NIST
National Institute of Standards and Technology

ITL INFORMATION TECHNOLOGY LABORATORY

Internet and Scalable Systems Research

Addressing Systemic Challenges to Our Network Centric Society

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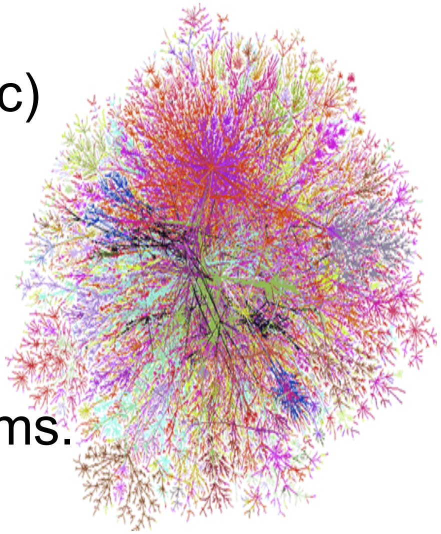
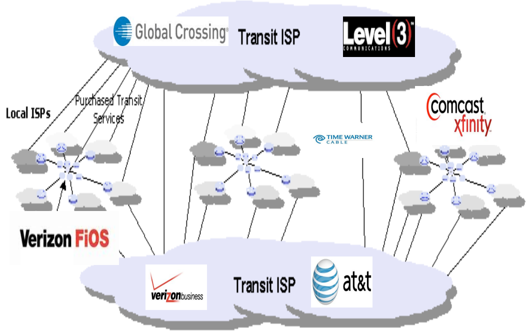
Evolving the Core Infrastructure of the Internet

- **Internet technologies** provide a technical basis for most systems (information, transportation, manufacturing, communications, defense, Government, education, etc) vital to our nation.
- **The Internet is at a cross roads** as the viability of several of its most basic infrastructural technologies (routing, naming and addressing) are threatened by inherent robustness vulnerabilities and scaling problems.
- **NIST is engaged in three critical efforts** aimed at fundamentally changing the structure/services of the Internet to address these threats:
  - **Internet Infrastructure Protection (IIP).**
  - **Next Generation Internet Technologies (NGI).**
  - **Measurement Science for Complex Information Systems (CxS).**





Fostering Real Change

- If you *only* standardize it … they won’t come.
  - Tragedy of the commons phenomena – “Evolving Core Capabilities of the Internet” - Journal on Telecommunications and High Technology Law, Vol. 3, 2004.
  - **How do you get changes to the infrastructure deployed?**

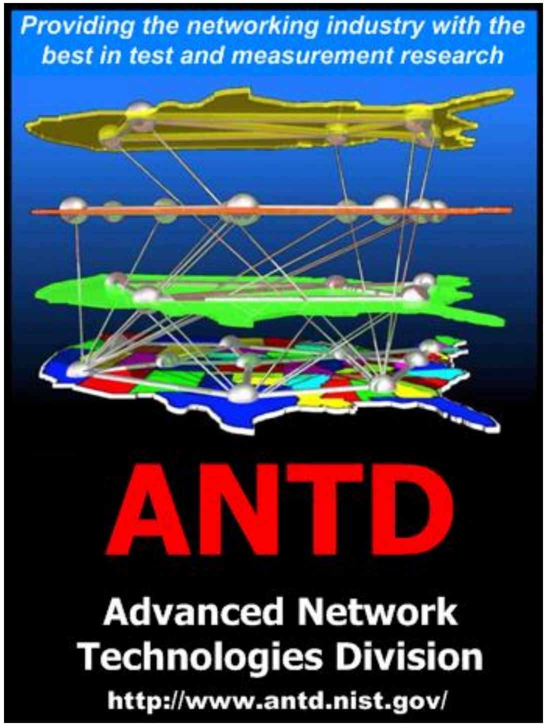
- The National Strategy to Secure Cyberspace
  - “The security and continued functioning of the Internet will be greatly influenced by the success or failure of implementing more secure and more robust BGP and DNS. The Nation has a vital interest in ensuring that this work proceeds. The government should play a role when private efforts break down due to a need for coordination or a lack of proper incentives.

SECURE CYBERSPACE

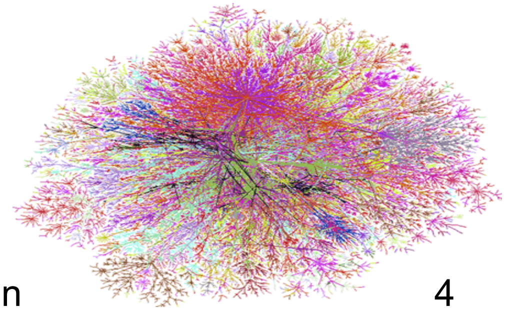
- **NIST ISSMG Goals: To change the Internet.**
  - Carrots – problem identification, research, designs, tests, measurements, standards, testbeds, prototypes, deployment guidance, training, outreach.
  - Sticks – FISMA reqs/auditing procedures, tech basis for other USG policies, FAR, FIPS.

ISSMG Mission / Competencies

- **Fostering New Network Technology** - The ISSMG works with industry to improve the quality and timeliness of emerging specifications and early implementations of next-generation Internet technologies and distributed information systems.
- **Advancing Network Metrology** - The emphasis of the group is on innovating and applying advanced measurement science to increase the robustness and expand the applicability of potentially disruptive Internet technologies.
- **Competencies** of the group include: modeling and analysis of emerging Internet technologies, measurement science for scalable information systems, design and evaluation of advanced network test and measurement techniques, and rapid prototyping and empirical measurement of early protocol designs.


Providing the networking industry with the best in test and measurement research
ANTD
Advanced Network Technologies Division
http://www.antd.nist.gov/

- Our efforts focuses on **Internet Scale problems, solutions and measurement techniques.**

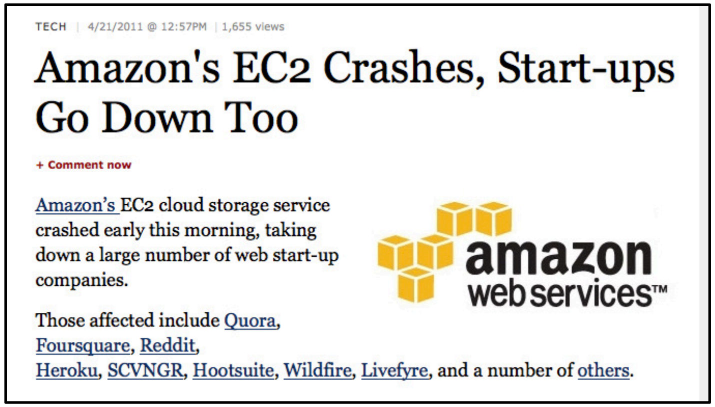


Need for NIST?

- **Understanding / Controlling Network Behavior**
  - “*[Despite] society’s profound dependence on networks, fundamental knowledge about them is primitive. [G]lobal communication … networks have quite advanced technological implementations but their behavior under stress still cannot be predicted reliably…. There is no science today that offers the fundamental knowledge necessary to design large complex networks [so] that their behaviors can be predicted prior to building them.*”

    Network Science 2006, a report from the National Research Council.

- **Cost of our current inability:**
  - “Cost of eBay's 22-Hour Outage Put At $2 Million”, Ecommerce, Jun 1999
  - “Last Week’s Internet Outages Cost $1.2 Billion”, Dave Murphy, Yankee Group, Feb 2000
  - “…the Internet "basically collapsed" Monday”, Samuel Kessler, Symantec, Oct 2003
  - “Network crashes…cost medium-sized businesses a full 1% of annual revenues”, Technology News, Mar 2006
  - “costs to the U.S. economy…range…from $65.6 M for a 10-day [Internet] outage at an automobile parts plant to $404.76 M for … failure …at an oil refinery”, Dartmouth study, Jun 2006
  - **Risks of deliberate attack even greater….**



TECH | 4/21/2011 @ 12:57PM | 1,655 views

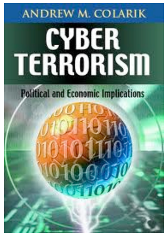
Amazon's EC2 Crashes, Start-ups Go Down Too

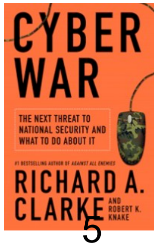
+ Comment now

Amazon’s EC2 cloud storage service crashed early this morning, taking down a large number of web start-up companies.

Those affected include Quora, Foursquare, Reddit, Heroku, SCVNGR, Hootsuite, Wildfire, Livefyre, and a number of others.

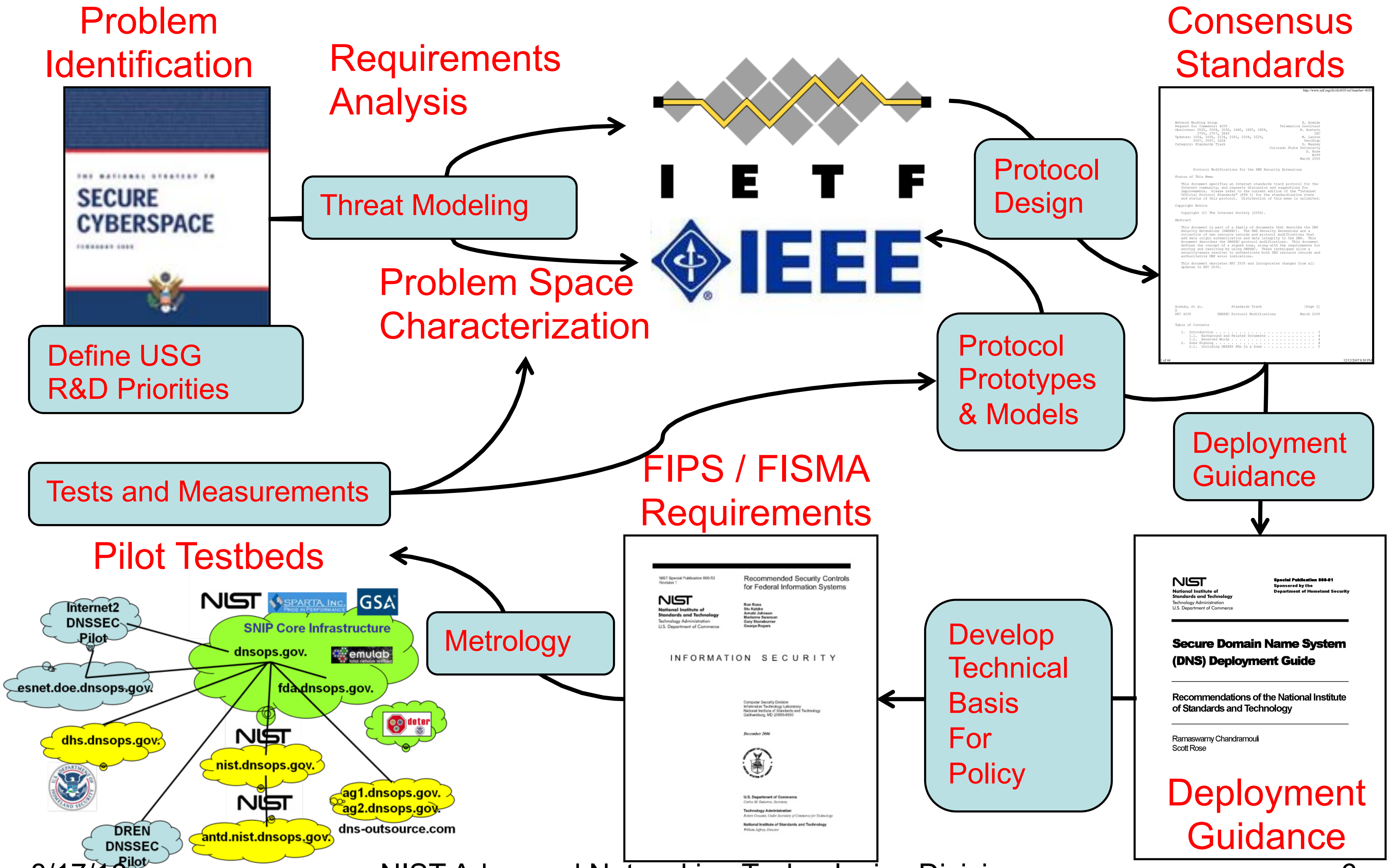
http://www.forbes.com/sites/tomiogeron/2011/04/21/amazons-ec2-crashes-start-ups/




CYBER WAR
THE NEXT THREAT TO NATIONAL SECURITY AND WHAT TO DO ABOUT IT
RICHARD A. CLARKE
AND ROBERT K. KNAKE

NIST Internet and Scalable Systems Research

What are NIST's Roles?



Problem Identification

THE NATIONAL STRATEGY TO SECURE CYBERSPACE FEBRUARY 2003

Define USG R&D Priorities

Requirements Analysis

Threat Modeling

Problem Space Characterization

Tests and Measurements

Pilot Testbeds

Metrology

Consensus Standards

Protocol Design

Protocol Prototypes & Models

Deployment Guidance

FIPS / FISMA Requirements

NIST Special Publication 800-53 Revision 1

Recommended Security Controls for Federal Information Systems

Ron Ross
Stu Katzke
Arnold Johnson
Marianne Swanson
Gary Stoneburner
George Rogers

INFORMATION SECURITY

Computer Security Division
Information Technology Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-8930

December 2006

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

Technology Administration
Robert Cresanti, Under Secretary of Commerce for Technology

National Institute of Standards and Technology
William Jeffrey, Director

Develop Technical Basis For Policy

Special Publication 800-81
Sponsored by the Department of Homeland Security

Secure Domain Name System (DNS) Deployment Guide

Recommendations of the National Institute of Standards and Technology

Ramaswamy Chandramouli
Scott Rose

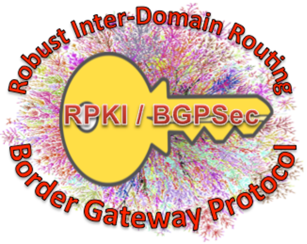
Deployment Guidance

ISSMG Techniques

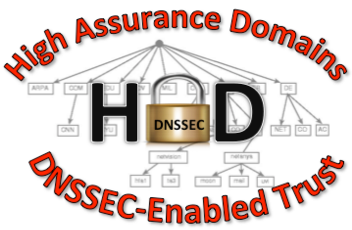
- **Analytical, Simulation & Emulation Modeling.**
  - Internet scale modeling for performance, scalability, vulnerability, robustness.
- **Protocol Design and Analysis.**
  - Internet Engineering Task Force (IETF).
- **Internet Scale Measurement and Data Analysis.**
  - Measurement and monitoring of Internet infrastructure.
  - Collaboration with various large scale measurement activities.
- **Rapid Prototyping.**
  - Open source reference implementations of emerging specifications.
- **Deployment guidance / profiles.**
  - Fostering commercial acquisition and deployment
- **Product Testing and Evaluation**
  - Test tools designed to assist implementers and early adopters.
  - Accredited testing laboratories for formal product interoperability and conformance.

ISSMG Projects

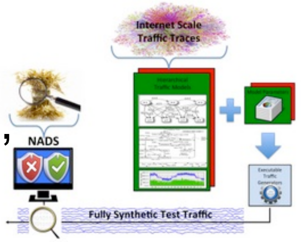
- **Robust Inter-Domain Routing** – Working with industry to improv global Internet routing security and robustness, Border Gateway Protocol (BGP), measurement monitoring and analysis of global BGP behavior, BGP security and performance issues, and next generation routing architectures.



- **High-Assurance Domains** – Research and develop Domain Name System (DNS) technologies, DNSSec security protocols, IETF DANE technologies to leverage the DNS as a key discovery and management infrastructure, use of DANE and other DNSSEC enabled technologies, X.509/PKIX certificate technologies, TLS / SSL implementation, and SMIME / PGP email security protocols.



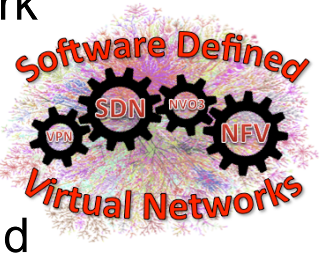
- **Network Anomaly Detection / Synthetic Traffic Generation** – Research and develop measurement science to advance the state of the art in network anomaly detection, network intrusion detection, synthetic traffic generation, statistical modeling of network traffic, machine learning, test and instrumentation of NAD/NID systems.



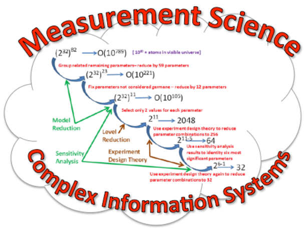
NIST Internet and Scalable Systems Research

ISSMG Projects

- **Software Defined Virtual Networks** – Develop test and measurement techniques to advance the state of the art in network virtualization, network service function chaining, software defined networks, technologies and techniques to address robustness safety and security of virtualized network services. Explore novel applications of NFV/SDN to domains such as network security and intrusion detection, support of machine to machine communications, support of advanced mobility and cloud computing.



- **Measurement Science of Complex Networks** - Research and develop of techniques to measure, predict and control macroscopic / emergent behavior in complex information systems, modeling and analysis techniques to characterize Internet scale networks and distributed systems, use of genetic algorithms to search for rare events, and runtime techniques to predict phase transitions in system behavior.


Measurement Science
$(2^{32})^{82} \rightarrow O(10^{789})$
[10^{80} = atoms in visible universe]
Group related remaining parameters– reduce by 59 parameters
$(2^{32})^{23} \rightarrow O(10^{221})$
Fix parameters not considered germane – reduce by 12 parameters
$(2^{32})^{11} \rightarrow O(10^{105})$
Select only 2 values for each parameter
$2^{11} \rightarrow 2048$
Use experiment design theory to reduce parameter combinations to 256
$2^{11-5} \rightarrow 64$
Use sensitivity analysis results to identity six most significant parameters
$2^{6-1} \rightarrow 32$
Use experiment design theory again to reduce parameter combinations to 32
Model Reduction
Level Reduction
Sensitivity Analysis
Experiment Design Theory
Complex Information Systems

ISSMG Projects

- **Advanced DDoS Mitigation Techniques** – Working with DHS S&T and industry to research and develop novel approaches to DDoS detection and mitigation, techniques to test and measure the effectiveness and impact of DDoS / spoofing mitigation techniques, develop deployment guidance for such techniques.

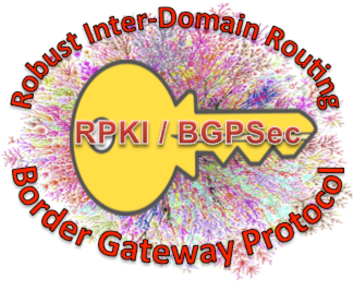
- **USGv6** – Working with other USG agencies and industry to develop and maintain the standards, test program, deployment guidance and test and measurement tools necessary to provide the technical underpinnings for wide scale adoption of IPv6 in the USG.

NIST Internet and Scalable Systems Research

Details on Select Projects

IIP – Robust Inter-domain Routing

- **Objective:** Working with industry to improve global Internet routing robustness, Border Gateway Protocol (BGP), measurement monitoring and analysis of global BGP behavior, BGP security and performance issues, and next generation routing architectures.



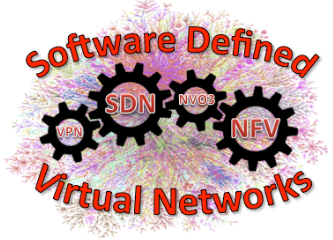
- **Select Accomplishments:**
  - IRTF Next Generation Routing Architecture - https://irtf.org/concluded/rrg
  - IETF Secure Inter Domain Routing - https://datatracker.ietf.org/wg/sidr/
  - NIST RPKI Monitor - http://rpki-monitor.antd.nist.gov/
  - NIST BGP SRx - http://www-x.antd.nist.gov/bgpsrx/
  - BRITE - https://brite.antd.nist.gov/
- **Plans:**
  - Standards – complete IETF BGPSEC RFC
  - Prototypes – complete and test BGP-SRX
  - Measurement – research and develop “big data” tools for BGP anomaly detection.
  - Tools – update BGPSEC test tools to final spec.
- **Collaborators:**
  - IETF, IRTF, DHS S&T, BBN, Google, IIJ, Parsons, Cisco, Juniper, NANOG.

IIP – High Assurance Domains

- **Objective:** Research and develop Domain Name System (DNS) technologies, DNSSec security protocols, IETF DANE technologies to leverage the DNS as a key discovery and management infrastructure, use of DANE and other DNSSEC enabled technologies, X.509/PKIX certificate technologies, TLS / SSL implementation, and SMIME / PGP email security protocols.
- **Select Accomplishments:**
  - IETF DANE - https://datatracker.ietf.org/wg/dane/
  - NCCOE DNS-Based Secure Email - https://nccoe.nist.gov/projects/building_blocks/secured_email
  - Test and Measurement Tools – https://www.had-pilot.com/
    - Testers for DANE enabled TLS, SMTP, SMIME and DMARC/DKIM/SPF deployment.
  - NIST SP 800-177 Trustworthy Email - http://csrc.nist.gov/publications/drafts/800-177/sp800-177_draft.pdf
  - NIST SP 800-81-2 Secure Domain Name System Deployment Guide - http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-81-2.pdf
- **Plans:**
  - Support NCCoE project, complete SP, enhance and deploy test tools.
- **Collaborators:**
  - IETF, M3AAWG, NCCOE, Verisign, Secure64, Microsoft, Comcast, ISC, …

NGI – Software Defined Virtual Networks

- **Objective:** Develop test and measurement techniques to advance the state of the art in network virtualization, network service function chaining, software defined networks, technologies and techniques to address robustness safety and security of virtualized network services. Explore novel applications of NFV SDN to domains such as network security and intrusion detection, support of machine to machine communications, support of advanced mobility and cloud computing.



- **Select Accomplishments:**
  - SDN / NFV Testbed – testbed of hardware / software SDN/NFV implementations and test tools.
  - UMON: Flexible and Fine Grained Traffic Monitoring in Open vSwitch - http://conferences2.sigcomm.org/co-next/2015/img/papers/conext15-final98.pdf
- **Plans:**
  - Development measurement / benchmarking techniques for SDN controllers and switches
  - R&D programmable measurement techniques for SDN and their application to DDoS detection and mitigation.
  - Formal analysis of OVS softswitch implementations.
- **Collaborators:**
  - GMU, NSA, UNH IOL, ONF,

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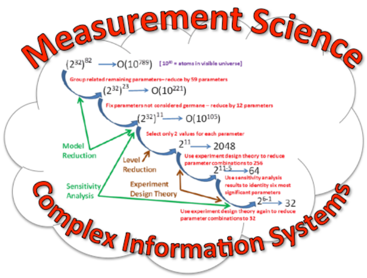
NGI – USGv6 Program

- **Objective:**
  - OMB Memorandum M-05-22 directed the National Institute of Standards and Technology (NIST) to develop the technical infrastructure (standards and testing) necessary to support wide scale adoption of IPv6 in the US Government (USG). In response NIST developed a technical standards profile for US Government acquisition of IPv6 Hosts and Routers, and a specification for Network Protection Devices. The USGv6 profile includes a forward looking set of RFCs published by the Internet Engineering Task Force (IETF), encompassing basic IPv6 functionality, and specific requirements and key optional capabilities for routing, security, multicasting, mobility, network management, and quality of service. The profile also contains a NIST established set of capability requirements for IPv6 aware firewalls and intrusion detection systems. In addition to the profiles, a testing program has been established to enable products to be tested for compliance with the profile by accredited laboratories.
- **Select Accomplishments:**
  - NIST SP 500-267 A Profile for IPv6 in the US Government.
  - NIST SP 500-273 USGv6 Test Methods: General Description and Validation.
  - NIST SP 800-119 Guidelines for the Secure Deployment of IPv6.
  - NIST IPv6 Deployment Monitor and Test Tool. - http://fedv6-deployment.antd.nist.gov/
- **Plans:**
  - Complete version 2 of the USGv6 profile and continue to evolve the testing program
- **Collaborators:**
  - UNH IOL, Fed V6 Task Force, OMB, GSA.

CxS – Measurement Science for Complex Networked Information Systems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- **Select Accomplishments:**
  - "Combing Genetic Algorithms & Simulation to Search for Failure Scenarios in System Models", SIMUL 2013 paper presentation, Venice, Italy, October 29, 2013.
  - "Predicting Global Failure Regimes in Complex Information Systems", NIST Cloud Computing Forum and Workshop 8, Gaithersburg, MD, July 9, 2015.
  - "Effective and Scalable Uncertainty Evaluation for Large-Scale Complex System Applications", Winter Simulation Conference, Savannah, GA, December 10, 2014.
  - Study of Proposed Internet Congestion Control Mechanisms, NIST Special Publication 500-282, May 2010, 534 pages.
  - See: **http://www.nist.gov/itl/antd/emergent_behavior.cfm**
- **Plans:**
  - Complete / publish research on influence of realism in network simulations.
  - Investigate validation techniques for simulations of large-scale networks.
  - Research runtime methods for predicting failures in networked information systems.
- **Collaborators:**

ISSMG Collaborations

- SDOs / IGOs
  IETF®
  ICANN Internet Corporation for Assigned Names and Numbers
  ARIN American Registry for Internet Numbers
- Consortia / Groups
  NANOG
  IRTF
  FSSCC
- Industry
  CISCO
  BBN TECHNOLOGIES
  Juniper® NETWORKS
  Google
  verizon
  T-Mobile
  amazon web services™
  VeriSign®
- USG
  U.S. DEPARTMENT OF COMMERCE NATIONAL TELECOMMUNICATIONS & INFORMATION ADMINISTRATION NTIA
  EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES OFFICE OF MANAGEMENT AND BUDGET
  GSA®
  U.S. DEPARTMENT OF HOMELAND SECURITY Homeland Security Science and Technology
  NCCoE NATIONAL CYBERSECURITY CENTER OF EXCELLENCE
  FEDERAL COMMUNICATIONS COMMISSION USA FCC
  NATIONAL SECURITY AGENCY UNITED STATES OF AMERICA

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Questions?

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