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THESIS

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THE NAVIGATION DATA LOGGER
FOR
A SUITCASE NAVIGATION SYSTEM

by

CHIN, YU-CHI
June 1991

Thesis Advisor:

Dr. Uno R. Kodres

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**THE NAVIGATION DATA LOGGER
FOR
A SUITCASE NAVIGATION SYSTEM**

by
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Commander R. O. C. NAVY
B. S. Chinese Naval Academy, 1977

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING SCIENCE

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THE NAVIGATION DATA_LOGGER FOR A SUITCASE NAVIGATION SYSTEM

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ABSTRACT

This thesis presents the design, implementation and description of a Data_Logger for the Suitcase Navigation System. All the programs and examples presented in this thesis were implemented in the Ada programming language, which has successfully incorporated the low_level I/O ports communication with high_level abstraction. The software is portable as desired and can be reused by LCCDS when needed.



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TABLE OF CONTENTS

I. INTRODUCTION	1
A. BACKGROUND	1
B. PURPOSE OF THIS THESIS.....	1
C. THESIS ORGANIZATION.....	1
II. SUITCASE NAVIGATION SYSTEM OVERVIEW	3
A. INITIAL PROBLEM STATEMENT	3
1. The Suitcase Navigation System Project	3
2. The Physical System	3
B. SYSTEM DESCRIPTION	4
C. SYSTEM OPERATIONS	5
1. CRT display	5
2. Plotter	5
3. Data Logger	5
4. Remote CRT	6
5. Keyboard.....	6
D. REQUIREMENTS ANALYSIS	6
1. The Statement of Purpose	6
2. Suitcase Navigation System Context Diagram	6
3. Suitcase Navigation System Level-0 DFD	7
III. DATA_LOGGER DESIGN	8
A. INTRODUCTION	8
B. DEFINE THE PROBLEM.....	9
C. IDENTIFY THE OBJECTS.....	10
D. IDENTIFY THE OPERATIONS	10
1. Operation 1: INITIALIZATION--Set up external Nav_sensors connection.....	10
2. Operation 2: External Nav_Sensor operation setup.....	11
3. Operation 3: LOGGER--Log and Convert	11
4. Operation 4: DATA_LOGGER-- the main program unit.....	11
5. Operation 5: POSITION_NOW--Display current data string	12
E. ESTABLISH THE COMMUNICATION	12
F. ESTABLISH THE INTERFACE.....	14

IV. DATA_LOGGER IMPLEMENTATION	16
A. SYSTEM-SENSOR INTERFACING	16
Code-1: Initialization	16
Code-2: Setup the Baud_Rate	17
B. SENSOR DATA HANDLER	18
Code-3: A main subprogram	19
C. SYSTEM DATA MANAGEMENT	21
Code-4: Display current position data	21
D. PROGRAM CODING	22
V. DESCRIPTION OF THE DATA_LOGGER	29
A. THE REQUIRED PROGRAM STRUCTURE	29
1. Hardware Structure	29
2. Software Structure	30
B. ADVANTAGES OF THE DATA_LOGGER	30
C. USER's MANUAL	31
VI. CONCLUSIONS AND RECOMMENDATIONS	32
A. CONCLUSIONS	32
B. RECOMMENDED FOLLOW-ON WORK	32
APPENDIX--I GPS Trimble-4000S	34
APPENDIX--II Predefined PACKAGE BIT	37
APPENDIX--III SAMPLE DATA	38
APPENDIX--IV Ada Program Examples	43
APPENDIX--V: USER's MANUAL (Operations and Responses)	51
APPENDIX--VI: TEXT NOTES FROM GRADY BOOCH	54
LIST OF REFERENES	56
INITIAL DISTRIBUTION LIST	57

LIST OF FIGURES

FIGURE-1: Basic Physical System.....	5
FIGURE-2: Suitcase Navigation System Context Diagram.....	6
FIGURE-3: Level Zero Data Flow Diagram.....	7
FIGURE-4: Process Nav_Sensor Data.....	8
FIGURE-5: The Environmental I/O Problems.....	9
FIGURE-6: Description of Logger Design.....	13
FIGURE-7: Description of Data_Logger Design.....	14
FIGURE-8: Description of Data_Logger I/O ports.....	15
FIGURE-9: Hardware Structure of Data_Logger.....	29

I. INTRODUCTION

A. BACKGROUND

The research interests of the Small Navigation Data Logger System was initially sponsored by the Pacific Missile Test Center (PMTTC), who uses various ships at their site and other locations around the world. They often need to have the navigation data from the system that the particular ship uses logged and displayed. This system can be one of many. Accordingly PMTTC desires a small, portable, data logger that will accept the inputs from any of several navigation systems. It will have to interface with only one system at once. The system should perform the function of "Accepting the data, logging the data, displaying the data graphically, plotting the data". Real time navigation will often be done from this system.

There are several systems that either exist or are being proposed to perform functions like this. Most are expensive, and require large amount of memory. In addition commercial systems do not provide the source code or other methods for easy upgrades for new systems. Some of the reasons for the large memory size of these systems is the desire to interface with different electrical standards. Our Suitcase Navigation System is concerned only with the RS-232 electrical standard interface.

B. PURPOSE OF THIS THESIS

The objective of this thesis is to provide a generic system, based on the Ada language, to create an interface to the Suitcase Navigation System, which accepts positional data from a class of Global Positioning Systems (GPS) and distributes this information to a variety users including the LCCDS's navigational subsystem. The central focus of the thesis is to design, implement, and experience to gather performance data of the Navigational Data_Logger System.

C. THESIS ORGANIZATION

Chapter II gives the Suitcase Navigation System overview. In order to assist the reader

in understanding the basic features of SNS, which follows the Yourdon's Modern Structured Analysis 1989 (Reference-2), to present a software develop method from the Requirements Analysis point of view. The Suitcase Navigation System's Context Diagram and level-0 Data Flow Diagram is presented in this chapter.

Chapter III, the object-oriented method suggested in Grady Booch's Software Engineering with Ada (Reference-3), is applied to the design of Navigation Data_Logger. In order to describe to the reader parts of the system function, the chapter defines the problem, identifies the objects, identifies the operations, establishes the communication, and establishes the interface.

Chapter IV describes the implementation of the Navigation Data_Logger, the System-Sensor Interface, the Sensor_Data Handler, The System Data Management, and program coding.

Chapter V describes the performance of the Data_Logger. We start from a required program structure, which described hardware structure and software structure. The simulation in our lab, provides experimental results for Hardware connection, Transmission Rate, and Conversion accuracy, we describe the working process, and also point out the effects and contacts. Then from the user's point of view we describes how to use the Data_Logger.

Chapter VI is the final chapter, which includes the Conclusions and Recommendations of some suggestions for future research and follow-on work.

Appendix.1: The specification of the RS-232 connections between external Navigation_Sensor and the working system.

Appendix.2: Predefined Ada package Bit specification.

Appendix.3: Sample data formats from external navigation sensor.

Appendix.4: Sample Ada programs for the project development.

Appendix.5: Navigation Data_Logger User's manual.

Appendix.6: Text Notes from Grady Booch.

II. SUITCASE NAVIGATION SYSTEM OVERVIEW

A. INITIAL PROBLEM STATEMENT

1. The Suitcase Navigation System Project

There is a need for an integrated navigation system for use with various ships or aircraft of opportunity. System must be self-contained, lightweight, portable, and multi-purpose. Systems should use off-the shelf components, to facilitate hardware replacement and minimize downtime. System would be utilized for the following tasks:

“Integrated Navigation, Tracking, and Positioning. Test and Evaluation of Equipment, System, and Weapons. Fleet Training Umpire. Range Surveying.”

System must be able to accept input data from various navigational sources. It will provide real-time processing of data and in the absence of data will use dead reckoning points derived from a Kalman Filter. It will allow output data to be displayed on CRT, and XY plotter.

2. The Physical System

- 1) Basic System: Computer (Laptop preferred), Keyboard, and CRT.
- 2) Accessories: Printer, UHF Modem, Remote CRT, and XY plotter.
- 3) Allowance for selection from the following input systems (initially desired are):
 - TI 4100 GPS Receiver
 - Trimble GPS Receiver
 - IEC GPS Receiver
 - Motorola GPS Receiver
 - Magellan GPS Receiver
 - Rockwell-Collins (JPO) GPS Receiver
 - Mini-ranger Radio Positioning System
- 4) Allowance for selection from the following output systems

- Data recorded by:
 - a. Disk, floppy or hard drive.
 - b. Tape.
 - c. Cassette.
 - d. Printer.
- Visually displayed by:
 - a. CRT.
 - b. Printer.
 - c. XY Plotter.
 - d. Remote CRTs connected via UHF modem (for use on flight station, bridge, or deck).

B. SYSTEM DESCRIPTION

System is turned on. Software must handle initial setup accessing I/O ports, through the hardware bus. CRT displays setup menu, requires keyboard entries. Requests the following:

- Mode type: provide external setup on navigation input systems.
- Type of input: primary, secondary, and tertiary navigation source and its format.
- XY plotter: plot functions.
- Navigational data recording: utilization, location, and rate.
- Printer recording: utilization, format, and rate.
- Remote CRT: utilization and setup.
- Verification of entries: user friendly design.

Figure-1 Basic Physical System of Suitcase Navigation System illustrates the example of the Suitcase Navigation System that PMTC proposed to the Naval Postgraduate School for the purpose of:

“To provide PACMISRANFAC/ PACMISTESTCEN with an integrated navigation system capability. This capability would provide to range users, a means to pre-plan range operations and to accurately navigate, position, and collect operational data. In addition, this capability may be the make or break point between a range user using or not using the range.”

-- Note: A work statement from PMTC.

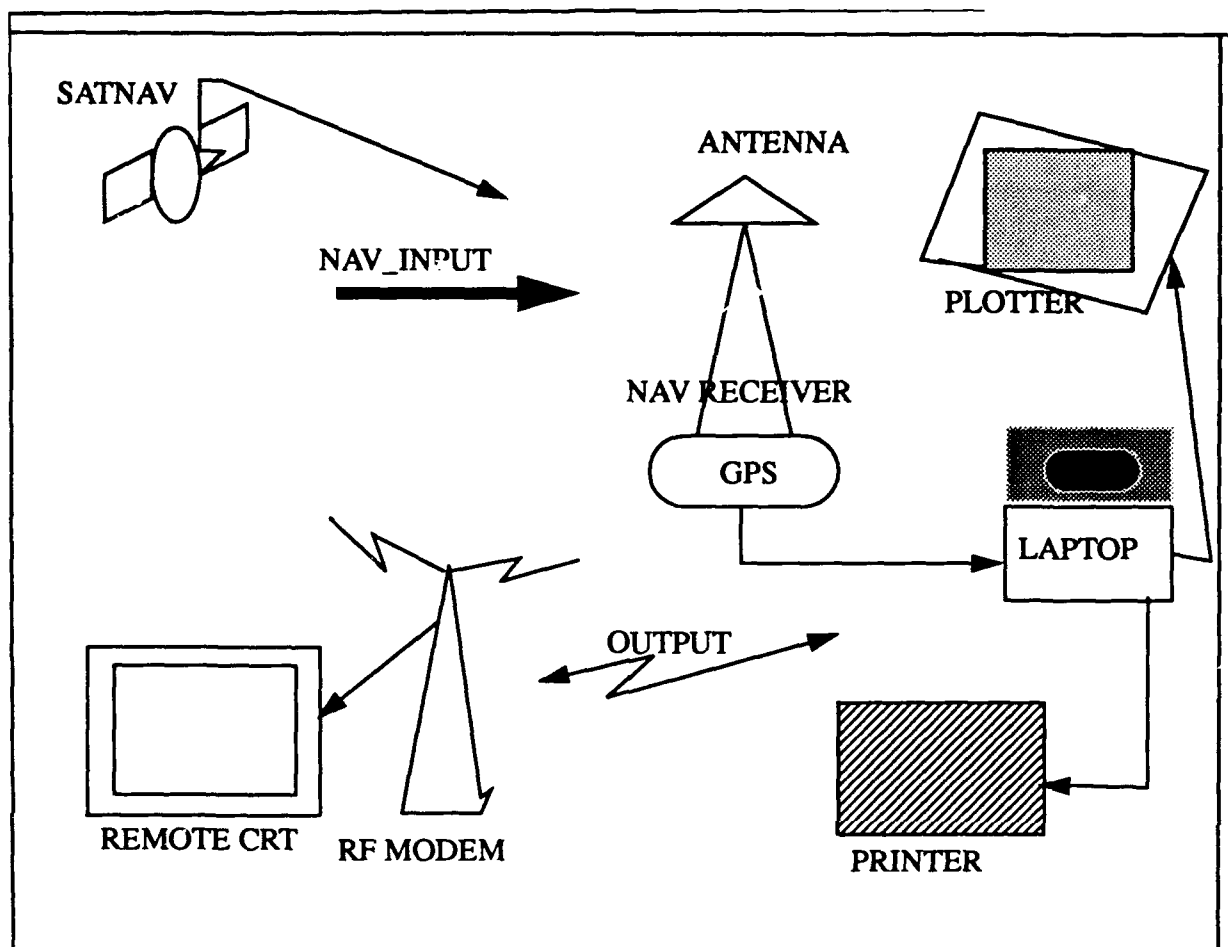


Figure-1: Basic Physical System

C. SYSTEM OPERATIONS

1. CRT display

Two-thirds of screen for graphic display and switchable provides: "duplicate of XY plotter, Positional Bulls-eye-Range and Bearing, Left/Right of Track-Waypoints". Remainder of screen provides "Data and Time, Latitude and Longitude, Range and Bearing for Bulls-eye and Waypoints, Help notations for program change toggles, Edge of plot sheet warning".

-- Statements from "World Range Suitcase Navigation Feasibility Study". (Reference-4)

2. Plotter

Responds as prompted from setup and/or program change toggles.

3. Data Logger

Responds as prompted from setup and/or program change toggles.

4. Remote CRT

Displays as prompted from setup and/or program change toggles.

5. Keyboard

Inputs system setup and provides program change toggles.

D. REQUIREMENTS ANALYSIS

1. The Statement of Purpose

The purpose of the Suitcase Navigation System (SNS) is to generate a general purpose Ada language based system, which takes inputs from different Global Positioning Systems, and record position data generated by any of the positioning system via an RS-232 interface. The general purpose software would be flexible and programmable by selecting components off the menu presented to the screen of the laptop. Any graphics capability of the laptop could be used to present the geographic position of the platform in an appropriate geometric design. (Reference-4)

2. Suitcase Navigation System Context Diagram

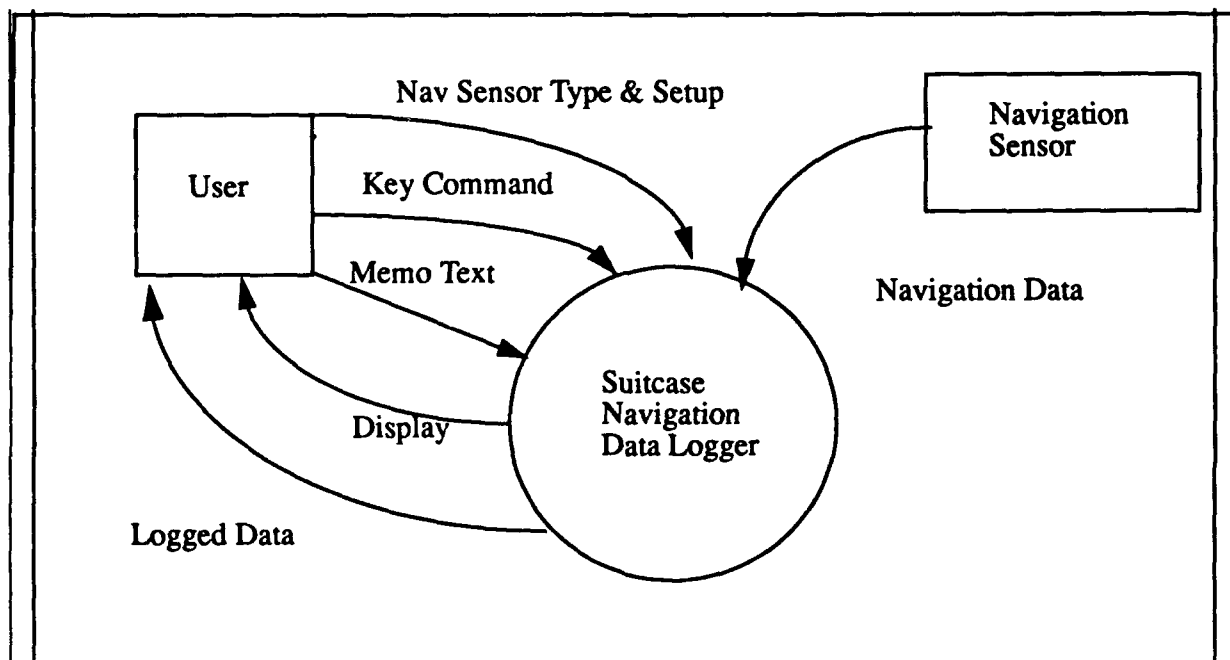


Figure-2: Suitcase Navigation System Context Diagram

3. Suitcase Navigation System Level-0 DFD

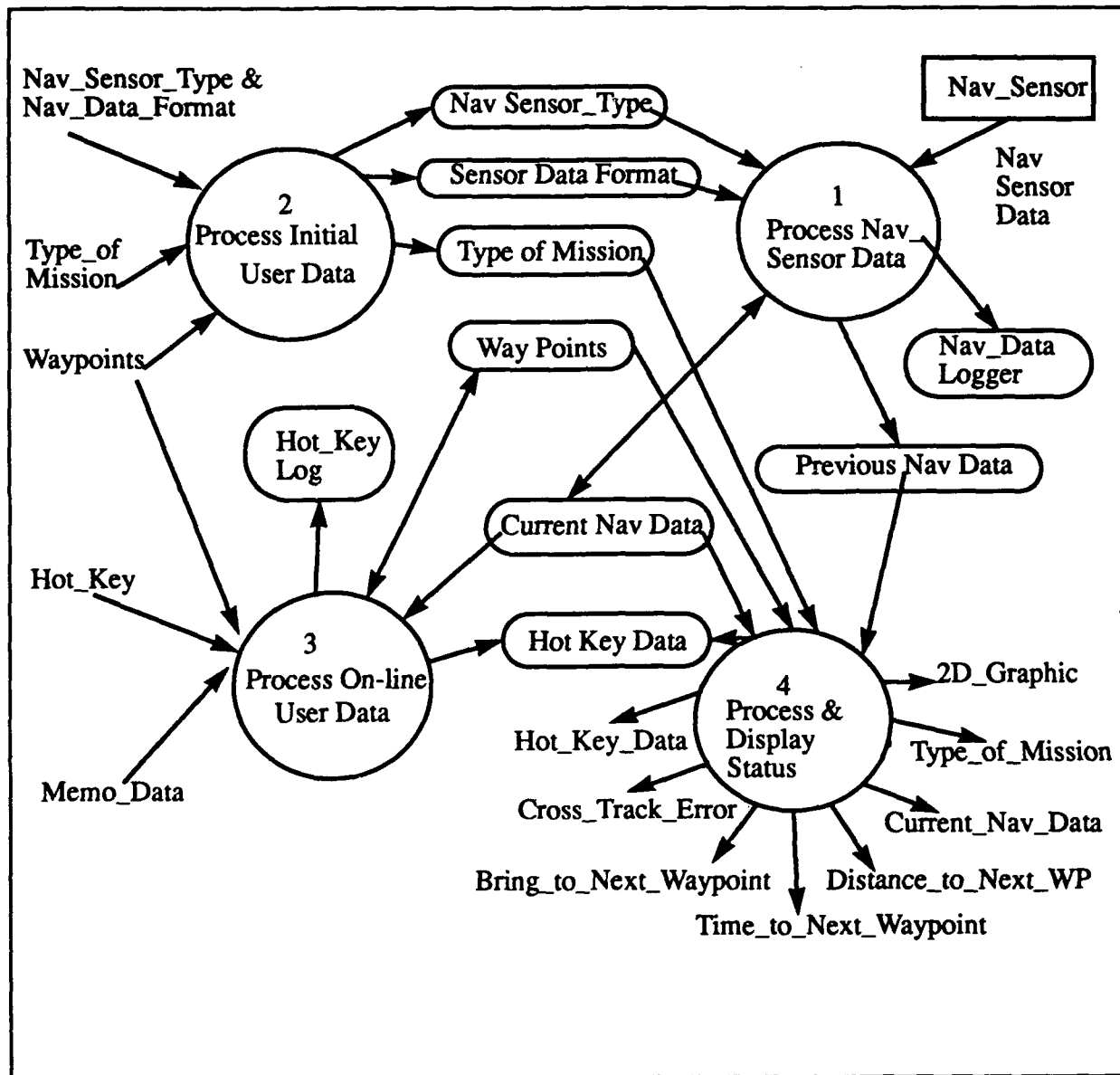


Figure-3: Suitcase Navigation System Level-0 DFD

III. DATA_LOGGER DESIGN

A. INTRODUCTION

The system is designed for the Suitcase Navigation System project. To implement Global Positioning System (GPS) data as the resource to satisfy the navigation problem needs, and using the highly accurate position to develop the whole system as a reliable console by means of Man Machine Interface. This thesis is look into the first bubble of the level-0 Data Flow Diagram, which interface the external nav_sensor, and process the nav_sensor data. Figure-4 illustrates the design.

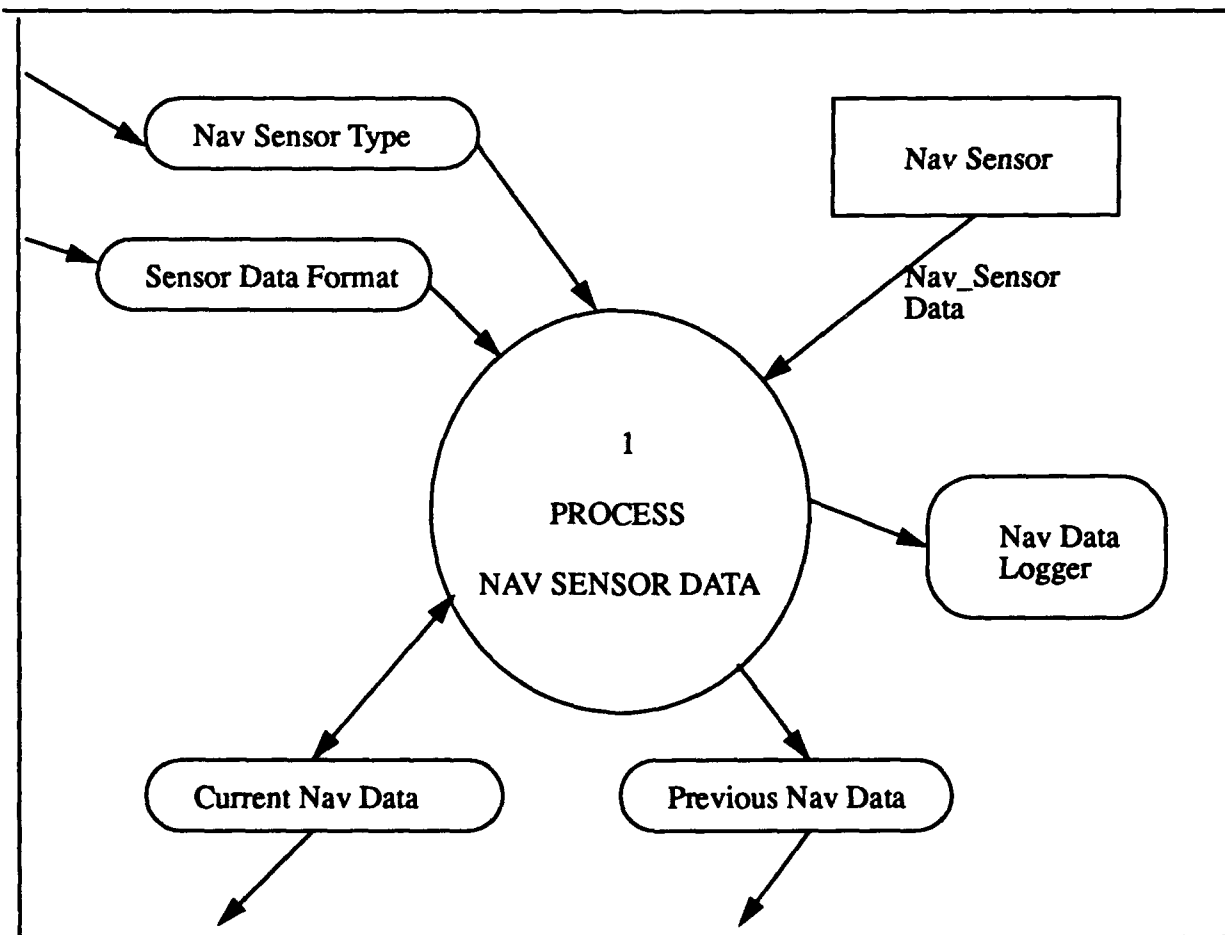


Figure-4: Process Nav_Sensor Data

B. DEFINE THE PROBLEM

The primary concern is the monitoring or control of real-time processes. Figure-5. The environmental I/O problem (Process Data Received From Sensor), illustrates the problem space. Our problem does involve several navigation sensors in various modes of operation. These sensors continuously sample the ambient data and transmit in several different rates. If a particular set of sensor data which is needed by the user, the Data_Logger shall be able to get and print it. The system also displays the data while it is logging or printing. We are presently using Trimble-4000s GPS as the external Nav_sensor, and a laptop computer as the hardware system.

To process nav_sensor data, the system need not only log the data, but allow the user to interact with the system by exception handling design (Hot_Key). Periodically, our system must be able to get the current data_string of navigation sensor to a permanent log. This can be done by pulling data out from the buffer file and print it. Printers have the nasty habit of running out of paper at the worst possible time; therefore, we have judged the printer to be the least reliable device in our system.

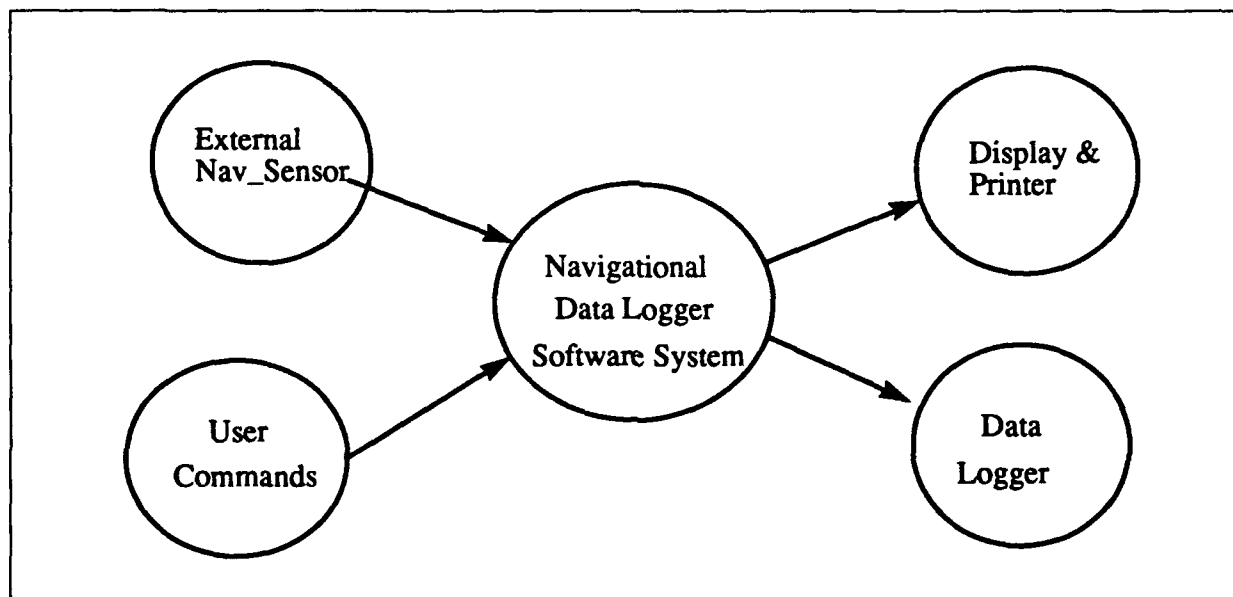


Figure-5: Environmental I/O problems

C. IDENTIFY THE OBJECTS

- External Nav_Sensors (GPS).
- CRT and Printer.
- Data_Logger.
- User_Commands.

The external Nav_Sensors defines a generic class of objects, whereas our system target is an instance of an object using the Trimble-4000 S GPS.

The CRT and Printer defines another set of external devices which act as a servers in the system.

Data logger defines the flow of data transfer, which identified the legal character from line ports, converts it and stores it. The data is logging to raw_data file, buffer file and display.

A user exists outside the design application, but the user can interact with the system via commands. A software development of hot key design will be implement in the future.

D. IDENTIFY THE OPERATIONS

To consider the behavior of each object, we shall specify the operations and identify the concurrence. According to Booch's concurrent real-time processing, we shall abstract the External Nav_Sensor as a concurrent entity. It's primary role is to continuously monitor the input data. CRT and Printer as server of Data_Logger, and Data_Logger as the actor of the software system. From the constrains of software support in Suitcase Navigation System, which assigned Laptop as the working system and DOS as the operating system, our project starts from the basic process operations that the DOS can support and upgrade in the future.

The Operations of the Navigation Data_Logger is organized as follows:

1. Operation 1: INITIALIZATION--Set up external Nav_sensors connection
 - *. Assign communication port: COM1 or COM2;
 - GET(NUM): Select proper com_port and assign variable value;
 - *.Assign transmission rate: Baud_Rate
 - GET(CH): Match the initial selection;
 - OUTPORT (P1, 128): Access baud_rate divisor;
 - GET(SELECTION): Setup the proper rate;

```
-- OUTPORT (P2, SYSTEM.BYTE(NUMBER)): Put LSB on 3f8 or 2f8;
-- OUTPORT (P3, 00): Put MSB on 3f9 or 2f9;
-- OUTPORT (P1, 03): Set parity, stop bit as (8--NONE--1);
-- OUTPORT (P4, 03): Set moden control register;
-- OUTPORT (P3, 00): Disable line control register;
-- RATES (P1, P2, P3, P4): Setup the transmission rate;
```

2. Operation 2: External Nav_Sensor operation setup

```
*. Port I/O: Set up the connecting ports to transmit sensor_data.
*. Value: Type of the measurement value(position data or measurement data).
*. Send_Rate: How often the data flow is (set up the baud rate).
. -- Note: operation 2 is operated externally by user
```

3. Operation 3: LOGGER--Log and Convert

```
*. Operations a logger to process GET_CHAR and logging
-- OPEN (FILE, OUT_FILE, NAME=>"POS.OUT"): Open buffer file to write;
-- GET_CHAR: Function to get and return the value;
-- PUT (A_CHAR): put data on the screen;
-- PUT (THE_FILE, A_CHAR): Put (while convert) data in the file;
-- PUT (FILE, A_CHAR): Put (while convert) data in to buffer file;
-- CLOSE (FILE): Close buffer file;
-- CLOSE (THE_FILE): Close the raw data file;
*. A function GET_CHAR: Get value from the assigned sensor in generic type
(SYSEM.BYTE) then convert the value into any desire format in the operation.
-- INPORT (PORT1,LINE): Check 3fd or 2fd for data available;
-- TSTBIT (INTEGER(LINE), 0): Find out the status;
-- CLRBIT (LINE_INT, 0): Reset the test bit;
-- OUTPORT (PORT1, SYSTEM.BYTE(LINE_INT)): Assign value to 3fd or 2fd;
-- Return VALUE of CHARACTER'VAL(DATA);
```

4. Operation 4: DATA_LOGGER-- the main program unit

```
*. Logging the imported sensor_data
-- INITIAL (PORT1, PORT2): Initialization of the system communication;
-- BAUD_RATE: Setup the transmission rate;
```

```

-- OPEN (THE_FILE, IN_FILE, NAME=>"POS.DAT"): Open file to store data;
-- KEYPRESS (CURRENT_INPUT): Hot key control function;
-- POSITION_NOW: Display and print out the hard copy;
-- LOGGER (PORT1, PORT2): Log sensor data from the setup com_port;
-- CLOSE (THE_FILE): Close the raw data file;
-- EXCEPTION: Handle the exception commands;

```

5. Operation 5: POSITION_NOW--Display current data string

*. Operations a display of data string as user desired.

```

-- OPEN (FILE, IN_FILE, NAME=>"POS.OUT"): Open buffer file to read;
-- GET (FILE, ITEM): Get from buffer file;
-- PUT (ITEM): Put the data (ITEM) on the screen;
-- CLOSE (FILE): Ready for other operation;

```

-- Note: We characterized Data_Logger as a Transducer Task for the whole Suitcase Navigation System. By the definition of Booch's tasks, A transducer is a task that both calls entries of other tasks and also provides a service to other units (such as process & display status in Suitcase Navigation System, or Integration System in LCCDS).

-- Note: The first iteration of this project does not use tasking for program coding, but the following updates may want to use tasking, because of more concurrent operations

E. ESTABLISH THE COMMUNICATION

To establish the communication we must consider the relationship among objects, now that we have identified the operations of each object in our system, we may start from the external Navigation sensor. The operation of the external navigation sensor is completely isolated from any other object. But the sensor's data is coupled to other operations. We call the data SYSTEM.BYTE, and the function to get the data GET_CHAR:

GET_CHAR must be able to see SYSTEM.BYTE;

GET_CHAR is a function type of subprogram, it checks the line register of the COM_PORT, and looking for the legal byte "[", which was assigned by the user and can be changed. The

return value of GET_CHAR is converted to CHARACTER, and distributed to different files and the display. A main subprogram that serves as the root of the system is required by Ada. We shall call this subprogram **LOGGER**, and it will contain the function (GET_CHAR). Additionally, this unit will be responsible for process & status display in the future. As a result:

LOGGER must see **GET_CHAR** and **POSITION_NOW**;

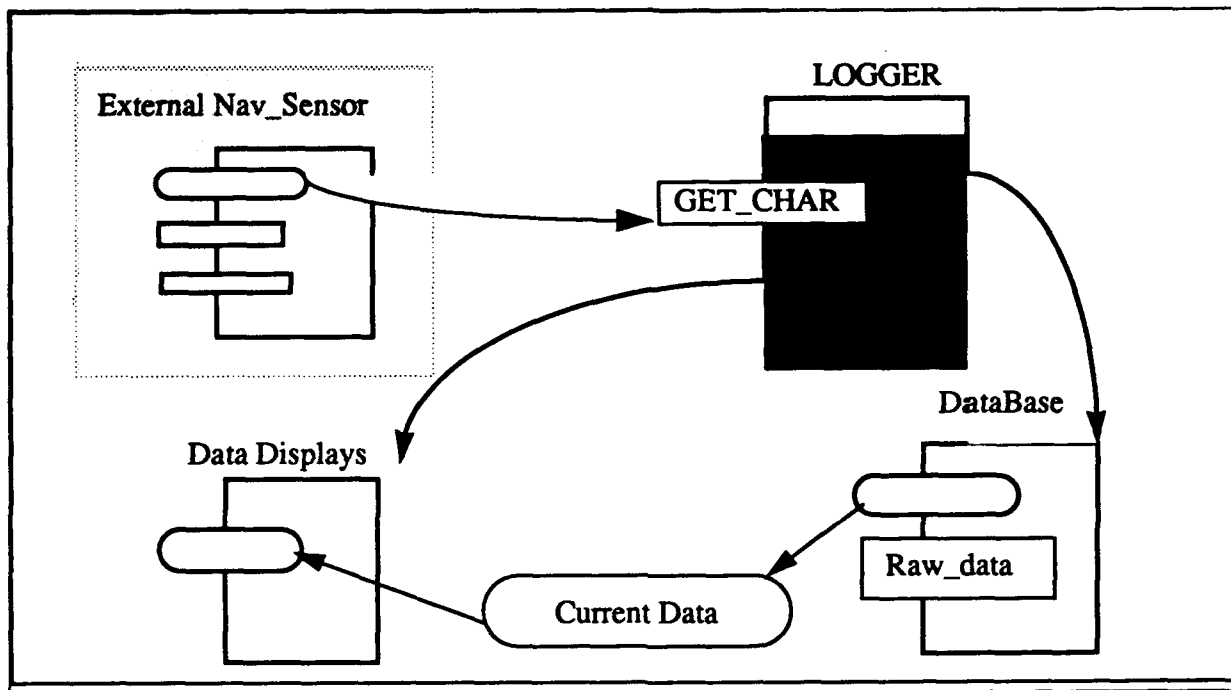


Figure-6: Description of Logger Design

Figure-6: illustrates these relationships. **DATA_LOGGER** is the main program, we will see four sub-units, which describes the whole operation:

- **INITIALIZATION**: Subprogram process commands to handle user initialization.
- **BAUD_RATE**: Subprogram process commands to establish proper communication.
- **POSITION_NOW**: Subprogram to support the **USER_COMMANDS**.
- **LOGGER**: Subprogram of periodic logging of sensor readings.

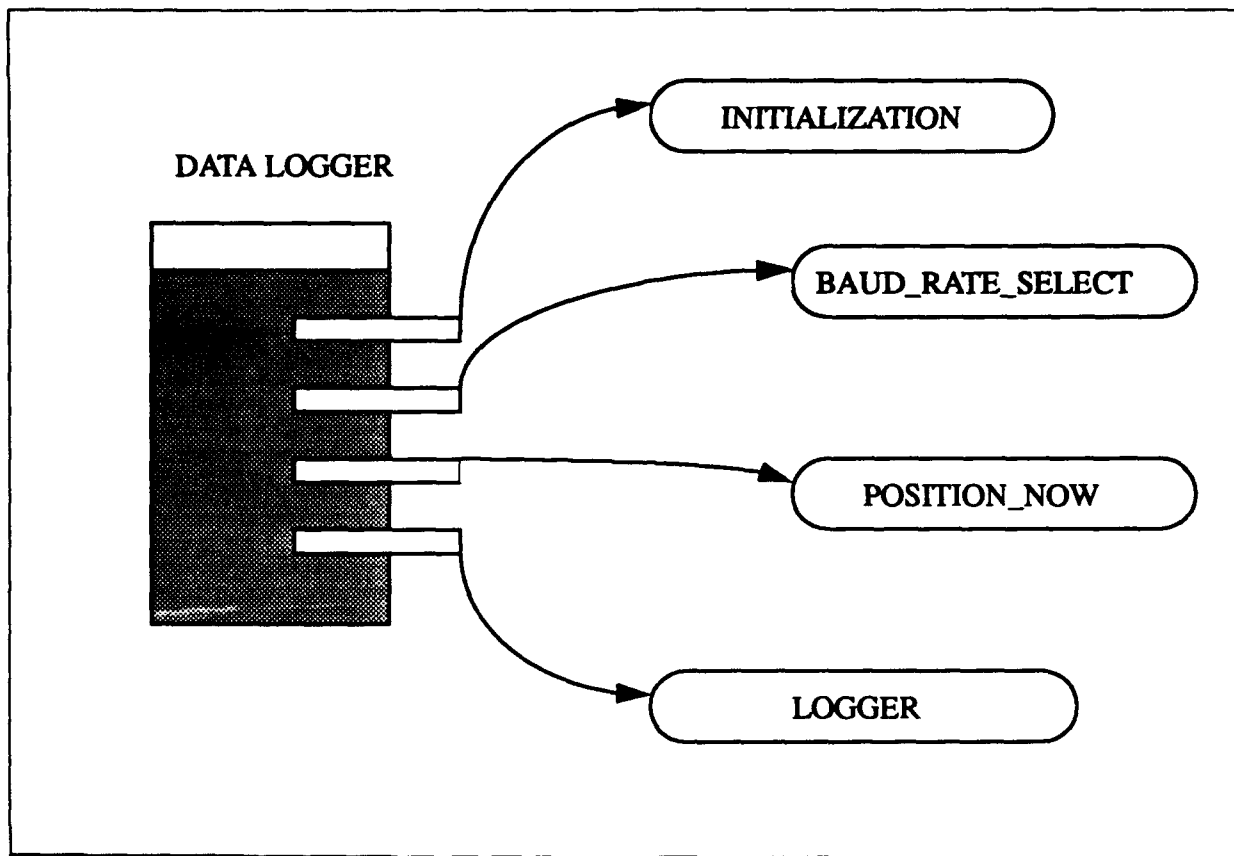


Figure-7: Description of Data_Logger Design

Figure-7: illustrates this level of the design. We also learned that at the interface of I/O ports the abstraction falls at a lower level in our design, and this ports are visible here only to the bodies of DATA_LOGGER. Figure-8: illustrates this level of the design.

F. ESTABLISH THE INTERFACE

The interface that we are concerned with here is mainly between Navigation sensor, Data_Logger, Printer, and User_Commands. In this thesis we are focused in the Navigation sensor interface through RS-232 and I/O ports interface from low_level to high_level language.

In early stage of this project, our lab has set up two PC connected by RS-232 as simulation system design for Suitcase Navigation System. Chapter V will present the simulation and

Appendix.1 introduces briefly the RS-232 interface for GPS (Trimble-4000). From the software designer's point of view, I/O ports interface (from low_level to high_level) to Ada is another main concern in this thesis. We have learned that Ada is capable to handle I/O in many different ways. In this project we use predefined package BIT (appendix.2), as port I/O interface support because package Bit can provide more control to the user. We will have more discussion in the next chapter about Data_Logger implementation.

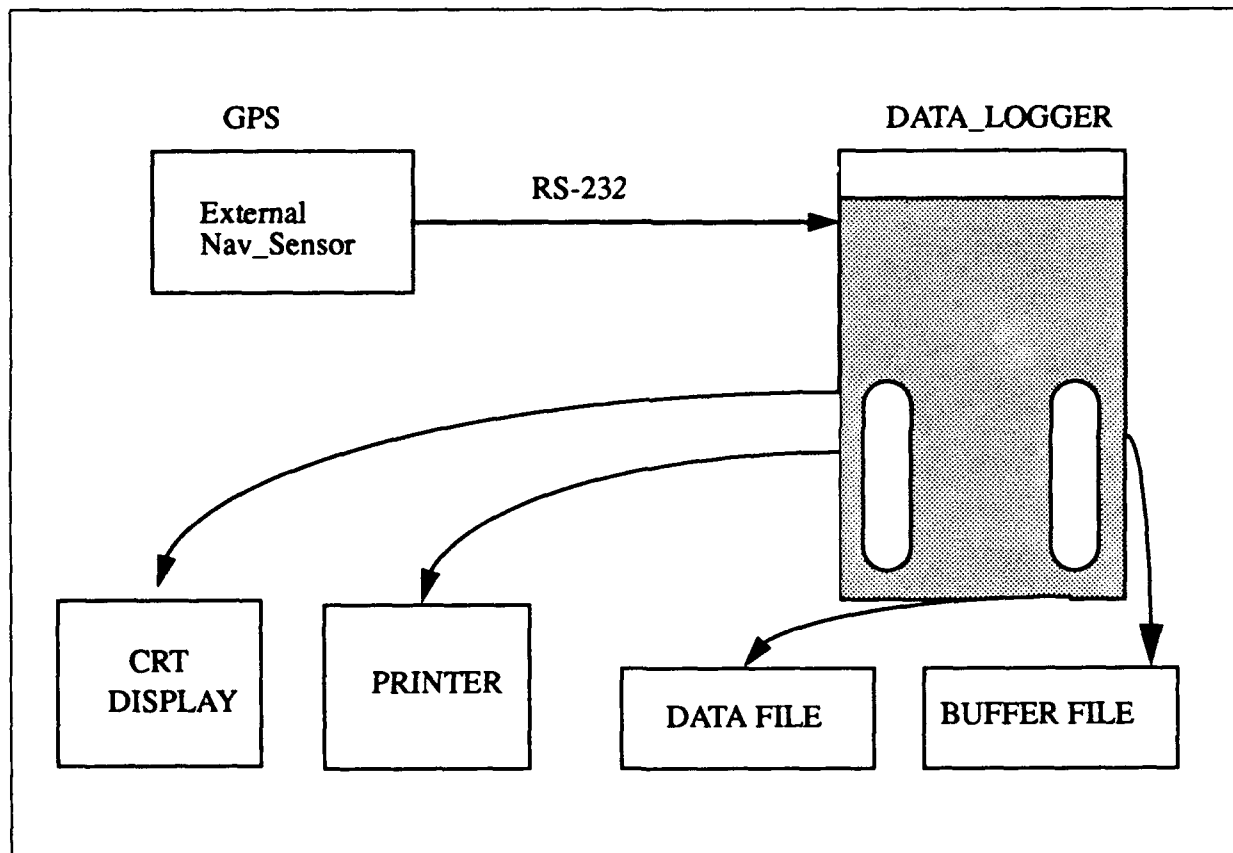


Figure-8: Description of Data_Logger I/O ports

IV. DATA_LOGGER IMPLEMENTATION

A. SYSTEM-SENSOR INTERFACING

To set up the interface between system and external sensor, we need to initialize the COM_PORT which is physically connected to the sensor. According to the pre-defined package BIT (Appendix.2), we have the procedures of SETBIT, CLRBIT which can set the bit number into the specified port and clear it when done, the function TSTBIT with in out VALUE in type INTEGER and assigned BIT number in type of BIT_NUM, which is subtype of INTEGER and range 0 .. 15. Also we have the capabilities to handle the VALUE in out as user assigned PORTNUM then put and get the VALUE in type SYSTEM.BYTE by using procedures INPORT and OUTPORT.

This is the design that we assign the COM_PORT:

Code-1: Initialization

-
- * First of all we want to set up the communication through the standard RS-232 connections, a procedure named INITIAL with two variables of type INTEGER, programmed to make the selection of COM_PORT (3f8 or 2f8), and set the status register ready (3fd or 2fd).
 - * Needs to be done every time when restart the system.
-

```
: -- A procedure to start the program
procedure INITIAL(PORT1, PORT2: out INTEGER) is
  NUM: INTEGER;
begin
  GET(NUM); -- to set up com_port number here
  case NUM is
    when 1 =>
      PORT1:= 1021;
      PORT2:= 1016;
      PUT_LINE("You've set Port1 = 1021, and Port2 = 1016");
    when 2 =>
```



```

    PORT1:= 765;
    PORT2:= 760;
    PUT_LINE("You've set Port1 = 765, and Port2 = 760");
when others =>
    PUT_LINE("Wrong key! Sorry, you should be more careful ");
end case; end INITIAL;

```

Code-2: Setup the Baud_Rate

* Secondly we setup the BAUD_RATE to complete the initialization of the system connector and communication transmit through RS-232.

```

-- A procedure to set the system baud_rate
procedure BAUD_RATE is
    CH: INTEGER;
    procedure RATES(P1, P2, P3, P4: in INTEGER) is
        NUMBER, SELECTION: INTEGER;
    begin
        OUTPUT (P1, 128); -- access Baud-Rate- Divisor
        GET(SELECTION);
        case SELECTION is
            when 1 =>
                NUMBER:= 96; -- Baud-Rate = 1200
            when 2 =>
                NUMBER:= 48; -- Baud-Rate = 2400
            when 3 =>
                NUMBER:= 24; -- Baud-Rate = 4800
            when 4 =>
                NUMBER:= 12; -- Baud-Rate = 9600
        end case;
        OUTPUT (P2, SYSTEM.BYTE(NUMBER)); -- convert the number into system.byte
    end RATES;
end BAUD_RATE;

```

```

-- put LSB on 3f8 or 2f8 (com1 or com2)set Baud
  OUTPORT (P3, 00); -- put MSB on 3f9 or 2f9
  OUTPORT (P1, 03); -- no p one s 8 bit
  OUTPORT (P4, 03); -- set modem control register
  OUTPORT (P3, 00); -- interrupt control register (disable)
end RATES;
begin
  GET(CH);
  case CH is
    when 1 =>
      RATES(1019, 1016, 1017, 1020); -- call subprogram RATES and passed the var value
    when 2 =>
      RATES(763, 760, 761, 764);
  end case;
end BAUD_RATE;

```

External sensor operation requires certain levels of set up process operate by user. As a good example, Appendix.1 presents a brief introduction of Trimble 4000 GPS using RS-232 interface to an external computer. Operation requires three basic things; such as Port I/O match, type of VALUE declaration, and transmission rate set up. One way or the other, the practical cable connection and interfacing set up procedures should be carefully done step by step and may be done by using a reliable little test program.

B. SENSOR DATA HANDLER

Before we receive sensor data from an external sensor, the system shall be ready for data input. Appendix.3 provides the formats of the sensor data, which we are interested in using in this project. In Ada, we like to use file as a main memories unit to help user handle data in and out. To make room and assign an address to an incoming data_string, we could simply use:

```
OPEN (TYPE => FILE_TYPE, MODE => OUT_FILE, NAME => "POS.DAT");
```

This is to open a file as a text `FILE_TYPE`, with mode as `OUT_FILE (WRITE)` and named `POS.DAT`. The system is then ready for `PUT` or `WRITE` some data into the file. While data is coming from the `COM_PORT`, where it is going to rest, what is the format of data, and how can we handle it is becoming our next concern.

Since we decided to use predefined package `BIT`, we know we are getting data in `BYTES`, and convert it into any type we need in the whole program. The main subprogram `LOGGER` that serves as the root of the system is programmed in this manner. It checks the line register for legal (defined by user) character, then log in the desired one. By the time when user monitor the input data on the screen, it stored into assigned file as well (`Raw_data`). On the other hand, our system keep the updated `data_string` in another buffer file called `POS.OUT` which store only the new updated position data, and ready to be used any time when the complete set of string is received.

Code-3: A main subprogram

* A main subprogram which contains the function `GET_CHAR` to get data from external navigation sensor and return `CHARACTER` data, then distributes data to `data_file`, `buffer_file`, and display.

-- A procedure to logging data

procedure `LOGGER` (`PORT1`, `PORT2`: in `INTEGER`) is

-- `port1 = 1021 | 765`, `port2 = 1016 | 760`

`A_CHAR`: `CHARACTER`;

`VALUE`: `SYSTEM.BYTE`;

-- A function to get data from GPS sensor

 function `GET_CHAR` return `CHARACTER` is

`LINE`, `DATA`: `SYSTEM.BYTE`;

`LINE_INT`: `INTEGER`;

 begin

 loop

`INPORT` (`PORT1`, `LINE`); -- check 3fd input data is available

 exit when `TSTBIT`(`INTEGER`(`LINE`), 0); -- loop until it's available

```

        if KEYPRESS then-- exit the loop
            raise ABORT_REQUEST;
        end if;
    end loop;
    LINE_INT:= INTEGER(LINE); -- convert LINE into integer
    CLRBIT(LINE_INT, 0); -- clear TESTBIT
    INPORT (PORT2, DATA); -- read data from 3f8
    OUTPORT(PORT1, SYSTEM.BYTE(LINE_INT)); -- put value back to 3fd
    return CHARACTER'VAL(DATA);-- return value in character
end GET_CHAR;

begin
    loop-- wait for the first legal char
        OPEN (FILE, OUT_FILE, NAME => "POS.OUT"); -- open a temp out file
        while GET_CHAR /= '[' loop-- process each message received
            null; -- and wait for start character
        end loop;
        PUT ('['); -- put start char on the screen
        PUT (THE_FILE, '['); -- put start char to file
        PUT (FILE, '['); -- put start character to temp file
        loop
            A_CHAR:= GET_CHAR; -- get and put the message
            PUT (A_CHAR); -- put data on the screen
            PUT (THE_FILE, A_CHAR); -- and to the file
            PUT (FILE, A_CHAR); -- and to the temp file
            exit when A_CHAR = ']'; -- line 185
        end loop; -- get another set of data
        CLOSE(FILE); -- close temp file here
        exit when KEYPRESS; -- exit loop
    end loop;
end LOGGER;

```

C. SYSTEM DATA MANAGEMENT

The system is getting data from an external sensor and it is coming in like a flow. Procedure **LOGGER** has the control of coming data flow by using line register checking, and so we can keep the data as clear as we want. It is the problem that how can we keep and get a real_time data from the system. Procedure **POSITION_NOW** is presenting a simple way to solve this problem, by using a separate procedure we make the buffer file **POS.OUT** play an independent work while system running and it provides real_time data. This design is very useful for Suitcase Navigation System at the present time, when the user needs the position in a good accuracy. It is also good for future system implementation, which needs a whole set of independent position data_string.

Code-4: Display current position data

* To responds the user's need in between operation, the system can be interrupted by a single user command, to pull out the current position data and be able to print.

-- A procedure to print the desire data_string

procedure **POSITION_NOW** is

ITEM: **CHARACTER**;

FILE: **FILE_TYPE**;

begin

OPEN (**FILE**, **IN_FILE**, **NAME** => "POS.OUT"); -- open the update file

 while not **END_OF_FILE**(**FILE**) loop

GET(**FILE**, **ITEM**); -- get the data

PUT(**ITEM**); -- put it on the screen

 end loop;

CLOSE(**FILE**);

end **POSITION_NOW**;

D. PROGRAM CODING

We programmed the system DATA_LOGGER for PC or LapTop which is supported by DOS operating system. Program coding was done in IntegrAda and will be refined later, when the project move up to automation boundary, and multi-tasking. Since this is the first software program for Suitcase Navigation System, our main effort is to make the basic function work. The goal is clear, the structure of the whole system is firm, the program coding is as good as any other Ada program, which is as follows:

```
-----
-- UNIT_NAME      | DATA_LOGGER.A
-- UNIT_DESCRIPTION | This program is designed for Suitcase Navigation
--                | data logger which logs data from GPS sensor store,
--                | puts it into a file and prints the data string by the
--                | user desire command
-- INPUTS          | GPS input raw data
-- OUTPUTS         | data record
-- CREATED         | 12 May 1991
-- AUTHOR          | CDR. Chin, Yu-Chi
-- ADVISOR         | DR. Uno R. Kodres
-----
```

```
with BIT, KEYBOARD, TEXT_IO, RTEXT_IO;
use BIT, KEYBOARD, TEXT_IO, RTEXT_IO;
```

procedure DATA_LOGGER is

```
-- program specification declaration to expose the parameters in out
procedure INITIAL(PORT1, PORT2: out INTEGER);
procedure LOGGER (PORT1, PORT2: in INTEGER);
package INTEGER_INOUT is new INTEGER_IO(INTEGER);
use INTEGER_INOUT;
-- global variable declaration
FILE, THE_FILE    : FILE_TYPE;
PORT1, PORT2, ROCK : INTEGER;
ABORT_REQUEST     : EXCEPTION;
```

```

-- A procedure to start the program
procedure INITIAL( PORT1,PORT2 : out INTEGER ) is
  NUM: INTEGER;
begin
  PUT_LINE(" AUTHOR : CDR. CHIN, YU-CHI R.O.C.N ");
  NEW_LINE;
  PUT_LINE(" ADVISOR : DR. UNO R. KODRES NPGS U.S.A. ");
  NEW_LINE;
  PUT_LINE(" DATE : 16 MAY 1991 ");
  delay 5.0;
  NEW_LINE(24);
  PUT_LINE("A brief guide to use this program :");
  NEW_LINE;
  PUT_LINE("1. Select COM_PORT & Make sure your system Baud_Rate is match");
  NEW_LINE;
  PUT_LINE("2. Run the procedure DATA_LOGGER at proper COM_PORT");
  NEW_LINE;
  PUT_LINE("3. Use Space_Bar and then Prt_Sc to get updated data_string");
  NEW_LINE;
  PUT_LINE("4. Use (q) or (Q) to exit the program");
  NEW_LINE;
  delay 5.0;
  PUT_LINE("Give the COM_PORT number in (1) or (2)");
  GET(NUM);
  -- to set up com_port number here
  case NUM is
    when 1 =>
      PORT1 := 1021;
      PORT2 := 1016;
      PUT_LINE("You've set Port1 = 1021, and Port2 = 1016");
    when 2 =>
      PORT1 := 765;
      PORT2 := 760;
      PUT_LINE("You've set Port1 = 765, and Port2 = 760");
    when others =>

```

```

    PUT_LINE(" Wrong key !! Sorry, you should be more careful ");
end case;
end INITIAL;
-- A procedure to set the system baud_rate
procedure BAUD_RATE is
    CH : INTEGER;

    procedure RATES(P1, P2, P3, P4 : in INTEGER) is
        NUMBER,
        SELECTION : INTEGER;
    begin
        OUTPUT (P1, 128);           -- access Baud-Rate- Divisor
        PUT_LINE ("SET THE SYSTEM BAUD-RATE AS YOUR DESIRE");
        PUT_LINE (" --- SELECTION IS --- ");
        PUT_LINE ("  1 = 1200      ");
        PUT_LINE ("  2 = 2400      ");
        PUT_LINE ("  3 = 4800      ");
        PUT_LINE ("  4 = 9600      ");
        NEW_LINE;
        GET(SELECTION);
        case SELECTION is
            when 1 =>
                NUMBER := 96;           -- Baud-Rate = 1200
                PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SET TO 1200 NOW");
            when 2 =>
                NUMBER := 48;           -- Baud-Rate = 2400
                PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SET TO 2400 NOW");
            when 3 =>
                NUMBER := 24;           -- Baud-Rate = 4800
                PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SET TO 4800 NOW");
            when 4 =>
                NUMBER := 12;           -- Baud-Rate = 9600
                PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SET TO 9600 NOW");
            when others =>

```



```

    PUT_LINE (" WRONG SELECTION !! TRY AGAIN !! ");
end case;
OUTPUT (P2,SYSTEM.BYTE(NUMBER)); -- convert the number into system.byte
    -- put LSB on 3f8 or 2f8 (com1 or com2)set Baud
OUTPUT (P3, 00);    -- put MSB on 3f9 or 2f9
OUTPUT (P1, 03);    -- 8 bit, no parity, one stop ( 8--NONE--1 )
OUTPUT (P4, 03);    -- set modem control register
OUTPUT (P3, 00);    -- interrupt control register (disable)
NEW_LINE;
PUT_LINE ("BAUD-RATE SETTING IS DONE !! ");
end RATES;

```

```

begin
NEW_LINE(5);
PUT_LINE("Now The program is design to setup the system BAUD_RATE");
NEW_LINE;
PUT_LINE("Make your choose for COM1 or COM2 : use -1- or -2-");
GET(CH);
case CH is
    -- set the value to ports
when 1 =>
    RATES(1019, 1016, 1017, 1020);    -- set baud_rate and parity
    PUT_LINE("FOR COM1 SETTING");    -- to com_port # 1
when 2 =>
    RATES(763, 760, 761, 764);    -- set baud_rate and parity
    PUT_LINE("FOR COM2 SETTING");    -- to com_port # 2
when others =>
    -- line 142
    PUT_LINE("WRONG KEY !! TRY AGAIN !!!");
end case;

```

```

end BAUD_RATE;

```

```

-- A procedure to print the desire data_string
procedure POSITION_NOW is
    ITEM : CHARACTER;

```

```

FILE : FILE_TYPE;

begin
  NEW_PAGE;
  NEW_LINE(5);
  PUT_LINE(" The current data_string is : ");
  NEW_LINE;
  OPEN (FILE, IN_FILE, NAME => "POS.OUT" ); -- open the update buffer file
  while not END_OF_FILE(FILE) loop          -- loop to get the whole string
    GET(FILE, ITEM);                        -- get the current data_string
    PUT(ITEM);                              -- put it on the screen
  end loop;                                -- out loop when done
  NEW_LINE(10);
  CLOSE(FILE);                             -- close file back to survey
end POSITION_NOW;

-- A procedure to log data from external nav_sensor
procedure LOGGER (PORT1, PORT2 : in INTEGER) is
  -- port1 = 1021/765, port2 = 1016/760
  A_CHAR    : CHARACTER;
  VALUE     : SYSTEM.BYTE;

  -- A function to get data from GPS sensor
  function GET_CHAR return CHARACTER is
    LINE, DATA : SYSTEM.BYTE;
    LINE_INT    : INTEGER;

  begin
    loop
      INPORT (PORT1, LINE);                -- check 3fd or 2fd is available
      exit when TSTBIT(INTEGER(LINE), 0); -- loop until it's available
    end loop;                             -- line 182
    LINE_INT := INTEGER(LINE);              -- convert LINE into integer
    CLRBIT(LINE_INT, 0);                   -- clear TESTBIT

```

```

    INPORT (PORT2, DATA);          -- read data from 3f8 or 2f8
    OUTPORT(PORT1, SYSTEM.BYTE(LINE_INT)); -- put value back to 3fd or 2fd
    if INTEGER(DATA) > 127 then      -- a test loop for bad data
        DATA := 42;                -- if not a character use '*'
    end if;
    return CHARACTER'VAL(DATA);
end GET_CHAR;

begin
    PUT_LINE("Waiting for the first legal character");
    loop
        -- wait for the first legal char
        OPEN (FILE, OUT_FILE, NAME => "POS.OUT"); -- open a temp out file
        while GET_CHAR /= '[' loop
            -- process each message received
            null;
            -- and wait for start character
        end loop;
        PUT ('[');
            -- put start char on the screen
        PUT (THE_FILE, '[');
            -- put start char to file
        PUT (FILE, '[');
            -- put start cgar to temp file
    loop
        --
        A_CHAR := GET_CHAR;
            -- get and put the message
        PUT (A_CHAR);
            -- put data on the screen
        PUT (THE_FILE, A_CHAR);
            -- and to the file
        PUT (FILE, A_CHAR);
            -- and to the temp file
        exit when A_CHAR = ']';
    end loop;
        -- get another set of data
    CLOSE(FILE);
        -- close temp file here
    exit when KEYPRESS;
        -- exit loop
end loop;
end LOGGER;

-- main program starts here

begin
    INITIAL (PORT1, PORT2);
        -- a brief program instruction
    BAUD_RATE;
        -- program to set system Baud_Rate
    OPEN (THE_FILE, OUT_FILE, NAME => "POS.DAT"); -- make file pos.dat available

```

```

loop
  if KEYPRESS(CURRENT_INPUT) then      -- press Space_Bar to interrupt and
    NEW_LINE;                          -- ready to print the screen
    PUT_LINE("New data_string is as follow:");
    NEW_LINE;
    ROCK:= KEY_VALUE;                  -- assign keypress to variable
    if ROCK = 32 then                  -- if Space_Bar is true then
      POSITION_NOW;                     -- bring the data to the screen
    elsif ROCK = 81 or ROCK = 113 then -- press (q) to exit the program
      raise ABORT_REQUEST;              -- raise exception
    end if;                            -- else program will keep running
  end if;                              -- no interruption
  LOGGER(PORT1, PORT2);                -- program to log sensor data
end loop;
exception
  when ABORT_REQUEST =>                -- exit the program
    CLOSE (THE_FILE);
    PUT_LINE ("END OF PROGRAM DATA_LOGGER.A");
end DATA_LOGGER;

```

V. DESCRIPTION OF THE DATA_LOGGER

A. THE REQUIRED PROGRAM STRUCTURE

1. Hardware Structure

The Navigation Data_Logger System is structured by 4 parts, which includes Antenna, GPS, Computer (PC or LapTop), and Printer. Since the external navigation sensor will be a generic positioning device, we will use the name GPS as generic Global Positioning System. For this program, we use Trimble-4000S GPS as the target Nav_Sensors, because it is available at school. Before we have the real GPS, our lab has set up two 286-Zenith PC connected by RS-232 cable to simulate the communications. By transmit data from computer A and received by computer B, we have learned that the wire connection through RS-232 will cause no problems for the project. By the time we got the GPS (Trimble-4000), the system is set up similar as Figure-9, and the software was written to be tested.

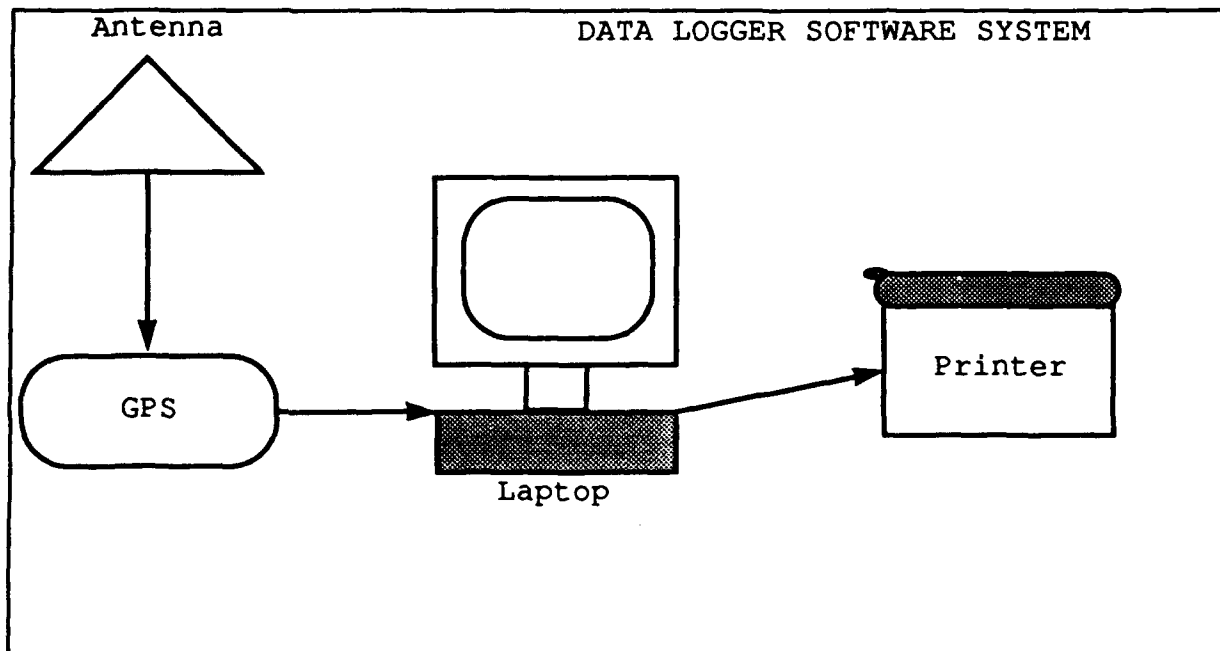


Figure-9: Hardware Structure of Data Logger

2. Software Structure

Ada is the only choice of software structure. As we have mentioned, Ada is well designed for the applications via concurrently, real-time control, exception handling, and unique input and output. But as well as the program needs, Ada provides low_level programming also. Because of the hardware constrains for the type of computer will be a LapTop or a 286 PC, the software is constrained to DOS supported program by definition. We went through the applications of Ada input/output and learned that programming for input/output (I/O) has always been like going to the dentist for a toothache, it's some-thing that language designers have to do, but they tend to put it off in the hope that it might go away.

Ada does not treat I/O as a thorn in the side of the language. Infact, with the extensibility provided by Ada's packaging mechanism and generic facilities, Ada does not have to provide any special language features to accommodate I/O. The user can build his own I/O routines for communication with unique devices. Furthermore, without adding any new language constructs, the user can use any predefined units for I/O of common data types, such as characters, integers, and real numbers, which can be selected as needed.

Here, we use TEXT_IO to handle the generic text_file I/O, which can support the data storage and transfer at the same time while the input data is presented on the screen it outputs to an existing file and a designed buffer file which stored the updated data_string and can be pull out by User_commands. We also use another predefined package BIT, to handle the port I/O. This package supports the capabilities of checking the status of assigned port, and be able to put and get I/O values from the ports, which gives the user a little bit more control over the external communication devices.

B. ADVANTAGES OF THE DATA_LOGGER

The Navigation Data_Logger System was the first Ada program of the Suitcase Navigation System. It satisfied the needs of SNS project requirement to log the positioning data in the logger, and also provides the screen display for easy reading, but most importantly it provides a single set of current position data_string, which is the real-time position that the operation

required. Any time when you need to mark the position or you need a fix on the open sea, the Space_Bar is the user command to bring the current position data_string to the screen. To get a hardcopy by using print screen won't disturb the program processing the Nav_Sensors, but provides the scientists an clear data_record, and a reliable global position.

C. USER's MANUAL

The instruction of how to use the Navigation Data_Logger System has been written as an operation process and responses in Appendix.5. Beyond that, user should be able to set up the external Nav_Sensor's function properly and capable to make the connection to the control system (computer) through RS-232. When the operation is on, user should know the basic serial COM_PORT's function and how to adjust the transmission rate (Baud_Rate). After the hardware set up, the user should carefully start the initialization and run the program under the brief guide.

Since this program is directed to Trimble-4000s GPS, the logical position data_string was bounded by the special characters '[' and ']'. It was programmed inside the procedure **LOGGER** and was very easy to redefined by change the boundary character and it's decimal representations. To avoid the programming language constrains, user can select the separated function program listed in Appendix.4 and collected the data as well.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The Suitcase Navigation System is designed for the people who do not know much about Navigation, but want to work in the environment which needs to collect this information. The project uses GPS as a fundamental sensor, to provide the crucial data. This thesis is an effort in developing a Navigation Data_Logger software system, that can satisfy the needs to process navigation sensor data.

In order to achieve this basic requirement, we start from data format analysis and single byte transmission, finally we programmed the Navigation Data_Logger software system. As we may recall from chapter-4, the performance of the Data_Logger is demonstrates that it is quite efficient, mainly for logging messages from GPS and transmitting data to Screen, Raw_data file, and Buffer file. User can view the data on the screen, store the data in Raw_data file, and get the hard copy from buffer file. The conclusion arise from our Navigation Data_Logger System design is that Ada is an high level language, but it can be used to handle low_level I/O, and support the software design in high level programming.

B. RECOMMENDED FOLLOW-ON WORK

As stated in Chapter I, this thesis is directed to the GPS , represented by Trimble-4000 for the Suitcase Navigation System. It is our hope that it can serve as a firm foundation for future and more enhanced implementations. During the process this thesis was being developed, many new ideas were brought up. We would like to give some suggestions for future enhancements in the system.

- 1) The database of Data_Logger should be the first concern of the program in the near future. For long term survey, we need a database manager support our Nav_Sensors data processor.

2) Different external sensors will be the second problem. The system I/O ports concurrence and real time programming can be support by Ada, a separate package abstraction of these I/O ports could be a high-level view of physical memory locations.

3) Hot_Key control, Ada exception handling and low-level features of I/O representation specification is highly recommended for concurrent real- time processing. As noted in Appendix.6 from Reference-3.

4) Remote control to external navigation sensor is a possible and the software to challenge the next Ada programmer. The Trimble manual and Appendix.1 explains further how this should be done.

APPENDIX--I GPS Trimble-4000S

Using the RS-232 interface for Trimble 4000.

1. Select proper cables and connectors to connected the GPS and computer.

--Select one of the connectors (ports) and make a connection in the way of Matching Pins.*

-- Note: * In general, the only signals that need to be connected are:

Trimble 4000	Computer Port
--------------	---------------

-----	-----
-------	-------

Ground-----	Ground
-------------	--------

TXD (Transmit Data)----->RXD (Receive Data)

RXD (Receive Data)<-----TXD (Transmit Data)

2. Turn on the system and wait until its self calibration completed.

-- Reference position needs to load at this moment. when CALIBRATION OK, and then

-- POSITION FIX 3,4, A display shows the GPS is in normal function.

3. Use the I/O key on the control panel to select I/O functions.

4. Select SETUP, BAUD, and the PORT you wish to use.

5. Set the Data_Logger receiving rate match the GPS send rate.

--All Trimble Model 4000 GPS receivers defaults to 9600 Baud, 8-bits, odd parity, and one

--stop bit (8-ODD-1), Data_Logger set up 8-bits none parity, and one stop bit (8-NONE-

1) set your GPS to match.

6. Select the I/O, and PRINT function to get the desire position data.

7. Remote control programming : To interact properly with the specific interface function desired.*

--Note: * The remote control interface allows an external computer to set the controls on

--GPS receiver and transfer the measurements and calculations to the computer.

8. Interact with a remote computer through a report session. *

--Note: * A description of The Report Session:

The Report Session is enabled by sending a special character, ATTENTION (35 D or 23 H).

The ATTENTION command switches the port on which it is received to become the remote control port, and the next byte received will be logged as a command and will trigger a report session when the system cycle reaches that step. At that time, the command will be echoed. --

-- Report Session loop:

1. Wait for first byte of next command.
 2. Echo the command.
 3. Read any other bytes of command (no echoing)
 4. Execute the command. This may include sending multiple bytes to the computer.
- * Note : There can be a significant delay between sending the first command and the echo.
This is especially true if the receiver is making synchronized measurements.

-- Something you have to know about Trimble-4000 remote control commands.

1. All commands start with a single byte that is evenly divisible by three.
2. The only other valid bytes are :
 - 35 d : ATTENTION;
 - 34 d : old-style ATTENTION;
 - 37 d : ACTIVITY REQUEST;
3. Any illegal bytes will cause an abort of the report session.
4. GPS will wait only 30 seconds for a command it will beep and exit the current session if more time than this elapses.
5. Command Formats:
 - [B] Bytes is single eight-bit INTEGER, range 0 .. 255;
(e.g. 255 for ON and 0 for OFF)
 - [D] BCD " Binary-Coded-Decimal " digit is single byte range 0 .. 9;
(e.g. Lat, Long. Hgt in command 51 d are sent as sequences of BCD digits.)
 - [R] Floating Point Real number. The real # represented is:
 $[R] = (-1)^s \times 2^{(exp-1023)} \times 1.mmmm.. mmmm.$
(i.e. IEEE 754 standard for long real numbers)
6. Unit of semicircles in use:
 - 1 semicircle = 180 degrees = Pi radians.

The Lat and Long values output over the remote control port are both sent in semicircles.

The values are sent as 8-byte real numbers using IEEE standard format. After converting to the receiving computer, the value will be in semicircles, range -1.0. +1.0 which means -180.0. +180.0 degrees. '+' = North & East, '-' = South & West. Another converting is desirable to include degrees, minutes, and seconds.

An example of semicircle to degrees :

(e.g. Semicircle = -0.6875833333

Degrees = 0.6875833333 * 180.0

= 123.765000 degrees

Minutes = fraction (123.765) * 60

= 0.765 * 60 = 45.9000 minutes

Seconds = fraction (45.9) * 60

= 0.900 * 60 = 54.00 seconds

Thus, (Longitude)

- 0.6875833333 (Semicircles)

= West 123.765000000 deg (decimal degrees)

or = West 123 deg 45.9000 min (degrees and decimal minutes)

or = West 123 deg 45 min 54.00 sec (degrees, minutes, seconds)

APPENDIX--II Predefined PACKAGE BIT

with SYSTEM;

use SYSTEM;

package BIT is

 subtype BIT_NUM is INTEGER range 0 .. 15;

 procedure SETBIT(VAL : in out INTEGER; BIT : in BIT_NUM);

 procedure CLRBIT(VAL : in out INTEGER; BIT : in BIT_NUM);

 function TSTBIT(VAL : in INTEGER; BIT : in BIT_NUM) return BOOLEAN;

 function LAND(VAL1, VAL2 : in INTEGER) return INTEGER;

 function LOR(VAL1, VAL2 : in INTEGER) return INTEGER;

 function LXOR(VAL1, VAL2 : in INTEGER) return INTEGER;

 function LNOT(VAL : in INTEGER) return INTEGER;

 function PEEK (ADDR : in INTEGER) return BYTE;

 procedure POKE (ADDR : in INTEGER; VAL : in BYTE);

 function PEEK (SEGMNT, OFFSET : in INTEGER) return BYTE;

 procedure POKE (SEGMNT, OFFSET : in INTEGER; VAL : in BYTE);

 function CODE_SEG return INTEGER;

 function DATA_SEG return INTEGER;

 procedure INPORT (PORTNUM : in INTEGER; VALUE : out BYTE);

 procedure OUTPORT (PORTNUM : in INTEGER; VALUE : in BYTE);

end BIT;

APPENDIX--III SAMPLE DATA

Different set of data from GPS and RPS

TRIMBLE 4000 GPS RECEIVER SETUP PARAMETERS MON 098 08-APR-91
21:24:07

GPS WEEK NUMBER: 0587
REFERENCE LATITUDE: 36:35.9000N
REFERENCE LONGITUDE: 121:52.5990W
REFERENCE HEIGHT: -0020.0 meters
FIXED HEIGHT: YES
REFERENCE FREQUENCY: +0.000E+00 delta f/f
FIXED FREQ: YES
LATITUDE OFFSET: 00:00.0000N
LONGITUDE OFFSET: 000:00.0000E
HEIGHT OFFSET: +0000.0 meters

MASKS

PDOP MASK: 07.0
ELEVATION MASK: 10 degrees
DATA AGE SINCE DECODE MASK: 03 hours

CALIBRATION DATA

CODE CALIBRATION: +00.01 +00.01 -00.06 -00.04 +00.06 -00.67 -01.77
-00.08 +00.
02 meters
CARRIER PHASE CALIBRATION: +000 +000 +000 +000 +000 +000 +000 +000
+000 mm
CALIBRATION TIME: 0010 secs

SV STATUS

HEALTHY SVS: 02 03 06 11 12 13 14 15 &
16 17 18 19 20 21 23
DISABLED SVS:
IGNORE HEALTH SVS (POSITIONING):
IGNORE HEALTH SVS (SURVEY):
AUTO SV SELECTION: MIN SVS 3, MAX SVS 4
AUTO INITIAL SV SEARCH
ALL-IN-VIEW SOLUTION: ENABLED

RS232 PORTS

PORT1: 9600 BAUD 8-ODD--1 START CC= 000 000 000 STOP CC= 000
000 000

POSITION, MEASUREMENTS

PORT2: 9600 BAUD 8-ODD--1 START CC= 000 000 000 STOP CC= 000
000 000

OFF

POSITION PRINT TIMER: 00 mins

PRINT ID: 00

DATA BASE

ION UPDATE: ENABLED

BUL UPDATE: ENABLED

DATA UPDATE: ENABLED

RECEIVER OPERATION

DOPPLER AIDING: ON

SYNC: 002.0 secs

OSCILLATOR DAC: ON

SV AVERAGING: 01.0 secs

POSITION AVERAGING: 0001

SOFTWARE

NAVIGATION PROCESSOR SOFTWARE VERSION: 3.24 16-AUG-89

SIGNAL PROCESSOR SOFTWARE VERSION: 3.20 23-MAR-89

PART ONE

FROM TRIMBLE 4000S

FUNCTION PRINT MODE POS (position):

WN	REF.LAT	REF.LON	REF.HGT	LAT.OFFSET	LON.OFFSET
HGT.OFF SV, POSAV					
G PDOP EL AGE MIN MAX REF.FRQ					
0587	36:35.9000N	121:52.5990W	-0020.0	00:00.0000N	000:00.0000E
+0000.0 01.0 000					
1	07.0	10	3	4	+0.000E+00
ID	DAY	DOY	DATE	TIME	LATITUDE
CLOCK	V.VE				
L	H.VEL	HDG	FREQ.OFFSET	CONT	S SVS
[00	MON	098	08-APR-91	21:24:03	36:35.9482N 121:52.5926W -0017 03.8
309263 +000.					
03	000.00	000.0	+5.4522E-11	0043 4	18,19,11,2]
[00	WED	059	28-FEB-90	07:08:13	36:18.2773N 121:59.7371W -0035 04.3
687719 +000.01 002.76 173.8 +4.2469E-11 0024 4 11,3,12,19]					
[00	WED	059	28-FEB-90	07:08:29	36:18.2653N 121:59.7351W -0035 04.3
687720 -000.00 002.79 169.6 +4.4440E-11 0025 4 11,3,12,19]					
[00	WED	059	28-FEB-90	07:08:44	36:18.2569N 121:59.7421W -0020 03.2
687785 +000.00 002.78 167.0 +3.2741E-10 0026 3 3,12,19]					
[00	WED	059	28-FEB-90	07:08:59	36:18.2455N 121:59.7375W -0020 03.2
687785 +000.00 002.84 160.5 +9.1577E-11 0027 3 3,12,19]					
[00	WED	059	28-FEB-90	07:09:32	36:18.2230N 121:59.7229W -0020 03.2
687791 +000.00 002.85 143.9 +3.8273E-11 0001 3 3,12,19]					
[00	WED	059	28-FEB-90	07:09:50	36:18.2134N 121:59.7046W -0026 02.2
687757 -000.01 002.75 133.4 +7.8132E-11 0001 4 11,3,12,6,19]					
[00	WED	059	28-FEB-90	07:10:05	36:18.2060N 121:59.6937W -0026 02.2
687758 +000.00 002.64 125.3 +7.4215E-11 0002 4 11,3,12,6,19]					
[00	WED	059	28-FEB-90	07:10:20	36:18.2004N 121:59.6820W -0026 02.2
687760 +000.02 002.54 116.6 +7.5696E-11 0003 4 11,3,12,6,19]					
[00	WED	059	28-FEB-90	07:10:35	36:18.1965N 121:59.6698W -0027 02.2
687761 +000.00 002.45 107.9 +7.5028E-11 0004 4 11,3,12,6,19]					
[00	WED	059	28-FEB-90	07:10:50	36:18.1959N 121:59.6600W -0034 03.5
687746 -000.01 002.36 100.2 +7.4971E-11 0005 4 11,3,12,6]					
SV	EL	AZM	SN	IODC	CONT
GPS	TIME	AVG	LAT	AVG	LON
AVG	HGT				
NO.	RMS	LAT	LON	HGT	AVG
CLK	CLK	RATE	AVG	FRQ	
11	31	037	13	0462	0005 +285056.512
36:18.1959N 121:59.6600W -					
0034.6 0001 00.00 00.00 00.00 687746 +0.0000E+00 +7.4971E-11 A					
03	36	255	16	0391	0139 +285056.512
12	72	278	18	0029	0052 +285056.512
06	09	159	11	0228	0005 +285056.512

PART TWO

FROM TRIMBLE 4000 XS

FUNCTION PRINT MODE MEAS:

[+1.62465152000E+08 +2.97336525754E+05 +4.09017287885E+06 -
5.79796142489E+05 -
5.79951245869E+05 +5.19603100000E+06 +2.08923525974E+07
+2.97319082170E+05 +1.8
0110329726E-01 +0.00000000000E+00 +0.00000000000E+0000900102218] [
+1.6246515200
0E+08 +3.470368450
75E+04 +4.09173391062E+06 +4.02280631719E+05 +4.02282417503E+05
+5.18200400000E
+06 +2.06316314375E+07 +3.46966031546E+04 +7.29198695187E-02
+0.00000000000E+00
+0.00000000000E+0000300102019] [+1.62465152000E+08
+5.47442764476E+04 +4.09390
777905E+06 +6.6662
4958540E+04 +6.66629219876E+04 +1.79614000000E+05
+2.35639205651E+07 +5.4726886
2247E+04 +4.14212197467E-02 +0.00000000000E+00
+0.00000000000E+0000200000811] (
+2.03328483276E-01 -6.77091561631E-01 -6.56408896315E+00 -
2.70732416499E+06 -4.
35348044922E+06 +3
.78176743118E+06 +2.83064040661E+00 +9.27233423855E+04 -
7.74005685580E-03) [00 M
ON 098 08-APR-91 21:07:53 36:35.9477N 121:52.5885W -0006 02.8
309292 +000.00 00
0.02 267.7 +2.2601E-11 0014 3 18,19,11]
[+1.62480256000E+08 +2.80252655781E+03 +4.09016570002E+06 -
5.85057548887E+05 -
5.85212616397E+05 +5.21113400000E+06 +2.08976139552E+07
+2.78805384002E+03 +1.1
0563354440E-01 +0.00000000000E+00 +0.00000000000E+0000500102318] [
+1.6248025600
0E+08 +3.547620969
67E+04 +4.09173033829E+06 +4.01510749528E+05 +4.01512559628E+05
+5.19710800000E
+06 +2.06324012107E+07 +3.54664817960E+04 +2.31367014084E-02
+0.00000000000E+00
+0.00000000000E+0000100101819] [+1.62480256000E+08
+4.92651948358E+04 +4.09390
054617E+06 +7.2135

PART THREE

FROM MINI-RANGER FALCON 484
FUNCTION PRINT POSITION :

```

05:48:26.4 15 29739.9 1 6      1.0 13  3403.8 1 6      0.9 1
17718.9 1 19
    2.8 4 23691.4 1 38      -1.4      608236.3  4073620.7  0.1 F4
0 C      3.6
    2.9\TTAG: 380343\ 9\
    05:48:28.4 15 29738.9 1 6      1.4 13  3402.5 1 6      1.7 1
17718.9 1 19
    3.4 4 23691.6 1 37      -1.1      608237.3  4073621.1  0.2 F4
0 C      3.6
    3.6\TTAG: 380367\ 0\
    05:48:30.4 15 29737.9 1 6      1.9 13  3400.3 1 6      3.3 1
17718.6 1 19
    4.3 4 23691.4 1 38      -0.2      608238.0  4073621.5  0.3 F4
0 C      3.6
    4.9\TTAG: 380410\ 0\
    05:48:32.4 15 29738.7 1 6      1.4 13  3402.5 1 6      1.8 1
17718.6 1 19
    3.6 4 23691.5 1 38      -1.1      608237.7  4073621.8  0.1 F4
0 C      3.6
    3.8\TTAG: 380433\ 0\
    05:48:34.4 15 29738.3 1 6      1.5 13  3403.0 1 6      1.6 1
17718.4 1 19
    3.7 4 23691.7 1 38      -1.5      608237.4  4073621.4  0.0 F4
0 C      3.6
    3.9\TTAG: 380457\ 0\
    05:48:36.4 15 29739.0 1 6      1.7 13  3401.3 1 6      2.5 1
17718.5 1 19
    3.9 4 23691.4 1 38      -0.7      608237.6  4073621.2  0.1 F4
0 C      3.5
    4.2\TTAG: 380499\ 0\
    05:48:38.4 15 29739.5 1 6      1.6 13  3401.9 1 6      2.2 1
17718.0 1 18
    4.0 4 23691.5 1 39      -1.1      608237.9  4073621.6  0.1 F4
0 C      3.6
    4.2\TTAG: 380523\ 0\
    05:48:40.4 15 29739.4 1 6      1.7 13  3400.8 1 6      2.7 1
17718.6 1 18
    3.9 4 23691.6 1 37      -0.5      608238.6  4073621.3  0.2 F4
0 C      3.6
    4.2\TTAG: 380546\ 0\

```

APPENDIX--IV Ada Program Examples

--Example 1

```
-----
-- UNIT_NAME      | DATA_IN.A
-- CSCI_NAME
-- UNIT_DESCRIPTION | THIS PROGRAM IS DESIGNED FOR RECIEVED DATA FROM
--                  EXTERNAL DEVICE AND DISPLAYED ON THE SCREEN.
-- INPUTS          | GPS DATA FILES i.e. line56.dat
-- OUTPUTS         | read on the screen
-- CREATED         | 13 March 1991
-- AUTHOR          | Chin, Yu-chi
-- ADVISOR         | Dr. Uno R. Kodres
-- DATE ----- AUTHOR ----- REVISION # -- PR # -----TITLE -----
-- 0313/1991      Chin, Yu-chi   1          DATA_IN.A
-----
```

```
with BIT, TEXT2_IO;
use BIT, TEXT2_IO;
```

```
procedure DATA_IN is
  PORTNUM : INTEGER := 1016;
  VALUE   : SYSTEM.BYTE;
begin
  INPORT (PORTNUM,VALUE);
  PUT_LINE ( "Port number " &INTEGER'IMAGE(PORTNUM)&
    " is currently " &SYSTEM.BYTE'IMAGE(VALUE) );
  PUT_LINE ( "----- DATA RECEIVED -----");
end DATA_IN;
```

-- Example 2

```
-----  
-- DATE ----- AUTHOR ----- REVISION # -- PR # ----- TITLE -----  
--9 April 1991  Chin, Yu-Chi      5          test12.a  
-----
```

```
with BIT, TEXT_IO;  
use BIT, TEXT_IO;  
procedure TEST12 is  
  LINE_INT,  
  PORTNUM : INTEGER ;  
  LINE,  
  DATA,  
  VALUE   : SYSTEM.BYTE;  
  COUNT   : INTEGER := 0;  
  package INTEGER_INOUT is new INTEGER_IO(INTEGER);  
  use INTEGER_INOUT;  
begin  
  loop  
    loop  
      INPORT (1021, LINE);    -- check 3fd see if input data is available  
      exit when TSTBIT(INTEGER(LINE),0); -- loop until it's availab  
    end loop;  
    LINE_INT := INTEGER(LINE); -- convert LINE into integer  
    CLRBIT(LINE_INT,0);       -- clear 3fd  
    OUTPORT(1021,SYSTEM.BYTE(LINE_INT)); -- put value back to 3fd  
    INPORT (1016, DATA);     -- read data from 3f8  
    PUT (CHARACTER'VAL(DATA)); -- put data on the screen  
    exit when INTEGER(DATA) = 93; -- exit when input data is ']'  
  end loop;  
  delay 1.0;                 -- test delay  
  PUT_LINE ("END OF RECEIVING DATA");  
end TEST12;
```

-- Example 3

```
-----  
-- UNIT_NAME      | TEST31.A  
-- UNIT_DESCRIPTION | This program is designed to set baud-rate form 1200 - 9600 for the  
--system which we want to use, the soft ware can easily expand by set more rate settings.  
-- AUTHOR         | CDR. Chin, Yu-Chi  
-- ADVISOR        | Dr. Uno R. Kodres  
-----
```

with BIT, TEXT_IO;

use BIT, TEXT_IO;

procedure TEST31 is

CH : INTEGER;

package INTEGER_INOUT is new INTEGER_IO(INTEGER);

use INTEGER_INOUT;

procedure TEST24(PORT1, PORT2, PORT3, PORT4 : in INTEGER) is

NUMBER,

SELECTION : INTEGER;

begin

OUTPORT (PORT1, 128); -- access Baud-Rate- Divisor

PUT_LINE ("SET THE SYSTEM BAUD-RATE AS YOUR DESIRE");

PUT_LINE (" --- SELECTION IS --- ");

PUT_LINE (" 1 = 1200 ");

PUT_LINE (" 2 = 2400 ");

PUT_LINE (" 3 = 4800 ");

PUT_LINE (" 4 = 9600 ");

NEW_LINE;

GET(SELECTION);

case SELECTION is

when 1 =>

NUMBER := 96; -- Baud-Rate = 1200

PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SETTING TO 1200 NOW");

```

when 2 =>
    NUMBER := 48;    -- Baud-Rate = 2400
    PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SETTING TO 2400 NOW");
when 3 =>
    NUMBER := 24;    -- Baud-Rate = 4800
    PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SETTING TO 4800 NOW");
when 4 =>
    NUMBER := 12;    -- Baud-Rate = 9600
    PUT_LINE ("YOUR SYSTEM BAUD-RATE IS SETTING TO 9600 NOW");
when others =>
    PUT_LINE (" WRONG SELECTION !! TRY AGAIN !! ");
end case;
    OUTPORT (PORT2,SYSTEM.BYTE(NUMBER));
-- convert the number into system.byte
-- put LSB on 3f8 or 2f8 (com1 or com2)set Baud
    OUTPORT (PORT3, 00);    -- put MSB on 3f9 or 2f9
    OUTPORT (PORT1, 03);    -- no p one s 8 bit
    OUTPORT (PORT4, 03);    -- set modem control register
    OUTPORT (PORT3, 00);    -- interrupt control register (disable)
    NEW_LINE;
    PUT_LINE ("BAUD-RATE SETTING IS DONE !! ");
end TEST24;

begin
NEW_LINE(5); SET_COL(5);
PUT_LINE("This program is designed to help you setup the system BAUD_RATE");
NEW_LINE;
PUT_LINE("Make your choose for COM1 or COM2 first : use -1- or -2-");
GET(CH);
case CH is
    when 1 =>
        TEST24(1019, 1016, 1017, 1020);
        PUT_LINE("FOR COM1 SETTING");
    when 2 =>

```

```
TEST24(763, 760, 761, 764);  
PUT_LINE("FOR COM2 SETTING");  
when others =>  
    PUT_LINE("WRONG KEY !! TRY AGAIN !!!");  
end case;  
end TEST31;
```

-- Example 4

```
-- UNIT_NAME      | test35.a
-- UNIT_DESCRIPTION | This program is designed for Suitcase Navigation
--                | data logger which log data from GPS sensor store
--                | it into a file and print the data string by the
--                | user desire command
-- INPUTS          | GPS input raw data
-- OUTPUTS         | data record
-- CREATED         | 12 May 1991
-- AUTHOR          | Chin, Yu-Chi
-- ADVISOR         | Uno R. Kodres
```

```
with BIT, KEYBOARD, TEXT_IO, RTEXT_IO;
use BIT, KEYBOARD, TEXT_IO, RTEXT_IO;
procedure TEST35 is
package INTEGER_INOUT is new INTEGER_IO(INTEGER);
use INTEGER_INOUT;
FILE, THE_FILE : FILE_TYPE;
ROCK           : INTEGER;
ABORT_REQUEST  : EXCEPTION;
  -- A procedure to print the desire data_string
procedure PRINT_DATA is
  ITEM : CHARACTER;
  FILE : FILE_TYPE;
begin
  NEW_PAGE;
  NEW_LINE(5);
  PUT_LINE(" The current data_string is : ");
  NEW_LINE;
  OPEN (FILE, IN_FILE, NAME => "POS.OUT" );      -- open the update file
  while not END_OF_FILE(FILE) loop
    GET(FILE, ITEM);          -- get the data
    PUT(ITEM);                -- put it on the screen
```



```

end loop;
NEW_LINE(10);
CLOSE(FILE);                                -- line 140
end PRINT_DATA;

-- A procedure as data logger
procedure DATA_LOGGER is
A_CHAR      : CHARACTER;
VALUE       : SYSTEM.BYTE;

-- A function to get data from GPS sensor
function GET_CHAR return CHARACTER is
LINE, DATA : SYSTEM.BYTE;
LINE_INT    : INTEGER;
begin
loop
    INPORT (765 , LINE);          -- check 2fd input data is available
    exit when TSTBIT(INTEGER(LINE), 0); -- loop until it's available
end loop;
    LINE_INT := INTEGER(LINE);      -- convert LINE into integer
    CLRBIT(LINE_INT, 0);           -- clear TESTBIT
    INPORT (760, DATA);           -- read data from 2f8
    OUTPORT(765, SYSTEM.BYTE(LINE_INT)); -- put value back to 2fd
    if INTEGER(DATA) > 127 then     -- a test loop for bad data
        DATA := 42;              -- if not a character use '*'
    end if;
    return CHARACTER'VAL(DATA);
end GET_CHAR;

begin
PUT_LINE("Waiting for the first legal character");
loop
    -- wait for the first legal char
    OPEN (FILE, OUT_FILE, NAME => "POS.OUT"); -- open a temp out file
    while GET_CHAR /= '[' loop      -- process each message received
        null;                      -- and wait for start character
    end loop;
    PUT ('[');                     -- put start char on the screen

```

```

PUT (THE_FILE, '[');          -- put start char to file
PUT (FILE, '[');              -- put start cgar to temp file
loop                          --
  A_CHAR := GET_CHAR;          -- get and put the message
  PUT (A_CHAR);                -- put data on the screen
  PUT (THE_FILE, A_CHAR);      -- and to the file
  PUT (FILE, A_CHAR);          -- and to the temp file
  exit when A_CHAR = ']';      -- line 185
end loop;                      -- get another set of data
CLOSE(FILE);                  -- close temp file here
exit when KEYPRESS;           -- exit loop
end loop;
end DATA_LOGGER;
begin
OPEN (THE_FILE, OUT_FILE, NAME => "POS.DAT");-- make file pos.dat available
loop
  if KEYPRESS(CURRENT_INPUT) then -- press Space_Bar to interupt and
    NEW_LINE;                      -- ready to print the screen
    PUT_LINE("New data_string is as follow :");
    NEW_LINE;                      -- line 201
    ROCK := KEY_VALUE;             -- assign keypress to variable
    if ROCK = 32 then              -- if Space_Bar is true then
      PRINT_DATA;                  -- bring the data to the screen
    elsif ROCK = 81 or ROCK = 113 then -- press (q) to exit the program
      raise ABORT_REQUEST;         -- raise exception line 206
    end if;                        -- else program will keep running
  end if;                          -- no interruption
  DATA_LOGGER;                   -- program to log sensor data
end loop;
exception
  when ABORT_REQUEST =>           -- exit the program
  CLOSE (THE_FILE);
  PUT_LINE ("END OF PROGRAM TEST35.A");
end TEST35;

```

APPENDIX--V: USER's MANUAL (Operations and Responses)

- O-1. Use RS-232 cable to connect the external Nav_Sensor and the Computer.
- O-2. Connected the antenna and printer. Use Figure-9.
- O-3. Start up the Nav_Sensor (GPS), and set the ASCII output mode.
- Select POS (position data) as the main position data, alternative selection will be MEAS
 - (measurement data), do not select BINPOS or BINMEAS.
 - (Use Sensor's operation manual to obtain the function control)
- O-4. Insert the disk and find out the working file (DATA_LOG.EXE).
- O-5. key in DATA_LOG and RETURN.
- R-1. Instructions to operate the program
- "A brief guide to use this program:
 - 1. Make sure your system Baud_Rate is matched
 - 2. Run the procedure DATA_LOGGER at proper COM_PORT
 - 3. Use Space_Bar and then Prt_Sc to get updated data_string
 - 4. Use (q) or (Q) to exit the program"
- R-2. Delay 5.0 seconds
- "Give the COM_PORT number in (1) or (2)"
- O-6. Key in your COM_PORT set up.
- R-3. when 1 =>
- "You've set Port1 = 1021, and Port2 = 1016"
- when 2 =>
- "You've set Port1 = 765, and Port2 = 760"
- R-4. "Make your choice for COM1 or COM2: use -1- or -2-"
- O-7. Again you want to set the Baud_Rate at the COM_PORT, Key in 1 or 2
- In this program set 1200 is relatively better than the others
- R-5. when 1 =>
- FOR COM1 SETTING
- when 2 =>
- FOR COM2 SETTING
- R-6. SET THE SYSTEM BAUD-RATE AS YOU DESIRE
- SELECTION IS ---
- 1 = 1200

2 = 2400

3 = 4800

4 = 9600

O-8. Key in your selection

R-7. when 1 =>

YOUR SYSTEM BAUD-RATE IS SET TO 1200 NOW

when 2 =>

YOUR SYSTEM BAUD-RATE IS SET TO 2400 NOW

when 3 =>

YOUR SYSTEM BAUD-RATE IS SET TO 4800 NOW

when 4 =>

YOUR SYSTEM BAUD-RATE IS SET TO 9600 NOW

R-8. Waiting for the first legal character

-- At this stage the program is running a procedure named `LOGGER` and

-- the function `GET_CHAR` keep checking the line register to seek the

-- legal character "[" (user defined) then pull it in to the system.

O-9. By observation the screen displays, you should be able to identify the
the transmission rate is good or not, if not, make your adjustment.

O-10. Use (Q) or (q) to quit the program, and reset the `Baud_Rate` or you can
use it any time when you want to quit the job.

R-9. END OF PROGRAM DATA_LOGGER.A

-- Warning ** When you quit the job, the raw data file will be renewed also. The best way
is pull the data out to another disk then reset the system as you desire. (copy
`POS.DAT` to A: `POS0001.DAT`)

O-11. Use SP (Space_Bar) to get the current position `data_string`, when you
hit the SP :

R-10. The current `data_string` is :

[05 THU 143 23-MAY-91 00:09:44 36:35.6893N 121:52.5101W -0015 01.7 787236 +00
0.0 000.0 274.5 +3.0286E-11 4092 3 13,6,12,2]

O-12. Use print screen (Shift_PrtSc) to get the hardcopy if you wish to

R-11. Printer prints the screen status.

R-12. Program keep on surveying, displaying the data on the screen.

NOTES: Things you might want to know:

1. Normally the GPS is default its functions for its own benefits, we shall carefully follow the Sensor's manual to operate it.
2. Trimble-4000S needs to set up a reference position and it should be with in 0.5 degree.
3. Offset position should normally be zeros.
4. The position will drift if the PDOP is over 15.0.
5. The external computer may have difficulty keeping up with the data at high rates, and may lose characters. If all data rates are above 2400, then the data communication is unreliable.
6. There are two separate program TEST31.EXE, and TEST35.EXE which handle the COM_PORT selection and BAUD_RATE setting separate from DATA_LOGGER, User can operate TEST31 to set up the connection, then run the program TEST35 to collect the navigation sensor data. (Source code exists in Appendix.4).

APPENDIX--VI: TEXT NOTES FROM GRADY BOOCH

EXCEPTION HANDLING AND LOW-LEVEL FEATURES

Where as assembly languages force us to work at the most primitive machine levels, high-order languages usually constrain us to work only at more abstract levels. Since programming in a high-order language is much more productive than in an assembly language, this is generally not a problem. However, we must sometimes refer to system-dependent features, such as the location of an input/output port or the representation of some data structure in memory. In the past, because high-order languages did not provide appropriate expressive power, we were forced to use a combination of high-order and assembly-language programs in solutions, an approach that complicated the solutions and hindered readability and maintainability.

In embedded computer systems, run-time reliability is also an important factor, (We are relating a satellite positioning system) there are sometimes exceptional situations beyond our control, such as hardware failures in peripheral devices or unexpected bursts of input data. We cannot predict when such situation might occur, but in a reliable system, they must be planned for. As a high-level language, Ada supports software development in both expressing low-level machine features and system-dependent features. In the best case, we would like the program to be able to respond to the exception, and continue processing with reduced capability. Ada permits us to write exception handlers to capture both predefined and user-defined exceptions.

[Reference Booch Chapter-17]

```
-- SHOW_ERROR : exception;  
-- When something happened;  
-- raise SHOW_ERROR;
```

REPRESENTATION SPECIFICATION

As mentioned earlier, in embedded computer systems we must concern ourselves not only with run-time reliability, but we must often refer to machine-dependent characteristics as well. Here we are designing our own I/O package for a unique device and need to refer to I/O ports at a certain location in memory. The desire is not to step outside our language, Ada provides several constructs with which we may refer to such low-level features (Ada provides four classes of representation specifications, namely: length specification, numeration type representation, record type representation, address specification).

Representation specifications should be applied only for the purpose of efficiency, this system required for interfacing with external systems, Ada lets us create abstractions about them in high level terms. When we then use one of the features, we are actually writing a particular bit string, and this same feature may be used to express the assembly language mnemonics of our target machine. Note that we may not associate two representations in a single task to avoid program errors. But there may be cases at different times where two representations are more efficient or perhaps map our view of the world better. Because we want to reorganize the record to be used in another task, we spool a given record to be saved on a secondary storage device. Our solution would be to have one index searching representation and one storage representation, the program control the data effectively.

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4. World Range Suitcase Navigation Feasibility Study, document dated 30 July, 1990, B. Cohenour, PMTC, RDD, Code 3144.
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