A Next-Generation Platform for Analyzing Executables

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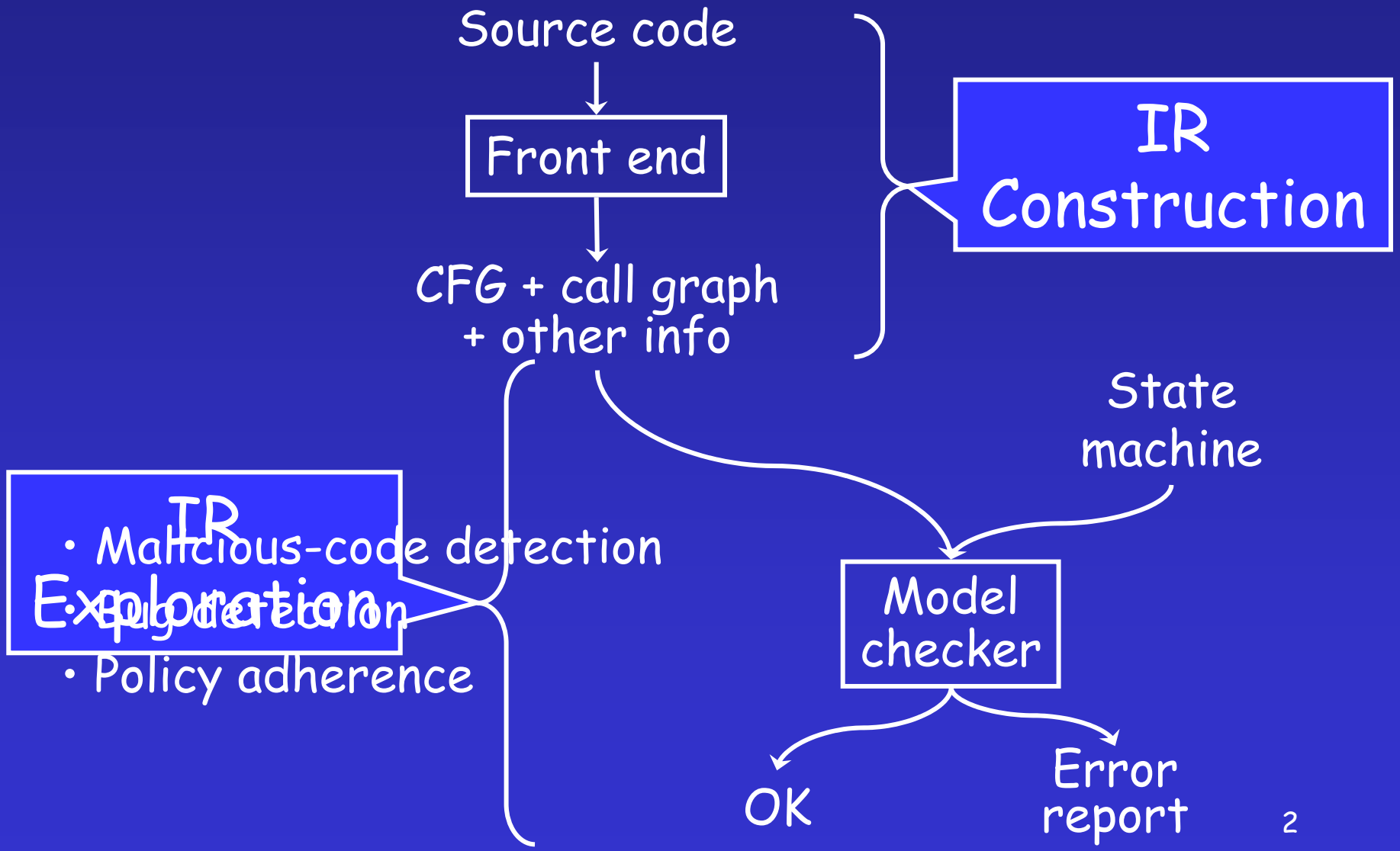
State-Space Exploration



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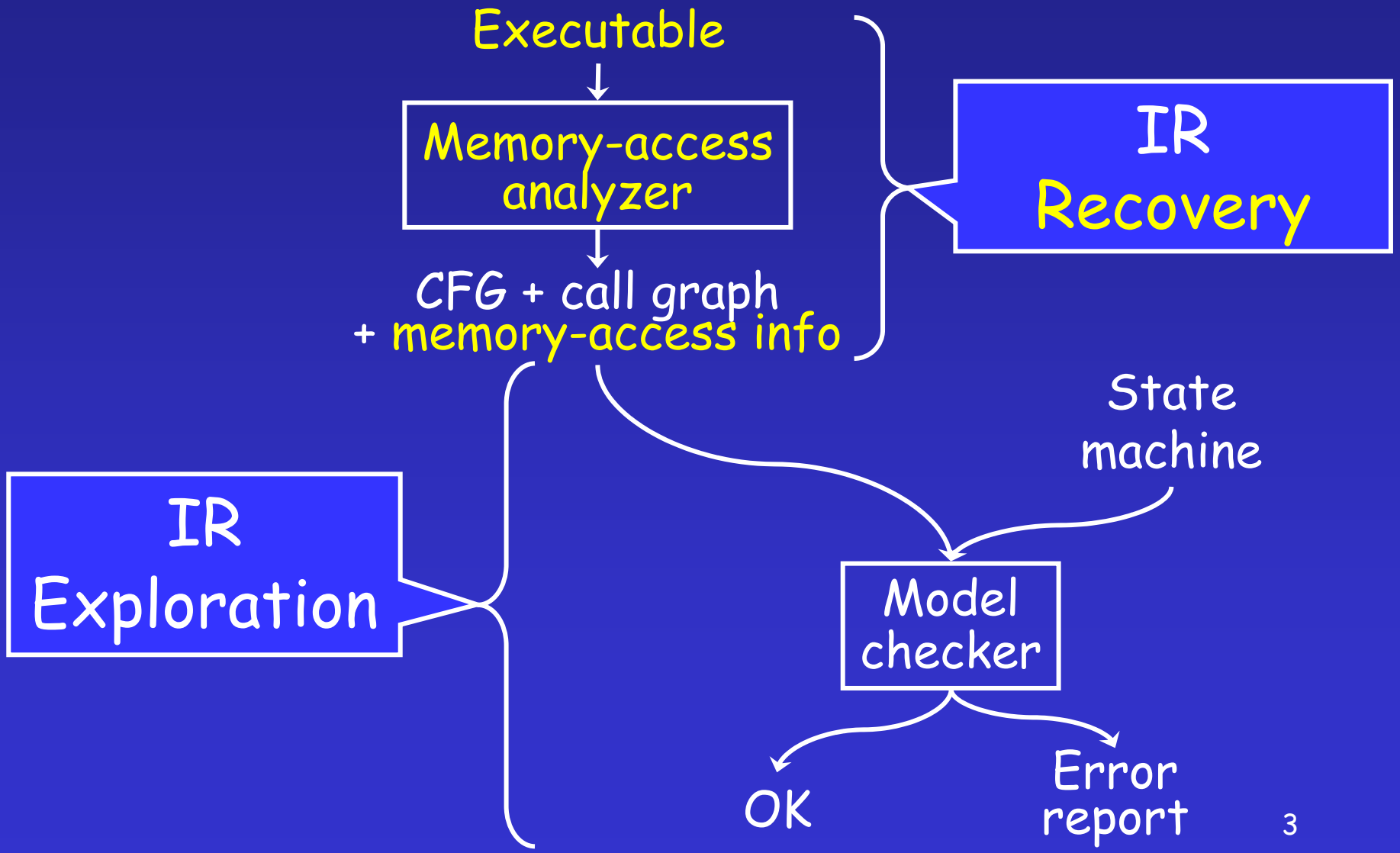


Why Executables?

- Reveals platform-specific choices made by compiler
  - What you see is what you get
- Some source-level issues go away
- Better platform for finding security vulnerabilities
  - Source-code tools: Lack of fidelity can allow vulnerabilities to escape detection

Minimizing Data Lifetime?

- Windows
  - Login process keeps a user's password in the heap after a successful login
- Should minimize data lifetime by
  - clearing memory
  - calling free()
- But . . .
  - the compiler might optimize away the memory-clearing code ("useless-code" elimination)

```
memset(buffer, '\0', len);
free(buffer);
```

→

```
free(buffer);
```

WYSINWYX: What You See Is Not What You eXecute

- Computers do not execute source-code programs; they execute machine-code programs that are generated from source code
- What is actually executed by the processor may not be what the programmer intends
  - overzealous optimizer
  - a language's semantics may leave some behaviors unspecified

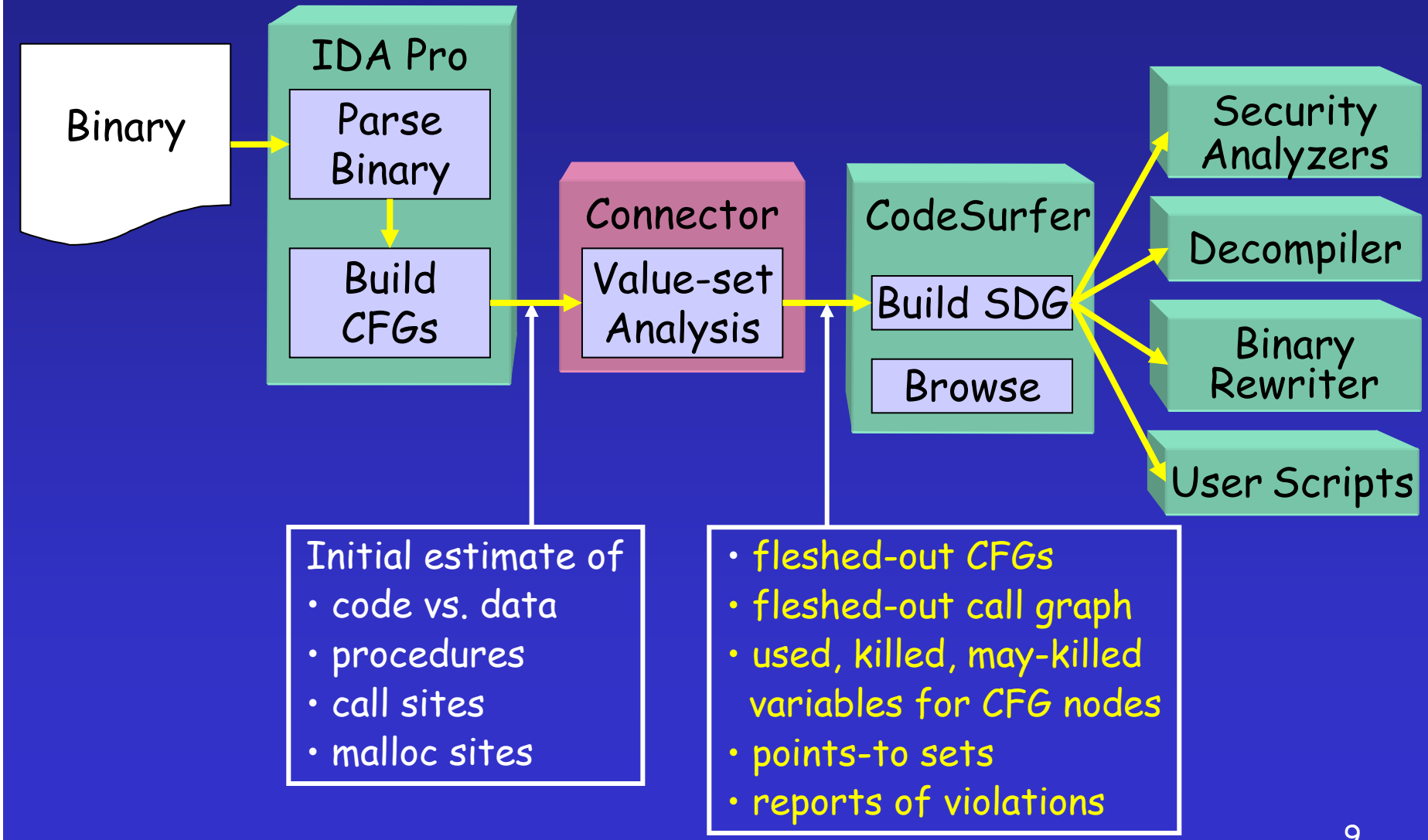
The Vision

- Code-inspection tools for security analysts
- Analyses for identifying
  - security vulnerabilities and bugs
  - malicious behavior (code vs. memory snapshots)
  - commonalities and differences
- Platform for
  - de-compilation
  - code obfuscation
  - installation of protection mechanisms
  - remediation of security vulnerabilities
  - de-obfuscation (w/ assistance from dyn. tools)

What Should a Tool Provide?

- **IR recovery**
  - control-flow graph (w/ indirect jumps resolved)
  - call graph (w/ indirect calls resolved)
  - identification of variables
  - values of pointers
  - used, killed, and possibly-killed variables for CFG nodes
  - data dependences
  - identification of types: base types, pointer types, structs, and classes
- No use of symbol-table or debugging information!!!
- **IR exploration**
  - API for traversal/searching/pattern matching
  - API for defining static-analyzers/model-checkers
  - GUI to investigate warnings
- **Cooperation with dynamic tools**

CodeSurfer/x86 Architecture



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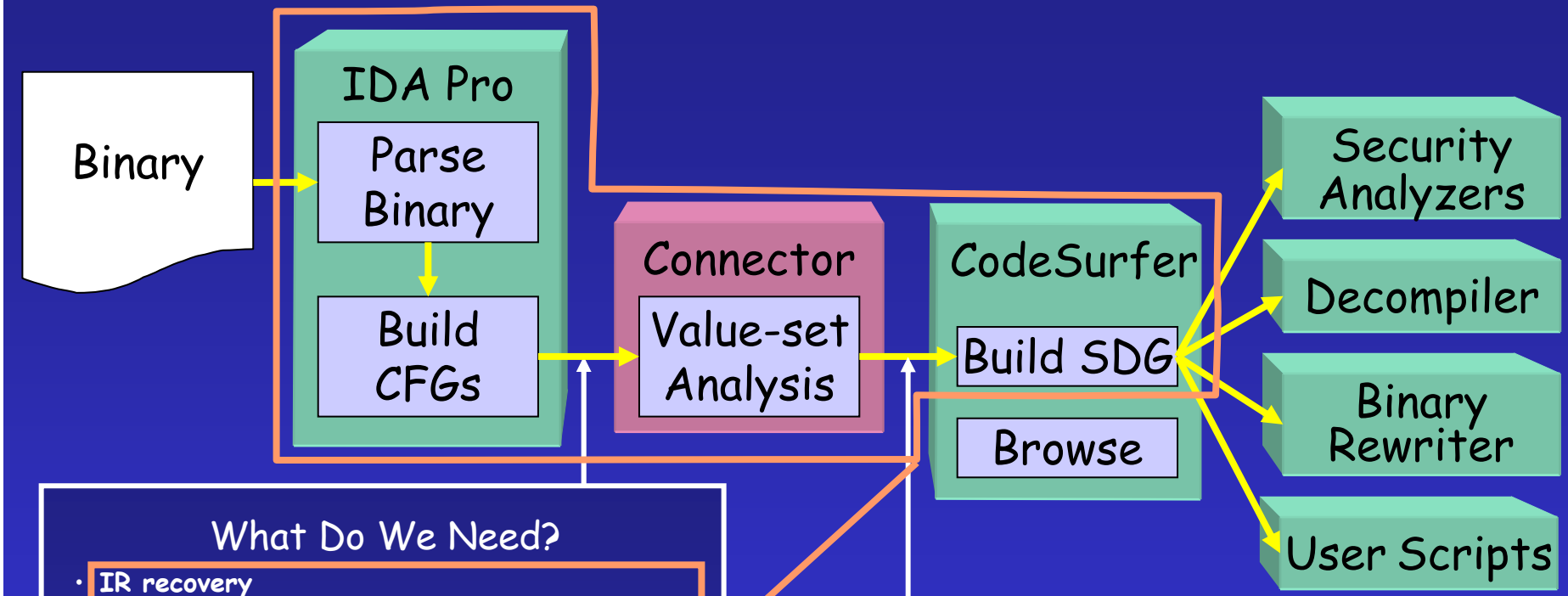

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  - [identification of types: base types, pointer types, structs, and classes]
- **GUI for code browsing and navigation**
- **Scripting language**
  - API for accessing the IR
  - API for modifying the IR
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- fleshed-out CFGs
- fleshed-out call graph
- used, killed, may-killed variables for CFG nodes
- points-to sets
- reports of violations

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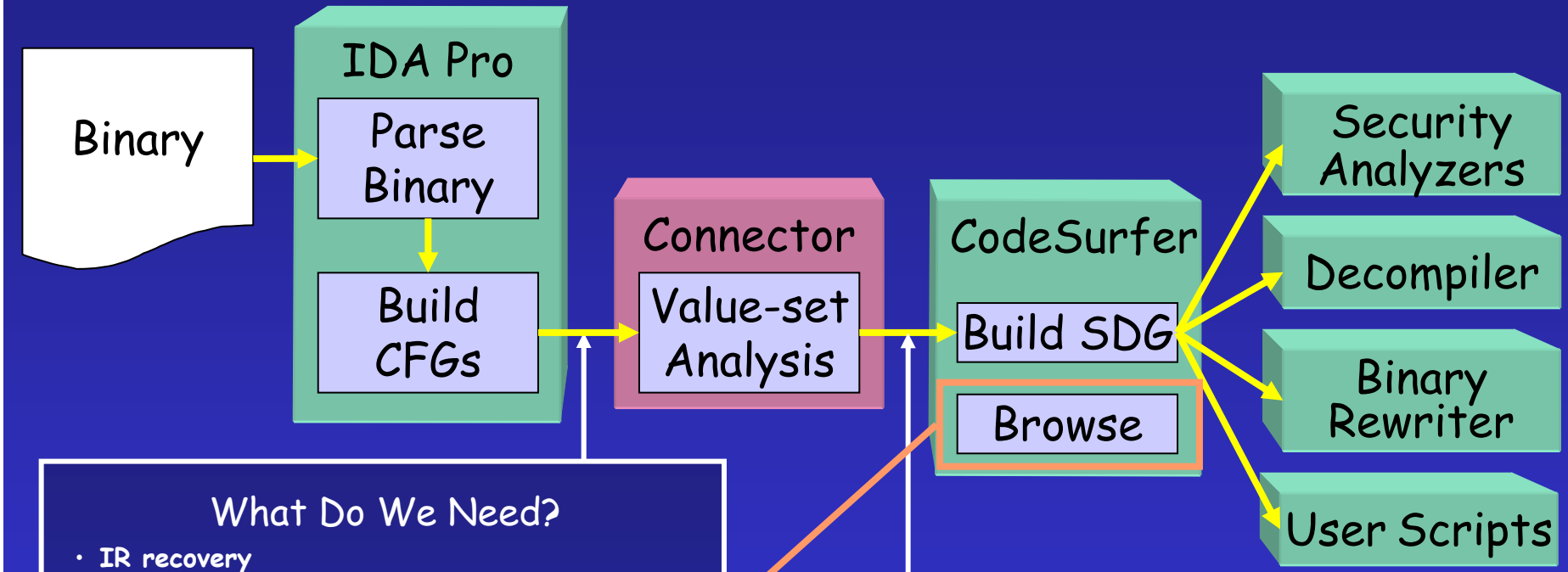

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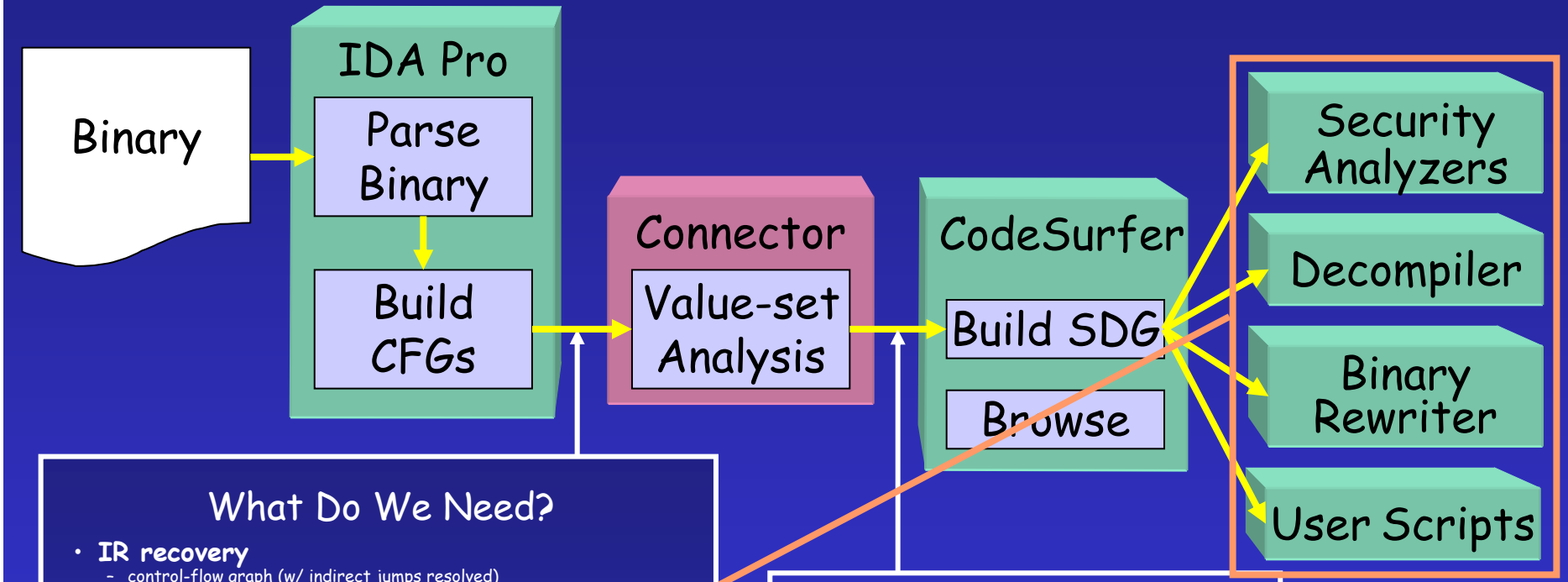

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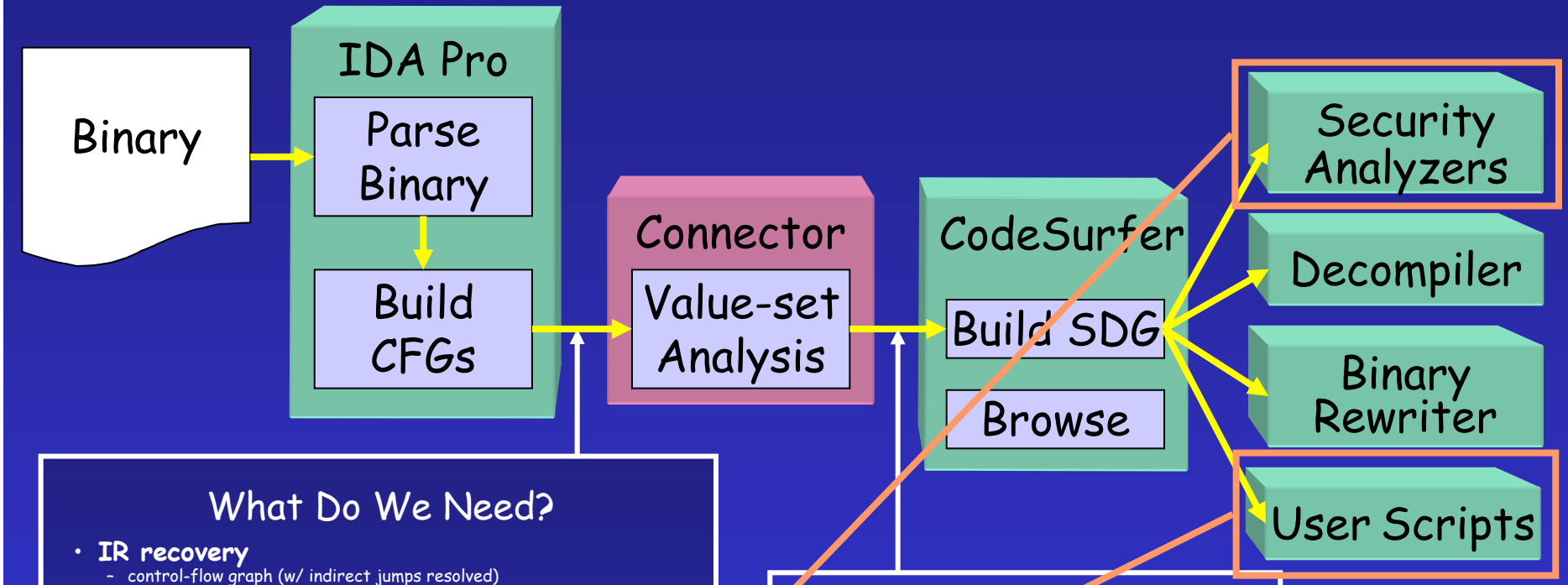

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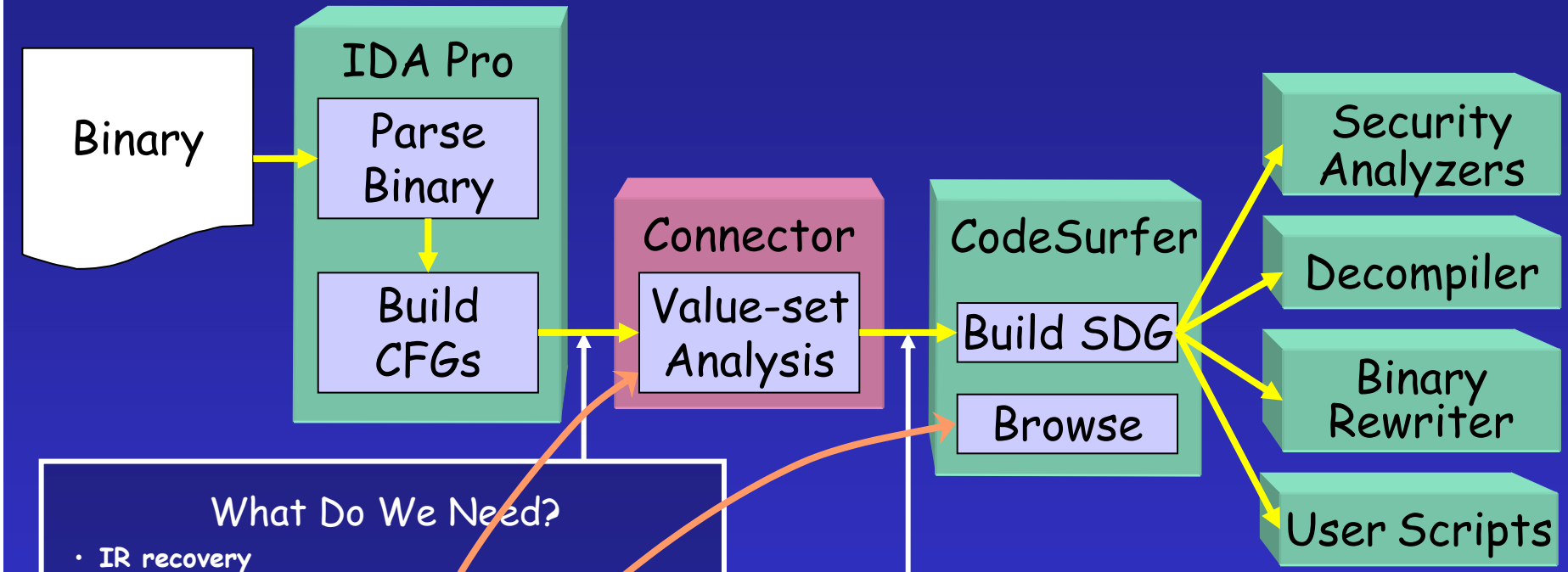

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An Application of CodeSurfer/x86

- Project at MIT Lincoln Labs (originally classified)
  - Adopted CodeSurfer/x86 (replacing IDA Pro)
  - DARPA funding under "Dynamic quarantine of worms"
  - PI: Rob Cunningham; PM: Anup Ghosh
- Given a worm . . .
  - What are its target-discovery, propagation, and activation mechanisms?
  - What is its payload?
- Use of CodeSurfer/x86's analysis mechanisms
  - Find system calls
  - Find their arguments
  - Follow dependences backwards to find where their values come from
  - . . .

Demo

- CodeSurfer/C
- CodeSurfer/x86

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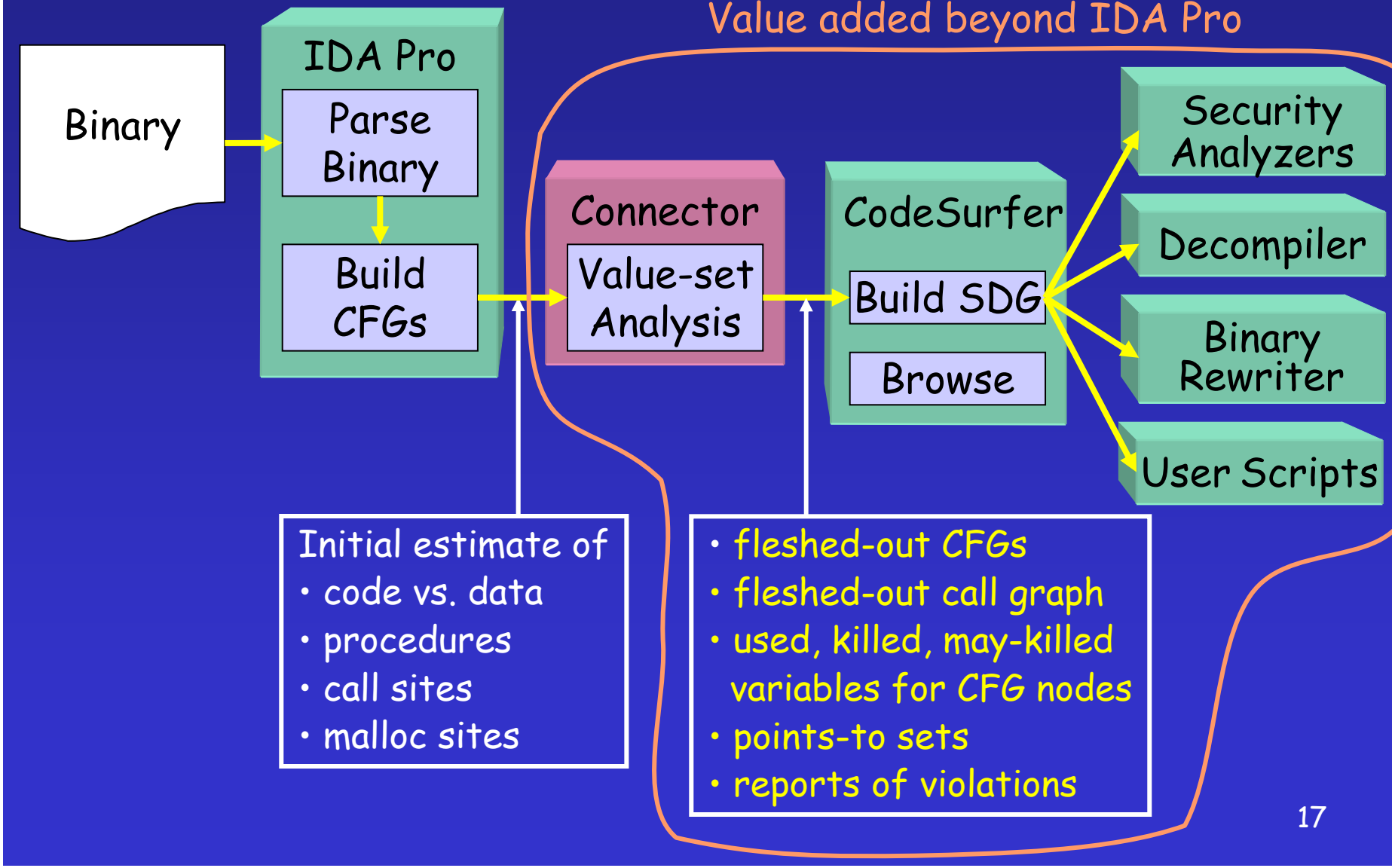

Another Talk: IR Exploration

- API for traversal/searching/pattern matching
- API for defining static-analyzers/model-checkers
  - Use a script to traverse IR
  - Create a model of the program
  - Invoke analyzer
- Path Explorer tool
  - Software-assurance plug-in to CodeSurfer/x86
  - Performs security-related analyses on the IR
  - Uses the GUI to investigate warnings

Why Executables?

- Reveals platform-specific choices made by compiler
- Makes visible other platform-specific artifacts
  - compiler bugs
- Some source-level issues go away
  - analyze the actual library code, not hand-written stubs
  - in-line assembly code
  - use of multiple source languages
- Better platform for finding security vulnerabilities
  - Source-code tools: Lack of fidelity can allow vulnerabilities to escape detection
- See http://www.cs.wisc.edu/~reps/#cc04

Balakrishnan and Reps, "Analyzing memory accesses in x86 executables" [CC04]
http://www.cs.wisc.edu/~reps/#cc04

Related Work

Debray et al., "Alias analysis of executable code" [POPL 98]

Cifuentes et al., "Assembly to high-level language translation" [ICSM 98]

A. Mycroft, "Type-based decompilation" [ESOP 99]

Linn et al., "Stack analysis of x86 executables" [Unpublished]

Guo et al., Practical and accurate low-level pointer analysis" [CGO 05]

Amme et al., "Data dependence analysis of assembly code" [PACT 98]

Questions & Discussion