National Aeronautics and Space Administration

NASA

Office of the Chief Technologist
NASA Langley Reseach Center

W. Keith Belvin



Emerging Technologies and Potential Impact for the NASA Mission

Presented at the AIAA SciTech Emerging Technologies Panel Session
Jan. 13-17, 2014



Four NASA Mission Areas



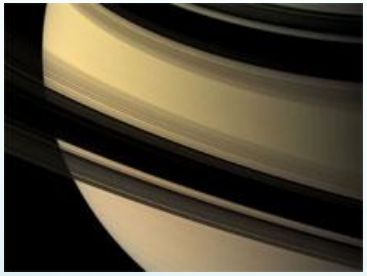
Aeronautics Research

Enable a safer, more secure, efficient, and environmentally friendly air transportation system.



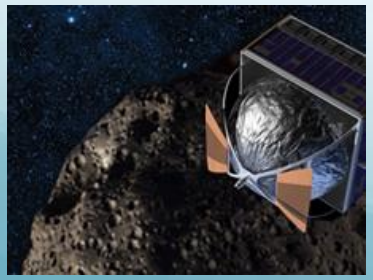
Human Exploration and Operations

Operate the International Space Station and prepare for human exploration beyond low Earth orbit.



Science

Exploring the Earth-Sun system, our own solar system, and the universe beyond.



Space Technology

Develop the crosscutting, advanced and pioneering new technologies needed for current and future missions, benefiting the aerospace industry and other agencies, and addressing national needs.

NASA Technology Area (TA) Roadmaps

TA01	Launch Propulsion Systems
TA02	In-Space Propulsion Technologies
TA03	Space Power and Energy Storage
TA04	Robotics, Tele-Robotics and Autonomous Systems
TA05	Communication and Navigation
TA06	Human Health, Life Support and Habitation Systems
TA07	Human Exploration Destination Systems
TA08	Science Instruments, Observatories and Sensor Systems
TA09	Entry, Descent and Landing Systems
TA10	Nanotechnology
TA11	Modeling, Simulation, Information Technology and Processing
TA12	Materials, Structures, Mechanical Systems and Manufacturing
TA13	Ground and Launch Systems Processing
TA14	Thermal Management Systems
TA15	Aeronautics

3

Some Important Tech Trends



Smart

- *Cognitive Computing*
- *Big Data Analytics*
- *Autonomous Systems*
- *Internet of Things*



Small

- *Military / Civil UAVs*
- *Personal Air Vehicles*
- *Satellites*
- *Sensors*



Sources

- *of ideas /solutions*
- *of funding*
- *of knowledge*
- *of air and space vehicles*

- ***Aero Systems***
- ***Robotic Space Exploration / Science***
- ***Human Space Exploration***

HRI 2013 TOKYO/JAPAN
March 3-6, 2013
8th ACM/IEEE International Conference on Human-Robot Interaction



Robots as Holistic Systems

8th ACM/IEEE International Conference on Human-Robot Interaction



Conference Topics

- Socially intelligent robots
- Robot companions
- Lifelike robots
- Assistive (health & personal care) robotics
- Remote robots
- Mixed initiative interaction
- Multi-modal interaction
- Long term interaction with robots
- Awareness and monitoring of humans
- Task allocation and coordination
- Autonomy and trust
- Robot-team learning



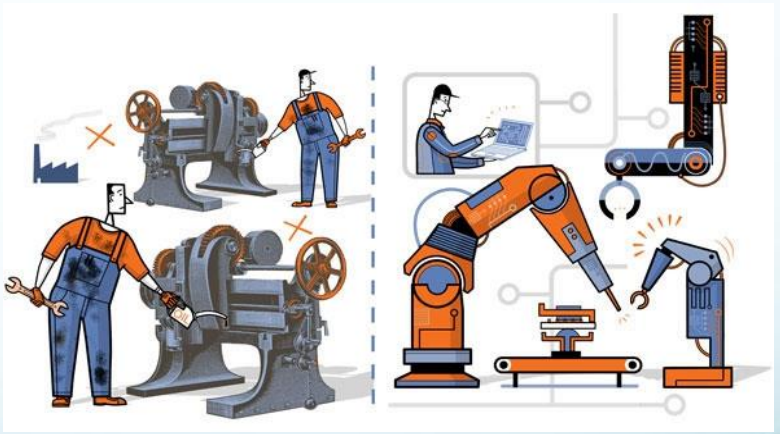
trends in … Robotics and Manufacturing

Smart

industrial revolution (early 19th century) -70 percent of American workers lived on the farm - automation eliminated all but 1 percent of their jobs - automation also created hundreds of millions of jobs in entirely new fields.

- ***3D printing***
- ***easy-to-use robots***
- ***collaborative manufacturing services***

Third Industrial Revolution



The wheel is almost coming full circle, turning away from mass manufacturing and towards much more individualized production.

Yes, Robots Are Coming for Our Jobs—Now What?: Scientific American
http://www.scientificamerican.com/article.cfm?id=yes-robots-are-coming-for-our-jobs-now-what&WT.mc_id=SA_CAT_SP_20130311
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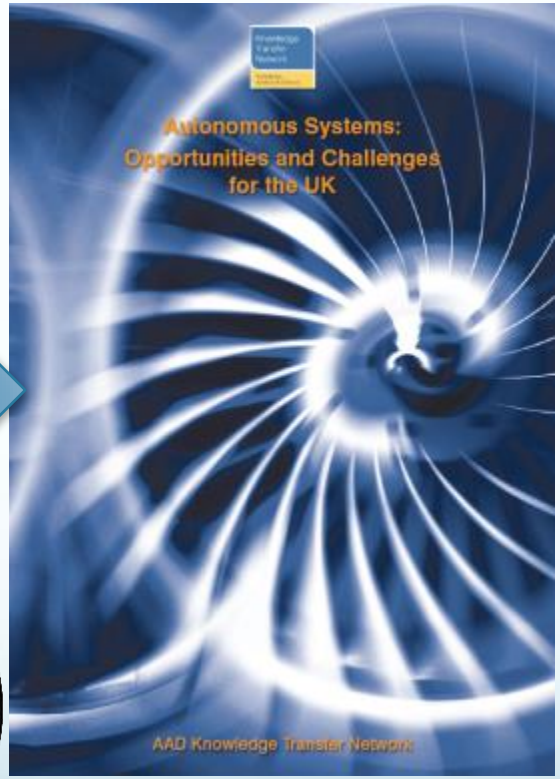
Autonomy - Can we trust it?

Smart



Medical and Surgery

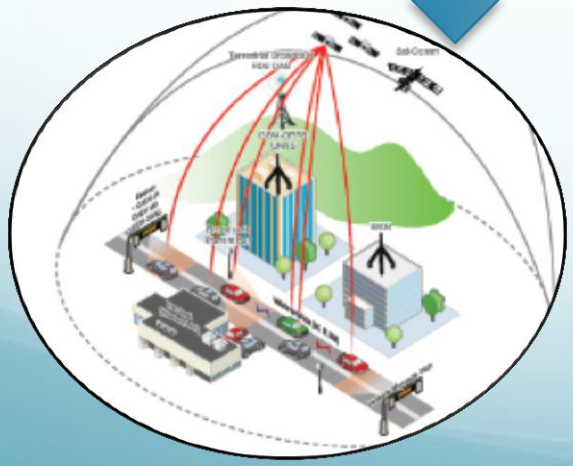
Autonomous Systems: Opportunities and Challenges for the UK





Google Driverless Car

Licensed in:
Nevada – 2011
Florida - 2012
California - 2012
…



Control of Complex Systems

Small Satellites Proliferate!





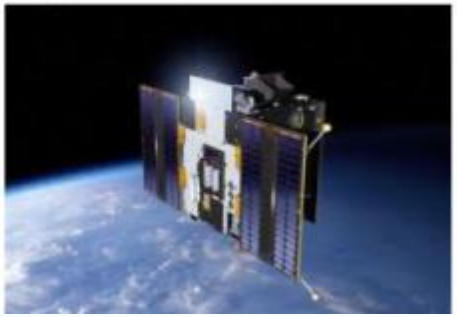


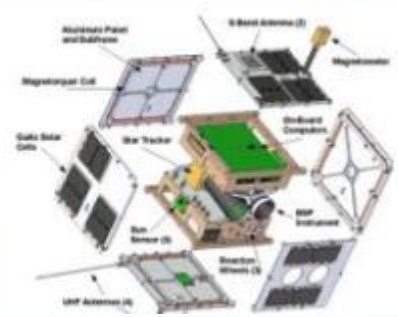
JOURNAL OF SMALL SATELLITES
RESEARCH, TECHNOLOGY, AND SYSTEMS

Division of Atmospheric and Geospace Sciences

CubeSat-based Science Missions for Geospace and Atmospheric Research

Small Satellite Systems

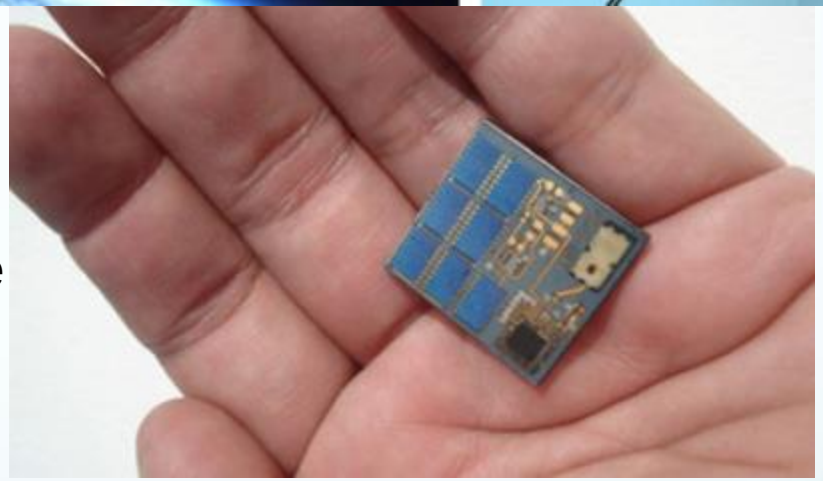




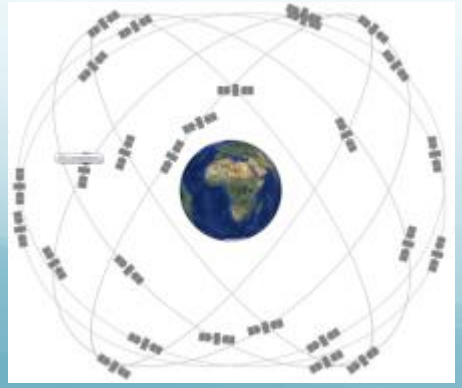




LOGAN, Utah —. From super-secret agencies and the U.S. military to academia and private firms, as well as world space agencies and NASA, ultra-small satellites are the big thing - be they minisatellites, microsatellites, nanosatellites, picosatellites, even the diminutive Femto satellite, weighing in at less than 100 grams.



Stamp-size satellites, developed at Cornell University, are getting a test run aboard the International Space Station.



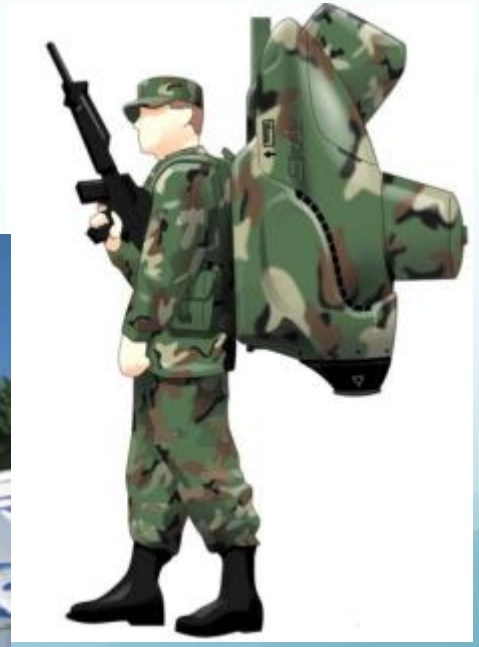
Small Aero Systems











TERRAFUGIA



The Transition® Production Prototype completed its first flight on March 23, 2012

Smart Dust – Ubiquitous Sensing

Smartdust is a system of many tiny microelectromechanical systems (MEMS) that can detect:

- Light
- Temperature
- Vibration
- Magnetism
- Chemicals
- …

Enabled by wireless computer networking, radio-frequency identification (RFID) and various forms of energy harvesting



Hitachi Creates RFID Powder



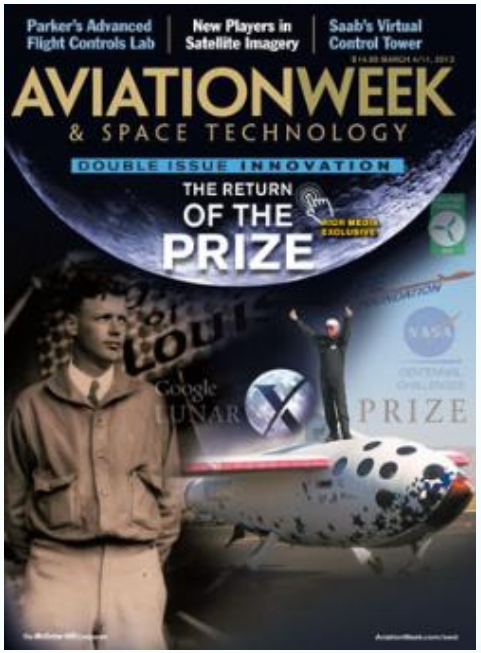
DARPA "Smart Dust" project - to build a self-contained, millimeter-scale sensing and communication platform.."

trends in … the "Crowd"

Crowd Sourcing

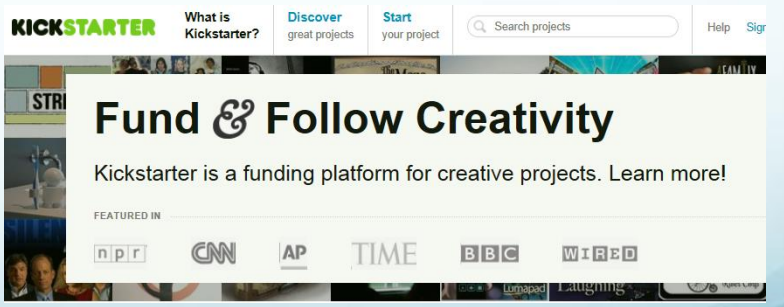
Prizes and Challenges Yield High Return

- Autonomous Vehicles
- Space Suits
- Lunar Landers
- Commercial Space
- …



Crowd Funding

the collective effort of individuals who network and pool their money, to support efforts initiated by other people or organizations…



Social Networks, Professional Networks, Virtual Meetings, …

People Want To Contribute to a Larger Cause

Sources

trends in … Knowledge

- ***Big Data***
- ***Machine Intelligence/ Analytics***
- ***Modeling and Simulation***
- ***Human Augmentation …***



And the Democratization of Knowledge

- ***Library of Utopia***
- ***Distance Learning***
- ***R&T moving***
  East and South…



But, the big change are global networks that tie people (innovators) together for ideation (new solutions) not just knowledge.

Technology is increasingly a networked and international enterprise.



Leadership in key fields will increasingly entail working with international partners.

Emergence of a Fourth Research Paradigm
Data Intensive Science and Discovery

1. **Thousand years ago – Experimental Science**
   Description of natural phenomena; Galileo

2. **Last few hundred years – Theoretical Science**
   Newton's Laws, Maxwell's Equations

3. **Last few decades – Computational Science**
   Simulation of complex phenomena

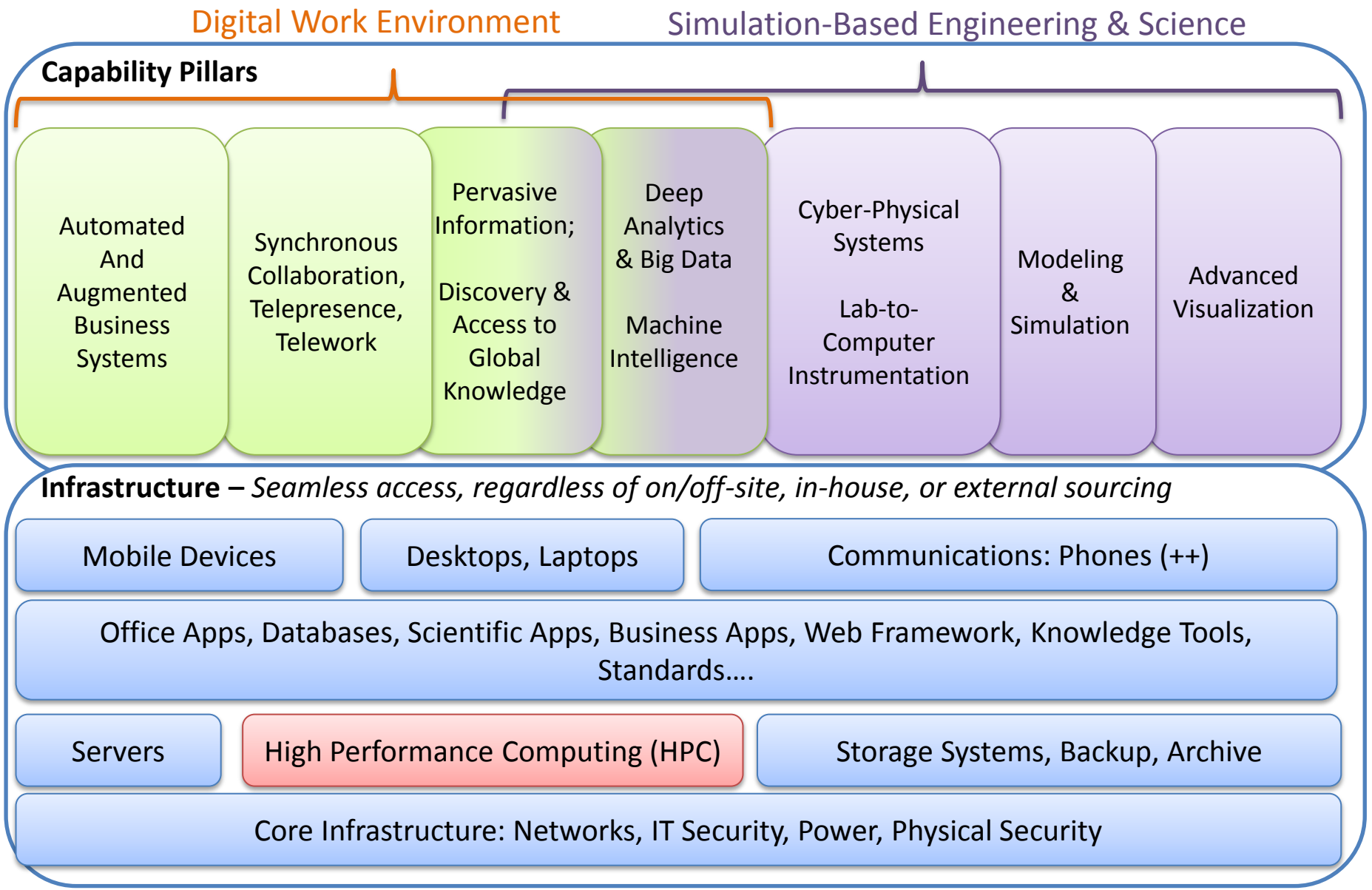
4. Today – **Data Intensive Science and Discovery**
   - Data from Instruments, simulations, sensors and satellites
   - Escience is the set of tools and technologies
     - For data mining, analysis and visualization
     - For collaboration and dissemination
     - For Ideation

Lots of Climate Research Data – opportunity for Discoveries

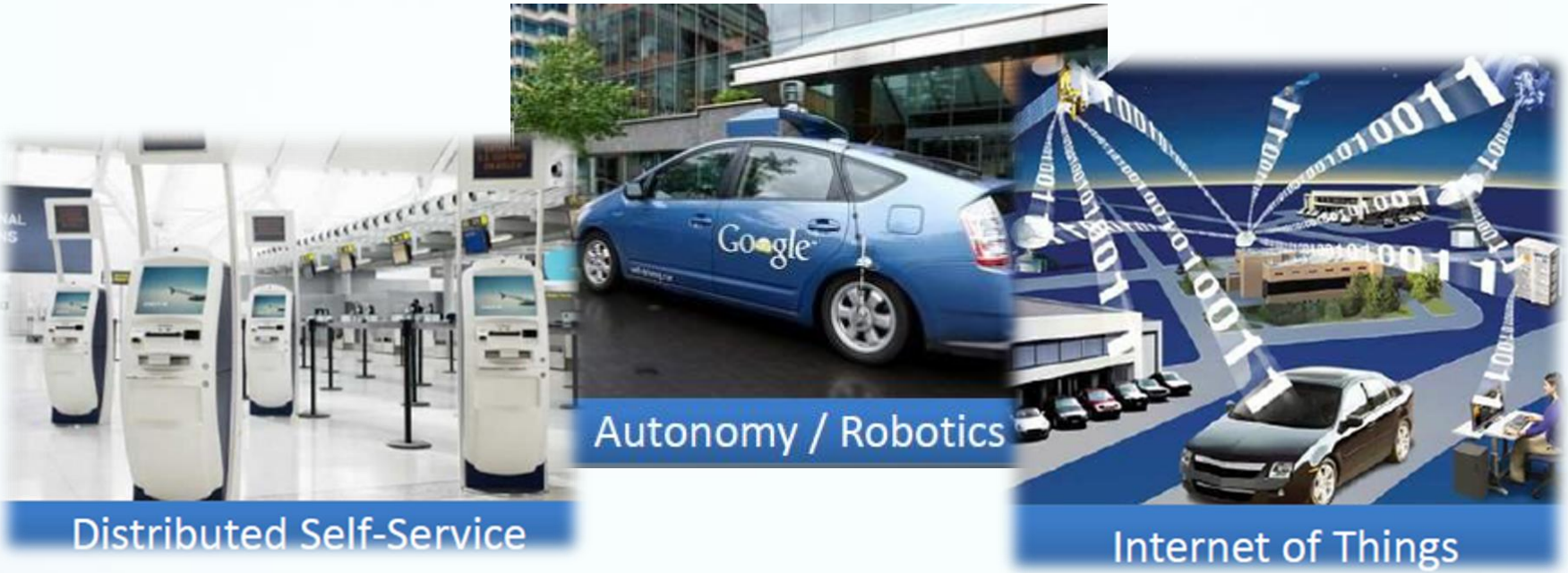




A Digital Transformation is At Hand



On-Demand Trends



- ***Amazon same day delivery …***



- ***Google launches same day delivery***
- ***Walmart mulls crowdsourcing for same-day shipping service***

On –Demand Mobility

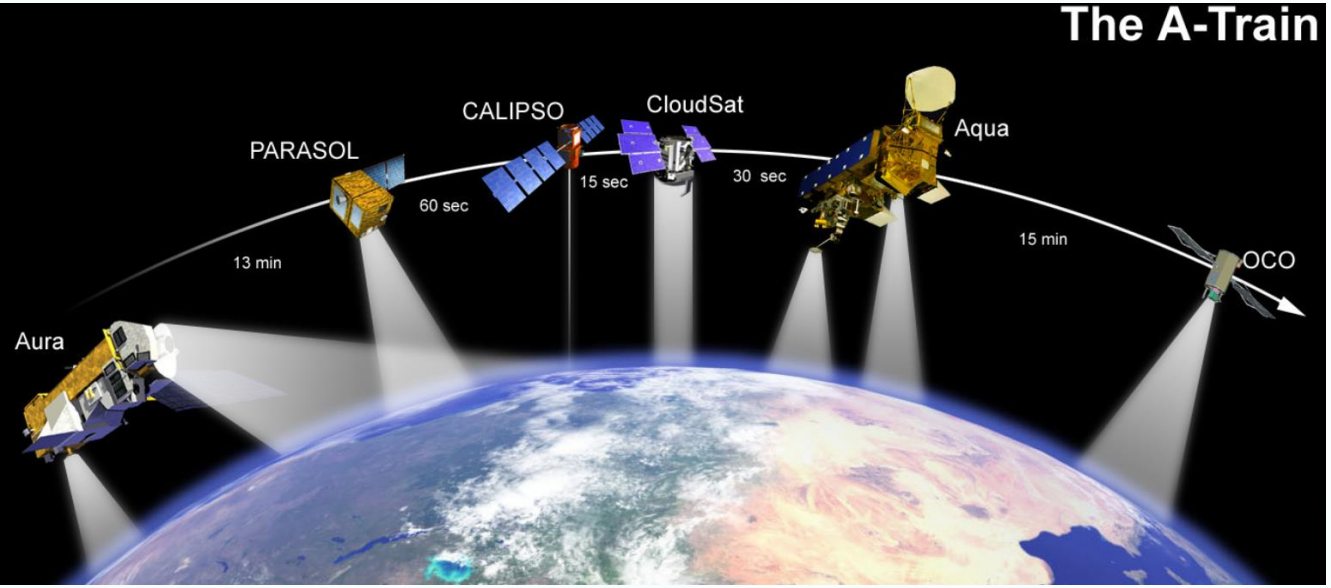


Aeronautics:

Point-to-Point Civil Aviation - on-demand air mobility, utilizing unmanned and personal aerial vehicles, to allow people and goods to travel wherever, whenever, enabled by a high degree of automation and autonomy.



Earth Science – New Approaches to Climate?

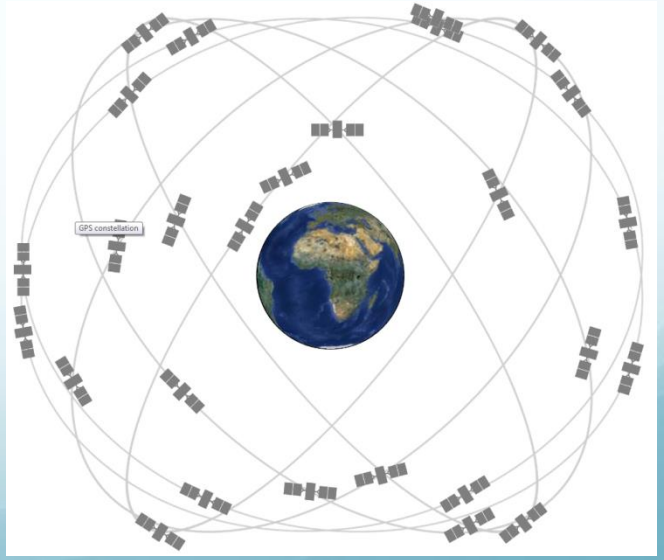


Active Remote Sensing

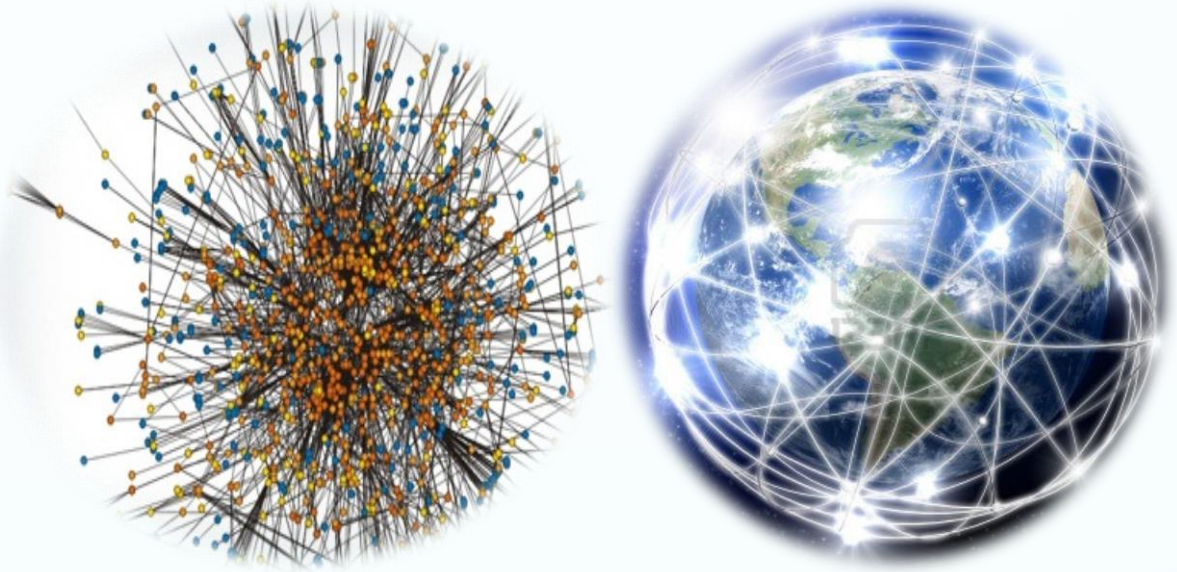
- *Lidar*
- *Inter-Satellite Calibration*
- *Large Instruments*

New Models for Earth's Atmospheric Science

- ***Swarms of Small Sats*** *– Increased temporal and spatial coverage (need to solve the calibration problem*
- ***In-Situ Smart Dust*** *– self configuring networks of ubiquitous sensors*



Thriving on Earth: Earth Vital Statistics



Healthy Planet Index

Create multi-scale Sensor-Webs across the Earth to provide continuous monitoring of the health of our planet by the early 2020s.

Cyber Physical Tipping Point



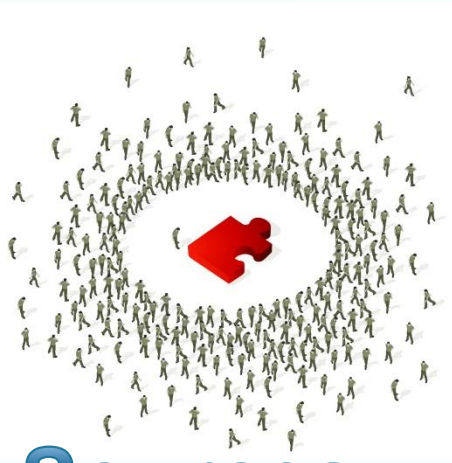
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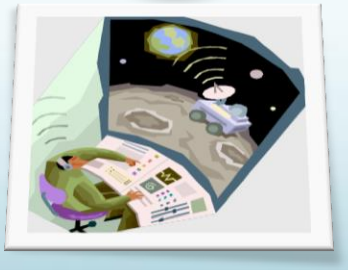
Small

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- *Personal Air Vehicles*
- *Satellites*
- *Sensors*



Sources

- *of ideas /solutions*
- *of funding*
- *of knowledge*
- *of air and space vehicles*



Nano & Quantum

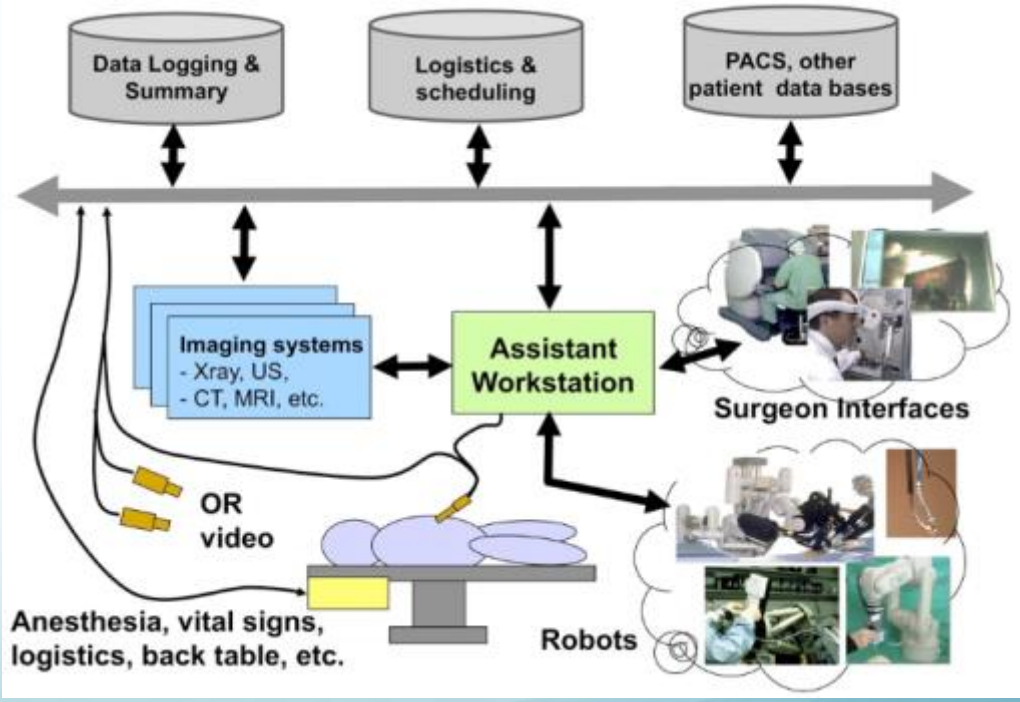
Energy

Cyber Physical Systems

Cyber-Physical Systems: The next revolution

- Cyber-physical systems (CPS) are physical and engineered systems
- Verification of cyber-physical systems still pose technical challenges
- IBM predicts 5 senses computing experiences within 5 years

Just as the internet transformed how computers and humans interact with one another, cyber-physical systems will transform ***how we interact with the physical world around us.***



A Revolution in Information and Knowledge Technology for the Crowd *(Space Exploration for Everyone)*

Virtual Exploration

Virtual Planetary Explorers



Five Senses Data Fusion

Citizen Scientists

Cloud: Computing/Data

Big Data Analytics

Participatory Exploration

Asteroid Challenge

Crowd Sourcing

Lunar Crater Challenge

"I want us to build a future of shared immersive tele-exploration."

http://www.theverge.com/2013/3/27/4154900/nasa-athlete-leap-motion-GDC

What is Technology?

Technology Definition: A solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem to enable a specific capability.

Government-Wide OMB Circular No. A-11 **Conduct of R&D****	
6.1 Basic Research:	A study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products.
6.2 Applied Research:	Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
6.3 Development:	Is directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

Summary

- NASA missions have always been technology enabled. Emerging technologies in the areas of small, smart, and cyber physical systems will:
  - Enable on-demand mobility
  - Provide ubiquitous sensing and big data synthesis for science and discovery
  - Accelerate the emergence of citizen explorers and scientists
- The third industrial revolution – robotic additive manufacturing - is critical to sustaining long duration space missions and permanent settlements.
- The fourth research paradigm – data intensive science and discovery – has huge potential implications for how work is done (work environment) and on simulation based innovation (at the systems level).
- Engineering Sciences – the precursor to technology- offer revolutionary changes to both what future missions NASA will pursue and how NASA will accomplish them.
  - Computationally Designed Materials
  - Non-Chemical Energetics, e.g. LENR
  - Synthetic Biology
  - Machine Intelligence, e.g. Autonomy of Cyber Physical Systems
  - Nano/Quantum sensors and devices
  - Human Augmentation

“ . . . the idea of the future being different from the present is so repugnant to our conventional modes of thought and behavior that we, most of us, offer a great resistance to acting on it in practice.”

John Maynard Keynes, 1937