Binder for Beginners
Everything a z-OS Programmer Ever Wanted to Know about Binding but Was Afraid to Ask

Session 7692

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What is the binder?

• Wikipedia® under linker (computing): “In IBM mainframe environments such as OS/360 this program is known as a linkage editor.”

• In z/OS it is the program management binder
program management binder

- BCP exclusive base element
  - Wave 0

- z/OS system linker
- Related utilities
- Programming interfaces
program management binder ...

- The binder converts the output of language translators and compilers into an executable program unit ...
  - ... that can either be read directly into virtual storage for execution or stored

- The binder processes object modules, load modules and program objects...
  - link-editing or binding multiple modules into a single load module or program object
  - ... with contiguous virtual storage addresses
program management binder …

• Symbol resolution
  • all *external* symbol references which need to be satisfied
    • between all input parts

• Relocation
  • all modules combined, relocated relative to origin address
    • Zero (or start of segment)
  • final relocation is done by the loader
    • based on information created by the binder
symbol resolution

- In Section A there is a call (reference) to B which will be statically linked to A
- Location of B relative to the call in Section A is determined at bind time
- Final relocation of entire executable program module determined at load time
There is an External Symbol Dictionary (ESD) entry for the location of B
There is an Relocation Dictionary (RLD) entry for the location in A to write the location of B
What if B is unresolved?

Module A

<table>
<thead>
<tr>
<th>Section A</th>
<th>000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD</td>
<td>000000</td>
</tr>
<tr>
<td>reference to B</td>
<td></td>
</tr>
<tr>
<td>TXT</td>
<td>L R15,=A(B+10)</td>
</tr>
<tr>
<td></td>
<td>adcon for B+10 000000A</td>
</tr>
<tr>
<td>RLD</td>
<td>relocation for B</td>
</tr>
</tbody>
</table>

Module AB

<table>
<thead>
<tr>
<th>Section A</th>
<th>000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD</td>
<td>000020</td>
</tr>
<tr>
<td>reference to B</td>
<td></td>
</tr>
<tr>
<td>TXT</td>
<td>L R15,=A(B+10)</td>
</tr>
<tr>
<td></td>
<td>adcon for B+10 000020A</td>
</tr>
<tr>
<td>RLD</td>
<td>relocation for B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section C</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section B</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
</tr>
</tbody>
</table>
z/OS system linker

- Really not the linkage editor!
  - Application programming interface
  - ...

- PDSE, UNIX
  - program object format – PO (COMPAT(PMx))
  - exclusively binder
  - loaded by program management loader

- PDS
  - load module format
  - just like the linkage editor used to do
    - HEWLKED anybody?
  - loaded by program management loader (program fetch)
z/OS system linker…

- Really, *the* one and only!
  - Batch LINKEDIT, IEWL, etc.
  - TSO LINK, LOAD, LOADGO
  - c89 (c++), cob2, pli, xlc (xlC)
  - IEBCOPY
  - ZAP
  - AMBLIST
  - batch loader (HEWLD[I[A]])
    - binder does it too
      - IEWLOAD/IEWBLODI/IEWBLDGO
      - single segment only (more later!)
z/OS system linker ...

- control language
- object
- dynamic library
- static library

linker

dynamic library
program
side files

static library
text files (maps, etc)
error messages
binder inputs

• SYSLIN

  • object modules
    • OBJ, XOBJ, GOFF

  • program modules (executables)
    • load modules
    • program objects

• control statements
binder outputs

• **SYSPRINT**
  - Messages (IEW2nnnns) also **SYSTERM**
  - DDname cross-reference
  - Message Summary

• **LISTing** of processing information

• Module **MAP**
  - Includes Data Set Summary

• Cross(\textbf{X}) **REF**erence between symbol definitions and references
  - includes DLL IMPORT/EXPORT table
### Module Map

<table>
<thead>
<tr>
<th>CLASS</th>
<th>LENGTH</th>
<th>ATTRIBUTES</th>
<th>LOAD</th>
<th>RMODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CODE</td>
<td>160</td>
<td>CAT, LOAD, RMODE=ANY</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OFFSET</td>
<td>0 IN SEGMENT 001</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ALIGN</td>
<td>DBLWORD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Section Class Map

<table>
<thead>
<tr>
<th>OFFSET</th>
<th>NAME</th>
<th>TYPE</th>
<th>LENGTH</th>
<th>DDNAME</th>
<th>SEQ</th>
<th>MEMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>7C</td>
<td>CEESTART</td>
<td>CSECT</td>
<td>7C</td>
<td>/0000001</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>this_is_a-g_name</td>
<td>CSECT</td>
<td>E0</td>
<td>/0000001</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>this_is_a-g_name</td>
<td>LABEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>main</td>
<td>LABEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CLASS binding attribute
CLASS loading behavior
Offset of LABEL main within section CSECT
Offset of LABEL main within CLASS C_CODE
MAP ...

*** MODULE MAP ***

CLASS C_WSA

LENGTH = 24
ATTRIBUTES = MRG, DEFER, RMODE=ANY
OFFSET = 0 IN SEGMENT 002
ALIGN = DBLWORD

CLASS binding attribute

CLASS loading behavior

binder made-up name for "private" symbol

CLASS binding

attribute

SEGMENT containing

CLASS

CLASS name
and attributes

Offset of PART world within
CLASS C_WSA

binder made-up name for "private" symbol

CLASS name
and attributes

Offset of PART world within
CLASS C_WSA

binder made-up name for "private" symbol

CLASS name
and attributes

Offset of PART world within
CLASS C_WSA

binder made-up name for "private" symbol

CLASS name
and attributes

Offset of PART world within
CLASS C_WSA
### Cross-Reference Table

<table>
<thead>
<tr>
<th>Class</th>
<th>Element</th>
<th>Reference</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CLASS C_CODE</td>
<td></td>
</tr>
<tr>
<td>2C CEESTART</td>
<td>V-CON</td>
<td>CEEMAIN</td>
<td>0 C_DATA</td>
</tr>
<tr>
<td>68 CEESTART</td>
<td>V-CON</td>
<td>CEEFMAIN</td>
<td>$UNRESOLVED</td>
</tr>
<tr>
<td>6C CEESTART</td>
<td>V-CON</td>
<td>CEEBLST</td>
<td>0 B_TEXT</td>
</tr>
<tr>
<td>74 CEESTART</td>
<td>V-CON</td>
<td>CEEBETBL</td>
<td>0 B_TEXT</td>
</tr>
<tr>
<td>78 CEESTART</td>
<td>V-CON</td>
<td>CEEROOTD</td>
<td>0 B_TEXT</td>
</tr>
<tr>
<td>14C this_is_a-g_name</td>
<td>A-CON</td>
<td>CEESTART</td>
<td>0 C_CODE</td>
</tr>
</tbody>
</table>

We can see that section CEESTART begins CLASS C_CODE.

All address constants in section CEESTART in CLASS C_CODE.

Location to which adcons in section CEESTART have resolved.
Symbol `world` is a part... we know from the Module MAP...

Adcon at X’1C’ in section `hw#S` refers to IMPORTED symbol `printf`. Location of `printf` not known until run-time.

<table>
<thead>
<tr>
<th>CLASS OFFSET SECT/PART (ABBREV)</th>
<th>ELEMENT OFFSET TYPE</th>
<th>SYMBOL (ABBREV)</th>
<th>SECTION (ABBREV)</th>
<th>ELEMENT OFFSET CLASS NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 hw#S</td>
<td>10 A-CON</td>
<td><code>world</code></td>
<td>$PRIV000003</td>
<td>20 C_WSA</td>
</tr>
<tr>
<td>18 hw#S</td>
<td>18 R-CON</td>
<td><code>printf</code></td>
<td></td>
<td>20 B_IMPEXP</td>
</tr>
<tr>
<td>1C hw#S</td>
<td>1C V-CON</td>
<td><code>printf</code></td>
<td></td>
<td>8 B_TEXT</td>
</tr>
<tr>
<td>20 world</td>
<td>20 A-CON</td>
<td><code>this_is_a-g_name</code></td>
<td>this_is_a-g_name</td>
<td></td>
</tr>
<tr>
<td>18 hw#S</td>
<td>18 A-CON</td>
<td><code>this_is_a-g_name</code></td>
<td>this_is_a-g_name</td>
<td></td>
</tr>
<tr>
<td>1C hw#S</td>
<td>1C V-CON</td>
<td><code>CEETHLOC</code></td>
<td>CEETLOCE</td>
<td></td>
</tr>
</tbody>
</table>
binder outputs …

• SYSPRINT extras; requires MAP or XREF

• Renamed symbol cross-reference
  • Usually only for special predefined list of C symbol names
  • Also RENAME control statement

• Long symbol abbreviation table
• Short Mangled Name report

• Symbol References Not Associated with any AdCon
  • “Dangling” External References
  • Also produced with LIST
  • Headings there even if empty
  • Due to external reference ESD entry from object module
all about AUTOCALL

- SYSLIB ddbname
- AUTOCALL control statements
- LIBRARY control statements

- PDSs and PDSEs
  - “C370LIB” Object Libraries
- UNIX archive files

- Traditionally
  - The unresolved symbol name is searched for as the member name
    - The expectation is that the member, if found, will contain the symbol

- Object Libraries and UNIX archives extend this
  - They have their own directories of defined symbol names
all about AUTOCALL …

- CALL (default) or NCAL
  - CALL=YES or NOCALL or CALL=NO

- SYSLIB ddname
  - Concatenation of data sets
    - All kinds – object modules, load modules, program objects
  - Searched for only after reading all SYSLIN input
all about AUTOCALL …

• AUTOCALL
  • UNIX “incremental”
  • Use this library right now
  • Then, forget about it!

• LIBRARY
  • Qualified with member/symbol for:
    • additional CALL (like INCLUDE but only if unresolved)
    • restricted NO-CALL
    • NEVER-CALL
  • Unqualified support added for UNIX final autocall
    • couldn’t do it with SYSLIB concatenation
    • Searched in order just before SYSLIB
load module vs. program object

Load Module

Program Object

Loaded Text

CSECT A
CSECT B
CSECT C

Unloaded Data

SYM data
IDR data
RLD data
ESD data

Class X

Section A

Element

Element

Part

Class Y1

Section B

Element

Element

Part

Class Y2

Section C

Element

Element

Part

Class Z
load module vs. program object …

• Load modules
  • Single-dimensional
  • Documented format
  • Format never to be (substantially) be changed

• Program objects
  • Multi-dimensional
    • Class vs. section
  • Format never to be documented
    • Changes regularly – COMPAT(PMnn) levels and zOSVnRn sublevels
      • Currently 8 levels and sublevels
other interesting / useful stuff

• Options for even more SYSPRINT!

  • **INFO** about service level of binder
  • **MSGLEVEL** of lowest severity messages to write
    • Default is all (0)
    • Suppresses text, no change to return code!
  • **LISTPRIV** for a listing of “private code” sections
    • and if so make it an error (YES)
    • or just informational (INFORM)
  • **STRIPSEC/STRIPCL** to remove and list “unneeded” stuff
    • To see the “removed” report requires **MAP** option
other interesting & useful stuff …

• **OPTIONS** = *ddname*

  • primarily invented to overcome JCL limitations…
    • typically in-stream data set
  
  • but can be convenient for example to have files of options common to a set of JCL
    • *making it easy to update options without changing JCL etc.*
other interesting & useful stuff …

- COMPRESSion=YES
  - Can significantly shrink size of program object on disk
  - **No Change** to size of in-storage program!
    - No Change to the program itself (loader / run-time data), only binder owned data
  - Distinguished in Save Module Attributes (LIST output):
    - MODULE SIZE (HEX)  00002BFC
    - DASD SIZE (HEX)    0000D000 (this had been 00015000)

- Requires COMPAT(ZOSV1R7)
  - AUTOMATICALLY happens, if beneficial, with this COMPAT level
    - default is COMPAT(CURRENT)
    - will still execute back to ZOSV1R3
      - but no rebind, AMBLIST, ZAP, etc.

- EDIT=NO
  - PERMANENTLY deletes the data that COMPRESS would have compressed
  - So no rebind, AMBLIST, ZAP, etc. anywhere
    - MODULE SIZE (HEX)  00002BFC
    - DASD SIZE (HEX)    00005000
other interesting & useful stuff …

• DLL – Dynamic Link Library
  • DYNAM=DLL
    • exported symbols to SYSDEFSD as IMPORT control statements
    • Control information (visible in MAP and AMBLIST output, macros in ‘SYS1.MACLIB’)
      •IEWBLIT section B_LIT class – Loader Information Table
      •IEWBCIE section B_IMPEXP class – Import/Export table
  • Language Environment high-level languages and High Level Assembler (LE provides macro)
  • Execution requires Language Environment run-time support
    • Function “descriptors” enable dynamic linking
  • Exploits deferred load C_WSA[64] class
    • Writable / Static Area
    • LE controls unique instance for each “enclave” of execution
  • Dynamic resolution follows all static resolution
other interesting & useful stuff …

- Program Signing (introduced in z/OS V1R11)
  - SIGN=YES
  - Digital signature is written into program object
    - Constructed based on program data
    - Becomes part of program
    - PDSEs supported only!
  - Requires SAF/RACF setup & services
    - Require keyring or PKCS #11 token to sign
    - Program must be identified as requiring digital signature for execution
      - … loader verifies correct digital signature prior to execution
  - Cannot use traditional (SMP/E) service methodology since only signer can bind
    - Could use EDIT=NO
common problems & helpful tips

• Mixed-case input

IEW2456E 9207 SYMBOL myfunc UNRESOLVED. MEMBER COULD NOT BE INCLUDED FROM THE DESIGNATED CALL LIBRARY.

• Traditional names (from OBJ) are uppercase
  • Compatibility dictates the default CASE=UPPER

• Affects options values and control statement symbols
  • Option names and control statement keywords are case insensitive
    • INCLUDE, include, Include

• Most often an issue for IMPORT control statements (DLLs)

• Recommendations
  • CASE=MIXED
    • Import Code,a.dll,myFunc
    • ‘quote_name’
      • INCLUDE ‘/u/barryl/C/hello.o’
      • include PDSELIB(‘hello’)
common problems & helpful tips …

• Long symbol names

  • Member names (at least in PDSs) are 8 characters

  • Problem introduced when building the object modules…
    • C/C++ LONGNAME option required

  • … or when creating the (object) libraries
    • UNIX archive libraries manage their own internal directory
    • data set based (“C370LIB”) Object Libraries have a special directory member
      • @@DC370$, @@DC390$
common problems & helpful tips …

• Long symbol names …

IEW2459W 9206 INCLUDED MEMBER s1 FAILED TO RESOLVE REFERENCE.

IEW2497W 9229 THE SYMBOL s1 WAS EXPECTED TO BE RESOLVED BY INCLUDING MEMBER SUB3 FROM THE LIBRARY DEFINED BY DDNAME C8961

• Worst case scenario!

  • Replacement object module incorrectly built (perhaps NOLONGNAME)
  • Directory member was previous built and not updated

• IEW2497W is new for R12

• Module already included, may resolve other symbols!
common problems & helpful tips …

• Unresolved but it’s there?

  • DYNAM=DLL may be required!

    • If “definition” is on IMPORT statement

      • *Otherwise binder processes IMPORTs but silently ignores them*
common problems & helpful tips …

• Where did *that* come from?
  • Modules brought in by autocall
  • Turning on LIST=ALL
  • New in R12

IEW2340I 1036 MEMBER NAME CEEROOTD IN THE LIBRARY DEFINED BY DDNAME SYSLIB IS BEING INCLUDED TO RESOLVE REFERENCE TO CEEROOTD

IEW2308I 1112 SECTION CEEROOTA HAS BEEN MERGED.

• Especially for archives & C370LIBs
common problems & helpful tips …

• for situations where options cannot otherwise be passed
  • particularly API based program

  •IEWPARMS
    • like OPTIONS

  •IEWDIAG
    • like SYSTERM with LIST=ALL, MSGLEVEL=0
common problems & helpful tips …

- **AMBLIST**
  - LISTOBJ – all object modules
  - LISTIDR – all identification records; user IDENTIFY, language, binder, zap (EDIT=YES required)
  - LISTLOAD – all program modules (EDIT=YES required!)
    - Like binder MAP and XREF and more!
    - PMAR (partially) decoded and (fully) dumped
    - MODLIST
      - *Section / Class information …*
      - … *including TEXT*
        - Merge class part initializers decoded
        - IEWBCIE / B.IMPEXP decoded
    - MAP
      - SEGMENT map
      - Numerical MAP
    - XREF
      - SEGMENT map
      - Numerical MAP and XREF
      - Alphabetical MAP and XREF
  - New in R12 – AMBLIST LISTLOAD ebcdic translation for load modules
more advanced stuff!

- **IEWTRACE ddname – TRACE option**
  - binder internal trace table
  - shows function entry / exit and other key processing points
  - shows ECODEs (part of which is 4 character code after message number)
  - can filter entries with TRACE=(start,end) or selectively TRACE='c[c…]'

- **IEWDUMP – DUMP option**
  - if allocated, automatically written upon terminal binder error or program check or abend
  - can be forced with DUMP option specifying ecode
    - binder continues processing for non-terminating condition
  - binder takes SNAP of binder storage and then formats key internal structures

- **note:** these diagnostics are normally used only for IBM problem determination
- limited information provided in program management documentation
more advanced stuff! …

- User exits – EXIT option
  - provide module exit name
  - MESSAGE
    - filter all messages of specified severity or higher
    - prevent or allow the message to print
    - no effect on final return code of binder
  - SAVE
    - notification of each primary (member) name and alias name to be saved
    - request retry for certain failures
  - INTFVAL (Interface Validation)
    - after all input processing, including autocall
    - examine all references (resolved and unresolved) for each section
    - can allow unresolved, can change resolution to another symbol or glue
    - default exit can result in error if target & reference disagree in
      1. ESD signature fields
      2. XPLINK attributes
      3. AMODE(64) mismatch
      4. Namespaces (like code (instructions) vs. data)
      5. Certain class attributes (like catenate vs. merge)
more advanced stuff! …

- Application Programming Interfaces (APIs)
  - data is input or output via buffers unique to each type of data
    - for example, ESDs
    - IEWBUFF macro can simplify creating buffers
      - allocate, initialize, map and delete buffers
      - not required
  - regular binder APIs
    - IEWBIND macro
      - not required
  - fast data access
    - for program objects only
      - faster due to direct access, bypass workmod conversion
    - request code interface
      - obsoleted IEWBFDA macro “unitary” interface
  - C APIs
    - NOXPLINK and XPLINK (new in R12!)
    - buffers in a header, C language oriented structures
    - simplifies access by automatically managing buffers for you
    - both regular API and fasta data access functions provided
program management documentation

- SA22-7643 - z/OS MVS Program Management: User’s Guide and Reference
  for options & control statements

- SA22-7644 - z/OS MVS Program Management: Advanced Facilities
  for binder APIs

- GA22-7589 - z/OS MVS Diagnosis: Tools and Service Aids
  for AMBLIST and SPZAP

- SA22-7782 - z/OS TSO/E Command Reference
  for LINK and LOADGO

- SA22-7802 - z/OS UNIX System Services Command Reference
  for c89 and ld