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ADVANCED INTEGRATED FIGHTER COCKPIT
STUDY

D. R. Zipoy, et al

Boeing Company

Prepared for:

Air Force Flight Dynamics Laboratory

June 1971

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**13. ABSTRACT** Two studies, "Integrated Information Presentation and Control System Study" (IIPACS) and "IIPACS Degraded Mode Analysis," were conducted by The Boeing Company under Air Force Contracts F33615-69-C-1544, dated March 1969, and F33615-70-C-1832, dated June 1970, respectively. This report presents, in summary fashion, a general description of the work accomplished to date on the development of a concept for the crew station of an advanced tactical fighter aircraft of the 1980 time period. Details of the work performed under these two contracts is reported in three volumes of AFFDL 54-70-79 as follows:

    o   Volume I   - "System Development" (IIPACS-1)
    o   Volume II  - "Systems Analysis" (IIPACS-1)
    o   Volume III - "Degraded Mode Analysis" (IIPACS-2)

Within the context of the initial study, a composite mission profile and scenario are presented to define the operational requirements for the system concept. Airplane configuration and performance are described, and the characteristics and capabilities of the on-board avionics are summarized. A full-sized, single-place cockpit mockup and three basic interior configurations have been fabricated to reflect study results and to serve as evaluation tools.

The second study, "IIPACS Degraded Mode Analysis," updates the concepts defined in the initial effort and includes analyses of contingency operations. Controls and displays resulting from the analyses are described, and mockups are fabricated and available for evaluation.

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| 14 KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Automatic Flight Management | | | | | | |
| Close Air Support Mission | | | | | | |
| Computer Control | | | | | | |
| Computer Generated Displays | | | | | | |
| Controls | | | | | | |
| Crewstation | | | | | | |
| Degraded Mode | | | | | | |
| Displays | | | | | | |
| Electronic Display | | | | | | |
| Energy Management | | | | | | |
| Functional Flow Diagram | | | | | | |
| Integrated Avionics | | | | | | |
| Integration | | | | | | |
| Sidearm Controllers | | | | | | |
| Stores Management | | | | | | |
| System Analysis | | | | | | |
| Weapon Delivery | | | | | | |
| Workload | | | | | | |

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AFFDL-TR-71-57

# ADVANCED INTEGRATED FIGHTER COCKPIT STUDY

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Military Airplane Systems Division

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TECHNICAL REPORT AFFDL-TR-71-57

May 1974

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# FOREWORD

This technical report documents the results of work conducted under USAF Contract No. F33615-69-C-1544 and Contract No. F33615-70-C-1832 by Advanced Crewstation Technology Laboratory personnel, Military Airplane Systems Division, The Boeing Company, Seattle, Washington. The objective of this work was to develop a concept for the crewstation development of an advanced fighter aircraft based on 1980-1985 technology.

The contracts were initiated jointly under Project No. 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles", which is managed by Mr. John H. Kearns, III, as Project Engineer and Principal Scientist for the Flight Deck Development Branch (FGR), Flight Control Division, Air Force Flight Dynamics Laboratory, and under Project 4167, "Integrated Avionics", which is managed by Mr. Richard D. Alberts, as Project Engineer for the Plans Office (XP), Air Force Avionics Laboratory. The work was performed as a part of Task 6190 21, "Advanced Integrated Fighter Cockpit Development Program", under the guidance of Mr. Robert R. Davis, Group Leader, and Capt N. A. Kopchick (FGR) as Task Engineer.

Acknowledgement of significant contributions during the first phase of the program (entitled "Integrated Information Presentation and Control System Study") goes to D. R. Zipoy, Principal Investigator; S. J. Premselaar, Lead Engineer, for systems analysis and cockpit configuration; I. L. Belyea for display design and cockpit human factors criteria; H. J. Hall, Jr., for cockpit and controller design as well as design and fabrication of mockups; R. E. Gargett for system analysis and avionics concepts; A. P. Augustiny for translation of the mockup designs into working drawings; F. V. Lane for timeline/workload evaluation; B. D. Nelson for airplane configuration concept and performance; and Capt N. A. Kopchick, Technical Monitor for the Air Force.

Significant contributions during the second phase of the program (entitled "IIPACS - Degraded Mode Analysis") were submitted by S. J. Premselaar as Principal Investigator; J. G. Hatcher for avionics design concepts and degraded mode analyses; R. L. Richardson for design concepts in aircraft systems and degraded mode analyses; R. L. Kinnaman for avionics and store management concepts; W. D. Smith for workload analyses; V. Foisey for the reliability study and failure ranking; and Capt N. A. Kopchick, Technical Monitor for the Air Force.

The work effort covered the period from March 1969 through March 1971. This report was submitted by the authors in April 1971 for publication as an AFFDL Technical Report. This report is being reissued in 1974 for administrative reasons.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

RICHARD L. RAVENELLE
Lt Col, USAF, Chief
Flight Deck Development Branch
Flight Control Division
AF Flight Dynamics Laboratory

# ABSTRACT

Two studies, "Integrated Information Presentation
and Control System Study" (IIPACS) and "IIPACS Degraded
Mode Analysis", were conducted by The Boeing Company
under Air Force Contracts F33615-69-C-1544, dated March
1969, and F33615-70-C-1832, dated June 1970, respectively.
This report presents, in summary fashion, a general
description of the work accomplished, to date, on the
development of a concept for the crew station of an
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period. Details of the work performed under these two
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    o   Volume I   - "System Development" (IIPACS-1)

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Within the context of the initial study, a composite
mission profile and scenario are presented to define the
operational requirements for the system concept. Airplane
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The second study, "IIPACS Degraded Mode Analysis,"
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# LIST OF ILLUSTRATIONS (Contd)

# LIST OF ABBREVIATIONS

AA, A/A--air-to-air

AAA--anti-aircraft artillery

ac--alternating current

A/C--aircraft

ACK--acknowledge

ACSA--auxiliary coded switch assembly

ADDR--air data dead reckoning

ADF--automatic direction finding

A/G--air-to-ground

AFCS--automatic flight control system

AGLR--air-to-ground ranging

AHRS--attitude heading reference system

AIs--airborne interceptors

AILA--airborne instrument landing approach

ALT--altitude hold

APU--auxiliary power unit

ARM--anti-radar missile

ATA--automatic target acquisition

ATF--automatic terrain following

AWACS--airborne warning and control system

BAC--battle area command

BARO--barometric

BCN--beacon

BDA--battle damage assessment

BITE--built-in test equipment

BRG--bearing

BS--boresight

BSD--battle situation display

CCC--central computer complex

CEP--circular error probability

cg--center of gravity

C&I--communication/identification

C/L--command link

CM--countermeasure

CMD--command

CMDS--countermeasures dispensing system

CNI--communications, navigation, and identification

CP--checkpoint

CRT--cathode ray tube

CSA--coded switch assembly

CSS--control stick steer

CSS--coded switch system

DBS--Doppler beam sharpening

dc--direct current

DIS--Doppler inertial satellite

D/L--data link

DME--distance measuring equipment

EAS--equivalent airspeed

ECD--energy control director

ECM--electronic countermeasures

ECS--environmental control system

EL--electroluminescence

EMP--electromagnetic pulse

E-O--electro-optical

EW--early warning

FAA--Federal Aviation Administration

FAC--forward air controller

FLIR--forward-looking infrared

FMACS--failure monitor and control system

FOV--field of view

GCA--ground control approach

GCI--ground control intercept

GM--ground map

GMS--ground map squint

GS--ground speed

H--altitude

HARS--heading and attitude reference system

HF--high frequency

HSD--horizontal situation display

HTT--hard target tracking

HUD--head-up display

IEGS--integrated engine-generator system

IFC--instrument flight conditions

IFF--identification, friend or foe

IFR--in-flight refueling

IIPACS--integrated information presentation and control
system study

IKC--integrated keyboard control

ILM--independent landing monitor

ILS--instrument landing system

IMS--independent monitoring system

IR--infrared

ITEMS--integrated total energy management system

ITO--instrument takeoff

LED--light emitting diode

LF--low frequency

LLLTV--low light level television

LORAN--long range navigation

LR--long range

LRU--line replaceable unit

MF--medium frequency

MMR--multimode radar

MPD--multipurpose display

MTI--moving target indicator

NAVSAT--satellite navigation

NAVSTEER--navigation steer

NFOV--narrow field of view

NM--nautical mile

nmi--nautical mile

OCS--off-center sector

PAL--prescribed action link

PP--present position

PPI--plan position indicator

PPR--preplanned route

PRF--pulse repetition frequency

PW--pulse width

RF--radio frequency

RHAW--radar homing and warning

RTB--return to base

SAM--surface-to-air missile

SAS--stability augmentation system

SAT--satellite

SIGINT--signal intelligence

SL--sea level

SMS--stores management system

S/N--signal to noise ratio

SPD CONT--speed control

STU--signal transfer unit

SUAWACS--Soviet Union airborne warning and control system

TAS--true airspeed

TF/TA--terrain following/terrain avoidance

TGT--target

TH--true heading

T/R--transmit and receive

V--velocity

VFC--visual flight conditions

VHF--very high frequency

VSD--vertical situation display

WCS--weapon control system

WECC--workload evaluation for cockpit crews

WFOV--wide field of view

X-hair--crosshair

αN--alphanumeric

# SECTION I

## INTRODUCTION

The U. S. Air Force let two contracts to The Boeing Company to develop an integrated presentation and control system concept that will cast the man-machine system into an effective tactical fighter weapon system during normal and degraded mode operations. These studies represent elements of an Air Force plan to develop an effective tactical fighter weapon system for the 1980 time period in deference to the requirements generated by the following postulation.

Developmental trends in high-performance aircraft and avionics are expected to result in a proliferation of controls and displays that demand an unprecedented level of occupation by the pilot--particularly those pilots flying advanced tactical fighters. Mission requirements for future tactical fighters will dictate system capabilities that will cope with not only the diverse environs of geography and weather both day and night, but also with the various gradations of cold, hot, and limited wars. The tactical fighter's arsenal must then range from guns to nuclear weapons with the gamut of conventional weapons between.

To be effective in its role, the tactical fighter weapon system must be capable of pinpoint navigation and high-accuracy weapon delivery. Additional complications include weapon deliveries at low altitude and supersonic speeds requiring a highly discriminatory and rapid target acquisition capability.

Technology in the 1980 time period will enable production of tools necessary to complete a complex mission; however, the pilot faces the overwhelming task of collecting, collating, integrating, and interpreting a mass of information during normal operations.

A system designed to serve the complex needs of an advanced tactical fighter may be expected to be vulnerable to equipment failure and battle damage. The weapon system must enjoy a high probability of survival and mission completion to be effective. As such, the capability to continue operations after sustaining failures to an identifiable level is considered mandatory.

Contingency operations impact the pilot's workload and may jeopardize mission success. The tactical fighter must have the controls and displays necessary to ensure that an effective weapon system is provided during all modes of operation.

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An integrated control and display system that presents only essential information in a format that can be translated easily by its user into direct control inputs must be developed. Many of the pilot's routine and repetitive tasks suggest automation to alleviate his workload.

# SECTION II

## SUMMARY

Two studies, "Integrated Information Presentation
and Control System Study," and "IIPACS Degraded Mode Study,"
herein referred to as IIPACS-1 and IIPACS-2, have resulted
in a systematic development of a tactical fighter cockpit
concept for use in the 1980 time period. The system pre-
sented provides the pilot full capability for effective on-
line overall weapon system management for normal and
degraded mode operations.

The systematic approach used in the IIPACS-1 study
is diagrammed in Figure 1. The level of automation required
to achieve the desired results is depicted in Figure 2.
System concepts, the aircraft seen in Figure 3, and three
cockpit configurations, Figures 4, 5, and 6, represent the
results of this study.

Figure 7 presents the program flow chart for IIPACS-2.
The results of the updating of IIPACS-1 and the degraded
mode analysis may be seen by comparing the IIPACS-1 wrap-
around cockpit layout, Figure 8, and the IIPACS-2 configura-
tion, Figure 9. A digest of the updated IIPACS avionics
system is presented on the pages following. The IIPACS-2
interface diagram and cockpit arrangement are enclosed in
a holder attached to the back cover of this document.

The conclusions reached on the basis of this study
indicate that the concepts presented will, if mechanized,
result in a weapon system that meets the needs for a
tactical fighter of the 1980 time period.
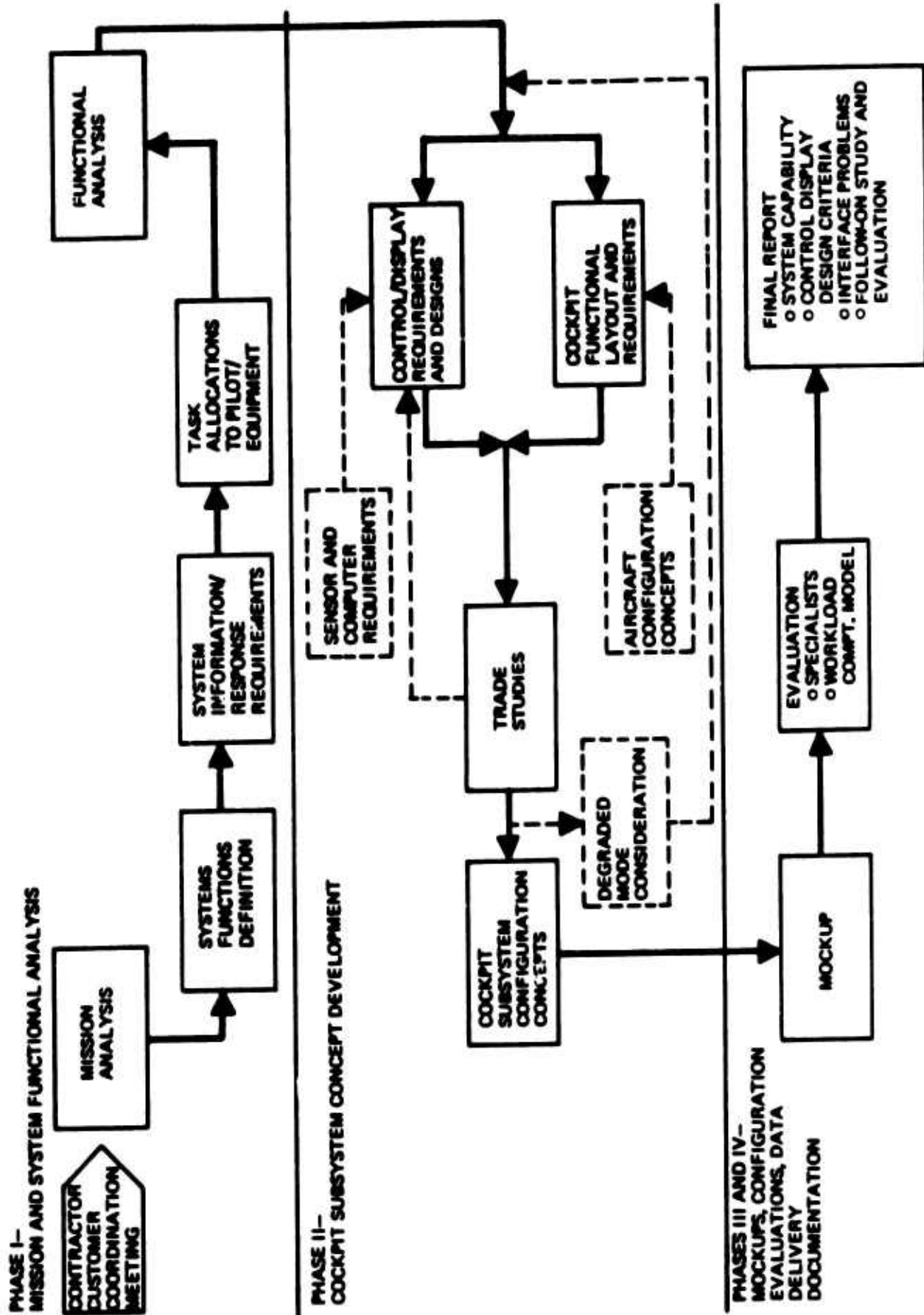
Figure 1. II PACS-1 Program Flow Chart

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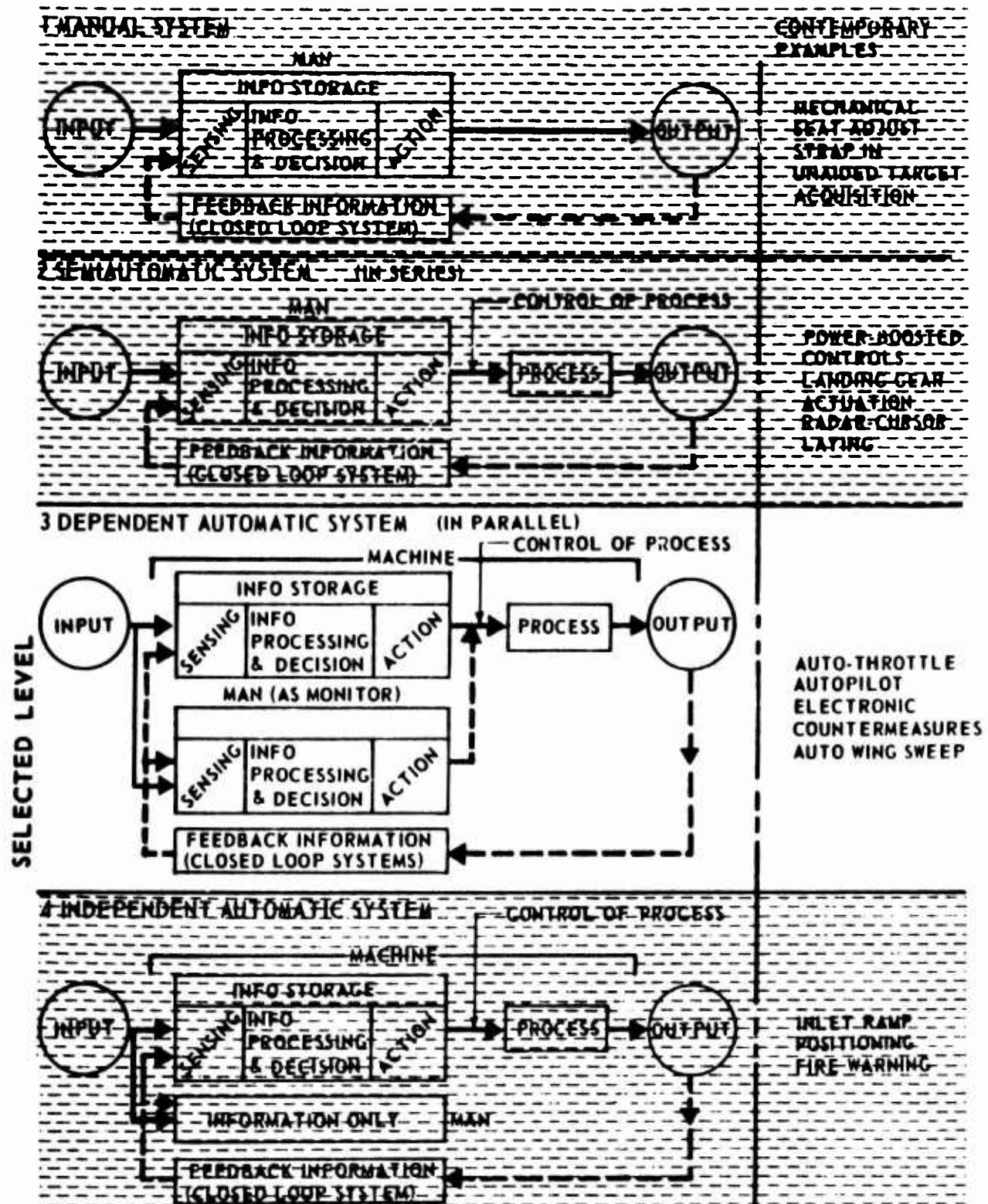
NOTE: ADAPTED FROM HUMAN FACTORS ENGINEERING: E.J. McCORMICK  McGRAW HILL INC. P 13

Figure 2    Man Machine Relationship

5
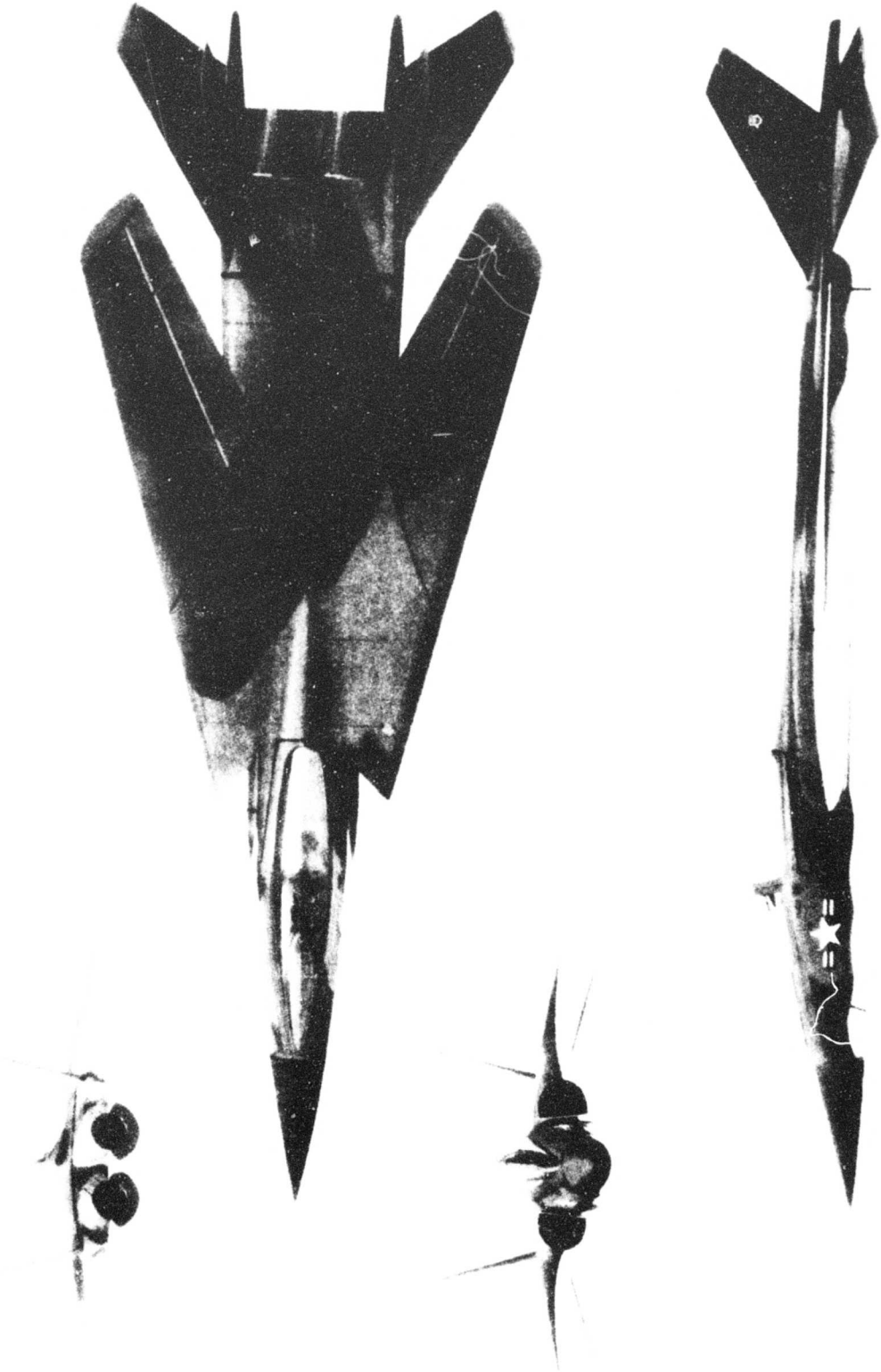
Figure 3. Study Aircraft
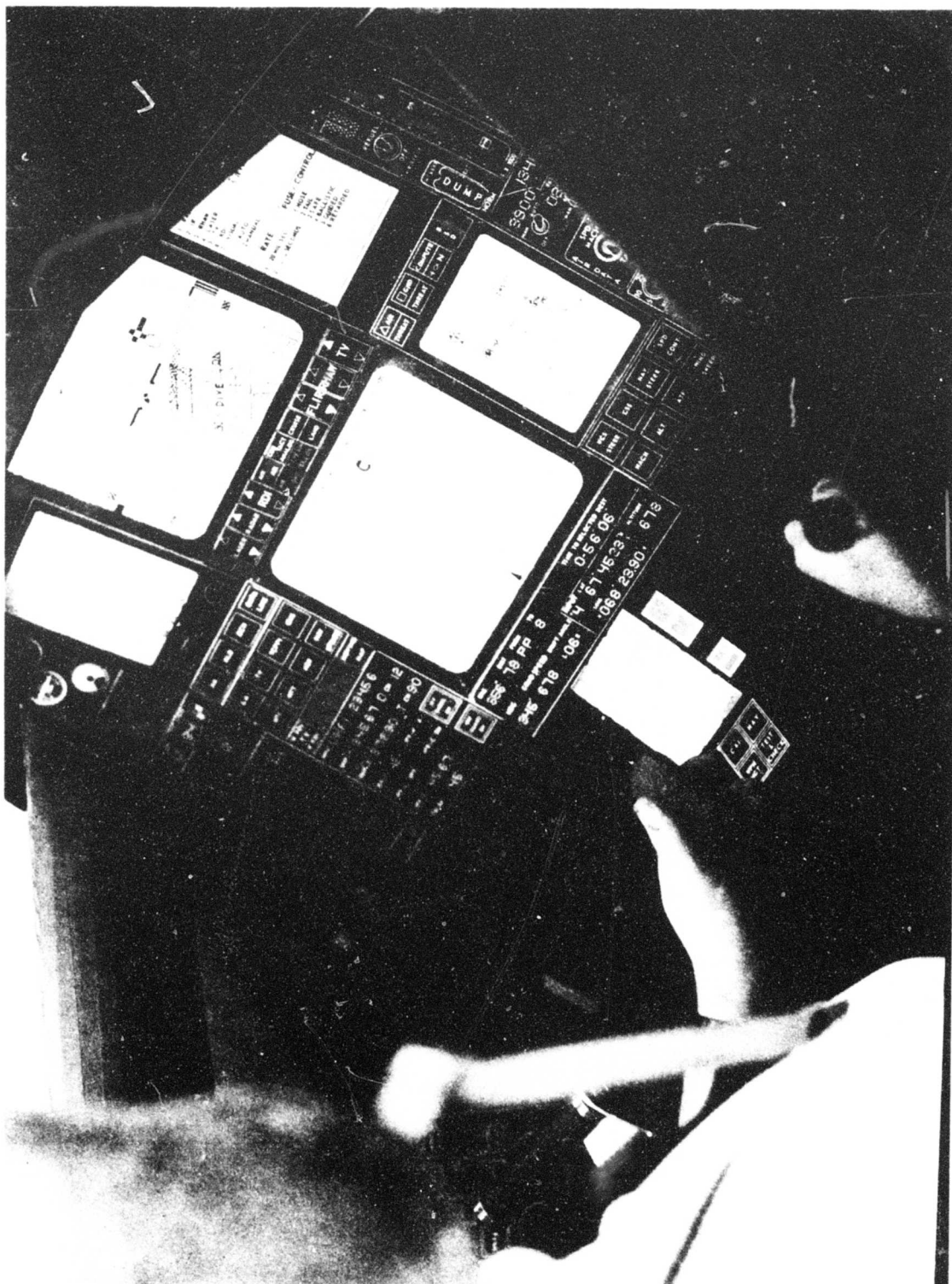
Figure 4. Center Stick Cockpit

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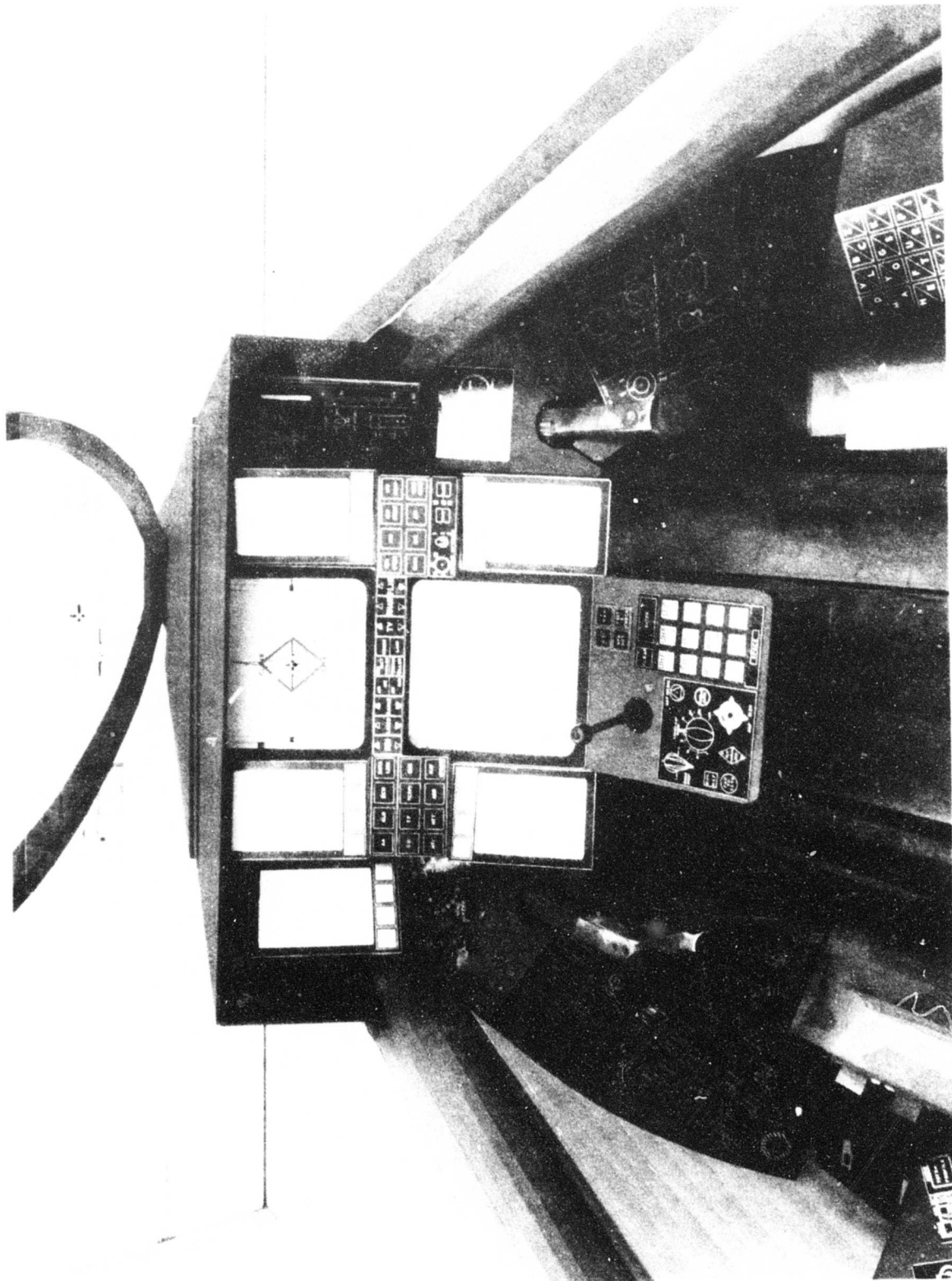
Figure 5. Panel Mounted Control Handle Cockpit
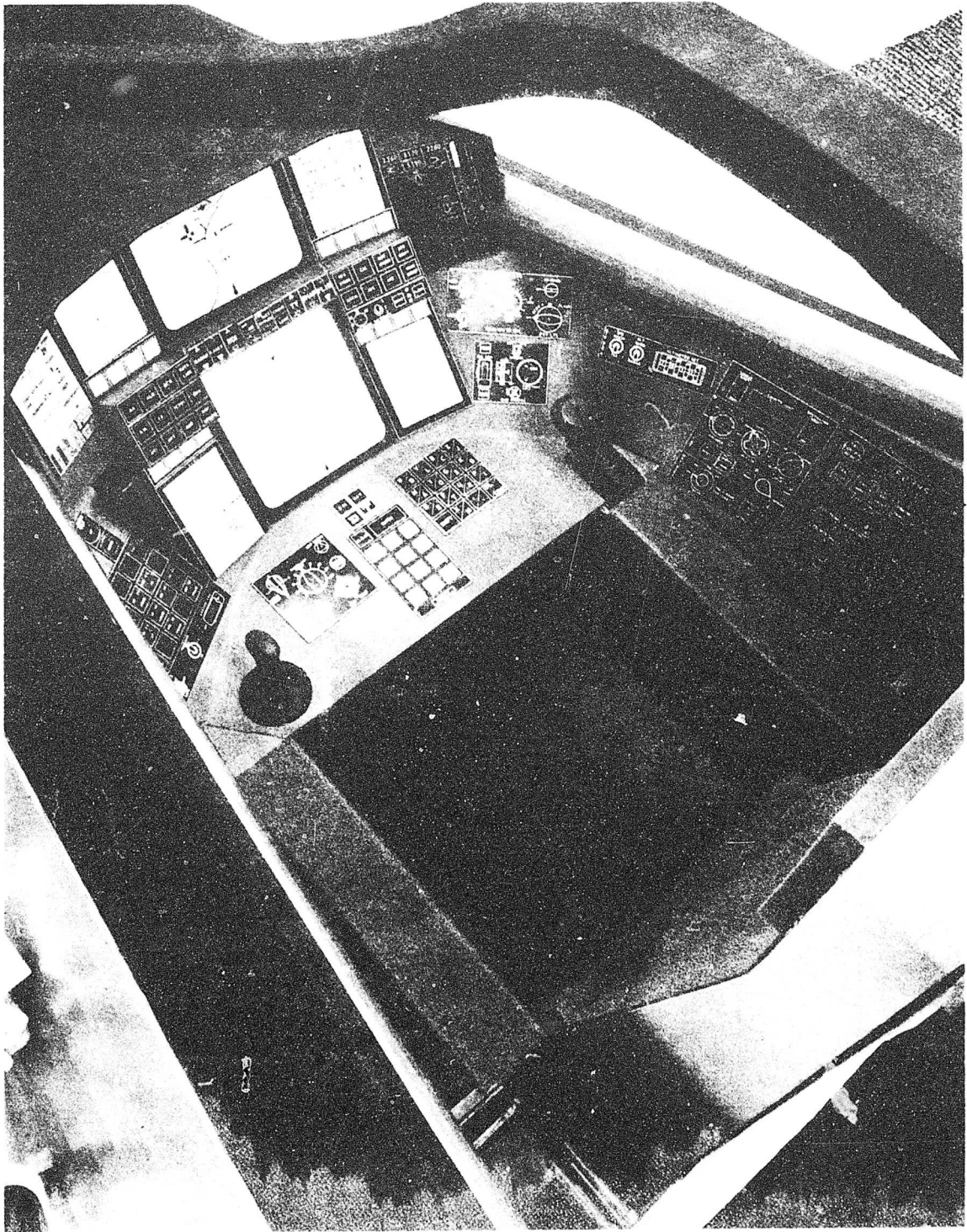
Figure 6. Wraparound Cockpit

**PHASE I**
**DEGRADED MODE SURVEY**

**PHASE II**
**DEGRADED MODE ANALYSIS AND DESIGN**

**PHASE III**
**MOCKUP AND EVALUATION**

**PHASE IV**
**DATA DELIVERY AND DOCUMENTATION**

IIPACS-I STUDY

RELIABILITY SURVEY

DATA ACQUISITION

SELECT FAILURE MODES

FUNCTIONAL FLOW BLOCK DIAGRAMS

SYSTEM INFORMATION ACTION REQUIRE-MENTS

MAIN MACHINE TASK ALLOCA-TIONS

EQUIPMENT TRADE STUDIES AND DESIGNS

CONTROL DISPLAY MOCKUP

AVIONIC INTER-FACE

EVALUATION

DOCUMENTATION

*Figure 7.    IIPACS–2 Program Flow Chart*

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Figure 8.   IIPACS-1 Wraparound Cockpit

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Figure 9.   IPRCS-2 Wraparound Cockpit

FAILURE MONITOR AND CONTROL

Equipment

General Description

Failure Monitor and Control
System (FMACS)

A programmed control system that performs on-
board test and checkout function of all aircraft
systems. While airborne these functions include
system status to the pilot and to remote moni-
tors via data links; provide warning of flight
safety conditions, automated corrective actions,
and display of these actions; and provide
notification of impending failures. On the
ground, these functions include automatically
controlled preflight, flight/mission readiness,
and fault isolation tests.

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COMMUNICATION/IDENTIFICATION

| Equipment | General Description |
|---|---|
| HF | Basic long range air-to-air and air-to-ground communications, with voice AM/SSB provisions; provides backup to Satellite relay link during Spread-Spectrum communications. |
| Spread-Spectrum Communications (SHF Band) | Basic secure voice/data link communication system between the IIPACS Aircraft and Command and Control; provides additional functions of "Guard" and IFF backup; computer programmed for spherical coverage--omni or directional beam control; compatible with integrated conformal/phased array antenna system. |
| Data Link | Provides data link for commands, messages, systems status (FMACS), processed sensor video, and battle damage assessment recorded data when transmitted via spread-spectrum communications. |
| Satellite | Relays RF information (voice/data) between IIPACS Aircraft and Command and Control at the spread spectrum frequencies. |
| IFF (Transponder) | Provides omnidirectional RF-coded response in answer to a spread-spectrum or radar interroga-tion pulse from a ground or airborne station. |
| IFF (Interrogator) | Interrogates other aircraft automatically at specified bearings when directed by other on-board systems through the central computer. Supplies coded interrogation instructions to the Multimode Radar and Spread-Spectrum Communica-tions during air-to-air encounters. In addition to "automatic" interrogation by the computer, means are provided for "manual" interrogation with either Dir. Comm. or Radar, after the target has been designated with the cursor. |

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FIRE CONTROL SUBSYSTEM EQUIPMENTS

| Equipment | General Description |
|-----------|--------------------|
| Multimode Radar | Conformal/planar array operating at X-band. Electronically scanned; electronically stabilized; spherical coverage; operating modes--terrain-following/terrain-avoidance,air-to-air target search/track, missile illumination, high resolution mapping (squint, spotlighting, and doppler beam sharpening), conventional mapping, ground moving target indication, situation, and beacon. Integrated with air-to-air IFF at X-band. |
| LLLTV | Electrostatic image orthicon with SEC target material and S-20 photosurface; 1000 TV lines resolution reducing to 500 lines at 10 ft-candles illumination; fibre optics image recitification; 18° by 24° total field of view (positionable over 360°) with both optical and electronic zoom to 3:1. |
| LASER | High power narrow beamwidth pulse type; provides accurate range and range-rate information to the aircraft weapon delivery system when used with LLLTV and FLIR. |
| FLIR | Passive infrared system operating on the temperature and emissivity of objects against a background; uses a technique known as opto-mechanical scanning; same field of view (18° by 24°) as LLLTV and positionable over 360° azimuth with both optical and electronic zoom to 3:1; uses common optics with LLLTV with scanning at 1024 lines and 30 frames per second. |

DISPLAYS

| Equipment | General Description |
|-----------|---------------------|
| HUD | Fold down storage of combiner glass; 20° vertically by 25° horizontally total field of view; automatic brightness level control; optically flat liquid crystal combiner; unique features of presenting Weapon TV/LLLTV/FLIR on a 1.5-inch elliptical area—focused to infinity; symbology and sensor data can be viewed in either day or night background conditions. The HUD has dual reticle (fixed and slaved) provisions and a built-in 16mm camera for simultaneous recording of all sight displays and the real world. |
| VSD | A 10-inch diagonal viewing surface; 1,024 TV line direct view color CRT that presents information of flight situation, control, and weapon delivery in an integrated form; uses digital display techniques data presentation in raster scan; CRT uses image enhancement techniques that will ensure proper visibility under all ambient light conditions; subsystem operational MTBF of 2,500 hours. |
| HSD | A 10-inch diagonal viewing surface interchangeable with the VSD; selectively combines CRT display information with a computer-generated, full-color moving map; provides present position, en route, target and terminal information as the situation dictates; composite combinations of full-color map and processed sensor data (MMR, LLLTV/FLIR, and Battle Situation) are available, depending on pilot selection and flight mode; oriented with either north or aircraft heading at the top of display. |

DISPLAYS (Contd)

General Description

Equipment

MPD's

A total of five displays with 3-1/2 by 4-1/2 inch
viewing surface are grouped around the VSD and
HSD; any one of five stored presentations can be
selected manually or automatically; calligraphic
information and maps are presented in various
colors while sensor information will be in shades
of one color.

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PENETRATION AIDS

| Equipment | General Description |
|---|---|
| RHAW and IR Warning Receiver | Threat energy sources are primarily in the S-through K-band and in the IR region. Passive receivers are provided to measure threat emission characteristics and threat direction. The central computer complex processes these data and determines threat identity. |
| RF and IR Jammers | An IR (tail) jammer and RF automatically computer programmed jammers are used to jam primary threat transmissions. Computer programming for the jammers is inserted with the cassette. |
| Countermeasure Dispensing System | Two dispensing systems, one on each side of the airplane are provided to selectively release a wide variety of prepackaged expendable counter-measures including chaff, flares, and expendable jammers. |

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CENTRAL COMPUTER COMPLEX

| Equipment | General Description |
|-----------|---------------------|
| Computer | The computer is extremely reliable because the IIPACS airplane is highly automated. The central computer is functionally integrated for maximum use but it contains separately located components to minimize performance degradation due to localized battle damage.<br><br>Computer performance estimates are for about one million operations per second using 130,000 memory locations. The minimum level of computing power, acceptable in degraded modes, is about one-half the normal computer size; that is, 500,000 operations per second and 65,000 memory locations. |
| Interface | Signal processors, buffers, switching circuits and other computer interface elements are included with the central computer complex. Both hard-wired and multiplexed circuits are used. A basic computer and avionics design requirement is to minimize heavy, costly interface. |

STORES MANAGEMENT SYSTEM

| Equipment | General Description |
|-----------|---------------------|
| Coded Switch Control | Replaces the prescribed action link (PAL) for nuclear weapons. Provides a means for manual insertion of the control code for nuclear consent. |
| Central Logic Unit | Includes interface logic and switching circuits needed to command and to secure status for all weapons. By integrated functions common to all weapons into a single central logic unit, lower cost and weight systems result. |
| Station Logic Unit | Used with the central logic unit. It includes only uncommon functions for particular weapons. The unit is located at the weapon station and is the only subsystem that must be changed or replaced when a different kind of weapon is loaded on a specific stores station. |

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NAVIGATION

| Equipment | General Description |
|---|---|
| Inertial Platform | Two inertial measuring units are provided. Associated computations are performed by the central computer complex. Accuracy is improved by including doppler from the multimode radar and by using Kalman error estimates. To minimize errors, inertial, satellite and all other sources of useful navigational data are compared. |
| Radar Altimeter | A conventional radar altimeter is provided to measure aircraft height above terrain. A second way to measure height above terrain is available with the multimode radar. |
| Satellite | Satellite navigation (NAVSAT) is the most accurate on-board means for navigation without fix updates. Satellite navigation is used when accurately placed navigational satellites are available. A receiver for satellite signals is provided. |
| Landing Aids | A receiver is included for ILS. The multimode radar, operating in a passive mode, is used to receive beacon ILM signals. GCA transmissions are received over the data link. The multimode radar, in an active mode, is used for AILA. |
| Heading and Attitude Reference System (HARS) | For improved accuracy in degraded modes, the HARS is a low quality inertial system. This allows for earth latitude error corrections if inertial system failures exist. With this feature, added navigational redundancy is provided. Including the HARS provides triple redundancy for fail operational performance in critical mission segments. |
| Air Data | Included are probes for ambient temperature, ambient pressure, dynamic pressure and ram air temperature. Anti-ice provisions are included. Air data computations are performed by the central computer complex |
| TACAN | Provides range and bearing to a known surface location. Primary use, with aircraft in-talled ground components is |

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NAVIGATION (Contd)

General Description

| Equipment | |
|---|---|
| TACAN (Contd) | for station-keeping and rendezvous. TACAN ground stations in war theaters are limited, and extensive use as a basic navigational method is sometimes restricted to peacetime operations. |
| Collision Avoidance | Time-frequency system synchronized to a ground station master time source. Transmits precise range, altitude and range rate information to other aircraft where data is analyzed and presented to the pilot as a warning if a collision is imminent. |

## SECTION III

## RESULTS AND DISCUSSION

1.   GROUND RULES AND ASSUMPTIONS

The cockpit of the tactical fighter is the focal point for the aircraft's systems and subsystems. Definition of the aircraft and its avionic system is a necessary first step to the development of an integrated control/display complex. The aircraft and avionic systems were developed within the framework of the following ground rules and assumptions:

Ground Rules

   o   One-man crew

   o   F-15 M-5 avionics package as a baseline system

   o   Air-to-ground combat is the primary operational mission

   o   Time-shared display techniques

   o   1980 avionics state of the art

   o   Pilot retains executive control over an automatic system

   o   Systems approach in the analysis

Assumptions

   o   Twin-engine airplane

   o   Maximum speeds: Mach 2.5 at altitude and 1.5 at sea level

   o   Air-to-air defense capability (M-5)

   o   Variable sweep wing

   o   Conventional takeoff and landing capabilities only

   o   Digital avionics interface

   o   System cost, weight, and reliability secondary considerations to crew performance

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## 2. MISSION PROFILE

The mission profile, Figure 10, was developed to determine system requirements. The profile is based on a composite mission and describes the assumed operational capability of the advanced tactical fighter. The lower profile plots time, in hours, on the abscissa against altitude. Significant events along the profile are identified. Mach number, as related to time and task, is indicated in the plot directly over the mission profile.

For clarity, a plan view and a three-dimensional view, Figures 11 and 12 respectively, augment the mission profile.

Mission segmentation facilitates analysis by providing smaller and more convenient units for study. The mission profile was divided into units of time for developing timelines and workloads. It was also divided into eight phases of flight to provide manageable elements to examine in the analysis, Figure 13.

In a sense, the composite mission for which the flight profile was drawn is unrealistic. The aircraft was launched to provide close air support. Ordinarily, the ordnance loading mix for such a mission would not permit the additional engagements imposed on this particular flight. The purpose of this approach to the problem is to create a worst case situation that is designed to subject the pilot to the most severe operational environment possible in terms of workload and endurance.

## 3. MISSION SCENARIO

The mission scenario, presented in the following paragraphs, describes the mission profile in an expanded form through narration.

In the ready room, Alpha Leader and his flight are in an alert status for a close air support mission. Checking the weather in the vicinity of potential battle areas, Alpha Leader finds that there is a deteriorating trend. At present, there is heavy cloud cover from approximately 2,000 feet above the terrain up to 27,000 feet. Briefings are received of the general battle situation, communication frequencies, ordnance loads, and the specific areas in which enemy surface-to-air missile (SAM) firings can be expected. Alpha Flight is assigned to Forward Air Controller (FAC) Charlie. After a quick run to the plane, the engines are started and all systems are checked for a go status. Calling the remainder of the flight, Alpha
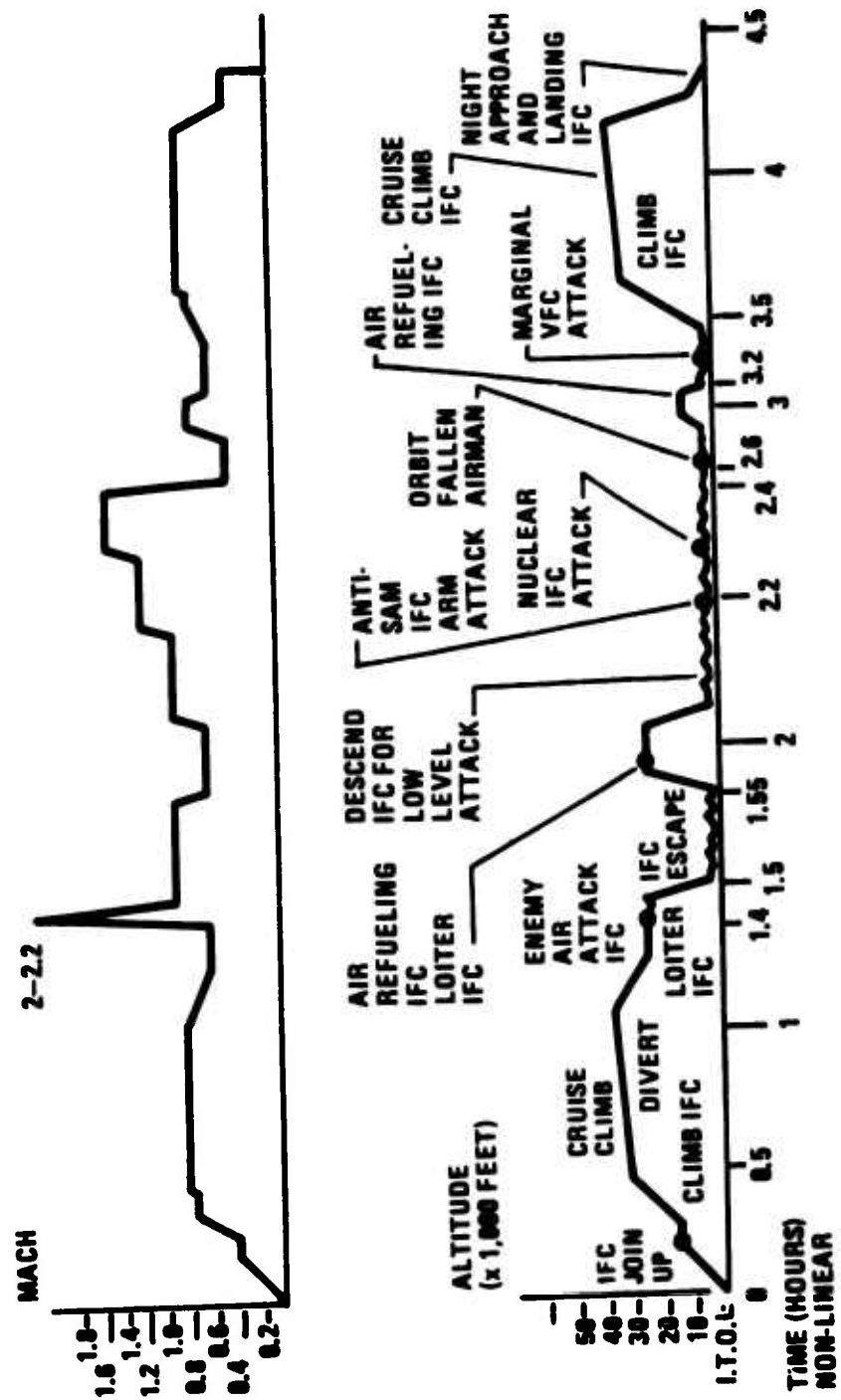
Figure 10. Mission Profile

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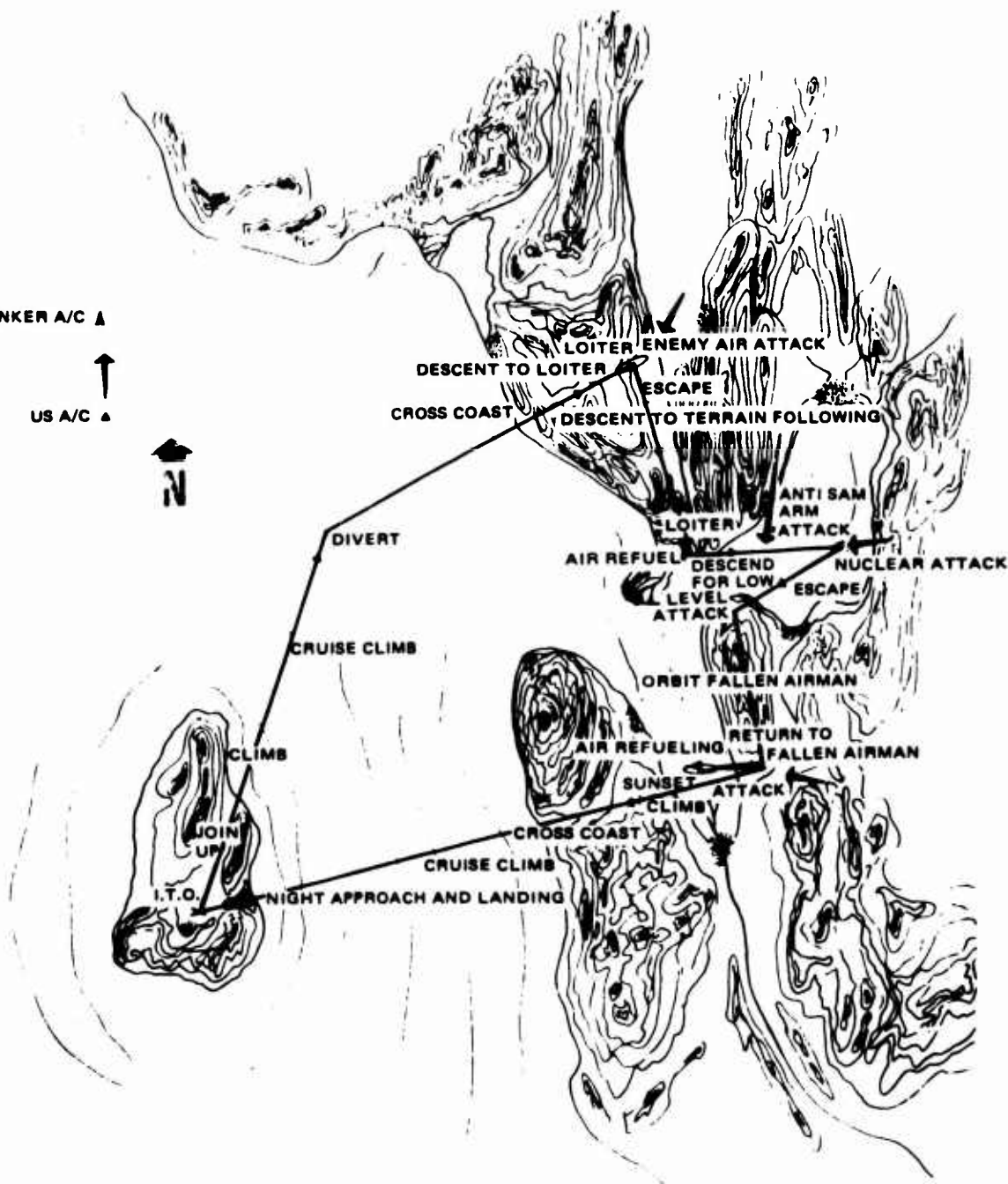
Figure 11. Mission Profile

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Figure 12. Mission Plot

LOITER AND
AIR-TO-AIR COMBAT

REFUEL
LOITER

TERRAIN
FOLLOWING

DELIVERY
SAM SITE

NUCLEAR WEAPON
DELIVERY

ORBIT DOWNED PILOT

AIR-TO-GROUND
MISSILE DELIVERY

DIVERT

REFUEL

IFR APPROACH

CLIMB OUT AND
RENDEZVOUS

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AIR TO-GROUND COMBAT

LOITER   A/R COMBAT   CLIMB   AIR REFUEL   LOITER   LOITER   CLIMB   AIR REFUEL   DESCENT   A/G COMBAT   LOW LEVEL

ENEMY AIR ATTACK IFC   IFC ESCAPE DESCENT TO TERRAIN FOLLOWING ALTITUDE   AIR REFUELING IFC   LOITER IFC   DESCEND IFC FOR LOW LEVEL ATTACK ANTI-SAM IFC ARM ATTACK   ORBIT FALLEN AIRMAN   AIR REFUELING IFC   RETURN TO FALLEN AIRMAN

NUCLEAR IFC ATTACK   ESCAPE   MARGINAL VFC ATTACK

TERRAIN FOLLOWING ALTITUDE

Figure 13. Mission Profile

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Leader determines that all are OK. Ground Control is
contacted and an immediate clearance is obtained to taxi
to runway 31. As the end of runway 31 is approached,
Alpha Leader calls the tower to obtain clearance for
takeoff. The tower has previously cleared all planes
from the landing approach and departure zones. Alpha
Leader and his flight are cleared for individual take-
offs with 15-second intervals. Cleaning up the airplane,
Alpha Leader contacts Departure Control for a steer
to the rendezvous point. Clearance and steers are
received. When rendezvous employing station-keeping tech-
niques is completed, a handoff from the Departure Control
to Battle Area Controller is made. Departing the coast,
visual flight conditions are encountered just before
reaching cruise altitude.

Cruise climbing toward the target area, control is
passed to FAC Charlie. Charlie briefs the flight on the
situation, but does not assign specific targets because
the situation is too fluid. Before reaching the assigned
loiter area, Charlie reports that the situation is taken
care of by ground action, and he releases Alpha Flight.
Battle Area Control is contacted for a new assignment.
The flight is diverted to a loiter area for FAC Pine Tree.
Passing the coastline, the flight arrives in the vicinity
of Pine Tree. The flight drops to optimum loiter altituae
and a briefing is received. Targets are not assigned at
this time, but Pine Tree confirms that Alpha Flight will
be needed soon.

A warning of enemy fighters heading for the loiter
area is received from Battle Area Control. Alpha Leader
acknowledges receipt of the warning and, in anticipation
of an air-to-air combat situation, selects and arms a
weapon. Heading and altitude commands are received from
Battle Area Control that should provide minimum intercept
probability. On-board warning devices indicate a tracking
condition and countermeasures are employed successfully
countering the attack. As the enemy passes Alpha Leader,
he determines that he is in a position to attack and
releases the selected air-to-air weapon. The area con-
troller indicates that another enemy plane is maneuvering
into an attack position. Alpha Leader elects to head for
the ground and employ instrument flight terrain following
tactics to avoid further attack. Battle Area Control
soon advises that the threat is over and that Alpha Flight
should return to loiter. Because of the unscheduled
diversion to a new target area and the air-to-air combat
episode, Alpha Flight air refuels while loitering.

During loiter, FAC Pine Tree briefs Alpha Leader
on the target and battle situation. The target is a large

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group of airborne troop-carrying vehicles reported by a picket craft to be moving across an expansive bay. A tactical nuclear weapon attack is authorized.

The attack path is guarded by a SAM site. Hoping to escape detection by employing terrain following, Alpha Leader descends to minimum instrument flight terrain following altitude. Arming an anti-radar missile (ARM), he continues to his assigned target on autopilot. On-board warning devices indicate sporadic tracking by SAM radar. Alpha Leader "pops up" and with an offset tactical maneuver he negates the SAM threat with the ARM weapon and returns to terrain following.

Doglegging as he proceeds to the target area, he elects to use electronic coordinates for fire control purposes, in lieu of line-of-sight sensors, to preclude further detection. Friendly forces in the area are advised of the zero time and coordinates of the impending nuclear attack. Alpha Leader configures for nuclear effects protection. Battle Area Control inserts the first arming vote into the tactical nuclear weapon and, nearing the Initial Point, Alpha Leader inserts the second arming vote. The weapon delivery and airplane escape maneuvers are executed on autopilot, and the target is destroyed.

Alpha Leader calls his flight to determine their status. Alpha Red is having propulsion trouble due to ground fire over enemy territory in a nearby sector. The condition deteriorates rapidly and Alpha Red elects to eject. Alpha Leader calls the remainder of the flight and sends them to the loiter area to await further assignment. Then he monitors Alpha Red's landing. The automatic beacon included in the escape package will only be used intermittently since it might pinpoint Alpha Red's position for enemy forces known to be in the vicinity. Alpha Leader calls Battle Area Control and requests that a rescue team be sent to pick up Alpha Red. The rescue craft are about 20 minutes away. Alpha Leader must stay on the scene to give the rescue craft an exact position and to afford protection for the downed pilot. Anticipating the need for refueling, Battle Area Control has dispatched a tanker to refuel Alpha Leader. At dusk, refueling in instrument flight conditions is completed about the same time as the rescue craft arrives. It is directed to Alpha Red's position.

Sweeping the area with the on-board sensors, the displays show a vehicle to be making its way toward Alpha Red. Nearing Alpha Red's position, Alpha Leader drops his plane below the cloud cover but cannot visually sight the vehicle hidden by the foliage. He assumes the vehicle to

be armored and selects and arms an appropriate weapon.
Using the provided sensors and displays, Alpha Leader
locates his target. One mile from the target in the
diminishing light, he makes a final visual check that
confirms the target to be an armored personnel vehicle.
The selected weapon is dispensed using the armament control
system in conjunction with the on-board sensors.

With the enemy threat removed, Alpha Leader climbs
to altitude to make the flight back to base; he crosses
the coastline relaxed, hungry, and thirsty. He takes a
candy bar from the sustenance compartment and drinks some
water. Otherwise, the night instrument cruise climb back
home is uneventful. All systems are checked and a report is
made to the home base maintenance group so that they will
have everything ready for his return.

As the base is neared, control is passed from Battle
Area Control to the Approach Controller. Contact is made
and an approach is established. Since the beginning of
the mission, the weather conditions at the base have gotten
worse. A heavy but patchy ground fog obscuring the runway
necessitates an instrument landing. As the airplane is
lined up on the landing beam, Alpha Leader is switched over
to the Final Controller for landing. Upon landing, Alpha
Leader switches to Ground Control for taxi instructions to the
assigned revetment. As the plane is parked and before the
engines are shut down, maintenance personnel, who have been
awaiting the arrival of Alpha Leader, make a final check
of all systems.

4.    AIRCRAFT SYSTEM CONCEPTS

To ensure currency with the latest and projected
technology in the related fields, fact-finding visits were
conducted both to military and industrial facilities.
A summary of these visits is given in Appendix II. Only
successfully demonstrated equipment, at least at a labora-
tory level, was considered as a candidate component for the
advanced tactical fighter. Boeing fighter studies, Boeing
consultants, and interviews with military personnel with
recent operational experience (Wild Weasel) were sources of
additional information.

The systems described are presented in the present
tense--as though the system existed in actual hardware form.
Equipment identified in contemporary terminology is done
so in the generic sense only. The intent in these cases
is to describe the function a system performs rather than
existing 1970 hardware.

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a. Aircraft Description and Performance

Figure ? shows the study airplane. Its maximum gross weight is approximately 52,000 pounds, which includes a 12,000-pound ordnance payload and 1,000 rounds of 20mm ammunition in addition to fuel. At a weight of 41,000 pounds, the design load factor is 8.0. Surface loading varies from approximately 120 pounds per square foot with wings out to 100 pounds per square foot with wings in at combat weight. Using engines strengthened for operations to Mach 1.5 at low altitude, the thrust-to-weight ratio is 1.4 at a combat weight of 35,000 pounds.

Sustained operations of Mach 1.2 in afterburner at sea level may be expected with a dash capability of Mach 1.5. At optimum altitude, speed performance is Mach 1.6 at military power, Mach 2.3 sustained, and Mach (dash) 2.5 with a variable inlet or Mach (dash) 2.4 with a fixed inlet. Dash speeds are temperature limited and may be held for about 1 minute. At military thrust, a speed of Mach 0.98 may be achieved at sea level carrying a full ordnance load.

Since the mission places primary emphasis on air-to-ground weapon delivery, the airplane's engines and inlets are optimized for low-altitude high-speed operation. Although the mission requires effective weapon delivery under instrument flight conditions, certain aspects of the stipulated close-support mission (e.g., troop strafing, etc.) require visual capability for the delivery of ordnance. Accordingly, the airplane concept is configured to provide the pilot with downward vision over-the-nose that will meet all mil lead requirements for the firing of guns and the release of stores (before target passes from view under the nose). A depression angle of 15° from the horizontal provides this capability using any existing ordnance except certain high-drag bombs that have some release parameters requiring larger angles. The over-the-nose vision provided also permits 4° descent path landing approaches to forward area bare bases without having the aircraft's nose obscuring direct view of the runway. Advanced base operations require relatively steep visual and instrument approaches to a landing. A vision plot from the eye reference point is presented in Figure 14.

The requirement for an automatic variable-sweep wing was dictated by the desire to achieve optimum lift-to-drag ratios for low-altitude attack operations over a broad velocity spectrum. A manual control option enables the pilot to improve airplane ride quality in turbulent air. In addition, the variable sweep wing

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ATOFF'S EQUAL AREA PROJECTION OF THE SPHERE
radius of projected sphere equals one decimeter
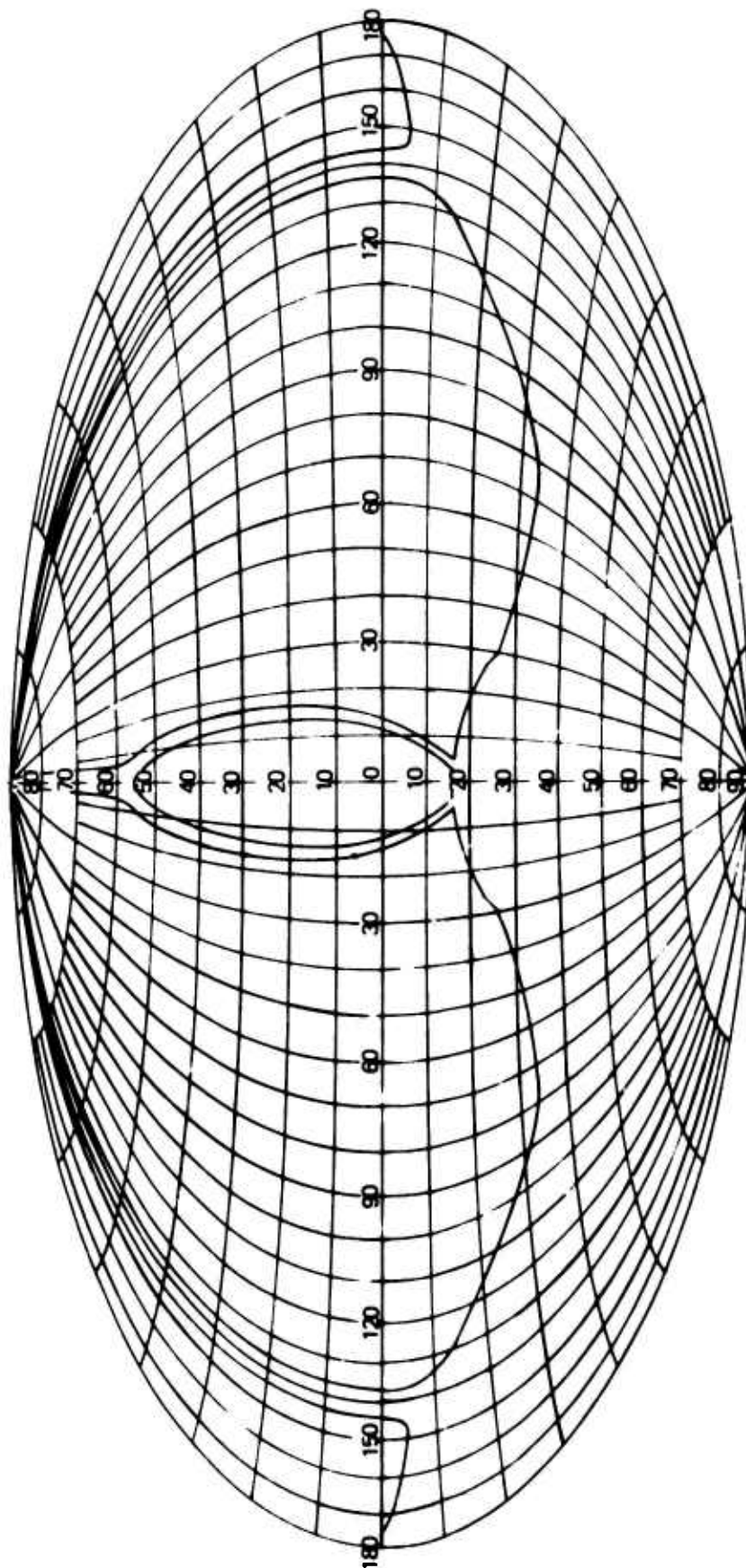


Figure 14.  Vision Plot

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aircraft provides superior short-field takeoff perform-
ance over that of a comparable fixed-wing aircraft.

   b.  Aircraft Systems

      The systems that comprise the overall tactical
fighter's weapon system are identified in the Interface
Diagram (located in pocket inside back cover).  Each
system was examined in every flight segment to determine
the impact of the failure, first on safety of flight and
then on mission completion.

      Although the systems were ranked according to
probability of failure, it was decided to assume battle
damage and examine all critical systems in every segment
of the mission.

      The requirement for a sophisticated failure
monitor and control system (FMACS) resulted from the failure
ranking study, Appendix I.  Data acquired for this study
showed that less than one-fourth of the listed aircraft
failures are detected in flight.  Although some failures
may be maintenance induced, indications were that a better
failure detection system was needed; consequently, the
FMACS was conceived.

      The following design concepts include a descrip-
tion of the contingency operation provisions added to the
system as a result of degraded mode considerations.

      (1)  Flight Control

      The primary control surfaces of the aircraft
provide flight control along all three planes of operation.
The primary control surfaces include movable horizontal
stabilizers, rudders, and flaperons incorporating artifi-
cial feel devices.  Continuous automatic damping about the
three axes of the airplane is provided.  A self-adaptive
gain system is incorporated to optimize aircraft response.
The spectrum of conditions to which the self-adaptive
gain system is tuned is modified by the mode of flight
selected.  Control harmonization (responses to the
controls with respect to the other controls) is also
affected by the mode of flight selected.  Adverse yaw
compensation provides signals to the rudder to reduce
control cross-coupling effects.

      The movable horizontal stabilizers, con-
trolling pitch, are augmented by redundant thrust vector
controls.  A high degree of maneuverability is achieved
by optimizing the coupled action of the two pitch control
devices.

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Yaw control is achieved by symmetrical displacement of the twin rudders. Roll control is accomplished by spoilers and stabilons. In the forward angles of wing sweep, spoilers and flaperons serve as roll controllers.

High-lift devices include leading-edge slats and slotted flaps. Direct lift control is accomplished with the flaperons. The slats are stressed for use during maneuvers involving high dynamic loadings.

Spoilers and thrust reversers are intended for both landing and in-flight use.

The survivable flight control system combines fly-by-wire aircraft control with duplex integrated hydraulic servo-actuator packages installed at each flight control surface location.

Each package contains a dual hydraulic actuator, two independent hydraulic power sources, and a quadruple signal path control unit. Each hydraulic power source is supplied electrical power from separate power sources; if electrical distribution malfunction occurs, power may be supplied through the auto bus tie, the Auxiliary Power Unit (APU), or a DC source. Reliability provided by this arrangement is considered equal to that of current mechanical/hydraulic systems.

Malfunction and warning of failure of any power or signal channel are presented to the crew as a caution warning of a single channel failure. Warning is presented by a flashing master caution light and a warning readout on the MPD. A single channel failure is not cause for an abort. If two channels fail, either power or control, the warning changes to a no-go situation prior to bomb safe line or point of no return. Warning would be presented by a flashing master caution voice warning and a readout on the MPD; the mission should be aborted. If this type failure occurs after passing the bomb safe line, decision to abort is at pilot's discretion.

(2) Propulsion

The aircraft is powered by two low bypass turbofan engines equipped with afterburners. Interchangeable engines, mounted side by side, may be started by the on-board APU. The engines are strengthened for dynamic pressure loadings through Mach 1.5 at sea level. Bleed air from either operating engine provides the means for starting the other.

(3)  Fuel

The aircraft fuel system consists of self-sealing wing and fuselage tanks filled with polyurethane to reduce sloshing.  Internal fuel capacity is 10,000 pounds.  An additional 5,000 pounds of fuel may be carried in inflatable auxiliary fuel tanks.

An inert gas or a fuel spray enrichening blanket is used to minimize fire and explosion hazard during combat.  External fuel is carried in inflatable auxiliary tanks or may be carried in drop tanks.  The system is designed so that all fuselage stored fuel may be drawn off by the engine-driven pumps if boost pumps fail.

The normal position of the cg control switch on the fuel system control panel permits the central computer complex (CCC) to control the distribution and transfer of fuel as required to maintain the aircraft cg within specified limits for any selected flight mode. This position affords the CCC flexibility in fuel management.  If degradation occurs, it will automatically select alternate methods of controlling the cg.  At some level of degradation, the pilot manually performs these functions. A few controls are provided to give the pilot sufficient cg control for safe flight.

Ground refuel-defuel is accomplished through a single point refueling receptacle.  A fuel/refuel control panel is located adjacent to the receptacle.  When activated, this panel governs system control and shutoff valves to permit selective fueling of any or all tanks in the aircraft without external power.  This panel displays fuel quantity as a digital readout.  Each tank may be refueled independently with gravity fillers.

Fuel is distributed in fuselage tanks in deference to cg requirements.  High-performance boost pumps permit rapid fuel transfer for in-flight and single-point refueling as well as cg control.  Provisions for gravity fueling are included.  Fuel dump from takeoff to landing weight may be accomplished within 5 minutes after initiation of the operation.

The aircraft can be refueled in flight from a tanker aircraft equipped with either a drogue or flying boom.  A common point for drogue or boom refueling is located in the pilot's forward field of view.

(4)  Electrical

The prime electrical power supply is an
engine-driven variable-speed generator (alternator), which
uses a hybrid arrangement with a solid-state DC link
converter to provide controlled frequency requried for
limited on-board equipment.  The AC generator produces
115-volt, three-phase power supply.  Additional on-board
power sources include an APU and a battery.

External and internal lights are provided.

The exterior lights include:  anti-collision/
fuselage, position, formation, air refueling, landing, and
taxi.

Anti-collision/fuselage lights are located
on the top and underside of the fuselage.  When extended,
the anti-collision lights flash red; when retracted, the
fuselage lights are white.

The position lights consist of the standard
configuration; a white light on the tail, a green light
on the right wing, and a red light on the left wing.  The
wing position lights on the wings' gloves illuminate to
conform with the specifications for position lights when
the wings are swept.

The formation lights correspond in color
to their respective position lights.  They are located on
the upper and lower surfaces of each wing tip.  Those lights
situated forward and aft on each side of the fuselage are
amber.

Air refueling lights are mounted in the
air refueling receptacle for flying-boom night in-flight
refueling operations.  Since the system is also compatible
with probe and drogue refueling, forward lighting is
provided for drogue illumination.

Landing and taxi lights are located on
the nose landing gear.  The lights are extinguished when
the gear is retracted.

(5)  Landing Gear

The retractable, tricycle landing gear
includes fairing doors that are sequenced closed in both
the retracted and extended positions, since the aircraft
will operate from unprepared fields. Brakes with anti-
skid provisions are included on all three wheels.  Collap-
sible, high-inflation tires inflate rapidly as the landing
gear extends.

(6)  Life Support

        The upward firing crew escape module
encompasses the pressurized cockpit and provides for safe
descent with an escape envelope extending from zero alti-
tude and zero speed through maximum operating altitudes
and maximum dynamic loadings.  Automatic parachute deploy-
ment occurs at altitudes less than 15,000 feet or as set
to meet operational needs.  Chaff dispensing and emergency
beacon transmission capabilities are provided and may be
deselected if desired.

        The environmental control system provides
the functions of cockpit air conditioning and pressuriza-
tion, transparent area clearance, avionic equipment
cooling, and anti-icing of flight surfaces and of sensors
as required.  Emergency operation provisions are also
included.

        Bleed air from the engines is manifolded
and passed through a precooler and an air cycle cooling
system.  Cooling air for the precooler is provided by the
avionics compartment cooling fan during ground operation
and ram air during flight.  The cooling air for the air
cycle cooling system is provided by an integral turbine-
driven fan drawing either compartment or ram air.  Turbine
discharge air, controlled to as low as 35°F, is passed
through a water separator before entering the cockpit.
Special design considerations are given to maintaining a
fog-/moisture-free cockpit and minimizing hot or cold air
drafts.

        The environmental control system (ECS)
maintains cockpit temperatures between +60°F and +80°F
during all flight operations and below 100°F for ground
operations on a MIL-STD-210A hot day.  Relative humidity
less than 70 percent is maintained during flight operation.
Provisions for a USAF standard anti-G suit are provided
for high altitude flight conditions.

        An on-board, regenerative oxygen system is
provided for life support.  This device uses bleed air
from the engine compressor as its source to separate
nitrogen and other gases and to produce a continuous flow
of pure oxygen to the pilot during aircraft operation.
A storage tank provides an additional source of oxygen.

        (7)  Miscellaneous Subsystems

        In addition to the flight controls,
individual hydraulic units serve the wing sweep, high-lift
devices, speed brakes, thrust vector control, gun chargers,

landing gear, nose-wheel steering, and landing gear brake systems. As in the flight control system, the units are compact, self-contained, electric-driven hydraulic pumps with an integral reservoir. Vulnerability to enemy firepower is reduced significantly by using dispersed redundant units.

The pneumatic system includes tire inflation, fuel tank pressurization, engine start, engine door operations, and engine anti-icing.

An electrically heated wind screen is used as an anti-icing device and provides protective resiliency against bird impact.

A liquid rain removal system that cleans bug and salt spray deposits from the windshield is included.

5.    AVIONICS SYSTEM CONCEPTS

The avionics concept described herein uses the M-5 version of the F-15 avionics as a point for departure. Innovative concepts and technological improvements are discussed. Some functions performed are called out by names that are familiar today; however, this does not imply that the equipment performing the function today will still be in use in 1980.

This avionics description and the display and control descriptions following apply primarily to the most sophisticated cockpit. Avionics specifications that go beyond the conceptual descriptions and into precise capabilities and requirements are not included as they do not influence cockpit design directly.

The section proceeds from descriptions of general concepts and equipment that affect many parts of the avionic subsystem to the specific system components including the displays and controls.

a.  Computer

Successful advanced tactical aircraft system operation depends heavily on the continued availability of computing power.  This dependency exists even when battle damage of component failure occurs.  This section of the report describes specific computing hardware and software requirements implied by such a dependency.

Weapon systems of the 1960's that use computer systems have computing hardware and software that are relatively vulnerable to computing hardware failures.  Only a limited class of failures can be overcome by developing the system's failure response in advance.  Most failures generally result in the complete loss of computing power, an intolerable situation for an advanced tactical fighter system.  To achieve the high degree of continued computing power availability necessary, the advanced tactical fighter system has a computer system that can:

o   Detect more than one failure.

o   Automatically establish a circumvention or recovery procedure to eliminate the effect of failures.

o   Provide a residual level of computing power that fully meets minimum essential computing requirements for the tactical fighter system.

The computer system can also handle specialized computing associated with the operation of synthetic aperture radars, pattern matching associated with automatic target recognition, and signature analysis of complex wave forms.  In addition, the computer system is supplemented with a digital data transmission system to permit communication with the rest of the avionics equipment within the advanced tactical aircraft system.  The digital data transmission system can operate in spite of component failure or battle damage.

Complementary to the essential system capabilities described above is the software system.  This system includes an executive program that is responsible for the operational management of the computing system while simultaneously checking for loss of computing power.  If such a loss occurs, the executive controls the circumvention procedures necessary to overcome its effects.  Application programs carry out the many functional tasks required by the advanced tactical fighter system.  Supporting software is also present in such areas a self-test and

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diagnostic procedures. This support software checks for
failure of any computing element or other avionics systems
able to communicate (through the digital data transmission
system) failure data to the central computer. Appropriate
evaluation and circumvention procedures are initiated
when a failure is detected. Lastly, ground support
programs exist to assist in the design, construction,
maintenance, and documentation of the operational computer
programs. These programs include compilers, assemblers,
file programs, etc.

The computing system for the advanced tactical
fighter system can execute some one million operations
per second, using about 131,000 locations of memory to
store programs and constants. The minimum level of
computing power to which the system can degrade is approxi-
mately one-half the nominal computer size; that is, 500,000
operations per second and 64,000 memory locations.

The computer system for the advanced tactical
fighter weapon system is configured as a multiple computer
system to provide continued computing power in spite of
battle damage or component failure. This multiple computer
configuration is organized into a multi-processor configura-
tion. The multi-processor system automatically assigns
computing tasks to separate elements of the computer
system. Additionally, it automatically reconfigures the
computer system in response to the detection of the loss
of individual computing elements. The multi-processor
configuration has certain specialized hardware features
as well as an advanced and sophisticated software executive
system to carry out automatic tasking and automatic recon-
figuration responsibility. In addition, the advanced
weapon system computer has excess (redundant) computing
elements to allow the system to reconfigure in response to
the loss of failed elements, and still provide the indi-
cated minimum computing capability. Approximately four
500,000-operations-per-second processor units are
available to ensure availability of the minimum computing
power requirement of 500,000 operations per second. The
memory system is divided into modules of some 16,000
locations per module. Timeline memory modules are installed
in the computer system to ensure continued availability of
at least four modules. A proportionally high level of
redundancy is carried out for the input/output areas of
the computer system, as well as the digital data trans-
mission subsystem. Therefore, if the entire system is
operative when a mission starts and the mission lasts
approximately 10 hours, the computing system for the
advanced tactical fighter weapon system will probably fail
to provide the necessary minimum computing power only once
in one million mission hours. It should be indicated that

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the cost in volume, weight, power, and dollars for the
indicated basic and redundant computing elements is quite
reasonable; i.e., only 2 cubic feet in volume are required
to house the entire computer system.

Installation of the computing hardware is only part
of the task of integrating a computer system into the
advanced tactical fighter weapon system. Developing the
necessary 100,000 to 200,000 statement program required by
the advanced tactical fighter system is a very significant
and difficult task. Software is a high leverage, long
lead time element for any system using a stored program
digital computer. The long lead time associated with
acquiring operational software is directly attributable
to the difficulties in defining functions to be carried
out in each part of the avionics system and, as a result,
the functions to be carried out in computer hardware and
software. Functional definition, analysis, logic flow
generation, design, development, and checkout and test of
software require a large integrated effort.

Special-purpose processors are provided to support
avionics elements such as the fixed-plane or conformal
design multimode phased array radars. These special-
purpose processors compute beam pointing and return signal
vectors even while the advanced tactical fighter system is
performing very rapid maneuvers. The computations involve
resolution of aircraft inertial attitude into the specific
coordinates of the conformal or fixed-plane radar system.
Similar special-purpose processors are used to solve
signature analysis problems associated with electronic
warfare and communications.

The computer performs computation, processing,
memory, and time standardization for the total airplane
system. The services include but are not limited to:

o   Autopilot

o   Stability Augmentation

o   Air Data

o   Primary and Secondary Navigation

o   Weapon Delivery

o   Energy Management

o   Fuel Management

o   Maintenance and Failure Detection and Processing

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o   Countermeasures Programming

o   Anti-Skid

o   Environmental Control

o   Auto Throttle

o   Phased Array Antenna Control

o   Automatic Target Acquisition and Identification

Multiplexing is a method for transferring data
items from one place to another using a single conductor.
With the digitization of the computer inputs at the source
instead of at the computer and the capability of using
computer outputs directly, it becomes desirable to use
multiplexing to interface system components.

Multiplexing greatly simplifies interconnecting
hardware and system maintenance by eliminating the need
for a multitude of wires, connectors, and junction boxes.
System modifications to add new functions or to change
functions can be accomplished without extensive rewiring;
however, the computer programming will need changing.
Multiplexing makes practical the wraparound cockpit, in
which the instrument panel is structurally secured to the
hinged canopy, by reducing the number of signal cables to
a minimum of three plus the redundant power wiring.
Redundant wiring can be routed into the canopy area at
different entry points to minimize the possibility of
battle damage.

Multiplexing mechanization is the subject of a
complete study.  A Boeing document (Ref. 1) discusses
many possible multiplexing alternatives and recommends a
modulation technique.  Two multiplexing methods might be
used profitably in this tactical fighter; one for the
normal digital interfaces and one for the displays.  For
the displays, a frequency division multiplex scheme,
similar to a cable TV system, could supply signals to the
raster-type displays.  Thus each display would become a
TV receiver with all the symbology developed in the
computer.

The most promising digital technique appears to be
pulse code modulation using split-phase, bipolar modula-
tion or phase-reversal modulation for the digital interface.
However, considering the very short cable runs that would
be used in the tactical fighter, possibly the internal
modulation technique used by most computers, non-return-to-
zero polar modulation, should be considered.  The relative
advantages and disadvantages of these and other techniques
are discussed at length in Ref. 1.

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To be effective in reducing interface complexity, multiplexing requires the standardization of the multiplexed signals to a single format. All sensors, controls, displays, and transducers should be designed to produce or accept the common standardized format. Standardization can be on an airplane basis, on an Air Force basis, or on a joint service basis. The degree of standardization depends on the desired degree of equipment interchangeability that can be accomplished without using adapter units.

b.   System Data Inputs

Four methods for feeding data into the system are suggested for use in the tactical fighter. These are a tape cassette, a data link, a keyboard, and human voice. Each method has a distinct use.

The tape cassette is used to program the mission into the computer. The program includes waypoint, checkpoint, target, and destination locations and navigation and communication frequencies. This tape is produced by a ground-based computer and carried on-board by the pilot. A read-only capability is employed in the airplane to preclude the possibility of inadvertent computer program loss.

Data link input is used to reprogram the flight from either a ground-based operation such as an air operations center, a forward air controller, or an airborne warning and control center. One other use may be to control the airplane from the ground during low visibility landings. When the pilot is physically incapacitated, the aircraft may be controlled remotely. Data link is considered to be an adjunct of the communications capability.

The basic keyboard, Figure 15, consists of an 8-key master keyboard select panel and 38 multifunction keys. Dedicated keys are included to perform the functions of clear, modify, display, enter, backspace, and space. The keyboard is energized when there is power on the system.

A pre-entry readout is provided for verification of keyed instructions before entry into the system.

The function of each key is:

CLEAR--Clears entry up to time of enter. Clears display
    when properly keyed and cleared.

MODIFY--Modifies information already in storage. Allows
    type over, thus replacing stored data.
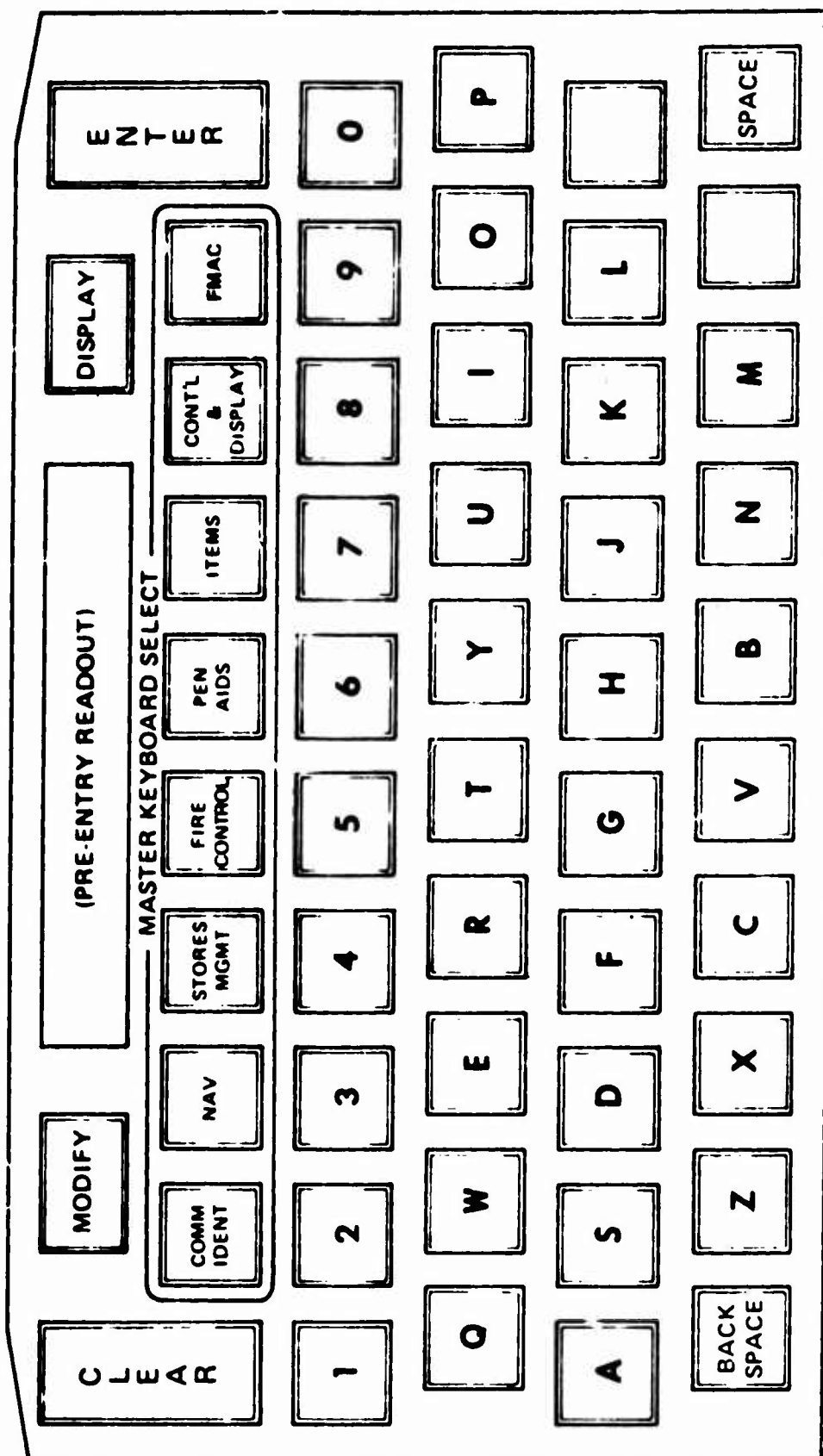
Figure 15. Basic Integrated Keyboard

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PRE-ENTRY READOUT WINDOW - Presents data as selected on keyboard before entry. If an entry error is made and the computer rejects information, selected data will pulse until correct entry is made.

DISPLAY - Displays total message to be entered on MPD #5, or displays any recalled message without modifying data.

ENTRY - Enters data into system and reverts keyboard to basic legend.

MASTER KEYBOARD SELECT - Contains 8 function keys used to call up selected functions.

FUNCTION KEYS - Thirty-eight multifunction keys with up to 48 separate functions per key are provided. A set of functions is called up for each master keyboard select key depressed.

BACK SPACE - Clears a single keyboard entry such as an error in frequency. Back space if repeated depressed will operate similarly to a typewriter backspace key providing the capability of correcting single digit on unit entries.

Keyboard/voice entry is selected on the mission control panel and keyboard entry is selected on the integrated keyboard to type in a computer program. When the switch is activated, a modified teletype keyboard legend (Figure 15) is presented and programming may be done by typing in abbreviated plain language.

To allow the pilot to command certain operational changes during critical flight phases, without requiring him to use the hands, the human voice can be used to call out frequency changes for the communication and navigation equipment. A Boeing-developed voice recognition device, based on International Business Machine patents, is in laboratory operation. It recognizes the sequential usage of key command words. The voice command entry technique allows the pilot to enter changes into the system without using the keyboard. It uses a faculty that has not been used formerly except for voice communications.

c. Failure Monitor and Control System (FMACS)

The FMACS for advanced tactical aircraft is more than the traditionally conceived on-board test and checkout system; it is a programmed control system that performs many airborne and ground-oriented functions.

While airborne, these functions include system status reporting to the pilot and data linked to a remote monitor, warning of flight safety conditions, automated corrective actions and display of these actions, and notification of impending failures. On the ground, these functions include automatically controlled preflight, flight/mission readiness, and fault isolation tests.

Integration of these functions under the operational control of FMACS has many advantages. The greatest advantage is that all systems are monitored, the data processed, and the operational modes controlled (either automatically or by the pilot) by one program control.

Figure 16 is a block diagram of the integrated FMACS equipment. The description of FMACS necessarily is a description of the operational role (or functions) of FMACS, and the displays, controls, subsystem monitors, and data processor integrated within the operational role of the FMACS.

While the aircraft is airborne, FMACS primarily reduces and simplifies the pilot's workload if any flight subsystem is in a degraded mode of operation. In many cases, FMACS can completely assume the tasks of restructuring the operational parameters of various systems to eliminate a failed or degraded system's impact on the pilot. In other cases, simple status displays in go, no-go, formats, plus simple corrective directions are displayed automatically to the pilot.

Total aircraft system status is determined and constantly monitored by FMACS. Subsystem status is not displayed to the pilot unless specifically requested through the integrated keyboard control. Only two buttons need to be depressed for the status of any subsystem to be reported on a preselected MPD: first, "test and check" is depressed; then, the name of the desired subsystem is depressed.

When the status of a subsystem changes, the change may or may not be reported automatically to the pilot. Changes in system status that involve either safety of flight or failure in mission performance will be presented to the pilot automatically. Failures affecting flight safety are presented to the pilot automatically through the Master Warning System. Emergency procedures are displayed on the preselected MPD. Failures that may affect mission performance are presented automatically on the MPD. Other failures are not displayed automatically, but are displayed when the pilot requests aircraft status through the integrated keyboard.

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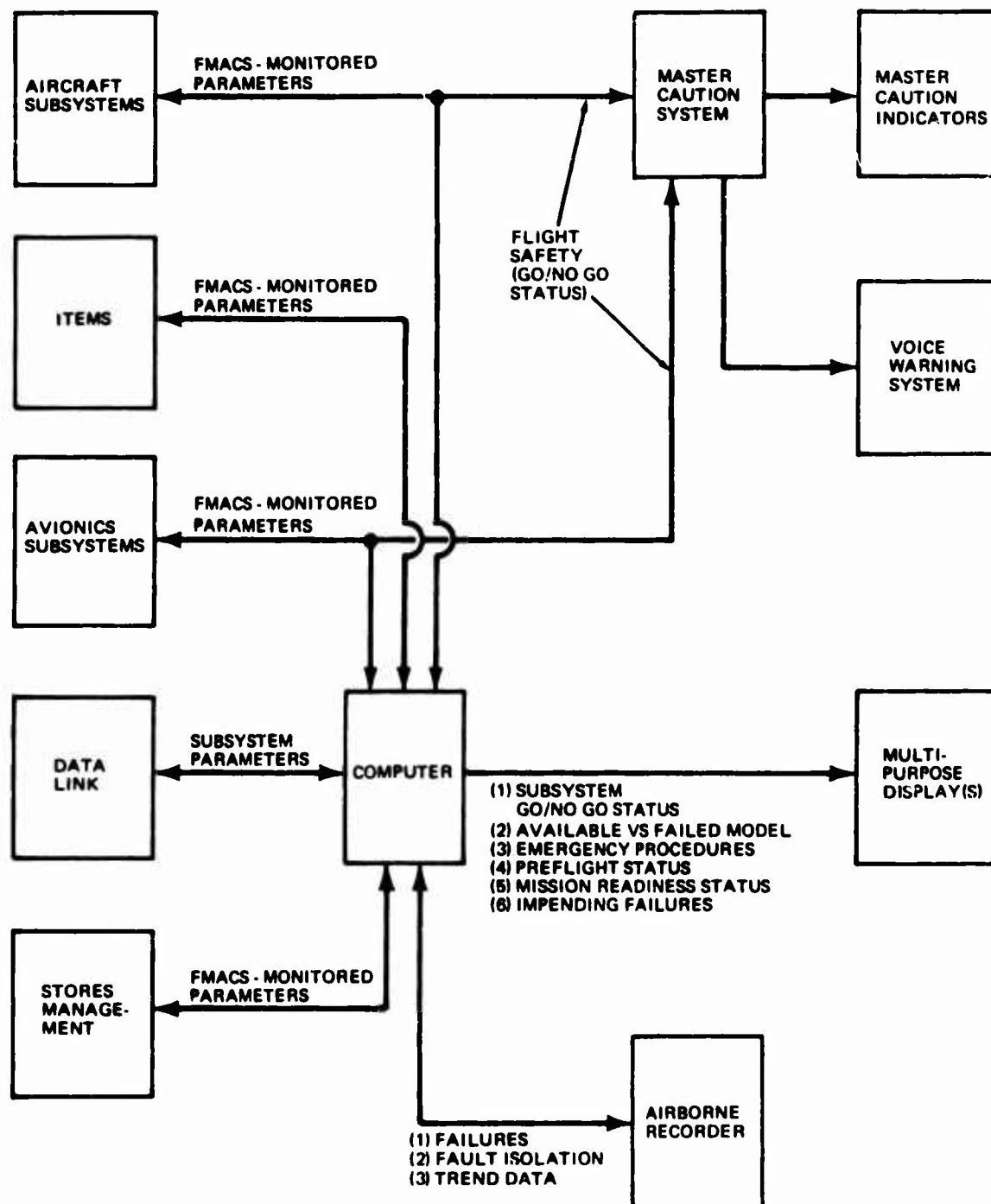
Figure 16. FMACS Control and Display Block Diagram

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The total aircraft status in all subsystems will be recorded on a read-write magnetic tape recorder, which under computer control can interface with the data link. Under certain conditions, an external source (i.e., AWACS) can obtain total airplane status automatically via data link and take the necessary corrective action for specific functions. The FMACS will also be capable of determining certain impending failures minutes and possibly hours before a total failure occurs. This feature is limited to only a few, high failure rate or long maintenance time line replaceable units (LRU's), such as hydraulic pumps, APU's, generators, and to some extent, the propulsion system. The principle of detecting impending failures through the content of metallic particles in the oil of a pump, or the noise of a pump, or the amount of flow-by in a hydraulic actuator has been proven for some time. Using these principles on specific pieces of equipment is certainly a feasible feature for the FMACS. In addition, if these impending failures could be mission critical, they will be displayed to the pilot via the MPD's.

While on the ground, the pilot and the line maintenance crews will have the following display formats available:

(1) Preflight Test

This test is done by depressing the FMACS pushbutton (Figure 17). If the airplane is on the ground, the preflight and mission ready pushbuttons will be illuminated. (These functions are inhibited in flight.) Depressing the preflight pushbutton will instruct the computer complex to perform a total system test. If subsystems are not in the proper configuration for test, ia?., power off, specific crew action instructions will be displayed on the MPD's. If a subsystem fails, the computer will automatically isolate and record the results, and display the crew action required to effect the repair on the MPD.

(2) Mission Ready Test

This test is done similarly to the preflight test; the FMACS pushbutton is depressed first, followed by the mission ready pushbutton. This test determines the status of the aircraft subsystems to determine whether those systems necessary for safe takeoff are in their operational mode and are functioning properly. This test is comparable to an automated checklist with pilot information and instructions being displayed on the MPD.
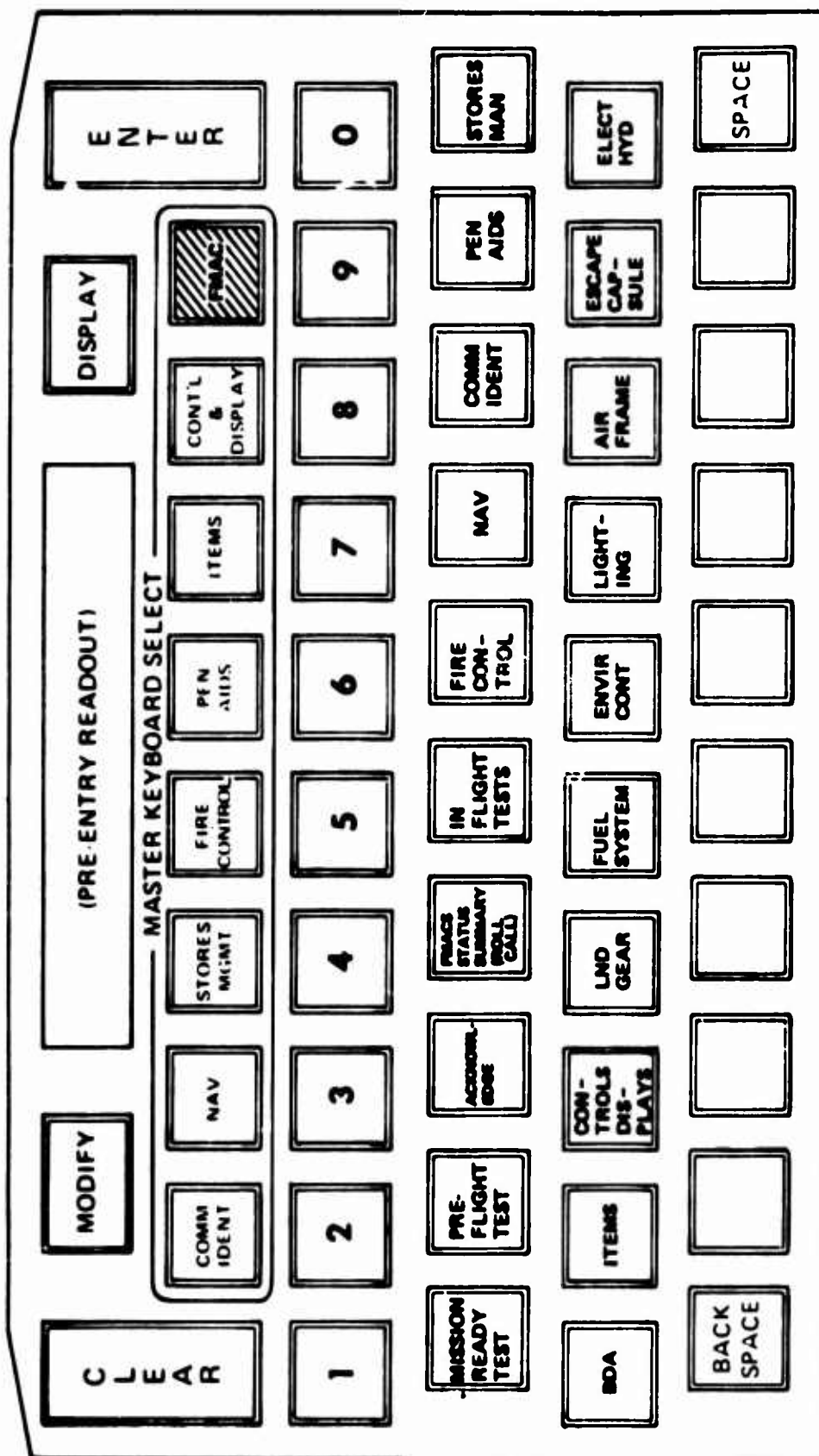
Figure 17. FMACS Control Keyboard

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### (3) Fault Isolation Tests

Fault isolation tests are conducted both in-flight and on the ground. In-flight fault isolation tests are conducted automatically by the computer complex on a low priority basis; i.e., when the computer workload is down. Fault isolation data will be recorded and transmitted via data link to a remote monitor and to the maintenance center to expedite aircraft repair. On-ground fault isolation will be done automatically as a function of the preflight test. For example, if preflight test results indicate that a system has failed, the computer will enter a fault isolation routine, determine the failed LRU, display the results on an MPD, and record the failed LRU information on tape for subsequent data link transmission to the maintenance center.

### (4) Trending (Long Term)

Key parameters indicative of degraded airplane performance are automatically recorded and transmitted to a remote monitor during specific phases of the mission profile on a sample basis. Since this information will be recorded in the same manner as status and fault isolation information, these measurements can also be sent by data link to the maintenance center for further processing to determine scheduled maintenance requirements.

Three groups of displays will be used for FMACS. They are the Master Caution System, flight instruments, and the MPD's.

### d. Master Caution System

Warning and Caution are presented to the pilot in up to four ways depending on criticality of the failure or malfunction detected. Types of warning are:

Catastrophis - results in loss of system, single or multiple deaths.

Type warning - Tactile - Seat vibration against small of back

Master Caution - Flashing aircraft symbol on VSD/HUD and master caution reset button "ON"

Voice - Plain language of system failure

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MPD - Readout of system failed
with emergency procedures

Other tactile warning devices, such as a stick
shaker, are installed as required to alert the
pilot of an impending unsafe condition.

Critical - Degrades system performance which
can result in pilot injury or substan-
tial damage

Type warning - Master Caution - Flashing aircraft
symbol on VSD/HUD
and master caution
reset button 'ON"
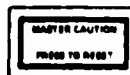
Voice - Plain language of system
failure

MPD - Readout of system failure
with emergency procedures

Marginal - Degrades system performance without
major system damage or personnel
injury but can be adequately counter-
acted or controlled

Type warning - Master Caution - Flashing aircraft
symbol on VSD/HUD
and master caution
reset button "ON"

MPD - Readout of system failure
with emergency procedures

Safe - Does not degrade system and will not produce
hazard to crew

Type warning - MPD - Readout of system failure
with emergency procedures

Integration of the FMACS with computer direction
and recording provides continuous sampling of system status,
immediate warning of malfunctions, presentation of programmed
emergency procedures, and transmission of system status
information to a remote monitor via data link. Automated
switching and control provided by the computer complex
offers an immediate response to malfunctions where human
reaction time precludes a sufficient response. Simultaneous
actuation of equipment is also provided where required to
safeguard the crew.

(1)  System Status

This information is a system-by-system presentation of available versus failed modes of operation.  The information provided to the pilot is in go, no-go format and relates to operational modes of the system, not to equipment nomenclature.  This display format is controlled through the integrated keyboard; depressing FMACS, the major aircraft and mission systems are listed on the keyboard as shown in Figure 17.
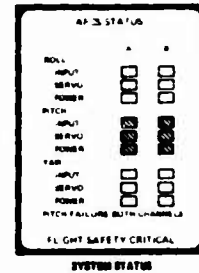
(2)  Corrective and Degraded Mode Procedures

This information is presented automatically in the same display format as system status when a no-go condition occurs.  As the corrective steps are taken, the display format changes as shown.
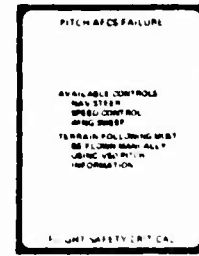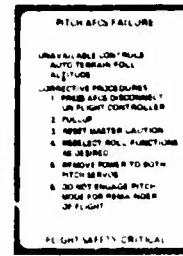
(3)  Impending Failure

This information is presented automatically when the FMACS detects a failure about to occur.

e.  Failure Mode Analysis--Signal Transfer Unit (STU)

The STU is a control unit for mixing and switching composite video to the MPD's.  Inputs to the STU include:  (1) video signals from the MPD Character Generator, VSD Generator, Horizontal Situation Display (HSD) Generator, TV CAmera, and the radar and FLIR Scan Converter; (2) MPD mode control commands in digital format from the Central Computer Complex; and (3) function control from the MPD controls.  Output signals are composite video signals to each of the five MPD units.

The STU is basically a digitally controlled analog switch system.  Two redundant logic networks are provided, because failure of this portion would remove computer control from all MPD's.  However, the analog switching network that directs the composite video to each MPD is not redundant, because the required data can be switched to a different display when one analog switch fails.  The analog switch portion, as well as the switching logic system, is expected to be highly reliable.

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f.  Scan Converter

The Scan Converter is a solid-state unit with 1024 by 1024 resolution elements. The scan converter is in four sections, each having 512 vertical elements by 512 horizontal elements.

Failure of a single discrete element within the scan converter core does not degrade the performance of the scan converter performance, because loss of individual cells of an actual image is not detectable on a display.

The impact of a massive failure in the write or read logic or the core itself (due to battle dama;?) can be reduced by redundancy, but this is a costly approach. An alternate and preferred method selected for IIPACS is redundancy provided by dividing the scan converter into four 512 by 512 elements, as described above. All four units operate as one unit with 1024 by 1024 resolution elements until one section becomes unusable. Then the system operates in a degraded 512 by 512 resolution element mode.

An FMACS Control Display Interface diagram is shown on Figure 18.

g.  Navigation

The primary function of a navigation system in a tactical combat aircraft is to provide en route navigation and weapon delivery information. The most demanding requirement for en route navigation is to fly to the target and deliver weapons under instrument flight conditions.

The basic navigation system description for the tactical combat aircraft for the 1980 time period includes the total avionics suit available in the aircraft. Detail performance data found in the Navigation Study, Appendix III, is given only for those theater-of-operation systems in the 1980 inventory.

The final navigation system selected from those classes shown in Figure 19 for IIPACS is comprised of three basic subsystems--Doppler, Inertial and Satellite (DIS), augmented with Radar, Data Link and DME position fixing. This system, shown in Figure 20, meets the functional requirements for the tactical mission. Two inertial systems with a backup Heading and Attitude Reference System (HARS) provide the redundancy and reliability required for "fail operational" during critical mission segments. The HARS is a simplified inertial system with a flux valve that provides heading during system initialization and degraded mode operation.
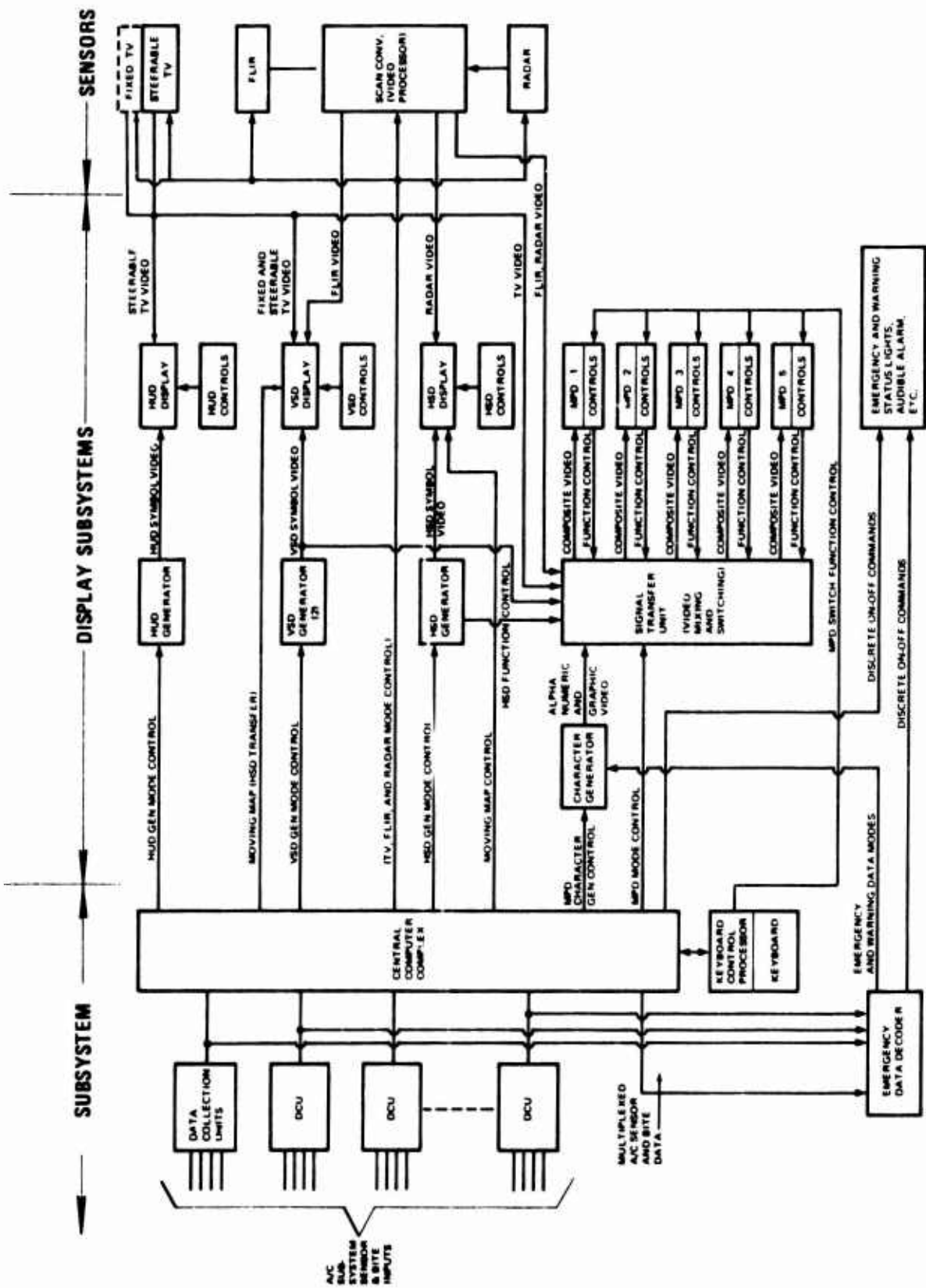
Figure 18. FMACS Control/Display Block Diagram

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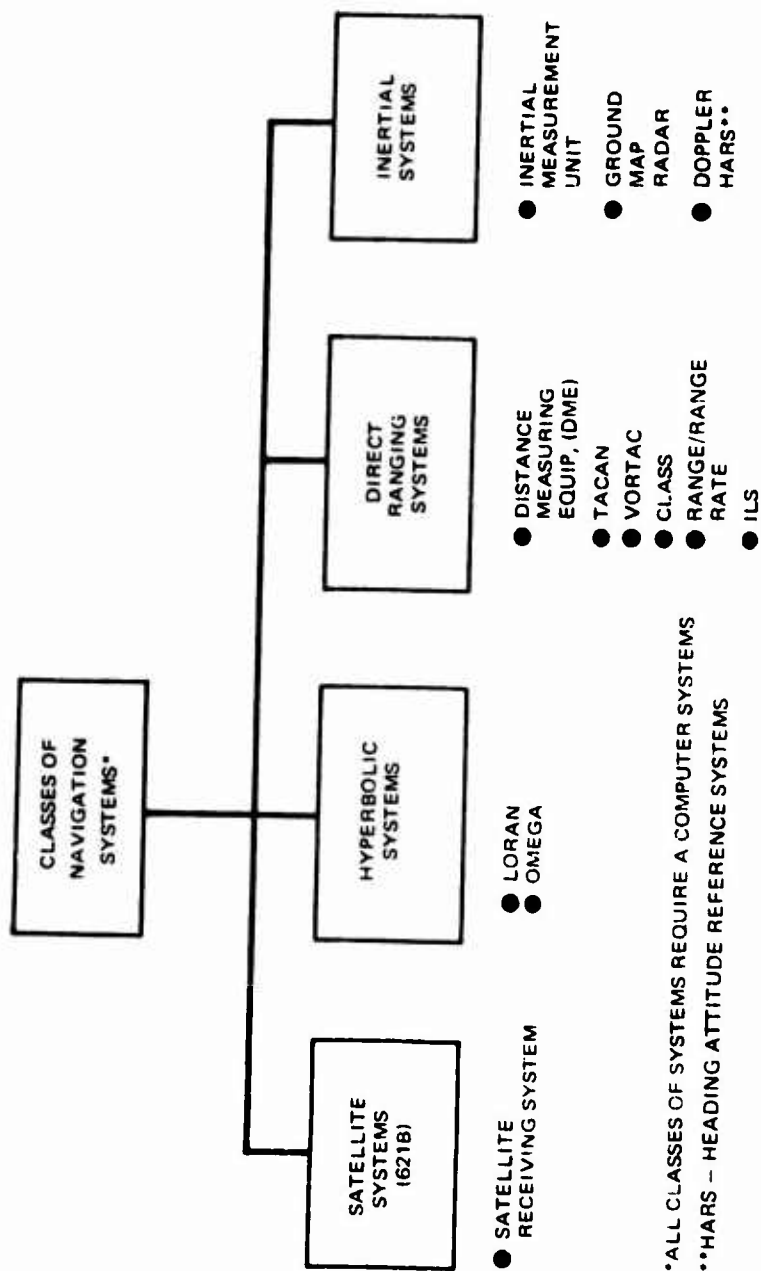
Figure 19. *Classes of Navigation Systems Available for Tactical Combat Aircraft*

CLASSES OF NAVIGATION SYSTEMS*

SATELLITE SYSTEMS (621B)
- SATELLITE RECEIVING SYSTEM

HYPERBOLIC SYSTEMS
- LORAN
- OMEGA

DIRECT RANGING SYSTEMS
- DISTANCE MEASURING EQUIP, (DME)
- TACAN
- VORTAC
- CLASS
- RANGE/RANGE RATE
- ILS

INERTIAL SYSTEMS
- INERTIAL MEASUREMENT UNIT
- GROUND MAP RADAR
- DOPPLER HARS**

*ALL CLASSES OF SYSTEMS REQUIRE A COMPUTER SYSTEMS
**HARS – HEADING ATTITUDE REFERENCE SYSTEMS

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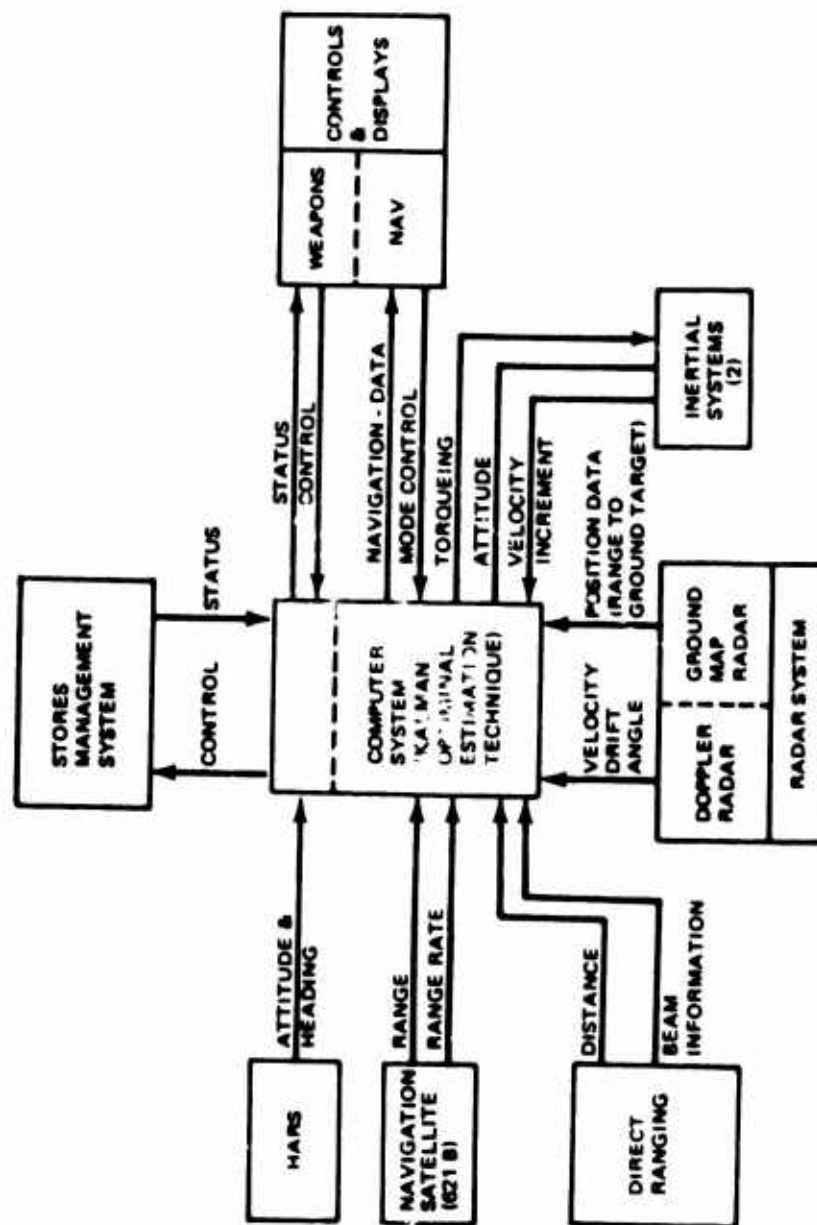
Figure 20. IIPACS Navigation Systems Block and Functional Interface Diagram

Degraded mode options available with the equipment are shown in Figure 21. The selection and switching logic for degraded modes is programmed in the navigation computer. For example, the NAVSAT is the primary source of navigation (position/velocity) data. If NAVSAT fails or if the aircraft moves to a position relative to the satellite cluster such that the NAVSAT data is less accurate than the Doppler-inertial data, the system automatically switches to the Doppler-inertial mode. Thus, the navigation system always operates in the most accurate available mode.

Selection and switching logic for Figure 21 degraded mode option is based on the failure hierarchy and criteria as follows:

(1) NAVSAT is the primary navigation mode and will be used whenever possible.

(2) A NAVSAT failure causes the navigation system to operate in a Doppler-inertial mode augmented by position fixes from the ground map radar. Figure 22 shows the system position error growth.

(3) A ground map radar failure causes the system to fly Doppler-inertial until the direct ranging network comes within line of sight. Thus, the system updates with range/range-rate information,

(4) A Doppler failure in the Doppler-inertial mode causes the system to operate in a free inertial mode with position fixes from the ground map radar. The Schuler oscillation will result in somewhat larger absolute errors, depending on the accuracy of the update. The position updates to the free inertial system should be made about once every 30 minutes. The average position error growth is given in Figure 22.

(5) A Doppler and ground map failure in the Doppler-inertial mode causes the system to operate in the free inertial mode until the direct ranging transponder field comes within view.

(6) A failure of the Doppler radar, ground map radar, and the direct ranging causes the system to operate in the free inertial mode. System position error growth is shown in Figure 23.
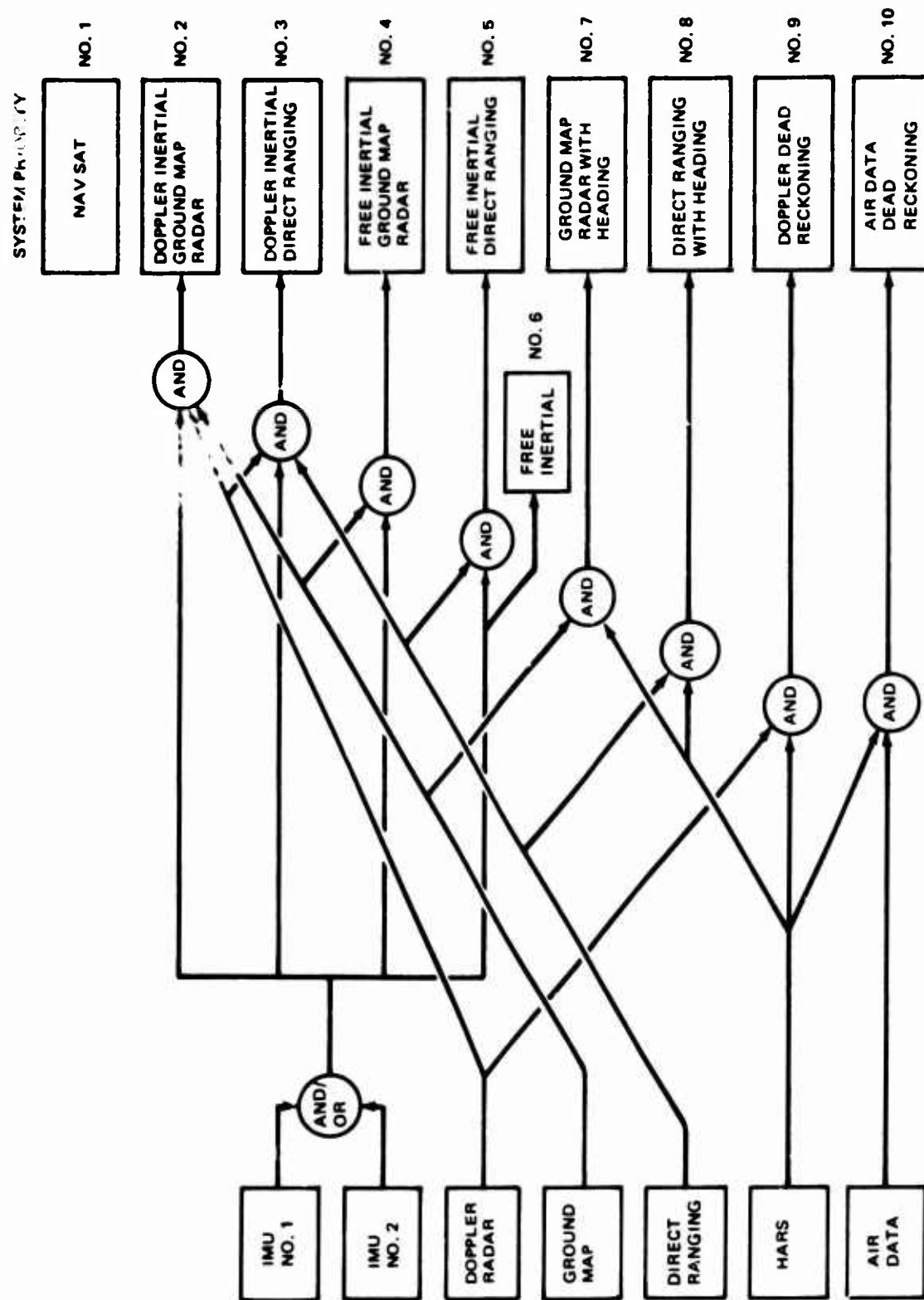
*Figure 21. Navigation System Options*
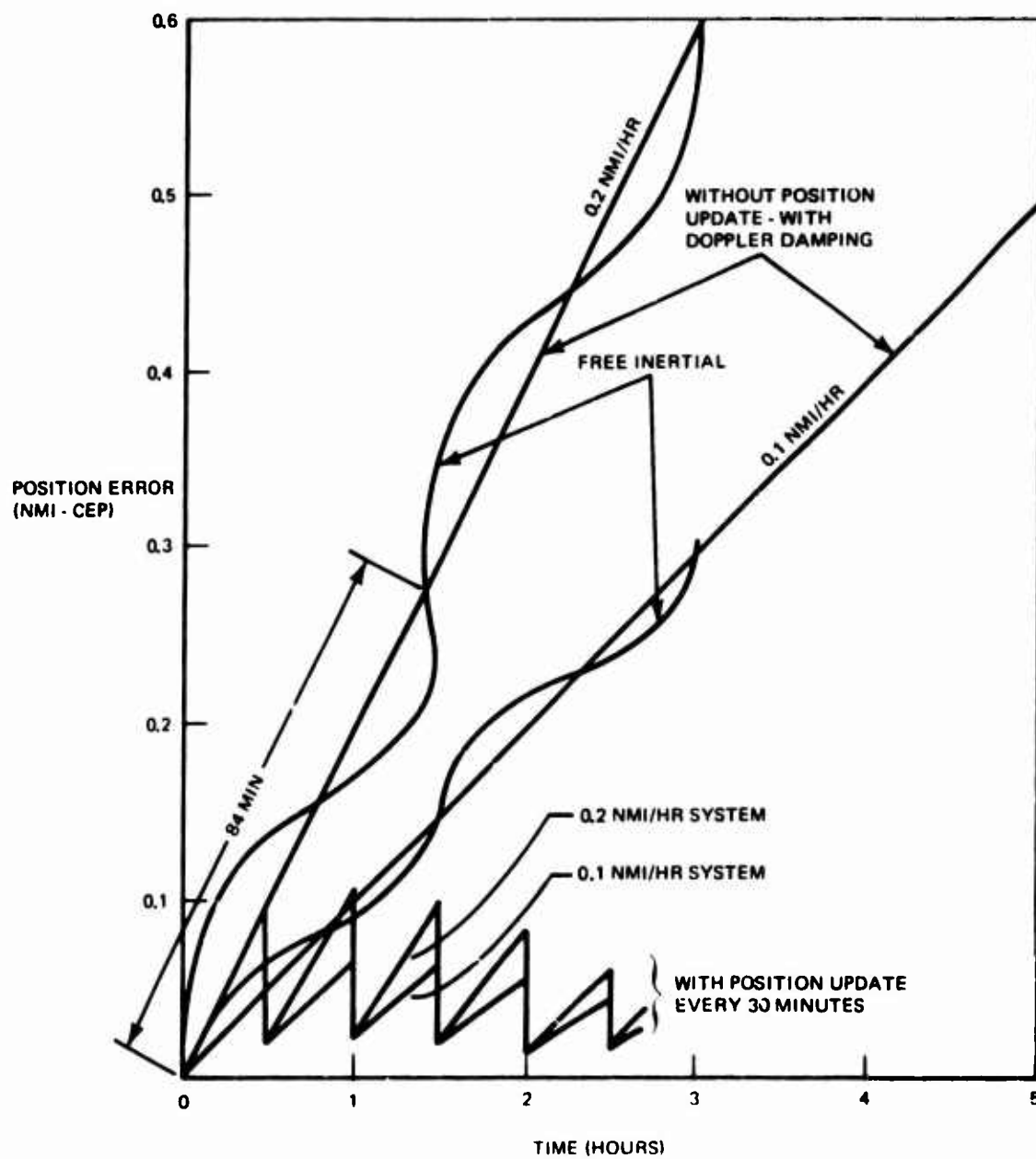
Figure 22. Doppler Inertial Performance With Position Updates

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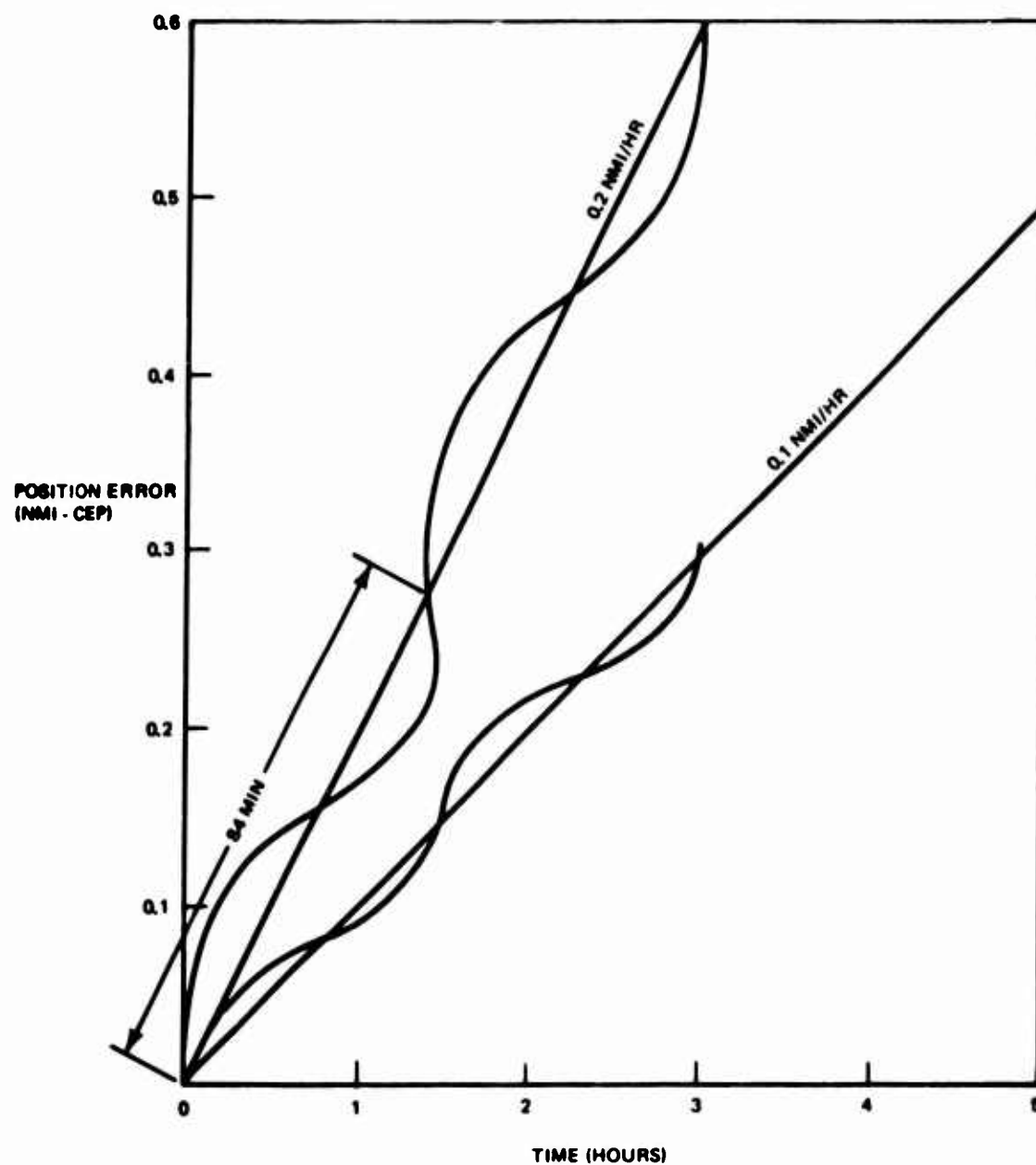
*Figure 23. Free Inertial System Performance*

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(7) Failure of both inertial measurement units
and the Doppler causes the system to operate
in a backup inertial (HARS) mode with
ground map radar updates.

(8) Failure of both inertial measurement units
and the ground map radar causes the system
to operate in a DME navigation mode with
attitude and heading obtained from HARS.
As the aircraft flies through the DME
field, position coordinates are computed
with range/range-rate to the transponders.

(9) Failure of both inertial measurement units,
ground map radar, and DME causes the system
to operate in a dead reckoning mode.
Heading from the HARS is combined with
Doppler to compute position of the aircraft.
A 5 to 10 nmi per hour CEP growth rate is
expected.

(10) Failure of all above sensors simply causes
the system to operate in an air data dead
reckoning (ADDR) mode. Air speed and
heading are used to navigate. This con-
tingency represents a very remote failure
pattern due to system redundancy.

h. Antennas

Spherical antenna coverage is needed to operate
against threats and targets approaching from different
directions. An integrated antenna design concept is
desired so that aircraft weight volume, structural shadow-
ing, and interference problems are minimized.

The integrated antenna system consists of multiple
phased array systems to satisfy the requirement for spherical
coverage. These multifunction arrays use an inertialess,
computer-controlled electronic beam steering system to
allow coordinated control with minimum reaction time.

Although acceptable designs with either planar
or conformal arrays are possible, a conformal array approach
with the antennas integrated into the aircraft structure
is expected to provide best coverage with minimum aircraft
weight and volume penalties.

The arrays are formed to follow airplane contoured
sections including those for the nose cone, fuselage
sections, and wing/empennage leading edges. Large volumetric
coverage is obtained by simultaneously exciting complementary

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array sections and by sequential excitation of numbers of adjacent array elements in a given section.

Conformal arrays have primary features common to more conventional antenna systems. The resolution and accuracy are still governed by the projected overall dimensions of the excited array sector (useful antenna area) and the number of active elements in the sector. Specialized antennas are needed for unique CNI and Pen Aids support functions at the lower frequencies.

Array sections are controlled for specific mission functions by preprogramming amplitude and phase changes to different antenna elements. Several specially shaped transmit/receive beams result. Changing amplitude and phase allows these beams to provide limited directional control for sequential or simultaneous multibeam operations. Weak preferred signal reception and/or nulling out of unwanted signals is accomplished by operating in a fully adaptive mode. This provides maximum directional gain to enhance preferred signal return.

The array design facilitates degraded mode operations. The antenna surface areas are vulnerable to damage caused by hostile action. The thinning effect of random hits results in a gradual degradation of array performance.

Single hits with small fragments provide minor damage because the arrays have elements containing individual phase shifters for element to element control. Antenna computer programs are arranged to delete defective or damaged elements; therefore, performance degradation is proportional to the number of elements lost.

Lens arrays, using protected feeds behind the arrays, improve operational performance in degraded modes. Power division, for subarrays is with waveguide and/or stripline feeds. Sectional sources, acting as subarray feeds, and radial waveguide, parallel-plate, distributed feeds tend to localize damage.

i. Communications

Communications, navigation, and identification systems are programmed for integration into one spread-spectrum bandwidth. Each function has a separate address code. Knowledge of the code and compatible equipment allows the users to communicate with each other.

The spread-spectrum technique is designed to reduce vulnerability to enemy jamming and to provide

simultaneous service to many stations or addressees.
Satellites are expected to handle hundreds of small mobile
terminals with varying power levels without the formal
network discipline normally used in satellite communications
between large ground terminals.

The greatest advantage in the spread spectrum
technique is that it can serve the frequency spectrum by
allowing the transmission of many low duty cycle RF users,
each with a dedicated frequency channel to operate a single
broad channel. Then each user contributes a small amount
of noise across the total band. When a high percentage of
the total possible users transmit simultaneously, the noise
level becomes high enough to cause interference with all
the using links. Normally this situation would have ar
extremely low probability of occurrence.

A secure or private code must be used to provide
anti-jam capability. Since each link is spread across the
entire available bandwidth, both CW and broadband jamming
must overcome the process gain of the spread-spectrum
system. Therefore, a great deal of jamming power is
required.

The controls necessary to operate a complete
spread-spectrum system must include the synchronization
and functions of interest, i.e., navigation, local and long
range communications, identification, etc., and address
codes. Insertion via keyboard of an address code or a
code sequence is adequate for full control of the spread-
spectrum system.

The communications keyboard, Figure 24, is chosen
by activating the C&I key on the master keyboard selector.
This illuminates the communications options of the keyboard
as shown. The sequence of events to choose a given destina-
tion for transmit-receive is:

   o  Press the PHONE BOOK key. A list of address
      codes will appear on the classic COMM. MPD.
      An address may be a ground station, airborne
      station (AWACS type), or another aircraft.
      Select a given code from the phone book.

   o  Press the following keys in sequence: ADDRESS
      CODE, 1, 2, 3, SEC, VOICE. This will choose
      address 123 and set up the proper secure voice
      coding in the spread-spectrum frequency
      channel. All selections will appear in the
      verification window before entry.
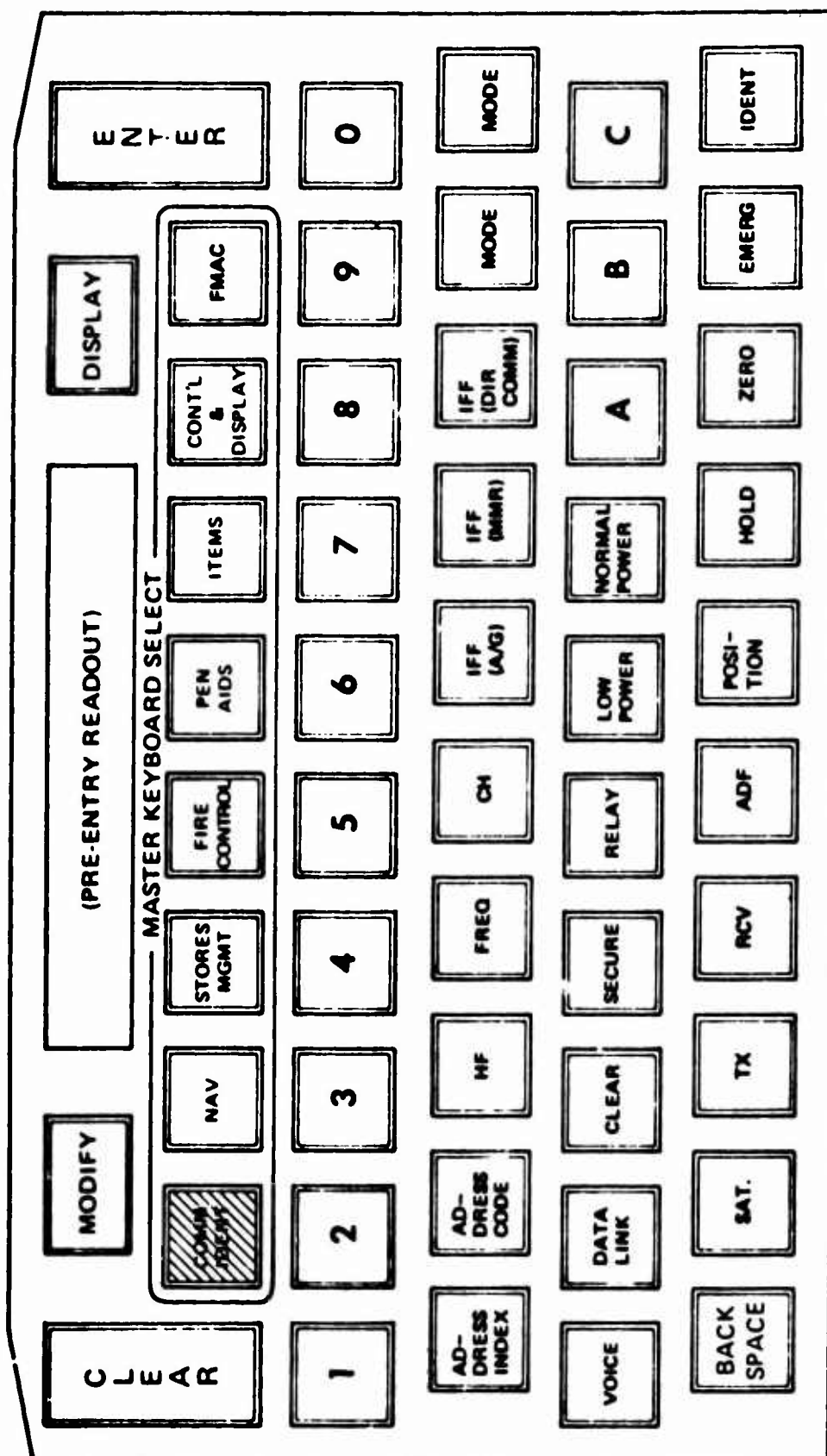
Figure 24. Communication and Identification Keyboard

o   Press the ENTER key to enter the data into
    the system and clear the keyboard for further
    use.  ADDRESS 123 SEC VOICE will appear in
    the COMM. MPD classic display and in the
    upper row of indicators at position one on
    the intercom panel.  Communication data for
    position two and position three would be
    programmed in a manner similar to that just
    described above.

j.   Identification, Friend or Foe (IFF)

The identification functions of the IIPACS aircraft
are accomplished with either of two independent systems.
In actual operation, however, they will have a common
phased or conformal array antenna system.  The IFF systems
are described below.

The directional communication IFF system is an in-
tegral part of the spread-spectrum communication band.
Frequency will be in the SHF band or higher for improved
directivity.  Spherical (360°) coverage is provided.  The
antennas are directional during transmit and receive.
The system can interrogate another aircraft at a specified
bearing when directed by on-board systems through the
central computer.

In an operational mission, the directional
communication atomic clock is synchronized to a master
time source--located at a ground station or airborne command
post.  When interrogated, the system responds in the same
direction as received with the proper code-secure or clear
depending on the threat environment.  On the other hand,
when performing the interrogation, the system directs RF
energy at a particular spot in space as determined by the
RHAW or MMR through the central computer complex.  The IFF
system can also transmit in any direction when commanded
by the pilot using the computer cursor control (useful
during "dogfight" at close ranges).

The multimode radar IFF system is integrated
with other MMR functions at the operating radar frequency.
Spherical (360°) coverage is provided.  Modes 1, 2, 3,
4 A/B and codes are integrated with existing radar pulses
with secure message structure contained within each pulse.

In an operational mission, IFF interrogation
may be directed at any target being tracked by the MMR.
Normally, all interrogations are performed through instruc-
tions from the central computer; however, the pilot may
choose to interrogate any particular target being tracked.
To perform the interrogation, the pilot designates the

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ground or airborne target with the crosshair, obtains a
lock-on, and interrogates. Identification is confirmed
by appropriate symbology near the radar return, or discrete
lights provided on the COMM./IDENT panel.

Justification for two completely independent
systems is based on:

o   Inadequacy of existing systems to perform
    directional IFF functions.

o   Need for redundant systems in a hostile
    environment to keep from being shot down or
    mistakenly shooting down a friendly because
    of a single system failure.

o   Need for 360° coverage at all times with two
    types of systems, either capable of performing
    directional identification in a secure mode
    at reduced power levels.

k.   Autopilot and Stability Augmentation

These computational functions
are performed in the central computer.
The sensors feeding the computations
and the computational elements are
sufficiently redundant to produce a
safe airplane. Stability augmenta-
tion cannot be deselected. The
various modes for automatic flight are:
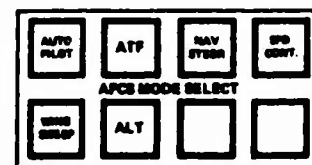
o   Control Stick Steer (CSS)

o   Navigation Steer (NAV STEER)

o   Speed Control (SPD CONT)

o   Altitude Hold (ALT)

o   Automatic Terrain Following (ATF)

o   Automatic Wing Sweep (WING SWEEP)

The stability augmentation system (SAS) installed
is sufficiently redundant to provide reliability equal to
the primary flight control system. The SAS is activated
whenever the aircraft is operating with no switching or
programming inputs required of the pilot.

Failure warning is provided by the FMACS/CCC
in the following manner:

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Single channel failure - Master caution flashing
plus readout on MP?

Dual channel failure  - Master caution flashing,
voice warning plus
readout on MPD

If two or more channels of the SAS are inoperative,
the pilot is advised to select a flight regime and mode
(i.e., cruise) that provides improved stability and to land
as soon as practicable.

1.  Penetration Aids

Although the tactical fighter's primary mission
is to destroy ground targets, self-defense using penetration
aids is also necessary.  Self-defense options, which include
evade, degrade (not to be confused with degraded modes as
implied by the nature of this study) and destroy, must be
used selectively to minimize primary mission penalties.

Evasion by maneuvering to increase range and
decrease closure rate is useful when the threat is not
positively identified (friend or foe) or when mission time
or distance to target or base is not critical.  Use of
evasion during terrain following is restricted.

Degradation with ECM, chaff, flares, decoys,
etc., is valuable against enemy threats.  It is not used
when electronic silence is required or where severe mission
degradation of friendly forces in the area is possible.

Destruction by counterattack is used with posi-
tively identified threats.  Counterattacks are a last
resort because they compromise the primary mission.
Valuable payload would be expended for purposes other than
ground target destruction.

The environment for the tactical fighter includes
both terminal and indirect threats.

The terminal threats are airborne interceptors
(AIs), SAMs, and anti-aircraft artillery (AAA).

Indirect threats are emitters that include the
SUAWACS airborne warning and control aircraft, ground
control intercept (GCI), height finders, early warning (EW)
and acquisition radars as well as communications networks.
Reception of signals from these emitters can be considered
attack warning.

Both enemy and friendly forces are expected to
be operating in the area.  When radar or IR signatures, visual

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sightings, and/or emissions from an unknown are received, classification as a threat is necessary until true identity becomes known.

Friendly and enemy emitters and signatures must be located to minimize the process of complex identity evaluations and action decisions. Continuous position update is also necessary.

If the decision is to destroy the threat, the threat becomes a target that competes for attention with primary mission-assigned targets. In this case, stores management and penetration aid functions must be worked in concert.

Complete penetration aids functional requirements and typical associated action decisions are shown in Figure 25. Threat concentrations in the vicinity of the tactical fighter will often be too high for manual processing in a one-man aircraft. The action decisions are performed by the central computer complex. Pilot veto is provided.

Countermeasures used on the tactical fighter include automatically programmed transmitters, an IR (tail) jammer, and dispensers for chaff, flares, and expendable jammers. These devices are installed internal to the airplane. The devices are programmed by logic designed into or read into the computer from the cassette. Controls are available for pilot selections. Dispensing rates for chaff and flares other than those preprogrammed may be chosen through the use of the integrated keyboard.

Passive receivers are used to determine the location of enemy emitters. Preprogrammed logic recognizes the threat by its signature. Threat energy sources are primarily in the S- through K-bands and in the IR region. Threat information is displayed to the pilot and used to activate the active countermeasures. The pilot's battle situation display is shown on one of the MPD's and/or on the HSD. Pilot emergency warning of an approaching terminal threat (such as missile launch) is provided by a voice warning that informs him of the clock sector and whether the enemy is high, level, or low.

Electronic jamming transmitters are packaged in interchangeable modules to allow use of various types of ECMs, depending on the enemy capability in the mission area. These transmitters are controlled by the computer from signature characteristics and field strength and from pre-established threat priority logic.

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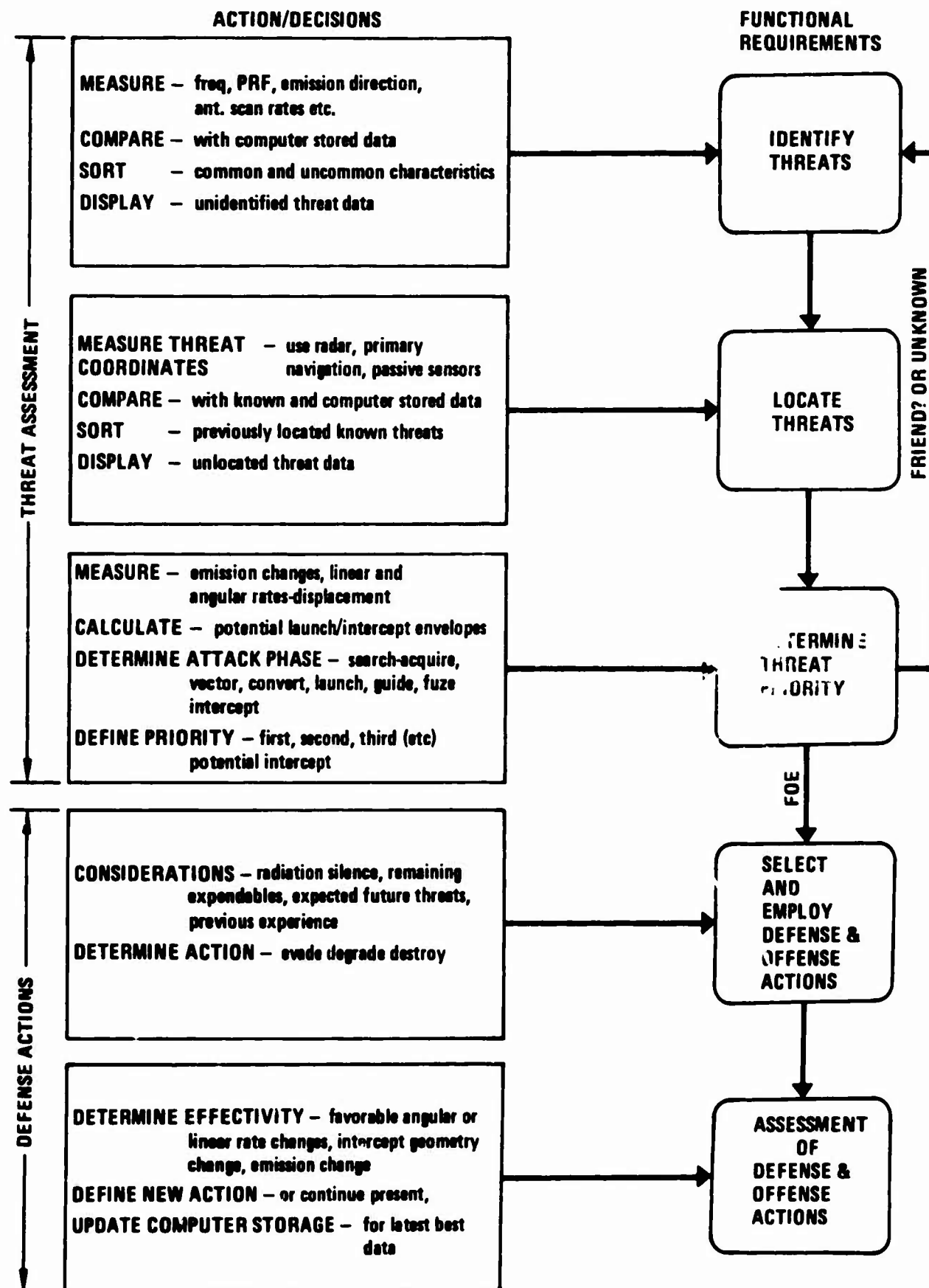
Figure 25. Penetration Aids - Actions and Functions

Expendables are in standardized packages so that mixed types can be loaded into the same dispenser. Expendables are released automatically or manually.

Lethal defense weapons include a short-range high-g missile capable of attacking AIs and launched long-range missiles. Air-to-ground radiation homing or TV contrast lock-on missiles, guns, and other weapons are used in the dual role of attack and self-defense. Decoys can be loaded in lieu of weapons. Weapons and decoys are programmed and controlled by the stores management system.

Passive penetration aids include radar and IR aircraft cross-section reduction. Vulnerability is reduced by use of armor in critical part locations, and by special structure designs. Ablating and reflecting materials on critical surfaces reduce vulnerability to LASER weapons.

The penetration aid system and interface block diagram is shown in Figure 26.

Normally, penetration aid system operation is automatic. The pilot is kept informed by the battle situation display. The display is a PPI type with the tactical aircraft centered. It provides threat location and identity priority and shows the assigned offensive, defensive action. Voice warnings are provided for new threats and attacking terminal threats.

Located threats are represented with a cross shown at proper range and bearing from the fighter. Threat identity and type are on the upper left quadrant of the cross, priority upper right, relative altitude lower left, and assigned action lower right. Dashes are placed in the quadrants when data are unavailable or impertinent. Strobes (dashed lines) are placed on the display when range measurements are not or cannot be made, such as when the threat is jamming and denying range.

Threat priorities are automatically assigned on a first, second, third potential intercept basis. Priorities on the battle situation display for threats are: terminal--red; immediate--amber; delayed--blue; safe--green.

The assigned action for the first priority threat is destruction as shown on the battle situation display. The threat is almost within attack range. The selected weapon(s), attack range envelope is presented as a fan pattern on the MPD. The weapon(s) may be released manually after the threat penetrates into the outer limit of the attack envelope. The fire control symbol, moving

71
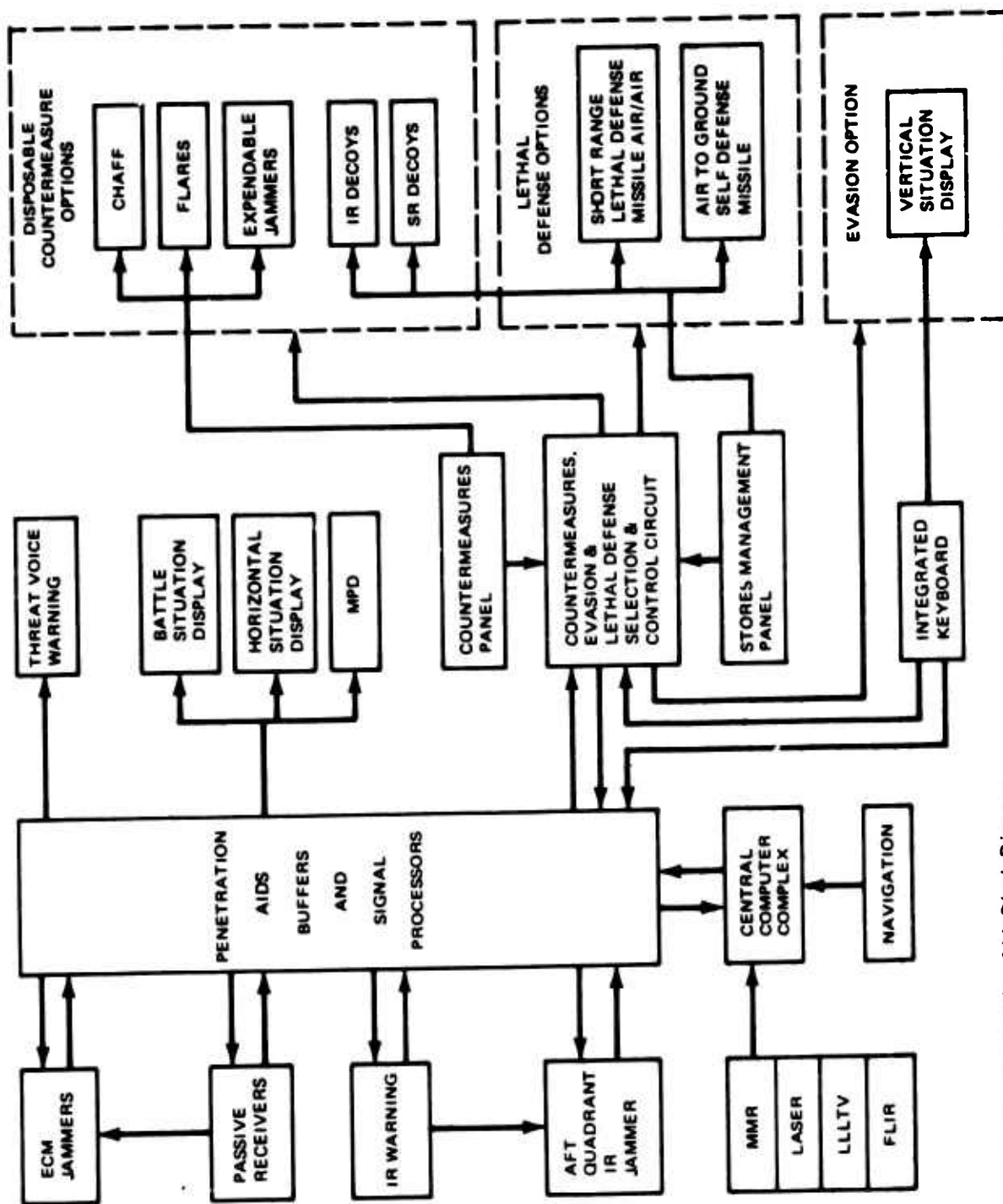
Figure 26. Penetration Aids Block Diagram

counterclockwise, is now at the 6 o'clock
position. Manual release is now possible.
Automatic release occurs at optimum
range, the 3 o'clock position. Minimum
range occurs at the 12 o'clock position.

If the decision is to evade, the weapon launch
envelope and fire control symbol would not be shown. A
voice and visual warning is given and ITEMS controls the
evasive maneuver. When the threat is successfully bypassed,
the threat priority is reordered.

If degradation (ECM) option is used,
a voice warning is given and the proper
system is tuned in automatically.
Colored, lighted buttons on the
countermeasure (CM) panel indi-
cate the system is operating.
Countermeasure system opera-
ting details such as expendables
remaining are shown on the
selected MPD.
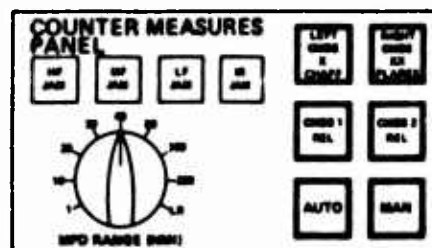
The effectiveness of offensive and defensive
actions is automatically determined and displayed. If the
threat priority does not change in a reasonable time,
alternate or complementary actions are executed automatically.
Appropriate warnings (flashing priority number) are presented
on the display. If the priority does change, operations
are completed or continued until the threats are no longer
of concern.

The computer stores threat characteristics and
countermeasure techniques for future use.

Typical logic showing the self-defense workload
and decision process for an air-to-air and a ground threat
has been developed. Results of the analysis are shown in
Figures 27 and 28.
Logic decisions apply to either the pilot or the
automatic system. The logic decision tasks shown are for a
single threat. The workload would increase in direct
proportion to the number of threats engaged.

Due to the complexity and workload involved in
performing the decision logic process, it is totally auto-
mated. The significant results of the decision process
are displayed as coded information on the threat cross of
the Battle Situation Display (BSD).

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Airborne Engagement

IRS & RHAWS Operating

Airborne Target Present — No / Yes

Radar Operating — No / Yes

RHAWS Detects Emission — No / Yes

Initiate IFF Interrogation

IFF Response — Yes / No

Friendly-Store Info & Continue Monitoring

RHAWS Identifies Emitter

Emitter Ident. With in X Sec — Yes / No

Emitter Is A Threat Type — Yes / No

IRS Detects Emission — Yes / No

Display Info To Pilot

Pilot Designates Emitter a Threat Type — Yes / No

Continue Monitoring & Penetrate

AAM Has Radar Capability — Yes or Unknown / No

ECM Appear Effective — Yes / No or Unknown

Continue Monitoring AAM Trajectory

Launch SRDM @ AAM

Initiate MMR Acq. On SRDM

TB Decoy Utilization Desired — Yes / No

Cease ECM On AI Radar & AAM Freq.

Launch TB Decoy On AI Radar Freq.

Initiate MMR Acq. On TB Decoy

Time Available For SRDM Interrupt On AAM — Yes / No

Initiate Anti-AAM & AI ECM

A

Flowchart (rotated). Text elements:

- Time Available For SRDM To Intercept On AAM — Yes / No
- Initiate Anti-AAM & A ECM
- Initiate MMR On TB Decoy
- MMR Acq TB Decoy — No / Yes
- Monitor AAM & TB Decoy Trajectories
- TB Decoy Is Effective — No / Yes
- Launch TB Decoy On AI Radar Freq.
- Cease ECM On AI Radar & AAM Freq.
- Eject Expendables
- Cease Ejecting Expendables
- Did AAM Miss The Penetrator — Yes / No
- Did AAM Destroy The Penetrator — No / Yes
- Penetration Terminated With Extreme Prejudice
- Time Available For Another SRDM To Intercept AAM — Yes / No
- Has The AI Been Destroyed Yet — No / Yes
- Did SRDM Miss The AAM — Yes or Unknown / No
- Continue Monitoring For AAM Destruct
- Did SRDM Miss The AI — No / Yes
- Continue Monitoring For AI Destruct
- Launch SRDM @ AAM
- Initiate MMR Acq. On SRDM
- MMR Acq. & Tracks SRDM — No / Yes
- SRDM Trajectory Good
- Monitor For AAM Destruct
- AAM Destruct Detected — No / Yes
- Pilot
- Pilot Dispense Emitter A Threat Type — Yes / No
- Continue Monitoring & Penetrate
- Cont. Passive Monitoring & Penetrate
- Avoidance Successful — Yes / No
- Emitter Is In The Track Mode
- Emitter In Search Mode — No / Yes
- Initiate Anti-Surv. ECM
- Radar Switches To Track Mode — No / Yes
- Continue Anti-Surveillance ECM
- Cease Anti-Surveillance ECM
- Initiate Anti-Track ECM
- Radar Switches To Surveillance Mode — No / Yes
- Continue Anti-Track ECM
- Continue MMR AI Monitor
- AI Within SRDM LR — No / Yes
- In R Km — Yes
- Emitter Is A Threat Type — No / Yes
- Is Carrier A Threat AI This Time — No / Yes
- Continue Passive Monitoring
- Monitor Threat Bearing
- Continue Monitoring Threat Bearing
- Initiate Maneuver
- Avoidance Maneuver Decision — Yes / No
- Emitter Is A S/T Type
- Emitter Is A TWS Type
- Initiate Anti Surv ECM
- No RF Signal Present
- Provide Pointing Info To MMR
- Initiate MMR SRI Acquisition On AI Tgts
- Any AI's Within AAM LR — Yes / No
- Continue Normal AI Acq.
- AI Acq — Yes / No
- AI Acq — Yes / No

Figure 27. Air to Air Engagement

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**Avoidance decision branch:**

- (A)
- Is Avoidance Permitted — Yes / No
- Is Avoidance Required — Yes / No
- Initiate Avoidance Action
- Should Counter measures Be Employed — No → Continue Penetration / Yes
- Initiate Counter measures → Continue Penetration

**SAM launch detection branch:**

- Radar Detects SAM Launch — No / Yes
- Initiate Radar Pattern Search In Emitter Area
- IRSS Detects SAM Launch — No / Yes
- RFSS Detects SAM Launch — No → Continue Penetration / Yes

**Main emitter branch:**

- Ground Based RF Emitter Present
- RFS Detects Emitter — Yes / No
- RFS Identifies Emitter — Yes / No
- After X Sec Display Parameters
- Decision On Emitter Type
- Is Emitter Threat Associated — Yes / No
- Emitter Is Non Threat Type → Continue Penetration
- Is Passive Ranging On Emitter Desired — Yes / No
- Initiate IFF Jamming
- Initiate Passive Ranging
- Is Emitter Fire Control Associated — No / Yes
- Emitter Is EW/GCI/HF → (A)
- Is Emitter Fire Control Acquisition — No / Yes
- Is SAM Directing Fire Control — No / Yes
- Emitter Is A AAA FCR → (A)
- (A)
- Is

Initiate Passive Ranging

Is Emitter Fire Control Associated — No → Emitter Is EW/GCI/HF → A
Yes ↓ A

Is Emitter Fire Control Acquisition — No → Is Emitter SAM Directing Fire Control — No → Emitter Is A AAA FCR → A
Yes ↓ A

Is Emitter SAM Directing Fire Control — Yes → Initiate Radar Pattern Search In Emitter Area

Radar Detects SAM Launch — No → IRSS Detects SAM Launch — No → RFSS Detects SAM Launch — No → Continue Penetration
Yes

IRSS Detects SAM Launch — Yes → Initiate Anti-SAM Countermeasures
RFSS Detects SAM Launch — Yes → SAM Launch AZ And/Or Data To Radar

Radar Detects SAM Launch — Yes → Radar Acquires & Tracks SAM — No (loop)
Yes → CM Are Effective — Yes → Continue Monitoring SAM Flight Trajectory
No → SAM Within Defense Missile Launch Range — No (loop)
Yes → Any Condition Of Higher Priority Existing — Yes → Delay Launch Until All Higher Priorities Have Been Cleared → Defense Missile Launch Still Req'd — No → Cease All Actions Continue Penetration
No → Launch Defense Missile At SAM → Initiate Radar Acq On Defense Missile → Radar Acquires & Tracks Defense Missile — No (loop) / Yes → Time Available For Penetration — No

C

Is Avoidance Permitted — No → (to Initiate Radar Pattern Search)
Yes → Is Avoidance Required — No → (up)
Yes → Initiate Avoidance Action → Should Countermeasures Be Employed — No / Yes → Initiate Countermeasures → Is Emitter A Threat To Pen. At This Time — No → Continue Penetration
Yes → Arm Launch Permitted — No → Continue Penetration
Yes → Arm Launch Desired — No → Continue Penetration
Yes → Any Condition Of Higher Priority — No / Yes → Launch Still Required — Yes → Delay Launch Until All Higher Priorities Are Cleared

Unk → Delay For X Seconds

Figure 28. Air to Ground Engagement

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m.  Stores Management System

The prime purpose for the tactical fighter is
weapons delivery.  As such, all systems related to the
aircraft are oriented to achieve this end.  Consequently,
the stores management system (SMS) depends both directly and
indirectly on virtually every system involved in the place-
ment of the appropriate store on the specific target.

Pounds payload per target destroyed is a primary
weapon system figure of merit.  To minimize expended
payload, precision weapon delivery is necessary.  Weapon
delivery accuracy requirements, which for some targets
may be about 10 to 50 feet, directly influence critical
design parameters of all fire control sensors and the navi-
gation system.

All-weather operation is required to continuously
maintain a tactical advantage.  Visual delivery and
delivery with options selected from the full complement of
on-board sensors are needed for flexibility.  Precision
data link or navigation-system-controlled automatic blind
(no pilot control operation) weapon delivery is desired
for preplanned targets.

High survivability is a requirement.  High
maneuverability and rapid speed changes are necessary to
evade enemy actions.  Weapons should be deliverable while
evasive tactics are being performed.  Self-defense is
needed.  Weapons for counterattacks should be carried.

Weapon options using a full spectrum of delivery
tactics should be possible to optimize weapon accuracy in a
variety of terrain, weather, and threat environments.

The SMS integrates all equipment affecting weapon
delivery.  The elements of weapon delivery include but are
not limited to:

o  Transfer of coded stores logic unit informa-
   tion on the weapon and its location

o  Preprogramming, storage, and recall of
   complete or partial stores delivery programs

o  Fuzing power, status, selection, etc.

o  Data transmission

o  Weapon environment such as aerosols (dust,
   bugs, ice, precipitation) and their effect
   on optics; temperature history; radiation;
   electromagnetic pulse, etc.

o   Release parameters affecting look angle
    on guided weapons or the flight path of
    ballistic weapons (such as local air flow,
    acceleration, hook or rail drag, aircraft
    mass, and other factors impacting ejection
    velocities)

o   Energy management integration into the fire
    control system and displays

o   Weapon release/weapon away information

o   Computing delivery envelopes and stepping
    to the next weapon envelope as the store is
    expended or its release parameters are
    compromised

o   Jettisoning and automatic safe jettisoning
    coupled with the ITEMS

o   In-flight training/simulation

Representative data showing typical parameters
for MPD displays and special integrated keyboards are
shown in Figure 29. Figure 30 shows stores management
system functional block diagram.

    n.   Target Acquisition Sensors

The Automatic Target Acquisition system
correlates data received from the MMR, LLLTV, FLIR, RHAW
and IR warning systems. Sensor data are processed through
the center computer complex and presented to the pilot on
demand. Techniques such as the image registration process
deal with the structure of the image as a whole, as
opposed to the detailed comparison of individual resolution
elements.

Four target acquisition sensors, low light and
daylight television, FLIR with azimuth and elevation
coverage forward of the airplane; radar with azimuth,
elevation, and range capability; and LASER as a range only
sensor, were assumed. These sensors are designed to have
the same azimuth and elevation coverage so targets detected
by each sensor can be positionally coordinated by the pilot
on his display. The three major sensors can be presented
simultaneously on the target acquisition display (VSD)
for identification by superposition of target data from
each sensor. For preplanned interdiction targets with
known coordinates, the cursor appears at the top of the
HSD at the predicted location.

INTEGRATED AVIONICS

| COMPUTER COMPLEX | CLU CONTROL FUNCTIONS | STATION LOGIC UNIT FUNCTIONS | WEAPON CONTROL DISPLAY — Control Functions | WEAPON CONTROL DISPLAY — Display Functions |
|---|---|---|---|---|
| Provide storage for:<br>a. Mission Planning Data<br>b. Threat Catalog Information<br>c. Backup Programs<br><br>Perform all weapon delivery computations and data processing such as:<br>a. Navigation<br>b. Bombing<br>c. Air-to-Air Surface<br>d. Missile Launch<br>e. Penetration Aids<br>f. Mission Control<br>g. Integrated Testing<br>h. System Interface Computation Functions | Mode Select<br>  Auto, Manual, Emergency, Test<br>Store/Station Select<br>Strike Option Selection<br>a. Delivery Mode<br>    Auto<br>    Manual<br>b. Fuze Options<br>    Nose    Ground Burst<br>    Tail    Contact<br>    All    Laydown<br>    Timer/Delay<br>    Air Burst<br>c. Trajectory Options<br>    Hi Level  Max Ave<br>    Lo Level  Max Pen<br>    Hi-Lo    Retard<br>    Lo-Hi    Free Fall<br>d. Release Options<br>    Manual  Dive/Toss<br>    Auto    Single-Pairs-<br>            Multiples<br>    Release Interval<br>e. Gun Control<br>    Ammo Select  Gun Charge/Safe<br>    Fuze Select<br>    Rate Select<br>f. Guidance Options (Missile)<br>    ARH, IR, Optical<br>    (Terminal) Frequency<br>    Command, Inertial Pro-<br>    grammed (Mid-course)<br>Strike Controls<br>a. Prearm, Arm, Safe<br>b. Rack Unlock<br>c. Nuclear Consent (CSS)<br>d. Wpn Release<br>Jettison Controls<br>    All<br>    Selective | Logic/Memory<br>a. Store type<br>b. No Stores Remaining<br>c. Store Parameters (Wgt., CG, Drag)<br>d. Store Limits (cruise-delivery speed, g-limits, temperature, altitude)<br>e. Delivery/Fuze Restrictions<br>Store Status<br>  Safe, Arm, Go/No-Go<br>Rack Status<br>  Locked<br>  Unlocked<br>Store Environment Monitor | Store Selection<br>a. Weapon Identification<br>b. Expendable Identification<br>Strike Option Selection<br>a. Delivery Mode Selection<br>    1) Radar Release<br>    2) Timer Release<br>    3) Manual Release<br>    4) Emergency Release (Backup)<br>b. Weapon Options<br>    1) Air Burst<br>    2) Ground Burst<br>    3) Free Fall<br>    4) Retard<br>    5) Contact Burst<br>c. Weapon Release/Launch Sequence<br>    1) Single<br>    2) Pairs<br>    3) Multiple<br>d. Weapon Release/Launch Rate<br>Strike Control Selection<br>a. Prearm/Safe Weapons<br>b. Consent to Prearm Nuclear Weapons<br>c. Consent to Release/Launch Nuclear Wpns<br>Release Selection<br>a. Normal (Automatic or Manual)<br>b. Emergency<br>c. Jettison<br>    1) Conventional<br>    2) Nuclear<br>Preprogram, Recall & Modify<br>Missile Guidance<br>Master Arm Enable<br>SMS Power On | Store Selection<br>Strike Option Selection<br>Strike Control Selection<br>*Release Selection Status:<br>a. Store Stations Not Loaded<br>b. Store Quantity Loaded<br>c. Store Quantity at Each Station<br>*d. Safe/Prearm Status of Wpn<br>*e. Safe/Prearm Status of Nuclear Weapon<br>*f. Lock/Unlock Status for Each Weapon<br>g. Master Caution if items c. and f. disagree<br>h. Carrier Restriction due to:<br>    1) Carrier Maneuver Restriction<br>    2) Store Airspeed, "G" Restriction and Look Angle<br>    3) Aircraft Weight<br>    4) Location and Type of Stores Remaining<br>    5) Aircraft Configuration (e.g., wing sweep, ldg. gear position, flap position)<br>i. Stores Release/Stores Away<br>j. Store Quantity Available at Each Station for Release, Launch, Firing, or Jettison<br>k. Stores Malfunction<br>l. SMS Equipment Malfunction<br><br>*Continuous or On-Demand Indications |

Figure 29. Stores Management Parameters
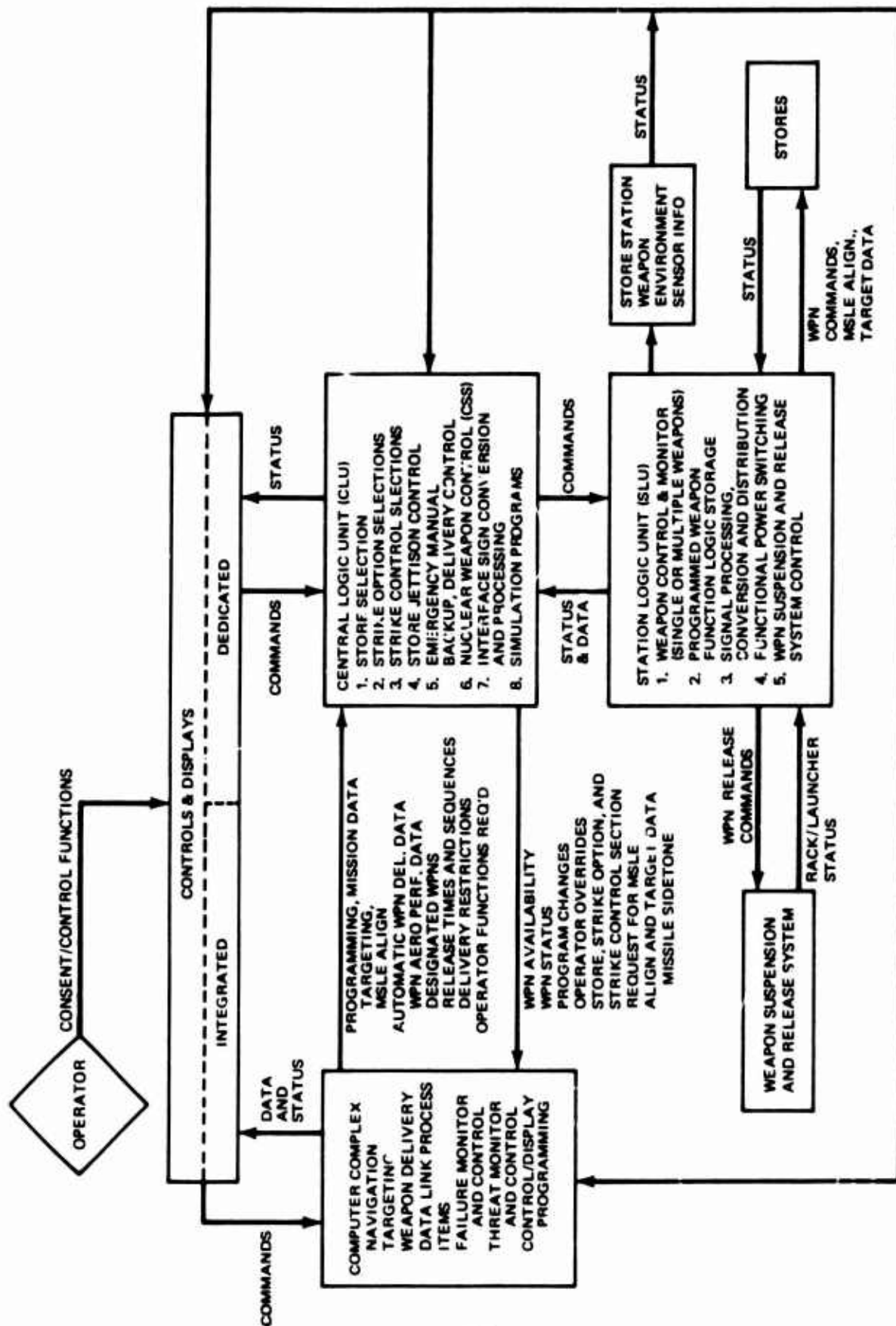
Figure 30. Stores Management System Functional Block Diagram

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Of the possible radar techniques available in this period, the one that appears to offer the most promise is the multiple emitter/receiver. This radar uses solid-state devices to generate the RF power. The only degradation suffered when partial failure occurs in the transmitting elements is that the beam sharpness is reduced. Scanning is electronic with a computer stabilized beam.

Received signal processing is of the monopulse type. Complete azimuth elevation and range data are obtained from each transmitted pulse. The processing also sorts out returns that exceed the background noise and land echoes by a given amount. Then these returns are examined for location with respect to the predicted navigation coordinates of a preplanned target. A symbol that represents a processed radar target appears on the VSD and HSD at the appropriate location. The cursor corresponds to the predicted target location and is manually moved to the target to achieve lock-on, first on the VSD, then the HSD.

Under lock-on conditions, the computer begins to perform a track-while-scan operation based on the cursor azimuth, elevation, and range at the time the pickle switch is pressed.

FLIR is capable of locating targets in azimuth and elevation. It detects objects that differ in temperature with respect to the temperature of the surroundings. The general background temperature is determined by processing techniques. Depending on the type and the presumed temperature of the target, a temperature difference or presentation threshold is preselected. Returns having a greater temperature differential than this threshold are presented on the VSD. A cursor can be placed over the target to initiate contrast tracking. The FLIR receiver is slaved to the inertial platform through the computer to aid in tracking and to stabilize the presentation. Boresight and field of view for the FLIR must be the same as the TV and radar to achieve target identification by superposition.

Television and radar are the two principal sensors. Television can see targets under low light conditions that cannot be detected by the unaided eye. Also under daylight conditions, the pilot can coordinate returns from TV, radar, and IR. Color TV is required for daytime operation; otherwise, the pilot would look out of the cockpit for color cues. The TV camera is stabilized to the heading of the airplane, or to a preset azimuth angle for use with offset bombing techniques.

Two fields of view should be available to the
pilot, a wide field for general search and a narrow field
for identification.  Two mechanizations are suggested:
(1) electronically magnify the image; and (2) use two
cameras, one with a broad field of view and a second
camera with a small field of view and high resolution.
Both images are presented on the VSD simultaneously with
the high resolution image replacing a portion of the low
resolution image at the correct relative location.  Either
of these techniques can be used for target identification.

The LASER is used as a ranging device to provide
distance to the target when a discrete narrow beam is
preferred, or the radar is inoperative, or when greater
accuracy is required.  Operation as an illuminator is not
contemplated, because the TV can perform this task in a
completely passive manner.  Both media are subject to the
same limitations of haze, fog, and clouds.  The LASER
provides range upon command by the pilot.

o.   Battle Damage Assessment/Reconnaissance

The IIPACS weapon system can gather battle
damage and/or reconnaissance data.  On-board sensors
sense the ground target area and aid in compiling suffi-
cient data to determine target viability before and after a
strike.  Such information is transmitted through data link
to the Battle Area Commander.

On-board equipment can detect and record sensor
data from the MMR, LLLTV/FLIR, RHAW, and EMP measuring
devices.  In addition, targeting and weapon delivery
information, navigation data, and voice recording are
continuously available through tape decks for playback to
the Command Post via data link.  Such data may be requested
at any time by the Command Post without assistance from the
pilot.

During high/low altitude penetration, battle
damage assessment (BDA) recordings are initiated automa-
tically at a preset range or time before scheduled weapon
release.  Recordings continue through detonation for post-
strike analysis.

During an operational situation, for example,
the recording devices may be started either through computer
instructions, data link, or manual commands using the
keyboard.

Computer instructions come from preprogrammed
time or range intervals before or after weapon detonation.
Recording instructions for turn-on, turn-off and/or playback

may come also from data link or keyboard commands. The Battle Area Commander may receive near-real-time sensor data from the IIPACS aircraft. Such data may be examined for tactical value and used either to direct the aircraft for additional targeting or to provide assessment data for instructing following aircraft. The radio bandwidth is large enough to handle radar and electro-optical sensor information being data linked to the Command Post. Navigation, targeting, and weapon delivery information will accompany the recording data to make the imagery more useful in the final damage assessment analysis. All sensor imagery data would be recorded on digital tapes compatible with on-board digital equipment.

The BDA function would be selected from the "FCS" options presented on the Master Keyboard Select panel. Various options pertaining to BDA appear on multi-legend keys as shown on the example keyboard. Each key carries at least 48 different legends that selectively appear as various functions are performed.

The BDA system would normally be in AUTO where all programming would be handled through the central computer; however, the pilot may select MANUAL and start, stop, or play back any recording.

6.  CONTROL/DISPLAY CONCEPTS

The study analyses were primarily oriented toward reducing the interpretive and integrative processes imposed on the pilot while he performs the complex mechanics of flying a sophisticated aircraft. The result of these analyses produced the concept of an ITEMS.

Energy management is by no means a new concept. Attempts at energy management first appeared with the issue of pilots' handbooks. The significance of energy management gained prominence with the appearance of the ME-163 toward the end of World War II. A. Leppisch, of ME-163 fame, may be credited with recognition of the refinement of energy management required for the optimization of high performance aircraft by developing idealized climb schedules. The most advanced work in the field is found in space vehicles and may be applied to aircraft.

Existing programs are reasonably accurate, but they are limited by deficiencies. Some of these deficiencies are identified by Dunlap (Ref. 2) as response time, display media, and the fact that they treat the problem almost exclusively in one plane of operation such as range-time altitude or zoom-climb. The requirement for the development of a three-dimensional total energy

management system in essentially real time is indicated in this study.

The proposed system dispenses with the requirement to present quantitative information. The ITEMS may be programmed to optimize a specific energy profile. Examples of some types, all in the vertical plane, are taken from Ref. 2. They are in part:

o   Minimum time climb

o   Minimum time altitude--range transition

o   Minimum fuel climb

o   Maximum range climb

o   Maximum range cruise

o   Maximum endurance cruise

o   Range-time-altitude rendezvous

o   Zoom climb to launch

Control of  g location, flexibility of flight controller gains, and flight control harmonization are necessary adjuncts to the ITEMS concept to preclude energy losses and/or to provide an optimum weapon delivery platform. Vietnam data indicate a need exists for high-g maneuvers throughout a spectrum of speed ranges. Figure 31 shows the accelerations as a result of control excursions at specific Mach numbers for an existing fighter aircraft. Such control parameters compromise the operational capabilities of a weapon system regardless of stick force per g.
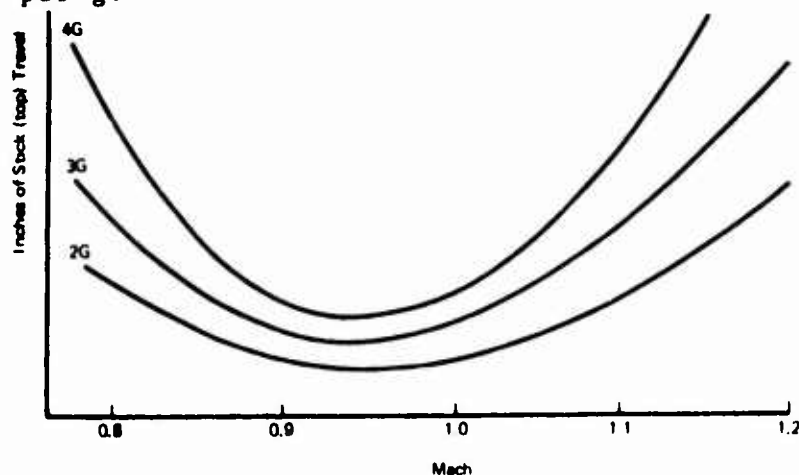


Figure 31.   Relationship of Acceleration to Control Input as Affected by Mach Number

As each mode of flight is selected,
the aircraft's stability and control
characteristics change in addition to
the associated displays. For example,
selection of the air-to-air mode will cause the cg to
move closer to the center of pressure to provide the
decreased stability necessary to high maneuverability.
Controller to control surface relationships gain will be
altered to counter the adverse yaw associated with high
roll rates at large angles of attack. Appropriate changes
will occur as the cruise, landing, and air-to-ground modes
are selected.

a. Cockpit Functional Layout

Personnel sizing and response to the environment
dicated the IIPACS cockpit configuration. The cockpit
functional layout was developed from three major inputs,
the pilot's reach and vision envelopes, the control and
display groupings, and the airplane configuration. The
envelopes are divided into sectors of increasing access
difficulty with respect to the eye reference point. The
control and display groupings resulted from the analysis
procedure, especially the ranking of these items as to
their importance to safety of flight and mission completion.

The use of the eye reference point was found
to be more realistic than the use of a seat reference,
considering the variations that exist in the buttocks to
eye dimensions. Target identity, target aiming, and
visual landing depend on proper alignment of the target,
a sight, and the pilot's eye. Therefore, the cockpit was
designed around the eye reference point.

The pilot obtains proper eye position when he
is fully restrained with seat and shoulder belts by align-
ing the eye with a reference provided by a collimated image
and a physical feature of the airframe. Seat tilt for
comfort is achieved by rotating the seat about the eye
reference point.

With the eye position fixed, the control/display
location limits were defined. According to Morgan (Ref.
3), viewing distance for controls and displays is limited
by reach distance and should not exceed 29.5 inches. A
minimum viewing distance of 13 inches is recommended;
however, it should preferably be not less than 20 inches.
For this study, a figure of 29 inches was used, resulting
in a sphere of 29-inch radius about the eye reference point.

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The primary, secondary, and tertiary viewing
areas are defined in Figure 32. The primary viewing area
is seen by moving only the eyes from the eye rest point
which is forward and down 15° with respect to the horizontal.
The secondary viewing area is seen by moving the head
while retaining the eyes in a straight-ahead position. The
tertiary viewing area is seen by a combination of eye and head
movement.

The primary reach area is defined as the volume
that can be reached by both hands while fully restrained
by the seat belt and shoulder harness; i.e., either hand
may be used on the control. Morgan (Ref. 3) defines this
volume as being 24 inches wide and extending out and up
from a point corresponding to the center of the pilot's
fist when the forearm is horizontal and the elbow is next
to the body. The far end of this reach volume is obtained
from the extension of the arm as far as possible in a
horizontal path. The top is obtained by raising the arm
to a 15° position, first with the elbow next to the body,
then extended horizontal from the shoulder.

The secondary reach volume is that area in
which the pilot may operate any type of control easily
using only one hand. Operation of these controls requires
turning, clamping, pushing, and pulling. The tertiary
volume is defined as that volume in which only limited
types of controls, such as toggles or pushbuttons, can be
operated easily. The reach areas are delineated on Figure
33.

Aircraft configuration constrained the instru-
ment panel size. The conical shape of the mockup, which
gives the pilot considerable shoulder room, results in a
reduced cross-sectional area at the instrument panel, 29 in-
ches forward of the eye reference point.

Further examination of the reach envelopes
indicated the lap area above the pilot's legs is also a
primary reach area. A removable lap panel was evaluated, and
it was decided to attach a lap panel to the forward panel
and to mount this assembly on the side-hinged canopy,
Figures 34 and 37. Thus, a wraparound effect was achieved
while pilot ingress-egress was made easier and access
to instruments was improved.

A conventional flat forward instrument panel
was designed as an alternate configuration (Figure 35).
This panel is attached to the airframe and has separate
side panels which butt up against the forward panel. A
unique feature of this cockpit configuration is the movable
armrests that provide the pilot greater comfort and improved

Figure 33. Pilot Reach Areas

Primary Reach
Secondary Reach
Tertiary Reach



Figure 32. Pilot Vision Areas

Primary Vision
Secondary Vision
Tertiary Vision
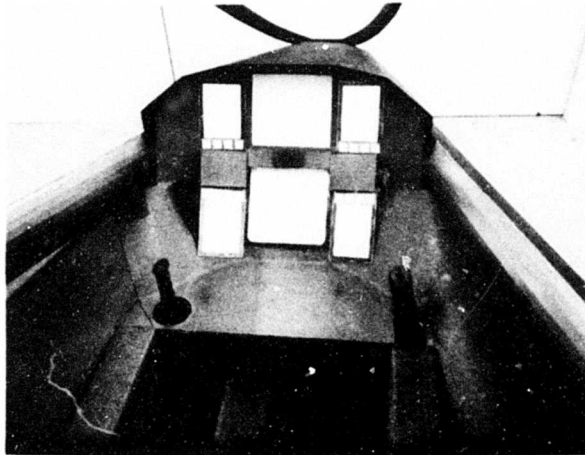
Figure 34. Wraparound Functional Layout
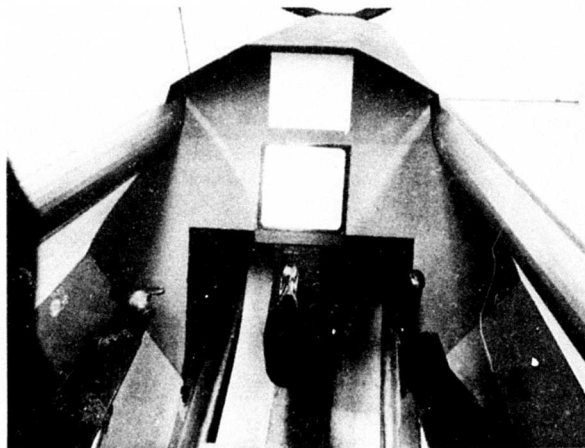


Figure 35. Center Stick Console Functional Layout
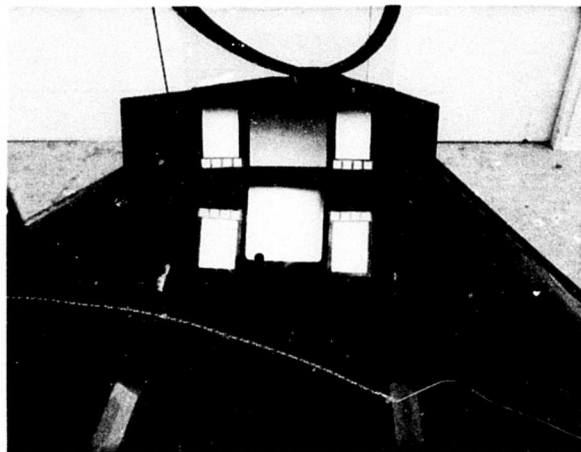


Figure 36. Panel Mounted Control Handle
Functional Layout

87
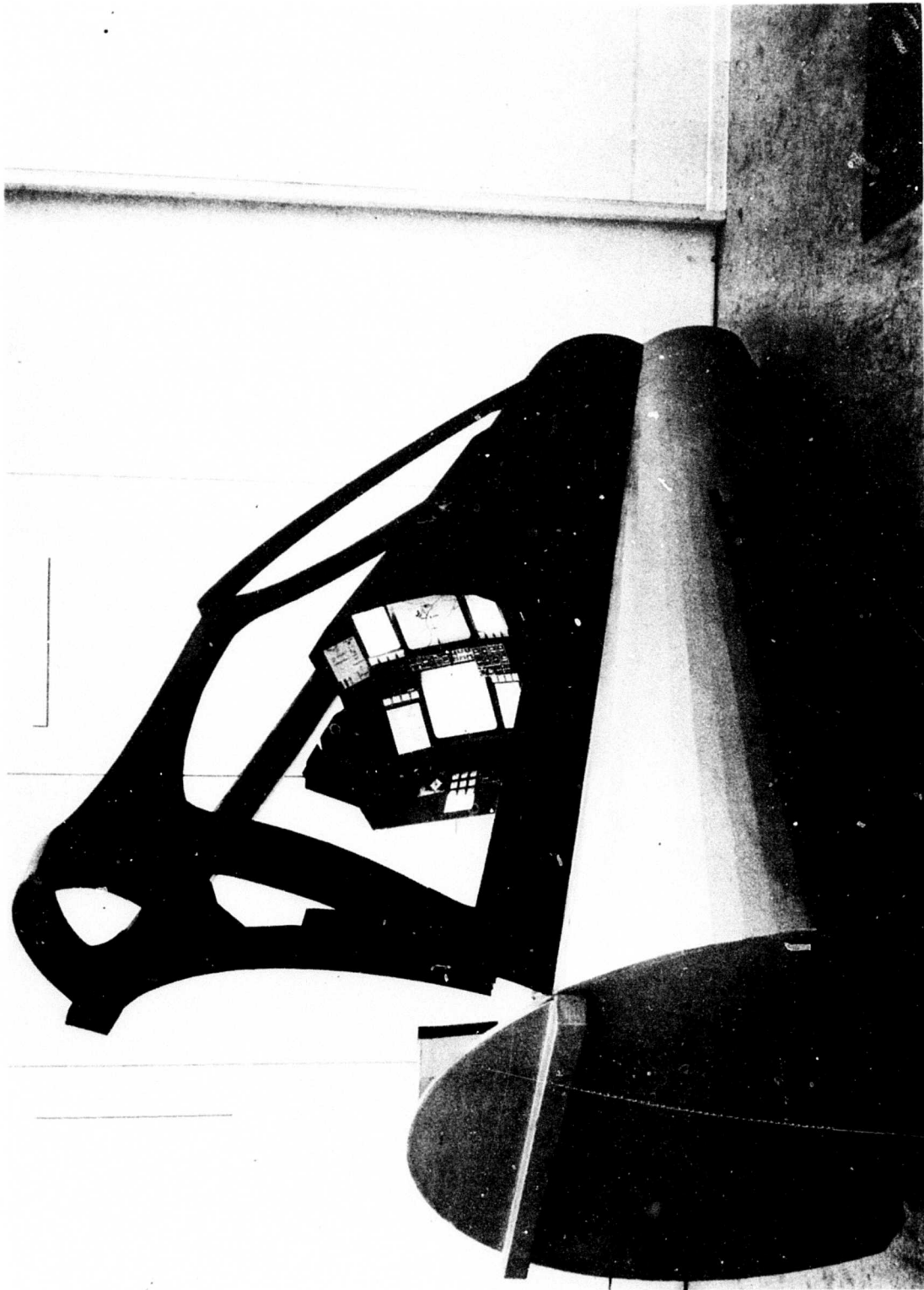
*Figure 37. Instrument Panel Raised With Canopy—Wraparound Cockpit*

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ingress/egress.  The armrests move laterally.  The flight
control stick is center-located.

The third configuration falls between the two
described above.  It has many features of the wraparound
concept including the raising of the instrument panel with
the canopy.  This configuration uses panel-mounted control
handles--flight controls that extend out of the instrument
panel and are gripped comfortably with each hand (with
the forearms on the armrests).  This concept is shown in
Figure 36.

b.  Control/Display Definition

The analysis described in detail in Vol. II,
Section III, defined the controls and displays included
in the cockpit.  To determine where these controls and
displays should be located with respect to the reach and
vision envelopes, each task was rated as to its importance.
These ratings governed task assignment to primary, second-
ary, or tertiary reach or vision areas.  Three possible
mechanization schemes were postulated for each control/
display function.  This resulted in trade studies being
performed to define the relative advantages and disadvantages.
Each control and display was initially treated as an inde-
pendent entity with grouping to be considered during inte-
gration.  Six alternate panel arrangements were developed
and are shown in Figure 38.  A combination of configura-
tions 3 and 6 of the Figure was selected.

Traditionally, controls have been grouped by
subsystem; however, the results of this analysis called
for similar functions to be performed on a common panel.
Once the common functions were defined and grouped, the
remaining functions associated with a given equipment type
were associated together.  For example, all navigation
controls (whether for an inertial platform or a TACAN)
are on the same panel.  Secondary and tertiary controls
may be upgraded, but a control may not be downgraded to a
lower ranked area.

Time-sharing was considered in selecting
control/display mechanizations.  The use of time sharing
minimized the multitude of special-purpose controls and
displays prevalent in today's airplanes.  This is espec-
ially true of displays.

A primary requirement for the tactical fighter
system is a superior all-weather, air-to-ground target
acquisition capability.  Radar, FLIR, low-light level and
daylight TV, and LASER sensors were selected to provide
targeting information.  Boeing-Wichita studies of display
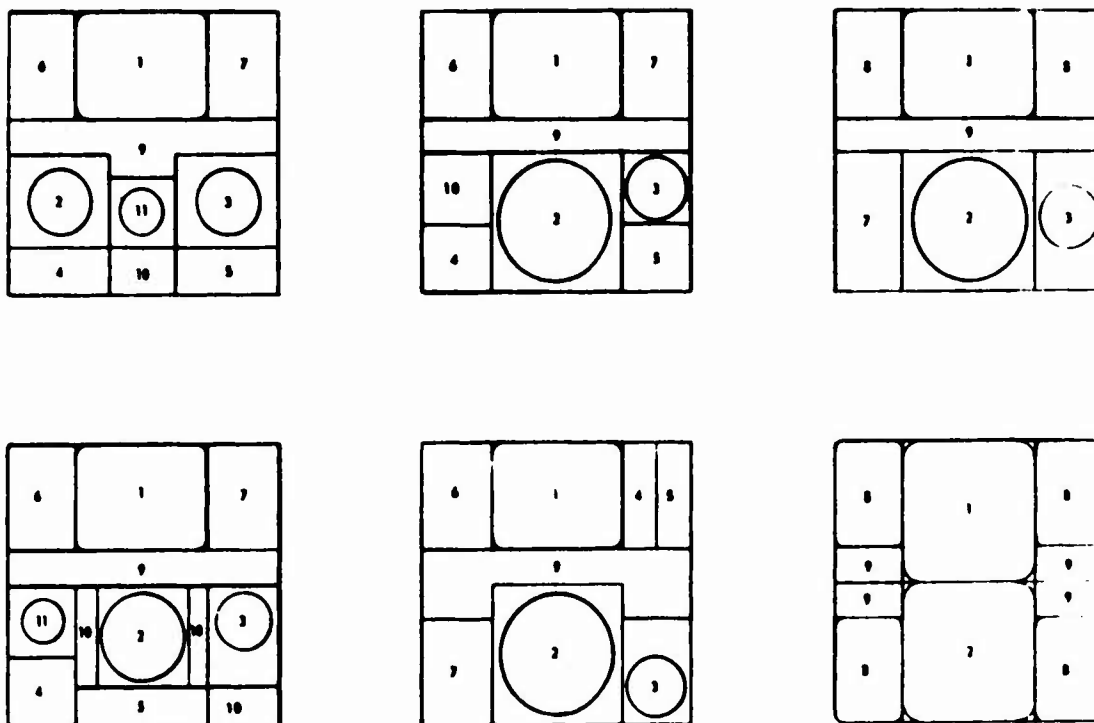
LEGEND

1. VERTICAL SITUATION DISPLAY (VSD)
2. HORIZONTAL SITUATION DISPLAY (HSD)
* 3. PASSIVE BATTLE SITUATION DISPLAY (BSD)
* 4. COMMUNICATION, NAVIGATION, IDENTIFICATION DISPLAY (CNI)
* 5. PRIMARY NAVIGATION DISPLAY
* 6. ENERGY MANAGEMENT DISPLAY (ITEMS)
* 7. WEAPONS STATUS DISPLAY
8. MULTIPURPOSE DISPLAY
9. DISPLAY CONTROLS
10. SECONDARY CONTROLS – GROWTH SPACE
11. HORIZONTAL NAVIGATION INDICATOR

* MAY BE REPLACED BY MULTIPURPOSE DISPLAY

Figure 38. Proposed Panel Layouts for Primary Vision Area

sizes for a combination of radar, IR, and TV sensors
(Ref. 4) recommended a display size of 6 by 8 inches at a
viewing distance of 30 inches. Working with these dimen-
sions and considering the need for horizontal targeting
information, two central panel displays were stacked
vertically with a space between them for sensor and flight
mode selection. The panel space remaining would not
accommodate conventional miniature instruments and the
remaining control functions. A time-sharing concept
using multipurpose displays (MPD's) evolved. These time-
shared displays are large enough to provide meaningful
information for data that do not require continuous
readout.

A HUD for use under visual and transitional
conditions was placed above the centrally located VSD and
HSD. These primary displays present essential aircraft
control and targeting information.

The MPD's are secondary and/or contingency
displays that may be used to augment primary displays.
The type of information presented on these displays includes
engine data, battle situation, communications selections,
etc. The MPD's are used intermittently or are monitored
quite closely depending on the parameters displayed and the
mission segment. With one exception, these MPD's are lo-
cated in the primary viewing area.

Building on the two primary displays and the
four MPD's grouped about them, the remaining controls and
displays were allocated to reach and vision areas based
on their relative importance. The resulting cockpit
functional layout is shown in Figure 39. This layout
only applies to the wraparound cockpit. Variations of
this layout are used for the other two cockpit configura-
tions.

(1) Primary Displays

Primary displays present essential and
ancillary information to the pilot for monitoring during
automatic flight or for direction during manual control
of the airplane. These essential data include command
information to tell the pilot what he should do or what
is being done for him to carry out the assigned mission.
The ancillary information contributes to the pilot's
confidence or is used only for specific flight phases.

Primary displays fall into a head-down or
head-up category. It is well known that a finite time is
required to refocus the eyes from near to far and from
far to near objects. Many factors enter into accommodation

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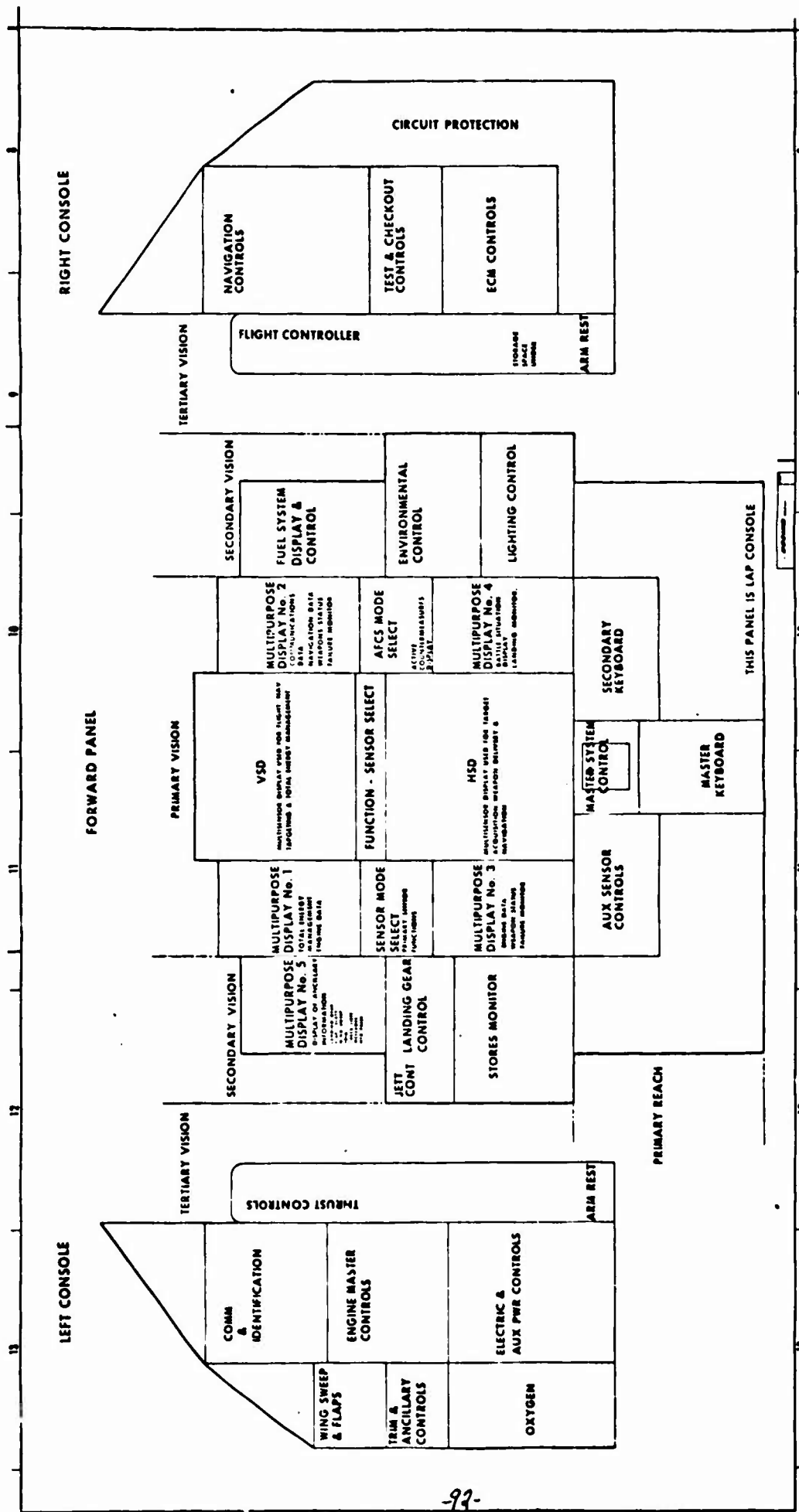
Figure 39  IIPACS-1 Wraparound Cockpit Functional Layout

time.  A principal one is age.  Data on accommodation inertia (focusing time) obtained in the Boeing Visiometrics Laboratory indicate the time to obtain a clear image when the observer shifts from near visual tasks to extra-cockpit vision can be significant.

Figure 40 reflects the factor of age as the contrast, in near to far refocusing time, for two age groups.  Figure 41 shows that the duration of the near task, at an instrument distance of 26 inches, is a factor.  After 30 seconds, refocusing to distance takes 3.2 seconds and this increases at 0.3 second per minute up to four minutes. The low illumination condition of a pilot's environment at night has a greater effect on refocusing time than a higher illumination condition as shown in Figure 42.

Two courses of action are open to resolve this problem.  One solution suggests the potential benefit that may be obtained from eyeglasses with special bifocal lenses that obviate the requirement for changes in focus, and enhance visual performance even for the younger pilot. These lenses would permit the pilot to remain focused at a distance, even when viewing the instruments.  An alter-nate solution is that either of the two display types (VSD and HUD) should independently provide sufficient informa-tion during critical mission segments to permit continuous pilot attention either in or out of the cockpit.

(a)  Head-Up Display (HUD)

The more conventional HUDs have a relatively large case closely associated with and attached to a combining glass.  HUDs of this type are considered incompatible with the tactical attack fighter cockpit configuration.  To obtain the minimum field of view (16°) with a conventional HUD, the combining glass should be placed from 20 to 26 inches from the eye reference point. The remainder of the displays are placed at 29 inches. There are two reasons for not placing a conventional HUD further from the eye; the first is that the subtended angle between the eye and the outline of the combining glass is reduced; the second is the reduction of vertical space available due to the convergence of the cowl and windshield.

Two other types of HUDs are available, both bringing the combining glass close to the eyes.  One mounts a small-sized binocular HUD to the airframe (Figure 43); the other places it on the pilot's helmet (Figure 44). Each of these approaches has drawbacks.  The prime problem with the HUD attached to the airframe is relative motion between the pilot's head and the display.  The helmet-mounted display allows the pilot to look in all directions,

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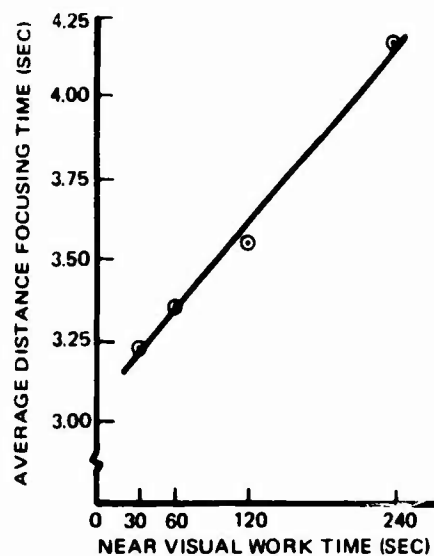
Figure 40: Average Time for 35 Observers
(Ages 21 to 55) to Change Focus
From 26 Inches to 20 Feet (Infinity)
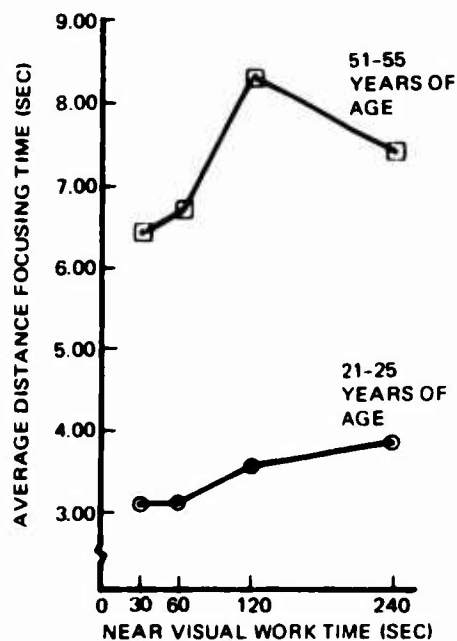


Figure 41: Time Required to Change Focus
from Near to Far for Two Differ-
ent Age Groups
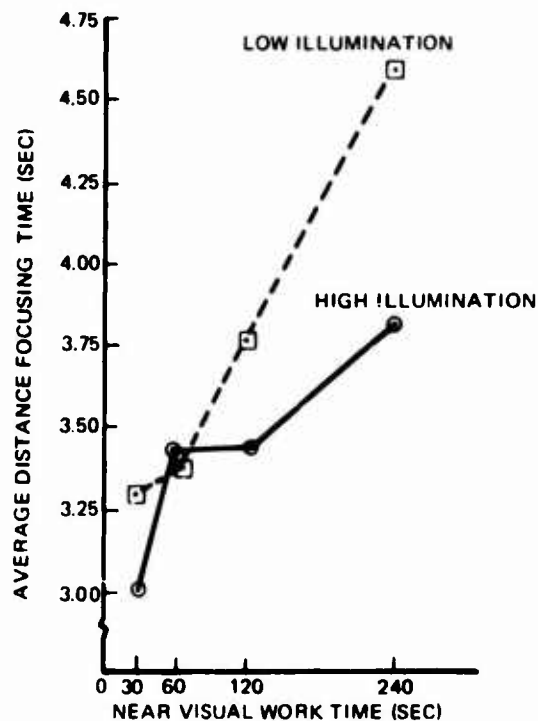


Figure 42: Effect of Illumination on Focus-
ing Time (Near to Far)

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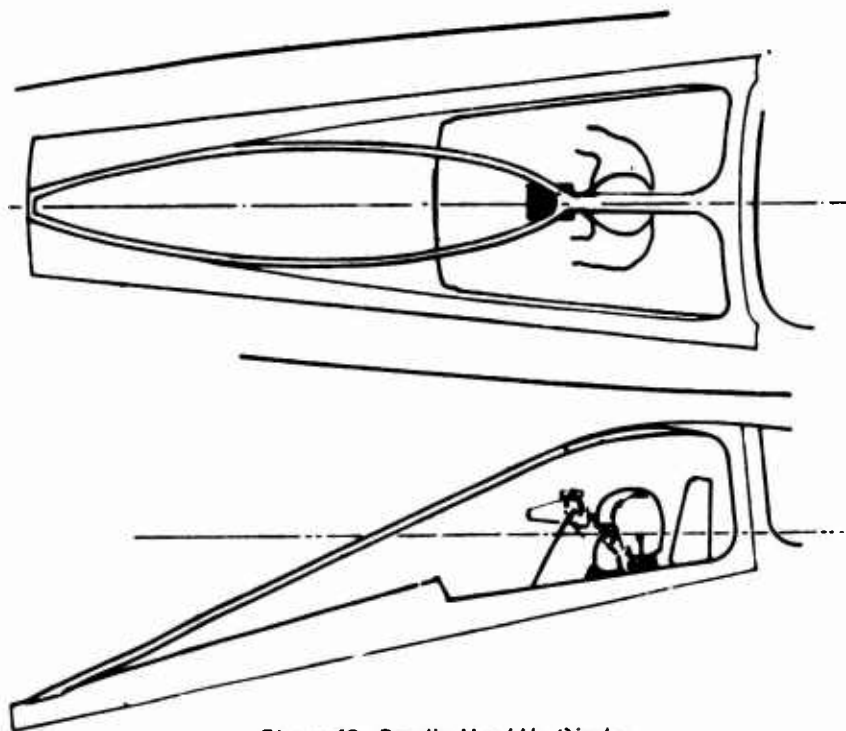
*Figure 43. Bendix Head-Up Display*
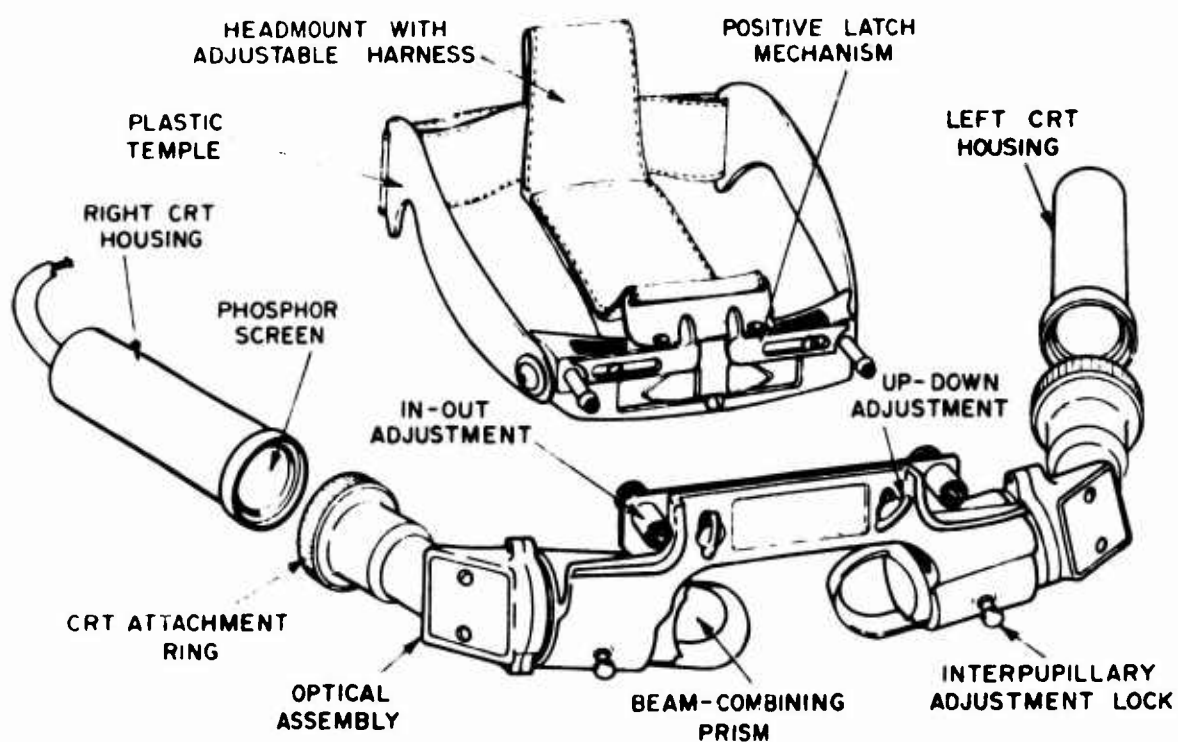


*Figure 44. Perkin Elmer Head-Up Display*

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but requires that the pilot's head position be known so that meaningful information can be displayed. A combination of a helmet position sensor and a helmet-mounted display appears promising.

Another potential HUD configuration would attach the electro-visual transducer and the necessary optics to the canopy frame above the pilot's head. The combining glass would be placed in the pilot's line of vision and attached to the canopy frame (Figure 45).

Data presented to the pilot duplicate those presented on the VSD, with the exception of the TV presentation. The controls for the VSD also select the data for the HUD. To temporarily deactivate the HUD, the master intensity control on the level control is used to reduce the presentation intensity.

The HUD configuration select d for the IIPACS provides total field of view of 20° vertically and 25° horizontally. The combining glass folds down out of the pilot's vision when not in use. Liquid crystals provide a means for opaquing selective portions to accommodate TV presentations projected to infinity (Figure 46).

(b) Vertical Situation Display (VSD)

The VSD is a 1024-line, direct-view color cathode ray tube that presents information of flight situation, control, and weapon delivery in an integrated form using a TV raster technique. The tube has sufficient light output to be visible under ambient light conditions encountered in flight.

Data presented include color symbology representing pitch, roll, heading, energy management commands, flight cues, and tactical information necessary for performance of a complete mission under instrument conditions.

(c) Horizontal Situation Display (HSD)

The HSD selectively combines a cathode ray tube display with a colored moving map. The display provides present position, en route, target, and terminal information as the situation dictates. The display unit uses a combination of full color moving map data and ground-mapping data from the forward-looking radar, weapons delivery information for air-to-air guidance, and threat warning from the RHAW equipment, depending on pilot selections and flight mode.

The map display can be derived from the computer memory full color. The map is automatically positioned by the navigation system. A chart slew switch permits the operator to slew the map in any direction to

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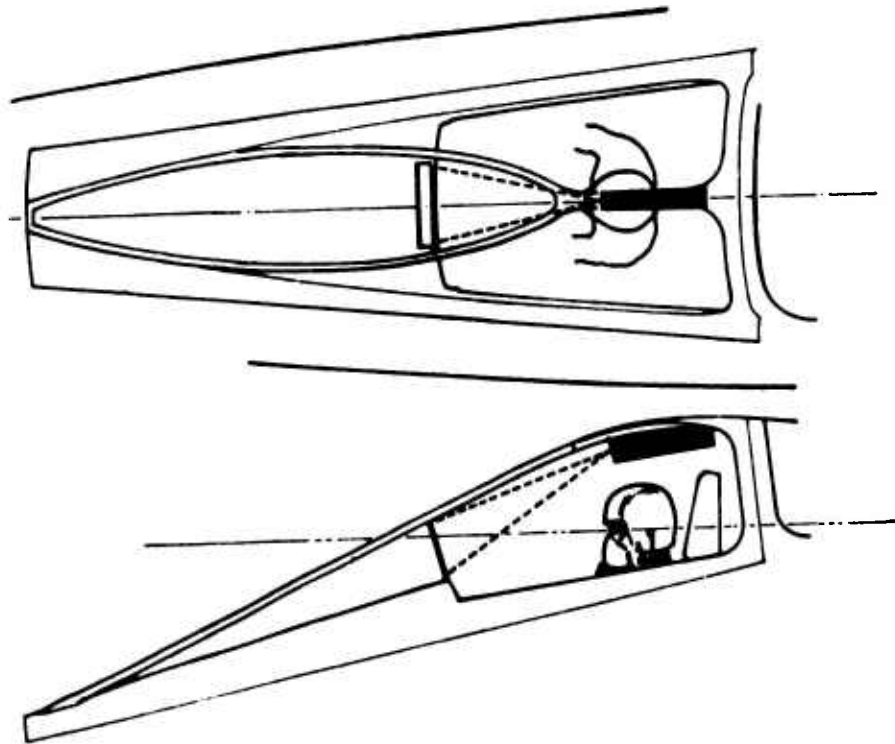
Figure 45. Potential Head-Up Display Configuration
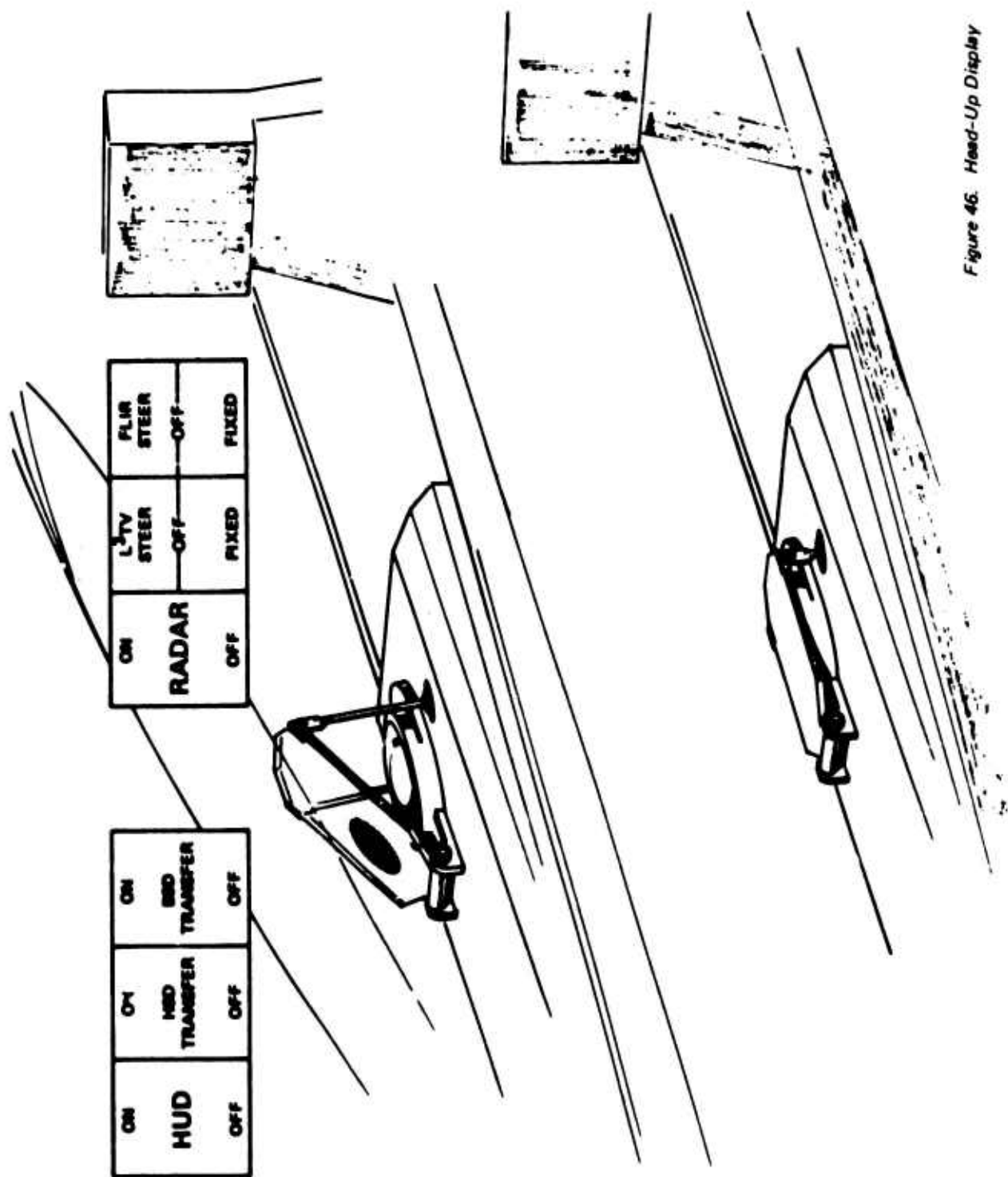
Figure 46. Head-Up Display

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look ahead, but the map always returns to the present
position when the switch is released.  The map may be
oriented with aircraft heading or north at the top of the
display, depending on pilot selection.

### (2)  Multipurpose Displays (MPD's)

MPD's are time-shared presentations that
display information supplemental to all normal flight phases
but may be essential to airplane operation during emer-
gencies.  Typical information shown on these displays
includes engine, navigation, altitude/airspeed, etc.
These displays are selected on a preprogrammed basis,
either as a part of the flight phase selection or by the
use of special controls.  VSD and HSD presentations must
be transferable to one or more of these displays if a primary
display fails.  These displays receive their information
over multiplexed lines from the computer complex.

### (3)  Secondary Controls/Displays

These panels provide information for
special functions and for less critical items that should
be available to the pilot on a continuous basis.  The
functions include fuel display and management and weapons
selection and location display.  These panels combine
controls and displays and can use a varied group of control
and display techniques, including plasma and electro-
luminescent presentations.

### (4)  Primary Controls

Primary controls form an interface between
the pilot and the airplane that is essential to system
survival and mission accomplishment.  The analysis placed
the following manual control tasks in the primary category:

o  Control of roll, pitch, and yaw

o  Control of roll and pitch trim

o  Ground steering

o  Automatic flight control system disconnect

o  Braking

o  Thrust reverser

o  Target designation

o  Gun firing

o  Weapon release

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The three cockpit configurations selected
for evaluation differed mainly in the location of the
primary flight controls. Trade studies selected only one
control type for each manual control task. These selected
controls were used in the wraparound cockpit configuration.
Alternate controls were used in the other two configura-
tions.

The shape of the flight control handles is
shown in Figures 47 through 49. In each case, the functions
of roll and pitch trim and manual weapon release are
included in the control configuration, as are other
miscellaneous tasks that conventionally are placed on the
"stick." On the ground, the anti-skid wheel brakes are
actuated when the pitch control stick is placed in the full
nose-down position.

The tasks of yaw control and ground steering
were assigned to the rudder pedals. Three-axis control
sticks were examined but were considered unnecessary and
excessively complex.

The task of target designation by the pilot
is important. It is a manual operation for both the air-
to-ground and air-to-air situations, especially when
multiple targets are present. For these conditions, a three-
axis designation (elevation, azimuth, range) control is
provided.

(5)   Secondary Controls

Secondary controls are important, but less
critical, to flight safety or to the mission completion.
Secondary controls include those needed to select display
formats, radar modes, autopilot modes, weapons, etc. Trade
studies resulted in the selection of each control. In
some instances, the process of defining the control panels
caused a second iteration of the analysis process to add
necessary controls; for example, sensor mode selections
were called for, but there was no callout of a range
selection task. This had to be added when the control
panel was designed that combined radar controls with those
for the horizontal map display. The ranges on the two had
to correspond, and a selection was necessary to make the
map usable for low-altitude attack and landing as well as
high-altitude navigation.

(6)   Tertiary Controls

Tertiary controls are relatively unimportant
to flight safety or to the mission. Examples of these
controls are the APU and the ECS.

Figure 47. Panel Mounted Controllers
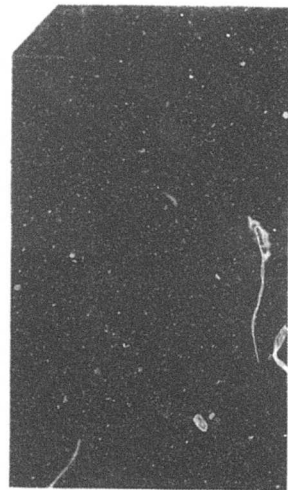


Figure 48. Side Arm Control



Figure 49. Center Stick

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c.   Displays

        Three display levels are used in configuring
these conceptual cockpits. Primary displays are the VSD,
HUD, and HSD.   These three display levels are placed in
the primary vision area.  A secondary display group, re-
ferred to as MPD's, performs various display functions for
the pilot depending on the flight phase.  These displays
are located in the primary vision area.  The third display
level is that associated with the controls.  These displays
are located in the secondary and tertiary vision areas.

        The primary and secondary displays use cathode
ray tubes (CRTs) or an equivalent display media.  In the
projected time period, changes in CRT technology and the
addition of new display devices should produce the capa-
bility to exhibit data to the pilot in bright sunlight or
in the absence of ambient light with high reliability and
at moderate cost.  The work underway to produce shorter,
ruggedized CRTs that have high brightness and can be seen
under high ambient light conditions is well documented.
Other developments in or emerging from the laboratories
include light emitting diodes, plasma displays, and liquid
crystals.  Electroluminescence (EL) is current state of the
art.  Westinghouse has demonstrated and tested EL under
high ambient light conditions.  The use of color to enhance
displayed data and to call the pilot's attention to specific
information is considered feasible.  A representative
group of display formats is discussed below.  Those formats
selected show the versatility that may be expected from the
system.

        (1)   Primary Displays

        (a)   Vertical Situation Display (VSD)

                The VSD is the primary attitude
reference.  In presenting attitude data to the pilot,
other optional information can be added to the VSD without
cluttering it beyond the pilot's capability to note changes.
These data are used for terrain following, target acquisi-
tion, and target attack.  Presentation of computer-
developed commands and total emergy management advisory
data allow the pilot to fly manually.

                The basic attitude display is an
elementary version of an electronic attitude indicator.
The presentation includes an airplane symbol, roll index,
roll attitude, yaw deflection bug, and a pitch reference
in the form of a horizon.  For normal flight monitoring,
this minimum display is sufficient.

This basic format is used in all VSD modes. Commands are those developed by the computer in its calculations for integrated total energy management. The display format used is described in the next paragraph.
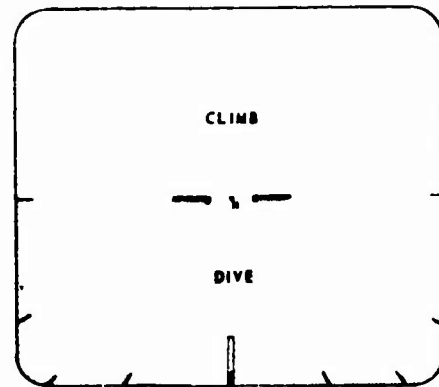
A shades-of-gray or a color coded format is provided for terrain following. Four terrain profiles are presented, with gates at 1/2, 1, 4, and 8 nmi, with the vertical bars representing the 1-nmi profile. The aircraft symbol indicates that the aircraft is in a dive as may be seen from its relationship to the horizon bar. Yaw is indicated by the double vertical bars near the center of the aircraft symbol. The energy control director (ECD) may be seen to the right pointing the path through a saddleback on the horizon. With an automatic tie-in such a discrepancy in aircraft position with respect to the ECD would not exist; however, a hypothetical case was established for the illustration. The squares to the left and bottom of the center of the ECD are sized and shaped to the "on flight path" configuration. The rectangle elongated from the basic square above indicates the nose-up command. The rate of elongation to the desired pitch angle is mechanized to conserve energy by programming the ideal-g schedule to the optimum angle of attack for climb under the given conditions. Simultaneously, the rectangle on the right similarly through the rate of elongation indicates ideal roll rate to the desired bank angle to minimize energy loss due to adverse yaw at that specific angle of attack and drag due to control deflection. It programs the bank angle, again in deference to normal acceleration. The circle directs energy requirements along the longitudinal axis. Since altitude represents a form of energy and the mass and drag of the aircraft is known, it may be exchanged for thrust independently or with the throttle directly affecting the circle's behavior. When longitudinal energy requirements are met, the circle is contiguous to the outer tips of the squares. Since a command pitch up and pitch down or turn left and turn right will not occur simultaneously, two of the command indicators will always be squares. A larger than "on energy level" circle commands an increase; conversely, a smaller circle commands a decrease in longitudinal energy.

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ITEMS has been designed to degrade gracefully
from a highly automatic control/display system to a rudi-
mentary system of displaying only that raw data neces-
sary to survival.

Certain displays are available to the pilot
on demand. For whatever reason he chooses, the pilot
can call forth these displays on any MPD. This is done
with the keyboard control. By selecting ITEMS from the
major systems available in the Master Keyboard Select row,
the following energy management display formats may be
inserted into any MPD, the VSD, the HUD, and/or the HSD:

    o  Air Data and Thrust

    o  Vn Envelope

    o  Climb Profile

    o  Thrust Required/Thrust Available

    o  Engines

    o  Landing Monitor

Heading, angle of attack, flight vector, pitch and roll,
and command information may be added to any display
depicting the vertical situation. Heading, distance, or
range may be added to any display depicting the hori-
zontal situation.

The pilot can select any combination of fixed
and steerable TV, radar, and FLIR target acquisition
sensors. The television sensor is used as the primary
VSD presentation during visual target acquisition. The
TV presentation is in color for daytime operation; it
is black and white at night. TV and FLIR are azimuth
and elevation sensors; however, by synchronizing all
sensors to a common line of sight, a third dimension
range is provided. If the three sensors are chosen,
their returns are superimposed, provided the target
produces returns in the RF, IR, and visual spectra. A
target designation cursor is placed on the target manu-
ally, the designation button is used, and the computer
uses the selected sensors to track the target.

In this illustration,
a power house is the preplanned
target. The circle represents
radar returns, the triangle
represents IR returns. The
pilot is manually controlling
the airplane in pitch as the
ECD is high with respect to
the airplane symbol. A pitch
up maneuver is being called for
to counter the dive which is
being used to get a better view
of the target. The pilot has not yet designated the target.
If he had, the ECD would be calling for a small turn to
the left, and the remaining radar and IR symbology would
have been removed. The target designation cursor is in
view only during the designation process.
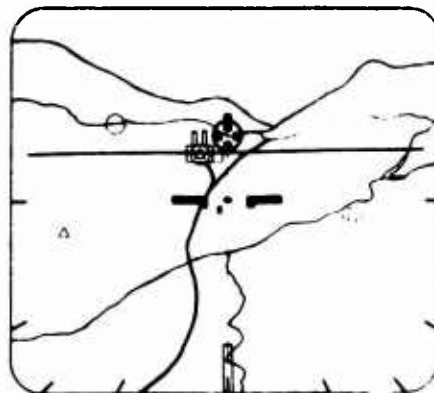
After target
designation, the final attack
sequence begins. When the
target nears the outer
release envelope of the
selected weapon, a fire
control symbol appears.
The energy management
symbol is retained. The
movement of the dot on the
fire control symbol repre-
sents qualitative range
rate. It appears at the
11 o'clock position and moves counterclockwise. The
6 o'clock position represents the maximum effective range
for the selected weapon, and the 12 o'clock position is
the minimum effective or safe firing range. The computer
continually updates weapon release parameters; therefore,
weapons are dispensed automatically when the dot is at
the 3 o'clock position and manually when the dot is between
the 6 and 12 o'clock positions. The fire control symbol
is also used as an approximate aiming window or reticle.
For steerable weapons (Walleye, Bullpup), the size
increases with decreasing range to compensate for the
weapon maneuver reduction as the target is approached.
Nonsteerable weapons require the same aiming accuracy
throughout their release envelope; therefore, the fire
control symbol is fixed in size for these weapons. Break-
away is represented by a large X on the display.
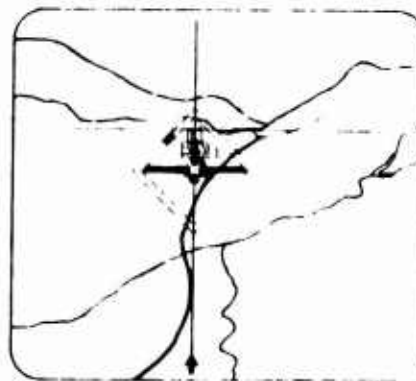
The weapons on board may be programmed sequen-
tially for use on a single target in a descending order of
the weapon's maximum release or firing envelope. In the
case of overlapping envelopes, fire control information is

dedicated to the maximum range weapon unless the pilot
overrides it. When minimum range of the weapon is reached
or when the weapon is dispensed, the fire control informa-
tion for the next weapon in succession is displayed. In
addition, the system has a multiple targeting capability.

(b) Head-Up Display (HUD)

The HUD presents information identi-
cal to that presented on the VSD, with the exception of
TV. (Steerable TV only is presented on HUD.) The total
energy management bug gives the pilot complete information
for all flight conditions. Control functions applicable
to the VSD produce corresponding changes on the HUD. HUD
brightness may be reduced to zero by means of the level
control panel.

(c) Horizontal Situation Display (HSD)

The HSD is the main source of heading
and position information. The information sources feeding
the display are the navigation system, the multimode radar,
and the passive identification system. A moving map can
be displayed in all modes. Radar PPI data is selectable.
VSD terrain following information is augmented by a terrain
clearance PPI presentation (situation display) on the HSD.

To provide sup-
plementary information to the
pilot, a moving map may be pre-
sented on the HSD alone or in c n-
junction with any range-azimuth
information available to the
system. The moving map is syn-
chronously slaved to the naviga-
tion sensors via computer inputs.



The air-to-
ground radar mode on the HSD has
four representations: (1) con-
ventional PPI, (2) terrain
avoidance "situation" display, (3) a selectable 1 x 1 or
2 x 2 NM "snapshot" presentation about the crosshair, and
(4) a 1, 2 or 4 NM swath width presented as a "passing
scene" during SQUINT mode. To give the pilot more antici-
patory information, the airplane symbol may be presented
at the bottom of the display when in OFF CENTER SECTOR
(OCS). The HSD presentation is a valuable adjunct to the
VSD when using the radar as a target location device. For
a preselected target along ground track with known coor-
dinates, the target designation cursor appears automatic-
ally at the top of the screen over the predicted map loca-
tion as that location comes within range. The

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computer, using data on the
circular error probability of
the selected navigation
sensors, processes the
radar returns to elimi-
nate all those extraneous
returns that lie outside
this circle.
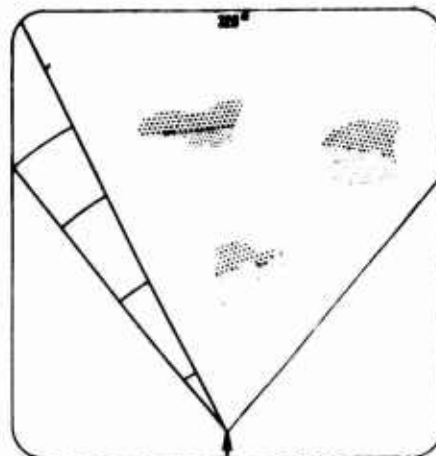
Moving
maps will be scaled to the
selectable display ranges.
Detail maps will be avail-
able for takeoff and landing.  Display brightness and
contrast are controlled by the level control.

(2)   Multipurpose Displays (MPD's)

MPD's are grouped around the VSD and HSD.
They present more vital information in the available primary
space than is possible with conventional instrumentation.
Graphic and alphanumeric information in color is tailored
to the flight phase and provides the pilot with compara-
tive data for increased confidence in system operation.

MPD presentations can be manually or auto-
matically selected.  Manual selection is made by using
the preprogrammed selector switches on the display.
Automatic selection is provided when a serious malfunction
occurs or a flight mode change causes a selected display
to be superseded.  A general malfunction presentation
appears if no special purpose display is provided.  In
either case, the failure display does not replace a presen-
tation that is essential to the current flight phase.  As
indicated above, the presentations can be called up on
one of several possible MPD's located at different places
on the instrument panel, depending on the configuration.
For this reason, the presentations discussed below do not
define presentation location.

(a)   Engine Instrumentation

The pilot checks
on his engine performance by scanning
the bargraphs.  These graphs are
designed so that all limitations
are at the same level.  Thus the
limit line is a straight line
across the presentation.  The
numeric value corresponding to
the height of the bar is shown
at the top of the bargraph.

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Below the bars are other data legends defining the bargraph parameter and action required.

(b)　Thrust/Airspeed,Altitude/Altitude Rate

The presentation is a backup for the total energy management command symbol on the VSD. Two versions of the thrust/airspeed/altitude/ altitude rate presentations have been designed. Both show the same data in different ways. The first uses alphanumerics extensively to reinforce a vertical tape type display. The left-hand bar is the thrust display with the commanded thrust shown as two horizontal lines and the actual value as an opaque square. When "On Command", the opaque square is centered exactly between the "Command" horizontal lines. The next bar to the right is the airspeed presentation with the triangles depicting upper and lower speed limits for the altitude condi- tion. The central line is the commanded airspeed, the cross- hatched square is the actual airspeed. When "On Command", the bar rests on top of the square. Of the two right-hand tapes, the left one is the altimeter with the command bar and actual altitude square. "On Command" indication is the same as in airspeed. Th altitude rate is shown by the right tape. The command is shown as the horizontal bar. The vertical bars working from a center scale reference represent the actual read- ing. The second format places the command and the actual numeric values within the confines of the symbol used, the command value on the left and the actual on the right. In each instance, the "On Command" indication is repre- sented by alignment of the command and actual boxes.
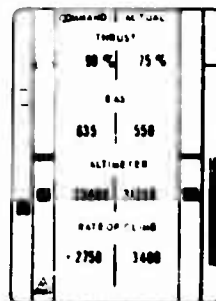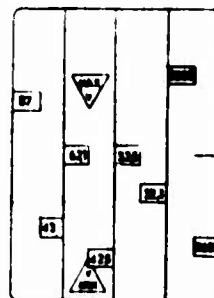
(c)　Energy Management

Three supplemental display formats that augment the ECD may be selected. They provide the

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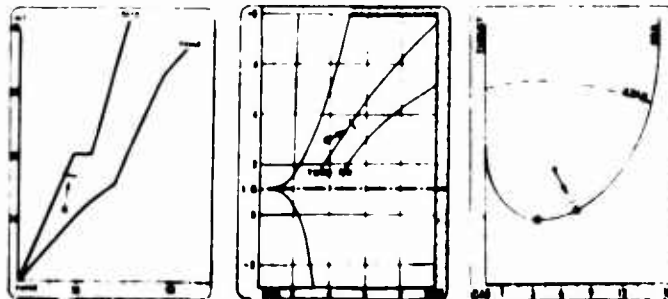
pilot with system confidence type information during the
ECD-directed flight phases.  The displays shown provide
predictibe energy management information when the ECD
is not directing the system or when the VSD is disabled.
The use of these presentations is described in detail.

The energy management display
format that is most useful during climb conditions pre-
sents altitude on the Y axis and range on the X axis.  The

curve labeled RATE is followed to
obtain a minimum time climb to a
predetermined position.  The curve
labeled RANGE is used to fly to a
maximum range climb profile.
The curve presented depends on the
selected flight mode.  The dot and
arrow indicate present position,
magnitude, and direction of
motion.  This presentation
may be monitored during automatic flight.  In manual
flight the pilot may use the presentation to guide him in
controlling the airplane.
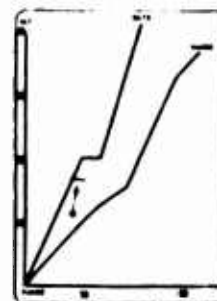
The RATE curve applies primarily
to the interceptor-type mission; however, it may be used
by the tactical fighter pilot to make an emergency evacua-
tion from his base or during a dogfight to make a maximum
rate climb.  The RANGE curve is used during any maximum
range altitude change.  The RANGE curve is used during
any maximum range interdiction missions or return to altitude
after terrain following.

These dynamic, computer-generated
curves depend on the changing input data.  These data
inputs include such parameters as static pressure, dynamic
pressure, angle of attack, navigation waypoints (range),
air temperature, throttle position, attitude, etc.  In
manual flight the pilot uses pitch control plus throttle
position to follow the maximum RANGE curve, while pitch
alone is used to follow the maximum rate curve since the
throttle would be in full afterburner position.  The dot
shown in the illustration represents present airplane
position in altitude-range space.  The arrow indicates
the motion vector.  As is the case for all vectors, it
represents direction and magnitude with respect to a
reference.  For illustration, the airplane has been placed
above the RANGE line, indicating too much altitude, and the
vector is shown extending beyond the bar, indicating
too much thrust (throttle setting for the particular pitch
condition).

The velocity-load factor (V-n)
diagram is used to determine
whether the airplane is approach-
ing an unsafe flight condition
for the current airplane
configuration and load conditions.
Reference to this diagrammatic
presentation relieves him of
having to make a mental approxi-
mation of his relative position
with respect to the limits.
He knows where he is and, thus,
can push his airplane to the
safe limits and obtain maximum
performance from it.
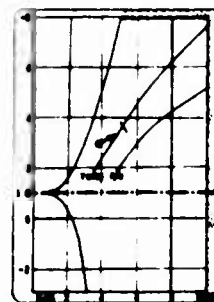
The boundaries of the V-n diagram
change to reflect the changing conditions of flight.  The
conditions are airplane gross weight, external configuration,
load symmetry, and air turbulence.  The external configura-
tion affects the stall boundary as well as the load limits.
For example, the g-loads that the airplane can safely
experience in normal flight are off limits when the flaps
are extended.  Also, wing sweep changes the stall and
limit boundaries.

The illustration shows the airplane,
represented by the dot, at a speed of 360 knots estimated
air speed (EAS) and a load factor of 2.9.  The arrow on
the dot indicates that speed and n are both increasing.
The straight and level steady-state flight condition would
find the dot on the 1-g line resting at the measured EAS.
Excursions from this position would be evidenced first by
the extension of the arrow from the dot.  Throttle position
change without changing pitch angle shows up as a change
in n, while pitch changes will affect both n and EAS.

The THRUST-EAS (thrust available-
thrust required) curve presents information needed to
obtain maximum range or endurance
flight or to properly control
the airplane during landing or
degraded mode engine-out
conditions.  Two curves are
presented:  one indicates
the total available thrust
that can be called for from
the two engines with full
afterburner for a given
altitude and airspeed; the
second shows the thrust required to maintain an airspeed
for the existing conditions.  The location for the air-
plane on this dynamically varying curve is indicated by
the circle with the cross in the center.  Two additional
points on the curve are presented.  The triangle indicates
the thrust-airspeed condition required to obtain maximum

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range from the airplane. The square has two functions: to indicate the maximum endurance condition, and to delineate the point at which the airplane controls reverse their effect. This effect is discussed in more detail below.

These curves are affected by various factors. Available thrust is changed by altitude (air density) and aircraft velocity. Required thrust is affected by gross weight, airplane configuration (flaps, wing sweep, landing gear), and airplane maneuvers. Because of the dynamics of the situation, it may not be feasible to generate this curve in real time for rapidly changing air-to-air combat maneuver conditions. These curves are useful in establishing the flight conditions needed for maximum endurance or maximum range flight, or in monitoring the airplane performance during landing where the airplane may be flown at speeds below the reversal point.

The characteristics of steady-state flight in the region of normal command (to the right of the square) are that lift is equal to weight and the power used is set equal to the power required. When the airplane is disturbed to some slightly greater airspeed, an excess of power exists and, when the airplane is disturbed to some slightly lower airspeed, a deficiency of power exists. This relationship is basically unstable because the variation of excess power to either side of the point tends to magnify the original disturbance. Flight in the region of reversed command is characterized by a relatively weak tendency of the airplane to maintain the trim speed naturally. In fact, it is likely that the airplane will exhibit no inherent tendency to maintain the trim speed in this regime of flight. For this reason, the pilot must give particular attention to precise control of speed when operating at reversed command speeds.

(d)   Communication/Identification (C&I)

The control selections made on the C&I panel and data received by the data link or from the voice input are presented on this display. Incoming data link messages are indicated in the lower box along with the time-to-go target.

(e)   Navigation

The drawing shows typical navigation information available to the pilot. Most of the items are

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self-explanatory, with the exception
of the items in the third box down.
The navigation mode is shown in
Doppler Inertial Satellite (DIS)
mode.   TACAN channel 126 is
selected and the satellite channel
is #26.   The bottom box presents
the information on the home base,
the next waypoint, or the data
being manually entered into the
computer via the keyboard.

(f)   Stores Management System (SMS)

The primary cockpit controls
and displays associated with the SMS
include:   the stores management
panel with its master arm and
gun selectors; the coded switch
selectors; the coded switch
panel for nuclear consent; the
MPD for presentation of stores
release options; a conventional
and, separately, a nuclear weapon
jettison button; and the integrated
keyboard control for preprogramming
the operation or to conduct a program
change in flight.
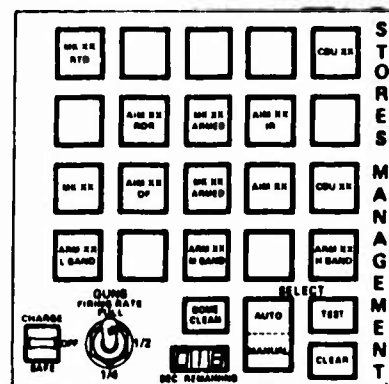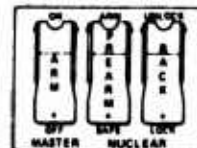
The SMS uses the computer complex to
integrate weapon selection, control, monitoring, and
release functions and to interface these functions
efficiently with the rest of the avionics subsystem.
The capability to carry and control mixed loads, including
nuclear weapons, is emphasized.   Display and sensor selec-
tion is integrated with stores control.   The logic of the
system is used to display only compatible options for the
weapons selected, thus simplifying crew tasks and decreasing
the chance for human error.

The Stores Management Control (SMC) Panel
is a continuously available panel with quick access for
monitoring and control of all on-board weapons.   The SMC
Panel continuously displays the store data on the back-
lighted pushbuttons.   The pushbuttons are used to select a
weapon or station(s) for subsequent control through the
integrated keyboard.   A pushbutton, used for cleaning
weapon electro-optical sensor domes, is included.   For
guns, Charge/Safe and Firing Rate switches are provided
on the SMC Panel, as well as a Time Remaining Counter
slaved to the firing rate switch.   The Master Armament
Switch controls all arming power to the SMS.   A Mode Select

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Switch allows the operator to select Auto, Manual, or Test modes of operation for the system. The Rack Lock and Prearm Switches are guarded and sealed toggles that provide the required nuclear weapon safety, and the recessed Jettison Switches provide the capability to quickly clean the airplane of conventional weapons (ALL) or to individually jettison nuclear weapons (SEL) that are in the SAFE condition.

Stores stations are flexible and can accommodate almost any weapon. Remote logic plugs are used to simplify computer programming and to prevent mistakes. Stores data are set during weapon loading into the remote logic plug (located at each station). This information is automatically transmitted to the computer and to the SMC Panel where it is displayed on the pushbutton identified with the weapon as weapon type number and status.

Arming and fuze selection is conducted while airborne for both nuclear and conventional weapons.

The coded switch system (CSS) replaces the PAL for nuclear weapons. The CSS will provide the same nuclear safety but will actually control arming power within the aircraft rather than the weapons. It may be deleted in a nuclear war. All weapons are at least partially preprogrammed for automatic delivery under normal operating conditions.
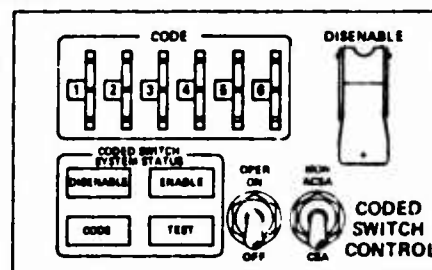


An automatic sequence is manually vetoed or overridden by pushing appropriate switches on the SMC Panel. This action sets up an MPD and integrated keyboard alphanumerics. By observing alternatives and following options presented on the MPD, the pilot can completely or partially reprogram weapon data. If the pilot makes a mistake, the system will not accept data but will, by means of the MPD, provide alphanumeric instructions to correct the error.

Degraded mode operation is provided with manual backup and complete manual delivery using an MPD and the integrated keyboard is possible. Manual operations are also included for improved flexibility and to allow for preengagement setups.

Automatic delivery using preprogrammed data or by data link is defined as the normal baseline delivery mode and does not require pilot decisions. The pilot is kept informed primarily with the SMC Panel. He can also monitor more detailed information with MPD's and the VSD. The integrated keyboard is not needed in automatic delivery except to switch and monitor displays.

The SMC Panel continuously displays the stores remaining and their locations on the airplane. A lighted pushbutton switch is provided on the panel for each store station. The switch is lighted white (blue, if nuclear) if a conventional store is loaded at that station. When a weapon or station is selected (automatically in this case), the switch light turns green and the stored program to be executed is presented on the MPD. Stores Away is indicated on the pushbutton by an amber light. A stores release signal without a stores-away signal will cause the affected pushbutton to turn red. The fire control diamond on the VSD/HUD will illuminate in colors corresponding to the pushbuttons status indication.
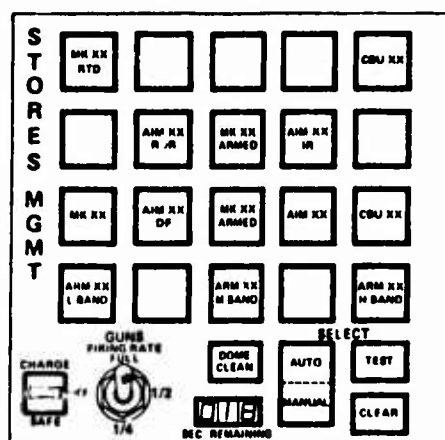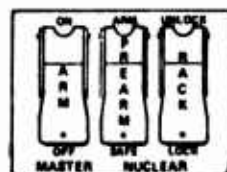
The pilot must always manually operate nuclear pre-arm and the coded switch system. When received over the secure communications data link, the command control code is manually inserted by the pilot through the six thumbwheel switches. The OPERATE switch is placed in the ON position to transmit the code to the Coded Switch Assembly (CSA). The CODE light illuminates to indicate that the CSA is cycling. and the DISENABLE light goes out. When the CSA cycling is complete and the proper code has been inserted, the ENABLE lamp is illuminated. Then the Auxiliary Coded Switch Assembly's (ACSA) status at each nuclear station

can be monitored by moving the CSA/ACSA switch to the ACSA
position (Momentary). If any ACSA is in the enabled
position, the ENABLE lamp will be illuminated again. If
a sum check code has been inserted, the TEST lamp will
illuminate at the end of the cycle, but the CSA will not
be enabled. The DISENABLE switch, protected by a camming
cover, provides the capability to disenable the controller
after a system test.

Separate on-board fire control sensors
and navigation sensors are available for target location.
Automatic or manual stores management may be selected.
Twenty-weapon stations are available. Weapons may be
released with or without the computer. A failed component
and an acceptable substitute can be switched out and in
either automatically or manually with the keyboard.

While in the automatic release mode,
stores may be released manually by depressing the stores
release button on the flight control stick prior to auto-
matic release. Override of the automatic release mode
may be affected by selecting "manual" on the SMS panel.
Automatic mode may be reselected at will.

The integrated keyboard is used for
program insertion and manual stores management. An asso-
ciated MPD provides supervisory instructions. Alphanumerics
for generalized weapon control are provided when the
integrated keyboard SMS key is pressed.

Options are
selected or changed by typing
the selected numerical option
shown on the MPD. Options not
selected are removed from the
MPD. When the last applicable
option has been selected or
changed, the MPD provides a
readout of all selections for
the operator's review before
insertion or initiation of the
program. The unused options
are removed from the MPD and
will be presented again only
upon command (SMS button).
Selected options are auto-
matically shown on the MPD when
the delivery program for that weapon is initiated. The
new program is inserted into memory with the ENTER button.
The program for any weapon may be recalled with the station
button on the SMC Panel (previously described).

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(g)  Malfunction

A FMAC-detected malfunction is auto-
matically placed on one of the
MPD's that is not being used
for flight or mission
critical data.  This presenta-
tion defines the malfunction in
plain English and calls out the
action to be taken.  It also
defines the limitations placed
on the remainder of the flight
by the malfunction.
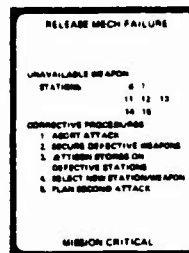
(h)  Battle Situation

The BSD is developed from sensed
enemy emissions in the RF and IR
spectra.  By receiving the energy
while the tac   al fighter is
moving, lines    . be computed
to the most probable location
of the enemy emitter.  Sorting
techniques and memory compari-
sons allow the emitter type to
be classified.  These data are
presented on a PPI-type display
with the airplane centered.  The
alphanumerics define the threat type and location.  For
the #1 airborne threat, a line is projected to show the
intercept point.  The pilot has the option of selecting
(through the keyboard) whether he wants to look at air,
ground, or both types of threats and whether he wishes to
have the alphanumerical information.
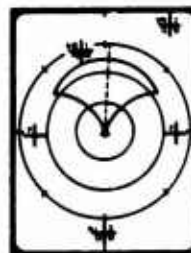
(i)  Landing Monitor

The landing monitor is intended as a
backup for the main VSD/HSD
landing displays.  It is a three-
dimensional, pictorial representa-
tion of the airplane position with
respect to the runway.  The dashed
glide slope line, the dot repre-
senting the airplane, and its vector
provide vertical alignment data.
The line in proximith to the arrowhead
denotes desired length.  The extension of the runway
centerline is identified along with its magnetic heading.
A second airplane location circle is shown on the hori-
zontal plane along with its vector.  The alignment of both
vectors with their respective correct paths is the desired
condition.

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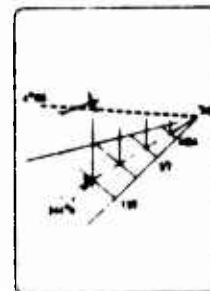
(3)   Secondary Displays

This group of displays was assigned to
secondary viewing areas as a result of the analysis.
With the exception of the fuel display, these presentations
are used during limited portions of the flight.

(a)   General Purpose Display (MPD-5)

This presentation
indicates position of landing gear,
wings, flaps, slats, and speed
brakes.  Other information includes
the amount of trim being used,
hydraulic system pressure, and an
alphanumeric advisory readout.  To
denote landing gear position, the
words "UP" and "DOWN" appear at
the appropriate gear locations.
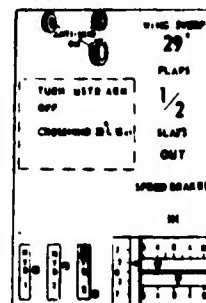
(b)   Fuel Management Panel

Aircraft cg is
controlled by the central computer
complex (CCC).  Flight mode is
select'd on the flight mode selector.
Appropriate cg range per selected
mode is activated, thus sensing
desired cg range.  Cg based on fuel
distribution is computed from fuel
quantity sensed in each fuel tank.
CCC controls transfer of fuel from
forward or aft tanks as required to
shift the cg in response to the
flight mode selected.  Wing and
external fuel is transferred auto-
matically to the fuselage cells
as necessary to maintain fuselage
fuel level at the most practical level to provide for the ex-
treme fore and aft shift of the cg.  Wing tanks are segmented
so that fuel transfer is from the in-board sections first.
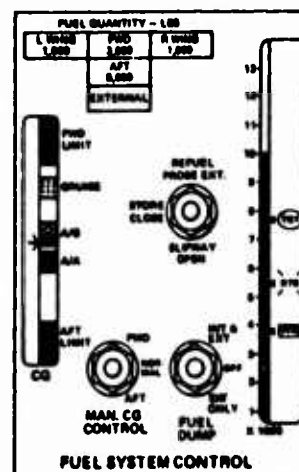
Fuel quantity is sensed by radio-
active sensors and converted to usable signals for applica-
tion to the cg control as well as for digital readout of
quantity for the pilot.  Fuel quantity in each tank and
the total quantity are presented in digital format on the
fuel control panel.

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Total fuel on board is also presented
on a vertical bargraph display. Three moving symbols are
used to signify fuel requirements for each mission programmed.
Navigation and total energy management system inputs are
integrated by the computer to position each of the symbols
with respect to the fuel required. The target (TGT)
symbol represents the quantity of fuel remaining on arrival
at the target if the preplanned route is followed. Return
to base (RTB) symbol is positioned opposite the fuel
remaining if the pilot elects to return to base at the most
economical cruise via a direct route, and PPR symbol shows
fuel remaining if the preplanned route and speed schedule
is followed for the entire mission. Mission fuel is
represented in green on the bargraph, and the reserve
fuel is shown as amber. Changes in mission route planning
and/or changes in power requirements will be presented as
changes in fuel required on the bargraph.

In-flight refueling (IFR) may be
accomplished either with boom-type or probe- and droge-
type refueling. Actuation of the IFR switch to Probe
extend will cause the refuel probe to extend and the system
valving to be positioned for receiving fuel from the tanker.
Actuation to the "slipway open" position opens the slipway
doors in preparation for boom-type refueling. The "Store"
close position sends a retract/close signal to the system
used during refueling. Refueling automatically sequences
fuel to each tank as required including external tanks as
desired, when selected on the integrated keyboard.

Fuel may be dumped selectively either
"external" or "internal and external" as required.
Selection of "internal and external" position will reduce
the fuel quantity to maximum landing weight in less than
5 minutes.

FMACS senses a failure of the automatic
cg control. Cg presentation and flight mode cg range are
unimpaired. Signal to the pilot is presented visually
and by voice. The computer triggered by the failure signal
presents information on an MPD to the pilot providing the
alternatives available.

Alternative 1:

CCC will use alternate paths as
required. This may be by computing
control surface displacement and
forces to determine cg. No pilot
action is required.

Alternate 2:

CCC will measure and maintain fuel
quantity ratio between forward and
aft tanks.  No pilot action is
required.

Alternate 3:

If computer is unable to perform
either of the above, manually
control fuel distribution to maintain
cg in selected flight mode range.

Other type failures which may occur are:

| | Failure | Corrective Action |
|---|---|---|
| (1) | Boost pump failure | Automatic crossfeed |
| (2) | Wing fuel transfer - pump failure | 1. Transfer fuel from one wing and dump fuel that cannot be transferred.<br>2. Pressurize both wing tanks and force fuel to fuselage tanks.  This bypasses pumps. |
| (3) | Fuel quantity digital readout failure | 1. Bargraph presents total.<br>2. Instruct CCC to give tankage fuel quantity. |
| (4) | IFR probe failure | Switch to boom-type refuel. |
| (5) | IFR slipway failure | Switch to probe/drogue type refuel. |
| (6) | TGT  RTB  PPP function failure | Instruction computer to provide fuel requirements for desired information; update as required. |

(c)  Communications

This panel,
used in the centerstick configura-
tion, uses light emitting diodes
(LEDs) to indicate the selected
communication and identification
modes.

### (d) Navigation

Used in the centerstick configuration, this navigation status panel uses LEDs to indicate the navigation selections and relative position of the flight. The information presented is in terms the pilot can most readily use, namely range, bearing, and time. Other pertinent information includes waypoint and a latitude-longitude readout.
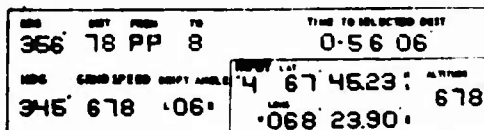
### (e) Auxiliary Power Unit (APU)

To give the tactical fighter an engine starting capability, an on-board APU is provided. This panel has all the displays and controls to make the APU a completely independent unit. It is one of the few hard wired units in the airplane for it must operate when the main alternators are inoperative. It has its own group of instruments and fire indication. If an APU fire occurs during start-up, the APU fire button is depressed to activate the extinguisher and shut down the system.
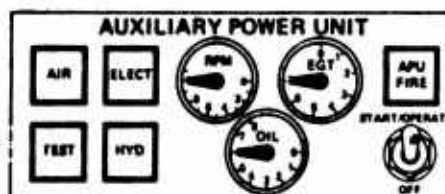
### d. Controls

#### (1) Primary Controls

This section discusses the selection and grouping of the primary controls. The primary controls are those that the pilot must use to control the airplane manually and to designate his identified target.

#### (a) Control Stick

The three conceptual cockpit designs resulting from the IIPACS program differ primarily in the type of control stick used. The advanced wraparound cockpit has a sidearm stick, the intermediate cockpit features brolly handle control, while the more conventional cockpit has a centerstick. While airborne, th control stick is the roll and pitch interface between the pilot and the airplane. On the ground, the control stick actuates the anti-skid braking system. Each stick design includes the capability to control the auxiliary functions of pitch and roll trim, nosewheel steer activation, stores release, gun trigger, and autopilot disconnect.

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Human engineering techniques were used to position the stick in a location comfortable for the pilot and to shape the stick so that it fits his hand. In each configuration, provision is made to give the pilot the capability to fly the airplane using his left hand.

The panel mounted control handles are displacement-type controls. The center and sidearm sticks could be either displacement- or force-type controls. Either type of control is compatible with fly-by-wire and variable stability controls that are considered desirable for this airplane system.

The wraparound cockpit has a sidearm stick located at the forward end of the right armrest. It uses the conventional stick operations of fore and aft for pitch and sideways for roll. The armrest location gives the pilot excellent support for his arm during high-g pullup maneuvers. Left-hand operation of the control stick is awkward and uncomfortable.

The wraparound sidearm flight controller was updated to reflect the results of the hand controller study (Ref. 5). The controller, Figure 50, uses conventional operations to control pitch and roll. The designation control provides an alternate (left- or right-hand) means for flight control.

The two panel-mounted control handles (Figure 5) are located just forward of the armrests and extend from the instrument panel. Pitch control is obtained by moving the handles fore and aft, roll by rotating them. The mechanical design of the rotational mechanism plus the method of mounting the handles use the capability of the forearm to rotate as a whole about the elbow joint. The fixed vertical position takes advantage of the small variation in eye to elbow distances between the 5th and the 95th percentile man. This displacement-type control normally makes use of the two hands; no backup control is needed if one arm is incapacitated.

The centerstick (Figure 4) is an adaptation of the conventional control stick and is designed to be comfortable for use by either hand. Being equally accessible to either hand, no backup control stick is required.

(b) Rudder Pedals

The rudder pedals are used for both rudder control and nosewheel steering. Nosewheel steering is disconnected when the oleo is extended.

TRIM 4-WAY SLIDE SWITCH

GUN

THUMB REST

AFCS DISCONNECT &
NOSE WHEEL STEERING

WEAPON RELEASE

PITCH &
WHEEL
BRAKES
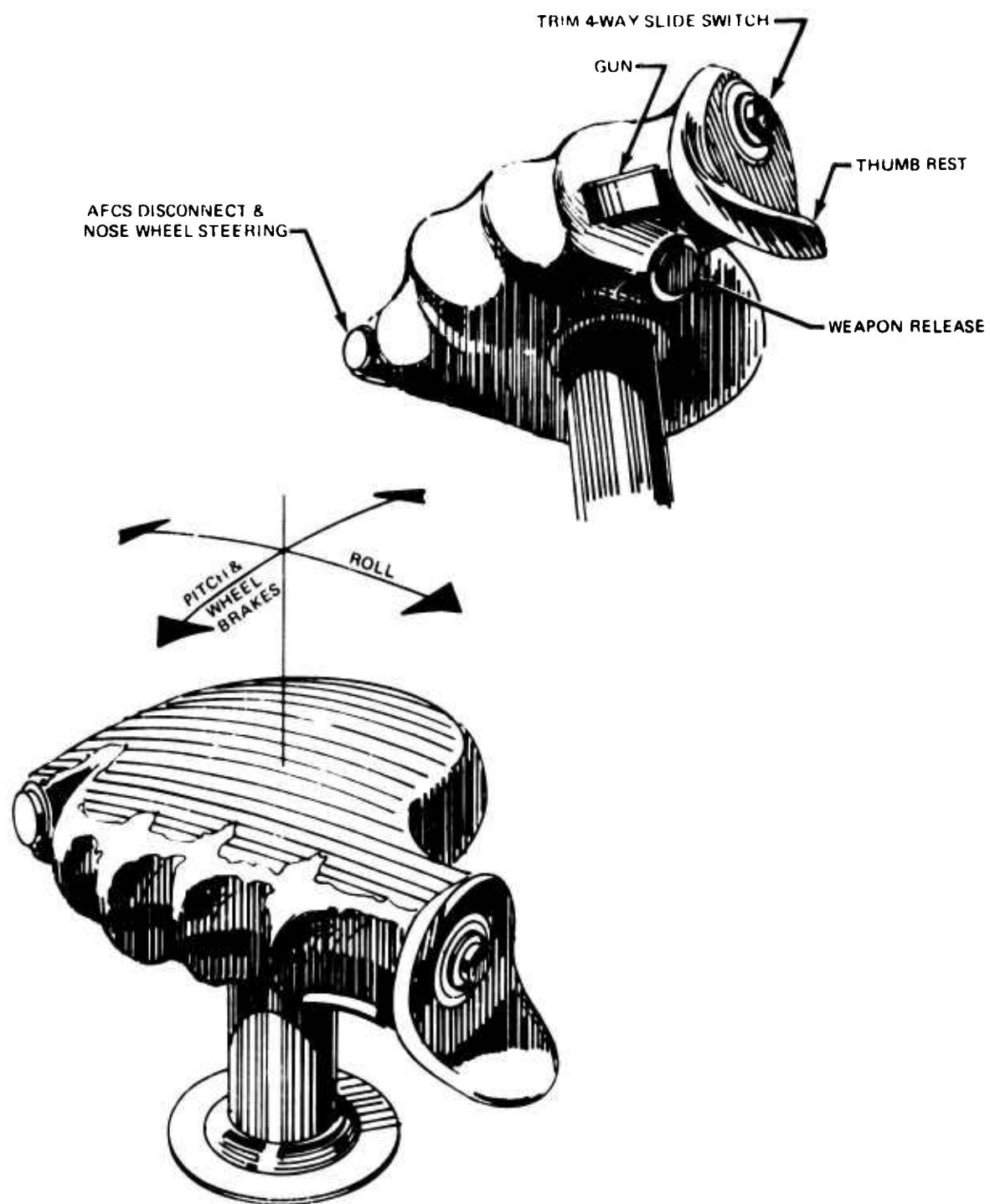
ROLL

Figure 50. Flight Controller

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### (c)   Throttle

Each cockpit has a different throttle concept.  Each configuration has a separate engine control panel that is used to start and trim the two engines.  Located on each of the throttles is the push to talk buttons the pilot uses when he wishes to transmit a voice message.  All the throttle concepts are compatible with the multiplex fly-by-wire concept.

The brolly-configured cockpit has dual throttles, one for each engine, located on the left console.  Thrust is increased by a linear displacement motion down and forward.  Afterburner is engaged by forcing the throttles beyond a detent.

The throttle on the centerstick configuration is located on the left movable armrest.  It is a force control and operates with a clockwise force to increase thrust and a counterclockwise force to decrease thrust.

The throttle for the wraparound cockpit is a vertical handle extending up from the horizontal lap console surface.  It is a rotary force control; that is, exerting a clockwise force on the control will cause the engines to increase thrust and a counterclockwise force will decrease thrust.  The single control output is transmitted to both engines.  To go into afterburner, the pilot is required to exert an even higher clockwise force than that required for a normal thrust increase.

The throttle controller for IIPACS-2, for the flight controller, was updated in accord with Ref. 5.  A single throttle is used for both engines.  Engines are synchronized automatically; however, manual engine trim controls are located on the master engine control panel for manual operations.

Thrust reversal is controlled by pressing the thrust reverser bar switch, Figure 51, and rotating the throttle grip to the desired setting.  Release of the enable bar holds the grip in the set position.  Using the enable bar and rotating the grip to the down position or manually overpowering the holding device provides forward thrust.

The microphone switch is a two-position control:  forward for normal communications, aft for voice commands to the computer.

ENGINE SYCH SW

REVERSER MOTION

TRIGGER BAR TO ENABLE REVERSER

SLIDE SW FOR MIC

SLIDE SW FOR SPD BR

LEFT SIDE VIEW

FRONT VIEW

RIGHT SIDE VIEW
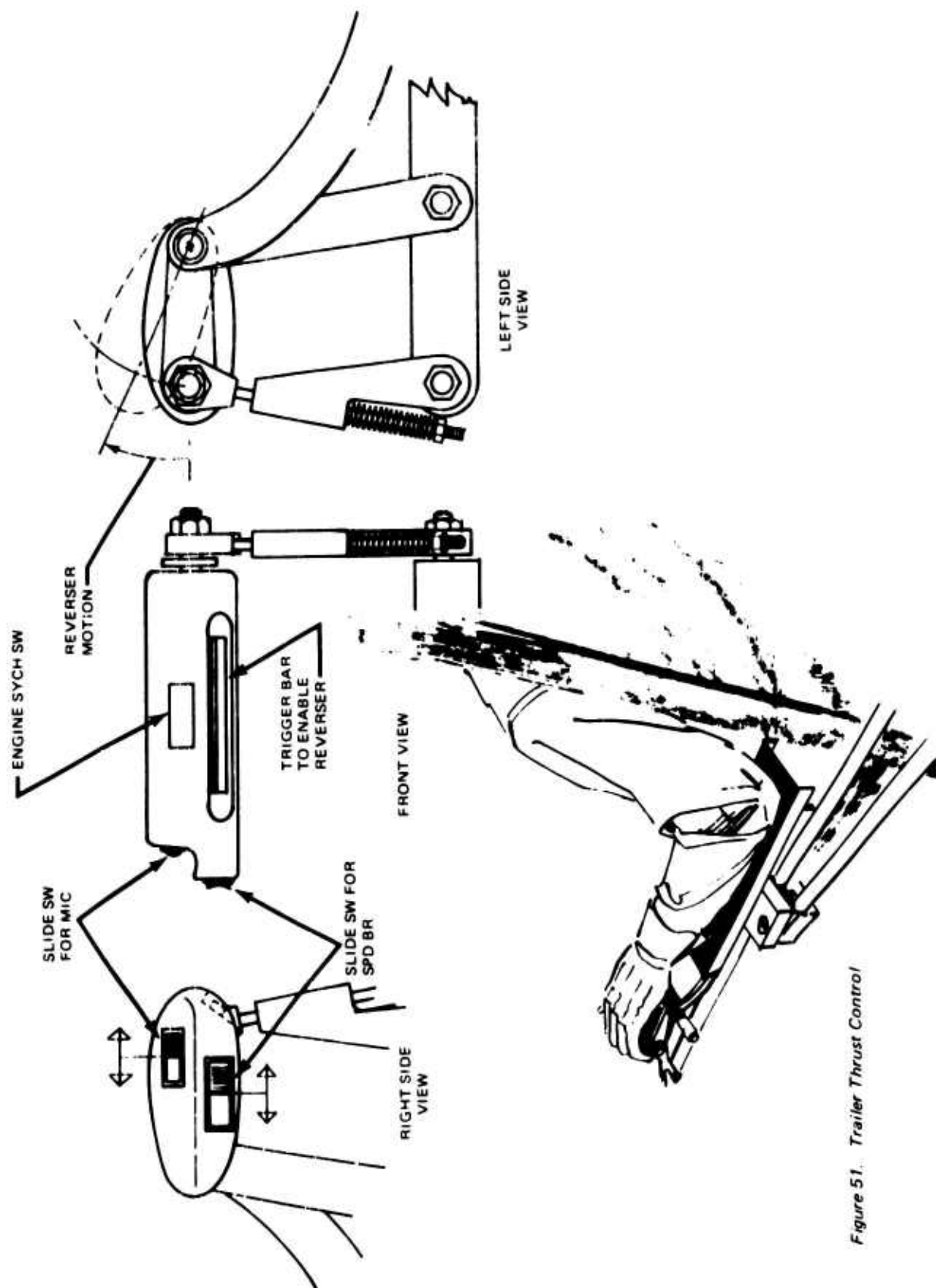
Figure 51. Trailer Thrust Control

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The speed brake switch is on the lower part of the grip. It is spring-loaded against the aft (open) position and detented to hold the switch in the forward (closed) position.

If throttle control fails, engines may be managed in two ways: first, selection of command airspeed through autopilot/autothrottle system; and second, direct input via the computer of the thrust setting desired. The data may be entered either by voice or the integrated keyboard.

(d)  Designation Controller

This control is required for cursor and sensor positioning during navigation updates, air-to-air tracking for IFF interrogation, and precision weapon delivery. In addition, the control may be used as a backup for the primary flight controller. Functional requirements for the designation or tracking control are to provide:

- o  Cursor displacement in range, azimuth, and elevation

- o  Target "lock-on" or "reject"

- o  Switching functions for:

  1)  ENABLE

  2)  Freeze/Erase

  3)  Navigation Update

  4)  MMR Antenna Elevation

The rate of cursor movement is a function of displacement angle. The handle returns to the neutral position (upright) when released.

The designation controller shown in Figure 52 stows flush with the table when not in use. When the UNLOCK button is pressed, the control springs to the vertical position and may be operated with either hand. Cursor movement on a display (HSD, VSD, or MPD) is related directly to "North-Up", or "Heading-UP"--either option is available on the Auxiliary Radar/Map Control. Switch functions on the control are explained as follows:

- o  ENABLE--Switch must be activated before any cursor positional functions are permitted

125
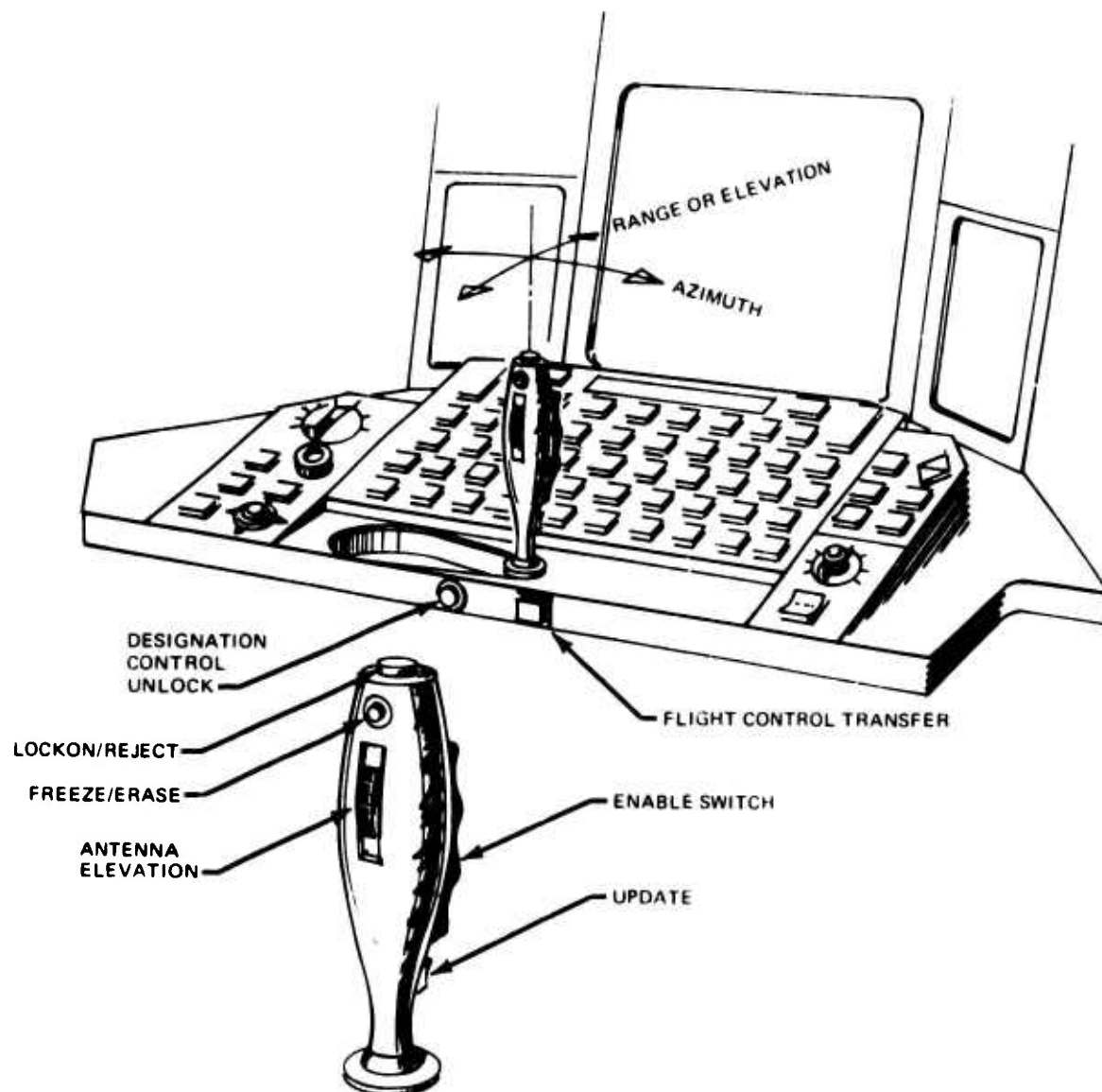
Figure 52. Designation Control (Stow Type)

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o LOCKON/REJECT--Pushbutton switch
  with "first" and "second" detents
  for cursor lock-on or rejection of
  any target

o ANTENNA ELEVATION--Used in air-to-
  air combat flight mode. Permits
  MMR antenna elevation control
  during "spotlight" mode

o FREEZE/ERASE--Permits detailed
  examination of MMR and E-O pre-
  sentations

o NAVIGATION UPDATE--Position updates
  the navigation computer after
  tracking a checkpoint

o BSD TRANSFER--Transfers the classic
  BSD to the HSD

o FLIGHT CONTROL TRANSFER--Transfers
  primary flight controller functions
  to the designation control

If all avionic systems function properly
during a mission, the cursor is automatically controlled
with the central computer. Through central computer
program instructions, the cursor is displaced in range,
azimuth, and elevation (depending on display and sensor
selection). If all goes well, the designation control
may remain "stowed" for the entire mission. However, if
certain mission critical systems degrade, provisions are
available for manual assistance in target acquisition and
other tracking tasks. The designation control provides
the pilot with an additional capability to designate and
track any air or ground target--moving or stationary. In
the degraded mode analysis, the primary method of designating
and tracking a target was awarded to a stick-type control.
Voice control is considered as backup and becomes primary
when primary flight controller functions are performed by
the designation control.

(2) Secondary Controls in a Primary Area

Secondary controls in a primary vision area
are those that are used to directly select the flight
display modes and to control sensor or airplane operation.

In the ensuing discussions of these controls,
tables are presented to define modes of operation that are
compatible or incompatible with one another. These are

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preliminary and may require further investigation. Depending on the criticality of the assumed incompatibility, the computer could be programmed to disengage all incompatible modes when a new mode is selected. Some incompatibilities are due to the viewer not being able to use the information, not of the system being incapable of producing it. In some respects, the control flexibility called out by this study is probably considerably more than would actually be needed. An example of this is the capability to preprogram any of the many multipurpose presentation formats onto any of the four main MPD positions.

(a)    Flight Mode and Display/Sensor Selection

Selection of flight modes (air-to-air, cruise, air-to-ground, and takeoff/land) causes several preprogrammed interactions to occur. Other actions affected relate to aircraft performance, e.g., stability control through cg location, flight control sensitivities, and flight control harmonization.

Normally, the VSD will present a contact analog display when the air-to-air, cruise, takeoff and land flight modes are selected. The exception to this classic program occurs whenever the aircraft is within 1,000 feet of the terrain, or whatever altitude is dictated by operational doctrine. At that point, terrain following "shades of gray" replaces the contact analog display.

When air-to-ground is selected, terrain following is displayed. When a self-defense requirement exists while terrain following, selection of air-to-air will cause the appropriate fire control information to be superimposed over the terrain following display.

The contact analog and terrain following switches enable overriding of programmed flight mode display relationships. These switches provide a capability to perform degraded mode or mission unique manual operations.

The Display Sensor Select Panel has been modified as a direct result of the flexibility designed into the new Integrated Keyboard Control. The modifications discussed below provide a high degree of control over display and sensor options available to the pilot. Each control is described in detail.

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### (b) Displays

Selection of the HUD "ON" will cause the combining glass to erect, Figure 46. By means of liquid crystals, an opaque 1.5-inch circular area, as viewed by the pilot, appears on the glass for display of steerable LLLTV/FLIR video. The sensor presentation is parallax compensated, bore-sighted to line of sight, and focussed to infinity. The opaque area provides the pilot with video scene equivalent to a 9-inch CRT installed on the instrument panel. Placing the video on the combining glass provides two advantages over the instrument panel installation: 1) The TV/FLIR presentation is aligned with the real world in the forward search area. 2) The video is collimated at infinity, eliminating the delays incurred in eye accommodation as the pilot exchanges attention between the real world and TV/IR views.

Magnification of the Steerable LLLTV/FLIR can be changed from wide to narrow field of view with controls on the E-O Auxiliary Sensor Control panel. When the HUD "OFF" position is selected, the combining glass is removed from the pilot's line of vision to a stow position, Figure 46. Whether the HUD switch is ON or OFF does not affect the normal presentations on the VSD or HSD. Selecting the HSD TRANSFER "ON" will cause imagery on the HSD and VSD to shift upward. For example, the VSD presentation transfers to the HUD position (1), and HSD transfers to the VSD position (2). Had the HUD been in a stow position when this button was depressed, it would immediately erect and display the appropriate VSD information. The HSD position (3) becomes blank but available for BSD information if the BSD transfer switch is activated.

Selecting the BSD TRANSFER "ON" will transfer the BSD presentation, normally on a classic MPD, to the HSD (3). The imagery (RADAR) on the HSD will disappear; however, map data may still be presented simultaneously with BSD information by simply depressing the MAP "ON" button located on the Auxiliary Radar/Map Control Panel.

### (c) VSD/HUD Sensor Select

The RADAR "ON" switch will allow radar targeting information (crosshair, target symbols, etc.) to be displayed on the VSD/HUD simultaneously with other imagery (TF/TA shades of gray, attitude, ITEMS flight director, fixed and steerable TV/FLIR). The switch "ON" and "OFF" does not affect information being presented on the HSD.

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The LLLTV STEERABLE/FIXED sensor
select is a three position pushbutton rocker switch
with a center OFF position.
Selecting the FIXED and/or
STEERABLE position permits
FIXED and/or STEERABLE TV
video to be displayed as a
composite video on the VSD.
Fixed LLLTV video is the
primary scene with STEERABLE LLLTV scene (centered on the
crosshair line of sight) shown in a small circular "cut-
out" area. Steerable TV video will be presented on the
HUD when the HUD "ON" switch is activated.

Selection of the FLIR STEERABLE/FIXED
sensors for display on the VSD/HUD is similar to that just
explained for the LLLTV. Because it is possible to inter-
lace video from separate sensors (sometimes called "level
splicing"), both LLLTV and FLIR sensors may be activated
simultaneously and displayed on the appropriate displays.

(d) Supplemental VSD/HSD Mode Selection

The Supplemental MMR Mode Selector is
used to select the following submodes as cued by the flight
mode selected:

Air-to-Air Mode

o AA-SEARCH/TRACK--Doppler processing is used to
   provide long-range detection of airborne targets
   during spherical search/track

o DOGFIGHT--Permits a narrow azimuth sector to be
   volumetrically searched. Target lock-on occurs
   automatically when the pilot points the aircraft
   in the near vicinity of the target

o STATIONKEEPING--Provides stationkeeping on all
   aircraft located within a 2-nmi radius

o BEACON (BCN)--Interrogates the airborne or ground
   radar transponder. The coded response appears on
   the HSD at the transponder location in range and
   azimuth and on the VSD in azimuth and elevation

o PASSIVE--Places the MMR in a receive only mode
   for all modes except TF/TA

o GROUND MAP (GM)--Provides conventional ground
   mapping data to the HSD

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o   SPOTLIGHT--(Degraded Mode)
    Provides manual search
    pattern capability with
    the MMR antenna programmed
    to a point in space.
    Numerical "bar scan" selec-
    tion is provided in the
    keyboard.

**RADAR MODE SELECT**
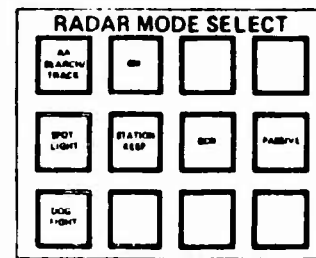
AIR TO AIR

## Air-to-Ground Mode

**RADAR MODE SELECT**

AIR TO GRND

o   AA-SEARCH/TRACK--(See Air-
    to-Air Mode above).

o   MOVING TARGET INDICATOR (MTI)
    RADAR--Detects targets
    moving with a ground velocity
    of 5 knots or more

o   MTI - LLLTV/FLIR--Detects targets with E-O
    sensors same as radar above.

o   GM--Provides conventional ground mapping data to
    the HSD

o   GROUND MAP SQUINT (GMS)--Aligns the antenna beam
    to produce a high resolution "passing scene"
    map at 45 degrees left or right of ground track.
    Swath width selection is made with the keyboard
    control.  Range selection is provided on the
    Radar/Map/Display Auxiliary Control

o   SITUATION--Processes radar data to indicate only
    ground features protruding above the flight path
    clearance plane.  Presented on the HSD

o   SPOTLIGHT--Provides high resolution radar imagery
    of an area (1 x 1, 2 x 2, or 4 x 4 nmi) about the
    crosshair

o   AIR-TO-GROUND LASER RANGING (AGRLR)--A pencil
    beam (LASER) is directed at the designated
    target to measure range

o   DOPPLER BEAM SHARPENER (DBS)--Provides ground
    mapping resolution improvement when the MMR
    antenna is more than $\pm 5$ degrees off ground track

o   PASSIVE--(See Air-to-Air Mode)

o   STATIONKEEPING--(See Air-to-Air Mode)

o   BEACON--(See Air-to-Air Mode)

131
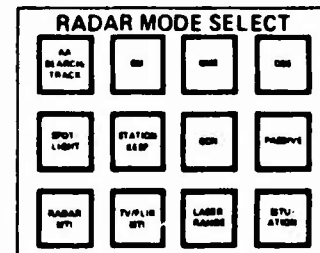
## Cruise

o   AA-SEARCH TRACK--(See Air-to-
    Air Mode)

o   STATIONKEEPING--(See Air-to-
    Air Mode)

o   GM--(See Air-to-Ground Mode)

o   GMS--(See Air-to-Ground
    Mode)

o   SPOTLIGHT--(See Air-to-
    Ground Mode)

o   BCN--(See Air-to-Air Mode)

o   DBS--(See Air-to-Ground Mode)

o   PASSIVE--(See Air-to-Air Mode)

o   LASER RANGING--(See Air-to-Ground Mode)

o   MTI - RADAR--_See Air-to-Ground Mode)

o   MTI - LLLTV/FLIR--(See Air-to-Ground Mode)
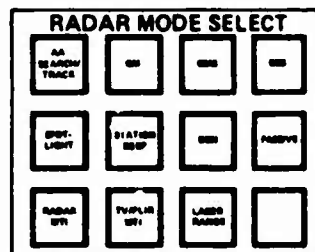
## Takeoff/Land Mode

o   INDEPENDENT LANDING MONITOR (ILM)--Provides
    pitch and lateral steering to a point on the
    runway.  In this mode, synchronized beacons are
    placed at specified points along the runway.
    Steering directions are based on position in
    space as measured with the MMR antenna in the
    "passive" mode, and calculated with the CCC.

o   STATIONKEEPING--(See Air-to-
    Air Mode)

o   SITUATION--(See Air-to-Ground
    Mode)

o   GM--(See Air-to-Ground Mode)

o   GMS--(See Air-to-Ground
    Mode)

o   SPOTLIGHT--(See Air-to-
    Ground Mode)

o   BCN--(See Air-to-Air Mode)

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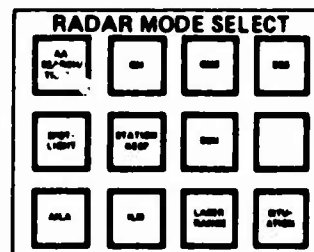
o   DBS--(See Air-to-Ground Mode)

o   AA-SEARCH/TRACK--(See Air-to-Air Mode)

o   LASER RANGING--(See Air-to-Ground Mode)

o   AILA--(Provides pitch and lateral steering
    through MMR tracking functions)

    (3)   Map/Radar/TV Auxiliary Panel

        This control panel allows the pilot to
select:

o   RADAR GAIN--Permits the pilot to adjust
    MMR receiver gain to the desired level

o   RADAR/MAP RANGE SELECT--Selects map and
    radar ranges in continuously variable
    steps from 1 to 40 nmi and incremental
    steps from 40 to 320 nmi

o   MAP SLEW--The map may be slewed from
    present position by depressing the
    button in the center and pushing the
    control in the direction desired.  Used
    mainly for "look ahead."  When released,
    the map returns to the computed present
    position.

o   MOVING MAP--Pushbutton control "ON" or
    "OFF" for presenting moving map data
    on the HSD display.  May be activated
    any time regardless of HSD sensor selec-
    tion (MMR or LLLTV/FLIR).  Map scale is
    controlled with radar/map range select
    knob.

o   N-UP/H-UP--Provides north-up or heading-
    up display orientation for HSD

o   PPI/OCS--Permits pilot to select HSD
    PPI or OFF-CENTER SECTOR (OCS) during
    search or track operation, respectively

o   OFFSET--Selects OFFSET "ON" or "OFF"
    during offset bombing for "no show"
    targets.  Also, used during AILA to
    track prominent "OFFSET" target during
    landing approach.

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(e)  Electro-Optical Auxiliary Control

The electro-optical (E-O) auxiliary control panel permits the pilot to select:

o  INDIVIDUAL SLAVING--
   Permits the pilot to
   slave LLLTV/FLIR/LASER
   line of sight inde-
   pendent of the radar.

o  BORESIGHT SLAVING--
   Slaves the E-O sensors
   sighting angle to the
   crosshair

o  STOW--Stows the E-O sensors to
   "O" azimuth and elevation angles

o  N-FOV-W--Selects a narrow or wide
   field of view for the LLLTV/FLIR
   sensors

o  CONTRAST LOCKON--Permits the pilot
   to perform target lockon after
   designation with the cursor control.
   Lockon is based on target contrast
   levels.

o  FAC TV FLTR--Pushbutton to insert
   or remove LASER illuminator filter
   during FAC target designation with
   LASER

(f)  Display Level Control

The Display Level Control lets the pilot adjust the intensity or contrast of all displays through the following controls:

o  DISPLAY SELECTOR--
   A detented rotary
   knob for selecting
   the HSD, VSD, HUD,
   and each of the
   five MPD's.



o  LEVEL ADJUSTOR--A depress-to-turn
   knob provided for adjusting display
   intensity or contrast, depending
   on which is selected.

o  INTENSITY/CONTRAST--Lighted push-
button selects either intensity or
contrast as an operating mode for
the level adjuster.
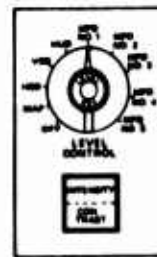
This control panel is conveniently
located on the lap console in the brolly and wraparound
cockpits.  It is to the left of the left knee cutout in
the centerstick cockpit.

(4)  Battle Situation Control/Display

By using the integrated keyboard and CM
panel, the pilot can selectively rather than collectively
program and reprogram most penetration aid functions.
Because time is limited, pilot actions are usually con-
fined to veto and degraded mode operations.

In dense threat environments, it is possible
to reduce BSD clutter manually.  The control display and
battle situation keys on the integrated keyboard, Figure
53, are used.  The pilot can add or delete air and ground
threats, priority, and launch envelope information.
Excepted are terminal threats that cannot be deleted
manually.  Any one of the five MPD's or the HSD may be
selected.  The HSD is needed when it is necessary to work
with numerous threats.

The pilot can manually request
detailed threat characteristics, change
threat identifiers, locations, and priorities.
The BSD transfer switch is pressed to do this.
This moves the BSD from an MPD to the HSD,
allows threats to be addressed with the
designation controller, and allows use of
the vacated MPD for threat data detail recall.

The penetration aids key on the integrated
keyboard is pressed to read out threat data details and
make manual changes.  The resulting keyboard is as on
Figure 54.  The threat is addressed on the HSD by the
designation controller by placing the cursor over the
threat of interest and pushing the lock-on button.
Pressing the identity key will then provide MPD recall of
complete computer stored threat data details.  Direction
finding steers will resolve nondeflection threat strobes
in either active or passive radar modes.

Threats of opportunity are stored with the
designation controller and the modify and location keys.
When the pilot is satisfied that the cursor is properly
over the threat, the lock-on button and the enter key are
depressed.

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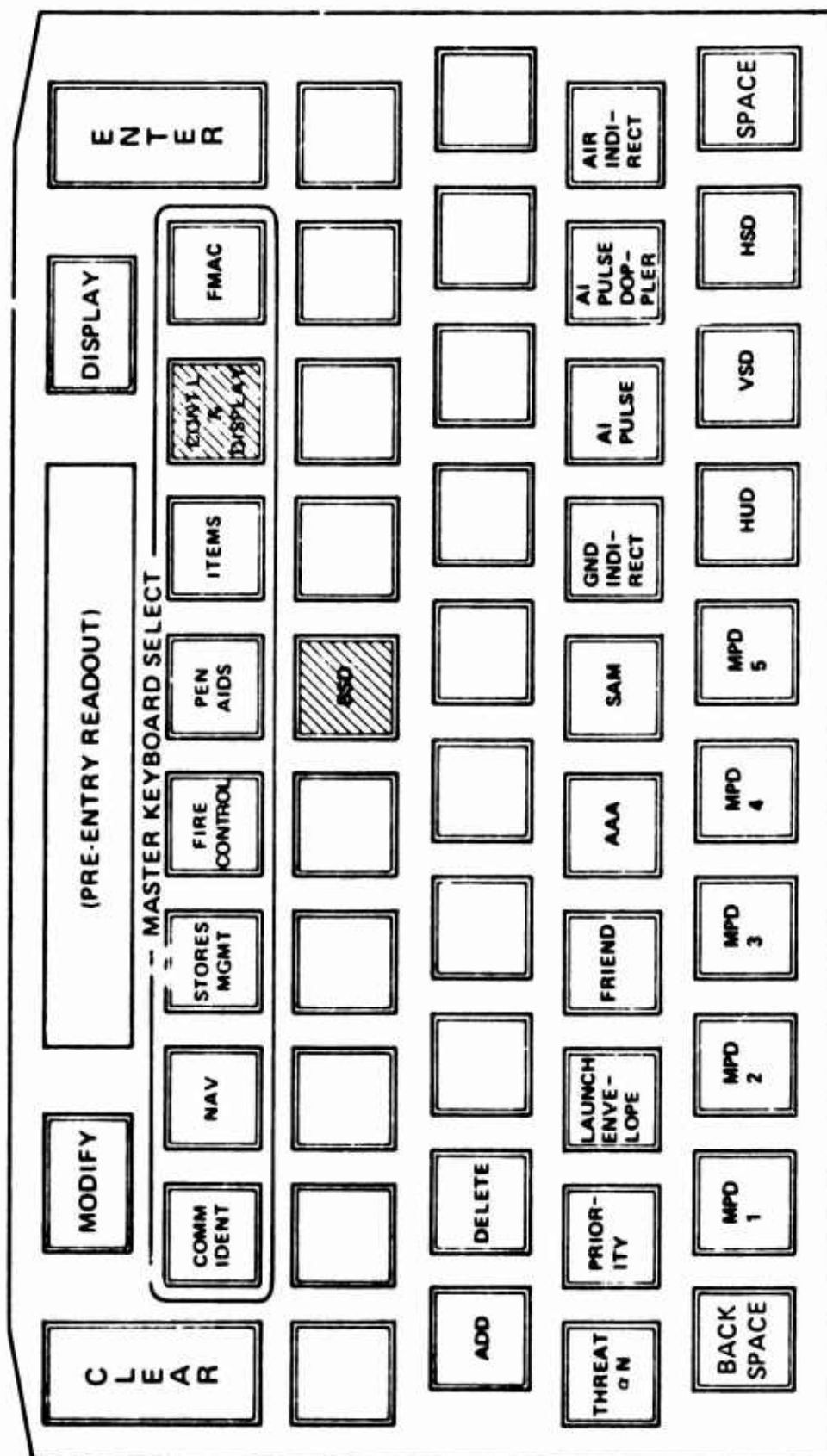
Figure 53. Control/Display Battle Situation Display Keyboard
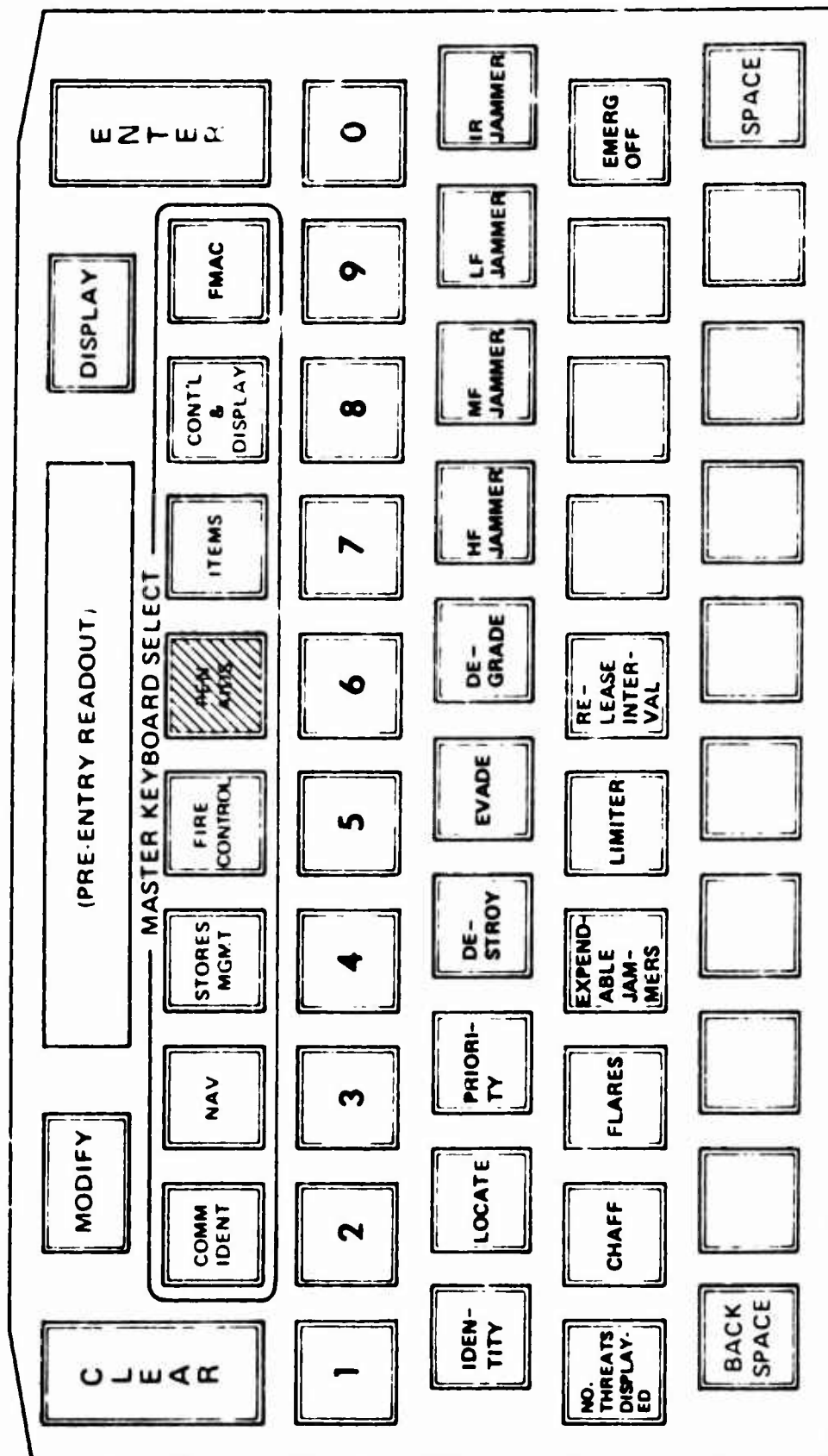
Figure 54. Penetration Aids Keyboard

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Priority and modify keys are used to change threat priority manually. The threat with a priority to be changed is addressed with the designation contro-ler. Then the new priority and a code for color is typed and entered.

Because judgment decisions are expected, manual selection of the offensive-defensive action options is allowed. Such actions are taken against the number 1 priority threat unless a threat is specifically designated with the designation controller. Then the designation controller provides a means to quickly override previously assigned priorities.

When the evade key is pressed, steering signals as previously discussed are shown on the VSD.

For degradation, quantities of chaff, flares, and other expendables to be released and release rates can be set up with the integrated keyboard. MPD readout of remaining expendables and other pertinent details are also provided.

Countermeasures can be selected and controlled by the CM panel. To enter the manual countermeasure mode, depress the "MANUAL" button on the CM panel. Depressing the appropriate countermeasures dispensing system (CMDS) button enables selection of a specific type or kind of expendable. Key words showing the type of expendable in position to release are shown on the CMDS release keys. Release is accomplished by depressing the associated CMDS "REL" button.
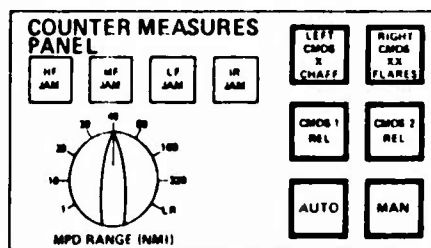
The range switch on the CM panel is used only when the BSD is located on an MPD. The long range (LR) position is to monitor all high altitude and low altitude activity. When the BSD is transferred to the HSD, the HSD range switch is used.

The integrated keyboard contains a "limiter" key to limit the number of threats allowed on the BSD.

If the "destroy" key is pressed, the battle situation and VSD presentations are the same as in the normal combat flight mode. Then the weapon can be

programmed and released either manually or automatically
with the SMS.

    (3)   Secondary Controls

        (a)  Mission Control Panel

            The mission control panel permits automatic
and manual loadings into the central computer.  The prepro-
grammed mission tape is placed into the "TAPE INSERT" cas-
sette receptacle which may be used for readout or programming.

            Operations that can be performed using this
panel are described below:

    o  AHRS STATUS--
       Displays align-
       ment or opera-
       tional status
       of the Auxili-
       ary Attitude
       and Heading
       Reference
       System.
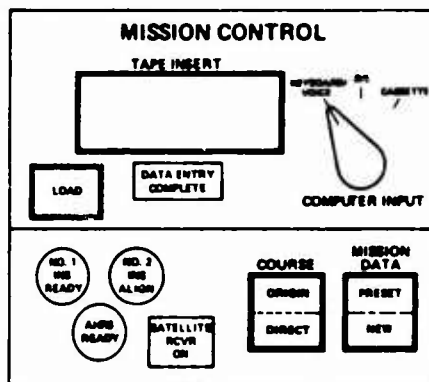


    o  #1 and #2 INS
       STATUS--Dis-
       plays align-
       ment or opera-
       tional status

    o  Indication of the satellite tracking
       status

    o  Computer Input

       - CASSETTE--Used when mission data tapes
         are loaded into the central computer

       - D/L--Used when mission data are loaded
         into the computer via data link

       - KEYBOARD/VOICE--This is the normal posi-
         tion for this switch.  It allows use of
         the keyboard or voice for data inputs
         to the CCC depending on voice entry
         switch position on the throttle

    o  LOAD--Permits loading the computer once
       the method has been selected

    o  TAPE INSERT--Entry for loading cassette
       data into the central computer

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o DATA ENTRY--Provides data loading
  status

o COURSE

  - DIRECT--Instructs the navigation
    computer to compute a course via
    the shortest route

  - INDIRECT--Instructs the navigation
    computer to compute a course for
    return to the preplanned flight
    route

o MISSION DATA

  - PRESET--The normal position for this
    switch.  The flight follows the
    preplanned route

  - NEW--Used in conjunction with the
    Computer Input switch and the
    Integrated Keyboard to enter new
    destinations, targets, waypoints,
    checkpoints, etc.

(b)  Comm/Ident Panel

The C&I control panel is the focal
point for rapid selection of
nearly all air-to-ground and
air-to-air communications
once the mode options have
been selected with the
Integrated Keyboard
Control (IKC).  IFF mode
and code options are pre-
sented on an MPD.  All
communication modes, once
selected on the IKC, are
presented on a classic MPD
display.
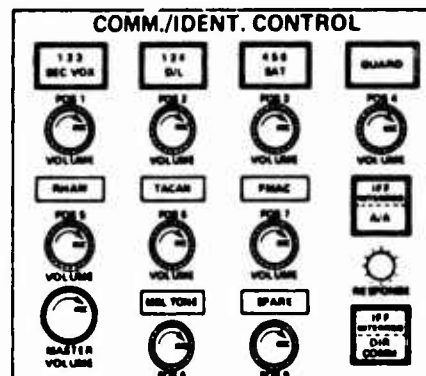


The panel, as shown, indicates at
position one, destination 123.  The SEC indicates the
spread spectrum channel is programmed for secure voice.
The multilegend pushbuttons illuminate at a low light level
when programmed for receive only and brightens when
depressed for transmit and receive.  Up to to four
positions may be activated for selective transmission,
including guard.  For positions one, two and three, the
pilot must activate a transmit switch, located on the
throttle control, before voice transmissions are actually

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radiated from the aircraft. Data link tie-in is completed by simply activating the transmit pushbutton control. In position four, the pilot may transmit on GUARD without activating the microphone on the throttle control.

A second means of air-to-air IFF interrogation is needed for the degraded mode. The comm/ident panel has pushbutton controls for activating or inhibiting the conventional IFF (integrated with the phased- or conformal-array antenna) as well as the directional IFF (contained in the spread-spectrum communication link). A discrete light (labeled "RESPONSE") illuminates if the proper response is received by either interrogation method.

The identification keyboard is chosen by pressing the C&I key on the master keyboard select. This illuminates the identification options of the keyboard. Most options are self-explanatory for setting up all modes for air-to-ground and air-to-air. Both identification systems with respective modes and codes appear on the COMM. MPD classic display. In addition, the Directional Comm.



and MMR IFF interrogate pushbuttons on the intercom panel light dimly, indicating systems programmed and ready for use. When either IFF interrogate button is pressed manually, it will light up brightly to indicate interrogation is being performed on the target designated by the tracking control cursor. A "RESPONSE" light on the ICS panel indicates receipt of a proper IFF response, in addition to the audio tune.
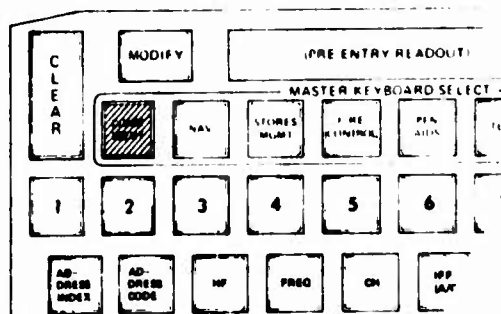
(c)    Environmental Control Panel

The ECS panel controls cabin pressurization, temperature, humdity, and through rain removal and defogging, external vision. In addition, controls are available to provide the environmental conditions necessary to survive in emergency situations.
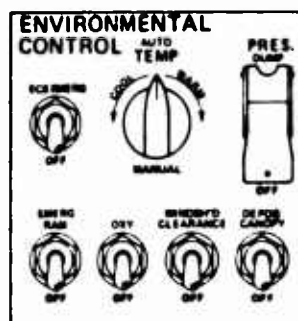
o   TEMPERATURE--Temperature is controlled automatically;
    however, the controller may be operated manually
    to provide comfort.  Relative humidity is main-
    tained throughout the temperature spectrum of
    control.

o   PRESSURIZATION/DUMP--Selecting the dump position
    turns the pressurization system off and opens
    gate valves to reduce cockpit pressure to ambient.

o   EMERGENCY RAM--Selection of emergency ram air
    when in the pressurization DUMP position provides
    a fast means for purging the cockpit of aerosols.
    Ram air is selected automatically when normal
    pressurization fails.  The emergency ram air
    switch provides a redundant means for obtaining
    pressure when the system fails.

o   ECS EMERGENCY--When placed in the ECS EMERG
    position, this switch turns off the normal
    pressurization system and, with automatic or
    manual selection of emergency ram, provides cockpit
    pressurization.

o   WINDSHIELD CLEARANCE--Actuation of this switch
    provides rain removal.  Anti-ice heat to the
    windshield is provided full time by embedded
    heating elements.

o   CANOPY DEFOG--When activated, heated air is
    circulated between the canopy glass layers to
    eliminate or preclude fogging of the interior
    transparent material.

o   OXYGEN--If pressurization or ambient air is
    absent, emergency oxygen can be provided by
    activating this switch.

(d)  Lighting Control Panel

The panel controlling exterior and
interior lighting is located to
the right of the major displays.
The exterior controls are quite
conventional and their operation
is self-evident.  The interior
light control is new and
uses an unusual method to
control cockpit lighting and display brightness from a
single point.  To operate the internal intensity control,
the pilot visualizes it as being located directly in front
of him; that is, between him and the lap console or instru-
ment panel.  Each line radiating out from the center of

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the control represents a specific control panel or display area relative to the central position. For example, the control is pushed directly up to change brightness on the flight mode select panel. Similarly, to decrease the intensity of the stores select panel, the center button is pushed in and the control is pushed to the left at about the 90° position. Beyond this 90° position, the panels on the left console are controlled. The right or left floods are controlled by moving the control to the R or L FLD position.

(e)    Landing Gear Control

Two simple pushbuttons are used to control the landing gear position.   Indication is provided on MPD #5.

(f)    Flaps and Wing Sweep Selector

A single handle is used to control both wing sweep and flaps. The two functions are interlocked so that only one can be selected at a time. Selection of any wing sweep other than the minimum 25° position requires the flaps to be in the UP position. Likewise, selection of any flap down position requires the wing sweep to be in the 25° position. Wing sweep is obtained by handle rotation while flap position is changed by handle translation. Position feedback is provided to the wing sweep selector during normal automatic wing sweep operations. Pushing the wing sweep selector in will permit override of the automatic wing sweep mode.
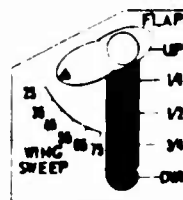
The arrestment switch located on the panel just ahead of the flight controller, was added so that equipment necessary to stop the aircraft at the end of the runway could be extended or retracted.

The emergency beacon is activated upon ejection. The emergency beacon disable switch permits the pilot to turn the emergency beacon off to prevent detection by enemy forces. This button switch is located on the right side of the front panel.

An abort switch is located on the panel just to the outboard side of the forwardmost

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position of the throttle.  Activation of this will cause:

- o  Thrust reversal

- o  Spoiler extension

- o  Wheel brake application

- o  Arresting equipment extension

(4)  Tertiary Controls

These controls are located on the side panels and are seldom used during flight.

(a)  Engine Control Panel

Controls on the Engine Control Panel are used to start, trim, and shut down the engines.  In starting the engines, the two rotary switches are placed in the OFF position and the guarded switches are turned ON.  Then the rotary switches are moved through the NORMAL START position to IDLE and the engines start automatically.  When the start is assured, the switch is placed into the RUN position.
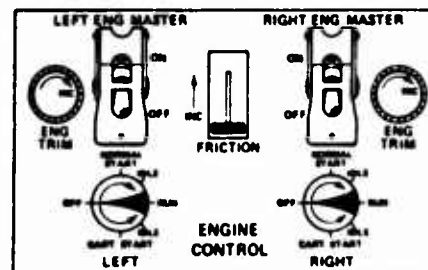
When the APU cannot be used for a start, the rotary switch for one engine is moved through the CARTRIDGE START position to IDLE and the engine starts automatically.  When the start is complete, the switch is placed in the RUN position.  When placed in the RUN position, the FRICTION lever controls the amount of force required to move the throttle.

Seat and rudder adjust and arrestment controls on this panel are self-evident.
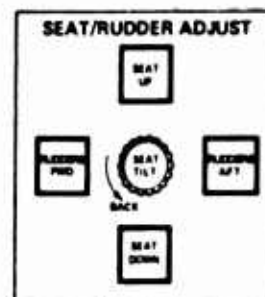
(b)   Electrical Control Panel

Switches on the
Electrical Control Panel are used
to select the electrical power
source used during startup and to
permit manual disconnect of the
alternator from the engine (subse-
quent to automatic disconnect if
failure occurs).  In addition, the
variable-speed, constant-frequency
converter is controlled and can be
reset.
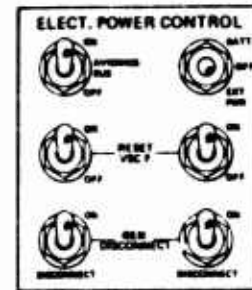
(c)   Canopy Lock/Release

This mechanism
controls the normal and emergency
canopy operations.
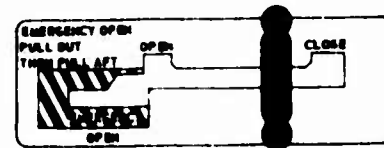
# 7. SUMMATION OF RESULTS AND DISCUSSIONS

The primary purpose of the tactical fighter is to deliver weapons on targets. The task must be accomplished with the fighter surviving any deterrents the enemy may have to protect the targets. This dictates a fighter with capability for a single pass kill and agility to maneuver and vary velocity to evade threats throughout the task. It must lock-on the target, quickly attain the weapon release vector, pull a large g load, and rapidly accelerate for escape after weapon release. The fighter must be able to accomplish the attack task with a variety of methods and weapons to increase target vulnerability. It must have flexibility for successfully meeting the many threat, target, terrain and weather environments. Weapon delivery options using a full spectrum of delivery tactics are required. Since the task is especially time constrained, the fighter must be able to do it quickly; e.g., the entire task may last as little as 20 seconds in a dense threat environment. Precision weapon delivery on the correct target is required since some targets must be struck with a CEP less than 4 feet. The tactical fighter needs a self-defense capability--carrying weapons for neutralizing both air-to-air and ground-to-air threats.

These critical requirements directly impact and drive tactical fighter design. All subsystems must be optimized and integrated for this end to achieve a superior attack task capability. Accordingly, the IIPACS concept is being developed for the successful execution of the attack task. Of necessity, it reflects innovative design solutions to achieve a superior, viable improvement over today's tactical weapon systems. Considerable equipment complexity, compared to today's systems, is incorporated into IIPACS to ensure required capability. This complexity is not considered a disadvantage, because high reliability and self-test features are an integral part of the basic concept. Proper use and allocation of complexity enhances system capability with cost benefits when the primary weapon system figure-of-merit is considered; i.e., pounds payload per target destroyed.

The attack task is functionally described in Figure 55. It starts with correct target acquisition and culminates in a successful escape from the target after a precise weapon release. Existing problems associated with

| FUNCTIONS | SEARCH | IDENTIFY | LOCK-ON | CLASSIFY AND SELECT WEAPONS | CONVERT | ENTER SLOT, REFINE AIM, & VERIFY TARGET | RELEASE | WEAPON GUIDANCE | ESCAPE AND DAMAGE ASSESSMENT |
|---|---|---|---|---|---|---|---|---|---|
| MAJOR PROBLEMS | • GEO-ORIENT<br>• SENSOR DISPLAY<br>• SEARCH AIDS<br>• TRAINING<br>• RECON/BRIEF | • BRIEFING AIDS<br>• COMPUTER REF<br>• SENSOR DISPLAY<br>• TRAINING<br>• DISPLAY AIDS | • SENSORS<br>• DESIGNATION CONTROL<br>• COMPUTER AID | • WEAPON/TARGET MATCHING<br>• WEAPONS MANAGEMENT | • TA RANGE<br>• MANEUVER-ABILITY<br>• WEAPON ROMTS<br>• SURVIVAL<br>• TRAINING | • STEERING<br>• SURVIVAL<br>• TRAINING<br>• COMPUTER AID<br>• DISPLAY | • WEAPON INSTALL/SEPARATION<br>• A/C STABILITY<br>• PATTERNING<br>• CCIP COMPUTATION | • AUTO TRACK<br>• SENSOR/DISPLAY<br>• MANEUVERS<br>• REMOTE CONTROL | • SURVIVAL<br>• SENSOR RECORD AND RECALL<br>• DELIVERY PARAMETERS RECORD & RECALL |

Figure 55.   Tactical Attack Mission

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the accomplishment of each task element are summarized in
the same figure. They are today's problems which IIPACS
attempts to solve. While sufficient data are not avail-
able to demonstrate IIPACS does solve these problems; it
does appear that the concept is pointed in the right
direction. As IIPACS is refined and tested under both
simulated and actual flight conditions, these problems
need to remain in the forefront to ensure their resolution.

The major IIPACS subsystems involved in the attack
task are presented in Figures 55 and 56, along with a
summary of information flow within this interface complex.
This complex (called the attack subsystem to identify
its function) recognizes the impact of combat stresses and
workload variations on pilot performance. Full advantage
is taken of the highly reliable, large capacity computer
systems forecast for the 1980 time period. Two redundant,
federated computer complexes are included in IIPACS to
form a primary control center to relieve the pilot of all
attack workloads except target acquisition/verification.
This control center interacts with the pilot in real-time and
is managed by the pilot usually with voice inputs during
this busy phase of the mission. The pilot is expected to
augment the computer in the area of threat management by
inserting current threat configuration information obtained
visually or via sensor interpretation. The computer, in
turn, will augment the pilot in target search identifica-
tion and classification by providing predicted target
locations, descriptions, enhancement cues, and processed
video. In specific instances, the pilot must select and
designate the target.

To assist the pilot in optimizing the survival/
precision weapon delivery trade, the computer predicts
weapon impact point and CEP spread and best delivery path
for threat evasion. Airplane steering precision, response,
and stability are enhanced for both autopilot and pilot
control. Control stick steering modes oriented toward
flight path control or attitude control working in con-
junction with special force generators in the airplane
provide improved agility and the capture of the weapon
release vector. The pilot may select airplane stability
characteristics to optimize those needed for air-to-ground
work and those for air-to-air self-defense work. Research
is required to optimally define design requirements for
the required novel airplane control characteristics.

To enhance pilot protection, the windshield provides
protection from 7.62mm shells and crew station titanium
protects against 23mm shells. It is desirable that the
windshield handle 23mm shells; however, research is required
to determine design feasibility without degrading pilot

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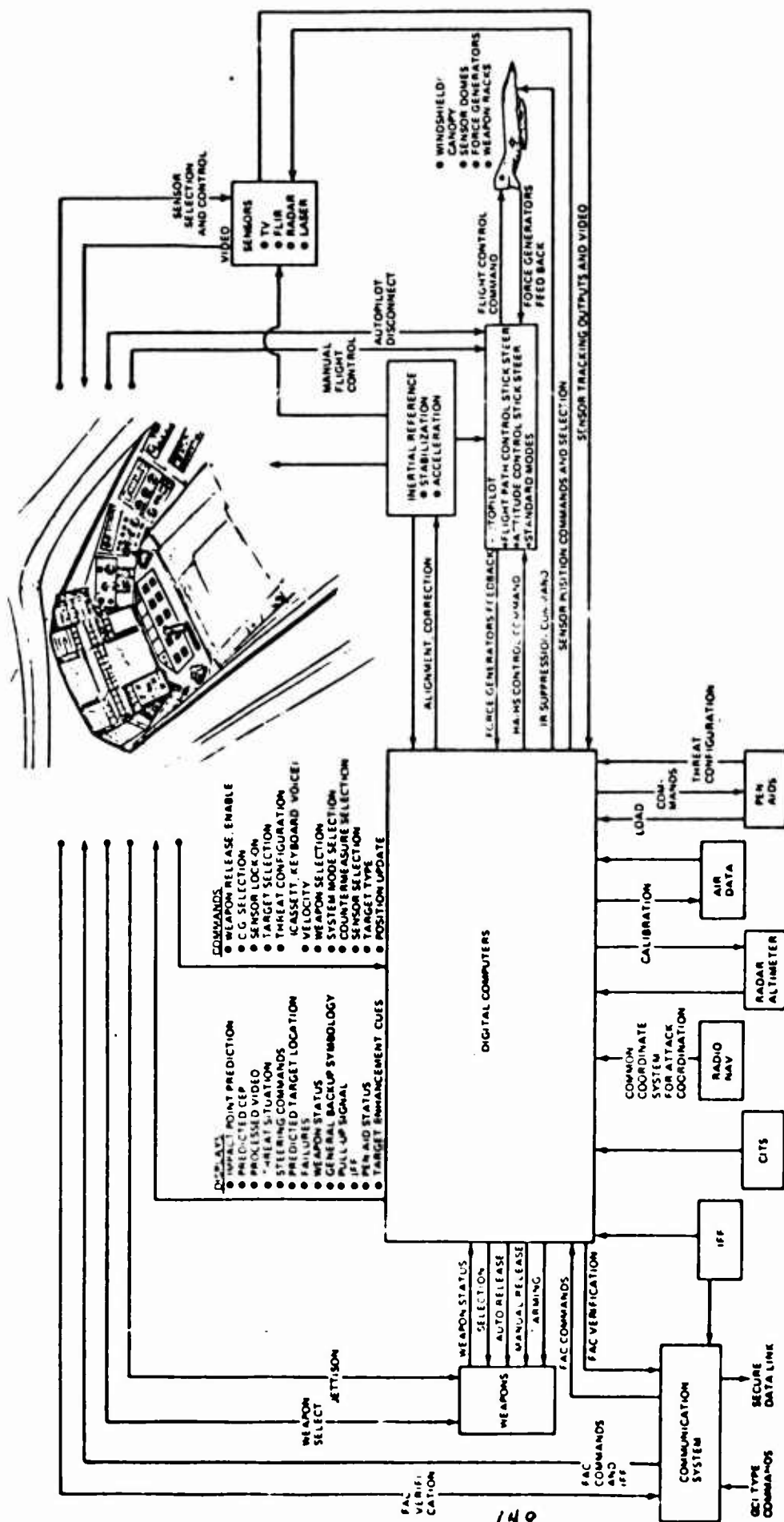
Figure 56. Attack Interface Diagram

visual target acquisition capability. It may be necessary
to add a steerable telescope to IIPACS for target
identification to permit proper windshield armor installa-
tion or install the pilot in a non-standard manner to
reduce windshield vulnerability area.

It is apparent that the key to the advanced attack
subsystem concept summarized here is the joint, interact-
ing control centers incorporated into IIPACS--the pilot
and the computer. Development work is required to detail
these control centers and identify exactly:

   o   How they must interact

   o   Their command task allocation

   o   Their cooperative aiding

   o   Intercommunication links and techniques

   o   Overrides and software

Technology is available. It remains to take full advantage
of this capability to optimize the pilot-computer integra-
tion required for successful cost/effective attack task
performance.

Details concerning the individual subsystems iden-
tified for the attack task are presented in previous
sections of this book.

# SECTION IV

## CONCLUSIONS AND OBSERVATIONS

1.    CONCLUSIONS

The three advanced tactical fighter cockpit configurations resulting from the IIPACS-1 study (Volumes 1 and 2) are feasible for development circa 1980. Since current specifications and standards were not a conceptual constraint, these cockpit configurations are substantially different from current aircraft. Development progressed from a systems-type analysis to mockup configurations.

The wraparound cockpit of an updated IIPACS-1 tactical fighter weapon system provided the baseline configuration for the degraded mode analysis. The study results provided control and display modifications and additions designed to permit a high degree of survivability and mission completion after sustaining failures to an identifiable level.

Specific conclusions are:

o   IIPACS concept, updated in response to advancing technology, offers a significant advance in tactical weapon system effectiveness.

Through a dependent system of automation, a reduction of pilot workload will be realized.

o   Time-sharing techniques and multipurpose controls and displays improve the integration of information and control functions is feasible.

o   Avionics concepts will provide a high degree of flexibility, thereby simplifying growth and updating problems.

o   Workload per unit of time during anomalies may well drop below that of normal operations. This is attributed to the fact that the pilot defers normal operations during contingency situation. This was borne out by the degraded mode workload evaluation and verified in film reviews of A6 emergency operations.

o   The controls and displays developed as a result of the degraded mode analysis will permit contingency operations without an overburdening pilot workload.

o   Weapon delivery accuracy requirements determine
    weapon system design criteria.  Systems integra-
    tion is vital to the realization of an effective
    weapon system.  Airframe and weapon designs
    must be complimentary to the avionics/fire control
    systems.

o   IIPACS-2 automation approaches those required for
    an unmanned system.  For specific missions and
    certain weather conditions, a pilot is still
    required on-board for target acquisition and
    verification.

o   The IIPACS has been defined sufficiently for
    full mission simulation.

o   The IIPACS concept is flexible enough that it
    can apply to systems other than tactical fighters.

2.    OBSERVATIONS

    During this study, it became evident that certain
problems relating to the weapon system should be pursued
in future research and development programs.  The following
paragraphs briefly describe specific areas of concern.

    a.   Automatic Target Acquisition

        Automatic target acquisition is a high priority
problem area.  A major breakthrough is required to advance
the technology of manned vehicles.  As such, sensor data
correlation and image processing techniques present the
greatest challenge.

    b.   Integrated Total Energy Management System (ITEMS)

        A total energy management system permits inte-
gration of the elements of flight normally performed by an
already overburdened pilot.  The system will optimize
aircraft performance while relieving the pilot from in-
consistent and inefficient integrative and interpretive
tasks.

        As the term "total energy" implies, all energy
exchange factors must be considered in determining an
optimum flight path and its relationship to a selected
point, fixed or in motion.  The parameters and equations
required to mechanize ITEMS need to be identified.

c.  Spherical/Conformal Array Antenna System

Conformal array antennas, transmitters, receivers, and associated computer programming need to be investigated. The uses for such a combination of elements include emitter location in spherical coordinates, emitter classification, and spherical air-to-air search. This study should define the requirements for frequency and volumetric coverage, accuracy, power, etc. From these requirements, the hardware should be breadboarded to prove concept feasibility. One area that needs considerable study before desired results can be achieved is the computer sizing and programming.

d.  Solid State Display Devices

Further work is needed to develop a solid state display technique which can satisfactorily replace the CRT by the 1980-85 time period. The use of time-sharing techniques presented in this study is indicative of the tren' toward multifunction displays. Currently, light emitting diodes show great promise as a suitable display technique in the IIPACSS technology time period.

Experimentally, liquid crystals have been used in place of phosphors in a CRT. Ambient lighting enhances the brilliance of a liquid crystal cathode ray display as opposed to the washout of the phosphor CRT in such an environment. An additional benefit of research in the liquid crystal field might be control of canopy trans-missivity as protection against strong ambient light conditions or visible energy from special weapons. Obliteration of the glass face of inoperative instruments in lieu of warning devices would be still another applica-tion of liquid crystals. Thin film EL offers yet another alternate for the aircraft cockpit application; however, its development may take longer than the two techniques previously mentioned.

e.  Simulation

The concepts evolved in this study must be evaluated. A simulation program can determine the feasi-bility of the unique features of the control/display concepts developed in the study. In addition to comparing the IIPACS configurations, the following innovations may be assessed:

o  Flyability of displays that are purely qualitative.

o  In-flight authority over control sensitivity, harmonization, wing sweep, and cg.

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o   Weapon management.

o   Voice command,

o   Degraded mode operation.

f.   Multiplexing Standardization

Accelerated use of digital techniques introduces
the problem of digital interface compatibility.  The advan-
tage offered by a common digital language and transmission
may be intuitively accepted.  All electrical/avionic
equipment for this aircraft should be procured to a speci-
fication that includes standardization of the following
interrelated elements:

o   Modulation technique.

o   Message structure.

o   Sample rate.

o   Interface signal definiticn and signal
    conditioning.

o   Interface system definition.

o   Bit/clock rate.

o   Transmission line characteristics.

o   Line drive and receiver elements.

g.   Voice Commanded Equipment

Voice command of equipment provides an effective
means for reducing foot/hand workload.  An additional
benefit to voice commanded equipment is the elimination
of the visual or tactile task requirement prior to the
foot/hand actuation.  A working model of such a device
has been developed.  A production model and exploitation
of the voice command device has as yet to be accomplished.

h.   Collateral Missions

Almost all combat aircraft presently used are
employed in missions for which they are not designed.
To avoid the problems of "growth" so prevalent in present
aircraft, the advanced tactical fighter calls for a design
capable of coping with the diverse environs of geography
and the many gradations of "cold," "limited," and "hot" wars.
Trends of future mission requirements must be determined
to facilitate design of this flexible weapon system.  A

collateral mission study could provide the necessary
information and indicate alternatives.

i.  Adaptive Controls and Stability

Control sensitivity and harmonization is of
paramount importance in aircraft design.  In-flight
authority over control sensitivities (gains) would permit
the tailoring of flight controls to match the needs of
each operational mode expected to be flown by the tactical
fighter.  Additional flexibility would be gained with
control over cg and wing sweep.

j.  Data Link

While the advantages of data link are well
known, its usefulness depends on RF vulnerability.  When
not jammed or assuming that secure data link could become
a reality, its advantage as a maintenance tool can be
expanded to alleviate cockpit workload.  By transmitting
real time information to a remote monitor, system trends
could be noted, anomalies could be anticipated. and the
skilled individual could act for the pilot, especially
during mission-critical emergencies.

k.  Central Computer

The multiprocessor, multimemory computer must be
simulated on an existing computer so that its performance
and the performance of the computer solving the various
types of data processing problems encountered in an avionics
system can be studied.  This will ensure that when the
computer is actually constructed, it will fulfill all
design requirements.

Partitioning of equipment in the avionics
system must be analyzed to determine where commonality of
processing is done for many different subfunctional ele-
ments as well as sensors.  If this repetition of common
processing occurs, the processing functions will be
combined to conserve total computer requirements.  This
elimination of redundant processing is made possible through
the concept of a centralized computing function.

Concepts such as the multifrequency, multi-
aperture antenna system and multispectral target detection
and identification systems which are not part of the present
F-15 Avionics System must be analyzed.  These new concepts
have the potential of adding significantly to the 1980-85
avionics system's performance.  The requirements that these
systems will place on the functionally centralized computer
must be identified, and an estimate of their effectiveness
must be made.

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The Integrated Presentation System and the IMS System must be interfaced for the system of the 1980's.

Communications, navigation, and identification (CNI) system interface with the IMS requires additional investigation.

1.  General

Additional analysis and supporting simulation test are needed to detail the computer-pilot interface for target acquisition and threat management during attack.

Special study is required to detail the display-flight control system-pilot interface to optimize evasive agility maneuvers, target capture and tracking, weapon release, and escape maneuvers during attack.

Research is necessary to optimize pilot protection during attack without compromising needed visual range for target acquisition and verification.

Test and analysis are required to determine the impact of electronic displays on crewstation lighting requirements.

In an environment where bugs, salt spray, dust, etc. are present, the transmissivity of the windows for the electro-optical sensors for the aircraft and the weapons may be compromised. A means for ensuring E-O sensor window transparency is considered an essential requirement.

The carriage of weapons with integral guidance sensors has been a perennial problem. A method for reducing airframe interference to an acceptable level while exacting a minimum penalty from either the weapon or the aircraft must be devised.

The concept of an integrated engine-generator system (IEGS) warrants investigation. The system uses a generator mounted on the engine shaft and is intended to be used as a motor for engine starting as well. Advantages are that it:

o   Increases electrical power extraction

o   Reduces pneumatic and hydraulic penalties

o   Reduces takeoff gross weight

o   Minimizes frontal area engine

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o   Reduces the size of the engine accessory
    gear box

        This study defined the equipment necessary
to perform the normal and contingency operations of a
tactical mission.  The pilot is considered an integral
part of the weapon system.  No attempt has been made to
analyze the system's degradation as a result of the pilot's
incapacitation to any level.  A separate study is required
to determine the impact the "subsystem man," when
degraded, has on overall weapon system effectiveness.

# APPENDIX I

## FAILURE RANKING AND RELIABILITY ESTIMATE

### 1.    FAILURE RANKING

In a contingency situation, a pilot must make a
decision to continue or abort a mission based on the
observed status of the aircraft and the availability of
accep able alternates.  A casualty may be either induced
by battle damage or the result of a failure.  Field
experience provides an indication of those subsystems most
prone to failure and is used in this study to assist in
establishing a priority for subsystems and failure modes
to be subjected to degraded mode analysis.

A summary of current-inventory fighter aircraft
failures and failure distribution is presented in Figure
I-1.  These data represent a summary of AF 66-1 failure
reporting for continental U. S. operation and exclude
battle-induced failures.  The figure is presented to accent
the finding that the pilot of today's aircraft is not aware
of a majority of the failures occurring to his aircraft.

Less than one-fourth the total listed aircraft
failures are detected in-flight while it is assumed that
nearly all failures do occur in, and as direct result of,
flight stress.  Conceding some failures to be maintenance-
induced and that some reported failures are trivial, there
is still clear indication that a requirement for better
failure detection does exist.  This study treats undetected
failures in a qualitative manner by planned incorporation
of a failure monitor and control system (FMACS), and by
control-display integration to detect and minimize the
effect of failure.

To define a point of study departure, the F-4C and
the F-111A were evaluated as the guide for a functional and
fault mode model.  The F-111A functional capabilities were
assessed to more closely approximate those defi ed by the
IIPACS flight scenario.  The F-111A data base is AF 66-1
CONUS field data reduced and summarized by the Boeing,
Military Airplane Systems Division, Data Center.  These
data form a decision parameter in the man-machine trades,
the FMACS implementation, the controls and displays selec-
tion, and the priority of Degraded Mode Analysis perform-
ance.  Figure I-2 provides a ranking of F-111A failures and
air aborts at the subsystem level.  Figure I-3 provides a
lower indenture ranking of subsystem failures.  Figure I-4
provides failure and air abort rates per 1,000 flight hours
at the two-digit Work Unit Code (WUC) level.

FIGURE I-1. FIGHTER FAILURE SUMMARY

| | F-105D | F-104C | T-38A | F-5A | F-4C | F-111A |
|---|---|---|---|---|---|---|
| 1. Total Failures per 1,000 Flight Hours | 3,809 | 3,463 | 1,234 | 872 | 1,596 | 1,454 |
| 2. Percentage of Total Failures Discovered in Flight | 12% | 12% | 10% | 7% | 22% | 24% |
| 3. Distribution of Total Failures | | | | | | |
| a) Electronics | 28% | 22% | 5% | 14% | 28% | 30% |
| b) Instr. - Autopilot | 6% | 4% | 5% | 3% | 6% | 5% |
| c) Propulsion | 12% | 20% | 51% | 46% | 10% | 16% |
| d) Airframe - Utility | 54% | 54% | 39% | 37% | 56% | 49% |
| | (100%) | (100%) | (100%) | (100%) | (100%) | (100%) |
| 4. Distribution of Failures Discovered in Flight | | | | | | |
| a) Electronics | 60% | 47% | 33% | 34% | 63% | 66% |
| b) Instr. - Utility | 18% | 8% | 10% | 28% | 5% | 12% |
| c) Propulsion | 6% | 2% | 33% | 15% | 5% | 7% |
| d) Airframe - Utility | 16% | 43% | 24% | 23% | 27% | 15% |
| | (100%) | (100%) | (100%) | (100%) | (100%) | (100%) |
| 5. Percent Flight Undetected Failures | | | | | | |
| a) Electronics | 74% | 74% | 34% | 83% | 51% | 47% |
| b) Instr. - Utility | 64% | 76% | 80% | 35% | 82% | 42% |
| c) Propulsion | 94% | 99% | 94% | 98% | 89% | 90% |
| d) Airframe - Utility | 96% | 90% | 94% | 96% | 89% | 93% |

# FIGURE I-2. F-111A FAILURE AND AIR ABORT RANKING

| WUC | SUBSYSTEM NOMENCLATURE | FAILURE RANKING | | DISCOVERED AIR ABORTS |
| | | TOTAL | IN FLIGHT | RANKING |
| --- | --- | --- | --- | --- |
| 11 | AIRFRAME | 1 | - | 11 |
| 23 | TURBOJET POWER PLANT | 2 | 3 | 1 |
| 73 | INERTIAL BOMB-NAV | 3 | 1 | 5 |
| 75 | WEAPONS DELIVERY | 4 | 18 | 12 |
| 14 | FLIGHT CONTROL | 5 | 8 | 4 |
| 13 | LANDING GEAR | 6 | 14 | 8 |
| 52 | AUTOPILOT | 7 | 5 | 2 |
| 45 | HYDRAULIC & PNEUMATIC PWR. | 8 | 16 | 7 |
| 76 | ELECTRONIC COUNTERMEASURES | 9 | 2 | 16 |
| 51 | INSTRUMENTS | 10 | 4 | 10 |
| 44 | LIGHTING | 11 | 13 | 17 |
| 41 | AIR CONDITIONING & PRESS. | 12 | 11 | 6 |
| 46 | FUEL | 13 | 10 | 3 |
| 16 | ESCAPE CAPSULE | 14 | 17 | - |
| 71 | RADIO NAVIGATION | 15 | 6 | - |
| 63 | UHF COMMUNICATIONS | 16 | 9 | 15 |
| 42 | ELECTRICAL POWER | 17 | 20 | 14 |
| 64 | INTERPHONE | 18 | 7 | 13 |
| 61 | HF COMMUNICATIONS | 19 | 12 | - |
| 74 | SIGHTING & CONTROL | 20 | 15 | - |
| 47 | LIQUID OXYGEN | 21 | 19 | 18 |
| 49 | FIRE DETECT & EXTINGUISH | 22 | - | 9 |
| 86-97 | (MISCELLANEOUS) | 23 | 21 | - |
| 69 | COMMUNICATIONS EQUIPMENT GEN. | 24 | - | - |

## FIGURE 1-3. F-111A FAILURE RANKING

| SUBSYSTEM | FAILURES DETECTED IN FLIGHT | FAILURES |
|---|---|---|
| FUSELAGE | - | 1 |
| TERRAIN FOLLOWING RADAR (APQ110) | 1 | 2 |
| ENGINE AIR INLET SYSTEM | 14 | 3 |
| WEAPONS PYLON INSTALLATION | 0 | 3 |
| INERTIAL BOMB-NAV SYSTEM (ATQ20) | 3 | 5 |
| RADAR SET (APQ113) | 2 | 6 |
| WEAPONS RACK SYSTEM | 32 | 7 |
| FLIGHT CONTROL SLAT SYSTEM | 21 | 8 |
| WINGS | - | 9 |
| A/B FUEL SYSTEM | 25 | 10 |
| WHEELS & TIRES | 57 | 11 |
| ENGINE THROTTLE SYSTEM AIRFRAME | 16 | 12 |
| WEAPONS BAY SYSTEM | 62 | 13 |
| ENGINE INSTRUMENTATION SYSTEM | 19 | 14 |
| AUTO. FLIGHT CONTROL SYSTEM | 9 | 15 |
| FLAP SYSTEM | 24 | 16 |
| RADAR RECEIVING SET, ECM (APS-109) | 4 | 17 |
| UHF RECEIVER TRANSMITTER (ARC-109) | 7 | 18 |
| TACAN NAVIGATION SYSTEM | 5 | 19 |
| AIR CONDITIONING SYSTEM | 15 | 20 |
| ALTIMETER (APN-167) | 6 | 21 |
| UTILITY HYDRAULIC POWER SUPPLY | 34 | 22 |
| AUTOPILOT AIR DATA SYSTEM | 8 | 23 |
| PRIMARY HYDRAULIC POWER SUPPLY | 46 | 24 |
| EXTERIOR LIGHTING SYSTEM | 41 | 25 |
| CREW ESCAPE MODULE | 40 | 26 |
| BRAKE SYSTEM | 66 | 27 |
| AC POWER SUPPLY SYSTEM | 39 | 28 |
| FLAP/SLAT SYSTEM | 28 | 29 |
| FUEL INDICATING SYSTEM | 11 | 30 |
| MAIN FUEL SYSTEM | 22 | 31 |
| FLIGHT CONTROL ROLL CHANNEL | 49 | 32 |
| FLIGHT INSTRUMENTS GENERAL | 12 | 33 |

FIGURE I-3 (Contd).  F-111A FAILURE RANKING

| SUBSYSTEM | FAILURES DETECTED IN FLIGHT | FAILURES |
|---|---|---|
| HF RADIO COMPONENTS (ARC-112) | 17 | 34 |
| INTERCOMM. SET | 10 | 35 |
| AUTOMATIC FLIGHT INSTRUMENTS | 13 | 36 |
| WEAPONS BAY GUN SYSTEM | - | 37 |
| FLIGHT CONTROLS, GENERAL | 23 | 38 |
| ECM RECEIVER SET (ALR-23) | 18 | 39 |
| ENGINE OIL SYSTEM TUBING | 72 | 40 |
| ENGINE FRONT & REAR FAN CASE SECTION | - | 41 |
| ENGINE OIL SYSTEM | 33 | 42 |
| LIQUID OXYGEN SYSTEM | 31 | 43 |
| FUEL SYSTEM INTEGRAL TANKS | 70 | 44 |
| ENGINE TURBINE SECTION | - | 45 |
| FLIGHT CONTROL PITCH CHANNEL | 52 | 46 |
| AIR-GROUND IFF (APX-64V) | 20 | 47 |
| INTERIOR LIGHTING SYSTEM | 35 | 48 |
| DC POWER SUPPLY | 64 | 49 |
| ESCAPE CAPSULE STABILIZATION GLOVE | 4ɔ | ſ |
| AUXILIARY INSTRUMENT SYSTEM | 27 | 5ᵤ |
| WEAPONS CONTROL SYSTEM | 55 | 52 |
| AIR PRESSURIZATION SYSTEM | 26 | 53 |
| LIGHTING-WARNING & CAUTION COMPONENTS | 42 | 54 |
| ENGINE STARTING SYSTEM | 78 | 55 |
| SIGHTING & CONTROL SYSTEMS | 29 | 56 |
| LANDING GEAR DOORS | 54 | 57 |
| HF ANTENNA COUPLER GROUP | 36 | 58 |
| ESCAPE CAPSULE EMERGENCY SYSTEM | 65 | 59 |
| WING SWEEP SYSTEM | 50 | 60 |
| LANDING GEAR GENERAL | 44 | 61 |
| MAIN LANDING GEAR | 67 | 62 |
| ENGINE AFTERBURNER COMBUSTION SECTION | - | 63 |
| ECM INTERFERENCE BLANKER | 30 | 64 |
| SPEED BRAKE | 47 | 65 |
| NOSE GEAR | 72 | 66 |

FIGURE I-3 (Contd). F-111A FAILURE RANKING

| SUBSYSTEM | FAILURES DETECTED IN FLIGHT | FAILURES |
|---|---|---|
| ENGINE AFTERBURNER NOZZLE SECTION | 73 | 67 |
| NOSEWHEEL STEERING | 56 | 68 |
| FLIGHT CONTROL YAW CHANNEL | 74 | 69 |
| UHF/ADF (ARA-50) | 48 | 70 |
| ENGINE FUEL SUPPLY SYSTEM | 69 | 71 |
| ENGINE FAN-INLET SECTION | - | 72 |
| FIRE DETECTION SYSTEM | - | 73 |
| ENGINE IGNITION SYSTEM | 68 | 74 |
| PNEUMATIC-POWER SUPPLY | - | 75 |
| COUNTERMEASURES DISPENSING SET (ALE-28) | 37 | 76 |
| INSTRUMENT SYSTEM, INSTRUMENTS GENERAL | 38 | 77 |
| ENGINE MOUNT INSTALLATION | - | 78 |
| REFUEL/DEFUEL SYSTEM | 51 | 79 |
| ENGINE TURBINE EXHAUST SYSTEM | - | 80 |
| ENGINE COMBUSTION CHAMBER SECTION | - | 81 |
| ELECTRICAL POWER SUPPLY SYSTEM | 61 | 82 |
| ENGINE MAIN GEAR BOX | 75 | 83 |
| ENGINE (COMPLETE) (TE30) | 76 | 84 |
| ILAS (ARN-58A) | 43 | 85 |
| ARRESTING HOOK SYSTEM | 53 | 88 |
| PITOT-STATIC SYSTEM | 53 | 88 |
| SURFACE ICE CONTROL & EMERGENCY RAM AIR | 77 | 89 |
| FIRE EXTINGUISHING SYSTEM | - | 90 |
| ENGINE ANTI-ICING AIR SYSTEM | - | 91 |
| ENGINE COMPRESSOR PRESSURE RATIO SYS. | - | 92 |
| ENGINE AFTERBURNER DIFFUSER SECTION | - | 93 |
| ENGINE DUCTING SYSTEM | - | 94 |
| ENGINE DIFFUSER SECTION | - | 95 |
| LIGHTING CONTROLS | 58 | 96 |
| FUEL SYSTEM VENT & PRESSURE SYSTEM | 59 | 97 |
| TAIL BUMPER SYSTEM | - | 98 |
| GENERAL PERSONNEL EQUIPMENT | 71 | 99 |
| COUNTERMEASURE SET (ALQ-41) | - | 100 |
| GUN CAMERA SYSTEM (KS-27C) | - | 101 |

## FIGURE I-4.    F-111 FAILURE RATE SUMMARY

| WUC | SUBSYSTEM NOMENCLATURE | TOTAL FAILURES PER 1,000 FLT HR | ATTACHING POINT FAILURES PER 1,000 FLT HR | IN FLIGHT FAILURES PER 1,000 FLT HR | AIR ABORTS PER 1,000 FLT HR |
|---|---|---|---|---|---|
| 11 | AIRFRAME | 296.0 | 264.0 | - | 0.1364 |
| 13 | LANDING GEAR | 63.0 | 10.3 | 3.35 | 0.2666 |
| 14 | FLIGHT CONTROL | 120.6 | 38.4 | 14.7 | 0.775 |
| 16 | ESCAPE CAPSULE | 24.7 | 12.8 | 2.2 | - |
| 23 | TURBOJET PWR PLT | 235.0 | 80.7 | 22.9 | 1.4198 |
| 41 | AIR COND & PRESS | 26.0 | 8.2 | 10.2 | 0.3162 |
| 42 | ELECTRICAL POWER | 20.4 | 8.9 | 1.6 | 0.0992 |
| 44 | LIGHTING | 26.9 | 12.8 | 4.1 | 0.0248 |
| 45 | HYDRAULIC & PNEU- MATIC POWER | 37.6 | 22.4 | 2.3 | 0.2914 |
| 46 | FUEL | 25.4 | 11.3 | 10.5 | 0.6634 |
| 47 | LIQUID OXYGEN | 6.9 | 1.4 | 1.7 | 0.0248 |
| 49 | FIRE DETECT & EXTINGUISH | 2.9 | 2.3 | - | 0.1612 |
| 51 | INSTRUMENTS | 29.7 | 3.6 | 20.9 | 0.1612 |
| 52 | AUTOPILOT | 41.6 | 2.2 | 20.0 | 0.8494 |
| 61 | HF COMMUNICATIONS | 14.6 | 3.2 | 7.6 | 0.0 |
| 63 | UHF COMMUNICATIONS | 22.0 | 6.2 | 10.8 | 0.0558 |
| 64 | INTERPHONE | 17.3 | 3.3 | 14.7 | 0.1054 |
| 69 | COMMUNICATIONS EQPT GENERAL | 0.6 | 0.4 | - | - |
| 71 | RADIO NAVIGATION | 24.6 | 3.1 | 16.6 | 0.0 |
| 73 | INERTIAL BOMB-NAV | 213.0 | 17.2 | 156.6 | 0.558 |
| 74 | SIGHTING & CONTROL | 13.6 | 4.2 | 2.4 | 0.0 |
| 75 | WEAPONS DELIVERY | 155.0 | 75.7 | 2.2 | 0.1302 |
| 76 | ELECTRONIC COUNTER- MEASURES | 36.0 | 2.4 | 24.8 | 0.0558 |
| 86- 97 | MISCELLANEOUS | 0.8 | 0.6 | 0.07 | - |
| | AIRCRAFT TOTALS | 1455.0 | 596.0 | 350.0 | 6.1 |

Two-digit WUC level defines major subsystems, such as Airframe or HF Communications. Three-digit WUC defines the primary components within the subsystem, such as HF antenna coupler. The succeeding lower level, four-digit breakdown identifies subassemblies, and five-digit WUC defines the lowest level piece-part in failure recording system.

Four- and five-digit WUC failure data are closely tied to a specific design, manufacturer, and piece-part application and, thus, provide too fine a granularity for projecting advanced concepts. Therefore, the more general-ized two- and three-digit summary data are judged to be better suited to this study. It is recognized that summary failure data at the major subsystem levels may introduce some failure rate error; however, since the data are used for relative failure trends and ranking, the effect of finite errors tend to cancel.

Note in Figure I-2 that an apparent incongruity exists, the subsystem "Airframe" indicates negligible failures discovered in flight while "Airframe" ranks 11 in subsystems causing air abort. This is attributable to summarizing and rounding-off the "Total" and "In flight" failures at the two- and three-digit WUC while abort failures are verified by the data system to the lowest identifiable component.

The Boeing data processing system reorders AF 66-1 data to provide reliability data as one output. The reliability data are selective failure sorts performed by computer correlation.

An excerpt from D6-57166-1TN, "Boeing AFM66-1 Electronic Data Processing Programs," provides the relia-bility failure definition:

"2.7    Reliability Final Printout

The Reliability Final printout is the standard report which is inserted directly into the detailed volumes of the field experience document. Subsystem and component reliability data are compiled directly by automatic processing machines. The first five volumes of the printout contain detailed reliability data at the five digit component level. Volume VI is a summary containing $\Sigma$ failure rate information at the two, three and four digit subsystem levels for all the systems on the aircraft.

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"2.7.1  Application of Failure Data

Some minor limitations should be recognized when
applying failure rate data at other than the
component (5 digit) level from this printout.
The breakdown of the Work Unit Code (as explained
in the introduction) identifies the system, sub-
system and component.  The actual reporting of a
malfunction may occur at any of the levels.
Depending on the circumstances a malfunction may be
called out against a five-digit code component, a
four-digit group of components, a three-digit sub-
system  or a two-digit system.

"The discretion permitted maintenance personnel in
reporting malfunctions may lead to possible duplicate
recording of failures.  The level at which a mal-
function is reported could depend on when it is
noticed.  If the trouble cannot be immediately
assessed at the proper component level, it may be
assigned to a higher level work unit code for
troubleshooting.  Later the malfunction, after
investigation, may be diagnosed to a specific
component and reported on another separate form.
Thus, a single malfunction can be counted as a
failure more than once.

"The failure of a component within a subsystem does
not means that the subsystem failed as often.  It
is possible that a component could fail and yet
not cause subsystem failure or some component
failures could be secondary failures.

"Duplication of failure rates can be avoided by using
the five digit component level data.  The user is
urged to apply the five-digit level numbers in his
computations instead of the four, three, or two
digit summaries when the most precise results are
desired.

"2.9.2  Definition of Terms

Failure:
As defined in this document, a failure has occurred
if a unit of work, other than regular servicing, is
required to restore an item to satisfactory condi-
tion.  Failure count was obtained from AFTO Form
349, subject to the following limitations:

1.  Units of work data having the following How
    Malfunctioned Codes were omitted:

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138 - Engine Removed - Engine Modification

141 - Engine Removed - Overseas Preparation

793 - No Defect - TCTO Kits Received by Base Supply

797 - No Defect - Technical Order Not Applicable -
Equipment to be Replaced, Modified or Not
Installed

799 - No Defect

800 - No Defect - Component Removed and/or
Reinstalled to Facilitate Other Maintenance

801 - No Defect - Technical Order Compliance

802 - No Defect - Partial Technical Order Compliance

803 - No Defect - Removed for Time Change

804 - No Defect - Removed for Scheduled Maintenance

811 - No Defect - Class I Modification

812 - No Defect - Associated Equipment Malfunction

"2.(a)  If data were taken from an On-Equipment Form,
failures were defined by the following "Action
Taken" Codes:

    F - Repair
    G - Repair and/or Replacement of Attaching Parts
    K - Calibrated - Adjustment Required
    I - Adjust
    S - Remove and Reinstall
    V - Clean
    Z - Corrosion Treatment

"2.(b)  If data were taken from a Shop Form, failures
were defined by "Action Taken" Codes:

    1 - Bench Check - NRTS (Not Repairable This
        Station) - Repair Not Authorized
    2 - Bench Checked - NRTS - Lack of Equipment,
        Tools or Facilities
    3 - Bench Checked - NRTS - Lack of Technical
        Skills
    4 - Bench Checked - NRTS - Lack of Parts
    5 - Bench Checked - NRTS - Shop Backlog
    6 - Bench Checked - NRTS - Lack of Technical
        Data

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```
              7 - Bench Checked - NRTS - Excess to Base
                  Requirements
              8 - Bench Checked - Returned to Depot Facility
                  by Direction of System Manager or Item
                  Manager
              9 - Bench Checked - Condemned
              A - Bench Checked and Repaired
              D - Bench Checked - Transferred to Another Base
              F - Repair
              G - Repair and/or Replacement of Attaching Parts
              K - Calibrated - Adjustment Required
              L - Adjust
              V - Clean
```

"Failure Mode:
 The mode of failure is defined by the "How Malfunctioned"
 Code.

"When Discovered Tabulation:
 Certain "When Discovered" codes have been combined, as listed
 below, to define the time at which a discrepancy was
 discovered.

```
         Before Flight (BF)
            A - Before Flight, Abort; Aircrew
            B - Before Flight, No Abort; Aircrew
            G - Ground Alert, Not Degraded
            N - Ground Alert, Degraded

         In Flight (IF)
            C - In Flight, Abort
            D - In Flight, No Abort
            P - Functional Check Flight

         Between Flights (BTF)
            E - After Flight - Aircrew
            F - Between Flights - Ground Crew

         Inspections (INS)
            All "When Discovered" Codes not listed above.
```

"Aborts:
 The following "When Discovered" codes define aborts:

```
         A - Before Flight; Abort, Aircrew
             Code "A" represents the cancellation of a
             scheduled flight prior to takeoff due to
             unsatisfactory equipment operation.
         C - InFlight; Abort
             Code "C" represents the termination of a flignt
             prior to successful completion of the assigned
             mission because of unsatisfactory equipment
             operation.
```

"The abort data was screened to ensure that only one abort
(flight or ground) was charged per scheduled mission and
to determine which component was the prime cause of the
aircraft abort.

"NRTS per 1,000 Unit Flight Hours:
Components which require off-base maintenance ("Not Repair-
able This Station") are indicated by the following
Action Taken Codes:

1 - Bench Checked - NRTS - Repair Not Authorized
2 - Bench Checked - NRTS - Lack of Equipment, Tools
    or Facilities
3 - Bench Checked - NRTS - Lack of Technical Skills
4 - Bench Checked - NRTS - Lack of Parts
5 - Bench Checked - NRTS - Shop Backlog
6 - Bench Checked - NRTS - Lack of Technical Data
7 - Bench Checked - NRTS - Excess to Base Requirements
8 - Bench Checked - Directed Return to Depot Facility

"Condemned per 1,000 Flight Hours;
Action Taken Code 9 (Bench Checked - Condemned)
defines a condemned component.

"QPA (Quantity per Aircraft):
The Quantity Per Aircraft indicates the total number of
a particular component installed on one aircraft.

"WUC:
The WUC consists of five characters and identifies
each aircraft system and component as defined in
AFM66-1, paragraph 9-12.  A sample printout with a
brief explanation of the headings is . . ."

The foregoing Boeing reliability-failure definition is
used in processing AFM66-1 data and provides the data base
for Figures I-2, I-3 and I-4.

2.   Reliability Estimate IIPACS

In addition to providing historical indication of sub-
system failure frequency for prioritizing degraded mode
analyses, an estimate of the mission reliability of the
resulting IIPACS is provided.  These data consider the
results of the degraded mode analyses, at the subsystem
level, and project 1975-85 avionics reliability capability.

Required aircraft functions can be described without
considering the physical mechanisms available or required
to provide the functions.  Reliability requirements can be
similarly dictated; however, reliability assessment cannot.
When determining the necessity for backup or alternate
functional capability based on reliability considerations,

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
the reliability parameter is determined by direct relation to (or a projection from) a known design and technology base.

Reliability estimates of hardware items to provide the functional requirements necessary for mission accomplishment are given in Figure I-5. These estimates reflect anticipated reliability capability for a 1975-85 time frame based on a reliability survey of electronic manufacturers and reliability growth factors applied to current design. (Historically, electronic reliability has been doubling approximately every 5 years.)

The equipment Mean Time Between Failures (MTBFs) listed are projected from current electronic technology and do not reflect major breakthrough or transition to alternate non-electronic techniques.

Based on the mission phases and flight scenario, defined for this aircraft, a mission reliability analysis of that hardware required to provide necessary mission and flight functions defined by the Degraded Mode Analyses is graphically presented on a mission phase basis in Figures I-6, -7, and -8. The mission reliability analysis identifies mission-essential redundant equipment, equipment that can provide functional backup, and equipment that provide safety of flight functions. It is to be noted that in addition to the electronic equipment necessary for integrated information presentation and control, the diagram also identifies all other major subsystems. The non-electronic subsystems are presented for information, but they are excluded from the mission reliability calculations. In Figures I-6, -7 and -8, this represents all subsystems to the right of the computer complex. Those dependent monitoring subsystems, such as ITEMS and FMAC, are considered to be contained within the prime hardware item and the computer complex. These subsystems, therefore, are not specifically identified in the reliability analysis.

Analysis symbols used are presented below with an explanation of their meaning in the diagrams:

| SYMBOL | IDENTIFICATION |
|---|---|
| | Mission-phase-essential item |
| | Safety of flight item |
| | Backup item, not normally energized this phase |
| | Mission-phase-essential item also providing backup |
| | Mission-phase-essential item being backed up (arrow head indicates unilateral backup)* |
| | 2 items in redundancy for increased functional reliability |
| | 2 items in redundancy. 1 must work for safety-of-flight (either one) |

*Example:
MMR can provide functional backup for TACAN but the converse is not true.

Based on each item's projected MTBF, the mission phase times and degraded mode use, mission reliability estimates of the I1PACS avionics are calculated to be:

| Mission Phase | Duration (Minutes) | Avionic Reliability |
|---|---|---|
| Start | 5 | 0.99988 |
| Takeoff | 5 | 0.99970 |
| Climb | 30 | 0.99078 |
| Rendezvous | 10 | 0.99948 |
| Cruise | 60 | 0.98887 |
| Loiter | 40 | 0.99324 |
| Air-Air Combat | 20 | 0.99639 |
| Refuel | 20 | 0.99764 |
| Penetrate | 20 | 0.99539 |
| Air-Ground Combat | 50 | 0.98725 |
| Approach & Land | 10 | 0.99956 |
| Mission Total | 270 | 0.9493 |

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# FIGURE I-5

## PROJECTED SUBSYSTEM RELIABILITY

| SUBSYSTEM EQUIPMENT | 1975-1985 Flight MTBF (Hrs) |
|---|---|
| **FIRE CONTROL SUBSYSTEM** | |
| Multimode Radar | 600 |
| Low Light Level TV | 1,000 |
| Forward Looking Infrared | 500 |
| LASER Ranger | 1,500 |
| Bomb Damage Assessment | 650 |
| **NAVIGATION SUBSYSTEM** | |
| Inertial Platform | 2,000 (ea) |
| Heading Attitude Ref System | 3,000 |
| Satellite Navigation System | 2,500 |
| Instrument Landing System | 5,000 |
| Radio Altimeter | 4,000 |
| TACAN | 3,000 |
| **COMMUNICATION & IDENTIFICATION** | |
| Collision Avoidance | 2,000 |
| HF Radio | 2,000 |
| SHF Spread Spectrum | 1,000 (ea) |
| Intercom | 4,000 |
| IFF Air-Air | 1,200 |
| IFF Air-Ground | 4,000 |
| **PENETRATION AIDS** | |
| Radar Home and Warn | 1,500 |
| ECM Jammer | 1,000 |
| Infrared Warning | 500 |
| Infrared Jammer | 1,000 |
| Chaff-Flare Dispenser | 500 |
| **CONTROLS AND DISPLAYS** | |
| Head-Up Display | 2,500 |
| Vertical Situation Display | 2,500 |
| Horizontal Situation | 1,000 |
| Multipresentation Display | 1,000 |
| Integrated Keyboard | 5,000 |
| **CENTRAL COMPUTER** | |
| Computer | 4,000 |

| MAJOR SUBSYSTEM | EQUIPMENT | MISSION PHASE → | START | TAKE-OFF | CLIMB | RENDEZVOUS |
|---|---|---|---|---|---|---|
| FIRE CONTROL SUBSYSTEM | MULTI-MODE RADAR | | | ○ | ○ | ○ |
| | LLLTV | | | | | |
| | FLIR | | | ○ | | |
| | LASER RANGER | | | | | |
| | D B A | | | | | |
| NAVIGATION SUBSYSTEM | INERTIAL PLATFORM | | ○○ | ◐○ | ◐○ | ◐○ |
| | H A R S | | | | | |
| | SATELLITE NAV | | ○ | ○ | ○ | |
| | I L S | | | | | |
| | RADIO ALTIMETER | | | ○ | | |
| | TACAN | | | ● | ● | ● |
| COMMUNICATION AND IDENTIFICATION | COLLISION AVOIDANCE | | | ● | ● | ● |
| | HF TRANSCEIVER | | | | | |
| | SHF SPREAD SPECTRUM | | ○○ | ○○ | ○○ | ○○ |
| | INTERCOMM | | ○ | ○ | ○ | ○ |
| | IFF AIR-AIR | | | | | ○○ |
| | IFF AIR-GROUND | | | ○ | ○ | ○ |
| PENETRATION AIDS | CHAFF-FLARE DISPENSER | | | | | |
| | R H A W | | | | | |
| | ECM JAMMER | | | | | |
| | IR WARNING | | | | | |
| | IR JAMMER | | | | | |
| CONTROLS AND DISPLAYS | H U D | | | | | |
| | V S D | | ○ | ● | ● | ● |
| | H S D | | | ● | ● | ● |
| | M P D | | ○○○○○ | ○○○○○ | ○○○○○ | ○○○○○ |
| | INTEGRATED KEYBOARD | | ○ | ● | ● | ● |
| CENTRAL COMPUTER | COMPUTER | | ● | ● | ● | ● |
| STORES MGMT | STORES LOGIC | | | | | |
| PROPULSION SYSTEM | ENGINES | | ● | ● | ● | ● |
| POWER SYSTEM | ELEC-HYDROL. | | ● | ● | ● | ● |
| FLIGHT CONTROL | A F C S | | ● | ● | ● | ● |
| FUEL SYSTEM | FUEL | | ○ | ● | ● | ● |
| ENVIRON. CONTROL | ENVIRON CONTROL | | ○ | ○ | ● | ● |
| AIRFRAME | AIRFRAME | | | ● | ● | ● |
| LANDING GEAR | GEAR | | ○ | ● | | |
| ESCAPE SUBSYSTEM | CAPSULE | | ○ | | | ○ |
| MISC UTILITIES | UTILITIES | | ● | ○ | ○ | ○ |
| LIGHTING SUBSYSTEM | LIGHTS | | ○ | ○ | ○ | |

SAFETY OF FLIGHT ITEM ●

Figure I-6. Mission Reliability Analysis

| MAJOR SUBSYSTEM | EQUIPMENT \ MISSION PHASE | CRUISE | LOITER | AIR-AIR COMBAT | REFUEL |
|---|---|---|---|---|---|
| FIRE CONTROL SUBSYSTEM | MULTI-MODE RADAR | | | | |
| | LLLTV | | | | |
| | FLIR | | | | |
| | LASER RANGER | | | | |
| | B D A | | | | |
| NAVIGATION SUBSYSTEM | INERTIAL PLATFORM | | | | |
| | H A R S | | | | |
| | SATELLITE NAV | | | | |
| | I L S | | | | |
| | RADIO ALTIMETER | | | | |
| | TACAN | | | | |
| COMMUNICATION AND IDENTIFICATION | COLL'SION AVOIDANCE | | | | |
| | HF TRANSCEIVER | | | | |
| | SHF SPREAD SPECTRUM | | | | |
| | INTERCOMM | | | | |
| | IFF AIR-AIR | | | | |
| | IFF AIR-GROUND | | | | |
| PENETRATION AIDS | CHAFF-FLARE DISPENSER | | | | |
| | R H A W | | | | |
| | ECM JAMMER | | | | |
| | IR WARNING | | | | |
| | IR JAMMER | | | | |
| CONTROLS AND DISPLAYS | H U D | | | | |
| | V S D | | | | |
| | H S D | | | | |
| | M P D | | | | |
| | INTEGRATED KEYBOARD | | | | |
| CENTRAL COMPUTER | COMPUTER | | | | |
| STORES MGMT | STORES LOGIC | | | | |
| PROPULSION SYSTEM | ENGINES | | | | |
| POWER SYSTEM | ELEC-HYDROL. | | | | |
| FLIGHT CONTROL | A F C S | | | | |
| FUEL SYSTEM | FUEL | | | | |
| ENVIRON. CONTROL | ENVIRON. CONTROL | | | | |
| AIRFRAME | AIRFRAME | | | | |
| LANDING GEAR | GEAR | | | | |
| ESCAPE SUBSYSTEM | CAPSULE | | | | |
| MISC UTILITIES | UTILITIES | | | | |
| LIGHTING SUBSYSTEM | LIGHTS | | | | |

SAFETY OF FLIGHT ITEM ●

Figure I-7. Mission Reliability Analysis

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Figure 1-8. Mission Reliability Analysis

| MAJOR SUBSYSTEM | EQUIPMENT | PENETRATE | AIR-GROUND COMBAT | LAND |
|---|---|---|---|---|
| FIRE CONTROL SUBSYSTEM | MULTI-MODE RADAR | | | |
| | LLLTV | | | |
| | FLIR | | | |
| | LASER RANGER | | | |
| | B D A | | | |
| NAVIGATION SUBSYSTEM | INERTIAL PLATFORM | | | |
| | H A R S | | | |
| | SATELLITE NAV | | | |
| | I L S | | | |
| | RADIO ALTIMETER | | | |
| | TACAN | | | |
| COMMUNICATION AND IDENTIFICATION | COLLISION AVOIDANCE | | | |
| | HF TRANSCEIVER | | | |
| | SHF SPREAD SPECTRUM | | | |
| | INTERCOMM | | | |
| | IFF AIR-AIR | | | |
| | IFF AIR-GROUND | | | |
| PENETRATION AIDS | CHAFF-FLARE DISPENSER | | | |
| | R H A W | | | |
| | ECM JAMMER | | | |
| | IR WARNING | | | |
| | IR JAMMER | | | |
| CONTROLS AND DISPLAYS | H U D | | | |
| | V S D | | | |
| | H S D | | | |
| | M P D | | | |
| | INTEGRATED KEYBOARD | | | |
| CENTRAL COMPUTER | COMPUTER | | | |
| STORES MGMT | STORES LOGIC | | | |
| PROPULSION SYSTEM | ENGINES | | | |
| POWER SYSTEM | ELEC-HYDROL. | | | |
| FLIGHT CONTROL | A F C S | | | |
| FUEL SYSTEM | FUEL | | | |
| ENVIRON. CONTROL | ENVIRON CONTROL | | | |
| AIRFRAME | AIRFRAME | | | |
| LANDING GEAR | GEAR | | | |
| ESCAPE SUBSYSTEM | CAPSULE | | | |
| MISC UTILITIES | UTILITIES | | | |
| LIGHTING SUBSYSTEM | LIGHTS | | | |

SAFETY OF FLIGHT ITEM ●

APPENDIX II

LIST OF TRIPS

| Name | Facility | Contact | Subject | Date |
|------|----------|---------|---------|------|
| J. Bloomfield<br>D. Lawrence | Control Data Corp.<br>Minneapolis, Minn. | S. J. Skiba, Program<br>Mgr. | Industry Survey - Adv.<br>Airborne Systems | 7/20 |
| J. Bloomfield<br>D. Lawrence<br>J. Premselaar | UNIVAC<br>Minneapolis, Minn. | W. D. Miller, Mgr.,<br>AF Avionics<br>J. R. Erhardt, Sys.<br>Design Engr.<br>E. C. Joseph, Staff<br>Scientist<br>F. B. Lowe, Dir. of<br>Marketing | Industry Survey - Adv.<br>Airborne Systems | 7/20 |
| J. Bloomfield<br>D. Lawrence<br>J. Premselaar | FDL, Dayton | R. D. Alberts - AVL<br>H. W. Basham - FDCL<br>R. E. Burain - Bunker<br>RAMO<br>R. R. Davis - FDCR<br>R. Green - FDCL<br>R. Guth - FDCL<br>J. H. Kearn - FDCR<br>Lt.Col. Knox - FDCR<br>Lt. N. A. Kopchick -<br>FDCR<br>A. J. Longiaru- FDCS<br>J. Mysing - AVWC<br>D. Schroll - ASNMC-10<br>Lt.Col. Studabaker-<br>AVL<br>R. S. Vokits-ASNMC-10<br>Lt. J. K. Warner -<br>ASNMC-10 | IIPACS-1 briefing | 7/21 |
| D. Lawrence<br>J. Premselaar | Loral Electronic<br>Systems, The Bronx,<br>N.Y. | L. Levene, Dep. Chief<br>Engr., Electronic<br>Warfare | Industry Survey - Radar<br>Homing Warning | 7/22 |

| Name | Facility | Contact | Subject | Date |
|------|----------|---------|---------|------|
| | | A. I. Paley, Product Line Mgr., Adv. Info. & Display Systems | | |
| D. Lawrence J. Premselaar | Bendix Teterboro, N. J. | J. Koltz, Sales, Special Products | Obtain information on armament control systems concepts | 7/22 |
| D. Lawrence J. Premselaar | NADC-Johnsville | J. Caswell - AMRD<br>R. Crosbie - AMRD<br>R. Decker - SAED<br>W. Miller - SAED<br>J. Nelson - LSEH-1<br>W. Ogden - SAED<br>H. Piranian - SAED | IIPACS-1 briefing | 7/23 |
| D. Lawrence J. Premselaar | HIPAAS Ad Hoc Comm. Washington, D. C. | K. Guttman - AIR-330C NAVAIR<br>Col. A. McBarron - AIR-03M NAVAIR<br>J. Plunkert - AIR-3032E NAVAIR<br>W. Sparrow - AIR-3032G NAVAIR | IIPACS-1 presentation | 7/24 |
| D. Lawrence J. Premselaar | Crew Systems Div. Washington, D. C. | Capt. W. E. Nowers, Dir.<br>CDR R. J. Hartranft | IIPACS-1 presentation | 7/24 |
| D. Lawrence J. Prerselaar | Avionics Division Washington, D. C. | J. Wolin, Head, Integ. Instrumentation & Display Section | IIPACS-1 presentation | 7/24 |
| J. Hatcher D. Lawrence J. Premselaar | Westinghouse Elec. Co., Defense & Space Ctr., Baltimore | R. Sima, B-57 LLLTV Prog. Mgr.<br>D. Boybns, EVS Systems<br>J. Holthaus, Crewstations Hdw. Dev. & Mockup<br>T. Stinnett, Cockpit Display Analysis | Industry Survey - State of art - LLLTV, FLIR, LASER, Auto. Tgt. Recognition & Display Design Concepts | 7/27 |

| Name | Facility | Contact | Subject | Date |
|---|---|---|---|---|
| J. Hatcher<br>D. Lawrence<br>J. Premselaar | Raytheon Co.<br>Bedford, Mass. | Dr. G. Tisdale, Mgr., Information Tech.<br>R. Price, Avionics Tactical Fighters<br>D. Mathews, Avionics, Bombers<br>W. Vasel, Design Study, Missiles<br>P. Mender, Mktg. Mgr., Avionics Systems | Industry Survey - Phased Array Radars for Adv. Fighters | 7/28 |
| J. Hatcher | Collins Radio Cedar Rapids, Ia. | D. Valentine, Asst. Proj. Mgr., CNI<br>J. Andrews, Staff Engr., Sat. Comm.<br>K. Black, Staff Engr, UHF<br>R. Vanderhamm, Relia-bility<br>K. Rutherford, Staff Engr., IFF<br>D. Schmidt, Flt. Inst./ Displays<br>C. Fenwick, Staff Engr., Integrated Keyboard Controls<br>H. Schweighofer, Staff Engr., CRT Adv. Design | Industry Survey - State of art - Adv. Comm/Ident Systems & Flight Instruments | 7/29 |
| D. Lawrence<br>J. Premselaar | Eglin AFB, Fla. | R. Compton - ADLY<br>M. Flyn - ADLY | Information relative to weapon system management | 7/29 |

| Name | Facility | Contact | Subject | Date |
|---|---|---|---|---|
| J. Bloomfield<br>J. Hatcher<br>D. Lawrence<br>J. Premselaar | Texas Instruments<br>Dallas, Texas | B. List, Dr., Systems & Info Science Lab.<br>C. Brcadnay, Avionics Systems<br>G. Bandy, Adv. Radars<br>J. Seveorin, Space Sys.<br>C. xon, Adv. FLIR<br>B. Bocha, Equip. Gp., CNI | Industry survey - Adv. radars, FLIRs and airborne computers | 7/30 |
| J. Hatcher<br>D. Lawrence<br>J. Premselaar | Litton Systems, Inc Guidance & Control Sys., Woodland Hills, Calif. | J. Murphy, Augmented Sys. Adv. Prog. Mgr. | Industry survey - Adv. Navigation Systems | 7/31 |
| J. Hatcher<br>D. Lawrence<br>J. Premselaar | Hughes Aircraft Culver City, Calif. | L. Seeberger, Mgr., Display Sys. Lab.<br>W. Carel, H. F., & Func. Design<br>J. Heard, Systems Design | Industry survey- Adv. Control/Display Concepts | 7/31 |

APPENDIX III

NAVIGATION SYSTEMS

1.    INTRODUCTION

This section describes the basic navigation system
for 1980 all-weather tactical combat aircraft.  The system
selection is based on detail performance data for those
postulated theater-of-operation systems in the 1980 inven-
tory.  Integration of these subsystems for the tactical
fighter aircraft by means of the computer software is a
most pressing consideration.

2.    SYSTEM DESCRIPTION

a.  Operational Description

The classes of navigation systems available
for tactical fighter aircraft are comprised of many sensors
as shown in Figure III-1.  A complete system using Figure
III-1 sensors is shown in the composite diagram on Figure
III-2.  Hyperbolic systems are considered but not included
in aircraft equipment lists.  Hyperbolic systems would be
included if expected trend toward satellite navigation does
not materialize.

The following discussion will be limited to the
navigation system required for precision navigation and
weapon delivery:  (1) Free Inertial/Doppler Inertial,
(2) Direct Ranging, (3) Hyperbolic, and (4) Satellite.

3.    FREE INERTIAL/DOPPLER-INERTIAL NAVIGATION

One of the simplest forms of navigation systems is
the free inertial system.  A block diagram of the system is
shown in Figure III-3.  The system provides basic navigation
data to the flight crew.  The accuracy of the information
depends on the quality of the inertial unit.  This type
system, however, exhibits a basic error growth rate shown
in Figure III-4.  (Note the 84-minute Schuler oscillation).
The average error growth rate of such a system is on the
order of 0.1 to 0.5 nmi per hour CEP.  The instantaneous
velocity error may be as much as 1 foot per second (1 sigma
each axis) because of the Schuler oscillation.  Thus, both
the navigational accuracy and the velocity error transferred
into a weapon delivery system are a function of both the
mission time and the time within the Schuler oscillation.
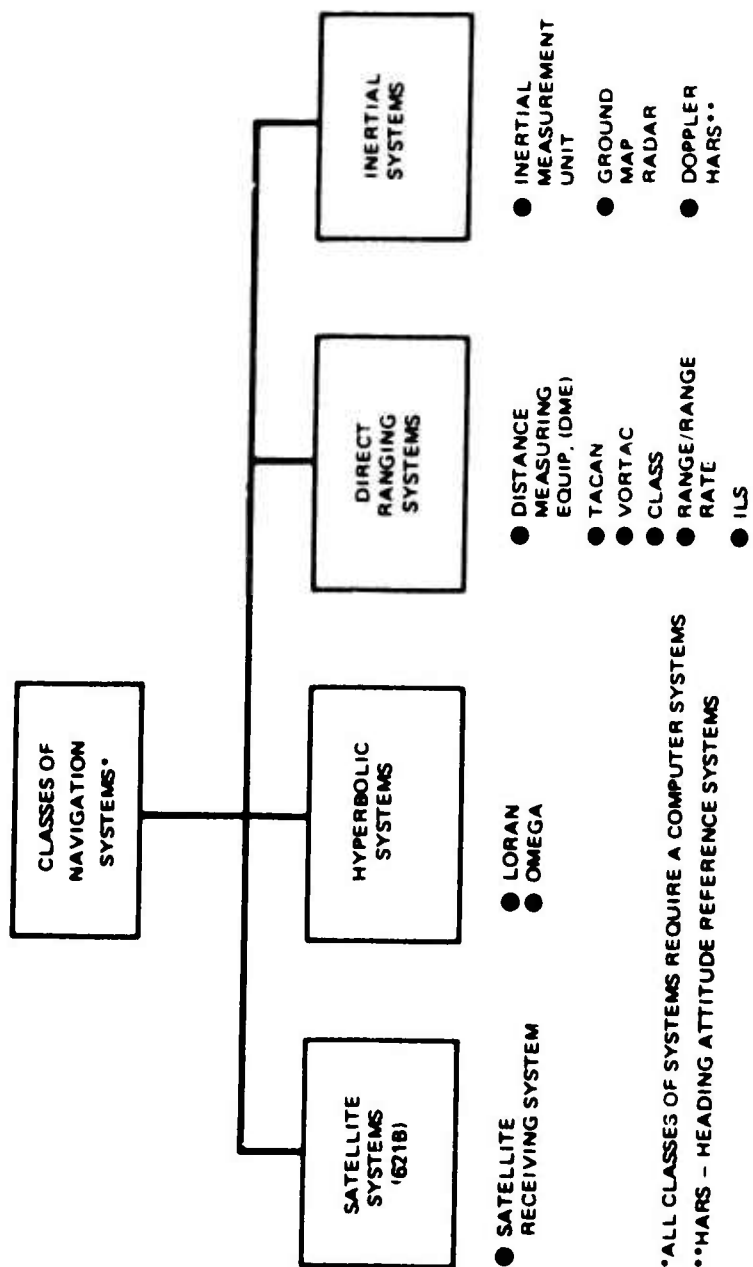
Figure III-1.  Classes of Navigation Systems Available for Tactical Combat Aircraft

181
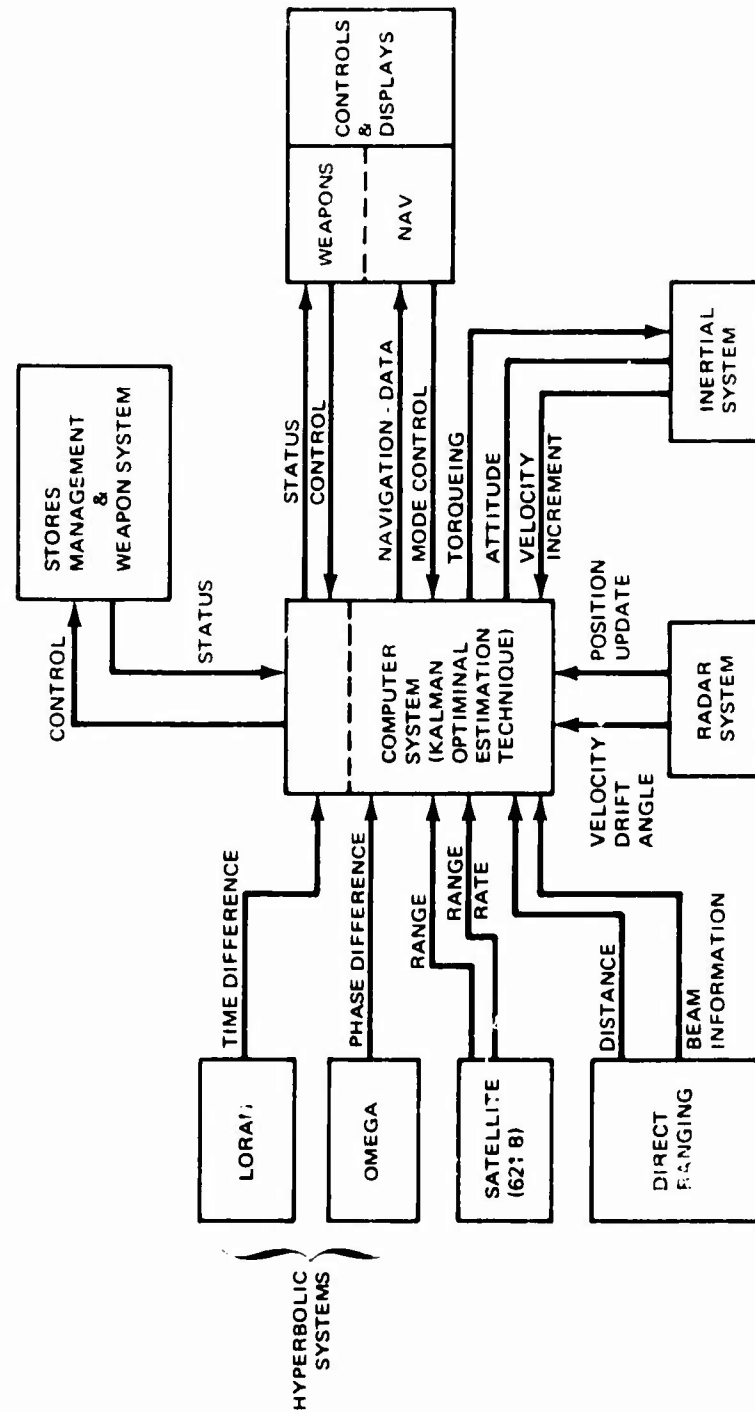
Figure III-2. Composite Navigation Systems Block Function Diagram

182
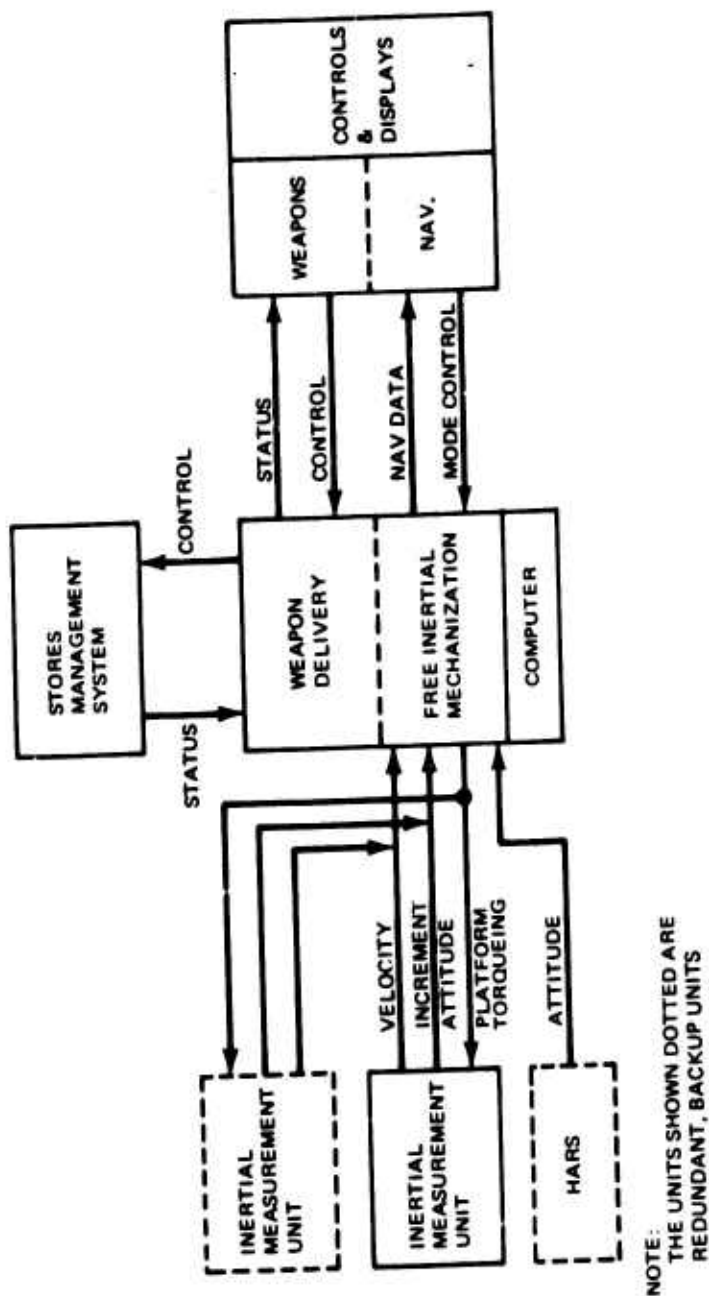
Figure III-3. Free Inertial Navigation System Functional Block Diagram

183
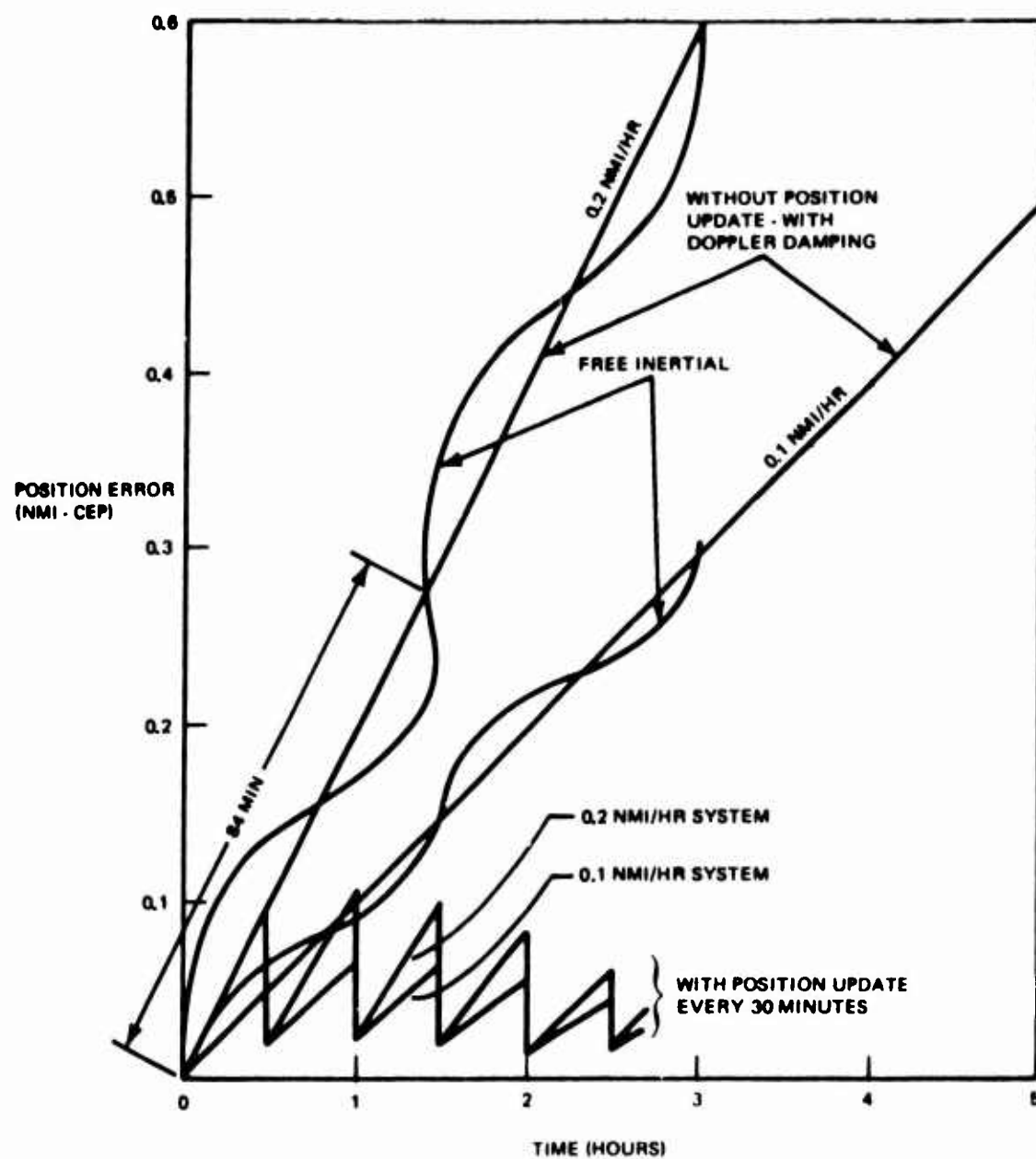
Figure III-4.   Doppler Inertial Performance with Position Updates

The addition of Doppler velocity damping to the basic navigation loop (Figure III-5) eliminates the Schuler oscillation. However, the error growth still increases as shown in Figure III-4. The addition of periodic position updating by, for example, a ground map radar to the navigation mechanization resets the position errors at each update period.

Navigation mechanizations for Doppler-inertial systems with updates from external references uses a Kalman estimation technique. This technique permits optimal use, in the least squares sense, of all data in the system. The performance of the total system is thereby improved. Both the position error and the error growth rate are reduced after two to three update periods, because the estimator calibrates bias errors. The amount of improvement is a function of the accuracy of the position update, the accuracy of the Doppler information, and the basic accuracy of the inertial measurement unit. The Doppler characteristics are shown in Table III-1.

Table III-1.   Doppler or Error Models

| Error Parameters | Doppler |
|---|---|
| Scale Factor Bias (%) | 0.07 |
| Boresight Bias (min) | 3.9 |
| Fluctuation Noise Ground Speed (ft/sec) | 1.72 |

The block diagram of Figure III-5 shows the basic inertial sensors in a redundant configuration. The attitude outputs of each of the inertial units are compared in two-out-of-three voting schemes to provide a criteria for malfunction detection and unit selection.

A backup-dead reckoning mode is implemented by using the heading outputs from the HARS and the velocity data from the Doppler sensors. These outputs, when compared to the position computations from each inertial measurement unit, provide a two-out-of-three voting scheme to assess the quality of the total navigation system.

4.    DIRECT RANGING SYSTEMS

The VORTAC and ILS systems are generally used in the CONUS with some limited application in the threater of operation. Generally, these systems are considered to be

185
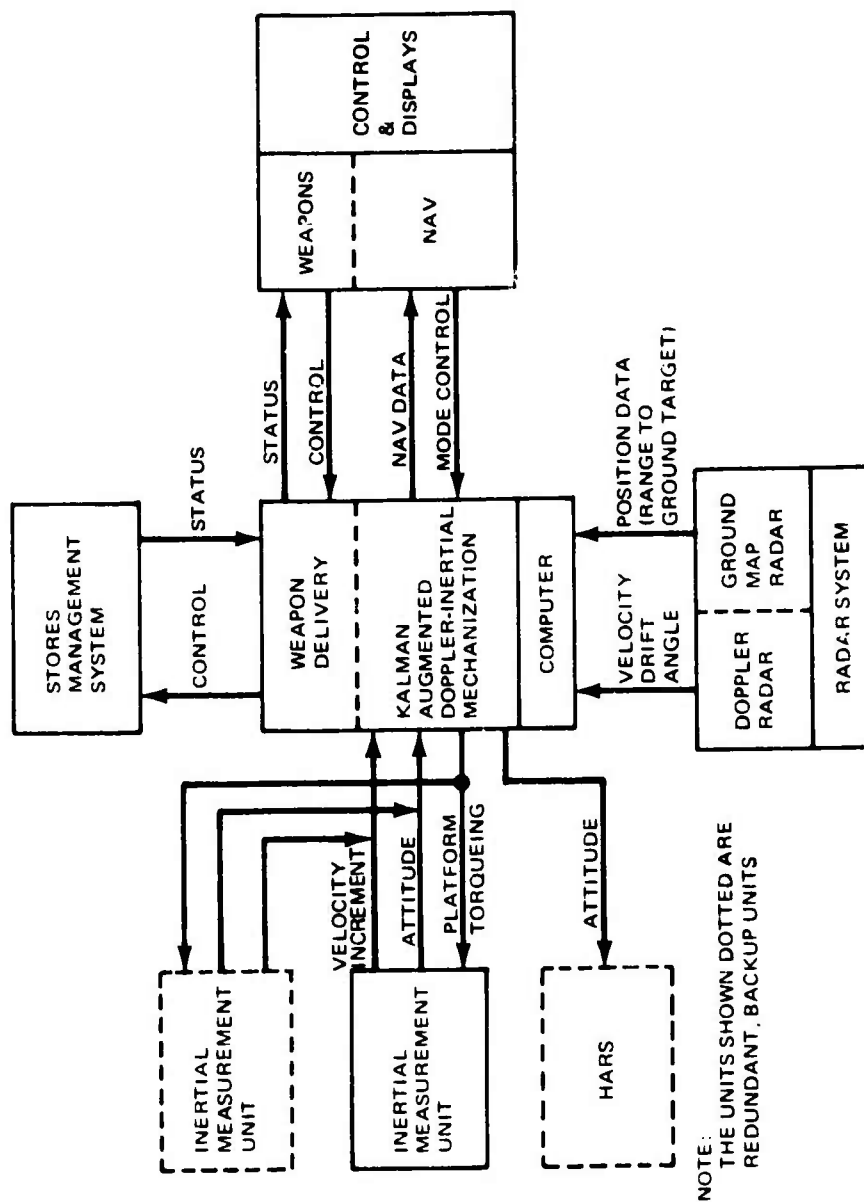
Figure III-5. Doppler-Inertial Functional Block Diagram with Position Updating

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aircraft guidance sensors used for routine point-to-point
navigation and for the terminal landing area. The type of
ground installations necessary for VORTAC are not practical
for a fluid tactical ground war. These systems are not
used on the outbound leg of a tactical mission; however,
they may be used to facilitate recovery of the aircraft on
the return leg of the mission.

Direct ranging systems under some conditions apply
to tactical combat aircraft missions for navigation. The
constraint imposed on these systems is the requirement for
ground radio equipment. In a fluid battle situation,
systems such as TACAN and VORTAC are useful only as recovery
navigational aids near es..blished air bases. Systems such
as Close Attack Support System (CLASS) and Range/Range Rate
require ground forward observers or ground transponders.
The concepts for both CLASS and the Range/Range Rate systems
are shown in Figures III-6 and III-7 respectively.

Figure III-6 shows that the CLASS concept requires
that the forward controller have an accurate knowledge of
his position relative to the target. The aircraft relative
to the forward controller is located by successively
interrogating a transponder carried by the forward controller.
Then, a trialateration computation is made to fix the
aircraft relative to the forward controller and, therefore,
relative to the target. A block diagram of CLASS is shown
in Figure III-8. Recent testing at Holloman indicates
position accuracies determinations are achievable that
permit accurate blind bombing of targets.

The Distance Measuring Equipment (DME) or range and
range-rate systems are generally the same as the CLASS
concept. The radio net is shown in conceptual form in
Figure III-7. The flight through the ground transponder
net permits determination of accurate range and range rate
information relative to the transponder. The range and
range rate information is used in a Kalman optimal estimator
to calibrate the navigation system.

5.     HYPERBOLIC SYSTEM

The two most familiar hyperbolic navigational aids
are the LORAN and OMEGA systems. The LORAN system net
operates three or more transmitters in the 100-KHz frequency
band (LORAN C and D). One transmitter is a master station.
The other stations are slaved to the master station time-
wise. Figure III-9 shows the loci for constant time
differences relative to the master slave pair. The inter-
section of the hyperbolae defines range relative to the
station complex. A receiver system that can measure time
of arrival difference from each of the master-slave pairs
will provide position information at the intersection of

TARGET
COORDINATES

FORWARD
CONTROLLER

$\Delta X_T$

$\Delta Y_T$

X

$\Delta X_{AT} = \Delta X_A + \Delta X_T$

$\Delta Y_{AT} = \Delta Y_A + \Delta Y_T$

AIRCRAFT
LOCATION

$\Delta X_A$

$\Delta Y_A$
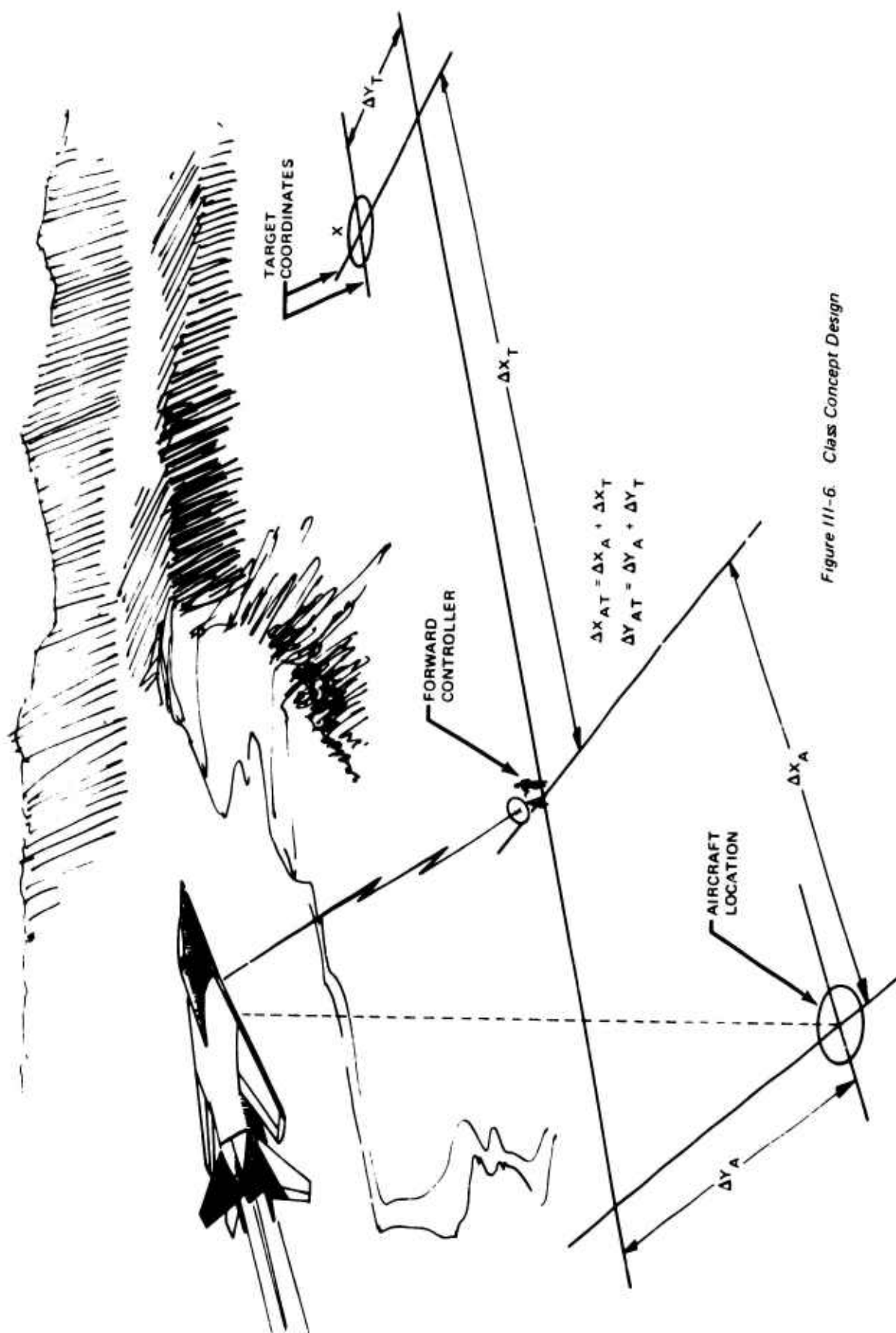
Figure III-6. Class Concept Design

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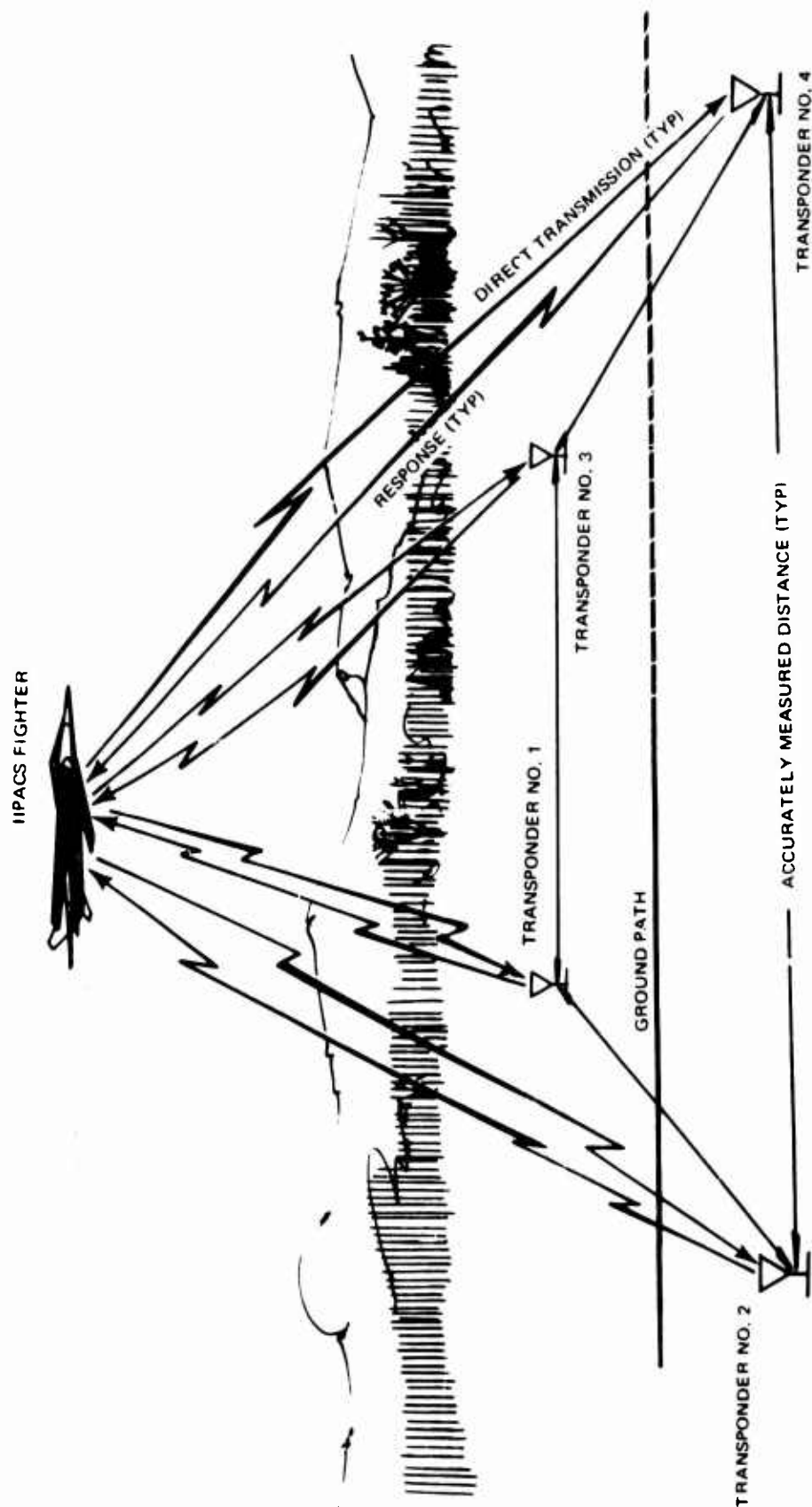
Figure III-7. Direct Ranging (DME) Concept – Position Fixing

Figure III-8. Range Range Rate Functional Block Diagram
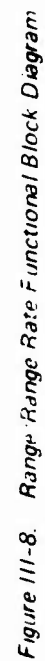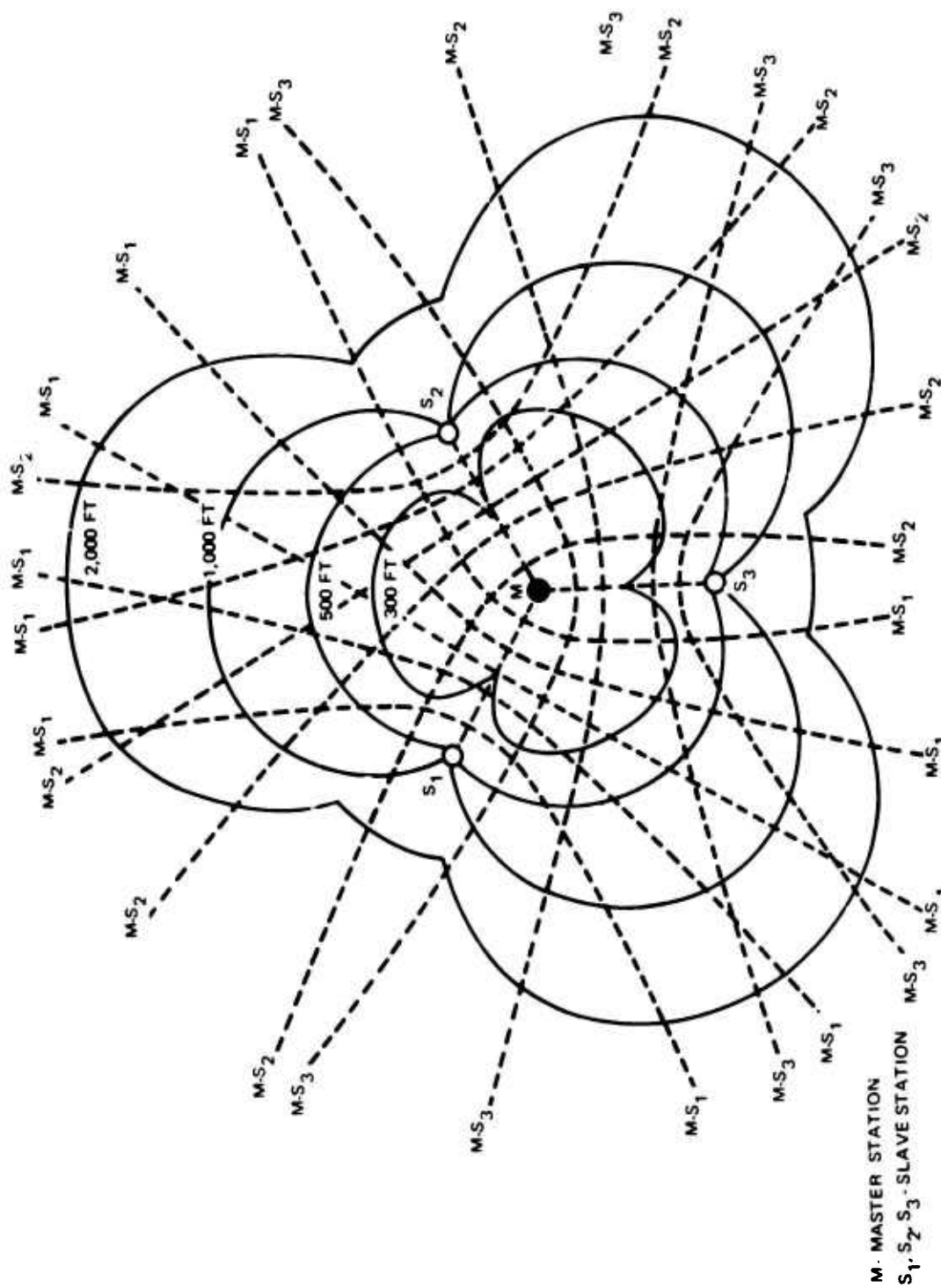
Figure III-9. Loran Accuracy Contours – Symmetric Configuration

M · MASTER STATION
S₁, S₂, S₃ · SLAVE STATION

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two hyperbolae. Then LORAN chains are available, an air-
craft can find its position to better than 1,500 feet (90th
percentile), depending on the location, or the receiver
relative to the LORAN chain and the geometry of the chain
itself. The dominant errors in the LORAN system are
propagation errors, timing errors, sky wave errors and
velocity tracking errors (in aircraft only). The errors
are modeled as observation errors in the Kalman estimator.

A RHO-RHO system of direct ranging to any station in
the LORAN chain is implemented if the receiver has an accurate
(atomic) clock. The receiver clock is synchronized with
the master clock before the mission and all time differences
are determined relative to the receiver clock. This time
difference is the range to the station. Loci of constant
time difference are circles relative to the transmitter.
Two intersecting circles provide two apparent locations of
the receiver (See Figure III-10). Direct ranging from a
third station eliminates the ambiguity. In general, all
three range circles will not intersect at one point because
of errors in the system. This results in a position
uncertainty. This position uncertainty is minimi ed by
modeling the system errors in a Kalman estimator.

The disadvantage of the LORAN system is the limited
coverage on a world-wide basis. The OMEGA system is being
put into operation by the Navy to eliminate this problem
in radio navigational aids. Four transmitting stations,
time synchronized, are now in operation providing limited
world-wide coverage. These stations are at Aldra, Norway;
Forresport, New York; Hawaii, and Trinidad. By 1972, the
Navy expects to have four additional transmitters operating
to complete the world-wide coverage. In addition, the power
outputs of the existing transmitters will be increased.

The OMEGA stations transmit at 10.2 KHz and 13.6 KHz
in assigned and identifiable time slots. The OMEGA re-
ceiver measures the phase difference from any two stations.
The lines of constant phase from any two stations form
hyperbolae similar to those of the LORAN system. Two
pairs of stations, as in the LORAN system, are needed to
form intersecting hyperbolae to fix the location of the
receiver.

The accuracy of the system is about 1 nmi during the
day and 2 nmi at night, after the major error sources are
compensated for in the computer. These error sources are
propogation errors due to the land/sea conductivity dif-
ferences, diurnal effects due to changes in the ionosphere
D layer composition as a function of the sun angle in the
propagation path, magnetic variation errors, latitude
errors (aircraft only). As in the LORAN system, the errors
are modeled in the Kalman estimator to improve system per-
formance.

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RECEIVER LOCATION

$S_1$

$R-S_1$

M

$R_M$

$S_2$

$R-S_2$

NOTE: LORAN SHADED AREA IS THE UNCERTAINTY
IN RECEIVER LOCATION DUE TO SYSTEM ERRORS

M = MASTER STATION
S.S. = SLAVE STATIONS

$R-S_1$ - RANGE FROM $S_1$ TO RECEIVER
$R-S_2$ - RANGE FROM $S_2$ TO RECEIVER
$R_M$ - RANGE FROM M TO RECEIVER
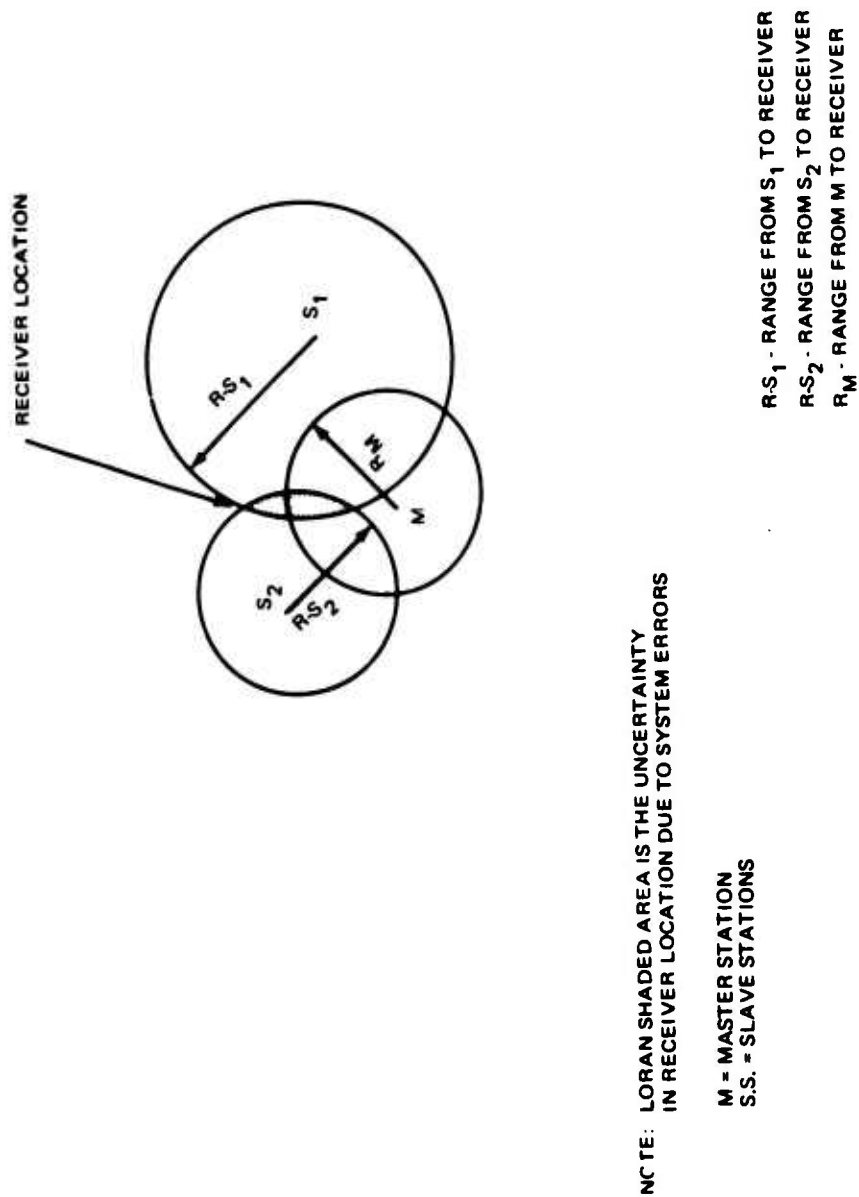
Figure III-10. RHO-RHO Ranging Concept

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A block diagram for the hyperbolic type of naviga-
tional aids in combination with the Doppler-inertial system
is shown in 'gure III-11. The inertial system with its
quiet velocity channels smoothes the noisy and sometimes
erroneous signals from the radio receivers. On the other
hand, the error growth rate (discussed in the section on
inertial systems) is bounded effectively by the radio aids.
Use of these sensors in a Kalman estimator improves the
performance of each sensor. For Doppler-Inertial-LORAN-
System, error bounds down to 300 feet CEP are achievable
for favorable receiver/station geometries. The Doppler-
Inertial OMEGA error bounds are between 0.5 to 1.0 nmi CEP.

6.      SATELLITE SYSTEMS (NAVSAT - 621B)

The Air Force 621B NAVSAT system provides navigation
data to any user within the radar range of the satellite
cluster. Three satellites are needed for a user to deter-
mine position information. Four satellites provide the
capability for the user to also determine altitude above the
terrain. Specific details of the system are classified.
The system accuracy will permit the user to determine
position with errors between 50 and 500 feet CEP, depending
on the satellite/user spatial geometry. The user is also
able to determine the velocity of the aircraft to less than
0.5 feet per second. A block diagram is shown in Figure
III-12.
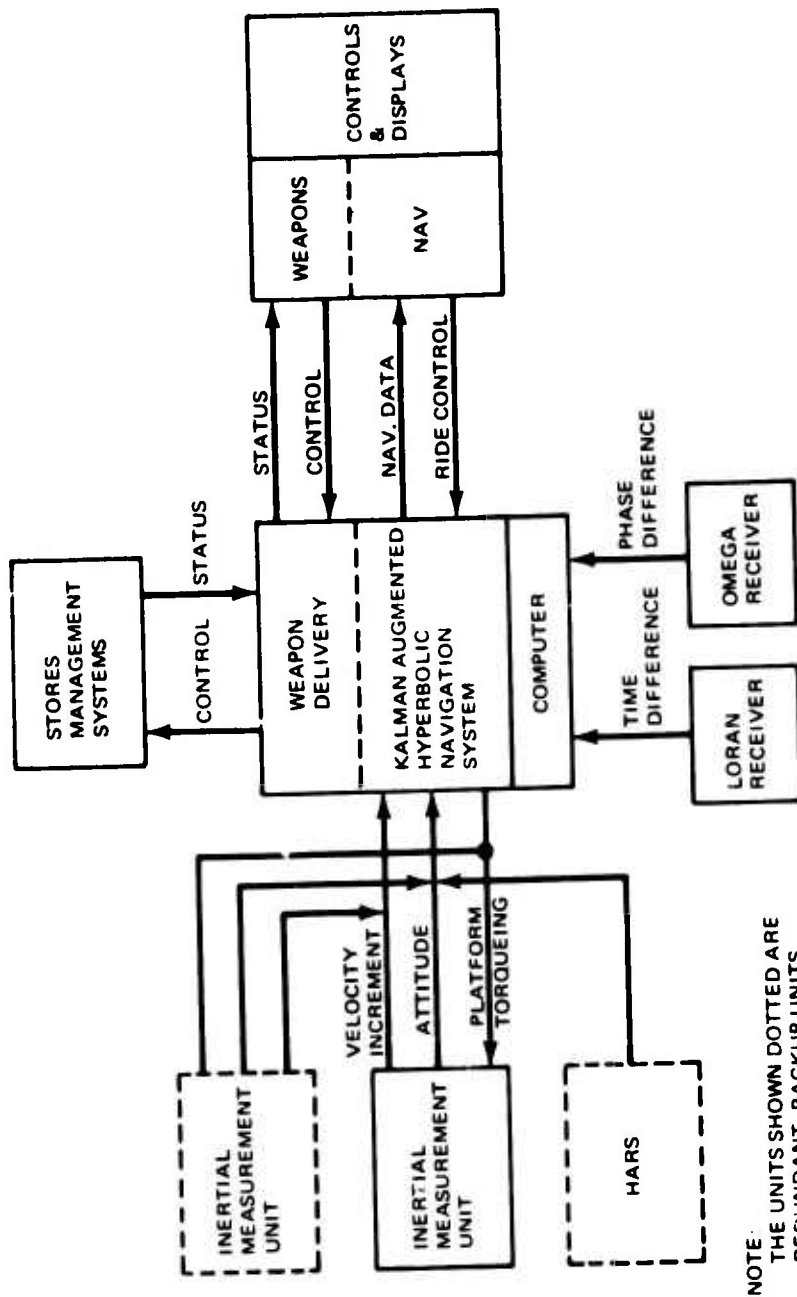
Figure III-11. Functional Block Diagram – Hyperbolic Radio Navigational Aids

195
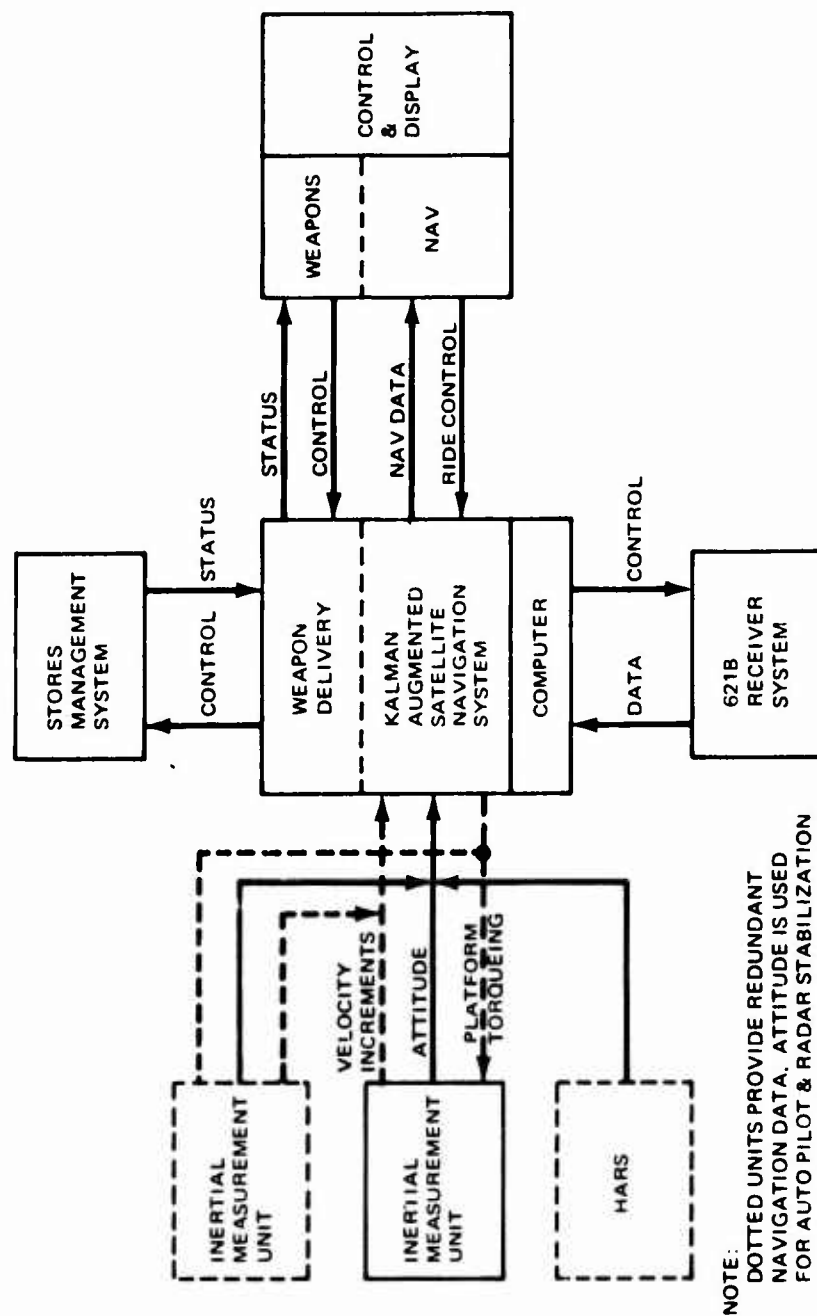
Figure III-12. Satellite Navigation Functional Block Diagram

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4. Brumaghim. A Review of Radar, Television, and Infrared Sensor Displays as Aids to Closed-Curtain Flight Capability of the B-52, D3-7178, The Boeing Company, September 23, 1968.

5. Hall, Way, and Belyea. Design and Evaluation of Primary Hand Controllers for Fighter Aircraft, AFFDL-TR-71-16, December 1970.

FUNCTIONAL INPUT/OUTPUTS

FUNCTIONAL OUTPUTS

## FIRE CONTROL

### MULTIMODE RADAR
Roll Stabilization
Pitch Stabilization
Mode Commands
Test Signals
Blanking Signal

### L³TV LASER
Ranging Command

### FLIR

(Left side inputs, partially cut off)
- & Range Rate
- Angle
- Angle
- Velocity
- Following
- Avoidance
- Altitude
- Angle
- Angle
- (Laser)
- Angle
- Angle
- Location

## NAVIGATION

### INERTIAL PLATFORM (NO. 1 & 2)
Roll Stabilization
Pitch Stabilization
Test Signals
Test Commands
Platform Erection
Platform Torquing

### SATELLITE

### MAGNETIC COMPASS
Magnetic Deviation
Magnetic Variation

### LANDING AIDS
Mode Commands

### COLISION AVOIDANCE

### RADIO ALTIMETER

### HEADING AND ATTITUDE REF.

### AIR DATA
Anti Ice

### TACAN
Frequency Command

(Left side inputs, partially cut off)
- Pitch/Heading
- Acceleration
- Angle Attack
- Side Slip
- Times
- No. 1, 2, 3
- Heading
- Altitude
- Altitude
- Attitude
- Temperature
- Pressure
- Temperature
- Altitude
- Velocity

### COMMUNICATION IDENTIFICATION

### DATA LINK COMMANDS & MESSAGES
Test Signals
Test Commands
Reply Messages
Target Reports
Threat Reports
Raw Video
A/C Identity
A/C Altitude
Weapon Status
Fuel Status
A/C Coordinates
A/C Speed
Engine Status
Oxygen Status
Fire Cont. Status
Discretes

(Left inputs)
- Control Messages
- to Go
- to Touchdown
- Position
- Points
- Coordinates
- Velocity
- Signals

### SPREAD SPECTRUM AND HF
Computer Stored Data
Tape Data
Scrambled Voice
Voice

---

Test Signals
Test Commands
A/C Status
Position Data
Target Data

Radar IR TV Video

## BOMB DAMAGE ASSESSMENT
- DATA RECORDER
- VIDEO RECORDER
- EMP RECORDER
- RADIATION RECORDER

---

Test Commands
Test Signals
Caution & Warning

## FAILURE MONITOR & CONTROL
Qualitative Performance (All Systems)
Quantitative Performance All Systems

---

Test Signals
Test Commands
Ramp Command
Thrust Command
Reverser Command
Vector Command
Windmill On/Off

## PROPULSION
### ENGINES
Air Temperature
Oil Pressure
Ramp Position
Oil Temperature
RPM
EPR
Thrust
Bearing Temperature
Vibration (Multiple)
Oil Particle Detector
Thrust Vector Position
Reverser Position

### THROTTLES

### THRUST VECTORING & REVERSERS
Start
Trim
Shutdown

---

Test Signals
Test Commands
Switching
VSCF Control
Cross Connect
Disconnect
Right Drive
Left Drive

## ELECT/HYD
### ALTERNATORS (1 & 2)
A/C DC Power
Frequency

### APU

### BATTERIES

### HYDRAULICS
Quantities
Pressure
Flow

---

Test Signals
Test Commands
Trim Commands
Aileron Commands
Elevator Commands
Rudder Commands
Flaps
Spoilers
Wing Sweep
Boundary Layer
Slats
Speed Brakes

## AERODYNAMIC CONTROLS
### SURFACES
Trims
Aileron Position
Elevator Position
Rudder Position
Spoiler Position
Wing Sweep Position
Slats

---

Test Signals
Test Command
Up Commands
Down Commands
Brake Commands
Nosewheel Commands
Door Commands

## LANDING GEAR
Engine Windmill Disable
Up Signals
Down Signals
Brake Slip
Brake Temperature
Hydraulic Pressure
Nose Wheel Steer
Weight (Each Wheel)
Door Position

---

Test Signals
Test Commands
Pressure/Fire Suppress
Pump Commands
In Flight Refuel
Dump Fuel

## FUEL SYSTEM
### TANKS PUMPS & GAUGES
Fuel Quantities
Flow Rates
Temperature
Pressure

Fuel Transfer Commands

### CG CONTROL
CG Shift

---

## INTEGRATED MASTER KEYBOARD DISPLAY MODE SELECTION FUNCTIONS

### ITEMS
A/G Combat
A/A Combat
Lo Alt Cruise
Hi Alt Cruise
Climb Profile Min Time
$V_n$ Envelope
Tavail Treqd
Climb Profile Min. Fuel
Landing Monitor
Air Data & Thrust
Navigation
Engines
Heading
Angle of Attack Pitch & Roll
Distance or Range
Mach
Gnd Speed
TAS
EAS

### NAVIGATION
Total Prog Route Input
Man or DL Route Change
Dist Bearing Time to Go
Next Tgt Data
Next Check Point Data
Nav Mode Data
Gnd Speed Drift Heading
Station Keep (TCN)
Add
Delete

### STORES MANAGEMENT
Stat Load Classic Del Man
Stat Load Classic Del Auto
Del Option Wpn Chosen
Del Sel Wpn Chosen
Rel Envelope Wpn Chosen
Wpn TV
Stores Rem Wpn Chosen

### FMAC
Hyd
Elect
Avionics A
Avionics B
Ldg Gear Hi Lift
Oxy Status
Test Proc 1 & 2

### BATTLE SITUATION
Threat α N
Threat Priority
Weapon Launch Envelopes
Friend
AAA
SAM
Gnd Indirect
A1 Pulse
A1 Pulse Doppler
Air Indirect

### ENGINE
Eng Disp
N1 Epr T/T
Vib Monitor
Temp Monitor
Fuel Flow
Ramp Positions
Preset Freq Sel

### COMM/IDENT
Phone Book
Msg Traffic
D/L Msg 1
D/L Msg 2
D/L Msg 3
IFF Interr Response Data
Auto Rng Expend
Nav CP's
Precision CP's
Nav Route
Waypoint Data
Short Route Home
Enroute Times
Wpn TV

### HSD
Items Symbology
E² Scan
B Scan
C Scan
Situation
Predictor
Add
Delete
Charts
Radar
Flicker
Add
Delete
Pitch & Roll Lines

### HUD/VSD
Artificial Horizon
Vv
H N
Heading
Predict
Items Symbology
Flight Path Marker
Legend Change Logic
Alpha Numeric Commands
MPD Transfer Command
HSD/VSD/HUD Transfer Commands
L³TV
FLIR
Laser
Laser Spot Seeker
AT$_A$
B D A
Wpn TV
Fixed TV
Emerg Off

### BASIC PROGRAMS

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## SWITCHING CIRCUITS

Items
Mission Ready
Profile/s Test
Acknowledge
FMACS Status
In Flight Test
Fire Control
Navigation
Comm Ident
Pen Aids
Stores Manage
Bomb Damage
Elect Hydraulic
Controls/Dis
Landing Gear
Fuel System
Environ Control
Lighting
Airframe
Escape Capsule
Elect Hyd
Address Input
Address Code
HF
Freq
Channel
IFF (AG)
IFF (MMR)
IFF (De Code)
Mode
Code
Voice
Data Link
Clear
Secure
Relay
Low Power
Normal Power
A
B
C
SAT
TX

RCV
ADF
Position
Hold
Zero
Emergency
Identity
Man. IFC A
Mach
TAS
EAS
Altitude Co
Terrain Fol
Clearance P
Heading
Capture
Nav Steer
AFCS On
AFCS Off
INS 1
INS 2
AHRS
Time (Z)
Radio Alt
SAT
TACAN
ILS
Doppler
Align
Operate
Update
Time Sync
Time Man
Align Status
Gyro Comp
TH Insert
Last Hdg
Runway
Mag Var
Mag Var
X-Hair Layer
N Lat
S Lat
E Long
W Long
Height Abo
Offset
Station Press
Baro Cal
Pres Position
CP
Dest
Target Press
Target of Op
Base
To
From
MMR
SAT
D/L
E-O
TACAN
Visual
Precision
D/L (TAC)

### SIGNAL PROCESSORS BUFFERS

**INPUTS**

**OUTPUTS**

Column 1 (HUD / HUD/VSD):

- A/G Combat
- A/A Combat
- Lo Alt Cruise
- Hi Alt Cruise
- Climb Profile Min Time
- $V_n$ Envelope
- Tavail Treqd
- Climb Profile - Min. Fuel
- Landing Monitor
- Air Data & Thrust
- Navigation
- Engines
- Heading
- Angle of Attack Pitch & Roll
- Distance or Range
- Mach
- Gnd Speed
- TAS
- EAS
- Total Prog Route Input
- Man or DL Route Change
- Dist Bearing Time to Go
- Next Tgt Data
- Next Check Point Data
- Nav Mode Data
- Gnd Speed Drift Heading
- Station Keep (TCN)
- Add
- Delete
- Stat Load Classic Del Man
- Stat Load Classic Del Auto
- Del Option Wpn Chosen
- Del Sel Wpn Chosen
- Rel Envelope Wpn Chosen
- Wpn TV
- Stores Rem Wpn Chosen
- Hyd
- Elect
- Avionics A
- Avionics B
- Ldg Gear Hi Lift
- Oxy Status
- Test Proc 1 & 2
- Thrust α N
- Thrust Priority
- Weapon Launch Envelopes
- Friend
- AAA
- SAM
- Gnd Indirect
- A1 Pulse
- A1 Pulse Doppler
- Air Indirect
- Eng Drop
- N1 Epr T/T
- Vib Monitor
- Temp Monitor
- Fuel Flow
- Ramp Positions
- Preset Freq Sel
- Phone Book
- Msg Traffic
- D/L Msg 1
- D/L Msg 2
- D/L Msg 3
- IFF Interr Response Data
- Auto Rng Expand
- Nav CP's
- Premsion CP's
- Nav Route
- Waypoint Data
- Short Route Home
- Enroute Times
- Wpn TV
- Items Symbology
- E² Scan
- B Scan
- C Scan
- Situation
- Predictor
- Add
- Delete
- Charts
- Radar
- Flicker
- Add
- Delete
- Pitch & Roll Lines
- Artificial Horizon
- Vi
- H R
- Heading
- Predict
- Items Symbology
- Flight Path Marker
- Legend Change Logic
- Alpha Numeric Commands
- MPD Transfer Command
- HSD/VSD/HUD Transfer Commands
- L³TV

Column 2 (Items — EMAC / COMM & IDENT / ITEMS / NAVIGATION):

- Items
- Mission Ready Test
- Preflight Test
- Acknowledge
- FMACS Status Summary
- In Flight Tests
- Fire Control
- Navigation
- Comm Ident
- Pen Aids
- Stores Management
- Bomb Damage Assess
- Elect Hydraul
- Controls/Displays
- Landing Gear
- Fuel System
- Environ Cont
- Lighting
- Airframe
- Escape Capsule
- Elect Hyd
- Address Index
- Address Code
- HF
- Freq
- Channel
- IFF (AG)
- IFF (MMR)
- IFF (Dir Comm)
- Mode
- Code
- Voice
- Data Link
- Clear
- Secure
- Relay
- Low Power
- Normal Power
- A
- B
- C
- SAT
- TX
- RCV
- ADF
- Position
- Hold
- Zero
- Emergency
- Identity
- Man. IFC Alt
- Mach
- TAS
- EAS
- Altitude Command
- Terrain Following
- Clearance Plane Set
- Heading
- Capture
- Nav Steer
- AFCS On
- AFCS Off
- INS 1
- INS 2
- AHRS
- Time (Z)
- Radio Alt
- SAT
- TACAN
- ILS
- Doppler (MMR)
- Align
- Operate
- Update
- Time Sync
- Time Man Start
- Align Status
- Gyro Compass
- TH Insert
- Last Hdg
- Runway Hdg
- Mag Var (E)
- Mag Var (W)
- X-Hair Laying
- N Lat
- S Lat
- E Long
- W Long
- Height Above SL
- Offset
- Station Pressure
- Baro Cal
- Pres Position
- CP
- Dest
- Target Preselect
- Target of Opportunity
- Base
- To
- From

Vertical labels: SWITCHING CIRCUITS · SIGNAL PROCESSORS BUFFERS · INTEGRATED MASTER KEYBOARD SYSTEM MODE SELECTION FUNCTIONS

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**Block 1 — HUD AND VERTICAL SITUATION DISPLAY (TYPICAL PREPROGRAM)**

Inputs:
- L³TV/FLIR Video Fixed
- L³TV/FLIR Video Steerable
- Roll, Pitch Yaw Attitude
- Radar Altitude
- Engine Thrust Command
- Course Error
- Baro Altitude
- Baro Alt Rate
- Heading
- Airspeed
- Selected Course
- Keyboard Functions
- Terrain Clearance at ½, 1, 2, & 4 Miles
- Test Commands

Outputs (RADAR MODE SELECT):
- AA Search Track
- Dogfight
- Station Keeping
- Beacon
- Passive
- MTI/Radar
- TV/FLIR MTI
- Laser Range
- Gnd Map
- Gnd Map Squint
- Situation
- Spotlight
- Dopp Beam Sharpening
- AILA
- ILM

**Block 2 — HORIZONTAL DISPLAY (TYPICAL PREPROGRAM)**
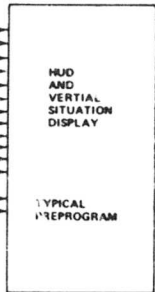
Inputs:
- Course Error
- Selected Course
- Radar Video
- Moving Map
- Bearing to Destination
- Distance To Destination
- Time to Destination
- Keyboard Functions
- Test Commands
- Terrain

Test Signals

Outputs (COMM & IDENTIFY CONTROL):
- Volume Position 1-9
- Master Volume
- IFF Interrog A/A
- IFF Interrog Dir Comm

**Block 3 — MULTIPURPOSE DISPLAY / ENERGY MANAGEMENT (TYPICAL PREPROGRAM)**
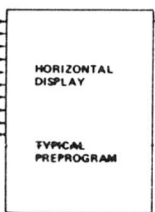
Inputs:
- Roll, Pitch, Yaw Attitude
- Pitch-Roll Command
- Speed Command
- Terrain Clearance at ½, 1, 2, & 4 NMI
- Engine 1 & 2 Inlet Temp
- Engine 1 & 2 Oil Temp
- Engine 1 & 2 Oil Pres
- Engine 1 & 2 Thrust
- Engine 1 & 2 RPM
- Engine Ramp Position
- Total Fuel
- Tank 1, 2, 3 Fuel
- Fuel Time Remaining
- CG Position
- Keyboard Functions
- Test Commands

Test Signals

Outputs (ELECTRO OPTICAL AUX CONTROL):
- Stow
- Boresight Slave
- Individual Slave
- Contrast Lock On
- Normal/Wide FOV
- Fac TV/FLIR
- Dome Clean

Outputs (ENGINE CONTROL):
- Master On/Off L&R Engine
- L&R Engine Trim
- Cart Start L&R Engine
- Normal Start L&R Engine
- Idle L&R Engine
- Friction

Outputs (ELEC POWER CONTROL):
- VSCF 1 & 2 On/Off
- Avionics Buss On/Off
- Gen 1 & 2 On/Disconnect
- Avionics Buss On/Off
- Batt/Off/Ext Power
- Normal/Cross Connect

**Block 4 — MULTIPURPOSE DISPLAY / CNI FUNCTIONS OR MALFUNCTION DISPLAY (TYPICAL PREPROGRAM)**

Inputs:
- Time Hrs-Min-Sec
- Time To Go
- Bearing to Gnd Station
- Distance to Gnd Station
- Nav Set Freq Channel
- Secondary Nav Mode Sel
- Ground Speed
- IFF Mode Code Display
- Malfunction M
- Com. Pos. 1-6
  - Address
  - Mode
- Preformatted D/L Messages
- Received D/L Messages
- Primary Nav Display
- Position Display Way Point
- Keyboard Functions
- Test Commands

Test Signals

Outputs (AUX RADAR CONTROL):
- Radar Map Range
- Radar Gain
- Offset On/Off
- Moving Map On/Off
- PPI/Off Center Sector
- North/Heading Up
- Map Slew

Outputs (FUEL CONTROL):
- Refuel Probe Ext/
- Slipway Open Close
- CG - Fwd/Aft/Normal
- Fuel Dump Ext/Int-Ext

- Stores Selection
- Gun Safe-Off-Charge
- Gun Fire Rate Fast Slow

**HUD AND VERTICAL SITUATION DISPLAY**

TYPICAL PREPROGRAM

R Video Fixed
R Video Steerable
Vert Attitude
ust Command
Rate
Course
Functions
urance
2, & 4 Miles
mmands

**RADAR MODE SELECT**

AA Search Track
Doghfight
Station Keeping
Beacon
Passive
MTI/Radar
TV/FLIR MTI
Laser Range

Gnd Map
Gnd Map Squint
Situation
Spotlight

Dopp Beam Sharpening
AILA
ILM

**DESIGNATION CONTROL**

Enable
Update
Antenna Elevation
Lock on Reject
Freeze Erase
Designation Cont Unlock
Flight Cont Transfer
$A_z$, EL, Range Drive Sig's

**HORIZONTAL DISPLAY**

TYPICAL PREPROGRAM

Error
Cr se
Video
Map
a Destination
To Destination
Destination
nd Functions
mmands

Test Signals

**COMMUNICATIONS IDENTIFICATION CONTROL**

Volume Position 1 9
Master Volume
IFF Interrog A/A
IFF Interrog Dir Comm

Oper System
Sec Vox D/L
Sat Guard
RHAW TACAN
FMAC IFF/AAA
IFF/Dir Comm

Missile Tone

IFF Response

**COUNTERMEASURES PANEL**

Left/Right Cmds Select
Expendable Selection
Auto/Man Release
MPD Range Sel

HF Jammer On
MF Jammer On
LF Jammer On
IR Jammer On

**DISPLAY/SENSOR SELECT PANEL**

HUD Combining Glass
HSD Transfer
BSD Transfer
Sel Radar
Sel Steer/Fix L$^3$TV
Sel Steer/Fix FLIR

**MULTIPURPOSE DISPLAY**

ENERGY MANAGEMENT

TYPICAL PREPROGRAM

Pitch, Yaw Attitude
Roll Command
Command
te Clearance
, 1, 2, & 4 NMI
1 & 2 Inlet Temp
1 & 2 Oil Temp
1 & 2 Oil Pres
1 & 2 Thrust
1 & 2 RPM
e Ramp Position
Fuel
1, 2, 3 Fuel
Time Remaining
Position
oard Functions
Commands

Test Signals

**ELECTRICAL OPTICAL AUX CONTROL**

Stow
Boresight Slave
Individual Slave
Contrast Lock On
Normal/Wide FOV
Fac TV/FLIR
Dome Clean

Operating Modes

**FLIGHT PHASE SELECT PANEL**

Air/Air
Contact Analog
Cruise
Terrain Following
To/Land
Air/Gnd

**FLAPS & WING SWEEP SELECTOR**

Wing Sweep Control
Flap Position Control
Auto Wing Sweep Disc

Wing Sweep Position

**ENGINE CONTROL**

Master On/Off L&R Engine
L&R Engine Trim
Cart Start L&R Engine
Normal Start L&R Engine
Idle L&R Engine
Friction

**YAW TRIM SPOILER**

Yaw Trim L&R
Spoiler Off/Arm

**ELECT POWER CONTROL**

VSCF 1 & 2 On/Off
Avionics Buss On/Off
Gen 1 & 2 On/Disconnect
Avionics Buss On/Off
Batt/Off/Ext Power
Normal/Cross Connect

**SEAT RUDDER ADJUST**

Seat Up/Down
Seat Tilt Cont
Rudders Fwd/Aft

**LANDING GEAR CONTROL**

Up/Down Select
Antiskid

Landing Gear Position

**CANOPY LOCK RELEASE**

Open/Close
Emergency Open

**AUX RADAR MAP CONTROL**

Radar Map Range
Radar Gain
Offset On/Off
Moving Map On/Off
PPI/Off Center Sector
North/Heading Up
Map Skew

Test Signals

**APU PANEL**

Air/Elec/Hyd Outputs
RPM
EGT
Oil
Start/Operate
Test
Fire Extinguisher

APU Fire Warning

**MULTIPURPOSE DISPLAY**

CNI FUNCTIONS OR MALFUNCTION DISPLAY

TYPICAL PREPROGRAM

Time - Hrs-Min-Sec
me To Go
ring to Gnd Station
nce to Gnd Station
Set Freq Channel
ndary Nav Mode Sel
round Speed
FF Mode Code Display
alfunction M
Com. Pos. 1-6
Address
Mode
formatted D/L Messages
rmed D/L Messages
imary Nav Display
Position Display Way Point
Keyboard Functions
Test Commands

Test Signals

**FUEL SYSTEM CONTROL**

Refuel Probe Ext/
Slipway Open Close
CG – Fwd/Aft/Normal
Fuel Dump Ext/Int-Ext

Fuel Quan
L Wing R Wing
Fwd Aft

Total Fuel
Quanity

Fuel Range
Target/Base
Mission

CG Location

Desired CG
Location A/A
A/G Cruise

**LIGHTING CONTROL**

Int Lights, R&L
Flood, R&L Console
and Flight Instrum

Master Int Brightness

Ext Lights
Steady/Flash

Anticollision
Air Refuel
Land
Test

Stores Selection
Gun Safe-Off-Charge
Gun Fire Rate Fast Slow
T me Remaining

Stores Location

Stores

**RUDDER PEDALS**

Pedal Position
Pedal Force

Yaw
Force
Feedback

Roll Force

**LANDING AIDS**
← Pitch
← Roll
← Heading
→ Mode Commands

**COLISION AVOIDANCE**

**RADIO ALTIMETER**
← Radar Altitude

**HEADING AND ATTITUDE REF.**
← Roll Attitude
← Pitch Attitude

**AIR DATA**
← Ambient Temperature
← Ambient Pressure
← Dynamic Pressure
← Ram Air Temperature
→ Anti Ice

**TACAN**
← Identity
← Range
← Bearing
→ Frequency Command

**COMMUNICATION IDENTIFICATION**

**DATA LINK COMMANDS & MESSAGES**
← A/C Control Messages
← Discretes
← Time to Go
← Range to Touchdown
← Base Position
← Way Points
← Destinations
← Target Coordinates
← Sensor Video
← Target Velocity
→ Test Signals
→ Test Commands
→ Reply Messages
→ Target Reports
→ Threat Reports
→ Raw Video
→ A/C Identity
→ A/C Altitude
→ Weapon Status
→ Fuel Status
→ A/C Coordinates
→ A/C Speed
→ Engine Status
→ Oxygen Status
→ Fire Cont. Status
→ Discretes

**SPREAD SPECTRUM AND HF**
← Voice Signals
← Hard Copy
← Soft Copy
→ Computer Stored Data
→ Tape Data
→ Scrambled Voice
→ Voice

**SATELLITE**
→ Mode Commands

**CLOCK SYSTEM**
← Time Signals

**AIR/AIR AIR/GND IFF**
← Interrogations
← Replys
→ Interrogation Command

**INTER COMM**
← Audio
→ Audio Mixing

**PENETRATION AIDS**
→ Test Signals
→ Test Commands
→ Selection & Control

**RHAWS LF, MF HF**
← Azimuth Angle
← Elevation Angle
← Receiver Signals

**RF JAMMERS**
← Radiated Signals
→ Mode Commands

**IR WARNING**
← Receiver Signals

**IR JAMMER (TAIL)**
← Radiated Signals

**EXPENDABLE COUNTERMEASURES**
← Stores Remaining
→ Dispenser Controls

**STORES MANAGEMENT**

**WEAPONS AND DECOYS**
← Identity
← Availability
← Missile Video
← Missile Side Tones
← Verification Signals
→ Mode Commands
→ Weapon Selections
→ Test Signals
→ Test Commands
→ Missile Head Aim
→ Initialization & Tuning

**BATTERIES**

**HYDRAULICS**
→ Quantities
→ Pressure
→ Flow

**AERODYNAMIC CONTROLS**

**SURFACES**
← Test Signals
← Test Commands
← Trim Commands
← Aileron Commands
← Elevator Commands
← Rudder Commands
← Flaps
← Spoilers
← Wing Sweep
← Boundary Layer
← Slats
← Speed Brakes
→ Trims
→ Aileron Position
→ Elevator Position
→ Rudder Position
→ Spoiler Position
→ Wing Sweep Position
→ Slats

**LANDING GEAR**
← Test Signals
← Test Command
← Up Commands
← Down Commands
← Brake Commands
← Nosewheel Commands
← Door Commands
→ Engine Windmill Disable
→ Up Signals
→ Down Signals
→ Brake Slip
→ Brake Temperature
→ Hydraulic Pressure
→ Nose Wheel Steer
→ Weight (Each Wheel)
→ Door Position

**FUEL SYSTEM**

**TANKS PUMPS & GAUGES**
← Test Signals
← Test Commands
← Pressure/Fire Suppress
← Pump Commands
← In Flight Refuel
← Dump Fuel
→ Fuel Quantities
→ Flow Rates
→ Temperature
→ Pressure

**CG CONTROL**
← Fuel Transfer Commands
→ CG Shift

**ENVIRONMENTAL CONTROL**

**CABIN PRESSURE CONTROL AND AIR CONDITIONING**
← Test Signals
← Test Commands
← Cockpit Alt. Commands
← Temperature Commands
← Defog Commands
← Ram Air Commands
→ Bleed Air Temperature
→ Bearing Temperature
→ Air Pressure(s)
→ Air Flow(s)
→ Cockpit Altitude
→ Cockpit Temperature
→ Cockpit Humidity

**ICE CONTROL**
← Command

**RAIN REMOVAL**
← Removal Command
→ Liquid Level

**OXYGEN**
← Command
→ Quantity
→ Pressure
→ Flow

**LIGHTING**

**LIGHTS**
← Canopy Transparency
← Intensity
→ Exterior
→ Interior

**MISC UTILITIES**

**FIRE DETECTION AND EXTINGUISHING SYSTEM**
← Temperature
→ Fire Warning

**AIRFRAME**
← Test Commands
← Test Signals

**ESCAPE CAPSULE**
← Eject
→ Emergency Life Support

**ITEMS**
← Energy Advantage
← Minimum Time
← Maximum Range
← Maximum Endurance
← Opt Performance
← This Altitude
← Best Altitude
← Alt Schedule
→ Air Data
→ Engine Performance
→ Fuel Burned
→ Aero Performance

**SYSTEMS**

**NOTES**

⊢→ Information for All Subsystems in a System Group

⊢→ Information for Subsystem Only

▷ Systems are Identified Functionally - Not by Physical Components

Left column (inputs):

- Quantities
- Pressure
- Flow

- Trims
- Aileron Position
- Elevator Position
- Rudder Position
- Spoiler Position
- Wing Sweep Position
- Slats

- Engine Windmill Disable
- Up Signals
- Down Signals
- Brake Slip
- Brake Temperature
- Hydraulic Pressure
- Nose Wheel Steer
- Weight (Each Wheel)
- Door Position

- Fuel Quantities
- Flow Rates
- Temperature
- Pressure

- CG Shift

- Bleed Air Temperature
- Bearing Temperature
- Air Pressure(s)
- Air Flow(s)
- Cockpit Altitude
- Cockpit Temperature
- Cockpit Humidity

- Liquid Level

- Quantity
- Pressure
- Flow

- Exterior
- Interior

- Fire Warning

- Emergency Life Support

- Air Data
- Engine Performance
- Fuel Burned
- Aero Performance

BASIC PROGRAMS

INTEGRATED MASTER KEYBOARD SYSTEM MODE FUNCTIONS
FIRE CONTROL SENSORS

HSD:
- Nav Route
- Waypoint Data
- Short Route Home
- Enroute Times
- Wpn TV
- Items Symbology
- E² Scan
- B Scan
- C Scan
- Situation
- Predictor
- Add
- Delete
- Charts
- Radar
- Flicker
- Add
- Delete

HUD/VSD:
- Pitch & Roll Lines
- Artificial Horizon
- Vv
- H h
- Heading
- Predict
- Items Symbology
- Flight Path Marker
- Legend Change Logic
- Alpha Numeric Commands
- MPD Transfer Command
- HSD/VSD/HUD Transfer Commands
- L³TV
- FLIR
- Laser
- Laser Spot Seeker
- AT_A
- B D A
- Wpn TV
- Fixed TV
- Emerg Off
- MMR
- Swath Width (MMR)
- Spot Light (MMR)
- Bar Scan (MMR)
- Situation Alt (+) (MMR)
- Situation Alt (-) (MMR)
- ISO Echo (MMR)
- Station Keep R___ (MMR)
- Pursuit (MMR)
- Interrupt (MMR)
- STU Out (MMR)
- ECCM Auto (MMR)
- ECCM Man (MMR)
- Freq Agility (MMR)
- Co Polariz (MMR)
- Cross Polariz (MMR)
- Vert Polariz (MMR)
- Horiz Polariz (MMR)
- Map/MMR Flicker Rate
- BS Slave
- Stow
- Indiv Slave
- Video (+)
- Video (-)
- Level Splice
- Flicker Rate
- LSS Overt
- LSS Covert
- FOV N
- FOV E
- Air/Gnd Ranging
- Laser Off
- Moving Vehicles All
- Trucks (ATA)
- Tanks (ATA)
- Train (ATA)
- Troop Carrier (ATA)
- Airborne Vehicles All (ATA)
- AI (ATA)
- SUAWACS (ATA)
- Helicopter (ATA)
- Priority (ATA)
- Fixed Targets All (ATA)
- SAM (ATA)
- AAA (ATA)
- Bridge (ATA)
- Dam (ATA)
- Airport (ATA)
- Staging Area (ATA)
- Fuel Dump (ATA)
- Playback (BDA)
- Footage Remain (BDA)

SIGNAL PROCESSORS BUFFERS
DEDICATED AND CENTRAL COMPUTER

NAVIGATION:
- Doppler (MMR)
- Align
- Operate
- Update
- Time Sync
- Time Man Start
- Align Status
- Gyro Compass
- TH Insert
- Last Hdg
- Runway ___
- Mag Var (E)
- Mag Var (W)
- X Hair Laying
- N Lat
- S Lat
- E Long
- W Long
- Height Above SL
- Offset
- Station Pressure
- Zero Cal
- Pres Position
- CP
- Dest
- Target Preselect
- Target of Opportunity
- Base
- To
- From
- MMR
- SAT
- D/L
- E O
- TACAN
- Visual
- Precision CP
- D/L (TACAN)
- Channel X (TACAN)
- Channel Y (TACAN)
- Short Range (TACAN)
- Long Range (TACAN)
- Rec Only (TACAN)
- T/R (TACAN)
- A/A (TACAN)
- Secure (TACAN)
- ECCM (TACAN)
- Precision (ILS)
- Beacon (ILS)
- AILA (MMR)
- GCA (D/L)
- Freq (ILS)
- GS Cmd (ILS)
- R/W Hdg (ILS)
- MDA (ILS)
- Station

STORES MANAGEMENT:
- Release Order
- Delivery Method
- Sequence
- Rates
- Fuze & Cont
- Allowable Mil Accuracy Symbology
- Identity
- Location
- Priority
- Destroy
- Evade
- Degrade

PENETRATION AIDS:
- HF Jammer
- MF Jammer
- IR Jammer
- No. Threats Displayed
- Chaff
- Flares
- Expendable Jammers
- Limiter
- Release Interval
- Emergency Off

FIRE CONTROL SENSORS:
- Fixed Targets All
- Auto (BDA)
- Manual (BDA)
- MMR Record (BDA)
- L³TV FLIR Record (BDA)
- RHAW Record (BDA)
- Data Record (BDA)
- Audio Record (BDA)
- Manual Start (BDA)
- Manual Stop (BDA)
- Retransmit Last Strike Rept (BDA)
- Fast Fwd
- Stop
- Fast Rev

INTEGRATED MASTER KEYBOARD SYSTEM MODE SELECTION FUNCTIONS

Right column (displays):

- Time Hrs Min Sec
- Time To Go
- Bearing to Gnd Station
- Distance to Gnd Station
- Nav Set Freq Channel
- Secondary Nav Mode Set
- Ground Speed
- IFF Mode Code Display
- Malfunction M
- Com Pos 1-6
  - Address
  - Mode
- Preformatted D/L Messages
- Received D/L Messages
- Primary Nav Display
- Position Display Way Point
- Keyboard Functions
- Test Commands

MULTIPURPOSE DISPLAY

CNI FUNCTIONS OR MALFUNCTION DISPLAY

TYPICAL PREPROGRAM

- Weapon Location
- Weapon Status
- Canned Weapon Programs
- Weapon Keyboard Functions
- Remaining Weapons & Stores
- Alternator 1 & 2 Power
- Alternator 1 & 2 Current
- Alternator 1 & 2 Volts
- Test Commands

MULTIPURPOSE DISPLAY

WEAPONS, OR POWER DISPLAY

TYPICAL PREPROGRAM

- Compass Marks
- Heading & Cardinal Numerics
- Airplane & Threat Symbols
- Runway Symbols
- Keyboard Functions
- Test Commands

MULTIPURPOSE DISPLAY

BATTLE SITUATION DISPLAY OR LANDING MONITOR

TYPICAL PREPROGRAM

- Landing Gear
- Flaps Slats
- Wing Sweep
- Trim
- Check List
- Messages
- Hyd Pressure
- Pitch Roll Yaw
- Keyboard Functions
- Test Commands

MULTIPURPOSE DISPLAY

ANCILLARY DATA

TYPICAL PREPROGRAM

DISPLAY

CENTRAL COMPUTER COMPLEX
COMPUTATION FUNCTIONS
- Navigation
- Weapon Release
- Terrain Following
- Air Data
- Signal Conversion
- Pen Aids Programming
- Auto Tgt Acq Processor
- Stores Management Programmer
- Tactical Situation Processor
- Digital System Processor
- Sensor Programming

## IIPACS INTERFACE DIAGRAM

MULTIPURPOSE DISPLAY — CNI FUNCTIONS OR MALFUNCTION DISPLAY — TYPICAL PREPROGRAM

Test Signals

- Hrs-Min-Sec
- To Go
- ing to Gnd Station
- ce to Gnd Station
- Set Freq Channel
- ary Nav Mode Sel
- ead Speed
- Mode Code Display
- ction M
- Pos. 1-6
- dress
- s
- matted D/L Messages
- ved D/L Messages
- ry Nav Display
- ion Display Way Point
- ard Functions
- Commands

MULTIPURPOSE DISPLAY — WEAPONS, OR POWER DISPLAY — TYPICAL PREPROGRAM

Test Signals

- pon Location
- pon Status
- ed Weapon Programs
- pon Keyboard Functions
- aining Weapons & Stores
- rnator 1 & 2 Power
- rnator 1 & 2 Current
- rnator 1 & 2 Volts
- Commands

MULTIPURPOSE DISPLAY — BATTLE SITUATION DISPLAY OR LANDING MONITOR — TYPICAL PREPROGRAM

Test Signals

- pass Marks
- ding & Cardinal Numerics
- lane & Threat Symbols
- ay Symbols
- board Functions
- Commands

MULTIPURPOSE DISPLAY — ANCILLIARY DATA — TYPICAL PREPROGRAM

Test Signals

- Landing Gear
- aps Slats
- ing Sweep
- Trim
- Check List
- ssages
- yd Pressure
- Pitch Roll Yaw
- Keyboard Functions
- Test Commands

DISPLAY

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AUX RADAR MAP CONTROL
- Radar Map Range
- Radar Gain
- Offset On/Off
- Moving Map On/Off
- PPI/Off Center Sector
- North/Heading Up
- Map Slew

FUEL SYSTEM CONTROL
- Refuel Probe Ext/
- Slipway Open Close
- CG – Fwd/Aft/Normal
- Fuel Dump Ext-Int-Ext
- Fuel Quan — L Wing R Wing — Fwd Aft
- Total Fuel Quantity
- Fuel Range Target/Base Mission
- CG Location
- Desired CG Location A/A A/G Cruise

STORES MANAGEMENT
- Stores Selection
- Gun Safe-Off-Charge
- Gun Fire Rate Fast Slow
- Firing Time Remaining
- Auto Man Select
- Test
- Clear
- Master Arm On-Off
- Prearm Arm-Safe
- Rack Unlock-Safe
- Weapon E/O Dome Clean
- Stores Location
- Stores Status

CODED SWITCH CONTROL
- Operate On&Off
- Monitor ASCA/CSA
- Disenable
- Command/Test
- Control Codes
- Control Code
- Coded Switch System Status
- Code Light
- Enable Light
- Disenable Light
- Test Light

EMERGENCY JETTISON
- Conv Weapons Jettison

SELECTIVE JETTISON
- Nuc Weapons Jettison

ENVIRONMENTAL CONTROL
- Oxygen On-Off
- Auto/Man Temp Cont
- Temp Select
- Pressure Pump
- Emer Ram
- Windshield Clearance
- Canopy Defog

MISSION CONTROL
- Input-Keyboard/Voice D/L Cassette
- Load
- Course-Direct/Origin
- Mission Data - Preset/New
- Tape/Keyboard/ Voice Insert
- Data Entry Complete
- Satellite Recv On
- Ins 1 & 2 Status
- AHRS Status

DISPLAY LEVEL CONTROL
- Intensity & Contrast
- Map, HSD, VSD, HUD
- MPD 1-5

CONTROLS

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APU PANEL
- Air/Elec/Hyd Outputs
- PPM
- EGT
- Oil
- Start/Operate
- Test
- Fire Extinguisher
- APU Fire Warning

LIGHTING CONTROL
- Int Lights, R&L
- Flood, R&L Console and Flight Instrum
- Master Int Brightness
- Ext Lights Steady/Flash
- Anticollision
- Air Refuel
- Land
- Test

RUDDER PEDALS
- Pedal Position
- Pedal Force
- Yaw Force Feedback

FLIGHT CONTROLLER
- AFCS Disconnect
- Nose Wheel Steer
- Gun Trigger
- Weapon Release
- Trim (4 Way)
- Roll Stick Force & Position
- Pitch Stick Force & Position
- Brake Command
- Roll Force Feedback
- Pitch Force Feedback

TRAILER THRUST CONTROL
- Microphone
- Speed Brake
- Reverser Enable
- Reverser Commands
- Throttle Commands
- Throttle Position

AFCS MODE SELECT
- Alt
- Nav Steer
- Speed Control
- Auto Terrain Foll
- AFCS Engage
- Wing Sweep

MASTER CAUTION
- Press to Reset

EMERGENCY BEACON
- Press to Disable

ABORT
- Go Around

ARRESTMENT
- Extend Retract

MPD 5

STORES MANAGEMENT

MISSION CONTROL

AUXILIARY POWER UNIT

TRAILER THRUST CONTROL

DESIGNATIO

HUD

MPD 1

VSD

MPD 2

MPD 5

RADAR MODE SELECT

MPD 3

HSD

MPD 4

STORES MANAGEMENT

(PRE ENTRY READOUT)

MODIFY

DISPLAY

MASTER KEYBOARD SELECT

CLEAR

ENTER

E-O
AUXILIARY
CONTROL

TRAILER THRUST CONTROL

DESIGNATION CONTROL STOWED

B

FLIGHT CONTROLLER

FLIGHT CONTROLLER