Silent Bugs Matter: A Study of Compiler-Introduced Security Bugs

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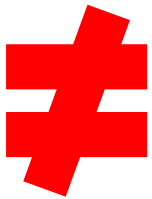
Correctness-Security Gap

```
// Security check attempting to protect against an integer overflow
if(i + 10 > i) return err;
```

```
// Attempt to scrub the sensitive data saved on stack
memset(secret, 0, sizeof(secret));
return;
```

Correctness  Security

Compiler-Introduced Security Bug (CISB)

What is a CISB?

Source Code	Secure to Execute
Compiler	Formally Correct
Binary	Insecure

CISB

Compiler-Introduced Security Bug (CISB)

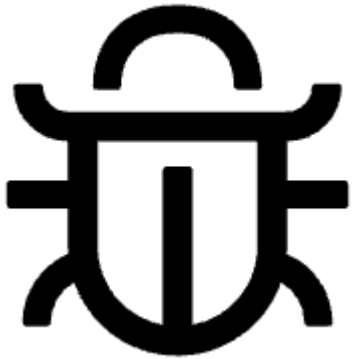
Characteristics of CISBs

- Wide-spreaded
- Possibly exploitable
- Controversial
- Not comprehensively studied

Urban legend?

It is important to study CISBs in the real world.

Research Questions



Root causes & Impacts

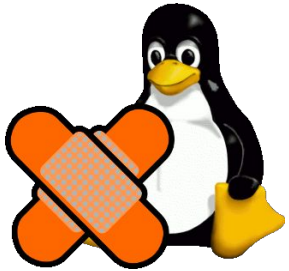
Knowledge & Views

Risks & Challenges

Bugs

Bug Collection:

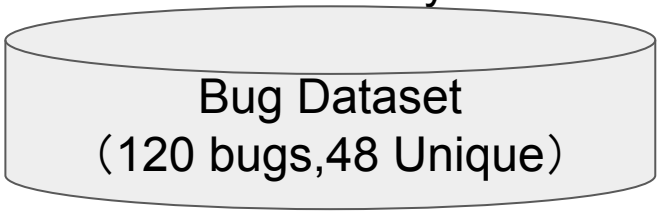
GCC/Clang Bugzilla reports



Linux kernel patch history
(Git commit messages)

Challenges and Solutions

- Needles in a Haystack ⇒ Keyword intersection
- Diverse opinions and mistakes ⇒ Correlation analysis
- No accepted definition, security is hard to model



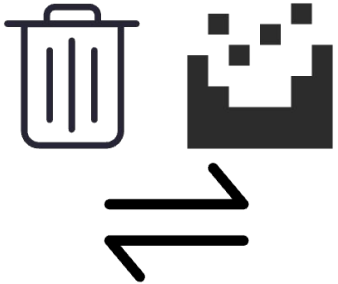
Bugs

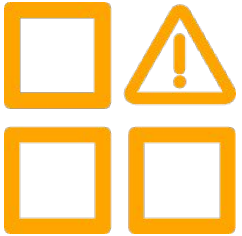
Root Causes	Compiler Behaviors	Security Impacts

Implicit Spec

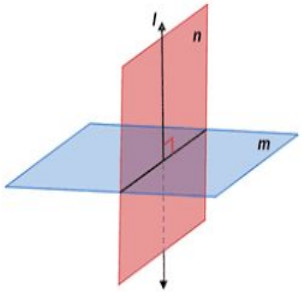
E.g., Undefined Behavior (UB)

```
if(i + 10 > i)
  return err;
```





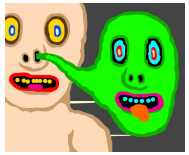
Orthogonal Spec



E.g., Sensitive Data Scrubbing

Bug Study Main Takeaways

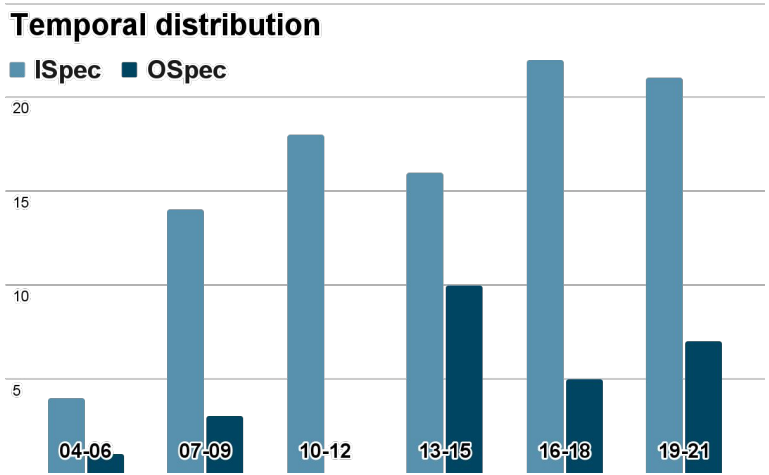
- No-UB assumption still a main fact (62%)



- Much more diverse than previous studies
  - Not only UB: default behavior and environment assumptions
  - New attack surface affected

- Higher incidence on recent years
- High security impacts
  - 9.8% security check bypassing

    20.5% information leaks



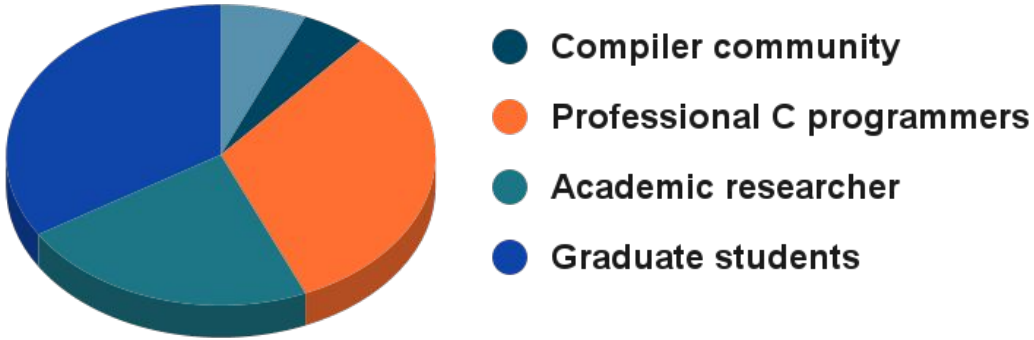
User Survey

Research scope

- knowledge and awareness
- experience and views

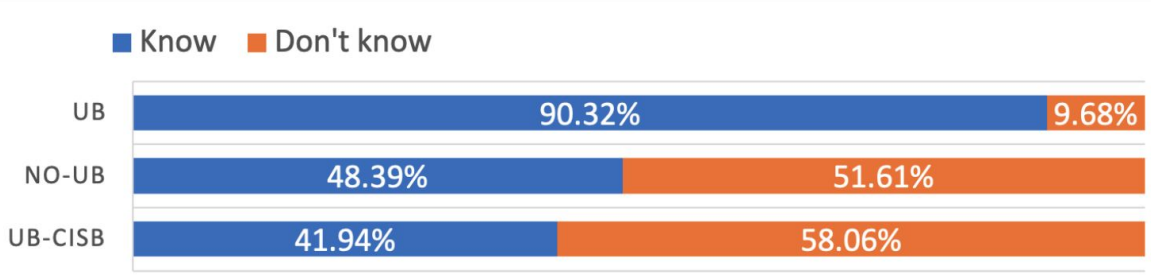
Pariticipants from academia, industry including compiler communities

（N=62）



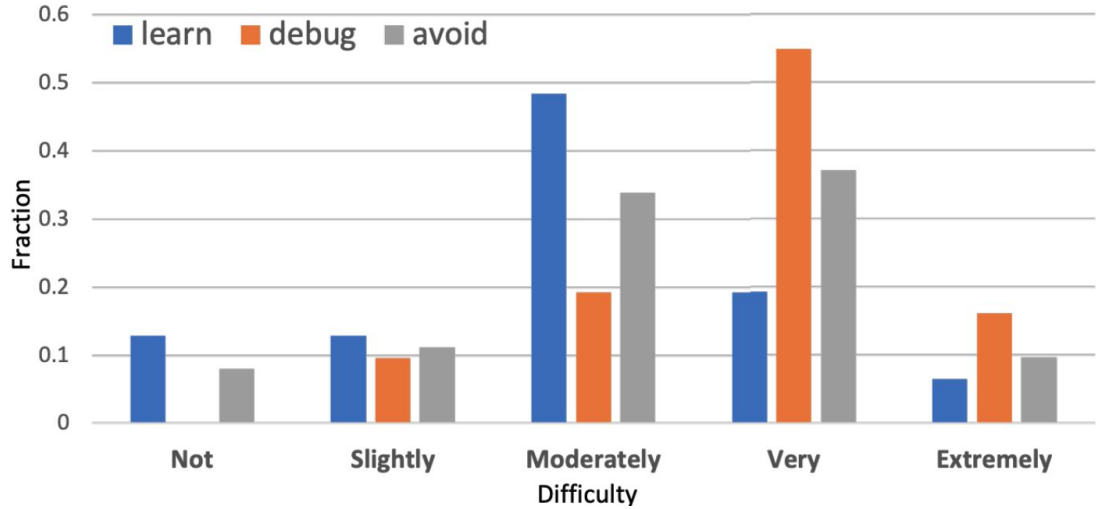
User Survey

Knowledge



- Not optimistic
- Gaps existed

Views



Feeling difficult to learn, debug and avoid

Mitigations

Programmer/User efforts : Risky

- hard to take care of about 180 related UB rules
- optimizations may disable preventions

Compiler options: Effectiveness and performance issues

- trade-off
- disabling optimizations is expensive and not always effective

Automatic prevention: Ad-hoc

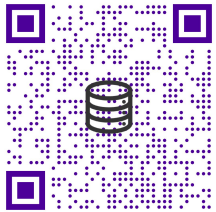
- call for work focusing directly on security boundaries

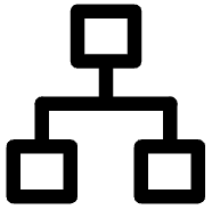
Conclusion

Dataset and taxonomy

User survey

Risks of existing mitigations





Backup

Difference between a UB bug and a UB-CISB:

A UB bug:

```
1 // the triggering of UB causes security issues
2 #define LEN SUFFIX 8;
3 int len = len buffer + LEN SUFFIX;
4 char *new buffer = (char*)malloc((size t)len*2);
```

Backup

Difference b

A UB-CISB:

```
1 // a UB CISB: the security issue emerges after
  compilation
2 #define LEN SUFFIX 8;
3 int len = len buffer + LEN SUFFIX;
4
5 if(len < len buffer)
6     exit(1);
7
8 char *new buffer = (char*)malloc((size t)len*2);
9
10
11
```

The compiler:
UB does not exist! A redundant check.
Let me eliminate the check.

The programmer:
Let me catch the UB in advance.
No security issues then.