SYSTEMS ENGINEERING RESEARCH CENTER

Systems Thinking Workshop

FHI 360 Conference Center
1825 Connecticut Ave NW 8th Floor, Washington, DC 20009

November 18, 2019

Dr. Brian Sauser (University of North Texas)

Dr. Jon Wade, (Stevens)

Kunal Batra (Stevens)

Agenda

09:30	*Registration*	
10:00	Opening Remarks	Dr. Jon Wade
10:15	Why Systemigrams: Where do they fit in the Sea of System Diagrams	Dr. Brian Sauser
10:35	30-year Retro/Per-spective Methodology, Media, Message	Dr. Brian Sauser
10:55	Systemigram Examples	Dr. Brian Sauser
11:15	*Break*	All
11:25	SystemiTool 2.0: It's not about the platform anymore	Dr. Jon Wade/Kunal Batra
12:00	*Meeting Adjourned*	

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Systems Thinking Workshop: Opening Remarks

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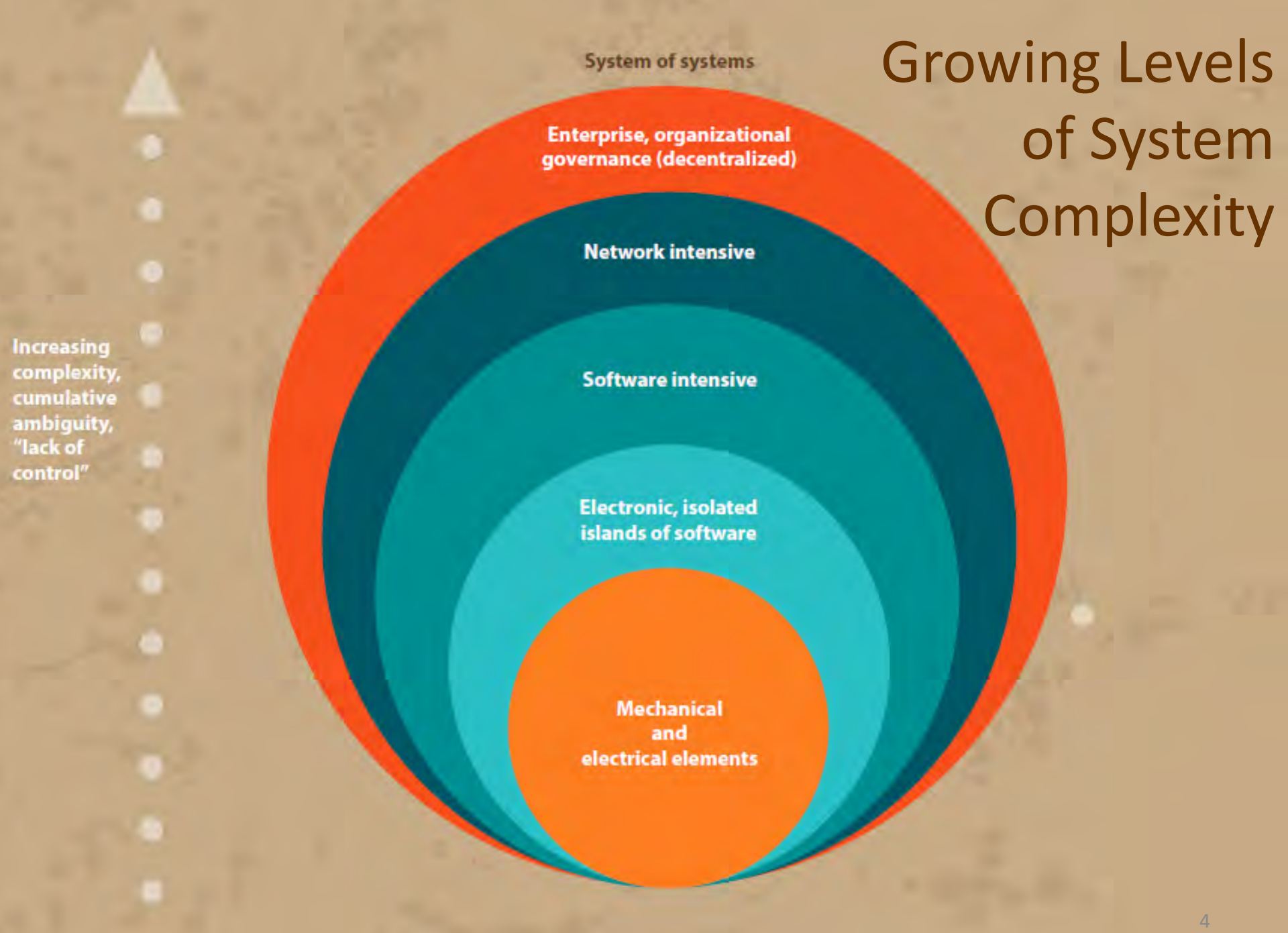
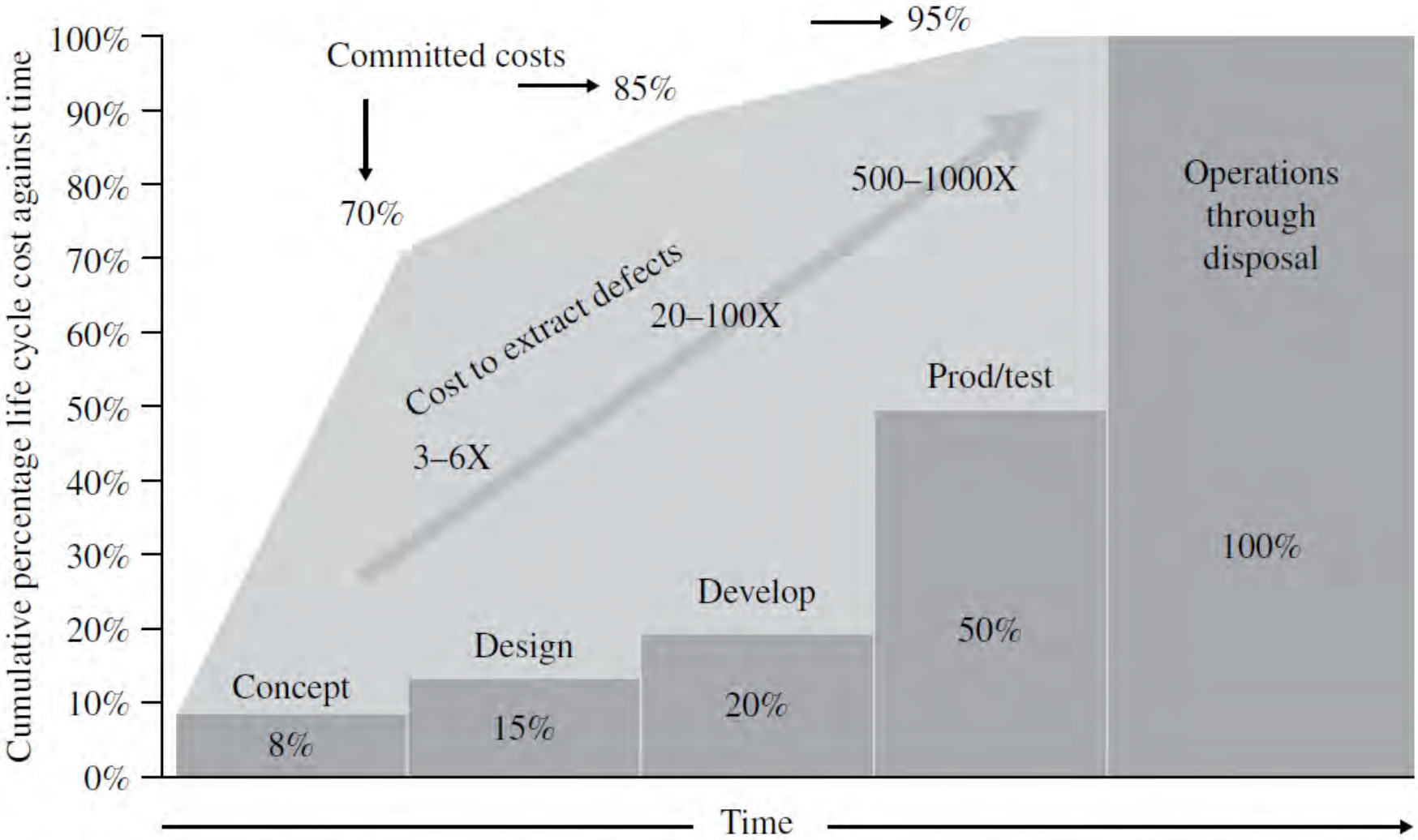
Dr. Jon Wade, (Stevens)

Growing Levels of System Complexity



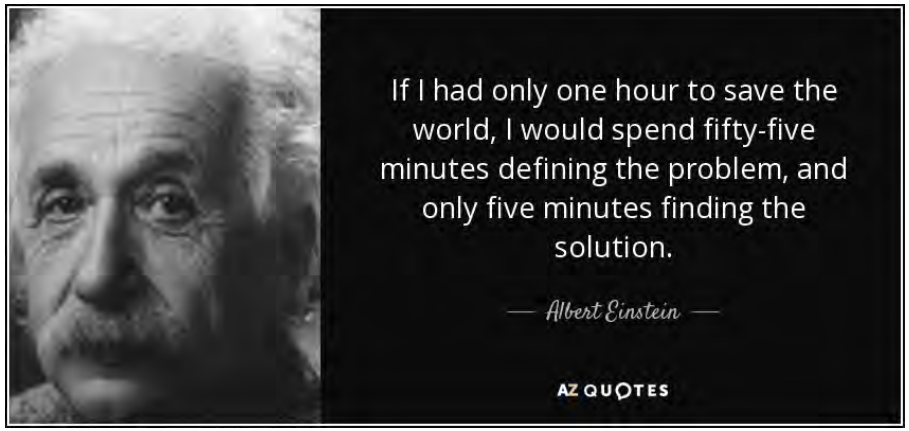
Source: INCOSE Vision 2025

Concept is Critical



DAU (1993). Committed Life Cycle Cost against Time. 3.1. Fort Belvoir, VA: Defense Acquisition University

Good systems engineering relies on systems thinking…



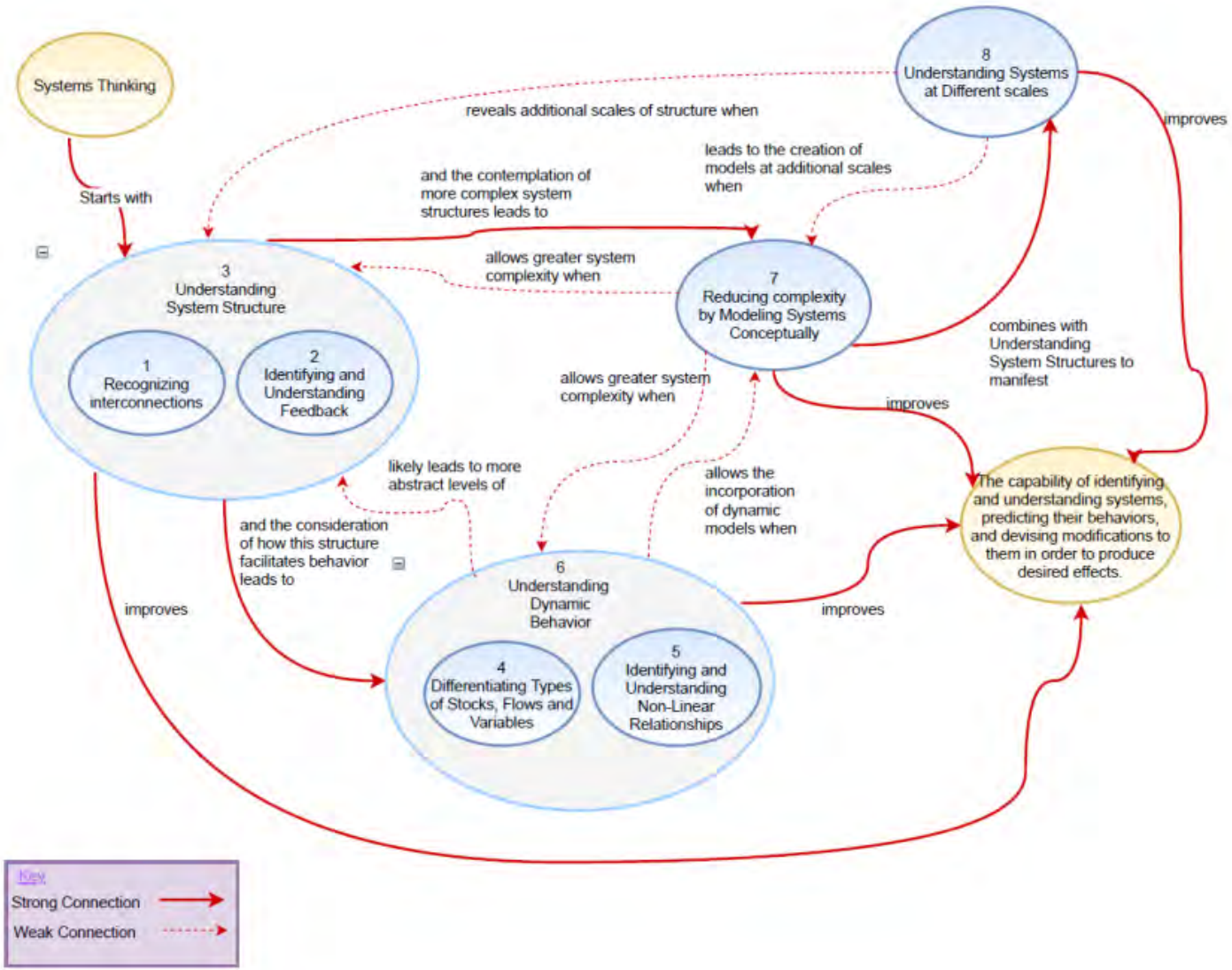
- Think outside before inside.
- Think what and why before how.
- Think relationships not just elements.
- Think long term not just initial capability.
- Think loops not lines.

- Outside focus includes:
  - Understanding the stakeholders (business, technology, organizational, political)
  - Understanding the environment and the system context
  - Understanding key drivers and constraints, including historical and legacy constraints; mission and opportunity constraints, inclusive of cost and schedule

Essentially, all models are wrong, but some are useful.

George Edward Pelham Box (October 18, 1919 – March 28, 2013) was a British mathematician and professor of statistics at the University of Wisconsin, and a pioneer in the areas of quality control, time series analysis, design of experiments and Bayesian inference.

Definition of Systems Thinking

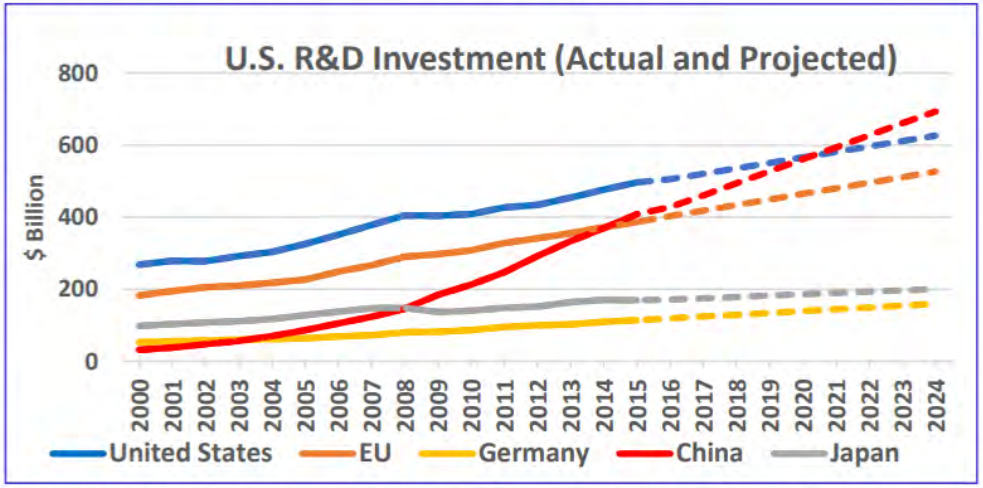


R. Arnold, J. Wade, "A Definition of Systems Thinking: A Systems Approach, CSER 2015.

The World Today

Technology Is Transforming the Battlespace

- The proliferation of knowledge and technology erodes historic U.S. advantages
- Our near-peers are increasing their rate of investment in military R&D
- A hyper-competitive environment for National Security technologies
- The discriminators are speed and cycle time



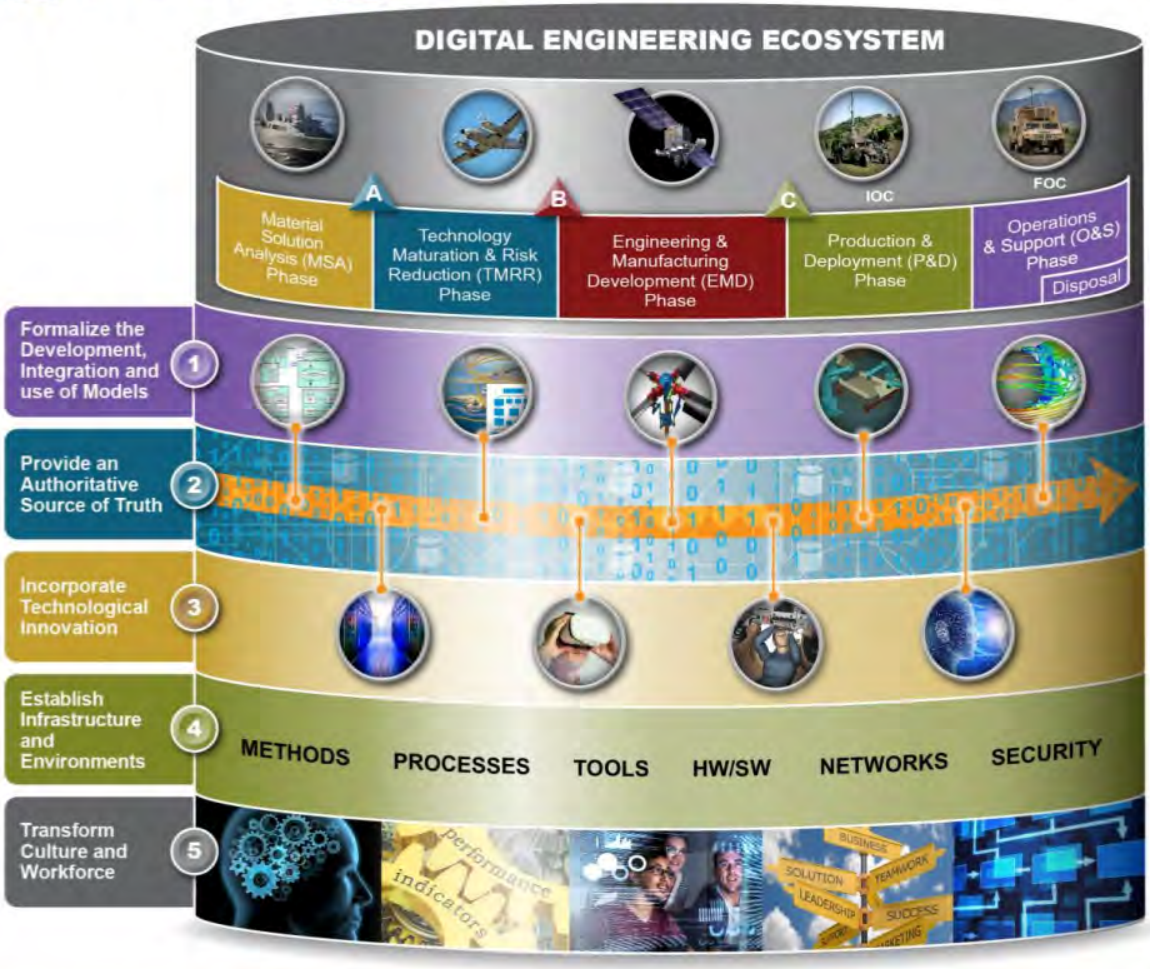
- NSF 2015 data predicted R&D investment parity with China in 2020
- Feb 2018, NSB estimates China R&D investment parity with U.S. by end of 2018

- 2017 GLOBAL R&D FUNDING FORECAST WINTER 2017 Industrial Research Institute, R&D Magazine

R&D – Research & Development
NSB – National Science Board

Digital Engineering Overview

- **What is Digital Engineering?**
  - Combines model-based techniques, digital practices, and computing infrastructure
  - Enables delivery of high pay off solutions to the warfighter at the speed of relevance
- **Reforms Business Practices**
  - Digital enterprise connects people, processes, data, and capabilities
  - Improves technical, contract, and business practices through an authoritative source of truth and digital artifacts



Modernizes how we design, operate, and sustain capabilities to outpace our adversaries

Systems Thinking & Digital Engineering

Digital engineering (DE):

- an engineering approach that captures and analyzes data that is in a digital format which is semantically rich and interconnected
- enables people to leverage the power of computing, visualization, and communication to significantly enhance efficiencies, quality, and innovation across the complex system development lifecycle

- Sandy Friedenthal, SERC DE Workshop, Nov. 15, 2019

How can systems thinking
be supported effectively in a
digital engineering environment?

SYSTEMS THINKING WORKSHOP

Brian Sauser
University of North Texas

November 18, 2019

SERC Research Review

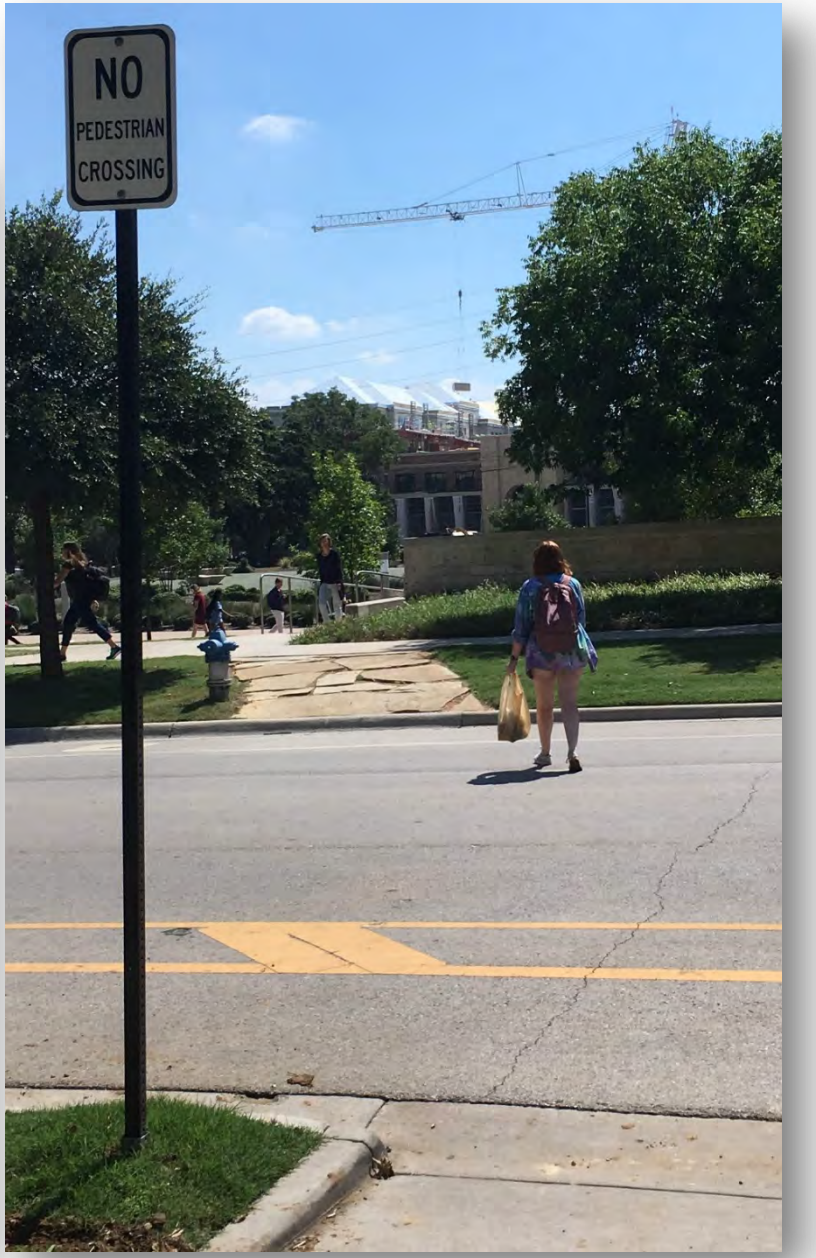
"… I stand at the edge of the future with the universe as my systems' boundary and standing beside me is what I believe will be the greatest of my Systems Shepards, John Boardman."

Brian Sauser
Systems Thinking: Coping with 21st Century Problems

WHY SYSTEMIGRAMS

Where do they fit in the Sea of System Diagrams?


NO
PARKING
FIRE
LANE
NO IDLING
Shut off
engine
while
parked


NO
PEDESTRIAN
CROSSING


Walmart
Home & Pharmacy
STOP
YIELD
FIRE LANE

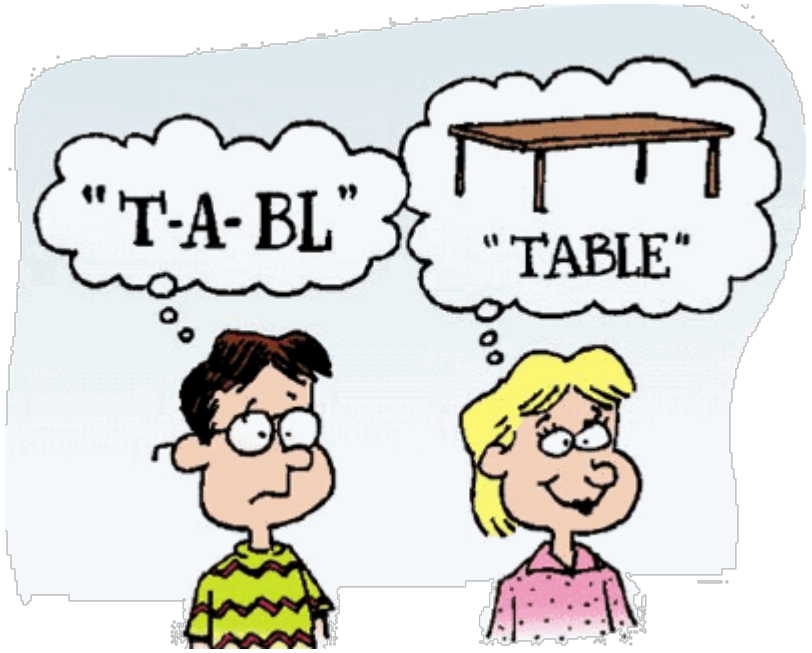
"The breaking of a wave cannot explain the whole sea."

~ Vladimir Nabokov

WE THINK IN PICTURES!?

A new study led by Elinor Amit, an affiliate of the Psychology Department (Harvard University), shows that people create visual images to accompany their inner speech even when they are prompted to use verbal thinking, suggesting that visual thinking is deeply ingrained in the human brain while speech is a relatively recent evolutionary development.

Peter Reuell. *The power of picturing thoughts*. The Harvard Gazette. May 11, 2017



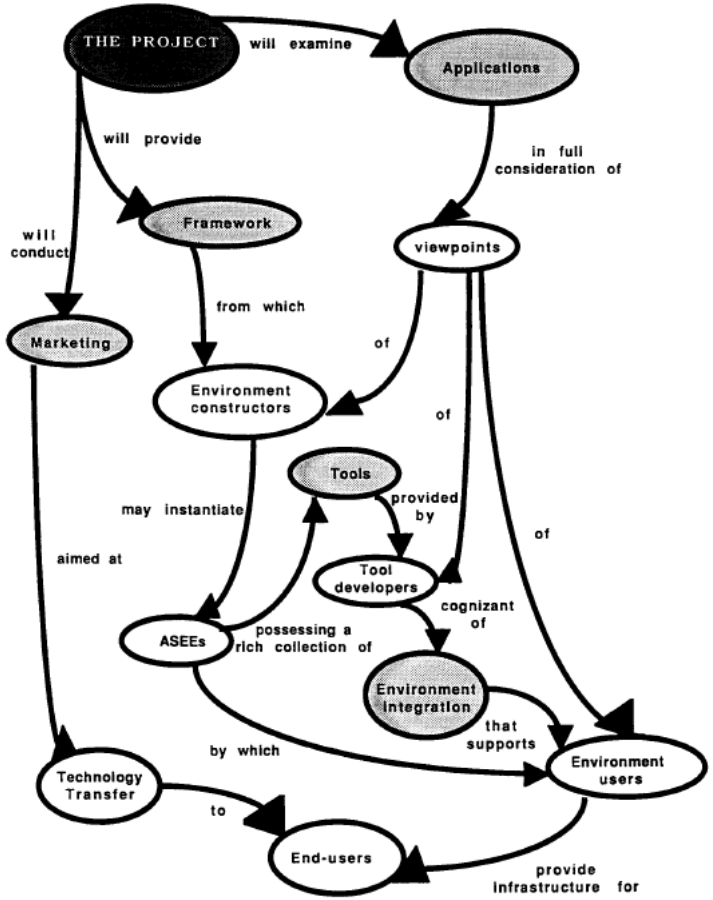
SYSTEMIGRAMS

A hybrid, from ***systemi***c dia***gram***

- Takes lengthy documentation and distills it down to "concentrated text" (or prose) covering the salient points of the system
- This reduced text (or narrative) represents a description of the problem situation
- A visual systemigram is then constructed, decomposing the prose into the individual, related threads, showing the flow of information, resources and actions

Systemigrams are powerful storytelling aids and are useful in providing a common foundation for group discussions

They do not remove the complexity from systems, but they can make complex systems understandable



30-YEAR RETRO/PER-SPECTIVE

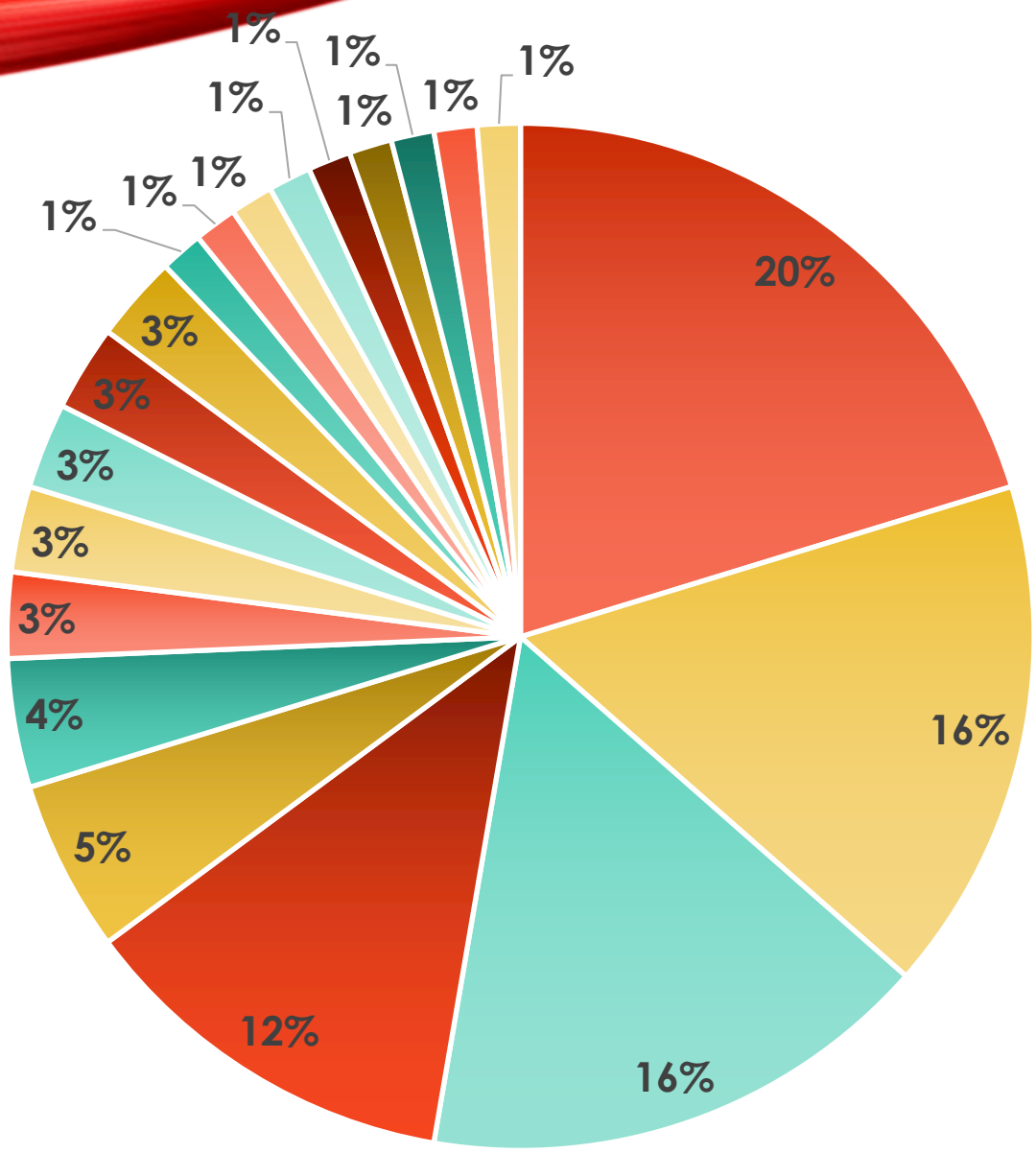
Methodology, Media, Message

1990-2019

Systemigrams		Barry Boehm	
Papers	402	744	Papers
Citations	5,997	29,568	Citations
Cites/Year	206.79	1019.59	Cites/Year
Cites/Paper	14.92	39.74	Cites/Paper
Author/Paper	2.53	2.94	Author/Paper
h-index	31	72	h-index

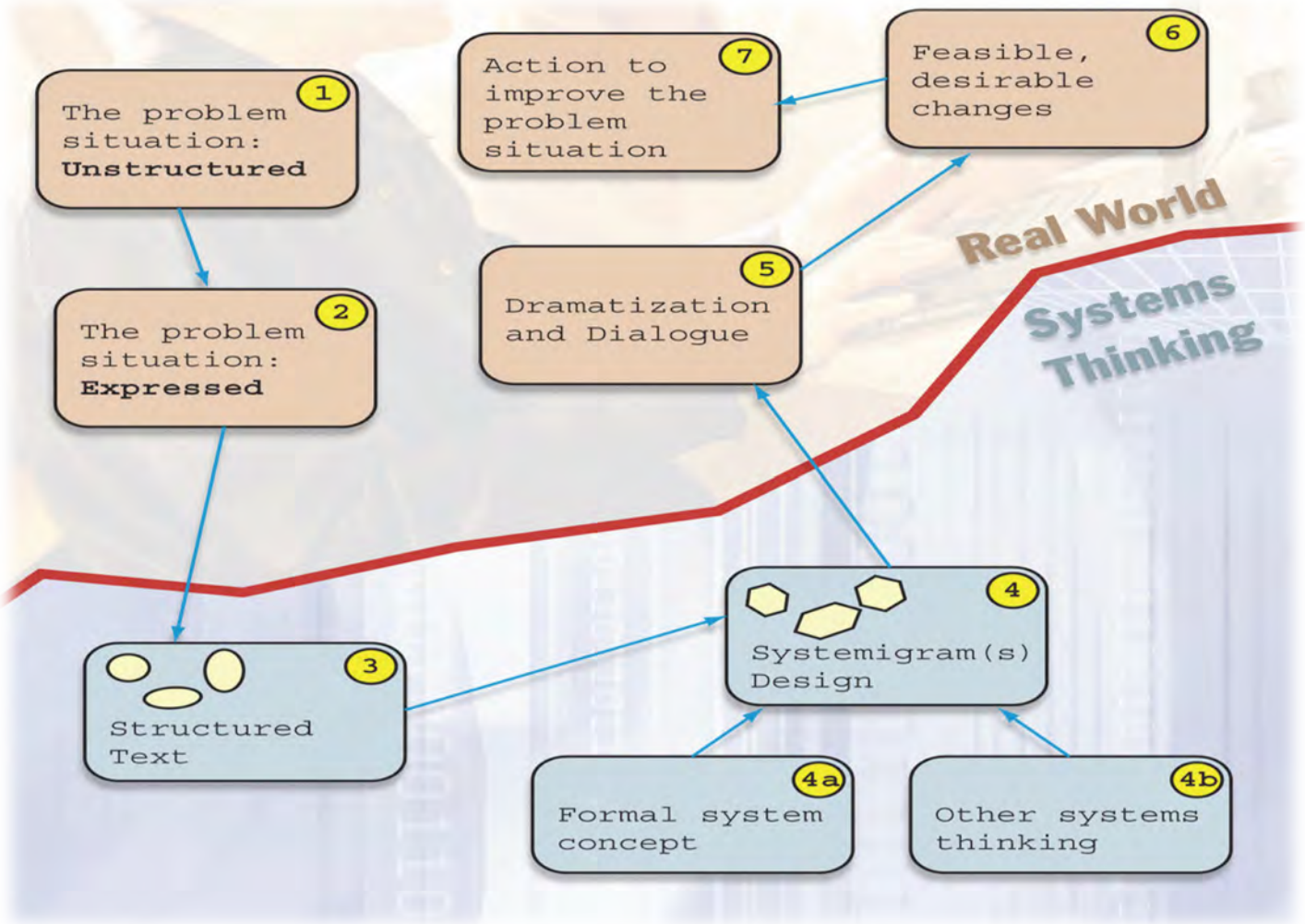
Data Source: Google Scholar
Data Compilation Tool: Harzing's Publish or Perish

Dissemination Outlet	Citation %
Books	30%
International Journal of Project Management	12%
Procedia Computer Science	10%
Dissertations/ Theses	8%
International Journal of Logistics Management	6%
IEEE Transactions on Systems, Man, and Cybernetics	6%
Systems Engineering	6%
White Papers	5%
International Journal of Sustainable Built Environment	4%
Book chapters	2%
Others (1% each)	11%



- Control and Syst. Engineering
- Org. Behavior and HR Man.
- Syst. thinking and Syst. Theory
- Man. Science and Ops. Research
- Modeling and Simulation
- K-12 learning environments
- Marketing
- Econ., Econometrics and Finance
- Comp. Science
- Geography, Planning and Dev.
- Medicine
- Nursing
- Health sciences (general)
- Business and Int'l. Man.
- Ind. and Manufacturing Eng.
- Info. Systems
- Hardware and Architecture
- Strategy and Management
- Decision Sciences
- Man. of Tech. and Innovation

BOARDMAN SOFT SYSTEMS METHODOLOGY

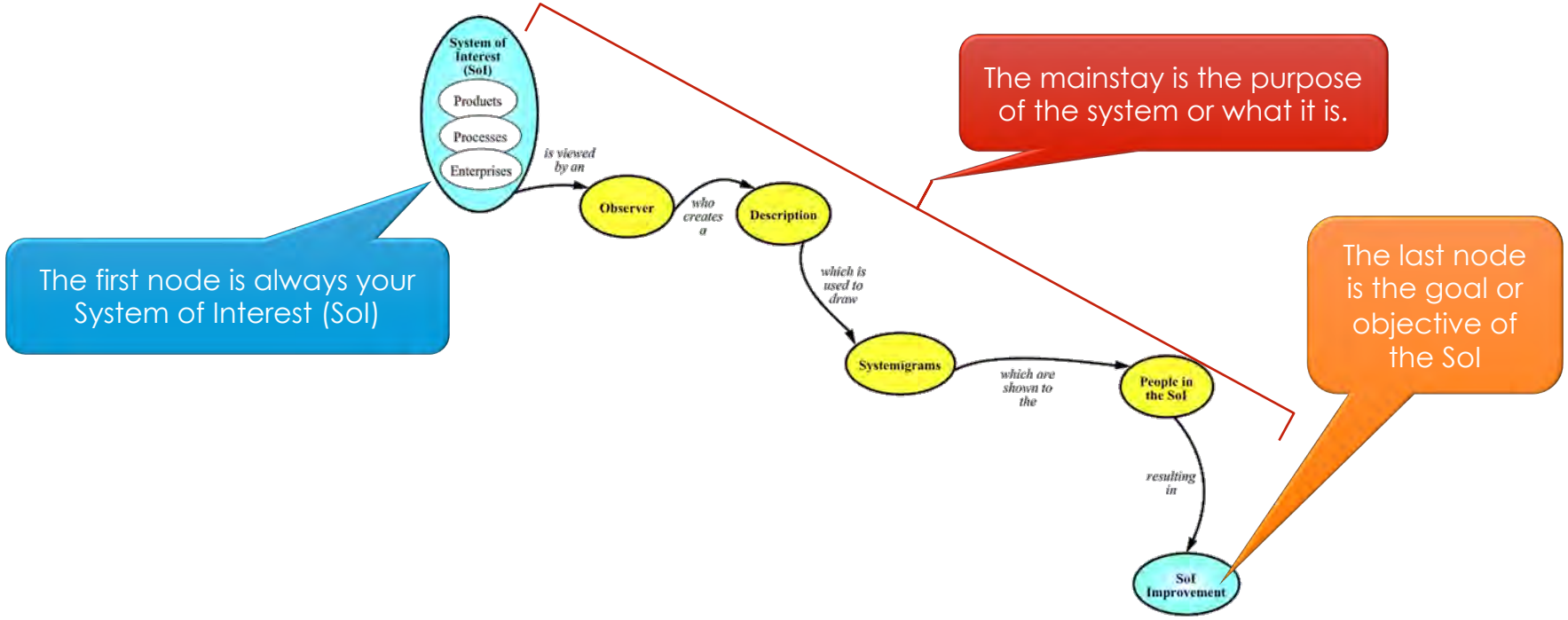


SYSTEMIGRAM DESIGN RULES

- Primary sentence ***(mainstay)*** which supports the purpose of the system will read from top left to bottom right.
  - This is the anchor for the entire visualization
  - Until one understands the picture as a whole there is always the chance that confusion, not clarity, will arise
  - The other segments of the systemigram flow out of and back into this mainstay, connecting as needed with its landmark noun phrase nodes

"Whatever affects one directly, affects all indirectly. I can never be what I ought to be until you are what you ought to be. This is the interrelated structure of reality."

~ Martin Luther King, Jr.



SYSTEMIGRAM DESIGN RULES

- Ideally there should be 15-25 nodes (**less** can make for a **trivial system** description, **more** can **create clutter** and illegibility)
  - For a node to be linked to another node n/2 links are necessary for an even number of nodes and (n+1)/2 links for an odd number.
  - For all nodes to be linked, n-1 links are necessary.
  - For all nodes to be linked to every other nodes n(n-1)/2 links are necessary for a non-planar graph.
  - With the number of nodes, it is possible to find the number of possible combinations: $2^{n(n-1)/2}$.

"If I can reach further, it is by connecting with influential nodes"

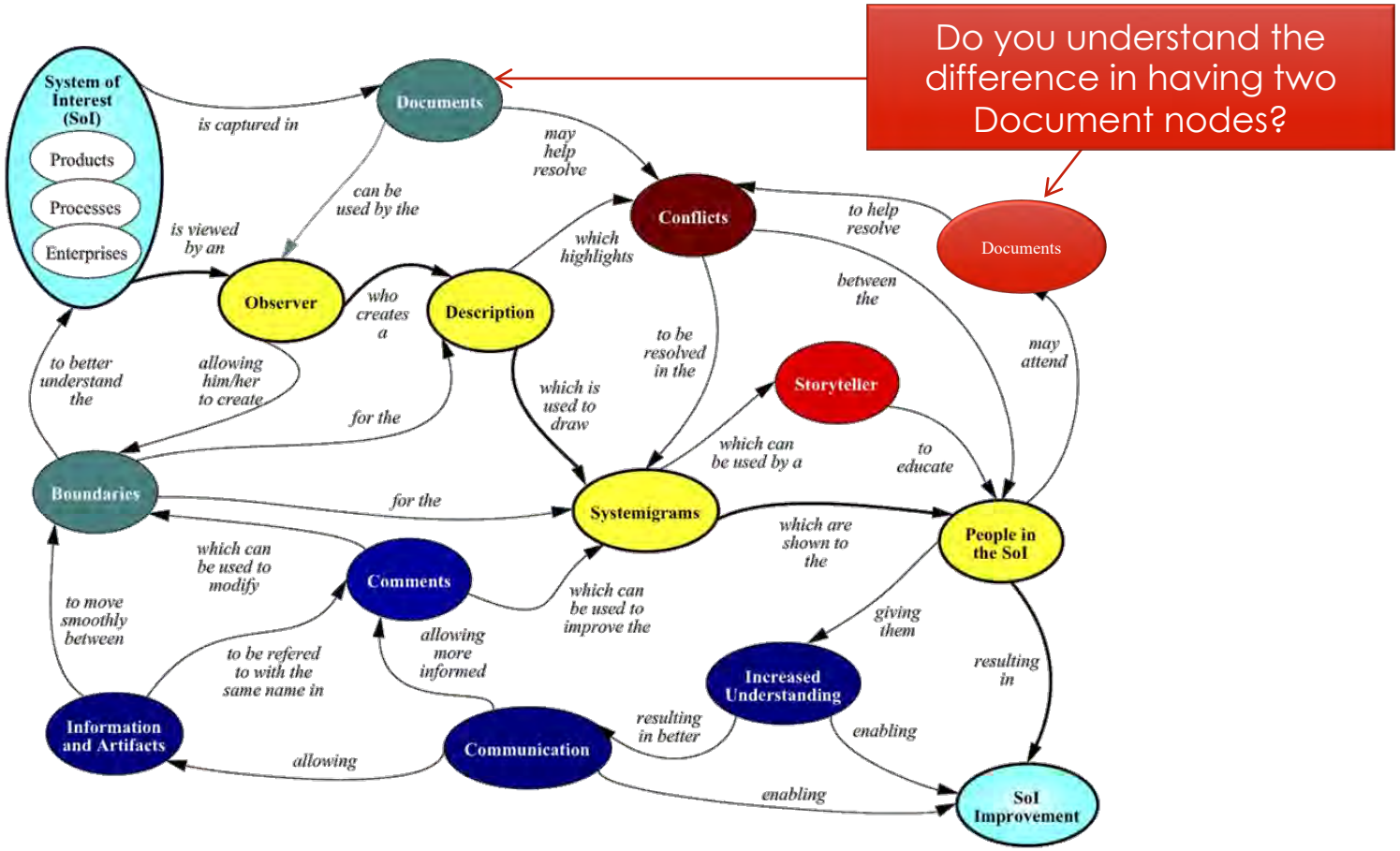
~ Gohar F. Khan, Digital Analytics for Marketing

SYSTEMIGRAM DESIGN RULES

- No repetition of nodes
  - Redundant nodes loses the essence of relationships…

"Too much of anything is bad, but too much good whiskey is barely enough."

~ ***Mark Twain***



SYSTEMIGRAM DESIGN RULES

Systemigrams are systems

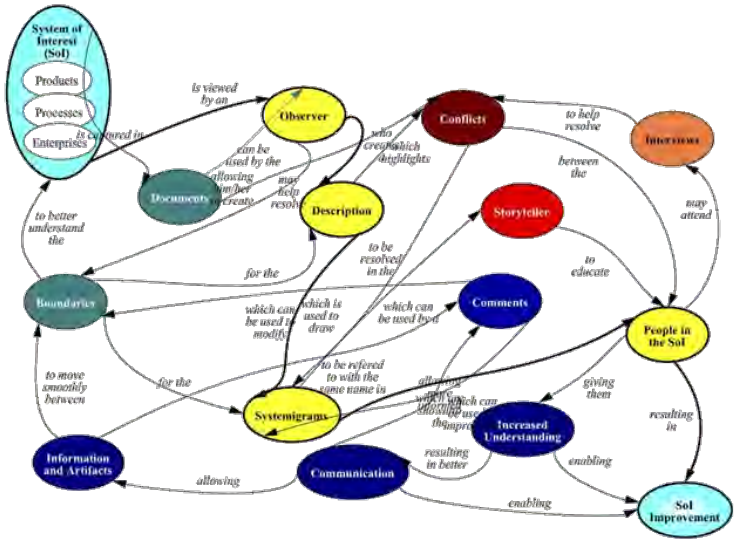
- Every system has a structure and process
- Structure is an arrangement of parts (nodes) and relationships (links)
  - Parts are nodes, represented by nouns and noun phrases
    - i.e. noun phrases (people, organizations, groups, artifacts, and conditions)
  - Relationships are links represented by verbs, and verb phrases (actions)
    - i.e. verb phrases (transformation, belonging, and being)

"In today's busy and fast paced environment there are too many unseen forces at work, by just connecting the dots I win BIG."

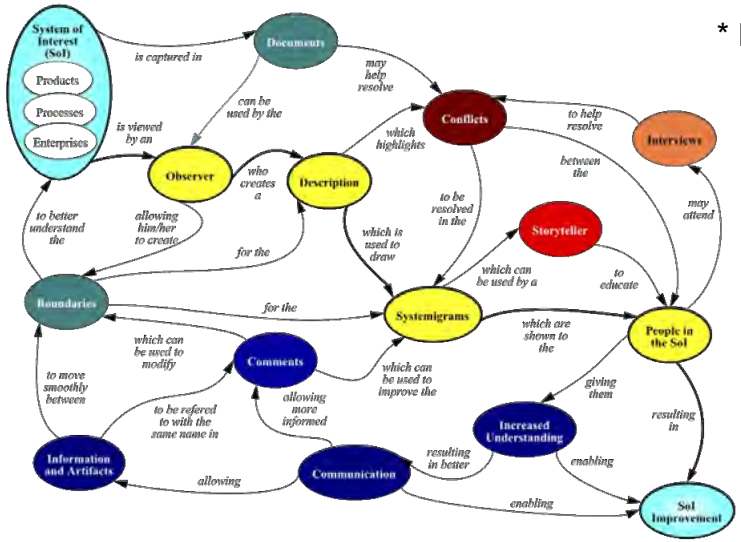
~ ***nick catricala***

SYSTEMIGRAM DESIGN RULES

- No cross-over of links
  - A design rule that not only makes the systemigram cleaner and clearer to view, but also leads to the observance of an important heuristic in systems design..
  - For a systemigram of 20 nodes, the total number of possible links is 190, whereas the actual number will be about 30
  - This ratio is about 15%, which is held to be the optimal ratio of interfaces in a system relative to how many there could be.*



VS



* Rechtin, E., *Systems Architecting*, Prentice Hall, New York, 1990.

SYSTEMIGRAM DESIGN RULES

- Beautification (e.g. shading and dashing of links and nodes)
  - should help the reader read the sentences in the diagram
- Exploit topology to depict why, how, what
  - (who, when, and where is built into system description)

"Consider a tree for a moment. As beautiful as trees are to look at, we don't see what goes on underground - as they grow roots. Trees must develop deep roots in order to grow strong and produce their beauty. But we don't see the roots. We just see and enjoy the beauty. In much the same way, what goes on inside of us is like the roots of a tree."

~ Joyce Meyer

SYSTEMIGRAMS VS MODELING PRINCIPLES

"If someone throws a fit because you set boundaries, it's just more evidence the boundary is needed."

~ Unknown

Principle	Systemigram Guidance
Correctness	• Mainstay which supports the purpose of the system reads from top left to bottom right • Ideally there should be 15-25 nodes • Nodes must contain noun phrases • Links should contain verb phrases (to reduce trivial links) • No repetition of nodes • No cross-over of links
Relevance	• Remember that the model is really "theirs". • Remember that the model is not really "theirs" • Remember that the model is not reality
Feasibility	• It should compare to reality (comparing 4 to 2 in the BSSM)
Clarity	• It should read well. • Beautification (e.g. shading and dashing of links and nodes) should help the reader read the sentences in the diagram • Exploit topology to depict why, how, and what (who, when, and where is built into system description)
Comparability	• It should compare to reality (comparing 4 to 2 in the BSSM)
Systematic Design	• Is it a system in its own right? • Does every node (except for the beginning and ending nodes) have an input and an output? • Can you follow any node to the end node?
Conciseness	• A model should be as simple as possible and no simpler • No repetition of nodes • No cross-over of links

SHOW ME THE _____

What is Resilience; Small Vessel Security; The SERC

STORYBOARDING

- **Remember:** Viewing a systemigram in segments is like viewing only scenes in a movie, it is the compilation of scenes that tell the story

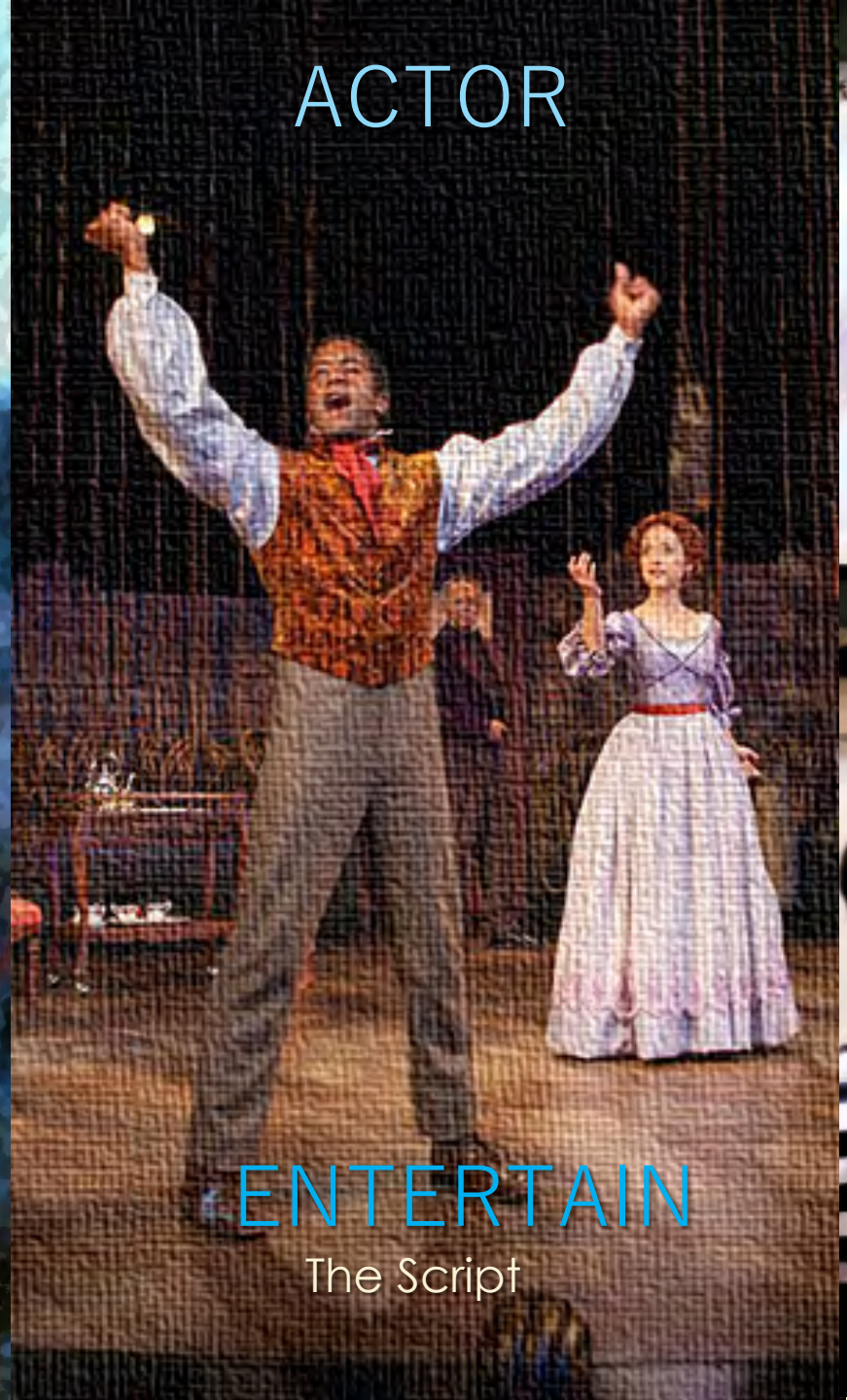
- Key to systemigram modeling is the ability of the modeler to **decompose the model into scenes** that can **articulate a story** of what the systemigram represents (storyboarding)

- A completed systemigram then is not the end of the story, but **the basis for telling a story**

- The story can be **told in a variety of ways** but all have the same generic format – to create a storyboard using carefully selected scenes, which are sub-nets of the systemigram

- **Each scene represents a key part of the message** but by the same token it begins to tell a more detailed message which can only be amplified by having the right people listen to the systemigram story

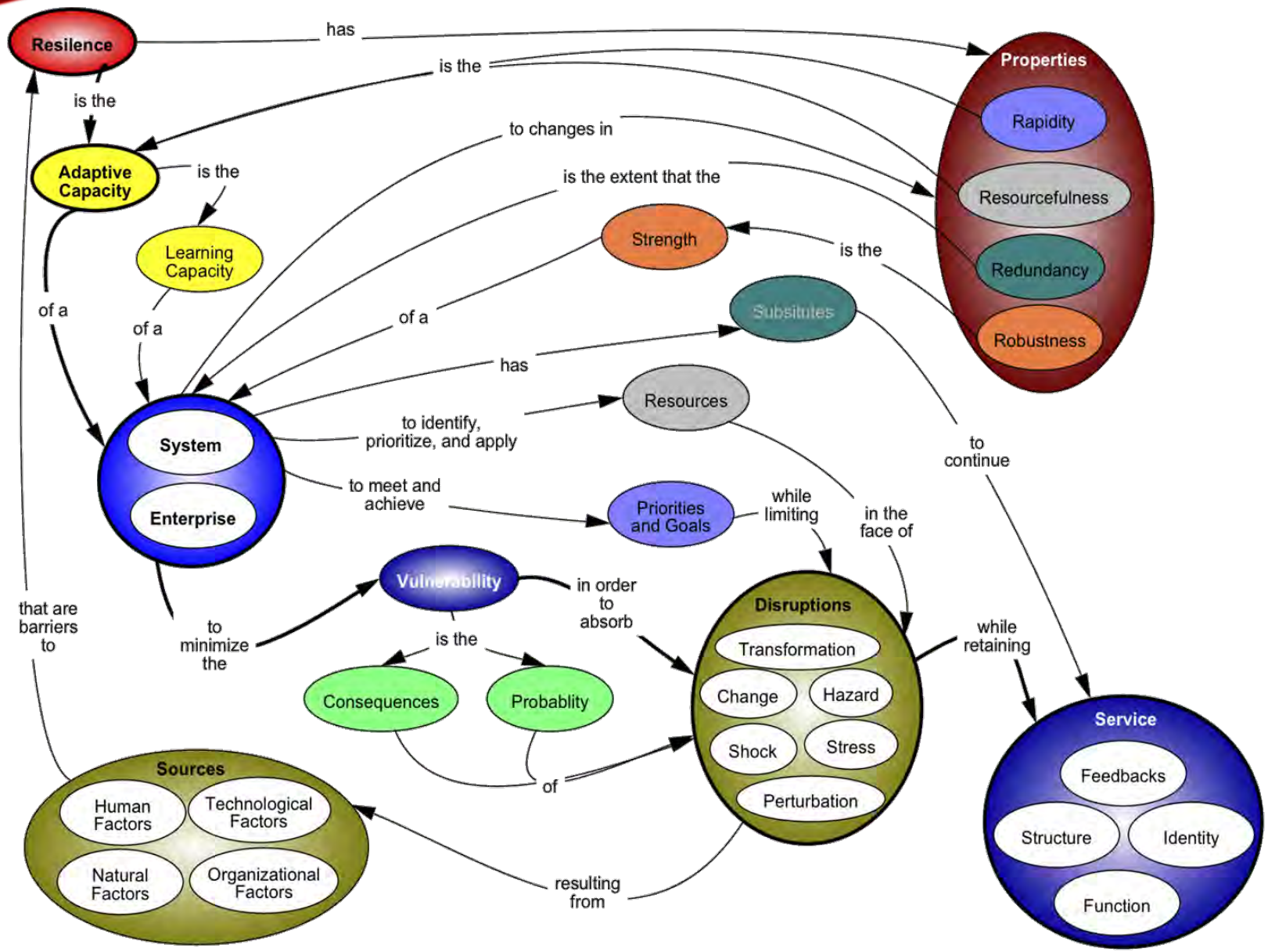

PREACHER
INSPIRE
The Sermon


ACTOR
ENTERTAIN
The Script

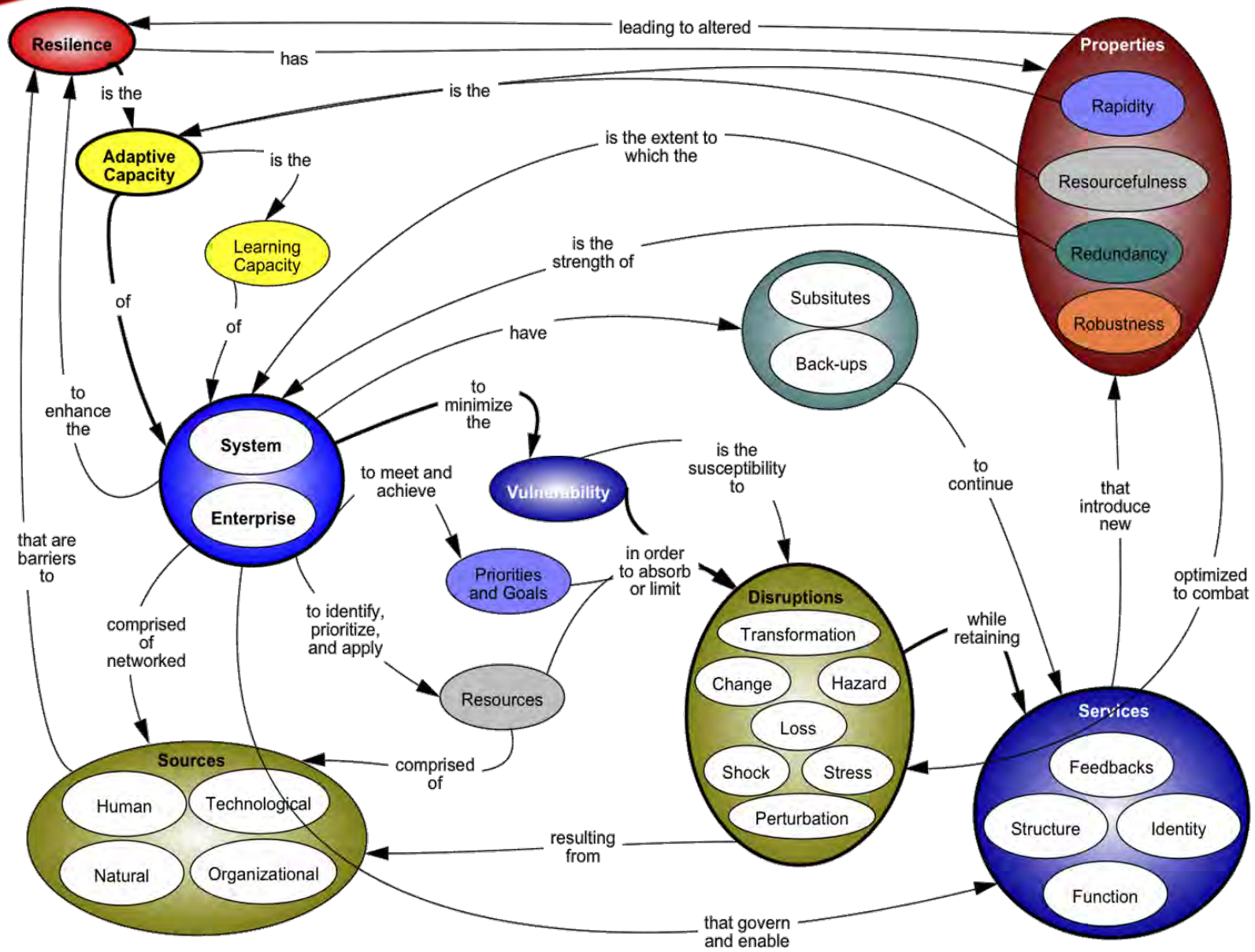

TEACHER
EDUCATE
The Lesson

WHAT IS RESILIENCE?

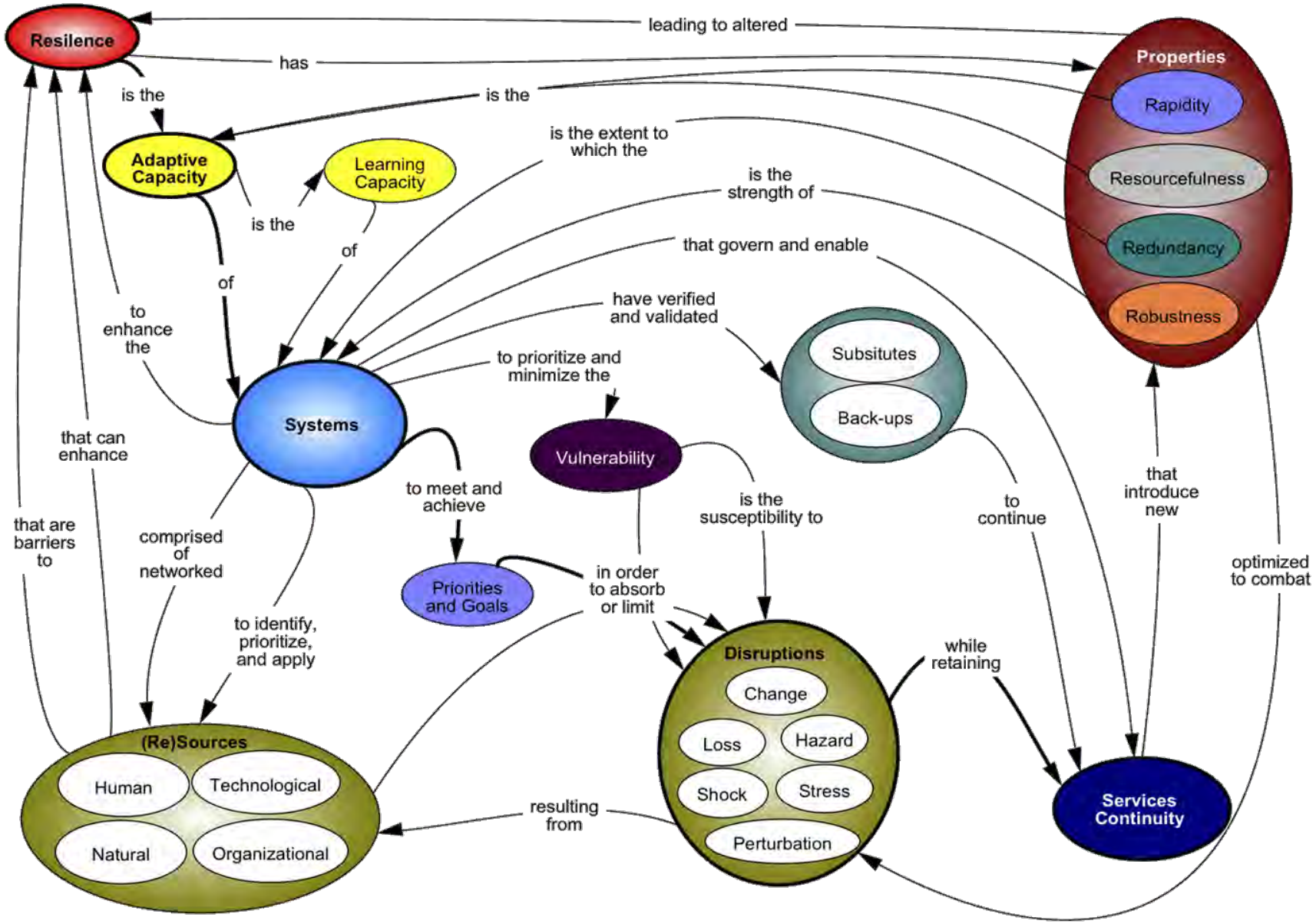
Initial Systemigram Based on Literature Review



Version 2.0 Based on Follow up Workshop

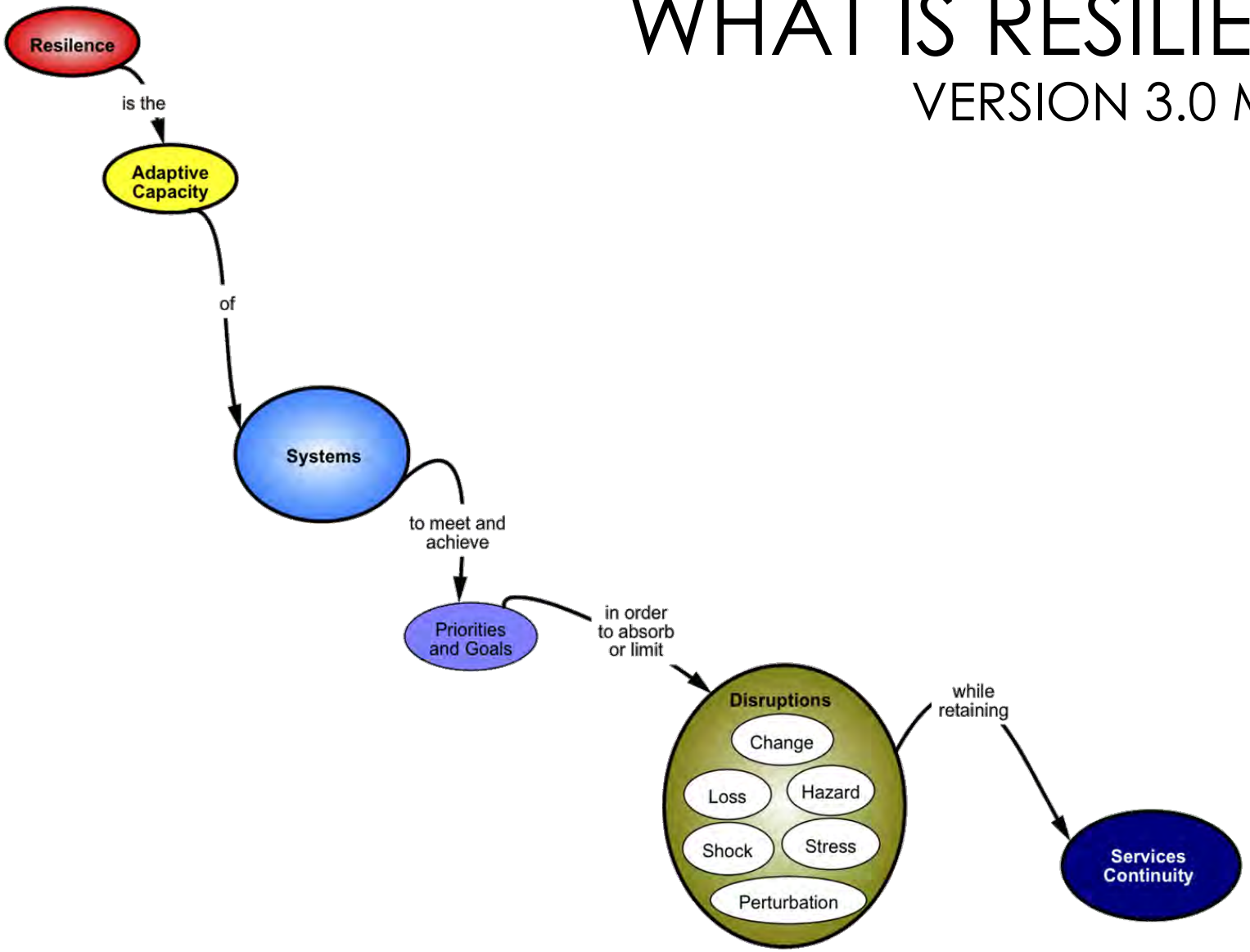


Version 3.0 Based on Final Workshop

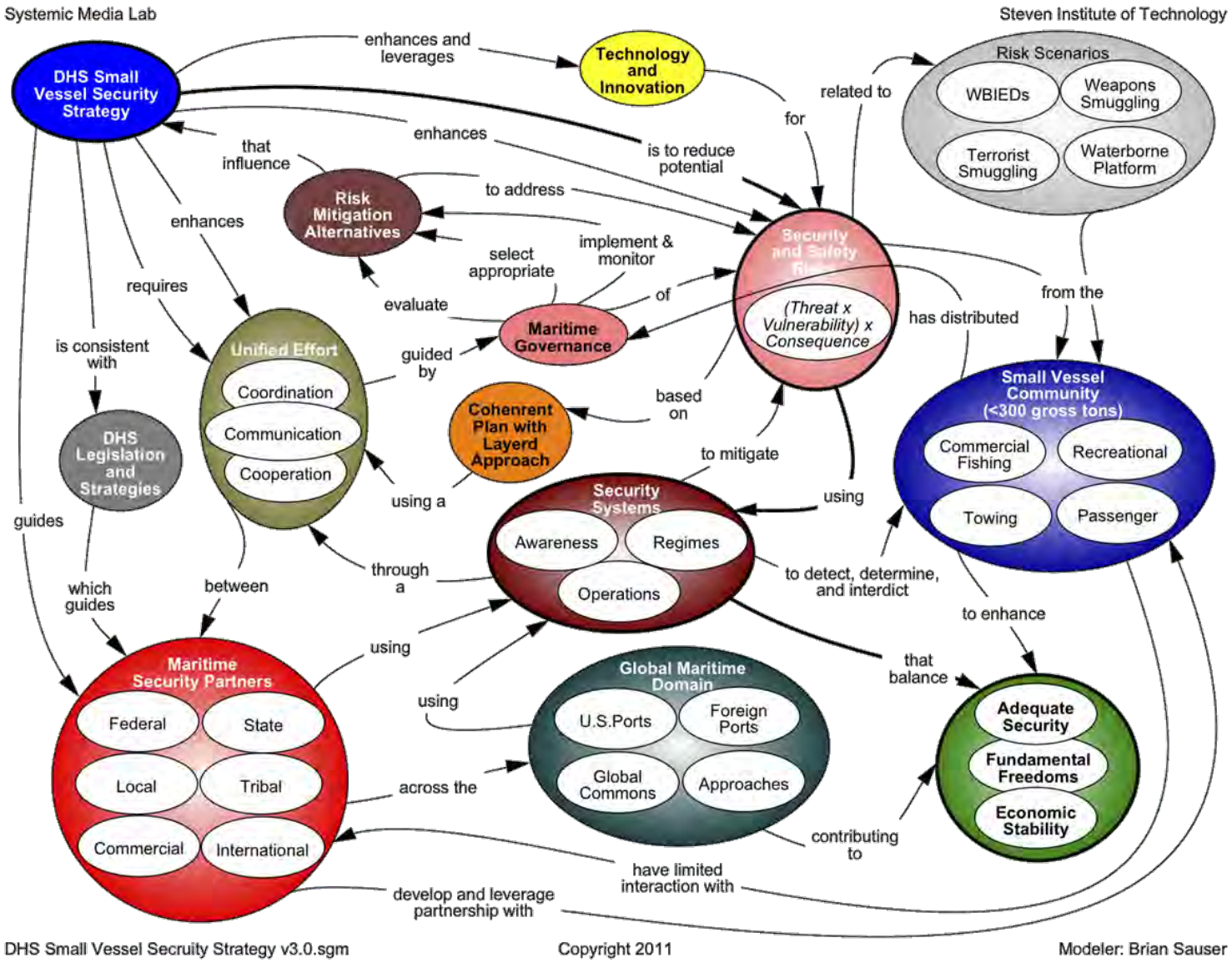


WHAT IS RESILIENCE?

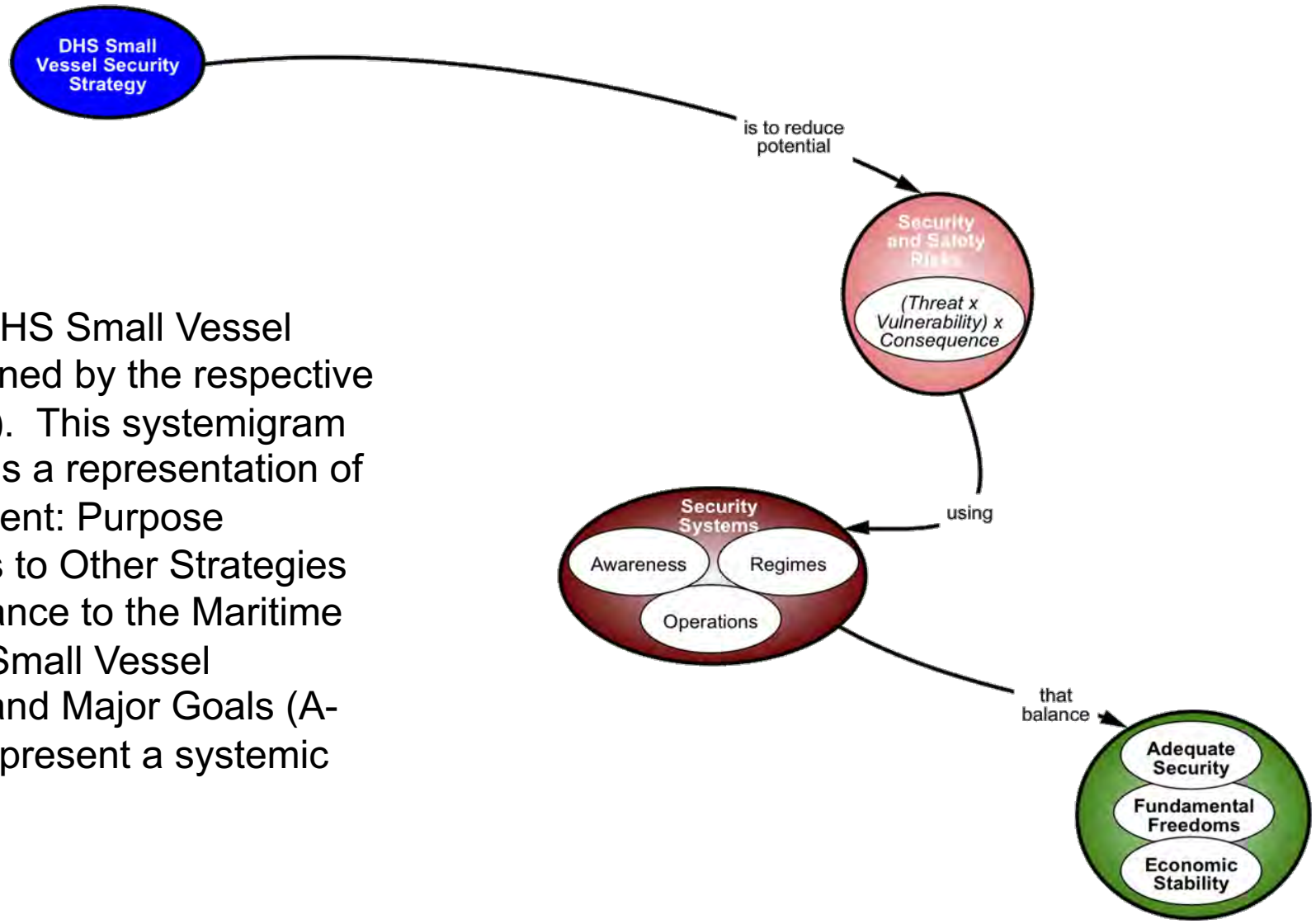
VERSION 3.0 MAINSTAY



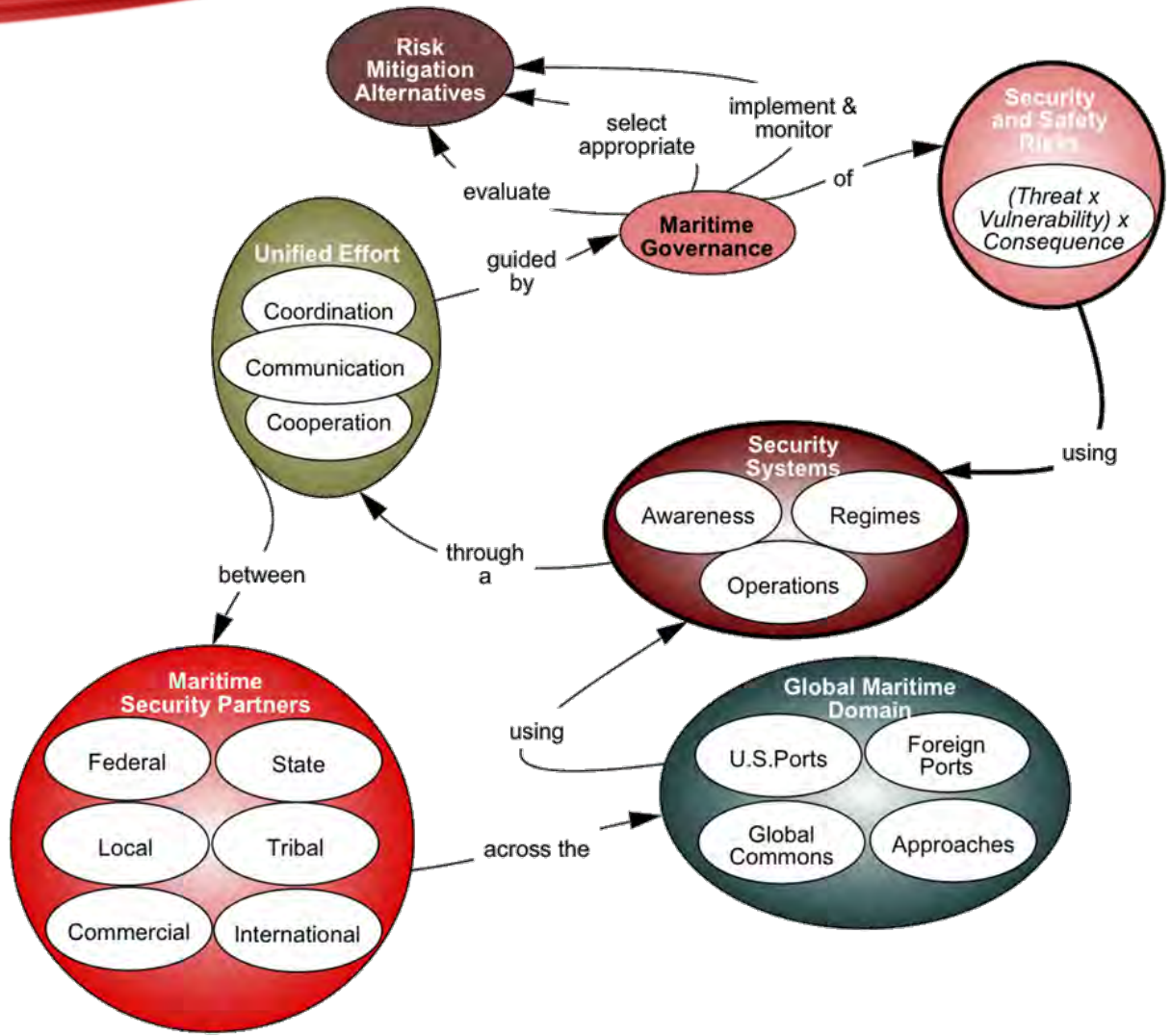
SMALL VESSEL SECURITY


Systemic Media Lab
Steven Institute of Technology
DHS Small Vessel Security Strategy
enhances and leverages
Technology and Innovation
related to
Risk Scenarios
WBIEDs
Weapons Smuggling
Terrorist Smuggling
Waterborne Platform
for
enhances
that influence
is to reduce potential
Risk Mitigation Alternatives
to address
Security and Safety Risk
(Threat x Vulnerability) x Consequence
select appropriate
implement & monitor
enhances
requires
evaluate
of
Maritime Governance
has distributed
from the
is consistent with
Unified Effort
Coordination
Communication
Cooperation
guided by
Cohenrent Plan with Layerd Approach
based on
Small Vessel Community (<300 gross tons)
Commercial Fishing
Recreational
Towing
Passenger
DHS Legislation and Strategies
to mitigate
using a
Security Systems
Awareness
Regimes
Operations
using
guides
through a
to detect, determine, and interdict
which guides
between
to enhance
using
that balance
Maritime Security Partners
Federal
State
Local
Tribal
Commercial
International
using
Global Maritime Domain
U.S.Ports
Foreign Ports
Global Commons
Approaches
Adequate Security
Fundamental Freedoms
Economic Stability
across the
contributing to
have limited interaction with
develop and leverage partnership with
DHS Small Vessel Secruity Strategy v3.0.sgm
Copyright 2011
Modeler: Brian Sauser

A systemigram was built of the DHS Small Vessel Security Strategy (SVSS) as defined by the respective strategy document (DHS, 2008a). This systemigram yielded 12 scenes. Each scene is a representation of a defining topic within the document: Purpose (Mainstay); Scope; Relationships to Other Strategies and Plans; Methodology; Importance to the Maritime Domain; Maritime Governance; Small Vessel Community; Small Vessel Risk; and Major Goals (A-D). Collectively, these scenes represent a systemic description of the SVSS.



Systemigram – Purpose

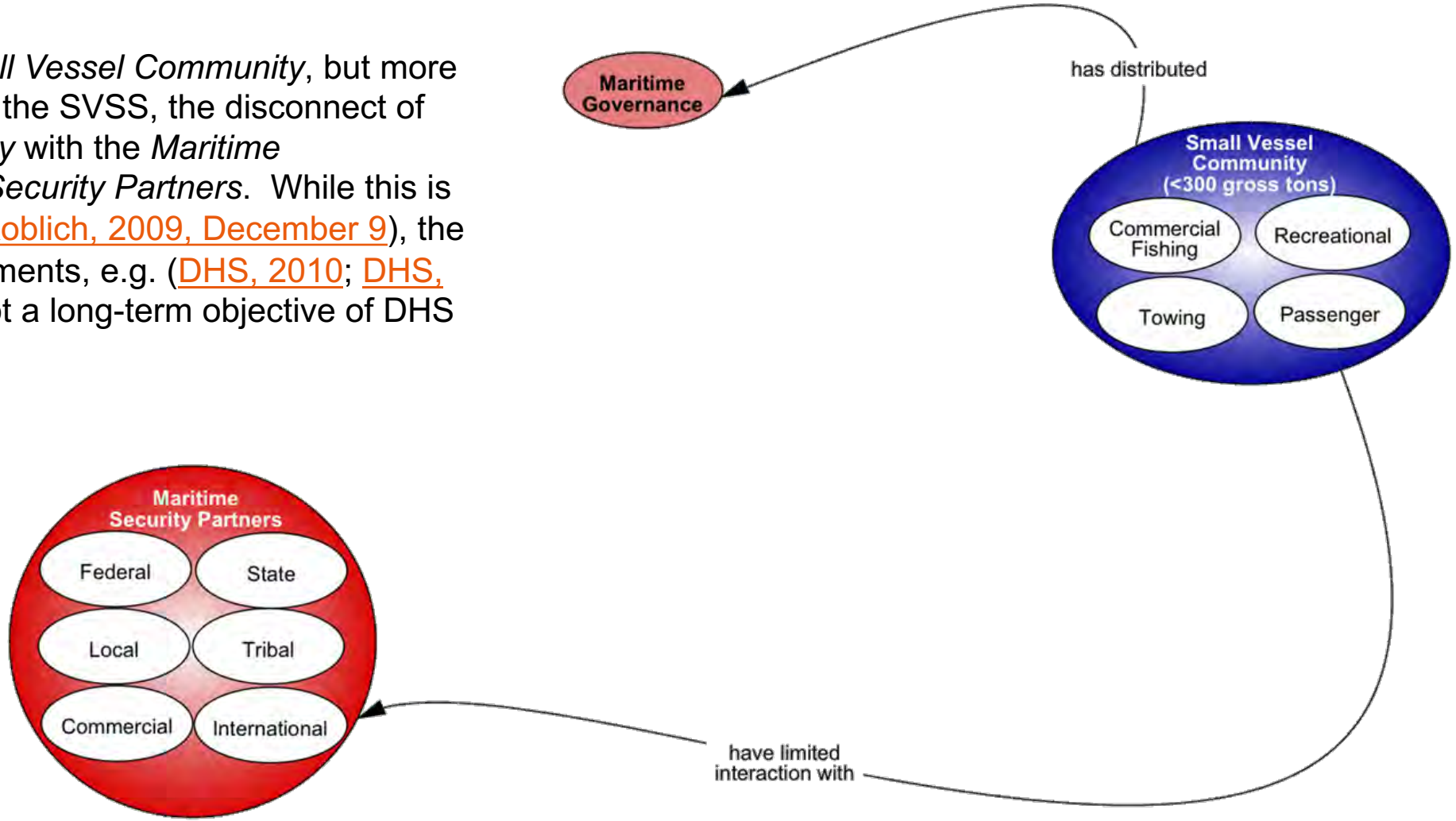


Governance is to steer an organization or set of constituencies based on established or customary guidelines for actualizing a desired status*. Maritime Governance, as depicted in this scene, represents the stakeholders and their actualization of *Risk Mitigation Alternatives* and the *Safety and Security Risks*. A key observation of this scene is that the *Small Vessel Community* is absent.

* Mansouri, M., Gorod, A., Wakeman, T. and Sauser, B., 2010. System of Systems Approach to Maritime Transportation Governance. Transportation Research Record: Journal of the Transportation Research Board, 2166: 66-73.

Systemigram – Maritime Governance

This scene depicts the *Small Vessel Community*, but more noticeable, as articulated in the SVSS, the disconnect of the *Small Vessel Community* with the *Maritime Governance* and *Maritime Security Partners*. While this is a reality in practices, see (Roblich, 2009, December 9), the SVSS and other DHS documents, e.g. (DHS, 2010; DHS, 2011), explain that this is not a long-term objective of DHS or the SVSS.

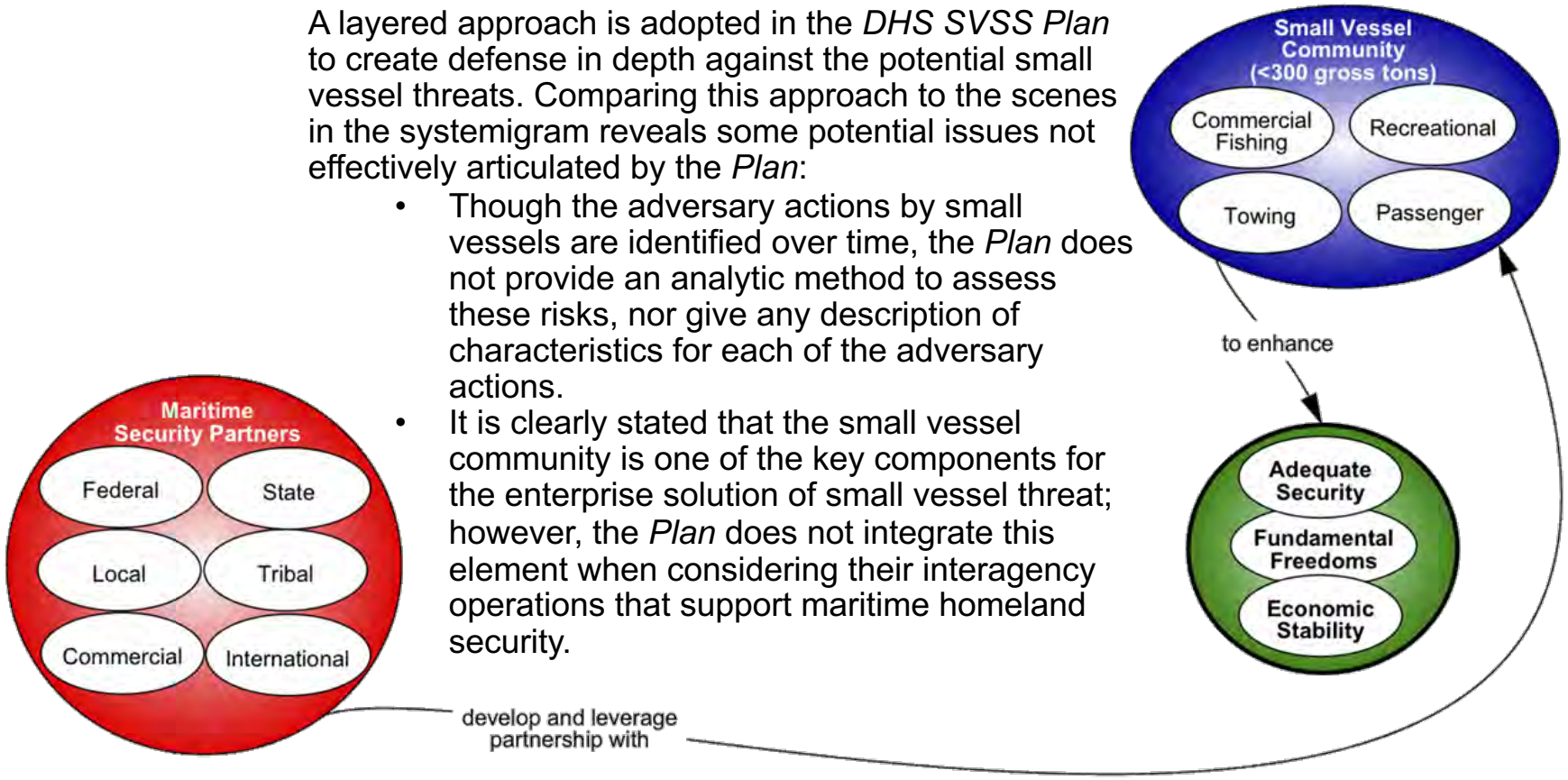


Systemigram – Small Vessel Community

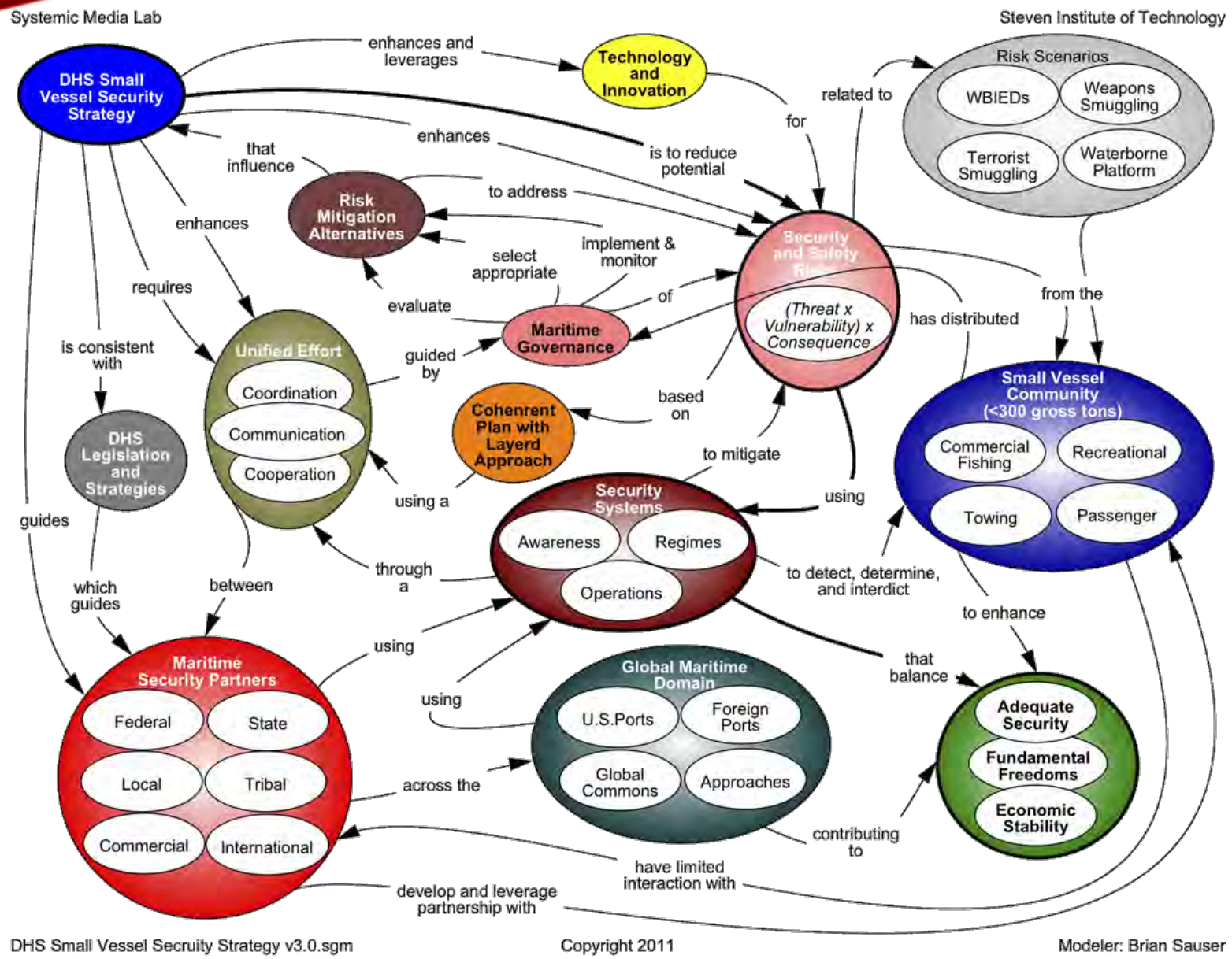
Major Goal A is related to the DHS commitment to engaging the community as part of the enterprise (DHS, 2010) to maritime domain awareness.

A layered approach is adopted in the *DHS SVSS Plan* to create defense in depth against the potential small vessel threats. Comparing this approach to the scenes in the systemigram reveals some potential issues not effectively articulated by the *Plan*:

- Though the adversary actions by small vessels are identified over time, the *Plan* does not provide an analytic method to assess these risks, nor give any description of characteristics for each of the adversary actions.
- It is clearly stated that the small vessel community is one of the key components for the enterprise solution of small vessel threat; however, the *Plan* does not integrate this element when considering their interagency operations that support maritime homeland security.



Systemigram – Major Goal A


Systemic Media Lab
Steven Institute of Technology
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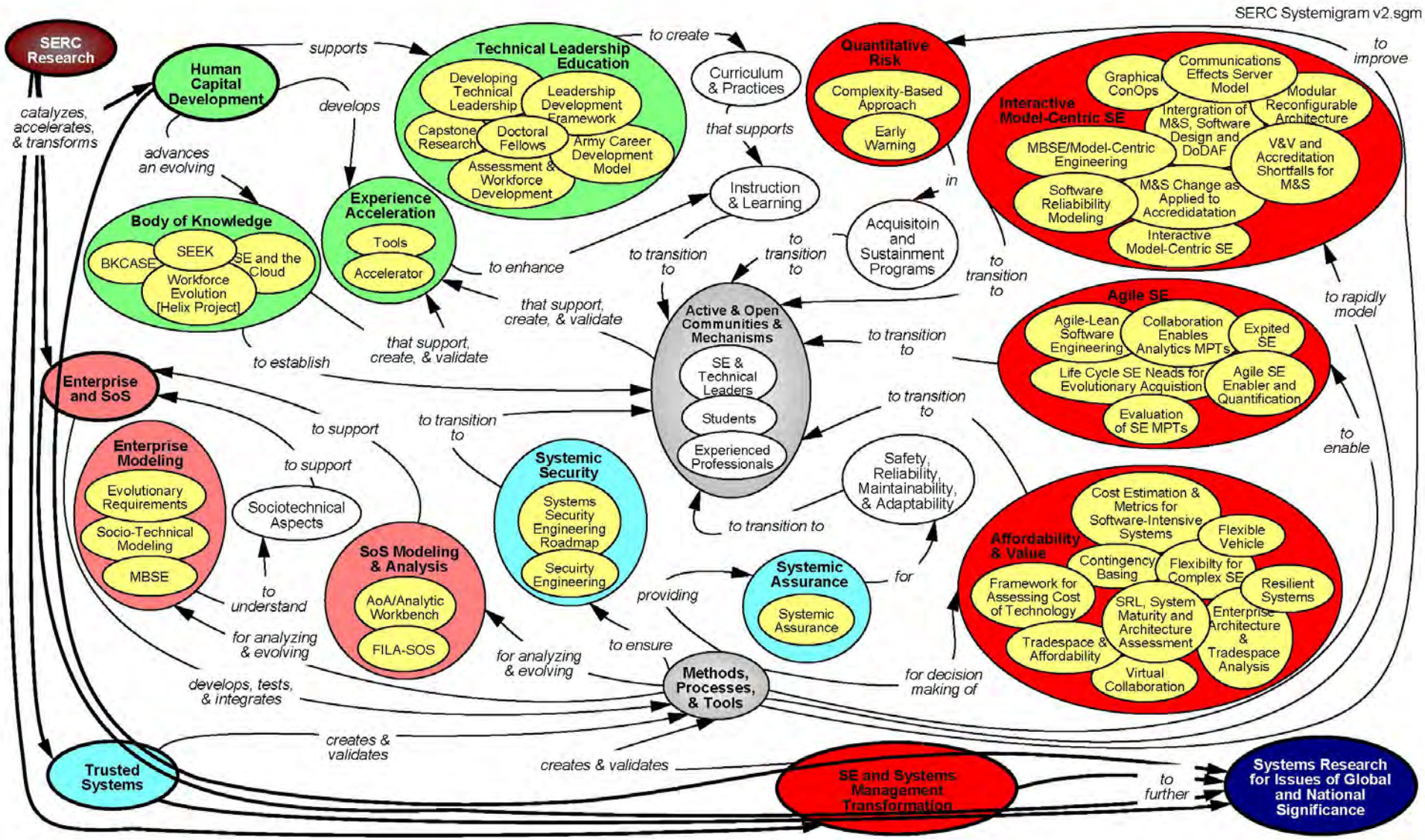
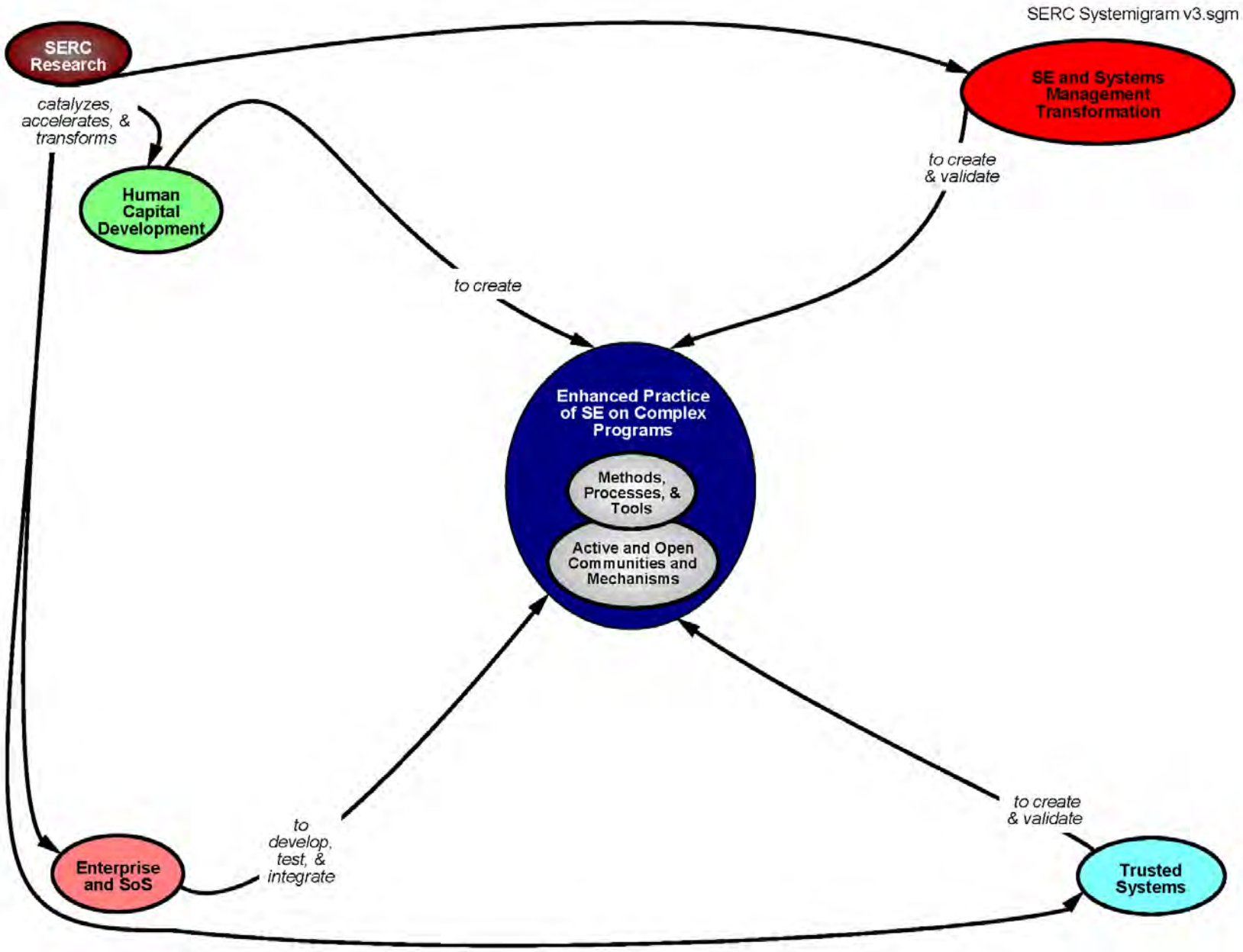
Commercial Fishing
Recreational
Towing
Passenger
DHS Legislation and Strategies
to mitigate
using a
using
Security Systems
Awareness
Regimes
Operations
guides
through a
to detect, determine, and interdict
which guides
between
to enhance
using
that balance
Maritime Security Partners
Federal
State
Local
Tribal
Commercial
International
using
Global Maritime Domain
U.S.Ports
Foreign Ports
Global Commons
Approaches
Adequate Security
Fundamental Freedoms
Economic Stability
across the
contributing to
have limited interaction with
develop and leverage partnership with
DHS Small Vessel Secruity Strategy v3.0.sgm
Copyright 2011
Modeler: Brian Sauser

SYSTEMS ENGINEERING RESEARCH CENTER (SERC)


SERC Systemigram v2.sgm
SERC Research
catalyzes, accelerates, & transforms
Human Capital Development
supports
develops
advances an evolving
Technical Leadership Education
Developing Technical Leadership
Leadership Development Framework
Capstone Research
Doctoral Fellows
Army Career Development Model
Assessment & Workforce Development
to create
Curriculum & Practices
that supports
Instruction & Learning
Quantitative Risk
Complexity-Based Approach
Early Warning
Interactive Model-Centric SE
Graphical ConOps
Communications Effects Server Model
Modular Reconfigurable Architecture
Intergration of M&S, Software Design and DoDAF
MBSE/Model-Centric Engineering
V&V and Accreditation Shortfalls for M&S
Software Reliability Modeling
M&S Change as Applied to Accredidatation
Interactive Model-Centric SE
to improve
in
Acquisitoin and Sustainment Programs
to transition to
Body of Knowledge
SEEK
BKCASE
SE and the Cloud
Workforce Evolution [Helix Project]
Experience Acceleration
Tools
Accelerator
to enhance
that support, create, & validate
to establish
Active & Open Communities & Mechanisms
SE & Technical Leaders
Students
Experienced Professionals
Agile SE
Agile-Lean Software Engineering
Collaboration Enables Analytics MPTs
Expited SE
Life Cycle SE Needs for Evolutionary Acquistion
Agile SE Enabler and Quantification
Evaluation of SE MPTs
to rapidly model
to enable
Enterprise and SoS
to support
Enterprise Modeling
Evolutionary Requirements
Socio-Technical Modeling
MBSE
Sociotechnical Aspects
to understand
SoS Modeling & Analysis
AoA/Analytic Workbench
FILA-SOS
for analyzing & evolving
Systemic Security
Systems Security Engineering Roadmap
Security Engineering
providing
to ensure
Systemic Assurance
Systemic Assurance
for
Safety, Reliability, Maintainability, & Adaptability
Affordability & Value
Cost Estimation & Metrics for Software-Intensive Systems
Flexible Vehicle
Contingency Basing
Flexibilty for Complex SE
Resilient Systems
Framework for Assessing Cost of Technology
SRL, System Maturity and Architecture Assessment
Enterprise Architecture & Tradespace Analysis
Tradespace & Affordability
Virtual Collaboration
for decision making of
Methods, Processes, & Tools
develops, tests, & integrates
creates & validates
Trusted Systems
SE and Systems Management Transformation
to further
Systems Research for Issues of Global and National Significance


SERC Systemigram v3.sgm
SERC Research
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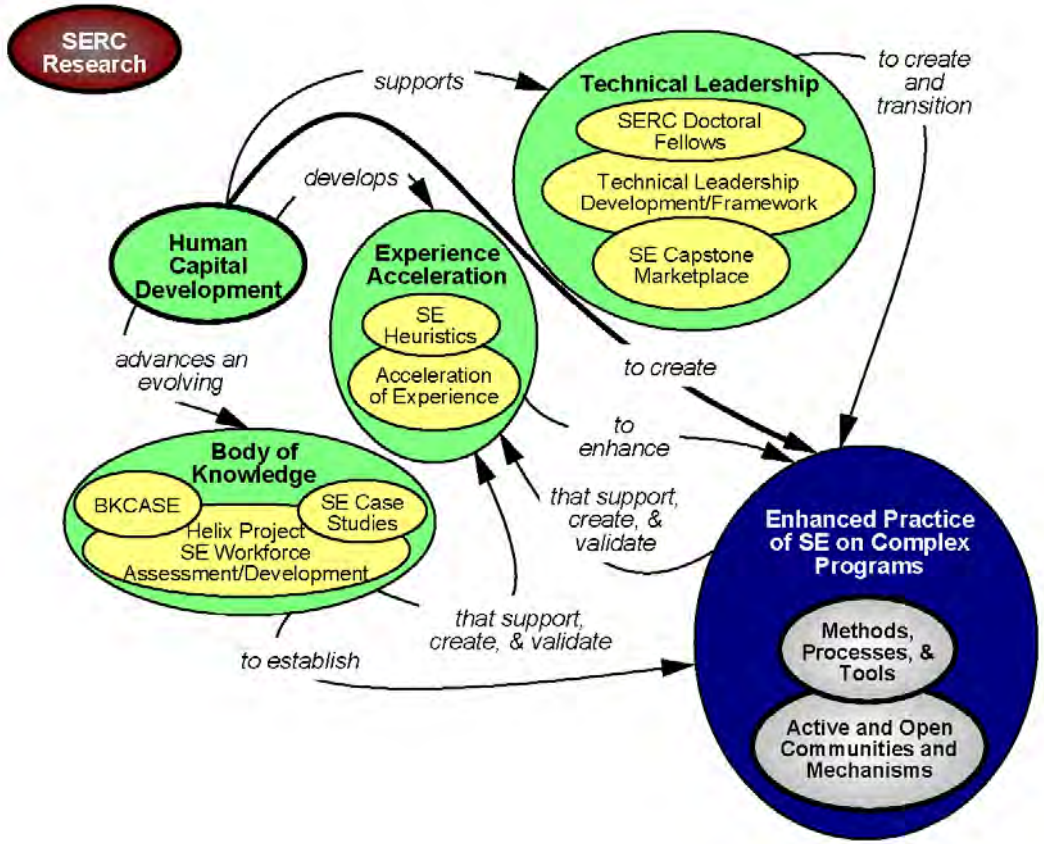
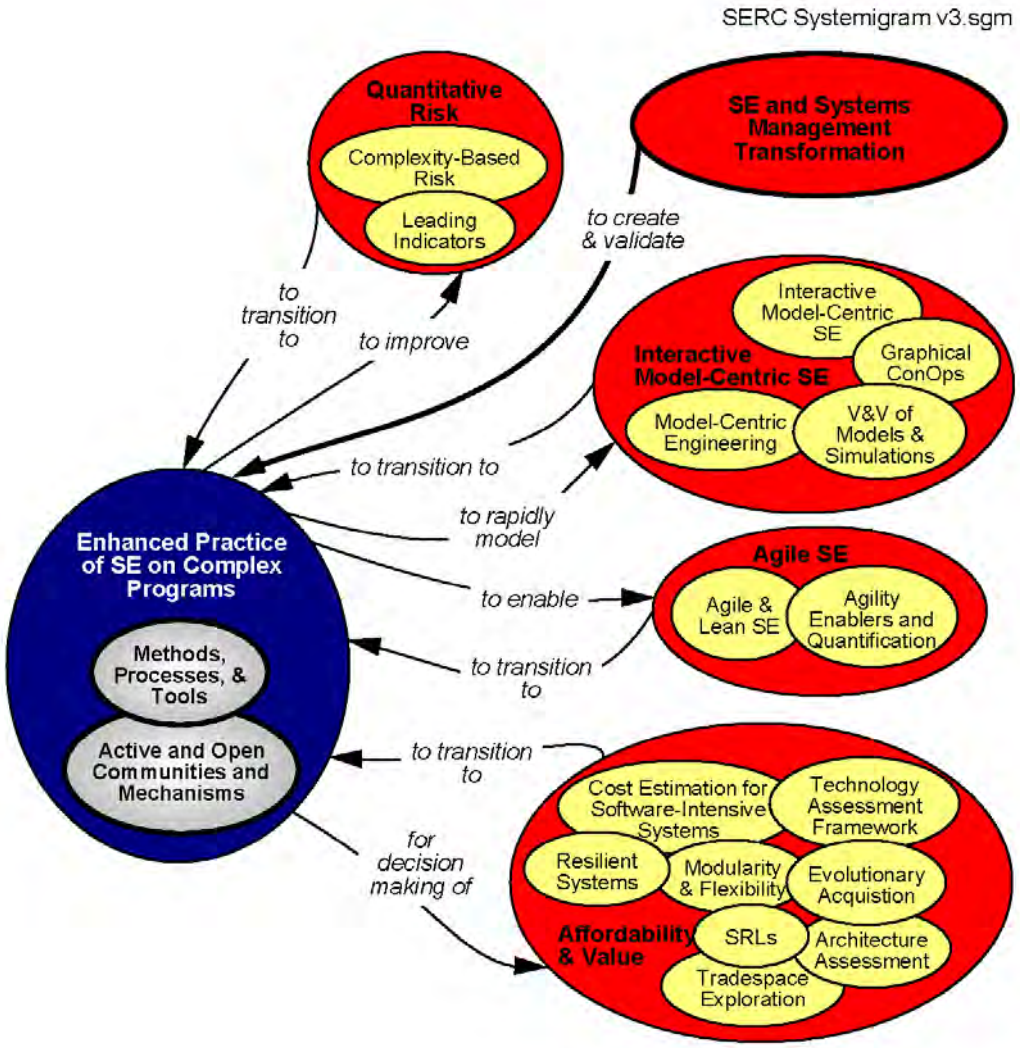
Human Capital Development
to create & validate
to create
Enhanced Practice of SE on Complex Programs
Methods, Processes, & Tools
Active and Open Communities and Mechanisms
to develop, test, & integrate
Enterprise and SoS
to create & validate
Trusted Systems

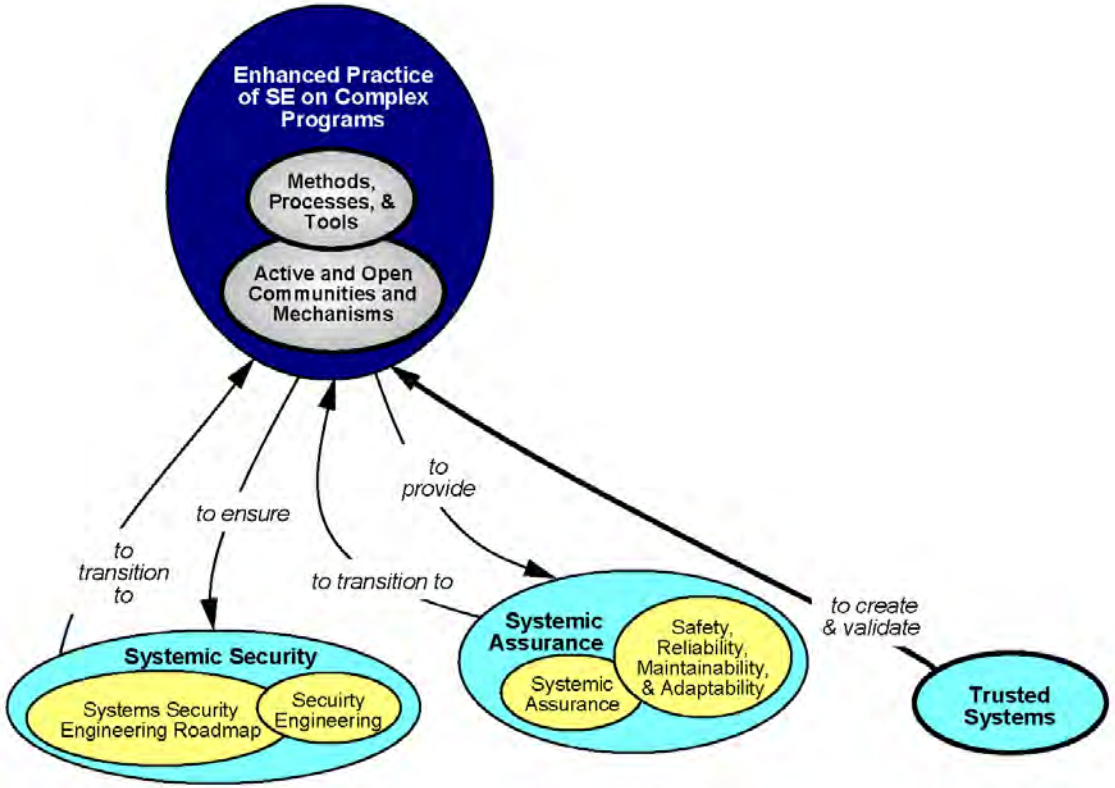

SERC Research
supports
Technical Leadership
SERC Doctoral Fellows
Technical Leadership Development/Framework
SE Capstone Marketplace
to create and transition
develops
Human Capital Development
Experience Acceleration
SE Heuristics
Acceleration of Experience
advances an evolving
to create
to enhance
Body of Knowledge
BKCASE
SE Case Studies
Helix Project
SE Workforce Assessment/Development
that support, create, & validate
Enhanced Practice of SE on Complex Programs
Methods, Processes, & Tools
Active and Open Communities and Mechanisms
that support, create, & validate
to establish

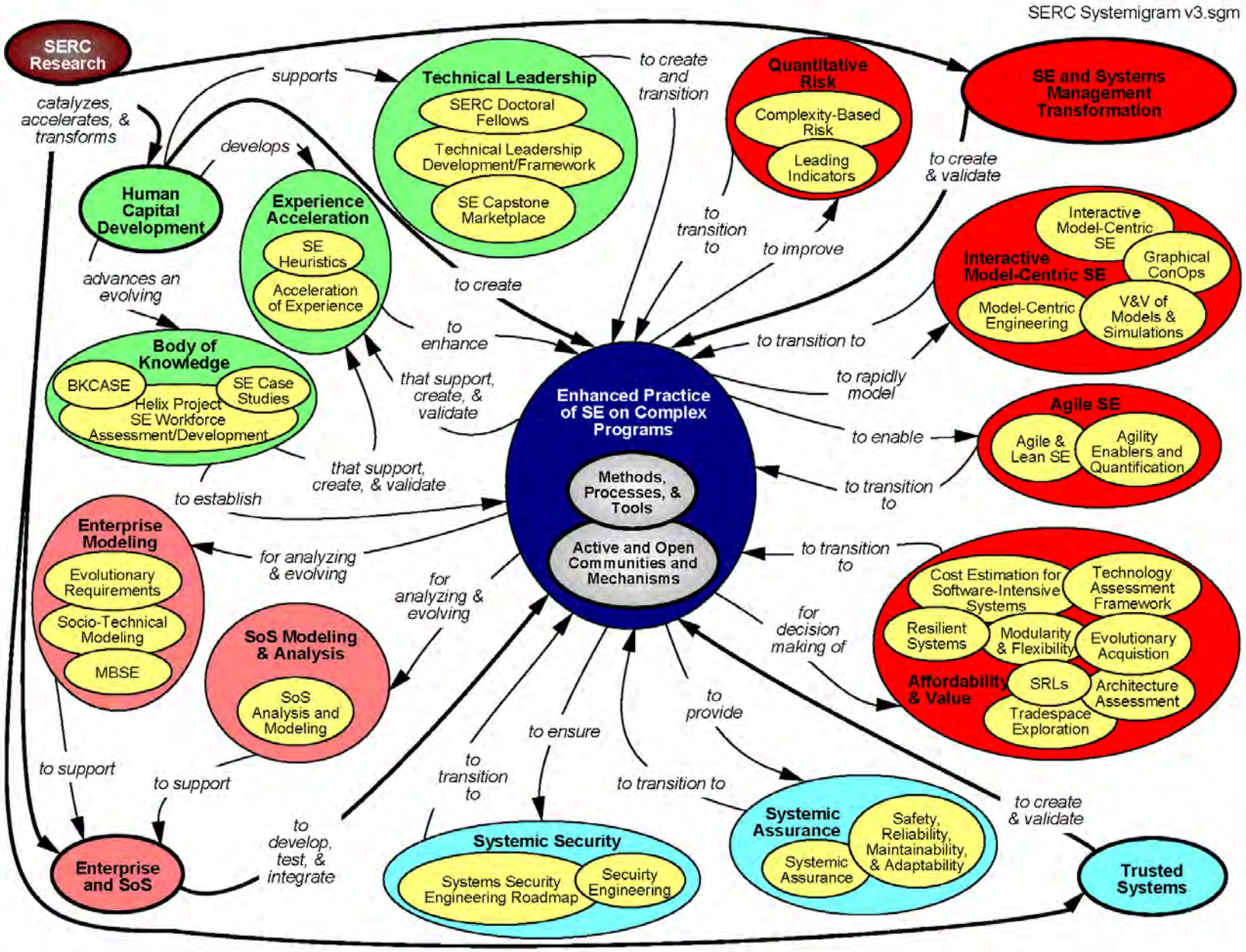
SERC Research



SERC Research

SERC Systemigram v3.sgm

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Model-Centric Engineering
V&V of Models & Simulations
to transition to
to rapidly model
Enhanced Practice of SE on Complex Programs
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Systemic Assurance
to create & validate
to develop, test, & integrate
Systemic Security
Systems Security Engineering Roadmap
Secuirty Engineering
Enterprise and SoS
Trusted Systems

HOW DO YOU KNOW WHEN YOU'RE DONE?

- This process should be repeated until a successful outcome of a BSSM is achieved.
- Success is defined as:
  - (i) the people concerned, i.e. stakeholders, feel that the problem has been solved; and/or
  - (ii) the problem situation has been improved; and/or
  - (iii) insights have been gained.

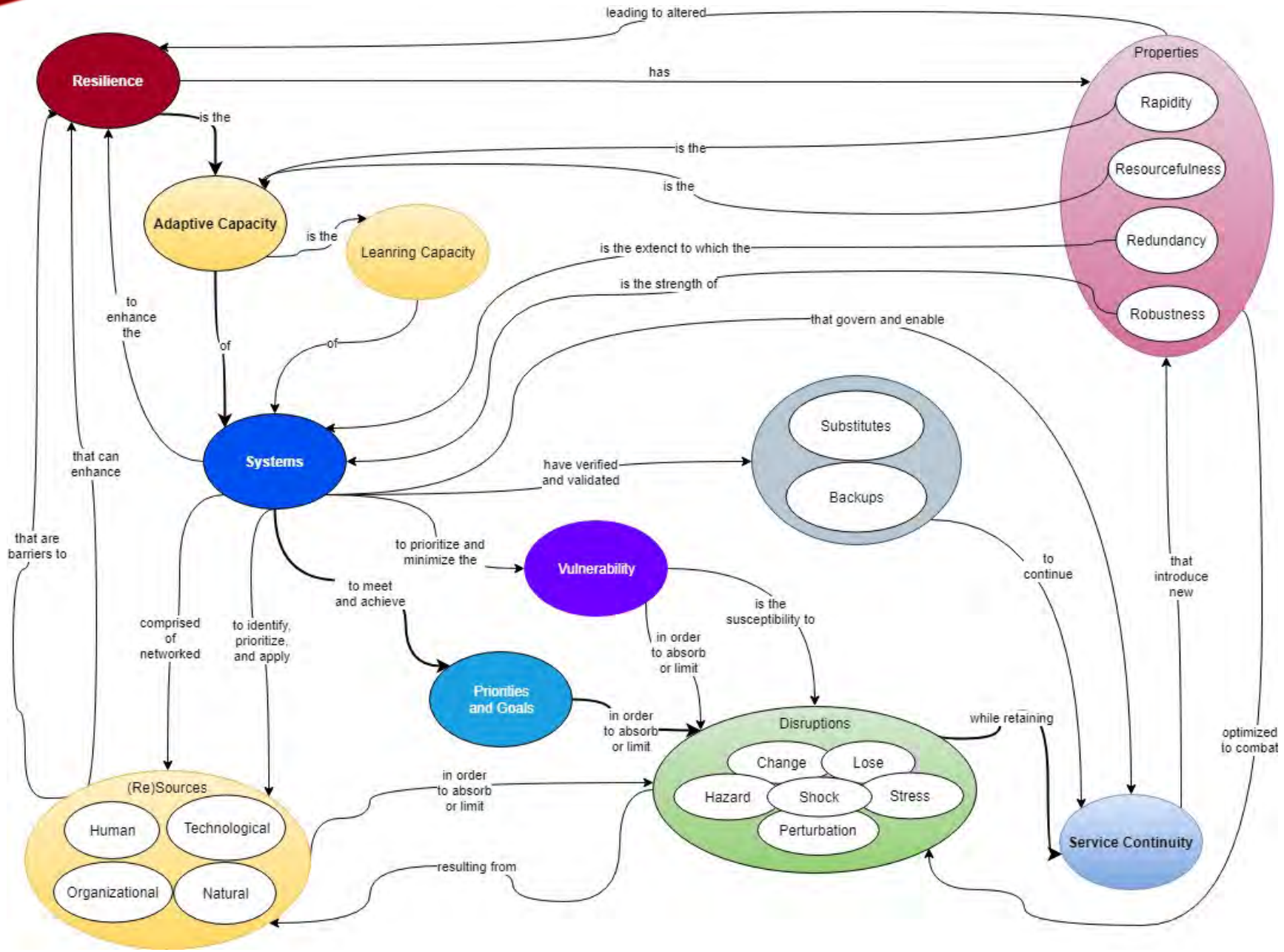
Rules for the Dialogue

Remember that the model is not really "theirs"! You constructed it from something that meant something to them but now means less than the model offers

Remember that the model is really "theirs". All you did was to present a fresh perspective on their system descriptions with hopefully some added value.

Remember that the model is not reality; rather it's an insightful commentary on reality that serves the purpose of shaping future reality with greater effect.

"EVERY GREAT JOURNEY ENDS IN A PLACE YOU NEVER KNEW IT WOULD TAKE YOU WHEN YOU STARTED."



John Boardman & Brian Sauser
Systemic Thinking: Building Maps for Worlds of Systems

SYSTEMS ENGINEERING RESEARCH CENTER

Systems Thinking Workshop: SystemiTool 2.0

FHI 360 Conference Center
1825 Connecticut Ave NW 8th Floor, Washington, DC 20009

November 18, 2019

Dr. Jon Wade, (Stevens)

Kunal Batra (Stevens)

Example: Defense Acquisition Programs

Concentrated Prose for Systemigram

Combat veterans define demanding requirements for the next generation of military equipment to ensure a successful conflict outcome. The technical challenges of the requirements lead design engineers to propose use of new technologies in the equipment.

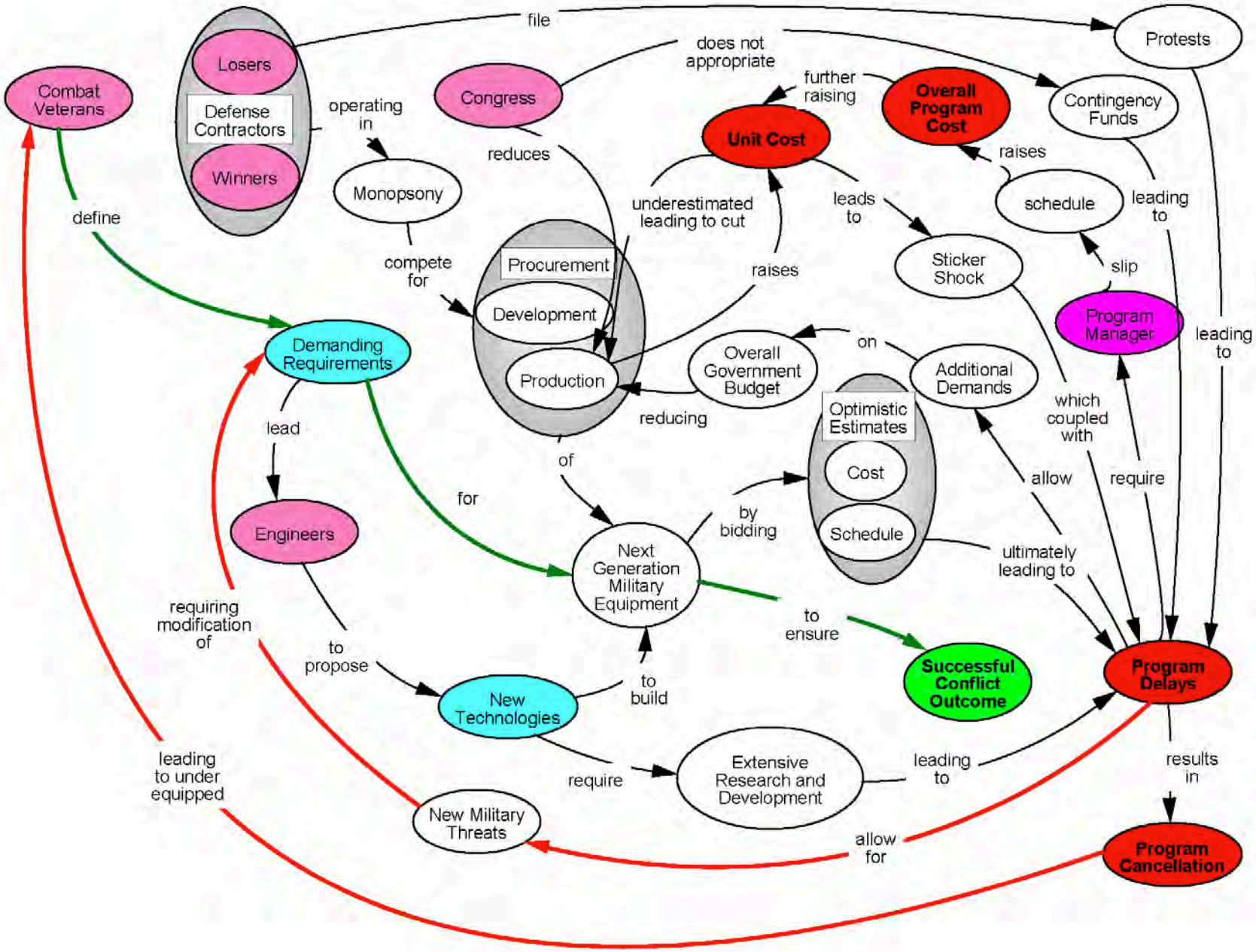
Defense firms, operating in a monopsony, compete for the right to develop and produce the technology by bidding optimistic cost and schedule estimates. These estimates are ultimately proven wrong and lead to program delays. Losing firms delay the program execution by filing protests.

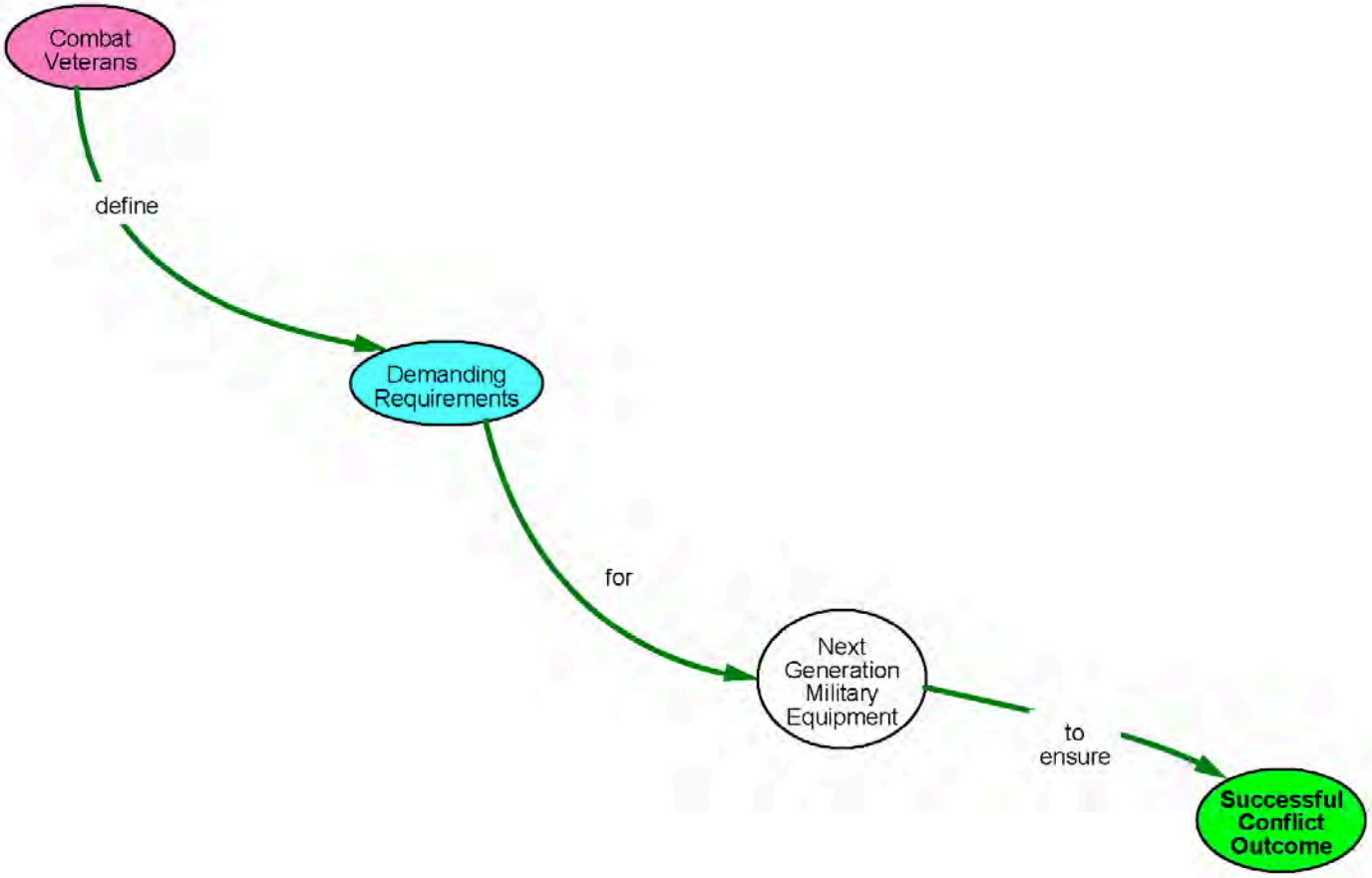
The technology needed to meet the established requirements is not yet fully available requiring extensive researcbh and development leading to delays.

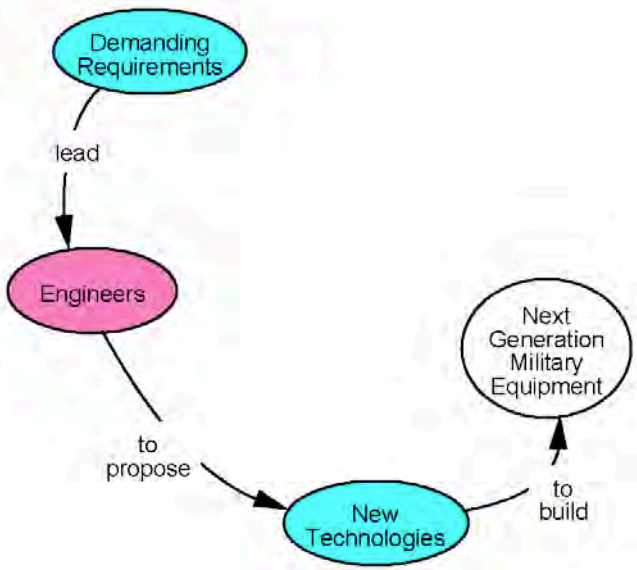
Delays are exacerbated because Congress declined to appropriate any contingency funds or to pay for schedule slack. Delays also allow new military threats to emerge and the original requirements must be modified. The Program Manager, reluctantly, proposes a schedule slip—even though this will substantially raise overall costs.

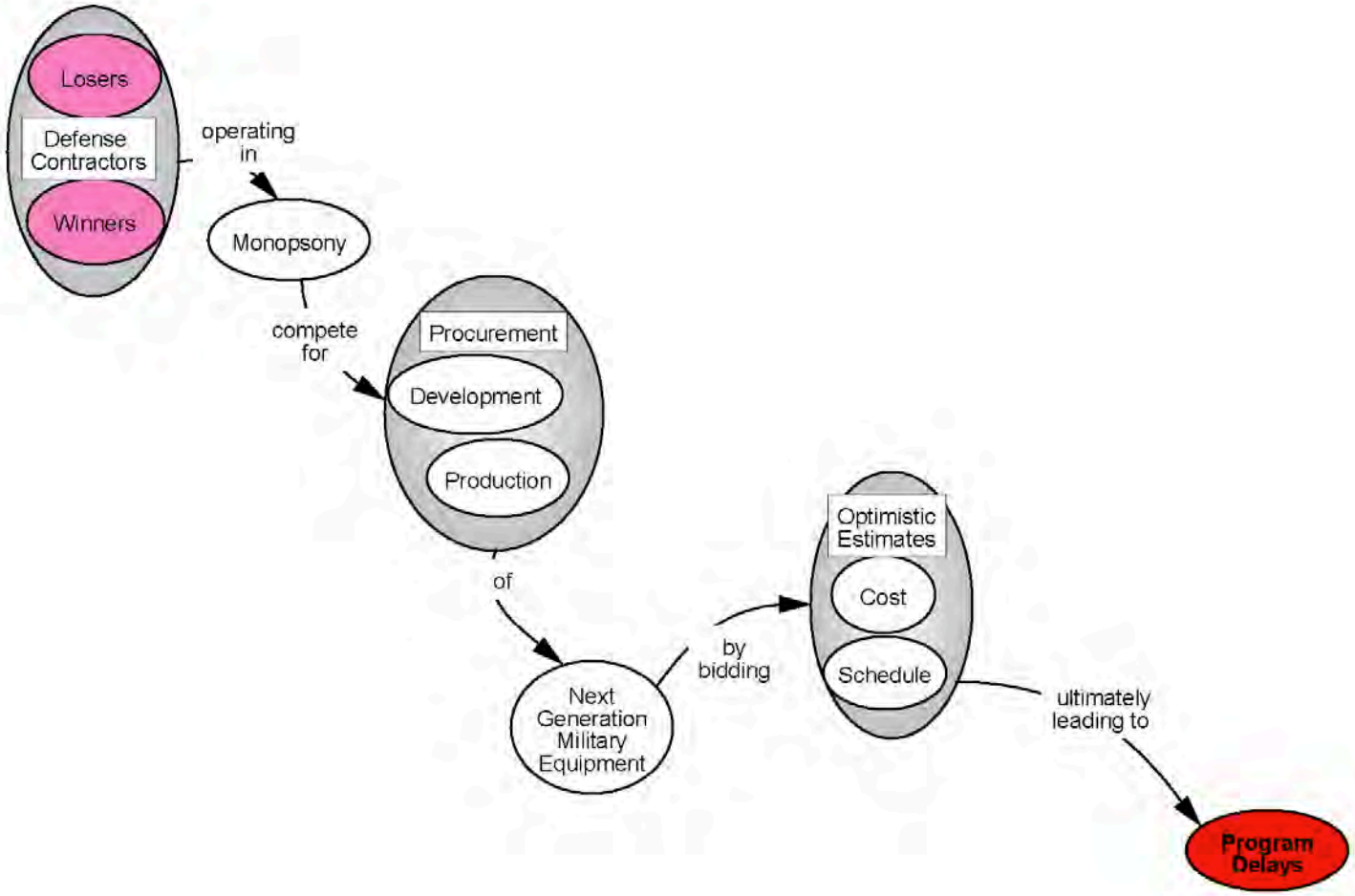
Unit cost of the item to be produced has been significantly underestimated making it necessary to cut in half the total number of items to be produced. Politicals seize the opportunity to reduce the production buy by another factor of two. Given the delays that have been suffered additional demands on the government's overall budget begin to emerge so production is further curtailed in both rate and quantity. Unit costs skyrocket. The troubled program is finally terminated, due to widespread sticker shock

The military officers who served as requirements generators thus return to their field assignments where they prepare their troops to go into combat with now 40-year-old equipment.


Combat Veterans
Losers
Defense Contractors
Winners
file
Protests
does not appropriate
Congress
operating in
Monopsony
reduces
further raising
Overall Program Cost
Contingency Funds
Unit Cost
raises
schedule
leading to
underestimated leading to cut
leads to
Sticker Shock
slip
define
compete for
Procurement
Development
Production
raises
Program Manager
leading to
Demanding Requirements
Overall Government Budget
on
Additional Demands
reducing
Optimistic Estimates
Cost
Schedule
which coupled with
lead
of
allow
require
for
by bidding
Engineers
Next Generation Military Equipment
ultimately leading to
requiring modification of
to ensure
Successful Conflict Outcome
Program Delays
to propose
to build
New Technologies
leading to under equipped
require
Extensive Research and Development
leading to
results in
New Military Threats
allow for
Program Cancellation


Combat Veterans
define
Demanding Requirements
for
Next Generation Military Equipment
to ensure
Successful Conflict Outcome


Demanding Requirements
lead
Engineers
to propose
New Technologies
to build
Next Generation Military Equipment


Losers
Defense Contractors
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operating in
Monopsony
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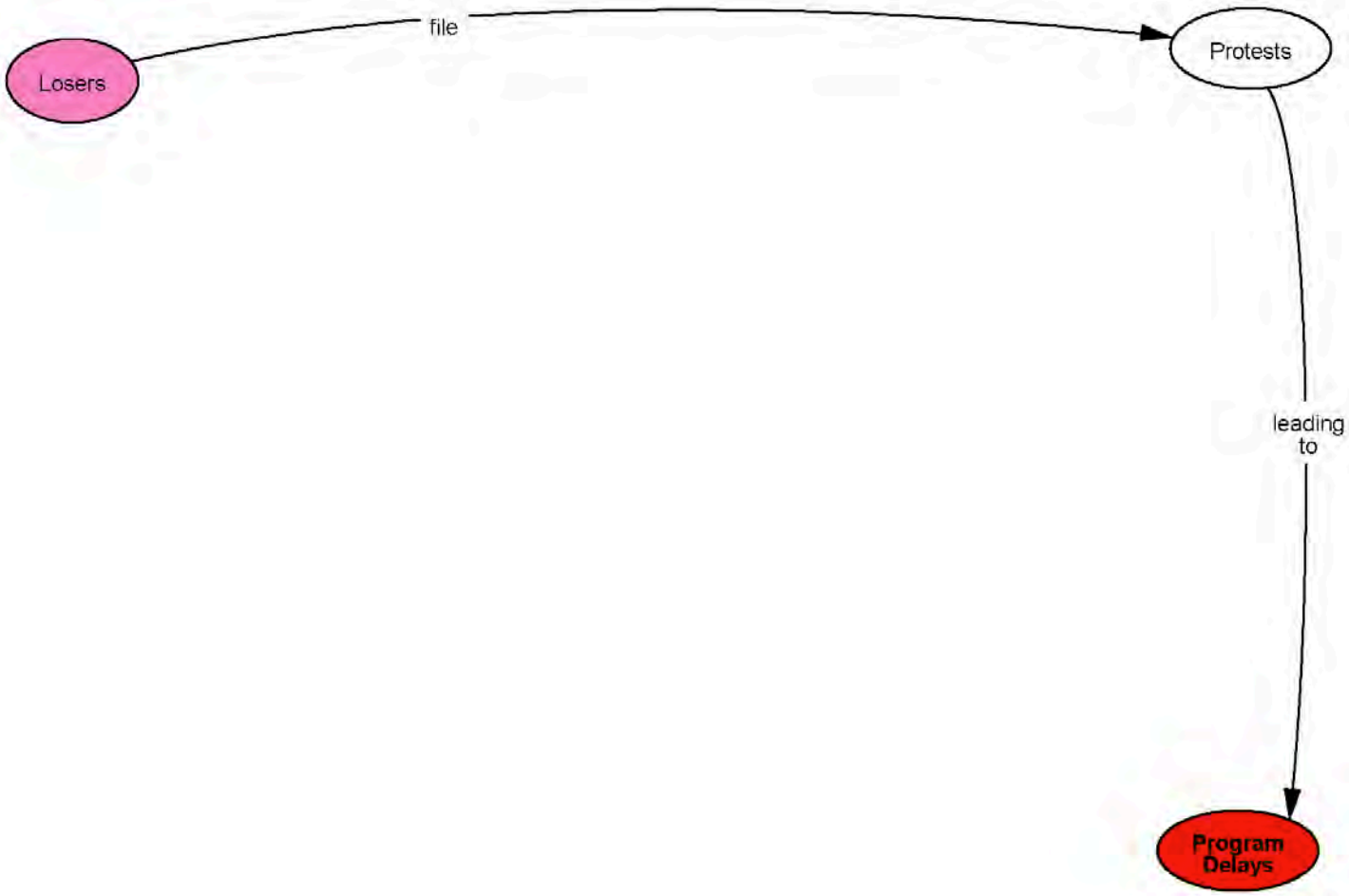
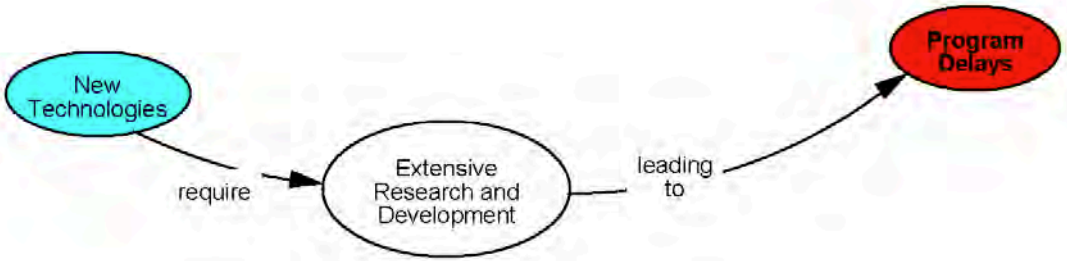
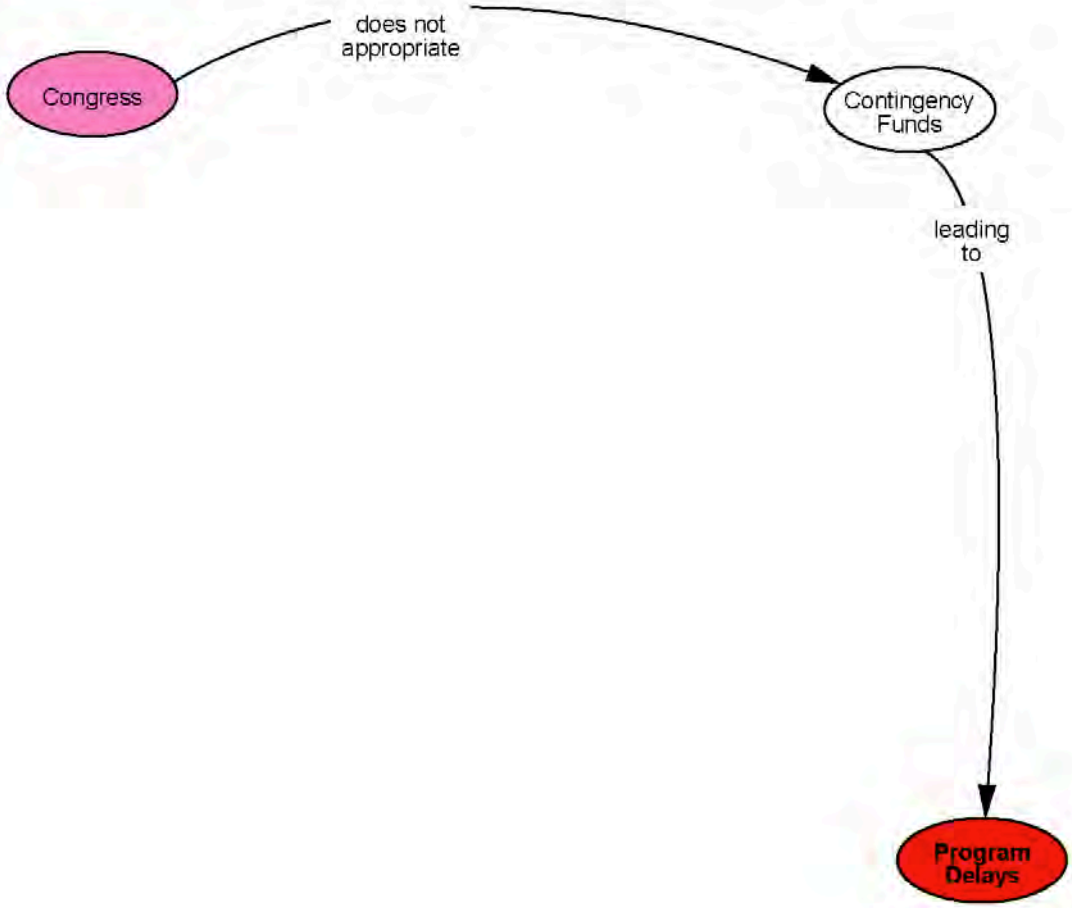
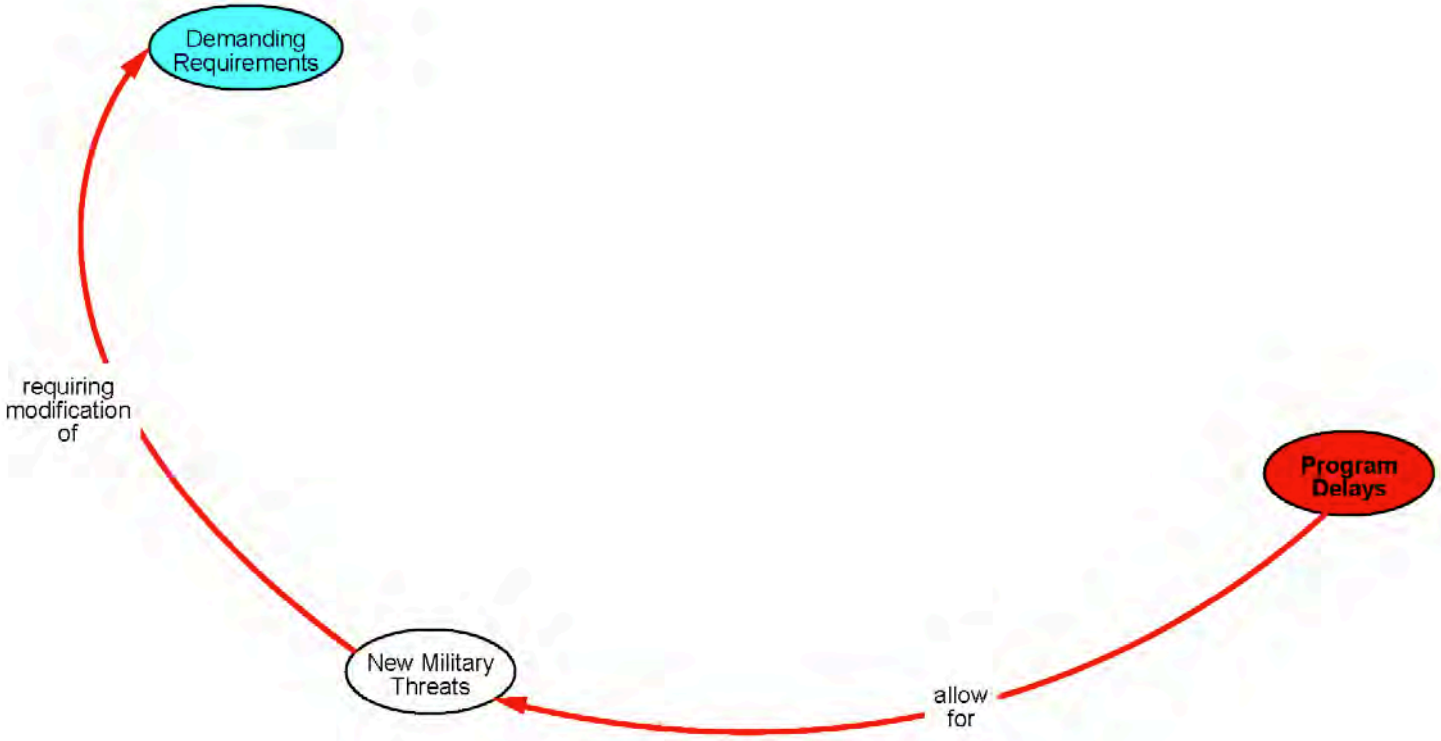
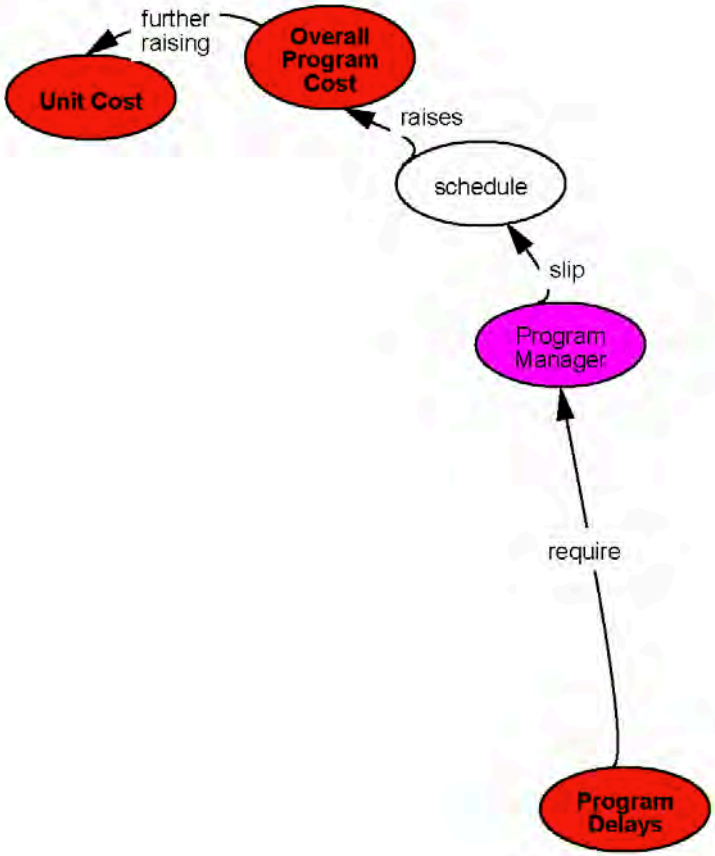
Procurement
Development
Production
of
Next Generation Military Equipment
by bidding
Optimistic Estimates
Cost
Schedule
ultimately leading to
Program Delays

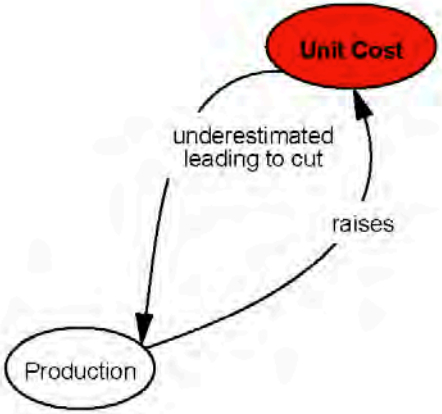

Losers
file
Protests
leading to
Program Delays

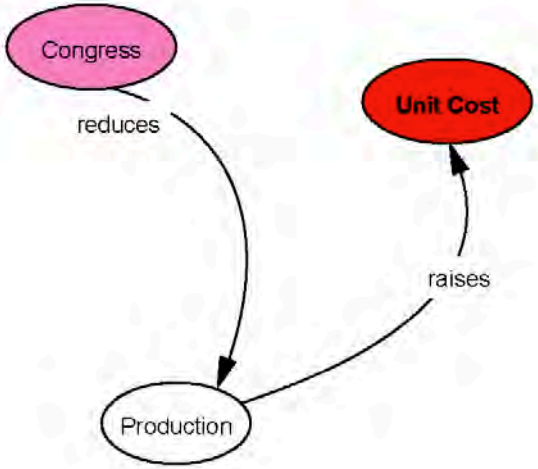

New Technologies
require
Extensive Research and Development
leading to
Program Delays

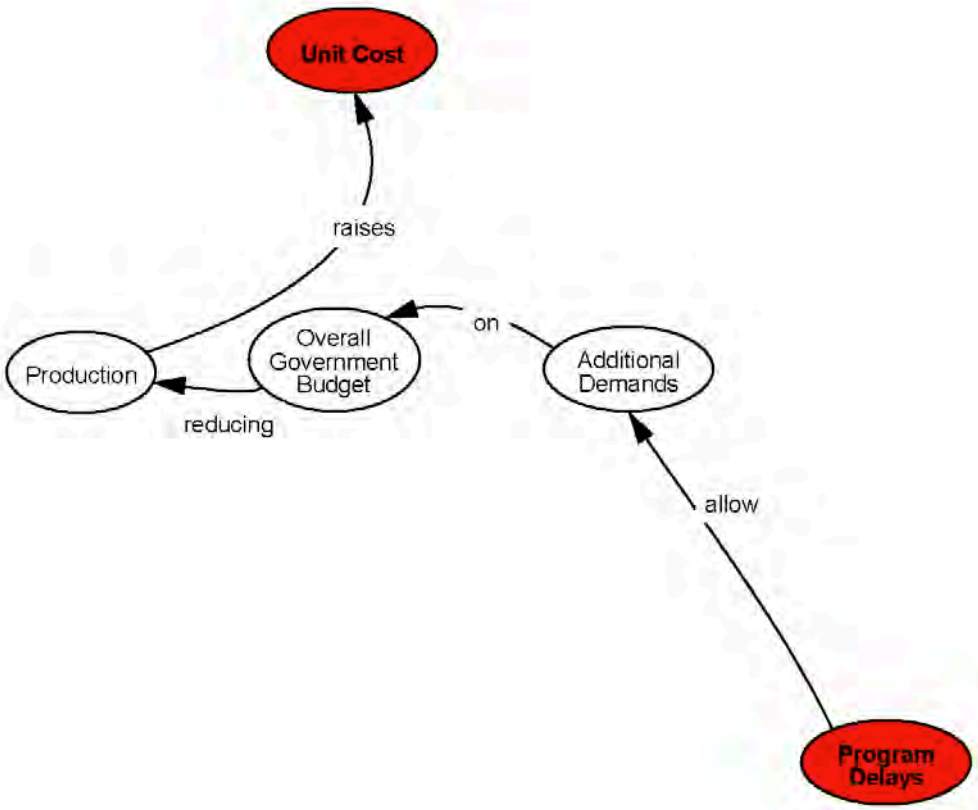

Congress
does not appropriate
Contingency Funds
leading to
Program Delays

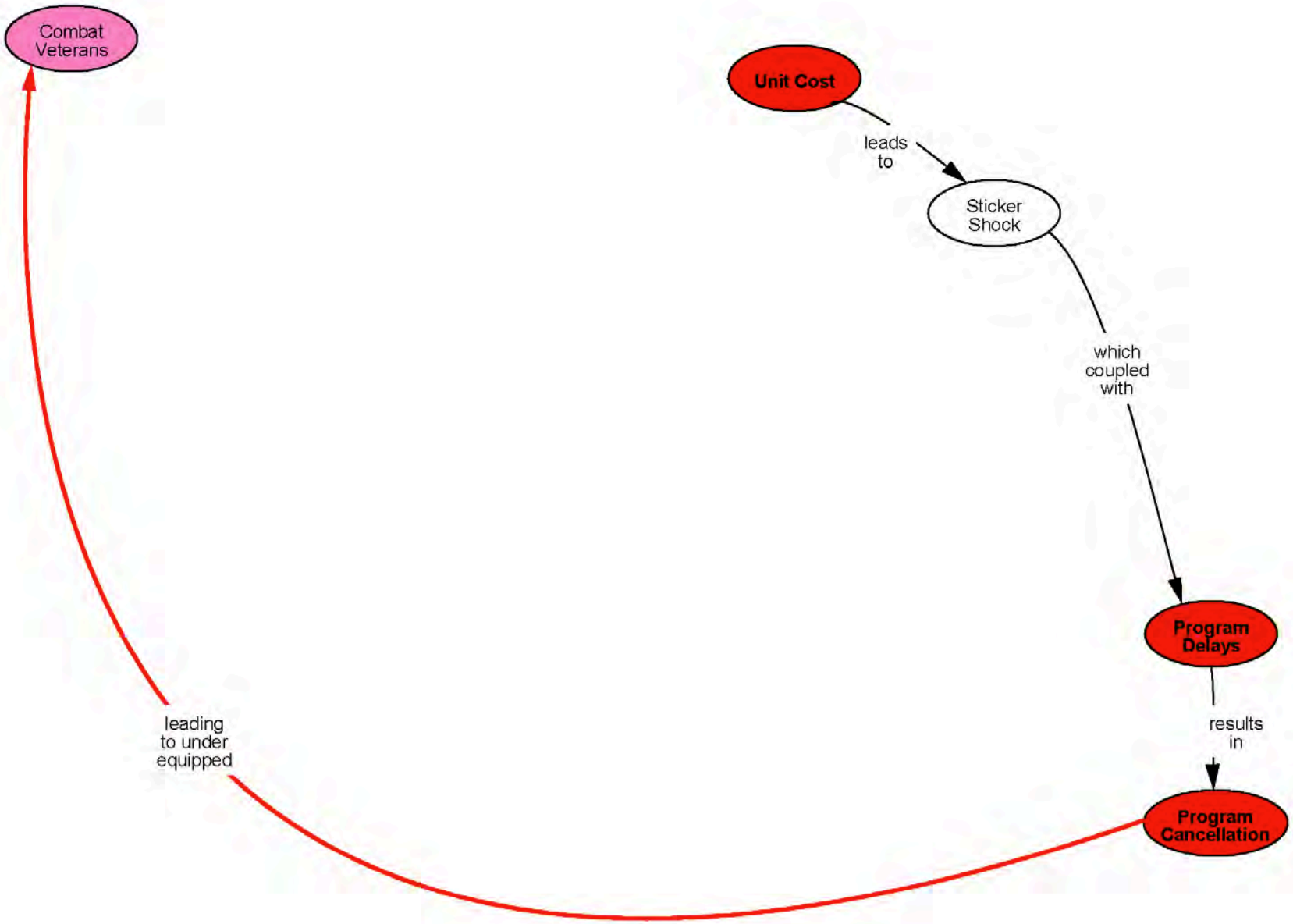

Demanding Requirements
requiring modification of
New Military Threats
allow for
Program Delays

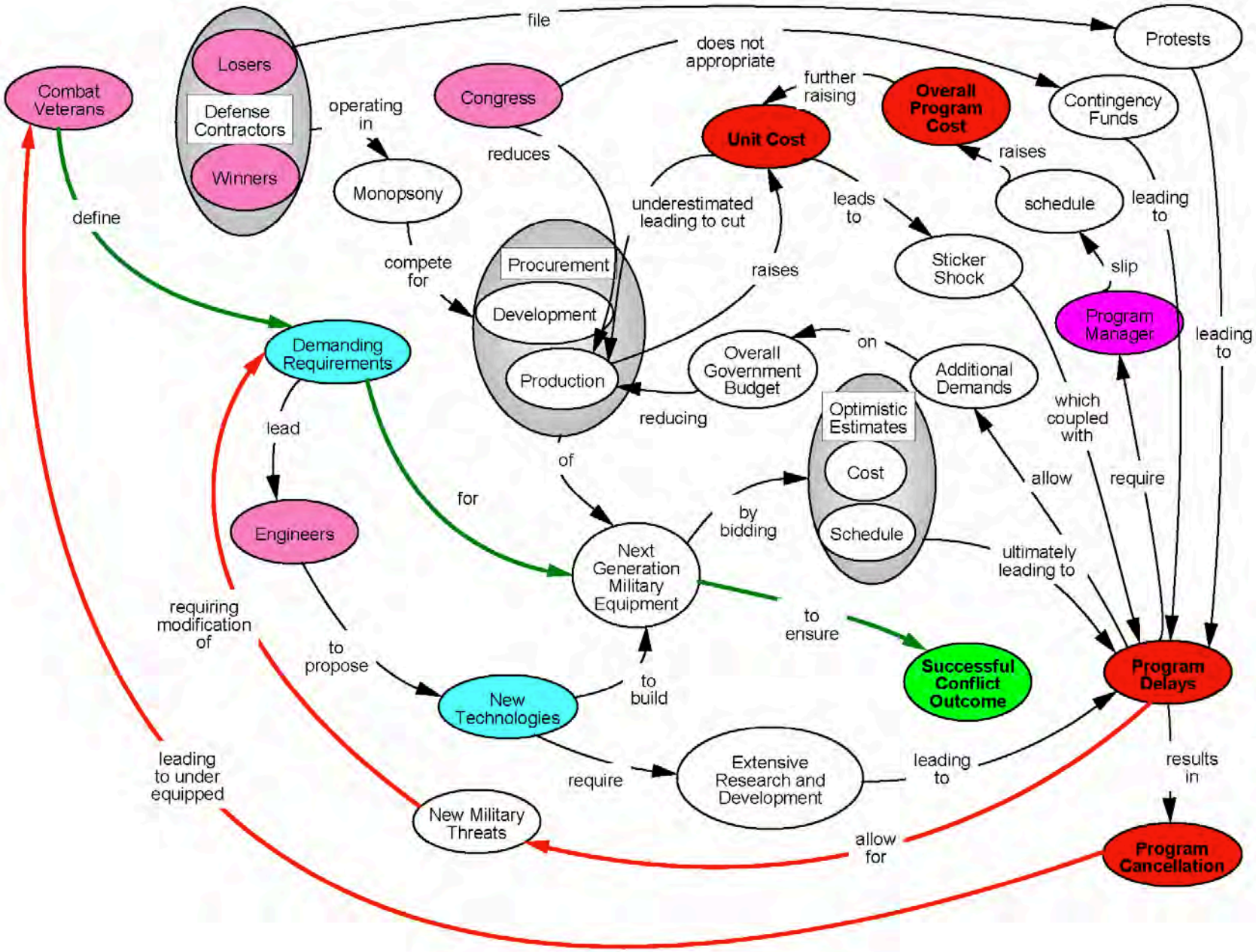

further raising
Overall Program Cost
Unit Cost
raises
schedule
slip
Program Manager
require
Program Delays


Unit Cost
underestimated
leading to cut
raises
Production


Congress
reduces
Unit Cost
raises
Production


Unit Cost
raises
Production
Overall Government Budget
reducing
on
Additional Demands
allow
Program Delays


Combat Veterans
Unit Cost
leads to
Sticker Shock
which coupled with
Program Delays
results in
Program Cancellation
leading to under equipped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New Technologies
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Extensive Research and Development
leading to
results in
New Military Threats
allow for
Program Cancellation

Systems Thinking & Digital Engineering

Digital engineering (DE):

- an engineering approach that captures and analyzes data that is in a digital format which is semantically rich and interconnected
- enables people to leverage the power of computing, visualization, and communication to significantly enhance efficiencies, quality, and innovation across the complex system development lifecycle

- Sandy Friedenthal, SERC DE Workshop, Nov. 15, 2019

Systems Thinking

A. Context – Systems Thinking

1. Systems Perspectives
2. Relationships
3. Dynamics

B. Human Centricity – Design Thinking

4. Design Thinking
5. Identifying Opportunities
6. Identifying Customer Needs
7. Preliminary Product Specifications

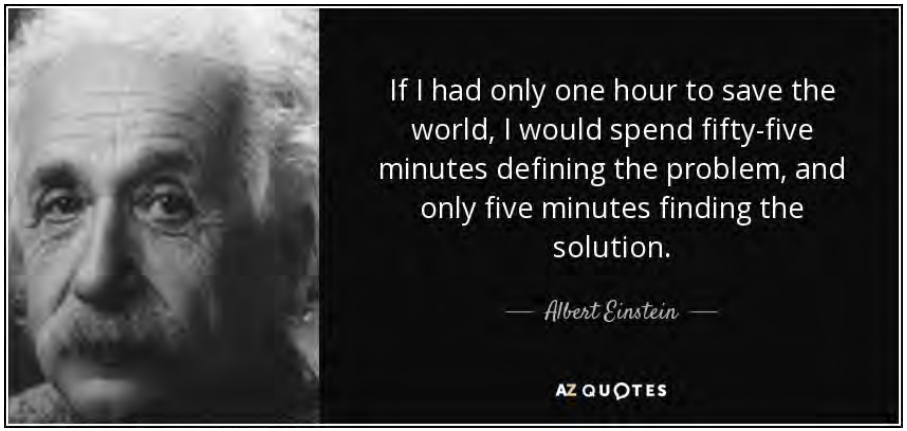
D. Conceptualization – Systems Engineering

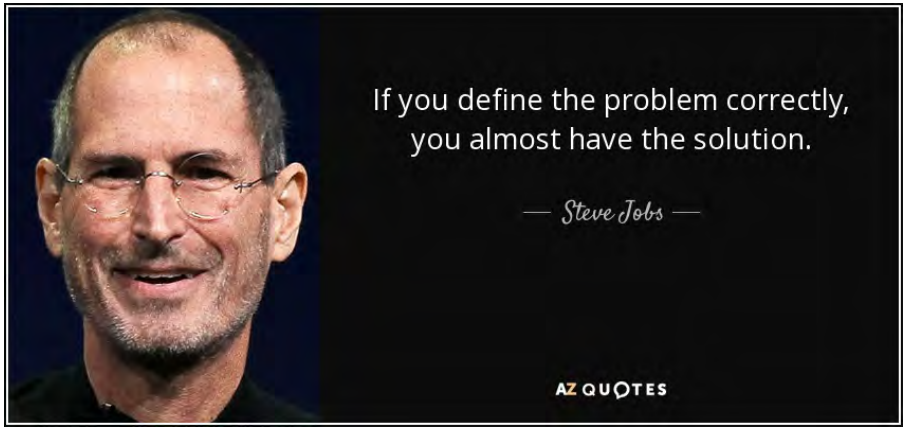
8. Concept Design
9. Concept of Operations
10. Use Case Scenarios
11. System Requirements
12. Economics & Financial Analysis

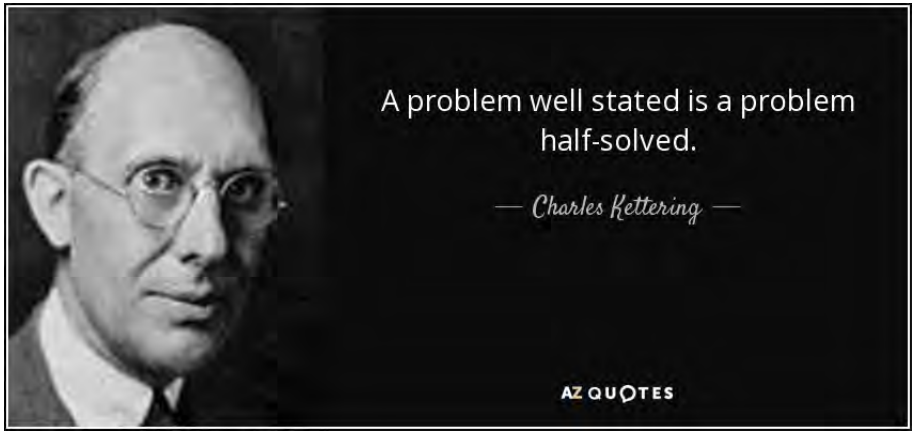
E. Integration & Deliverables

13. Project Presentations
14. Final Report

Problem Statement: Why?







Root Definition: System Purpose

A Root Definition is a structured description of a system. It is a clear statement of activities which take place (or might take place) in the organization being studied.

It consists of three elements: **what, how, why**

and is of the form:

A System to do X, by (means of) Y, in order to achieve Z.

X – **What** the System does
Y – **How** it does it
Z – **Why** it is being done

The **'what'** is the immediate aim of the system,
The **'how'** is the high-level means of achieving that aim,
The **'why'** is the longer-term aim of the purposeful activity.

Peter Checkland
British management scientist: developer of soft systems methodology (SSM)

CATWOE: Multiple Perspectives

- CUSTOMERS – who are the stakeholders, beneficiaries/victims?
- ACTOR(S) – who are the implementers?
- TRANSFORMATION – what does the system do?
- WORLD VIEW – what point of view justifies its existence to the customers?
- OWNER – who has the authority to change the system?
- ENVIRONMENT – what are the external constraints?

Systems and Software Engineering Division

School of Systems & Enterprises

Stevens Institute of Technology

Problem

There is a critical shortage of systems and software engineers who are capable of addressing the increasing complexity of the challenging systems problems that need to be addressed to ensure the well-being and sustainability of humankind

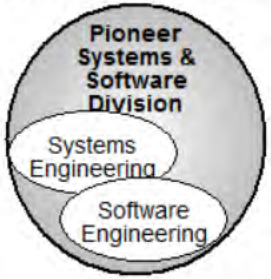
Root Definition

Pioneer Systems and Software organization composed of top-notch, diverse faculty, which creates courses and workshops that are integrated in relevant, practitioner-based programs that are used to instruct high-quality students who are enabled to tackle complex problems of international significance.

CATWOE

Area	*Students*	*Stevens Institute*	*Academic Faculty*	*Employers*	*SERC*
Customers	Parents	*<description>*	*<description>*		DoD
Actors	Instructors, other students, administration	*<description>*	*<description>*		DoD, collaborating institutions, researchers
Transformation	Hard work & tuition -> capabilities & degrees	*<description>*	*<description>*		Funding and research -> new knowledge & systems impact
Worldview	Get a education that can support a great career	*<description>*	*<description>*		Enable national security & prospertity
Owner	University	*<description>*	*<description>*		US Govt
Environment	Campus, classrooms and	*<description>*	*<description>*		US laws, university regulations, funding levels

Systems Software Mission and Vision



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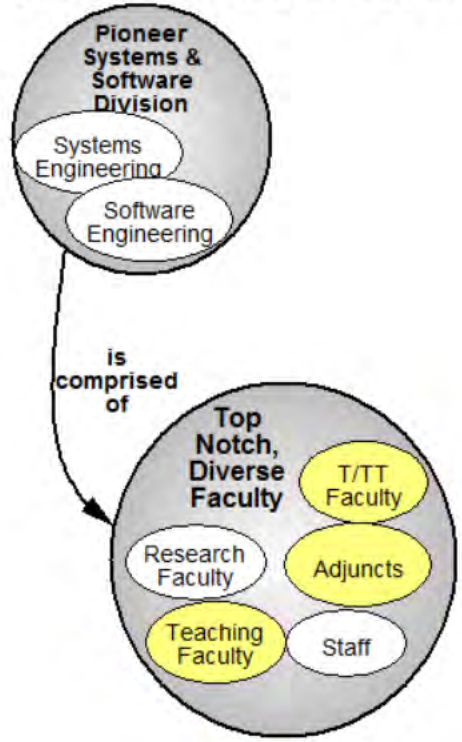

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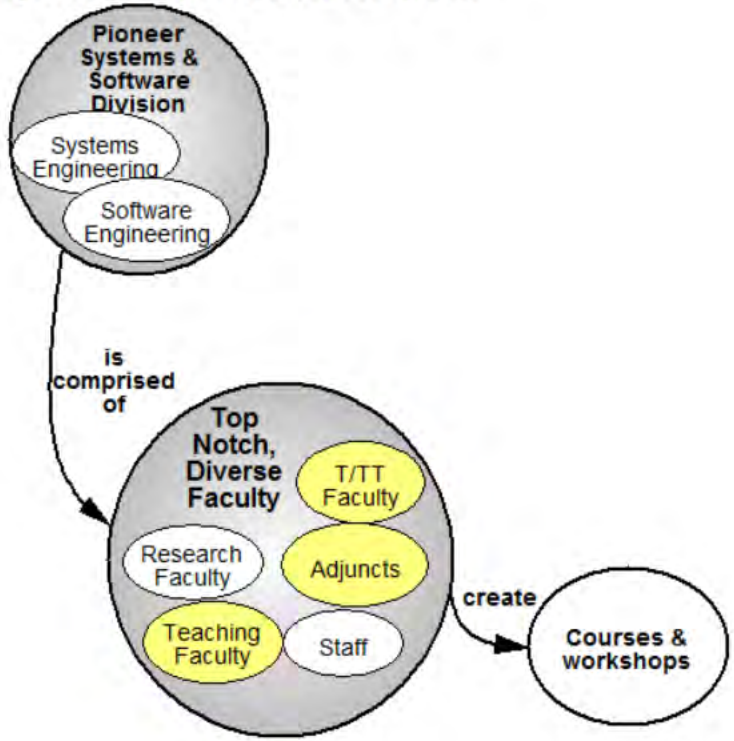

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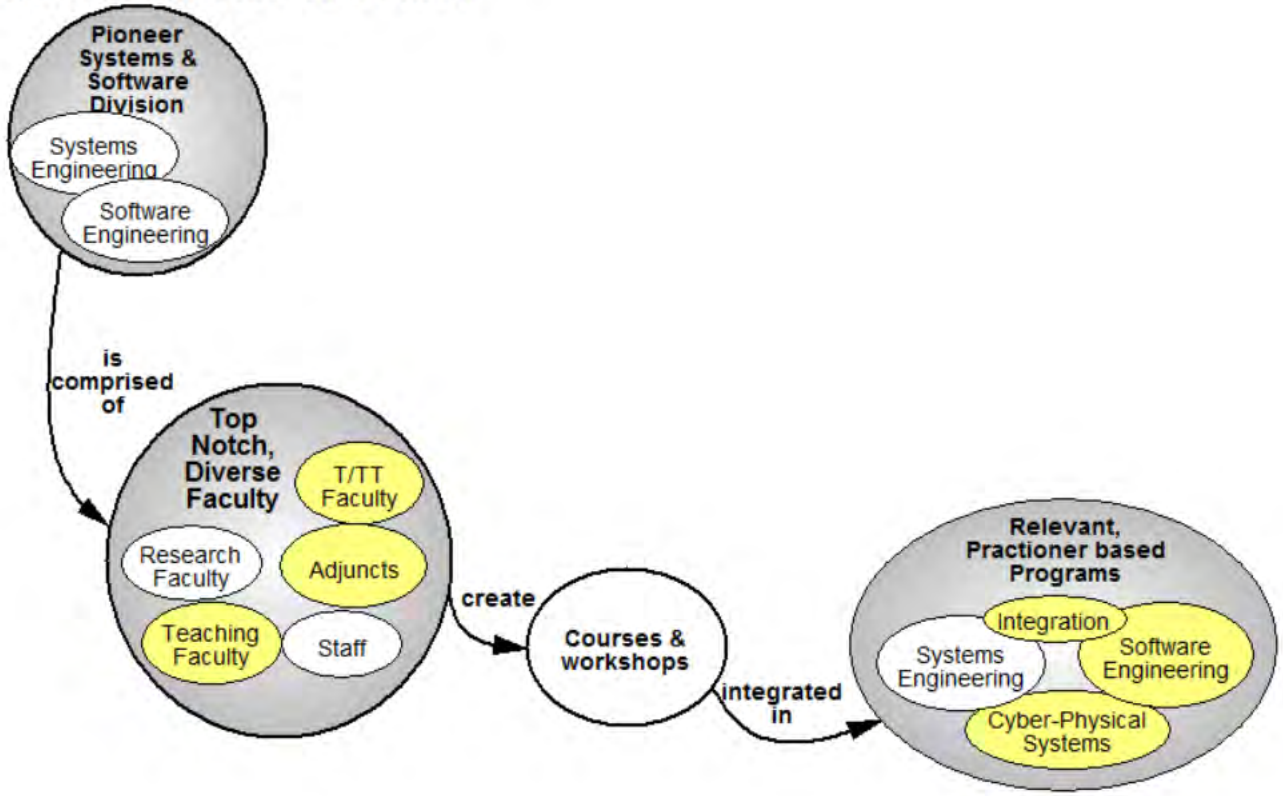

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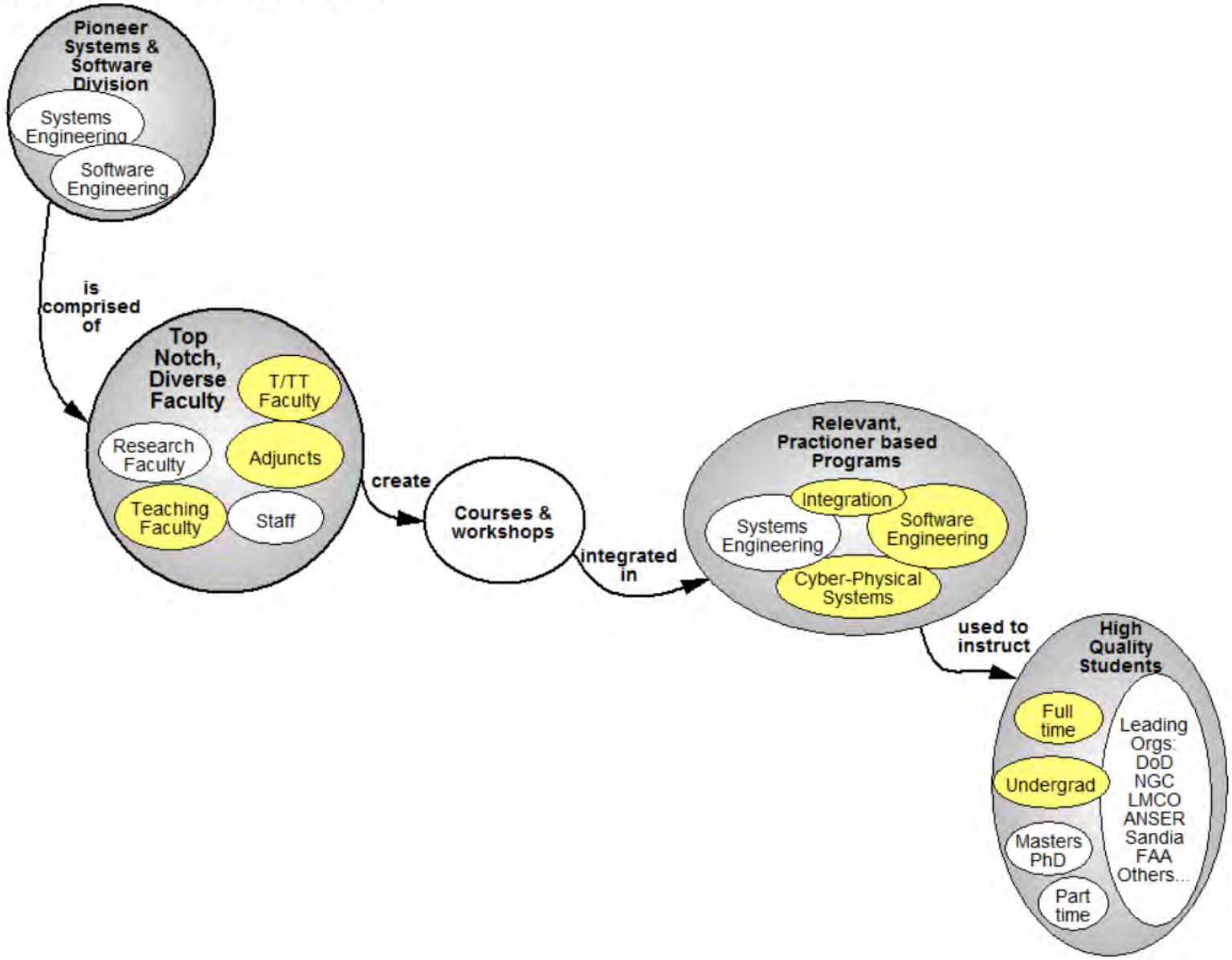

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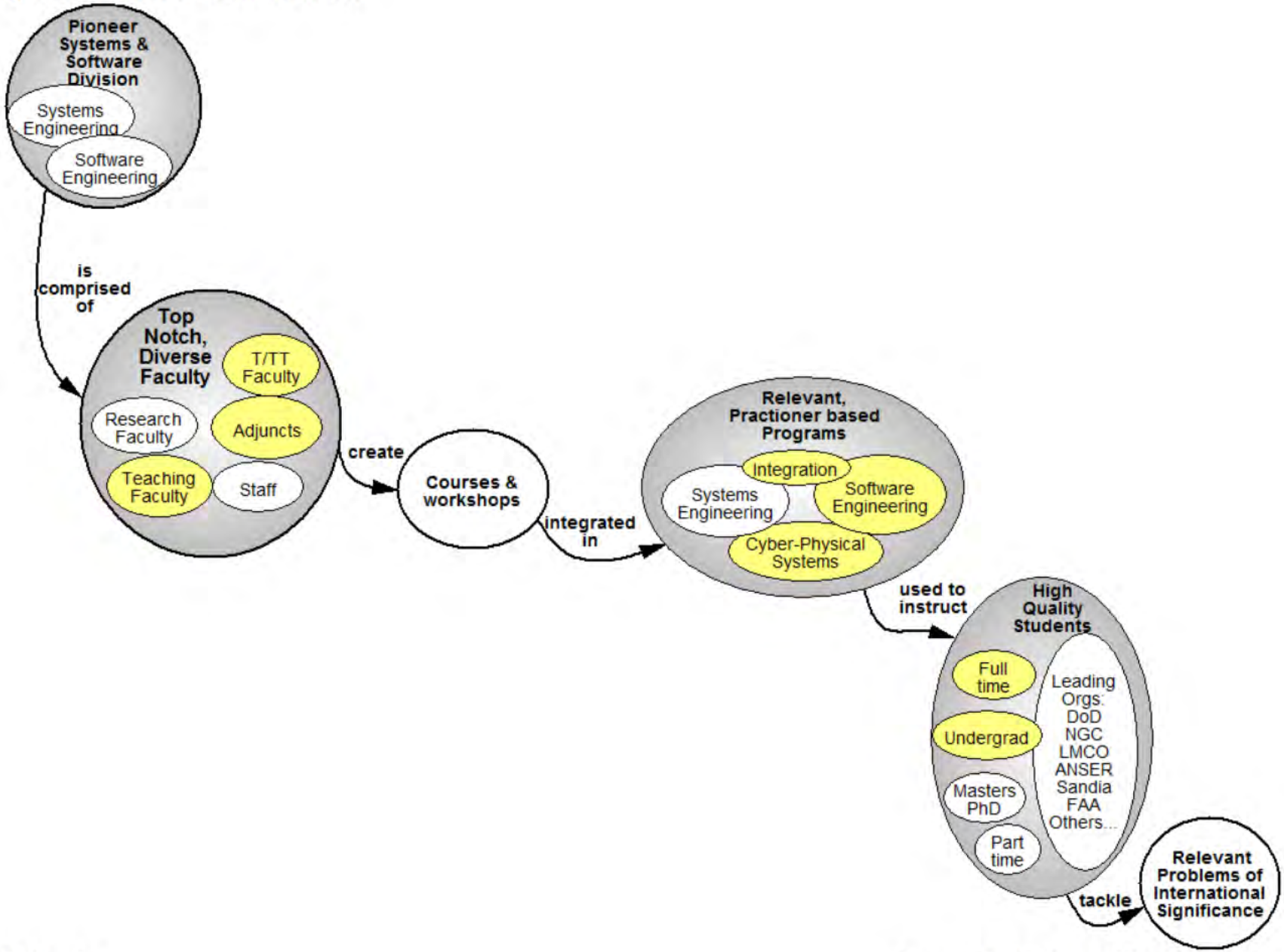

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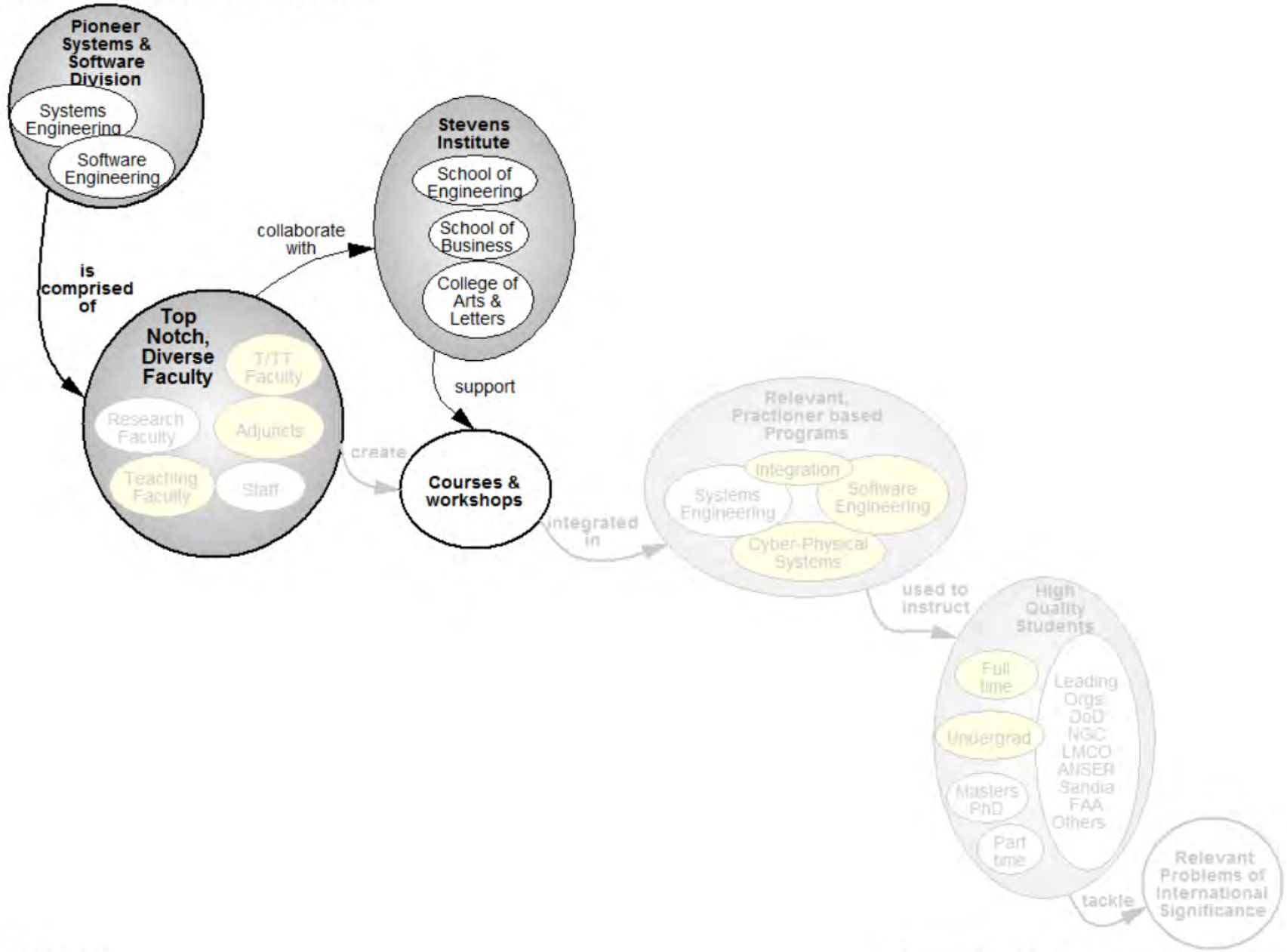
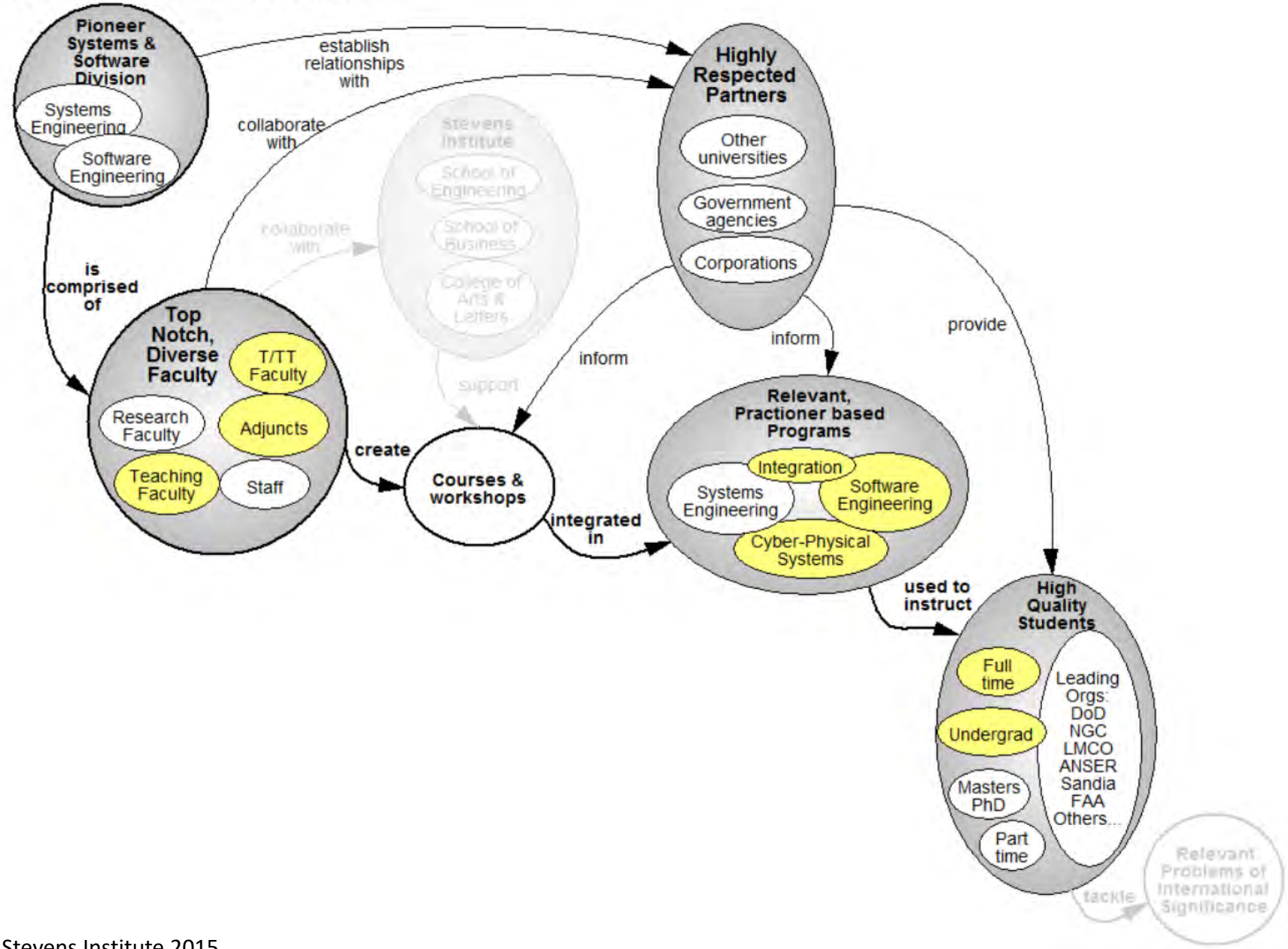
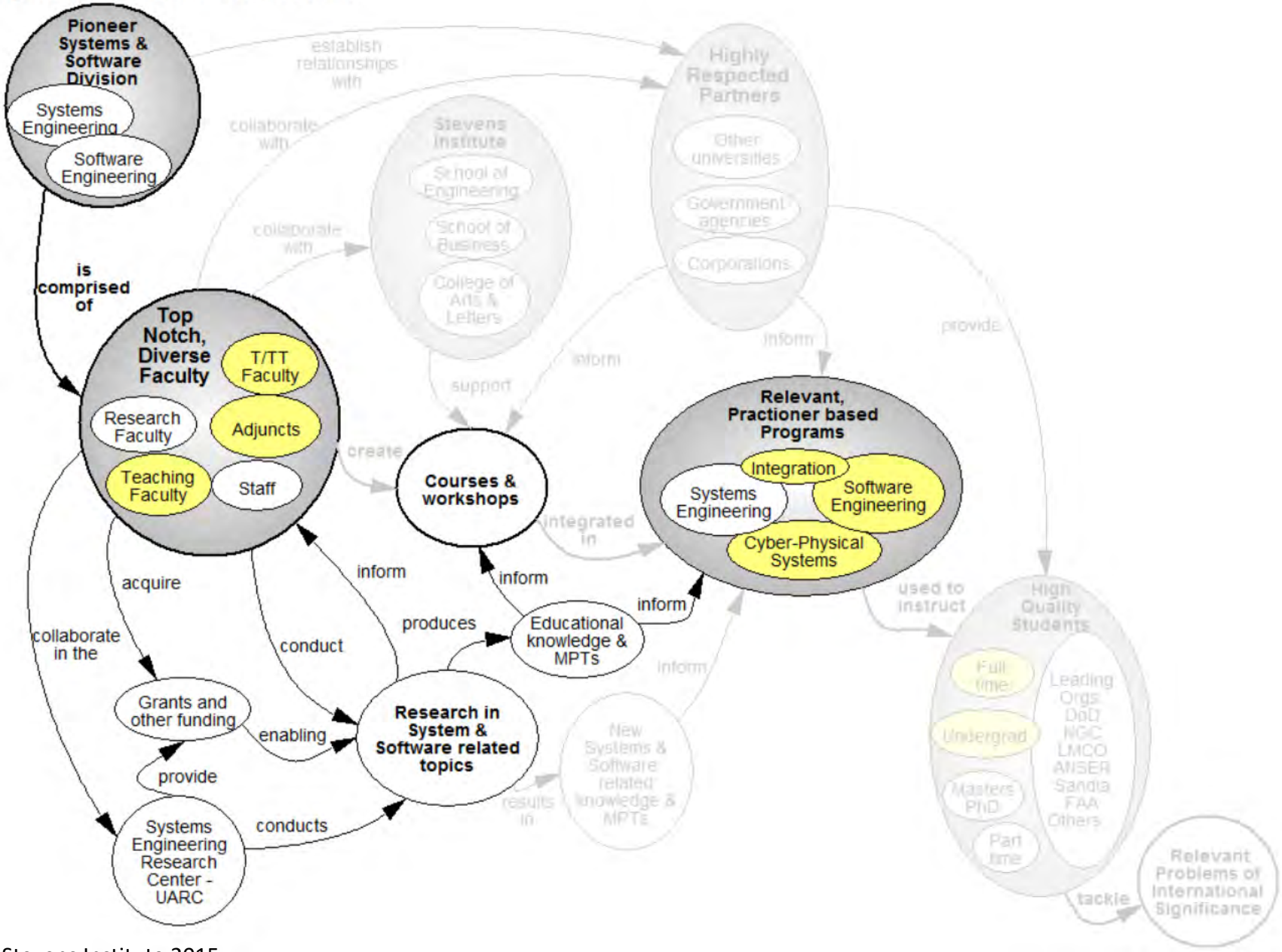


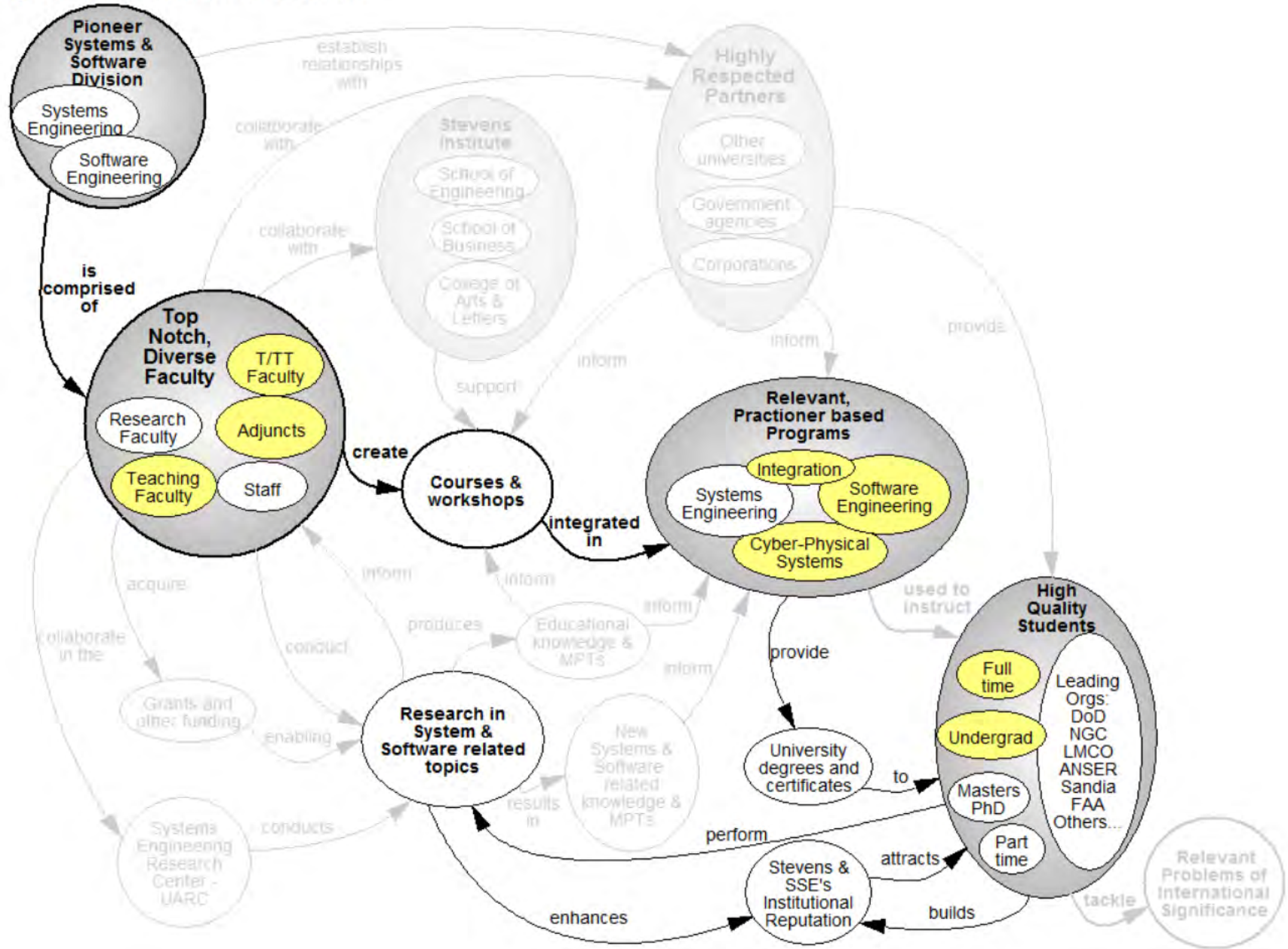
Systems Software Mission and Vision



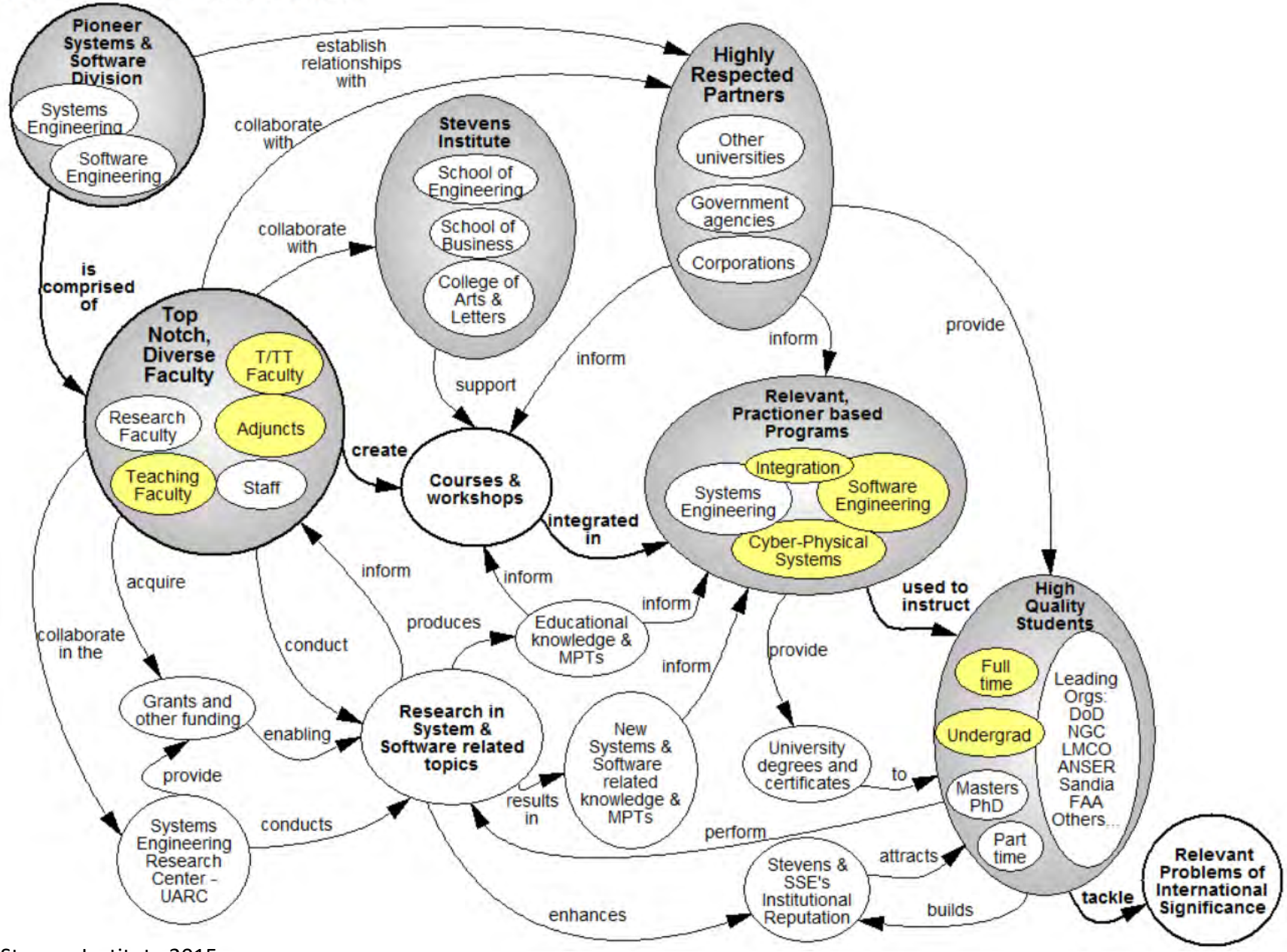
Systems Software Mission and Vision



Systems Software Mission and Vision



Systems Software Mission and Vision



Systems Thinking & Digital Engineering

Digital engineering (DE):

- an engineering approach that captures and analyzes data that is in a digital format which is semantically rich and interconnected
- enables people to leverage the power of computing, visualization, and communication to significantly enhance efficiencies, quality, and innovation across the complex system development lifecycle

- Sandy Friedenthal, SERC DE Workshop, Nov. 15, 2019

Join us in making Systemitool the the vehicle to integrate systems thinking with the SE digital engineering environment