Technical Report

CMU/SEI-88-TR-024
ESD-TR-88-025

System Specification Document:
Shipboard Inertial Navigation System Simulator
and External Computer

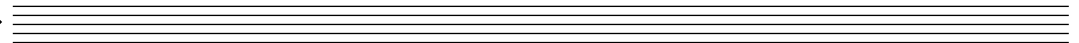**B. Craig Meyers**
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October 1988

System Specification Document: Shipboard Inertial Navigation System Simulator and External Computer

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Real-Time Embedded Systems Testbed Project

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Abstract: This document specifies high-level requirements for a shipboard inertial navigation system (INS) simulator and an external computer system that will interface with the inertial navigation system simulator.

1. Introduction

This document, developed in conjunction with the Real-Time Embedded Systems Testbed Project at the Software Engineering Institute (SEI), specifies high-level requirements for a shipboard inertial navigation system (INS) simulator. Additionally, this document contains requirements for an external computer system that will interface to the INS.

The document is organized in the following manner: Chapter 2 provides some background information, Chapter 3 describes the system, Chapter 4 describes the hardware configuration, Chapter 5 states the implementation software requirements, Chapter 6 discusses the applicable reviews to be conducted for the work, Chapter 7 discusses the applicable test requirements, and Chapter 8 lists deliverables for the project.

2. Background

The Software Engineering Institute is a federally funded research center operated by Carnegie Mellon University under contract with the Department of Defense. The principle mission of the SEI is to transfer technology into the real-time, embedded systems community. One SEI project deals with Real-Time Embedded Systems Testbed; this project's goals include:

- Exploration of issues in the application of Ada to real-time, embedded systems, with particular emphasis on issues dealing with the runtime environment.

- Transition of knowledge concerning the use of Ada to the real-time, embedded system community.

A goal of the Real-Time Embedded Systems Testbed Project at the SEI is to develop software for a system which may serve as a baseline application. This group has chosen to implement a simulator for a shipboard INS for two reasons:

1. Inertial navigation systems play a basic role in providing fundamental information for other shipboard systems.

2. Typically, shipboard inertial navigation systems are small in relation to other software-intensive shipboard systems.

Note that the goals of the SEI project are equally served by the implementation of an INS simulator or a full-scale INS software development effort. Another reason for developing an INS simulator is that one of the currently deployed systems, the AN/WSN-5, exhibits characteristics of other shipboard systems, and has certain characteristics which are believed to be a reasonable test for the application of Ada. These include:

- The INS must perform time-critical processing in a periodic manner. This leads to consideration of cyclic executives versus event-driven executives. Also, the ability to perform processing at precisely timed intervals is required. It is also expected that the basic design will need to examine issues related to intertask communication.

- The INS must respond to input from external computer systems. Such input is in the form of digital messages which must be processed in a time-critical manner. Thus, for example, an external computer may involve consideration of an event-driven executive and the processing of interrupts.

- The INS involves considerable bit manipulation. Thus, data which is transferred to an external computer system may contain "m" bits of data to the left of the binary decimal place, and "n" bits to the right. Such data formats are typical in shipboard systems. Hence, the ability to process such data may lead to a consideration of representation specifications in Ada.

- Finally, several larger issues are related to the application of Ada to real-time systems. For example, Ada supports certain design precepts such as data abstraction and object-oriented design. The development of the software for this project shall employ these techniques.

In summary, then, the choice of developing an INS simulator is based on two factors: (1) that it can serve as a vehicle for the exploration of issues common to typical real-time systems, and (2) that it can serve as a vehicle for the exploration of issues relative to Ada runtime environments. A study of issues and questions applicable to Ada may be found in reference [7].

3. System Description

The software to be developed for this project is composed of two major functional units. Each of these is discussed in the following subsections.

3.1. Inertial Navigation System Simulator

The purpose of a shipboard inertial navigation system is to provide external computer systems with accurate measurements of quantities concerning ship position and motion. Ship motion concerns a variety of measurements; first, there are measurements of ship velocity relative to some particular coordinate system. The second type of motion reported is information about the pitch and roll of the ship, as well as rates of change of these quantities. Additionally, the INS provides information concerning the external environment, such as a measure of the ocean current's velocity.

It is crucial that the above information be reported to external computers in real-time. An example of this is provided by the computations necessary for the alignment of a missile guidance set. That is, in order to successfully align a guidance set in a missile, accurate data concerning motion of the platform is required. It is necessary, therefore, for the inertial navigation system to provide accurate and timely information to an external computer system. This external system may then perform alignment computations, which are transferred to an embedded processor in a missile.

The software to be developed for this project is a simulator of the two-way AN/WSN-5 inertial navigation system described in references [2]-[4]. The software shall simulate the motion of the platform, and then transfer this information to an external computer by digital messages. It is important to note that from the point of an external system, the simulator to be developed will appear identical to the currently deployed WSN-5. Specifically, the system shall enforce the time-critical processing with regard to message handling, including protocols, as the current system. The major distinction between the simulator to be developed and the current system is that the simulator will not perform extensive numerical computations, such as Kalman filtering. A performance specification for the INS Simulator is available in reference [5].

The simulator to be developed may also be used as a test vehicle for an external system. For example, the INS operator shall have the ability to enter commands which include the following:

1. Provide for changing basic parameters used in the equations to calculate simulated ship motion.

2. Provide for changing ship course.

3. Provide for changing ship speed.

4. Provide for a ''fault injection'' mechanism. Thus, the INS operator shall be able to specify values of quantities which are out of the normal range. These injected faults, which are transferred to the external computer system, may be used to test the response of the external system to invalid input data.

3.2. External Computer

A functional requirement of the INS is to be able to transmit and receive data from an external computer in a time-critical manner. The data transfers are accomplished by digital messages. The purpose of the external computer to be developed in this project is to provide for message transmission to and from the INS simulator. The software to be developed for the external computer shall meet the time-critical demands of the INS with regard to message transmission. However, only a minimum of functionality shall be included in the external computer. This is because this system is principally developed to test the INS Simulator. A performance specification for the external computer is available in reference [6].

4. Hardware Configuration

The hardware configuration for the systems to be developed is depicted in Figure 1. All systems shall be initially resident in MicroVAX II processors with VT220 terminals used as the operator terminal. Communication between the INS and the external computer shall be via 16-bit, parallel interfaces.

Also shown in Figure 1 is an external monitoring system which interfaces between the INS simulator and the external computer. The purpose of the external monitoring system is to be able to ''capture'' data in real-time as it is transmitted across the interface as illustrated in Figure 1. Data collected by the external monitoring system shall be used in the system testing phase of the project.

Note that one of the goals of the SEI Real-Time Embedded Systems Testbed Project is to transition the developed software from the MicroVAX to a 68000 processor. This work will be described at a later date.

Figure 1: Hardware Configuration

5. Implementation Software Requirements

The software to be developed for this project shall be written in Ada in accordance with reference [1]. Exceptions to the use of Ada are granted for the following purposes, where assembler language may be used:

- built-in test software

- low-level I/O drivers

The runtime operating system shall be the VAXELN, which is a real-time operating system developed by Digital.

6. Project Reviews

During the course of this project, reviews are expected to be conducted. In addition to internal reviews, the following reviews shall be conducted:

- A preliminary design review, when the basic high-level design is completed.

- A critical design review, when the detailed design is completed.

The Critical Design Review shall be held at the Naval Surface Weapons Center (NSWC) in Dahlgren, Virginia. Members of the NSWC Technical Staff shall participate in the review.

7. Test Requirements

It is the responsibility of the development group to test the software before delivery. As a minimum, this shall include:

1. Verification that all permitted operator commands may be successfully executed. This includes testing that all parameters are within specified ranges, where applicable.

2. Verification that the system will reject an invalid command from the operator.

3. A system stress test of at least four hours' duration. The output from this test shall be the dataset collected by the external monitoring system, as well as the data collected from data extraction. These datasets shall be used to assure that message transmissions were completed successfully and within specified timing constraints.

There is no requirement that the system be tested in order to assure that internal timing requirements are met. Such testing, while recommended, may be done at the discretion of the development group. There is no stated test requirement for internal timings due to the fact that the required "instrumentation" may adversely affect the performance of the system. Note, however, that the ability to satisfy internal timing constraints may be verified from the data collected by the external monitoring system.

Note that the volume of data available for collection by the external monitoring system may be considerable. During the four-hour stress test, there are approximately 250,000 messages transmitted by the INS simulator. In terms of the amount of data available, this is approximately 10 million bytes of data. Clearly, the requirement of validating this data is a considerable task. The validation of the system stress test shall be conducted by NSWC using a tool called CASSANDRA. This is a tool developed for analysis of large time-ordered datasets and has been used by several groups at NSWC in verification of real-time systems.

8. Deliverables

The following five items constitute a minimum set of deliverables by the development group:

1. A performance specification for the INS simulator (reference [5]).

2. A performance specification for the external computer (reference [6]).

3. A detailed design document for each system.

4. A listing of the source code for each system, both hardcopy and machine-readable.

5. A tape containing the data collected from the system stress test.

An analysis of the system stress test shall be delivered by NSWC to the development group. This will describe the results of the data collected, as well as the analysis of time-critical message handling.

Additionally, the Real-Time Embedded Systems Testbed Project at the SEI is expected to produce reports dealing with various aspects of this work.

There is no requirement that any of the above documentation shall be in the form specified by DoD Standard 2167.

References

The following documents apply to this work:

1. DoD Instruction 5000.31, July 1986.

2. Program Performance Document for the Inertial Navigation Set AN/WSN-5, May 1985.

3. Program Design Specification for the Inertial Navigation Set AN/WSN-5, May 1985.

4. Interface Design Specification for the Inertial Navigation Set AN/WSN-5 to External Computer, NAVSEA T9427-AA-IDS-010/WSN-5, August 1982.

5. B. Craig Meyers and Nelson H. Weiderman, *Performance Specification for a Shipboard Inertial Navigation System Simulator,* CMU/SEI-88-TR-23, October 1988.

6. B. Craig Meyers and Hans Mumm, *Performance Specification for an External Computer System,* CMU/SEI-88-TR-25, October 1988.

7. Nelson H. Weiderman, et al., *Ada for Embedded Systems: Issues and* Questions, CMU/SEI-87-TR-26, December 1987.