Assembler University 201:

What is the Assembler Trying to Tell Me?

A Guide to Some Answers

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Synopsis:

Assembler Language problems are sometimes difficult to locate and correct. The IBM High Level Assembler for z/OS, z/VM, and z/VSE provides many helpful features that can help; these notes provide an overview of those features.

Invitation

Suggestions for improvements and additions are welcomed.

Publications and Web Site

The currently available product publications for High Level Assembler for z/OS, z/VM, and z/VSE are:

- High Level Assembler for z/OS, z/VM, and z/VSE *Language Reference*, SC26-4940
- High Level Assembler for z/OS, z/VM, and z/VSE *Programmer's Guide*, SC26-4941
- High Level Assembler for z/OS, z/VM, and z/VSE *Licensed Program Specifications*, GC26-4944
- High Level Assembler for z/OS, z/VM, and z/VSE *Installation and Customization Guide*, SC26-3494

The currently available product publications for High Level Assembler for z/OS, z/VM, and z/VSE Toolkit Feature are:

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

The currently available product publications for High Level Assembler for z/OS, z/VM, and z/VSE for Linux on zSeries are:

- High Level Assembler for Linux on System z *User's Guide*, SC18-9611

HLASM publications are available online at the HLASM web site:

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

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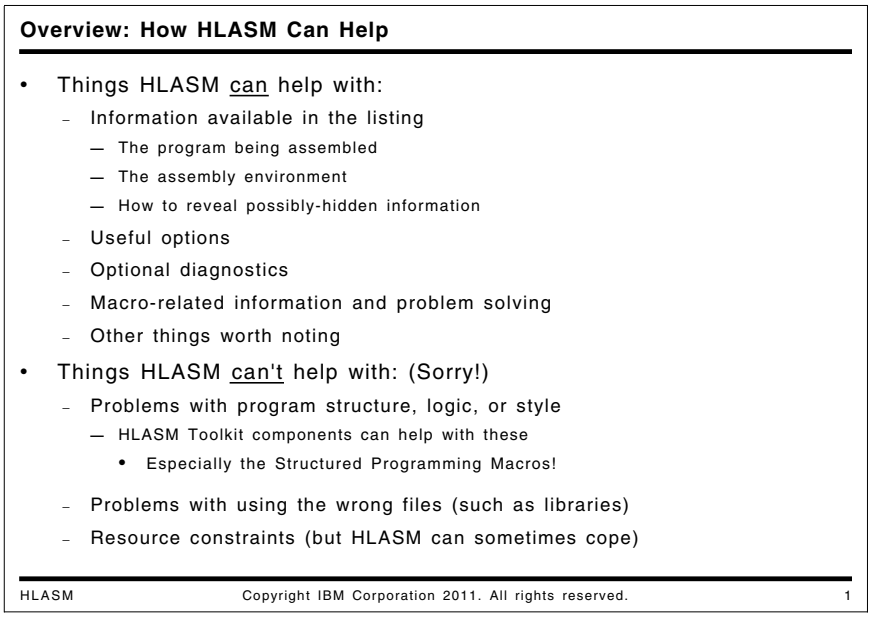
Contents

Overview



The High Level Assembler for z/OS, z/VM, and z/VSE (HLASM) provides extensive information about the programs it assembles and its assembly environment, and supports flexible controls over both the displayed information and diagnostics to be applied to the program.

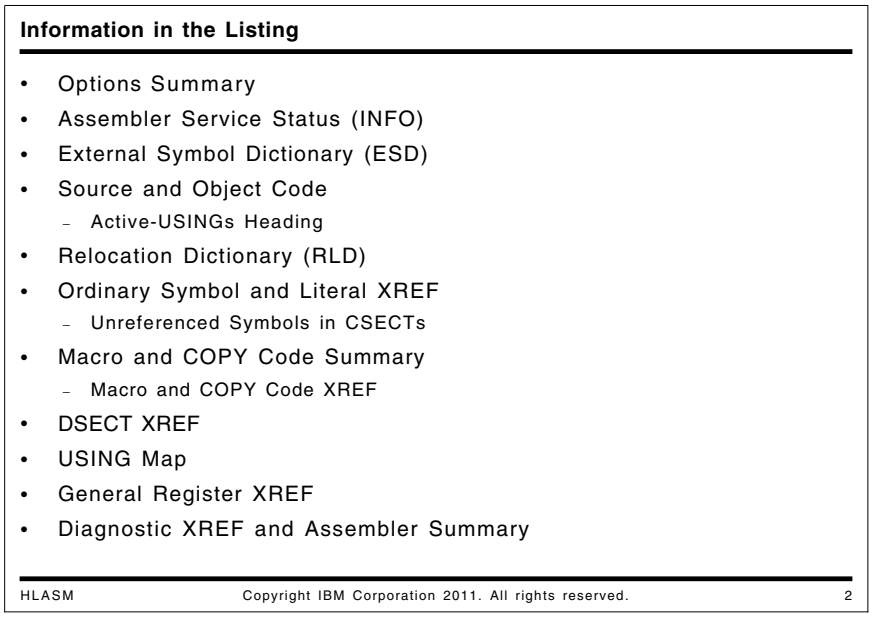
This document summarizes many ways to benefit from the capabilities of the High Level Assembler, particularly for locating problems with Assembler Language programs.

While we will focus mainly on information in the assembly listing, a complete summary of all aspects of the assembly is written to the SYSADATA data set when the ADATA option is specified. The ADATA records do not depend on other options that might affect the listing.

High Level Assembler is designed to assemble programs efficiently, but it does not try to create an "overview" or comprehensive analysis of the program as a whole. Thus, matters such as coding style, program structure and organization, and logic are largely invisible to the assembler. Certain statements with wide-ranging effects, such as USING statements, are analyzed with care, but this analysis is based only on the information known at the time the statement is processed.

The High Level Assembler for z/OS, z/VM, and z/VSE Toolkit Feature provides several components that can help with understanding and managing programs "in the large" such as the Interactive Debug Facility, the Program Understanding Tool, and the Source Cross-Reference Utility.

Information in the Listing

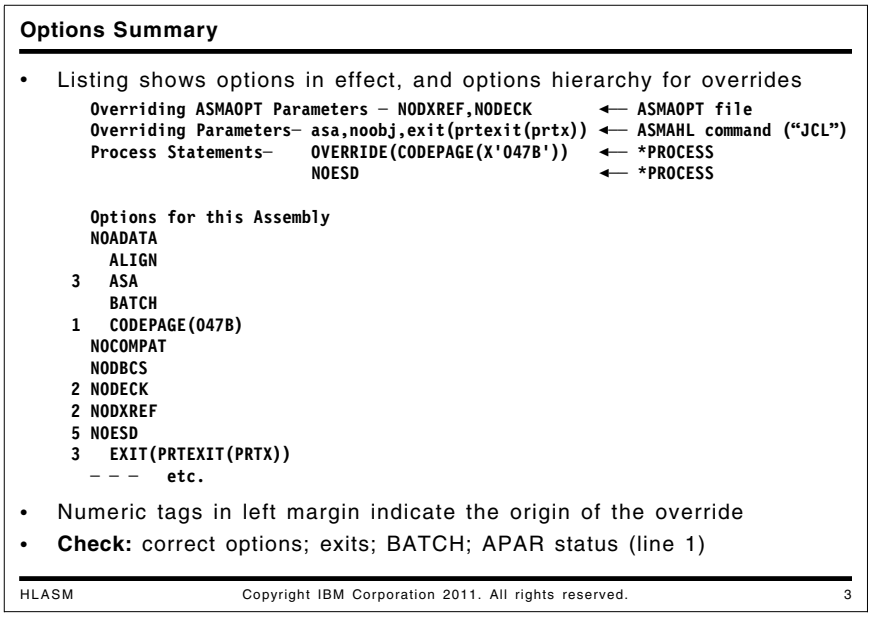


The High Level Assembler listing contains useful information about all aspects of an assembly. This information is produced in many different areas, some parts of which can be included or excluded under the control of options and source-program statements. The listing includes some or all of the following sections, in this order:

- Options Summary
- Assembler Service Status (INFO)
- External Symbol Dictionary (ESD)
- Source and Object Code
  - Active-USINGs Heading
- Relocation Dictionary (RLD)
- Ordinary Symbol and Literal XREF
  - Unreferenced Symbols in CSECTs
- Macro and COPY Code Summary
  - Macro and COPY Code XREF
- DSECT XREF
- USING Map
- General Register XREF
- Diagnostic XREF and Assembler Summary

We will discuss each of these in turn, describing useful information you can find in each section of the listing.

Options Summary



The first page of the listing file contains:

- The latest PTF is shown on the very first line.
- Fixed, non-overridable installation default options that were specified with DELETE operand of the ASMAOPTS installation macro.
- User-supplied options from the ASMAOPT file.
- User-supplied options from invocation parameters.
- *PROCESS-statement options.
- A list of all options in effect.
- A list of overriding DDnames.

An example is shown in slide 3.

The options used for an assembly are determined according to the following hierarchy (highest to lowest; the numbering corresponds to the numbers used in the options summary to indicate overrides):

0 Fixed installation defaults

1 *PROCESS OVERRIDE options

2 Options from the ASMAOPT file (or VSE Librarian member ASMAOPT.USEROPT)

3 Options in JCL PARM (MVS, VSE) or ASMAHL command (CMS)

4 Options on JCL OPTION statement (VSE)

5 Options on *PROCESS statements

6 Non-fixed installation defaults

This summary tells you the options used for the assembly. Additional information is provided about any errors in the requested options.

*PROCESS options must be the first records of the source file; the first non-PROCESS statement terminates the process-options scan.

Things Worth Checking

- The first line of the first page shows the latest service applied to the assembler. If you're interested in knowing what was changed or fixed, specify the INFO option, described next.
- Check that the specified options are the ones you really want. Information about overrides can help you determine how the final values of the options were derived.
- Check whether I/O exits are specified: they can control all assembler files (except its utility "work" file), and therefore can control what is read into the assembler and what is produced as output. For example, certain parts of the listing may have been moved, modified, or suppressed by a listing exit (including the fact that the exit is present)! (See also "I/O Exits" on page 70.)
- Check whether BATCH mode has been specified. Programs that assemble or link one way with NOBATCH may behave differently with BATCH. (See also "BATCH Option" on page 29.)
- Check that no non-PROCESS lines appear before your last *PROCESS statement. You can also use the PROFILE option and the ASMAOPT data set to specify assembler options.

Assembler Service Status (INFO Option)

Assembler Service Status (INFO Option)

- HLASM prints its service status, other useful information
  - Latest PTF number is ***always*** on the ***first*** line of the listing
- Example of the printed text:

```
        The following information describes enhancements and changes to the
        High Level Assembler Product.

        The information displayed can be managed by using the following options:
        INFO           - prints all available information for this release.
        INFO(yyyymmdd) - suppresses items dated prior to "yyyymmdd".
        NOINFO         - suppresses the product information entirely.

 20100204  APAR PM06119 Fixed
        NOCOMPAT option not recognized on invocation parms
        when COMPAT(SYSLIST) has been set as the default in
        ASMADOPT.

 20100316  APAR PM09235 Fixed
        Alignment for XD item in ESD incorrect and shows doubleword
        alignment instead of the correct alignment for the length
```

- **Check:** current service status; language changes

HLASM 4

If you specify the INFO option, High Level Assembler will print a summary of the status of all service that has been applied to *your* copy of the assembler. Slide 4 shows an example.

You can request a subset of this service status data by specifying a date: INFO(yyyymmdd) requests the assembler not to display service-status information prior to that date.

Things Worth Checking: If the behavior of your assembler has changed, service may have been applied that you weren't aware of. Conversely, you may understand that a problem has been fixed, but it still seems to be present on your assembler. Checking the output of the INFO option can help you determine its exact service status.

External Symbol Dictionary (ESD Option)

External Symbol Dictionary (ESD Option)

- The external names defined and referenced by this assembly
- Standard assembly

```
Symbol   Type   Id     Address  Length   Owner Id Flags Alias-of
SECT_A    SQ 00000001 00000000 00000026             00
MYCOM     CQ 00000002 00000000 00000060             00
MY_XD     XD 00000003 0000000F 00000018
SECT_B    SQ 00000004 00000000 00000038             00
BDATA     LD          00000030           00000004
```

- Quadword-aligned sections, SECTALGN(16) option

```
Symbol   Type   ID     Address  Length  Owner Id Flags Alias-of
SECT_A    SD 00000001 00000000 0000002C            01
MYCOM     CM 00000002 00000000 00000060            00
MY_XD     XD 00000003 00000007 00000018
SECT_B    SD 00000004 00000030 00000038            02
BDATA     LD          00000030          00000004
```

- Names are normally in upper-case letters

HLASM 5

External Symbol Dictionary (ESD Option) ...

- Each item (except LDs) is assumed to be independently relocatable
- Each symbol has a type and an identifying number (its “ESD ID”)
  - Section definitions (types SD, CM, PC; or SQ, CQ, PQ if quad aligned)
    - PC sections may cause MODE problems, even if zero length
    - Usual cause: EQUs appearing before first section is initiated
  - Entry point definitions (type LD)
    - LD-ID identifies the section in which the symbol is an entry
  - External references (types ER, WX)
    - Names of symbols referenced by this assembly but defined elsewhere
  - External Dummy definitions (type XD)
    - Symbols naming DXD instructions, or DSECT names in Q-cons
- ALIAS information
  - ALIAS instruction changes an existing external name to another
  - Linkers and loaders see the changed name, not the original
- **Check:** correct name/length/type; mixed-case aliases; Private Code; AMODE/RMODE; NOTHREAD option

HLASM 6

The ESD option causes HLASM to display information about all external symbols in the object file. There are four general types of external symbol produced by the assembler if the NOGOFF option is specified, or five if the GOFF option is specified.

The following figure illustrates an ESD listing for the traditional object module format.

```
Symbol   Type   ID     Address  Length  Owner Id Flags Alias-of
SECT_A    SD 00000001 00000000 0000002C            01
MYCOM     CM 00000002 00000000 00000060            00
MY_XD     XD 00000003 00000007 00000018
SECT_B    SD 00000004 00000030 00000038            02
BDATA     LD          00000030          00000004
```

Figure 1. Example of External Symbol Dictionary listing (NOGOFF option)

If you had specified the SECTALGN(16) option to request quadword alignment of all sections, the ESD listing would appear as in Figure 2. The SQ, CQ, and PQ codes indicate that the respective sections will be quadword aligned.

```
Symbol   Type   Id     Address  Length   Owner Id Flags Alias-of
SECT_A    SQ 00000001 00000000 00000026            00
MYCOM     CQ 00000002 00000000 00000060            00
MY_XD     XD 00000003 0000000F 00000018
SECT_B    SQ 00000004 00000000 00000038            00
BDATA     LD          00000030           00000004
```

Figure 2. Example of External Symbol Dictionary listing (NOGOFF and SECTALGN(16) options)

The discussion of the SUPRWARN option on page 35 explains some considerations when using the SECTALGN option.

In the ESD listing, eight fields are displayed.

1. Symbol: the external symbol. By default, all external symbols are converted to upper case letters, even if they appear in mixed case in the source file. The ALIAS instruction must be used to obtain lower case letters or special characters in external symbols. (See “ALIAS Information” on page 8.)
2. Symbol type: a two-letter code
   - Section definition

     SD,SQ An ordinary control section, specified by a CSECT, RSECT, or START instruction

     CM,CQ A common control section, specified by a COM instruction

     PC,PQ A control section with a blank name, typically caused by instructions like EQU preceding other section-initiating statements (see “Private Code Sections” on page 9).

   - Label definition (**LD**)

     An entry point in a section. An LD item has no ESDID of its own; rather, it has an “Owner ID” or “LD ID”, the ESDID of the section in which this name is an entry. The “address” of the LD item should be compared to the address of its owning section; the difference between the two is the symbol's offset within its owning the section.

   - External reference

     ER A strong external reference that is expected to be resolved to a symbol definition during linking and binding; if not found among the input modules, a library search is usually done.

     WX A weak external reference that can be resolved to a symbol definition during linking and binding, but will not cause library search.

   - External Dummy definition (**XD**)

A symbol appearing in the name field of a DXD instruction, or the name of a DSECT that has appeared as the operand of a Q-type address constant.

- Element definition (**ED**) (GOFF option only)

  This is the name of a binder class; the combination of a section name and a class name defines an element. The LD-ID of the class is that of the section to which it belongs. Entry points within an element are assigned an LD-ID of the owning element. (See Figure 3 on page 8 for an example.)

3. ID: the ESD ID assigned to the symbol

   Each symbol has a unique identification number called its "ESD ID" (except for LD items). Because each distinct ID is assumed to represent an independently relocatable item, this is also called its "relocation ID".

4. Address: the assembler-assigned address of the symbol.

   If a section starts at a nonzero address (either due to a START statement operand, or due to the presence of multiple control sections), this starting address is adjusted to zero during program linking and binding, and all related addresses are adjusted by the same amount. The NOTHREAD option causes non-initial sections to have zero origin.

   For XD items, this field contains a number one less than the desired boundary alignment of the item at bind time:

   `X'0'` byte alignment
   `X'1'` halfword alignment
   `X'3'` fullword alignment
   `X'7'` doubleword alignment
   `X'15'` quadword alignment

5. Length: the assembler-assigned length of the symbol

6. Owner ID: the ESDID of the section or element in which the LD item is an entry point.

7. Flags: these indicate the AMODE and RMODE information associated with the symbol. Five bits in the Flags byte are used to indicate the AMODE and RMODE of an external symbol: these can be designated `B'..RA.rab'`, where

   `R` means RMODE(64)
   `A` means AMODE(64)
   `r` means RMODE(31)
   `a` means AMODE(31)
   `b` means AMODE(24)

   If all bits are zero, the modes were unspecified, and default to 24/24. Additional combinations are supported:

   - if both "a" and "b" are one, it means AMODE(ANY); that is, 24 or 31
   - if both "R" and "A" are one (meaning both RMODE and AMODE are 64), the RMODE(31) bit "r" is also set, so that existing loaders can load programs below the 2GB "bar"

   In Figure 1 on page 6, symbol `SECTA` has flags `X'01'` meaning RMODE(24),AMODE(24); and symbol `SECTB` has flags `X'02'` meaning RMODE(24),AMODE(31).

   In the NOGOFF (old) object module format, entry (LD) names have no addressing mode.

8. Alias: the character string that appears in the object file in place of the symbol's original name, if an alias was specified. (See "ALIAS Information" on page 8.)

Not all of these fields appear for every symbol type.

Figure 3 on page 8 illustrates an ESD listing when the GOFF option is specified.

```
Symbol   Type   ID     Address  Length   LD ID   Flags Alias-of
SECT_A    SD 00000001
B_PRV     ED 00000002                    00000001
B_TEXT    ED 00000003 00000000 0000002C 00000001   01
SECT_A    LD 00000004 00000000           00000003   01
MYCOM     SD 00000005
B_PRV     ED 00000006                    00000005
B_TEXT    ED 00000007 00000000 00000060 00000005   00
MYCOM     CM 00000008 00000000           00000007
MY_XD     XD 00000009 00000007 00000018
SECT_B    SD 0000000A
B_PRV     ED 0000000B                    0000000A
B_TEXT    ED 0000000C 00000030 00000038 0000000A   02
SECT_B    LD 0000000D 00000030           0000000C   02
BDATA     LD 0000000E 00000030           0000000C   02
```

Figure 3. Example of External Symbol Dictionary listing (GOFF option)

Figure 3 shows several differences from the simpler form in Figure 1 on page 6: for each SD item, the assembler assumes that no other classes might be declared, so it emits these default items:

- ED ("Element Definition") with names for default classes (which may be empty)
  - `B_PRV` for external dummy symbols
  - `B_TEXT` for text not directed to a declared class
- LD items for the name of the SD item (RMODE/AMODE information *is* provided for LD items in the GOFF object format)

Addresses and lengths are assigned to ED items, not to SD items.

One other difference is that the common declaration for symbol `MYCOM` appears as an SD item and as a CM item: the latter is simply an indication to the binder that `MYCOM` should be linked according to the old rules for common sections.

Things Worth Checking

- Verify that all external symbols have the correct names, types, addresses, and lengths.
- For LD items, check that the LD offset is within its owning section or element. That is, the LD address does not exceed the section (or element) address plus its length.
- If an assembly has multiple sections, it is possible to refer from one section to symbols in another without declaring them in EXTRN statement. If the sections are always assembled together, this is not a problem; but if subsequent program linking replaces one of the sections, references to it from other sections will very probably no longer be correct.
- Verify that AMODEs and RMODEs are what you intended.

ALIAS Information

The assembler's ALIAS instruction changes a syntactically valid external symbol to another character string in the object module. This assembly-time operation causes a "normal" external symbol defined by the program — that is, a symbol using characters valid in the Assembler Language — to be changed to a different name (its "alias") in the External Symbol Dictionary. This permits Assembler object modules to be linked with those from other languages whose external symbols contain characters that would otherwise be invalid in the Assembler Language.

The ALIAS instruction permits 64-character external names when the GOFF option is specified, and 8-character names if the old (NOGOFF) object format is used. This fragment of a source program:

```
        EXTRN STAR_X,Lower,Abc
STAR_X  ALIAS C'*X'
Lower   ALIAS C'Lower'
ABC     ALIAS C'Xyz'
```

Figure 4. Example of ALIAS statements for external symbols

produces this portion of the ESD listing:

```
                                    External Symbol Dictionary

Symbol   Type   Id     Address  Length     LD ID  Flags Alias-of
X         SD 00000001 00000000 00000000             00
*X        ER 00000002                                  STAR_X
Lower     ER 00000003                                  LOWER
Xyz       ER 00000004                                  ABC
```

Figure 5. Example of ALIAS and the External Symbol Dictionary

In Figure 4, the EXTRN instruction in the source program declares three external symbols, STAR_X, Lower, and Abc. In the absence of the ALIAS instructions, these would appear in the ESD as STAR_X, LOWER, and ABC (all in upper case). The ALIAS instructions cause HLASM to change those names to *X, Lower, and Xyz in the object file's External Symbol Dictionary records. Internal to the program, they must still be referenced by their original names. For example,

```
        DC   V(Star_X,LOWER)
```

would generate address constants that resolve only to the "ALIASed" names (*X and Lower).

Don't use the ALIASed name in adcons. In Figure 4, the presence of

```
        DC   V(XYZ)
```

will generate an assembly error (on the ALIAS statement!).

Things Worth Checking: If mixed case symbols are generated by ALIAS statements, check that your binder/linker can recognize and process them correctly.

Private Code Sections

"Private Code" is the name given to blank section names, because without ENTRY points in blank sections, there is no way for other code to refer to it.

The presence of PC sections in an assembly is usually unintended, and can have some unexpected side-effects. Suppose you wrote code as in Figure 6:

This fragment of a source program:

```
R1    Equ   1
      - - -
CODE  Start 0
CODE  RMode 31
      - - -
```

Figure 6. Program that generates unintended Private Code

The assembly produces this portion of the ESD listing:

```
Symbol   Type   Id     Address  Length     LD ID  Flags Alias-of
          PC 00000001 00000000 00000000             00  ◄── Possible problem?
CODE      SD 00000002 00000000 00000004             06
```

Figure 7. External Symbol Dictionary from program generating Private Code

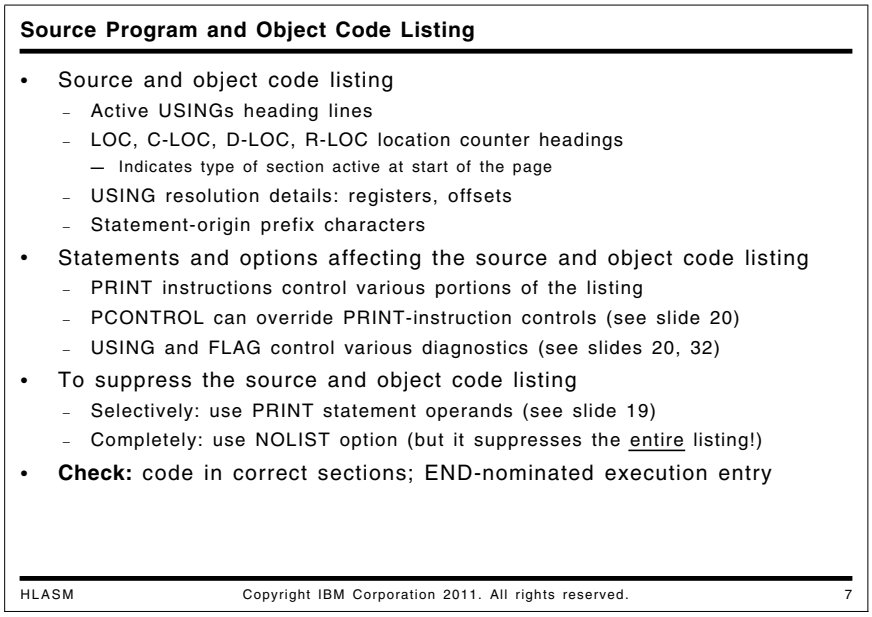
The ESD in Figure 7 contains a zero-length PC section, which has *different* AMODE and RMODE settings than the Code section. When linked, the default AMODE(24) and RMODE(24) values of the PC section may cause the desired values specified for the CODE section to be downgraded.

Things Worth Checking

- Typically, Private Code (PC) sections in an assembly have zero length, and should have no impact on a program's size at link time. However, the presence of PC sections in an assembly can lead to other problems:
  - Because they are assigned default AMODE(24) and RMODE(24) values, an entire bound module may be assigned those attributes even though others were intended. Examples are shown in Figure 6 on page 9 and in Figure 34 on page 30.
  - In the absence of LTORG instructions, the assembler puts the literal pool at the end of the first control section. If this is the Private Code section, it is unlikely that the literals will be addressable from other sections, causing diagnostics to be issued for each literal reference. The literals may also reside in an unexpected section, even though they might appear to be addressable.

  The z/OS binder usually discards zero-length PC sections, but they should always be avoided.

Source Program and Object Code Listing



The source and object code listing contains several useful bits of information in addition to statements, object code, and messages.

- The page heading can display a summary of USINGs active at the start of the page. This helps you understand how based addresses on each page will be resolved, without having to read and annotate the entire program prior to that point. This USING heading can be

enabled or disabled with the PRINT instruction's UHEAD and NOUHEAD operands, or by specifying the PCONTROL option (see “PCONTROL Option and the PRINT Instruction” on page 31).

The information for each USING specifies the base location, the range of the USING (in parentheses), and the base register. The range is not shown if it is the default (X'1000' times the number of base registers). If the USING is dependent, it will show the base register and the offset at which the USING is anchored; if it is labeled, the label will appear preceding the name of the DSECT.

```
Active Usings: Record,R4  ZipCode(X'F9A'),R4+X'66'  Sect1(X'CA6'),R15
HF.PhoneNo(X'F90'),R4+X'70'  WF.PhoneNo(X'F86'),R4+X'7A'  OLD.Record,R5
NEW.Record,R6
```

Figure 8. Example of Active Usings heading

In Figure 8, the first and third USINGs (based at Record and Sect1) are ordinary; the second is dependent; the fourth and fifth are labeled dependent; and the last two are labeled. Only the third USING specified an explicit range limit; the other USINGs whose ranges are less than the X'1000' default are dependent USINGs anchored at a nonzero offset from the basing register. (See Figure 16 on page 22 for an example of a Using Map corresponding to this Using Heading.)

- The Location Counter column heading indicates whether a CSECT, DSECT, RSECT, or COM section is currently in effect. The heading is LOC, D-LOC, R-LOC, or C-LOC, respectively.
- For USING-resolution displays, both the first-operand value and the registers specified as bases are shown for ordinary USINGs. The base-displacement resolution and first and second operand addresses used are provided for dependent USINGs. Dependent USINGs display the actual offset of the anchor location.
- In the space between the statement number and the statement itself, a nonblank character indicates that the statement was derived from some other source than the primary input stream, or was processed in a special way:

  `+` The statement was generated by a macro, or is the result of conditional assembly substitution.

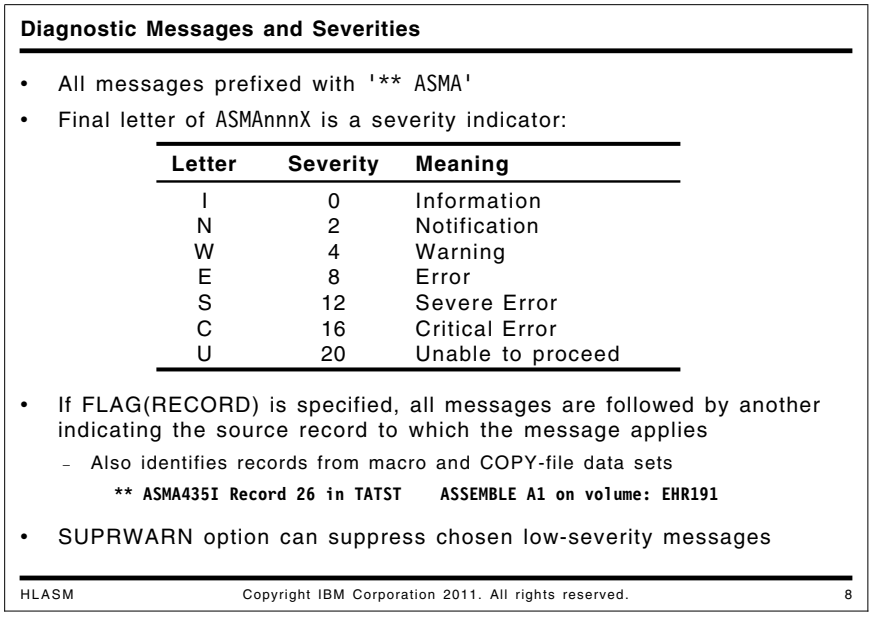
  – The statement was taken from the input stream and assigned to a conditional assembly variable by an AREAD instruction.

  `>` The statement was introduced into the input stream by an AINSERT statement.

  `=` The statement was introduced into the input stream by a COPY statement.

Things Worth Checking

- The “LOC” heading of each page's location counter designates the type of section currently being assembled; verify that it's what you intend.
- Verify that the nominated entry point on the END statement refers to the desired execution start address, and that it lies within the bounds of the section to which it belongs.



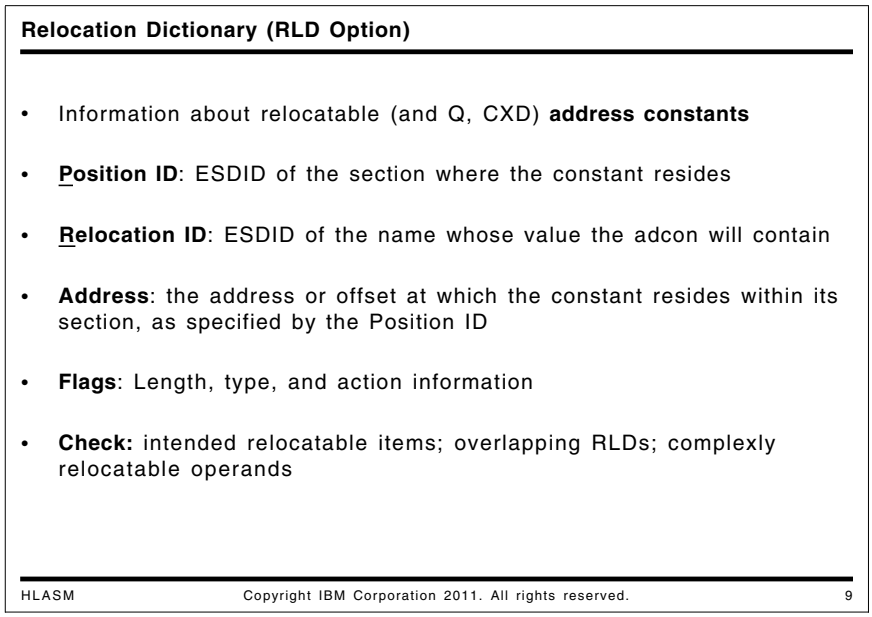
Messages issued by High Level Assembler have the form ** ASMAnnnX, where nnn is a three-digit message number, and X is a severity indicator, as shown in slide 8.

Some messages may not appear in the listing if portions have been hidden by PRINT OFF instructions (see "TERM Option" on page 28) or if the diagnostics are subject to option control and have been disabled (see "FLAG(severity) Option" on page 39), or suppressed (see "SUPRWARN Option" on page 35).

If the FLAG(RECORD) option is active, each diagnostic message is followed by an ASMA435I message indicating both the name of the source or library file and the relative record number associated with the message.

Relocation Dictionary (RLD Option)

The Relocation Dictionary shows which fields in the object module will contain values supplied by post-assembly processes.



The sample program in Figure 9 illustrates four types of address constants requiring relocation following assembly. The four adcon types are V, A, CXD, and Q; examples are shown in Figure 9. Types A and V are addresses, type Q is an offset, and a CXD constant is a length.

```
ASect  Start 0              ◄── Control section
       Extrn EX             ◄── External symbol
       Entry NTRY           ◄── Entry declaration
       BRASL 14,EX          ◄── External relative branch
       DC    V(EX)          ◄── V-type adcon
NTRY   DC    A(EX-ASect)    ◄── A-type adcon with two external symbols
       CXD                  ◄── Cumulative external dummy length
EXDUM  DXD   F              ◄── External dummy section
       DC    QL2(EXDUM)     ◄── Q-type adcon
       END
```

Figure 9. Sample Program with address constant types

The ESD listing from the assembly (when the NOGOFF option is specified) is shown in Figure 10:

```
Symbol   Type   Id     Address  Length     LD ID
ASECT     SD 00000001 00000000 00000010
EX        ER 00000002
NTRY      LD          00000004           00000001
EXDUM     XD 00000003 00000003 00000004
```

Figure 10. Sample Program with address constants: ESD listing

The ESD listing shows the ESD IDs assigned to the symbols, as described in “External Symbol Dictionary (ESD Option)” on page 5.

When the RLD option is specified, HLASM provides a summary of all fields requiring relocation, as shown in Figure 11 on page 14.

```
 Pos.Id   Rel.Id   Address Type  Action
00000001 00000000 00000008  J 4    ST   ◄── Type J; Rel.Id = 0 for CXD
00000001 00000001 00000004  A 4     −   ◄── Type A; note address 004; subtracted
00000001 00000002 00000002 RI 4     +   ◄── Type RI; relative external reference
00000001 00000002 00000000  V 4    ST   ◄── Type V; stored
00000001 00000002 00000004  A 4     +   ◄── note address is also 004; added
00000001 00000003 0000000C  Q 2    ST   ◄── Type Q; length 2 bytes
```

Figure 11. Sample Program with address constants: RLD listing

The five fields in the RLD listing are:

1. Position ID: the ESD ID of the section in which the adcon resides.
2. Relocation ID: the ESD ID of the item according to which the adcon field will be relocated (or "adjusted"); the term "relocation" is used even if the contents of the adcon is not a relocated address. CXD items have Relocation ID zero.
3. Address: the location within the section indicated by the Position ID where the adcon is located.
4. Type: the two entries indicate the type of constant and its length in bytes. The types are:

   J Length
   A,V Address
   Q Offset
   RI Relative-Immediate

5. Action: at link/bind time, the result of relocating the adcon is either stored into the adcon's field (indicated by ST), or added to (+) or subtracted from (−) the text in the adcon's field.

In the example in Figure 9 on page 13, the constant named NTRY indicates that the difference of two external symbols should be placed in the adcon field; the two corresponding RLD items appear in the RLD Listing in Figure 11 at address 00000004, with two different Relocation IDs.

Things Worth Checking

- Check that there are as many relocatable items as you expect.
- Check that overlapping RLDs (with the same Position ID and address, as shown in Figure 11) are really intended. Sometimes, two adcons are accidentally placed in the same location, causing unexpected double relocations at bind time, execution time, or both.

Symbol Cross-Reference (XREF Option)

Ordinary Symbol and Literal Cross-Reference (XREF Option)

- XREF has three sub-options (default: SHORT, UNREFS)
  - XREF(FULL) for all symbols, referenced or not
  - XREF(SHORT) for referenced symbols only
  - XREF(UNREFS) lists unreferenced non-DSECT symbols
    - Helps locate dead code, dead data items
    - Ignored if XREF(FULL) is specified
- Displays information about each symbol (example on next slide)
  - Symbol, length attribute, value
  - Relocation ID, relocatability tags (especially "C"), symbol type, where defined
  - References, including tags indicating use: Branch, Drop, Modification, Using, eXecute
    - Symbol Batch_Init is a branch target (B tag)
    - Symbol Err_Buff modified (M tag); a USING base (U tag)
    - Symbol Move_Msg is executed (X tag)
    - Symbol R1 appears in USING (U tag) and DROP (D tag) instructions
- **Check:** usage tags; relocation ID and type; attributes; duplicate or replaceable literals

HLASM 10

When the XREF option is specified, HLASM produces several styles of symbol cross-reference information. Because large programs may contain many unreferenced symbols, a more readable listing is produced if you specify the XREF(SHORT) option.

Slide 11 shows an excerpt from a symbol cross-reference, illustrating the key features of that part of the listing.

Ordinary Symbol and Literal Cross-Reference Example

```
Symbol   Length  Value Id   R Type Asm Program Defn References
  ...
BadEQU        1 000004 0001 C   U              666             <-- note C relocation
Batch_Init    2 00035C 0001     H              493  399B  490B  <-- note B tag
Batch_Len     8 000018 FFFF A   U              772  497
Batch_Msg_1  39 0006A1 0001     C              681  469   469   716
  ...
Err_Buff      1 000000 FFFD     J              787  127U  517M  <-- note U tag
Err_Msg     255 000000 FFFD     C              788  277M  481M  486M  <-- note M tags
ESD_Item      1 000000 FFFB     J              804  349U  831   <-- note U tag
  ...
Move_Msg      6 0004A6 0001     I              645  641X        <-- note X tag
PPtr     QUALIFIER
  ...                                                          note U,D tags
  ...                                                            |   |
R1            1 000001 0001 A   U  GR32         53  123U  128D  132M  133M  133   135
                                                    215D  248M  262   348M  349U  373M
  ... etc.
```

- B= Branch target, D = Drop, M = Modified, U = Using, X = Executed

HLASM 11

The ordinary symbol and literal cross-reference illustrated in slide 11 displays the following items:

- The symbol, in the form it was first encountered and entered into the symbol table.
- Whether the symbol (see PPtr) is a qualifier defined in a labeled USING statement.

- The length attribute of the symbol (in decimal).
- The value of the symbol (in hexadecimal).
- The relocation ID (relocatability attribute) of the symbol, which relates the symbol directly to its "owning" control section. Relocation ID values are also found in the ESD listing, or in the DXREF listing (described on page 20) for symbols defined in DSECTs.
- The column headed by "R" provides information about the relocatability properties of each symbol. Absolute symbols are flagged with an A, complexly relocatable symbols are flagged with a C, and simply relocatable symbols (the most common case) are not flagged.
- The type attribute of the symbol. Note that this is the type attribute of the symbol's final definition, and may *not* be the attribute value used during conditional assembly! (This situation is discussed further at "Lookahead Mode" on page 73.)
- The Assembler attribute of the symbol, if any was assigned.
- The Program attribute of the symbol, if any was assigned.
- The statement number at which the symbol was defined.
- In the cross-reference of symbol uses, High Level Assembler provides indicator tags following the statement number to identify uses of the symbol in that statement:
  - In USING (U) and DROP (D) instructions
  - As targets of EXecute (X) instructions
  - Modification (M) tags for operand symbols naming fields whose contents may be modified by the action of the instruction
  - Branch target (B) tags for symbols used as operands of branch instructions.

  The modification (M) tags let you determine which symbol uses are for read references, and which are for write (modification) references. This helps you easily find the few instructions that might have changed the value of a variable or the contents of a named register. Examples are shown in slide 11 on page 15.

Things Worth Checking: The XREF contains a wealth of useful information, and is worth checking carefully.

- Check that the tags indicate expected uses of the symbol. For example, a symbol naming a constant should not have an "M" tag, indicating the statement number of an instruction that appears to have modified it.
- Check whether the relocation type (the R column) of any symbol is "C". While the assembler lets you define complexly relocatable symbols, such uses are very rare, and are most often an error that can otherwise be difficult to find.
- Verify that the length and type attributes are as expected. Sometimes a symbol defining a field is defined with an EQU statement and assigned a (default) length attribute 1, where a different length was intended.
- Sometimes a type attribute value will be assigned by a macro, using a value that does not print as a normal character (or print at all!). Verify that such symbols have the properties you expect, or that the symbols are of no direct interest to your program.
- Check for multiple appearances of literals; these may occur if there is more than one LTORG instruction in the program. Sometimes the number of literals can be reduced by careful placement of literal pools, or by replacing the literal reference with an instruction having an immediate operand.

XREF(SHORT,UNREFS) Options and Unreferenced Symbols

Symbols defined in ordinary (non-dummy) control sections but not referenced elsewhere in the program may be separately displayed by specifying the (default) XREF(SHORT,UNREFS) option, without displaying *all* unreferenced symbols. This display is normally much shorter than a FULL cross-reference, and can help in eliminating unneeded constants, storage areas, and "dead code". An example is shown in Figure 12, where the unreferenced symbol was defined at statement 418.

```
                    Unreferenced Symbols Defined in CSECTs
Defn  Symbol

 418  Normal_Dump
```

Figure 12. Example of XREF(UNREFS) listing

If XREF(FULL) is specified, High Level Assembler ignores the UNREFS suboption and displays all symbols, whether referenced or not.

Things Worth Checking: Programs can often be "cleaned up" by checking areas where unreferenced symbols appear:

- Unreferenced symbols among statements can sometimes indicate segments of "dead" code that is never referenced and can be removed, either by deleting them, or by adding conditional-assembly AGO statements to skip over the unused statements (this keeps the statements in the source file in case they ever need to be reactivated).
- Unreferenced constants and work areas can often be removed.

Unreferenced DSECTs

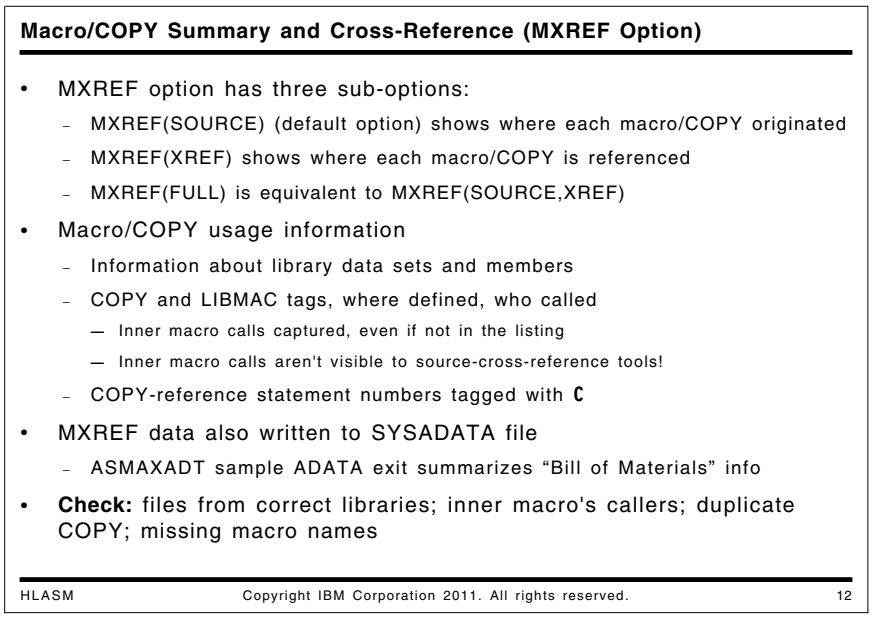
Sometimes DSECTs are declared (or copied into, or macro-generated) but none of its symbols are used. To reduce the "clutter" in the program (and to minimize chances for accidental misuse of symbols), you may want to remove unreferenced DSECTs. To check whether a DSECT can be removed:

- Assemble the program with the XREF(FULL) and DXREF options.
- Locate the relocation ID of the DSECT in the DSECT XREF (see Figure 15 on page 20 for an example).
- Scan the symbol XREF for references to symbols with that ID. If there are none, the DSECT is unreferenced.
- Otherwise, check that all references to those symbols are made from statements within the DSECT. For example, in

  ```
  DS1    DSECT ,
  DSA    DS    A
  DSB    DS    XL4
  DSC    EQU   *-DSA
         ORG   DSA
  DSD    DS    CL8
  ```

  the symbol DSA is referenced twice by symbols belonging to the DSECT. If the only references are made by statements in the DSECT, it can be considered unreferenced.

Macro-COPY Summary and Cross-Reference (MXREF Option)



The MXREF option specifies whether or not macro and COPY-member information should be included in the output listing. It has three suboptions: SOURCE, XREF, and FULL. MXREF(SOURCE) is the usual default.

- If you specify the MXREF(SOURCE) option, the macro and COPY source summary provides the data set or file name and volume identification for *every* file from which a member was taken, as well as an indication of whether it was a primary (SYSIN) source file or a library (SYSLIB) file, and a concatenation number to distinguish among concatenated input or library files. A list of members used is provided for each library, including inner macros and nested COPY statements.

  An example of the Macro and Copy Code Source Summary is shown in Figure 13.

```
                        Macro and Copy Code Source Summary

 Con Source                      Volume   Members
  P1 PRIMARY INPUT                        MYMAC
  L1 OSMACRO  MACLIB   S2         MNT190   FREEMAIN GETMAIN  RETURN   SAVE     TIME
  L4 ASMAMAC  MACLIB   S2         MNT190   ASMAXITP
```

Figure 13. Example of MXREF(SOURCE) output

  In this assembly, two macro libraries (OSMACRO and ASMAMAC) were referenced, even though at least four were specified in the SYSLIB concatenation. The members retrieved from each library are shown. The library files are identified by the information in the first column as “L1” and “L4”: these refer to library files (L) in concatenation sequence positions 1 and 4 respectively.

  If a macro definition was part of the SYSIN stream, the words “PRIMARY INPUT” are shown instead of a file name. (See also the discussion of the allocated-files information in “Assembly Summary” on page 24, and the example in Figure 18 on page 25.)

- If you specify the MXREF(XREF) option the cross-reference provides for each macro or COPY segment, its member name (if from a library), the concatenation number, which macro called it, the statement number at which it was defined, and the statement numbers at which

references to it were made. This XREF information is provided even if inner calls do not appear on the listing (e.g. by default, or if PRINT NOGEN or PRINT NOMCALL have been specified).

An example is shown in Figure 14.

```
                    Macro and Copy Code Cross Reference

Macro     Con  Called By        Defn  References
ASMAXITP   L4  PRIMARY INPUT       -  833
FREEMAIN   L1  PRIMARY INPUT       -  564
GETMAIN    L1  PRIMARY INPUT       -  165
RETURN     L1  PRIMARY INPUT       -  294, 527, 567
SAVE       L1  PRIMARY INPUT       -  110
TIME       L1  PRIMARY INPUT       -  256C          <-- 'C' tag means it was COPYed
```

Figure 14. Example of MXREF(XREF) output

The same library concatenation-number indicators are used here as in Figure 13 on page 18: "L4" for the fourth library in the concatenation, and "L1" for the first. This example shows that all the macros except RETURN are referenced only once, and the C tag following the statement number for the TIME macro shows that the macro was COPYed into the source stream.

The "–" in the "Defn" column means that the macro was not defined in the source stream.

- If you specify the MXREF(FULL) option, both the source summary and the cross-reference are produced.

The MXREF output is a valuable resource for tracking macro and COPY-file usage. Note also that the MXREF data is written to the SYSADATA file when you specify the ADATA option; it is then easy to extract useful data, either during the assembly (using an I/O exit) or later. A sample ADATA I/O exit (ASMAXADT) is provided with the High Level Assembler; it provides information about all members read from each library file. For further information, see Appendix I of the *High Level Assembler Programmer's Guide*.

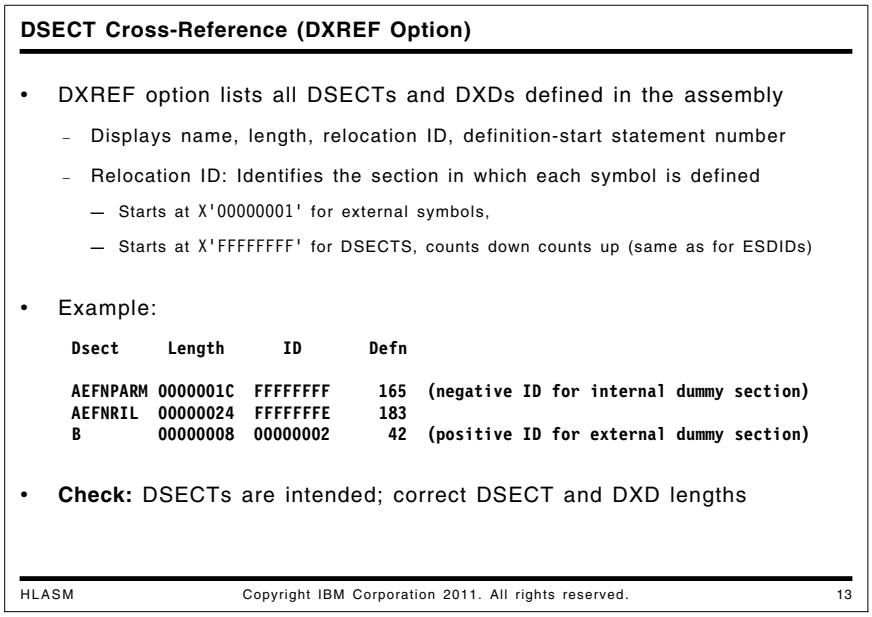
This information helps you manage version control, impact analysis, reassembly analysis, multiple library controls, and other code management tasks.

When you specify LIBMAC (via option or ACONTROL statement) and MCALL (via PCONTROL(MCALL) option or PRINT MCALL statement), additional valuable information may be available to you in the MXREF listing. This data also helps in possible error-tracing situations (see "Macros and Conditional Assembly" on page 62).

Things Worth Checking

- Verify that each macro and COPY file comes from the intended library. Multiple instances of a macro in different concatenated data sets can produce unexpected results.
- If a COPY file is referenced more than once, verify that the enclosing scope of the COPYed text will not cause duplicate definitions or a COPY loop (if conditional-assembly backward branches are used in the COPY text). An example showing how this problem can arise is discussed on page 75.
- Check that inner macros are called by the intended callers.
- Check for macro names that should appear but don't (see "Mnemonic Collisions" on page 67).

DSECT Cross-Reference (DXREF Option)



The DXREF option controls whether or not a dummy section (DSECT and DXD) cross-reference should be printed in the output listing. It displays:

- the name of the dummy section,
- the section's length,
- the relocation ID assigned to the section, and (this helps in identifying all symbols “belonging” to the section)
- the statement number where the definition begins.

Relocation IDs are assigned to external symbols starting at `X'00000001'` and counting up (this is the ESD ID of the external symbol), and starting at `X'FFFFFFFF'` for internal sections and counting down. Both internal and external dummy sections will appear in the DSECT cross-reference listing, as shown in Figure 15.

```
Dsect     Length      ID       Defn

AEFNPARM 0000001C  FFFFFFFF     165  (negative ID for internal dummy section)
AEFNRIL  00000024  FFFFFFFE     183
B        00000008  00000002      42  (positive ID for external dummy section)
```

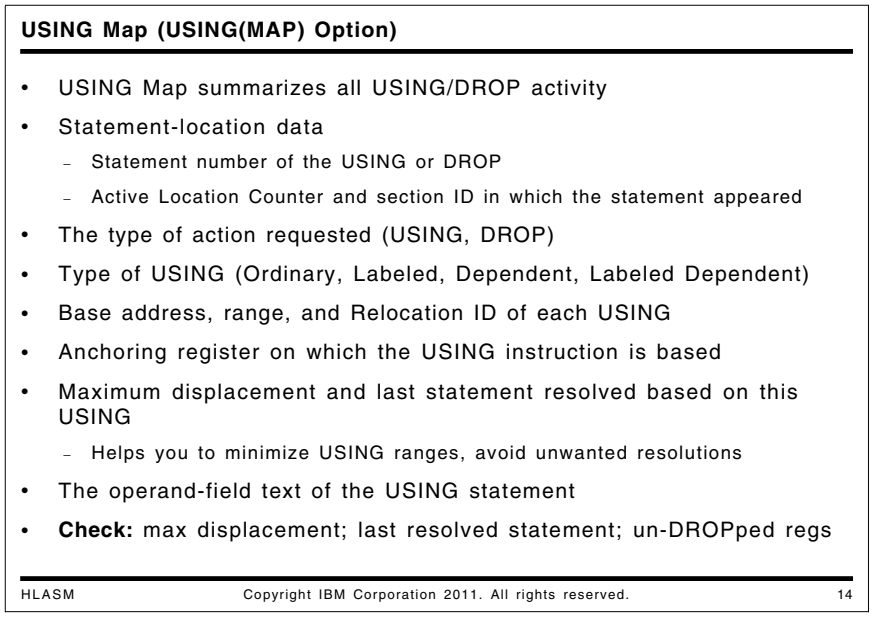
Figure 15. DSECT Cross-Reference with internal and external dummy sections

The first two DSECTs are internal (their IDs begin with `X'FFFF..'`) and the last (B) is an external dummy section. The presence of a positive ID value means that the external symbol is either a DXD name, or a DSECT name that has appeared as the operand of a Q-type address constant.

Things Worth Checking

- Verify that DSects (with negative relocation IDs) are indeed intended to be dummy sections, and that their length is as expected. (Sometimes you might forget to resume a CSect, making the preceding DSect contain extra or unwanted statements.)
- Check that DXD (external dummy section) names have the correct length. Their alignment is shown in the ESD listing, as noted on page 7.

USING Map (USING(MAP) Option)



The USING(MAP) option requests a USING Map in the listing. It summarizes all activity relating to the USING and DROP (and PUSH and POP USING) instructions in the program that control resolutions of symbolic addresses into base-displacement form. As illustrated in Figure 16 on page 22, the information provided includes:

- The statement number of the USING or DROP instruction.
- Under the “Location” heading, the “Count” and “Id” columns give the Location Counter value and the Relocation ID of the section at the point where the USING or DROP was issued.
- The “Action” column indicates whether the statement is USING or DROP.
- Under the “Using” heading, the “Type”, “Value”, “Range”, and “Id” columns describe the type of each USING, the base address of the USING, the range of resolution if a range limit is specified, or if a dependent USING is anchored at a nonzero offset, and the Relocation ID of the base address. The “Reg” column shows the register(s) assigned as base(s), or involved in DROP instructions.
- The “Max Disp” column shows the maximum displacement calculated for the specified base register. Large values indicate that object(s) addressed by that register may run out of addressability if more statements are added.
- The “Last Stmt” column indicates the last statement in which the register was used to resolve an address (that is, the effective end of the USING's domain). This can help you to place your DROP instructions to minimize the domain of a USING, in order to avoid accidental resolutions with incorrect base registers.
- The “Label and Using Text” displays the operands of the USING statement, including the qualifier, if any.

```
                                  Using Map

Stmt  ---Location--- Action --------------Using----------- Reg Max  Last Label and Using Text
      Count     Id          Type         Value  Range  Id      Disp Stmt
   2  000000  000001 USING  ORDINARY    000000 000CA6 0001  15 C94   805 (*,End),R15
   6  00001E  000001 USING  ORDINARY    000000 001000 FFFF   4 0A0       Record,R4
  47  00021C  000001 USING  LAB+DEPND  +000070 000F90 FFFD   4 007       HF.PhoneNo,HomeFone
  48  00021C  000001 USING  LAB+DEPND  +00007A 000F86 FFFD   4 007       WF.PhoneNo,WorkFone
  49  00021C  000001 USING  DEPENDENT  +000066 000F9A FFFE   4 006       ZipCode,Zip
  93  00000C  000001 DROP                                    4           HF
  93  00000C  000001 DROP                                    4           WF
 710  0005BC  000001 USING  LABELED     000000 001000 FFFF   5 07E       OLD.Record,R5
 711  0005BC  000001 USING  LABELED     000000 001000 FFFF   6 07E       NEW.Record,R6
 812  00000C  000001 DROP                                    4           R4
 812  00000C  000001 DROP                                   15           R15
```

Figure 16. Example of a Using Map

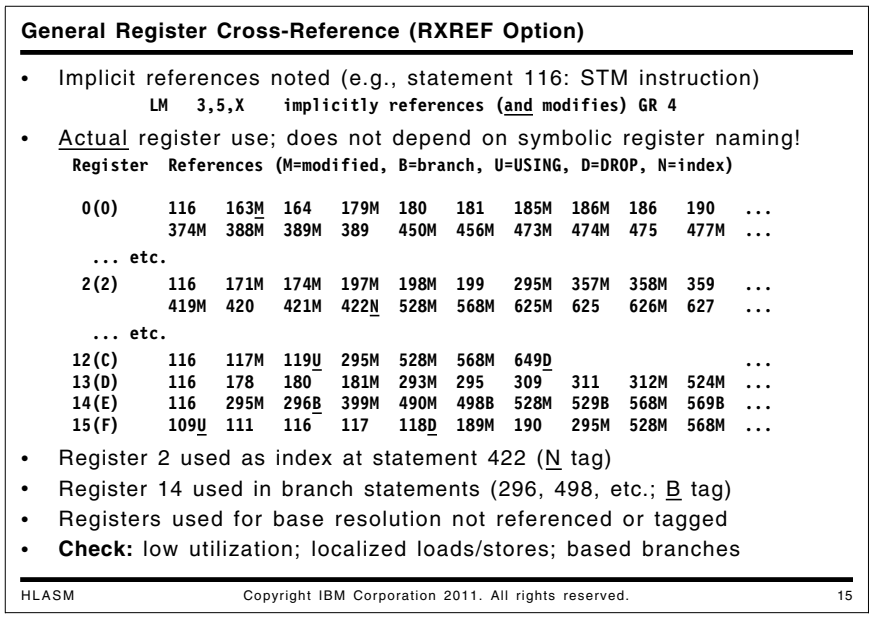
This example has been edited slightly to fit a narrower field than is actually displayed on the listing. An example of each of the four USING types is shown, and qualifier names have been prefixed to the base location name. A corresponding Using Heading is shown in Figure 8 on page 11.

For Dependent and Labeled Dependent USINGs, the “Value” column shows the offset from the anchoring location.

Things Worth Checking

- If the maximum displacement value is zero, it can indicate either that there is only a reference to the base address of a target field (such as the beginning of a DSect), or that there are no addressing references to that register (in which case the USING can be eliminated and the register assigned to other uses).
- Check for maximum-displacement values approaching `X'FFF'`. This can indicate that the base register may be about to exceed its addressability range. You can specify the USING(LIMIT(xxx)) option (described on page 47) to ask HLASM to tell you when a base register is approaching addressability limits.
- Check the statement number of the last statement resolved for each USING, and put appropriate DROP instructions as closely as possible after that statement. This can help avoid later undesired resolutions against that base register.
- Check for un-DROPped registers. Their presence can also cause undesired resolutions.

General Register Cross-Reference (RXREF Option)



HLASM produces a cross-reference of all general register usage when the RXREF option is specified. Slide 15 shows an excerpt from a typical general-register cross-reference. All sixteen registers are shown in a complete listing, with implicit *and* explicit references indicated; cases where a register is assigned as a base register by normal base-displacement resolution are not shown.

The register cross-reference is *independent* of, and more useful than, the symbol cross-reference: "absolute" non-symbolic register references (such as those generated by many system macros) are not shown in the symbol cross-reference, but *are* shown in the register cross-reference. Implicit register uses (as in multiple-register instructions like LM, STM, D, M, SLDL, etc.) are also shown, even though the register number is not specified in the instruction itself.

The register cross-reference includes tags on statement numbers where the statement causes the register to be

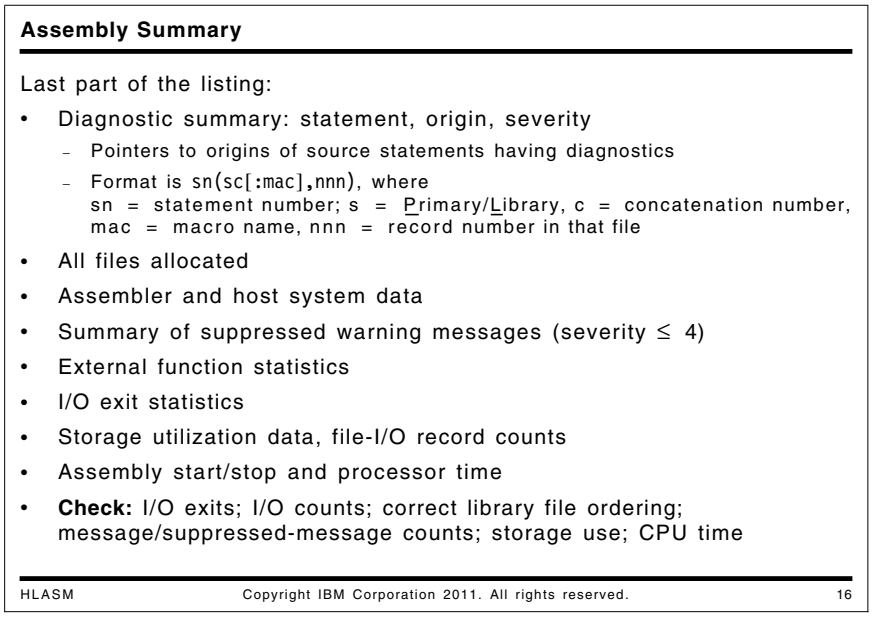
- modified (`'M'` tag)
- specified as a base register in a USING statement (`'U'` tag)
- used as an index register (`'N'` tag)
- used in a DROP statement (`'D'` tag)
- used as a branch-target address (`'B'` tag)

This information is very helpful, especially in finding instructions that modify a register in unexpected ways.

Things Worth Checking

- Registers with low levels of (or no) utilization can be identified to achieve better register-usage balance.
- Closely located store/load activity for a register can indicate a need for more registers usable as base registers. Modifying the code to utilize relative branch instructions can free some base registers for other uses.

Assembly Summary



The diagnostic and assembly summary includes information about the entire assembly, including detailed information about the number of I/O actions, memory usage, number of diagnostic messages, suppressed messages, host system, Assembler version, and other related data.

- All flagged statements are listed by statement number; if the FLAG(RECORD) option is active, each statement number is accompanied with information specifying the exact source record and the file from which it was read. For example, a small assembly with several intentional errors produced this portion of the diagnostic summary:

```
Statements Flagged

   1(P1,1), 4(L1:XXX,2), 6(P1,3), 7(L1:YYY,5), 8(L1:YYY,4), 9(P1,5)

    6 Statements Flagged in this Assembly     12 was Highest Severity Code
```

Figure 17. Example of compact diagnostic summary

  In Figure 17, the list of flagged statements gives the statement number, and in parentheses the file identifier (described in Figure 18 on page 25) and the member (if any) from that file, and the record number within that file that caused the error. The final line gives the number of statements causing diagnostics, and the highest severity associated with the messages.

  Using this information, you can quickly locate and correct the files or library members.

- The name of the assembler, its release level, and current PTF level. The system environment is also shown.
- All input and output data set names, member names, and volume IDs are displayed, listed by DDname, including concatenations (even if no macros or COPY files are taken from a library), as shown in Figure 18 on page 25.

```
Datasets Allocated for this Assembly

 Con DDname   Dataset Name                    Volume  Member
  P1 SYSIN    ASMAOXO2 ASSEMBLE D1           EHR192
  L1 SYSLIB   OSMACRO  MACLIB   S2           MNT190
  L2          ASMAFMAC MACLIB   A1           EHR191
  L3          ASMSMAC  MACLIB   L2           EHR195
  L4          ASMAMAC  MACLIB   S2           MNT190
     SYSLIN   ASMAOXO2 TEXT     D1           EHR192
     SYSPRINT ASMAOXO2 LISTING  D1           EHR192
```

Figure 18. Example of Allocated Data Sets/Files summary information

This example (run on CMS) shows that a single file was allocated for all but SYSLIB, for which four concatenated libraries were allocated. The order of concatenation is indicated in the "Con" column, where "L" means "Library" and "P" means "Primary Input", and the following numeric gives the concatenation order.

- A list of all messages suppressed by the SUPRWARN option, if any, is also displayed (see "SUPRWARN Option" on page 35).

```
Suppressed Message Summary

Message     Count   Message     Count   Message ...
    33        1       303        0        ...
```

Figure 19. Example of Suppressed Message summary

- External function statistics include the name of each function, the number of calls of each type, and the number of messages issued and their maximum severity.

  The following example shows the results of a test program that passed valid and invalid data to two functions.

```
External Function Statistics
 ----Calls----  Message   Highest  Function
 SETAF   SETCF    Count  Severity  Name
   195       1       55      12    LOG2        <-- arithmetic function
     1      13        2      12    REVERSE     <-- character function
```

Figure 20. Example of summary Function Statistics

LOG2 is an arithmetic function, REVERSE is a character function; each was called once in the wrong mode to verify that it produced the expected severity-12 error message issued by each function.

- I/O exit statistics describe the exit type, exit name, number of calls to the exit, number of messages produced, and number of records added or deleted. The following figure shows the information produced from a sample exit.

```
Input/Output Exit Statistics
Exit Type  Name      Calls  ---Records---  Diagnostic
                            Added Deleted  Messages
OBJECT     OBJX         10      3       0        1
```

Figure 21. Example of assembly I/O exit activity

- The central storage available and used for the assembly.

```
     5551K allocated to Buffer Pool          Storage required    1540K
```

Figure 22. Example of assembly storage utilization

- I/O statistics describe the number of reads and writes for each file used by the assembler.

```
   792 Primary Input Records Read       1283 Library Records Read
     0 ASMAOPT Records Read             1359 Primary Print Records Written
    14 Punch Records Written               0 ADATA Records Written
```

Figure 23. Example of assembly I/O activity

- The start and stop times of the assembly, an estimate of processor time required for the assembly, and the final return code of the assembly.

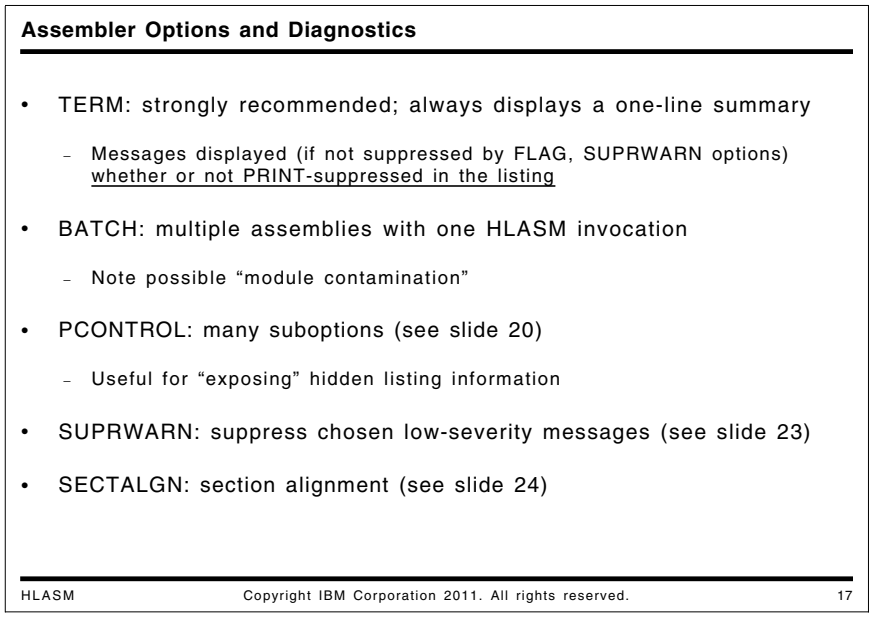
```
  Assembly Start Time: 11.00.11 Stop Time: 11.00.12 Processor Time: 00.00.00.1101
  Return Code 000
```

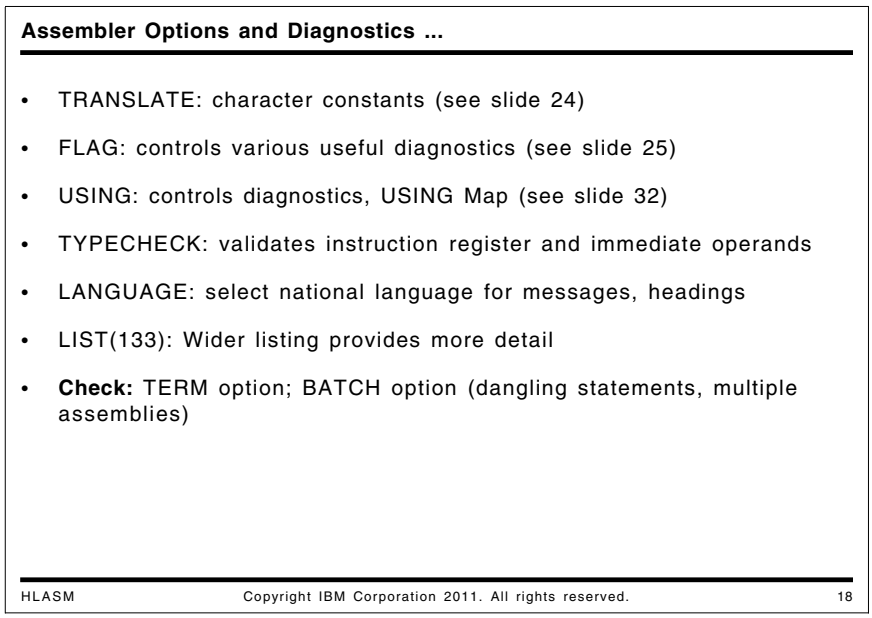
Figure 24. Example of assembly time estimates

Things Worth Checking

- Verify that I/O exits are ones you expect, and that the processing performed on input and output records looks reasonable. A listing exit can even suppress or modify information in the listing (including data about I/O exits!).
- Check that the files and data sets used for the assembly are as intended, and that library concatenations are in the correct order.
- I/O counts can help you determine that a reasonable number of records has been read or written.
- Information about storage use can be very helpful in setting storage sizes accurately, to avoid over-allocation, added costs, and assembly-time overheads.
- Check that the estimate of processing time appears to be consistent with other assemblies of roughly the same size of the current program. Larger values could indicate that some macros could be improved, or that the assembler itself is processing certain items inefficiently.

Assembler Options and Diagnostics





You can specify several High Level Assembler options to help find problems that might otherwise be obscure. These options include TERM, BATCH, PCONTROL, FLAG, and USING. Other options can help you reduce the effort to create desired results; these include LANGUAGE, LIST, SECTALGN, TYPECHECK, and TRANSLATE.

TERM Option

The terminal output display (on SYSTERM) summarizes the assembly's behavior, showing all diagnostic messages (if any). The message display is *not* affected by PRINT or other statements that may prevent them from being seen on the listing; they may be suppressed by the SUPRWARN option (see page 35) or by the FLAG(severity) option (see page 39) if the severity of the message is lower than the FLAG value.

TERM supports two suboptions (WIDE and NARROW). The blank-compressed NARROW layout is more readable and helps the output fit better on an 80-character-wide display. The WIDE format does not compress blanks, and may be more appropriate for screens that can display the full listing line length.

- A single-line summary is given for a successful assembly. This summary line reduces the amount of clutter on your terminal when assembling a “batch” of modules.
- The Deck-ID (if any; from a TITLE statement) is included in the summary message. This information helps you monitor the progress of a batch of assemblies, and associate diagnostic messages with the proper portion of the input file.

Suppose we assemble the small program shown in the following figure; the SPLAT mnemonic is intentionally unknown, and is meant to generate an error message.

```
        PRINT OFF
        SPLAT
        PRINT ON
        SPLAT
        END
```

Figure 25. Source program with intentional errors

When this program is assembled, the PRINT OFF statement will cause the first SPLAT instruction *and its associated diagnostic* to be suppressed, as the extract from the listing file shown in Figure 26. The ASMA057E error message associated with statement 3 has been suppressed by the preceding PRINT OFF statement.

```
                                      2      PRINT OFF
                                      4      PRINT ON
                                      5      SPLAT
** ASMA057E Undefined operation code - SPLAT
                                      6      END
```

Figure 26. Source program with errors (some not visible)

If the TERM option is specified, then all error messages are visible, as shown in the following extract of the terminal display for this assembly:

```
                                      3      SPLAT
ASMA057E Undefined operation code - SPLAT
                                      5      SPLAT
ASMA057E Undefined operation code - SPLAT
Assembler Done      2 Statements Flagged /   8 was Highest Severity Code
```

Figure 27. TERM display with errors (all visible)

Things Worth Checking

- Specifying the TERM option is recommended, especially during program development.

- If you suspect that messages have been hidden in PRINT-OFF regions, the PCONTROL(ON) option will override all PRINT OFF statements; see page 33.

BATCH Option

The BATCH option lets you complete multiple assemblies with a single invocation of the assembler. However, programs assembled with the BATCH option sometimes produce unexpected assembly-time errors or even bind-time errors.

- When the NOBATCH option is specified, the assembler stops reading the input file when it has processed the first END instruction, whether or not that END record is the last record in the input file. Thus, any trailing records are ignored.
- When the BATCH option is specified, the assembler completes each assembly when its END instruction is encountered, reinitializes, and then continues to read the input file for further source modules. If the records following an END instruction do not form a valid source program, unexpected diagnostics may be produced; and if these following records *do* form a valid source program, their presence in the object file may cause unexpected behavior at link/bind time.

Extra (Dangling) Statements

Sometimes the END instruction of an assembly is followed by extra records whose presence is seen only when the BATCH option is specified.

Suppose we create an input file with a complete assembly plus some additional "dangling" statements, as illustrated in the following figure:

```
A    CSect
Con  DC    F'1'
     END
*    Define a constant
```

Figure 28. Source file with dangling statement

This program was assembled with various combinations of the BATCH and TERM options:

- NOBATCH and NOTERM: no errors detected; the assembly appears to be error-free, as expected.

```
000000                00000 00004     1 A    CSect
000000 00000001                       2 Con  DC    F'1'
                                      3      End
```

Figure 29. Listing of source file with dangling statement: NOBATCH, NOTERM

- NOBATCH and TERM: no errors, and a satisfactory terminal message. Again, the assembly appears to be problem-free.

```
Assembler Done No Statements Flagged
```

Figure 30. Terminal display for source file with dangling statement: NOBATCH, TERM

- BATCH and NOTERM: a second assembly with diagnostics:

```
000000                00000 00004     1 A    CSect
000000 00000001                       2 Con  DC    F'1'
                                      3      End
 --- many listing lines later ---
                                      1 * Define a constant
** ASMA140W END record missing
```

Figure 31. Listing of source file with dangling statement: BATCH, NOTERM

The assembly now completes with a nonzero return code (the severity depends on what kinds of statements follow the first END statement). Thus, a program that "always" assembled successfully in the past may appear to have been contaminated with new, unsuspected errors. This can be particularly annoying if the first assembly is very large, because the small second assembly may not be easy to find at the end of the main assembly listing. The next example shows how to remedy this.

- BATCH and TERM: a second assembly with diagnostics:

```
000000                00000 00004     1 A    CSect
000000 00000001                       2 Con  DC    F'1'
                                      3      End
 --- many listing lines later ---
                                      1 * Define a constant
** ASMA140W END record missing
```

Figure 32. Listing of source file with dangling statement: BATCH, TERM

The terminal display shows clearly that more than one assembly was being processed:

```
Assembler Done No Statements Flagged
ASMA140W END record missing
Assembler Done      1 Statement  Flagged /   4 was Highest Severity Code
```

Figure 33. Terminal display for source file with dangling statement: BATCH, TERM

Batch Assemblies and Private Code

The presence of Private Code (PC) sections can "contaminate" a bound module (see also the discussion of Private Code on page 10). Suppose you assemble a program with an added fragment, specifying the BATCH option. Consider this example of a source file:

```
A    CSect
A    AMode 31
A    RMode 31
               ...and lots of other stuff
     End
R1   Equ   1
     End
```

Figure 34. Source file with extra assembly

When assembled, *two* object files and External Symbol Dictionaries are generated:

```
Symbol   Type   Id     Address  Length     LD ID  Flags Alias-of
A         SD 00000001 00000000 00000AF8             06

Symbol   Type   Id     Address  Length     LD ID  Flags Alias-of
          PC 00000001 00000000 00000000             00  ◄— AMODE 24, RMODE 24
```

Figure 35. ESD from source file with extra assembly

When the two object files are linked, the added Private Code (PC) section might force the linked module's AMODE/RMODE to the lowest values (24/24), rather than the intended 31/31.

Things Worth Checking

- Don't "hide" unwanted or unused statements after the END statement; better, use AGO statements to skip the records.
- If unexpected errors occur in an otherwise "clean" assembly, check for the presence of the BATCH option and more than one assembly listing.
- If bind-time addressing or residence modes are not as expected, check for extra records following the first END instruction that were assembled due to the BATCH option. (Private Code can also cause this condition, as discussed on page 9.)
- Message ASMA140W may indicate the presence of "dangling" statements, possibly following the only (intended) END instruction.

PCONTROL Option and the PRINT Instruction

PRINT Instruction Operands

- PRINT instruction operands affect the source and object code listing
  - **ON, OFF**: control display of source/object code listing
    - Be careful: PRINT OFF also disables message printing on the listing
    - Messages are always visible if TERM option is specified
  - **DATA, NODATA**: control display of DC-generated data
  - **GEN, NOGEN**: control display of conditional-assembly generated statements
  - **MCALL, NOMCALL**: control display of inner macro calls
  - **MSOURCE, NOMSOURCE**: control display of macro-generated source statements
  - **UHEAD, NOUHEAD**: control display of Active-USINGs heading
- NOPRINT operand allowed on PRINT, PUSH, POP
  - Allows these statements to hide themselves!
  - But PCONTROL option can override them (see slide 20)

HLASM 19

The PRINT instruction supports six pairs of complementary operands, each pair enabling or disabling selected portions of the source and object code listing. However, useful information may be hidden because parts of the listing have been suppressed by NOxxx or OFF operands.

The operands of the PRINT instruction are:

ON, OFF
These operands enable and disable lines in the source and object code listing, including diagnostic messages. Specifying the TERM option will let you see all diagnostic messages

not suppressed by the FLAG(n) option, even though PRINT settings may prevent their appearance in the listing. The examples at "TERM Option" on page 28 show how this works.

DATA, NODATA
If NODATA is specified, the listing will show only the first line of data generated by DC instructions (usually, at most 8 bytes). If DATA is specified, all generated data will be displayed.

GEN, NOGEN
If the GEN operand is specified, all statements generated by conditional assembly or macros, except for inner macro calls, are displayed with a + character to the left of the statement. The NOGEN operand suppresses the display of these generated statements.

When PRINT NOGEN is in effect, High Level Assembler displays the location counter value in effect for the first macro-generated code on the same line as the source statement.

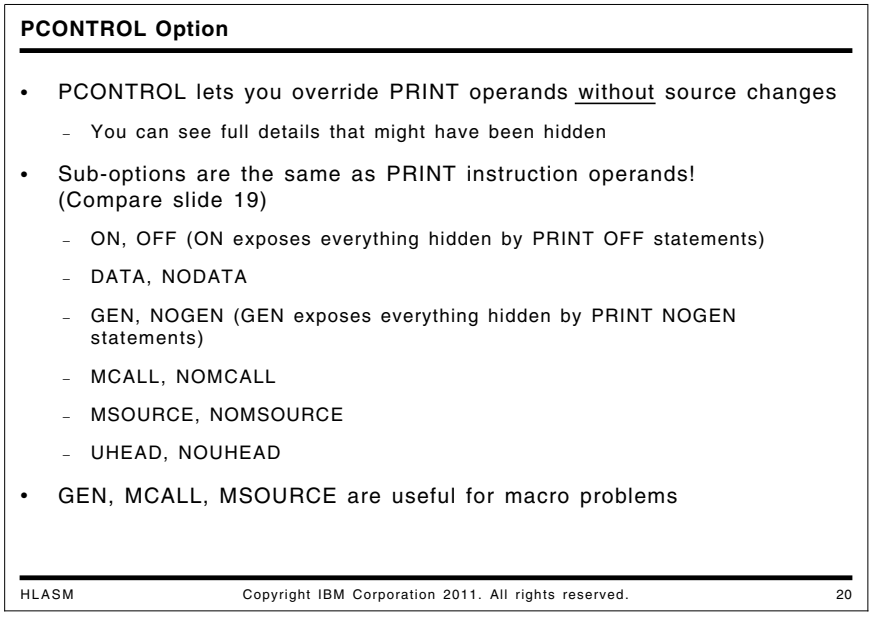
MCALL, NOMCALL
The MCALL operand controls the printing of inner macro calls. When an outer-level (or "top-level") macro is called, the assembler displays that call on the listing (if other controls do not prevent its appearance), and subsequent inner calls are displayed. This helps you debug complex nested macro interactions.

Additional information is shown in the Macro Summary and XREF, described on page 18. Macro calls displayed in the listing by the MCALL facility are not affected by the COMPAT(MACROCASE) option, discussed on page 65.

MSOURCE, NOMSOURCE
The NOMSOURCE operand suppresses the display of subsequent macro-generated source statements while still showing the generated object code. See "PCONTROL(MSOURCE) Option" on page 34 for further details.

UHEAD, NOUHEAD
The UHEAD operand controls the printing of the USING heading at the top of each page. Specifying NOUHEAD suppresses the USING heading on subsequent pages of the listing.

PCONTROL Option



The PCONTROL option can be used to "globally" override all occurrences of PRINT instructions appearing anywhere in the source program: OFF and ON, [NO]DATA, [NO]UHEAD, [NO]GEN, [NO]MCALL, and [NO]MSOURCE. With this option you can force the display of code that would otherwise be invisible or obscured in normal listings, without having to modify *any* element of the source code itself.

PCONTROL(ON) Option

Long sequences of statements that appear in every assembly may become so familiar that they need not be present in the listing, so they are sometimes suppressed by PRINT OFF statements. Later changes to the program may cause errors in regions previously hidden by PRINT OFF, so the reasons for the error can be hard to find. Rather than modify PRINT instructions in *every* block of statements in such regions, simply reassemble with the PCONTROL(ON) option, and all statements in such PRINT-OFF regions will be displayed. (The TERM option is also very helpful in these situations.)

PCONTROL(DATA) Option

Most DC instructions generate small enough strings of data bytes that all "interesting" bytes are displayed. If, however, you want to verify that correct data has been generated *without* having to insert PRINT DATA instructions in the source program, just reassemble with the PCONTROL(DATA) option.

PCONTROL(GEN) Option

The PCONTROL(GEN) option can help you find problems with macros and data declarations by causing generated statements from macros or open-code conditional assembly to appear in the listing. This provides additional detail that helps locate problems with such statements and their generators.

PCONTROL(MCALL) Option

PCONTROL(MCALL) Option

- Controls display of inner macro calls
- Suppose you write these three simple macros:

```
   Macro                  Macro                  Macro
   TOP    &a,&b,&c        MIDDLE &x,&y,&z        BOTTOM  &j
   MIDDLE &c,&a,&b   &n   SetA   &x*&y+3*&z      MNote  '&j'
   MEnd                   BOTTOM &n              MEnd
                          MEnd
```

- The TOP macro transposed its arguments; invoked with NOMCALL active, no inner calls are visible:

```
  *Process PControl(NoMCALL)
         TOP    2,3,5        Expect: 2×3+3×5 = 21
 +19                         Hmm...  What went wrong ??
```

- When TOP is called with MCALL active, inner calls are visible:

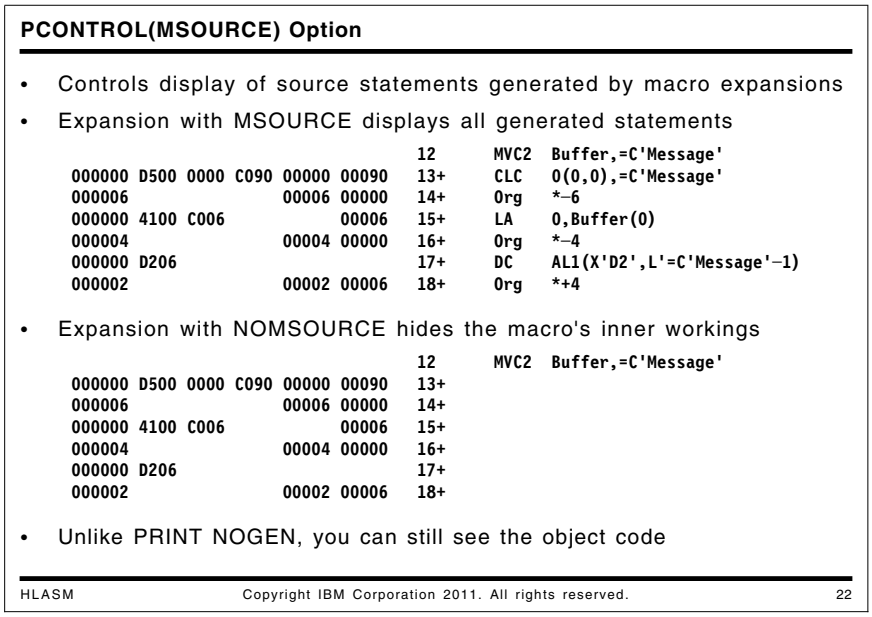
```
  *Process PControl(MCALL)
         TOP    2,3,5
 +       MIDDLE 5,2,3        Aha! Arguments were rearranged!
 +       BOTTOM 19           Got 5×2+3×3 = 19 instead
 +19
```

HLASM 21

The PCONTROL(MCALL) option specifies that *all* macro calls should be displayed, inner calls as well as top-level calls from open code. This can help you determine the flow of control *and* the values of arguments through levels of macro calls. The example in slide 21 shows how MCALL exposes the arguments of inner macro calls.

Macro calls are displayed in their original “as-created” case, independent of the COMPAT(MACROCASE) option, discussed on page 65.

PCONTROL(MSOURCE) Option



There are times when complicated schemes are used in macros to generate object code, and while seeing the generated machine language may be helpful, the generated statements themselves may be confusing. By specifying the PCONTROL(NOMSOURCE) option, the source lines may be suppressed without eliminating the generated machine language. An example is shown in slide 22.

Note that this option requires that PRINT GEN statements or the PCONTROL(GEN) option be active; otherwise, the generated statements will not be printed in the listing.

PCONTROL(UHEAD) Option

Some types of USING-related problems can be analyzed more easily if all active USING instructions are known when statements are analyzed. Specifying the PCONTROL(UHEAD) option causes High Level Assembler to display the “Active Usings” heading described on page 10; PCONTROL(NOUHEAD) suppresses it.

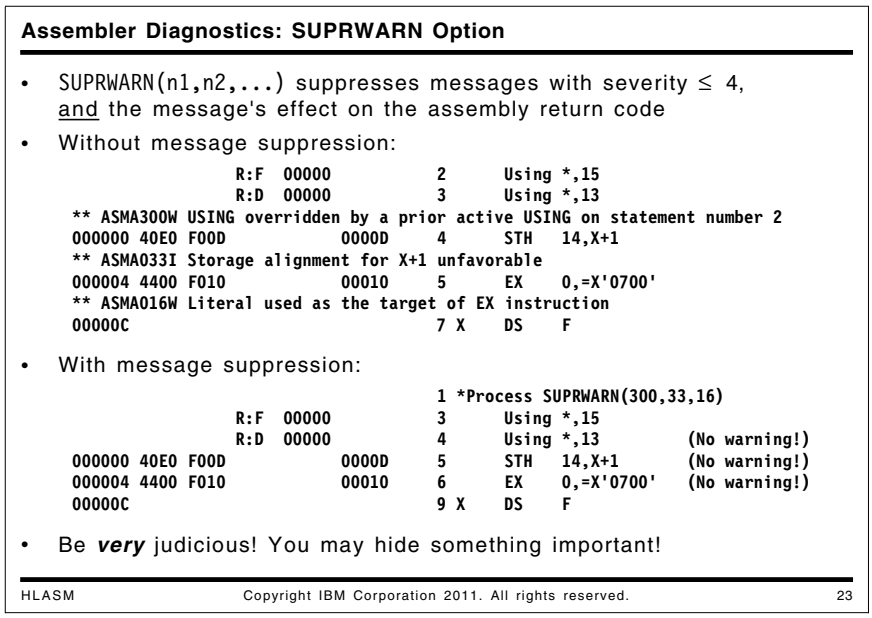
NOPRINT Operands on Certain Statements

The NOPRINT operand of the PRINT, PUSH, and POP instructions can help eliminate distracting detail in the listing and can make it easier to use High Level Assembler as a “cross-assembler” for other processor architectures. However, the NOPRINT operand hides the statement itself, which may make it harder to locate statements controlling the listing.

Note: Even if a program contains statements with NOPRINT operands, they are still available in the SYSADATA file described on page 71.

Things Worth Checking: Check that all needed source statements and/or generated data in the listing are visible. If parts are not visible, assemble the program with the appropriate PCONTROL options.

SUPRWARN Option



The SUPRWARN option lets you request that selected warning messages should not be issued. The option specifies a list of message numbers that will be ignored and not appear in the listing or on the terminal. Suppressing any message also removes its effect on the Assembler's return code.

For example, the code fragment in Figure 36 produces three diagnostic messages:

```
                 R:F  00000           2      Using *,15
                 R:D  00000           3      Using *,13
** ASMA300W USING overridden by a prior active USING on statement number 2
000000 40E0 F00D            0000D     4      STH   14,X+1
** ASMA033I Storage alignment for X+1 unfavorable
000004 4400 F010            00010     5      EX    0,=X'0700'
** ASMA016W Literal used as the target of EX instruction
00000C                               7 X    DS    F
```

Figure 36. Assembly with intentional warning messages

These informational and warning messages can be suppressed by specifying the SUPRWARN option shown in Figure 37:

```
                                     1 *Process SUPRWARN(300,33,16)
                 R:F  00000          3      Using *,15
                 R:D  00000          4      Using *,13         (No warning!)
000000 40E0 F00D            0000D    5      STH   14,X+1       (No warning!)
000004 4400 F010            00010    6      EX    0,=X'0700'   (No warning!)
00000C                               9 X    DS    F
```

Figure 37. Assembly with warning messages suppressed

Message numbers with severity greater than 4 cannot be suppressed. If specified, they will be rejected with a warning message, as shown in Figure 38 on page 36:

```
   Process Statements-     suprwarn(1)     <-- Assembler option listing

** ASMA319W Message 1 specified for suprwarn option, but severity is too high.
          Message ignored.
   - - -
*process suprwarn(1)                      <-- Source file
```

Figure 38. SUPRWARN option and message for invalid message number

Use the SUPRWARN option with great care. As many of the other examples in this document show, certain apparently harmless conditions can actually cause problems that would otherwise be difficult to find.

Things Worth Checking: Be sure to check the list of suppressed messages in the "Assembly Summary" page at the end of the listing (see Figure 19 on page 25 for an example). Verify that all the messages can indeed safely be ignored.

SECTALGN and TRANSLATE Options

Assembler Options SECTALGN and TRANSLATE

- SECTALGN(nnn) controls Assembler's alignment of control sections
  - nnn a power of 2. For OBJ: 8 or 16; for GOFF: 8 ≤ nnn ≤ 4096
  - Avoids need for creating binder statements with PUNCH/REPRO, e.g.

```
PUNCH '  PAGE   MAIN'
PUNCH '  ORDER  MAIN,SUB(P)'
```

- TRANSLATE(xx) controls translation of C-type character constants
  - Affects **all** C-type constants, and character terms if option COMPAT(TRANSDT) is also specified
  - CA, CE constant subtypes provide localized control

```
DC   CA'Text'    Always generates ASCII
DC   CE'Text'    Always generates EBCDIC
DC    C'Text'    Affected by TRANSLATE option

LA   0,C'$'      Affected by TRANSLATE and COMPAT(TRANSDT) options
```

  - Can help avoid unexpected translations if TRANSLATE option is specified
- **Check:** Section alignments; presence of PUNCH/REPRO statements; use of TRANSLATE option

HLASM 24

SECTALGN Option

The SECTALGN option lets you specify that section alignments at assembly time should be more stringent than the default doubleword alignment. This can be especially important for quadword-aligned data, and can sometimes be used to improve performance.

SECTALGN takes values expressed as a power of two. For example,

```
SECTALGN(16)
```

causes HLASM to begin each section on a quadword boundary.

Valid values of the SECTALGN option depend on the type of object file produced: for standard (OBJ) files, values 8 and 16 are valid; for GOFF files, all powers of two between 8 and 4096 are valid. Not all operating systems may support extended alignments, so HLASM issues a warning:

```
** ASMA216W Quad-word alignment in NOGOFF object text
```

On z/OS systems this warning can be ignored or suppressed.

For GOFF files used to create Program Objects, alignments specified for sections apply to all elements owned by the section.

TRANSLATE Option

The TRANSLATE option lets you specify that all C-type character constants should generate data using a different code page than the standard "Green-Card" EBCDIC (code page 37). If you specify no sub-option, HLASM will translate all such constants to ASCII; character self-defining terms will be translated if you *also* specify the COMPAT(TRANSDT) option. You can create your own translation table, as described in Appendix L of the HLASM *Programmer's Guide*.

If only certain constants should be translated to ASCII, you can use the CA subtype; and if all but certain constants are to be translated to your specified character set, you can specify the TRANSLATE option and then the CE subtype to specify that the constant must be in EBCDIC. You can also specify the COMPAT(TRANSDT) option to translate character self-defining terms with the same translate table.

```
DC   CA'Text'    Always generates ASCII;  no TRANSLATE effect
DC   CE'Text'    Always generates EBCDIC; no TRANSLATE effect
DC    C'Text'    Affected by TRANSLATE option

LA   0,C'$'      Affected by TRANSLATE and COMPAT(TRANSDT) options
```

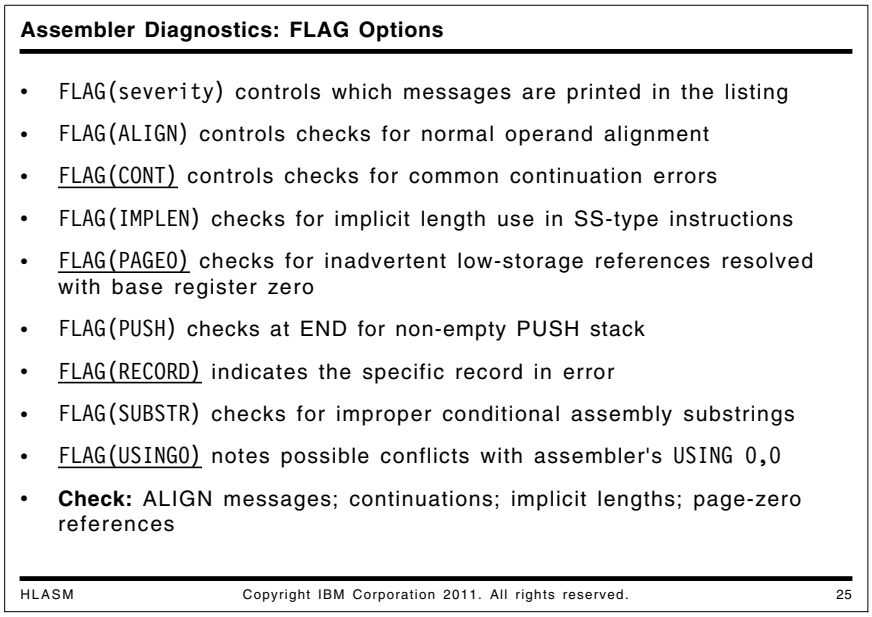
Figure 39. Translation of character constants and terms

There is no support for CA- and CE-type character self-defining terms.

Things Worth Checking: Verify that section alignments are as intended, and that they are not so strict that space may be wasted in the executing program.

If the TRANSLATE option is specified, verify that it specifies the intended translation table and target code page, and that only the intended constants were translated.

FLAG Option



You can request High Level Assembler diagnostics to help find problems that might not otherwise be evident. Many of these are controlled by the FLAG option and the USING option (page 47).

FLAG options include the following:

- FLAG(severity) controls which messages are printed in the listing, as described on page 39.
- FLAG(ALIGN) controls checking for potential problems with operand alignment, as described on page 39.
- FLAG(CONT) controls checks for possible errors in coding continuation statements. This option is discussed on page 40.
- FLAG(IMPLEN) controls checks for possibly unintentional omission of the length specification in SS-type instructions. Examples are shown on page 41.
- FLAG(PAGE0) controls checks for possible inadvertent references to addresses in the first 4K bytes of storage, as illustrated on page 42.
- FLAG(PUSH) checks at the end of the assembly for a non-empty PUSH stack, as described on page 44.
- FLAG(RECORD) causes HLASM to add a second message following a diagnostic to indicate the record number and source file from which the flagged statement was read. This option is discussed on page 44.
- FLAG(SUBSTR) controls checks for possible errors in coding conditional assembly substring notation. This is discussed on page 64.
- FLAG(USING0) notes possible conflicts with the assembler's implicit `USING 0,0` instruction. The implications of such conflicts are discussed on page 45.

All the FLAG sub-options except RECORD are controllable dynamically with the ACONTROL instruction, discussed on page 69.

FLAG(severity) Option

The **severity** value in the FLAG option is a decimal value between 0 and 255. Terminal messages (controlled by the TERM option) and listing messages are treated as follows:

- Assembler messages with severity indicators less than **severity** will not appear on the terminal or in the listing.
- MNOTE messages with severity indicators less than **severity** will not appear on the terminal, but will still be be printed in the listing without this prefixed text:

  ```
  ** ASMA254I *** MNOTE ***
  ```

Messages displayed on the terminal will be displayed if their severity is greater than or equal to **severity**.

Things Worth Checking: The FLAG(severity) option should always specify 0; otherwise, useful messages may be obscured.

FLAG(ALIGN) Option

FLAG(NOALIGN) causes High Level Assembler to suppress all warning messages when an alignment inconsistency is detected between a storage operand and a referencing instruction. When FLAG(ALIGN) is specified, the messages issued depend on the ALIGN option; the relationship between these two options is shown in the following table.

ALIGN,FLAG(ALIGN)	NOALIGN,FLAG(ALIGN)
• ASMA033I • ASMA212W • ASMA213W	• ASMA212W • ASMA213W

Table 1. Alignment Warning Messages and Their Dependence on ALIGN

The three messages are:

`ASMA033I` Issued where operand alignment is not on a natural boundary; for example, a LH instruction with an odd memory address.

`ASMA212W` Issued when a branch-target address is odd.

`ASMA213W` Issued where correct operand alignment is required; for example, a CS instruction.

Suppose your program refers to an operand that is not aligned on a normal boundary:

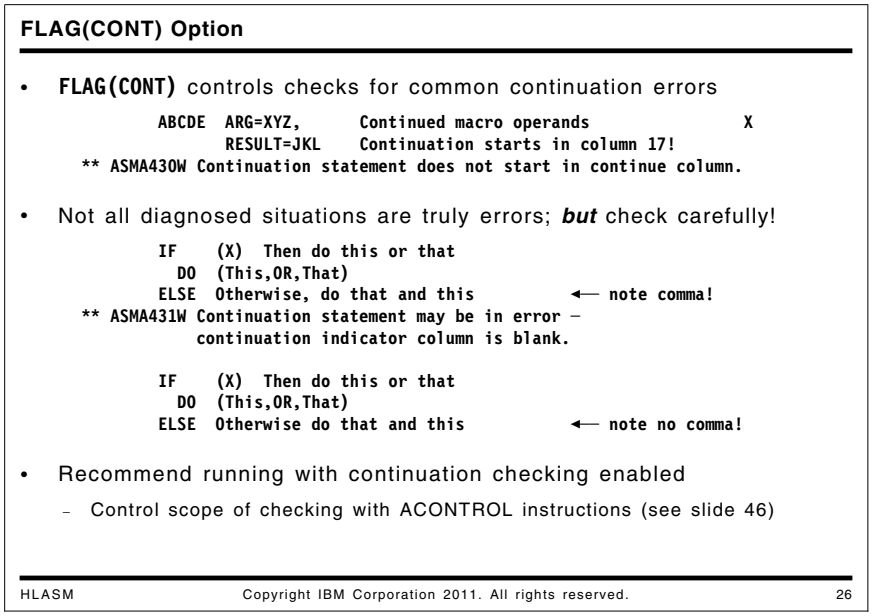
```
*PROCESS FLAG(ALIGN)
      L     0,X           X is not on a fullword boundary
** ASMA033I Storage alignment for X unfavorable

*PROCESS FLAG(NOALIGN)
      L     0,X           X still not on a fullword boundary; no message
```

Figure 40. Example of FLAG(ALIGN) option

The informational message is suppressed by either the FLAG(NOALIGN) or SUPRWARN(33) options.

Things Worth Checking: Alignment errors may cause performance degradation, and they could imply misaligned references to fields in a shared data structure mapped with a DSECT.

FLAG(CONT) Option and Continuation Statement Checking



A common source of errors is improper coding of continuation statements (the assembler language is unfortunately inflexible in its statement format!). Such errors can be extremely difficult to find and correct, so HLASM provides the FLAG(CONT) option to enable checking for continuation errors. The checks are neither exhaustive nor definitive, but they detect many typical errors.

In this example of calling the macro-instruction ABCDE,

```
         ABCDE  ARG=XYZ,      Continued macro operands               X
                RESULT=JKL    Continuation starts in column 17!      ◄— Error
  ** ASMA430W Continuation statement does not start in continue column.
```

Figure 41. Example of incorrect statement continuation

the continuation line begins in column 17, rather than in column 16 as intended. This would normally result in the second operand (RESULT=JKL) being ignored, which is probably not what was intended.

Occasionally, continuation checking flags statements that are in fact correct or harmless. For example, suppose you are using structured-programming macros in which the ELSE macro has no operands; a typical statement might look like this:

```
         ELSE         Take the other action
```

The remark **"**Take**"** appears to be a normal positional operand, so no diagnostic appears. However, if you had written

```
         ELSE         No, take the other action
```

Then the presence of the comma after the word "No" would make it appear to be the first operand in a list. The absence of a continuation indicator is (mis-)understood to indicate a missing operand, and the assembler will flag the statement with an ASMA431W warning message.

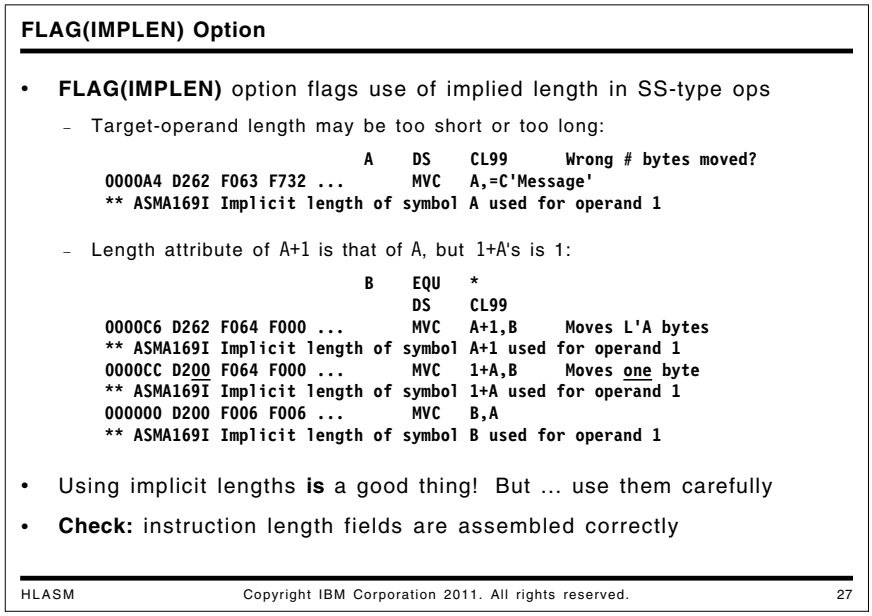
Continuation checking can be disabled by specifying the FLAG(NOCONT) option.

FLAG(CONT) helps you find one of the most insidious Assembler Language errors: when statements are continued, misplacement of a single character can cause portions of statements to be ignored. Specifying this option causes High Level Assembler to flag unusual or suspicious but difficult-to-find errors in specifying continued and continuation statements:

- An operand on a continued record ends with a comma, and a continuation statement is present, but the continuing statement does not begin in the "continue" column (usually, 16).
- A list of operands ends with a comma, but the continuation column (usually, 72) is blank.
- The continuing statement starts in the continue column, but there is no comma present following the operands on the previous continued record.
- The continued record is full, but the continuation record does not start in the continue column.

Things Worth Checking: Continuation checking can be *very* valuable; it is strongly recommended as a regular diagnostic. You can use the ACONTROL instruction (described on page 69) with FLAG(NOCONT) and FLAG(CONT) operands to localize checking around statements known to be correct.

FLAG(IMPLEN) Option and Length Specifications



Occasionally an SS-type instruction requiring a length field will resolve the length implicitly, by using the length attribute of the the appropriate operand. This may or may not be intended:

```
                          B    EQU   *
                          A    DS    CL99
0000A4 D262 F063 F732 ...      MVC   A,=C'Message'   Wrong number of bytes moved?
** ASMA169I Implicit length of symbol A used for operand 1

0000C6 D262 F064 F000 ...      MVC   A+1,B           Moves L'A bytes
** ASMA169I Implicit length of symbol A+1 used for operand 1

0000CC D200 F064 F000 ...      MVC   1+A,B           Moves one byte
** ASMA169I Implicit length of symbol 1+A used for operand 1

000000 D200 F006 F006 ...      MVC   B,A
** ASMA169I Implicit length of symbol B used for operand 1
```

If you specify FLAG(IMPLEN) as an option or as an operand of an ACONTROL instruction, HLASM will issue an informational (severity zero) message when implicit lengths are used.

Things Worth Checking: Using implied lengths is a good practice, and is almost always correct, having the assembler check these uses helps you ensure that an error has not been overlooked.

Length attribute references to equated symbols can sometimes cause problems. For example:

```
     Bad Code                              Better Code
T    DS    CL24                      TLen  Equ   24
TLen Equ   L'T         Bad!          T     DS    CL(TLen)
     - - -                                 - - -
     MVC   X(L'TLen),T (Length 1!)          MVC   X(TLen),T
```

FLAG(PAGE0) Option and Unintended Low-Storage References

FLAG(PAGE0) Option

- Page 0 reference: **FLAG(PAGE0)** option flags “baseless” resolutions (potentially **very** important in Access Register mode!)

```
 *!     BR   14         was intended...
        B    R14        Branch to address 14
 ** ASMA309W Operand R14 resolved to a displacement with no base register

 *!     MVC  A,=C'A'    was intended...
        MVC  A,C'A'     Move bytes to A, starting at address 193
 ** ASMA309W Operand C'A' resolved to a displacement with no base register

 *!     LA    0,8       was intended...
        LH    0,8       (What if the 2 bytes at address 8 contained 8!)
 ** ASMA309W Operand 8 resolved to a displacement with no base register

 *!     MVC   6(,2),B   was intended...
        MVC   6(2),B    Length 2, base register zero (protection exception?)
 ** ASMA309W Operand 6(2) resolved to a displacement with no base register

        L     1,0(2)    Possible AR-mode problem?
 ** ASMA309W Operand 0(2) resolved to a displacement with no base register
    (Generated instruction 58120000 has base register 0: no AR qualification)
```

HLASM 28

Infrequently a programmer will write an instruction operand that assembles without diagnostics, but the operand address is resolved with respect to register zero. For example:

```
         B    R14             Intended:    BR    14
         CLC  X(1),C'0'       Intended:    CLC   X(1),=C'0'
         LH   R2,X'0018'      Intended:    LH    R2,=X'0018'
or
         LH   R2,X'0018'      Intended:    LA    R2,X'0018'
```

Figure 42. Statements accidentally referencing page zero

HLASM resolves the absolute expression in the operand with register zero as the base register.

In each case, a reference is made to the first 4K bytes of storage, or "Page 0". If you specify FLAG(PAGE0) as an option or as an operand of an ACONTROL instruction, HLASM will flag such uses with a warning message (except when the operand is used in an LA instruction).

Note that *based* references to page zero are valid, and are not flagged:

```
         USING PSA,R0          Page-zero mapping DSect
         L     R1,PSACVT       etc.
```

Similarly, *explicit* references to page zero are not flagged:

```
         L     1,16(0,0)  Explicit reference is OK

         L     1,16       Typical implicit reference
** ASMA309W Operand 16 resolved to a displacement with no base register
```

This warning can be extremely important for programs executing in Access-Register (AR) mode, because the index field of an instruction is not qualified by an Access Register. For example:

```
         L     1,0(2)
```

is assembled as though it had been written

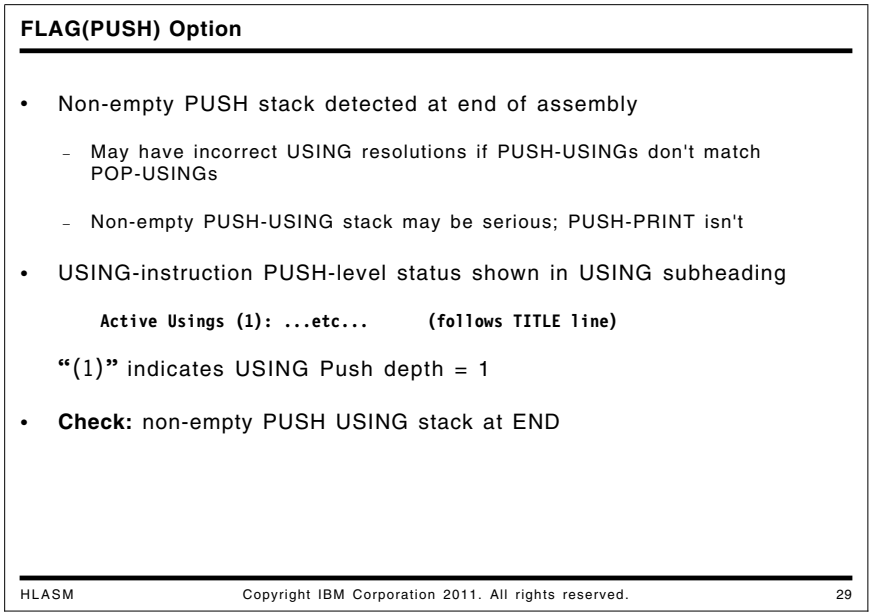
```
         L     1,0(2,0)       Object code 5812 0000
```

This will use general register 2 for a "base" address when not in AR mode; but in AR mode, Access Register 2 will not be referenced! To obtain correct addressing in all modes, the statement should be written

```
         L     1,0(0,2)       Object code 5810 2000
```

Things Worth Checking: This diagnostic is strongly recommended: it can catch errors that may otherwise be unnoticed for a long time. It is especially important for programs that may execute in AR mode.

FLAG(PUSH) Option and Non-Empty PUSH Stack



The PUSH instruction lets you save the status of PRINT, USING, and ACONTROL statements. At the end of the assembly, HLASM checks to see if the PUSH stack is empty; if not, it issues diagnostic ASMA138W. The depth of the USING stack is indicated in the "Active Usings" heading on each page, as shown in slide 29. The diagnostic can be suppressed with the FLAG(NOPUSH) option.

Things Worth Checking: While a non-empty PUSH stack is rarely serious, it could indicate that a USING environment was suspended and not restored, which could mean that incorrect base-displacement resolutions were derived for statements that follow the point where a POP USING statement should have appeared. Specifying this option can help detect such oversights.

FLAG(RECORD) Option

The FLAG(RECORD) option causes High Level Assembler to provide supplementary information (with each diagnostic message, and in the diagnostic summary) about the data set name and relative record number within that data set for the statement involved. This option can help you locate the original source statement requiring correction.

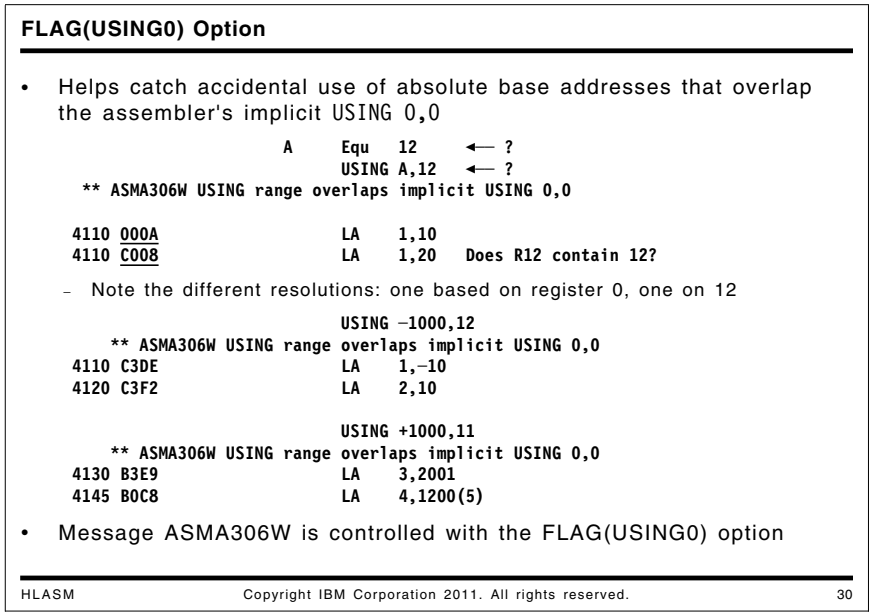
Figure 43 illustrates the additional ASMA435I message produced when FLAG(RECORD) is specified:

```
** ASMA062E Illegal operand format - T'V
** ASMA435I Record 26 in TATST    ASSEMBLE A1 on volume: EHR191

** ASMA137S Invalid character expression - 4)
** ASMA435I Record 35 in TATST    ASSEMBLE A1 on volume: EHR191
```

Figure 43. Examples of ASMA435I message

The ASMA435I messages show the name of the file and the number of the record in that file where the diagnostic was issued. This makes it easy to edit and correct the source file at the same time the listing is being scanned for diagnostic messages.

FLAG(USING0) Option: USINGs With Absolute Base Address



If you specify a USING instruction with an absolute base address whose range overlaps that of the assembler's "implicit USING 0,0", HLASM will issue message ASMA306W.

Suppose the following statements appear in a program, where the symbol A was meant to be relocatable:

```
                    A     Equ   12
                          USING A,12
 ** ASMA306W USING range overlaps implicit USING 0,0

4110 000A                 LA    1,10
4110 C008                 LA    1,20
```

Note that the two values 10 and 20 are resolved quite differently: because a valid displacement cannot be calculated for the implied absolute address 10 from existing USINGs, the assembler uses its implicit USING 0,0 to resolve the value with base register zero. The absolute address 20 can be resolved with a *smaller* displacement (8) using base register 12, as indicated.

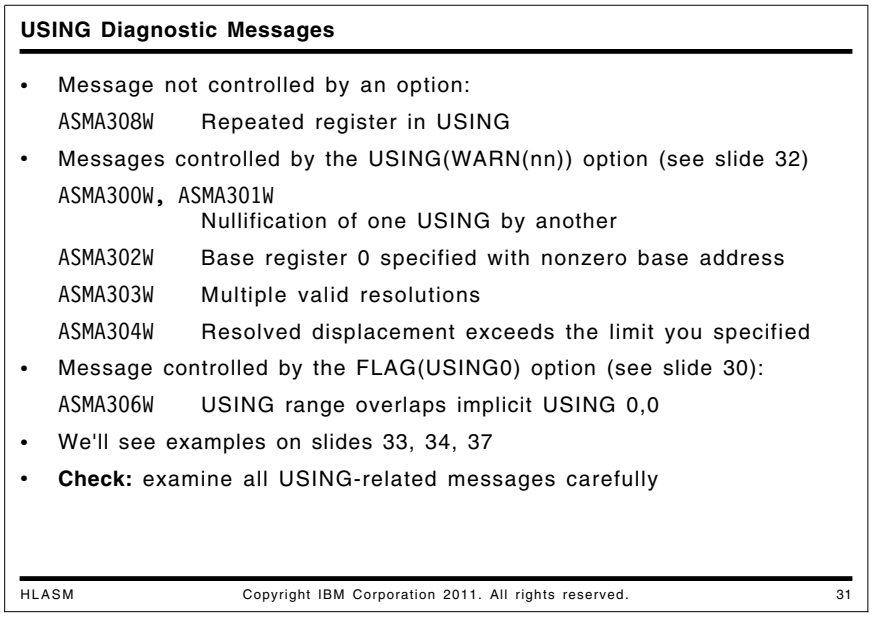
If a USING instruction specifies an absolute base address whose range overlaps the range of the assembler's "implicit" USING 0,0 then unexpected resolutions might occur:

```
                          USING -1000,12
    ** ASMA306W USING range overlaps implicit USING 0,0
4110 C3DE                 LA    1,-10
4120 C3F2                 LA    2,10

                          USING +1000,11
    ** ASMA306W USING range overlaps implicit USING 0,0
4130 B3E9                 LA    3,2001
4145 B0C8                 LA    4,1200(5)
```

Additional USING diagnostics are described below.

Things Worth Checking: While absolute base values are rarely used intentionally, they can cause serious problems in code written to assume they will never be present. This diagnostic can help avoid errors that may otherwise be difficult to find.

USING Diagnostic Messages



Because USING errors can be difficult to find and can have serious impacts on program execution, HLASM provides extensive checking for potential misuse.

Remember that the assembler uses these resolution rules for base-displacement addressing:

1. The assembler searches the USING Table for entries with a relocatability attribute matching that of the implied address (which will almost always be simply relocatable, but may be absolute). (If the implied address is complexly relocatable, no match will be found.)
2. For all matching entries, the assembler checks to see if a valid displacement can be derived. If so, it will select as a base register that register which yields the smallest nonnegative displacement. If the smallest valid displacement exceeds the USING range (usually 4095 bytes), the assembler will indicate the amount by which the implied address was not “reachable”.
3. If more than one register yields the same smallest displacement, the assembler will select as a base register the highest-numbered register.
4. If no resolution has been completed and the implied address is absolute, attempt a resolution with register zero and base zero.
5. If a long displacement is being resolved, the smallest nonnegative displacement is chosen; if none is available, the smallest negative displacement is chosen.

Five USING diagnostics are controlled by the USING(WARN) option, and one of them also depends on the USING(LIMIT) option (described on page 47). One USING diagnostic is controlled by the FLAG(USING0) option, as discussed previously on page 45.

One other USING diagnostic is not controlled by an option. Previous assemblers did not diagnose repeated uses of the same base register in one USING instruction; such (admittedly unusual) specifications could lead to unexpected resolutions, when all but the last instance of a register was ignored! In early assemblers, the instruction

```
USING base,12,11,12,11
```

was treated as being equivalent to the four statements

```
                        USING base,12
                        USING base+4096,11
                        USING base+8192,12
                        USING base+12288,11
```

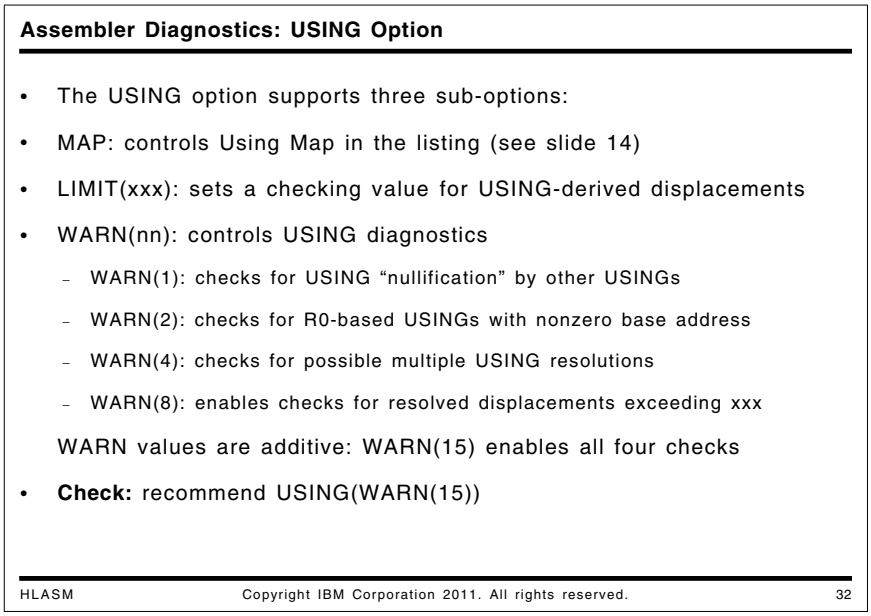
so the first two “USINGs” were effectively ignored.

High Level Assembler diagnoses this situation:

```
                        USING base,12,11,12,11
** ASMA308E Repeated register 12
** ASMA308E Repeated register 11
```

The statement is ignored; you could find that some or all of your program has no addressability.

USING Option



USING options to be described include the following:

- USING(MAP) controls the presence of the USING Map, as described on page 21.
- USING(LIMIT(xxx)) checks for displacements that exceed the specified limit (“xxx”) in addressability resolutions.
- USING(WARN(nn)) controls checking for errors associated with the USING instruction.

USING(LIMIT(xxx))

This causes the assembler to check all calculated displacements. If the USING(WARN(8)) option is active and any displacement exceeds the xxx value, a warning message will be issued. This helps you detect portions of the program that may be in danger of running out of addressability when new statements are added.

USING(WARN(nn))

The WARN(nn) suboption of the USING option helps you check for several common USING-instruction errors and oversights. Because USING instructions are the most important of the Assembler Language's addressing facilities, these features help you diagnose possible misuses. These sub-options are:

WARN(1) Warnings are enabled for two common errors involving cases where an ordinary USING instruction will cause either a previous or a subsequent USING instruction to be ignored by the assembler. The terminology used in the High Level Assembler's message is that one USING is “nullified” (or “made inactive”) by another.

WARN(2) The use of register zero as a base register with a nonzero absolute base is detected. This helps to isolate errors caused by forgetting that General Register 0 cannot be used as a base register.

WARN(4) Multiple valid resolutions are flagged. In some programs, this may be an error. In other cases, the structure of the program may cause USING ranges to overlap. (An overlap of exactly one byte will not be flagged.)

This diagnostic may indicate a potential problem when in fact there is none. This condition can be controlled by specifying a USING range limit, as described in “USING Range Limits” on page 51. However, it should not be suppressed automatically: a detailed example of the importance of this diagnostic will be shown in “Fixing USING Problems with Multiple Resolutions (ASMA303W)” on page 50.

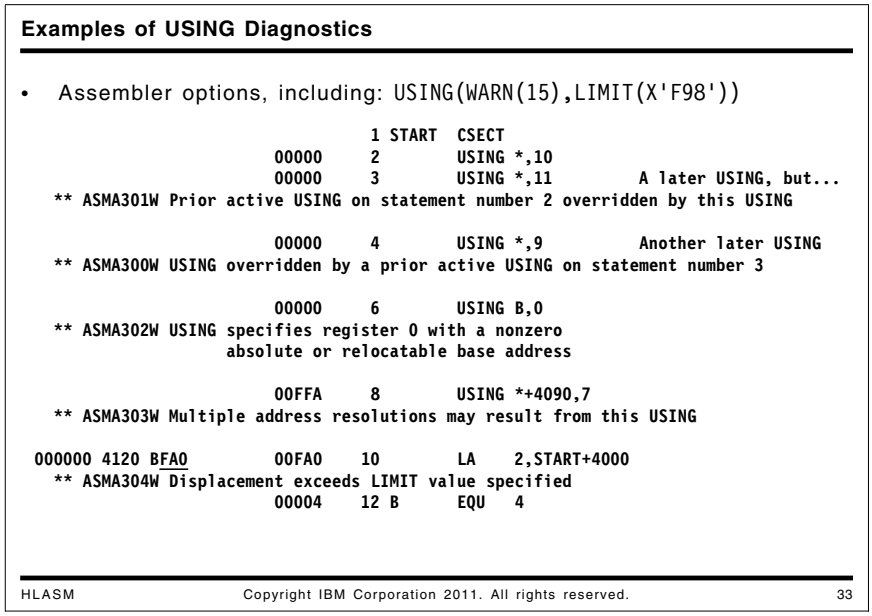
WARN(8) Warnings can be issued if the range of addressability of a base register exceeds a specified threshold. This is very helpful when a growing program is nearing limits of addressability, and you want to be warned when the remaining addressability falls below a threshold you specify in the LIMIT sub-option of the USING option.

You can enable combinations of these diagnostics by adding the WARN values: for example, WARN(3) specifies that the first two conditions should be flagged. The default is WARN(15).

USING instructions with absolute base expressions and nonzero base registers whose range overlaps that of the assembler's “implicit” USING 0,0 are controlled by the FLAG(USING0) option, as described on page 45.

Things Worth Checking: All programs should be assembled with WARN(15) as the default.

USING Diagnostics: Examples



The program fragment in Figure 44 shows how High Level Assembler detects possible USING error conditions. The LIMIT sub-option was specified as LIMIT(X'F98').

```
                                1 START  CSECT
                         00000  2        USING *,10
                         00000  3        USING *,11
   ** ASMA301W Prior active USING on statement number 2 overridden by this USING

                         00000  4        USING *,9
   ** ASMA300W USING overridden by a prior active USING on statement number 3

                         00000  6        USING B,0
   ** ASMA302W USING specifies register 0 with a nonzero
                        absolute or relocatable base address

                         00FFA  8        USING *+4090,7
  ** ASMA303W Multiple address resolutions may result from this USING

 000000 4120 BFA0  1     00FA0  10       LA    2,START+4000
   ASMA304W ** WARNING ** Displacement exceeds LIMIT value specified
                         00004  12 B      EQU   4
```

Figure 44. USING diagnostics example

This example shows each of the four diagnostic messages issued under the control of the WARN sub-option of the USING option.

1. The ASMA301W message is issued because the second USING instruction (statement 3) causes the preceding USING to be made inactive. The second USING has the same base address but a higher-numbered register, so it will always be selected in preference to the first.
2. The ASMA300W message is issued because the third USING instruction (statement 4) will be ignored. *Even though it appears in the program later than the preceding USING instruction*

(statement 3), it will be ineffective because it has both the same base address and a *lower-numbered* register than the preceding USING.

This condition often occurs because it is easy to forget the assembler's complex address-resolution rules, and to assume that a “later” USING automatically supersedes an “earlier” USING.

3. The ASMA302W message occurs because a nonzero base address has been specified in a USING instruction designating base register zero.

4. The ASMA303W message indicates that the range of this USING instruction overlaps the range of some previous USING instruction.

   While this is not necessarily an error, it may represent an oversight because it is unusual to provide more than one base register for addressing a part of a program. This message can help you locate risky USING specifications more easily.

5. The ASMA304W message indicates that the displacement calculated for the LA instruction at statement 10 (X'FA0', at key **1**) exceeded the LIMIT value specified.

   It is also worth noting that the base register specification digit X'B' indicates that register 11 was used for address resolution: only the second USING instruction based on register 11 (statement number 3) is truly “in effect!”

Fixing USING Problems with Multiple Resolutions (ASMA303W)

The ASMA303W warning message indicates that multiple base-displacement resolutions may be derived from two or more USING statements in the program. Sometimes the warning is produced for a situation that is obviously safe; but there are times when a subtle problem may be highlighted by the warning. The following examples should help convince you not to disable this warning message “automatically”.

We will show three examples of coding that could produce this warning. The first is quite harmless, the second is intentional and/or unavoidable, while the third illustrates a potentially very dangerous situation.

Multiple USING Resolutions: (1) Entry-Point USINGs

Overlapping USING-Range Warning: Simple Case

- Typical warning for overlapping USINGs in prolog/entry code:

```
       1 Enter    Start 0
       2          Using *,15
       3          STM   14,12,12(13)      Save registers
       4          LR    11,15             Set local base register in R12
       5          LR    12,11             Second base
       6          AH    12,HW4096         Add 4096 for second base value
       7          B     DoSaves           Skip over constant
       8 HW4096   DC    H'4096'           Constant
┌──►
│      9          Using Enter,11,12       Provide local addressability
│         ** ASMA303W Multiple address resolutions may result from
│                     this USING and the USING on statement number 2
└──◄  10          Drop  15                Drop R15
```

- First impulse: suppress the warning (??)
  - May not be the best idea...
- Easy to fix: move the 'Drop 15' at statement 10 to precede the 'Using Enter,11,12' at statement 9

HLASM 34

In a typical entry-point coding sequence like that in Figure 45, if the USING warnings are enabled the assembler will flag the second USING statement with a warning:

```
 1 Enter    Start 0
 2          Using *,15
 3          STM   14,12,12(13)      Save registers
 4          LR    11,15             Set local base register in R12
 5          LR    12,11             Second base
 6          AH    12,HW4096         Add 4096 for second base value
 7          B     DoSaves           Skip over constant
 8 HW4096   DC    H'4096'           Constant
 9          Using Enter,11,12       Provide local addressability
   ** ASMA303W Multiple address resolutions may result from
               this USING and the USING on statement number 2
10          Drop  15                Drop R15
```

Figure 45. Simple multiple-resolution USING warning

In this case, the warning is not helpful because the DROP statement on the following line removes the possibility of subsequent resolutions that might "ignore" R12. This "problem" is easy to fix: simply move the DROP 15 statement before the preceding USING instruction.

USING Range Limits

USING Range Limits

- May not want USING range to extend to "full" value
  - Normally, 4096 bytes per base register
- Can limit range by specifying an endloc of allowed range:

  USING (baseloc,endloc),regs
- Addressability range restricted to [baseloc,endloc-1]
- endloc may exceed baseloc+4095 without warning
  - Assembler uses the default range [baseloc,baseloc+4095]
    - Except for long-displacement instructions
- Assembler checks for:
  - baseloc ≤ endloc (ASMA313E if not)
  - baseloc and endloc having same relocatability attribute (ASMA314E if not)
- Range limits can help eliminate "unavoidable" overlaps

HLASM 35

The second example of USING range overlaps occurs when two segments of code or data are assigned their own base registers. Before we see how this could occur, we will discuss a feature of USING instructions that helps with this and other USING-range situations.

You might want to ensure that a given USING instruction is not used to resolve implied addresses beyond a known limit. High Level Assembler lets you explicitly specify the range of validity for a USING statement, by providing a *pair* of values as the first operand of the USING statement:

```
USING (baseloc,endloc),regs
```

The endloc address is the first location *not* addressed by this USING; thus the addressable locations in the USING's range lie between baseloc and endloc-1. If the endloc value exceeds baseloc+4095, the range is the normal 4096 bytes starting at baseloc. In effect, the number of bytes addressed is

```
bytes addressed = min(4096,endloc-baseloc)
```

The assembler also checks that the intended range is non-empty; if endloc ≤ baseloc, the assembler issues an error message:

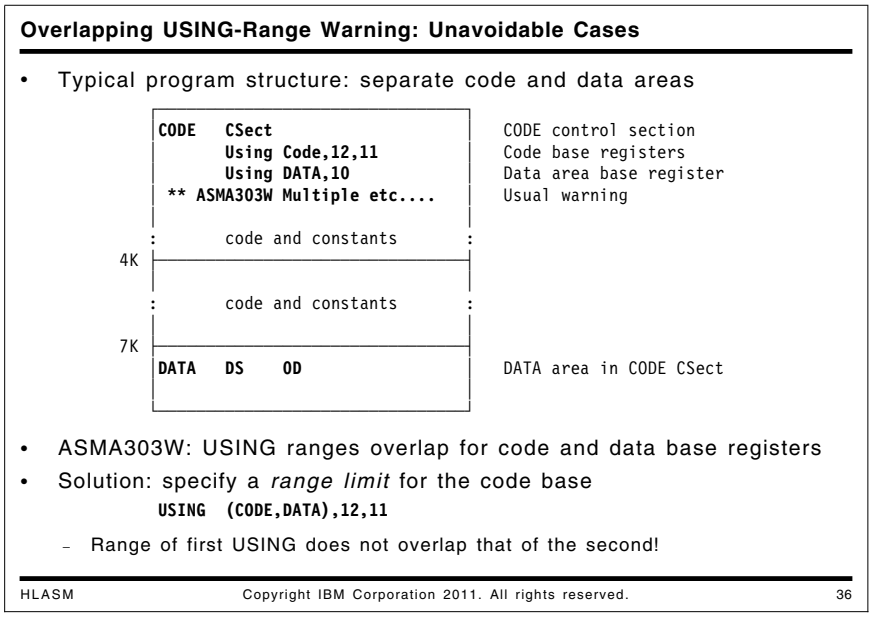
```
        USING (*,*),10
** ASMA313E The end value specified in the USING is less than or equal
           to the base value
```

Similarly, if the baseloc and endloc values have different relocatability attributes, the endloc address cannot be used to limit the range starting at baseloc, and the assembler indicates an error:

```
        USING (*,1000),10
** ASMA314E The base and end values have differing relocation attributes
```

Range limit checking is ignored for long-displacement resolution.

Multiple USING Resolutions: (2) Unavoidable Range Overlaps



The structure of a program may cause USING instruction ranges to overlap. For example, a program in which the code area is followed by a data area requiring different base registers cannot control the fact that the USING ranges overlap. This situation will normally encounter the ASMA303W diagnostic indicating the (known and expected) fact that the ranges overlap. Sometimes, users feel compelled to disable the warning (at the possible expense of not detecting errors like the one illustrated in “Multiple USING Resolutions: (3) A Complex Example” on page 53 below).

Suppose your program is structured as in Figure 46 on page 53:

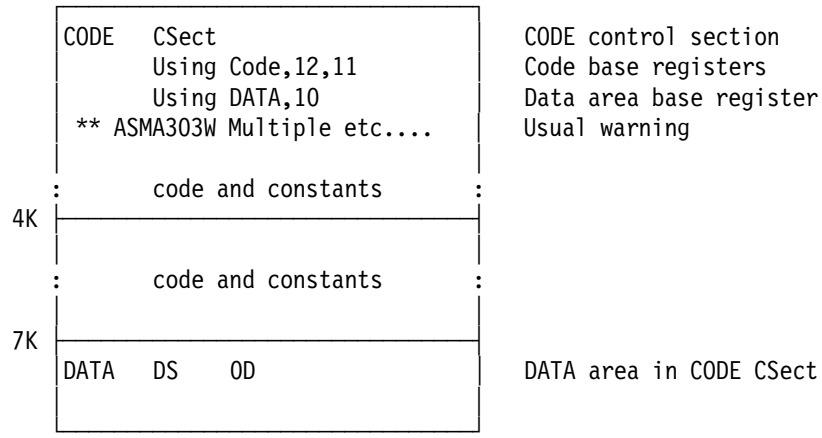


Figure 46. Program structure with USING range overlaps

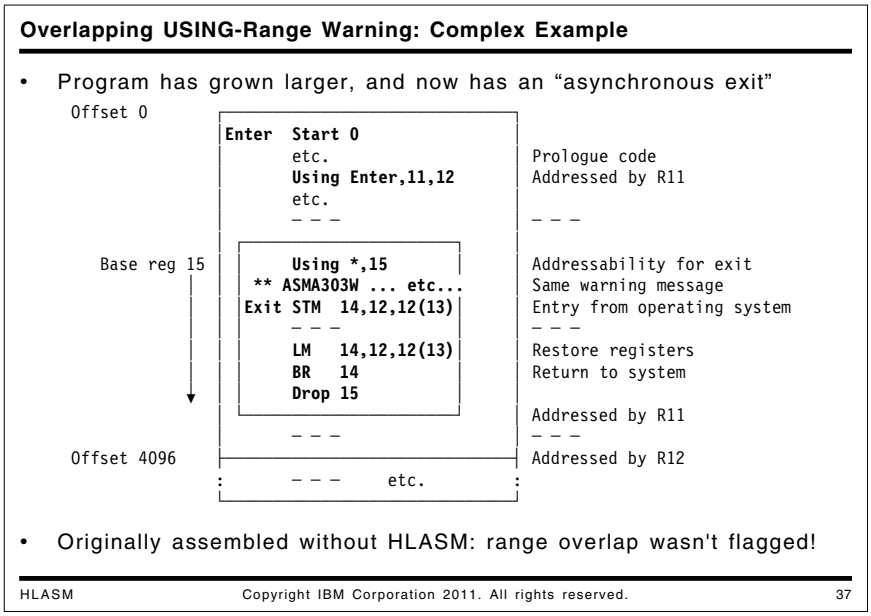
You can eliminate this apparently unavoidable range overlap by specifying

```
USING  (CODE,DATA),12,11
```

The range of the USING for code addressability will be exactly the "code and constants" area in Figure 46, and the ASMA303W diagnostic message will not appear.

Things Worth Checking: ASMA303W messages mean that you might profitably specify USING range limits. (This is always a good practice.)

Multiple USING Resolutions: (3) A Complex Example



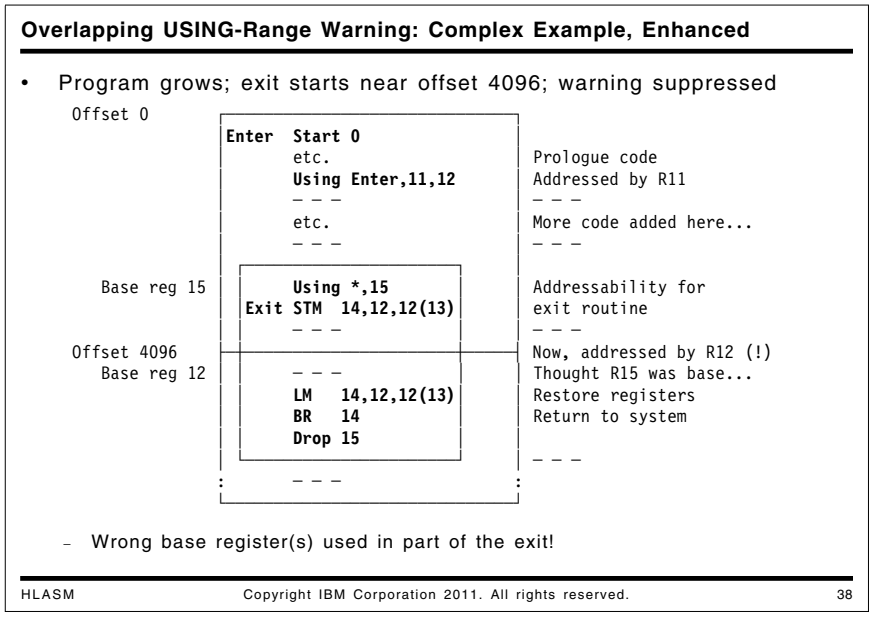
Now, suppose we add further code to the program in Figure 46. It now includes a small routine that acts as an "exit" from some system service (such as a timer or program interruption), and will be entered from the operating system at the label `Exit` with R15 set to the address of that entry point. The exit routine does something and then returns to the system at the address in R14. The DS instruction in Figure 47 on page 54 (reserving 3000 bytes) is meant to indicate the presence of additional code.

```
Enter    Start 0
         Using *,15
         STM   14,12,12(13)      Save registers
         LR    11,15             Set local base register in R12
         LR    12,11             Second base
         AH    12,HW4096         Add 4096 for second base value
         B     DoSaves           Skip over constant
HW4096   DC    H'4096'           Constant
         Drop  15                Drop R15
         Using Enter,11,12       Provide local addressability
*
DoSaves  DC    0H'0'
         LA    10,SaveArea       Point to local save area
         ST    13,SaveArea+4     Store back chain in our area
         ST    10,8(,13)         Forward chain in caller's area
         LR    13,10             Point R13 to our area

*------------------------------ Begin processing
         DS    3000x             Lots of code doing good things
*
         Using Exit,15
  ** ASMA303W Multiple address resolutions may result from
              this USING and the USING on statement number 10
Exit     STM   14,12,12(13)      Save exit registers
         B     *+4               Code to possibly ...
         B     *+4               ...do something useful

         - - - - -               ...lots more code

         LM    14,12,12(13)      Restore registers
         BR    14                Return to caller
         Drop  15
*------------------------------ End processing
         DS    2000x             More code doing good things
SaveArea DC    18F'0'            Local save area
```

Figure 47. USING-warning program, elaborated

This code segment will work as the writer expected, and (after testing is complete) he will probably believe that it has been fully debugged. The ASMA303W warning for the `USING Exit,15` instruction will appear to be spurious, and he may be tempted to suppress it.

Multiple USING Resolutions: (3) Complex Example, Enhanced



Now, suppose that more code has been added preceding the exit routine, so that instead of 3000 bytes of code preceding the exit, there are now 4040 bytes, as illustrated below.

```
Enter    Start 0
         - - -                  (As above)
*------------------------------ Begin processing
         DS    4040x            Lots more code than before!
*
         Using Exit,15
Exit     STM   14,12,12(13)     Save exit registers
         B     *+4              Code that might actually ...
         B     *+4              ... do something useful

         - - - - -              ... lots more code

         LM    14,12,12(13)     Restore registers
         BR    14               Return to caller
         Drop  15
*------------------------------ End processing
SaveArea DC    18F'0'           Local save area
         End
```

Figure 48. USING-warning program elaborated and extended

The source code in the exit routine seems (and is) no different from the code in Figure 47 on page 54, but the *assembled statements* have a subtle and critically important difference, as shown in this fragment of the assembly listing:

```
  Loc  Object Code  Addr1 Addr2 Stmt   Source Statement
000000                             1 Enter    Start 0
               R:F  00000          2          Using *,15
000000 90EC D00C           0000C    3          STM   14,12,12(13)      Save registers
000004 18BF                         4          LR    11,15            Set local base register in R12
000006 18CB                         5          LR    12,11            Second base
000008 4AC0 F010           00010    6          AH    12,HW4096        Add 4096 for second base value
00000C 47F0 F012           00012    7          B     DoSaves          Skip over constant
000010 1000                         8 HW4096   DC    H'4096'          Constant
                                    9          Drop  15               Drop R15
             R:BC  00000           10          Using Enter,11,12      Provide local addressability
                                   11 *
000012                              12 DoSaves  DC    0H'0'
000012 41A0 C018           01018   13          LA    10,SaveArea      Point to local save area
000016 50D0 C01C           0101C   14          ST    13,SaveArea+4    Store back chain in our area
00001A 50A0 D008           00008   15          ST    10,8(,13)        Forward chain in caller's area
00001E 18DA                         16          LR    13,10            Point R13 to our area
                                   17 *
000020                              18          DS    4040x            Lots of code
                                   19 *
               R:F  00FE8           20          Using Exit,15          R15 intended as base reg
   ** ASMA303W Multiple address resolutions may result from this USING
               and the USING on statement number 10
000FE8 90EC D00C           0000C   21 Exit     STM   14,12,12(13)      Save exit registers
000FEC 47F0 F008           00FF0   22          B     *+4              Do something useful
                                                - - - - -
000FFC 47F0 C000  <---     01000   26          B     *+4              Do something useful
001000 47F0 C004  <---     01004   27          B     *+4              Do something useful
                                                _ _ _ _ _
001010 98EC D00C           0000C   31          LM    14,12,12(13)     Restore registers
001014 07FE                        32          BR    14               Return to caller
```

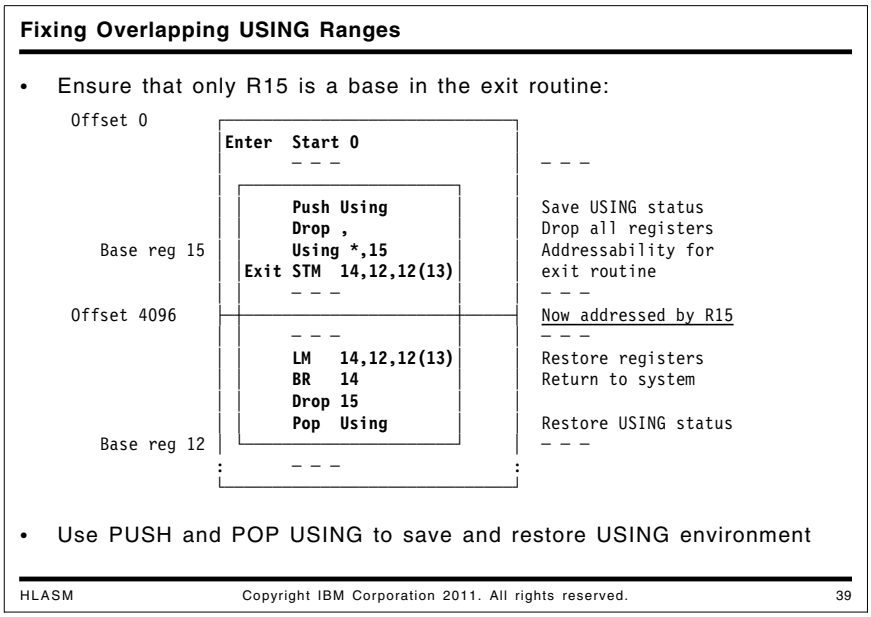
Figure 49. USING-warning program elaborated and extended: problems

The ASMA303W warning message following statement 20 is the key to understanding what has happened. Had this message been suppressed, most of us would not notice in the object code for statements 26 through 30 that register 15 is *not* being used as a base register throughout the exit! (Starting at statement 26, the assembler has used register 12 rather than register 15 as the base register for resolving the implied addresses.)

If the register contents at entry to the exit routine do not contain the base registers used for the main program, any branch instructions resolved with respect to registers 11 and 12 will undoubtedly branch “wildly”. Finding this problem will probably involve hunting through the newly added code in the main program (after all, the program worked correctly before the new code was added!) rather than by checking the base registers assigned in the exit.

The added code in the main program has “pushed” the start of the exit routine near to the boundary of addressability for registers 11 and 12. The 4K-byte boundary marking the start of addressability for R12 begins a few bytes after the start of the exit routine; at that point, the register yielding the smallest displacements for the exit's instructions is no longer R15, but R12, so the assembler uses it to resolve implied addresses whose value exceeds X'1000' (the limit of addressability using R11).

Unfortunately, the rules used by the assembler to resolve implied addresses into base-displacement form (summarized on page 46) may be difficult to remember, and can lead to programming errors that can be quite difficult to correct. The High Level Assembler's warning messages for USINGs help make it less necessary for you to remember those rules.



Fixing the problem is easy: insert PUSH USING and DROP instructions before the exit, and a POP USING following the exit, to ensure that only register 15 is used as a base register for the exit's statements. The effect of doing this can be seen in the following extract of an assembly of the program with the PUSH and POP instructions:

```
  Loc  Object Code    Addr1 Addr2  Stmt   Source Statement

000020                            18          DS    4040x            Lots of code

                                  20          Push  Using            Save USING-table status
                                  21          Drop  ,                Drop all base registers

                 R:F  00FE8       23          Using Exit,15
000FE8 90EC D00C           0000C  24 Exit     STM   14,12,12(13)     Save exit registers
000FEC 47F0 F008           00FF0  25          B     *+4              Do something useful
                                              - - - - -
000FFC 47F0 F018  ←        01000  29          B     *+4              Do something useful
001000 47F0 F01C  ←        01004  30          B     *+4              Do something useful
                                              - - - - -
001010 98EC D00C           0000C  34          LM    14,12,12(13)     Restore registers
001014 07FE                       35          BR    14               Return to caller

                                  37          Pop   Using            Restore USING status
001016 5800 C01C  ←        0101C  38          L     0,SaveArea       Check address resolution
00101A 0000
00101C 0000000000000000           40 SaveArea DC    18F'0'           Local save area
                                  41          End
```

Figure 50. USING-warning program elaborated and extended: problem fixed

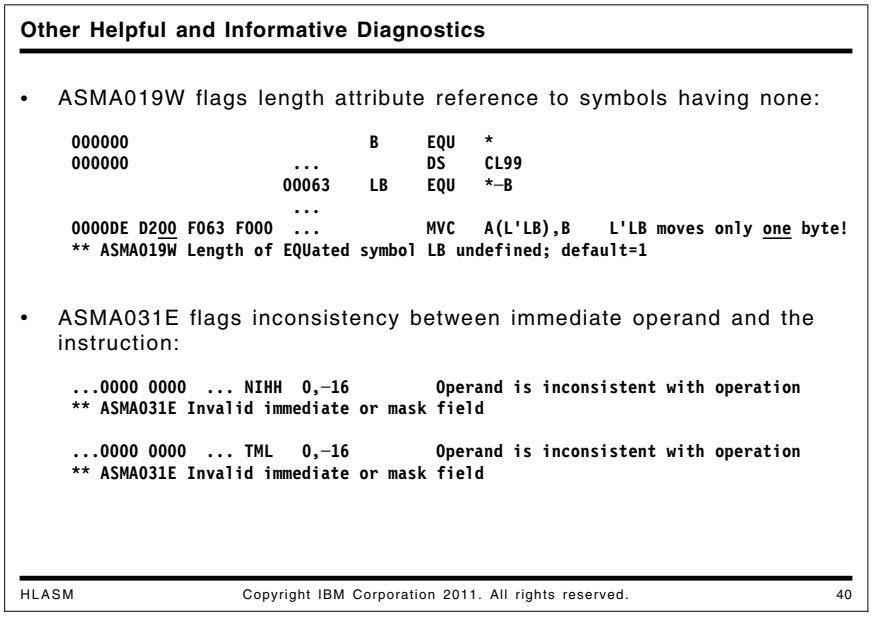
The USING at statement 23 is now used for address resolution throughout the exit, and all implied addresses are correctly resolved with base register 15.

This example also shows another reason the PUSH/POP technique has worked: at statement 38, the instruction in the main program that refers to the symbol SaveArea has been resolved with register 12 as a base.

You can't fix this instance of overlapping USING ranges with range limits, because these ranges are *intentionally* overlapping rather than merely adjacent!

As these examples show, High Level Assembler tries to indicate potential trouble areas involving USING instructions. There will be cases where the messages describe situations that may not actually be errors; but you should analyze each diagnostic carefully.

Other Helpful and Informative Diagnostics



Some other diagnostics may help you find obscure behaviors.

ASMA019W: Undefined Length of EQUated Symbol

If a length value is defined using an EQU expression, you might forget to use that value and use its length attribute instead:

```
000000                          B     EQU   *
000000                   ...          DS    CL99
                       00063    LB    EQU   *-B
                         ...
0000DE D200 F063 F000    ...          MVC   A(L'LB),B    L'LB moves only one byte!
** ASMA019W Length of EQUated symbol LB undefined; default=1
```

Figure 51. Example of ASMA019W diagnostic for Length Attribute of a length

Using the length attribute of a length was probably not intended; just remove the `L'` to fix the statement. Another fix is to define a length attribute on the EQU statement that defines `LB`:

```
000000                          B     EQU   *
000000                   ...          DS    CL99
                       00063    LB    EQU   *-B,99       Define length attribute 99
                         ...
0000DE D262 F063 F000    ...          MVC   A(L'LB),B    Moves 99 bytes
```

While valid, the added obscurity seems self-defeating.

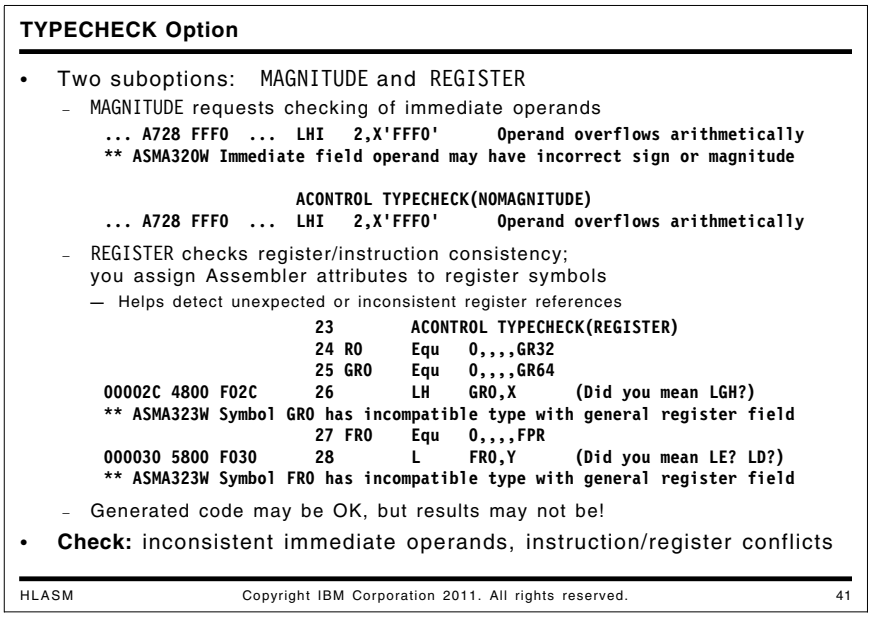
ASMA031E: Invalid immediate or mask field

Some instructions support an immediate field whose values can be specified in many ways. Operands are evaluated to 32 bits, and the assembler checks that they do not exceed the size of the instruction field. Figure 52 shows examples of 16-bit operands flagged by HLASM.

```
...0000 0000  ... NIHH  0,-16         Operand is inconsistent with operation
** ASMA031E Invalid immediate or mask field
...A514 FFF0  ... NIHH  1,65520       Operand is logically valid
...A524 FFF0  ... NIHH  2,X'FFF0'     Operand is logically valid
...0000 0000  ... TML   0,-16         Operand is inconsistent with operation
** ASMA031E Invalid immediate or mask field
...A711 FFF0  ... TML   1,65520       Operand is valid as a mask
...A721 FFF0  ... TML   2,X'FFF0'     Operand is valid as a mask
```

Figure 52. Examples of ASMA031E diagnostic

TYPECHECK Option



The TYPECHECK option supports two sub-options, MAGNITUDE and REGISTER.

TYPECHECK(MAGNITUDE)
Checks for correct specification of operands in immediate instructions.

TYPECHECK(REGISTER)
Checks for consistent instruction vs. register references for symbols used to name registers.

TYPECHECK(MAGNITUDE) Option

Immediate operands are used in many contexts. Most immediate instructions use three types of operand:

- arithmetic, with values in the range −32768 to +32767.
- logical, with values in the range 0 to X'FFFF'.
- mask, with values in the range 0 to X'FFFF'.

Because operands are evaluated to 32 bits, take care to specify them in a form consistent with their use in the instruction. For example:

```
...A708 FFF0  ... LHI   0,-16         Operand is arithmetically valid
...A718 FFF0  ... LHI   1,65520       Operand overflows arithmetically
** ASMA320W Immediate field operand may have incorrect sign or magnitude
...A728 0FFF  ... LHI   2,X'0FFF'     Operand is arithmetically valid
...A728 FFF0  ... LHI   2,X'FFF0'     Operand overflows arithmetically
** ASMA320W Immediate field operand may have incorrect sign or magnitude
...A728 FFF0  ... LHI   2,X'FFFFFFF0' Operand is valid arithmetically
```

Figure 53. Examples of ASMA320W diagnostic

HLASM attempts to verify that the form of the immediate operand is consistent with the type of instruction. Thus, for example, X'FFF0' is considered invalid for the LHI instruction, because the result will be negative, not positive. If you want to specify a negative arithmetic operand using hexadecimal notation, be sure to specify the correct number of high-order 1-bits.

Things Worth Checking: Verify that immediate operands are generated with the correct sign and value.

TYPECHECK(REGISTER) Option

The REGISTER suboption lets you specify the specific type of register intended for use in an instruction. The supported assembler attributes are

```
AR    CR    CR32  CR64  FPR   GR    GR32  GR64
```

corresponding respectively to Access Register, either-length Control Register, 32-bit Control Register, 64-bit Control Register, Floating Point Register, either-length General Register, and 32-bit and 64-bit General Register.

The assembler can check whether a register referenced by an instruction corresponds to the type you specified.

```
                      24 R0     Equ   0,,,,GR32
                      25 GR0    Equ   0,,,,GR64
00002C 4800 F02C      26        LH    GR0,X      (Did you mean LGH?)
** ASMA323W Symbol GR0 has incompatible type with general register field

                      27 FR0    Equ   0,,,,FPR
000030 5800 F030      28        L     FR0,Y      (Did you mean LE? LD?)
** ASMA323W Symbol FR0 has incompatible type with general register field
```

Figure 54. Examples of register type checking

This example shows how HLASM can help you clarify register use, as well as check for possible inconsistencies between an instruction and the referenced register.

Things Worth Checking: Verify that instructions reference registers consistent with intended operand type and length.

LANGUAGE Option

High Level Assembler supports messages and listing headings in English, German, Japanese, and Spanish, by specifying these options:

LANGUAGE(DE) German
LANGUAGE(EN) Mixed-case English
LANGUAGE(ES) Spanish
LANGUAGE(JP) Japanese
LANGUAGE(UE) Upper-case English

For example, here is the same message in English, German, and Spanish:

```
** ASMA019W Length of EQUated symbol LB undefined; default=1
** ASMA019W Länge des EQU Symbols LB nicht definiert; Standardwert=1
** ASMA019W Longitud del símbolo EQUated LB indefinida; por omisión=1
```

LIST(133) Option

The traditional listing width is 121 characters (one byte for carriage control). By expanding the listing to 133 characters, HLASM provides additional detail:

- Location Counter values are displayed as 8 hexadecimal digits, corresponding to support for program sizes larger than 16MB;
- an extra digit is available for statement numbers;
- more information is provided for macro names and nesting levels on generated statements.

Figures 55 and 56 illustrate the differences: Figure 55 is the familiar 121-byte “narrow” listing format, as specified by the LIST(121) option.

```
000110                          130+IHB0012A DS    0H                                                    01-WTO
000110 0A23                     131+         SVC   35                  ISSUE SVC 35                      01-WTO
000112 181D                     133          LR    1,13              Point to local save area
000114 58D0 D004          00004 134          L     13,4(,13)         Get system's save area pointer
                                136          FREEMAIN R,A=(1),LV=72  Free the local save area
000118 4100 0048          00048 137+         LA    0,72(0,0)                 LOAD LENGTH             01-FREEM
00011C 0A0A                     138+         SVC   10                        ISSUE FREEMAIN SVC      01-FREEM
                                140          RETURN (14,12),RC=0     Return with code zero
00011E 98EC D00C          0000C 141+         LM    14,12,12(13)              RESTORE THE REGISTERS   01-RETUR
000122 41F0 0000          00000 142+         LA    15,0(0,0)                 LOAD RETURN CODE        01-RETUR
```

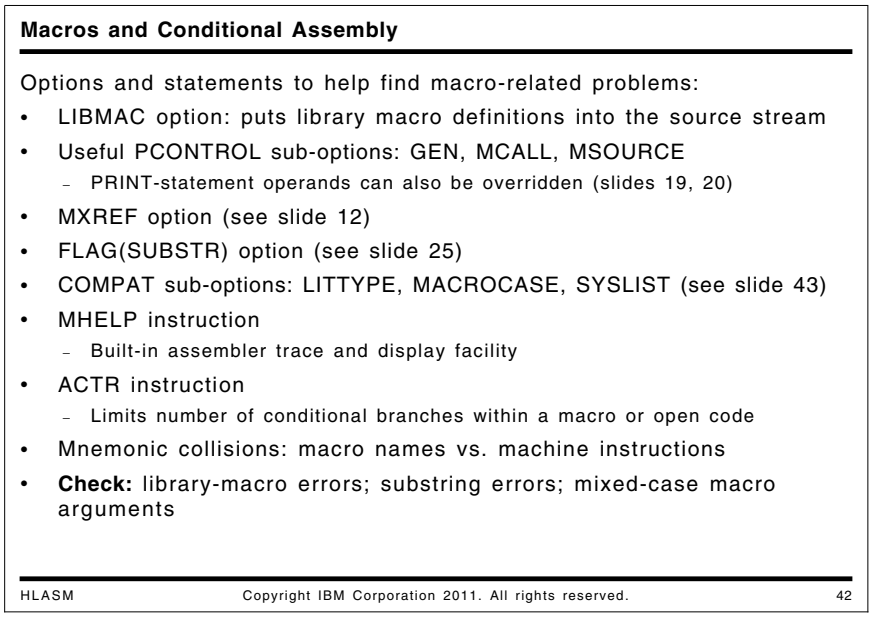
Figure 55. Example of macro expansion with LIST(121)

In the wider 133-byte listing format shown in Figure 56, Location Counter and address values display eight hexadecimal digits, and all eight characters of the statement-generating macro name appear at the right end of the line.

```
00000098                                70+IHB0006A DS    0H                                                    01-WTO
00000098 0A23                           71+         SVC   35                  ISSUE SVC 35                      01-WTO
0000009A 181D                           73          LR    1,13              Point to local save area
0000009C 58D0 D004          00000004    74          L     13,4(,13)         Get system's save area pointer
                                        76          FREEMAIN R,A=(1),LV=72  Free the local save area
000000A0 4100 0048          00000048    77+         LA    0,72(0,0)                 LOAD LENGTH             01-FREEMAIN
000000A4 0A0A                           78+         SVC   10                        ISSUE FREEMAIN SVC      01-FREEMAIN
                                        80          RETURN (14,12),RC=0     Return with code zero
000000A6 98EC D00C          0000000C    81+         LM    14,12,12(13)              RESTORE THE REGISTERS   01-RETURN
000000AA 41F0 0000          00000000    82+         LA    15,0(0,0)                 LOAD RETURN CODE        01-RETURN
000000AE 07FE                           83+         BR    14                        RETURN                  01-RETURN
```

Figure 56. Example of macro expansion with LIST(133)

The GOFF option requires the LIST(133) option, because 8-digit values are used for the Location Counter and other address-related fields.



There are many options and statements that can help you locate problems with macros.

- The LIBMAC option causes HLASM to bring the source statements of the macro definition into the input stream. Normally, macros are read from the library and encoded internally, so that errors found during encoding and expansion cannot be identified with a specific line within the macro definition. By bringing the macro definition in the source stream, each line has a statement number that can be used to identify specific statements in case of error.
- The PCONTROL option lets you force portions of the listing to be displayed. These options are especially helpful with macro problems:
  - PCONTROL(GEN) is described on page 33.
  - PCONTROL(MCALL) is described on page 33.
  - PCONTROL(MSOURCE) is described on page 34.
- The MXREF option causes HLASM to show all macros and COPY segments used by the program, where they were used, and where they were called. Details are described on page 18.
- The FLAG(SUBSTR) option causes HLASM to check for potential problems with conditional assembly substring operations, as described on page 64.
- Three COMPAT sub-options can help with problems of compatibility with older assemblers, as well as providing greater freedom in the way you write your programs. Details are on page 64.
- For really difficult macro problems, the MHELP instruction provides extensive tracing and display capabilities, described on page 66.
- If you suspect a macro may be looping, the ACTR instruction lets you limit the number of conditional assembly “branches”; see page 67.

LIBMAC Option

The LIBMAC option causes High Level Assembler to treat library macros as though they were defined inline where they were first referenced in the source program. This helps you track the causes of errors in library macro definitions without having to extract them from the library and insert them into the source program.

In this example, a macro BadMac with a potential error was installed in a macro library, and called with an argument that causes an error. Without LIBMAC, HLASM reports the error as being "somewhere" in the macro.

```
                            4        BadMac   65535
** ASMA103E Multiplication overflow; default product=1 - BADMA  ◄──?
                            5┼*,&A*&A = 1                                    01-BADMA  ◄──?
```

Figure 57. Error from library macro

Lacking better clues as to the source of the error, you might be forced to retrieve the macro definition and study or test it to find the problem. If you specify the LIBMAC option, or precede the call with an ACONTROL LIBMAC instruction (see page 69), the macro definition will be placed inline at the point of the call. This lets HLASM identify the line in the macro definition that caused the error.

In Figure 58, the same macro is called; HLASM indicates the number (00008) of the problem statement.

```
                            6        MACRO
                            7 &L     BADMAC  &A
                            8 &X     SETA    &A*&A
                            9        MNOTE   *,'&&A.*&&A. = &X.'
                           10        MEND
                           11        BadMac   65535
** ASMA103E Multiplication overflow; default product=1 - 00008  ◄── The error statement number
                           12+*,&A*&A = 1                                  01-00009
```

Figure 58. Error from library macro pinpointed by LIBMAC option

Now, the MNOTE output at statement 12 identifies the statement number (00009) in the macro that generated the output; without LIBMAC, it simply displays the name of the macro, as shown in Figure 57.

PCONTROL Options Relating to Macros

Three PCONTROL sub-options are useful in finding and debugging macro-related problems: GEN, MCALL, and MSOURCE. Details are provided at "PCONTROL Option and the PRINT Instruction" on page 31.

Macro-COPY Cross-Reference (MXREF Option)

The MXREF option produces a great deal of helpful information (see page 18). When used with the LIBMAC and PCONTROL(MCALL) options, the most detailed levels of data are produced.

FLAG(SUBSTR) Option and Conditional-Assembly Substrings

The HLASM *Language Reference* manuals state that substring operations of the form

```
&SubStr  SetC  '&CharVar'(&Start,&Len)   &Len characters starting at &Start
```

are valid only if the extracted substring lies entirely within the bounds of the subject string (&CharVar in this example), and that the assembler diagnoses any misuse. A typical technique for extracting the remainder of a character string used to be something like this:

```
&SubStr  SetC  '&CharVar'(&Start,255)    Take rest of characters at &Start
```

The choice of 255 as the length value can also be misleading, because HLASM supports SETC variables and macro-arguments up to 1024 bytes in length.

To allow such programs to continue to assemble without a diagnostic, specify the FLAG(NOSUBSTR) option. However, a better approach is to use the explicit "remainder of string" notation:

```
&SubStr  SetC  '&CharVar'(&Start,*)     Take rest of characters at &Start
```

This lets the assembler to diagnose "true" errors in specifying substrings.

FLAG(SUBSTR) tells High Level Assembler to diagnose improper character substrings in the conditional-assembly language. For example:

```
&C     SETC   'ABCDE'(4,5)
```

specifies a substring (five characters, starting with 'DE') that extends beyond the end of the original string; this is an error. Normally, High Level Assembler issues the ASMA094W warning message; if FLAG(NOSUBSTR) is specified, High Level Assembler suppresses the warning.

Things Worth Checking: FLAG(SUBSTR) can help in macros and conditional assembly statements to detect coding errors that might produce unexpected or unpredictable results.

COMPAT Option

COMPAT Option

- COMPAT option enforces "old rules":
- COMPAT(MACROCASE): ***Unquoted*** macro arguments converted *internally* to upper case

```
AbEnd  1,Dump     Mixed-case argument is accepted, converted
MyMac  'Arg'      Quoted, not converted
MyMac  t'x        Not a quoted string: not converted!
```

  NOCOMPAT(MACROCASE): macro arguments must be typed in the expected (upper) case

```
AbEnd 1,DUMP      Argument must be in upper case
```

- COMPAT(SYSLIST): Inner-macro arguments have no list structure

  NOCOMPAT(SYSLIST): Inner-macro arguments may have list structure

HLASM 43

The COMPAT option lets you control the degree of compatibility High Level Assembler should enforce for programs written for old assemblers.

There are four areas of intentional incompatibility between HLASM and Assembler H in the ways they treat the input text of the program:

- sensitivity to the case of the input text
- the handling of substituted sublists in macro arguments and character-variable strings
- the case of unquoted macro operands

These differences can be controlled by using the COMPAT option, or with ACONTROL COMPAT(...) statements, described on page 69.

COMPAT(MACROCASE) Option: Mixed-Case Macro Operands

The COMPAT(MACROCASE) option lets you write macro calls using mixed-case operands for macros that were written to expect upper-case operands. COMPAT(MACROCASE) specifies that High Level Assembler should *internally* translate lower case characters in unquoted macro arguments to upper case before the macro is expanded.

For example, in older assemblers where all instruction mnemonics and operands were in upper case letters, you would write something like this:

```
ABEND  13,DUMP
```

to invoke the system Abnormal End service. With High Level Assembler you may want to write

```
AbEnd  13,Dump
```

for increased readability.

The problem is that the ABEND macro was written when only upper-case operands were allowed, so that the internal logic of the macro checks for the presence of a DUMP operand (all capital letters) and does not recognize the mixed-case operand “Dump”.

If you specify the COMPAT(MACROCASE) operand, HLASM will automatically convert the mixed-case operand to upper case just before passing it to the internal logic of the macro, which then recognizes DUMP as the operand, even though the original source statement is unchanged.

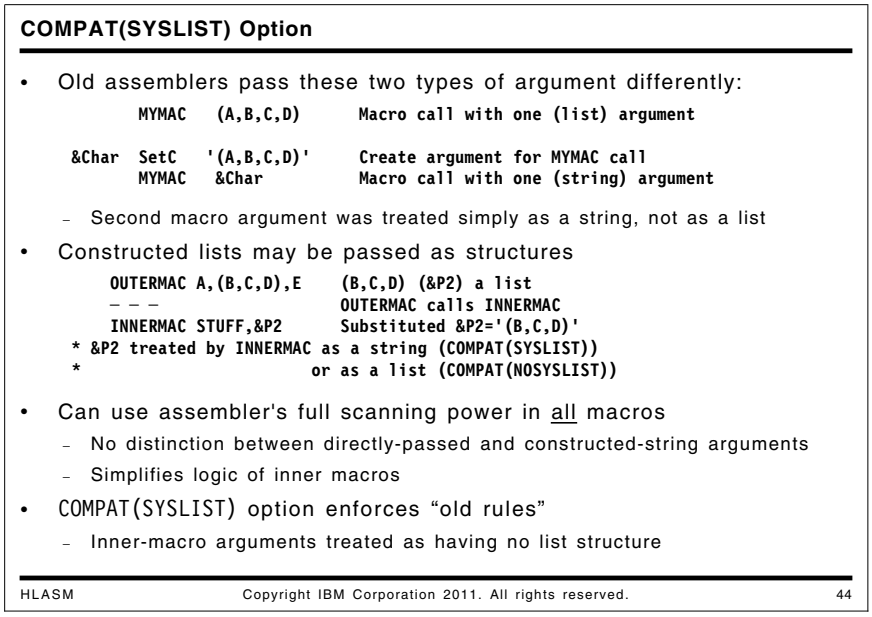
Note that quoted operands begin and end with an apostrophe; otherwise, they are treated as unquoted operands. For example, in

```
MyMac  'Arg'        Quoted, not converted
MyMac  t'x          Not converted!
```

the operand *contains* a “quote”, but does not start and end with quotes.

Things Worth Checking: If familiar, frequently-used macros appear to generate spurious error messages, check whether operands were specified in mixed case (and the macro was not written to recognize them). Specifying the COMPAT(MACROCASE) option may be all that's needed to fix the problem.

COMPAT(SYSLIST) Option: Inner-Macro Argument Lists



In older assemblers, character strings substituted as operands of calls to inner macros were treated only as unstructured character strings, no matter what was their actual structure. This meant that argument scanning techniques might depend on whether the macro was invoked from open code or from another macro; inner macros had to parse the operands one character at a time.

HLASM permits substituted operands to be treated as having a list structure accessible to the assembler through the normal &SYSLIST facilities such as the number and count attributes, as well as the usual ability to designate sublists and sublist elements symbolically or by using a subscript notation. This means that macros need not be written differently depending on whether they will be invoked as “outer” or “inner” macros.

If you want HLASM to treat operands and SETC variables as in previous assemblers, specify the COMPAT(SYSLIST) option, or with ACONTROL instructions (see page 69). However, if you specify the COMPAT(NOSYSLIST) option, High Level Assembler can recognize substituted sublists as having a list structure. Thus you can construct complex macro operands in an outer macro to be passed as list structures to inner macros. This can help remove many unnecessary distinctions between outer and inner macros.

MHELP Instruction

For macro debugging, the MHELP instruction is more general but less specific than the MNOTE instruction. Once an MHELP option is enabled, it stays active until it is reset. The MHELP operand specifies which actions should be activated; the value of the operand is the sum of the “bit values” for each action:

1 Trace macro calls
2 Trace macro branches
4 AIF dump
8 Macro exit dump
16 Macro entry dump
32 Global suppression
64 Hex dump
128 MHELP suppression

These values are additive: you may specify any combination.

MHELP is valuable when really difficult macro problems must be resolved. Its output can be large, so you may want to use it only for critical parts of the program.

ACTR Instruction

The ACTR instruction limits the number of conditional assembly branches (AIF and AGO) executed within a macro invocation (or in open code). It is written

```
ACTR  arithmetic_expression
```

where the value of the "arithmetic_expression" sets an upper limit on the number of conditional assembly branches interpreted by the assembler. In the absence of an ACTR instruction, the default ACTR value is 4096, which is adequate for most macros.

ACTR is most useful if you suspect a macro may be looping or branching excessively; you can set a lower ACTR value to limit the number of allowed branches. ACTR has "local scope", and if used must be specified separately for each macro where it's needed. An interesting example showing how ACTR can help is described at "COPY Loops and Excess DASD or CPU Use" on page 75.

Mnemonic Collisions

New HLASM instruction mnemonics sometime collide with the names of macros you use. This could generate incorrect code or assembly errors. For example, the MSG instruction (Multiply Single) and a "MSG" (Message) macro probably have very different operands:

```
MSG   reg,operand        machine instruction
MSG   'Message'          macro instruction
```

An existing program using a MSG macro received diagnostics when HLASM implemented the MSG instruction.

There are two solutions to the problem of mnemonic collisions:

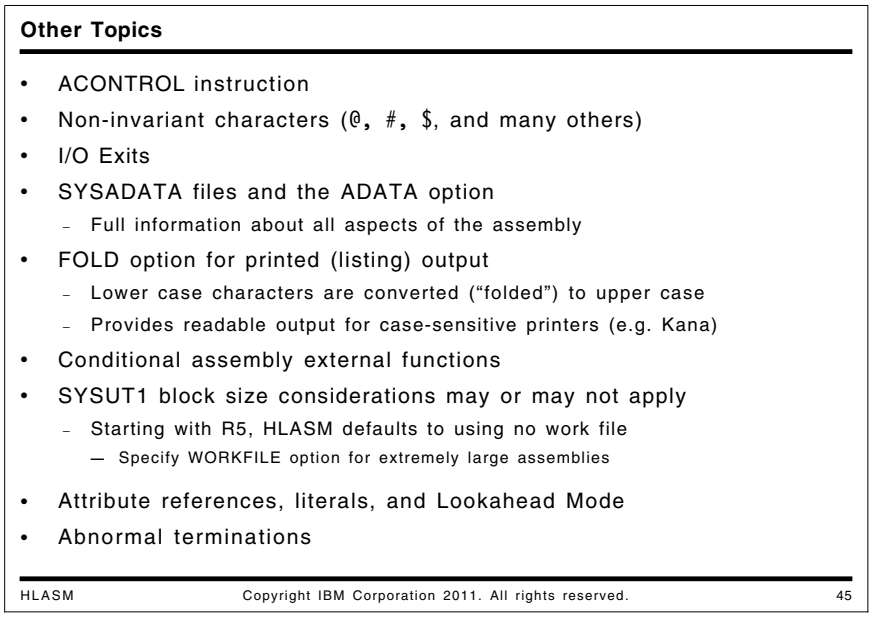
1. Use ACONTROL OPTABLE to have HLASM switch to a lower-level opcode table.
2. Use mnemonic tags.

For example:

```
****** Solution using ACONTROL OPTABLE
         MSG   0,LongNum          Machine instruction
         ACONTROL OPTABLE(ESA)    Switch to ESA opcode table
         MSG   'Any collisions?'  Macro instruction
         ACONTROL OPTABLE(UNI)    Switch back to full opcode table
         MSG   1,SecondNum        Machine instruction

****** Solution using mnemonic tags
         MSG:ASM  0,LongNum       Machine instruction
         MSG:MAC  'No collision'  Macro instruction
```

Figure 59. Two solutions to mnemonic collisions

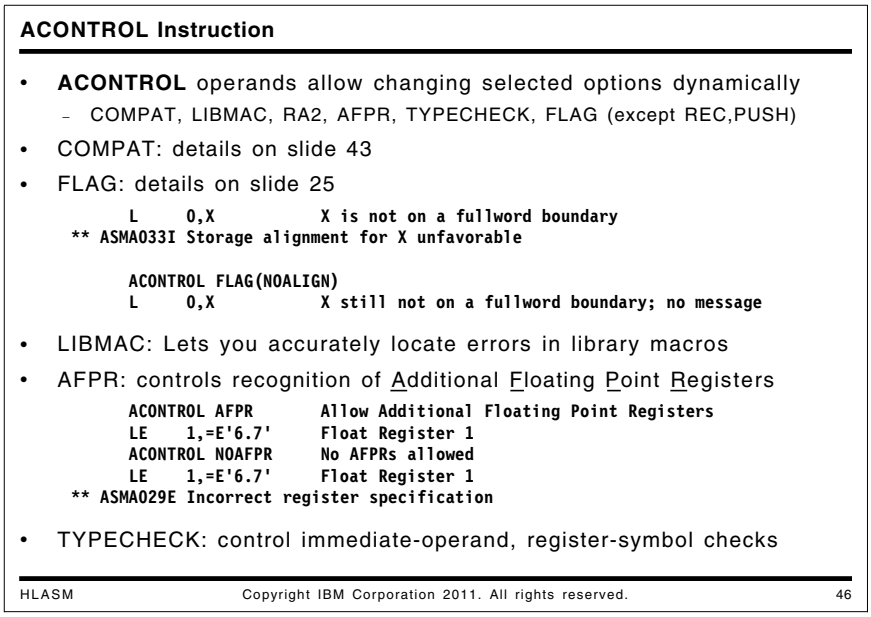
The mnemonic tags `:ASM` and `:MAC` were introduced with HLASM 1.6.



Other useful capabilities include:

- The ACONTROL instruction (see page 69) lets you control dynamically the settings of certain options. This gives you more flexibility and precision in selecting ranges of statements for chosen diagnostic checks.
- Some characters are not “invariant” across all EBCDIC encodings; see page 70 for details.
- I/O exits can modify input and output files, so the presence of exits may mean that the assembler's listing (which itself may be modified!) might not accurately reflect all inputs or outputs. Exits are discussed on page 70.
- The ADATA option causes HLASM to generate a SYSADATA “side file” containing useful information about the assembly. See page 71 for details.
- The FOLD option discussed on page 71 may have changed the appearance of the listing.
- External functions can add capabilities beyond the “native” facilities of the assembler; these are described on page 71.
- Certain assembly problems can be fixed by increasing the block size of the assembler's SYSUT1 utility file; omitting the WORKFILE option causes the entire assembly to be done in central storage. See page 72.
- Sometimes the behavior of an assembly depends on the order of the statements in the source program. Some considerations are discussed on page 72.
- Some assembler abnormal terminations are due to internal errors, while others may be due to apparently normal coding techniques, as discussed on page 74.

ACONTROL Instruction



The ACONTROL instruction lets you dynamically change the settings of certain assembler options. For example, you can specify the FLAG(CONT) option to request that High Level Assembler check for possible continuation statement errors, and then turn off the checking around a chosen set of statements.

The examples of the FLAG(CONT) option in slide 26 on page 40 showed how diagnostics for continuation errors could be suppressed. If you want to retain this valuable checking for the entire program except for a particular statement, you can “bracket” the trusted statement with ACONTROL instructions controlling FLAG(CONT) checking. Normal checking might cause a message like the following:

```
              ELSE  Otherwise, do that and this          ←— note comma!
** ASMA431W Continuation statement may be in error -
   continuation indicator column is blank.
```

With ACONTROL instructions, the message is suppressed:

```
              AControl FLAG(NOCONT)              Suspend checking
              ELSE  Otherwise, do that and this
              AControl FLAG(CONT)                Resume checking
```

The error shown in Figure 58 on page 63 could also have been exposed by placing an ACONTROL instruction before the macro call:

```
        AControl LibMac
        BadMac   65535
```

Things Worth Checking: You might be inclined to avoid certain useful diagnostics because one or two valid statements in a program are flagged by the assembler. Rather than suppress the diagnostics entirely, it is better to bracket the valid statements with ACONTROL statements, so that the rest of the program will still be checked.

Non-Invariant Characters

Each EBCDIC character is assigned an encoding that defines its numeric value. For example, the letter A is assigned value 193, or X'C1'. This is what makes character self-defining terms equivalent to other forms such as binary and hexadecimal.

Most of the EBCDIC characters having syntactic validity in the Assembler Language have the same encoding across EBCDIC code pages. However, three characters: the at sign (@), the sharp or (US) pound sign (#), and the dollar sign ($) have *non-invariant* encodings. These three non-invariant characters are not assigned consistent values, *even though they are valid in symbols*!

For example, a program that scans data for the presence of a dollar sign or other special character might use CLI instructions such as

```
CLI   0(R4),C'$'     Assumes C'$' = X'5B' =  91
CLI   0(R4),C'#'     Assumes C'#' = X'7B' = 123
CLI   0(R4),C'@'     Assumes C'@' = X'7C' = 124
```

only to find that the encoding of the data being scanned does not use the same representation of the dollar sign assumed by the assembler when the program was assembled.

Other characters that sometimes cause problems include the left and right “square brackets” ([and]); the left and right “curly” braces ({ and }); the cent sign (¢); the vertical bar (|); the exclamation point (!); the caret (^); and the “back-slash”. If your program might be used with other EBCDIC code pages (or be transmitted to ASCII-based environments), such characters should be avoided.

The “Syntactic Character Set” with encodings common to all EBCDIC code pages are the space (blank) and these 81 characters:

- upper and lower case alphabetics A-Z, a-z
- numeric digits 0-9
- the special characters

```
. , : ; ? ( ) ' " / - _ & + % * = < >
```

Things Worth Checking: You should avoid using non-invariant characters in any program that may be assembled outside the USA, or which might process data that originates elsewhere. Even using non-invariant characters in symbols might cause a program not to assemble correctly if program modifications are made on systems using different encodings.

I/O Exits

I/O exits can process all records being read and written by the assembler, and therefore have considerable control over the object file and what you see in the listing. The final page of the assembly listing shows what actions have been taken by each exit (see the example on page 25). While it is possible for a listing exit to hide the presence of all exits, such a situation is very unlikely.

I/O exits can also produce diagnostic messages that will appear in the listing.

Things Worth Checking: The presence of SYSIN or SYSLIB exits can mean that source records have been modified; the presence of SYSLIN or SYSPUNCH exits can mean that object records have been modified; and the presence of a SYSPRINT exit can mean that the listing has been modified. The SYSTERM and SYSADATA exits rarely modify records.

SYSADATA File

If you specify the ADATA option, HLASM produces a SYSADATA file containing information about all aspects of the assembly, even if parts of the listing are suppressed. The file is intended to be read by programs (unlike the listing, which is formatted for human readers), such as debuggers, program understanding tools, "bill-of-materials" processors, and so forth. An example of a SYSADATA exit that creates a list of all library members and the data sets they came from is provided with HLASM as a sample program; it is described in the *High Level Assembler Programmer's Guide, SC26-4941*.

The SYSADATA file contains all the information in a full listing (except for that produced by the INFO and OPTABLE(xxx,LIST) options), even if part or all of the listing is suppressed or if a SYSPRINT exit is active.

HLASM supports ADATA exits that allow record selection and suppression. Also, the layout of the records has been modified, and an optional ASMAXADR exit is provided to reformat ADATA files to R4 format. See the *High Level Assembler Programmer's Guide, SC26-4941*.

FOLD Option

The FOLD option specifies that all alphabetic characters in the listing (whatever their original case) should be produced in upper case only. Only the listing file is affected by the FOLD option; character data entered in lower case will of course be converted to the appropriate lower case code points in the object module;

This option is provided so that environments that use the EBCDIC code points of lower case letters for other ideograms or scripts, such as Katakana and Hiragana, can be printed readably.

The case of messages and text sent to the SYSTERM file (normally, the terminal) is not affected by the FOLD option.

Things Worth Checking: Because all lower case letters are forced to upper case on all listing lines, you should check carefully that the contents of DCs, SETC values, ESD aliases, and symbol type attributes in the symbol XREF have not been obscured.

External Conditional Assembly Functions

HLASM's Support for external conditional assembly functions allows you to access capabilities not supported directly by the assembler, such as special processing of conditional assembly data and interfaces to the assembler's operating environment.

Your listing may also contain messages produced by external functions (and that are not documented in the HLASM manuals). The final page of the assembly listing summarizes the functions called and the actions they take; see the example in Figure 20 on page 25.

Things Worth Checking: The presence of external-function calls can mean that special (possibly environment-dependent) code is being generated by macros or other conditional assembly statements.

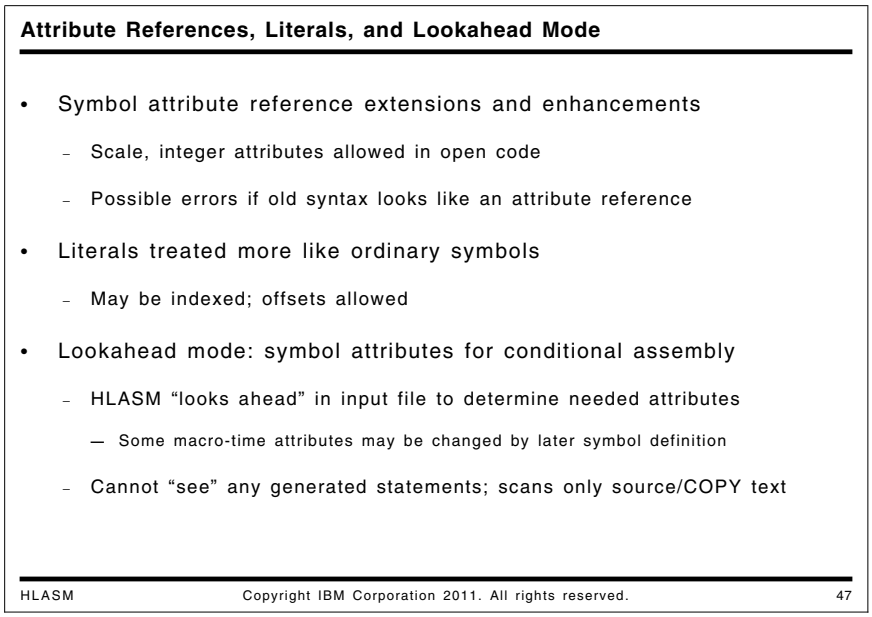
SYSUT1 Block Size

If you specify the WORKFILE option, certain diagnostics may appear that wouldn't if you specify NOWORKFILE (which causes the assembly to be done entirely in central storage). The assembly summary page (see Figure 22 on page 26) provides an estimate of the amount of central storage that would be required if no work file is used. The size of internal work areas used by High Level Assembler for statement analysis and expression evaluation is limited to the block size of the SYSUT1 work file, even if enough central storage is available that no blocks need be written to the work file.

Sometimes a program assembles without error on one system or with one set of invocation JCL or commands, but fails on another system or with a different set of invocation JCL or commands. This unpredictable behavior may be due to a smaller SYSUT1 block size in the latter situation. When the work file is used, the SYSUT1 block size should be as large as possible, consistent with the capabilities of the device to which SYSUT1 is assigned.

Things Worth Checking: Some assembler errors such as messages ASMA105U, ASMA170S, or ASMA253C may be correctable by specifying larger block sizes on SYSUT1.

Attribute References, Literals, and Lookahead Mode



High Level Assembler recognizes certain attribute references in contexts where they were not allowed by previous assemblers. The only attribute reference formerly permitted in “open code” was the Length Attribute Reference (`L'`); High Level Assembler supports Scale (`S'`) and Integer (`I'`) Attribute references in open code. Conditional assembly allows the use of references to the Length, Scale, Integer, Type (`T'`), Count (`K'`), Opcode (`O'`), Number (`N'`), and Definition (`D'`) attributes of variable symbols.

Things Worth Checking

- Some unusual operands using character strings starting with a single letter followed by an apostrophe might be recognized by High Level Assembler as attribute references where previous assemblers had ignored them.
- Symbol attributes may differ between macro-generation and final assembly phases; see the comments on page 73.

Literal Extensions

High Level Assembler lets you use literals in wider contexts than previous assemblers. For example, in machine instruction statement operands, a literal may be used as an ordinary relocatable term, or may be indexed:

```
IC    0,=F'193'+3        Insert an EBCDIC 'A' (poor coding!)
IC    1,=C'12345'(2)     Insert an EBCDIC digit
```

Previous assemblers required that the literal be the only term in the operand, and indexing was not allowed.

Attribute references to literals are allowed in most contexts, whether or not the literals were previously defined.

Literals may also be used as macro instruction operands, and type attribute references to those operands will return a reasonable value for all references.

Lookahead Mode

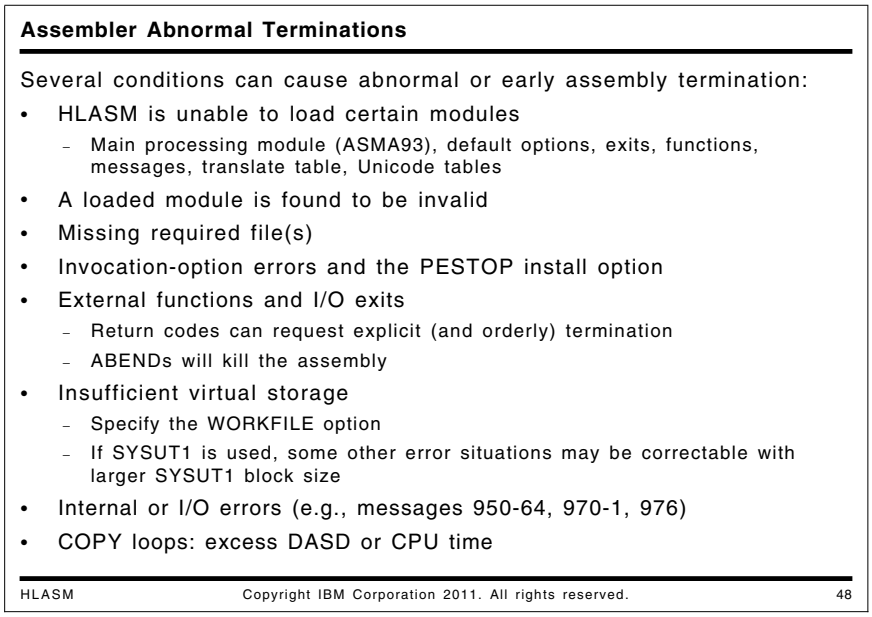
Whenever an attribute of an unknown symbol is required during a conditional assembly operation, HLASM suspends normal operation and enters “lookahead mode”. The input stream is scanned until the first instance of the required symbol is found. Its attributes are then entered into the symbol table and normal processing is resumed. Attributes of other symbols found during the search are entered into the symbol table, so that attribute references to those symbols will not cause lookahead.

Whenever lookahead mode is invoked, the source text is compressed and stored in internally, so the input file need not be reread. Further requests for statements from the input stream will be taken from the lookahead file until it is exhausted, when input will resume from the primary (SYSIN) file.

Conditional assembly might later generate *different* definitions of symbols from those found during lookahead mode; the attributes are “corrected” when the symbols are generated. Note also that only the *attributes* of a symbol are determined in lookahead mode; the value and relocatability attributes are unknown until conditional assembly and the first assembly passes are complete.

Things Worth Checking: Symbol attributes used for conditional assembly might be different from the attributes at the end of the assembly; the symbol cross-reference will show only the final values.

Assembler Abnormal Termination



Sometimes an abnormal termination of an assembly is caused by source-program or assembly-environment conditions over which the assembler has little or no control.

Loaded Modules and Required Files

HLASM loads certain modules dynamically depending on the options specified for the assembly. If any of these modules is unavailable, or when loaded is found to have an invalid format, the assembler will terminate immediately.

Similarly, if a file required for the assembly is missing (such as SYSIN, or other files required for the options you specified), the assembly is terminated.

Option Errors and PESTOP

If the PESTOP option is specified when HLASM is installed, any error in options processing will terminate the assembly. This can save the time and resources needed to re-run a complete assembly that you discarded because of the errors.

I/O Exits and External Functions

Exits and functions run in same task and space as the assembler itself, so their errors can cause the assembly to fail; there is no error recovery in assembler itself. Assembler failures are rare, so if you are using exits or external functions, check to see if the problem may have originated in input-output exits or external functions; such errors may be difficult to detect.

Virtual Storage

When the work file is used, HLASM can write much of its working data to its utility file, but some portions must remain in central storage throughout the assembly. Insufficient storage can cause the assembler to terminate in many different ways. By default, HLASM does not use a utility file, so you may need to specify the WORKFILE option, provide for additional storage, or specify the largest possible blocksize for SYSUT1, as noted in “SYSUT1 Block Size” on page 72.

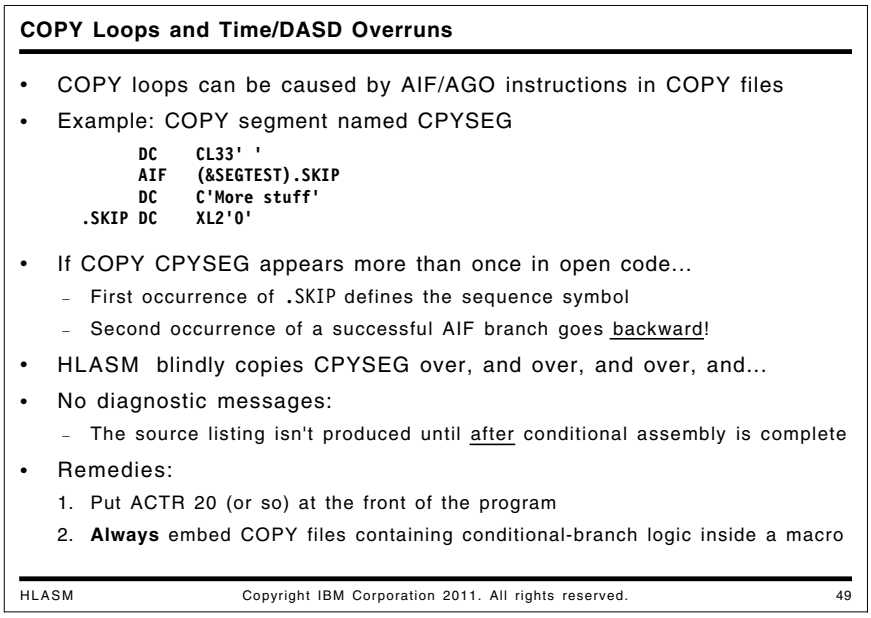
The assembly summary also includes information about the amount of storage used (see Figure 22 on page 26).

Internal and I/O Errors

Occasionally an internal error in the assembler will cause an abnormal termination. Some of these errors are accompanied by a message indicating that HLASM has detected the error itself; others may cause an ABEND condition. If reproducible, these should be reported to IBM Service.

I/O errors may be caused by incorrect JCL, or may be transient conditions that can be corrected by moving or restoring a file.

COPY Loops and Excess DASD or CPU Use



Sometimes HLASM uses unexpectedly large amounts of CPU time (or SYSUT1 DASD space) and increasing the allotment of either doesn't fix the problem; and, no error messages are produced to help locate the problem!

An apparently normal coding practice might cause this behavior. Suppose you write a COPY file named CPYSEG that contains some conditional assembly logic:

```
        DC    CL33' '
        AIF   (&SEGTEST).SKIP
        DC    C'More stuff'
.SKIP DC    XL2'0'
```

Then, suppose you copy this segment into (say) a DSECT:

```
DATA1 DSECT
      COPY  CPYSEG
```

This causes no problems, whether &SEGTEST is true (1) or false (0). Suppose now that you want to use the same data structure in a second DSECT:

```
DATA2 DSECT
      COPY  CPYSEG
```

HLASM effectively sees a code sequence like this:

```
DATA1 DSECT
*     COPY  CPYSEG
      DC    CL33' '
      AIF   (&SEGTEST).SKIP
      DC    C'More stuff'
.SKIP DC    XL2'0'              ◄— defines .SKIP
DATA2 DSECT
*     COPY  CPYSEG
      DC    CL33' '
      AIF   (&SEGTEST).SKIP         May branch backward!
      DC    C'More stuff'
.SKIP DC    XL2'0'              ◄— duplicate definition ignored!
```

The first COPY causes the sequence symbol .SKIP to be defined. The second COPY can cause one of two problems for HLASM. First, if &SEGTEST is false, no conditional assembly branch is taken, statement processing flows sequentially without branching, and HLASM will diagnose a redefinition of the sequence symbol .SKIP.

The more serious problem occurs when &SEGTEST is true, because the second AIF will branch back to the *first* occurrence — the definition — of .SKIP! But this precedes the COPY instruction following the declaration of the *second* DSECT, so HLASM executes COPY CPYSEG repeatedly, eventually exceeding the CPU time limit or using up all the space allocated to central storage or to the SYSUT1 utility file.

Because HLASM must read the entire source program (and possibly buffer it to DASD if there's not enough central storage) before it produces a listing, the end of the program is never found, and no warnings can be produced.

There are two ways to “expose” the problem. One is to insert an ACTR instruction at the beginning of the program:

```
      ACTR  20     Allow only 20 successful conditional assembly branches
```

This will terminate the COPY loop, and HLASM may then be able to provide meaningful information. (Choose an ACTR value appropriate to the number of successful conditional assembly branches you expect in the program.)

The best approach is to use a macro. If a COPY file must contain any conditional assembly logic, encapsulate that logic in a macro definition. Using the previous example, you could write

```
      MACRO
      CPYSEG
      GBLB   &SEGTEST
      DC     CL33' '
      AIF    (&SEGTEST).SKIP
      DC     C'More stuff'
.SKIP DC     XL2'0'
      MEND
```

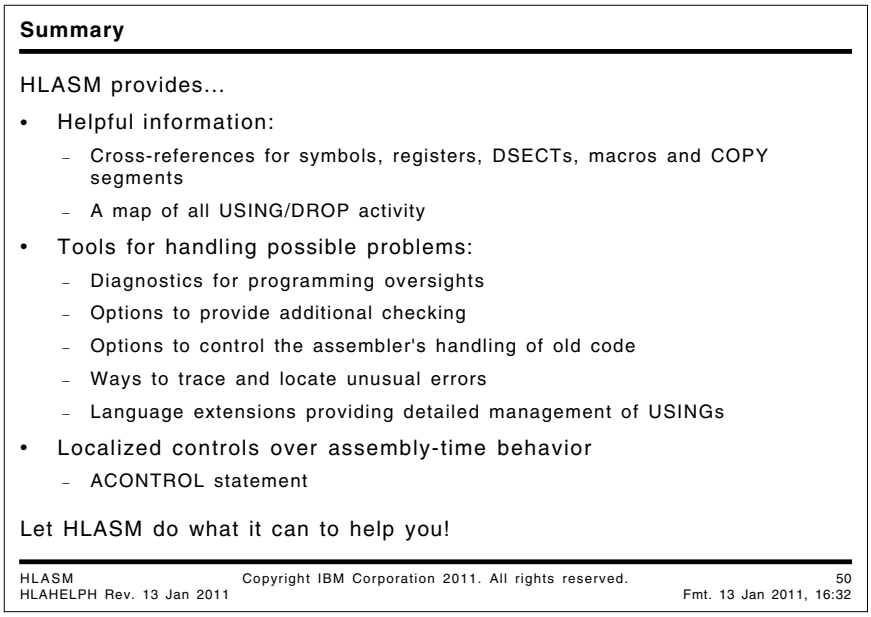
and then write the program with macro calls instead of COPY instructions:

```
DATA1 DSECT
      CPYSEG
DATA2 DSECT
      CPYSEG
```

Looping inside a macro is likely to limit any potential damage.

Things Worth Checking: Check for AIF and AGO instructions in COPY segments, and consider replacing the segments with macros that provide the same function. This will limit the scope of conditional assembly branching.

Summary



HLASM supports many enhanced features that ease the daily chores of finding and fixing problems in Assembler Language programs. While it can't find errors of logic (the HLASM Toolkit Feature can help with this!), many of the features can help reduce the likelihood of error, or can provide information useful in locating and identifying problems.

Index

Special Characters

A

B

C

D

E

F

G

H

I

L

M

N

O

P

Q

R

S

T

U

V

W

X