SoK: Eternal War in Memory

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In: Oakland '14

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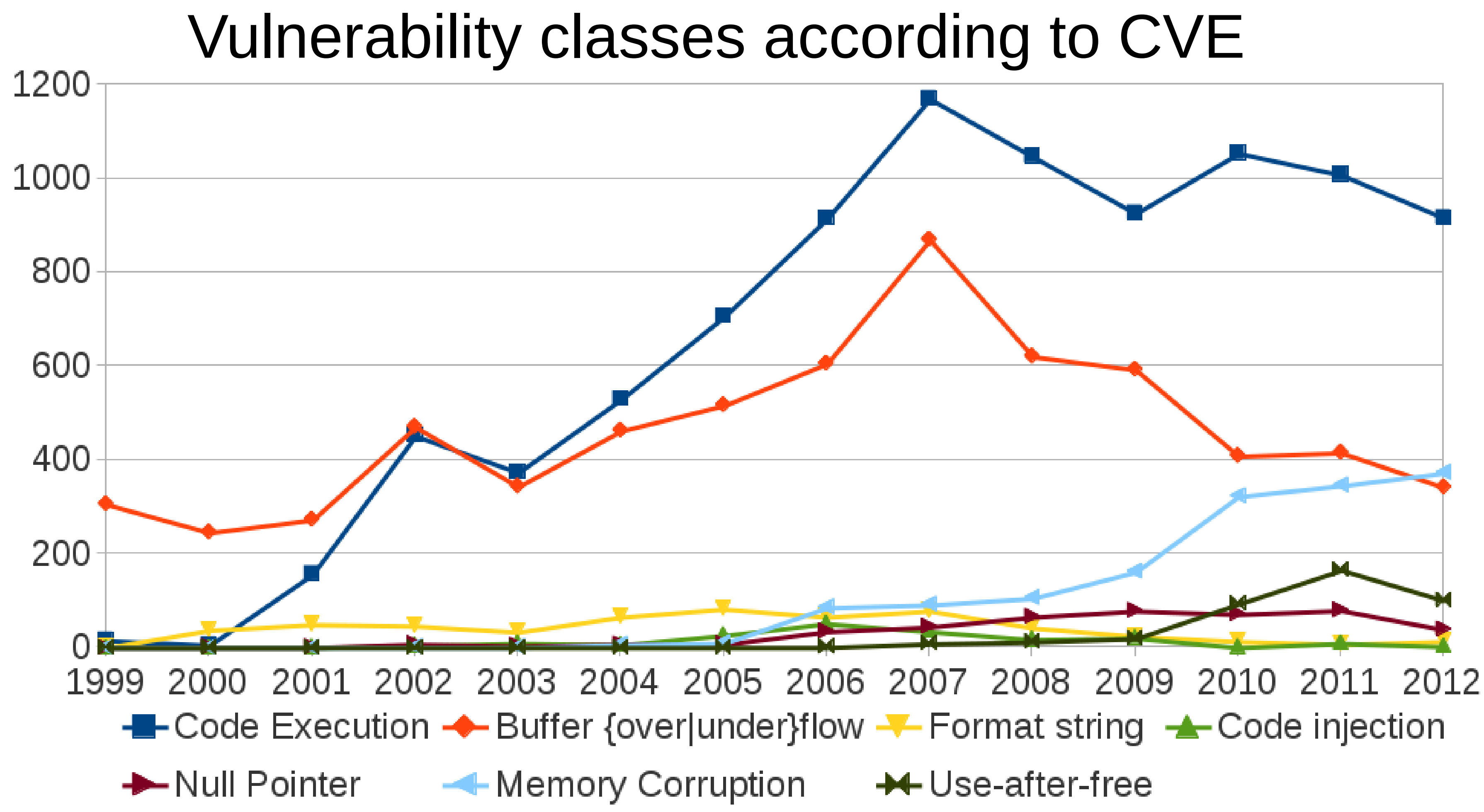
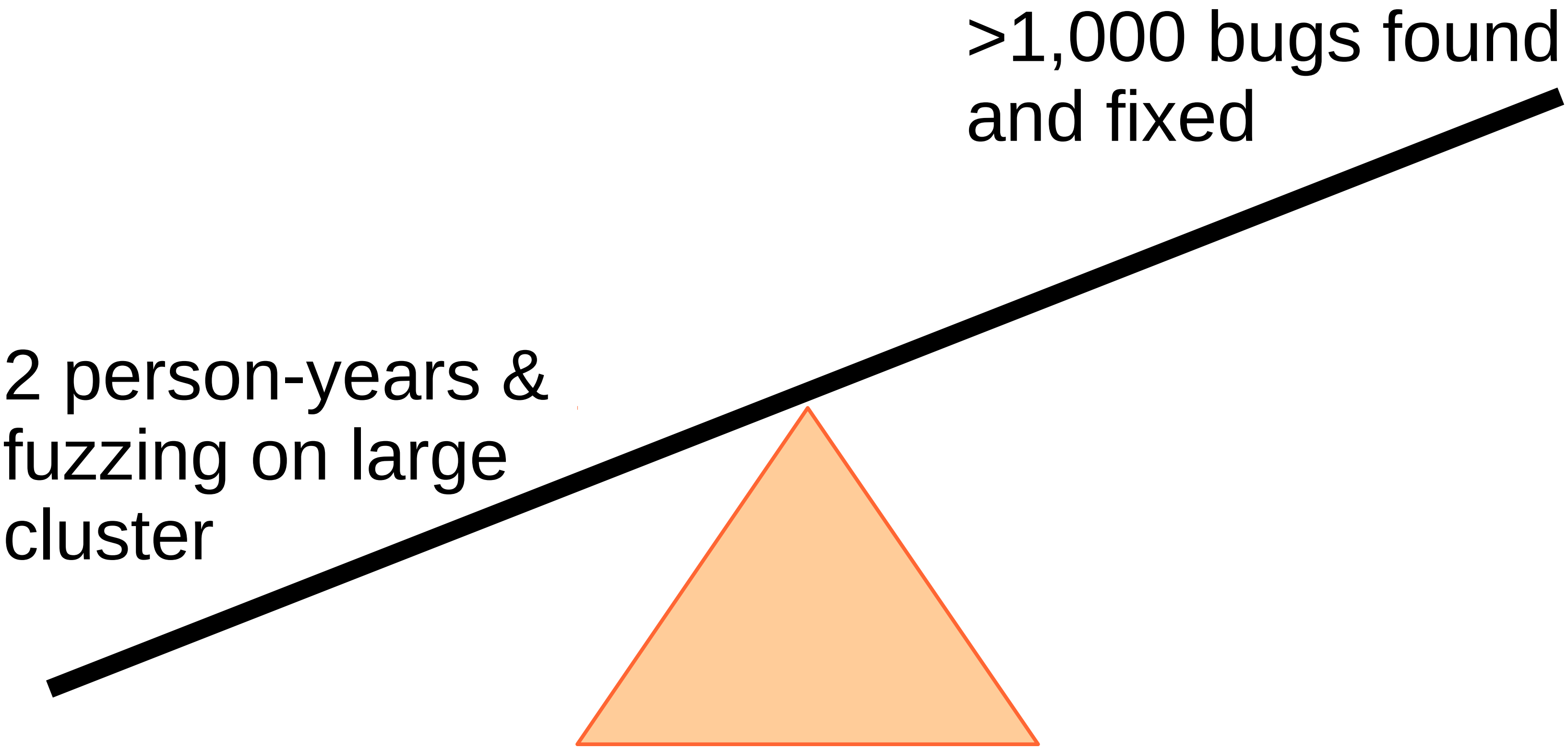
http://hexhive.github.io

Memory attacks: an ongoing war



FFmpeg and a thousand fixes



http://j00ru.vexillium.org/?p=2211 Jan-10, 2014

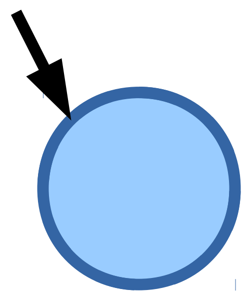
Software is unsafe and insecure

- Low-level languages (C/C++) trade type safety and memory safety for performance
  - Programmer responsible for all checks
- Large set of legacy and new applications written in C / C++ prone to memory bugs
- Too many bugs to find and fix manually
  - Protect integrity through safe runtime system

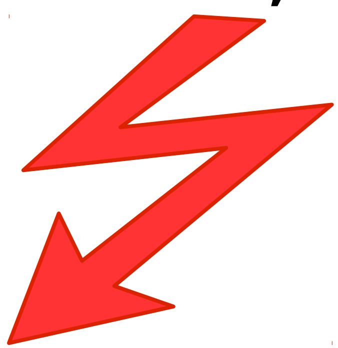
A Model for Memory Corruption

Memory (un-)safety: invalid deref.

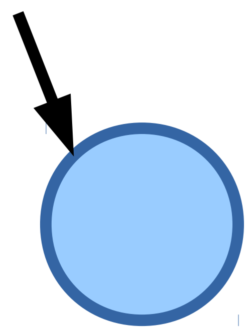
Dangling pointer:
(temporal)



```
free(foo);
*foo = 23;
```



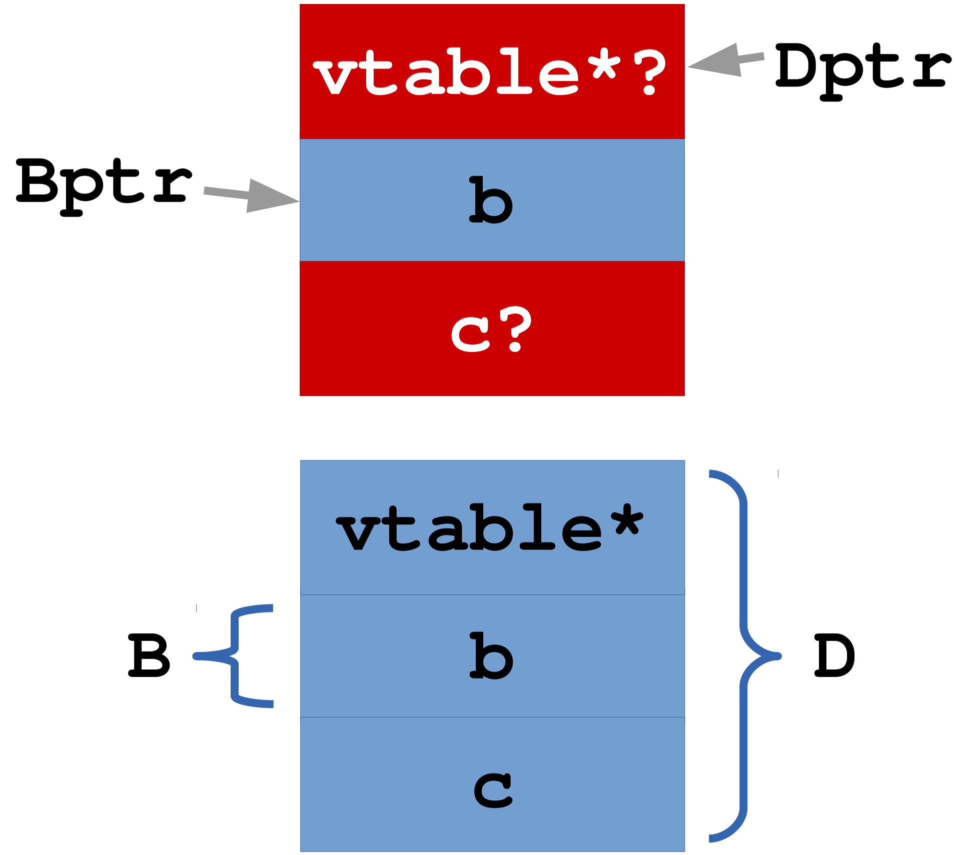
Out-of-bounds pointer:
(spatial)



```
char foo[40];
foo[42] = 23;
```

Violation iff: pointer is read, written, or freed

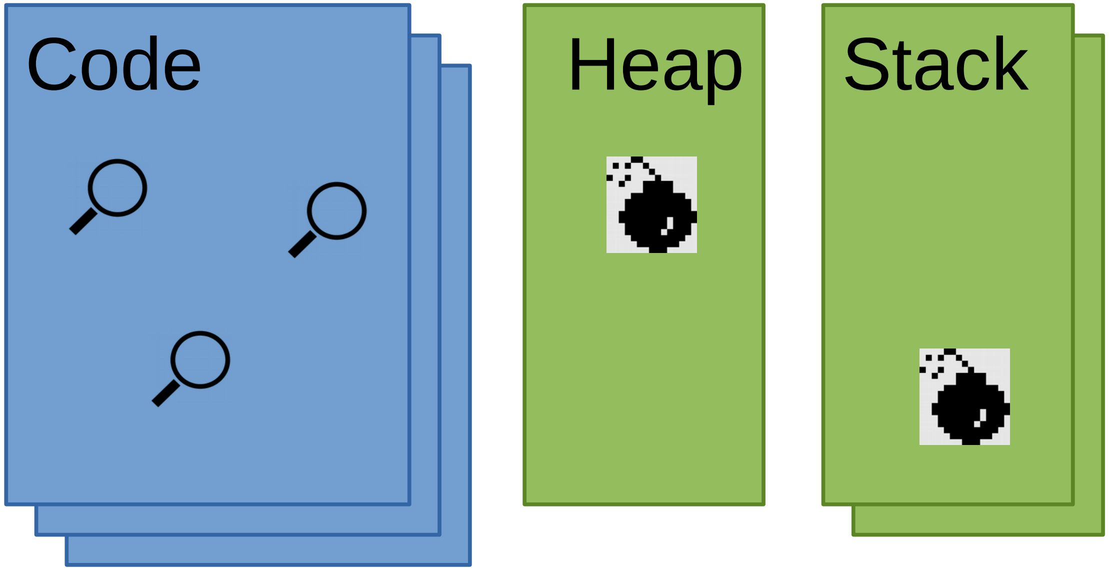
Type Confusion




```
class B {
   int b;
};
class D: B {
   int c;
   virtual void d() {}
};
…
B *Bptr = new B;
D *Dptr = static_cast<D*>B;
Dptr->c = 0x43; // Type confusion!
Dptr->d();      // Type confusion!
```

Attack scenario: code reuse

- Find addresses of gadgets
- Force memory corruption to set up attack
- Leverage gadgets for code-reuse attack
- (Fall back to code injection)



Benign control-flow

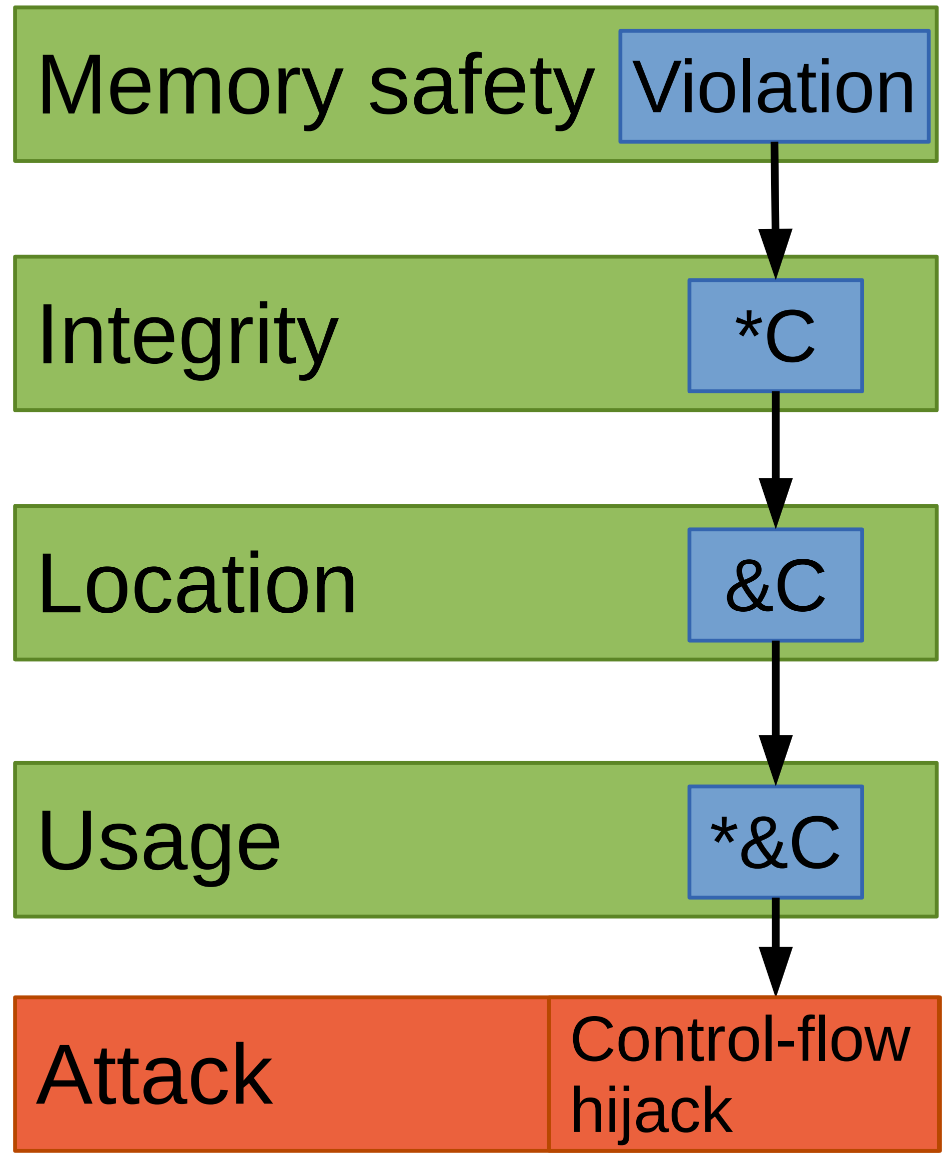
```
void vuln(char *u1) {
   // strlen(u1) < MAX ?
   char tmp[MAX];
   strcpy(tmp, u1);
   ...
}
vuln(&exploit);
```

tmp[MAX]
Saved base pointer
Return address
1st argument: *u1
Next stack frame

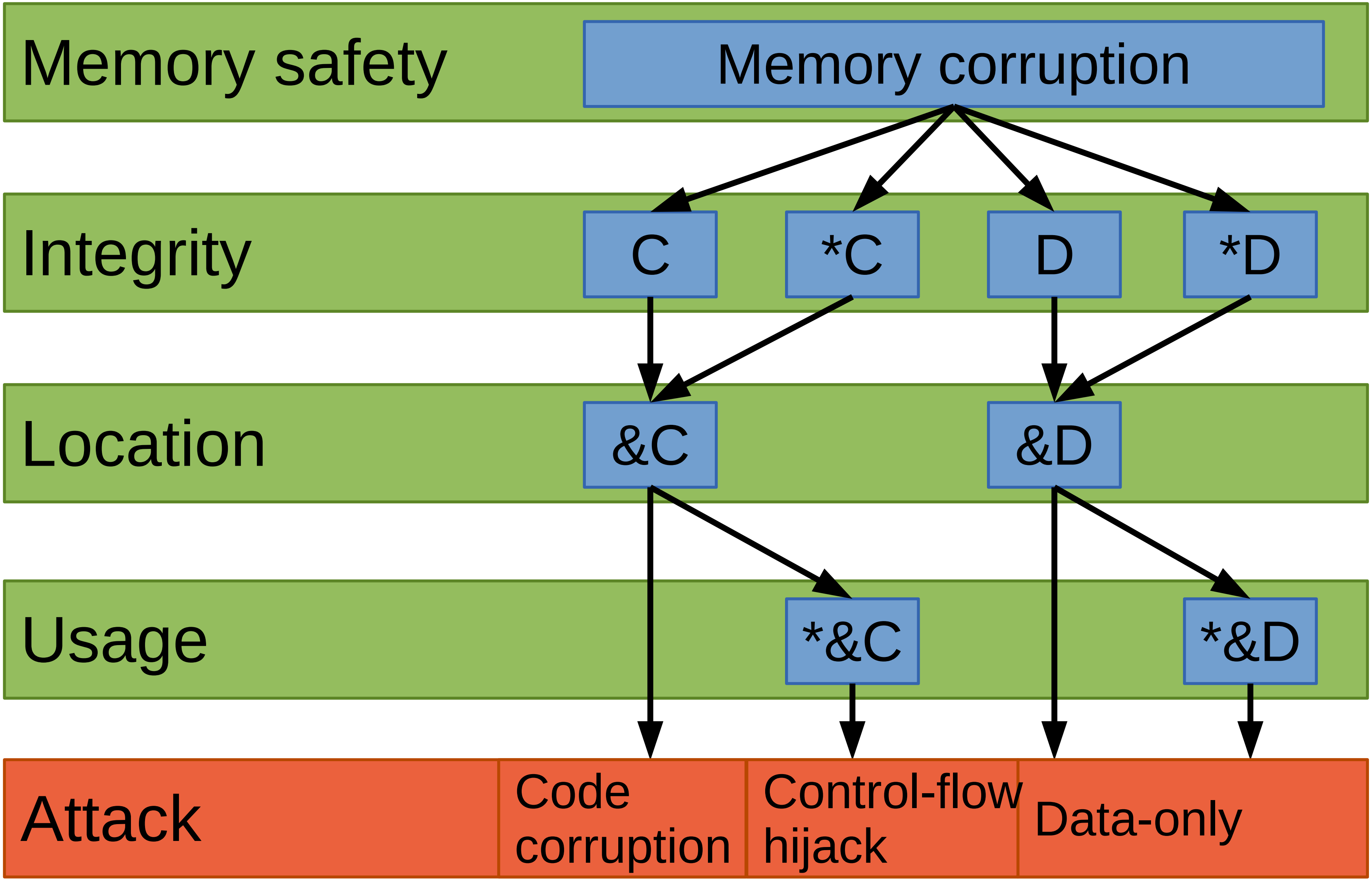
Control-flow hijack attack

```
void vuln(char *u1) {
   // strlen(u1) < MAX ?
   char tmp[MAX];
   strcpy(tmp, u1);
   ...
}
vuln(&exploit);
```

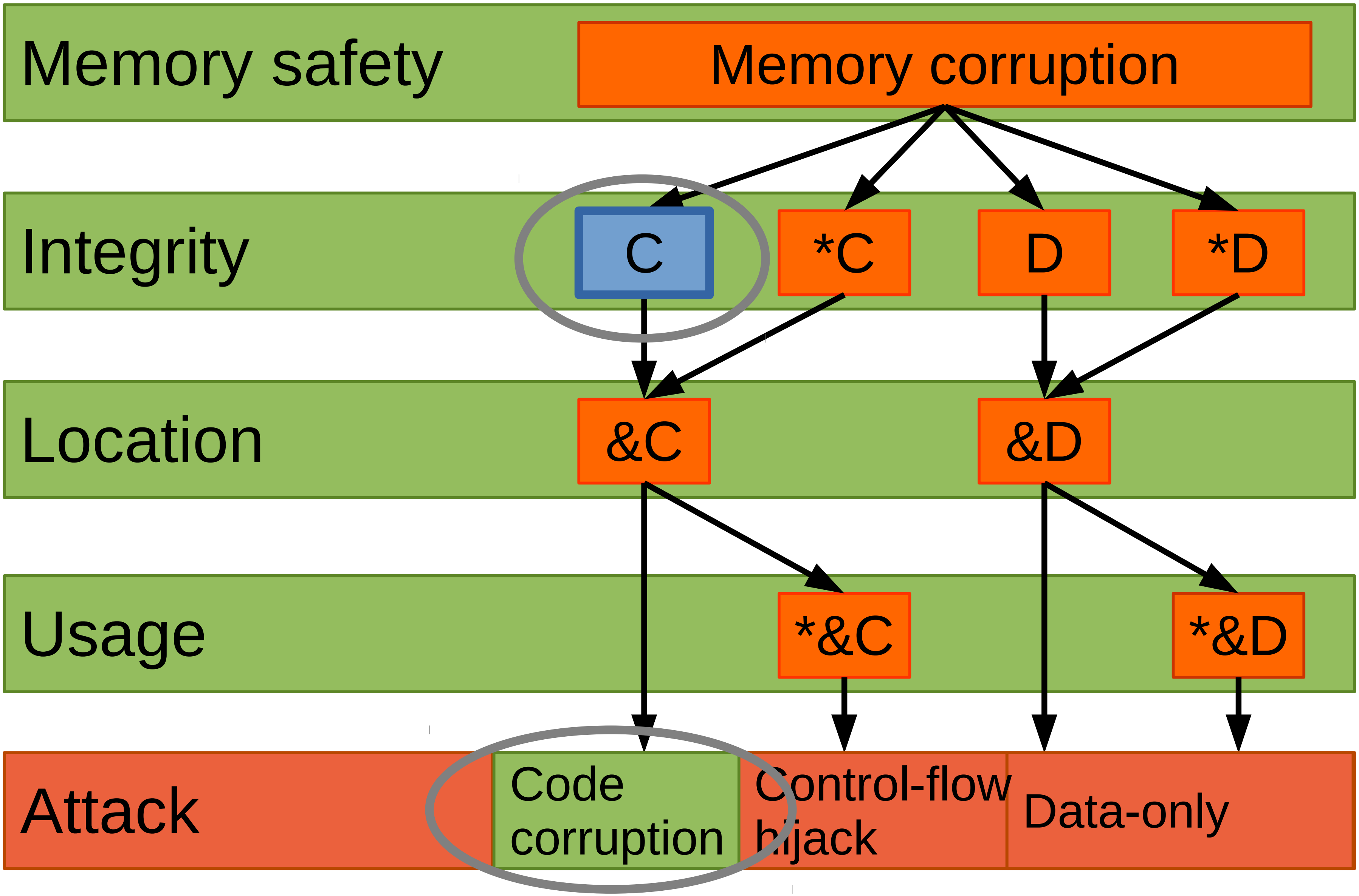
Don't care
Don't care
Points to &system()
Base pointer after system()
1st argument to system()



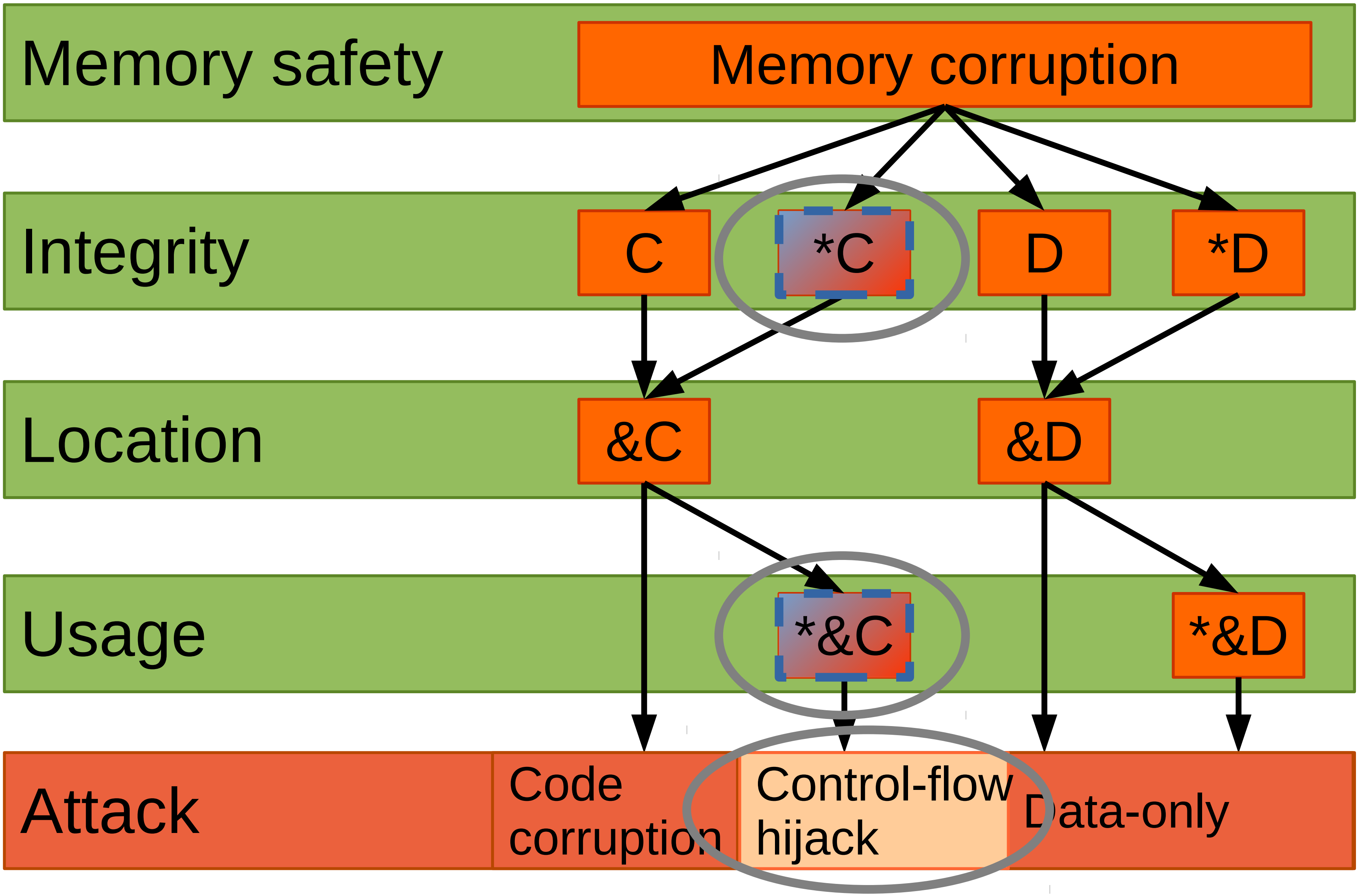
Model for memory attacks



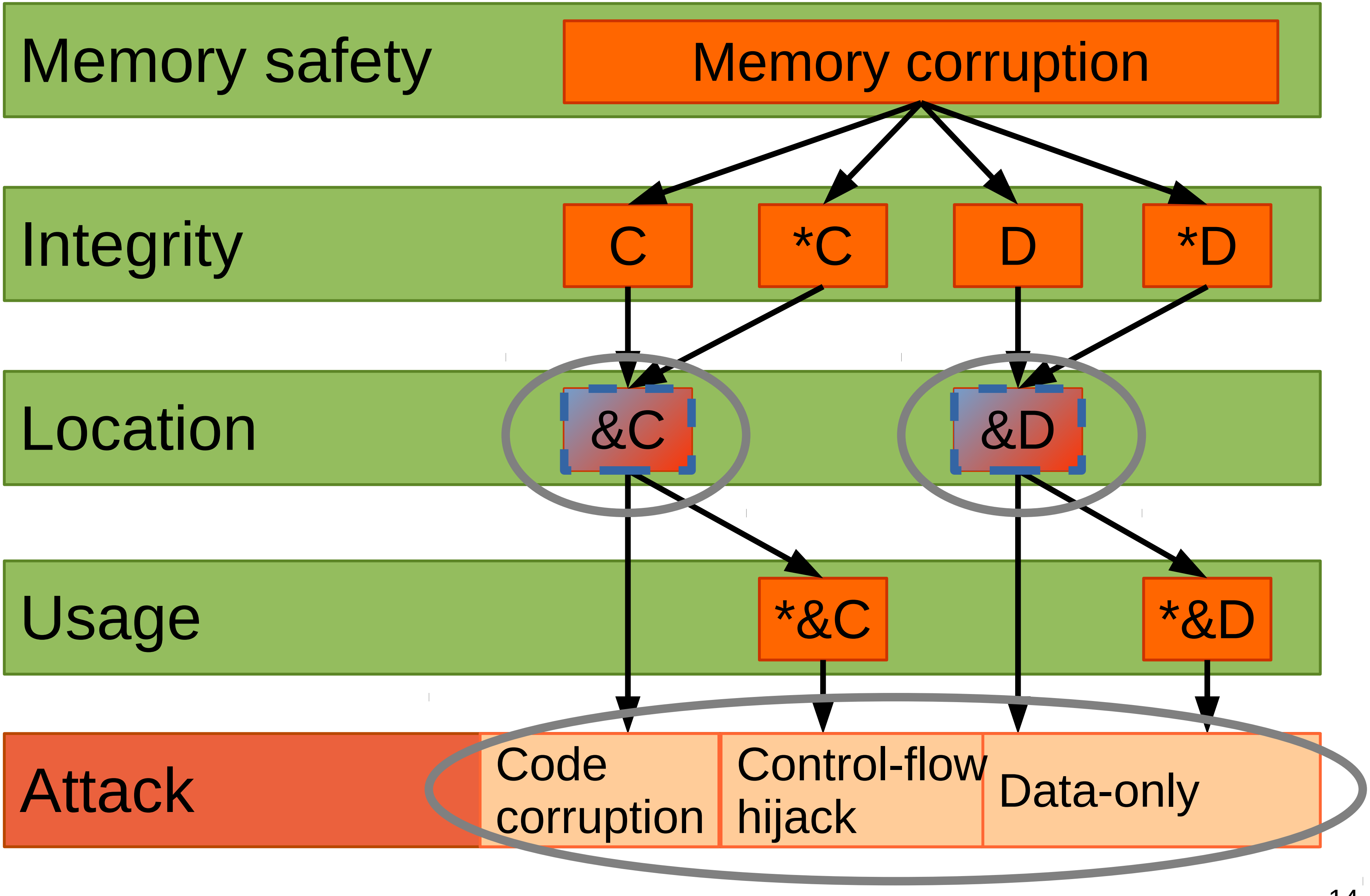
Data execution prevention



Stack canaries and SEH

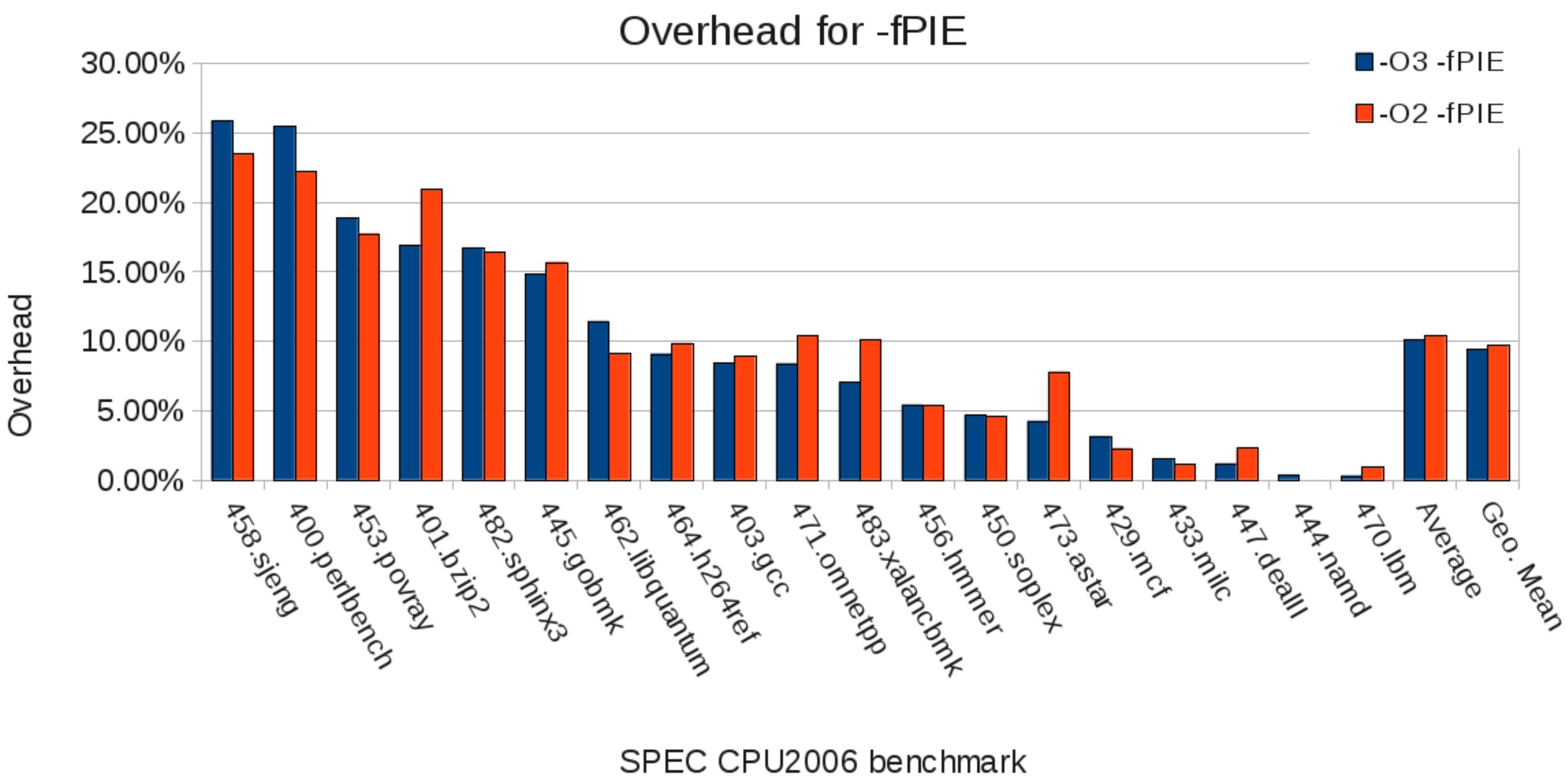


Address space layout random.

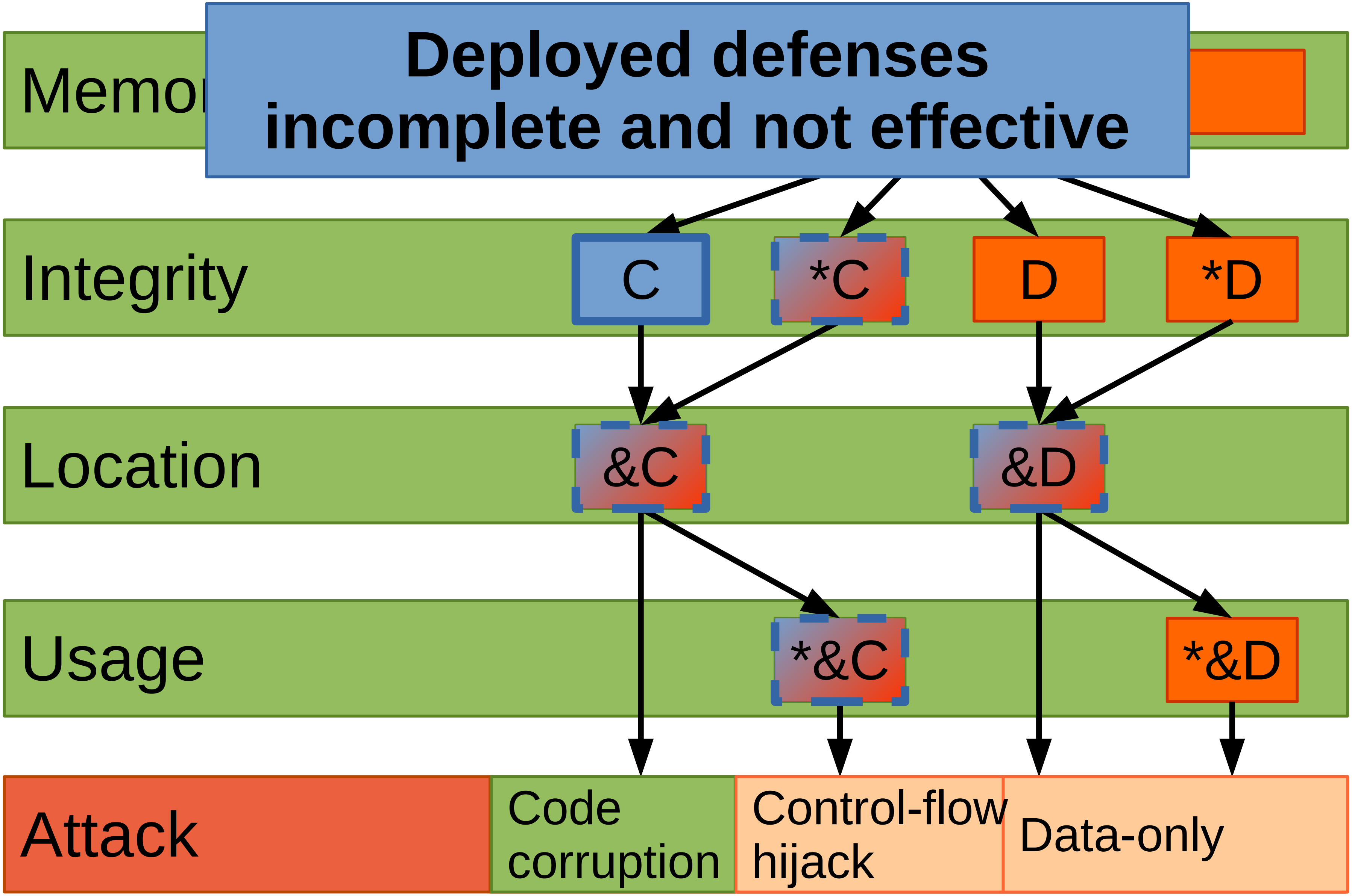


ASLR: Performance overhead

- ASLR uses one register for PIC / ASLR code
  - Performance degradation on x86



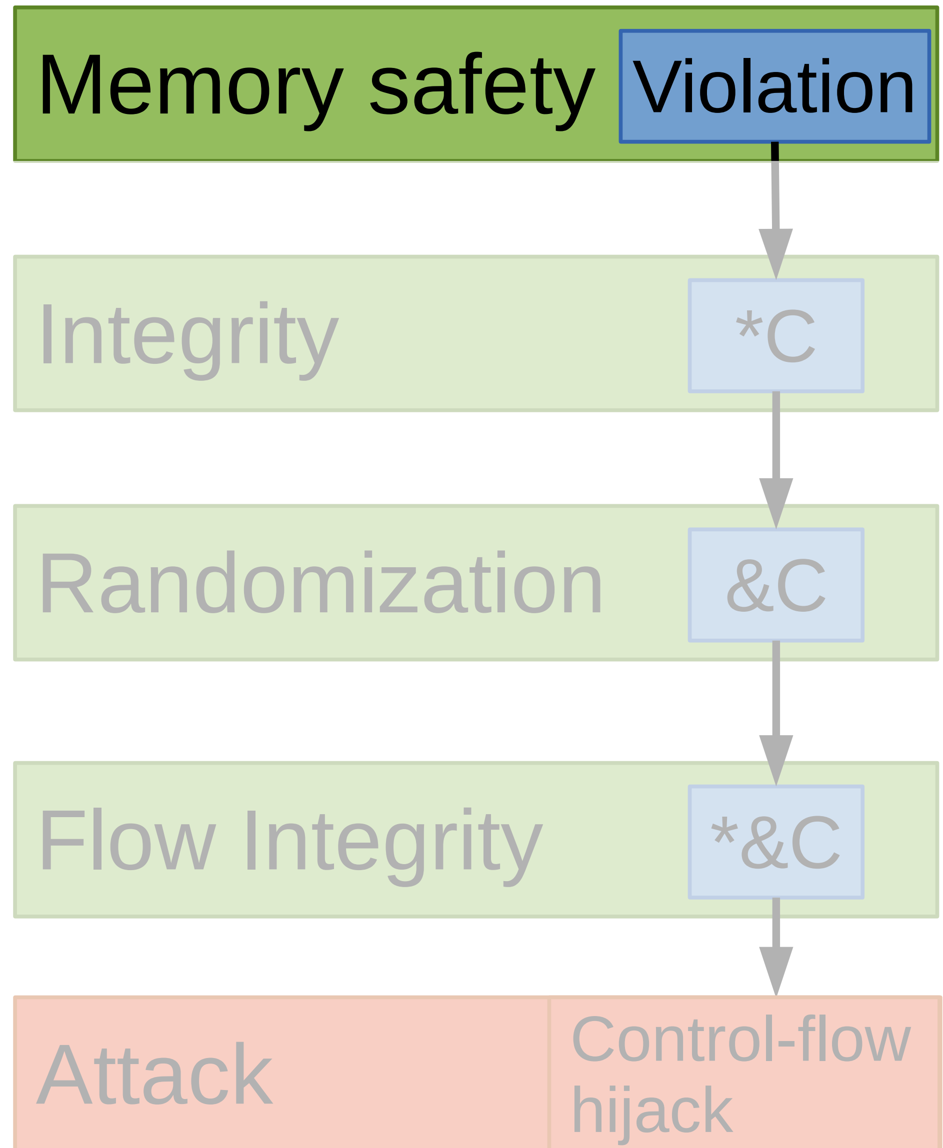
Widely deployed defenses



Defense strategies

Stop memory corruption

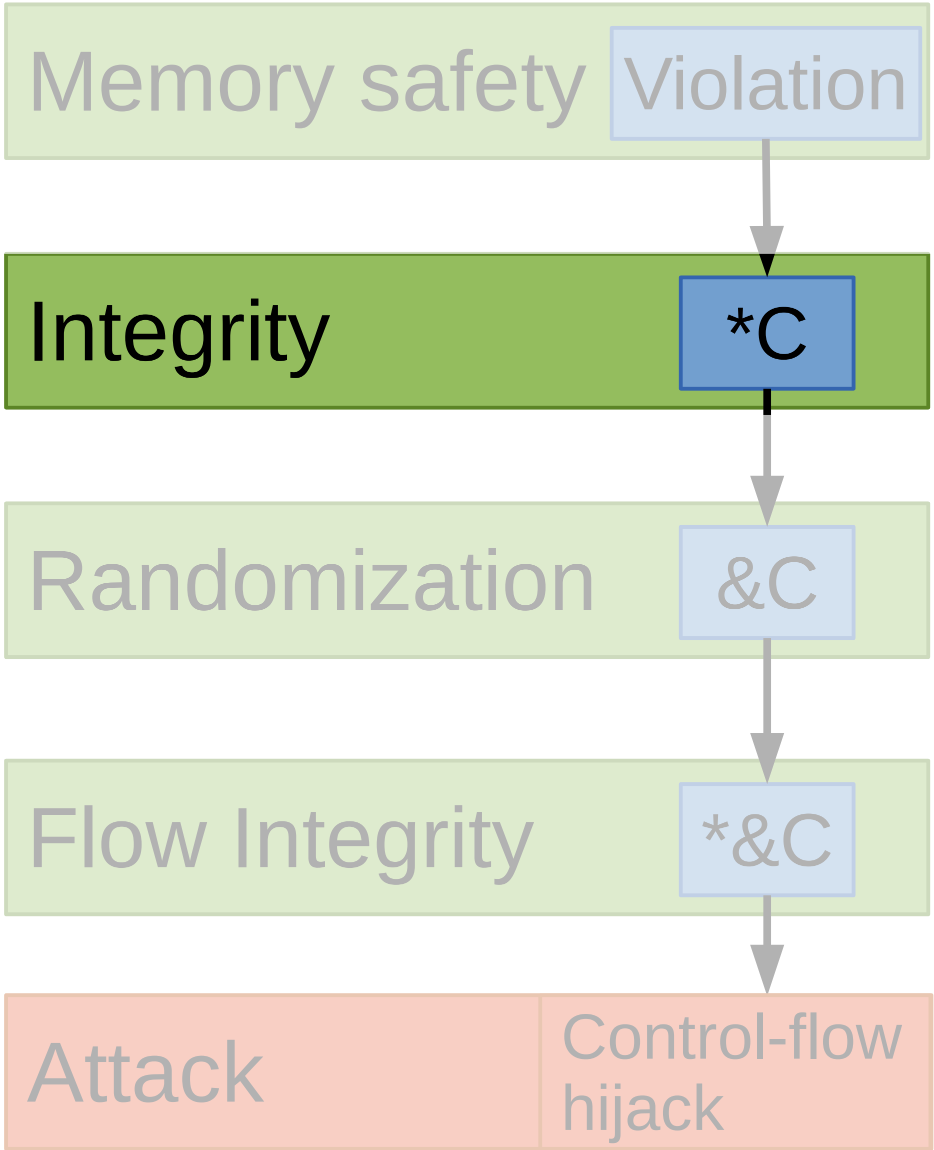
- Safe dialects of C/C++: CCured, Cyclone
- Retrofit on C/C++: SoftBounds+CETS
- Rewrite in safe language: Java/C#



Defense strategies

Enforce integrity of reads/writes

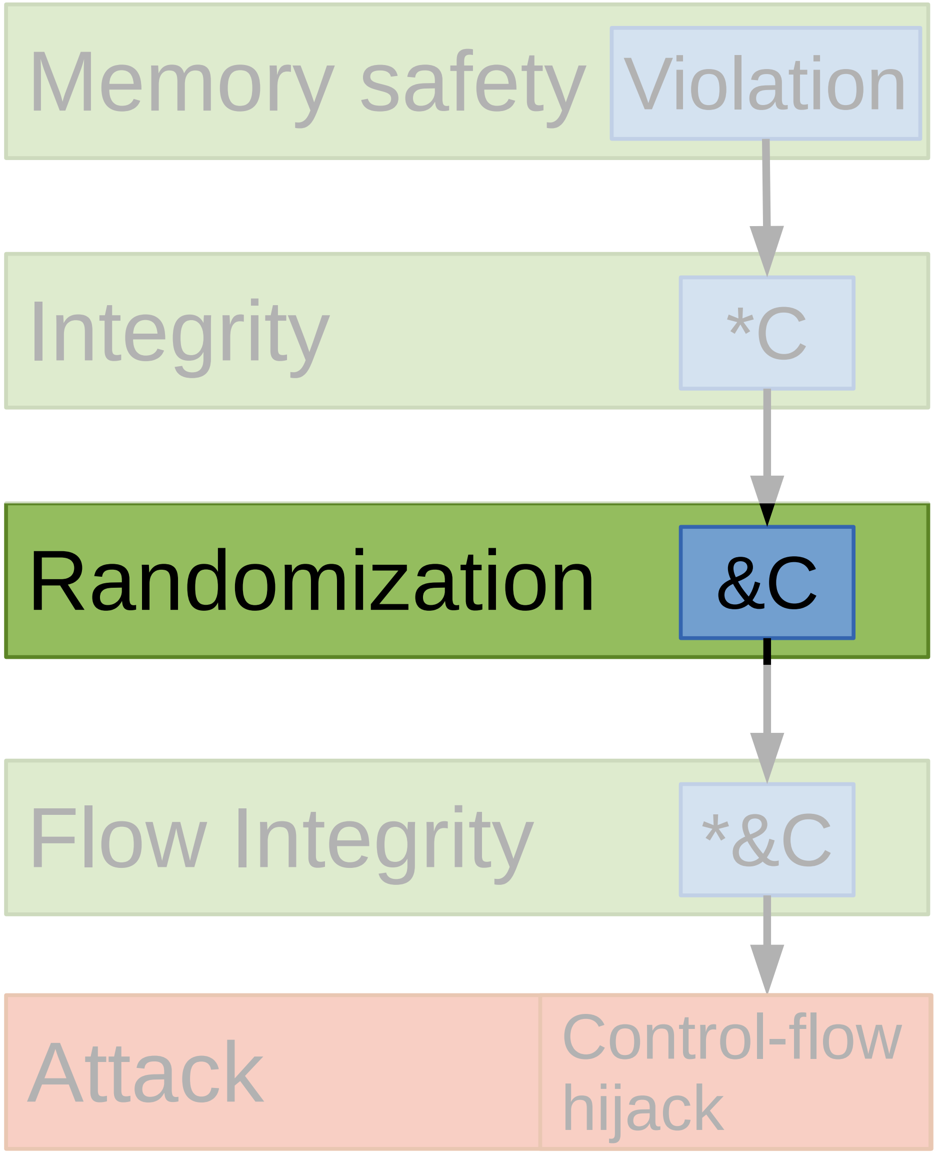
- Write Integrity Testing
- (DEP and W^X for code)



Defense strategies

Probabilistic defenses

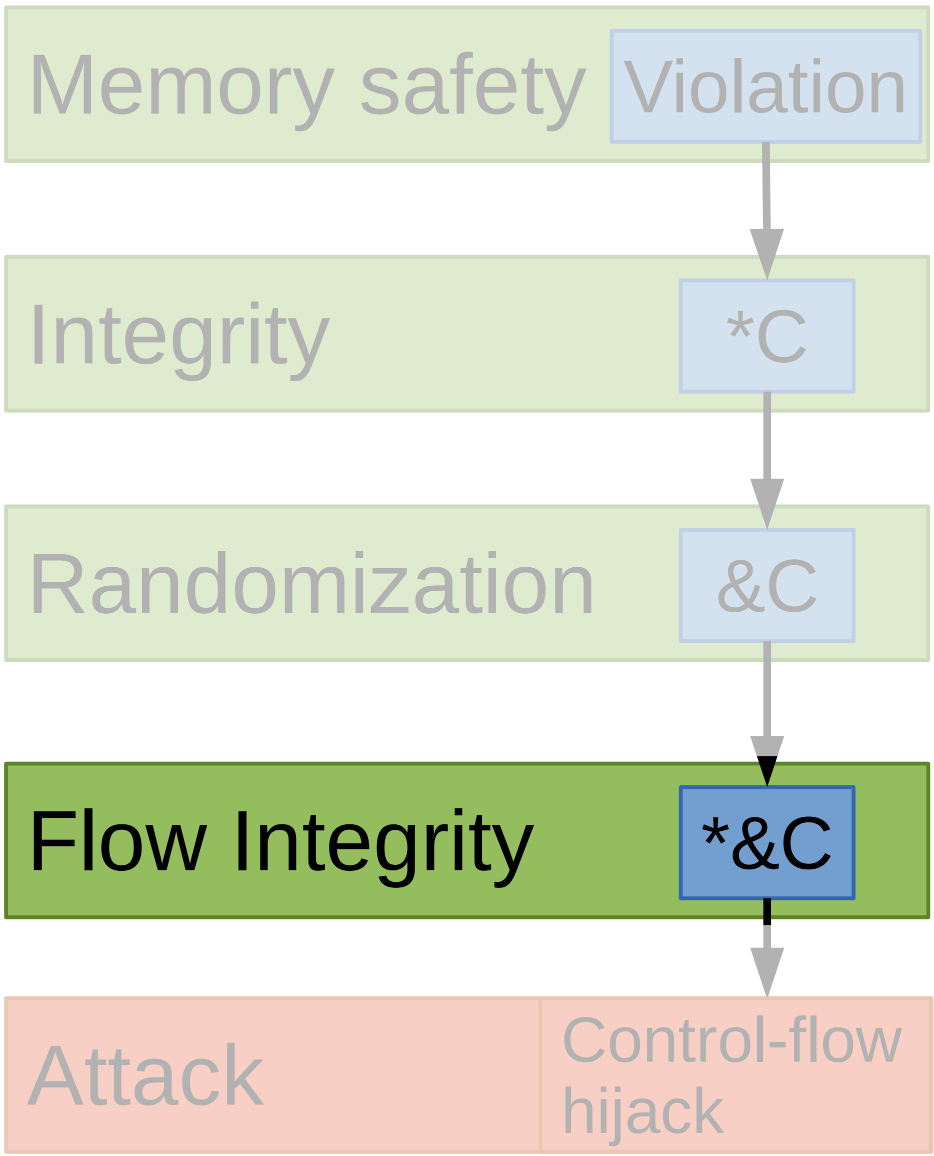
- Randomize locations, code, data, or pointer values



Defense strategies

Protect control transfers

- Data-flow integrity
- Control-flow integrity



Model for memory attacks

- Model allows reasoning and classification
  - Classify security policies and defense mechanisms
  - Reason about power of attacks
- Identify properties that enable wide adoption
  - Low overhead is key (<10%)
  - Compatibility with legacy code and source code
  - Protection against class(es) of attacks

SoK: Eternal War in Memory, **IEEE Symposium on Security and Privacy'13** (Oakland)
Eternal War in Memory, **IEEE Security and Privacy'14** Magazine

Conclusion

Conclusion

- Low level languages are here to stay
  - We need protection against memory vulnerabilities
  - Enforce performance, protection, compatibility
- Mitigate control-flow hijack attacks
  - Secure execution platform for legacy code
  - Code-pointer integrity for source code
- Future directions: strong policies for data
  - Protect from other attack vectors