Terry Benzel
USC Information Sciences Institute
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The Science of Cyber Security Experimentation

Background

Cyber-threat continues to accelerate
Far fewer cyber-defense technologies
Gap between threat and defense widened
Increasingly sophisticated attack technology
- unprecedented power
- resources
- global reach

Increasingly by nation states

What Can We do About It?

Solution – build less vulnerable systems to begin with!

Create fundamental understanding and reason about systems through experimental means

Key aspect – enable science based experimentation

Hard Problem

All Too Often

Why There is No Science in Cyber Science [A panel discussion at NSPW 2010] Maxion, Longstaff, McHugh

1. Have an idea for a “new” tool that would “help” security
2. Program/assemble the tool (the majority of the work)
3. Put it on your local net
4. Attack your system
5. Show the tool repels the attack
6. Write up “the results” and open-source the tool
7. (optional) Start up a company which might succeed

Instead - Objectives

Perform experimental research of scale and complexity representative of the real world

Extract understanding through experimental research

Collect, leverage, and share experimental artifacts and learnings

Cyber Security Experimentation

Class of experimental cyber science applied to sets of problems - networked cyber systems and often cyber physical networked systems

Goal - enable experimental cyber science aimed at study of behavior, phenomena, providing fundamental understanding

The DETER Project

DETERLab

The Facility

The DETER Facility

A general purpose, flexible platform for modeling, emulation, and controlled study of large, complex networked systems

- Elements located at USC/ISI (Los Angeles), UC Berkeley, and USC/ISI (Arlington, VA)
- Funded by NSF and DHS, started in 2003
- Based on Emulab software, with focus on security experimentation
- Shared resource – multiple simultaneous experiments subject to resource constraints
- Open to academic, industrial, govt researchers essentially worldwide – very lightweight approval process

DETERLab = Hardware + Software

Hardware

- Experiment nodes, Ethernet switches
- https://trac.deterlab.net/wiki/Installation

Open Source Software

- DETER manages stable repository
- Communities can copy/ specialize this repo
- Communities can share, exchange

DETER accepts contributions to stable base

Physical Platform

- ~440 PC-based nodes
  - Berkeley, CA - ~200 Nodes
  - Los Angeles, CA - 220 Nodes
  - Arlington, VA – 20 Nodes
- Interconnect
  - 1 Gb/s – LA-UCB
  - 1-10 Gb/s LA-Arlington
- Local and Remote access

Key Capabilities

Technical elements

- DETER Core
- Scalable Modeling and Emulation
- Risky Experiment Management
- Multiparty Experiments
- Federation
- Partner Cluster Deployment

RESEARCH PROGRAM

Research Goals

Advance our understanding of of experimental cybersecurity *science and methodologies*

- Enable new levels of rigor and repeatability
- Transform low level results to high level understanding
- Broaden the domains of applicability

Advance the *technology of experimental infrastructure*

- Develop technologies with new levels of function, applicability, and scale

Share *knowledge, results, and operational capability*

- Facility, data and tools
- Community and knowledge

Scalable Modeling and Emulation

The problem:

Traditional testbeds can model and emulate *small* systems at a *fixed* level of fidelity.

The challenge:

Many real problems require modeling of *large, complex* systems at an *appropriate* (“good enough”) level of fidelity.

That level may be *different* for different parts of the modeled system.

Think of this as “smearing the computation power around to just where it’s needed”.

Containers

DETER **containers** use virtualization to support larger experiments

Containers use several different types of virtualization

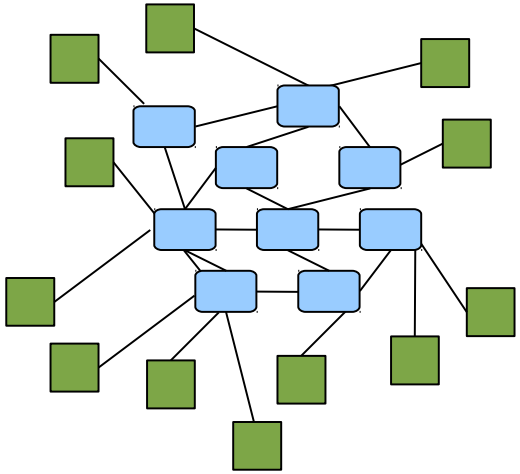
Selecting different virtualization types allows a trade-off:

One container per physical machine high fidelity.

More containers per physical machines less fidelity.

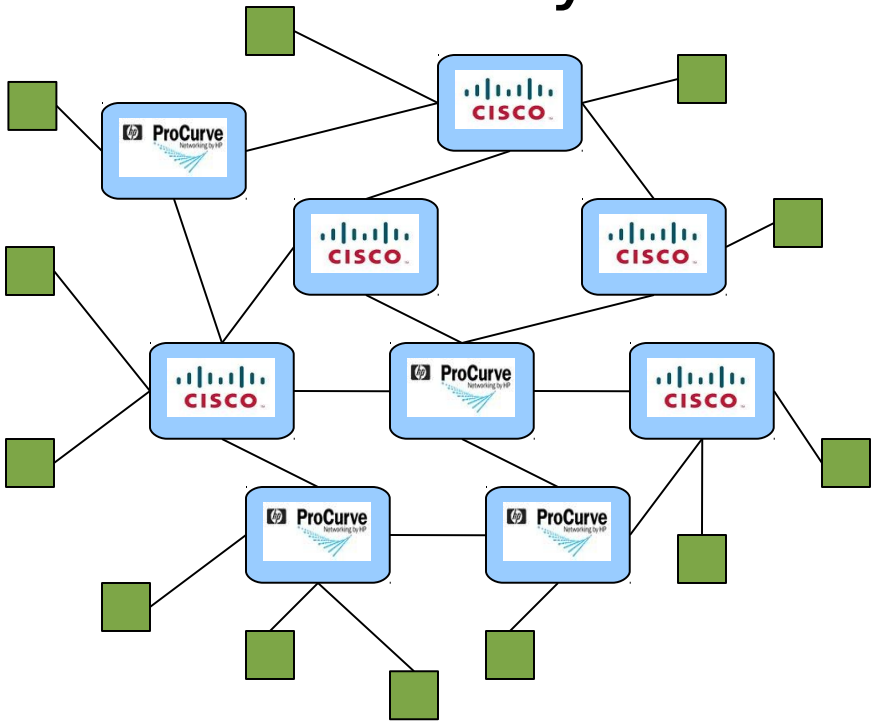
Defining Experiment Scenarios

Experiment Topology

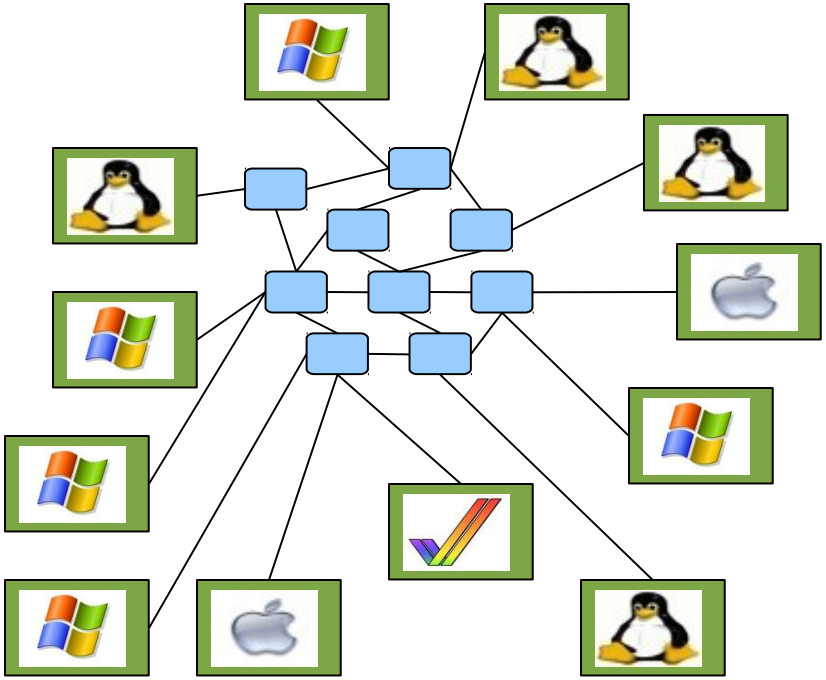


Different Scenarios: Different Abstractions

BGP Security



Worm Propagation



Methodologies, Models and Technologies

Representing the (near infinite) world in the (rather finite) testbed

Automating everything that can be automated for repeatable, realistic testing

Automating (albeit imperfectly) that which can’t be automated (e.g. Humans)

Scalable Control and Instrumentation

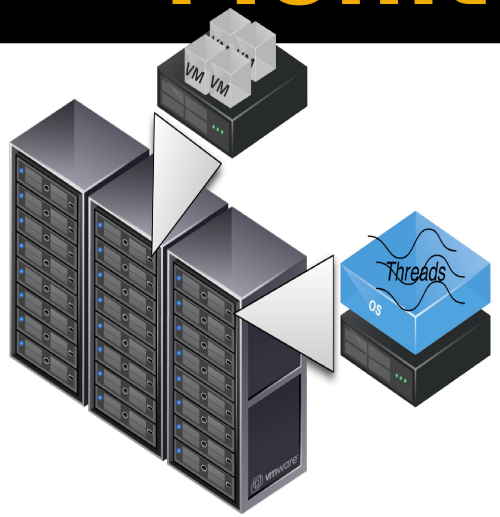
Experiment scenarios require many disparate elements to be combined within a single overall scenario.
These elements must be:

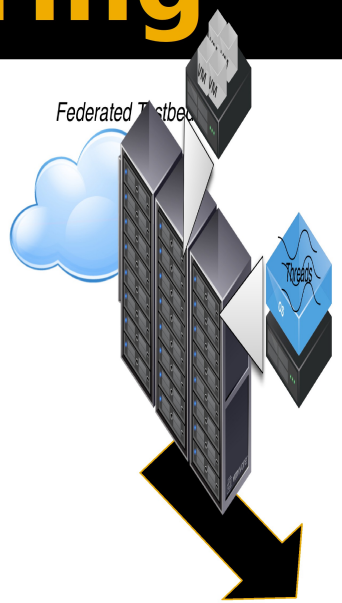
- deployed, initialized, configured,
- monitored and coordinated
- instrumented with real-time and post-mortem data collection

…throughout the execution of the experiment.

DETER’s MAGI agent infrastructure provides an architecture for scalable control and instrumentation

Experiment Control & Monitoring





500

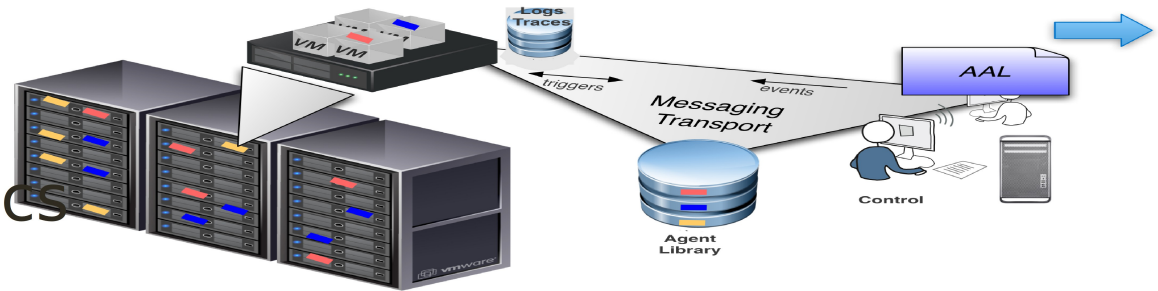
100K

Nodes

Agents

Scalable and flexible

Rich Control Semantics



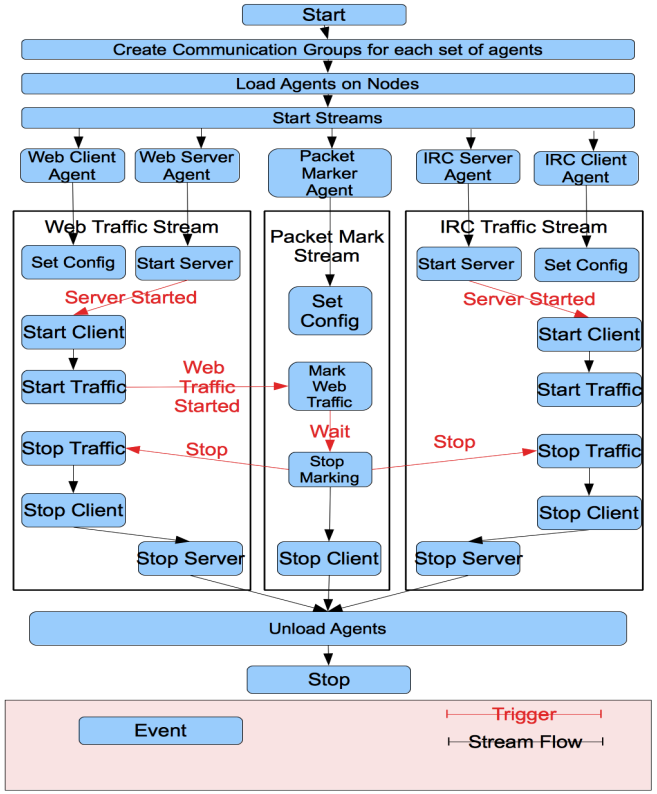
Montage Agent Infrastructure

Leverage strengths of previous generation technologies
- tevc, SEER

Control Semantics
- time based and event based
  - triggers
- workflows

25+ agents and growing
- traffic, monitoring

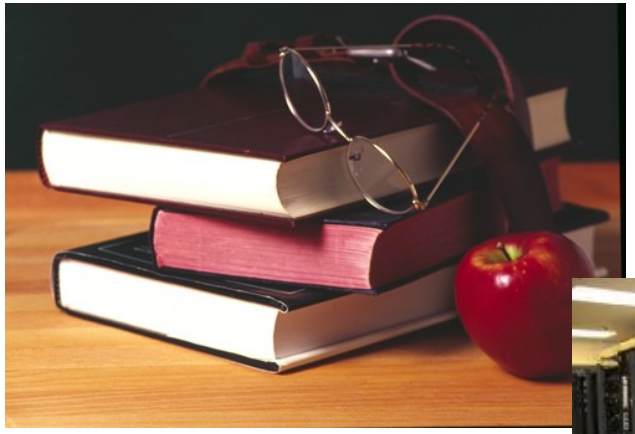
Users and contributors
- DeterLab Users
- Education

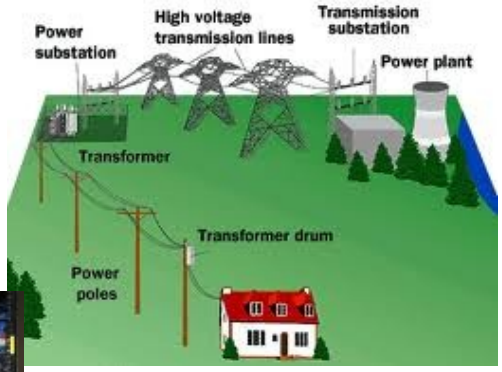


DETERLab

Federation

Multiple Communities





Specialized environments
Different domains of expertise

Partner Clusters

DeterLab cluster at the partner's facilities
- Partner's hardware and network resources

Federation technology enables interoperation with DeterLab
Current partners underway
- Pacific Northwest National Labs (PNNL)
- University of Illinois, Urbana – Champaign (UIUC)
- Defense Research Department Canada (DRDC)
- BBN Technologies, a Raytheon Company
- Battelle Labs
- SRI International

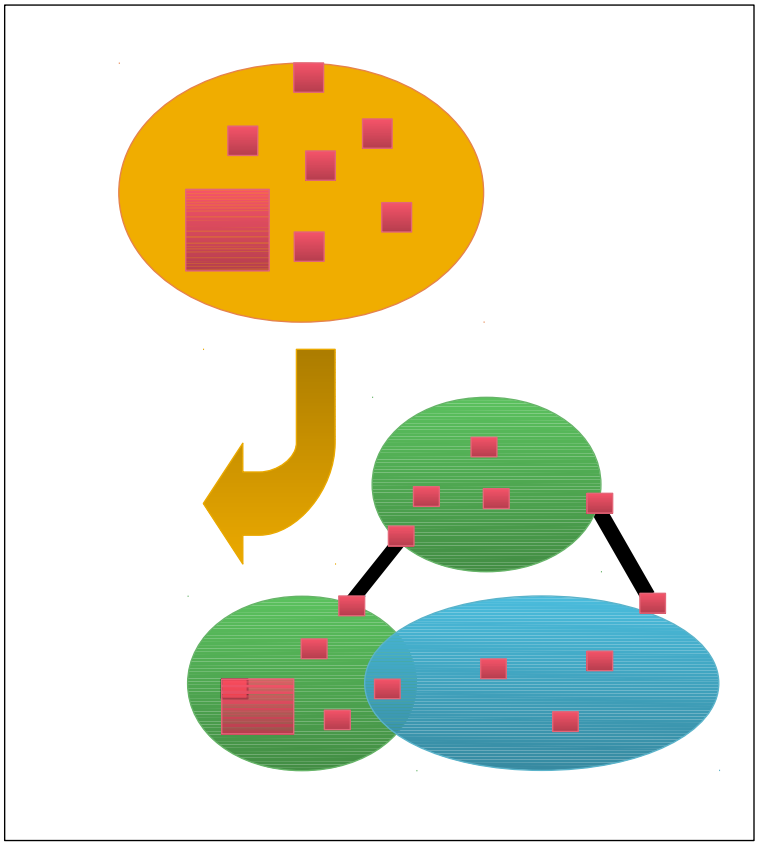
Different types of organizations and cluster hardware Contributions back to ISI DETER Core

Dynamic Federation

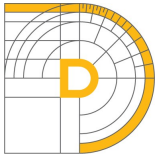
On-demand creation
of experimental scenarios
spanning
multiple, *independently controlled* facilities

Goals and Benefits

- Scale
- Access to unique resources
- Accommodation of usage policy constraints
- Data & knowledge sharing
- Information hiding



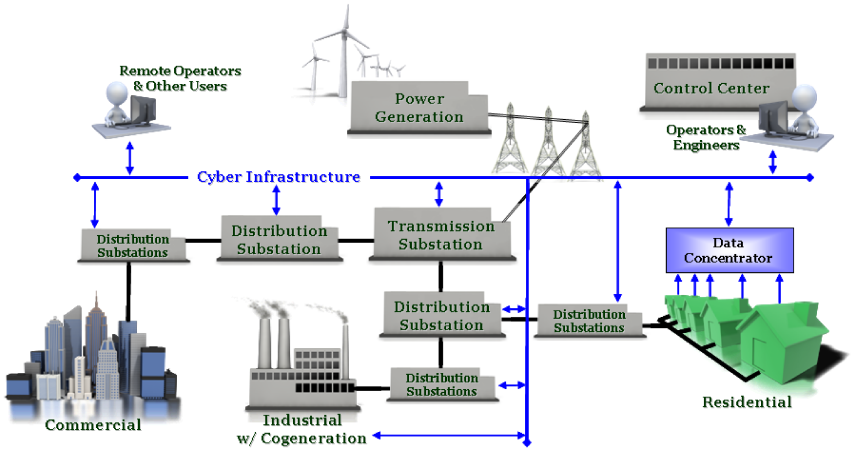
DETER-Enabled Federated Testbeds



The Department of Homeland Security (DHS)
Science & Technology Directorate Cyber Security Division

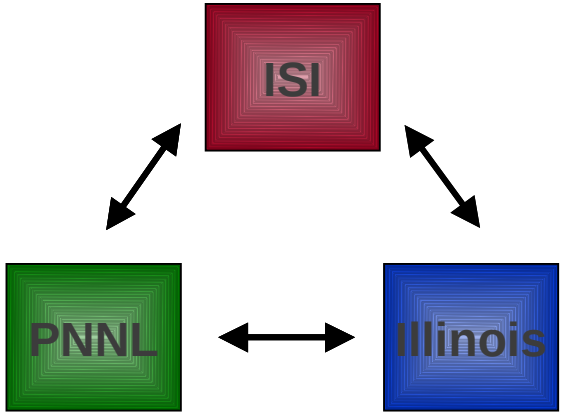
The Department of Energy (DoE)
Office of Electricity Delivery and Energy Reliability

DEFT Consortium Goals



- Provide research infrastructure
  - Integrate geographically distributed cyber and physical resources and tools
  - Shared, distributed, and federated capability

- Support experimental research
  - Cyber physical systems
  - Wide range of security, reliability, performance, and other challenges



The DETER Community

Community and Outreach

- Content sharing support
  - Experiments, data, models, recipes
  - Class materials, recent research results, ideas
- Shared spaces
  - Outreach: Conferences, tutorials, presentations
  - Share and connect: Website, exchange server
  - Common experiment description: Templates
  - Build community knowledge: domain-specific communities
- Education support
  - NSF CCLI grant: develop hands-on exercises for classes
  - Moodle server for classes on DETER

DETER User Institutions

Government

Air Force Research Laboratory
DARPA
Lawrence Berkeley National Lab
Naval Postgraduate School
Sandia National Laboratories

Industry

Agnik, LLC
Aerospace Corporation
Backbone Security

BAE Systems, Inc.
BBN
Bell Labs
Cs3 Inc.
Distributed Infinity Inc.
EADS Innovation Works

FreeBSD Foundation
iCAST
Institute for Information Industry

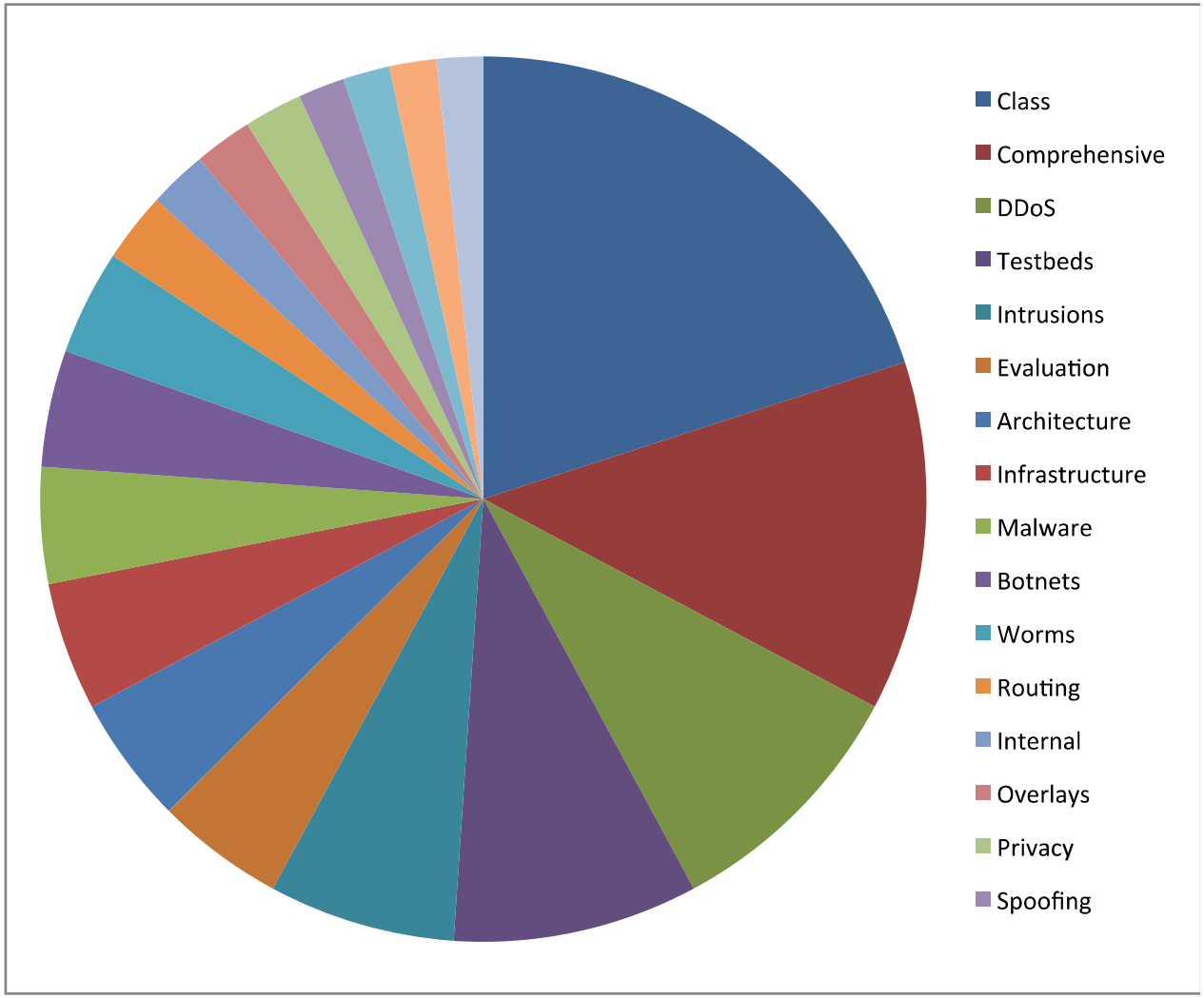
Intel Research Berkeley

Academia

Carnegie Mellon University
Columbia University
Cornell University
Dalhousie University
DePaul University
George Mason University
Georgia State University
Hokuriku Research Center
ICSI
IIT Delhi
IRTT
ISI
Johns Hopkins University
Lehigh University
MIT
New Jersey Institute of Technology
Norfolk State University
Pennsylvania State University
Purdue University
Rutgers University
Sao Paulo State University
Southern Illinois University
TU Berlin
TU Darmstadt
Texas A&M University
UC Berkeley
UC Davis

UC Irvine
UC Santa Cruz
UCLA
UCSD
UIUC
UNC Chapel Hill
UNC Charlotte
Universidad Michoacana de San Nicolas
Universita di Pisa
University of Advancing Technology
University of Illinois, Urbana-Champaign
University of Maryland
University of Massachusetts
University of Oregon
University of Southern Callfornia
University of Washington
University of Wisconsin - Madison
USC
UT Arlington
UT Austin
UT Dallas
Washington State University
Washington University in St. Louis
Western Michigan University
Xiangnan University
Youngstown State University

DETER User Research



Education

Hands on exercises
Students gain from direct observation of attacks and interaction
Pre packaged for both student and teacher
    Buffer overflows, command-injection, middle-in-the-middle, worm modeling, botnets, and DoS

Facility support for class administration

Conclusion

Benefits

Transformative research and facility for cyber security R&D
Experimental science:
    Fostering fundamental understanding world complexity

Contribution transformation of field
Proactive robustness and away from reactive security

Summary and Call to Action

Growing DETER Community increasingly engaged in experimental science of cyber security

Collaboration key part of DETER mission

We are HIRING!

Marina del Rey and Arlington, VA

Join us

http://deter-project.org/