: An NSF I/UCRC Center on Intelligent Storage:

Overview of Internet of Things

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UNIVERSITY OF MINNESOTA

Outline

- Internet Things vs. Cyber Physical Systems
- What tends are driving Internet of Things?
- A Few Examples (Impacts are obvious)
- Taiwan's Opportunities and Challenges
- Conclusions

Internet of Things vs. Cyber Physical Systems

- In Europe and Asia, Internet of Things (IOT) are commonly used
- In USA, Cyber Physical Systems (CPS) are used
- Are these two different?
- Other highly related terms: Pervasive Computing and Ubiquitous Computing

Internet Things

From Wikepedia

- In computing, the term **Internet of Things** (also known as the **Internet of Objects**) refers to the networked interconnection of everyday objects.[1] It is generally viewed as a self-configuring wireless network of sensors whose purpose would be to interconnect all things.[1] The concept is attributed to the original Auto-ID Center, founded in 1999 and based at the time in MIT[2]

A Good Video Explanation of Internet Things
http://www.readwriteweb.com/archives/internet_of_things_explained_video_intro.php

What are Cyber Physical Systems?

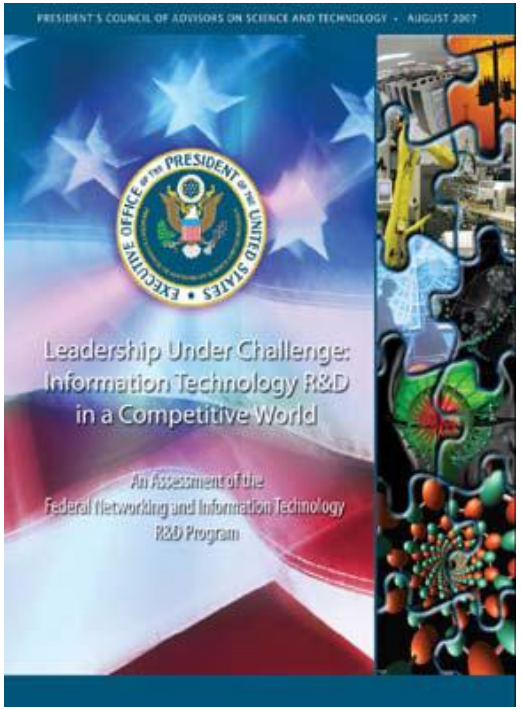
- CPS deeply integrate **computation, communication, and control into physical systems**
- CPS exploit pervasive, networked computation, sensing, and control, i.e., "Internet of [**controlled**] **things**"
- "CPS will transform how we interact with the physical world just like the Internet transformed how we interact with one another."*

*Some content from my colleagues from NSF; CPS Summit Website: http://varma.ece.cmu.edu/summit/index.html

A National Priority

Eight priority areas for competitiveness, with four designated as having the highest priority in Network and Information Technology (NIT): Systems Connected with the Physical World, Software, Digital Data, and Networking

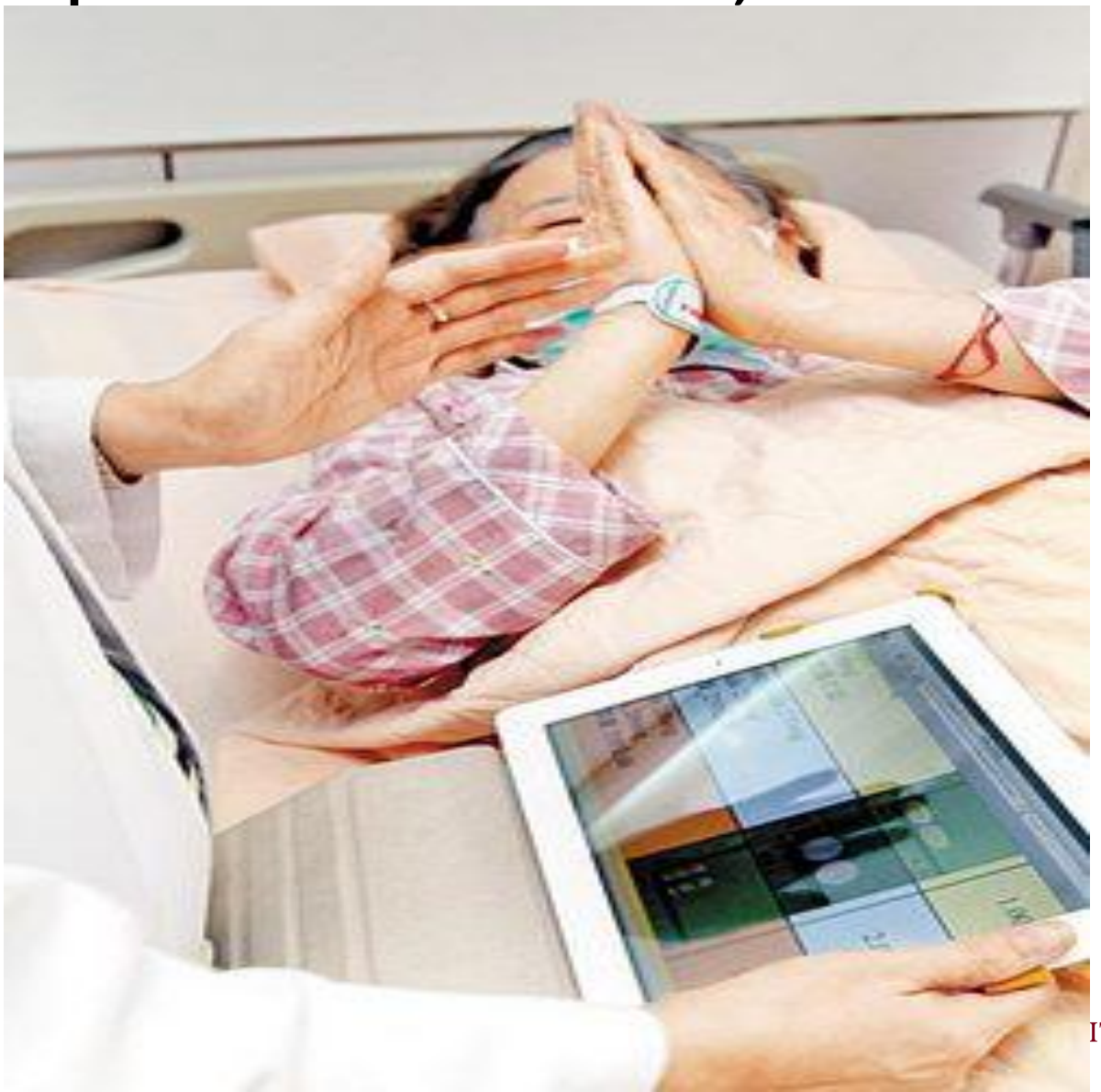
NIT systems connected with the physical world (cyber-physical systems): Essential to the effective operation of U.S. defense and intelligence systems and critical infrastructures ; At the core of human-scale structures and large-scale civilian applications



President's Council of Advisor's on Science and Technology (PCAST), Computational Science: America's Competitiveness Leadership Under Challenge: Information Technology R&D in a Competitive World, August 2007.

雲端生活啟動 等車、看病變即時

Taipei News Oct. 16, 2011



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What are the computing and communications trends behind Internet of Things?

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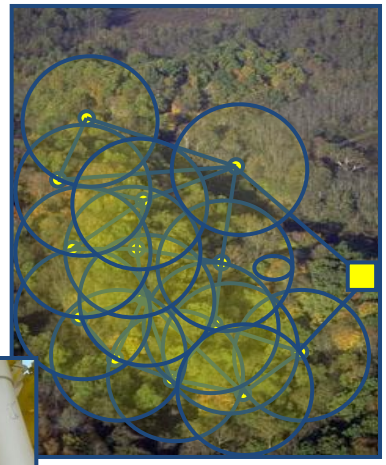
Instrument and Connect the World !

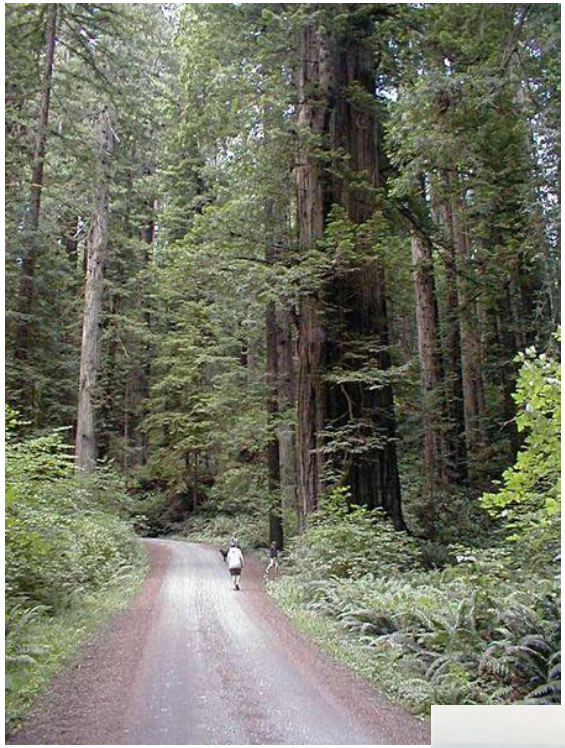
- **Bridge Monitoring**
- **Building**
  - **Environment**
  - **Controls**
- **Earthquake**
  - **Monitoring**
- **Elder Care**
- **Factories**
- **Fire Response**
- **First Responders**
- **Forest Management**
- **Soil Monitoring**
- **Supply Chain**
- **Wind Response**
- ***… and more more***





Sensors Everywhere



Sonoma Redwood Forest

Credit: Arthur Sanderson at RPI

Hudson River Valley

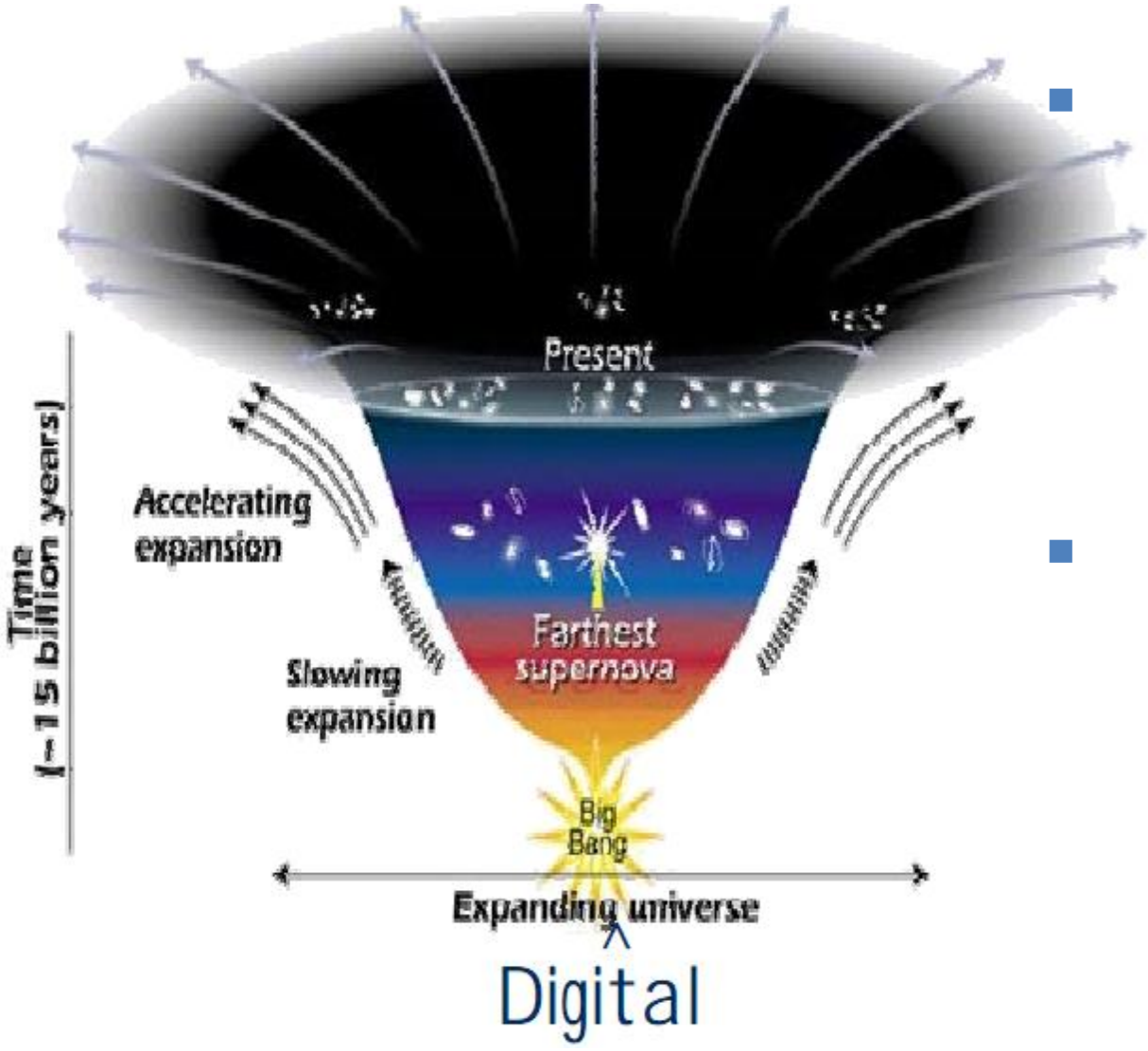
Kindly donated by Stewart Johnston

smart buildings

Credit: MO Dept. of Transportation

smart bridges

Digital Explosion



- The digital universe will grow over six-fold, from 281 exabytes in 2007 to 1,773 exabytes in 2011
- > 90% of the information in the digital universe is unstructured and absolute # of files growing faster than the TBs

----from IDC Survey presented in ISW 2008

New Data Format?

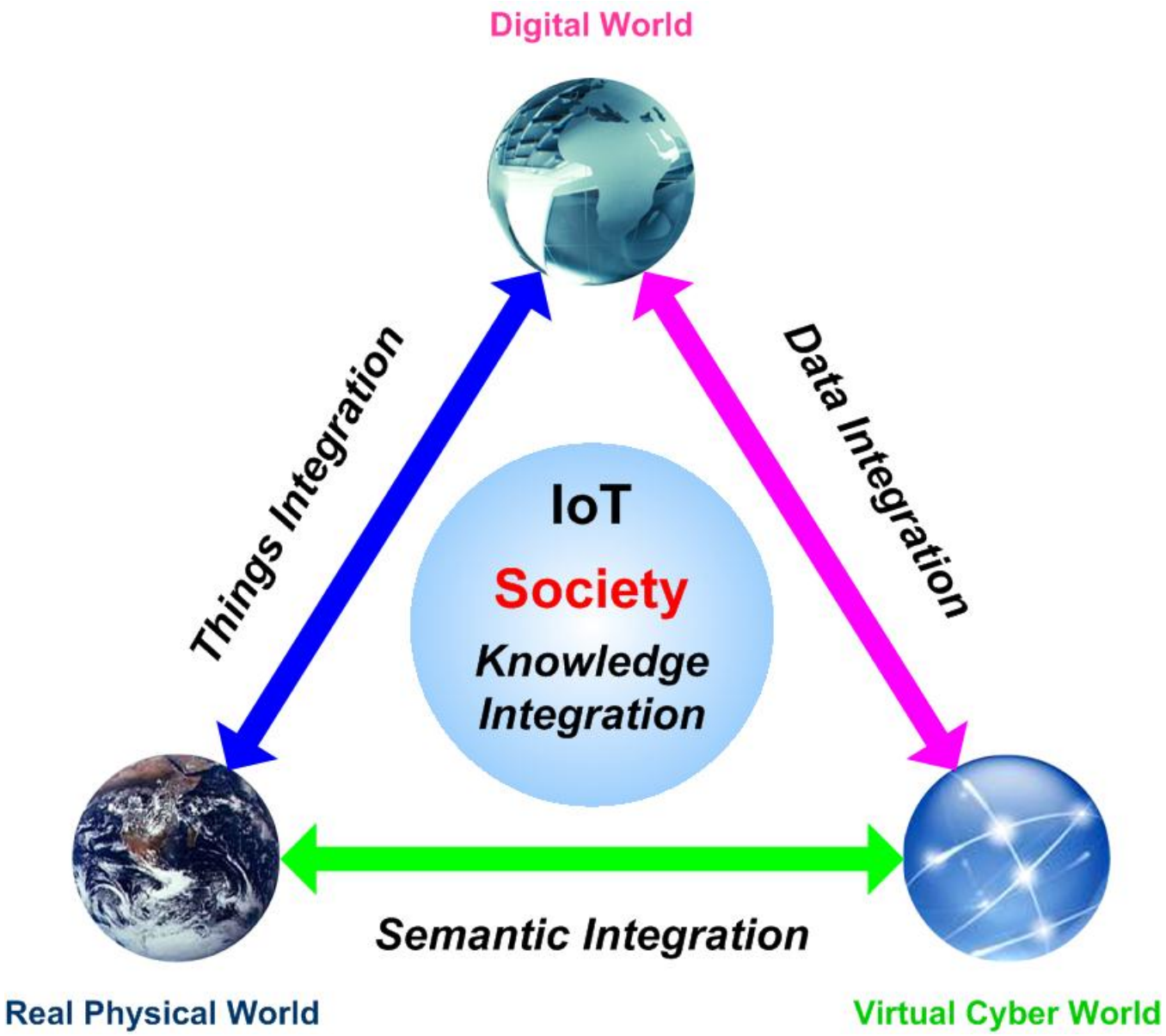
1. Surveillance video data collected by Air Force drones
   - One year's collection requires 24 years' processing (NYT, January 10, 2010)
2. Analog TV broadcasting becomes digital
3. Surveillance video cameras are widely deployed

Facts in This New Environment

- Extremely large Internet reaches every corner of the earth
- Support massive mobility
- Large number of smart embedded sensors are in our daily objects
- Each sensor can compute, communicate and sense;
- They form the largest network ever and generate huge amount of data
- Each sensor generates data continuously with two important dimensions: time and location coordinate
- We are drowning in data and loss in Internet
- A new Internet architecture and new ways to handle data are required

More Future Trends

- Embedded processors with great processing power and big storage space will be deployed all over the places
- Computers start to show intelligence over human in certain aspects (Considering Watson the computer becomes the winner of Jeopardy, American favorite quiz show and speech recognition of iPhone 4S)
- Huge amount of useful data are available and more are generated from every corner of the earth


Digital World
Things Integration
Data Integration
IoT
Society
Knowledge
Integration
Semantic Integration
Real Physical World
Virtual Cyber World

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A Few More Examples

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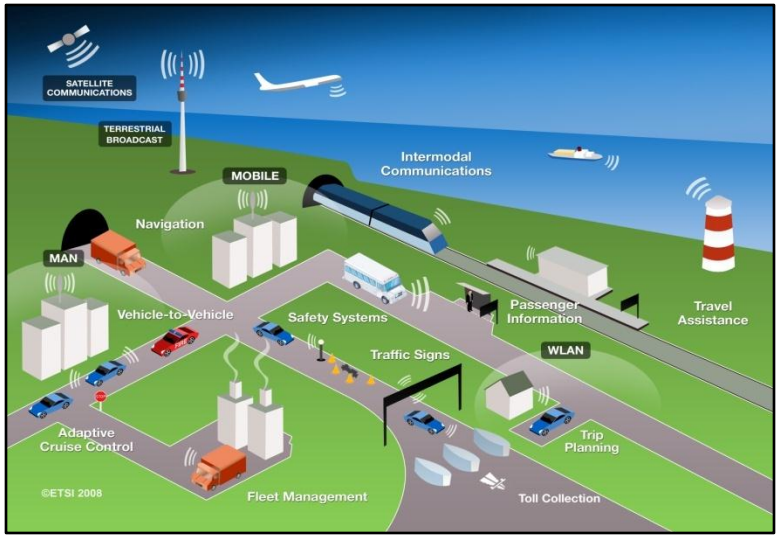
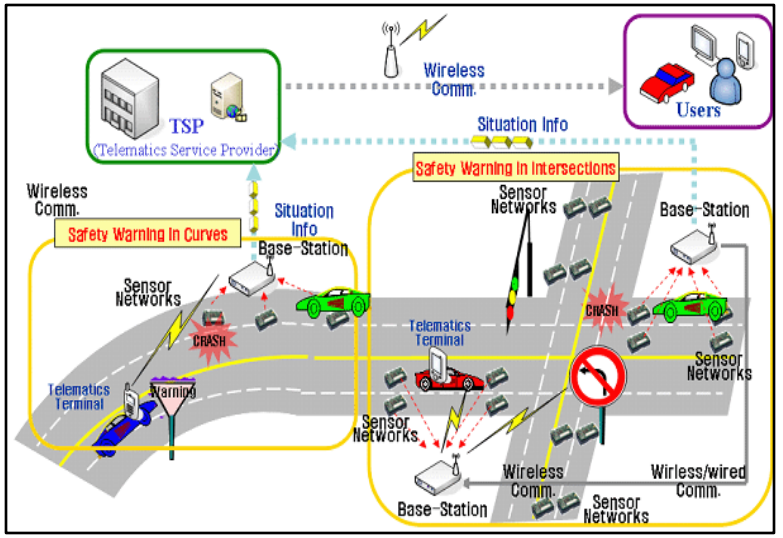
A Few *Example* Opportunities*

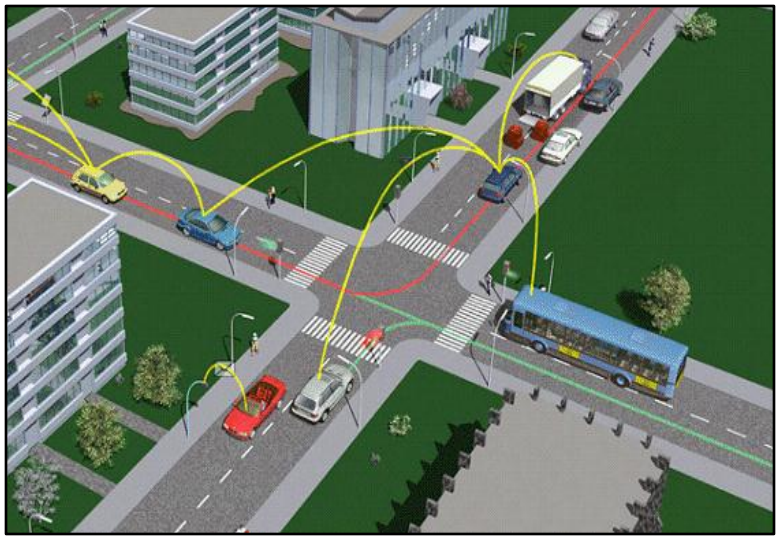
Transportation	▪ Faster and more energy efficient aircraft ▪ Improved use of airspace ▪ Safer, more efficient cars
Energy and Industrial Automation	▪ Homes and offices that are more energy efficient and cheaper to operate ▪ Distributed micro-generation for the grid
Healthcare and Biomedical	▪ Increased use of effective in-home care ▪ More capable devices for diagnosis ▪ New internal and external prosthetics
Critical Infrastructure	▪ More reliable and efficient power grid ▪ Highways that allow denser traffic with increased safety

* Cyber-Physical Systems Executive Summary, CPS Steering Group, March 6, 2008. Available on-line: http://varma.ece.cmu.edu/summit/

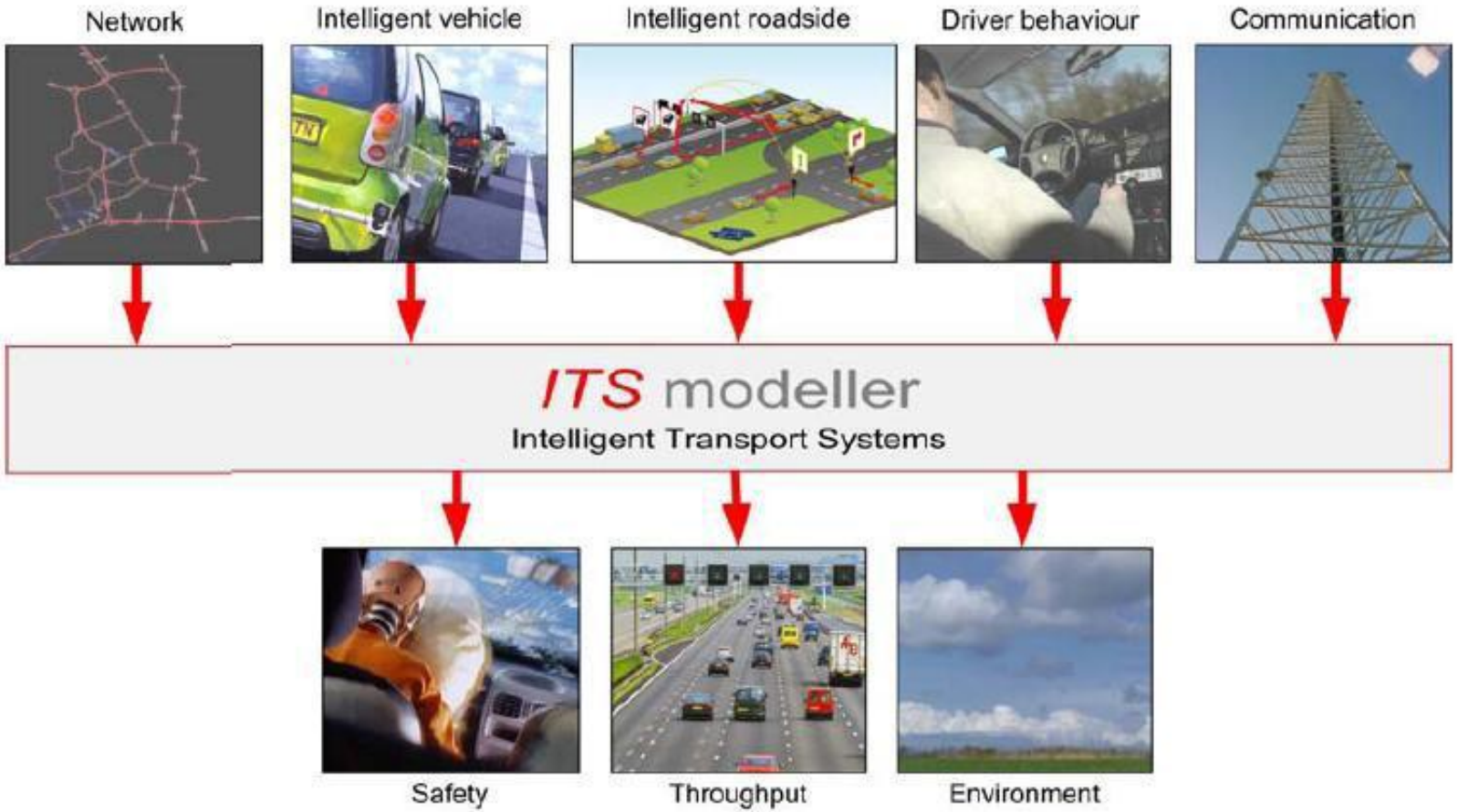
Intelligent Transportation Systems







ITS modeller: A modelling environment for Intelligent Transport Systems, including co-operative systems



Consider NASA As An Example

NASA Satellite and In Situ Observations

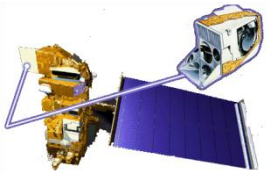
SRTM

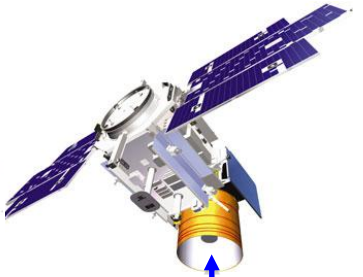
LANDSAT

MODIS

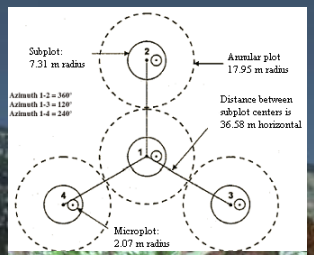
ALOS PALSAR

ICESat



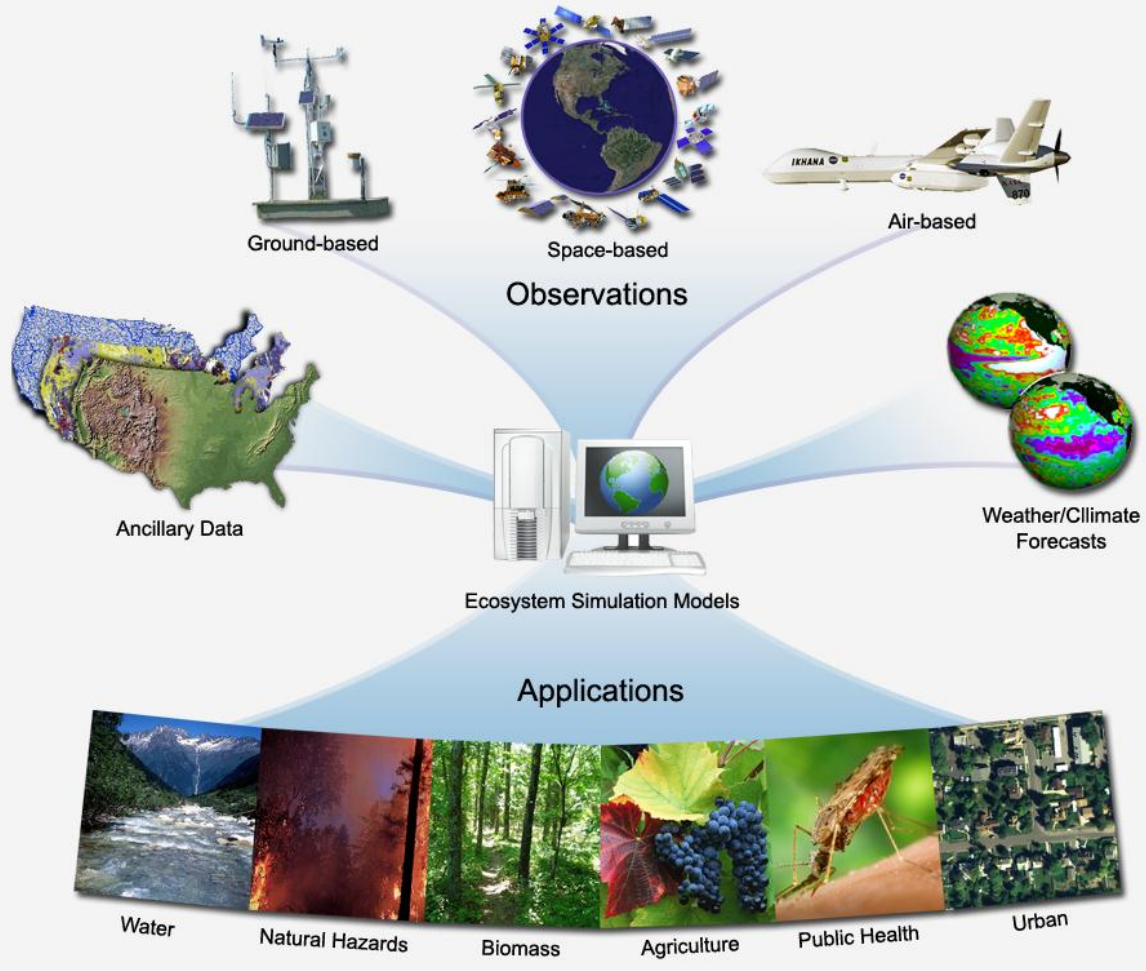


USDA FS, FIA Data



Terrestrial Observation and prediction system (TOPS)

A data - modeling system for integrating satellite, surface data with simulation models to produce ecological nowcasts and forecasts



Key elements:

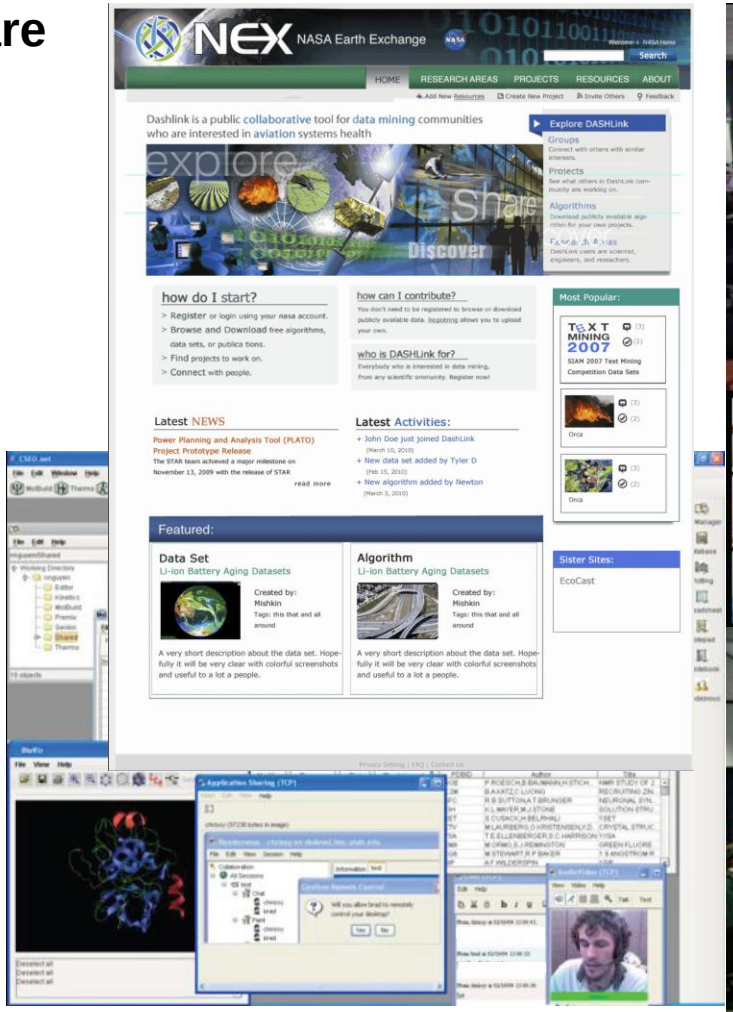
- Monitoring
- Modeling
- Forecasting
- Local to Global

Focus on biogeo-chemical cycles

Nemani et al., 2009, RSE

Collaboration Tools

Share



Conference

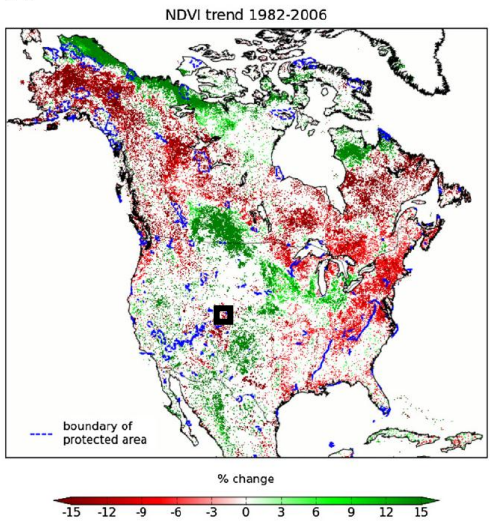
Collaborate

Visualize

Leveraging collaborative research tools at NASA

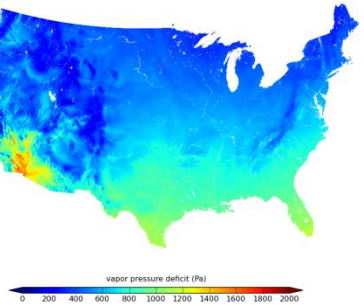
NEX in support of the National Climate Assessment

Satellite monitoring

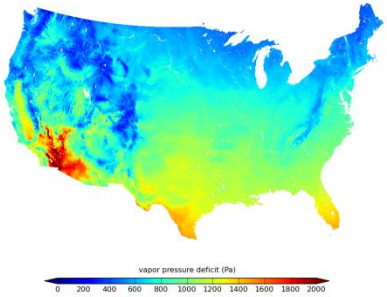


High-Resolution (1km) climate data

Historical

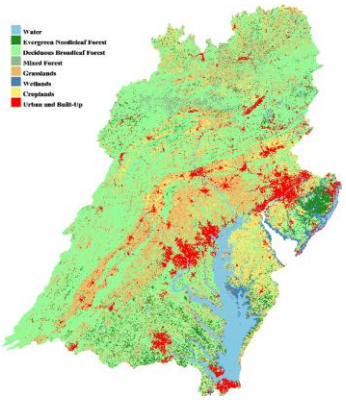


Projected

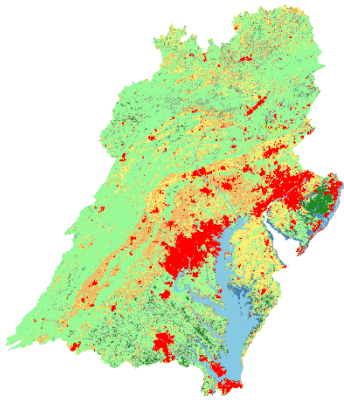


10+ teams working

Modeling Land cover changes

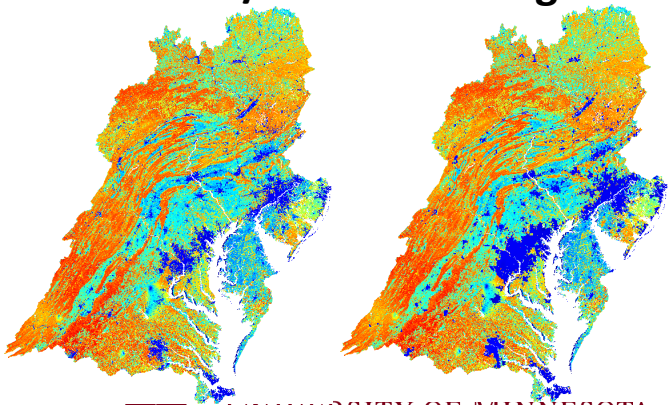


Baseline LC (2000)



Forecast LC (2030)

Vegetation responses to climate/land use changes

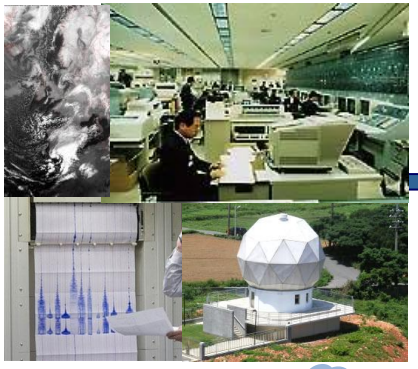


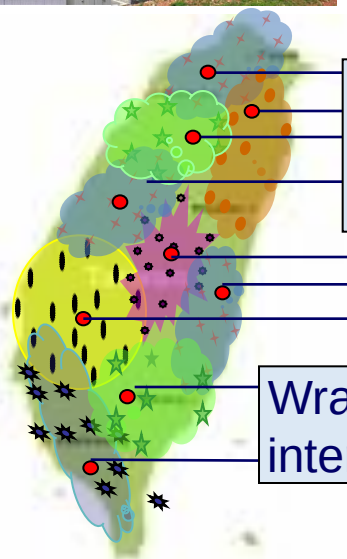
Bridge Monitoring & Prognostic

Info. sources

OpenISDM lead by Prof. Jane Liu at ISS Academic Sinica

Applications





Filtering and Fusion

Wrapper interface

Access control and privacy protection services

Eyewitness reports, news, twitter, etc.

data.gov.tw datasets

GIS, Census data

Road/traffic conditions

Weather models, data and forecast

OpenSensorIS

Data on water levels & flow rates, moisture profile, slide susceptibility; seismic activities; bridge stress, air quality, etc.

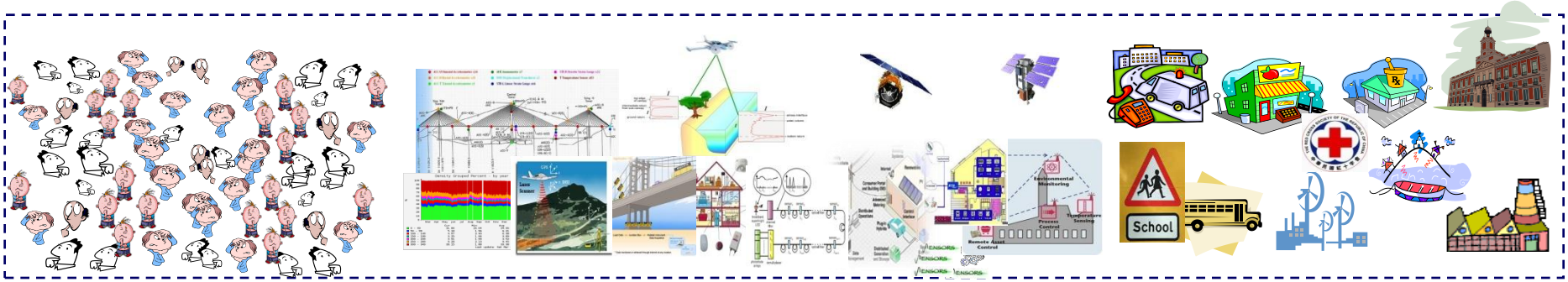
Information fusion, mining and access APIs

Sahana & other DMS

Real-time C3

Disaster prevention & warning

Disaster risk management



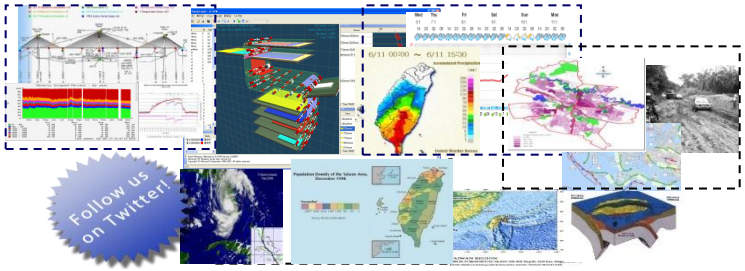
Access Control, Privacy Protection and Information Flow Control Mechanisms

Networking & feed services

pipes ZOHO Creator dapper FEED43 FEED FOR FREE Google Reader

Data hosting

Data caches



Data repository for Research and planning

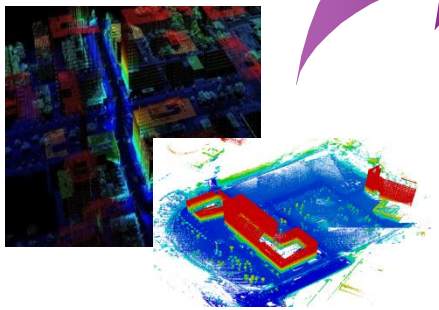
Information Extraction, Filtering, Fusion and Mining Services

Disaster Management Applications and Services

Wuxi Internet of Things Institute

Wuxi Cloud Computing Center

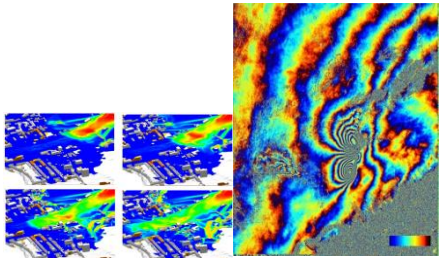
数字城市 lead by Prof. Ni at SIAT



空间数据存储

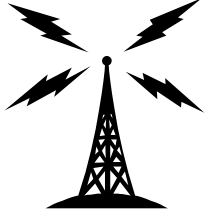
安全隐私保护

动态数据获取



突发事件查询

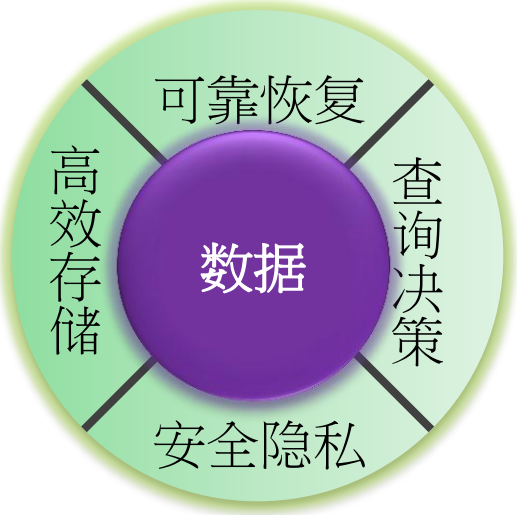
多维数据融合



信息通信

社会民生

健康医疗



环境监测

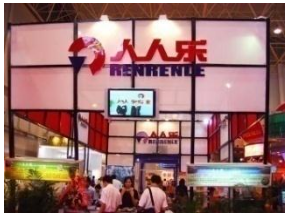
国防安全

环境生态

传感器

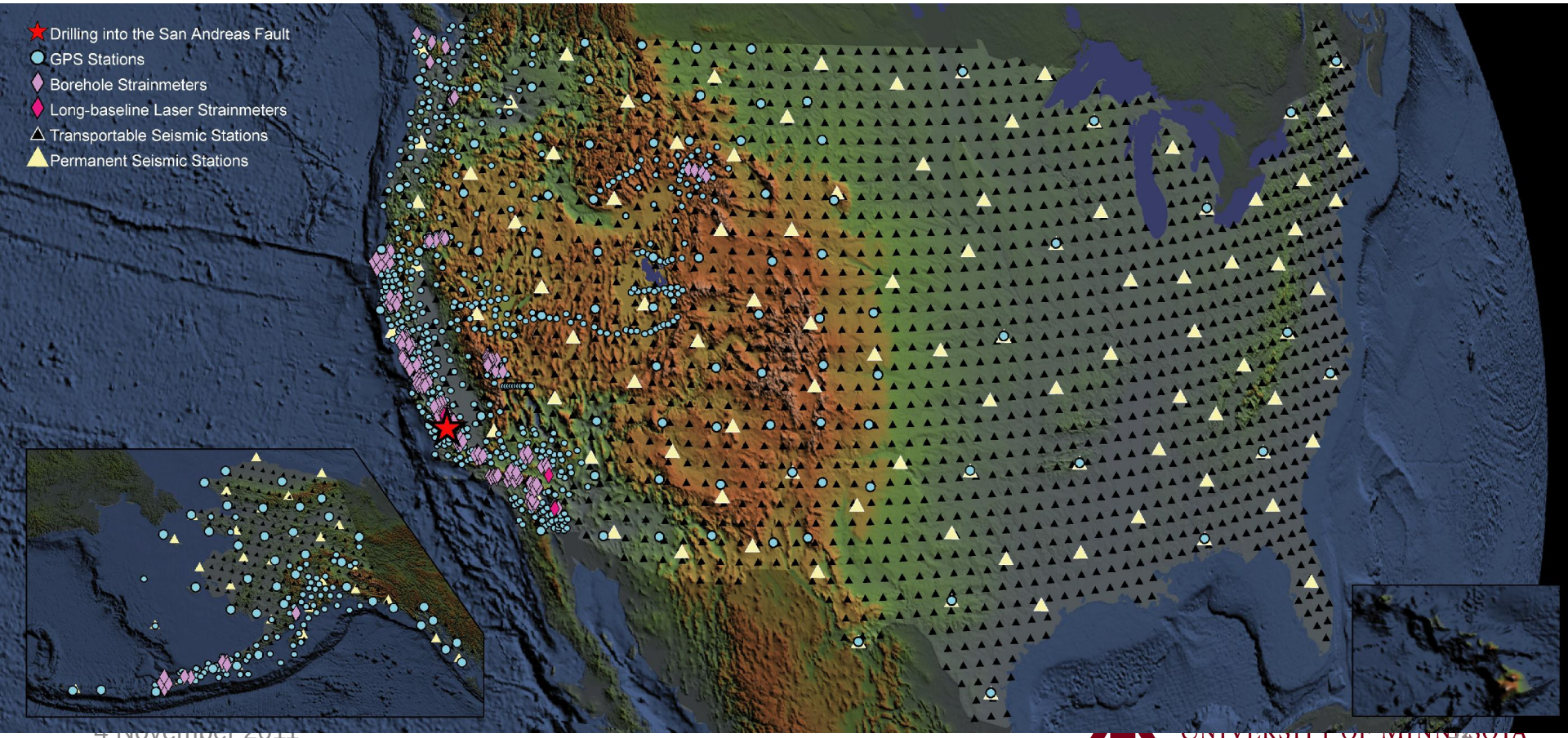
交通物流

城市规划

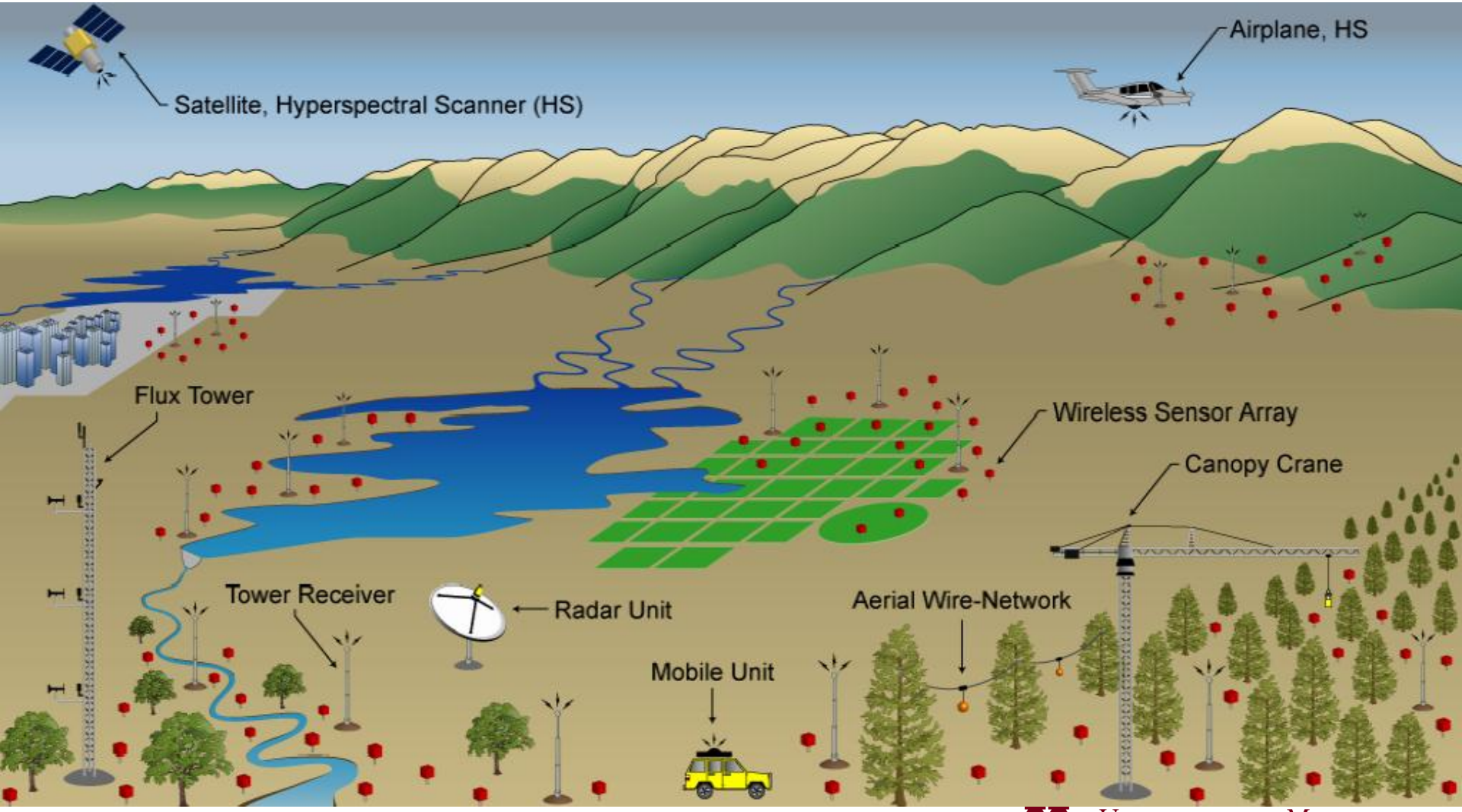


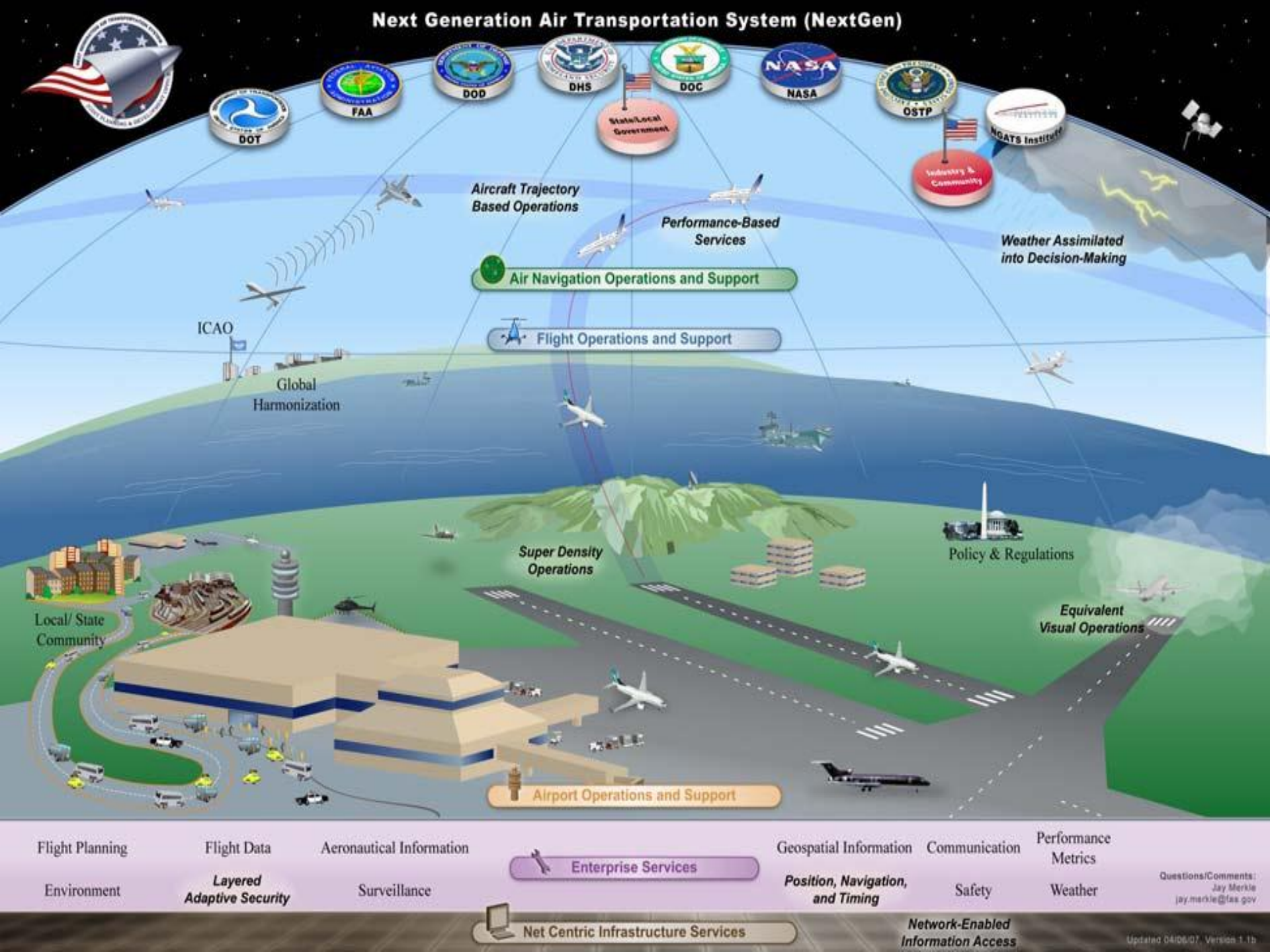
EarthScope:
A Continental-Scale Network

- **15-year effort to understand earthquakes, volcanism, and plate movements in N. America**
  - **400 seismometers, 1000 GPS stations, 180 strainmeters**



NEON:
National Ecological Observatory Network




Next Generation Air Transportation System (NextGen)
DOT
FAA
DOD
DHS
DOC
NASA
OSTP
State/Local Government
Industry & Community
NGATS Institute
Aircraft Trajectory Based Operations
Performance-Based Services
Weather Assimilated into Decision-Making
Air Navigation Operations and Support
Flight Operations and Support
ICAO
Global Harmonization
Super Density Operations
Policy & Regulations
Local/ State Community
Equivalent Visual Operations
Airport Operations and Support
Flight Planning
Flight Data
Aeronautical Information
Enterprise Services
Geospatial Information
Communication
Performance Metrics
Environment
Layered Adaptive Security
Surveillance
Position, Navigation, and Timing
Safety
Weather
Questions/Comments: Jay Merkle jay.merkle@faa.gov
Net Centric Infrastructure Services
Network-Enabled Information Access
Updated 04/06/07, Version 1.1b

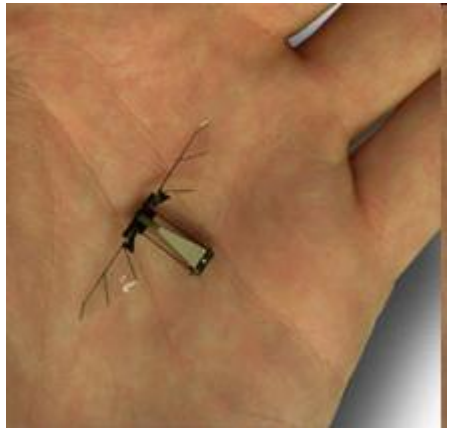
Smart Fliers

Credit: Boeing

An airplane is a network of computers.

Credit: NASA/JPL

smart helicopters



Credit: Harvard university

smart insects

Research Challenges

- How to design small smart devices?
- Extremely Large Systems (How to build? How to diagnosis? Self-Organizing? Self-Learning and Adapting?)
- How to deign a fully integrated system?
- Operating with inaccurate data?
- How to manage and maintain data? (new data representation? new data structure? new data integration?)
- How to manage and preserve data for more than 100 years
- How to get the right data at the right time? (publish-subscribe model vs. event driven)

Taiwan's Opportunities

- Hardware , software, systems, services, and applications (Vertically integrated solutions become extremely important)
- Choose and concentrate on a few areas
- Strengthen core technologies
- Full coordination among government, industry and academia

Next Generation SCADA/DCS: Cyber Control of our Physical Infrastructures

- **Our critical physical infrastructures depend on SCADA and DCS. SCADA and DCS depend on the gathering, monitoring, and control of information from distributed sensing devices.**
- **How to provide safety, security and convenience to every citizen of Taiwan?**
- **Can you adapt the principles of designing these systems to commercial systems?**

HTC Phone

VS.

iPhone

With Strengths in Embedded Processors Go for Specialized Sensors and Mobile Applications

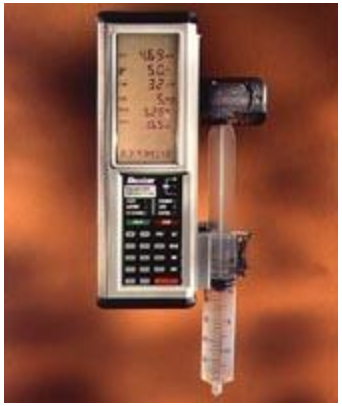
Smart Cars

Credit: PaulStamatiou.com

Cars drive themselves

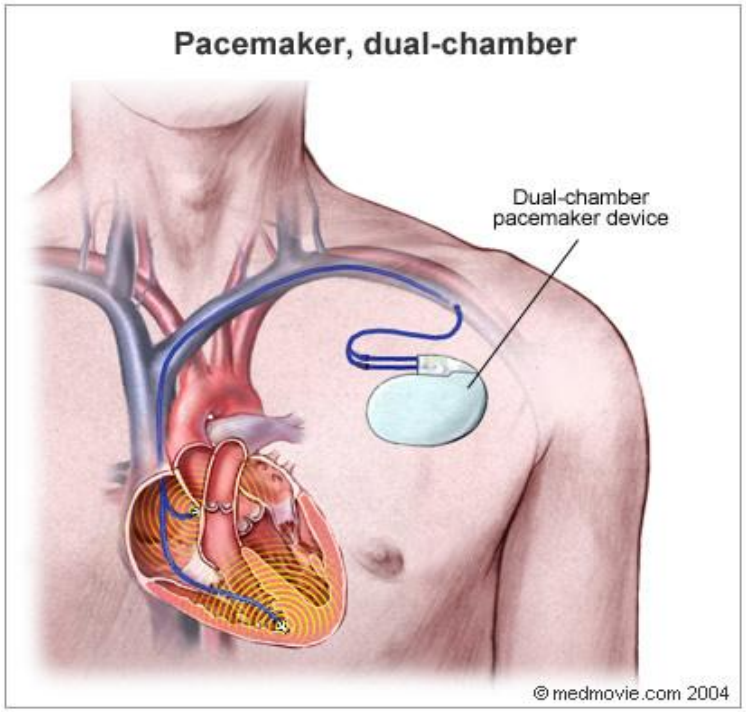
Car Control Software,
Embedded Sensors, and ITS

Smart Health with Embedded Medical Devices



Credit: Baxter International

infusion pump



pacemaker

Credit: Siemens AG

scanner

Tele-Surgery

Internet Datacenters

115kv

0.3% loss
99.7% efficient

13.2kv

8% distribution loss
.997^3*.94*.99 = 92.2%

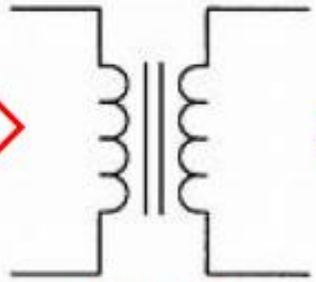
13.2kv

2.5MW Generator
~180 Gallons/hour

UPS:
Rotary or Battery

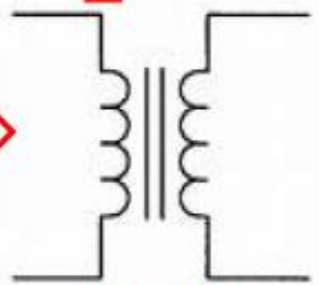
6% loss
94% efficient, >97% available

13.2kv



0.3% loss
99.7% efficient

480V



0.3% loss
99.7% efficient

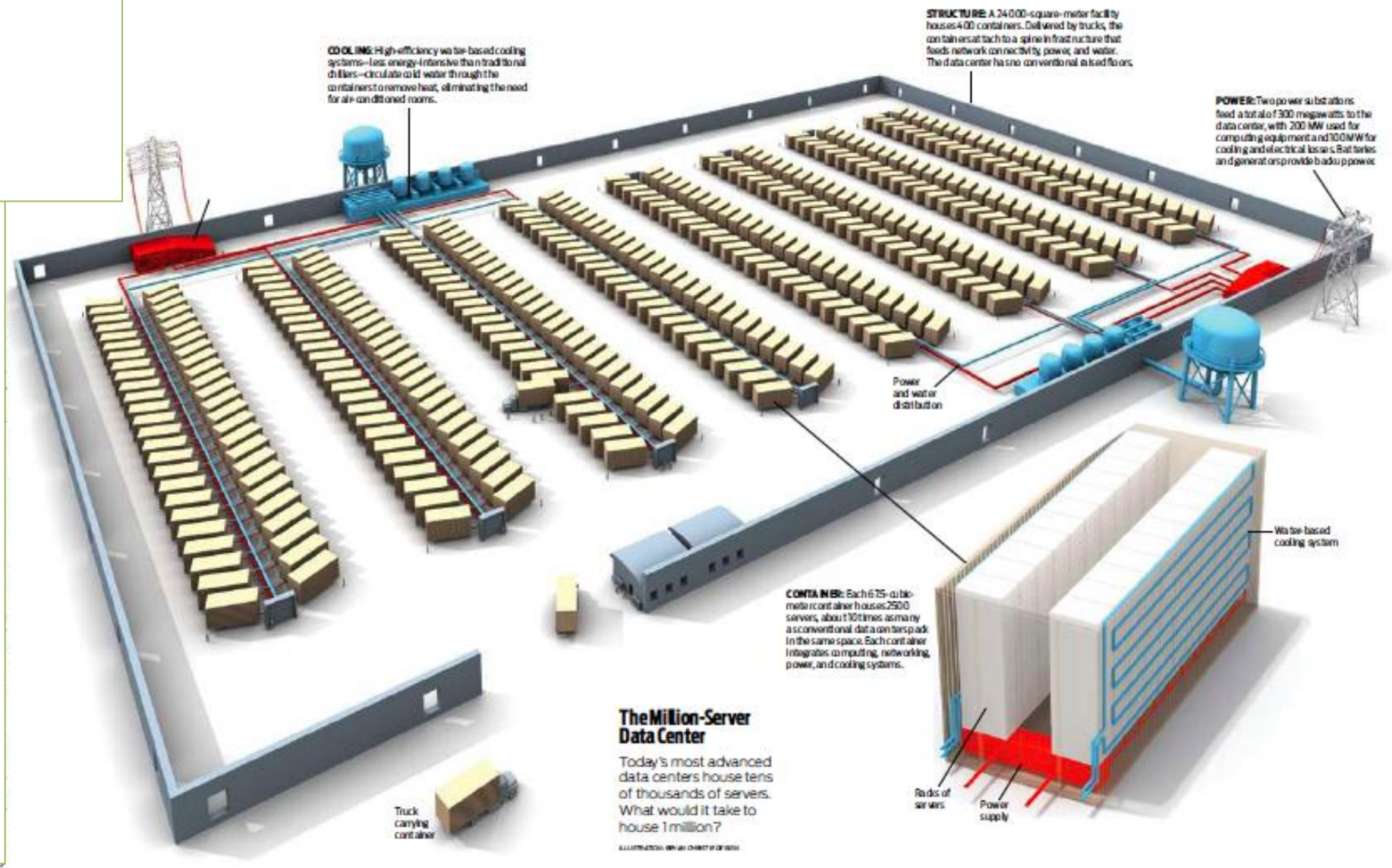
208V

IT LOAD

~1% loss in switch
Gear and conductors

Containerized Datacenters

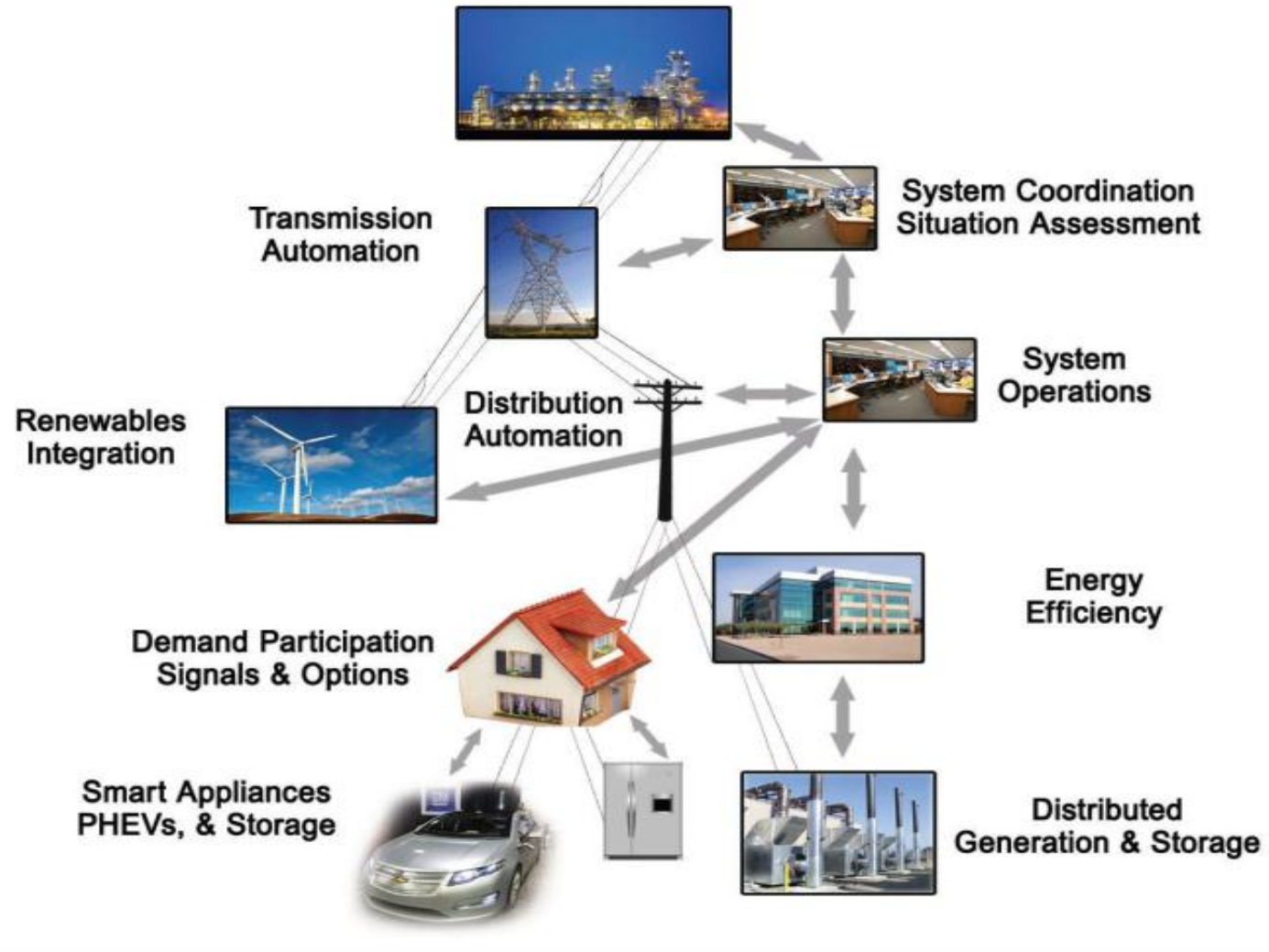
Microsoft's Chicago Modular Datacenter



Smart Grid and Alternative Energy

48

Consumer-to-Utility

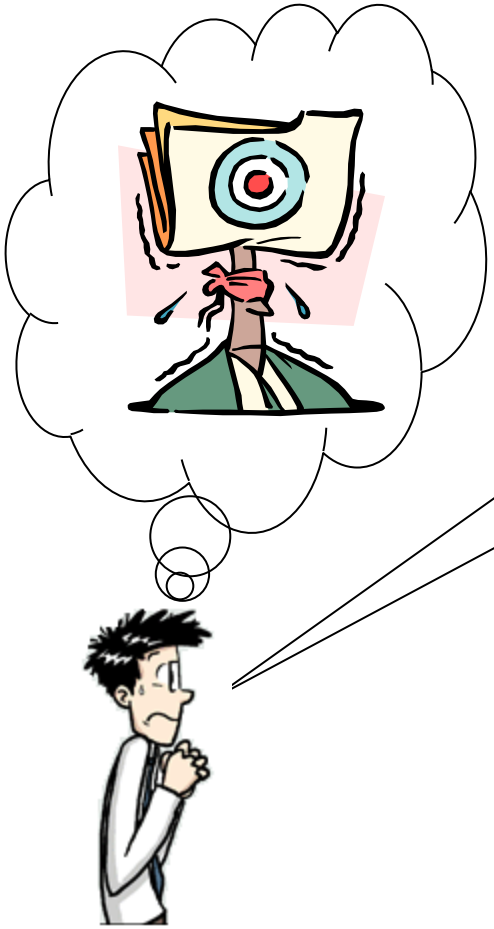


Retrieved 8/27/09 from page 2 at http://www.oe.energy.gov/DocumentsandMedia/SGSRMain_090707_lowres.pdf.

Conclusions

- Follow the Computing and Communications Trends
- Truly Is Multi-Disciplinary for Total Solutions
- Concentrate on A Few Areas
- Security and Privacy Issues Are Paramount
- Collect, Interpret and Understand Data in Real-Time
- Touches and Improves Our Daily Life
- Building A New World

Thank You!



Questions?