



Systems Engineering Advancement Research Initiative

**Systems Engineering in Systems-of-Systems:
The Shortfall in Education & Staffing
*An Educator/Research Perspective***

Dr. Donna H. Rhodes

Massachusetts Institute of Technology

rhodes@mit.edu

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Traits of Contemporary Systems Leaders

1. Powerful integrative leaders focusing on societal needs using approaches beyond traditional engineering
2. Able to consider “context” as design variable rather than a constraint
3. Intellectual skills to deal with many socio-technical dimensions
4. Higher order abilities for analysis and synthesis
5. Be capable of “situational leadership” – think and act in context of situation, and think both locally and globally

Five Concerns

Who We Educate

1. Pipeline of good candidates is insufficient for demand
2. Shift from “no-software” to “software-only” backgrounds in systems engineering student population
3. Certification may be desirable for some reasons but will not solve the SoS skill problem
4. Multi-generational systems population presents challenges in several ways
5. Classical academic acceptance criteria may not be suitable for situation at hand



Perspectives on Critical Skills Needed for SoSE

1. Situational leadership
2. Advanced system/enterprise architecting
3. Collaborative systems thinking
4. Anticipatory and options-based thinking

CRITICAL SKILLS (1) *Situational Leadership*

Develop ‘situational leadership’ abilities of engineers in regard to making decisions at multiple levels – component, system, SoS

- Decisional trade-off for local versus global system value delivery
- Sometimes “context” as design variable rather than a constraint

...leading
development
of a product?



seari.mit.edu

...leading
development of a
system family?



...a system?



CRITICAL SKILLS (2)

Advanced Architecting and Design Skills

- Innovation at the interfaces
 - Loose vs tight coupling
- Creating value through new synthesis
- Holistic approach to architecting product systems, services and enterprises
- Designing for changeability
 - Including entry/exit of constituent systems over time
- Advanced tradespace exploration and decision making

Vision is necessary, but not sufficient, to achieve fundamental changes in service values and operational forms and formations. We need to test the balance among joint and combined platforms and forces and to prompt not only technical innovation but also doctrinal and organizational innovation.

Haffa and Patton 1998

CRITICAL SKILLS (3) *Collaborative Systems Thinking*

- Emergent systems thinking greater than individuals
- Quickly build shared value/consensus in complex, diverse situations
- Incentives for SoS participation
- Challenge of global environment
- Thinking about capabilities vs requirements
- Perform in dynamic, uncertain environments



CRITICAL SKILLS (4) *Anticipatory and Options-based Thinking*

- Anticipating and responding to changing contexts and expectations
- Ability to think in terms of scenarios
- Identify and develop real options for systems and enterprises
- Understanding how systems react to internal/external impacts – including developing knowledge of constructs for impact analysis and methods decision making

*..... it does not matter that
they have got it wrong.*

*What matters is their
capacity to get it right quickly
when the moment arrives.*

Howard 1974

What Educational Innovations are Needed?

- Integrating discovery and learning with focus on impact
 - Fostered by cohort philosophy, approach, enablers
- Game/simulation based learning
 - New types of “classrooms” and venues for collaborative learning
 - Collaboration venues and use of industry/government venues
- Grand challenges and similar projects as part of degree programs
 - Dynamic and innovative engineering under extreme conditions



Students Design a Space System ESTEC 2002



Five Concerns

How We Educate

1. Challenges in academic setting to develop cross-disciplinary programs
2. Balancing needs in developing system generalists and domain specialists
3. Academic system still favors individual contributors versus collaborative contribution
4. Who can teach the SoS level skills – and how to motivate traditional faculty to collaborate in this regard
5. Lack of research funds for developing new education innovations and building collaborative learning venues