IACS	Multiplexed Integrated Display	Multiplexed Via RT
12.24	Transmission Chip Detector				X
12.25	Engine Chip Detector				X
12.27	Transmission Oil Hot Switch				X
12.28	Transmission Oil Pressure Switch				X
12.29	Transmission Oil Bypass Switch				X
12.30	Engine Fuel Pump Pressure Switch				X
12.31	Engine Oil Pressure Switch				X
12.32	Fuel Filter Bypass Switch				X
12.33	Engine Oil Float Switch				X
12.34	Engine Oil Bypass Switch				X
12.36	RPM Actuator Motor	X			
12.37	Fuel Valve Motor	X			
12.38	Torque Transmitter				X
12.39	Fuel Quanity Indicator				X
12.40	Tow Hydraulic Solenoid	X			
12.41	No. 1 Hydraulic Bypass Solenoid	X			
12.42	No. 2 Hydraulic Bypass Solenoid	X			
12.43	Emergency Hydraulic Pressure Solenoid	X			
12.44	Emergency Hydraulic Return Solenoid	X			
12.45	Emergency Hydralic Pump Solenoid	X			

TABLE 4. ENGINE COMPARTMENT (Sheet 3 of 3)

Item Description	Remains Hardwired	Multiplexed		
		IACS	Integrated Display	Via RT
12.46 Emergency Hydraulic Pump Overload Switch				X
12.47 Hydraulic Test Switch				X
12.48 Armament Hydraulic Solenoid	X			
12.49 Forward Fuel Boost Pump Switch				X
12.50 Aft Fuel Boost Pump Switch				X
12.51 External Power	X			
12.52 Engine Inlet Air Detector				X
12.53 Turbine Gas Temperature Sensor				X
12.54 Fuel Filter Flow Sensor				X

TABLE 5. AFT SECTION

Item Description		Remains Hardwired	Multiplexed		
			IACS	Integrated Display	Via RT
1.8	IFF Diversity Transponder (APX-100)		CCU		
1.14	IFF KIT-1A Computer (Transponder)		CCU		
1.15.2	Security Set (TSEC/KY-58)		CCU		
2.1	Automatic Direction Finder ARN-89A		CCU		
2.4	Conus Nav. Rec (VOR/LOC) R-2023/ARN-123		CCU		
2.14	Remote Compass Transmitter	X			
2.16	PMD Electronic Assembly Unit				X
2.20	Vertical Gyro				X
9.2	Radar Warning Comparator				X
9.6	IR Jammer/Transmitter				X
9.7	IR Receiver/Transmitter				X
10.9	HUD Signal Display Unit				X
12.22	42° Chip Detector				X
12.23	90° Chip Detector				X
14.8	Missile Command Amplifier				X
14.9	Electronics Power Supply	X			
15.4	Right Tail Position Light				X
15.5	Left Tail Position Light				X
15.6	Anti-Collision Light				X
					X

TABLE 6. WING COMPARTMENT

Item Description		Remains Hardwired	Multiplexed Via RT	
			Port	Starboard
7.1	Left Hand Inboard Rocket Signal Unit (SU)		X	
7.2	Right Hand Inboard Rocket Signal Unit (SU)			X
7.3	Left Hand Jettison Inboard		X	
7.4	Right Hand Jettison Inboard			X
7.5	Left Hand XM18 Gun SU		X	
7.6	Right Hand XM18 Gun SU			X
7.7	Left Hand Outboard Rocket SU		X	
7.8	Right Hand Outboard Rocket SU			X
7.9	Left Hand Jettison Outboard		X	
7.10	Right Hand Jettison Outboard			X
14.1	Tow Launcher (4 each)		X (2)	X (2)
14.13	Accelerometers (2 each)		X (1)	X (1)
14.14	Actuators (2 each)		X (1)	X (1)
14.15	Resolvers (2 each)		X (1)	X (1)

also be designed and programmed for redundant operation in case of failure. The two displays will be designed with an embedded terminal so that they are 1553B compatible. The addition of these displays has resulted in the deletion of many of the controls and displays that appear in the Step 3 equipment list. A more detailed description of each type of terminal device shall be presented later in this report.

(3) Without Integrated Display. There is a small suite of peripheral equipment that will not be accessed via IACS or the integrated displays identified in the above discussion. These pieces of peripheral equipment must be tied to the multiplex bus via some type of device. The remote terminal (RT) will be used to interface the peripheral equipment that is not tied to an embedded terminal unit.

(4) Remote Terminal Equipment. The RT's peripheral equipment is listed in Tables 7 through 10. The suite of recommended equipment for the respective RT's has been chosen primarily in accordance with the proximity of the LRU to the RT. During the actual design it may be found that slight changes may be necessary.

The peripheral equipment is to be interfaced to the multiplexed bus via one or more RT's. The final decision and determination will be dependent on the equipment design. It should be kept in mind that the number of RT's or black boxes needed to accomplish the tasks should be kept to a minimum as a design goal, since that will ultimately result in reduced weight.

TABLE 7. PILOT'S RT PERIPHERAL EQUIPMENT

Laser Tracker Electronic Assembly	Heads-Up Display (HUD)
Helmet Sight System Electronic Interface Assembly	Miscellaneous Panel (pilot)
Radar Warning Indicator	Pilot Collective Stick
Infrared (IR) Control Panel/Indicator	Pilot Cyclic Stick
Pitot Heater	Power Distribution Station

TABLE 8. GUNNER'S RT PERIPHERAL EQUIPMENT

Telescopic Sight Unit (TSU)	Miscellaneous Panel (Gunner)
Gunner Collective Stick	Universal Turret System (UTS)
Gunner Cyclic Stick	Barometric Altimeter
Gunner Hydraulic/Jettison Panel	Projected Map Display
Acquisition Panel	Environmental Control System (ECS)

TABLE 9. ENGINE RT PERIPHERAL EQUIPMENT

Airspeed Electronic Pressure Unit	Transmission Oil Hot Switch
Rotor Tachometer Generator	Transmission Oil Pressure Switch
Engine Tachometer Generator	Transmission Oil Bypass Switch
Forward Fuel Boost Pump	Engine Fuel Pump Pressure Switch
Aft Fuel Boost Pump	Engine Oil Pressure Switch
Start Relay	Fuel Filter Bypass Switch
Idle Stop Solenoid	Engine Oil Float Switch
Ignition Solenoid	Radar Altimeter
Fuel/Oil Valve	Engine Oil Bypass Switch
Emergency Hydraulic Pump	Torque Transmitter
Gas Producer Tachometer Generator	Fuel Quantity Indicator
No. 1 Hydraulic Pressure Switch	Emergency Hydraulic Pump Overload Switch
No. 2 Hydraulic Pressure Switch	Hydraulic Test Switch
Emergency Hydraulic Pressure Switch	Forward Fuel Boost Pump Switch
Forward Fuel Level Low Switch	Aft Fuel Boost Pump Switch
Aft Fuel Level Low Switch	Engine Inlet Air Detector
Engine Fire Sensor	Turbine Gas Temperature Sensor
Transmission Chip Detector	Fuel Filter Flow Sensor
Engine Chip Detector	

TABLE 10. AFT SECTION RT PERIPHERAL EQUIPMENT

IR Jammer/Receiver Electronics	42-degree Chip Detector
Rate Gyro	90-degree Chip Detector
Vertical Displacement Gyro	Power Distribution Station
Radar Warning Comparator	Projected Map Display (PMD) Electronic Assembly Unit
HUD Signal Display Unit	Position Lights
Missile Command Amplifier	Anticollision Lights

The peripheral equipment will be interfaced to the multiplexed bus via a "smart" remote terminal. Several signals (discretes) will require transformations from parallel entry at the I/O port to a serial data word. The designer will be required to perform the necessary structuring and design the terminal for the respective applications.

The equipment tied to the wing stores RT will include the TOW weapons, rocket, and mini-gun POD's when attached. The multiplex system will be designed to operate the different weapons systems via the multiplex bus.

During the actual design, another look will be taken to determine if the aft equipment could be tied to the bus via a different I/O port (i.e., tied to the IACS CCU). The IACS central control unit will have an embedded terminal and perform as an RT for the listed peripheral equipment.

d. Controls/Displays. The following section addresses the analysis performed in the evolution of integrated controls and displays for the Night Cobra.

(1) Operational Problems of Controls and Display. In nap-of-the-earth (NOE) flight, both crewmembers are occupied with monitoring external references simultaneously. The crewmembers' attention will be primarily focused on the external references such as flight control, navigation, and terrain/obstacle avoidance tasks. For NOE operations, the control/display functions must be streamlined to provide the crewmembers with faster access to both information and control.

Attempts to solve these problems have led to the development of helmet sight, helmet mounted displays, and head-up displays, with varying degrees of success and associated problems. Barnes[4] has shown that during terrain following flights (100 knots air-speed and 50-feet absolute altitude) 85 percent of the pilot's attention was devoted to external references, 10 percent was devoted to flight instruments, and 6 percent was devoted to system monitoring. Table 11[4] shows the percent of time pilots used specific instruments while performing given tasks in actual flight.

Considering the scan time available for systems monitoring, that is, engine, power, and so forth, of the Step 3 configuration, it is very probable that the pilot would not detect a rapidly developing out-of-tolerance condition by reference to the Step 3 instrumentation when flying NOE.

In addition, integrating the traditional round cockpit instruments into the appropriate scale symbology and graphics necessary to manage flight and weapon delivery on a mission segment basis reduces the amount of cockpit panel space required when multiformatted displays are used.

(2) Control/Display Integration Study

(a) Introduction. The Night Cobra coordinated attack mission scenario was selected and analyzed. Mission segment flows were developed and associated mission segment tactical information needs analyzed. From the mission segment flows, critical mission segments were identified and operational sequence diagrams (OSD's) developed to assess control and display requirements and means of improving reaction time, reducing exposure times through multiplexed control and display automation.

Weapon mode procedures were analyzed and reduced to flows and time lines to assess the control and display impact on critical reaction and exposure times affecting crew and helicopter survivability in a high intensity engagement.

(b) Summary Conclusions. As a result of the analyses presented in paragraph (c), it is apparent that tactical data for effective mission operations are both planned and instantaneous, and follow a piecewise directed mission flow. The segmentation of the mission flow further sets attention, demand, and priority to certain tactical data peculiar and/or critical to the mission segment operation.

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[4] Barnes, J. A., "Analysis of Pilot's Eye Movements During Helicopter Flight," Technical Memorandum 11-72, Human Engineering Laboratory, Aberdeen Proving Ground, MD, April 1972.

TABLE 11. PERCENT OF TIME PILOTS USED SPECIFIC INSTRUMENTS WHILE PERFORMING GIVEN TASKS IN ACTUAL FLIGHT

Task	Instrument									
	Attitude Indicator	Altimeter	Airspeed Indicator	Compass	Vertical Velocity	Rate of Turn	Torque Meter	Dual Tachometer	Engine Instruments	External References
Spot Hover IGE Visual	3	2	1	2	2	1	2	2	1	85
Spot Hover IGE Instruments	25	12	7	18	12	3	15	13	11	
Spot Hover OGE	27	22	17	17	20	2	11	12	7	
360° Hovering Turn OGE	15	19	9	1	5		5	5	3	38
Vertical Climb	29	30	9	7	20	3	7	6	5	
Vertical Descent	4	5	4	3	1		2	4	7	75
Cruise, 60K, Visual	10	8	7	13	7	1	5	4	4	48
Cruise, 60K, Instruments	23	21	12	14	10	2	8	8	11	
Standard Rate Turn, 60K	23	18	9	19	9	7	6	6	6	
Climb, 60K, 500 FPM	19	17	11	19	19	2	8	6	7	
Climb from Hover	23	23	7	6	16	3	6	5	4	15
Initial Descent to 500 Feet, 60K	31	27	24	17	24		6	7	10	
Reverse Direction of Flight, 60K	23	18	9	19	9	7	6	6	6	
Cruise, 100K, Visual	10	8	7	13	7	1	5	4	4	48
Cruise, 100K, Instruments	23	21	10	15	10	2	4	5	5	
Standard Rate Turn, 100K	14	25	2	25	14	1	3	3	3	
Terrain Following, 100K	2	2	2	2	2		2	2	2	85
Climb, 100K, 500 FPM	8	15	13	10	12	3	4	9	3	
Descent, 100K, 500 FPM	27	29	16	11	17	2	6	7	7	
180° Descending Turn, 100K	35	18	15	8	8	3	3	4	5	3
Reverse Direction of Flight, 100K	14	25	2	25	14	1	3	3	3	

During mission segments in which crew attention is directed at critical tasks, essential task data and other critical instantaneous information must be integrated and effectively presented to the crewmembers with a minimum of time and confusion. The human factors consideration of the data presented is of paramount importance.

The integration of the controls and displays recommended for the Night Cobra, as specified in the AVSAR II Electronic System functional specification, is a result of this effort.

(c) Approach. An overview of the study approach, which involved the attack scenarios, development of mission flows, and so forth, is presented in Figure 2.

(d) Mission Profile. The Night Cobra mission profile (Figure 3) was analyzed for the essential mission segment data required during the operation of each segment of the attack helicopter's mission profile.

(e) Mission Segment Times. Mission segment times are summarized in matrix form for each segment of the 2-hour attack mission. These figures are presented in Figure 4. Attention is directed at mission segments 1.0 and 2.0, whose preparation consumes an inordinate amount of time and could seriously affect operational readiness to respond to a maximum effort to stop a mechanized assault. As shown, after the first coordinated attack, should the helicopter and crew survive the tactical environment, the estimated remaining time on station, forward edge of the battlefield (FEBA), would be 1 hour, 28 minutes and 49 seconds.

The Night Cobra armament of eight TOW missiles would be expended in approximately 50 minutes if fired individually in a 7.0 through 13.0 mission segment sequence. This leaves approximately 38 minutes for cannon and rocket fire to provide suppressing fire for other Night Cobras firing TOW missiles. In this situation, the rocket mode reaction time impacts the survivability of the rocket launching helicopter.

The Night Cobra's prime targets for a coordinated attack are the enemy mobile ground to air defense units, mechanized armor, and personnel carriers operating in the FEBA.

(f) Mission Segment Data. Mission segment data are obtained from both internal and external sensors of the coordinated attack helicopter system. These data are largely processed by on-board distributed processors, navigation, fire control, air data, communications, and so forth.

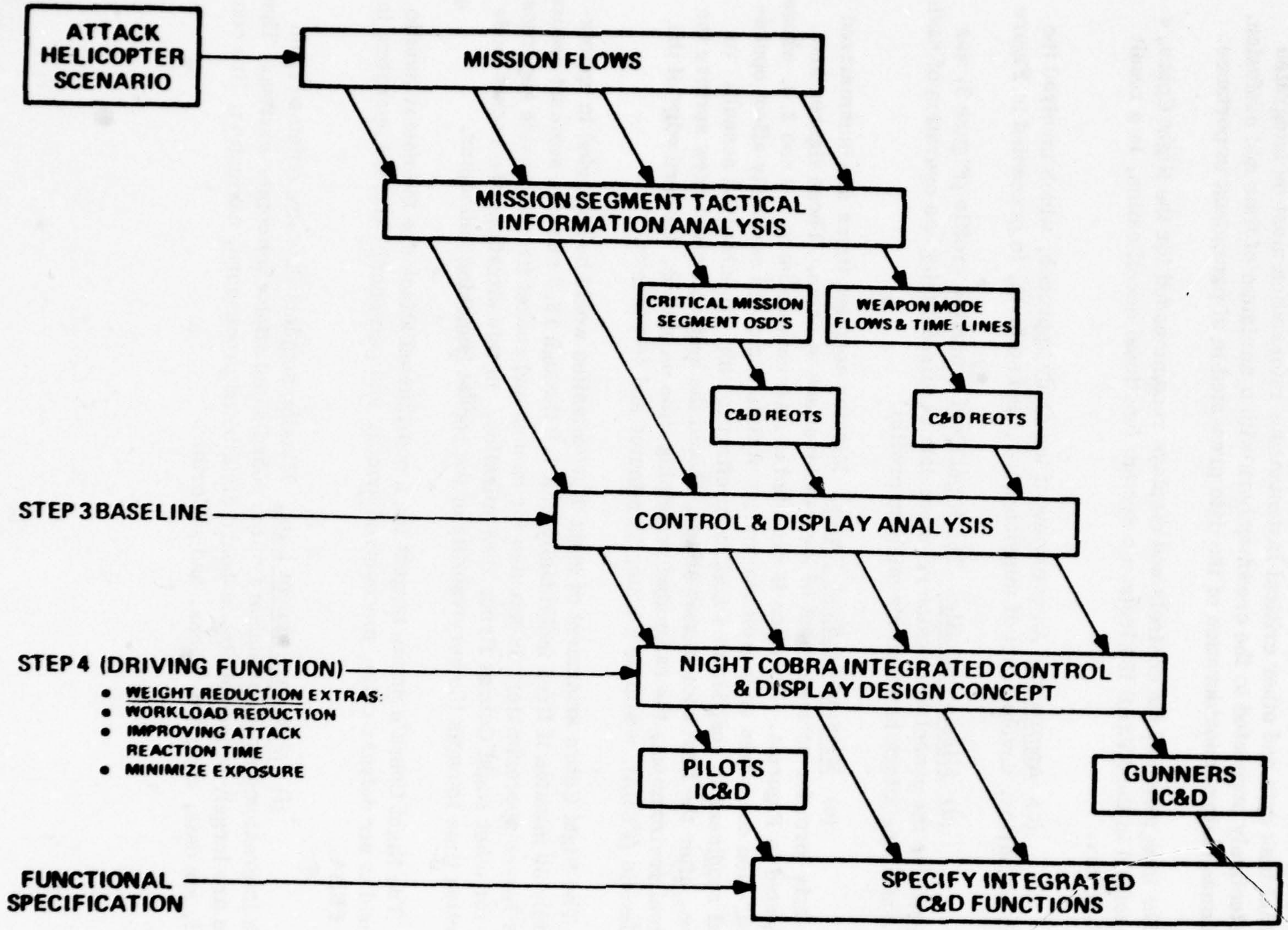

Figure 2. Control/display integration

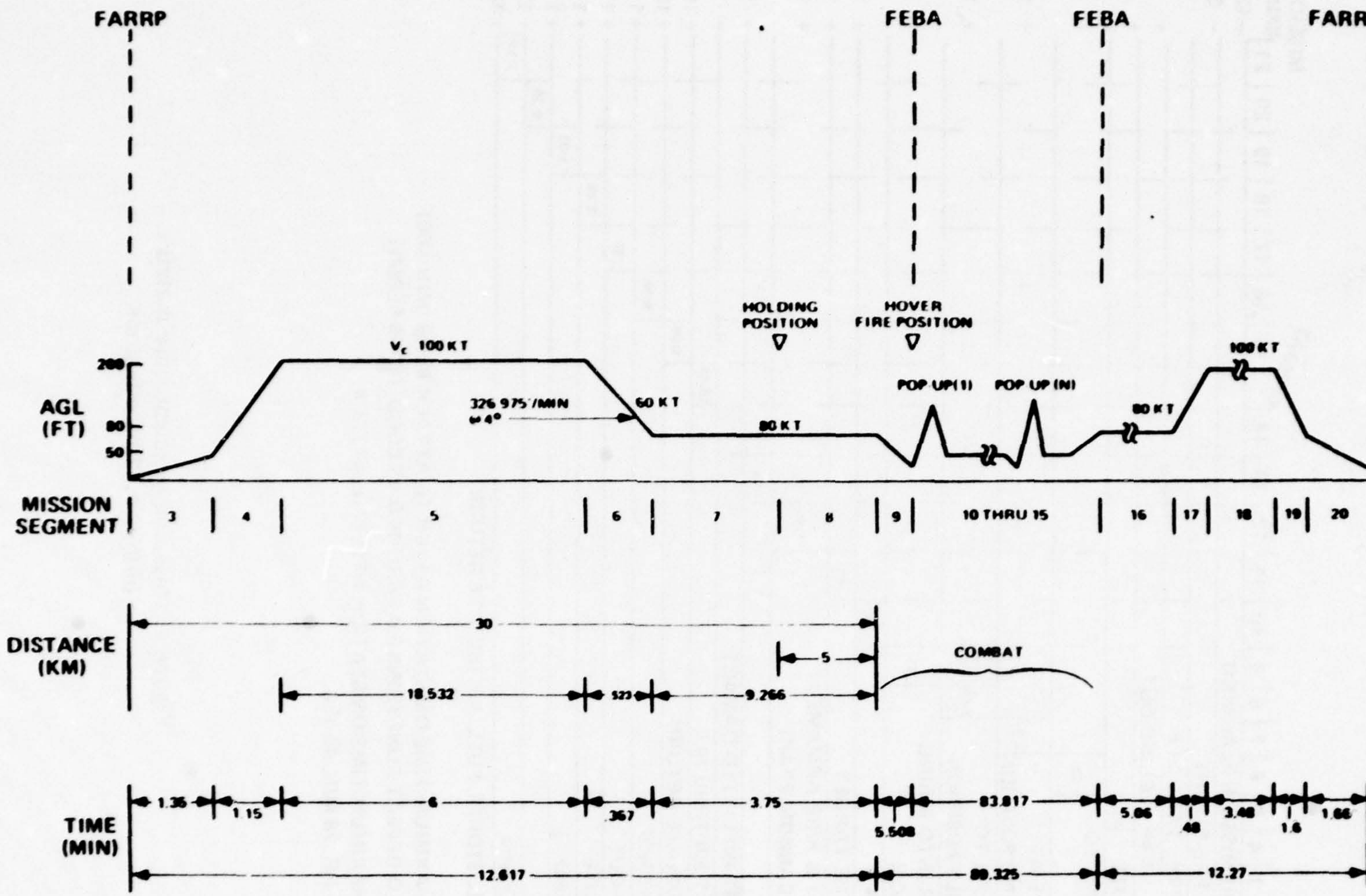

Figure 3. Mission profile

No.	Function	Segment Time (min:sec)	Column
1	PREMISSION PLANNING	72:	1
2	PRE-FLIGHT	51:	2
3	TAKE-OFF	1:21	3
4	CLIMB-OUT	1:09	4
5	ENROUTE	6:00	5
6	DESCEND TO NOE	:22	6
7	ARRIVE AT HOLDING POSITION	2:11	7
8	ENROUTE TO ASSAULT POSITION	2:49	8
9	HOVER INTO FIRING POSITION	:31	9
10	POP-UP	:25	10
11	ACQUIRE TARGET	:42	11
12	SELECT & FIRE ARMAMENT (TOW, CANNON, FFAR)	1:30	12
13	MASK	:22	13
14	REPORT INFLICTED DAMAGE	1:30	14
•	REPEAT 8.0 THRU 14.0	88:49	• (COMBAT)
15	COORDINATE RETURN	1:04	15
16	DEPART NOE	5:06	16
17	CLIMB-OUT	:29	17
18	ENROUTE	3:29	18
19	DESCEND	1:01	19
20	LAND	1:39	20
21	SHUTDOWN	7:11	21

MISSION TIME (MIN:SEC): −123:00; − 51:00; 0:00; + 1:21; + 2:30; + 8:30; + 8:52; + 11:03; + 13:52; + 14:23; + 14:48; + 15:30; + 17:00; + 17:22; + 18:52; + 107:41; + 108:45; + 113:22; + 113:51; + 117:20; + 118:21; + 120:00; + 127:11

* UNTIL STORES, FUEL, A/C DICTATE RETURN

- MAXIMUM TIME ON STATION AFTER 1st ATTACK 88:49 (MIN:SEC) TO REPEAT FUNCTIONS 8.0 THRU 14.0 AS CONDITIONS PERMIT.
- MAXIMUM TIME ON STATION AFTER 1st ATTACK 1 HR, 28 MIN, 49 SEC.

Figure 4. Mission segment time matrix (min:sec, 2 hr mission)

Figure 5 presents a conceptualization of mission data space integration impacting the control and display functional integration. For the sake of brevity, the control and display functions shown at 8.0 span all mission data segments. As illustrated here, the crew and helicopter are operating in mission segment 8.0, en route to the assault phase. The control and display functional data needs will sequentially change as the mission progresses from one state to the next.

An objective of this study was to determine the unique set of data needs for the Night Cobra and reduce these needs to control and display requirements on a mission segment basis so that display and control integration could be effectively achieved. Table 12 lists mission data parameters which are mission segment active.

(g) Critical Operational Sequence Diagrams (OSD's). Mission segment flow diagrams, threats, and attack mode time lines were analyzed and assessed in order to identify critical operational sequences for the Night Cobra in a coordinated attack. Critical sequences were found to occur in the following situations:

1. Takeoff and climbout (descend and land)

2. En route evasion

3. NOE flight-evasion

4. TOW attack

5. Direct rocket attack with laser ranging

6. TSU firing gun attack.

Operational sequence diagrams were generated for the following sequences:

1. Takeoff and climbout

2. Weapon delivery

(a) TOW attack

(b) Direct rocket attack with laser ranging

(c) TSU firing gun attack

(h) En Route and NOE Flight-Evasion Sequences. The en route-evasion and NOE flight-evasion sequences contain too many random variables concerned with terrain and threats to be meaningfully reduced to specific or general OSD's. However, from the point of view of critical mission segment data concerning reaction and exposure

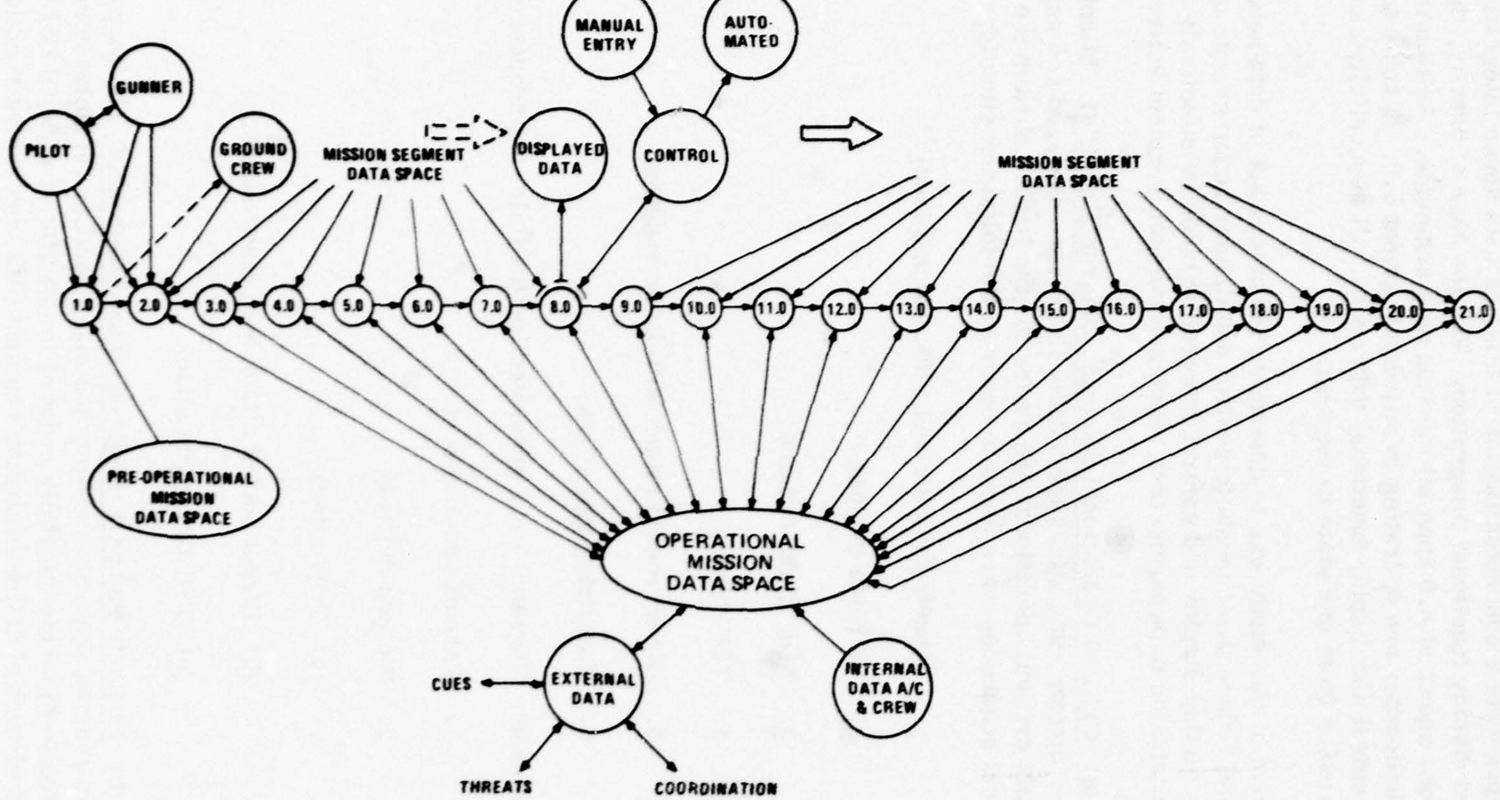

Figure 5. Conceptualization of control and display integration of mission segment data

TABLE 12. MISSION DATA PARAMETERS (Sheet 1 of 5)

Parameter	Symbol	Unit
1. Initial Pressure Altitude	IPA	ft
2. Gross Weight	GRWT	lb
3. Climb Out True Air Speed	COTAS	kts
4. Distance	DIS	nmi
5. Cruise Fuel Flow	CFF	lb/hr
6. Maximum Range	MAXR	nmi
7. Time on Station	TOS	min;sec
8. MAX Torque Available	MAXQ	%
9. Torque Required to Hover	TRHQ	%
10. Free Air Temperature	FAT	o/c
11. Hover Height	HH	ft
12. Obstacle Height	OH	ft
13. Rate of Climb	ROC	ft/min
14. Engine RPM	ERPM	%
15. Rotor RPM	RRPM	%
16. Turbine Gas Temperature Change	TGT	deg/c
17. MAX R/C	MIAS	kt
18. Change in Torque for Climb	ΔTFCQ	%
19. Level Flight Torque at R/C IAS	LFTQ	%
20. Fuel Flow	FF	lb/hr
21. Cruise Speed True Air	CSTAS	kt
22. Cruise Torque	CTQ	%
23. Cruise Speed Indicated	CSIAS	kt
24. Idle Fuel Flow	IFF	lb/hr
25. Fuel Used	FU	lb
26. Final Pressure Altitude	FPA	ft
27. Time Lapse	ΔT	min

TABLE 12. MISSION DATA PARAMETERS (Sheet 2 of 5)

Parameter	Symbol	Unit
28. Wind velocity	W_V	km/hr, kt
29. Wind direction	W_D	Deg
30. Maximum Endurance		
31. Engine Oil Temperature	EOT	Deg/c
32. Turbine Gas Temperature	TGT	Deg/c
33. Engine Oil Pressure	EOP	
34. Transmission Oil Temperature	TOT	Deg/c
35. Transmission Oil Pressure	TOP	
36. Heading	H	Deg
37. Course	C	Deg
38. Bearing to Destination	BTD	Deg
39. Course Deviation	CD	Deg
40. Distance to Fly	DTF	nmi
41. Barometric Altitude	BALT	ft
42. Radar Altitude	RALT	ft
43. Vertical Airspeed	V_V	H/min, ft/min
44. Ground Speed	V_G	km/hr, kt
45. Heading Speed	V_H	km/hr/kt
46. Lateral Speed	V_D	km/hr/kt
47. Roll	$\pm\theta_X$	Deg
48. Pitch	$\pm\theta_Y$	Deg
49. Yaw	$\pm\theta_Z$	Deg
50. Horizon (Artificial)		None
51. Aircraft Reference		None
52. Turn/Slip		None
53. Latitude	LAT	Deg, Min
54. Longitude	LONG	Deg, Min

TABLE 12. MISSION DATA PARAMETERS (Sheet 3 of 5)

Parameter	Symbol	Unit
55. UTM Zone		
56. UTM Area		
57. UTM Easting		km
58. UTM Northing		km
59. Variation		Deg
60. Track Angle		Deg
61. Time	T	hr, min, sec
62. Cross Track Deviations	XTK	km
63. Track Angle Error	TKE	Deg
64. Magnetic Heading	MAGH	Deg
65. Fore-Aft TAS	V_U	kt
66. Lateral TAS	V_V	kt
67. Vertical TAS	V_W	kt
68. Down Wash Velocity	V_{DW}	kt
69. Tree Height	H_T	ft
70. Pilot Line of Sight Cosine	PLOS	
71. Gunner Line of Sight Cosine	GLOS	
72. Static Pressure	SP	psia
73. Fly-To-Dest No.	FTD #	Whole Numbers
74. Checkpoint Bearing	CPB	Deg
75. Checkpoint Range	CPR	km
76. VHF-FM FREQUENCY	VHF-FM	MHz
77. VHF-AM FREQUENCY	VHF-AM	MHz
78. UHF-AM FREQUENCY	UHF-AM	MHz
79. Fire Control Retical AZ	FCRAZ	ms
80. Fire Control Retical EL	FCREL	ms
81. Gun EL Command	GELC	

TABLE 12. MISSION DATA PARAMETERS (Sheet 4 of 5)

Parameter	Symbol	Unit
82. Gun AZ Command		
83. TSU ACQ Command EL		
84. TSU ACB Command AZ		
85. TSU-GUN EL Command		
86. R/ALT Position		
87. R/ALT Command		
88. TSU Position		
89. Gun Position		
90. PHS-AZ Command		
91. PHS-EL Command		
92. GHS-AZ Command		
93. GHS-EL Command		
94. TSU-GUN AZ Command		
95. Laser Range		km
96. AZ Rate		Deg/Sec
97. EL Rate		Deg/Sec
98. R/ALT EL Command		
99. ALT ACQ Command		
100. PHS ACQ Command		
101. ADF FREQUENCY		MHz
102. VOR/ILS FREQUENCY		
103. Radar Threat Bearing		deg
104. Unit Vector in Direction of Launcher to Target	$\vec{B}$	unit
105. Time of Flight from Launcher to Target	TOF	sec
106. Vector Velocity of Aircraft	$\vec{U}_A$	m/sec
107. Muzzle Velocity	U_B	m/sec

TABLE 12. MISSION DATA PARAMETERS (Sheet 5 of 5)

Parameter	Symbol	Unit
108. Wind Vector	$\vec{W}$	m/sec
109. Velocity Vector of Target	$\vec{V}_T$	m/sec
110. Axial Moment of Inertion	A	lb/ft^2
111. Acceleration Vector Due to Gravity	G	m/sec^2
112. Position Vector of Projectile	$\underset{\rightarrow}{X}$	m
113. Air Density	ρ	Kg/m^3
114. Standard ICAO Atmosphere (Density at Sea Level)	P_S	Kg/m^3
115. Slant Range	R	m
116. Aircraft Angle of Attack		rad
117. Aircraft Angle of Sideslip	B	rad
118. Aircraft Roll Angle	θ	rad
119. Launcher Elevation		rad
120. Aircraft Pitch Attitude		rad
121. True Airspeed	V_a	m/sec
122. Azimuth Retical Setting	σ_a	rad
123. Elevation Retical Setting	σ_e	rad

time of the Night Cobra to enemy radar-directed gun threats, the self-protection subsystem on board the aircraft should be integrated into the multiplexed architecture to provide the pilot threat bearing priority (immediacy) and classification.

(i) Operational Sequence Diagrams. The OSD's discussed here and presented in Appendix B are for mission segments in which crew and aircraft performance are critical. These diagrams depict pilot/copilot gunner actions/decisions controlling flight/avionics/weapon systems through manual input actions of the Step 3 baseline equipment configuration. The sequences make certain assumptions initializing the sequence and proceed from there in an action decision fashion, the granularity of which is limited by the documentation available. They are useful in determining areas in which the multiplexed avionics architecture can facilitate automation, reduce crew workload, and improve reaction times, enhancing survivability in the expected threat environment.

(j) Takeoff and Climbout. The takeoff and climbout sequence covers the pilot actions and decisions during mission segments 3.0 and 4.0. This phase is critical from a number of standpoints, depending on the sequence initializations. It can be expected that the Night Cobra will make several reload and refuel trips after the first run and mission of the day.

This OSD assumes a fully loaded 10,000 lb gross-weight aircraft on its first flight of the day. Preflight preparations have been completed, and engine runup is satisfactory. The total OSD sequence time is 2 minutes and 30 seconds and assumes a cruise altitude of 200 feet above ground level (AGL).

Mission data items 1 through 18, 28, and 29, exception reporting of item 31 through 35, and EAHD items 41 through 51, listed in Table 12, are all essential to the pilot's ability to transition the aircraft to the cruise speed and heading. Obviously 30 parameters plus exception data must be reduced to a meaningful presentation of flight performance.

Lack of power to clear obstacles and power or engine failure during this sequence are states in which the pilot may find himself, with a fully loaded helicopter. Successful recovery by autorotation depends on two factors — altitude and airspeed — reached at the time of failure. During the takeoff and climbout sequence, it is dependent on the pilot's experience and the feel of the aircraft. The EAHD presentation, projected in a heads-up fashion, would aid the pilot during the takeoff and climbout sequence.

(k) TOW Attack Sequence. The TOW attack sequence covers mission segments 9.0, 10.0, 11.0, 12.0, and 13.0. This sequence spans a 4 minute, 30.5 second portion of the combat mission and assumes a coordinated daylight attack with the Night Cobra covertly brought up to a predesignated firing position. Target range is at the maximum TOW range of 3.75 km. Exposure time is one minute, 22.5 seconds from unmask to onset of mask. Target designation is by aeroscout or ground scout lasing the target. Acquisition and hand-off is via the Night Cobra's airborne laser tracker to the TSU.

(l) Direct Rocket Attack Sequence. The direct rocket attack sequence covers mission segments 9.0, 10.0, 11.0, 12.0, and 13.0. This sequence spans a 5-minute, 0.33-second portion of the combat mission and assumes a coordinated daylight pop-up attack firing rockets from a near zero ground velocity.

1. Target slant range is 2000 meters and average rocket velocity is 600 m/sec.

2. Exposure time is 1 minute, 48.33 seconds from unmask to mask.

3. Range is laser determined.

The pop-up fire height is 17.453 meters (57.75 ft). The target sight-line depression angle is -0.5 degrees. The range from the firing position to the target is 2000 meters (6561.43 ft). The mask rotor clearance distance is 15 meters (49.21 ft). Mask height is 17.32 meters (56.83 ft). The height above the mask exposure to target is 0.123 meters (0.92 ft). This assumes the firing position is the closest mask to the target.

The pilot in the Cobra in level flight has a forward field of view (FOV) of $+10^{\circ}$ in the horizontal line of sight (HLS) and $+90^{\circ}$, -1° in the vertical line of sight (VLS). This means the pilot must nose the helicopter down the direction of the target 3° to 6°, maintain position and altitude until he acquires the target, and fire the rockets.

The gunner would be the first crewmember to have a line of sight to the target as the helicopter unmasks. (See Figures 6 and 7).

It should be pointed out in this sequence that in such an attack there is not one single target, but numerous dispersed targets and threats which may or may not be known to the attacking helicopter.

(m) TSU Firing Gun Attack Sequence. This sequence assumes a pop-up tactic and not a running attack. The sequence spans mission segments 9.0, 10.0, 11.0, 12.0, and 13.0 and takes approximately 4 minutes and 14 seconds. Like the previous OSD's, this sequence is also coordinated and is most likely to support other Cobras firing TOW missiles to provide hold-down support (button up the enemy). Exposure time is 2 minutes, 1 second from unmask to mask.

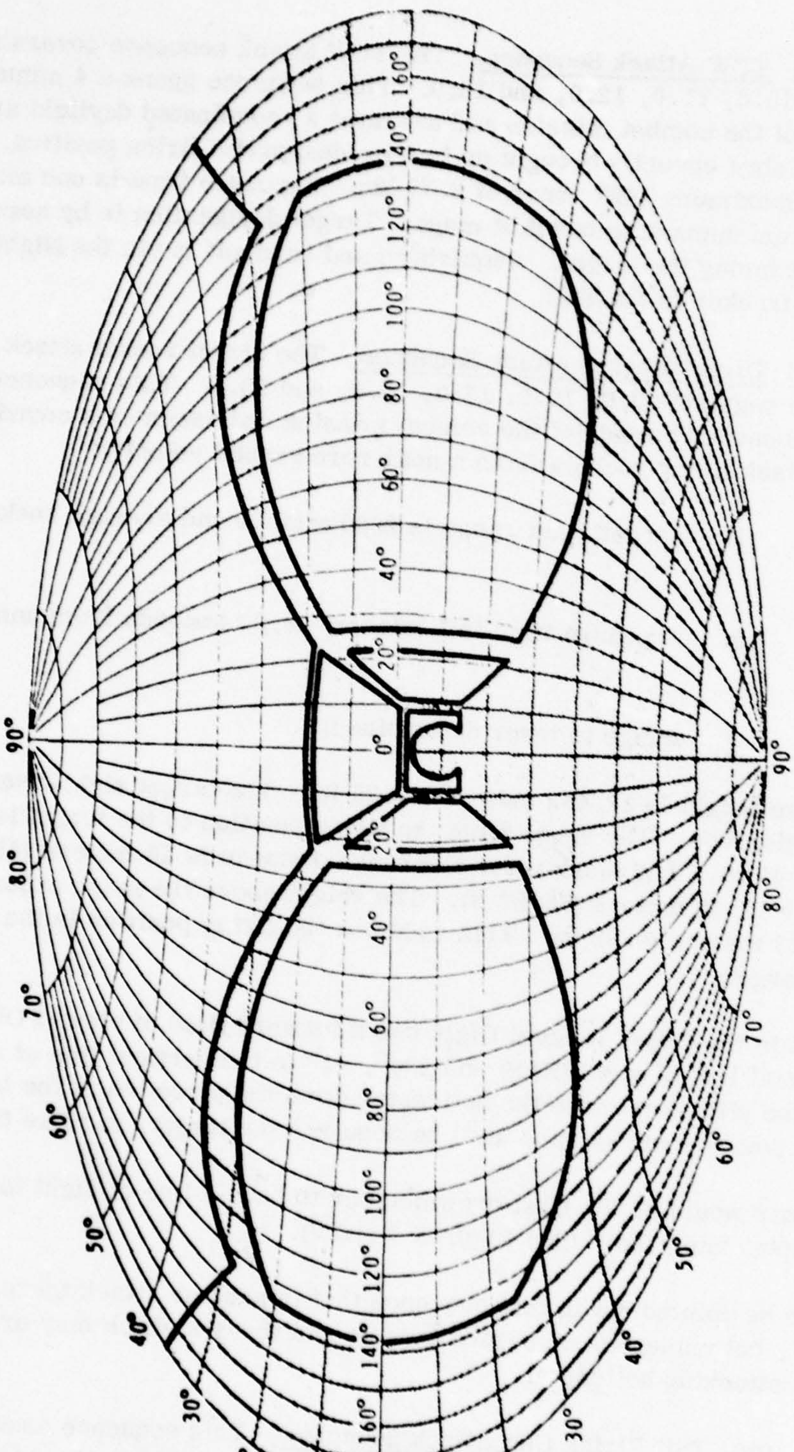

Figure 6. Pilot's field of view

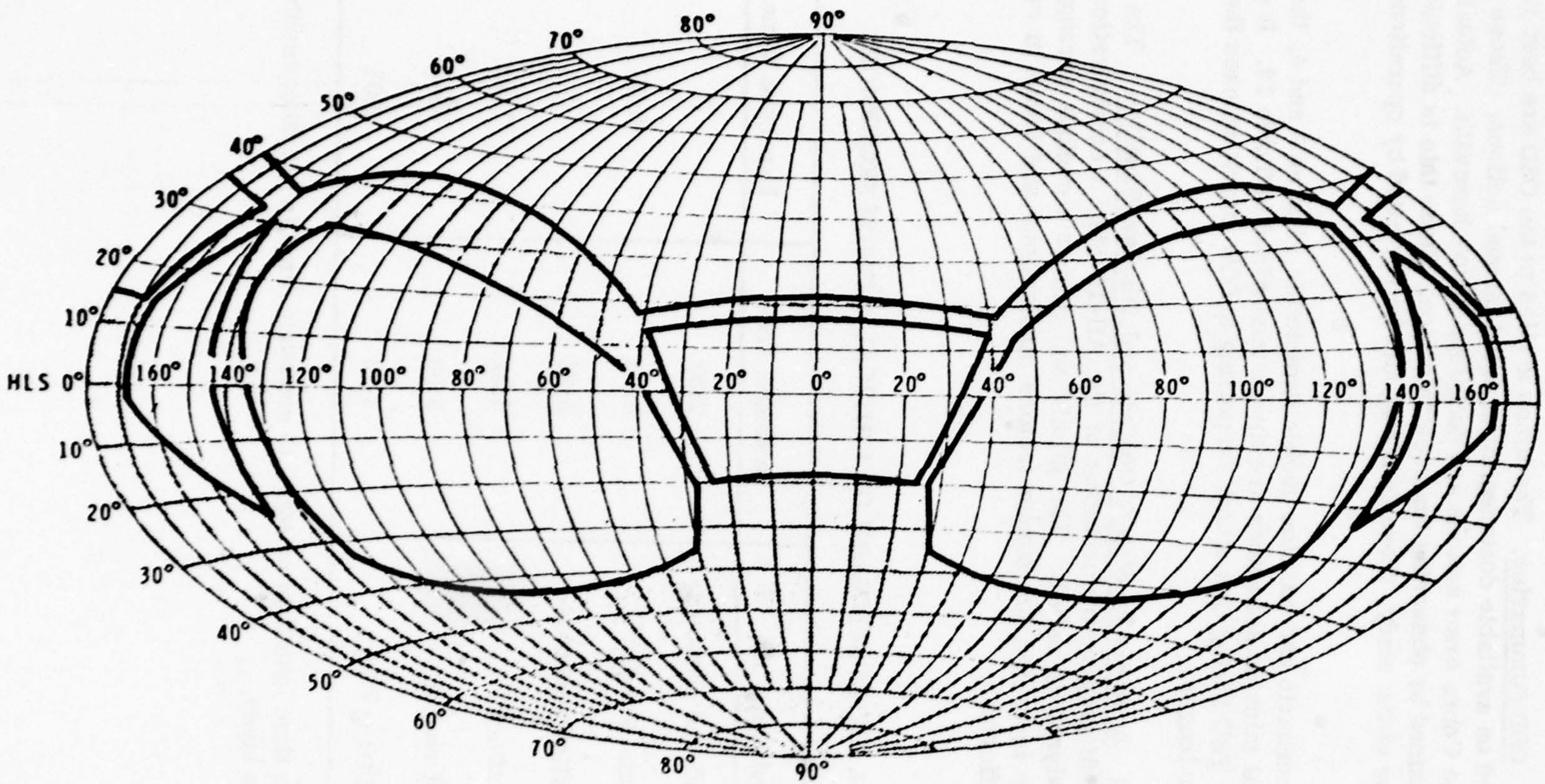

Figure 7. Copilot's field of view

(n) OSD Summaries. The times applied to the OSD are best judgment times based on available documentation timed manual actions. These OSD's are typical of the Cobra crew actions and decisions shown herewith. Actual times should be determined by observing the crew in action. Since this is difficult and outside the scope of the study, these OSD's should be reviewed by operational personnel.

Within the scenario and mission profile depicted in Figures 3 and 4, the following critical mission sequences are time summarized in Table 13. It can be seen that the TSU Firing Gun attack supporting a TOW attack exposes the gun firing helicopter longer.

(o) Analysis of Step 3 Control and Display Baseline. The cockpit control and display instrumentation of the AH-1S Step 3 configuration was studied and analyzed in detail. The pilot's and gunner's cockpit arrangements were physically inspected for human factors applications and found in certain areas to be deficient.

TABLE 13. TIME SUMMARY OF CRITICAL MISSION SEQUENCES

Critical Sequence	Sequence Time	Exposure Time
1. Takeoff and climbout	2:30	*
2. En route-evasion	6:08	6:08
3. NOE-flight-evasion	5:22	*
4. TOW attack	4:31	1:23
5. Direct rocket	5:00	1:48
6. TSU Firing Gun	4:14	2:01

*Exposure time less than or equal to sequence time is not determinable from this study.

(p) Summarization of Step 3 Instrumentation Complexity

1. Pilot's Cockpit. The pilot's cockpit of the Step 3 configuration contains 41 LRU items which involve functional control and display of aircraft flight and avionics weapon modes through the manual manipulation and viewing of 328 sub-items:

(a) 118 switches

(b) 123 controls and displays

(c) 87 circuit breakers

2. Gunner's Cockpit. The gunner's cockpit of the Step 3 configuration contains 22 LRU items which involve function control and display of aircraft flight and avionics/weapon modes through the manual manipulation and viewing of 148 sub-items:

(a) 64 switches

(b) 84 controls and displays

(q) Human Factors Problems Identified. The dc circuit breaker panel mounted behind and to the right of the pilot's right shoulder presents a problem in viewing and manually resetting tripped circuit breakers in flight. Also, there is no way to deliberately and selectively trip or open circuit breakers to equipment and ordinance with EM incompatibility HERO and RADHAS problems.

The pilot's seat is vertically adjustable but not horizontally adjustable. With the harness on and unlocked it was difficult to lean forward with ease to reach the front instrument panel controls. The instrument panel should be brought forward at least two inches and primary in-flight manual data entry should be entered on the left hand side of the console within the range of easy and comfortable arm and wrist movement. Data entry should be easily accomplished with a gloved hand and provide tactile feedback of switch operation and visual display of data entry for verification. On the whole, the Step 3 instrument panel is a very busy and cluttered layout of traditional aircraft instruments, especially ill-suited for low-level flight.

(r) Step 4 Control and Display Functional Integration. The consolidation of control and display data by generic avionics system grouping, utilizing a minimum of multiformat displays for the Night Cobra, results in the following control and display utilization:

A. Nonintegrated:

	Display and Control	Unit	Generic System
1.	Projected map display	PMD	Navigation
2.	Radar warning display	RWI	Self-Protection
3.	AUX compass	MAG Comp	Navigation
4.	Clock	CLK	Navigation and time
5.	Heads-up display	HUD	Fire Control
6	FLIR augment TOW sight	FACTS	Fire Control

B. Integrated:

	Display and Control	Unit	Generic System
1.	Integrated avionics control system (IACS)	PCP, GCP	Communication • UHF-AM • VHF-AM • VHF-FM • IFF • Voice security Navigation • Doppler • ADF • VOR/ILS • HARS
2.	Electronic Attitude and Heading Display	EAHD	Flight control • Cruise • NOE flight • Transition • Hover • Pop-up
3.	Flight Management Display	FMD	Engine control and monitor External Lighting

Display and Control	Unit	Generic System
3. Flight Management Display (Continued)		**Armament** • Mode • Status • Inventory **Electrical System** • Power control • Power distribution **Flight control** • Stabilization (SCAS)

Figure 8 presents the Step 4 display and the control group serving the input/output needs for provision of mission segment data. The provision of the integrated control and display suite for the Night Cobra described in the Night Cobra multiplex architecture specification will enhance its night operations.

Table 14 summarizes the Step 3 to Step 4 display absorption which results in a 53 percent reduction in complexity as shown in Table 15.

(s) Step 4 Control and Display Data Flow. Mission data flow analysis of the Night Cobra avionics/weapon system architecture reveals that there are over 100 communication links (disegs) in the Step 4 operational source/sink data flow network (Figure 12) facilitated by the MIL-STD-1553 data bus. There are approximately 410 uniquely addressable data words transmitted either aperiodically or periodically at update rates of 25, 50, and 100 Hz.

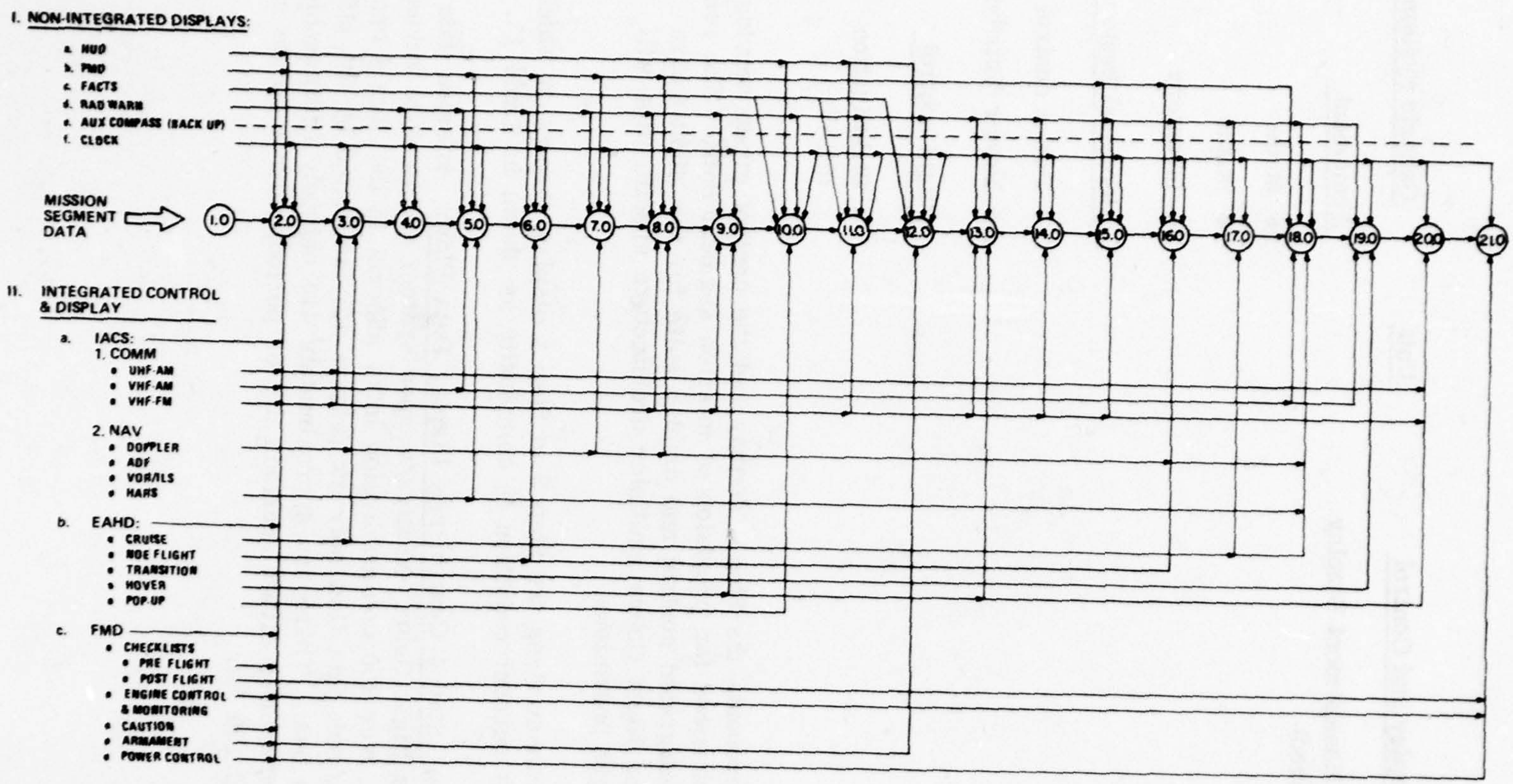

Figure 8. Step 4 Control and Display Group I/O

TABLE 14. CONTROL AND DISPLAY INTEGRATION

	Step 3	Step 4	Percent Reduction
Pilot (41 Items)	(13 Items)		
— Switches	118	64	45.7
— Control/Display	123	39	68.3
— Circuit Breakers	87	0	100.0
TOTAL	328	103	68.6
Gunner (22 Items)	(10 Items)		
— Switches	64	85	-32.8
— Control/Display	84	35	58.3
TOTAL	148	120	18.9
	476	223	
Total Percent Reduction in Complexity = 53.2 percent			

The Night Cobra's data flow network shown in Figure 9 is a graph of the Cobra's avionics/weapon system sink/source modes. Crew displays are indicated by a double circle. Mode abbreviations are included in the Glossary of the report.

e. Automation. The analysis of the Night Cobra mission scenario as depicted in the top-level mission flow diagram, Figure 10, and supported by detailed functional flow diagrams of each major mission segment (Appendix C), reveals the following areas in which automation of manual functions presently performed by the pilot, gunner (copilot), and ground crew may be implemented and facilitated by the multiplexed avionics architecture of this report. These mission segments are the following:

(1) Preflight (2.0)

(2) En route (5.0)

(3) Descent to NOE (6.0)

(4) Hover (9.0)

TABLE 15. NIGHT COBRA INTEGRATED DISPLAYS

Step 3 Crew Avail	Step 3 Displays / Step 4 Displays	P/G EAHD	P/G FMD	P/G IACS	P HUD	G PMD	P RWI	P Clock	G Compass	Step 4 Crew Avail
		Integrated Set					Nonintegrated			
P/G	• Torque	X	*		X					P/G
P	• Radar Altitude	X	*		X					P/G
P/G	• Barometric Altitude	X	*							P/G
P	• Radar Warning						X			P
P/G	• ADI	X	*							P/G
P	• HSI	X	*							P/G
P/G	• Target		X							P/G
P/G	• Gas Prod Tachometer		X							P/G
P	• Eng Oil Temp/Pressure		X							P/G
P	• Xmsn Oil Temp/Press.		X							P/G
P	• Fuel Quantity		X							P/G
P/G	• Engine/Rotor Tach		X							P/G
P	• Volt/Amps		X							P/G
P	• RMS		X							P/G
P/G	• Armament, Guns, etc.		X							P/G
P/G	• Airspeed	X	*							P/G
P/G	• Vertical Airspeed	X	*							P/G
P/G	• Communications			X						P/G
G	• Navigation			X						P/G
P	• Power		X							P/G
P/G	• Caution, Warning		X							P/G
G	• Compass								X	G
P	• Clock							X		P
G	• TOW		X							G

P = Pilot; G = Gunner

*Back-Up

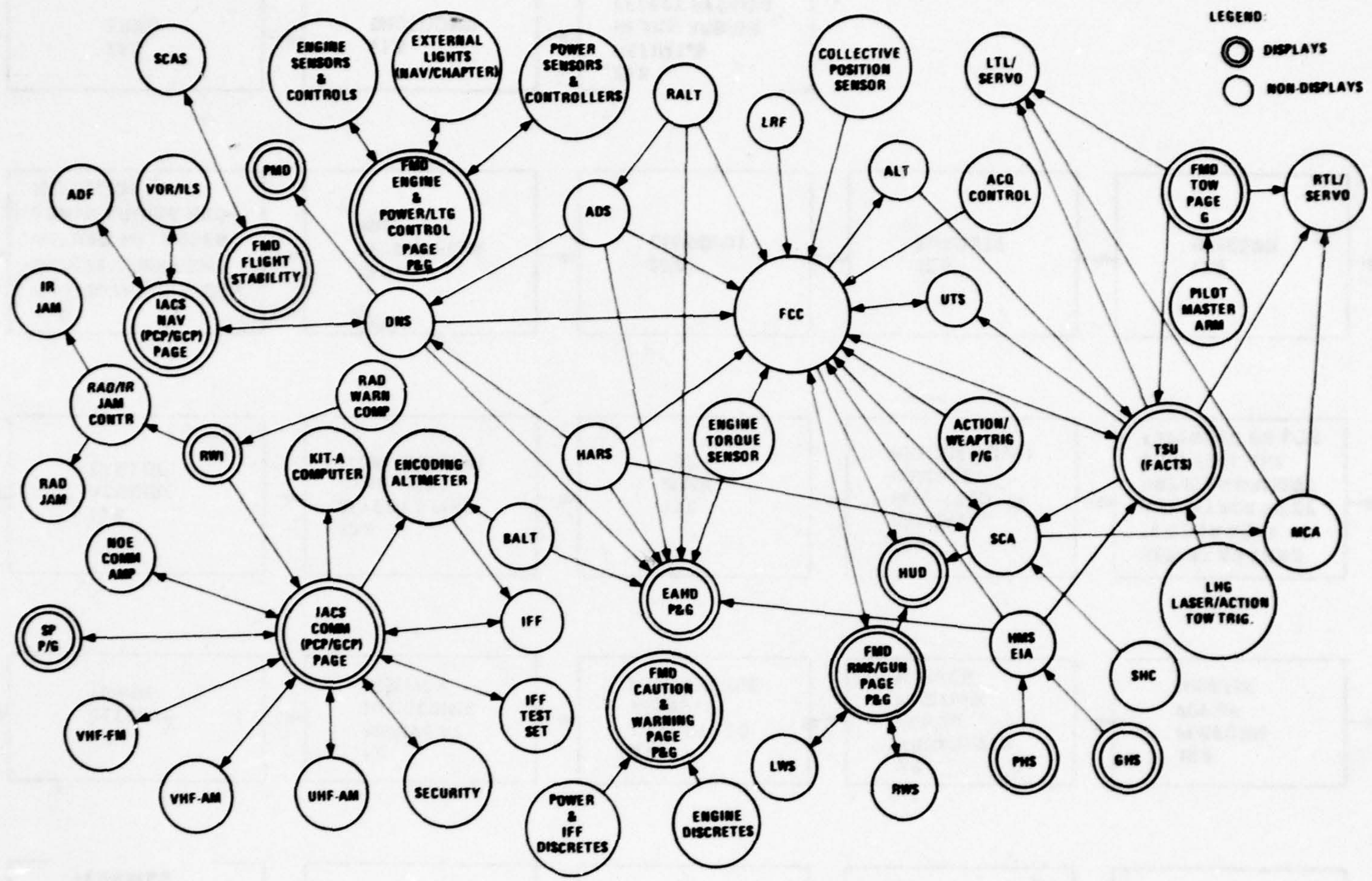

Figure 9. Night Cobra data flow network

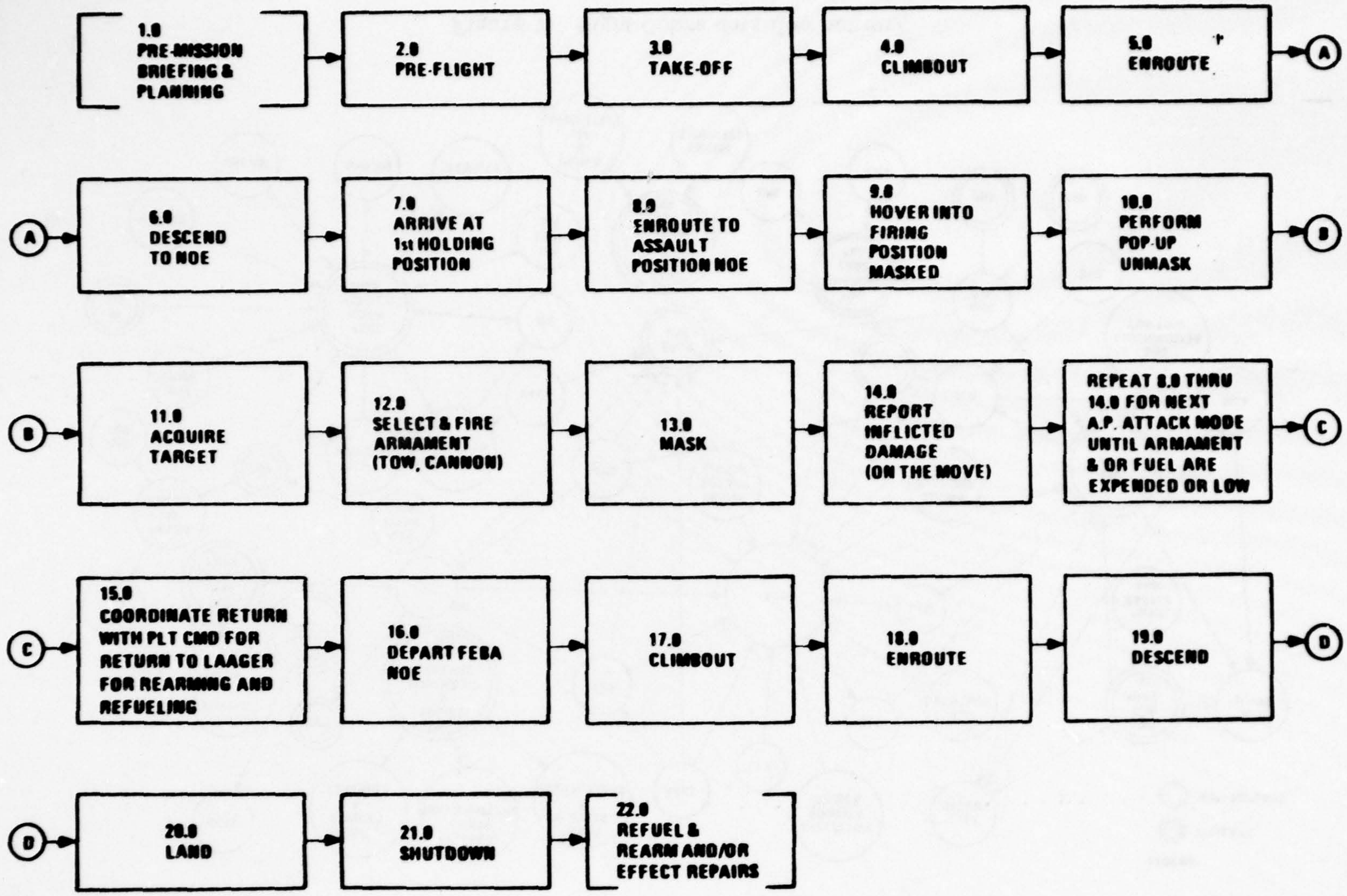

Figure 10. Top-level mission flow diagram

(5) Select and fire armament (12.0)

(6) Depart FEBA NOE (16.0)

Table 16 summarizes the multiplex architecture automation impact on the Night Cobra subsystems.

The sections that follow define the areas of automation achievable within the above mission segments which will result in crew workload reduction, reduced exposure, and decreased cockpit control/display complexity.

(1) Preflight Automation. The following checklists may be automated and presented to the pilot/gunner through a suitable multiformat display (MFD). These checklists are:

(a) Interior check

(b) Prestarting check

(c) Pretakeoff check

(d) Prelanding check

The status of more than 50 percent of the items in the above checklist can be determined by the multiplexed architecture described in this report.

When selected to be displayed, these checklists can be automatically programmed and automatically stepped through listed items as the condition is satisfied, relieving the gunner read/pilot respond response action. This frees the gunner to respond to other checks, cutting down further checkout time. A cursor can be employed which blinks until the particular item is satisfied, then advances to the next item in the checklist sequence.

The time required to implement the above checklists can greatly be reduced by automation. In combat, the advantages gained will be improved mission effectiveness, better reaction/response time to combat situations, and enhanced cross utilization of Army pilots as the need for attack pilots arises.

(2) Select and Fire Armament Automation. The functional and time line analysis of Step 3 Cobra weapon employment and target acquisition modes revealed that the rocket employment modes required the longest time for mode procedure (see Table 17). In the table, the first 14 entries list the mean estimated modes times in seconds, based on maximum weapon delivery ranges. All attacks are assumed to be coordinated and made from a pop-up near hover reference masked firing position.

TABLE 16. MULTIPLEX ARCHITECTURE AUTOMATION IMPACT

MUX ARCHITECTURE AUTOMATION IMPACT ON AH-1S FLIGHT SUBSYSTEM	MISSION SEGMENTS																					
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
1. FLIGHT CONTROL																						
• Terrain following NOE flight						X							X			X						
• Auto flight					X																	
• Stabilization										X												
• Hover									X	X												
• Pop-up										X			X									
• Evasion						X			X	X						X	X	X	X			
2. NAVIGATION																						
• Terrain position information	X				X	X																
• Masking information	X					X																
• Guidance					X	X										X	X	X	X			
3. COMMUNICATIONS																						
• Internal:																						
a. Multi-format					X				X	X												
b. Digital intercomm		X			X																	
c. Voice warning and caution		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
• External:																						
a. Communications management							X	X	X					X	X							
b. Coordinations						X	X	X	X					X	X							
4. TARGETING																						
• Pre	X							X														
• Designation									X													
• Acquisition											X											
5. Stores MGT/Armament Control		X										X										X
6. Energy Management																						
• Control		X										X								X	X	X
• Distribution		X																				
• Generation																						
• Conservation																						
7. Engine & Flight Management		X	X														X			X	X	
8. R&M																						X

TABLE 17. MODE PROCEDURE TIMES

	Mean Estimated Mode Time (sec)
1. TSU Firing Gun	31
2. GHS Firing Gun (Normal)	29
3. GHS Firing Gun (Pilot Override)	29
4. PHS Firing Gun (Method No. 1)	29
5. PHS Firing Gun (Method No. 2)	29
6. Fixed Forward	27
7. Rocket Direct (Estimated Range)	37
8. Rocket Direct (Laser Ranging)	49
9. Indirect Rocket	49
10. First Rocket Backup	35
11. Second Rocket Backup	34
12. Gunner Firing Rockets	8
13. TOW Prelaunch	15
14. TOW Postlaunch	10
15. PHS TSU Acquisition	12
16. GHS TSU Acquisition	7
17. ALT TSU Acquisition	10
18. HUD Test	2
19. HUD Boresight	5
20. Laser Ranging	10

The weapon mode functional flow diagrams and time lines in Appendix D suggest that the attack mode manual procedure functions can be automated to a great extent and facilitated by the Step 4 multiplexed architecture. A three-character mnemonic mode label may be entered through a multiformat keyboard to set weapon mode and parameters.

Table 18 summarizes the estimated impact in percent crew mode workload unburdening. It can be seen that mnemonic weapon mode labels have the greatest impact on unburdening the rocket delivery mode, which is primarily the pilot's responsibility. It is recommended that this be reviewed with operating personnel.

The analysis done in this study based on the data presented in Table 18 indicates the following:

(a) Weapon mode mnemonic automation will reduce the attack mode crew workload by approximately 40.55 percent over the manual baseline.

(b) The rocket attack mode crew workload reduction ranges from 52.67 to 70.35 percent of the manual baseline.

(c) The TOW prelaunch mode crew workload can be decreased 40 percent.

(d) Since all attack requires unmasking, automation will increase the Night Cobra survivability by reducing exposure time.

(3) Repair and Maintenance Automation. The digital multiplexed architecture of the Night Cobra will facilitate the remove and replace maintenance of the multiplexed avionics on board the helicopter. It is recommended that a field multiplex bus tester be procured along with the Step 4 conversion of the AH-1S. This field test unit would access the aircraft from a recessed covered connector on the side of the aircraft. The multiplex bus test set would utilize the 00000 address and be able to exercise the bus and all remote 1553 terminals (RT's) as well as imbedded data terminals (DT's) in all 1553 compatible avionics connected to the bus.

All terminal status and avionics built-in test (BIT) equipment will be exercised by the bus tester routine and deviant and no-go situations will be displayed to the maintenance personnel using the tester to indicate the station and access cover number of the AH-1S Step 4 modification (see Figure 11).

TABLE 18. ATTACK MODE AUTOMATION

Mode	Mnemonic	Manual Reaction Time (sec)	Automated Reaction Time (sec)	Total Crew Time Unburden (Δ T)	Percent Crew Workload Unburden
1	TFG	31	25	- 7	22.58
2	GFG	29	23	- 6	20.69
3	PFG	29	24	- 4	13.79
4	FFG	27	24	- 4	14.81
5	DRE	37	11	-26	69.59
6	DRL	49	23	-26	52.67
7	IDR	49	16	-33	66.86
8	FRB	35	10	-25	70.35
9	SRB	34	11	-23	66.94
10	GFR1	8	8	0	0
11	GFG2	17	16	- 1	5.88
12	TBL	15	8	- 7	46.67
13	TAL	10.25	0	0	0
		372.41		-151	

TFG . . . . TSU Firing Gun
GFG . . . . GHS Firing Gun
PFG . . . . Pilot Firing Gun
FFG . . . . Fixed Forward Gun
DRE . . . . Direct Rocket (Estimated Range)
DRL . . . . Direct Rocket (Laser Range)
FRB . . . . First Rocket Backup
SRB . . . . Second Rocket Backup
GFR1. . . . Gunner Firing Rocket
GFG2. . . . Gunner Firing Guns
TBL . . . . TOW Prelaunch
TAL . . . . TOW Postlaunch

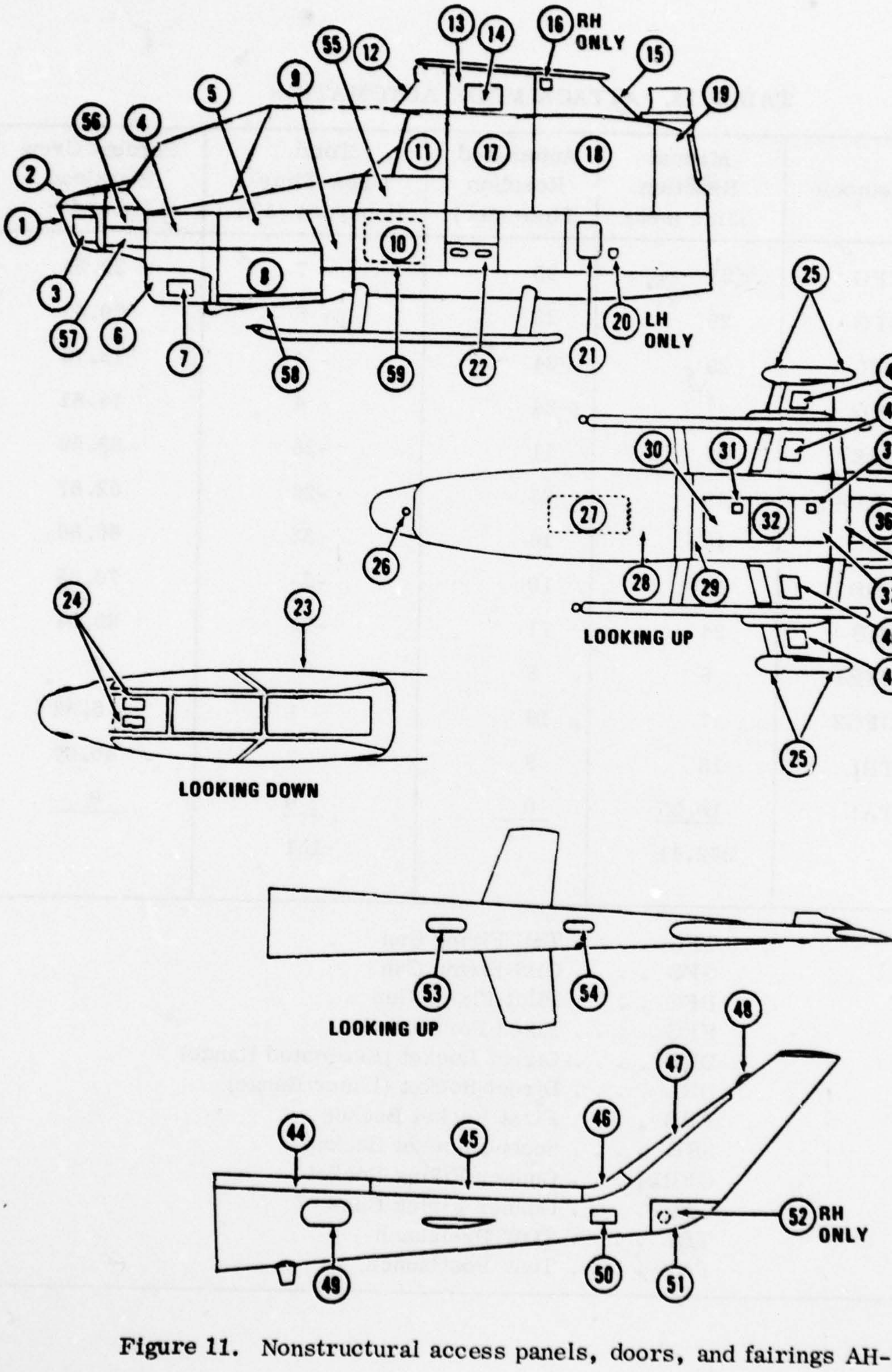

Figure 11. Nonstructural access panels, doors, and fairings AH-1S

f. Bus Controller Concept

(1) Introduction. A prime consideration in the multiplex design was to determine an approach that would allow a bus controller to effectively control the data bus traffic. The interface with IACS required a dynamic bus control approach. However, for the remainder of the system, either a command/response approach or a dynamic bus control approach were candidates for implementation. Therefore, both methods were evaluated to determine a Night Cobra bus controller concept.

(2) Design. Two bus controller control schemes were investigated in preparing the design. Both normal and error conditions were considered. The options are as follows:

Option A — Dynamic bus control is provided to each remote terminal on a scheduled basis to peform tasks as selected by the remote terminal;

Option B — Command/response allows bus control to be resident within the bus controllers, with remote terminal transmission authorized as scheduled or upon remote terminal request.

(3) Option A Concept. This approach allows the bus controller to relinquish control of the bus to remote terminals (RT's) for short periods of time in order to communicate with other RT's within the system. The bus controller has a list of tasks to perform, with each task performed periodically; the periodic rate may vary according to the task requirement. The bus controller searches the task list until a task is found which requires initiation. The bus controller then determines whether communications can be established with the required RT on the main bus in order to perform that task. If the RT and bus controller can communicate, dynamic bus control is offered to the RT in order to perform the task. If the RT and bus controller are not able to communicate on the main bus, communications are initiated on the alternate bus.

Upon receipt of dynamic bus control, the RT communicates with any RT in the system, as the task requires. Upon completion of the task, bus control is returned to the bus controller.

(4) Option B Concept. In this approach, the bus controller has total control of the bus. When a task is scheduled to be performed, the bus controller checks the status of the receiving and transmitting RT to determine whether they can communicate via the main bus. If communications are available, the bus controller transmits a receive command, followed by a transmit command, to the appropriate RT's. The data transfer then occurs. If the main bus is not available, communications are initiated on the alternate bus. In addition, the bus controller periodically solicits requests from the RT's for transmission of data that is not regularly scheduled.

(5) Considerations

(a) Core Size/Maintainability. Option A relieves the bus controller of the responsibility of knowing which RT is to receive data for any given task. This knowledge is contained solely within the RT that has a task to perform. This simplifies preparation of the task list and decreases the amount of redundant data in the system. However, the code to accept dynamic bus control has to be implemented in each RT as well as in each bus controller. In addition, each RT has to include a code to prepare several command words: dynamic bus control, transmit status word, and receive data.

Option B consolidates the transmission of all command words within the bus control function, resulting in a core savings within the RT's. However, the bus controller in using this option must store RT-to-RT transfer data for each task; this increases core size within the bus controller. In addition, logic must be implemented in all RT's that transfer data on an exception basis to respond to a transmit vector word command and to prepare the status and data word associated with that command.

Based on the analysis above, core requirements should be fairly similar. Implementation of core to prepare command words in Option A is offset by the option requirement to maintain RT-to-RT task lists in multiple bus controllers. However, program maintenance should be less costly and easier with Option B; the code is consolidated in the bus controllers, rather than distributed throughout the system. Therefore, any changes made need to be modified in a single program.

(b) Error Processing. Option A allows RT's to perform any data transfer when control of the bus is received. The RT is responsible for notifying another RT of an intent to transmit data and then performs the data transmission. The RT is not tied to performing a specific data transfer because the bus controller performs the transmit/receive notification for each data transmission. However, in an error situation there are significant limitations to this approach. Since the bus controller has no knowledge of which RT is to receive data, the transmitting RT may not be able to communicate with the receiving RT on the bus for which dynamic control is received. Solving this problem by placing the receiving RT in the task list would only limit the flexibility originally intended. Another solution, forcing each RT to compile its own RT-to-RT status table, would significantly increase core and timing requirements in the system.

In contrast, Option B requires that the bus controller consider whether a bus is suitable for transmission by determining the status of both the receiving and transmitting RT on that bus. This method precludes providing an RT with a bus that cannot be effectively used. In addition, Option B allows both of the bus controllers to closely

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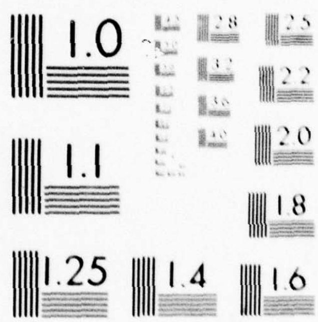

MICROCOPY RESOLUTION TEST CHART
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monitor the message traffic for errors. The bus controller can easily tell whether the information in a command word is valid by making a comparison against the task list. Finally, the responsibility for all decisions or error processing resides within the bus controllers.

(c) Data Transfer. Option A allows more flexibility as far as data transfer is concerned. When allocated dynamic control, an RT can effect any transfer within its repertoire.

Implementation of Option B relieves the RT's of the requirement to determine which set of data to transmit at any given time. The RT's must follow a fixed transmission exchange; deviations are allowed only in response to a transmit vector word command.

(d) Weight. Implementation of Option A implies that all remote terminals must be intelligent terminals, in order to perform the control functions inherent in the dynamic control bus philosophy. The addition of the hardware required to turn an RT into an intelligent terminal would add about 0.5 lb to each RT. The system has the capability to expand by adding up to ten more terminals. Option B will accept either a remote terminal or an intelligent terminal without the penalty of additional weight; the system designer is left with a choice.

(e) Overhead/Timing. Dynamic bus control is effected through the use of a command word with a mode code of 00000, followed by a status word accepting or rejecting control. This sequence occurs twice each time bus control is transferred; once from the bus controller to the RT, and once from the RT back to the bus controller. In accordance with Draft MIL-STD-1553B, this exchange shall take from 96 to 112 μsec. Therefore, whenever dynamic control is used, the additional time required as opposed to a command/response approach is as follows:

Type of Information Transfer	Time Lost (μsec)
1. RT-RT transfer	48-56
2. BC-RT transfer	96-112
3. RT-BC transfer	96-112
4. Dynamic control rejected	96-112

The figures above assume a single message transmission for each dynamic control exchange. If multiple messages are transmitted with each dynamic control transfer, the time lost can reach zero, and total overhead can be reduced. However, at the update rates specified for the Night Cobra (100, 50, and 25 Hz) and with twenty remote and embedded terminals, significant reductions in overhead are not achievable. For example, assuming that one terminal transmits one message (RT-to-RT transfer) at

100 Hz, and that five terminals transmit one message (4 RT-to-RT transfers, 1 RT-to-BC transfer) each at 50 Hz, the overhead in implementing Option A in lieu of Option B is 384 to 448 μsec (19.2 to 22.4 percent) every 20 msec. For the full system, the overhead would be even greater.

(6) Recommendation. In view of the advantages and disadvantages of both options, Option B was selected for implementation in the Night Cobra.

g. Redundant Bus Use

(1) Introduction. A dual bus, dual controller multiplex configuration was selected for the Night Cobra to ensure that the system did not provide a single point of failure. This configuration provides a system designed with a number of design approaches for using the two buses. However, in view of a MIL-STD-1553B restriction that states, "only one bus can be active at any given time. . . ," only two design options were considered for implementation in the Night Cobra application. The options are as follows:

Option A — Restrict all normal message traffic to a single bus, freeing the alternate bus for traffic in response to failures.

Option B — Time-share the use of the two buses for all message traffic.

(2) Option A Concept. This option restricts all normal message traffic to a single bus, which is controlled by the main bus controller. In the case of failures, traffic would be routed to the second bus by the main bus controller.

Upon determination that the main bus controller had failed, the alternate bus controller would assume control of both buses.

Control of both buses by a single bus controller would ensure that both buses were not operating simultaneously.

(a) Advantages. Option A has one important advantage; the code will be fairly simple to develop and implement, since all traffic shall be controlled by a single bus controller. This advantage is especially important in terms of life-cycle maintenance costs.

In the case of a single failure, either on the main bus or in an RT transmitter or receiver, Option A would allow the main bus controller to switch transmission to the alternate bus. This would be handled during the normal course of events upon detection of such a failure. No degradation in system performance would occur.

(b) Disadvantages. The only disadvantage in implementing Option A occurs in the case of a dual failure which affects both buses. Neither bus controller would be able to communicate with all RT's on the data bus system. Therefore, certain RT-to-RT information transfers would not be possible from either bus controller. To implement the code necessary to anticipate and correct for such occurrences would be extremely costly in terms of core requirements and system complexity. All RT's would be required to have the capability to reroute messages when bus failures occurred. Life-cycle software costs would be increased enormously by this additional logic.

(3) Option B Concept. Option B would necessitate the splitting of all tasks between two main bus controllers. Each bus controller would have control of a bus and would be allocated certain tasks to perform. Authority to transmit could be passed between controllers either through commands authorizing transmission or through time slicing.

In the event of a bus failure, tasks would have to be reallocated between the two controllers so that all information transfers could occur. RT-to-RT status as well as bus controller-to-RT status would have to be taken into account in the reallocation process. Some dual bus failures could also be handled by having the bus controllers reroute traffic on the appropriate bus.

(a) Advantages. The major advantage in Option B is available only upon failure of both buses. However, even rerouting of traffic is effective only in some cases. Conditions could exist where several RT's are isolated from both bus controllers. Secondly, the probability of two bus failures is low, and the cost of developing the logic to implement and maintain this capability would be extremely high in terms of both core and dollars.

(b) Disadvantages. Authority to transmit would have to be passed between the two controllers at a minimum of twice the rate of the most frequent periodic in the system, which is currently foreseen at 100 Hz. If commands authorizing transmission were used, the overhead would be in excess of 60 μsec every 5 msec, or 12 percent. If time-slicing were used, periodic clock synchronization might be required. The overhead would be substantially reduced, but the chance of overlapping activity would be greater.

The task reallocation process would be expensive in terms of core and system complexity. Code would have to be developed to recognize the failures and reallocate the tasks. Also, additional message traffic between the two bus controllers would have to be developed to report the reallocation process.

Finally, the Option B design would be significantly more complex than the Option A design; this must be considered in weighing development and life-cycle maintenance costs.

(4) Summary. Option A provides a simpler, less costly design that is effective for single bus failures.

Option B provides a more costly design in terms of core, dollars, and time, is effective for single bus failures, and can handle some dual bus failures.

(5) Recommendation. In view of the advantages and disadvantages of both options, Option A was selected for implementation in the Night Cobra. Development and life-cycle maintenance costs will be less, and the probability of the failure of both buses is low enough that the capability to handle this situation is cost effective.

4. SYSTEM ANALYSIS

a. Cobra Wire Weight Calculations and Weight Savings

(1) Introduction. One important benefit gained by the implementation of multiplex technology is a significant reduction in wire. This reduction translates into a weight saving described below.

(2) Analysis. The set of drawings listed in Table 19 were the documents used for determination of the wire size, length, type, and set. A summary of this information is shown herein. The majority of the wire used aboard the aircraft consisted of two basic types:

M81044/20-XX	18 to 22 GA (typical)
30-155-XXX	16 to 22 GA (multiconductor)

The total weight of the above wire was determined to be 74.8 kg (164.9 lb) (see Table 20).

The coaxial cabling used for RF type equipment has been excluded from this study since the RF equipment was not a candidate for multiplexing. The remaining wires to be considered are the heavy gauge wires which are larger than 16 GA. Table 21 represents a summation of these wires, which have a combined weight of 14.15 kg (31.2 lb).

From the documentation reviewed, therefore, the total wire weight, for the Night Cobra is equal to 88.95 kg (196.1 lb).

Several items on board the aircraft were studied in detail to determine what amount of their wire would be deleted when multiplexed. The following equipment or subsystems were looked at in specific detail:

(a) TOW weapons system

(b) Lighting

(c) Wing stores

These three subsystems have approximately one-half (50 percent) of the aircraft wire on board. This study has revealed that approximately 49 percent of this wire shall be deleted when the system is converted to a multiplexed architecture. If this savings is extrapolated to the total aircraft wire weight we shall find that there is a potential saving of 43.54 kg (96 lb).

(3) Conclusions. The wire saving shown above indicates that the multiplexing architecture can cause a significant reduction in the aircraft wire weight. The potential savings may be enhanced further by the application of a solid-state controller to system architecture. These estimates are conservative, and during the actual design greater savings may be realized.

TABLE 19. AH-1S WIRING DIAGRAMS

DRAWING NUMBER	SYSTEM
209-075-060	dc Power System
209-075-061	ac Power System
209-075-062	Lighting and Caution
209-075-063	Flight Control and Hydraulics
209-075-064	Engine System
209-075-065	Environmental System
209-075-066	Turret
209-075-067	Tow Missile System
209-075-068	Wing Stores System
209-077-041	Automatic Direction Finder
209-077-042	AN/ARC-114 Radio
209-077-043	AN/ARC-116 Radio
209-077-044	AN/ARC-115 Radio
209-077-045	AN/APX-72 IFF System
209-077-046	4 C.D.G. Circuit Breaker Panel, Avionics
209-077-048	AN/ASN-43 Gyrocompass System
209-077-049	VOR LOC, Glide Slope, Marker Beacon System
209-077-050	Avionics, APR-39 Radar Warning System
209-077-051	AN/APN-209 Radar Altimeter
209-077-055	Proximity Warning System

TABLE 20. LIGHT TO MEDIUM GAUGE WIRING DATA

Wire Type	Length (feet)	Density (lb/1000 ft)	Weight (lb[1])	Number of Conductors
M81044/20-22GA	13,090	3.2	41.9	830
20	2,805	4.7	13.2	180
18	623	7.0	4.4	45
30-155-22GA Single	2,182	6.8	14.8	132
Pair	2,805	11.6	32.5	360
Triple	519	15.8	8.2	102
20 Single	3,117	8.7	27.1	205
Pair	312	15.4	4.8	30
Triple	104	21.7	2.3	18
16 Pair	468	25.5	11.9	52
Triple	104	36.1	3.8	9
TOTALS	26,129	—	164.9	1,963

Note 1: Wire weight (lb) = length (1000 ft) x density (lb/1000 ft)

TABLE 21. HEAVY GAUGE WIRING DATA

Wire Type	Length (feet)	Density (lb/1000 ft)	Weight (lb)
M81044/20-8GA	79.3	58.5	4.7
10	12.4	31.8	0.4
12	75.3	20.4	1.5
5086/2-00GA	3.7	500.0	1.8
1	6.3	305.0	1.9
2	2.4	250.0	0.6
4	20.2	165.0	3.3
8	29.2	70.0	2.0
22759/2-1GA	5.3	340.0	1.8
7072-2GA	40.8	107.0	4.4
140-008-4GA	10.9	180.0	2.0
30-164-1- ALML	37.7	9.1	3.4
CHRM	37.7	9.1	3.4
TOTALS	361.2	—	31.2

(4) Summary

	Weight	Length	No. of Conductors
Lt. to Med. Gauge	164.9 lb		
Length (different types)		2619 ft	
No. of Conductors			1963
Heavy Gauge	31.2 lb		
Length		361.2 ft	
No. of Conductors			Unknown
Total Wire Weight	196.1 lb		
Remaining after multiplex	100.1 lb		
Potential Savings	96 lb	(49 percent of wire on board)	

b. Control/Display Weight Analysis

(1) Introduction. An important objective of the AVSAR study was to determine the impact of the integration of controls and displays on the Night Cobra cockpit weight. The following analyzes the impact on the cockpit area and describes the considerations in arriving at a final Step 4 cockpit design.

(2) Analysis. To perform the analysis, the Step 3 cockpit equipment was broken out of the equipment list, by gunner's and pilot's cockpit, and weights were determined for each equipment item, as shown in Table 22. In several cases, as shown in the table, weights were estimated. Total weights for the cockpit equipment are as follows:

Pilot's Cockpit	46.82 kg (103.22 lb)
Gunner's Cockpit	20.49 kg (45.18 lb)
TOTAL WEIGHT STEP 3 COCKPIT	67.31 kg (148.40 lb)

As the design progressed from the Step 3 baseline, three cockpit configurations were considered. The weight variations of these three configurations and Step 3 are tabulated in Table 23.

TABLE 22. COCKPIT INSTRUMENTATION (Sheet 1 of 5)

PILOT:

Item	AH-1S Step 3 (Baseline)				AH-1S Step 4			
	Description	GSN	Designation	Weight (lb)	Description	GSN	Designation	Weight (lb)
1	ADF Control Panel	10.10	C-7392A/ARN-89A	0.20	Deleted[1]			
2	VOR Control Panel	10.20	C-1004*/ARN-123(V)	1.70	Deleted[1]			
3	Radar Warning Panel	10.40	C-9326( )/APR-39	0.30	Deleted[2]			
4	Radar Warning Indicator	10.50	ID-1150( )/APR-39	2.00	Radar Warning Indicator	10.50	ID-1150( )/APR-39	2.00
5	Intercom	10.80	C-6533( )/ARC	1.80	Intercom	10.80	C-10414( )/ARC	1.80
6	Laser Tracker	10.10		1.50	Laser Tracker	10.10		1.50
7	TGT Indicator	10.16	209-075-651-3	0.60	Deleted[2]			
8	Amplitude/Voltage Indicator	10.17	209-075-659-3	0.50	Deleted[2]			
9	Transmission Oil Temperature/ Pressure	10.19	209-075-658-1	0.60	Deleted[2]			
10	Torque Indicator	10.21	209-075-653-7	1.50	Deleted[3,4]			
11	ECS/LTG Panel	10.22		1.60	Deleted[2]			
12	IRCM Panel	10.23		0.20	Deleted[2]			
13	Barometric Altimeter Indicator	10.27	AAU-31A	1.90	Deleted[3]			
14	IFF Control Panel	10.28	C-10096( )/APX-100	1.75	Deleted[1]			
15	Communication Security Control	10.29	C-8157/ARC	2.00	Deleted[1]			
16	Radar Altimeter Indicator	10.30	ID-1917/APN-209	1.60	Deleted[3,4]			
17	Armament Panel	10.32		1.80	Deleted[2]			
18	SCAS Panel	10.33		1.00	Deleted[2]			
19	Fuel Quantity Indicator	10.35	209-060-602-17	0.70	Deleted[2]			

TABLE 22. COCKPIT INSTRUMENTATION (Sheet 2 of 5)

PILOT:

Item	AH-1S Step 3 (Baseline)				AH-1S Step 4			
	Description	GSN	Designation	Weight (lb)	Description	GSN	Designation	Weight (lb)
20	Gas Producer Tachometer	10.36	209-075-652-0	0.80	Deleted[2]			
21	Head-Up-Display	10.37	209-947-391	15.22	HUD	10.37	209-947-301	15.22
22	Compass Control Panel	10.39	C-6347( )/ASN-43	1.80	Deleted[1]			
23	Gyro Heading Indicator	10.40	ID-2103A	7.00	Deleted[3]			
24	HSI Control	10.41		1.80				
25	ADI	10.44		6.00	Deleted[3]			
26	Engine Oil Temperature/ Pressure	10.46	209-075-656-1	0.80	Deleted[2]			
27	Clock	10.47	ABU-11/A	0.50	Clock	10.47	ABU-11/A	0.50
28	Engine/Rotor Tachometer Indicator	10.48	209-075-665-5	1.90	Deleted[2]			
29	Air Speed Indicator	10.49	209-075-661-1	1.10	Deleted[3]			
30	Vertical Air Speed Indicator	10.52	209-075-663-1	1.75	Deleted[3]			
31	Rocket Panel	10.56		6.00	Deleted[2]			
32	ac Circuit Breaker Panel	10.57		5.90	Deleted[2]			
33	dc Circuit Breaker Panel	10.58		3.70	Deleted[2]			
34	Power Panel	10.59		1.00	Deleted[2]			
35	Engine Panel	10.60		1.80	Deleted[2]			
36	Miscellaneous Jettison Panel	10.61		1.20	Miscellaneous Jettison	10.61		1.20
37	UHF Control	10.68	AN/ARC-164	10.00	Deleted[1]			

TABLE 22. COCKPIT INSTRUMENTATION (Sheet 3 of 5)

PILOT:

Item	AH-1S Step 3 (Baseline)				AH-1S Step 4			
	Description	GSN	Designation	Weight (lb)	Description	GSN	Designation	Weight (lb)
38	VHF AM Control	10.69	AN/ARC-115	6.50	Deleted[1]			
39	Caution Panel	10.70		2.70	Deleted[2]			
40	Master Caution Indicator	10.71		0.20	Master Caution Indicator	10.71		0.20
41	Fire Indicator	10.72		0.20	Fire Indicator	10.72		0.20
42	N/A				Primary Control Panel	10.13		10.00
43	N/A				Status Panel	10.15		2.50
44	N/A				Flight Management Display	10.85		20.00
45	N/A				Electronic Attitude and Heading Display	10.86		16.00
			TOTAL	103.22			TOTAL	71.12

NOTES:

1. Absorbed by IACS
2. Absorbed by FMD
3. Absorbed by EAHD
4. Displayed on HUD
5. Displayed on PMD

TABLE 22. COCKPIT INSTRUMENTATION (Sheet 4 of 5)

GUNNER:

Item	AH-1S Step 3 (Baseline)				AH-1S Step 4			
	Description	GSN	Designation	Weight (lb)	Description	GSN	Designation	Weight (lb)
1	DNS Computer Display	10.30	CP-1252( )/ASN-128	7.50	Deleted[1]			
2	Intercom	10.70	C-6533( )/ARC	1.80	Intercom	10.70	C-10414	1.80
3	TGT Indicator	10.16	209-075-651-3	0.60	Deleted[2]			
4	Attitude Indicator	10.20		5.00	Deleted[3]			
5	Torque Indicator	10.21	209-075-653-1	0.80	Deleted[3]			
6	Gas Producer Indicator	10.36	209-075-652-9	0.80	Deleted[2]			
7	RMI	10.45	ID-2105/A	2.20	Deleted[3,5]			
8	Engine/Rotor RPM Indicator	10.48	209-075-655-5	1.90	Deleted[2]			
9	Air Speed Indicator	10.49	209-075-652-9	1.10	Deleted[3]			
10	Barometric Altimeter	10.51	AAU-31A	1.90	Deleted[3]			
11	Vertical Airspeed	10.52	209-075-663-1	1.75	Deleted[3]			
12	Laser Range Finder Panel	10.53		0.30	Laser Range Finder Panel	10.53		0.30
13	Tow Control Panel	10.54	209-071-129	5.50	Deleted[2]			
14	Armament Control Panel	10.66		3.10	Deleted[2]			
15	AN/ARC-114 Control Panel	10.67	AN/ARC-114	6.40	Deleted[1]			
16	Hydraulic Jettison Panel	10.75		0.60	Hydraulic/Jettison Panel	10.75		0.60
17	Caution Panel	10.76		1.40	Deleted[2]			
18	Master Caution Indicator	10.77		0.60	Master Caution Indicator	10.77		0.60

TABLE 22. COCKPIT INSTRUMENTATION (Sheet 5 of 5)

GUNNER:

Item	AH-1S Step 3 (Baseline)				AH-1S Step 4			
	Description	GSN	Designation	Weight (lb)	Description	GSN	Designation	Weight (lb)
20	ACQ Panel	10.79		0.20	ACQ Panel	10.79		0.20
21	Compass (Mag)	10.80		1.50	Compass (Mag)	10.80		1.50
22	Miscellaneous Panel	10.84		0.23	Deleted[2]			
23	N/A				Projected Map Display	10.12	AN/ASN-99	21.00
24	N/A				Primary Control Panel	10.13		10.00
25	N/A				Status Panel	10.15		2.50
26	N/A				Flight Management Display	10.85		20.00
27	N/A				Electronic Attitude and Heading Display	10.86		16.00
			TOTAL	45.18			TOTAL	74.50
			Number Items 22				Number Items 11	

NOTES:

1. Absorbed by IACS
2. Absorbed by FMD
3. Absorbed by EAHD
4. Displayed on HUD
5. Displayed on PMD

TABLE 23. PERCENT WEIGHT VARIATIONS

	Pilot	Gunner	Total
Step 3	103.22 lb 69.56%	45.18 lb 30.44%	148.40 lb
Mini-Review (20 Oct. 78)	88.3 lb 55.08%	72.0 lb 49.92%	160.3 lb
PDR (16 Nov. 78)	56.42 lb 56.79%	42.93 lb 43.21%	99.35 lb
Final Configurations	71.12 lb 48.84%	74.5 lb 51.16%	145.62 lb

The weight data of Table 22 is plotted in Figure 12 and shows graphically the effects of Step 4 integration. The three integrated configurations developed during the course of the AVSAR II study are all characterized by a more equal weight distribution providing full, dual functional capability utilizing multiplex data transfer and multi-format integrated displays.

The final configuration evolved based on a desire to reduce weight, while at the same time preserving the integrity of Step 4 equipment. Therefore, rather than integrating additional functions into IACS, the engine, caution, and armament control and display functions were integrated into a separate flight management display (FMD). This provided a reduction in complexity and an even closer pilot-to-gunner instrumentation weight balance.

Table 23 shows the Step 4 final cockpit configuration. It also notes where the functions provided by deleted Step 3 equipment are integrated in the Step 4 configuration.

Weights for the Step 4 cockpit equipment were determined based on information compiled from prime development and equipment specifications, planned preproduction models of similar equipment, and human factors considerations. Total weight for Step 4 cockpit equipment is as follows:

Pilot's Cockpit	32.26 kg (71.12 lb)
Gunner's Cockpit	33.79 kg (74.50 lb)
TOTAL WEIGHT STEP 4 COCKPIT	66.05 kg (145.62 lb)

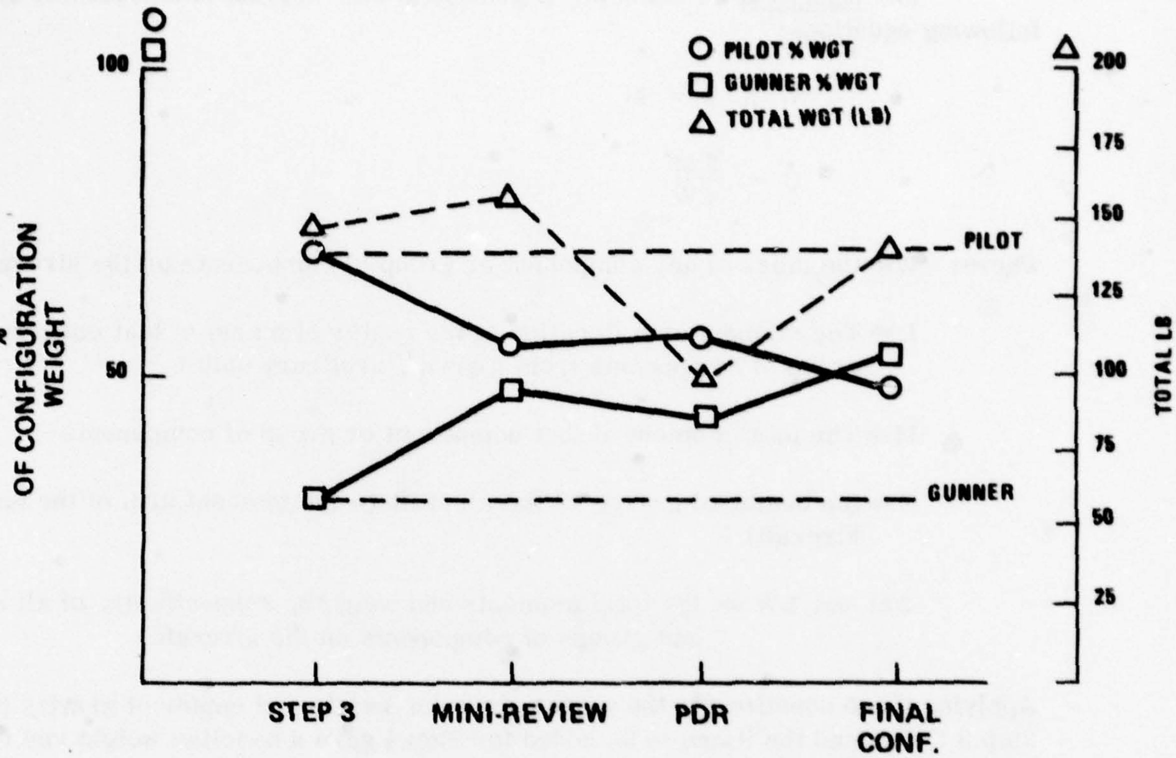

Figure 12. Baseline versus integrated configurations

Therefore, the integration of controls and displays for the Night Cobra has provided a weight savings of 10.79 kg (23.78 lb) over the Step 3 baseline. This number is further reduced to 1.26 kg (2.78 lb) by the Step 4 addition of the Projected Map Display (PMD), a 9.52 kg (21.0-lb) unit. This added capability in Step 4 by the PMD was not available in the Step 3 cockpit layout.

(3) Conclusion. The total weight of the Step 4 cockpit layout represents a 16.02 percent weight reduction over the Step 3 baseline due to the integration of controls and displays, as well as a 1.9 percent control and display net weight reduction overall. The weight savings has been accomplished while increasing the functional capability available to both crewmembers, providing a high degree of redundancy in case of failure, and decreasing crew workload.

c. Effects of Multiplexing on Moment/Balance (Center of Gravity)

(1) Introduction. In the process of implementing a multiplex system on the Night Cobra, it was recognized that the addition/deletion of equipment and removal of

wire, with the accompanying weight and weight location changes, would have an effect on the aircraft moment. It was determined that the center of gravity movement resulting from multiplexing does not have an adverse effect on the balance of the aircraft.

(2) Analysis. The center of gravity of any aircraft is determined by the following equations:

$$W \times L = M$$

$$C = \frac{\Sigma M}{\Sigma W}$$

where: W = the mass of any component or group of components on the aircraft

L = The moment arm (location of the center of mass) of that component or group of components from a given, arbitrary datum

M = The total moment of that component or group of components

C = the center of gravity of the aircraft (= the moment arm of the entire aircraft)

ΣM and ΣW = the total moments and weights, respectively, of all components and groups of components on the aircraft

Applying these equations to the values given for weight and center of gravity (CG) of the Step 3 Cobra and the items to be added for Step 4 gave a baseline weight and CG as shown in Table 24. It should be noted that the CG shifts forward from its Step 3 location,[5] although not beyond the allowable limits given in the AH-1S operator's manual (between 489.46 and 506.22 cm or 192.7 and 199.3 in) for a gross weight of 4,695 kg (10,350 lb). This weight and moment excludes ballast, which may be added to adjust the CG.

After implementation of the proposed multiplex system including IACS and the integrated cockpit display, not only is weight reduced but the center of gravity shifts backward toward the Step 3 center, as shown in the table. Also shown in the table is the amount of ballast at the ballast location of 1,031 cm (406.1 in) required to restore the center of gravity to the 496.5 cm (195.5 in) location of Step 3 if desired, for both the nonmultiplex and multiplex versions. Since the center of gravity is still within the permitted envelope, this adjustment may not be necessary.

(3) Conclusions. As shown above, the effect of the multiplex system on the center of gravity is to move it aft. The movement is slight, about 2.54 cm or 1 in compared to the nonmultiplex Step 4 Cobra, and in a favorable direction (toward the center of the allowable range); the final location is within the allowable range. It is concluded, therefore, that movement of the center due to multiplexing is not detrimental to aircraft balance and a ballast savings of 32 lb is achievable.

[5] Step 3 includes 32 lb of ballast.

TABLE 24. MOMENT CALCULATIONS

AH-1S CONFIGURATION	AH-1S WEIGHT	CENTER OF GRAVITY	MOMENT
STEP 3	10,184#	195.5"	1,990,972#"
STEP 4 W/O MUX, BALLAST	10,351#	192.88"	1,996,525#"
STEP 4 W/MUX W/O BALLAST	10,325	194.7"	2,010,277#"

BALLAST (AT 406.1") REQUIRED FOR 195.5" C.G.

AH-1S CONFIGURATION	BALLAST WEIGHT	AH-1S WEIGHT
STEP 4 W/O MUX,	+ 130#	10,481#
STEP 4 W/MUX	+ 40#	10,365#

d. Bus Loading Analysis

(1) Introduction. This analysis was performed in order to estimate the worst-case loading of the Night Cobra multiplex data bus system. While a worst-case load is not truly representative of the loading on the bus during actual tactical operations, the analysis does provide a reasonable measure for sizing the multiplex data bus system.

(2) Assumptions. Several assumptions were made in performing the analysis:

(a) All information transfers were RT-to-RT transfers, with the following transmission times:

2 command words	40 μsec
Response time	8 μsec
2 status words	40 μsec
Intermessage gap	4 μsec
Total Time	92 μsec

To the 92 μseconds was added a 20 μsec/data word.

(b) A representative data transfer was formulated based on signal count and information flow data. The results of this analysis are compiled in Table 25 and shows correspondence between the number of messages to be transmitted, the number of data words per message, and the update rate.

(c) Table 25 includes data transfers that are mutually exclusive because of the following:

1. Data transfers are identified for two or more modes of operation, and the system is not capable of performing these functions simultaneously.

2. Data transfers are identified for both normal and backup operation, and only in case of equipment failure would the backup data be required.

(d) Table 25 also includes data transfers that are periodic only upon system demand and for short intervals of time when demanded.

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 1 of 13)

1.	FCC → HUD	6 Data Words	50 Hz update
	1. Range smoothed	14 bits	
	2. Radar altitude	13 bits	
	3. Magnetic heading	9 bits	
	4. Torque	10 bits	
	5. FC reticle Az	12 bits	
	6. FC reticle EL	12 bits	
2.	LRF → FCC	4 Data Words	100 Hz update
	1. Special code	8 bits	
	2. 1000 meters	8 bits	
	3. 100 meters	8 bits	
	4. 10 meters	8 bits	
3.	FCC → RMS	2 Data Words	50 Hz update
	1. Time of flight	16 bits	
	2. FCC	1 bit	
4.	RMS → FCC	3 Data Words	50 Hz update
	1. Warhead fuse selected	8 bits	
	2. Canopy height	8 bits	
	3. Manual range	8 bits	
5.	ADS → FCC	6 Data Words	50 Hz update
	1. Fore-aft TAS (V_u)	8 bits	
	2. Lateral TAS (V_v)	8 bits	
	3. Vertical TAS (V_w)	8 bits	
	4. Air pressure (P_{lbs})	8 bits	
	5. Air temperature (T_{air})	8 bits	
	6. Downwash velocity	8 bits	
6.	RALT → FCC	1 Data Word	50 Hz update
	1. Height above (AGL)	10 bits	
7.	RALT → ADS	1 Data Word	50 Hz update
	1. Height above (AGL)	10 bits	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 2 of 13)

8.	TMS → HUD		2 Data Words	50 Hz update
	1.	Left missile firing		
	2.	Right missile firing		
9.	DNS → FCC		6 Data Words	25 Hz update
	1.	Position coor-UTM	3 words	
	2.	Velocity - UTM	3 words	
10.	DNS → PMD		7 Data Words	50 Hz update
	1.	Coarse x command	12 bits	
	2.	Fine x command	8 bits	
	3.	y command	11 bits	
	4.	Orientation	12 bits	
	5.	Heading	12 bits	
	6.	Bearing	12 bits	
	7.	Dist (to fly to dest)	16 bits	
11 and 12.	DNS → PMD EAU → PMD		1 Data Word	25 Hz update
	1.	Discrete word	12 bits	

- scale 1
- scale
- centered
- decentered
- north up
- $\overline{\text{north up}}$
- scale 3
- hold
- slew left
- slew right
- slew up
- slew down

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 3 of 13)

13. HDG REF → DNS — 6 Data Words — 25 Hz update

1.	Heading (2 x) sine and cosine	10 bits
2.	Pitch (2 x) sine and cosine	10 bits
3.	Roll (2 x) sine and cosine	10 bits

14.

DNS → IACS — 64 Data Words — 25 Hz update

1.	PP lat/long	4 words
2.	PP UTM	4 words
3.	PP variation	1 words
4.	Ground speed	1 words
5.	Track angle	1 words
6.	Wind speed	1 words
7.	Wind direction	1 words
8.	Spheroid	1 words
9.	Dist (to fly to dest)	1 words
10.	Bearing (to fly to dest)	1 words
11.	Time	1 words
12.	XTK	1 words
13.	TKE	1 words
14.	Fly-to-dest No./tgt str No.	1 words
15.	Disp dest. coor-lat/long	1 words
16.	Disp dest. coor-UTM	1 words
17.	Disp dest. variation	1 words
18.	Disp dest. No.	1 words
19.	Distance (fly-to-dest)	1 words
20.	Bearing (fly-to-dest)	1 words
21.	Time	1 words
22.	XTK	1 words
23.	TKE	1 words
24.	Fly-to-dest No./tgt str No.	1 words
25.	Disp dest coor-lat/long	4 words
26.	Disp dest coor-UTM	4 words
27.	Disp dest. variation	1 words
28.	Disp dest number	1 words
29.	True heading	1 words
30.	V_x, V_y, V_z	3 words
31.	V_h, V_d, V_v	3 words

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 4 of 13)

15.	IACS → DNS	22 Data Words	25 Hz update
	Lat/lon or UTM control word No. 2	5 words	
	Windspeed wind direction control word No. 1	3 words	
	Ground speed track control word No. 1	3 words	
	Spheroid control word No. 1	2 words	
	Variation control word No. 2	2 words	
	Distance bearing control word No. 3	3 words	
	PMDS map data control word No. 4	3 words	
	Control word No. 1	1 word	
16.	IACS → VHF-FM	2 Data Words	25 Hz update
	1. Frequency	16 bits	
	2. Mode	8 bits	
17.	VHF FM → IACS Control	3 Data Words	25 Hz update
	1. Frequency	16 bits	
	2. Mode	8 bits	
	3. Go/no go indication	TBD	
18.	VHF AM → IACS Control	3 Data Words	25 Hz update
	1. Frequency	15 bits	
	2. Mode	8 bits	
	3. Go/no go indication	TBD	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 5 of 13)

19. IACS → VHF-AM — 2 Data Words — 25 Hz update

1.	Frequency	15 bits
2.	Mode	8 bits

20. UHF-AM → IACS Control — 2 Data Words — 25 Hz update

1.	Frequency	15 bits
2.	Mode	8 bits
3.	Go/no go indication	TBD

21. IACS → UHF-FM — 2 Data Words — 25 Hz update

1.	Frequency	15 bits
2.	Mode	8 bits

22. IACS → NOE COMM AMP — 1 Data Words — 25 Hz update

1.	NOE control	1 to 8 bits

23. ADF → IACS Control — 3 Data Words — 25 Hz update

1.	Frequency	15 bits
2.	Mode	8 bits
3.	Go/no go indication	TBD

24. IACS → ADF — 2 Data Words — 25 Hz update

1.	Frequency	15 bits
2.	Mode	8 bits

25. VOR/ILS → IACS Control — 3 Data Words — 25 Hz update

1.	Frequency (2)	11 bits
2.	Mode	4 bits
3.	Go/no go indication	TBD

26. IACS → VOR/ILS — 3 Data Words — 25 Hz update

1.	Frequency (VOR)	11 bits
2.	Frequency (ILS)	11 bits
3.	Mode	4 bits

27. COMM Security → IACS Control — 1 Data Words — 25 Hz update

1.	Mode control indication	5 bits

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 6 of 13)

28. IACS → COMM Security — 3 Data Words — 25 Hz update

1. Mode — 5 bits
2. Logic data — 15 bits
3. Mode Select data — 9 bits

29. IFF → IACS Control — 2 Data Words — 25 Hz update

1. Mode — 14 bits
2. Go-no-go indication — 5 bits

30. IACS Control → IFF — 5 Data Words — 25 Hz update

1. Mode — 14 bits
2. Mode 1 code — 5 bits
3. Mode 3/A code — 12 bits
4. Mode C code — 11 bits
5. Test enable — 5 bits

31. IFF Test Set → IACS Control — 1 Data Word — 25 Hz update

1. Control response — 7 bits

32. IACS Control → IFF Test — 1 Data Word — 25 Hz update

1. Control — 7 bits

33. IACS Cont. → Encoding Alt. — 1 Data Word — 25 Hz update

1. Mode C Code — 10 bits

34. IACS Cont. → KIT-A Com. — 1 Data Word — 25 Hz update

1. Control — 7 bits

35. HSIU → FCC — 6 Data Words — 50 Hz update

1. x PHS (i) — 12 bits
2. x PHS (j) — 12 bits
3. x PHS (k) — 12 bits
4. x GHS (i) — 12 bits
5. x GHS (j) — 12 bits
6. x GHS (k) — 12 bits

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 7 of 13)

36.	FCC → HSIU	6 Data Words	50 Hz update
	1. (i) x Bore → PHS	12 bits	
	2. (j) x Bore → PHS	12 bits	
	3. (k) x Bore → PHS	12 bits	
	4. (i) x Bore → GHS	12 bits	
	5. (j) x Bore → GHS	12 bits	
	6. (k) x Bore → GHS	12 bits	
37.	FCC → ALT	3 Data Words	50 Hz update
	1. x Bore → ALT (i)	12 bits	
	2. x Bore → ALT (j)	12 bits	
	3. x Bore → ALT (k)	12 bits	
38.	Eng. Torque → FCC	1 Data Word	50 Hz update
	1. Percent Q	10 bits	
39.	ALT → TSU	2 Data Words	50 Hz update
	1. ALT-TSU Az	12 bits	
	2. ALT-TSU El	12 bits	
40.	FCC → TSU (FCC)	3 Data Words	50 Hz update
	1. (i) x Bore	12 bits	
	2. (j) x Bore	12 bits	
	3. (k) x Bore	12 bits	
41.	FCC → UTS (FCC)	2 Data Words	50 Hz update
	1. Gun command Az error	12 bits	
	2. Gun command El error	12 bits	
42.	UTS → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) UTS position	12 bits	
	2. (j) UTS position	12 bits	
	3. (k) UTS position	12 bits	
43.	TSU → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) x TSU	12 bits	
	2. (j) x TSU	12 bits	
	3. (k) x TSU	12 bits	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 8 of 13)

44.	UTS → TSU ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) UTS position	12 bits	
	2. (j) UTS position	12 bits	
	3. (k) UTS position	12 bits	
45.	TSU → UTS ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) x TSU	12 bits	
	2. (j) x TSU	12 bits	
	3. (k) x TSU	12 bits	
46.	FCC → UTS (FCC)	2 Data Words	50 Hz update
	1. Gun command Az error	12 bits	
	2. Gun command El error	12 bits	
47.	FCC → GHS (FCC)	3 Data Words	50 Hz update
	1. (i) x Bore	12 bits	
	2. (j) x Bore	12 bits	
	3. (k) x Bore	12 bits	
48.	UTS → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) UGT	12 bits	
	2. (j) UGT	12 bits	
	3. (k) UGT	12 bits	
49.	GHS → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) x GHS	12 bits	
	2. (j) x GHS	12 bits	
	3. (k) x GHS	12 bits	
50.	UTS → GHS ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) UGT	12 bits	
	2. (j) UGT	12 bits	
	3. (k) UGT	12 bits	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 9 of 13)

51.	GHS → UTS ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) x GHS	12 bits	
	2. (j) x GHS	12 bits	
	3. (k) x GHS	12 bits	
52.	FCC → UTS (FCC)	2 Data Words	50 Hz update
	1. Gun command Az error	12 bits	
	2. Gun command El error	12 bits	
53.	FCC → PHS (FCC)	3 Data Words	50 Hz update
	1. (i) x Bore	12 bits	
	2. (j) x Bore	12 bits	
	3. (k) x Bore	12 bits	
54.	UTS → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) UGT	12 bits	
	2. (j) UGT	12 bits	
	3. (k) UGT	12 bits	
55.	PHS → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) x PHS	12 bits	
	2. (j) x PHS	12 bits	
	3. (k) x PHS	12 bits	
56.	UTS → PHS ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) UGT	12 bits	
	2. (j) UGT	12 bits	
	3. (k) UGT	12 bits	
57.	PHS → UTS ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) x PHS	12 bits	
	2. (j) x PHS	12 bits	
	3. (k) x PHS	12 bits	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 10 of 13)

58. PHS → TSU (FCC) — 3 Data Words — 50 Hz update

1.	(i) x PHS	Az and El TSU	12 bits
2.	(j) x PHS		12 bits
3.	(k) x PHS		12 bits

59. FCC → PHS (FCC) — 3 Data Words — 50 Hz update

1.	(i) x Bore	12 bits
2.	(j) x Bore	12 bits
3.	(k) x Bore	12 bits

60. TSU → FCC (FCC) — 3 Data Words — 50 Hz update

1.	(i) TSU	12 bits
2.	(j) TSU	12 bits
3.	(k) TSU	12 bits

61. TSU → PHS ($\overline{FCC}$) — 3 Data Words — 50 Hz update

1.	(i) TSU	12 bits
2.	(j) TSU	12 bits
3.	(k) TSU	12 bits

62. FCC → GHS (FCC) — 3 Data Words — 50 Hz update

1.	(i) TSU Bore	12 bits
2.	(j) TSU Bore	12 bits
3.	(k) TSU Bore	12 bits

63. TSU → FCC (FCC) — 3 Data Words — 50 Hz update

1.	(i) TSU	12 bits
2.	(j) TSU	12 bits
3.	(k) TSU	12 bits

64. GHS → TSU (FCC) — 3 Data Words — 50 Hz update

1.	(i) x GHS	TSU Az and El	12 bits
2.	(j) x GHS		12 bits
3.	(k) x GHS		12 bits

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 11 of 13)

65.	TSU → GHS ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) TSU	12 bits	
	2. (j) TSU	12 bits	
	3. (k) TSU	12 bits	
66.	ALT → TSU (FCC)	3 Data Words	50 Hz update
	1. Az Alt	12 bits	
	2. El Alt	12 bits	
	3. Spare	12 bits	
67.	TSU → FCC (FCC)	3 Data Words	50 Hz update
	1. (i) TSU	12 bits	
	2. (j) TSU	12 bits	
	3. (k) TSU	12 bits	
68.	FCC → ALT (FCC)	3 Data Words	50 Hz update
	1. (i) x Bore	12 bits	
	2. (j) x Bore	12 bits	
	3. (k) x Bore	12 bits	
69.	TSU → ALT ($\overline{FCC}$)	3 Data Words	50 Hz update
	1. (i) TSU	12 bits	
	2. (j) TSU	12 bits	
	3. (k) TSU	12 bits	
70.	RALT → EAHD	1 Data Word	50 Hz update
	1. Height above ground (ASL)	10 bits	
71.	DNS → EAHD	5 Data Words	25 Hz update
	1. Heading velocity (VH and VD)	15 bits ea.	
	2. Vertical velocity (VV)	15 bits	
	3. Bearing (fly-to-dest)	11 bits	
	4. Lateral velocity (V_y)	15 bits	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 12 of 13)

72.	HDG REF → EAHD (HARS)		8 Data Words	50 Hz update
	1.	Heading (2 words)	12 bits	
	2.	Pitch (2 words)	12 bits	
	3.	Roll (2 words)	12 bits	
	4.	Turn rate (2 words)	12 bits	
73.	Engine Torque → EAHD		1 Data Word	50 Hz update
	1.	Percent Q	10 bits	
74.	PHS → EAHD		3 Data Words	50 Hz update
	1.	(i) x PHS	12 bits	
	2.	(j) x PHS	12 bits	
	3.	(k) x PHS	12 bits	
75.	Eng. Discretes → Caut. & Warn.		2 Data Words	25 Hz update
	1.	Eng. chip (P)	1 bit	
	2.	42° chip (P)	1 bit	
	3.	90° chip (P)	1 bit	
	4.	XMSN chip (P)	1 bit	
	5.	Chip detector (G)	1 bit	
	6.	Eng oil press (P&G)	1 bit	
	7.	XMSN oil press (P& G)	1 bit	
	8.	Eng oil bypass (P)	1 bit	
	9.	XMS oil bypass (P)	1 bit	
	10.	Eng. inlet air (P)	1 bit	
	11.	XMNS oil hot (P)	1 bit	
	12.	Eng. fuel pump (P)	1 bit	
	13.	FWD fuel boost (P)	1 bit	
	14.	Fuel filter (P)	1 bit	
	15.	Fuel low (P)	1 bit	
	16.	Aft fuel boost (P)	1 bit	
	17.	Hyd press No. 1	1 bit	
	18.	Hyd press No. 2	1 bit	
	19.	Emer. Hyd Pump on	1 bit	

TABLE 25. NIGHT COBRA DATA WORD DIRECTORY (Sheet 13 of 13)

76.	Pow. & IFF Disc. → Caut. & Warn.	1 Data Word	25 Hz update
	1. Dc gen (P)	1 bit	
	2. Main inverter (P)	1 bit	
	3. Stby inverter (P)	1 bit	
	4. Ext pwr (P)	1 bit	
	5. Gov emerg (P)	1 bit	
	6. IFF code hold (P)	1 bit	
	7. IFF caution (P)	1 bit	
	8. 42^o chip det (P)	1 bit	
	9. 90^o chip det (P)	1 bit	
77.	ADS → EAHD	4 Data Words	50 Hz update
	1. Fore-aft TAS (V_u)	8 bits	
	2. Lateral TAS (V_v	8 bits	
	3. Vertical TAS (V_w)	8 bits	
	4. Downwash velocity	8 bits	
78.	BARO → EAHD	1 Data Word	50 Hz update
	1. Height above sea level	10 bits	
79.	Power Dist. Sta. → FMD	32 Data Words	Aperiodic
	1. 32 Power Controller Commands	16 bits	
80.	FMD → Power Dist. Sta.	32 Data Words	Aperiodic
	1. 32 Power Controller Commands	16 bits	

(3) Analysis. To calculate the worst-case bus load over a one-second period of time, the following formula was used:

$$\text{Total percentage of data bus load} = \frac{\sum_{x-1}^{4} R_x \left(\sum_{\substack{\text{All messages} \\ \text{at } R_x}} (20\,D + 92)\ M \right)}{100}$$

where

R_x is the update rate:

R_1 = 1 Hz (Operator Action)

R_2 = 25 Hz

R_3 = 50 Hz

R_4 = 100 Hz

D is the number of data words per message.

M is the number of messages that contain D data words at an update rate of R_x.

These calculations show a total data bus load of 56.4 percent.

(4) Conclusion. The worst-case load analysis supports the design of a single multiplex data bus system. If this load is realistically assessed in terms of tactical operation, a peak representative bus load would be 50 percent or less when taking into account mutually exclusive data transfers, data transfers occurring on demand, and a reasonable number of operator actions.

e. Bus Controller Loading Analysis

(1) Introduction. The bus controllers in the Night Cobra multiplex system are specified to reside in remote terminals that also support other system functions. Therefore, the timing and core requirements for a bus controller must be able to coexist with these system functions. This analysis describes the considerations that were used in the determination of bus controller time and core requirements.

(2) Time Requirements

Assumptions. Several critical assumptions are made in the analysis, as follows:

(a) All information transfers are RT-to-RT transfers involving two command words (CW) and two status words (SW). Since the RT-to-RT transfer is the most expensive transfer type in terms of system time, this assumption leads to a worst-case analysis.

(b) Each RT-to-RT transfer involves the transmission of an average of four data words. The average number of data words per transfer is actually 3.65 data words.

(c) Worst-case loading is 80 percent on the multiplex data bus during a 20-msec period of time.

(d) Representative loading is 50 percent on the multiplex data bus during a 20-msec period of time.

(e) The worst-case transmission time for an RT-to-RT transfer is as follows:

2 command words	40 μsec
Response time	8 μsec
2 status words	40 μsec
4 data words	80 μsec
Intermessage gap	4 μsec
Total Time	172 μsec

Based on a 20-msec period of time, with 172 μsec per information transfer, the maximum number of transfers that can occur is 116.27. For purposes of this analysis, 116 information transfers per 20-msec period of time will be used.

Processing. A bus controller has two primary functions in controlling the message traffic on the multiplex data bus:

(a) Information Transfer Initiation. A bus controller shall have a list of tasks to be performed, each with a specific periodicity and a predetermined set of command words (transmit and receive). The bus controller shall search the task list for the next task due to be processed and pass the command words to the RT for transmission. Processing of service requests and errors requires less time than the periodic processing and, therefore, for worst-case analysis only, periodic processing is considered.

(b) Status Work Processing. A bus controller shall, upon receipt of a status word, check the status field (bits 9 through 19) for all zeroes, which indicate no error.

Analysis. For an 80 percent load, the multiplex data bus will have 93 information transfers per 20 msec. Therefore, the bus controller would have to contend with the following amount of traffic:

Number of Actions	Description
93	Information transfer initiation
186	Status word processing
279	Total number of actions

In a 20-msec period of time, therefore, a bus controller will have to accomplish 279 separate actions, or one action every 71.68 μsec.

Based on the bus controller flow diagram, it is estimated that information transfer initiation takes an average of 50 μsec per action and status word processing takes an average of 10 μsec per action. Therefore, the bus controller function will consume 6510 μsec every 20 msec for a load of 32.55 percent, with a total multiplex data bus load of 80 percent.

For a 50 percent load, the multiplex data bus will have 58 information transfers per 20 msec. Therefore, the traffic for the bus controller is as follows:

Number of Actions	Description
58	Information transfer initiation
116	Status word processing
174	Total number of actions

In a 20-msec period of time, the bus controller will have to accomplish 174 separate actions, or one action every 114.94 μsec.

Again assuming an average of 50 μsec for information transfer initiation and 10 μsec for status word processing, the bus controller function will consume 4,060 μsec every 20 msec for a total load of 20.30 percent, with a total multiplex data bus load of 50 percent.

(3) Core Requirements

Assumptions. Several critical assumptions are made in this analysis, as follows:

(a) An information transfer table exists containing four words per information transfer.

(b) An RT status table exists containing two words per RT.

(c) Each word contains 16 bits.

Analysis. Based on system analysis, the total number of information transfers is approximately 150. Therefore, the table size requirement for 150 information transfers is 500 words. The Night Cobra multiplex data bus system contains a total of 18 RT's. Therefore, a bus controller would have to store an RT status table of 34 words.

Two work tables of 35 words apiece would also be required for the transmission and reception of command, status, and data words.

Based on the bus controller flow diagrams, the word count is as follows:

Function	Number of Words
Command word transmission	310
Status word processing	445
Bus selection	180
Service request	390
Timeout	60
System monitoring	310
BC error processing	115
RT error processing	270
Total Instruction Word Count	2080

Therefore, the total word count for the bus controller should be approximately as shown:

Instruction word count	2080
Data word count	604
Total word count	2684

f. Critical Signal Analysis

(1) Introduction. In designing the Night Cobra multiplex data bus system, an important consideration was whether to multiplex critical signals — signals in which flight or weapon safety is of concern. This analysis addresses the issue by examining several methods of transmitting the data over the bus and determining the probability of invalid data being accepted and used by the system.

(2) Assumptions. Two assumptions were made in performing the analysis:

(a) MIL-STD-1553B defines "a maximum word error rate of one part in 10^7 . . . when operating in the presence of additive white Gaussian noise distributed over a bandwidth of 1.0 kHz to 4.0 MHz at an rms amplitude of 200 mV." It further defines a word error to "include any fault which causes the message error bit to be set in the terminal's status word, or one which causes a terminal not to respond to a valid command." This analysis assumes a bit error rate of one part in 10^7, operating without added noise and considering an error to be a bit that has been *incorrectly transmitted*. Therefore, the error rate assumed for this analysis is extremely conservative (the actual bit error rate is significantly higher, approaching 10^{-12}); however, for the purpose of a comparative analysis, the worst-case error rate assumed is sufficient.

(b) A single bit error in any single word constitutes a parity error, and the information will be discarded by the terminal. Likewise, any odd number of bit errors within a single word constitutes a parity error.

(c) The probability of an error (P_e) being accepted as valid data is calculated as follows:

$$P_e = \sum_{n=1}^{8} \left(\frac{17!}{(17-2n)!} \right) (P \text{ (2n bit errors)})$$

where P (2n bit errors) $= (10^{-7})^{2n}$ (assuming independence between bit errors)

Therefore,

$$P_e = \frac{17!}{15!} \text{ (P (2 bit errors) } + \frac{17!}{13!} \text{ (P (4 bit errors) } + \ldots$$

$$= 272 \ (10^{-7})^{2} + 57120 \ (10^{-7})^{4} + \ldots$$

$$= 2.72 \times 10^{-12} + 5.712 \times 10^{-25} + \ldots$$

For purposes of the analysis, the probability of any two bit errors occurring in a single word will be assumed to be 2.72×10^{-12}.

(3) Analysis. The following methods of transmitting data were examined:

Option A — Transmit the data and rely on the safeguards built into the system.

Option B — Transmit the data in conjunction with a validity flag.

Option C — Transmit the data in two redundant messages.

Option A. Option A relies totally on the *safeguards* inherent in the MIL-STD-1553B requirements to ensure data integrity. An invalid critical signal will be propagated through the system if at least one of two bit errors occurs in the critical signal field. The probability of this occurrence is as follows:

$$P_e = \Big[\text{P (error in critical data bit)} \Big] \Big[\text{P (error in any remaining bit)} \Big]$$

$$= (10^{-7}) \left(\frac{16!}{15!} \right) (10^{-7})$$

$$= 16 \times 10^{-14} \quad \text{(assuming independence between bit errors)}$$

Therefore, Option A provides an error probability of 1.6×10^{-13} for a critical signal. This method imposes no requirement for coding/decoding on the system software and is optional in terms of transmission and processing time.

Option B. Option B introduces a validity flag which resides, where possible, in the same data word as the data being validated. The probability of an error occurring simultaneously in both a data bit and its validity bit is as shown:

$$P_e = \Big[P \text{ (error in critical data bit)} \Big] \Big[P \text{ (error in validity bit)} \Big]$$

$$= (10^{-7})\ (10^{-7})$$

$$= 10^{-14}$$

Therefore, Option B provides an error probability of 10^{-14} for a critical signal. Option B imposes a requirement on the system software for coding and decoding the validity bit, which will also cause a minimal increase in processing time. There is no increase in transmission time.

Option C. Option C proposes the transmission of a message containing critical data twice in order to validate that data. The probability of error using Option C is the probability of both messages being transmitted with the critical signal data in error:

$$P_e = P \Big[\text{Critical data in first transmission bad} \Big] \Big[P \text{ (Critical data in second transmission bad)} \Big]$$

$$= (16 \times 10^{-14})\ (16 \times 10^{-14})$$

$$= 256 \times 10^{-28}$$

$$= 2.56 \times 10^{-26}$$ for a critical signal (assuming independence between bit errors)

This method imposes a requirement on the software to transmit each message twice which increases processing time. In addition, transmission time will be increased by almost 200 μsec in the case of a critical signal contained in a four data word message.

(4) **Conclusion.** Table 26 sums up the four options presented. As noted earlier, critical signals may have critical timing requirements associated with them; therefore, Option C is not desirable due to the rather large increases in transmission

times. Option B provides an increase of almost an order of magnitude in the probability of error over Option A, with only a slight increase in processing time and software requirements. Based on the assumption that a critical signal is more important than other signals and, therefore, that additional protection is worthwhile, Option B provides the most acceptable solution to the problem of transmitting critical signals over the data bus.

TABLE 26. SUMMARY OF OPTIONS FOR CRITICAL SIGNAL ANALYSIS

Option	Error Probability	Software Requirements	Processing Time	Transmission Time
A	2.56×10^{-28}	No increase	No increase	No increase
B	10^{-14}	Increased	Slight Increase	No increase
C	2.56×10^{-26}	Increased	Slight Increase	Increased by ≈ 200 μsec

g. Weight and Cost Analysis. The primary purpose of the AVSAR study is to determine the weight impact of introducing multiplex and integrated control and display technology into the Night Cobra. This analysis ties together the weight savings for the entire helicopter as well as projecting the cost delta for the new design.

(1) Analysis. The baseline weight for the AH-1S Step 3 Night Cobra is 4,619.5 kg (10,184 lb). An additional 89.13 kg (196.5 lb) will be added by the addition of the following Step 4 systems: FLIR Augmented Cobra TOW Sight (FACTS), NOE communication, projected map display, IACS, and 2000 hp T53 Engine. Therefore, the baseline Step 4 Night Cobra weight, prior to the introduction of multiplexing or integrated control and display techniques, is 4,730 kg (10,428 lb).

Table 27 lists the equipment to be removed from the Night Cobra, along with weight and cost estimates. Table 28 lists the equipment to be added to the Night Cobra as a result of the new design. Totaling the tables and adding a 15-percent allowance for installation weight, the weights are as follows:

Equipment weight removed	93.9 kg	(207.0 lb)
Equipment weight added	105.4 kg	(232.3 lb)
Total Equipment Weight Savings	-11.5 kg	(-25.3 lb)

TABLE 27. EQUIPMENT DELETED, STEP 4 NIGHT COBRA (Sheet 1 of 3)

Item	Description	Designation/AN Nomenclature	Weight (lb)
1.3	Radio set (VHF-FM)	AN/ARC-114A	7.0
1.5	Radio set (VHF-AM)	AN/ARC-115	7.2
2.13	Gyromagnetic compass	CN-998/ASN-43	6.9
2.20	Vertical Gyro		6.8
6.1	Fire control computer (FCC) Connectors		6.0
6.4	Interface control unit (right side)		13.5
8.2	Fire detector amplifier/control unit		0.5
10.1	Automatic direction finder control panel	C-7392A/ARN-89A	0.2
10.2	VOR/ILS navigation facility control	C-10048/ARN-123(V)	1.7
10.3	Doppler navigation system display unit	CP-1252/ASN-128	7.5
10.4	Radar warning/control	C-9326( )/APR-39	2.0
10.16.1	Turbine gas temperature indicator (gunner)		0.6
10.16.2	Turbine gas temperature indicator (pilot)		0.6
10.17	dc volt/amplifier meter	209-075-659-3	0.5
10.19	Transmission oil temperature/pressure indicator	209-075-658-1	0.6
10.20	Attitude indicator (turn/bank) ADI, (gunner)		6.0
10.21.1	Torque indicator (gunner)	209-075-663-7	0.8
10.21.2	Torque indicator (pilot)	209-075-663-7	1.5
10.22	Environmental control system (ECS)		1.6
10.23	IR control panel and indicator (jammer)		0.2 (est.)

TABLE 27. EQUIPMENT DELETED, STEP 4 NIGHT COBRA (Sheet 2 of 3)

Item	Description	Designation/AN Nomenclature	Weight (lb)
10.27	Barometric altimeter (pilot)	AAU-31A	1.9
10.28	IFF control	C-10009( )/APX-100	1.75
10.29	Security control panel	TSEC/KY-28	6.0
10.30	Radar altimeter indicator	(ID-1917)/APN-209	1.6
10.32	Master armament control panel (pilot)		1.8
10.33	SCAS control panel		1.0
10.35	Fuel quantity indicator		0.7
10.36.1	Gas producer tachometer (gunner)	209-075-653-9	0.8
10.36.2	Gas producer tachometer (pilot)	209-075-653-9	0.8
10.39	Compass controller panel	C-6347( )/ASN-43	1.8
10.40	Horizontal situation indicator (HSI)	ID-2103A	7.0
10.41	HSI display control panel		1.8
10.44	Attitude indicator (turn/bank) ADI (pilot)	ID-2104/A	6.0
10.45	Radio magnetic indicator (RMI) (gunner)	ID-2105/A	2.2
10.46	Engine oil temperature/pressure indicator	209-075-656-1	0.8
10.48.1	Engine/rotor RPM (dual tachometer) (gunner)	229-075-665-5	1.9
10.48.2	Engine/rotor RPM (dual tachometer) (pilot)	229-075-665-5	1.9
10.49.1	Airspeed indicator (pilot)	209-075-666-1	1.1
10.49.2	Airspeed indicator (gunner)	209-075-666-2	1.1
10.51	Barometric altimeter (gunner)	AAU-31A	1.9
10.52.1	Vertical airspeed indicator (pilot)	209-073-663-1	1.9

TABLE 27. EQUIPMENT DELETED, STEP 4 NIGHT COBRA (Sheet 3 of 3)

Item	Description	Designation/AN Nomenclature	Weight (lb)
10.52.2	Vertical airspeed indicator (gunner)	209-073-663-2	1.75
10.56	RMS control and display panel		6.0
10.57	ac circuit breaker panel		5.9
10.58	dc circuit breaker panel		3.7
10.59	Power control panel		1.0
10.60	Engine control panel (pilot)		1.8
10.66	Armament control panel (gunner)	209-075-719-1	3.1
10.70	Caution panel (pilot)		2.7
10.71	Master caution indicator (pilot)		0.2
10.76	Caution panel (gunner)		1.4
12.10	Emergency hydraulic pump switch		0.5
14.5	Launcher servo electronics control unit		6.0
15.0	Instrument panel power supply (pilot)		3.3
15.9	Instrument panel power supply (gunner)		3.3
15.11	Flasher		1.5
	Miscellaneous relays, CKT breakers		21.0

TABLE 28. EQUIPMENT ADDED, STEP 4 NIGHT COBRA

Description	Weight (lb)	Cost ($)
FLIR augmented Cobra TOW sight	64.0	TBD
NOE communication	62.0	21,700
Integrated avionics control system	42.5	28,000
Projected map display	57.0	25,000
2000 HP T53 engine (increase in weight)	16.0	TBD
AN/ARC-186	10.0	5,000
HARS gyro	9.0	10,000
HARS electronic control amplifier	8.0	*
Electronic attitude and heading display (pilot)	16.0	6,500
Electronic attitude and heading display (gunner)	16.0	6,500
Flight management display (pilot)	20.0	8,000
Flight management display (gunner)	20.0	8,000
Remote terminals (6)	72.0	42,000
Barometric altimeter	1.0	
Solid-state controllers (70)	10.0	7,000
Solid-state controller interface unit (2)	20.0	14,000

*Cost included in cost of HARS gyro.

However, the new design provides for additional savings based on wire weight and moment analysis, as follows:

Total equipment weight savings:	-11.5 kg	(-25.3 lb)
Total wire weight savings:	43.5 kg	(96.0 lb)
Total ballast savings:	14.5 kg	(32.0 lb)
Total Weight Savings	46.5 kg	(102.7 lb)

A total weight savings of 46.7 kg (103 lb), therefore, provides a Step 4 Night Cobra weight of 4,646.2 kg (10,325 lb), a reduction in weight of 10 percent.

(2) Cost Analysis. Estimated production costs for added equipment, where available, are provided in Table 28. In addition, the estimated development cost to implement the modifications and provide new equipment is in the range of 7 to 10 million dollars.

Current plans are to modify 290 Cobra's to the Step 4 configuration. Amortizing the development costs over 290 units, the cost per unit (worst case) is $34,483. Adding to this figure the total hardware cost from Table 28 of $181,700 (less the cost of FACTS and the 2000-hp T53 engine), the modification cost per AH-1S helicopter should be approximately $216,183.

5. SYSTEM INTEGRATION

a. Remote Terminal Equipment. The remote terminals (RT's) with their proposed subsystem peripheral equipment list are as shown herein. Each RT with its respective subsystem equipment shall require a different set of modules to perform it's specific functions. Where possible the modules shall be standardized.

The RT shall be designed such that the terminal addresses are externally programmable. The specific functions performed by each RT shall be determined by the specific set of modules inserted into the main frame. The set of RT's aboard the aircraft shall be capable of performing the following set of tasks as applicable:

(1) Converting synchro signal data (60 or 400 Hz) into digital data which is bus compatible

(2) Encoding or decoding discrete signal data with common update rates into bus compatible words

(3) Responding to commands that require built-in test (BIT) data

(4) Performing Manchester biphase encoding/decoding

(5) Distributing the appropriate information (signals) to the peripheral equipment

(6) Decoding the mode codes and responding accordingly

(7) Shutting down a transmitter upon command from the bus controller

(8) Performing bit counts, word counts, and parity checks

(9) Power monitoring and control for its own peripheral equipment

(10) Performing analog-to-digital (A/D) or D/A conversion upon demand

(11) Performing fault isolation to determine which module is at fault

The RT's shall be constructed for ease of maintenance.

(1) Pilot's RT. The equipment listed in Table 29 represents all of the peripheral equipment tied to the RT. Buffering of all input/output signals shall be performed by the RT's electronics.

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TABLE 29. PILOT'S RT PERIPHERAL EQUIPMENT

Laser Tracker Electronic Assembly	Head-Up Display (HUD)
Helmet Sight System Electronic Interface Assembly	Miscellaneous Panel (pilot)
Radar Warning Indicator	Pilot Collective Stick
Infrared (IR) Control Panel/Indicator	Pilot Cyclic Stick
Pitot Heater	Power Distribution Station

Examples of potential processing to be performed by the pilot's RT are as follows:

(a) Upon command to transmit laser tracker information, the RT will have to transmit a service request to the bus controller. When the bus controller returns a transmit vector word command, the pilot's RT will be required to return a data word with a service request number and an active indication, implying that data transmission will remain periodic (at 100 Hz) until the RT requests termination. Termination will occur in a similar manner; the only difference is an inactive rather than an active indication will be returned to the bus controller. This processing is typical throughout the RT's for information that must be periodically transmitted on an exception basis.

(b) Similar processing must be accomplished for the pilot collective stick. In this case, however, the RT must recognize that a switch or button (i.e., fire) on the collective stick has been depressed and must initiate a service request to the bus controller. In response to the transmit vector word, a service request number and an inactive indication will be transmitted by the pilot's RT, indicating a one-time data transmission. A second message sequence is not necessary to terminate transmission.

These two examples are fairly representative of the processing that must be accomplished within each RT on the bus, especially when subsystem processing is initiated by operator action.

(2) Gunner's RT/Bus Controller. The equipment listed in Table 30 represents the peripheral equipment tied to the gunner's RT/bus controller. An additional set of cards which perform the bus controllers function shall be required for the gunner's RT mainframe. The RT portion of the RT shall be standardized.

The gunner's RT, in the role of main bus controller, will require additional processing, as shown in Figures 13 through 18. An explanation of each flow is provided below.

TABLE 30. GUNNER'S RT PERIPHERAL EQUIPMENT

Telescopic Sight Unit (TSU)	Miscellaneous Panel (Gunner)
Gunner Collective Stick	Universal Turret System (UTS)
Gunner Cyclic Stick	Barometric Altimeter
Gunner Hydraulic/Jettison Panel	Project Map Display
Acquisition Panel	Environmental Control System (ECS)

(a) Command Word Transmission. The command word transmission procedure (see Figure 13) is entered at the beginning of each minor frame and following a successful transmission. The information transfer table is entered, depending on the minor frame, and each item in the table is examined. If the item is active (to be transmitted), bus selection is accomplished. If bus selection is successful, the information transfer sequence is initiated. If bus selection is unsuccessful, the next item in the table is examined. Processing continues until the table is exhausted.

(b) Bus Selection. The bus selection procedure (see Figure 14) selects a bus for an information transfer sequence. The main bus is checked first to ensure that both the receiving and transmitting terminals are available on the main bus. If either terminal is not available, the same check is made for the alternate bus. This procedure returns an indication as to which bus will be used for the information transfer and an indication of whether it was possible to schedule a bus. If it was not possible to schedule a bus, the information transfer will not be attempted.

(c) Status Word Processing. The status word processing procedure (see Figure 15) validates status words received by the bus controller. If the status word is invalid, if the status word terminal address is not the same as the command word terminal address, or if the busy or message error bits are set RT, error recovery is accomplished by the main bus controller while the alternate bus controller records the error. If the dynamic bus control acceptance bit is set in response to a dynamic bus control command word, the bus controller will release control of the bus and set a 4-msec timeout. If the service request bit is set, service request processing will be initiated.

(d) Service Request Processing. The service request processing procedure, (see Figure 16), handles the transmission of the transmit vector word command and the servicing of that command. If the procedure was entered based on a set service request bit, the transmit vector word command is transmitted to further determine the type of service required. Once the transmit vector command response is returned, this procedure will perform one of the following: locate the command words to be

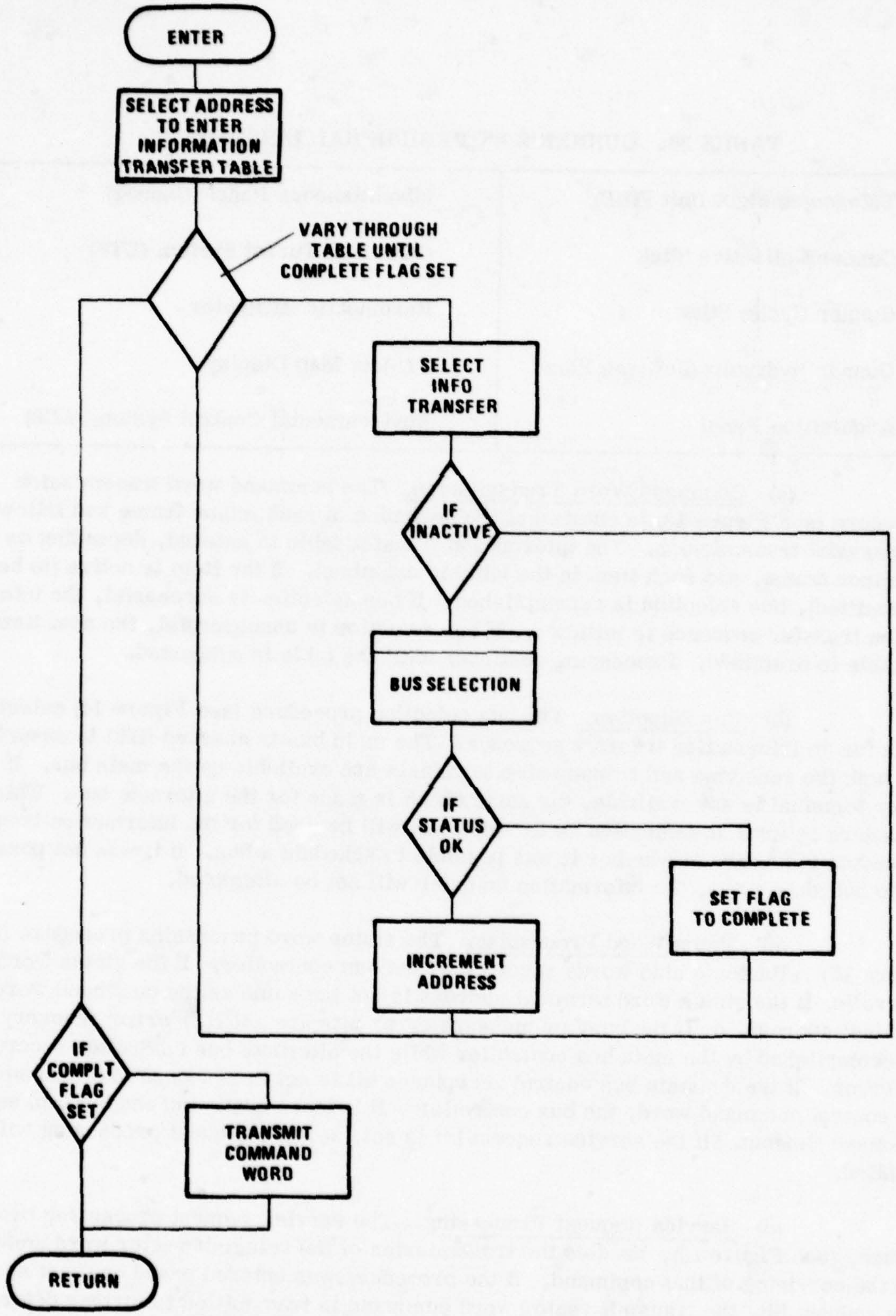

Figure 13. Command word (CW) transmission

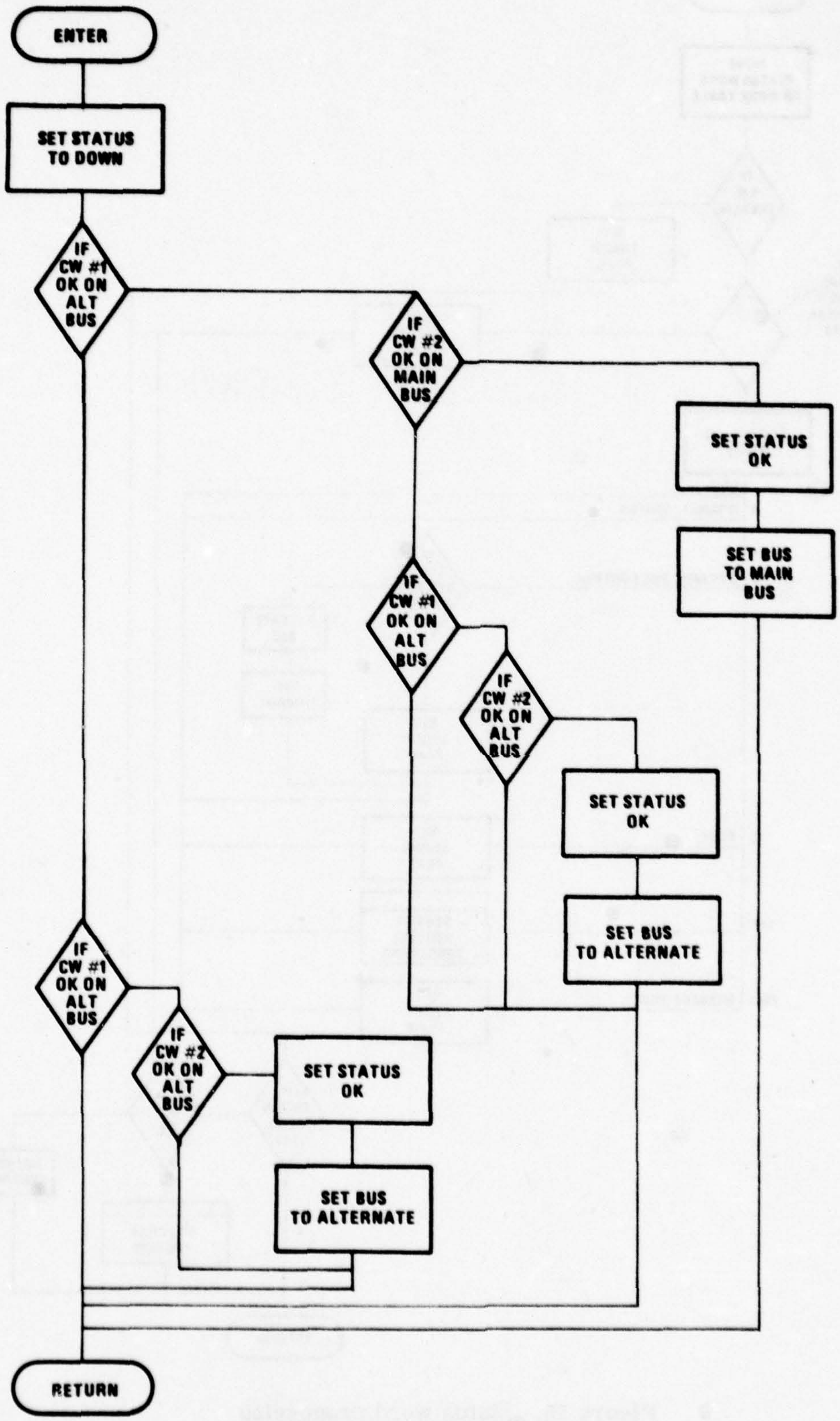

Figure 14. Bus selection

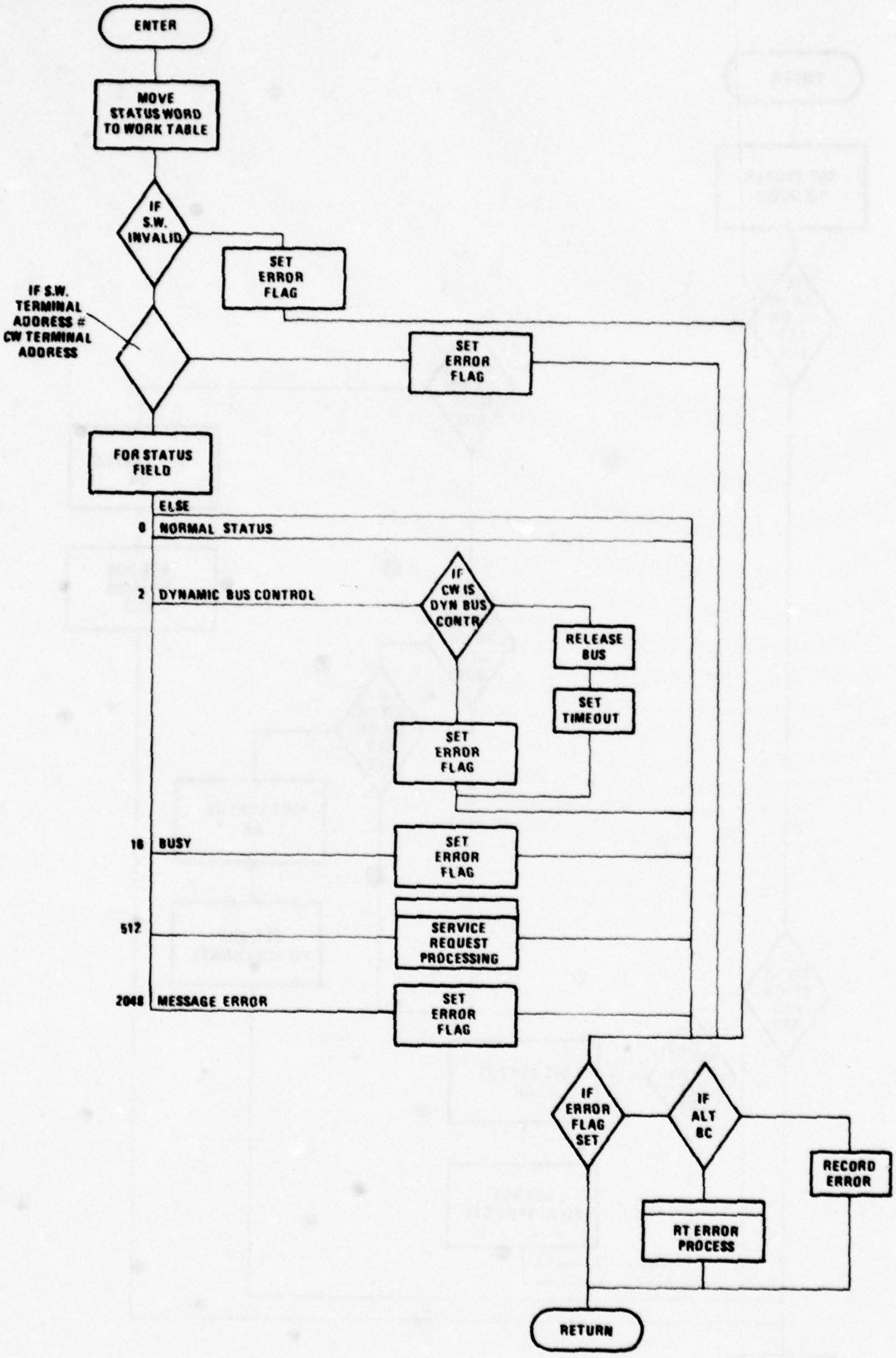

Figure 15. Status word processing

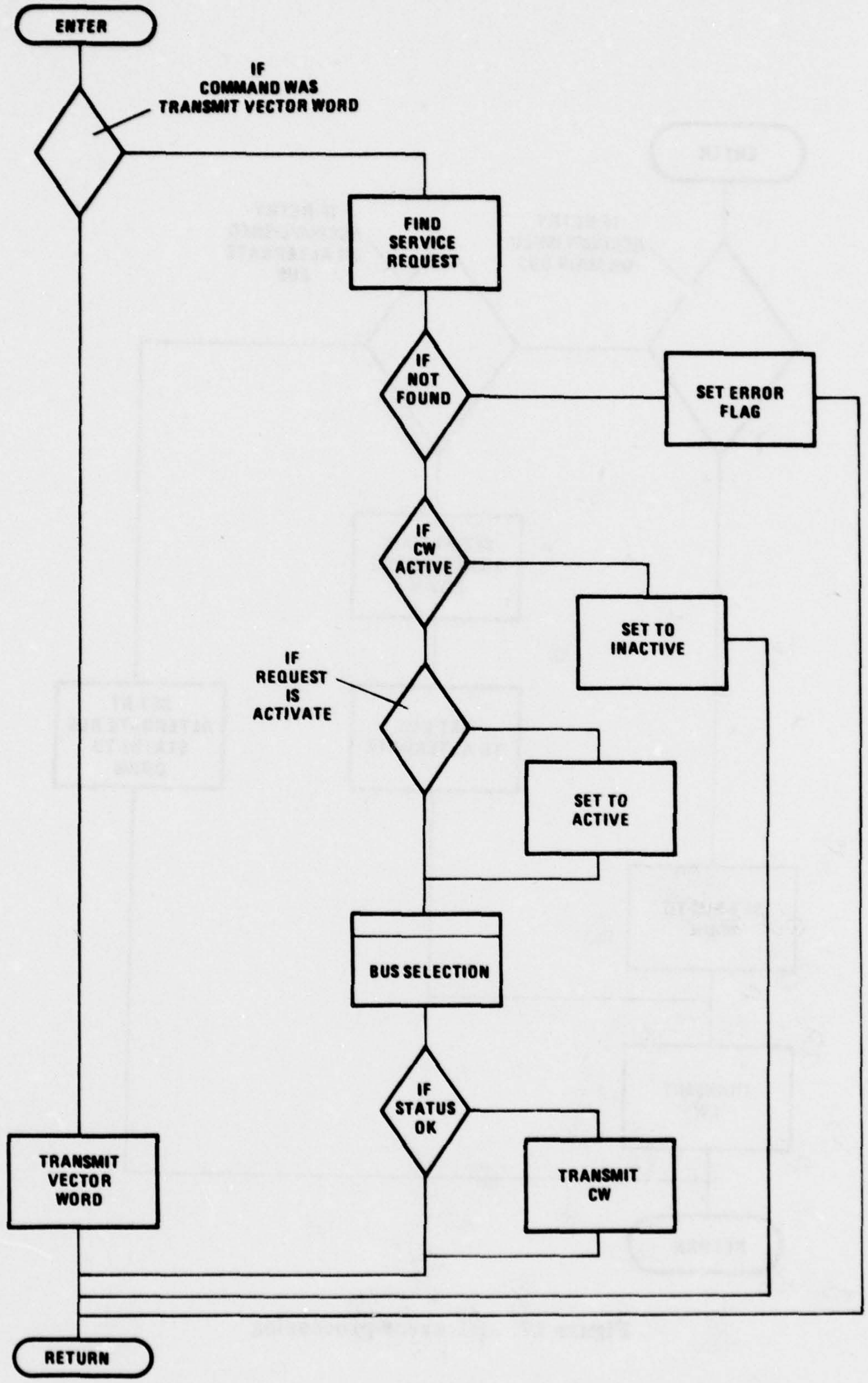

Figure 16. Service request processing

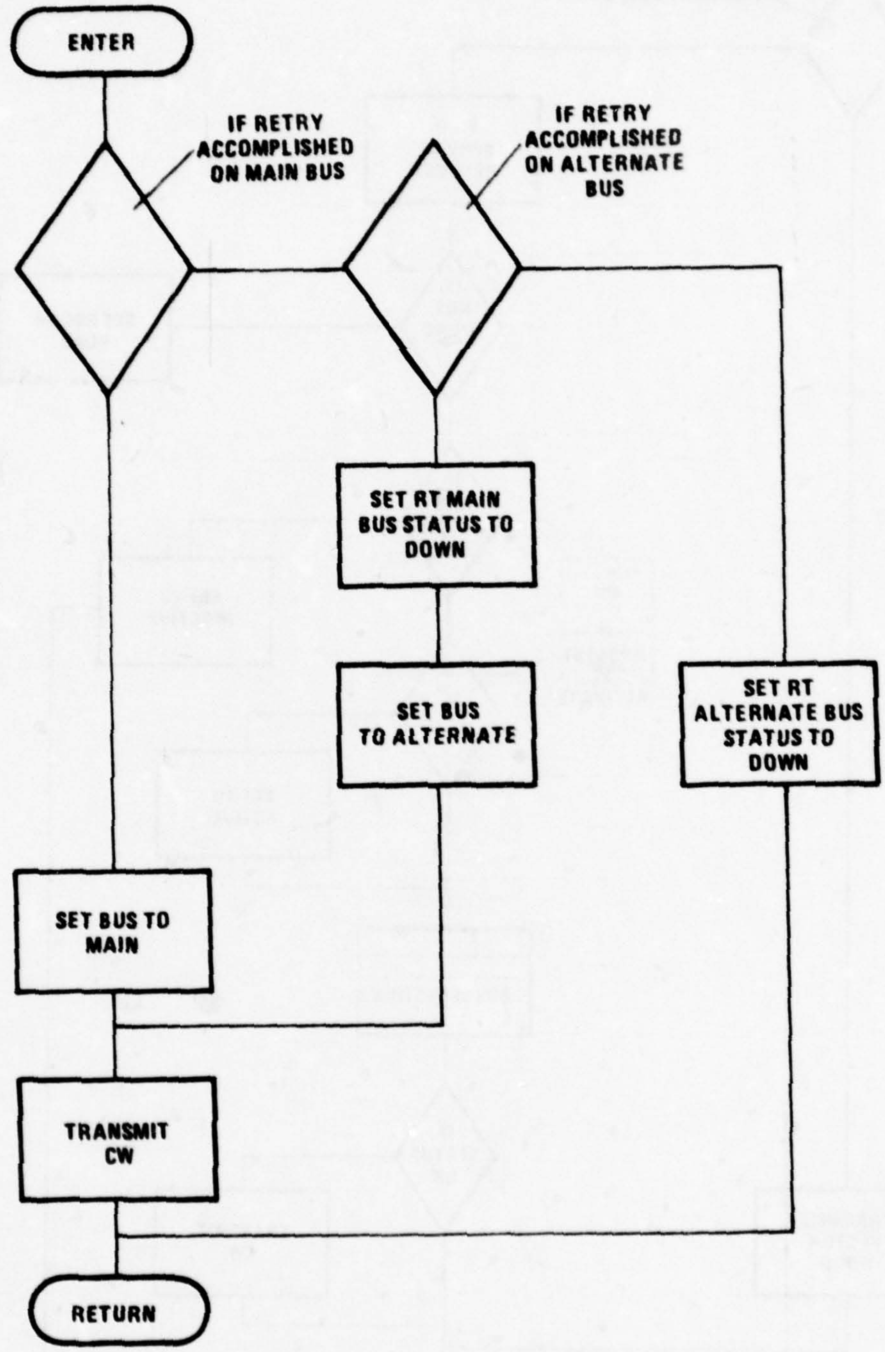

Figure 17. RT error processing

SYSTEM MONITORING PROCESSING

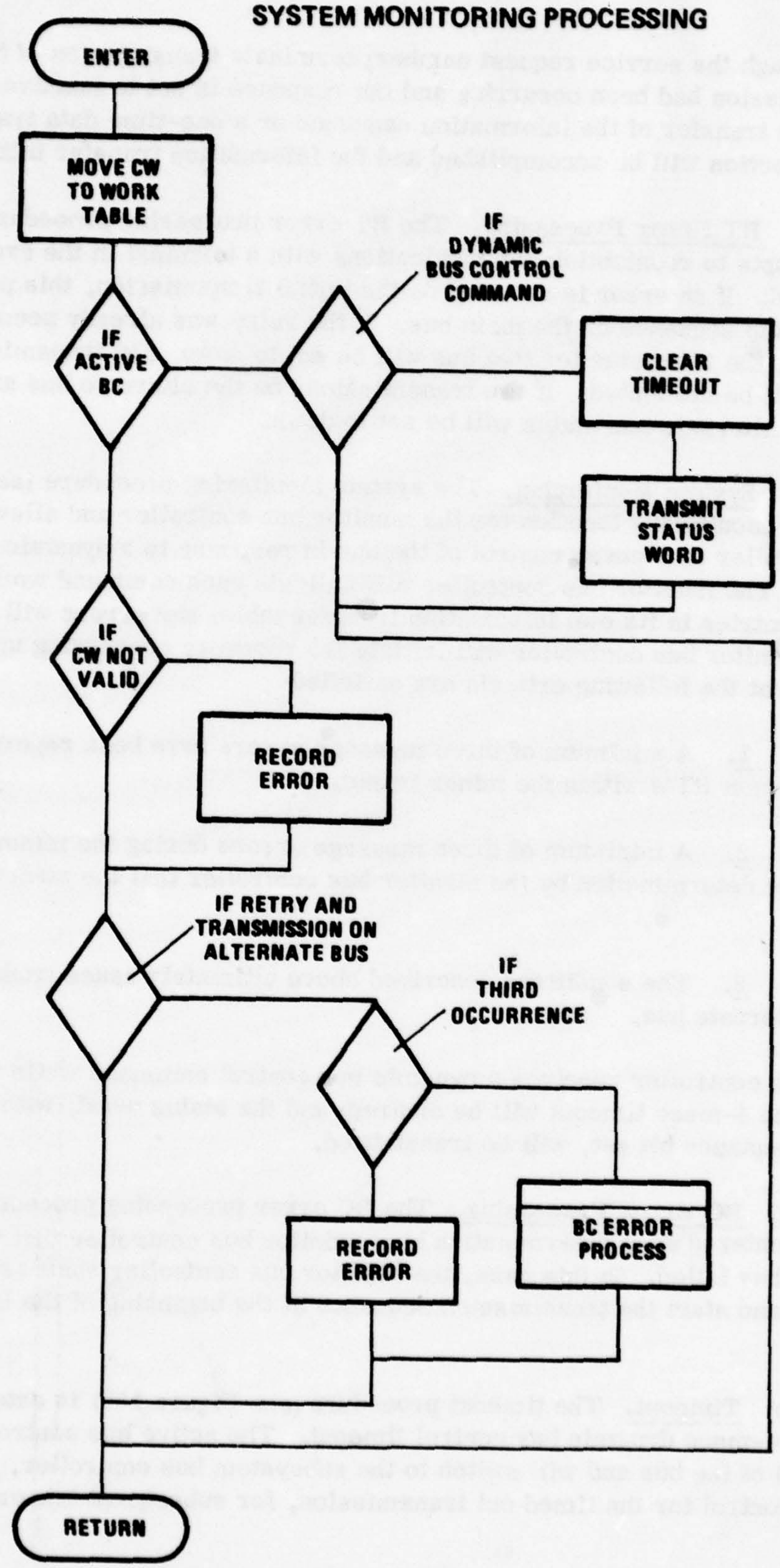

Figure 18. System monitoring procedure

transmitted through the service request number; terminate transmission of the command words if transmission had been occurring and the response is set to inactive; or initiate either a periodic transfer of the information sequence or a one-time data transfer. Finally, bus selection will be accomplished and the information transfer initiated.

(e) RT Error Processing. The RT error processing procedure (see Figure 17) attempts to reestablish communications with a terminal in the event an error is detected. If an error is detected on the initial transmission, this procedure will retransmit the sequence on the main bus. If the retry was already accomplished on the main bus, the RT status for that bus will be set to down, and transmission on the alternate bus will be attempted. If two transmissions on the alternate bus are unsuccessful, the RT alternate bus status will be set to down.

(f) System Monitoring. The system monitoring procedure (see Figure 18) provides the monitoring function for the monitor bus controller and allows the active bus controller to recover control of the bus in response to a dynamic bus control command. The monitor bus controller will validate each command word transmitted against entries in its own information transfer table; any errors will be recorded. The monitor bus controller will initiate BC recovery processing upon determination that the following criteria are satisfied:

1. A minimum of three message errors have been reported by at least three different RT's within the minor frame.

2. A minimum of three message errors during the minor frame coincide with the determination by the monitor bus controller that the command word is invalid.

3. The conditions described above ultimately cause transmission to occur on the alternate bus.

If the active bus controller receives a dynamic bus control command while monitoring the data bus, the 4-msec timeout will be cleared; and the status word, with the dynamic bus control acceptance bit set, will be transmitted.

(g) BC Error Processing. The BC error processing procedure (see Figure 19a) is entered upon determination by a monitor bus controller that the active bus controller has failed. In this case, the monitor bus controller shall assume control of the bus and start the transmission sequence at the beginning of the last minor frame.

(h) Timeout. The timeout procedure (see Figure 19b) is entered upon expiration of the 4-msec dynamic bus control timeout. The active bus controller will assume control of the bus and will switch to the subsystem bus controller, which was not given bus control for the timed out transmission, for subsequent transmissions.

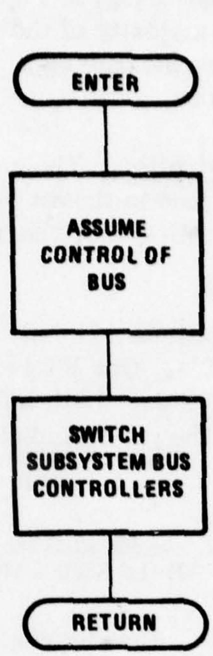

Figure 19a. BC error processing

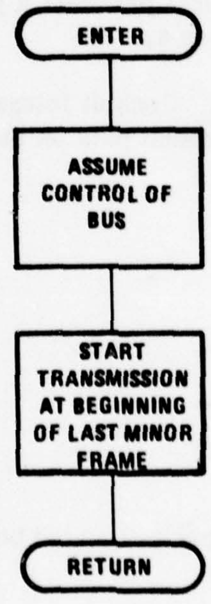

Figure 19b. Timeout Processing

(3) Engine RT. The equipment listed in Table 31 represents the peripheral equipment tied to the engine RT. The majority of the signals required for multiplexing are discrete signals, which will require bit packing. Several signals are analog and will require conversion for bus transfers.

(4) AFT Section RT/Bus Controller. The equipment listed in Table 32 represents the peripheral tied to the RT located in the aft section of the aircraft. The aft RT functions as the alternate bus controller and, therefore, includes the same processing described for the gunner's RT.

(5) Wing Stores RT. The equipment listed in Table 33 represents the peripheral equipment tied to two separate RT's. One RT is located on the port side of the aircraft and the other on the starboard side. Both RT's shall be designed to interface with the same suite of equipment, but the programmable terminal addresses shall be different.

b. Integration of AH-1S Controls and Displays. This section discusses the integrated approach recommended for the AH-1S Step 4 Night Cobra.

(1) Problems and Constraints. Considering the added weight and the increased functional capability of the Step 4 additions to the AH-1S, it was paramount to assess the weight reduction due to multiplexing and cockpit control and display integration. This was the foremost aspect and driving function of this study.

The physical limitations of both cockpit instrument panels area and depth are major factors in instrument panel layout. The requirement to place the PMD (ID-1665/ASN-99) in the gunner's instrument panel presents a physical installation problem the solution to which is presented in Section 6.

(2) Recommended Approach. Cockpit integration for both the pilot and gunner is achieved by integrating mission segment data on the following multiformat displays:

(a) FMD

(b) EAHD

(c) PMD

(d) HUD

(e) IACS control panel

Crew station description and layouts are presented below.

TABLE 31. ENGINE RT PERIPHERAL EQUIPMENT

Airspeed Electronic Processor Unit	Transmission Oil Hot Switch
Rotor Tachometer Generator	Transmission Oil Pressure Switch
Engine Tachometer Generator	Transmission Oil Bypass Switch
Forward Fuel Boost Pump	Engine Fuel Pump Pressure Switch
Aft Fuel Boost Pump	Engine Oil Pressure Switch
Start Relay	Fuel Filter Bypass Switch
Idle Stop Solenoid	Engine Oil Float Switch
Fuel/Oil Valve	Radar Altimeter
Emergency Hydraulic Pump	Engine Oil Bypass Switch
Gas Producer Tachometer Generator	Torque Transmitter
No. 1 Hydraulic Pressure Switch	Fuel Quantity Indicator
No. 2 Hydraulic Pressure Switch	Emergency Hydraulic Pump Overload Switch
Emergency Hydraulic Pressure Switch	Hydraulic Test Switch
Forward Fuel Level Low Switch	Forward Fuel Boost Pump Switch
Aft Fuel Level Low Switch	Aft Fuel Boost Pump Switch
Engine Fire Sensor	Engine Inlet Air Detector
Transmission Chip Detector	Turbine Gas Temperature Sensor
Engine Chip Detector	Fuel Filter Flow Sensor

TABLE 32. AFT SECTION RT PERIPHERAL EQUIPMENT

IR Jammer/Receiver Electronics	42-degree Chip Detector
Rate Gyro	90-degree Chip Detector
Vertical Displacement Gyro	Power Distribution Station
Radar Warning Comparator	Projected Map Display (PMD) Electronic Assembly Unit
HUD Signal Display Unit	Position Lights
Missile Command Amplifier	Anticollision Lights

TABLE 33. WING STORES RT PERIPHERAL EQUIPMENT (PORT AND STARBOARD)

Inboard Rocket Pod	Guided Missile Launcher
Inboard Jettison	Accelerometer
XM-18 Gun Pod	Actuator
Outboard Rocket Pod	Resolver
Outboard Jettison	

(a) Pilot Station Description. The Night Cobra's pilot station consists of a rear tandem seating position in the AH-1S whose cockpit width is approximately 78.74 cm (31 in). Right and left 15.24-cm (6-in) wide lateral horizontal consoles contain the following:

1. Left-hand console:

   a. Collective stick with control head

   b. FMD keyboard (data entry)

2. Right-hand console: primary control panel (PCP), IACS

The pilot's instrument panel measures 32.5 cm (13 in) at the top, upon which is mounted a HUD. The base of the instrument panel extends the width of the cockpit by 78.74 cm (13 in). A central area of 17.78 cm (7 in) in width extends from the top to the bottom, a distance of 55.88 cm (22 in). The displays mounted in the column from top to bottom are the following (see Figure 20):

1. Master caution indicator/fire

2. Status panel (SP IACS)

3. Electronic attitude and heading display (EAHD)

4. Flight management display (FMD)

To the left of the EAHD is mounted the laser tracker, and directly below the laser tracker is mounted the miscellaneous jettison panel.

The radar warning indicator (RWI) is mounted to the right of the EAHD, and below the RWI is mounted the pilot's clock.

The cyclic stick is floor-mounted between the pilot's legs. His feet rest on control pedals beneath the instrument panel.

A key-operated ignition security switch is mounted on the lower right-hand instrument panel. A foot-operated starter switch is provided to the pilot as well as a foot-operated push-to-talk switch.

The ICS intercom and communication selection unit is mounted to the left of the FMD.

(b) Copilot (Gunner) Station Description. The Night Cobra's copilot station consists of a forward tandem seating position in the AH-1S. The copilot (gunner) cockpit is approximately 66.04 cm (26 in) wide. On both sides of the gunner, 7.62-cm (3-in) consoles contain the following:

1. Left console:

   a. FMD key entry

   b. Collective stick

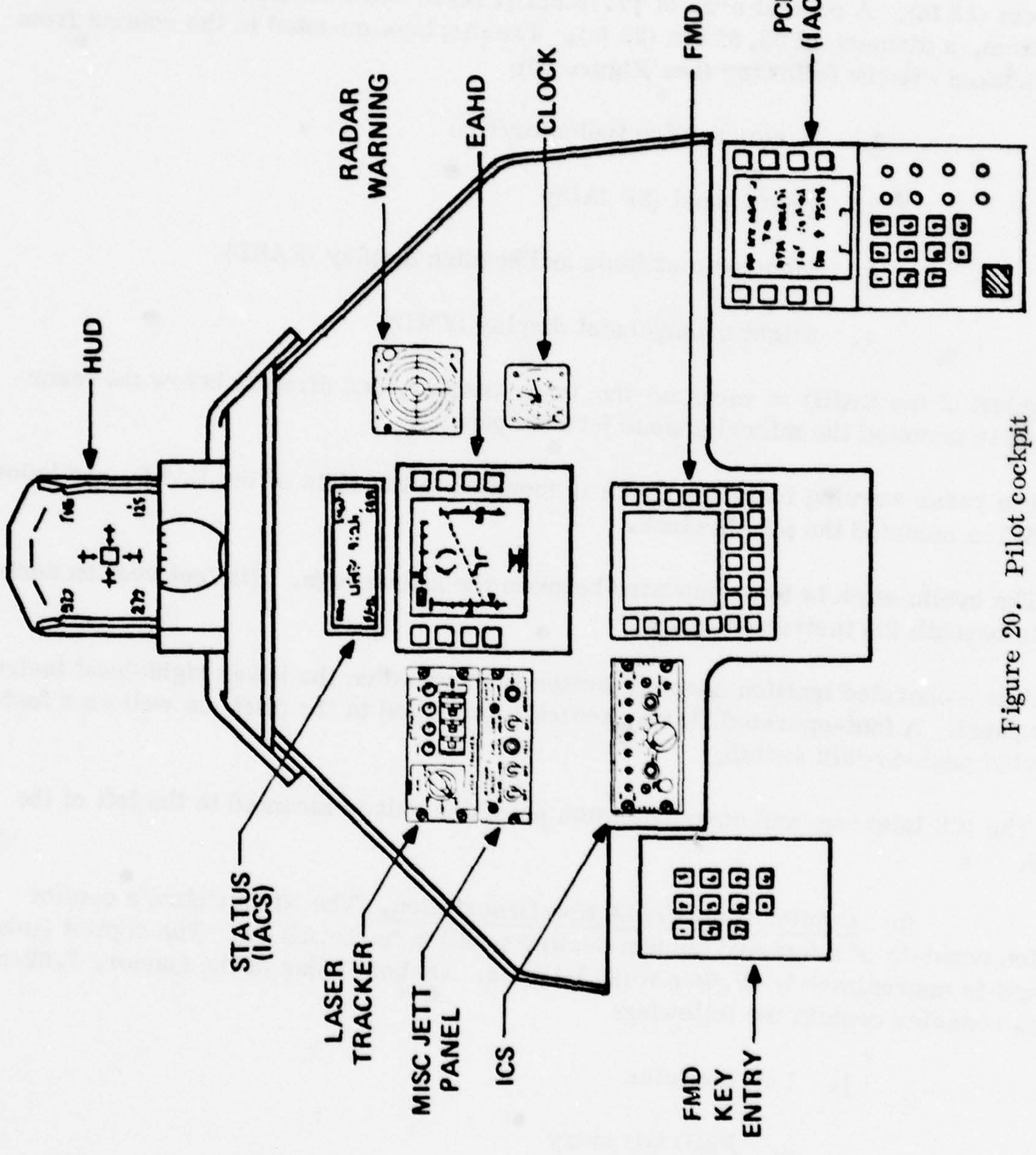

Figure 20. Pilot cockpit

1. Right console:

a. ICS intercom and communication selection unit

b. Cyclic grip

The instrument panel has the FLIR augmented TOW sight mounted in the lower middle portion. The TSU sighting tube projects up approximately 15.25 cm (6 in) into a 13.97-cm (5.5-in) cutout of the gunner's instrument panel. This leaves a 20.32 cm x 13.95 cm (8.0 x 5.5 in) area directly above and behind the TOW sight in which the IACS SP is mounted at the top. See Figure 21.

The left-hand portion of the gunner's instrument panel at its widest point is 35.56 cm (14 in) high and 24.77 cm (9.75 in) wide. The gunner's EAHD shall be mounted in the upper portion of this area. Directly below this, the gunner's flight management display shall be mounted. The hydraulic/jettison panel is mounted in the irregular space to the left of the EAHD and FMD.

The right-hand portion of the gunner's instrument panel consists of an irregular area composed of two rectangles, with height and width of 25.4 cm x 27.3 cm (10.0 in x 10.75 in) and 10.16 cm x 15.47 cm (4.0 in x 6.09 in). At the top of this area, the master caution indicator shall be mounted. Directly below this shall be the PMD. The gunner's IACS control panel (GCP) is mounted below and to the right of the PMD occupying a portion of the 25.4 cm x 27.3 cm (10.0 in x 10.75 in) and 10.16 cm x 15.47 cm (4.0 in x 6.09 in) areas. To the left of the IACS control panel and above the TOW-sight joystick are mounted the airborne laser tracker (ALT)/pilot's helmet sight (PHS) acquisition panel and the laser range control panel.

(3) Flight Management Display (FMD). The flight management display shows caution, advisory messages, checklists, engine health, and power performance of the attack helicopter in nonattack mission segments. The FMD as a multipurpose control and display is programmed to provide armament and weapon mode management data display prior to and during the attack phase of the Cobra deployment. The various armament modes set by the crew are retained until withdrawn via a multiformat keyboard entry associated with the FMD.

Functional Definition. The FMD consists of a MIL-STD-1553B digital terminal, a microprocessor, raster symbol generator, image buffers, symbol generator output control, video processor, CRT, control electronics, and low- and high-voltage power supply. The FMD has a usable CRT screen area of 10.16 cm x 10.16 cm (4 in x 4 in); the FMD provides monochrome display during daylight operation

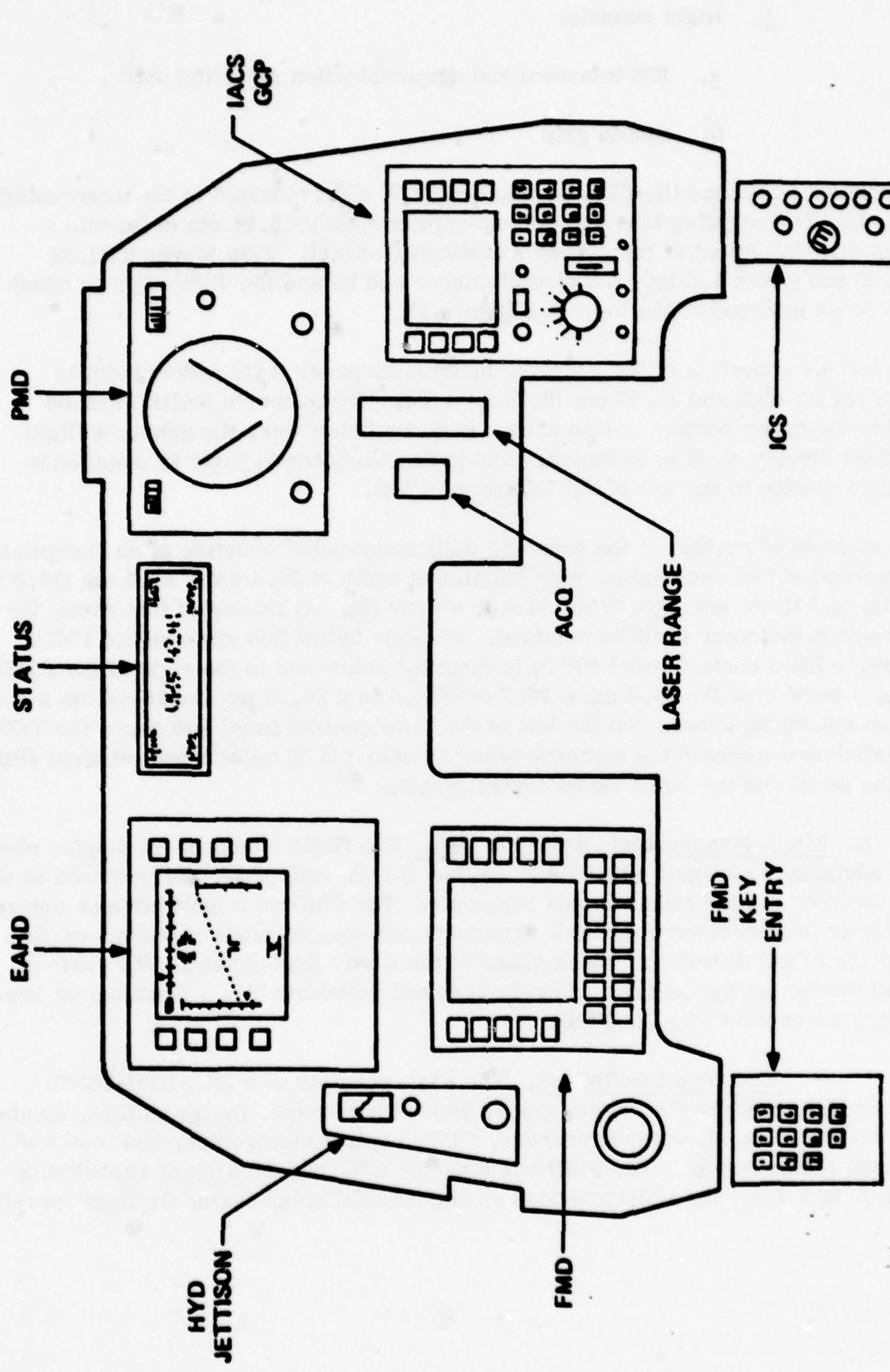

Figure 21. Gunner (copilot) cockpit

and red display during night operation. It is desirable but not required to provide green and yellow display information per MIL-C-25050. The FMD shall have the following interfaces:

1. MIL-STD-1553B bus

2. Video: 525 lines (EIA-R5-170). Provision shall be made to accept at least two video sources with composite 1-volt peak signals.

An appropriate contrast filter with a match bandpass shall be employed. A highlight brightness of 513.9 cd/m^2 (150 fl) should be achieved. The contrast ratio for low ambience shall be 30:1; for high ambience, that is, 107,639 lx (10,000 fc), the contrast ratio shall be 6:1. Discernible gray shades for low ambience shall require 10 shades as a minimum, and 6 shades are the minimum for high ambience, 107,639 lx (10,000 fc).

Jitter is less than one-half of a line width.

Physical size (height/width/length) is not to exceed 13.97 cm x 16.51 cm x 27.94 cm (5.5 in x 6.5 in x 11 in).

Weight is not to exceed 9.07 kg (20 lb).

Power should be approximately 100 watts.

Definition of Operating Modes. The FMD display control is implemented by a set of six illuminated push-button switches located in a vertical column on the right- and left-hand sides of the CRT display.

The left-hand column of six switches serves the following three functions:

(a) Caution warning for subsystems served. When a parameter within the designated subsystem is beyond programmed performance or bit, the indicator will blink at the following rates:

1. Critical. Immediate attention to subsystem page; 4 blinks per second with a 50 percent on-off ratio

2. Noncritical. Immediate attention not required; 1 blink per second with a 50 percent on-off ratio

(b) Page Call. Single push of subsystem switch shall cause the entire subsystem performance/status page to be presented on the display.

(c) Reset. Double push resets the blinking light. Switch legend stays on, yellow for caution, red for alert, until the condition is corrected; then the switch legend returns to green illumination, indicating satisfactory subsystem operation.

The left-hand column of switches includes, top-to-bottom, the following subsystems:

1. Engine
2. Fuel
3. Lubrication/hydraulics
4. Electrical
5. Mechanical
6. Armament

The right-hand column of six switches is reserved for U.S. Army Avionic Research and Development Activity (AVRADA) symbology and graphics as a redundant cockpit backup for the EAHD. These switches are, top-to-bottom:

1. Cruise
2. NOE (transition)
3. Hover
4. Pop-up
5. CONUS navigation

These switches control unique mission segment symbology and graphics selection and are selected by the crewmembers. The transition from hover to pop-up graphics may be automatically switched by sensing appropriate helicopter parameters. At the bottom of the FMD and as a separate dedicated FMD integrated subsystem switch panel are two horizontal rows of 9 switches. These switches are the following:

1. Engine startup checklist
2. Prestart checklist
3. Pretakeoff checklist
4. Postflight checklist
5. Alternator
6. Emergency hydraulics
7. Generator
8. Battery
9. Test
10. Governor auto
11. Fuel
12. Engine de-ice
13. Force trim
14. Idle step
15. SCAS
16. Roll
17. Pitch
18. Yaw

Switches 5 through 18 interface with MIL-STD-1553B digital terminal of the FMD to format flight management subsystem control words. Switches 1 through 4 interface with microprocessor and initiate a programmed checklist which is automatically stepped down the list as the condition is satisfied. A cursor blinks until the condition is met.

The primary mode of display of the FMD is inflight exception display and mission mode flight dynamics. Associated with the FMD is a separate multiswitch data entry device in which to enter mode selection and control of subsystems monitored. This entry device interfaces with the FMD microprocessor to generate MIL-STD-1553B compatible control and data words which exit via the FMD's digital terminal.

(4) Electronic Attitude Heading Display. The EAHD provides essential mission segment flight control data under IFR conditions to either pilot or copilot when assuming flight responsibility. The EAHD shall have the capability of accepting night vision sensor and ESM sensor presentations during critical mission segments of the Night Cobra attack mission. The EAHD consists of a raster-driven CRT (monochrome for daylight operation and red for night operation, with optional green and yellow color display capability).

Functional Definition. The EAHD consists of MIL-STD-1553B digital terminal, microprocessor, symbol generator, image buffers, symbol generator output control, video selection, video processor, CRT/control electronics, and low- and high-voltage power supply. The EAHD has a usable CRT screen size of 12.7 cm x 12.7 cm (5 in x 5 in). The EAHD shall have the following interfaces:

MIL-STD-1553B bus interface

Video interface: 525 lines, composite input, video signal range of 1 volt peak, response 15 MHz. Provision is made to accept at least two video sources with composite video.

Raster synchronization employs a phase lock loop for controlled picture stability. A highlight brightness of 513.9 cd/m^2 (150 fL) should be achieved. The contrast ratio for low ambience shall be 30:1 and for high ambience, 10,763 lx (1000 fc).

Jitter is to be less than one-half of a line width.

Physical size (height/width/length) is not to exceed 17.78 cm x 19.05 cm x 27.94 cm (7 in x 7.5 in x 11 in).

Weight not to exceed 7.26 kg (16 lb).

Power is approximately 85 watts.

Definition of Operating Modes. The EAHD modes are front panel operator selected for mission segment graphics. Control of mission mode display is implemented by a set of five illuminated pushbutton switches located in a vertical column on the right- and left-hand sides of the CRT display. These switches will be illuminated when selected either manually or automatically. In accordance with Type I, aviation colors of MIL-C-25050 will be used.

The left-hand column of switches is reserved top-to-bottom for the following functions:

(a) Sensor 1 — Low light level television (LLLTV) (growth)

(b) Sensor 2 — FLIR (growth)

(c) Map video and terrain mask (growth)

(d) Conus navigation

The right-hand column of switches is employed to enter the following mission segment graphic mode using AVRADA symbology for helicopter flight. These switch functions are the following, top-to-bottom:

(a) Cruise (en route)

(b) Transition NOE

(c) Hover

(d) Pop-up

The cruise mode is designed for high-speed and high-altitude flights in which precise control of the helicopter flight path is not necessary. This is altitude in excess of 60.96 m (200 ft) above ground level (AGL) and at a speed over 100 knots.

The transition (NOE) mode is designed for moderate-speed NOE flights, or at speeds less than 80 knots.

The hover mode is designed for the pilot to hold a precise hover with approximately zero ground speed within the doppler drift error.

The pop-up mode is designed to allow the pilot to hold the horizontal ground position during the mask and unmask maneuvers.

(5) Projected Map Display (PMD) AN/ASN-99. The present AN/ASN-99 PMD display presents an integration problem regardless of the location in which it is

mounted. The ID-1665/ASN-99 measures 15.24 cm x 17.78 cm x 39.7 cm (6 in x 7 in x 15.63 in). The 39.7-cm (15.63-in) length presents a problem, since both the pilot's and the gunner's instrument panel depth is 30.48 cm (12 in) or less in the desired viewing area of the instrument panel.

The gunner's upper right-hand instrument panel appears to offer the best location both physically and functionally for en route navigation.

This location would result in one of the following choices:

(a) The PMD projects out from the gunner's instrument panel by approximately 9.2 cm (3.63).

(b) The back wall in that area will be tilted forward to accommodate the ID-1665/ASN-99.

(6) Head-Up Display (HUD). The proposed Step 3 HUD packaging poses several problems:

(a) It hangs over the pilot's instrument panel, obscuring the upper half of the instrument panel when the pilot is in a harnessed, locked, seat-back position.

(b) It presents a hazard to the pilot in the event of a crash.

(c) It utilizes a CRT to write only four variables and seven armament symbols:

1. Torque

2. Heading

3. Range and source

4. Radar altitude

5. Fire control aiming symbols

6. Gunner's sightline symbols

7. TOW prelaunch window symbol

8. TOW postlaunch window symbol

9. Left/right missile select symbol

10. Stadiometric reticle symbol

11. Boresight reference symbol

c. Information Transfer Approach. In a command/response system, an RT-to-RT transfer is the most expensive type of transfer in terms of protocol overhead. This analysis was performed to determine whether a reduction in this overhead could be achieved.

(1) Concept. The basic concept is to find the most efficient mix of RT-to-RT transfers and a combination RT-to-BC/BC-to-RT transfers. In the second type of transfer, data would be transmitted from numerous RT's to the bus controller. The data would then be buffered by the bus controller and sent in a single message to a single RT. Several assumptions have been made:

(a) All the data from the numerous RT's are intended for a single RT.

(b) The data rates are identical.

(c) The bus controller can pack all the data received in a single message.

This process can be repeated for any sink (RT) that has numerous sources (numerous RT's).

(2) Analysis. An RT-to-RT transfer consists of the following set of words: two command words, two status words, and some number, Y, of data words. In addition, there are two intermessage gaps (IMG), each of a duration of 4.0 to 12.0 μsec. A worst case calculation would be 4.0 μsec. Therefore, since each word takes 20 μsec to transmit, the total time to transmit an RT-to-RT transfer can be represented by the following equations:

$$\text{Total time} = 2\,(20\ \mu\text{sec}) + 2\,(20\ \mu\text{sec}) + Y\,(20\ \mu\text{sec}) + 2\,(4.0\ \mu\text{sec})$$

$$= 40\ \mu\text{sec} + 40\ \mu\text{sec} + 20\,Y\ \mu\text{sec} + 8.0\ \mu\text{sec}$$

$$= \underline{88\ \mu\text{sec} + 20\,Y\ \mu\text{sec}}$$

An RT-to-BC/BC-to-RT transfer consists of the following set of words for each transfer: one command word, one status word, and some number, Y, of data words.

There is a single IMG of 4.0 to 12.0 μsec. Therefore, the total time to transmit a single transfer can be represented by the following equations:

$$\text{Total time} = 1\ (20\ \mu\text{sec}) + 1\ (20\ \mu\text{sec}) + Y\ (20\ \mu\text{sec}) + 1\ (4.0\ \mu\text{sec})$$

$$= \underline{44\ \mu\text{sec} + 20\ Y\ \mu\text{sec}}$$

The RT-to-RT transfer and the RT-to-BC transfer times are affected by the number of RT's, X, providing data. Including this factor and setting the two sets of equations equal, a break-even point can be determined in terms of X and Y:

$$(X)\ (88\ \mu\text{sec} + 20\ Y\ \mu\text{sec}) = (X)\ (44\ \mu\text{sec} + 20\ Y\ \mu\text{sec}) + (44\ \mu\text{sec} + 20\ Y\ \mu\text{sec})$$

$$(\#RT)\ (\text{RT-RT total time}) = (\#RT)\ (\text{RT-BC total time}) + (\text{BC-RT total time})$$

$$88\ X\ \mu\text{sec} + 20\ XY\ \mu\text{sec} = 44\ X\ \mu\text{sec} + 20\ XY\ \mu\text{sec} + 44\ \mu\text{sec} + 20\ Y\ \mu\text{sec}$$

$$\underline{44\ X\ \mu\text{sec} = 44\ \mu\text{sec} + 20\ Y\ \mu\text{sec}}$$

By now, assuming some number of RT's, X, as sinks, the number of data words, Y, can be calculated as shown, assuming X = 5:

$$(44)\ (5)\ \mu\text{sec} = 44\ \mu\text{sec} + 20\ Y\ \mu\text{sec}$$

$$22\ \mu\text{sec} = 44\ \mu\text{sec} + 20\ Y\ \mu\text{sec}$$

$$176\ \mu\text{sec} = 20\ Y\ \mu\text{sec}$$

$$8.8 = Y$$

Given X = 5 and Y = 8.8, the average number of data words per RT-to-BC transfer is Y/X or 8.8/5 = 1.76 data words/transfer. Therefore, with 5 RT's acting as sources, an RT-to-RT transfer would be more efficient if the average number of data words per transfer exceeded 1.76. In reality, however, a fraction of a data word can not be transferred on the bus and, therefore, the actual ratio of Y/X is 8/5, or 1.6 data words/transfer. Figure 22 shows a plot of Y versus X, for both the theoretical and actual conditions. Data for the plots are shown in Table 34.

d. Conclusion. Based on the data from Table 34, in order for an RT-to-BC/BC-to-RT transfer to be used, the average number of data words/transfer would have to be less than two (2). The method is not efficient if the number of RT's is two or less.

The Night Cobra multiplex data bus system was then analyzed to determine whether conditions existed in which an RT-to-BC/BC-to-RT transfer would be advantageous. The FCC was the only sink identified with a sufficient number of messages to take advantage of this technique, however, the average number of data words in this set of messages is considerably above the limit shown by the analysis. Therefore, the decision was made to implement all RT-to-RT transfers for the Night Cobra application.

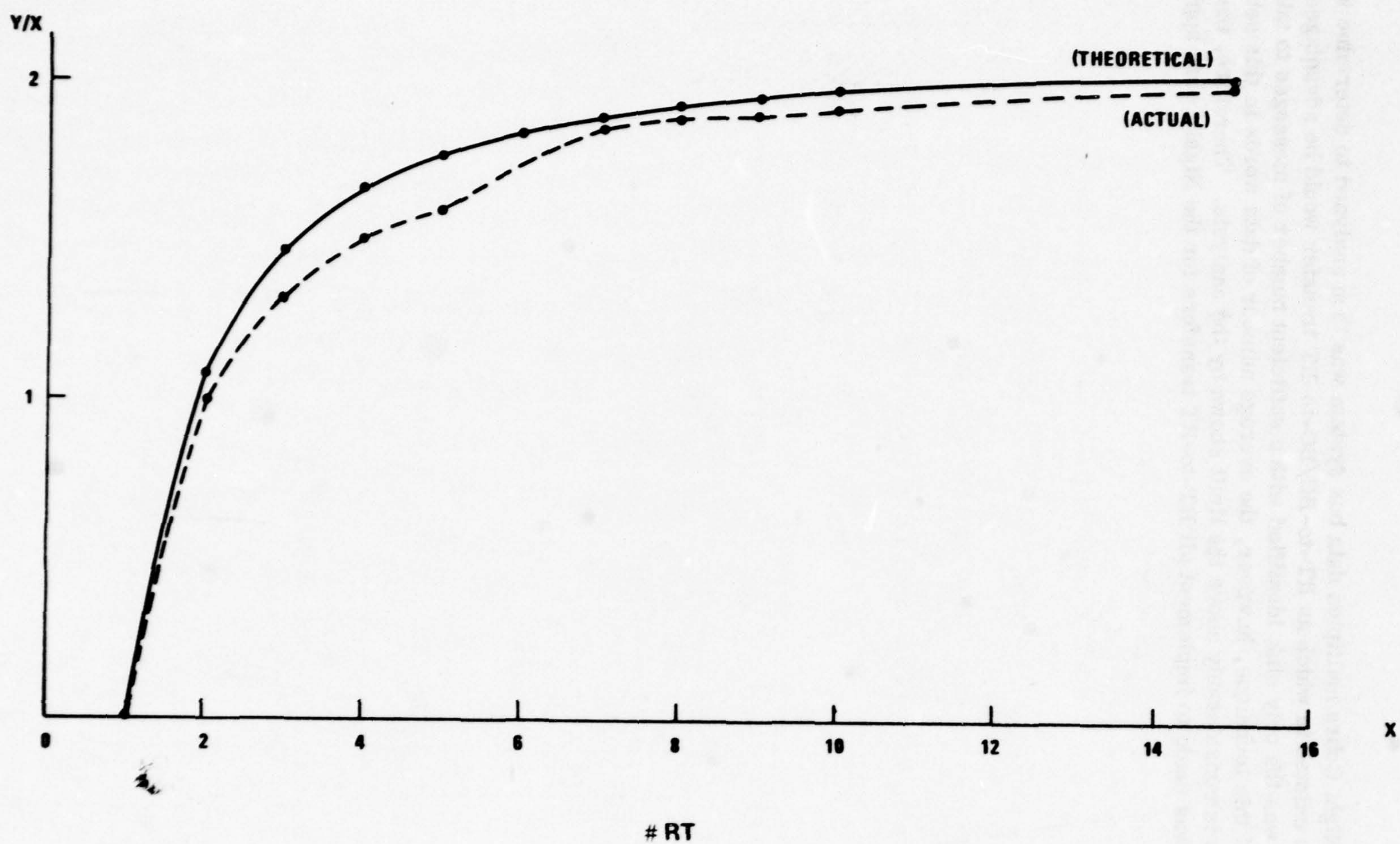

Figure 22. Average number of data words/transfer

TABLE 34. INFORMATION TRANSFER DATA

No. of RT's (X)	No. of Data Words/ Transfer (Y)	Average No. of Data Words/ RT's (Y/X)	No. of Data Words/ Transfer (Truncated) (Y_T)	Average No. of Data Words/ Transfer (Truncated) (Y_T/X)
1	0	0	0	0
2	2.2	1.1	2	1
3	4.4	1.47	4	1.33
4	6.6	1.65	6	1.5
5	8.8	1.76	8	1.6
6	11	1.83	11	1.83
7	13.2	1.88	13	1.85
8	15.4	1.92	15	1.87
9	17.6	1.95	17	1.89
10	19.8	1.98	19	1.9
15	30.8	2.05	30	2.0

6. FUTURE CONSIDERATIONS

a. Control/Display Future Considerations. A number of areas discussed earlier in this report are potential candidates for control/display integration but may not be realizable by the 1982 time frame. These areas are summarized here as recommended control/display areas that warrant further investigation.

(1) PMD. Ideally, from a true display and control integration point of view and considering the ballast weight and redundancy factors, it is desirable to incorporate the projected map display as a video input to either EAHD or FMD. This feature will be selectable for both pilot and gunner as the need requires. The ID-1665/ASN-99 weighs 9.5 kg (21 lb) and occupies a volume of 15.24 cm x 17.78 cm x 39.7 cm or 10,757.4 cm^3 (6 in x 7 in x 15.63 in or 656.46 cm^3).

Since the ASN-99 is composed of two LRU's, projected map display ID-1665/ASN-99 and electronics assembly CV-2662/ASN-99, the film cassette and transport could be removed as a separate unit, mounted in the boom, and projected on an iconoscope device. The map video could be displayed on any raster display in either cockpit.

The delta in weight at most would be the difference in adding the weights of the iconoscope and circuits. This $+\Delta W$ could be offset by a change in ballast. This assumes that vibrations in the boom are within reasonable limits and do not modulate the iconoscope image.

PMD Relocation/Ballast Impact (using English units)

Location	21#	CG	C_L	21#	W_B
	2	$\bullet_d \rightarrow$ CG	$\bullet$	24	
	48	193	200	312	400
STA					

$21 \times 145 = 208\ \Delta W_B$

$\Delta W_B = 14.71$ lb

$21 \times 119 = 2499 \quad (16 + 21)\ 119 = 4248.3$

$2499 = d \cdot 10210 \qquad 4248.3 = d \cdot 10210$

$d = 0.2447$ inches $\quad d = 0.4161$ inches

The CG may move back approximately 0.5 in and is well within the center of gravity envelope (see Figure 23).

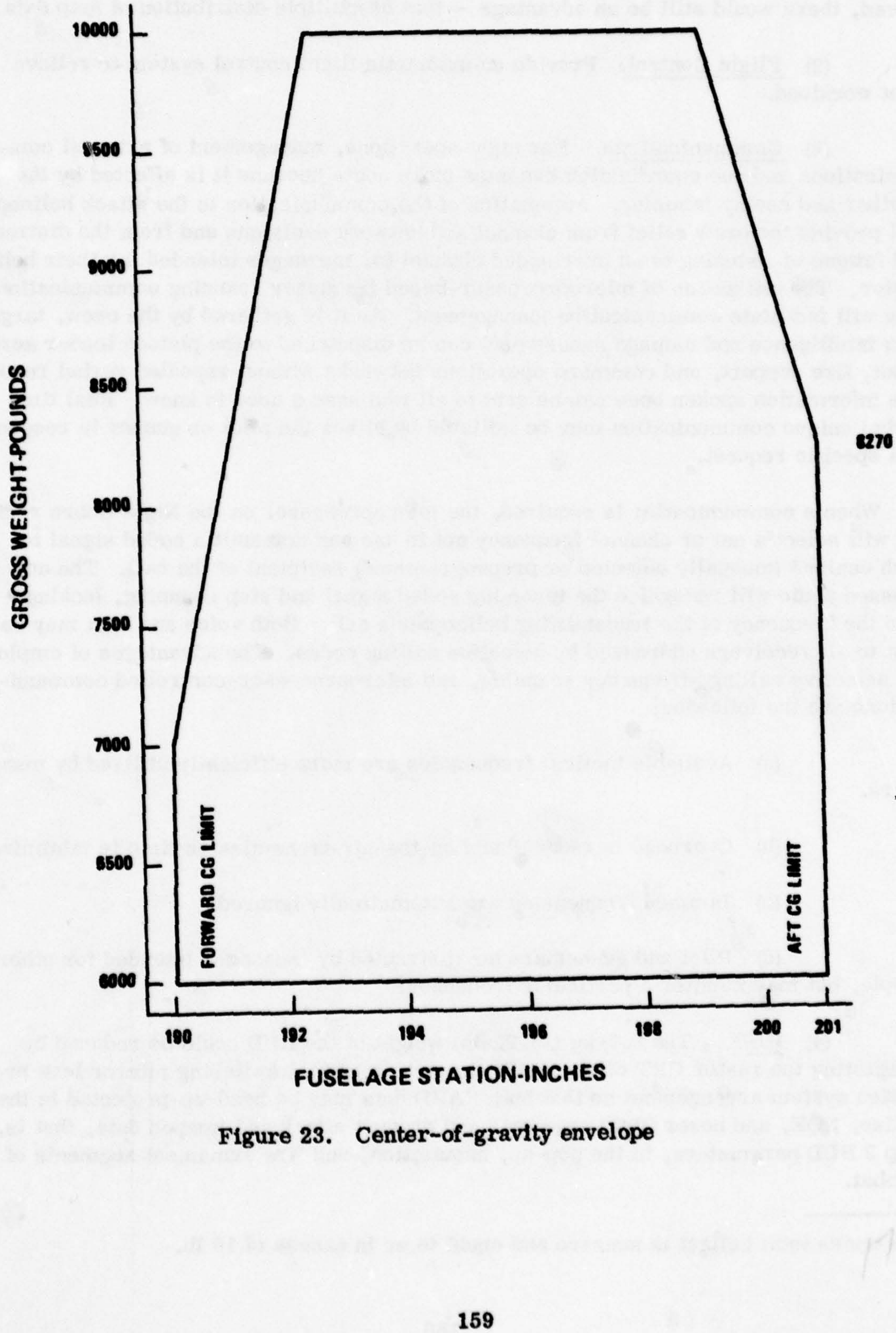

Figure 23. Center-of-gravity envelope

If the iconoscope and its electronics were to match the 14.71 lb in ballast[6] removed, there would still be an advantage — that of multiple distribution of map data.

(2) Flight Control. Provide an automatic flight control system to relieve pilot workload.

(3) Communications. For night operations, management of external communications and cue coordination becomes more acute because it is affected by the weather and enemy jamming. Automation of the communication to the attack helicopter will provide the crew relief from channel and network decisions and from the distraction and fatigue of listening to an overloaded channel for messages intended for their helicopter. The utilization of microprocessor-based frequency scanning communication sets will facilitate communication management. As it is gathered by the crew, target data intelligence and damage assessment can be dispatched to the platoon leader aeroscout, fire support, and command operations networks without repeated verbal reports. The information spoken once can be sent to all who have a need to know. Real time verbal unique communication may be initiated by either the pilot or gunner in response to a specific request.

When a communication is required, the microprocessor on the Night Cobra radio set will select a net or channel frequency not in use and transmit a coded signal to each desired (manually selected or preprogrammed) recipient of the call. The addressed radio will recognize the incoming coded signal and stop scanning, locking onto the frequency of the transmitting helicopter's call. Both voice and data may be sent to all receivers addressed by selective calling codes. The advantages of employing selective calling, frequency scanning, and microprocessor-controlled communications are the following:

(a) Available tactical frequencies are more efficiently utilized by many users.

(b) Overhead is reduced and on-the-air-transmission time is minimized.

(c) Jammed frequencies are automatically ignored.

(d) Pilot and gunner are not distracted by messages intended for other people, but may monitor a particular frequency.

(4) HUD. The 6.9-kg (15.22-lb) weight of the HUD could be reduced by integrating the raster CRT of the EAHD through an optical switching mirror lens projection system arrangement so that both EAHD data may be head-up-projected in the cruise, NOE, and hover flight segments and present attack and weapon data, that is, Step 3 HUD parameters, in the pop-up, acquisition, and fire armament segments of combat.

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[6] Assumes total ballast is nonzero and equal to or in excess of 15 lb.

The additional advantage to be gained is head-up presentation of future night sensor capability such as LLTV and FLIR.

(5) Voice Multiplex. Voice multiplex could be incorporated once adequate isolation of red/black separation can be demonstrated.

(6) Multifunction Raster-Type Display System. The PMD, Radar Warning display, and the HUD are amenable to integration once a multifunction raster-type display system is adopted. The PMD should be video remoted to save weight and provide flexibility. The radar warning indicator display could be absorbed by the EAHD graphics.

Because of space constraints, the HUD should be combined with the EAHD to provide other heads-up graphics in the cruise, transition, hover, and pop-up modes in addition to the fire control graphics. To utilize the raster CRT of the EAHD combined through a switchable mirror lens projection arrangement would result in a weight savings, better night operation capability in all mission segments where external cues demand the pilot's attention, and improved overall reliability.

b. Software Tools and Documentation. Software tools are an integral part of the computer software development, test, and maintenance process. Therefore, in the procurement of tactical software, the delivery of software tools becomes just as important as the delivery of the tactical software; without the software tools, test and maintenance of the tactical software become impossible. The intent of this guide is to describe software tools that may be necessary during the Night Cobra software life cycle; to discuss the use of each tool at each phase of the life cycle; and to outline the documentation that would be required to effectively use each tool.

Paragraph (1) below describes the layout of the set of software tools; paragraph (2) provides a description of the documentation required during the software life cycle.

(1) Software Tools

(a) Simulator. Simulation techniques are used throughout the software life cycle. In general, a simulator provides the target system with the inputs or responses in the same format provided by the device being simulated. However, a single simulator may not satisfy the requirements of all phases of the life cycle.

For the purposes of development and maintenance, a simulator (or simulators) should be procured that is capable of testing all remote or embedded terminals individually. This simulator should be a fairly simple program that allows user-specified data to be transmitted over the bus and then records all responses for later analysis. Of prime importance to the procuring agency is the user interface. In the case of a simulator, this interface is a simulator "language" which allows a user to express a scenario or test case in terms the simulator can use in providing inputs and responses. Investment in a simulator "language" that is easy for the user to learn and use should have a high priority. The effort to develop such a language is inexpensive compared to the number of man-hours that can be saved in development and maintenance by a good language; the preparation of scenarios and test cases is a labor intensive effort, with much of the time requirement dictated by how easy it is to get the information into the simulator.

Test simulation requirements are more stringent than the requirements for development and maintenance. Rather than test each individual component, the system should be tested as a system. Therefore, the system simulator should be capable of simulating the environment outside of the Night Cobra multiplex data system, with one important exception: the crewmembers' interface with the system should not be simulated during system test. The general requirements for a system simulator can be defined as follows:

1. The simulator must provide inputs and responses, in the format that is provided by the device being simulated, in real time.

2. Design of the tactical software should not be dependent upon the simulator design.

3. The simulator must provide realistic responses to any crewmember control action.

4. A test director must have the capability to control the simulator and interactively change scenario conditions.

5. Provision should be made to allow the introduction of failures in the system.

6. The simulator should be capable of recording all message traffic on the multiplex data bus as well as data within the simulator software.

7. Maximum uninterrupted run time for a single system scenario should be at least two hours.

Proper specification of the system simulator for the purpose of system test can provide an important benefit: the simulator can also be used for crew training.

(b) Data Reduction. Data reduction programs are used throughout the software life cycle in the analysis of system performance. They do not necessarily reside on the same computer that is being tested and are normally not required to operate in real time. The purpose of the data reduction program is to sift through the tremendous quantity of data that was generated during test or development activities and to provide the system analyst with a concise summary of how the system performed. Numerous capabilities can be provided by data reduction software: complex algorithms intended to study a certain system function, time ordering of data for further analysis, error determination, reformatting of data for report generation, and so forth.

Each data reduction program developed for the Night Cobra application should be documented and deliverable, in order to preclude duplication of effort.

(c) Debug Aids. Debug aids are critical tools in the development, test, and maintenance of tactical software. They provide the programmer or analyst with a method of examining selected portions of the software in an effort to identify and isolate program errors. Several debug aids are briefly described below.

A dump allows the recording of the contents of a computer's memory to provide a snapshot of the state of the computer on demand. A dump is normally in octal, and provision should be made to allow an operator to select a portion of core to be dumped.

An inspect-and-change routine allows a computer operator to call up (usually from a keyboard device) a particular memory location and inspect the contents. The operator can, if desired, change the contents of that core location.

A breakpoint can be inserted by a computer operator to stop execution when the breakpoint is reached. This feature is typically used to determine whether a specific program path is being executed or to determine the values of specific variables in response to a known set of input data.

A memory map provides location and/or size information about all or selected parts of a computer program.

A software monitor program provides detailed statistics about a system performance. This program resides in memory and can examine such things as core usage, queue length, and individual program operation.

A trace program records the chronological sequence of events taken by a target program during its execution. These results can be used to determine the extent of test coverage, the frequency of executing instructions, and similar statistics.

(d) Compiler/Assembler. Compilers and/or assemblers are essential tools in any software project. If a higher order language is used in the Night Cobra application, a compiler will be required to translate the source program into an assembly language form for subsequent assembly to machine language, or to translate the higher order language directly into an equivalent machine language program. If assembly language is used or if the compiler's end product is in assembly language form, an assembler will be required to complete the translation to machine language.

(2) Documentation. During a software life cycle, the need for adequate documentation cannot be overemphasized; the development and maintenance is a labor intensive business and inadequate documentation only serves to magnify the problem of providing and maintaining a usable product. The documentation described below is essential to provide continuity and direction throughout the software life cycle.

Two of the documents described, Software Development Plan and Software Configuration Management Plan, are required for the overall management of the software development process. The Software Configuration Management Plan is also necessary throughout the software maintenance cycle. The remaining documents constitute a set which totally describes each software item procured. A complete set of documentation should be deliverable with each software program procured, including software tools.

(a) Software Development Plan. The Software Development Plan (SDP) describes the comprehensive plan for the management of the development effort for the computer program. The SDP includes a description of the development organization, a description of the design approach, milestones and schedules, and resource allocation.

The SDP provides the contractor with the means to coordinate schedules, control resources, initiate actions, and monitor the progress of the development effort. The SDP provides the procuring activity with detailed knowledge of the schedule, organization, and resource allocation planned by the contractor. It is the basic tool which the procuring activity uses in monitoring the contract work effort.

This document also provides information of management philosophy and methodology, project organization, the system design and implementation approach, support facility requirements, and the quality assurance approach.

(b) Software Configuration Management Plan. The Software Configuration Management Plan describes the configuration management organization (Software Configuration Control Board) dedicated to computer software management; the responsibilities of the members; the relationship among the several offices/divisions; the policies and procedures for identifying and documenting the functional and physical characteristics of configuration items required by the contract; procedures for controlling changes to configuration items during development and/or maintenance; procedures for recording and reporting change processing implementation status; and the external software relationships required to maintain total system compatibility.

(b) Data Reduction. Data reduction programs are used throughout the software life cycle in the analysis of system performance. They do not necessarily reside on the same computer that is being tested and are normally not required to operate in real time. The purpose of the data reduction program is to sift through the tremendous quantity of data that was generated during test or development activities and to provide the system analyst with a concise summary of how the system performed. Numerous capabilities can be provided by data reduction software: complex algorithms intended to study a certain system function, time ordering of data for further analysis, error determination, reformatting of data for report generation, and so forth.

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This document provides the means to consolidate all policies, procedures, organizational descriptions, resources, and schedules relating to configuration management. Through this plan, control of the software can be maintained, providing a program whose characteristics are known and whose outputs and reactions are predictable.

This document typically describes the software configuration management organization and software configuration identification procedures and provide a means of controlling problems and changes.

(c) Program Performance Specification. The Program Performance Specification describes in detail all the operational and functional requirements necessary to design, test, and maintain the required software. It provides the logical, detailed descriptions of the performance requirements of a digital processor program. It indicates compatibility with all components of the real-time avionic system, including the digital processor and conversion equipment, as well as with other interfaced avionic weapon systems.

This document is used as the controlling document for the software item, enabling the assessment of the satisfactory completion of the software. In addition, all changes to the software, during maintenance, must be measured against the Program Performance Specification to determine impact on the software and compatibility with other elements of the system.

(d) Program Design Specification. The Program Design Specification document is the design description of the software. It is based upon the performance requirements defined in the Program Performance Specification, specifies the programming approach for implementing the digital processor program itself, and defines the program architecture for further program composition.

(e) Program Description Document. The Program Description Document provides a complete technical description of all subprogram functions, structures, operational environments, operating constraints, data base organization, source and object code listing, and diagrammatic/narrative flows. Each subprogram or function is described in its own volume, with referenced appendixes as necessary. Each Program Description Document is directly responsive to the Program Design Specification and to any appropriate software and/or program specification. The Program Description Document is specifically oriented to programming logic and programmer's language. The aim should be to describe and completely define the basic subprogram logic and program procedures for each application subprogram and for each system control subroutine.

The Program Description Document serves as the essential instrument for subsequent use by maintenance personnel diagnosing troubles, making adaption changes, designing and implementing modifications to the system, and for introducing or adding new subprogram functions to the completed program. During the development process, this document can be reviewed to ensure compliance with the requirements defined by the Program Performance Specification.

(f) Data Base Design Document. The Data Base Design Document provides a complete detailed description of all common data items necessary to carry out the functions of the software. Common data is that data required by two or more subprograms. This document is based on the Program Performance Specification and is developed in consonance with the Program Design Specification and concurrently with the Program Description Document.

The Data Base Design Document may be used for final computer software design review. This document is also used for the life-cycle program maintenance by the program maintenance activity. The application in this regard safeguards the data base during life-cycle configuration management.

(g) Program Package. The Program Package consists of the software program source and deck listing, an error-free source/object listing produced by an assembly or compilation of the source decks, a complete cross reference listing produced by a compilation of the source decks, and any data which are necessary to cause programs to run properly (for example, adaptation data, data file contents, setup data, and program parameter values).

The program material items are required to produce, maintain, and update the software.

(h) Software Test Plan. A test plan defines the total scope of the testing to be performed. It identifies the particular level of testing and describes its contributing role for ensuring the reliability and certified acceptance of the computer program. Individual test requirements are listed for every test to be conducted at the specified level of testing. The test plan contains precise statements of the purpose, scope, and schedule for the individual test being planned. It identifies the degree of testing and the specific functions that are involved in the test. Also, the specific objectives of the test are defined, and a summary of the test methods and the type of system environment to be used are included.

The test plan is required to ensure that the technical requirements described by the Program Performance Specification are met and to describe how system integration is to be verified.

(i) Software Test Procedures. Test procedures present detailed instructions for test setup and test execution and for the evaluation of test results. They provide for the collection of quantitative test results, upon which the determination of test success or failure is based. The procedures are developed from the test plans and other relevant documents. Test procedures are the documentation tools required to perform the actual testing of the system.

(j) Software Test Report. Test reports are the vehicle by which the results of a test are documented. They are used to describe, define, and evaluate discrepancies between the intended system, function, or program design and the program capability as produced in code. The test report briefly describes the purpose and nature of the test. It discusses detail, deviations from the test plans, and/or test procedures required in the complete performance of the test; for example, substitution of required equipment, patches in the program being tested, or changes to support programs.

The test report is used to determine the degree of acceptability of the software. It is used to compare the test results with the established requirements for a system function. It is also used to weigh potential design improvements and functional tradeoffs that may have been determined through the testing processes.

(k) User's Manual. The user's manual provides personnel with the necessary instructions concerning usage of the software. This includes limitations/ restrictions, formatting information, purpose and use, and a functional description of inputs. In addition, operation of the software and hardware should also be addressed.

7. REFERENCES

	Document No.	Title
1.	TM-55-1520-221-20	Organizational Maintenance Manual, Army model AH-1G.
2.	209-947-384A	Specification ( ) airdata subsystem, Part I of two parts.
3.	209-947-369A	Prime Item Development Specification ( ) for the M65 Tow missile subsystem, Part I of two parts
4.	TM55-1520-221-10	Operator's manual, Army model AH-1G helicopter
5.	TM11-1520-221-20	Organizational maintenance manual, electronic equipment configuration
6.	TM11-1520-221-20C2	Organizational maintenance manual, electronic equipment configurations, Army model AH-1G, AH-1Q helicopters
7.	TM11-1520-221-34	Direct support and general support maintenance manual, electronic equipment configurations Army model AH-1G helicopter
8.	BEL November 30, 1977 Amended February 20, 1978	Modernized cobra fire control modes and armament controls and displays
9.	209-947-385A	Fire control computer (FCC) without navigation capabilities
10.	209-947-381	Fire control computer, part I of two parts
11.	209-947-382	Fire control computer program
12.	209-947-393	Fire control computer signal interface control document
13.	SE-00364	XM136 helmet sight subsystem specification, part I
14.	SE-00364	XM136 helmet sight subsystem specification, part II.
15.	TM55-1520-236-10	Technical manual final draft operator's manual, AH-1S helicopter

	Document No.	Title
16.	TM11-1520-236-20	Technical manual, organization maintenance manual for electronic equipment configuration AH-1S helicopter
17.	TM11-1520-236-34	Technical manual, direct supply and general support maintenance electronic configuration AH-1S helicopter
18.	ENAC77-1 REV1	Characteristics for a moderate accuracy inertial navigation system (INS), 28 March 1978
19.	Draft MIL-STD-1553B 6 June 1978	Aircraft internal time division command/response multiplex data bus
20.	209-947-389	Airdata subsystem signal interface control document
21.	209-947-386A	Fire control computer program
22.	209-947-384A	Page changes 9-30-77
23.	209-947-385A	Page changes 9-23-77
24.	209-947-385A	Page changes 11-21-77
25.	209-947-210	Prime item development specification for the XM65 tow missile system
26.	209-947-396B	Prime item development specification for the M65 Tow missile subsystem, part I of two parts
27.	209-947-383A	Head-up display subsystem, part I of two parts
28.	209-947-383B	Head-up display subsystem, part I of two parts
29.	209-947-390	Head-up display signal interface control, document 2-25-77
30.	209-947-394A	Page changes 9-21-77
31.	EL-CP1062-0001B	Integrated avionic control system (IACS) 8 April 1976

	Document No.	Title
31.	209-947-397	Modification specification model, AH-1S modernized
32.	Technical memorandum 9-77 AM CMS Cont 677716.11.H700B	Advanced scout helicopter man-machine interface investigation
33.	EL-CP1062-0001B	Amendment No. 2, integrated avionics control (IACS), 24 March 1977
34.		Night vision goggles, AN/PVS-5
35.		AN/ALQ-136 (XE-2) installation data
36.	TM9-4931-363-14&P	Operator, organizational, direct support and general support maintenance manual for fire control subsystem test set AN/GSM-249.
37.	TM9-1270-212-14&P	Operator, organizational, direct support, and general support maintenance manual for fire control helmet-directed XM128 and fire-control subsystem helmet-directed XM136
38.	209-020-004 through 209-475-043	Wiring microfilm engineering document card
39.	TM55-1500-323-25	Installation practices for aircraft electric and electronic wiring
40.	Singer-Kearfott July 21, 1978	SKD/Army review of alternate configurations for LDNS-PMDS/IACS integration

	Specification	Title
1.	MIL-I-49077 (EL)	Installation and acceptance testing of altimeter set, AN/APN-209(V)
2.	MIL-A-81605B (AS)	Altimeter set AN/APN-194(V)
3.	MIL-I-49091 (EL)	Installation and acceptance testing of receiver-transmitter RT-1167/ARC 164(V) UHF-AM Radio

	Specification	Title
4.	MIL-R-55664A (EL)	Radio set, AN/ARC-116( )
5.	MIL-R-55662 (EL)	Radio set, AN/ARC-114( )
6.	MIL-STD-765A	General requirements for aircraft compass swinging
7.	MIL-R-55663 (EL)	Radio set, AN/ARC-115( )
8.	MIL-STD-1333A	Aircrew station geometry
9.	MIL-HDBK-759	Human factors engineering design for Army materiel
10.	MIL-I-83336B (USAF)	Indicator-attitude, self-contained, 3-inch, general specification
11.	MIL-A-81851 (AS)	Altimeter AAU-31/A
12.	MIL-I-5721 C	Amendment 1
13.	MIL-I-5721 C	Indicator, indicated airspeed, 20, 250 knots
14.	MIL-D-8804 A	De-icing system, pneumatic boot, aircraft, general specification
15.	MIL-I-27710 C	Indicator, attitude, remote
16.	MIL-A-2726 A	Amendment 2 accelerometer, aircraft
17.	MIL-A-27261 A (USAF)	Accelerometer, aircraft
18.	MIL-C-38207 A (ASG)	Clock, aircraft, mechanical ABU-11A
19.	MIL-C-38207 A (ASG)	Amendment 1 clock aircraft, mechanical ABU-11/A
20.	MIL-C-38214 B (USAF)	Compass, magnetic, mounted

	Specification	Title
21.	MIL-C-38214 B (USAF)	Amendment 1 compass, magnetic, mounted
22.	MIL-I-49162 (EL)	Navigational set, doppler AN/ASN-125 installation and acceptance testing of
23.	MIL-N-49098 (EL)	Navigational set doppler AN/ASN-128( ) (XE-2)
24.	MIL-W-5088 F	Wiring, aerospace vehicle

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APPENDIX A

INTERFACE SUMMARY SHEETS

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

10.0 SUBSYSTEM DISPLAY & CONTROL
10.4 EQUIPMENT AN/APR-39 (SHEET 1 of 2)

UNIT C-[illegible] AN/[illegible]
UNIT NAME [illegible]

No.	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
1	SPARE	J1 / 1		NONE		–	–	–			–	
2	28VDC SW OUT	2		J1-12 RADAR COMPARATOR		DC POWER						
3	ST SW	3		J1-13 RADAR COMPARATOR		DISCRETE						
4	DISCRM SW	4		J1-14 RADAR COMPARATOR		DISCRETE						
5	MA LAMP	5		J1-15 RADAR COMPARATOR		DC POWER						
6	SPARE	6		NONE		–	–	–			–	
7	MA LAMP	7	NONE	J1-7 RW INDICATOR		DC POWER						
8	AUDIO	8		J1-8 RW INDICATOR		AC ANALOG						
	28VDC SW OUT	9		J1-9 RW INDICATOR		DC POWER						
10	GROUND	10		H5-2300TB1		GND						
11	SHIELD GND	11				SHIELD GND						[illegible]
12	28VDC PWR IN	12	2A1J1-H	2A1P1-H 3422CB[illegible]		DC POWER		SOURCE 5 AMP				RADAR [illegible] CKT BKR
13	28VDC LAMP	13		K3-8TB4		DC POWER						
14	AUDIO OUT	14		A6-230TB3		AC ANALOG						
15	SPARE	15		NONE		–	–	–			–	
16	"	16		↑		–	–	–			–	
17	"	17				–	–	–			–	
	"	18				–	–	–			–	
19	"	19		↓		–	–	–			–	
20	SPARE	20		NONE								
21	[illegible] OUT MA LAMP	21		NOT USED								

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AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

10.0 SUBSYSTEM DISPLAY & CONTROL

10.9 EQUIPMENT HEADS-UP DISPLAY SYSTEM (SHEET 1 OF 2)

UNIT ______ of ______

UNIT NAME HEADS-UP SIGNAL PROCESSOR

NO.	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS [illegible]
1	ALT TARGET EL			-H ALT		Synchro					22	130
2	ALT TARGET AZ			-I "		Synchro					↑	127
3	ALT LOCK-ON TRACK			-J "		Synchro						128
4	[illegible]	TOW/SCA		HUD SIGNAL PROCESSOR		DISCRETE	"1"=10V±1V "0"=[illegible]	SINK 1 MA				32
5	[illegible]	TOW/SCA		HUD SIGNAL PROCESSOR		DISCRETE	"1"=10V±1V [illegible]	SINK 1 MA				33
6	ATTACK [illegible]	A/C 28VDC		HUD SIGNAL PROCESSOR		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA				34
7	READY MODE	A/C 28VDC		HUD SIGNAL PROCESSOR		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA			↓	35
8	FIRE/ABLE [illegible]	A/C 28VDC		HUD SIGNAL PROCESSOR		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA			22	36
[illegible]	TSU AZ ANGLE	TOW/SCA		HUD SIGNAL PROCESSOR		DC ANALOG					STP [illegible]	37
[illegible]	TSU AZ ANGLE RETURN	TOW/SCA		HUD SIGNAL PROCESSOR		DC ANALOG					STP [illegible]	37
11	TSU EL ANGLE	TOW/SCA		HUD SIGNAL PROCESSOR		DC ANALOG					STP #21	35
[illegible]	TSU EL ANGLE RETURN	TOW/SCA		HUD SIGNAL PROCESSOR		DC ANALOG					STP [illegible]	35
[illegible]	AZ COURSE [illegible]	TOW/SCA		HUD SIGNAL PROCESSOR		DC ANALOG					STP #23	33
[illegible]	AZ COURSE [illegible]	TOW/SCA		HUD SIGNAL PROCESSOR		DC ANALOG					STP [illegible]	33
[illegible]	LOW ALTITUDE LIMIT	HUD PROCESSOR		RADAR ALT APN-209		DISCRETE	"1"=0V "0"=5.5V	SINK 10MA			22	43
[illegible]	HIGH ALTITUDE LIMIT	HUD PROCESSOR		RADAR ALT APN-209		DISCRETE	"1"=0V "0"=5.5V	SINK 10MA			22	42
[illegible]	DISPLAY [illegible]	A/C 28VDC		HUDS/HUD		DISCRETE	"1"=28VDC "0"=OPEN				22	115
[illegible]	FIXED [illegible]	A/C PWR	PILOT ACTION SWITCH	HUD SIGNAL PROCESSOR		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA			22	[illegible]
[illegible]	SPARE DISCRETE			HUD SIGNAL PROCESSOR		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA			22	[illegible]
[illegible]	DIRECTIONAL [illegible]	HUD (CONTROLS)		FCC		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA			22	[illegible]
[illegible]	SPARE DISCRETE	A/C 28VDC		HUD SIGNAL PROCESSOR		DISCRETE	"1"=28VDC "0"=OPEN	SINK 5MA			22	[illegible]

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

10.0 **SUBSYSTEM** DISPLAY & CONTROL

10.9 **EQUIPMENT** HEADS-UP DISPLAY SYSTEM (SHEET 2 of 2)

UNIT ________ **of** ________

UNIT NAME HEADS-UP SIGNAL PROCESSOR

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
21	HUD DATA			HUD SIGNAL PROCESSOR		SERIAL DIGITAL			9600 BAUD	50	STP 22	48
[illegible]	HUD. DATA RET. [illegible]			"		SERIAL DIGITAL			" "	50	STP 22	48
[illegible]	FCC GOOD	FCC		HUDS		DISCRETE	"1" = +28VDC "0" = OPEN	SINK 250MA			[illegible]	[illegible] 20
[illegible]	HUD GO/NO GO			A/C CAUT PANEL		DISCRETE	"1" = +28VDC "0" = OPEN	SINK 60MA			[illegible]	98
[illegible]	[illegible] LRF [illegible]	LEU		HUD SIGNAL PROC		SERIAL DIGITAL			9600 BAUD	100	STP 22	52
27	RAW LRF DATA [illegible]	LEU		"		SERIAL DIGITAL			" "	100	STP 22	52
28	LEFT MISSILE FIRING	TMS		HUD		DISCRETE	"1" = 0 ± 1V "0" = OPEN	SINK 50MA			2-22	49
29	RIGHT MISSILE FIRING	TMS		HUD		DISCRETE	"1" = 0 ± 1V "0" = OPEN	SINK 50MA			2-22	50

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AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

SUBSYSTEM CONTROL AND DISPLAY

10.16.1 EQUIPMENT TURBINE GAS TEMPERATURE [1M11] GNR
1M11 P1

UNIT ______ of ______
UNIT NAME TURB GAS TEMP
209-075-064

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
1	TUR... LIGHTING	P1-A	L230	TORQUE P1 E	DC	LIGHTING	28VDC	LAMP	1 BIT	1 HZ	22	LTG
	LTG			TB5	DC	LIGHTING	28VDC	LAMP	NA	—	22	
											22	
2		D	E28-1TB3	1TB 3	GND	GND	GND	—	—	NA	22	ENG INSTR GND.
3	TEMP-THERMO COUPLE	T	19TB3 E40C-CHROM(+)	TURB. GAS THERMOCOUPLE P5-A	DC	ANALOG	MV	HIGH	8 BITS	10HZ	CHROM	THERMO
4	TEMP. THERMO COUPLE	U	19TB3 E41C-ALML(-)	P5-B	DC	ANALOG	MV	HIGH	8 BITS	10HZ	ALML	COUPLE
	LTG	P1-A	8TB5 (L220)	GAS PROD P1E	DC	LIGHTING	28VDC	LAMP	1 BIT	—	22	GENERAL LTG
				DUAL TACH P1E						—		
				ALTM P1E						—		
5		P1-B	8TB5 (L250)	ALTM P1-X						1HZ		
				TRQ P1-F						—		
				GAS PROD P1-F						—		
				DUAL TACH P1 H						—		
6	28VDC PWR	P1-C	E84 1TB3	P. TURB GAS TEMP P1C	DC	POWER	28VDC		1BIT	1HZ		28VDC
				DC CK BKR PUL	DC	POWER	28 VDC	5A CIR BKR	1 BIT	1HZ		28VDC ESS BUS

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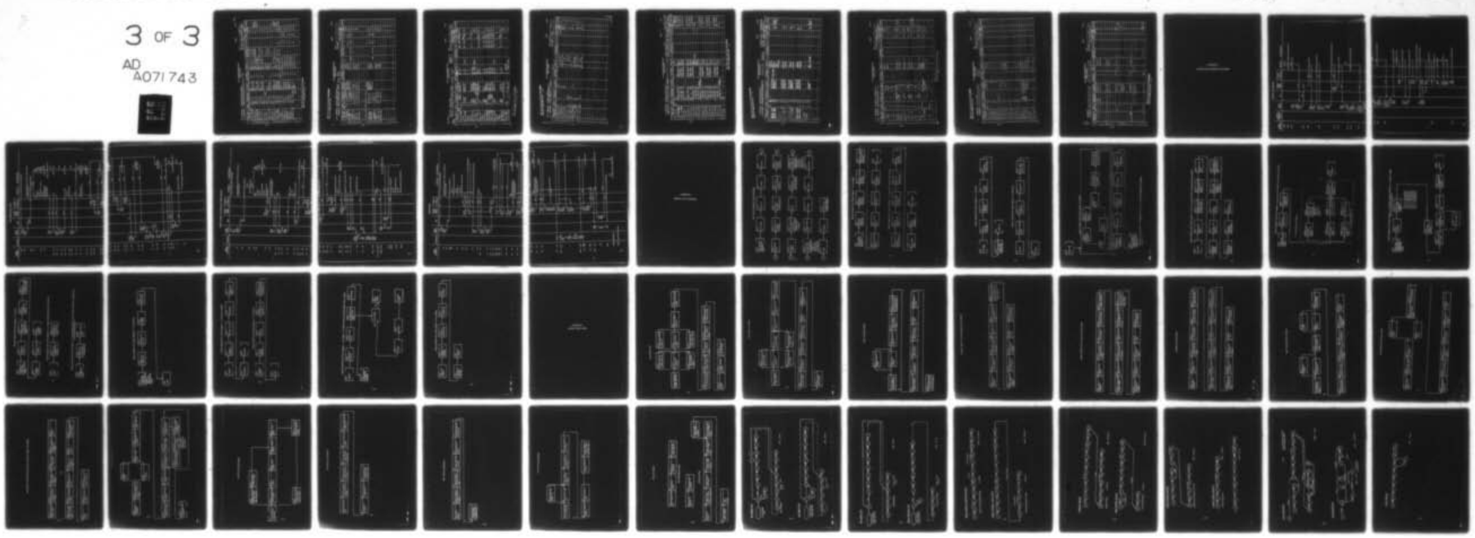

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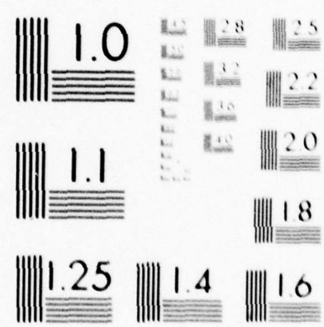

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AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

10.0 SUBSYSTEM DISPLAY & CONTROL

10.33 EQUIPMENT STABILIZATION CONTROL AUGMENTATION SYSTEM

UNIT ______ of SCAS

UNIT NAME SCAS CONTROL PANEL

209-075-063 9A1

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
1	PITCH NO-GO	J1 -R	C235	SAU 9A2 N	DC	DISCRETE	28VDC	∞/DS1 Lamp			22	
2	PITCH SOL	-A	C250	PITCH HYD SOL. 9L7 P1-D	DC	DISCRETE	gnd	∞/gnd			20	
3	+28VDC FROM SAU	-M	C229	SAU 9A2 G	DC	DISCRETE	28VDC/0V	SW 2,3,4 HOLDING COIL			20	SW POS HOLDING
4	EMERGENCY DISENGAGE	-P	C246	PILOT CYCLIC STK 4A3 J1 U	DC	DISCRETE	28VDC/gnd				22	HOLDING COIL
5	ROLL NO-GO	-D	C226	SAU 9A2 R	DC	DISCRETE	28 VOLTS	∞/DS2 LAMP			22	
6	ROLL SOL	-B	C251	ROLL HYD SOL 9L8 P1 D	DC	DC POWER	28VDC	∞/gnd			20	
7	DIMMER	-B	C195 F 8TB4			DC ANALOG					22	
8	YAW NO-GO	-F	C213	SAU 9A2 P1 P		DISCRETE		∞/DS3 LAMP			22	
9	YAW SOL	-S	C252	YAW HYD SOL 9L9 P1-D	DC	DISCRETE		∞/gnd			20	
10	SHIPS GROUND	-G	C244	GND	—	—	—	—	—	—	20	—
11	EMERGENCY DISENGAGE	-H	C245	GUN CYCLIC STK 5A2 J1 V	DC	DISCRETE	28VDC/GND	HOLDING COIL			22	HOLDING COIL
12	+28VDC SHIP	-U	C249	DC CKT BKR PNL 2A1 J2 B	DC	POWER	28VDC	5A CB	NA		20	SCAS PWR
13	115VAC SHIP	-T	C248	AC ARMT CKT PNL 3A1 J1 M	400HZ AC	POWER	115VAC	1A CB	NA		SHLD 22	SCAS PWR
14	115VAC TO SAU	-V	C214	SAU 9A2 P1 P	400 HZ AC	POWER	115VAC		1 BIT	2 HZ	SHLD 20	
15	PITCH SOL (+28VDC)	-S	C247	PITCH HYD SOL 9L7 P1 A	DC	POWER	28 VDC		1 BIT	1 HZ	20	
16	YAW SOL (+28VDC)	-C	C242	YAW HYD SOL 9L9 P1 A	DC	POWER	28 VDC		↓	↓	20	
17	ROLL SOL (+28VDC)	E	C243	ROLL HYD SOL 9L8 P1 A	DC	POWER	28 VDC				20	
18	+28VDC TO SAU	-N	C230 ⊠	SAU 9A2 P1 H	DC	POWER	28VDC				22	
			⊠	SCAS COMP 9A3 P1 D	DC	POWER	28VDC				22	

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AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

10.36 SUBSYSTEM DISPLAY & CONTROL

EQUIPMENT GAS PRODUCER TACH IM12 GNR, IM 2 PILOT

UNIT ______ of ______

UNIT NAME 209-075-064

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
1	ENG GND	P1-B	1TB3 43 E26 D22	PLT GPT 1TB3 #7		GND	—	—	—	—	22	
2	GAS PROD TACH GEN	A	E27 D22	ENG. ACCESS DISC. 1P6-H	K	ANALOG			8 BITS	8Hz	22	
3	28VDC	C	1TB3-43 E42 D22	PNL DC CB	K	PWR	28VDC	5A CB	1 BIT	8HZ	22	
4	ENG INSTR JCT GND	D	E33A 22N	GND 1TB3 85		GND	—	—	—	—	22	
5	GEN LTG	E	L230K22	8TB5 K1	K	ANALOG LTG					22	
6	GEN LTG	F	L250 J22N	8TB5 K3	K	ANALOG LTG					22	
	PILOT GAS PRODUCER TACH			IM2								
7	ENG GND	B	E26C22	GNR GPT/ ENG DISC		GND			—	—	22	
8	GAS PROD TAC GEN	A	E27C22	ENG ACCESS DISC	K	ANALOG			8 BIT	8HZ	22	
9	28VDC	C	E42C22	PN DC CB	K	PWR	28VDC	5A CB	1 BIT	8Hz	22	
10	ENG INSTR JCT GND	D	E23A22N			GND			—	—	22	
11	GEN LTG	E	L203A22		K	ANALOG LTG					22	
12	GEN LTG	F	L170G22		K	ANALOG LTG					22	

10.76

W46

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

SUBSYSTEM LIGHTING

EQUIPMENT Caution Lighting System (Sheet 1 of 2)

8A3

UNIT ______ of ______

UNIT NAME Gunner's Caution PNL 209-075-062

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESP		SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
1	ENG. OIL PRESS	8A3 P1 – A	☒	ENG OIL PRESS SW 1S13 P1-A		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
	SPARE	– B											
2	ENG FUEL PUMP	– C	☒ ☒	ENG FUEL PUMP PRESS SW 1S11, 1S12		yes	dis	+28vdc		1 BIT, 1 Hz	BIT/SEC	22	
	SPARE	– D											
	SPARE	– E											
	HYDR PRESS No 1	– F	☒	PRESS SW 1S6P1-A		yes	dis			1 BIT, Hz	BIT/SEC	22	
	DC GEN	– G	☒	BUS CNTRL Relay 2K7-A3		yes	DC PWR	+28vdc				22	
	GOV EMER	– H	W103A122	GND HUG 8XA6-63		yes	dis					22	
3	FUEL LOW	– J	☒ (AFT)	FUEL LEVEL LOW SW 1TB7-4		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
	SPARE	– K											
	CHIP DET	– L	☒	XMSN, ENG, 1S3,1S4,		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
	EMER HYDR PUMP	– M	☒	Press SW 1S20P1-C		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
	XMSN OIL PRESS	– N	☒	XMSN OIL PRESS SW 1S9P1-A		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
	XMSN OIL TEMP	– P	☒	XMSN OIL HOT 1S8 SW		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
4	FUEL FILTER	– R	☒	FUEL FIL BYPASS SW 1S14P1-A		yes	dis	+28vdc		1 BIT, 1 Hz	BIT/SEC	22	
	SPARE	– S											
	SPARE	– T											
	HYDR PRESS No 2	– U	☒	PRESS SW 1S7P1-A		yes	dis			1 BIT, 1 Hz	BIT/SEC	22	
	EXT COND DIMMING LT CONTROL	– V	L257A22	(B12) GND HUG 8XA6-60								22	
	SYSTEM GND	– W					GND					22	
	SYS PWR INPUT	– X	W19C22	(A1) GND LTG 8TB5-G6			DC POWER	+28vdc				22	

A-7

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AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

14C SUBSYSTEM WEAPON/ARMAMENT
14.7 EQUIPMENT TOW WEAPON SUBSYSTEM SH. 2 of 2

UNIT 7070071-129 of XMG5
UNIT NAME SCA

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
22	FIRE/MANEUVER MODE	SCA		HUD		DISCRETE	28 VDC			50 HZ	SINGLE UNSHLD'D 22	36
23	TSU AZIMUTH ANGLE	↕		↕		DC ANALOG	±2.2 VDC				SHLD'D TWST PR 22	37
24	TSU ELEVATION ANGLE					↕	↕				↕	38
25	AZIMUTH COARSE POINTER			HUD			±2.2 VDC					39
26	AZ RATE		FCC				±13 VDC					30
27	EL RATE	SCA	↕ -			DC ANALOG	"				STP 22	31
28	LOW MAGNIFICATION MODE	TOW L.H. GRIP		SCA		DISCRETE	28 VDC				-	120
29	ROLL RATE	SCAS RATE GYRO				AC ANALOG	5.6 VRMS				STP 22	70
30	PITCH RATE	↕				↕	↕				↕	71
31	YAW RATE	SCAS RATE GYRO	FCC			AC ANALOG	5.6 VRMS				STP 22	72

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

1.0 SUBSYSTEM COMMUNICATIONS

1.? EQUIPMENT C-6533( ) ARC INTERCOMM SET (SHEET 1 of 2)

2301 CP2

UNIT ______ of C-6533( )ARC

UNIT NAME ICS CONTROL CHANNEL See Fig F02 (TM-11-1520-236-34)

NO.	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
1	SHIELD	J1 K				SHIELD					22	SHLD RET LINE
2	MKR BCN AUDIO IN	HH	2301 TB3-C10		3KHz AUDIO	AC ANALOG					22	SHLD
3	[illegible] AUDIO IN	LL	2301 TB3 - C6		3KHz AUDIO	AC ANALOG					22	SHLD
4	IFF AUD IN	FF	2301 TB3 - F6		3KHz AUDIO	AC ANALOG					22	SHLD
5	SPARE	VV	—	—		—				—		
6	ADF AUD IN	WW	2301 TB3- K10		3KHz AUDIO	AC ANALOG					22	SHLD
7	VOR AUD IN	UU	" - K6		3KHz AUDIO	AC ANALOG					22	SHLD
8	INPH AUDIO	DD	2301 TB3 - A11		3KHz Audio	AC ANALOG					22	SHLD
[illegible]	CHASSIS GND	H	2301 TB1- H3			CHASSIS GROUND	0 VDC			—	20	
10	AUDIO COMMON	Z	2301 TB1 - B1			AUDIO COM (GND)				—		
11	RCVR AUD IN #1	KK	2301 Z1 J1- D2	AUDIO THRESHOLD	3KHz AUDIO	AC ANALOG					22	SHLD
12	XMTR AUD IN #1	V	2301 TB3 - H1		3KHz AUDIO	AC ANALOG					22	SHLD
13	XMTR CONTR #1	X	2301 TB3- D1			DISCRETE						
14	RCVR AUD IN #2	SS	2301 TB3 - K3		3 KHz AUDIO	AC ANALOG					22	SHLD
15	XMTR AUD IN #2	R	2301 TB3 - B3		3 KHz AUDIO	AC ANALOG					22	SHLD
16	XMTR CONTR #2	T	2301 TB3 - C3			DISCRETE						
17	RCVR AUD IN #3	PP	2301 TB3 - H3		3 KHz AUDIO	AC ANALOG					22	SHLD
18	XMTR AUD IN #3	L	2301 TB3 - B1		3 KHz AUDIO	AC ANALOG					22	SHLD
19	XMTR CONTR #3	N	2301 Z1 J1- C1	AUDIO THRESHOLD		DISCRETE					22	
20	SPARE	MM	—	—	—	—						
21	SPARE	F	—	—	—	—						

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

1.6 SUBSYSTEM COMMUNICATIONS
1.19 EQUIPMENT COMMUNICATIONS SECURITY SET x1 (SHEET 2 of 2) 2301Z1

UNIT MD-( )/A of TSEC/KY-28
UNIT NAME AUDIO THRESHOLD
TM 11-1520-236-34, F02-7

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)		INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
22	[illegible]	J2	A6	—	—		SHIELD TERMINATION						
23	ARC 164 AUDIO TRANSMIT HI		D6		UHF-AM RADIO SET 2302TA1P1-K	3KHZ AUDIO	AC Analog					22	TWISTED PAIR SHIELD
24	ARC 164 AUDIO TRANSMIT RET		B6		UHF-AM RADIO SET 2302TA1P1-L	—	AUDIO RET					22	TWISTED PAIR SHIELD
25			A5				SHIELD TERMINATION						
26	SPARE		C4				—						
27	[illegible] #3		B2		2C3 CONTL PANEL 2301C1P1P1-N		DISCRETE					22	
28	[illegible] #2		B1		2C3 CONTL PANEL 2301C1P1P1-T		DISCRETE					22	
29	[illegible]		D3				—						
30	[illegible] #3		C1		2C3 CONTL [illegible] 2301C2P1-N		DISCRETE					22	
31	[illegible] #2		C3		2C3 CONTL [illegible] 2301C2P1-T		DISCRETE					22	
32	[illegible]		A4				—						
33	Transmit Control		A2		VHF-AM RADIO SET 2303TA1P1-H		DISCRETE					22	
34	Transmit Control		A3		UHF-AM RADIO SET 2302TA1P1-H		DISCRETE					22	
35	[illegible]		C2				—						
36	SPARE		D1				—						
37	SPARE		D2				—						
	[illegible]		A1		KY-28 [illegible] 2319CB1		DC POWER	28VDC				20	Non ESS BUS

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

4.0 SUBSYSTEM FLIGHT CONTROL

4.17 EQUIPMENT ATTITUDE GYRO

UNIT ________ of ________

UNIT NAME ATTITUDE GYRO MS 3476 L 16-26S

NO.	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESPONSE	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
	GND	P1-Y	—	gnd	—	GND	—	—	—	—	22	
	GND	L	—	gnd	—	GND	—	—	—	—	22	
	NC	M	—	NA	—	—	—	—	—	—	—	
	NC	S	—	NA	—	—	—	—	—	—	—	
	NC	U	—	NA	—	—	—	—	—	—	—	
	PITCH Z	P	TERM BD F6A22	P-ADI P1-C		SYNCHRO	Δ115V			30HZ	SHLD 22	3 WIRE
	PITCH Y	H	TB F6A22	P1-B		SYNCHRO	Δ115V			30HZ	22	SHLDED
	NC	N		NA		—					—	
	PITCH X	R	TB F6A22	P1-A		SYNCHRO	Δ115V			30HZ	22	
	NC	W		NA		—					—	
	ROLL Z	F	TB F3A22	PILOT ADI P1-F		SYNCHRO	Δ115V			30HZ	SHLD 22	
	ROLL Y	E	TB F3A22	P1-E		SYNCHRO	Δ115V			30HZ	22	3 WIRE
	NC	X	—	NA		—					—	SHIELDED
	NC	C	—	NA		—					—	
	ROLL X	D	TB F3A22	P1-D		SYNCHRO	Δ115V			30HZ	22	
	GND	ZVGAKT	—	GND		GND					22	
	115V 400HZ	B	F1C22	CKT BKR PNL PILOT ATTD IND		DISCRETE POWER	Δ115V			1H	22	
		J	14A22	PILOT ADI J1-Z		?	115V				22	
	NC	A,B,C	—	NA	—	—	—	—	—	—	—	

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AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

5.2 SUBSYSTEM TGT. ACQ

EQUIPMENT TOW MISSILE SYSTEM

20A1

UNIT ______ of ______

UNIT NAME TELE SIGHT UNIT
209-075-467

	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. RESP	MUX	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
	EL SAMPLE PULSE	20A1P01 W		MCA 20A5P03 BB			discrete					22	
	K(T) CHANGE	V		LL									
	WIDE/MEDIUM SWITCH	BB		NN									
	AGC CLAMP RELEASE	DD		EE									
	CARRIER FREQ. CHANGE	EE		KK									
	MEDIUM-NARROW SWITCH	HH	20P327Y	JJ									
	AZ MEDIUM B/S ADJUST	B		SCA 20A2P03 E									
	EL MEDIUM B/S ADJUST	H		EC			discrete						
	VSI RETURN	K		SCA 20A2P02 V		NO	analog						
	RETURN	T		K		NO							
	AZ BAND PASS	U		J									
	RETURN	M		M		NO							
	EL BANDPASS	L		L									
	EL VSI	W		U									
	AZ VSI	FF		T			analog						
	B/S POT EXCIT MINUS	Z	☒ TST CONN SCA	20J33 / GG 20A2P02 X		YES	discrete						
	B/S POT EXCIT PLUS	AA	☒ TST CONN SCA	20J33 / FF 20A2P02 W		YES	discrete						
	10 V DC	S		ELEC TOW CONT 20A7P02 C		NO	D.C. POWER	10 V					
	-20 V DC	I		P		NO	"	-20 V					
	DC RETURN	J		W		NO	"						
	20 V AC	K		Q		NO	"	20 V				22	

8.0
8.4
8.7

2445-1 7-5-76 (5)

AH-1S SUBSYSTEM INTERFACES
SIGNAL LISTING

SUBSYSTEM ____________

EQUIPMENT ENVIRONMENTAL SYSTEM

| 10C3 | [illegible] | [illegible] | 3[illegible]4 |

UNIT ______ of ______

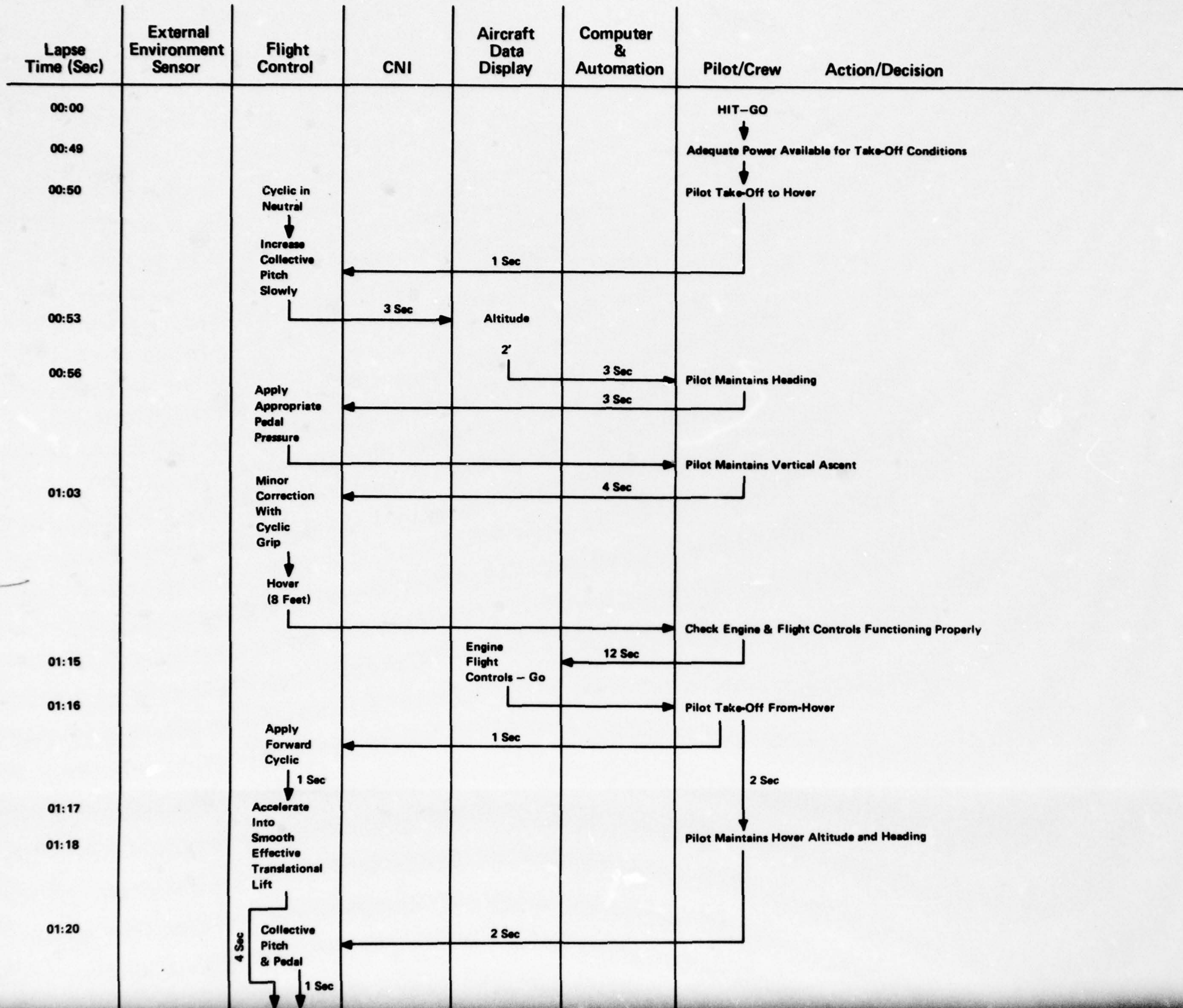
UNIT NAME [illegible] & PITOT HEATER
209-075-065

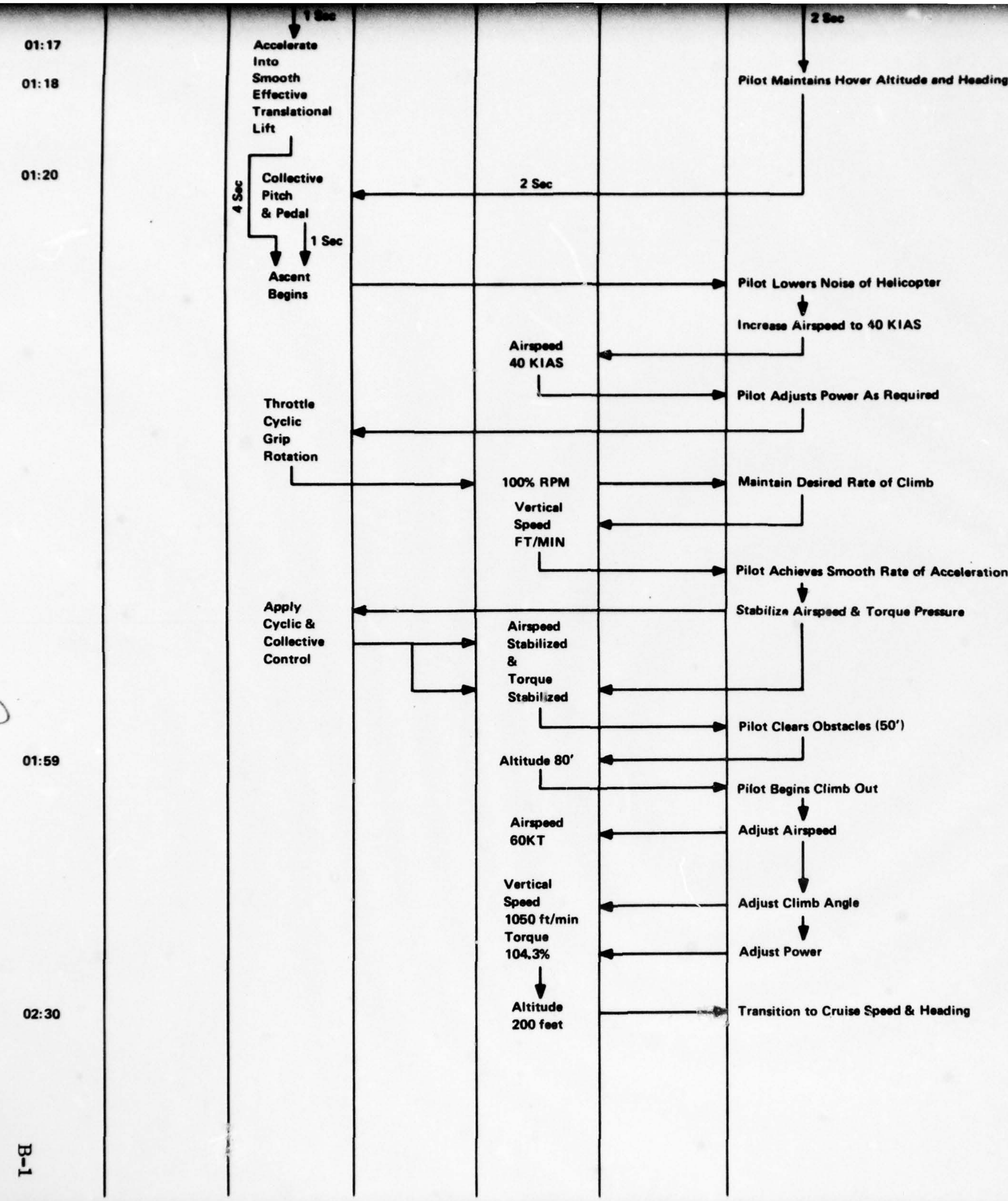
NO.	SIGNAL NAME FUNCTION	ORIGIN (CONN./PIN)	INTERMEDIATE DESTINATION	ULTIMATE DESTINATION	BANDWIDTH/ FREQ. REST	MUX	SIGNAL TYPE	VOLTAGE	IMPEDANCE SOURCE/SINK	RESOLUTION	UPDATE RATE	WIRE TYPE/ GAUGE	REMARKS
	[illegible]	10L3	☒	HTR CONT RLY 10XK1A3			[illegible]	28VDC				2[illegible]	
	[illegible]	10L3 GND	☒	GROUND				GROUND				2[illegible]	
8.4	[illegible]	10HR1J1A	10P2 A	PILOT ECS PNL 10A1P1 E			DISCRETE	28VDC				2[illegible]	
	GROUND	"	B	GROUND				GROUND				2[illegible]	
		2A1P1 L		PILOT ECS PNL 10A1P1 S		[illegible]	CONT DC	28 V[illegible]	< 5			22	10C[illegible]2
[illegible]		F		E			PULSE "	"	< 5			2[illegible]	10CB1
[illegible]		G		HTR CONTROLLER 10XK1 X1			"	"	< [illegible]			2[illegible]	10C[illegible]
[illegible]		D		3/15 HTR RLY 3K4E1			"	"	< 1			22	10C[illegible]
	28 VDC 3Φ [illegible]	3K4L1		ECS PNL 2A1P1 D		ON	[illegible]	28VDC	< 1 A			2[illegible]	
		L2	10P1 A	10CR1-			DISCRETE	"	"			2[illegible]	
				[illegible] 10S4			"	"	"			2[illegible]	
	[illegible] RELAY	2K4A2		10K2 A2		NO			~ 35A			12	HI POWER

APPENDIX B

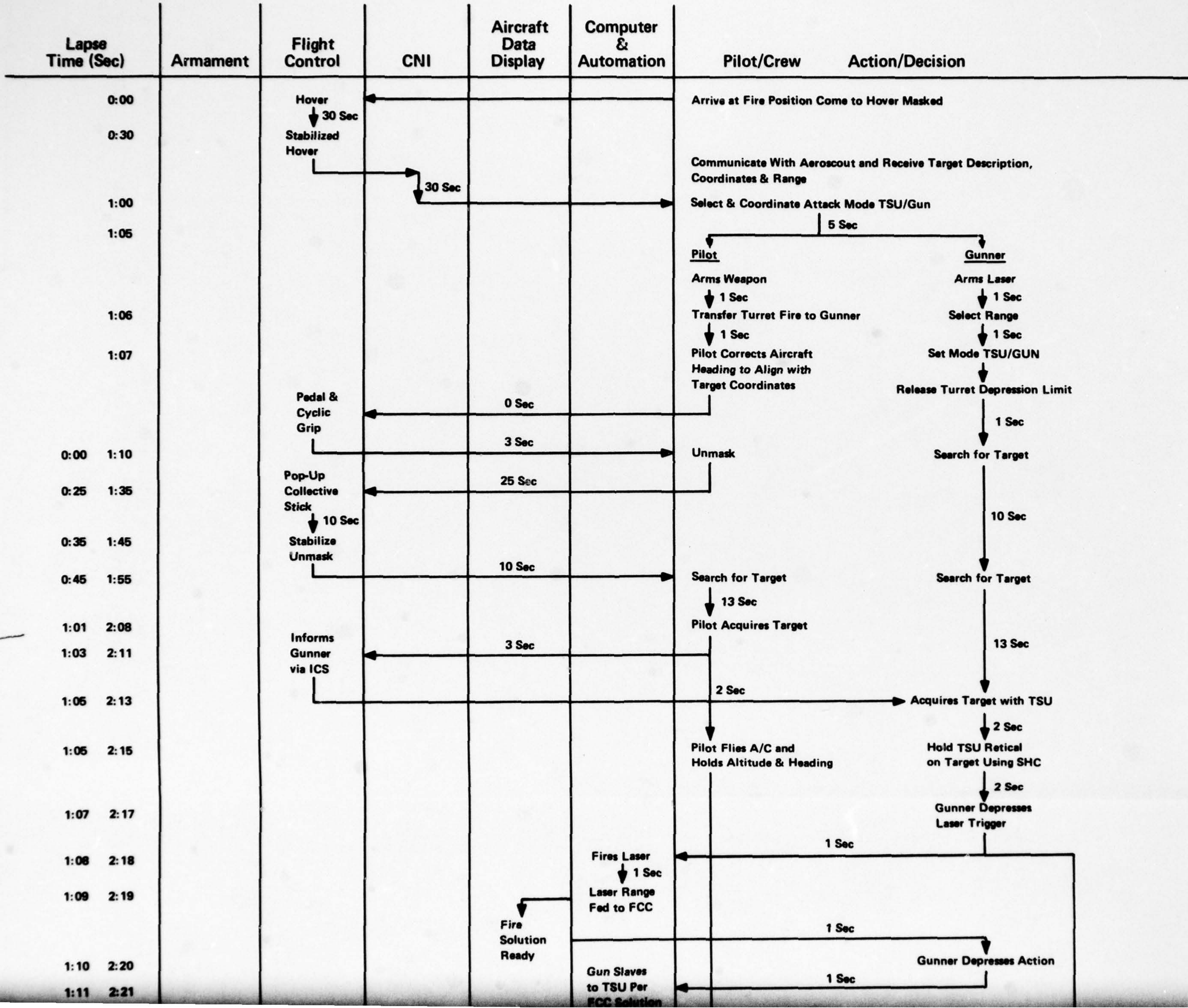
OPERATIONAL SEQUENCE DIAGRAMS

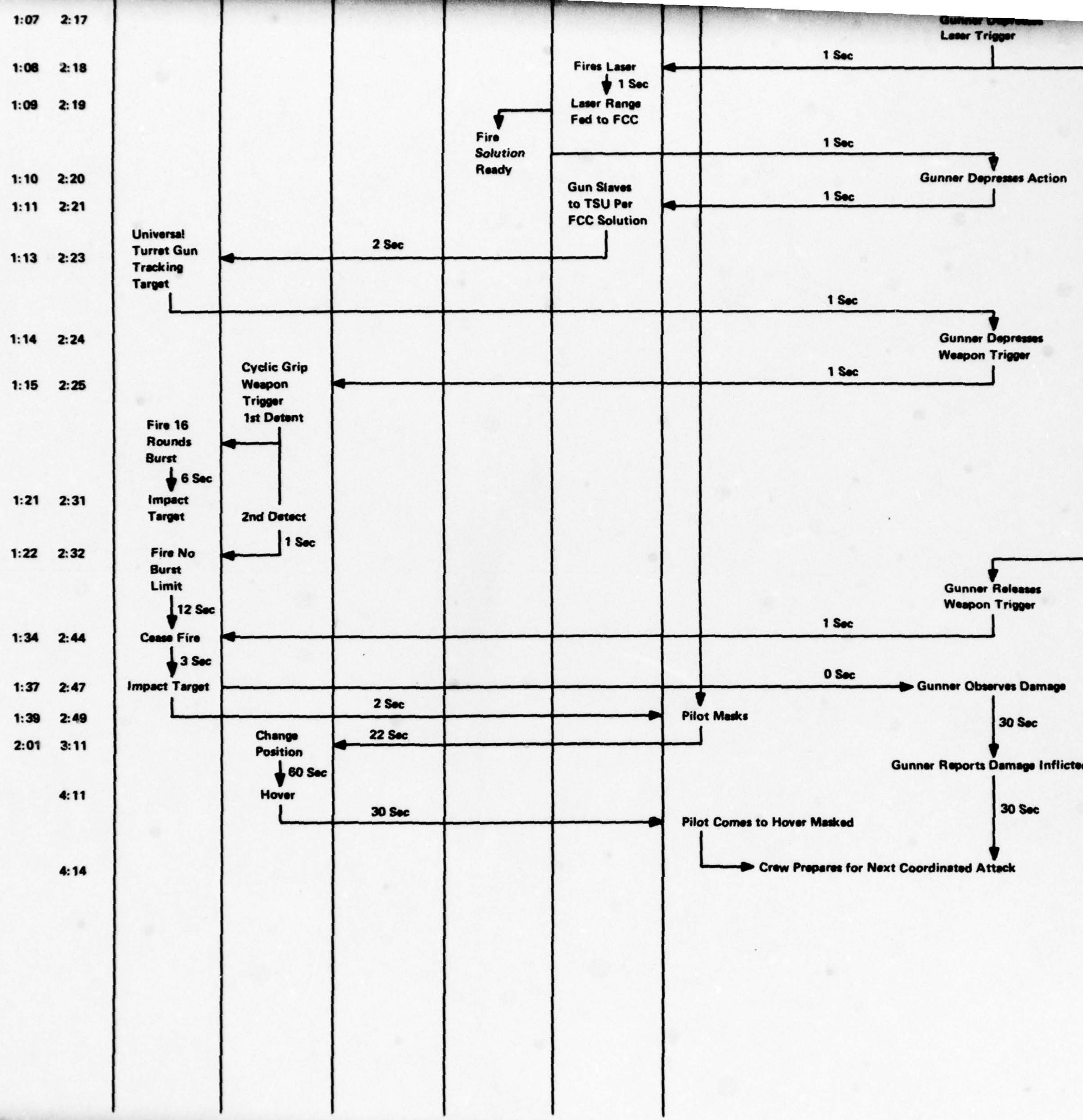
TAKE-OFF & CLIMB OUT



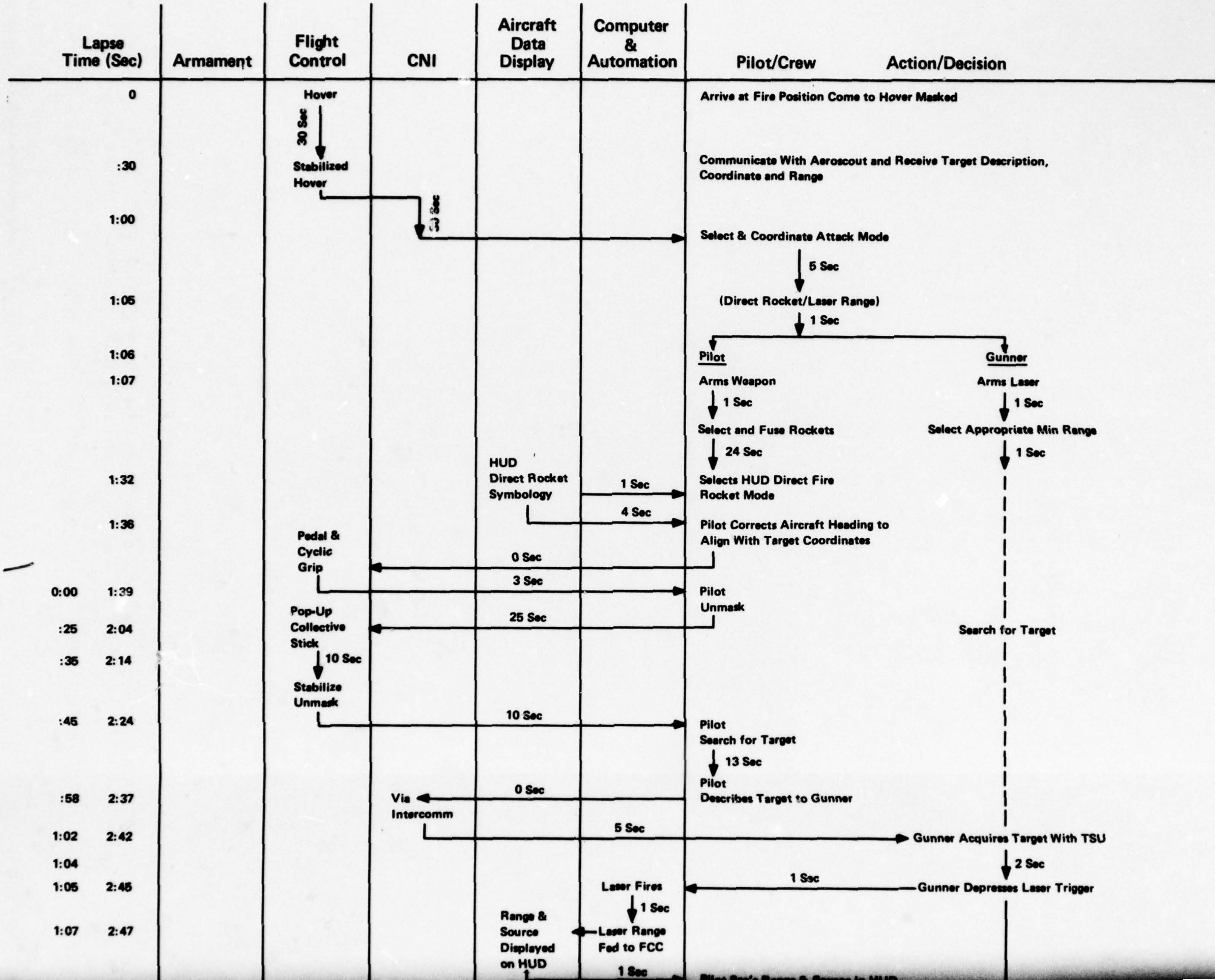

01:17
01:18
01:20
01:59
02:30
1 Sec
Accelerate Into Smooth Effective Translational Lift
4 Sec
Collective Pitch & Pedal
1 Sec
Ascent Begins
Throttle Cyclic Grip Rotation
Apply Cyclic & Collective Control
2 Sec
Airspeed 40 KIAS
100% RPM
Vertical Speed FT/MIN
Airspeed Stabilized & Torque Stabilized
Altitude 80'
Airspeed 60KT
Vertical Speed 1050 ft/min Torque 104.3%
Altitude 200 feet
2 Sec
Pilot Maintains Hover Altitude and Heading
Pilot Lowers Noise of Helicopter
Increase Airspeed to 40 KIAS
Pilot Adjusts Power As Required
Maintain Desired Rate of Climb
Pilot Achieves Smooth Rate of Acceleration
Stabilize Airspeed & Torque Pressure
Pilot Clears Obstacles (50')
Pilot Begins Climb Out
Adjust Airspeed
Adjust Climb Angle
Adjust Power
Transition to Cruise Speed & Heading

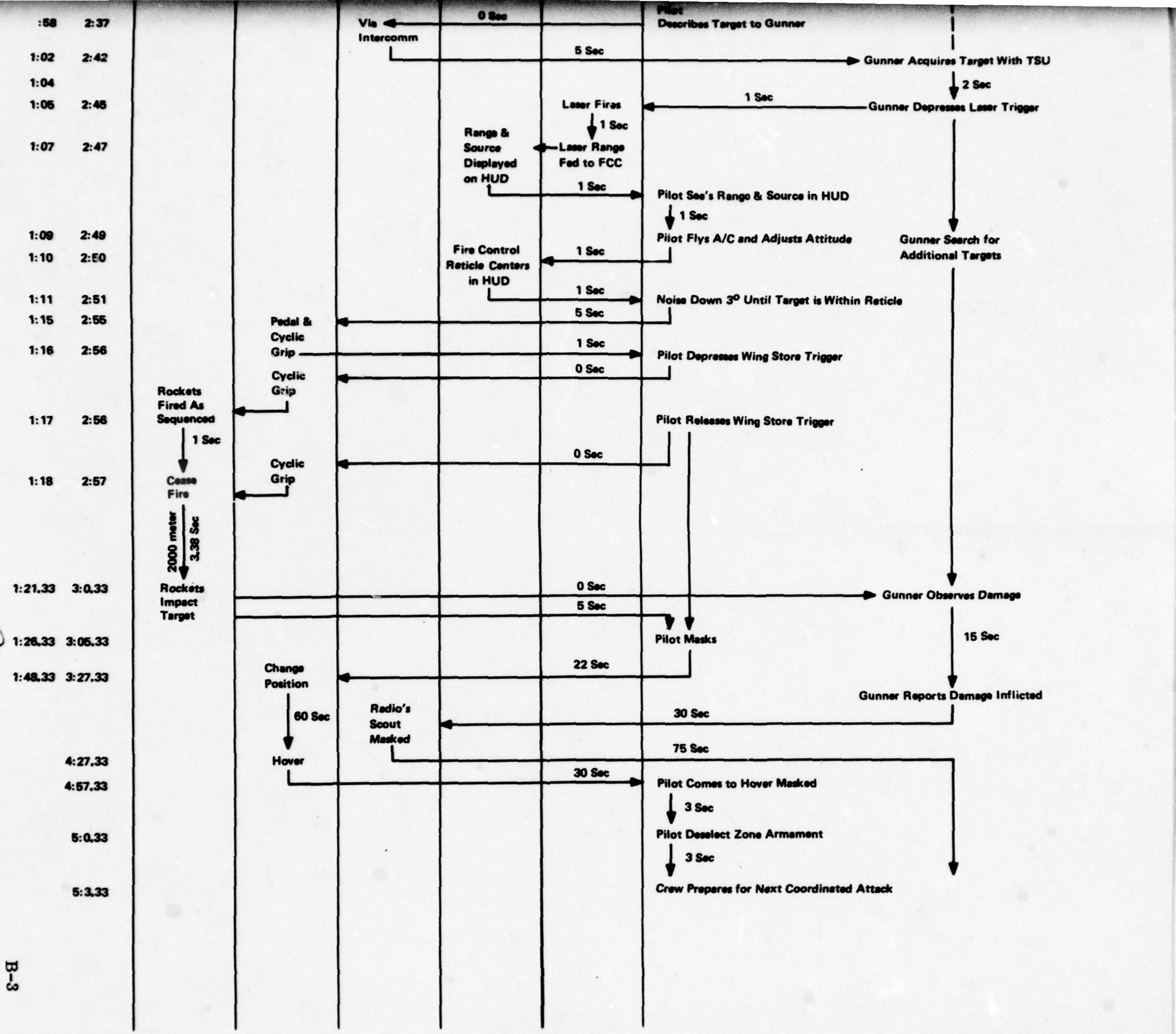
TSU FIRING GUN ATTACK




1:07 2:17
1:08 2:18
1:09 2:19
1:10 2:20
1:11 2:21
1:13 2:23
1:14 2:24
1:15 2:25
1:21 2:31
1:22 2:32
1:34 2:44
1:37 2:47
1:39 2:49
2:01 3:11
4:11
4:14
Gunner Depresses Laser Trigger
1 Sec
Fires Laser
1 Sec
Laser Range Fed to FCC
Fire Solution Ready
1 Sec
Gunner Depresses Action
1 Sec
Gun Slaves to TSU Per FCC Solution
2 Sec
Universal Turret Gun Tracking Target
1 Sec
Gunner Depresses Weapon Trigger
1 Sec
Cyclic Grip Weapon Trigger 1st Detent
Fire 16 Rounds Burst
6 Sec
Impact Target
2nd Detect
1 Sec
Fire No Burst Limit
Gunner Releases Weapon Trigger
12 Sec
1 Sec
Cease Fire
3 Sec
Impact Target
0 Sec
Gunner Observes Damage
2 Sec
Pilot Masks
30 Sec
22 Sec
Change Position
Gunner Reports Damage Inflicted
60 Sec
Hover
30 Sec
30 Sec
Pilot Comes to Hover Masked
Crew Prepares for Next Coordinated Attack

DIRECT ROCKET ATTACK WITH LASER RANGING

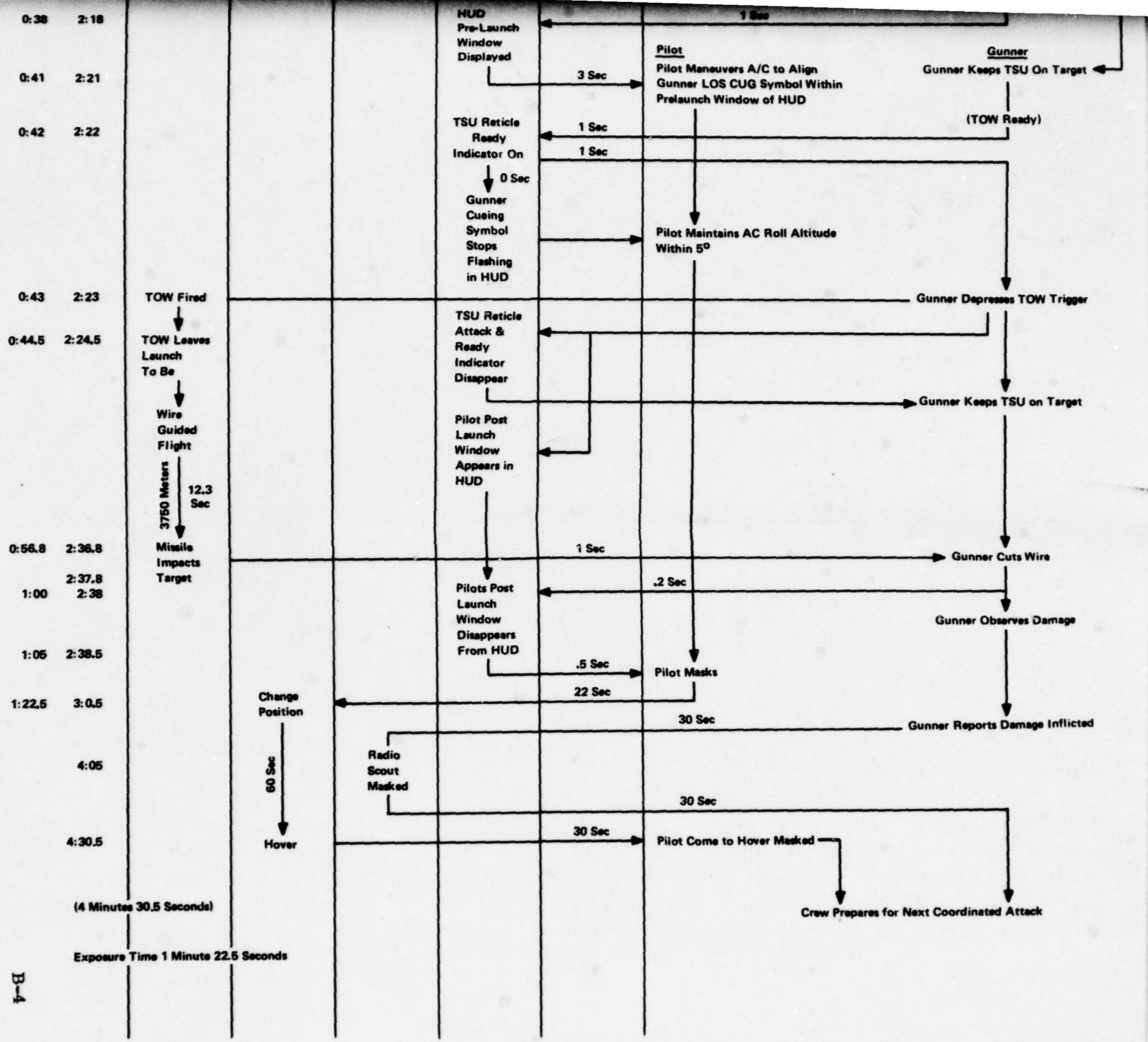




:58 2:37
1:02 2:42
1:04
1:05 2:46
1:07 2:47
1:09 2:49
1:10 2:50
1:11 2:51
1:15 2:55
1:16 2:56
1:17 2:56
1:18 2:57
1:21.33 3:0.33
1:26.33 3:05.33
1:48.33 3:27.33
4:27.33
4:57.33
5:0.33
5:3.33
Pilot
Describes Target to Gunner
0 Sec
Via Intercomm
5 Sec
Gunner Acquires Target With TSU
2 Sec
Gunner Depresses Laser Trigger
1 Sec
Laser Fires
1 Sec
Laser Range Fed to FCC
Range & Source Displayed on HUD
1 Sec
Pilot See's Range & Source in HUD
1 Sec
Pilot Flys A/C and Adjusts Attitude
Gunner Search for Additional Targets
1 Sec
Fire Control Reticle Centers in HUD
1 Sec
Noise Down 3° Until Target is Within Reticle
5 Sec
Pedal & Cyclic Grip
1 Sec
Pilot Depresses Wing Store Trigger
0 Sec
Cyclic Grip
Rockets Fired As Sequenced
Pilot Releases Wing Store Trigger
1 Sec
0 Sec
Cyclic Grip
Cease Fire
2000 meter
3.38 Sec
Rockets Impact Target
0 Sec
Gunner Observes Damage
5 Sec
Pilot Masks
15 Sec
22 Sec
Change Position
Gunner Reports Damage Inflicted
30 Sec
60 Sec
Radio's Scout Masked
75 Sec
Hover
30 Sec
Pilot Comes to Hover Masked
3 Sec
Pilot Deselect Zone Armament
3 Sec
Crew Prepares for Next Coordinated Attack

TOW ATTACK

Lapse Time (Sec)		Armament	Flight Control	CNI	Aircraft Data Display	Computer & Automation	Pilot/Crew Action/Decision
	0		Hover				Arrive at Fire Position Comets Hover Masked
			30 Sec				
	:30		Stabilize Hover				Communicate With Aeroscout and Receive Target Description, Coordinates, and Range
	1:00						
	1:05						Select & Coordinate Attack Mode
	1:06						5 Sec Pilot Selects Alt Code (ALT Alt TSU TOW)
	1:07						1 Sec Pilot Arms Weapons 1 Sec Pilot Transfers Weapon Control to Gunner
	1:08				HUD On HUD Normal	1 Sec	
	1:09					1 Sec	Gunner Selects Missile
					TSU Mag Set Lo	1 Sec	
	1:12		Pedal & Cyclic Grip			0 Sec	Pilot Corrects Aircraft Heading to Align with Target Coordinates
	1:15					3 Sec	Pilot Unmasks
0:00	1:40		Pop-Up Collective Stick			25 Sec	
			10 Sec				
0:10	1:50		Stabilize Unmasked				
0:20	2:0				10 Sec	ALT-TSU Acquisition	
0:33	2:13					13 Sec	Gunner Aligns TSU Crosshairs on Target
0:34	2:14				TSU Mag Set HI	1 Sec	
0:35	2:15						
0:36	2:16						Gunner Depresses Action
0:37	2:17				TSU Reticle Attack Indicator On	1 Sec	
0:38	2:18				HUD Pre-Launch Window Displayed	1 Sec	
0:41	2:21					3 Sec	Pilot Pilot Maneuvers A/C to Align Gunner LOS CUG Symbol Within Prelaunch Window of HUD Gunner Gunner Keeps TSU On Target
0:42	2:22				TSU Reticle Ready Indicator On	1 Sec 1 Sec	(TOW Ready)
					0 Sec		

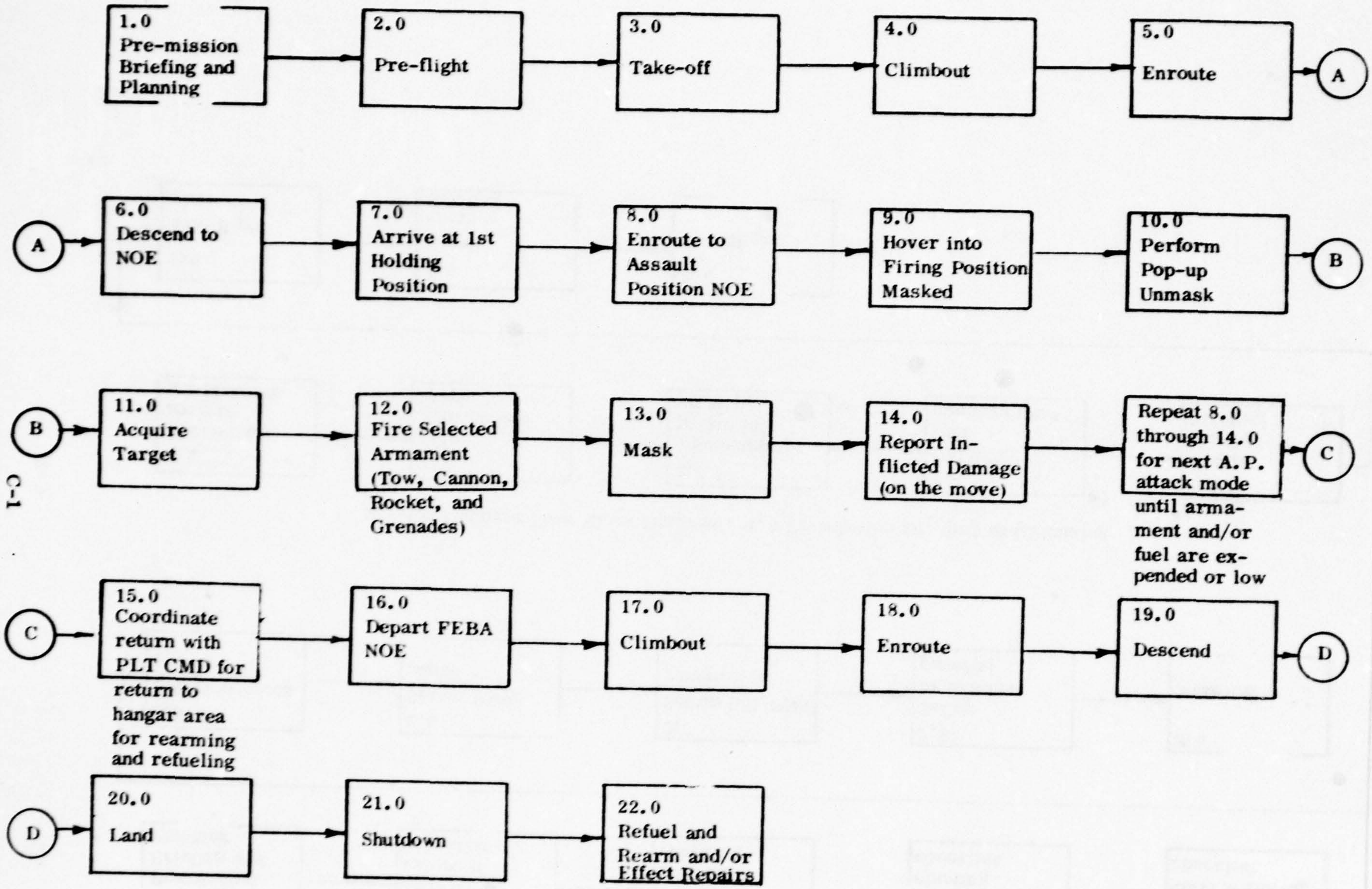


0:38 2:18
0:41 2:21
0:42 2:22
0:43 2:23
0:44.5 2:24.5
0:56.8 2:36.8
2:37.8
1:00 2:38
1:05 2:38.5
1:22.5 3:0.5
4:05
4:30.5
(4 Minutes 30.5 Seconds)
Exposure Time 1 Minute 22.5 Seconds
TOW Fired
TOW Leaves Launch To Be
Wire Guided Flight
3750 Meters
12.3 Sec
Missile Impacts Target
Change Position
60 Sec
Hover
Radio Scout Masked
HUD Pre-Launch Window Displayed
TSU Reticle Ready Indicator On
0 Sec
Gunner Cueing Symbol Stops Flashing in HUD
TSU Reticle Attack & Ready Indicator Disappear
Pilot Post Launch Window Appears in HUD
Pilots Post Launch Window Disappears From HUD
1 Sec
3 Sec
1 Sec
1 Sec
1 Sec
.2 Sec
.5 Sec
22 Sec
30 Sec
30 Sec
30 Sec
Pilot
Pilot Maneuvers A/C to Align Gunner LOS CUG Symbol Within Prelaunch Window of HUD
Pilot Maintains AC Roll Altitude Within 5°
Pilot Masks
Pilot Come to Hover Masked
Gunner
Gunner Keeps TSU On Target
(TOW Ready)
Gunner Depresses TOW Trigger
Gunner Keeps TSU on Target
Gunner Cuts Wire
Gunner Observes Damage
Gunner Reports Damage Inflicted
Crew Prepares for Next Coordinated Attack

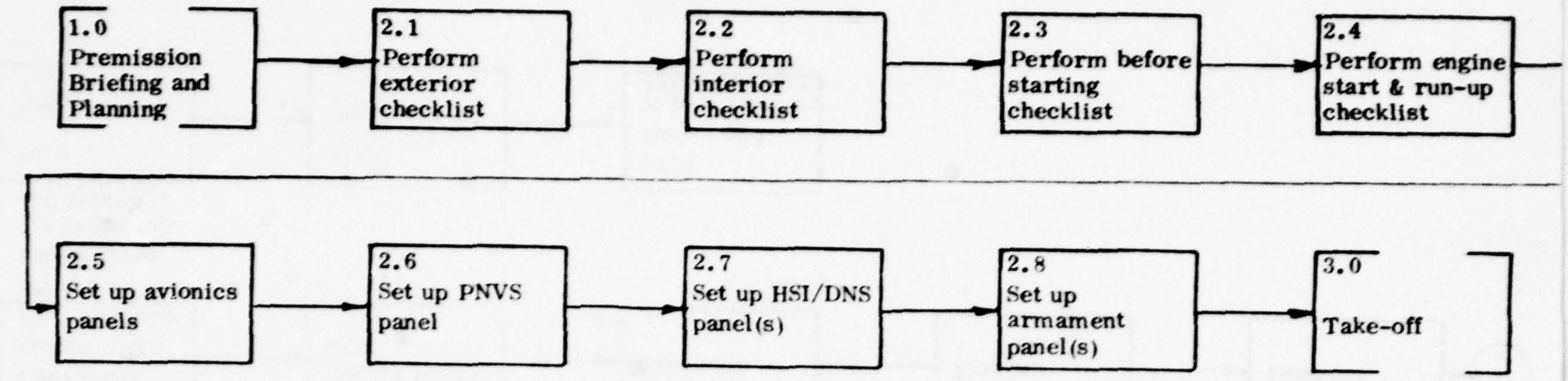
APPENDIX C

MISSION FLOW DIAGRAMS

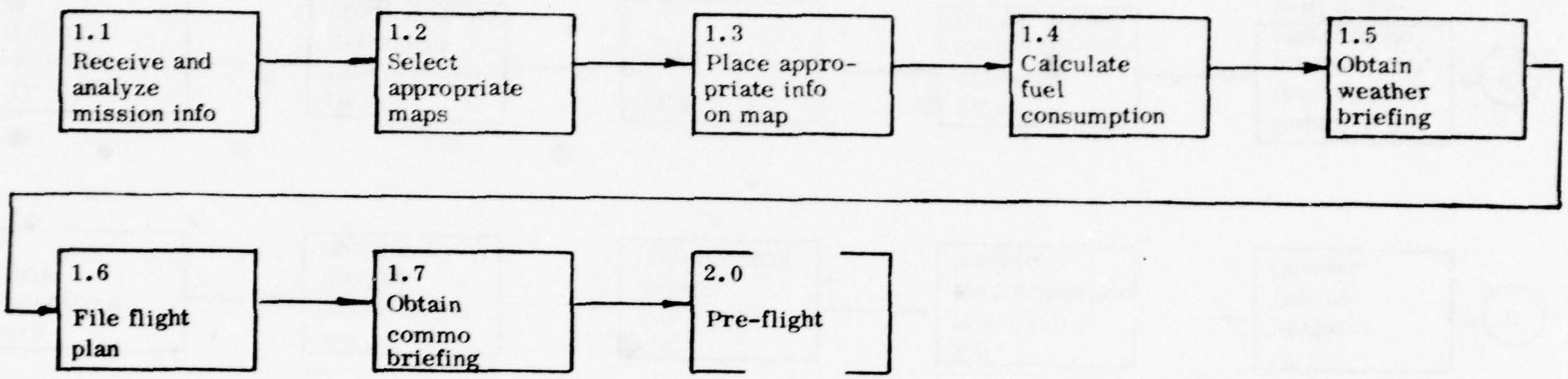
TOP LEVEL MISSION FLOW DIAGRAM



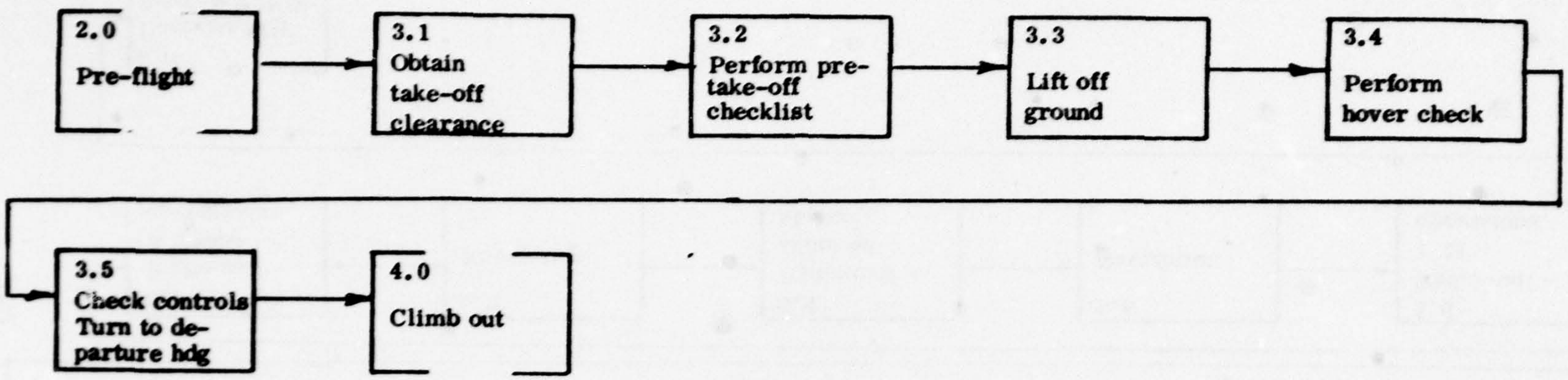
Mission Segment Flow Block Diagram: 2.0 Pre-flight



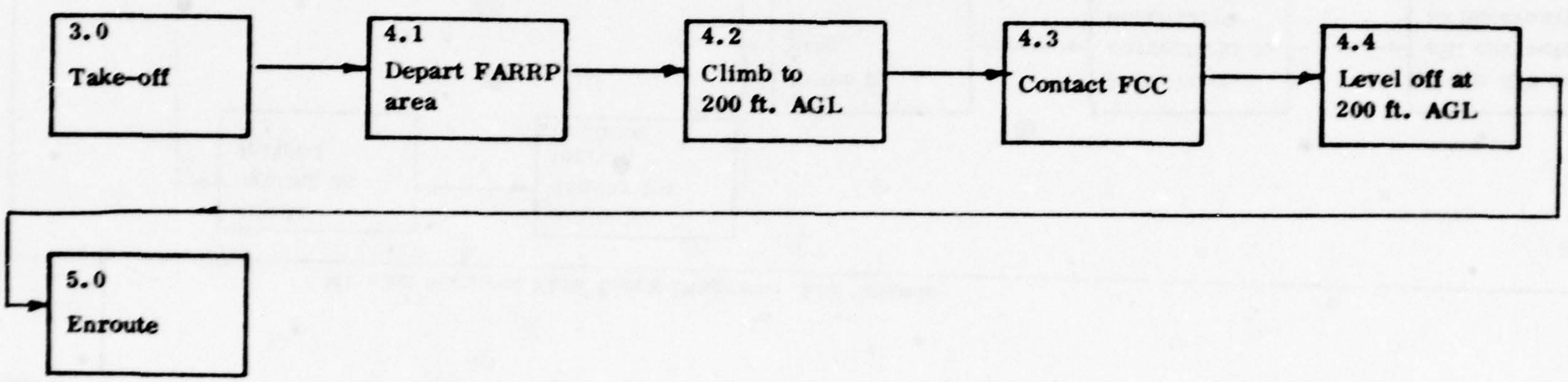
Mission Segment Flow Block Diagram: 1.0 Premission Briefing and Planning



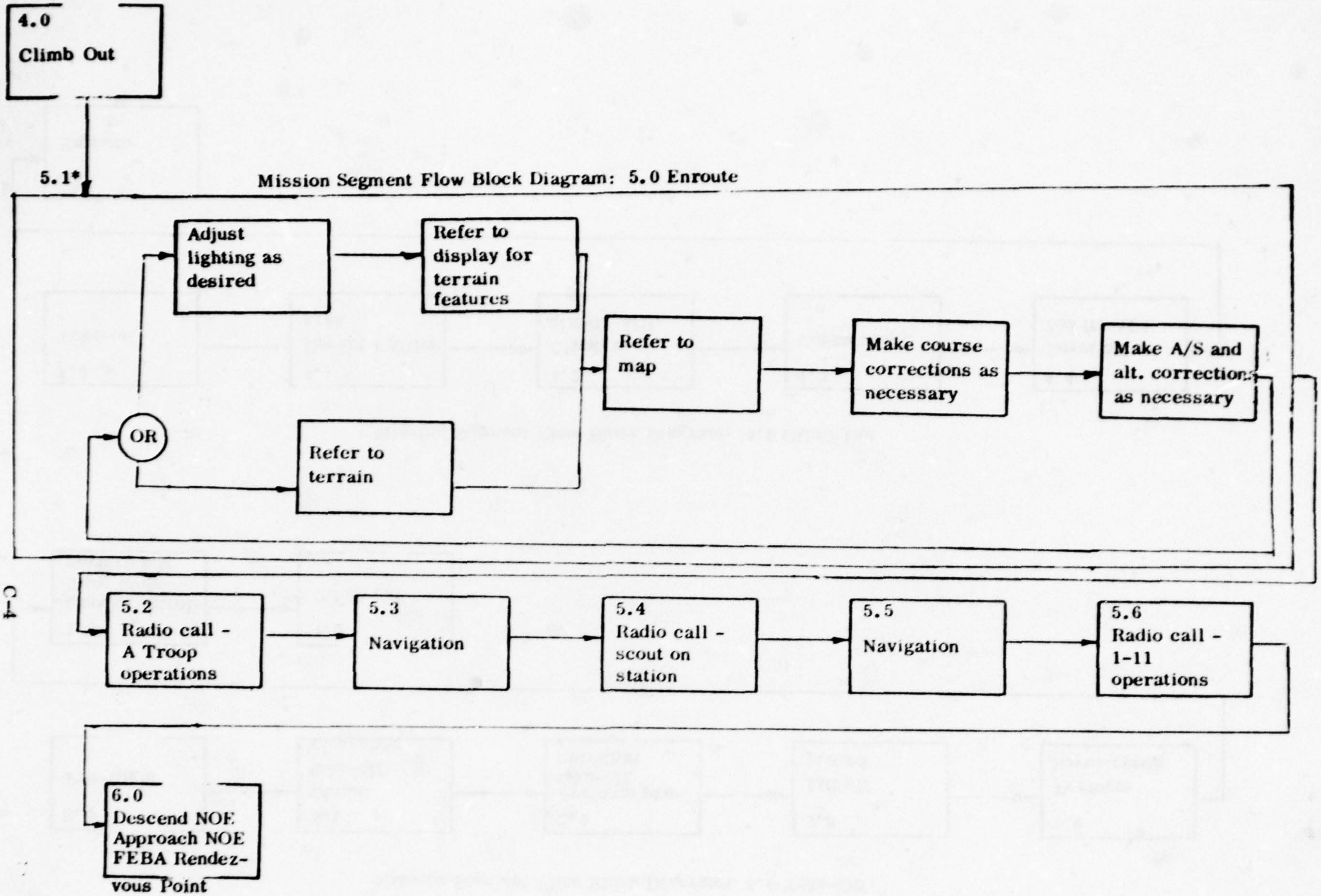
Mission Segment Flow Block Diagram: 3.0 Take-Off



Mission Segment Flow Block Diagram: 4.0 Climb Out

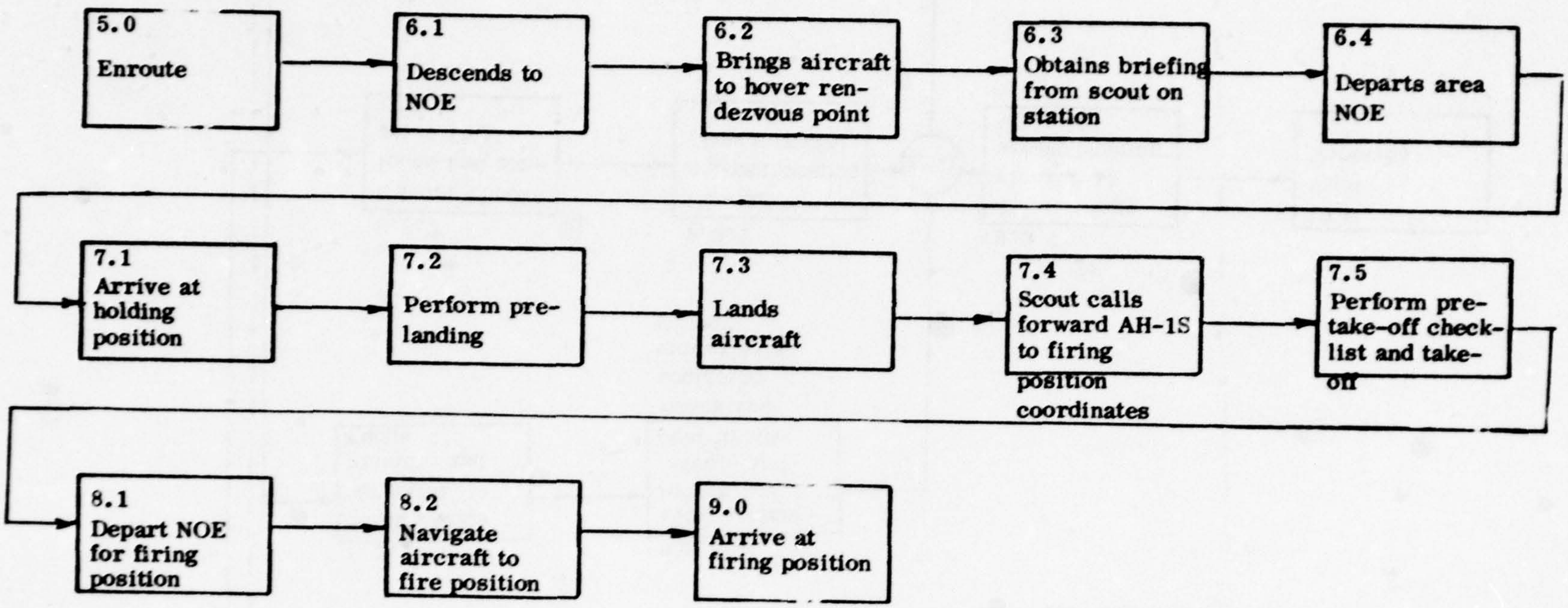


Mission Segment Flow Block Diagram: 5.0 Enroute

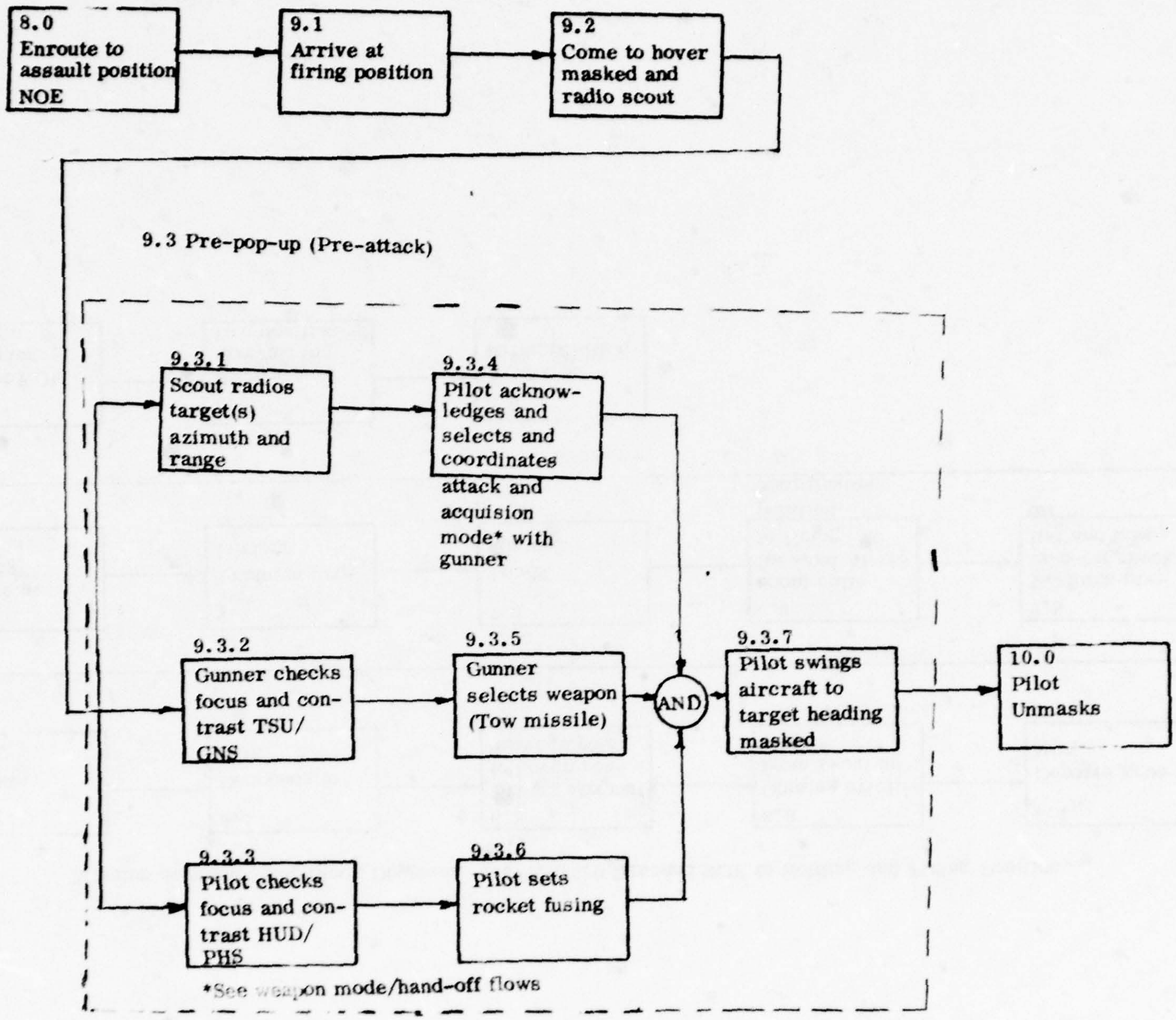


*This block represents the flow diagram for navigation and will be designated by navigation from here on.

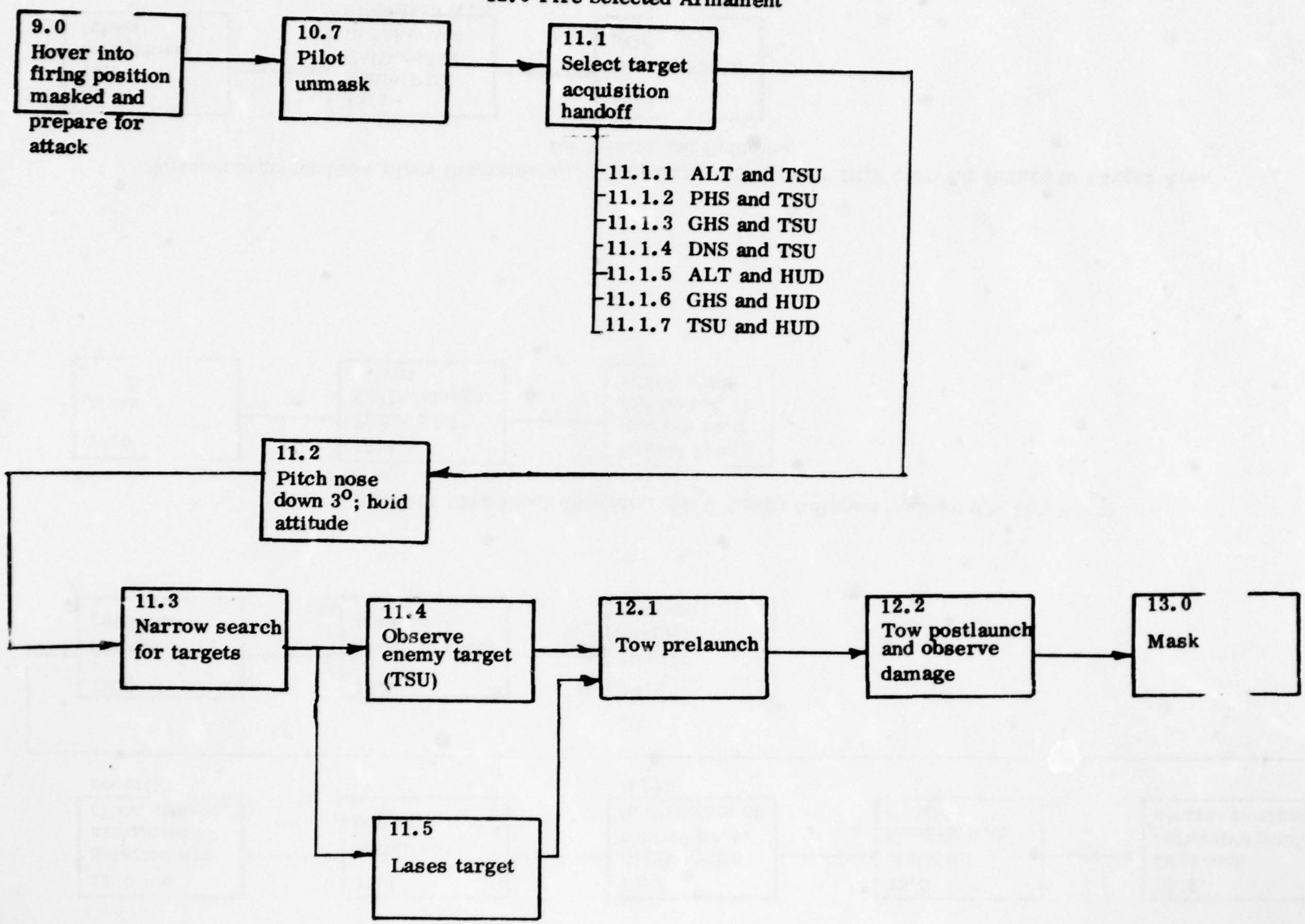
Mission Segment Flow Block Diagram: 6.0/7.0/8.0 Descend NOE to Holding and Firing Position



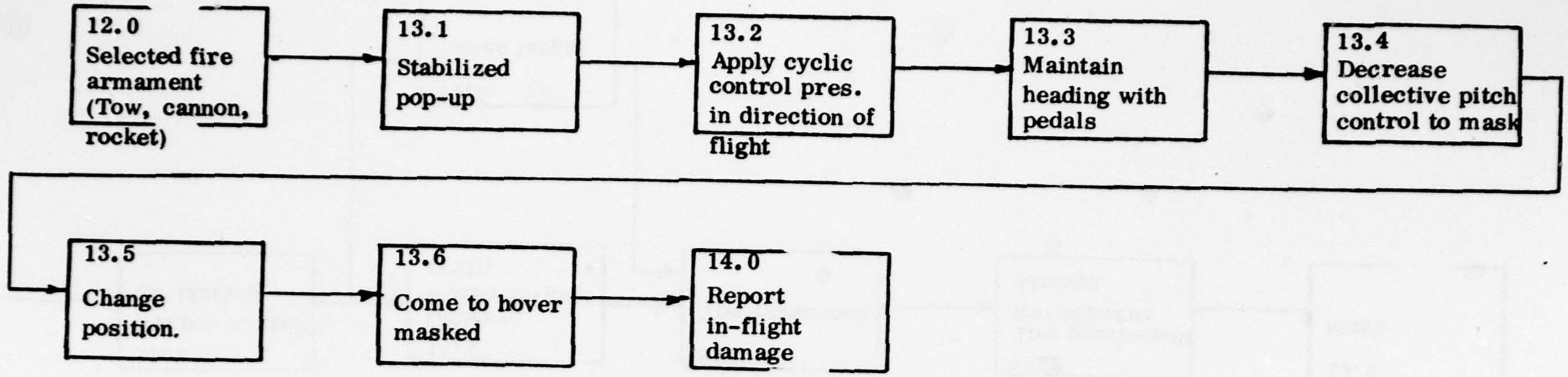
Mission Segment Flow Block Diagram: 9.0 Arrive at Fire Position and Prepare for Attack



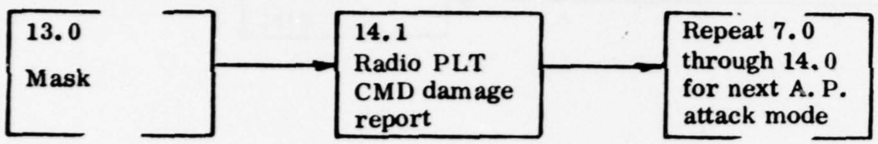
Mission Segment Flow Block Diagram: 10.0 Perform Pop-Up (Unmask), 11.0 Acquire Target, 12.0 Fire Selected Armament



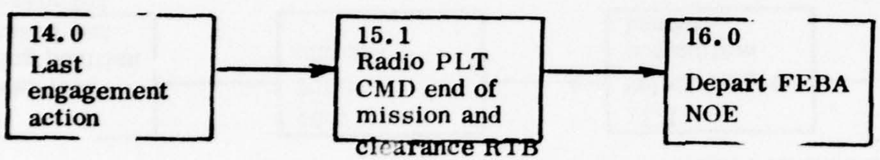
Mission Segment Flow Block Diagram: 13.0 Mask



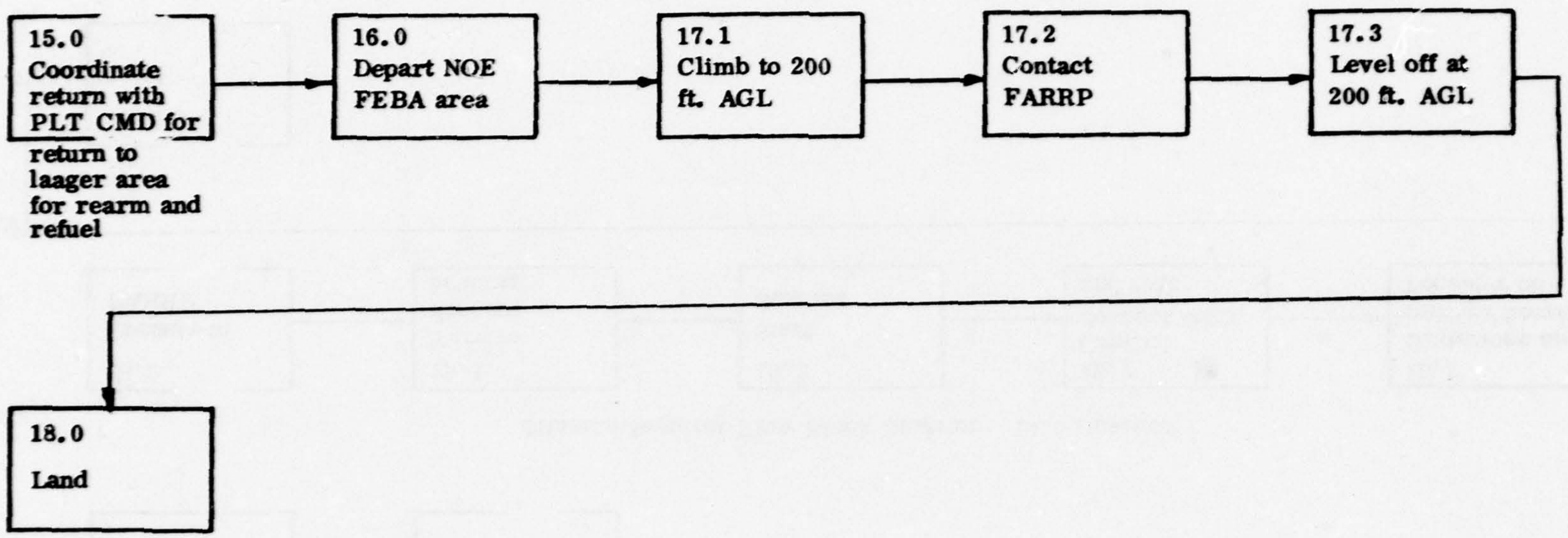
Mission Segment Flow Block Diagram: 14.0 Report Inflicted Damage (On The Move)



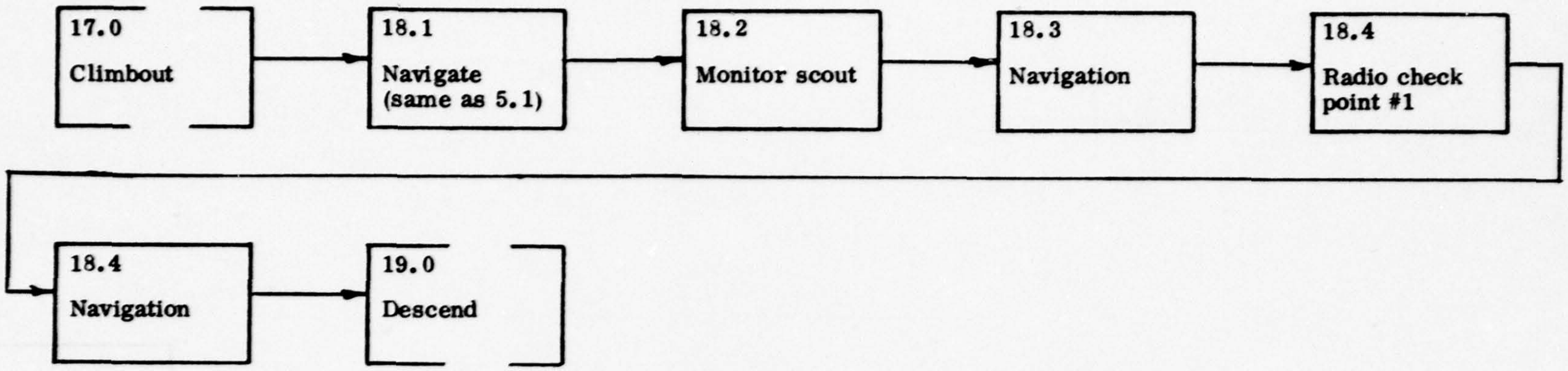
Mission Segment Flow Block Diagram: 15.0 Coordinate Return with PLT CMD for Return to Laager Area for Rearm and Refueling



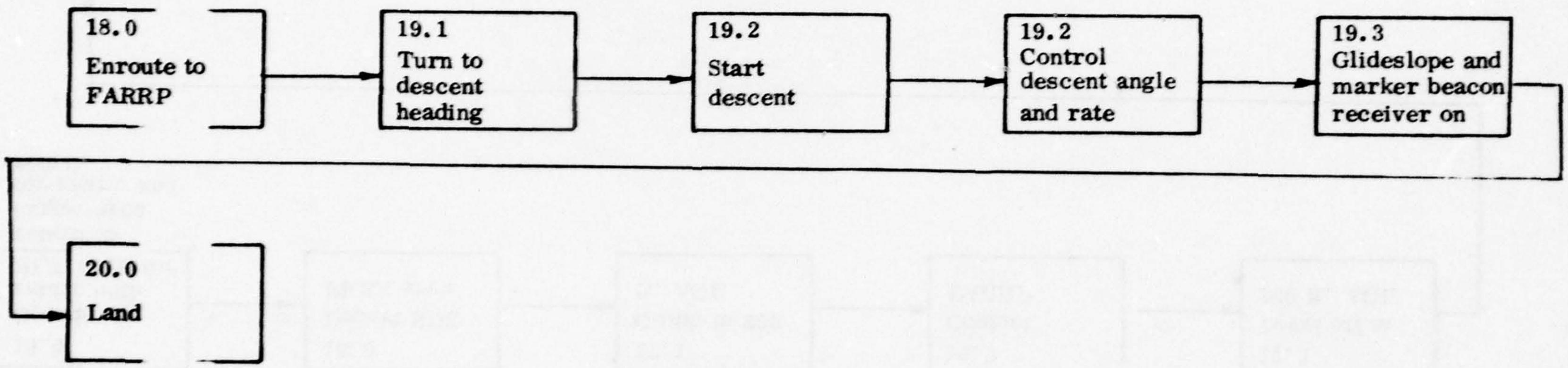
Mission Segment Flow Block Diagram: 17.0 Climb Out



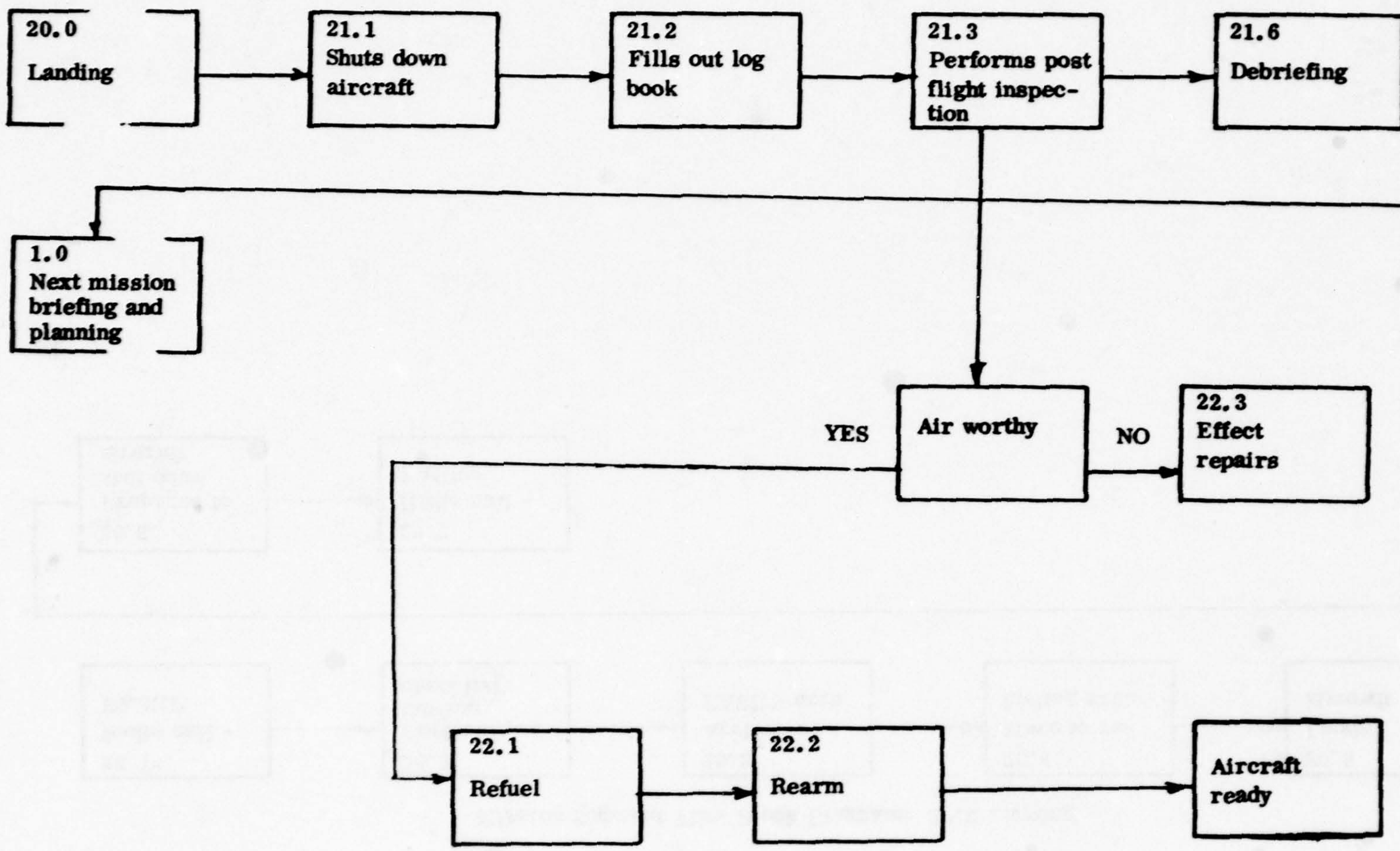
Mission Segment Flow Block Diagram: 18.0 Enroute to FARRP



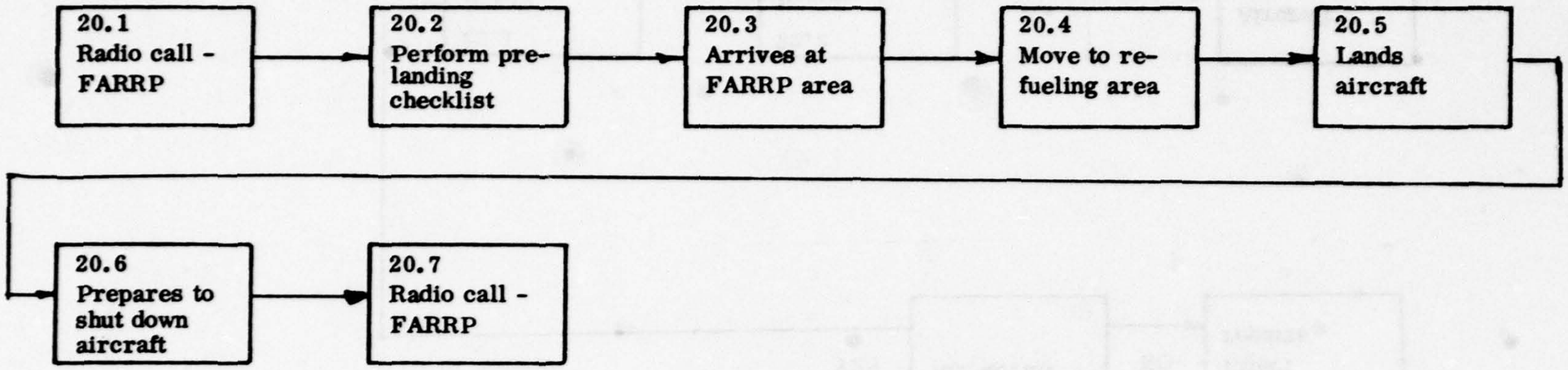
Mission Segment Flow Block Diagram: 19.0 Descend



Mission Segment Flow Block Diagram: Post Flight: 21.0 Shutdown and 22.0 Refuel/Rearm and/or Repair



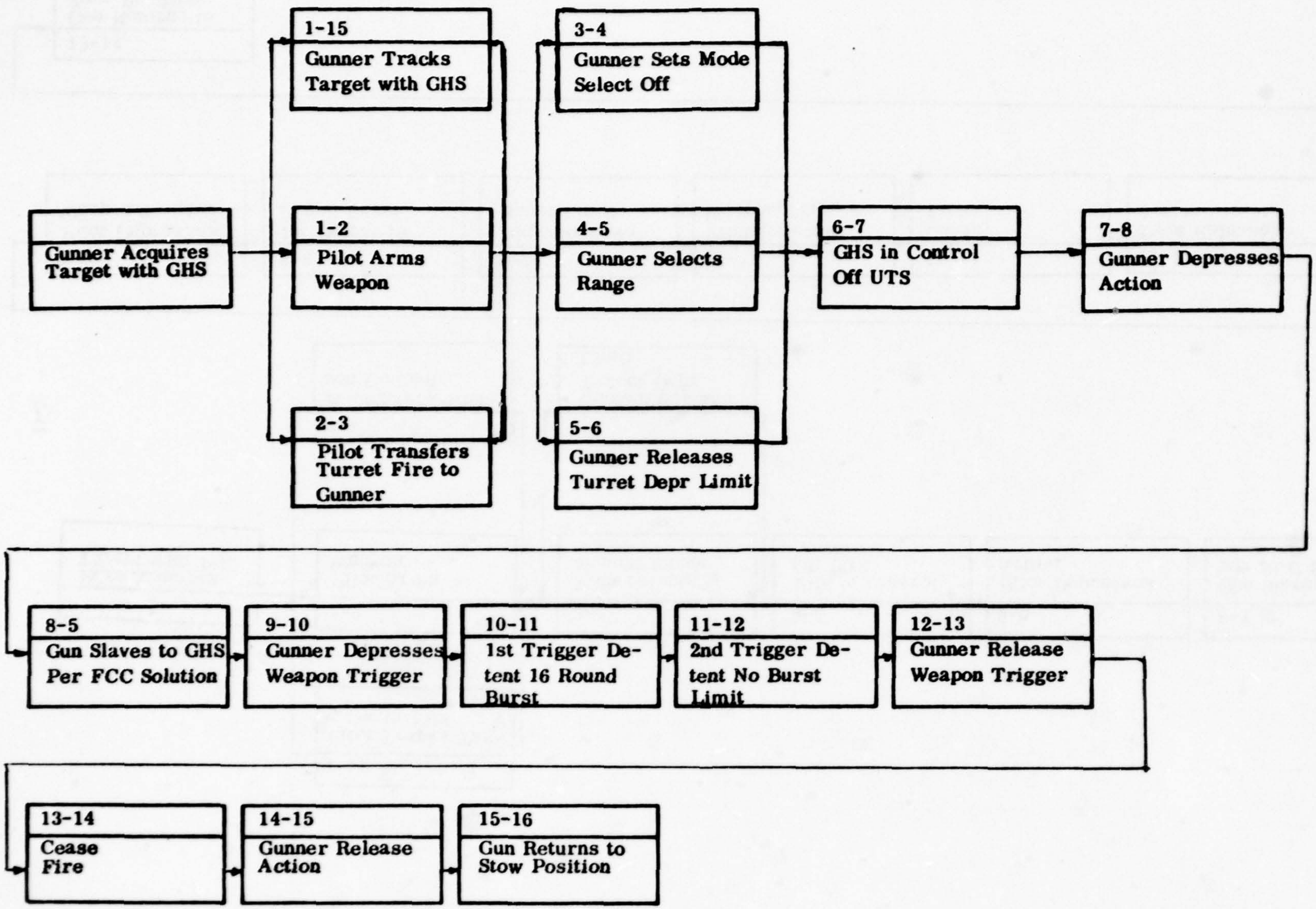
Mission Segment Flow Block Diagram: 20.0 Landing



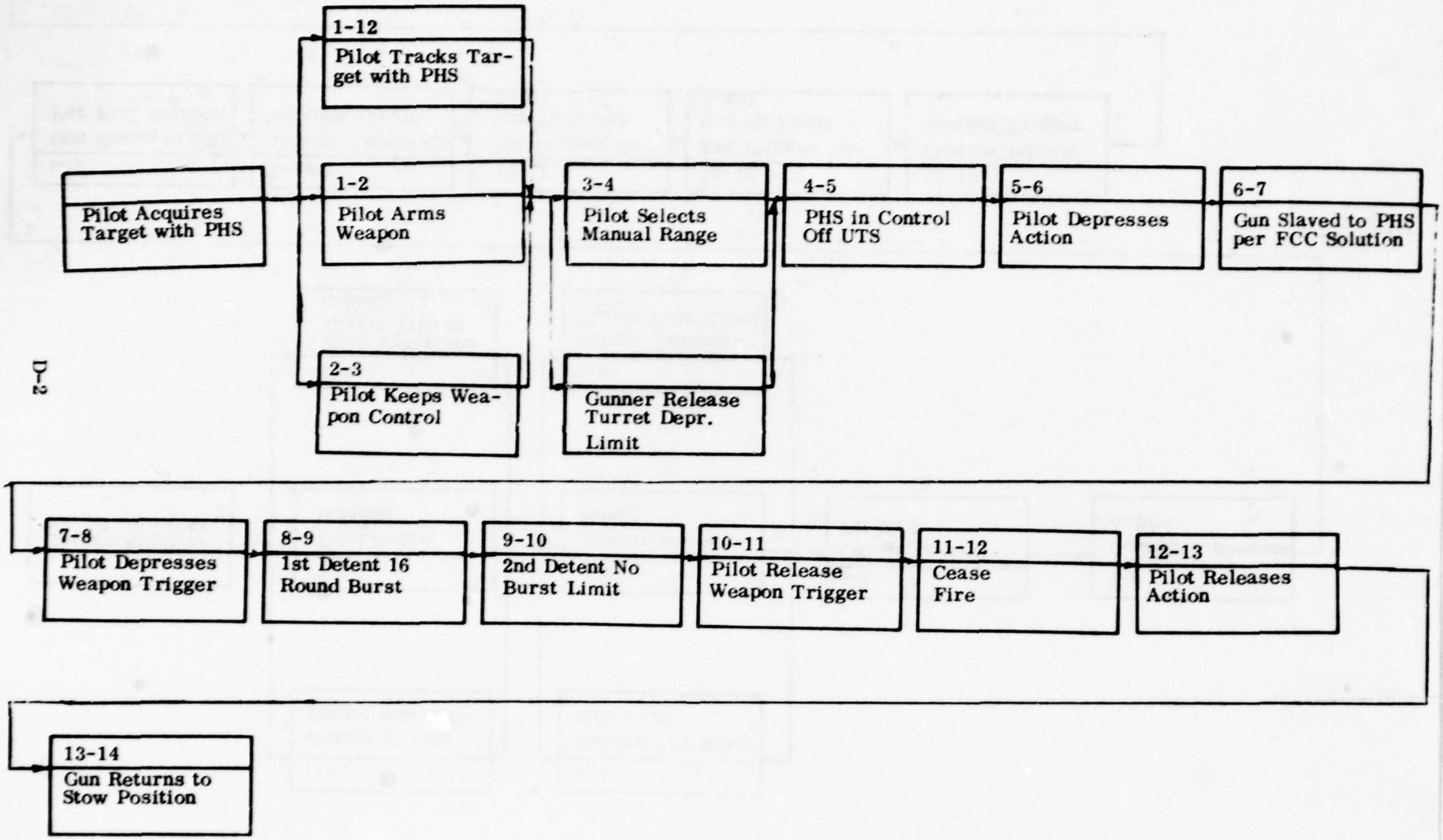
APPENDIX D

MISSION TIME LINES

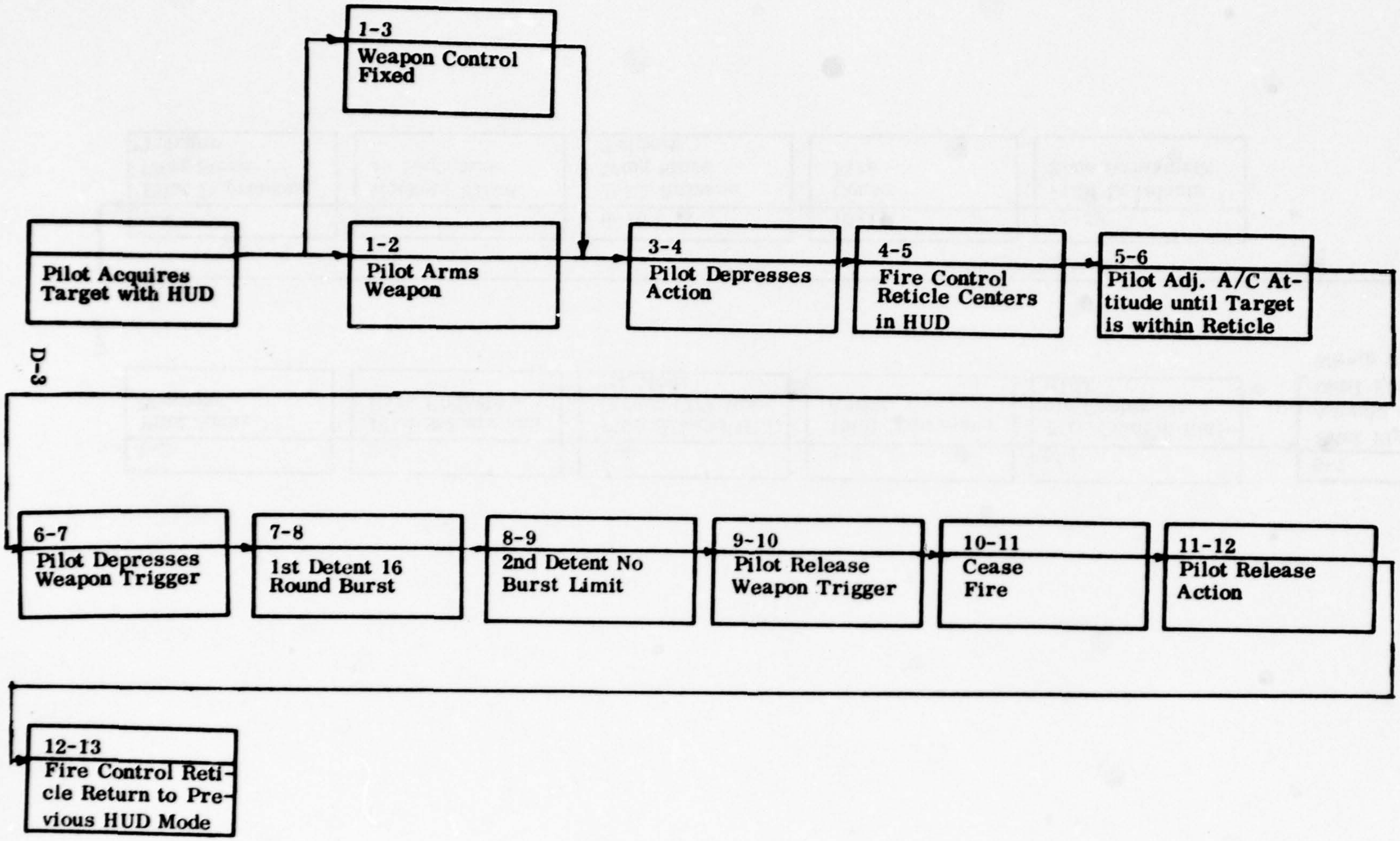
GHS FIRING GUN



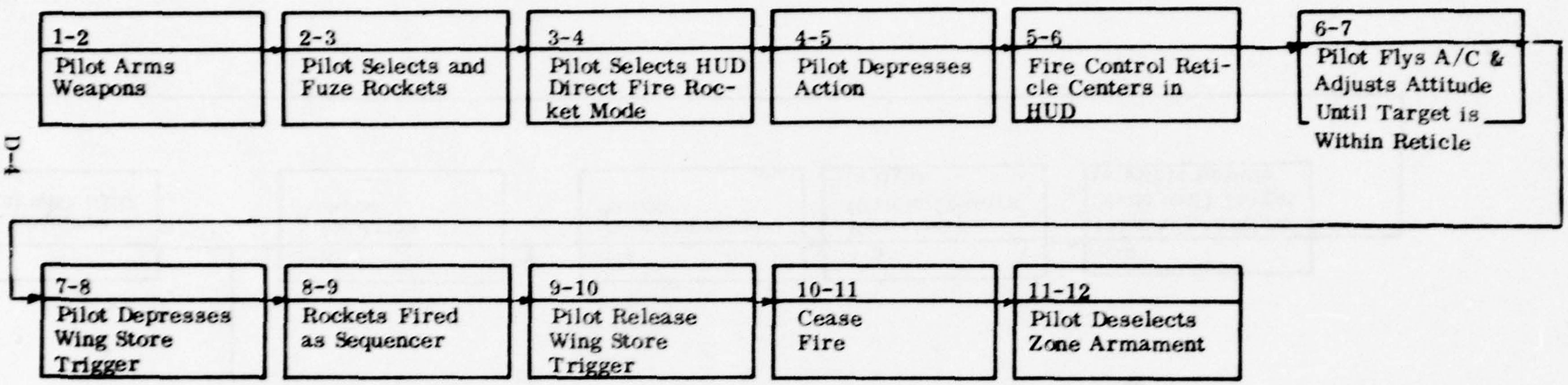
PHS FIRING GUN MODE



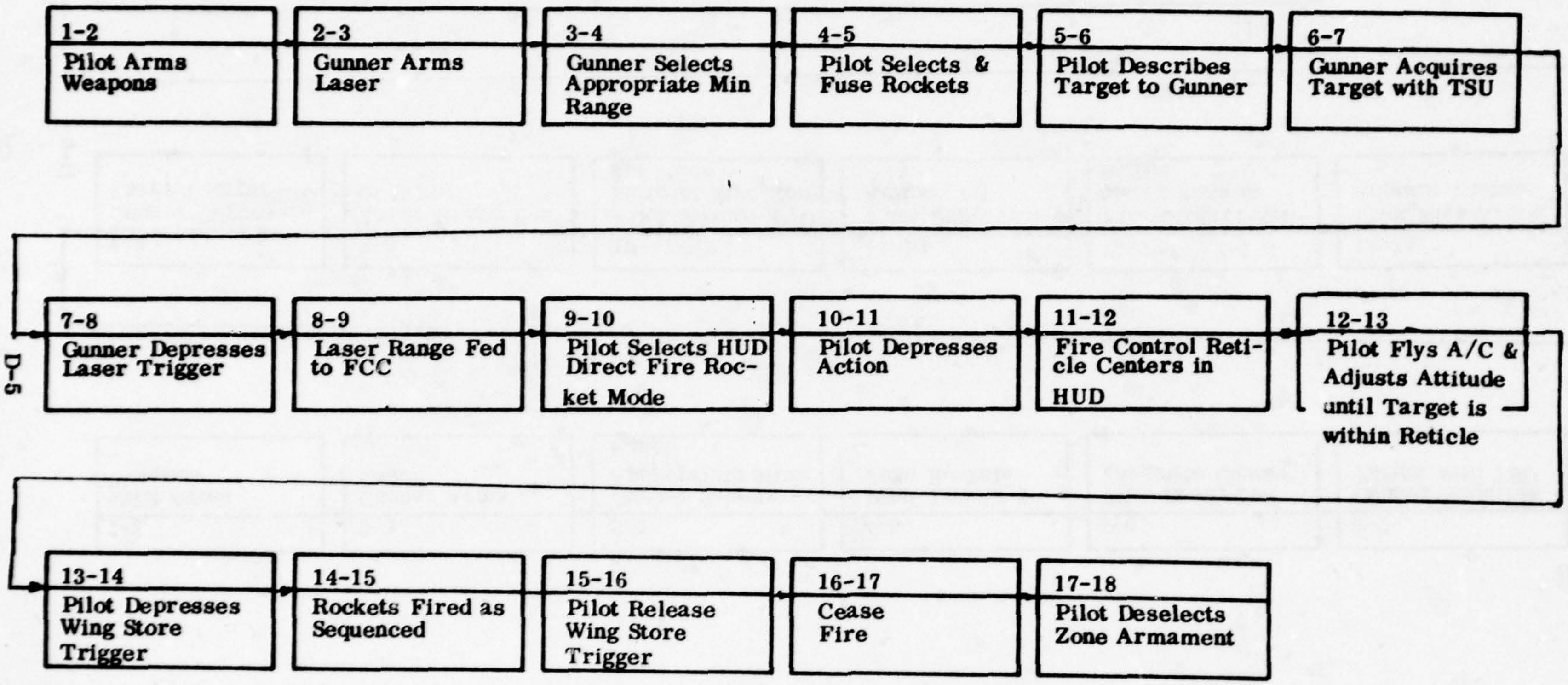
FIXED FORWARD MODE



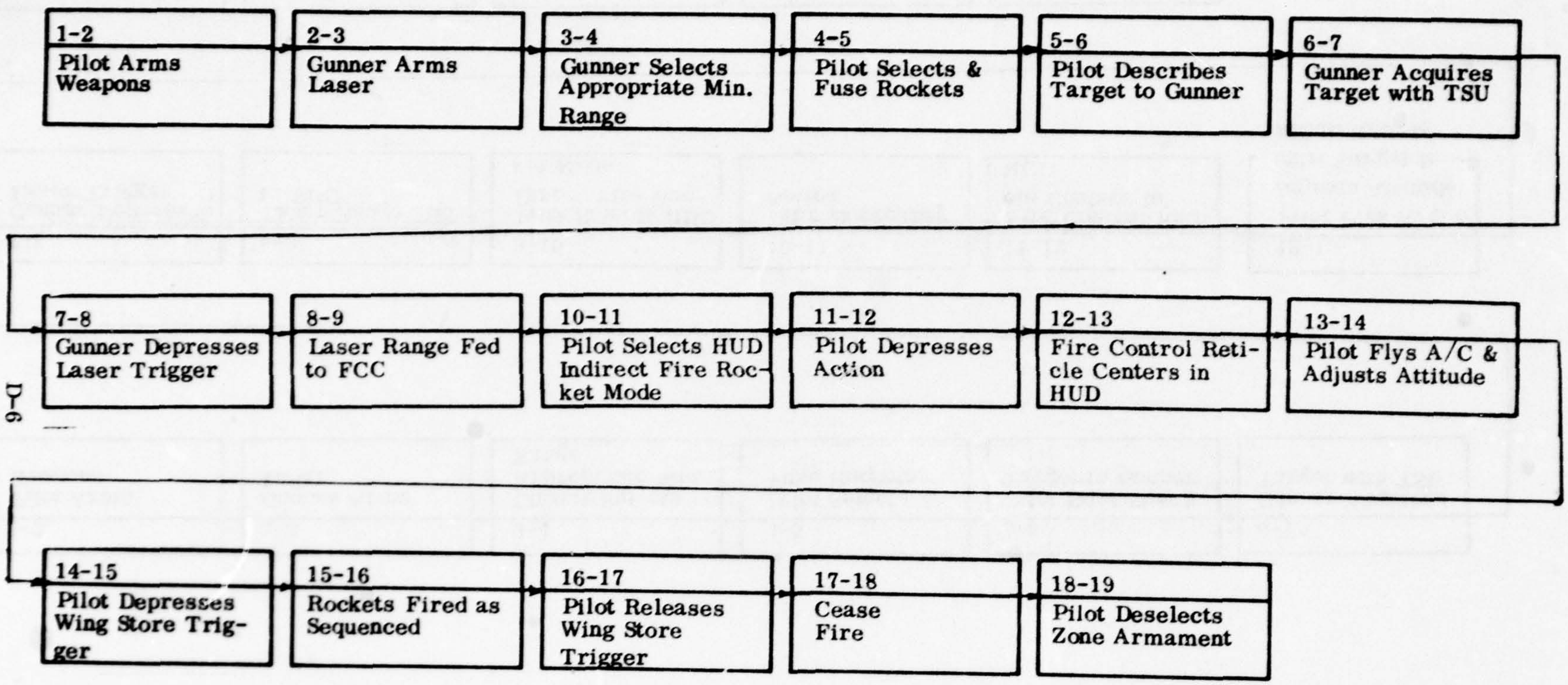
ROCKET DIRECT WITH ESTIMATED RANGE MODE



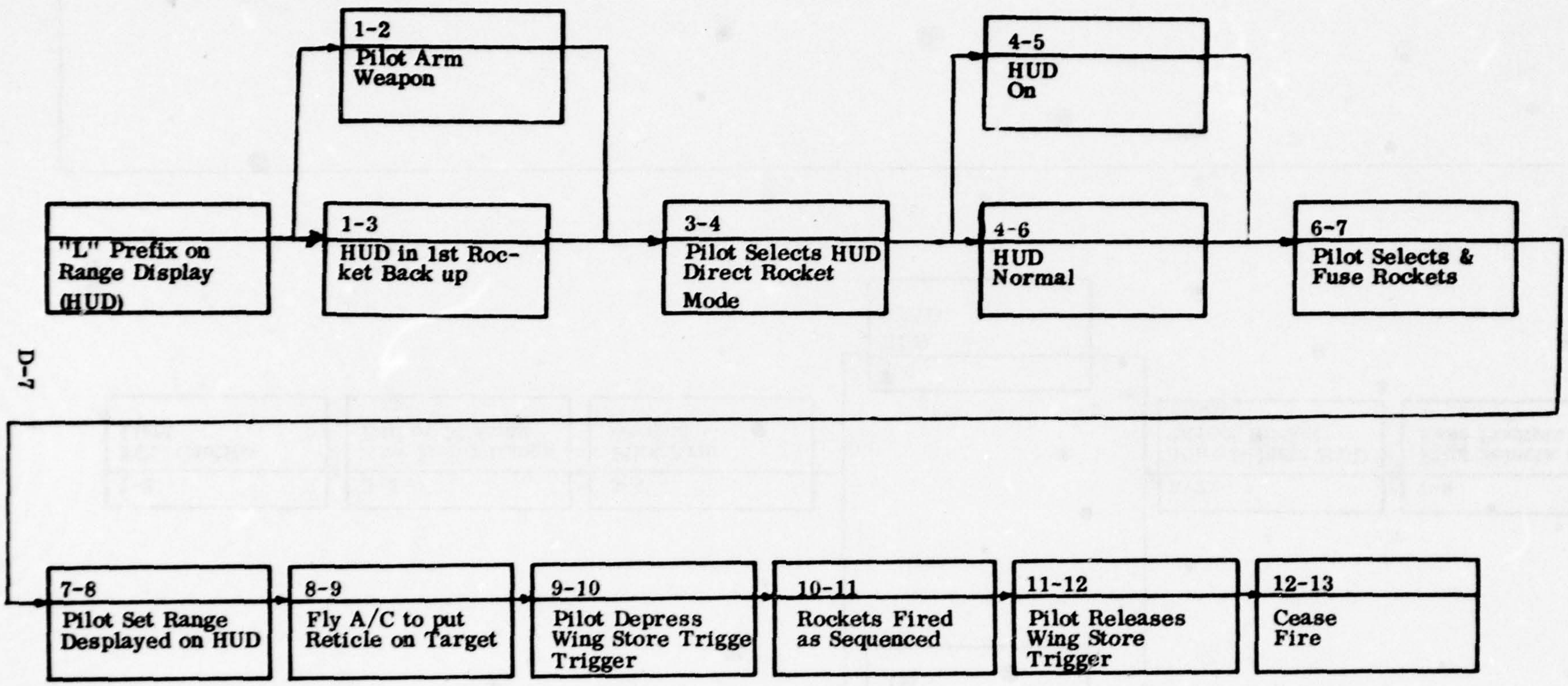
ROCKET DIRECT WITH LASER RANGING MODE



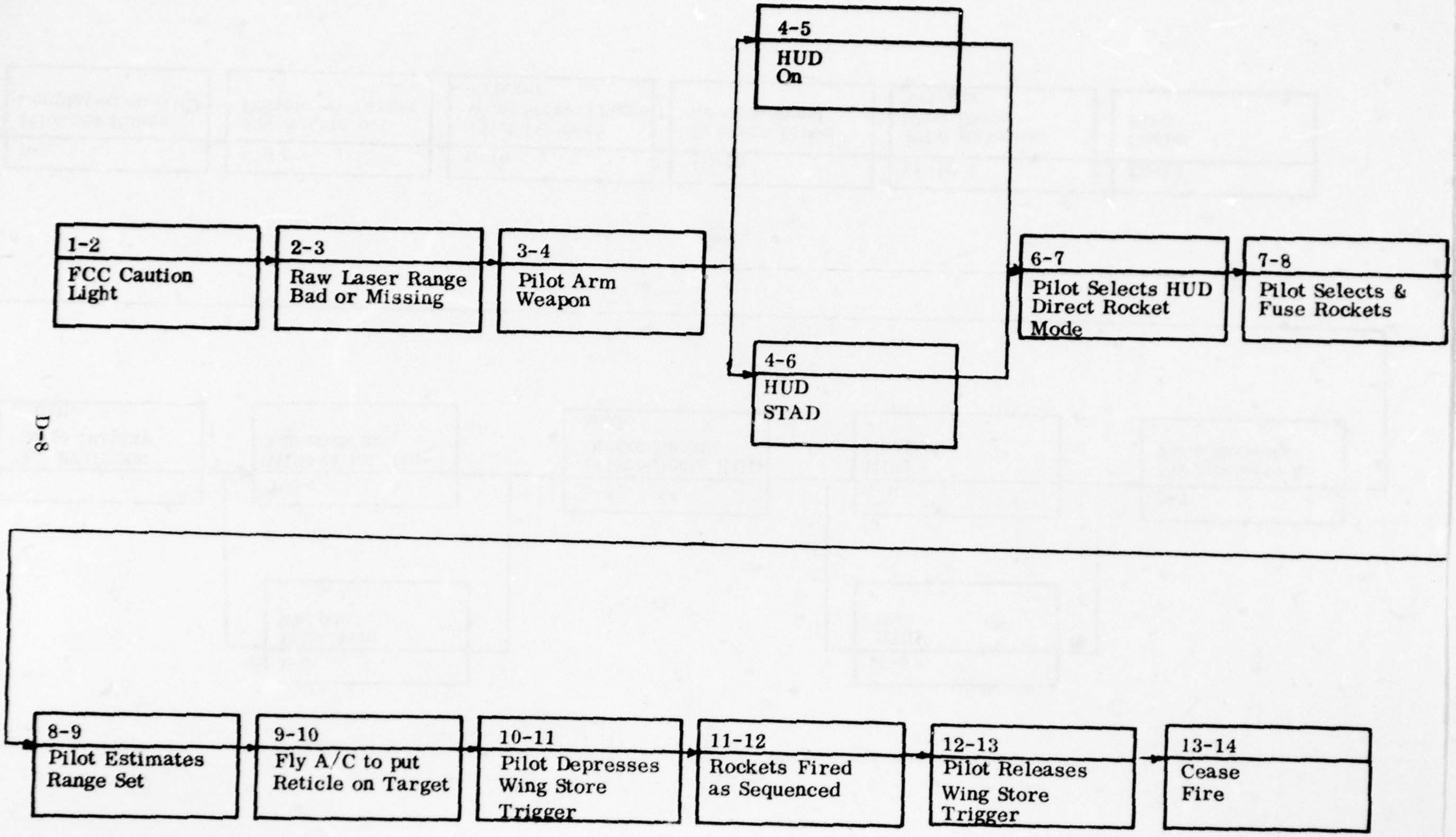
INDIRECT ROCKET MODE



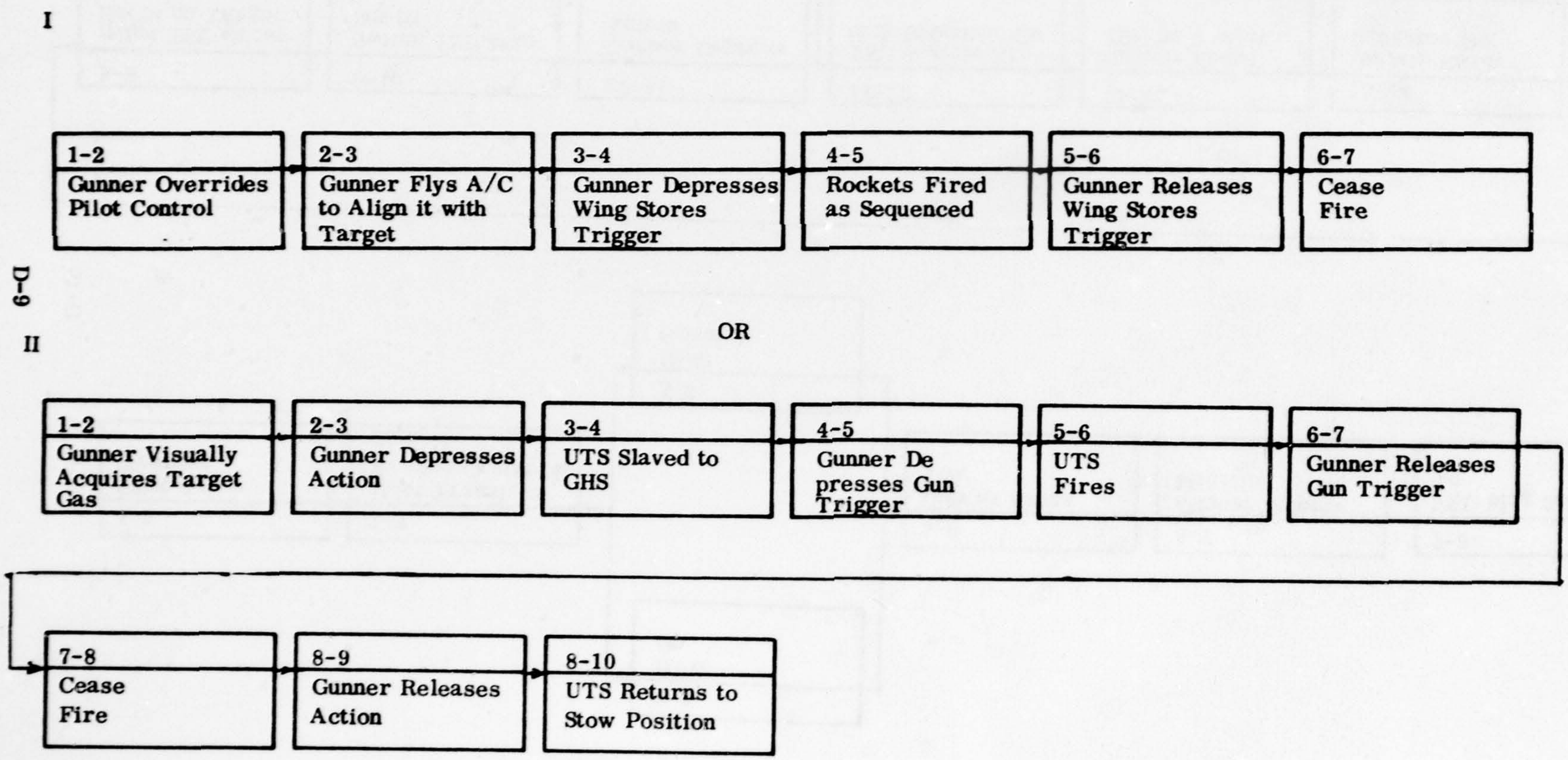
FIRST ROCKET BACKUP MODE



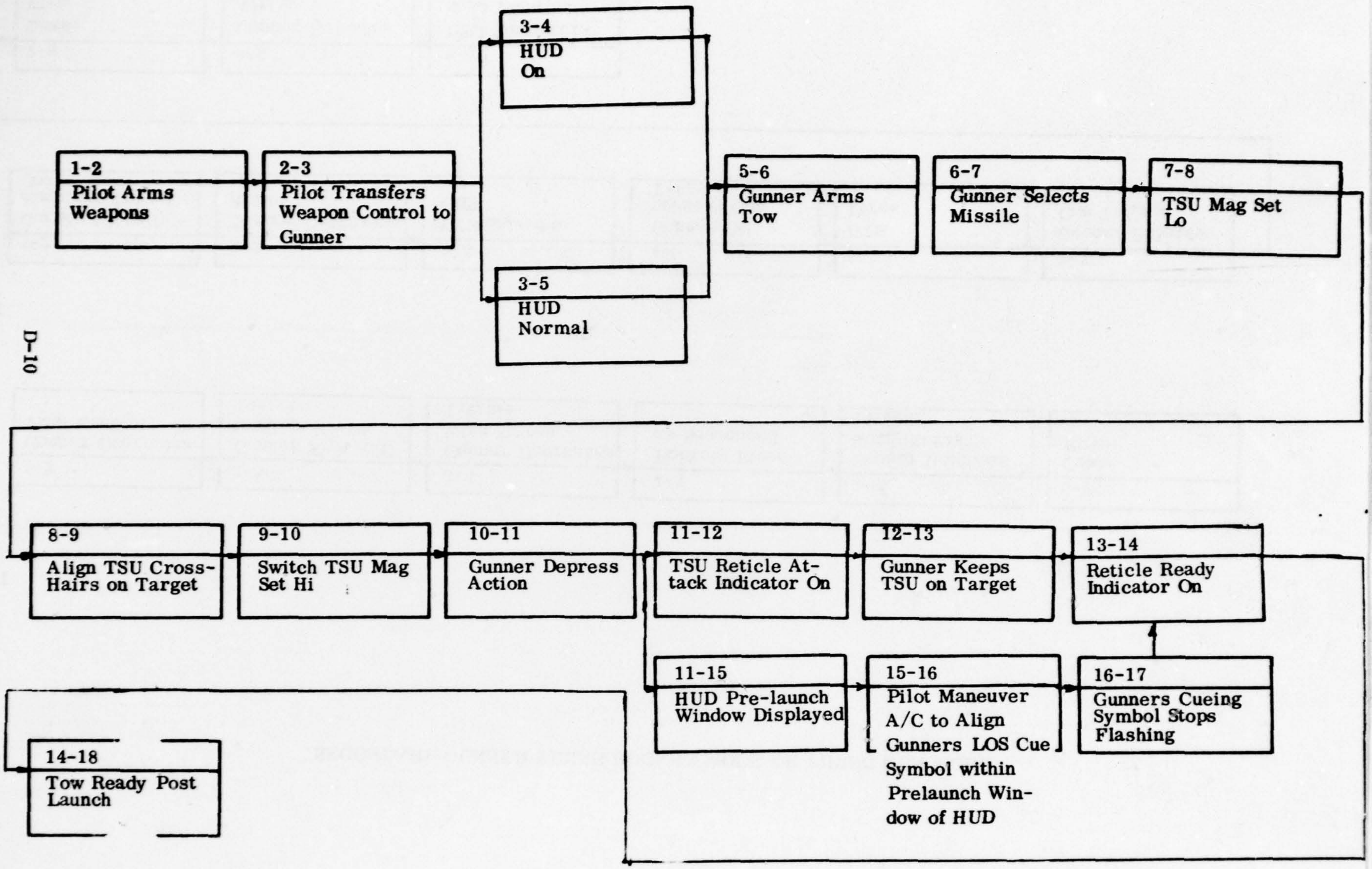
SECOND ROCKET BACKUP MODE



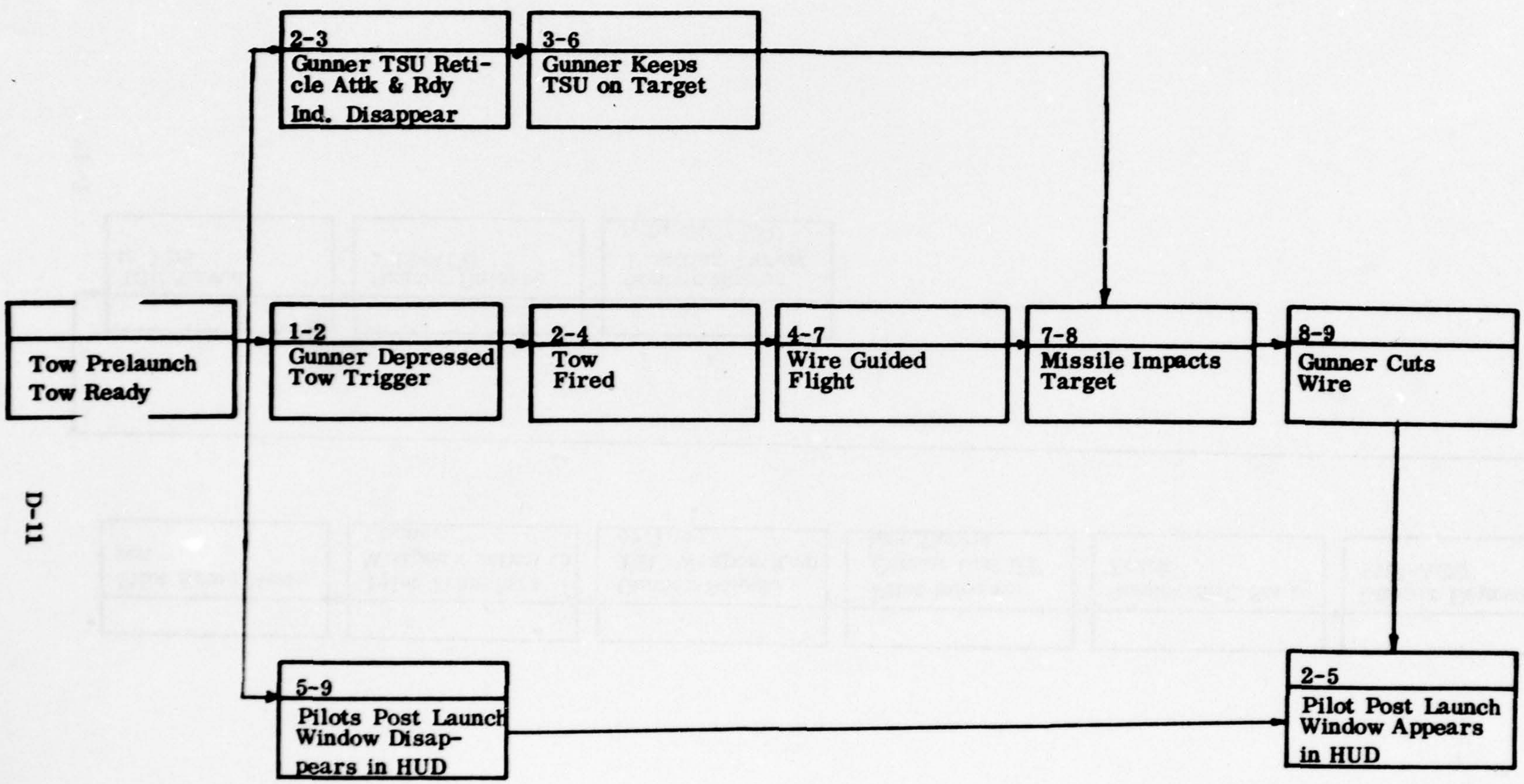
SECONDARY GUNNER FIRING ROCKET MODE OR FIRING GUN MODE



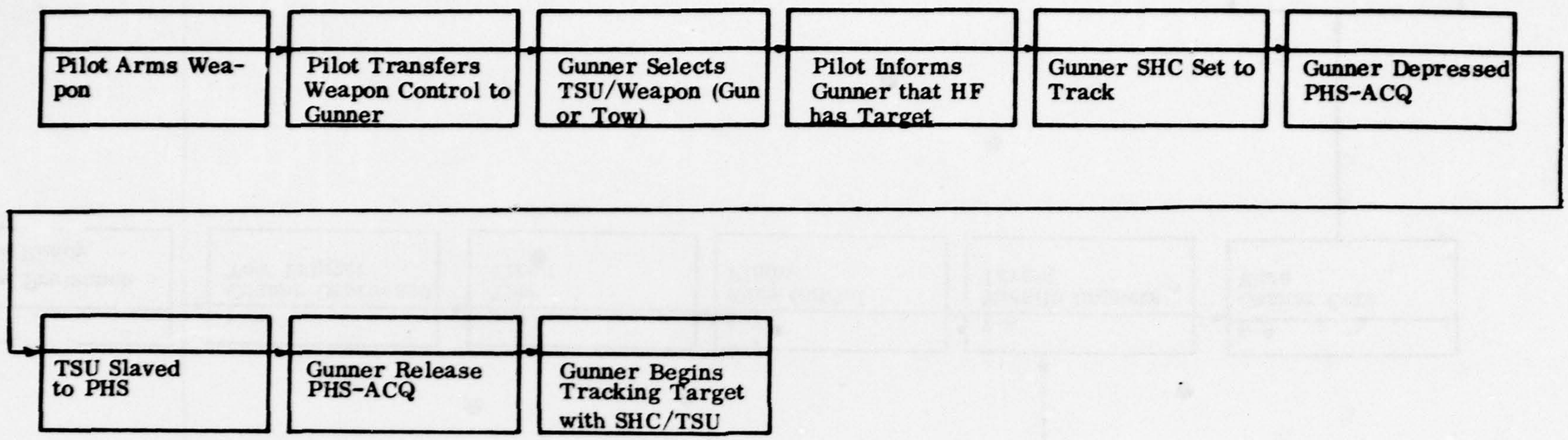
TOW PRELAUNCH MODE



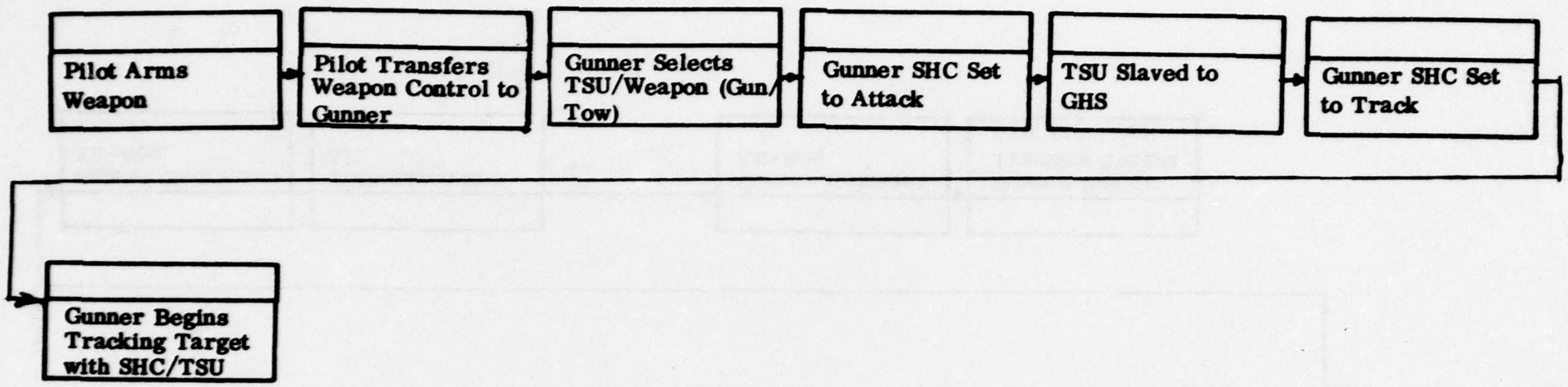
TOW POST LAUNCH MODE



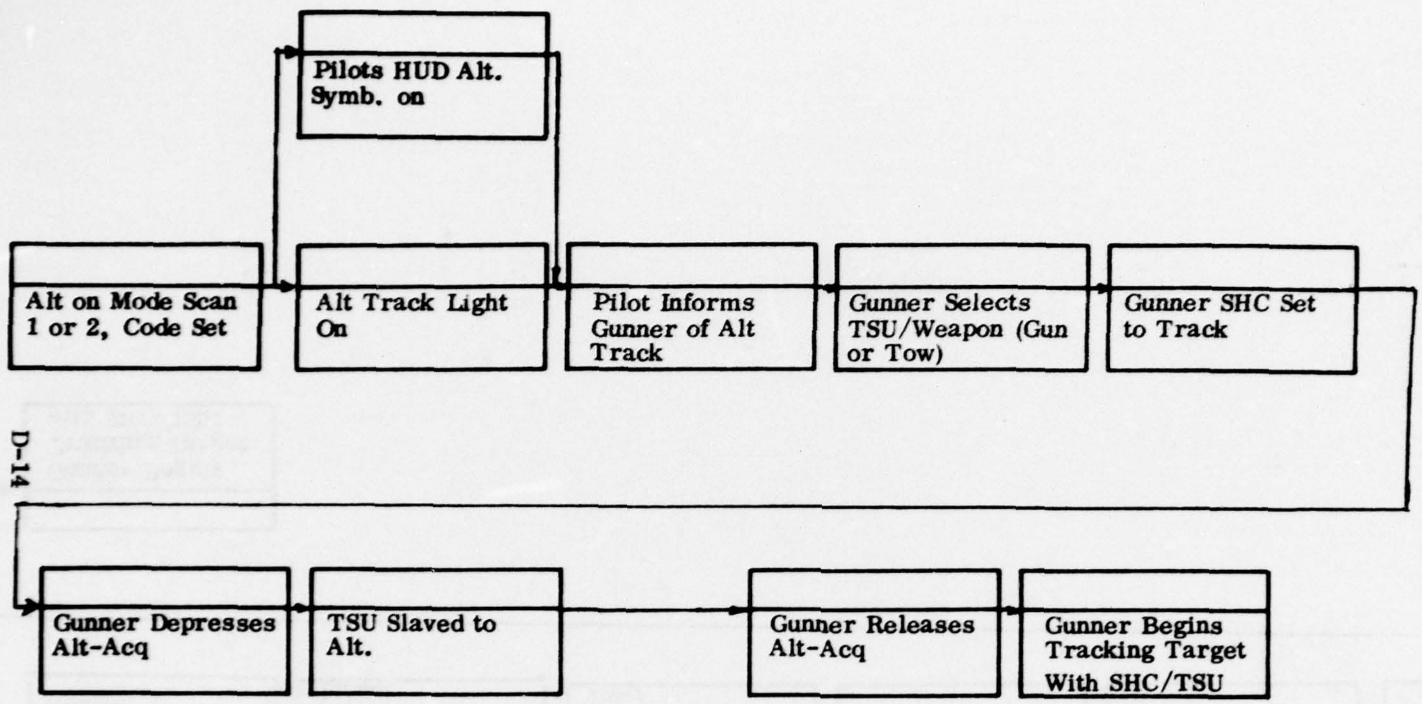
PHS → TSU ACQUISITION



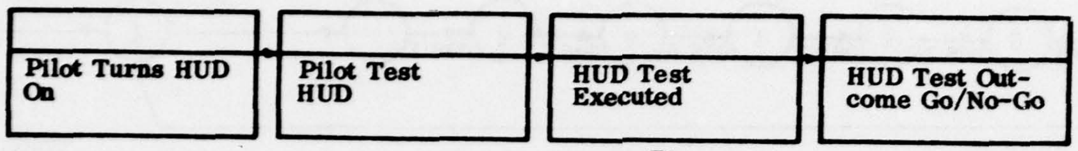
GHS → TSU ACQUISITION



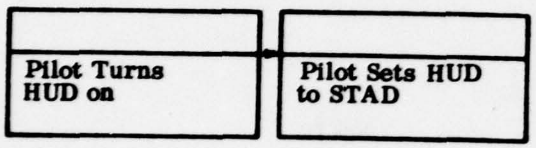
ALT → TSU ACQUISITION



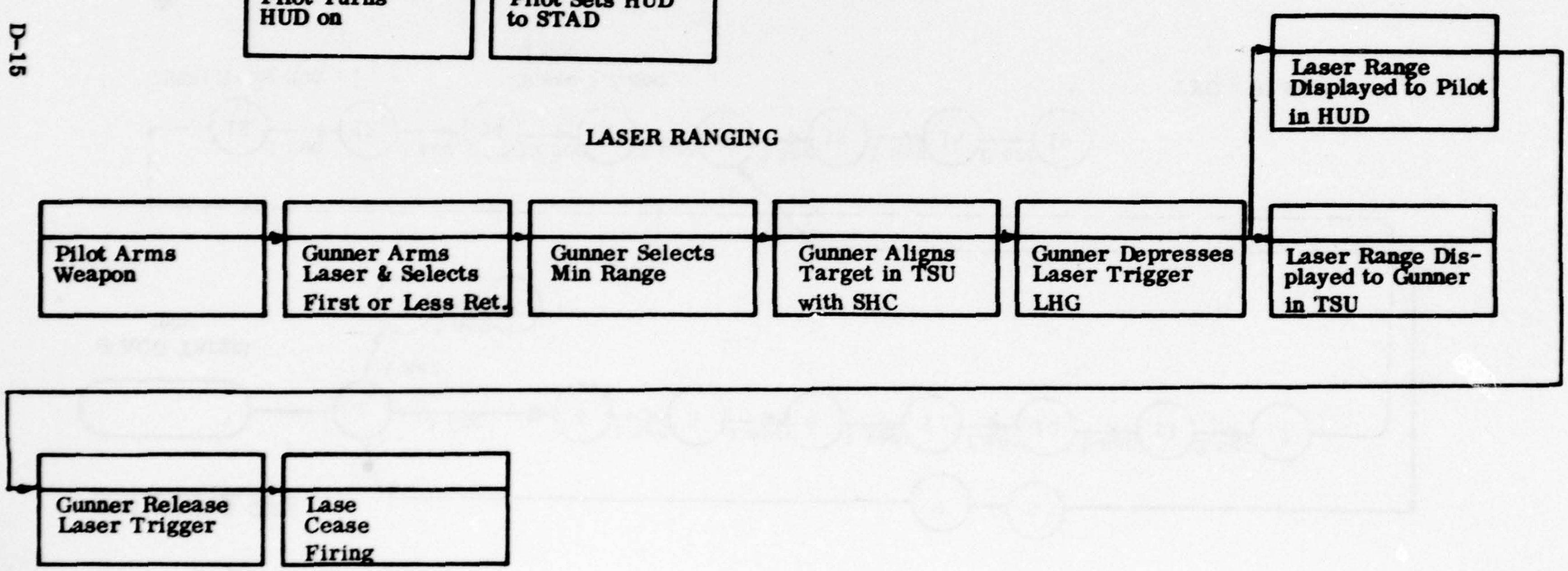
HUD TEST MODE



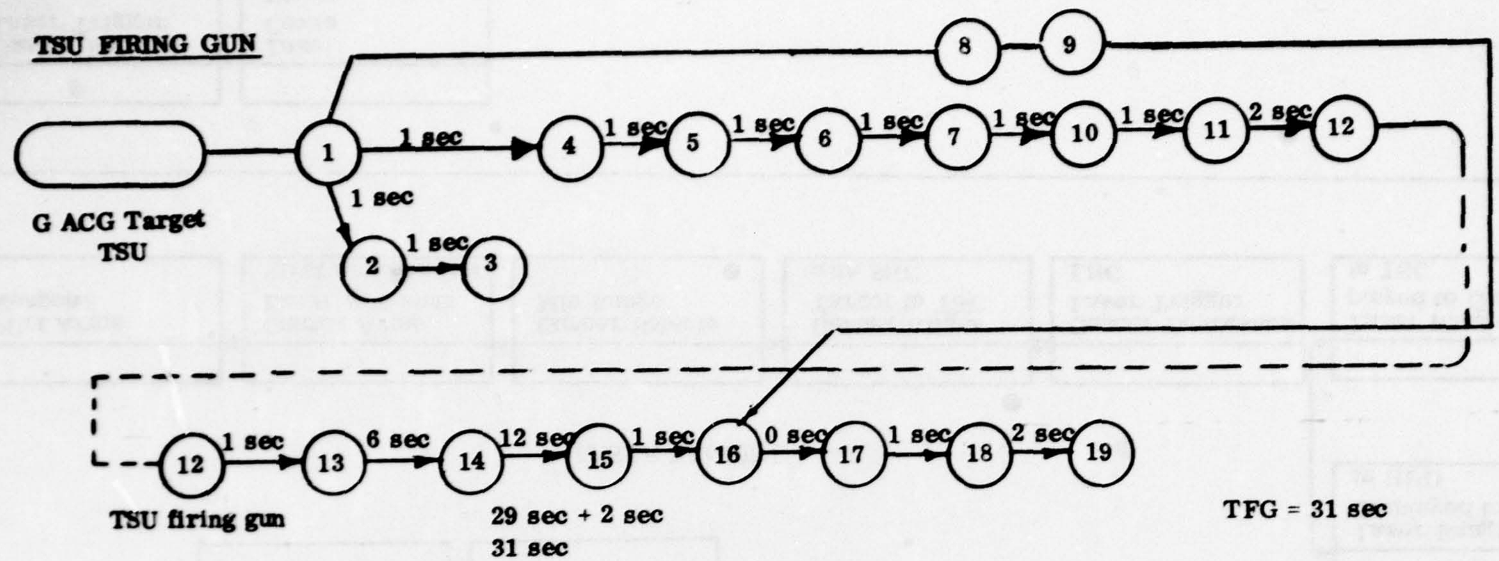
HUD BORESIGHT MODE



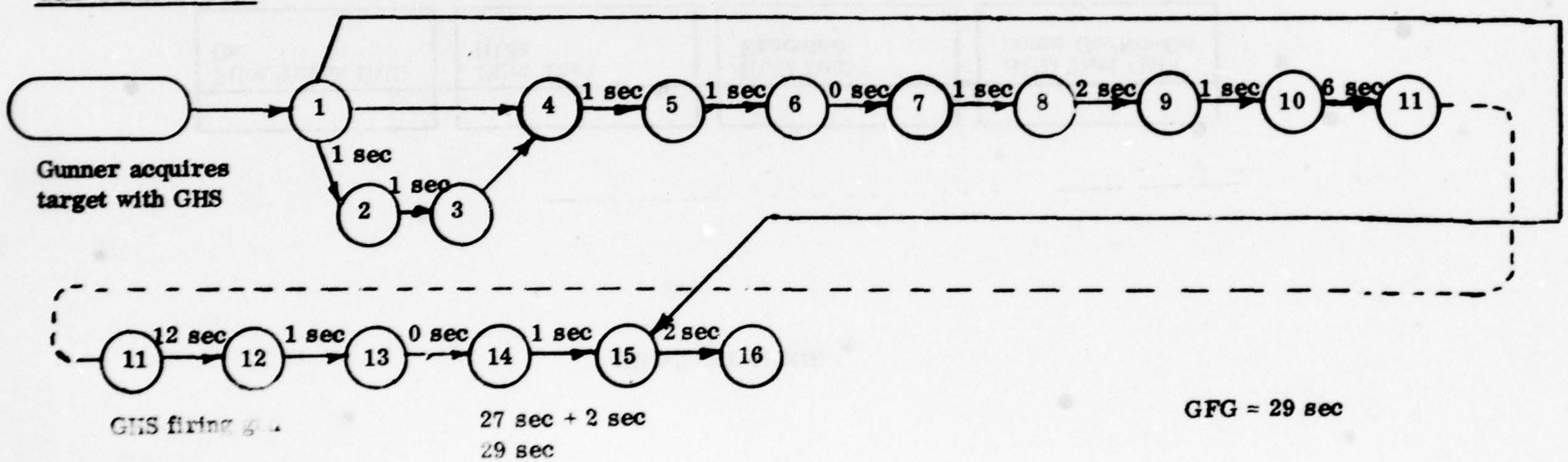
LASER RANGING



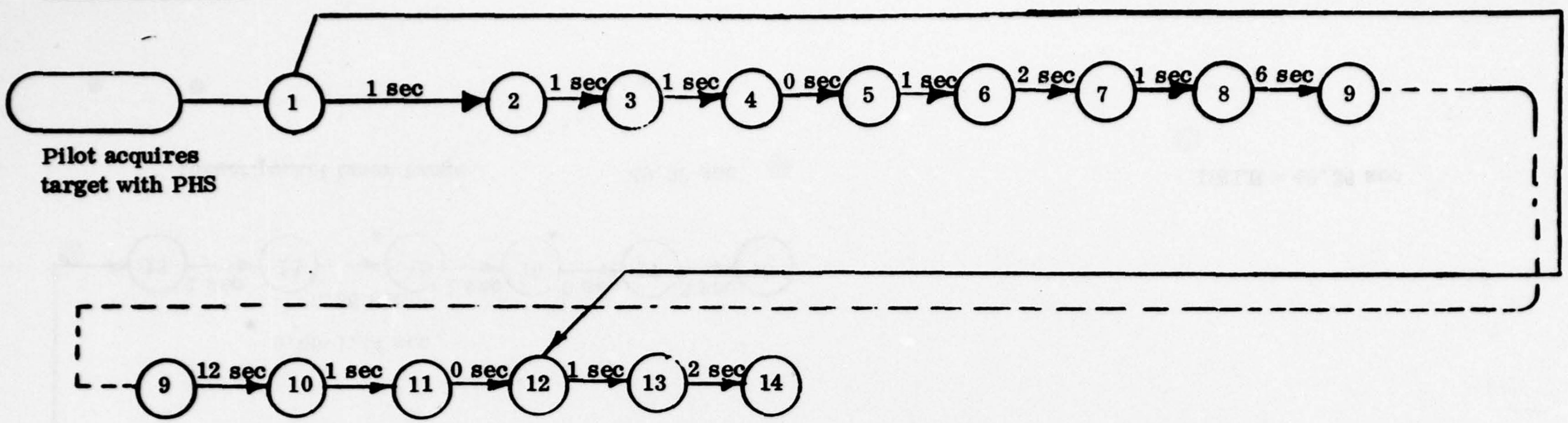
TSU FIRING GUN



GHS FIRING GUN



PHS FIRING GUN

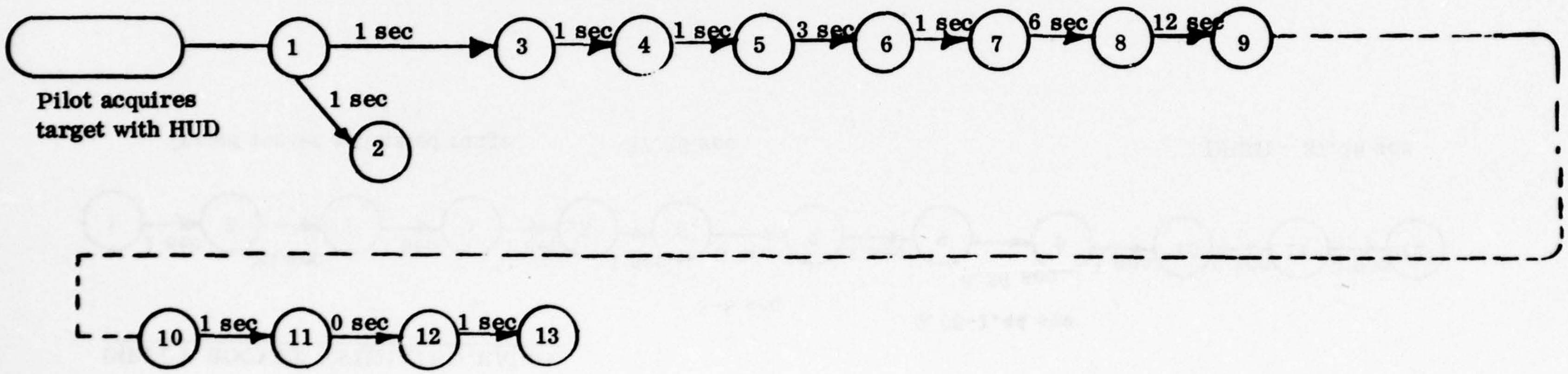


PHS firing gun

27 sec + 2 sec
29 sec

PFG = 29 sec

FIXED FORWARD GUN

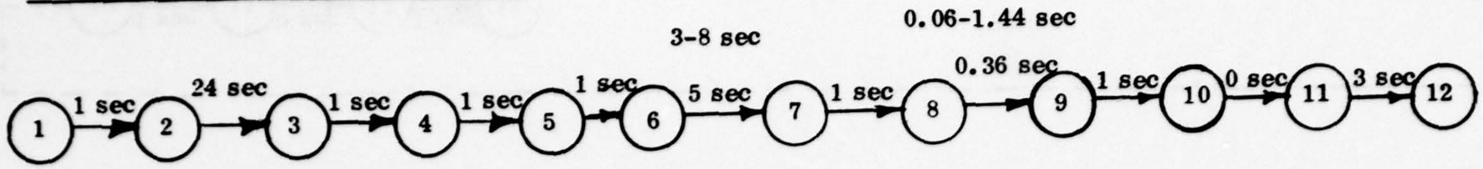


Fixed forward gun

26 sec + 1 sec
27 sec

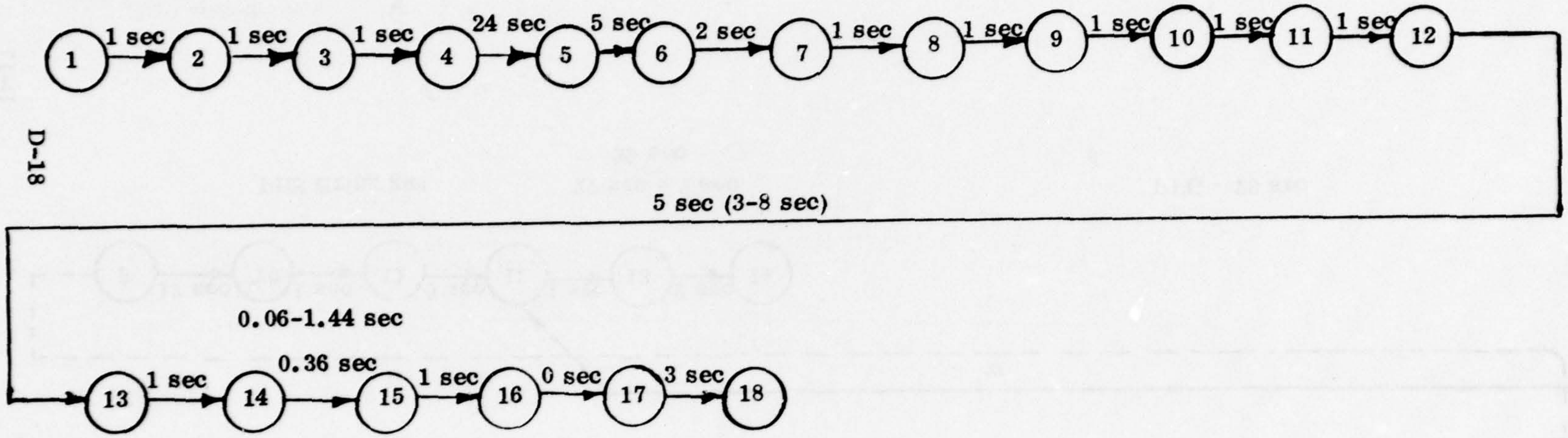
FFG = 27 sec

DIRECT ROCKET ESTIMATED RANGE



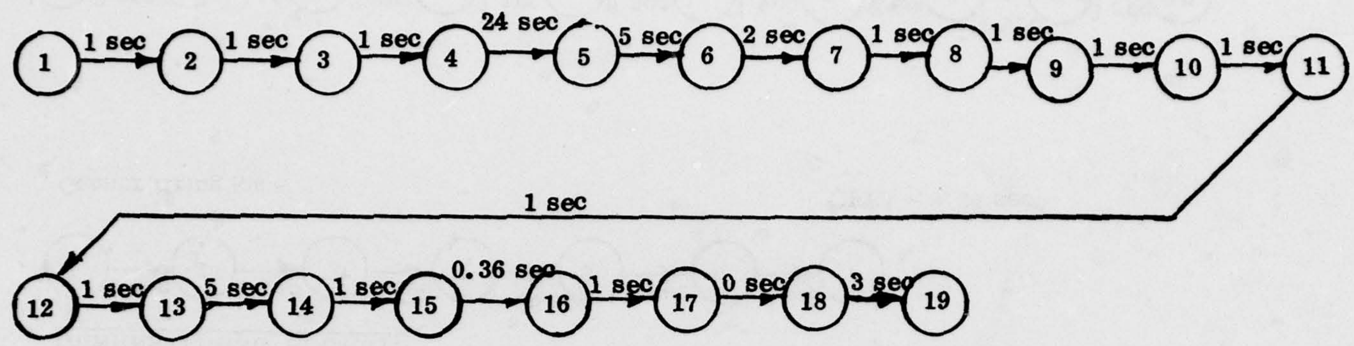
Direct rocket estimated range 37.36 sec DRER = 37.36 sec

DIRECT ROCKET LASER RANGE



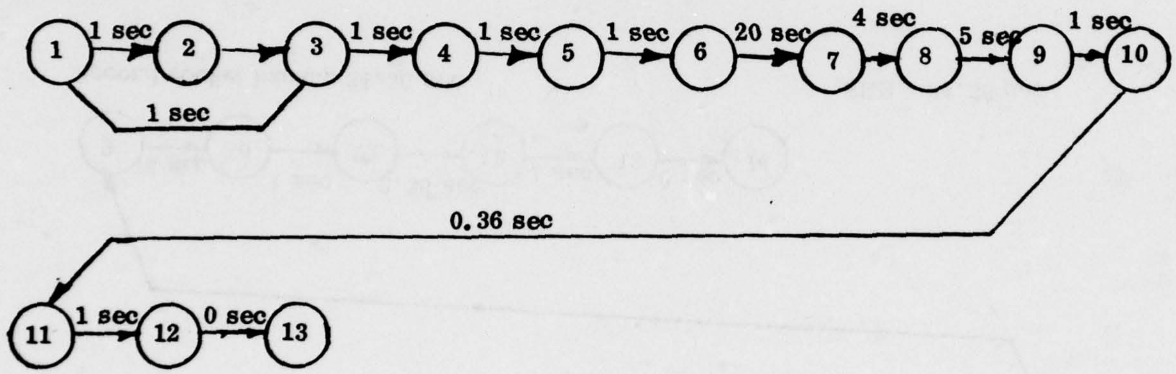
Direct rocket laser range 49.36 sec DRLR = 49.36 sec

INDIRECT ROCKET



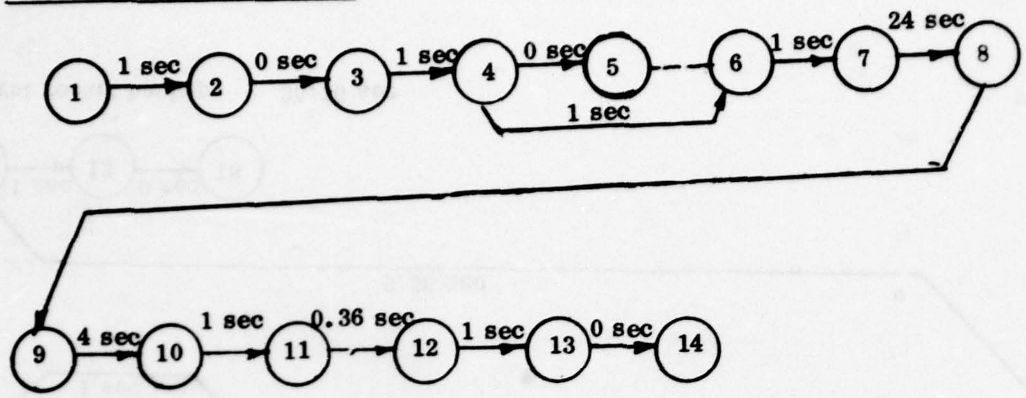
Indirect rocket 49.36 sec IDR = 49.36 sec

FIRST ROCKET BACKUP



First rocket backup 35.36 sec FRB = 35.36 sec

SECOND ROCKET BACKUP

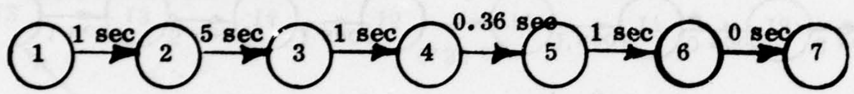


Second rocket backup 34.36 sec

SRB = 34.36 sec

GUNNER FIRING ROCKETS

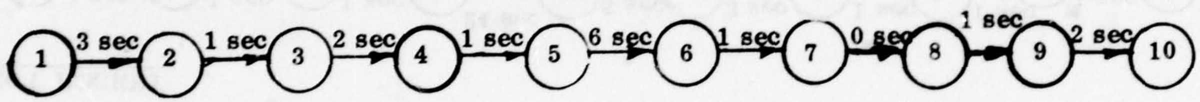
I



Gunner firing guns

GFR1 = 8.36 sec

II

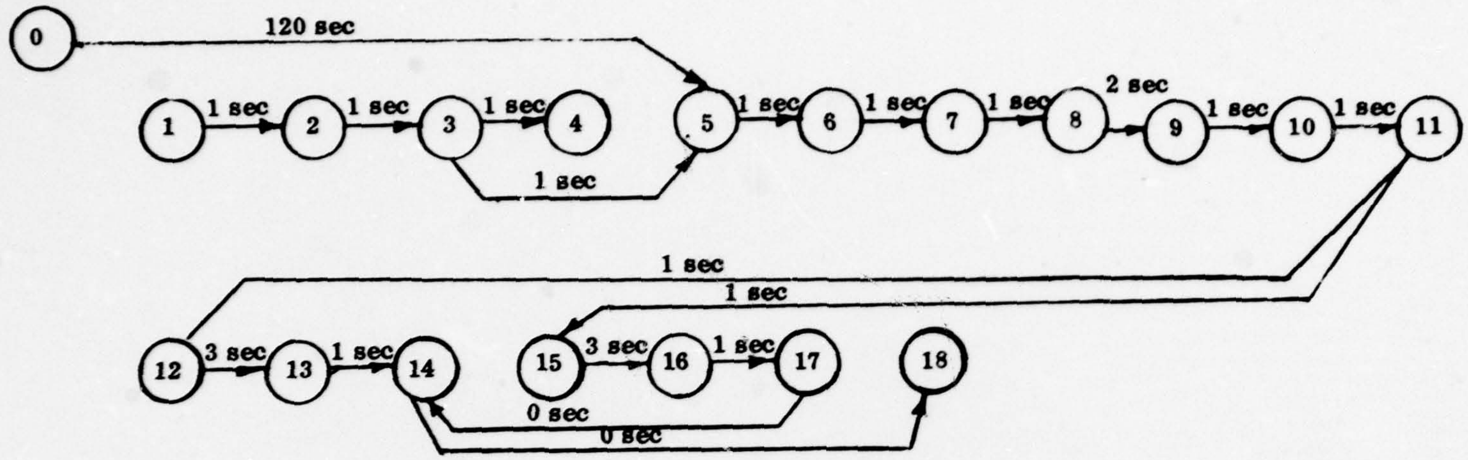


GFG2 = 17 sec

TOW PRELAUNCH

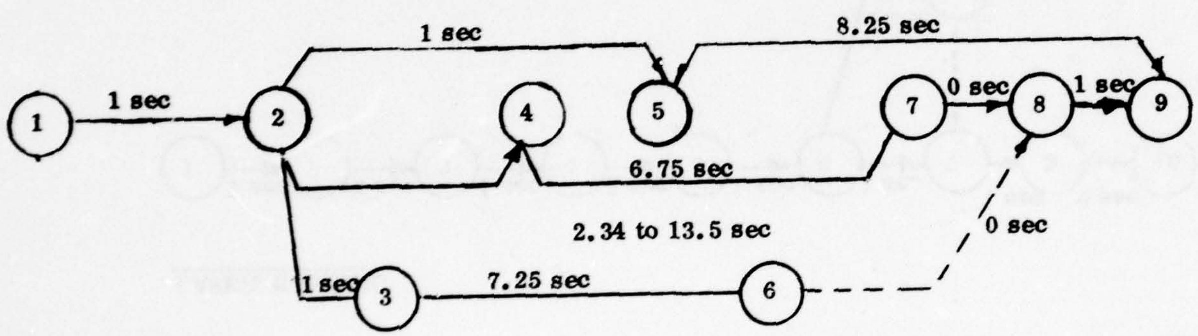
(0-5)*

Tow should be in tow/stby before entering FEBA



TPRL = 15 sec

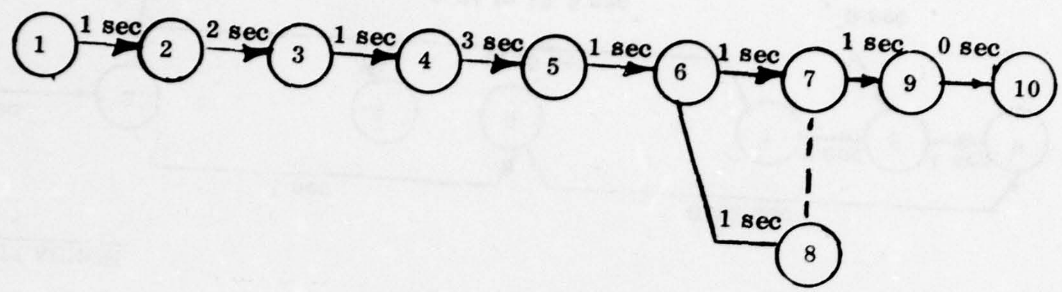
TOW POSTLAUNCH



TPRL + TPOL = 25.25 sec ave
= 32 sec max

TPOL = 10.25 sec

LASER RANGING



LRG = 10 sec