Decision-making Under Risk and Uncertainty

A Federal Science Agency Perspective

Government-University-Industry Research Roundtable
June 19, 2012

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Director, National Science Foundation

NSF Is at "Ground Zero" of U.S. Science Enterprise

NSF sponsors fundamental research across all S&E disciplines and research on STEM education

< 6% overhead; NSF performs no internal research

Annually supports ≈ 285,000 individuals at 1,800 institutions

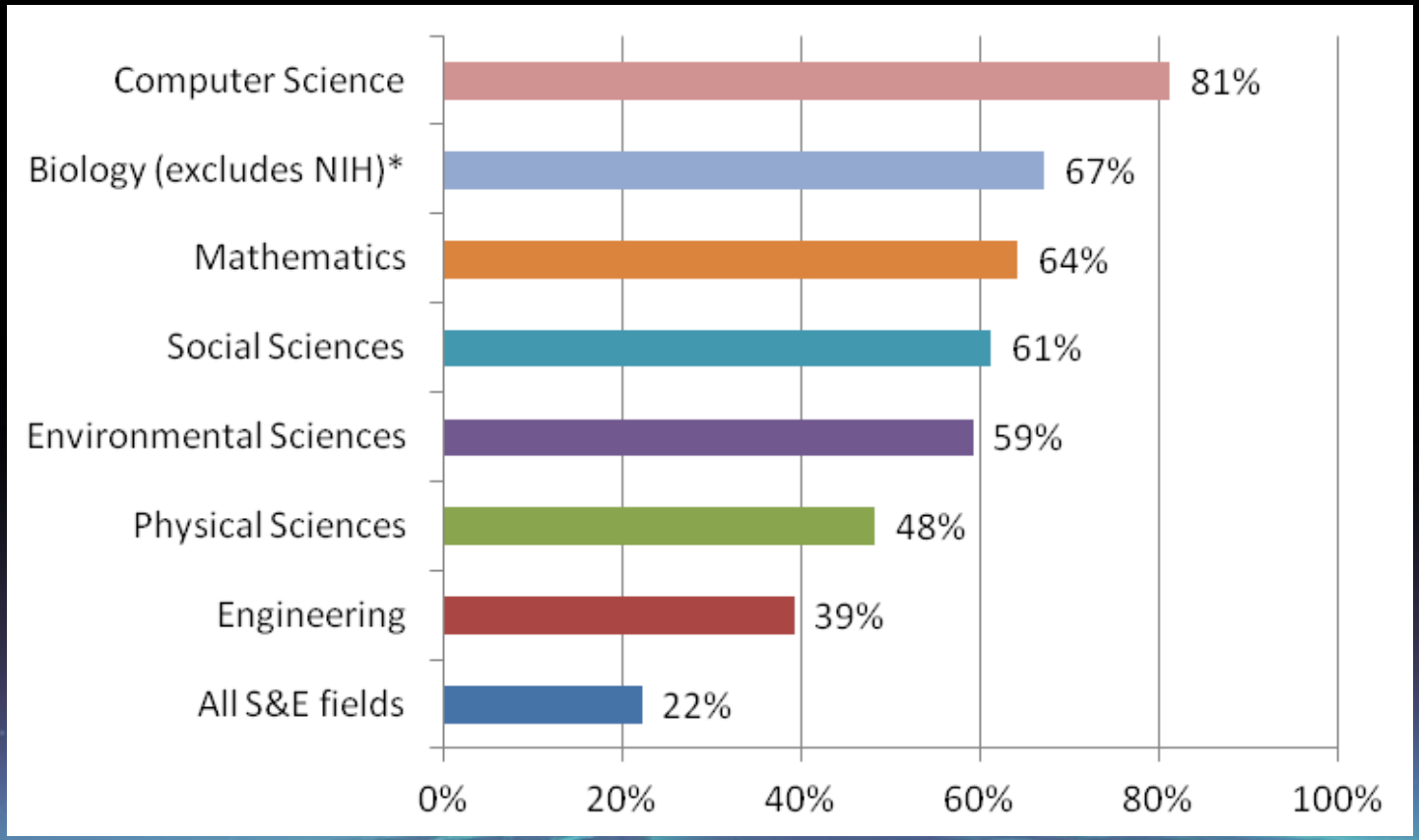
> 46,500 Graduate Research Fellows (GRFs) supported by NSF since 1952. Approx. 40,000 RAs per year.

- 197 Nobel Prize laureates supported by NSF since NSF's inception (1950)
- About 510 Nobel Prizes awarded since 1951 (NSF supported 40% of those)
  - 30 NSF GRFs are Nobel laureates
  - 440 GRFs are members of the National Academy of Sciences

Economic and societal impact

NSF by the Numbers

NSF Support of Academic Basic Research
In Selected Fields
(as a percentage of total federal support in 2008)



Source: NSF Survey of Federal Funds for Research and Development

Decision-making under risk and uncertainty

Unpredictable, uneven, “sub-annual” budget planning

Irreversible damage to intellectual disciplines and innovation ecosystem based on short-term responses to transient issues

Focus on long-term issues under overwhelmingly short attention span

Strong headwinds in international competition for ideas, talent, human capital development, and innovation

Unknown, uncontrollable and unintended consequences

Risk of “losing the future”

Key discoveries will “collect dust”; “inconvenient” findings will be actively ignored

We will squander domestic S&T talent

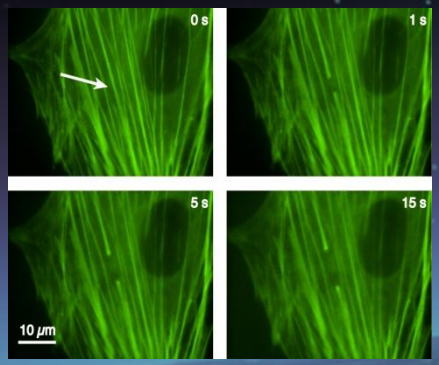
Globalized science will not be guided by shared principles

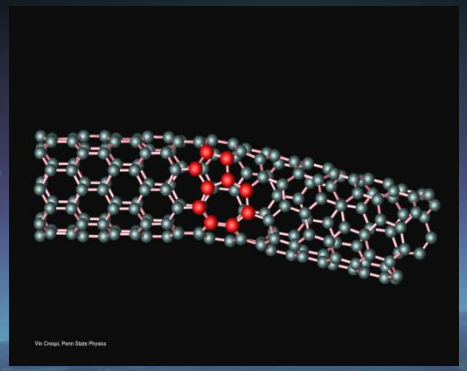
We will not fuel our fundamental science engine with the high-octane promise of interdisciplinary research

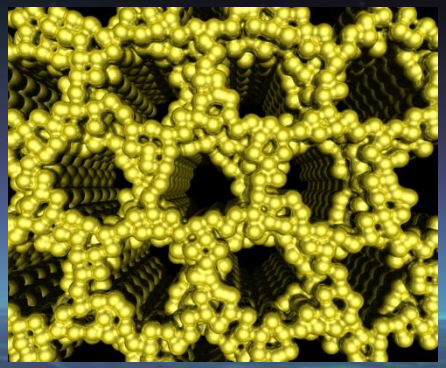
Short-term and parochial interests will overwhelm evidence-based, long-horizon scientific findings

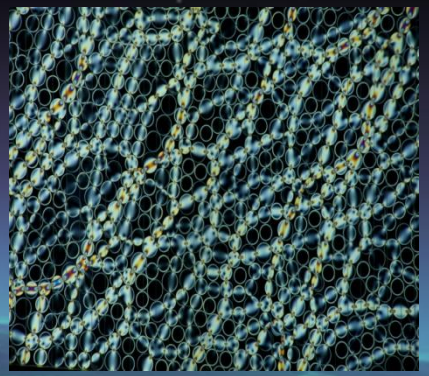
The U.S. Innovation Ecosystem

- U.S. has been a global innovation engine >50 years
- U.S. is magnet for talent from around the globe
- U.S. universities are at/near the top of global rankings
- U.S. has well-developed system of higher education with public and private support models
- U.S. has well-established infrastructure with institutions to identify, support, & nurture research, scientific ethics, & integrity
- U.S. has unique models for university-industry-national lab interactions









Risks to the U.S. Innovation Ecosystem

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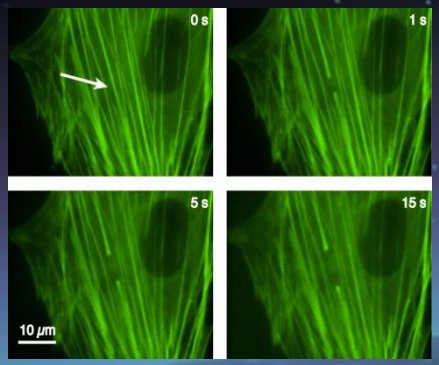
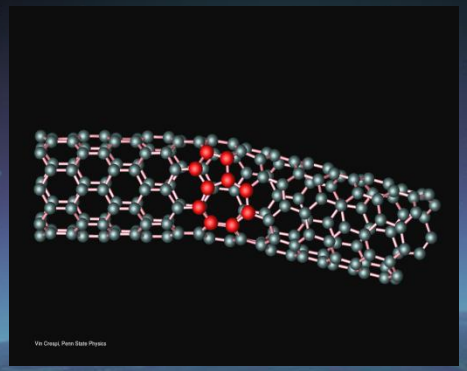
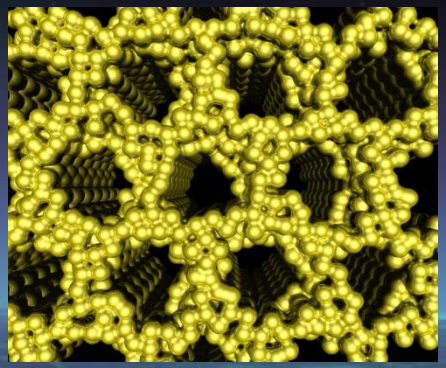
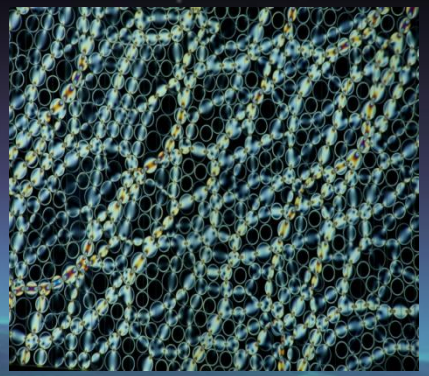
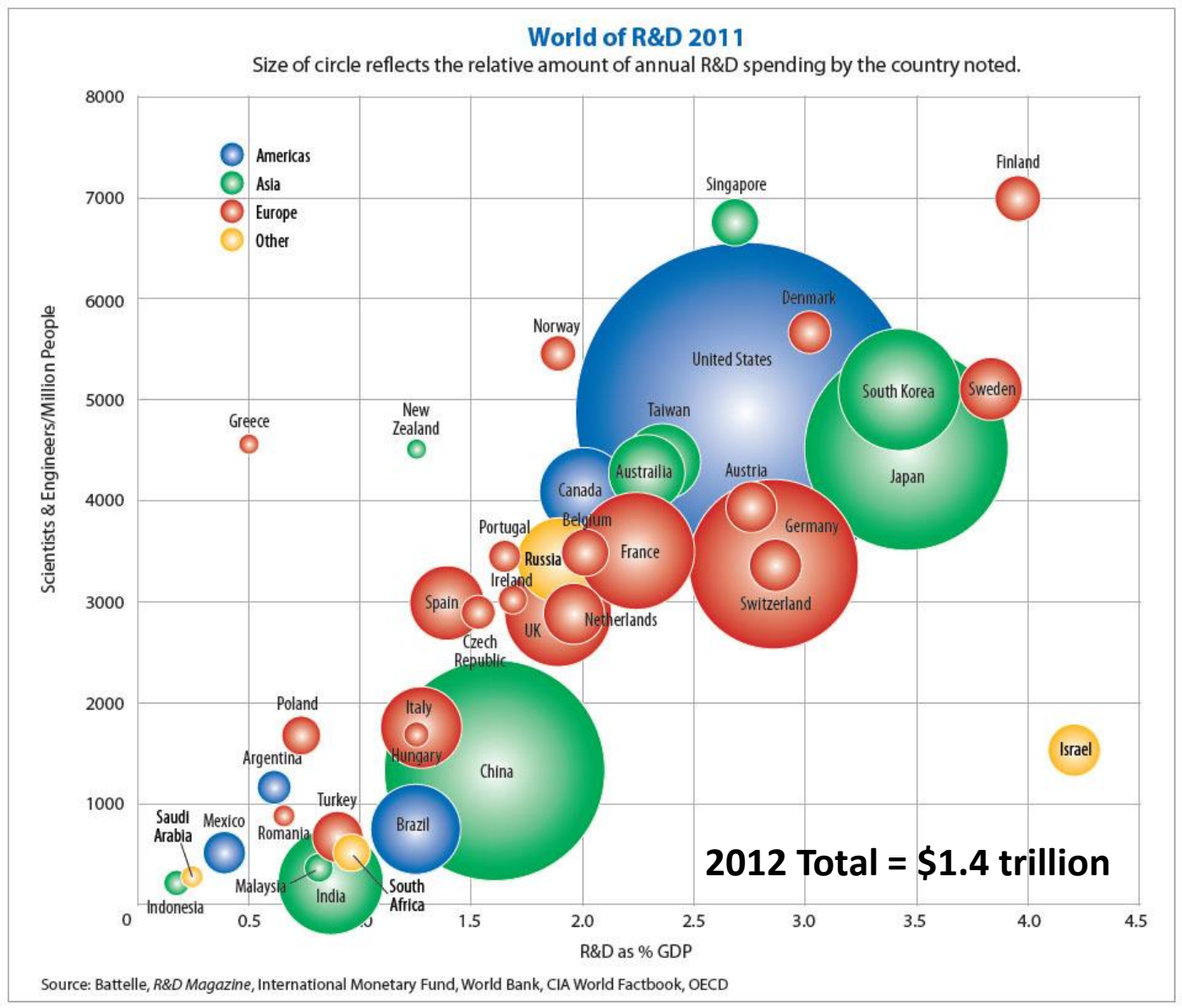
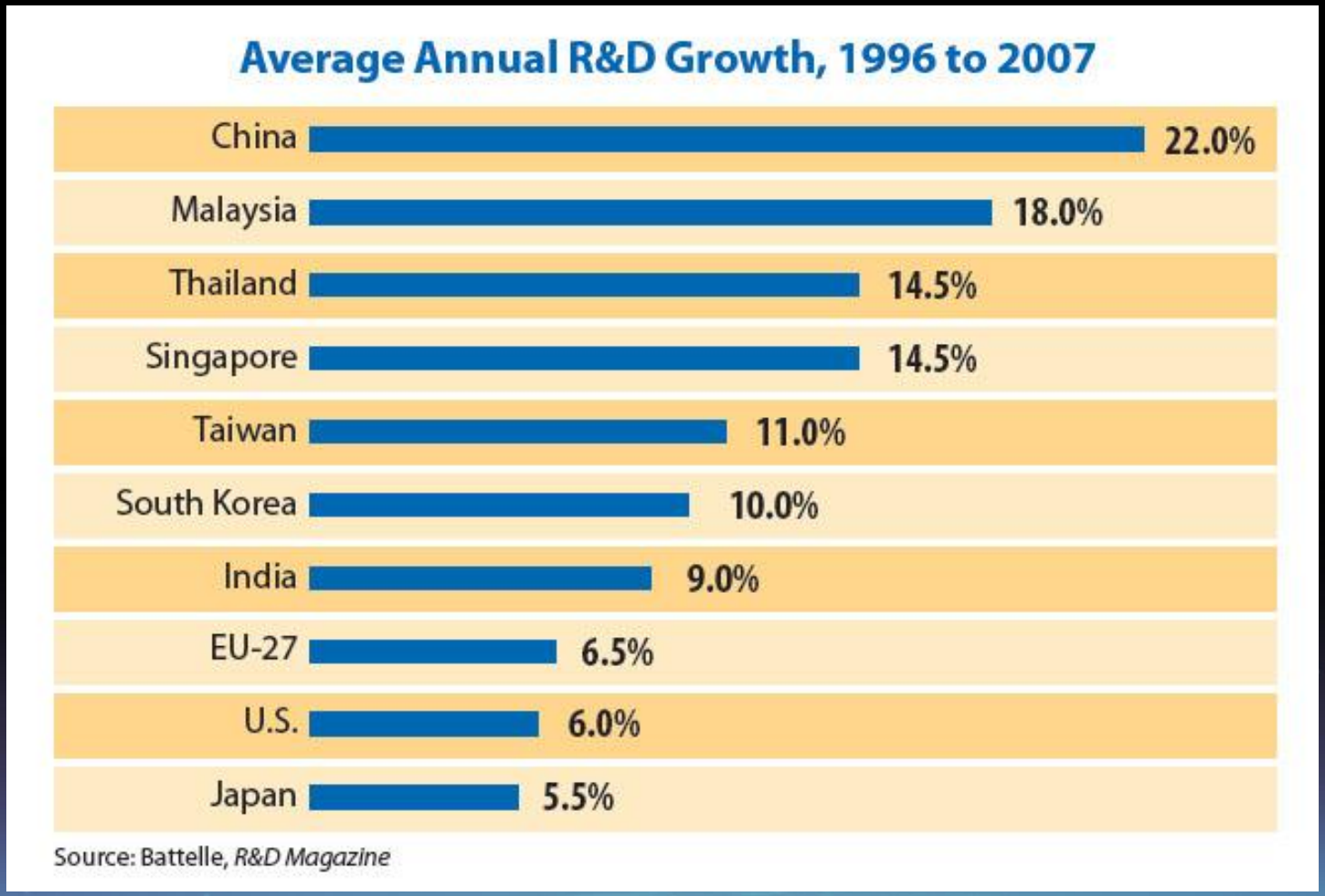


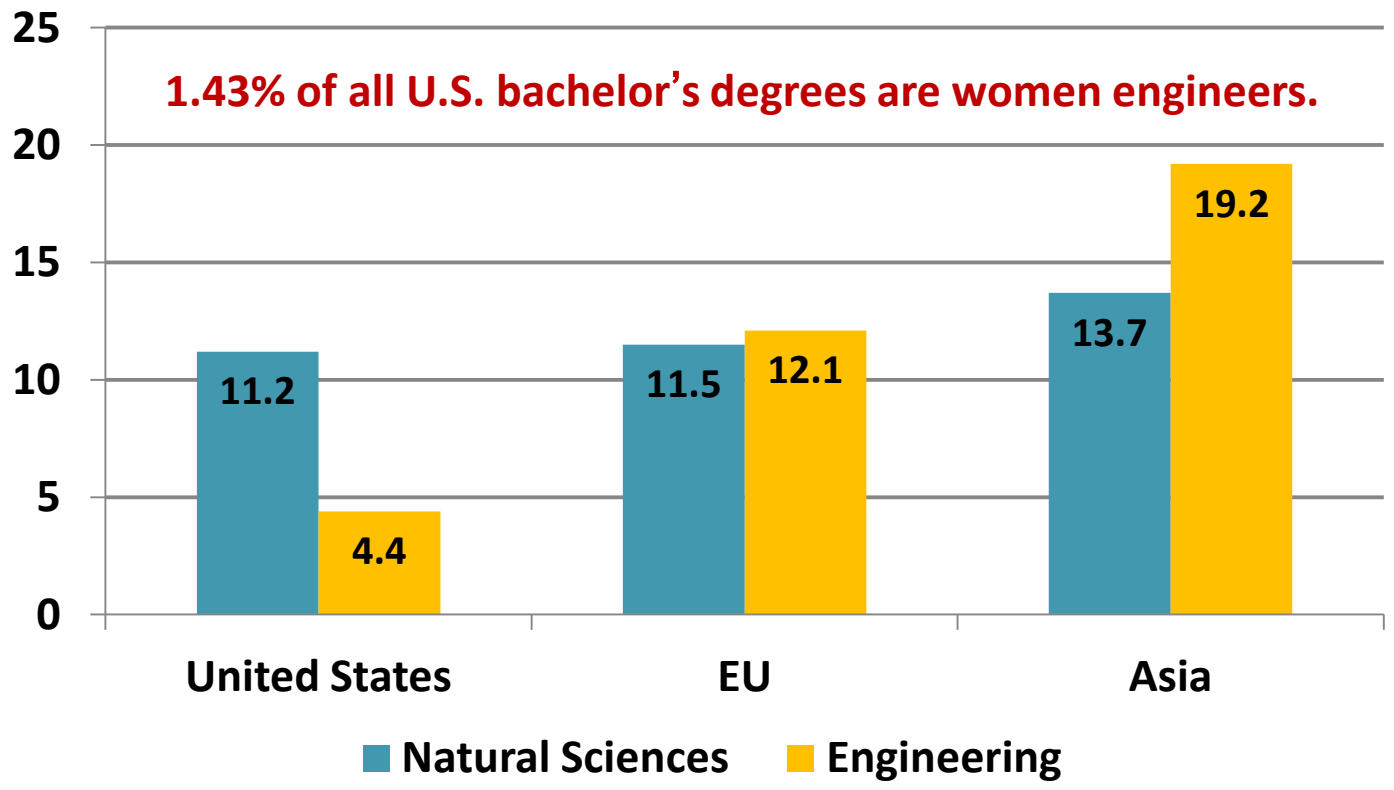
World R&D 2011



R&D Rates of Growth



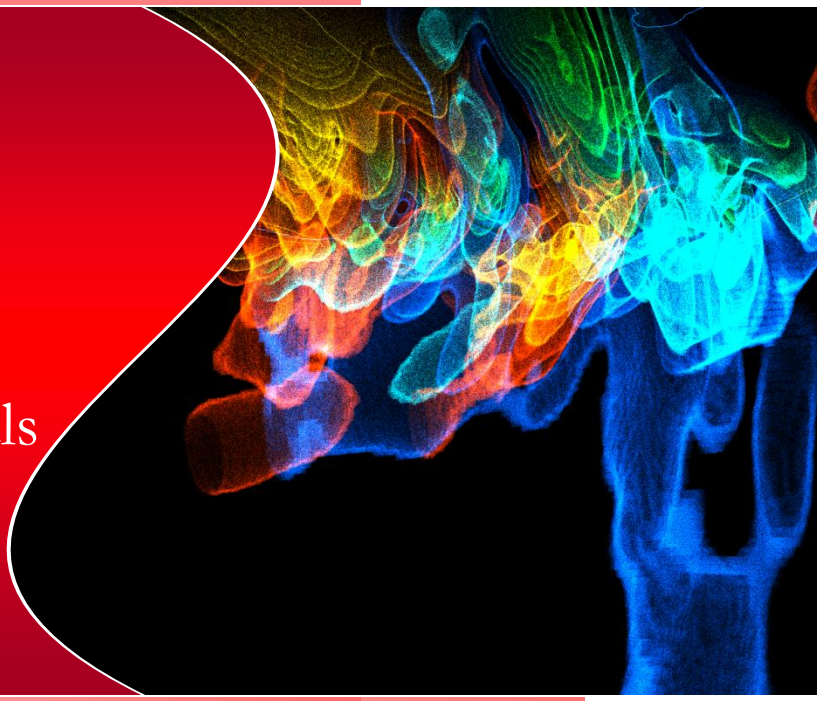
Risks that could undermine future innovation: Percentage of Undergraduate Degrees in the Natural Sciences and Engineering (2008)



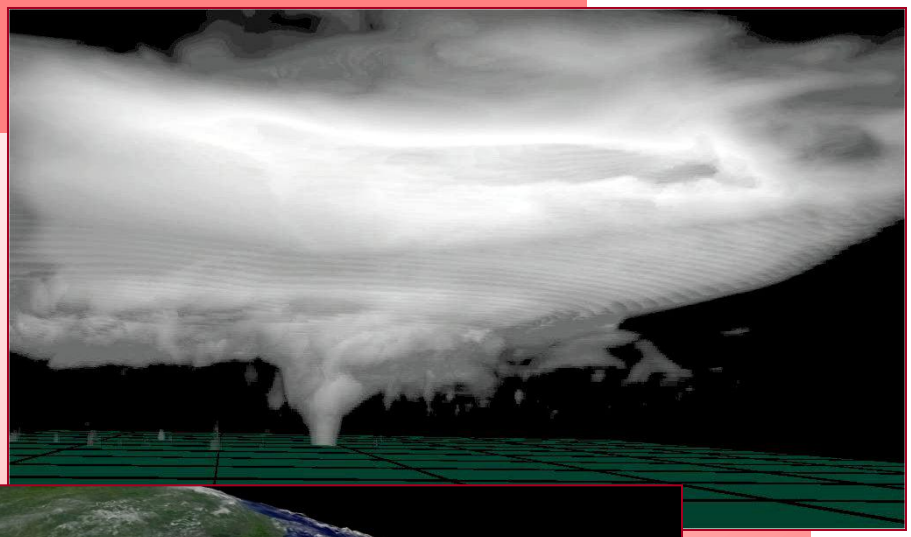
National Science Board, *Science and Engineering Indicators 2012*.

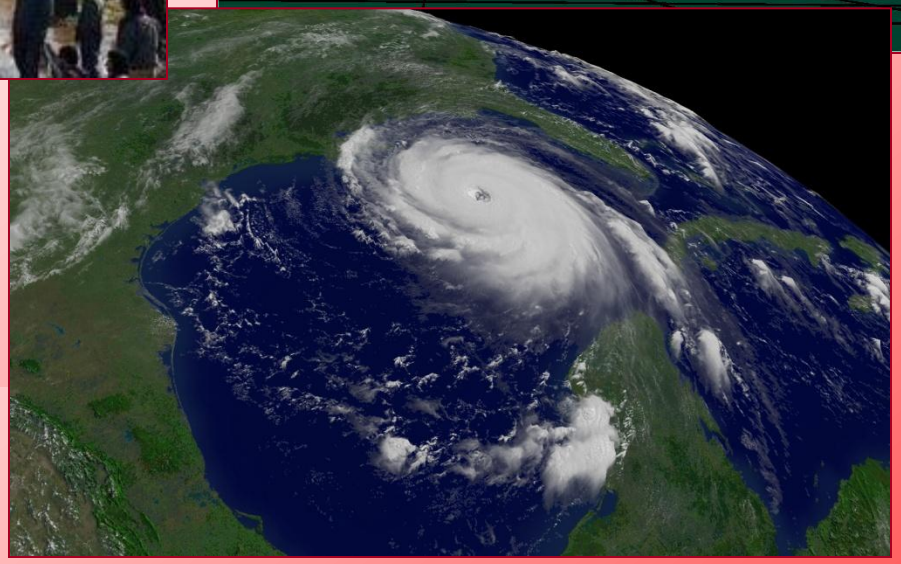
Timely and Urgent Risks in the Biosphere

- Weather and climate forecasting
- Disaster vulnerability and responses
- Dynamics of alienation and conflict
- Economic and political dynamics
- Dynamically responsive sensors/materials
- Disease epidemiology
- Sustainable energy technologies



Better Forecast Behavior of Complex, Rapidly Changing Systems





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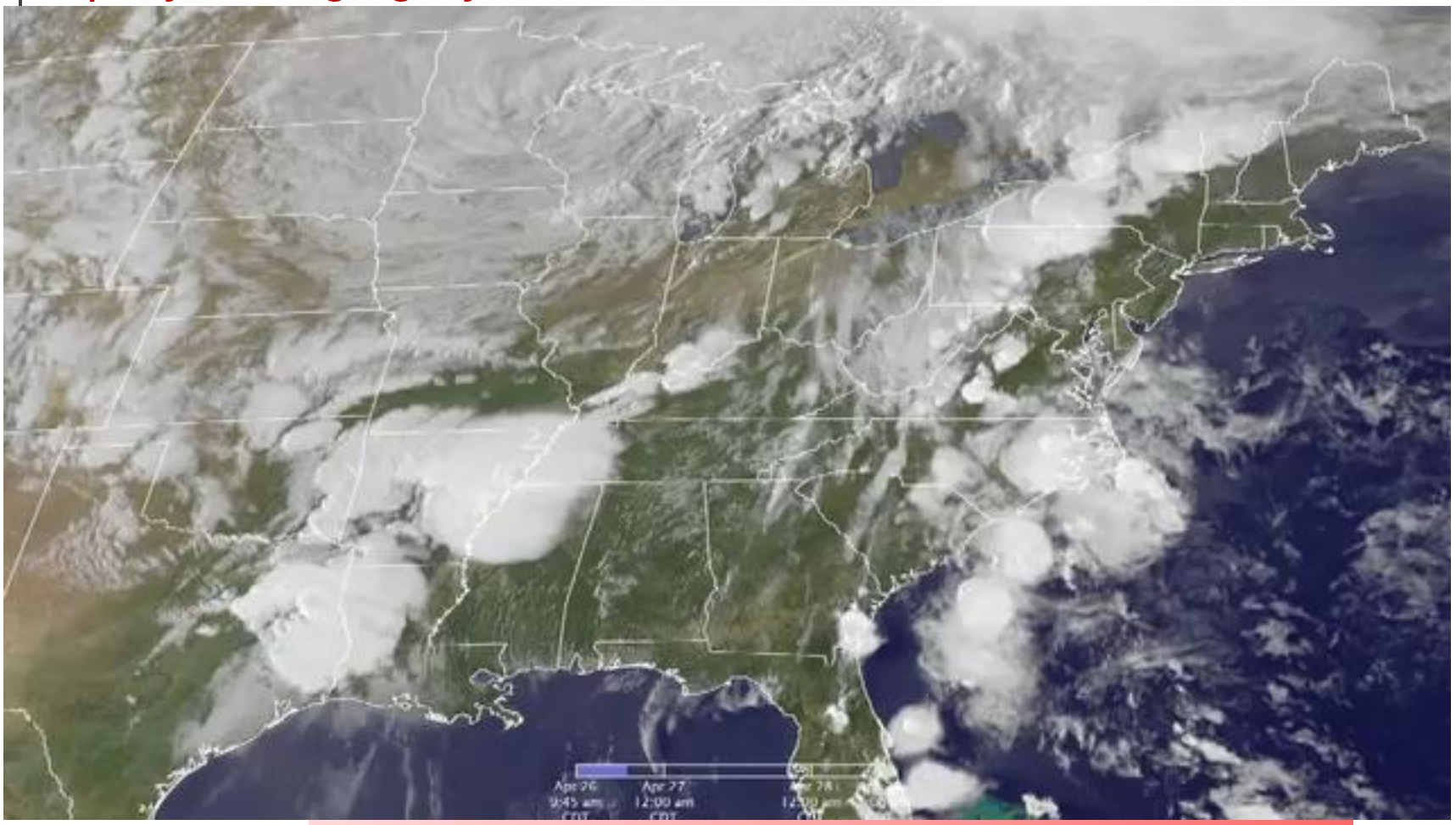
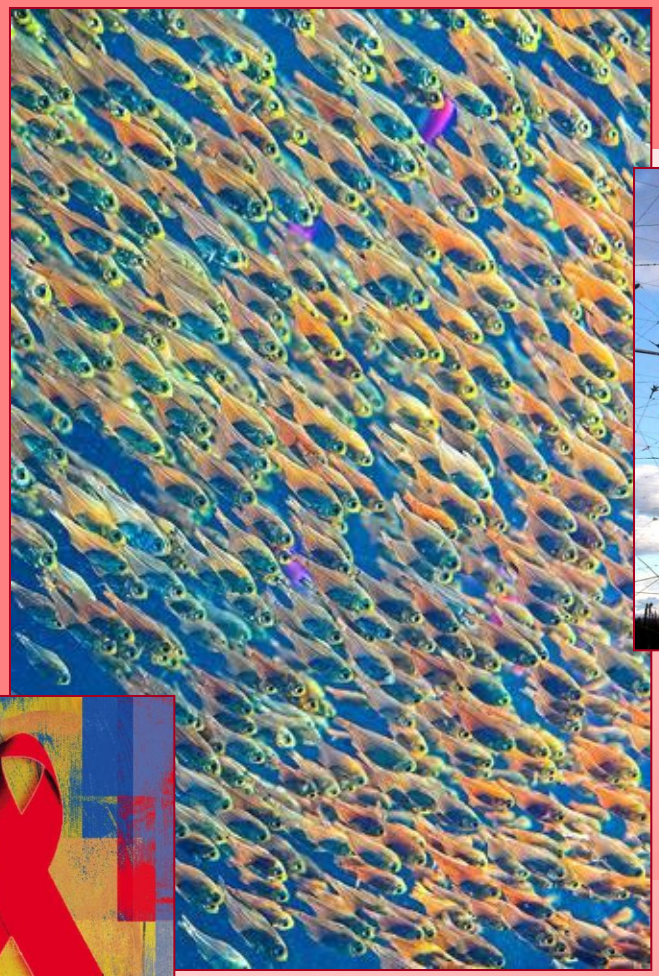
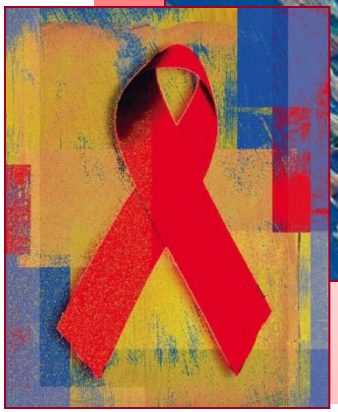


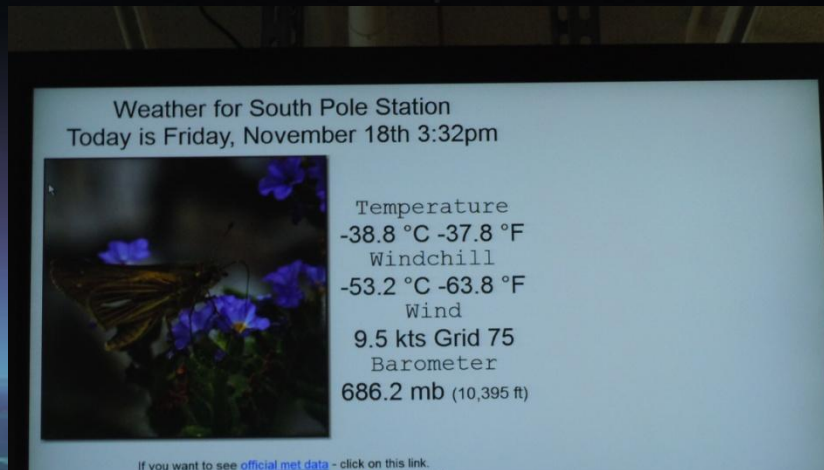
Natural sciences along with social/behavioral sciences

Improve Predictions of Collective Behavior



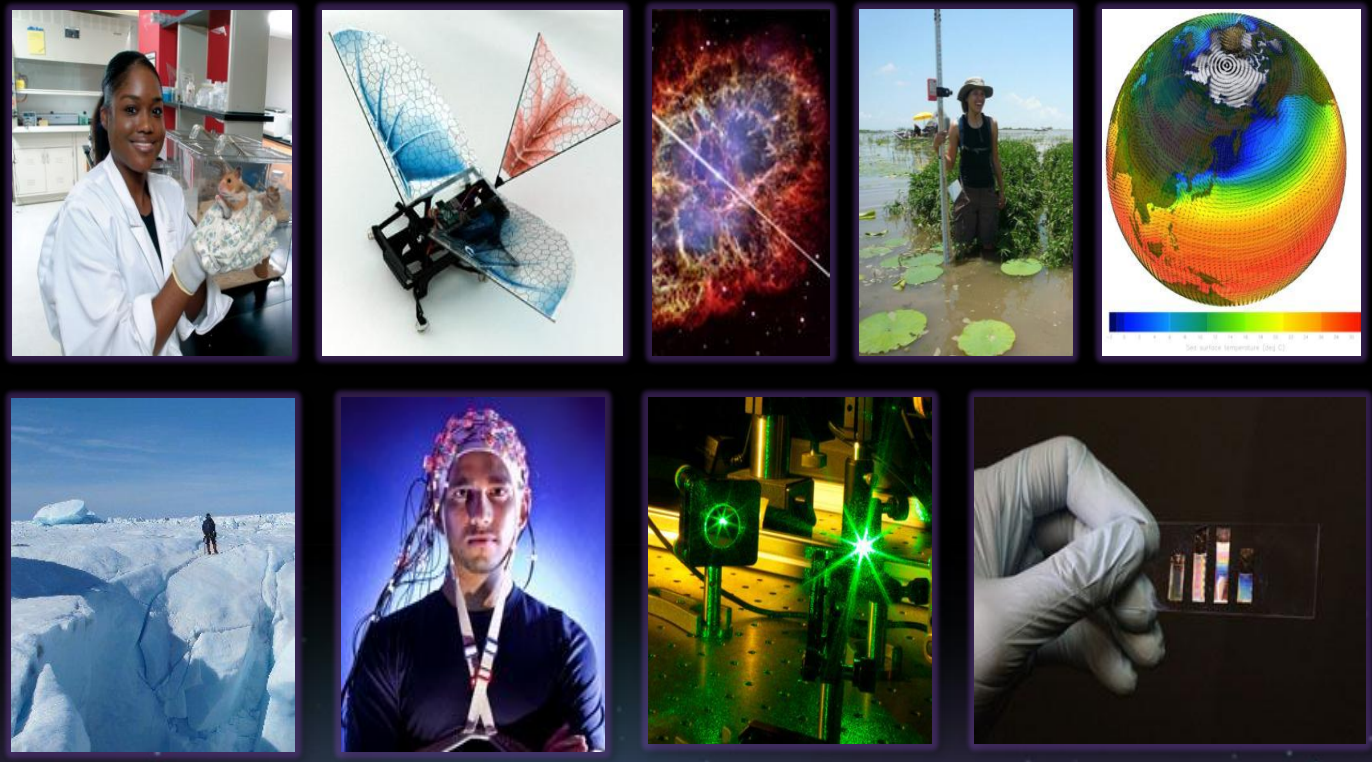


Polar programs: Risks & rewards



Better Understand Structural Tendencies of Non-orderly Appearing Phenomena

Fundamental Science and Engineering Research and Education

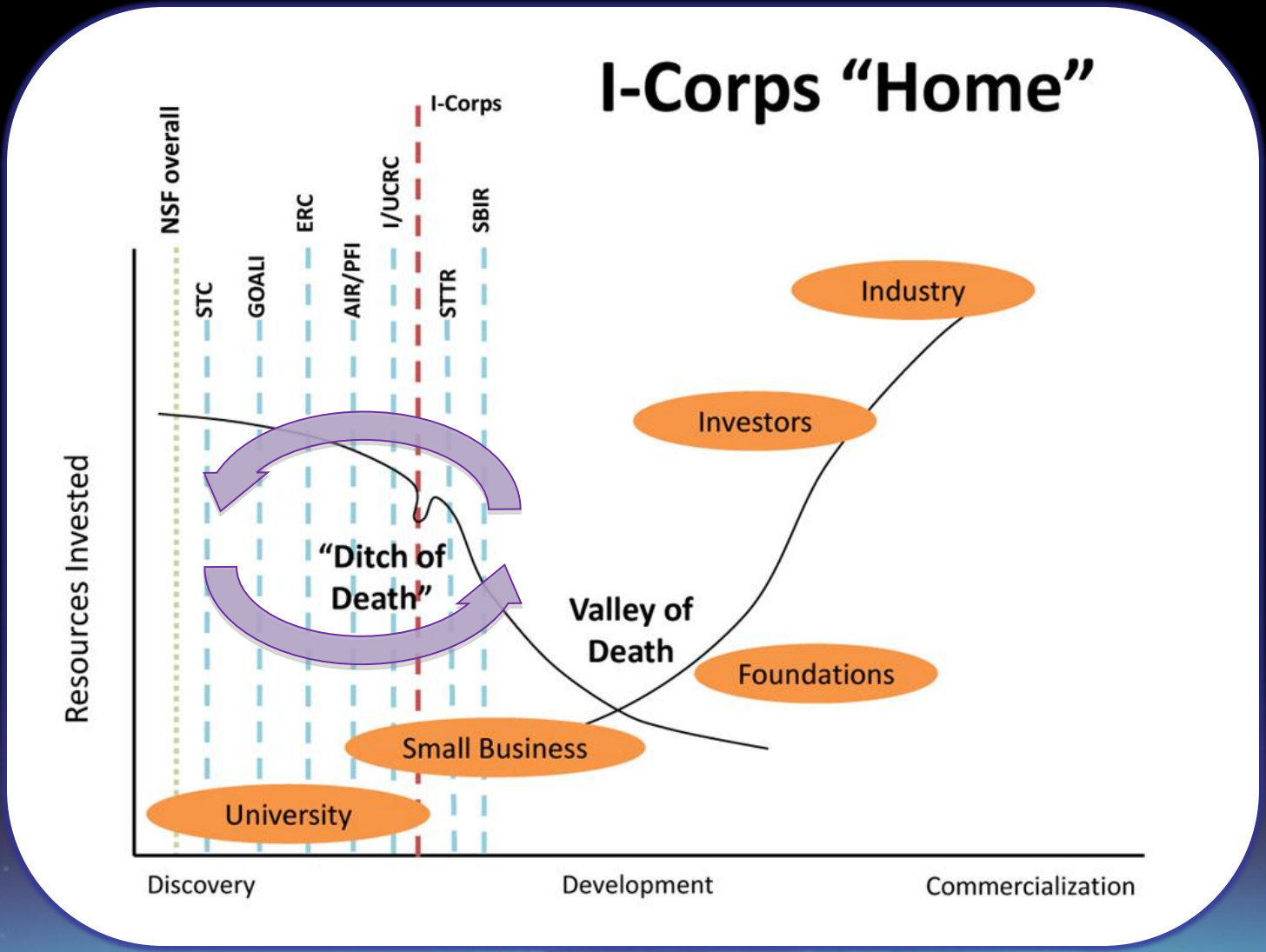


Investing in NSF core programs to drive progress in science, technology and innovation

Principled commitment to support young scientists and to broaden participation

Innovation Corps (I-Corps)

Launched July 29, 2011



SAVI: Science Across Virtual Institutes

Launched October 5, 2011

NSF Career-Life Balance Initiative

Launched September 26, 2011

Global Science Engagement and Cooperation

Global Science

- Identify and implement shared principles for collective action amid stiff global competition
- Leverage better for leadership during times of severe fiscal constraint

GLOBAL SUMMIT ON MERIT REVIEW

GLOBAL RESEARCH COUNCIL

Inaugural Summit at NSF
May 2012
Arlington, VA

Next meeting…….

Co-hosted by Brazil and Germany

Berlin, 28-29 May, 2013

Good science anywhere is good for science everywhere provided that ……

NSF RAPID Awards Aimed Squarely at Risk

Deepwater Horizon Oil Spill

Key information:

- Extent of the plume
- Composition of the oil mixture

RAPID award deployment of the NSF-funded underwater vehicle ***Sentry*** in the Gulf of Mexico.

NSF RAPID Grants Address Risk & Uncertainty

Deepwater Horizon Oil Spill

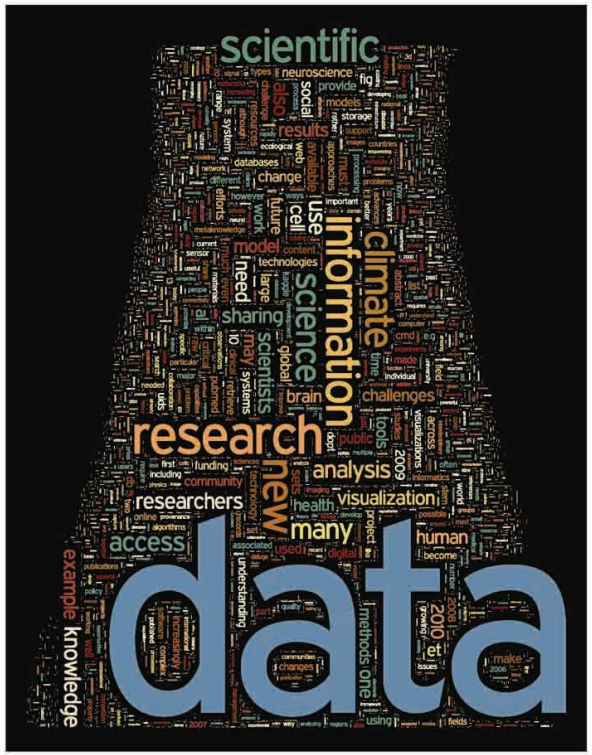
Total RAPID Awards: >70

RAPID Awards: $9M

Total Ship Costs: >$5M

Explosive Growth in Size, Complexity, & Data Rates

- **Enormous static or streaming data sets** are generated by modern experiments and observations
- **Automatic extraction of new knowledge** about the physical, biological , and cyber world continues to accelerate
- **Data-driven discovery is** revolutionizing scientific exploration and engineering innovations
- Multi-cores, concurrent and parallel algorithms, virtualization and advanced server architectures will enable **data mining and machine learning**, and **discovery and visualization**



A word cloud generated from all of the content from the Dealing with Data special section. From *Science* (Feb 11, 2011) 331 (6018). Reprinted with permission from AAAS.

Big Data & Sustainability Research

- Expeditions in Computing: Data-driven Understanding of Climate Change
- Coupled Natural & Human Systems: Understanding Consequences of Water-use Decisions in Arctic
- Earth Systems Modeling: A Regional Earth-system Model of the Northeast Corridor
- Water Sustainability & Climate: Regional Climate Variability & Patterns of Urban Development

Risk: Will We Have the Skilled People for Big Data?

"By 2018 the United States alone faces a shortage of 140,000 to 190,000 people with analytical expertise and 1.5 million managers and analysts with the skills to understand and make decisions based on the analysis of big data."

Source: McKinsey&Company (May 2011), "Big data: The next frontier for innovation, competition, and productivity." Available at: http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Big_data_The_next_frontier_for_innovation

NSF Strategy to Address Big Data

Scientific community building and governance

Cyber-infrastructure

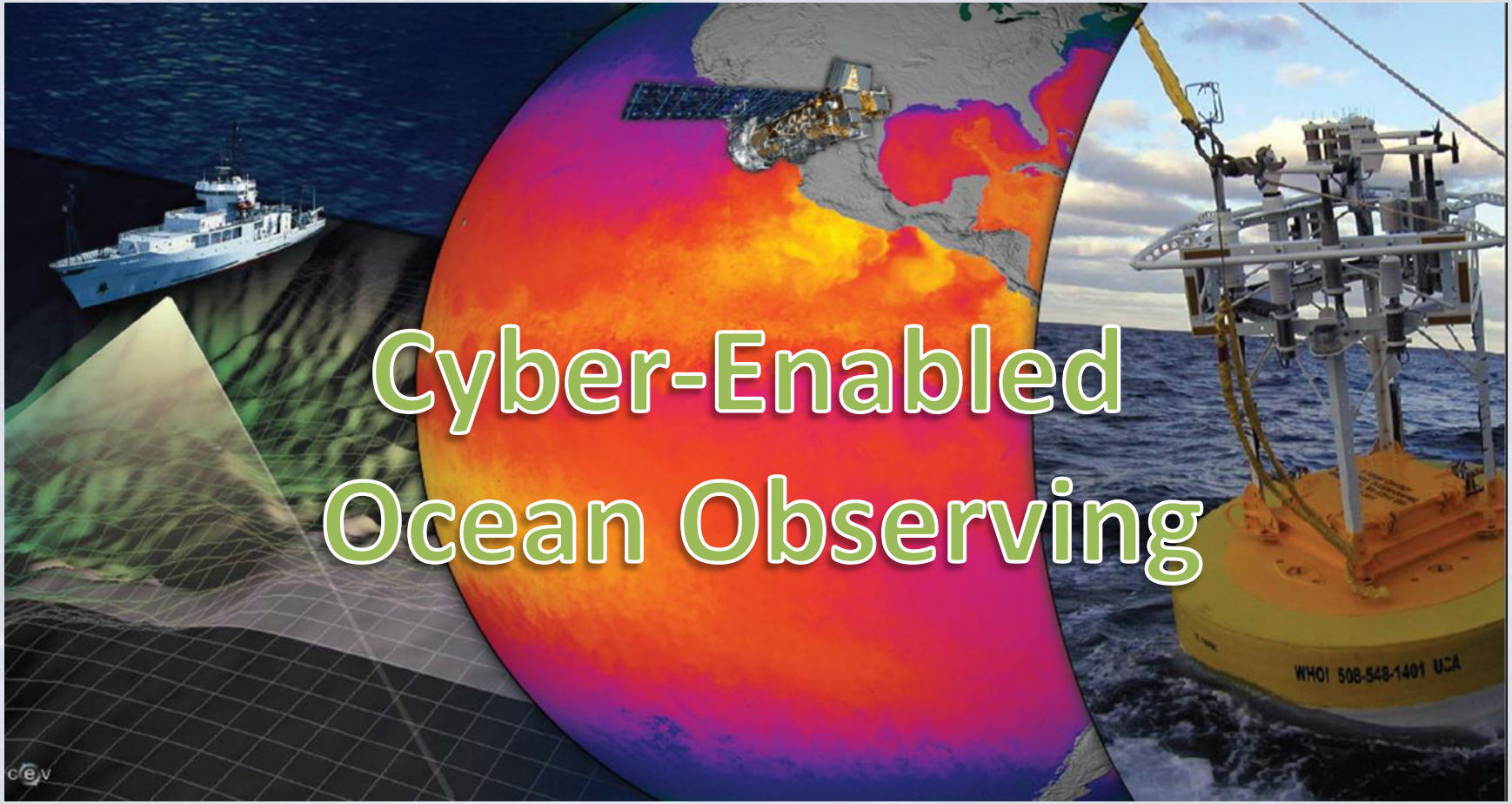
Foundational research

Education and workforce development

Prizes and competitions

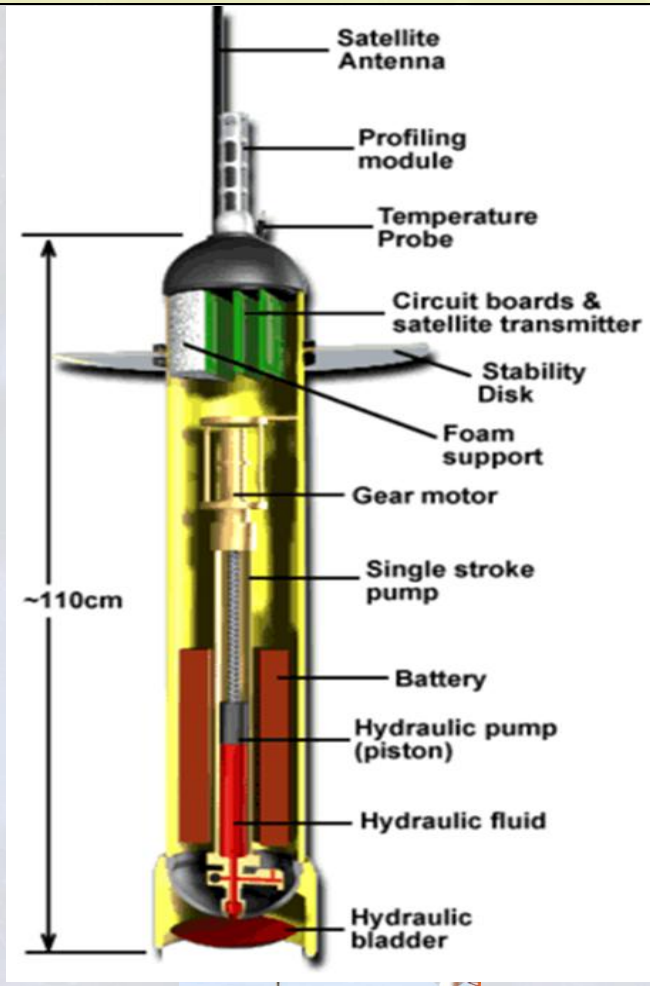
NSF Big Data Strategy

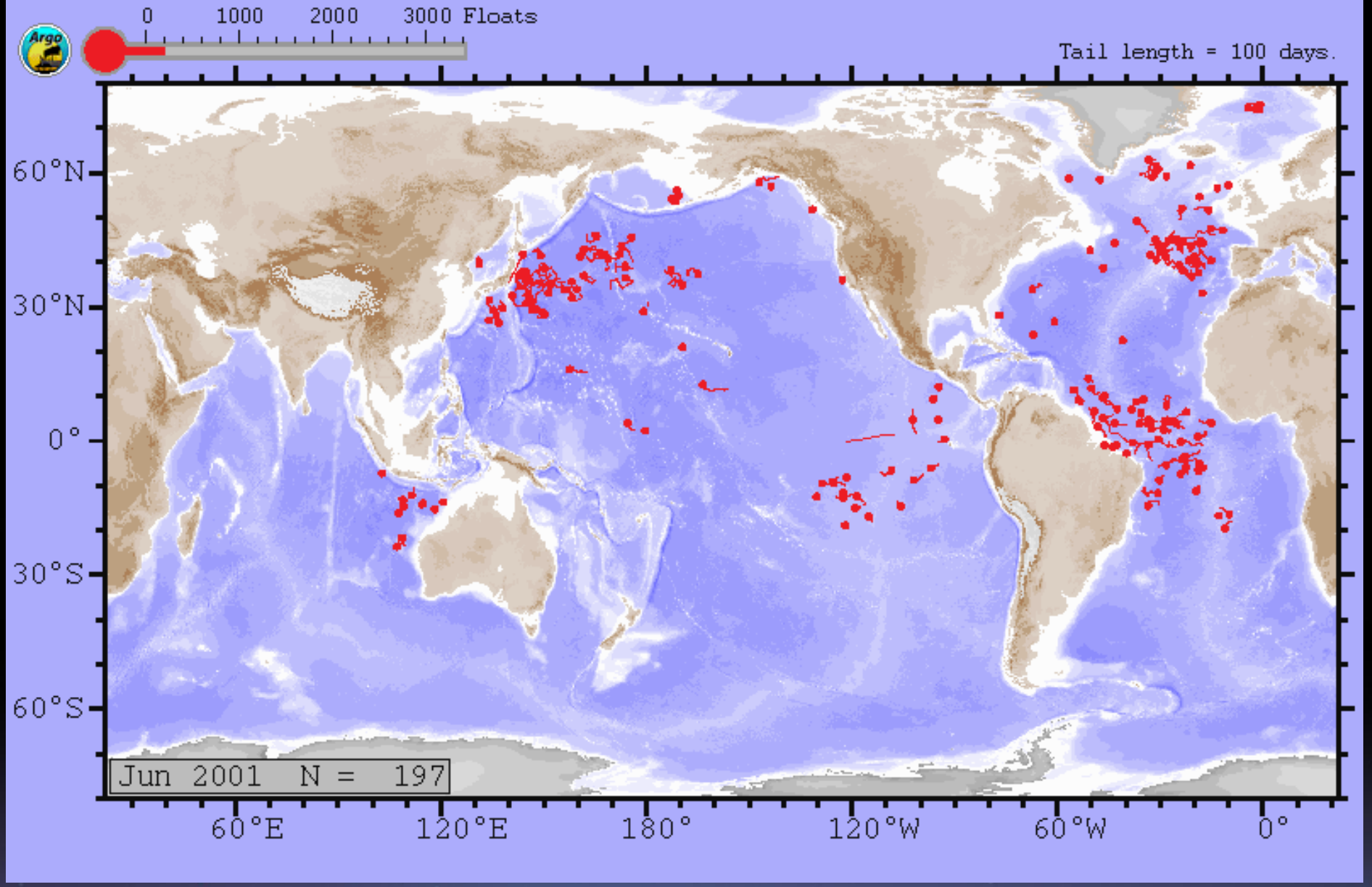
Understanding our ecosystem



Cyber-Enabled Networks

Made possible by more than three decades of float technology research.





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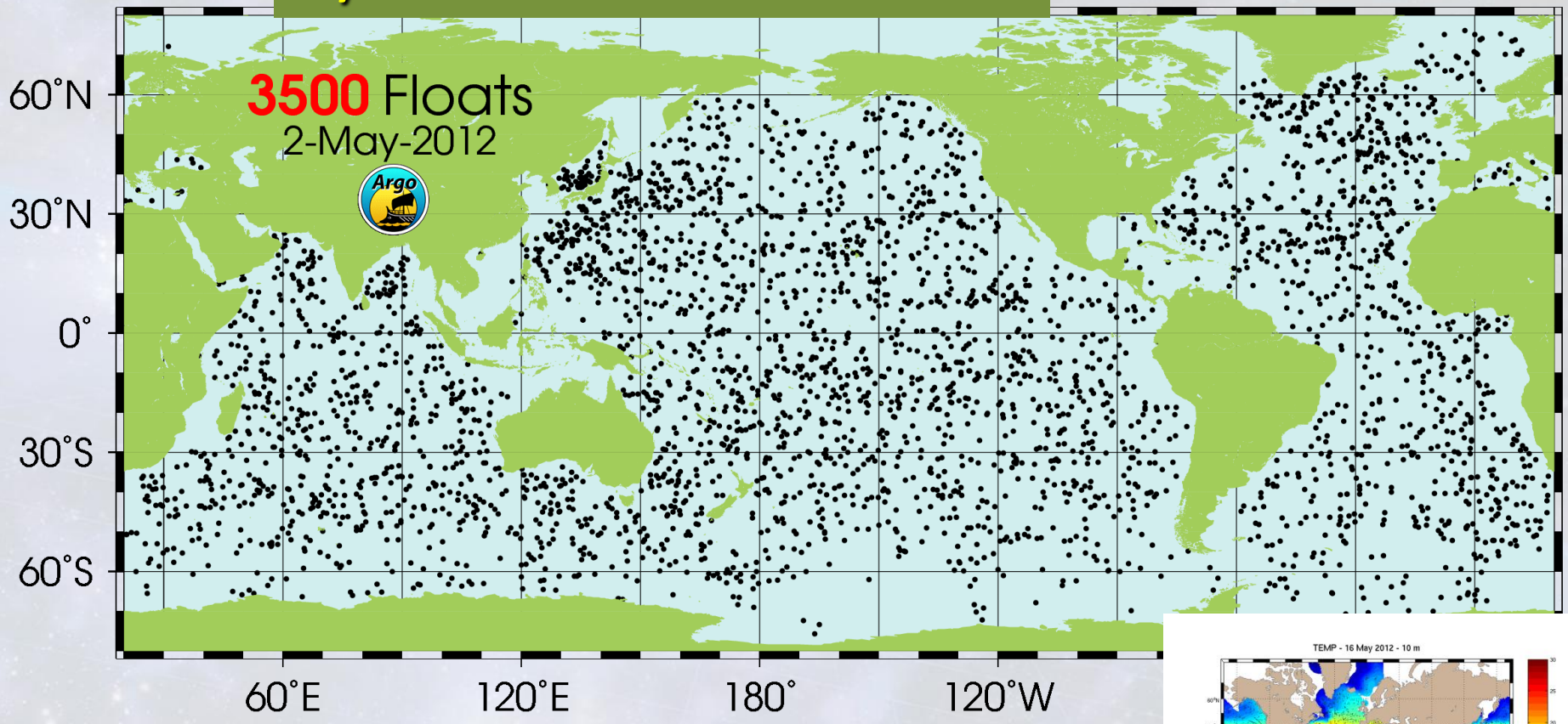
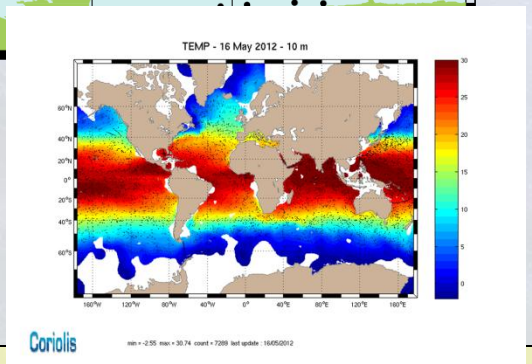




More than 50 NSF awards related to the network and its results…

Volcanic Eruptions

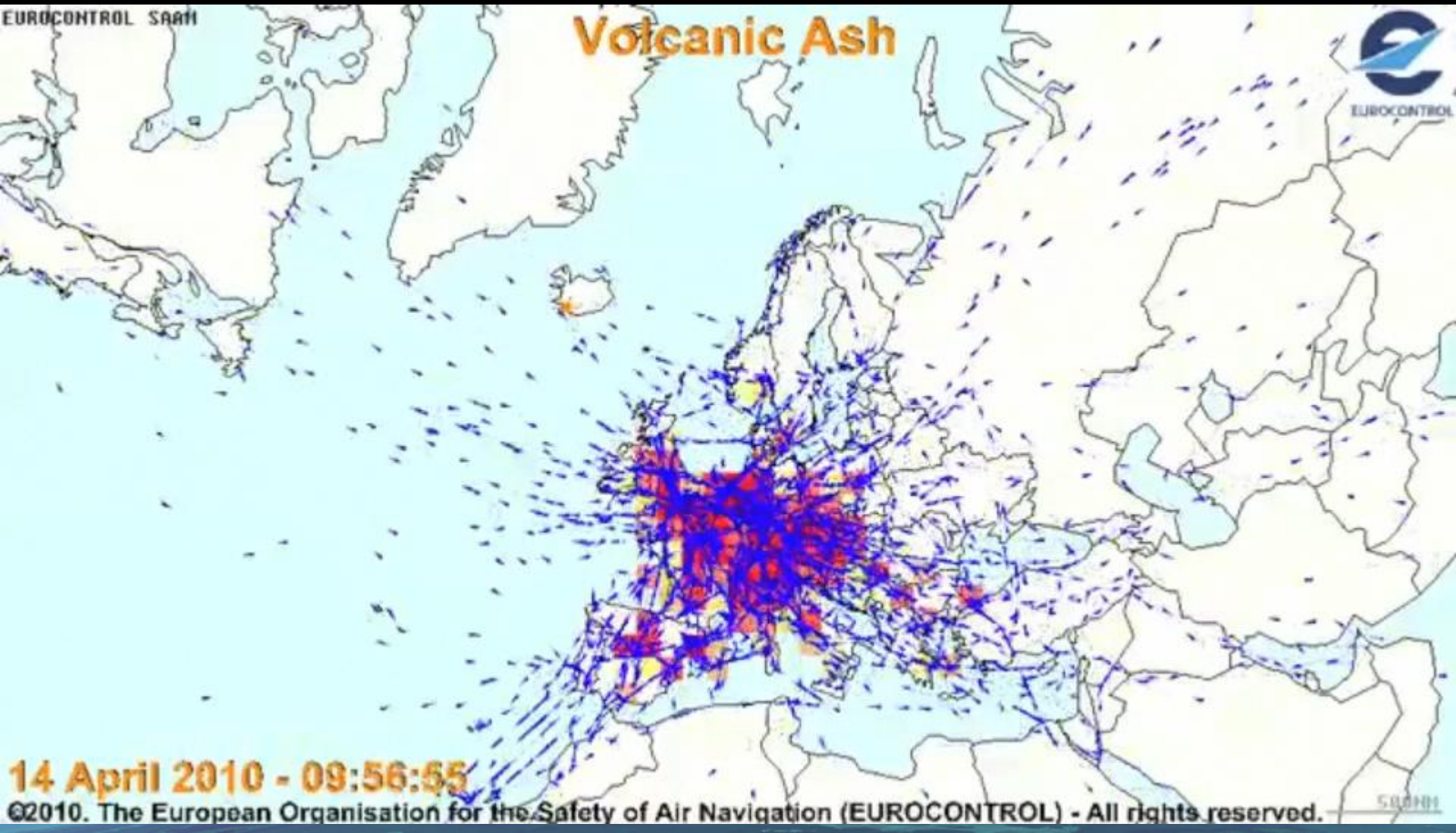
- 2010 eruption of Eyjafjallajökull
- Over 100,000 flights cancelled[1]
- $1.7B airline industry loss
- Four NSF awards (including two CAREER awards and a RAPID RUI)

Photo by Bjarki Sigursveinsson

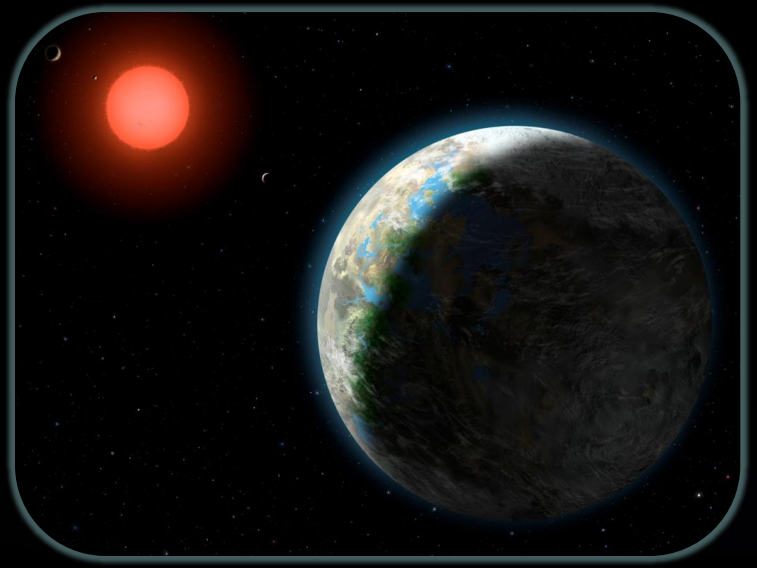
[1]http://www.eurocontrol.int/articles/volcanic-ash-cloud-timeline-2010-events

Volcanic Ash and Plane Tracks

(courtesy of ITO Data Visualizations/EUROCONTROL)



New Era of Science



Era of Observation
(Theory, experiment, computation, “citizen science”)

Era of Data and Information