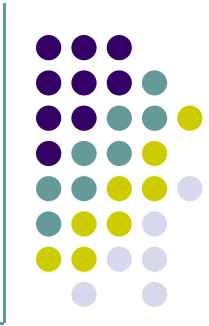
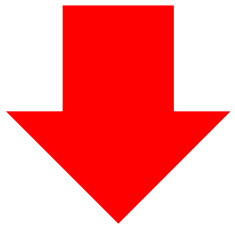


Welcome to SENG 480B / CSC 485A / CSC 586A Self-Adaptive and Self-Managing Systems

Dr. Hausi A. Müller
Professor and Associate Dean Research
Department of Computer Science
University of Victoria



http://courses.seng.uvic.ca/courses/2015/summer/seng/480a
http://courses.seng.uvic.ca/courses/2015/summer/csc/485a
http://courses.seng.uvic.ca/courses/2015/summer/csc/586a

Outstanding TAs

Lorena

Nina

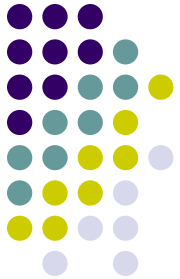
Ron

Announcements

- Monday, May 18
  - Victoria Day — no class
- Thursday, May 21
  - Lorena Castañeda — ULS
- Monday, May 25
  - Lorena Castañeda — ULS
- Friday, May 29
  - A1 due
  - Email addresses for Part III posted
  - URL

iRobot's new drone is a rock-steady flyer

Reading Assignments



- ULS Book Section 1-3 on-line at
  - http://www.sei.cmu.edu/uls/the_report.html

- Murray (Ed.): Control in an Information Rich World Report of the Panel on Future Directions in Control, Dynamics, and Systems, SIAM (2003)
  - Chapters 1 & 2
  - http://www.cds.caltech.edu/~murray/cdspanel/report/cdspanel-15aug02.pdf

Groups for A1 Part III

G1	Ernest Aaron, Adel Adil, Luuk Veenis
G2	Maryi Arciniegas Mendez, Navdeep Bahia, Richard Wagner
G3	Simar Arora, Miles Barr, Evan Wilde
G4	Fei Chen, David Bayly, Elliot Wyman
G5	Shu Chen, Jonathan Bowen, Gueorgui Zahariev
G6	Harsh Dawar, Joshua Braidek, Zhenyu Zhang
G7	Erkan Ersan, Po An Chen, Pufan Zheng
G8	Maria Ferman Guerra, Jason Cho, Zhanxue Zhu
G9	Khushboo Gandhi, Sebastian Craig, Mohammad Bin Abdulsalam
G10	Harneet Kaur, Yongjun Xu, Timothy Dalton,
G11	Francis Harrison, Meric Demiriz, Jorge Conde Gomez Llanos
G12	Stephan Heinemann, Sean Debroni, Tory Borsboom-Hanson
G13	Harshit Jain, Rodney Gelera, John Cox
G14	Sumit Kadyan, Alice Gibbons, Fraser DeLisle
G15	Navpreet Kaur, Zhuoli Xiao, Adnan Duale
G16	Parminder Kaur, Abhinandan Jagdev, Dustin Faulkner
G17	Waseem Khan, Anthony Kohan, Xiaotian Li
G18	Nishant Khanna, Patrick Lavoie, Connor McConkey
G19	Akshay Khot, Junru Yang, Ian Leslie
G20	Carlene LeBeuf, Siqi Li, Darren Prince
G21	Ye Liang, Ran Wei, Bowen Liu, Simon Taft
G22	Junnan Lu, Colum McClay, Jiashu Xiong
G23	Adithya Rathakrishnan, MacKay McGillivray, Shuo Yen Yu
G24	Arturo Reyes Lopez, Brenda McPhail, Mohammed Nader Zuhri Yafi
G25	Babak Tootoonchi, Daniel Oon, Muhammad Zubair
G26	Sam Wang, Hernan Rossi, Samuel Navarrete
G27	Stephan Wasylishen, Victoria Sahle, Sahibdeep Sran

Email will be disseminated shortly

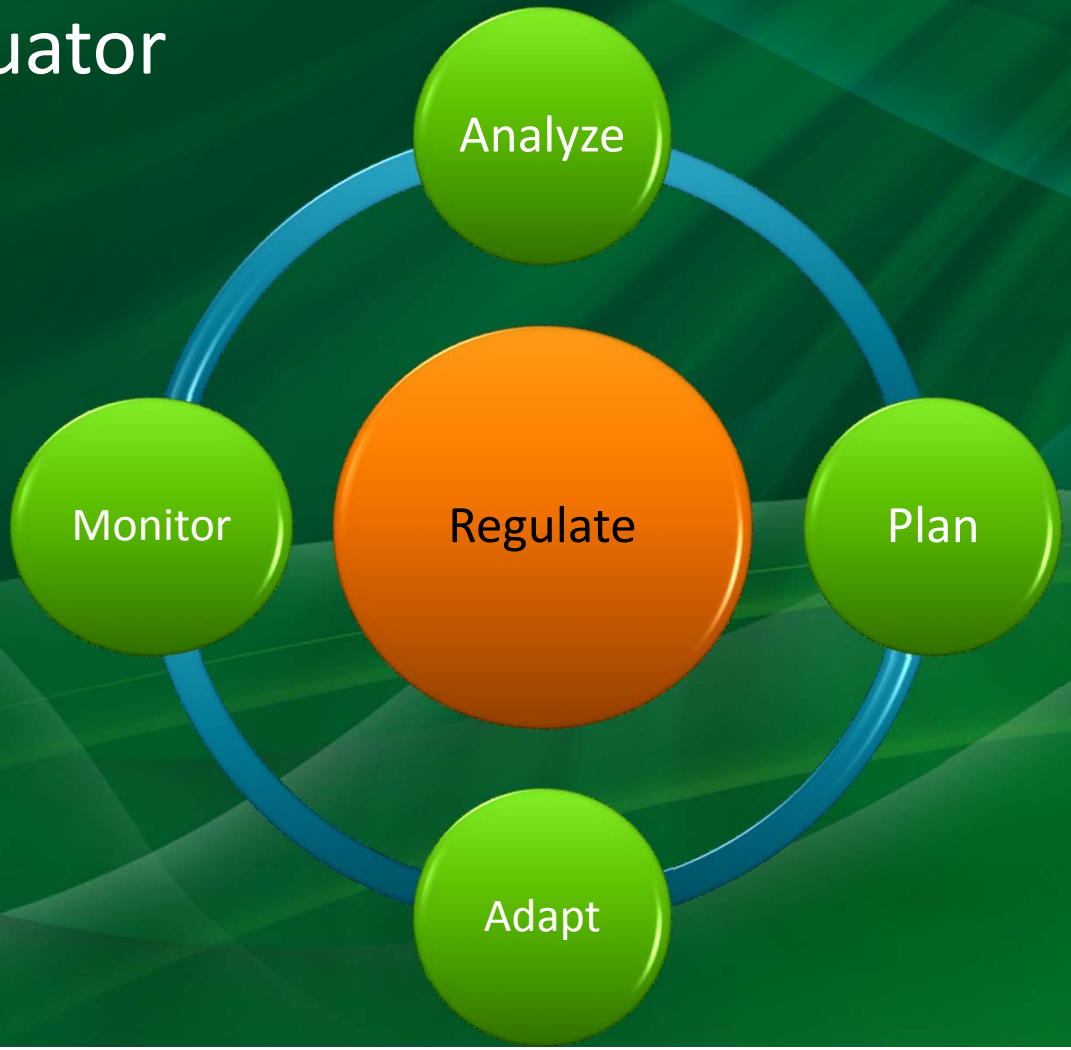
If you are uncomfortable about disseminating your email to the class list send me a note

Terms to study on the web

- Internet of things
- Industrial Internet (GE)
- Cyber-physical systems
- Ultra-large-scale systems
- Digital ecosystem
- Wearable computers
- The age of context
- Context awareness
- Situational awareness
- Big data
- Big data analytics
- Ubiquitous computing
- Pervasive computing
- Cloud computing
- Green computing
- Sensors and actuators
- Smart systems
- Google driverless car
- Google glass
- Microsoft Hololens
- iRobot
- Quadcopters

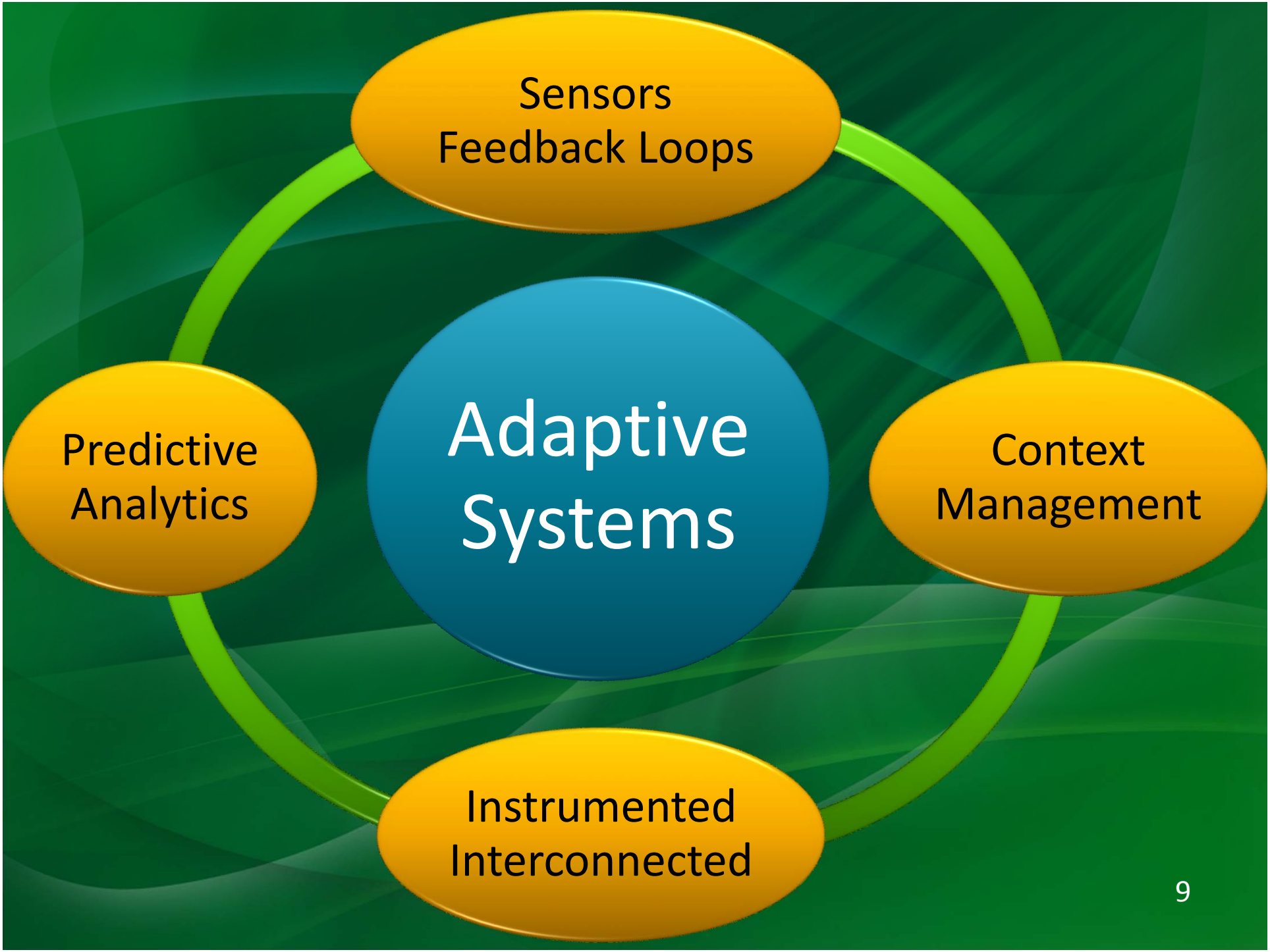
Adapt on the Fly—at Runtime

- Sensors give us the ability to monitor things
- Depending on the measures, things can adapt via actuator



Smarter System Characteristics

Smarter systems adapt at runtime


Sensors
Feedback Loops
Predictive
Analytics
Adaptive
Systems
Context
Management
Instrumented
Interconnected

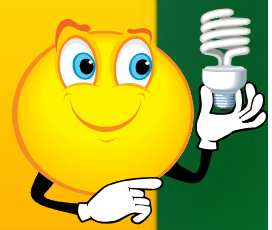
We need a new discipline

Software Engineering @ Runtime

Software Engineering @ Runtime

- Requirements@runtime
- Models@runtime
- Monitoring@runtime
- V&V@runtime
- Adaptation@runtime
- Analysis@runtime
- CM@runtime
- Assurance@runtime

- Profound impact on SE and CS
- Rethink software design and evolution for highly adaptive software systems
- Feedback loops and control theory are key

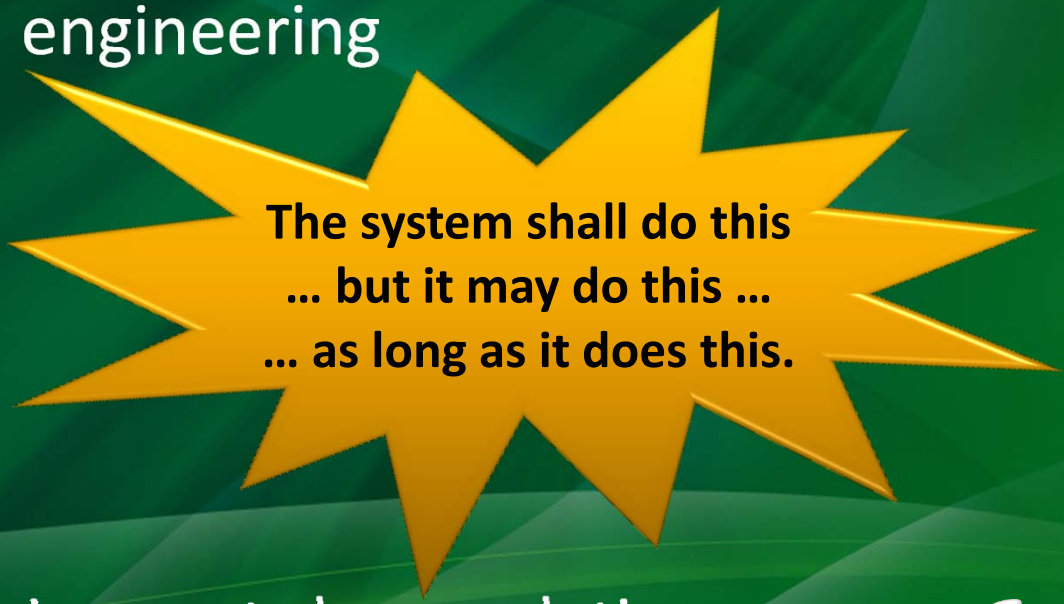


Boundary between development-time and run-time is disappearing

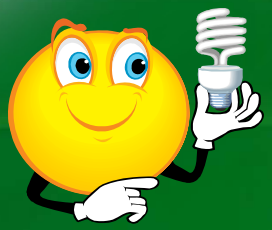
- Baresi, Ghezzi: The disappearing boundary between development-time and run-time. In: *FSE/SDP Workshop on Future of Software Engineering Research (FoSER 2010)*, pp. 17-22 (2010)

Requirements @ Runtime

- **From** satisfaction of requirements through traditional, top-down engineering



- **To** satisfaction of requirements by regulation of complex, decentralized systems



How much environment uncertainty can we afford? What's the cost?
What benefits do we accrue by accommodating context uncertainty?

Models @ Run.time

- Runtime model representation and management
- Models @ Run.time need reflection
- Goal models for NF requirements
- Runtime verification of statecharts
- Dynamic context models
- UML behavioral models at runtime
- Applying MDE tools at runtime
- GUI runtime adaptation models
- Model synchronization
- Models for security analysis

- Bencomo: Workshop Series on Models@run-time, http://www.comp.lancs.ac.uk/~bencomo/WorkshopMRT.html
- Bencomo: Workshop Series on Requirements@run.time, http://www.comp.lancs.ac.uk/~bencomo/RRT/
- Dagstuhl Seminar: Models@run.time, 2011 http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=11481

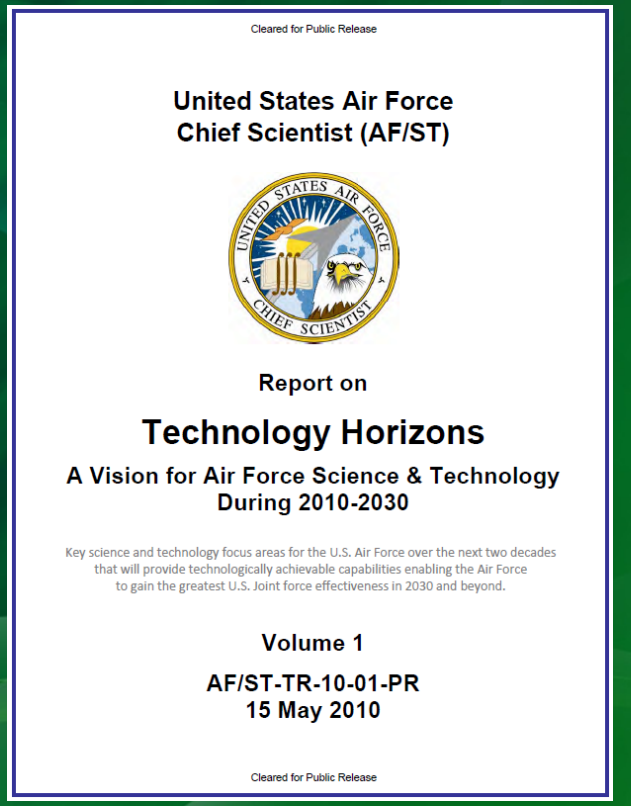
Make feedback loops first class

Autonomic control loop

- Müller, Pezzè, Shaw: Visibility of control in adaptive systems, *Proc. Second Int. Workshop on Ultra-Large-Scale Software-Intensive Systems (ULSSIS 2008)*, pp. 23-26 (2008)

Assurance @ Runtime
Make V&V @ Runtime First Class

- V&V ensures that software satisfies requirements and quality attributes
- Runtime V&V ensures proper system operation during adaptation
- Certifiable V&V methods are critical for smart systems



Cleared for Public Release

United States Air Force
Chief Scientist (AF/ST)

Report on

Technology Horizons

A Vision for Air Force Science & Technology
During 2010-2030

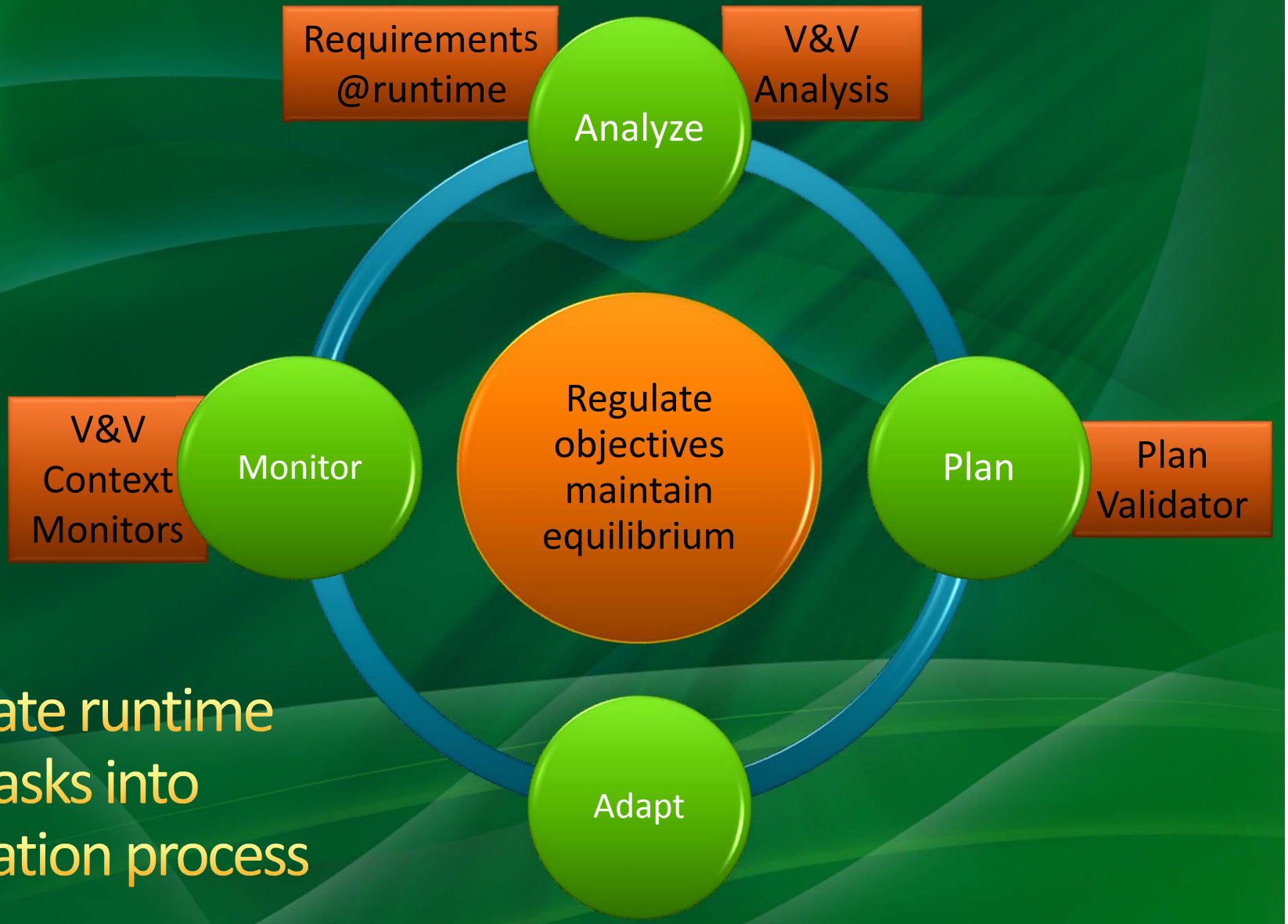
Key science and technology focus areas for the U.S. Air Force over the next two decades that will provide technologically achievable capabilities enabling the Air Force to gain the greatest U.S. Joint force effectiveness in 2030 and beyond.

Volume 1

AF/ST-TR-10-01-PR
15 May 2010

Cleared for Public Release

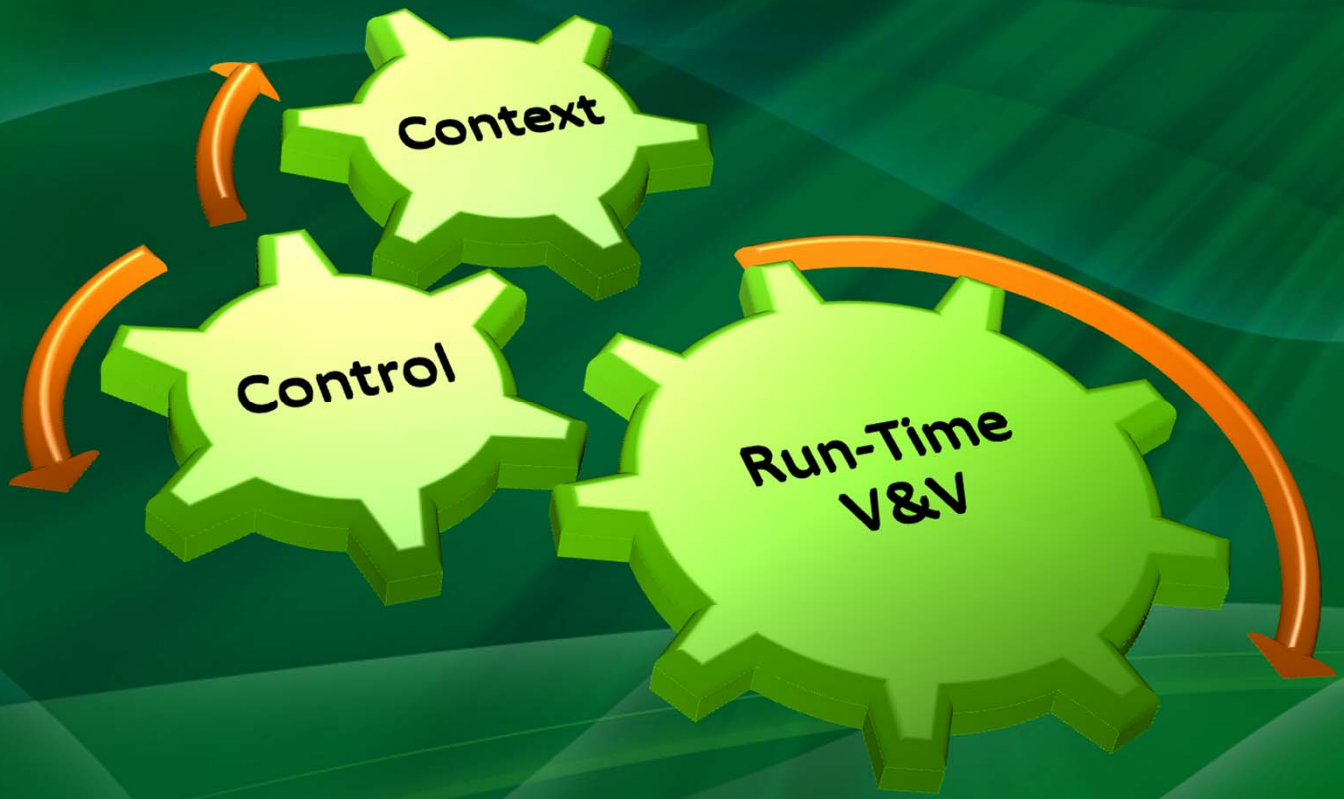
- Dahm: Technology Horizons: A Vision for Air Force Science & Technology During 2010-2030. TR USAF (2010)
- Villegas, et al.: A Framework for Evaluating Quality-Driven Self-Adaptive Software Systems, In: *Proc. 6th ACM/IEEE Software Engineering for Adaptive and Self-Managing Systems (SEAMS 2011),* pp. 80-89 (2011)
- Tamura, Villegas, Müller, et al.: Towards practical runtime verification and validation of self-adaptive software systems. In: de Lemos, Giese, Müller, Shaw (Eds.), *Software Engineering for SAS,* Springer (2012)



Integrate runtime V&V tasks into adaptation process

- Tamura, Villegas, Müller, et al.: Towards practical runtime verification and validation of self-adaptive software systems. In: de Lemos, Giese, Müller, Shaw (Eds.), *Software Engineering for SAS,* Springer (2012)

Control Science



Control science can be defined as a systematic way to study certifiable V&V methods and tools to allow humans to trust decisions made by self-adaptive smart systems.

Cyber-Physical Systems

Convergence of Computing, Communications, and Control

- CPS encompass
  - computational and physical components
  - seamlessly integrated and closely interacting
  - sense the changing state of the real world
- CPS complexity
  - numerous spatial and temporal scales
  - controlling computational and physical components
  - highly networked communications
- CPS interconnected capabilities
  - integrated networking
  - computing
  - controlling
  - sensing and actuation
- CPS impact
  - societal impact is enormous
  - virtually every engineered system is affected by advances in these interconnected capabilities
- CPS applications
  - expected to be more transformative than the IT revolution of the past three decades
- Related terms — subsystems of CPS
  - Internet of things (IoT)
  - Industrial Internet (II)
  - Systems for a smarter planet (smart cities, smart grid, smart cars, smart everything)

The 3 I's of Smart Systems

Instrumented Interconnected Intelligent

- IBM: What 'Smarter' Means, http://www.ibm.com/smarterplanet/us/en/index.html?re=sph (2012)
- IBM: Smarter Government, http://www.ibm.com/smarterplanet/ca/en/ (2011)
- Siegele: Smart Systems: Living in a see-through world, *The Economist* (2010)
- Siegele: Smart Systems, *The Economist,* Special Report, http://www.economist.com/node/17388368 (2010)
- IBM: The Internet of Things, http://www.youtube.com/watch?v=sfEbMV295Kk (2012)
- G. Golden: IBM Watson and the Future of Work, http://www.garrygolden.net/2011/10/15/future-of-work-202-ibm-watson-siri/ (2011)

Great Videos

Something profound is happening ...

Instrumented

We now have the ability to measure sense and see the exact condition of practically anything.

Interconnected

People, systems, and objects can communicate and interact with each other in entirely new ways.

Intelligent

We can respond to changes quickly and accurately and get better results by predicting and optimizing for future events.

Something profound is happening ...

We now have the ability to measure sense and see the exact condition of practically anything.

"When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it your knowledge is of a meager and unsatisfactory kind"

—Lord Kelvin

Something profound is happening ...

Over the past three years people have given up their location and time privacy —willingly

Something profound is happening ...
The Smart Systems Revolution

Instrumented Interconnected Intelligent

Confluence of Sensors, Networks, Devices, Clouds, and Apps

IBM Initiative
Smarter Systems for a Smarter Planet

The world is getting smarter

More instrumented, interconnected, intelligent

Smart traffic systems

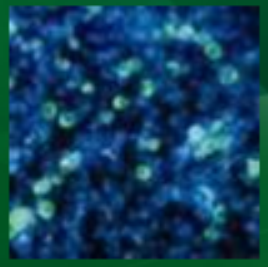
Intelligent oil field technologies

Smart food systems

Smart healthcare

Smart energy grids

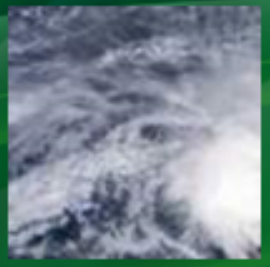
Smart retail



Smart water management

Smart supply chains

Smart countries



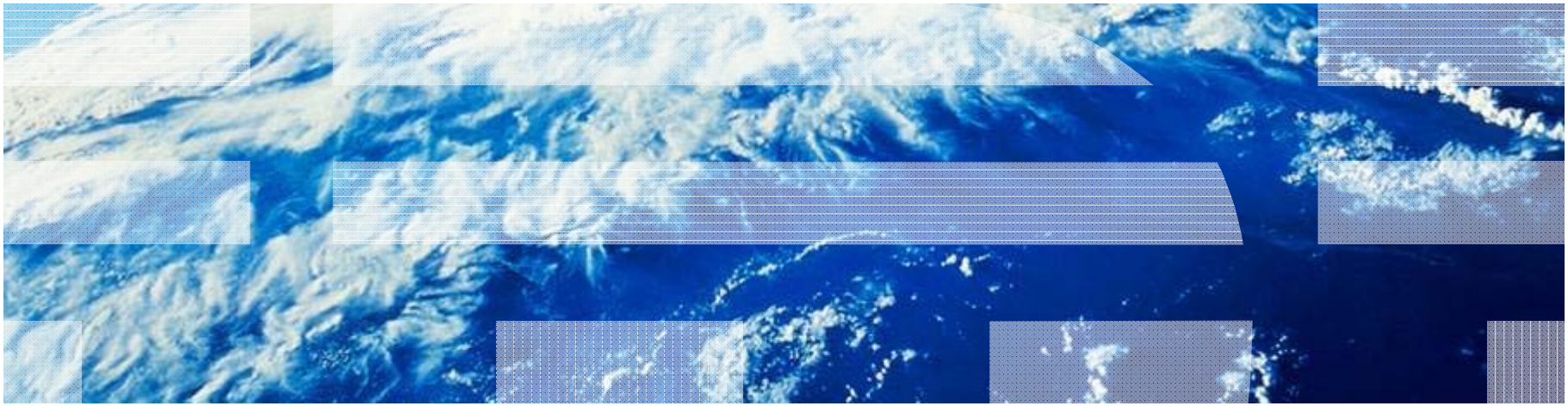
Smart weather

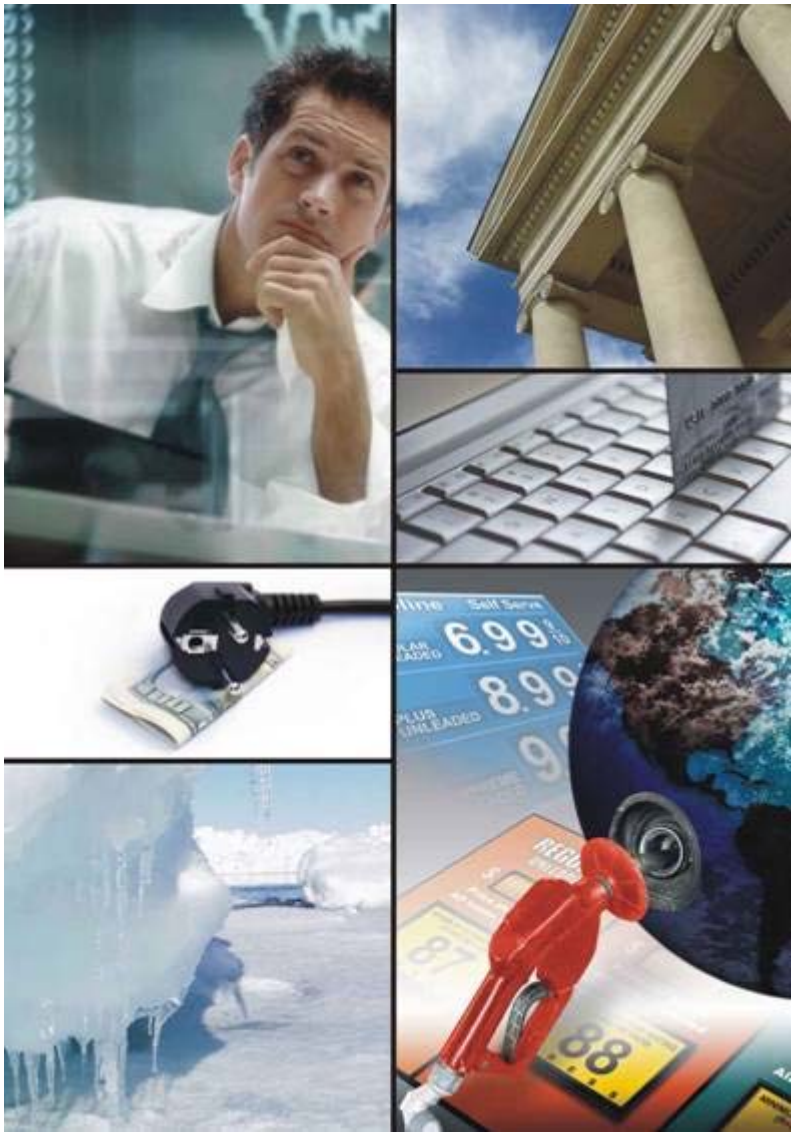
Smart regions

Smart cities

Presenter's name
Title
email
date

Let's Build a Smarter Planet:
Green Infrastructure





Reality of a globally integrated business world.

- Economic downturn requires doing more with the same and using self funding projects.
- Business and organizations need to use less energy and water.
- Use electricity required for day-to-day operations as efficiently as possible.
- Sustainability has emerged as a new business imperative.

These issues are interwoven.

The need for an energy efficient infrastructure is clear.

35%

IT energy expense is expected to increase 35% in the next four years.

8 in 10

More than 80% of CEOs expect climate change regulation 5 years.

40%

Buildings account for 40% of worldwide energy consumption.

Mandate for change is strong.

Inefficiencies in current infrastructure

- Reduce energy costs up to 40% a year.
- Extend the life of IT and defer CAPX and OPEX cost.

No accurate measure of energy use enterprise wide.

- Document and benchmark current energy metrics.
- Enable readiness for rapidly emerging regulatory environment.

Facilities management is not integrated.

- Impacts more than 50% of your energy expense.
- Leverage asset management for tax, utility, stimulus incentives.

Green Infrastructure is an instrumented and interconnected system enabled by intelligent energy management.

IT Equipment

- Energy efficient hardware
- Virtualization and consolidation
- Active energy management
- Tiered storage

Applications and Data

- Lifecycle management, retention, archiving of data
- Optimization of application servers
- Application performance monitoring
- Data deduplication, compression and clean up

Data Center

- Accurate thermal and energy usage assessments
- Extend life of existing infrastructure
- Rationalize infrastructures across company
- Design flexibility into new data center infrastructure

Real estate and facilities

- Trend analysis and building maintenance diagnostics
- Building management systems integration
- Process management automation
- Dashboard reporting

Energy Management

- IT and Infrastructure interfaces
- Threshold controls
- Optimize assets for energy efficiency
- Track and verify energy efficiency

IT Equipment:
Virtualization and consolidation boost utilization.

Server Virtualization

Up to 30-70% TCO savings

- Up to 33-50% floor space and facility costs.
- 33-70% hardware costs.
- Up to 50% maintenance costs.
- Up to 33% support costs.

Storage Virtualization

Up to 25% less capacity needed

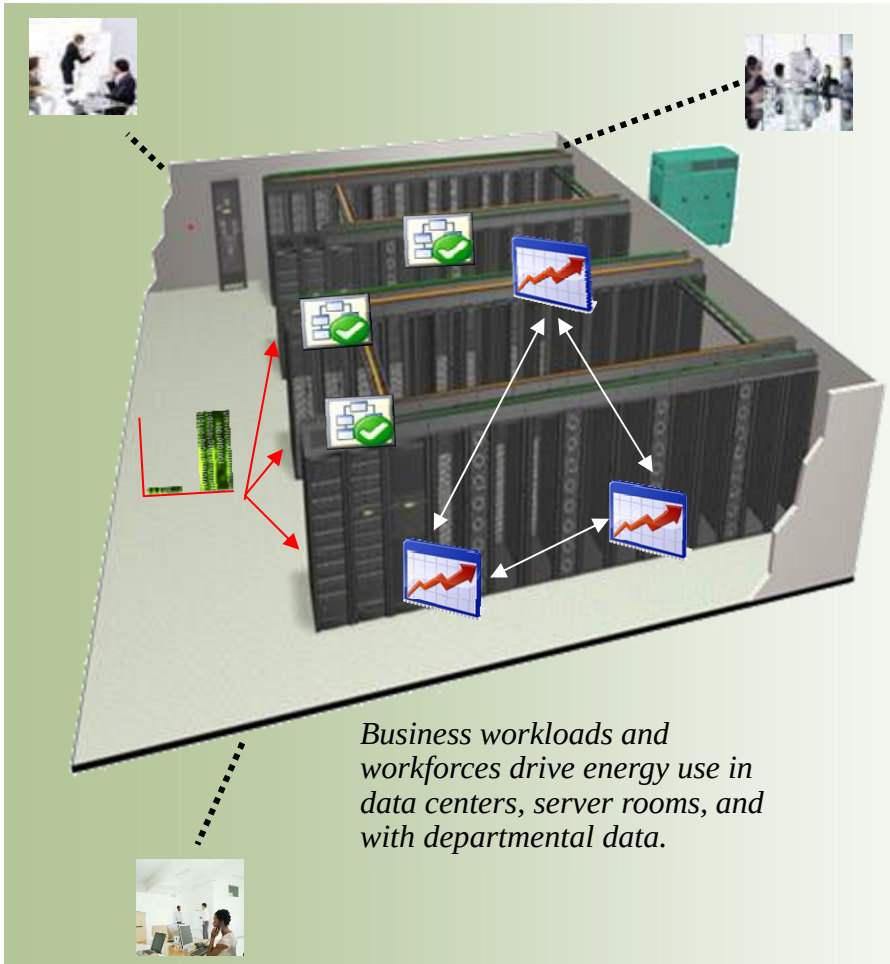
- Up to $50,000 power savings per 1,000TBs of installed storage.
- Up to 60% migration costs savings.
- Up to 300% increase in utilization

Client Virtualization

Up to 40% overall TCO savings

- Up to 45% power savings.
- Up to 90% deskside support.
- Up to 50% on helpdesk.
- Up to 75% in security and user administration.

Applications and Data :
Improve operations and environmental impact.



Business workloads and workforces drive energy use in data centers, server rooms, and with departmental data.

Measure and **control** energy usage of applications, manage storage infrastructure for efficiency.

Tivoli. software

Lower energy cost of applications with application level **virtualization** that increases utilization while meeting transaction level service level agreements.

WebSphere. software

Intelligent management of information via **de-duplication, compression** and hierarchical storage to reduce both storage and energy costs.

Information Management

Optimize application design and deployment architecture for reduced resource and energy needs.

Rational. software

Data Center:
Efficient growth with modular designs.

Scalable modular data center.

Up to 20% less than traditional designs.

- Turnkey center for 500-2,500 sq ft.
- Implement in 8-12 weeks.

Enterprise modular data center.

Defer 40-50% of capex and opex cost.

- Standardized design for 5-20K sq feet.
- Save up to 50% operational costs.

Portable modular data center.

Fully functional data center.

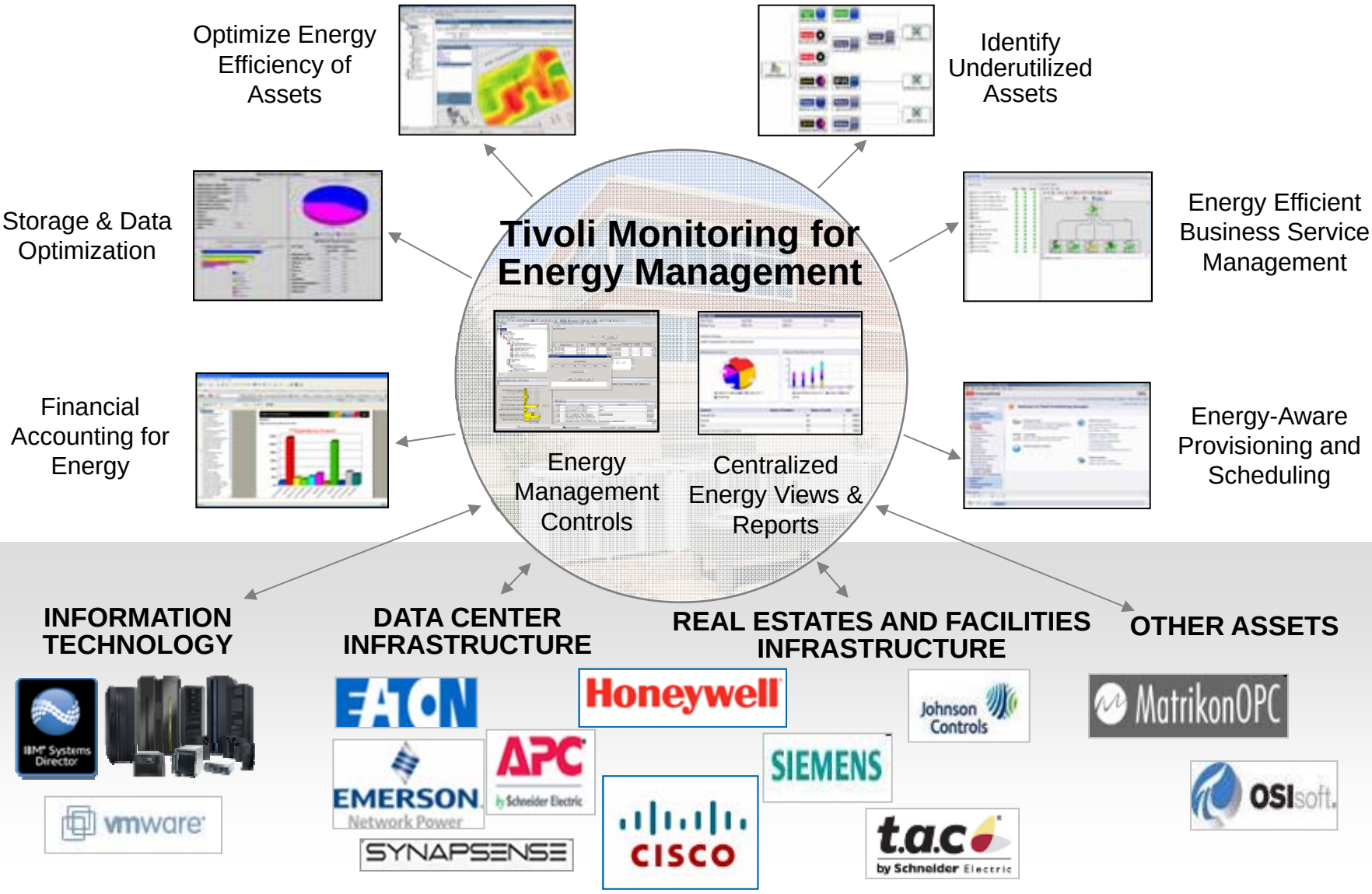
- Rapidly deploy in 12-14 weeks.
- Ease of maintenance.
- Open architecture.

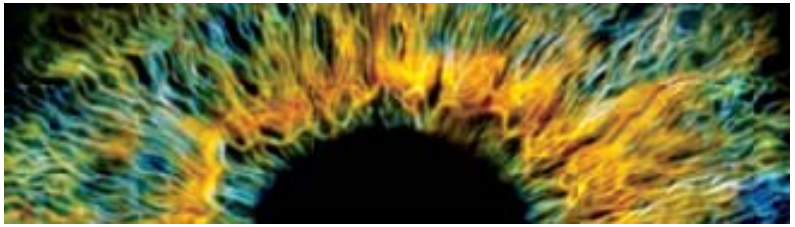
High density zone.

35% lower cost than site retrofit.

- In-row cooling for cooling on demand.
- No disruption to existing operations.
- Avoid over provisioning of cooling.

Real estate and facilities Energy Management across the infrastructure





We've only just begun to uncover what is possible when building a sustainable solutions…

- By helping to lower energy costs across-the-board for our clients; which also helps them overcome current operational barriers.
- Strengthening our clients' reputation while helping them meet environmental regulation requirements.
- Help create products and services that can give rise to new markets for our clients.

Let's work together to drive real progress in our time.

"The world is on the threshold of a new era of innovation and change with the rise of the **Industrial Internet**."

– Peter C. Evans,
GE Director of Global Strategy and Analytics

– Marco Annunziata,
GE Chief Economist

www.ge.com/sites/default/files/Industrial_Internet.pdf Nov 2012

The Industrial Internet Economy
Canadian Financial Post, May 2013

- The seeds of the Industrial Internet are already being planted in the Canadian economy.
- Sensor technologies are deployed in machinery to monitor equipment operations and manage the schedules and routes of transportation fleets.
- The Industrial Internet revolution begins with the choices of business visionaries.
- It will be managed and made valuable by the decision makers who rise to its opportunities.

http://business.financialpost.com/category/news/executive-summary/industrial-internet

Ted Talk by Marco Annunziata 12:37 mins

Chief Economist of General Electric Co.

http://www.ted.com/talks/marco_annunziata_welcome_to_the_age_of_the_industrial_internet

What caught your eye?