the gamedesigninitiative at cornell university

Lecture 16

Debugging Strategies

There are Two Main Strategies

- **Confirmation**
  - Confirm everything you believe to be true
  - Find the thing that is not actually true
  - In worse case, have to look at every line of code
- **Binary Search**
  - Identify where the code is working properly
  - Identify where the code is not working properly
  - Limit confirmation to the space in between

There are Two Main Strategies

- **Confirmation**
  - Confirm everything you believe to be true
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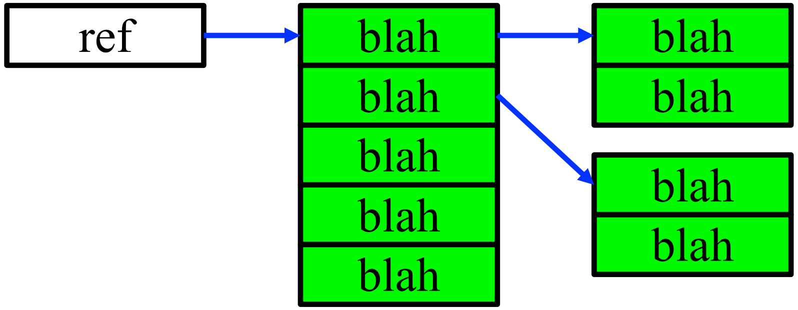
  - In worse case, have to look at

Everything else is a fancy tool to do this

-
  - Identify where the code is working properly
  - Identify where the code is not working properly
  - Limit confirmation to the space in between

The Challenge of Finding Errors

- *Access errors* are the hardest
  - Refer to object in memory
  - Object is deleted somehow
  - Refer to attribute of object
  - May/may not cause crash
- Remember the 1110 rule
  - Error found != error cause
  - Cause is somewhere before
- Must work up the *call stack*
  - Part of the **binary search**



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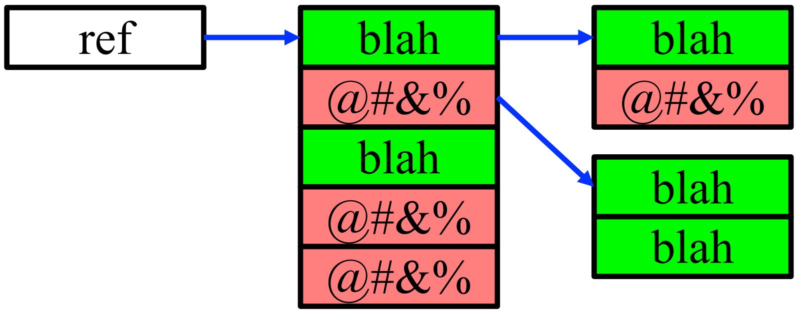


- “Deletion” is not immediate
  - Marks it for deletion
  - Will be deleted later
- Can still access object
  - Data corrupted as recycled

Primitive Confirmation Tools

- **Logging** (`CULog`)
  - Print out a variable value to check it
  - Alternatively print out a trace of program flow
  - **Goal**: View the internal program state
- **Assertions** (`CUAssert`)
  - Check that your assumption is true
  - Crash the code if it is not
  - **Goal**: Make error closer to the crash

Primitive Confirmation Tools

- `CULog(statement, v1, v2, v3...)`
  - Uses same syntax as printf()
  - Need to use char* to display string names
  - **Ex**: `CULog("Node is %s", node->getName().c_str())`
- `CUAssert(test, statement, v1, v2, v3...)`
  - Test is any boolean statement
  - Remainder of arguments act like printf()
  - **Ex**: `CUAssert(index > 0, "index is %d", index)`

Problems with Logging

- **Verbose**
  - Code with print every animation frame
  - Way too much information to sort through
  - Most game designers will log to a file
- **Distortionary**
  - Logging and other I/O is a blocking operation
  - Will change the thread behavior of your app
  - Can cause errors to appear/disappear

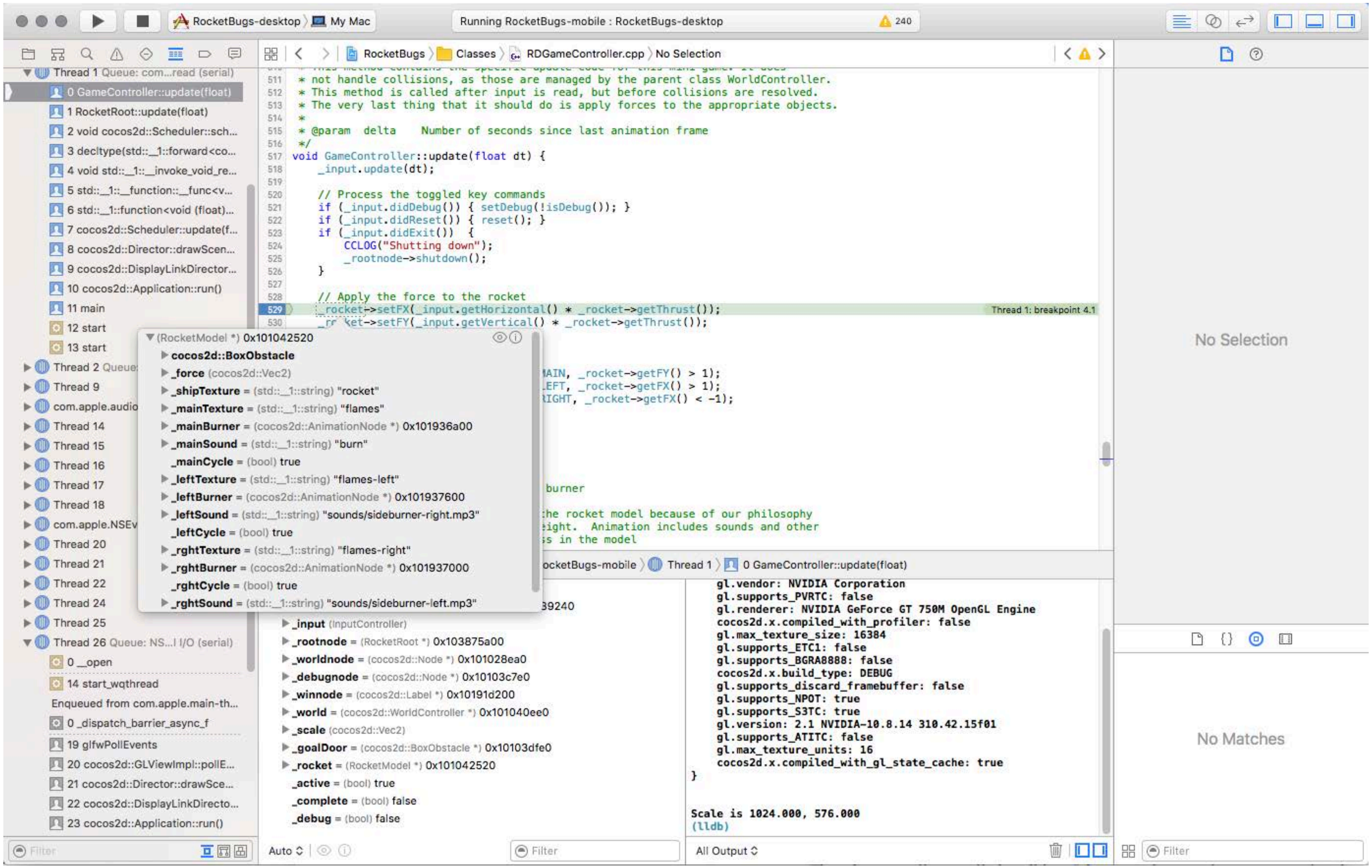
Advanced Tools

- **Breakpoints**
  - Stop the execution of the code
  - Can continue running from that point
  - Can continue one step at a time
- **Watches**
  - Look at the value of an individual variable
  - Can drill down into object attributes
  - But only works when variable is in scope

Advanced Tools

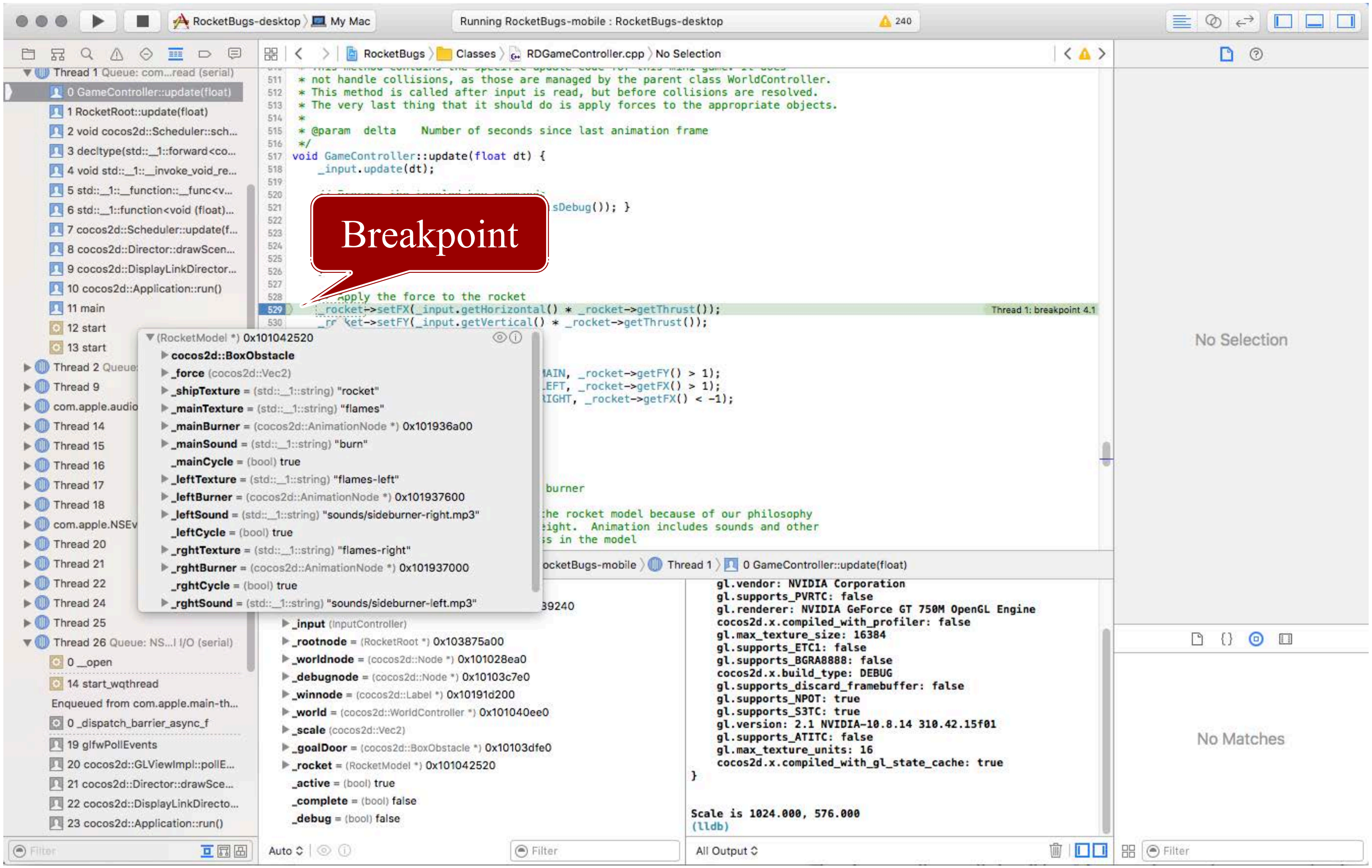
- **Memory Dumps**
  - Look at a raw memory location
  - Does not require a variable to be in scope
  - Good way to look at heap for corruption
- **Thread Monitors**
  - Stack traces for all running threads
  - All threads are frozen by a breakpoint
  - Allows you to compare state across threads

XCode Tools



RocketBugs-desktop
My Mac
Running RocketBugs-mobile : RocketBugs-desktop
RocketBugs
Classes
RDGameController.cpp
No Selection
No Matches

XCode Tools



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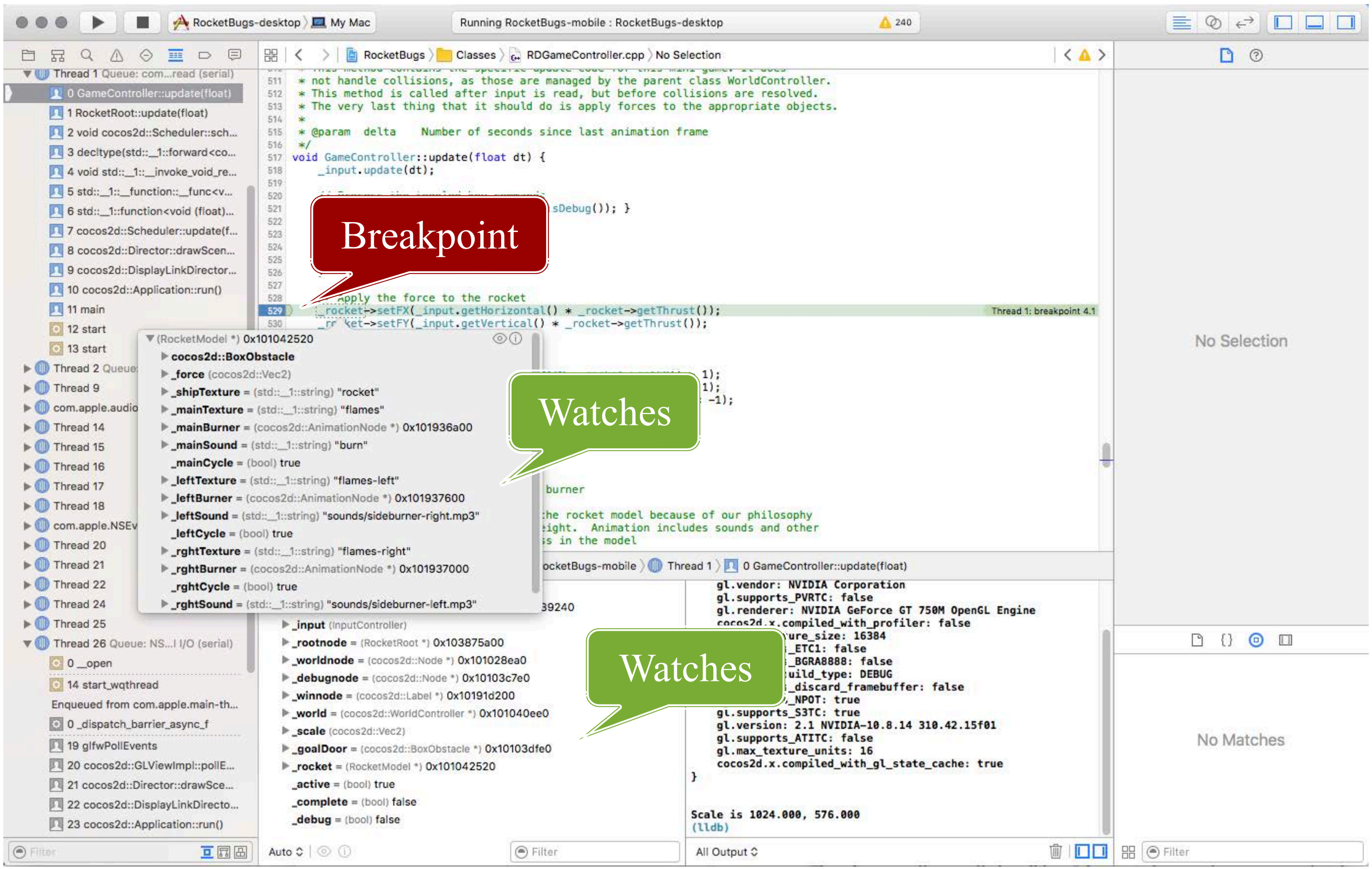

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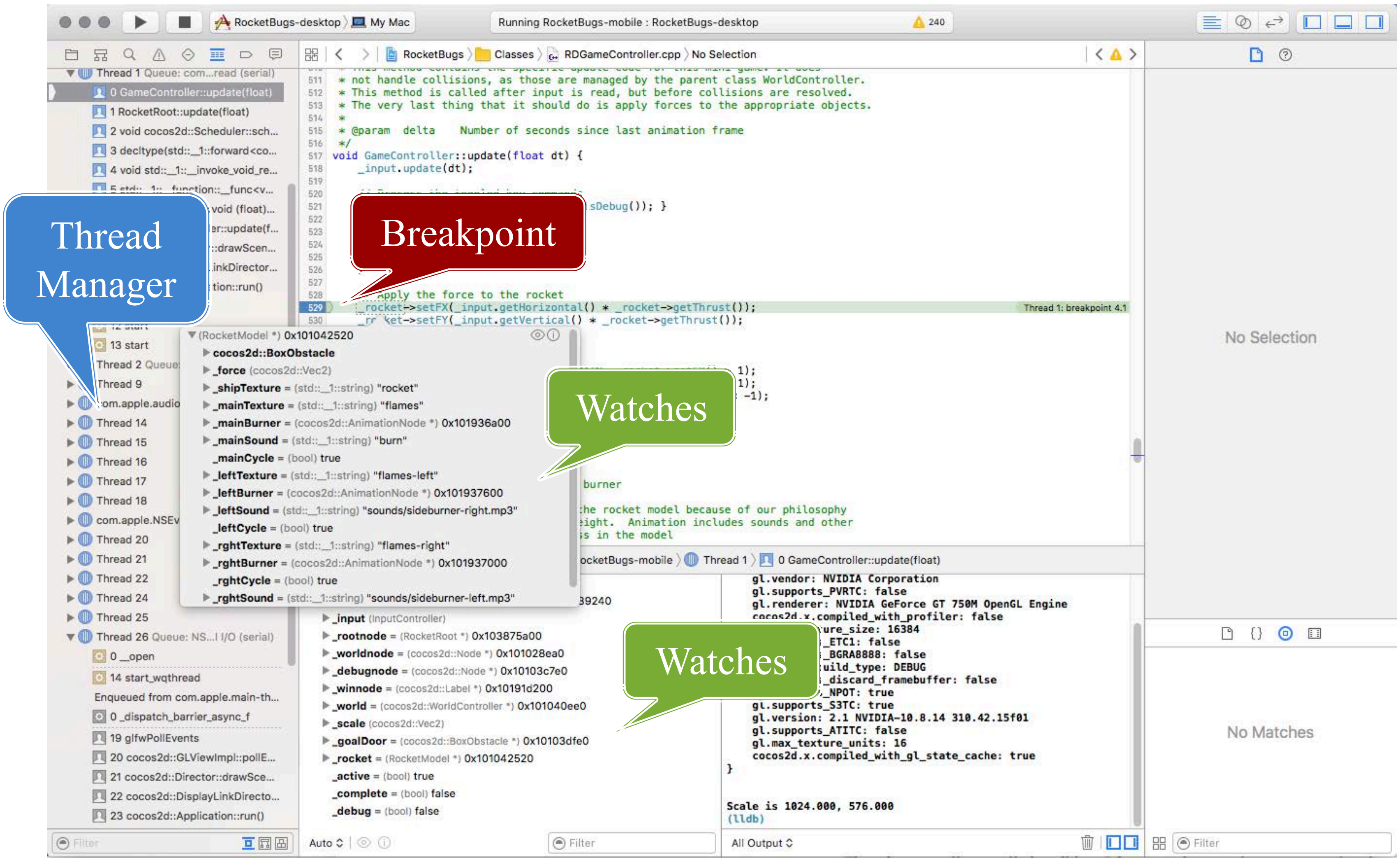

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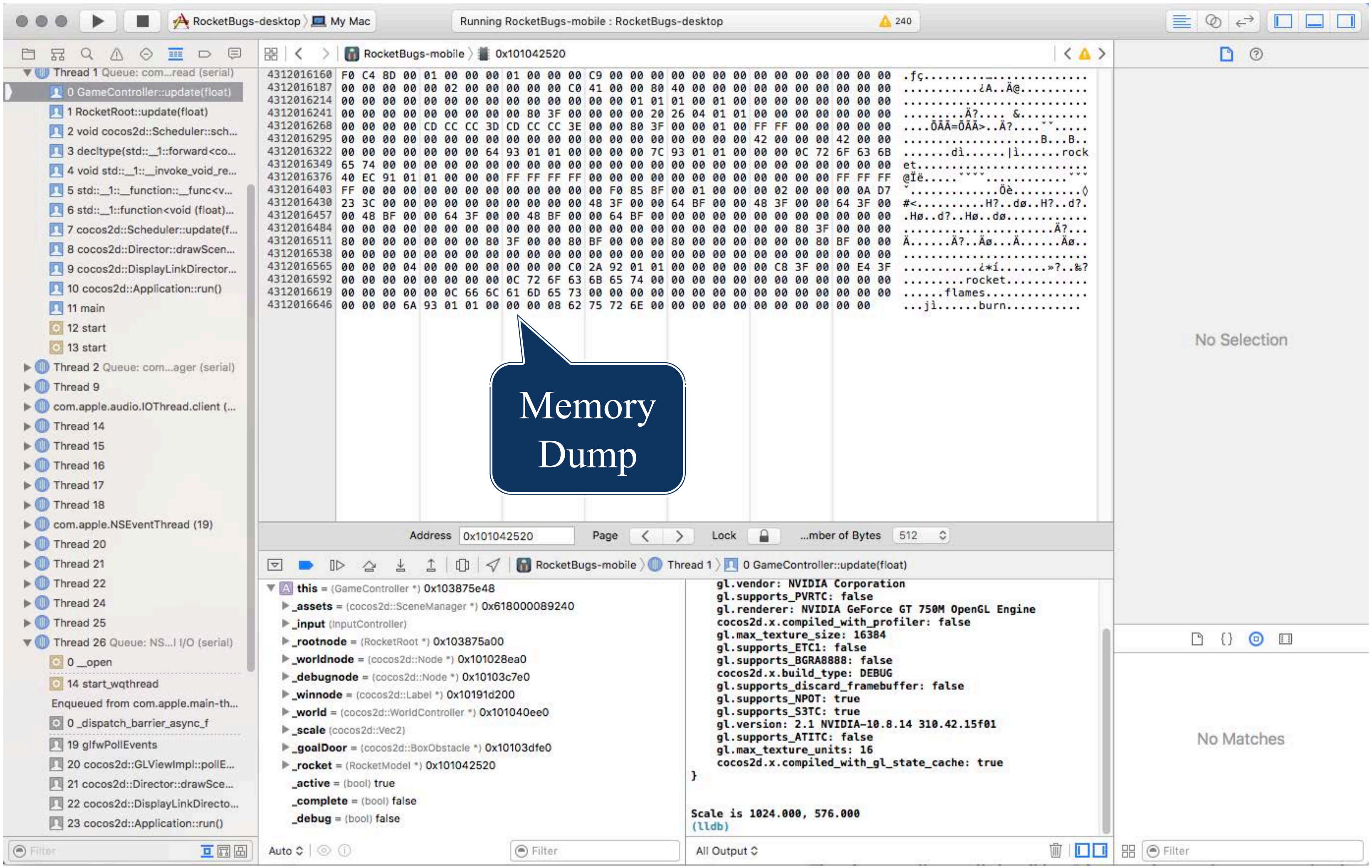
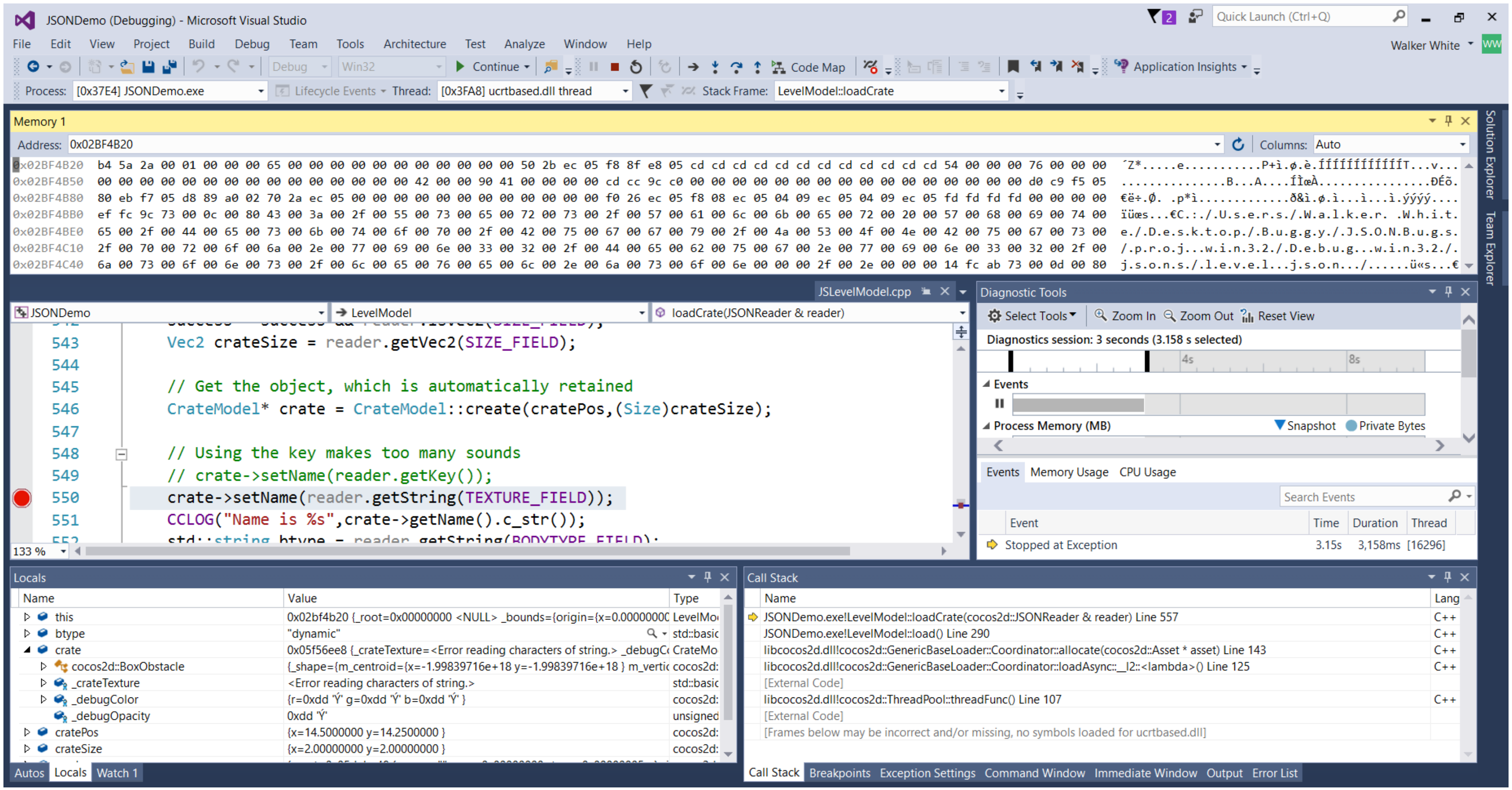


Visual Studio Tools



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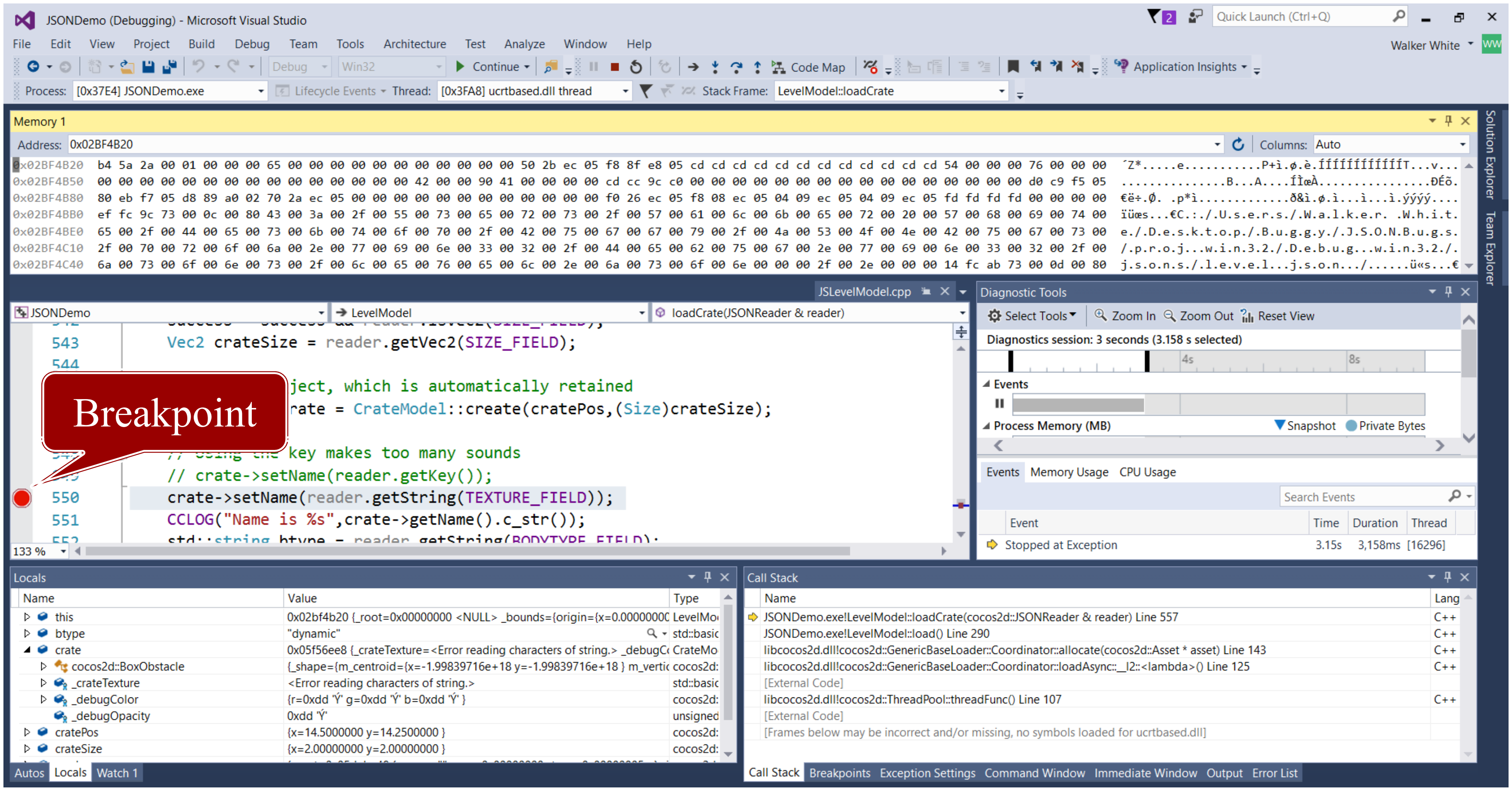
Visual Studio Tools



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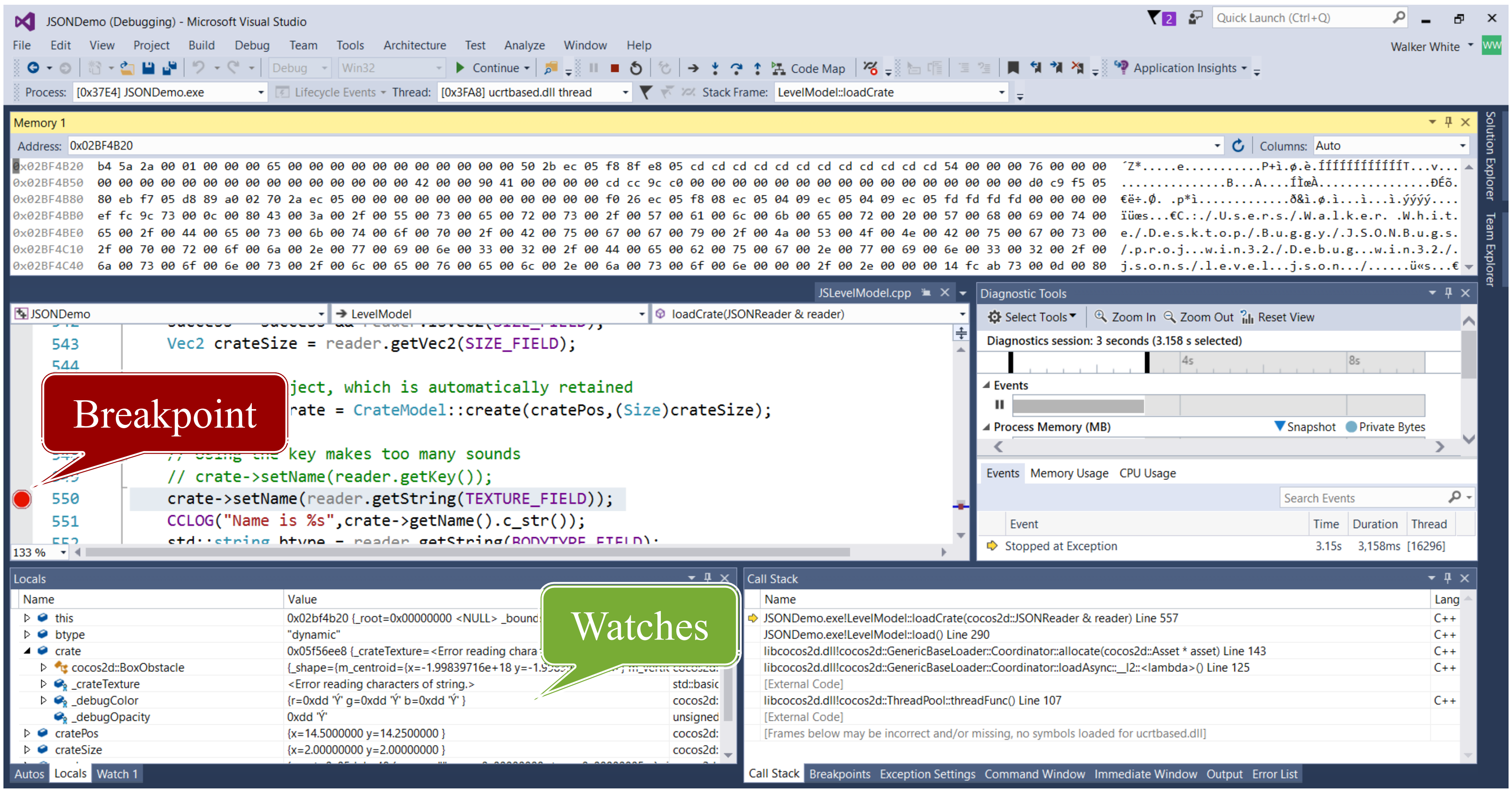

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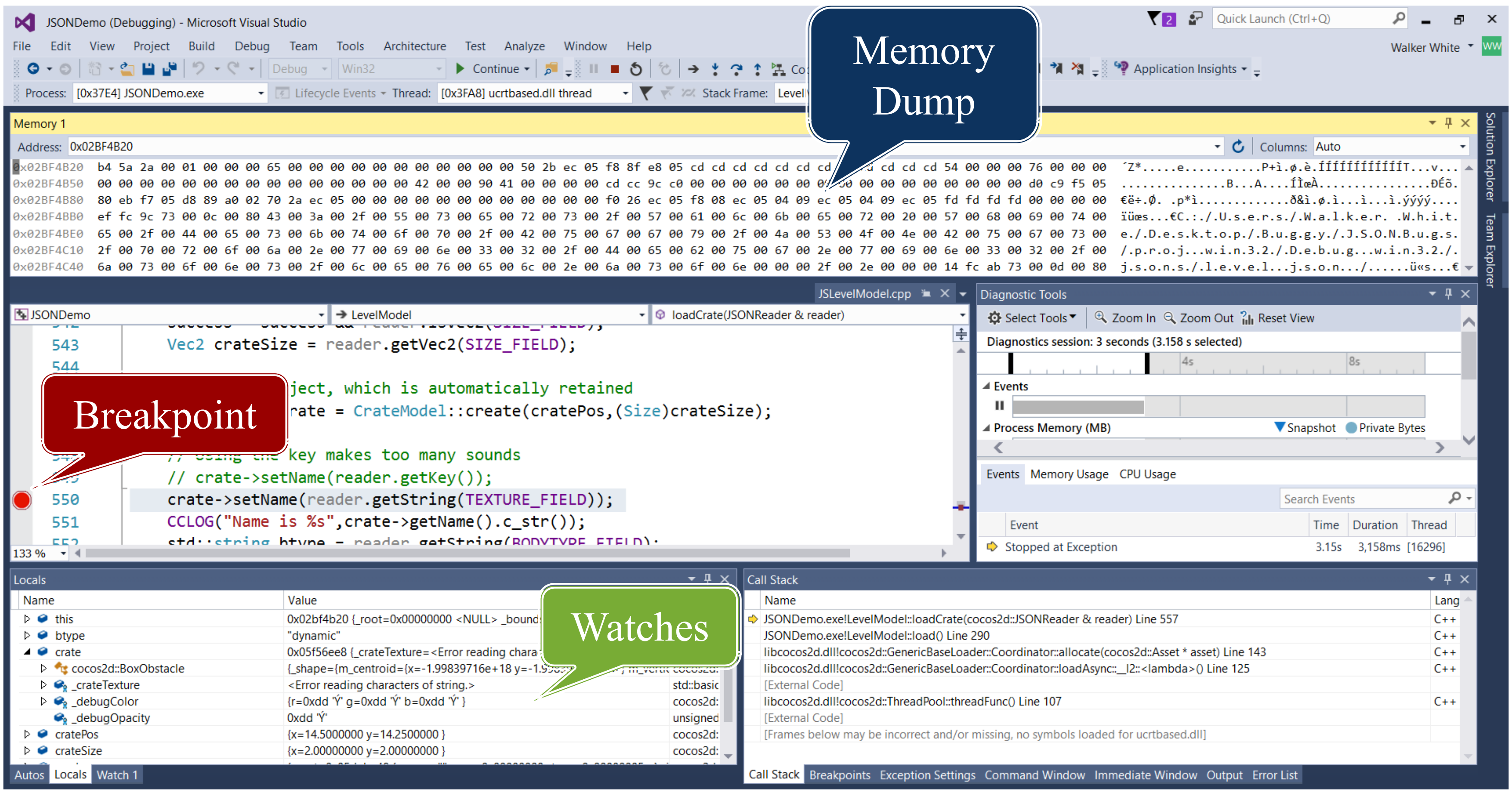
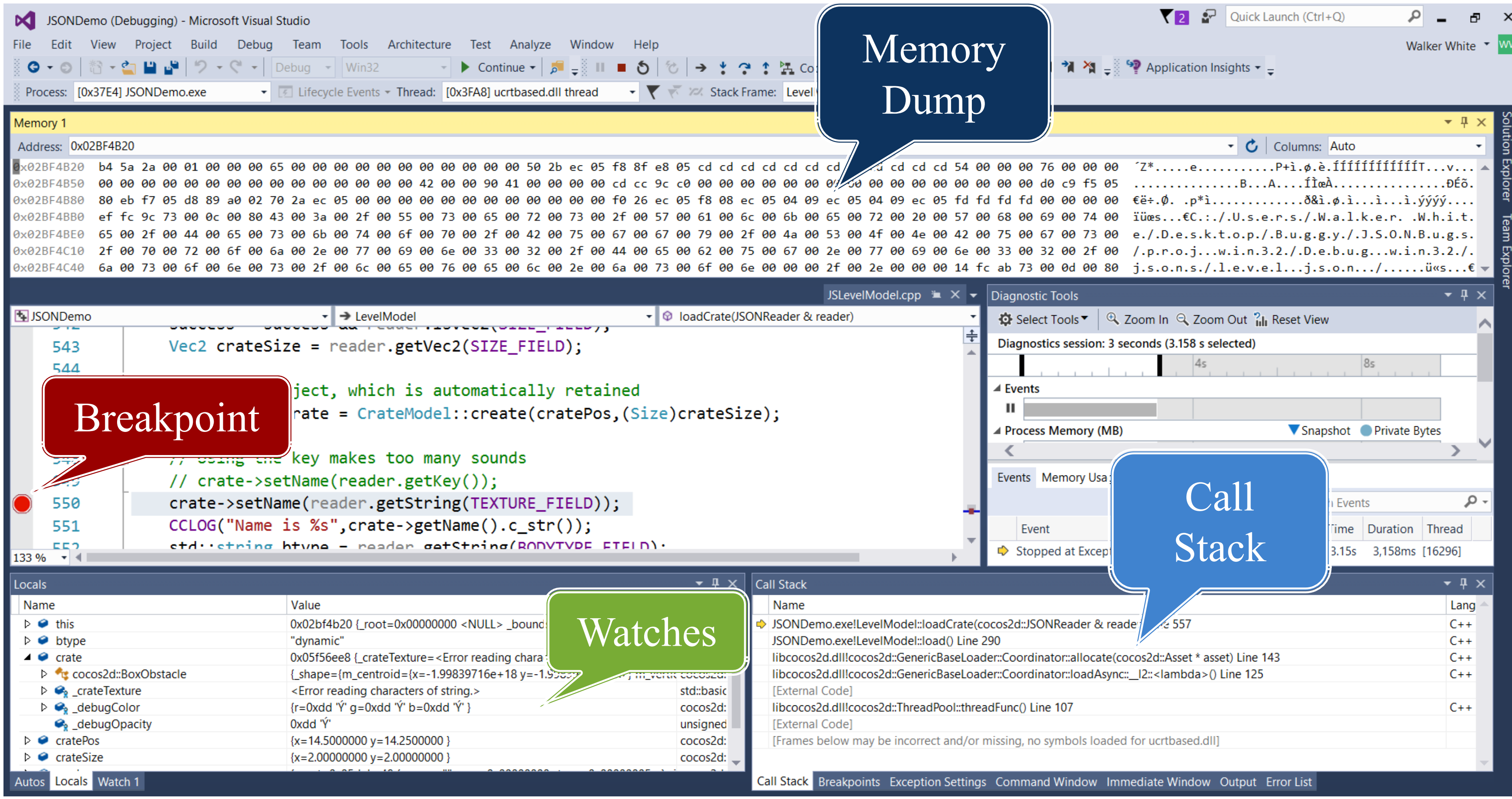
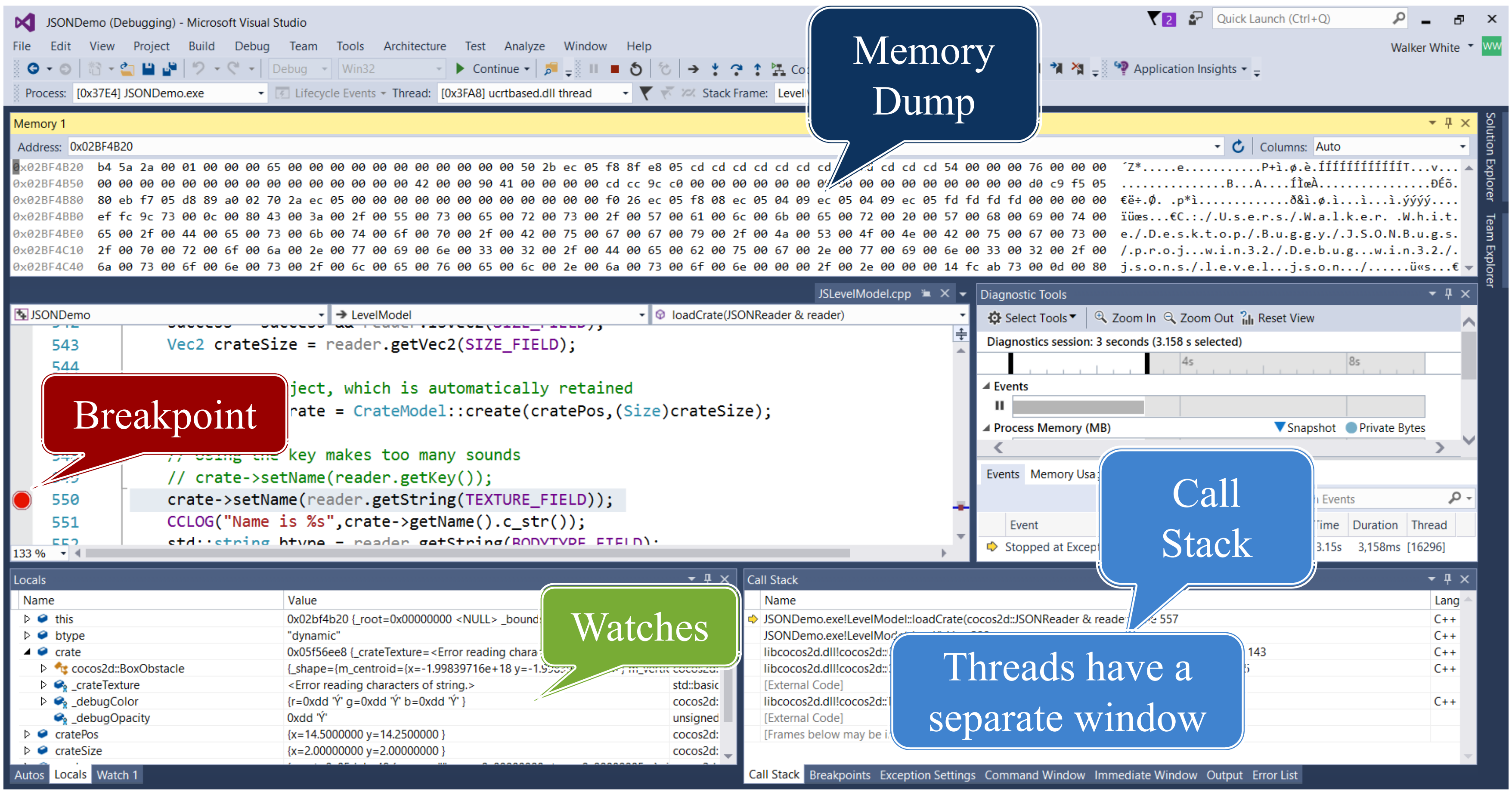


Visual Studio Tools



Visual Studio Tools



Breakpoint Strategies

- **Break early**
  - Break before the error, to check everything is okay
  - Step forward and watch how the code changes
- **Break infrequently**
  - If you always break, cannot initialize or animate anything
  - Design special conditionals for your breakpoint
- **Break on deletion**
  - Put breakpoints inside of all your destructors
  - Allows you to track accidental deletion

Problems with Code Stepping

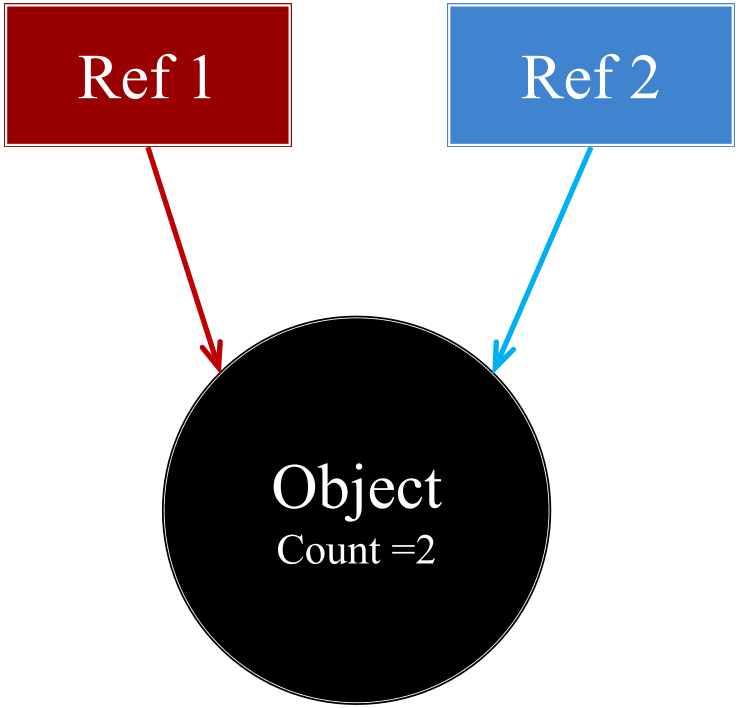
- Code stepping is not "thread safe"
  - Will never leave your current thread
  - Have to choose "continue" instead of "step"
- Makes it very difficult to find thread errors
  - May miss when a variable changes state
  - We had many problems in an old `AudioEngine`
- **Solution**: Rely heavily on assertions
  - Assert every variable shared across threads
  - Assert them everywhere they may change

Case Study: JSON Loading

- Problem in Cocos2d-x, an older engine
  - Not a C++11 compliant engine
  - Did not support smart pointers (or anything)
  - Instead all game objects had *reference counting*
- Manual reference counting leads to mistakes
  - Only slightly better than manual deletion
  - Even Apple has abandoned this in Objective-C
- But very instructive for **debugging memory**

Aside: Reference Counting

- Every object has a **counter**
  - Tracks number of “owners”
  - No owners = memory leak
  - Increment when get reference
- Often an explicit method call
  - Historically called `retain()`
- Decrement when reference lost
  - Method call is `release()`
  - If makes count 0, delete it



Scene Graphs the Old Way

```
// create a new instance
Node* node = Node::create();
node->retain();

// Add the node to scene graph
scene->addChild(node);

// Release the local reference
node->release();

// Remove from scene graph
scene->removeChild(node);
```

Raw pointers!!

Manual refence counts!!

Scene Graphs the Old Way

```
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```

Custom allocator

Reference count 1

Reference count 2

Reference count 1

Reference count 0

node is **deleted**

Scene Graphs the Old Way

```
// create a new instance
Node* node = Node::create();
node->retain();

// Add the node to scene graph
scene->addChild(node);

// Do not release the local reference

// Remove from scene graph
scene->removeChild(node);
```

Custom allocator

Reference count 1

Reference count 2

Reference count 1

Memory Leak!

Case Study: JSON Loading

- Problem was a thread *race condition*
  - Appeared on Windows, but not MacOS
  - Because of particular Windows thread schedule
  - But technically unsafe on all platforms
- Found by putting **breakpoints in destructors**
  - Models getting deleted immediately after creation
  - Watched the reference counts to find problem
  - There was a stray `release()` before `retain()`

Case Study: b2BlockAllocator

- *Memory address* problem in Box2D engine
  - Problem was because we put Box2D in a DLL
  - Required stepping through the allocation process
  - Required **memory dumps** to view the heap
- Problem with the *static global variables*
  - DLLs have a distinct global space
  - BlockAllocator was initialized inside of the DLL
  - When it was used outside the DLL, not initialized

Summary

- Two main strategies to debugging
  - **Confirmation:** Make sure code does what you think
  - **Binary Search:** Find where confirmation wrong
- Primitive tools in code on all platforms
  - Logging with `CULog`
  - Assertions with `CUAssert`
- Advanced tools in professional IDEs
  - Breakpoints and Watches
  - Thread Monitors (to see call stack)
  - Memory Dumps