HLASM
IBM's High Level Assembler

Calling Conventions

Static Linkage

24-bit and 31-bit addressing modes

LANGUAGE

High Level Assembler for z/OS & z/VM & z/VSE

Version 1 Release 6

REFERENCES

- *HLASM Programmer's Guide*, SC26-4941-08, 2017
- *IBM z/Architecture Principles of Operation*, SA22-7832-12, 2019
- *MVS Programming: Assembler Services Guide*, SA23-1368-40, 2019
- *Assembler Language Programming for IBM System z™ Servers*, 2nd edition 2016, by John Ehrman
- *Basic IBM Mainframe Assembly Language Programming, 2016* by Kevin C. O Kane

Question

How do we preserve states when control is passed from one program to another?

Scope

1. Primary mode programs
2. Code written with static save areas and linkage.
3. Programs that have static areas defined internally.

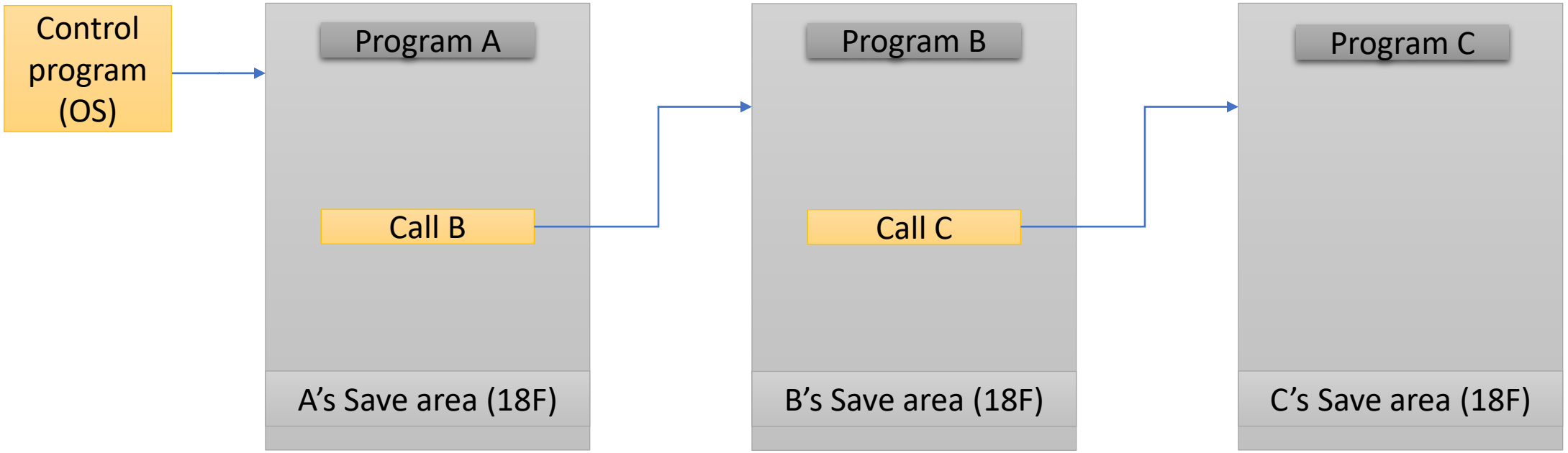
   i.e. “traditional” or “standard” linkage

Note: Rentrant programs / recursion are out of scope

Primary mode programs

1. execute all of their instructions in primary ASC mode
2. ASC = address space control
3. Address Space = the range of addresses available to a computer program
4. ASC Mode = program uses the contents of GPRs to resolve an address to a specific location. The ASC mode of the called program determines where a program saves registers (calling program save area or the linkage stack).

Program A calls Program B, and Program B calls C



The Calling Process - Roles

The calling program (aka Caller)
- is a program that is calling another subroutine/program*
- it must know where to transfer control

The called program (aka Target or Callee)
- is the called subroutine/program
- it must know where to return control

* the words “subroutine” and “program” are used interchangeably

The Calling Process - Linkage

A set of conventions used by an operating system where programs:

1. call one another
2. pass arguments
3. return values

Key Items to Consider

1. Control how to pass control to a subroutine and return
2. Argument passing how to provide data needed by the subroutine and access its results
3. Status preservation how to ensure that nothing important is lost, modified, or destroyed in the process

Linkage - Status Preservation

The issues

1. What data/info should be preserved?
2. Who should do the preserving: the calling program or the target program?

"A primary mode program is one that executes all its instructions in primary ASC (address space control) mode and does not change the contents of ARs (access registers) 2 through 13."

z/OS MVS Assembler Services Guide, Chapter 2 - Linkage Conventions

z/OS MVS Assembler Services Guide, Chapter 2 – Linkage Conventions

A calling program provides its target program with a 72-byte register save area unless the target program's interface requirements are otherwise specified. It is the caller's responsibility to provide a save area that meets the specifications provided by the target program.

The calling program obtains storage for the save area from its primary address space. The save area must begin on a word boundary.

Before invoking the target program, the calling program loads the address of the save area into general-purpose register 13.

etc.

John Ehrman, Section 37.4 [24- and 31-bit addressing modes]

By convention, the caller provides a “standard” 18-word save area, and its address is passed to the callee in GR13. The caller's general registers are stored starting at offset +12 in the order GR14, GR15, GR0, GR1, GR2, ..., GR12.

The easiest way to save the registers is to execute the instruction

```
STM 14,12,12(13)
```

This saves GR14-GR12 in caller's save area before the called program modifies any of them.

This [STM] is often one of the first instructions executed by a called program.

Linkage - 24-bit or 31-bit addressing mode

Every program that calls another has a local save area.

Lowest level programs (which don’t call another) don’t need a save area.

The target must save and restore the caller's register.

Concept the target can take advantage of its (possibly) economical use of registers by saving and restoring only the ones it modifies.

Linkage – High level process

Caller (A) ---> Target (B)

Program A calls B

Program B saves A's registers in A's save area (register preservation)

Program B stores A’s save area address in its own save area (B to A chain)

Program B stores its save area address in A’s save area (A to B chain)

Program B sets a base register and performs is work (local addressability)

Program B restores A's registers before returning control to A

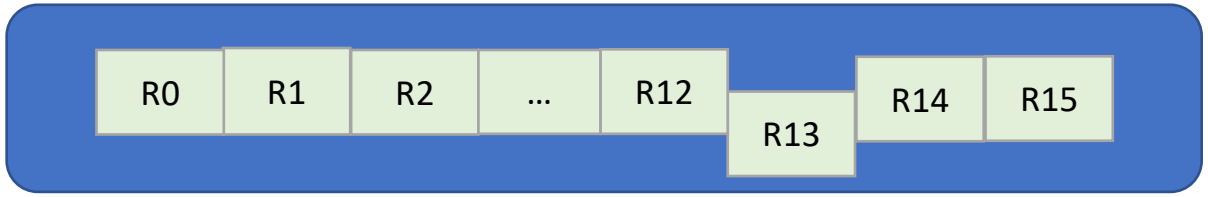
Note: this is a static save area model, meaning there is defined storage in each program for purposes of linkage (i.e. storage space is part of the programs; it is not dynamically allocated at run time)

Linkage – Registers convention

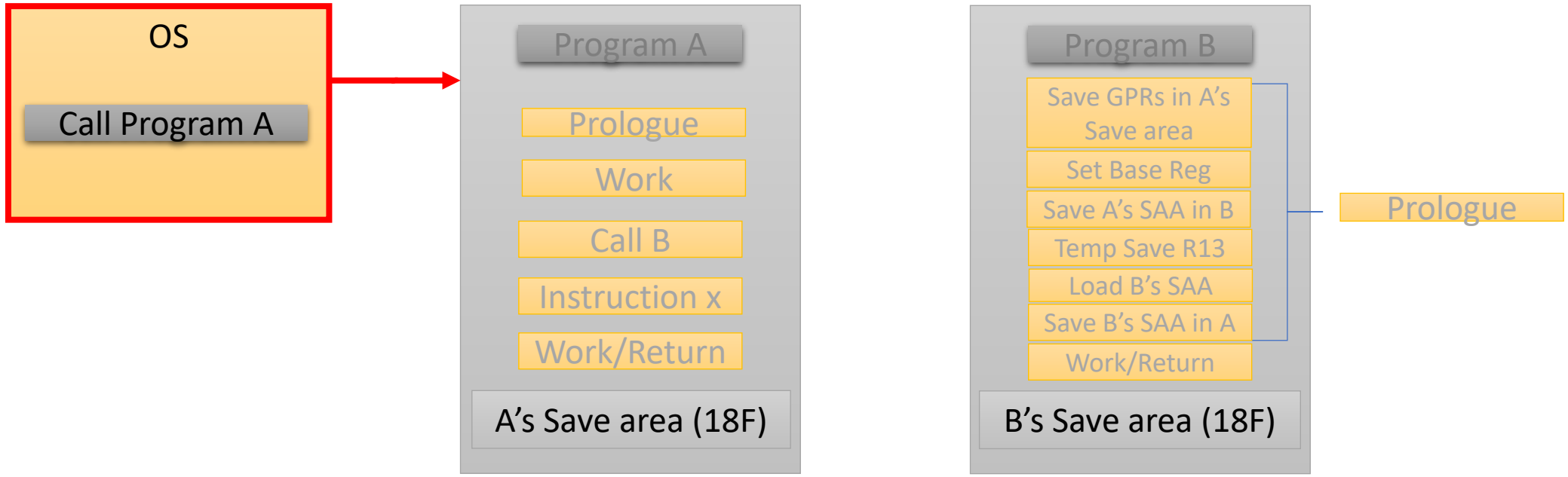
R0,R1	parameter registers, used by the CALL macro (as example) to pass parms (addresses of data) to the called program; a table of addresses in memory; each address points to a parameter; R1=0 if no parms are being passed
R13	save area register - address of caller's save area; called program stores caller's registers here; save area is 18 full words
R14	return register - address in caller's space; when finished, the called program branches here
R15	entry point register – address of the called program's entry point; the address of the first instruction in called program

OS Calls Program A

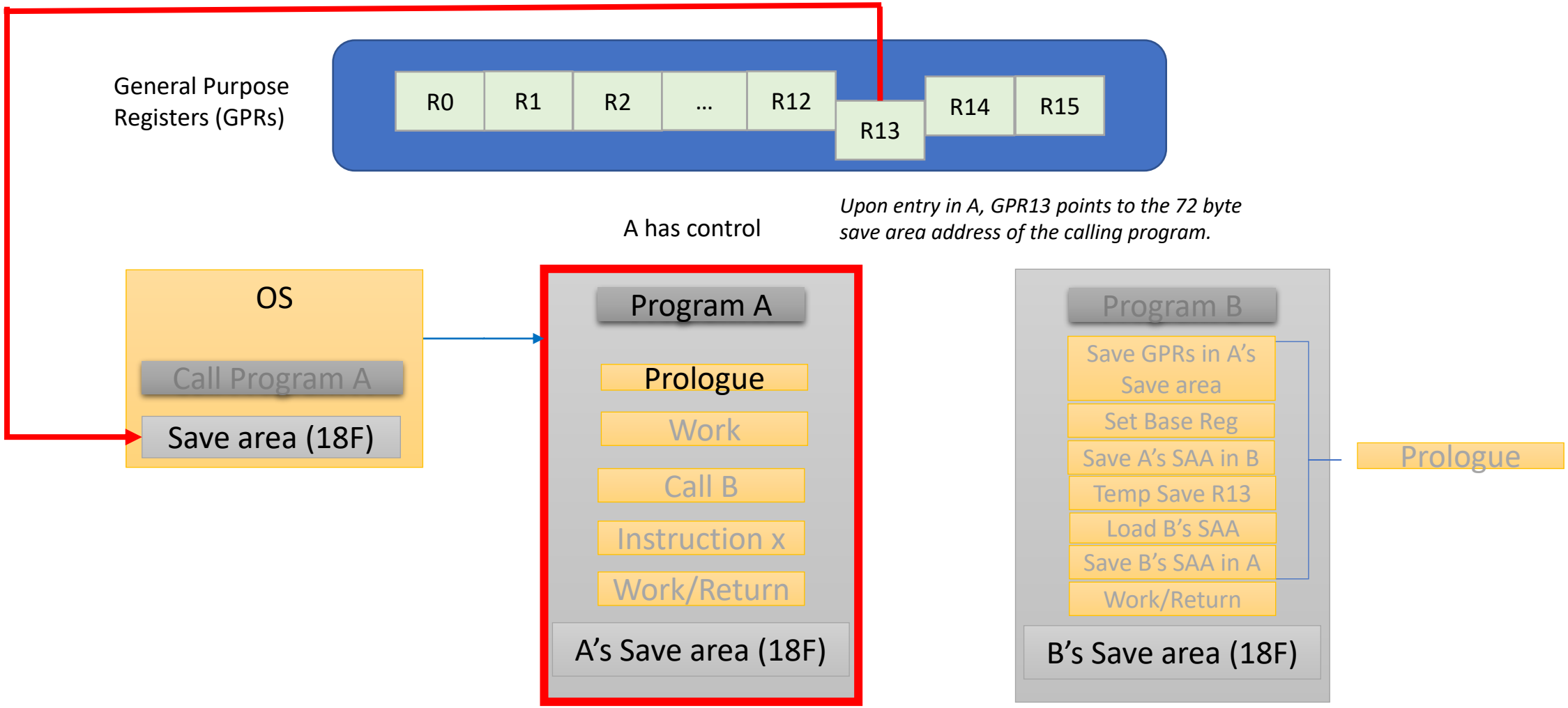
General Purpose Registers (GPRs)



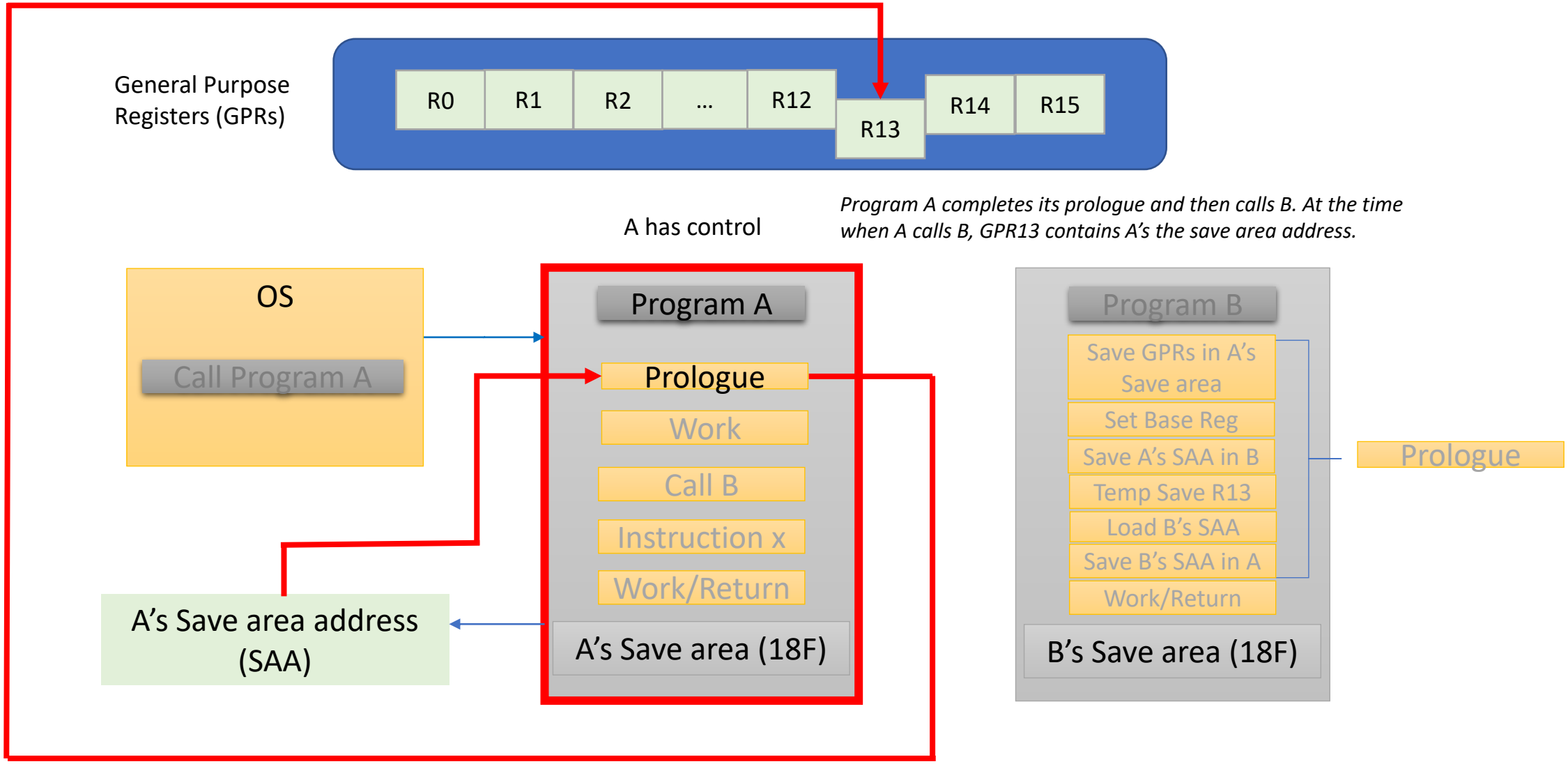
OS has control



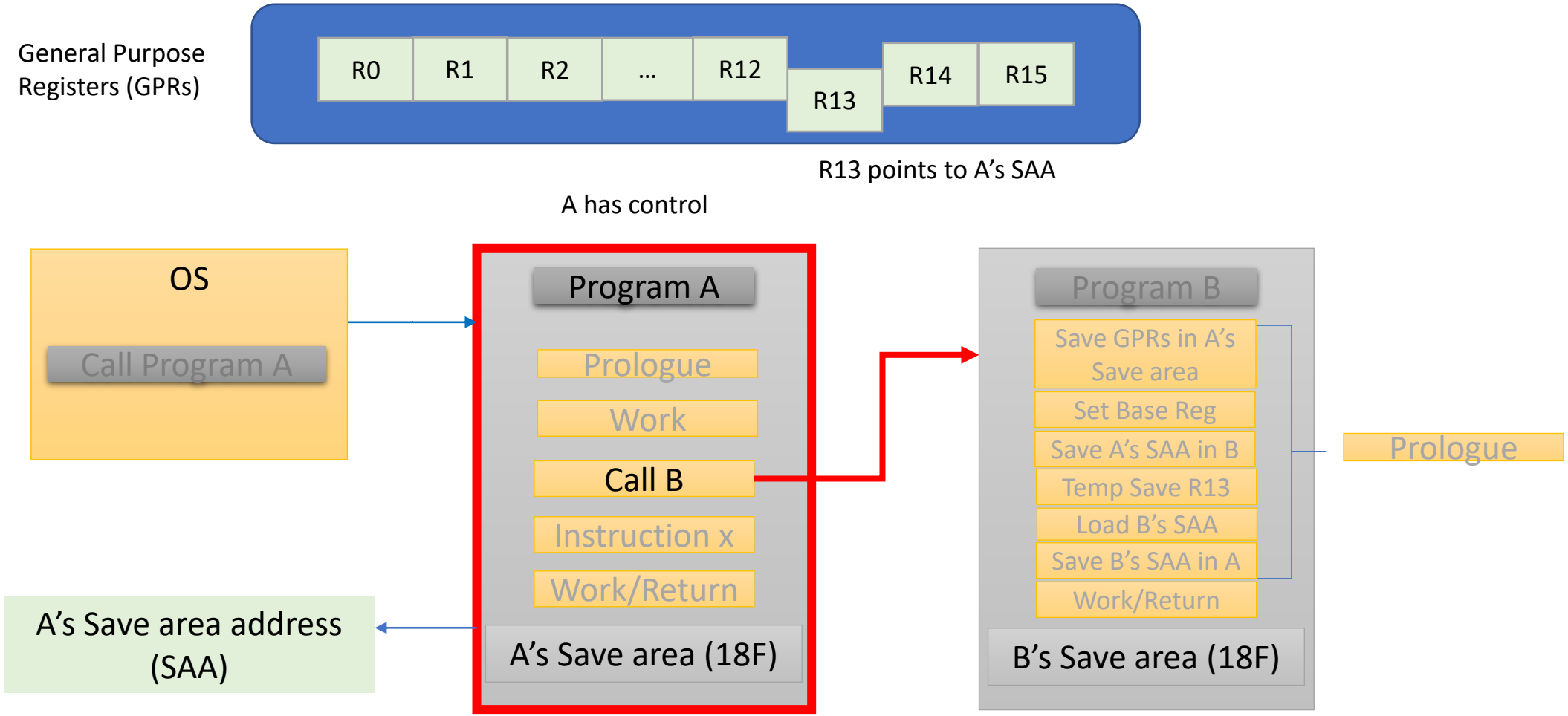
Program A completes its Prologue



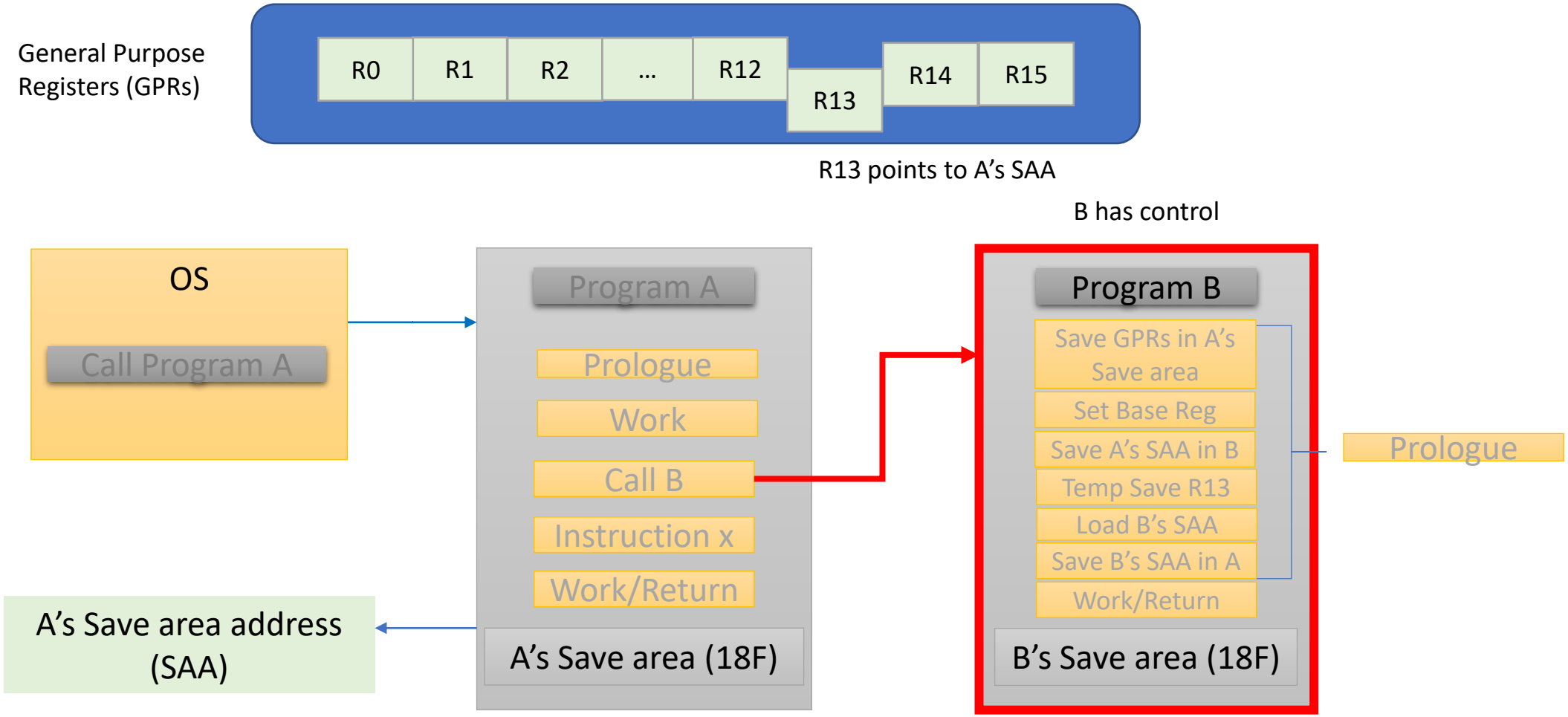
Program A completes its Prologue



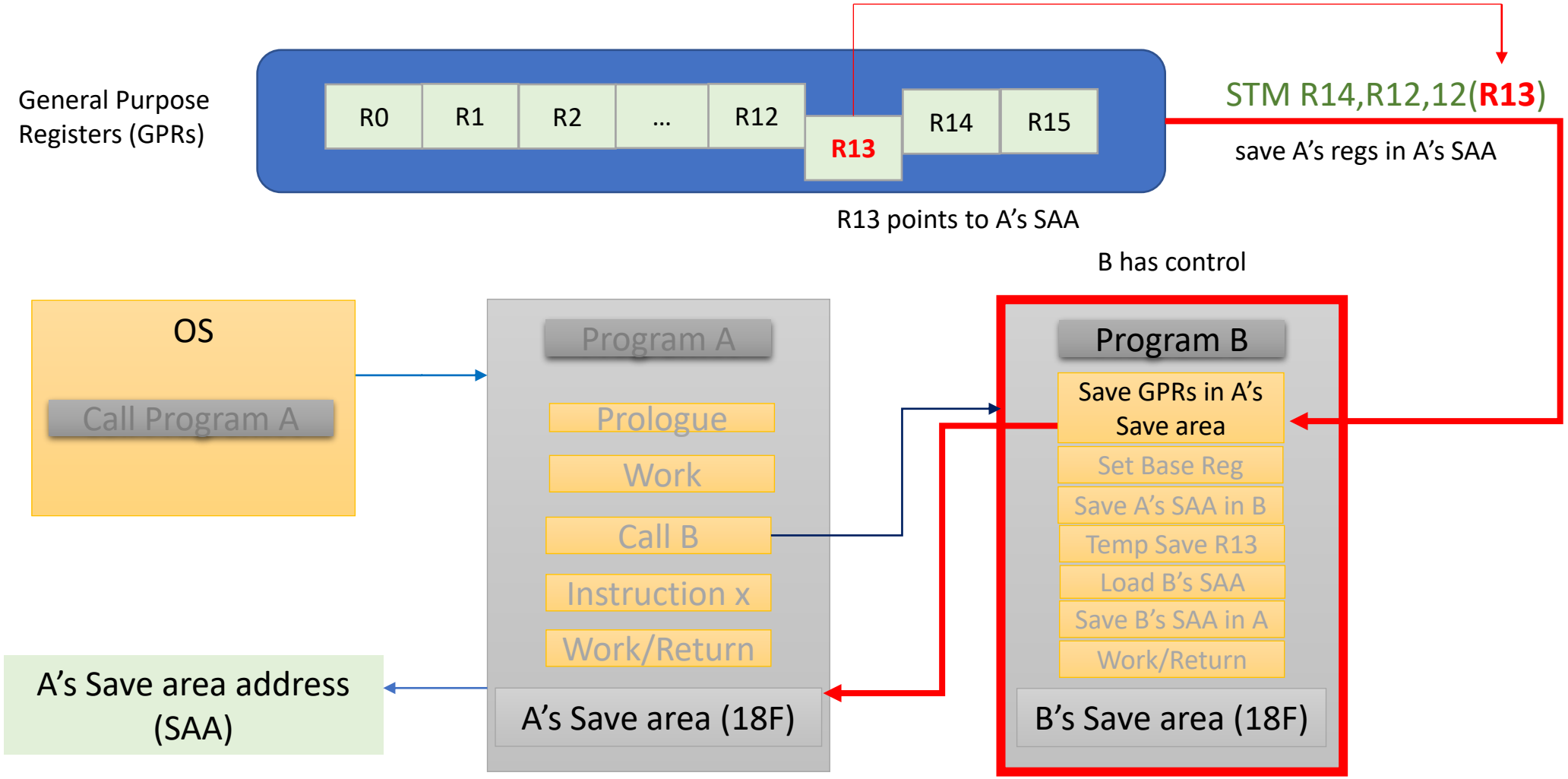
Program A calls Program B



Program B Prologue

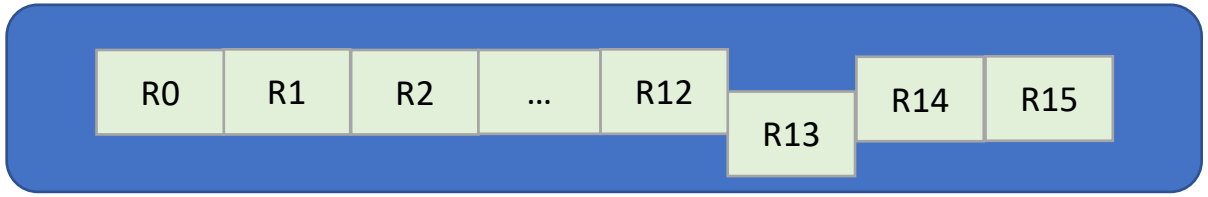


Program B Prologue



Program B Prologue

General Purpose Registers (GPRs)

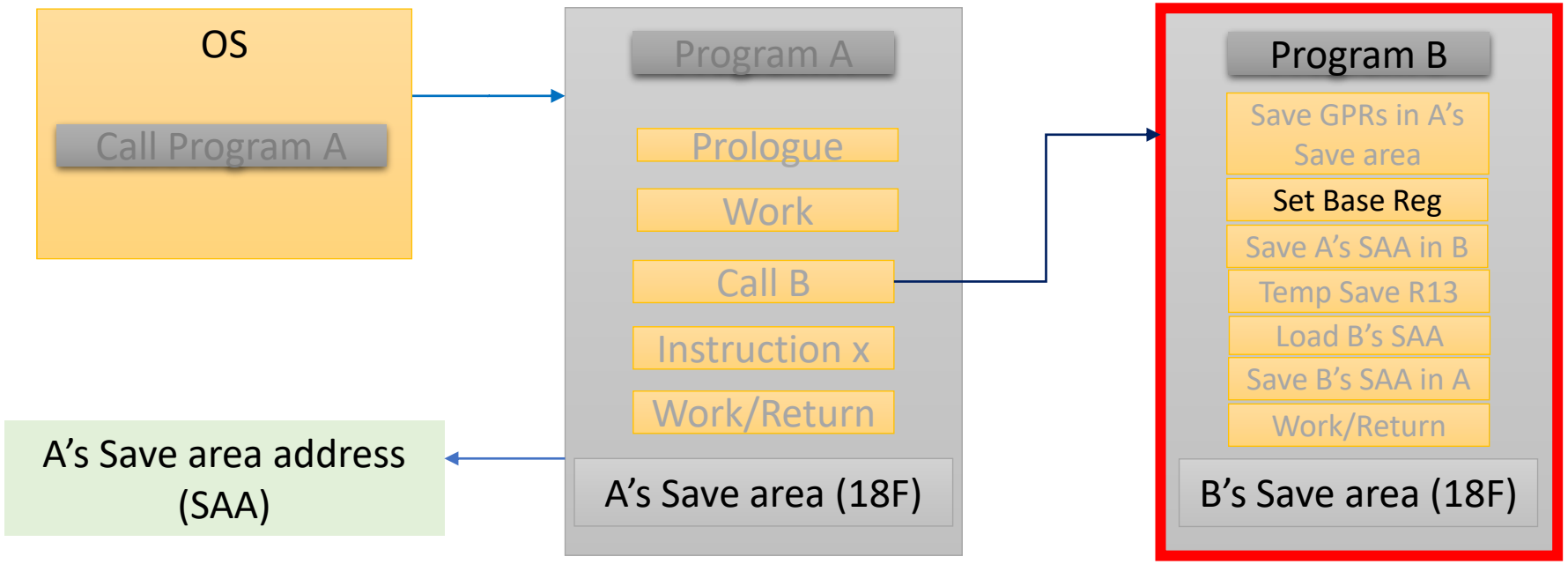


R13 points to A's SAA

BASR R12,R0 [*]
USING *,R12

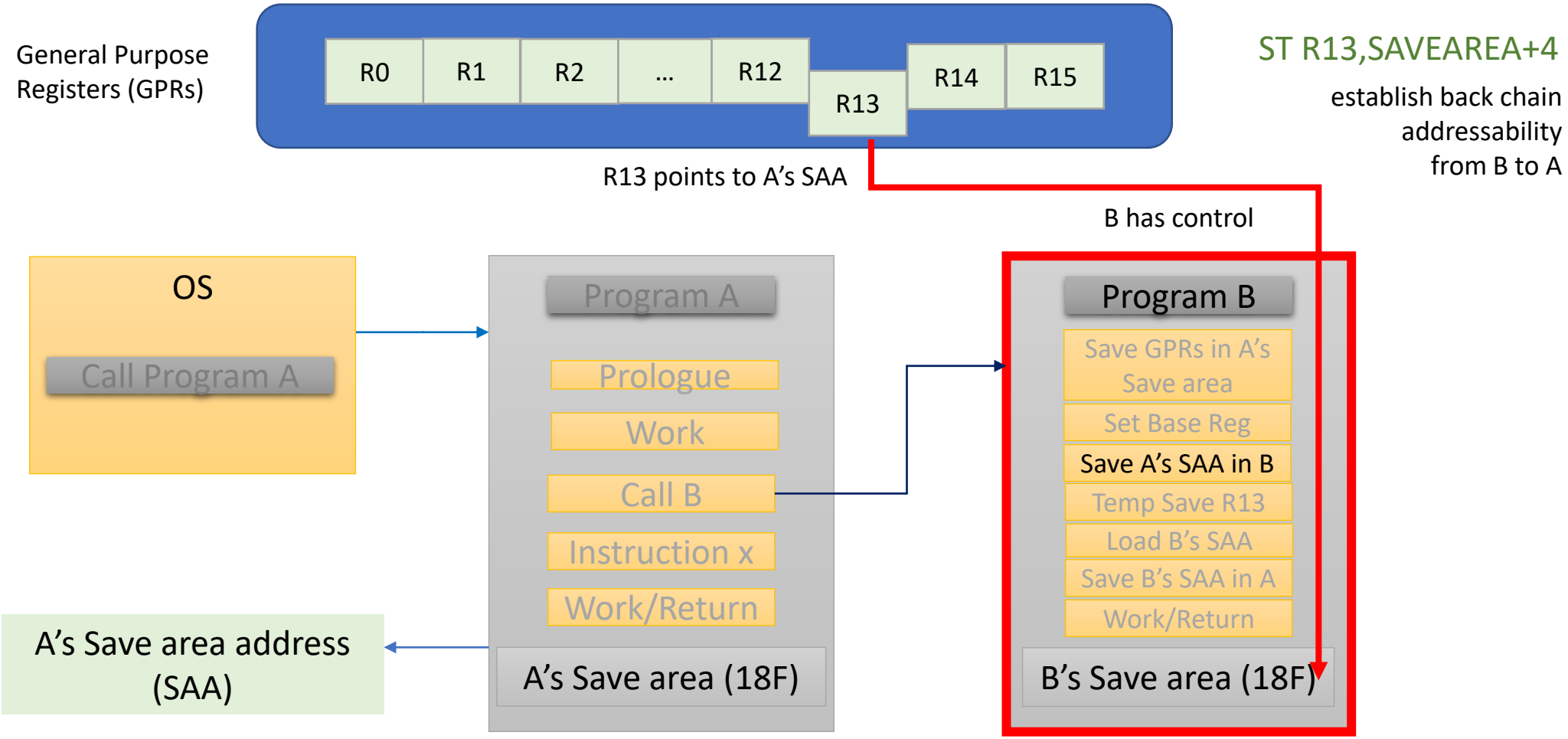
establish a base register in B

B has control

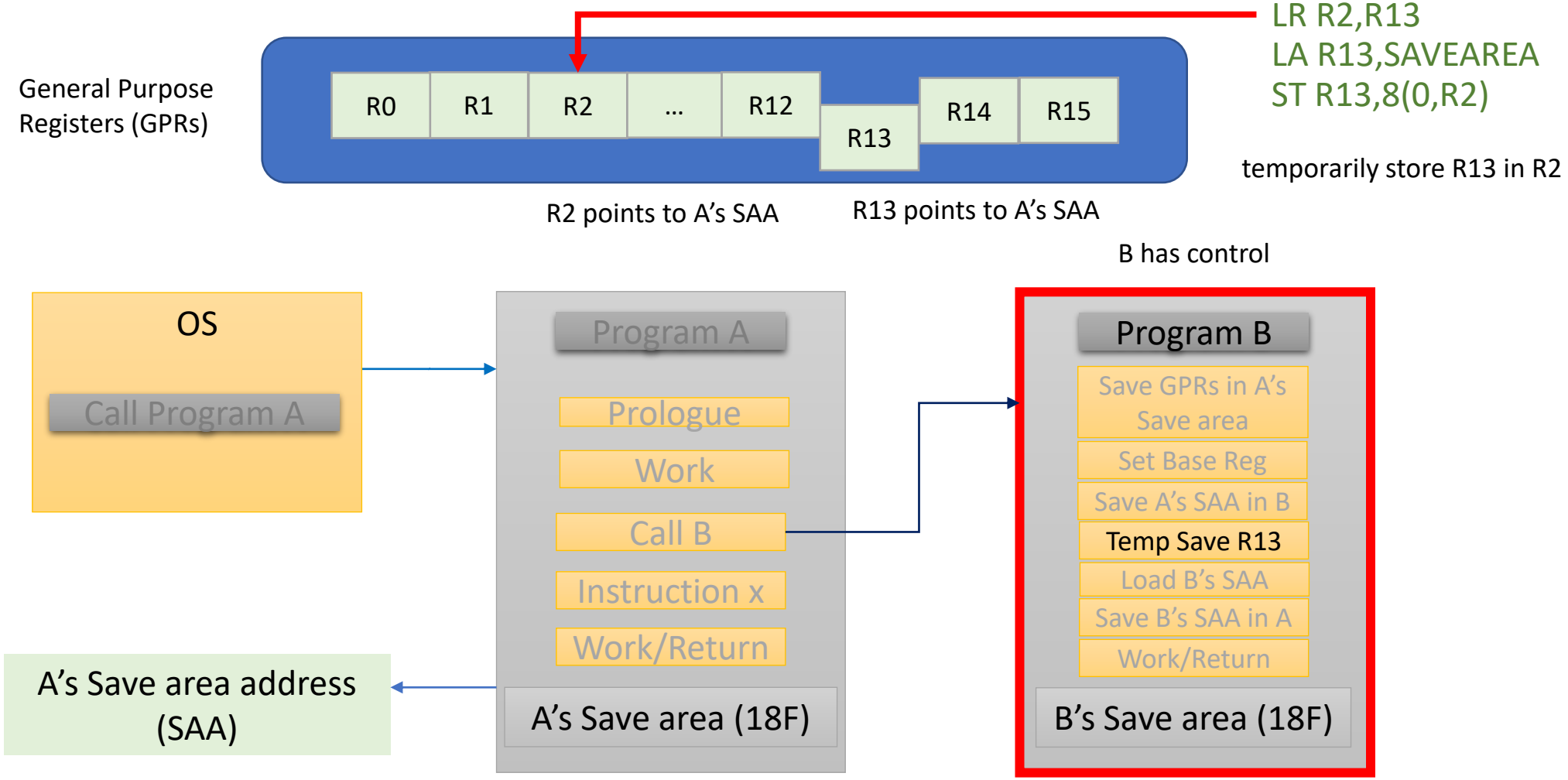


[*] see **z Architecture Principles of Operation**, Appendix A for Linkage Instructions (BAL, BALR, BAS, BASR, BASSM, BSM)

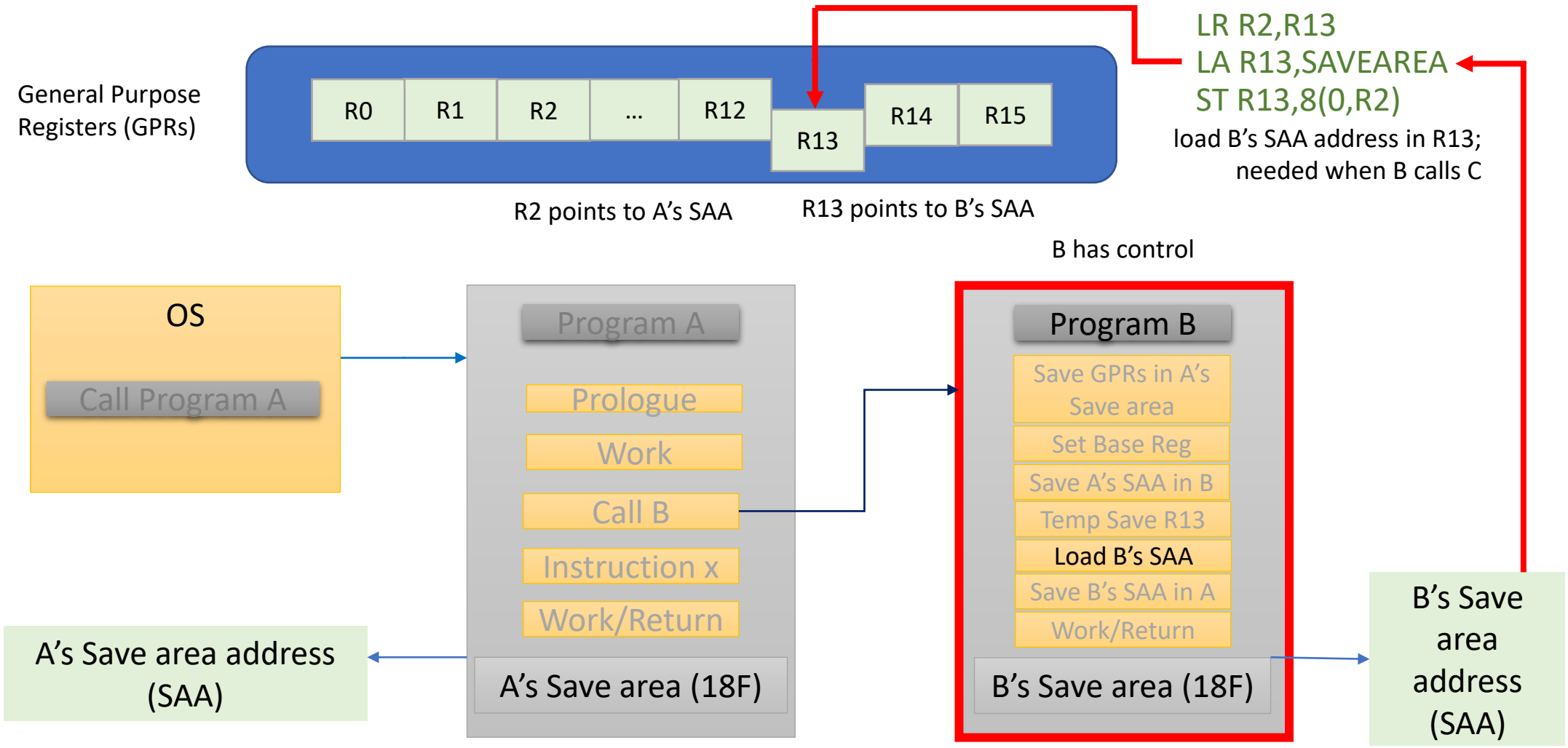
Program B Prologue



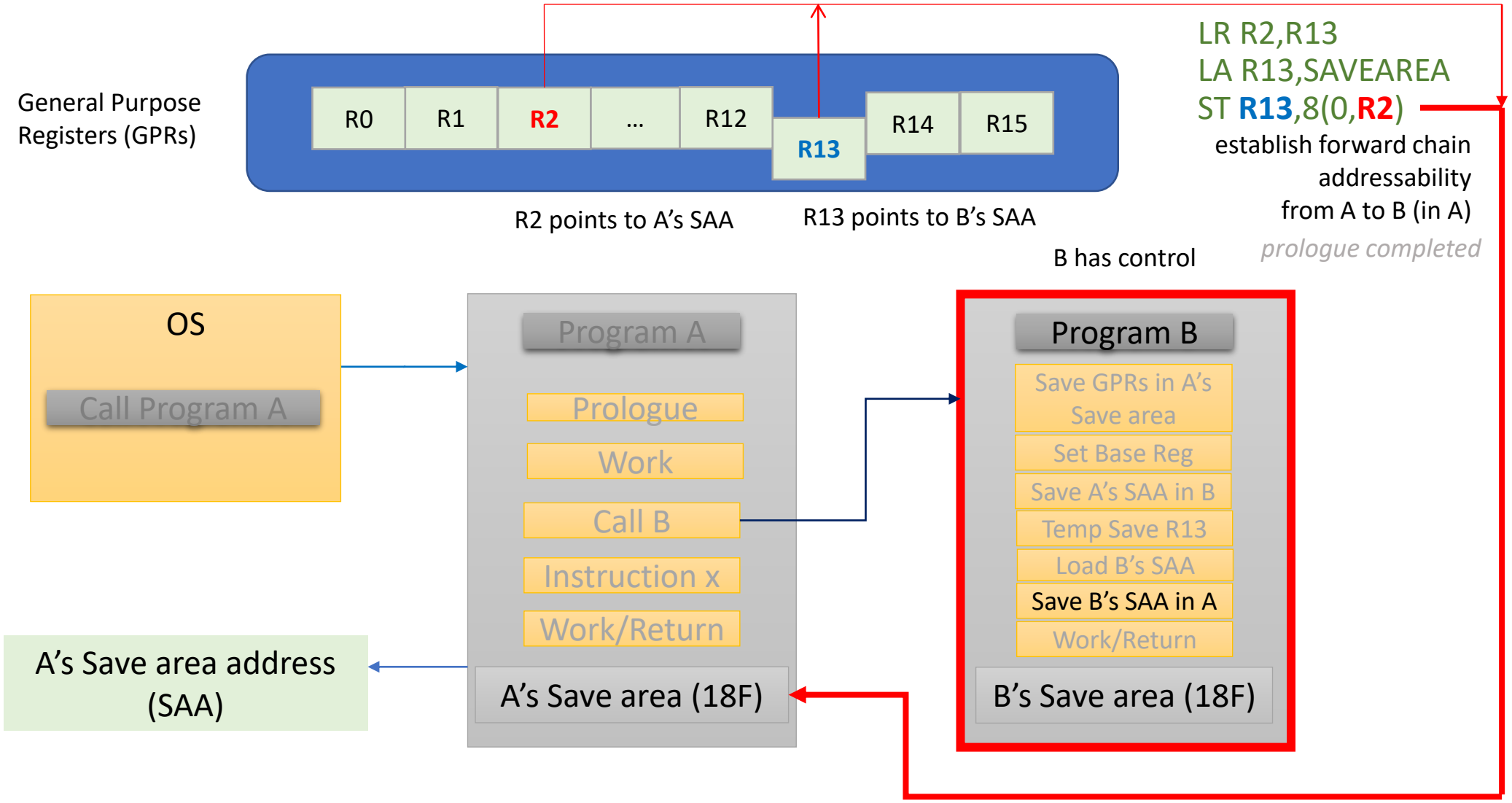
Program B Prologue



Program B Prologue

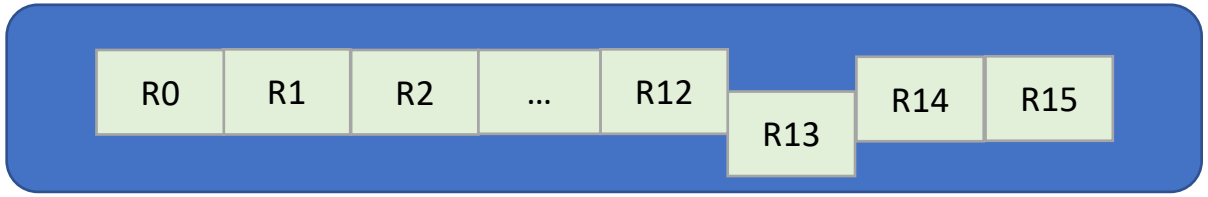


Program B Prologue



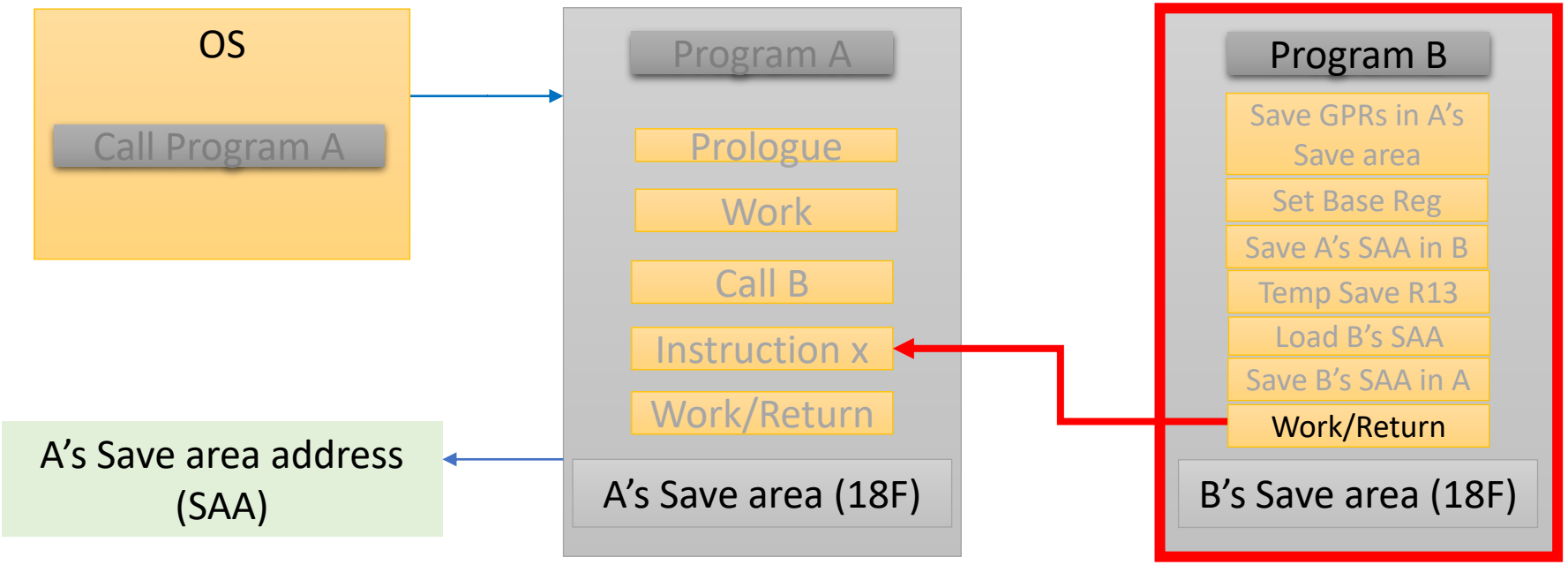
Program B Epilogue (i.e. Return)

General Purpose Registers (GPRs)




```
L     R13,SAVEAREA+4
LM    R14,R12,12(R13)
LA    R15,0
BR    R14
```

B has control



Save area in Program B

SAVEAREA DS 18F 18 fullwords (18x4 bytes = 72 bytes)

Return address

Entry address

Word 0	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8	Word 9	Word 10	Word 11	Word 12	Word 13	Word 14	Word 15	Word 16	Word 17
0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
Reserved	Back Chain	Forward Chain	R14	R15	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12

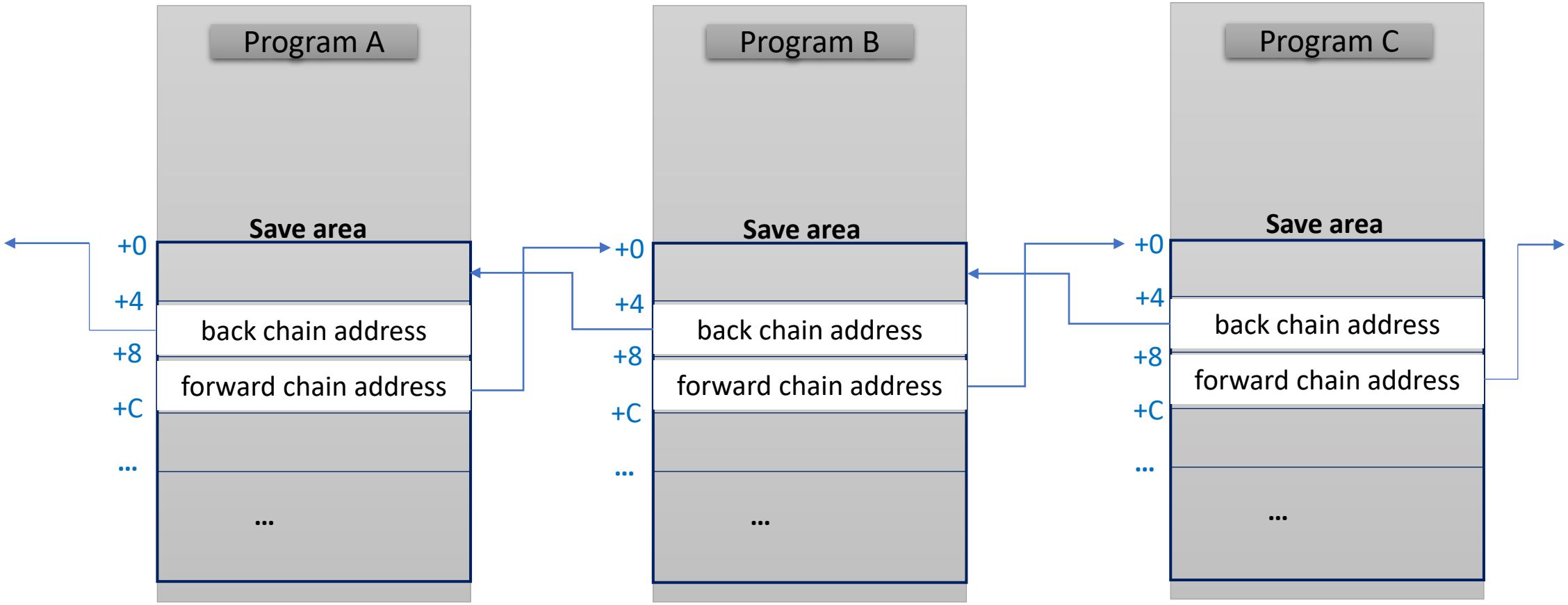
Program B saved registers; if B calls C, then C will save them here via STM R14,R12,12(R13)

Address of called Program C save area

Address of caller save area (Program A)

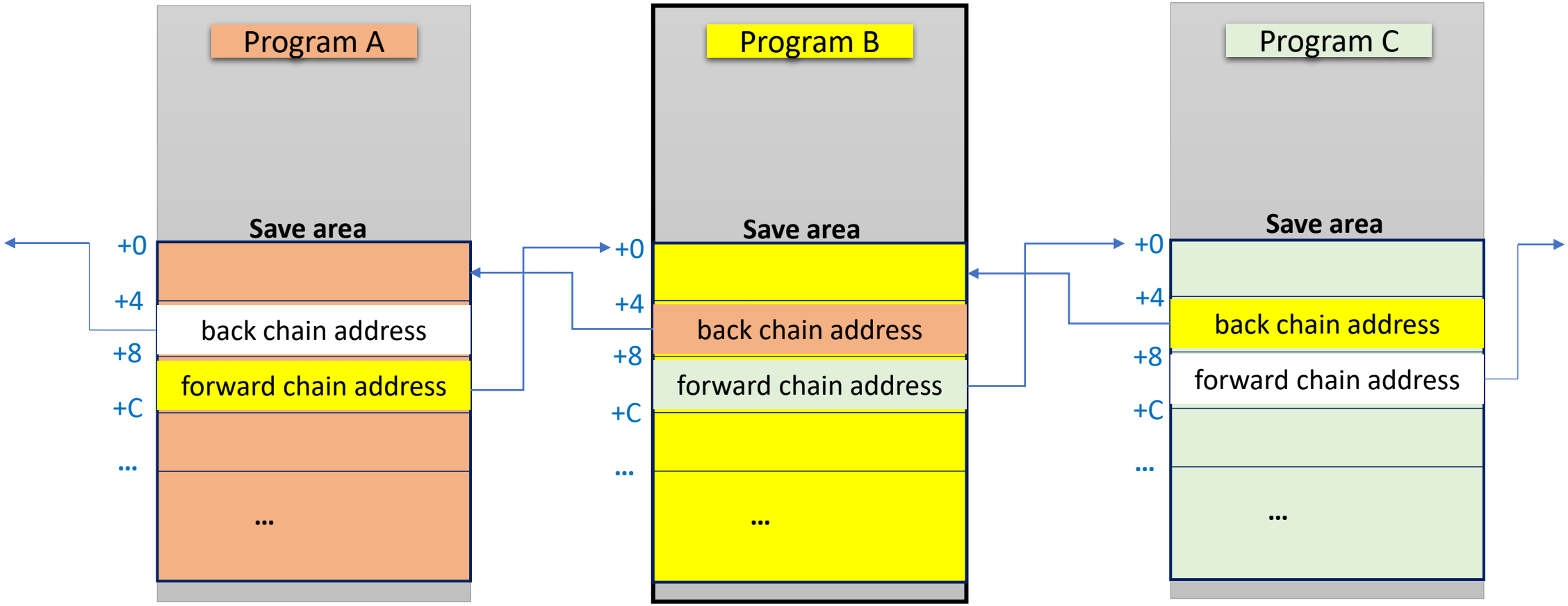
Chained save areas

Adapted from John Ehrman's book



Program B save area

Word 0	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8	Word 9	Word 10	Word 11	Word 12	Word 13	Word 14	Word 15	Word 16	Word 17
0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
Reserved	Back Chain	Forward Chain	R14	R15	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12



Linkage – Prologue Code in Program B

```
PGMB    CSECT
        STM     R14,R12,12(R13)     STM Store Multiple (a 32-bit instruction)
                                    STM saves only the low-order 32 bits of the GPRs
                                    STM takes registers R14, R15, R0, R1 ... R12 and stores them successively in 4
                                    byte full words in caller's save area (address is R13)
                                    there is an offset of 12 bytes into the A's save area
        BASR    R12,R0              stores the address immediately following BASR in R12
        USING   *,R12               establish R12 as base register
        ST      R13,SAVEAREA+4      store caller's save area address in B's save area at Word 1 (back chain)
        LR      R2,R13              copy R13 to R2 temporarily
        LA      R13,SAVEAREA        load this program's save area address in R13 for calls to C
        ST      R13,8(0,R2)         store B’s SAA in A’s SAA at Word 2; this is forward chain from A to B
```

Linkage – Epilogue Code in Program B

```
          ...
            instructions                work
          ...
              L     R13,SAVEAREA+4      retrieve address of caller's save area (Program A)
              LM  R14,R12,12(R13)       restore registers
              LA    R15,0               set return code to 0
              BR    R14                 return control to caller (Program A)
          ...
SAVEAREA   DS   18F
              LTORG *
              END PGMB
```

Example using IBM's Master The Mainframe Portal

PDS	Z51288.DATA.$JOBDECK
Member	TASM01

<u>Job card info</u>

Jobname	TASM01
Proc	HLASMCLG
Pgm Name	ASMT01
Output	G.PRINTER DD SYSOUT=*

Example using IBM's Master The Mainframe Portal

Job card

```
File  Edit  Edit_Settings  Menu  Utilities  Compilers  Test  Help

EDIT       Z51288.DATA.$JOBDECK(TASM01) - 01.01            Columns 00001 00072
Command ===>                                                Scroll ===> CSR
****** ***************************** Top of Data ******************************
000001 //TASM01 JOB  CLASS=A,NOTIFY=&SYSUID,MSGCLASS=X,MSGLEVEL=(1,1)
000002 //ASM    EXEC PROC=HLASMCLG
000003 //SYSIN  DD   *
000004          TITLE  'TASM01 - STATIC LINKAGE DEMO'
000005          PRINT  ON,NODATA,NOGEN
000006 ***************************************************************
000007 *     REGISTER EQUATES                                        *
000008 ***************************************************************
000009 R0       EQU   0
000010 R1       EQU   1
000011 R2       EQU   2
000012 R3       EQU   3
000013 R4       EQU   4
000014 R5       EQU   5
```

Prologue

```
File  Edit  Edit_Settings  Menu  Utilities  Compilers  Test  Help
EDIT       Z51288.DATA.$JOBDECK(TASM01) - 01.02          Member TASM01 saved
Command ===>                                              Scroll ===> CSR
000022 R13      EQU    13
000023 R14      EQU    14
000024 R15      EQU    15
000025 ***************************************************************
000026 *      SYMBOLIC EQUATES                                       *
000027 ***************************************************************
000028 SINGLE   EQU    X'09'       WRITE AND SPACE 1
000029 DOUBLE   EQU    X'11'       WRITE AND SPACE 2
000030 ***************************************************************
000031 ASMT01   CSECT                          STANDARD ENTRY CODE
000032          STM    R14,R12,12(R13)         STORE REGS IN CALLER'S SAA
000033          BASR   R12,R0                  ESTABLISH R12 AS BASE REG
000034          USING  *,R12
000035          ST     R13,SAVEAREA+4          SAVE CALLER'S SAA IN CURRENT SAA
000036          LR     R2,R13                  COPY R13 TO R2 TEMPORARILY
000037          LA     R13,SAVEAREA            LOAD R13 WITH CURRENT SAA
000038          ST     R13,8(R0,R2)            STORE THIS SAA IN CALLER'S SAA
000039 ***************************************************************
000040 * BEGIN THE PROGRAM LOGIC. FIRST OPEN THE INPUT AND OUTPUT FILES
000041 ***************************************************************
000042          OPEN   (PRINTER,(OUTPUT))
000043          MVI    PRC1,DOUBLE             PREPARE TO DOUBLE SPACE HEADER
000044          PUT    PRINTER,PRHEAD          PRINT THE HEADER
000045          MVI    PRC2,DOUBLE             PREPARE TO SINGLE SPACE REPORT
000046          PUT    PRINTER,PRINTLN         PRINT THE HEADER
000047 *
000048 * DISPLAY PACKED FIELDS
000049          MVI    PRCLN1,DOUBLE           DOUBLE SPACE LINE
000050          UNPK   VALUE1(6),APK           CONVERT APK FROM PACKED TO ZONED
000051          PUT    PRINTER,PRINTLN1        PRINT LINE TYPE 1
000052 *
000053          MVI    PRCLN1,SINGLE           SINGLE SPACE LINE AFTERWARDS
000054          MVC    VALUE1,VALUE1B          BLANK OUT VALUE1
000055          UNPK   VALUE1(3),BPK           MOVE 2 BYTES TO VALUE1
000056          PUT    PRINTER,PRINTLN1        PRINT LINE TYPE 1
000057 *
000058 * NOTE: DONT NEED A SINGLE SPACE MOVE TO PRINT LINE; DONE ABOVE
 F1=Help     F2=Split    F3=Exit     F4=Expand   F5=Rfind    F6=Rchange
 F7=Up       F8=Down     F9=Swap     F10=Left    F11=Right   F12=Cancel
```

SDSF Job log

```
Display  Filter  View  Print  Options  Search  Help
SDSF OUTPUT DISPLAY TASM01   JOB00459  DSID     2 LINE 0       COLUMNS 02- 81
COMMAND INPUT ===>                                            SCROLL ===> CSR
********************************* TOP OF DATA ********************************
                   J E S 2  J O B  L O G  --  S Y S T E M  S 0 W 1  --  N O D E

11.31.28 JOB00459 ---- WEDNESDAY, 01 JAN 2020 ----
11.31.28 JOB00459  IRR010I  USERID Z51288   IS ASSIGNED TO THIS JOB.
11.31.28 JOB00459  IEF677I WARNING MESSAGE(S) FOR JOB TASM01   ISSUED
11.31.28 JOB00459  ICH70001I Z51288   LAST ACCESS AT 11:28:40 ON WEDNESDAY, JANU
11.31.29 JOB00459  $HASP373 TASM01   STARTED - INIT 1    - CLASS A        - SYS
11.31.29 JOB00459  -                                    -----TIMINGS (MINS.)--
11.31.29 JOB00459  -STEPNAME PROCSTEP    RC    EXCP    CONN       TCB       SRB   C
11.31.29 JOB00459  -ASM      C           00     101      18       .00       .00
11.31.29 JOB00459  -ASM      L           00      37       8       .00       .00
11.31.29 JOB00459  -ASM      G           00      13       1       .00       .00
11.31.29 JOB00459  -TASM01   ENDED.  NAME-                      TOTAL TCB CPU TIM
11.31.29 JOB00459  $HASP395 TASM01   ENDED - RC=0000
------ JES2 JOB STATISTICS ------
  01 JAN 2020 JOB EXECUTION DATE
           133 CARDS READ
           597 SYSOUT PRINT RECORDS
             0 SYSOUT PUNCH RECORDS
            46 SYSOUT SPOOL KBYTES
          0.01 MINUTES EXECUTION TIME
        1 //TASM01 JOB  CLASS=A,NOTIFY=&SYSUID,MSGCLASS=X,MSGLEVEL=(1,1)
          IEFC653I SUBSTITUTION JCL - CLASS=A,NOTIFY=Z51288,MSGCLASS=X,MSGLEVEL=
        2 //ASM    EXEC PROC=HLASMCLG
        3 XXASMACLG  PROC
          XX*
          XX*******************************************************************
          XX*
          XX*  Licensed Materials - Property of IBM
          XX*
          XX*  5696-234   5694-A01
          XX*
          XX*  Copyright IBM Corporation 1992, 2008 All Rights Reserved.
          XX*
          XX*  US Government Users Restricted Rights - Use, duplication
          XX*  or disclosure restricted by GSA ADP Schedule Contract
F1=HELP      F2=SPLIT     F3=END      F4=RETURN    F5=IFIND     F6=BOOK
```

```
Display  Filter  View  Print  Options  Search  Help
-------------------------------------------------------------------------------
SDSF STATUS DISPLAY ALL CLASSES                          LINE 1-2 (2)
COMMAND INPUT ===>                                          SCROLL ===> CSR
NP   JOBNAME  JobID    Owner    Prty Queue      C  Pos  SAff  ASys Status
?    TASM01   JOB00459 Z51288      1 PRINT      A  1456
     Z51288   TSU00457 Z51288     15 EXECUTION           S0W1  S0W1
```

SDSF Step Name

```
Display  Filter  View  Print  Options  Search  Help
-------------------------------------------------------------------------------
SDSF JOB DATA SET DISPLAY - JOB TASM01   (JOB00459)    LINE 1-6 (6)
COMMAND INPUT ===>                                          SCROLL ===> CSR
NP   DDNAME   StepName ProcStep DSID Owner    C Dest                Rec-Cnt Page
     JESMSGLG JES2                  2 Z51288   X LOCAL                    21
     JESJCL   JES2                  3 Z51288   X LOCAL                    53
     JESYSMSG JES2                  4 Z51288   X LOCAL                    72
     SYSPRINT ASM      C          102 Z51288   X LOCAL                   285
     SYSPRINT ASM      L          103 Z51288   X LOCAL                   153
S    PRINTER  ASM      G          106 Z51288   X LOCAL                     5
```

SDSF PRINTER Output

```
 Display  Filter  View  Print  Options  Search  Help
 ------------------------------------------------------------------------------
 SDSF OUTPUT DISPLAY TASM01   JOB00459  DSID   106 LINE 0       COLUMNS 02- 81
 COMMAND INPUT ===>                                            SCROLL ===> CSR
********************************* TOP OF DATA *********************************
          *** HLASM TESTING DS AND DC COMMANDS ***
          PRINTLN: DATAPR STARTS HERE
          PACKED DECIMAL FIELDS:    01234E
          PACKED DECIMAL FIELDS:    34E
          PACKED DECIMAL FIELDS:    1234E
******************************** BOTTOM OF DATA ********************************
```

Summary

Static Linkage, non-reentrant, no recursion

24-bit or 31-bit addressing mode

Status preservation – ensuring nothing important is lost, modified, or destroyed in the process

Summary (cont.)

When working with standard linkage convention in z/OS, and dealing with 24- and 31-bit addressing mode (i.e. 32-bit registers), then

general registers 2 through 14 (R2-R14) must be saved by the callee and restored to their original values before control is returned to the caller.

Linkage – other topics

- 64-bit addressing mode & Format-4 save areas
- Program interaction in mixed more and Format-5 save areas
- Entry point identifiers
- Calling point identifiers
- Save area return flags
- Return codes
- Floating-point register conventions
- Assisted linkage
- Argument passing (variable length argument lists)

Presentation and JCL

https://github.com/MannyASM/HLASM_CallingConventions_StaticLinkage

Presentation	0001_HLASM_CallingConventions_StaticLinkage.pptx
JCL	ASM_TASM01_JOB_MTM.txt

OTHER REFERENCES

Redbooks

http://www.redbooks.ibm.com/

z/OS Library v2R4

https://www-01.ibm.com/servers/resourcelink/svc00100.nsf/pages/zOSV2R4Library

Manuals

z/OS ISPF User's Guide Vol I, z/OS ISPF User's Guide Vol II
z/OS MVS JCL User's Guide
z/OS SDSF User's Guide
z/OS MVS Data Areas Volume 1 (ABE - IAR)
z/OS MVS Data Areas Volume 2 (IAX - ISG)
z/OS MVS Data Areas Volume 3 (ITK - RQE)
z/OS MVS Data Areas Volume 4 (RRP - XTL)

Moshix Mainframe Channel

https://www.youtube.com/channel/UCR1ajTWGiUtiAv8X-hpBY7w

OTHER REFERENCES (cont.)

IDCP – Institute for Data Center Professionals

http://idcp.marist.edu/enterprisesystemseducation/zos_program_overview/assemblerprogrammingcertificate.html

Northern Illinois University

http://faculty.cs.niu.edu/~byrnes/csci360/notes.html

IBM Master The Mainframe

https://masterthemainframe.com/ (students)

https://www-01.ibm.com/events/wwe/ast/mtm/audit.nsf/enrollall (non-students)