U.S. Department of Energy

Office of Science

Cybersecurity for Distributed Science: Fortifying the Front-lines of the Cybersecurity War

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Threats

- Viruses
- Worms
- Malicious software downloads
- Spyware
- Stolen credentials
- Insider Threat
- Denial of service
- Root kits
- Session hijacking
- Agent hijacking
- Man-in-the-middle
- Network spoofing
- Back doors
- Exploitation of buffer overflows and other software flaws
- Phishing
- Audits / Policy / Compliance
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Example - Credential Theft

- Widespread compromises
  - Over 20++ sites
  - Over 3000+ computers
  - Unknown # of accounts
  - Very similar to unresolved compromises from 2003
- Common Modus Operandi
  - Acquire legitimate username/password via keyboard sniffers and/or trojaned clients and servers
  - Log into system as legitimate user and do reconnaissance
  - Use “off the shelf” rootkits to acquire root
  - Install sniffers and compromise services, modify ssh-keys
  - Leverage data gathered to move to next system
- ***The largest compromises in recent memory (in terms of # hosts and sites)***

Cybersecurity Trend - Reactive

- Firewall everything – only allow through vetted applications with strong business need
- Users never have administrator privileges
- All software installed by administrators
- ***All systems running automated central configuration management and central protection management***
- ***Background checks for ALL government employees, contractors, and users with physical presence for issuance of HSPD-12 cards (PIV)***
- ***No access from untrusted networks***
- ***Conformance and compliance driven***
- ***It is a war***

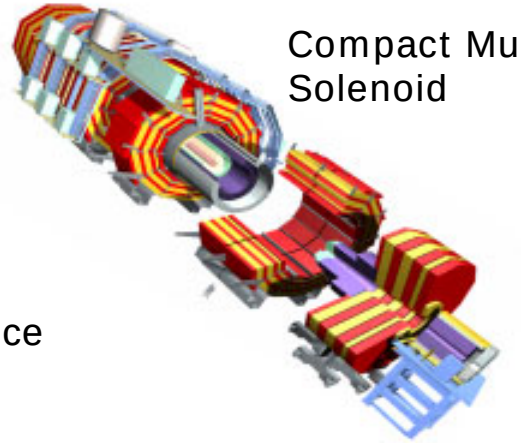
Distributed Science Reality

- Collaborations include as many as 1000's of scientists
- Collaborators located all over the world
- Many users never visit the site
- Virtual organization involved in managing the resources
  - Include multiple sites and countries
  - Distributed data storage
  - Distributed compute resources
  - Shared resources
- Do not control the computers users are accessing resources from
- High performance computing, networking, and data transfers are core capabilities needed
- Authentication, authorization, accounting, monitoring, logging, resource management, etc built into middleware
- ***These new science paradigms rely on robust secure high-performance distributed science infrastructure***

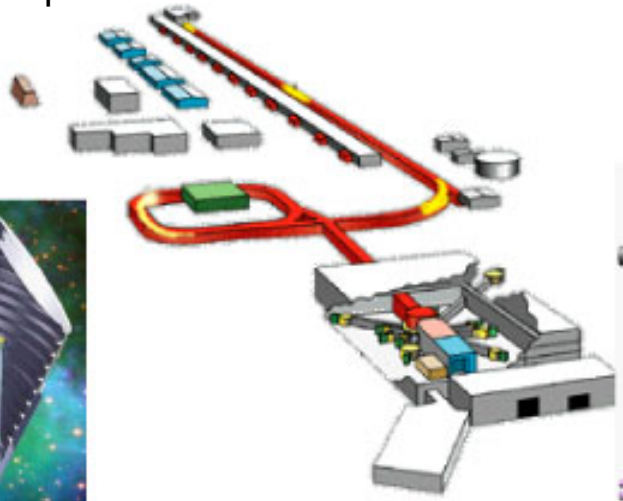
Experiments

Atlas Detector

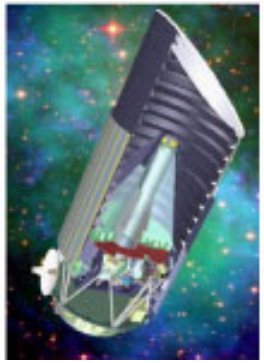
Compact Muon Solenoid



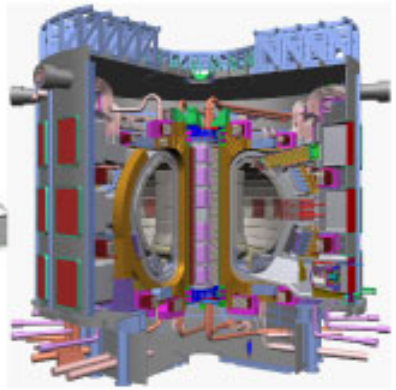
Spallation Neutron Source



Ultrahigh Voltage Electron Microscope

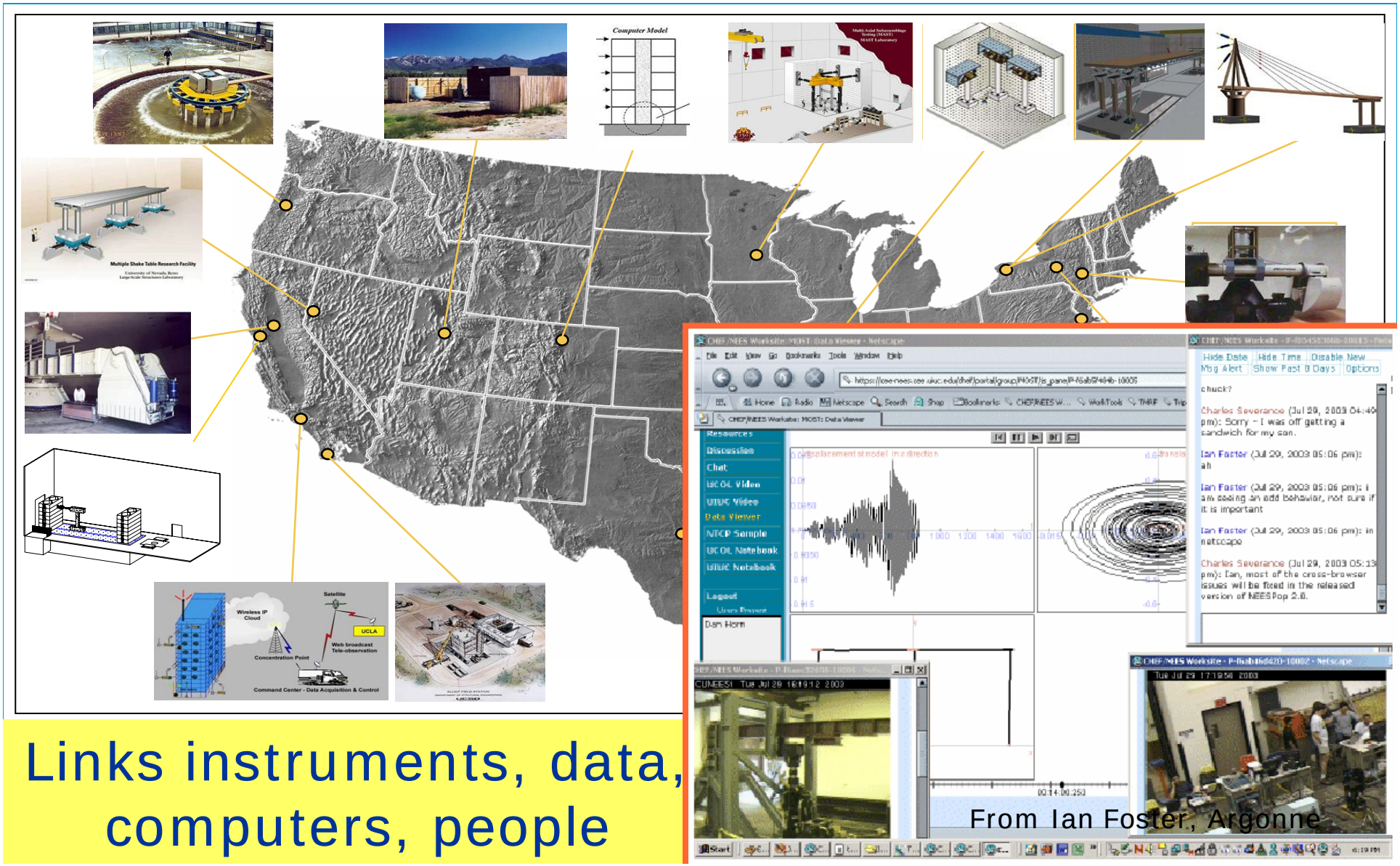


Supernova/ Acceleration Probe



ITER Tokamak

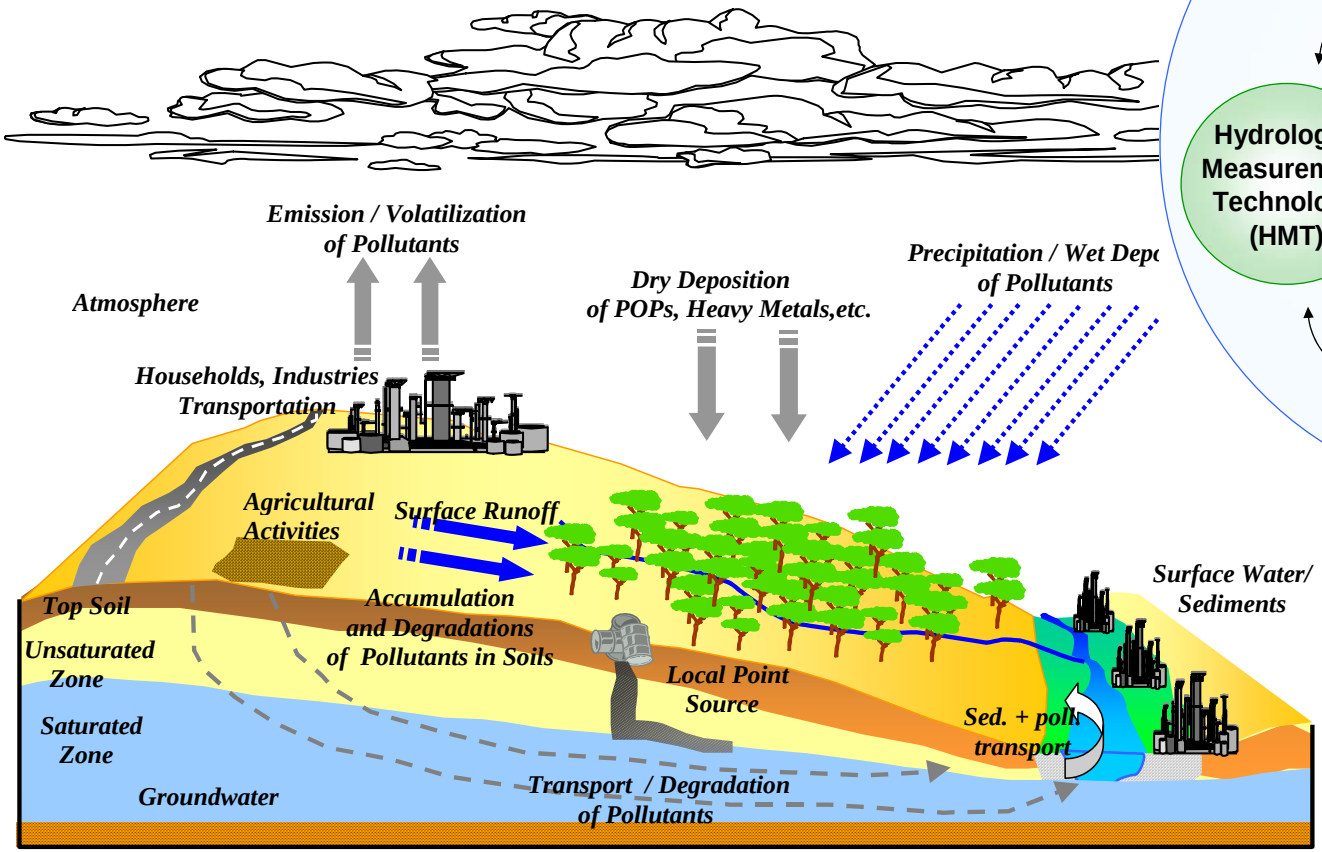
NSF Network for Earthquake Engineering Simulation



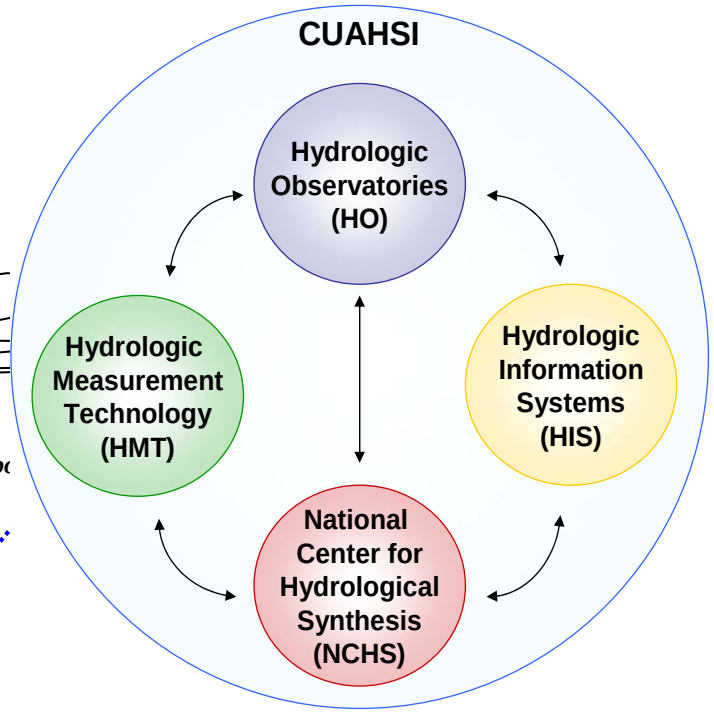
Links instruments, data, computers, people

From Ian Foster, Argonne

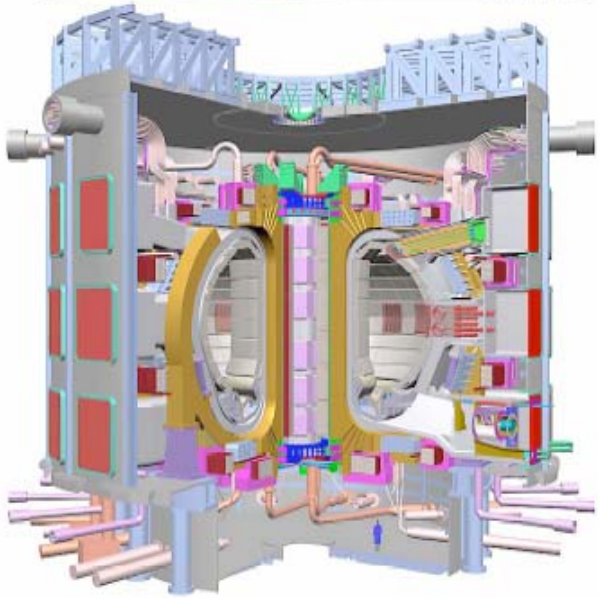
Hydrology Synthesis – CUAHSI/NSF

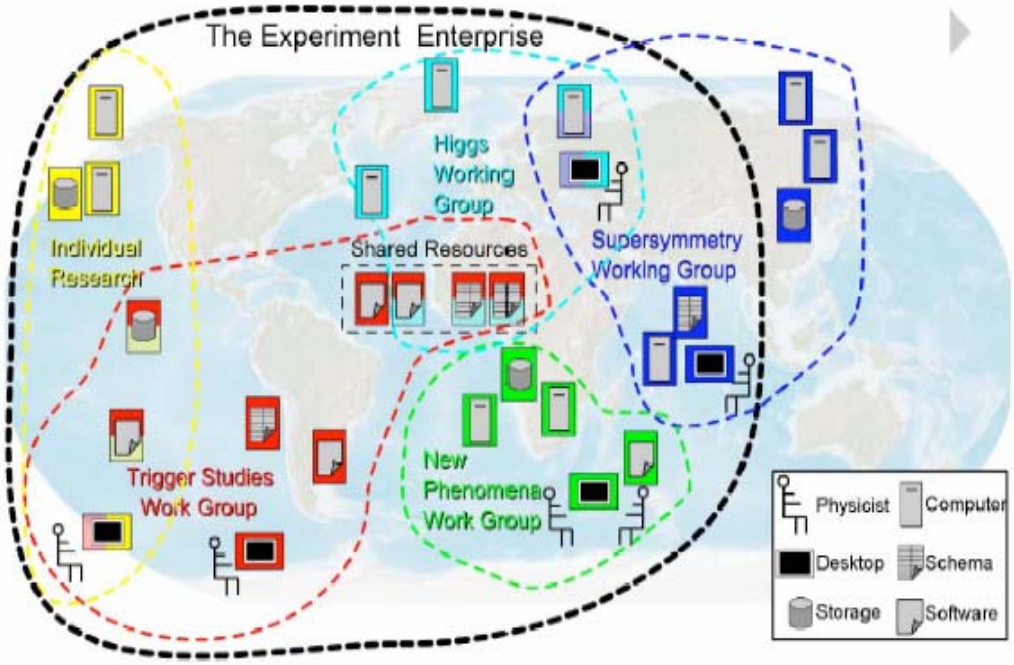


HydroView



Science Has Become a Team Sport

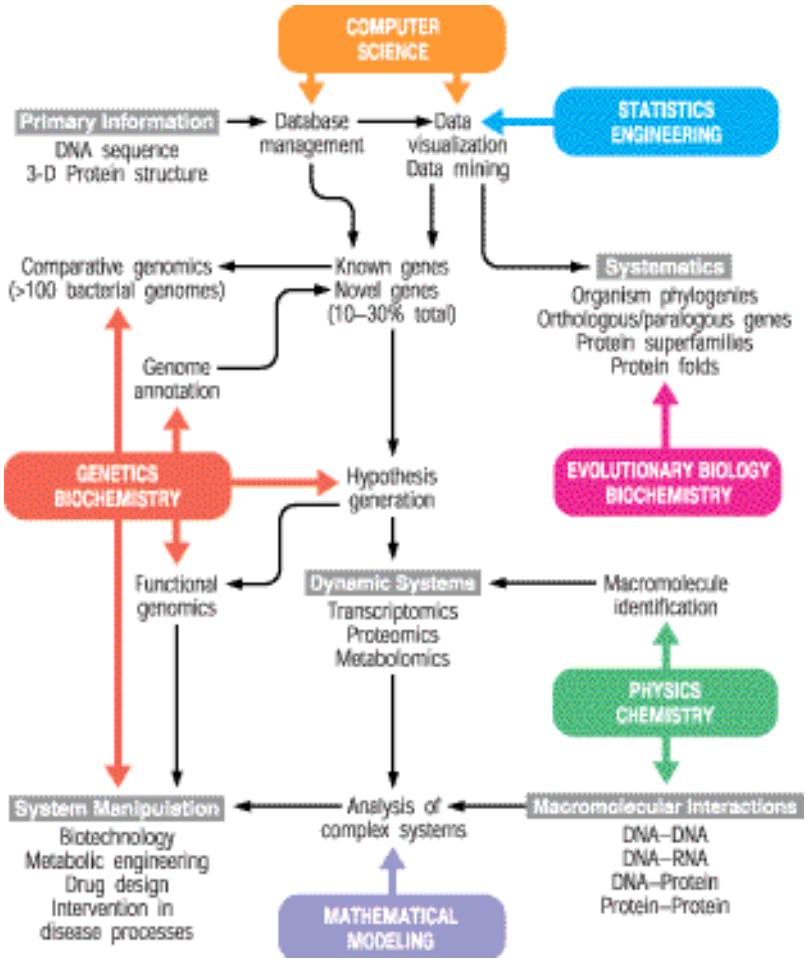




from Dave Schissel, GA

Teams Sharing Data and Expertise

Systems Biology: "studying *biological systems by systematically perturbing them (biologically, genetically or chemically); monitoring the gene, protein, and informational pathway responses; integrating these data; and ultimately formulating mathematical models that describe the structure of the system and its responses to individual perturbations"* *(Ideker et al., 2001 Annu, Rev. Genom. Hum. Genet. 2:343)*



Konopka, 2004 *ASM News* 70:163

from Yuri Gorbi, PNNL

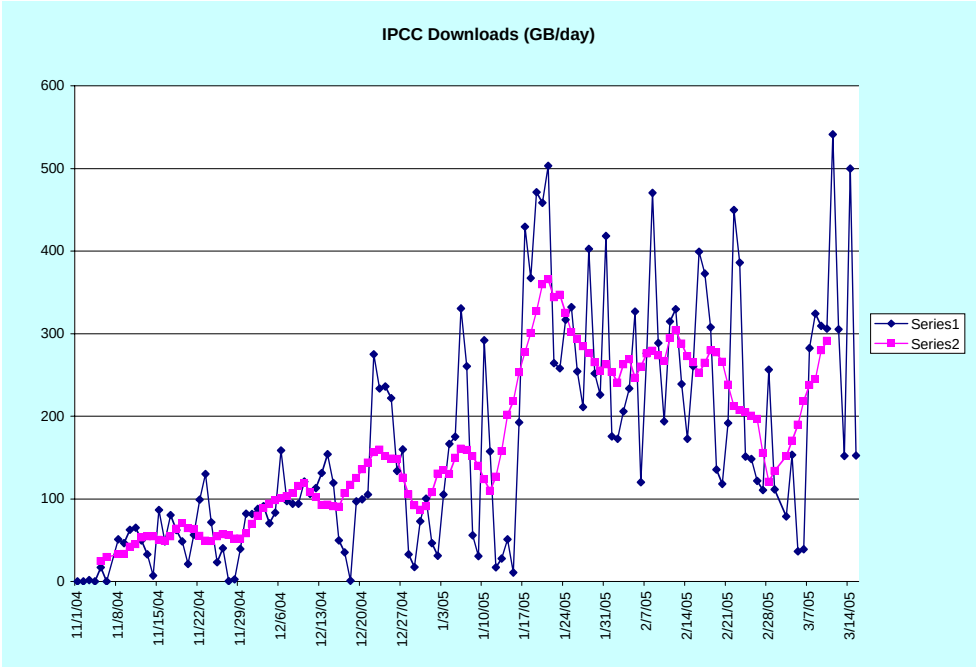
Science Requirements for Networks - 2003

Science Areas	2003 *End2End* Throughput	5 years End2End Throughput	5-10 Years End2End Throughput	Remarks
High Energy Physics	0.5 Gb/s	100 Gb/s	**1000 Gb/s**	high bulk throughput
Climate (Data & Computation)	0.5 Gb/s	160-200 Gb/s	**N x 1000 Gb/s**	high bulk throughput
SNS NanoScience	Not yet started	1 Gb/s	**1000 Gb/s + QoS for control channel**	remote control and time critical throughput
Fusion Energy	0.066 Gb/s (500 MB/s burst)	0.198 Gb/s (500MB/ 20 sec. burst)	**N x 1000 Gb/s**	time critical throughput
Astrophysics	0.013 Gb/s (1 TBy/week)	N*N multicast	**1000 Gb/s**	computational steering and collaborations
Genomics Data & Computation	0.091 Gb/s (1 TBy/day)	100s of users	**1000 Gb/s + QoS for control channel**	high throughput and steering

Delivering Climate Data

- Earth System Grid (ESG) provides production service (secure portal) to distribute data to the greater climate community.
  - Over 18 terabytes (~40k files) published since December 2004
  - About 300 projects registered to receive data
  - Over 22 terabytes of data downloaded (~125K files) with 300 gigabytes daily.
- Analysis results of IPCC data, distributed via ESG, were presented by 130 scientists at a recent workshop (March 2005).

Enabling Access to Climate Data from the Intergovernmental Panel on Climate Change



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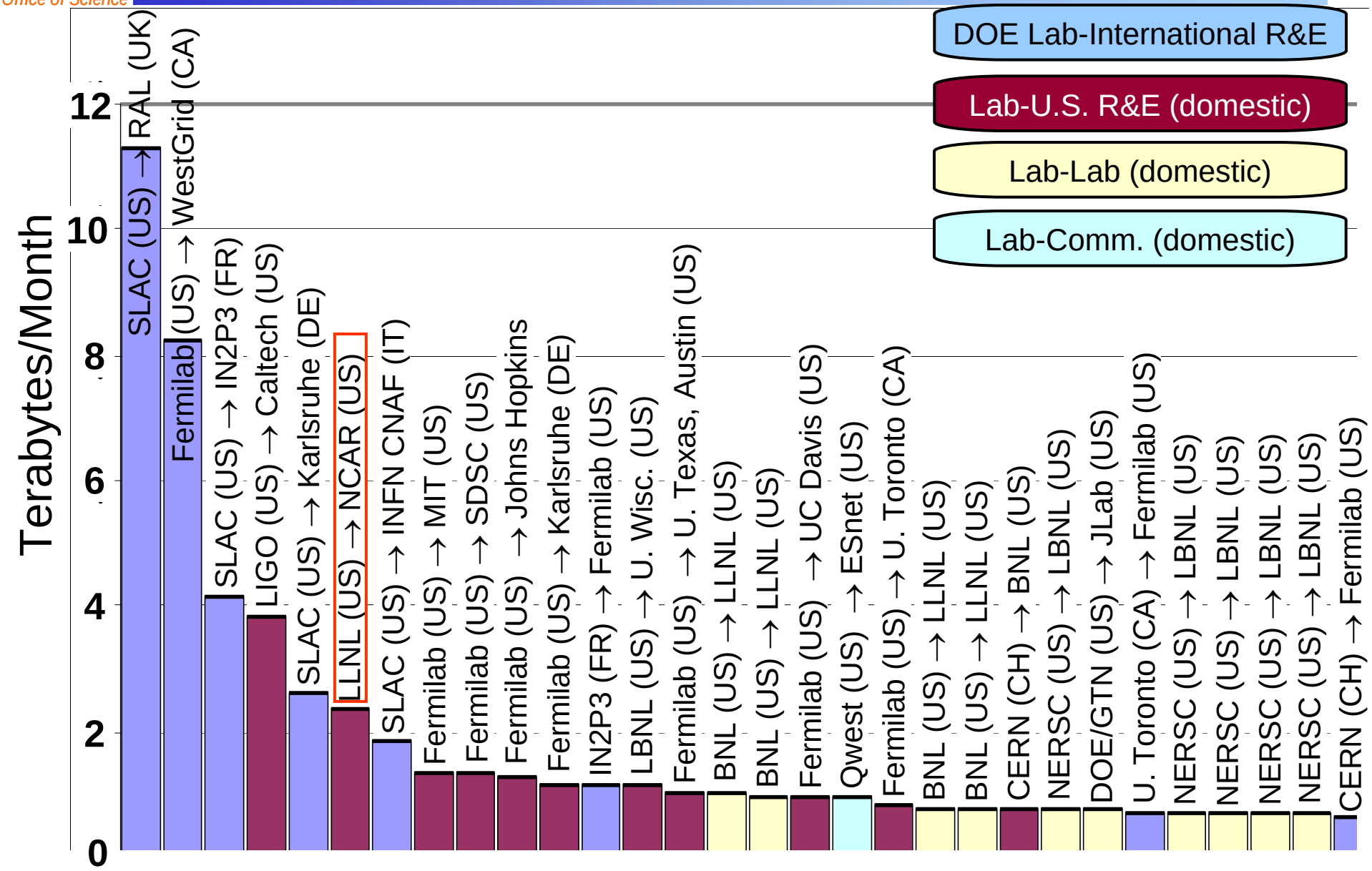
Source and Destination of the Top 30 ESnet Flows, Feb. 2005



Cybersecurity and Infrastructure to Support Distributed Science

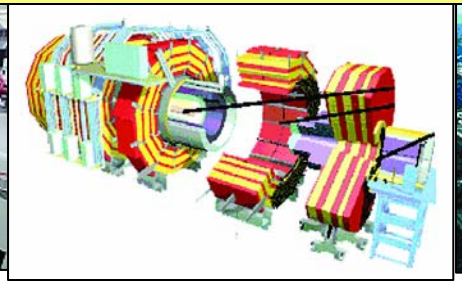
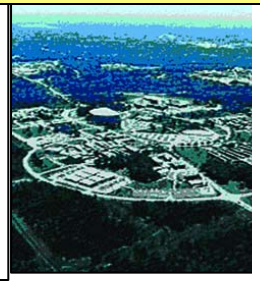
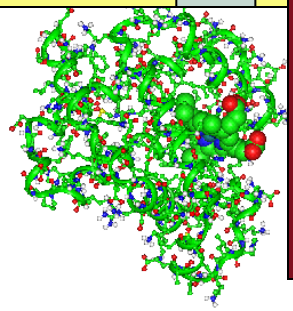
- Preserve
  - Access to national user facilities
  - Participation in international collaborations
  - Ability to host scientific databases and repositories
  - Innovation and prototyping capabilities
- Protect
  - High performance computers
  - Experiment systems
  - Desktop and laptop systems
  - Ability to do science
- ***Need to figure out how to preserve and support open science while protecting the resources from cyber incidents***

Robust Science Support Framework

Web Services, Portals, Collaboration Tools, Problem Solving Environments

- Authentication and Authorization
- Resource Discovery
- Secure Communication
- Event Services And Monitoring
- Data Transfer
- Scheduling
- Data Curation
- Compute Services
- Application Servers
- Asynchrony Support
- Virtual Organization

Cybersecurity Protections

Current Research Middleware Reality wrt Cybersecurity

- Distributed Science Infrastructure is developed independent of operational cybersecurity considerations
  - Implications of site mechanisms
  - Protections from malicious code
  - Vulnerability testing
  - Interoperability with site cybersecurity mechanisms
  - Not commercial software
- Typically there is a long process of debugging prototype deployments
  - Negotiating ports and protocols with each site's cybersecurity group
  - Debugging unexpected behaviors
  - Debugging middleware security mechanisms
  - Identifying causes of performance problems
- ***This is a cross-agency and international issue***

Science is on the Front Lines

- The techniques needed to protect the open science environment today are needed by other environments tomorrow – Past examples
  - Network intrusion detection
  - Insider threat
  - Defense in depth
  - High performance capabilities
- A next set of concerns
  - Reducing credential theft opportunities
  - Detection of insider attacks
  - Communication and coordination between components to recognize and react to attacks in real time
  - Tools which address day zero-1 vulnerabilities
  - Improved analysis techniques – data mining and semantic level searches
  - Prevention and detection of session hi-jacking

Current Operational Reality

- Cybersecurity group
  - Protect border
  - Protect network
  - Some host protections
  - Control access patterns
- System Administrators
  - Protect hosts
  - Authorize users
  - Define access capabilities
- Applications and software
  - Authenticate users
  - Authorize users
  - Open ports/connect to servers/transfer data
- Virtual Organizations
  - Fine-grained authorization
  - Policy enforcement

Protecting High Performance Distributed Science

- Coordination between cybersecurity components
  - Border intrusion detection mechanisms
  - Network intrusion detection mechanisms
  - Host security mechanisms
  - Software authentication and authorization mechanisms
- Authentication mechanisms for users who never physically visit the site
- Analysis of cybersecurity data particularly in high-performance environments
- Efficient forensics information gathering
- Cybersecurity as an integral consideration in building middleware
- Proxy mechanisms
- Continuous data collection and data correlation
- Forensics collection including middleware
- Improved recovery capabilities – it is currently weeks to recover a supercomputer
- Operations, research, and middleware developers teamed
- ***A new operations oriented Cybersecurity R&D effort is needed to help protect open science***

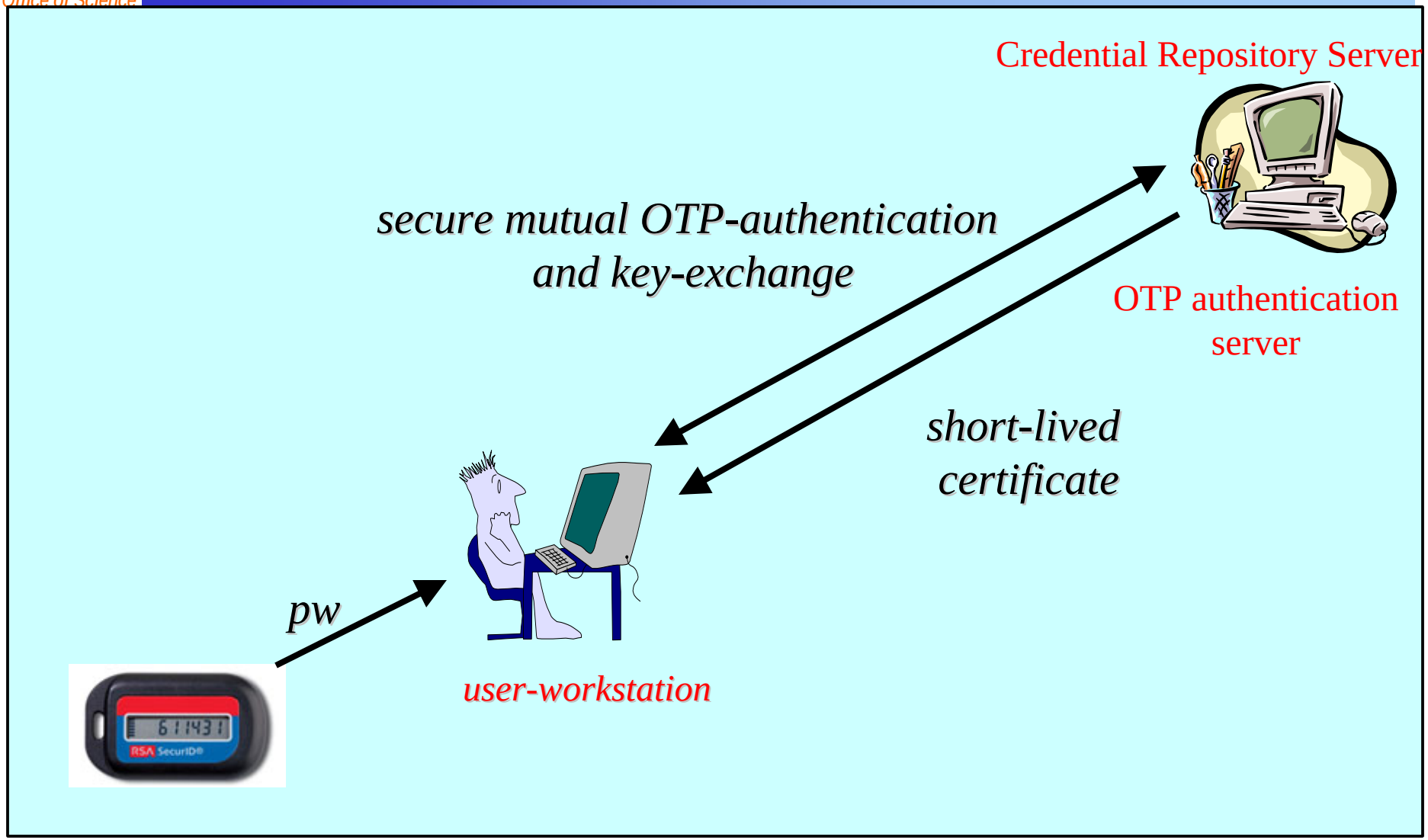
Example Advantages of Research and Operations Working Together

- Bro – network intrusion detection
  - Implemented and deployed through teaming between research and operations
  - Introduced layered approach to high-speed intrusion detection
  - Protocol awareness allowed detection of anomalous behavior at the protocol level
  - Developed policy language and interpreter to describe policy
  - Research platform for investigation of new approaches and events
  - Developments based on experience with real traffic and the operational environment
  - Currently leveraging the Bro communication capabilities to add decryption of encrypted traffic streams

Example2: One-time Password

- Deploying at many sites and facilities to combat credential theft
- Many products out there on the market
- 1-factor, 2-factor, cards, software-based, etc
- Federation an important issue to reduce cost and the number of tokens a user must carry – must be secure to avoid creating cross-site propagation vectors
- Analysis from a cryptographic perspective of the various tools identified important short-comings
- Needs to be integrated with distributed science infrastructure to be fully realized

Using OPKeyX in Grid environments



Proposed Cybersecurity R&D Program

- Coordination of distributed science software infrastructure with cybersecurity mechanisms
  - Authentication, authorization, and encryption in the middleware can coordinate with the cybersecurity systems to open temporary ports etc
- Coordination between cybersecurity components
  - Significantly improve detection of attacks
  - Notify broadly of attacks as they are identified
  - Help recognize insider attacks
  - Improve handling of encrypted sessions
- Improved risk- and mission-based cybersecurity decisions
  - Research and development of methodologies for cyber assessment
- Tools for the high-performance computing environment
  - Analysis tools which can efficiently ingest and analyze large quantities of data
  - Semantic level investigation of data
  - Security tools for high bandwidth reserved paths
- Improved data collection, forensics, recovery
- ***Focus on practical solutions, integrating middleware security, and working with operations personnel during the design, development, and testing***

Conclusions

- Distributed science has become core to the conduct of science
- Robust, **secure**, and supported distributed science infrastructure is needed
- Attackers are getting more malicious and quicker to exploit vulnerabilities
- Need to set the example for protecting distributed infrastructure
- COTS is a key component of the solution but will not solve many aspects of the problem
- ***Need to partner cybersecurity operations, cybersecurity researchers, system administrators, and middleware developers***