Using Cost Models to Capture Project Risk: A Knowledge-Based Approach

Dr. Ricardo Valerdi
Massachusetts Institute of Technology
October 22, 2009
[rvalerdi@mit.edu]

We Share A Goal: Enterprise Excellence

NORTHROP GRUMMAN

BOEING

LOCKHEED MARTIN

OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY

Rockwell Collins

DEPARTMENT OF THE NAVY AIR SYSTEMS COMMAND

SECRETARY OF THE AIR FORCE SAF/AQ ACQUISITION

Raytheon

LAI MIT

LEAN ADVANCEMENT INITIATIVE TM

ULA TM

United Launch Alliance

USA®

United Space Alliance

DEFENSE CONTRACT MANAGEMENT AGENCY DEPARTMENT OF DEFENSE

SPACE & MISSILE SYSTEMS CENTER

NAVSEA

NAVAL SEA SYSTEMS COMMAND

DFAS

Your Financial Partner @ Work

Pratt & Whitney

A United Technologies Company

BAE SYSTEMS

Sikorsky

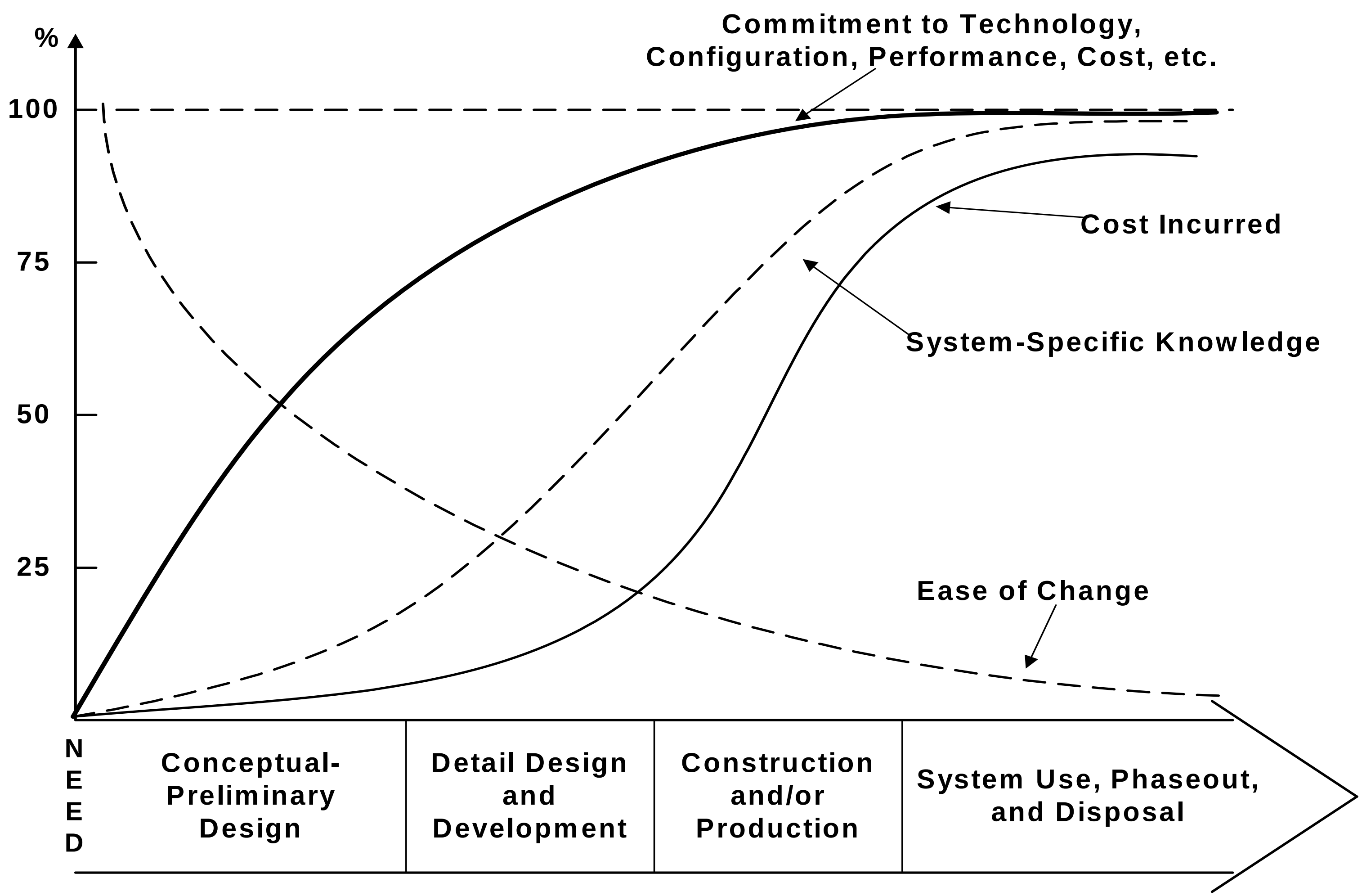
A United Technologies Company


EdNet LAI
EDUCATE MOTIVATE INNOVATE
NORTH CAROLINA STATE UNIVERSITY
NC STATE UNIVERSITY
DAU
Defense Acquisition University
EMBRY-RIDDLE
AERONAUTICAL UNIVERSITY
UAH
The University of Alabama in Huntsville
Northeastern University
AFIT
The Air Force Institute of Technology
MIT
Massachusetts Institute of Technology
UNIVERSITÀ DEGLI STUDI DI SALERNO
universo di saperi
University of Virginia
Darden School of Business
University of Michigan
Arizona State University
Missouri S&T
Cal Poly
Wright State University
Loyola College in Maryland
Georgia Tech
Tecnológico de Monterrey
Montana State University
Boise State University
WSU
The University of Warwick
WPI
Jacksonville University
USF University of South Florida
San Jose State University 1857
Indiana State University 1865
Purdue University
University of Bath School of Management
Old Dominion University
The University of Iowa
Iowa City, Iowa
Cranfield University
University of Louisiana Lafayette
Universidad Anáhuac | Puebla
USC University of Southern California
Macon State College
The University of Tennessee UT Knoxville
LMU | LA Loyola Marymount University
Saint Louis University
UPAEP
Universidad Popular Autónoma del Estado de Puebla
The University of Texas-Pan American

Risk Assessment Lessons Learned in the U.S. Department of Defense

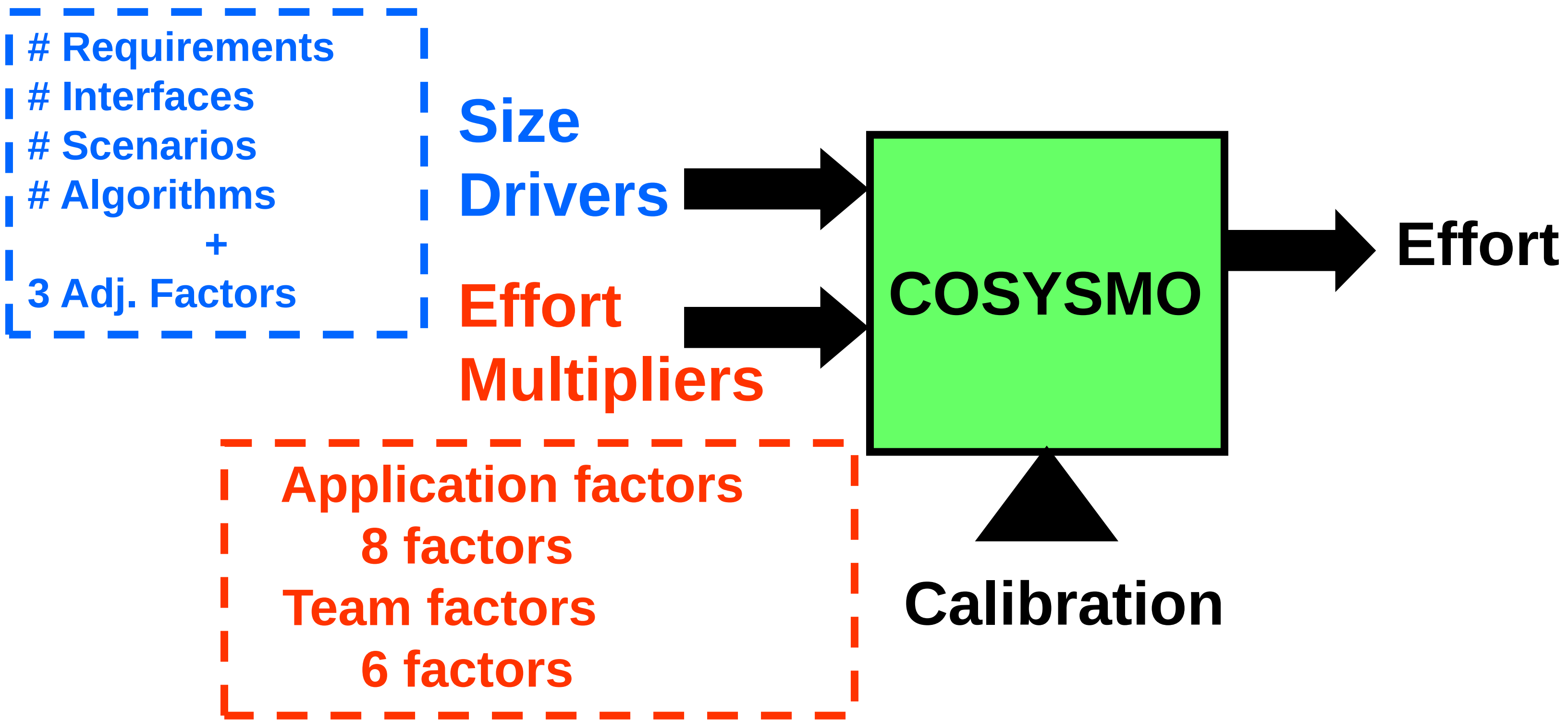
1. Systems engineering can be the blessing or the curse
   - Resource estimation methods are being developed
2. Technology maturity and requirements stability are controllable risks
   - Cost models help understand this relationship
3. People risks are often underestimated
   - Experience and capability are not interchangeable
4. By the time the risk is identified, it's too late!
   - Need leading indicators (not lagging indicators)

Cost Commitment on Projects



Blanchard, B., Fabrycky, W., *Systems Engineering & Analysis*, Prentice Hall, 1998.

Constructive Systems Engineering Cost Model



Systems Engineering Processes

EIA/ANSI 632, *Processes for Engineering a System* (1999).

- **Acquisition and Supply**
  - Supply Process
  - Acquisition Process
- **Technical Management**
  - Planning Process
  - Assessment Process
  - Control Process
- **System Design**
  - Requirements Definition Process
  - Solution Definition Process
- **Product Realization**
  - Implementation Process
  - Transition to Use Process
- **Technical Evaluation**
  - Systems Analysis Process
  - Requirements Validation Process
  - System Verification Process
  - End Products Validation Process

COSYSMO Data Sources

Boeing	*Integrated Defense Systems (Seal Beach, CA)*
Raytheon	*Intelligence & Information Systems (Garland, TX)*
Northrop Grumman	*Mission Systems (Redondo Beach, CA)*
Lockheed Martin	*Transportation & Security Solutions (Rockville, MD)* *Integrated Systems & Solutions (Valley Forge, PA)* *Systems Integration (Owego, NY)* *Aeronautics (Marietta, GA)* *Maritime Systems & Sensors (Manassas, VA; Baltimore, MD; Syracuse, NY)*
General Dynamics	*Maritime Digital Systems/AIS (Pittsfield, MA)* *Surveillance & Reconnaissance Systems/AIS (Bloomington, MN)*
BAE Systems	*National Security Solutions/ISS (San Diego, CA)* *Information & Electronic Warfare Systems (Nashua, NH)*
SAIC	*Army Transformation (Orlando, FL)* *Integrated Data Solutions & Analysis (McLean, VA)*
L-3 Communications	*Greenville, TX*

LAI MIT
LEAN ADVANCEMENT INITIATIVE ™

COSYSMO Model

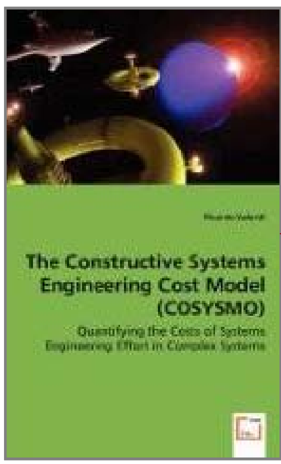
$$PM_{NS} = A \cdot \left(\sum_k (w_{e,k}\Phi_{e,k} + w_{n,k}\Phi_{n,k} + w_{d,k}\Phi_{d,k}) \right)^E \cdot \prod_{j=1}^{14} EM_j$$

Policy & Contracts

NASA, U.S. AIR FORCE, Department of Defense, U.S. ARMY

Commercial Implementations

SystemStar™
SEER®
PRICE



Proprietary Implementations

- SEEMaP
- COSYSMO-R
- SECOST
- Systems Eng. Cost Tool

Raytheon, LOCKHEED MARTIN, BAE SYSTEMS, BOEING

10 Academic Theses

Academic Curricula

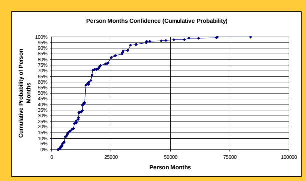
SMU, MIT, George Mason University, Naval Postgraduate School, UC San Diego, University of Southern California

Traditional Cost and Schedule Risk Estimation

Determine Sources of Risk
- Risk Taxonomy
- Organizational Lessons Learned

Assess/ Estimate Possible Risk Impacts
- Ranges of Values of Size, Productivity, & Other Parameters

Estimate Cost & Schedule Risks
- Ranges of Cost & Schedule Values & Probabilities

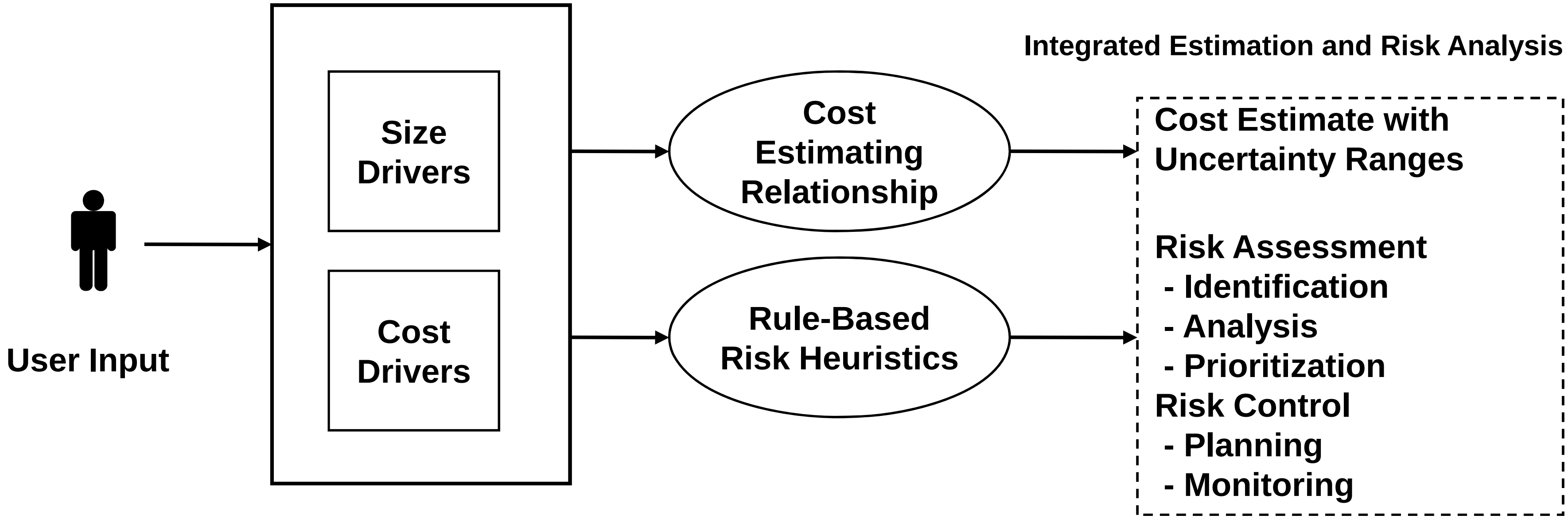


Risk Assessment

Select Cost and Schedule

Management Decision

Expert COSYSMO Operation



Madachy, R. & Valerdi, R., Knowledge-Based Risk Assessment for Systems Engineering: Expert COSYSMO, working paper, 2009.

Initial Risk Conditions

	SIZE	RQMT	ARCH	LSVC	MIGR	TRSK	DOCU	INST	RECU	TEAM	PCAP	PEXP	PROC	SITE	TOOL
SIZE (REQ + INTF + ALG + OPSC)		21	21	9	12	5	4	7	10	8	9	11	7	6	7
Requirements Understanding			17	9	7	8	3	5	9	5	10	8	5	4	1
Architecture Understanding				9	10	12	3	7	11	6	11	11	5	6	4
Level of Service Requirements (the ilities)					5	7	4	5	3	6	4	4	2	3	2
Migration Complexity (legacy system considerations)						8	1	10	1	4	7	7	3	5	4
Technology Risk (maturity of technology)							2	8	6	4	9	5	3	3	5
Documentation match to life cycle needs								2	3	4	4	2	6	2	3
Number and Diversity of Installations or Platforms									4	3	5	6	4	8	5
Number of Recursive Levels in the Design										4	8	7	7	2	5
Stakeholder Team Cohesion											7	9	3	8	3
Personnel/team capability												12	9	8	5
Personnel Experience and Continuity													10	8	3
Process Capability														5	8
Multisite Coordination															8
Tool Support															

high risk

medium risk

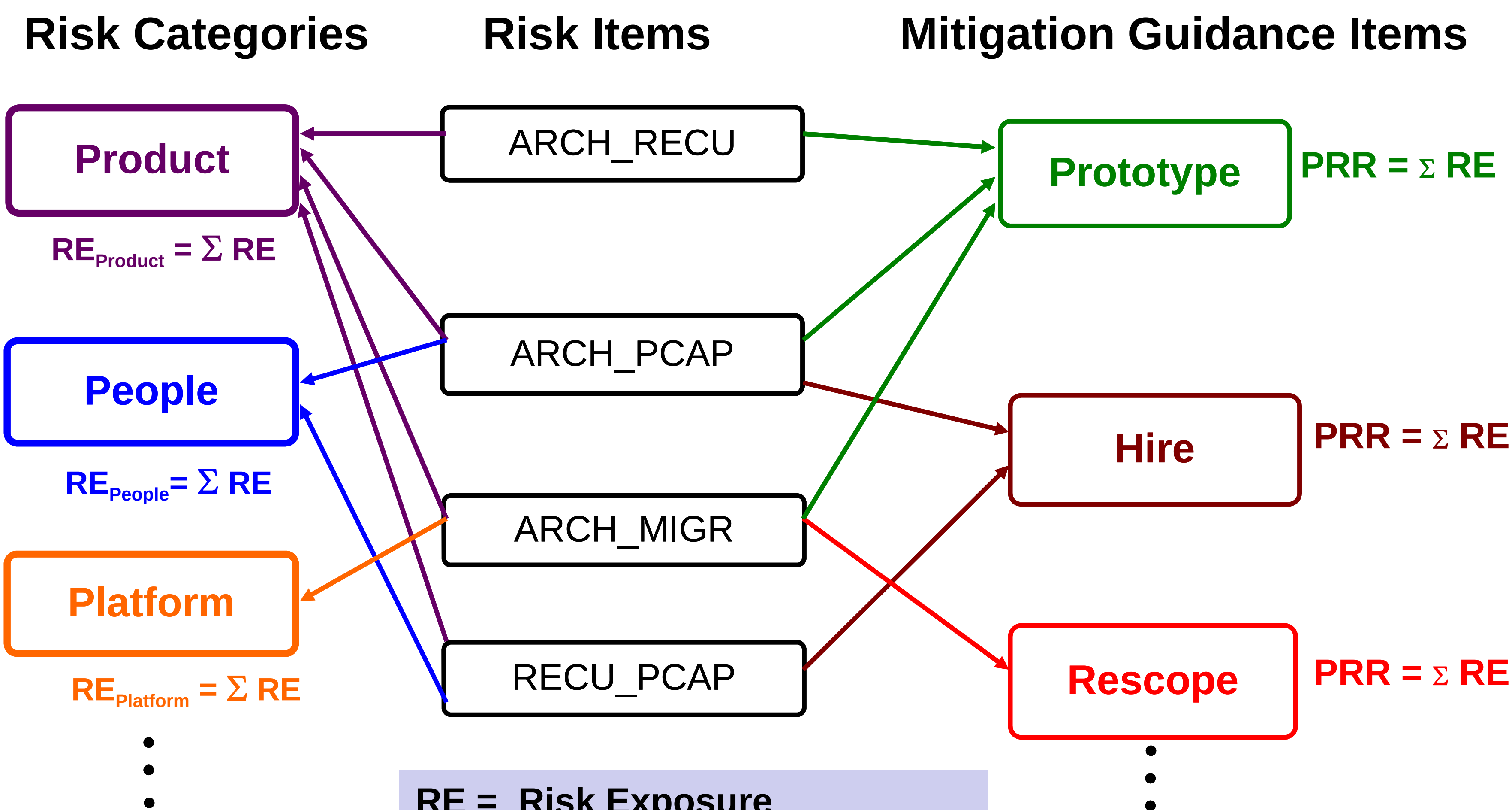
low risk

small x = 0.5; big X = 1

n = 19

Valerdi, R. & Gaffney, J., Reducing Risk and Uncertainty in COSYSMO Size and Cost Drivers: Some Techniques for Enhancing Accuracy, 5th Conference on Systems Engineering Research, Hoboken, NJ, March 2007.

Risk Network

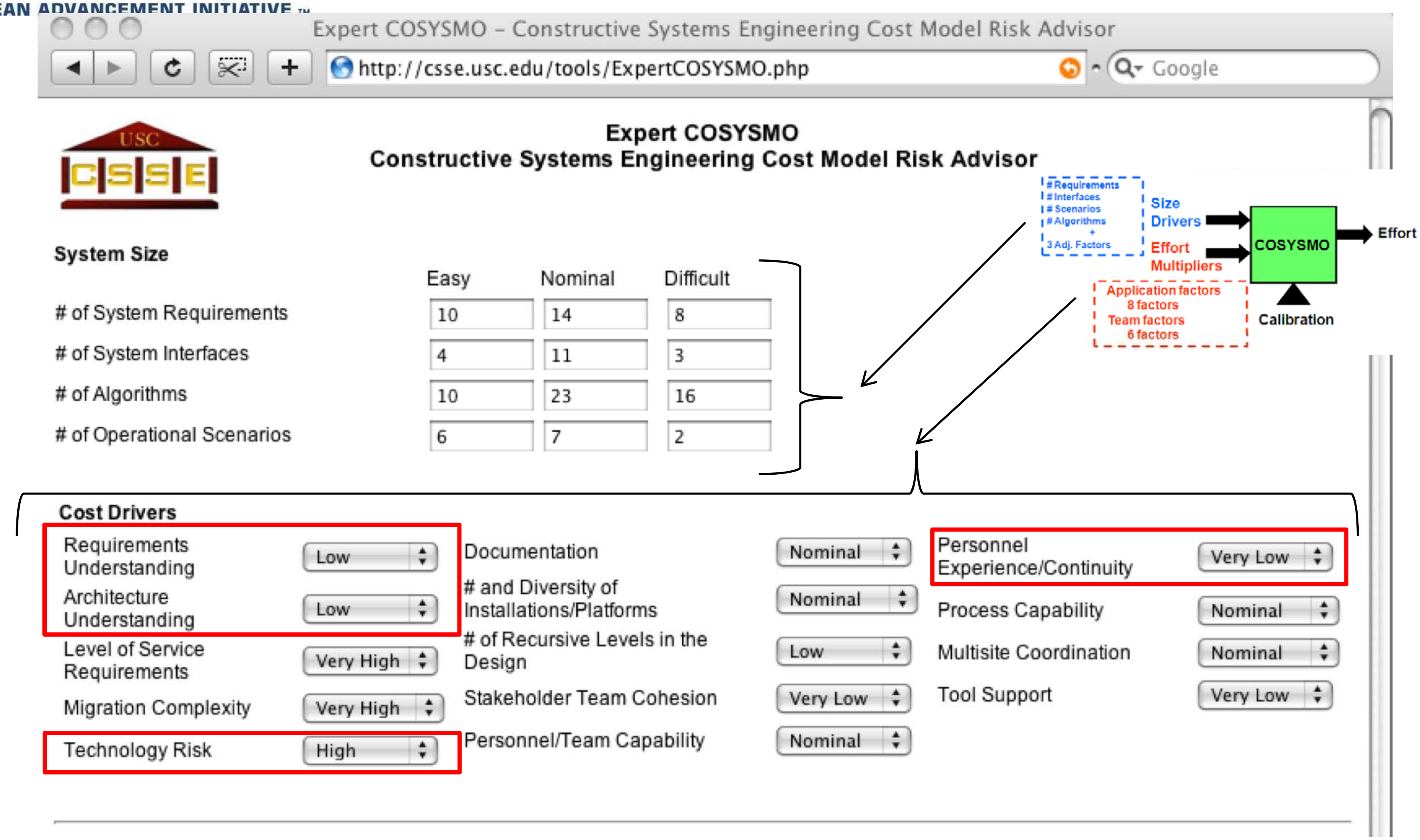


RE = Risk Exposure

PRR = Potential Risk Reduction

Madachy, R. & Valerdi, R., Knowledge-Based Risk Assessment for Systems Engineering: Expert COSYSMO, working paper, 2009.

Expert COSYMO Inputs



http://csse.usc.edu/tools/ExpertCOSYMO.php

Expert COSYSMO Outputs

LAI MIT
LEAN ADVANCEMENT INITIATIVE ™

Systems Engineering Effort = 3635 Person-months

Effort Distribution (Person-Months)

Phase / Activity	Conceptualize	Develop	Operational Test and Evaluation	Transition to Operation
Acquisition and Supply	71.3	129.8	33.1	20.4
Technical Management	136.0	234.9	154.5	92.7
System Design	370.9	436.3	185.4	98.2
Product Realization	70.9	163.6	174.5	136.3
Product Evaluation	202.9	304.3	450.9	169.1

Risk Summary

Product	60
Process	2
Personnel	20

Prioritized Risks

High	Medium	Low
requ_arch arch_trsk arch_pexp	requ_serv requ_migr requ_trsk arch_serv arch_migr arch_team serv_trsk serv_team migr_trsk migr_pexp	requ_team requ_serv requ_serv requ_serv requ_serv arch_tool serv_migr serv_pexp serv_tool migr_team migr_tool trsk_team trsk_pexp trsk_tool

Outputs - Risk Mitigation Advice

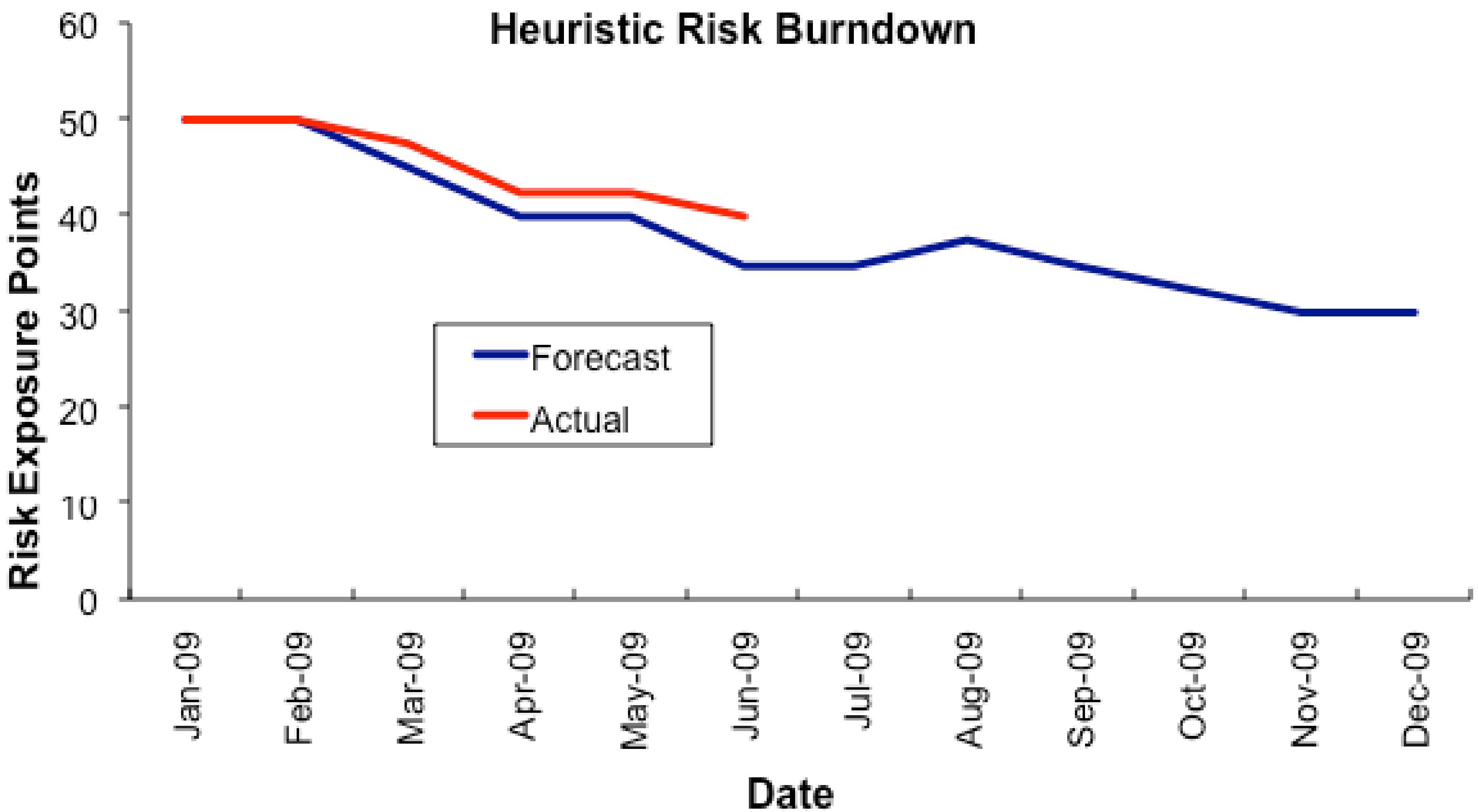
Risk Mitigation Guidance

The risk mitigation guidance below shows alternatives for consideration in specific project environments.

Risk Severity	Description	Alternatives
High	Requirements Understanding = Very Low *and* Architecture Understanding = Very Low	Subcontract, prioritize requirements, cancel project
High	Architecture Understanding = Very Low *and* Technology Risk = Very High	Early prototyping, trade studies, negotiation on priorities
High	Architecture Understanding = Very Low *and* Personnel Experience/Continuity = Very Low	Hire experts, establish educational benefits, conduct training

Risk Exposure Trends as Leading Indicators

- Risk burndown tracked as mitigation actions are executed and other changes occur



Publicly Available Resources

- U.S. General Accountability Office (http://gao.gov/)
  - Investigative arm of the U.S. Congress
- RAND Corporation (http://rand.org/)
  - Public think tank
  - "Managing Risk in USAF Force Planning"
- Defense Acquisition University (https://acc.dau.mil)
  - One of several U.S. Military Universities
  - "DoD Risk Management Guidebook "

