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Research Center

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## SERC ASRR Presentation:

# USC Systems Engineering Research


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**Viterbi School of Engineering**

**University of Southern California**


**October 15, 2009**

# Outline



- USC SE Research Strategy
- Center for Systems and Software Engineering (CSSE)
- Systems Architecting and Engineering (SAE) Program
- Systems Engineering Transformation (SET) Research

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# USC SE Research Strategy

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- **Research and develop SE technology addressing key future needs**
  - **Address leading-edge project needs (e.g., rapid capability fielding)**
- **Integrate multiple SE perspectives**
  - **Product, process, property, success models**
  - **Hardware, software, and human models**
- **Transition technology into practice (e.g., on programs)**
  - **Affiliates program, project support contracts**
  - **$10 M/year: DoD SERC/other, DHS, NASA, NSF**
- **Grow future systems engineering leaders**
  - **MS-SAE, MSCS-SE, Ph.D., internships**
  - **Encourage student-driven research**
  - **Continually align education and research**
  - **Offer SE specialty in selected domains (aerospace, healthcare, …)**

# CSSE Vision



**Be a premier applied research organization in systems and software creation with specific emphasis on accelerating development and deployment processes and creating innovative approaches and architectures for integrating complex human/hardware/software-intensive systems**

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# USC-wide Collaboration

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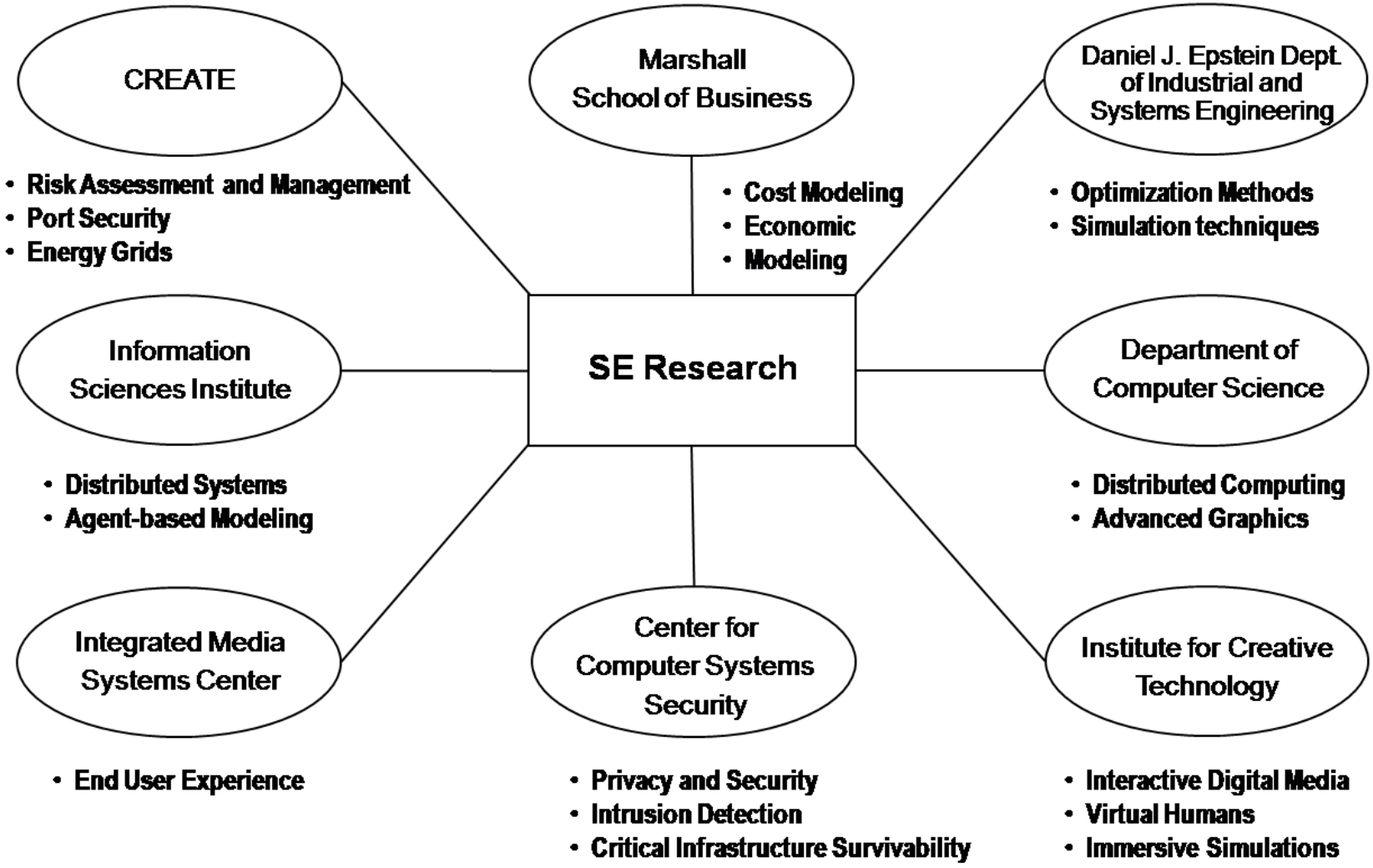


# CSSE Pillars



- **Interdisciplinary Collaboration**
- **Stakeholder Value Satisfaction**
- **Emergence and Evolution**
- **Multiperspective Model-Based Framework**
- **Human System Integration**
- **Systems Architecting and Engineering**

# Interdisciplinary Collaboration



- Engage partners and affiliates in industry and government
- Focus on realworld problem
- Expand scope of collaboration from information exchange to collaborative development
- Exploit relevant theories
  - Win-win Theory W for collaboration
  - Theory of Creative Option Generation for decision making
- Supported by Multiperspective Model-based Framework
  - process models, product models, property models, success models

# Stakeholder Value Satisfaction



- Support complex negotiations in which rights and needs of stakeholders are accommodated in timely fashion
- Based on value-based theory and stakeholder win-win Theory W
- WikiWinWin used to identify and resolve issues and reach agreements
- Exploitation of Incremental Commitment Model
  - Organizes a system's life cycle around a series of Incremental Commitment milestones
  - Builds on both value-based process model and the spiral model

# WikiWinWin: Identify and Resolve Issues



## Current Win Condition

- Name: Budget for Development
- Category: BudgetAndSchedule
- Statement: Development costs should be $0, including cost of COTS, excluding client time spent by client.

## Identify Issues

| Name | Statement | Timestamp | Creator | Role | Provide Options |
|---|---|---|---|---|---|
| Cost of COTS | There is a possibility that no free COTS product exists that would satisfy the requirements and have the desired stability | 16 Mar 2007 18:14 | DaYang | Developer | enter |

## List of Issues, Options, and Agreements

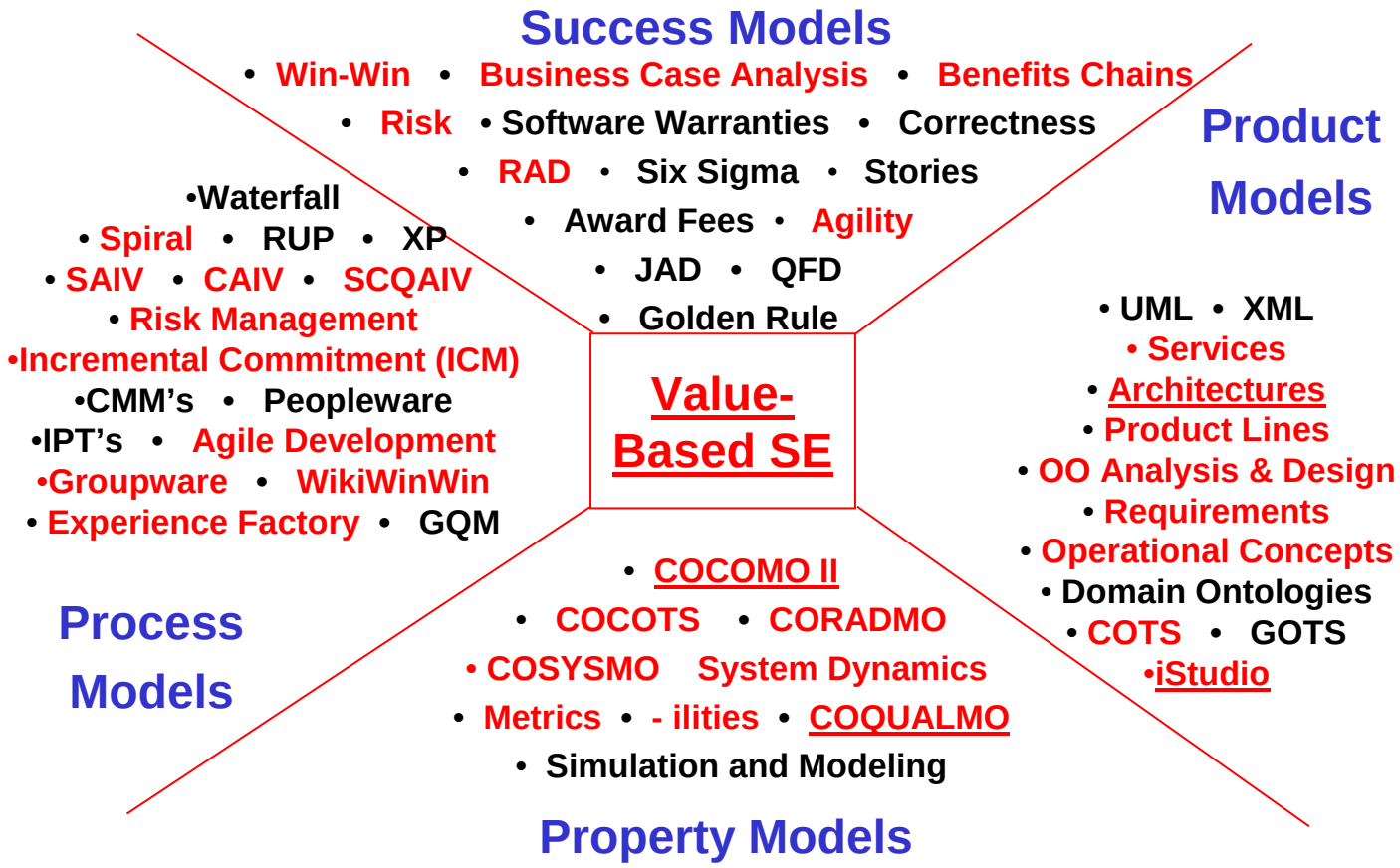
- ISSUE: Cost of COTS
  - OPTION: The most suitable FREE COTS software will be used.
  - OPTION: No COTS usage.
  - OPTION: If no COTS is expensive, I could pay up to $1000 for COTS.
  - OPTION: We find a suitable COTS, which costs $200. [As Agreement=Yes]

# Emergence and Evolution



- **Adaptive, evolutionary, opportunistic processes**
  - **Surface requirements early through iterative prototyping and usage**
  - **Movement toward decentralized control**
- **Complex adaptive systems**
  - **Self-organization and emergent behavior**
  - **Socio-technical, geo-political, economic, behavioral, environmental considerations**
  - **Guided/influenced through incentives and inhibitors**

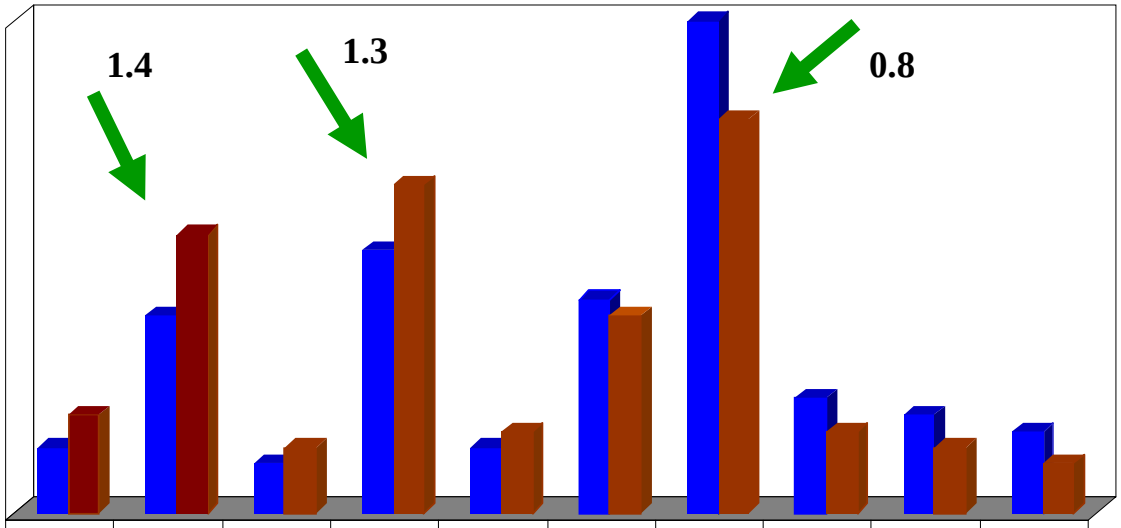
# USC: Model Integration Research



# Current Model-Driven SE Covers Only Product Models



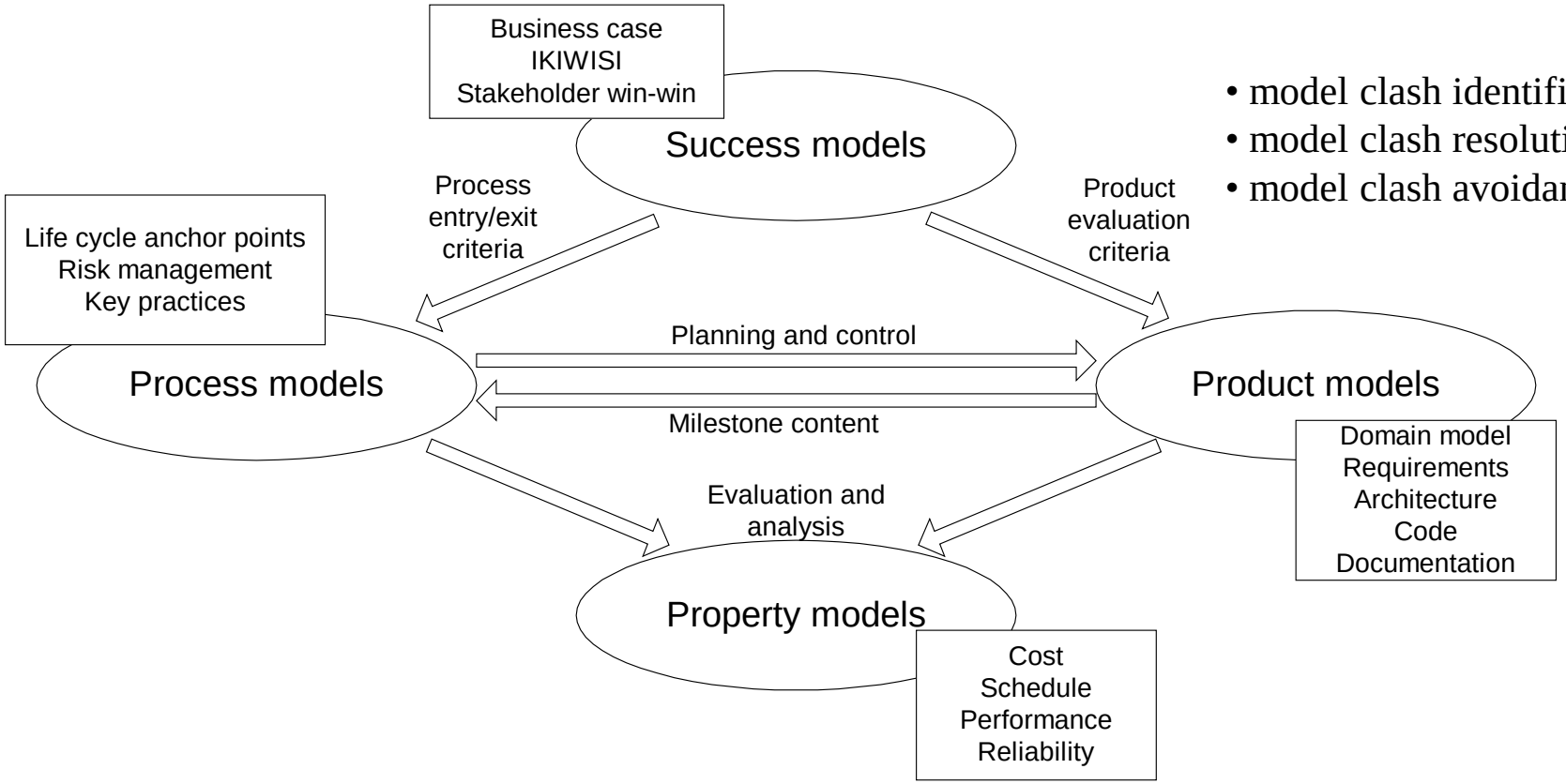
- **Only 30% of model clashes; 24% of risk**




| | *Success-Property* | *Success-Product* | *Success-Success* | *Product-Property* | *Process-Property* | *Property-Property* | *Product-Product* | *Process-Process* | *Product-Process* | *Success-Process* |
|---|---|---|---|---|---|---|---|---|---|---|
| *% of Clashes* | *4* | *12* | *3* | *16* | *4* | *13* | *30* | *7* | *6* | *5* |
| *% of Risk* | *6* | *17* | *4* | *20* | *5* | *12* | *24* | *5* | *4* | *3* |

- **Model Clash: Incompatible assumptions among adopted models**

# Multiperspective Model-Based Framework




- model clash identification
- model clash resolution
- model clash avoidance

**Each perspective informs and provides evaluation criteria for the other perspectives.**

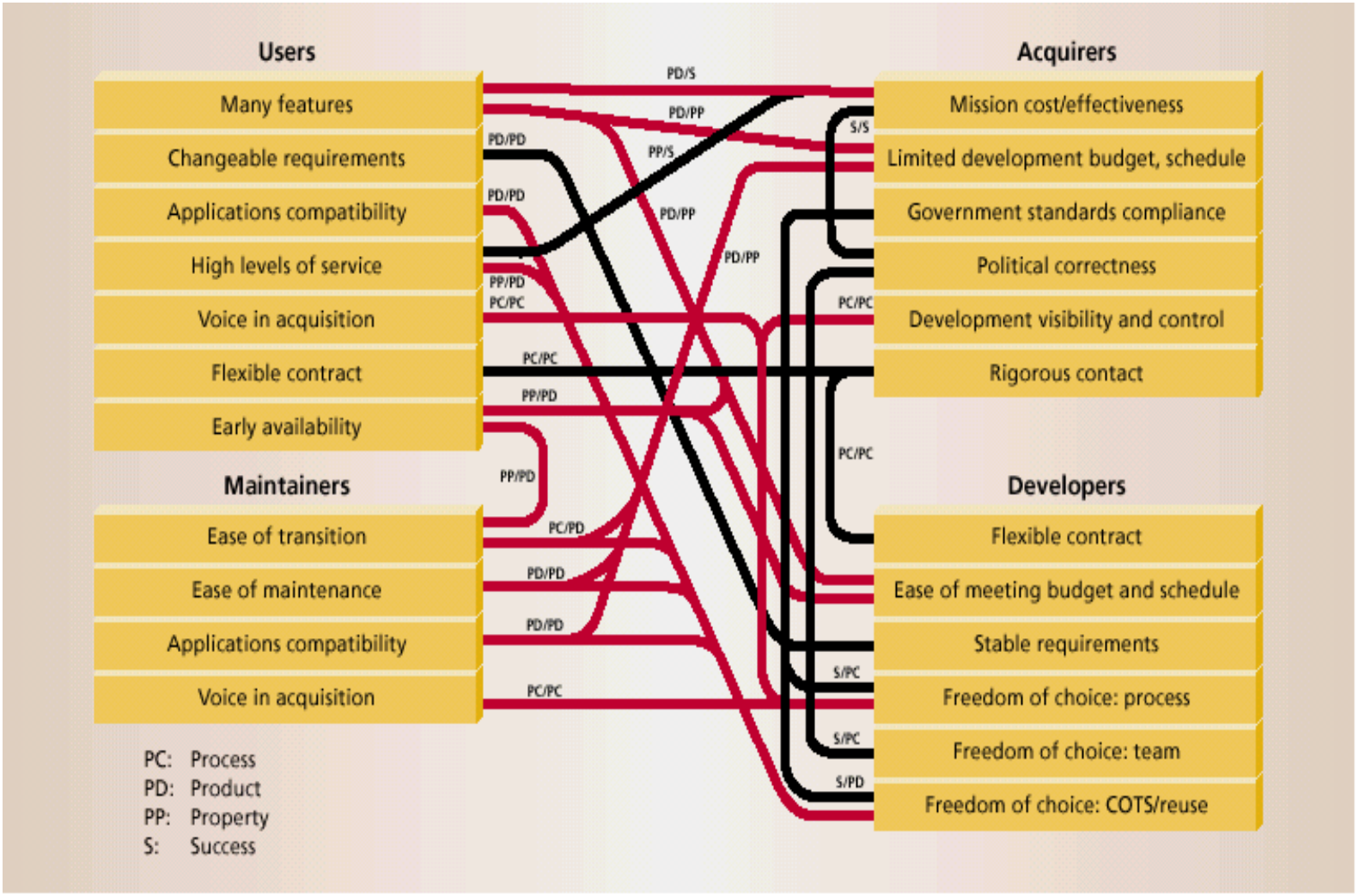
# Model Research Examples



- **Success model: Stakeholder win-win**
- **Product models: XTEAM for architecture definition and tradeoff analysis**
- **Process models: Incremental Commitment Model; systems of systems**
- **Property models: COSYSMO; security models**

# Model Clashes SpiderWeb: MasterNet





# Human System Integration



- **Humans are critical to successful systems operations, yet …**
  - **Human role generally addressed only as part of Front-End Analysis and CONOPS/UI design**
  - **System architects continue to focus on human and system characteristics in isolation, not together**
  - **Program Managers driven by schedule, cost, and weight considerations, not HSI**
  - **Human Factors professional unable to articulate HSI value to systems engineers**
- **Unwarranted assumptions about the human can lead to tragic accidents**
  - **Humans are not optimal information processors, they get fatigued, they don't multi-task well**
  - **Humans are creative, rarely exactly right, and not usually completely wrong**
  - **Human decision making is influenced by social and cultural norms**
- **A potential high payoff research vector is developing a methodology for facilitating the introduction of HSI considerations at appropriate points in the system lifecycle**

Source: Madni, A.M. "Integrating Humans with Software and Systems: Technical Challenges and a Research Agenda," *INCOSE Journal of Systems Engineering*, Vol. 13, No. 3, 2010.

# Systems Architecting and Engineering



- Informed by Eb Rechtin's pioneering insights in this field
- Systems Architecting and Engineering Program led by Azad Madni (Director) and Stan Settles (Co-Director)
- Emphasis on concurrently engineering products and processes, requirements and solutions, development and operations
- Combination of heuristic reasoning and mathematical optimization
- Balance economic and technical considerations
- Principles reflected in USC's value-based system and software engineering approaches

# SE Transformation Research Goals

- Identify and exploit high payoff computing technologies that can transform systems engineering for the operational challenges of the 21st Century
- Exploit unique human capabilities (e.g., adaptive capacity) of a trained workforce when integrating humans with software and systems to dramatically enhance operational effectiveness
- Specify research thrusts along with success criteria to achieve these goals

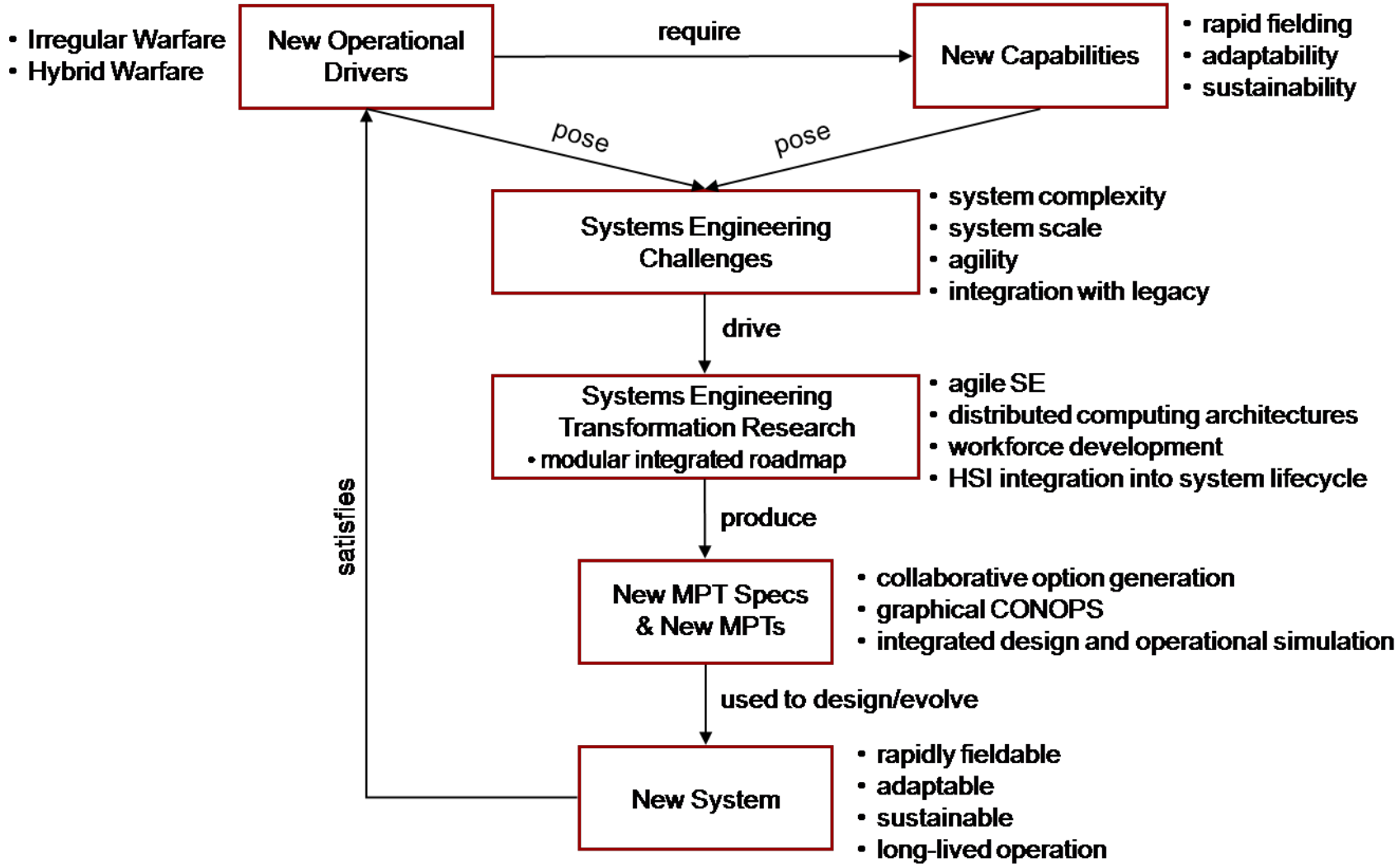
# Operational Drivers



- **Irregular Warfare**
  - emphasis on D, I, and E in DIME
  - center of gravity - - indigenous population
  - need to influence socio-cultural terrain
  - non-state networks/actors embedded in civilian population
  - focus on psychological effects and non-kinetic influence of “locals”
  - difficult to define success criteria… but technology is a key differentiator
- **Hybrid Warfare**
  - a blurring of modes of war, combatants, and the technologies that are brought to bear
  - Traditional warfare with counter-terrorism and counter-insurgency operations

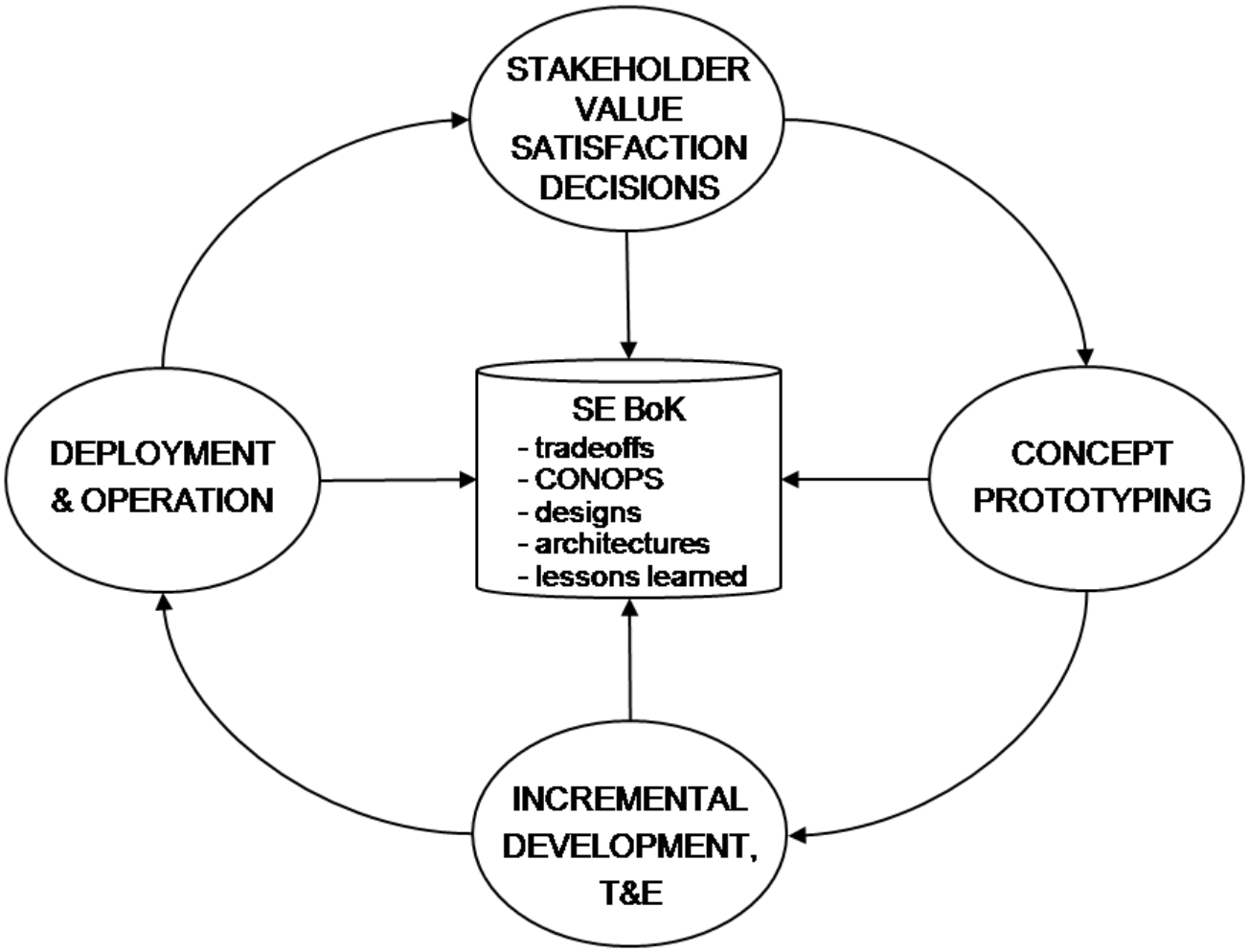
**We cannot kill or capture our way to victory…**
**– Secretary of Defense Robert Gates**

# SE Transformation Approach



# Transformational Construct






- value-driven
- incremental
- model-aided
- risk-managed

# Transformation Vectors



- **New Architectural Paradigms (complexity, scalability, adaptivity)**
- **Mobile and Context-aware Computing (temporal and spatial flexibility)**
- **Agile, Iterative, User-driven Processes (incremental feedback, larger user pool)***
- **Dynamic Adaptation (maintain quality, utility and value in face of change)**
- **Correct by Construction Approach (lower integration time, costs)**
- **Incorporate Human-System Integration Methods (exploit human adaptive capacity) into system life cycle models (e.g., Incremental Commitment Model)**
- **Workforce development (leadership, sociocultural awareness, economics of SE)**

* Madni, A.M. "Agile Systems Architecting: Placing Agility Where it Counts," *Conference on Systems Engineering Research (CSER)*, 2008.

# Summary



- USC research strategy is geared to meeting operational needs of the 21st century
- Our multi-perspective modeling framework is intended to uncover and correct model "clashes" thereby reducing development and integration risks
- CSSE has wide reach within the Viterbi School of Engineering, Marshall School of Business, and Rossier School of Education
- SAE program is continuing to develop courses that incorporate our research findings and that respond to Defense procurement, acquisition, engineering, and operational needs

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# Dr. Azad Madni

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- Professor, Epstein Department of Industrial and Systems Engineering
- Director, Systems Architecting and Engineering Program

- Research Interests:
  - intelligent systems, adaptive architectures, model-based systems engineering, agile systems engineering, game-based simulation, cognitive engineering
- Awards & Honors:
  - 1999 Tibbetts Award winner for California, SBA
  - 2000, 2004 Developer of the Year Award winner from the SCSC
  - 2000 Distinguished CEO of *ComputerWorld's* Top 100 Emerging Companies
  - 2006 C.V. Ramamoorthy Distinguished Scholar Award, SDPS
  - 2008 President's Award, IDPT Biennial World Conference, SDPS
  - Fellow of IEEE, INCOSE, SDPS, IETE, Assoc. Fellow of AIAA
  - Marquis' Who's Who in Science and Engineering, Who's Who in America.
- Research Sponsors:
  - OSD, DARPA, DHS S&T, HSARPA, MDA, AFRL, AFOSR, RDECOM, CECOM, TATRC, ARI, AMCOM, HEL, ONR, NRL, SPAWAR, NAVSEA, NAVAIR MARCOR, PMTRADE, STRICOM, NIST, DoE, and NASA
- Education:
  - B.S., M.S. and Ph.D. degrees in engineering from UCLA
  - Graduate of AEA/Stanford Institute Program for Senior Executives

# Thank you for your kind attention.