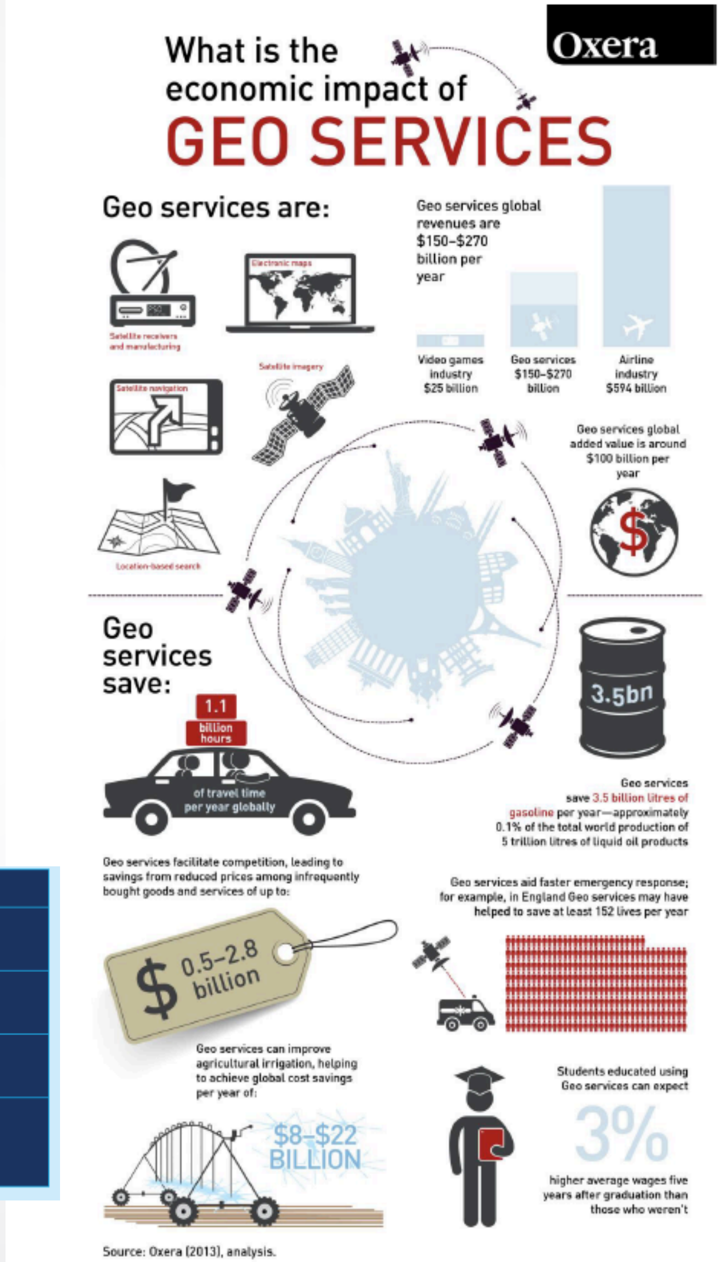
Pushing the Integration Envelope of Cyberinfrastructure to Realize the CyberGIS Vision

Shaowen Wang

CyberGIS Center for Advanced Digital and Spatial Studies
CyberInfrastructure and Geospatial Information Laboratory
Department of Geography and Geographic Information Science
Department of Computer Science
Department of Urban and Regional Planning
National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign

XSEDE-ECSS Symposium
January 21, 2014

Late 20th Century	The New Reality
Maps were produced by a few highly trained people in government agencies and surveying companies	Everyone is a mapmaker and many phenomena are observable.
Only sophisticated groups (e.g., Department of Defense, oil exploration groups) used GIS technologies	Everyone uses location-based services
Only specialized software (e.g., ArcGIS, Oracle SQL) could edit or analyze geographic information	Every platform is location aware
User expectations were modest (e.g., assist in producing and distributing paper maps and their electronic counterparts)	Rising expectations due to vast potential and risks



USGS science for a changing world — The National Map

USGS Home
Contact USGS
Search USGS

3D Elevation Program (3DEP)

The National Map Home >> 3D Elevation Program (3DEP)

3DEP Resources

The 3DEP Elevation Program - Summary of Program Direction (USGS Fact Sheet 2012-3089)

National Enhanced Elevation Assessment (NEEA)

3DEP Executive Forum

Alaska Mapping Roundtable

3DEP '*In the News*'

A Huge Laser-Mapping Project Is Redrawing America

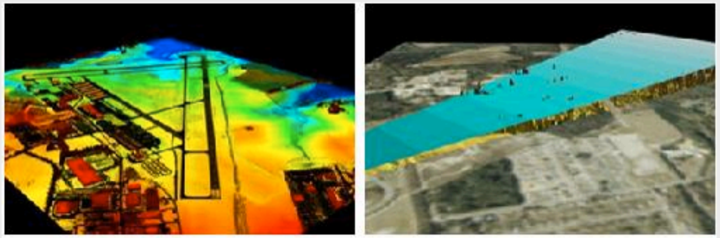
Remapping Coastal Areas Damaged by Hurricane Sandy

3DEP State Fact Sheets

- Alaska
- California
- Colorado
- Idaho
- Minnesota
- Rhode Island
- Texas
- Virginia
- Washington
- Wisconsin

Contact Us

Introduction and Goals


Lidar is used to detect potential obstacles that present hazards to air navigation.

The 3D Elevation Program (3DEP) initiative is being developed to respond to growing needs for high-quality topographic data and for a wide range of other three-dimensional representations of the Nation's natural and constructed features. The primary goal of 3DEP is to systematically collect enhanced elevation data in the form of high-quality light detection and ranging (lidar) data over the conterminous United States, Hawaii, and the U.S. territories, with data acquired over an 8-year period. Interferometric synthetic aperture radar (ifsar) data will be collected over Alaska, where cloud cover and remote locations preclude the use of lidar over much of the State. The 3DEP initiative is based on the results of the National Enhanced Elevation Assessment.

Applications - A Few Examples

3DEP will provide expanded benefits to a range of Federal, State, local, and private industry applications. Some examples of the value of improved elevation data include:

- The Federal Emergency Management Agency (FEMA) expects that a national enhanced elevation program could reduce the amount of time needed to update its flood maps. These enhanced data could provide significant benefits to the communities and citizens that are customers of the National Flood Insurance Program. For example, updated information could be delivered to affected communities and homeowners more quickly.
- Using lidar data, U.S. Geological Survey (USGS) scientists discovered a surface rupture along the Tacoma fault in the State of Washington. This discovery led to a redesign of the structural elements of a $735-million suspension bridge across the Tacoma Narrows. When lidar data enable the identification of active faults near major infrastructure, mitigation steps may be taken to avoid potential catastrophes.
- In the State of Alaska, poor-quality elevation data pose an ongoing threat to aviation safety. Improved elevation data for cockpit navigation and flight simulators may save lives each year by reducing accidents resulting from the inability to safely fly over obstacles in airspace.
- In 2010, an estimated 262.3 million acres of farm lands were harvested in the United States at total product values of $356.2 billion. The value to America's farmers of public domain lidar for all precision agriculture nationwide is believed to be potentially worth up to $2 billion annually.

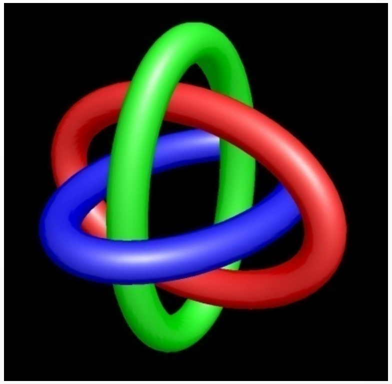
Transition to 3DEP

Theory + Experiment + Computation + 'Big' Data

- **Heterogeneous**
  - Syntactic
  - Semantic
- **Dynamic**
  - Spatial and temporal
  - E.g. social media
- **Massive**
  - Produced by individuals
  - Accessible to individuals
- **Large-scale**
  - Global coverage
- **Fine granularity**
  - Individual-level
  - High-resolution
- **Distributed access**
  - Interoperability
  - Privacy
  - Security

Integration – Holism

- *"The whole is more than the sum of its parts. "*
  - By Aristotle in the *Metaphysics*



Borromean rings, *after Daniel E. Atkins*

Image source: http://www.phy.ornl.gov/theory/dean/RIATG/web_pages/structure_one_pager.html

nsf.gov - Funding - Cyberinfrastructure Framework for 21st Century Science and Engineering - US National Science Foundation (NSF)

National Science Foundation
WHERE DISCOVERIES BEGIN

NSF Web Site

Home | Funding | Awards | Discoveries | News | Publications | Statistics | About | FastLane

Funding

Find Funding
A-Z Index of Funding Opportunities
Recent Funding Opportunities
Upcoming Due Dates
Advanced Funding Search
Interdisciplinary Research
How to Prepare Your Proposal
About Funding

Proposals and Awards

Proposal and Award Policies and Procedures Guide
Introduction
Proposal Preparation and Submission
- Grant Proposal Guide
- Grants.gov Application Guide

Award and Administration
- Award and Administration Guide

Award Conditions
Other Types of Proposals
Merit Review
NSF Outreach

Email Print Share

Crosscutting/NSF-wide

Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21)

CIF21 Vision Statement

CIF21 will provide a comprehensive, integrated, sustainable, and secure cyberinfrastructure (CI) to accelerate research and education and new functional capabilities in computational and data-intensive science and engineering, thereby transforming our ability to effectively address and solve the many complex problems facing science and society.

CONTACTS

For general inquiries about CIF21 activities: nsf-cif21-info@nsf.gov

For a list of CIF21 contacts at NSF, visit our contact page.

For a list of cyberinfrastructure components visit our CI resources page.

SYNOPSIS

Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21) is a portfolio of activities to provide integrated cyber resources that will enable new multidisciplinary research opportunities in all science and engineering fields by leveraging ongoing investments and using common approaches and components.

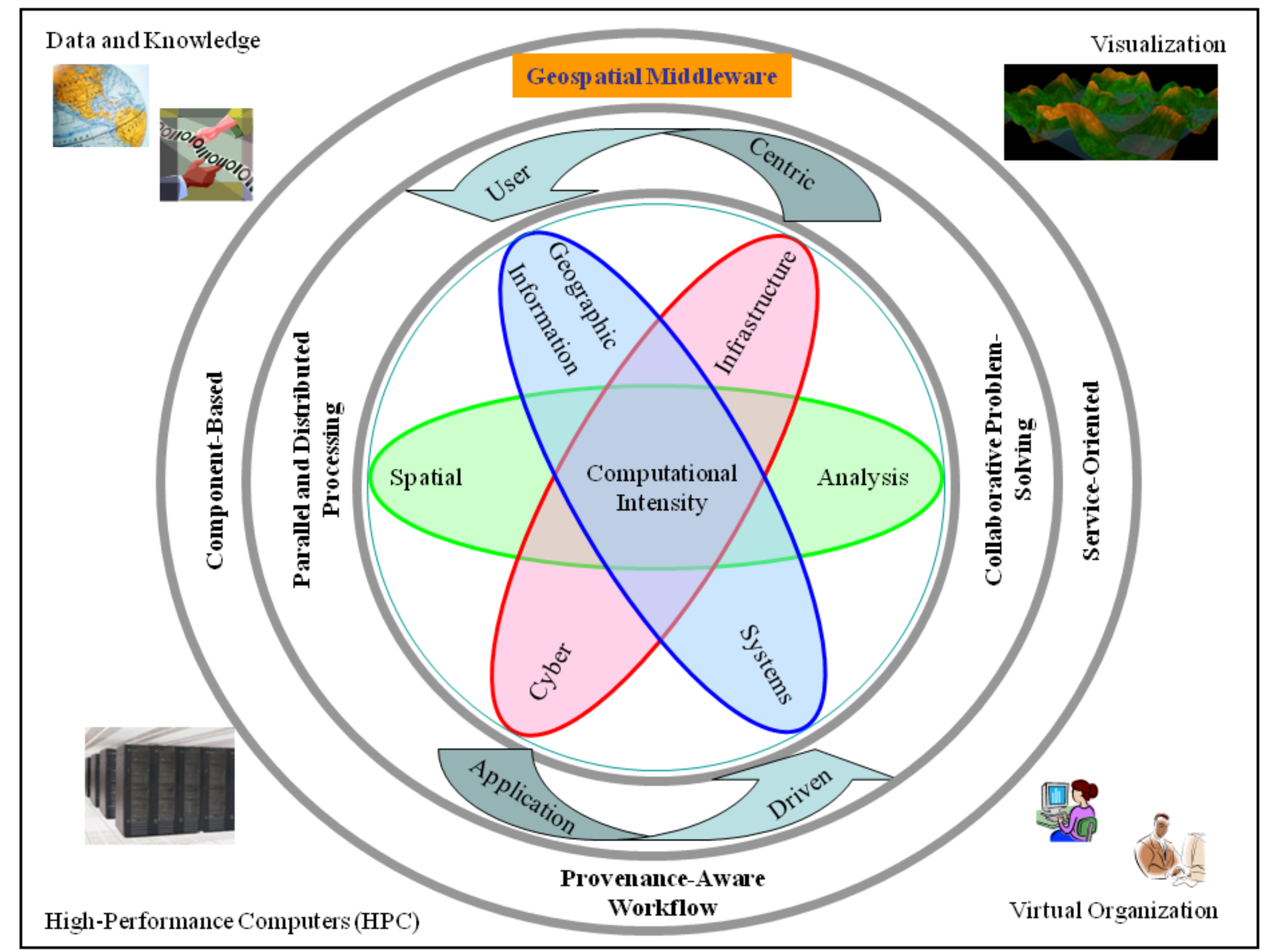
Researchers in all fields of science and engineering are being challenged in two key directions. The first challenge is to push beyond the current boundaries of knowledge to provide ever-deeper insights through fundamental disciplinary research by addressing increasingly complex questions, which often requires extremely sophisticated integration of theoretical, experimental, observational and simulation and modeling results. These efforts, which have relied heavily on observing platforms and other data collection efforts, computing facilities, software, advanced networking, analytics, visualization and models have led to important breakthroughs in all areas of science and engineering and represent a very strong bottom-up approach to the necessary research infrastructure.

The second, and more extensive challenge, is to synthesize these fundamental ground

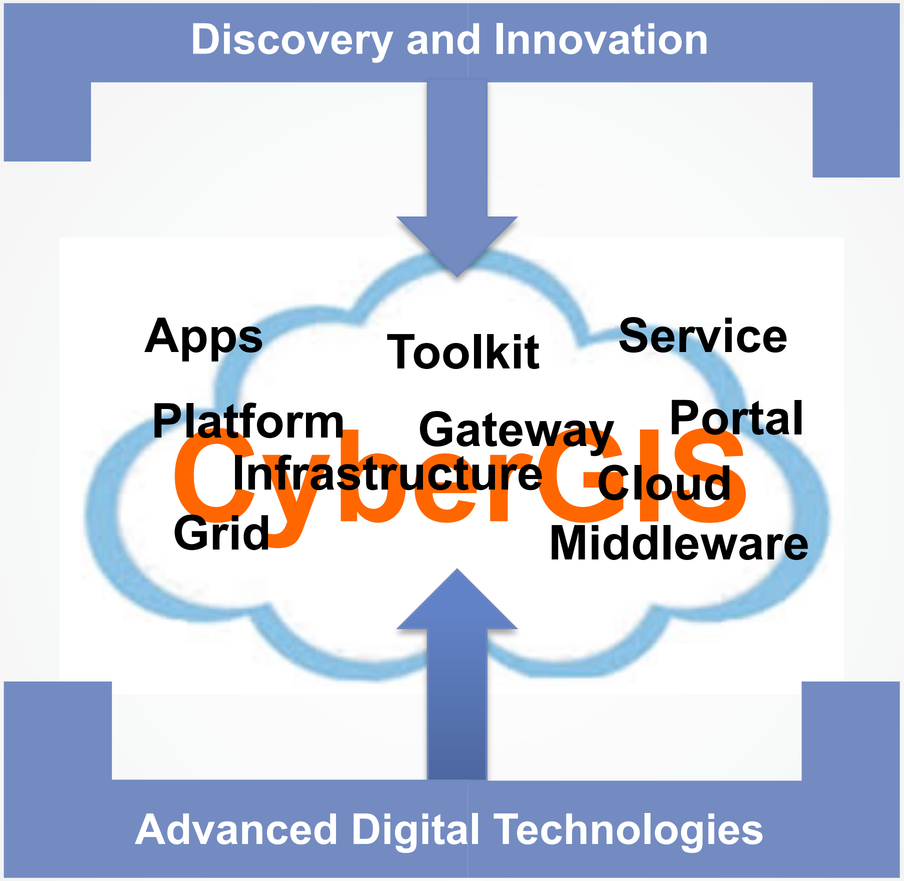
CIF21 Vision Statement

CIF21 will provide a comprehensive, integrated, sustainable, and secure cyberinfrastructure (CI) to accelerate research and education and new functional capabilities in computational and data-intensive science and engineering, thereby transforming our ability to effectively address and solve the many complex problems facing science and society.

CyberGIS Vision



Wang, S. 2010. “A CyberGIS Framework for the Synthesis of Cyberinfrastructure, GIS, and Spatial Analysis.” *Annals of the Association of American Geographers*, 100(3): 535-557

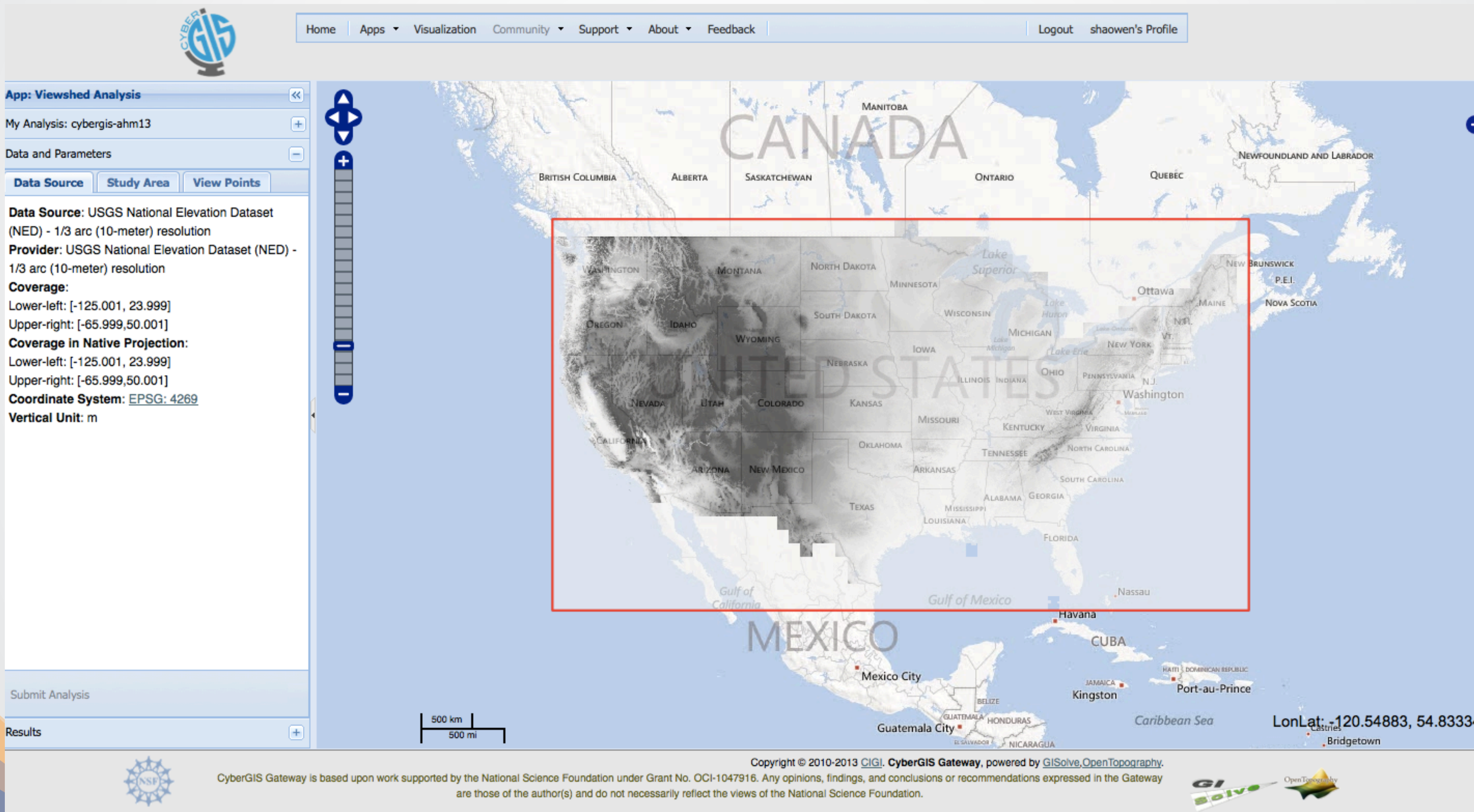


Wang, S. 2013. "CyberGIS: Blueprint for Integrated and Scalable Geospatial Software Ecosystems." *International Journal of Geographical Information Science*, 27 (11): 2119-2121

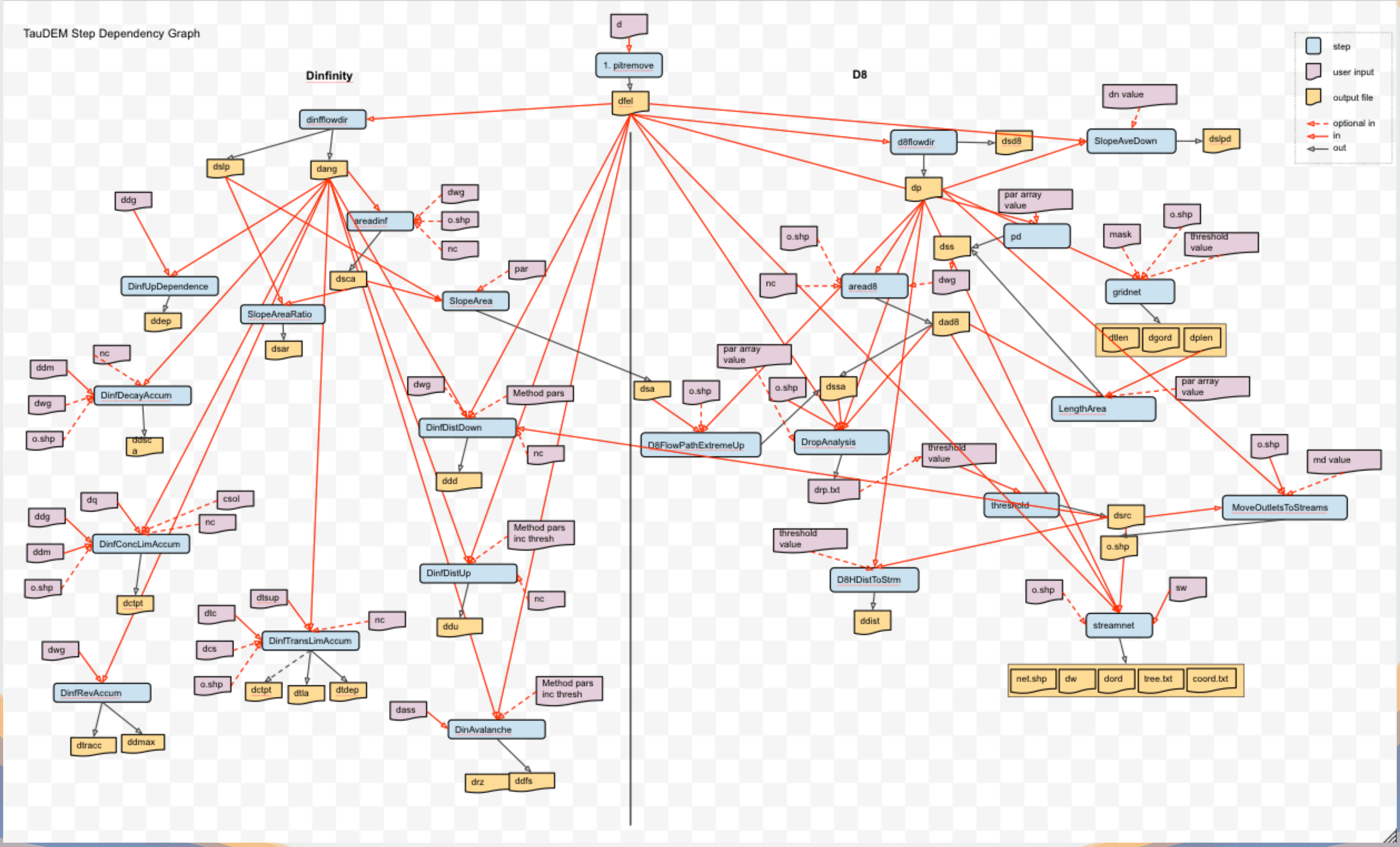
Grand Challenges & Opportunities

- To create and sustain open, scalable, and intelligent CyberGIS
- CyberGIS is not only about innovating infrastructure and systems, but also about advancing and transforming geospatial research and education in the digital age

Big Spatial Data

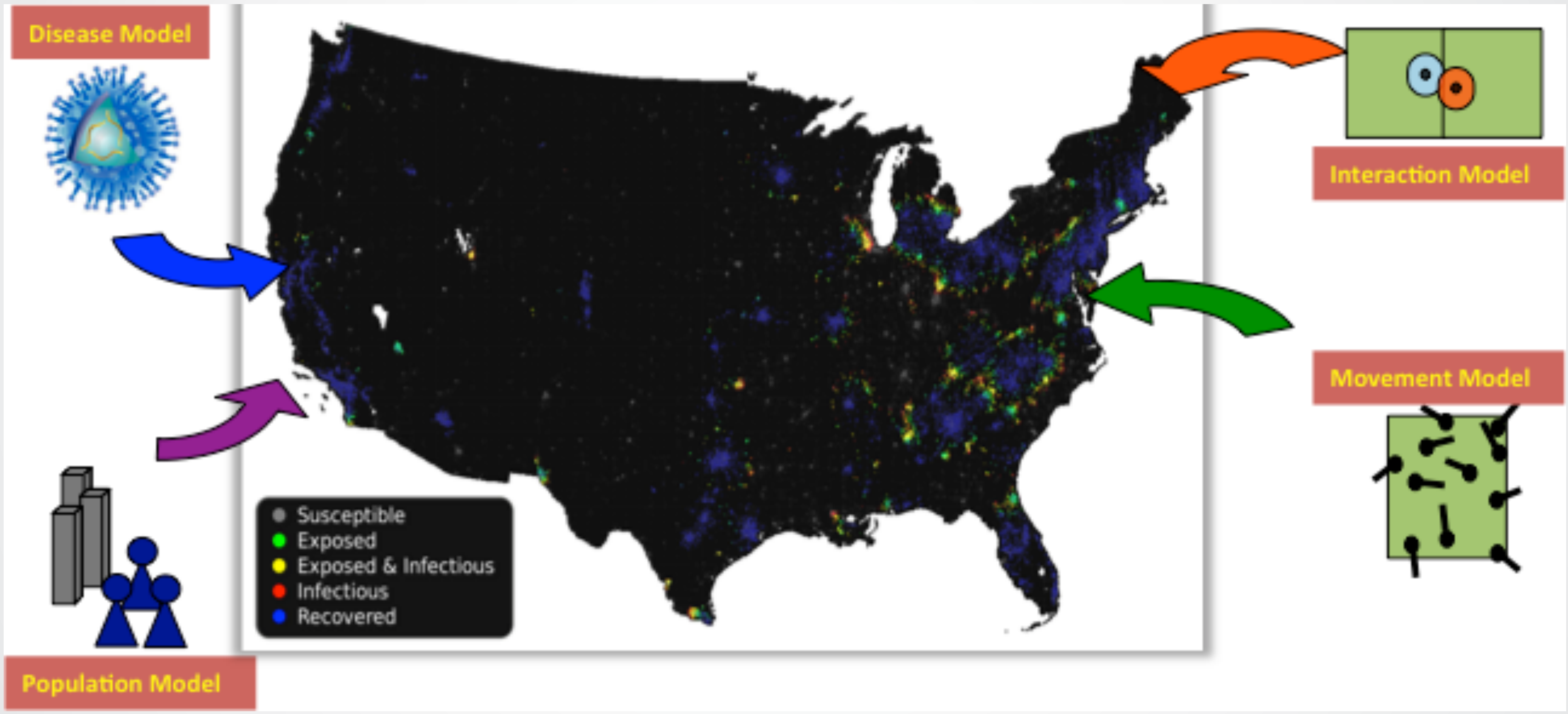


TauDEM Workflow



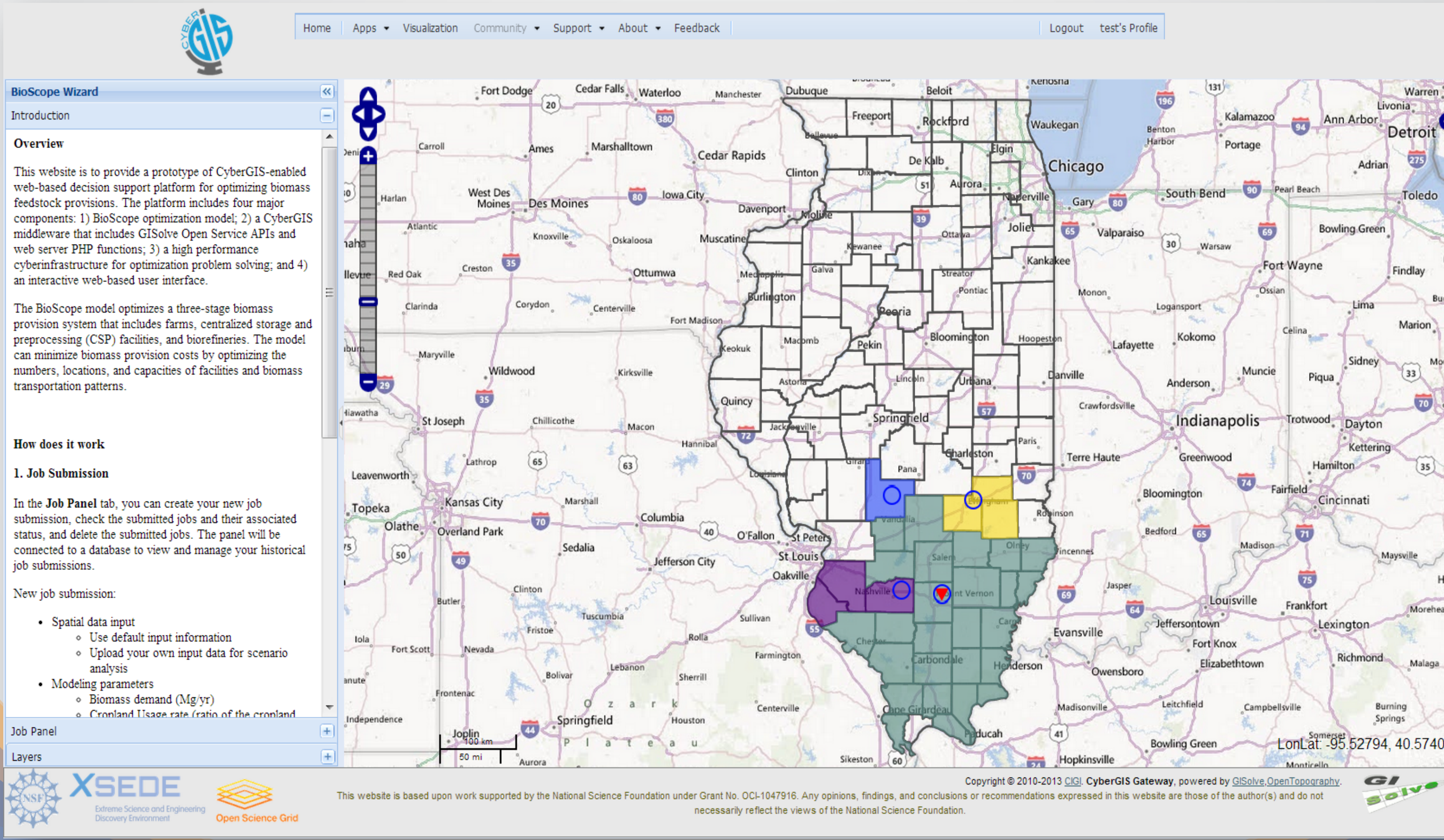
Collaborative Work by *David Tarboton, Yan Liu, Ye Fan, and Shaowen Wang*

Big Spatial Simulation



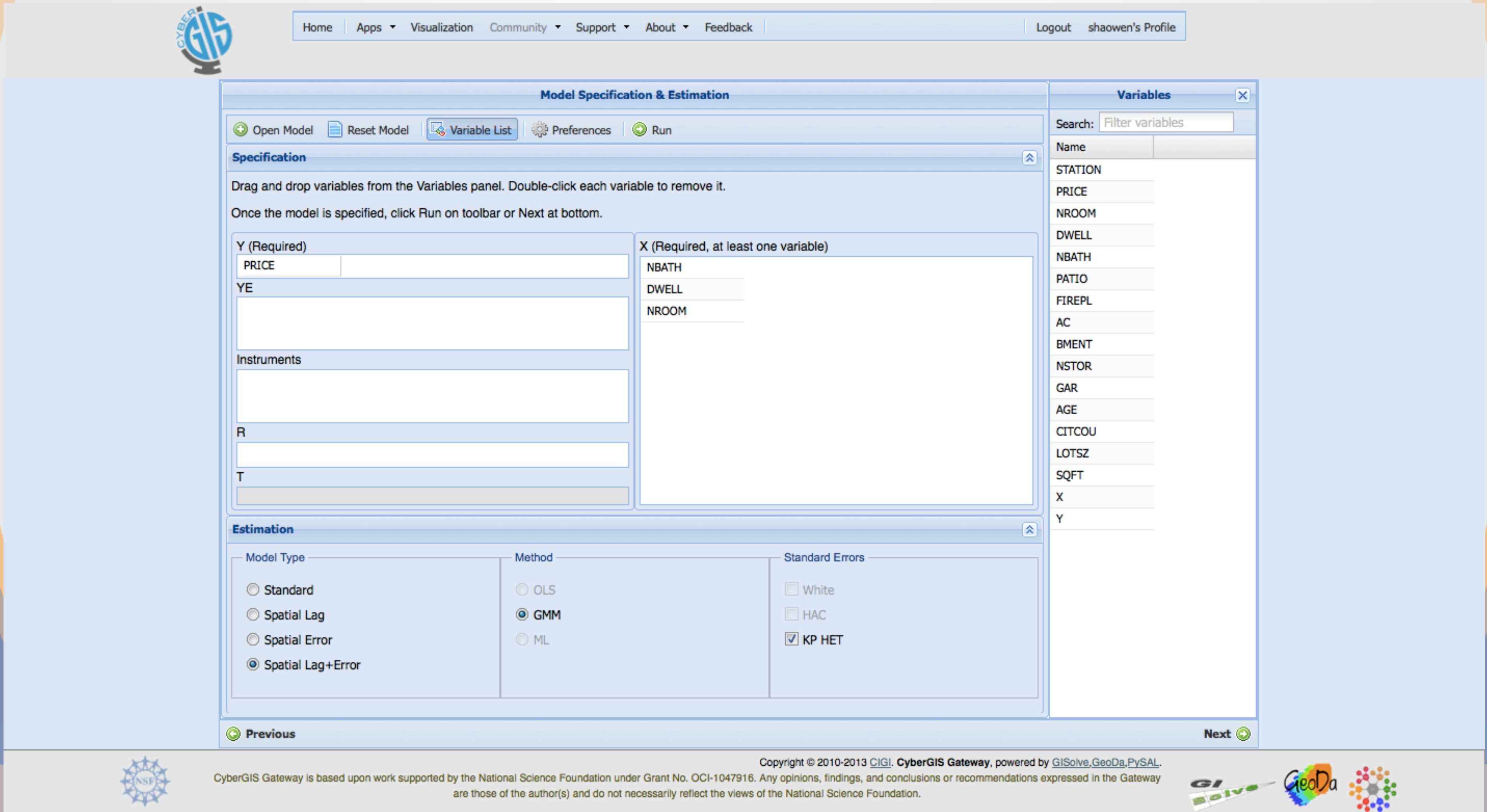
Collaborative Work by *Eric Shook and Shaowen Wang*

Complex Spatial Decision Making



Collaborative Work by *Hao Hu, Tao Lin, Yan Liu, Luis F. Rodríguez, and Shaowen Wang*

Collaborative Geospatial Knowledge Discovery



NSF SI2-SSI: CyberGIS Project
$4.43 million, Year: 2010-2015

Principal Investigator
- Shaowen Wang

Co-Principal Investigators
- Luc Anselin
- Budhendra Bhaduri
- Timothy Nyerges
- Nancy Wilkins-Diehr

Senior Personnel
- Michael Goodchild
- Sergio Rey
- Marc Snir
- E. Lynn Usery

Chair of the Science Advisory Committee
- Michael Goodchild

Project Manager
- Anand Padmanabhan

Project Staff
- ASU: Wenwen Li and Rob Pahle
- ORNL: Ranga Raju Vatsavai
- SDSC: Choonhan Youn
- UIUC: Yan Liu and Anand Padmanabhan
- Graduate and undergraduate students

Industrial Partner: Esri
- Steve Kopp and Dawn Wright

Cyber-Environments

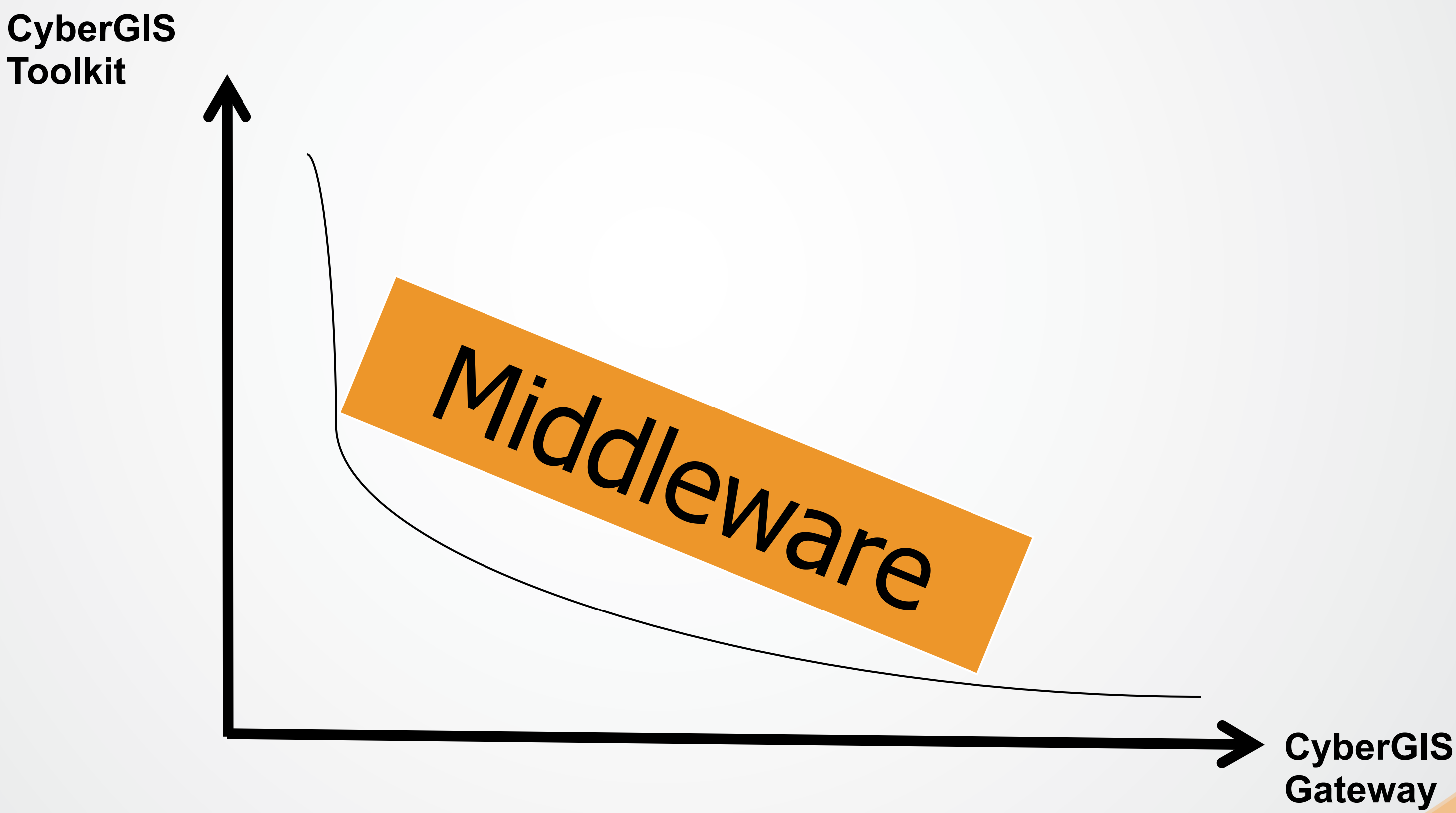
- Parallel
  - Used to be regarded as a way for speeding up GIS functions and spatial analysis
  - Now becoming a must for GIS and spatial analysis to be built on
    - Multi- and many-core
    - GPU (graphics processing unit)
- Heterogeneous architecture
- Mobile
- Distributed
  - Service-oriented
  - Clouds

Extreme-scale computing, information, and communication systems

BLUE WATERS
SUSTAINED PETASCALE COMPUTING

- Nearly 27,000 compute nodes and more than 4,000 graphics processing unit accelerators
- More than 1.5 petabytes of memory
- More than 25 petabytes of disk storage
- Up to 500 petabytes of tape storage

CyberGIS for What and Whom?



CyberGIS Communities

- **Science and Technology Communities**
  - Advanced cyberinfrastructure
  - Climate change impact assessment
  - Emergency management
  - Geographic information science
  - Geography and spatial sciences
  - Geosciences
  - Social sciences
  - Etc.
- **User Communities**
  - Biologists
  - Geographers
  - Geoscientists
  - Social scientists
  - General public
  - Broad GIS users
  - Etc.

CyberGIS Gateway and ArcGIS Online Integration

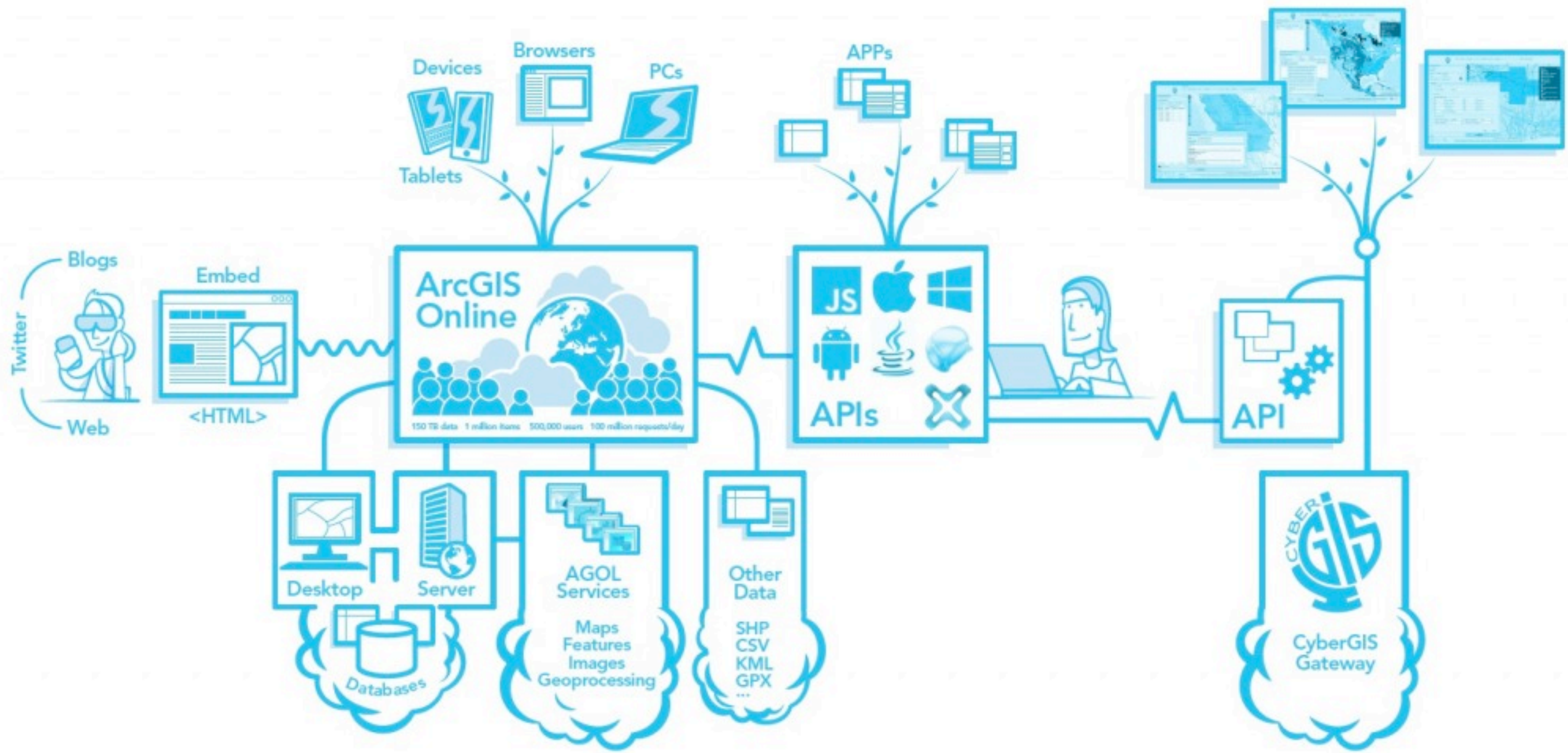
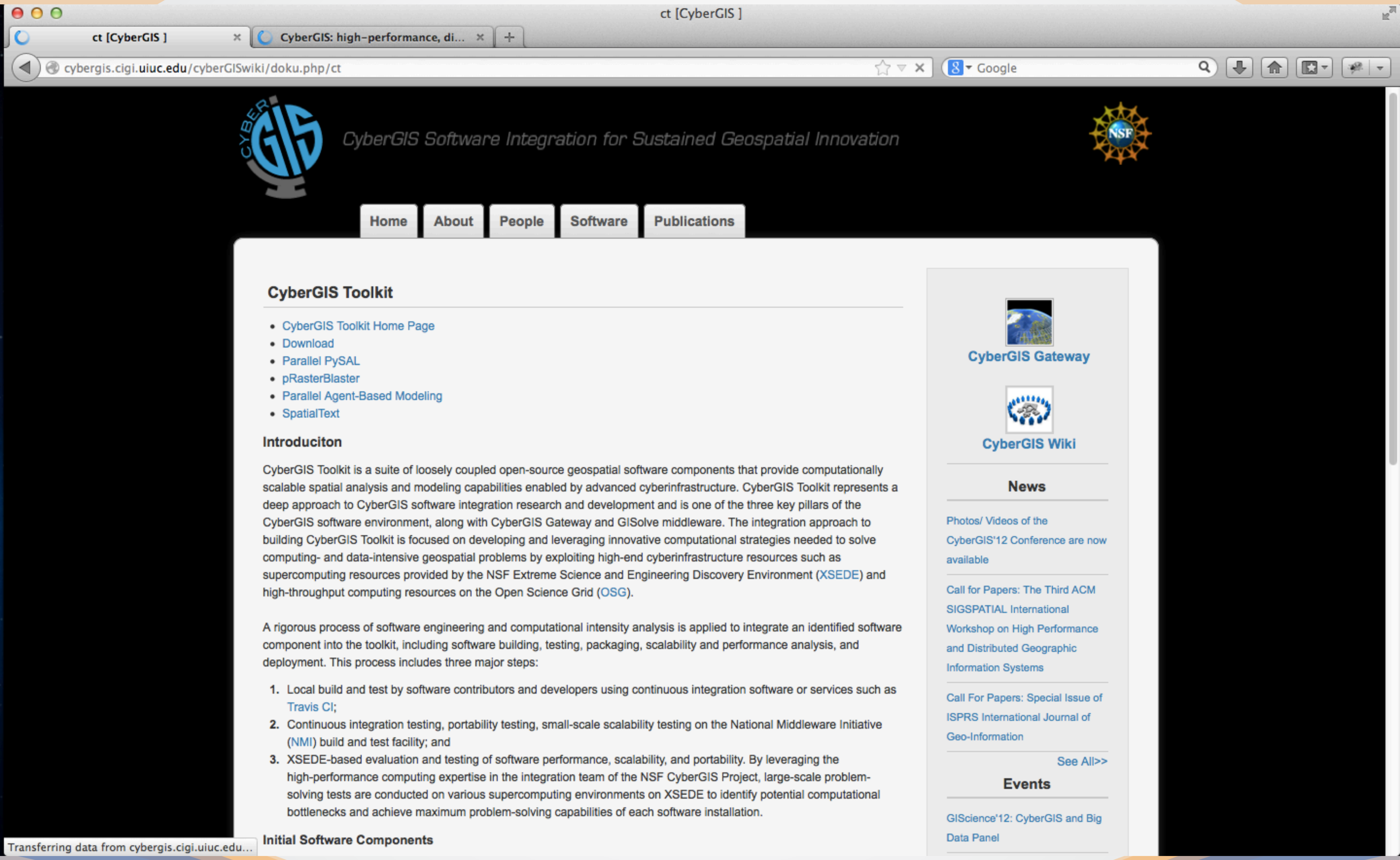
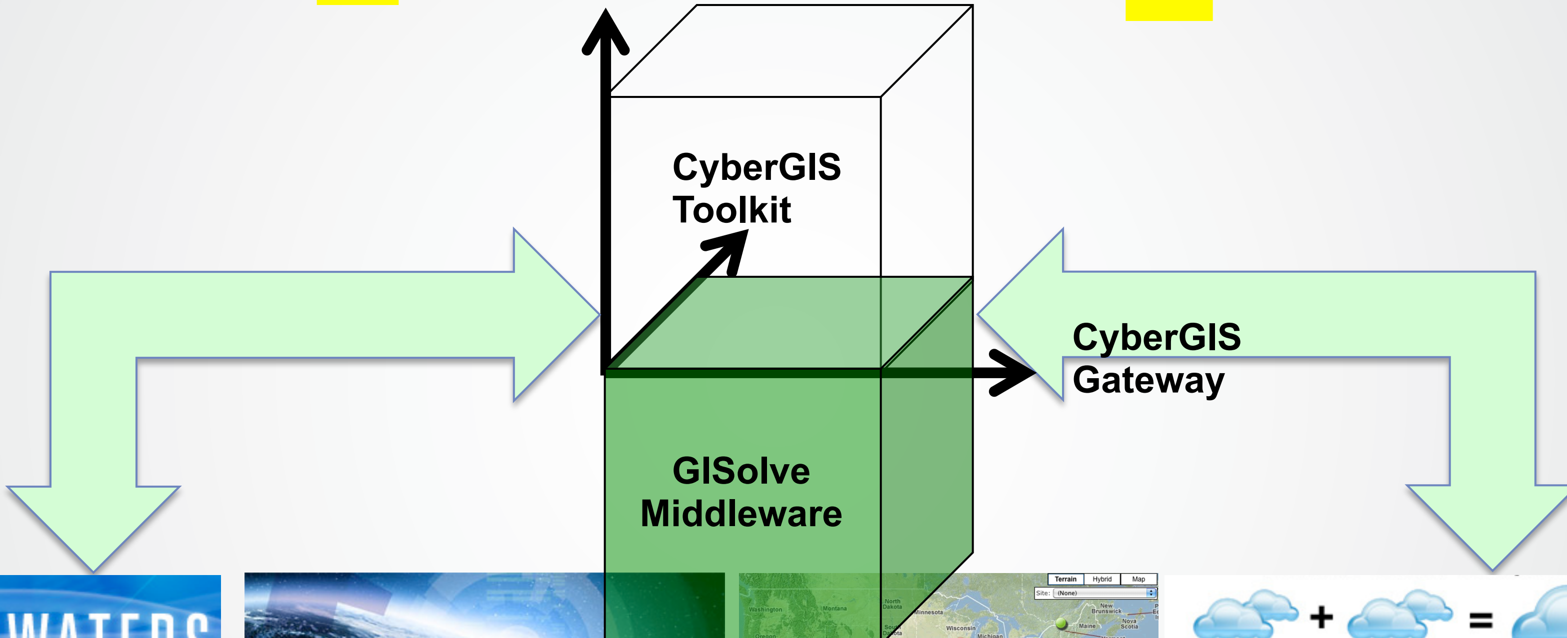


Image source: http://blogs.esri.com/esri/arcgis/2013/10/01/what-is-cybergis/

CyberInfrastructure and Geospatial Information Laboratory

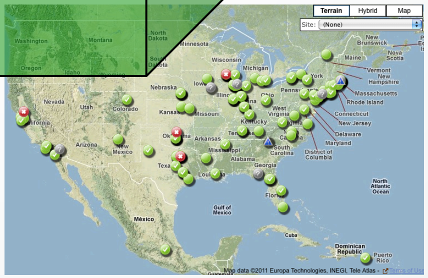


Integrated Digital and Spatial Studies



www.ncsa.illinois.edu/BlueWaters/

www.xsede.org



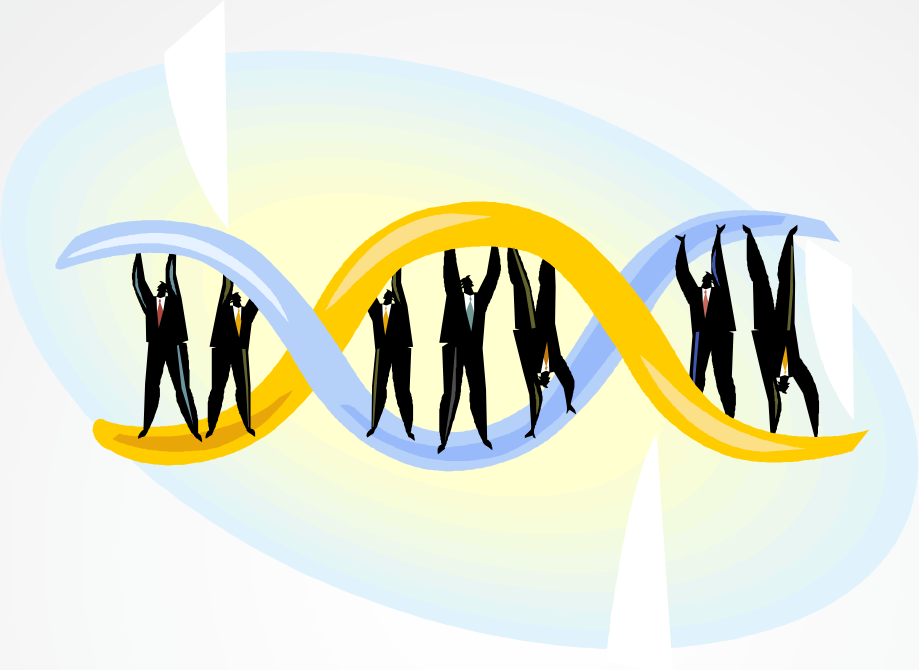
www.opensciencegrid.org

http://lakjeewa.blogspot.com/2011/09/what-is-cloud-computing.html

Spatial Computational Principles/Theories

- Spatial
  - Distribution
  - Dependence
  - Heterogeneity
  - Integration
  - Representation
  - Uncertainty
  - Etc.
- Computational
  - Complexity vs. intensity
  - Uncertainty vs. validity
  - Performance vs. reliability
  - Etc.

SCALE



- Curriculum and pedagogy
- Partnerships
- Open ecosystems

CyberGIS Center for Advanced ...

cybergis.illinois.edu

CyberGIS Center for Advanced Digital and Spatial Studies

Home | About Us | Affiliates | Projects | Events

CyberGIS Center

The CyberGIS Center for Advanced Digital and Spatial Studies (CyberGIS Center) was established in 2013 as a partnership among several units at the University of Illinois at Urbana-Champaign. CyberGIS—referred to as geographic information science and systems (GIS) based on advanced infrastructure of computing, information, and communication technologies (aka cyberinfrastructure or e-infrastructure)—represents a vibrant interdisciplinary field for bridging advanced cyberinfrastructure, geographic information science and technologies, and various geospatial knowledge domains. The mission of the CyberGIS Center is to empower advanced digital and spatial studies through innovation of CyberGIS technologies and applications.

Spatially heterogeneous and multi-scale changes across the globe, such as population growth, climate change, competing land uses, and accelerated resource and environmental degradation, have created grand challenges ranging from energy and environmental sustainability to health and wellness. To tackle these challenges, which exhibit tremendous geo and spatial complexity, requires the consideration of interactions of spatial patterns and their driving processes across a number of spatial and temporal scales by combining rich spatiotemporal data, analytics and models to form novel problem-solving approaches enabled by CyberGIS.

The CyberGIS Center is well poised to revolutionize many areas of scholarship, ranging from engineering and science to the humanities, and focuses on the following four interrelated themes while engaging a number of related fields (examples provided within parentheses) across campus and beyond:

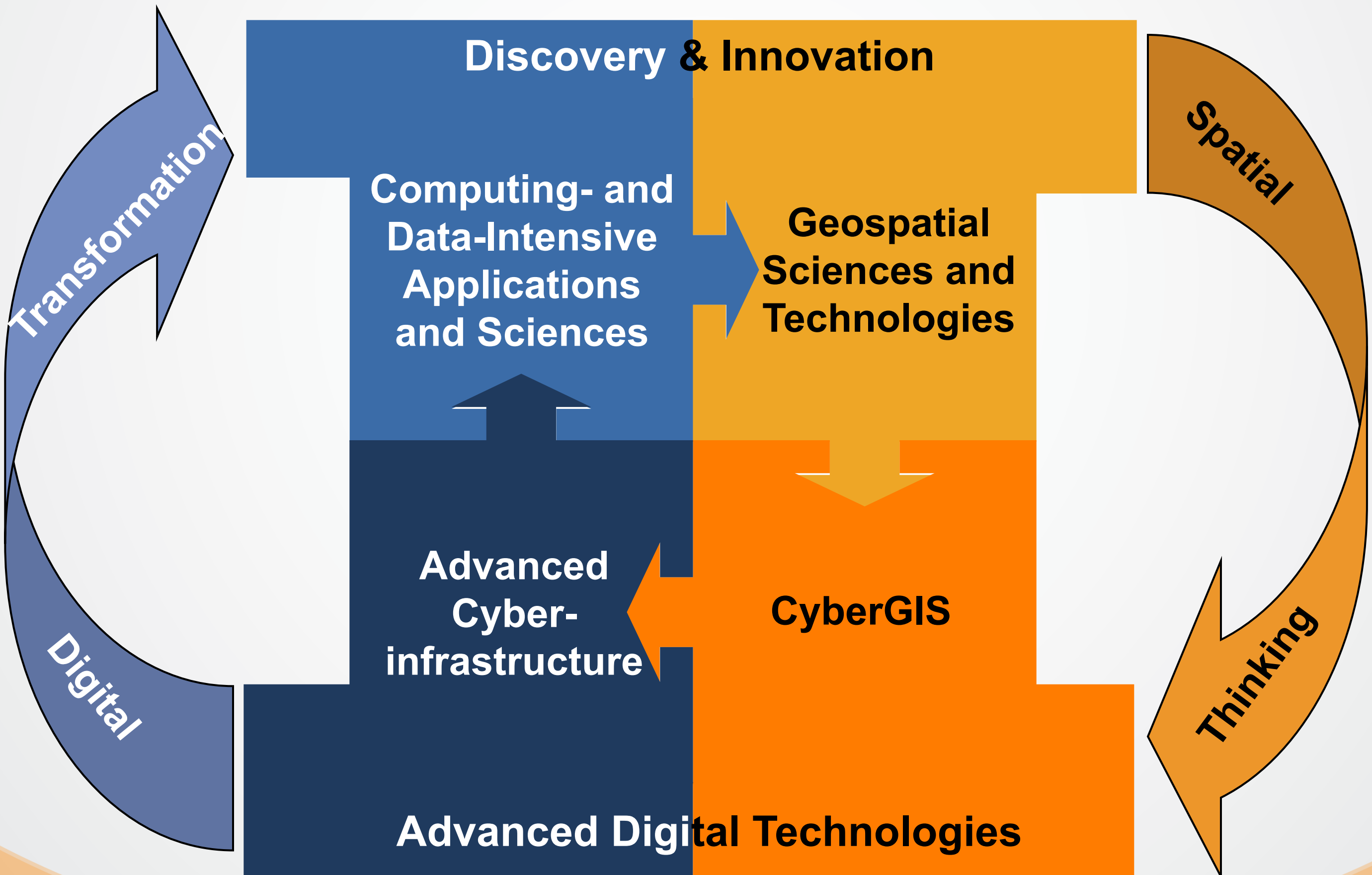
- **Sciences and technologies of CyberGIS** (e.g., advanced cyberinfrastructure, computer science, computational science, geography and geographic information science, library and information science, mathematics, and statistics);
- **Research and engineering applications of CyberGIS for enabling creative work, discovery, and innovation** (e.g., agriculture, applied health sciences, atmospheric sciences, business, civil and environmental engineering, geography and geographic information science, geology, history, political science, sociology, urban and regional planning, and veterinary medicine);
- **Human and societal dimensions of CyberGIS** (e.g., business, communication, geography and geographic information science, industrial and enterprise systems engineering, and psychology); and
- **CyberGIS education, outreach, and training** (all of the aforementioned fields).

The CyberGIS Center is hosted at the National Center for Supercomputing Applications at the University of Illinois, and directed by Dr. Shaowen Wang.

NCSA

National Center for Supercomputing Applications at the
University of Illinois at Urbana-Champaign

Vision


Discovery & Innovation
Computing- and Data-Intensive Applications and Sciences
Geospatial Sciences and Technologies
Advanced Cyber-infrastructure
CyberGIS
Advanced Digital Technologies
Transformation
Digital
Spatial
Thinking

Acknowledgments

- Federal Agencies
  - Department of Energy's Office of Science
  - National Science Foundation
    - BCS-0846655
    - EAR-1239603
    - OCI-1047916
    - IIS-1354329
    - PHY-0621704
    - PHY-1148698
    - TeraGrid/XSEDE SES070004
  - US Geological Survey (USGS)
- Industry
  - Environmental Systems Research Institute (Esri)

Acknowledgments – UIUC

- College of Liberal Arts and Sciences
- Department of Geography and Geographic Information Science
- Graduate School of Library and Information Science
- National Center for Supercomputing Applications
- Office of the Vice Chancellor for Research
- Prairie Research Institute
- School of Earth, Society, and Environment

Thanks!

- **Comments / Questions?**
- **Email: shaowen@illinois.edu**