Vulnerability and Information Flow Analysis of COTS

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Cost of Software Development Motivates Use of COTS software

- High cost of software development
  - increased complexity
  - increasing degree of concurrency
  - increasing quality-assurance demands
  - other factors . . .
- Increased deployment of COTS
- CIP/SW TOPIC #6
  - Protecting COTS from the inside

COTS Spending on the Rise

- In 1991 DoD's SAI initiative mandates defense contractors to consider COTS in their programs
- Today, a significant percentage of their IT budget is allocated to COTS
- Other countries are taking similar steps

Source: Jane's Information Group
http://www.janes.com/
Note: IT Budget refers to total spent on

Advantages and Disadvantages of COTS

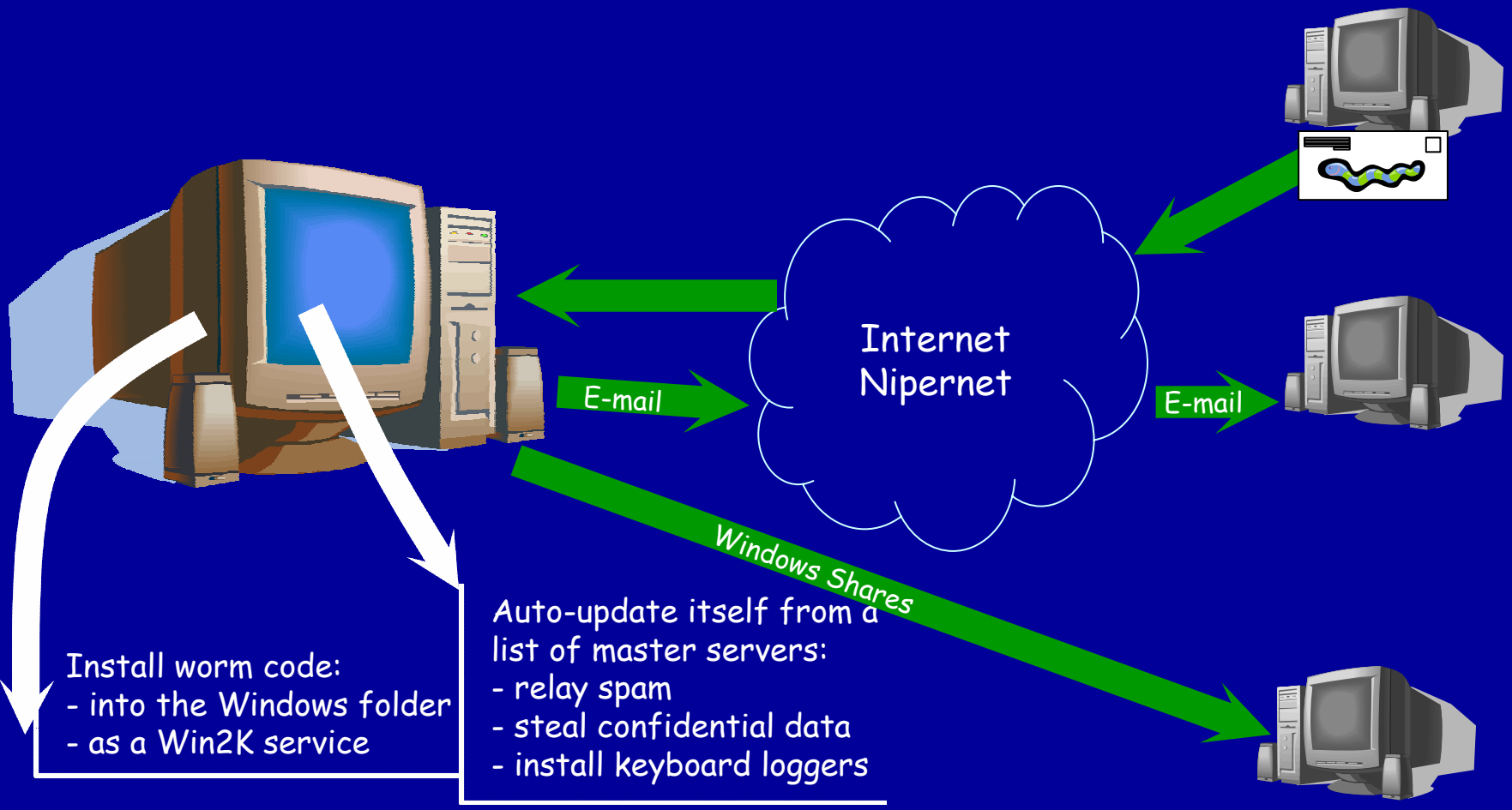
- Advantages
  - reduced cost
  - promotes modular design
  - partitions the testing effort
- Disadvantages
  - higher risk of vulnerabilities
  - general quality-assurance issues

Unsafe Malicious Code

- Viruses
  - Gain access through infected files
- Worms
  - Spread over the network
- Trojans
  - Hide harmful behavior under the guise of useful programs
- Most often: combined code
  - worm + virus + trojan
- Distinguishing characteristics: something observable happens

Malicious Code Example:

Internet worm Sobig.E

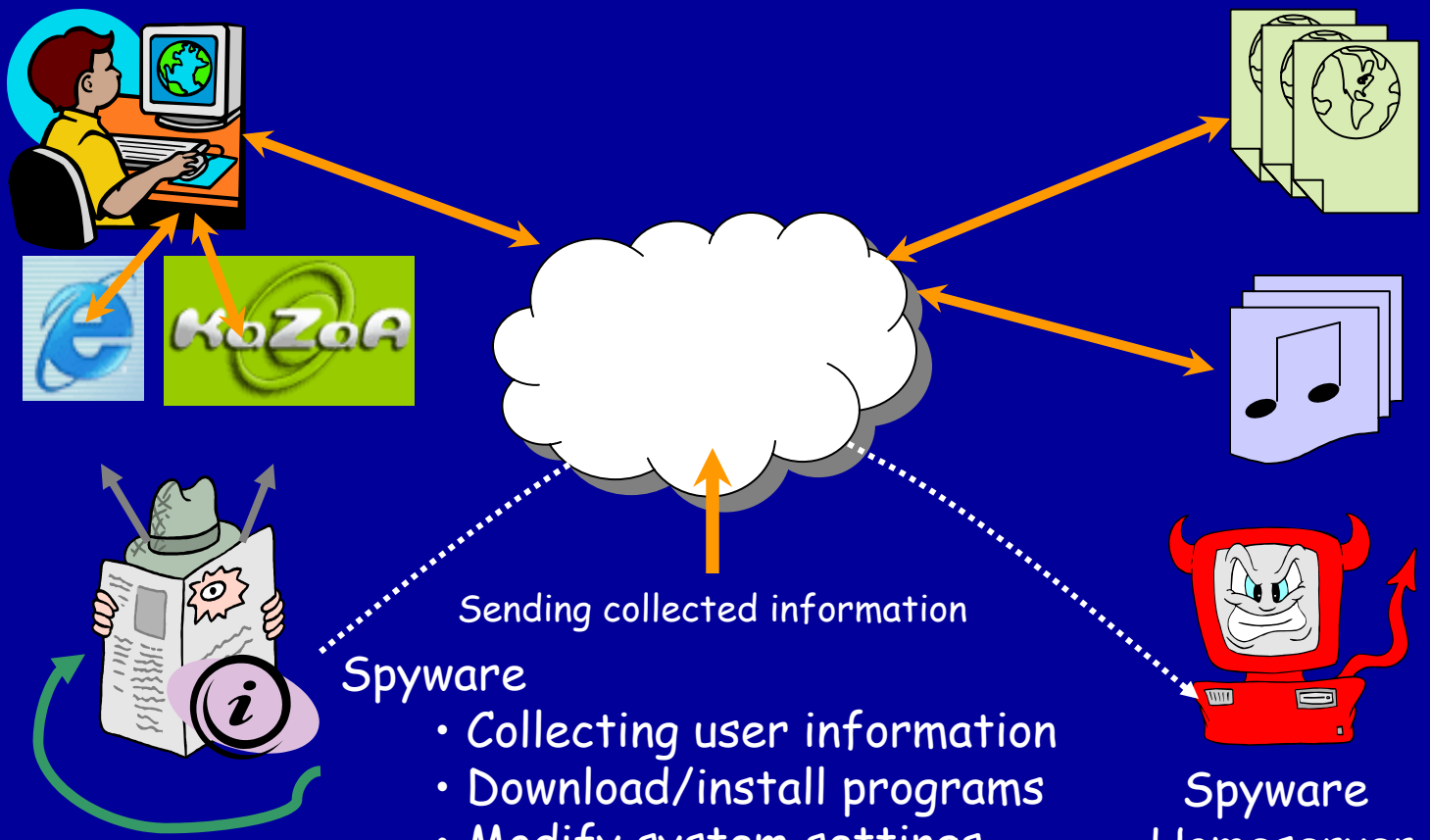


What Is Spyware?

- Spyware is software that
  - Is non-destructive (unlike a virus)
  - Operates in background—not easily observable
  - Is often installed silently by other software
  - Usually integrated with desired functionality

- Privacy-violating malicious code
  - Provides useful functionality
  - But, "leaks" sensitive information

KaZaa in Operation



Spyware
- Collecting user information
- Download/install programs
- Modify system settings

Spyware Homeserver

Spyware Summary

- Install a useful program
  - Play DVDs
- But …
  - Also install "spy" software, which monitors user behavior
    - Example: Monitor web traffic
- Aureate Media, Real Networks
- Consult
  - http://grc.com/optout.htm
- Maybe can be used by advisors/managers☺

Problems and Challenges

- Cannot expect to have source code for COTS software
  - Solution: we target executables
- Should handle unsafe and privacy-violating malicious code
  - Solution: initially targeted unsafe malicious code, but have started work on Spyware
- Certain executables are very hard to analyze statically
  - Solution: developed a sandboxing technology

WiSA and SandboX86: Static and Dynamic Approaches for COTS

- We have proposed the Wisconsin Safety Analyzer
  - vulnerability analysis
    - Handles unsafe malicious code
  - information flow analysis of COTS
    - Handles privacy-violating malicious code (Spyware)
- Develop technology for static and dynamic analysis of binaries
  - Original plan to focus on static analysis
  - Realized that we need multiple-lines of defense
  - Started working on dynamic analysis as well and developed a sandboxing system called SandboX86
- Investigate applications

Tools for Reducing the Risk of COTS Deployment

Static analysis and rewriting of executables

Sandboxing and dynamic slicing

Evaluation and testing

Tools for Reducing the Risk of COTS Deployment

Static analysis and rewriting of executables

Malicious code detection
Model-based HIDS
Program Obfuscation

Sandboxing and dynamic slicing

Containing malicious behavior
Discovering potential privacy violations

Evaluation and testing

Testing malware detectors
Testing NIDS

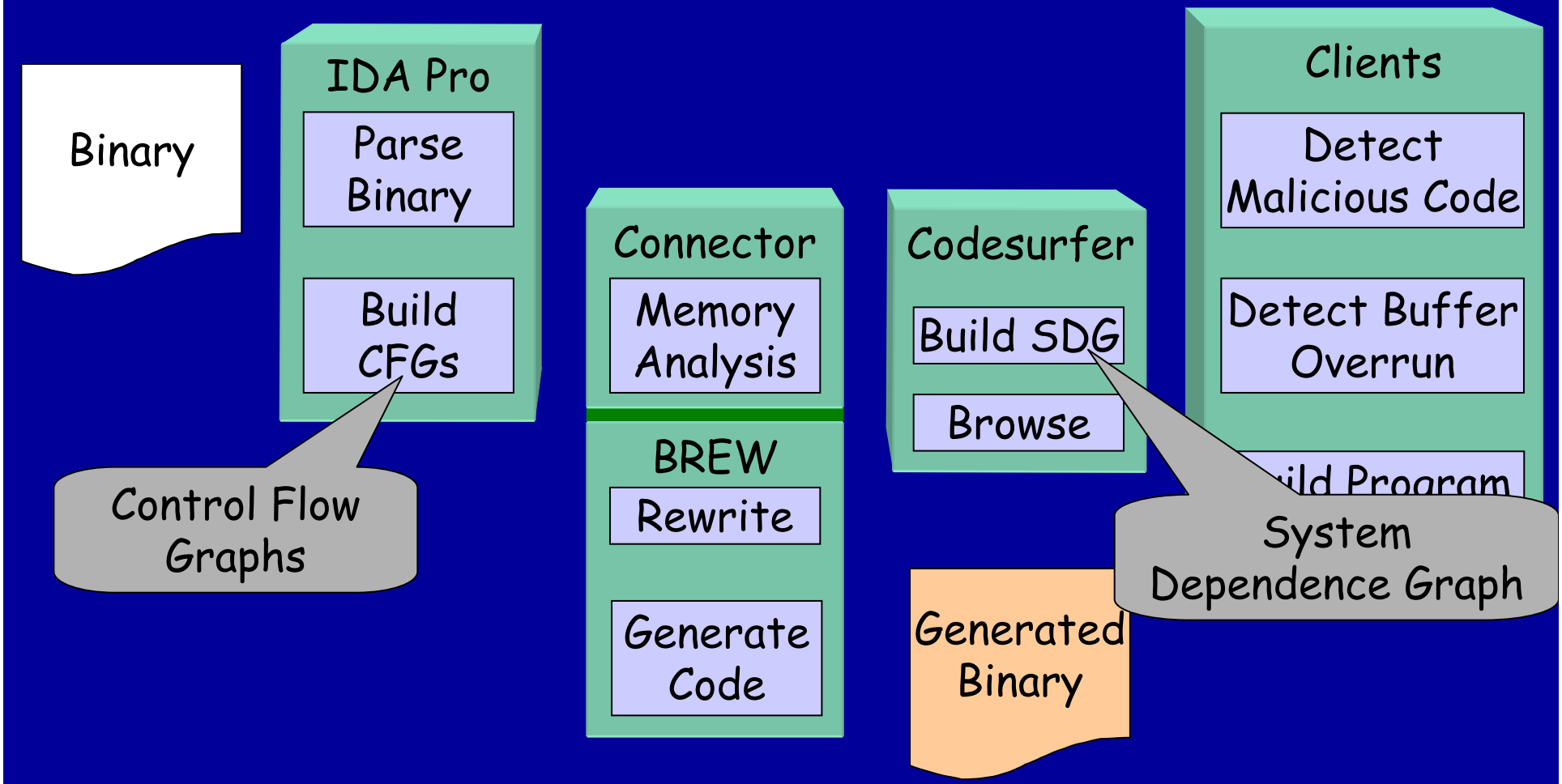
IDA Pro

- Decompilation tool
- Supports several executable file formats like COFF, ELF ....
- Gather as much information as possible
  - e.g. Names of functions, parameters to functions
- Is extensible through a built-in C-like language

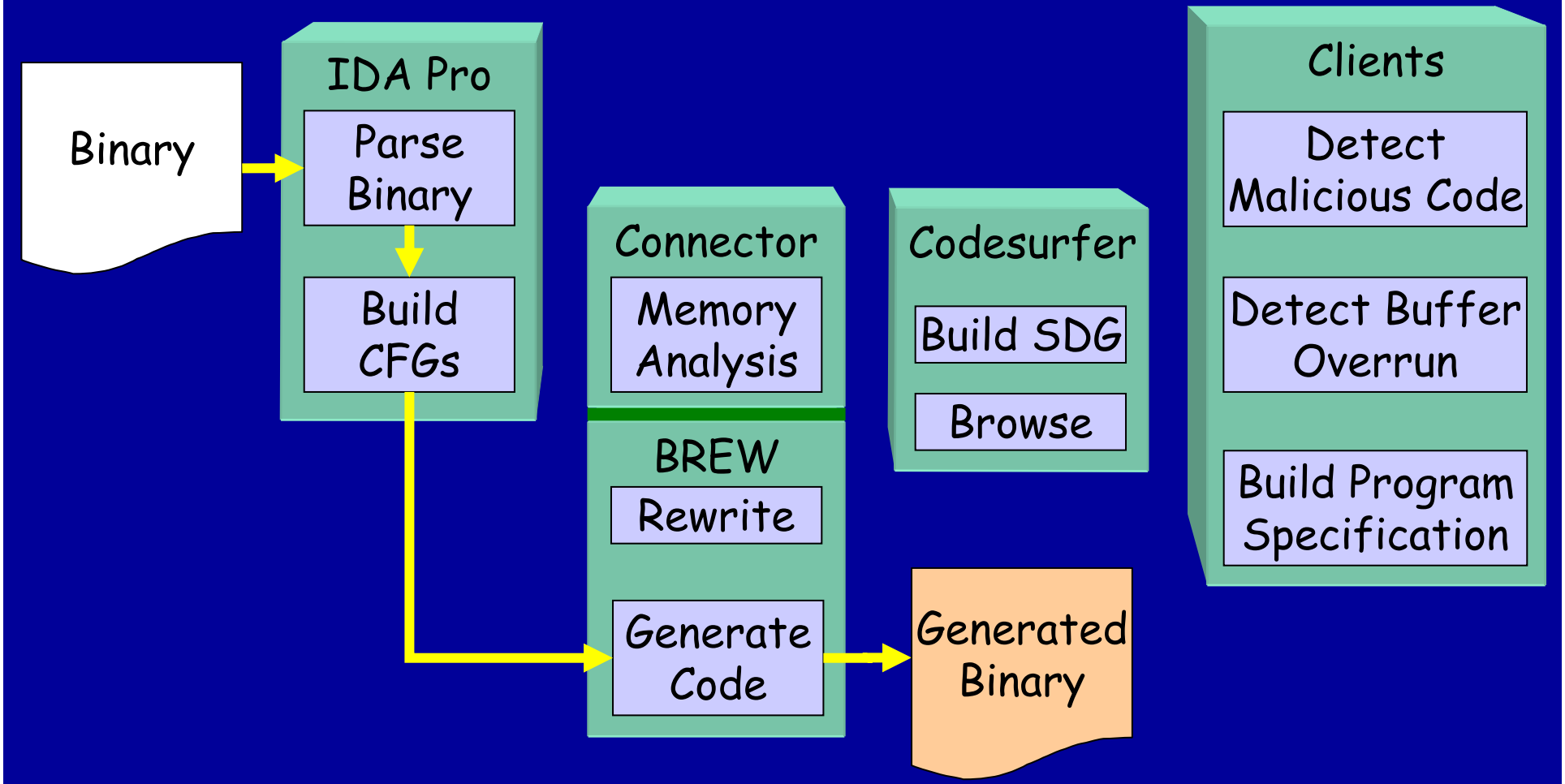
Codesurfer

- A program-understanding tool
- Analyzes the data and control dependences
  - stores in System Dependence Graph(SDG)
  - Helpful in static analysis
- API to access information stored in IRs
  - Platform for additional static analysis
- The API can be extended

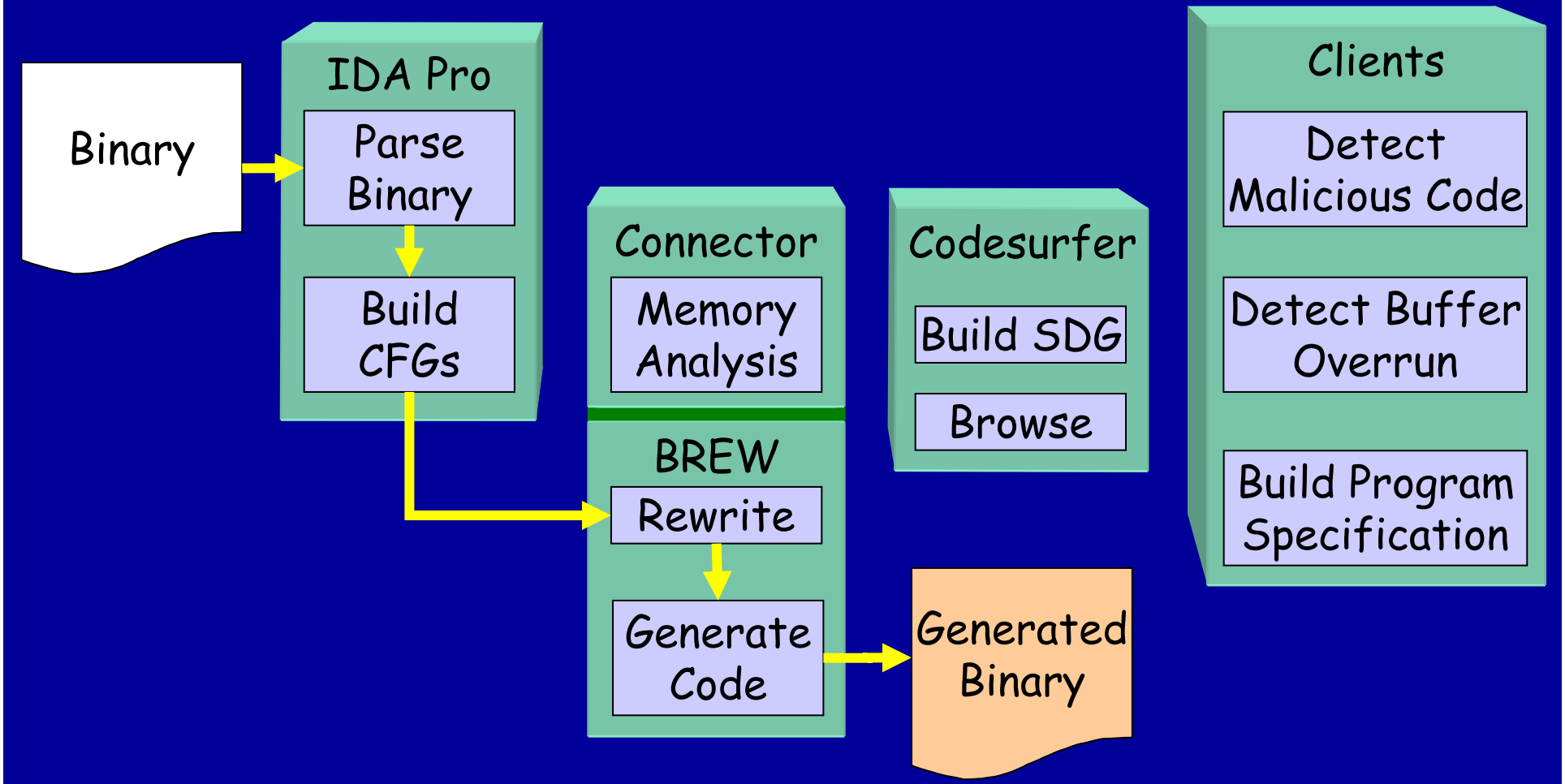
Architecture



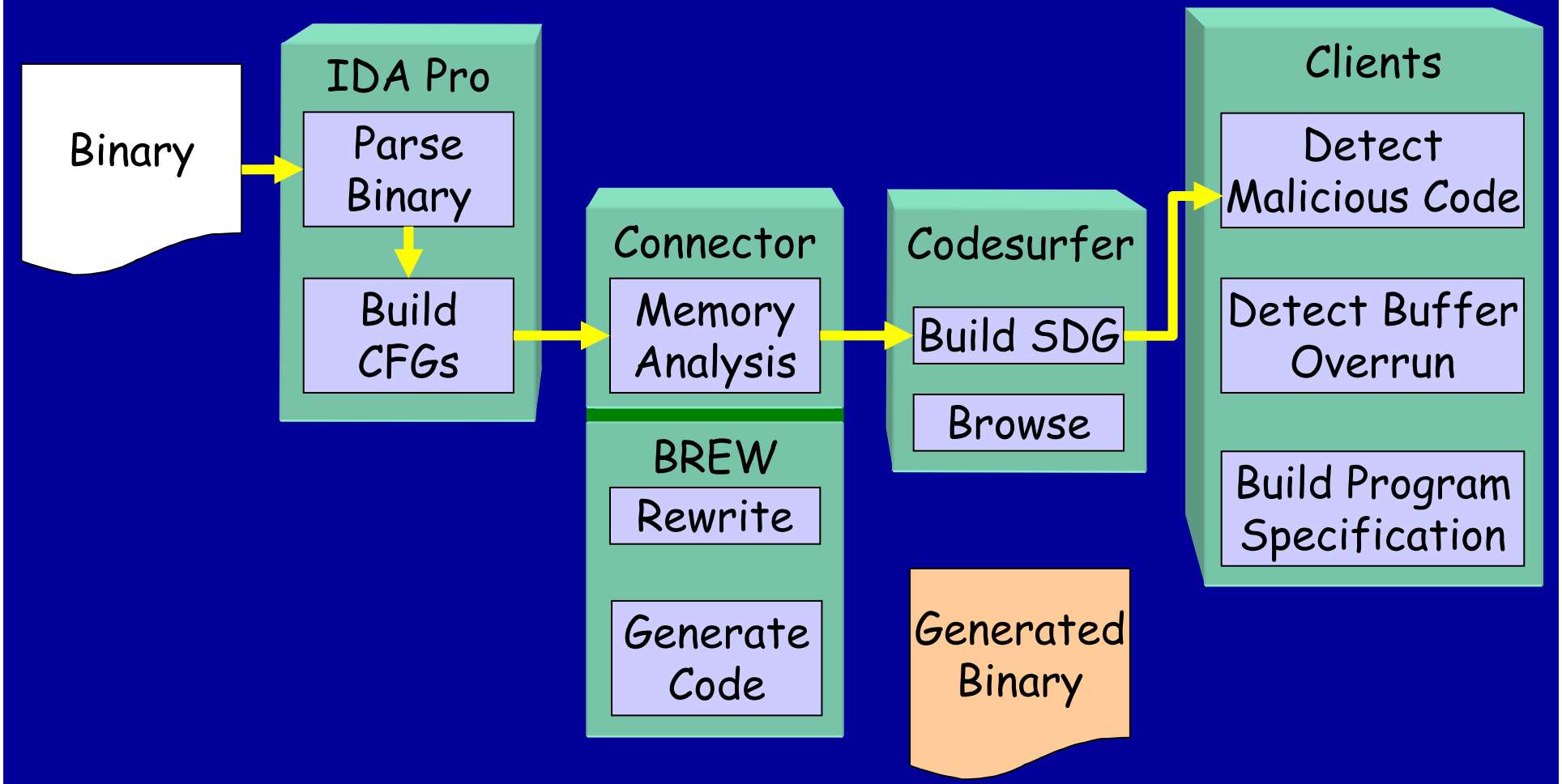
Code Generation



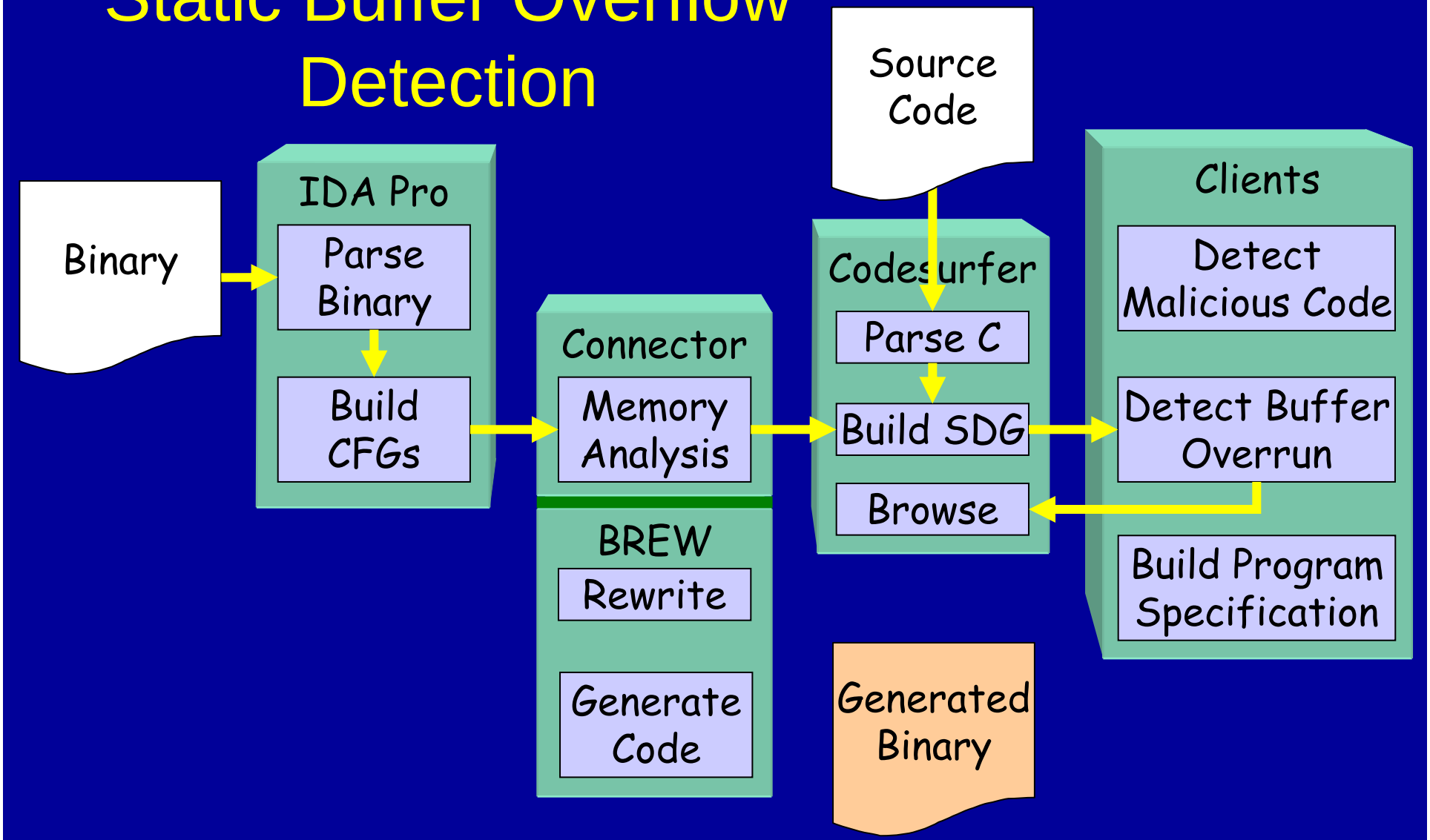
Dynamic Buffer Overflow Detection



Malicious Code Detection



Static Buffer Overflow Detection



Team

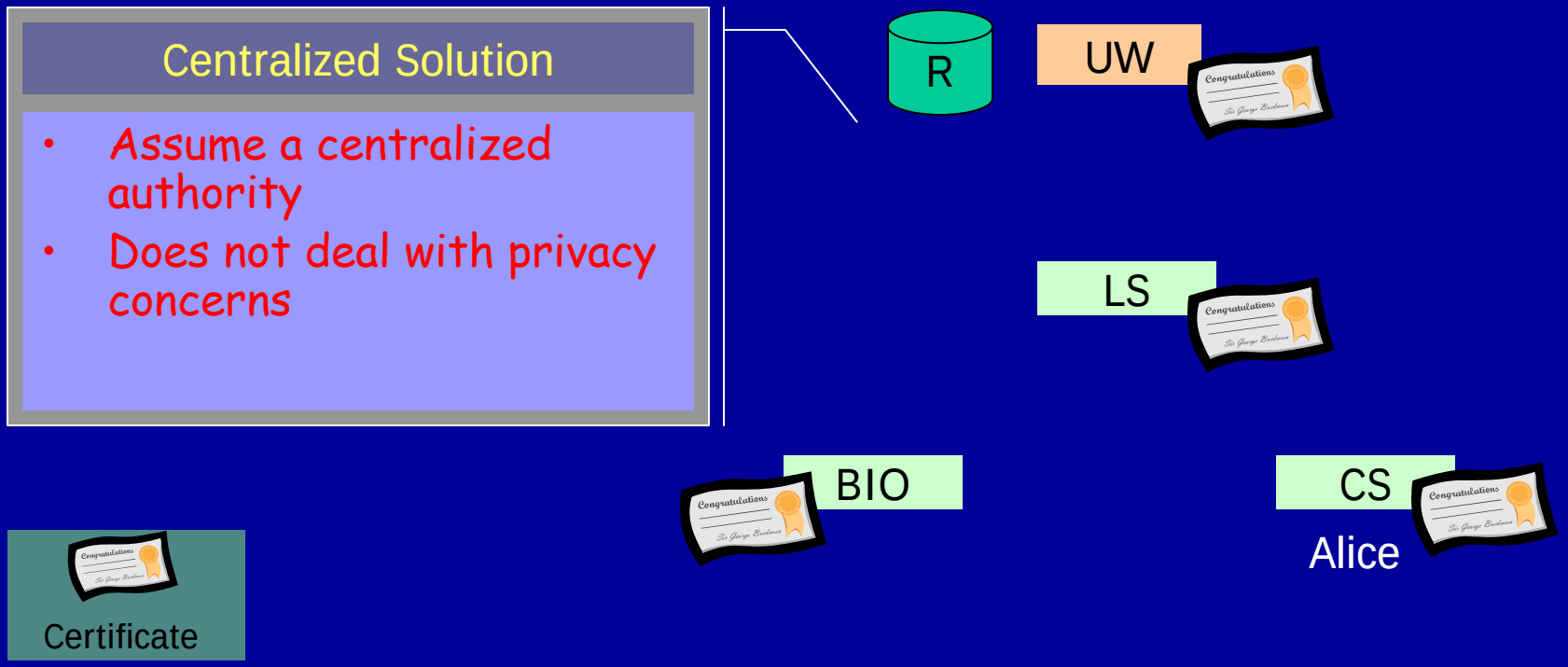
- Somesh Jha
  - Analysis of malicious code, intrusion detection, verification of security protocols, and trust management
- Bart Miller
  - Distributed computing, kernel instrumentation, intrusion detection
- Tom Reps
  - Static-analysis techniques, trust management, and model checking

Six Graduate Students

- Gogul Balakrishnan
- Mihai Christodorescu (US citizen)
- Vinod Ganapathy
- Jon Giffin (US citizen)
- Shai Rubin (Prelim)
- Hao Wang (US citizen)
- Louis Kruger heavily interacts with our group
- Summary
  - Three US citizens
  - All are Ph.D. students and have passed their qualifiers
  - Three students have passed their prelims

Problem: Cross-Domain Authorization (Hao Wang)

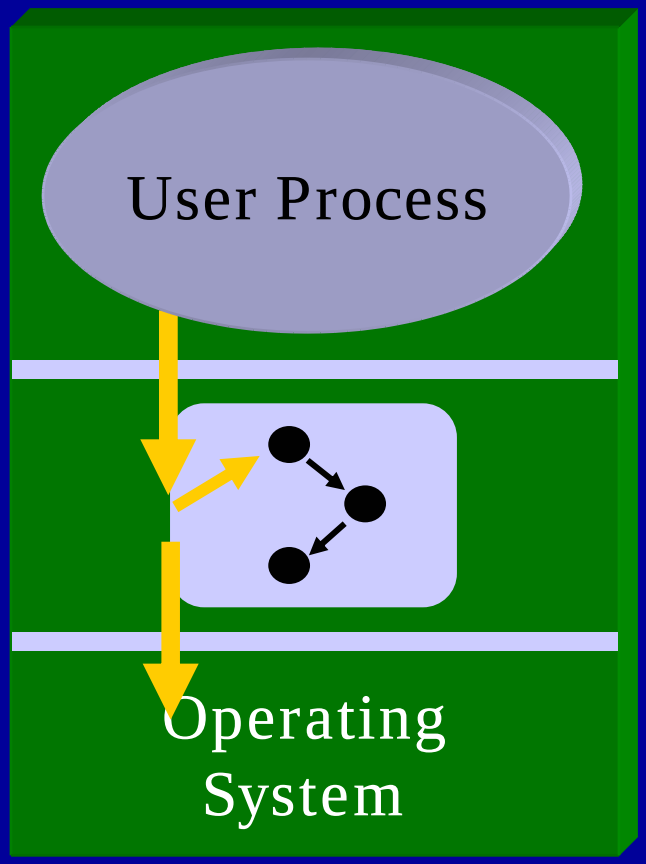
Q1: Should Alice be allowed to access R in domain UW?
Q2: If so, prove it!



Solution: Distributed Certificate-Chain Discovery Using WPDS

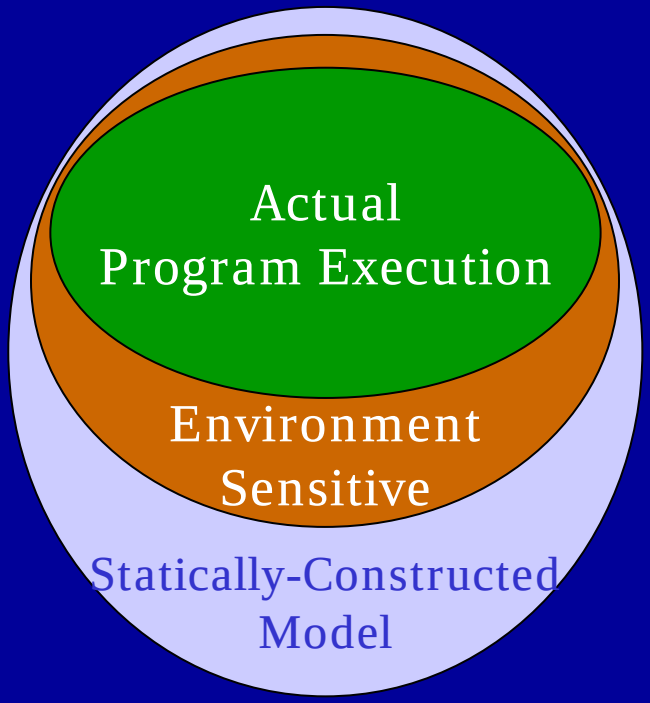
- Developed a distributed algorithm to solve the cross-domain authorization problem
  - Apply techniques from a well-studied domain (WPDS) to a new problem domain (SPKI/SDSI)
- Addressed shortcomings of existing approaches
  - Distributed algorithm $\Rightarrow$ No need for centralized authority
  - Preserve users' privacy
- Implemented a prototype
  - Scalable—tested in a simulated environment with up to 1,600 certificates

Model-Based Intrusion Detection (Jon Giffin)



- Detect deviations from model of normal system-call execution behavior
- Context-sensitive data-flow analysis for system-call argument recovery

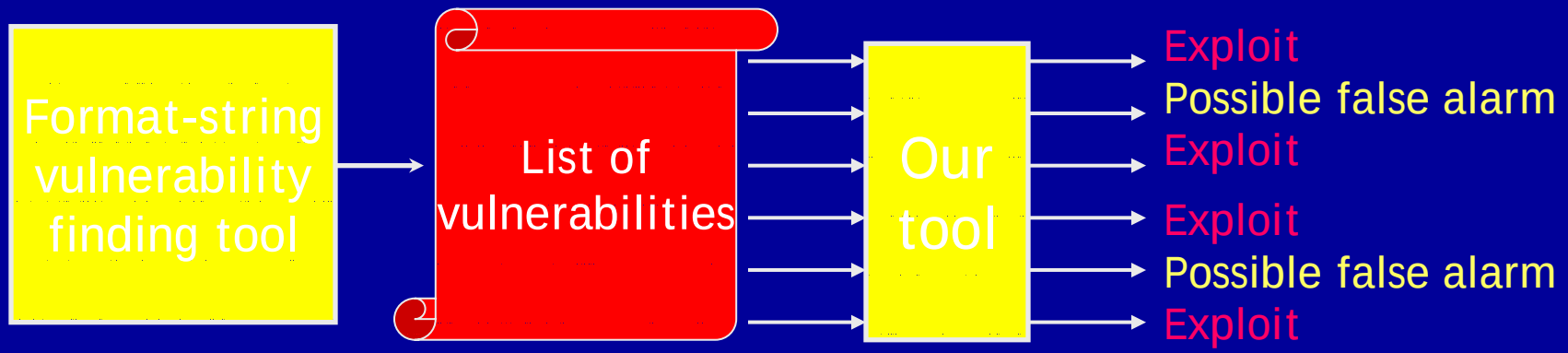
Environment-Sensitive Models



- Program execution often depends upon data values in execution environment
- Environment-sensitive models restrict allowed execution given environment values

Discovering API-Level Exploits (Vinod Ganapathy)

- Key concept: Exploit-finding is different because of need to model low-level details.
- Benefits: Improved vulnerability-detection.
  - Exploitable vulnerabilities versus false alarms.
  - Capability to find variants of exploits.
- Case study: Format-string exploit-finding tool.
  - Finds exploits against real-world applications.



Security Testing

1. NIDS

   Problem: Find an attack instance that eludes a NIDS.
   Solution: Attack generation using natural deduction.

   Shai Rubin · Somesh Jha · Bart Miller

2. Virus scanners

   Problem: Generate virus sample that evades AV tool.

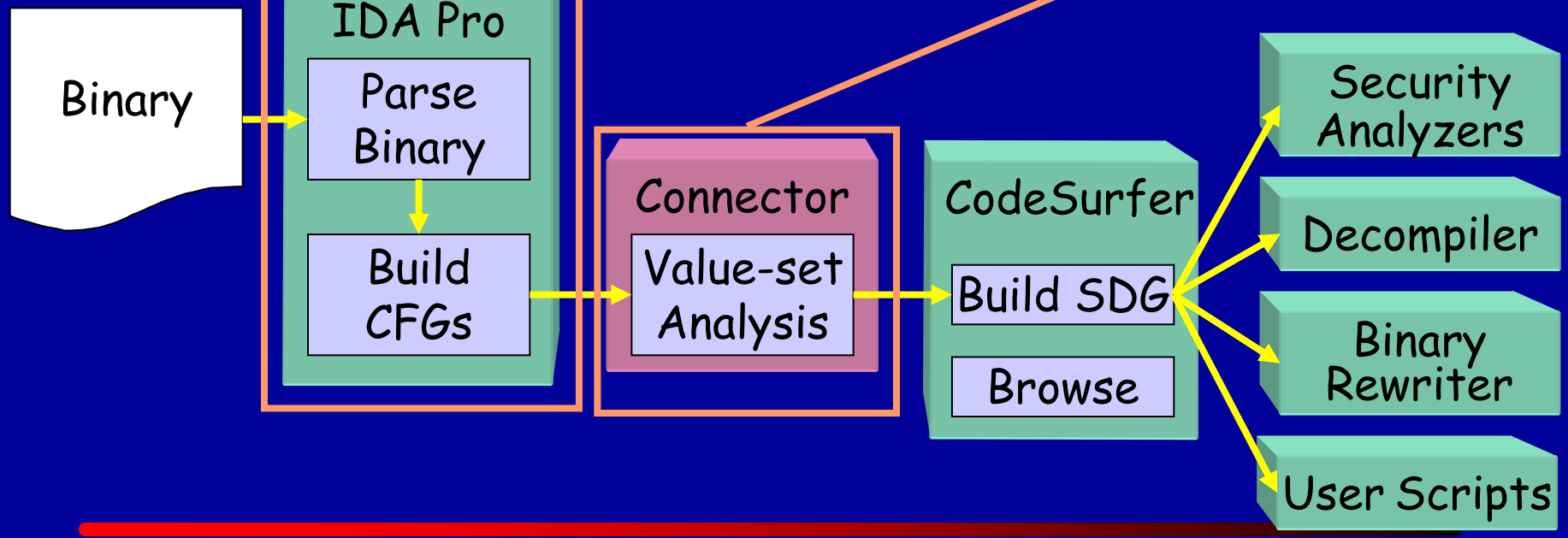
   Solution: Guided attack generation using oracle access.

   Mihai Christodorescu · Somesh Jha

Challenges in Static Analysis of x86 Executables (Gogul Balakrishnan)

- Distinguishing between code and data
- Identifying variables

- Identifying parameters
- Resolving indirect jumps
- Resolving indirect calls
- Identifying may-aliases



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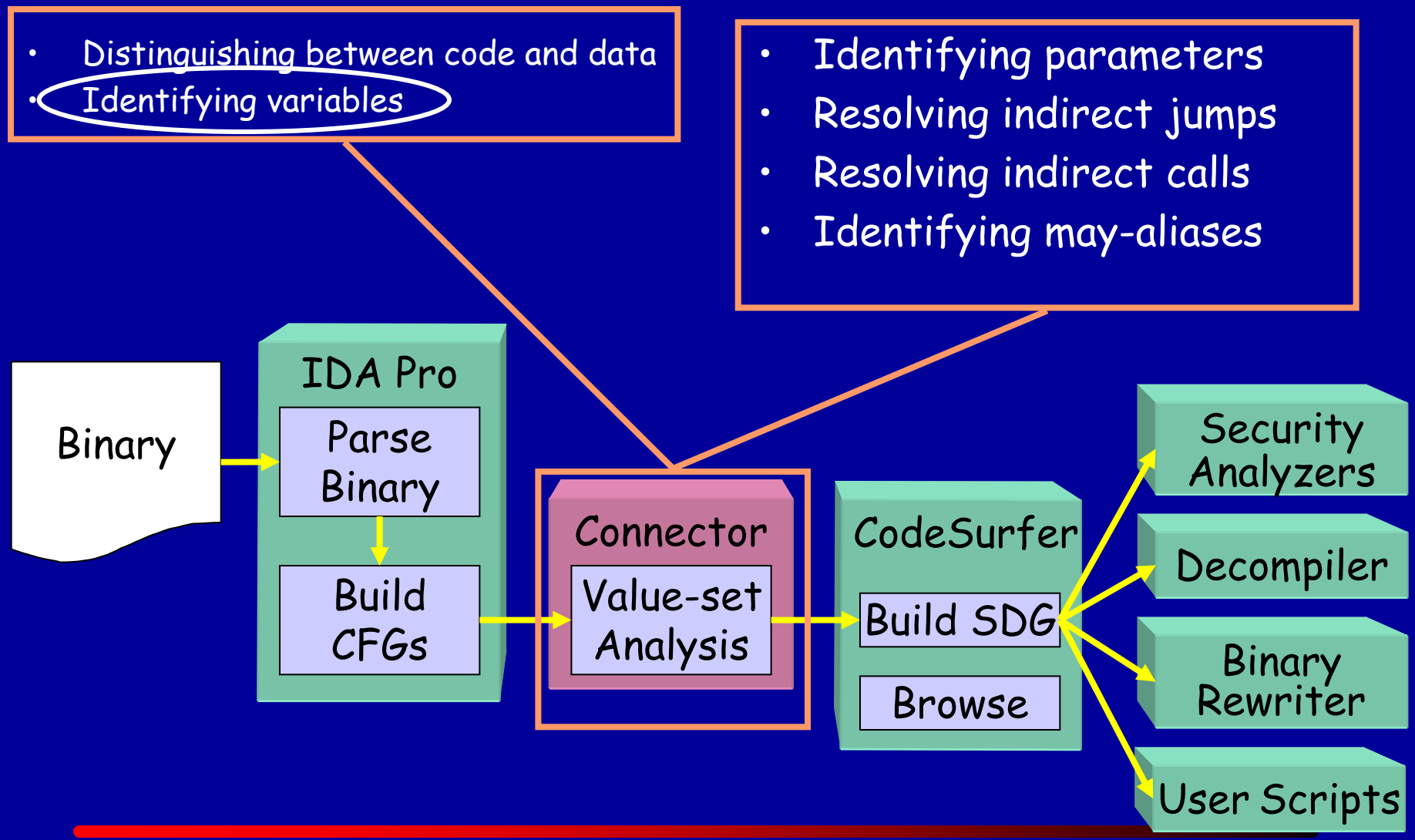

Science and Technology

Research

DoD Relevance

Education

- Research Papers
  - 18 papers accepted in major conferences (USENIX Security, Oakland, CCS, NDSS, CSFW, ISSTA, ICSE)
  - 3 best paper awards
  - > 10 related publications
- PIs served on several program committees and reviewed for several journals
- See the overview document for details

Science and Technology

Technology

DoD Relevance

Education

- Developed a significant infrastructure for analyzing and rewriting x86 binaries
  - Collaboration with GrammaTech
- Applicable to several research problems
  - Identifying buffer overruns
  - Malicious code detection
  - Protection, event logging, remediation..
- Created many technology-transfer and collaborative opportunities

Science and Technology

DoD Relevance

Education

Tools

- WiSA infrastructure
  - Discovering buffer overruns
  - Malicious-code detection
  - Constructing models for intrusion detection
  - Many more under development …
- SandboX86
  - Sandbox applications using a security policy
  - Discovering spyware features in unknown applications
- Our analysis techniques do not require access to source code
  - Can be readily applied to COTS software
- Reduces risk of deploying COTS

Science and Technology

DoD Relevance

Education

Tech Transfer

- GrammaTech (GT) an important vehicle for technology transfer
- GT -> UW
  - GT implemented an important piece of the architecture
- UW -> GT
  - Value-set analysis (Gogul)
  - BREW infrastructure (Jon, Mihai, and Hao)
  - Buffer-overrun-detection tool (Vinod)

Science and Technology

DoD Relevance

Education

Tech Transfer

- Starting to explore collaborative opportunities with Sandia National Laboratories
  - System Assessment and Research Center
- Doug Ghormley from Sandia came and gave a talk
- Louis Kruger (UW) is a summer intern at Sandia
  - Working on using BREW for "classified" applications
  - Will give a talk about this

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