

Look What I Found Under The Bar!

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Agenda

- Overview of Language Environment storage areas
 - Control blocks, stack, heap
 - Which can you control?
- How to control Language Environment Storage
- Tuning Storage
- More advanced tuning
- Sources of Additional Information



Language Environment Storage Areas

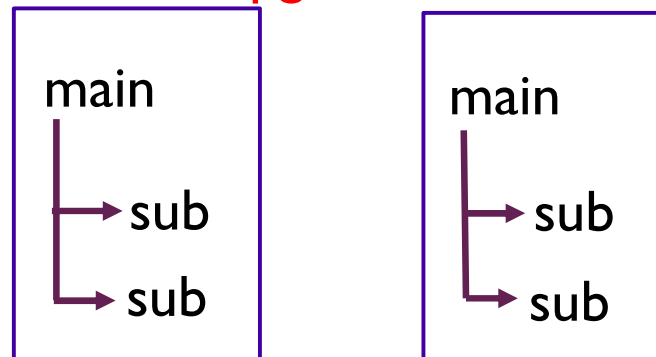
- Language Environment Control Blocks
 - Region level
 - Normally 1 region per address space
 - Process level
 - Normally 1 process per address space
 - Enclave level
 - Potentially many per address space
 - Thread level
 - Potentially very many per address space

Language Environment Storage Areas

region - address space

process - application

enclave - pgm - enclave

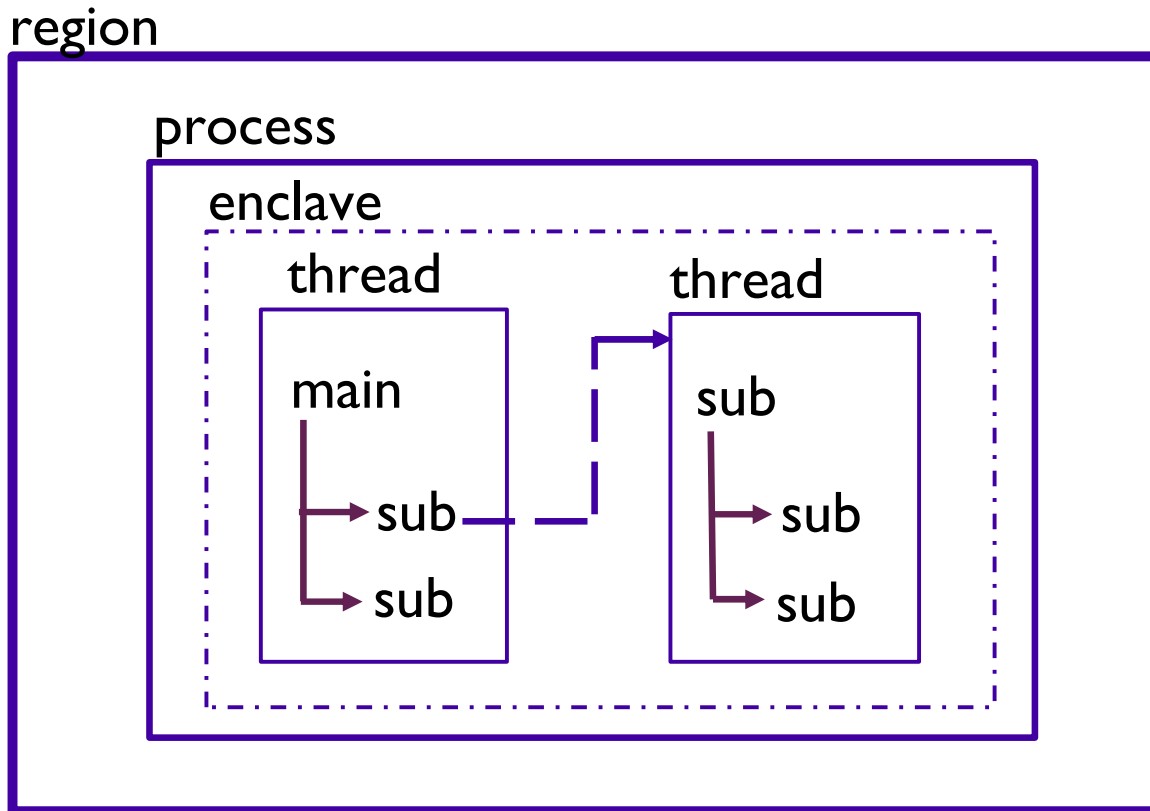




Language Environment Storage Areas

- Language Environment Enclave
 - Every “main” program is a new enclave
 - Every “link” is a new enclave
 - Contains
 - CEECAA, CEEEDB, CEEOCB, stacks, heaps, environment variables, and much more!
 - “Extra” enclaves are expensive both to initialize and in storage usage.

Language Environment Storage Areas



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Language Environment Storage Areas

- Language Environment Thread
 - Only created by `pthread_create()`
 - Contains
 - CEECAA, stacks, and a little more
 - Threads are not nearly as expensive as enclaves.
 - Used mostly by C/C++
 - Enterprise PL/I multitasking uses threads



Language Environment Storage Areas

- Language Environment Stacks
 - Stacks
 - Last In, First Out structures
 - Allow programs to be reentrant
 - Thread level structures
 - “Main” programs have separate stacks
 - “Linked” programs have separate stacks
 - Pthreads have separate stacks



Language Environment Storage Areas

- Language Environment supports 2 independent stacks
 - User stack – (poorly named)
 - Used by user programs and Language Environment
 - Library stack
 - Used “rarely” by Language Environment
 - Always below the 16M line



Language Environment Storage Areas

- DATA in stacks
 - “Chunks” are called stack segments
 - Made up of 1 or more DSAs
 - DSA – Dynamic Save Area
 - Also called a “stack frame”
 - DSAs contain
 - Register Save Area (RSA)
 - NAB – Next Available Byte
 - Automatic (local) variables
 - C – int i;
 - PL/I – declare i fixed;
 - NOT COBOL WORKING-STORAGE
 - COBOL LOCAL-STORAGE in stack



Language Environment Storage Areas

- Language Environment Heaps
 - Heaps
 - Completely random access
 - Allows storage to be dynamically allocated at runtime
 - Enclave level control structures
 - Each 'main' has a separate stack and heap
 - Each 'link' causes a separate stack and heap
 - pthreads share a single heap for all threads



Language Environment Storage Areas

- Language Environment Heaps
 - Four independently maintained sets of heap segments all with similar layouts:
 - User Heap
 - COBOL WORKING-STORAGE
 - C/C++ (malloc or operator new)
 - PL/I dynamic storage (allocate)
 - LE Anywhere Heap
 - COBOL and LE above the line CBs
 - LE Below Heap
 - COBOL and LE below the line CBs
 - Additional Heap
 - Defined by the user



Controlling Storage

- Run-time options dealing with stacks
 - STACK(init,inc,ANY|BELOW,KEEP|FREE,dsInit,dsInc)
 - Init - Initial size of storage "chunk" allocated and managed by LE for user stack
 - Inc - When init is full, size of next storage "chunk" (increment)
 - ANY|BELOW - Location of storage
 - ANY Anywhere in 2G virtual storage
 - Below Always below 16M line
 - Required when all31(OFF)
 - KEEP|FREE - What to do when done with inc
 - KEEP Do not free the storage "chunks"
 - FREE Free the storage "chunks"
 - DsInit - Initial size of storage "chunk" (XPLINK)
 - DsInc - When initial full, size of next "chunk" (XPLINK)



Controlling Storage

- Run-time options dealing with stacks
 - LIBSTACK(init,inc,KEEP|FREE)
 - Init - Initial size of storage "chunk" allocated and managed by LE for library stack
 - Inc - When init is full, size of next storage "chunk" (increment)
 - KEEP|FREE - What to do when done with inc
 - KEEP Do not free the storage "chunks"
 - FREE Free the storage "chunks"
- NOTE: No ANY|BELOW, LIBSTACK always below the 16M line



Controlling Storage

- Run-time options dealing with stacks
 - THREADSTACK(ON|OFF,init,inc,ANY|BELOW,KEEP|FREE,dsInit,dsInc)
 - ON|OFF – Whether or not to use THREADSTACK for pthreads
 - Init - Initial size of storage “chunk” (like STACK)
 - Inc - Increment size of storage “chunk” (like STACK)
 - ANY|BELOW - Location of storage
 - ANY Anywhere in 2G virtual storage
 - Below Always below 16M line
 - Required when all31(OFF)
 - KEEP|FREE - What to do when done with inc
 - KEEP Do not free the storage “chunks”
 - FREE Free the storage “chunks”
 - DsInit, Dsinc – XPLINK “chunk” sizes



Controlling Storage

- Runtime options dealing with the heaps
 - HEAP(init,inc,ANY|BELOW,KEEP|FREE,int24,inc24)
 - User heap - mostly application use
 - init - Initial size of the "chunk" of storage obtained to be managed by LE for user heap
 - Inc - When initial "chunk" is full, size of next "chunk" (minimum)
 - ANY|BELOW - Location of "chunk"
 - Not sensitive to ALL31 setting
 - KEEP | FREE - What to do when done with the increment when empty
 - KEEP - Do not free the storage "chunks"
 - FREE - Free the storage "chunks"
 - int24 - Initial size of the "chunk" of storage obtained
 - (if ANY specified but BELOW requested (minimum))
 - inc24 - Size of next "chunk"
 - (if ANY specified but BELOW requested (minimum))



Controlling Storage

- Runtime options dealing with the heaps...
 - ANYHEAP(init,inc,ANY|BELOW,KEEP|FREE)
 - Thread stack storage lives in anyheap!!! Tune if multi-threaded
 - LE use - normally above the line
 - init - Same as HEAP.
 - inc - Same as HEAP. (minimum)
 - ANY | BELOW - Location of storage
 - KEEP | FREE - Same as HEAP
 - BELOWHEAP(init,inc,KEEP|FREE)
 - LE use - always below the line
 - init - Same as HEAP.
 - inc - Same as HEAP. (minimum)
 - KEEP | FREE - Same as HEAP



Initializing Storage

- STORAGE(getheap, freeheap, dsa alloc)
 - Getheap – Initialize heap storage
 - NONE – no overhead
 - One byte hex value to initialize storage with when heap element obtained
 - 00 similar to WSCLEAR option
 - Relatively low overhead
 - Freeheap – Initial heap storage
 - NONE – no overhead
 - One byte hex value to initialize storage with when heap element freed
 - Useful for debug purposes or security
 - Relatively low overhead



Initializing Storage

- STORAGE(getheap, freeheap,dsa alloc)
 - DSA alloc – Initialize stack storage
 - NONE – No initialization – no overhead
 - CLEAR – Entire unused initial stack segment is cleared just before the main program is given control – low overhead
 - A one byte hex value to initialize storage with when stack frame (DSA) is obtained
 - EXTREMELY HIGH OVERHEAD
 - EXTREMELY HIGH OVERHEAD
 - EXTREMELY HIGH OVERHEAD

Initializing Storage

- Simple program that makes lots of calls
 - STORAGE(,,none)

```
=====
-                                     REGION      --- ST
- STEPNAME PROCSTEP PGMNAME      CC      USED      CPU TIME
- GO                STORRTO      00      60K      0:00:00.56
```

- STORAGE(,,00)

```
=====
-                                     REGION      --- ST
- STEPNAME PROCSTEP PGMNAME      CC      USED      CPU TIME
- GO                STORRTO      00      60K      0:00:02.15
```

- STORAGE(,,CLEAR)

```
=====
-                                     REGION      --- ST
- STEPNAME PROCSTEP PGMNAME      CC      USED      CPU TIME
- GO                STORRTO      00      60K      0:00:00.57
```

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Initializing Storage

- Best ways to ensure the proper initial value for your variables
 - Use compiler initialization
 - Set them prior to use in your program



Tuning storage

- Objectives
 - Use as little storage as possible
 - Have program run as efficiently as possible
- The above objectives are often at odds with each other. (But not always)
- One way to make a program run faster is to “throw” more storage at it.
 - Care must be taken to use storage wisely
 - Much of what will talk about can be done without recompiling or reworking the program.



Tuning storage

- Simple example
 - In a test environment (not production) use the RPTSTG run-time option.
 - A report will be generated describing the storage used by the program.
 - This information can be used to assist with better settings of Language Environment run-time options



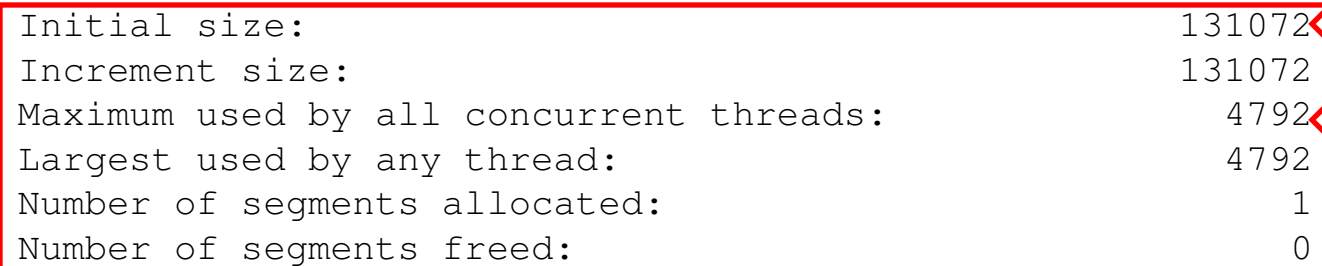
Tuning storage

■ Simple example

Storage Report for Enclave main 02/07/11 5:12:26 PM
Language Environment V01 R12.00

STACK statistics:

Initial size:	131072
Increment size:	131072
Maximum used by all concurrent threads:	4792
Largest used by any thread:	4792
Number of segments allocated:	1
Number of segments freed:	0



THREADSTACK statistics:

Initial size:	0
Increment size:	0
Maximum used by all concurrent threads:	0
Largest used by any thread:	0
Number of segments allocated:	0
Number of segments freed:	0

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Tuning storage

■ Simple example...

LIBSTACK statistics:

Initial size:	4096
Increment size:	4096
Maximum used by all concurrent threads:	0
Largest used by any thread:	0
Number of segments allocated:	0
Number of segments freed:	0

THREADHEAP statistics:

Initial size:	4096
Increment size:	4096
Maximum used by all concurrent threads:	0
Largest used by any thread:	0
Successful Get Heap requests:	0
Successful Free Heap requests:	0
Number of segments allocated:	0
Number of segments freed:	0

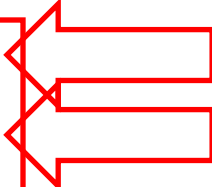


Tuning storage

■ Simple example...

HEAP statistics:

Initial size:	32768
Increment size:	32768
Total heap storage used (sugg. initial size):	3328
Successful Get Heap requests:	4
Successful Free Heap requests:	2
Number of segments allocated:	1
Number of segments freed:	0



HEAP24 statistics:

Initial size:	8192
Increment size:	4096
Total heap storage used (sugg. initial size):	0
Successful Get Heap requests:	0
Successful Free Heap requests:	0
Number of segments allocated:	0
Number of segments freed:	0



Tuning storage

■ Simple example...

ANYHEAP statistics:

Initial size:	16384
Increment size:	8192
Total heap storage used (sugg. initial size):	616
Successful Get Heap requests:	6
Successful Free Heap requests:	2
Number of segments allocated:	1
Number of segments freed:	0

BELOWHEAP statistics:

Initial size:	8192
Increment size:	4096
Total heap storage used (sugg. initial size):	0
Successful Get Heap requests:	0
Successful Free Heap requests:	0
Number of segments allocated:	0
Number of segments freed:	0



Tuning storage

- Now using stack(8k,4k) heap(4k,4k)

STACK statistics:

Initial size:	8192
Increment size:	4096
Maximum used by all concurrent threads:	4792
Largest used by any thread:	4792
Number of segments allocated:	1
Number of segments freed:	0

...snip...

HEAP statistics:

Initial size:	4096
Increment size:	4096
Total heap storage used (sugg. initial size):	3328
Successful Get Heap requests:	4
Successful Free Heap requests:	2
Number of segments allocated:	1
Number of segments freed:	0



Tuning storage

- A bit more meaty!
 - Testcase requests 50000 random pieces of storage of sizes from 1 to 32K in size
 - Then the storage is freed.
 - We'll run the program without tuning
 - We'll then re-run the program (same random values) after tuning
 - Have we saved storage? Performance?

Tuning storage

■ Untuned example

STACK statistics:

Initial size:	131072
Increment size:	131072
Maximum used by all concurrent threads:	204184
Largest used by any thread:	204184
Number of segments allocated:	3
Number of segments freed:	0

...Snip...

HEAP statistics:

Initial size:	32768
Increment size:	32768
Total heap storage used (sugg. initial size):	819229056
Successful Get Heap requests:	50002
Successful Free Heap requests:	50000
Number of segments allocated:	27949
Number of segments freed:	0

- Note: 27949 segments of 32k each – 915,832,832 bytes

Tuning storage

- Tuned HEAP(100M,100M) STACK(256K,256K)

STACK statistics:

Initial size:	262144
Increment size:	262144
Maximum used by all concurrent threads:	200944
Largest used by any thread:	200944
Number of segments allocated:	1
Number of segments freed:	0

...Snip...

HEAP statistics:

Initial size:	104857600
Increment size:	104857600
Total heap storage used (sugg. initial size):	818334944
Successful Get Heap requests:	50002
Successful Free Heap requests:	50000
Number of segments allocated:	8
Number of segments freed:	0

- Note: 8 segments of 100M each – 838,860,800 bytes!!!

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Tuning storage

- Look what else happened!

- Untuned

```
=====
-                                     REGION          --- STEP TIMINGS ---
- STEPNAME PROCSTEP PGMNAME      CC      USED      CPU TIME  ELAPSED TIME  EXCP
- CLPG      COMPILE  CBCDRVR      00      72K      0:00:00.06  0:00:02.84    1590
- CLPG      PLKED    EDCPRLK      04      60K      0:00:00.01  0:00:00.99    534
- CLPG      LKED     HEWL         00      92K      0:00:00.01  0:00:00.63    174
- CLPG      GO       PGM=* .DD    00      60K      0:00:15.44  0:00:18.02    505
=====
```

- Tuned

```
=====
-                                     REGION          --- STEP TIMINGS ---
- STEPNAME PROCSTEP PGMNAME      CC      USED      CPU TIME  ELAPSED TIME  EXCP
- CLPG      COMPILE  CBCDRVR      00      72K      0:00:00.06  0:00:03.67    1555
- CLPG      PLKED    EDCPRLK      04      60K      0:00:00.01  0:00:01.25    535
- CLPG      LKED     HEWL         00      92K      0:00:00.01  0:00:00.50    170
- CLPG      GO       PGM=* .DD    00      60K      0:00:00.12  0:00:01.45    501
=====
```

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Tuning storage

- What about KEEP vs FREE
 - Testcase requests 50000 random pieces of storage of sizes from 1 to 32K in size
 - Free 20000 pieces, then get 20000 more
 - Free everything
 - We'll run the program without tuning and FREE
 - We'll run the program without tuning and KEEP
 - What have we done to storage and performance?

Tuning storage

■ Untuned

HEAP statistics: **(Using FREE)**

Initial size:	32768
Increment size:	32768
Total heap storage used (sugg. initial size):	819982896
Successful Get Heap requests:	70002
Successful Free Heap requests:	69999
Number of segments allocated:	39122
Number of segments freed:	39120

HEAP statistics: **(Using KEEP)**

Initial size:	32768
Increment size:	32768
Total heap storage used (sugg. initial size):	819983152
Successful Get Heap requests:	70002
Successful Free Heap requests:	70000
Number of segments allocated:	27952
Number of segments freed:	0

- Note: You can't determine storage used to back segments now

Tuning storage

- Performance – not a huge difference but KEEP is faster!

- **FREE**

```
=====
-                                     REGION          --- STEP TIMINGS ---
- STEPNAME  PROCSTEP  PGMNAME      CC      USED      CPU TIME    ELAPSED TIME    EXCP
- CLPG      COMPILE   CBCDRVR       00      72K      0:00:00.06   0:00:04.95      1496
- CLPG      PLKED     EDCPRLK       04      60K      0:00:00.01   0:00:02.46      504
- CLPG      LKED      HEWL          00      92K      0:00:00.01   0:00:01.13      171
- CLPG      GO        PGM=* .DD    00      60K      0:00:25.79   0:01:02.34      474
=====
```

- **KEEP**

```
=====
-                                     REGION          --- STEP TIMINGS ---
- STEPNAME  PROCSTEP  PGMNAME      CC      USED      CPU TIME    ELAPSED TIME    EXCP
- CLPG      COMPILE   CBCDRVR       00      72K      0:00:00.06   0:00:03.15      1493
- CLPG      PLKED     EDCPRLK       04      60K      0:00:00.01   0:00:00.87      505
- CLPG      LKED      HEWL          00      92K      0:00:00.01   0:00:00.46      171
- CLPG      GO        PGM=* .DD    00      60K      0:00:22.34   0:00:24.85      469
=====
```

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Tuning storage

- Look what happens when we tune.

HEAP statistics:

```
Initial size:                104857600
Increment size:              104857600
Total heap storage used (sugg. initial size):  819088944
Successful Get Heap requests: 70002
Successful Free Heap requests: 69999
Number of segments allocated: 8
Number of segments freed:    0
```

```
-----
-                                     REGION          --- STEP TIMINGS ---
- STEPNAME  PROCSTEP  PGMNAME      CC      USED      CPU TIME  ELAPSED TIME  EXCP
- CLPG      COMPILE  CBCDRVR      00      72K      0:00:00.06  0:00:02.67   1499
- CLPG      PLKED    EDCPRLK     04      60K      0:00:00.01  0:00:00.81   547
- CLPG      LKED     HEWL        00      92K      0:00:00.01  0:00:00.32   171
- CLPG      GO       PGM=*.DD    00      60K      0:00:00.15  0:00:01.04   496
```

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More advanced tuning

- What about those pesky Language Environment control blocks?
 - No externals to help
 - Effort can be made to reduce the number of enclaves
 - Use dynamic calls rather than linking to next program
 - Hard to see the results without using system tools... but let's try



More advanced tuning

- Simple program does a LINK to another program
 - A new enclave is created
 - This 2nd program continues to get storage until it runs out
 - It is able to obtain 21568K of storage



More advanced tuning

- Add to program to call down through 5 nested enclaves
 - Last enclave is able to obtain 20576K of storage
- Add to program to call down through 10 nested enclaves
 - Last enclave is able to obtain 19808K of storage
- Storage being consumed is to:
 - Load programs
 - Create enclave control blocks
 - This includes stacks and heaps
 - 1760K of storage usage (21568K-19808K)



More advanced tuning

- Change programs to use dynamic call rather than LINK
 - One call case – 21728K of storage available
 - Five call case – 21664K of storage available
 - Ten call case – 21600K of storage available
- Note how much less storage is consumed.
 - Basically just the amount to load the programs
 - 128K for 10 calls deep (21728K-21600K)



Summary

- Storage run-time option has high overhead for initializing the stack
- Use RPTSTG to tune your stack, heap and other storage sizes
- KEEP is faster than FREE
- Use dynamic call versus LINK
 - Requires program update or recompile



Sources of Additional Info

- All Language Environment documentation available on the Language Environment Web site



- Language Environment Debugging Guide
- Language Environment Programming Reference
- Language Environment Programming Guide
- Language Environment Web site
 - http://www.ibm.com/systems/z/os/zos/features/lang_environment