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

Dr. Hausi A. Müller

Professor

Department of Computer Science

University of Victoria

http://courses.seng.uvic.ca/courses/2013/summer/seng/480b
http://courses.seng.uvic.ca/courses/2013/summer/csc/485b
http://courses.seng.uvic.ca/courses/2013/summer/csc/586b

1

Announcements

- Fri, July 5 **Smart Applications on Virtual Infrastructure**
    - Prof. Venkatesh Srinivasan
    - Balasubramanian, Desmarais, Müller, Stege, Venkatesh: Characterizing problems for realizing policies in self-adaptive and self-managing systems
      In: *Proc. 6th Int. Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS 2011)*, pp. 70-79, ACM Press, May 2011.
- Midterm grading
    - I will grade it ☺
    - Should be graded by July 10
- Policy Presentation
    - Angela and Alessia

Situational Awareness (SA)

- SA is the perception of environmental and personal context with respect to time and space
- Comprehension of its meaning and its projection into the future
- Critical to decision-making in complex, dynamic situations

- Applications
  - Mars Curiosity
  - Aviation—UAV, drones
  - Military command and control
  - Emergency services

- Applications
  - Driving a car
  - Crossing a street
  - Playing soccer
  - Playing basketball
  - Shopping

Intuitively we know how critical and valuable context is. But context is complicated.

"Context is the new battleground between Android, iOS, Windows, Symbian and Apple, Google, IBM, Microsoft, Nokia, Samsung."

The Age of Context

Simple can be harder than complex. You have to work hard to get your thinking clean to make it simple.
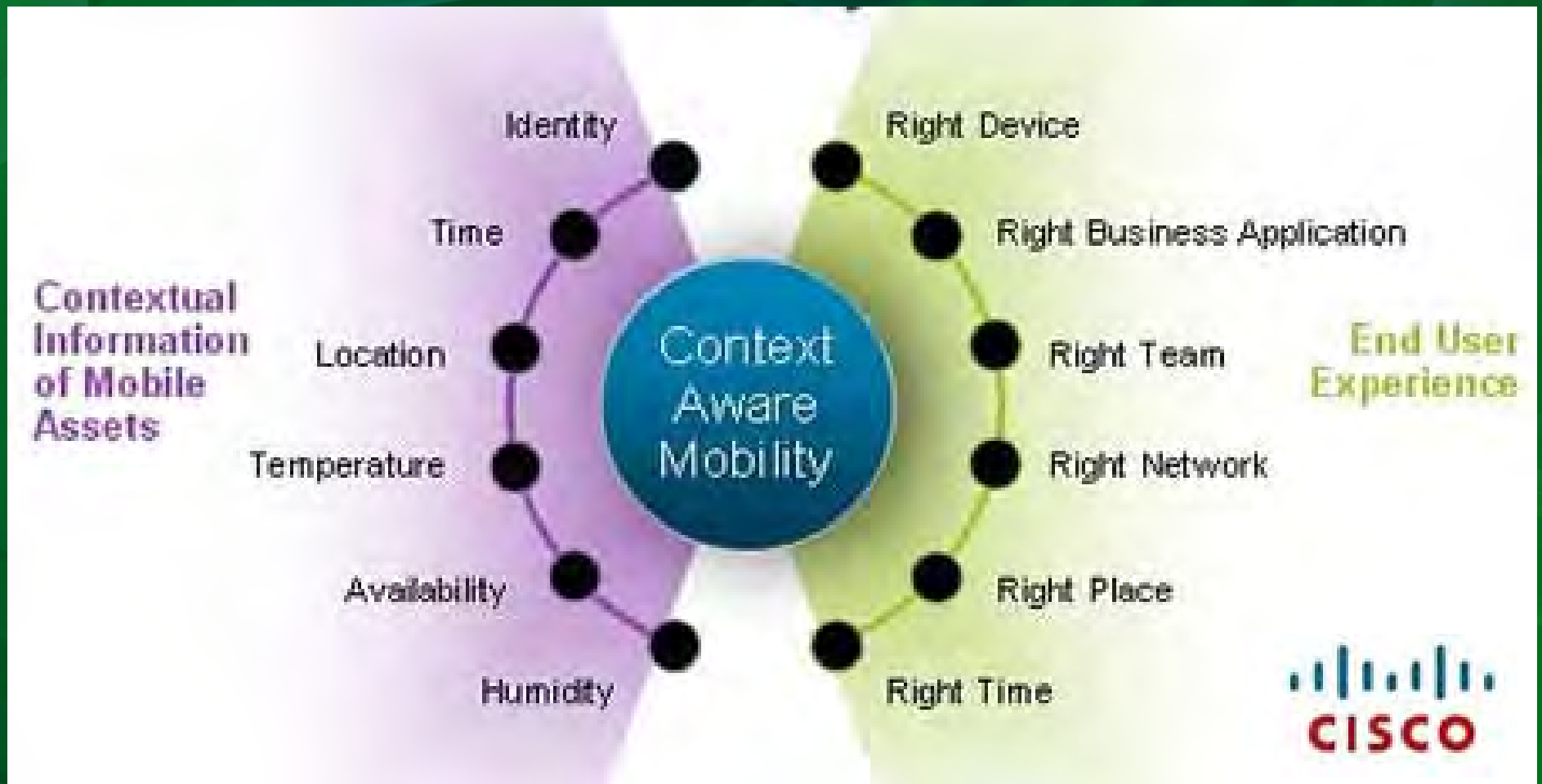
Steve Jobs, BusinessWeek, 1998

5

Pillars of Context

- The Internet of Things
  - Sensors for location, light, motion, temperature
  - Record, transmit findings to control instruments
- Semantic web, Big data
  - Clouds store massive data on people, places, things
  - Information about everything accessible on the web
- Digital mapping
  - Every square inch of the world is mapped
- Really smart mobile devices
  - Every person has one
  - Highly customized smart applications
- Mature social media
  - Highly personalized virtual networks
- Wearable computers
  - Google glasses, Google driverless car

Highly Dynamical Software Systems

R. Scoble, S. Israel: *The Age of Context: How It Will Change Your Life & Work, 2013.*   6

Context Aware Mobility

Nate Silver

- American statistician, sabermetrician (analysis of baseball), psephologist (scientific analysis of elections and writer

- In 2008 correctly predicted the winner of US presidential election in 49 out of 50 states and all 35 US Senate races

- In 2009 named one of The World's 100 Most Influential People by *Time Magazine*

- In 2010 his *FiveThirtyEight* blog was licensed for publication by *The New York Times*

- Book: The Signal and the Noise: Why Most Predictions Fail – But Some Don't. New York: Penguin, 2012

- In 2012 correctly predicted the winner of all 50 states and 31 out of 35 US Senate races

- On Nov 12 *The Signal and the Noise* was named Amazon's #1 Best Book of the Year for 2012

Big Data — Signal to Noise Ratio

- As data available to an organization grows, the percentage of data that the organization can actually process is decreasing
- Smart real time analytics

Big Data Holds a Lot of Context

- Smart real time analytics
- Exploit context to reduce the signal to noise ratio
- Become situation-aware

Data **AVAILABLE** to an organization

Signals and Noise

Data an organization can **PROCESS**

What is the difference?

Big Data — Signal to Noise Ratio

- As data available to an organization grows, the percentage of data that the organization can actually process is decreasing
- Smart real time analytics

Big Data Holds a Lot of Context

- Smart real time analytics
- Exploit context to reduce the signal to noise ratio
- Become situation-aware

Applications for Big Data Analytics

Smarter Healthcare

Multi-channel sales

Finance

Log Analysis

Homeland Security

Traffic Control

Telecom

Search Quality

Manufacturing

Trading Analytics

Fraud and Risk

Retail: Churn, NBO

12

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

13

Self-Adaptive Systems (SAS)

- A SAS can alter its behaviour at runtime (on the fly) in response to its perception of **SEAMS 2012**
  - its environment
  - its own state

  by adapting itself

- SAS abilities
  - Assess its own behaviour
  - Observe its context or environment
  - Adapt without shut down
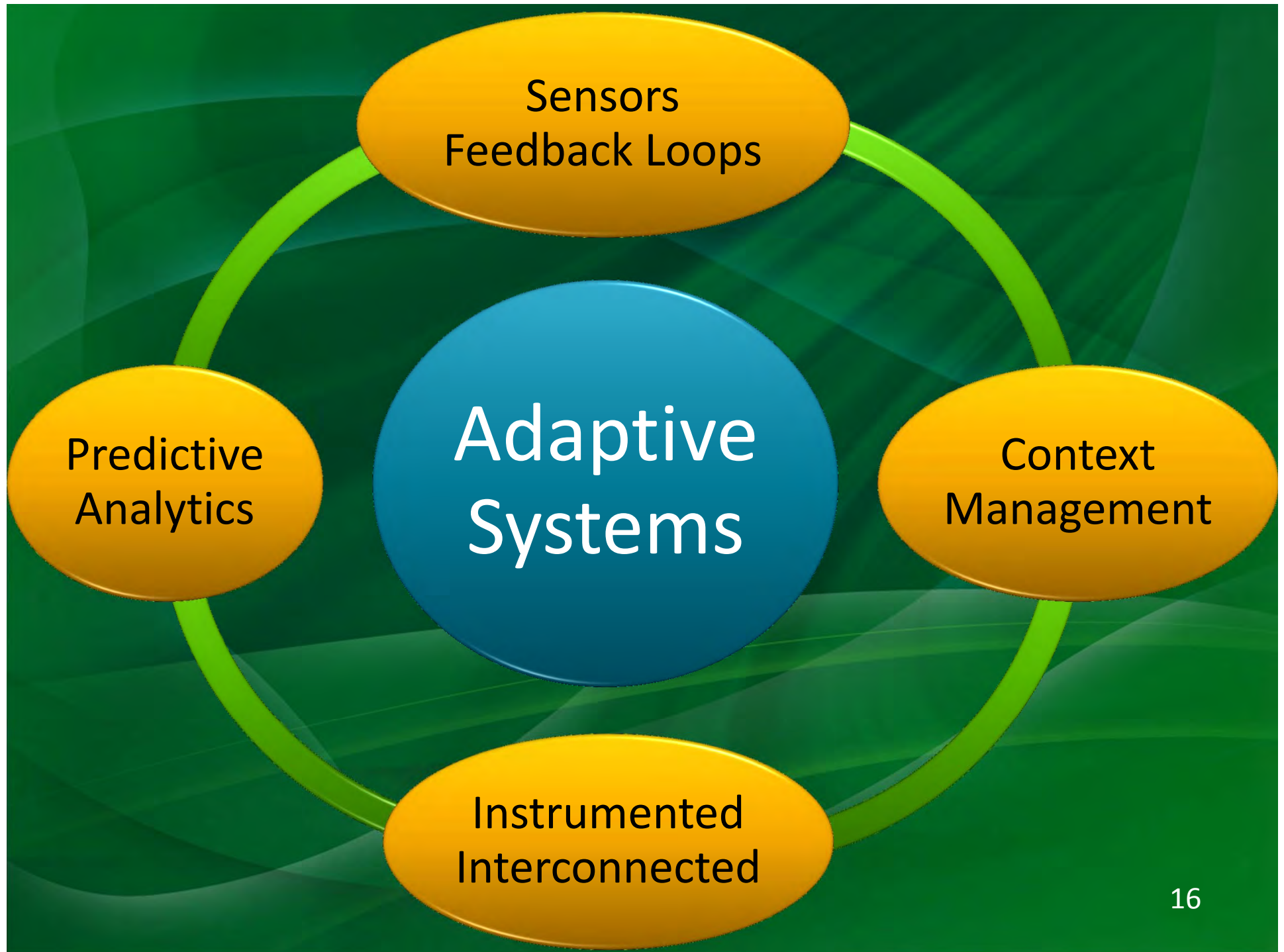
- Oreizy, et al.: An Architecture-Based Approach to Self-Adaptive Software, *IEEE Intelligent Systems,* pp. 54-62 (1999)
- MacManus: Why Software is More Important Than Sensors in the Internet of Things, ReadWriteWeb (2010)

Smarter System Characteristics

- Goals change at runtime
- High degree of dynamism
- High degree of uncertainty
- Requirements change at runtime

Smarter systems adapt at runtime

16

How should we teach the concepts of highly dynamical software systems in the age of context?

How do we integrate these topics into computing science and software engineering curricula?

17

Ian Sommerville
Software Engineering
9th Edition
2010

SOMMERVILLE

SOFTWARE ENGINEERING

9

Contents at a Glance

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)
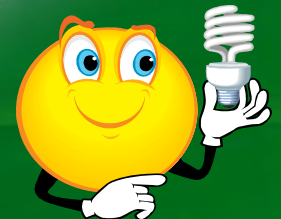
20

Requirements @ Runtime

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

The system shall do this ... but it may do this ... ... as long as it does this.

- **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?
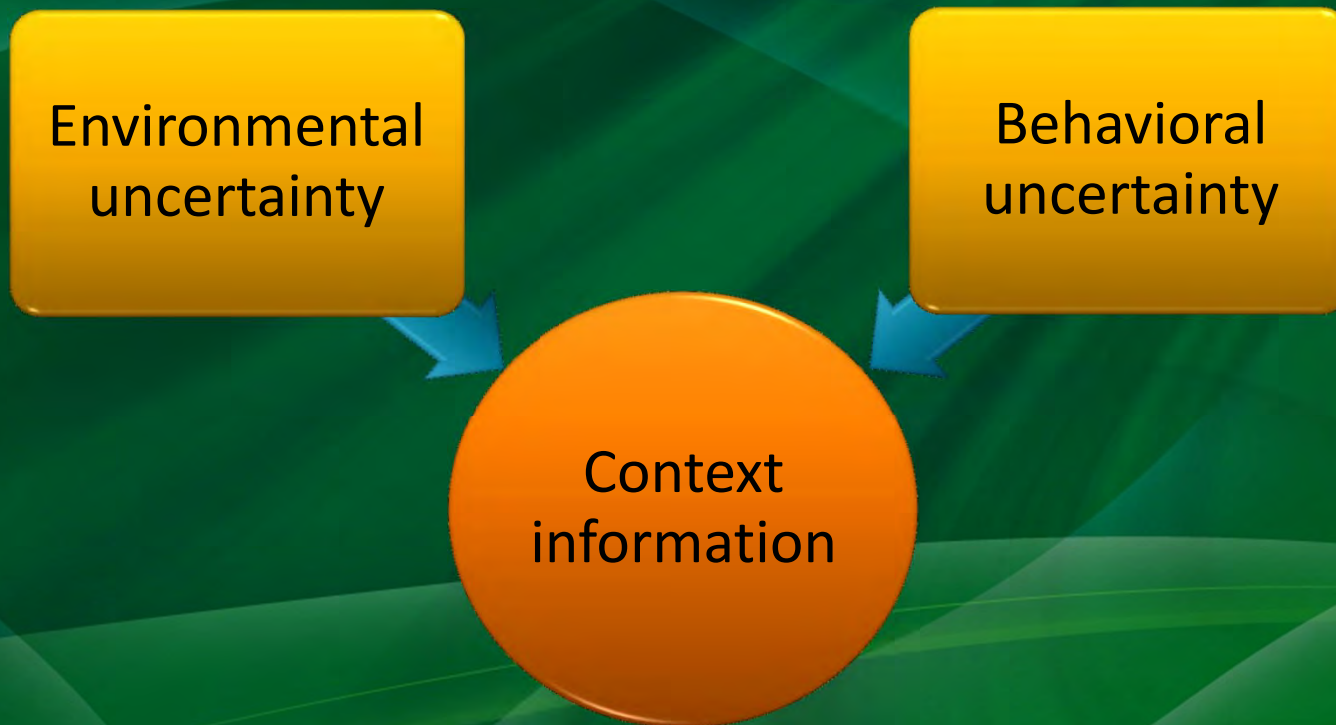
Models @ Run.time

- 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

Context Models @ Runtime

Environmental uncertainty

Behavioral uncertainty

Context information

➤ Coutaz, Crowley, Dobson, Garlan: Context is key, *CACM* 48(3) (2005)
➤ Whittle et al.: RELAX: A language to address uncertainty in self-adaptive systems requirements, *Requirements Engineering* 15(2):177-196 (2010)
➤ Inverardi, Mori: Feature-oriented evolutions for context-aware adaptive systems. In: *Proc. IWPSE-EVOL,* pp. 93-97, (2010)

23

Make Context First Class

Context representation
- Modeling of relevant context
- Context management strategies
- Adaptation of context models at runtime

Context management
- Adaptive context management strategies
- Gathering, provisioning
- Context reasoning

24

Make feedback loops first class

Autonomic control loop

- Analyze
- Monitor
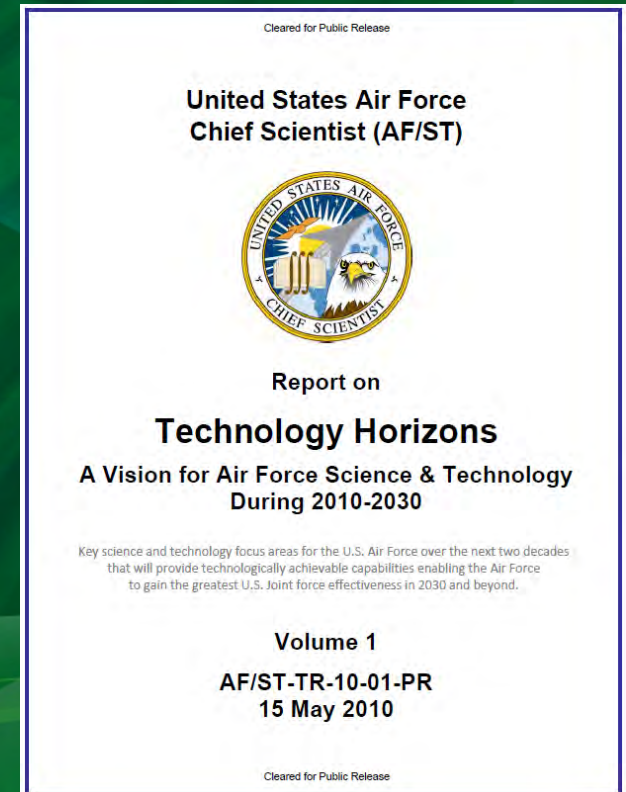- Regulate objectives maintain equilibrium
- Plan
- Adapt
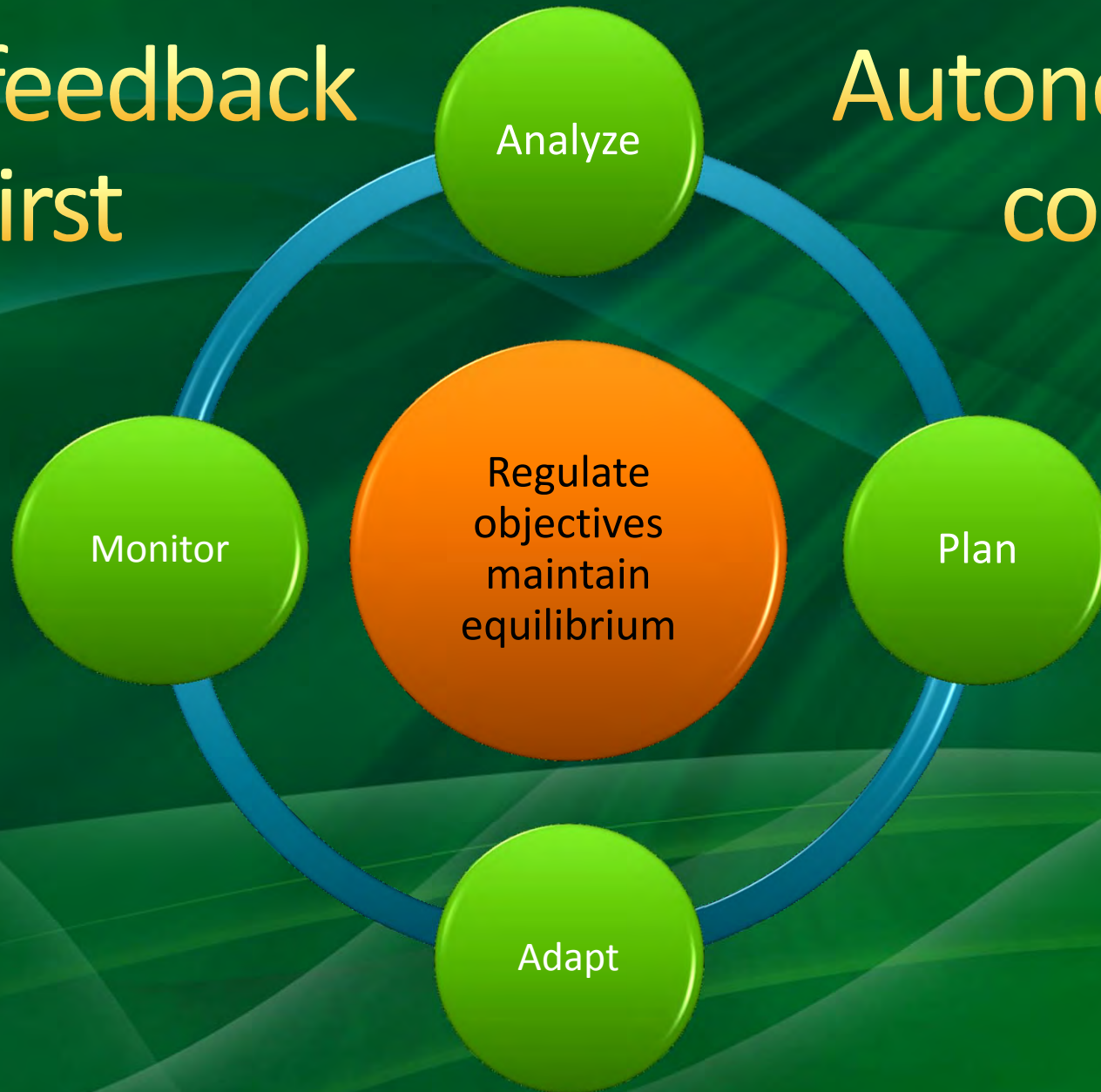
➢ Müller, Pezzè, Shaw: Visibility of control in adaptive systems, *Proc. Second Int. Workshop on Ultra-Large-Scale Software-Intensive Systems (ULSSIS 2008)*, pp. 23-26 (2008)
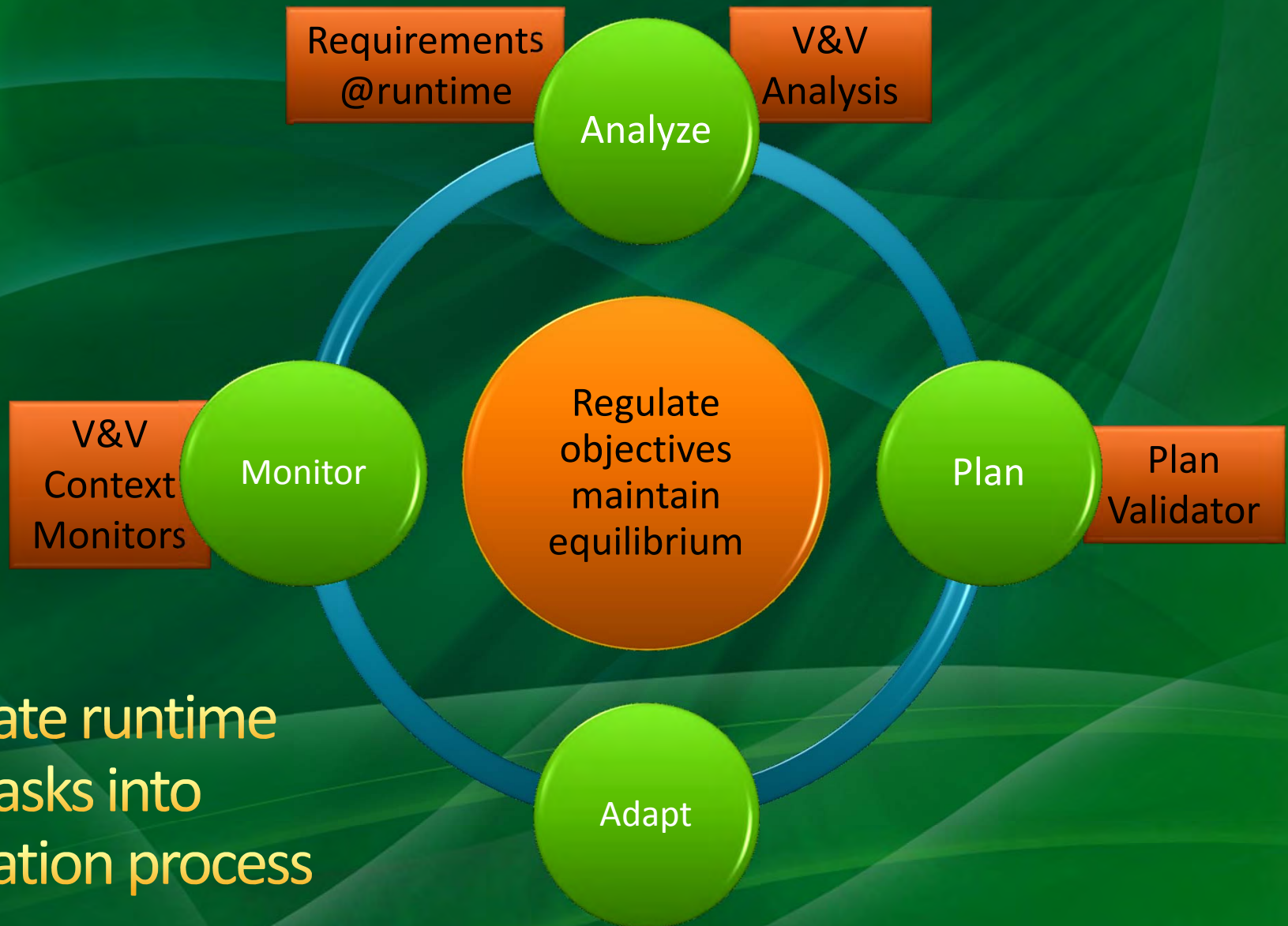
Assurance @ Runtime
Make V&V @ Runtime First Class

- 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

Requirements @runtime

V&V Analysis

V&V Context Monitors

Plan Validator

Analyze

Monitor

Regulate objectives maintain equilibrium

Plan

Adapt

➢ 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)

27
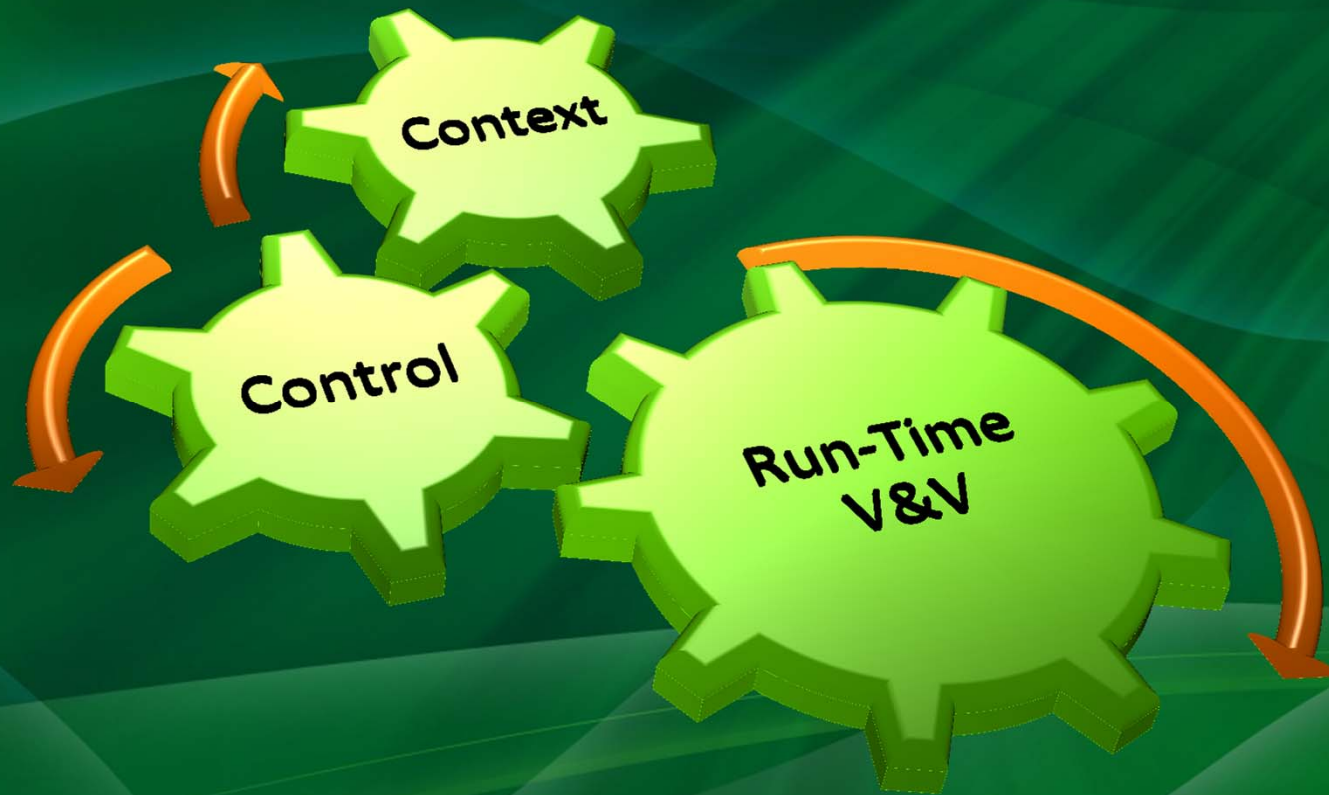
Control Science

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. 28

Our Research Objective

Conduct fundamental research on situation-aware
self-adaptive software-intensive systems
to optimize their dynamic capabilities

Context Management

Feedback Control

Runtime V&V