CHAPTER 5

Timing Requirements

Periodic and demand functions are separated because the relevant timing information is different. Otherwise, the functions appear in the same order as in Chapter 4.

5.1. TIMING REQUIREMENTS FOR PERIODIC FUNCTIONS

In the following table, the entry ‘‘current’’ means the same value that appears in the ‘‘Current Rate’’ column for that function.

Function Name	Current Rate	Minimum Allowable Rate	Maximum Useful or Allowable Rate
IMS:			
Torque platform X axis	20 ms	40 ms	current
Torque platform Y axis	20 ms	40 ms	current
Torque platform Z axis	20 ms	40 ms	current
Flash INA light	not significant		
FLR:			
Update azimuth-cursor position[1]	80 ms	current	40 ms
Update range-cursor position	80 ms	current	40 ms
Update antenna azimuth	40 ms	current	current
Update antenna elevation	40 ms	current	current
Output ground track velocity	200 ms	current	current
Update flight path angle	200 ms	current	current
HUD:			
Update AS coordinates[1]	40 ms	40 ms	40 ms
Update ASL coordinates	67 ms	80 ms	40 ms
Update ASL angle	67 ms	80 ms	40 ms
Update barometric altitude	40 ms	80 ms	current
Update flight director coordinates	67 ms	80 ms	40 ms
Update FPM coordinates	67 ms	80 ms	40 ms
Update HUD magnetic heading	200 ms	current	40 ms
Update HUD pitch angle	40 ms	current	current
Update PUAC coordinates	200 ms	current	40 ms
Flash PUAC	40 ms		
Update HUD roll angle	40 ms	80 ms	current
Update lower solution cue coordinates	200 ms	current	40 ms
Update upper solution cue coordinates	200 ms	current	40 ms
Flash solution cues	200 ms		
Update HUD vertical velocity	40 ms	current	current
Update HUD vertical derivative	40 ms	current	current

Function Name	Current Rate	Minimum Allowable Rate	Maximum Useful or Allowable Rate
Map:			
Output azimuth ring angle	200 ms	current	40 ms
Output destination pointer angle	200 ms	current	40 ms
Output orientation angle	200 ms	current	40 ms
Update filmstrip position[1]	200 ms	current	40 ms
Panel:			
Panel display functions	1000 ms	1000 ms	100 ms
HSI:			
Update bearing indicator	200 ms	current	current
Update ground track angle	200 ms	current	current
Update range indicator	200 ms	current	current
ADI:			
Update azimuth steering needle position	67 ms	80 ms	current

5.2. TIMING REQUIREMENTS FOR DEMAND FUNCTIONS

For all the demand functions, the rate of demand is so low that it will not constitute a significant CPU-load.

For the starred entries, the desired maximum delay is not known; the entry is the maximum delay in the current OFP, which we will use as an approximation. In one case, both the current and desired values are given. The current value would be good enough to satisfy requirements, but the desired rate would be preferred.

Function name	Maximum delay to completion
IMS:	
Switch AUTOCAL light on/off	*200 ms
Switch computer control on/off	*200 ms
Issue computer failure	not significant
Change scale factor	*200 ms
Switch X slewing on/off	*200 ms
Switch Y slewing on/off	*200 ms
Switch Z slewing on/off	*200 ms
Change latitude-greater-than-70-degrees	*200 ms
Switch INA light on/off	*200 ms
FLR:	
Enable radar cursor	200 ms
Slave or release slave	40 ms
HUD:	
Switch AS on/off	*200 ms
Switch ASL on/off	200 ms

[1]When these display items are slewed, the only timing requirement is that their movement appear to a human to be continuous.

Function name	Maximum delay to completion
Flash FPM	40 ms
Switch pullup cue on/off	40 ms
Switch both solution cues on/off	*40 ms
Switch velocity indicators on/off	*1000 ms
ASCU:	
Switch bomb release on/off	2 ms
Switch fire ready on/off	2 ms
Switch bomb tone on/off	concurrent with release enable
Panel:	
Change window display	300 ms (desired); 1000 ms (current)
Accept pilot data entry	40 ms
Change panel MARK display	200 ms
Switch panel ENTER light on/off	40 ms

CHAPTER 6

Accuracy Constraints on Software Functions

The purpose of Chapter 6 is to state the acceptable errors or tolerances for each of the functions described in Chapter 4. Accuracy requirements vary with A/C situation, weapon type, mode of operation and other factors.

Our original intention was to have Chapter 6 contain tables defining the tolerances in a way analogous to the tables defining the output values in Chapter 4. Unfortunately, the data necessary to complete such tables are not available to us. In a development of a totally new weapon system, the mission analysis necessary to determine these requirements would have been justified. Knowledge of the tolerances would be necessary to make rational choices of computation methods, data representation and resource allocation. In the present system, we have available a model with acceptable performance, and we know that the methods and representations used in that model are adequate to the task. For that reason, we have omitted Chapter 6 from this document and take as our requirement that we must meet or exceed the accuracy of the present system.

CHAPTER 7

Undesired Event (UE) Responses

7.0. INTRODUCTION

This chapter describes system responses to undesired events, such as hardware malfunctioning. It includes both responses made by the current OFP and hypothetical responses considered reasonable by system engineers. If our only purpose were to duplicate the current OFP, this chapter would be redundant, since the current responses are described in Chapter 4. However, we are also concerned with making the system easy to change. One very common change to a system is an improved response to an undesired event. To anticipate these changes, we have sketched the kinds of responses that might be considered useful.

For each response, we have indicated in the two columns to the right a) whether it is performed in the current OFP, and b) the system engineers' judgment of its usefulness. Responses are classified ‘’Y’’’ (Yes), ‘’N’’’ (no) and ‘’M’’’ (maybe). We included some responses judged not useful in order to keep a record of their consideration.

Although the responses are organized by means of detection, we do not describe how each of the UEs is detected. We organized them in this way because it gave us a systematic approach, so that we could be reasonably sure of completeness. We continue to use it because we believe gaps will show up more clearly.

	Current	Desired
UEs detected by periodic self checks		
a. IMS not functioning		
1) Inform pilot (currently !DATA 98! display).	Y	Y
2) Go to backup NAV mode (*IMS fail*).	Y	Y
b. Doppler not functioning		
1) Inform pilot (currently !Data 98! display).	Y	Y
2) Switch navigation modes. (From *DIG* or *DI* to *I*; from *UDI* to *OLB*).	Y	Y
3) If it starts functioning again, wait five seconds before using data.	Y	Y
c. ADC not functioning		
1) Set barometric altitude to nominal value: 4500 ft.	Y	Y
2) Inform pilot (Mark window when !Data 98! displayed).	Y	Y
3) Use other sources of velocity and altitude.	Y	Y
4) Do not do baroaltitude damping of vertical velocity.	Y	Y
5) Allow pilot to enter winds in keyboard.	Y	Y

	Current	Desired
d. FLR not functioning		
1) Flash solution cues to inform pilot if FLR not functioning when slant range sampled.	Y	Y
2) Revert to radar altimeter ranging or barometric altimeter ranging, depending on value of !Data 24!.	Y	Y
e. Radar Altimeter not reasonable.		
1) Inform pilot.	N	M
2) Revert to barometric altimeter ranging.	Y	Y
f. Memory checksum incorrect		
1) Stop - Force failsafe and switch computer fail light on.	Y	M
2) Run in a "restricted state." Navigate, no computed weapon release, warn pilot. If function performed by faulty memory area can be identified, leave out that function.	N	M
g. SINS data bad		
1) Inform pilot by wiggling HSI #2 needle.	Y	Y
UE's detected by software demand self checks		
a. Memory checksum fails (on ground)		
1) Stop - Force failsafe and switch computer fail light on.	Y	M
b. Computer instruction self test fails (not currently tested)		
1) Inform pilot by switching computer fail light on.	N	Y
2) Run in a "restricted state." Navigate, no computed weapon release, warn pilot. If function performed by facility memory area can be identified, leave out that function.	N	M
c. Signal Converter Self-test fails (currently only on ground)		
1) Turn fail light on; enter wait state.	Y	M
2) Record which test failed for later analysis.	N	M
d. HUD test pattern fails test (detected with help of pilot)		
1) Possible symbol substitution. (Training and human factors problems.)	N	M
UEs detected by pilot		
a. Pilot puts in incorrect data then notices it		
1) Rejection acknowledged.	Y	Y
2) Pilot may start over.	Y	Y

	Current	Desired
b. ASCU code incorrect (Rarely occurs; always part of pilot preflight check).		
1) Allow pilot to override hardware supplied data.	N	N
c. IMS producing bad data		
1) Pilot selects backup mode (*Grid* or *Mag Sl*).	Y	Y
d. ADC producing bad data		
1) Pilot should be able to declare ADC data failure.	N	Y
2) Behavior same as hardware detected failure.	N	Y
e. FLR not functioning		
1) Pilot turns it off.	Y	Y
f. HUD not functioning		
1) Pilot turns HUD off. HUD down weapon delivery modes may be entered.	Y	M
2) Pilot should be able to indicate nature of failure.	N	Y
3) Symbol substitution should be done on request.	N	M
g. ASCU not functioning		
1) Weapon delivery functions stopped. Software should not interfere.	N	Y
h. PMDS not functioning		
1) System ignores PMDS. PMDS indicates failure.	N	Y
i. TC-2 panel control not functioning		
1) Use armament panel to inform computer. Considered too complex for pilots.	N	N
2) Perform most frequently needed services with system aware that the panel is not functioning.	N	M
j. Radar altimeter not functioning		
1) Pilot turns it off.	Y	Y
2) Revert to baroaltimeter ranging.	Y	Y
k. Slew Control not functioning		
1) Pilot can inform computer.	N	Y
2) OFP ignores slew control.	N	Y
3) Alternate input source used to indicate slew.	N	N
l. Doppler not functioning		
1) Pilot switches it off.	Y	Y

	Current	Desired
2) Behaves as if the computer detected the failure.	Y	Y
m. TACAN not functioning		
1) Pilot won't use it.	Y	Y
2) System should ignore it.	Y	Y
n. AOA data bad		
1) Pilot can inform computer.	N	Y
2) Computer ignores input and uses a constant.	N	N
3) Pilot can change the constant.	N	N
o. SINS communication not functioning (ground only)		
1) No action.	Y	Y
p. Weight on wheel switch not functioning		
1) Possible Action: Override (might not be permitted).	N	N
q. Release enable switch not functioning		
1) Pilot informs computer to ignore setting of switch.	N	Y
2) Alternate input designated.	N	M
r. Designate switch not functioning		
1) Pilot informs computer.	N	M
2) Pilot can use release enable switch as alternate input.	Y	M
s. HSI not functioning		
1) Pilot informs computer.	N	Y
2) Display "distance to target" on HUD at pilot option.	N	M
3) Make other items available on panel.	N	M
t. ADI not functioning		
1) No action.	Y	M
u. Flight recorder not functioning		
1) Pilot informs computer.	N	Y
2) Don't ship data to flight recorder.	N	Y
v. Bomb tone not functioning		
1) Computer need not perform bomb tone functions.	N	Y
2) Possible use of light or HUD display symbol.	Y	Y
UEs detected by timeouts		
a. GO/NO-GO counter hits zero		
1) Save data.	N	Y

	Current	Desired
2) Pilot informed by 8's in window.	Y	Y
UEs detected by computer hardware		
a. DIAGNOSE instruction (not used in flight)		
1) None.	Y	M
b. Power interruption		
1) Perform a restart if airborne and IMS ready. Otherwise, perform a complete reinitialization.	Y	M

CHAPTER 8

Required Subsets

8.0. INTRODUCTION

Chapter 4 characterizes the functions of the A-7 OFP. The primary requirement is that the OFP be able to perform all of these functions. In addition, we require that the program be structured to facilitate the development of a set of *function subsets* that will:

(a) perform only a subset of the services performed by the whole OFP;

(b) be obtained by the removal of clearly identified sections of code and data structures without modification* of the remaining programs.

(c) use an amount of memory space and execution time roughly comparable to that which would have been used if the program had been originally developed to perform only that subset of the functions.

Note that these requirements cannot be satisfied by simply ''turning off'' the unneeded functions. The space and time consumed by the implementation of those functions would not be made available for other purposes.

These requirements can be reformulated by saying that when the subset systems are needed, they should use time and space in proportion to the complexity of the services, and the bigger subsets and the OFP itself should be obtained by adding code to the smaller subsets without modifying the code of the smaller subsets.

8.1. POTENTIAL SUBSETS

This section describes the potentially required OFP subsets in more detail.

8.1.1. Output Subsets

We consider a set of output data items to be a *user package* if it would not be useful to output just one of these items. For example, the Aiming Symbol azimuth (//ASAZ// and Aiming Symbol elevation (//ASEL//) form a user package because the HUD is not able to display the Aiming Symbol unless both of these items are provided.

There must be a subset available to transmit each user package. For example, there should be a subset available to perform the function

Display Azimuth Steering Line (AZIMUTH, ELEVATION, ANGLE)

A subset is required for each HUD symbol, for IMS-slew for each axis, for IMS-torque for each axis, for FLR antenna control, for FLR cursor display, for bomb release and fire ready, for PMDS display positioning, for panel display, for HSI bearing to destination, ground track, range to destination, for bomb tone, for ADI and for the miscellaneous discrete items.

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* It may be necessary to reassemble, using new assembly-time constants.

8.1.2. Input Subsets

We consider input data items to form a *user package* if one must know the value of one to make use of the value of the others. For example, we consider True Heading Cosine and True Heading Sine a user package because one must know both cosine and sine to determine the quadrant. There must be a subset capable of reading in any of these input user packages. These will include magnetic heading, pitch, role, true heading, X, Y, and Z accelerations, barometric altitude, mach number, true airspeed, FLR lockon and slant range to target, ASCU status, PMDS status, each of the panel switches and thumbwheels, radar altitude, slew control position and movement, the various MFS and ARP input switches, Doppler drift angle, Doppler ground speed, TACAN range and bearing to destination, AOA, and SINS inputs. The SINS subset is not needed when airborne. The memory allocated to it may be used for other purposes while airborne provided that it can be regenerated when a SINS input is available.

8.1.3. Hardware Test Subsets

There should be a subset capable of executing the hardware test sequences for any of the hardware units. Since these tests are not conducted when airborne, the remarks made about the SINS input subset apply here as well.

8.1.4. Scheduling Subset

There will be a subset of the system that provides for the synchronization and scheduling of a fixed number of concurrent activities with real-time deadlines. By means of reassembly it will be possible to adjust the space to take advantage of a decrease in the number of such activities or to allow for an increase in the number of such activities.

8.1.5. Real-time Input Data Base

The system will include a subset that makes current values of the input data items available to the rest of the OFP. This subset will use the input subsets and the scheduling subset. The data base subset will be so constructed that if certain data items are not needed, the memory space and cpu time devoted to maintaining those items can be saved at the cost of a reassembly operation.

8.1.6. Periodic Output Data Base

For those data items that must be output periodically, there will be a subset that maintains a record of the most recent values and sends them to the appropriate devices at the necessary intervals. This subset will use the output subsets and scheduling subset. It will be so constructed that if certain items are not being transmitted, the memory space and CPU time devoted to maintaining those items can be saved by means of a reassembly operation. This subset makes pseudo-output commands available to the rest of the OFP which then acts as if there was continuous output of the items in the data base.

8.1.7. Navigation Subsets

The system shall be capable of performing navigation functions without the presence of any of the weapons delivery software. In particular, the software required to maintain an estimate of current position and heading shall function without the presence of any weapons delivery software. It shall be possible to provide navigation information to the pilot through either the HUD, the HSI, the PMDS, or the panel even if the software used to display information on the other three devices is not available. Similarly, there shall be subsets available to perform navigation services using only a subset of the normal input devices wherever alternate means of obtaining the necessary input are available.

8.1.8. Weapons Delivery Subsets

There shall be functional subsets available for each of the possible subsets of the weapons carried on the aircraft. In the event that a weapon is not available or used, it shall be possible to generate a subset of the system in which the table space and code used for that weapon is made available for other uses.

8.1.9. Pilot Display Subsets

It shall be possible to produce a subset that eliminates some of the information displayed to the pilot. For example, a subset that does not include PMDS display functions should be available.

8.1.10. Alignment and Calibration Subsets

Subsets shall be available that can only perform land-based alignment or only perform ship-based alignment. Subsets without air alignment capabilities shall be available. All systems should be able to perform functions without the presence of the land or ship alignment code when airborne.

8.2. REQUIRED SUBSETS

This section describes all subsets that shall actually be delivered. Each is specified by describing the differences between it and the full OFP specified elsewhere in this document.

8.2.1. The Useful Subset

8.2.1.1. Data items

Data items belonging to the following devices shall not be included:

Bomb Tone (see Section 2.3.4)
Projected Map Display Set (see Section 2.1.6)
Shipboard Inertial Navigation System (see Section 2.2.8)
TACAN (see Section 2.2.6)
Waypoint Information System (see Section 2.2.11)

The following additional data items shall not be included:

//AUTOCAL//
//CURAZCOS//
//CURAZSIN//
//CURPOS//
//IMSNA//
/PNLTEST/

Only the following !Weapon Class! members shall be included: GN, HD, MD, SL, SH, SM, UN. All others shall be returned as UN.

8.2.1.2. Modes

Only the following modes shall be included. Actions which would cause an entry into one of the deleted modes shall cause no transition:

Alignment:	*Landaln*
Navigation:	*I*, *DIG*

Nav Update:	*HUDUpd*, *UNone*
Weapon:	*Nattack*, *Noffset*, *Manrip*, **NBnotShrike**, *WNone*
Test:	none

8.2.1.3. Functions

The following functions are not included:

A function to drive a deleted output item;
Update SINS X and Y Offsets Display;
Update SINS Z Offset and Delta Heading Display;
Update Map Coordinates Display;
Update DATA 03 through Update DATA 22;
Update DATA 26; !Land! shall always be true;
Update DATA 71 (lower window);
Update DATA 90;
Update DATA 91 (lower window);
Update DATA 92/93 (lower window);
Update DATA 94.

CHAPTER 9

Expected Types of Changes

9.0. INTRODUCTION

This chapter characterizes the requirement changes that can be expected in the future. It is impossible to give specific details of any particular change, but we wish to point out the aspects of this document that cannot be considered fundamental when designing the system. However, there are a few fundamental assumptions about the system that are not expected to change whatever enhancements are made. These are listed in Section 9.1.

9.1. FUNDAMENTAL ASSUMPTIONS

9.1.1 The flight characteristics and weapon characteristics are adequately characterized by the mathematical models documented in Refs. 6,7,10,11,12, 13,25. The flight conditions and mission conditions are such that the approximations made in deriving the equations will remain sufficiently accurate. All parameters that can vary from aircraft to aircraft, location to location, or weapon to weapon, are adequately identified in the referenced documents.

9.1.2 Point of impact (weapon delivery) calculation can not be accurately performed if alignment or location data are not accurate.

9.1.3 The computer will not be assigned ‘‘background’’ functions with non-real-time computation such as map-making, digital picture processing, etc.

9.1.4 When writing the programs, realistic (worst-case) upper bounds on memory requirements and cpu cycle requirements for each function can be predicted and will be independent of flight conditions.

9.2. COMPUTER CHANGES

9.2.1 The computer might be replaced by a TC-2A.

9.2.2 Additional channel hardware might be added to the TC-2.

9.2.3 Additional interlocks or improvements might be added to the present TC-2 channels.

9.2.4 A completely different computer might be substituted (very unlikely).

9.2.5 A register other than the A register might be used as an I/O buffer.

9.2.6 TC-2 Panel may be used for other parameters or pilot selectable switches.

9.3. INTERFACE CHANGES

9.3.1. General

(a) Assignment of devices to channels may be changed.

(b) Assignment of bits to discrete words may be changed.

(c) All data representations may be changed.

9.3.2. FLR

(a) Display symbology may be changed.

(b) Range characteristics could be improved.

9.3.3. HUD

(a) Data Item Identity codes could be changed.

(b) Symbols could be added.

(c) Computer controlled intensity or color could be added with a new HUD.

9.3.4. Other Uses of Flight Recorder

(a) Flight recorder might be used as a serial output channel.

9.3.5. ASCU

(a) ASCU might be replaced by computer controllable unit.

9.3.6. PMDS

(a) Map might be replaced by a unit that can be positioned more quickly (unlikely).

(b) Other film-strip formats and scaling might be used.

9.3.7. TC-2 Panel

(a) Additional switches or positions may be added (very likely).

9.3.8. Slew Control

(a) An extension dimension might be added (in A-6, but not likely for A-7).

9.3.9. Doppler Radar Set

(a) Precision might be increased (very unlikely).

9.3.10. Weapon Characteristic Parameters Are Subject to Change (Frequently)

9.4. FUNCTION CHANGES

9.4.1. General

(a) Improved processing algorithms might be added (e.g., Kalman filters).

(b) Performance rates and time limits are considered subject to change.

(c) New display information might be added (includes all pilot displays).

(d) More accuracy might be required.

(e) Comparison of redundant inputs (e.g., barometric vs. FLR slant range) may be added to detect major errors.

(f) New sensors (e.g., Forward Looking Infra-Red (FLIR)) may be added.

9.4.2. HUD

(a) Additional information might be provided by flashing, intensity (unlikely), color (unlikely), or new symbols.

(b) Meaning associated with symbols could be changed (Flight Path Marker, PUC are not allowed to change).

9.4.3. Panel

(a) Data entered by pilot could be displayed after ENTER pushed, so that he can verify (likely).

(b) Display before entering could be omitted.

9.4.4. New Weapons Functions

(a) Some weapons might require computer control after release (not likely).

(b) Some new weapons might require programming just before release (already planned).

(c) Some weapons might transmit data to computer after release.

(d) Some weapons might be tracked by A/C sensors after release and their positions displayed to pilot (not likely).

9.4.5. RECON Functions

(a) Camera and similar equipment might be added with computer control performing such functions as camera control after pilot does target designate (considered but unlikely).

9.4.6. In-flight A/C Monitoring Functions

(a) The computer might be provided with sensors monitoring A/C systems and required to warn the pilot of abnormal conditions by means of HUD display (not likely for A-7 but planned for other aircraft).

9.4.7. SYSGEN Capability Shipboard

(a) It may be necessary to remove portions of the OFP and add others when a special pod is changed (missionized software).

9.4.8. Suspension of Low Priority Activities to Allow Special Functions

(a) It may be necessary to cease certain functions (e.g., displays, monitoring functions) in order to free computing resources for some demand function (example: map driving during bomb run).

9.4.9. Internal A/C Communications Functions

(a) Software might have to serve as data link between other devices by getting data from one device and sending data to some other (not likely).

9.4.10. Accept Information Over Data Link While Airborne

(a) Updates in the air with the aid of ground stations might be required.

(b) Airborne A/C may accept destination data over data link.

9.4.11. Lateral Control of Aircraft

9.4.12. Parallel Processing of Release/Impact Points, Etc. for Several Weapons

9.4.13. Calculations for Two Destinations (One a Target) (Already Planned)

9.4.14. More Support for Moving Targets

9.4.15. Multi-step Flight Path Navigation

9.4.16. Electronic Warfare Counter Measures

(a) Example: checks on reasonableness.

9.4.17. Computer Self-test During Flight