High Level Assembler:

Benefiting From Its Powerful New Features

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HLASM Options: Overview

- HLASM accepts option specifications from several sources:
  - *PROCESS statements in the program being assembled
  - an external ASMAOPT file
  - invocation parameters
  - installation defaults
- Options apply to various assembly activities:
  - Assembly: BATCH, PROFILE, SIZE
  - Source file: DBCS, OPTABLE, COMPAT, SYSPARM
  - Object file: GOFF, TEST, TRANSLATE, CODEPAGE
  - Assembler I/O: EXIT, ADATA, DECK, OBJECT, TERM
  - Listing: ASA, ESD, FOLD, LINECOUNT, RLD, PCONTROL, INFO, LIBMAC, LIST, USING(MAP), THREAD
    - Messages: ALIGN, FLAG, LANGUAGE, RENT, RA2, USING(WARN), USING(LIMIT)
    - Cross-References: symbols, general registers, macro/COPY members, DSECTs

New Ordinary-Assembly Statements

- HLASM provides many new assembler instruction statements:

`*PROCESS`	Source-file assembly options
`ACONTROL`	Dynamic control of certain options
`ADATA`	User data kept with the SYSADATA file
`ALIAS`	Modifies external symbols in object file
`CEJECT`	Conditional control of listing pagination
`CATTR`	Assign class names and attributes
`EXITCTL`	Provide control data to I/O exits
`XATTR`	Assign attributes to external symbols

Enhanced Ordinary-Assembly Statements

- Existing statements are enhanced by HLASM:

AMODE/RMODE	Extended to support 64-bit addressing
COPY	Supports variable-symbol operand in open code
DC	Many new constant types:

EB,DB,LB	IEEE Floating Point
EH,DH,LH	Hex Floating Point
AD,FD	8-byte address, binary
CU	Sixteen-bit Unicode
J,R	Length, PSECT Address

Blanks allowed in quoted nominal values (except C, G)
No nominal value needed if duplication factor is zero

PRINT	Accepts MCALL, MSOURCE, UHEAD operands
PUSH/POP	Accepts ACONTROL operand
RSECT	Declares a read-only section
USING/DROP	Extended for labeled and dependent USINGs

Conditional Assembly Enhancements

- New conditional-assembly statements have been added and enhanced:

`AEJECT/ASPACE`	Control formatting of macro definition listing
`AINSERT`	Place constructed records into “pre-input” buffer
`AREAD`	Supported operands: CLOCKB, CLOCKD, NOPRINT, NOSTMT
`SETAF, SETCF`	Invoke externally-defined conditional assembly function

- Other enhancements include:
  - Many new system (&SYS) variable symbols
  - Simpler variable symbol declaration
  - Enhanced substring notation
  - Predefined absolute symbols in conditional assembly expressions
  - Easier scanning of macro-argument sublists

Other Useful Language Enhancements

- Unary minus supported in arithmetic expressions
- DXD operand alignment rationalized
- NOPRINT operand supported on several statements
- Attribute-reference extensions
  - `O'` ("Operation Code")
  - `I', S'` in open code
- Literals as macro operands treated more sensibly
- Literals in machine instructions treated more as "ordinary symbols"
- Attribute references to literals return reliable values

Mixed-Case Input

- All IBM mainframe assemblers accept mixed case in:
  - remarks fields of assembler and machine instruction statements

```
NAME    OPCODE  OPERAND,OPERAND     Remarks may be in mixed case
        PRINT   DATA                PRINT all generated text
```

  - comment statements

```
*       Comment statements may also be in mixed case
```

  - quoted character strings in character constants and self-defining terms

```
MIXCON  DC    C'AbBbCcDdeE'   Character Constant
SELFDEF LA    R1,C'a'         Character self-defining term
```

  - macro instruction statement operand values.

```
MACCALL MACOP  Positional,KEY=KeyValue   Macro call operands
```

Mixed-Case Symbols and Operation Codes

- High Level Assembler permits lowercase characters in
  - symbolic operation codes
  - ordinary symbols
  - variable symbols
    - local and global
    - system (&SYS)
    - macro-instruction positional and keyword parameter names
  - sequence symbols
- Operation codes and symbols treated as identical to their uppercase equivalents.

```
label    a    reg9,storage_operand(indexreg)    )) These are
Label    A    Reg9,Storage_Operand(IndexReg)    )) equivalent
LABEL    A    REG9,STORAGE_OPERAND(INDEXREG)    )) statements
```

- Symbol Table displays each symbol as it was first encountered.

Mixed-Case Macro Arguments

- Mixed-case symbols do **not** change macro argument handling:
  - Characters in macro arguments are always left in their original case
  - Macro calls using mixed-case characters in arguments will work in High Level Assembler just as in previous assemblers.

```
LABEL   MACCALL  Positional_Value,KEYWORD=Key_Value     All assemblers

Label   MacCall  Positional_Value,KeyWord=Key_Value     HLASM only
```

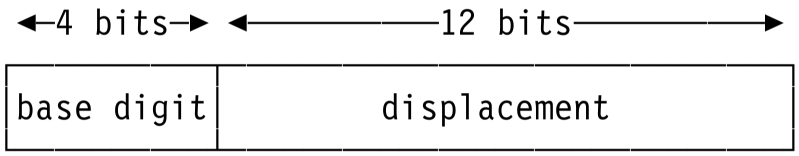
- Keyword and Positional **values** are unchanged
  - Passing mixed-case values may require internal macro changes if such values must be recognized.
    - UPPER function can help!
  - Use COMPAT(MACROCASE) option if existing macros expect uppercase operands

```
        abend  13,dump     Works correctly with CPAT(MC)
```

Ordinary USING Statements

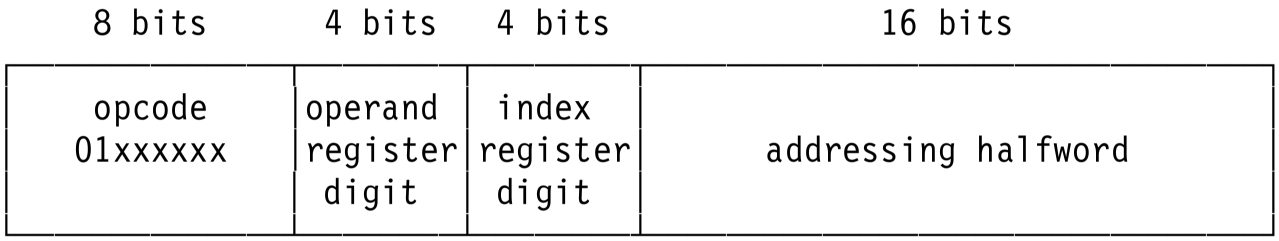
Addressing Halfwords and Effective Addresses

- Many instructions generate addresses from *addressing halfwords*:



Effective Address = displacement + if (b ≠ 0) then C(Rb) else 0

- For RX-type instructions, an *index* may be used:



Effective Address = displacement + if (b ≠ 0) then C(Rb) else 0
+ if (x ≠ 0) then C(Rx) else 0

Manually-Specified Base and Displacement

- Consider assigning bases and displacements symbolically
  - Displacements derived “manually” for each symbol reference

```
Location      Name     Operation  Operand

  0000                 BASR       6,0
  0002        BEGIN    L          2,N-BEGIN(0,6)
  0006                 A          2,ONE-BEGIN(0,6)
  000A                 ST         2,N-BEGIN(0,6)
              ------- 22 bytes of stuff -------
  0024        N        DC         F'8'
  0028        ONE      DC         F'1'
```

  - Each storage address specifies two items: an origin and a register
- Prefer to specify those just once
- Hence, the `USING` statement!

Assembler-Calculated Base and Displacement

- USING combines base-register and base-location information
  - Relation to actual addressing instructions is unknown!

```
         BASR     6,0
         USING    BEGIN,6
BEGIN    L        2,N
         A        2,ONE
         ST       2,N
_____________________________
N        DC       F'8'
ONE      DC       F'1'
```

- Benefits:
  - Simplified references to addressable operands
  - Assembler assigns registers and calculates displacements
  - Improved readability and maintainability

Ordinary USING Statements: Summary

- Your promise to the assembler:
  - Assume this location will be in that register
  - Calculate base-displacement resolutions
  - Run-time addresses will be evaluated correctly
- Limitations
  - Symbolic addressing requires USINGs
    - Whether or not run-time addressing requires distinct registers
  - Multiple resolution problems
  - Base register resolution and selection rules are too easy to forget:
    1. Search USING Table for entries with relocatability attribute matching that of the expression to be resolved (no match: ASMA307W)
    2. Select entry (or entries) yielding smallest valid displacement (beyond USING range: ASMA034W indicates how far)
    3. Select highest-numbered register with that smallest displacement
    4. If an absolute expression is unresolved, try R0 with base zero
- It's very easy for you and the assembler to mis-communicate...!

New USING Statements

Goals of Any Addressing Methodology

- Increased opportunities for clear, simple coding
  - Easier to write, understand, and maintain
- Support efficient coding
  - Maximize performance without devious obscurities
  - Minimize need to remember arcane language rules
- Let the Assembler assign registers and displacements
  - Better controls over resolutions
  - More understandable and maintainable code
- Encourage fully-symbolic references to all objects

Problems with Ordinary USING Statements

- Ordinary USINGs have several shortcomings:
  1. Cannot make simultaneous references to multiple instances of a given control section
     - Unless you write “tortured” code
  2. Cannot map more than one DSECT per register
     - Unless you write “tortured” code
  3. Cannot specify fixed relationships among DSECTs at assembly time
     - Unless you write “tortured” code
- New USING statements in High Level Assembler
  - Alleviate all these problems
  - Coding can be simpler, cleaner, more understandable
  - Less need to understand complex assembler rules
  - Avoid encoding data structuring info in referencing instructions

New USING Statements in High Level Assembler

1. Labeled USINGs
   - Simultaneous reference to multiple instances of an object
   - One object per register
2. Dependent USINGs
   - Address multiple objects with a single register
   - Greater program efficiency (fewer base registers required)
   - Dynamic structure remapping during execution
3. Labeled Dependent USINGs
   - Combines benefits of Labeled and Dependent USINGs
   - Simultaneous reference to (possibly multiple) occurrences of multiple objects with a single register
   - Easier mapping of complex data structures

Labeled USING Statements and Qualified Symbols

- Some definitions:
  1. A qualified symbol is of the form ***qualifier.ordinary_symbol***
  2. A qualifier is an ordinary symbol also
     - Qualifiers may not be used as symbols in other contexts
  3. A qualifier is defined as such by appearing in the name field of a USING statement:

```
qualifier  USING  base,register
```

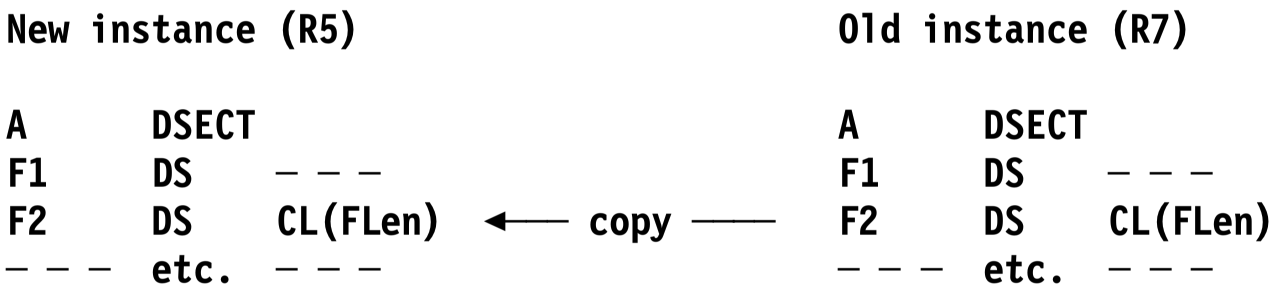
- Examples:

```
A       USING  Z,5         Qualifier A        Use:       A.B
LEFT    USING  BLOCK,9     Qualifier LEFT               LEFT.DATA
RECORD1 USING  MAPPING,3   Qualifier RECORD1      RECORD1.FIELD4
```

- Qualifiers permit “directed resolution” to a specific register

Managing Two Copies of a Data Structure

- We wish to copy a field F2 between two active copies of a DSECT:



- We'd like the assembler to understand statements like

  MVC $F2_{NEW}$,$F2_{OLD}$ **or** **MVC NEW_F2,OLD_F2**

- Solutions with ordinary USINGs have some shortcomings...
  - likely to be harder to understand and maintain
  - more opportunities for incorrect or inefficient code
  - harder for assembler to diagnose potential problems
  - require deeper understanding of complex instruction and language rules

Managing Two Copies of a Structure (The Hard Way)

- Some examples of solutions with ordinary USINGs:

  1. Incorrect usage:

```
USING  A,5                    USING  A,7
USING  A,7          or        USING  A,5
MVC    F2,F2                  MVC    F2,F2
```

  2. With manually-calculated displacements (1):

```
USING  A,5            map new instance of A
MVC    F2,F2-A(7)     move from old to new (Correct, but ugly)
```

  3. With manually-calculated displacements (2):

```
USING  A,7            map old instance of A
MVC    F2-A(5),F2     move from old to new (WRONG!)
```

  4. With manually-calculated displacements (3):

```
USING  A,7            map old instance of A
MVC    F2-A(,5),F2    move from old to new (Correct, but uglier)
```

Managing Two Copies of a Structure (The Hard Way)...

5. With (strangely) manually-calculated displacements (4):

```
USING  A,5            map new instance of A
USING  0,7            map old instance of A (somewhat...)
MVC    F2,F2-A        move from old to new

- - -                 more statements (forgetting to drop R0)

LA     1,100          Resolved on R7! (X'41107064')
```

6. With (desperately) manually-calculated displacements (4):

```
USING  A,5             map new instance of A
USING  0+X'F999',7     map old instance of A (differently)
MVC    F2,F2-A+X'F999' move from old to new
```

7. Manual assignments may be **wrong** if the size of DSECT A exceeds 4K bytes

```
       USING  A,5,6           map new instance of A
 *     USING  A,7,8           implicit map of old instance of A
       MVC    F2,F2-A(7)      F2-A might exceed 4095?
```

Managing Two Copies of a Structure (The Hard Way)...

8. With an intermediate temporary (1):

```
USING  A,7            map old instance of A
MVC    TEMP(FLen),F2  move from old to temp
USING  A,5            map new instance of A
MVC    F2,TEMP        move from temp to new (WRONG!)
```

9. With an intermediate temporary (2):

```
USING  A,7            map old instance of A
MVC    TEMP(FLen),F2  move from old to temp
DROP   7              must DROP register 7 first
USING  A,5            map new instance of A
MVC    F2,TEMP        move from temp to new (RIGHT!)
```

10. With a duplicated copy of the DSECT:

```
B      DSECT                 B is a copy of A
G1     DS    - - -
G2     DS    CL(FLen)
- - -  etc.  - - -
       USING  B,7            map old instance of A (named B)
       USING  A,5            map new instance of A
       MVC    F2,G2          move from old to new
```

- Each of these examples is not untypical of current coding styles...

Labeled USINGs: The Best Solution

- Labeled USINGs provide a simple solution:

```
OLD [1] USING  A,7              map old instance of A
NEW [2] USING  A,5              map new instance of A
        MVC    NEW.F2,OLD.F2    move field from old to new
               [4]      [3]
```

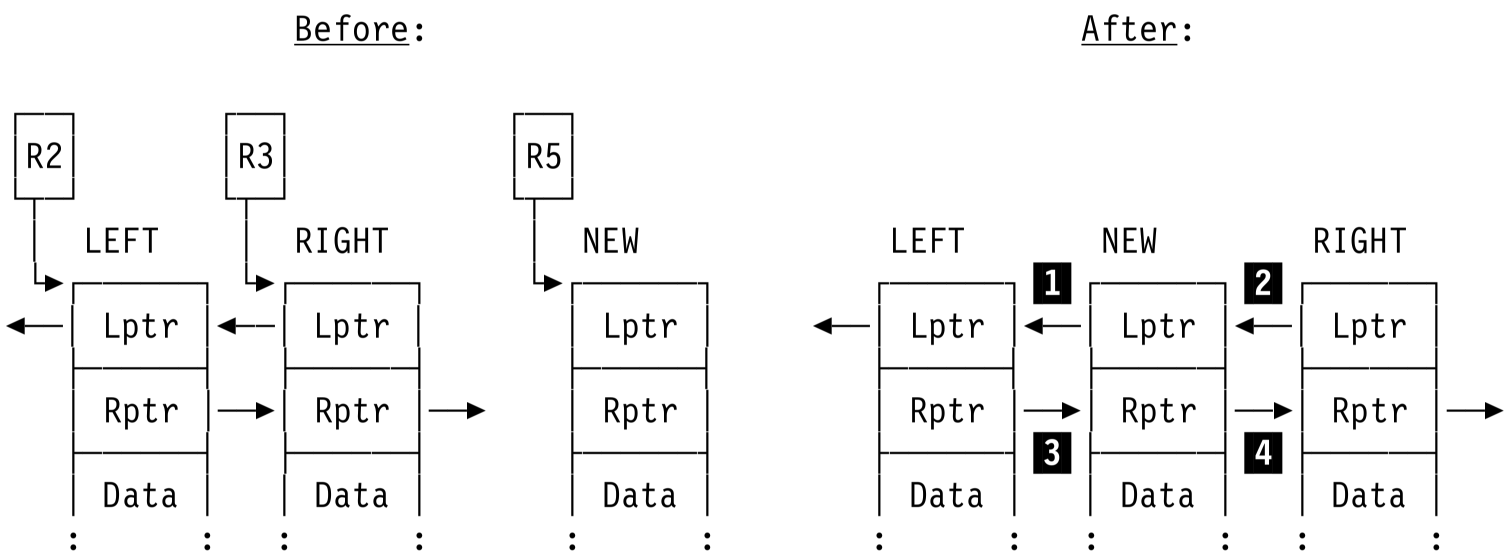
  - Qualifier OLD [1] resolves symbol [3] and qualifier NEW [2] resolves [4]

- Advantages of labeled USINGs
  - data objects need only one definition
  - all references are fully symbolic
  - no manually-specified displacements and registers
  - efficient solution is also the most natural
  - no need to understand obscure details of Assembler Language

- You can address multiple instances of CSECTs also!

Example: Doubly-Linked List Structure

- Insert a NEW element in a doubly-linked list:



- Labeled USINGs provide clean, understandable solution
  - Many complex, obscure solutions possible with ordinary USINGs

Labeled USINGs: Doubly-Linked List

- Code with labeled USINGs is very simple:

```
BLOCK  DSECT
Lptr   DS    A              Pointer to left  element
Rptr   DS    A              Pointer to right element
Data   DS    XL24,D,E etc.  Data fields within BLOCK
       — — —

RNew   Equ   5                          R5 points to New element
Left   USING Block,2                    Labeled USING
Right  USING Block,3                    Labeled USING
New    USING Block,RNew                 Labeled USING
       — — —
       MVC   New.Lptr,Right.Lptr   1    Qualified symbols
       ST    RNew,Right.Lptr       2    Qualified symbol
       MVC   New.Rptr,Left.Rptr    3    Qualified symbols
       ST    RNew,Left.Rptr        4    Qualified symbol
```

- Advantages: clarity, simplicity, readability, efficiency, maintainability

Labeled USING Statements: a Summary

- Resolutions done only for symbols with matching qualifier
- Normal resolution rules still apply
  - Matching relocatability attribute
  - Displacement cannot exceed 4095
- May be concurrent with ordinary USING for same register

```
         USING  A,9          Ordinary USING
 Q       USING  A,9          Labeled  USING
         - - -
         LA     0,A+40       Resolved only with Ordinary USING
         LA     1,Q.A+40     Resolved only with Labeled  USING
         DROP   9            Drop ordinary USING; labeled still active
         LA     2,Q.A+40     Resolved only with Labeled  USING
         DROP   Q            Drop labeled USING
```

- Care is recommended!
  - Avoid mixing qualified and unqualified symbol references

Dependent USING Statements

- Let you address multiple DSECTs with one base register
  - Provide improved ways to manage data structures
- Syntax is the same as for ordinary USINGs:

```
USING  symbol,base
```

- Except that the second operand is interpreted differently:

ordinary: second operand is absolute, between 0 and 15

```
USING  symbol,register
```

dependent: second operand is relocatable, addressable

```
USING  symbol,anchor_location
```

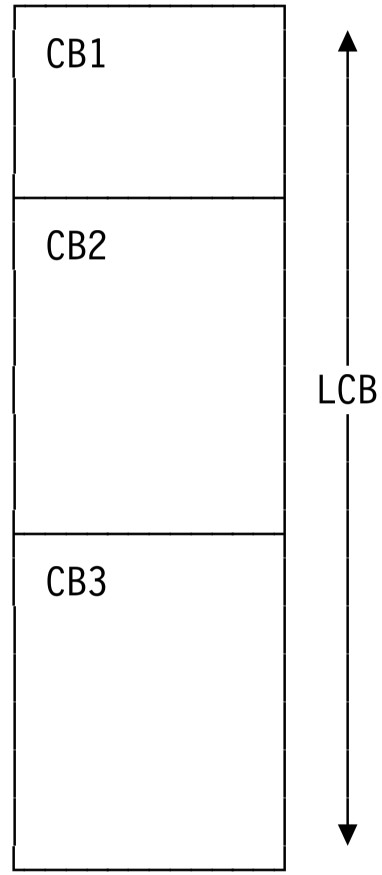
- First operand is “based” or “anchored” at second operand location

Dependent Using Statement Examples

- Example: DSECTs B and C anchored at different offsets within A

```
        R:F  00000          9       USING  A,15     Ordinary: Addr(A) in R15
      F 020  00000 00020   10       USING  B,A+32   Dependent: B at A+X'20'

00058 4100 F028    00008   12       LA     0,B2     B2 at offset X'28' from A

      F 030  00000 00010   14       USING  C,B+16   Dependent: C at B+X'10'

0005C 4100 F080    00050   16       LA     0,C2     C2 at offset X'80' from A

00000                      18 B     DSECT
00000                      19 B1    DS     D        Offset    0  from B
00008                      20 B2    DS     D        Offset    8  from B

00000                      22 C     DSECT
00000                      23 C1    DS     CL80     Offset    0  from C
00050                      24 C2    DS     XL8      Offset X'50' from C

00000                      26 A     DSECT
00000                      27       DS     XL256
```

Dependent USING Example: Contiguous Control Blocks



Contiguous
Control Blocks

```
CB1     DSECT ,          Define control block 1
CB1F1   DS    D
CB1F2   DS    CL40
LCB1    EQU   *-CB1      Length of block 1

CB2     DSECT ,          Define control block 2
CB2F1   DS    24F
LCB2    EQU   *-CB2      Length of block 2

CB3     DSECT ,          Define control block 3
CB3F1   DS    XL8,CL80
LCB3    EQU   *-CB3

LCB     EQU   LCB1+LCB2+LCB3  Total length
```

Contiguous Control Blocks: Ordinary USINGs

- Ordinary USINGs require a register for each DSECT:

```
*       GET (LCB bytes) STORAGE FOR ALL 3 BLOCKS, BASE ADDRESS IN R7
        - - -
        USING CB1,7             Anchor the first storage block
        LA    6,CB1+LCB1        Calculate address of second block
        USING CB2,6             Anchor the second storage block
        LA    4,CB2+LCB2        Calculate address of third block
        USING CB3,4             Anchor the third storage block
```

- Defects:
  - Extra base registers
  - Additional initialization overhead
- Devious coding techniques:

```
        USING CB1,7             Anchor the first storage block
        L     0,CB1+LCB1+(CB2F1-CB2)+8  3rd element of CB2F1 array
        - - -
```

- Defects:
  - Complex coding that is hard to understand and maintain
  - Relationships among CBs is embedded in each referencing instruction

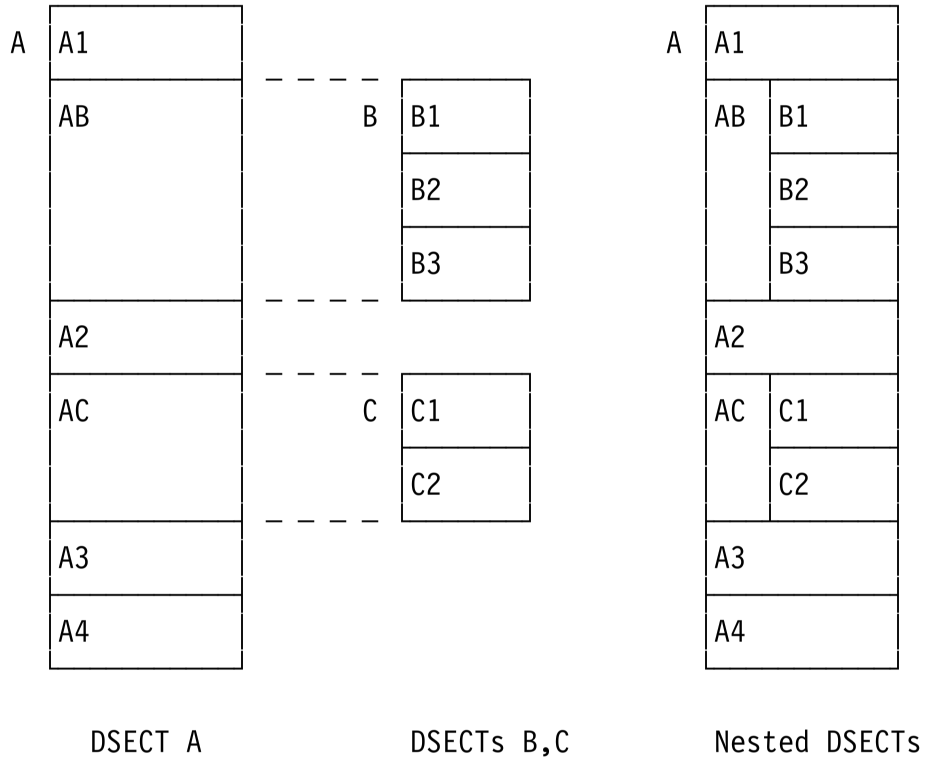
Contiguous Control Blocks: Dependent USINGs

- Dependent USINGs require only a single base register:

```
*       GET (LCB bytes) STORAGE FOR ALL 3 BLOCKS, BASE ADDRESS IN R7
        - - -
        USING CB1,7             Anchor the full storage block
        USING CB2,CB1+LCB1      Adjoin CB2 to CB1 (dependent USING)
        USING CB3,CB2+LCB2      Adjoin CB3 to CB2 (dependent USING)

        STM   14,12,CB2F1+12    Addresses resolved with
        XC    CB3F1,CB3F1       ... just one base register (R7)
        UNPK  CB1F1,CB1F2(4)    ... for all these instructions
```

- Advantages:
  - Minimal number of base registers needed
  - No run-time initialization overhead
  - Independently defined data structures

Dependent USING Example: Nested Structures




```
A       DSECT
A1      DS      24F
AB      DS      CL(LB)
A2      DS      6CL80
AC      DS      CL(LC)
A3      DS      XL16
A4      DS      CL256

B       DSECT
B1      DS      CL44
B2      DS      6D
B3      DS      4A
LB      EQU     *-B

C       DSECT
C1      DS      96D
C2      DS      4XL20
LC      EQU     *-C
```

Nested Structures with Multiple Ordinary USINGs

- Each DSECT requires its own base register:

```
*                          Assume address of A is in R7
         USING A,7         Ordinary USING for A
         LA    5,AB        Address of AB in R5
         USING B,5         Ordinary USING for B
         LA    4,AC        Address of AC in R4
         USING C,4         Ordinary USING for C
```

- Defects:
  - Loss of efficiency: extra registers, execution-time setup
  - Precise relationship of instructions to structure elements is not as clear

Nested Structures with Dependent USINGs

- Dependent USINGs allow these to be addressed with a single register:

```
*                               Assume address of A is in R7
         USING A,7              Ordinary USING for A
         USING B,AB             Dependent USING: anchor B at AB
         USING C,AC             Dependent USING: anchor C at AC
```

- Benefits of dependent USINGs:
  - More efficient solution
    - Minimal number of registers needed for addressing
    - No execution-time register setup
  - Simpler, clearer code
    - Clear separation of data definitions and instructions

Nested Structures with One Ordinary USING

- Can map nested structures with a single ordinary USING
  - Calculate DSECT offsets “manually”

```
*                           Assume address of A is in R7
         USING A,7          Ordinary USING for A
         - - -
         L     0,AB+(B3-B)  Field B3 within DSECT B
         C     0,AC+(C2-C)  Field C2 within DSECT C
```

- Will need to write a lot of this if many references to DSECT fields
- Dependent USING is clearer, easier to write and maintain

```
         USING A,7          Ordinary USING for A
         USING B,AB         Map DSECT B into A at AB
         USING C,AC         Map DSECT C into A at AC
         - - -
         L     0,B3         Field B3 within DSECT B
         C     0,C2         Field C2 within DSECT C
```

- Let the assembler do the hard work!
  - It calculates the same displacements as you did (with difficulty)

Mapping Message Fields with the Message Itself

- Suppose your message has several fields to fill:

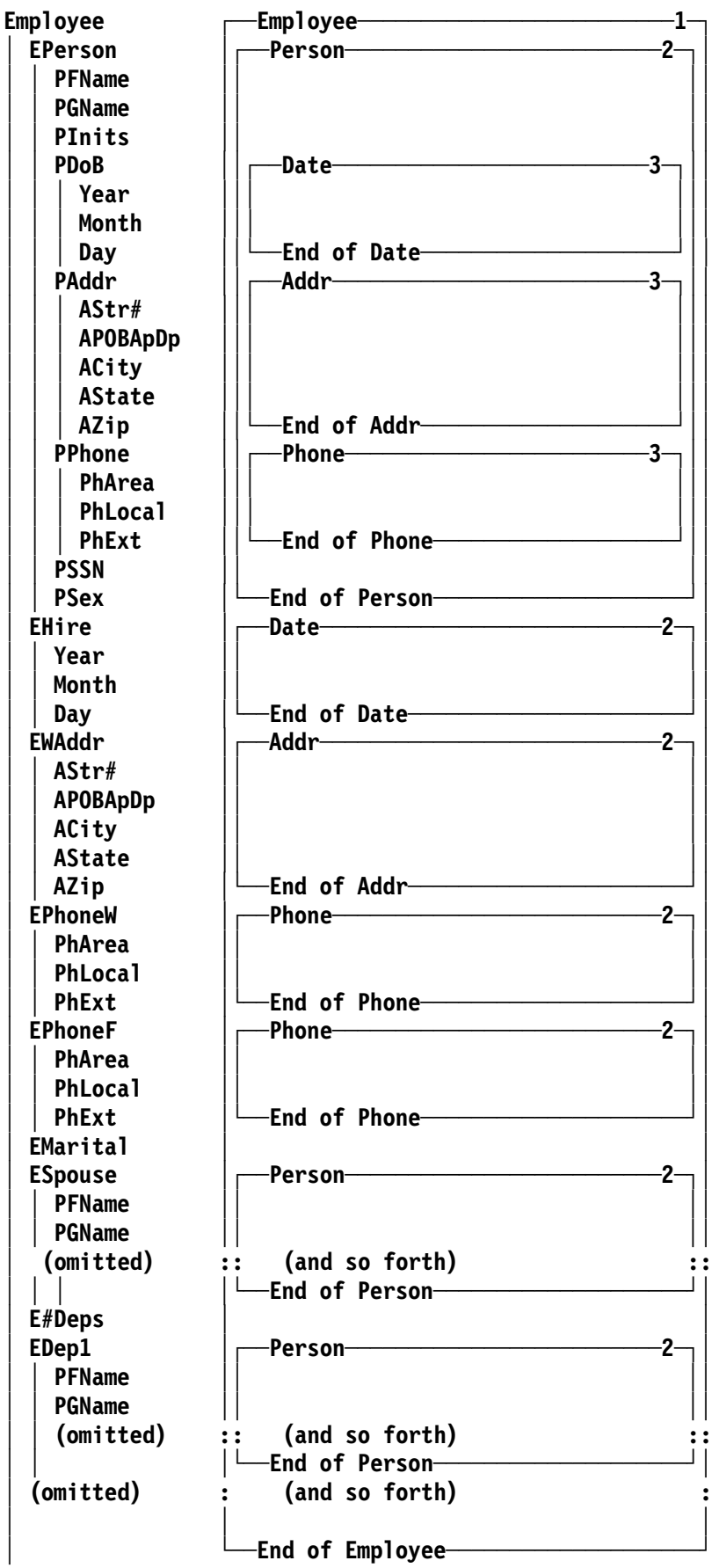
```
Messages CSect ,
Msg1     DC    C'This message for '
Msg1To   DC    C'xxxxxxxx'          Modified field
         DC    C' from '
Msg1From DC    C'yyyyyyyy'          Modified field
Msg1L    Equ   *-Msg1               Length of message
```

- Move the message to a buffer, then map the constant onto the buffer:

```
         Push  Using                Save USING status
         L     10,=A(Messages)      Point to messages
         Using Messages,10
         MVC   Buffer(Msg1L),Msg1   Move to buffer
         Drop  10                   Don't reference original
         Using Msg1,Buffer          Map original onto buffer
         MVC   Msg1To,ToName        Move "To" name
         MVC   Msg1From,FromName    Move "From" name
         Pop   Using                Restore USING status
```

- No need for separate DSects describing the message's fields

DSECT Nesting in an Employee Record



Labeled Dependent USING Statements

- Labeled dependent USINGs combine the benefits of labeled and dependent USINGs:
  - labeled: multiple copies of an object may be active simultaneously
  - dependent: many objects may be addressed with a single base register
- Syntax combines elements of labeled and dependent USINGs

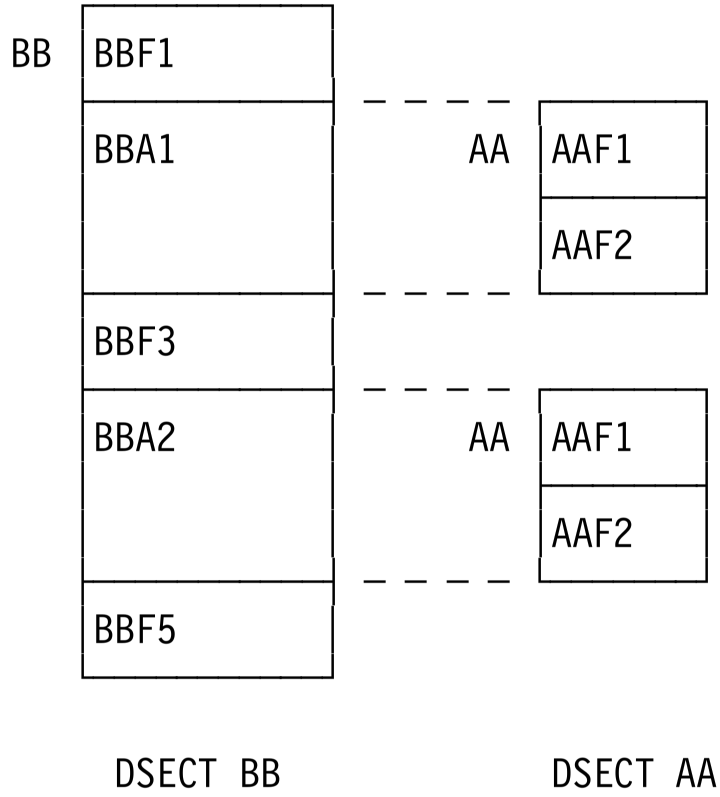
```
label    USING operand1,operand2       Operand2 is relocatable
```

- Example: overlay two instances of DSECT DZ within A

```
Z1       USING DZ,A+12       Overlay DZ at A+12, qualify with "Z1"
Z2       USING DZ,A+82       Overlay DZ at A+82, qualify with "Z2"
```

Two Nested Identical Structures

- Nest two instances of AA within BB




```
AA      DSECT
AAF1    DS      XL5
AAF2    DS      XL8
LAA     EQU     *-AA

BB      DSECT
BBF1    DS      XL17
BBA1    DS      XL(LAA)
BBF3    DS      XL11
BBA2    DS      XL(LAA)
BBF5    DS      XL7
LBB     EQU     *-BB
```

Addressing Two Nested Identical Structures

- With ordinary USINGs

  censored

- Labeled USINGs require 3 base registers, “setup” overhead

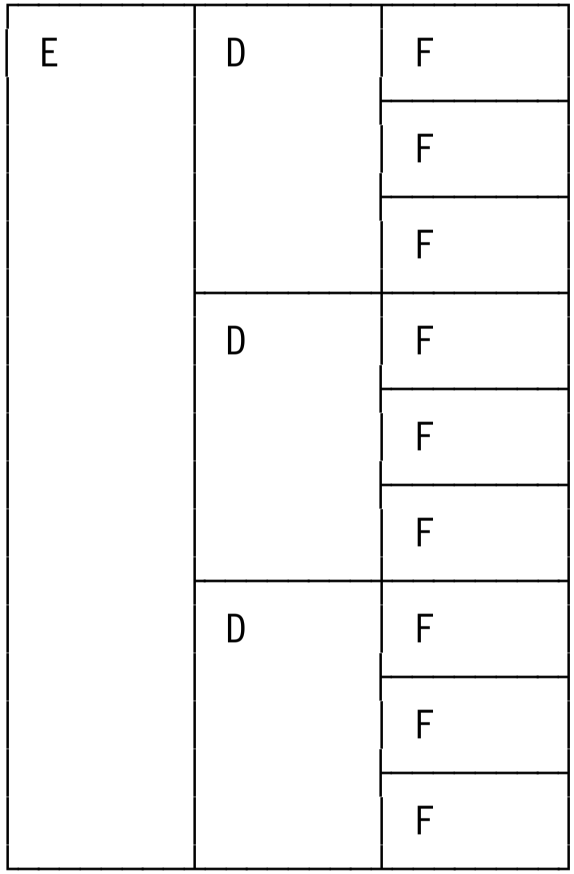
```
        USING BB,10             R10 points to BB
        LA    11,BBA1           R11 points to 1st copy of AA
A1      USING AA,11             Labeled USING for 1st copy of AA
        LA    12,BBA2           R12 points to 2nd copy of AA
A2      USING AA,12             Labeled USING for 2nd copy of AA
```

- Labeled dependent USINGs require only one base register

```
        USING BB,10             R10 points to BB
A1      USING AA,BBA1           Labeled dependent USING for 1st copy of AA
A2      USING AA,BBA2           Labeled dependent USING for 2nd copy of AA
```

- Even if BB exceeds 4K bytes, this is still better

Multiple Nested Structures




```
F       DSECT ,
X1      DS    XL5
X2      DS    XL5
LF      EQU   *-F

D       DSECT ,
F1      DS    XL(LF)
F2      DS    XL(LF)
F3      DS    XL(LF)
LD      EQU   *-D

E       DSECT ,
D1      DS    XL(LD)
D2      DS    XL(LD)
D3      DS    XL(LD)
```

- Problems:
  - Multiple instances of structures D and F
  - Ordinary or labeled USINGs require 13 base registers!

Multiple Nested Structures: Labeled Dependent USINGs

- Mapping nested structures with labeled dependent USINGs

```
         USING E,7                          1 Top level
*                                           |
D1E      USING D,D1       1                 |  2 Map D1 into E at D1
D1F1     USING F,D1E.F1     2               |  |  3 Map F1 into D1 at F1
D1F2     USING F,D1E.F2     2               |  |  3 Map F2 into D1 at F2
D1F3     USING F,D1E.F3     2               |  |  3 Map F3 into D1 at F3
*                                           |  2 Middle level
D2E      USING D,D2       1                 |  |  Map D2 into E at D2
D2F1     USING F,D2E.F1     3               |  |  3 Map F1 into D2 at F1
D2F2     USING F,D2E.F2     3               |  |  3 Map F2 into D2 at F2
D2F3     USING F,D2E.F3     3               |  |  3 Map F3 into D2 at F3
*                                           |  2 Middle level
D3E      USING D,D3       1                 |  |  Map D3 into E at D3
D3F1     USING F,D3E.F1     4               |  |  3 Map F1 into D3 at F1
D3F2     USING F,D3E.F2     4               |  |  3 Map F2 into D3 at F2
D3F3     USING F,D3E.F3     4               |  |  3 Map F3 into D3 at F3
```

- Qualifiers indicate which references apply to which instance

Multiple Nested Structures: Referencing Fields

- All symbol references to individual fields are qualified:

```
*   Move fields named X within DSECTs described by F
    MVC   D1F1.X1,D1F1.X2        Within bottom-level DSECT D1F1
    MVC   D1F3.X2,D1F1.X1        Across bottom-level DSECTs in D1
    MVC   D3F2.X2,D3F3.X2        Across bottom-level DSECTs in D3
    MVC   D2F1.X1,D3F2.X2        Across bottom-level DSECTs in D2 and D3

*   Move DSECTs named F within DSECTs described by D
    MVC   D3E.F1,D3E.F3          Within mid-level DSECT D3E
    MVC   D1E.F3,D2E.F1          Across mid-level DSECTs D1E, D2E

*   Move DSECTs named D within E
    MVC   D1,D2                  Across top-level DSECTs D1, D2
```

- Can address structures as fields, sub-sub-structures, and sub-structures

Array of Identical Data Structures

- Suppose you have a small array of identical data structures:

```
Struc    DSect ,
StrF1    DS    CL8          First field
StrF2    DS    F            Second field
StrF3    DS    A            Third field
LStruc   Equ   *-Struc      Structure Length
```

- Then, map each element with its own qualifier

```
EL1      Using Struc,9                    Map first element
EL2      Using Struc,EL1.Struc+1*LStruc   Map second element
EL3      Using Struc,EL1.Struc+2*LStruc   Map third  element
EL4      Using Struc,EL1.Struc+3*LStruc   Map fourth element
         - - -                            etc.
```

- Then, you can reference fields among elements:

```
         L     1,EL3.StrF2          Get field 2 from element 3
         A     1,EL5.StrF3          Add field 3 from element 5
         MVC   EL2.StrF1,EL4.StrF1  Move field 1 from element 4 to 2
```

Two MVS DCBs Within a Program

- Program fragment containing two DCBs and code:
  part of program must copy input-DCB's LRECL to output DCB

Old Way

```
          LA    3,OUTDCB             Point to Output DCB
          LA    2,INDCB              Point to Input DCB
          USING IHADCB,2             Use DSECT mapping of Input DCB
          MVC   DCBLRECL-IHADCB(2,3),DCBLRECL    Copy IN LRECL to OUT
          - - -
INDCB     DCB   DDNAME=..., etc.
OUTDCB    DCB   DDNAME=..., etc.
          - - -
          DCBD  DSORG=PS,DEVD=DA,...etc.  Generate IHADCB DSECT
```

New Way

```
          USING *,12
          - - -
IN   1    USING IHADCB,INDCB               Labeled dependent USING
OUT  2    USING IHADCB,OUTDCB              Labeled dependent USING
          - - -
          MVC   OUT.DCBLRECL,IN.DCBLRECL   Addresses resolved via R12
                 2             1
```

- Only one register needed to address code and two DSECTs!

Personnel-File Employee Record

- Example: a “personnel-file” record describing an employee

```
Employee DSECT ,                  Employee record
EPerson  DS    CL(LPerson)        Person field
EHire    DS    CL(LDate)          Date of hire
EWAddr   DS    CL(LAddr)          Work (external) address
EPhoneW  DS    CL(LPhone)         Work telephone
EPhoneF  DS    CL(LPhone)         Work Fax telephone
EMarital DS    X                  Marital Status
ESpouse  DS    CL(LPerson)        Spouse field
E#Deps   DS    CL2                Number of dependents
EDep1    DS    CL(LPerson)        Dependent 1
EDep2    DS    CL(LPerson)        Dependent 2
EDep3    DS    CL(LPerson)        Dependent 3
LEmploye EQU   *-Employee         Length of Employee record
```

- Many fields are described by other DSECTs:
  - Person, Date, Addr, Phone

Personnel-File Employee Record: “Person” Fields

- An individual is described by the `Person` DSECT:

```
Person   DSECT ,                Define a "Person" field
PFName   DS    CL20             Last (Family) name
PGName   DS    CL15             First (Given) name
PInits   DS    CL3              Initials
PDoB     DS    CL(LDate)        Date of birth
PAddr    DS    CL(LAddr)        Home address
PPhone   DS    CL(LPhone)       Home telephone number
PSSN     DS    CL9              Social Security Number
PSex     DS    CL1              Gender
LPerson  EQU   *-Person         Length of Person field
```

- Some fields are described by other DSECTs:
  - `Date, Addr, Phone`

Personnel-File Employee Record: “Date,” “Addr” Fields

- Dates and addresses are described by `Date, Addr` DSECTs:

```
Date     DSECT ,                  Define a calendar date field
Year     DS    CL4                YYYY
Month    DS    CL2                MM
Day      DS    CL2                DD
LDate    EQU   *-Date             Length of Date field
         ORG   Date
DateF    DS    0CL(LDate)         Full YYYYMMDD date
         ORG   ,                  End of Date DSECT

Addr     DSECT ,                  Define an address field
AStr#    DS    CL30               Street number
APOBApDp DS    CL15               P.O.Box, Apartment, or Department
ACity    DS    CL24               City name
AState   DS    CL2                State abbreviation
AZip     DS    CL9                U.S. Post Office Zip Code
LAddr    EQU   *-Addr             Length of Address field
         ORG   Addr
AddrF    DS    0CL(LAddr)         Full address
         ORG   ,                  End of Addr DSECT
```

Personnel-File Employee Record: Comparing Birth Dates

- Example 1: Compare employee and spouse birth dates
  - Requires two active instances of Person DSECT

```
         USING Employee,10         Assume R10 points to the record

PE   1   USING Person,EPerson     Overlay Person DSECT on Empl. field
PS   2   USING Person,ESpouse     Overlay Person DSECT on Spouse field

* Example 1: Compare Employee and Spouse Dates of Birth

         CLC   PE.PDoB,PS.PDoB    Compare Employee/Spouse birth dates
               1       2
```

- Employee's Date of Birth (PDoB) qualified by PE (1), spouse's by PS (2)

Personnel-File Employee Record: Comparing Dates

- Example 2: Compare employee date of hire to dependent 1 birth date
  - Two active instances of `Date` DSECT

```
* Example 2: Compare Date of Hire to Birthdate of Dependent 1

EHD  3   USING Date,EHire          Overlay Date DSECT on Date of Hire

PD1  4   USING Person,EDep1        Overlay Person DSECT on Dependent 1
DD1  5   USING Date,PD1.PDoB       Overlay Date DSECT on Dependent 1
                       4

         CLC   EHD.DateF,DD1.DateF Compare hire date to Dep 1 DoB
               3         5

         DROP  EHD,DD1             Remove both date associations
```

- Dependent's `Person` DSECT qualified by PD1 (4)
- Hire date qualified by EHD (3), dependent birthdate by DD1 (5)

Personnel-File Employee Record: Copying Addresses

- Example 3: Copy employee address to dependent 2 address
  - Two active instances of Addr DSECT

```
* Example 3: Copy Employee Address to Dependent 2 address

AE   6   USING Addr,PE.PAddr       Overlay Addr DSECT on Employee name
                    1
PD2  7   USING Person,EDep2        Overlay Person DSECT on Dependent 2
AD2  8   USING Addr,PD2.PAddr      Overlay Addr DSECT on Dep. 2 Person
                    7

         MVC   AD2.AddrF,AE.AddrF  Copy Employee Addr to Dependent 2
               8         6

         DROP  PD2                 Remove Dependent 2 associations
```

- Dependent's Person DSECT qualified by PD1 (7)
- Employee address qualified by AE (6), dependent's by AD2 (8)

Summary of USING Statements

USING Type	La-bel	Register Usage	Oper-and 1 Based on	Operand 2	Operand 2 Location in Storage	Number of Instances of Active Objects
Ordi-nary	no	one register per object	register	absolute [0,15]	anywhere in storage	only one active instance of an object at a time
Label-ed	yes	one register per object	register	absolute [0,15]	anywhere in storage	as many active instances of an object as registers assigned

Summary of USING Statements ...

USING Type	La-bel	Register Usage	Oper-and 1 Based on	Operand 2	Operand 2 Location in Storage	Number of Instances of Active Objects
Depen-dent	no	multiple objects per register	operand 2	relocatable, addressable	within addressability range of ordinary USINGs	multiple active objects of different types
Labeled Depen-dent	yes	multiple objects per register	operand 2	relocatable, addressable	within addressability range of ordinary USINGs	multiple active objects of the same or different types

DROP Statement Extensions

USING Type	DROP Statement
Ordinary	By register number
Labeled	By qualifying label (dropping the register has no effect)
Dependent	By register number (all sub-dependent USINGs dropped automatically)
Labeled Dependent	By qualifying label (dropping the register has no effect)

- Examples:

```
          Ordinary:     DROP  9
           Labeled:     DROP  QUAL
         Dependent:     DROP  12
   Labeled Dependent:   DROP  QUAL
```

Generalized Object File Format (GOFF)

- *Removes limitations associated with old object module format:*
  - External names to 63 characters
  - Section sizes up to 2GB (addresses to 31 bits)
  - Multi-component, multi-modal modules
  - Ability to retain “Assembler Data” with object code
  - And much more...
- Controlled by `GOFF` option
  - Independent of `DECK` or `OBJECT`
    - Assembler produces only one type of object file, old or new
  - Requires “wide” listing format (LIST(133) or LIST(MAX) option)
  - Enables use of CATTR, XATTR statements
    - Assign class names and external symbol attributes
    - One assembly can create many RMODE(24) and RMODE(31) “segments”
    - Entry points can have their own AMODEs
- Utilizes enhanced capabilities of DFSMS Binder, Program Objects
  - Existing programs can use GOFF transparently

Internal Conditional-Assembly Functions

- All IBM System/360/370/390 assemblers provide four functions:
  - Boolean connectives (AND, OR, NOT) and character substrings

```
&Bool1  SetB  (&Bool2 AND (&Bool3 OR NOT &Bool4))   Boolean functions
&Char1  SetC  '&Char2'(&Start,&Length)              Substring function
```

- High Level Assembler provides 16 *internal* functions:
  - Arithmetic functions for arithmetic (fullword integer) values
    - Masking/logical operations: AND, OR, NOT, XOR
    - Shifting operations: SLL, SRL, SLA, SRA
  - Boolean connective: XOR
  - Character functions:
    - Unary operations: UPPER, LOWER, DOUBLE, BYTE, SIGNED
    - Binary operations: INDEX, FIND
  - Extensible to other functions as required

- . . . and two statements for invoking *external* functions:
  - Arithmetic-valued functions: SETAF
  - Character-valued functions: SETCF

Internal Arithmetic-Valued Functions

- Arithmetic functions operate on fullword integer (SETA) values
- Masking/logical operations: AND, OR, NOT, XOR

```
&A_And  SetA  ((&A1 AND &A2) AND X'FF')
&A_Or   SetA  (&A1 OR (&A2 OR &A3))
&A_Xor  SetA  (&A1 XOR (&A3 XOR 7))
&A_Not  SetA  (NOT &A1)+&A2
&A      SetA  (7 XOR (7 OR (&A+7)))    Round &A to next multiple of 8
```

- Shifting operations: SLL, SRL, SLA, SRA

```
&A_SLL  SetA  (&A1 SLL 3)          Shift left 3 bits, unsigned
&A_SRL  SetA  (&A1 SRL &A2)        Shift right &A2 bits, unsigned
&A_SLA  SetA  (&A1 SLA 1)          Shift left 1 bit, signed
&A_SRA  SetA  (&A1 SRA &A2)        Shift right &A2 bits, signed
```

- Any combination...

```
&Z   SetA  ((3+(NOT &A) SLL &B))/((&C-1 OR 31)*5)
```

Boolean Operators

- Logical operators: AND, OR, NOT previously available

```
&A      SetB  (&V gt 0 AND &V le 7)          &V between 1 and 7
&B      SetB  ('&C' lt '0' OR '&C' gt '9')   &C not a digit
&Z      SetB  (&A AND NOT &B)
```

- New operator: XOR

```
&S      SetB  (&B XOR (&G OR &D))
&T      SetB  (&X ge 5 XOR (&Y*2 lt &X OR &D))
```

- Simplifies “either but not both” testing:

```
&NotBoth  SetB  ((&J OR &K) AND NOT (&J AND &K))  Previously
&NotBoth  SetB  (&J XOR &K)                       With XOR
```

- Evaluation priority: NOT, AND, OR, XOR

Internal Character Functions

- Seven internal character-valued functions
- Unary functions: UPPER, LOWER, DOUBLE, BYTE, SIGNED

```
&X_Up    SetC   (Upper '&X')   All letters in &X set to upper case
&Y_Low   SetC   (Lower '&Y')   All letters in &Y set to lower case
&Z_Pair  SetC   (Double '&Z')  Ampersands/apostrophes in &Z doubled
&Blank   SetC   (Byte 64)      Sets &Blank to C' '
&Minus3  SetC   (Signed -3)    Sets &Minus3 to '-3'
```

- Binary arithmetic-valued functions: INDEX, FIND
- INDEX returns offset of first match in 1st operand string of 2nd operand string

```
&First_Match SetA  ('&BigStrg' INDEX '&SubStrg')  First string match
&First_Match SetA  ('&HayStack' INDEX '&OneLongNeedle')
```

- FIND returns offset of first match in 1st operand string of any character of the 2nd operand

```
&First_Char  SetA  ('&BigStrg' FIND  '&CharSet')  First char match
&First_Char  SetA  ('&HayStack' FIND  '&ManySmallNeedles')
```

External Conditional-Assembly Functions

- Two types of external, user-written functions
  1. Arithmetic functions: like `&A = AFunc(&V1, &V2, ...)`

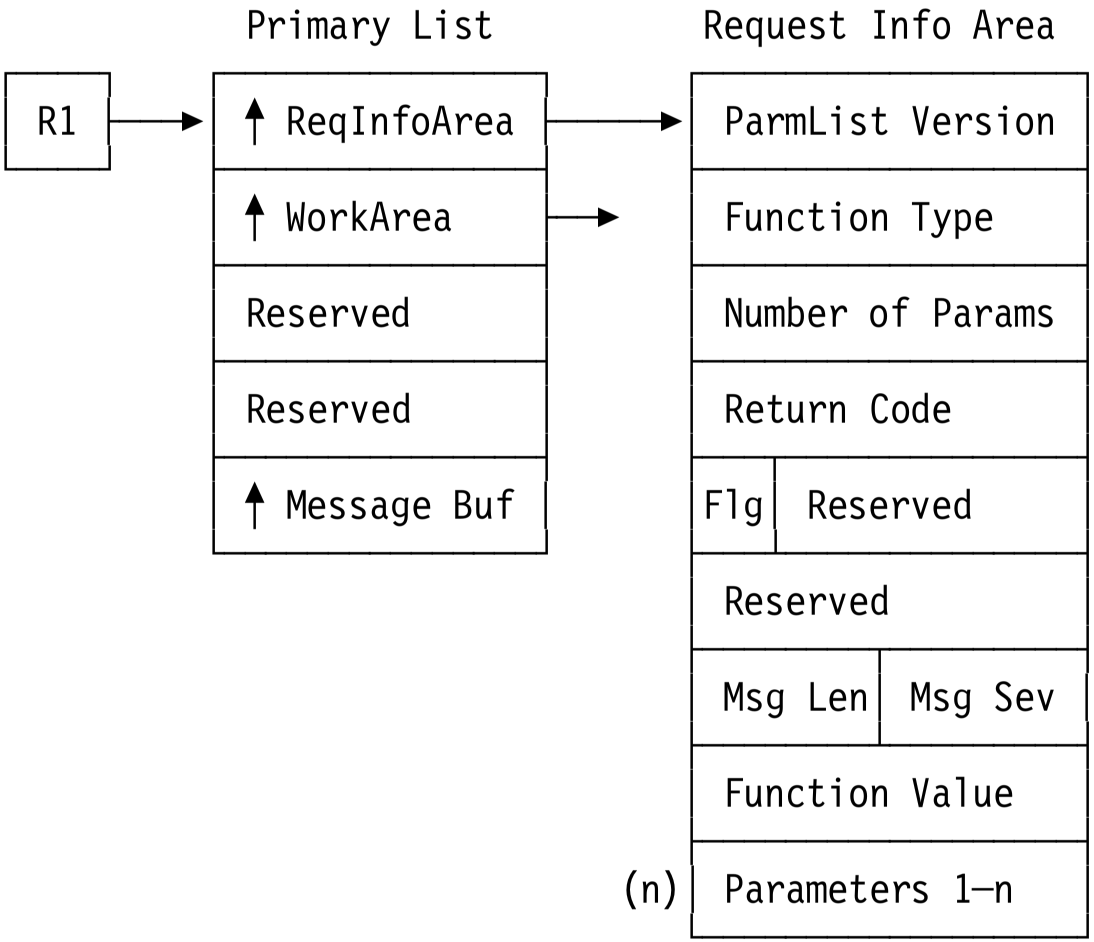
```
&A     SetAF  'AFunc',&V1,&V2,...      Arithmetic arguments
&LogN  SetAF  'Log2',&N                Logb(&N)
```

  2. Character functions: like `&C = CFunc('&S1', '&S2', ...)`

```
&C     SetCF  'CFunc','&S1','&S2',...  String arguments
&RevX  SetCF  'Reverse','&X'           Reverse(&X)
```

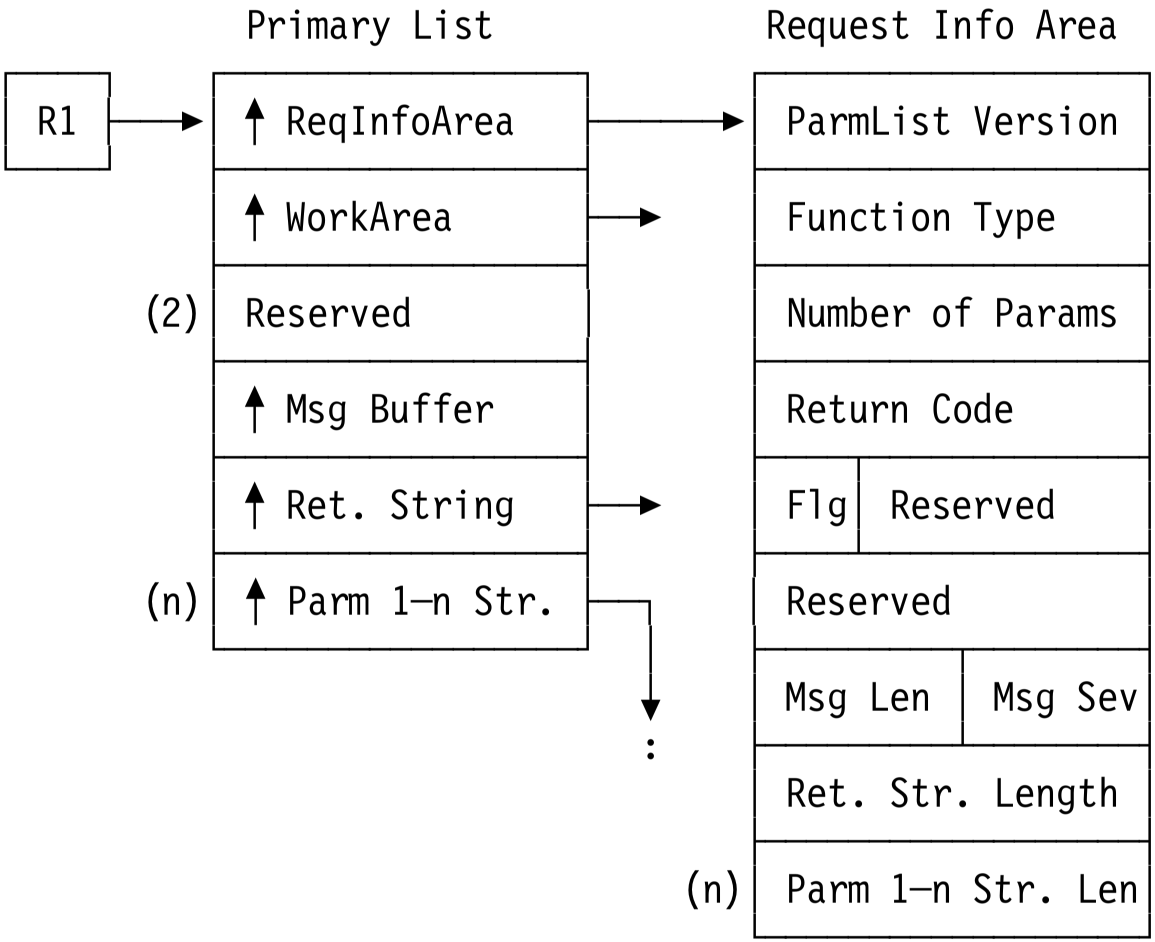
- Functions may have zero to many arguments
- Assembler's call uses standard linkage conventions
  - Assembler provides a save area and a 4-doubleword work area
- Functions may provide messages for the listing (as may I/O exits)
- Return code indicates success or failure
  - Failure return terminates the assembly

SETAF External Function Interface



- (n) means the field is repeated **n** times
- HLASM provides a 32-byte work area

SETCF External Function Interface



- (n) means the field is repeated **n** times
- HLASM provides a 32-byte work area

System Variable Symbols: History and Overview

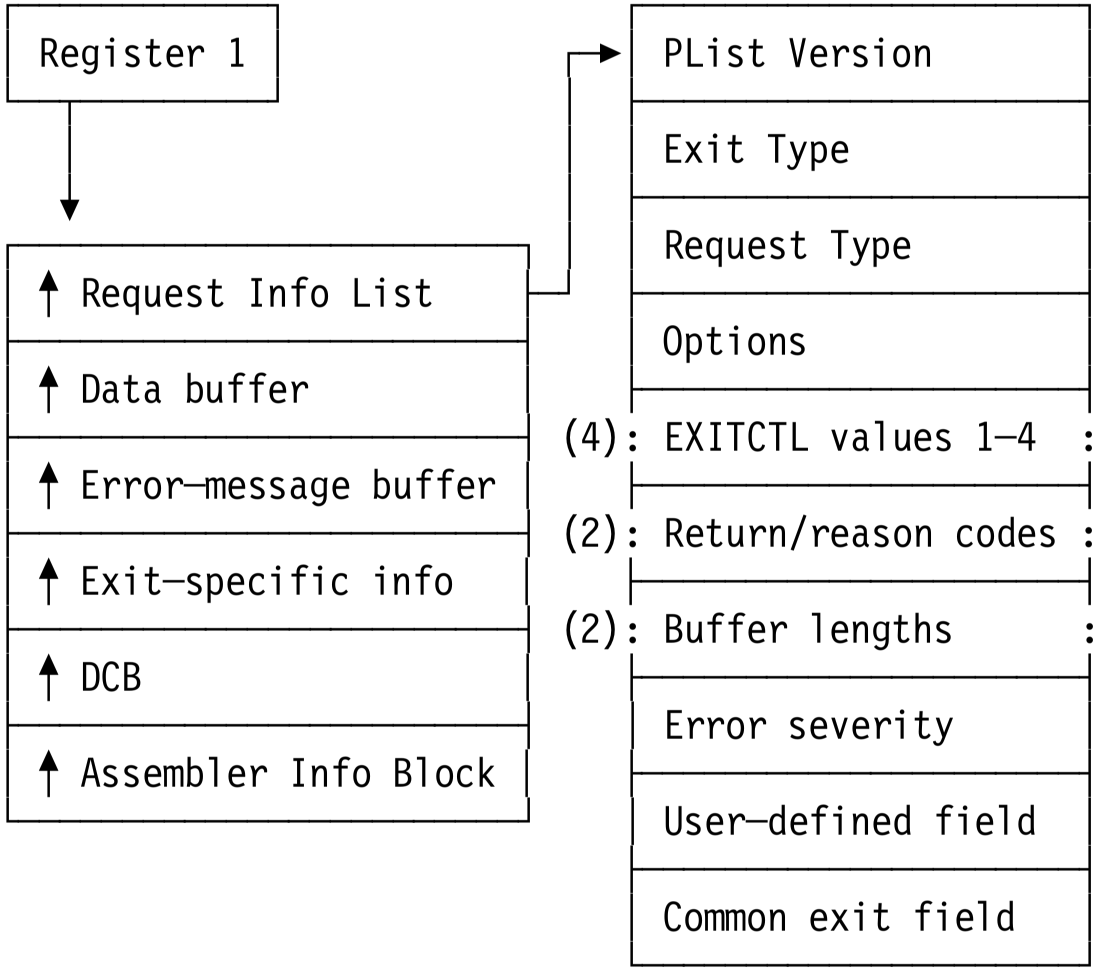
- Symbols whose value is defined by the assembler
  - Three in the OS/360 (1966) assemblers: `&SYSECT, &SYSLIST, &SYSNDX`
  - DOS/TOS Assembler (1968) added `&SYSPARM`
  - Assembler XF (1971) added `&SYSDATE, &SYSTIME`
  - Assembler H (1971) added `&SYSLOC`
  - High Level Assembler provides 39 additional symbols
- Symbol characteristics include
  - Type (arithmetic, boolean, or character)
  - Type attributes (mostly `'U'` or `'O'`)
  - Scope (usable in macros only, or in open code and macros)
  - Variability (when and where values might change)

Input-Output Exits

- HLASM supports powerful exit interfaces for all user files
  - SYSIN, SYSLIB, SYSPRINT, SYSPUNCH, SYSLIN, SYSTERM, SYSADATA
- Exits have as little or as much control as desired
  - Modify, insert, delete records
  - Monitor or assist assembler I/O, or replace it entirely
- Exits may produce diagnostic messages with each interaction
- Three sample exits provided:
  - Print (ASMAXPRT): options page deleted or moved to end of listing; summary page optionally deleted
  - Input (ASMAXINV): accepts V-format SYSIN records
  - ADATA (ASMAXADT): extracts/formats macro/COPY members and their library names
- `EXITCTL` statement provides source-file information to exits

Input-Output Exit Communication

- All assembler/exit communication via I/O Exit Parameter List
- Full control information
  - Control information
  - Data set information
  - Buffers, message area
  - Exit anchor word
- Assembler, exit are “coroutines”



Example Object-File Exit: OBJX

- Add Linkage Editor-Binder control statements after object modules
  - NAME and up to 32 ALIASes, optional SETSSI
    - BATCHed assemblies are properly separated by NAME statements
    - Can create multiple PDS members in two assembly-link steps

- Invoked by specifying EXIT option:

```
          EXIT(OBJEXIT(OBJX[(exit-parm)]))
or              EX(OBX(OBJX[(exit-parm)]))
```

- OBJX exit handles four one-character parameters in `exit-parm`

Q Do not write summary information messages
R Add (R) to NAME statements
S Provide SETSSI statements with YYDDDHHM date/time
T Provide tracing and debugging information