C Style Guide

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C Style Guide

Goddard Space Flight Center

Greenbelt, Maryland 20771

National Aeronautics and Space Administration

NASA
C STYLE GUIDE

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The Software Engineering Laboratory (SEL) is an organization sponsored by the National Aeronautics and Space Administration/Goddard Space Flight Center (NASA/GSFC) and created to investigate the effectiveness of software engineering technologies when applied to the development of applications software. The SEL was created in 1976 and has three primary organizational members:

- NASA/GSFC, Software Engineering Branch
- University of Maryland, Department of Computer Science
- Computer Sciences Corporation, Software Engineering Operation

The goals of the SEL are (1) to understand the software development process in the GSFC environment; (2) to measure the effect of various methodologies, tools, and models on the process; and (3) to identify and then to apply successful development practices. The activities, findings, and recommendations of the SEL are recorded in the Software Engineering Laboratory Series, a continuing series of reports that includes this document.

The major contributors to this document are

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Many people in both the Software Engineering Branch at NASA/GSFC and in the Software Engineering Operation at CSC reviewed this document and contributed their experiences toward making it a useful tool for Flight Dynamics Division personnel.

Single copies of this document can be obtained by writing to

- Software Engineering Branch
- Code 552
- Goddard Space Flight Center
- Greenbelt, Maryland 20771
ABSTRACT

This document discusses recommended practices and style for programmers using the C language in the Flight Dynamics Division environment. Guidelines are based on generally recommended software engineering techniques, industry resources, and local convention. The Guide offers preferred solutions to common C programming issues and illustrates through examples of C code.
C Style Guide

1 INTRODUCTION

1.1 Purpose ................................................................. 1
1.2 Audience .............................................................. 1
1.3 Approach .............................................................. 1

2 READABILITY AND MAINTAINABILITY .................... 3

2.1 Encapsulation and Information Hiding .................... 3
2.2 White Space ........................................................ 4
  2.2.1 Blank Lines .................................................... 5
  2.2.2 Spacing ........................................................ 5
  2.2.3 Indentation ..................................................... 6
2.3 Comments ........................................................... 6
2.4 Meaningful Names ................................................ 8
  2.4.1 Standard Names .............................................. 9
  2.4.2 Variable Names ............................................. 10
  2.4.3 Capitalization ............................................... 11
  2.4.4 Type and Constant Names ............................ 11

3 PROGRAM ORGANIZATION ..................................... 13

3.1 Program Files .................................................... 13
3.2 README File .................................................... 14
3.3 Standard Libraries ............................................. 14
### Table of Contents

3.4 Header Files ................................................................. 14
3.5 Modules ................................................................. 15
3.6 Makefiles ............................................................... 15
3.7 Standard Filename Suffixes ............................................. 16

4. FILE ORGANIZATION ................................................. 17
4.1 File Prolog ..................................................................... 18
4.2 Program Algorithm and PDL ........................................... 20
  4.2.1 Sequence Statements ............................................. 21
  4.2.2 Selection Control Statements ................................... 21
  4.2.3 Iteration Control Statements ................................... 24
  4.2.4 Severe Error and Exception Handling Statements ........ 25
4.3 Include Directive ......................................................... 27
4.4 Defines and Typedefs ....................................................... 28
4.5 External Data Declarations and Definitions ...................... 28
4.6 Sequence of Functions .................................................. 28

5. FUNCTION ORGANIZATION ........................................... 31
5.1 Function Prologs .......................................................... 31
5.2 Function Arguments ..................................................... 32
5.3 External Variable Declarations ....................................... 33
5.4 Internal Variable Declarations ....................................... 33
5.5 Statement Paragraphing ................................................ 33
5.6 Return Statement ........................................................ 34

6. DATA TYPES, OPERATORS, AND EXPRESSIONS ............... 37
6.1 Variables ...................................................................... 37
6.2 Constants ..................................................................... 37
  6.2.1 Const Modifier ...................................................... 38
  6.2.2 #define Command ............................................... 38
### Table of Contents

6.2.3 Enumeration Types ................................................................. 38
6.2.4 Simple Constants ................................................................. 39
6.3 Variable Definitions and Declarations ........................................... 39
   6.3.1 Numbers ........................................................................... 39
   6.3.2 Qualifiers .......................................................................... 40
   6.3.3 Structures .......................................................................... 40
   6.3.4 Automatic Variables .......................................................... 40
6.4 Type Conversions and Casts ....................................................... 41
6.5 Pointer Types ........................................................................... 42
6.6 Pointer Conversions ................................................................. 42
6.7 Operator Formatting ................................................................. 42
6.8 Assignment Operators and Expressions ....................................... 43
6.9 Conditional Expressions ............................................................ 45
6.10 Precedence and Order of Evaluation .......................................... 45

7 STATEMENTS AND CONTROL FLOW ............................................. 47

7.1 Sequence Statements ............................................................... 47
   7.1.1 Statement Placement .......................................................... 47
   7.1.2 Braces .............................................................................. 48
7.2 Selection Control Statements ...................................................... 50
   7.2.1 If ....................................................................................... 50
   7.2.2 If Else ............................................................................... 50
   7.2.3 Else If ............................................................................... 51
   7.2.4 Nested If Statements .......................................................... 51
   7.2.5 Switch .............................................................................. 53
7.3 Iteration Control Statements ....................................................... 53
   7.3.1 While ............................................................................... 54
   7.3.2 For .................................................................................... 54
   7.3.3 Do While ........................................................................... 55
7.4 Severe Error and Exception Handling ........................................... 55
   7.4.1 Gotos and Labels ............................................................... 55
   7.4.2 Break .............................................................................. 55
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8  PORTABILITY AND PERFORMANCE</td>
<td>57</td>
</tr>
<tr>
<td>8.1 Guidelines for Portability</td>
<td>57</td>
</tr>
<tr>
<td>8.2 Guidelines for Performance</td>
<td>58</td>
</tr>
<tr>
<td>9  C CODE EXAMPLES</td>
<td>59</td>
</tr>
<tr>
<td>9.1 Makefile</td>
<td>60</td>
</tr>
<tr>
<td>9.2 C Program File: RF_GetReference.c</td>
<td>64</td>
</tr>
<tr>
<td>9.3 Include File: HD_reference.h</td>
<td>79</td>
</tr>
<tr>
<td>FIGURES</td>
<td></td>
</tr>
<tr>
<td>Figure 1 Information Hiding</td>
<td>4</td>
</tr>
<tr>
<td>Figure 2 Program Organization</td>
<td>13</td>
</tr>
<tr>
<td>Figure 3 Standard Filename Suffixes</td>
<td>16</td>
</tr>
<tr>
<td>Figure 4 File Organization Schema</td>
<td>17</td>
</tr>
<tr>
<td>Figure 5 Program File Prolog Contents</td>
<td>18</td>
</tr>
<tr>
<td>Figure 6 Header File Prolog</td>
<td>20</td>
</tr>
<tr>
<td>Figure 7 Function Organization Schema</td>
<td>31</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>83</td>
</tr>
<tr>
<td>INDEX</td>
<td>85</td>
</tr>
<tr>
<td>STANDARD BIBLIOGRAPHY OF SEL LITERATURE</td>
<td></td>
</tr>
</tbody>
</table>
INTRODUCTION

"Good programming style begins with the effective organization of code. By using a clear and consistent organization of the components of your programs, you make them more efficient, readable, and maintainable."

Steve Oualline, *C Elements of Style*

1.1 Purpose

This document describes the Software Engineering Laboratory (SEL) recommended style for writing C programs, where code with “good style” is defined as that which is

- Organized
- Easy to read
- Easy to understand
- Maintainable
- Efficient

1.2 Audience

This document was written specifically for programmers in the SEL environment, although the majority of these standards are generally applicable to all environments. In the document, we assume that you have a working knowledge of C, and therefore we don’t try to teach you how to program in C. Instead, we focus on pointing out good practices that will enhance the effectiveness of your C code.

1.3 Approach

This document provides guidelines for organizing the content of C programs, files, and functions. It discusses the structure and placement of variables, statements, and
comments. The guidelines are intended to help you write code that can be easily read, understood, and maintained.

- Software engineering principles are discussed and illustrated.
- Key concepts are highlighted.
- Code examples are provided to illustrate good practices.
READABILITY AND MAINTAINABILITY

This section summarizes general principles that maximize the readability and maintainability of C code:

- Organize programs using encapsulation and information hiding techniques.
- Enhance readability through the use of white space.
- Add comments to help others understand your program.
- Create names that are meaningful and readable.
- Follow ANSI C standards, when available.

2.1 Encapsulation and Information Hiding

Encapsulation and information hiding techniques can help you write better organized and maintainable code. Encapsulation means grouping related elements. You can encapsulate on many levels:

- Organize a program into files, e.g., using header files to build a cohesive encapsulation of one idea.
- Organize files into data sections and function sections.
- Organize functions into logically related groups within individual files.
- Organize data into logical groups (data structures).

Information hiding refers to controlling the visibility (or scope) of program elements. You can use C constructs to control the scope of functions and data. For example:

- Encapsulate related information in header files, and then include those header files only where needed. For example, #include <time.h> would be inserted only in files whose functions manipulate time.
- A variable defined outside the current file is called an external variable. An external variable is only visible to a function when declared by the extern declaration, which may be used only as needed in individual functions.
Figure 1 illustrates the information hiding concept. The code consists of two files, three functions, and six variables. A variable name appears to the right of each line that is within its scope.

<table>
<thead>
<tr>
<th>File</th>
<th>Code</th>
<th>Scope</th>
</tr>
</thead>
</table>
| x.c  | `#include "local.h"
    int a = 2;
    static int b = 3;
    main()
    {
        int c = a + b;
        xsub(c);
    }` | a ab abc |
|      | `xsub(d)
    int d;
    {
        int e = 7 * d;
        ysub(e);
    }` | ab ab d ab de |
|      | `#include "local.h"
    ysub(f)
    int f;
    {
        extern int a;
        printf("%d\n", a + f);` | a f |
| y.c  | `...` | a f |

**Figure 1 Information Hiding**

### 2.2 White Space

Write code that is as easy as possible to read and maintain (taking into consideration performance tradeoffs for real-time systems when it is appropriate). Adding white space in the form of blank lines, spaces, and indentation will significantly improve the readability of your code.
2.2.1 Blank Lines

A careful use of blank lines between code "paragraphs" can greatly enhance readability by making the logical structure of a sequence of lines more obvious. Using blank lines to create paragraphs in your code or comments can make your programs more understandable. The following example illustrates how the use of blank lines helps break up lines of text into meaningful chunks.

Example: code paragraphing

```c
#define LOWER 0
#define UPPER 300
#define STEP 20

main() /* Fahrenheit-Celsius table */
{
    int fahr;

    for (fahr = LOWER; fahr <= UPPER; fahr = fahr + STEP)
        printf("%4d %6.1f
", fahr, (5.0/9.0)*(fahr - 32));
}
```

However, overuse of blank lines can defeat the purpose of grouping and can actually reduce readability. Therefore, use a single blank line to separate parts of your program from one another.

2.2.2 Spacing

Appropriate spacing enhances the readability of lexical elements such as variables and operators. The following examples illustrate how to use individual spaces to improve readability and to avoid errors. The second example is not only harder to read, but the spacing introduces an error, where the operator /* will be interpreted by the compiler as the beginning of a comment. Put one space after a comma to improve readability, as shown in the third example below.

Example: good spacing

```c
*average = *total / *count; /* compute the average */
```

Example: poor spacing

```c
*average=*total/*count; /* compute the average */
```

Example: comma spacing

```c
concat(s1, s2)
```
Readability and Maintainability

2.2.3 Indentation

Use indentation to show the logical structure of your code. Research has shown that four spaces is the optimum indent for readability and maintainability. However, in highly nested code with long variable names, four-space indentation may cause the lines of code to overrun the end of the line. Use four spaces unless other circumstances make it unworkable.

Example: four-space indentation

```c
main()
{
    int c;
    c = getchar();
    while (c != EOF)
    {
        putchar(c);
        c = getchar();
    }
}
```

2.3 Comments

Judiciously placed comments in the code can provide information that a person could not discern simply by reading the code. Comments can be added at many different levels.

- At the program level, you can include a README file that provides a general description of the program and explains its organization.
- At the file level, it is good practice to include a file prolog that explains the purpose of the file and provides other information (discussed in more detail in Section 4).
- At the function level, a comment can serve as a function prolog.
- Throughout the file, where data are being declared or defined, it is helpful to add comments to explain the purpose of the variables.

Comments can be written in several styles depending on their purpose and length. Use comments to add information for the reader or to highlight sections of code. Do not paraphrase the code or repeat information contained in the Program Design Language (PDL).
This section describes the use of comments and provides examples.

- **Boxed comments**—Use for prologs or as section separators.
- **Block comments**—Use at the beginning of each major section of the code as a narrative description of that portion of the code.
- **Short comments**—Write on the same line as the code or data definition they describe.
- **Inline comments**—Write at the same level of indentation as the code they describe.

**Example: boxed comment prolog**

```
/*******************************************/
 /* FILE NAME */
 /* PURPOSE */
 *******************************************/
```

**Example: section separator**

```
/*******************************************/
```

**Example: block comment**

```
/*
 * Write the comment text here, in complete sentences.
 * Use block comments when there is more than one sentence.
 */
```

**Example: short comments**

```c
double ieee_r[];  /* array of IEEE real*8 values */
unsigned char ibm_r[]; /* string of IBM real*8 values */
int count;  /* number of real*8 values */
```

- Tab comment over far enough to separate it from code statements.
- If more than one short comment appears in a block of code or data definition, start all of them at the same tab position and end all at the same position.
Example: inline comment

```c
switch (ref_type)
{
    /* Perform case for either s/c position or velocity
     * vector request using the RSL routine c_calpvs */
    case 1:
    case 2:
    ...
    case n:
}
```

In general, use short comments to document variable definitions and block comments to describe computation processes.

Example: block comment vs. short comment

preferred style:

```c
/*
 * Main sequence: get and process all user requests
 */
while (!finish())
{
    inquire();
    process();
}
```

not recommended:

```c
while (!finish()) /* Main sequence: */
{
    /* */
    inquire(); /* Get user request */
    process(); /* And carry it out */
    /* As long as possible */
```

2.4 Meaningful Names

Choose names for files, functions, constants, or variables that are meaningful and readable. The following guidelines are recommended for creating element names.
• Choose names with meanings that are precise and use them consistently throughout the program.

• Follow a uniform scheme when abbreviating names. For example, if you have a number of functions associated with the "data refresher," you may want to prefix the functions with "dr_".

• Avoid abbreviations that form letter combinations that may suggest unintended meanings. For example, the name "inch" is a misleading abbreviation for "input character." The name "in_char" would be better.

• Use underscores within names to improve readability and clarity:
  ```
  get_best_fit_model
  load_best_estimate_model
  ```

• Assign names that are unique (with respect to the number of unique characters permitted on your system).

• Use longer names to improve readability and clarity. However, if names are too long, the program may be more difficult to understand and it may be difficult to express the structure of the program using proper indentation.

• Names more than four characters in length should differ by at least two characters. For example, "systst" and "sysstst" are easily confused. Add underscores to distinguish between similar names:
  ```
  systst sys_tst
  sysstst sys_s_tst
  ```

• Do not rely on letter case to make a name unique. Although C is case-sensitive (i.e., "LineLength" is different from "linelength" in C), all names should be unique irrespective of letter case. Do not define two variables with the same spelling, but different case.

• Do not assign a variable and a typedef (or struct) with the same name, even though C allows this. This type of redundancy can make the program difficult to follow.

2.4.1 Standard Names

Some standard short names for code elements are listed in the example below. While use of these names is acceptable if their meaning is clear, we recommend using longer, more explicit names, such as "buffer_index."
Example: standard short names

- c   characters
- i, j, k   indices
- n   counters
- p, q   pointers
- s   strings

Example: standard suffixes for variables

- _ptr   pointer
- _file   variable of type file*
- _fd   file descriptor

2.4.2 Variable Names

When naming internal variables used by a function, do not duplicate global variable names. Duplicate names can create hidden variables, which can cause your program not to function as you intended. In the following example, the internal variable “total” would override the external variable “total.” In the corrected example, the internal variable has been renamed “grand_total” to avoid the duplication.

Example: hidden variable

```c
int total;
int func1(void)
{
    float total;    /* this is a hidden variable */
    ...
}
```

Example: no hidden variable

```c
int total;
int func1(void)
{
    float grand_total;    /* internal variable is unique */
    ...
}
```

In separate functions, variables that share the same name can be declared. However, the identical name should be used only when the variables also have the identical meaning. When the meanings of two variables are only similar or coincidental, use unique names to avoid confusion.
2.4.3 Capitalization

The following capitalization style is recommended because it gives the programmer as well as the reader of the code more information.

- **Variables**: Use lower-case words separated by underscores.
- **Function names**: Capitalize the first letter of each word; do not use underscores.
- **Constants**: Use upper-case words separated by underscores.
- **C bindings**: Use the letter "c" followed by an underscore and the binding name.

**Example**: capitalization style

- `open_database` variables
- `ProcessError` function names
- `MAX_COUNT` constants
- `c_ephemrd` C bindings

2.4.4 Type and Constant Names

- **Type names** (i.e., created with typedef): Follow the naming standards for global variables.

- **Enumeration types** (declared using enum) and **constants** declared using const: Follow the naming conventions for constants.
This section discusses organizing program code into files. It points out good practices such as grouping logically related functions and data structures in the same file and controlling the visibility of the contents of those files. Figure 2 illustrates the organizational schema that the discussion will follow.

<table>
<thead>
<tr>
<th>Program</th>
<th>README</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard libraries</td>
<td>&lt;stdio.h&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;math.h&gt;</td>
</tr>
<tr>
<td>Header files</td>
<td>&quot;globals.h&quot;</td>
</tr>
<tr>
<td></td>
<td>&quot;types.h&quot;</td>
</tr>
<tr>
<td>Program files</td>
<td>program_file.c</td>
</tr>
<tr>
<td></td>
<td>File prolog</td>
</tr>
<tr>
<td></td>
<td>Usage and operating instructions</td>
</tr>
<tr>
<td></td>
<td>Header file includes</td>
</tr>
<tr>
<td></td>
<td>External definitions and declarations</td>
</tr>
<tr>
<td></td>
<td>Functions</td>
</tr>
<tr>
<td></td>
<td>Function prolog</td>
</tr>
<tr>
<td></td>
<td>Function parameters</td>
</tr>
<tr>
<td></td>
<td>Internal definitions and declarations</td>
</tr>
<tr>
<td></td>
<td>Statements</td>
</tr>
<tr>
<td></td>
<td>Operators</td>
</tr>
<tr>
<td></td>
<td>Expressions</td>
</tr>
<tr>
<td>Module files</td>
<td>module_file.c</td>
</tr>
<tr>
<td>Compilation</td>
<td>utilities</td>
</tr>
<tr>
<td>Makefile</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 Program Organization

3.1 Program Files

A C program consists of one or more program files, one of which contains the main() function, which acts as the driver of the program. An example of a program file is
given in Section 9. When your program is large enough to require several files, you should use encapsulation and data hiding techniques to group logically related functions and data structures into the same files. Organize your programs as follows:

- Create a README file to document what the program does.
- Group the main function with other logically related functions in a program file.
- Use module files to group logically related functions (not including the main function).
- Use header files to encapsulate related definitions and declarations of variables and functions.
- Write a Makefile to make recompiles more efficient.

3.2 README File

A README file should be used to explain what the program does and how it is organized and to document issues for the program as a whole. For example, a README file might include

- All conditional compilation flags and their meanings.
- Files that are machine dependent.
- Paths to reused components.

3.3 Standard Libraries

A standard library is a collection of commonly used functions combined into one file. Examples of function libraries include "stdio.h" which comprises a group of input/output functions and "math.h" which consists of mathematical functions. When using library files, include only those libraries that contain functions that your program needs. You may create your own libraries of routines and group them in header files.

3.4 Header Files

Header files are used to encapsulate logically related ideas; for example the header file "time.h" defines two constants, three types, and three structures, and declares seven functions needed to process time. Header files may be selectively included in your program files to limit visibility to only those functions that need them.
Header files are included in C source files before compilation. Some, such as “stdio.h” are defined system-wide, and must be included by any C program that uses the standard input/output library. Others are used within a single program or suite of programs. An example of a header file is given in Section 9.

- Use #include <system_name> for system include files.
- Use #include “user_file” for user include files.
- Contain in header files data definitions, declarations, typedefs, and enums that are needed by more than one program.
- Organize header files by function.
- Put declarations for separate subsystems in separate header files.
- If a set of declarations is likely to change when code is ported from one platform to another, put those declarations in a separate header file.
- Avoid private header filenames that are the same as library header filenames. For example, the statement #include <math.h> will include the standard library math header file if the intended one is not found in the current directory.
- Include header files that declare functions or external variables in the file that defines the function or variable. That way, the compiler can do type checking and the external declaration will always agree with the definition.
- Do not nest header files. Use explicit #include statements to include each header file needed in each program file.
- In the prolog for a header file, describe what other headers need to be included for the header to be functional.

3.5 Module Files

A module file contains the logically related functions, constants, types, data definitions and declarations, and functions. Modules are similar to a program file except that they don’t contain the main() function.

3.6 Makefiles

Makefiles are used on some systems to provide a mechanism for efficiently recompiling C code. With makefiles, the make utility recompiles files that have been changed since the last compilation. Makefiles also allow the recompilation commands to be stored, so that potentially long cc commands can be greatly abbreviated. An example of a Makefile is given in Section 9. The makefile

- Lists all files that are to be included as part of the program.
• Contains comments documenting what files are part of libraries.
• Demonstrates dependencies, e.g., source files and associated headers using implicit and explicit rules.

3.7 Standard Filename Suffixes

The suggested format for source code filenames is an optional prefix (e.g., to indicate the subsystem), a base name, and an optional period and suffix. The base name should be unique (length may vary depending on your compiler; some limit filenames to eight or fewer characters) and should include a standard suffix that indicates the file type. Some compilers and tools require certain suffix conventions for filenames. Figure 3 lists some standard suffixes; or use those dictated by your compiler.

<table>
<thead>
<tr>
<th>File Type</th>
<th>Standard Suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>C source file</td>
<td>.c</td>
</tr>
<tr>
<td>Assembler source</td>
<td>.s</td>
</tr>
<tr>
<td>Relocatable object</td>
<td>.o</td>
</tr>
<tr>
<td>Include header</td>
<td>.h</td>
</tr>
<tr>
<td>Yacc source</td>
<td>.y</td>
</tr>
<tr>
<td>Lex source</td>
<td>.l</td>
</tr>
<tr>
<td>Loader output file</td>
<td>.out</td>
</tr>
<tr>
<td>Makefile</td>
<td>.mak</td>
</tr>
<tr>
<td>Linker response files</td>
<td>.link or .rsp</td>
</tr>
</tbody>
</table>

Figure 3 Standard Filename Suffixes
FILE
ORGANIZATION

The organization of information within a file is as important to the readability and maintainability of your programs as the organization of information among files. In this section, we will discuss how to organize file information consistently. Figure 4 provides an overview of how program file and module information should be organized.

<table>
<thead>
<tr>
<th>File Prolog, including the algorithm expressed in PDL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Usage and Operating Instructions, if applicable for program files only</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Header File Includes, in this sequence:</th>
</tr>
</thead>
<tbody>
<tr>
<td>#include &lt;stdio.h&gt; (or &lt;stdlib.h&gt;)</td>
</tr>
<tr>
<td>#include &lt;other system headers&gt;</td>
</tr>
<tr>
<td>#include &quot;user header files&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Defines and Typedefs that apply to the file as a whole, including:</th>
</tr>
</thead>
<tbody>
<tr>
<td>enums</td>
</tr>
<tr>
<td>typedefs</td>
</tr>
<tr>
<td>constant macro defines</td>
</tr>
<tr>
<td>function macro defines</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>External Data Declarations used by this file</th>
</tr>
</thead>
<tbody>
<tr>
<td>extern declarations of variables defined in other files</td>
</tr>
<tr>
<td>non-static external definitions used in this file (and optionally in others if they are declared in those files using extern)</td>
</tr>
<tr>
<td>static external definitions used only in this file</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>function prolog</td>
</tr>
<tr>
<td>function body</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>More External Data Declarations used from point of declaration to end of file</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>More Functions</th>
</tr>
</thead>
</table>

Figure 4 File Organization Schema
4.1 File Prolog

A file prolog introduces the file to the reader. Every file must have a prolog. Figure 5 is an example of a prolog outline; field values are described below.

```
/*                        *                        */
* FILE NAME:               *                        */
*                        *                        */
* PURPOSE:                 *                        */
*                        *                        */
* FILE REFERENCES:         *                        */
*                        *                        */
* Name                     I/O         Description */
* ---                     ---            -------   */
*                        *                        */
* EXTERNAL VARIABLES:      *                        */
* Source: <               >                  */
*                        *                        */
* Name    Type   I/O         Description */
* ---      ---     ---            -------   */
*                        *                        */
* EXTERNAL REFERENCES:    *                        */
*                        *                        */
* Name                     Description */
* ---                     -------   */
*                        *                        */
* ABNORMAL TERMINATION CONDITIONS, ERROR AND WARNING MESSAGES: */
*                        *                        */
* ASSUMPTIONS, CONSTRAINTS, RESTRICTIONS: */
*                        *                        */
* NOTES:                   *                        */
*                        *                        */
* REQUIREMENTS/FUNCTIONAL SPECIFICATIONS REFERENCES: */
*                        *                        */
* DEVELOPMENT HISTORY:    *                        */
*                        *                        */
* Date    Author  Change Id  Release  Description Of Change */
* ---      ------  --------  -------  ------------------------ */
*                        *                        */
* ALGORITHM (PDL)         *                        */
*                        *                        */
*/                        */                        */
```

Figure 5 Program File Prolog Contents

- File Name—Specify the name of the file.
- Purpose—Briefly state the purpose of the unit.
• **File References**—Specify the name, I/O, and description of files used by functions within this file. If the file does not have file references, indicate so by entering “none.”

• **External Variables**—Specify the source, name, type, I/O, and description of variables being used by the unit that do not come in through the calling sequence. If the unit does not have external variables, indicate so by entering “none.”

• **External References**—Specify the exact name of each unit called or invoked by this unit, followed by a one-line description of the unit. If the unit does not have external references, indicate so by entering “none.”

• **Abnormal Termination Conditions, Error and Warning Messages**—Describe the circumstances under which the unit terminates abnormally. List error messages that this unit issues and briefly explain what triggers each.

• **Assumptions, Constraints, Restrictions**—Describe the assumptions that are important to the design and implementation of the unit (e.g., “It is assumed that all input data have been checked for validity.”) Include descriptions of constraints and restrictions imposed by the unit (e.g., “The unit must complete its execution within 75 microseconds.”) This section contains information that explains the characteristics and peculiarities of the unit.

• **Notes**—Specify any additional information needed to understand the file’s data or functions.

• **Requirements/Functional Specifications References**—Provide traceability between requirements and specifications and implementation.

• **Development History**—Outline the file’s development history:
  - **Date**, day, month, and year of the change
  - **Author**, author of the current implementation or change to the unit
  - **Change Id**, an identification number for the change; e.g., if the change is related to a numbered SPR, that number may be used to correlate the change to the SPR
  - **Release**, current software release and build in abbreviated form
  - **Description of Change**, brief narrative describing the change

• **Algorithm (PDL)**—Describe the algorithm used in the program in PDL format. See Section 4.2 for a detailed discussion of algorithm/PDL.
Header files (non-program files) such as those containing global definitions, prototypes, or typedefs, should have an abbreviated prolog as shown in Figure 6.

```
/* ----------------------------------------------- */
* NAME: *
* *
* PURPOSE: *
* *
* GLOBAL VARIABLES: *
* *
* Variable Type Description *
* ----------- ---- ------------- *
* *
* DEVELOPMENT HISTORY: *
* *
* Date Author Change Id Release Description Of Change *
* ----- ------ ----------- ------- ----------------- *
* *
* -----------------------------------------------*/
```

Figure 6 Header File Prolog

4.2 Program Algorithm and PDL

This section of the file prolog describes the overall algorithm of the program or any special or nonstandard algorithms used. This description in the prolog does not eliminate the need for inline comments next to the functions. In fact, adding comments to your functions is recommended to help others understand your code.

In the SEL environment, programmers follow a prescribed PDL style which is documented both in the *Programmer's Handbook for Flight Dynamics Software Development* as well as CSC's *SSDM* (see Bibliography). The PDL constructs are summarized here, along with the corresponding C code. These guidelines are consistent with the *Programmer's Handbook*.

PDL describes the processing and control logic within software units through the use of imperative English phrases and simple control statements. Follow these general guidelines when creating PDL:

- Indent by four spaces the statements defining the processing to occur within a PDL control structure (unless the code is highly nested and it would run off the right side of the page).
- Within a control structure, align each PDL control structure keyword (e.g., align the IF, ELSE, etc.). Also align each embedded statement.
• If a single PDL statement spans multiple print lines, begin each statement continuation line one space to the right of the parent line.

PDL includes four types of statements, which are described in detail in the paragraphs to follow:

• Sequence
• Selection Control
• Iteration Control
• Severe Error and Exception Handling

4.2.1 Sequence Statements

A PDL sequence statement describes a processing step that does not alter logic flow. Specify this type of PDL statement as a declarative English-language sentence beginning with a single imperative verb followed by a single direct object.

verb object

Assignment statements may be used only in the event that mathematical formula must be specified.

\[ C = A + B \]

To call a unit, use a verb (e.g., CALL) followed by the unit name. The unit name may be followed by a list of descriptive parameters from the calling sequence to that unit or by a phrase describing the function or purpose of the unit being called.

\[ \text{CALL } <\text{unit name}> \]

To signal the end of processing within a unit, use the verb RETURN. A return statement implies an immediate return to the calling entity.

\[ \text{RETURN} \]

4.2.2 Selection Control Statements

Selection control statements define the conditions under which each of several independent processing paths is executed. There are three PDL selection control structures: IF THEN ELSE, IF THEN, and CASE. Each of them is shown below in its PDL format and with an example of corresponding C code.
4.2.2.1 IF THEN ELSE

The basic format of an if then else statement is:

```
IF condition THEN
  true processing
ELSE
  false processing
ENDIF
```

Example: PDL

```
IF shuttle and payload mode THEN
  CALL addstr to display shuttle title
ELSE IF freeflyer only mode THEN
  CALL addstr to display ff title
ELSE
  CALL addstr to display both titles
ENDIF
```

Example: C code

```
if (objdisp == SHUT_PAYLOAD)
  addstr("SHUTILE DATA")
else if (objdisp == FF)
  addstr("FREEFLYSR DATA")
else
  addstr( "SHUITLE/FF DATA")
```

4.2.2.2 IF THEN

The general format of an if then statement is:

```
IF condition THEN
  true processing
ENDIF
```

Example: PDL

```
IF offset between request time and time of last calculated s/c position and velocity vectors exceeds wait time THEN
  COMPUTE elapsed seconds between epoch time and request time
ENDIF
```

Example: C code

```
if ((t_request - t_rv_ref) > t_wait)
  eptime = t_request - orbital_t_epoch;
```
4.2.2.3 CASE

The general format of a case statement is:

```
DO CASE of (name)
CASE 1 condition:
   case 1 processing
CASE 2 condition:
   case 2 processing
.
.
CASE n condition:
   case n processing
ELSE (optional)
   else-condition processing
ENDDO CASE
```

OTHERWISE can be substituted for the ELSE keyword.

Example: PDL

```
DO CASE of axes color
   black:
      set color to black
   yellow:
      set color to yellow
   red:
      set color to red
   OTHERWISE:
      set color to green
ENDDO CASE
```

Example: C code

```
switch (axescolor)
{
   case 'B':
      color = BLACK;
      break;
   case 'Y':
      color = YELLOW;
      break;
   case 'R':
      color = RED;
      break;
   default:
      color = GREEN;
      break;
}
```
4.2.3 Iteration Control Statements

Iteration control statements specify processing to be executed repeatedly. There are three basic iteration control structures in PDL: **DO WHILE**, **DO FOR**, and **DO UNTIL**.

### 4.2.3.1 DO WHILE

The general format of a do while statement is:

```
DO WHILE "continue loop" condition true
    true processing
ENDDO WHILE
```

*Example: PDL*

```
DO WHILE ui buffer not empty
    CALL process_ui issue requests
ENDDO WHILE
```

*Example: C code*

```
while (ui_buf != EMPTY)
    process_ui(ui_buf, num);
```

### 4.2.3.2 DO FOR

The general format of a do for statement is:

```
DO FOR specified discrete items
    loop processing
ENDDO FOR
```

*Example: PDL*

```
DO FOR each axis view (X, Y, Z)
    CALL setview to create view
ENDDO FOR
```

*Example: C code*

```
for (i=0; i < 4; i++)
    setview(sys, i);
```
4.2.3.3 **DO UNTIL**

The general format of a do until statement is:

```
DO UNTIL "exit loop" condition true
  loop processing
ENDDO UNTIL
```

**Example: PDL**

```
DO UNTIL no ui requests remain
  CALL process_ui to issue requests
ENDDO UNTIL
```

**Example: C code**

```
do
  process_ui(ui_buf, num);
  while (ui_count != 0);
```

4.2.4 Severe Error and Exception Handling Statements

When a serious error or abnormal situation occurs several levels deep in if or do statements, you may want simply to set an error flag and return to the caller. Using only the constructs described so far, the choices are limited to setting an abort flag and checking at each level of nesting. This can quickly complicate an otherwise clean design. Two PDL statements are available to aid in the handling of severe errors and exceptions: **ABORT** to (abort_label) and **UNDO**.

4.2.4.1 **ABORT**

ABORT to is used to jump to a named block of processing at the end of the routine. The block's purpose is to set a fatal error indication and exit the routine. Placing all abort processing at the end of the routine helps all abnormal condition logic to stand out from the normal processing.

**Example: PDL**

```
DO WHILE more records remain to be processed
  read next record from file
  IF an invalid record is encountered
    ABORT to INV_REC_FND
  ENDIF

(cont'd next page)
```
Example: ABORT PDL (cont'd)

    (process this record)
    ENDDO WHILE
    ...
    RETURN
    INV_REC_FND:
    inform user of the invalid record just found
    set invalid record indicator
    RETURN

In C, you use a goto statement to exit out of nested loops. Note that you should use goto statements only for unusual circumstances. In most cases, it is possible to use structured code instead of using a goto. The two examples below show the same scenario using structured code and using a goto statement.

Example: structured code

    while (... && no_error)
      for (...)
        if (disaster)
          error = true;
        if error
          error_processing;

Example: goto statement

    while (...)
      for (...)
        if (disaster)
          goto error;
    error:
      error_processing;

4.2.4.2 UNDO

UNDO is used within a do (while, for, until) construct to terminate the current loop immediately. That is, processing jumps to the statement following the ENDDO of the current do construct. In C, you could use a break statement to exit out of an inner loop. If you can avoid the use of breaks, however, do so.
Example: PDL

DO WHILE more records remain to be processed
    read next record from file
    IF an invalid record is encountered
        UNDO
        ENDIF
        (process this record)
        ENDDO WHILE

Example: C code with break statement

while <more records remain to be processed>
{
    read next record from file
    if <an invalid record is encountered>
        break;
        process this record
    }

Example: C code with no break statement

while (more records remain to be processed && no_error)
{
    read next record from file
    if <an invalid record is encountered>
        error = true;
    else
        process this record
    }

4.3 Include Directive

To make header file information available to your program files, you must specifically include those header files using the #include preprocessor directive. For optimum efficiency and clarity, include only those header files that are necessary.

- If the reason for the #include is not obvious, it should be commented.
- The suggested file order is:

    #include <stdio.h> (or <stdlib.h>)
    #include <other system headers>
    #include "user header files"
4.4 Defines and Typedefs

After including all necessary header files, define constants, types, and macros that should be available to the rest of the file (from the point of declaration to the end of the file). Include the following, in the sequence shown:

- Enums
- Typedefs
- Constant macros (#define identifier token-string)
- Function macros (#define identifier(identifier, ..., identifier) token-string)

4.5 External Data Declarations and Definitions

After defining constants, types, and macros, you should next have a section in your file to declare external variables to make them visible to your current file. Define those variables that you want to be available ("global") to the rest of the file. The suggested sequence for declaring and defining external data is:

- Extern declarations of variables defined in other files
- Non-static external definitions used in this file (and, optionally, in others if they are declared in those files using the extern declaration)
- Static external definitions used only in this file

4.6 Sequence of Functions

This section provides general guidelines for arranging functions in the program file. The organization of information within functions is described in Section 5.

- If the file contains the main program, then the main( ) function should be the first function in the file.
- Place logically related functions in the same file.
- Put the functions in some meaningful order.
  - A breadth-first approach (functions on a similar level of abstraction together) is preferred over depth-first (functions defined as soon as possible before or after their calls).
  - If defining a large number of essentially independent utility functions, use alphabetical order.
- To improve readability, separate functions in the same file using a single row of asterisks.
• Place functions last in a program file, unless (due to data hiding) you need to declare external variables between functions.

Example: functions with separators

```c
/**************************************************************/
main prolog
main body
/**************************************************************/
function_a prolog
function_a body
/**************************************************************/
function_b prolog
function_b body
/**************************************************************/
```

Example: functions with an external variable

```c
/**************************************************************/
func1()
{
    ...
}
/**************************************************************/

/* The following external variable will be available
/* to func2 but not to func1 */
int count;
/**************************************************************/

func2()
{
    ...
}
```
This section discusses guidelines for organizing information within functions. Figure 7 provides an overview of how information should be organized within functions.

<table>
<thead>
<tr>
<th>Function prolog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the function</td>
</tr>
<tr>
<td>Arguments of the function</td>
</tr>
<tr>
<td>Return value of the function</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Function argument declarations</td>
</tr>
<tr>
<td>External variable declarations</td>
</tr>
<tr>
<td>Internal variable declarations</td>
</tr>
<tr>
<td>Automatic internal variable definitions</td>
</tr>
<tr>
<td>Static internal variable definitions</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Statement “paragraphs” (major sections of the code)</td>
</tr>
<tr>
<td>Block comment introducing the algorithm to be performed by the group of statements</td>
</tr>
<tr>
<td>Statements (one per line)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Return statement</td>
</tr>
</tbody>
</table>

**Figure 7 Function Organization Schema**

### 5.1 Function Prologs

Every function should have a function prolog to introduce the function to the reader. The function prolog should contain the following information:

- **Function name**
  - One or more words all in lower case and separated by underscores
  - Upper case OK if name includes a proper noun (e.g., Gaussian_distribution)
  - Followed by brief descriptive comment
- **Arguments** listed one per line with the type, I/O, and a brief description
- **Return value** describes what the function returns
Example: function prolog

```
/********************************************
 *
 * FUNCTION NAME: *
 *
 * ARGUMENTS: *
 *
 * ARGUMENT TYPE I/O DESCRIPTION *
 * ------- ---- --- ************ *
 *
 * RETURNS: *
 *
 ***************************************/
```

For a function with a non-boolean return value or no return value (a return of void), the name should be an imperative verb phrase describing the function’s action, or a noun phrase. For a function that returns a boolean value, its name should be a predicate-clause phrase.

Example: imperative verb phrase

- obtain_next_token
- increment_line_counter

Example: noun phrase

- top_of_stack
- sensor_reading

Example: predicate-clause phrase

- stack_is_empty
- file_is_saved

5.2 Function Arguments

Declare function arguments when the function is defined (even if the type is integer). Define functions arguments beginning in column 1. Note that arguments are explained in the function prolog, and therefore do not require explanatory comments following the function declaration.
Example: function argument declarations

```c
int getline (char *str, int length)
{
   ...
}
```

5.3 External Variable Declarations

Declare external variables immediately after the opening brace of the function block.

Example: external variable declaration

```c
char *save_string(char *string)
{
   extern char *malloc();
   ...
}
```

5.4 Internal Variable Declarations

Internal variables—i.e., those used only by the function (also known as local variables)—should be defined after the external variables. Follow these guidelines for internal-variable declarations:

- Align internal variable declarations so that the first letter of each variable name is in the same column.
- Declare each internal variable on a separate line followed by an explanatory comment.
  - The only exception is loop indices, which can all be listed on the same line with one comment.
- If a group of functions uses the same parameter or internal variable, call the repeated variable by the same name in all functions.
- Avoid internal-variable declarations that override declarations at higher levels; these are known as hidden variables. See Section 2.4.2 for a discussion of hidden variables.

5.5 Statement Paragraphing

Use blank lines to separate groups of related declarations and statements in a function (statement "paragraphing") to aid the reader of the code. In addition, inline comments can be added to explain the various parts of the function.
Example: statement paragraphing

```c
char *save_string(char *string)
{
    register char *ptr;

    /*
    * if allocation of the input string is successful,
    * save the string and return the pointer; otherwise,
    * return null pointer.
    */
    if ((ptr = (char *)malloc(strlen(string) + 1)) != (char *)NULL)
        strcpy(ptr, string);
    return (ptr);
}
```

5.6 Return Statement

The **return statement** is the mechanism for returning a value from the called function to its caller. Any expression can follow `return`:

```c
return (expression)
```

- Using an expression in the return statement may improve the efficiency of the code. Overdoing its use, however, increases the difficulty of debugging.
- Do not put multiple return and exit statements in a function, unless following this rule would result in convoluted logic that defeats the overriding goal of maintainability.
- Always declare the return type of functions. Do not default to integer type (int). If the function does not return a value, then give it return type void.
- A single return statement at the end of a function creates a single, known point which is passed through at the termination of function execution.
- The single-return structure is easier to change. If there is more to do after a search, just add the statement(s) between the for loop and the return.
Example: single return

```c
found = FALSE;
for (i=0 ; i<max && !found ; i++)
    if (vec[i] == key )
        found = TRUE;
return(found);
```

Example: multiple returns

```c
for (i=0 ; i<max ; i++)
    if (vec[i] == key)
        return(TRUE);
return(FALSE);
```
This section provides examples of the proper way to format constant and variable definitions and declarations and discusses data encapsulation techniques. There are several general guidelines to follow when working with types:

- Define one variable or constant per line.
- Use short comments to explain all variables or constants.
- Group related variables and constants together.

6.1 Variables

When declaring variables of the same type, declare each on a separate line unless the variables are self-explanatory and related, for example:

    int year, month, day;

Add a brief comment to variable declarations:

    int x; /* comment */
    int y; /* comment */

Group related variables. Place unrelated variables, even of the same type, on separate lines.

    int x, y, z;
    int year, month, day;

6.2 Constants

When defining constants, capitalize constant names and include comments. In constant definitions, align the various components, as shown in the examples below. In ANSI C, there are several ways to specify constants: const modifier, #define command, and enumeration data types.
6.2.1 Const Modifier

Use the const modifier as follows:

```c
const int SIZE 32;   /* size in inches */
const int SIZE 16 + 16; /* both evaluate to the number 32 */
```

6.2.2 #define Command

The #define preprocessor command instructs the preprocessor to replace subsequent instances of the identifier with the given string of tokens. It takes the form:

```c
#define IDENTIFIER token-string
```

In general, avoid hard-coding numerical constants and array boundaries. Assign each a meaningful name and a permanent value using #define. This makes maintenance of large and evolving programs easier because constant values can be changed uniformly by changing the #define and recompiling.

```c
#define NULL 0
#define EOS '\0'
#define FALSE 0
#define TRUE 1
```

Using constant macros is a convenient technique for defining constants. They not only improve readability, but also provide a mechanism to avoid hard-coding numbers.

6.2.3 Enumeration Types

Enumeration types create an association between constant names and their values. Using this method (as an alternative to #define), constant values can be generated, or you can assign the values. Place one variable identifier per line and use aligned braces and indentation to improve readability. In the example below showing generated values, low would be assigned 0, middle 1, and high 2. When you assign values yourself, align the values in the same column, as shown in the second example.

Example: generated values

```c
enum position
{
  LOW,
  MIDDLE,
  HIGH
};
```
Data Types, Operators, and Expressions

Example: assigned values

```c
enum stack_operation_result
{
    FULL     = -2,
    BAD_STACK = -1,
    OKAY     = 0,
    NOTEMPTY = 0,
    EMPTY    = 1
};
```

6.2.4 Simple Constants

Use the const modifier instead of the #define preprocessor to define simple constants. This is preferable because #define cannot be used to pass the address of a number to a function and because #define tells the preprocessor to substitute a token string for an identifier, which can lead to mistakes (as illustrated in the example below).

Example: using #define

```c
#define SIZE 10 + 10 /* 10 + 10 will be substituted for SIZE */
...
area = SIZE * SIZE; /* this evaluates to 10 + 10 * 10 + 10 */
    /* which is 10 + (10 * 10) + 10 = 120 */
```

Example: using the const modifier

```c
const int SIZE = 10 + 10; /* SIZE evaluates to the number 20 */
...
area = SIZE * SIZE; /* this evaluates to 20 * 20 = 400 */
```

6.3 Variable Definitions and Declarations

6.3.1 Numbers

Floating point numbers should have at least one number on each side of the decimal point:

```
0.5  5.0  1.0e+33
```

Start hexadecimal numbers with 0x (zero, lower-case x) and upper case A-F:

```
0x123  0xFFF
```
Data Types, Operators, and Expressions

End long constants in upper-case L:

123L

6.3.2 Qualifiers

Always associate qualifiers (e.g., short, long, unsigned) with their basic data types:

```c
short int x;
long int y;
unsigned int z;
```

6.3.3 Structures

The use of structures is one of the most important features of C. Structures enhance the logical organization of your code, offer consistent addressing, and will generally significantly increase the efficiency and performance of your programs.

Using common structures to define common elements allows the program to evolve (by adding another element to the structure, for example), and lets you modify storage allocation. For example, if your program processes symbols where each symbol has a name, type, flags, and an associated value, you do not need to define separate vectors.

Example: structures

```c
typedef struct symbol
{
char *name;
int type;
int flags;
int value;
} symbol_type;
symbol_type symbol_table[NSYM];
```

6.3.4 Automatic Variables

An automatic variable can be initialized either where it is declared or just before it is used. If the variable is going to be used close to where it is declared (i.e., less than one page later), then initialize it where it is declared. However, if the variable will be used several pages from where it is declared, then it is better practice to initialize it just before it is used.
Example: variable initialized where declared

```c
int max = 0;
/* use of max is within a page of where it is declared */
for (i=0; i<n; i++)
    if (vec[i] > max)
        max = vec[i];
```

Example: variable initialized where used

Use an assignment statement just before the for loop:

```c
int max;
...
/* several pages between declaration and use */
...
max = 0;
for (i=0; i<n; i++)
    if (vec[i] > max)
        max = vec[i];
```

Or use the comma operator within the for loop:

```c
int max;
...
/* several pages between declaration and use */
...
for (max = 0, i=0; i<n; i++)
    if (vec[i] > max)
        max = vec[i];
```

### 6.4 Type Conversions and Casts

Type conversions occur by default when different types are mixed in an arithmetic expression or across an assignment operator. Use the cast operator to make type conversions explicit rather than implicit.

Example: explicit type conversion (recommended)

```c
float f;
int i;
...
f = (int) i;
```
Example: *implicit type conversion*

\[
\text{float } f; \\
\text{int } i; \\
\ldots \\
\text{ } f = i;
\]

### 6.5 Pointer Types

Explicitly declare pointer entities (variables, function return values, and constants) with pointer type. Put the pointer qualifier (*) with the variable name rather than with the type.

*Example: pointer declaration*

\[
\text{char } *s, *t, *u;
\]

### 6.6 Pointer Conversions

Programs should not contain pointer conversions, except for the following:

- **NULL** (i.e., integer 0) may be assigned to any pointer.
- **Allocation functions** (e.g., malloc) will guarantee safe alignment, so the (properly cast) returned value may be assigned to any pointer. Always use sizeof to specify the amount of storage to be allocated.
- **Size.** Pointers to an object of given size may be converted to a pointer to an object of smaller size and back again without change. For example, a pointer-to-long may be assigned to a pointer-to-char variable which is later assigned back to a pointer-to-long. Any use of the intermediate pointer, other than assigning it back to the original type, creates machine-dependent code. Use it with caution.

### 6.7 Operator Formatting

- Do not put space around the **primary operators**: →, , and [ ]:
  
  \[
  p->m \quad s.m \quad a[i]
  \]

- Do not put a space before **parentheses** following function names. Within parentheses, do not put spaces between the expression and the parentheses:
  
  \[
  \exp(2, x)
  \]
• Do not put spaces between unary operators and their operands:
  \(!p \quad \neg b \quad ++i \quad \neg n \quad *p \quad &x\)

• **Casts** are the only exception. *do put a space* between a cast and its operand:
  \((long) m\)

• Always put a space around assignment operators:
  \(c1 = c2\)

• Always put a space around conditional operators:
  \(z = (a > b) ? a : b;\)

• **Commas** should have one space (or newline) after them:
  \(strncat(t, s, n)\)

• **Semicolons** should have one space (or newline) after them:
  \(for (i = 0; i < n; ++i)\)

• For other operators, generally put one space on either side of the operator:
  \(x + y \qquad a < b && b < c\)

• Occasionally, these operators may appear with no space around them, but the operators with no space around them must bind their operands tighter than the adjacent operators:
  \(printf(fmt, a + 1)\)

• Use side-effects within expressions sparingly. No more than one operator with a side-effect (=, op=, ++, --) should appear within an expression. It is easy to misunderstand the rules for C compilation and get side-effects compiled in the wrong order. The following example illustrates this point:
  \(if ((a < b) && (c == d)) \ldots\)

  If a is not < b, the compiler knows the entire expression is false so \((c == d)\) is never evaluated. In this case, \((c == d)\) is just a test/relational expression, so there is no problem. However, if the code is:
  \(if ((a < b) && (c == d + ))\)

  d will only be incremented when \(a < b\) because of the same compiler efficiency demonstrated in the first example.
CAUTION: Avoid using side-effect operators within relational expressions. Even if the operators do what the author intended, subsequent reusers may question what the desired side-effect was.

- Use comma operators exceedingly sparingly. One of the few appropriate places is in a for statement. For example:

```c
for (i = 0, j = 1; i < 5; i++, j++);
```

- Use parentheses liberally to indicate the precedence of operators. This is especially true when mask operators (&, |, and ^) are combined with shifts.

- Split a string of conditional operators that will not fit on one line onto separate lines, breaking after the logical operators:

```c
if (p->next == NULL &&
    (total_count < needed) &&
    (needed <= MAX_ALLOC) &&
    (server_active(current_input)))
{
    statement_1;
    statement_2;
    statement_n;
}
```

6.8 Assignment Operators and Expressions

C is an expression language. In C, an assignment statement such as “a = b” itself has a value that can be embedded in a larger context. We recommend that you use this feature very sparingly. The following example shows a standard C idiom with which most C programmers are familiar.

Example: embedded assignments

```c
while ((c = getchar()) != EOF)
{
    statement_1;
    statement_2;
    statement_n;
}
```

However, do not overdo embedding of multiple assignments (or other side-effects) in a statement. Consider the tradeoff between increased speed and decreased maintainability that results when embedded statements are used in artificial places.
Example: nonembedded statements

total = get_total ();
if (total == 10)
    printf("goal achieved\n");

Example: embedded statements (not recommended)

if ((total = get_total()) == 10)
    printf("goal achieved\n")

6.9 Conditional Expressions

In C, conditional expressions allow you to evaluate expressions and assign results in a shorthand way. For example, the following if then else statement

    if (a > b)
        z = a;
    else
        z = b;

could be expressed using a conditional expression as follows:

    z = (a > b) ? a : b;  /* z = max(a, b) */

While some conditional expressions seem very natural, others do not, and we generally recommend against using them. The following expression, for example, is not as readable as the one above and would not be as easy to maintain:

    c = (a == b) ? d + f(a) : f(b) - d;

Do not use conditional expressions if you can easily express the algorithm in a more clear, understandable manner. If you do use conditional expressions, use comments to aid the reader’s understanding.

6.10 Precedence and Order of Evaluation

There are 21 precedence rules. Rather than trying to memorize the rules or look them up every time you need them, remember these simple guidelines from Steve Oualline’s C Elements of Style:

- * % / come before + and -
- Put ( ) around everything else
7

STATEMENTS
AND CONTROL FLOW

This section describes how to organize statements into logical thoughts and how to format various kinds of statements. The general principles for writing clear statements are as follows:

• Use blank lines to organize statements into paragraphs and to separate logically related statements.
• Limit the complexity of statements, breaking a complex statement into several simple statements if it makes the code clearer to read.
• Indent to show the logical structure of your code.

7.1 Sequence Statements

This section describes the rules for formatting statements in blocks.

7.1.1 Statement Placement

Put only one statement per line (except in for loop statements):

```c
switch (axescolor)
{
    case 'B':
        color = BLACK;
        break;
    case 'Y':
        color = YELLOW;
        break;
    case 'R':
        color = RED;
        break;
    default:
        color = GREEN;
        break;
}
```

SEL-94-003 47
Avoid statements that rely on side-effect order. Instead, put the variables with operators ++ and -- on lines by themselves:

```c
*destination = *source;
destination++;  
source++;  
a[i] = b[i++];
```

It is recommended that you use explicit comparison even if the comparison value will never change. For example, this statement:

```c
if (! (bufsize % sizeof (int)))
```

should be written instead as

```c
if ((bufsize % sizeof (int)) == 0)
```

to reflect the numeric (not boolean) nature of the test.

### 7.1.2 Braces

Compound statements, also known as blocks, are lists of statements enclosed in braces. The brace style we recommend is the Braces-Stand-Alone method. Place braces on separate lines and align them. This style, which is used throughout this document, allows for easier pairing of the braces and costs only one vertical space.

**Example: Braces-Stand-Alone method**

```c
for (i = 0, j = strlen(s)-1; i < j; i++, j--)
{
    c = s[i];
    s[i] = s[j];
    s[j] = c;
}
```

Although C does not require braces around single statements, there are times when braces help improve the readability of the code. Nested conditionals and loops can often benefit from the addition of braces, especially when a conditional expression is long and complex.

The following examples show the same code with and without braces. We encourage the use of braces to improve readability. Use your own judgment when deciding whether or not to use braces, remembering that what is clear to you may not be obvious to others who read your code.
Example: braces improve readability

```c
for (dp = &values[0]; dp < top_value; dp++)
{
    if (dp->d_value == arg_value
        && (dp->d_flag & arg_flag) != 0)
    {
        return (dp);
    }
}
return (NULL);
```

Example: no braces

```c
for (dp = &values[0]; dp < top_value; dp++)
    if (dp->d_value == arg_value &&
        (dp->d_flag & arg_flag) != 0)
        return (dp);
return (NULL);
```

- If the span of a block is large (more than about 40 lines) or there are several nested blocks, comment closing braces to indicate what part of the process they delimit:

  ```c
  for (sy = sytable; sy != NULL; sy = sy->sy_link)
  {
      if (sy->sy_flag == DEFINED)
      {
          ...
      } /* if defined */
      else
      {
          ...
      } /* if undefined */
  } /* for all symbols */
  ```

- If a for or while statement has a dummy body, the semicolon should go on the next line. It is good practice to add a comment stating that the dummy body is deliberate.

  ```c
  /* Locate end of string */
  for (char_p = string; *char_p != EOS; char_p++)
      ; /* do nothing */
  ```

- Always put a space between reserved words and their opening parentheses.
- Always put parentheses around the objects of sizeof and return.
7.2 Selection Control Statements

This section discusses the recommended formatting for selection control statements. Examples are given to show how to format single statements as well as blocks of statements.

7.2.1 If

- Indent single statements one level:

  ```
  if (expression)
  one_statement;
  ```

- Indent a block of statements one level using braces:

  ```
  if (expression)
  {
    statement_1;
    ...
    statement_n;
  }
  ```

7.2.2 If Else

- If else statements that have only simple statements in both the if and else sections do not require braces but should be indented one level:

  ```
  if (expression)
  statement
  else
  statement
  ```

- If else statements that have a compound statement in either the if or else section require braces and should be indented one level using braces:

  ```
  if (expression)
  one_statement;
  else
  {
    statement_1;
    ...
    statement_n;
  }
  ```
7.2.3 Else If

For readability, use the following format for else if statements:

```plaintext
if (expression)
  statement[s]
else if (expression)
  statement[s]
else
  statement[s]
```

7.2.4 Nested If Statements

7.2.4.1 If/If

Use nested if statements if there are alternative actions (i.e., there is an action in the else clause), or if an action completed by a successful evaluation of the condition has to be undone. Do not use nested if statements when only the if clause contains actions.

Example: good nesting

```plaintext
status = delta_create((Callback)NULL, &delta);
if (status == NDB_OK)
{
  if ((status = delta_record_condition(...) ) == NDB_OK &&
      (status = delta_field_condition(...) ) == NDB_OK &&
      (status = delta_field_condition(...) ) == NDB_OK)
    status = delta_commit(delta, ...);
  (void) ndb_destroy_delta(delta);
}
```

Example: inappropriate nesting

```plaintext
status = delta_create((Callback)NULL, &delta);
if (status == NDB_OK)
{
  status = delta_record_condition(delta, ...);
  if (status == NDB_OK)
  {
    status = delta_field_condition(delta, ...);
    if (status == NDB_OK)
    {
      (cont'd next page)
    }
  }
}
Example: inappropriate nesting (cont'd)

```c
{  
    status = delta_field_condition( ...);
    if (status == NDB_OK )  
        status = delta_commit(delta, ...);
}
(VOID) ndb_destroy_delta(delta);
return(status);
```

7.2.4.2 If If Else

Because the else part of an if else statement is optional, omitting the "else" from a nested if sequence can result in ambiguity. Therefore, always use braces to avoid confusion and to make certain that the code compiles the way you intended. In the following example, the same code is shown both with and without braces. The first example will produce the results desired. The second example will not produce the results desired because the "else" will be paired with the second "if" instead of the first.

Example: braces produce desired result

```c
if (n > 0)  
{  
    for (i = 0; i < n; i++)  
    {  
        if (s[i] > 0)  
        {  
            printf("...");  
            return(i);  
        }  
    }  
}  
else /* CORRECT -- braces force proper association */  
printf("error - n is zero\n");
```
Example: absence of braces produces undesired result

```c
if (n > 0)
    for (i = 0; i < n; i++)
        if (s[i] > 0)
            { printf("...");
            return(i);
        }
    else    /* WRONG -- the compiler will match to closest */
        /* else-less if */
        printf("error - n is zero\n");
```

7.2.5 Switch

For readability, use the following format for switch statements:

```c
switch (expression)
{
    case aaa:
        statement[s]
        break;
    case bbb: /* fall through */
    case ccc:
        statement[s]
        break;
    default:
        statement[s]
        break;
}
```

Note that the fall-through feature of the C switch statement should be commented for future maintenance.

All switch statements should have a default case, which may be merely a "fatal error" exit. The default case should be last and does not require a break, but it is a good idea to put one there anyway for consistency.

7.3 Iteration Control Statements

This section discusses the recommended formatting for iteration control statements. Examples are given to show how to format single statements as well as blocks of statements.
7.3.1 While

For one statement, use the following format:

```c
while (expression)
    one_statement;
```

For a block of statements, use:

```c
while (expression)
{
    statement_1;
    ...
    statement_n;
}
```

7.3.2 For

Use the following formats:

```c
for (expression)
    one_statement;
for (expression)
{
    statement_1;
    ...
    statement_n;
}
```

If a for loop will not fit on one line, split it among three lines rather than two:

```c
for (curr = *listp, trail = listp;
     curr != NULL;
     trail = &(curr->next), curr = curr->next)
{
    statement_1;
    ...
    statement_n;
}
7.3.3 Do While

For readability, use the following format:

```
do
  {  
    statement_1;
    statement_2;
    statement_3;
  }
while (expression)
```

7.4 Severe Error and Exception Handling

This section discusses the recommended formatting for goto statements and labels. We also discuss the use of the break statement. Recommendations in this section correspond to the severe error and exception handling guidelines given in Section 4.2.4. Note that although gotos and labels are legal constructs of the C language, we do not recommend using them if you can write clear structured code without them.

7.4.1 Gotos and Labels

Goto statements should be used very sparingly, as in any well-structured code. They are useful primarily for breaking out of several levels of switch, for, and while nesting, as shown in the following example:

```
for (...)  
{  
  for (...)  
  {  
    ...  
    if (disaster)  
    {  
      goto error;
    }  
  }  
}  
...  
error:  
  error processing  
```

7.4.2 Break

A break statement can be used to exit an inner loop of a for, while, do, or switch statement at a logical breaking point rather than at the loop test. The following
Examples, which remove trailing blanks and tabs from the end of each input line illustrate the difference.

Example: logical break

```c
while ((n = getline(line, MAXLINE)) > 0)
{
    while (--n >= 0)
    {
        if (line[n] != ' ' && line[n] != 't' &&
            line[n] != '
')
            break;
    }
}
```

Example: loop test

```c
while ((n = getline(line, MAXLINE)) > 0)
{
    while (--n >= 0 &&
            (line[n]==' ' || line[n]=='t' || line[n]=='\n'))
        ; /* void */
    ...
}
```
PORTABILITY AND PERFORMANCE

Code is often developed on one type of computer and then ported to and executed on another. Therefore, it is judicious to make the code as portable as possible, requiring no changes or minimal ones—such as changes to system-specific header files. When writing software, consider the following guidelines that will enhance portability and performance.

8.1 Guidelines for Portability

- Use ANSI C whenever it is available.
- Write portable code first. Consider detailed optimizations only on computers where they prove necessary. Optimized code is often obscure. Optimizations for one computer may produce worse code on another. Document code that is obscure due to performance optimizations and isolate the optimizations as much as possible.
- Some code/functions are inherently nonportable. For example, a hardware device handler, in general, can not be transported between operating systems.
- If possible, organize source files so that the computer-independent code and the computer-dependent code are in separate files. That way, if the program is moved to a new computer, it will be clear which files need to be changed for the new platform.
- Different computers have different word sizes. If you are relying on a (predefined) type being a certain size (e.g., int being exactly 32 bits), then create a new type (e.g., typedef long int32) and use it (int32) throughout the program; further changes will require only changing the new type definition.
- Note that pointers and integers are not necessarily the same size; nor are all pointers the same size. Use the system function sizeof(...) to get the size of a variable type instead of hard-coding it.
- Beware of code that takes advantage of two's complement arithmetic. In particular, avoid optimizations that replace division or multiplication with shifts.
- Become familiar with the standard library and use it for string and character manipulation. Do not reimplement standard routines. Another person reading
your code might see the reimplementation of a standard function and would need to establish if your version does something special.

- Use #ifdefs to conceal nonportable quirks by means of centrally placed definitions.

Example: centrally placed definitions

```
#ifdef decus
#define UNSIGNED_LONG long
#else
#define UNSIGNED_LONG unsigned long
#endif
```

### 8.2 Guidelines for Performance

- Remember that code must be maintained.
- If performance is not an issue, then write code that is easy to understand instead of code that is faster. For example,

  replace: \[ d = (a = b + c) + r; \] with: \[ a = b + c; \]
  \[ d = a + r; \]

- When performance is important, as in real-time systems, use techniques to enhance performance. If the code becomes "tricky" (i.e., possibly unclear), add comments to aid the reader.
- Minimize the number of opens and closes and I/O operations if possible.
- Free allocated memory as soon as possible.
- To improve efficiency, use the automatic increment `++` and decrement operators `--` and the special operations `+=` and `*=` (when side-effect is not an issue).
- ANSI C allows the assignment of structures. Use this feature instead of copying each field separately.
- When passing a structure to a function, use a pointer. Using pointers to structures in function calls not only saves memory by using less stack space, but it can also boost performance slightly. The compiler doesn’t have to generate as much code for manipulating data on the stack and it executes faster.
C CODE EXAMPLES

The following examples illustrate many of the principles of good style discussed in this document. They include:

• A Makefile, which provides an efficient mechanism for building several executables.
• A .c file, which illustrates program file organization and principles of readability.
• An include file, which illustrates clear and maintainable definition and organization of constants and external variables.
9.1 Makefile

# Makefile for UIX Testing ..
#
#
# J. Programmer
#
# This makefile can build 8 different executables. The executables
# share some of the same code and share libraries.
#
# Object code for the executables
#
INIT_OBJS = oi_seq_init.o oi_seq_drv_l.o
GEN_SCREEN_OBJS = oi_seq_gen_screen_PRIVATE.o
  oi_seq_drv_l.o
  oi_seq_resize_pane.o
  oi_seq_get_pane_sizes_PRIVATE.o
  oi_seq_init.o
FATAL_OBJS = oi_seq_drv_2.o
  oi_seq_fatalPRIVATE.o
PROC_FOCUS_EVENTS_OBJS = oi_seq_drv_3.o
  oi_seq_proc_focus_events.o
LOAD_OBJS = oi_seq_load_drv.o
  oi_seq_load.o
  print_seq.o
SUB_BUILD_1 = \
  oi_seq_init.o
  oi_seq_gen_screen_PRIVATE.o
  oi_seq_resize_pane.o
  oi_seq_get_pane_sizes_PRIVATE.o
  oi_seq_proc_focus_events.o
  oi_seq_load.o
  oi_seq_change_exec_type.o
  oi_seq_file_errorPRIVATE.o
  oi_seq_enable_sequencePRIVATE.o
  oi_seq_new_appPRIVATE.o
  oi_seq_prep_load.o
  oi_seq_change_currentPRIVATE.o
  oi_seq_set_detail_panePRIVATE.o
  oi_seq_retrieve_detail_panePRIVATE.o
  oi_seq_subbld_1.o
SUB_BUILD_2 = \

BUILD_2 = \n    oi_seq_change_currentPRIVATE.o\n    oi_seq_change_exec_type.o\n    oi_seq_enable_sequencePRIVATE.o\n    oi_seq_fatalPRIVATE.o\n    oi_seq_gen_screenPRIVATE.o\n    oi_seq_init.o\n    oi_seq_load.o\n    oi_seq_new_appPRIVATE.o\n    oi_seq_proc_focus_events.o\n    oi_seq_quit.o\n    oi_seq_retrieve_detail_panePRIVATE.o\n    oi_seq_save.o\n    oi_seq_set_detail_panePRIVATE.o\n    oi_seq_seqcr_check_seqPRIVATE.o\n    oi_seq_seqcr_continue.o\n    oi_seq_seqcr_handle_sigchld.o\n    oi_seq_seqcr_spawnPRIVATE.o\n    oi_seq_seqcr_start.o\n    oi_seq_seqcr_term.o\n    oi_seq_reconfigure_panePRIVATE.o\n    oi_seq_reconfigure_panePRIVATE.o\n    oi_seq_b2_stubs.o\n    oi_session_mgr_main.o
# These are included in all executables
OBJS = test_main.o oi_seq_data.o stubs.o

INTERNAL_DEFINES = -DTEST_NO_NCSS
DEFINES =
DEBUG = -g
CUSTOM_FLAGS = -posix -W3 -DXTFUNCPROTO -DFUNCPROTO
CFLAGS = $(DEBUG) $(CUSTOM_FLAGS) $(INCDIR) $(DEFINES)\
         $(INTERNAL_DEFINES)

# INCLUDE PATHS
INCDIR = -I/u/cmps3/UIX/dev/include \-
         -I/u/cmps3/UIX/codebase5/sco/source

# LIBRARIES
NCSS_LIBS = -lncss_c -lrpcsvc -lrpc -lsocket
XLIBS = -lxT Xm_s -lxmu -lxX11_s -1FW
UIX_LIBS = -luixdiag -luixutil
UIX_LIBS2 = -lmgr

# Compilation for the executables ...
test_init: $(INIT_OBJS) $(OBJS)
    $(CC) -o test_init $(INIT_OBJS) $(OBJS) $(UIXLIBDIR)\$(NCSS_LIBS)\$(UIX_LIBS) $(XLIBS)
test_gen_screen: $(GEN_SCREEN_OBJS) $(OBJS)
    $(CC) -o test_gen_screen $(GEN_SCREEN_OBJS) $(OBJS) $(UIXLIBDIR)\$(NCSS_LIBS) $(UIX_LIBS) $(XLIBS)
test_fatal: $(FATAL_OBJS) $(OBJS)
    $(CC) -o test_fatal $(FATAL_OBJS) $(OBJS) $(NCSS_LIBS) $(UIXLIBDIR)\$(UIX_LIBS) $(XLIBS)
test_proc_focus_events: $(PROC_FOCUS_EVENTS_OBJS) $(OBJS)
    $(CC) -o test_proc_focus_events $(PROC_FOCUS_EVENTS_OBJS) $(OBJS)\$(UIXLIBDIR) $(UIX_LIBS)
test_load: $(LOAD_OBJS) $(OBJS)
    $(CC) -o test_load $(LOAD_OBJS) $(OBJS)\$(UIXLIBDIR) $(UIX_LIBS) $(XLIBS)
sub_build_1: $(SUB_BUILD_1) $(OBJS)
    $(CC) -o @ $(SUB_BUILD_1) $(OBJS) $(UIXLIBDIR) $(NCSS_LIBS)\$(UIX_LIBS) $(XLIBS)
sub_build_2: $(SUB_BUILD_2) $(OBJS)
    echo $(SUB_BUILD_2) $(CC) -o @ $(SUB_BUILD_2) $(OBJS) $(UIXLIBDIR) $(NCSS_LIBS)\$(UIX_LIBS) $(XLIBS)
built_2: $(BUILD_2)
$(CC) -o $@ $(BUILD_2) $(UIXLIBDIR) $(NCSS_LIBS)\
  $(UIX_LIBS) $(XLIBS)

clean:
  /bin/rm $(INIT_OBJS) $(OBJS) $(GEN_SCREEN_OBJS) $(FATAL_OBJS)\
  $(LOAD_OBJS) $(SUB_BUILD_1)

depend:
  makedepend -- $(CFLAGS) -- '/bin/ls *.c'

# DO NOT DELETE THIS LINE -- make depends on it.

# [a jillion lines that are dependencies generated by makedepend go here]
9.2 C Program File: RF_GetReference.c

DATA FILE NAME: RF_GetReference.c

PURPOSE: This function determines if a requested reference vector is in need of update. It uses analytic routines to update vectors and these updates are reflected in the reference.h include file.

FILE REFERENCES:

Name.IO.Description

none

EXTERNAL VARIABLES:

Source: debug.h

Name.Type.IO.Description

debug_file_handle.FILE*.I.File handle for debug file name

debug_level.int[9].I.Debug level array

Source: HD_reference.h

Name.Type.IO.Description

ephem_file_luong.long.I.FORTRAN logical unit number for the ephemeris file

ephem_method.char.I.Method for computing ephemeris information:

F = Use ephemeris file

A = Compute analytically using Keplerian elements

keplerian.double[6].I.Keplerian orbital elements at the epoch time (orbital_t_epoch):

[1] Semimajor axis [km]

[2] Eccentricity

[3] Inclination [rad]

[4] Right ascension of the ascending node [rad]
### C Code Examples

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>m_order</td>
<td>Order of magnetic field</td>
</tr>
<tr>
<td>maxit</td>
<td>Maximum number of iterations to converge the true anomaly</td>
</tr>
<tr>
<td>MU_E</td>
<td>Earth gravitational constant [km^3/sec^2]</td>
</tr>
<tr>
<td>NUMPTS</td>
<td>Number of points used by the EPHEMRD interpolator</td>
</tr>
<tr>
<td>orbital_t_epoch</td>
<td>Base epoch time of the orbital elements [sec]</td>
</tr>
<tr>
<td>THREEB</td>
<td>Gravitational constant of perturbations [Km^2]</td>
</tr>
<tr>
<td>ttol</td>
<td>Tolerance in the calculations of the true anomaly [rad]</td>
</tr>
<tr>
<td>t_b_ref</td>
<td>Time of last calculated Earth magnetic field vector [sec]</td>
</tr>
<tr>
<td>t_e_ref</td>
<td>Time of last calculated S/C to Earth unit vector [sec]</td>
</tr>
<tr>
<td>t_m_ref</td>
<td>Time of last calculated S/C to Moon unit vector [sec]</td>
</tr>
<tr>
<td>t_o_ref</td>
<td>Time of last calculated orbit normal unit vector [sec]</td>
</tr>
<tr>
<td>t_rv_ref</td>
<td>Time of last calculated S/C position and velocity vectors [sec]</td>
</tr>
<tr>
<td>t_s_ref</td>
<td>Time of last calculated S/C to Sun unit vector [sec]</td>
</tr>
<tr>
<td>e_pos</td>
<td>S/C to Earth unit vector</td>
</tr>
<tr>
<td>m_pos</td>
<td>S/C to Moon unit vector</td>
</tr>
<tr>
<td>mag_field</td>
<td>Earth magnetic field vector [mG]</td>
</tr>
<tr>
<td>mag_field_unit</td>
<td>Earth magnetic field unit vector</td>
</tr>
<tr>
<td>orbit_normal</td>
<td>Orbit normal unit vector</td>
</tr>
<tr>
<td>s_c_pos</td>
<td>S/C position vector [km]</td>
</tr>
<tr>
<td>s_c_vel</td>
<td>S/C velocity vector [km/sec]</td>
</tr>
<tr>
<td>s_pos</td>
<td>S/C to Sun unit vector</td>
</tr>
</tbody>
</table>

### EXTERNAL REFERENCES:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>c_ephemrd</td>
<td>Retrieves vectors from an ephemeris file and interpolates them for a requested time</td>
</tr>
<tr>
<td>c_calpvs</td>
<td>Generates S/C position and velocity vectors using J2 effects</td>
</tr>
<tr>
<td>c_sunlunp</td>
<td>Generates Earth to Sun or Earth to Moon vectors</td>
</tr>
<tr>
<td>c_emagfld</td>
<td>Generates Earth magnetic field vectors</td>
</tr>
<tr>
<td>c_nmlist</td>
<td>Opens the magnetic field file for reading</td>
</tr>
</tbody>
</table>
C Code Examples

* GetSun
  Compute s/c to Sun unit vector
* GetOrbitNormal
  Compute orbit normal vector
* GetEarth
  Compute s/c to Earth vector
* GetMoon
  Compute s/c to Moon unit vector
* SecsToCalendar
  Converts time from seconds to standard calendar format
* c_packst
  Converts time from standard calendar format to an unpacked array format
* c_calmjd
  Computes the modified Julian date of an unpacked array format time
* c_jgrenha
  Computes the Greenwich Hour Angle using analytical data
* c_unvec3
  Unitizes a vector and computes its magnitude

* ABNORMAL TERMINATION CONDITIONS, ERROR AND WARNING MESSAGES:
  none

* ASSUMPTIONS, CONSTRAINTS, RESTRICTIONS: none

* NOTES:
  CALLED BY: InitReference, CalcNadirAngle, ConvertAttitude,
  ComputeAttitude, CompSunNad, CalcLambdaPhi

* REQUIREMENTS/FUNCTIONAL SPECIFICATIONS REFERENCES:
  FASTRAD Functional Specifications, Sections 4.3.1 - 4.3.6

* DEVELOPMENT HISTORY:
  Date    Name      Change ID  Release Description
  ------- ----------- --------- ---------- ---------------------------------------------
  09-16-93 J. Programmer 1      1      Prolog and PDL
  10-25-93 J. Programmer 1      1      Coded
  11-16-93 J. Programmer 1      1      Controlled
  12-02-93 J. Programmer 1      1      Integrated new RSL routines
  12-20-93 J. Programmer 12     1      Created intermediate variables for #define arguments of calpvs
                                           in order to pass by address
  02-15-94 J. Programmer 15     2      Corrected time errors using RSL routines
  05-03-94 J. Programmer 3      3      Enhancements to RSL prototypes
  05-10-94 J. Programmer 3      3      Added Earth magnetic field read capability
  05-10-94 J. Programmer 3      3      Added ephemeris read capability
ALGORITHM
*
* DO CASE of reference type
*
* CASE 1 or 2, request is for s/c position or velocity vectors
*
*   IF offset between request time and time of last calculated s/c
*   position and velocity vectors exceeds wait time THEN
*   COMPUTE elapsed seconds between epoch time and request time
*   IF ephemeris method is for reading file THEN
*     CALL c_ephemrd to read ephemeris file getting s/c position and
*     velocity vectors
*     ELSE (analytic computation)
*     CALL c_calpvs to generate new s/c position and velocity
*     vectors
*     ENDIF
*   SET new time of last calculated s/c position and velocity
*     vectors to request time
*   ENDIF
*
* IF reference type is for s/c position vector THEN
*   SET return vector to s/c position vector
* ELSE
*   SET return vector to s/c velocity vector
* ENDIF
*
* CASE 3, request is for s/c to Sun unit vector
*
*   IF offset between request time and time of last calculated s/c to
*   Sun unit vector exceeds wait time THEN
*   CALL SecsToCalendar c_packst and c_calmjd to get modified
*     Julian date
*   CALL c_sunlunp to generate new Earth to Sun vector
*   CALL GetSun to compute new s/c to Sun unit vector
*   SET new time of last calculated s/c to Sun unit vector to
*     request time
*   ENDIF
C Code Examples

* SET return vector to s/c to Sun unit vector
* CASE 4 or 5, request is for Earth magnetic field vector or Earth
  magnetic field unit vector
* IF offset between request time and time of last calculated Earth
  magnetic field vector exceeds wait time THEN
* CALL SecsToCalendar c_packst and c_calmjd to get modified
  Julian date
  CALL c_jgrenha to get the Greenwich Hour Angle
  CALL c_emagfld to generate new Earth magnetic field vector
  CALL c_unvec3 to SET Earth magnetic field unit vector
* SET new time of last calculated Earth magnetic field vector to
  request time
* ENDIF
* IF reference type is for Earth magnetic field vector THEN
  SET return vector to Earth magnetic field vector
  ELSE
  SET return vector to Earth magnetic field unit vector
  ENDIF
* CASE 6, request is for orbit normal unit vector
* IF offset between request time and time of last calculated orbit
  normal unit vector exceeds wait time THEN
* CALL GetOrbitNormal to generate new orbit normal unit vector
* SET new time of last calculated orbit normal unit vector to
  request time
* ENDIF
* SET return vector to orbit normal unit vector
* CASE 7, request is for s/c to Moon unit vector
* IF offset between request time and time of last calculated s/c to
  Moon unit vector exceeds wait time THEN
* CALL SecsToCalendar c_packst and c_calmjd to get modified Julian
  date
  CALL c_sunlunp to generate new Earth to Moon vector
  CALL GetMoon to compute new s/c to Moon unit vector
* SET new time of last calculated s/c to Moon unit vector to
  request time
* ENDIF
* SET return vector to s/c to Moon unit vector
```
* CASE 8, request is for s/c to Earth unit vector
* IF offset between request time and time of last calculated s/c to
* Earth unit vector exceeds wait time THEN
* CALL GetEarth to compute new s/c to Earth unit vector
* SET new time of last calculated s/c to Earth unit vector to
* request time
* ENDIF
* SET return vector to s/c to Earth unit vector
* END CASE
* RETURN
*
*******************************************************************************/

/* Include global parameters */
#include "HD__debug.h"
#include "HD__reference.h"

/* Declare Prototypes */
void c_ephemrd (long , long , long , double , double *,
                double *, double *, double *, long *);
void c_calpv3 (double , double , double *, double *,
                double , double , double ,
                double *, double *, long *);
void c_sunlunpv (double , double , double *, double *);
void c_emagflv (long , double , double , double , double *,
                double , double *,
                double *, double *, long *);
void c_nmlist (long , long *, char *, long *);
void c_packst (double , double *);
void c_calmjd (double *, double *);
void c_jgrenha (double , double , long , long , double *,
                long *);
void c_unvec3 (double *, double *, double *);
void GetSun (double[3], double[3]);
void GetOrbitNormal(double[3]);
void GetEarth (double[3]);
void GetMoon (double[3], double[3]);
double SecsToCalendar(double);

*******************************************************************************/

/* FUNCTION NAME: GetReference
* ARGUMENT LIST:
* Argument Type IO Description
*/
C Code Examples

ref_type int I Type of reference data requested
    = 1, S/C position vector
    = 2, S/C velocity vector
    = 3, S/C to Sun unit vector
    = 4, Earth magnetic field vector
    = 5, Earth magnetic field unit vector
    = 6, Orbit normal unit vector
    = 7, S/C to Moon unit vector
    = 8, S/C to Earth unit vector

t_request double I Time of requested reference vector

t_wait double I Wait time between reference vector calculations

t_ref_vector double[3] 0 Requested reference vector

RETURN VALUE: void

*******************************************************************************/

void GetReference(int ref_type, double t_request, double t_wait, double ref_vector[3])
{
    /*
    LOCAL VARIABLES:
    */
    /*
    Variable Type Description
    */
    /*
    ref_type int I Type of reference data requested
    */
    /*
    sun double[3] Earth to Sun vector [km] (from c_sunlunp)
    */
    /*
    moon double[3] Earth to Moon vector [km] (from c_sunlunp)
    */
    /*
    caldate double Epoch time in calendar format
    */
    /*
    starray double[6] Epoch time in unpacked array format
    */
    /*
    mjd double Modified Julian Date [days]
    */
    /*
    gha double Greenwich Hour Angle [rad]
    */
    /*
    aldiff double A.1 - UT1 time difference [sec]
    */
    /*
    numsselc long Number of secular terms of nutation to compute (1-39, nominally 1)
    */
    /*
    numterm long Number of nonsecular terms of nutation to compute (1-106, nominally 50)
    */
    /*
    fdumm double Unused return value (from c_unvec3)
    */
    /*
    ierr long Return code from RSL routines
    */
    /*
    m double Variable for #defined MU_E
    */
    /*
    t double Variable for #defined THREEB
    */
    /*
    eptime double Elapsed seconds between epoch time and requested time [sec]
    */
    /*
    dpos double Array of dummy position vectors used by ephemris read routine
    */
    /*
    dvel double Array of dummy velocity vectors used by ephemris read routine
    */
    /*
    loop_counter int Loop counter
    */
    /*
    i int Loop counter
    */
* j int Loop counter */

double int sun[3], moon[3], caldate, starray[6], mjd, gha,
    aldiff, fdumm;
double int m, t;
double int eptime;
long int numselc, numterm;
long int ierr = -100;
long int two = 2;
long int four = 4;
long int zero = 0;
int int i,j;
char *mag_path = "/public/libraries/rsl/hpux/emag1990.dat";

static int loop_counter = 0;
static double int dpos[3][100], dvel[3][100];

/* Initialize local parameters for RSL routines */

aldiff = 0.0;
numselc = 1;
umterm = 50;

if (debug_level[RF] > TRACE)
    fprintf(debug_file_handle,"ENTER GetReference\n");

if (debug_level[RF] > INPUT)
{
    fprintf(debug_file_handle,"\tINPUT\n");
    switch (ref_type)
    {
    case 1:
        fprintf(debug_file_handle,
            "\t\treference type (ref_type = 1) S/C position vector\n");
        break;
    case 2:
        fprintf(debug_file_handle,
            "\t\treference type (ref_type = 2) S/C velocity vector\n");
        break;
    case 3:
        fprintf(debug_file_handle,
            "\t\treference type (ref_type = 3) S/C to Sun unit vector\n");
        break;
    case 4:
        fprintf(debug_file_handle,
            "\t\treference type (ref_type = 4) Earth mag field vector\n");
        break;
    case 5:
        fprintf(debug_file_handle,
            "\t\treference type (ref_type = 5) Earth mag field unit vector\n");
        break;
    }
C Code Examples

case 6:
    fprintf(debug_file_handle,
        "\t\treference type (ref_type = 6) Orbit normal unit vector\n");  
    break;

case 7:
    fprintf(debug_file_handle,
        "\t\treference type (ref_type = 7) S/C to Moon unit vector\n");  
    break;

case 8:
    fprintf(debug_file_handle,
        "\t\treference type (ref_type = 8) S/C to Earth unit vector\n"); 
    break;
}

    fprintf(debug_file_handle,
        "\t\trequest time [sec] (t_request) = %f\n", t_request);
    fprintf(debug_file_handle,
        "\t\twait time [sec] (t_wait) = %f\n", t_wait);

/* Begin Case of reference type */

switch (ref_type)
{

/* Perform case for either s/c position or velocity vector request
 * using the RSL routine c_calpvs */

case 1:
case 2:

    if (debug_level[RF] > INPUT)
    {
        fprintf(debug_file_handle,
            "\t\tlast pos and vel vector time [sec] (t_rv_ref) = %lf\n", 
            t_rv_ref);
        fprintf(debug_file_handle,
            "\t\tephemeris read method flag (ephem_method) = %c\n", 
            ephem_method);
    }

    if (((t_request - t_rv_ref) > t_wait))
    {
        eptime = t_request - orbital_t_epoch;

        if (debug_level[RF] > INTERMEDIATE)
        {
            fprintf(debug_file_handle, "\tINTERMEDIATE\n"");
            fprintf(debug_file_handle,
                "\t\tRequest time [secs from reference] (eptime) = %lf\n", 
                eptime);
        }

        if (ephem_method == 'F')
        {
            if (loop_counter == 0)
{ 
    for (i=0; i<100; i++)
        for (j=0; j<3; j++)
        {
            dpos[j][i] = 0.0;
            dvel[j][i] = 0.0;
        }
    loop_counter++;
}

c_ephemrd(ephem_file_lu, four, zero, eptime,
            dpos, dvel, s_c_pos, s_c_vel, &ierr);

if (ierr)
    if (debug_level[R] > TRACE)
        fprintf(debug_file_handle,
                "***** Error code from c_ephemrd = %ld\n", ierr);
else
{
    m = MU_E;
    t = THREEB;

c_calpvs(eptime, m, keplerian, t, ttol, maxit, s_c_pos, s_c_vel, &ierr);

    if (ierr)
        if (debug_level[R] > TRACE)
            fprintf(debug_file_handle,
                    "***** Error code from c_calpvs = %ld\n", ierr);

    if (debug_level[R] > INTERMEDIATE)
    {
        fprintf(debug_file_handle,
                "Earth gravitational constant [km^3/sec^2]
                (MU_E) = %lf\n", MU_E);
        fprintf(debug_file_handle,
                "Grav. constant [Km^2]
                (THREEB) = %lf\n", THREEB);
        fprintf(debug_file_handle,
                "ttolerance of true anomaly [rad]
                (ttol) = %lf\n", ttol);
        fprintf(debug_file_handle,
                "max iters of true anomaly (maxit) = %d\n", maxit);
        fprintf(debug_file_handle,
                "time of request [sec from epoch]
                (eptime) = %lf\n", eptime);
        fprintf(debug_file_handle,
                "semi major axis [km]
                (keplerian[0]) = %lf\n", keplerian[0]);
        fprintf(debug_file_handle,
                "eccentricity (keplerian[1]) = %lf\n", keplerian[1]);
        fprintf(debug_file_handle,
                "keplerian[2]) = %lf\n", keplerian[2]);
    }
\"t\tinclination [rad] (keplerian[3]) =  
%lf\n*,keplerian[2]);
fprintf(debug_file_handle,
\"t\tra of asc node [rad] (keplerian[4]) =  
%lf\n*,keplerian[3]);
fprintf(debug_file_handle,
\"t\targ of perigee [rad] (keplerian[5]) =  
%lf\n*,keplerian[4]);
fprintf(debug_file_handle,
\"t\tmean anomaly [rad] (keplerian[6]) =  
%lf\n*,keplerian[5]);
}
}

\t_rv_ref = \t_request;

if (debug_level[RF] > INTERMEDIATE)
{
    fprintf(debug_file_handle,
\"t\ts/c position vector [km] (s_c_pos) = \lf,%lf,%lf\n*,
    s_c_pos[0],s_c_pos[1],s_c_pos[2]);
    fprintf(debug_file_handle,
\"t\ts/c velocity vector [km] (s_c_vel) = \lf,%lf,%lf\n*,
    s_c_vel[0],s_c_vel[1],s_c_vel[2]);
}
}

if (ref_type == \t)
    for (i=0 ; i<3 ; i++)
        ref_vector[i] = s_c_pos[i];
else
    for (i=0 ; i<3 ; i++)
        ref_vector[i] = s_c_vel[i];
break;

/* Perform case for s/c to Sun unit vector request using the RSL
 * routine c_sunlunp */
case 3:
    if (debug_level[RF] > INPUT)
        fprintf(debug_file_handle,
\"t\tlast sun vector time [sec] (t_s_ref) = \lf\n*,t_s_ref);
    if ((\t_request - t_s_ref) > t_wait)
    {
        caldate = SecsToCalendar(\t_request);
        c_packst (caldate,starray);
        c_calmjd (starray,&mjd);
        c_sunlunp(mjd,\t_request,sun,moon);
        GetSun (sun,s_pos);
        t_s_ref = \t_request;
    }
if (debug_level[RF] > INTERMEDIATE)
{
    fprintf(debug_file_handle,"\tINTERMEDIATE\n");
    fprintf(debug_file_handle,
            "\t\tModified Julian Date [days] (mjd) = %lf\n", mjd);
    fprintf(debug_file_handle,
            "\t\ttime of request [sec] (use t_request see above) \n");
}
}

for (i=0 ; i<3 ; i++)
    ref_vector[i] = s_pos[i];
break;

/* Perform case for Earth magnetic field vector or Earth magnetic
 field unit vector using RSL routines c_emagfld and c_unvec3 */

case 4:
    case 5:
    if (debug_level[RF] > INPUT)
        fprintf(debug_file_handle,
                "\t\tlast Earth mag field vector time [sec] (t_b_ref) = %lf\n",
                t_b_ref);
    if ((t_request - t_b_ref) > t_wait)
    {
        caldate = SecsToCalendar(t_request);
        c_packst (caldate,starray);
        c_calmjd (starray,&mjd);
        c_jgrenha(mjd,alldiff,numslez,numselt,&gha,&ierr);
        if (ierr)
            if (debug_level[RF] > TRACE)
                 fprintf(debug_file_handle,
                         "**** Error code from c_jgrenha = %ld\n",ierr);
        c_nmlist(1,&two,mag_path,&ierr);
        if (ierr)
            if (debug_level[RF] > TRACE)
                 fprintf(debug_file_handle,
                         "**** Error code from c_nmlist = %ld\n",ierr);
        c_emagfl2(two,mjd,t_request,gha,s_c_pos,m_order,mag_field,&ierr);
        if (ierr)
            if (debug_level[RF] > TRACE)
                 fprintf(debug_file_handle,
                         "**** Error code from c_emagfl2 = %ld\n",ierr);
        c_unvec3 (mag_field,mag_field_unit,&fdumm);
        t_b_ref = t_request;
if (debug_level[RF] > INTERMEDIATE)
{
    fprintf(debug_file_handle,"\tINTERMEDIATE\n");
    fprintf(debug_file_handle,
            "\tModified Julian Date [days] (mjd) = %lf\n", mjd);
    fprintf(debug_file_handle,
            "\tttime difference [sec] (alldiff) = %lf\n\", alldiff);
    fprintf(debug_file_handle,
            "\tnutation number (numselc) = %d\n", numselc);
    fprintf(debug_file_handle,
            "\tnutation number (numterm) = %d\n", numterm);
    fprintf(debug_file_handle,
            "\tGreenwich Hour Angle [rad] (gha) = %lf\n", gha);
    fprintf(debug_file_handle,
            "\toorder of magnetic field (m_order) = %d\n\", m_order);
    fprintf(debug_file_handle,
            "\ts/c position vector [km] (s_c_pos) = %lf,%lf,%lf\n"," s_c_pos[0],s_c_pos[1],s_c_pos[2]);
    fprintf(debug_file_handle,
            "\tttime of request [sec] (use t_request see above) \n");
}

if (ref_type == 4)
    for (i=0 ; i<3 ; i++)
        ref_vector[i] = mag_field[i];
else
    for (i=0 ; i<3 ; i++)
        ref_vector[i] = mag_field_unit[i];
break;

/* Perform case for orbit normal unit vector request */

case 6:
/* Debug : Intermediate */

if (debug_level[RF] > INPUT)
    fprintf(debug_file_handle,
            "\tlast normal unit vector time [sec] (t_o_ref) = %lf\n"," t_o_ref);

if ((t_request - t_o_ref) > t_wait)
{
    GetOrbitNormal(orbit_normal);
    t_o_ref = t_request;
}

for (i=0 ; i<3 ; i++)
    ref_vector[i] = orbit_normal[i];
break;
/* Perform case for s/c to Moon unit vector request using the RSL *
* routine c_sunlunp */

case 7:
    if (debug_level[RF] > INPUT)
        fprintf(debug_file_handle,
                "\t\tlast moon vector time [sec] (t_m_ref) = %f\n", t_m_ref);

    if (((t_request - t_m_ref) > t_wait)
    {
        caldate = SecsToCalendar(t_request);
        c_packst (caldate,starray);
        c_calmjd (starray,&mjd);
        c_sunlunp(mjd,t_request,sun,moon);
        GetMoon (moon,m_pos);
        t_m_ref = t_request;

        if (debug_level[RF] > INTERMEDIATE)
            {
                fprintf(debug_file_handle,"\tINTERMEDIATE\n");
                fprintf(debug_file_handle,
                        "\t\tModified Julian Date [days] (mjd) = %f\n", mjd);
                fprintf(debug_file_handle,
                        "\t\tttime of request [sec] (use t_request see above) \n");
            }
    }

    for (i=0 ; i<3 ; i++)
        ref_vector[i] = m_pos[i];
    break;

/* Perform case for s/c to Earth unit vector request */

case 8:
    if (debug_level[RF] > INPUT)
        fprintf(debug_file_handle,
                "\t\tlast Earth vector time [sec] (t_e_ref) = %f\n", t_e_ref);

    if (((t_request - t_e_ref) > t_wait)
    {
        GetEarth(e_pos);

        t_e_ref = t_request;
    }

    for (i=0 ; i<3 ; i++)
        ref_vector[i] = e_pos[i];
    break;
if (debug_level[RF] > OUTPUT) {
    fprintf(debug_file_handle, "\tOUTPUT\n");
    fprintf(debug_file_handle, "\t\trequested reference vector (ref_vector) = %lf,%lf,%lf\n", ref_vector[0], ref_vector[1], ref_vector[2]);
}

if (debug_level[RF] > TRACE)
    fprintf(debug_file_handle, "EXIT GetReference\n\n");

return;

} /* end */
9.3 Include File: HD_reference.h

/*************************************************************/
* FILE NAME: HD_reference.h
* PURPOSE: Defines all reference data variables.
* GLOBAL VARIABLES:
* Variables Type Description
* __________ ----------- -----------------------------------------
* e_pos double[3] S/C to Earth unit vector
* ephem_file_lu long FORTRAN logical unit number for the ephemeris file
* ephem_file_name char[30] Name of the ephemeris file
* ephem_method char Method for computing ephemeris information:
* = Use ephemeris file
* A = Compute analytically using Keplerian elements
* keplerian double[6] Keplerian orbital elements at the epoch time
* (orbital_t_epoch):
* [1] Semimajor axis [km]
* [2] Eccentricity
* [3] Inclination [rad]
* [4] Right ascension of the ascending node [rad]
* [5] Argument of perigee [rad]
* [6] Mean anomaly [rad]
* m_order long Order of magnetic field
* m_pos double[3] S/C to Moon unit vector
* mag_field double[3] Earth magnetic field vector [mG]
* mag_field_unit double[3] Earth magnetic field unit vector
* maxit  long  Maximum number of iterations to converge the true anomaly
* MUE  double  Earth gravitational constant [km^3/sec^2]
* NUMPTS  int  Number of points used by the EPHEMRD interpolator
* orbit_normal  double[3]  Orbit normal unit vector
* orbital_t_epoch  double  Base epoch time of the orbital elements [sec]
* s_c_pos  double[3]  S/C position vector [km]
* s_c_vel  double[3]  S/C velocity vector [km/sec]
* s_pos  double[3]  S/C to Sun unit vector
* t_b_ref  double  Time of last calculated Earth magnetic field vector [sec]
* t_e_ref  double  Time of last calculated S/C to Earth unit vector [sec]
* t_m_ref  double  Time of last calculated S/C to Moon unit vector [sec]
* t_o_ref  double  Time of last calculated orbit normal unit vector [sec]
* t_rv_ref  double  Time of last calculated S/C position and velocity vectors [sec]
* t_s_ref  double  Time of last calculated S/C to Sun unit vector [sec]
* THREEB  double  Gravitational constant of perturbations [Km^2]
* ttol  double  Tolerance in the calculations of the true anomaly [rad]
DEVELOPMENT HISTORY:

<table>
<thead>
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<th>Date</th>
<th>Author</th>
<th>Change ID</th>
<th>Description of Change</th>
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<tr>
<td>09-23-93</td>
<td>J. Programmer</td>
<td>1</td>
<td>Prolog and PDL</td>
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<tr>
<td>10-07-93</td>
<td>J. Programmer</td>
<td>1</td>
<td>Controlled</td>
</tr>
<tr>
<td>12-02-93</td>
<td>J. Programmer</td>
<td>1</td>
<td>Integrated new RSL routines</td>
</tr>
<tr>
<td>12-17-93</td>
<td>J. Programmer</td>
<td>2</td>
<td>Added maxit and ttol;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>added MU_E and THREEB as #defines</td>
</tr>
<tr>
<td>04-06-94</td>
<td>J. Programmer</td>
<td>3</td>
<td>Corrected the THREEB value</td>
</tr>
<tr>
<td>05-10-94</td>
<td>J. Programmer</td>
<td>3</td>
<td>Added ephemeris read capability</td>
</tr>
</tbody>
</table>

*******************************************************************************

#define MU_E 398600.8
#define THREEB 66042.0
#define NUMPTS 4

extern long ephem_file_lu;
extern double e_pos[3];
extern char ephem_file_name[30];
extern char ephem_method;
extern double keplerian[6];
extern long m_order;
extern double m_pos[3];
extern double mag_field[3];
extern double mag_field_unit[3];
extern long maxit;
extern double orbit_normal[3];
extern double orbital_t_epoch;
extern double s_c_pos[3];
extern double s_c_vel[3];
extern double s_pos[3];
extern double t_b_ref;
extern double t_e_ref;
extern double t_m_ref;
extern double t_o_ref;
extern double t_rv_ref;
extern double t_s_ref;
extern double ttol;
BIBLIOGRAPHY


*Indian Hill C Style and Coding Standards*, Bell Telephone Laboratories, Technical Memorandum 78-5221 (1978)


INDEX

A
Abnormal termination conditions
  in file prolog 19
Abort statement 25
Algorithm 20
  in file prolog 19
  PDL 19
Allocation functions 42
ANSI C 3, 37, 57, 58
Array boundaries 38
Assignment
  operator 43
  statement 44
Assumptions
  in file prolog 19
Author
  in file prolog 19
Automatic variable 40
  initializing 40

B
Bind operands 43
Blank lines 5
  overuse 5
Block comments 7
Boxed comments 7
Braces 48
  Braces-Stand-Alone method 48
Breadth-first approach
  ordering functions 28
  Break statement 55

C
C binding 11
Call statement 21
Capitalization 11
Case statement 23
Cast operator 41, 43
Change id
  in file prolog 19
Comma
  operator 43, 44
  spacing 5
Comments 6
  and PDL 6
  block 7
  boxed 7
  file prolog 6
  function prolog 6
  inline 7, 8
  README file 6
  short 7
Compound statements 48
Conditional
  expressions 45
  nested 48
  operator 43
const
  modifier 11, 38
  vs. define 39
Constant formatting 37
  long 39
  macros 28, 38
  names 11
  numerical 38

Constraints
  in file prolog 19

D
Data declarations
  external 28
Data hiding 14
Data sections
  encapsulation 3
Data structures
  encapsulation 3
Date
  in file prolog 19
Declaration
  extern 3, 28, 33
  external variables 33
  function
    parameters 32
    variable 39
define
  vs. const 39
Definitions
  external 28
  non-static 28
  static external 28
  variable 39
Description of change
  in file prolog 19
Development history
  in file prolog 19
Directive
  include 27
do for statement 24
do until statement 25
do while statement 24, 55

E
else if statement 51
Encapsulation 3, 14
data sections 3
data structures 3
files 3
function sections 3
enum 11, 28
Enumeration types 11, 38
names 11
Error handling 55
Error messages
in file prolog 19
Exception handling 25, 55
Expressions
conditional 45
extern 3, 28, 33
External data
declarations 28
External references
in file prolog 19
External variables 3, 28
declarations 33
in file prolog 19
non-static 28
static 28
with functions 29

F
File
encapsulation 3
header 14
Makefile 15
module 15
name
in file prolog 18
organization 17
program 13
README 6, 14
references
in file prolog 19
File organization
schema 17
File prolog 6, 18
abnormal
termination
conditions 19
algorithm 19
assumptions 19
author 19
change id 19
constraints 19
date 19
description of
change 19
development
history 19
ero error messages 19
external references
19
external variables
19
file name 18
file references 19
in release 19
notes 19
PDL 19
purpose 18
requirements
references 19
restrictions 19
warning messages
19
Filename suffixes 16
Floating point
numbers 39
for statement 54
Function 31
allocation 42
alphabetical listing
of 28
macros 28
name 11, 43
function prolog 31
ordering
breadth-first
approach 28
organization
schema 31
organization
schema 31
parameters
declaration 32
prolog 6, 31
function name 31
parameters 31
return value 31
separating 28
sequence 28
with external
variables 29

G
Global variables 28
goto statement 55

H
Hard-coding
array boundaries 38
numerical constants
38
Header files 3, 14
prolog 20
time.h 14
Hexadecimal numbers
39
Hidden variable 10, 33

I
if else statement 50
if statement 50
if then else statement
22
if then statement 22
Include directive 27
Indentation 6
two spaces 6
Information hiding 3
element 4
Inline comments 7, 8
Internal variables 33
declaration 33
naming 10
Iteration control
statements 24, 53
do for 24
Index

do until 25
do while 24, 55
for 54
while 54

L
Labels 55
Libraries
  math.h 15
  standard 14
stdio.h 14
Long constants 39
Loops 48
  indices 33
  nested 26

M
Macros
  constant 28
  function 28
main() 28
Maintainability 3
Makefile 15
  example 60
math.h 15
Module file 15

N
Names 3, 8
  and hidden
    variables 10
C binding 11
  constant 8, 11
  enumeration types 11
  file 8
  function 8, 11, 31, 43
  long variable 6
  standard 9
  standard filename
    suffixes 16
  standard suffixes 10
  type 11
  variable 4, 10
  variables 8
Nested
  conditionals 48
  if statements 51
  loops 26
Non-static external
  definitions 28
Notes
  in file prolog 19
Null pointer 42
Numbers 39
  floating point 39
  hexadecimal 39
Numerical constants 38

O
Operators
  assignment 43
  binding operands 43
  cast 41, 43
  comma 43, 44
  conditional 43
  formatting 43
  parentheses 43
  precedence 44
  primary 43
  semicolons 43
  side-effects 44
  unary 43
Organization
  file 17
  functions 31
  program 13
  statements 47

P
Paragraphing 5, 33
Parameters
  function prolog 31
Parentheses
  operator 43
  precedence 44
PDL 20
  comments 6
  exception handling 25
general guidelines 20
  in file prolog 19
iteration control
  statements 24
    do for 24
    do until 25
    do while 24
selection control
  statements 21
    case 23
    if then 22
    if then else 22
sequence
  statements 21
    call 21
    return 21
severe error
  handling 25
  abort 25
  undo 26
types of statements 21
Performance
  guidelines 58
  real-time systems 58
Pointer conversions 42
  allocation functions 42
    null 42
    size 42
Pointer types 42
Portability
  guidelines 57
  standard library 57
  two’s complement 57
    word size 57
Precedence
  operators 44
    rules 46
Primary operator 43
Program
  files 13
    organization 13
Prolog
  file 18
    function 31
Index

header file 20
Purpose
in file prolog 18

Q
Qualifiers 40

R
Readability 3
README file 6, 14
Real-time systems
portability 58
Release
in file prolog 19
Requirements
references
in file prolog 19
Restrictions
in file prolog 19
Return
sequence
statement 21
statement 34
multiple returns 35
single return 35
value
function prolog 31

S
Schema
file organization 17
function
organization 31
program
organization 13
Scope 3
variables
example 4
Selection control
statements 50
case 23
else if 51
if 50
if else 50
if then 22
if then else 22
nested if 51
PDL 21
switch 53
Semicolons 43
Sequence
of functions 28
Sequence statements
21, 47
call 21
return 21
Severe error handling
statement 25, 55
abort 25
break 55
goto 55
undo 26
Short comments 7
Side-effect 44
order 48
Size 39, 42
integer 38, 57
pointers 57
portability 57
word 57
sizeof 42, 48, 49
Spaces 4, 5
and operators 43
comma spacing 5
PDL indentation 20
reserved words 49
white space 3
Standard libraries 14
portability 57
Statement 47
assignment 44
break 26, 55
call 21
case 23
compound 48
do for 24
do until 25
do while 24, 55
else if 51
exception handling
25
for 54
goto 26, 55
if 50
if else 50
if then 22
if then else 22
iteration control 24,
53
nested if 51
return 21, 34
selection control 21,
50
sequence 21, 50
severe error
handling 25
side-effect order 48
switch 53
while 54
Statement
paragraphing 33
Static external
definitions 28
stdio.h 14, 15, 17, 27
Structured code 26, 55
Structures 40
Style 1
Suffixes
filename
Switch statement 53

T
Termination conditions
in file prolog 19
time.h 14
Two’s complement
arithmetic 57
Type
conversions 41
enumeration 11, 38
names 11
pointer 42
Typedef 11, 28

U
Unary operator 43
Undo statement 26

88  SEL-94-003
Index

V

Variable
  automatic 40
  declarations 39
  definitions 39
  external 3, 28
  formatting 37
  global 28
  hidden 10, 33
  internal 33
  names 10
  scope 4
Visibility 3

W

Warning messages
  in file prolog 19
While statement 54
White space 4
  blank lines 5
  indentation 6
  spaces 5
Word size 57
The technical papers, memorandums, and documents listed in this bibliography are organized into two groups. The first group is composed of documents issued by the Software Engineering Laboratory (SEL) during its research and development activities. The second group includes materials that were published elsewhere but pertain to SEL activities.

SEL-ORIGINATED DOCUMENTS

SEL-76-001, Proceedings From the First Summer Software Engineering Workshop, August 1976
SEL-77-002, Proceedings From the Second Summer Software Engineering Workshop, September 1977
SEL-78-005, Proceedings From the Third Summer Software Engineering Workshop, September 1978
SEL-78-007, Applicability of the Rayleigh Curve to the SEL Environment, T. E. Mapp, December 1978
SEL-79-005, Proceedings From the Fourth Summer Software Engineering Workshop, November 1979
SEL-80-005, A Study of the Musa Reliability Model, A. M. Miller, November 1980
SEL-80-006, Proceedings From the Fifth Annual Software Engineering Workshop, November 1980


SEL-81-012, *The Rayleigh Curve as a Model for Effort Distribution Over the Life of Medium Scale Software Systems*, G. O. Picasso, December 1981


SEL-82-004, *Collected Software Engineering Papers: Volume 1*, July 1982


SEL-82-102, *FORTRAN Static Source Code Analyzer Program (SAP) System Description (Revision 1)*, W. A. Taylor and W. J. Decker, April 1985

SEL-82-105, *Glossary of Software Engineering Laboratory Terms*, T. A. Babst, M. G. Rohleder, and F. E. McGarry, October 1983

SEL-82-1206, *Annotated Bibliography of Software Engineering Laboratory Literature*, L. Morusiewicz and J. Valett, November 1993


SEL-87-003, Guidelines for Applying the Composite Specification Model (CSM), W. W. Agresti, June 1987
SEL-87-009, Collected Software Engineering Papers: Volume V, November 1987
SEL-87-010, Proceedings of the Twelfth Annual Software Engineering Workshop, December 1987
SEL-88-002, Collected Software Engineering Papers: Volume VI, November 1988
SEL-88-004, Proceedings of the Thirteenth Annual Software Engineering Workshop, November 1988
SEL-88-005, Proceedings of the First NASA Ada User’s Symposium, December 1988
SEL-89-005, Lessons Learned in the Transition to Ada From FORTRAN at NASA/Goddard, C. Brophy, November 1989
SEL-89-007, Proceedings of the Fourteenth Annual Software Engineering Workshop, November 1989
SEL-89-301, Software Engineering Laboratory (SEL) Database Organization and User’s Guide (Revision 3), L. Morusiewicz, December 1993
SEL-90-002, The Cleanroom Case Study in the Software Engineering Laboratory: Project Description and Early Analysis, S. Green et al., March 1990

BI-4
SEL-90-004, Gamma Ray Observatory Dynamics Simulator in Ada (GRODY) Experiment Summary, T. McDermott and M. Stark, September 1990

SEL-90-005, Collected Software Engineering Papers: Volume VIII, November 1990


SEL-91-004, Software Engineering Laboratory (SEL) Cleanroom Process Model, S. Green, November 1991


SEL-91-102, Software Engineering Laboratory (SEL) Data and Information Policy (Revision 1), F. McGarry, August 1991


SEL-93-001, Collected Software Engineering Papers: Volume XI, November 1993


SEL-93-003, Proceedings of the Eighteenth Annual Software Engineering Workshop, December 1993


SEL-94-003, C Style Guide, J. Doland and J. Valett, August 1994
SEL-RELATED LITERATURE


BI-11


NOTES:
1. This article also appears in SEL-82-004, *Collected Software Engineering Papers: Volume I*, July 1982.
2. This article also appears in SEL-83-003, *Collected Software Engineering Papers: Volume II*, November 1983.
4. This article also appears in SEL-86-004, *Collected Software Engineering Papers: Volume IV*, November 1986.
8. This article also appears in SEL-90-005, *Collected Software Engineering Papers: Volume VIII*, November 1990.
**C Style Guide**

This document discusses recommended practices and style for programmers using the C language in the Flight Dynamics Division environment. Guidelines are based on generally recommended software engineering techniques, industry resources, and local convention. The Guide offers preferred solutions to common C programming issues and illustrates through examples of C Code.