



## Group Discussion Summary

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- New Forces/Opportunities/Requirements/Visions
- Example Applications
- Technical Problems
- Research Directions and Approaches
- Other Required Research
- Benefits or how we will make the world a better or safer place
- Observations on Approach
- What Could be Accomplished When
- Metrics of Progress

# Forces and Visions



- Everything is a computer
- Everything is a networked computer
- Everything is potentially interdependent
- Things connect to the real world
- Increasing heterogeneity

# Forces and Visions



- Complexity Threshold has arrived!
- **Fact:** Systems are growing and will keep growing
  - With growth comes increasing complexity and, thus,
  - A pressing need to keep application programming relatively independent of the complex issues of distribution and scale
- **Inherent Complexities**
  - discrete platforms
  - integration is the norm
  - partial failures are the norm
  - continuous operation and upgrade
  - changing environment and configuration
  - satisfaction of end to end properties in resource constrained environments
  - dynamic non-deterministic base
- Moving to Affordable and Dependable National Scope Critical Systems
- Consistent Experience over changing environments
- Save \$ or construct larger systems as the dividend from a new approach to development
- A constant need to stay at the leading edge of knowhow
- A vaccine against software system failure
- Software catalytic converters to clean up the mess

# Example Applications



- Integrated Medical Systems
- Terrorist Identification Systems
- Traffic control
  - Sensor data from 1000s of vehicles
- Swarms of UAVs
- National Voting System
- Theater battle management
  - varying granularities of coordination/missions in a hostile environment
- Supply chain management
- Community analysis of scientific data
  - Soft-real-time response and query optimization from 1000s of users, via coordinated management of 1000s of resources
- Home power management



- Supporting resource management of multiple cross-cutting properties
  - ▣ Timeliness, quality, security, power, reliability, etc
  - ▣ Resource constrained (embedded) development and views: QoS, time/dependability/energy/footprint
- Lack of end-to-end properties in composite systems
- Lack of a computational model that allows for engineering tradeoffs
- Dynamic resource behaviors (in time and space): failure, variable load, changing requirements, ...
- Legacy: things that were not designed to work together now need to

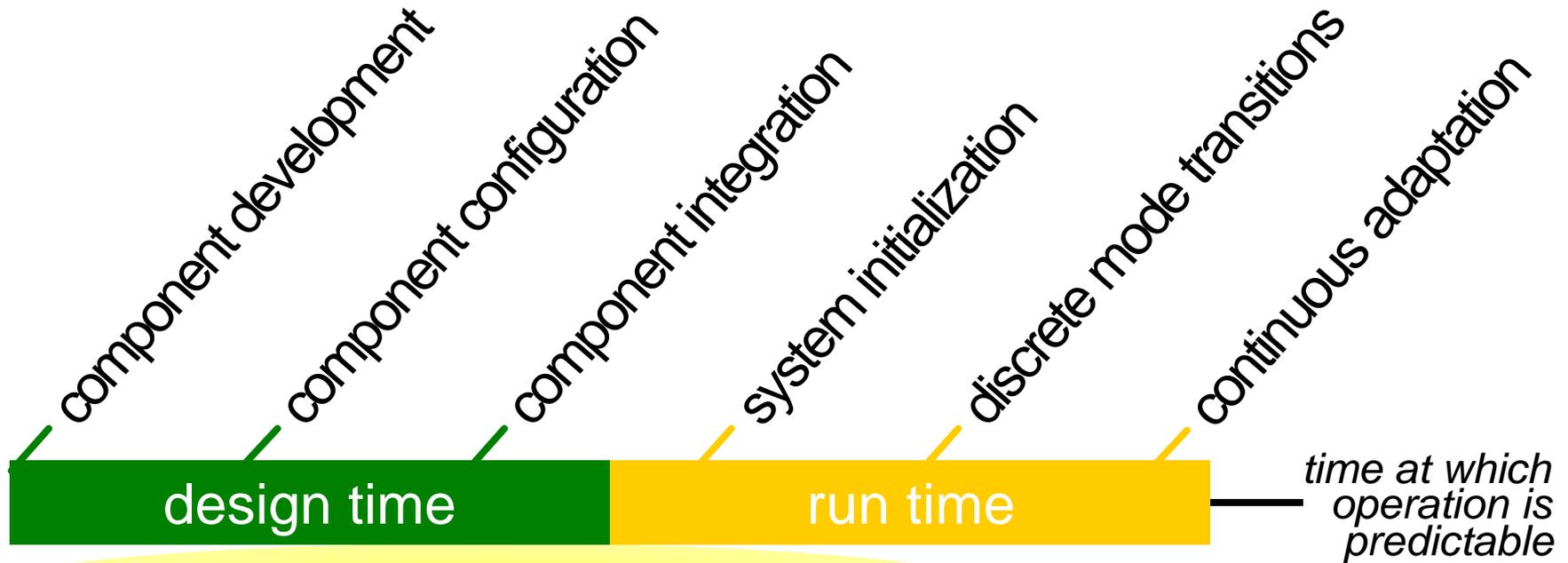


- Risk, trust and control management
  - ▣ Policy/security/admin domains
  - ▣ Safety and validation of very dynamic systems
  - ▣ privacy
- Scale
  - ▣ Number of entities
  - ▣ Size of entities
  - ▣ Distance between entities
  - ▣ Number of entities composed in a single computation
  - ▣ Timescale over which network centric systems exist and non-stop behavior

# Technical Challenges (continued)



## Verifiability and Certifiability



**current research leverages**

**current practice assumes**

">\$1B to certify"

**Need To Extend Both Verification Timeline and Locality To Leverage Emerging Technologies**

# Compelling Research Directions and Approaches



- Four complementary thrusts that need to be addressed at all levels; one crosscutting/ coupling issue
- (1) View based projections that when combined deal with “the aggregate end-to-end problems”
  - New and flexible engineering tradeoffs
  - Operation at massive scales
  - Dynamic resource behaviors
  - Risk, trust and safety management



- (2) Work on basic mechanisms that underlie “the problems” and the “views”
  - Resource tradeoffs: QoS mechanisms, RT, etc
  - Adaptive behavior
  - Scaling in various dimensions
  - Distributed control and coordination
  - adaptively using reflective (“own system”) information
- (3) Coordinated Multi-level resource management techniques
- (4) Construction of large systems with global behavior by composition of (small scale) network centric components; interoperability



## View-Based Development

- Define Views
  - structural and behavioral (e.g. security, safety, rt perf., reliability, control, ...)
- Define Desired Analysis and Composition
  - Automating system configuration and generation of models
  - Predicting system level behaviors from local models
  - multi-dimensional tradeoff
  - global policy informs local behavior
  - Integration of views
- Develop Software Engineering Tools To Support All Above
  - define view representations
  - Define Automated Generation From Models/Analysis
  - Verify Conformance of Implementation to View



- Development of metrics (benchmarks) to allow system developers to quantify (evaluate) the “-ilities” that their systems exhibit in practice
- Runtime Adaptability
- longer term evolvability
- (Automated) configuration and management of large-scale distributed applications

# A Cut at Integrating Ideas



**Future distributed systems will increase in size and complexity in order to meet the appetite for increased scope, competitive advantage and opportunistic interoperability deriving from easy connectivity**

**But number of interactions increases superlinearly with size, and overlapping attributes linearize, inadvertently customize and complexify the development process and product, making change impossible.**

**And number of interactions is proportional to schedule, cost, & defects[i.e. productivity], and to dependability and performance bounds [i.e. is it useful/useable]**

**Problem further exacerbated by distributed system characteristics, heterogeneous nature, intruders, nondeterministic substrate, ...**

**Elements of a Solution:**

- 1. Factor problem specification into multiple, higher level, semantically sound, views to isolate complexity, reduce interactions, overlap, & inconsistencies, and promote change.**
- 2. Populate these views with a quantifiable spectrum of varying cost solutions**
  - Provide automated support for sound \*composition\* of multiple views into composite high level specifications(models) while also facilitating tradeoff decision-making during the composition.**
  - Then provide automated support for the design and implementation of the specifications, via automated analysis of implementations and/or automated generation of implementations.**
  - Co-evolve the interconnected high level models and the implementations using the automated support toolset.**

**Many research issues: is this feasible?, representation of specifications, composition methods, quantification of attributes, ...**



- Building These Large Highly Distributed Systems Will Be More Affordable and Predictable and Safer...
- Societal
  - Build things that we just can't build now
  - Increase quality of future networked systems etc.: design by engineering not debugging
  - reduce exploding software development costs for the complex requirements of network centric systems in the real world
- Training
  - Seed industry (and academia) with people able to write new software & engineer new systems
- Better use of human resources
  - higher productivity
  - better match to people skills



- **Teamwork is fundamental**
  - cross-panel integration and result integration
  - large collaborative R&D effort is required to enable this large vision, to complement important individual efforts
  - industry buy in
- **Need for large-scale projects to help us discover the real problems and validate partial results**
  - common infrastructure
  - common challenge applications
- **International collaboration is desirable**

# Schedule and Expectations





- Transfer to real users
- commercial co-funding
- Discrete Experiments and Evaluation of Partial Results
- use challenge application to derive measures of success for the decomposition/composition technology



## In No Particular Order

- Aspects
- Better tools
- integration of various views --> running code
- informal techniques --> formal semantics
- adaptive middleware
- decomposition methodology & tools toward better blueprints
- tying implementation to the end effect result
- integrated properties & tradeoffs
- higher level RT abstraction
- distributed control
- invariant centric development practices
- global constraints transformed to local behavior, and dynamically recover from damage
- self-regulating software
- late binding