A SOFTWARE ENGINEERING ENVIRONMENT FOR WEAPON SYSTEM SOFTWARE: FUNCTIONAL DESCRIPTION FOR THE CODE AND TEST PHASE

George Mebus
Software and Computer Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

NADC
30 NOVEMBER 1982
Tech. Info.
PHASE REPORT

Approved For Public Release; Distribution Unlimited

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
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Appendix A - Software Functional Description  
Appendix B - SPF Performance Requirements
A Software Engineering Environment for Weapon System Software: Functional Description for the Code and Test Phase

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1. Purposes of a SEE

"Software Engineering" is concerned with developing software systems that satisfy the requirements of the user over the whole life of the system; a SEE assists the accomplishment of software engineering through sets of computer facilities, integrated software tools, and uniform engineering procedures. The term "weapon system software" inherently implies a concern with software for embedded computer systems and support over the entire life-cycle. Among the aims of a SEE are to increase productivity, support development of reproducible software and promote standardization of software and software development methods. The industrialization of computer hardware is already successful in these areas; the SEE will enable a similar industrialization of computer software.

Productivity

To increase productivity, the SEE must let users work in the most productive mental surroundings, i.e., at a high level of abstraction, dealing with the problems they are to solve, rather than the details of the host computer system. DoD recognized this when they emphasized High Order Languages (HOL's) and Ada\(^1\) in particular. The SEE must automate what can be automated to free users of details irrelevant to their work (how to access the compiler, organization of file structures, etc.), and guide users in systematic software development.

This guidance will both disencumber users and restrict what they can do. Structured programming provides a taste of this freedom with restriction. It makes one's thinking about decisions easier by providing a standard set of control structures. It also restricts use of a large class of possible control statements because they may adversely affect program quality. Thus, productivity is enhanced by both the provisions and the restrictions of structured programming. The SEE's guidance will have similar benefits.

Software sharing is also essential to increased productivity. Repeated re-invention of software is a costly waste of resources. Software developers should be able to make general, flexible

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\(^1\) Ada is a Registered Trademark of the Ada Joint Program Office - U.S. Government
subprograms that can be freely shared. The programming language used greatly affects the generality of software modules. But the software engineering environment also affects the ability to know about the software components as well as the freedom to access them. SEE will provide convenient support of software sharing.

Reproducibility

The Navy must be able to reproduce its software. This means that the Navy must have control over the tools used to generate the software. A contractor's proprietary tools must not be part of the software development process because they tend to lock the contractor into the project for the entire life cycle. Also, the Navy must limit users' ability to make arbitrary changes to their data base information. For example, if someone can modify the object code so that it does not reflect the associated source code (a current capability of the MTASS SYSGEN) then the Navy cannot always reproduce the object code from the source.

Standardization

Standardization is essential to the above topics. It is also necessary for automated Configuration Management. The SEE will enforce both internal standards (file formats, file contents, file and tool accesses, development data collection, etc.) and external standards (e.g., compliance with MIL-STD-1679).

Standardization carries much weight in the aims of Ada. Ada is intended to be a standard language across all DoD with neither subsets nor dialects. A standard language support system is also envisioned. Proposed benefits of these standardizations include user transportability, software transportability and reduced re-invention. SEE standardizations have similar virtues to promote higher productivity and better software.

One important feature of the SEE is the standard data base structure, automatically provided and maintained. A typical benefit is the transition of software from software developer to the Software Support Activity (SSA). Although usually a tedious, expensive process it becomes trivial when both developer and SSA have the software in standardized SEE data bases throughout the different life cycle phases.

2. Present Navy Efforts

MTASS

The Machine Transportable AN/UYK-20, AN/AYK-14 Support Software (MTASS) is a set of tools for military software development, hosted on several large commercial computers and targeted for the military computers mentioned in its name as well as the AN/UYK-44. The tools are cooperative in that the outputs of some are the inputs of others. They are standardized in that they work the same way on the various hosts and they provide a basic set of tools for all programmers of the
target machines. The set is not complete in that some use of auxiliary host machine tools is required (e.g., for source and object library maintenance). PMS-408 maintains the MTASS source code and distributes only the object.

SHARE/7

An interactive operating system for the AN/UYK-7 military computer. It allows direct user manipulation of files, tapes and tools. While the Navy controls who may use SHARE/7, there is no Navy control over its use, the content or structure of files or the methods of tool invocation.

UNIX

An interactive operating system for DEC VAX computers and other commercial hosts. UNIX has an extensive compatible tool set, a flexible convenient file system and good internal communication among tools. Most tools do a simple operation on a file, producing another file as a result. Many desirable file processing operations can be quickly developed by stringing various tools together. UNIX provides a tree-structured file system with flexible ways of accessing and processing groups of files. Since UNIX is a general purpose commercial operating system, the Navy does not control its distribution and use.

FASP

A Navy integrated software development environment, hosted on large-scale commercial computers and targeted to fully support all Navy standard military computers. FASP enforces development standards through the mandatory use of "procedures" tailored by parameters to do the required tasks. The automated procedures remove the necessity for users to directly access either tools or files. Thus they release users from the tedious intricacies of operational detail, while giving advanced programming capabilities to the user, control of the tools to the Navy, and control of the files to a project manager. The manager is also able to control the use of both procedures and parameters via a set of "keys" which establish the system privileges afforded to each user. A set of management report procedures enhance management visibility by producing reports from data automatically gathered during software development.

Two versions of FASP currently exist. One hosted on CDC CYBER machines, using KRONOS and NOS operating systems, supports many major Navy projects using the Navy standard embedded military computers (e.g., AN/AYK-14, AN/UYK-44, AN/UYS-1). Extensive tool development was done to make an integrated environment. The CYBER version of FASP has been in use for the past seven years. The second version, which supports microprocessor code development, is hosted on VAX machines.

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2 UNIX is a trademark of Bell Laboratories.
3 DEC and VAX are trademarks of Digital Equipment Corporation.
using the UNIX operating system. A much greater use of existing operating system facilities was made in UNIX than with the CYBER operating system. A faster, easier implementation was possible because the UNIX tools were more easily combined and new tools were more easily created through use of the UNIX shell and the C language. NAVAIRDEVCEN is the developer and maintainer of FASP.

Ada MAPSE

The Minimum Ada Program Support Environment (MAPSE) will be an environment for military software development. The goals are to have a transportable tool set, good inter-tool communication, and standard tools for all users. STONEMAN defines requirements of the MAPSE. The Ada Program Support Environment (APSE) is less clearly defined although broad principles and goals exist. PMS-408 will control the Navy Ada MAPSE as it does MTASS.

3. Distinctives of the SEE

Two notable areas of the SEE are its technical characteristics and user-friendliness. Technical characteristics are design features of the SEE, while user-friendliness is an intended by-product of them.

Technical Characteristics

Multiple language support is essential for the SEE. Even when Ada is firmly established, the SEE must still maintain existing fleet software written in a variety of current Navy-standard languages. Differences in compiler facilities, object libraries, and target computer emulators require different tool sets for each supported language. The SEE will offer standardized facilities for dealing with the several language systems to provide a consistent framework for software maintenance.

Procedures perform specific high-level jobs important to software life cycle phases. Procedures are predefined sets of host computer commands that do the software development jobs by ensuring that appropriate tools are properly sequenced and invoked, that appropriate files are properly accessed and created, that development information is collected and saved, etc. The SEE may develop and execute hundreds of operating system statements in doing a single procedure. Procedures are invoked by commands whose names reflect the jobs they do (e.g., Develop Software, Execute Tests). Mnemonic abbreviations are available for convenience (e.g., DEVSW, EXTEST). The procedure operations are tailored by parameters (like Translator or its abbreviation XLATR), most of which have default values (like XLATR=ADA). These parameter values add the flexibility required by specific tasks. A procedure handles all complexities of tool invocation and sequencing, data base management, error recovery, and collection of development statistics, with no need for the users' involvement or awareness.

Encapsulated data bases are standard sets of files with standard organizations. For a set of software modules a data base contains source, object, tests, test results, development histories,
documentation, etc. With a fixed structure that users cannot directly change, the SEE assures that the proper information in the proper relationship is available for Configuration Management (CM) reporting, management tracking and re-creation of software. It can check the internal integrity of a data base. Regularity of the data base results in efficient processing and also allows efficient enhancement of the SEE in that any new language-independent procedure can be applied to any SEE data base, thus reducing development cost.

**User-friendliness**

Programmers are lifted above internal details of the host operating system and repetitive operations. Some details are unrelated to program design and coding (such as compiler access or object library directives) and are prone to error. Others may even be dangerous. If unrestricted access to files were allowed, users could independently modify any file, potentially destroying file relationships. The SEE assures that tools are accessed and sequenced properly, requiring users to provide only their program data as inputs.

Managers benefit in two areas: visibility and control. Visibility is presented through a series of software and CM reporting procedures. They tell what software has been developed, the current testing activity, how development is tracking previous estimates, etc.

The manager initially exercises control when creating new data bases or defining "keys" for programmers. Subsequent control is a result of the key definitions. For example, a manager may not want a new programmer to be able to modify a data base but only make temporary changes for the present. The keys may then prevent use of modifying procedures like Develop Software, but allow procedures that produce reports. Similarly, the manager can restrict a programmer from using an particular version of a translator by restricting the use of the Translator parameter, forcing the default value to be used when software is modified.

4. **Purpose of the Software Functional Description**

Appendix A presents the Software Functional Description of a SEE. The design is general and applicable to all Navy software development. The Functional Description concentrates on the code and test phases but the adequacy and advantages of its organization clearly apply to earlier phases as well.

Discussing a complex system like a SEE often becomes a confusion of details and specifications that cloud the power and usefulness of the capabilities the system affords. For clarity this Software Functional Description shows the salient features of a SEE at a fairly high level—the user interface. The features are organized by user activities (e.g., Develop Software, Execute Tests, Document). Each activity has an associated "procedure" in the SEE and an associated command name to invoke the procedure.

The Functional Description is arranged as a representative list
of procedures corresponding to the discrete steps performed by programmers and software managers. In itself this list demonstrates how the SEE helps to organize user activity. Each procedure is individually presented in the Functional Description in several ways. First, a narrative text verbally describes the intent of a procedure and the capability it provides. Next, the appropriate parameters are listed to show how the users can control the operations performed. The parameter list also shows the level of detail users must consider.

After this a graphic display shows what goes on "behind the scenes" from the viewpoint of software architecture. This graphic display uses structured English to define the flow of control. The control flow description is coupled with a parallel pictorial diagram that defines the data flow. These two parallel flow descriptions illustrate several things:

- the many automated steps executed by the procedure in response to the single command invocation;

- just how parameters affect the processing and provide the needed flexibility;

- data flow information, data base contents used and produced, and other necessary file information;

- the protection given to processing, tools and data base contents;

- automatic provisions for error recovery.

In all, the Software Functional Description shows the degree to which software development can be automated and indicates the complexity that users need not contend with, but which is instead designed into the SEE. It is intended to give a clear picture of the operation of a SEE that meets needs of software developers, managers and the Navy.
APPENDIX A

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1. INTRODUCTION

Reference (a), "The Industrialization of Weapon System Software," advances the concept of a Software Engineering Environment (SEE) composed of a Software Production Facility (SPF) and a set of hardware/software Integration Facilities (IFs). The SPF is used to develop, test and maintain operational software which is then sent to the IFs for integration. Functionally, the SPF provides named "procedures" as the first level of user communication. These procedures automatically invoke specific software tools to perform the prescribed sequences of operations. They use a Data Base Management System (DBMS) to manage the storage and retrieval of data developed during the operations.

As described in reference (a), the SPF provides three phases of software support: requirements, design, and code & test. This software Functional Description identifies the functional groups of procedures provided by the SPF. For each group, narrative descriptions and process flow diagrams of the procedures are given followed by a list of the procedures, the tools they invoke, and the data base contents used and produced by the tools.
2. REFERENCE DOCUMENTS

### ABBREVIATIONS

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<td>DBMS</td>
<td>Data Base Management System</td>
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<td>FD</td>
<td>Functional Description</td>
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<td>IF</td>
<td>Integration Facility</td>
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<tr>
<td>INST</td>
<td>Instrumented (resulting from software probes inserted in source code)</td>
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<td>Machine Transportable AN/UYK-20, AN/AYK-14 Support Software</td>
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4. PROCEDURES, COMMANDS AND PROCESSING

The SPF is driven by procedures which are invoked by simple user commands. This system provides:

- Automated standards enforcement
- Centralized data collection
- Convenience and flexibility for the software developer
- Control, security and visibility for the software manager

4.1 Procedures

A procedure is a set of SPF computer directives which:

- Automates a particular software production task
- Invokes the proper tools in the proper sequence
- Handles all file manipulations and correspondences
- Automatically records job statistics

Procedures are available to meet all user needs (e.g., specify, design, develop, test, maintain, document, track) throughout the software life cycle. They require only information and data pertinent to the user's specific software production tasks (not tool invocations and file processing), thus simplifying the user's work.

A procedure may perform many smaller tasks, handling all details of data collection and tool invocation in the process. For example, the DEVELOP SOFTWARE procedure invokes an editor for text development, invokes the user-specified translator (e.g., CMS-2M compiler) to translate or retranslate all affected software modules, and invokes an object code interface extractor to identify all externals. The source and object code are always kept synchronized and job statistics are automatically collected for project tracking.

4.2 Software Tools

The software tools available through the SPF cover the full range of functions for mission software design, development, and maintenance. Examples are:

- requirements tools
- design tools
- editors
- translators
- system generators
- analyzers
- data extractors
- report generators
4.3 Data Bases

SPF procedures use a Data Base Management System (DBMS) to manage the storage and retrieval of data developed during SPF usage. The DBMS creates and maintains a hierarchical project tree file structure in which data bases are terminal nodes (or "leaves") of the tree. Project managers configure the project tree to reflect the structure of their projects. Figure 1 shows such a tree structure for a typical Navy software project.

Data bases are the repositories for the software and all information related to the software. A particular data base is assigned to developing and maintaining software for a particular operational capability. A data base will contain:

- requirements specifications and documentation
- design specifications and documentation
- source and object code for one or more modules
- system generator directives
- load modules (executable programs)
- tests and test results
- histories - items, changes, metrics
- configuration management information
- interface data - source and text inclusions, subroutine calls, external definitions and references

4.4 Commands

Each procedure is invoked by a command. Each command is a string of characters which begins with a procedure name, to identify the procedure to be performed. The name is typically followed by parameter value specifications. These values give the user flexibility in directing the performance of the procedure to accomplish the specific function required. There are two kinds of commands:

Immediate commands are executed as soon as received and validated by the SPF.

Queued commands are collected on a command queue for later processing.

All commands are processed as described in section 4.6.
FIGURE 1
SOFTWARE PRODUCT HIERARCHY TREE
4.5 Process Flow Diagrams

Process Flow Diagrams are used in this Functional Description to describe the unique operation of each procedure supported by the SPF. They consist of two associated parts:

(1) a structured English description (using standard IF-THEN-ELSE-ENDIF and DOWHILE-ENDDO constructions) of the control flow for a procedure, and

(2) a data flow diagram showing process performed, tools used, data base contents used and produced, and other information required by the procedure. A legend of diagram symbols is shown in Figure 2.

When a procedure is performed, a certain amount of "standard" processing is done before and after the "unique" processing for that procedure. This standard processing done for each procedure is shown in Figure 3 using a structured English description.

4.6 Command Processing

The SPF reads and validates the user's commands. In a batch processing mode, each valid command is executed as it is received.

In an interactive mode, any command recognized as "immediate" is executed immediately. All others are placed on the command queue for later execution. Upon receipt of the EXECUTE COMMAND QUEUE command, the SPF will execute the queued commands.

Command processing is illustrated by a process flow diagram in Figure 4.
Verify user access rights for this procedure
IF verification fails
THEN raise abort flag
- Notify user
ELSE
  - (unique process flow for procedure)
ENDIF
IF abort flag is not raised
THEN save production data
- Make "saved" files permanent
ENDIF
Save job statistics
Make job statistics permanent

Figure 3 - Standard Processing for Procedures
**DOWHILE** no LOGOFF command received
- **DOWHILE** no valid LOGON command received
- Read and identify command
- IF not LOGON
- THEN notify user that LOGON is required
- ELSE invoke LOGON processor
  
  - See process flow for LOGON paragraph 8.4.1.1
  - **ENDDO** (user is now identified)
- Read and identify command
- IF not identifiable
- THEN notify user
- ELSE validate command
- IF error
- THEN notify user
- ELSE
  - Append default values of unspecified parameters
  - IF an immediate command
  - THEN execute the command
  - ELSE put the command on the command queue
  - **ENDIF**
- **ENDIF**
- **ENDDO**

**Figure 4 - Command Processing**
5. SOFTWARE REQUIREMENTS SPECIFICATION AND ANALYSIS PROCEDURE GROUPS

Studies of requirements tools, particularly RSL/REVS and PSL/PSA, and their integration into a Software Engineering Environment are ongoing. Results of the studies are not available at the time of this draft.
6. SOFTWARE DESIGN PROCEDURE GROUPS

A study of software design methodologies is ongoing. The aim of the study is to identify one or a combination of methodologies which will best serve Navy Weapon System software and identify how automated tools can aid the use of that methodology. Results of the study are not available at the time of this draft.
7. **SOFTWARE CODE AND TEST PROCEDURE GROUPS**

### 7.1 Software Development Procedures

The "code" part of "code and test" is oriented toward operational software development. Developers must be able to establish a safe repository for their software, develop that software and make loadable object code for test integration and fleet issue. They must also be able to get current information about the software content and organization, and control the disposition of job output.

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TOOLS</th>
<th>DB CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create/Copy/Save/Restore DB</td>
<td>DBMS</td>
<td>File</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Directories/Dependencies</td>
</tr>
<tr>
<td>Develop SW</td>
<td>Text Editors</td>
<td>Source/Object Code</td>
</tr>
<tr>
<td></td>
<td>Translators</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Object Interface Extractors</td>
<td>SW Histories</td>
</tr>
<tr>
<td>Install External SW</td>
<td>Preprocessors</td>
<td>Source/Object Code</td>
</tr>
<tr>
<td></td>
<td>Translators</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Object Interface Extractors</td>
<td>SW Histories</td>
</tr>
<tr>
<td>Share SW</td>
<td></td>
<td>Source/Object/Tests/Text</td>
</tr>
<tr>
<td>Copy SW</td>
<td>Source Selector Translators</td>
<td>Source (and possibly Object/</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SW Histories/</td>
</tr>
<tr>
<td></td>
<td>Object Interface Extractors</td>
<td>SW Interfaces</td>
</tr>
<tr>
<td>Create Load Module/Tape</td>
<td>System Generator</td>
<td>System Generator Script</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Object Code</td>
</tr>
<tr>
<td>Print Reports</td>
<td>Data Extractor</td>
<td>Database Contents</td>
</tr>
<tr>
<td></td>
<td>Report Generator</td>
<td>Source Code</td>
</tr>
</tbody>
</table>

**Figure 5 - Summary of Software Development Procedures**
7.1.1 Create/Copy/Save/Restore a Data Base

The SPF, through the DBMS, automatically maintains each data base and the information on it. Use of these procedures is typically restricted by the software manager.

7.1.1.1 Create a Data Base

The SPF creates the files and directories comprising an initial configuration of a data base with a specified identifier at a specified project tree terminal node.
7.1.1.2 **Copy a Data Base**

The SPF creates a new data base at a specified node. The data base duplicates the file structure and contents of a specified alternate data base.

**COPY A DATA BASE**

- **params:**
  - Data Base Identifier (DBID)
  - Alternate Data Base Identifier (DBIDALT)

- Establish data base with DBID
- Create data base files
- Copy contents of DBIDALT files into DBID files
7.1.1.3 **Save a Data Base**

The SPF copies the specified data base structure and contents to a specified magnetic tape. A data base may be saved for baselining or for file damage protection beyond that automatically provided by the SPF.

**SAVE A DATA BASE ON TAPE**

- params:
  - Data Base Identifier (DBID)
  - Tape Identifier (TAPEID)

- Copy DBID files to TAPEID tape
7.1.1.4 **Restore a Database**

The SPF creates a new data base and copies the contents of the specified magnetic tape into the data base, thus completing the restoration of an archived data base.

**RESTORE A DATA BASE FROM TAPE**

**params:**
- Data Base Identifier (DBID)
- New Data Base Identifier (DBIDNEW)
- Tape Identifier (TAPEID)

**IF tape not recorded from DBID**
THEN raise abort flag
ELSE establish data base with DBIDNEW
- Create data base files
- Copy TAPEID contents into DBIDNEW files
ENDIF
7.1.2 Develop Software

This procedure allows entry of source code into a data base and subsequent modification of source code. All source affected by entry or modification is automatically (re)translated to ensure that source and object code are always synchronized. Other information developed and saved on the data bases are software histories and software interface information (cross references, externals information, software dependencies).
7.1.3 Install External Software

Existing software developed outside of the SPF requires additional processing when transferring it to SPF data bases. Requirements on SPF processing of external software depend on the developers adherence to the content and formats specified in reference (a). In particular, preprocessors may be required if the source code is written in a language that is not a Navy standard programming language. Conversely, if Navy standard tools were used to develop the software (e.g., MTASS), it will not only make source code transfer simpler but may also permit transfer of tests and test results to the SPF.

After source code is in acceptable SPF form in data bases, the DEVELOP SOFTWARE procedure will be used to maintain it.
7.1.4 Share/Copy Software

7.1.4.1 Share Software

Source code may be shared from a master data base to ensure that naming conventions and special data values are applied consistently throughout the project software. Object code, sections of tests and documentation text may also be shared among data bases.

### SHARE SOFTWARE

**params:**
- Alternate Data Base Identifier (DBIDALT)
- Software Type (SWTYPE)

Access SWTYPE file (source/object/test/text) from DBIDALT
Make a temporary copy for future access
7.1.4.2 Copy Software

When code is copied from one data base to another, the integrity is always maintained either by copying all pertinent information (e.g., source, object, histories, etc.) or by copying only the source code and developing the rest by translation.

---

**COPY SOFTWARE**

params:
- Data Base Identifier (DBID)
- Alternate Data Base Identifier (DBIDALT)
- Retranslation Request Indicator (RETRANSLATE)
- Source Code Translator (TRANSLATOR)

Access source code from DBIDALT
Access shared source code (if there)
Invoke Source Selector:
- Read user commands
- Read selected source members
- Produce input to TRANSLATOR

IF RETRANSLATE = YES
THEN invoke TRANSLATOR
  - Read source code
  - Produce object code
- IF fatal error
  THEN raise abort flag
  ELSE save source code
- * Save object code
- * Save member history information
- * Save source interface information
- * Invoke Object Interface Extractor
- * Read object
- * Produce object interface information
- * Save object interface information
  ENDIF
ELSE copy member history information
  * Copy source interface information
  * Copy object code
  * Copy object interface information
ENDIF
7.1.5 Create Load Module/Tape

Load tapes may be created for integration or fleet issue. Load modules can be saved on a data base for: multiple tape creation, inclusion on a multiple-data base tape, or testing with a target computer emulator. Directives for a system generator are entered into and maintained on the data base. The generators use the directives and relocatable object code from the data base to create the load module file/tape.

CREATE LOAD MODULE/TAPE

params:
Data Base Identifier (DBID)
System Generator Script (SGSCRIPT)
Tape Identifier (TAPEID)

Access object code from DBID
Access shared object copy (if there)
Access SGSCRIPT
Invoke System Generator

- Read SGSCRIPT
  Process object code
  Produce load module file or load tape

OLD DBID -> SYSTEM GENERATOR -> SHARED OBJECT COPY

NEW DBID

OBJECT

SGSCRIPT

LOAD MODULE
7.1.6 Print Reports

A variety of reports, useful in various stages of software development and maintenance, is available. The reports are produced from data base information which was explicitly or implicitly collected in the data base by the SPF. Representative information is: source code, software histories, software dependencies (nesting, externals), code statistics, translators used, etc.
7.2 Software Testing Procedures

Testing is oriented toward software evaluation. The testers must be able to identify, develop and execute tests. They must also be able to evaluate the results and effectiveness of the tests.

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TOOLS</th>
<th>USED</th>
<th>PRODUCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze Source Code</td>
<td>Source Analyzer</td>
<td>Source Code</td>
<td>Analysis Results</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analysis Results</td>
<td></td>
</tr>
<tr>
<td>Develop Tests</td>
<td>Test Case Generator</td>
<td>Analysis Results</td>
<td>Test Schema Data</td>
</tr>
<tr>
<td></td>
<td>Text Editor</td>
<td>Test Scripts</td>
<td>Test Scripts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Test Histories</td>
<td></td>
</tr>
<tr>
<td>Instrument Code</td>
<td>Source Instrumentor</td>
<td>Source Code</td>
<td>Inst Source</td>
</tr>
<tr>
<td></td>
<td>Translator</td>
<td></td>
<td>Inst Object</td>
</tr>
<tr>
<td></td>
<td>System Generator</td>
<td></td>
<td>Inst Load Module</td>
</tr>
<tr>
<td>Execute Tests</td>
<td>Computer Emulator</td>
<td>Test Script (Inst) Load Module</td>
<td>(Inst) Test Results</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test Histories</td>
</tr>
<tr>
<td>Debug Tests</td>
<td>Computer Emulator</td>
<td>Source Code</td>
<td>Test Scripts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Test Scripts</td>
<td>Test Results</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load Modules</td>
<td>Test Histories</td>
</tr>
<tr>
<td>Regression Test</td>
<td>Computer Emulator</td>
<td>Test Results</td>
<td>Test Results</td>
</tr>
<tr>
<td></td>
<td>Test Results Comparator</td>
<td>Test Scripts</td>
<td>Test Histories</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load Modules</td>
<td></td>
</tr>
<tr>
<td>Analyze Test Results</td>
<td>Test Results Analyzer</td>
<td>Inst Test Results</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 - Summary of Software Testing Procedures
7.2.1 Analyze Source Code

A static analyzer examines source code and previous analyses to enforce standards, check for coding errors and perform quantitative analyses. It also provides information for test case development (e.g., value ranges of variables).
7.2.2 **Develop Tests**

A test consists of sequences of directives for a target computer emulator to specify the environment in which a load module will be executed as well as to specify the execution data to be sampled. Tests are saved as scripts and maintained on the database just as system generator scripts are. Examples of environment specifications are memory and register initialization, and the values and timing of input data. Execution data include values in registers, memory, program counter, emulated clock timings and output data. Additional directives may identify those areas of test results which are important for regression test comparisons.

---

**DEVELOP TESTS**

**params:**
- Data Base Identifier (DBID)
- Test Case Generator Request (TESTGEN)

**Access analysis results and test histories**

**IF TESTGEN = YES**

**THEN invoke Test Case Generator**

- Read analysis results and test histories
- Read user commands
- Produce Test schema data

**ENDIF**

Access test scripts

Invoke Editor:

- Read test scripts, test schema data
- Read user commands
- Produce new test scripts

Save test scripts
7.2.3 Instrument Code

Instrumentation of code provides a significant improvement in testing and evaluating test effectiveness. A source code instrumenter identifies the optimum locations for inserting "software probes" (calls to information-collecting programs) then instruments the source code by inserting the probes, and adding the programs. The source is automatically translated to create instrumented object code from which an instrumented load module is generated. All are saved on the data base.

INSTRUMENT CODE
params:
- Data Base Identifier (DBID)
- Source Code Translator (TRANSLATOR)
- Source Instrumenter Script (SISCRIPIT)
- System Generator Script (SGSCRIPIT)
Access source code and SISCRIPIT
Access shared source copy (if there)
Invoke Source Instrumenter
  - Read SISCRIPIT and source code
  - Produce instrumented source
IF fatal errors
  THEN raise abort flag
ELSE save instrumented source
  - Invoke TRANSLATOR
  - Read instrumented source
  - Produce instrumented object
  - IF fatal errors
    THEN raise abort flag
    ELSE save instrumented object
    - Access SGSCRIPIT
    - Invoke System Generator
    - - Read SGSCRIPIT and instrumented object
    - - Produce instrumented load module file
    - - IF fatal errors
    - - THEN raise abort flag
    - - ELSE save load module file
    - ENDIF
ENDIF
ENDIF

OLD DBID | NEW DBID
---|---
SOURCE | INST SOURCE
SISCRIPIT | INST OBJECT
SOURCE INSTRUMENTOR | INST LOAD MODULE
TRANSLATOR | SGSCRIPIT
SYSTEM GENERATOR |
7.2.4 Execute Tests

Test execution uses a computer emulator program to evaluate development progress by executing load module code as the target hardware would; that is, it will go through the same internal states. But the fact that all emulated memory and registers are fully accessible at any point in the execution provides detailed visibility into the software execution. The existence of source code pointers in the object allows source-level direction and evaluation. Further, the use of instrumented load modules provides test effectiveness information.

EXECUTE TESTS

params:
  Data Base Identifier (DBID)
  List of Tests To Be Run (TESTLIST)

Access TESTLIST
Access shared test script copy (if there)
DOWHILE tests remain to be done
  • Access test script and load module
  • Associated with test
  • Invoke Computer Emulator
  • Load load module into memory
  • Process test script
  • Produce test results
  • Produce test histories
ENDDO
7.2.5 Debug Tests

To isolate problems in software or in test scripts, the SPF provides interactive control of the computer emulator. The computer emulator gives source code traces of instructions executed to aid the user in debugging source code.

This procedure is for interactive use only; no test results are saved on the data base.

---

**Debug Tests**

**Params:**  
Data Base Identifier (DBID)

Access tests, source, loadmodules  
Access shared test and source copies (if there)  
Invoke Computer Emulator

- Perform user commands  
  (eg, load loadmodules, execute scripts)  
- Provide source code traces

---

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7.2.6 Regression Test

Tests are automatically or explicitly rerun when changes are made to determine whether any previously established capabilities have been compromised (i.e., have regressed). The sections of the new test results which are designated as "important" are compared with the same parts of the previous results. The new results are saved and the tester informed of any changes that occurred in important areas.
7.2.7 Analyze Test Results

A test results analyzer examines the results of testing instrumented object code to identify code paths highly used or not used at all, major time-usage areas and time allocation violations, actual ranges of variables and range assertion violations.
8. COMMON PROCEDURE GROUPS

8.1 User Assistance Procedures

The SPF must have adequate documentation about available features and usage, and about current and future events affecting SPF usage. They must also be able to communicate with SPF personnel for additional aid. User assistance procedures are invoked by immediate commands.

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>List Bulletin</td>
<td>Lister</td>
</tr>
<tr>
<td>List News</td>
<td>Lister</td>
</tr>
<tr>
<td>List Help</td>
<td>Lister</td>
</tr>
<tr>
<td>List User Manual</td>
<td>Lister</td>
</tr>
<tr>
<td>Contact SPF Personnel</td>
<td>Electronic Mail System</td>
</tr>
</tbody>
</table>

Figure 7 - Summary of User Assistance Procedures
8.1.1 List Bulletin

This procedure produces a brief note concerning current or future events for SPF users. A bulletin is generally a notice that refers the user to the new user's manual or news volumes for details. When a user runs a batch job, this procedure is automatically invoked, causing the message to be printed on the first page of the output listing.
8.1.2 List News

The news is an SPF-maintained library of timely narratives which contain the details omitted from the bulletin. News items are available individually or in groups.

```
LIST NEWS
params: ITEMS
Access news file
Invoke Lister
Copy news ITEMS to output

ITEMS
NEWS
LISTER
OUTPUT
```

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8.1.3 List Help

"Help" is stable information about SPF procedures and their commands, providing such information as data formats required, notable features and examples of use. Additional help is typically available at several levels of SPF usage, both inside and outside of tool invocations.

**LIST HELP**

params: COMMAND

- Access help file
- Invoke Lister

[Diagram: flowchart showing COMMAND, HELP, LISTER, and OUTPUT connections with Copy COMMAND information to output instruction]
8.1.4 List User Manual

A new copy of the current User Manual is available for printing by the SPF user. Individual sections, or the entire new manual may be printed.
8.1.5 **Contact SPF Personnel**

This procedure enables users to mail a message to SPF maintenance personnel or permits interactive communication.

Diagram:
- **CONTACT SPF PERSONNEL**
  - params: (none)
  - Invoke Electronic Mail System
  - Send message to SPF personnel or enable two-way communication

- **MAIL SYSTEM**
  - **USER**
  - **SPF PERSONNEL**
  - **SPF MAIL BOX**
8.2 Software Management Procedures

The SPF must also be an effective management tool, providing visibility and control of the software development and maintenance process. The manager must be able to control and get reports on his/her subordinates, software data bases, software products, and documentation. The reports must identify development progress against projections, provide SPF usage information, and provide for software configuration management.

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TOOLS</th>
<th>USED</th>
<th>PRODUCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configure a Project</td>
<td>Tree Maintainer</td>
<td>Project Tree Structure</td>
<td>Project Tree Structure</td>
</tr>
<tr>
<td>Control Access</td>
<td>Keys Maintainer</td>
<td>Keys</td>
<td>Project Tree Structure</td>
</tr>
<tr>
<td>Print Progress Reports</td>
<td>Report Generator</td>
<td>DB Contents</td>
<td></td>
</tr>
<tr>
<td>Identify SW Configuration</td>
<td>Project Data Extractor</td>
<td>Project File Contents</td>
<td></td>
</tr>
<tr>
<td>Release SW</td>
<td></td>
<td>DB</td>
<td>DB</td>
</tr>
<tr>
<td>Track STRs/SCPs/SEPs</td>
<td>Tracker</td>
<td>STR/SCP/SEP Log</td>
<td>STR/SCP/SEP Log</td>
</tr>
<tr>
<td>Configuration Status Accounting</td>
<td>Project Data Extractor</td>
<td>Project Files</td>
<td>STR/SCP/SEP Log</td>
</tr>
</tbody>
</table>

Figure 8 - Summary of Software Management Procedures
8.2.1 Configure a Project

The software manager defines a project tree structure that reflects the hierarchy of the work groups and software products comprising his/her project, as shown in Figure 1. The leaves of the tree are the data bases.
8.2.2 Control Access

The software manager controls creation and modification of the project tree structure. He/she can limit access to limbs or leaves of the tree to specified users as well as restricting the use of SPF procedures to specified users. Examples of procedure restrictions are source or test modification, sharing or copying from a data base, use of alternate translator versions and establishing or changing user access keys. The access keys are the means by which the manager controls the project.
8.2.3 Print Progress Reports

A report generator produces a variety of reports on the software development process from information gathered by the DBMS. The reports include software development histories, testing histories, software metrics, SPF utilization, cost accounting, and job statistics.
8.2.4 Identify Software Configuration

Configuration reports are produced for specified software products identifying each of their component elements in the project tree. The report may be produced for that portion of the project for which the requesting manager has the access rights. For example, given the structure in figure 1, the MAD manager could not get a report for the entire AOP, but the Operational Software manager could. The reports include software histories, and software statistics (metrics).
8.2.5 Release Software

This procedure transitions software from a development environment to a maintenance or quality assurance environment where configuration status accounting, access restrictions and access reporting may be performed in a more rigorous fashion. At this point the software elements are linked to an STR/SCP/SEP section of data base for control and/or reporting purposes.

**RELEASE SOFTWARE**

*params:*
- Data Base Identifier (DBID)

Copy development version of DBID to release version
8.2.6 Track STRs, SCPs, and SEPs

The SPF maintains a project log of STRs/SCPs/SEPs. This log is linked to released software for control and/or reporting purposes. The SPF will maintain all necessary information about the STR/s/SCPs/SEPs and will provide reports on status of all or selected items from the log as requested.
8.2.7 Configuration Status Accounting

An audit report is produced showing the element hierarchy, part number, and version number for each element. An expanded report includes the date of all changes, the STR/SCP/SEP number that initiated the change, the name of the engineer who made the change, and the validation and verification dates for the element.

**Diagram:**

```
CONFIGURATION STATUS ACCOUNTING
params:
  Project identifier (PROJECT)

Invoke PROJECT Data Extractor
  - Read manager commands
  - Extract software product information
  - Produce report
```

- SOFTWARE MANAGER
- PROJECT DATA EXTRACTOR
- REPORT
- OLD PROJECT
- PROJECT FILES
- LOG

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8.3 Documentation Production Procedures

Descriptive documents can be produced semi-automatically from the information collected by the SPF from the software production activity.

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TOOLS</th>
<th>DB CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document</td>
<td>Data Extractor</td>
<td>Document Text</td>
</tr>
<tr>
<td></td>
<td>Text Editor/Prompter</td>
<td>Document</td>
</tr>
<tr>
<td></td>
<td>Document Formatter</td>
<td>History</td>
</tr>
</tbody>
</table>

**Figure 9 - Summary of Document Production Procedures**
8.3.1 Document

The user specifies how data is to be selected and processed and provides narrative text through a text editor/prompter. A document formatter produces the final document.
8.4 Context Control Procedures

Context control provides the user with necessities and valuable conveniences not covered in the other common procedure groups (e.g., controlling the command queue, setting global values). By their nature, context control procedures are invoked by immediate commands.

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TOOLS</th>
<th>USED</th>
<th>PRODUCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logon</td>
<td>Key Validator</td>
<td>Keys</td>
<td>System Utilization Record</td>
</tr>
<tr>
<td>Logoff</td>
<td>Wrapup</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List Global Parameters</td>
<td>Lister</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set/Clear Global Parameters</td>
<td>Globals Maintainer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List Command Queue</td>
<td>Lister</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activate/Deactivate Command Queue</td>
<td>Command Queue Maintainer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Execute Command Queue</td>
<td>Command Queue Executor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generate Scripts</td>
<td>Editor/Prompter</td>
<td></td>
<td>Scripts</td>
</tr>
<tr>
<td>Examine Output</td>
<td>Text Scanner</td>
<td></td>
<td>Output Listings</td>
</tr>
<tr>
<td>Save Output</td>
<td>DBMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Print Output</td>
<td>Lister</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 10 - Summary of Context Control Procedures
8.4.1 Logging Procedures

8.4.1.1 Logon

The user identifies him/herself and the project to be worked on. The list of access permissions assigned to the user is made available to subsequently executed procedures.
8.4.1.2 Logoff

The SPF terminates the session, ties up loose ends, establishes system usage statistics which are both printed and recorded for accounting purposes.
8.4.2 Global Parameter Handling Procedures

The SPF affords the user the one-time setting of default values for frequently used parameters.

8.4.2.1 Set Global Parameters

The user specifies parameter values to be applied as defaults for subsequent commands.

**SET GLOBAL PARAMETERS**

- params:
  - List of any param = value (PARMVALS)

Access Global Parameter List (Globals)
Invoke Globals Maintainer
  - Read Globals
  - Read input PARMVALS
  - Validate parameters and values
  - Add/change valid PARMVALS in Globals
  - Notify user of invalid entries

[Diagram of the process flow]
8.4.2.2 Clear Global Parameters

The user specifies parameter names to be reset to system default values.

**CLEAR GLOBAL PARAMETERS**

**params:**
List of any param names (PARMLIST)

Access Global Parameter List (Globals)
Invoke Globals Maintainer

- Read Globals
- Read input PARMLIST
- Remove valid PARMLIST names from Globals
- Notify user of any invalid entries
8.4.2.3 **List Global Parameters**

The SPF provides a listing of each globally set parameter and its current default value.

**LIST GLOBAL PARAMETERS**

- **params:**
  - List of any parameter names (PARMLIST)

- **Access Global Parameter List (Globals)**
- **Invoke Lister**

  - Read Globals
  - Read input PARMLIST
  - Copy valid PARMLIST values to output
  - Notify user of invalid entries

- **Output**
8.4.3 **Command Queue Handling Procedures**

The SPF allows the user to inspect the command queue contents, change the activation status of any entry and execute the activated commands.

8.4.3.1 **Activate/Deactivate Command Queue**

A command is normally activated when initially placed on the queue and deactivated when executed. This command changes the activation status of specified commands on the queue.
8.4.3.2 Execute Command Queue

The SPF executes each activated command on the queue until all have been executed or a procedure aborts.

EXECUTE COMMAND QUEUE

params: (none)

Access Command Queue
Invoke Command Queue Executor

DOWHILE an activated command is on the queue
  • execute next activated command
ENDDO
8.4.3.3 *List Command Queue*

Each command in the queue is listed with its activation status and the values of all its parameters, whether explicitly specified or supplied by default.

---

**LIST COMMAND QUEUE**

- **params:**
  - List of Command Queue Entries (QEs)

  **Access Command Queue**
  - Invoke Lister
    - Read Command Queue
    - Read QEs
    - List requested entries on output
    - Notify user of any invalid entries

**COMMAND QUEUE**

**QEs**

**LISTER**

**OUTPUT**
8.4.4 Data Creation Procedures

8.4.4.1 Generate Scripts

The SPF assists the user in preparing scripts for use in other procedures. The scripts are saved on the data base to provide repeatability and accountability.

---

**GENERATE SCRIPTS**

params:
- Data Base Identifier (DBID)
- Procedure name (PROCNAME)
- Script Name (SCRIPT)

Invoke Editor/Prompter

DOWHILE no END command received
- Request input appropriate to PROCNAME
- Build appropriate script
ENDDO

Save script
8.4.5 Output Handling Procedures

Output from procedures is collected for later inspection and disposal.

8.4.5.1 Examine Output

This is an interactive procedure to perform operations such as finding all error messages on output without listing the entire output, or determining whether the job output should be printed and/or saved.

EXAMINE OUTPUT
params: (none)

Access output file
Invoke Text Scanner

Process user directives
Scan output file accordingly

USER
OUTPUT
TEXT SCANNER

A-58
8.4.5.2 **Save Output**

The user can elect to save an output listing on the data base for purposes such as establishing the success of translations for future audit/report/contract deliverables, or to produce multiple copies of listings.

---

**SAVE OUTPUT**

params:
- Name of saved output file (NAME)
- Data Base Identifier (DBID)

Save output file as NAME on DBID
8.4.5.3 **Print Output**

The user can have the output listing printed on a specified device or deleted.

```
PRINT OUTPUT
params:
  Identity of printer (PLACE)
Dispose output file to printer
```

```
OUTPUT

PLACE
```
9. **VERIFICATION AND VALIDATION PROCEDURE GROUPS**

Studies of verification and validation tools are ongoing. Results of these studies are not available at the time of this draft. See Section 7.2, Software Testing Procedures, for related SPF capabilities.
10. QUALITY ASSURANCE PROCEDURE GROUPS

Studies of Quality Assurance tools are ongoing. Results of these studies are not available at the time of this draft. See section 8.2, Software Management Procedures, for related SPF capabilities.
APPENDIX B
SPF PERFORMANCE REQUIREMENTS

The total SPF system includes the host computer and the system software. The system software implements the procedures described in the body of this document. As a system, certain performance characteristics are essential for successful operation; they are: data base capacity, job processing and software tool performance.

Data base capacity includes the projects supported, source and object code, tests, documentation and production information.

Job processing includes the average job load, CPU time and job turnaround time.

Software tool performance includes the time used in processing jobs of varying sizes.

The following data reflect the minimum performance baseline for the SPF.

DATA BASE CAPACITIES

40 PROJECTS
400 ACCOUNTS
1,000 DATA BASES
40,000 MODULES (COMPILABLE MEMBERS)
30,000 INCLUDED MEMBERS
12,000,000 SOURCE LINES
12,000,000 OBJECT WORDS
3,000,000,000 BYTES OF DATA BASE STORAGE

JOB PROCESSING

11,000 JOBS PER MONTH
150 HOURS TOTAL CPU TIME PER MONTH
1 HOUR AVERAGE BATCH JOB TURNAROUND
SOFTWARE TOOL PERFORMANCE

Definition of jobs:

a. The DEVELOP SOFTWARE procedure invokes the CMS-2M Compiler as one of its translators. The procedure edits source code, identifies modified source modules, invokes the translator to produce object code and saves the source and object on the project data base. Timings for typical CMS-2M systems are given below.

(1) Small - 17 CMS-2M source lines
(2) Medium - 468 CMS-2M source lines
(3) Large - 1043 CMS-2M source lines

b. The GENERATE LOAD MODULE/TAPE procedure invokes the SYSGEN 20/14 System Generator to create a load module file or load tape. The job size is determined by the length and the number of elements being loaded, and the resolution of unsatisfied externals. Timings for typical object elements are given below.

(1) SMALL - 5 AYK-14 relocatable object elements with a total length of 30 (hex) words
(2) MEDIUM - 2 AYK-14 relocatable object elements with a total length of 231A (hex) words
(3) LARGE - 11 AYK-14 relocatable object elements with a total length of 2006 (hex) words

c. The EXECUTE TESTS procedure invokes the UYK-20/AYK-14 Computer Emulator to exercise developed object code load modules and save the test results. Timings for typical emulator instruction executions are given below.

(1) SMALL - emulated 500 instructions
(2) MEDIUM - emulated 5000 instructions
(3) LARGE - emulated 50000 instructions
Timings:

CMS-2M Compiler:

<table>
<thead>
<tr>
<th>JOB</th>
<th>CP TIME</th>
<th>I/O TIME</th>
<th>WALL CLOCK TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sec</td>
<td>sec</td>
<td>min:sec</td>
</tr>
<tr>
<td>SMALL</td>
<td>0.161</td>
<td>2.773</td>
<td>00:09</td>
</tr>
<tr>
<td>MEDIUM</td>
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<td>26.201</td>
<td>00:51</td>
</tr>
<tr>
<td>LARGE</td>
<td>8.818</td>
<td>53.836</td>
<td>01:32</td>
</tr>
</tbody>
</table>

SYSGEN System Generator:

<table>
<thead>
<tr>
<th>JOB</th>
<th>CP TIME</th>
<th>I/O TIME</th>
<th>WALL CLOCK TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sec</td>
<td>sec</td>
<td>min:sec</td>
</tr>
<tr>
<td>SMALL</td>
<td>0.066</td>
<td>6.810</td>
<td>00:13</td>
</tr>
<tr>
<td>MEDIUM</td>
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<td>6.851</td>
<td>00:12</td>
</tr>
<tr>
<td>LARGE</td>
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<td>13.774</td>
<td>00:22</td>
</tr>
</tbody>
</table>

UYK-20/AYK-14 Emulator:

<table>
<thead>
<tr>
<th>JOB</th>
<th>CP TIME</th>
<th>I/O TIME</th>
<th>WALL CLOCK TIME</th>
</tr>
</thead>
<tbody>
<tr>
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<td>sec</td>
<td>min:sec</td>
</tr>
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<tr>
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</tr>
<tr>
<td>LARGE</td>
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