

Heap Damage

Is your insurance up-to-date?

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Agenda



- What do heaps look like?
- What kind of damage might you see?
- Who caused the damage?
- Calling the police!
- Let the adjuster have a look.
- Sources of Additional Information

What do heaps look like?



- Language Environment Storage Management
 - Heaps
 - Completely random access
 - Allows storage to be dynamically allocated at runtime
 - Enclave level control structures
 - Each 'main' has its own enclave and therefore heap
 - Each 'link' create a new enclave and therefore heap
 - pthreads share a single heap for all threads

What do heaps look like?



- Language Environment Storage Management
 - 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

What do heaps look like?



- Heap Layout
 - Based on algorithm from IBM's Watson Research Center
 - FAST 1ST!!!
 - Storage Efficiency 2nd
 - Error checks 3rd
 - Elements of user requested length
 - User responsible for requesting storage be freed.

What do heaps look like?

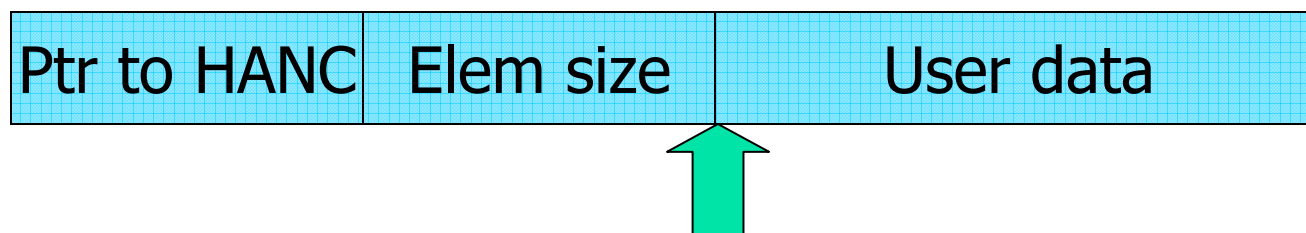


- Heap Layout continued...
 - Header
 - x'20' byte header (8 fullwords of data)
 - Eyecatcher 'HANC'
 - Pointer to next Heap segment or HPCB
 - Pointer to previous Heap segment or HPCB
 - Heapid (user heap = 0)
 - Pointer to beginning of segment
 - Root address (largest free element in segment)
 - Heap Segment Length
 - Root element length (size of largest free element)

What do heaps look like?



- Heap Layout continued...
 - Allocated element
 - 8 byte header
 - Pointer to beginning of heap segment (HANC)
 - Size of element including header
 - User portion
 - Address returned to user



What do heaps look like?



- Heap Layout continued...
 - Free elements
 - Maintained in a Cartesian Tree
 - Larger elements toward the root
 - Smaller elements toward the leaves
 - Lower addresses to the left
 - Higher addresses to the right
 - Each free area contains x'10' bytes of information about **OTHER** free elements.
 - Left node address
 - Right node address
 - Left node size
 - Right node size

What do heaps look like?



■ Heap Layout continued...

- Free elements
 - The root element

Ptr to elem E	Ptr to elem F	Size of E	Size of F
Element B Element B has higher address than element A Elements E and F are equal or smaller than B			

Ptr to elem A	Ptr to elem B	Size of A	Size of B
ROOT Element Additional free space within this element This is the root element so it is the largest free element			

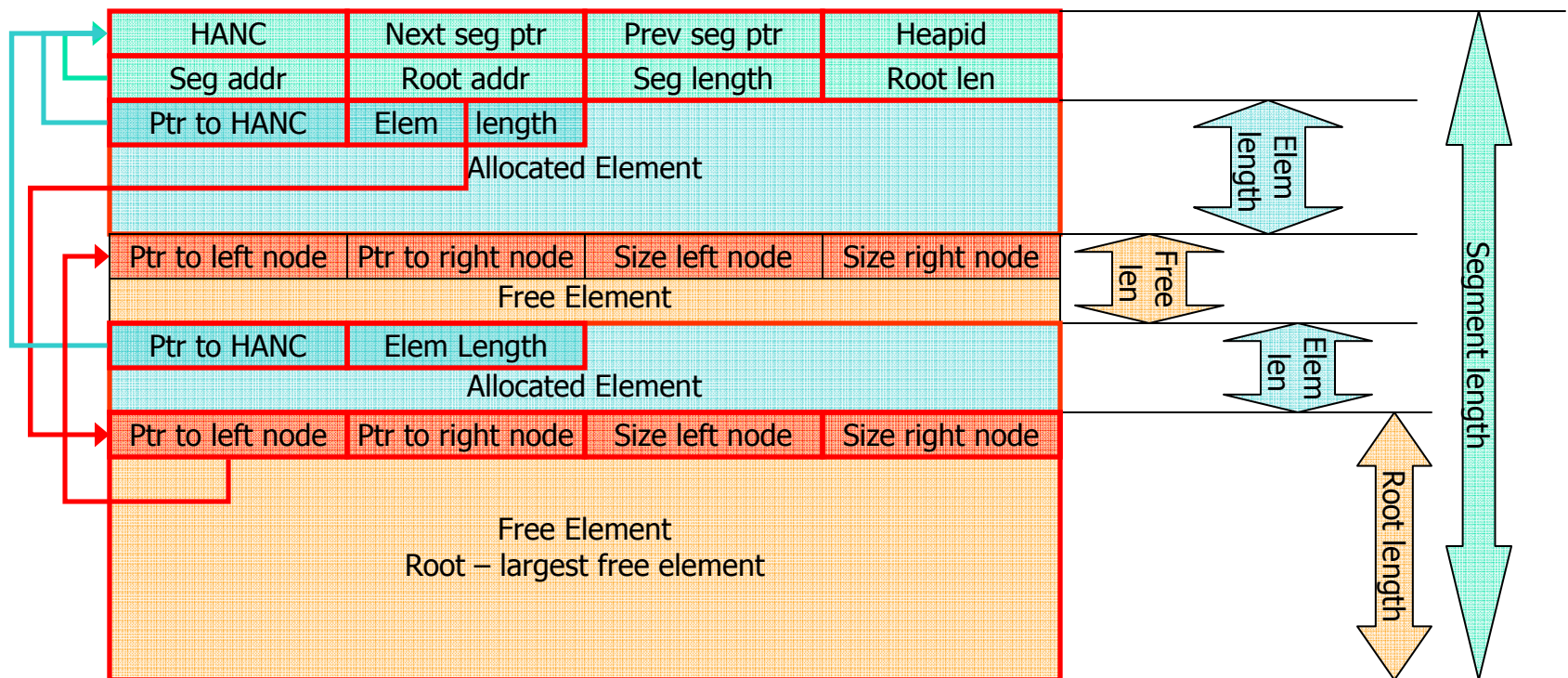
Ptr to elem C	Ptr to elem D	Size of C	Size of D
Element A Element A has a lower address than element B Elements C and D are equal or smaller than B			

- Free elements pointing to 0
 - End that branch of the tree
- Free elements pointing to element with size of 8
 - The eight byte element begins a "twig"
 - May be multiple 8 byte elements

What do heaps look like?



- Heap Layout continued... A "simple" example



What do heaps look like?



- Processing
 - Allocation
 - The Free Element tree of the latest heap segment is searched starting at the root for the smallest element which will satisfy the request.
 - If no free element found in that segment earlier segments are searched.
 - If no free element is large enough to satisfy the request, an additional heap segment is allocated via GETMAIN.
 - The needed storage from the free element is then allocated (8 byte header filled out).
 - If additional storage is left over in the element it is added to the free tree as a new free element.
 - A pointer to the user storage (after the 8 byte header) is returned to the user.

What do heaps look like?



- Processing

- Free

- Size of element is determined from the 8 byte header.
 - Element (including header) is returned to the free tree
 - If free element is adjacent to an existing free element the elements are combined into a larger free element
 - The free tree will be restructured as necessary.
 - If the entire heap is now free the segment will be FREEMAINED if FREE is specified.

What kind of damage might you see?



- Header crash!
 - The HANC eyecatcher or other fields of the header might be crashed into (overlaid).
 - Often caused by owner of storage before (lower address) the heap segment.
 - Could take a significant amount of time to determine damage occurred.

What kind of damage might you see?



- Allocated element crash
 - The 8 bytes prior to the user data is crashed into.
 - Won't be detected until an attempt is made to free this element.
 - If crash is larger than 8 bytes the occupants (user data) could also be damaged.

What kind of damage might you see?



- Free element crash
 - The first 16 bytes of a free element contain information about the free tree.
 - Won't be detected until an attempt is made to get storage where this element is big enough to hold the data.
 - Crash is usually caused by the owner of the previous storage at the time of the crash.
 - Watch out for hit and run!



Who caused the damage?



- Header crashes are rare, but normally determining the storage owner prior to the segment is straight forward.
 - Might need to use storage alteration slip
- Allocated and Free element crashes are often less clear
 - Watch out for those hit and runs!

Who caused the damage?



- In almost all cases the damage is caused by the application
 - Determining which piece of the application can be difficult
 - Time to call the police!

Calling the police!



■ Sample program to cause heap damage

```
000100 IDENTIFICATION DIVISION.  
000200 PROGRAM-ID. SHAREHP.  
000300  
000400 DATA DIVISION.  
000500 WORKING-STORAGE SECTION.  
000600 01 WS-EYE PIC X(4) VALUE "WS-B".  
000700 01 HEAPID PIC S9(9) BINARY VALUE 0.  
000800 01 STORAGE-SIZE-24 PIC S9(9) BINARY VALUE 24.  
000900 01 STORAGE-SIZE-16 PIC S9(9) BINARY VALUE 16.  
001000 01 STORAGE-SIZE-8 PIC S9(9) BINARY VALUE 8.  
001100 01 ADDRESS-0 POINTER.  
001200 01 ADDRESS-1 POINTER.  
001300 01 ADDRESS-2 POINTER.  
001400 01 WS-DATA.  
001500 03 WS-DATA1 PIC X(16) VALUE "1234567890123456".  
001600 03 WS-DATA2 PIC S9(9) BINARY VALUE 0.  
...  
003100 LINKAGE SECTION.  
003200 01 HEAP-DATA-AREA PIC X(17).  
003300 PROCEDURE DIVISION.
```



Calling the police!



- Sample program to cause heap damage...

```
003400    MAIN-PROG.  
003500        DISPLAY "STARTING SHAREHP..."  
003600        CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-16,  
003700                ADDRESS-0, FC.  
003800  
003900        CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-16,  
004000                ADDRESS-1, FC.  
004100  
004200        CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-16,  
004300                ADDRESS-2, FC.  
004400  
004500        CALL "CEEFRST" USING ADDRESS-1, FC.  
004600  
004700        SET ADDRESS OF HEAP-DATA-AREA TO ADDRESS-2.  
004800        MOVE WS-DATA TO HEAP-DATA-AREA.  
004900  
005000        CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-8,  
005100                ADDRESS-1, FC.  
005200        GOBACK.
```

Calling the police!



- Eyewitness calls 911 to report the crash!

```
08.51.19 JOB25721 ---- WEDNESDAY, 16 FEB 2005 ----
08.51.20 JOB25721 $HASP373 JMONTIGO STARTED - WLM INIT - SRVCLASS WMLLONG - SYS AQFT
08.51.20 JOB25721 IEF403I JMONTIGO - STARTED - TIME=08.51.20
08.51.23 JOB25721 IEA995I SYMPTOM DUMP OUTPUT 345
345 USER COMPLETION CODE=4039 REASON CODE=00000000
345 TIME=08.51.21 SEQ=09748 CPU=0000 ASID=00BA
345 PSW AT TIME OF ERROR 078D1000 A01ECE96 ILC 2 INTC 0D
345 ACTIVE LOAD MODULE ADDRESS=201256C0 OFFSET=000C77D6
345 NAME=CEEPLPKA
345 DATA AT PSW 201ECE90 - 00181610 0A0D58D0 D00498EC
345 AR/GR 0: 80AB5B3E/84000000 1: 00000000/84000FC7
345 2: 00000000/20381F88 3: 00000000/00000002
...
345 E: 00000000/A01E0DDE F: 00000000/00000000
345 END OF SYMPTOM DUMP
08.51.23 JOB25721 IEA993I SYSMDUMP TAKEN TO POSIX.JMONTI.SHARE.HEAP.SYSMDUMP
08.51.23 JOB25721 IEF450I JMONTIGO GO - ABEND=S000 U4038 REASON=00000001 347
347 TIME=08.51.23
```

Calling the police!



- More eyewitness testimony.

```
STARTING SHAREHP...
```

```
CEE0802C Heap storage control information was damaged.
```

```
From compile unit SHAREHP at entry point SHAREHP at statement 896 at  
compile unit offset +000005C2 at entry offset +000005C2 at address 201011B2.
```

- Eyewitness seemed to turn around at the sound of the crash
 - Can describe that there is damage
 - Can tell where they are when they first saw the damage
 - But CANNOT tell you who was at fault!

Calling the police!



■ Going through the police report

CEE3DMP V1 R6.0: Condition processing resulted in the unhandled condition.

02/16/05 8:51:23 AM

Page: 1

Information for enclave SHAREHP

Information for thread 8000000000000000

Traceback:

DSA Addr	Program Unit	PU Addr	PU Offset	Entry	E Addr	E Offset	Statement	Load Mod	Service	Status
20381648	CEEHDSP	201DD170	+00003F58	CEEHDSP	201DD170	+00003F58		CEEPLPKA	UQ91316	Call
203814B0	CEEHSGLT	201EF1B8	+0000005C	CEEHSGLT	201EF1B8	+0000005C		CEEPLPKA	HLE7709	Exception
20381398	CEEV#GTS	202BBFF8	+00000698	CEEV#GTS	202BBFF8	+00000698		CEEPLPKA	HLE7709	Call
203812E8	CEEVGTST	202CC720	+00000072	CEEVGTST	202CC720	+00000072		CEEPLPKA	HLE7709	Call
20381100	IGZCFCC	2034AB78	+000002CA	IGZCFCC	2034AB78	+000002CA		IGZCPAC		Call
20381030	SHAREHP	20100BF0	+000005C2	SHAREHP	20100BF0	+000005C2	896	SHAREHP		Call

- Has details about what led up to the witness realizing there was a crash.
 - CEEV#GTS was the witness in this case!
- Tells us who "detected" the error, not who "caused" the error.

Calling the police!



- Looking at the damage more closely

```
Initial (User) Heap : 203A1018
+000000 203A1018 C8C1D5C3 201230B8 201230B8 00000000 A03A1018 203A1160 00008000 00007EB8 | HANC.....-.....=.|
+000020 203A1038 203A1018 000000E0 000000D3 00000000 00000000 00000000 00000000 00000000 | .....L.....|
+000040 203A1058 00000000 00000000 C9C7E9E2 D9E3C3C4 00000000 00000000 00000000 00000000 | .....IGZSRTCD.....|
+000060 203A1078 00000000 00000000 E2E8E2D6 E4E34040 00000000 00000000 0E000000 00000000 | .....SYSOUT .....|
+000080 203A1098 0F000000 00000000 E6E260C2 00000000 00000000 00000000 00000028 00000000 | .....WS-B.....|
+0000A0 203A10B8 00000010 00000000 00000008 00000000 203A1120 00000000 203A1138 00000000 | .....|
+0000C0 203A10D8 203A1150 00000000 F1F2F3F4 F5F6F7F8 F9F0F1F2 F3F4F5F6 00000000 00000000 | ...&...1234567890123456.....|
+0000E0 203A10F8 00000000 00000000 00000000 00000000 E6E260C5 00000000 00000000 00000000 | .....WS-E.....|
+000100 203A1118 203A1018 00000018 00000000 00000000 00000000 00000000 00000000 00000000 | .....|
+000120 203A1138 00000000 00000000 00000000 00000000 203A1018 00000018 F1F2F3F4 F5F6F7F8 | .....12345678|
+000140 203A1158 F9F0F1F2 F3F4F5F6 003A1130 00000000 00000018 00000000 00000000 00000000 | 90123456.....|
+000160 203A1178 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 | .....|
+000180 203A1198 - +007FFF 203A9017 same as above
```

- Damage normally occurs in User Heap so check there first

203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	003A1130	00000000	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
203A1198	- +007FFF	203A9017			same as above			

	HANC	Next	Prev	HeapId		Root	Len	R. Len
203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	003A1130	00000000	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
203A1198	- +007FFF	203A9017						same as above

Calling the police!



■ Sample program CEEDUMP

```
Initial (User) Heap                               : 203A1018
+000000 203A1018 C8C1D5C3 201230B8 201230B8 00000000 A03A1018 203A1160 00008000 00007EB8 |HANC.....-.....=.|
+000020 203A1038 203A1018 000000E0 000000D3 00000000 00000000 00000000 00000000 00000000 |.....L.....|
+000040 203A1058 00000000 00000000 C9C7E9E2 D9E3C3C4 00000000 00000000 00000000 00000000 |.....IGZSRTCD.....|
+000060 203A1078 00000000 00000000 E2E8E2D6 E4E34040 00000000 00000000 0E000000 00000000 |.....SYSOUT.....|
+000080 203A1098 0F000000 00000000 E6E260C2 00000000 00000000 00000000 00000028 00000000 |.....WS-B.....|
+0000A0 203A10B8 00000010 00000000 00000008 00000000 203A1120 00000000 203A1138 00000000 |.....|
+0000C0 203A10D8 203A1150 00000000 F1F2F3F4 F5F6F7F8 F9F0F1F2 F3F4F5F6 00000000 00000000 |...&...1234567890123456.....|
+0000E0 203A10F8 00000000 00000000 00000000 00000000 E6E260C5 00000000 00000000 00000000 |.....WS-E.....|
+000100 203A1118 203A1018 00000018 00000000 00000000 00000000 00000000 00000000 00000000 |.....|
+000120 203A1138 00000000 00000000 00000000 00000000 203A1018 00000018 F1F2F3F4 F5F6F7F8 |.....12345678|
+000140 203A1158 F9F0F1F2 F3F4F5F6 003A1130 00000000 00000018 00000000 00000000 00000000 |90123456.....|
+000160 203A1178 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 |.....|
+000180 203A1198 - +007FFF 203A9017                same as above
```

- The crash resulted in the CEE0802C error.
- This is a simple case with a single small heap.
- Large heaps and/or multiple heaps are difficult to diagnose by hand.
- Problem 1!!!!

Calling the police!



■ Problem 2 – modify the program slightly

```
003600      CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-16,  
003700                          ADDRESS-0, FC.  
003800  
003900      CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-16,  
004000                          ADDRESS-1, FC.  
004100  
004200      CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-16,  
004300                          ADDRESS-2, FC.  
004400  
004500      CALL "CEEFRST" USING ADDRESS-1, FC.  
004600  
004700      SET ADDRESS OF HEAP-DATA-AREA TO ADDRESS-2.  
004800      MOVE WS-DATA TO HEAP-DATA-AREA.  
004900  
004910      CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-24,  
004920                          ADDRESS-1, FC.  
004930  
005000      CALL "CEEGTST" USING HEAPID, STORAGE-SIZE-8,  
005100                          ADDRESS-1, FC.  
005200      GOBACK.
```

Calling the police!



■ Problem 2 – Hit and Run!

```
Initial (User) Heap : 203A1018
+000000 203A1018 C8C1D5C3 1FF230B8 1FF230B8 00000000 A03A1018 203A1180 00008000 00007E98
+000020 203A1038 203A1018 000000E0 000000D3 00000000 00000000 00000000 00000000 00000000
+000040 203A1058 00000000 00000000 C9C7E9E2 D9E3C3C4 00000000 00000000 00000000 00000000
+000060 203A1078 00000000 00000000 E2E8E2D6 E4E34040 00000000 00000000 0E000000 00000000
+000080 203A1098 0F000000 00000000 E6E260C2 00000000 00000000 00000000 00000018 00000000
+0000A0 203A10B8 00000010 00000000 00000008 00000000 203A1120 00000000 203A1168 00000000
+0000C0 203A10D8 203A1150 00000000 F1F2F3F4 F5F6F7F8 F9F0F1F2 F3F4F5F6 00000000 00000000
+0000E0 203A10F8 00000000 00000000 00000000 00000000 E6E260C5 00000000 00000000 00000000
+000100 203A1118 203A1018 00000018 00000000 00000000 00000000 00000000 00000000 00000000
+000120 203A1138 00000000 00000000 00000000 00000000 203A1018 00000018 F1F2F3F4 F5F6F7F8
+000140 203A1158 F9F0F1F2 F3F4F5F6 203A1018 00000020 00000018 00000000 00000000 00000000
+000160 203A1178 00000000 00000000 003A1130 00000000 00000018 00000000 00000000 00000000
+000180 203A1198 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
+0001A0 203A11B8 - +007FFF 201A9017 same as above
```

- Same overlay occurs with element at 203A1160
- However damage now moved to 203A1180 – HIT AND RUN!!!!
- Why? Bigger problem!

	HANC	Next	Prev	HeapId		Root	Len	R. Len
203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	003A1130	00000000	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000

Request for 32 (x'20') bytes comes in – 24 + 8 byte header
Follow root to 203A1160 – non zero pointer – but size only x'18 – no room

	HANC	Next	Prev	HeapId		Root	Len	R. Len
203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	003A1130	00000000	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000

So use the first x'20' bytes for a new allocated element.

	HANC	Next	Prev	HeapId		Root	Len	R. Len
203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	003A1130	00000000	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000

Remainder of free element must be returned to free tree.
 So copy the information from existing free element.

	HANC	Next	Prev	HeapId		Root	Len	R. Len
203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	003A1130	00000000	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	003A1130	00000000	00000018	00000000	00000000	00000000

Remainder of free element must be returned to free tree.
 So copy the information from existing free element.

	HANC	Next	Prev	HeapId		Root	Len	R. Len
203A1018	C8C1D5C3	201230B8	201230B8	00000000	A03A1018	203A1160	00008000	00007EB8
203A1038	203A1018	000000E0	000000D3	00000000	00000000	00000000	00000000	00000000
203A1058	00000000	00000000	C9C7E9E2	D9E3C3C4	00000000	00000000	00000000	00000000
203A1078	00000000	00000000	E2E8E2D6	E4E34040	00000000	00000000	0E000000	00000000
203A1098	0F000000	00000000	E6E260C2	00000000	00000000	00000000	00000028	00000000
203A10B8	00000010	00000000	00000008	00000000	203A1120	00000000	203A1138	00000000
203A10D8	203A1150	00000000	F1F2F3F4	F5F6F7F8	F9F0F1F2	F3F4F5F6	00000000	00000000
203A10F8	00000000	00000000	00000000	00000000	E6E260C5	00000000	00000000	00000000
203A1118	203A1018	00000018	00000000	00000000	00000000	00000000	00000000	00000000
203A1138	00000000	00000000	00000000	00000000	203A1018	00000018	F1F2F3F4	F5F6F7F8
203A1158	F9F0F1F2	F3F4F5F6	201A1018	00000020	00000018	00000000	00000000	00000000
203A1178	00000000	00000000	003A1130	00000000	00000018	00000000	00000000	00000000

Now create the allocated element
 Problem 2! Damage has moved



Let the adjuster have a look

- **SYSMDUMP – IPCS**
 - **Use VERBX LEDATA 'HEAP'**
 - **First ENSM – Enclave Storage Management CB**

Language Environment Product 04 V01 R06.00

Heap Storage Control Blocks

```
ENSM: 201230A0
+000000 EYE_CATCHER:ENSM ST_HEAP_ALLOC_FLAG:00000000
+000008 ST_HEAP_ALLOC_VAL:00000000 ST_HEAP_FREE_FLAG:00000000
+000010 ST_HEAP_FREE_VAL:00000000 REPORT_STORAGE:00000000
+000018 UHEAP:C8D7C3C2 203A1018 203A1018 00008000 00008000 00002000 00001000 00000000 00
+000048 AHEAP:C8D7C3C2 2037D000 2037D000 00004000 00002000 00002000 00001000 00000000 00
+000078 BHEAP:C8D7C3C2 20123118 20123118 00002000 00001000 00002000 00001000 80000000 00
+0000A8 ENSM_ADDL_HEAPS:F0F00000
```



Let the adjuster have a look

- **SYSDUMP – IPCS**
 - Then HPCB and header for user heap

User Heap Control Blocks

```
HPCB: 201230B8
+000000 EYE_CATCHER:HPCB FIRST:203A1018 LAST:203A1018

HANC: 203A1018
+000000 EYE_CATCHER:HANC NEXT:201230B8 PREV:201230B8
+00000C HEAPID:00000000 SEG_ADDR:A03A1018 ROOT_ADDR:203A1160
+000018 SEG_LEN:00008000 ROOT_LEN:00007EB8
```

This is the last heap segment in the current heap.



Let the adjuster have a look

- **SYSDUMP – IPCS**
 - Next is the free tree information
 - **NOTE: *ERROR*** indicates an error was found

Free Storage Tree for Heap Segment 203A1018

Depth	Node Address	Node Length	Parent Node	Left Node	Right Node	Left Length	Right Length
0	203A1160	00007EB8	00000000	003A1130	00000000	00000018	00000000

ERROR The left node address does not fall within the current heap segment



Let the adjuster have a look

- **SYSMDUMP – IPCS**
 - Next map all elements in heap segment

Map of Heap Segment 203A1018

To display entire segment: IP LIST 203A1018 LEN(X'00008000') ASID(X'0181')

203A1038: Allocated storage element, length=000000E0. To display: IP LIST
203A1038 LEN(X'000000E0') ASID(X'0181')

203A1040: 000000D3 00000000 00000000 00000000 00000000 00000000 00000000
00000000 |...L.....|

203A1118: Allocated storage element, length=00000018. To display: IP LIST
203A1118 LEN(X'00000018') ASID(X'0181')

203A1120: 00000000 00000000 00000000 00000000
|..... |



Let the adjuster have a look

- **SYSMDUMP – IPCS**
 - Showing error as we go...

```
203A1130: Allocated storage element, length=00000000. To display: IP LIST
203A1130 LEN(X'00000008') ASID(X'0181')
203A1138: 00000000 00000000
|.....|
```

```
*ERROR* The heap segment address in the allocated storage element header is not
valid
WARNING This storage element may be a free storage node not found during free
storage tree validation
*ERROR* The length of this storage element is zero
WARNING Attempting to identify a resume location after encountering a storage
element validation error
```



Let the adjuster have a look

- **SYSMDUMP – IPCS**
 - Finally Summary information
 - Amount of allocated and free storage
 - Number of elements
 - Identifies if there were errors in this heap segment
 - Problem 1, send it off to the repair shop!

Summary of analysis for Heap Segment 203A1018:

```
Amounts of identified storage:  Free:00007EB8  Allocated:00000110  Total:00007FC8
Number of identified areas   :  Free:         1  Allocated:         4  Total:         5
00000018 bytes of storage were not accounted for.
Errors were found while processing this heap segment.
This is the last heap segment in the current heap.
```




Let the adjuster have a look

- HEAPCHK runtime option
 - Runtime debug tool to help diagnose a heap damage problem
 - In many cases any heap damage may not be noticed until significant time has passed – A hit and run!
 - The HEAPCHK runtime option forces all the heap segments to be validated on a regular basis.
 - Gets a dump closer to the the one at fault.
 - Generates a U4042 ABEND
 - Use System dump, if needed, to debug.



Let the adjuster have a look

- HEAPCHK runtime option ...
 - HEAPCHK(ON|OFF,freq,delay,depth,pooldepth)
 - ON - turns HEAPCHK on (performance dog)
 - OFF - normal processing
 - freq
 - Defaults to 1, indicates every call to a heap routine (get or free) validates the heap
 - Other values for less frequent checks
 - delay
 - Allows some number of calls to occur prior to 'freq' being used.
 - depth
 - Depth of traceback for storage leak
 - pooldepth
 - Depth of heappools trace



Let the adjuster have a look

■ Eyewitness calling 911 (with HEAPCHK(ON))

```
17.12.44 JOB22865 ---- WEDNESDAY, 16 FEB 2005 ----
17.12.45 JOB22865 $HASP373 JMONTIGO STARTED - WLM INIT - SRVCLASS WLMLONG - SYS AQFT
17.12.45 JOB22865 IEF403I JMONTIGO - STARTED - TIME=17.12.45
17.12.48 JOB22865 IEA995I SYMPTOM DUMP OUTPUT 937
937 USER COMPLETION CODE=4042 REASON CODE=00000000
937 TIME=17.12.45 SEQ=11443 CPU=0000 ASID=018E
937 PSW AT TIME OF ERROR 078D1000 A01AB242 ILC 2 INTC 0D
937 ACTIVE LOAD MODULE ADDRESS=201256C0 OFFSET=00085B82
937 NAME=CEEPLPKA
937 DATA AT PSW 201AB23C - 00181610 0A0D47F0 B10A1811
937 AR/GR 0: 80AB5B3E/84000000 1: 00000000/84000FCA
937 2: 00000000/00000000 3: 00000000/00000001
...
937 E: 00000000/00000000 F: 00000000/00000000
937 END OF SYMPTOM DUMP
17.12.48 JOB22865 IEA993I SYSMDUMP TAKEN TO POSIX.JMONTI.SHARE.HEAP.SYSMDUMP
17.12.48 JOB22865 IEF450I JMONTIGO GO - ABEND=S000 U4042 REASON=00000000 939
939 TIME=17.12.48
```



Let the adjuster have a look

- More eyewitness testimony (with HEAPCHK(ON))
 - In this case CEE37xx messages are very meaningful
 - The damage has not yet moved
 - Full debug may still need to be done with SYSMDUMP and IPCS
 - Use a storage alteration (SA) SLIP if needed (non-CICS)
 - Problem 2 Solved! ?

```
STARTING SHAREHP...
```

```
CEE3701W Heap damage found by HEAPCHK run-time option.
```

```
CEE3707I Left pointer is bad in the free tree at 203A1160 in the heap  
segment beginning at 203A1018.
```

```
203A1140: 00000000 00000000 203A1018 00000018 F1F2F3F4 F5F6F7F8 F9F0F1F2  
F3F4F5F6 |.....1234567890123456|
```

```
203A1160: 003A1130 00000000 00000018 00000000 00000000 00000000 00000000  
00000000 |.....|
```

```
CEE3702S Program terminating due to heap damage.
```

Summary



- Summary for heaps
 - Heap used for dynamic storage
 - CEEDUMPs contain information on heap errors but they are difficult to find
 - SYSTEM DUMPs using LEDATA 'HEAP' make debug much simpler
 - Use HEAPCHK runtime option to debug
 - Big performance hit



Sources of Additional Info



- All Language Environment documentation available on the z/OS DVD collection and on the Language Environment website
 - Language Environment Debug Guide
 - Language Environment Runtime Messages
 - Language Environment Programming Reference
 - Language Environment Programming Guide
 - Language Environment Customization
 - Language Environment Migration Guide
 - Language Environment Writing ILC Applications
- Language Environment Web site
 - http://www-03.ibm.com/systems/z/os/zos/features/lang_environment/