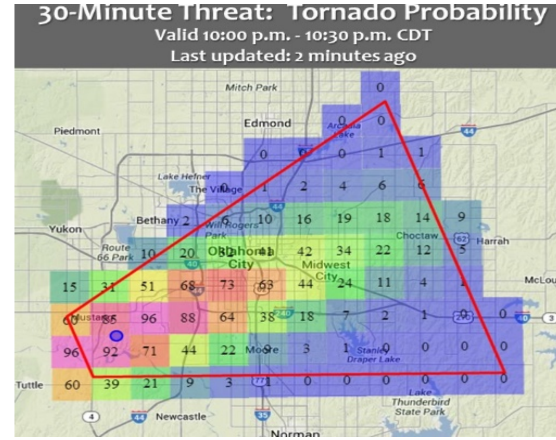
Environmental Information in Every Decision

NASA's Earth Science DISASTERS



Philip Ardanuy, INNOVIM

David Green, NASA Science Mission Directorate, Earth Science Division

Applied Sciences Disaster Program

George Komar, NASA Earth Science Technology Office

Steve Marley, JeTSI

Peter Neilley, The Weather Company – An IBM Business

Carl Schueler, Schueler Consulting

Environmental Information in Every Decision

- Envisioning the "To Be" State
- Global Changes; Evolving Societal Needs
- Technological Advances and Maturation
- Intersections
- Realizing the Vision

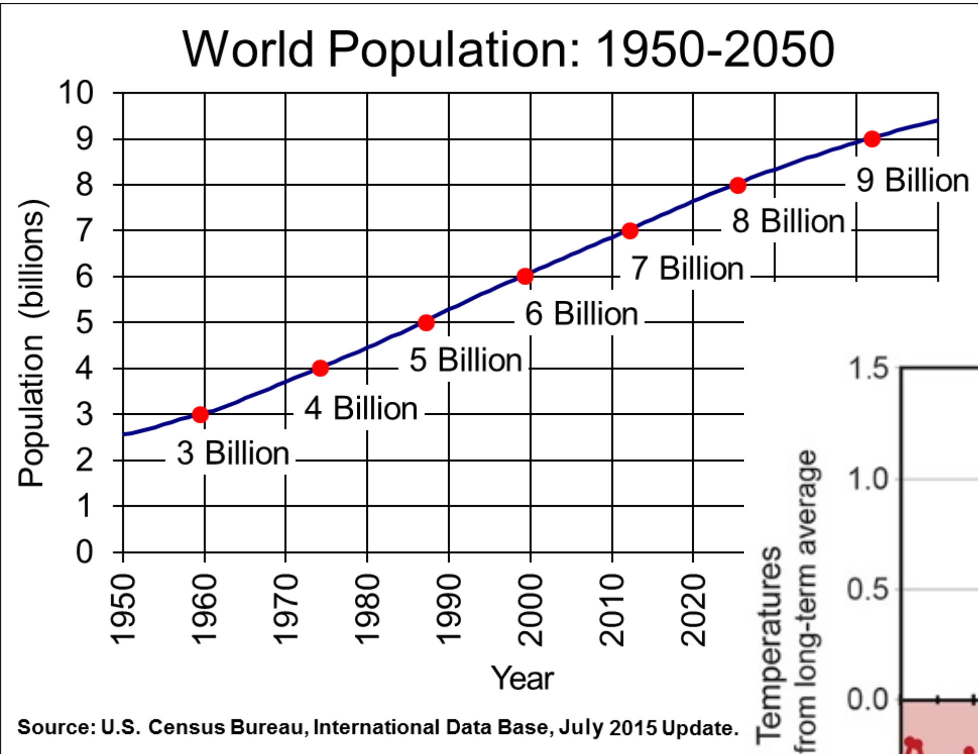
Envisioning the "To Be" State

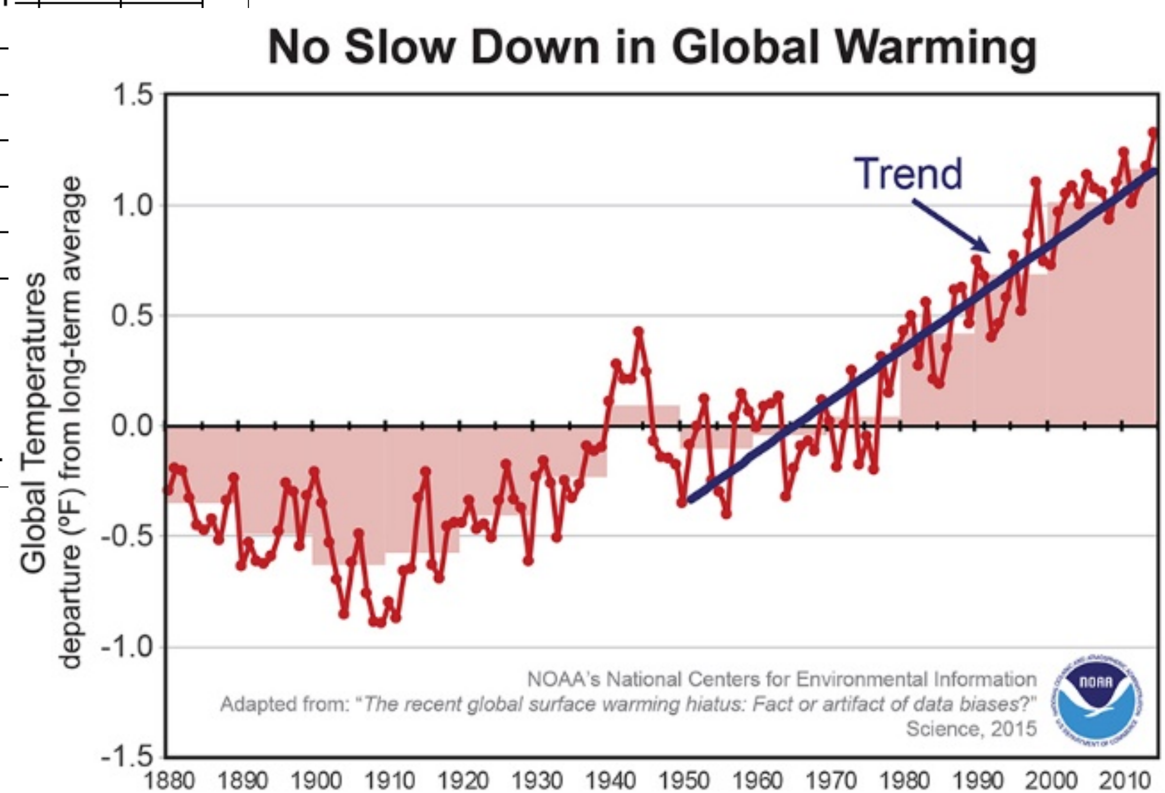
- Guiding vision statements are important, defining the future world we expect to interact with
- Bill Gate's vision statement, "***A PC on every desktop***," was simple, and gave Microsoft the broad scope to innovate
- Our vision is:

BMW Dynamic Light Spot (DLS)
Photo credit: bmwblog.com

"Environmental Information in Every Decision"

Global Changes; Evolving Societal Needs





Contrary to much recent discussion, the latest corrected analysis shows that the rate of global warming has continued, and there has been no slow down

Photo credit: US Census Bureau, NOAA

Global Changes; Evolving Societal Needs

POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

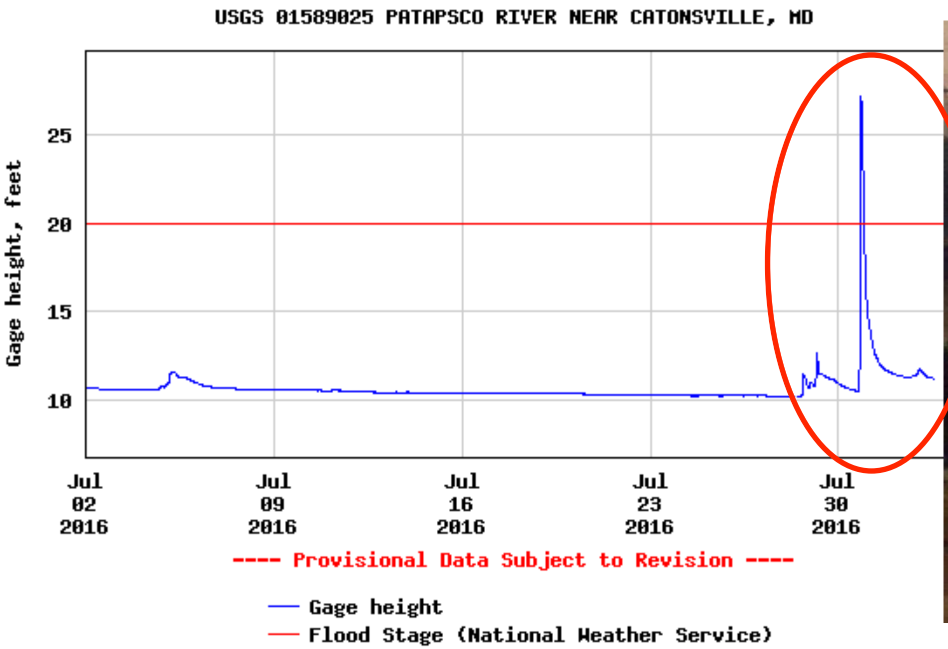
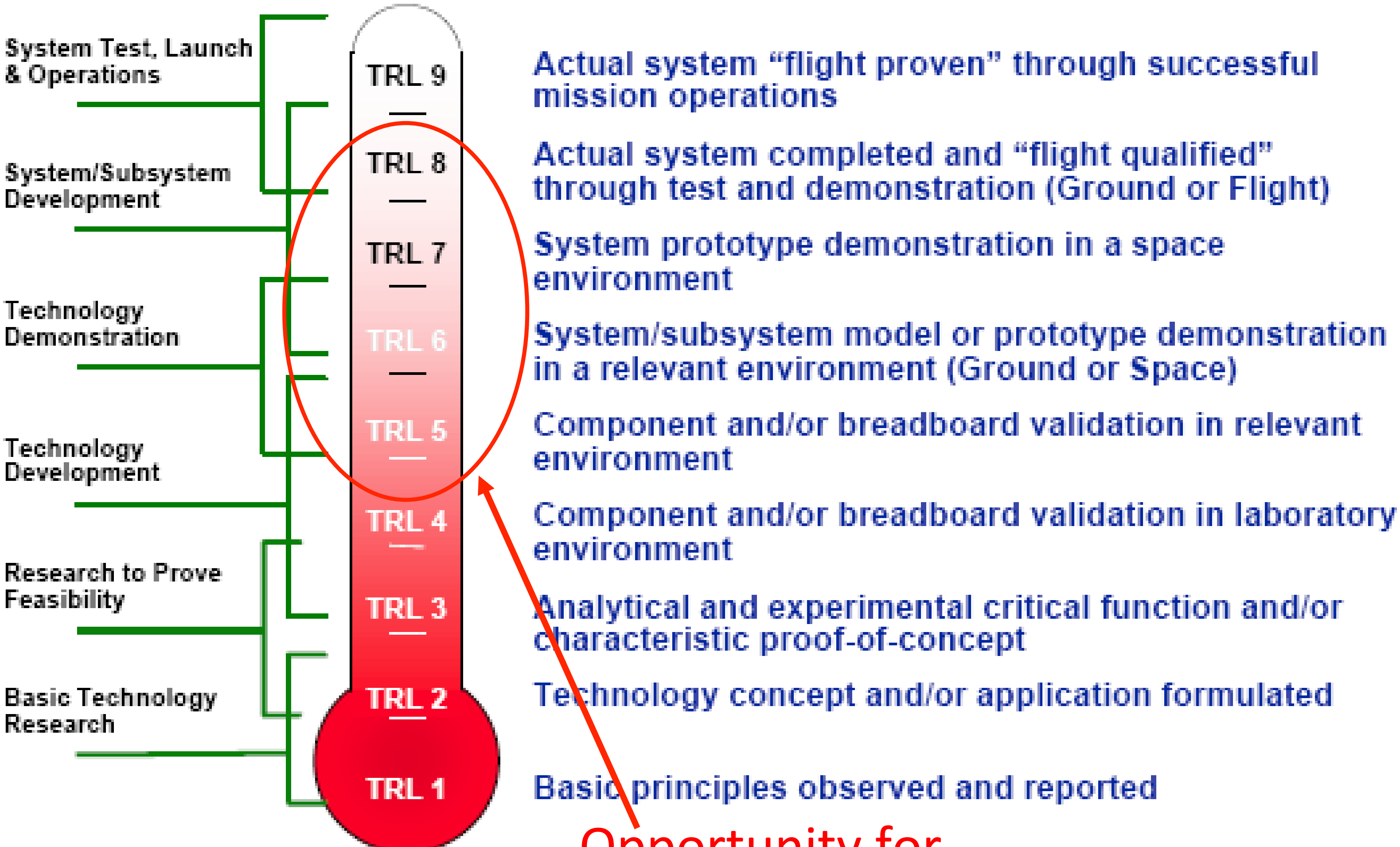


Photo credit: USGS, http://environmentalgeography.blogspot.com/ and http://hococonnect.blogspot.com/2016/08/a-tale-of-two-rivers-and-some-thoughts.html

Technological Advances and Maturation



Opportunity for technology transition

Photo credit: NASA

"From Research to Operations in Weather Satellites and NWP: Crossing the Valley of Death" (2000)

- "In the 1970s, in an effort to assist in the transition of satellite observational data from research to operations, NASA conducted the Operational Satellite Improvement Program (OSIP) that was responsible for developing new instruments for environmental satellites
- In this program, NASA developed the prototype instruments, flew them frequently on high altitude aircraft missions for a preliminary checkout, and then deployed them on research spacecraft for a complete evaluation
- Successful instruments were then available for transition to the operational NOAA satellite series
- For budgetary and mission clarity reasons, NASA canceled the program in 1982
- NOAA never developed a replacement for OSIP; instead, it continued with a procurement practice of specifying the instrument performance and having the contractor deliver the instrument for flight on the operational satellites
- This procedure did not allow for the iterative development process that was so successful in the OSIP program "

“Lessons Learned From the GOES Experience”

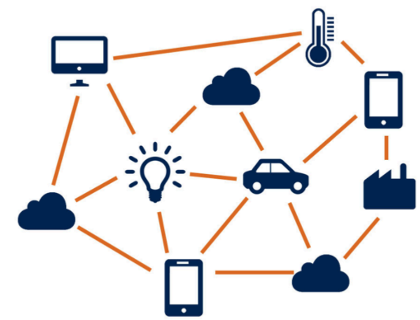
- U.S. Congress, Office of Technology Assessment, "**The Future of Remote Sensing from Space Civilian Satellite Systems and Applications**,“ OTA-ISC-558 (Washington, DC: U.S. Government Printing Office, July 1993)
- *“If Congress wishes NASA to continue to engage in research and development for NOAA's operational sensors and satellites, it could direct NASA to reinstate the OSIP budget line for sensor development and provide sufficient funds to support OSIP.*
- *In addition, Congress could direct NASA and NOAA to develop a more effective relationship for the development of new operational systems.*
- *Alternatively, Congress could fund NOAA sufficiently to allow NOAA to develop its own sensors*.”

Seven Emerging Sea Changes in Environmental Information Processing

- Internet of Things
- Cognitive Sciences
- Multi-disciplinary decision making
- Emergence of the private sector
- Ubiquitous low-cost computing
- Miniaturization of Flight Systems
- Exascale computing

1. The Internet of Things

- Plethora of connected devices with the ability to:
  – Sense their local environment
  – Share the information they collect
  – Receive information from other sources
  – Process data in the device
  – Make, communicate and/or act on decisions autonomously.



- Each device's primary purpose is often not environmental monitoring: e.g. smartphones, automobiles, aircraft, surveillance cameras etc.
- Often enables new decisions, rather than replacing an existing decision process
  – A ”smart” building proactively managing its internal environment
  – A “smart” car initiating traction control based on improved strategic road info; identifying pedestrians in night vision and alerting driver
  – A farmer's management system making strategic irrigation decisions

2. Cognitive Sciences

- Rapidly improving ability of artificial intelligence
  - Natural language processing enabling effective interaction with humans and human information
  - Ability to understand unstructured data (e.g. images, video, written information) effectively.
  - Adaptive reasoning based on the environment.

- The self driving car is a perfect example of an environmental sensor with local cognitive computing and decision making.
- Enables an entirely new generation of uses of environmental information previously not even conceived.

3. Multi-disciplinary decision making

- Single discipline stovepipes rapidly breaking down.
- The most effective decisions employ intelligence from multiple sources and sciences.
- For example, effective agricultural management may require deep understanding of :
  - Environment sciences
  - Economic and societal sciences
  - Information technologies
  - Civil engineering

4. Emergence of the Private Sector

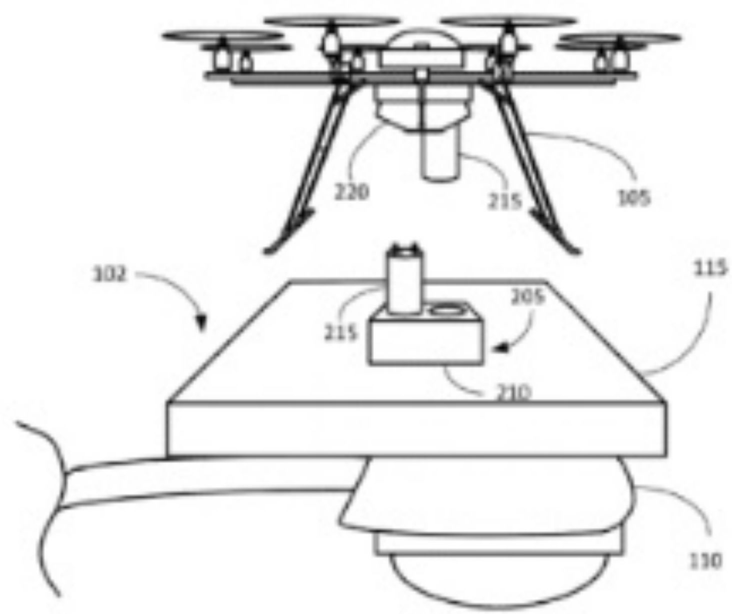
- Private sector rapid adoption of technologies unlocks immense new value in environmental information
- Enables private investment in systems and technologies previously afforded only by governments, e.g.
  - Space borne observing systems
  - High performance computing systems
  - Communication systems
- More rapid deployments of new capabilities
- New social fabric in access and use of environmental information that will likely rapidly evolve in coming decades.

5. Ubiquitous low-cost computing

- Processing power will move to the edge
  - Current State - Operational Science is predominantly performed either centrally (NSOF, NCEP, ECMWF, UKMet) or at a fixed number of sites (e.g. WFO's)
  - Future State – Processing capacity for "Value Added" science will be ubiquitous via cloud. Anyone, can access the data and provide product

6. Miniaturization of Flight Systems

- Increased transition to smallsats and cubesats
- ESSP and EV instruments and missions
- Disaggregation into formations and trains
- Nanosensors and drones



Amazon was awarded U.S. patent number [9387928](9387928) for UAS docking stations that can be attached to structures such as telephone poles or street lamps. Courtesy http://theuavdigest.com/tag/amazon/

7. Exascale Computing: In a Decade
~2025 NCEP 1 km global Grid

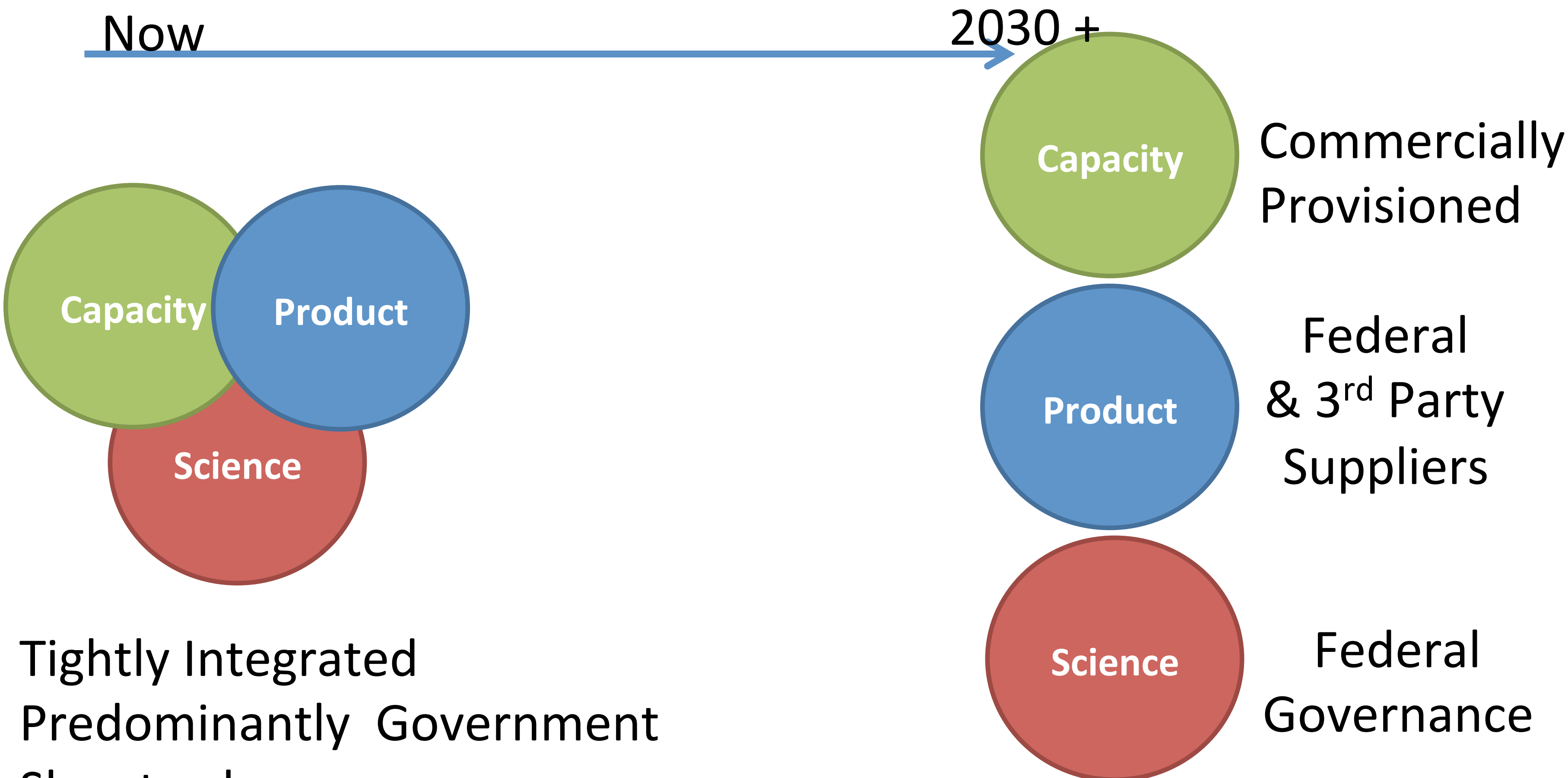
35-year Reanalysis	Resolution	Data Size
MERRA and MERRA2 – Current NASA reanalysis	50 KM	400 TB
Current NASA operational resolution	25 KM	1.6 PB
Current NOAA operational resolution; 15 of 35 years will be complete by this fall (2015 – THIS YEAR)	12 KM	6.4 PB
Cloud permitting models, still parameterized (currently have a 2 year simulation)	7 KM	26 PB
Current high resolution climate runs (currently have a 3 month simulation)	3 KM	102 PB
Resolving deep convection – currently simulate 1 model day per wall clock day (model climate in real time)	1 KM	410 PB
Cloud permitting – need cloud and coupled ocean atmosphere models	0.75 KM	1.6 EB

What are the derived satellite data assimilation requirements to best initialize this model and maximize forecast skill?

Consequence for Government

- Federal Government has traditionally controlled the quality of operational science through being the sole-source.
- As processing becomes ubiquitous, governance of operational science needs to move away from the products, and be focused on the algorithms that generate the products, so that 3rd parties can generate customer tuned products based on authorized/governed algorithm templates
- Federal Government will still dominate primary citizen services (e.g. alerts/warnings)

Operational Science



- Tightly Integrated
- Predominantly Government
- Slow to change

- Loosely Integrated
- Multiple Providers
- Agile to end-user needs

Case Study: The National Water Model

	Analysis & Assimilation	Short-Range	Medium-Range	Long-Range
Cycling Frequency	Hourly	Hourly	Daily at 06Z	Daily Ens (16 mem)
Forecast Duration	- 3 hrs	0-15 hours	0-10 days	0-30 days
Forecast Latency (latency of external forcing data accounts for most of delay)	1 hour	1 hour 45 mins	6 hours	19 hours
Meteorological Forcing	MRMS blend/ HRRR/ RAP bkgnd.	Downscaled HRRR/RAP blend	Downscaled GFS	Downscaled & bias-corrected CFS
Spatial Discretization & Routing	1km/250m/NHDPlus Reach	1km/250m/NHDPlus Reach	1km/250m/NHDPlus Reach	1 km/NHDPlus Reach

Assimilation of USGS Obs

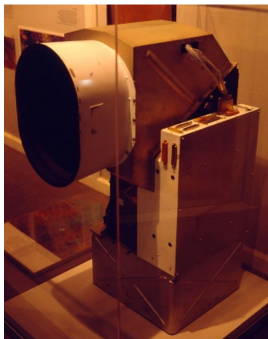
Reservoirs (1260 water bodies parameterized with level pool scheme)

What are the derived satellite data assimilation requirements to best initialize this model and maximize forecast skill?

Case Study: NASA Contributes through all Phases of the Disaster Cycle

Case Study: Agricultural Security

Landsats 1-5 MultiSpectral Scanner (MSS)



Landsats 4-7 Thematic Mapper (TM)

Landsat 8 Operational Land Imager (OLI)

Current technology cannot meet future agricultural requirements

- Expensive (Landsat-8 $855m)
- Weekly 30m data: Precision Farming desires daily 3m data
- Daily Landsat 30m data requires 12 Landsats
- 3m data cannot be generated by Landsat

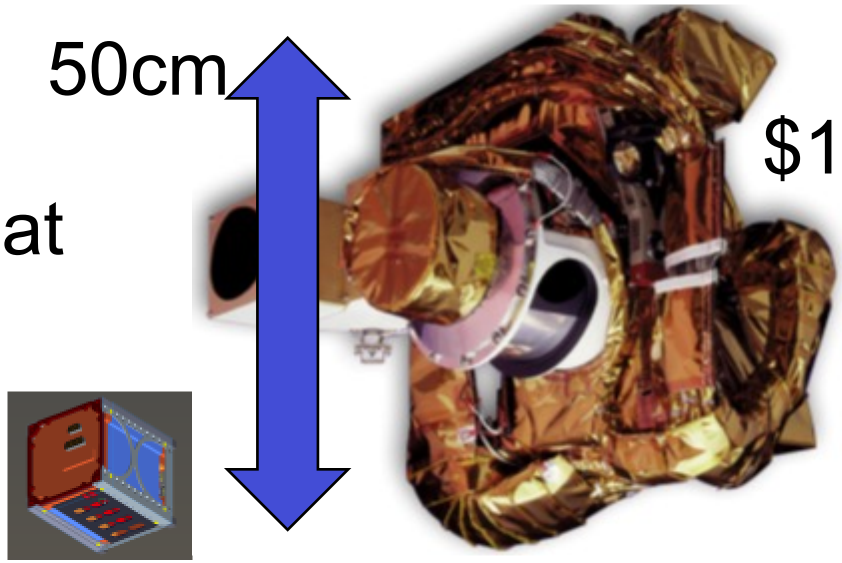
Landsat 1972-2016: MSS, TM, & OLI

SeaHawk--HawkEye: Nearly Two Orders-of-Magnitude Cost & Mass Reduction

50cm

$2M CubeSat HawkEye

1kg

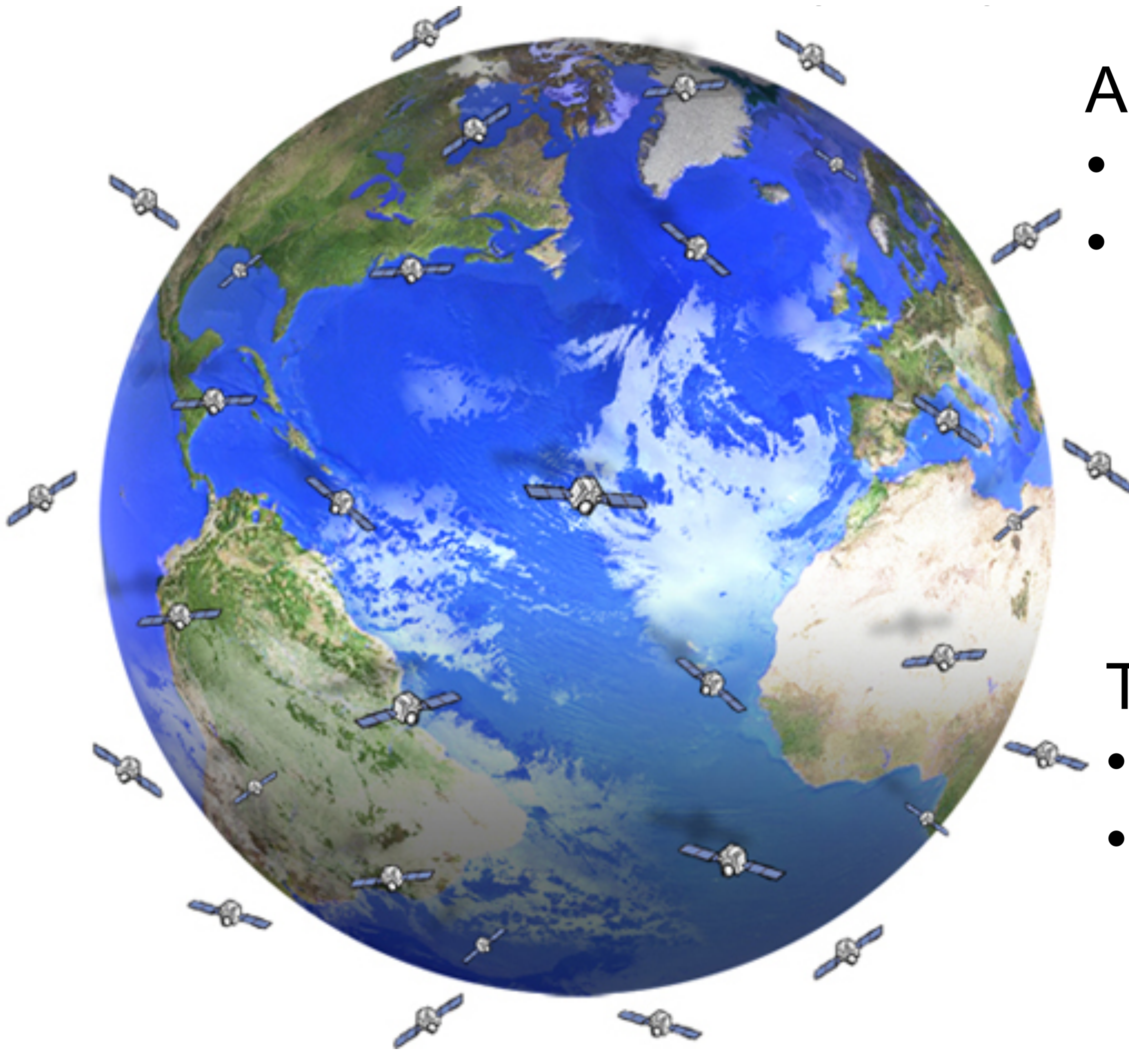


$100M SeaWiFS

50kg

Parameter	HawkEye	SeaWiFS	Comment
Cost ($M)	2	100	Including Spacecraft and Launch
Mass (kg)	0.87	46	SeaWiFS scanner + 24kg electronics (not shown)
Dimensions (cm) Volume (liters)	10x10x10 1.25	51x51x51 125	SeaWiFS Scanner only
Power (Watts)	18	88	
Data Rate (Mbps)	40	2	
IFOV (urad) GIFOV (m)	140 135@705km	1560 1100@705km	HawkEye 120m at 540km SeaHawk orbit
Spectral Bands	Eight vis/NIR	Eight vis/NIR	HawkEye matches SeaWiFS spectral bands
Swath (km)	400@705km	2800@705km	HawkEye swath 350km at 540km orbit

Intersection of Agricultural Requirements & Remote Sensing



Agriculture:
- 3m Spatial resolution
- Daily global coverage

Technology:
- 50 20x20cm NanoSats
- 10% Landsat-8 cost

Future Intersections

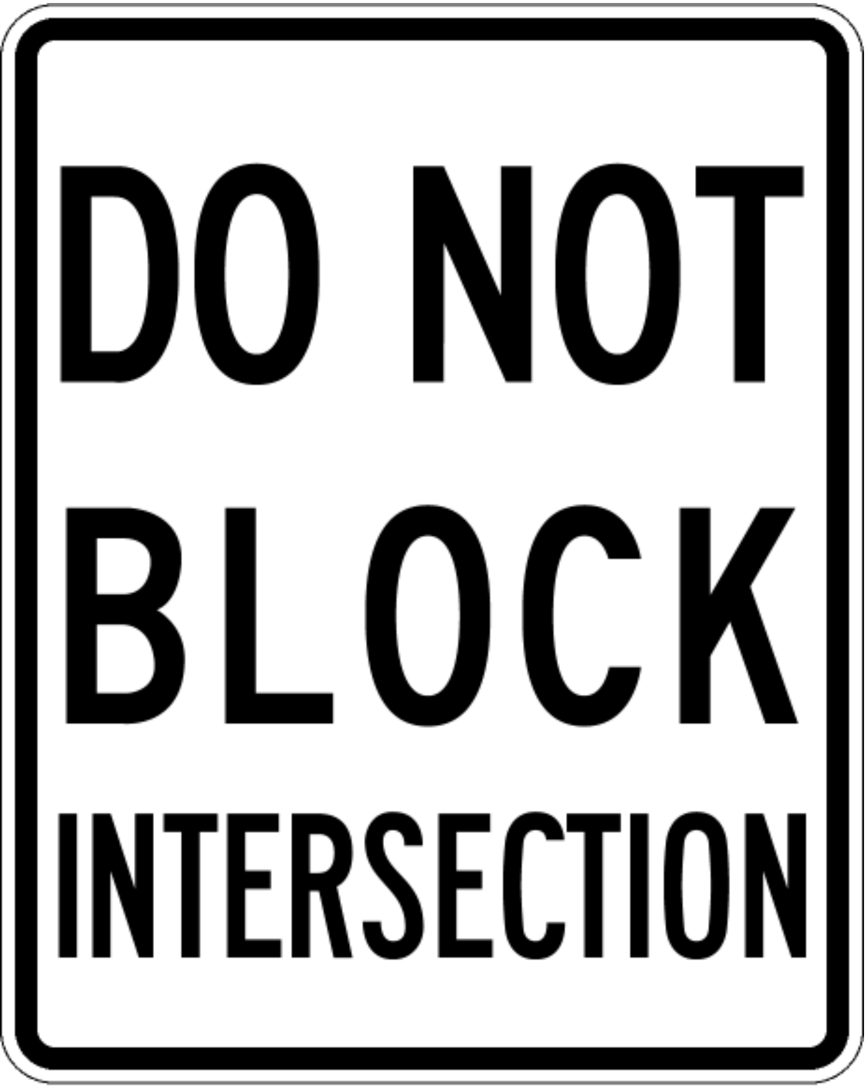


Photo credit: http://www.trafficsign.us

- We must expect new intersections between evolving societal needs and exponentially increasing technological maturities…
- We must have the agility to create and seize opportunities at those singular points in time when requirements, architectures, and designs are frozen…
- These determine the development and operations, for the…
- **next three decades**