HLASM
IBM's High Level Assembler

Calling Conventions
Static Linkage
24- 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
- *Assembler Language Programming for IBM System z™ Servers*, 2nd edition 2016, by John Ehrman
- *Basic IBM Mainframe Assembly Language Programming,* by Kevin C. O Kane

Question

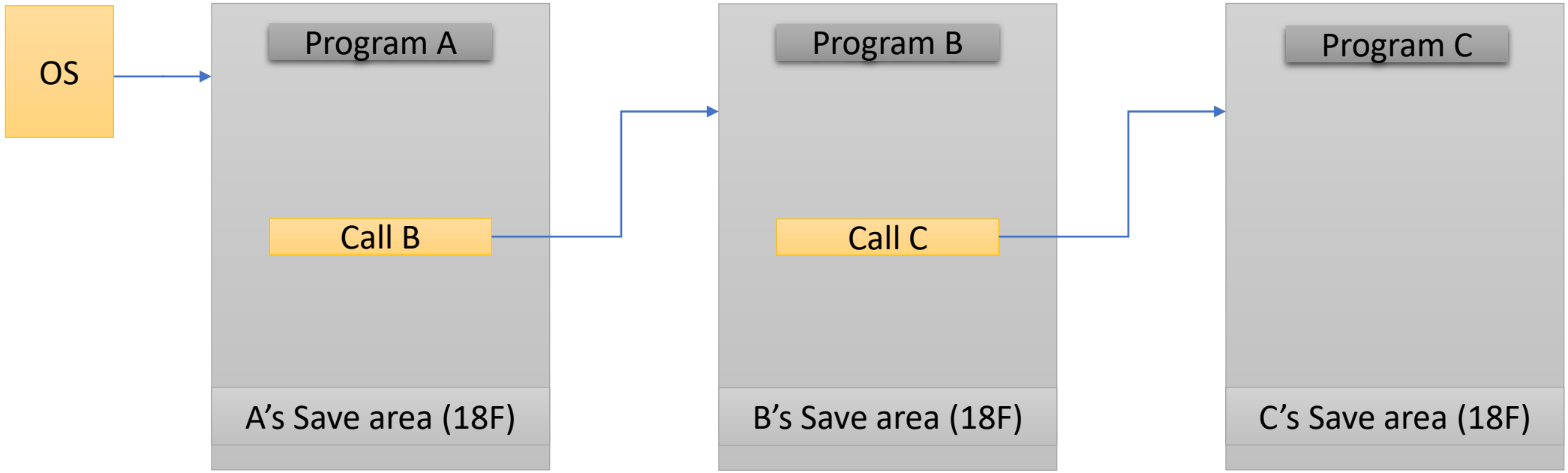
How do we preserve states when control is passed from a program to another program?

Scope Code written with static save areas and linkage

Programs that have static areas defined internally

Rentrant programs / recursion are out of scope

Program A calls Program B, and Program B calls C



The Calling Process - Roles

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

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: caller or callee

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 callee must save and restore the caller's register.

Concept the callee 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) ---> Callee (B)

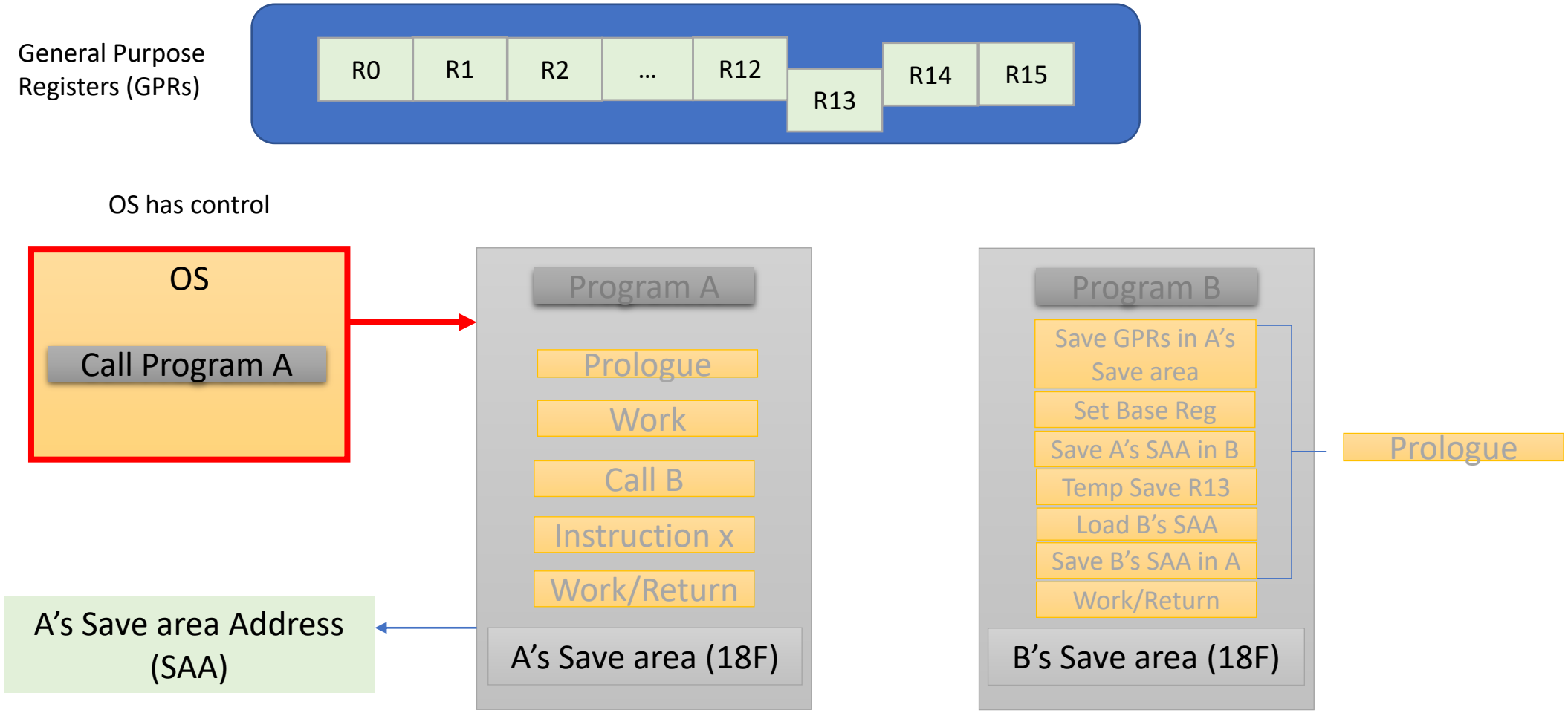
Program A calls B
Program B saves A's registers in A's save area (register preservation)
Program B stores A’s save area address in its own save area (B to A chain)
Program B stores its save area address in A’s save area (A to B chain)
Program B sets a base register and performs is work (local addressability)
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)

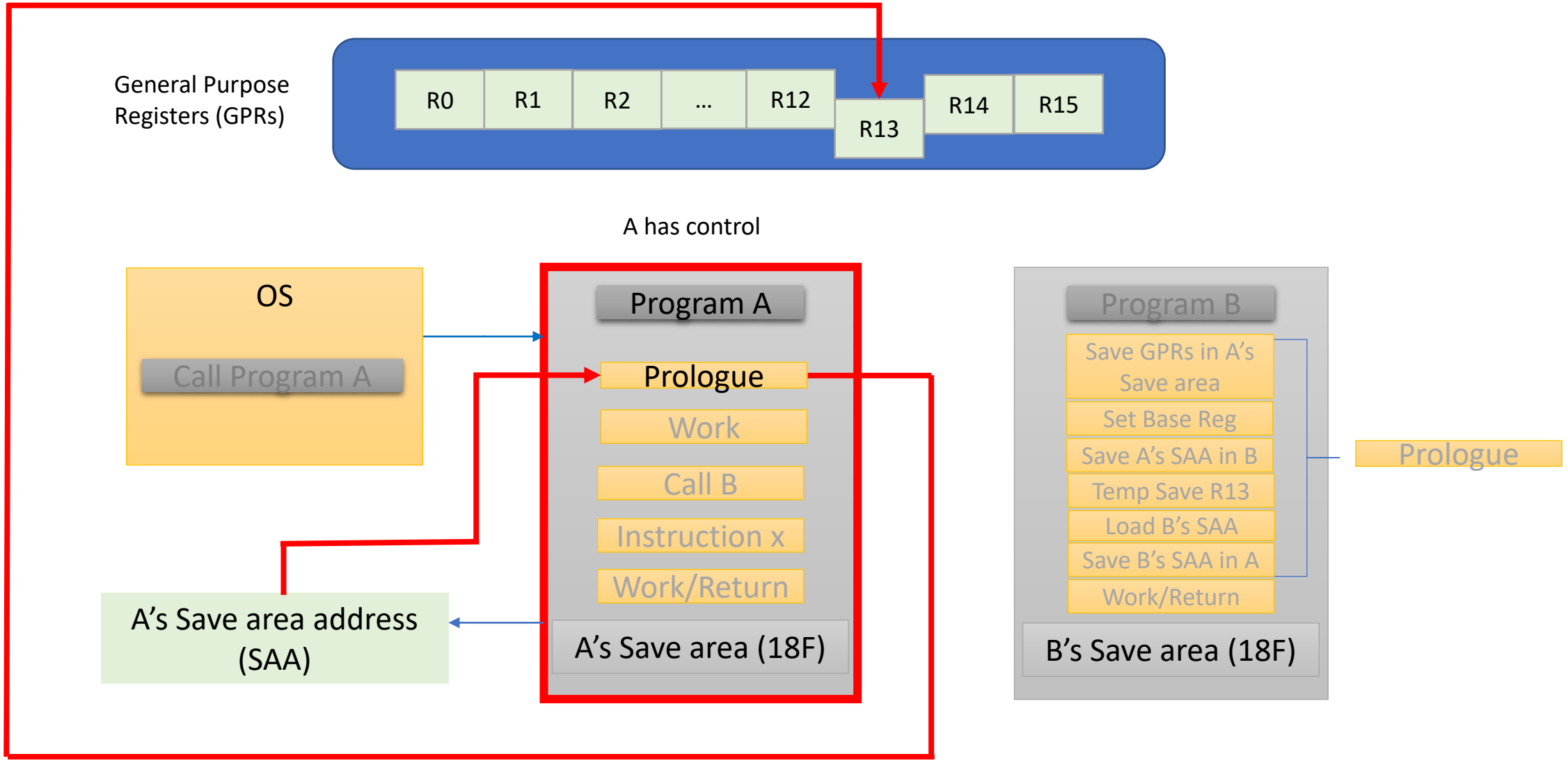
Linkage – Registers convention

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

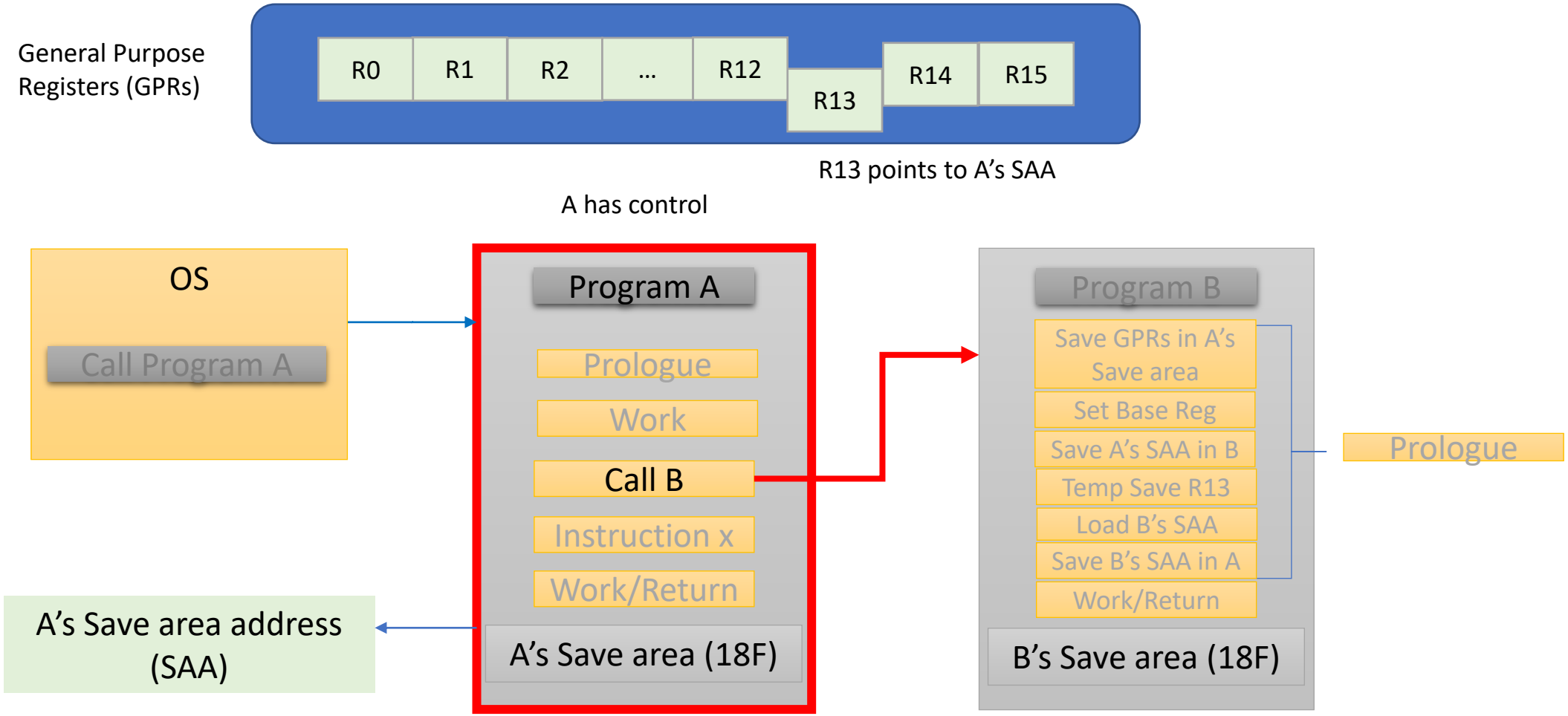
OS Calls Program A



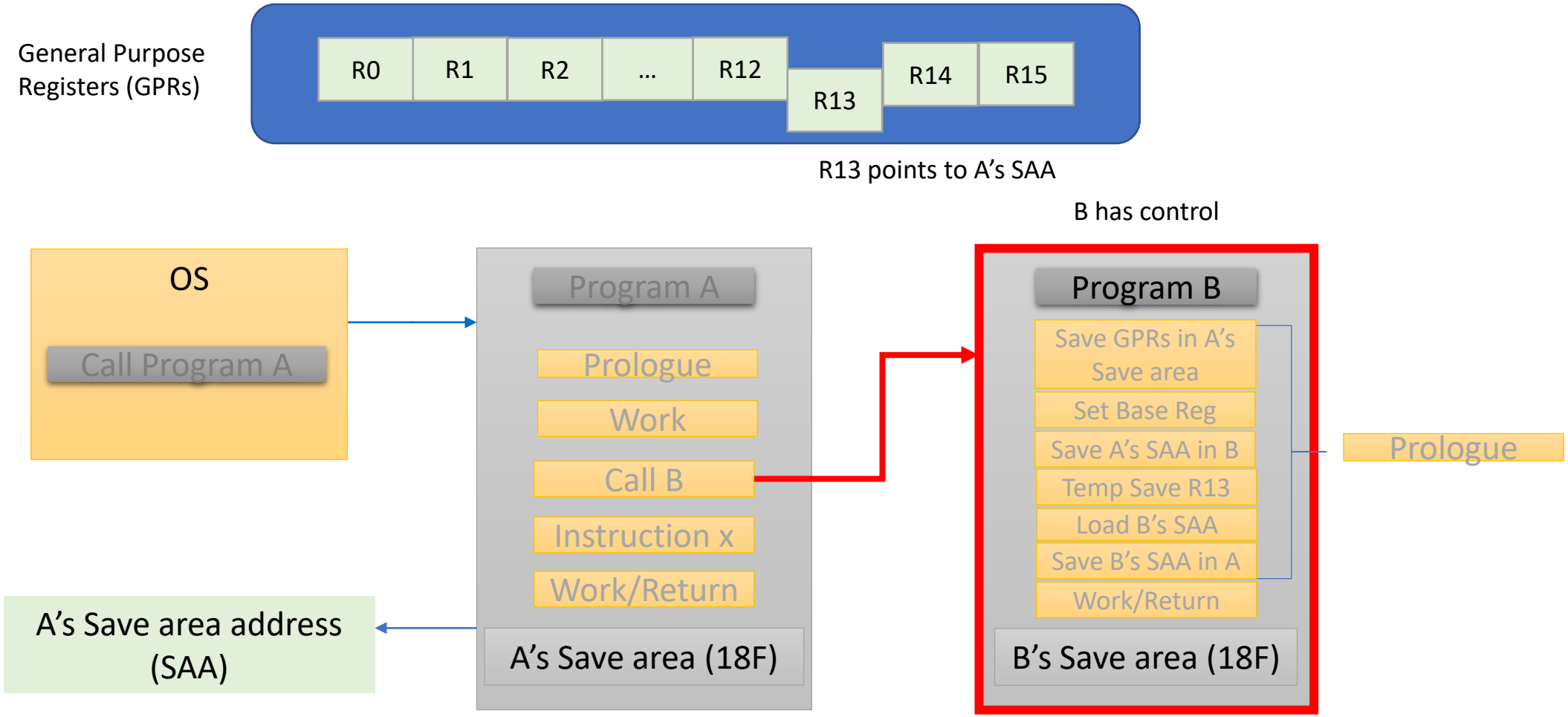
Program A completes its Prologue

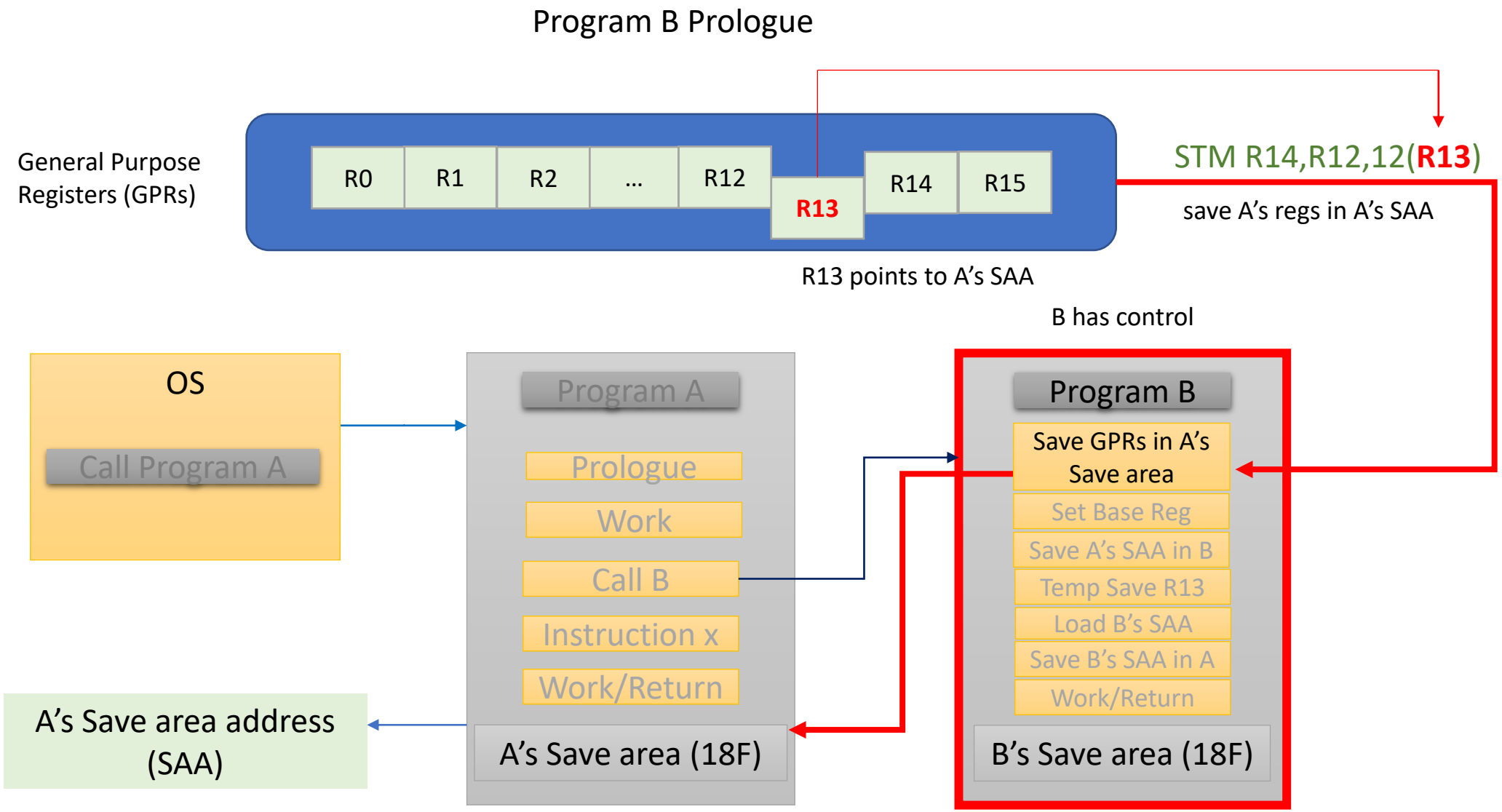


Program A calls Program B



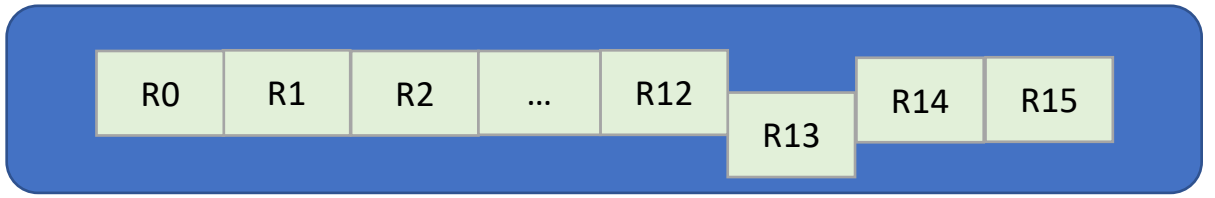
Program B Prologue




Program B Prologue
General Purpose Registers (GPRs)
R0
R1
R2
...
R12
R13
R14
R15
STM R14,R12,12(R13)
save A's regs in A's SAA
R13 points to A's SAA
B has control
OS
Call Program A
Program A
Prologue
Work
Call B
Instruction x
Work/Return
A's Save area (18F)
A's Save area address (SAA)
Program B
Save GPRs in A's Save area
Set Base Reg
Save A's SAA in B
Temp Save R13
Load B's SAA
Save B's SAA in A
Work/Return
B's Save area (18F)

Program B Prologue

General Purpose Registers (GPRs)

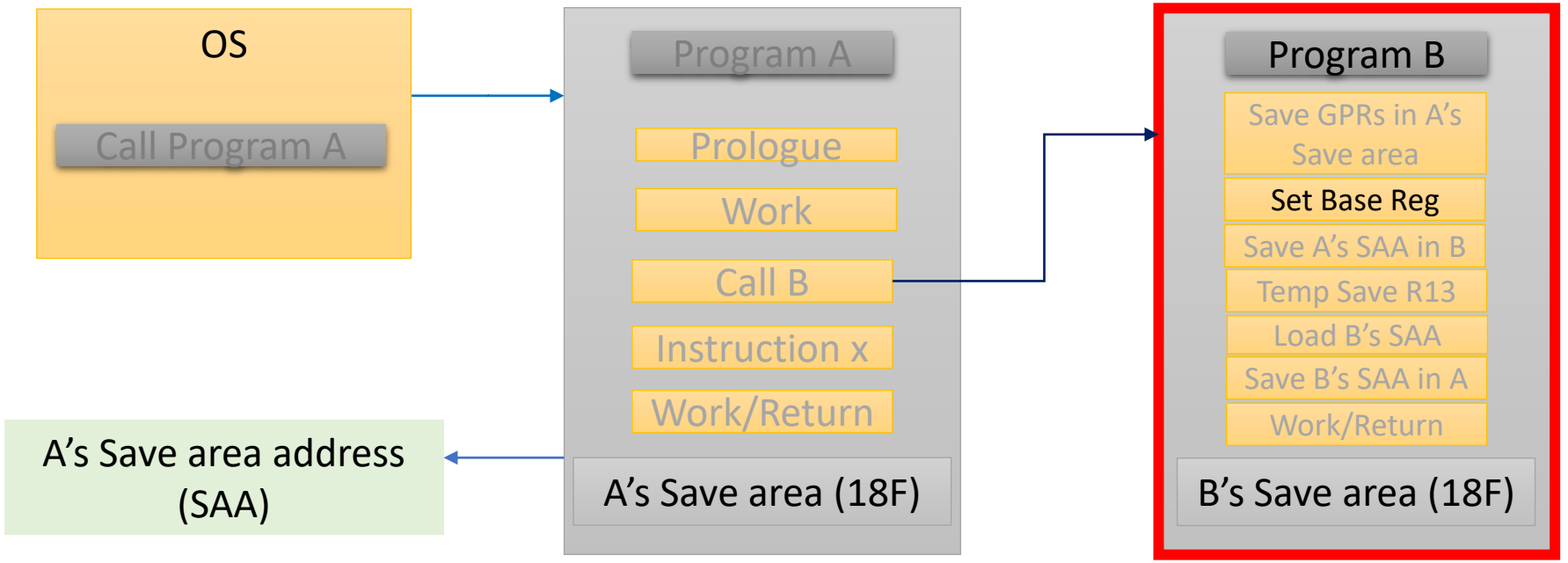


BASR R12,R0 [*]
USING *,R12

establish a base register in B

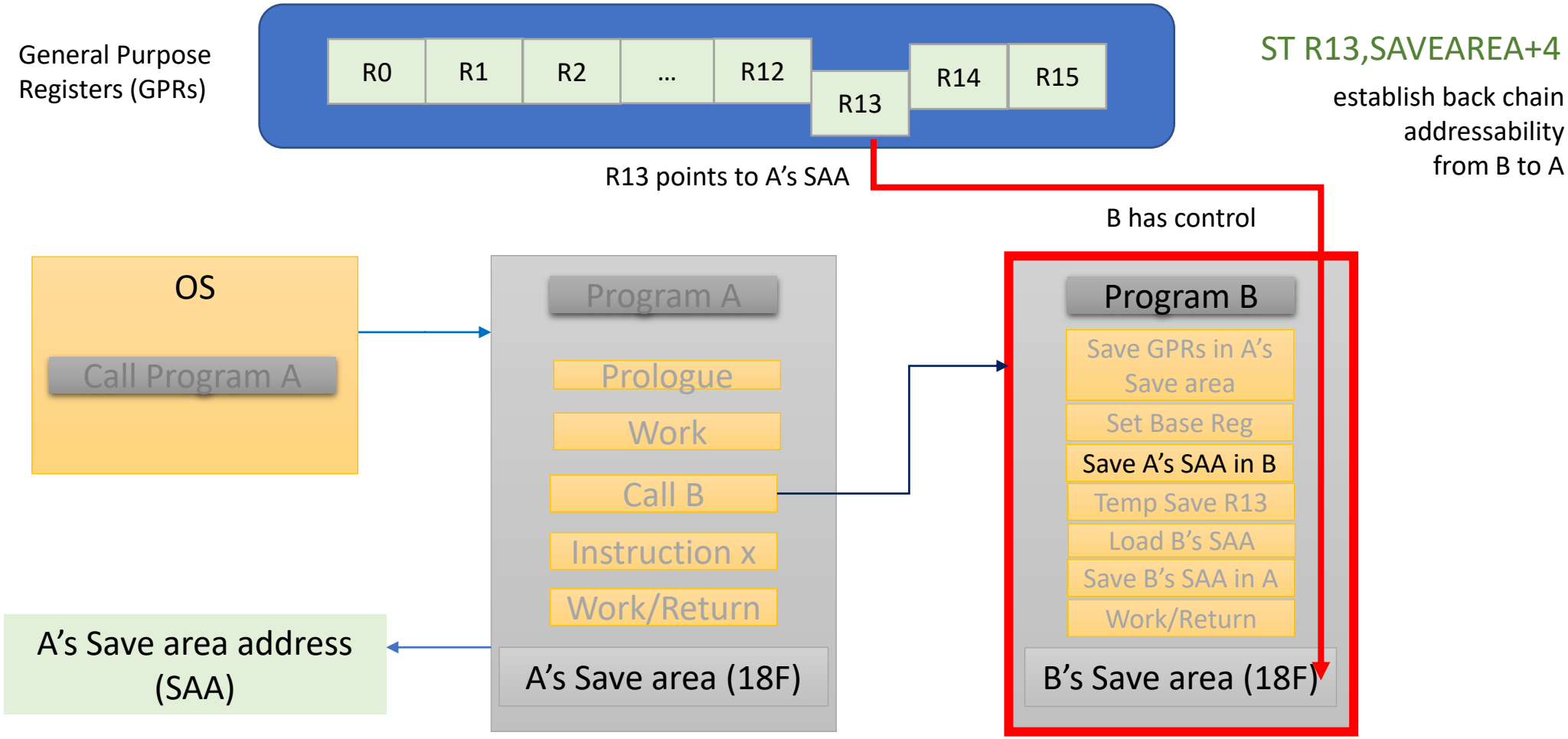
R13 points to A's SAA

B has control

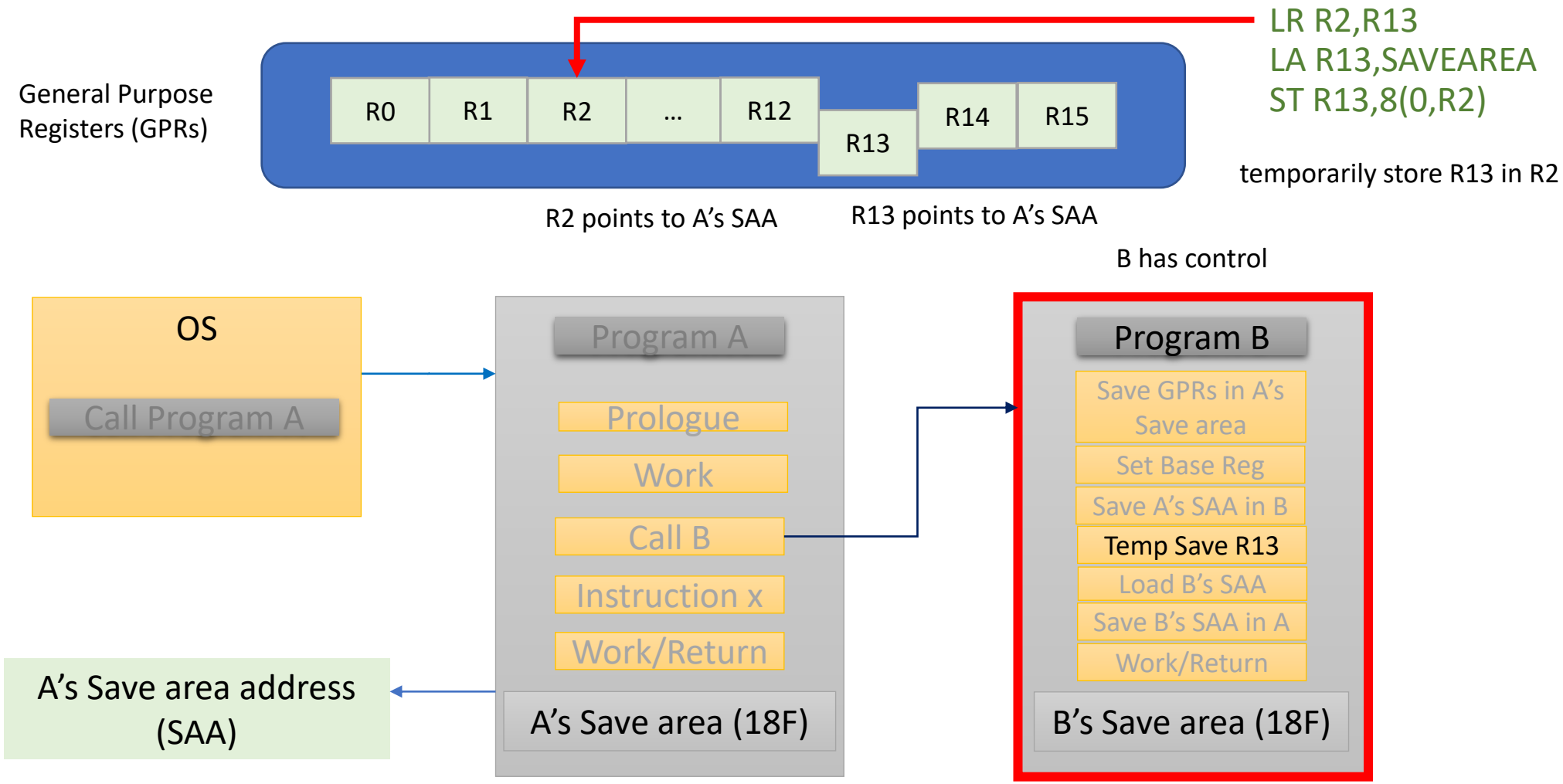


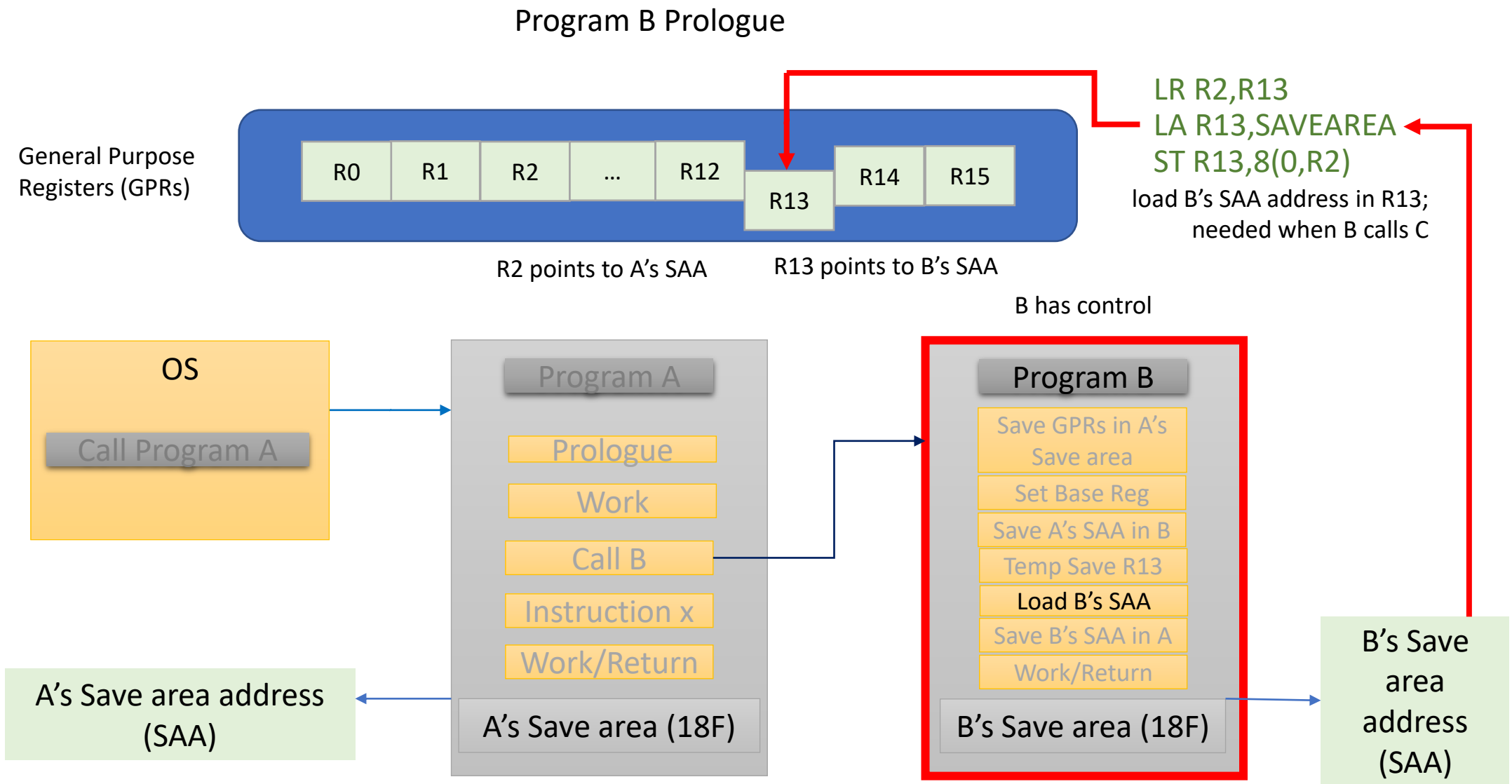
[*] see **z Architecture Principles of Operation**, Appendix A for Linkage Instructions (BAL, BALR, BAS, BASR, BASSM, BSM)

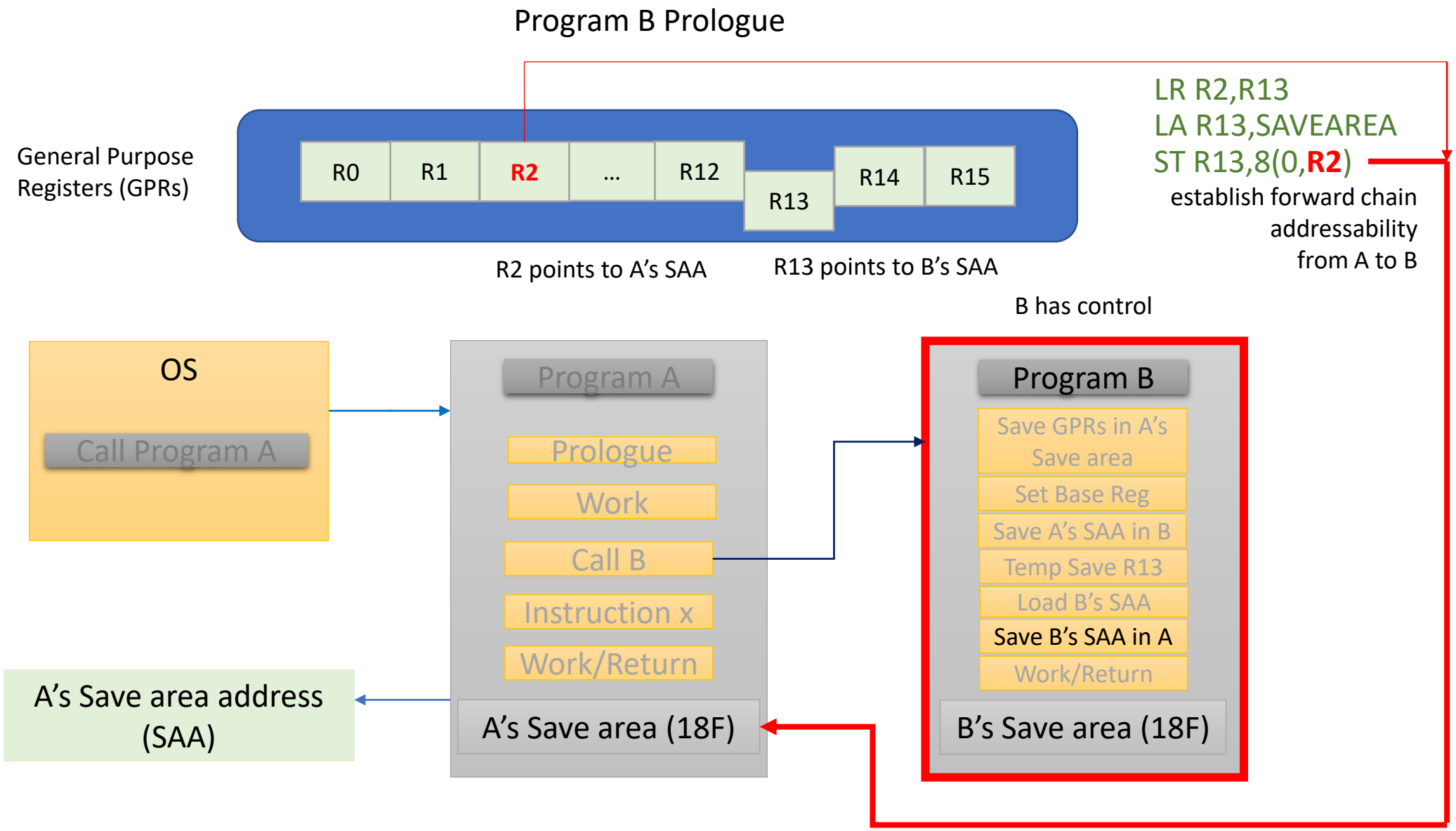
Program B Prologue



Program B Prologue

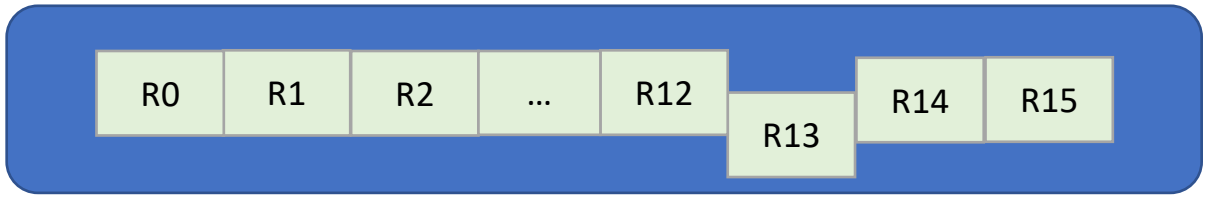



Program B Prologue
General Purpose Registers (GPRs)
R0
R1
R2
...
R12
R13
R14
R15
LR R2,R13
LA R13,SAVEAREA
ST R13,8(0,R2)
load B's SAA address in R13; needed when B calls C
R2 points to A's SAA
R13 points to B's SAA
B has control
OS
Call Program A
Program A
Prologue
Work
Call B
Instruction x
Work/Return
A's Save area (18F)
A's Save area address (SAA)
Program B
Save GPRs in A's Save area
Set Base Reg
Save A's SAA in B
Temp Save R13
Load B's SAA
Save B's SAA in A
Work/Return
B's Save area (18F)
B's Save area address (SAA)

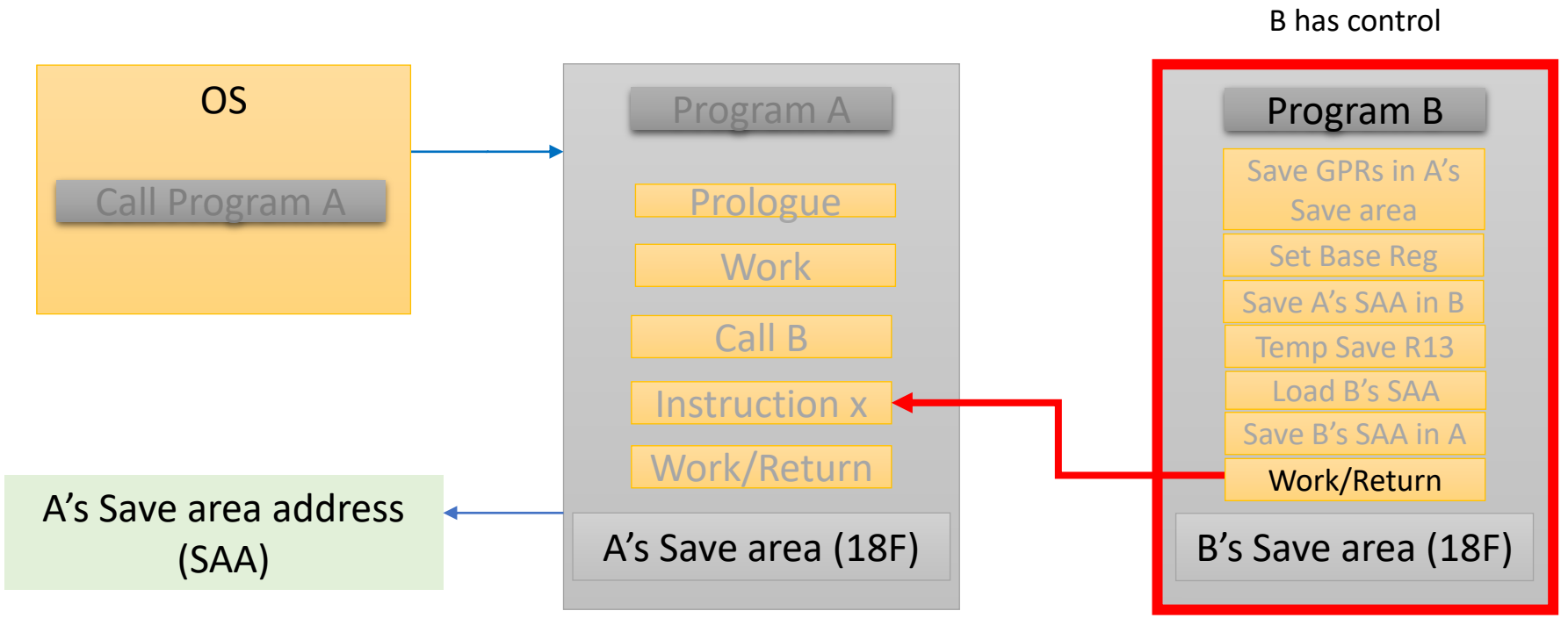

Program B Prologue
General Purpose Registers (GPRs)
R0
R1
R2
...
R12
R13
R14
R15
R2 points to A's SAA
R13 points to B's SAA
LR R2,R13
LA R13,SAVEAREA
ST R13,8(0,R2)
establish forward chain addressability from A to B
B has control
OS
Call Program A
Program A
Prologue
Work
Call B
Instruction x
Work/Return
A's Save area (18F)
A's Save area address (SAA)
Program B
Save GPRs in A's Save area
Set Base Reg
Save A's SAA in B
Temp Save R13
Load B's SAA
Save B's SAA in A
Work/Return
B's Save area (18F)

Program B Epilogue (i.e. Return)

General Purpose Registers (GPRs)



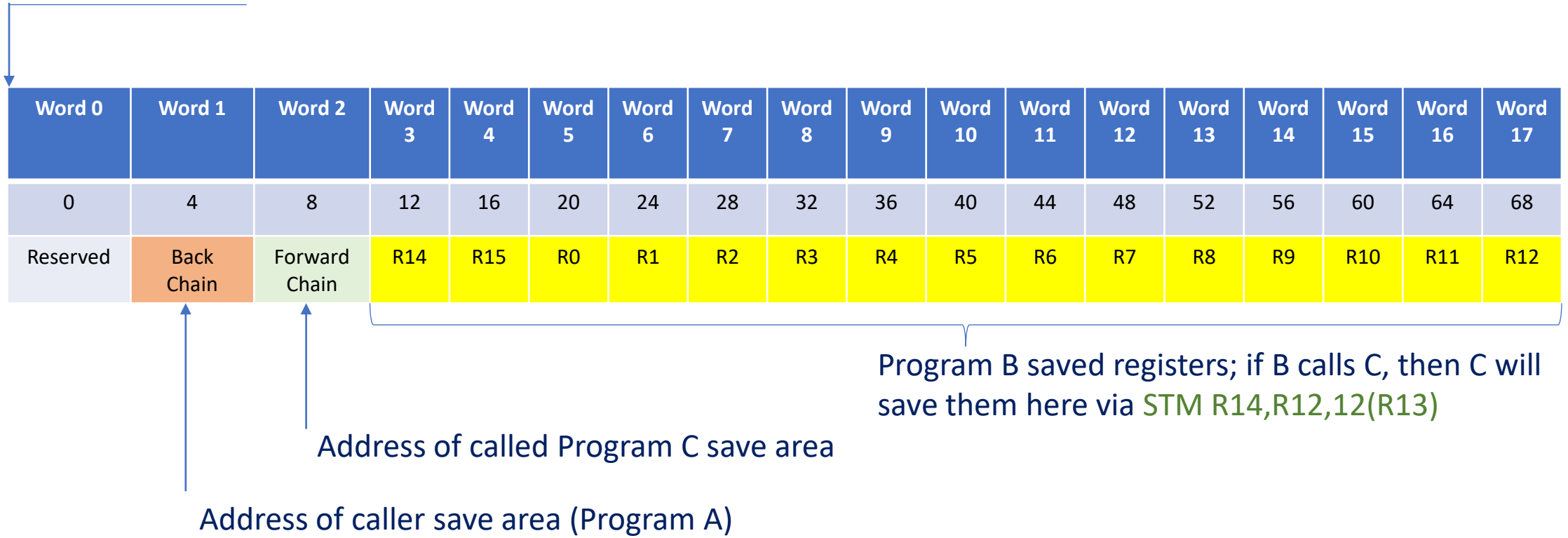

```
L     R13,SAVEAREA+4
LM    R14,R12,12(R13)
LA    R15,0
BR    R14
```



Save area in Program B

SAVEAREA DS 18F

18 fullwords (18x4 bytes = 72 bytes)



Save area in Program B

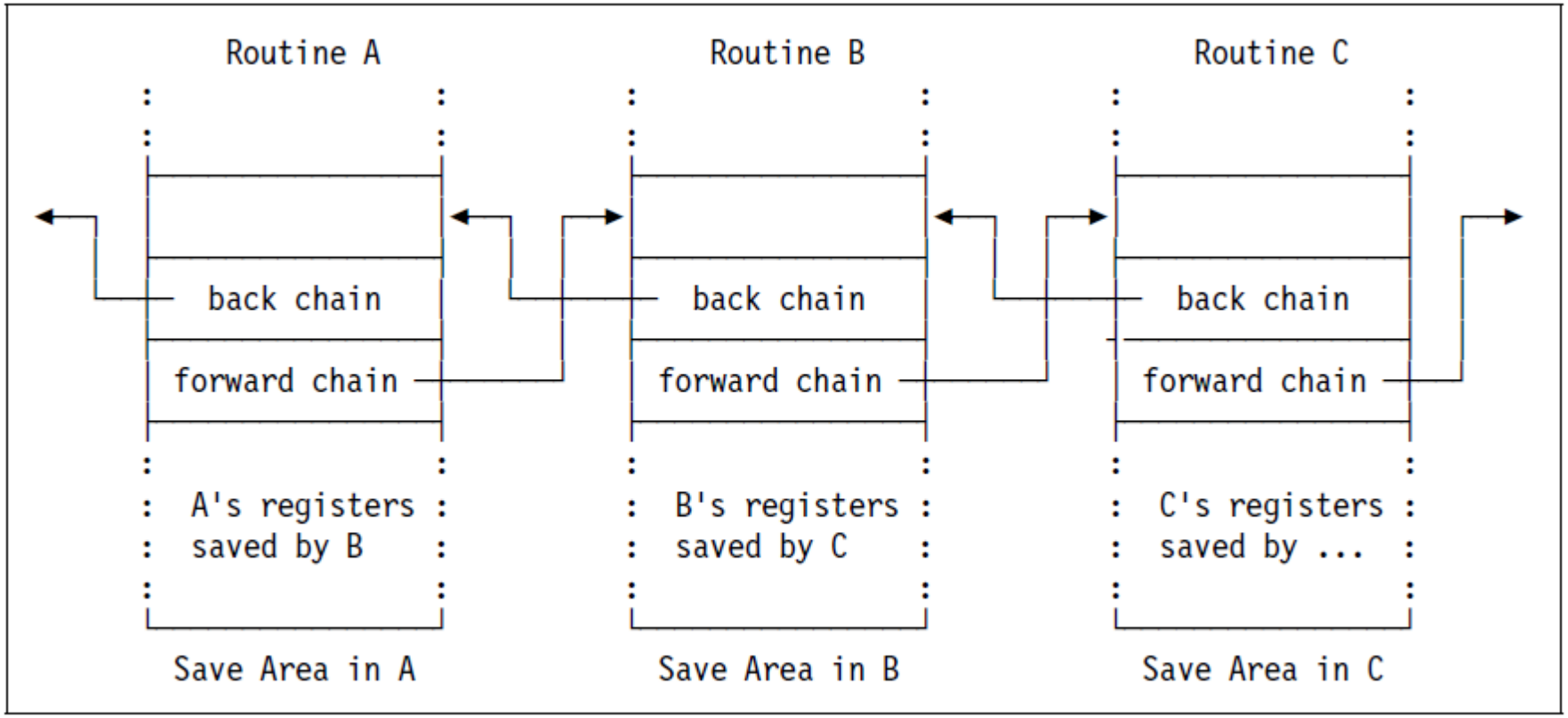


Figure 499. Chained save areas

Source: John Ehrman's book

Save area in Program B

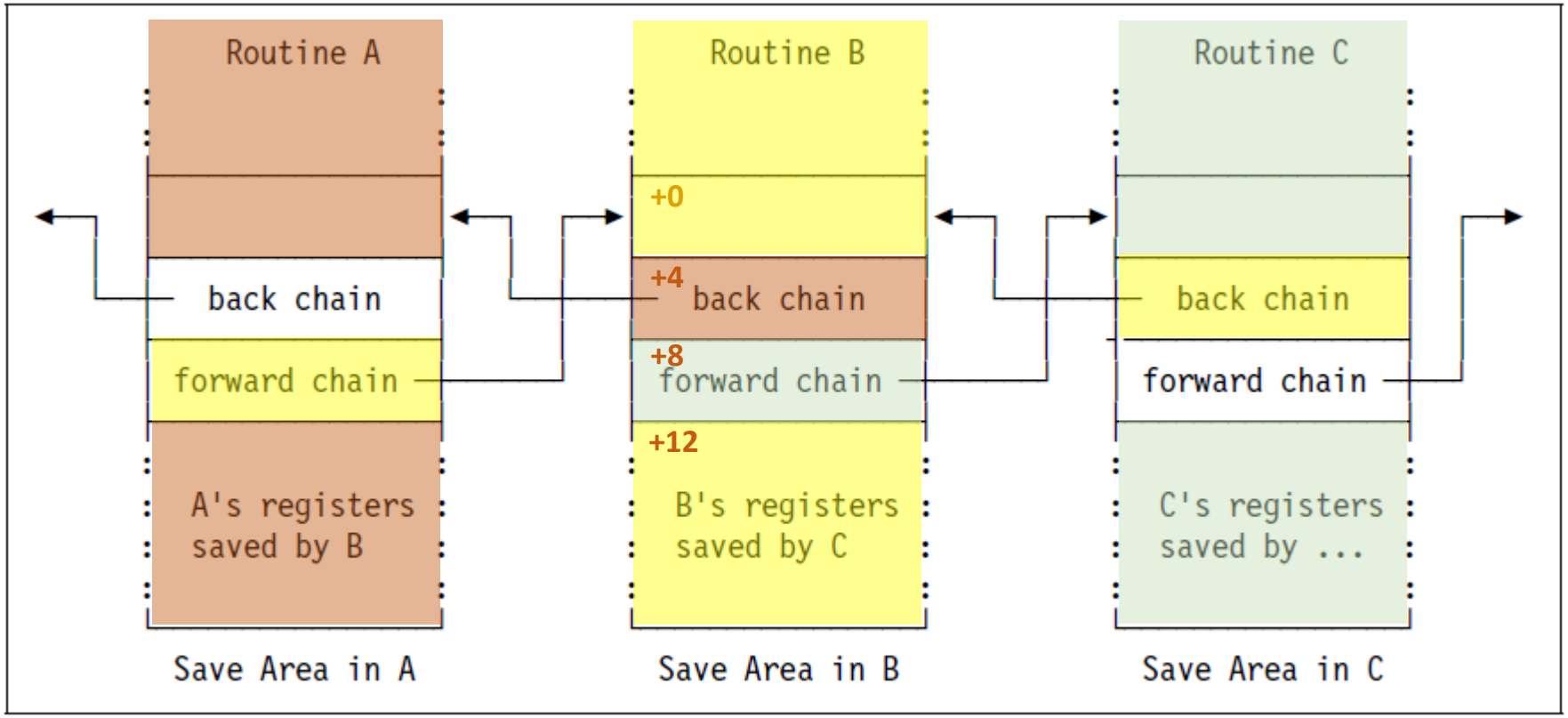


Figure 499. Chained save areas

Source: John Ehrman's book

Linkage – Prologue Code in Program B

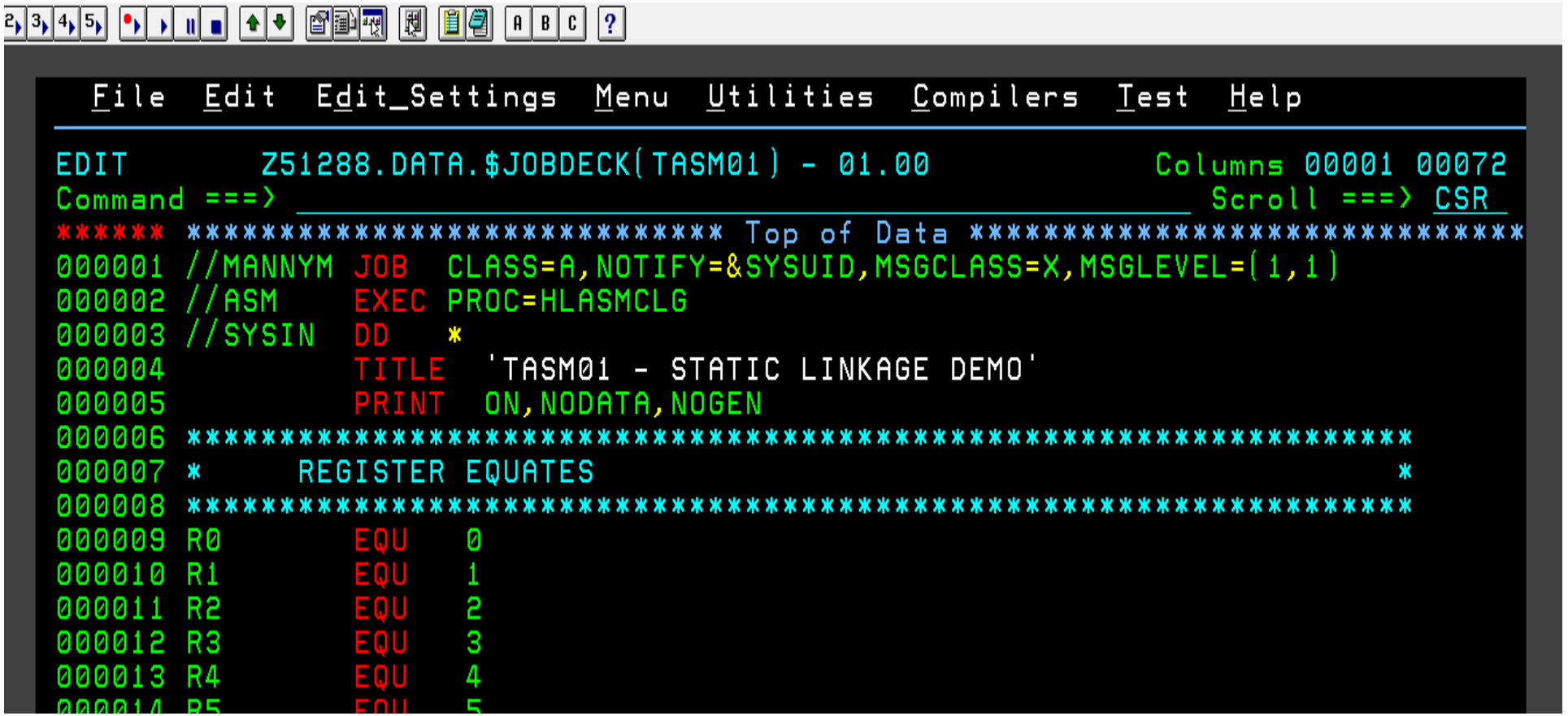
```
PGMB    CSECT
        STM     R14,R12,12(R13)   STM Store Multiple (a 32-bit instruction)
                                  STM saves only the low-order 32 bits of the GPRs
                                  STM takes registers R14, R15, R0, R1 ... R12 and stores them successively in 4
                                  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

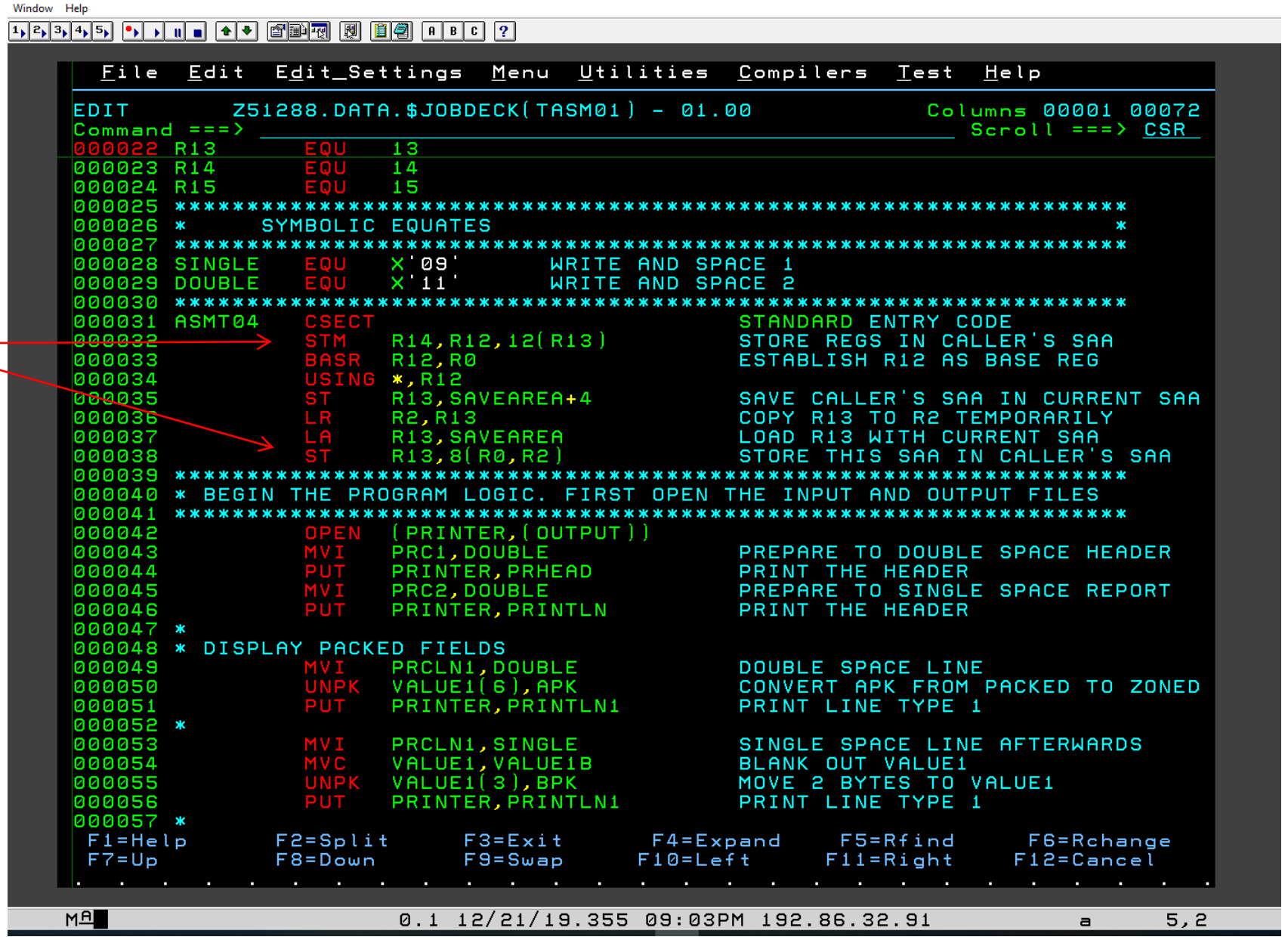
```
            ...
              instructions                work
            ...
               L     R13,SAVEAREA+4     retrieve address of caller's save area (Program A)
               LM  R14,R12,12(R13)      restore registers
               LA    R15,0              set return code to 0
       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

Example using IBM's Master The Mainframe Portal

Job card

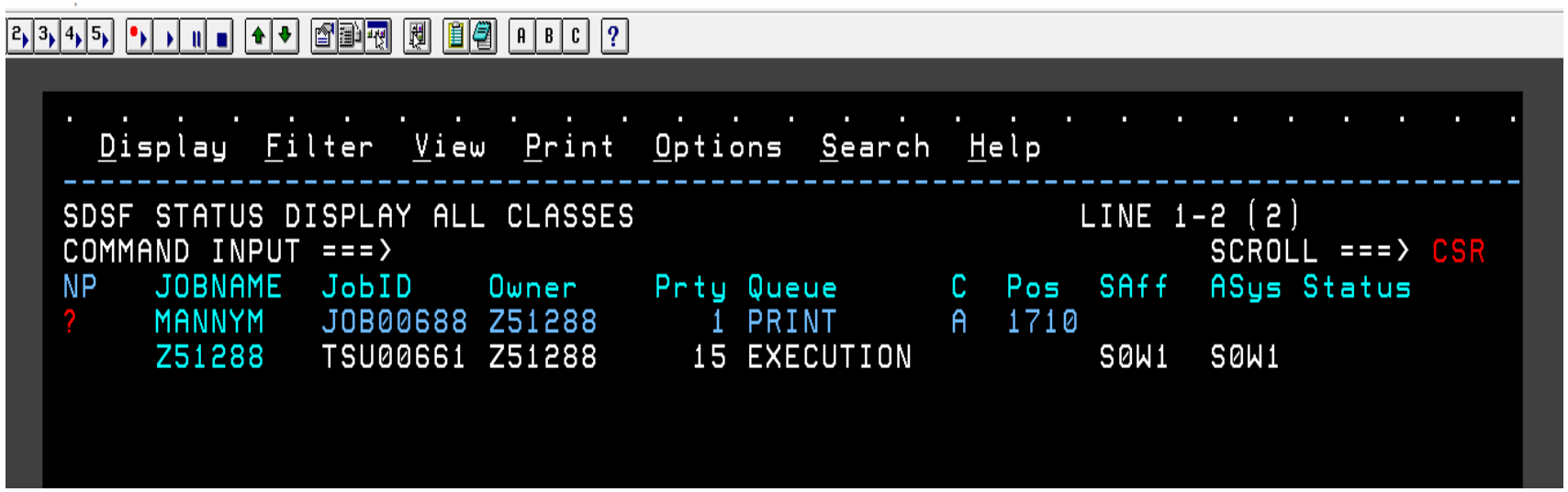


Prologue

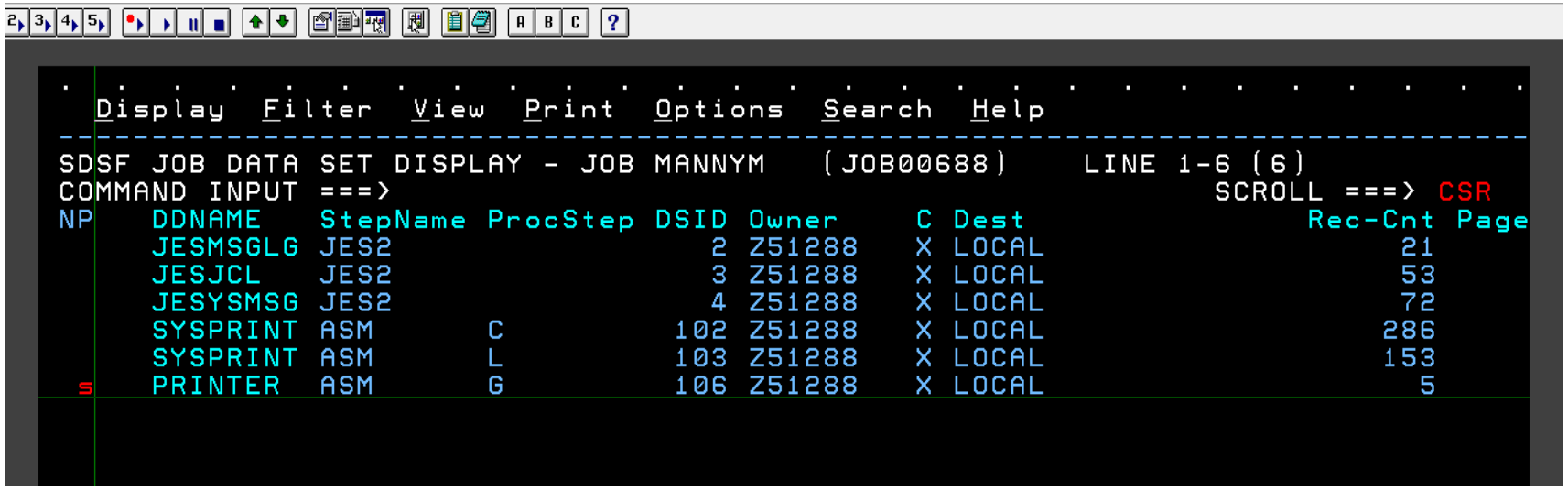

Window Help
File Edit Edit_Settings Menu Utilities Compilers Test Help
EDIT Z51288.DATA.$JOBDECK(TASM01) - 01.00 Columns 00001 00072
Command ===> Scroll ===> CSR
000022 R13 EQU 13
000023 R14 EQU 14
000024 R15 EQU 15
000025 **
000026 * SYMBOLIC EQUATES *
000027 **
000028 SINGLE EQU X'09' WRITE AND SPACE 1
000029 DOUBLE EQU X'11' WRITE AND SPACE 2
000030 **
000031 ASMT04 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 *
F1=Help F2=Split F3=Exit F4=Expand F5=Rfind F6=Rchange
F7=Up F8=Down F9=Swap F10=Left F11=Right F12=Cancel
MA 0.1 12/21/19.355 09:03PM 192.86.32.91 a 5,2

SDSF Job log

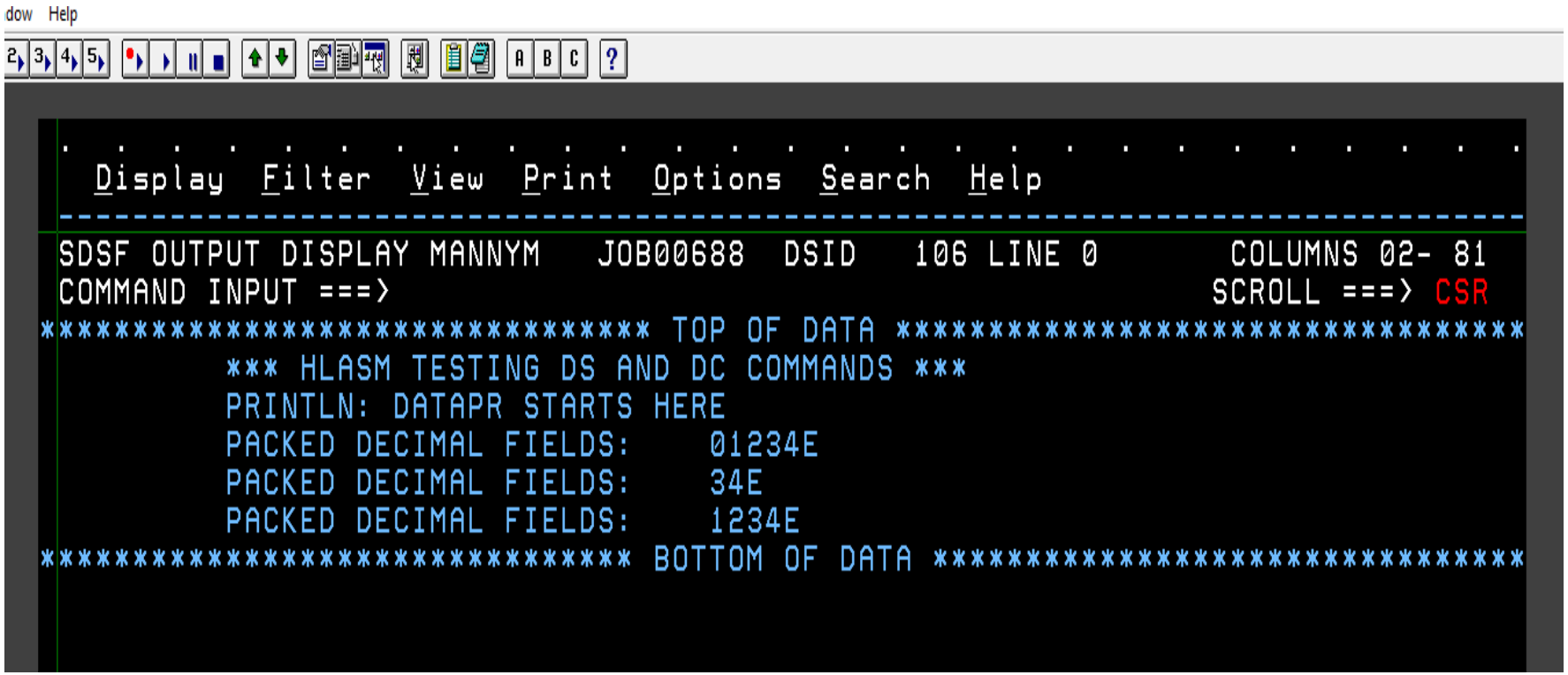

Window Help
Display Filter View Print Options Search Help
SDSF OUTPUT DISPLAY MANNYM JOB00688 DSID 2 LINE 0 COLUMNS 02- 81
COMMAND INPUT ===> SCROLL ===> CSR
TOP OF DATA
J E S 2 J O B L O G -- S Y S T E M S 0 W 1 -- N O D E
19.57.58 JOB00688 ---- SATURDAY, 21 DEC 2019 ----
19.57.58 JOB00688 IRR010I USERID Z51288 IS ASSIGNED TO THIS JOB.
19.57.58 JOB00688 IEF677I WARNING MESSAGE(S) FOR JOB MANNYM ISSUED
19.57.58 JOB00688 ICH70001I Z51288 LAST ACCESS AT 19:51:34 ON SATURDAY, DECEM
19.57.58 JOB00688 $HASP373 MANNYM STARTED - INIT 1 - CLASS A - SYS
19.57.59 JOB00688 - -----TIMINGS (MINS.)--
19.57.59 JOB00688 -STEPNAME PROCSTEP RC EXCP CONN TCB SRB C
19.57.59 JOB00688 -ASM C 00 103 19 .00 .00
19.57.59 JOB00688 -ASM L 00 37 8 .00 .00
19.57.59 JOB00688 -ASM G 00 13 1 .00 .00
19.57.59 JOB00688 -MANNYM ENDED. NAME- TOTAL TCB CPU TIM
19.57.59 JOB00688 $HASP395 MANNYM ENDED - RC=0000
------ JES2 JOB STATISTICS ------
21 DEC 2019 JOB EXECUTION DATE
134 CARDS READ
598 SYSOUT PRINT RECORDS
0 SYSOUT PUNCH RECORDS
46 SYSOUT SPOOL KBYTES
0.01 MINUTES EXECUTION TIME
1 //MANNYM 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
F1=HELP F2=SPLIT F3=END F4=RETURN F5=IFIND F6=BOOK



SDSF
Step Name



SDSF PRINTER Output



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)