null & NullReferenceException

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  - *"I call it my **billion-dollar mistake**. It was the invention of the null reference in 1965. At that time, I was designing the first comprehensive type system for references in an object oriented language (ALGOL W). My goal was to ensure that all use of references should be absolutely safe, with checking performed automatically by the compiler. But **I couldn't resist the temptation to put in a null reference, simply because it was so easy to implement**. This has led to innumerable errors, vulnerabilities, and system crashes, which have probably caused a billion dollars of pain and damage in the last forty years."*

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Part of "memory safety":

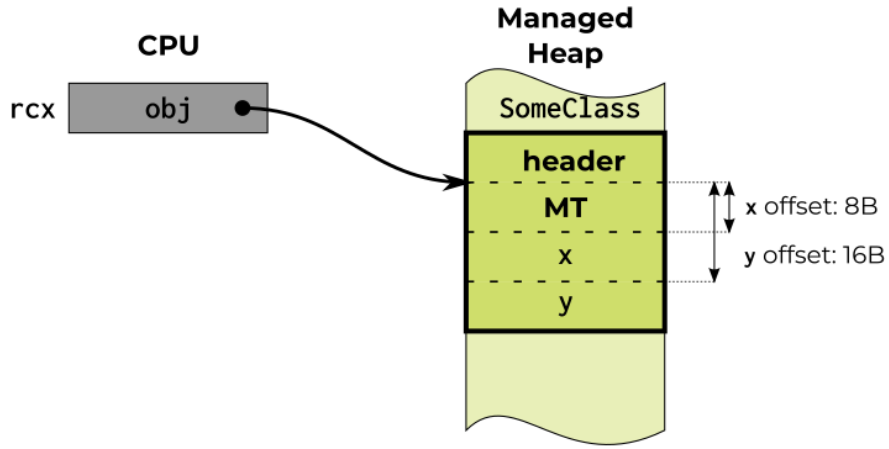
- it's better to be hit by `NullReferenceException` than by random error few hours later
- but... it is even better to have language that does not allow to have non-initialized/zeroed references
  - like F#
  - like C# trying to be with *nullable reference types*

null

```
public class C {
  static public void M(SomeClass obj) {
    Console.WriteLine(obj.Y);
    ...
  }
}

public class SomeClass {
  public long X;
  public long Y;
}
```

```
.method public hidebysig static
void M (class SomeClass obj) cil managed
{
  ldarg.0
  ldfld int32 SomeClass::Y
  call void System.Console::WriteLine(int32)
  ret
}
```



- **rcx** is the first argument - reference (address) to the **obj**
- **ldfld** is access to field **Y** - we need to add **Y** field offset (**0x10** is **16**)

```
C.M(SomeClass)
    mov rcx, [rcx+0x10]
    jmp System.Console.WriteLine(Int64)
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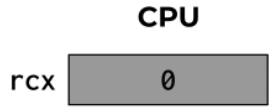

- if **obj** is **null** - reference (address) to the **obj** is just **0**
- **ldfld** is access to field **Y** - we need to add **Y** field offset (**0x10** is **16**) to... **0**
- we will access address **0x0000000000000010**

```
C.M(SomeClass)
  mov rcx, [rcx+0x10]
  jmp System.Console.WriteLine(Int64)
```

- this is handled by operating system as **invalid access to the protected page** - first 4kB of every process
- .NET runtime wraps it to re-throw as **NullReferenceException**

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What exception it will generate?

```
Unsafe.Read<byte>((void*)0);
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Well, this trying to access **the second page** (**`0x1_000`** is 4kB) which is not special. But it is probably not allocated to our process.

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Well, this trying to access **the second page** (**0x1_000** is 4kB) which is not special. But it is probably not allocated to our process. So, this is also invalid access to the page, but for every other than the first page, it is wrapped by .NET runtime into **AccessViolationException**.

null

Careful watcher may ask - but **what if object is bigger than 4kB**?! Trying to access some distant fields (or array elements) will try to access beyond the first, specially protected page:

```
public class SomeClass
{
  public long Field0;
  public long Field1;
  ...
  public long Field8230;
}

public static void Test(SomeClass obj)
{
  Console.WriteLine(obj.Field8000); // if obj is null, throws AccessViolationException...?!
}
```

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  ...
  public long Field8230;
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public static void Test(SomeClass obj)
{
  Console.WriteLine(obj.Field8000); // if obj is null, throws AccessViolationException...?!
}
```

But, JIT is clever! In such case, it adds null checking of the entire object **before** field access:

```
C.Test(SomeClass)
  ...
  cmp [rcx], ecx          ; Invalid address access handled as NullReferenceException
  mov rcx, [rcx+0xfa08]
  call System.Console.WriteLine(Int64)
  ...
```

null

```
public class C {
  static public void M() {
    SomeClass obj;
    ...
    obj = DoSomething();
    Console.WriteLine(obj.Y);
    ...
  }
}
```

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.method public hidebysig static
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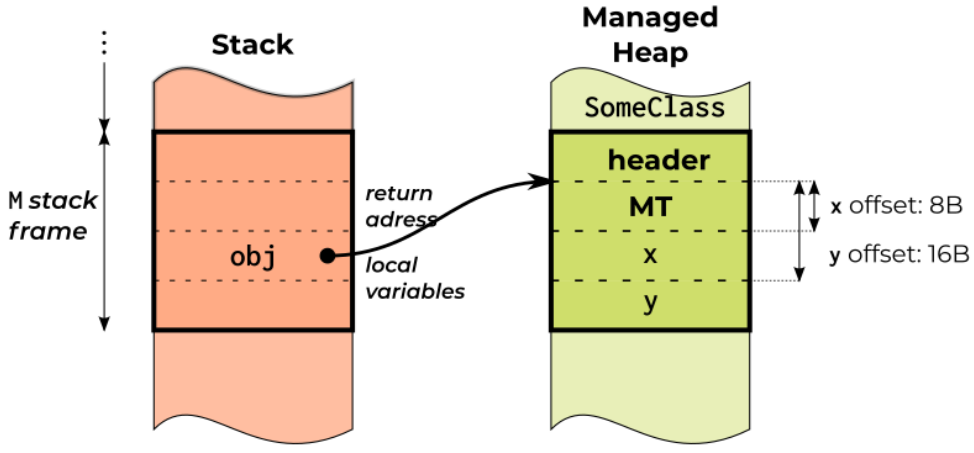

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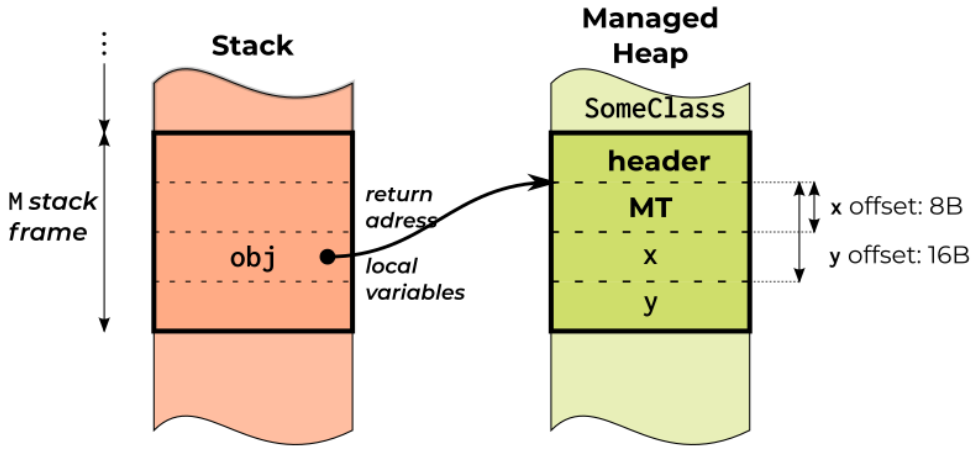


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C.M(SomeClass)
  ...
  call C.DoSomething()
  mov rcx, [rax+0x10]
```

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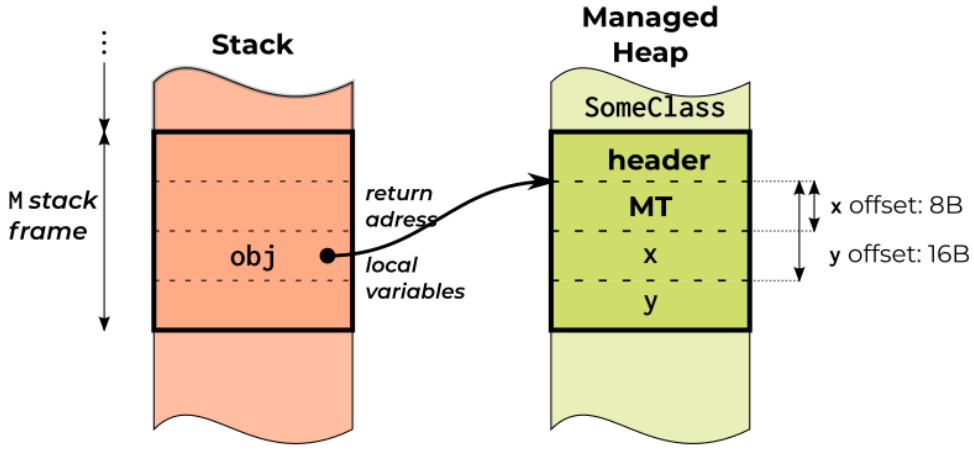


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If **DoSomething** returns (in **rax**) a valid reference - everything is fine.

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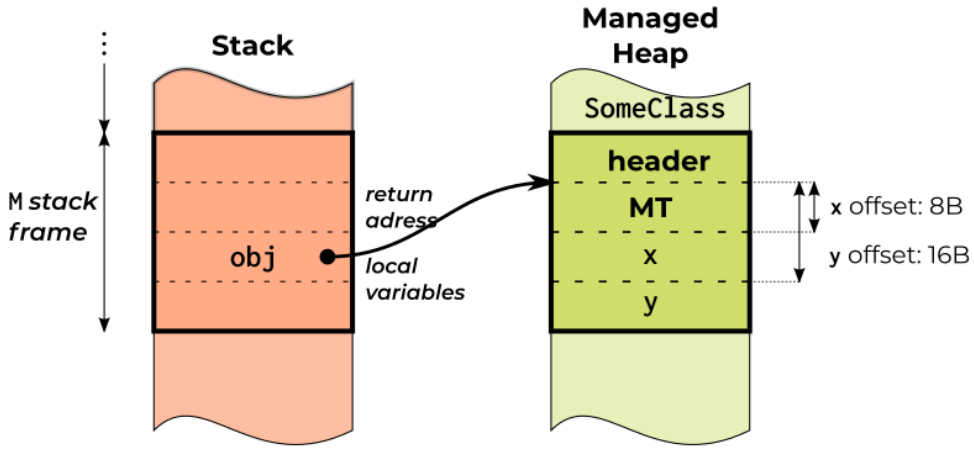


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If **DoSomething** returns (in **rax**) a valid reference - everything is fine.

If it returns **null** (0) - again we try to access address **0x10** (the first page).

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- BTW, compilers try to disallow usage of uninitiated variables:

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- we can disable stack zeroing **and** allow to use uninitialized locals (😱) - we will come to that...

`null` or not to `null`?

There is a popular question - does it make sense to **manually** null references as soon as we don't need them:

```
var x = new X();
x.DoSomething();
x = null;
await DoSomeLondRunningCallAsync();
```

This is nice question...

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This is nice question...but we need more GC knowledge to answer. We will return to it in the next modules!

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    (we will show some of them during the course)