Systems Engineering: Meeting the Challenges of the 21st Century

Jon Wade
Associate Dean of Research
School of Systems and Enterprises
Stevens Institute of Technology
Hoboken, NJ

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The Role of SE

Systems Engineering

What: Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems.

How: It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.

Source: INCOSE definition 14 June 2004

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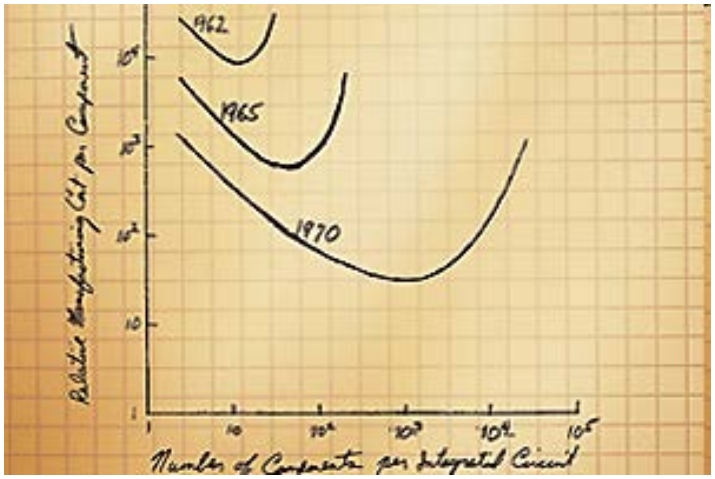
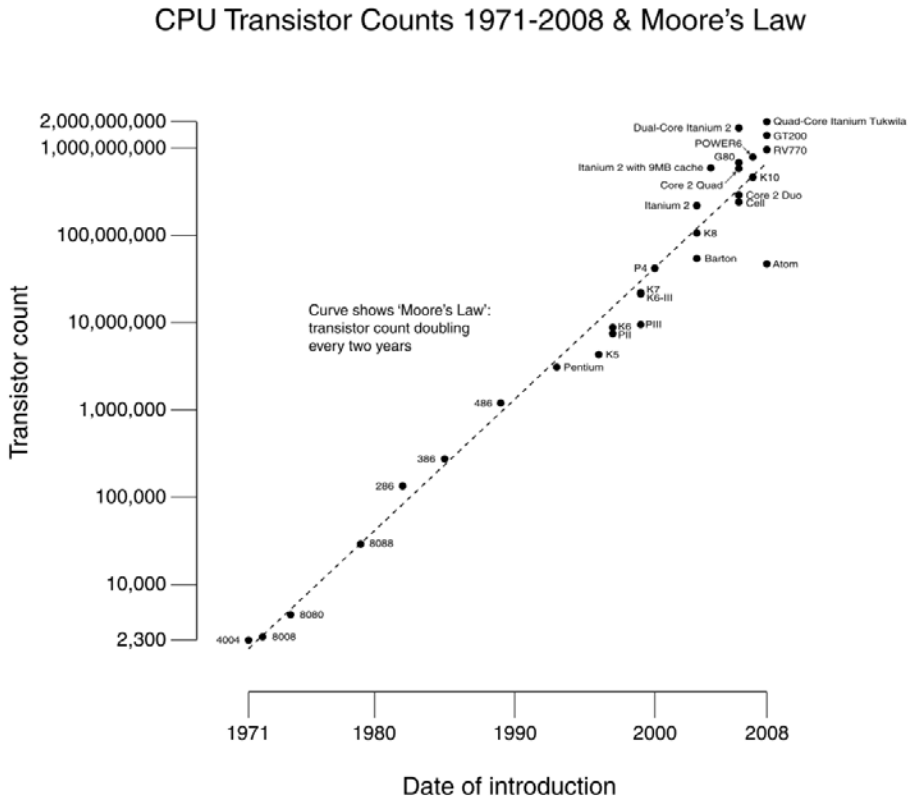
The Power of Scaling





The density of transistors at minimum cost per device doubles every 24 months.

- Gordon Moore, 1965

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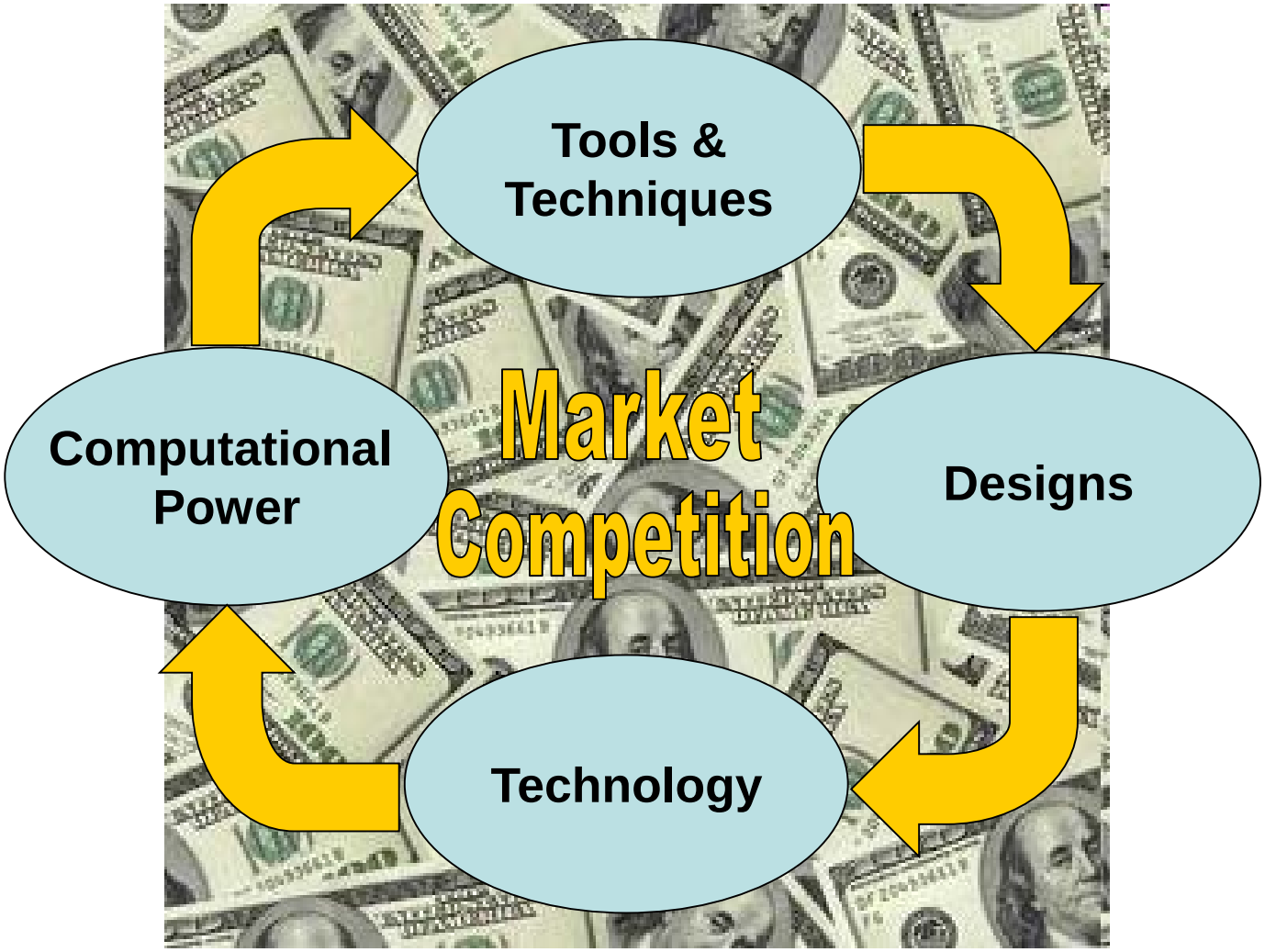
Virtuous Cycle



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Birth of the WWW

Compute Power

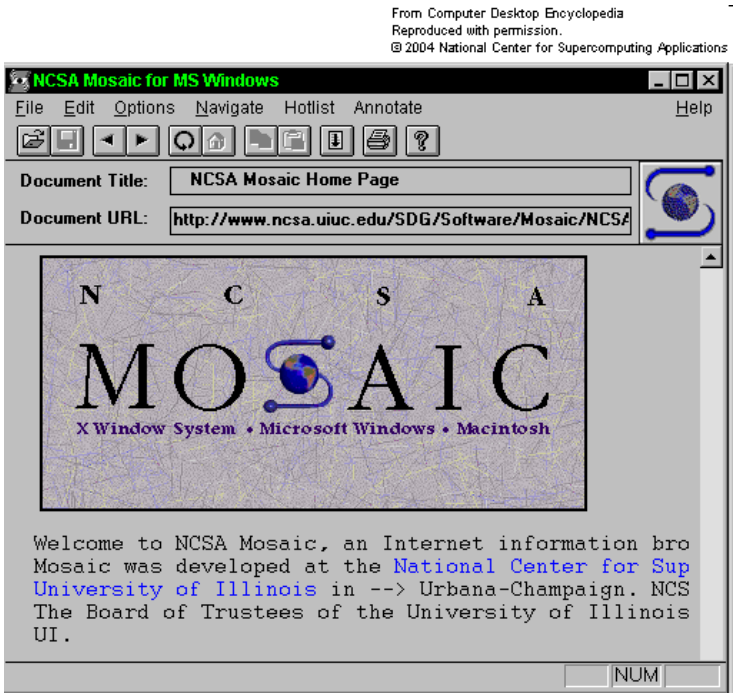
+

Bandwidth

+

DARPA

+



The Networked Universe

System Trends

1. **Complexity:** adaptive & emergent
2. **Criticality:** essential to day to day life
3. **Security:** increasingly valuable & vulnerable
4. **Time Compression:** we're all on internet time
5. **Legacy:** unplanned, ill-suited & growing
6. **Workforce:** great diversity, youth are perhaps best equipped for change & virtualization

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SE Practices

- Current SE practices, to a large degree, are an early mainframe era implementation based on the Systems Principles and Theory developed in the 1930's through 1950's.
- Traditional SE Methods, Processes and Tools (MPTs) are not appropriate for net-centric systems with dynamic requirements, swiftly changing technologies, short planning cycles and action oriented management and practitioners.
- Linear improvement cannot keep up with the exponentially growing demands that are enabled by the underlying technologies and amplified by the aforementioned trends.
- Human capabilities are not improving at exponential rates.

Is Systems Engineering on the Curve?

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Transforming SE

We postulate that the new paradigm must be:

- **Agile:** Allowing for quality, timely development with an incomplete and changing set of system requirements.
- **Integrated:** Part of the main development process and not an additional set of discretionary tasks.
- **Lean:** Providing the greatest amount of benefits with the minimal number of steps and least amount of effort.

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Transforming SE

We postulate that the new paradigm must be:

- **Leveraged:** Enabling exponential capability growth through the leveraging of computational and information technologies, and prior Systems work.
- **Extensible:** Providing the capability to expand and enhance capabilities for future growth without having to make major changes in the infrastructure.
- **Implementable:** Enabling widespread impact through workforce education and broad application.

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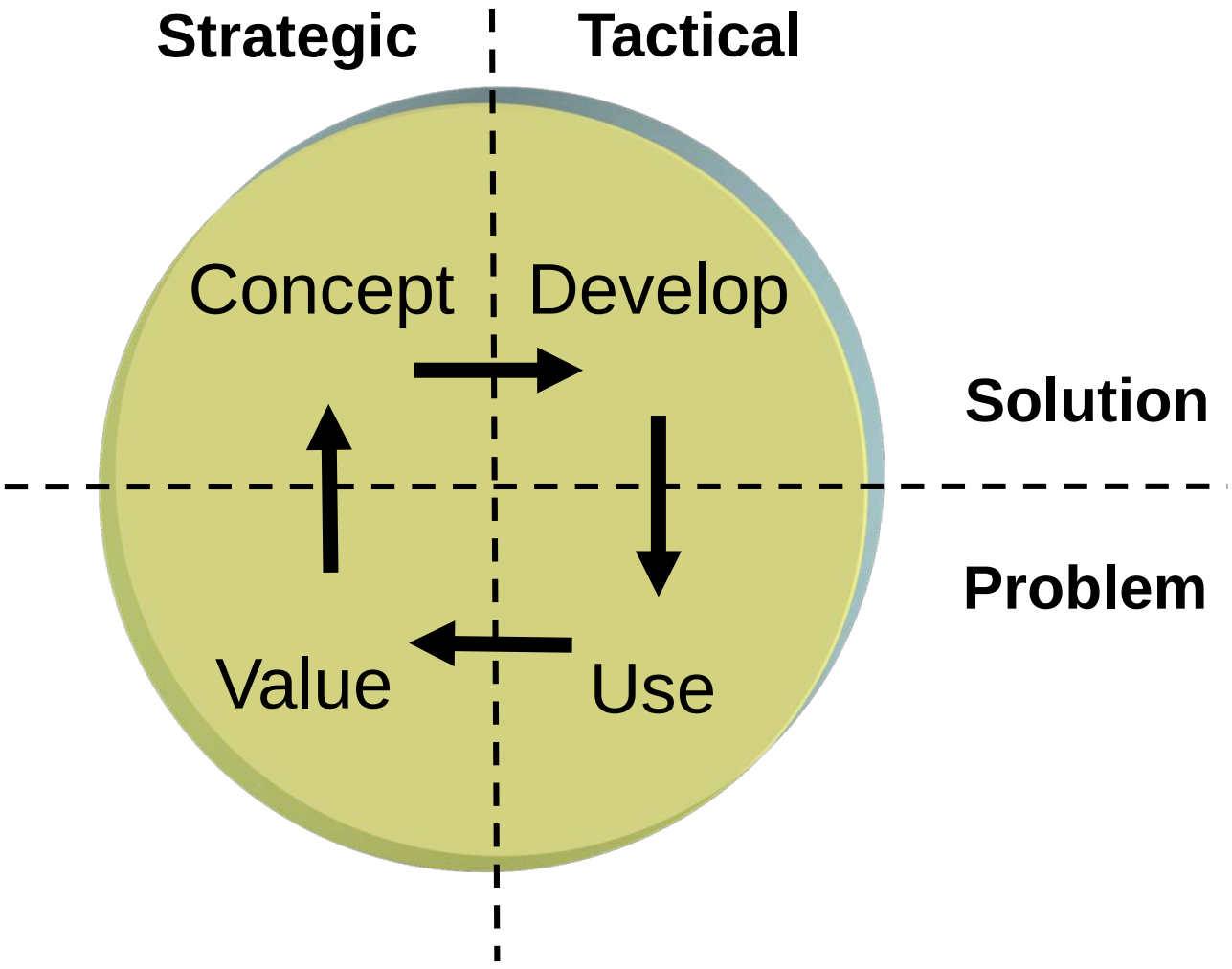
SE 'Phases'



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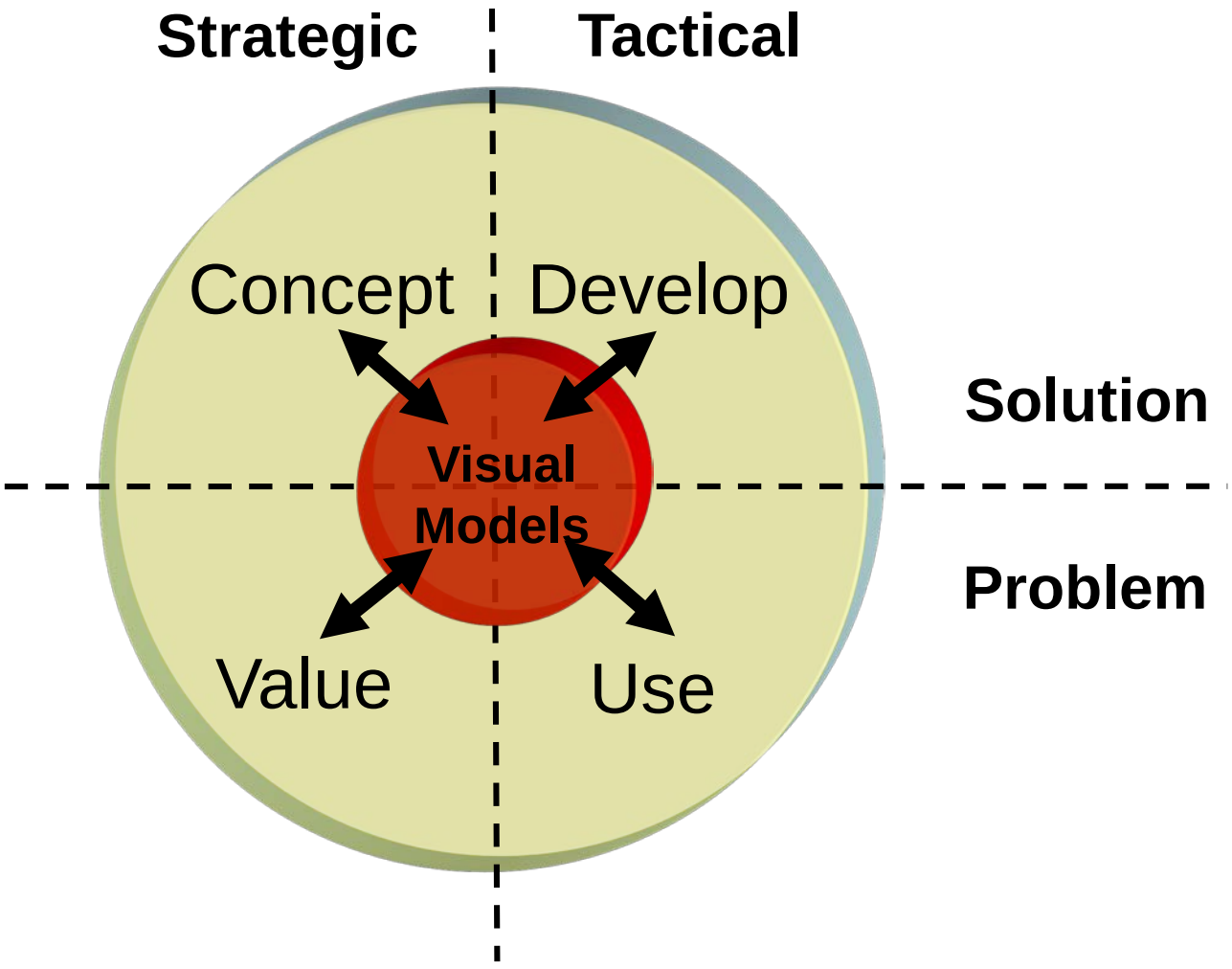
SE 'Phases'



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Necessary Changes

- Document based -> Model based
- Linear -> Opportunistic
- Sequential -> Consistent
- Human avoided -> Human integrated

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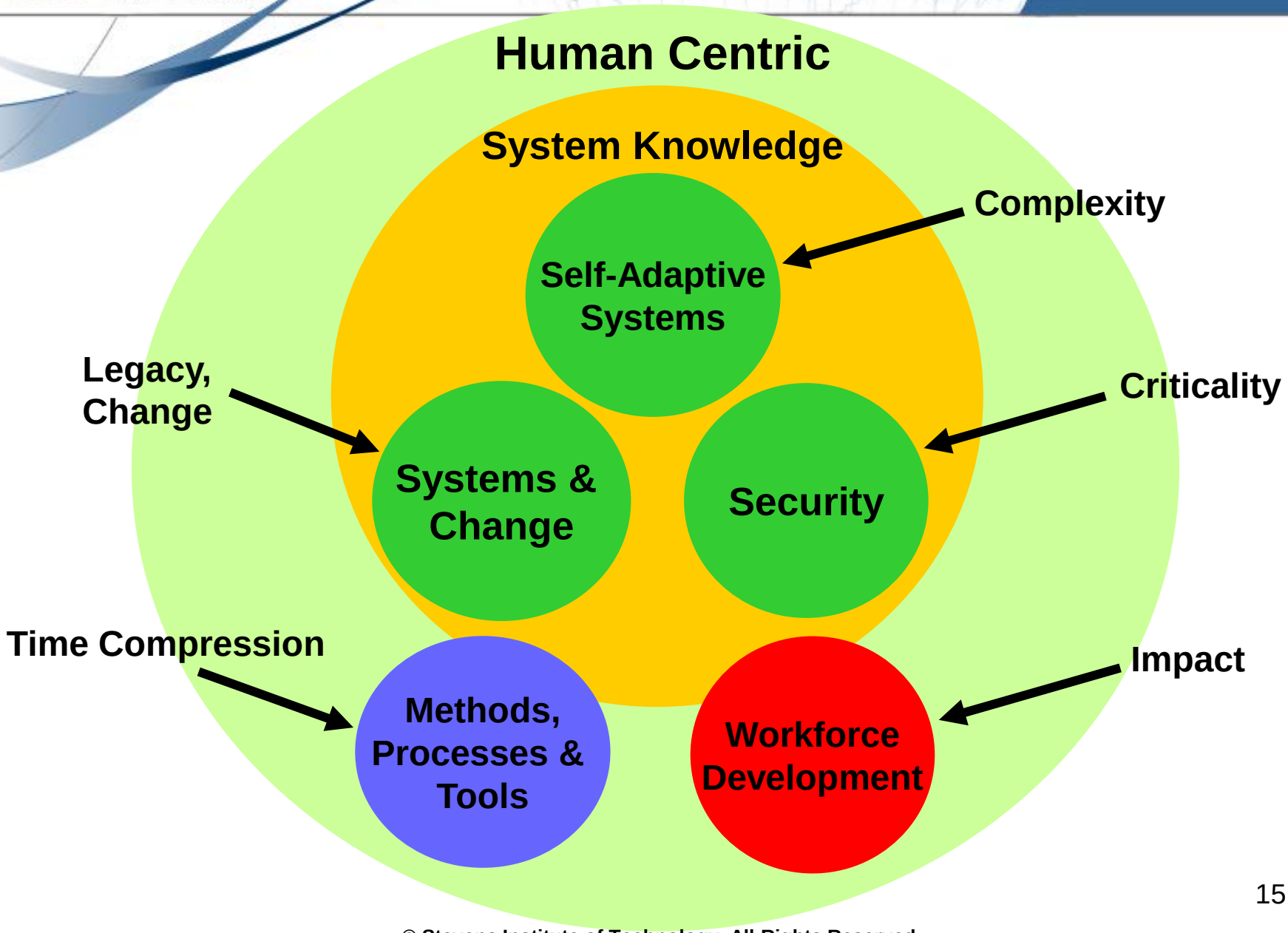

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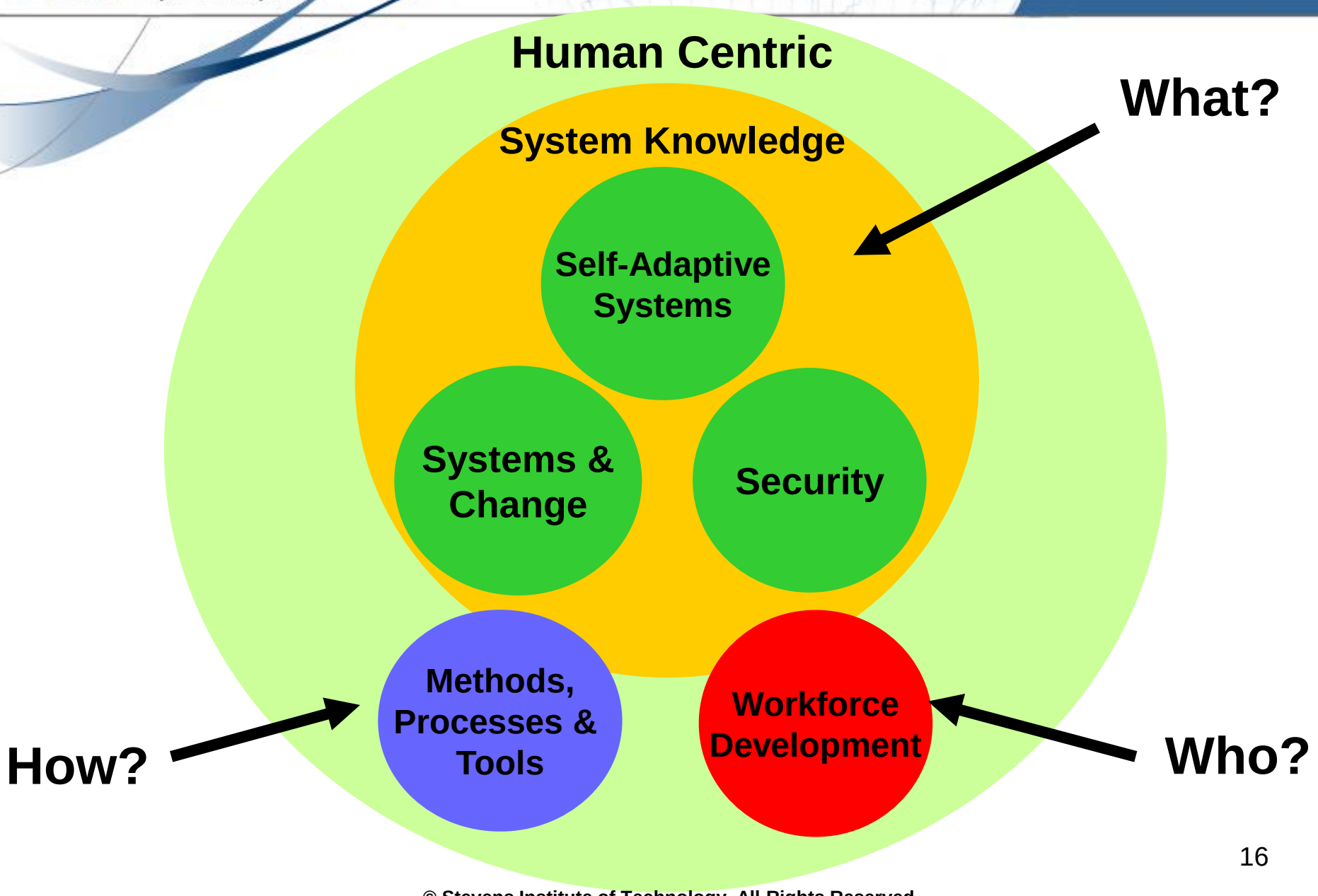

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SIT Research

Self-Adaptive Systems:

- Center for Complex and Adaptive Sociotechnical Systems – Ali Mostashari
- Resilient Systems – Roshanak Nilchiani
- Change-Adaptive Systems & Enterprises RT – Ali Mostashari

Systems & Change:

- Systems Development & Maturity Laboratory – Brian Sauser
- Systems Readiness Level – Brian Sauser
- Cost modeling – Jose Ramirez-Marquez

Security:

- Maritime Security Laboratory - Julie Pullen
- Center for Secure and Resilient Maritime Commerce - Michael Bruno – SES
- Security RT – Stas Tarchalski

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SIT Research

How? - Methods, Processes & Tools:

- Graphical Conops RT – Rob Cloutier
- Evaluation of MPTs RT– Rich Turner
- System Engineering Transformation RT – Jon Wade
- Systemigrams – Brian Sauser
- Architectural Patterns – Rob Cloutier

Who? - Workforce Development:

- GSwe2009 – Art Pyster
- BKCASE – Art Pyster
- Technical Leadership RT – John Farr
- Asynchronous Learning – Alice Squires
- Experience Accelerator RT – Jon Wade
- Game Competition – Eirik Hole
- SE Competencies – Rashmi Jain
- CIESE – Beth McGrath

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Model Aided SE

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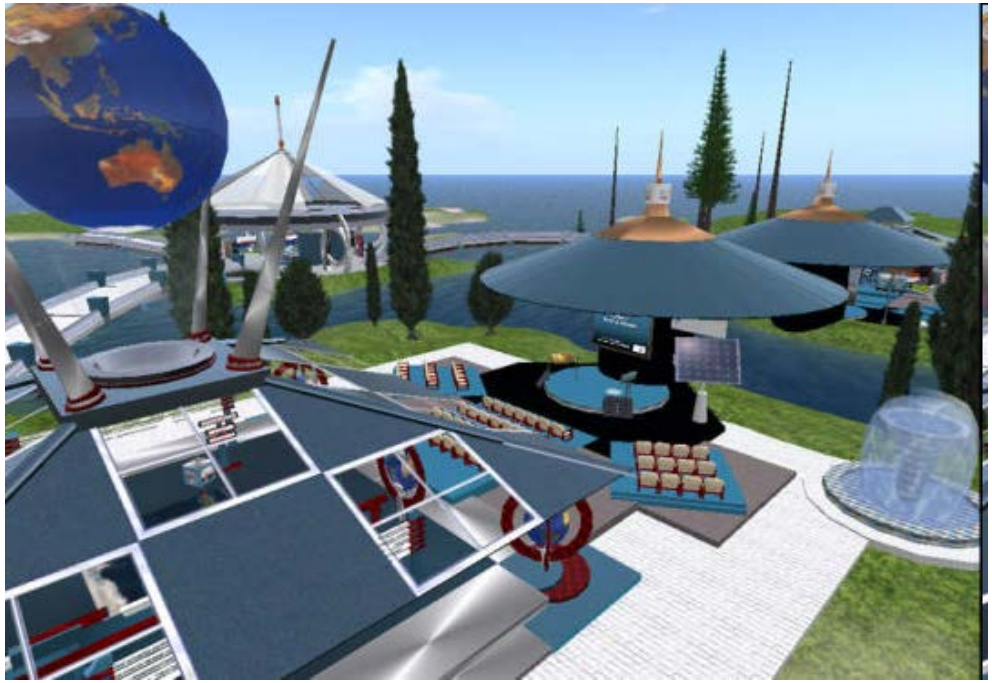
Which is more Intuitive?



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Or Collaborative?

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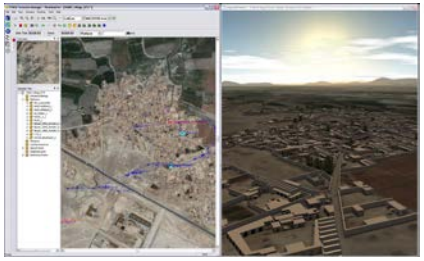
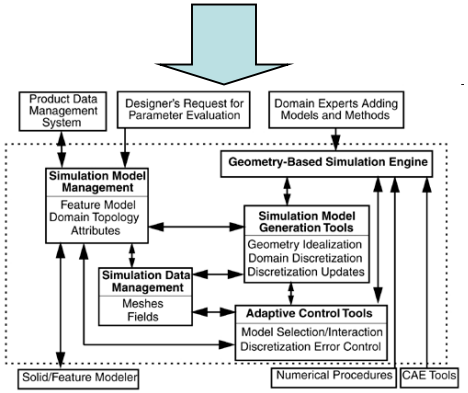
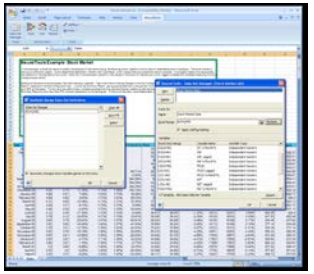


Portfolio of Canned Scenarios

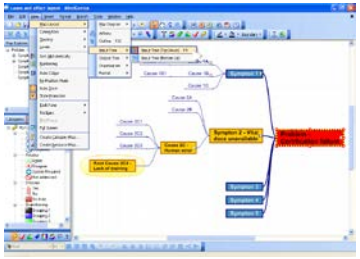
Graphical interface to allow interactive, collaborative creation of modular CONOPS model



DOTMLPFP Simulator



Customizable Presentation of Results



Cause & Effect Analysis

Development of Systems Engineers

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What's More Effective?

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SE Experience Accelerator

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Self-Adaptive Systems

"*I think the next century (21st) will be the century of complexity.*" Stephen Hawking

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Distributed "Control"

	Rules-based	Principles-based
Quantity	•Relatively large number	•Relatively small number
Content	•Specific guidance •Short-term focus •State processes	•Ideas & concepts •Long-term focus •State outcomes
Purpose	•Prescribe actions of individuals •Provide group coordination through authority	•Guide thinking •Provide group coordination through influence

Source: *Requirements Engineering for Complex Adaptive Systems: Principles vs. Rules*, CSER 2009, Polacek & Verma.

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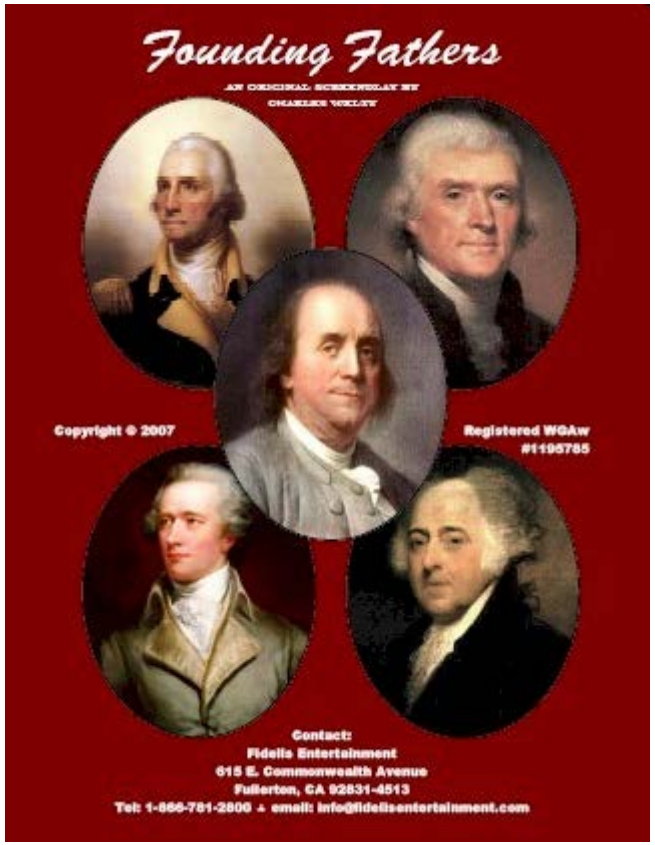
Self-Adaptive Example



Architects

Architecture

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We depend on it

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