High Level Assembler:

Toolkit Feature Technical Overview

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Synopsis:

This document provides an overview of the IBM High Level Assembler for MVS & VM & VSE Toolkit Feature and shows how its components can be used at all stages of program development and deployment. Demonstration and trial versions of some Toolkit components are on the HLASM web site:

`http://www.ibm.com/software/ad/hlasm/`

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Publications, Collection Kits, Web Sites

The currently available product publications for High Level Assembler for MVS & VM & VSE are:

- High Level Assembler for MVS & VM & VSE *Language Reference*, SC26-4940
- High Level Assembler for MVS & VM & VSE *Programmer's Guide*, SC26-4941
- High Level Assembler for MVS & VM & VSE *General Information*, GC26-4943
- High Level Assembler for MVS & VM & VSE *Licensed Program Specifications*, GC26-4944
- High Level Assembler for MVS & VM & VSE *Installation and Customization Guide*, SC26-3494

- High Level Assembler for MVS & VM & VSE *Toolkit Feature Interactive Debug Facility User's Guide*, GC26-8709
- High Level Assembler for MVS & VM & VSE *Toolkit Feature User's Guide*, GC26-8710
- High Level Assembler for MVS & VM & VSE *Toolkit Feature Installation and Customization Guide*, GC26-8711
- High Level Assembler for MVS & VM & VSE *Toolkit Feature Interactive Debug Facility Reference Summary*, GC26-8712

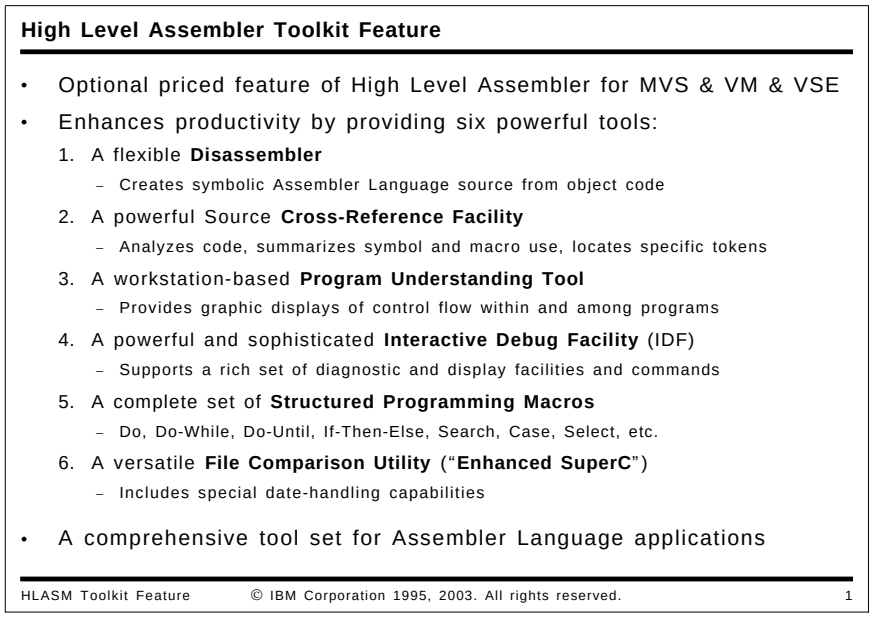
- High Level Assembler for MVS & VM & VSE *Release 2 Presentation Guide*, SG24-3910

Soft-copy High Level Assembler for MVS & VM & VSE publications are available on the following *IBM Online Library Omnibus Edition* Compact Disks:

- *VSE Collection*, SK2T-0060
- *MVS Collection*, SK2T-0710
- *Transaction Processing and Data Collection*, SK2T-0730
- *VM Collection*, SK2T-2067
- *OS/390 Collection*, SK2T-6700 (BookManager), SK2T-6718 (PDF)

HLASM publications are available online at the HLASM web site:

`http://www.ibm.com/software/ad/hlasm/`



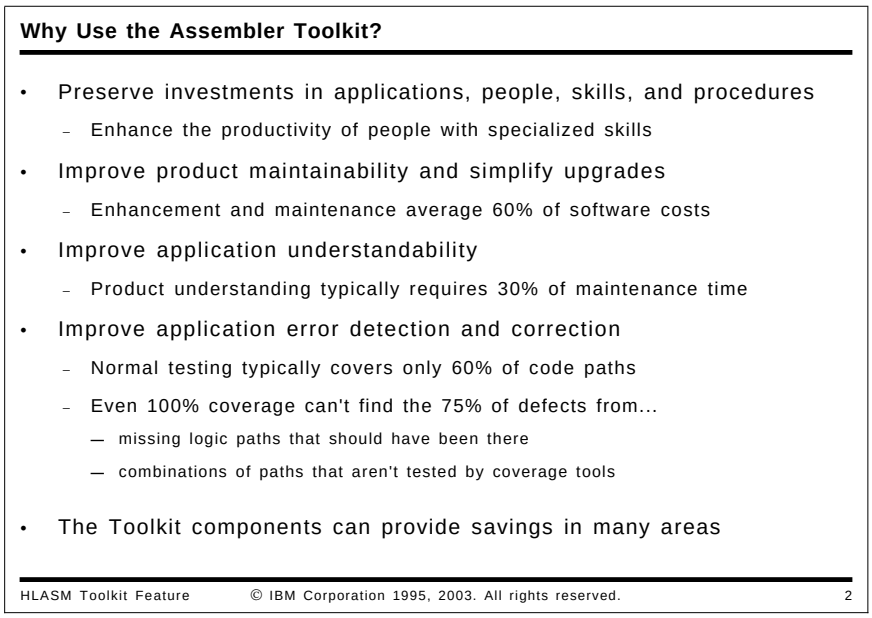
High Level Assembler Toolkit Feature

The High Level Assembler Toolkit Feature is an optional, separately priced feature of IBM High Level Assembler. It provides a powerful and flexible set of six tools to improve application recovery and development, and to assist in program preparation, analysis, debugging, and maintenance on z/OS*, z/VM*, OS/390*, MVS/ESA*, VM/ESA*, and VSE/ESA* systems. These productivity-enhancing tools are:

- **Disassembler**, a tool which converts binary machine language to Assembler Language source statements. It helps you understand programs in executable or object format, and enables recovery of lost source code.
- **Cross-Reference Facility**, a flexible source-code analysis and cross-referencing tool. It helps you determine variable and macro usage, analyze high-level control flows, and locates specific uses of arbitrary strings of characters.
- **Program Understanding Tool**, a workstation-based program analysis tool. It provides multiple and "variable-magnification" views of control flows within single programs or across entire application modules.
- **Interactive Debug Facility**, a powerful and sophisticated symbolic debugger for applications written in Assembler Language and other compiled languages. It simplifies and speeds the development of correct and reliable applications. (It is not intended for debugging privileged or supervisor-state code.)
- **Structured Programming Macros**, a complete set of macro instructions that implement the most widely used structured-programming constructs (IF, DO, CASE, SEARCH, SELECT). These macros simplify coding and help eliminate errors in writing branch instructions.
- **File Comparison Utility** (known as "Enhanced SuperC"), a versatile file searching and comparison tool. It can scan or compare single file or groups of files with an extensive set of selection and rejection criteria. Typical uses include comparing an original source file with a modified source file, or a pre-migration application output file with a post-migration output file. Newly added functions include "smart comparisons" of date fields to assist date "windowing".

Together, these tools provide a powerful set of capabilities to speed application development, diagnosis, and recovery.

This presentation provides an overview of the features and use of each of the six Toolkit components. They are based on tools that have been used widely and tested extensively inside IBM before being "packaged" in the High Level Assembler Toolkit.



Why Consider Using the Toolkit?

The six components of the High Level Assembler Toolkit Feature help you in managing all stages of application recovery, understanding, development, test, and maintenance. Among the reasons you may consider in using the Toolkit are:

1. Preserve investments in applications, people, skills, and procedures

   Many organizations have substantial investments in applications or application components written in Assembler Language. Converting to other languages has many costs (many hidden, and many significant), so it is important to continue to maintain and enhance existing code. This also helps to preserve investments in personnel and their knowledge of the applications, as well as in the organization's established estimation, development, test, and maintenance procedures.

2. Improve application maintainability and understandability

   Application maintenance is usually the largest cost element of an application, so several Toolkit components will be valuable in helping you with understanding and maintaining Assembler Language code.

3. Improve application error correction

   Testing typically detects only a fraction of latent errors in applications before they are deployed; finding and fixing those problems is helped by the Toolkit.

The components of the High Level Assembler Toolkit Feature can help you save time, reduce costs, improve product quality, and increase customer satisfaction.

Hardware Requirements

The High Level Assembler Toolkit Feature requires the same hardware environments as IBM High Level Assembler for MVS & VM & VSE Version 1 Release 4. Requirements for 24-bit Virtual Storage are:

- Disassembler: 100K bytes
- IDF: 600K bytes
- XREF: depends on number and sizes of modules being scanned
- SuperC: depends on number and sizes of modules being scanned
- ...plus working storage (depending on the application)

The Program Understanding Tool (ASMPUT) component of the High Level Assembler Toolkit Feature requires a workstation capable of running OS/2, Windows 95, 98, 2000, or NT with a minimum of 16 MB memory (32 MB recommended) and 80 MB of available hard-drive space, plus a host-sytem connection or other means of transferring SYSADATA files to the workstation for analysis.

Software Requirements

The High Level Assembler Toolkit Feature operates in all MVS/ESA and VM/ESA environments where IBM High Level Assembler for MVS & VM & VSE Version 1 Release 4 (MVS & VM Edition) operates. On MVS, the Interactive Debug Facility's macro facilities require TSO/E V2 or later.

On z/OS and OS/390, the High Level Assembler Toolkit Feature is an optional element; it operates in all environments where the same level of the High Level Assembler base element operates.

The High Level Assembler Toolkit Feature operates in VSE/ESA Version 2 (or later) environments where IBM High Level Assembler for MVS & VM & VSE Version 1 Release 4 (VSE Edition) operates. On VSE, the Interactive Debug Facility requires VSE Version 2.2 or later.

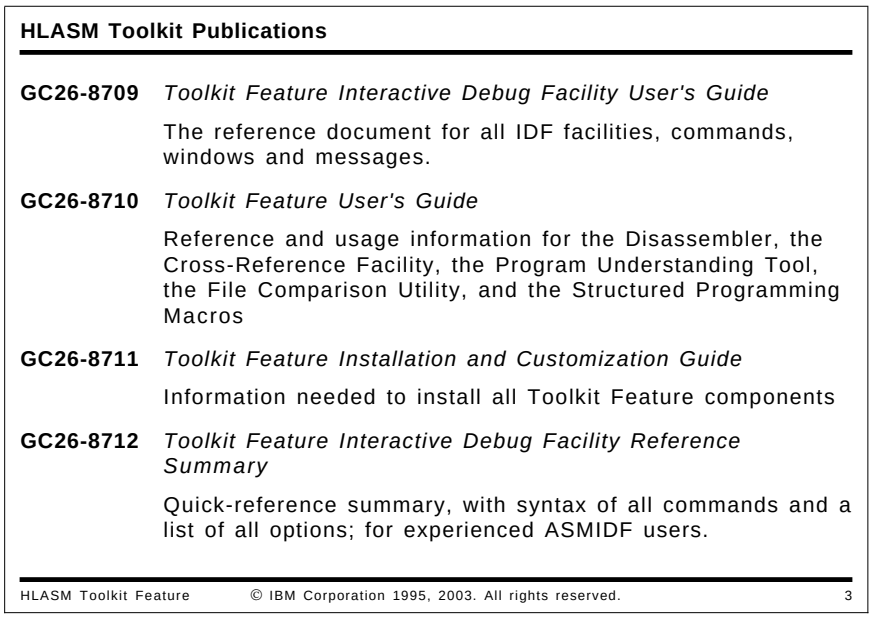
The Toolkit Feature's components can be used independently of High Level Assembler. However, the most productive uses of many of the Toolkit Feature's components rely on SYSADATA files produced by High Level Assembler for MVS & VM & VSE.

Note: The SYSADATA files should not be created if the GOFF or XOBJECT option is in effect.

The Program Understanding Tool (ASMPUT) component of the High Level Assembler Toolkit Feature requires one of:

- OS/2* Version 4 (8H1425) with fixpack 8 or later
- Windows* 95
- Windows 98
- Windows 2000
- Windows NT Version 4.0 with Service Pack 3 or later, on Intel workstations only.

A recommended host-connection software package is eNetwork Personal Communications Version 4.2.1 (8H8735), which supports OS/2 and Windows.



Publications

The four publications for the High Level Assembler Toolkit Feature are:

GC26-8709 *Toolkit Feature Interactive Debug Facility User's Guide*

The main reference document that describes all IDF facilities, commands, windows and messages.

GC26-8710 *Toolkit Feature User's Guide*

Reference and usage information for the Disassembler, the Cross-Reference Facility, the Program Understanding Tool, the Enhanced SuperC File Comparison Utility, and the Structured Programming Macros

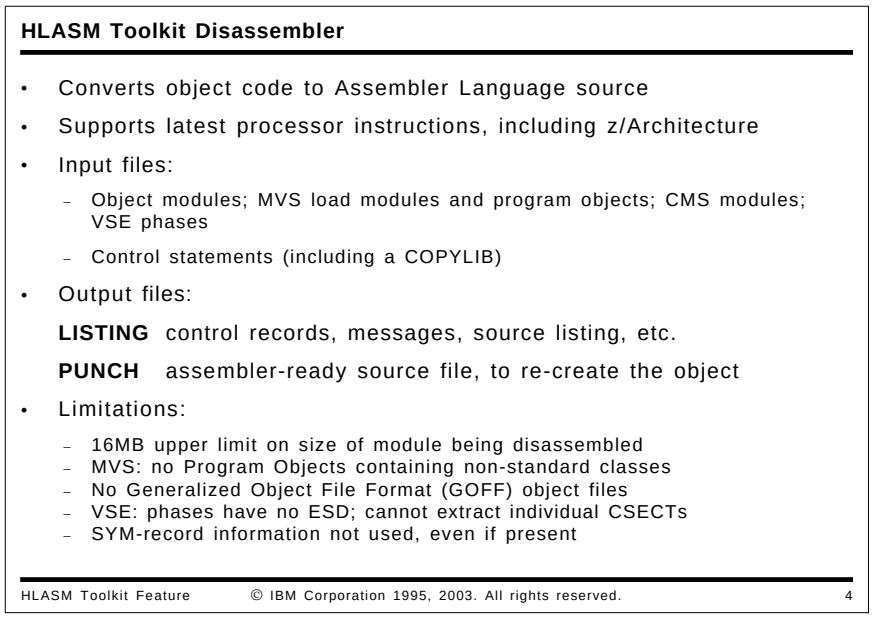
GC26-8711 *Toolkit Feature Installation and Customization Guide*

Information needed to install all Toolkit Feature components

GC26-8712 *Toolkit Feature Interactive Debug Facility Reference Summary*

Quick-reference summary, with syntax for all commands and a list of all the options. This booklet is intended for experienced ASMIDF users.

For more information about ordering the High Level Assembler Toolkit Feature, refer to Software Announcement 295-498, dated December 12, 1995.



HLASM Toolkit Disassembler

The High Level Assembler Toolkit Feature's Disassembler lets you extract single control sections (CSECTs) from object modules or from executables such as MVS load modules, CMS modules, and VSE phases. It converts them to Assembler Language statements that can be assembled to generate the same object code. A control file (including a COPYLIB of previously created control statements) supplies information to guide the Disassembler in producing a more readable and modifiable output source program.

The Disassembler produces two output files:

Listing Various sections describe the module being disassembled, control records, messages, text listing and the source listing.

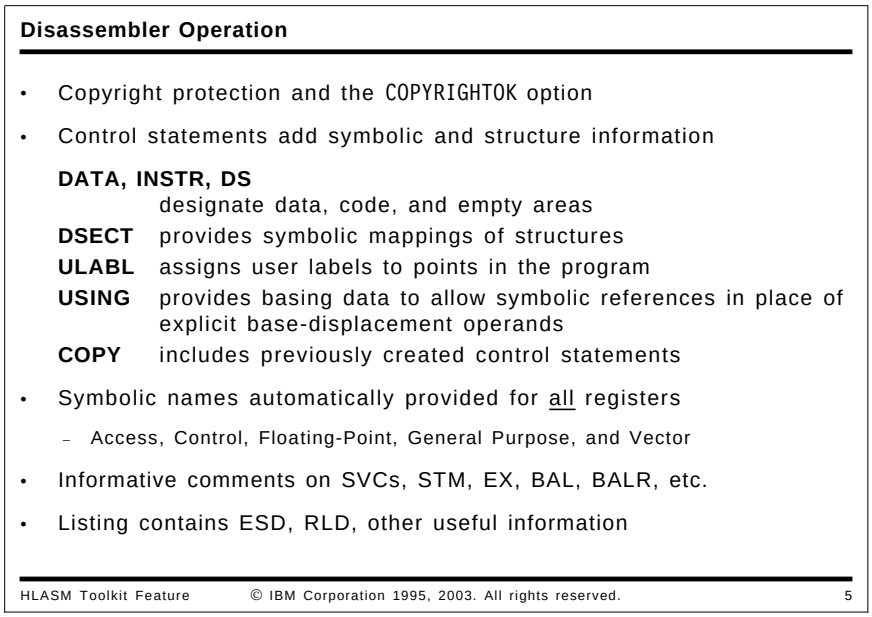
Punch An assembler language source file that can be used directly as input to the assembler to recreate the object text file.

The Disassembler currently has the following limitations:

- 16MB upper limit on the size of the module being disassembled
- On MVS: Program Objects containing non-standard classes (i.e., classes not defined and owned by the DFSMS/MVS Binder) cannot be disassembled.
- Generalized Object File Format (GOFF) object files cannot be disassembled.
- On VSE: Because VSE executable phases have no External Symbol Dictionary (ESD), the Disassembler cannot extract individual CSECTs, nor produce a useful ESD report.

  Note: VSE utilities can create an object-module file from a phase; that object module may also be disassembled.
- SYM-record information is not used, even if present in the object file or load module.

Publication GC26-8710, *High Level Assembler for MVS & VM & VSE Toolkit Feature User's Guide* describes all the control records, JCL requirements, and error messages for the Disassembler.



Disassembler Operation

The COPYRIGHTOK option controls the processing of control sections that contain copyright information. By default, the disassembler will scan the object code for the following data:

- (c)
- (C)
- © (at code point X'B4')
- “Copyright” in any combination of upper case and lower case letters.

If any one of these is found, message ASMD010 will be issued and the disassembly will stop. However, if you specify the COPYRIGHTOK option, then you are acknowledging that you own the copyright for the module or that you have obtained permission from the copyright owner to disassemble the module. In this case the Disassembler will issue message ASMD008 to acknowledge this, and processing will continue.

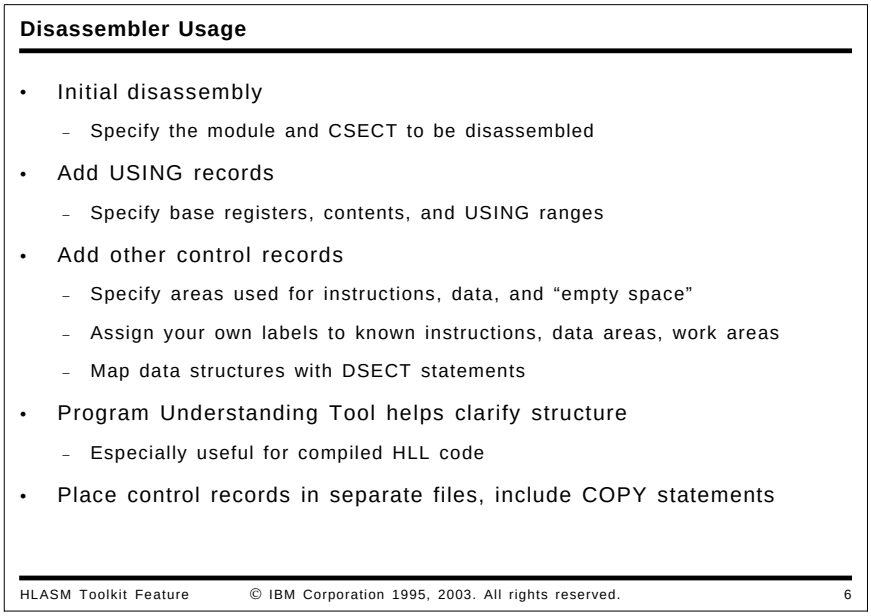
The Disassembler operates in two passes: Pass 1 reads and processes all the control records, and builds storage tables for later use. The main tables are for labels, USINGs and DSECTs. Pass 2 performs the actual disassembly, analyzing the module's machine language text and writing assembler language instructions to the listing and punch files.

Your first control statement specifies the module and control section to be disassembled. Additional control statements provide further guidance and helpful information to the Disassembler, allowing it to create a more readable program. You can supply sets of control statements in the primary input stream to the Disassembler, or (as each set is developed) you can save them in a library and direct the Disassembler to read them using COPY control statements.

- You can describe the layout of the control section with control statements asserting that certain areas of the module contain data only, instructions only, or are known to be uninitialized.
- You can request symbolic resolutions of halfword base-displacement storage by supplying control statements giving base addresses and the base registers to be used for addressing.
- You can assign your own labels to designated positions in the program, and define data structures (DSECTs).
- The Disassembler automatically assigns symbolic names to registers. Branch instructions use extended mnemonics where possible, and supervisor call (SVC) instructions are identified when known. (The Disassembler cannot create source programs that recover original macro calls, of course!)

- The Disassembler listing provides a full summary of the inputs and outputs of the disassembly, and the reconstructed Assembler Language source program is placed in a separate PUNCH file.

When the disassembler-generated statements are assembled by High Level Assembler using the ADATA option, the resulting SYSADATA file (also called the ADATA file) may be used as input to other Toolkit Feature components. This combination of facilities can help you recover lost source code written in *any* compiled language.



Disassembler Usage Examples

Some examples of the disassembler will use the object file from the program listed in Figure 1 below. The object text file in each of the following three examples is identical. Each example has its own set of control records:

1. Initial run (DISASM1)
2. Add USING records (DISASM2)
3. Add other control records (DISASM3)

The control files used for these disassemblies are discussed starting at “Sample Disassembler Control Files: DISASM1” on page 8. (Note that because the examples were run under CMS, the first operand of the first control statement is ignored; the name is used only to distinguish the three samples.)

```
Trace CSect
      stm   r14,r12,12(r13)        Save caller's registers
      lr    r12,r15                Establish Base
      Using trace,r12              and tell the assembler
      st    r13,savearea+4         Chain
      la    r2,savearea              the
      st    r2,8(,r13)                savеareas
      la    r15,12                 set default return code
```

Figure 1 (Part 1 of 2). Sample Program for Disassembly

```
       oc    myflag,myflag           Have we been here?
       bz    exit                    Get out now
       xc    myflag,myflag           Clear the flag
       st    r8,areaaddr             Set up address of area
       mvc   arealen,=f'8192'        Set up length of area
       la    r15,8                   Set the return code

exit   l     r13,savearea+4          Point to previous area
       st    r15,16(,r13)            Store the return code
       mvc   24(4,r13),=a(dump_data) Point saved R1 at Parm list
       lm    r14,r12,12(r13)         Restore the registers
       br    r14                     Return
       Ltorg
myflag    dc  F'1'
savearea  ds  9d
dump_data dc  f'1'
areaaddr  dc  a(0)
arealen   dc  f'0'
titlea    dc  a(title)
title     dc  cl16'Hello world'
r2        Equ 2
r8        Equ 8
r12       Equ 12
r13       Equ 13
r14       Equ 14
r15       Equ 15
       End
```

Figure 1 (Part 2 of 2). Sample Program for Disassembly

Sample Disassembler Control Files: DISASM1

The initial version of the control file specifies only a single statement, to designate the module name and the CSECT name. (Under CMS, the module name DISASM1 is ignored.)

```
DISASM1 TRACE
* This is the minimum requirement - the control record which
* specifies the module (not used on VM) and the CSECT.
```

Figure 2. Initial Set of Disassembler Control Statements

The output of this disassembly contains no USING statements and no internal labels; all addressing is in base-displacement form, as illustrated in Figure 3 on page 9 below. (Note that the last statement before END is a call on the ASMDREG macro: this macro is supplied with the Toolkit Feature, and simply defines the names of the general purpose registers R0 through R15. It is equivalent to the REGEQU macro, which unfortunately is not available on all platforms.)

```
TRAC     TITLE 'Disassembly of CSECT TRACE    of Load Module DISASM1 '
*               Produced by ASMDASM on 98.120 at 14:06
TRACE    CSECT
         STM   R14,R12,12(R13)             Save regs
         LR    R12,R15
         ST    R13,92(,R12)
         LA    R2,88(,R12)
         ST    R2,8(,R13)
         LA    R15,12
         OC    80(4,R12),80(R12)
         BZ    52(,R12)
         - - -   ...etc...
         DC    CL16'Hello world     '
         ASMDREG
         END
```

Figure 3. Sample Disassembly With Minimal Control Statements

Sample Disassembler Control Files: DISASM2

After inspecting the initial disassembly, we have determined that register 12 should be used as a base register, so we add a USING control statement. (Remember: under CMS, the module name DISASM2 is ignored.)

```
DISASM2 TRACE
* Now we have added a USING record which specifies that
* the USING applies to all addresses between X'000000' and X'0000C0',
* register 12 (X'C') is to be used as a Program base register
* and that the value loaded into the register is X'000000'
USING 000000 0000C0 C P 000000
```

Figure 4. Disassembler Control Statements Specifying USING

The output from this disassembly would use symbolic labels for storage references based on register 12. The generated names are of the form Annnnnn where nnnnnn is the hexadecimal offset of the label from the base of the control section. This is illustrated in Figure 5 on page 10 below.

```
TRAC     TITLE 'Disassembly of CSECT TRACE    of Load Module DISASM1 '
*               Produced by ASMDASM on 96.176 at 14:32
TRACE    CSECT
         USING *,R12
A000000  EQU   *
         STM   R14,R12,12(R13)             Save regs
         LR    R12,R15
         ST    R13,A00005C
         LA    R2,A000058
         ST    R2,8(,R13)
         LA    R15,12
         OC    A000050(4),A000050
         BZ    A000034
         XC    A000050(4),A000050
         - - -   ...etc...
A0000B0  EQU   *
         DC    CL16'Hello world     '
         ASMDREG
         END
```

Figure 5. Sample Disassembly With USING Control Statement

Sample Disassembler Control Files: DISASM3

For the final disassembly, we observe that there is a save area at offset X'000058' that we will call SAVEAREA, and this area is uninitialized space; also, there appears to be a fullword at offset X'000050' used as a FLAG, so we add three new control statements.

```
DISASM3 TRACE
USING 000000 0000C0 C P 000000
* The following defines a label SAVEAREA for an area which starts at
* offset X'000058' and is 72 bytes long (18 fullwords)
ULABL SAVEAREA 000058 072
* This defines the area from X'000058' to X'00009F' as an
* uninitialized storage area (this will force the use of the DS opcode)
DS 000058 00009F
* another label definition - FLAG at offset X'50' for 4 bytes
ULABL FLAG     000050 004
```

Figure 6. Disassembler Control Statements Specifying Additional Info

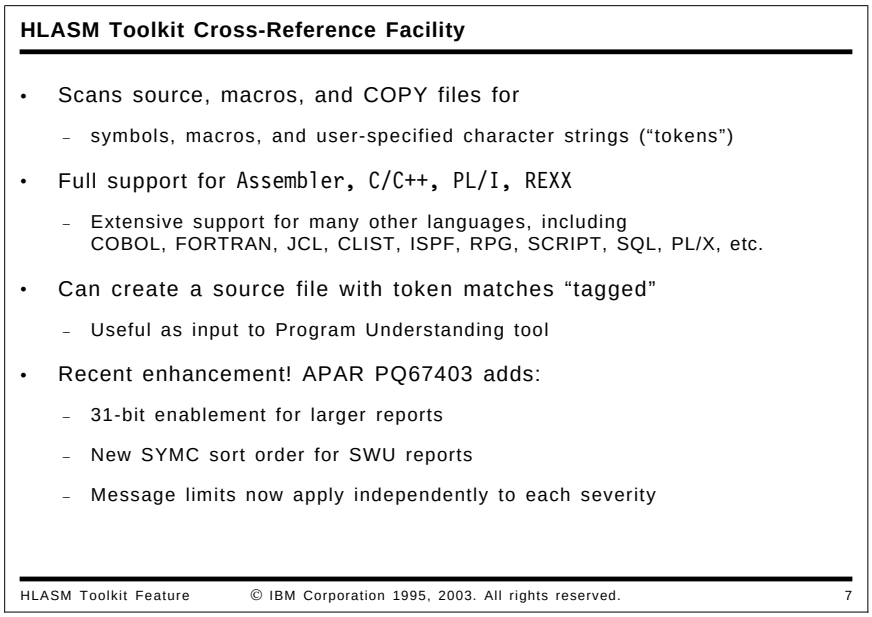
The output from this (possibly final) disassembly is shown in Figure 7 on page 11 below:

```
TRAC     TITLE 'Disassembly of CSECT TRACE    of Load Module DISASM1 '
*               Produced by ASMDASM on 1998.120 at 17:58
TRACE    CSECT
         USING *,R12
A000000  EQU   *
         STM   R14,R12,12(R13)             Save regs
         LR    R12,R15
         ST    R13,SAVEAREA+4
         LA    R2,SAVEAREA
         ST    R2,8(,R13)
         LA    R15,12
         OC    FLAG(4),FLAG
         BZ    A000034
         XC    FLAG(4),FLAG
         ST    R8,A0000A4
         MVC   A0000A8(4),A000048
         LA    R15,8
A000034  L     R13,SAVEAREA+4
         ST    R15,16(,R13)
         MVC   24(4,R13),A00004C
         LM    R14,R12,12(R13)             Restore regs
         BR    R14                         Exit
         SPACE
A000048  DC    F'08192'
A00004C  DC    A(A0000A0)
FLAG     DC    F'00001'
         DC    F'0'
SAVEAREA DS    CL72
A0000A0  EQU   *
         DC    F'00001'
A0000A4  DC    F'0'
A0000A8  DC    F'0'
         DC    A(A0000B0)
A0000B0  EQU   *
         DC    CL16'Hello world     '
         ASMDREG
         END
```

Figure 7. Disassembler Output for Sample Program

Further refinements are possible, but the most important features of this simple program are now evident.

When analyzing the successive disassemblies, many users have found that it helps to analyze the logical structure of the program using the Program Understanding Tool (described on page 14). It can help you identify loops, calls, and other major code segments.

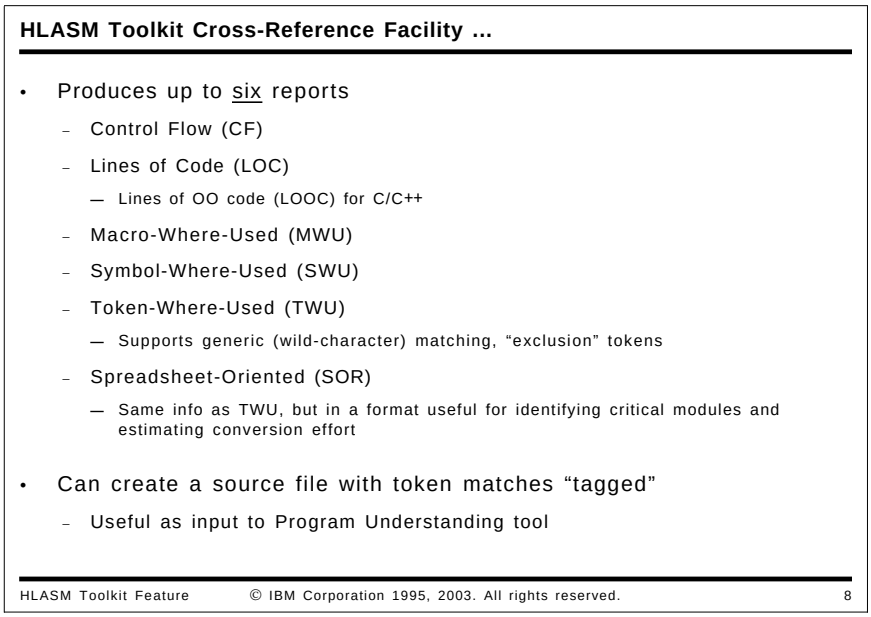


HLASM Toolkit Cross-Reference Facility

The High Level Assembler Toolkit cross-reference tool (ASMXREF) supports your maintenance tasks by analyzing and scanning source programs, macro definitions, INCLUDE and COPY books and other files for symbols, macro calls, and user-specified tokens. The source programs may be written in Assembler Language, C/C++, PL/I, or REXX. Other languages supported for a subset of the available reports include COBOL, FORTRAN, ASM88, CLIST, “Generic”, ISPF panels and skeletons, JCL, MASM, Modula, Pascal, QMF/SQL, RPG, and SCRIPT.

ASMXREF can also be used for identifying fields of application importance such as DATE, TIME, and YYMMDD. You additionally specify tokens to be *excluded*, so that searches for a token such as ″MM″ can reject matches on tokens such as SUMMER. Furthermore, an arbitrary “match anything” character (sometimes called a wildcard character) can be used to create generic tokens such as ″YY*″; the scan will then search for occurrences of the token with any other characters allowed in the position of the arbitrary character.

ASMXREF does not support VSAM files.



Control Flow Report: The CF report tabulates all intermodule program references as a function of member or entry point name. Additional language-specific capabilities are provided for selected languages.

Lines of Code Report: The LOC report provides a count, arranged by part, of the number of source lines in the part, the executable and non-executable statements and the number of comment lines in the part. Appropriate tags can be used to indicate lines changed, deleted, added, or moved, as well as to indicate programmer activity.

Lines of Object Oriented Code Report: There is a special subset of the LOC report for C/C++: the LOOC (Lines of Object Oriented Code) reports the Lines of Code (LOC) per class and per object, and objects per class, containing data similar to that in the “standard” LOC report. “Shipped Source Instructions” (SSI) indicates the number of executable and non-executable instructions that are not blank or comments.

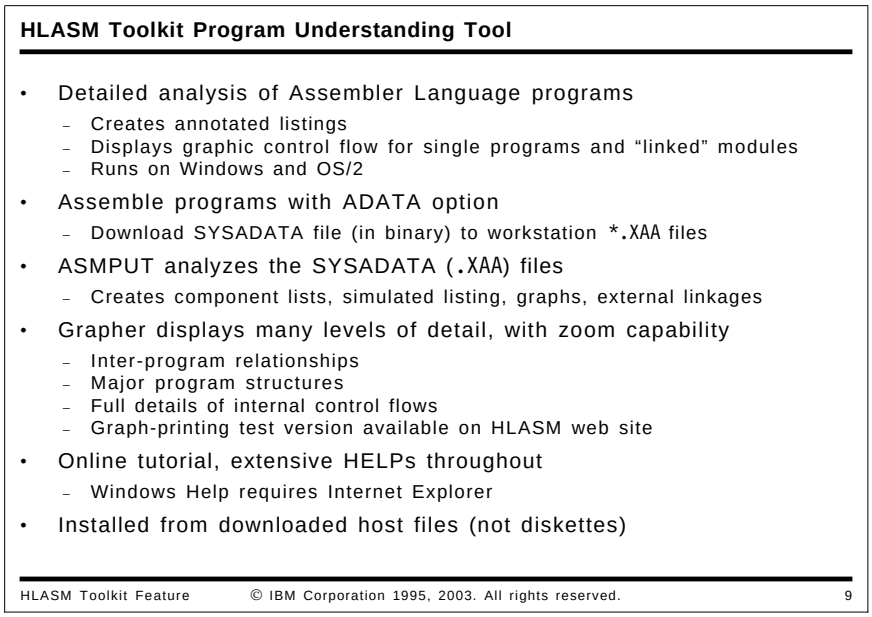
Macro Where Used Report: The MWU report lists all macros or functions invoked and all segments copied, including the type and frequency of the invocation or reference.

Symbol Where Used Report: The SWU report lists all symbols referenced within the source members, and the type of reference. These symbols can be variables or macros.

Token Where Used Report: The TWU report shows for each module scanned the number of lines of code, the number of occurrences of each token, and the total number of token matches. Tokens may also be excluded from matching.

When you create the TWU report, a “tagged source program” is also generated. This file contains special language-specific inserted comment statements where tokens are found. Subsequent assembly of a “tagged” file helps you track important variables during control-flow analysis using the Program Understanding Tool.

Spreadsheet Oriented Report: The SOR report contains the same information as the TWU report, as a comma-delimited file suitable for input into a standard spreadsheet application. This tabular information helps you identify the critical modules in an application and estimate the effort required for needed modifications.



HLASM Toolkit Program Understanding Tool

The Program Understanding Tool (ASMPUT) helps you analyze and extract information about Assembler Language applications, using a graphical user interface to display graphical and source views of an application's structure. ASMPUT extracts application analysis information from the SYSADATA file generated during host assembly by HLASM; this ADATA file is downloaded to the workstation for analysis and display on Windows or OS/2 Warp* 4.

ASMPUT can display linked views of selected programs and modules including:

- a Content view
- an Assembled Listing view
- a graphical Control Flow view
- an Expanded Source Code view.

These views provide complete high, medium, and low level information about Assembler Language applications.

- At the highest level, you can discover the relationships among programs and modules within an application.
- A mid-level view displays the calling structures among programs within a module, including routines external to a program.
- At the lowest level, you can examine details of internal control flows within each program.

ASMPUT lets you display multiple views of a given program or module. These multiple views are linked: scrolling through one view automatically scrolls through all other open views of that program, module, or application. Linked views help you see quickly the association between the assembled source code and the graphical control-flow representations of the program.

At any time, you can narrow or expand the focus of your analysis by zooming in or out on areas of particular interest. For example, you can use the VIEW CONTENTS window to scroll through the contents of an application and simultaneously see the change in control flow information displayed in the VIEW CONTROL FLOW window.

ASMPUT displays several folders which provide a complete inventory of application analysis information, program samples, tools, documentation, extensive help files, and a detailed online tutorial to help you learn to use ASMPUT for analyzing Assembler Language applications. Installation is simplified by packaging all Toolkit components as host files; ASMPUT files are then downloaded to the workstation.

The initial window gives direct access to all needed files, functions, and information needed to analyze assembler language programs.

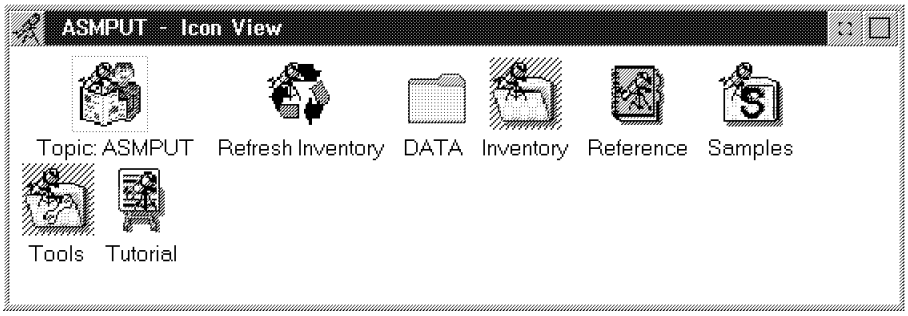


Figure 8. Example of the ASMPUT window

The shaded icons in this window indicate that the **Tools** and **Inventory** windows are also open. Following ADATA analysis, you can display many different views of a program. A view of the initial analysis might be the source file, as shown in the following figure:

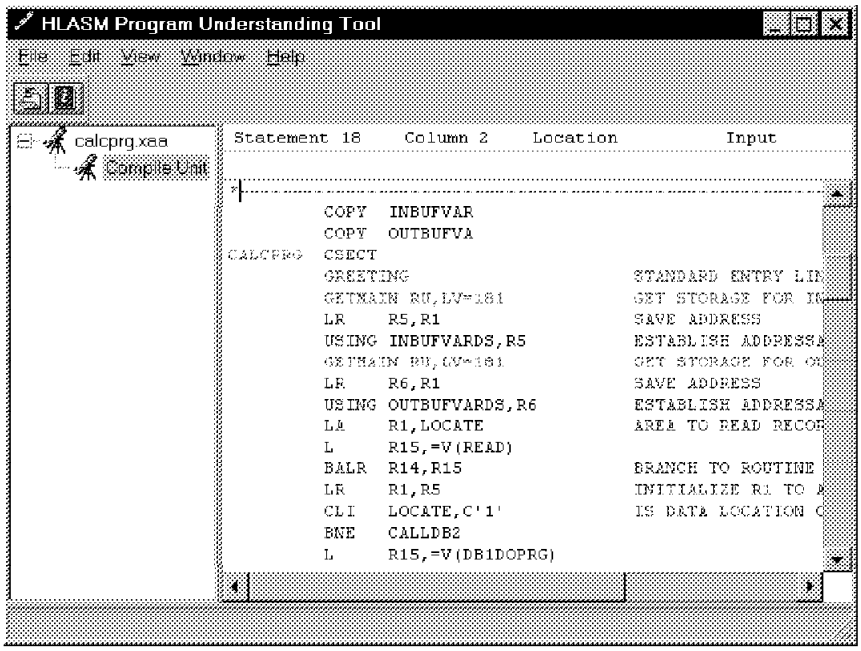


Figure 9. Example of the ASMPUT source listing

The Program Understanding Tool uses different colors to highlight machine, assembler, and macro instructions. Other listings display the program's components (source, macro, and COPY files), or the control flow analysis, where “basic blocks” (sequences of instructions ending at a branch) are identified.

The control flow graphs are the heart of ASMPUT. For example, a top-level view of the control flow graph for the CALCPRG sample program appears like this:

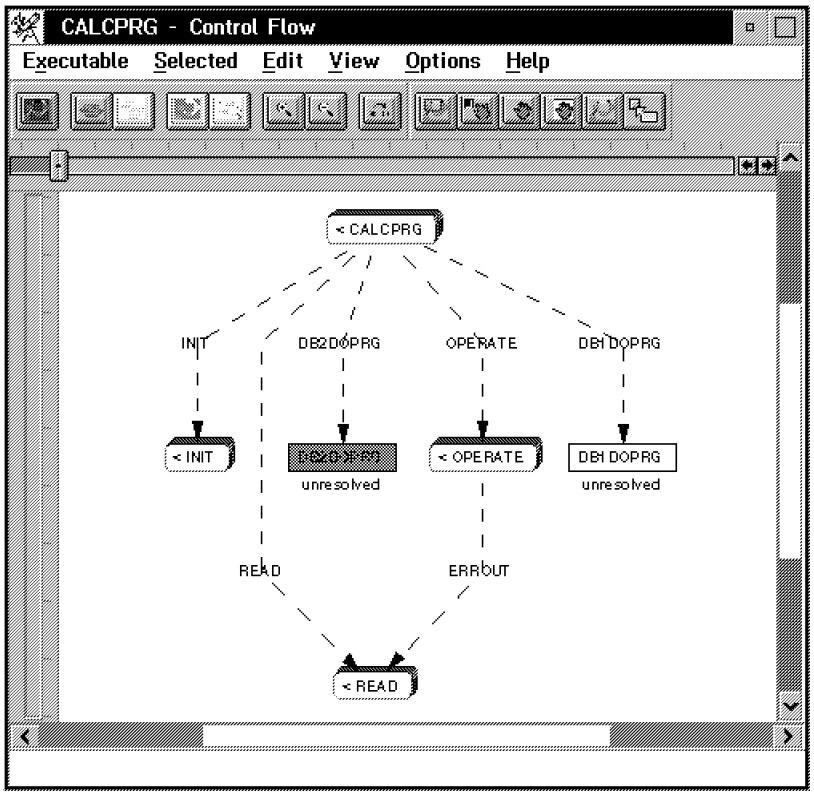


Figure 10. Example of the Control Flow View

The next level of detail shows the structure of each of the routines called from the main CALCPRG program:

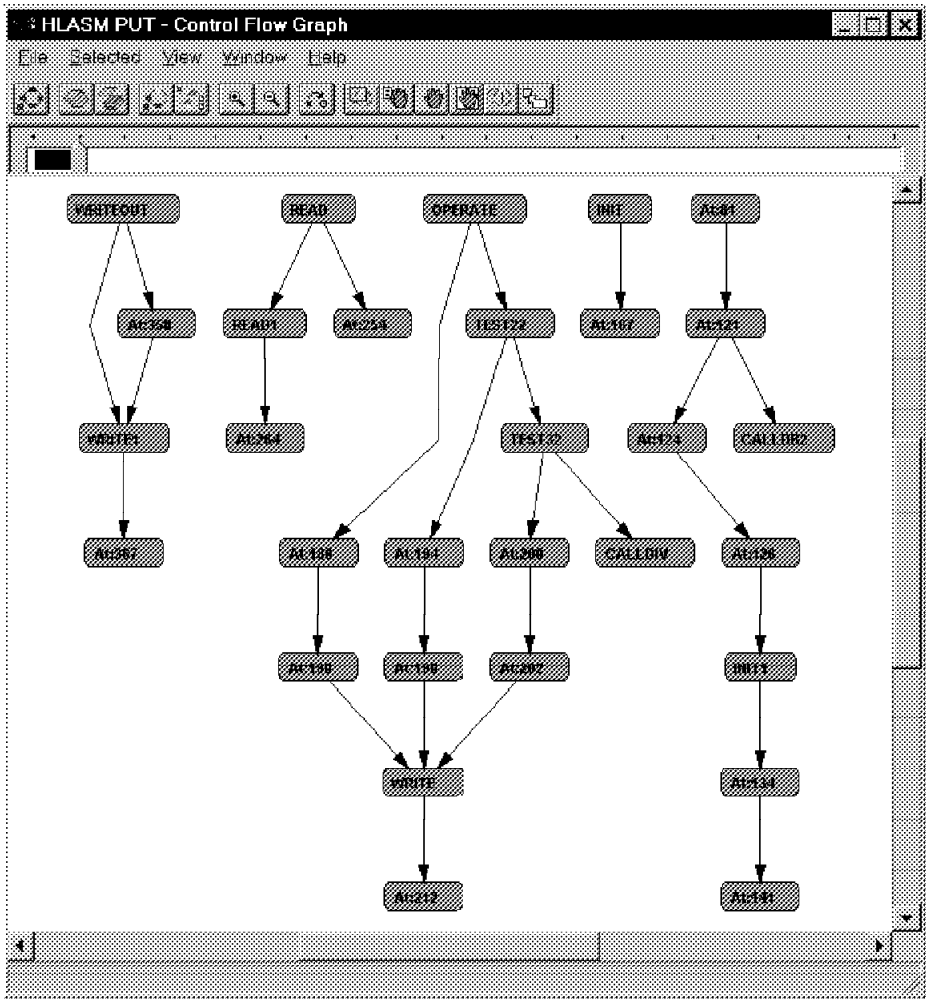


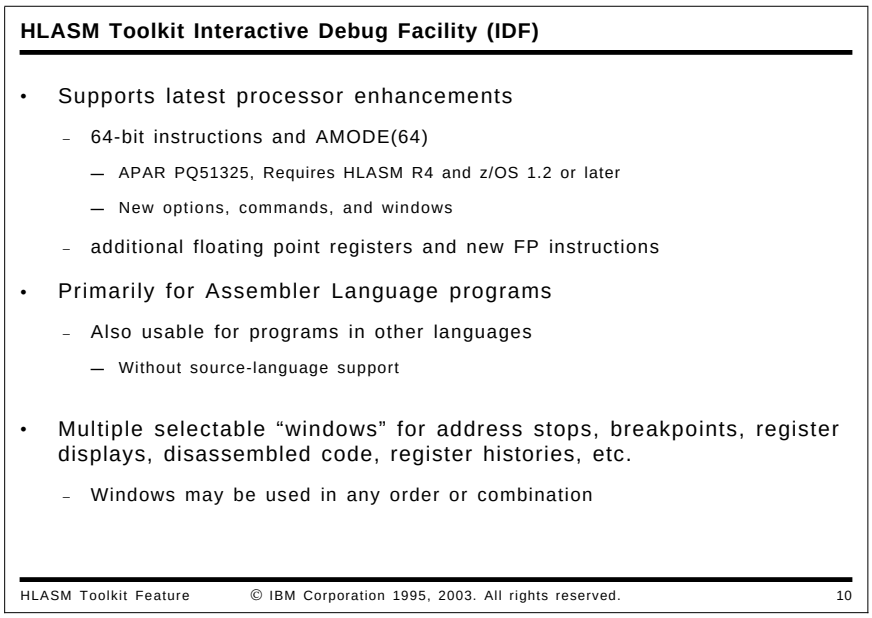
Figure 11. Example of a More Detailed Control Flow View

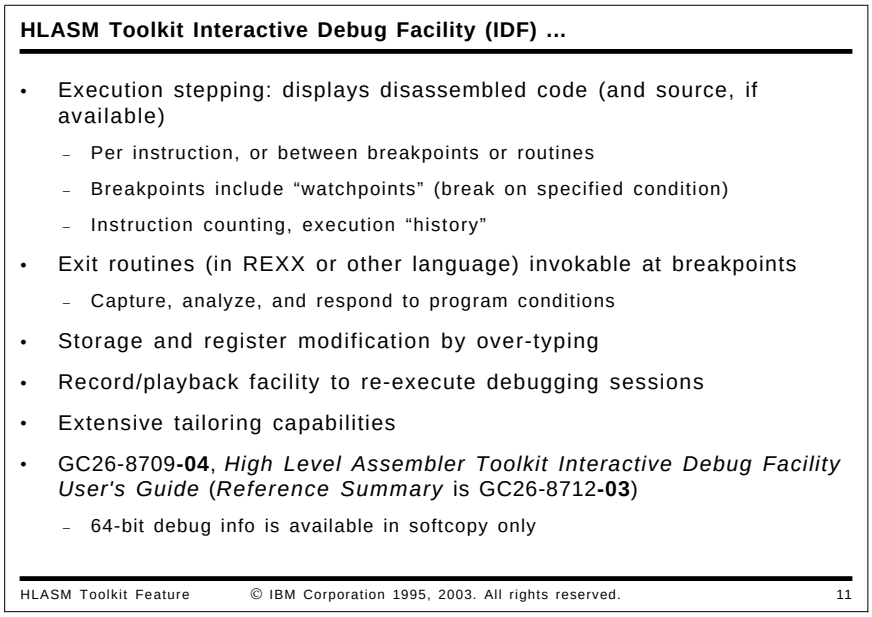
Using the **View** pull-down, you can expand or collapse the “layers” of detail being displayed.

Note the following:

- ASMPUT R4 accepts ADATA files from previous releases of HLASM, but previous releases of ASMPUT cannot accept ADATA files from later HLASM releases.
- The OS/2 version of ASMPUT shipped with HLASM R3 works only with HLASM R3 ADATA files. If you have ADATA files generated by HLASM R2 and want to continue to use them, you should retain your copy of the OS/2-based ASMPUT shipped with HLASM R2.

  Note: HLASM R2 service was withdrawn as of December 31, 2001.
- ASMPUT R4 should apply service for APAR PQ41190.
- ASMPUT R3 should apply service for APARs PQ26063 and PQ20235.



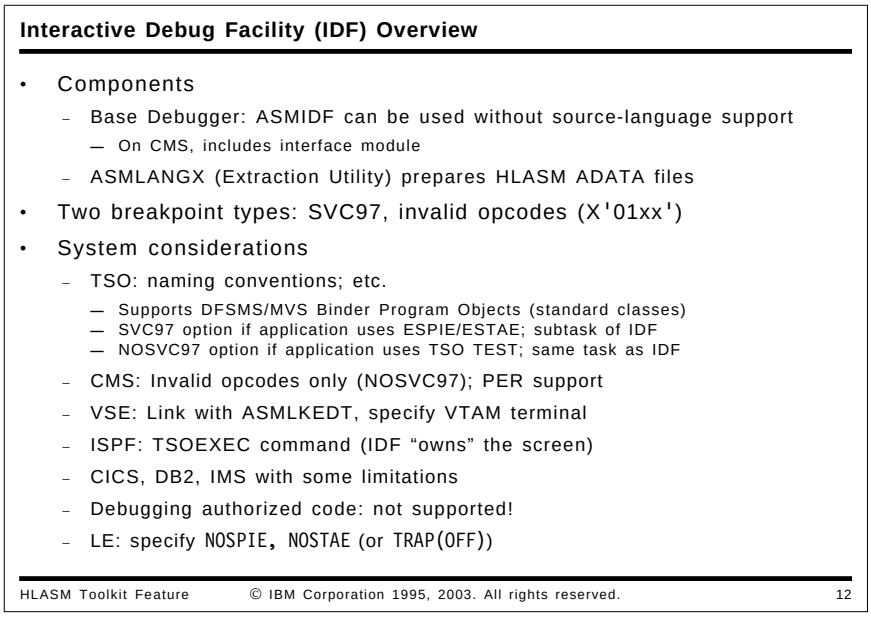


HLASM Toolkit Interactive Debug Facility (IDF)

The High Level Assembler Toolkit Feature Interactive Debug Facility (IDF) supports a rich set of capabilities that speed error detection and correction. While IDF is intended primarily for debugging Assembler Language programs on MVS, VM, and VSE systems, it can also be used advantageously to debug programs written in most high level languages, though without the source-language support facilities provided for Assembler Language code.

- IDF supports all new z/Architecture instructions and the additional floating-point registers introduced with the G5 processor families. (It also shares a common disassembly routine with the Disassembler and several other system components, ensuring correct handling of all instructions by each.)
  - Support for 64-bit debugging was added via APAR PQ51325 (PTFs MVS UQ57987, CMS UQ57988, VSE UQ57989). The enhancements include one new option (AMODE64), four new commands (EPNAMES, GPRG, GPRH, and REGS64), and two new windows (for Entry Point Names and 64-bit registers). The support is available only in HLASM R4.

- IDF provides multiple selectable views of a program, including separate windows for address stops, breakpoints, register displays, object code disassembly, storage dumps, language-specific support, register histories, non-traced routines, and other information. These views can be used in any order or combination.
- Execution of a program can be controlled by stepping through individual instructions or between selected breakpoints or routines.
- If source code is available (which will almost always be the case for programs assembled with High Level Assembler), IDF can display source statements as the program is executed.
- The power of IDF is greatly magnified by its ability to pass control from any breakpoint to user exit routines written in REXX or other languages that can capture and analyze program data, and respond dynamically to program conditions.
- Instruction executions can be counted, and an instruction execution history can be maintained.
- Storage areas and register contents can be modified dynamically during debugging by simply typing new values on the displays.
- IDF supports a special class of conditional breakpoints called watchpoints, which are triggered only when a user-specified condition occurs.
- A command-level record and playback facility allows a debugging session to be re-executed automatically.
- Extensive tailoring capabilities allow you to establish a familiar debugging environment. Most debugging actions can be easily controlled by PF-key settings.



Interactive Debug Facility (IDF) Overview

The original IDF provided a debugger without any source-language capability. It can still be used in that way, and any reference to the “base debugger” implies using IDF without its source language capabilities.

IDF comprises two main components:

1. On TSO, the base debugger is the load module ASMIDF. This is a TSO command processor; it will only run in that environment with a real terminal.

On CMS, the base debugger consists of two modules; ASMIDF and ASMIDFMA. ASMIDF is a self-relocating nucleus extension. This loads the main module, ASMIDFMA, as a nucleus extension at the start of a debugging session, and deletes it at the end.

On VSE, the ASMIDF debugger runs in batch mode. A VTAM terminal must be available.

2. The other component of ASMIDF is ASMLANGX, the extraction utility that reads SYSADATA files and creates the ASMLANGX files (with source statements, symbols, and type information) for later use by the language-support component of ASMIDF.

IDF uses two different breakpoint techniques, both of which overlay instructions at the point where the breakpoint is required:

TSO Invalid opcodes of the form X'01xx' or SVC 97 instructions

CMS Invalid opcodes of the form X'01xx' (SVC 97 not supported)

VSE Invalid opcodes of the form X'01xx'

The implications of these choices will be described shortly. IDF inserts these breakpoint opcodes when it is about to begin executing the target program. When any “event” occurs, the original instructions are restored before control is returned to you, so that all displays will show your program without the breakpoint overlays. Note that some other debuggers depend on having the compiler insert special links to the debugger, which limits their usefulness for code that is fully optimized for production environments. IDF, on the other hand, is a lower-level debugger that uses opcode overlays to set breakpoints.

- TSO considerations
  - Debuggable modules

    IDF supports debugging of programs in both the old load module format and in the Program Object formats produced by the DFSMS/MVS or z/OS Binder so long as the Program Object classes are those assigned and owned by the Binder.

  - SVC97 and NOSVC97 options

    By default, ASMIDF uses the TSO TEST SVC (SVC97). You must use the SVC97 technique when debugging an application which itself uses ESTAE or ESPIE. This is because the application's ESTAE/ESPIE setup will take precedence over IDF's. (This is not available under ISPF unless you use the standard TSOEXEC command to set up the appropriate environment; the same restriction applies to the TSO TEST command.)

    NOSCV97 works by telling ASMIDF that it is not to use SVC97; it then uses invalid opcodes to set breakpoints.

  - TSO naming conventions

    ASMIDF was originally developed as a CMS tool and later ported to TSO, so there are a lot of CMS conventions throughout the manuals. TSO users must translate their DDNAMES and member names from a CMS-like file name using the following scheme:

CMS	TSO Equivalent
fn	PDS member name (ignored if using sequential file)
ft	DDNAME, which in turn points to the TSO dataset
fm	not used on TSO

  - TSO TEST

    You MUST use the “invalid opcode” technique (NOSVC97) when debugging an application which itself uses the TSO TEST facilities. This is because TSO TEST is limited to one use per address space.

- CMS considerations

  IDF/CMS by default uses the invalid opcode technique, which is “full function” on CMS. Instead of using ESTAE/ESPIE on CMS, IDF steals the Program New PSW. IDF/CMS also uses the CP

PER/TRACE facilities. This technique is required for debugging read-only code (e.g. within a DCSS) on CMS. (MVS/TSO unfortunately doesn't expose any PER facilities to an application program.) Currently, the additional Floating Point Registers (AFPR) are not supported on CMS.

- VSE considerations

  The program is first link edited with a special version of the VSE/ESA Linkage Editor (ASMLKEDT) that captures external symbols and places that information in the librarian member `phasename.MAP`.

  - VSE naming conventions

    File naming conventions are derived from their CMS equivalents:

CMS	VSE Equivalent
fn	VSE librarian member name
ft	DLBL name, which in turn points to the VSE dataset name
fm	not used on VSE

  Currently, the additional Floating Point Registers (AFPR) are not supported on VSE.

- ISPF Considerations

  Chapter 21 of the IDF User's Guide briefly discusses using ASMIDF with ISPF (for TSO) applications. The invocation command is different, depending on whether the application being debugged resides in the STEPLIB or ISPLLIB allocations. The manual also discusses the use of TSOEXEC, breakpoint method selection, and an example of debugging ISPF dialogs.

  ASMIDF does not use ISPF services. It is a TSO Command Processor and will assume control of the entire screen. So if you had a split screen under ISPF and started up ASMIDF on one of the logical screens, the other logical screen(s) would not be available for display until you exited ASMIDF. It may be useful to look at the SWAP option; there is a short section “Programs performing Full-screen I/O” on page 44.

- CICS Considerations

  IDF may be used to debug CICS only if you run IDF on a TSO logon and run then CICS as a program within the TSO region. IDF is not intended for debugging CICS transactions in a production environment.

- DB2 Considerations

  The IDF Reference manual discusses using ASMIDF with DB2 applications (for MVS).

  1. The IDF option NOSVC97 is required.
  2. When testing under LE/370, the LE options NOSPIE and NOSTAE must be used.

- IMS Considerations

  While IDF has not been tested in the IMS environment, it should be possible to debug Batch Message Programs that run under TSO. Care must be taken with DBREAK commands, to ensure that “code” breakpoints are not overlaid on IMS PSB modules.

- Authorized code

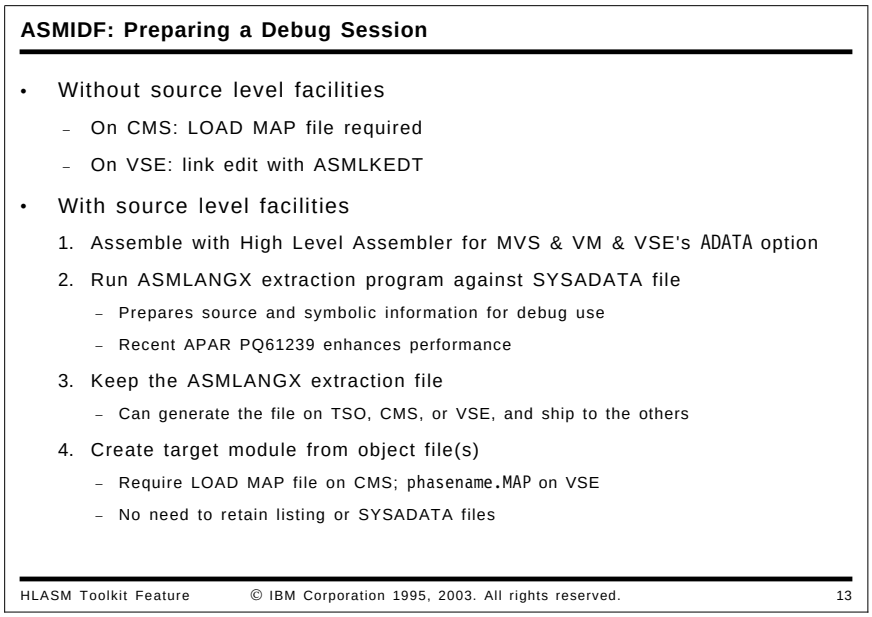
  IDF as shipped is not authorized and hence will not debug programs that use authorized services.

- Language Environment (LE)

  Just specify the LE option TRAP(OFF) (or the options NOSPIE and NOSTAE), so that Interactive Debug Facility can gain control on breakpoints and other exceptions.

- Assembler Language Considerations

  ASMIDF does not support dependent USINGs (labeled or not), USING-range specifications, or USINGs that do not cover the base of their range (e.g. `USING A+5000,2`).



Preparing a Debug Session

ASMIDF may be used to debug a program at the assembler object-code level.

- On CMS the LOAD MAP file must be retained; it is used to determine the location of the program's CSECTs and external symbols. The LOAD MAP file should be renamed so that the file name matches that of the executable module (MODMAP option)
- On TSO, ASMIDF extracts the required information from the load module itself and no extra information is required.
- On VSE, link edit the program with the supplied ASMLKEDT link editor, to capture information about external symbols in the output phase.

To use the source level facilities of ASMIDF, some preparation is required:

1. The assembly must be done with the ADATA option specified and the resultant SYSADATA file used as input to the next step. (The ADATA option and the characteristics of the SYSADATA file are described in the HLASM Programmer's Guide, SC26-4941.)

   Note: There is no special support in IDF for labeled and dependent USING statements.

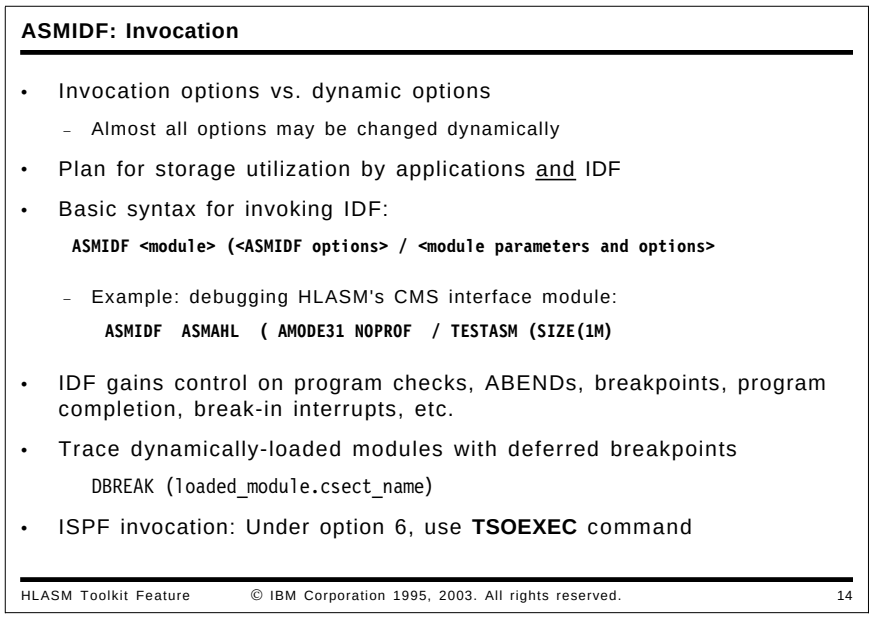
2. Run ASMLANGX using the SYSADATA file as input. This will create an extraction ASMLANGX file that will be used during the debugging session. (The SYSADATA and ASMLANGX files should have the same name.)

   Note: An appendix in the IDF User's Guide describes some useful EXECs.

3. Create the target module from the object-file text as normal; on CMS, retain the (renamed) LOAD MAP file, and on VSE retain the phasename.MAP file.

4. The only file required by ASMIDF for source level debugging is the ASMLANGX file; you may erase both the LISTING and SYSADATA files, if desired.

The extraction file produced by ASMLANGX may be created on any MVS, CMS, or VSE system and then be shipped to any of the others.



ASMIDF Invocation

While most option settings may be changed while ASMIDF is running, some may only be set on the command line, for example, AMODE31.

Also note that some programs will consume all available storage, leaving none available for operation of ASMIDF. There are two ways of dealing with this:

1. Load all required files before allowing the program to commence
2. Reduce the storage that the program will obtain.

The debugger always starts in control, and will set up the traps/intercepts that it needs before handing over control to the user program. If the user program then sets up its own traps/intercepts, subsequent actions depend on the underlying operating system.

ASMIDF initializes itself so that if any “interesting event” occurs within the target module, ASMIDF will receive control. Such an event could be any one of the following:

- Program check
- ABEND
- Breakpoint reached (including Watchpoints)
- Program completion
- Break-in interrupt
- Module load (for deferred breakpoints)
- PER interrupt (CMS only)

Unless one of these events occurs, the target program executes without interference from ASMIDF and generally without degradation (slightly dependent on PER options used in CMS).

If you are trying to follow execution through a routine that is “unknown” to IDF, it checks to see that the PSW remains within the program's defined limits and will warn you if you're about to go outside those bounds. The warning is just to let you know that IDF is about to lose control of the session; you can choose to continue if you want. There are several ways around this “unknown routine” problem:

1. Ensure that IDF knows about all modules you'd like to trace. Using DBREAK will help, as IDF sets up the appropriate control blocks itself (TRIGGER LOAD may also help).
2. You can tell IDF about any loaded modules via the SET MODULE command.

```
SET MODULE name BASE address   will tell IDF the start address
SET MODULE name SIZE llllll    will tell IDF the length
```

3. SET TRACEALL ON will allow IDF to trace anywhere.

Under ISPF, it is recommended that you invoke ASMIDF via the TSOEXEC command: from option 6 under ISPF, issue:

```
TSOEXEC ASMIDF IEFBR14
```

You may also invoke ASMIDF with the NOSVC97 option: from option 6 under ISPF, issue:

```
ASMIDF IEFBR14 (NOSVC97
```

but this requires certain limitations on the target program's behavior.

ASMIDF: Useful Options

PROFILE/NOPROFIL
IDF by default looks for PROFILE ASM (a REXX exec)

AMODE24/AMODE31/AMODE64
Sets initial AMODE of target program

AUTOSIZE/NOAUTOSZ
Controls automatic window resizing

PATH, FASTPATH
Counts number of instruction executions

LIBE Specifies library containing target application module

CMDLOG, RLOG
Create or append to or replay command log file

Useful ASMIDF Options

There are over 50 invocation options; most of their settings can be modified dynamically during debugging by appropriate commands.

- PROFILE/NOPROFIL

  By default, ASMIDF will run a REXX EXEC named PROFILE ASM during its initialization. This EXEC may be used to customize the environment to your particular needs.

  The PROFILE option allows you to specify a different filename while the NOPROFIL option disables any profile invocation. No error messages are issued if the profile is not found.

  Note: No profile is provided with the toolkit; however, a sample profile is illustrated in Figure 12 on page 25.

- AMODE24/AMODE31/AMODE64

  If your target program needs to be started in a particular addressing mode, then use one of these options to set that mode.

- AUTOSIZE/NOAUTOSZ

  By default, ASMIDF will AUTOSIZE the displayed windows as windows are opened and closed. You may decide that you'd like to keep the screen layout consistent with particular windows in specific places; in this case the NOAUTOSZ option stops ASMIDF re-sizing the windows.

- PATH, FASTPATH

  This option provides the user with two new facilities:

  1. ASMIDF will display the number of times that an instruction has been executed.
  2. ASMIDF retains a history of the last 1023 instructions executed. This history may be accessed via the HISTORY command.

  There are some additional variations on PATH that may be useful: PATHFILE and FASTPATH.

- LIBE

  This option will tell ASMIDF to load the target module from the specified library, rather than using the default search order. This is useful on TSO if your test library is not in the default search order.

- CMDLOG and RLOG

  These two options provide a record and playback facility.

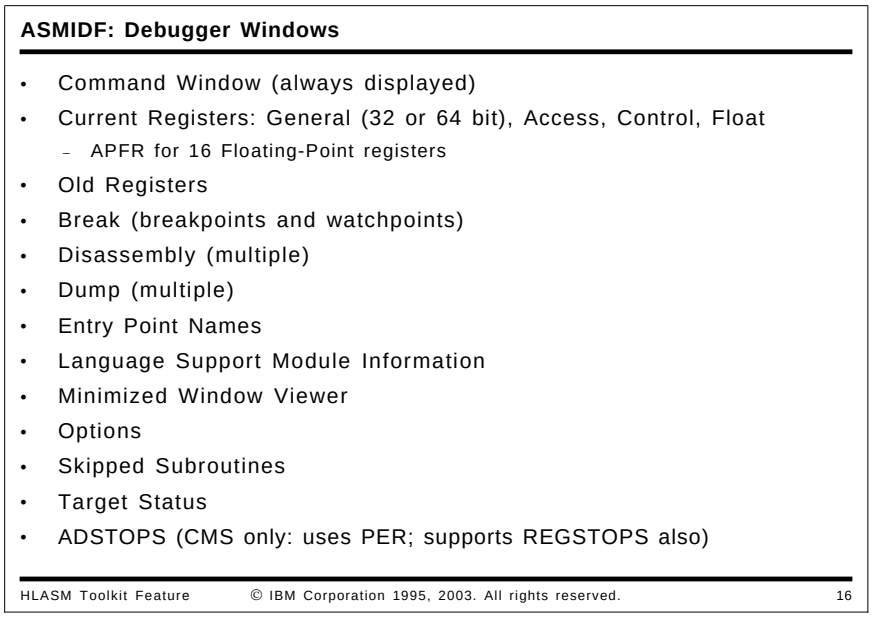
  CMDLOG will cause ASMIDF to log each command in a log file (on CMS, ASM CMDLOG fm; on TSO, the dataset defined by the CMDLOG DD name; and on VSE, the dataset defined by the CMDLOGO DLBL name).

  If RLOG is specified, then once the PROFILE has completed and the target is ready for execution, all the commands in the log file will be replayed.

  Note: CMDLOG will ***append*** to an existing log file. This can cause unexpected results when the log file is then used by RLOG.

```
/*--------------------------------------------------------------------*/
/*   This is a sample PROFILE ASM.  To try it, pick your favorite     */
/*   module and then issue:                                           */
/*                                                                    */
/*    ASMIDF module (profile sampprof                                 */
/*--------------------------------------------------------------------*/

 'SET PFK 2 Macro REGS'           /* Define a new PF key - see User  */
                                  /* Guide p241 for REGS macro       */

 'COLOR WRYG'                     /* Customize the colors            */

 'SHOW SOURCE'                    /* Suppress disassembly display    */

 'SET HEXDISP ON'                 /* Display all output in hex       */

 'SET HEXINPUT ON'                /* Numeric input default is hex    */

 'SET MSG <<< This is ASMIDF profile SAMPPROF >>>'
 Exit
```

Figure 12. Sample profile for ASMIDF



ASMIDF: Debugger Windows

ASMIDF is cursor sensitive: if an argument is missing from a command then it will use the current cursor position and attempt to derive the argument from that.

Some commands allow the user to specify which window the command should apply to. This is done by adding an equal sign followed by the window number. For example, CLOSE =3 will close window number 3. (The window number is displayed as the first part of the title).

Opening and closing of windows is done by:

1. Issuing the appropriate command for that window. These commands act as toggles: if the specified window is not open it will be opened; otherwise the specified window will be closed.

   For example, the command REGS will cause the current register window to be displayed (provided that the Current Registers window is not already open).

2. Issuing the OPEN command with the desired window type will open the window if possible (for example, OPEN DUMP).

3. Issuing the CLOSE command against the window.

Most windows will only allow one window of that type to be displayed at a time. However, it is possible to open multiple disassembly and dump windows at once. (The MINimize, MAXimize and ORDER commands may be helpful in this situation to improve readability).

An example of a screen containing multiple windows is shown in Figure 13 on page 27.

A brief description of each window type follows. By default, the windows are positioned one after another vertically, except that the AdStops, Break, and Skipped Subroutines windows are positioned at the right edge of the screen.

- Command Window (always displayed)

  The Command Window contains the command input area, the message display area, and the PF-key settings (this portion may be customized).

- Current Registers (see window 01 in Figure 13)

  The Current Registers Window displays the current PSW, General Purpose, and Floating Point registers. The Control and Access registers can also be displayed. The contents of the PSW or registers can be modified simply by overtyping.

```
┌01─Current Registers──┌05─Break Points──────────────────────────────┐
│ (TCAT) @PROLOG+44    │ w00057752 (TCAT) @DL00029                  │
│  R0 00009025  R1 0001│   Condition:  = c r3,=f'3'                 │
│  R4 FEFEFEFE  R5 FEFE│  00057788 (TCAT) LOCRET                    │
│  R8 FEFEFEFE  R9 0005└─────────────────────────────────────────────┘
│ R12 800576E0 R13 00012130 R14 000145CC R15 800576E0 FPR6 0000000000000000  │
┌02─Old Registers──────────────────────────────────────────────────────────┐
│ (TCAT) @PROLOG+40                    PSW 078D10008005771E (CC mask= 4 L) │
│ 0005771E 9620 C0BA                OI    CTGOPTN3,32                      │
│  R0 00009025  R1 000120D4  R2 FEFEFEFE  R3 FEFEFEFE FPR0 0000000000000000 │
│  R4 FEFEFEFE  R5 FEFEFEFE  R6 FEFEFEFE  R7 FEFEFEFE FPR2 0000000000000000 │
│  R8 FEFEFEFE  R9 000577BC R10 FEFEFEFE R11 FEFEFEFE FPR4 0000000000000000 │
│ R12 800576E0 R13 00012130 R14 000145CC R15 800576E0 FPR6 0000000000000000 │
┌03─Disassembly────────────────────────────────────────────────────────────┐
│ (TCAT) @PROLOG+32                                                        │
│  00057716 92C1 C0CA                MVI   CTGTYPE,193                     │
│  0005771A 943F C0BA                NI    CTGOPTN3,63                     │
│  0005771E 9620 C0BA                OI    CTGOPTN3,32                     │
│  00057722 4190 07D8                LA    R9,2008                         │
│  00057726 5090 C108                ST    R9,CATWRK                       │
│  0005772A 1F88                     SLR   R8,R8                           │
│  0005772C 5080 C10C                ST    R8,CATWRKUS                     │
│  00057730 4190 C108                LA    R9,CATWRK                       │
│  00057734 5090 C0C4                ST    R9,CTGWKA                       │
│  00057738 4170 0002                LA    R7,2                            │
┌04─Storage Dump───────────────────────────────────────────────────────────┐
│ (TCAT) CTGOPTN3                                                          │
│  0005779A     21                            │  .            │          │
│ (TCAT) CTGOPTN4                                                          │
│  0005779B       00                          │   .           │          │
│ (TCAT) CTGENT                                                            │
│  0005779C 000577BC                          │ ....          │          │
│ (TCAT) CTGCAT                                                            │
│  000577A0 00000000                          │ ....          │          │
│ (TCAT) CTGWKA                                                            │
│  000577A4 00000000                          │ ....          │          │
│ (TCAT) CTGDSORG                                                          │
└──────────────────────────────────────────────────────────────────────────┘

==> ____________________________________________________________________

1 Stmtstep   2 Regs       3 Quit       4 Until       5 Run         6 Dump
7 Previous   8 Next       9 Disasm    10 Break      11 Step       12 Retrieve
```

Figure 13. Example of Several Open IDF Windows on One Screen

If the REGS64 or GPRG commands are issued, the registers are displayed as 64-bit registers and the PSW is displayed as a 128-bit field, as shown in Figure 14 on page 27.

```
┌01─Current Registers──────────────────────────────────────────────────┐
│ (TESTVAR) TESTVAR                                                    │
│              EPSW FF00000000000000 0000000000000ACC0 (CC mask=8 E)   │
│  R0 00000000 FEFE000F  R8 00000000 FEFE080F FPR0 0000000000000000    │
│  R1 00000000 0000D024  R9 00000000 FEFE090F FPR2 0000000000000000    │
│  R2 00000000 FEFE020F R10 00000000 FEFE0A0F FPR4 0000000000000000    │
│  R3 00000000 FEFE030F R11 00000000 FEFE0B0F FPR6 0000000000000000    │
│  R4 00000000 FEFE040F R12 00000000 0000ACC0                          │
│  R5 00000000 FEFE050F R13 00000000 0000D058                          │
│  R6 00000000 FEFE060F R14 00000000 00090466                          │
│  R7 00000000 FEFE070F R15 00000000 0000ACC0                          │
└──────────────────────────────────────────────────────────────────────┘
```

Figure 14. Current Registers Window, as opened with REGS64

- Additional Floating-Point Registers (AFPR)

  Under TSO, if AFPR support is available on the processor, all sixteen floating-point registers and the Floating-Point Control Register are displayed and may be updated by overtyping.

- Old Registers (see window 02 in Figure 13)

  The Old Registers Window shows the value of the PSW and the General and Floating Point registers the last time IDF was in control. If your program is “single stepping”, the contents of this window are the “before” values prior to executing the current instruction.

- Break (breakpoints and watchpoints) (see window 05 in Figure 13)

  The Break Window lists active breakpoints and watchpoints, along with any commands associated with them.

- Disassembly (multiple) (see window 03 in Figure 13)

  The Disassembly Windows display storage contents as disassembled Assembler Language instruction statements. Locations at which breakpoints or watchpoints have been set are highlighted. Modifications can be made by overtyping the instruction.

- Dump (multiple) (see window 04 in Figure 13)

  The Dump Windows display storage in dump format (both hexadecimal or character). Modifications can be made by overtyping either portion of the display.

  An example of a screen showing storage dumps of two modules is shown in Figure 15.

```
┌01─Storage─Dump──────────────────────────────────────────────────────┐
│ (ASMXDACP) ASMXDACP                                                 │
│  0015FB18 47F0F0DE D3898385 95A28584 40D481A3 │ åÒÒúLicensed Mat │
│  0015FB28 85998981 93A2406D 40D79996 978599A3 │ erials - Propert │
│  0015FB38 A8409686 40C9C2D4 40C1E2D4 D3C1D5C7 │ y of IBM ASMLANG │
│  0015FB48 E7404DC3 5D40C396 97A89989 8788A340 │ X (C) Copyright  │
│  0015FB58 C9C2D440 F1F9F9F5 4B40C193 9340D989 │ IBM 1995. All Ri │
│  0015FB68 8788A3A2 40D985A2 8599A585 844B40E4 │ ghts Reserved. U │
│  0015FB78 E240C796 A5859995 948595A3 40E4A285 │ S Government Use │
│  0015FB88 99A240D9 85A2A399 8983A385 8440D989 │ rs Restricted Ri │
│  0015FB98 8788A3A2 406040E4 A2856B40 84A49793 │ ghts - Use, dupl │
│  0015FBA8 898381A3 89969540 96994084 89A28393 │ ication or discl │
│  0015FBB8 96A2A499 85409985 A2A39989 83A38584 │ osure restricted │
│  0015FBC8 4082A840 C7E2C140 C1C4D740 E2838885 │  by GSA ADP Sche │
│  0015FBD8 84A49385 40C39695 A3998183 A340A689 │ dule Contract wi │
│  0015FBE8 A38840C9 C2D440C3 9699974B 400007FE │ th IBM Corp. ..Ú │
│ (ASMXMAIN) ASMXMAIN                                                 │
│  0015FBF8 47F0F016 10C1E2D4 E7D4C1C9 D54040F9 │ åÒÒ..ASMXMAIN  9 │
│  0015FC08 F54BF2F9 F60090EC D00C18CF 41B0CFFF │ 5.296.°Ö}..ō.[ō. │
│  0015FC18 47F0C028 00163FF8 5870C024 58007690 │ åÒ{....8ïø{.ï.Î° │
│  0015FC28 181D1B10 5A00D000 47D0C040 00000002 │ ....!.}.å}{ .... │
│  0015FC38 50001000 D20F1048 D04818FD 18D150FD │ &...K..ç}ç.Ù.J&. │
│  0015FC48 000450D0 F00898F1 F010D203 D0581000 │ ..&}0.q10.K.}ï.. │
│  0015FC58 5860D058 58806000 5080D100 58A0D050 │ ï-}ïïØ-.&ØJ.ï·}& │
│  0015FC68 4120D212 5020A160 D70C2000 20004190 │ ..K.&..-P......° │
│  0015FC78 D2835090 A164D779 90009000 4130A110 │ Kc&°.ÄP.°.°.....  │
└─────────────────────────────────────────────────────────────────────┘
```

Figure 15. Example of IDF DUMP Window

- Entry Point Names

  This scrollable window displays the names of entry points in the section currently being debugged. If the name is longer than 8 characters, up to 64 are displayed; an 8-character contraction of the name is also shown.

```
┌03─Entry point name──────────────────────────────────────────More:+-┐
  Program TESTIDF   Entry short name TESTIDF  Address 00018EF8
Long name TESTIDF
└──────────────────────────────────────────────────────────────────┘
```

Figure 16. Entry Point Names Window

- Language Support Module Information (multiple)

  The Language Support Module (LSM) Window can be opened when language-extraction data is available. It can display the values of symbolic variables, as well as the status of the available information.

- Minimized Window Viewer

  The MINIMIZE command can be used to temporarily minimize a window, to make more space available on the screen for other windows. The Minimized Window shows the type and number of the minimized windows.

- Options

  The Options Window displays the current status of IDF options; some of the options can be modified by overtyping their values.

- Skipped Subroutines

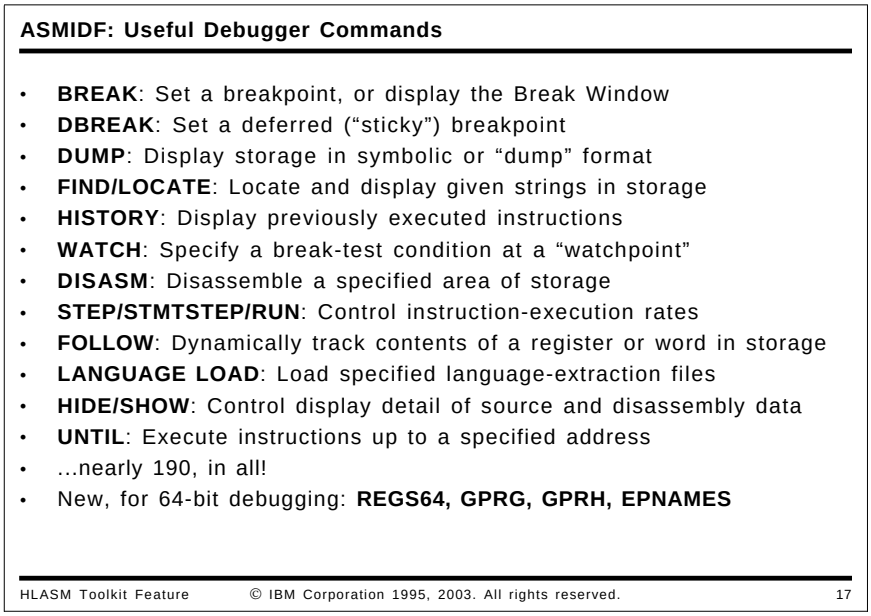
  The Skipped Subroutines Window displays the addresses and names of subroutines for which single-stepping, statement stepping, or instruction counting is being bypassed.

- Target Status

  The Target Status Window displays information about all programs known to IDF.

- ADSTOPS (CMS only: uses PER; supports REGSTOPS also)

  The AdStops Window displays the storage ranges to be checked for storage alteration events, and the General Purpose Registers to be checked for register alteration events.



ASMIDF: Useful Debugger Commands

This list shows some of the commands available within ASMIDF. It is by no means comprehensive (there are nearly 190 available commands); the complete list is provided in Chapter 2 of the IDF User's Guide.

You can enter instruction and data addresses symbolically if the Language Support Module (language extraction) is available. This can greatly simplify debugging of “familiar” modules.

Some useful commands are the following:

- BREAK

  Set a breakpoint, or display the Break Window. At most 64 active breakpoints can be set. (In practice, this is many more than normal applications will need.)

- DBREAK

  Set a deferred (“sticky”) breakpoint: these can be used for debugging modules not yet loaded into storage.

- DUMP

  Display storage in symbolic or “dump” format, with overtyping modifications in hex or character format.

- FIND/LOCATE

  Locate and display given strings in storage, using a syntax like that of the ISPF editor FIND command or of the XEDIT LOCATE command.

- HISTORY

  Display previously executed instructions when the PATH or PATHFILE option has been specified. This allows you to review the flow of execution that led to the current instruction.

- WATCH

  Specifies a break-test comparison to be checked each time control passes the “watchpoint”; a break occurs only if the condition is true.

- DISASM

  This command requests disassembly of a designated area of storage.

- STEP/STMTSTEP/RUN

  These three commands control instruction-execution rates: RUN executes until the next “event” occurs; STEP executes an instruction at a time; and STMTSTEP executes all instructions associated with a single source-language statement.

- FOLLOW

  The FOLLOW command will cause a Dump Window to automatically track the value of a 4-byte area of storage, or the contents of a register.

- LANGUAGE LOAD

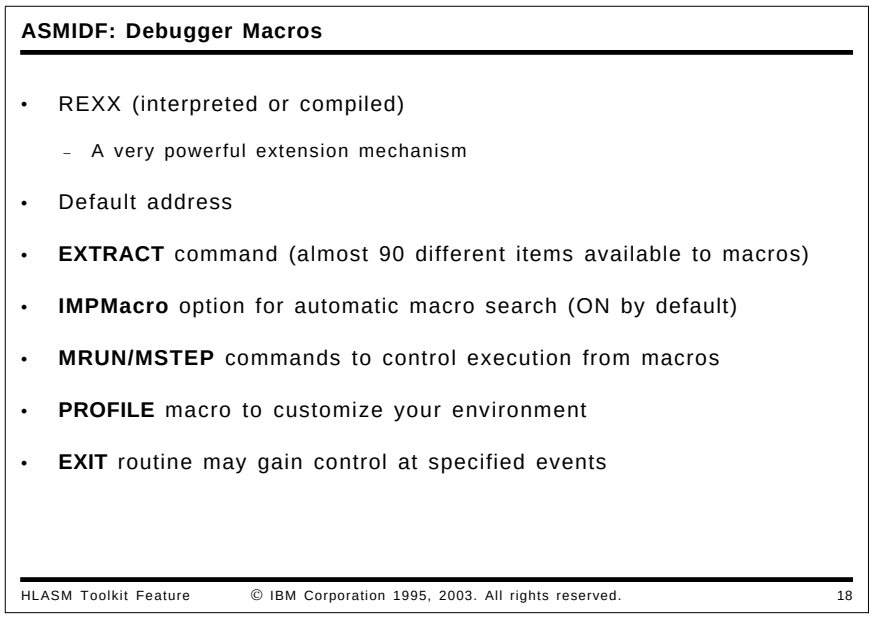
  Loads specified language-extraction files for general or module-specific use.

- HIDE/SHOW

  These two commands control the amount of detail when source code and disassembled storage is being displayed.

- UNTIL

  Executes instructions up to (but not including) a specified address.



ASMIDF: Debugger Macros

ASMIDF provides an extremely flexible and powerful macro facility that you may use to customize your debugging environment. All the macros used by ASMIDF are written in REXX, but you may also write them in “compiled REXX”. Some examples are provided in the IDF User's Guide.

ASMIDF provides many useful facilities to assist the macro writer. Some of these are:

- Default address. ASMIDF sets up a REXX environment that allows the user to direct commands to ASMIDF for processing.

  On CMS, there are some restrictions on the address; these are detailed in Chapter 15 of the User's Guide.

- EXTRACT command. This allows the macro to obtain a great variety of information from ASMIDF about the current environment (see the example below of the REGS macro). Nearly 90 different types of debugger and target-program data are available.

- IMPMacro option. This option (which is set on by default) causes ASMIDF to search for a macro if the entered command is not found in the ASMIDF command table.

- MRUN/MSTEP commands. These cause the target program to immediately resume execution until the next event; control is then returned to the macro.

There are two special macros within ASMIDF; the PROFILE macro and the EXIT macro.

- The PROFILE macro is driven during ASMIDF initialization and may be used to completely customize the user environment.

- EXIT is a special purpose routine which, if enabled via the EXITEXEC command, is given control at various significant events. If the EXIT macro sets a return code of 1, then ASMIDF will NOT display that event to the user and execution of the target will resume as normal. The EXIT routine (whose name is set by the SET EXITEXEC command) may be written in a compiled or assembled language for added convenience or performance, if you specify the CMPEXIT option.

  Chapter 17 of the IDF User's Guide describes EXIT routines.

ASMIDF: Debugger Macros, Example 1

```
/*================================================================\
| TRAP macro:  uses DBREAK to load and break on the entry point of |
|              a loadable module                                   |
| PARAMETERS:  name - module name                                  |
|              symbol - external symbol to set break point on      |
\================================================================*/

arg name symbol .
if name == '' then exit 99
if symbol == '' then symbol = name
'DBREAK ('name'.'symbol')'  /* Issue DBREAK at start of CSECT    */
'MRUN'               /* Program will run until DBREAK is matched */
'QUAL' name                /* Change qualifier                   */
'LAN LOAD' symbol          /* Load extraction file               */
'BREAK' symbol             /* Remove breakpoint at module start */
exit
```


ASMIDF: Debugger Macros, Example 1

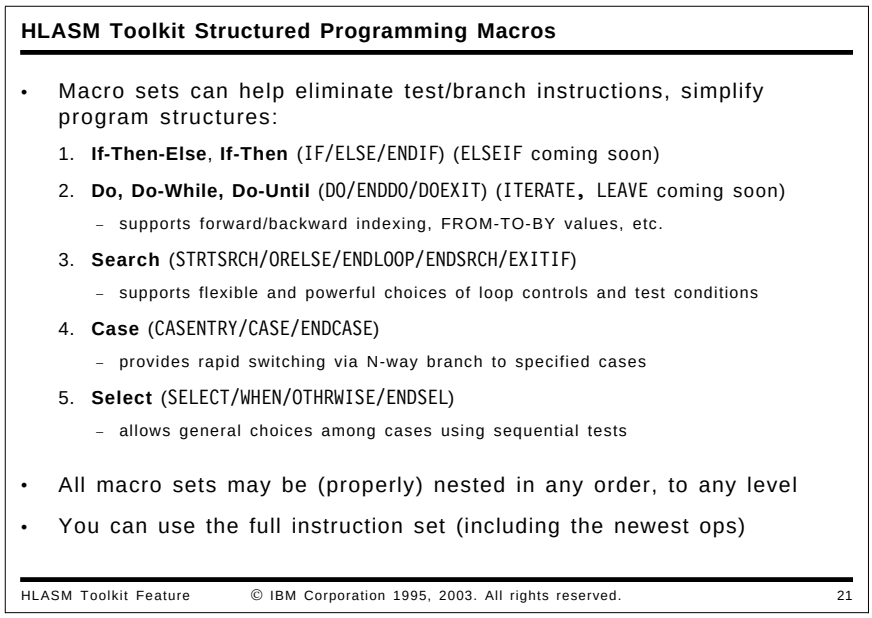
The TRAP macro will set a deferred breakpoint for a module, and then allow the program to RUN until that breakpoint is reached. At that breakpoint, it will change the qualifier for symbols to match the name of the routine to be entered, and then will LANGUAGE LOAD the symbol-extraction file for that section. Finally, it removes the (deferred) breakpoint, and returns control to the user.

ASMIDF: Debugger Macros, Example 2

```
/*REXX ---------------------------------------------------------------*/
/*            REGS - Toggle the current registers window.             */
/*                                                                    */
/* When the REGS window is opened, it will be moved on the ASMIDF     */
/* display so that it is the first window.                            */
/*--------------------------------------------------------------------*/

 'REGS'                          /* Toggle REGS window               */

 'Extract Cursor'                /* Obtain window information        */
 n = Find(display,'REGS')        /* Is REGS window present?          */
 If n ¬= 0 Then                  /* Yes?  Force to be 1st window     */
   'ORDER ='n

 Exit
```


ASMIDF: Debugger Macros, Example 2

The REGS macro (taken from Chapter 16 of the IDF User's Guide) shows how the EXTRACT command may be used to obtain information about the current debugging environment. It checks to see if the REGS window is available, and if so puts it at the top of the display list using the ORDER command.



HLASM Toolkit Structured Programming Macros

The High Level Assembler Toolkit Feature Structured Programming Macros simplify the coding and understanding of complex control flows, and help to minimize the likelihood of introducing errors when coding test and branch instructions. The macros support the most widely used structured-programming control structures and eliminate the need to code most explicit branches.

The Toolkit Feature Structured Programming Macros can be used to create the following structures:

- IF/ELSE/ENDIF

  One-way or two-way branching, depending on simple or complex test conditions.

- DO/ENDDO and STRTSRCH/ORELSE/ENDLOOP/ENDSRCH

  A rich and flexible set of looping structures with a variety of control and exit facilities.

- CASENTRY/CASE/ENDCASE

  Fast N-way branching, based on an integer value in a register. Deciding which branch to take is made at the CASENTRY macro; a direct branch to the selected CASE is then done, followed by an exit at the ENDCASE macro.

  There is no OTHRWISE facility within this macro set.

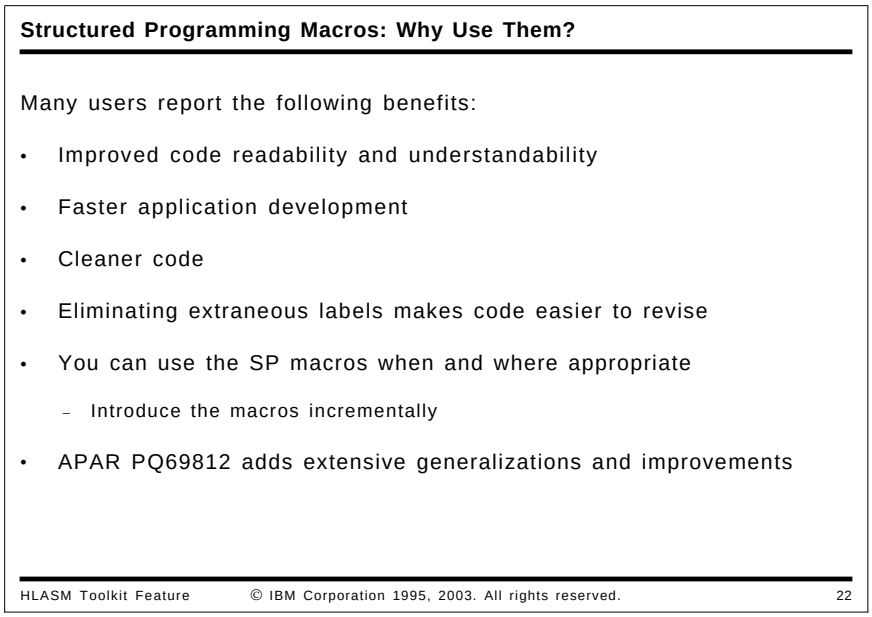
- SELECT/WHEN/OTHRWISE/ENDSEL

  Sequential testing, based on sets of comparisons. These macros create a series of tests that are evaluated in the order they are specified in the program. If a test is true, the WHEN section of code for that test will be executed, followed by an exit at the ENDSEL macro.

  If no test is satisfied, then the OTHRWISE section (if present) will be performed.

All the macro sets may be nested, and there are no internal limits to the depth of nesting. Tests made by the various ENDxxx macros ensure that each structure's nesting closure is at the correct level, and diagnostic messages (MNOTEs) are issued if they are not.

Note: The Structured Programming Macros do not currently generate relative branch instructions. If you want to use such branches, consider the IEABRC copy file. (See the *z/OS Assembler Services Reference* for details.)



Why Use the Structured Programming Macros?

Experience with Structured Programming Macros has shown many benefits, including

- Improved code readability and understandability

  Since application understanding and maintenance has significant costs, the improvements provided by the macros can reduce those costs.

- Faster application development

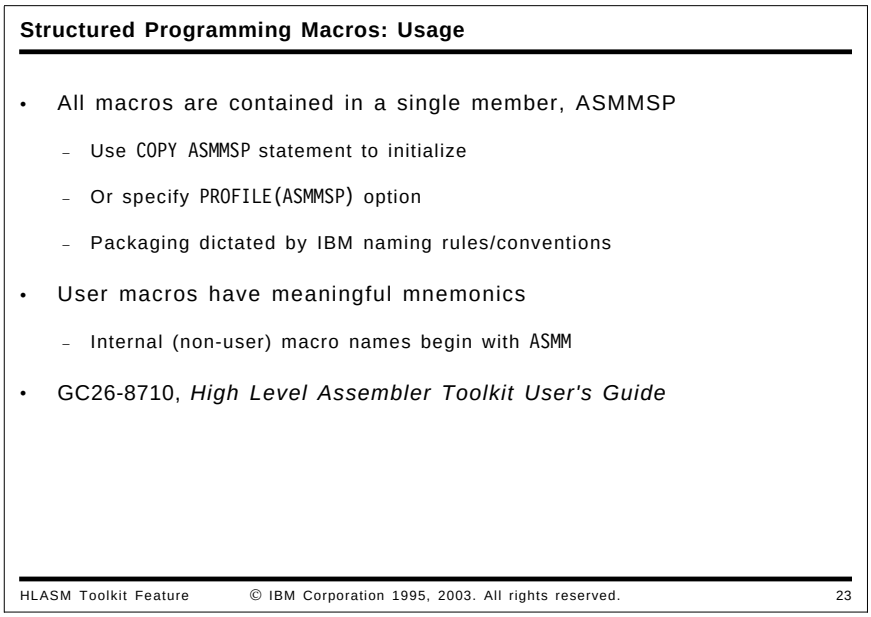
  The macros simplify logic and need fewer statements to write, which can therefore speed your development tasks.

- Cleaner and more readable code

  The macros can help eliminate extraneous statements and statement labels that might clutter the logic of a program, so the code is easier to write and read.

- Incremental use

  You can use as few or as many of the macros as you like, and when you like; they can be introduced incrementally into existing programs. Thus, you aren't forced to make major changes to your code to start taking advantage of the macros' benefits.



Structured Programming Macros: Usage

To use the macros, you must code COPY ASMMSP within the source. This will define all the macros as inline macros. Once this has been done you can use all the macros described without any further limitations. Alternatively, the High Level Assembler PROFILE(ASMMSP) option could be used to automatically include the ASMMSP member into the source without requiring any source changes.

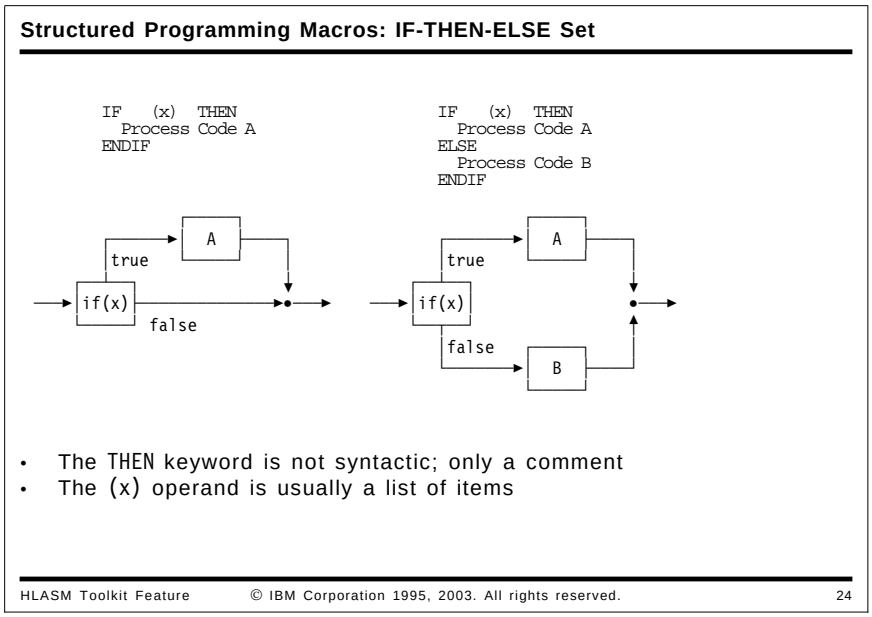
Due to IBM Corporate product-naming standards, all distributed part names must start with the product prefix. In the case of these macros, this resulted in the creation of the ASMMSP member which contains all the “high level” user macros such as IF, CASE, etc. All supplied members have a prefix of ASMM.

The “user” macros are grouped in the following five sets:

- IF/ELSE/ENDIF
- DO/DOEXIT/ENDDO
- STRTSRCH/EXITIF/ORELSE/ENDLOOP/ENDSRCH
- CASE/CASENTRY/ENDCASE
- SELECT/WHEN/OTHRWISE/ENDSEL

We will describe each of these sets in turn.

Note: The structured-programming macros generate base-displacement branch instructions, and therefore assume a base register provides addressability. If you intend to use them in a context where relative branch instructions are desired, you may need to provide local addressability for the macros.



Structured Programming Macros: If-Then-Else

These “IF-THEN-ELSE” macros (IF/ELSE/ENDIF) provide for a one- or two-way branch depending on a condition. You may select execution of one of two blocks of code depending on a true-false condition.

The one-way branch is illustrated in Figure 17:

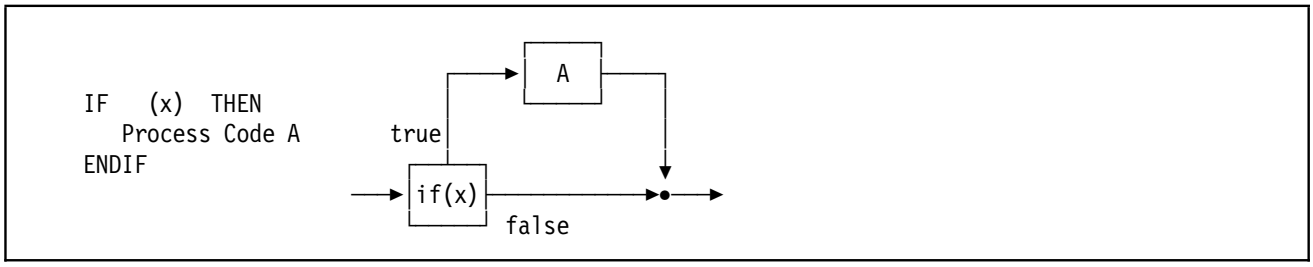


Figure 17. IF-THEN Control Structure

The two-way branch is illustrated in Figure 18:

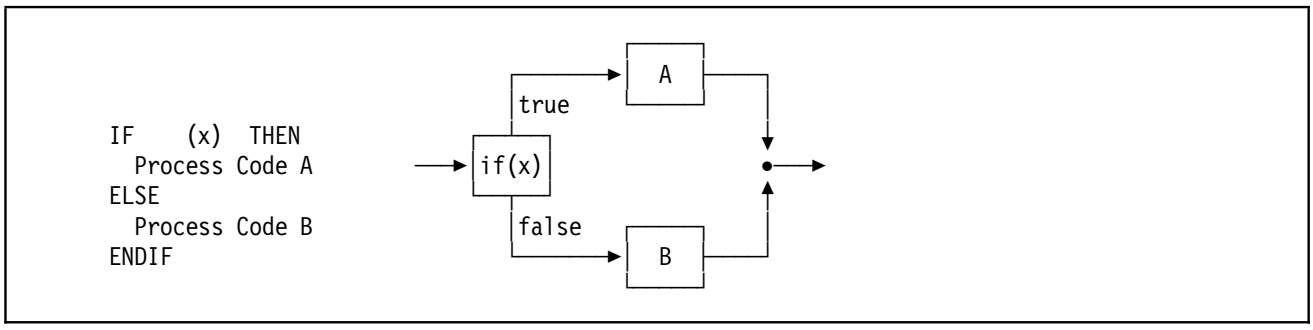
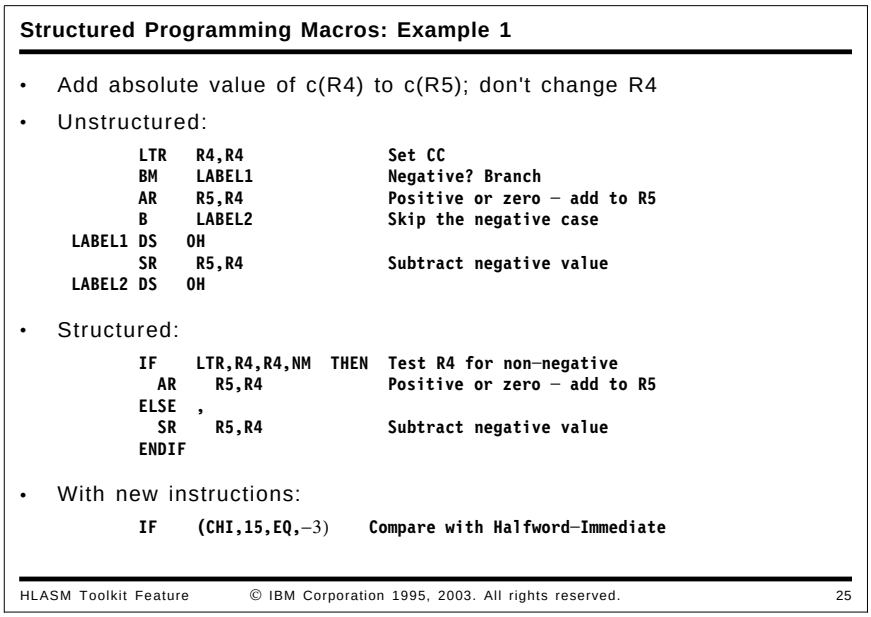


Figure 18. IF-THEN-ELSE Control Structure



Structured Programming Macros: Example 1

This assembler program segment shows how to test a variable and then execute one of two paths depending on the value of the variable. The “problem” requires that we add the absolute value of the contents of R4 to R5, without disturbing R4.

This IF/ELSE/ENDIF structure is first coded using basic assembler language and then using the toolkit macros. The unstructured assembler language segment could appear as follows:

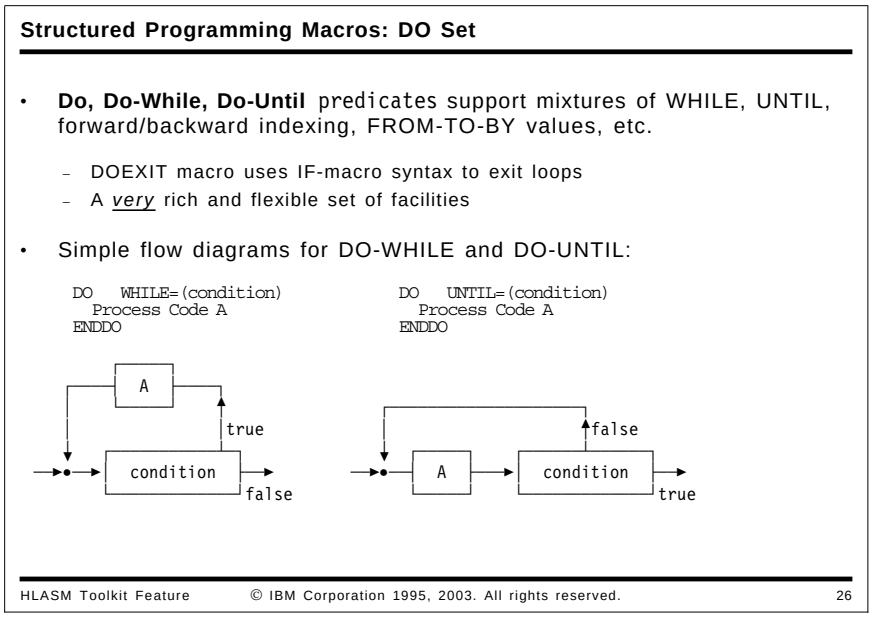
```
        LTR   R4,R4              Set CC
        BM    LABEL1             Negative? Branch
        AR    R5,R4              Positive or zero - add to R5
        B     LABEL2             Skip the negative case
LABEL1  DS    OH
        SR    R5,R4              Subtract negative value
LABEL2  DS    OH
```

The structured equivalent could be written as follows (remember that the THEN “keyword” is only a comment; it is not part of the syntax of the IF/ELSE macros):

```
        IF    LTR,R4,R4,NM  THEN  Test R4 for non-negative
          AR    R5,R4             Positive or zero - add to R5
        ELSE  ,
          SR    R5,R4             Subtract negative value
        ENDIF
```

and the results would be identical to the original (non-structured) statements:

```
        IF    LTR,R4,R4,NM  THEN  Test R4 for non-negative
+             LTR  R4,R4
+             BC 15-11,#@LB1
          AR    R5,R4             Positive or zero - add to R5
        ELSE  ,
+             BC   15,#@LB3
+#@LB1        EQU  *
          SR    R5,R4             Subtract negative value
        ENDIF
+#@LB3      EQU *
```



Structured Programming Macros: Do, Do-While, Do-Until

These macros provide for executing a block of code repeatedly until some limit is reached or some condition is satisfied (DO, DO-WHILE, DO-UNTIL macros). The conditions controlling the looping and the termination condition may be specified in a rich set of combinations:

- with FROM,TO,BY specifications, or with infinite looping
- by counting
- with forward or backward indexing
- with explicit specification of BXH or BXLE
- DO-WHILE and DO-UNTIL (or mixed with any other DO type)
- DOEXIT macro uses IF-macro syntax to exit loops

We will illustrate only one of the possibilities here. The DO-WHILE and DO-UNTIL control structures are illustrated in Figure 19 below:

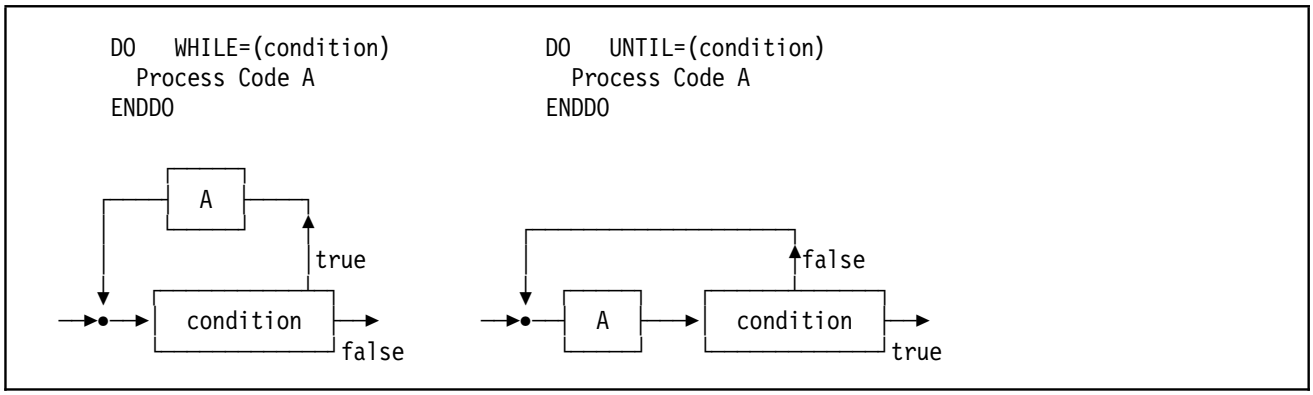
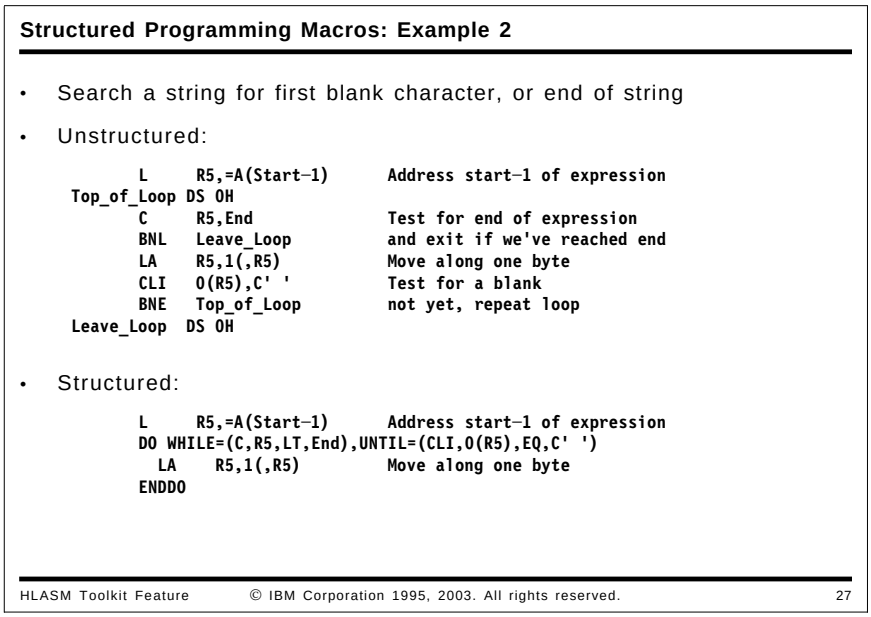


Figure 19. DO-WHILE and DO-UNTIL Control Structures



Structured Programming Macros: Example 2

This assembler program segment shows a simple loop that scans storage until either a blank is found or the end-of-string address is reached.

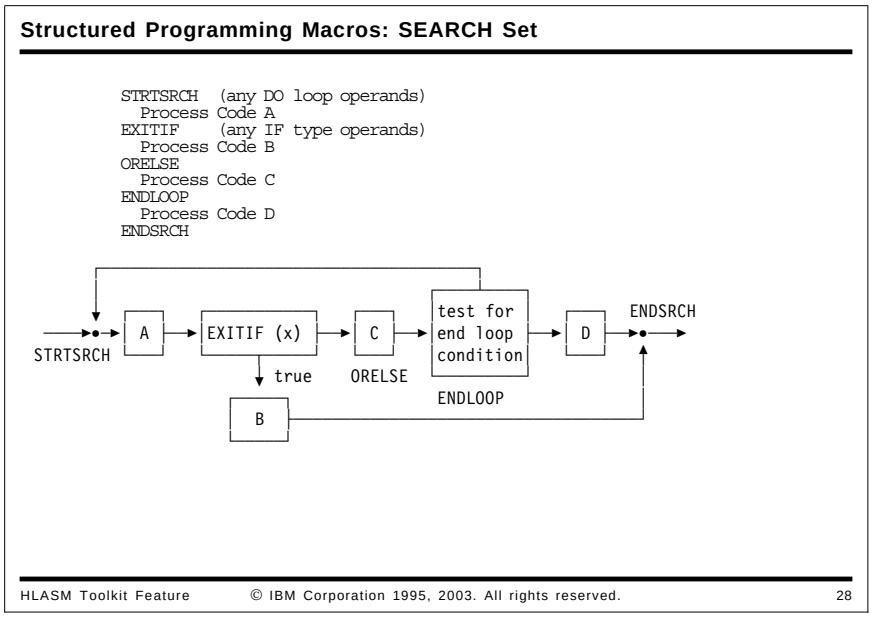
This DO/ENDDO structure is first coded using basic assembler language and then using the toolkit macros. The unstructured assembler language might appear as follows:

```
        L     R5,=A(Start-1)      Address start-1 of expression
  Top_of_Loop DS OH
        C     R5,End              Test for end of expression
        BNL   Leave_Loop          and exit if we've reached end
        LA    R5,1(,R5)           Move along one byte
        CLI   0(R5),C' '          Test for a blank
        BNE   Top_of_Loop         not yet, repeat loop
  Leave_Loop  DS OH
```

The same example could be coded using the DO and ENDDO macros as follows:

```
        L     R5,=A(Start-1)      Address start-1 of expression
        DO WHILE=(C,R5,LT,End),UNTIL=(CLI,0(R5),EQ,C' ')
          LA    R5,1(,R5)         Move along one byte
        ENDDO
```

Note that in both examples the required COPY ASMMSP statement is not shown.



Structured Programming Macros: Search Set

These macros provide for executing a search loop with flexible controls over exit and iteration conditions (SEARCH macros).

The control structure supported by the Search Set is shown in Figure 20 below:

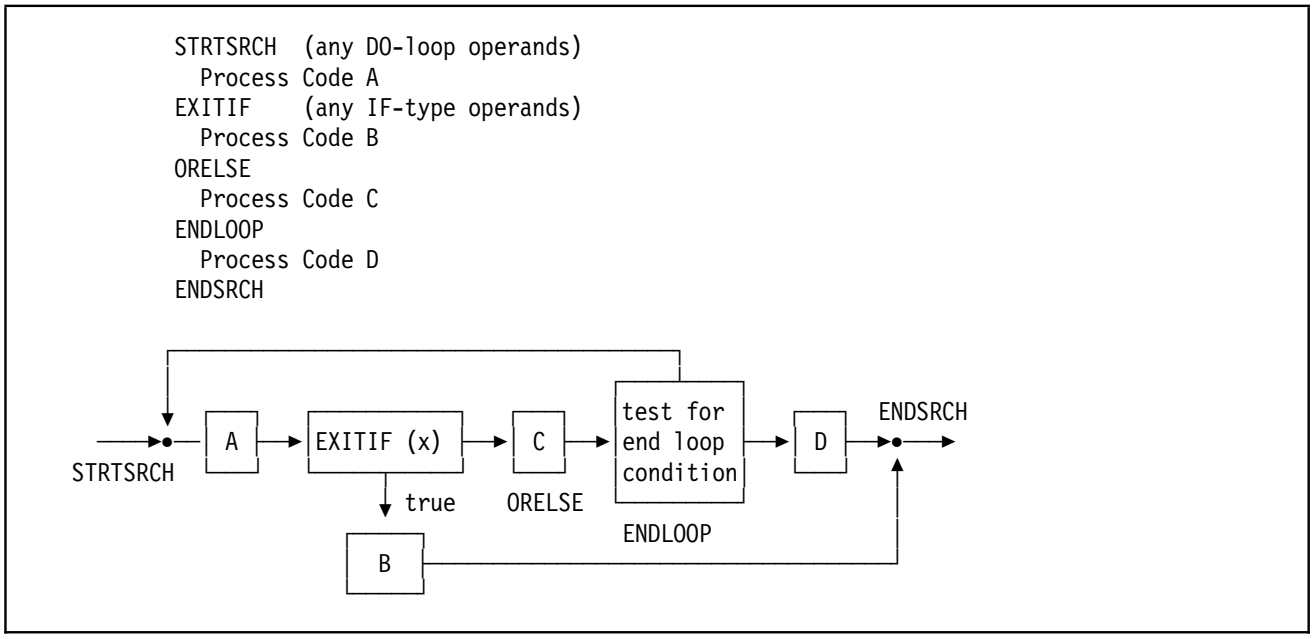
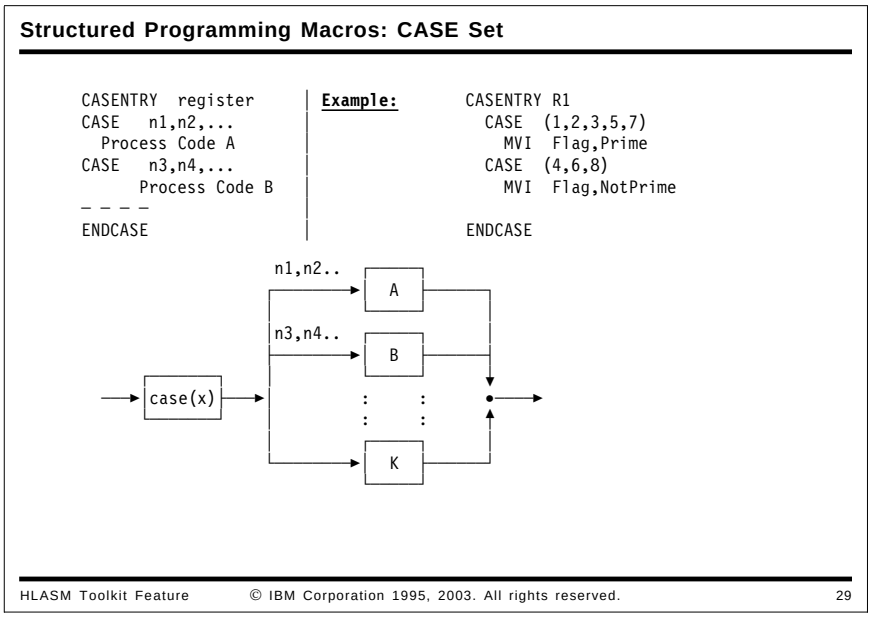


Figure 20. SEARCH Control Structures



Structured Programming Macros: Case Set

These macros provide for executing a block of code selected from a set, based on an integer value contained in a general register. The integer value may also be a power of two, as specified by the optional POWER= keyword.

The selected case is branched to directly, using one of two selection mechanisms depending on whether the branching should use a “vector” of addressable branch instructions (VECTOR=B) or a table of address constants (VECTOR=BR).

The CASE control structure is illustrated in Figure 21 below:

```
CASENTRY  register                    CASENTRY R1
CASE   n1,n2,...                        CASE  (1,2,3,5,7)
  Process Code A                          MVI  Flag,Prime
CASE   n3,n4,...                        CASE  (4,6,8)
      Process Code B                      MVI  Flag,NotPrime
. . .
ENDCASE                               ENDCASE
```

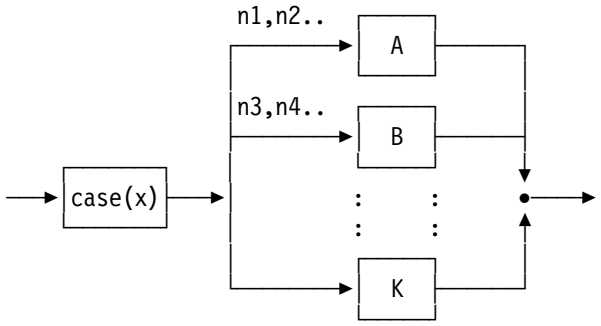


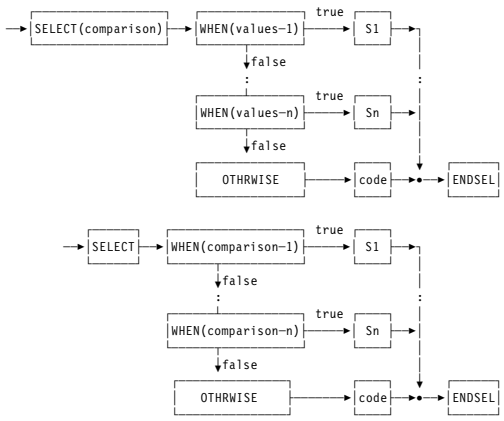
Figure 21. CASE Control Structures

A simple example of the CASE macros is the following:

```
          CasEntry R1
            Case  (1,2,3,5,7)
               MVI  Flag,Prime
            Case  (4,6,8)
               MVI  Flag,NotPrime
          EndCase
          - - -
Flag      DC    X'0'
Prime     Equ   X'80'
NotPrime  Equ   X'40'
```

Figure 22. CASE Example

Structured Programming Macros: SELECT Set



 30

Structured Programming Macros: SELECT Set ...

```
SELECT (comparison)           Compare instruction & condition
WHEN   (list-of-values-1)     Values for this comparison
   <statements-1>             Statements for these cases
WHEN   (list-of-values-2)     Values for this comparison
   <statements-2>             Statements for these cases
. . .
WHEN   (list-of-values-n)     Values for last comparison
   <statements-n>             Statements for these cases
OTHRWISE
   <statements>               Executed if no matching WHEN
ENDSEL
```

Example:

```
SELECT  C,R1,Eq
  WHEN  (=F'1',=F'2',=F'3',=F'5',=F'7')
     MVI  Flag,Prime
  WHEN  (=F'4',=F'6',=F'8')
     MVI  Flag,NotPrime
  OTHRWISE
     MVI  Flag,Unknown
ENDSEL
```

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Structured Programming Macros: Select Set

These macros provide for executing a block of code selected from a set of blocks, based on a varied choice of comparisons.

While they are structurally similar to the CASE set, their behavior is quite different. Each WHEN clause is tested in the order specified until a “true” condition is found, when the corresponding block of statements will be executed; the optional OTHRWISE block is executed if no WHEN clause is true. The structure of one form of the Select Set is illustrated below:

```
SELECT (comparison)           Compare instruction & condition
WHEN   (list-of-values-1)     Values for this comparison
   <statements-1>             Statements for these cases
WHEN   (list-of-values-2)     Values for this comparison
   <statements-2>             Statements for these cases
. . .
WHEN   (list-of-values-n)     Values for last comparison
   <statements-n>             Statements for these cases
OTHRWISE
   <statements>               Statements executed if no matching WHEN
ENDSEL
```

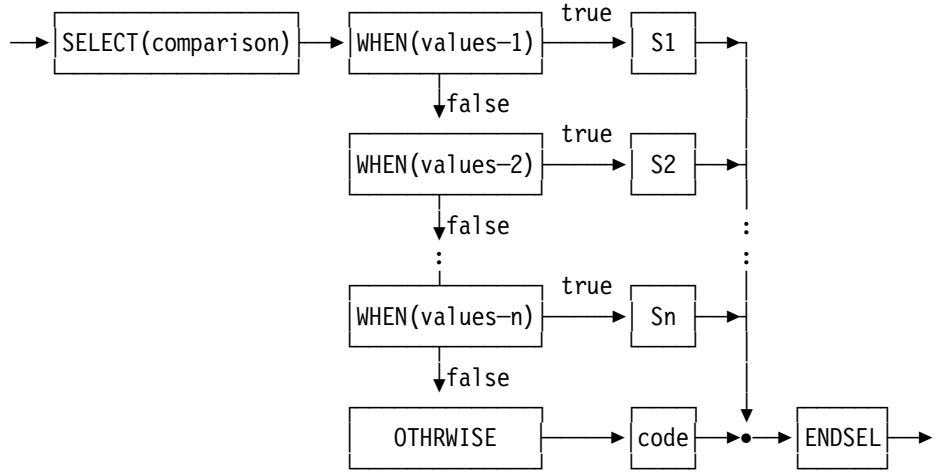
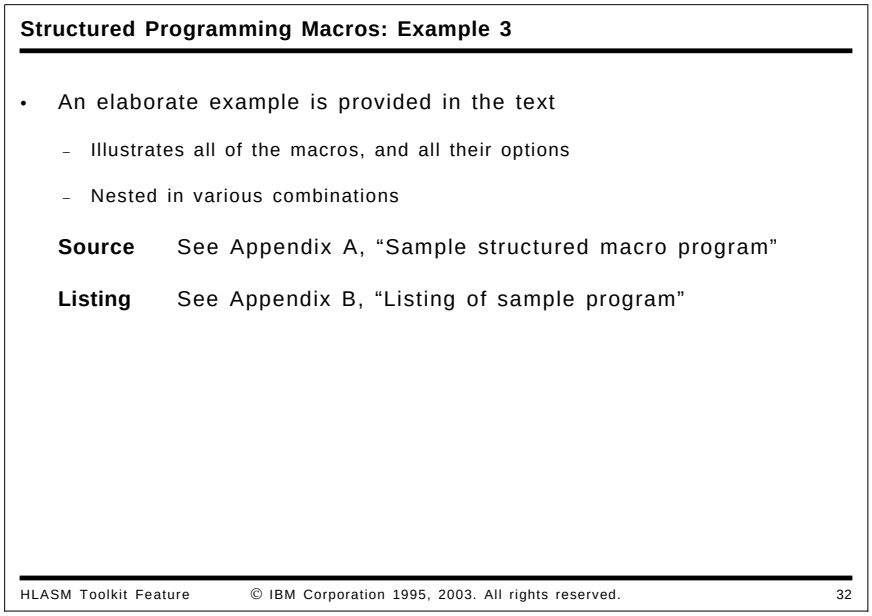


Figure 23. SELECT Control Structures

A simple example of the SELECT macros is the following:

```
          Select  C,R1,Eq
            When  (=F'1',=F'2',=F'3',=F'5',=F'7')
               MVI  Flag,Prime
            When  (=F'4',=F'6',=F'8')
               MVI  Flag,NotPrime
            Othrwise
               MVI  Flag,Unknown
          EndSel
          - - -
Flag      DC    X'0'
Prime     Equ   X'80'
NotPrime  Equ   X'40'
Unknown   Equ   X'01'
```

Figure 24. SELECT Example



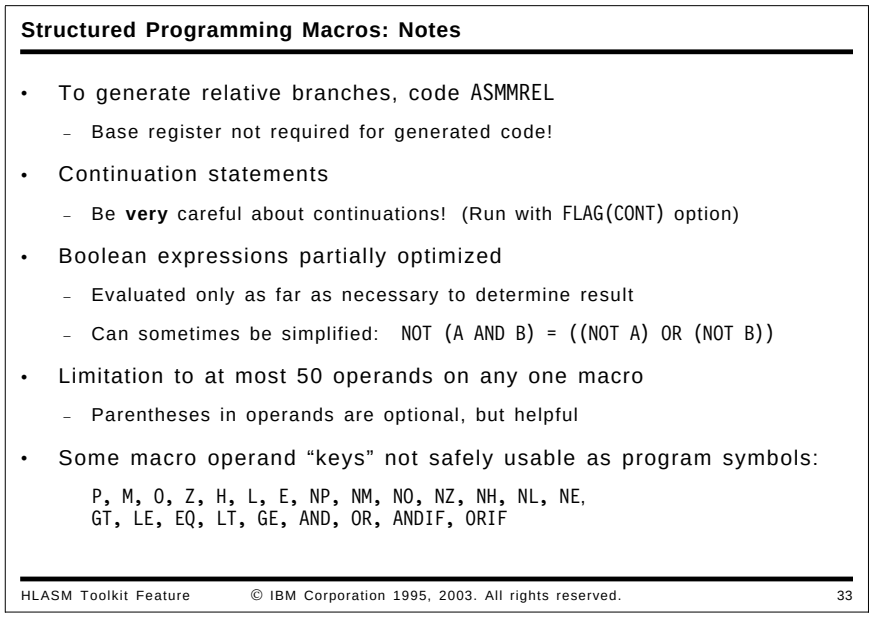
Structured Programming Macros: Extended Example

An extensive sample program is provided in Appendix A, “Sample structured macro program” on page 56. It shows the use of more complicated structures and the nesting of macros. (Note that no macros from the SELECT set are illustrated.)

The assembly listing is provided in Appendix B, “Listing of sample program” on page 59. The listing was created by the following (CMS) commands:

1. Access the High Level Assembler Toolkit disk
2. GLOBAL MACLIB ASMSMAC
3. ASMAHL SAMPLE (PROFILE(ASMMSP),NOESD,NORLD,NOXREF,NOMXREF,NOUSING

The expansion of the macros is shown in the listing; if this expansion is not desired then you may use the PC(NOGEN) option to suppress the generated lines.



Structured Programming Macros: Notes

The Structured Programming Macros can now generate either based or relative branch instructions. To obtain the latter, just code the ASMMREL macro.

Some minor points are worth remembering:

- Be very careful to place any continued operands in the correct column. The normal assembler rules apply (along with any changes that the ICTL statement may have introduced). The assembly-time option FLAG(CONT) can help determine where the rules have not been followed.
- Not only are the instructions generated by the macros nearly optimal, the macros do not need to evaluate all the terms in a Boolean expression before branching. In the following statement:

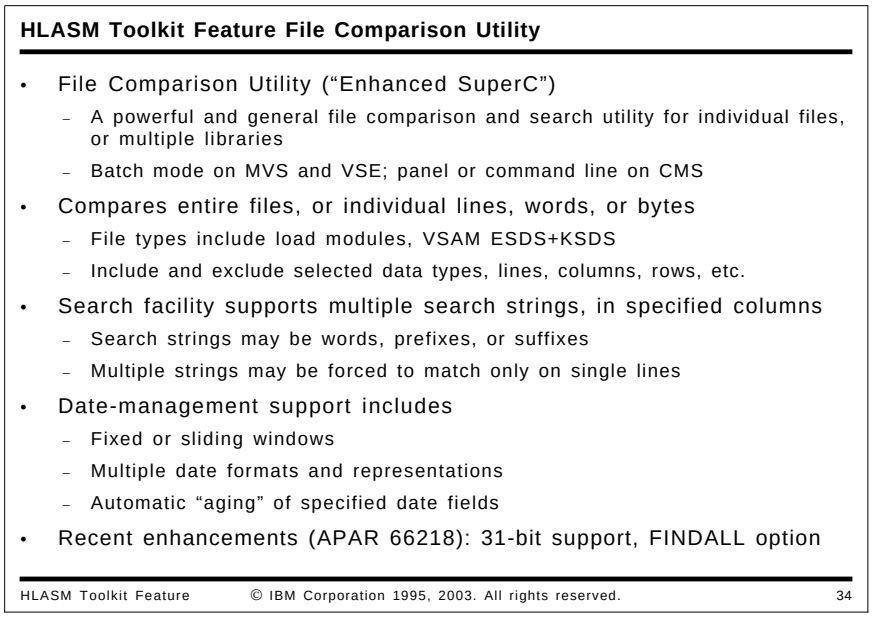
  ```
  IF (LTR,R5,R5,P),AND,(LTR,R6,R7,P)
  ```

  the second load and test (LTR) instruction will *not* be executed if the first LTR sets a negative or zero condition code, as the macros "know" that the expression must return false after only the first part has been evaluated.

  A small reminder about Boolean logic: you can sometime simplify the operands of a test by rewriting expressions:

  ```
  NOT (A AND B)   is equivalent to   ((NOT A) OR (NOT B))
  ```

- Most of the original limitations of these macros have been removed. (They were caused by previous assemblers having fixed array sizes; in HLASM, arrays are dynamic in nature and will grow as required.) One limitation remains: Boolean expressions are limited to fifty (50) operands. This count includes any operators such as AND, OR, etc.
- The use of parentheses in Boolean expressions is optional, but may assist with the understanding of the logic.
- Some "keys" required for correct operand parsing should not be used as ordinary program symbols: P, M, O, Z, H, L, E, NP, NM, NO, NZ, NH, NL, NE, GT, LE, EQ, LT, GE, AND, OR, ANDIF, ORIF.
- Because the macros do not generate relative branch instructions, a base register is required for the generated code.



HLASM Toolkit Feature File Comparison Utility

The High Level Assembler Toolkit Feature File Comparison Utility, also known as Enhanced SuperC, is a versatile program that can be used to compare two sets of data (using the Comparison Facility) or to search a specific set of data for a nominated search string (using the Search Facility).

Enhanced SuperC executes in batch mode on MVS and VSE, and on VM via a CMS panel or command line interface. You can compare sequential files, or select multiple or all members of libraries. You can also compare VSAM files on MVS and VSE.

Enhanced SuperC's Comparison Facility requires only the names of the two items to be compared. The Search Facility requires only the name of the item to be searched and the search string to be used. You can tailor the comparison or search according to your requirements, using process statements and process options.

With the Comparison Facility, you can:

- compare single files, or multiple files in one or more libraries
- specify the “level” of comparison (file, line, word or byte)
- exclude certain data from the comparison, such as specific sets of rows or columns, or records (such as page headings) containing specified character strings.
- restrict the comparison to certain types of data
- control the type of listing output produced
- specify that an update file be produced
- compare two files that have been reformatted (reformatted files contain such differences as indentation level changes, spaces inserted or deleted)
- detect word changes within documents
- stop immediately when a difference is detected.

Enhanced SuperC's Search Facility lets you specify:

- one or more search strings
- if multiple search strings are sought, whether they are independent of each other or if they must be present on the same line of the member/file being searched
- if the search string is a word, a prefix, or a suffix
- the position in the line of a search string
- the number of lines to be listed which appear before and after the line where the search string was found.

Enhanced SuperC is also a valuable tool for managing post-Y2K date comparisons (such as for "windowing" of two-digit years). It supports:

- many different date formats (particularly in regard to 2-digit and 4-digit year representations)
- a fixed "window" where date comparisons will take place within fixed year boundaries
- a sliding "window" where the year range is based on the current year
- the ability to compare files where the fields have different formats, such as one file having 4-digit year values and the other having 2-digit year values
- comparing year data where a year value is compressed in one file and uncompressed in the other
- the ability to successfully compare data, reports, forms, screens, and panels where data has moved within a line due to adding century digits to 2-digit years.

Complex date comparisons may be performed on dates in many formats, while including or excluding specified sets of rows (lines) and/or columns. (The description in the manual section titled "Year 2000 Date Definitions" is very generally useful, despite its title!)

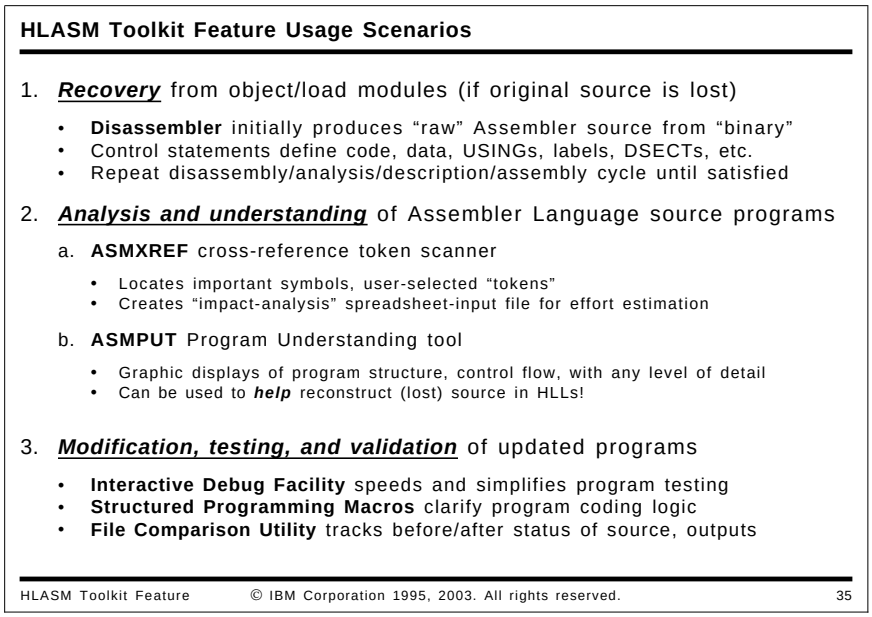
The year Date Aging option "ages" all of the defined dates in either the new or old file: a specified number of years is added to the "year" portion of each designated date in the file before they are compared.[1]

Date Definition statements define the location and format of date fields in the input file. Dates may be described in a wide variety of formats, including allowing "separator" characters (such as : or /). Internal representations supported include character, zoned decimal, packed decimal, and unsigned packed decimal (hex).

The Y2PAST option uses a fixed or sliding window to specify a 100-year period for determining the century-part of a date when only a 2-digit year appears in the data.

---

[1] Aging dates and comparing them is not always straightforward, due to leap years. See Appendix A ("Other Matters to Consider Before You Test") in the Redbook *VisualAge 2000 Test Solution: Testing Your Year 2000 Conversion*, SG24-2230-01.



HLASM Toolkit Feature Usage Scenarios

We will describe how you might use the High Level Assembler Toolkit Feature for typical program recovery, development, analysis, conversion, and maintenance tasks. These three scenarios show how the challenges of such tasks can be completed with greater speed and simplicity using the Toolkit Feature.

The Toolkit Feature components will be described in three scenarios:

- recovery and reconstruction of symbolic Assembler Language source code
- analysis and understanding of complex Assembler Language programs
- modification, testing, and validation of applications.

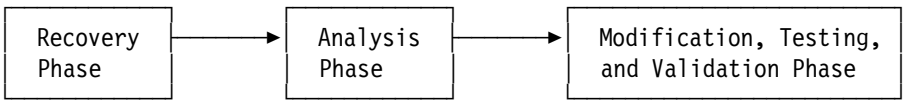


Figure 25. Typical Scenarios for Toolkit Feature Usage

1. ***Recovery and reconstruction*** of Assembler Language source statements from object/load modules for which the original source is lost. The Disassembler initially produces non-symbolic Assembler Language source from object code. You can add control statements iteratively to help define code, data, USINGs, labels, and DSECTs symbolically.

2. ***Analysis and understanding*** of Assembler Language source programs can benefit from three Toolkit components: the Cross-Reference Facility, the Program Understanding Tool, and the Interactive Debug Facility.

   a. The Cross-Reference Facility source analyzer and token scanner can be used to locate important symbols, user-selected tokens, macro calls, inter-module references, and other helpful data. ASMXREF can also create an “impact-analysis” file for input to a spreadsheet application for effort estimation and impact assessment. Another ASMXREF output is a tagged Assembler Language source file: when assembled with the ADATA option, this file produces a SYSADATA file for you to use with the Program Understanding Tool.

   b. The Program Understanding Tool provides graphic displays of program structure, control flow, a simplified listing, and other views with any desired level of detail. With the ADATA file created

from the tagged source produced by ASMXREF, key areas of the program can be rapidly located and analyzed.

c. The Interactive Debug Facility is by design a “program understanding” tool that lets you monitor the behavior of programs at every level of detail. Data flows may be monitored and traced among registers and storage, even showing the operations of individual instructions!

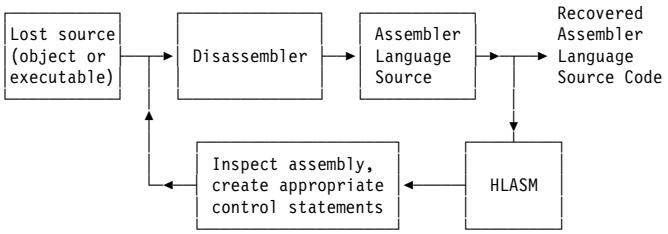
   This scenario is sometimes called the “Discovery” phase of application development, when program understanding and impact analysis are key activities.

Note that the combination of Disassembler, Cross-Reference Facility, and Program Understanding Tool can be used to help reconstruct lost source in compiled High Level Languages.

3. ***Modification and testing*** of updated programs is simplified by using the powerful Interactive Debug Facility. At the same time, program logic can be simplified by replacing complex test/branch logic with the Structured Programming Macros. These activities are typical of the “Development” phase of application development.

   Validation: At each stage where the application has been changed, you will probably want to compare its “pre-modification” output to its “post-modification” output, retaining the output files (sometimes called “base logs”) for subsequent validation tests. The File Comparison Utility Enhanced SuperC is designed specifically for such tasks. Validation, in the form of extensive testing, is the final important milestone on the road to application “Deployment”.

HLASM Toolkit Feature: Recovery and Reconstruction



- Start with object code (object files or executables)
- Disassemble and inspect; create control statements to describe the program more fully
- Repeat this cycle as more of the program is understood
- Readable source is used as input to later phases

HLASM Toolkit Feature 36

Recovery and Reconstruction

During the Recovery and Reconstruction phase, you will typically begin with a program in object or executable format (except CMS MODULEs). Using the Disassembler and by providing suitable control statements, you can create an Assembler Language source program with as much structure and symbolic labeling as you like.

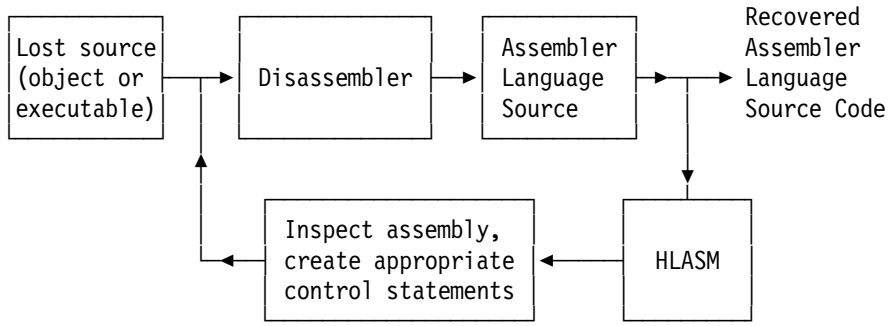
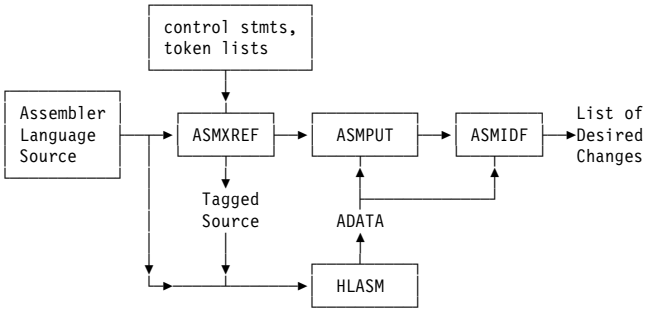


Figure 26. Toolkit Feature: Recovery and Reconstruction Scenario

The disassembly/analysis/description/assembly cycle may be repeated until satisfactory Assembler Language source code is obtained.

The initial steps do not require reassembly of the generated Assembler Language source, as appropriate control statements are usually easy to determine from the Disassembler's listing. As the recovered program approaches its final form, you should assemble it with HLASM to ensure the validity of your new source program.

HLASM Toolkit Feature: Analysis and Understanding



- ASMXREF scans assembler source programs, identifies key items
  - Create “tagged” source file identifying important “tokens”
- Assemble; ASMPUT uses ADATA to analyze control flows
- Use IDF to trace data flows in detail

HLASM Toolkit Feature 37

Analysis and Understanding

The most complex aspect of application maintenance and migration is analyzing and understanding the code. There are three components of Toolkit Feature that can help:

- ASMXREF can locate all uses of a variable name or any character string. A tagged Assembler Language source program may also be produced.
- ASMPUT provides graphical views of control flows within and among programs and modules.
- The Interactive Debug Facility helps you monitor and track the behavior of individual instructions and data items.

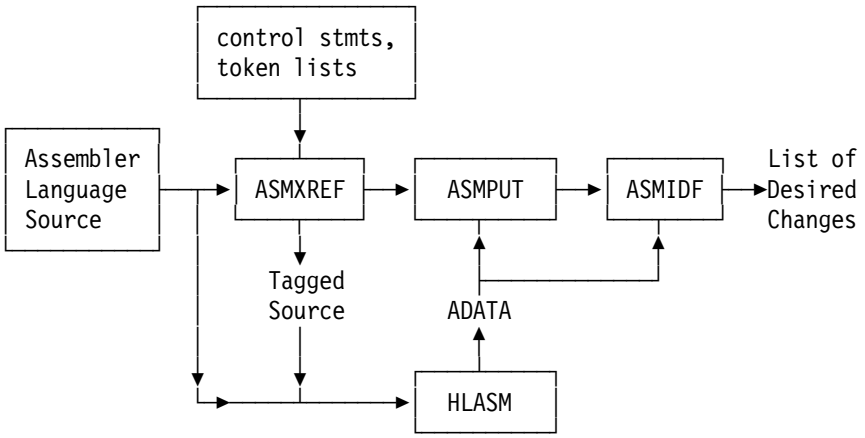
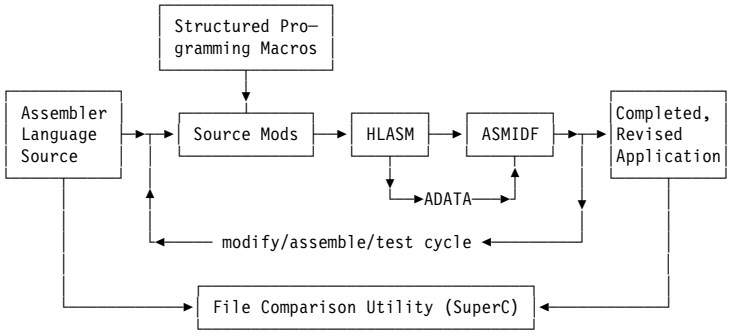


Figure 27. Toolkit Feature: Analysis and Understanding Scenario

While each of these components has valuable capabilities, using them in combination can provide great synergy in analyzing and understanding program behavior.

HLASM Toolkit Feature: Modification and Testing



- Modify Assembler Language source at desired points
- Assemble and execute the program, test with IDF
- Make indicated modifications until result is satisfactory
- Compare original and updated source files to validate changes

HLASM Toolkit Feature 38

Modification and Testing

After you have used the Toolkit's disassembler, ASMXREF, and ASMPUT components to determine the needed modifications, the Structured Programming Macros can be added to simplify the coding and logic of the program.

The Enhanced SuperC comparison utility can then be used to compare the original and updated source files to validate the placement and coverage extent of all modifications.

You can then test the updated code using the rich and flexible features of the Interactive Debug Facility. After each assembly/debug cycle, you can further modify the source code, repeating the process until the completed application is accepted for installation in a production library.

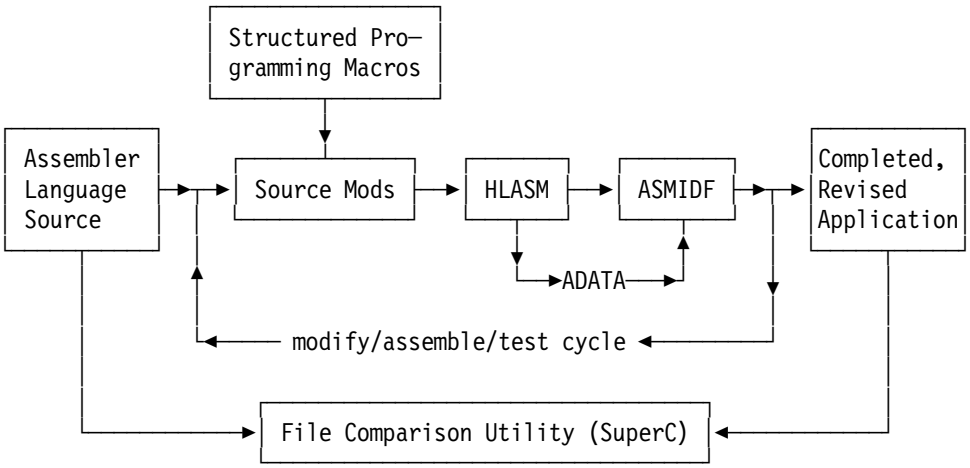
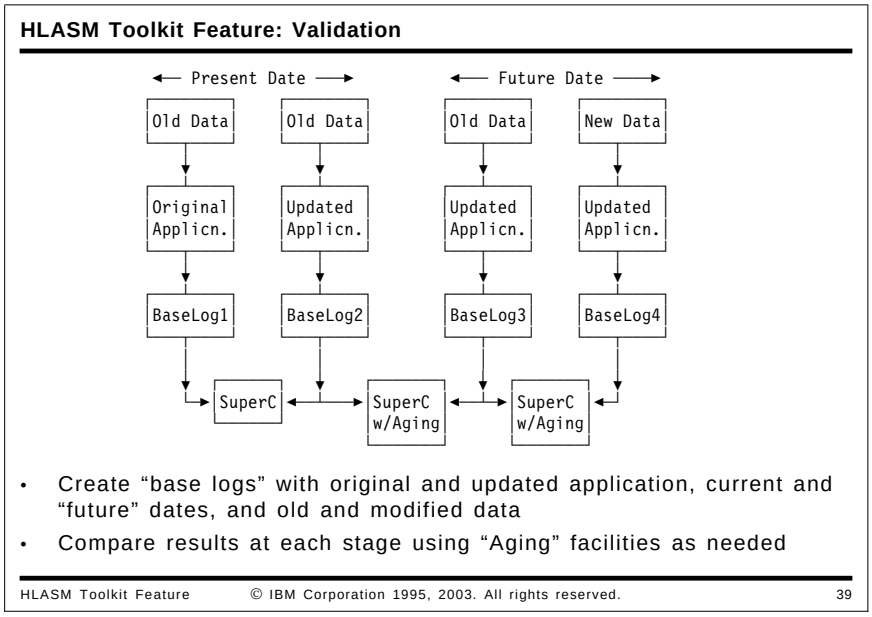


Figure 28. Toolkit Feature: Modification and Testing Scenario



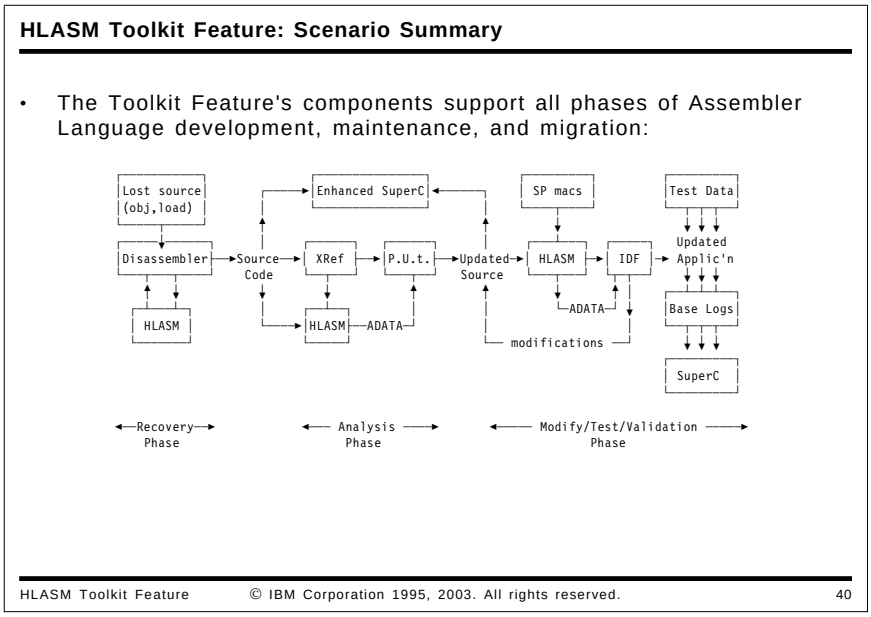
Validation

After some set of modifications has been made to the application, you will probably need to validate its operation. Typical steps in such a process include the following:

1. Run the original unmodified program with a representative set of “old data”, and with the current date set to some manageable “current” date prior to the selected starting date.
2. Run the modified program with the same set of “old data” and the same current date. (There are many techniques available for setting chosen “current” dates on a system.)
3. Use Enhanced SuperC to compare the outputs to ensure that no regressions have been introduced into the existing function of the application. If some date fields have been expanded (such as in report headings), use the date-format facilities of Enhanced SuperC to specify how they should be expanded and compared.
4. Run the modified program with the same “old data” and a new current date.

5. Use Enhanced SuperC to compare these new outputs with the previous two, using Enhanced SuperC's “aging” facilities to ensure correct current-date-dependent behavior.
6. Run the modified program with “new data” and the same new current date.
7. Use Enhanced SuperC to compare the outputs, using “aging” facilities to validate data-dependent behavior.

While not a complete support plan, the above steps are typical of date-sensitive and date-windowing migration and maintenance activities. At each stage, the File Comparison Utility can provide powerful insights into the extent and correctness of code modifications.



These scenarios illustrate how the High Level Assembler Toolkit Feature provides a varied and powerful set of tools supporting all aspects of application development, maintenance, enhancement, and testing. The following figure summarizes these capabilities:

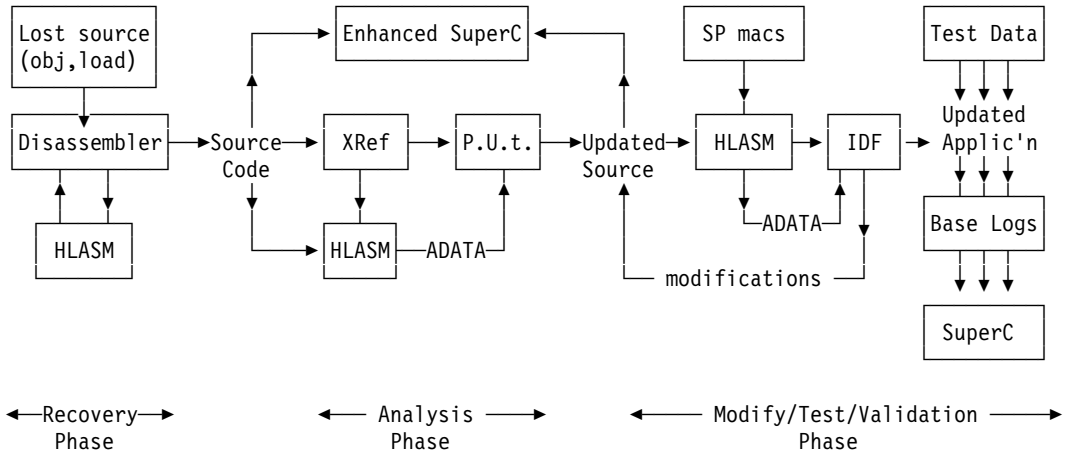
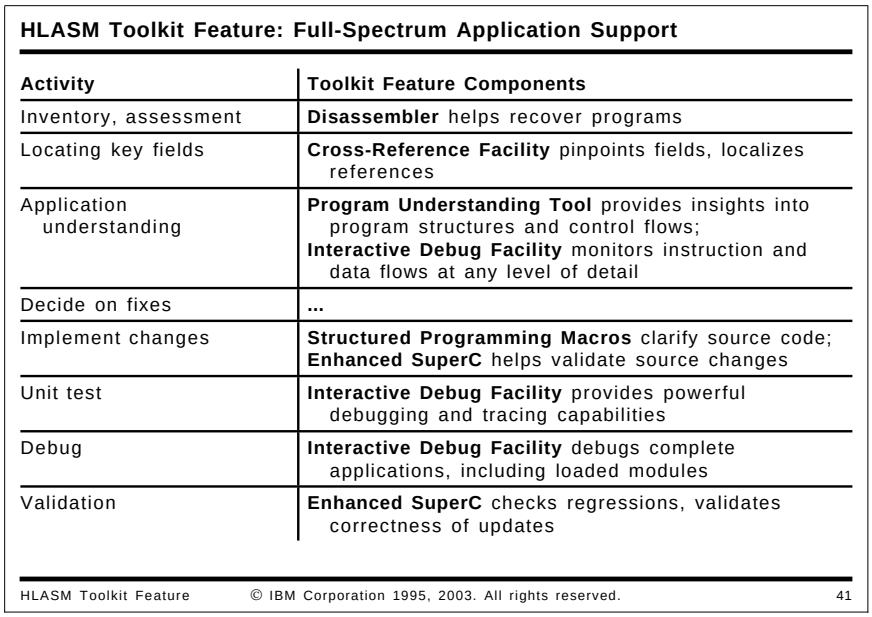


Figure 29. Toolkit Feature: Summary of Usage Scenarios

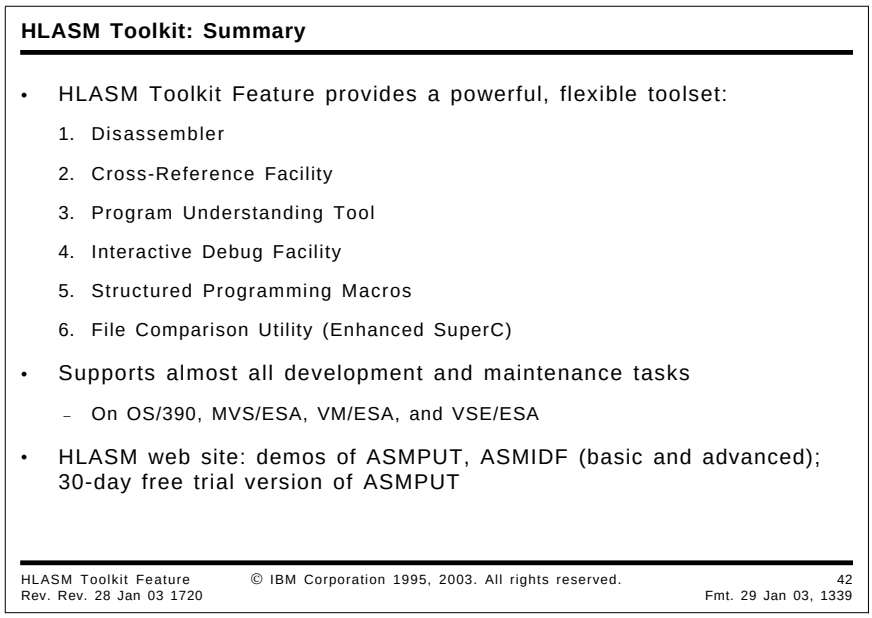


HLASM Toolkit Feature: Full-Spectrum Application Support

A typical process for managing the full spectrum of application recovery, development, debugging, and maintenance activities includes several steps. Figure 30 shows the Toolkit Feature tools useful in each step.

Figure 30. Toolkit Feature Components and Full-Spectrum Application Support

Activity	**Toolkit Feature Components**
Inventory and assessment	The **Disassembler** can help recover programs previously unretrievable or unmodifiable.
Locating fields and their uses	The **Cross-Reference Facility** pinpoints fields and localizes references to them.
Application understanding	The **Program Understanding Tool** provides powerful insights into program structures and control flows. The **Interactive Debug Facility** monitors instruction and data flows at any level of detail.
Decide on fixes and methods	
Implement changes	The **Structured Programming Macros** clarify source coding by reducing the need for coding branches and tests, replacing them with readable structures. **Enhanced SuperC** helps verify that source changes are complete.
Unit test	The **Interactive Debug Facility** provides powerful debugging and tracing capabilities for verifying the correctness of changes.
Debug	The **Interactive Debug Facility** helps debug complete applications, including dynamically loaded modules.
Validation	**Enhanced SuperC** checks regressions, validates correctness of updates



Summary

As the preceding examples have shown, the High Level Assembler Toolkit Feature provides a flexible, comprehensive, and powerful set of tools that support many of your application development and maintenance tasks.

Appendix A. Sample structured macro program

```
SAMPLE   CSECT
         BALR  R12,0
         USING *,R12
         IF    AR,R2,R3,NZ,OR,                                  X
               (CLI,WORD1,EQ,X'C1'),ORIF,                       X
               H,AND,                                           X
               CLM,R2,M1,LT,DEC(BASEREG)
           LA  R3,X'01'
           DO  WHILE=(7),UNTIL=(ICM,R2,M1,D2(B2),NZ)
           DOEXIT M
             LA  R3,X'02'
           DOEXIT (CLCL,R2,NL,R4),ANDIF,                        X
               ICM,R2,M1,D2(B2),Z,OR,                           X
               LTR,R2,R3,M,ORIF,                                X
               10,AND,                                          X
               (CR,R2,NM,R3)
             LA  R3,X'03'
             STRTSRCH  WHILE=(CLM,R2,M1,GE,D2(B2)),UNTIL=P
             EXITIF  Z,AND,                                     X
               LTR,R2,R3,0,ORIF,                                X
               (CLC,DEC(L,B),EQ,=C'WORD'),AND,                  X
               NP
               LA  R3,X'04'
             ORELSE
               LA  R3,X'05'
             EXITIF  CC=5
               LA  R3,X'06'
             ENDLOOP
               LA  R3,X'07'
             ENDSRCH
           DOEXIT  CC=10
           ENDDO
             LA  R3,X'08'
           IF  (5),ORIF,                                        X
               (CR,R2,NE,R3),ANDIF,                             X
               P,AND,                                           X
               (ICM,R2,M1,D2(B2),0),ORIF,                       X
               CL,R2,LT,D2(B2),OR,                              X
               (LTR,R2,R3,Z)
             LA  R3,X'09'
           ELSE
             LA  R3,X'0A'
           ENDIF
         ENDIF
*
         IF    AR,R2,R3,Z,OR,                                   X
               CR,R3,EQ,R4,AND,                                 X
               AR,R2,R4,NZ,OR,                                  X
               CR,R2,NE,R3
           LA  R3,X'10'
         ENDIF
```

```
*
         IF    AR,R2,R3,Z,AND,                                  X
               CR,R3,EQ,R4,OR,                                  X
               AR,R2,R4,NZ,AND,                                 X
               CR,R2,NE,R3
           LA  R3,X'11'
         ENDIF
*
         IF    AR,R2,R3,Z,ORIF,                                 X
               CR,R3,EQ,R4,ANDIF,                               X
               AR,R2,R4,NZ,ORIF,                                X
               CR,R2,NE,R3
           LA  R3,X'12'
         ENDIF
*
         IF    AR,R2,R3,Z,ANDIF,                                X
               CR,R3,EQ,R4,ORIF,                                X
               AR,R2,R4,NZ,ANDIF,                               X
               CR,R2,NE,R3
           LA  R3,X'13'
         ENDIF
*
         DO    INF
           LA  R5,X'00'
         DOEXIT  (0)
           LA  R5,X'05'
           DO  FROM=(R3,10),TO=(R4,-1)
             LA  R5,X'0A'
           DOEXIT  (CR,R3,E,R5)
             LA  R5,X'0F'
             DO  WHILE=(NR,R2,R4,Z)
               LA  R5,X'10'
             DOEXIT  (NZ)
               LA  R5,X'15'
             ENDDO
             LA  R5,X'1A'
           ENDDO
           LA  R5,X'1F'
         ENDDO
*
         CASENTRY  R4,POWER=3
         CASE  (16,32)
           LA  R4,X'03'
           CASENTRY  R4,VECTOR=BR
             LA  R2,X'10'
           CASE  1,3,4
             LA  R3,X'20'
           CASE  5
             LA  R3,X'30'
           ENDCASE
           CASENTRY  R4,POWER=1,VECTOR=B
           CASE  4
             LA  R3,X'40'
           CASE (2)
             LA  R3,X'50'
           ENDCASE
```

```
         CASE  24
           CASENTRY  R4,POWER=0
           CASE  1
             SELECT  C,R2,GE
               WHEN (=F'100')
                 LA   R0,3
               WHEN (=F'1000')
                 LA   R0,4
               WHEN (=F'10000')
                 LA   R0,5
               OTHRWISE
                 LA   R0,10
               ENDSEL
             LA  R3,X'60'
           CASE  2
             LA  R3,X'70'
           ENDCASE
         ENDCASE
*
         SELECT  CLC,WORD1,EQ
           WHEN  (=C'+',=C'-')
             LA    R0,1
           WHEN  (=C'*',=C'/')
             LA    R0,2
           OTHRWISE
             SR    R0,R0
             CASENTRY  R4,POWER=2
             CASE  8
               LA  R3,X'80'
             ENDCASE
           ENDSEL
*
WORD1    DC    CL1'A'
B        EQU   4
BASEREG  EQU   5
B2       EQU   6
DEC      EQU   16
D2       EQU   32
L        EQU   64
LENGTH   EQU   4
M1       EQU   6
R0       EQU   0
R1       EQU   1
R2       EQU   2
R3       EQU   3
R4       EQU   4
R5       EQU   5
R6       EQU   6
R12      EQU   12
         END   SAMPLE
```

Appendix B. Listing of sample program

```
                                    High Level Assembler Option Summary                 (PTF UQ72178)   Page    1
                                                                                       HLASM R4.0  2003/01/29 12.02
  No Overriding ASMAOPT Parameters
  Overriding Parameters-  Profile(ASMMSP),LineCount(0),List(121)
  Process Statements-     NoESD,NoRLD,NoXref,NoRXref,NoMXref,NoUsing,PControl(NoUHead)


  Options for this Assembly
  NOADATA
    ALIGN
    ASA
    BATCH
    CODEPAGE(047C)
  NOCOMPAT
  NODBCS
  NODECK
    DXREF
5 NOESD
  NOEXIT
    FLAG(0,ALIGN,CONT,NOEXLITW,NOIMPLEN,PAGE0,PUSH,RECORD,SUBSTR,USING0)
  NOFOLD
  NOGOFF
  NOINFO
    LANGUAGE(EN)
  NOLIBMAC
3   LINECOUNT(0)
3   LIST(121)
5 NOMXREF
    OBJECT
    OPTABLE(UNI,NOLIST)
5   PCONTROL(NOUHEAD)
  NOPESTOP
3   PROFILE(ASMMSP)
  NORA2
  NORENT
5 NORLD
5 NORXREF
    SIZE(MAX,ABOVE)
    SYSPARM()
    TERM(NARROW)
  NOTEST
  NOTHREAD
  NOTRANSLATE
5 NOUSING
5 NOXREF

  No Overriding DD Names
                                                                                                        Page    2
  Loc  Object Code    Addr1 Addr2  Stmt   Source Statement                                HLASM R4.0  2003/01/29 12.02
                                      1 *PROCESS NoESD,NoRLD,NoXref,NoRXref,NoMXref,NoUsing,PControl(NoUHead)
                                      2          COPY ASMMSP   Generated for PROFILE option
                                   1356 *        PRINT OFF,NOPRINT
                                   1357 *        COPY  ASMMSP
                                   1358 *        PRINT ON,NOPRINT
000000                00000 002EE  1359 SAMPLE   CSECT
000000 05C0                        1360          BALR  R12,0
                 R:C  00002        1361          USING *,R12
                                   1362          IF    AR,R2,R3,NZ,OR,                                   X
                                                       (CLI,WORD1,EQ,X'C1'),ORIF,                        X
                                                       H,AND,                                            X
                                                       CLM,R2,M1,LT,DEC(BASEREG)
000002 1A23                        1382+                  AR              R2,R3                           03-ASMMP
000004 4770 C01A           0001C   1383+                  BC              7,#@LB2                         03-ASMMP
000008 95C1 C2D2           002D4   1384+                  CLI             WORD1,X'C1'                     03-ASMMP
00000C 4780 C01A           0001C   1385+                  BC              8,#@LB2                         03-ASMMP
000010 47D0 C0CC           000CE   1386+                  BC              15-2,#@LB1                      03-ASMMP
000014 BD26 5010           00010   1387+                  CLM R2,M1,DEC(BASEREG)                          03-ASMMP
000018 47B0 C0CC           000CE   1388+            BC           15-4,#@LB1                              02-ASMMI
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00001C                          1389+#@LB2              DC  0H                                  02-ASMMI
00001C 4130 0001        00001   1390            LA  R3,X'01'
                                1391            DO  WHILE=(7),UNTIL=(ICM,R2,M1,D2(B2),NZ)
000020                          1397+#@LB4              DC 0H                                  02-ASMMD
000020 4780 C098        0009A   1405+                BC              15-7,#@LB3             04-ASMMP
                                1415            DOEXIT M
000024 4740 C098        0009A   1422+            BC              4,#@LB3                    02-ASMMI
000028 4130 0002        00002   1423              LA  R3,X'02'
                                1424            DOEXIT (CLCL,R2,NL,R4),ANDIF,                          X
                                                    ICM,R2,M1,D2(B2),Z,OR,                             X
                                                    LTR,R2,R3,M,ORIF,                                  X
                                                    10,AND,                                            X
                                                    (CR,R2,NM,R3)
00002C 0F24                     1449+                CLCL            R2,R4                  03-ASMMP
00002E 4740 C03E        00040   1450+                BC              15-11,#@LB12           03-ASMMP
000032 BF26 6020        00020   1451+                ICM R2,M1,D2(B2)                       03-ASMMP
000036 4780 C098        0009A   1452+                BC              8,#@LB3                03-ASMMP
00003A 1223                     1453+                LTR             R2,R3                  03-ASMMP
00003C 4740 C098        0009A   1454+                BC              4,#@LB3                03-ASMMP
000040                          1455+#@LB12          DC              0H                     03-ASMMP
000040 4750 C048        0004A   1456+                BC              15-10,#@LB14           03-ASMMP
000044 1923                     1457+                CR              R2,R3                  03-ASMMP
000046 47B0 C098        0009A   1458+            BC              11,#@LB3                   02-ASMMI
00004A                          1459+#@LB14             DC  0H                                 02-ASMMI
00004A 4130 0003        00003   1460              LA  R3,X'03'
                                1461              STRTSRCH  WHILE=(CLM,R2,M1,GE,D2(B2)),UNTIL=P
00004E                          1468+#@LB17             DC 0H                                  02-ASMMD
00004E BD26 6020        00020   1477+                CLM R2,M1,D2(B2)                       04-ASMMP
000052 4740 C088        0008A   1478+                BC              15-11,#@LB16           04-ASMMP
                                1488              EXITIF  Z,AND,                                         X
                                                    LTR,R2,R3,0,ORIF,                                  X
                                                    (CLC,DEC(L,B),EQ,=C'WORD'),AND,                    X
                                                    NP
000056 4770 C05E        00060   1508+                BC              15-8,#@LB23            03-ASMMP
00005A 1223                     1509+                LTR             R2,R3                  03-ASMMP
00005C 4710 C06C        0006E   1510+                BC              1,#@LB24               03-ASMMP
000060                          1511+#@LB23          DC              0H                     03-ASMMP
000060 D53F 4010 C2D6 00010 002D8 1512+              CLC             DEC(L,B),=C'WORD'      03-ASMMP
000066 4770 C074        00076   1513+                BC              15-8,#@LB25            03-ASMMP
00006A 4720 C074        00076   1514+            BC          15-13,#@LB25                   02-ASMMI
00006E                          1515+#@LB24             DC  0H                                 02-ASMMI
00006E 4130 0004        00004   1516                LA  R3,X'04'
                                1517              ORELSE
000072 47F0 C08C        0008E   1520+              BC              15,#@LB15                  01-00874
000076                          1521+#@LB25             DS  0H                                 01-00875
000076 4130 0005        00005   1522                LA  R3,X'05'
                                1523              EXITIF  CC=5
00007A 47A0 C084        00086   1528+            BC          15-5,#@LB26                    02-ASMMI
00007E 4130 0006        00006   1529                LA  R3,X'06'
                                1530              ENDLOOP
000082 47F0 C08C        0008E   1532+            BC              15,#@LB15                  01-00628
000086                          1533+#@LB26             DS  0H                                 01-00629
000086                          1535+#@LB20          DC              0H                     02-ASMMP
000086 47D0 C04C        0004E   1536+                BC              15-2,#@LB17            02-ASMMP
00008A                          1537+#@LB16                DC                   OH             02-ASMMP
00008A 4130 0007        00007   1538                LA  R3,X'07'
                                1539              ENDSRCH
00008E                          1542+#@LB15             DS  0H                                 01-00758
                                1543            DOEXIT  CC=10
00008E 47A0 C098        0009A   1548+            BC              10,#@LB3                   02-ASMMI
                                1549            ENDDO
000092                          1552+#@LB7           DC              0H                     02-ASMMP
000092 BF26 6020        00020   1553+                ICM R2,M1,D2(B2)                       02-ASMMP
000096 4780 C01E        00020   1554+                BC              15-7,#@LB4             02-ASMMP
00009A                          1555+#@LB3                 DC                   OH             02-ASMMP
00009A 4130 0008        00008   1557              LA  R3,X'08'
                                1558            IF  (5),ORIF,                                          X
                                                    (CR,R2,NE,R3),ANDIF,                               X
                                                    P,AND,                                             X
                                                    (ICM,R2,M1,D2(B2),0),ORIF,                         X
                                                    CL,R2,LT,D2(0,B2),OR,                              X
                                                    (LTR,R2,R3,Z)
00009E 4750 C0A6        000A8   1589+                BC              5,#@LB31               03-ASMMP
0000A2 1923                     1590+                CR              R2,R3                  03-ASMMP
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0000A4 4780 C0B2          000B4  1591+               BC              15-7,#@LB30                    03-ASMMP
0000A8                           1592+#@LB31         DC              0H                             03-ASMMP
0000A8 47D0 C0B2          000B4  1593+               BC              15-2,#@LB30                    03-ASMMP
0000AC BF26 6020          00020  1594+               ICM R2,M1,D2(B2)                               03-ASMMP
0000B0 4710 C0C0          000C2  1595+               BC              1,#@LB32                       03-ASMMP
0000B4                           1596+#@LB30         DC              0H                             03-ASMMP
0000B4 5520 6020          00020  1597+               CL              R2,D2(0,B2)                    03-ASMMP
0000B8 4740 C0C0          000C2  1598+               BC              4,#@LB32                       03-ASMMP
0000BC 1223                      1599+               LTR             R2,R3                          03-ASMMP
0000BE 4770 C0C8          000CA  1600+             BC          15-8,#@LB33                        02-ASMMI
0000C2                           1601+#@LB32                 DC  0H                                 02-ASMMI
0000C2 4130 0009          00009  1602               LA  R3,X'09'
                                 1603             ELSE
0000C6 47F0 C0CC          000CE  1606+               BC             15,#@LB34                      01-00348
0000CA                           1607+#@LB33                 DS  0H                                 01-00350
0000CA 4130 000A          0000A  1608               LA  R3,X'0A'
                                 1609             ENDIF
0000CE                           1612+#@LB34                 DS  0H                                 01-00569
                                 1613           ENDIF
0000CE                           1616+#@LB1                  DS  0H                                 01-00569
                                 1617 *
                                 1618           IF    AR,R2,R3,Z,OR,                             X
                                                      CR,R3,EQ,R4,AND,                           X
                                                      AR,R2,R4,NZ,OR,                            X
                                                      CR,R2,NE,R3
0000CE 1A23                      1639+               AR              R2,R3                          03-ASMMP
0000D0 4780 C0E4          000E6  1640+               BC              8,#@LB36                       03-ASMMP
0000D4 1934                      1641+               CR              R3,R4                          03-ASMMP
0000D6 4770 C0E8          000EA  1642+               BC              15-8,#@LB35                    03-ASMMP
0000DA 1A24                      1643+               AR              R2,R4                          03-ASMMP
0000DC 4770 C0E4          000E6  1644+               BC              7,#@LB36                       03-ASMMP
0000E0 1923                      1645+               CR              R2,R3                          03-ASMMP
0000E2 4780 C0E8          000EA  1646+             BC          15-7,#@LB35                        02-ASMMI
0000E6                           1647+#@LB36                 DC  0H                                 02-ASMMI
0000E6 4130 0010          00010  1648               LA  R3,X'10'
                                 1649           ENDIF
0000EA                           1652+#@LB35                 DS  0H                                 01-00569
                                 1653 *
                                 1654           IF    AR,R2,R3,Z,AND,                            X
                                                      CR,R3,EQ,R4,OR,                            X
                                                      AR,R2,R4,NZ,AND,                           X
                                                      CR,R2,NE,R3
0000EA 1A23                      1675+               AR              R2,R3                          03-ASMMP
0000EC 4770 C104          00106  1676+               BC              15-8,#@LB37                    03-ASMMP
0000F0 1934                      1677+               CR              R3,R4                          03-ASMMP
0000F2 4780 C100          00102  1678+               BC              8,#@LB38                       03-ASMMP
0000F6 1A24                      1679+               AR              R2,R4                          03-ASMMP
0000F8 4780 C104          00106  1680+               BC              15-7,#@LB37                    03-ASMMP
0000FC 1923                      1681+               CR              R2,R3                          03-ASMMP
0000FE 4780 C104          00106  1682+             BC          15-7,#@LB37                        02-ASMMI
000102                           1683+#@LB38                 DC  0H                                 02-ASMMI
000102 4130 0011          00011  1684               LA  R3,X'11'
                                 1685           ENDIF
000106                           1688+#@LB37                 DS  0H                                 01-00569
                                 1689 *
                                 1690           IF    AR,R2,R3,Z,ORIF,                           X
                                                      CR,R3,EQ,R4,ANDIF,                         X
                                                      AR,R2,R4,NZ,ORIF,                          X
                                                      CR,R2,NE,R3
000106 1A23                      1715+               AR              R2,R3                          03-ASMMP
000108 4780 C110          00112  1716+               BC              8,#@LB40                       03-ASMMP
00010C 1934                      1717+               CR              R3,R4                          03-ASMMP
00010E 4770 C116          00118  1718+               BC              15-8,#@LB39                    03-ASMMP
000112                           1719+#@LB40         DC              0H                             03-ASMMP
000112 1A24                      1720+               AR              R2,R4                          03-ASMMP
000114 4770 C11C          0011E  1721+               BC              7,#@LB41                       03-ASMMP
000118                           1722+#@LB39         DC              0H                             03-ASMMP
000118 1923                      1723+               CR              R2,R3                          03-ASMMP
00011A 4780 C120          00122  1724+             BC          15-7,#@LB42                        02-ASMMI
00011E                           1725+#@LB41                 DC  0H                                 02-ASMMI
00011E 4130 0012          00012  1726               LA  R3,X'12'
                                 1727           ENDIF
000122                           1730+#@LB42                 DS  0H                                 01-00569
                                 1731 *
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                                1732          IF    AR,R2,R3,Z,ANDIF,                                      X
                                                    CR,R3,EQ,R4,ORIF,                                      X
                                                    AR,R2,R4,NZ,ANDIF,                                     X
                                                    CR,R2,NE,R3
000122 1A23                     1757+                  AR              R2,R3                                 03-ASMMP
000124 4770 C12C        0012E   1758+                  BC              15-8,#@LB43                           03-ASMMP
000128 1934                     1759+                  CR              R3,R4                                 03-ASMMP
00012A 4780 C132        00134   1760+                  BC              8,#@LB44                              03-ASMMP
00012E                          1761+#@LB43            DC              0H                                    03-ASMMP
00012E 1A24                     1762+                  AR              R2,R4                                 03-ASMMP
000130 4780 C13C        0013E   1763+                  BC              15-7,#@LB45                           03-ASMMP
000134                          1764+#@LB44            DC              0H                                    03-ASMMP
000134 1923                     1765+                  CR              R2,R3                                 03-ASMMP
000136 4780 C13C        0013E   1766+            BC          15-7,#@LB45                                   02-ASMMI
00013A 4130 0013        00013   1767             LA  R3,X'13'
                                1768          ENDIF
00013E                          1771+#@LB45               DS  0H                                           01-00569
                                1772 *
                                1773          DO    INF
00013E                          1779+#@LB48               DC  0H                                           02-ASMMD
00013E 4150 0000        00000   1781             LA  R5,X'00'
                                1782          DOEXIT  (0)
000142 4710 C184        00186   1789+            BC              1,#@LB47                                 02-ASMMI
000146 4150 0005        00005   1790             LA  R5,X'05'
                                1791             DO  FROM=(R3,10),TO=(R4,-1)
00014A 4130 000A        0000A   1797+                   LA  R3,10                                        02-ASMMD
00014E 4840 C2E6        002E8   1798+              LH  R4,=H'-1'                                         02-ASMMD
000152                          1799+#@LB52               DC  0H                                           02-ASMMD
000152 4150 000A        0000A   1803               LA  R5,X'0A'
                                1804             DOEXIT  (CR,R3,E,R5)
000156 1935                     1812+                CR              R3,R5                                 03-ASMMP
000158 4780 C17C        0017E   1813+            BC              8,#@LB51                                 02-ASMMI
00015C 4150 000F        0000F   1814               LA  R5,X'0F'
                                1815               DO  WHILE=(NR,R2,R4,Z)
000160 47F0 C16E        00170   1821+                   BC              15,#@LB57                        02-ASMMD
000164                          1823+#@LB58                DC 0H                                         02-ASMMD
000164 4150 0010        00010   1832                 LA  R5,X'10'
                                1833               DOEXIT  (NZ)
000168 4770 C174        00176   1840+            BC              7,#@LB56                                 02-ASMMI
00016C 4150 0015        00015   1841                 LA  R5,X'15'
                                1842               ENDDO
000170                          1845+#@LB57              DC              0H                                02-ASMMP
000170 1424                     1846+                    NR              R2,R4                             02-ASMMP
000172 4780 C162        00164   1847+                    BC              8,#@LB58                          02-ASMMP
000176                          1848+#@LB56                   DC                    0H                     02-ASMMP
000176 4150 001A        0001A   1850               LA  R5,X'1A'
                                1851             ENDDO
00017A                          1854+#@LB53              DC              0H                                02-ASMMP
00017A 8734 C150        00152   1855+                    BXLE R3,R4,#@LB52                                 02-ASMMP
00017E                          1856+#@LB51                   DC                    0H                     02-ASMMP
00017E 4150 001F        0001F   1858             LA  R5,X'1F'
                                1859          ENDDO
000182 47F0 C13C        0013E   1862+                BC              15,#@LB48                             02-ASMMP
000186                          1863+#@LB47                DC                    0H                     02-ASMMP
                                1865 *
                                1866          CASENTRY  R4,POWER=3
000186 8A40 0001        00001   1870+             SRA R4,3-2                                               01-00190
00018A 5A40 C192        00194   1872+             A    R4,#@LB65                                           01-00203
00018E 5840 4000        00000   1873+             L    R4,0(,R4)                                           01-00204
000192 07F4                     1874+             BCR  15,R4                                               01-00205
000194 00000260                 1875+#@LB65             DC A(#@LB63)                                       01-00206
                                1876          CASE  (16,32)
000198                          1879+#@LB66               DS  0H                                           01-00115
000198 4140 0003        00003   1880             LA  R4,X'03'
                                1881             CASENTRY  R4,VECTOR=BR
00019C 8B40 0002        00002   1885+                SLA R4,2-0                                           01-00188
0001A0 47F4 C1B2        001B4   1886+             BC    15,#@LB67(R4)                                      01-00219
0001A4 4120 0010        00010   1887               LA  R2,X'10'
                                1888             CASE  1,3,4
0001A8                          1891+#@LB69               DS  0H                                           01-00115
0001A8 4130 0020        00020   1892               LA  R3,X'20'
                                1893             CASE  5
0001AC 47F0 C1CA        001CC   1896+              BC              15,#@LB68                              01-00113
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0001B0                          1897+#@LB70             DS  0H                                  01-00115
0001B0 4130 0030        00030   1898              LA  R3,X'30'
                                1899            ENDCASE
0001B4 47F0 C1CA        001CC   1901+#@LB67             BC          15,#@LB68                   01-00415
0001B8 47F0 C1A6        001A8   1902+               BC          15,#@LB69                   01-00430
0001BC 47F0 C1CA        001CC   1903+               BC          15,#@LB68                   01-00440
0001C0 47F0 C1A6        001A8   1904+               BC          15,#@LB69                   01-00430
0001C4 47F0 C1A6        001A8   1905+               BC          15,#@LB69                   01-00430
0001C8 47F0 C1AE        001B0   1906+               BC          15,#@LB70                   01-00430
0001CC                          1907+#@LB68             DS  0H                                  01-00445
                                1909            CASENTRY  R4,POWER=1,VECTOR=B
0001CC 8B40 0001        00001   1913+                SLA R4,2-1                                 01-00188
0001D0 47F4 C1DE        001E0   1914+            BC    15,#@LB71(R4)                         01-00219
                                1915            CASE  4
0001D4                          1918+#@LB73             DS  0H                                  01-00115
0001D4 4130 0040        00040   1919              LA  R3,X'40'
                                1920            CASE (2)
0001D8 47F0 C1EA        001EC   1923+              BC          15,#@LB72                       01-00113
0001DC                          1924+#@LB74             DS  0H                                  01-00115
0001DC 4130 0050        00050   1925              LA  R3,X'50'
                                1926            ENDCASE
0001E0 47F0 C1EA        001EC   1928+#@LB71             BC          15,#@LB72                   01-00415
0001E4 47F0 C1DA        001DC   1929+               BC          15,#@LB74                   01-00430
0001E8 47F0 C1D2        001D4   1930+               BC          15,#@LB73                   01-00430
0001EC                          1931+#@LB72             DS  0H                                  01-00445
                                1933          CASE  24
0001EC 5840 C25E        00260   1936+             L     R4,#@LB63                           01-00110
0001F0 07F4                     1937+             BCR   15,R4                               01-00111
0001F2                          1938+#@LB75             DS  0H                                  01-00115
                                1939            CASENTRY  R4,POWER=0
0001F2 8B40 0002        00002   1943+                SLA R4,2-0                                 01-00188
0001F6 5A40 C1FE        00200   1945+              A    R4,#@LB78                             01-00203
0001FA 5840 4000        00000   1946+              L    R4,0(,R4)                             01-00204
0001FE 07F4                     1947+              BCR  15,R4                                 01-00205
000200 0000024C                 1948+#@LB78           DC A(#@LB76)                          01-00206
                                1949            CASE  1
000204                          1952+#@LB79             DS  0H                                  01-00115
                                1953              SELECT  C,R2,GE
                                1957                WHEN (=F'100')
000204 5920 C2DA        002DC   1961+          C                   R2,=F'100'                  01-01130
000208 4740 C212        00214   1962+          BC          15-11,#@LB81                        01-01138
00020C 4100 0003        00003   1963                  LA    R0,3
                                1964                WHEN (=F'1000')
000210 47F0 C236        00238   1966+          BC            15,#@LB80           SKIP TO END   01-01106
000214                          1967+#@LB81             DS  0H                                  01-01109
000214 5920 C2DE        002E0   1970+          C                   R2,=F'1000'                 01-01130
000218 4740 C222        00224   1971+          BC          15-11,#@LB83                        01-01138
00021C 4100 0004        00004   1972                  LA    R0,4
                                1973                WHEN (=F'10000')
000220 47F0 C236        00238   1975+          BC            15,#@LB80           SKIP TO END   01-01106
000224                          1976+#@LB83             DS  0H                                  01-01109
000224 5920 C2E2        002E4   1979+          C                   R2,=F'10000'                01-01130
000228 4740 C232        00234   1980+          BC          15-11,#@LB85                        01-01138
00022C 4100 0005        00005   1981                  LA    R0,5
                                1982                OTHRWISE
000230 47F0 C236        00238   1984+          BC            15,#@LB80           SKIP TO END   01-00937
000234                          1985+#@LB85             DS  0H                                  01-00940
000234 4100 000A        0000A   1986                  LA    R0,10
                                1987                ENDSEL
000238                          1989+#@LB80             DS  0H                                  01-00702
000238 4130 0060        00060   1991              LA  R3,X'60'
                                1992            CASE  2
00023C 5840 C24A        0024C   1995+              L     R4,#@LB76                           01-00110
000240 07F4                     1996+              BCR   15,R4                               01-00111
000242                          1997+#@LB87             DS  0H                                  01-00115
000242 4130 0070        00070   1998              LA  R3,X'70'
                                1999            ENDCASE
000246 5840 C24A        0024C   2001+              L     R4,#@LB76                           01-00410
00024A 07F4                     2002+              BCR   15,R4                               01-00411
00024C 00000258                 2003+#@LB76           DC A(#@LB77)                          01-00412
000250 00000204                 2004+               DC    A(#@LB79)                       01-00428
000254 00000242                 2005+               DC    A(#@LB87)                       01-00428
000258                          2006+#@LB77             DS  0H                                  01-00445
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                                    2008          ENDCASE
000258 5840 C25E            00260   2010+             L     R4,#@LB63                                          01-00410
00025C 07F4                         2011+             BCR   15,R4                                              01-00411
00025E 0000                             +
000260 00000274                     2012+#@LB63               DC A(#@LB64)                                       01-00412
000264 00000274                     2013+                 DC    A(#@LB64)                                    01-00425
000268 00000198                     2014+                 DC    A(#@LB66)                                    01-00428
00026C 000001F2                     2015+                 DC    A(#@LB75)                                    01-00428
000270 00000198                     2016+                 DC    A(#@LB66)                                    01-00428
000274                              2017+#@LB64               DS  0H                                             01-00445
                                    2019 *
                                    2020          SELECT  CLC,WORD1,EQ
                                    2024            WHEN  (=C'+',=C'-')
000274 D500 C2D2 C2E8 002D4 002EA   2028+         CLC                   WORD1,=C'+'                          01-01130
00027A 4780 C286            00288   2029+         BC              8,#@LB90                                   01-01134
00027E D500 C2D2 C2E9 002D4 002EB   2030+         CLC                   WORD1,=C'-'                          01-01130
000284 4770 C28E            00290   2031+         BC            15-8,#@LB89                                  01-01138
000288                              2032+#@LB90               DS  0H                                             01-01141
000288 4100 0001            00001   2033              LA    R0,1
                                    2034            WHEN  (=C'*',=C'/')
00028C 47F0 C2D2            002D4   2036+         BC              15,#@LB88             SKIP TO END          01-01106
000290                              2037+#@LB89               DS  0H                                             01-01109
000290 D500 C2D2 C2EA 002D4 002EC   2040+         CLC                   WORD1,=C'*'                          01-01130
000296 4780 C2A2            002A4   2041+         BC              8,#@LB92                                   01-01134
00029A D500 C2D2 C2EB 002D4 002ED   2042+         CLC                   WORD1,=C'/'                          01-01130
0002A0 4770 C2AA            002AC   2043+         BC            15-8,#@LB91                                  01-01138
0002A4                              2044+#@LB92               DS  0H                                             01-01141
0002A4 4100 0002            00002   2045              LA    R0,2
                                    2046            OTHRWISE
0002A8 47F0 C2D2            002D4   2048+         BC              15,#@LB88             SKIP TO END          01-00937
0002AC                              2049+#@LB91               DS  0H                                             01-00940
0002AC 1B00                         2050              SR    R0,R0
                                    2051              CASENTRY  R4,POWER=2
0002AE 5A40 C2B6            002B8   2056+              A     R4,#@LB95                                          01-00203
0002B2 5840 4000            00000   2057+              L     R4,0(,R4)                                          01-00204
0002B6 07F4                         2058+              BCR   15,R4                                              01-00205
0002B8 000002C8                     2059+#@LB95             DC A(#@LB93)                                       01-00206
                                    2060              CASE  8
0002BC                              2063+#@LB96               DS  0H                                             01-00115
0002BC 4130 0080            00080   2064                LA  R3,X'80'
                                    2065              ENDCASE
0002C0 5840 C2C6            002C8   2067+              L     R4,#@LB93                                          01-00410
0002C4 07F4                         2068+              BCR   15,R4                                              01-00411
0002C6 0000                             +
0002C8 000002D4                     2069+#@LB93               DC A(#@LB94)                                       01-00412
0002CC 000002D4                     2070+                 DC    A(#@LB94)                                    01-00425
0002D0 000002BC                     2071+                 DC    A(#@LB96)                                    01-00428
0002D4                              2072+#@LB94               DS  0H                                             01-00445
                                    2074            ENDSEL
0002D4                              2076+#@LB88               DS  0H                                             01-00702
                                    2078 *
0002D4 C1                           2079 WORD1    DC    CL1'A'
                       00004        2080 B        EQU   4
                       00005        2081 BASEREG  EQU   5
                       00006        2082 B2       EQU   6
                       00010        2083 DEC      EQU   16
                       00020        2084 D2       EQU   32
                       00040        2085 L        EQU   64
                       00004        2086 LENGTH   EQU   4
                       00006        2087 M1       EQU   6
                       00000        2088 R0       EQU   0
                       00001        2089 R1       EQU   1
                       00002        2090 R2       EQU   2
                       00003        2091 R3       EQU   3
                       00004        2092 R4       EQU   4
                       00005        2093 R5       EQU   5
                       00006        2094 R6       EQU   6
                       0000C        2095 R12      EQU   12
000000                              2096          END   SAMPLE
0002D8 E6D6D9C4                     2097                =C'WORD'
0002DC 00000064                     2098                =F'100'
0002E0 000003E8                     2099                =F'1000'
0002E4 00002710                     2100                =F'10000'
0002E8 FFFF                         2101                =H'-1'
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0002EA 4E                       2102                =C'+'
0002EB 60                       2103                =C'-'
0002EC 5C                       2104                =C'*'
0002ED 61                       2105                =C'/'
                               Diagnostic Cross Reference and Assembler Summary                            Page    3
                                                                                          HLASM R4.0  2003/01/29 12.02
     No Statements Flagged in this Assembly
HIGH LEVEL ASSEMBLER, 5696-234, RELEASE 4.0, PTF UQ72178
SYSTEM: CMS 16                     JOBNAME: (NOJOB)     STEPNAME: (NOSTEP)   PROCSTEP: (NOPROC)
Datasets Allocated for this Assembly
 Con DDname   Dataset Name                                Volume  Member
  P1 SYSIN    SAMPLE2  ASSEMBLE A1                       EHR191
  L1 SYSLIB   OSMACRO  MACLIB   S2                       $CM019
  L2          ASMAFMAC MACLIB   A1                       EHR191
  L3          ASMSMAC  MACLIB   D1                       EHR192
  L4          ASMAMAC  MACLIB   S2                       $CM019
  L5          CLASSMAC MACLIB   L1                       EHR195
  L6          OSMACRO1 MACLIB   S2                       $CM019
     SYSLIN   SAMPLE2  TEXT     A1                       EHR191
     SYSPRINT SAMPLE2  LISTING  A1                       EHR191
     SYSTERM  TERMINAL

   8176K allocated to Buffer Pool,         373K would be required for this to be an In-Storage Assembly
    161 Primary Input Records Read        2663 Library Records Read                 0 Work File Reads
      0 ASMAOPT Records Read               464 Primary Print Records Written        0 Work File Writes
     18 Punch Records Written                0 ADATA Records Written
Assembly Start Time: 12.02.48 Stop Time: 12.02.48 Processor Time: 00.00.00.0609
Return Code 000
```