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Functional Performance Specification
for an External Computer System Simulator

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August 1988

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Technical Report

CMU/SEI-88-TR-25

ESD-TR-88-026

August 1988

Functional Performance Specification for an External Computer System Simulator



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Carnegie Mellon University
Pittsburgh, Pennsylvania 15213

This technical report was prepared for the

SEI Joint Program Office
ESD/XRS
Hanscom AFB, MA 01731

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Review and Approval

This report has been reviewed and is approved for publication.

FOR THE COMMANDER


Karl H. Shingler
SEI Joint Program Office

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Inertial Navigation System

Functional Performance Specification for an External Computer System Simulator

Abstract: This document defines the functional and performance requirements for the external computer system (ECS) simulator that interfaces with the inertial navigation system simulator. Both the ECS simulator and the INS simulator are being developed in Ada by the Real-Time Embedded Systems Testbed Project at the Software Engineering Institute (SEI). The ECS simulator is similar to a real-world ECS, but has reduced functionality. This document provides specifications for the major functions of the ECS simulator.

1. Introduction

This document contains the functional and performance requirements for the external computer system (ECS) simulator that interfaces with the inertial navigation system (INS) simulator. This document was developed by the Real-Time Embedded Systems Testbed Project of the Software Engineering Institute.

In the real world the INS provides accurate information about ship position and motion on a time-critical basis to the ECS. The ECS interfaces with the INS and is capable of receiving and transmitting messages to the INS. The ECS also has functional requirements for providing information to launch controllers (such as missile guidance sets) and other shipboard systems.

The functionality of the ECS simulator is similar to the real-world ECS functionality, but less complex. The ECS simulator receives simulated ship position and motion information on a time-critical basis from the INS simulator. The ECS simulator interfaces with the INS simulator and receives messages from and transmits messages to the INS simulator. The major differences between the real-world ECS and ECS simulator are (1) the ECS simulator will not provide information to shipboard systems, and (2) the ECS simulator will not build and transmit the Navigation Satellite (NAVSAT) message. The ECS simulator does transmit and receive the remaining messages that are specified in reference [1]. It does adhere to the message formats, time constraints, and communications protocols that are specified in that reference.

This document specifies the functional and timing requirements for the ECS simulator. Thus, this program is developed to interface with the INS simulator. However, the scope of this document is to present message processing functions and the operator interaction. Detailed processing, such as missile guidance set alignment, is not considered in this document.

2. Functional Overview

This chapter briefly discusses the basic functional and performance requirements applicable to the ECS simulator, which interfaces with the INS simulator. References [1] and [2] are applicable to this system. The major functional description of the ECS simulator includes the following seven functions:

1. Initialization
2. Enable/disable communications
3. Message processing
4. Operator interface
5. Database management
6. Data logging
7. Scripting

Each of these functions is briefly described in the following subsections. A detailed description of these functions is provided in Chapter 3.

2.1. Initialization Function

The initialization function is responsible for initializing all variables used in the program. This function is initiated upon the start of program execution. Following completion of this function, control is transferred to the operator interface function.

2.2. Enable/Disable Communications Functions

The initiation and termination of interface communications between the INS simulator and ECS simulator are the responsibility of the ECS simulator and are under control of the operator. The purpose of these functions is to perform the steps necessary to enable and disable communications. The operator may enable communications any time communications have been disabled. The operator may also re-enable communications while communications are enabled. Communications may be disabled any time they have been enabled.

2.3. Message Processing Function

The message processing function is responsible for processing all messages to and from the INS simulator. As such, this function is also responsible for testing the state of communications between the INS simulator and the ECS simulator. The message processing involves the transfer of messages that contain 16-bit data words and appropriate 16-bit external functions, described in reference [1].

The following messages are transmitted from the INS Simulator to the ECS Simulator:

1. Test data
2. Navigation data periodic
3. Time and status data
4. Attitude periodic data

The attitude periodic data message is transmitted every 61.44 ms, and the navigation data periodic message is transmitted every 980 ms.

The following messages are transmitted from the ECS simulator to the INS simulator:

1. Test data
2. Select data

The select data message is used to request messages the INS simulator is to transmit to the ECS simulator. The message processing function also performs validation checks on inter-computer messages received.

2.4. Operator Interface Function

The ECS simulator has an operator console for (1) displaying the values of incoming messages, (2) allowing the operator to enter commands, (3) displaying alerts, and (4) displaying the ECS simulator status. The screen layout is shown in Figure 1. The upper part of the screen is the message display area where data contained in the incoming messages are displayed. Below this is the command input area where the operator enters commands. Next comes the alert display area where messages to the operator are displayed. At the bottom of the screen is the status display area where the status of ECS simulator events is displayed (e.g., the state of communications with the INS simulator, which select data message was last transmitted, and the status of data logging, scripting, and the enabling of test data messages).

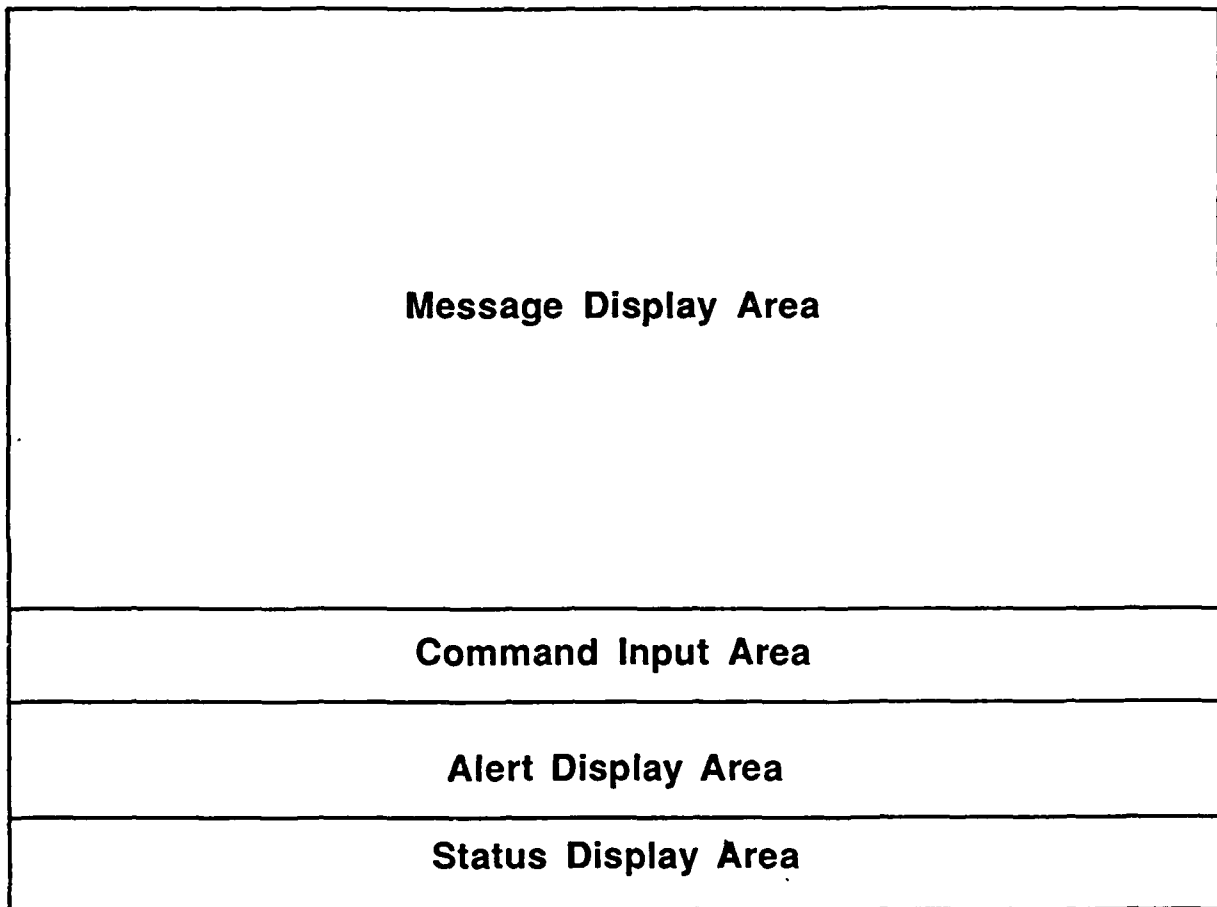


Figure 1: ECS Operator Console Screen Allocation

The operator commands may be grouped into the following categories:

1. **ECS simulator Initialization.** The operator starts the ECS simulator by issuing a command that starts the real-time clock.
2. **Communications control.** The operator has the ability to enable or disable communications between the INS simulator and ECS simulator.
3. **Message Selection.** This category of commands allows the operator to choose the kind of select data message to be transmitted to the INS simulator. This category includes the commands for enabling and disabling the periodic test data message. The select data message tells the INS simulator to begin transmitting the navigation data periodic message, the attitude data periodic message, both, or neither. The transmission of the periodic test data message is enabled and disabled by the operator.

4. **Data logging.** The operator may specify that data logging is enabled or disabled. When enabled, all words (both message words and external functions) transmitted to the ECS simulator (from the INS simulator) are recorded to a disk file that is available for post-processing. Time tags of the message arrival times are included in the log file.
5. **Fault Injection.** Fault injection provides the operator with the ability to change the values of the parameters that are sent in messages to the INS simulator. The intent of this capability is to provide a method for assessing the response of the INS simulator to faulted values.
6. **Scripting.** Scripting provides the capability of sending to the INS simulator a prescribed sequence of external functions and message words contained in a user-defined script file. When transmitted to the INS simulator, the normal send or receive protocols are bypassed.
7. **Use file.** An alternative way for the operator to enter commands is by means of use files. These files are built off-line. They may contain any of the commands discussed in Section 3.4.2.

The fault injection, scripting, data logging, and use-file capabilities are all useful for testing purposes.

2.5. Database Management Function

The database management function is responsible for maintaining the current values of selected variables. The values of these variables are updated by messages input from the INS simulator, as well as by the operator. This function also provides information that is periodically displayed to the external computer system operator.

2.6. Data Logging Function

The data logging function provides the capability of recording to disk file all external functions and message words that are sent from the INS simulator to the ECS Simulator. These log files may be examined and analyzed by post-processing routines. The ECS simulator operator has the ability to turn data logging on and off.

2.7. Scripting Function

The scripting function is responsible for providing a means for sending user-defined scripts that may contain external functions and message words, to the INS simulator. This is accomplished by bypassing the normal ECS simulator send and receive protocols. The script files are built off-line. Console commands allow the operator to load and run script files. The scripting function provides a capability for testing INS simulator communications protocol and message validation.

3. Detailed Processing Requirements

This chapter specifies the detailed processing requirements applicable to the ECS Simulator. The following discussion is intended to be used in conjunction with the requirements specified in reference [1]. That is, the details of the message processing, such as protocols and internal timing constraints, are contained in the cited reference and will not be repeated here. This discussion is based on functional criteria.

3.1. Initialization Function

The initialization function is initiated upon program execution and is responsible for setting values of all variables used by the ECS simulator. All internal variables are required to be initialized within this function.

Additionally, this function performs all initialization for variables used in connection with message processing. A list of the applicable messages and their initial values is listed in Table 1.

3.2. Enable/Disable Communications Functions

The purpose of the enable communications function is to establish or re-establish communications between the ECS simulator and the INS simulator. This function is initiated by the ECS simulator operator. When this function is invoked, the enabling sequence begins with the ECS simulator transmitting an enable communications (ATTN2) external function to the INS simulator. The meanings of all external functions discussed in this document are listed in Appendix 1. The subsequent steps of the enable processing message interchange are specified in reference [1].

The purpose of the disable communications function is to allow the operator to disable communications between the ECS simulator and the INS simulator. When the operator has requested that communications with the INS simulator be disabled, control is transferred to this function.

The disabling of communications is accomplished by the ECS simulator transmitting a disable communications (ATTN4) external function to the INS simulator. Upon receipt of this message, the INS simulator terminates the transmission of all messages to the ECS simulator.

Table 1: ECS Simulator to INS Simulator Messages and Initial Values

Test Data Message

Field Name	Value
Message Type	16
Number of Words	4
Source	0
Test Word 1 (TW1)	125252 (octal)
Test Word 0 (TW0)	052525 (octal)

Select Data Message

Field Name	Value
Message Type	1
Number of Words	4
Data Identification (DID)	3
Test Word 1 (TW1)	125252 (octal)
Test Word 0 (TW0)	052525 (octal)

3.3. Message Processing Function

The message processing function is responsible for all message-dependent processing between the ECS simulator and the INS simulator. This processing is specified in terms of the following:

1. Message validation requirements
2. Test data message processing
3. Message-dependent processing

3.3.1. Message Validation Requirements

Certain basic message validation requirements are applicable to the message processing function. These are:

1. All messages received from the INS simulator shall contain a valid message type.
2. All messages received from the INS simulator shall contain a correct number of words for the message type received.

3. The basic test word patterns (TW0 and TW1) contained in each message shall be correct.
4. For external functions only, the external function must not be received out of sequence.
5. The message transmission shall comply with data transfer and message sequence protocols.

The details regarding what happens when an error is detected in any of the above are specified in reference [1].

3.3.2. Test Message Processing

To verify the integrity of intercomputer data transmission, provision is made for the interchange of test data messages between the ECS simulator and the INS simulator. Test message processing occurs (1) when the ECS simulator transmits periodic test data messages and (2) during the enabling communications sequence. The details of the test message processing are found in reference [1].

3.3.3. Message-Dependent Processing

For certain messages received from the INS simulator, the ECS simulator shall perform special processing. This involves validating certain fields within messages and is specified in the following:

Upon receipt of a navigation data periodic message from the INS simulator the following quantities shall be validated:

1. Latitude
2. Longitude
3. East component of ownship velocity
4. North component of ownship velocity
5. East component of ocean velocity
6. North component of ocean velocity
7. Ownship speed
8. EMLog calibration correction
9. Ownship heading
10. Ownship pitch
11. Ownship roll
12. Radial error estimate
13. Time of gyro reset
14. Greenwich Mean Time
15. Start of message Greenwich Mean Time
16. Integral of velocity north
17. Integral of velocity east

Upon receipt of a time and status data message, the following fields shall be validated:

1. Status
2. Local status
3. Remote status
4. Greenwich Mean Time

Upon receipt of an attitude periodic data message, the following information will be validated:

1. Ownship heading
2. Ownship pitch
3. Ownship roll
4. Ownship heading rate
5. Ownship pitch rate
6. Ownship roll rate
7. Greenwich Mean Time
8. East component of ownship velocity
9. North component of ownship velocity
10. Vertical component of ownship speed
11. Ownship speed

For each of the above messages, the ECS simulator shall validate that the received data fields are within the bounds specified in reference [1], where applicable. If a value is outside the specified range, an alert shall be displayed on the operator console and communications shall be re-initialized with the INS simulator.

3.4. Operator Interface Function

The operator interface function is responsible for displaying information to the operator as well as allowing the operator to provide input to the system. This function is described in terms of a message display function, command input function, alert display function and status display function. Each is described below.

3.4.1. Message Display Function

The top portion of the screen is reserved for the display of select information contained in the navigation data periodic message, attitude data periodic message and time and status data message. The information displayed is shown at the top of Figure 2.

ECS Emulator			
WSN-5-EC-OD4 (ATT)	WSN-5-EC-OD2 (NAV)	Latitude:	xx.xx North
Vel East: xxx.xx knots	Vel East: xxx.xx knots	Longitude:	xxx.xx West
Vel North: xxx.xx knots	Vel North: xxx.xx knots	Cum East:	xxxxxxx.x feet
Vel Vert: xxx.xx knots		Cum North:	xxxxxxx.x feet
Speed: xxx.xx knots	Speed: xxx.xx knots	WSN-5-EC-OD3 (T/S)	
Heading: xxx.xx deg	Heading: xxx.xx deg	GMT:	xx.xx.xx hms
Pitch: xxx.xx deg	Pitch: xxx.xx deg		
Roll: xxx.xx deg	Roll: xxx.xx deg	MESSAGE ARRIVAL TIMES	
Head Rate: xx.xx deg/s		Attitude:	xxxxx.xxx sec
Pitch Rate: xx.xx deg/s		Navigation:	xxxxx.xxx sec
Roll Rate: xx.xx deg/s	TGR: xx.xx.xx hms	Time/Stat:	xxxxx.xxx sec
GMT: xx.xx.xx hms	SOM GMT: xx.xx.xx hms	Test:	xxxxx.xxx sec
	GMT: xx.xx.xx hms		
ECS>			
<hr/>			
COMMS: Disabled	SCRIPT: Not Loaded	DATA LOG: Inactive	
TEST MSG: Disabled	ATTITUDE MSG: Not Selected	NAVIGATION MSG: Not Selected	

Figure 2: Sample Operator Console Layout

The message display function updates the message display area at a rate of once every second.

3.4.2. Command Input Function

This function is responsible for the input, parsing, and interpreting of commands and data from the operator. Any errors detected in the processing of these commands results in an alert being issued to the operator and the erroneous command is ignored.

3.4.2.1. ECS Simulator Initialization

The operator starts the ECS simulator by issuing the following command:

BEGIN

This starts the real-time clock. It allows periodically scheduled tasks (e.g., the display processor) to be dispatched in response to clock interrupts. This will cause the ECS Simulator notion of wall clock time and elapsed time to be updated at each clock interrupt. This command must be executed before communications can be enabled.

3.4.2.2. Communications Control

The operator has the ability to enable and disable communications between the INS simulator and the ECS simulator. The form of the command to enable communications is:

ENABLE COMMS

This causes the ECS simulator to attempt to establish a communications link with the INS simulator. If the ECS simulator is able to establish communications, the communication status display in the status display area the operator console (see Figures 1 and 2) will be updated to indicate that communications have been enabled. If the ECS simulator is not able to establish communications with the INS Simulator, an alert will be raised.

The command to disable communications is:

DISABLE COMMS

This causes the ECS simulator to break the communications link with the INS simulator. The communications status display will be updated to indicate that communication has been disabled. The initial state of communications between the INS simulator and ECS simulator is disabled. The ENABLE COMMS command must be invoked prior to the DISABLE COMMS command.

3.4.2.3. Message Selection

The first message selection command is the select data message (SDM) command. By invoking this command, the operator has the ability to instruct the ECS simulator to build and transmit a select data message. This command tells the INS simulator to start sending the navigation data periodic message, attitude data periodic message, both messages, or neither. The command can only be invoked after communications have been established. This is accomplished with the following command:

SDM [NAV | ATT | BOTH | NONE]

The initial state is that neither the navigation data periodic message nor attitude data periodic message are transmitted by the INS simulator. Execution of this command causes the the ECS simulator to send the proper select data message to the INS simulator. The status display of the operator console (see Figures 1 and 2) will be updated to indicate which messages are currently selected.

The remaining two message selection commands control the transmission of the periodic test data messages sent from the ECS simulator to the INS simulator. The operator instructs the ECS simulator to begin sending the periodic test data messages by entering the following command:

ENABLE TEST

The periodic test data messages are transmitted at a rate of no more than one per second. The test periodic message display in the status display area of Figure 2 will be updated to indicate that the transmission of test data messages has been enabled.

The operator instructs the ECS simulator to discontinue sending test data messages to the INS simulator by issuing the following command:

DISABLE TEST

This causes the ECS simulator to stop sending the test data messages to the ECS. The test message display in the status display area of the operator console (see Figures 1 and 2) will be updated to indicate that the transmission of test data messages has been disabled. The initial state of the ECS simulator is for the periodic test data message to be disabled. The ENABLE TEST command must be invoked prior to the DISABLE TEST command.

The BEGIN and ENABLE COMMS commands must be invoked prior to issuing any message-selection command.

3.4.2.4. Data Logging

The operator has the ability to log all data transmitted from the INS simulator to the ECS simulator, to a disk file. This includes message words and external functions. To instruct the ECS simulator to begin data logging, the operator issues the following command:

DATALOG ON {FILE_NAME}

Note that FILE_NAME is an optional argument. If not provided, data will be logged to a default file. This command may be issued at any time. When the command is issued, the data logging status in the status display area of the operator console (see Figures 1 and 2) will be updated to indicate that data logging is active.

The operator instructs the ECS simulator to stop logging by issuing the following command:

DATALOG OFF

This will cause the ECS simulator to stop logging incoming messages to the log file. When the command is executed, the data-logging status will be set to inactive in the status display area.

Both data logging commands may be issued prior to the BEGIN command. The DATALOG ON command must be submitted prior to the DATALOG OFF command.

3.4.2.5. Fault Injection

The operator has the ability to inject faults. This allows the operator to change the values of certain quantities that are output by the ECS simulator. The format of this command is as follows:

FAULT <VARIABLE_NAME> = <FAULT_VALUE>

The name of the variable that is to be changed is specified by <VARIABLE_NAME>. The value the variable is faulted to is specified by <FAULT_VALUE>. A check is made to assure that the requested fault is within the range specified for the variable in reference [1]. In the event that the requested fault is out of range, an alert is issued to the operator and the variable is not faulted. Before a FAULT command may be issued, communications must be enabled.

3.4.2.6. Scripting

The operator has the ability to load and execute user-defined script files that are built off-line. Scripting provides the capability for testing the response of the INS simulator communications protocol to erroneous sequences of external functions sent from the ECS simulator. It also provides a means for testing INS simulator message validation.

Each script file is identified by a script file name. To make the scripts available to the ECS simulator, the operator issues the following command:

LOAD SCRIPTS {FILE_NAME}

The FILE_NAME is an optional argument. When not provided, the LOAD SCRIPTS command will load the scripts from a default script file.

To run a script that has been loaded through a previous LOAD SCRIPTS command, the operator issues the following command:

RUN SCRIPT [SCRIPT_NAME]

This causes the ECS simulator to bypass the normal send or receive protocols, and execute the named script instead. SCRIPT_NAME corresponds to a script name within the script file. A script file may contain multiple scripts. When the script is done running, the operator is notified by an alert. The operator is also notified if the named script could not be found.

The script commands may both be executed prior to the ENABLE COMMS command, but not prior to the BEGIN command.

3.4.2.7. Use File

Support of command procedures for the ECS simulator is provided to allow the operator to easily enter repetitive sequences of commands. The use of this command also facilitates testing. This capability allows the operator to build various command procedures off-line and then call them up to be executed by issuing the following command:

USE FILE {FILE_NAME}

This command causes the command procedure stored in FILE_NAME to be read in and executed. Upon completion of the command procedure, the operator is notified by an alert. This command may be issued prior to the BEGIN command.

3.4.3. Alerts Display Function

The alerts display function is responsible for notifying the operator when error conditions have occurred. This function is initiated by other functions when an alert condition has been raised. The alert is displayed (immediately) when an error occurs. Alerts are raised for error conditions such as the following:

- Command entered out of sequence
- Data logging file does not exit

- Data logging file has read-only protection
- Command is incorrectly spelled
- Script file does not exist
- Invalid message received
- Out of sequence external function received
- Faulted value is out of range
- Other error conditions

3.4.4. Status Display Function

The purpose of the status display function is to provide the operator with the status of a number of events. These include:

1. The status of the communications link between the INS simulator and ECS simulator. The communications link is either enabled or disabled.
2. The status of the scripting function. A script file has either been loaded or not loaded. When loaded, the script file name is displayed in the the status display area of the operator console (see Figures 1 and 2).
3. The status of the data logging function. Data logging is either active or inactive.
4. The status of the ECS simulator test data message. The test data message has either been enabled or disabled.
5. The INS simulator message requested by the most recently transmitted select data message. The initial state is that neither the attitude data periodic message nor the navigation periodic data message is transmitted to the ECS simulator.

3.5. Database Management Function

The database management function is responsible for maintaining values of all appropriate data needed by the system. This shall include, as a minimum, the quantities specified in Table 1 and those listed in Section 3.3.3.

This function is initiated upon receipt of a valid message from the INS simulator. In this case, the database quantities are updated to reflect the information transmitted from the INS simulator.

The function is also initiated by requests from the operator to change values of database quantities and to provide information for display to the operator.

3.6. Data Logging Function

The purpose of the data logging function is to provide the capability of recording to disk file all data (messages and external functions) received by the ECS simulator from the INS simulator. The data logging function is enabled by the operator input function. Section 3.4.2.3 gives the operator commands for turning data logging on and off. (Post-processing routines are used for decoding and analyzing log file data.)

The following general requirements apply to the data logging function:

1. When the data logging capability is turned on, all incoming raw, uninterpreted data from the INS simulator are logged to the specified file, along with a message-arrival time stamp. If the data logging capability is turned on and the request is to turn the data logging capability on, then an alert is raised and the request is ignored.
2. If the data logging capability is turned off and the request is to turn the data logging capability off, then an alert is raised and the request is ignored.
3. If an invalid request is received (e.g., incorrect syntax or a log file with the specified name does not exist), then an alert is issued to the operator and the request is ignored.
4. If a request is received to turn the data logging function on and the file name is valid, the specified file is opened. The data logging status display in the status display area of the ECS simulator console will indicate that data logging is active.
5. If an error is encountered opening the file, an alert will be issued to the operator, and the request ignored.
6. If a request is received to turn the data logging function off, the ECS will discontinue logging incoming data to the log file, the current log file will be closed, and the data logging status display in the status display area of the ECS simulator console will indicate that data logging is inactive.

3.7. Scripting Function

The purpose of the scripting function is to provide the capability to send user-defined scripts containing sequences of external functions and message words to the INS simulator. Scripting bypasses the normal ECS simulator send and receive protocols. It provides a means for testing the INS simulator communications protocol and message validation.

The following general requirements apply to the scripting function:

1. If a request is received to load a script file, the name of the script file specified by the operator is verified. If no script file with the specified name exists, then an alert is issued to the operator and the request is ignored.
2. A single script file may contain more than one script. Each script within a script file is identified by a unique name.

3. If a request is received to load a script file and the format of the script file or its contents is incorrect, then an alert is issued to the operator and the request is ignored.
4. When a script file is loaded, the script status display in the status display area of the ECS simulator console is updated to indicate that a script file is currently loaded.
5. If a request is received to run a script file and the script file has not been loaded, then an alert is issued to the operator and the request is ignored.

Script files are built off-line. Content and format of script files are beyond the scope of this document.

References

1. Interface Design Specification for the Inertial Navigation Set AN/WSN-5 to External Computer, NAVSEA T9427-AA-IDS-010/WSN-5, August 1982.
2. B. Craig Meyers and Nelson H. Weideman, Functional Performance Specification for an Inertial Navigation System, CMU/SEI-88-TR-23, August 1988.

Appendix 1: List of Acronyms and Abbreviations

ACK	acknowledge (i.e., received a valid message)
ATT	attitude data periodic message
ATTN1	time-out condition
ATTN2	enable communications
ATTN4	disable communications
ECS	external computer system
EMLog	electromagnetic log
INS	inertial navigation system
NAK	not-acknowledge (i.e., received invalid message)
NAV	navigation data periodic message
NAVSAT	navigation satellite
SDM	select data message
TW0	test word 0
TW1	test word 1

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS NONE	
2a. SECURITY CLASSIFICATION AUTHORITY N/A		3. DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE DISTRIBUTION UNLIMITED	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CMU/SEI-88-TR-25		5. MONITORING ORGANIZATION REPORT NUMBER(S) ESD-TR-88-026	
6a. NAME OF PERFORMING ORGANIZATION SOFTWARE ENGINEERING INSTITUTE	6b. OFFICE SYMBOL <i>(If applicable)</i> SEI	7a. NAME OF MONITORING ORGANIZATION SEI JOINT PROGRAM OFFICE	
6c. ADDRESS (City, State and ZIP Code) CARNEGIE MELLON UNIVERSITY PITTSBURGH, PA 15213		7b. ADDRESS (City, State and ZIP Code) ESD/XRS1 HANSCOM AIR FORCE BASE, MA 01731	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION SEI JOINT PROGRAM OFFICE	8b. OFFICE SYMBOL <i>(If applicable)</i> SEI JPO	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F1962885C0003	
8c. ADDRESS (City, State and ZIP Code) CARNEGIE MELLON UNIVERSITY SOFTWARE ENGINEERING INSTITUTE JPO PITTSBURGH, PA 15213		10. SOURCE OF FUNDING NOS.	
		PROGRAM ELEMENT NO.	PROJECT NO. N/A
		TASK NO. N/A	WORK UNIT NO. N/A
11. TITLE (Include Security Classification) Functional Performance Specification for an External Computer System Simulator			
12. PERSONAL AUTHOR(S) B. Craig Meyers and Hans Mumm			
13a. TYPE OF REPORT FINAL	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Yr., Mo., Day) August 1988	15. PAGE COUNT 29 pp.
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	inertial navigation system	
	SUB. GR.	ship position and motion	
		functional and training requirements	
		functional performance specification	
19. ABSTRACT (Continue on reverse if necessary and identify by block number) <p>This document defines the functional and performance requirements for the external computer system (ECS) simulator that interfaces with the inertial navigation system simulator. Both the ECS simulator and INS simulator are being developed in Ada by the Real-Time Embedded Systems Testbed Project at the Software Engineering Institute (SEI). The ECS simulator is similar to a real-world ECS, but has reduced functionality. This document provides specifications for the major functions of the ECS simulator.</p>			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input checked="" type="checkbox"/>		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED, UNLIMITED	
22a. NAME OF RESPONSIBLE INDIVIDUAL KARL SHINGLER	22b. TELEPHONE NUMBER <i>(Include Area Code)</i> (412) 268-7630	22c. OFFICE SYMBOL SEI JPO	