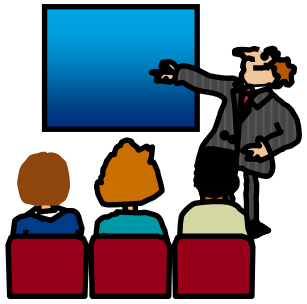
Slowed down by LE? Perhaps the CEEPIPI service can help!

Thomas Petrolino
IBM Poughkeepsie
tapetro@us.ibm.com



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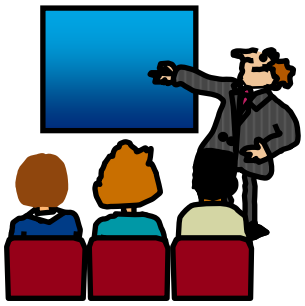
Agenda

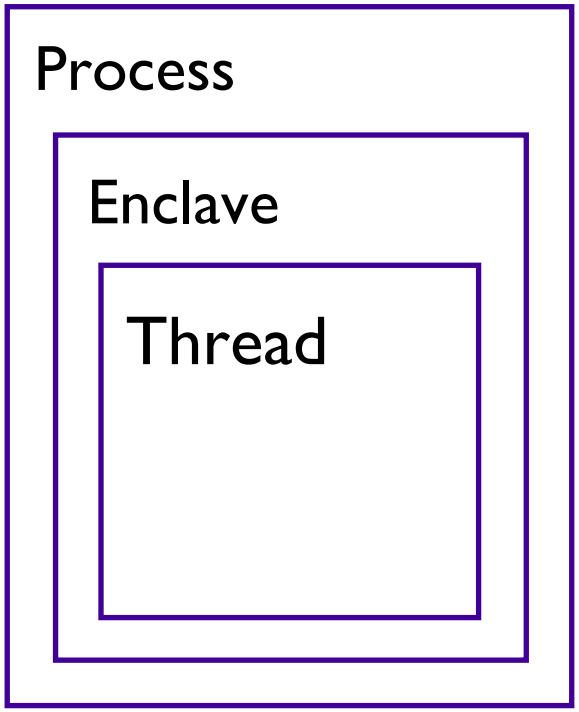
- Understanding The Basics of PreInitialization
- Writing a Preinit Application
- Other Preinit Topics
- A Preinit Example
- Sources of Additional Information

Understanding The Basics of PreInitialization



Background - LE Init/Term

- Process - Collection of Resources (LE message file, library code/data)
  - unaffected by HLL semantics, logically independent address space
- Enclave - Collection of Routines (Load modules, Heap, external data)
  - defines scope of HLL semantics, first routine is designated "main"
- Thread - "thread" of execution (Stack, raised conditions)
  - share the resources of the enclave



Understanding The Basics

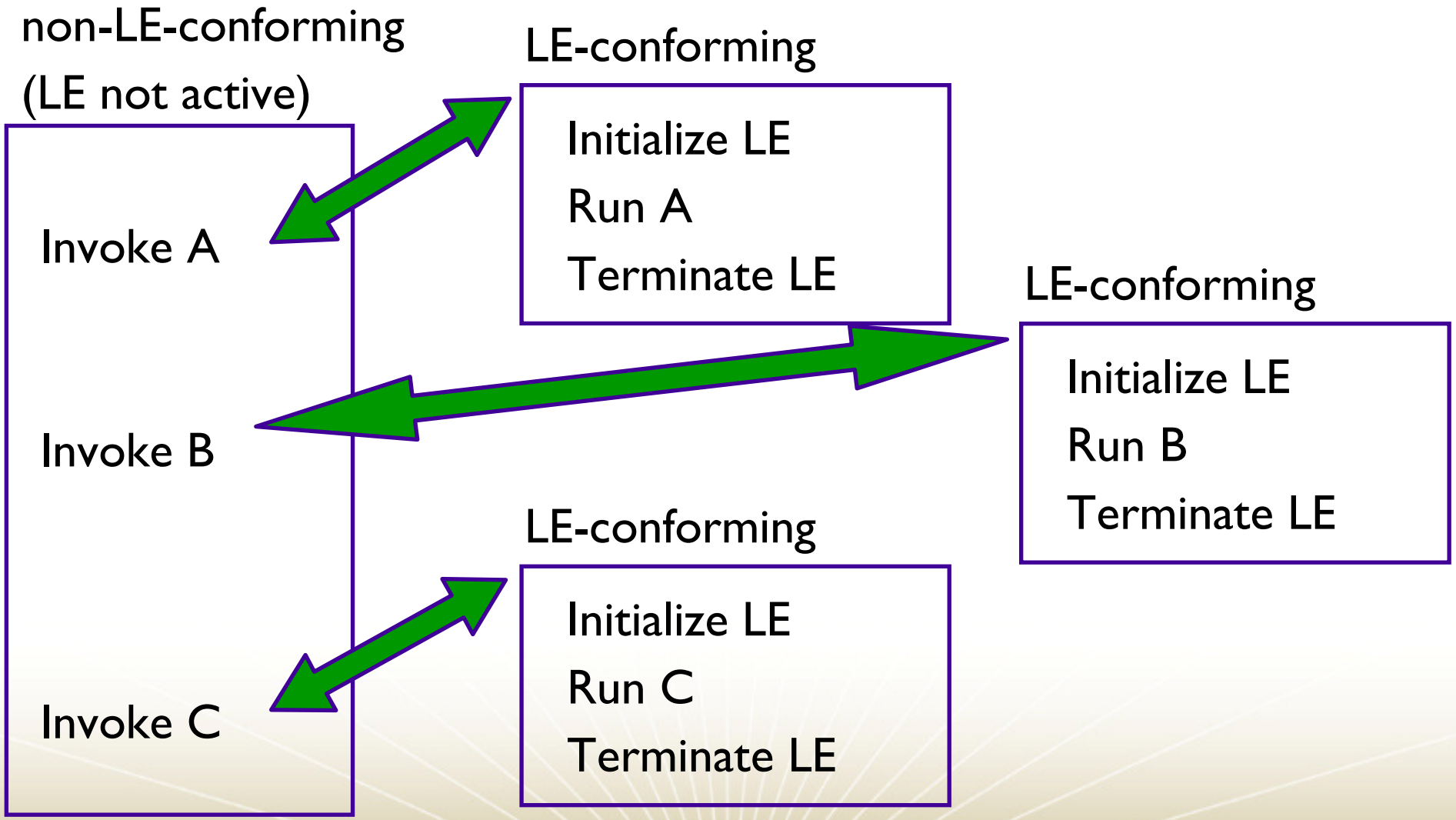
- Read Language Environment Programming Guide, Chapter 30 "Using preinitialization services" (SA22-7561)

- Read Language Environment Programming Guide for 64-bit Virtual Addressing Mode, Chapter 22 “Using preinitialization services with AMODE 64” (SA22-7569)

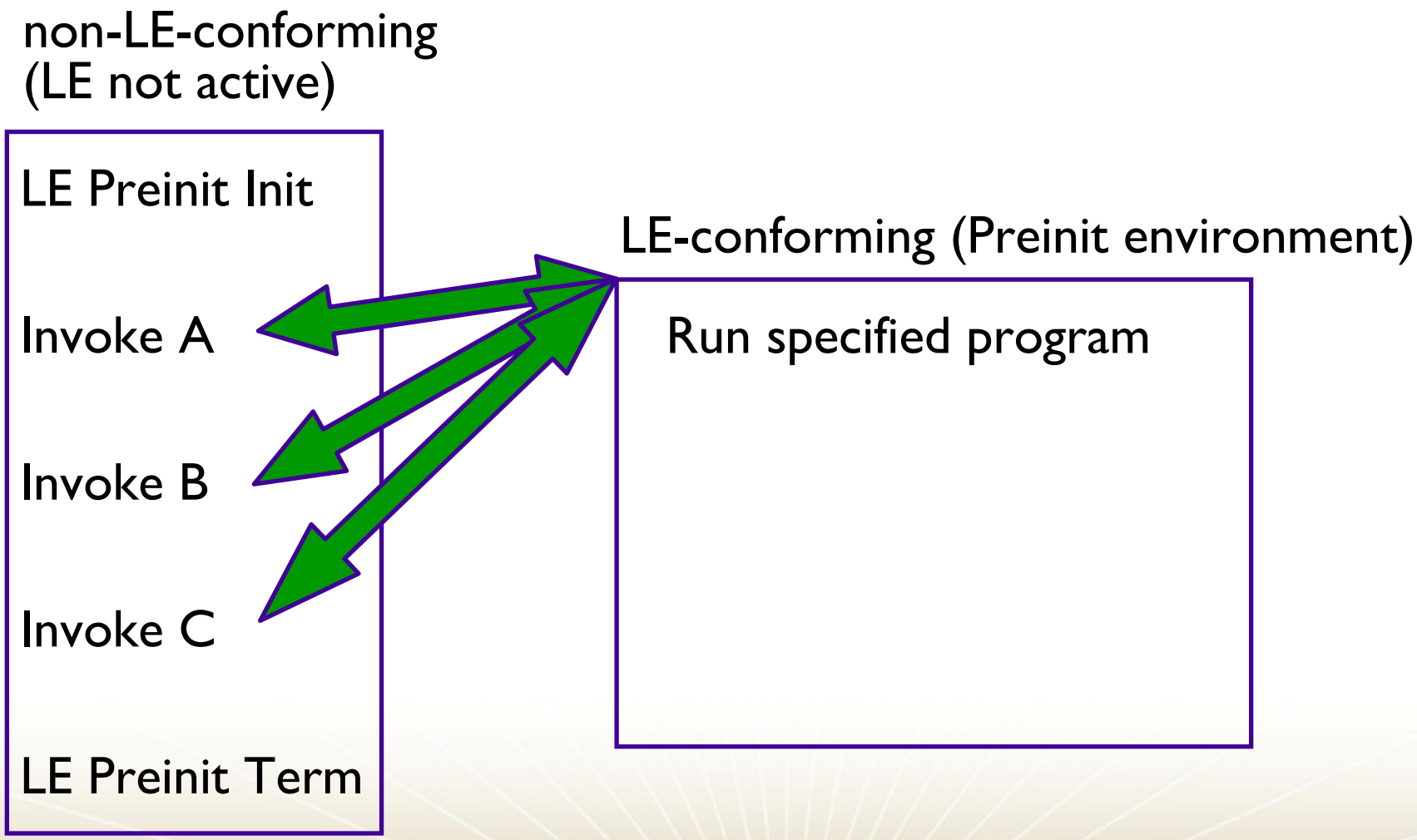
Understanding The Basics…

- You can use preinitialization to enhance the performance of certain applications
- Preinitialization lets a non-LE-conforming application (eg. Assembler) initialize an LE environment once, perform multiple executions of LE-conforming programs using that environment, and then explicitly terminate the LE environment
- Because the environment is initialized only once (even if you perform multiple executions), you free up system resources and allow for faster responses to your requests.

A non-Preinit scenario



Same application using Preinit



Older forms of preinitialization

- The following is a list of pre-LE language-specific forms of preinitialization. These environments are supported by LE but will not be enhanced.
  - C and PL/I -- supports prior form of C and PL/I preinitialization (PICI) through use of Extended Parameter List
  - C++ -- no prior form of preinitialization
  - COBOL -- supports the prior form of COBOL preinitialization through use of RTEREUS run-time option and ILBOSTP0 and IGZERRE functions
  - Fortran -- no prior form of preinitialization
- LE Library Routine Retention (LRR) is also supported but is not the "preferred" method

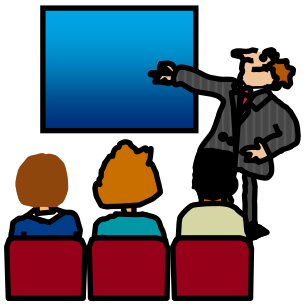
Restrictions on pre-LE preinitialization

- POSIX(ON)
- XPLINK
- AMODE 64

Users of preinitialization

- Numerous IBM products currently utilize preinitialization
  - Program Management Binder – for C++ demangler
  - DB2 – for stored procedures
  - CICS – TS V3.1 for XPLINK support
  - . . .
- Many IBM customers…

Writing a Preinit Application



The Preinit Application

- A Preinit application consists of:
  - One or more HLL routines
  - A Preinit Table
  - A Preinit Assembler Driver

HLL Routines

An example subroutine: Notice anything unusual?

```
CBL LIB,QUOTE
   IDENTIFICATION DIVISION.
   PROGRAM-ID. HLLPIPI.
   DATA DIVISION.
   WORKING-STORAGE SECTION.
   PROCEDURE DIVISION.
         DISPLAY "COBOL subprogram beginning".
         DISPLAY "Called using LE Preinitialization".
         DISPLAY "Call subroutine interface.".
         DISPLAY "COBOL subprogram returns to caller.".
         GOBACK.
```

Your answer should be “Nope!”

HLL Routines

- Written in
  - C
  - C++
  - PL/I
  - COBOL
- May be main or subroutine
  - If using an XPLINK or AMODE 64 subroutine, it must be declared “fetchable”

The Preinit table

- The Preinit table identifies routines to be executed (and optionally loaded) in a Preinit environment
  - It contains routine names and/or entry point addresses
  - It is possible to have an "empty" Preinit table with empty rows
    - routines can be added later using the Preinit *add_entry* interface
- In the Preinit table, entry point addresses are maintained with the High Order Bit set to indicate AMODE of routine
  - HOB on, routine is AMODE31 and invoked in 31 bit mode
  - HOB off, routine is AMODE24 and invoked in 24 bit mode
- CEEBXITA (Asm User Exit), CEEBINT (HLL User Exit), CEEUOPT are obtained from *first entry in Preinit table*

Generate the Preinit table

- LE provides the following assembler macros to generate the Preinit table
  - **CEEXPIT** generates a header for the Preinit table
  - **CEEXPITY** generates an entry within the Preinit table
    - specify entry *name* and/or *entry_point* address of the routine
    - each invocation generates a row in the Preinit table
    - if *name* is blank and *entry_point* is zero, then an empty row is added to the Preinit table
  - **CEEXPITS** identifies the end of the Preinit table
  - **CELQPIT**, **CELQPITY**, **CELQPITS** for AMODE 64
- The size of the Preinit table cannot be increased dynamically

The Preinit Table

Declared in the data section of the Preinit Assembler Driver:

```
          :
          :
* ========================================================================
* Preinitialization Table.
* ========================================================================
*
PPTBL     CEEXPIT ,                    Preinitialization Table with index
          CEEXPITY HLLPIPI,0           dynamically loaded routine
          CEEXPITY ,HLLEXTRN           statically-bound routine
          CEEXPITY ,                   empty Table slot
          CEEXPITS ,                   Endof PreInit table
*
          EXTRN    HLLEXTRN
*
          :
          :
```

The Preinit Assembler Driver

- The Preinit Assembler Driver is responsible for:
  - Loading the Preinit Interface module
  - Initializing / Terminating the Preinit environment
  - Calling HLL routines using the Preinit environment

The Preinit Interface Module

- The main Preinit interface is the loadable module "CEEPIPI“
  - The AMODE 64 Preinit interface is the loadable module “CELQPIPI”
- CEEPIPI handles the requests and provides services for:
  - LE Environment Initialization
  - Application Invocation
  - LE Environment Termination
- All requests for services by CEEPIPI must be made from a non-Language Environment environment
- The parameter list for CEEPIPI is an OS standard linkage parameter list
  - First parameter on each call to CEEPIPI is a Preinit function code

Loading CEEPIPI

```
          :
          :
*
* Load LE CEEPIPI service routine into main storage.
*
          LOAD   EP=CEEPIPI              Load CEEPIPI routine dynamically
          ST     R0,PPRTNPTR             Save the addr of CEEPIPI routine
*
          :
          :
```

Preinit Initialization

- LE supports three forms of preinitialized environments
- They are distinguished by the level of initialization
  - **init_main** - supports the execution of main routine
    - initializes LE environment through process-level
    - each **call_main** invocation initializes enclave- and thread-level
  - **init_sub** - supports the execution of subroutines
    - initializes LE environment through process-, enclave-, and thread-level
    - each **call_sub** invocation has minimal overhead
  - **init_sub_dp** - a special form of the init_sub that allows multiple preinitialized environments, for executing subroutines, to be created under the same task (TCB). For AMODE 64 **init_sub** is comparable.
    - Only one POSIX(ON) environment per TCB

Preinit Initialization...

- ***main*** Environment
  - Advantages
    - A new, pristine environment is created
    - Run-Time options can be specified for each application
  - Disadvantages
    - Poorer performance
- ***sub*** Environment
  - Advantages
    - Best performance
  - Disadvantages
    - The environment is left in what ever state the previous application left it (including WSA, working storage, etc)
    - Run-Time options cannot be changed

Initializing a Preinit Environment

```
*
* Initialize an LE Preinitialization main environment.
*
INIT_ENV EQU   *
         LA    R5,PPTBL                  Get address of Preinit Table
         ST    R5,@CEXPTBL               Ceexptbl_addr ->Preinit Table
         L     R15,PPRTNPTR              Get address of CEEPIPI routine
* Invoke CEEPIPI routine
         CALL  (15),(INITMAIN,@CEXPTBL,@SRVRTNS,TOKEN)
* Check return code:
         LTR   R2,R15                    Is R15 = zero?
         BZ    CMAIN                     Yes (success)..go to next section
* No (failure)..issue message
         WTO   'ASMPIPI: call to (INIT_MAIN) failed',ROUTCDE=11
         C     R2,=F'8'                  Check for partial initialization
         BE    TMAIN                     Yes..go do Preinit termination
* No..issue message & quit
         WTO   'ASMPIPI: INIT_MAIN failure RC is not 8.',ROUTCDE=11
         ABEND (R2),DUMP                 Abend with bad RC and dump memory
```

Initializing a Preinit Environment

```
*
* Initialize an LE Preinitialization subroutine environment.
*
INIT_ENV EQU   *
         LA    R5,PPTBL                  Get address of Preinit Table
         ST    R5,@CEXPTBL               Ceexptbl_addr ->Preinit Table
         L     R15,PPRTNPTR              Get address of CEEPIPI routine
* Invoke CEEPIPI routine
         CALL  (15),(INITSUB,@CEXPTBL,@SRVRTNS,RUNTMOPT,TOKEN)
* Check return code:
         LTR   R2,R15                    Is R15 = zero?
         BZ    CSUB                      Yes (success)..go to next section
* No (failure)..issue message
         WTO   'ASMPIPI: call to (INIT_SUB) failed',ROUTCDE=11
         C     R2,=F'8'                  Check for partial initialization
         BE    TSUB                      Yes..go do Preinit termination
* No..issue message & quit
         WTO   'ASMPIPI: INIT_SUB failure RC is not 8.',ROUTCDE=11
         ABEND (R2),DUMP                 Abend with bad RC and dump memory
```

Calling the HLL Routine

- Language Environment provides services to invoke either a main routine or subroutine.
  - When invoking **main** routines, the environment must have been initialized with **init_main**
  - When invoking **subroutines**, the environment must have been initialized with **init_sub** or **init_sub_dp**
- The Preinit environment identified by ***token*** is activated before the specified routine is called
- After the called routine returns, the environment becomes "dormant“
- The parameter list is passed to the application as-is
  - XPLink & 64-bit convert from OS format to XPLink

Calling the HLL Routine…

- It is important to provide the parameter list in the exact format that the compiled routine is expecting
  - C Example: 'TESTPGM 10 5' when interactively invoked
  - C function prototype: main(int argc, char **argv)
  - Assembler parameter list layout:

```
PARMPTR  DC A(PARMLIST)           Pointer to PARMLIST
*
PARMLIST DS 0A                    Parameter List
ARGC     DC F'3'                  Number of arguments
ARGVPTR  DC A(ARGV)               Pointer to Argument Array
*
ARGV     DS    0A                 Argument Array
ARCV0    DC    A(ARGV0S)          Pointer to Argument 1
ARGV1    DC    A(ARGV1S)          Pointer to Argument 2
ARGV2    DC    A(ARGV2S)          Pointer to Argument 3
*
ARGV0S   DC    C'TESTPGM',X'00'   Argument 1
ARGV1S   DC    C'10',X'00'        Argument 2
ARGV2S   DC    C'5',X'00'         Argument 3
```

Calling a HLL Main

```
          :
          :
*
* Call the main, which is loaded by LE
*
CMAIN    EQU   *
         L     R15,PPRTNPTR              Get address of CEEPIPI routine
         CALL  (15),(CALLMAIN,PTBINDEX,TOKEN,RUNTMOPT,PARMPTR,          X
               ENCRETC,ENCRSNC,APPLFBC)
* Check return code:
         LTR   R2,R15                    Is R15 = zero?
         BZ    TMAIN                     Yes (success)..go to next section
* No (failure)..issue message & quit
         WTO   'ASMPIPI: call to (CALL_MAIN) failed',ROUTCDE=11
         ABEND (R2),DUMP                 Abend with bad RC and dump memory
         :
         :
```

Calling a HLL Subroutine

```
          :
          :
*
* Call the subroutine, which is loaded by LE
*
CSUB      EQU   *
          L     R15,PPRTNPTR            Get address of CEEPIPI routine
          CALL  (15),(CALLSUB,PTBINDEX,TOKEN,PARMPTR,                    X
                  SUBRETC,SUBRSNC,SUBFBC)
* Check return code:
          LTR   R2,R15                  Is R15 = zero?
          BZ    TSUB                    Yes (success)..go to next section
* No (failure)..issue message & quit
          WTO   'ASMPIPI: call to (CALL_SUB) failed',ROUTCDE=11
          ABEND (R2),DUMP               Abend with bad RC and dump memory
          :
          :
```

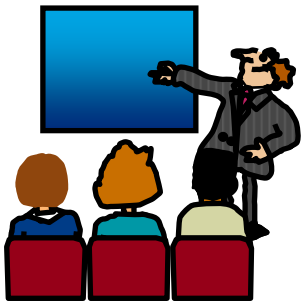
Preinit Termination

- The Preinit application terminates the Preinit environment once it is no longer needed
- Termination performs cleanup of the resources associated with the environment
- A single Termination service handles all types of Preinit environments

Terminating the Preinit Environment

```
         :
         :
*
* Terminate the environment
*
TSUB     EQU   *
         L     R15,PPRTNPTR           Get address of CEEPIPI routine
         CALL  (15),(TERM,TOKEN,ENV_RC)
* Check return code:
         LTR   R2,R15                 Is R15 = zero ?
         BZ    DONE                   Yes (success)..go to next section
* No (failure)..issue message & quit
         WTO   'ASMPIPI: call to (TERM) failed',ROUTCDE=11
         ABEND (R2),DUMP              Abend with bad RC and dump memory
*
         :
         :
```

Other Preinit Topics



Reentrancy Considerations

- You can make multiple calls to **main** routines or **subroutines**
- In general, you should specify only reentrant routines for multiple invocations:
  - Multiple calls to a reentrant **main** routine are not influenced by a previous execution of the same routine
  - For example, external variables are reinitialized for every call to a reentrant **main**

☞ If you have a nonreentrant COBOL program, condition IGZ0044S is signalled when the routine is invoked again

☞ If you have a nonreentrant C main() program that uses external variables, then when your routine is invoked again, the variables will be in last-use state

☞ Multiple calls to reentrant **subroutines** reuse the same working storage, it is only initialized once during (*call_sub*)

Stop Semantics in Preinit subs

- When one of the following occurs within a preinitialized environment *for subroutines*, the logical enclave is terminated:
  - C exit(), abort(), or signal handling function specifying a normal or abnormal termination
  - COBOL STOP RUN statement
  - PL/I STOP or EXIT
  - an unhandled condition causing termination of the (only) thread
- The process level of the environment is retained
- Modules in Preinit table are not deleted
- The next call to a subrtn in this environment will initialize a new enclave (possibly with different user exits)

Additional Preinit Services

- Calling a Subroutine By Address
  - call_sub_addr: Invoke a subroutine by address within an already initialized environment

- Improving Performance of a Sequence of Calls
  - start_seq: Start a sequence of uninterruptible calls to a number of subroutines
  - end_seq: Terminate a sequence of uninterruptible calls to a number of subroutines

Additional Preinit Services…

- Managing the Preinit Table
  - add_entry: Dynamically add a routine to an environment
  - delete_entry: Delete an entry from the Preinit table, making it available to a later add_entry
- Extracting Information from an Environment
  - identify_environment: Determine characteristics of a Preinit environment
  - identify_entry: Identify the language of an entry in the Preinit table
  - identify_attributes: Identify the attributes of an entry in the Preinit table

User Exit Invocation

	init_sub, init_sub_dp	call_main	call_sub or call_sub_addr ended with STOP semantics	term for "clean" init_sub or init_sub_dp environment	term
CEEBXITA (enclave init)	X	X	X(next call)		
CEEBINT (HLL exit)	X	X	X(next call)		
C atexit() functions		X	X	X	
CEEBXITA (enclave term)		X	X	X	
CEEBXITA (process term)				X	X

- Main environments: CEEBXITA and CEEBINT application-specific user exits are taken from the main routine being called.
- Sub environments: CEEBXITA and CEEBINT application-specific user exits are taken from the first entry in Preinit table.
- All other occurrences are ignored!

XPLINK Preinit

- Preinit applications can run XPLINK-compiled programs in a Preinit environment.
- LE initializes *either* an XPLINK environment or a "regular" (non-XPLINK) environment
  - Main: XPLINK environment if routine in first Preinit Table entry is XPLINK
  - Subroutine: XPLINK environment if routine in first Preinit Table entry is XPLINK, or if XPLINK(ON) run-time option is specified

XPLINK Preinit...

- call_main may cause an environment switch
  - If running a non-XPLINK environment, *and* either the program was compiled XPLINK or XPLINK(ON) was specified, the environment will be rebuilt XPLINK, *and remain that way.*
- Sub environments do not switch
  - A call to an XPLINK subroutine in a non-XPLINK environment will result in a "mismatch" error.
- Recommendation: Do not use non-XPLINK routines in an XPLINK Preinit environment.

Service routines

- Under Preinit, you can specify several service routines for use with running a main routine or subroutine in the preinitialized environment
- To use the routines, specify a list of addresses of the routines in a service routine vector
  - Pass the address of this list on the *init_main, init_sub, or init_sub_dp* interfaces
  - The *service_rtns* parameter that you specify contains the address of the vector itself
  - If this pointer is specified as zero (0), LE routines are used instead of the service routines
- Why?
  - Execution environment has its own storage or program management services
- Now supported in AMODE 64 Language Environment
  - z/OS V1.9: @Load and @Delete service routines
  - z/OS V1.11: @Getstore, @Freestore, and @Msgrtn service routines

Service routines...

- Count
  - the number of fullwords that follow
- User Word
  - passed to the service routines
  - provides a means for your routine to communicate to the service routines
- @Workarea
  - address of a work area of at least 256 bytes that is doubled word aligned. First word contains the length of area provided. Required if service routines present in vector
- @Load
  - loads named routines for application management
- @Delete
  - deletes routines for application management

Service routines...

- @Getstore
  - allocates storage on behalf of the storage manager. This routine relies on the caller to provide a save area, which can be the @Workarea
- @Freestore
  - frees storage on behalf of storage manager
- @Exceprtn
  - traps program interrupts and abends for condition management
- @Msgrtn
  - allows error messages to be processed by caller of the application

Preinit Diagnostics

- Preinit Trace Table
- IPCS Support to format Preinit control blocks and trace table

Preinit Diagnostics…

- Preinit Trace Table Characteristics
  - Tracing is always active
    - Begins when the Preinit environment is initialized and ends when the environment is terminated
  - Trace is kept in an in-storage trace table
    - Fixed size (4096 bytes)
    - Wraps when the end has been reached

Preinit Diagnostics…

- New keyword for the LEDATA IPCS Verbexit:
  - **PTBL**(value) - Formats Preinit control block and trace table based on value:
    - "**CURRENT**“ - Preinit data associated with the current or specified TCB is displayed.
    - <**address**> - Preinit data at that address is displayed.
    - “*“ – Data for all active and dormant Preinit environments within the current address space are displayed; *** *This option is time-consuming* ***.
    - "**ACTIVE**“ – Display Preinit data associated with each TCB in the address space.

Preinit Diagnostics…

LEDATA PTBL Output – Preinit Control Block

```
=== > VERBEXIT LEDATA 'PTBL(CURRENT)'

PreInitialization Programming Interface Trace Data
 CEEPIPI Environment Table Entry and Trace Entry :
  Active CEEPIPI Environment (  Address 25805CB0 )
  Eyecatcher  : CEEXIPTB
  TCB address : 008D1B08

 CEEPIPI Environment :
  Non-XPLINK Environment
  Environment Type : MAIN
  Sequence of Calls not active
  Exits not established
  Signal Interrupt Routines not registered
  Service Routines are not active

  CEEPIPI Environment Enclave Initialized
  Number of CEEPIPI Table Entries = 2
```

Preinit Diagnostics…

LEDATA PTBL Output – Preinit Control Block…

```
CEEPIPI Table Entry Information :
     CEEPIPI Table Index 0   ( Entry 1    )
      Routine Name   = HLLCRTN
      Routine Type   = C/C++
      Routine Entry Point   = A5810B38
      Routine Function Pointer   = A5810CC0
      Routine Entry is Non-XPLINK
      Routine was loaded by Language Environment
      Routine Address was resolved
      Routine Function Descriptor was valid
      Routine Return Code     = 0
      Routine Reason Code     = 0
```

Preinit Diagnostics…

LEDATA PTBL Output – Preinit Control Block…

```
Entry of routine in CEEPIPI Table for Index 0 ( 25805DB8 )

     +000000 25805DB8  A5810CC0 25811B30 80000000 00000000
                       00000000 00000000 00000000 00000000
                       |va...a.........................|
     +000020 25805DD8  00000000 00000000 00000000 A5810B38
                       00000003 258117C8 00000003 25810B38
                       |............va.......a.H.....a..|
     +000040 25805DF8  A5810B38 000014C8 C8D3D3C3 D9E3D540
                       00000000 00000000 00000000 00000000
                       |va.....HHLLCRTN ................|

    CEEPIPI Table Index 1   ( Entry 2    )  not in use.
```

Preinit Diagnostics…

LEDATA PTBL Output – Preinit Trace Table

```
CEEPIPI Trace Table Entries :
     Call Type =  INIT_MAIN
      PIPI Driver Address  = A5800A82
      Load Service Return Code   = 0
      Load Service Reason Code   = 0
      Most Recent Return Code    = 0
      Most Recent Reason Code    = 0
      An ABEND will be issued if storage can not be obtained
      PreInit Environment will not allow EXEC CICS commands
      Service RC = 0 :A new environment was initialized
```

Preinit Diagnostics…

LEDATA PTBL Output – Preinit Trace Table…

```
Call Type =  ADD_ENTRY
 Routine Table Index         = 1
 Routine Name  = HLLPIPI
 Routine Address = A5812E20
 Load Service Return Code    = 0
 Load Service Reason Code    = 3
 Service RC = 0 :The routine was added to the PreInit table.

Call Type =  CALL_MAIN
 Routine Table Index      = 1
 Enclave Return Code      = 0
 Enclave Reason Code      = 0
 Routine Feedback Code    = 0000000000000000
 Service RC = 0 :The environment was activated and the
    routine called.
```

Preinit Diagnostics…

LEDATA PTBL Output – Preinit Trace Table…

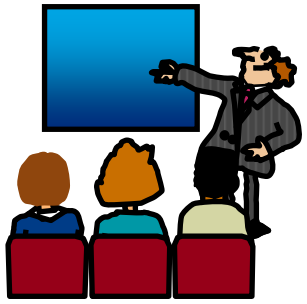
```
Call Type =  DELETE_ENTRY
 Routine Table Index     = 1
 Routine Name  = HLLCOBOL
 Routine Address = A5812E20
 Service RC = 0 :The routine was deleted from the
    PreInit table.

Call Type =  CALL_MAIN
 Routine Table Index     = 0
 Enclave Return Code     = 0
 Enclave Reason Code     = 0
 Routine Feedback Code   = 0000000000000000
 Service RC = 0 :The environment was activated and
    the routine called.
```

A Preinit Example

The following example provides an illustration of an assembler program ASMPIPI ASSEMBLE invoking CEEPIPI to:

- **Initialize a LE Preinit subroutine environment**
- **Load and call a reentrant C/COBOL/PLI subroutine**
- **Terminate the LE Preinit environment**



Example

- Following the assembler program are interchangeable examples of the program HLLPIPI written in:
  - C, COBOL, and PL/I
- HLLPIPI is called by an assembler program, ASMPIPI.
- ASMPIPI uses the Language Environment preinitialized program subroutine call interface
- You can use the assembler program to call the HLL versions of HLLPIPI.

Example...

```
*
*COMPILATION UNIT: LEASMPIP
*************************************************************************
*                                                                       *
* Function: CEEPIPI - Initialize the Preinitialization                  *
*                     environment,call a Preinitialization              *
*                     HLL program,and terminate the environment.        *
*                                                                       *
* 1. Call CEEPIPI to initialize a subroutine environment under LE.      *
* 2. Call CEEPIPI to load and call a reentrant HLL subroutine.          *
* 3. Call CEEPIPI to terminate the LE Preinitialization environment.    *
*                                                                       *
* Note: ASMPIPI is not reentrant.                                       *
*                                                                       *
*************************************************************************
```

Example...

```
* ======================================
* Standard program entry conventions.
* ======================================
ASMPIPI  CSECT
         STM   R14,R12,12(R13)          Save caller's registers
         LR    R12,R15                  Get base address
         USING ASMPIPI,R12              Identify base register
         ST    R13,SAVE+4               Back-chain the save area
         LA    R15,SAVE                 Get addr of this routine's save area
         ST    R15,8(R13)               Forward-chain in caller's save area
         LR    R13,R15                  R13 -> save area of this routine
*
* Load LE CEEPIPI service routine into main storage.
*
         LOAD  EP=CEEPIPI               Load CEEPIPI routine dynamically
         ST    R0,PPRTNPTR              Save the addr of CEEPIPI routine
```

Example...

```
*
* Initialize an LE Preinitialization subroutine environment.
*
INIT_ENV EQU   *
         LA    R5,PPTBL                  Get address of Preinit Table
         ST    R5,@CEXPTBL               Ceexptbl_addr ->Preinit Table
         L     R15,PPRTNPTR              Get address of CEEPIPI routine
* Invoke CEEPIPI routine
         CALL  (15),(INITSUB,@CEXPTBL,@SRVRTNS,RUNTMOPT,TOKEN)
* Check return code:
         LTR   R2,R15                    Is R15 = zero?
         BZ    CSUB                      Yes (success)..go to next section
* No (failure)..issue message
         WTO   'ASMPIPI: call to (INIT_SUB) failed',ROUTCDE=11
         C     R2,=F'8'                  Check for partial initialization
         BE    TSUB                      Yes..go do Preinit termination
* No..issue message & quit
         WTO   'ASMPIPI: INIT_SUB failure RC is not 8.',ROUTCDE=11
         ABEND (R2),DUMP                 Abend with bad RC and dump memory
```

Example...

```
*
* Call the subroutine, which is loaded by LE
*
CSUB     EQU   *
         L     R15,PPRTNPTR              Get address of CEEPIPI routine
         CALL  (15),(CALLSUB,PTBINDEX,TOKEN,PARMPTR,                    X
               SUBRETC,SUBRSNC,SUBFBC)
* Check return code:
         LTR   R2,R15                    Is R15 = zero?
         BZ    TSUB                      Yes (success)..go to next section
* No (failure)..issue message & quit
         WTO   'ASMPIPI: call to (CALL_SUB) failed',ROUTCDE=11
         ABEND (R2),DUMP                 Abend with bad RC and dump memory
```

Example...

```
*
* Terminate the environment
*
TSUB     EQU   *
         L     R15,PPRTNPTR              Get address of CEEPIPI routine
         CALL  (15),(TERM,TOKEN,ENV_RC)
* Check return code:
         LTR   R2,R15                    Is R15 = zero ?
         BZ    DONE                      Yes (success)..go to next section
* No (failure)..issue message & quit
         WTO   'ASMPIPI: call to (TERM) failed',ROUTCDE=11
         ABEND (R2),DUMP                 Abend with bad RC and dump memory
*
* Standard exit code.
*
DONE     EQU   *
         LA    R15,0                     Passed return code for system
         L     R13,SAVE+4                Get address of caller's save area
         L     R14,12(R13)               Reload caller's register 14
         LM    R0,R12,20(R13)            Reload caller's registers 0-12
         BR    R14                       Branch back to caller
```

Example...

```
* ================================================================
* CONSTANTS and SAVE AREA.
* ================================================================
SAVE             DC    18F'0'
PPRTNPTR         DS    A                  Save the address of CEEPIPI routine
*
* Parameters passed to an (INIT_SUB) call.
INITSUB          DC    F'3'               Function code to initialize for subr
@CEXPTBL         DC    A(PPTBL)           Address of Preinitialization Table
@SRVRTNS         DC    A(0)               Addr of service-rtns vector,0 = none
RUNTMOPT         DC    CL255''            Fixed length string of runtime optns
TOKEN            DS    F                  Unique value returned(output)
*
* Parameters passed to a (CALL_SUB) call.
CALLSUB          DC    F'4'               Function code to call subroutine
PTBINDEX         DC    F'0'               The row number of Preinit Table entry
PARMPTR          DC    A(0)               Pointer to @PARMLIST or zero if none
SUBRETC          DS    F                  Subroutine return code (output)
SUBRSNC          DS    F                  Subroutine reason code (output)
SUBFBC           DS    3F                 Subroutine feedback token (output)
```

Example...

```
*
* Parameters passed to a (TERM) call.
TERM     DC    F'5'                          Function code to terminate
ENV_RC   DS    F                             Environment return code (output)
* ===============================================================
* Preinitialization Table.
* ===============================================================
*
PPTBL    CEEXPIT ,                           Preinitialization Table with index
         CEEXPITY HLLPIPI,0                  0=dynamically loaded routine
         CEEXPITS ,                          Endof PreInit table
*
         LTORG
R0       EQU   0
R1       EQU   1
...
R14      EQU   14
R15      EQU   15
         END   ASMPIPI
```

Example...

C Subroutine Called by ASMPIPI

```
#include <stdio.h>

HLLPIPI ()
{
     printf("C subroutine beginning \n");
     printf("Called using LE PreInit call \n");
     printf("Subroutine interface.\n");
     printf("C subroutine returns to caller \n");
}
```

Example...

COBOL Program Called by ASMPIPI

```
CBL LIB,QUOTE
      *Module/File Name: IGZTPIPI
      ************************************************************
      *                                                          *
      * HLLPIPI is called by an assembler program, ASMPIPI.      *
      * ASMPIPI uses the LE preinitialized program               *
      * subroutine call interface. HLLPIPI can be written        *
      * in COBOL, C, or PL/I.                                    *
      *                                                          *
      ************************************************************
       IDENTIFICATION DIVISION.
       PROGRAM-ID. HLLPIPI.
       DATA DIVISION.
       WORKING-STORAGE SECTION.
       PROCEDURE DIVISION.
           DISPLAY "COBOL subprogram beginning".
           DISPLAY "Called using LE Preinitialization".
           DISPLAY "Call subroutine interface.".
           DISPLAY "COBOL subprogram returns to caller.".
           GOBACK.
```

Example...

PL/I Routine Called by ASMPIPI

```
/*Module/File Name: IBMPIPI                                        */
/*****************************************************************/
/*                                                                */
/* HLLPIPI is called by an assembler program, ASMPIPI.            */
/* ASMPIPI uses the LE preinitializedprogram                      */
/* subroutine call interface.HLLPIPI can be written               */
/* in COBOL,C,or PL/I.                                            */
/*                                                                */
/*****************************************************************/
HLLPIPI: PROC OPTIONS(FETCHABLE);
          DCL RESULT FIXED BIN(31,0)INIT(0);
          PUT SKIP LIST
              ('HLLPIPI: PLI subroutine beginning.');
          PUT SKIP LIST
              ('HLLPIPI: CalledLE Preinit Call ');
          PUT SKIP LIST
              ('HLLPIPI: Subroutine interface.');
          PUT SKIP LIST
              ('HLLPIPI: PLI program returns to caller.');
          RETURN;
END HLLPIPI;
```

Sources of Additional Information

- LE Debug Guide and Runtime Messages
- LE Programming Reference
- LE Programming Guide (64-bit too!)
- LE Customization
- LE Migration Guide
- LE Writing ILC Applications
- Web site
  - http://www.ibm.com/servers/eserver/zseries/zos/le/