CISE Research Infrastructure Investments

Advanced Cyberinfrastructure

Computing & Communication Foundations

Computer & Network Systems

Information & Intelligent Systems
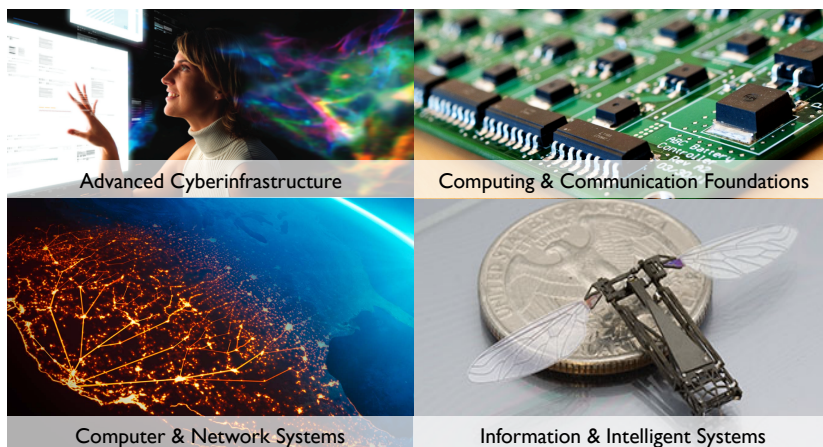
Jim Kurose
Assistant Director, Computer and Information Science and Engineering

National Science Board, May 2016

Innovating CISE   Innovating S&E

CISE investments are transforming science and society
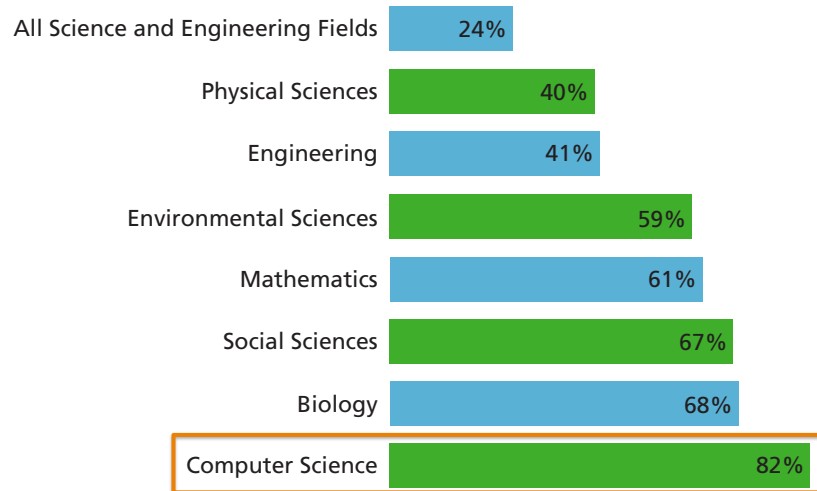

Innovating CISE   Innovating S&E   2

NSF investments are critical to the academic CISE research community

NSF support of Academic Basic Research (as a percentage of total federal support)

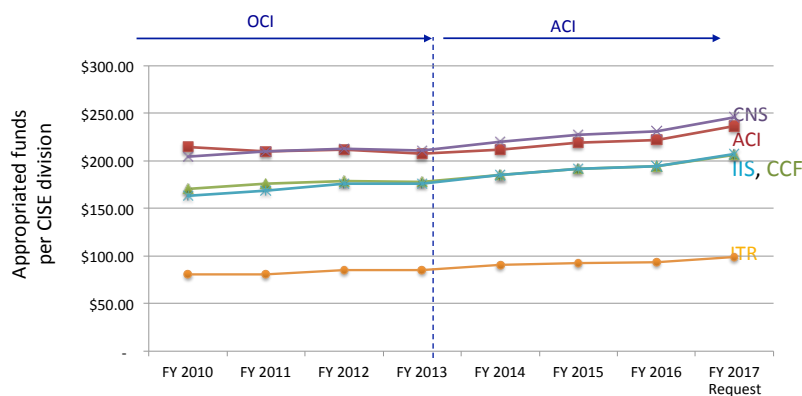|	
All Science and Engineering Fields	24%
Physical Sciences	40%
Engineering	41%
Environmental Sciences	59%
Mathematics	61%
Social Sciences	67%
Biology	68%
Computer Science	82%

Source: NSF/NCSES, Survey of Federal Funds for Research & Development, FY 2014

Innovating CISE   Innovating S&E   3

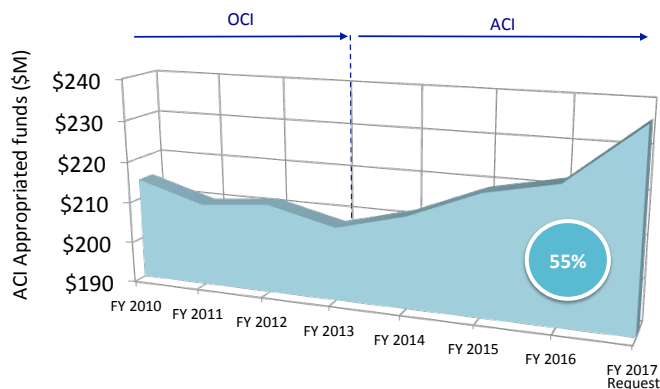## CISE budget supports modest, sustained growth across all divisions

Innovating CISE   Innovating S&E   4

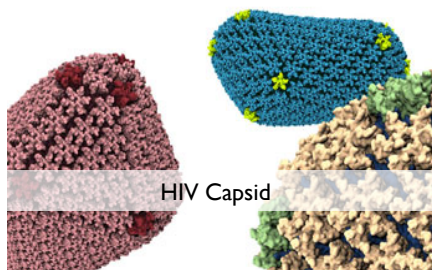## CISE supports research infrastructure for the CISE and NSF research communities

OCI   ACI

55%

55% of ACI budget supports research infrastructure in FY16

6% of other CISE division's budgets support research infrastructure in FY16

Innovating CISE   Innovating S&E   5

CISE-led infrastructure enables discoveries

Software Defined Networks

HIV Capsid

LIGO Detection

iPlant/CyVerse

Innovating CISE   Innovating S&E   6

Testbeds are critical infrastructure for CISE community

NSF FUTURECLOUD
- Cloud software architecture and experimentation
- $20M over 3 years

CloudLab
Chameleon

NETWORK RESEARCH TESTBEDS
- Wide-area wired and wireless networks, network emulation
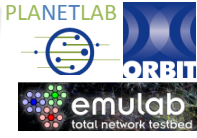- $25M over 13 years
- > 10K users

PLANETLAB
ORBIT
emulab
total network testbed

US IGNITE
- Enabling a new generation of distributed gigabit apps
- $25M over 5 years
- >35 communities

usignite

GLOBAL ENVIRONMENT FOR NETWORKING INNOVATIONS (GENI)
- At-scale virtual laboratory enabling experimentation with deeply programmable slices of the network
- $100M over 10 years
- >6500 users

geni
Exploring Networks of the Future

Innovating CISE   Innovating S&E   7

Looking forward
CISE research testbeds

Advanced Wireless

- **Research:** Dynamic spectrum sharing, Millimeter-wave, Massive MIMO, SDN/NFV, Architecture, Service management
- **Testbeds:** Campus testbeds, Leveraging GENI, NSFFutureCloud; Smart & Connected Communities

Cybersecurity

- **Real-world and hypothetical scenarios**: Experimentation in isolation from production systems
- **Collaboration:** Data, scenarios, software and tools, experimental procedures, results
- Interagency collaboration in alignment with *2016 Federal Cybersecurity R&D Strategic Plan*
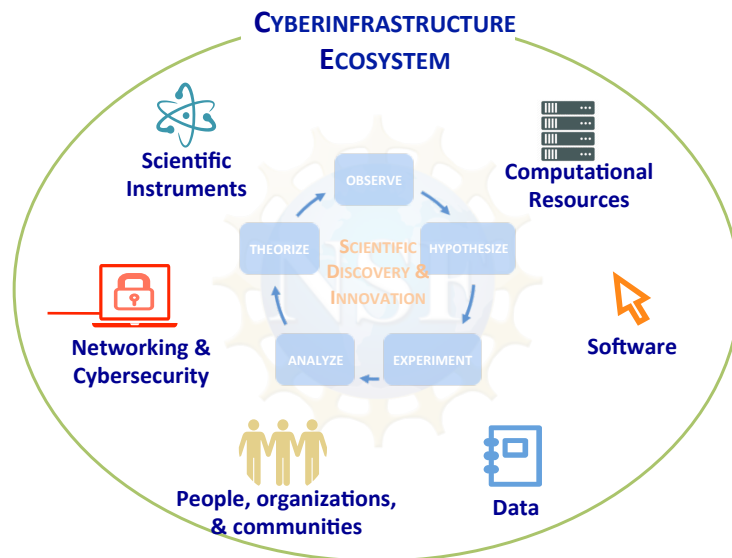
Innovating CISE   Innovating S&E   8

CISE leads an expansive view of research infrastructure driven by research priorities and the scientific process

CYBERINFRASTRUCTURE
ECOSYSTEM

Scientific Instruments

Computational Resources

OBSERVE

THEORIZE — SCIENTIFIC DISCOVERY & INNOVATION — HYPOTHESIZE

ANALYZE — EXPERIMENT

Networking & Cybersecurity

Software

People, organizations, & communities

Data

Innovating CISE   Innovating S&E   9

Network connections link U.S. campuses and facilitate international research coordination

Hawaii

San Juan

CAMPUS CYBERINFRASTRUCTURE (CC*): Upgrades networking capabilities for >200 campuses across 44 states to support science applications and distributed research projects
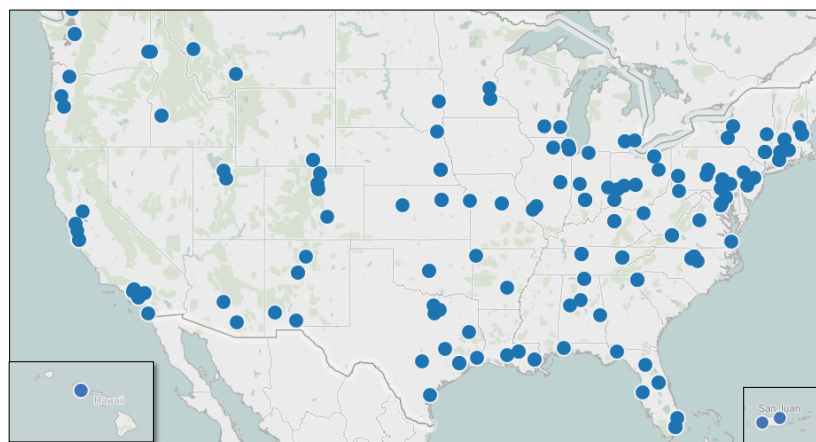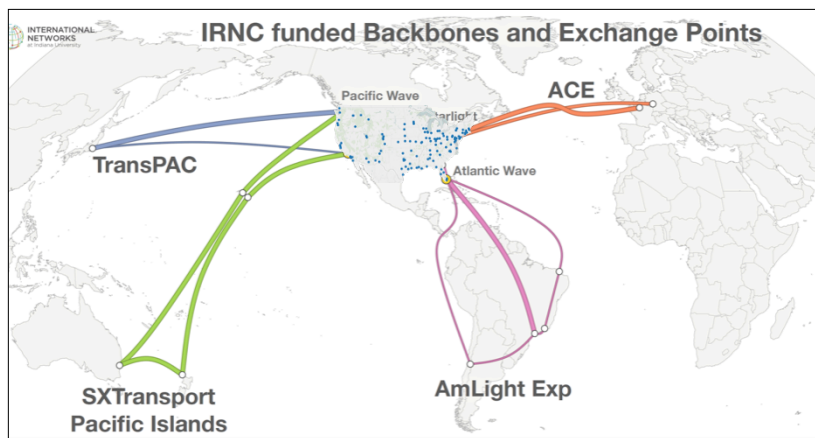
Innovating CISE   Innovating S&E   10

Network connections link U.S. campuses and facilitate international research coordination

IRNC funded Backbones and Exchange Points

INTERNATIONAL RESEARCH NETWORK CONNECTIONS (IRNC): International network services to advance global S&E research and education

Innovating CISE   Innovating S&E   10

A diversity of computational resources support the nation's data- and computational-intensive science

Legend:
Large-scale computation
Long-tail and high-throughput
Data Intensive
Cloud

Innovating CISE   Innovating S&E   11

A diversity of computational resources support the nation's data- and computational-intensive science

| 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |

Blue Waters/UIUC

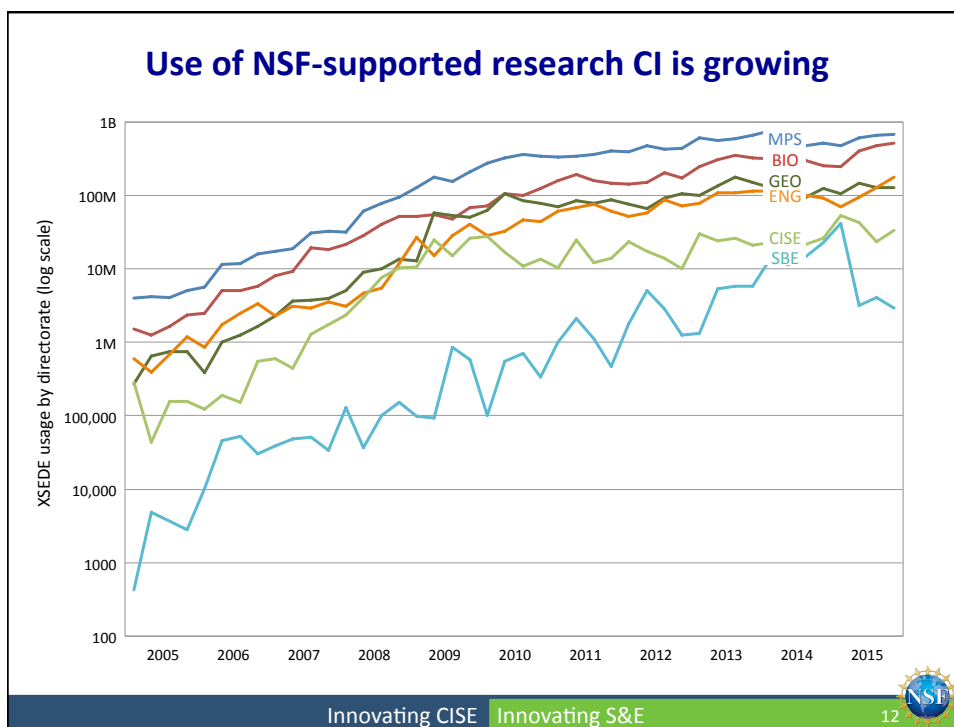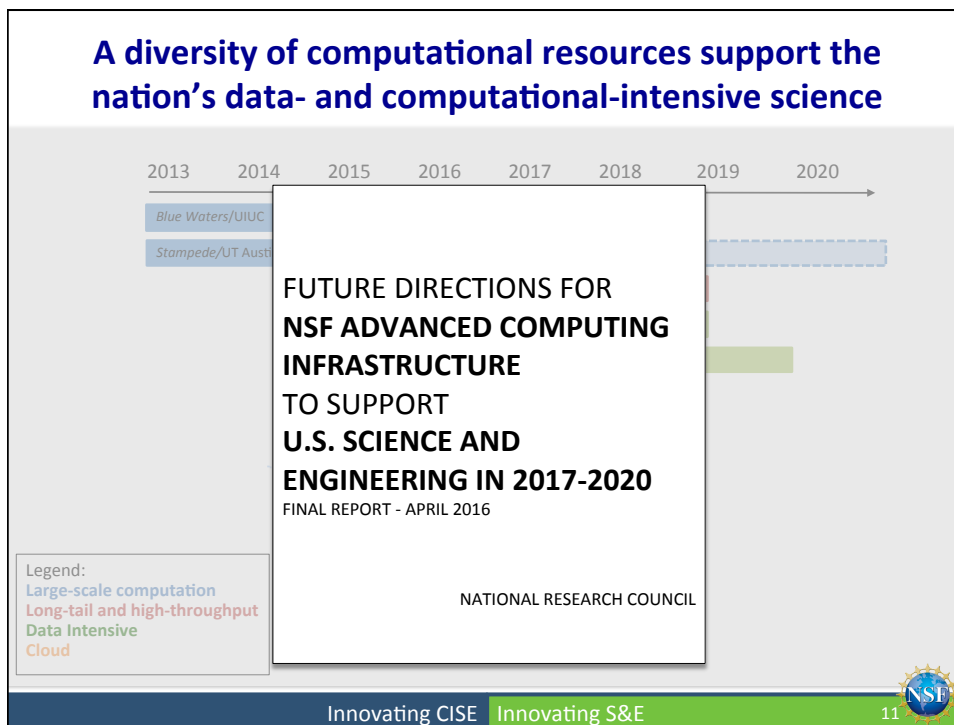*Stampede*/UT Austin

FUTURE DIRECTIONS FOR
NSF ADVANCED COMPUTING INFRASTRUCTURE
TO SUPPORT
U.S. SCIENCE AND ENGINEERING IN 2017-2020
FINAL REPORT - APRIL 2016

NATIONAL RESEARCH COUNCIL

Legend:
Large-scale computation
Long-tail and high-throughput
Data Intensive
Cloud

Innovating CISE   Innovating S&E   11

Use of NSF-supported research CI is growing

Innovating CISE   Innovating S&E   12

Slide 12

Use of NSF-supported research CI is growing

XSEDE usage by directorate (log scale)

MPS
BIO
GEO
ENG
CISE
SBE

2x Number of active institutions **DOUBLED**

3x Number of PIs per project has **TRIPLED**

5x Number of active users **QUINTUPLED**

1B
100M
10M
1M
100,000
10,000
1000
100

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

Innovating CISE   Innovating S&E   12

Slide 13

XSEDE connects people, services, and resources

Seamless access to national CI

Training and community building

XSEDE
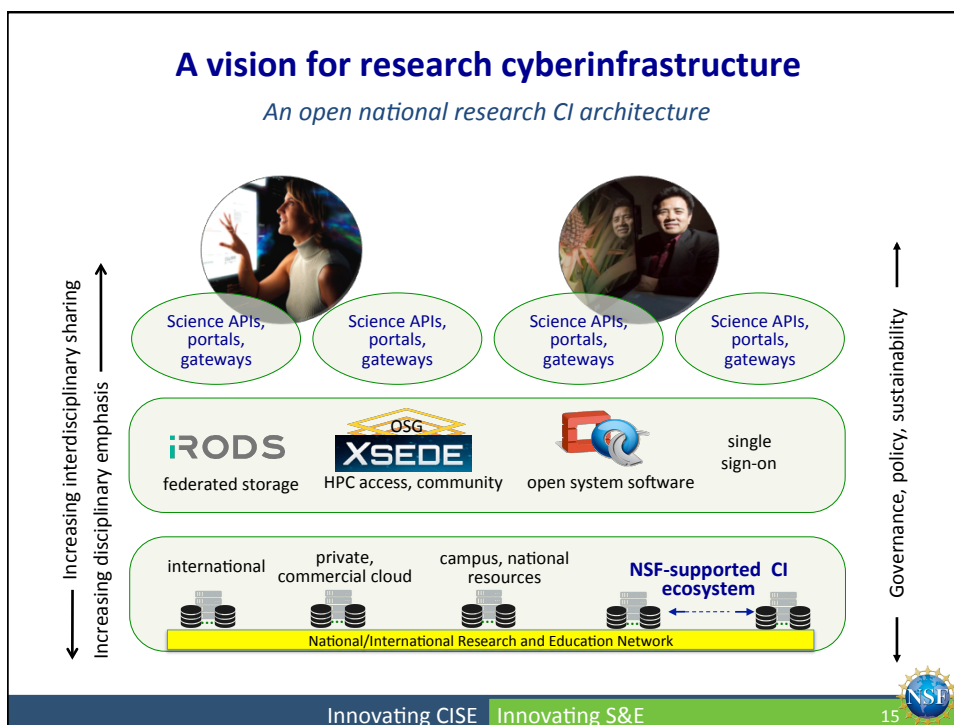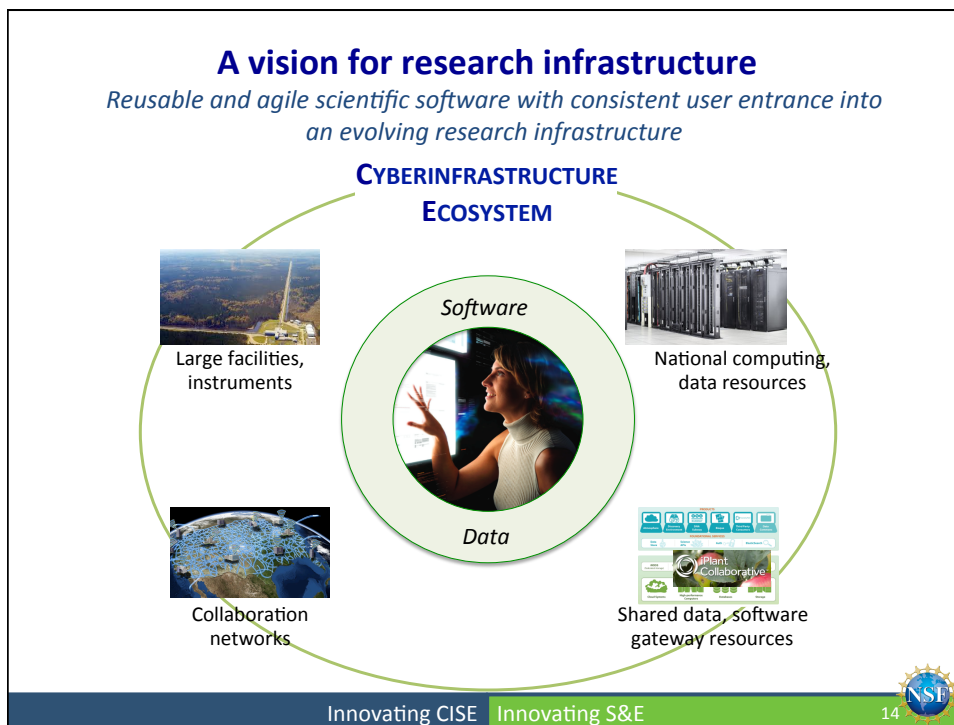Extreme Science and Engineering Discovery Environment

Software interface

Linking domain and CI experts

Benbrook

Innovating CISE   Innovating S&E   13

8

A vision for research infrastructure

Reusable and agile scientific software with consistent user entrance into an evolving research infrastructure

CYBERINFRASTRUCTURE
ECOSYSTEM

Software

Large facilities, instruments

National computing, data resources

Data

Collaboration networks

Shared data, software gateway resources

Innovating CISE   Innovating S&E   14

A vision for research cyberinfrastructure

An open national research CI architecture

Increasing interdisciplinary sharing
Increasing disciplinary emphasis

Governance, policy, sustainability

Science APIs, portals, gateways

Science APIs, portals, gateways

Science APIs, portals, gateways

Science APIs, portals, gateways

iRODS
federated storage

OSG
XSEDE
HPC access, community

open system software

single sign-on

international

private, commercial cloud

campus, national resources

NSF-supported CI ecosystem

National/International Research and Education Network

Innovating CISE   Innovating S&E   15

Looking forward

Exploring the cutting edge of next-generation research CI

Data Infrastructure Building Blocks (DIBBs)

Data-centric CI capabilities to accelerate interdisciplinary research

Awards: Early Implementation ($4M), Pilot Demonstration ($500K)

Software Infrastructure for Sustained Innovation (SI²)

Accelerating and sustaining software as CI

Awards: Scientific Software Elements (SSE, $5M), Scientific Software Integration (SSI, $12.5M)
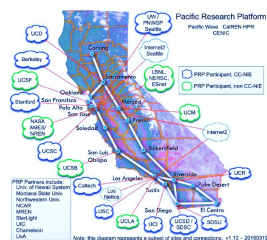
Pacific Research Platform: A West Coast big data freeway system (Smarr et al., UCSD)

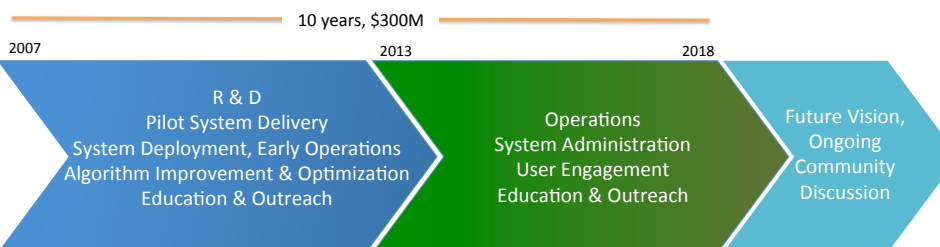CyberGIS: Evolving GIS software for sustained geospatial innovation (Wang et al., UIUC)

Innovating CISE   Innovating S&E   16

Looking forward

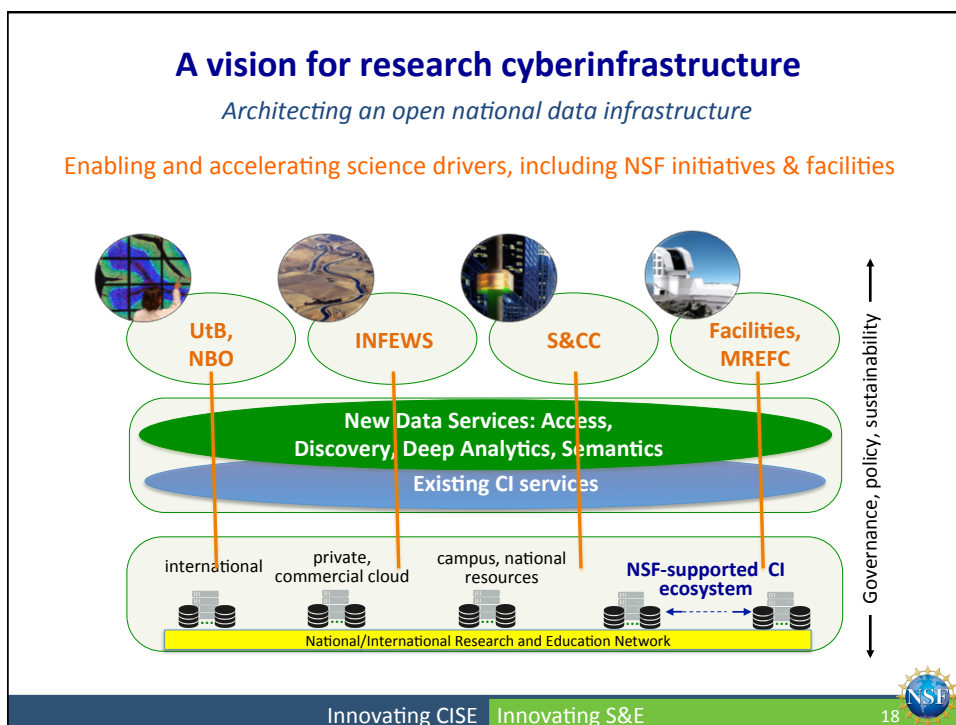*Critical support for the most demanding science projects*

10 years, $300M

2007   2013   2018

R & D
Pilot System Delivery
System Deployment, Early Operations
Algorithm Improvement & Optimization
Education & Outreach

Operations
System Administration
User Engagement
Education & Outreach

Future Vision,
Ongoing
Community
Discussion

Image courtesy of NCSA at the University of Illinois

Blue Waters

Innovating CISE   Innovating S&E   17

A vision for research cyberinfrastructure

Architecting an open national data infrastructure

A vision for research cyberinfrastructure

Architecting an open national data infrastructure

Enabling and accelerating science drivers, including NSF initiatives & facilities
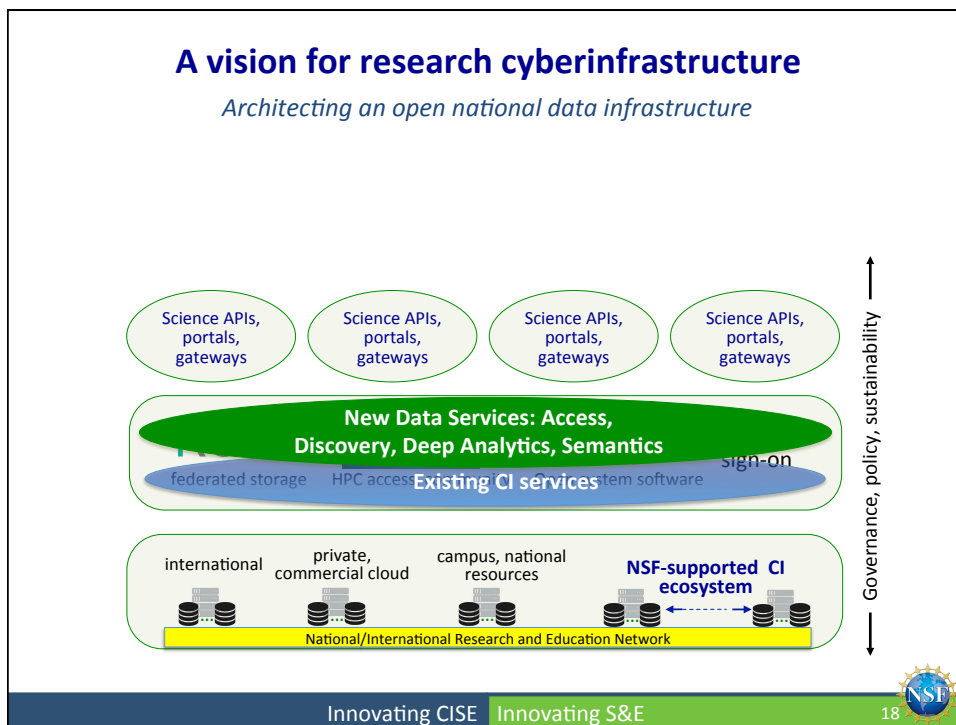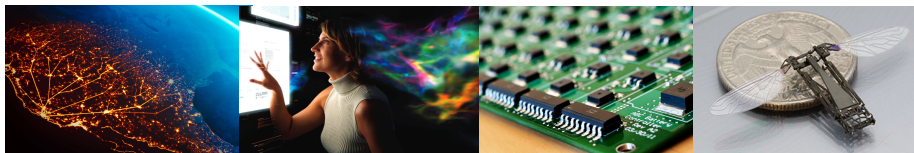
Computer & Information Science & Engineering:
Research and infrastructure enhancing our world

- **Ubiquity:** CISE investments are critical to science and society.

- **Engagement:** Research infrastructure enables advances in CISE as well as the broader scientific enterprise.

- **Urgency:** Continued and increasing investment in CISE and CISE-led research infrastructure is a national imperative.

Innovating CISE   Innovating S&E   19