

**The DFSMS/MVS Binder and Its
“Program Object” Format:
What The New Program Model
Will Mean to You**

SHARE 96 (Feb. 2001), Session 8170

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March 1, 2001

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Note: This is NOT a tutorial on Binder usage!

1. The DFSMS/MVS Binder and Program Loader
 - Replacing the Linkage Editor and Batch Loader
2. Review of old object and load modules
3. New executable-module structures: Program Objects
 - All about Sections, Classes, Elements, and Parts
 - How Program Objects are like and unlike Load Modules
4. Compatibility with old Object and Load Modules
5. New treatments of familiar binding techniques
6. The Generalized Object File Format
7. Dynamic Link Library support
8. Glossary and References

The Binder and Program Loader: Overview

Some useful abbreviations...

PM	Program Management
LM	Load Module
PO	Program Object
OM	Object Module (Traditional Format)
GOFF	Generalized Object File Format

PM1 DFSMS/MVS V1R1: “Modern” program management

- New Binder and Program Loader
- Support for PDSE libraries
- Linkage Editor compatibility support

PM1.1 DFSMS/MVS V1R2: Support for HFS

PM2 DFSMS/MVS V1R3:

- Enhanced PO structure
- Split-RMODE modules, distributed loading
- GOFF/ADATA support
- Fast-path data retrieval API

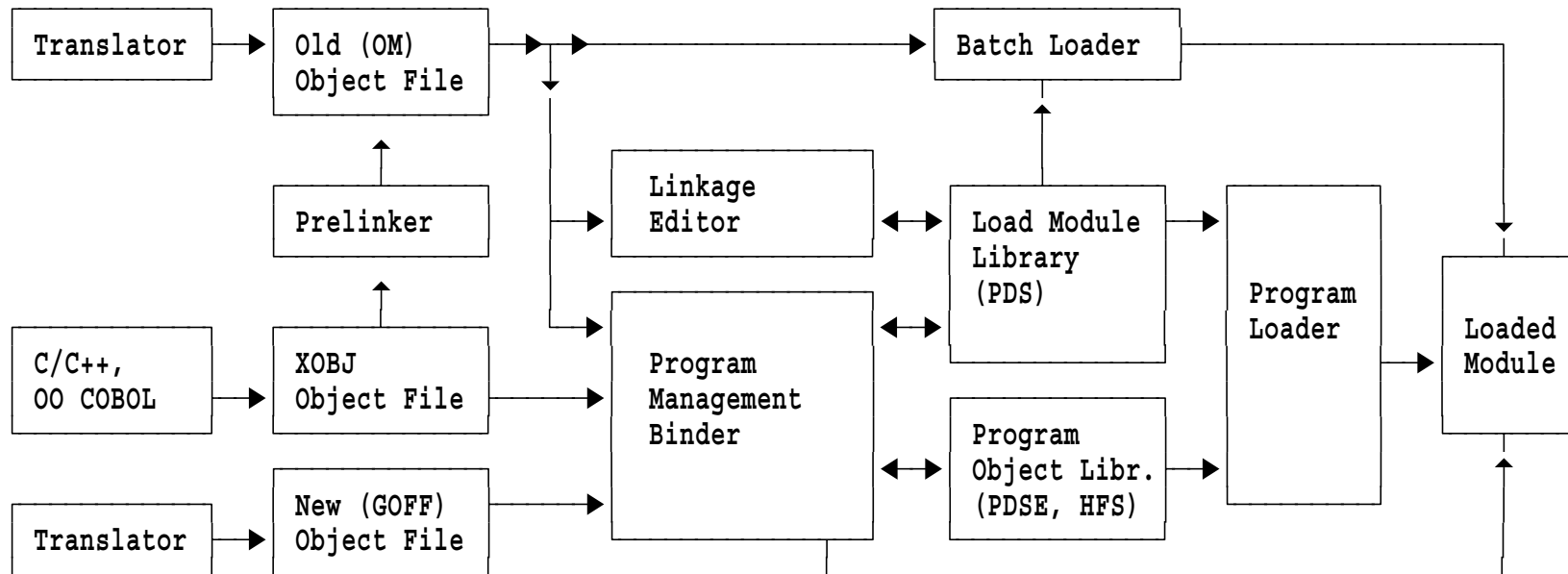
PM3 DFSMS/MVS V1R4: some items require OS/390 V2R4, LE 1.8

- Binder includes C/C++ Prelinker functions, new options, control statements
- Support for DLLs (including HFS, Archive files)
- Dynamic Linklib and Dynamic LPA support for PDSEs

PM3.1 OS/390 V2 R10: XPLINK support

- Mangled/demangled names table, external-symbol and HFS-file attributes

- Totally new product and new technology
 - **Binder** replaces Linkage Editor, Batch Loader;
Program Loader (PMLoader) extends and generalizes Program Fetch
 - Requires OS/390 and DFSMS/MVS
- Answers a large set of customer requirements, including a vast array of usability and performance problems
 - Many new options, messages, added information, detailed diagnostics
 - Almost all internal constraints and “Table Overflow” conditions eliminated
- Creates **Program Objects** (a new form of “executable”)
 - Supports long names, multiple text classes, new adcon types, and much more!
 - “Linear” format permits efficient “DIV” mapping directly to virtual storage
 - Stored in PDSE's (which fix almost all PDS problems: space, integrity, compression, performance, shareability, etc.), or in HFS
- Base for all future enhancements
 - Linkage Editor and Batch Loader are “Functionally Stabilized”



Note: Arrowheads indicate direction of data flow.
 ↔ means a component can be produced as output or read as input.

- LMs reside only in PDSs; POs reside only in PDSEs or HFS files
- Can mix OM and GOFF to produce PO or LM (LM restricts features)
 - “Source→ OM→ LKED→ LM” equivalent to “Source→ GOFF→ Binder→ LM”
- Can bind PO and LM to produce either (LM restricts features)

- External and module-alias names to 1024 bytes
 - Character set X'41'-X'FE', plus SI/SO; optional case sensitivity
 - Long names OK for autocall, control statements, APIs, all resolutions
- POs support multiple text classes, total text length up to 1GB
 - “Split-RMode” modules allow separation of code/data text blocks by RMode
 - Uniform treatment of Associated Data (“ADATA”), other non-loaded classes
- Supports new **Generalized Object File Format**, OM, and XOBJ
 - **GOFF**: produced by C/C++ and High Level Assembler; defined by Binder
 - **OM**: traditional Object Module
 - **XOBJ**: produced by C/C++, OO-COBOL; extension of OM
 - Binder converts XOBJ internally to GOFF format; output of bind must be a PO
- Extended support for OS/390 Unix System Services

- Prelinker elimination enhances usability, efficiency
 - Rebindable output: no need to relink from object
 - Simpler service: can ship only the necessary object files
- Integrated processing for specialized C/C++ features
 - C370LIB, HFS archive files for autocall resolution
 - Prelinker control statements, renaming, new classes, mangled names, etc.
 - LE runtime routines load (non-reentrant) Writable Static Area (WSA)
- Dynamic Link Libraries (DLLs) (more at slides 52-55)
 - New functions in Binder, Program Loader, LE, Contents Supervision
 - Defer linking/loading to run-time decisions
- Binder Interface Exit
 - Allows modifying existing resolutions, renaming, forcing new autocall search

-
- POs *mapped* into virtual storage (except from HFS files)
 - Page-fault loading (“page mode”) or pre-loaded (“move mode”)
 - Page mode (default):
 - Mapped into virtual storage using Data In Virtual (DIV)
 - Entire module mapped if shorter than 96K bytes, or if bind option FETCHOPT=PRIME was specified
 - Otherwise, segments (up to 64K each) mapped as referenced
 - Move mode:
 - Preloads and maps entire module in intermediate storage, then moves to destination
 - Accommodates directed loads, “packed” modules, overlay, V=R
 - Can load/delete “deferred-load” classes on request
 - POs (including DLLs and deferred-load classes) can be staged in LLA
 - PDSEs, POs, DLLs support and exploit “Dynamic LPA”

- Binder API eliminates need to understand Program Object format
 - Allows format changes for new hardware and software technology
 - Three different PO formats have already been used!
 - Old PO formats loadable by current and future versions of PMLoader
 - Future format enhancements will be transparent to users
- API supports input and retrieval of all PO data
 - All PO data available (including user data, “ADATA”)
 - “FastData” API for read-only access to PO data
- PM supports “transportable” format for Program Objects
 - Recommend using IEBCOPY to move POs among MVS data sets!
 - IEWTPORT service creates format resembling buffers of text, RLDs, IDRs, CESDs, etc. accessed using the Binder Interface
 - Output usable for reconstructing Program Objects
 - Use is now deprecated

**A Brief Review of Old Object
and Load Modules**

- Control Section (**CSECT**)
 - The basic indivisible unit of linking and text manipulation
 - A collection of program elements bearing *fixed* positional relationships to one another; its addressing and/or placement relative to other Control Sections does not affect the program's run-time logic
 - Ordinary (**CSECT**) and Read-Only (**RSECT**) have machine language text; Common (**COM**) and Dummy (**DSECT**) have no text
- External Symbol (“public”; internal symbols are “private”)
 - A name known at program linking time, whose value is intentionally not resolved at translation time
- PseudoRegister (or, External Dummy Section)
 - A special type of external symbol whose value is resolved at link time to an *offset* in an area (the “PRVector”) to be instantiated during execution
- Address Constant (“Adcon”)
 - A field within a Control Section into which a value (typically, an address) will be placed during program binding, relocation, and/or loading

- Five types of (card-image) records:

ESD External Symbol Dictionary (C/C++ generates a variant, **XSD**)

TXT Machine Language instructions and data (“Text”)

RLD Relocation Dictionary (for address constants)

SYM Internal Symbols

END End of Object Module, with **IDR** (Identification Record) data

- At least one control section per object module
- “Batched” translations may produce multiple object modules
- For the fascinating details, see:

High Level Assembler for MVS & VM & VSE *Programmer's Guide*, SC26-4941

OS/390 DFSMS Program Management, SC27-0806

- Describes four basic types of **external symbols**:

SD,CM Section Definition: the name of a control section
(Blank-named control section called “Private Code,” **PC**)

LD Label Definition: the name of a position at a fixed offset
within a Control Section; typically, an Entry Point

ER,WX External Reference: the name of a symbol defined
“elsewhere” to which this module wants to refer
(**WX** = “Weak External”; not a problem if it's unresolved)

PR PseudoRegister: the name of a PseudoRegister
(The Assembler calls it an “External Dummy Section,” **XD**)

PR names are in a separate “name space” from all other
external symbols, and may match non-PR names without
conflict.

- Two external symbol scopes: library (SD, LD, ER); module (PR, WX)

- Four external symbol types:

SD Section Definition: owns LDs

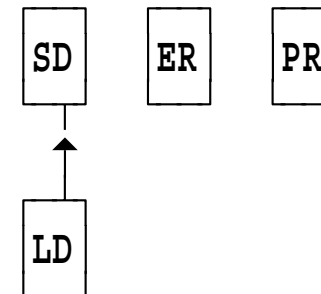
LD Label Definition: entry point within an SD

ER External Reference

PR/XD Pseudo-Register/External Dummy: this section's view of (contribution to) the PRV

- Lack of ownership of ER and PR items can cause problems when relinking
- We will contrast this with the new (at slide 25)

Old External Name Ownership Hierarchy



- A program with each symbol type:

```

Sect_A  Start 0          (SD)
        DC    5D'0.1'
        Entry A_Entry  (LD)
A_Entry DC    Q(My_XD)

        Extrn External (ER)
        Wxtrn Weak_Ext (WX)
MyCom   COM    ,        (CM)
        DS    12D

My_XD   DXD    3D       (XD)

Sect_B  CSect          (SD)
        DC    7D'1.0'

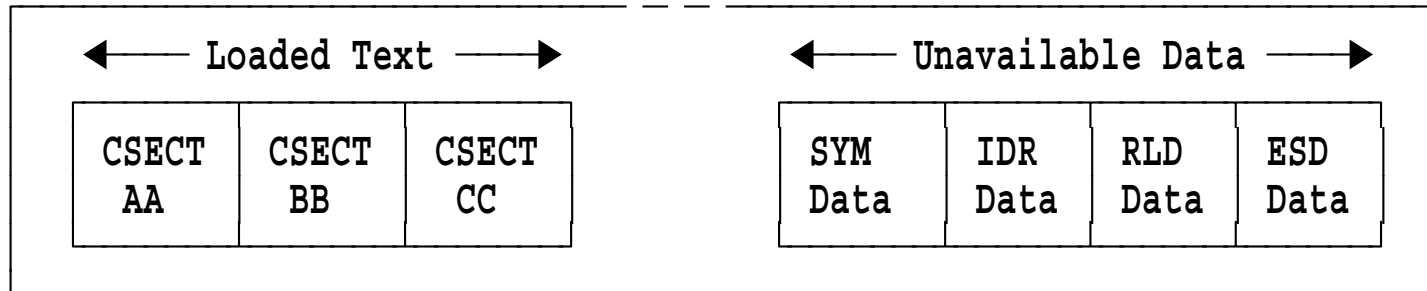
        CSect ,        (PC)
        DC    A(MyCom)
        End   Sect_A
    
```

- External Symbol Dictionary:

Symbol	Type	Id	Address	Length	LD ID
SECT_A	SD	00000001	00000000	0000002C	
A_ENTRY	LD		00000028		00000001
EXTERNAL	ER	00000002			
WEAK_EXT	WX	00000003			
MYCOM	CM	00000004	00000000	00000060	
MY_XD	XD	00000005	00000007	00000018	
SECT_B	SD	00000006	00000030	00000038	
	PC	00000007	00000068	00000004	

- A_ENTRY is in SECT_A (LD ID = 1), at offset X'28'
- Private Code has blank section name

- Load modules have a **one**-dimensional “block format” structure:



- All loaded text has a **single** set of attributes
 - One RMODE, one AMODE; entire module is R/W or R/O (“RENT”)
 - All text is loaded relative to a single relocation base address
 - Effectively, a **single-component** module
- Other module data not accessible via “normal” services

**New Executable Structures:
Program Objects**

- Some new terms are introduced, some old terms are used differently
 - No “Control Sections” in a PO (CSECTs are mapped to **elements**)
- **Section**: a “handle” (*neither a CSECT name nor an external name*)
 - Used in control statements to manage Binder actions
- **Class**: attributes are important; name is rarely referenced
- **Element**: indivisible unit of text (analogous to an OM CSECT)
- **Part**: Commons and PseudoRegisters (and initializing text)
 - Translator-defined **Part Views** (PVs) are bound into Program Object **Part Definitions**
- Five ESD symbol types: SD, ED, PV (or PR), LD, ER (see slide 25)
 - Compared to OM's four: SD different; ED new; PR generalized; LD, ER same (see slide 14)
 - Four external symbol scopes: section, module, library, import-export
- Two **binding attributes** and **binding methods**: CAT and MRG
 - Linkage Editor used both, but less rigorously (details at slide 32)

- Most easily visualized as a two-dimensional structure:

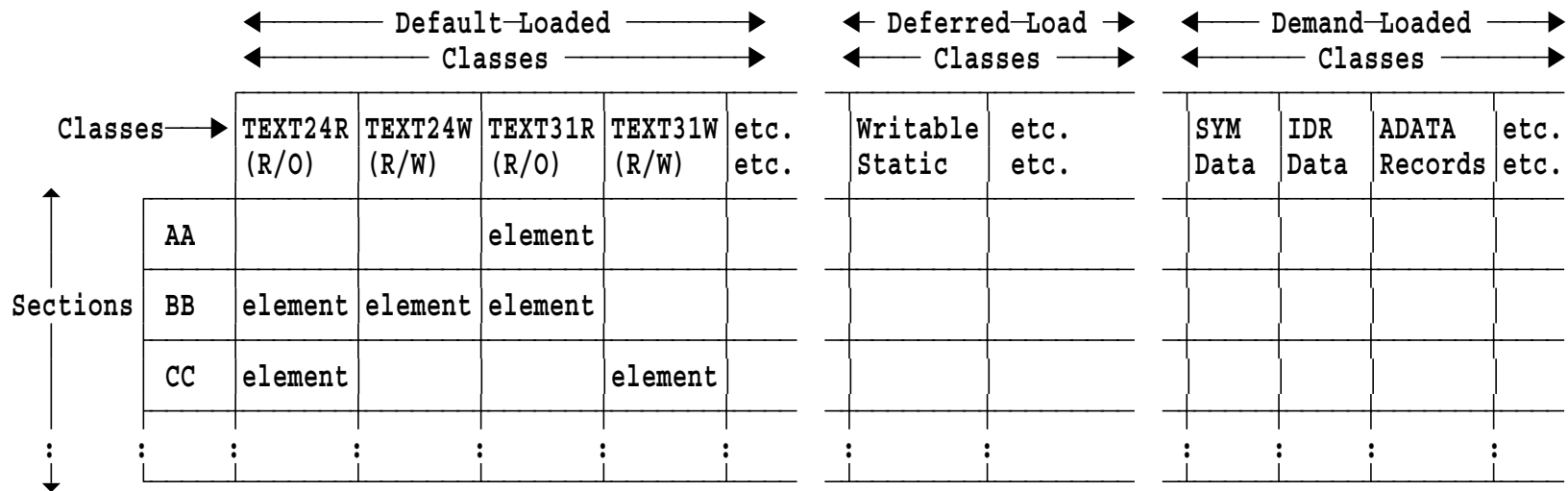
	Class X	Class Y	Class Z
Section A	Element	Element	Element
Section B	Element	Element	Element

- One dimension is determined by a **section name**
 - Analogous to OM Control Section name (but not the same!)
- Second dimension is determined by a **class name**
 - Analogous to a loadable module's name (but not the same!)
 - Attributes (e.g. RMODE) assigned to each class (see slide 22)
- The unit defined by a section name and a class name is an **element**
 - Viewable as the “intersection” of a section and a class

-
- A ***section*** is the program unit manipulated (replaced, deleted, ordered, or aligned) by user control statements during binding
 - Operations on a section apply to all elements within the section
 - Including rejection!
 - Each ***section*** may supply contributions to one or more ***classes***
 - According to their desired binding and loading characteristics
 - Assembler Language example (slide 50) illustrates this
 - Section names must be unique within a Program Object
 - As for Load Modules
 - **Note:** Section names are not external names or implied labels
 - Not used to resolve external references
 - Label Definitions (LDs) within elements are used to identify positions in text
 - Binder-created sections “own” module-level data
 - E.g. class maps, SYM data, module-level ADATA, Part Views
 - User code should avoid section names starting with **IEWB..!**

-
- Each class has uniform loading/binding characteristics and behavior
 - All section contributions to each class are bound together in a ***segment***
 - More than one class may have identical attributes (e.g., RMODE(31))
 - Binder may put classes with identical attributes into one segment (class offsets may be different from segment offsets)
 - Class loading characteristics determine the load-time placement of the segments in virtual storage
 - Loadable segments are loaded as separately relocated non-contiguous entities
 - Not all segments are normally loadable (e.g. IDR)
 - POs may have multiple class segments (each analogous to a Load Module!)
 - Class names (max. 14 characters) are purely mnemonic, and are rarely externalized
 - Naming conventions required for class sharing, and to avoid class-name collisions among independent compilation units
 - Names of the form `letter_symbol` are reserved!
 - Example: names like `C_xxx` reserved to compilers, `B_xxx` to Binder
 - `B_MAP` describes names and contents of each class
 - `B_ESD` contains external names
 - `B_IMPEXP` contains imported/exported external names (for DLL support)

- Separate attributes may be assigned to each class, such as:
 - **RMODE**: indicates placement in virtual storage of a loaded segment
 - Loadability
 - **LOAD**: The class is brought into memory when the program is initially loaded
 - Same as Load Module's usual behavior
 - **NOLOAD**: The class is not loaded with the program; may not contain adcons
 - Non-text classes are always NOLOAD; application loads via Binder API
 - **DEFERRED LOAD**: The class is prepared for loading, instantiated when requested
 - Useful for byte-stream data such as pre-initialized private writable static data areas in shared (re-entrant) programs
 - Text type: **Byte-stream** (machine language) or **Record-like** (IDR, ADATA)
- Other attributes are accepted by the Binder for future use:
 - Read-only/Read-write; Movable/Nonmovable; Shareable/Nonshareable

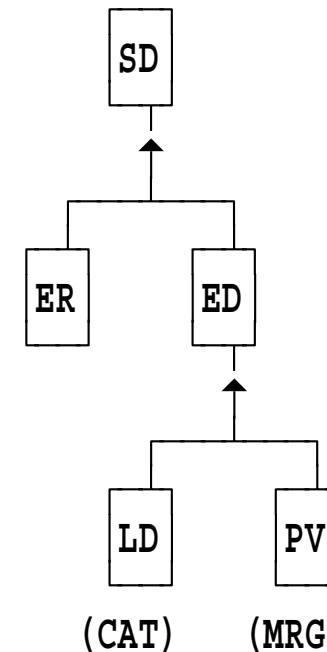


- New concept: separately relocatable **classes** of module data
 - All elements in each class have identical behavioral attributes (e.g., RMODE)
 - Each loaded class segment has its own relocation origin
 - Effectively, a *multi-component* (multi-LM?) module! (compare slide 16)
- Demand-loaded (NOLOAD) classes accessible via Binder services
- Deferred-load classes require special Program Loader interface

- Integrated support for any type of program-related data
 - IDR data, translator's "Associated Data" (ADATA), user data
- PO keeps module-related and user data together in one place
 - Source statements (possibly encoded), source-file information, etc.
 - Internal symbols, debugging breakpoint tables, NLS messages, etc.
 - User information, history data, documentation, instructions, etc.
- Application requests data via Binder's "FASTDATA" API
 - Delivers what was "Unavailable Data" in Load Modules
- Allows problem determination and debugging "in place"
 - Helps tools locate bugs when and where they happen
- Reduces need for complex configuration management tools
 - Module-specific items (source, object, listings, executables) need not be tracked separately

- Five external symbol types:
 - SD** Section Definition; owns other types
 - ED** Element Definition: defines the class to which this element (and its text, parts, and/or labels) belongs; owned by an SD
 - LD** Label Definition: entry point within an element; owned by an ED; only in a CAT class
 - PV** Part View: this section's view of (contribution to) a part within a class; owned by an ED; only in a MRG class
 - ER** External Reference: owned by an SD
- Strict ownership rules prevent orphaned symbols (OBJ has orphans; see slide 14)

New External Name Ownership Hierarchy



Compatibility

- All functionality of old OM/LM behavior is retained
- Old code is mapped by the Binder as follows:

OM	Binder's Mapping
SD	SD; create ED for class B_TEXT and LD at element's origin for section name
LD	LD
ER, WX	ER
CM	SD with "common" flag; create ED for class B_TEXT and LD at element's origin for section name
PC	Binder assigns unique numeric names (displayed as PRIVnnnnn)
PR, XD	PV; create ED for class B_PRV
TXT	Text records
RLD	RLD records
END	END; deferred length (if any) placed on a new record type
SYM	ED for class B_SYM

- Assembler supports similar mappings when GOFF option is specified...

• Sample program:

```

Sect_A  Start 0          (SD)
        DC    5D'0.1'
        DC    Q(My_XD)

MyCom   COM    ,        (CM)
        DS    12D

My_XD   DXD    3D       (XD)

Sect_B  CSect ,        (SD)
        Entry B_Data   (LD)

B_Data  DC    7D'1.0'

        End    Sect_A
    
```

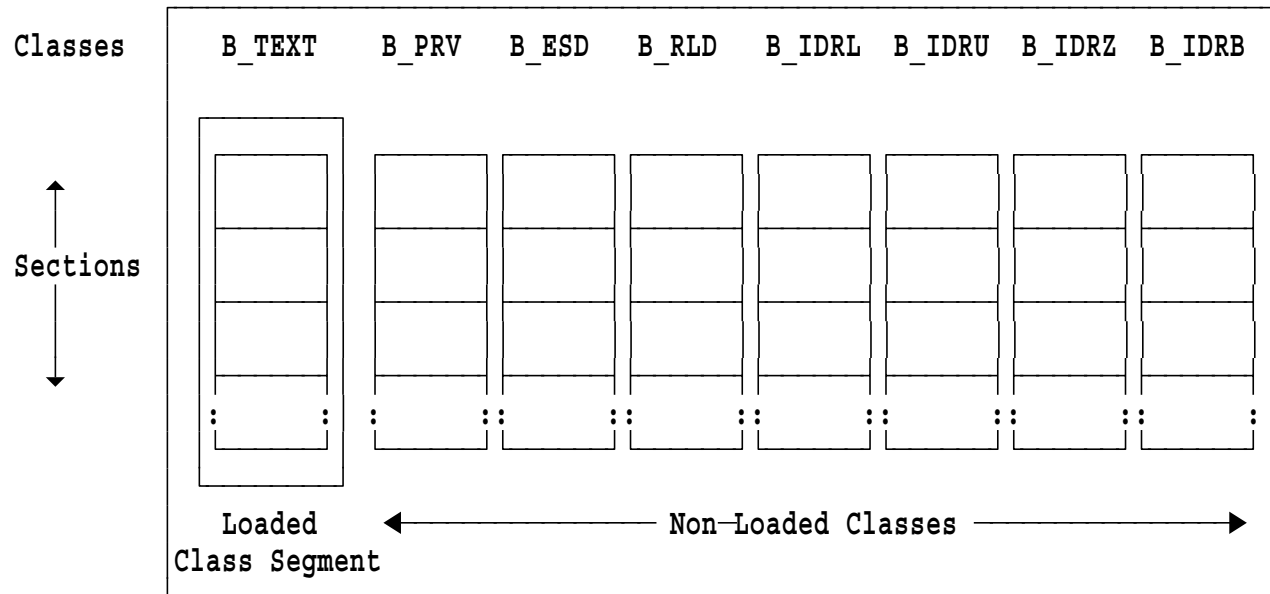
• OM ESD (HLASM **OBJECT** option)

Symbol	Type	Id	Address	Length	LD ID
SECT_A	SD	00000001	00000000	0000002C	
MYCOM	CM	00000002	00000000	00000060	
MY_XD	XD	00000003	00000007	00000018	
SECT_B	SD	00000004	00000030	00000038	
B_DATA	LD		00000030		00000004

• GOFF ESD (HLASM **GOFF** option)

Symbol	Type	Id	Address	Length	LD ID
SECT_A	SD	00000001			
B_PRV	ED	00000002			00000001
B_TEXT	ED	00000003	00000000	0000002C	00000001
SECT_A	LD	00000004	00000000		00000003
MYCOM	SD	00000005			
B_PRV	ED	00000006			00000005
B_TEXT	ED	00000007	00000000	00000060	00000005
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
SECT_B	LD	0000000D	00000030		0000000C
B_DATA	LD	0000000E	00000030		0000000C

- Old modules are mapped into POs (if SYSLMOD is a PDSE):



- B_TEXT “Loaded Class” behaves like traditional LM's text (see slide 16)
- B_ESD is like LM CESD; B_RLD is like LM Control/RLD records
 - B_IDRx classes hold IDR data from **L**anguage translators (L), **U**ser (U), **S**uperZap (Z), and **B**inder (B)

IEBCOPY of PDS to PDSE invokes the Binder to do the conversions

- Link Editor: linking modules with mixed RMODEs forces the LM to most restrictive value
 - Only way to split a program into RMODE(24) and RMODE(31) parts:
 - Link them separately; execute one part, which loads the other
 - No external-symbol references between the two modules
(LOAD/LINK only know entry point name and address of loaded module)
- Binder: **RMODE(SPLIT)** option creates a PO with two text classes
 - Affects only class B_TEXT:
 - RMODE(24) CSECTs (from class B_TEXT) moved to TEXT_24 class,
RMODE(31) CSECTs (from class B_TEXT) moved to TEXT_31 class
 - TEXT_24 class loaded below 16M, TEXT_31 class loaded above 16M
 - Supports full capabilities of inter-module external symbol references
 - As if entire program was linked as a single LM in “most restrictive” style!
 - Internal symbol inter-class references usable (see example at slide 50)
 - Simple solution to LM's AMODE/RMODE complexities
 - User code must handle addressing-mode switching, of course!
 - Without RMODE(SPLIT) option, B_TEXT is bound as with LMs
- Recommendation: let the Binder determine RMODEs

Improved Binding Techniques

- Link Editor binding algorithms
 - Retained
 - Generalized
 - Treated more rigorously

Classes have one of two *binding attributes*:

1. **Catenate** (CAT)

- Section contributions (*elements*) are aligned and catenated end-to-end
 - The familiar manner of text binding
- Ordering determined in the normal manner
- **Note:** Only the first element with a given section and class name is retained; others are rejected (same as LKED's CSECT rejection)

2. **Merge** (MRG)

- A generalization of LKED/LDR binding of CM, PR items
- Section contributions are named **Part Views** (PVs)
 - Each section supplies its own view of any number of shareable external data items
- Views are “overlaid” in Merge binding (they map the same storage)
 - Part Views are bound into **Part Definitions** (PDs) (see examples on slides 34-35)
 - Part Definitions subsequently bound into segments by catenation
- Parts are accessible to any section referencing the part
- **Note:** All Part Views are retained, whether or not identically named

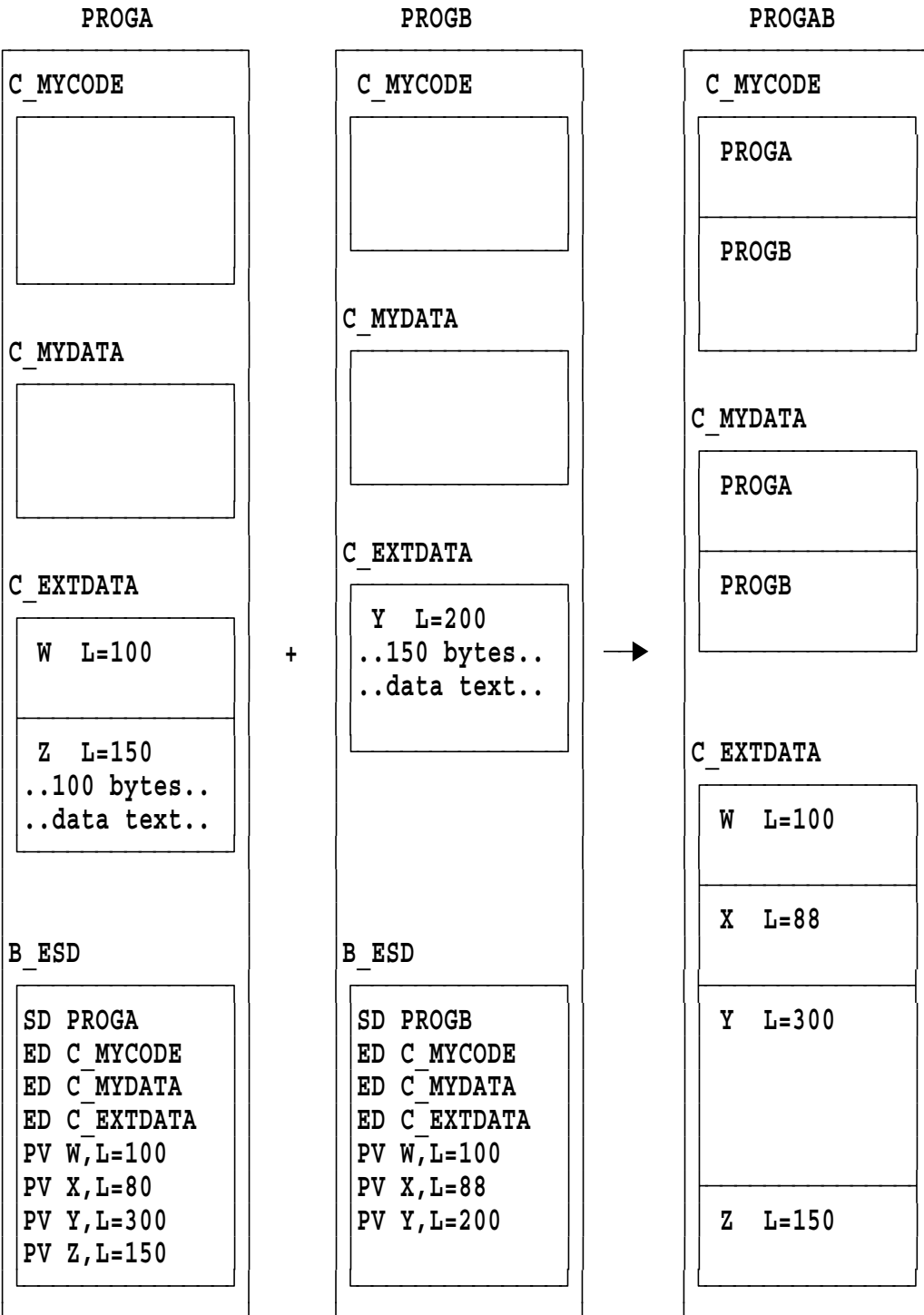
- Programs PROGA and PROGB are bound to form PROGAB:
 - In addition to the C_MYCODE and C_MYDATA classes, the two programs have each defined external data items in class C_EXTDATA:
 - PROGA has defined four external data objects, W, X, Y and Z.

<u>SYMBOL</u>	<u>DEFINED LENGTH</u>
W	100
X	80
Y	300
Z	150

- PROGB has defined three external data items, W, X and Y.

<u>SYMBOL</u>	<u>DEFINED LENGTH</u>
W	100
X	88
Y	200

- If initial text was provided for W, X, Y, or Z, it would be saved in class B_PARTINIT to enable correct re-binding
- In the next figure, only compiler-defined text/ESD classes are shown
 - The resultant ESD for PROGAB is a combination of the two input ESD items (and has been omitted to improve readability)



Before Binding:
Class ABCD

Part Views				
	A	B	C	D
Sect. X	L=40 A=3		L=600 A=3	L=12 A=0
Sect. Y	L=26 A=2	L=395 A=0		L=4 A=2
Sect. Z	L=80 A=3		L=100 A=2	L=5 A=0

After Binding:
Class Segment ABCD

Part Definitions				
	A	B	C	D
Sect. X'03'	L=80 A=3	L=395 A=0	L=600 A=3	L=12 A=2

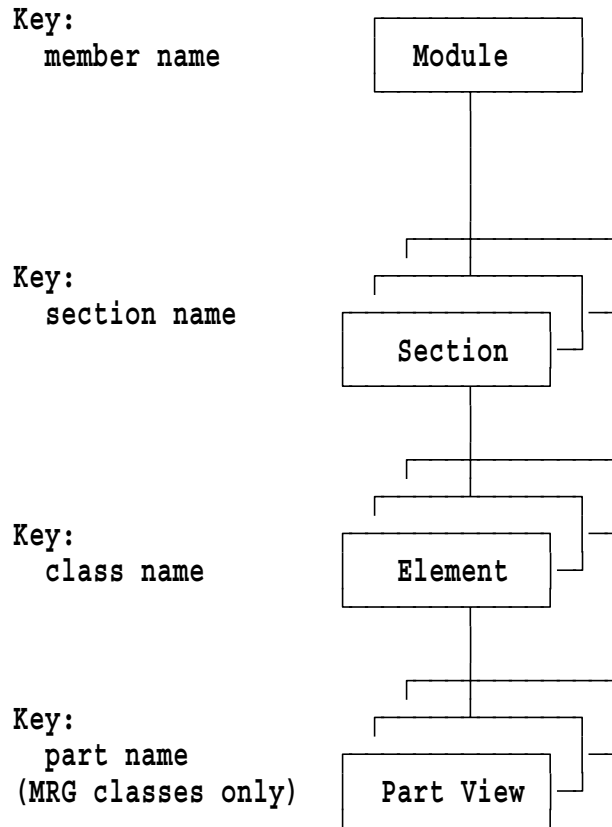
Note: alignment boundary = 2^A

- PVs are “merged” by name, to determine maximum length and strictest alignment
 - Creates a **Part Definition** for each part name (PD is owned by a “module-level” section)
 - Parts may be ordered by priority
- PDs are then catenated within the class (in some order) to form the class's segment
- Initializing text (if any) assigned to each PD
- In this example (assuming catenation in A-B-C-D order), Class ABCD has
 - Alignment = 3 (doubleword)
 - Length = $80+395(+5)+600+12 = 1092$ (the +5 aligns Part C's boundary)
- PVs kept, so that all PDs can be re-created on re-bind

- Length of any class or part
 - Implemented in Assembler Language as J-type address constant
 - Generalization of “Cumulative External Dummy” (CXD, length of PRV)
- Offset of a part or label within its class
 - Generalization of Assembler's Q-type address constant
- Binder/Loader “Token”
 - Used for requesting PMLoader virtualization of DEFERRED LOAD classes
- High order V-con bit (HOB) can be set according to AMODE of target
 - Controllable by compiler, via RLD entry
 - Controllable by bind-time “HOBSET” option, for V-cons only

Binder Inputs and Outputs

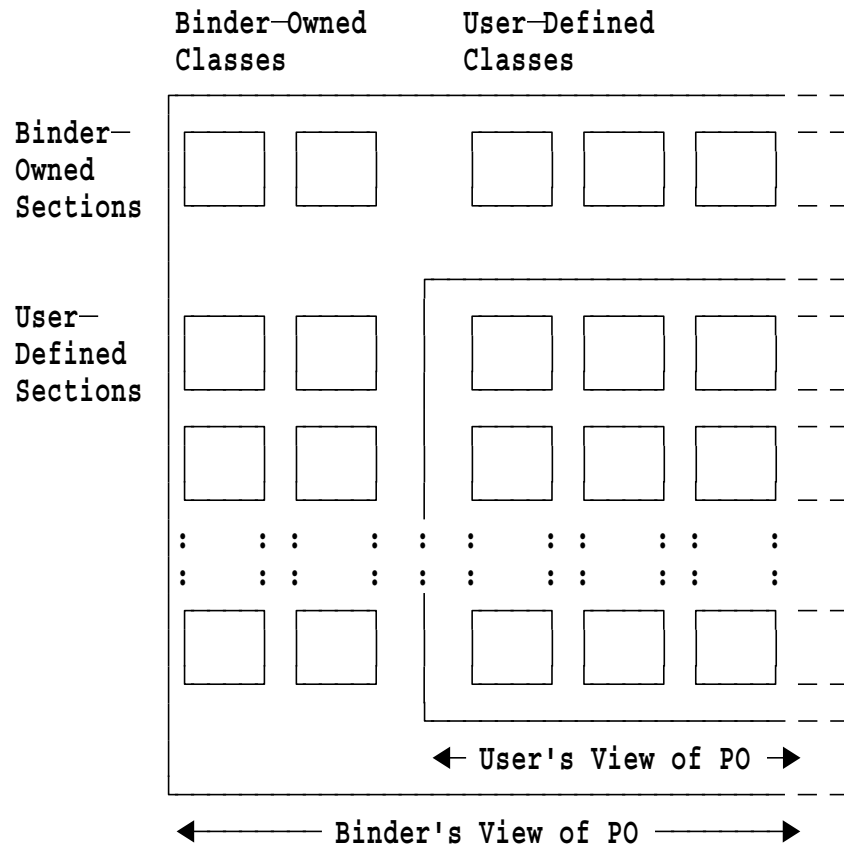
- Some pictorial views of binding and loading



PO structure as seen by the translator and Binder user:

- **Section** roughly equivalent to a “compilation unit”
 - Consists of **elements** in various classes
- MRG classes are constructed from **Part Views**

Binder Output view is more complex!



Text classes are bound into **segments**

- A segment may contain multiple classes if they have identical attributes

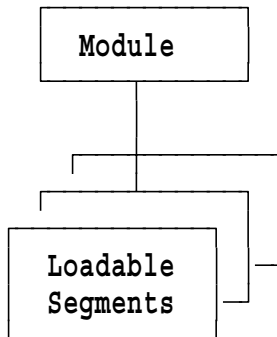
Binder retains extra “module-level” data for re-bindability

- Part Views and initializing text
- control information (e.g. B_ESD)
- IDR data, module map, etc.

in reserved section names like

- X'00000001' for B_ classes, orphaned ER/PR items
- X'00000003' for PVs, linkage descriptors, initializing data
- IEWBLIT for LE support
- IEWBCIE for DLL support

Key:
member/alias name



Key:
class name
(= Segment ID)

PO structure seen by PMLoader:

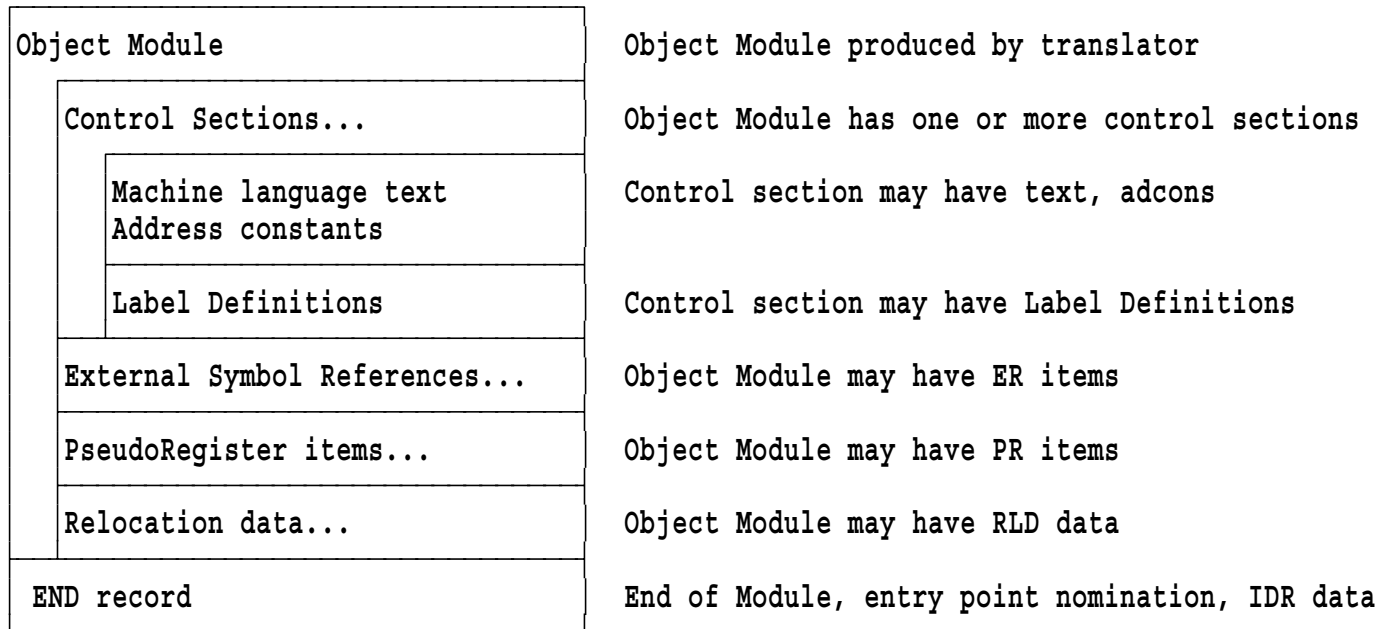
- PO consists of one or more **class segments**, some of which are “loadable”
- PMLoader loads and relocates segments
 - Each segment is like a LM: relocated with its **own** origin address
 - **Distributed** or **scatter** loading
- Library member names (entry points and aliases) must be in same “primary” class segment as the module entry point

**The Generalized Object File
Format**

- **Generalized Object File Format**
- Complete replacement for old Object Module
 - Generated by High Level Assembler for most architected functions
 - C/C++ implementation in OS/390 V2R10
- Supports needs of languages, PO structure, Binder
 - long external names
 - 32-bit length and offset fields (vs. 24 in OM)
 - multiple text classes
 - up to 1 million (or more) ESDIDs
 - user and associated data (ADATA) in object stream
 - ...and many other forms of attributes and descriptive data

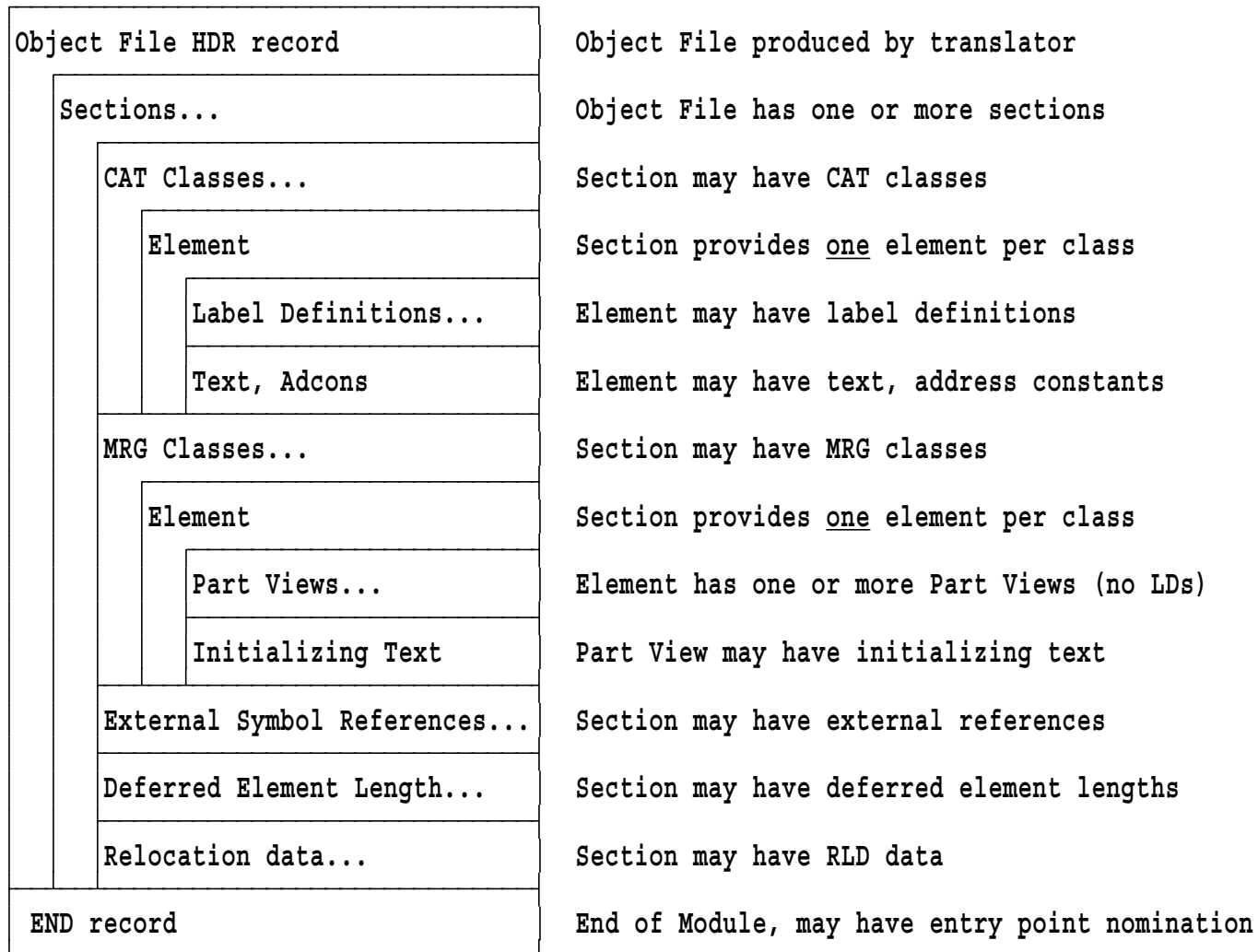
- Six record types (similar to the five OM types)
 1. Module Header (new): CCSID, translator product identification, etc.
 2. External Symbol Dictionary: long names, rich set of types and attributes
 3. Text: object code, IDR (OM: only on END), ADATA (OM: only in text or a side file)
 4. Relocation Dictionary: relocation information
 5. Deferred Element Length (new): formerly on OM END record
 6. End: with optional Entry-Point nomination
- Open-ended, flexible architecture; allows growth and expansion
- Documented in *OS/390 DFSMS Program Management, SC27-0806*

- Object modules describe a **one**-dimensional structure:



- Contrast with GOFF structure (slide 45)

- GOFF files: linearized two-dimensional structure; classes in any order



- GOFF option creates a GOFF file
 - Existing, unmodified code will go into special “compatibility” classes
 - B_TEXT for text, B_PRV for pseudo-registers (see slides 27-28)
 - Requires LIST(133) option for wide listing format
- Section names specified with START, CSECT, RSECT
- CATTR statement defines class name, specifies Class ATTRibutes:
 classname CATTR attribute[,attribute]...

classname

a valid PO class name; it must follow the rules for naming external symbols, except that:

- class names are restricted to a maximum of 14 characters
- all class names of the form *letter_symbol* are reserved for IBM-defined purposes

attribute

binder attributes to be assigned to the class

- XATTR statement declares additional external-symbol attributes

- Attributes currently supported by the Binder:

ALIGN(*n*) Aligns class elements on a 2^n boundary ($0 \leq n \leq 12$)
Currently: for text, 3, 11, or 12; for PVs, 0-3

MERGE The class has the merge binding attribute
(default = CAT)

NOLOAD The class is not loaded when the PO is brought into
storage (default = LOAD)

DEFLOAD Requests deferred loading of the class

RMODE(24) The class has residence mode 24

RMODE(31) The class has residence mode 31

RMODE(ANY) The class may be placed in any addressable storage;
equivalent to RMODE(31)

- Attributes currently accepted (but not supported) by the Binder:

MOVABLE The class is reenterable, and can be moved
(It is adcon-free, and can be mapped to different virtual
addresses in different address spaces)

EXECUTABLE, NOTEXECUTABLE (or null)
The class can/cannot be branched to or executed;
null operand means “unspecified”

READONLY The class may be storage-protected

REFR The class is marked refreshable

RENT The class is marked reenterable

REUS, NOTREUS The class is marked reusable or not

- CATTR must be preceded by START, CSECT, or RSECT
 - A section name must be defined first
 - Unlike OM, no blank section is initiated
 - Text following CATTR belongs to the element defined by the section and class names
- If several CATTR instructions have the same class name:
 - the first occurrence establishes the class and its attributes
 - the rest indicate the continuation of the class, and may not specify attributes
- Default attributes for CATTR (if none are specified) are:

```
ALIGN(3),NOTREUS,RMODE(24)
```

 - Same as the assembler's OM defaults

- The module defines one section (Sect_A), two classes (Code24, Code31):

```

Sect_A  CSect ,                Start of section 'Sect_A'

Code24  CAttr RMode(24),Executable Define 'Code24' Class
***** Portion loaded below 16MB

      Entry Start                Declare name of entry point
Start  AMode 24                  Entry point has AMODE(24)
      Using *,15                  Establish addressability
Start  Save (14,12),,*          Save registers
      ---                          ...set up save areas, etc.
      LR 12,15                    R12 is base register
      Drop 15                      Drop old base
      Using Start,12              Establish addressability
      ---                          Finish init'z'n code

      L 15,=A(X'80000000'+MainCode) Point to Code31
      BASSM 14,15                  Call MainCode
      ---

      LtOrg                        RMode(24) literal pool
D31Addr DC A(Data31)              Addr(data above 16M)
Data24  DC ...                    ...data below 16M...

Code31  CAttr RMode(31),Executable Define 'Code31' Class
***** Portion loaded above 16MB
      Using *,15                  Establish base regs etc.
MainCode Save (14,12),,*          'MainCode' is INTERNAL!
      ---

D24Addr DC A(Data24)              Addr(data below 16M)
Data31  DC ...                    ...data above 16M...
      End Start                    Nominate 'Start' entry

```

- Note inter-element references using internal symbols!
- Note AMODE for entry-point name: LD items have AMODEs, sections don't (classes have RMODEs)
 - Not all LDs in a section have one AMODE!

- The assembled example creates the following ESD listing:

External Symbol Dictionary

Symbol	Type	Id	Address	Length	LD ID	Flags	(Annotations)
SECT_A	SD	00000001					(Section definition)
B_TEXT	ED	00000002	00000000	00000000	00000001	00	(Default class; length=0)
SECT_A	LD	00000003	00000000		00000002	00	(Label for section)
CODE24	ED	00000004	00000000	00000074	00000001		(User class)
START	LD	00000005	00000000		00000004	01	(Label in CODE24; AMODE(24))
CODE31	ED	00000006	00000078	00000012	00000001		(User class)

- Section SECT_A (SD) “owns” elements (ED) in three classes:

B_TEXT “owns” the label (LD) for SECT_A
 – created by HLASM because it doesn't know if other classes will be defined

CODE24 “owns” the label (LD) for START

CODE31 has no externally visible labels

- LD ID column shows “Owning ID”

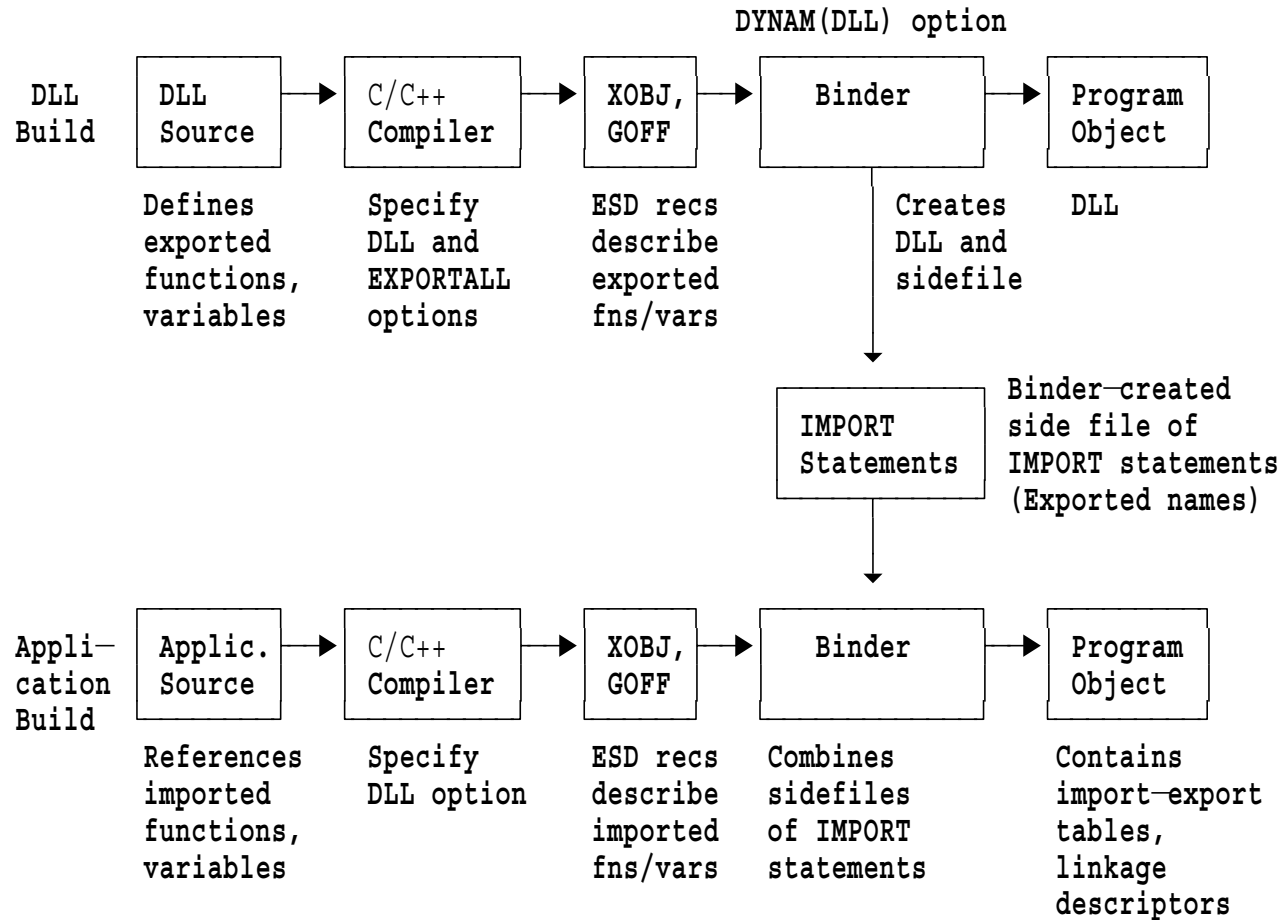
Dynamic Link Libraries (DLLs)

- Dynamic linking: binding of external names at execution time
 - DLLs provide one form of dynamic linking; LE is required
- DLL creator identifies names of functions and variables to be **exported**
 - Makes them available in a “side file” for runtime binding to other applications
 - Compiler indicates “import-export” status in object file
- DLL-using application identifies functions and variables to be **imported**
 - User must specify compiler DLL option and Binder controls statement
- Binder also provides the IMPORT control statement

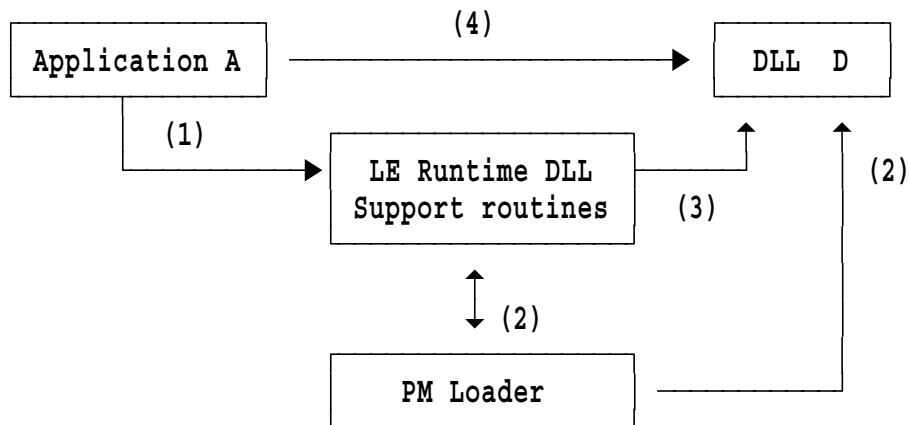
```
IMPORT  CODE|DATA,dll_name,identifier
```

- Compilers and HLASM XATTR statement declare EXPORT status
- Binder creates side file, import-export tables and linkage descriptors
 - DYNAM(DLL) option required for DLL creator and user
- LE runtime support routines load and link specified names

- Example using C/C++: create a DLL, then the application



- Example: Application A imports names from DLL D:



- (1) First reference to an imported name passes control to LE
- (2) LE DLL-support routines invoke PMLoader to load the DLL
- (3) Linkage to DLL name is completed:
 - LE uses import-export table to update descriptors for code/data items
 - Different “linkages” are used for code (functions) and data (variables)
- (4) Subsequent application references go directly to the requested (imported) name in the DLL

**Summary, Glossary, and
References**

	Old (Load Modules)	New (Program Objects)
Components	Link Editor, Program Fetch, Batch Loader	Binder, Program Loader
Library	PDS	PDS, PDSE, HFS
Executables	One-dimensional; single RMODE	Two-dimensional; multiple segments and RMODEs
Size limit	16MB	1GB
Symbols	8 characters	1024 characters
Symbol types	SD, LD, ER, PR	Same, plus ED
Module info	IDR only; no system support	Any data; Binder API
DLL support	Prelinker required	Integrated
Extensibility	Not possible	Open-ended architecture

- New technology for MVS “executables”
 - Efficient storage and loading
 - Flexible program segmentation
 - Generalized mechanisms for inter-component references
- Satisfies many requirements from customers, languages, operating systems and hardware
- Retained (but non-obtrusive) information about programs
- Defined Application Programming Interfaces to all functions/data
- Open-ended designs for all items
 - Easy to generalize, enhance and improve
 - Enables Program Management evolution to meet future requirements
- ***For You:*** Much more flexibility in creating program structures

- ADATA** Associated Data: program data stored in a PO which is not required for binding, loading, or execution.
- API** Application Programming Interface
- CAT** CATenate: a binding method whereby section elements within a
- CCSID** Coded Character Set ID: identifies a character set used in an assembly or compilation.
- class** A cross-section of Program Object data with uniform format, content, function, and behavioral attributes.
- Common** A CSECT having length and alignment attributes (but no text) for which space is reserved in the Program Object (see Part View)
- compilation unit**
A “fresh start” of a translator's symbol tables. There may be more than one compilation unit per source input file.

deferred load

A class attribute requesting the PMLoader prepare the class (a Prototype Section, or “PSect”) for rapid loading on request during execution. (Usually, for non-shared classes.)

distributed loading

See “scatter loading”

element The unit of module data uniquely identified by a class name and a section name.

external data

Module data accessible by multiple sections, each defining its own view as a Part View.

GOFF Generalized Object File Format, a new and extensible object file supporting Binder and PMLoader features.

linear format

The format of a PO, “loaded” by DIV mapping.

loadable A class attribute indicating that the class is to be loaded with the module.

load module (LM)

The original form of MVS executable, stored in record format.

MRG MeRGe: a binding method whereby identically named Part Views within a class are overlaid (“merged”) before catenation.

noload A class attribute indicating that the class may be “demand loaded” by the application.

Part View (PV), PseudoRegister (PR), External Dummy (XD)

A named subdivision of a MRG class having length and alignment attributes for which space is **not** reserved in the LM or PO (see Common); used to describe a pseudoregister or external data item. Resolved to an offset within the class segment.

PM1 The Binder, Loader and related program management services available in DFSMS/MVS V1R1.0 and V1R2.0. Emulates Linkage Editor/Loader function; simple PO structure.

- PM2** Extensions to the program management services delivered with DFSMS/MVS V1R3.0. Significant modifications and enhancements to PM1 PO structure.
- PM3** Extensions to the program management services which became available with DFSMS/MVS V1R4.0. Significant modifications and enhancements to PO structure and function.
- PM3.1** In OS/390 V2R10; XPLINK support
- program object**
The new form of MVS executable, stored in linear format.
- record format**
The format of a LM, loaded by Program Fetch I/O operations.
- relocation** The load-time conversion of address constants from module or class displacements to virtual addresses.

scatter loading

The loading of module text into non-contiguous areas of virtual storage according to class attributes stored with the module. Also referred to as *distributed loading*.

section

(1) A cross-section of Program Object data stored under a single name. A section consists of elements belonging to one or more classes. (2) A generic term for control section, dummy section, common section, etc.; a collection of items that must be bound or relocated as an indivisible unit.

segment

The aggregate of all section contributions to a single class, stored in consecutive locations on DASD and (optionally) loaded as a single entity into virtual storage. Each segment has its own relocation base address.

text

(1) The class(es) of module data containing the executable instructions and data. (2) A class attribute indicating that locations within the class may contain and/or be the target of address constants.

1. OS/390 DFSMS Program Management (SC27-0806)
2. DFSMS/MVS V1R3.0 Presentation Guide (GG24-4391), chapter 6
3. "Linkers and Loaders," by Leon Presser and John R. White, *ACM Computing Surveys*, Vol. 4 No. 3, Sept. 1972, pp. 149-167.
4. Linkage Editor and Loader User's Guide
5. Linkage Editor, Loader Program Logic manuals

These publications describe the Assembler Language elements that create inputs to the Linkage Editor, Loader, and Binder.

6. High Level Assembler for MVS & VM & VSE Language Reference (SC26-4940)
7. High Level Assembler for MVS & VM & VSE Programmer's Guide (SC26-4941)