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

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

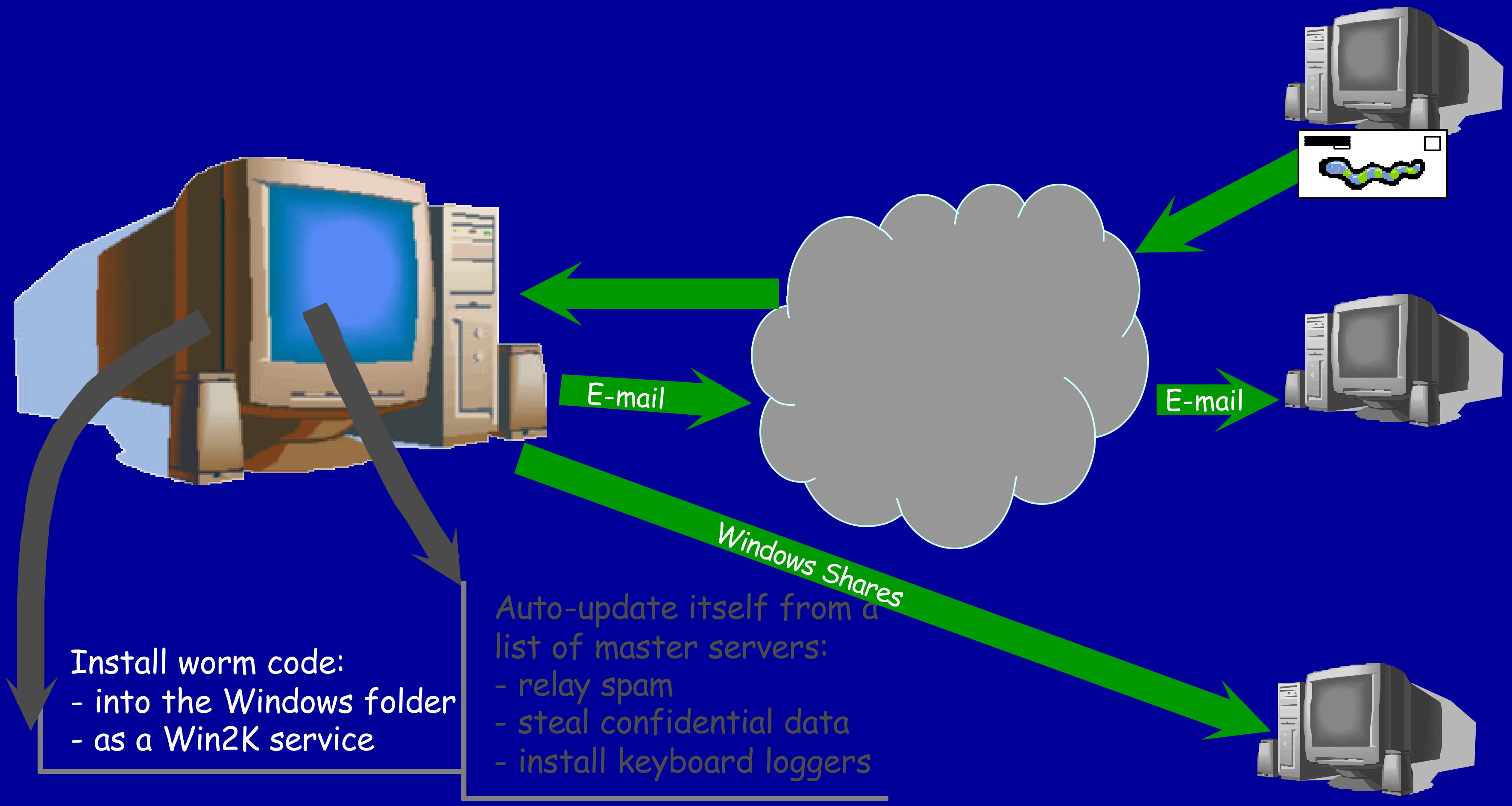
- Viruses
  - Gain access through infected files
- Worms
  - Spread over the network
- Trojans
  - Hide harmful behavior under the guise of useful programs

- Most often: combined code
  - worm + virus + trojan

- Distinguishing characteristics: something observable happens

Malicious Code Example:

Internet worm Sobig.E



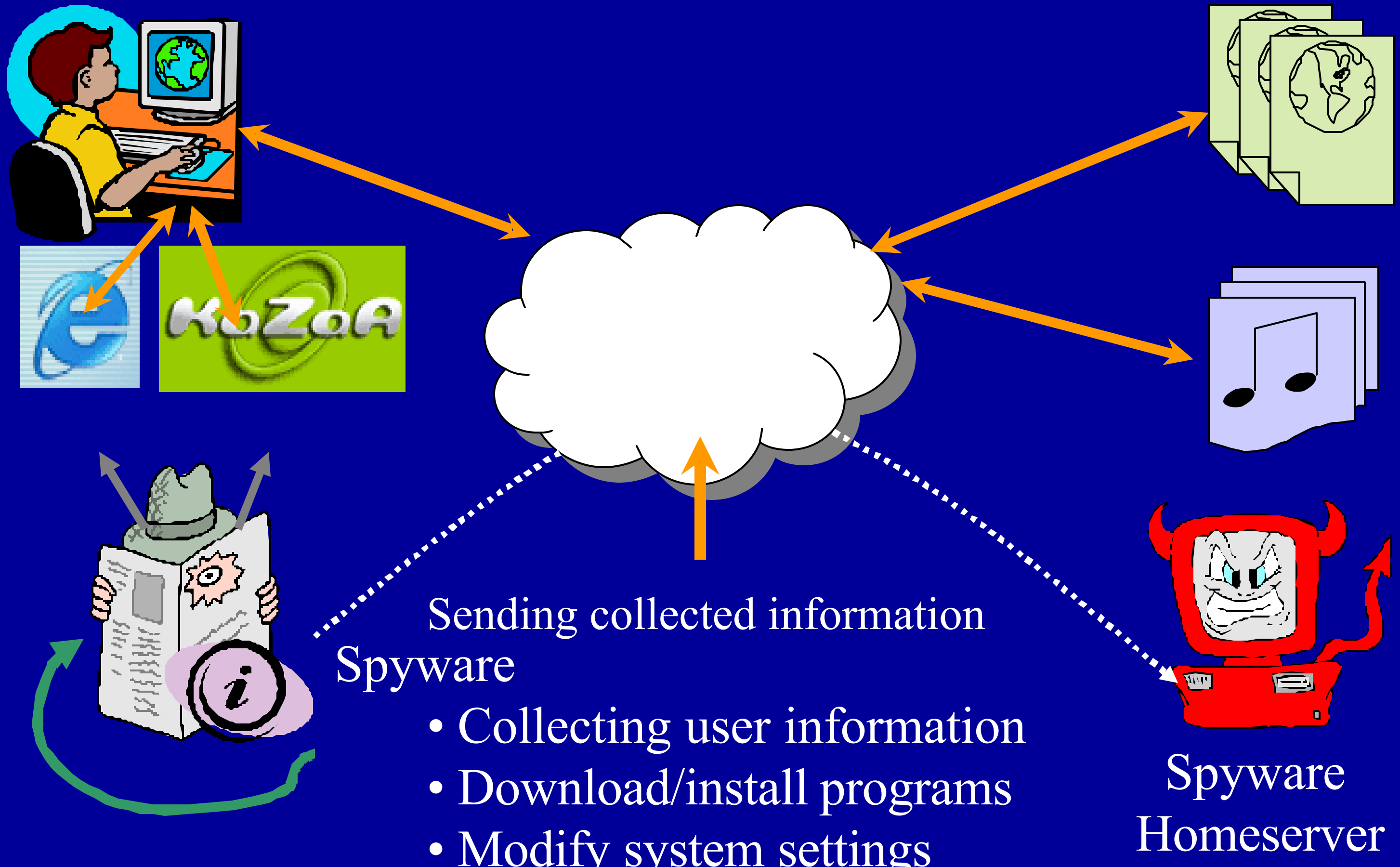
Install worm code:
- into the Windows folder
- as a Win2K service

Auto-update itself from a list of master servers:
- relay spam
- steal confidential data
- install keyboard loggers

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



Sending collected information

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 Development

Static Analysis and Rewriting of Executables

- Protection from code injection attacks
- Remediation
- Malicious code detection

Sandboxing or Dynamic Analysis

- Enforcing behavior using security policies
- Discovering malicious behavior

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
- Hao Wang (US citizen)
- Summary
  - Three US citizens
  - All are Ph.D. students and have passed their qualifiers
  - Working hard towards their prelims

Research

- Research Papers
  - 8 papers accepted in major conferences (USENIX Security, Oakland, CCS, NDSS, CSFW)
  - 4 under submission
  - > 10 related publications
- PIs served on several program committees and reviewed for several journals
- See the overview document for details

Collaboration

- Collaboration with other research projects
- Wenke Lee, Georgia Tech
  - Has done extensive work on applications of dynamic analysis to host-based intrusion detection
  - Models constructed using dynamic analysis leads to false-alarms
- We were able to influence his research

Collaboration with Wenke Lee, Georgia Tech

- Previously researched dynamic analysis methods to recover calling context
- Collaborated on static version of this work
  - Compared with our Dyck model
  - Developed static model formalisms
- Future: research hybrid techniques
  - Methods to recover calling context
  - Combine static & dynamic analysis
- Is part of a large project on intrusion detection funded by DARPA and NSF

Technology

- 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

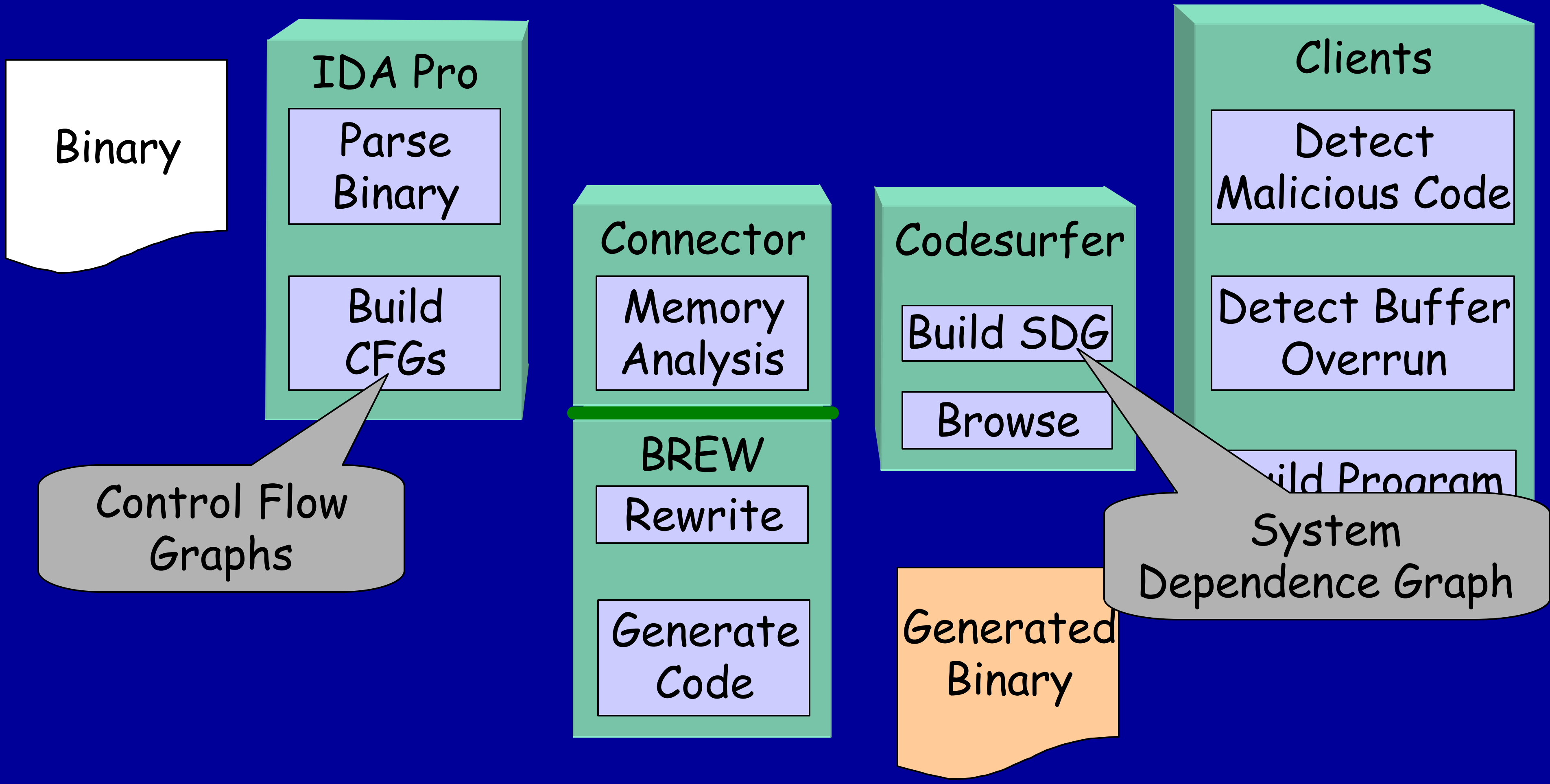
IDA Pro

- 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

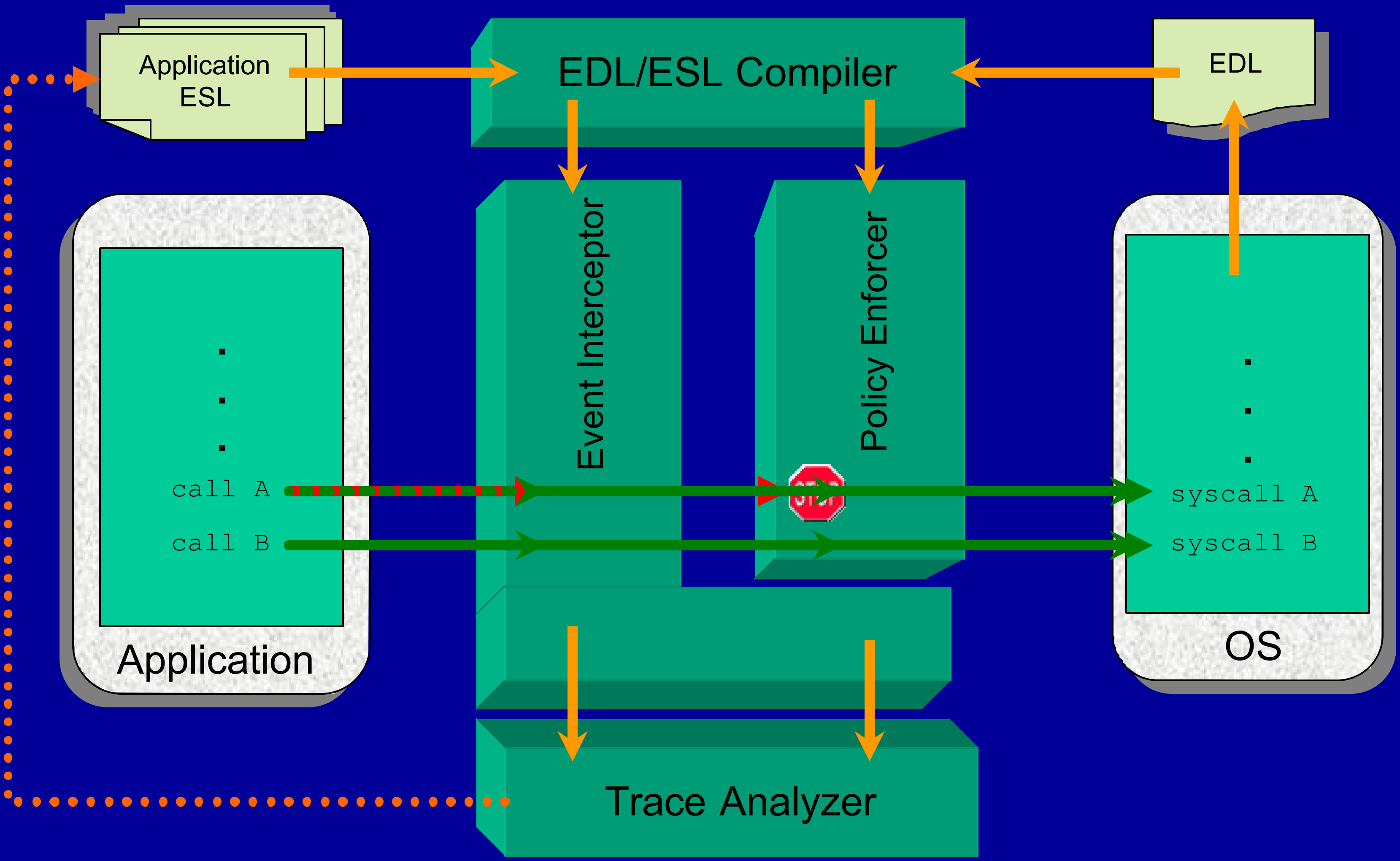
Architecture



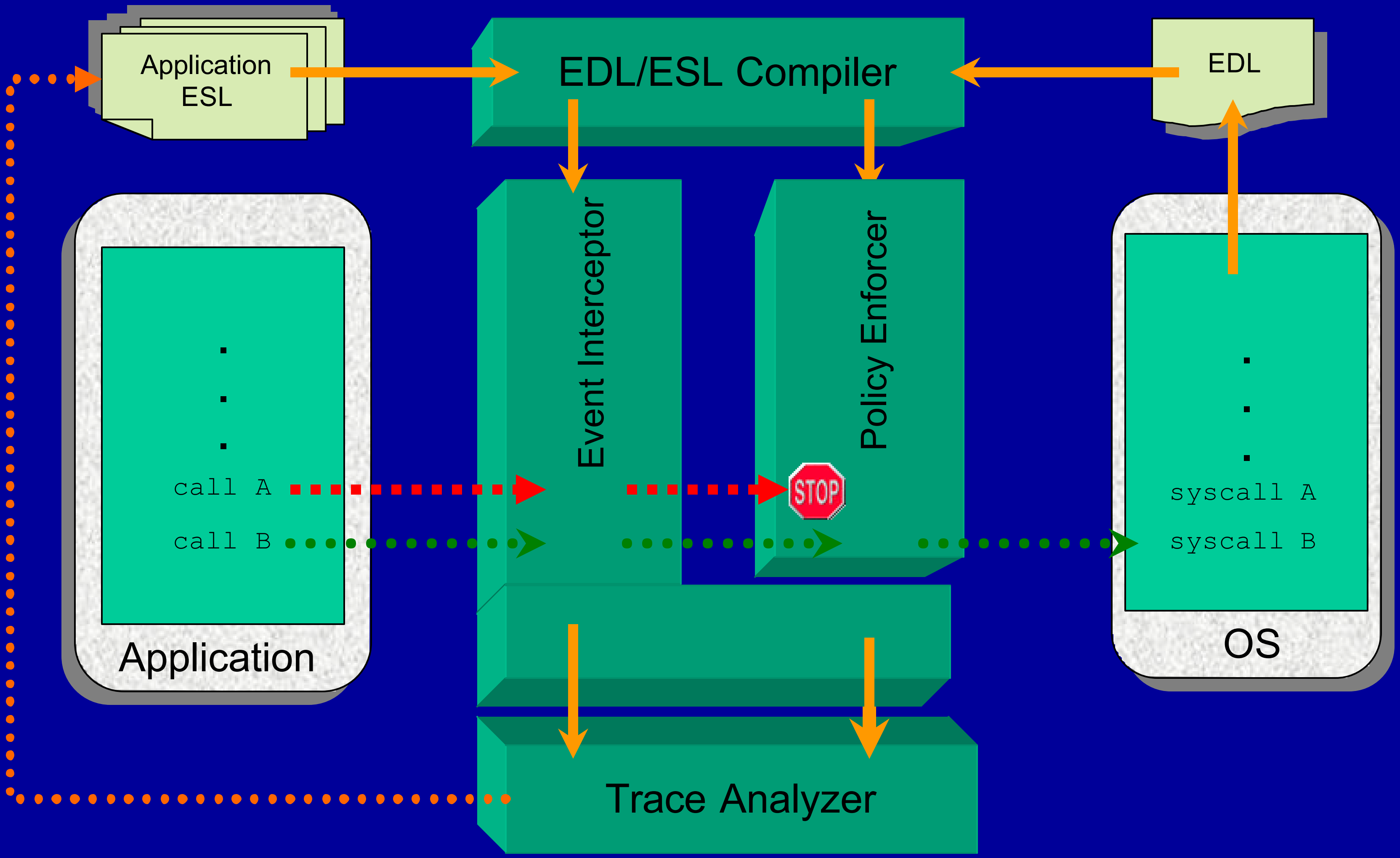
Technology

- Developed a significant infrastructure for sandboxing Windows applications
  - Enforce a security policy at the interface between the application and OS
- Developed a dynamic-slicing tool to discover dependences between events
  - Used to discover spyware features in applications
  - Form of information flow
- Applications and research
  - Sandbox popular applications (KaZaa and RealOne Player)

Sandboxing Architecture: SandboX86



SandboX86


Application
ESL
EDL/ESL Compiler
EDL
Event Interceptor
Policy Enforcer
.
.
.
call A
call B
Application
STOP
.
.
.
syscall A
syscall B
OS
Trace Analyzer

Science and Technology

DoD Relevance

Tools

Education

- 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

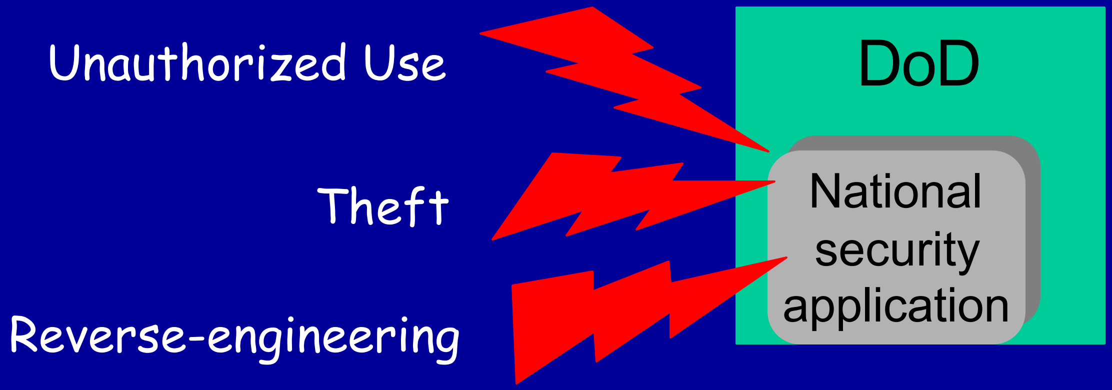
Tech Transfer

- 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)
- Tim Teitelbaum will talk more about this

- Starting to explore collaborative opportunities with Connie Heitmeyer's group at NRL
- Connie Heitmeyer visited UW-Madison on Oct 3 to give a talk and discussed collaborative opportunities
- There are definitely opportunities
  - Establishing "correspondence" between code and specification
  - Code understanding tools

SAFE for Software Protection

- DoD Anti Tamper and Software Protection Initiative (Dec. 2001)



- AFRL S/W Protection Compilation (Nov. 2003)
  - Workshop to develop a framework to use compilers for software protection
  - SAFE research presentation

SAFE for Exploit Classification

LOCKHEED MARTIN ATL

- ATL is planning to develop an intrusion-tolerant system based on biological metaphors
- Advanced Technology Laboratories (Cherry Hill, NJ)
  - Interested in using SAFE technology to classify exploit code
- Meeting in October 2003 established feasibility of approach
  - Possible DARPA proposal

Ph.D Students

- Gogul Balakrishnan
  - Status: Passed qualifiers in programming languages (PL)
  - Subject: Static analysis of executables
  - Advisor: Tom Reps
- Mihai Christodorescu
  - Status: Passed qualifiers in PL
  - Subject: Malicious code detection
  - Advisor: Somesh Jha
- Vinod Ganapathy
  - Status: Passed qualifiers in PL
  - Subject: Verifying security APIs
  - Advisor: Somesh Jha

Ph.D Students

- Jon Giffin
  - Status: Passed qualifiers in operating systems (OS)
  - Subject: Static analysis techniques for intrusion detection
  - Advisors: Somesh Jha and Bart Miller
- Shai Rubin
  - Status: Passed qualifiers in PL
  - Subject: Formalizing network intrusion detection systems (NIDS)
  - Advisors: Somesh Jha and Bart Miller
- Hao Wang
  - Status: Passed qualifiers in OS
  - Subject: Detecting and containing Spyware
  - Advisor: Somesh Jha

Courses

- Introduction to Information Security
  - Audience: Seniors
  - Topics covered
    - Basic cryptography
    - Various attacks and malicious code
    - Security protocols
    - System security (firewalls and IDSs)
  - Instructor: Somesh Jha
- Analysis of Software Artifacts
  - Audience: Graduate students
  - Topics covered
    - Model checking
    - Other formal methods (SCR, Alloy, …)
    - Other assorted topics (real-time systems, …)
    - Analysis techniques for security properties
  - Instructor: Somesh Jha

- Distributed Systems
  - Audience: Graduate students
  - Topics covered
    - Language issues
    - Distributed shared memory
    - Replication and fault tolerance
    - Authentication
    - Mobile computing
  - Instructore: Bart Miller
- Other related course taught by B. Miller and T. Reps

Seminars

- Established a security seminar series
  - Several external speakers presented on various topics related to INFOSEC
  - Several internal speakers presented their work and some recent work by others
  - Topics covered
    - Applied cryptography
    - Watermarking
    - Legal issues such as DMCA

- Distinguished lecture series being organized by Somesh Jha has a security focus
  - Amir Pnueli
  - Fred Schneider
  - David Dill
  - Dan Boneh
  - Doug Tygar
- Established a security reading group
  - Mostly graduate students
  - Read papers from major conferences (Oakland, CCS, Usenix Security)
  - Read some classic papers (suggested by Connie Heitmeyer and Jon McHugh at the Williamsburg meeting)

Order of Presentations

- Somesh Jha: WiSA Architecture Overview and Applications
  - Analysis of executables
  - Sandboxing applications
- Tom Reps: Static Analysis of x86 Binaries
- Bart Miller: Attacks and Defenses
- Somesh Jha and Tim Teitelbaum (GT): Wrap-up
- Afternoon: Demos and posters by students

Contact Information

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