8th Annual Systems Engineering Conference
"Focusing on Mission Areas, Net-Centric Operations and Supportability of Defense Systems"

San Diego, CA

24-27 October 2005

Agenda

Tuesday, 25 October 2005

Open Remarks: by Mr. Bob Rassa, Director, Systems Supportability, Raytheon; Chair, Systems Engineering Division, NDIA
Keynote Address: by Mr. John Landon, Deputy Assistant Secretary of Defense (NII), C3ISR & IT Acquisition

Plenary Session - Revitalization of Systems Engineering Within DoD:

- State of Systems Engineering within DoDs, Mr. Mark D. Schaeffer, Deputy Director, Systems Engineering, OUSD (AT&L)
- USAF Systems Engineering Initiatives, Mr. Terry Jaggers, SAF/AQR (Science & Technology & Engineering)
- System Engineering Re-vitalization within DoN Status, Mr. Carl Siel, ASN(RDA) Chief Engineer
- Army SE Overview, Mr. Douglas K. Wiltsie, Assistant Deputy, Acquisition and Systems Management, Office of the Assistant Secretary of the Army, Acquisition Logistics and Technology
- "Implementation of ESE/A", Mr. Kelly A. Miller, NSA/CSS CSE

Luncheon Keynote Speaker: by Mr. Gregory Shelton, Corporate Vice President, Engineering, Technology, Manufacturing and Quality, Raytheon Company

Tracks 1 & 2 - Systems Engineering Effectiveness:

- Technical Planning for Acquisition Programs: An OSD Perspective, Col Warren Anderson, OUSD (AT&L) Defense Systems
- Implementation of Policy Requiring Systems Engineering Plans for Air Force Programs – Results and Implications, Mr. Kevin Kemper, Air Force Materiel Command
- Systems Engineering Revitalization at SPAWAR Systems Center Charleston, Mr. Michael T. Kutch, Jr., SPAWAR Systems Center
- Systems Engineering for Software Assurance, Ms. Kristen Baldwin, OUSD (AT&L) Defense Systems
- Revitalization of Systems Engineering: Past, Present and Future, Ms. Karen B. Bausman, Air Force Center for Systems Engineering
- Enabling Technology Readiness Assessments (TRAs) with Systems Engineering, Dr. Jay Mandelbaum, Institute for Defense Analyses
- A Taxonomy of Operational Risks, Mr. Brian Gallagher, Software Engineering Institute
- A Method for Reasoning About an Acquisition Strategy, Mr. Joseph Elm, Software Engineerin Institute
- WBS-Based Approach to Understanding and Predicting Program Risk, Bruce M. Heim, DCMA, Boeing Long Beach
- Program Support: Perspectives on Technical Planning and Execution, Mr. Dave Castellano, OUSD (AT&L) Systems Engineering

Track 3 - Test & Evaluation in Systems Engineering:

- Interweaving Test and Evaluation Throughout the Systems Engineering Process - Presentation and Paper, Mr. Josh Tribble, AVW Technologies

Track 4 - Net Centric Operations:

- Net-Centricity & Net-Ready - Beyond Technical Interoperability & C4ISR, Mr. Jack Zavin, ASD(NII), DoD CIO/A&I Directorate
- A Strategy for Managing Development and Certification of Net-Centric Services within the Global Information Grid, Mr. Bernal Allen, DISA, GE 4
- Next Generation Enterprise Information Management Appliances, Mr. Michael Lindow, The MITRE Corp.

Track 5 - Logistics:

- Logistics Transforming: Achieving Knowledge-Enabled Logistics, Mr. Jerry Beck, OSD Office of ADUSD(LPP)
- Condition Based Logistics, Mr. Ron Wagner, CoBaLt Technology
- System Supportability and Life Cycle Product Support: A Systems Perspective, Dinesh Verma, Stevens Institute of Technolog
- The Management of Logistics in Large Scale Inventory Systems to Support Weapon System Maintenance, Mr. Eugene A. Beardslee, SAIC

Track 7 - Systems Safety:

- System Safety in Systems Engineering DAU Continuous Learning Module, Ms. Amanda Zarecky, Booz Allen Hamilton
- Enabling System Safety Through Technical Excellence, Col Warren Anderson, OUSD (AT&L) Defense Systems
- Applying CMMI to System Safety, Mr. Tom Pfitzer, APT Research, Inc.
- System Safety Engineering: An Overview for Engineers and Managers, Mr. Pat L. Clemens, APT Research, Inc.
- Using MIL-STD-882D to Integrate ESOH into SE, Mr. Sherman G. Forbes, USAF - SAF/AQRE

Track 8 - Software Supportability:

- The Proper Specification of Requirements, Mr. Al Florence, The MITRE Corporation
- C-17 Software Development Process, John R. Allen, The Boeing Company 4
- Successful Verification and Validation Based on the CMMI Model, Mr. Tim Olson, Quality Improvement Consultants, Inc.
- “Automated Software Testing Increases Test Quality and Coverage Resulting in Improved Software Reliability.”, Mr. Frank Salvatore, High Performance Technologies, Inc.
- Software Supportability: A Software Engineering Perspective, Ms. Stephany Bellomo, SAIC

Wednesday, 26 October 2005

Tracks 1, 2 & 3 - Systems Engineering Effectiveness:

- Decision Analysis and Resolution, Mr Robert Trifiletti, Jr., US Army ARDEC
- Defining System Development Lifecycles to Plan and Manage Projects Effectively, Mr. Bruce A. Boyd, The Boeing Company
- Systems Engineering, Program Management conjoined Disciplines over the Project Life Cycle, Mr. William Lyders, ASSETT, Inc.
- Tailoring USAF Systems Engineering for the Life Cycle: One Shape, Multiple Dimensions, Mr. Jeff Loren, MTC Technologies, Inc. (SAF/AQRE)
- Architecture-Based Systems Engineering and Integration, Dr. Rick Habayeb, Virginia Polytechnic Institute & State University
- A Complementary Approach to Enterprise Systems Engineering, Dr. Brian White, The MITRE Corporation
- Implementing Systems Engineering Processes to Balance Cost and Technical Performance, Dr. Mary Anne Herndon, Transdyne Corporation
- Program Support: Perspectives on Technical Planning and Execution, Mr. Dave Castellano, OUSD (AT&L) Systems Engineering
- Application of Risk Management in a Net-Centric Environment, Ms. Rebecca M. Cowen-Hirsch, DISA
- “Requirements Management Tips and Tricks”, Mr. Frank Salvatore, High Performance Technologies, Inc.
- Engineering and Implementing Raytheon Missile Systems Engineering Design to Cost Metric - Presentation and Paper, Mr. Edward Casey, Raytheon Missile Systems
- System Engineering Metrics, Mr. James Miller, Air Foce Materiel Command
- Technical Performance Measures, Mr. Jim Oakes, BAE Systems
- TurboTax® for Systems EngineerinTurboTax® for Systems Engineering, Michael T. Kutch, Jr., SPAWAR
- A Practical Application of A Practical Application of the Non-Advocate Review, Mr. Bruce Nishime, The Boeing Company
- Systems Engineering and the Software Laws of Thermodynamics, Dr. Thomas F. Christian Jr., 402 SMXG
- Unmanned Aerial Vehicle Survivability Influence on System Life Cycle Cost, Mr. Chuck Pedriani, SURVICE Engineering
- Effective SE Metrics Tailored to the Acquisition Life Cycle, Ms. Laura Trioilia, US Army ARDEC
- Innovative Procurement Strategies, Mr. David Eiband, Defense Acquisition University
- Next Generation Combat Systems - An Overview of Key Development Concepts, Mr. Matthew Montoya, The JHU Applied Physics Laboratory Mr. Edward Casey, Raytheon Missile Systems
- Converting High-Level Systems Engineering Policy to a Workable Program, Mr. James Miller, Air Force Materiel Command
- AFRL Systems Engineering Initiative - Risk Managment for Science and Technology, Mr. William Nolte, USAF-AFRL
- System Engineered Research and Development Magement, Dr. Steven Ligon, SAIC
- The Return of Discipline, Ms. Jacqueline Townsend, Air Force Materiel Command

Track 4 - Net Centric Operations:

- Testing Net-Centric Systems of Systems: Applying Lessons Learned from Distributed Simulation, Mr. Doug Flournoy, The MITRE Corp.
- A Multi-Mission Network Centric Warfare Platform, Peder Jungck, CloudSheild Technologies
- Challenges Challenges in Development of System of Systems (SoS) Architectures in a Net Centric Environment, Dr. Abraham Meilich, Lockheed Martin
- Matrix Mapping Tool (MMT), Dr. Judith Dahmann, AT&L/DS MITRE

Track 5 - Logistics:

- Defense Logistics as Chaos Theory, Mr. John Sells, Tobyhanna Army Depot
- Process for Evaluating LogisticProcess for Evaluating Logistics Readiness Levels (LRLs) for Acquisition Systems, Ms. Elizabeth Broadus, Booz Allen Hamilton, Inc.
- The Management of Logistics in Large Scale Inventory Systems to Support Weapon System Maintenance, Mr. Eugene A. Beardslee, SAIC
- System of Systems Analysis of Future Combat Systems Sustainment Requirements, Mr. Ivan W. Wolnek, The Boeing Company
- Readiness & Supportability Program Readiness & Supportability Programs, Mr. Robert M. Cranwell, Sandia National Laboratories (SNL)
- Data Management in a Performance Based Logistics Environment, Denise Duncan, LMI

Track 5 - Best Practices & Standardization:

- CMMI for Services, Mr. Juan Ceva, Raytheon Company
- Out of the Ordinary: Finding Hidden Threats by Analyzing Unusual Behavior, Mr. John Hollywood, RAND

Track 6 - Modeling & Simulation:

- Improving M&S Support to Acquisition: A Progress Report on Development of the Acquisition M&S Master Plan, Mr. Jim Hollenbach, Simulation Strategies, Inc.

- Next Generation Manufacturing Technology Initiative and the Model - Based Enterprise, Mr. Richard Neal - IMTI
- Problem Space Modeling: A Dynamic Future for Requirements Analysis, Mr. Jeffrey O. Grady, JOG System Engineering, Inc.
- Systems Modeling Language Systems Modeling Language (SysML) Overview & Update, Rick Steiner, Raytheon Company
- Data Management Support for Modeling and Simulation, Mr. Denise Duncan, LMI
- Digital Data Management an Update, Ms. Cynthia C. Hauer, Millennium Data Management, Inc.
- The Use of Simulation in the Management of Logistics in Large Scale Inventory Systems to Support Weapon System Maintenance, Mr. Eugene A. Beardslee, SAIC

Track 7 - System Safety:

- Mission Sustainment Through Environment, Safety, and Occupational Health (ESOH) Risk Management, Ms. Trish Huheey, ODUSD (I&E)
- Lessons Learned with the Application of MIL-STD-882D at the Weapon System Explosives Safety Review Board, Ms. Mary Ellen Caro, Ordnance Safety & Security Activity
- Industry Perspectives and Identified Barriers to the Use of MIL-STD-882D for Integrating ESOH Considerations into Systems, Mr. Jon Derickson, BAE Systems
- System Safety in Systems Engineering Process, Dr. Ray C. Terry, SURVICE Engineering Company
- Enabling Army Level Risk Mitigation, Mr. Bill Edmonds, US Army Combat Readiness Center
- Evolution of MIL-STD-882E, Mr. Robert McAllister, US Air Force Materiel Command
- Integrating MIL-STD-882 System Safety Products into the Concurrent Engineering Approach to System Design, Build, Test, and Delivery of Submarine Systems At Electric Boat, Mr. Ricky Milnarik, General Dynamics

Track 8 - Legacy Systems Sustainment:

- Sustaining Software-Intensive Systems - A Conundrum, Ms. Mary Ann Lapham, Carnegie Mellon Software Engineering Institute
- Algorithm Description Documentation and Validation Process, Mr. Mike Bailey, Raytheon Company
- ATSRAC: Background, Results and Future Impact on the Aviation Industry, Mr. Kent V. Hollinger, The MITRE Corp.
- Jammer Integration Roadmap, Mr. Adam McCorkle, GTRI
- Open Systems Architecture (OSA) and Standard Interfaces as Mission Capability Enablers, William H. Mish, Jr., AMSEC
- Naval Air Systems Command Integrated In-Service Reliability Program (IISRP), Mr. Les Wetherington, Integrated In-Service Reliability Program (IISRP)

8th Annual Systems Engineering Conference

"Focusing on Mission Areas, Net-Centric Operations and Supportability of Defense Systems"

Event # 6870

October 24-27, 2005

San Diego, CA

Onsite Program

NDIA
NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

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INCOSE
INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING

Sponsored by the
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and INCOSE
Supported by
Office of Under Secretary of
Defense, Acquisition Technology &
Logistics, Defense Systems,
Director, Systems Engineering

Sunday, October 23, 2005

5:00 PM-7:00 PM Registration for Tutorials and General Conference
(Tutorials are an additional $200 registration fee)

Monday, October 24, 2005

7:00 AM - 5 PM Registration

7 AM Continental Breakfast for Tutorial Attendees ONLY
(Tutorials are an additional $200 registration fee)

8:00 AM - 5 PM Tutorial Tracks (Please refer to following pages for Tutorials Schedule)

12 Noon - 1 PM Buffett Lunch

1:00 PM - 5 PM Tutorial Tracks (Please refer to following pages for Tutorials Schedule)

5:00 PM - 6 PM Reception in Display Area (Open to All Participants)

Tuesday, October 25, 2005

7:00 AM Registration & Continental Breakfast

8:15 AM Introductions
Mr. Sam Campagna, Director, Operations, NDIA

8:30 AM Opening Remarks
Mr. Bob Rassa, Director, Systems Supportability, Raytheon;
Chair, Systems Engineering Division, NDIA

8:40 AM - 9:30 AM Keynote Address
Mr. John Landon, Deputy Assistant Secretary of Defense (NII)
(C3ISR & IT Acquisition)

9:30 AM - 10 AM Break in Display Area

10:00 AM - 12 Noon Plenary Session: Revitalization of Systems Engineering Within DoD
Moderator:
Mr. Mark Schaeffer, Deputy Director, Defense Systems, and Director, Systems Engineering, OUSD (AT&L)
Panelists:
Mr. Terry Jaggers, Director, SAF/AQR (Science, Technology & Engineering)
Mr. Carl Siel, ASN (RDA)CHENG
Mr. Doug Wiltsie, US Army (Invited)
Mr. Kelly Miller, NSA (Invited)

12 Noon - 1:30 PM Luncheon Speaker
Mr. Greg Shelton, Vice President, Engineering Manufacturing Technology & Quality, Raytheon

1:30 PM - 5 PM Concurrent Sessions (Please refer to following pages for session schedule)

5:00 PM - 6:30 PM Reception in Display Area

Monday, October 24, 2005

7:15 AM	Registration & Continental Breakfast

Room	8:00 AM	9:45 AM	10:15 AM	12 Noon	1:00 PM	2:45 PM	3:15 PM	5 PM-6 PM
Regency A	TRACK 1 Tutorial How to Define System Engineering Processes That are Short and Usable Session 1A1 **Mr. Tim Olson, Quality Improvement Consultants, Inc.**	Break	TRACK 1 Tutorial How to Define System Engineering Processes That are Short and Usable (Continued) Session 1B1 **Mr. Tim Olson, Quality Improvement Consultants, Inc.**	Buffet Lunch	TRACK 1 Tutorial Systems Engineering Planning - A Tutorial Session 1C1 **Col Warren Anderson, OUSD (AT&L) Defense Systems**	Break	TRACK 1 Tutorial Systems Engineering Planning - A Tutorial (Continued) Session 1D1 **Col Warren Anderson, OUSD (AT&L) Defense Systems**	Reception in Display Area
Regency B	TRACK 2 Tutorial Integrating Systems Engineering with Earned Value Management Session 1A2 **Mr. Paul Solomon, Northrop Grumman Corp.**		TRACK 2 Tutorial Integrating Systems Engineering with Earned Value Management (Continued) Session 1B2 **Mr. Paul Solomon, Northrop Grumman Corp.**		TRACK 2 Tutorial Using a Measurement Framework to Successfully Achieve Measur-able Results Session 1C2 **Mr. Tim Olson, Quality Improvement Consultants**		TRACK 2 Tutorial Using a Measurement Framework to Successfully Achieve Measurable Results (Continued) Session 1D2 **Mr. Tim Olson, Quality Improvement Consultants**	
Regency C	TRACK 3 Tutorial Up-To-Date Systems Requirements Tutorial Session 1A3 **Mr. Jeffrey Grady , JOG Systems Engineering, Inc.**		TRACK 3 Tutorial Up-To-Date Systems Requirements Tutorial (Continued) Session 1B3 **Mr. Jeffrey Grady, JOG Systems Engineering, Inc.**		TRACK 3 Tutorial Requirements Development and Management Session 1C3 **Mr. Al Florence, The MITRE Corp.**		TRACK 3 Tutorial Requirements Development and Management (Continued) Session 1D3 **Mr. Al Florence, The MITRE Corp.**	
Mission A	TRACK 4 Tutorial Exploring the System Solution Space using Behavior Analysis and Simulation: Applying M&S to System Engineering Session 1A4 **Mr. James Long, Vitech Corp.**		TRACK 4 Tutorial Exploring the System Solution Space using Behavior Analysis and Simulation: Applying M&S to System Engineering (Continued) Session 1B4 **Mr. James Long, Vitech Corp.**		TRACK 4 Tutorial Air Force Integrated Collabora-tive Environment (AF-ICE) - An Air Force and Industry Partner overview and update Session 1C4 **Mr. Rick Peters, Air Force Material Command**		TRACK 4 Tutorial Air Force Integrated Collabora-tive Environment (AF-ICE) - An Air Force and Industry Partner overview and update (Continued) Session 1D4 **Mr. Rick Peters, Air Force Material Command**	
Mission B	TRACK 5 Tutorial Systems/Software/Hardware Quality Assurance Session 1A5 **Mr. Al Florence, The MITRE Corp.**		TRACK 5 Tutorial Systems/Software/Hardware Qual-ity Assurance (Continued) Session 1B5 **Mr. Al Florence , The MITRE Corp.**		TRACK 5 Tutorial The Return on Investment from Software Engineering Best Practices: An Introduction Session 1C5 **Mr. Thomas McGibbon, ITT Industries**		TRACK 5 Tutorial The Return on Investment from Software Engineering Best Prac-tices: An Introduction Session 1D5 **Mr. Thomas McGibbon, ITT Industries**	
Mission C	TRACK 6 Tutorial Innovative Design for Six Sigma (DFSS) Approaches to Test and Evaluation: A Hands-On Experience Session 1A6 **Dr. Mark Kiemele, Air Academy Associates**	Break	TRACK 6 Tutorial Innovative Design for Six Sigma (DFSS) Approaches to Test and Evaluation: A Hands-On Experi-ence (Continued) Session 1B6 **Dr. Mark Kiemele , Air Academy Associates**		TRACK 6 Tutorial What Makes A Simulation Credible? Cost-Effective VV&A in the Systems Engineering Process Session 1C6 **Mr. David Hall, SURVICE Engineering Company**	Break	TRACK 6 Tutorial What Makes A Simulation Cred-ible? Cost-Effective VV&A in the Systems Engineering Process (Continued) Session 1D6 **Mr. David Hall, SURVICE Engineering Company**	
Garden A	TRACK 7 Tutorial Object Oriented Systems Engineering Methodology (OOSEM) Session 1A7 **Dr. Abraham Meilich, Lockheed Martin**		TRACK 7 Tutorial Object Oriented Systems Engineering Methodology (OOSEM)(Continued) Session 1B7 **Dr. Abraham Meilich, Lockheed Martin**		TRACK 7 Tutorial Object Oriented Systems Engineering Methodology (OOSEM)(Continued) Session 1C7 **Dr. Abraham Meilich, Lockheed Martin**		TRACK 7 Tutorial Object Oriented Systems Engineering Methodology (OOSEM)(Continued) Session 1D7 **Dr. Abraham Meilich, Lockheed Martin**	
Garden F	TRACK 8 Tutorial TBA Session 1A8		TRACK 8 Tutorial TBA Session 1B8		TRACK 8 Tutorial Performability (Performance and Reliability) Modeling Session 1C8 **Dr. Meng-Lai Yin, Raytheon**		TRACK 8 Tutorial Performability (Performance and Reliability) Modeling Session 1D8 **Dr. Meng-Lai Yin, Raytheon**	

Tuesday, October 25, 2005

1:30 PM

Room	Track	Session	Presentation	Presentation
Regency A	TRACK 1 Systems Engineering Effectiveness	Session 2C1	The Return of Discipline **Dr. Yvette Weber, HQ AFMC, USAF**	Technical Planning for Acquisition Programs: An OSD Perspective **Col Warren Anderson, OUSD (AT&L) Defense Systems**
Regency B	TRACK 2 Systems Engineering Effectiveness	Session 2C2	Technology Readiness Assessments: A Key Aspect of the Systems Engineering Process **Dr. Jay Mandelbaum, Institute for Defense Analyses**	Taxonomy of Operational Risks **Mr. Brian Gallagher, Software Engineering Institute**
Regency C	TRACK 3 Test & Evaluation in Systems Engineering	Session 2C3	Applying the Systems Engineering Approach to the Test and Evaluation Process **Mr. Raymond Beach, NAVAIR**	Intelligent Data Analysis Options to Support Aircraft/Ship Systems Testing **Mr. Dean Carico, Naval Air Warfare Center**
Mission A	TRACK 4 Net Centric Operations	Session 2C4	Guiding DoD's move into the Information Age **Mr. Jack Zavin, ASD(NII)/DoD CIO**	Challenges in Development of System of Systems (SoS) Architectures in a Net Centric Environment **Dr. Abraham Meilich, Lockheed Martin**
Mission B	TRACK 5 Logistics	Session 2C5	Intro to Logistics & Supportability **Mr. Jerry Beck, OSD Office of ADUSD(L&MR)**	Condition Based Logistics **Mr. Ron Wagner, CoBaLt Technology**
Mission C	TRACK 6 Integrated Diagnostics	Session 2C6	Intro to Integrated Diagnostics **Mr. Dennis Hecht, The Boeing Company**	Diagnostic Software - What your average developer doesn't know **Mr. Theodore Marz, Carnegie Mellon University - Software Engineering**
Garden A	TRACK 7 Systems Safety	Session 2C7	System Safety in Systems Engineering DAU Continuous Learning Module Overview **Ms. Amanda Zarecky, Booz Allen Hamilton**	System Safety in the Systems Engineering Process **Dr. Ray Terry, SURVICE Engineering Company**
Garden F	TRACK 8 Software Supportability	Session 2C8	Proper Specification of Software Requirements **Mr. Al Florence, The MITRE Corporation**	C-17 Software Development Process **Mr. Hafez Lorseyedi, The Boeing Company**

3:00 PM

Break in Display Area

3:30 PM

Room	Track	Session	Presentation	Presentation	Presentation
Regency A	TRACK 1 Systems Engineering Effectiveness	Session 2D1	Implementation of Policy Requiring Systems Engineering Plans for Air Force Programs – Results and Implications **Mr. Kevin Kemper, US Air Force**	Systems Engineering Revitalization at SPAWAR Systems Center Charleston **Mr. Michael Kutch, Jr., SPAWAR Systems Center**	Engineering for Software Assurance **Ms. Kristen Baldwin, OUSD(AT&L)**
Regency B	TRACK 2 Systems Engineering Effectiveness	Session 2D2	A Method for Reasoning About an Acquisition Strategy **Mr. Joseph Elm, Software Engineering Institute**	WBS Based Risk Assessment **Mr. Bruce Heim, (DCMA) Boeing Long Beach**	
Regency C	TRACK 3 Test & Evaluation in Systems Engineering	Session 2D3	Interweaving Test and Evaluation throughout the Systems Engineering Process **Mr. Joseph Tribble, AVW Technologies**	Recent Innovations in Design for Six Sigma (DFSS) Testing Approaches to Speed Technology to the Marketplace **Dr. Mark Kiemele, Air Academy Associates**	Flight Testing Airborne Radar Systems to Improve System Performance **Mr. Mark London, NAVAIR**
Mission A	TRACK 4 Net Centric Operations	Session 2D4	Real-Time Tactical Services for the GIG **Mr. John Noble, JHU Applied Physics Laboratory**	Next Generation Enterprise Information Management Appliances **Mr. Michael Lindow, The MITRE Corp.**	
Mission B	TRACK 5 Logistics	Session 2D5	FRACAS Implementation using ITLog **Mr. William Jacobs, Raytheon**	Creating a Logistics Health Management System **Mr. Gary O'Neill, Georgia Tech Research Inst.**	
Mission C	TRACK 6 Integrated Diagnostics	Session 2D6	Designing for Health; A Methodology for Integrated Diagnostics/Prognostics **Mr. Larry Butler, Raytheon**	COTS-Based Solution for Integrated Test and Diagnostics **Dr. Ion Neag, TYX Corp.**	
Garden A	TRACK 7 System Safety	Session 2D7	Revitalizing System Safety as One of the Key Elements to Revitalizing Systems Engineering in Department of Defense Acquisition Programs **Col Warren Anderson, OUSD (AT&L) Defense Systems**	Linking System Safety to Systems Engineering **Ms. Paige Ripani, Booz Allen Hamilton**	Integrating MIL-STD-882 **Mr. Rick Milnarik,**
Garden F	TRACK 8 Software Supportability	Session 2D8	Successful Verification and Validation Based on the CMMI Model **Mr. Tim Olson, Quality Improvement Consultants, Inc.**	Automated Software Testing Increases Test Quality and Coverage Resulting in Improved Software Reliability **Mr. Frank Salvatore, High Performance Technologies, Inc.**	Software Supportability: A Software Engineering Perspective **Mrs. Stephany Bellomo, SAIC**

5:30 - 7:00 PM

Reception in Display Area

Wednesday, October 26, 2005

7:15 AM **Registration & Continental Breakfast**

8:15 AM

Room	Track	Presentation 1	Presentation 2
Regency A	TRACK 1 Systems Engineering Effectiveness — Session 3A1	Tailorable Decision Analysis and Resolution process and tools for enterprise wide application — ***Mr. Robert Trifiletti, Jr., US Army ARDEC***	Defining System Development Lifecycles to Plan and Manage Projects Effectively — ***Mr. Bruce Boyd, The Boeing Company***
Regency B	TRACK 2 Systems Engineering Effectiveness — Session 3A2	Application of Risk Management across Engineering and Acquisition — ***Ms. Rebecca Cowen-Hirsch, Defense Systems Agency***	Requirements Engineering Tips and Tricks — ***Mr. Frank Salvatore, High Performance Technologies, Inc.***
Regency C	TRACK 3 Systems Engineering Effectiveness — Session 3A3	Effective SE Metrics Tailored to the Acquisition Life Cycle — ***Ms. Laura Troiola, US Army - ARDEC***	Innovative Procurement Strategies — ***Mr. David Eiband, Defense Acquisition University***
Mission A	TRACK 4 Net Centric Operations — Session 3A4	Joint Battle Management Command & Control RoadMap - Panel — ***Moderators: Dr. Vitalij Garber, Ms. Robin Quinlan, DUSD (AT&L) DS/SI Panelists: Maj Gen Charles Simpson, USAF MG Michael Vane, USA***	Joint Battle Management Command & Control RoadMap - Panel — ***Moderators: Dr. Vitalij Garber, Ms. Robin Quinlan, DUSD (AT&L) DS/SI Panelists: Maj Gen Charles Simpson, USAF MG Michael Vane, USA***
Mission B	TRACK 5 Logistics — Session 3A5	Improving Supportability on Currently Deployed Weapon Systems — ***Mr. John Sells, Tobyhanna Army Depot***	Process for Evaluating Logistics Readiness Levels (LRLs) for Acquisition Systems — ***Mr. Robert Ernst, NAVAIR***
Mission C	TRACK 6 Modeling & Simulation — Session 3A6	Improving M&S Support to Acquisition — ***Mr. James Hollenbach, Simulation Strategies, Inc.***	Improving M&S Support to Acquisition (Continued) — ***Mr. James Hollenbach, Simulation Strategies, Inc.***
Garden A	TRACK 7 System Safety — Session 3A7	A Model Linking Safety, Threat and Other Critical Causal Factors to Their Mitigators" Relative to (Software, Hardware, and Human System Integration — ***Ms. Janet Gill, NAVAIR***	Mission Sustainment Through Acquisition Environment, Safety, and Occupational Health (ESOH) Risk Management — ***Ms. Karen Gill, Booz Allen Hamilton***
Garden F	TRACK 8 Software Supportability — Session 3A8	Sustaining Software-Intensive Systems – A Conundrum — ***Ms. Mary Ann Lapham, SEI***	Algorithm Description Documentation and Validation Process — ***Mr. Michael K. Bailey, Raytheon***

9:45 AM **Break in Display Area**

10:15 AM

Room	Track	Presentation 1	Presentation 2
Regency A	TRACK 1 Systems Engineering Effectiveness — Session 3B1	System Engineering, Program Management conjoined Disciplines over the Project Life Cycle — ***Mr. William Lyders, ASSETT, Inc.***	Tailoring USAF Systems Engineering for the Life Cycle: One Shape, Multiple Dimensions — ***Mr. Jeff Loren, MTC Technologies, Inc. (SAF/AQRE)***
Regency B	TRACK 2 Systems Engineering Effectiveness — Session 3B2	Engineering and Implementing RMS Engineering DTC Metrics — ***Mr. Edward Casey, Raytheon Missile Systems***	System Engineering Metrics — ***Mr. James Miller, United States Air Force***
Regency C	TRACK 3 Systems Engineering Effectiveness — Session 3B3	Using Systems Engineering Principles to Transform R & D Into a Military System Solution — ***Dr. James Dill, Foster-Miller***	Next Generation Combat Systems - An Overview of Key Development Concepts — ***Mr. Matthew Montoya, The JHU Applied Physics Laboratory***
Mission A	TRACK 4 Net Centric Operations — Session 3B4	Network-Centric Capabilities Development for Ground Mobile Forces — ***Ms. Diane Hanf, The MITRE Corp.***	Testing Net-Centric Systems of Systems: Applying Lessons Learned from Distributed Simulation — ***Mr. R. Douglas Flournoy,***
Mission B	TRACK 5 Logistics — Session 3B5	The Management of Logistics in Large Scale Inventory Systems to Support Weapon System Maintenance — ***Mr. Eugene Beardslee, SAIC***	System of Systems Analysis of Future Combat System Sustainment Requirements — ***Mr. Ivan Wolnek, The Boeing Company***
Mission C	TRACK 6 Modeling & Simulation — Session 3B6	Next Generation Manufacturing Technology Initiative and the Model-Based Enterprise — ***Mr. Richard Neal, IMTI***	Problem Space Modeling — ***Mr. Jeffrey O. Grady, JOG Systems Engineering, Inc.***
Garden A	TRACK 7 System Safety — Session 3B7	Army Acquisition Programs' Installations, Environmental, Safety, and Occupational Health Considerations — ***Mr. Donald Artis, Jr., Office of the DASA(ESOH)***	Current DoD Acquisition Policies and Guidance on the use of MIL-STD-882D to Integrate Environment, Safety, and Occupational Health (ESOH) Considerations into the Systems Engineering Process — ***Mr. Sherman Forbes, USAF - SAF/AQRE***
Garden F	TRACK 8 Legacy Systems Sustainment — Session 3B8	The Integration of Systems Engineering and Enterprise Architecture with respect to the Modernization of Legacy Systems - Panel — ***Mr. Owen Williams, Science Applications International Corp.***	The Integration of Systems Engineering and Enterprise Architecture with respect to the Modernization of Legacy Systems - Panel (Continued) — ***Mr. Owen Williams, Science Applications International Corp.***

12 Noon **Lunch Speaker: Dr. Dale Uhler, Acquisition Executive, US SOCOM**

Wednesday, October 26, 2005

1:30 PM

Room	Track	Session	Presentation 1	Presentation 2
Regency A	TRACK 1 Systems Engineering Effectiveness	Session 3C1	Architecture Based Systems Engineering And Integration **Dr. Rick Habayeb, Virginia Tech**	A Complementary Approach to Enterprise Systems Engineering **Dr. Brian White, The MITRE Corp.**
Regency B	TRACK 2 Systems Engineering Effectiveness	Session 3C2	Technical Performance Measures **Mr. Jim Oakes, BAE Systems**	Turbo Tax for Systems Engineering **Mr. Michael Kutch, Jr., SPAWAR**
Regency C	TRACK 3 Systems Engineering Effectiveness	Session 3C3	Converting High-Level Systems Engineering Policy to a Workable Program **Mr. James Miller, US Air Force**	Revitalization of Systems Engineering; Past, Present and Future **Ms. Karen Bausman, USAF Center for Systems Engineering**
Mission A	TRACK 4 Net Centric Operations	Session 3C4	What is the difference between Multi-Level Security (MLS) and Multiple Secure Levels (MSL) Architectures and why do you care? **Mr. Paul Vazquez, Jr., Raytheon NCS**	A Network Centric Warfare Platform With Multiple Missions in Mind **Mr. Peder Jungck, CloudShield Technologies**
Mission B	TRACK 5 Logistics	Session 3C5	Reaping the benefits of PBL/CSL **Ms. Denise Duncan, LMI**	Priming & Tuning the ERP/MRO Engine: Integrated Through-life Supportability Data Management **Mr. Patrick Read, Pennant Canada, Ltd**
Mission C	TRACK 6 Modeling & Simulation	Session 3C6	Update on SysML **Mr. Rick Steiner, Raytheon**	Data Management to support M&S **Ms. Denise Duncan, LMI**
Garden A	TRACK 7 System Safety	Session 3C7	Lessons Learned with the Application of MIL-STD-882D Within the Navy's Weapon System Explosives Safety Review Board **Ms. Mary Caro, Naval Ordnance Safety & Security Activity**	Industry perspectives and identified barriers to the use of MIL-STD-882D for integrating ESOH considerations into Systems **Mr. Jon Derickson, United Defense**
Garden F	TRACK 8 Legacy Systems Sustainment	Session 3C8	The Aging Transport Systems Rulemaking Advisory Committee: Background, Results and Future Impact on the Aviation Industry **Mr. Kent Hollinger, The MITRE Corp.**	Jammer Integration Roadmap **Mr. Adam McCorkle, Georgia Tech Research Institute**

3:00 PM

Break in Display Area

3:30 PM

Room	Track	Session	Presentation 1	Presentation 2	Presentation 3
Regency A	TRACK 1 Systems Engineering Effectiveness	Session 3D1	Implementing SE Processes to Balance Cost and Technical Performance **Dr. Mary Anne Herndon, SAIC**	A Revolutionary Model to Support Early CAIV Trades and Cost Predictions **Mr. Bryan Piggott, InfoEdge**	
Regency B	TRACK 2 Systems Engineering Effectiveness	Session 3D2	A Practical Application of the Non-Advocate Review **Mr. Bruce Nishime, The Boeing Company**	Systems Engineering and the Software Laws of Thermodynamics **Dr. Thomas Christian, Jr., 402 SMXG**	Unmanned Aerial Vehicle Survivability Influence on System Life Cycle Cost **Mr. Charles Pedriani, SURVICE Engineering**
Regency C	TRACK 3 Systems Engineering Effectiveness	Session 3D3	AFRL Systems Engineering Initiative – Risk Management for Science and Technology **Mr. William Nolte, USAF-AFRL**	System Engineered Research and Development Management **Dr. Steven Ligon, SAIC**	
Mission A	TRACK 4 Net Centric Operations	Session 3D4	Systems Engineering Analysis and Control Methods to Assure Electromagnetic Spectrum Access **Mrs. Renae Carter, DISA Defense Spectrum Office**	A Strategy for Managing the Development and Certification of Net-Centric Services within the Global Information Grid **Mr. Bernal Allen, Defense Systems Agency**	
Mission B	TRACK 5 Best Practices & Standardization	Session 3D5	On the Shoulders of CMM: CMMI + COTS + OA + nNIH = less (cost) + more (capability) **Mr. Luke Campbell, NAVAIR**	CMMI for Services **Mr. Juan Ceva, Raytheon RIS**	
Mission C	TRACK 6 Modeling & Simulation	Session 3D6	Enterprise Digital Data Management **Ms. Cynthia Hauer, Millennium Data Management, Inc.**	The Use of Simulation in the Management of Logistics in Large Scale Inventory Systems to Support Weapon System Maintenance **Mr. Eugene Beardslee, SAIC**	Ensuring Accomplishment of Performance Based Logistics Objectives Using Model-Based Systems Engineering **Mr. Timothy Tritsch, Vitech Corp.**
Garden A	TRACK 7 System Safety	Session 3D7	Comparisons and Contrasts Between ISO 14001, OHSAS 18001, and MIL-STD-882D and their Suitability for the Systems Engineering Process **Mr. Kenneth Dormer, USAF Contractor (SAF/AQRE)**	Evolution of Military Standard 882E **Mr. Jimmy Turner, Raytheon**	USMC Expeditionary Fighting Vehicle (EFV): A Vehicle Designed with Environmental, System Safety, and Occupational Health (ESOH) in Mind **Ms. Sandra Fenwick, USMC DRPM AAA**
Garden F	TRACK 8 Legacy Systems/ Open Systems	Session 3D8	NAVAIR Integrated In-Service Reliability Program - Aging Aircraft/Keeping Legacy Systems Viable **Ms. Debbie Vergos, Naval Air Systems Command**	Delivering Effective Solutions in the Age of Open Source Technology **Mr. Edward Beck, Computer Sciences Corp.**	

5:30 PM

Conference Adjounrs for the Day

Thursday, October 27, 2005

7:15 AM — **Registration & Continental Breakfast**

8:15 AM

Room	Track	Presentation 1	Presentation 2
Regency A	TRACK 1 Systems Engineering Effectiveness — Session 4A1	A Systems Affordability Approach Using Raytheon Six Sigma Design — ***Ms. Yvette Thornton, Raytheon***	Requirements Engineering Tips and Tricks — ***Mr. Frank Salvatore, HPTI***
Regency B	TRACK 2 Systems Engineering Effectiveness — Session 4A2	Surveying SE Effectiveness — ***Mr. Joseph Elm, Software Engineering Institute***	Integrated Survivability Assessment (ISA) in the Systems Engineering Process — ***Mr. David H. Hall, SURVICE Engineering Company***
Regency C	TRACK 3 Systems Engineering Effectiveness — Session 4A3	10 Golden Questions for Concept Exploration and Development — ***Dr. Dan Surber, Raytheon Technical Services Co.***	The C-17 Systems Engineering Experience — ***Mr. Kenneth Sanger, The Boeing Company***
Mission A	TRACK 4 Net Centric Operations — Session 4A4	Net Centric Test & Evaluation — ***Mr. Ric Harrison, DISA***	Profiling and Testing Procedures for a Net-Centric Data Provider — ***Mr. Derik Pack, Space & Naval Warfare Systems Center - Charleston***
Mission B	TRACK 5 Best Practices & Standardization — Session 4A5	Process Architecture and Criteria for Lessons Learned — ***Mr. Thomas Cowles, Raytheon Space & Airborne Systems***	Successful Strategies To Improve Your Requirements — ***Mr. Tim Olson, Quality Improvement Consultants, Inc.***
Mission C	TRACK 6 Modeling & Simulation — Session 4A6	Application of a State-Machine Model for the Analysis & Optimization of Task-Post-Process-Use [TPPU] and Task, Process, Exploitation and Disseminate [TPED] Processes — ***Mr. Richard Sorensen, Vitech Corp.***	A Heuristics Systems Engineering Approach to Modeling and Analysis of the U.S. Strategic Highway Network (STRAHNET) — ***Mr. Gerard Ibarra, Southern Methodist University***
Garden A	TRACK 7 Education & Training in SE — Session 4A7	Educating Future Systems Engineers: US Military Academy Reception-Day Simulation and Optimization — ***LTC Simon Goerger, Department of Systems Engineering***	
Garden F	TRACK 8 Net Centric Operations — Session 4A8	The Role of the Operator and System Engineer in the Force Modernization Environment — ***Mr. Thomas Nelson, Jacobs Sverdrup***	TBA

9:45 AM — **Break in Display Area**

10:15 AM

Room	Track	Presentation 1	Presentation 2
Regency A	TRACK 1 Systems Engineering Effectiveness — Session 4B1	How the Pro-Active Program (Project) Manager uses a Systems Engineer's Trade Study as a Management Tool, and not just a Decision-Making Process — ***Mr. Art Felix, US Navy***	Experience in Supporting Systems Engineering Project Management Using CORE — ***Mr. George Blaine, United Dfense, LP***
Regency B	TRACK 2 Systems Engineering Effectiveness — Session 4B2	A systems approach to Accelerating Testing, a case study — ***Mr. Douglas Chojecki, Stewart & Stevenson, TVSLP***	Applying the Systems Engineering Method to the Joint Capabilities Integration and Development System (JCIDS) — ***Mr. Christopher Ryder, JHU Applied Physics Laboratory***
Regency C	TRACK 3 Systems Engineering Effectiveness — Session 4B3	Performance-Based System Architecture Design in Global Hawk UAV — ***Mr. Deepak Shankar, Mirabilis Design, Inc.***	X-47, Joint Unmanned Air Systems (J-UCAS) Program Update — ***Mr. Rick Ludwig, Northrop Grumman Corp.***
Mission A	TRACK 4 Net Centric Operations — Session 4B4	Joint Integrated BMC4I Systems Research for Upgrading Current and Legacy BMC4I Systems — ***Mr. Billy Bradley, Jr., Raytheon Integrated Defense Systems***	Model Driven Architecture - Lessons Learned in Model Assessments for Large Scale Joint Implementation — ***Ms. Denise Bagnall, Naval Surface Warfare Center***
Mission B	TRACK 5 Best Practices & Standardization — Session 4B5	Mature and Secure: Creating a CMMI and ISO/IEC 21827 Compliant Process Improvement Program — ***Mr. Michele Moss, Booz Allen Hamilton***	Performance-Based Earned Value — ***Mr. Paul Solomon, Northrop Grumman Corp.***
Mission C	TRACK 6 Modeling & Simulation — Session 4B6	Systems Engineering Approach to Research, Analyze, Model and Simulate the Interdependencies of Container Shipping and the United States Critical Infrastructure System-of-Systems — ***Ms. Susan Vandiver, Southern Methodist University***	Using Commercial Simulation Software to Model Linear and Non-Linear Processes: US Military Academy Reception-Day Simulation and Optimization — ***LTC Simon Goerger, Department of Systems Engineering***
Garden A	TRACK 7 Education & Training in SE — Session 4B7	Systems Engineering Professional Development and Certification — ***Mr. Gerard Fisher, The Aerospace Corp.***	Education and Training in Systems Engineering Support Processes — ***Ms. Cynthia Hauer, Millennium Data Management, Inc.***
Garden F	TRACK 8 Net Centric Operations — Session 4B8	JCIP: The JBMC2 Roadmap's SoSE-Based Process for Identifying and Developing Capabilities Improvements — ***Dr. John Hollywood, RAND Corp.***	Matrix Mapping Tool (MMT) — ***Dr. Judith Dahmann, The MITRE Corp.***

12 Noon — **Lunch at the Islandia Restaurant**

Thursday, October 27, 2005

Room	1:00 PM			3:00 PM
Regency A	TRACK 1 Systems Engineering Effectiveness Session 4C1	Standard Approach to Trade Studies for the Systems Engineer **Mr. Art Felix, US Navy**	Effective Implementation of Systems Engineering at the Aeronautical Systems Center: A Systems Engineering Tool Set **Mr. Edward Kunay, US Air Force**	Conference Adjourns
Regency B	TRACK 2 Systems Engineering Effectiveness Session 4C2	Systems Engineering to Enable Capabilities-based Acquisition **Ms. Kristen Baldwin, OUSD/(AT&L) DS/Systems Engineering**	Are New Acquisition Programs Taking Longer to Develop/Field and If so Why? **Dr. Dennis Strouble, Air Force Institute of Technology**	
Regency C	TRACK 3 Systems Engineering Effectiveness Session 4C3	A Systems Architectural Model for Man-Packable Intelligence, Surveillance, and Reconnaissance Micro Aerial Vehicles **Maj Joerg Walter, AFIT/SYE**	EW Integration Roadmap **Mr. Byron Coker, Jr., Georgia Tech/GTRI**	
Mission A	TRACK 4 Net Centric Operations Session 4C4	Enabling Net Centric Capability through Secured Integrated Networks of Modular and Open Architectures **Dr. Cyrus Azani, OSJTF/NGC**	Open Systems Architecture & Standard Interfaces as Mission Capability Enablers **Mr. William Mish, Jr., AMSEC**	
Mission B	TRACK 5 Best Practices & Standardization Session 4C5	TBA	What CMMI Can Learn From the PMBOK **Mr. Wayne Sherer, US Army ARDEC**	
Mission C	TRACK 6 Modeling & Simulation Session 4C6	MS2 Moorestown Modeling and Simulation (M&S) Support Approach **Mr. David Henry, Lockheed Martin MS2**	Science-Based Modeling and Simulation on DoD High Performance Computers **Dr. Larry Davis, High Performance Computing Modernization Program**	
Garden A	TRACK 7 Education & Training in SE Session 4C7	Training Your Systems Engineering Workforce **Mr. Michael Kutch, Jr., SPAWAR**	Filling the Expertise "Gap" **Mr. John White, US Air Force**	
Garden F	TRACK 8 Net Centric Operations Session 4C8	TBA	TBA	

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SYSTEM SAFETY

Evolution of MIL-STD-882E

Bob McAllister, USAF
Jimmy Turner, Raytheon

History

- Long ago
  - Analyses done after the fact
- Ballistics Sys Div Exhibit 62-41 (1962)
  - Ballistic missiles
- MIL-S-38130A (June 1966 and March 1967)
  - Aircraft, space, & electronics
- MIL-STD-882 (July 1969)
  - Mgmt emphasis & industry involvement
- MIL-STD-882A (June 1977)
  - Hazard probabilities and risk acceptance
- MIL-STD-882B (Mar 1984 and July 1987)
  - Individual tasks
- MIL-STD-882C (Jan 1993 and Jan 1996)
  - Integrated hardware and software tasks
- MIL-STD-882D (Feb 2000)
  - Acquisition reform

Risk Levels & Matrices

- Mil-S-38130A
  - No levels nor matrix
- MIL-STD-882
  - No matrix. Defined hazard levels
- MIL-STD-882A
  - No matrix – reversed hazard levels.
  - New qualitative probability levels
- MIL-STD-882B
  - Qualitative risk matrices in appendix
- MIL-STD-882C
  - Qualitative and quantitative matrices in Appendix.
  - Established risk acceptance levels
- MIL-STD-882D
  - Qualitative matrix, but quantitative probability levels.
- MIL-STD-882E (draft)
  - Multiple matrices and risk levels

Qualitative matrix (-882B)

FREQUENCY OF OCCURRENCE	HAZARD CATEGORIES			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	V NEGLIGIBLE
(A) FREQUENT	1A	2A	3A	4A
(B) PROBABLE	1B	2B	3B	4B
(C) OCCASIONAL	1C	2C	3C	4C
(D) REMOTE	1D	2D	3D	4D
(E) IMPROBABLE	1E	2E	3E	4E

Quantitative Matrix (-882C)

HAZARD CATEGORY FREQUENCY	(1) CATASTROPHIC	(2 CRITICAL	(3) MARGINAL	(4) NEGLIGIBLE
(A) FREQUENT (X > 10-1)*	1A	2A	3A	4A
(B) PROBABLE (10-1 > X > 10-2)*	1B	2B	3B	4B
(C) OCCASIONAL (10-2 > X > 10-3)*	1C	2C	3C	4C
(D) REMOTE (10-3 > X > 10-6)*	1D	2D	3D	4D
(E) IMPROBABLE (10-6 > X)*	1E	2E	3E	4E

* Example of quantitative criteria

Qualitative Matrix (-882D)

TABLE A-III. **Example mishap risk assessment values**.

SEVERITY PROBABILITY	Catastrophic	Critical	Marginal	Negligible
Frequent	1	3	7	13
Probable	2	5	9	16
Occasional	4	6	11	18
Remote	8	10	14	19
Improbable	12	15	17	20

Probability Levels (-882D)

- Frequent — more than 10^{-1}
- Probable — between 10^{-2} and 10^{-1}
- Occasional — between 10^{-3} and 10^{-2}
- Remote — between 10^{-6} and 10^{-3}
- Improbable — less than 10^{-6}

882D: Numbers are for individual item, not fleet

882C: Doesn’t specify

Origin of numbers?

- Done by committee (like a camel)
- Not enough probability levels to change single order of magnitude (skipped ahead from 10^{-3} to 10^{-6})
- Why 10^{-6}?
  - Originated in munitions world
  - Seemed ‘unapproachable. (‘Not one in a million!’)

Why 882E

- MIL-STD-882D complied with Acquisition Reform
  - Tells ‘what’ to do, not ‘how’
  - Specifies eight generic system safety steps
    - Have a plan
    - Identify hazards
    - Assess their risks
    - Take action on the risks
    - Accept residual risks
  - 882 D removed the 882C System Safety Tasks
  - Considered to be too ‘watered-down’
- We overdid it, so need a more robust standard

MIL-STD-882E Drafts

- Mid 2004, first draft MIL-STD-882E
  - Re-instated System Safety Tasks
  - Re-instated software criticality matrix
  - Changed Mishap Risk Assessment Value (MRAV) to Mishap Risk Index (MRI)
- Early 2005, Second draft
  - Add new Tasks on Safety Critical Functions and FHAs, etc
  - Re-instate Task usage matrices
  - Re-instate “F” probability level (designed out/impossible)
  - Revised the risk matrices
    - = $10K to $20K
    - = Expanded ‘Low risk range’

Next?

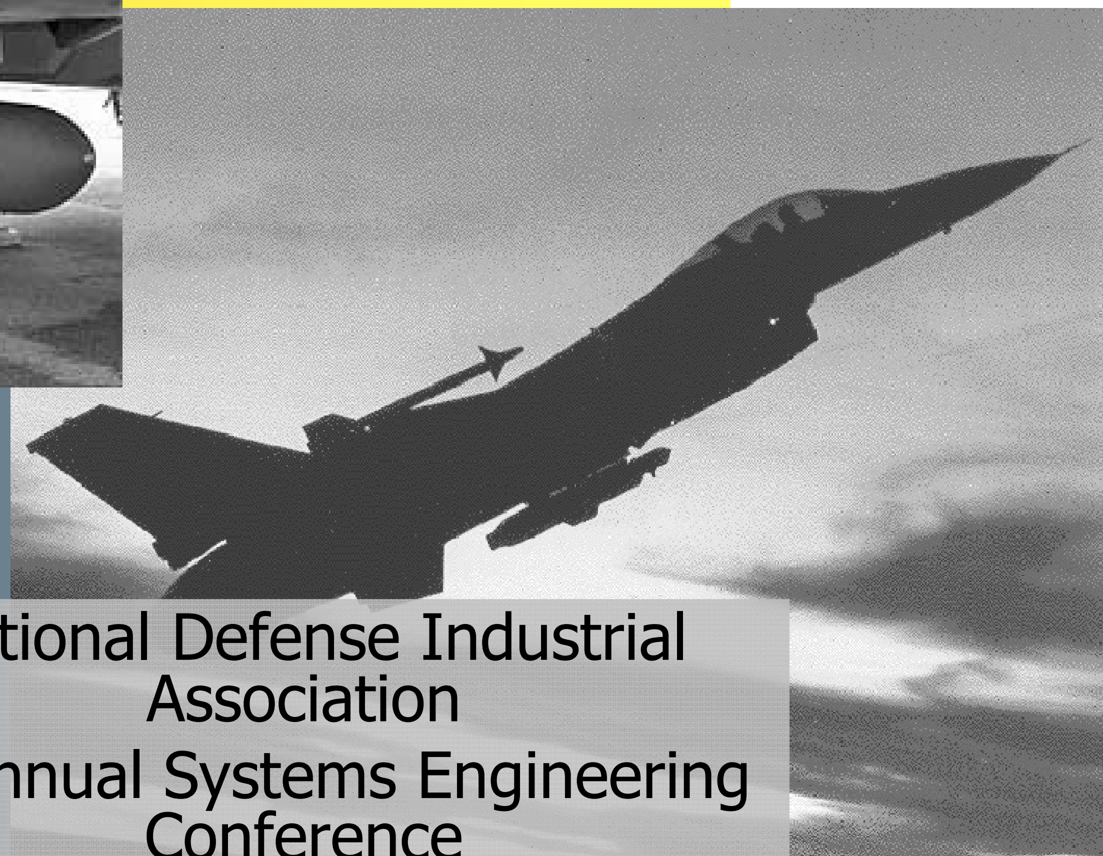
- Summer 2005, third draft
  - Re-structuring for better logic flow
  - Multiple risk matrices – upper <u>right</u> is High
  - New precedence step – added Engineering Safety Features

    (Examples include the emergency core cooling system of a nuclear reactor and loss-of-tension braking for elevators; full-time, on-line redundant paths; interlocks; ground-fault circuit interrupters and uninterruptible power supplies)
  - Five system safety 'Elements; instead of 8 Steps
- Being coordinated by GEIA G-48 (System Safety) Panel
- Publish, fall/winter 2005

Questions?

Jammer Integration Roadmap

(Unclassified)



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National Defense Industrial Association

8th Annual Systems Engineering Conference

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Integrated Platforms

- F-16C+
  - ANG
  - AFRC
- AO/A-10
  - ANG
  - AFRC
  - ACC

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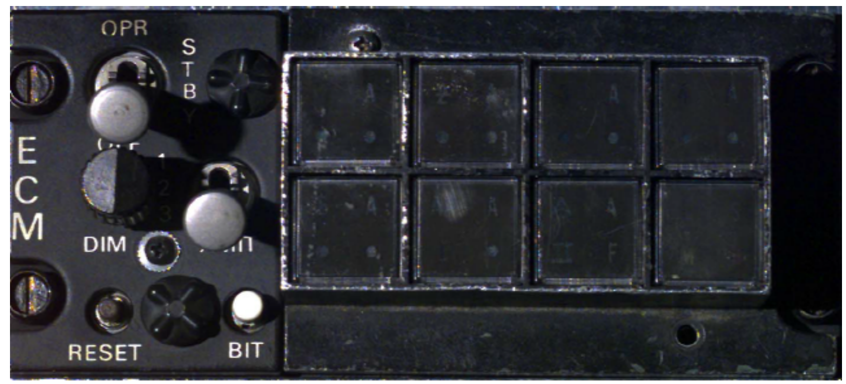
Out With The Old…

- The C-9492 is a Replacement for the C-6631 Analog Control Head
- The C-9492 Controls the ECM Pod via a 28V Discrete Power Signal, a Clock Signal, and a Pulse Position Data (PPD) line
- PPD is a Serial, Bi-Directional , Time Multiplexed Data Bus



…In With The New

- SWV 1.0B3 was the First Fielded Version of the ALQ-213 Software (1998)
- SWV 1.0B3 Supported the PPD Interface for the ALQ-131, ALQ-184, & ALQ-184(V)9 ECM Pods
- SWV 2.0B5 is Currently in Flight Test. This is the Introduction of the Threat Response Processor (TRP)
- SWV 3.0F of the ALQ-213 Begins the 1553 Integration Between the Control Head and the ECM Pods (2004)

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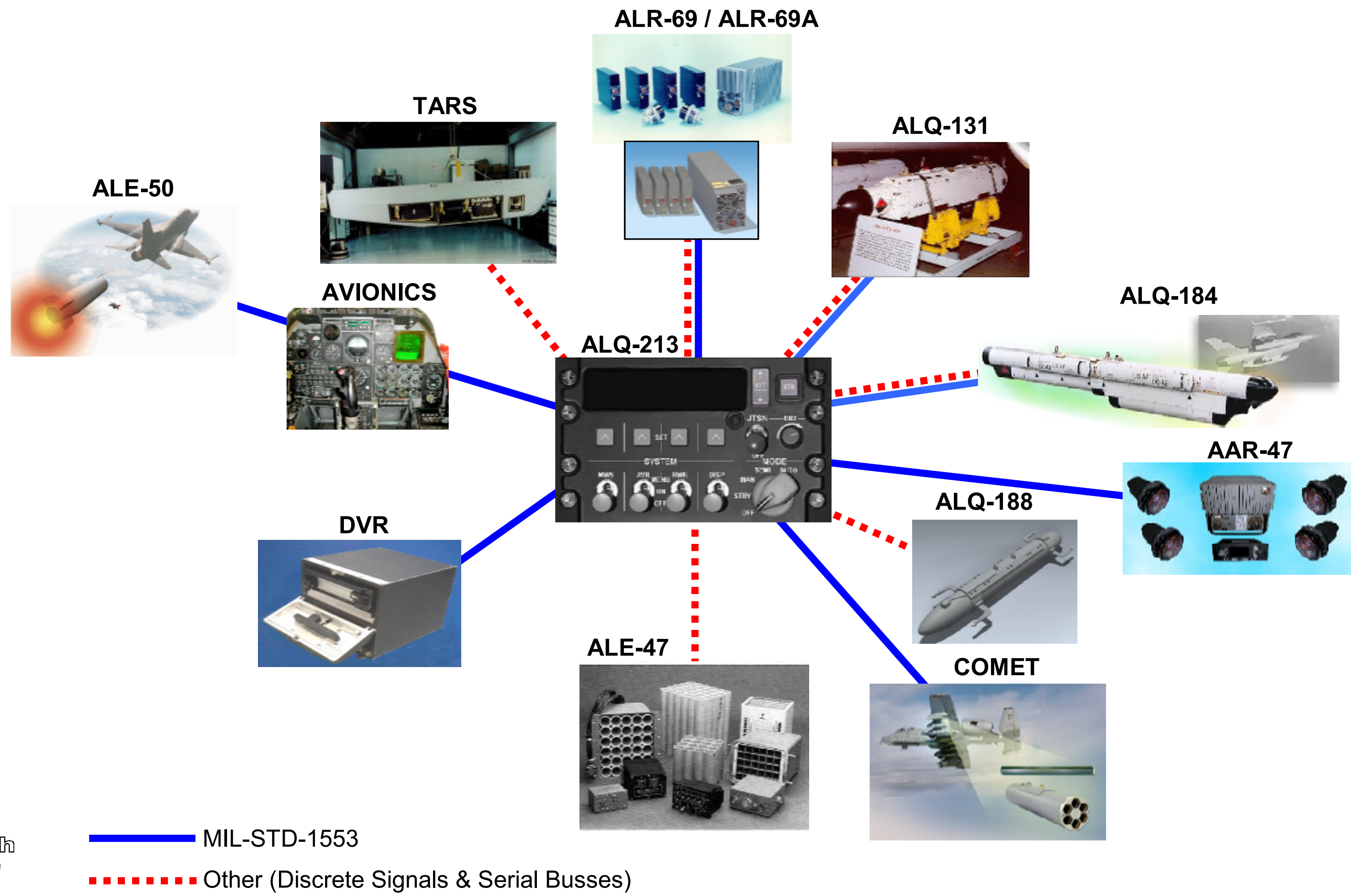
ALQ-213 Subsystem Control



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ALQ-213 SWV 3.0F

- Engineering Release I (3.0F1)
  - December 2004
  - Initial Polling of ALQ-131 1553 Data
- Engineering Release II (3.0F2)
  - May 2005
  - Initial Polling of ALQ-184
  - Introduction of ALQ-131 Status Reporting with 1553 Data
- Engineering Release III (3.0F3)
  - September 2005
  - Introduction of ALQ-184 Status Reporting with 1553 Data
  - Refinements made to ALQ-131 Status Reporting
  - Introduction of ALR-69/ALQ-131 Correlation

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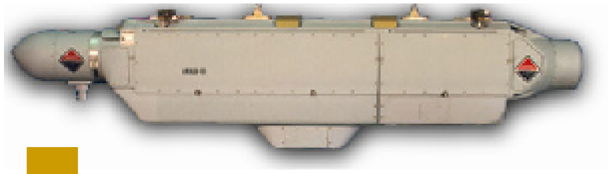
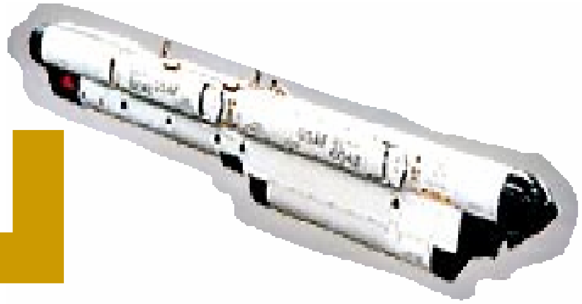
ALQ-213 Polling of Jammer Data



- Configuration
- Status
- Track Files
- Preset Jamming

ALQ-131



- Configuration
- Status
- Subband Freq Limits
- Pod Instrumentation
- Jamming Activity

ALQ-184

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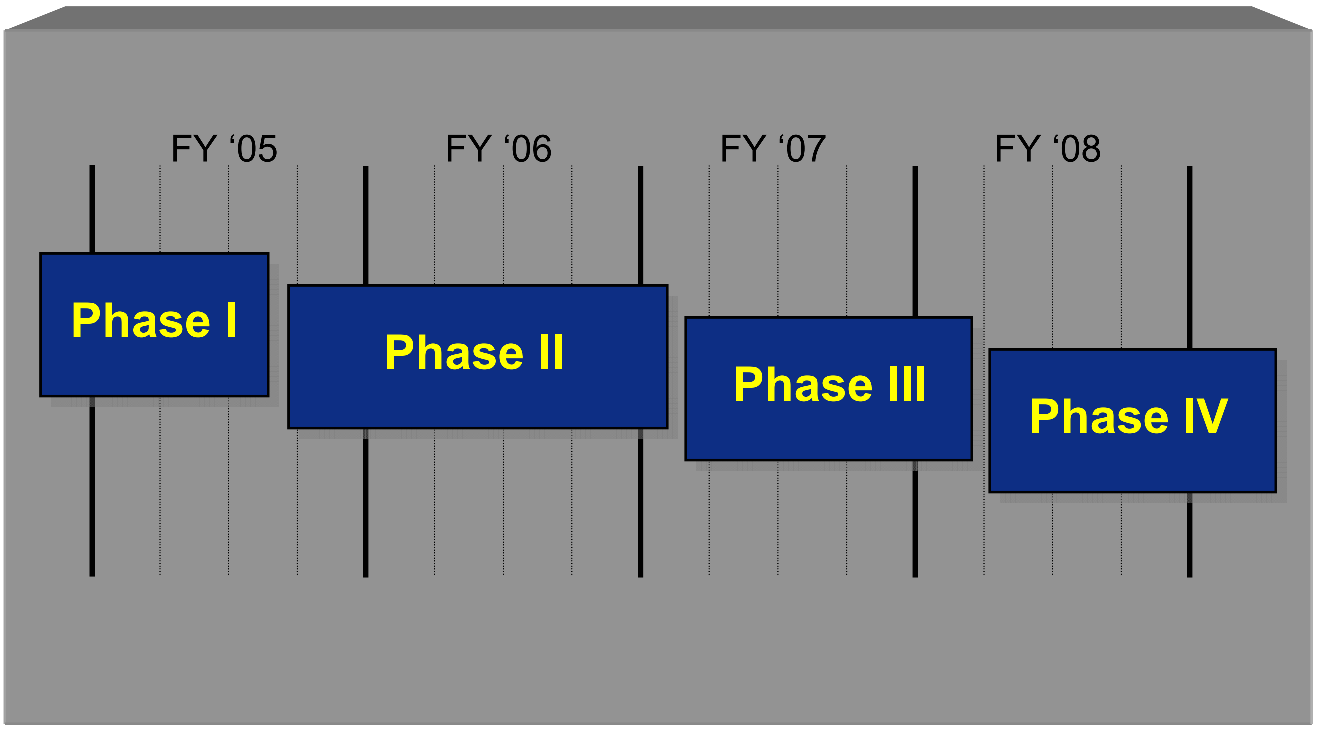
Jammer Integration Roadmap



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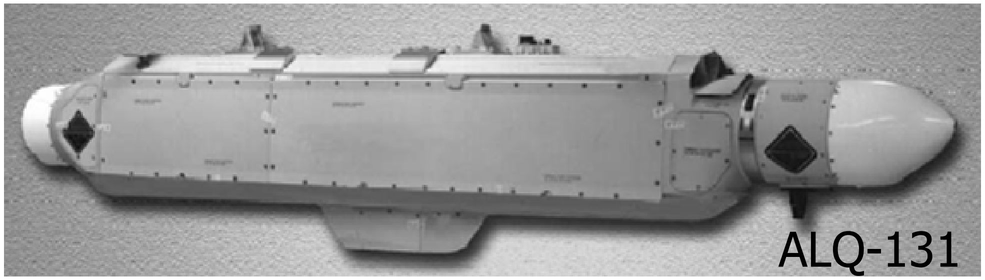
Phase I:

- Development and Installation of the 1553 Hardware Kits
- Definition of Interfaces
- Formation of Integration Working Group
- ALQ-213 Polling of Jammer Data
- Compliance with Defined 1553 ICDs



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Phase II:

- ALQ-213 Control of Pod Modes with 1553
- Correlate Threat Identification with ALQ-213
- Update Mission Data Tools for Correlation
- Increase Pod R&M Data for Post Mission Maintenance
- Coordinate Jamming, Dispensing, and Aircraft Maneuvers for Optimized Responses
- Incorporate Pod Reprogramming via 1553
- Provide Jamming Indication on ALR-69 Display

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Phase III:

- Incorporate Jammer Threat Identification to Resolve ALR-69 Ambiguities
- Remove Jammer Interference From RWR Display
- Optimize Jamming Response via ALQ-213 TRP
- Remove Jammer Interference From Fire Control Radar (FCR) Display
- Send Data to RWR for Direction Finding (DF)
- Incorporate Real-Time Pod Status for ALQ-213 TRP Compensation

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Phase IV:

- Incorporate Advanced Location Systems
- Optimize the Integrated EW Suite for Threat Identification and Warning
- Incorporate Advanced Chaff and Jamming Techniques
- Enable Cooperative Jamming with Multiple Jammers
- Incorporate Real Time Pod Status for Pilot Go/No-Go and Fault Analysis
- Provide Advanced ECM Techniques Directed by TRP

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Threat Identification for ALQ-213 Correlation

- Threat Identification will Lead to the Following Benefits:
  - Identification of Jammed Threats on RWR
  - Optimized Threat Response
  - Resolution of RWR Ambiguities
  - Declutter of RWR Display

BEFORE INTEGRATION

AFTER INTEGRATION

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Real-Time Pod Status for TRP Compensation

- 1553 Jammer Status Messages will Allow TRP to Select Jammer Techniques Based on the Specific Health of the Pod
- Current Functionality Only Allows the TRP to Base Decisions on Jammer Presets When the R/P is Non-Functional
- TRP Logic Must Consider “Age-In” and “Nuisance” Faults
- Refined Decisions can be Made by the TRP on a Band, Sub-Band, or Channel Level

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Advanced ECM Techniques

- Combining Jamming and Dispense Programs to Increase Survivability
- Critical Elements include: Timing, Order, and Resource Management by the ALQ-213
- Time Resolution of Combined Techniques is Critical When Transferring Between Jamming and Dispensing
- Examples: Illuminated Chaff, Terrain Bounce

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Questions?

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LOCKHEED MARTIN

Challenges in Development of System of Systems (SoS) Architectures in a Net Centric Environment

Abe Meilich, Ph.D., C.C.P.

Lockheed Martin Integrated Systems and Solutions

Net Centric Integration, System of Systems Engineering)

NDIA SE Conference October 2005

Agenda

- Challenges of Systems of Systems (SoS) Engineering – Implications on Scope and Management of the Net Centric, DOD Enterprise
- How to use DODAF to help create a SOA architecture
- SoS Interoperability
- Network Centric Operations Industry Consortium (NCOIC) support to SoS architecture standards

Some Observations on Architecting SoS

- "SoS [engineering] may not turn out to be primarily an engineering field."
- "Systems engineering is based on the assumption that if given the requirements the engineer will give you the system."
  - Source: "*System of Systems Symposium: Report on a Summer Conversation*", *November 2004*, Potomac Institute for Policy Studies.
- How do we set boundaries in order to create a defendable set of requirements?
  - Allow scope expansion but build a flexible interface specification according to requirements we need to vision today?
  - Hidden issue: What is context of data behind interface?
- Is the spiral approach low risk and the best approach?
  - Dependent on robust Infrastructure [e.g., GIG, NCES, NCOE, etc.] is in place, mission applications can evolve their functionality
  - Most likely, evolution through Darwinian survival will be the long term trend

Some Observations on Architecting SoS

- Static designs with well defined specifications worked very good in a stove-piped environment
  - Net Centric, flexible solutions can no longer follow this paradigm and expect to survive
- Optimality and efficiency is not as important as run-time interoperability with services that were not envisioned at design time - flexibility, compose-ability, extensibility are now much more important
- "…processes that have good asymptotic properties, and that can evolve to keep performing in unstable environments…"* are the properties that one really desires for longevity in hostile, asymmetric environments
- Will architecture frameworks like DODAF be sufficient to help us do this?
  - Growing recognition that DODAF (in its present form) is insufficient to capture the SoS emergent behavior - it probably shouldn't?
- The dynamics of cognitive and social processes do not obey static representations and rules of architecture

* *"System of Systems Symposium: Report on a Summer Conversation", November 2004,* Potomac Institute for Policy Studies.

Some Observations on Architecting SoS

- **It has been noted that the only way to really SE a SoS is to <u>experiment as the system evolves</u> as opposed to "design" the system.**
  - **"Rapid experimentation will be more effective than attempting to create a master plan for a complete solution."[1]**
  - **"… by asking and observing what people do and providing them with evolving prototypes, the architect can identify and validate what people find useful and therefore provides value to the enterprise." [1]**
- **Traditionally, single systems designed for specific context and specific missions; SoS has changing context and has to adapt to changing missions**
  - **Solution? Leverage Family of Systems (FoS) approach**
- **But – Can we afford its complexity?**
  - **Less expensive to spiral software than spiral physical systems**
  - **Can M&S save cost and will it be affordable for complex systems?**

1 Goodhart, Brian and McCabe, Rich. "What Is Enterprise Architecture?", SPC, 2004

Some observations on Architecting SoS

- **Systems tend to be architected based on workflow**
  - **Look at today's most popular enterprise architecting practices (i.e., engineer human processes similarly to any other system component: as sequences of actions with measurable inputs and outputs — that is, a *workflow)***
- **The precision and clarity of specification possible with this approach is necessary for hardware or software, but, as [Pajerek 2000] shows, is not terribly helpful for human only processes and easily becomes a drawback.**
  - **"Only the simpler, more straightforward processes lend themselves to a workflow treatment, and by and large, these tasks should be automated entirely to free up people to concentrate on the creative tasks where they are needed most."[1]**

[1] Pajerek, Lori. "Processes and Organizations as Systems: When the Processors are People, Not Pentiums." *Systems Engineering: Journal of the International Council on Systems Engineering* 3: (June 2000).

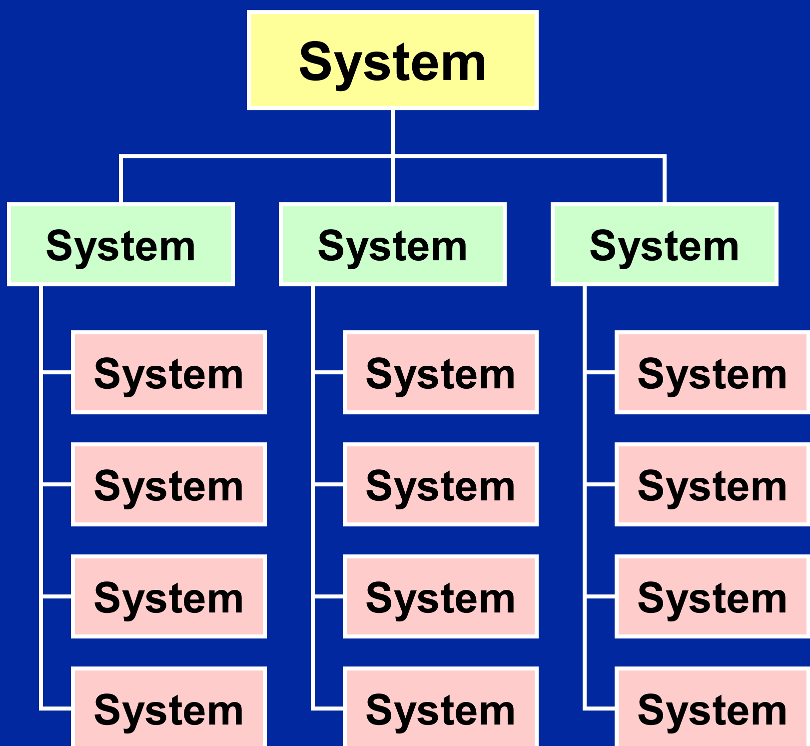
Some observations on Architecting SoS

- "…Most SoS problems involve open systems which lack a clear boundary. Our existing tool set mostly requires closing the problem by defining some boundary and assuming no surprises come from the outside..."
- "Better tools are needed by the SoS community …. While emergence has been a source of fascination for the complexity community for some time, we still do not know how to deal with emergent phenomena in a rigorous way."
- "A third challenge area is that of dealing with systems that include autonomous agents. At least part of the reason SoS differs from classically understood systems engineering is that all SoS-type networks necessarily contain people and perhaps other types of agents. The behavior of agents cannot be dictated by the engineer; agents can take on a life of their own, so to speak. This is one of the big reasons unexpected phenomena can emerge in SoS situations."

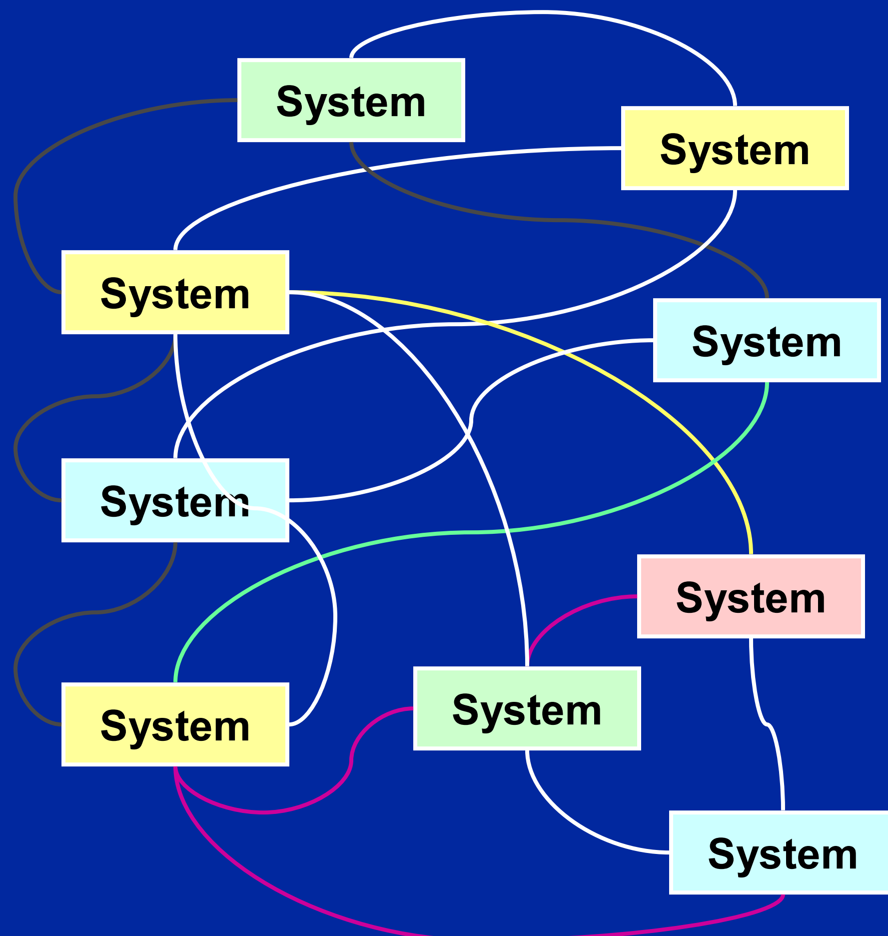
Source: "*System of Systems Symposium: Report on a Summer Conversation", November 2004,* Potomac Institute for Policy Studies.

SoS vs FoS

Hierarchy (SoS)

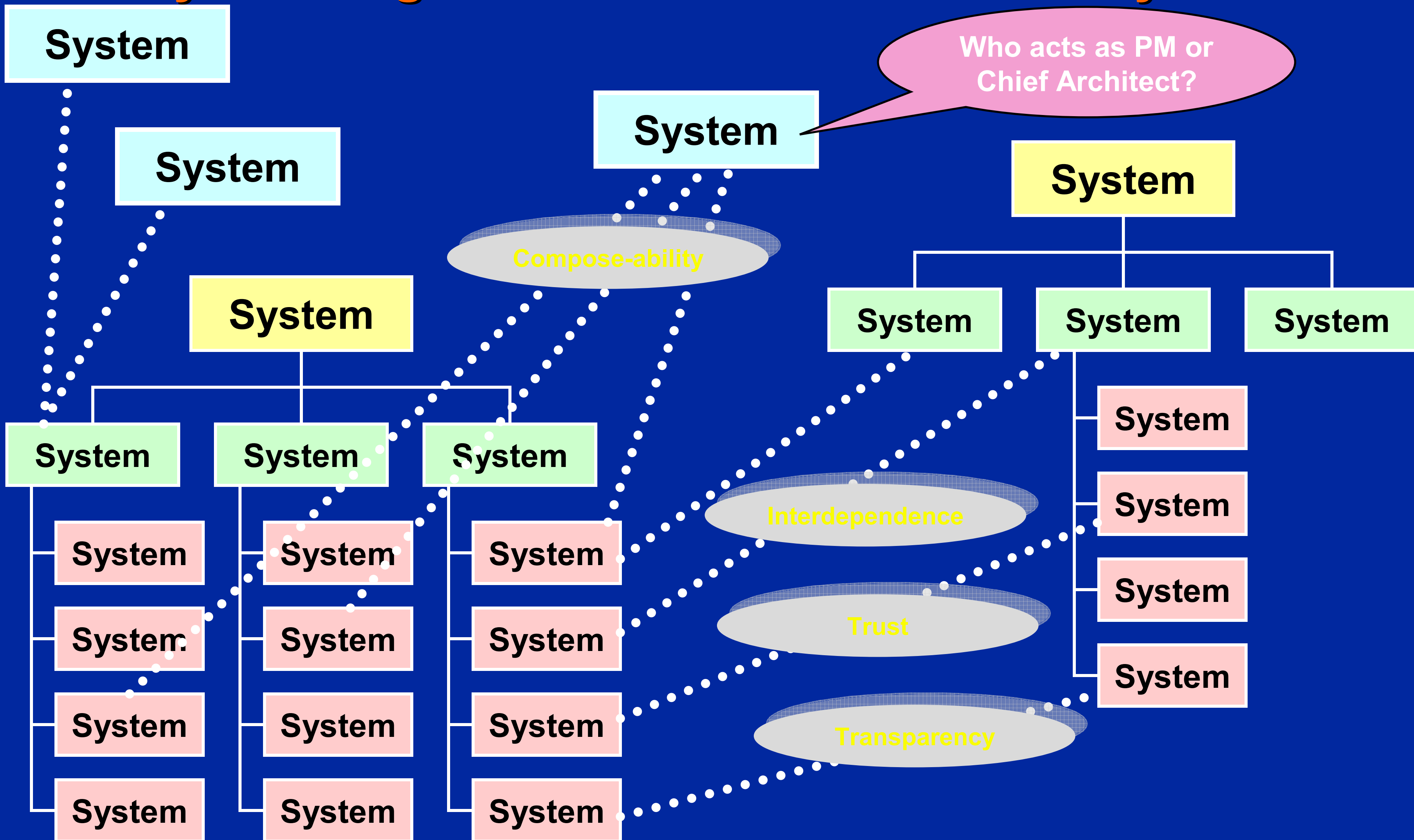


Networked Design (FoS) >> Run time SoS



Source: “Modeling and Architecture Considerations for Systems of Systems”, James Martin (Aerospace Corp) , 11 May 2004

In a NetCentric Environment >> Some Systems May "Belong" to More than One Parent System



Source: "Modeling and Architecture Considerations for Systems of Systems", James Martin (Aerospace Corp), 11 May 2004

Tiered Hierarchy of Architectures

TIER 0

National / Int'l Architectures
US, NATO, Other Countries

TIER 1

Department / Federal Architectures
DOD, IC, HLS, DOC, DOT, …

TIER 2

Cmd/Service/Agency Architectures
Air Force, Army, Navy, …

TIER 3

Mission Area / X-MA Architectures
Space, Wx, Combat Ops, Mobility, …

TIER 4

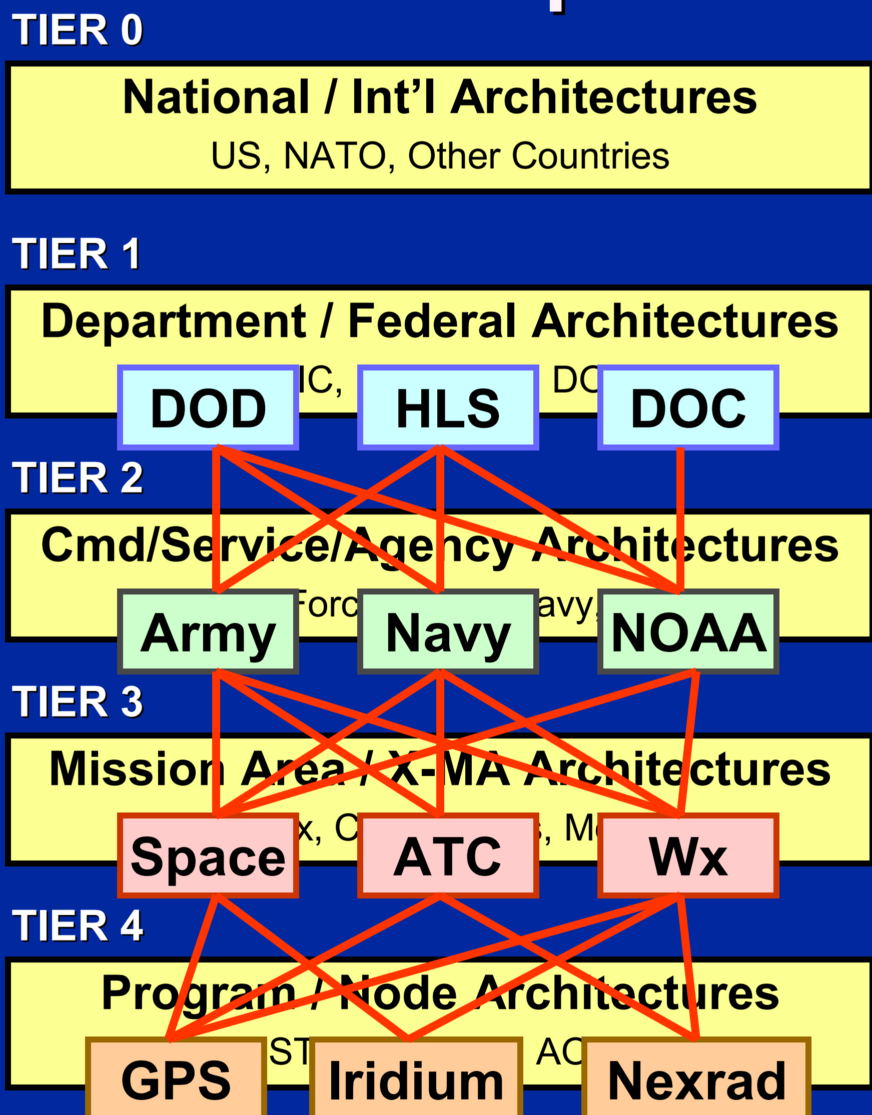
Program / Node Architectures
MILSTAR, AFSCN, AOC, …

Enterprise Architectures

Architectures for Mission Areas, Programs & Nodes & "Systems"

Source: "Modeling and Architecture Considerations for Systems of Systems", James Martin (Aerospace Corp) , 11 May 2004

Not Strictly a "Decomposition" Hierarchy



Department / Federal

Cmd / Service / Agency

Mission Area / X-MA

Program / Node

Source: "Modeling and Architecture Considerations for Systems of Systems", James Martin (Aerospace Corp) , 11 May 2004

Systems Exist at Different Levels

TIER 0

National / Int'l Architectures
US, NATO, Other Countries

- Unified Cryptologic Architecture
- National Security Space Environmental Monitoring System

TIER 1

Department / Federal Architectures
DOD, IC, HLS, DOC, DOT, …

- DOD Global Information Grid (GIG)
- Federal Enterprise Architecture (FEA)

TIER 2

Cmd/Service/Agency Architectures
Air Force, Army, Navy, …

- NSA Enterprise Architecture
- Air Force Enterprise Architecture

TIER 3

Mission Area / X-MA Architectures
Space, Wx, Combat Ops, Mobility, …

- Space Mission Area
- NOAA Observing System Architecture (NOSA)

TIER 4

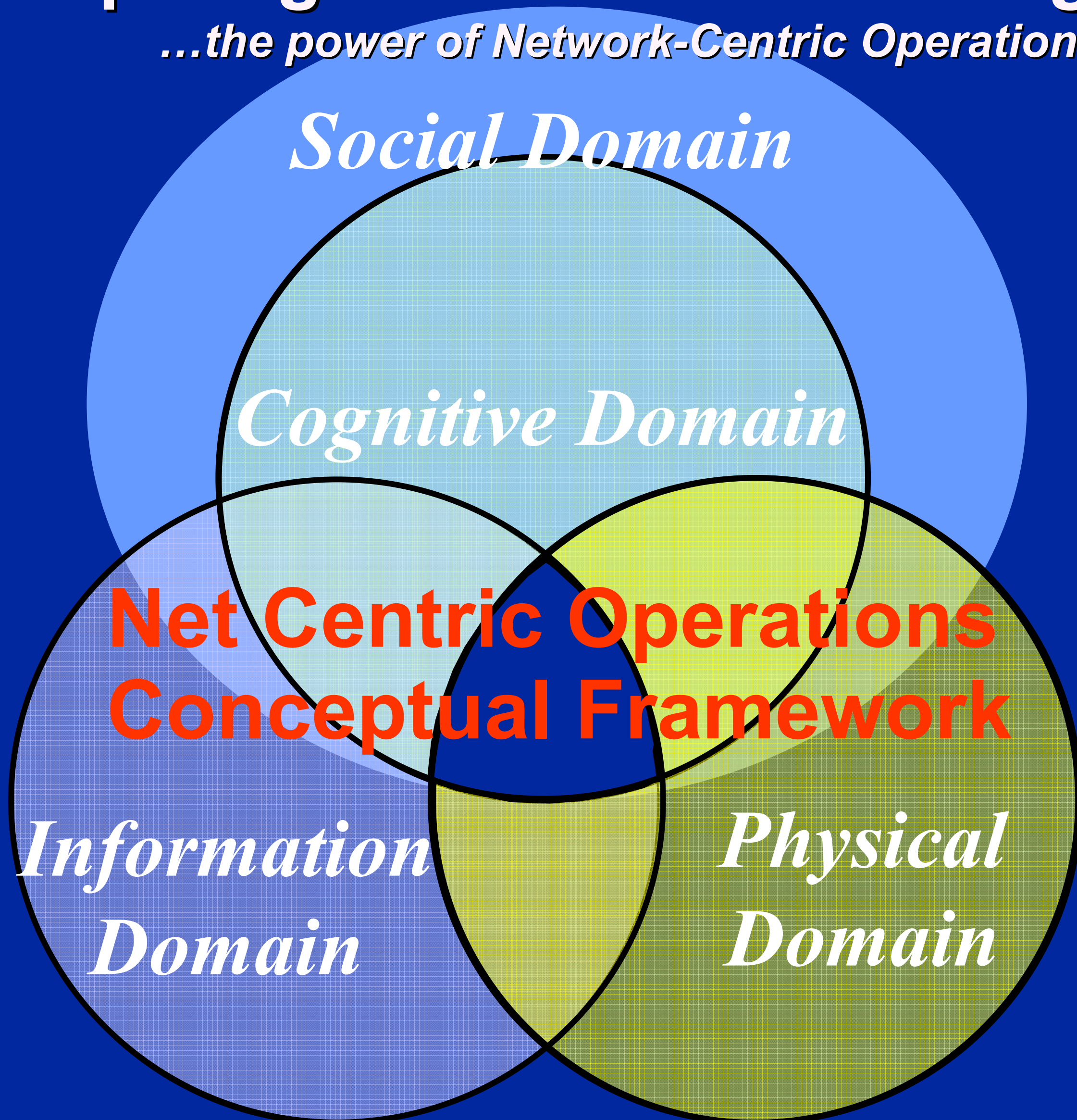
Program / Node Architectures
MILSTAR, AFSCN, AOC, …

- Integrated Overhead Sigint Architecture (IOSA)
- Future Imagery Architecture (FIA)

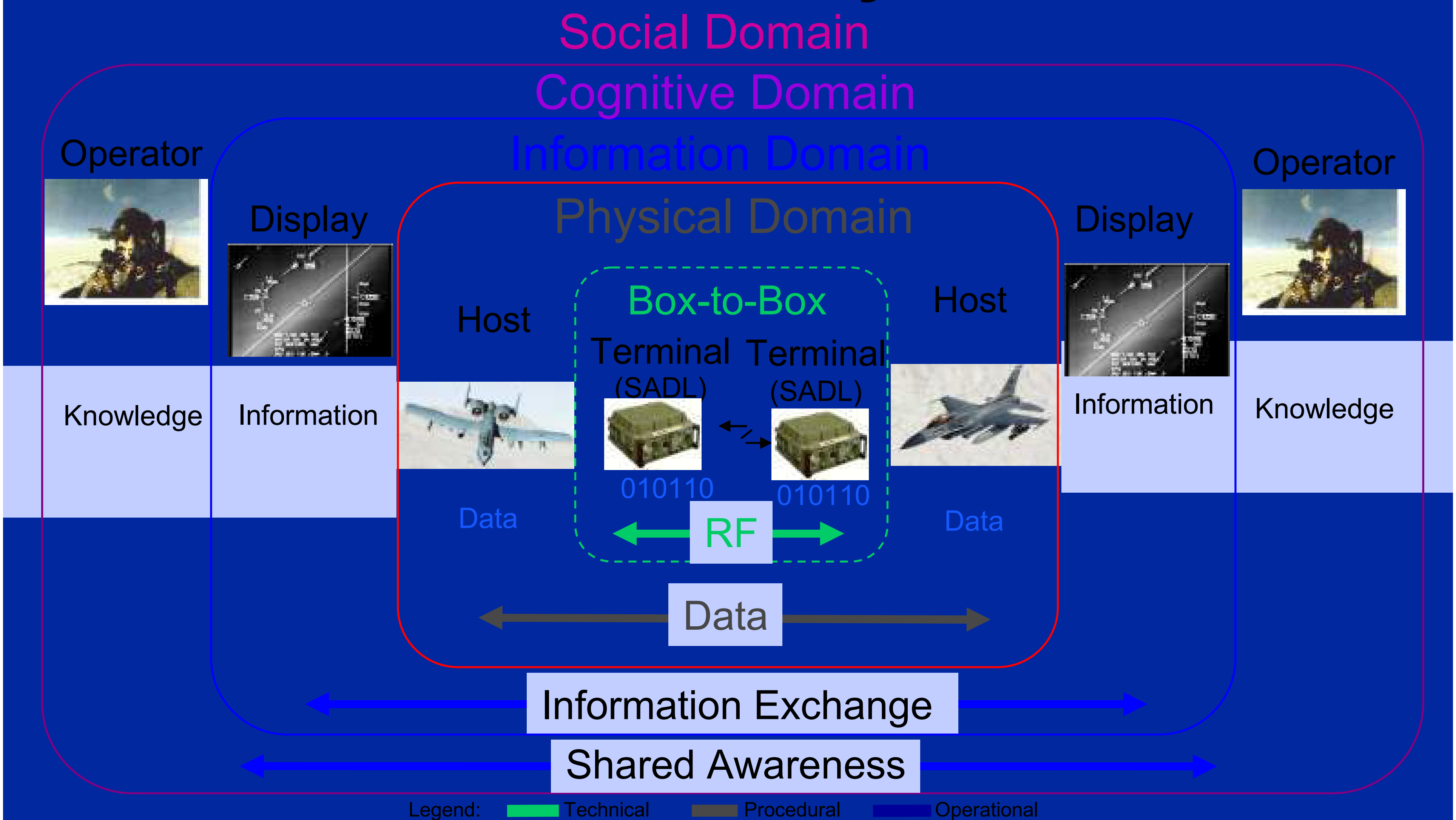
Source: "Modeling and Architecture Considerations for Systems of Systems", James Martin (Aerospace Corp) , 11 May 2004

Competing in the Information-Age

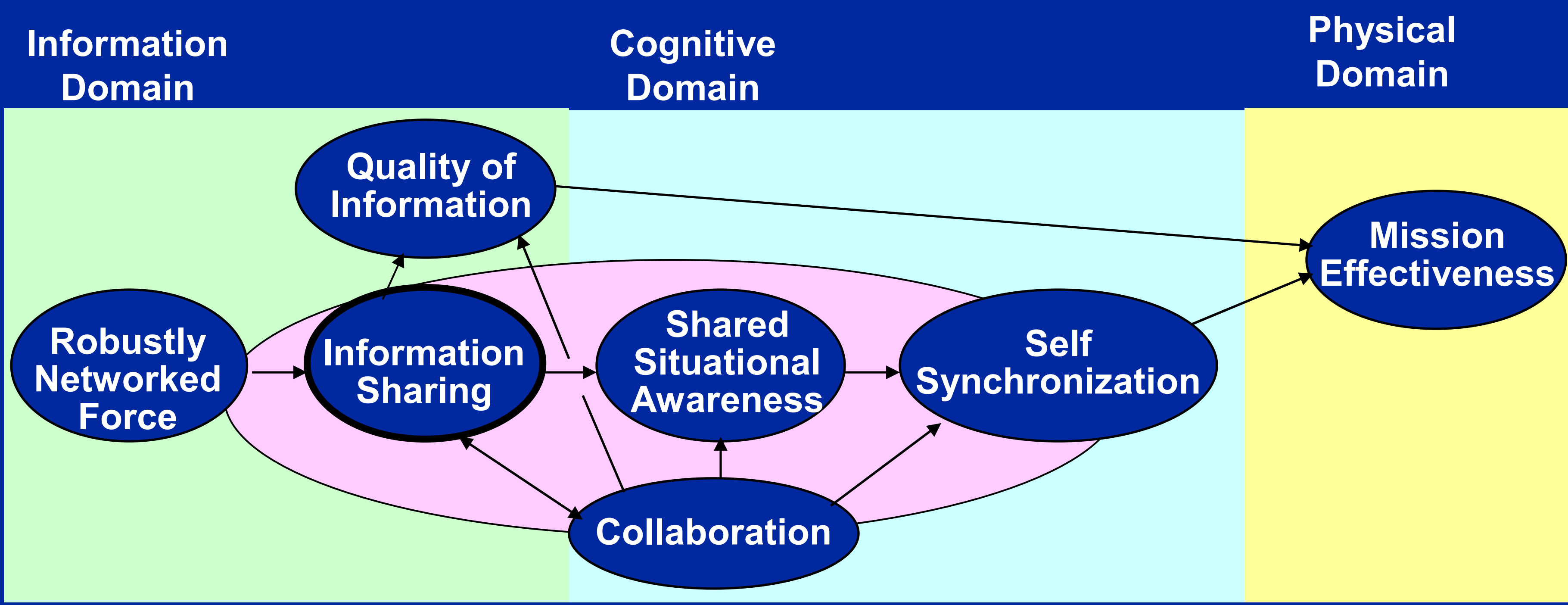
…the power of Network-Centric Operations



Close Air Support Mission: Domain Overlay



Linked Hypotheses: The NCW Value Chain



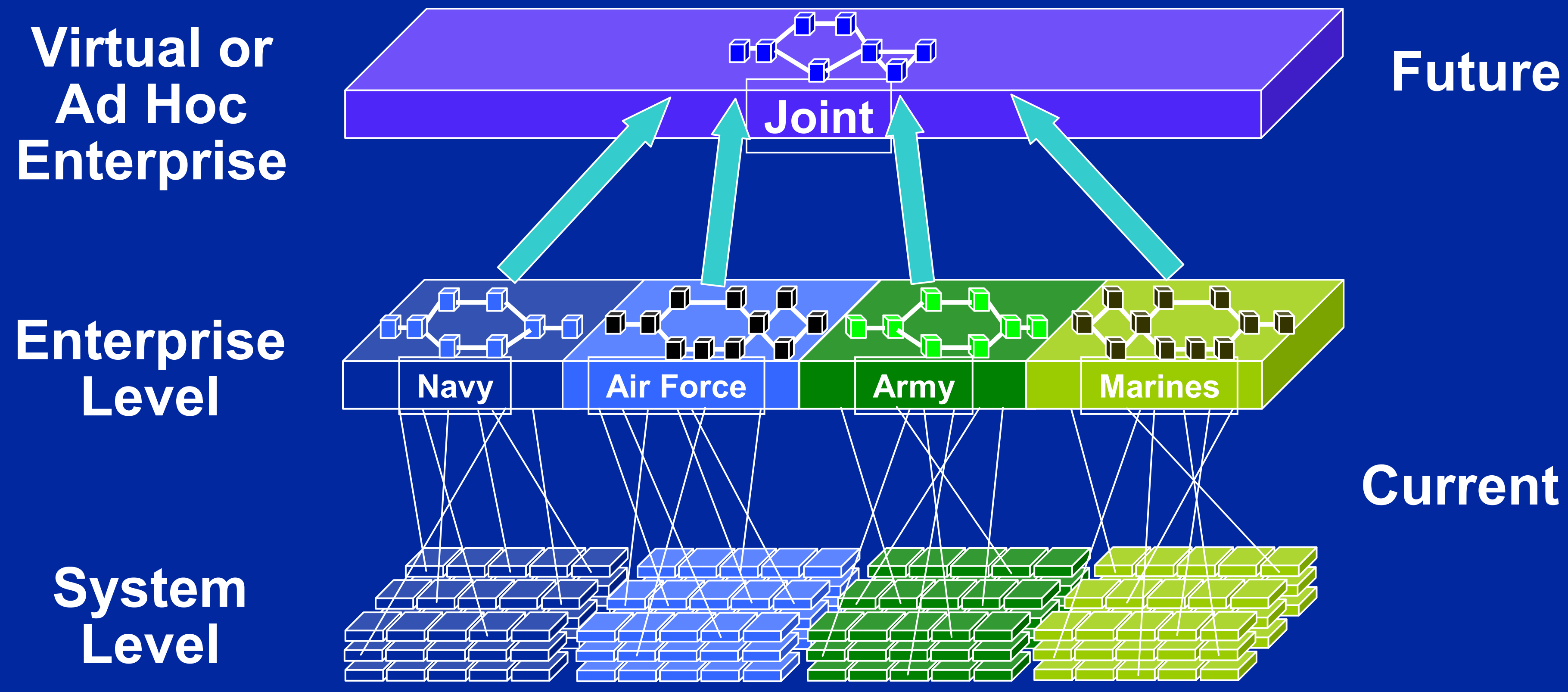
- Information Domain
- Cognitive Domain
- Social Domain
- Physical Domain

Implications for NCW SoS Systems Engineering

- **SoS Engineering is a consolidated discipline that borrows from:**
  - System Engineering (Physical and Information Domain; and Structured management of other disciplines)
  - Operational Analysis (All Domains)
  - Decision Analysis (Physical, Information, and Cognitive Domains)
  - Modeling and Simulation (All Domains)
  - Value Engineering (All Domains)
  - Cognitive Modeling (Cognitive Domain)
  - Collaboration Theory (Social Domain)

Implication: Training, competency, and domain knowledge beyond present common application of these disciplines

Vision for the Future



Determine how to use Service Oriented Architecture (SOA) concepts in support of achieving net-centricity in a multi-service environment

Source: "Developing Architectures in a Cross Service Environment" , Murray Daniels (MITRE) , 28 Sept 2004

Service Oriented Architecture (SOA)

Service-Oriented Architecture is architectural style whose goal is to achieve loose coupling[1] among interacting services[2]

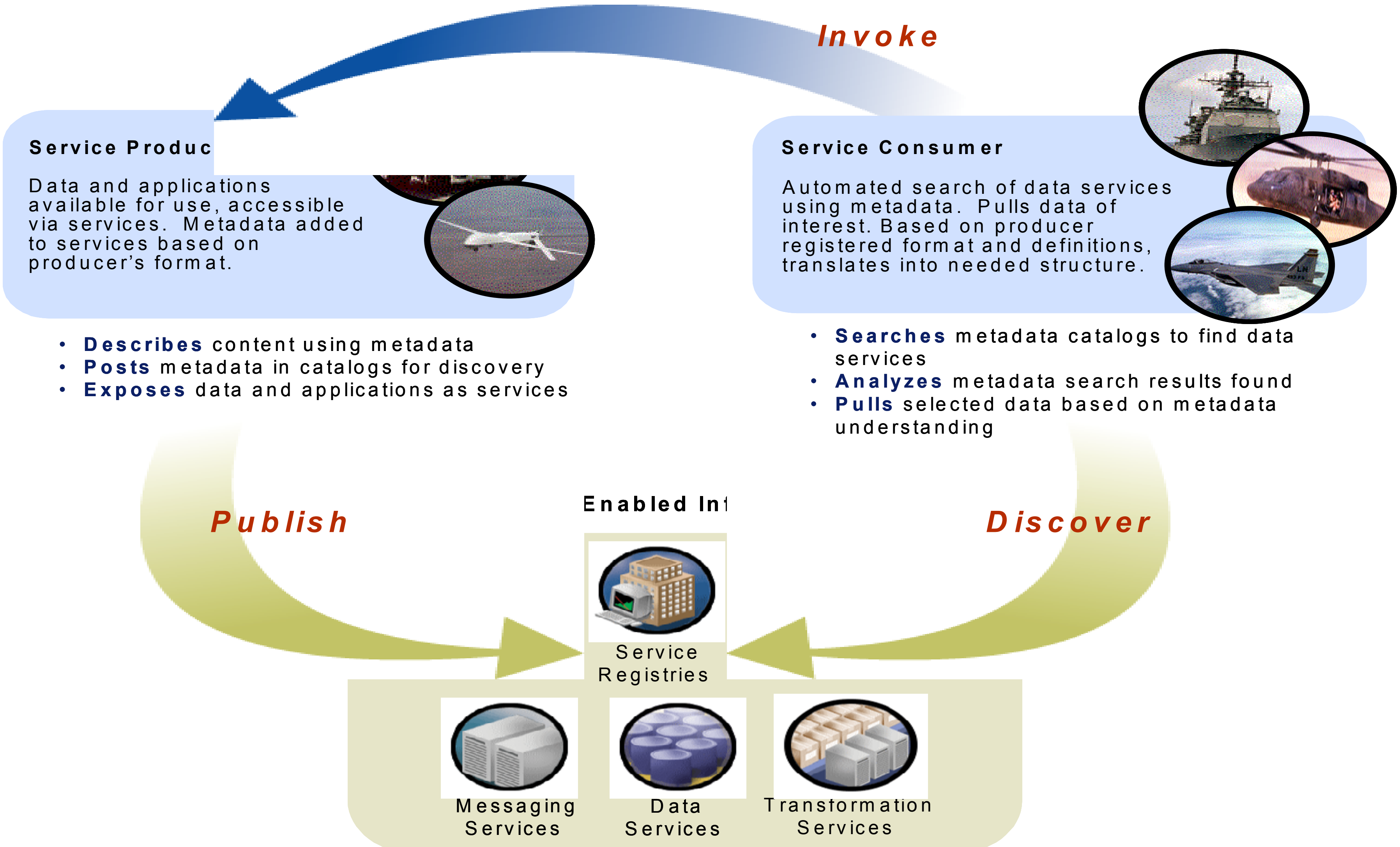
New set of Problems here

[1] Loose coupling describes the configuration in which artificial dependency has been reduced to a minimum

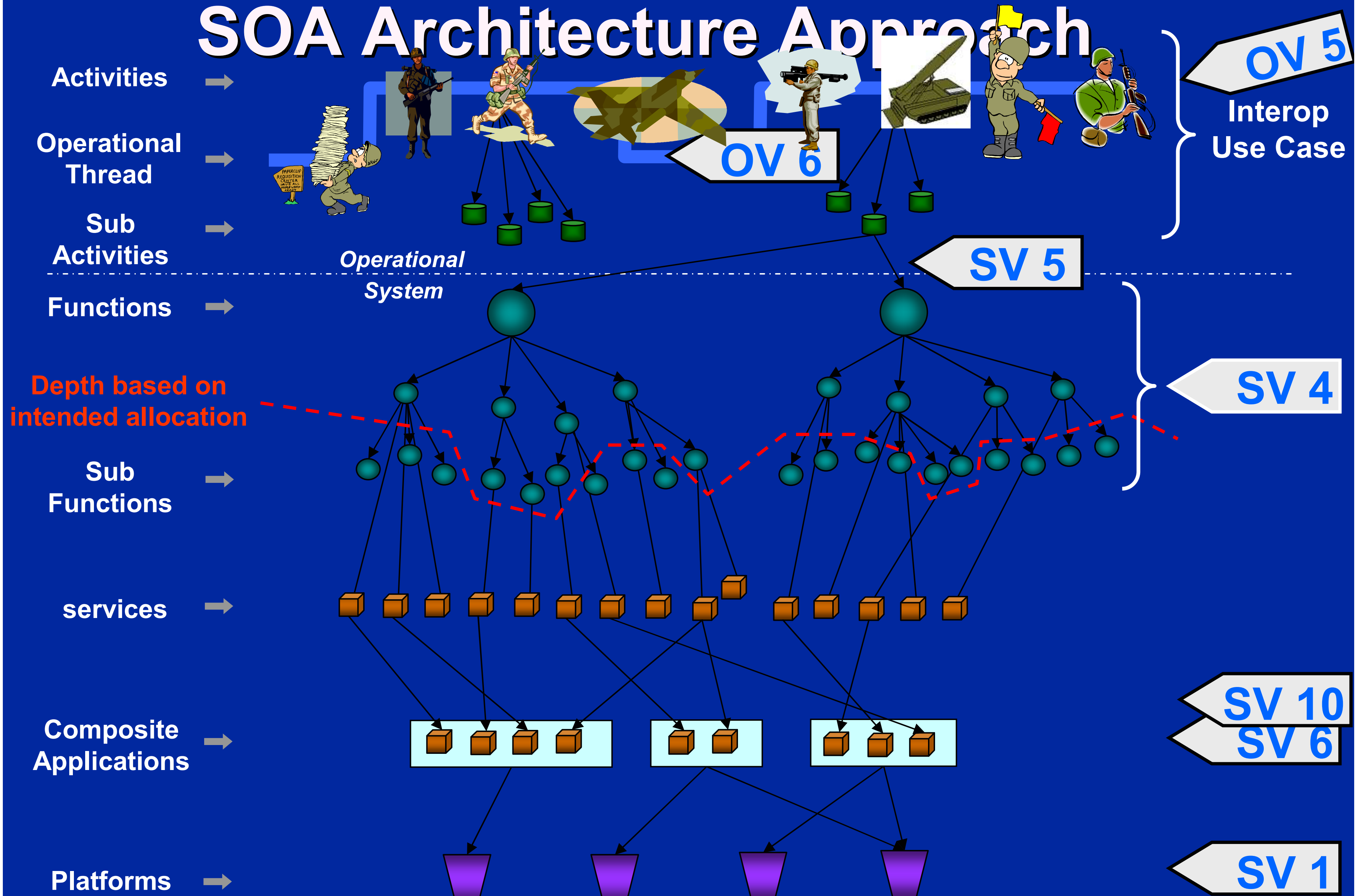
[2] A service is a set of actions that form a coherent whole for both service providers and service requesters

Robust Interface Definition and Access Required

Service Oriented Architecture

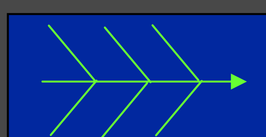


SOA Architecture Approach



Modified from: "Developing Architectures in a Cross Service Environment" , Murray Daniels (MITRE) , 28 Sept 2004

Example

Architecture data		Feeds	Service Arch
Activities	• Analyze Unplanned Immediate Targeting Opportunities - Build Watch List		Use Case, OV-5,6
		Mapping	SV-5
System Function	• Target Information Management - Target List Management		SV-4
Information Services	• Target List Management Service - addTargetsToList - isTargetInList		SV-10, SV-6
Platform Allocation	• Target List Service allocated to (e.g. AOC, JSTARS, …)		SV-1
Roadmap			Roadmap

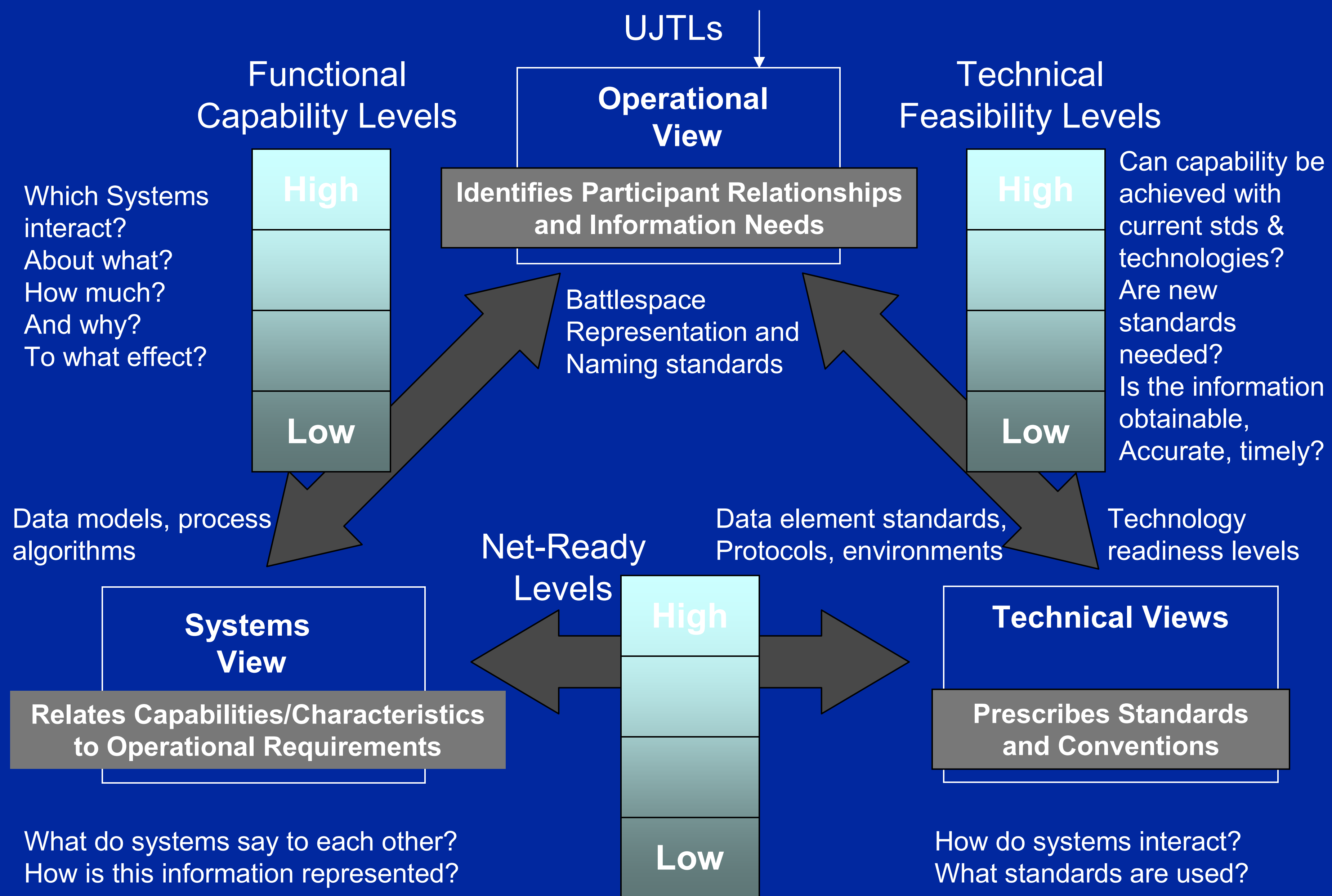
AV-2

Source: "Developing Architectures in a Cross Service Environment" , Murray Daniels (MITRE) , 28 Sept 2004

Growing Importance of Interoperability

- Network Centric warfighting concepts push systems towards greater interaction (and dependency!)
- Advent of the GIG increasingly makes systems accessible to one another
- Growing experience with coalition operations drives coalition interoperability
- Commercial adoption of the Internet increases customer “sense of the possible”

DODAF Views and Interoperability Assessment Criteria



How should we tackle the SOS SE future?

- **Process**
  - **Update our SoS SE processes for a NC environment to guide us internally (within our companies) and externally (e.g., for DOD: JCIDS 3170, DODI 4630, DOD 5000.2, etc.)**
  - **Share ideas presented here and conduct further research in SoS SE, SoS Architecture development and SoS/FoS utilization**
    - » Business Model - Openness must be balanced with competition

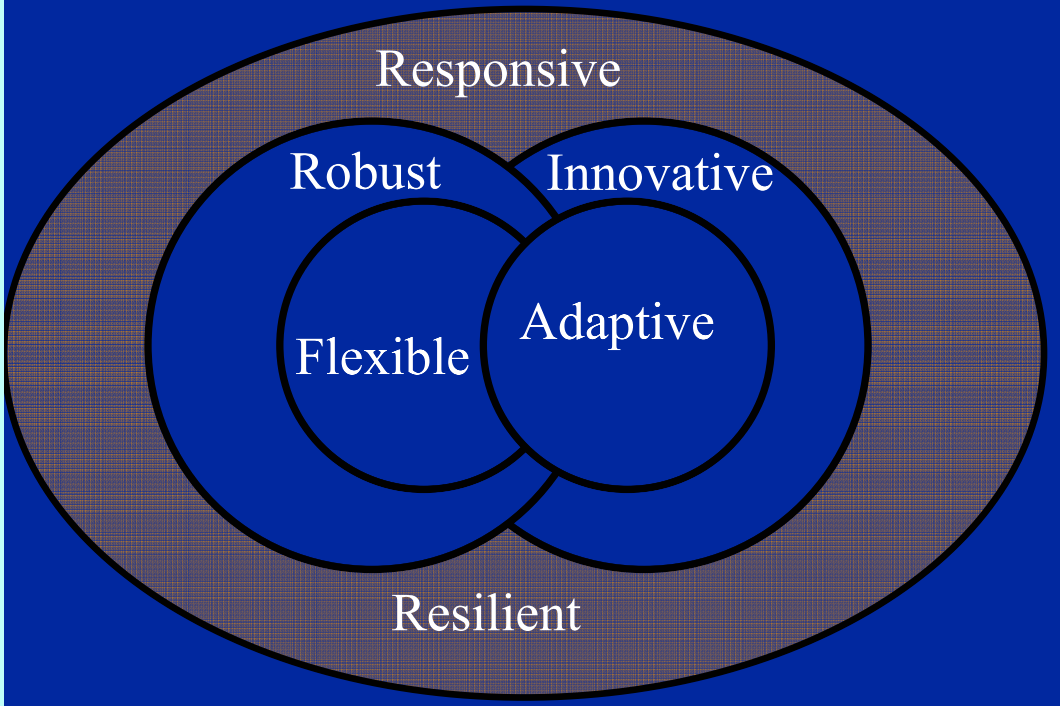
How should we (DOD and Contractors) tackle the SOS SE future?

- **Implementation**
  - **Participate in evolving Consortiums (NCOIC, W2COG, NCOIF, etc.) that will help set standards for architecture and systems/services development on the GIG, for example:**
    - » NCOIC –[www.ncoic.org]
      - – NCOIC Interoperability Framework (NIF) WG
        - • NIF defines the applications, data, and communications elements required to design and evaluate Network-Centric Systems with respect to interoperability
      - – NetCentric Analysis Tool (NCAT) WG
      - – Services and Information Interoperability WG
      - – Others

Agility

- **21st Century Security Challenges characterized by huge amounts of uncertainty and risk**
- **Agility is the answer to uncertainty and risk**

***Robust* -** effective across a range of conditions;
***Resilient* –** able to function / degrade gracefully / reconstitute when damaged
Responsive - speed of recognition and action;
Flexible - multiple ways to succeed, seamless shifting;
Innovative – learning and solving
Adaptive – alteration in C2 organization and process.



Summary

- Challenges to Integration of FoS into SOS architectures
  - Complexity
  - Dependency
  - Emergent Behavior (tradeoff flexibility and compose-ability versus predictability)
  - Collaboration

- Web Services and SOA are not the only solution
  - (e.g., some Sensor to Shooter pairings)

- The key to implementation success
  - New and evolved services must be easy to use and very quick to train – change is a constant in this equation
  - Quickly discoverable services on the GIG - the Operator will require time-sensitive information superiority on the battlefields of the future
  - Agility is the preferred MOE

Goal: Embrace, Manage, and Hide Complexity of SoS – Maximize Flexibility and Ease of Use for the User

System Engineering Metrics

26 Oct 05

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Why Measure Systems Engineering?

- When performance is measured … performance improves
- When performance is measured and reported … the rate of performance improves
- When performance is measured, reported, and compared … the rate of performance continues to improve

Problem

- Sys Eng Scope is Huge, So …
  – What tenets should be measured?
  – What are the key characteristics?
  – How can it apply across different programs and organizations?

- Sys Eng Important, But …
  – No accepted, standard metrics
  – No measure of sys eng current status
  – No metrics for both PM and upper management

Sys Eng Metrics Key Characteristics

- Must Measure Major Components of Sys Eng
- Must Be Targeted for Management
- Must Be Few in Number
- Must Describe Current Status, Not Lagging
- Must Allow For Comparison Between Programs, Organizations, and Time
- Must Be Cumulative (Ability to Roll-Up)
- Must Avoid Extensive Data Collection Efforts

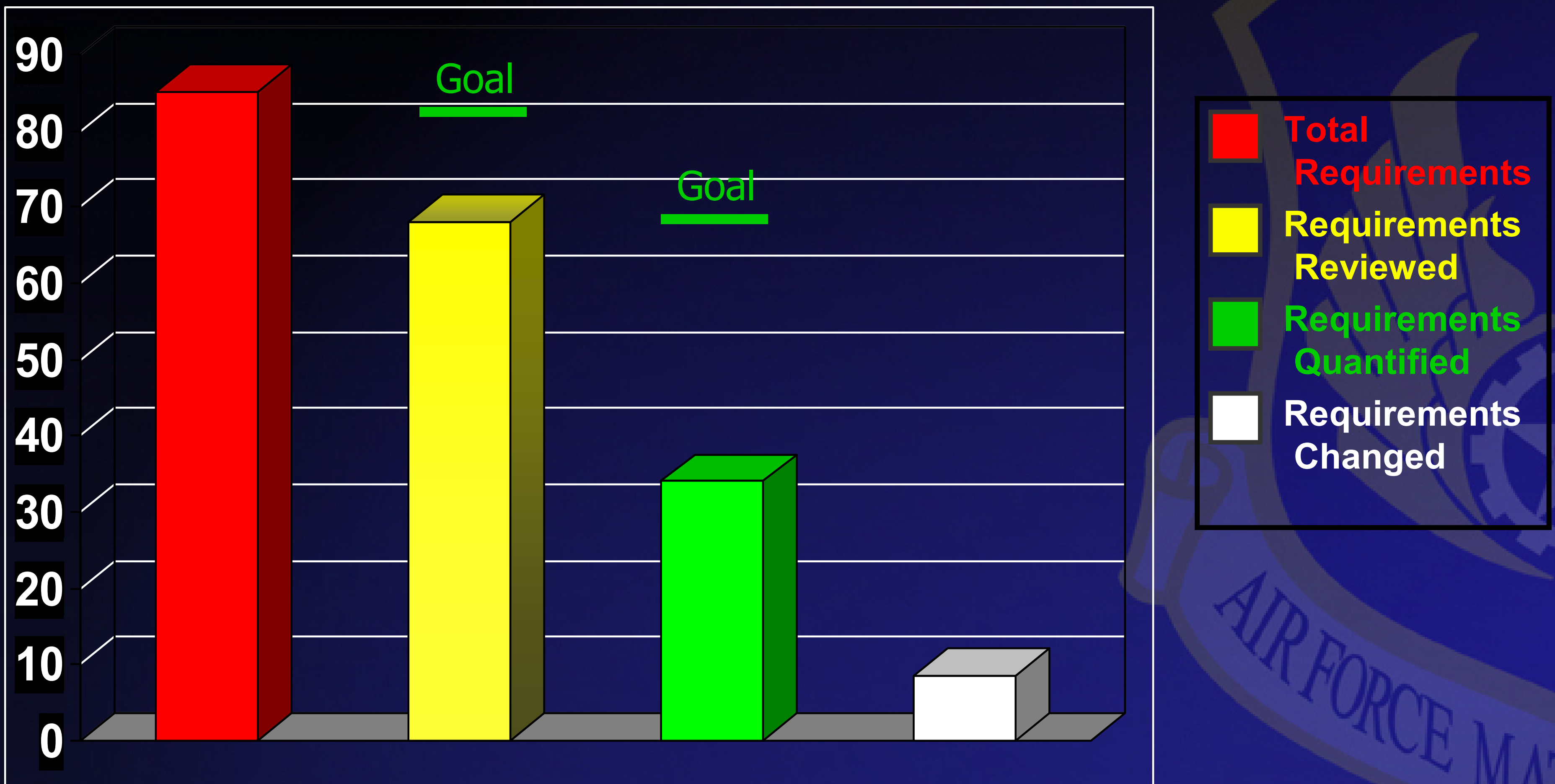
Solution: Sys Eng "Dashboard"

- Measure Five Key Areas of Sys Eng:
  - Requirements Management
  - Risk Management
  - Incentivizing Contractors
  - Robustness/LCC
  - Process Management
- Used on All Programs
- Regularly Shown at Organization Staff Meetings

1. Requirements Management Metric

- Most Important Area
- Quantify, quantify, quantify
- Level of Detail
  - Appropriate to Life Cycle
  - Examples
- Objective Review
- Agreement & Understanding
  - User
  - Contractor
  - Program Manager
- Sources

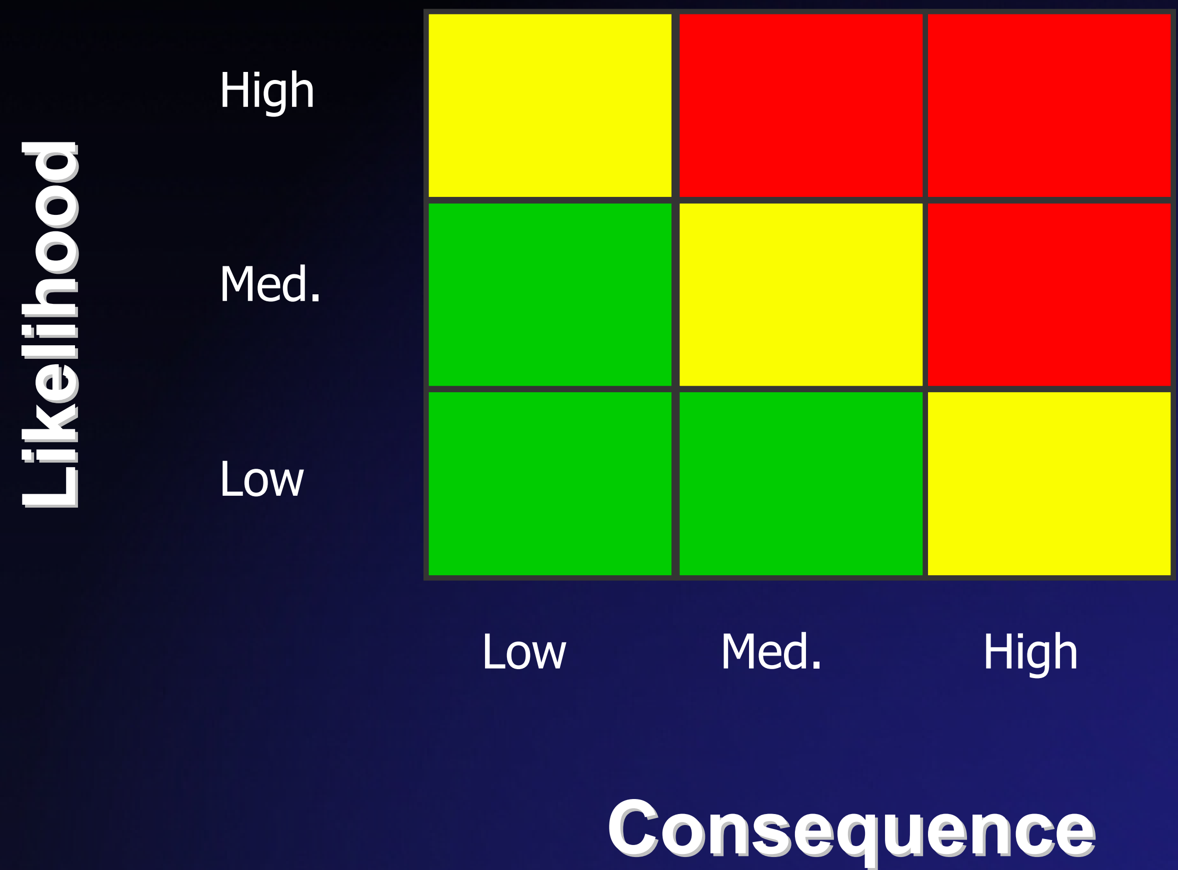
Requirements Management Metric



2. Risk Management Metric

- Proactive
- Dynamic
- Reviewed Regularly
- Tangible Reduction Plan
- Tracked

Basic Risk Rating Chart



RISK ASSESSMENT

HIGH - Unacceptable. Major disruption likely. Different approach required.

MODERATE - Some disruption. Different approach may be required.

LOW - Minimum impact. Minimum oversight needed to ensure risk remains low.

Risk Assessment Metric

Likelihood	Consequence: Low	Consequence: Med.	Consequence: High
High	0	4	2
Med.	6	1	4
Low	3	4	3

# of Risks
10
4
13

Risk Management Metric

Likelihood	Low	Med.	High
High	0	2/4	1/2
Med.	1/6	0/1	3/4
Low	1/3	2/4	2/3
	Consequence		

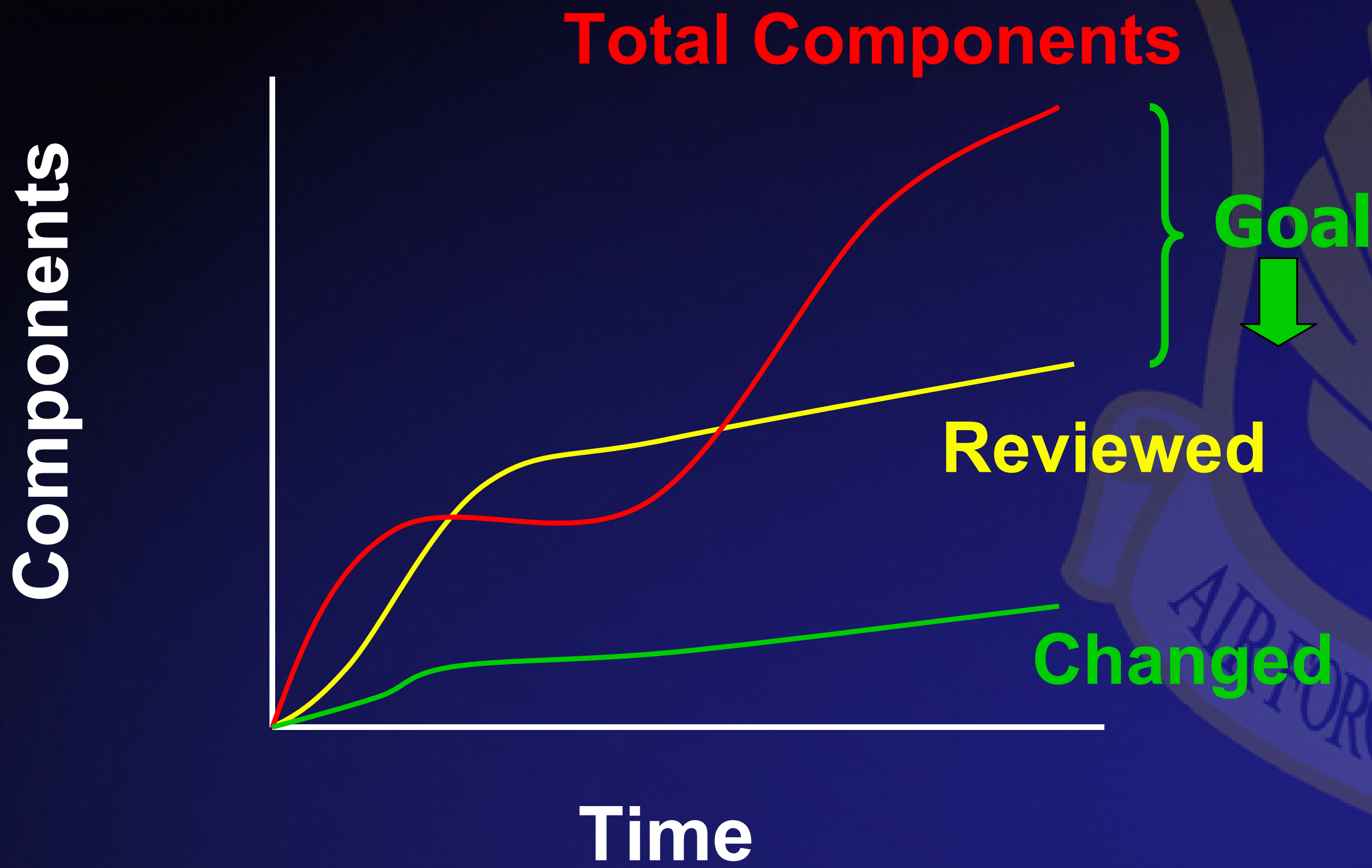
% With Plan

Red	60%
Yellow	50%
Green	30%

3. Robustness/LCC Metric

- Hard to Measure
- Measures More the “Attempt” or Effort
- Can Include Underlying Processes
  - Example: Type of paint <u>or</u> the paint application process
- Need “Toolbox” Vice One Approved Way
  - Lean processes
  - Trade studies
  - Benchmarks
  - Combining components
  - COTS
  - Paredo Charts
  - Etc.

Robustness/LCC Metric



4. Incentivizing Contractors Metric

- Required for USAF by Policy
  - Policy Memo 03A-005, 9 Apr 03
  - Subject: “Incentivizing Contractors for Better Systems Engineering”
  - Signed by Marvin R. Sambour, Assistant Secretary of the Air Force (Acquisition)

- “A more robust SE environment can only be achieved through joint cooperative efforts with our contractors.”

- “…incentivize your contractors to perform robust SE…”

Incentivizing Contractors Metric

% of Contracts with Sys Eng Incentives

5. Process Management Metric

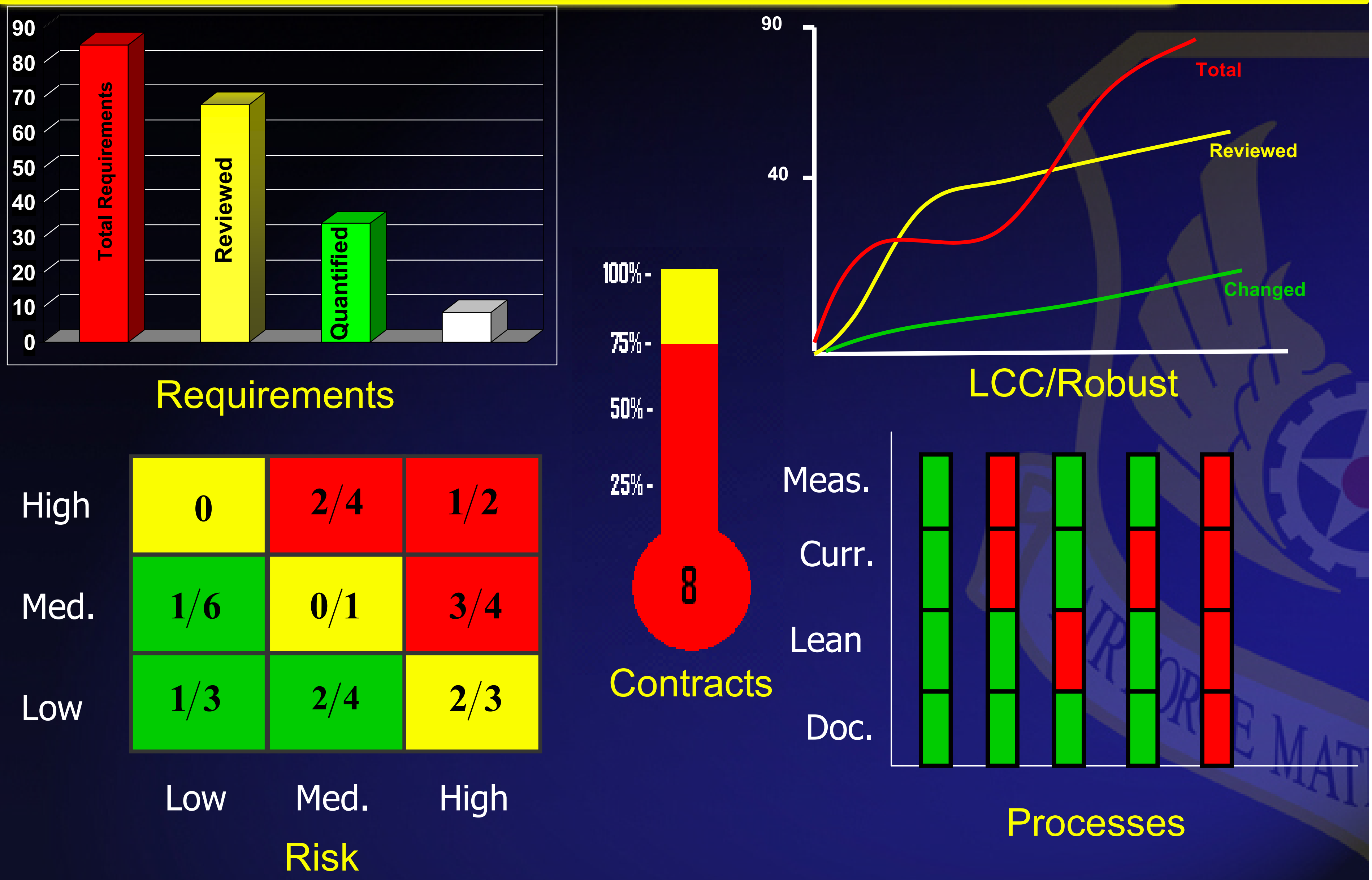
- List Program’s Key Processes
  - Configuration Management
  - Waivers
  - Quality
  - Aircraft Structural Integrity Program
  - Deficiency Reviews
  - Etc.
- Each Program Does Own Processes
- For Each Process, 4 “Steps”
  - Define & Document
  - Lean, Improve or Refine
  - Keep Current by Periodic Reviews
  - Measure the Process

Process Management Metric

Program Sys Eng Dashboard

- Developed Individual Metrics for the Five Key Areas of Systems Engineering:
  - Requirements Management
  - Risk Management
  - Incentivizing Contractors
  - Robustness/LCC
  - Process Management
- Now Put it All Together For the Proposed Program's Sys Eng Dashboard…

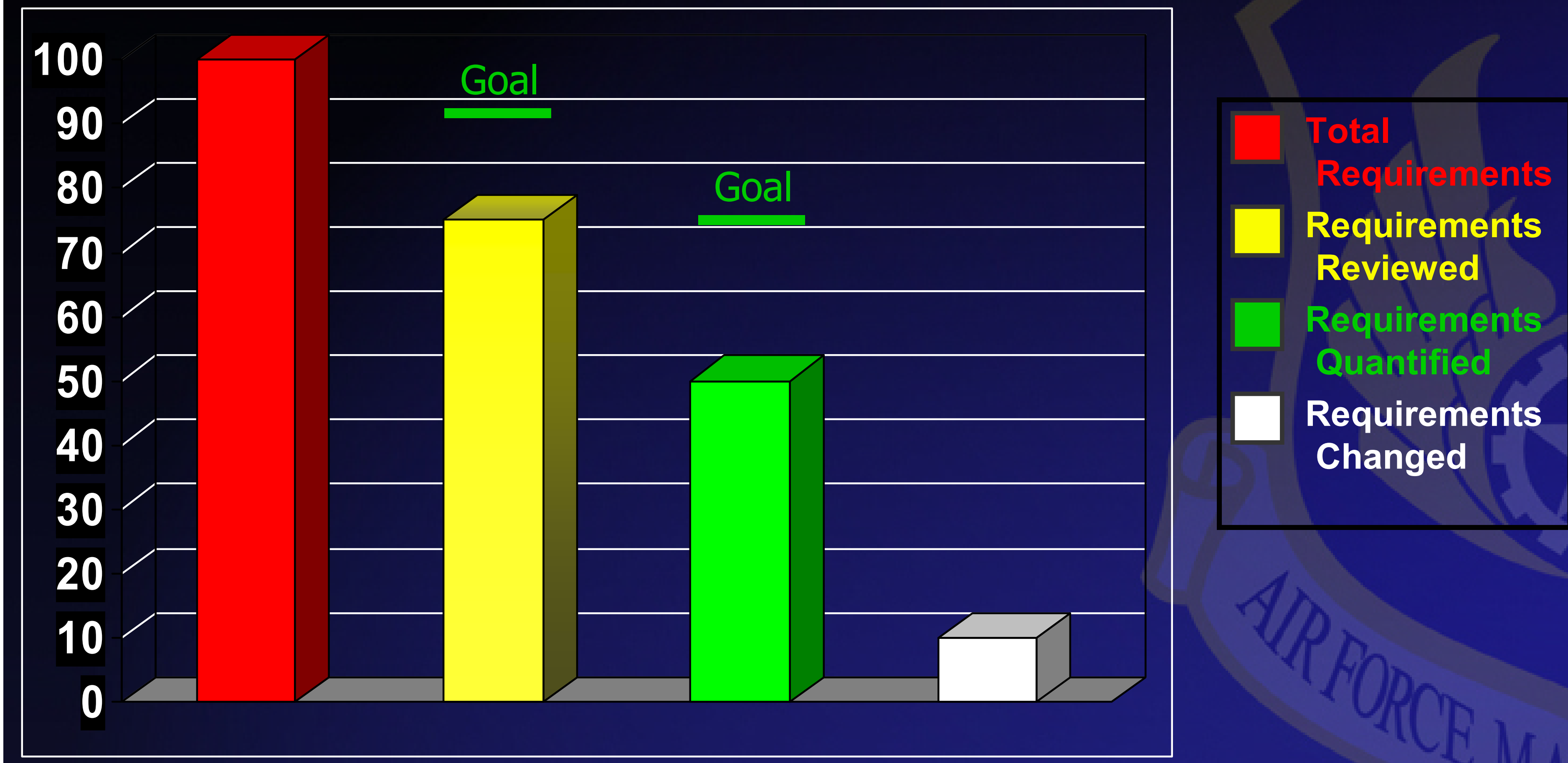
Program Sys Eng Dashboard



How to Roll-Up from Program to Organization

- Requirements Management
  - Convert each program to a percentage
  - Display average (each program has equal weight)
- Risk Management
  - Convert each program “square” to percentage
  - Display average “square’s” percentage (equal weight)
- Incentivizing Contractors
  - Bottom number equals sum of contracts
  - Depict percentage of contracts (program independent)
- Robustness/LCC
  - Calculate reveiwed/changed as a percentage
  - Display avg percentage (equal weight)
- Process Management
  - Depict overall percentage for each category (process/program independent)

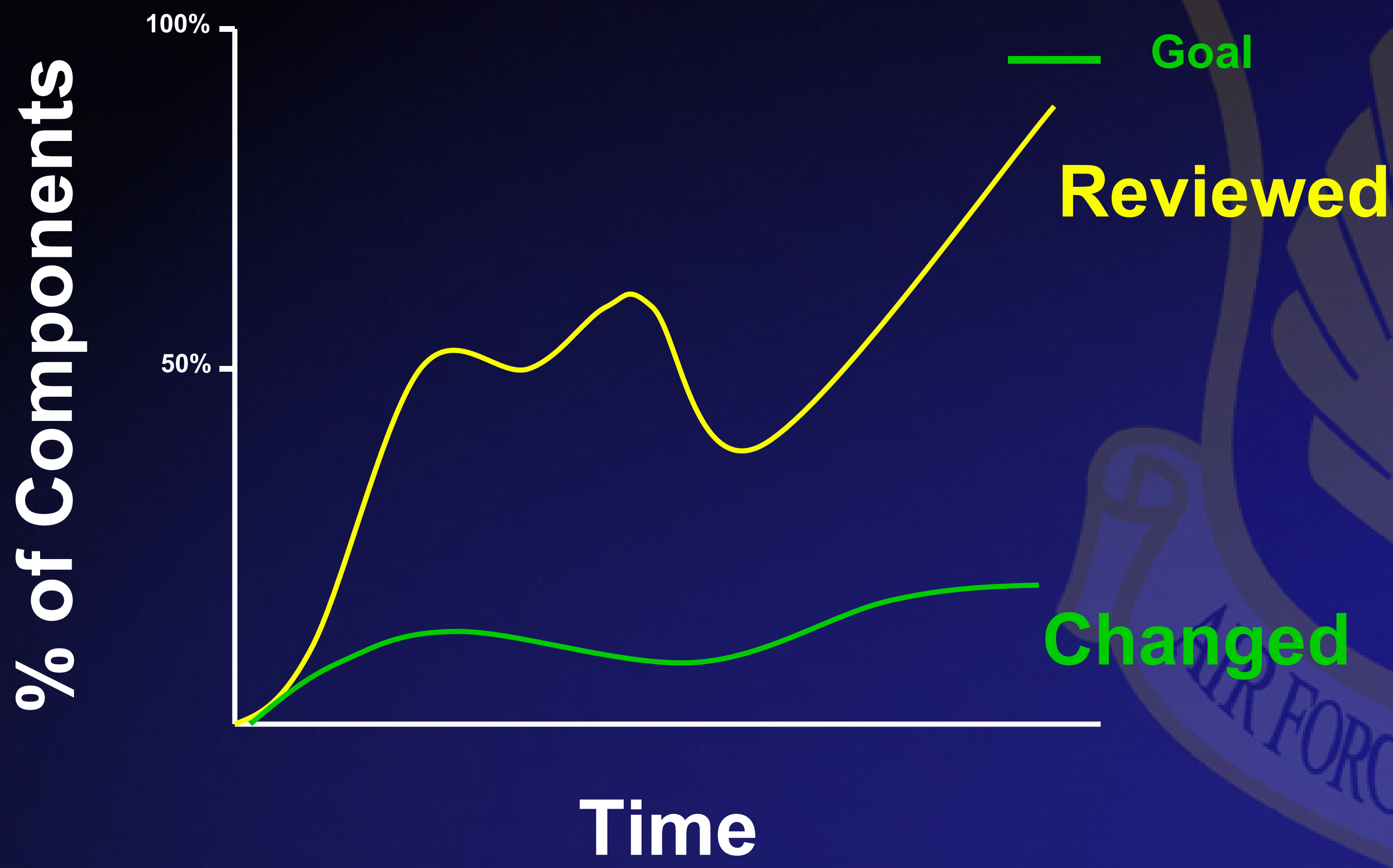
Organization Requirements Metric (%)



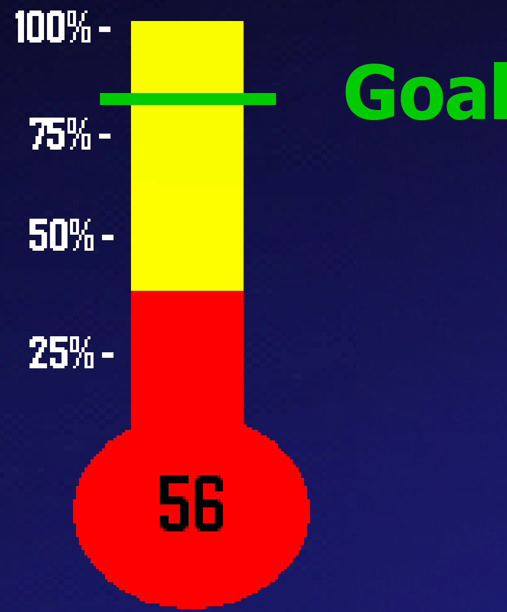
Organization Risk Metric (%)

Likelihood	Low	Med.	High	% w/ Plan
High	20	40	80	60%
Med.	5	50	60	36%
Low	10	5	40	7%
	Consequence			

Organization Requirements Metric (%)

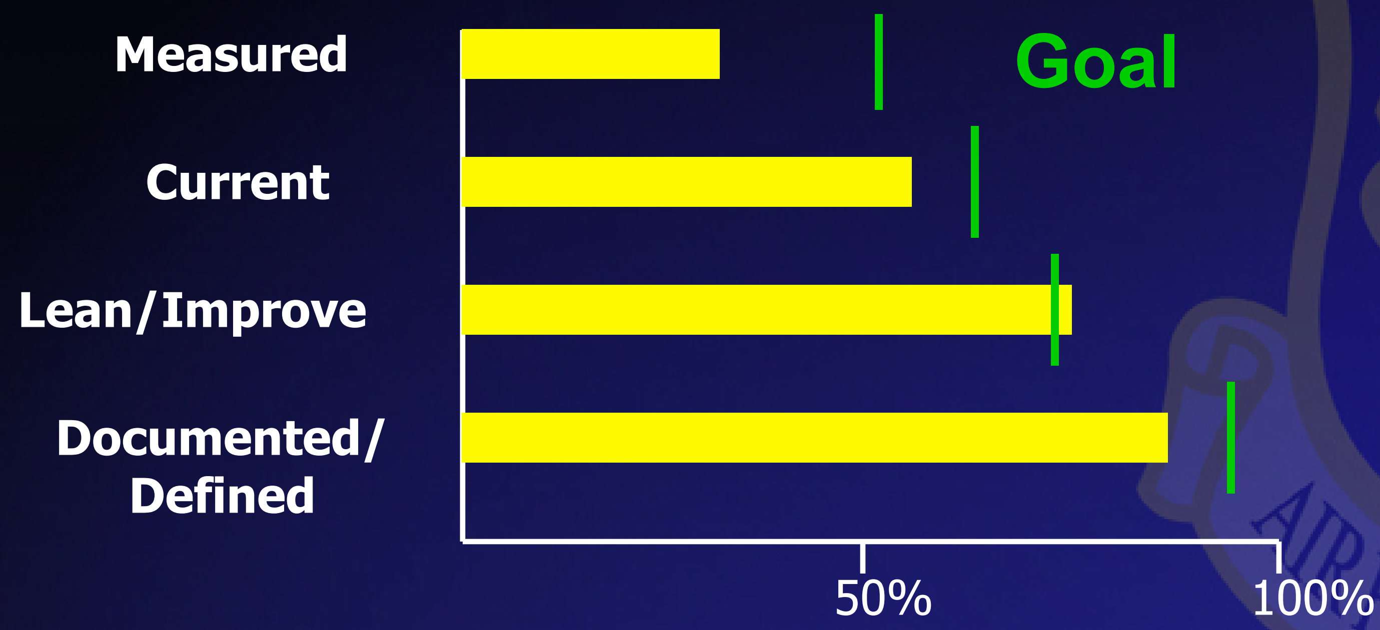


Organization Incentivizing Contractors Metric

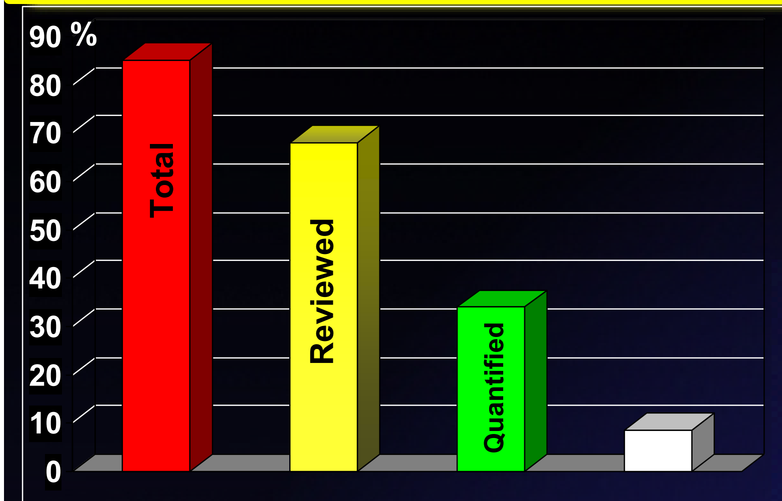


% of Contracts with Sys Eng Incentives

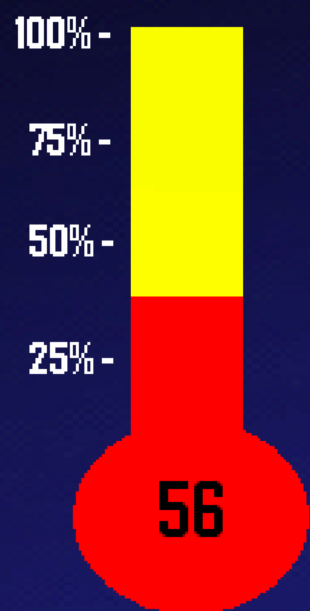
Organization Process Metric (%)



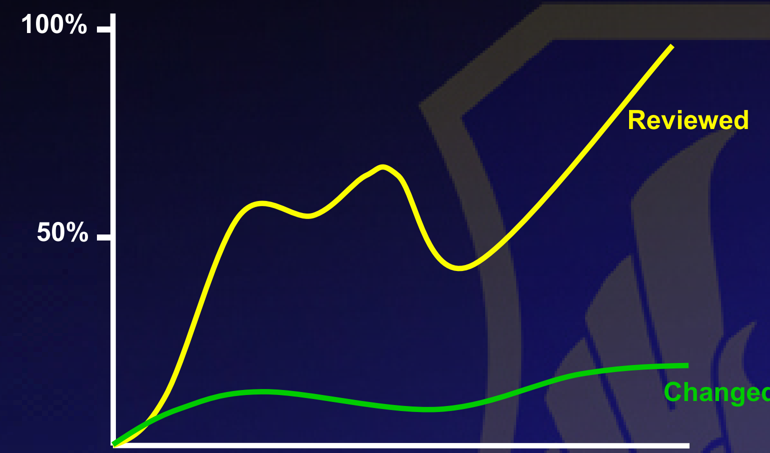
Organization Sys Eng Dashboard



Requirements



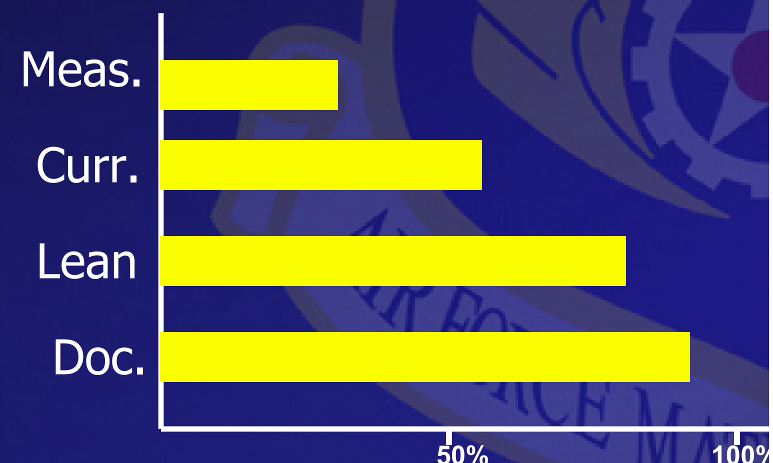
Contracts



LCC/Robust

	Low	Med.	High
High	20	40	80
Med.	5	50	60
Low	10	5	40

Risk



Processes

Summary

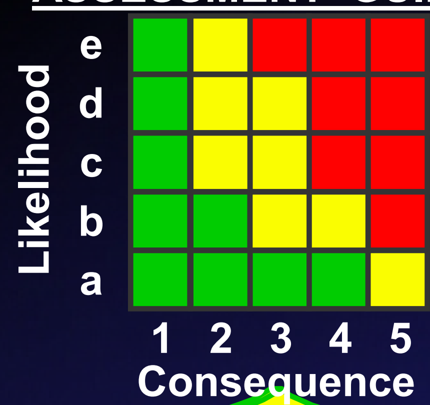
- Sys Eng Important, but No Consistent Way to Measure…Until Now
- Need Concurrent Metrics…Not Lagging
- Metrics For Management…Essential to Drive Action
- What to Measure…Sys Eng "Dashboard"
- Means To Use…Regular Part of an Organization's Overall Management Indicators

- **Allows Comparison…Drives Improvement**

Questions?

Sample: 5 - Level Risk Rating Chart

ASSESSMENT GUIDE



LIKELIHOOD:

Level	What Is The Likelihood The Risk Will Happen?
a	Remote
b	Unlikely
c	Likely
d	Highly Likely
e	Near Certainty

RISK ASSESSMENT

HIGH - Unacceptable. Major disruption likely. Different approach required. Priority management attention required.

MODERATE - Some disruption. Different approach may be required. Additional management attention may be needed.

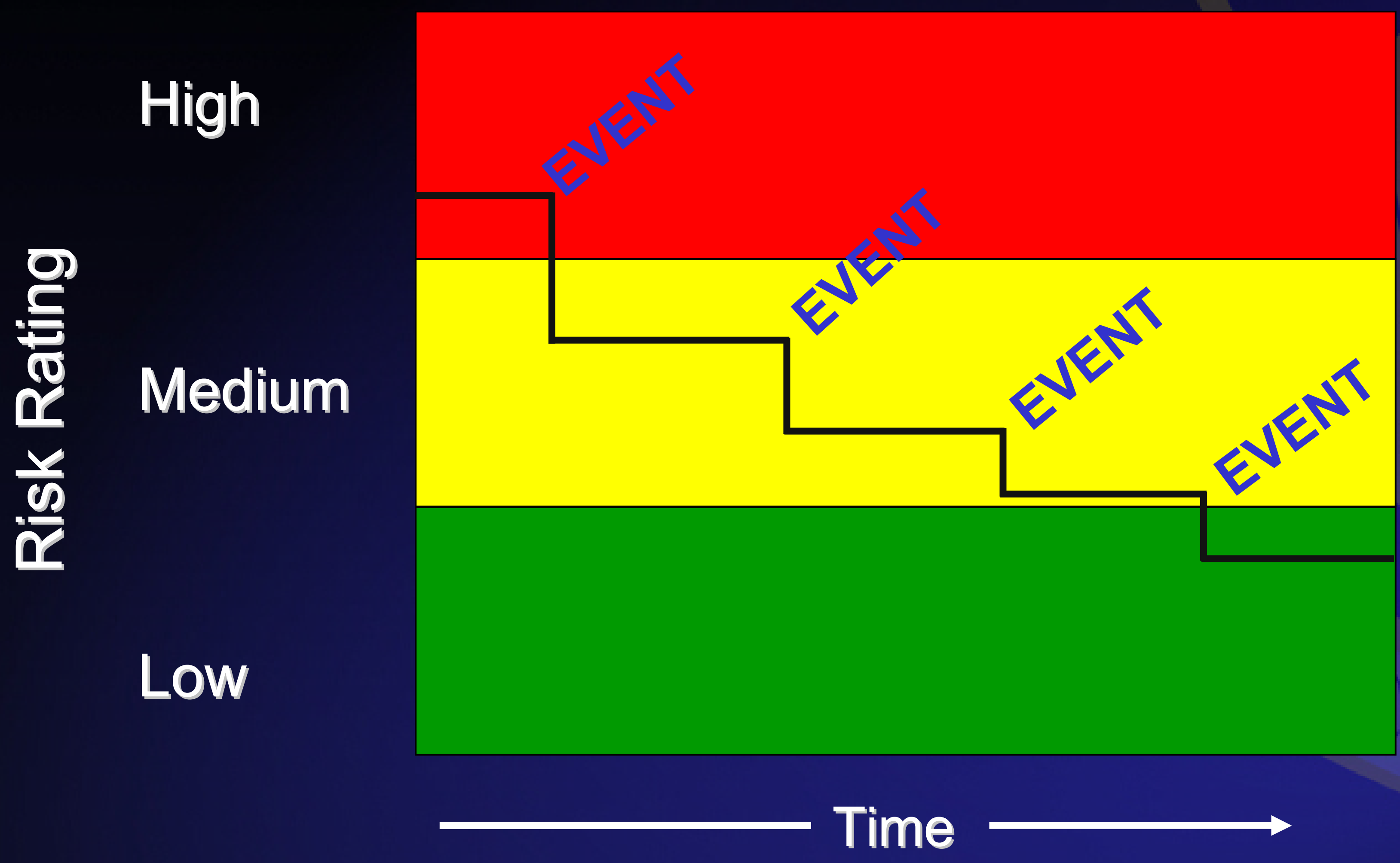
LOW - Minimum impact. Minimum oversight needed to ensure risk remains low.

CONSEQUENCE:

Given The Risk Event is Realized, What is the Magnitude of the Impact?

Level	Technical Performance	and/or	Schedule	and/or	Cost	and/or	Impact on Other Teams
1	Minimal or no impact		Minimal or no impact		Minimal or no impact		None
2	Acceptable with some reduction in margin		Additional resources required; able to meet need dates		< 5%		Some impact
3	Acceptable with significant reduction in margin		Minor slip in key milestone; not able to meet need dates		5 - 7%		Moderate impact
4	Acceptable, no remaining margin		Major slip in key milestone or critical path impacted		> 7 - 10%		Major impact
5	Unacceptable		Can't achieve key team or major program milestone		> 10%		Unacceptable

Risk Handling Plan - "Waterfall"



Converting High-Level Systems Engineering Policy to a Workable Program

26 Oct 05

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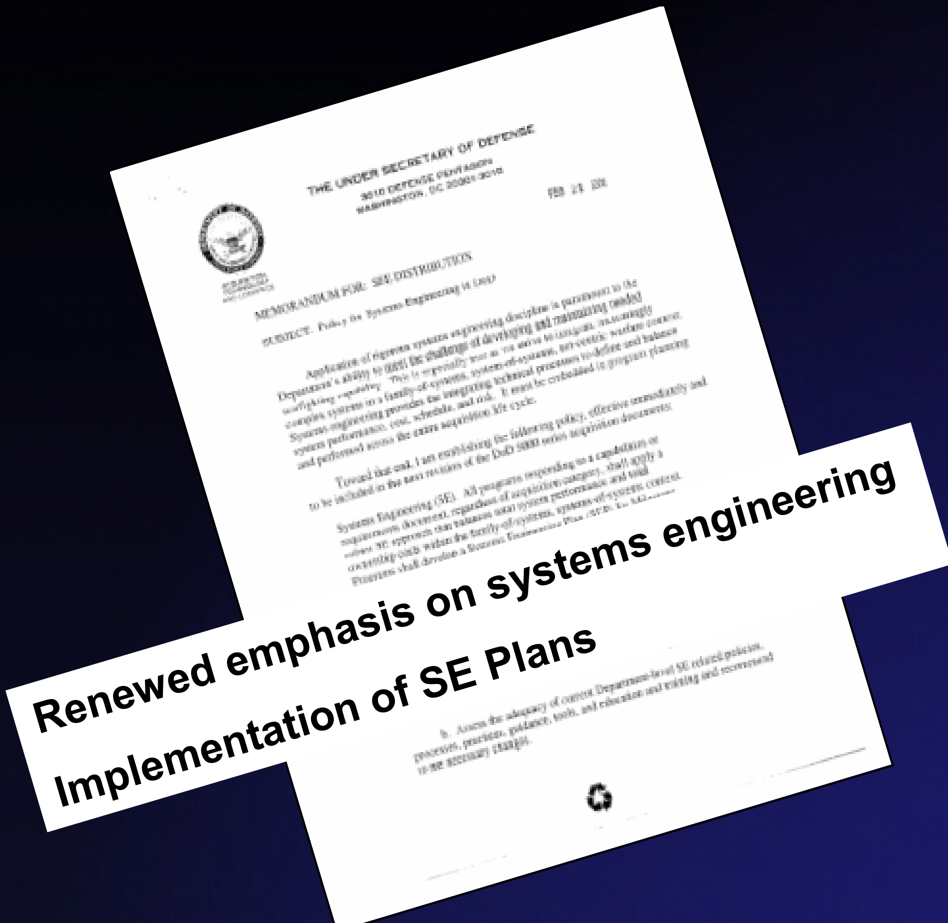
Background

- Prior to 1997, numerous incidents, mishaps and configuration occurred in the Air Force (AF)
- AF recognized need for a disciplined technical process for the development and sustainment of AF systems
- In 1997, AF instituted the Operational Safety, Suitability and Effectiveness (OSS&E) Program
- OSS&E Focused on *sustainment* due to trend in field support process deficiencies

Background (Cont)

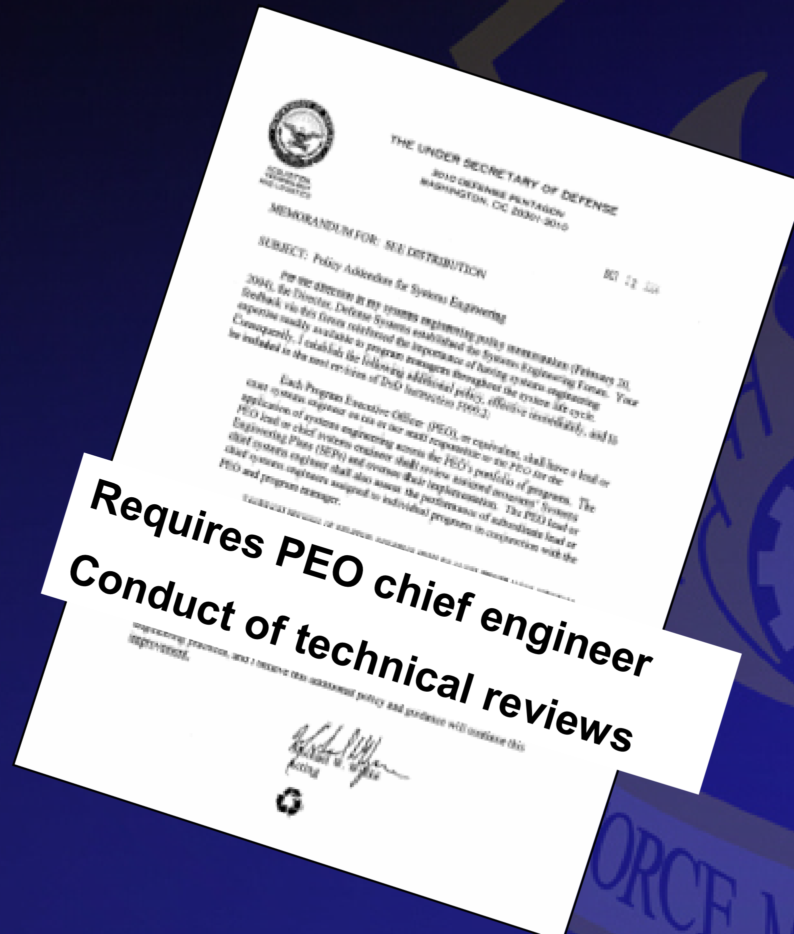
- OSS&E mandated 6 levels for certification
  - Included milestones, metrics, and entry/exit criteria for each level
- Implemented throughout the AF
  - Certification of Level 6 required by Oct 05
- Good effort, supported by most Chief Engineers
- However, OSS&E is a subset of systems engineering
- Over last 2 years, AF started releasing high-level policy regarding systems engineering

AF and DoD Sys Eng Policy



Renewed emphasis on systems engineering

Implementation of SE Plans



Requires PEO chief engineer

Conduct of technical reviews

SE Policy Addendum

Signed by the Marvin R. Sambour, Asst. SecAF (Acquisition) Apr 03 & Jan 04

- **Policy Memo 03A-005, 9 Apr 03**
  - Subj: Incentivizing contractors for Better Systems Engineering
  - "An immediate transformation imperative for all our programs is to focus more attention on the application of Systems Engineering principles…"
  - Directing the following:
    - A. Assess ability to incentivize contractors to perform robust SE
    - B. Develop SE performance incentives
    - C. Include SE processes/practices during all program reviews
- **Policy Memo 04A-001, 7 Jan 04**
  - Subj: Revitalizing Air Force and Industry Systems Engineering (SE) – Increment 2
  - "…intended to institionalize key attributes of an acceptable SE approach and outcome…"
  - "…must focus on an end state…"

Systems Engineering Policy in DoD

Signed by the Honorable Mike Wynne, USD(AT&L) (Acting) Feb 20, 2004

- All programs, regardless of ACAT shall:
  - Apply an SE approach
  - Develop a Systems Engineering Plan (SEP)
    - Describe technical approach, including processes, resources, and metrics
    - Detail timing and conduct of SE technical reviews
- Director, DS tasked to provide SEP guidance for DoDI 5000.2
  - Recommend changes in Defense SE
  - Establish a senior-level SE forum
  - Assess SEP and program readiness to proceed before each DAB and other USD(AT&L)-led acquisition reviews

SEP Implementation Guidance

Per OUSD(AT&L) Defense Systems Memo signed Mar 30, 2004

- Submitted to MDA at each Milestone, SEP describes:
  - Systems engineering approach
    - Specific processes and their tailoring by phase
    - Both PMO and Contractor processes
  - Systems technical baseline approach
    - Use as control mechanism, including TPMs and metrics
  - Technical review criteria and outcomes
    - Event driven
    - Mechanism for assessing technical maturity and risk
  - Integration of SE with IPTs and schedules
    - Organization, tools, resources, staffing, metrics, mechanisms
    - Integrated schedules (e.g., IMP and IMS)

SE Policy Addendum

Signed by the Honorable Mike Wynne, USD(AT&L) (Acting) Oct 22, 2004

- Each Program Executive Officer (PEO) shall have a lead or chief systems engineer
- The PEO lead or chief systems engineer shall:
  - Review assigned programs' SEPs and oversee their implementation
  - Assess the performance of subordinate lead or chief systems engineers
- Technical reviews shall:
  - Be event driven (vice schedule driven)
  - Conducted when the system under review meets review entrance criteria as documented in the SEP
  - Include participation by subject matter experts independent of the program, unless waived by SEP approval authority in the SEP

Defense Acquisition Guidebook, Chapter 4, Section 4.2

- SE terminology, models, and standards
  - Technical Management Processes

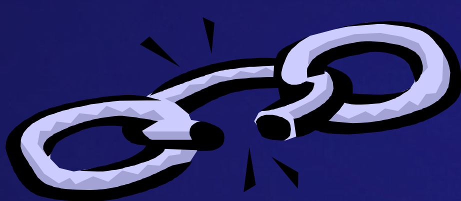
•Decision Analysis •Technical Planning •Technical Assessment •Requirements Mgmt	•Risk Management •Configuration Mgmt •Technical Data Mgmt •Interface Management

  - Technical Processes

•Requirements Development •Logical Analysis •Design Solution •Implementation	•Integration •Verification •Validation •Transition

So What is the Problem?

- High-level policy is a good and necessary first step, however, a more detailed direction is essential to turn the policy into a workable, grass-roots program



So What Do We Do About It?

- Propose a step-by-step approach to begin implementing systems engineering throughout the organization
- Is a tangible approach that is:
  – Aimed at the working level
  – Affects all phases of a program's lifecycle
  – Applicable throughout entire organization
  – Accounts for organization's progress through metrics
- Approach is based on the OSS&E construct

Summary of the OSS&E Construct

- Level 1 Criteria—Chief Engineer Assigned
- Level 2 Criteria—Configuration Control Processes Established
- Level 3 Criteria—Document Plan to Assure and Preserve OSS&E Baseline Characteristics
- Level 4 Criteria—OSS&E Baselines Developed and Coordinated with User
- Level 5 Criteria—OSS&E Assessment of Fielded Systems, Resolve Disconnects with Baseline
- Level 6 Criteria—Monitor and Maintain Full OSS&E Policy Compliance

Notional Sys Eng Implementation Phases

- Phase 1: Awareness of Need
- Phase 2: Workforce Training/Education
- Phase 3: Identify Applicable Programs/Orgs
- Phase 4: Identify and Define Processes
- Phase 5: Incentivize Contractors/Partners
- Phase 6: Develop Library of Tools
- Phase 7: Track Progress via Metrics

Phase 1: Awareness of Need

- **Phase 1 Taskings:**
  - Identify Focal Point for SE policy, practice and implementation
  - Brief senior leaders on SE Defintion, SE policy, and SE "reinvigoration" plan
  - Develop "Road Show" for subordinate offices and/or programs
- **Exit Criteria:**
  - Focal Point identified and appointed
  - Senior leaders briefed with documented support/concurrence
  - Road show presented to all applicable offices/programs

Phase 2: Workforce Training/Education

- **Phase 2 Taskings:**
  - Define minimum training/certification requirements
  - Train working level engineers
  - Train program managers
  - Train Lead/Chief Engineers and Directors of Engineering
- **Exit Criteria:**
  - 80% of working level engineers trained
  - 95% of program managers trained
  - 100% of Lead/Chief Engineers, and Directors of Engineering trained

Phase 3: Identify Applicable Programs/Orgs

- Phase 3 Taskings:
  - List all applicable Programs/Organizations, such as:
    - All OSS&E identified programs
    - Other major progams and projects
    - Engineering Contracts
    - Technology Insertion Projects
    - Relevant functional offices (Engineering, Logistics…)
  - Notify each affected program and organization
  - May do incrementally, but if so, build schedule
- Exit Criteria:
  - Documented process to identify programs/orgs
  - Clear, comprehensive list
  - Schedule phase due dates for all programs/organizations

Phase 4: Identify and Define Processes

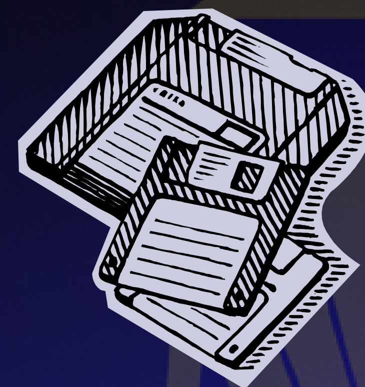
- Phase 4 Taskings:
  - Develop list of applicable common processes
    - At a minimum include:
      - Requirements Management
      - Risk Management
      - Configuration Management
      - Test Management
      - Life Cycle Cost/Robustness
  - Define/standardize each process
    - Use best practices
    - Clearly document each process
  - Systems Engineering Plan (SEP)
- Exit Criteria:
  - List of common, documented processes

Phase 5: Incentivize Contractors/Partners

- **Phase 5 Taskings:**
  - Devise selection criteria
  - List applicable contracts
  - Develop tailorable “template”
  - Ensure language in contracts
  - Determine how to verify SE compliance
- **Exit Criteria:**
  - List of all targeted contracts
  - SE an incentivized factor in all applicable contracts
    - Given the nature of contracts, this can be a sliding scale, e.g 25% in FY06, 50% by 2007, etc…

Phase 6: Develop Library of Tools

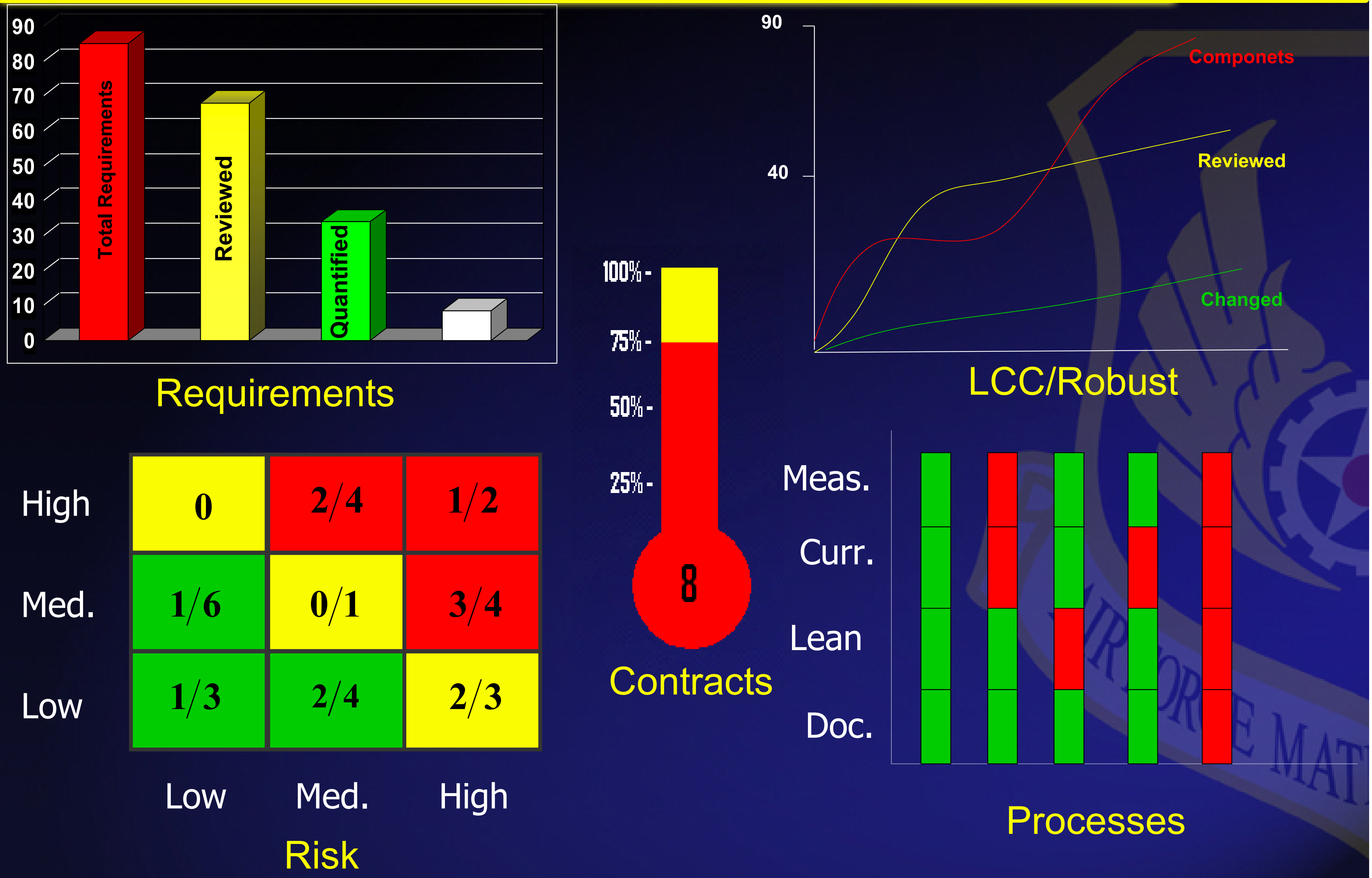
- Phase 6 Taskings
  - Define "How To" and examples for:
    - Risk Management
    - Requirement Management
    - Configuration Management
    - Designing for Life Cycle Cost
    - Others
      - M&S
      - Tech Perf Measurement
      - Trade Studies
      - Fishbone Analysis
      - Peer Reviews
      - Test Management
      - Best Practices
      - Paredo Charts
      - Case studies
      - Lessons Learned
      - Trend Analysis
      - Etc
  - Exit Criteria
    - Documented, advertised, dynamic, and accessible library of tools/techniques



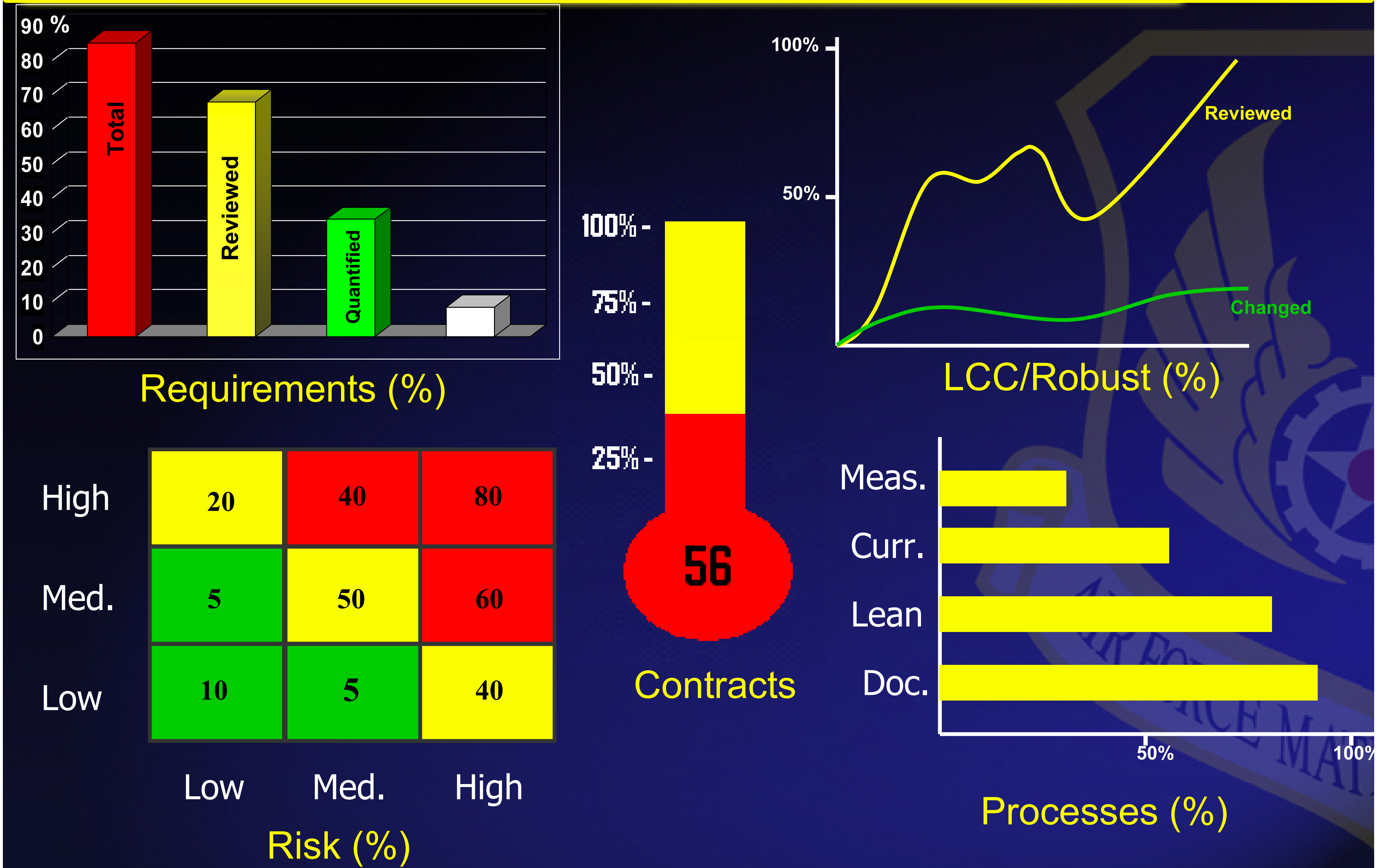
Phase 7: Track Progress via Metrics

- Phase 7 Taskings
  - Develop a set metrics
  - Determine when and at what level(s) they will be regularly briefed
- Exit Criteria
  - Developed set of metrics
  - Metrics displayed regularly at staff meetings

Sample Program Sys Eng "Dashboard"



Sample Organization Sys Eng "Dashboard"



Summary

- AF is releasing necessary high-level policy regarding SE
- Need a workable grass-roots means to implement SE
- Developed a notional 7 phase approach
  - Similar to OSS&E construct
  - Aimed at the working level
  - Affects entire lifecycle
  - Applicable to whole organization
  - Accounts for progress

- **Provides a concrete, tangible starting point to help first line supervisors and working engineers begin implementing systems engineering**

Questions?

OSS&E- Level 1

- Level 1 Criteria—Chief Engineer Assigned
- Exit Criteria
  - System/End-Item (S&EI) on OSS&E S&EI List
  - Chief Engineer identified on OSS&E S&EI list
  - Process is in place to update S&EI list (1.1.1 a)

OSS&E- Level 2

- Level 2 Criteria—Configuration Control Processes Established
- Exit Criteria
  - Configuration control processes identified and documented at the program level
  - Configuration control process training requirements identified
  - Configuration control processes are in-place and operating
  - Delegated authority identified and documented

OSS&E- Level 3

- Level 3 Criteria—Plan to Assure and Preserve OSS&E Documented
- Exit Criteria
  - Plan shall include strategies/approach for:
    - Identifying, reconciling, and preserving OSS&E baseline characteristics
    - Achieving and/or maintaining required certifications
    - Establishing OSS&E program level and product line metrics
    - Identifying data system feedback mechanisms
  - OSS&E Execution Plan coordinated with:
    - Appropriate Product, Logistic, Test, and Specialty Centers

OSS&E- Level 4

- Level 4 Criteria—OSS&E Baselines Developed and Coordinated with User
- Exit Criteria
  - OSS&E baseline characteristics identified
  - Critical Characteristics for measuring safety, suitability, and effectiveness selected
  - OSS&E baseline characteristics and metrics coordinated with users

OSS&E- Level 5

- **Level 5 Criteria—OSS&E Assessment of Fielded Systems/End-Items**
- **Exit Criteria**
  - Fielded system/end-item data gathered
  - OSS&E baseline characteristics assessment completed
  - OSS&E baseline disconnects identified
  - Recommended corrective actions to users

OSS&E- Level 6

- Level 6 Criteria—Full OSS&E Policy Compliance
- Exit Criteria
  – Level 5 corrective actions completed
  – All required certifications in place and maintained
  – Metrics and feedback systems monitoring OSS&E health
  – Processes established and in place to maintain OSS&E baseline characteristics

8th Annual Systems Engineering Conference

Sponsored by the

National Defense Industrial Association

San Diego CA

October 2005

Integrating MIL-STD-882 System Safety Products Into The Concurrent Engineering Approach To System Design, Build, Test, And Delivery Of Submarine Systems At Electric Boat.

Ricky Milnarik

Introduction

Electric Boat has been building submarines for the U. S. Navy for over 100 years.

In 1900 Electric Boat delivered the U. S. Navy's first submarine, the USS Holland.

Introduction

Subsequent to the USS Holland, Electric Boat has delivered over 270 submarines to the U.S. Navy.

In October 2004 the USS VIRGINIA, the first ship in a new class of fast attack submarines, was delivered the U. S. Navy.

Introduction

The VIRGINIA Class Submarine is the first class of submarine built at Electric Boat that uses the Integrated Product and Process Development (IPPD) process to conduct, manage and status the ship design, ship construction and life cycle support.

The IPPD process is a dynamic concurrent engineering concept that includes integration of system safety engineers into design/ build teams (DBT).

Introduction

Before the IPPD process was implemented a serial approach to submarine design-to-construction was taken.

Upon Navy approval of the drawings a full scale wooden mockup of the lead ship was built and maintained.

The dynamics of the design/build team concept is made possible through the use of the Computer Aided Three-Dimensional Interactive Application (CATIA) software design tool to develop electronic mockups in place of building wooden mockups.

Introduction

The design/build team concept also necessitated tailoring how traditional MIL-STD-882 system safety program products were developed and used to provide a complete evaluation of the system(s) under development.

Integrated Product and Process Development

The basis for IPPD is the design-to-build approach.

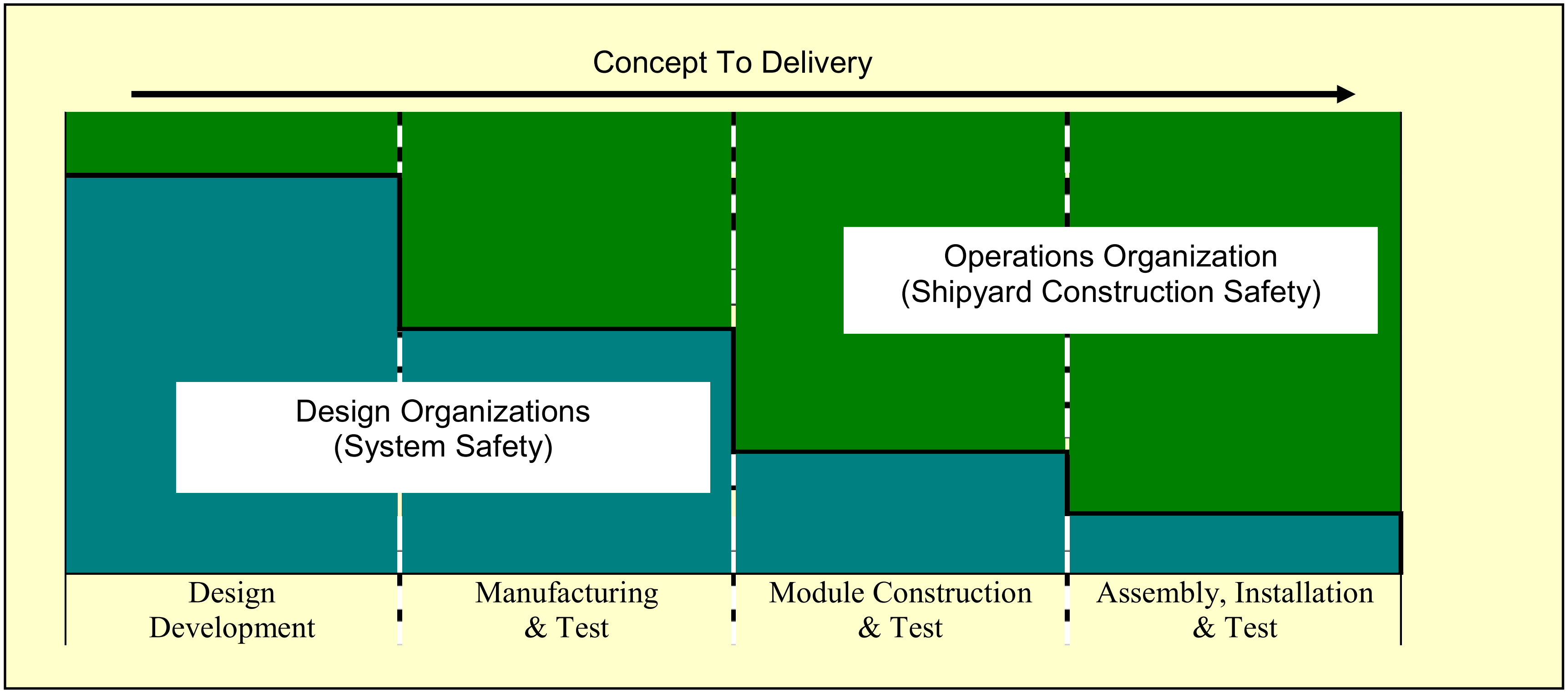
This methodology consists of activity-based product management and concurrent engineering DBTs.

Team assignments are structured in accordance with program development and manufacturing needs.

Integrated Product and Process Development

Ensures that all requirements of conceptual engineering, design, fabrication, assembly, and test, that support system safety are evaluated and analyzed early in the acqusition process.

Integrated Product and Process Development



IPPD Team Staffing

Design / Build Teams

Design Build Teams consist of:

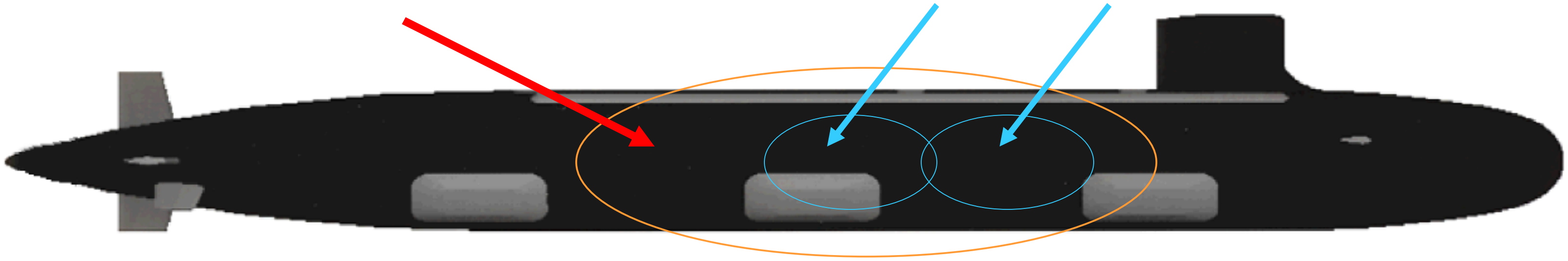
- Program Management Teams
- Functional Area Teams
- System Integration Teams (SIT)

Design / Build Teams

DBT functional managers / technical leaders have direct management and control of their specific functional areas.

FUNCTIONAL AREA TEAM

SYSTEM INTEGRATION TEAMS



Design / Build Teams

DBTs also manage both technology and program development and exercise authority in ensuring component and system integrity via technical design reviews and approval circuits.

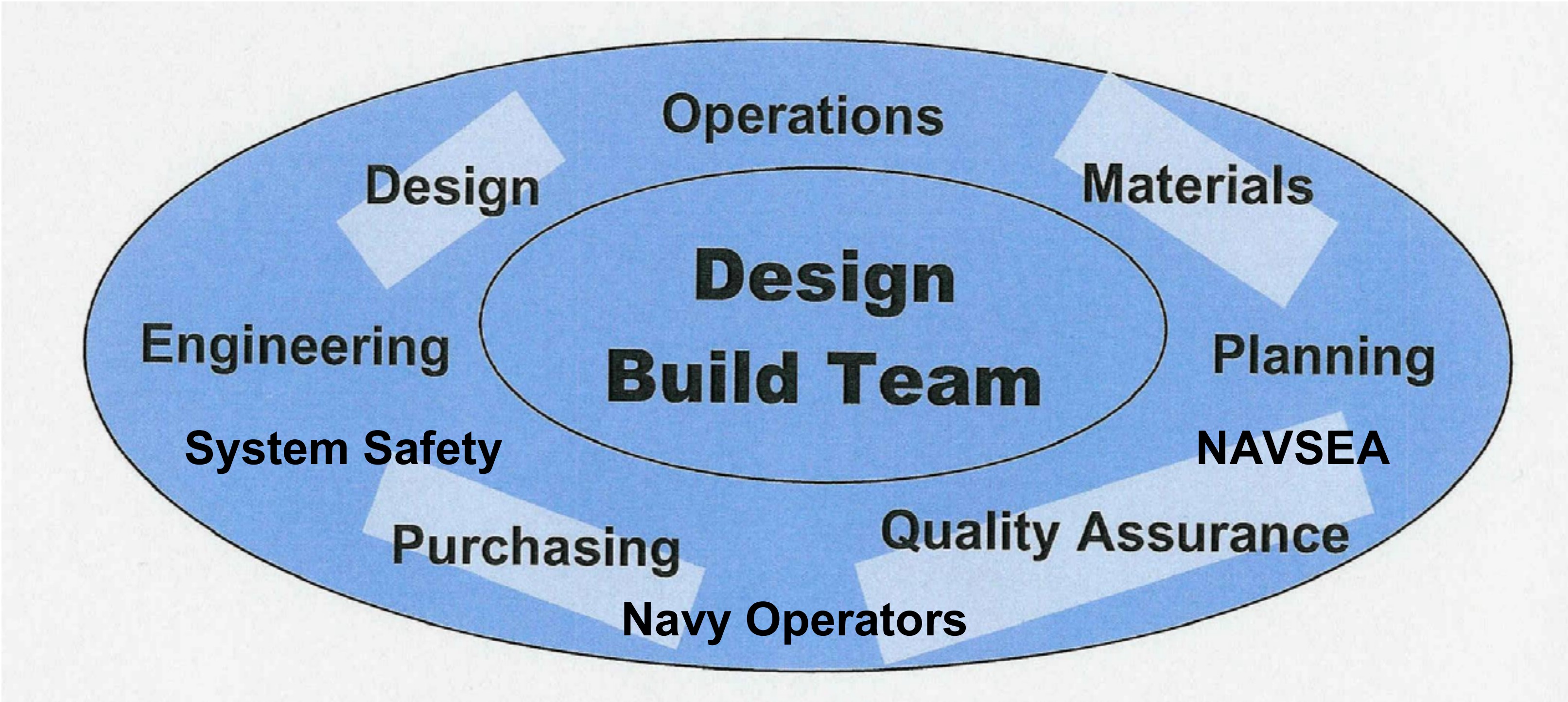
This responsibility broadens the awareness and involvement of team members and creates a sense of ownership of the design efforts and system safety products.

Design / Build Teams

DBTs are made up of representatives from Electric Boat, government suppliers, government laboratory personnel, Navy operators, independent government review/certification board members (e. g. Weapon System Explosives Safety Review Board, SUBSAFE , Deep Submergence System (diver safety) etc.) and teaming shipyards.

Design / Build Teams

A typical DBT makeup is shown below



System Integration Teams

System Integration Teams (SITs) develop, integrate, and optimize systems in the ship and prepare technical deliverables by:

Developing and evaluating system concepts and new components, conducting trade-off studies, developing system diagrams, class drawings, component specifications etc.

Performing safety analyses on new and significantly modified legacy ship systems and components in accordance with the System Safety Program Plan.

System Integration Teams

Establishing technical interfaces with government agencies, laboratories, and other contractors.

Integrating discipline-specific individuals and individuals with appropriate specialty expertise (e.g. system safety engineers, production, finance, integrated logistics support environmental compliance etc.).

System Integration Teams

Typical Submarine Systems

Torpedo Ejection	Trim and Drain	Propulsion Plant
Vertical Launch	Low Pressure Air	High Pressure Air
Weapons Handling	Main Hydraulic	Main Seawater
Communications (Radio)	HVAC	Ships Entertainment
Combat Control Subsystem	External Hydraulic	AC Power/Interior
Combat Launch Control	Ship Control	Masts and Antennas
Navigation	Fresh Water	Atmosphere Monitoring
Sonar	AC Electrical Power	Interior Communication
Total Ship Monitoring	DC Electrical Power	Auxiliary Seawater
Non-Tactical Data Processing	Lighting	Main Ballast Tank Low
Escape and Rescue	Fire Fighting	Pressure Blow

System Safety Process

Tailoring of the system safety process centered around:

- Formalized SIT meetings.
- Conduct of safety hazard analyses as a team product.
- Use of CATIA for safety hazard analyses and Human Systems Integration (HSI) into design products.

System Safety Process

SIT Meetings

Since the SITs contain all the key players and decision makers for the system under development. Each SIT meeting:

- doubles as a safety working group meeting
- documents system and safety design decisions
- documents unresolved issues and assigns action items
- is documented on official minutes to ensure continuity

System Safety Process

Safety Hazard Analyses

Traditional MIL-STD-882 system safety tasks were used to identify potential hazards.

- Preliminary Hazard Analyses
- Safety Requirements Analyses
- Software Analyses
- Subsystem Hazard Analyses
- System Hazard Analyses
- Operating and Support Hazard Analyses

System Safety Process

Safety Hazard Analyses (cont'd)

Because of the dynamics of the DBT process it was decided that updating previously completed hazard analyses, when additional information became available, was not feasible.

Instead each completed hazard analysis portrayed a snap shot in time of the system under evaluation.

System Safety Process

Safety Hazard Analyses (cont'd)

Each subsequent hazard analysis built upon the previous analysis conducted.

Significant design changes or identification of new hazards that came up between hazard analyses were documented on an Analysis Completion Summary (ACS) Report for continuity.

System Safety Process

ANALYSIS COMPLETION SUMMARY

System: ______________ **Cognizant Engineer:** ______________

Date Initiated: ___________ **Date Completed:** ________________

Enclosures:

Analysis Summary:

SAMPLE

SAFETY ANALYSIS WORKSHEETS (attached)

1. ____________________ 2. ____________________

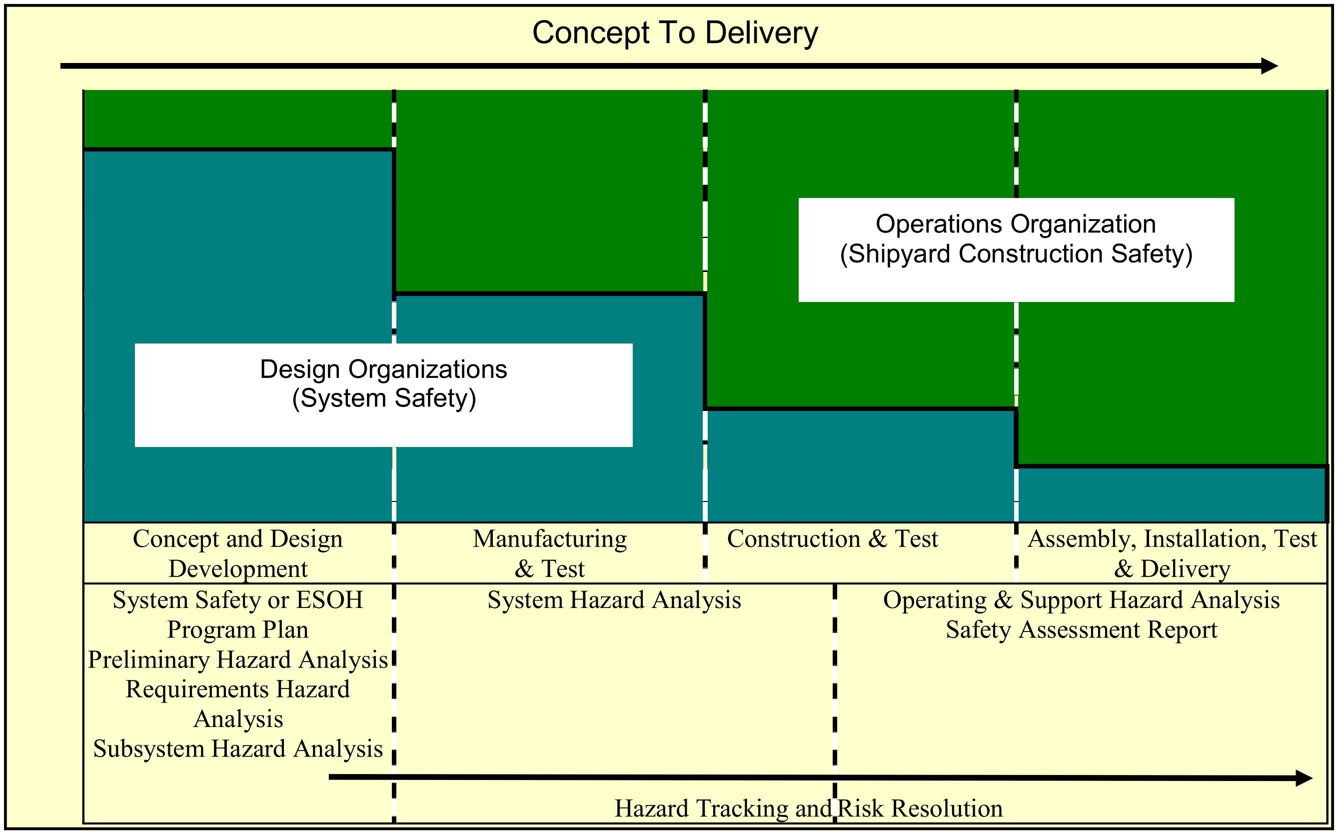
3. ____________________ 4. ____________________

Safety Engineer: ________________________________

Team Leader: ___________________________________

System Safety Process

Safety Hazard Analyses (cont'd)



Design Development and System Safety Products

System Safety Process

Safety Hazard Analyses (cont'd)

Provide System Safety Objective Quality Evidence for the systems under development:

- Completed safety hazard analyses
  - Analysis Completion Summary Reports
- SIT meeting minutes
- Program design review findings
- Independent government review board findings
  - Weapon System Explosives Safety Review Board
- Hazard closure forms

System Safety Process

CATIA Program

Electronic design data created in CATIA is controlled and stored in the CATIA Data Manager as the central repository that supports the various elements of the IPPD process.

CATIA displays were projected on screens in Electronic Visualization Simulation (EVS) rooms during SIT meetings allowing SIT members to view the latest system design and arrangements.

System Safety Process

CATIA Program (cont'd)

Examples of HSI efforts through the use of CATIA were:

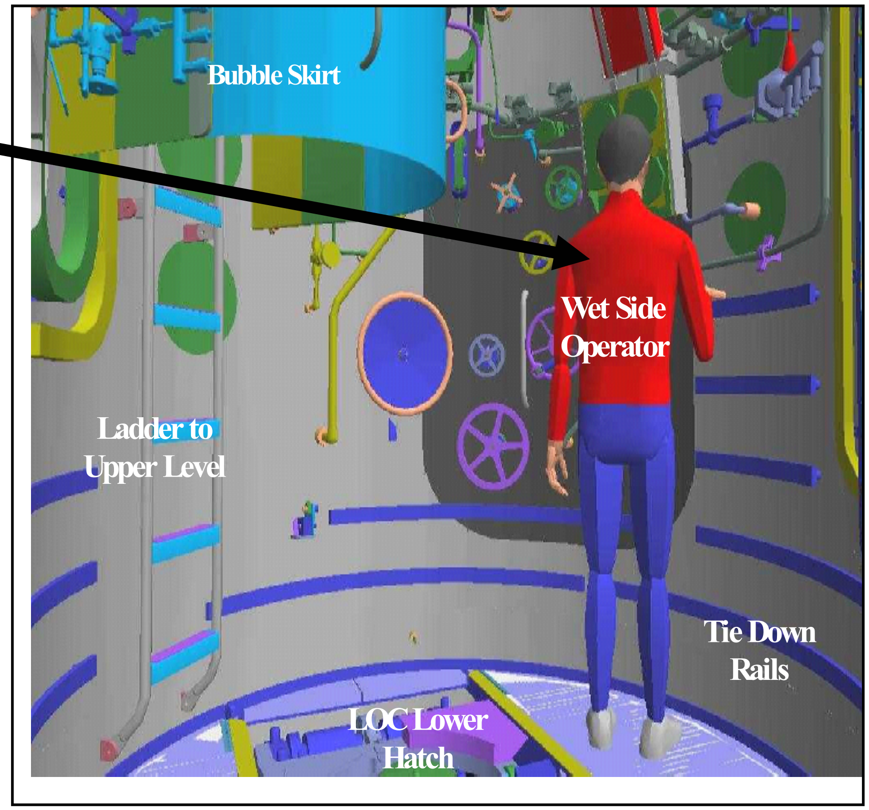
- Reserving pull-spaces on drawings for racking out equipment during maintenance.
- Readily identifying interference with other systems/subsystems/equipment.
- Demonstrating critical equipment removal and replacement flow-paths.
- Reserving spaces on drawings for access to vital equipment (safety of ship).

System Safety Process

<u>CATIA Program</u> (cont'd)

Ergo Man

Representing fifth through ninety-fifth percentile body dimensions) used to evaluate system design in terms of whole-body fit, access/emergency egress, reach and visual field etc.



SSGN Lockout Chamber

System Safety Process

CATIA Program (cont'd)

Through the use of CATIA, system safety engineers identified HSI issues early and throughout the design phase.

- Eliminating the need for separate operator and maintainer human engineering analyses.

Unresolved HSI issues were documented in applicable hazard analyses or analysis completion summary reports.

Lessons Learned

The IPPD process not readily accepted by all DBT members e.g., contractors, subcontractors, government agencies not using or familiar with the design build team process.

The IPPD process only as good as the DBT training provided to team members.

Lessons Learned

The IPPD process resulted in a lower number of documented hazards measured against traditional system safety processes (metrics, added value of a system safety program) because most hazards were designed out during the SIT meetings.

DBT members treated system safety engineers as partners rather than “safety police”.

OPEN SYSTEMS ARCHITECTURE (OSA) AND STANDARD INTERFACES AS MISSION CAPABILITY ENABLERS

Tom Schiller
Andrew Levine
Naval Surface Warfare Center, Carderock Division
William H. Mish Jr
M. Rosenblatt and Son an AMSEC LLC Company

INTRODUCTION

- DoD POLICIES and DIRECTIVES
  - Application of new DoD 5000 series and Joint Integration and Development Systems (JCIDs) to ship acquisition programs through the implementation of the Open Systems Joint Task Force (OSJTF) Modular Open Systems Approach (MOSA)
- CHANGING THREATS
  - New mission capabilities
  - Technology refresh to adapt to changing world climate
  - Requires rapid system and component change-out
- FLEXIBLE FORCE – MODULAR ADAPTABLE FLEET
  - Allows for rapid change of a multi-mission ship
  - Allows a single ship to have multiple capabilities to support and defend against air, surface and submersibles assets
- AFFORDABLE FLEET – FAMILY OF SHIPS
  - Allows for cross-platform component commonality and interchangeability between ships and ship designs

DOD DIRECTIVE 5000.1
THE DEFENSE ACQUISITION SYSTEM

"Acquisition programs shall be managed through the application of a systems engineering approach that optimizes total system performance and minimizes total ownership costs. A modular, open-systems approach shall be employed, where feasible."

Department of Defense

DIRECTIVE

NUMBER 5000.1
May 12, 2003
Certified Current as of November 24, 2003

USD(AT&L)

SUBJECT: The Defense Acquisition System

References: (a) DoD Directive 5000.1, "The Defense Acquisition System," October 23, 2000 (hereby canceled)
(b) DoD Instruction 5000.2, "Operation of the Defense Acquisition System," May 12, 2003
(c) DoD 5025.1-M, "DoD Directives System Procedures," current edition
(d) Title 10, United States Code, "Armed Forces"
(e) Section 2350a of title 10, United States Code, "Cooperative Research and Development Projects: Allied Countries"
(f) Section 2751 of title 22, United States Code, "Need for international defense cooperation and military export controls; Presidential waiver; report to Congress; arms sales policy"
(g) Section 2531 of title 10, United States Code, "Defense memoranda of understanding and related agreements"
(h) Federal Acquisition Regulation (FAR), current edition
(i) Section 1004, Public Law 107-314, "Bob Stump National Defense Authorization Act for Fiscal Year 2003," "Development and Implementation of Financial Management Enterprise Architecture"
(j) DoD Directive 8500.1, "Information Assurance (IA)," October 24, 2002
(k) DoD Directive 4630.5, "Interoperability and Supportability of Information Technology (IT) and National Security Systems (NSS)," January 11, 2002
(l) DoD Directive 2060.1, "Implementation of, and Compliance with, Arms Control Agreements," January 9, 2001

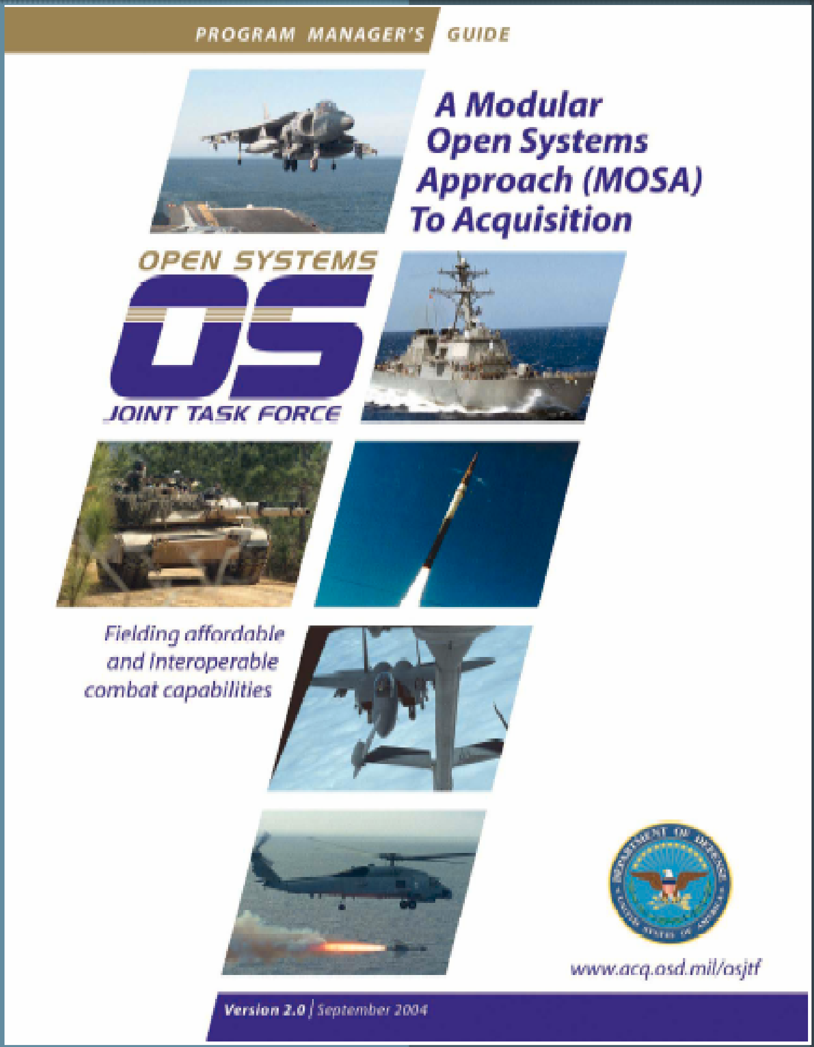
1. PURPOSE

This Directive:

1.1. Reissues reference (a) and authorizes publication of reference (b).

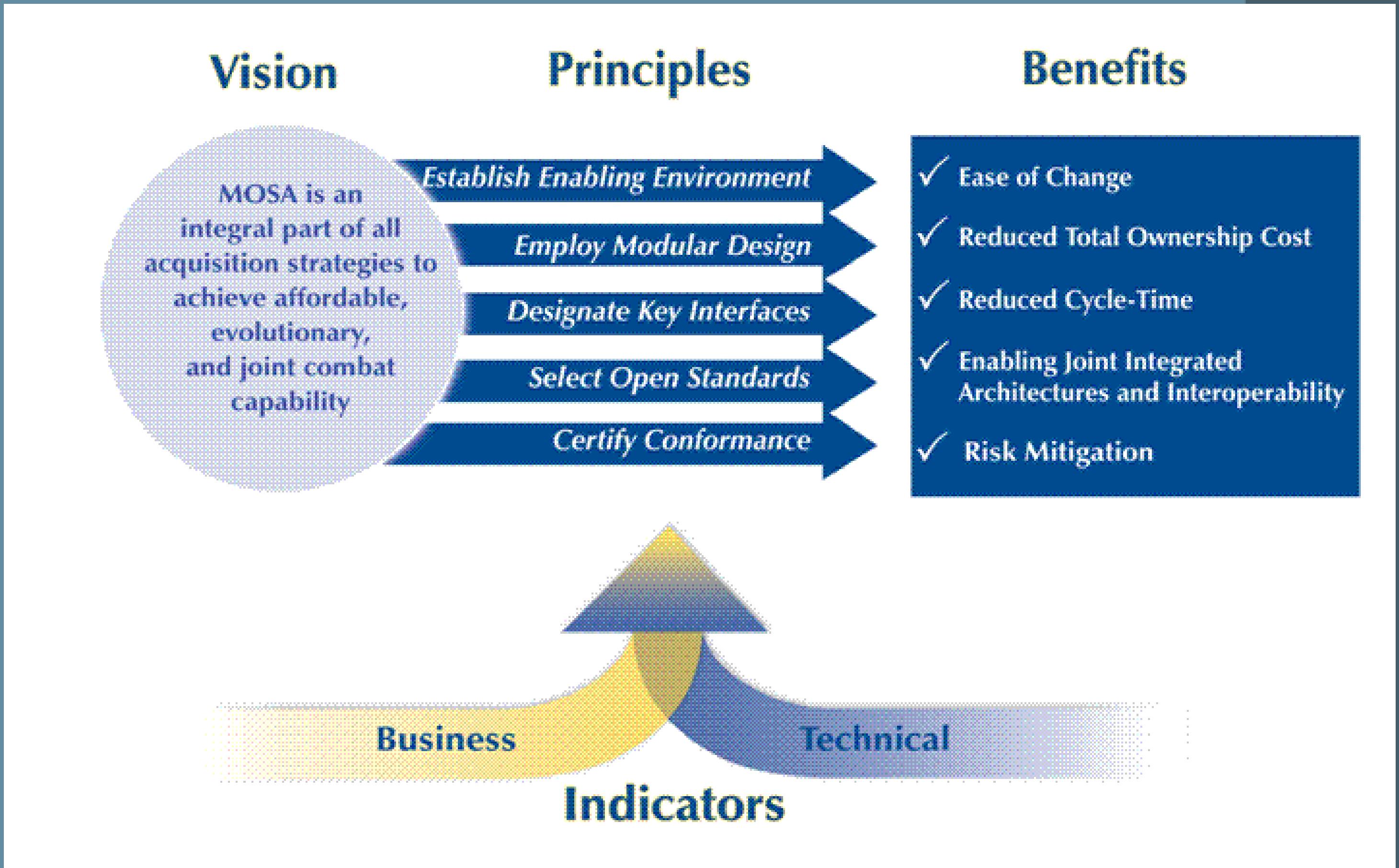
OPEN SYSTEMS JOINT TASK FORCE (OSJTF)

"The OSJTF's modular, open systems approach is a key enabler in the Department's focus on joint architectures and evolutionary approach to weapon systems acquisition. All acquisition programs should employ a modular, open systems approach."



MODULAR OPEN SYSTEMS APPROACH (MOSA)

Integrated Business and Technical Strategy



MOSA AS AN ENABLER

- The MOSA approach is an enabler to achieve the following objectives:
  - Adapt to evolving requirements and threats
  - Promote transition from science and technology into acquisition and deployment
  - Facilitate systems integration
  - Reduce the development cycle time and total life-cycle cost
  - Ensure that the system will be fully interoperable with all the systems which it must interface, without major modification of existing components
  - Leverage commercial investment
  - Enhance access to cutting edge technologies and products from multiple suppliers
  - Enhance commonality and reuse of components among systems
  - Mitigate the risks associated with technology obsolescence
  - Mitigate the risk of a single source of supply over the life of a system
  - Enhance life-cycle supportability
  - Increase competition

THE NAVY'S NEED FOR MODULES AND OPEN SYSTEMS

"Controlling cost while decreasing the cycle time for technology insertion will require the use of open architectures, module interface standards, commercial processors, etc. in conjunction with strict configuration control."

Mr. John J. Young, Jr., Assistant Secretary of the Navy (Research, Development, and Acquisition) before the procurement subcommittee of the house armed services committee United States House of Representatives Fiscal Year 2003 Navy/Marine Corps Shipbuilding programs March 20th 2002.

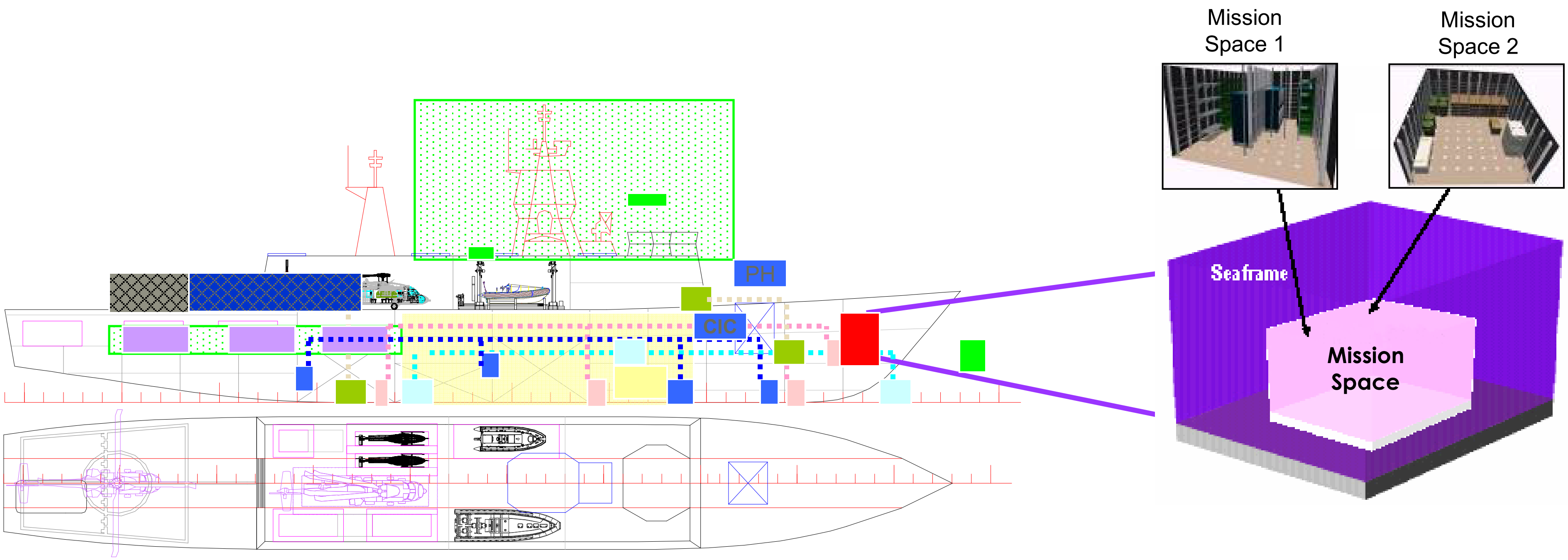
NAVY OPEN SYSTEMS INITIATIVES

- Affordability Through Commonality (ATC) program transitioned to Total Ship Open Systems Architecture (TOSA)
- TOSA IPT formed in 1998
  - Acquisition reform with emphasis on "letting Industry do it"
  - Bring **Open Systems Architectures** (OSA) concepts to ship design
  - Reduce the Total Ownership Cost (TOC) of ships
    - Achieve Fleet-Wide commonality through maximum use of commercial equipment while managing risk
    - Use of non-proprietary OSA and standard interfaces
    - Facilitate improved systems expansions and upgrades in response to changing missions and technology
- Major Products
  - Process to develop **Open System Architectures** for ships
  - Open CIC, HVAC, and Environmental Quality Systems concepts developed
  - Technology Management for DD21 and LCS
- Architectures, Interfaces, and Modular Systems (AIMS) current ongoing initiative evolved from TOSA

ARCHITECTURES, INTERFACES, AND MODULAR SYSTEMS (AIMS) PROGRAM

- Current U.S. Navy RDT&E Program to promote increased Navy use of OSA and modularity
- VISION
  - To create a Modular Adaptable Ship (MAS) through development of open architecture based zones such as C4I, Weapons, and Sensor zones
- GOALS
  - To reduce ship life-cycle costs
  - Enable technology refresh insertion
  - Promote competition
  - Improve mission capability and flexibility
  - To facilitate life-cycle adaptability
- Examine ship designs at the systems, subsystems, and component level to determine what level of modularity makes sense

AIMS VISION – MODULAR ADAPTABLE SHIP



OPEN FUNCTIONAL ZONES

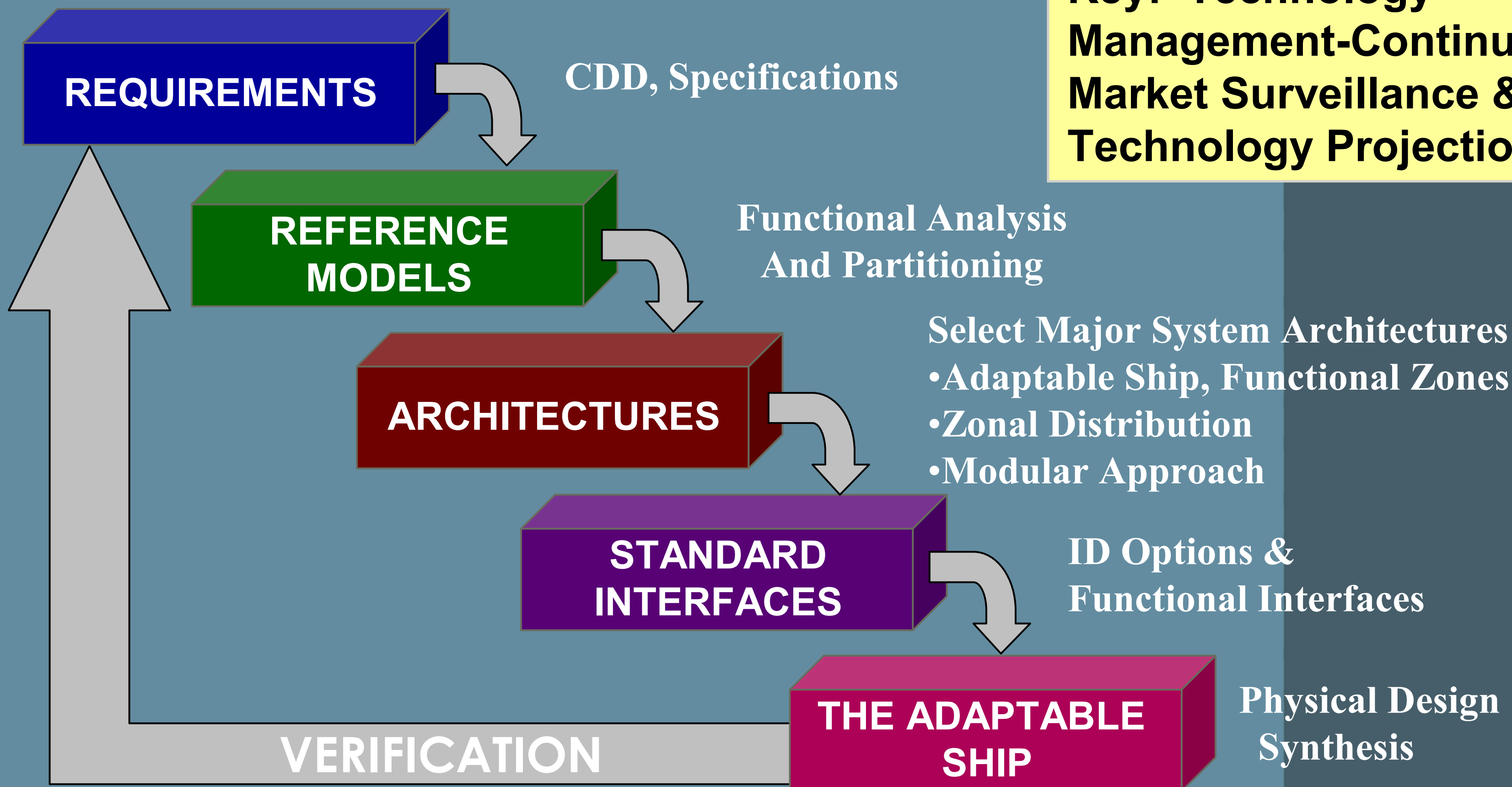
- **Modular C4I Zones**
- **Modular Offboard Vehicle Zones**
- **Modular Weapons Zones**
- **Modular Sensors / Topside Zones**
- **Modular Machinery Zones**
- **Modular Human Support Zones**
- **Other (SOF modules, ISR, modules)**

KEY INTERFACES

- **Data & information (OACE)**
- **Physical (Geometric & Tolerances)**
- **Weight and CG / VCG**
- **Services: Electrical, Air,Cooling**
- **Piping connections**
- **Monitoring & Control Sensors**
- **Human Factors**
- **Survivability/Vulnerability: shock, vibration, EMI, EMC, etc.**

NAVY AIMS PROCESS

Key: Technology Management-Continuous Market Surveillance & Technology Projection



CASE STUDY – OSA AND MODULAR RECONFIGURABLE SPACES

User Needs

–Multi-Mission Ship on a Single Seaframe

–Rapid Mission Reconfiguration

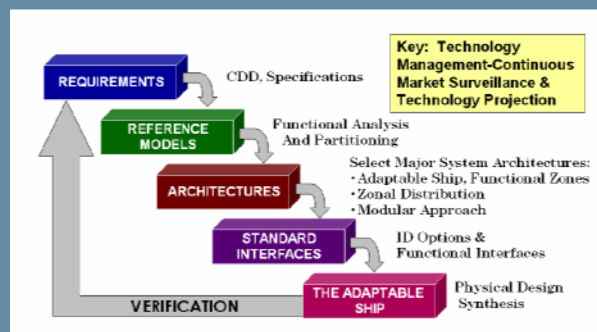
–Increase Availability

–Rapid Technology Refresh or Insertion

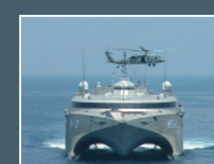
–Supportability

Modular Reconfigurable Spaces

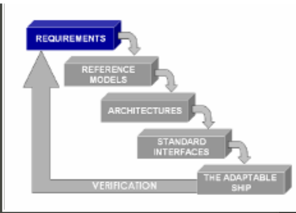
AIMS Process Execution

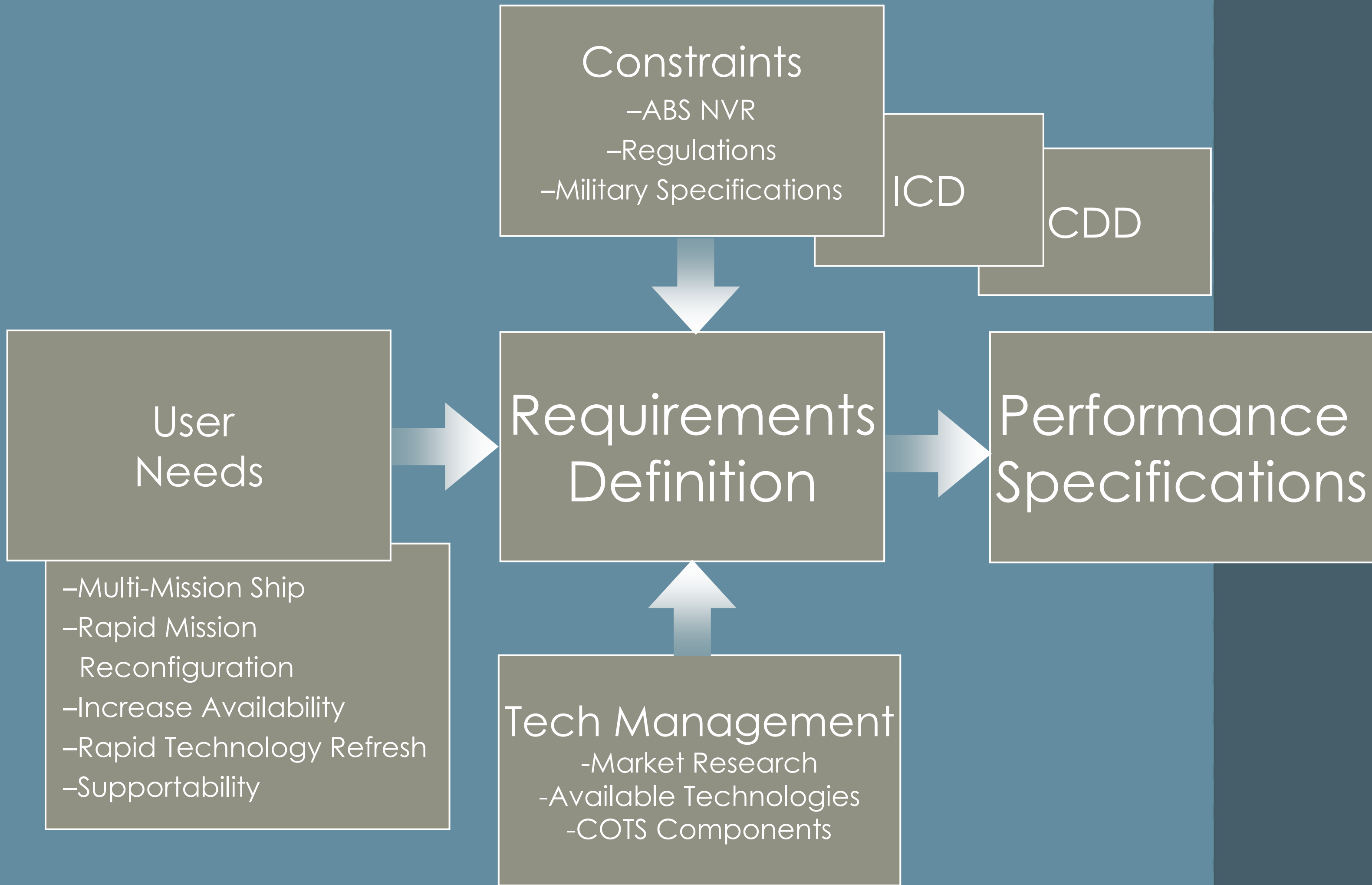


Mission Capable Ship

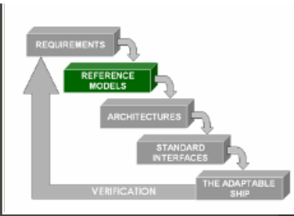


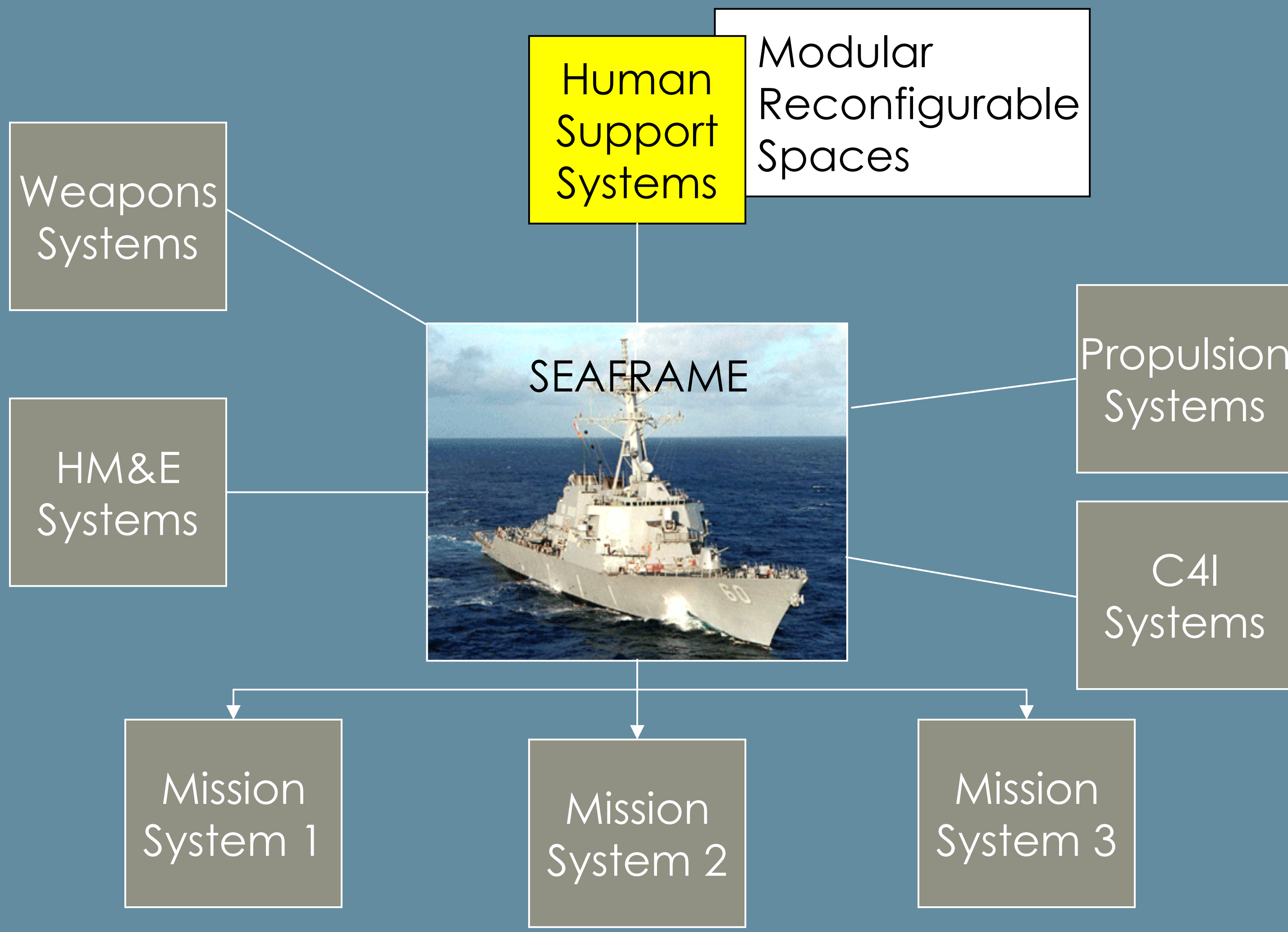
REQUIREMENTS ANALYSIS



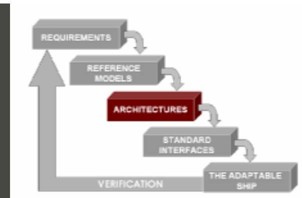


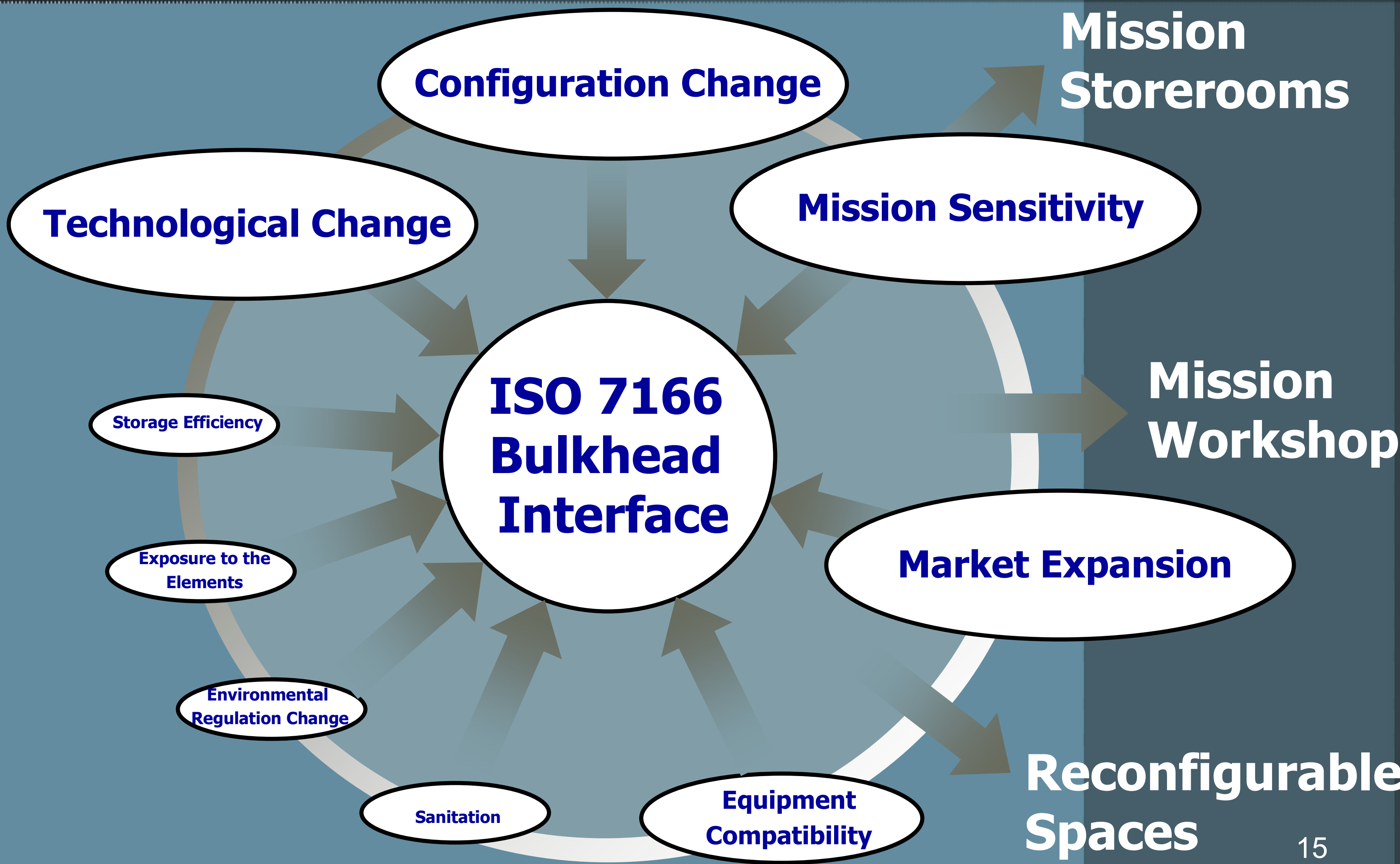
FUNCTIONAL ANALYSIS



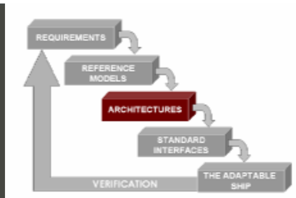


MODULAR OSA
HUMAN SUPPORT ZONE TRADE STUDY



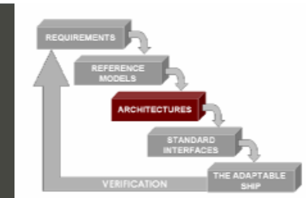


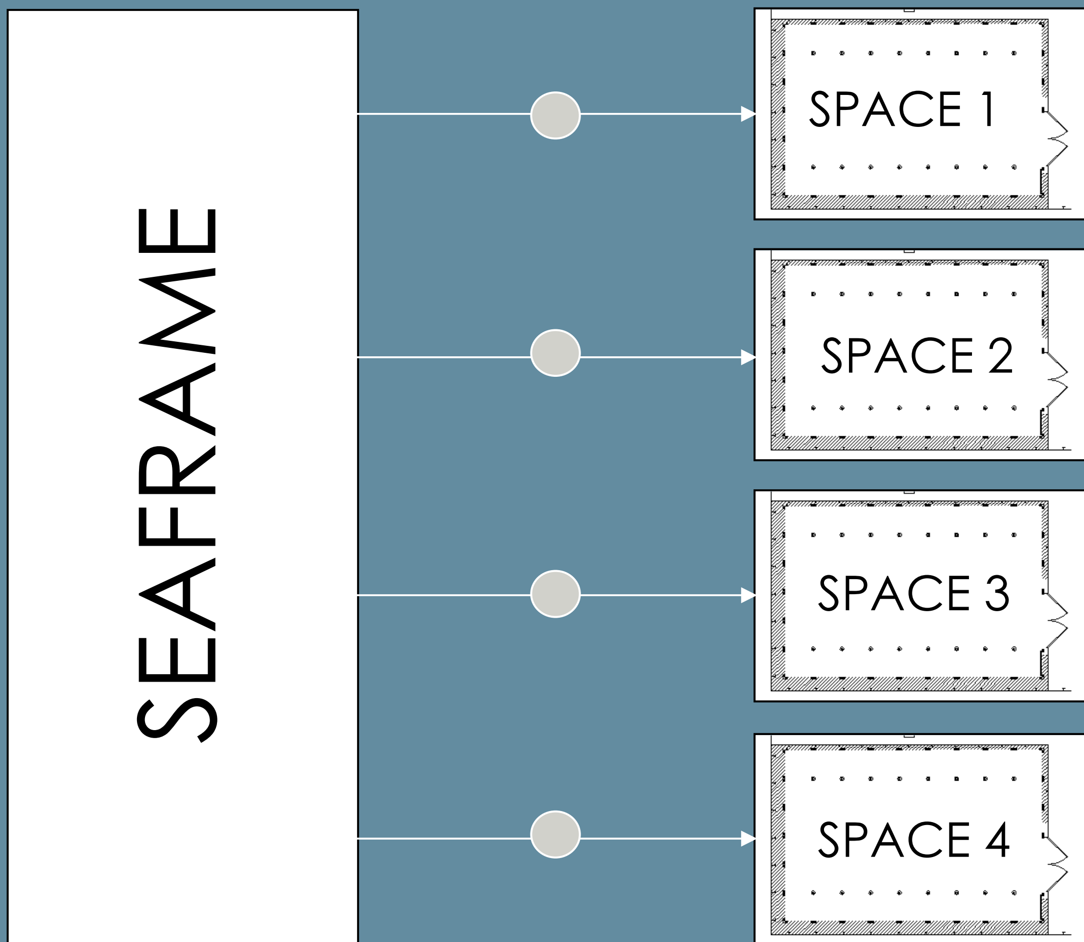
FUNCTIONAL AREA SELECTION EXAMPLE



		Compartment Attributes									
	Attribute Weighting	5	5	5	3	2	2	2	2	5	
Estimated Number of Compartments on Ship	**Functional Area**	Tech. Change	Configuration Change	Mission Sensitivity	Equipment Applicability	Storage Efficiency	Environmental Change	Sanitation	Exposure to Elements	Market Expansion	**Ranking**
3-4 Mission 11 Storerooms	Mission Storeroom: Aviation Storerooms, Hangers, Workshops	1	5	5	5	2	3	3	5	5	121
1	Reconfigurable Space	2	5	5	3	1	1	3	4	5	112
11	Stateroom Crew (4)	1	4	1	4	1	1	4	5	5	89

OPEN SYSTEMS ARCHITECTURE MODULAR RECONFIGURABLE SPACE

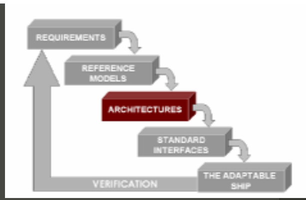




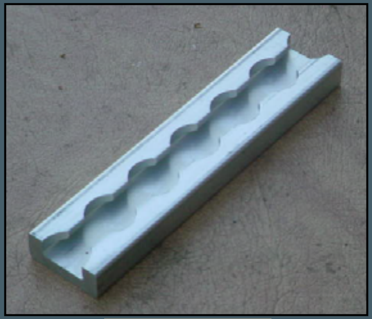
Key Interfaces:

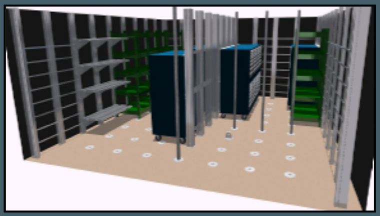
- Data & information (OACE)
- Physical (Geometric & Tolerances)
- Weight and CG / VCG
- Services: Electrical, Air, Cooling
- Piping connections
- Monitoring & Control Sensors
- Human Factors
- Survivability/Vulnerability: shock, vibration, EMI, EMC, etc.

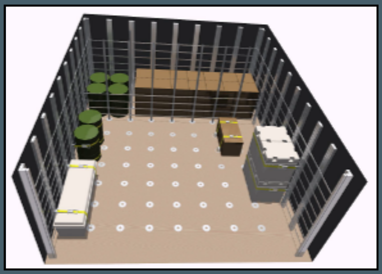
KEY INTERFACES
MODULAR RECONFIGURABLE SPACE



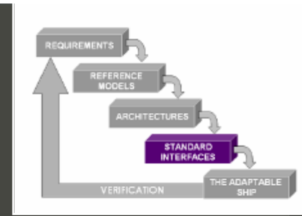
- Data
- Distributed Systems – HVAC, electrical, fluids, etc.
- Structural - foundations
  - International Standards Organization (ISO) 7166
    - Aircraft Rail and Stud Configuration for Passenger Equipment and Cargo Restraint
    - Increase core modularity, mission readiness and contain costs by incorporating ISO 7166 bulkhead interfaces

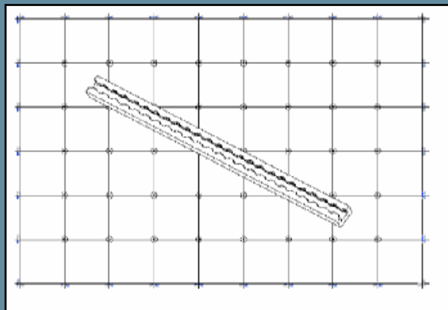




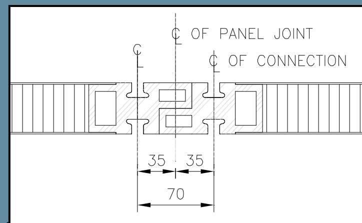


OPEN SYSTEMS ARCHITECTURE AND STANDARD INTERFACE DEFINTIONS

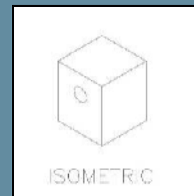




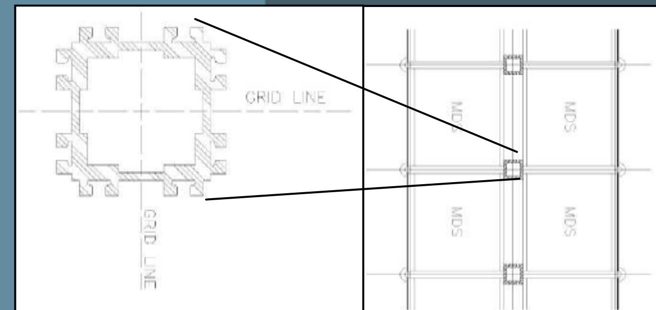
Standardized Dimensional Grid System



Double ISO 7166 Interface

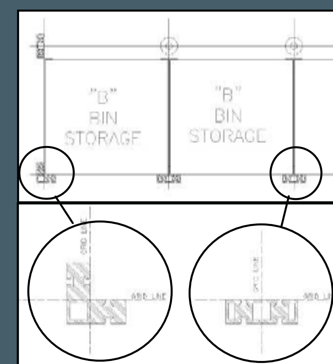


Welded Deck Pins

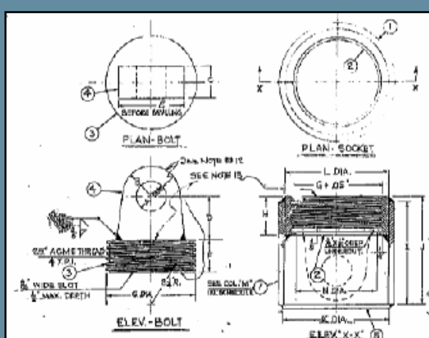


Removable Columns

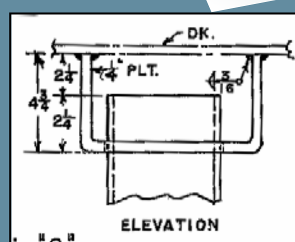
Modular Architecture
Leverages off of Previous Programs
ATC Integrated Joiner Bulkhead Project
TOSA Reconfigurable Stowage
Hull Type Drawings



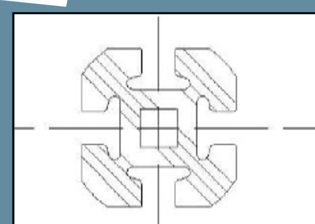
Removable Perimeter Columns



Reversible Deck Sockets

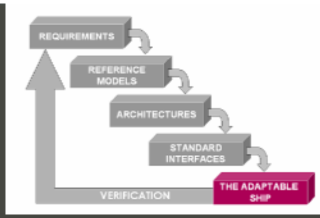


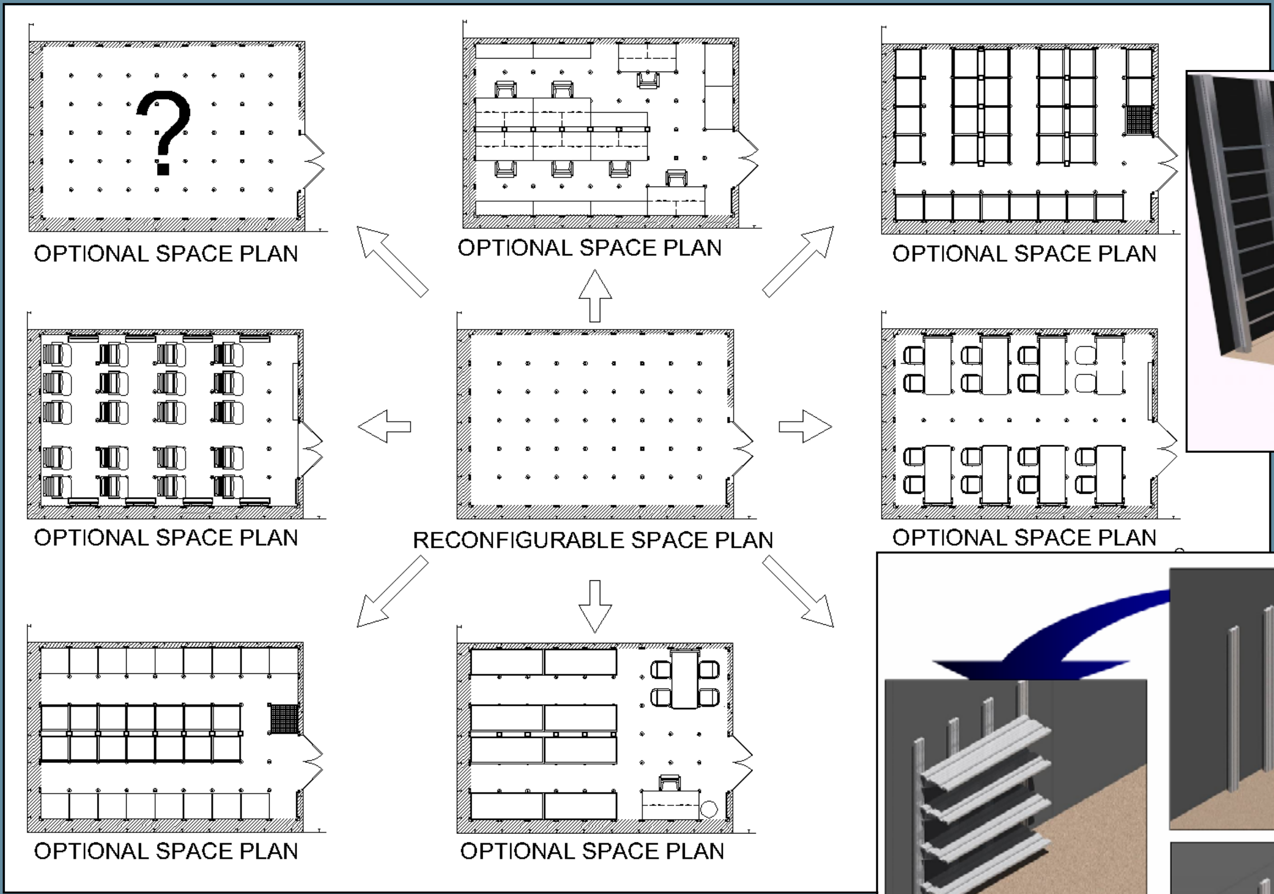
Overhead Column Sockets

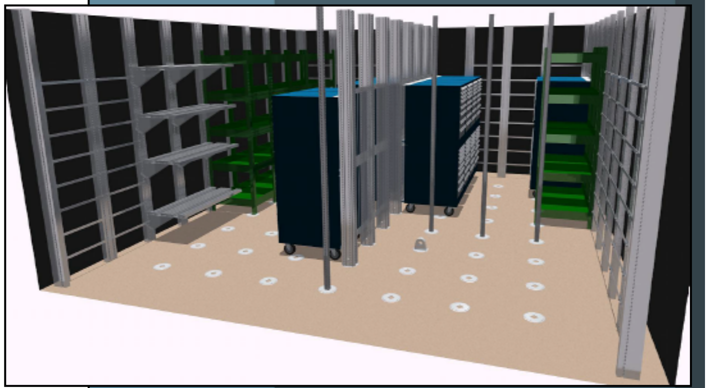


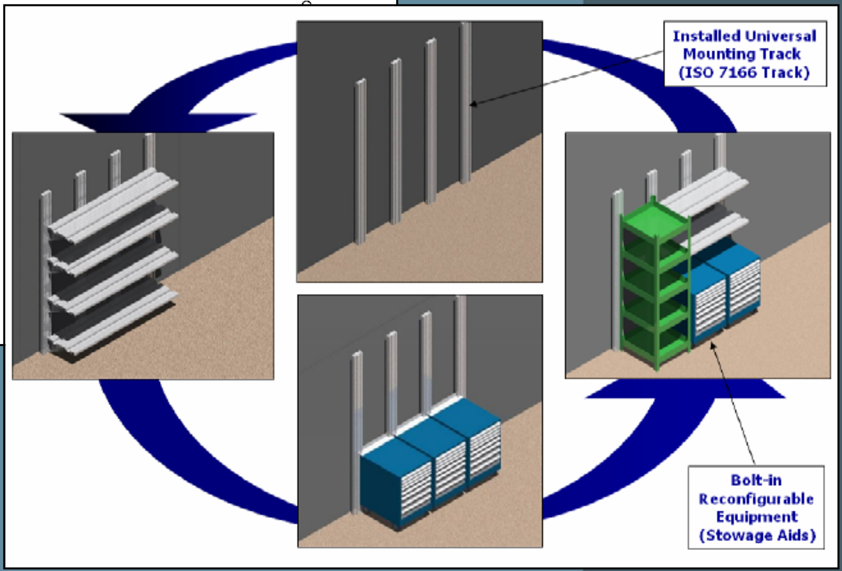
Removable Bulk Storage Telescoping Battens

MODULAR OSA SPACES – RECONFIGURATION OPTIONS

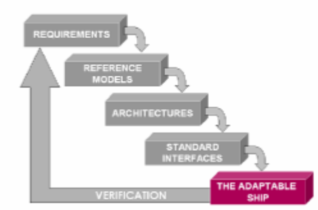








MODULAR OSA KEY: INTERFACE CONTROL



Sea Frame Development

Conceptual Design

High Level Impacts to Seaframe Architecture

Perform Concept Studies to Identify:

- Module Stations including Weapons, Air, Sea, Sensors, and Support
- Gross Mission Characteristics
- Initial Mission Communications

Preliminary Design

Refined Architecture Required for Seaframe Development

Interface Document

- Mission System Physical Requirements
- Notional Mission Packages
- Baseline Tech Architecture for Mission System Interfaces:
  - -Area, Volume, Weights
  - -Number of Module Stations
  - -Clearances
  - -Ship Services: Power, Cooling, Air/Water,Data Link
  - -Launch, Recovery and Handling
  - -Core and Reconfigure Systems
  - -Stand Alone Resource Stations
  - -Ammunition

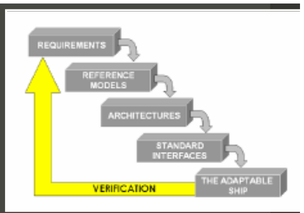
Final Design

Interface Specification for Detailed Design

Interface Control Document (ICD)

- Seaframe definition:
  - Detailed foundation definitions
  - Network
  - Communications
  - Command and Control Software
- Mission reconfiguration definition:
  - Detailed connection definitions
  - Focused Mission Package

RECONFIGURABLE SPACE VERIFICATION: BUSINESS CASE ANALYSIS



			Total Cost	Material Cost	Labor Cost	Cycle Time	Weight	Occurrences During Ship Life	**Life Cycle Cost**	**Life Cycle Availability**
Ship Life Cycle Phase	**Development**	Multi Bulk	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A
	Procurement	Multi Bulk	9% 35%	-64% 26%	54% 42%	28 Day 18 Day	-855 kg 465 kg	1	9% 35%	28 Day 18 Day
	O&M/ Overhaul	Multi Bulk	90% 70%	N/A	N/A	54 Day 84 Day	N/A	3	90% 70%	162 Day 252 Day
	Disposal	Multi Bulk	85% 87%	N/A	N/A	N/A	N/A	1	85% 87%	N/A
Total									**40% 80%**	**190 Day 270 Day**

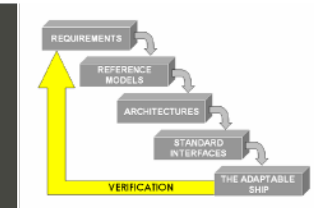
ISO 7166 has Slight Decrease/ Increase over Conventional

ISO 7166 has Decrease/Increase over Conventional

ISO 7166 has Significant Decrease/Increase over Conventional

ISO 7166 is Equal to Conventional

BUSINESS CASE ANALYSIS RESULTS



New Build

Conventional

Layout Compartment (Chalk locations)

- Subbases or Clips (Foundation)
  - Retrieve From Warehouse
  - Scribed for local irregularities, sheer, and camber
  - Cut, Weld and Watertight sealed to the deck
- Welding "Hot Work"
  - Requires Multiple Fire watches
  - Working and Adjacent Compartments must be prepped
    - Removal of paint
    - Removal of insulation
    - Removal of heat affected equipment and items
  - All welded areas must be cleaned and repainted
- Underlayment & deck covering (where specified) must be installed around foundations
- Stowage Aid Installation to Foundation
  - All foundations are different
  - Specific Stowage aid that mates with installed foundation must be located and retrieved
  - Each Stowage Aid mounts in a different manner requiring multiple tool sets, techniques
- Sway Braces must be installed
  - Custom Manufactured to fit into the mounting location
  - Weld to bulkhead or overhead "Hot Work"
  - Doublers must be installed on Stowage Aid in way of sway brace fasteners
  - Clean and paint, repair insulation

Multipurpose	64 Days
Bulk	52 Days

ISO 7166

Deck Sockets are built into the deck.

- Layout Perimeter (Chalk Locations) (accuracy very important)
- Deck Clips are welded around the perimeter of the deck on a regular grid spacing.
- Overhead sockets are welded in the overhead on a regular grid spacing interior and perimeter ("Hot Work" Custom Manufacturing and Fitting)
- Underlayment & deck covering installed (Where specified)
- Perimeter columns inserted in overhead socket and slid over deck clips, bolted in place.
- Interior Removable Columns are installed where required
  - Flip deck bolt in deck socket
  - Slide column in overhead socket
  - Pin column through deck socket
- Stowage Aid Installation
  - Retrieve stowage aid from warehouse
  - Bolt stowage aids to ISO track

Multipurpose	36 Days
Bulk	34 Days

Conventional **ISO 7166**

ISO 7166 Faster and Cheaper

Reconfiguration

Conventional

- Engineering Change Drawings
- Stowage Aid Removal
  - Empty stowage aid
  - Remove deck covering and underlayment
  - Unbolt stowage aid from sway braces, subbase , clips (foundation)
  - Cut sway braces, subbase , clips (foundation) from ship structure ("Hot Work")
  - Grind smooth, paint, repair insulation
- Layout Compartment
- Subbases or Clips (Foundation)
  - Retrieve From Warehouse
  - Scribed for local irregularities, sheer, and camber
  - Cut, Weld and Watertight sealed to the deck
- Welding "Hot Work"
  - Requires Multiple Fire watches
  - Working and Adjacent Compartments must be prepped
    - Removal of paint
    - Removal of insulation
    - Removal of heat affected equipment and items
  - All welded areas must be cleaned and repainted
- Underlayment and deck covering must be installed around foundations; repair insulation
- Stowage Aid Installation to Foundation
  - All foundations are different
  - Specific Stowage aid that mates with installed foundation must be located and retrieved from warehouse
  - Each Stowage Aid mounts in a different manner
- Sway Braces must be installed
  - Custom Manufactured to fit into the mounting location
  - Weld to bulkhead or overhead, "Hot Work"
  - Doublers must be installed on Stowage Aid in way of the sway brace fasteners
  - Clean and paint, repair insulation

Multipurpose	59 Days
Bulk	81 Days

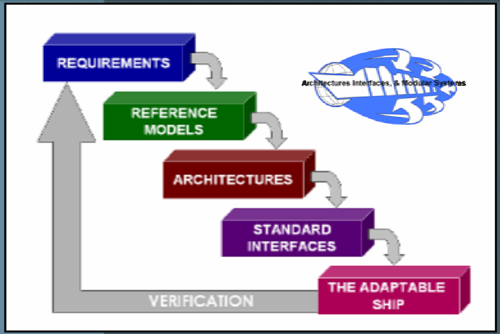
ISO 7166

- Interior Removable Columns are installed or removed where required
  - Flip deck bolt in deck socket
  - Slide column in overhead socket
  - Pin column through deck socket
- Stowage Aid Installation
  - Retrieve stowage aid from warehouse
  - Bolt stowage aids to ISO track

Multipurpose	5 Days
Bulk	7 Days

ISO 7166 Faster and Cheaper

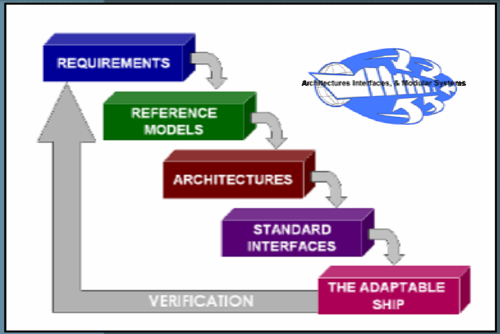
SUMMARY AND CONCLUSIONS



- Modular reconfigurable spaces based on OSA and Standard Interfaces:
  - Cost effective solution to meet User Needs.
  - Satisfies Capabilities Requirements and User Needs more efficiently and effectively than conventional system.
  - Enables:
    - Mission flexibility (rapid reconfiguration)
    - Supportability (common components)
    - Technology refresh/insertion

OTHER OSA ACCOMPLISHMENTS – INTERFACE CONTROL DOCUMENT (ICD)

- Former TOSA team members assigned to Mission Systems and Ship Integration Team (MSSIT) for a major ship acquisition program
- Developed J-5 Appendix to RFP and Contract: ICD Requirements
  - Focused initially on HM&E interfaces for preliminary design
  - Progressive definition to include additional interfaces
- Developed J-10 Appendix to RFP and Contract: OSA Open Architecture Requirements



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Barbara Shapter, Shirley Bockstahler-Brandt,
Alan Joice, and David Verven

The Johns Hopkins University Applied Physics Laboratory

Note these slides are extensively annotated. Full text is available by printing in PowerPoint "notes pages".

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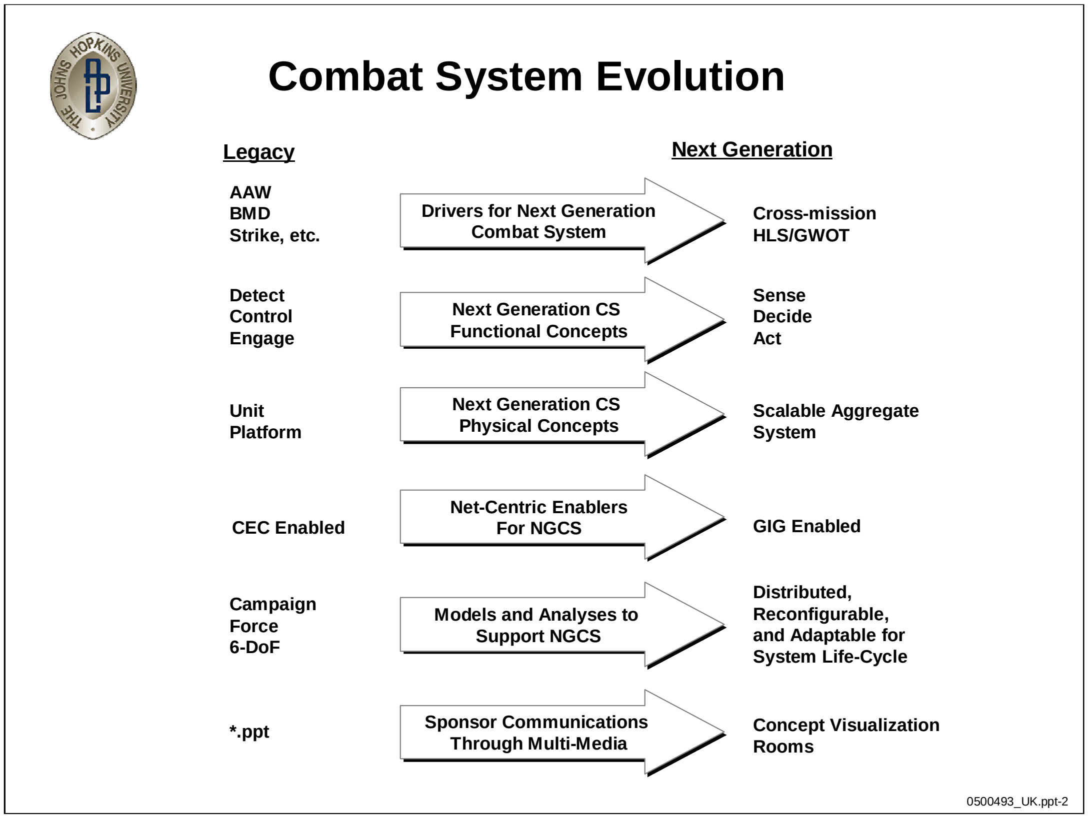
Abstract

Threats to ground, air, space, and sea are increasingly diverse, and the large set of operating environments for our Armed Forces now includes non-traditional roles of law enforcement, humanitarian aid, and homeland defense – all markedly different missions that must be performed against a backdrop of terrorism. At the same time, long-time threats, such as cruise and ballistic missiles, are becoming increasingly sophisticated, more difficult to counter, and more widely distributed. These factors pose critical challenges to the collective defensive posture and the ability to achieve fiscally acceptable solutions with next generation systems. After reviewing the threats and problems anticipated, a set of generic key concepts for next generation combat systems (NGCS) is proposed: aggregation, automation, and adaptation, along with three derivative areas: operational control, human understanding, and communications. The authors propose that such concepts be developed and built into systems in a general and consistent manner.

To help verify these key concepts, the authors illustrate their use through notional application to the Ballistic Missile Defense System (BMDS).[1] Finally, the relationship between these key concepts and the emerging Global Information Grid (GIG) is examined.

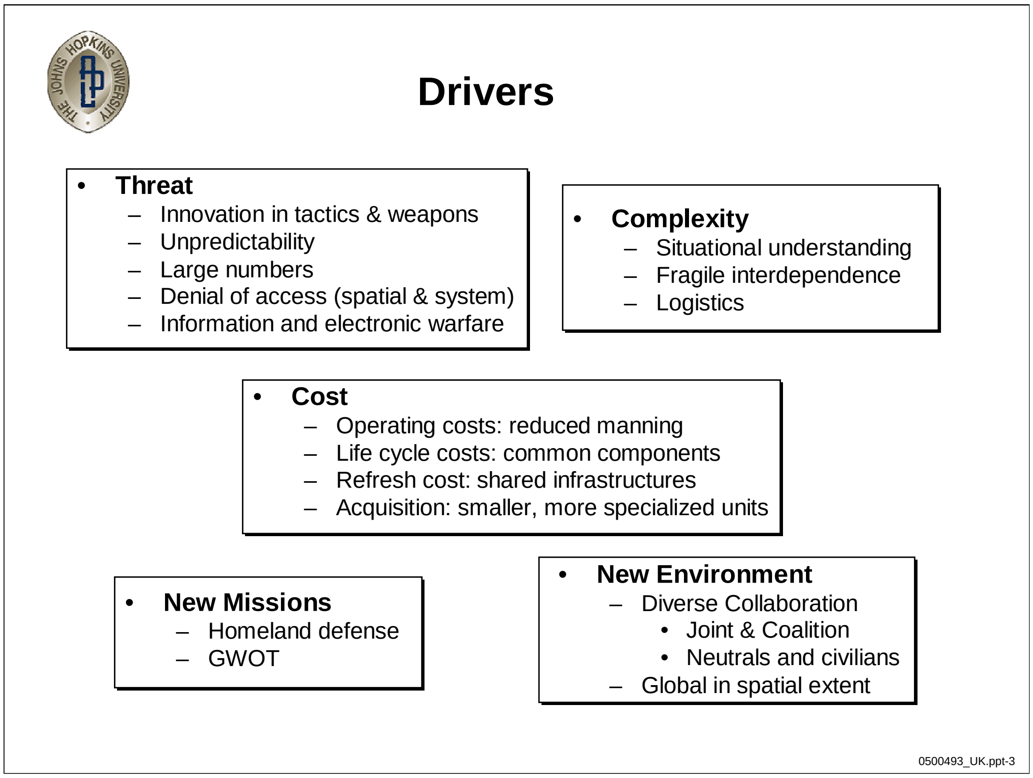
[1] Acronyms are also expanded on the last page of text.



Combat systems have evolved considerably over time to reach their current level of capability and integration among component systems. In early systems, “integration” was performed by people using skills and processes developed through training and experience to achieve objectives only possible through the synergy of multiple systems. Key in the evolution of the Navy’s current generation of combatants was the development of the Aegis Combat System. In Aegis, the Navy achieved an integrated fighting ship that “represented a major transformation, in which the ship, the combat systems and the training systems were designed as a single unit.”[1] Integration among systems within the ship became the realm of automation and tailored, managed responses governed by “doctrine”.

Many factors are pressing the evolution of combat systems beyond our current legacy capability. Achieving the “next generation” envisioned on the right-hand side of the slide will require us to address a large set of driving functions and develop technology enablers.

[1] “History of Aegis,” http://www.nps.navy.mil/meyerinstitute/history.htm.



Drivers for Change

While the current state of combat system capability is unparalleled in naval history, complacency is not acceptable. The environment in which naval forces operate is constantly changing, and a corresponding evolution of our capabilities is required. Drivers for this evolution include the following:

Threat – The weapons employed by our adversaries continue to evolve. Some threats are evolving in technical sophistication, making it increasingly difficult to develop single combatant solutions that provide the desired sureness of defense. These weapons are also seeing greater proliferation.

> A new generation of cruise missiles … could lead to weapons that are effective to ranges of approximately 600-800 km. While primarily pursued as naval weapons, conversion to land-attack variants would be a relatively straightforward process. The Iranian anti-ship cruise missile case points to a larger problem of attempting to control the spread of cruise missiles: an increasing number of suppli-ers, low cost, ready availability of dual-use technologies, and weak international controls. In acquiring production capabilities, Iran is also poised not only to further develop, but also to export a range of cruise missiles[1]

Enemy states and organizations are also evolving unorthodox approaches that stress our ability to adapt systems and methods to counter them. The lessons of 9/11 and current operations in Iraq are clear evidence of a trend that enables smaller and smaller groups to have significant impact.

> Not only is it likely that many of the conflicts facing the West will be of an asymmetrical nature, it is also likely that these threats will come from diverse and simultaneous sources. For example, the possibility that conventional terrorism and LIC [low intensity conflict] will be accompanied or compounded by cyber/infrastructure attacks, damaging vital commercial, military and government information and communications systems, is of great concern. In this sense, a major Western country could suffer greatly at the hands of an educated, equipped and committed group of fewer than 50 people. Such an attack could have an effect vastly disproportionate to the resources expended to undertake it[2]

Under other potential conflict scenarios, threats may appear in large numbers, stressing our ability to manage a complete response, and challenging our ability to create cost-compatible solutions.

[1] "Ra'ad cruise missile boosts Iran's military capability," Scott Jones, ***Jane's Intelligence Review***, 1 April, 2004.

[2] "Intelligence Gathering on Asymmetric Threats – Part One," Kevin O'Brien and Joseph Nusbaum ***Jane's Intelligence Review***, 1 October, 2000.

New Missions **–** The mission set for Navy combat systems is constantly expanding. Humanitarian aid, low intensity conflict, law enforcement, and terrorist attacks were not primary concerns (or even envisioned in some cases) when constructing many of today's combat systems. New mission needs are pushing the Navy out of its traditional operating format. GWOT requires the ability to respond rapidly and simultaneously in many areas of the world. As described in a draft Navy strategy[1], four national security challenges stem from the GWOT: irregular (uncon-ventional methods), catastrophic (rogue employment of weapons of mass destruction [WMD]), traditional, and disruptive (application of breakthrough technologies).

> "The agility of operational deployed naval forces supporting a Joint Force Commander provide the United States with extraordinary overseas reach…The increasingly urgent task for the Navy, and the larger Joint Force, is to determine what forces and concepts are required to meet the four challenges outlined by the Secretary of Defense"[1].

The difficult part is that these will be sustained mission obligations with three of the four demanding an innovation cycle much shorter than for traditional combat equipment. Combat system responses must vary dramatically depending on these missions, and future combat systems must be able to configure themselves rapidly and easily to the future changing mission environment.

New Operating Environment – Joint operation is expected to predominate, and coalition operation will become even more common. "The joint force, because of its flexibility and responsiveness, will remain the key to operational success in the future."[2] While this is not a new trend, the extent to which military planners are incorporating it as standard procedure is of note. There is still much to do in aligning our individual combatant capabilities to the notion of a coherently operated joint force. In an address to the 17th International Seapower Symposium, Admiral Mike Mullen, Chief of Naval Operations, extended this principle to encompass the international Navy community in commenting on the difficulty of addressing "irregular and unrestricted warfare"[3]: "Perhaps the most profound effect of today's challenges is the increased value of cooperation between friends, allies, coalition partners, and like-minded nations. Despite differences in size or structure of our navies, cooperation today is more necessary than ever before".

Complexity Management – As combat systems have evolved, they have become more complex, making the task of effective employment increasingly difficult. These complexities must be explicitly recognized and addressed in future combat systems. A key example is the difficulty we have in understanding the tactical situation: what are we in a position to do, what will our automation do without our intervention, and what new courses of action should be formulated. Increasing the interdependency among components of a system-of-systems introduces additional complexity. Widespread joint operations and their associated component interdependencies pose that risk. Efforts to address robustness and integrity must keep pace with the growth toward more interconnected capabilities to stem the tendency toward fragility. While often viewed as mundane, the ability to support operations must also be considered. As stated recently, "Absent a concomitant revolution in the support activities of defense, the Revolution in Military Affairs will quickly outrun the ability of logistics, personnel, medical and other systems to support it."[4]

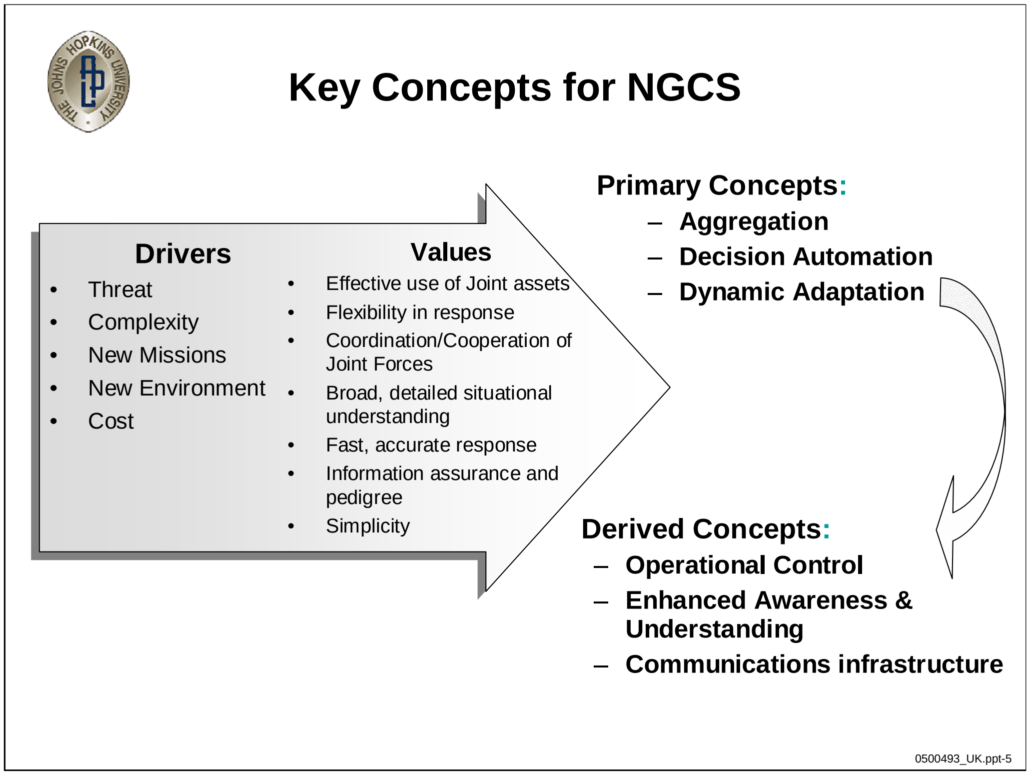
Cost – Pressure to control cost is present in all aspects of new and existing systems: development, production, operation, and maintenance. Achieving standardization of function and interfaces is an approach to more efficiently developing elements of the combat system. It allows them to be used across many systems which will share the development and maintenance burden. The Navy is exploring the concept of smaller, more mission-focused combatants (e.g. littoral combat ship). While the smaller, more focused unit provides a lower unit production cost, it will need to work closely together and with other joint assets in order to fulfill all missions. Reduced manning on the Navy's major combatants has been a cost reduction objective for quite some time. Progress in the operator/decision maker area has improved the ability to accomplish more, but it is unclear whether the current pace of progress is keeping up with the growing complexity of the systems, number of options, and collection of roles that face the modern-day warfighter.

[1] "Navy 3/1 Strategy: The Maritime Contribution to the Joint Force in a changed Strategic Landscape," N3/N5, April, 2005.

[2] "Joint Vision 2020," Chairman of the Joint Chiefs of Staff, May 2000.

[3] From "Remarsk as Delivered for the 17th International Seapower Symposium," ADM Mike Mullen, Naval War College, 21 September, 2005, as recorded in http://www.chinfo.navy.mil/navpalib/cno/speeches/mullen050921.txt.

[4] From leading change in a new era http://www.defenselink.mil/pubs/dodreform/fullreport.pdf



Concepts

There are many viewpoints painting a vision of the operational future, the needs of the various services in the coming era, and the transformational efforts that will be required to reach these goals. Some of these visions are documented in references cited throughout this paper. The fusion of these many thoughts into a small number of key concepts was a difficult exercise in synthesis that applied loosely structured events and exercises. Ideas on potential concepts and their relationships to drivers and values were collected and merged where possible. We made significant use of "mindmaps" [1] to organize ideas from reference sources, and later, to consolidate them. Governing this effort was a theme: What fundamental concepts could be developed or extended to enhance the capabilities of the combat system no matter what the mission, no matter what new weapon technology might bring, and no matter what tactics an adversary might apply? The notion is that key advances in integration of capabilities (at the combat system level) if established in a common form, can amplify the steady march of progress in sensors, and weapons – independent of specific technology.

The concepts that emerged from this effort appear in the slide above: aggregation, automation, and adaptation are three primary concepts[2], with operational control, enhanced awareness and understanding, and communications infrastructure as "derived" concepts. (The derived concepts support the primary concepts.) Each of these is defined below, with the primary concepts addressed in more detail in subsequent sections. (Amplification of the derivative concepts will be reserved for a later paper.)

Instances of these concepts have emerged with some of our more advanced capabilities. However, they have emerged in specialized form for particular domains. It is felt that these concepts are (or should become) fundamental tools in modern combat systems. They should be built into the system at the most fundamental levels and in a generic way. This will allow the concepts to permeate the combat systems of a force and bring about a dramatic magnification of capabilities.

[1] "Definition of Mindmaps," Tony Buzan, http://www.mind-map.com/EN/mindmaps/definition.html

[2] It is important to note that we still consider this a work in progress. We have a strong feeling that there may be more "primary" concepts that we have not yet labeled.

Aggregation is the pooling of resources from independent units to collaboratively perform mission tasks. In aggregation, resources (or portions of them) from independent systems are nominated to be constituents of a resource pool. Those resources are then applied to broad mission objectives that might be unachievable by any individual unit. How such resources are identified, partitioned, tasked, and controlled is critical to a robust operational capability. These form the primary areas of interest for aggregation concept development.

(Decision) Automation is the ability of a "system" to autonomously initiate actions or develop alternatives for human decision. This is not a new concept; it is quite analogous to the "automated doctrine" used in Aegis. The difference is in the breadth of generality and capability that we are striving for. The goal is to significantly increase the set of information on which decisions are based (including expanding that information set beyond the confines of the individual unit) and to grow the collection of "actions" that can be taken. The term "actions" is intended to be very encompassing, e.g., it includes the capability to prompt the human decisionmaker to action, issue alerts, provide recommendations, alter/highlight displays, or even modify the internal processing (parameters or rules) of a system component. Decisions are automated through a rich set of rules linking the initiation of each action to specific observable events.

Adaptation is the ability of the combat system to respond rapidly to changes in asset participation, environment, mission, or threat. Our forces operate in an environment in which change is constant. Threat tactics change, the environment changes, systems arrive and depart as participants in a force, and the capabilities of those systems change with upgrades and new installations. This requires us to establish a mature approach to managing responses to the various types of change. Change cannot be considered an anomaly.

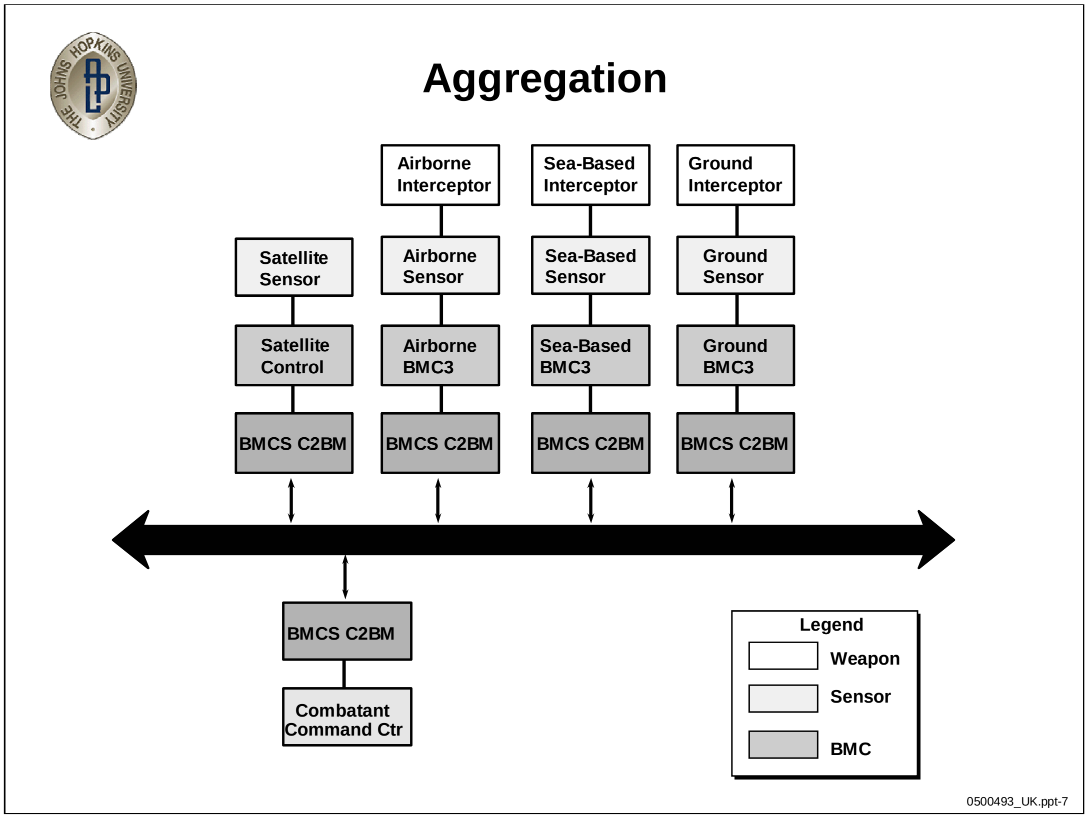
Operational Control is the ability to monitor and manage the dynamic automated aggregate operations. There are two very different aspects to this concept. First, the appropriate interactions among decision makers at all levels of command must be established and supported. Passing of "control" (or even lesser responsibility) of a resource from the unit that owns it to another unit that may be making more global decisions, is a significant change that must be considered by the operational community. Establishing the principles by which that may occur (in a general sense) will be a significant undertaking but is critical to advancing the aggregation concept. Secondly, there must be reliable and predictable control of the aggregate system (including its automation and adaptation functions) in order for these concepts to be operationally acceptable. More rigorous approaches to ensuring that components will behave as desired, and only as desired, must be established.

Enhanced Awareness and Understanding is the ability to develop comprehensive situational understanding. This is a long pursued objective, and progress has been made in many existing and emerging systems. But it is also clear from observations of the Human Machine Interface aboard the USS Ronald Reagan that there is yet work to do [1]. The growth of aggregate functionality and increased automation will also increase the complexity of understanding how systems will respond and what controls need to be manually asserted. Simply understanding "what will the system do if I leave it alone" is not a trivial exercise.

Communications infrastructure comprises the services that enable collaboration among aggregate components and warfighters. None of this will happen without communications and, more importantly, without communications that is much more capable, predictable, and robust than currently available. The establishment of the GIG recognizes this need[2]. The key is for the GIG development to fully recognize the communication requirements of combat systems.

[1] "Sail-Around Evaluation: The Battle Management Organization and Human Machine Interface as part of the USS Ronald Reagan Combat System," Draft Report, Technology Management Group, Inc., February 2005.

[2] Global Information Grid Capstone Requirements Document, JROCM 134-01, 30 August, 2001

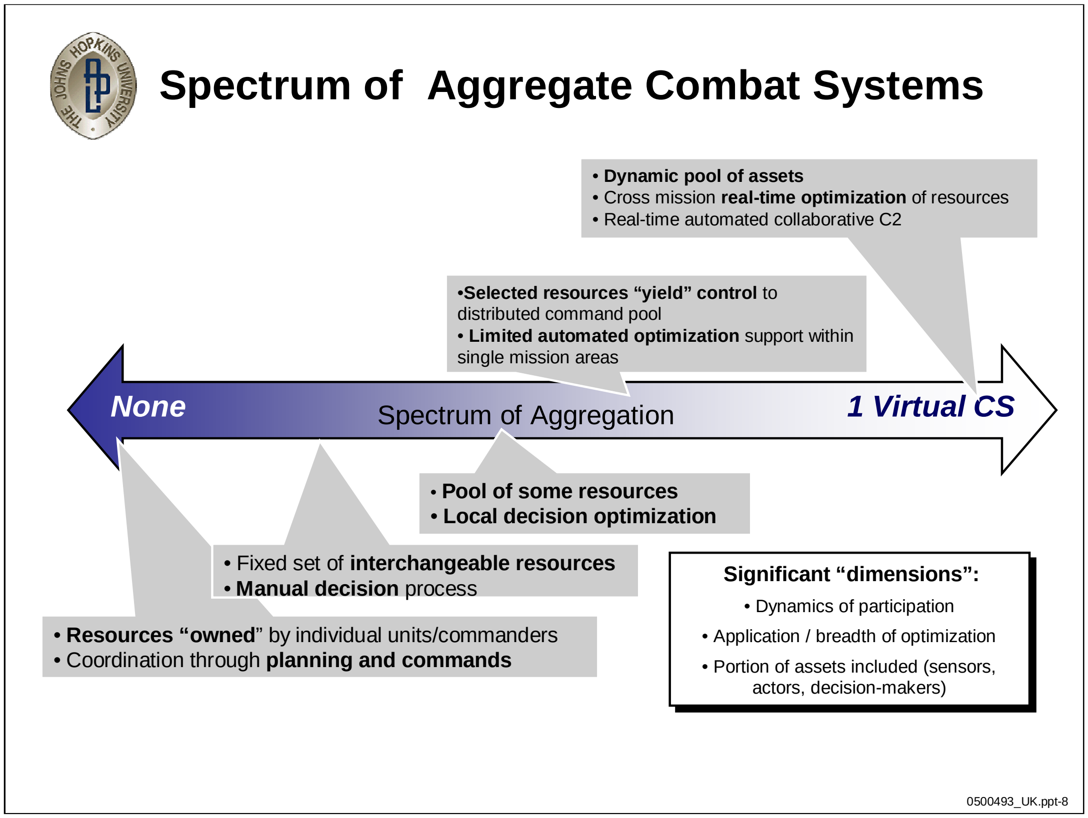


Aggregation

Aggregation is simply the application of all available and appropriate resources to a mission, independent of which unit hosts them. Examples of aggregation are emerging in current systems. The Ballistic Missile Defense System's (BMDS) overall concept is clearly one in which a diverse collection of assets is applied to multi-mission objectives of national missile defense and regional defense against short and long range ballistic missiles. No single system or unit can "solve" the problem. It is only through the synergy of multiple sensor and weapon systems (and their associated combat systems) that operationally viable solutions are achieved. The slide above depicts a notional interconnect of different components in the BMD system. The Command and Control Battle Management (C2BM) component of that enterprise is tasked with providing the required coordination among components to support the complex objectives. A second example of emerging aggregation is the Navy's Cooperative Engagement Capability (CEC). This provides a sensor information sharing and integration system that creates improved tactical awareness and also enables multi-unit supported guidance for engagements[1]. It seems that we are on the front edge of a technologically supported ability to reap the benefits of much more closely coordinated behavior among our individual systems. As suggested by the Undersecretary of Defense for Acquisition, Technology, and Logistics at an Armed Forces Communication and Electronics Association (AFCEA) conference, "I can think of no more critical need than the development and fielding of a joint battle management capability. … A key objective is to provide robust capabilities and innovative approaches for the full spectrum of potential missions using a system of systems approach."[2]

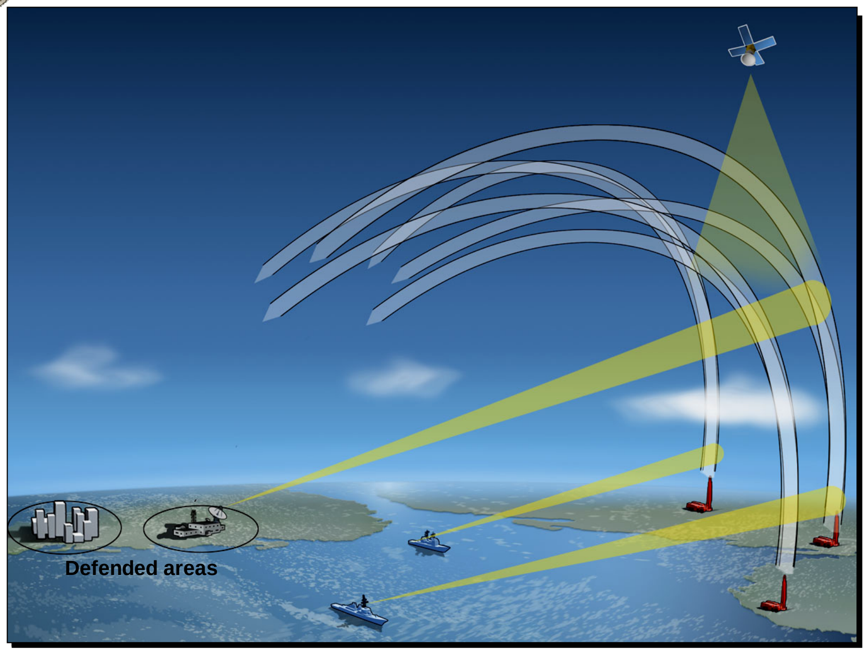
[1] "CEC: Sensor Netting with Integrated Fire Control," C. J. Grant, Johns Hopkins APL Technical Digest Vol 23, Nos. 2 and 3, 2002.

[2] As reported in "CHIPS – The Department of the Navy Information Technology Magazine," Summer 2004, http://www.chips.navy.mil/archives/04_summer/Web_pages/Michael_Wynne.htm.



We can look at aggregation as a spectrum of behavior (depicted above) ranging from simple single-objective human coordinated efforts to fully automated, real-time optimization of resource use across multiple missions. While drawn as a single-dimension continuum, the spectrum has somewhat independent dimensions of breadth (the number of resources addressed), scope (the set of objectives simultaneously addressed), and dynamism (the ease/speed with which the management adapts to new conditions). The appropriate working point within this spectrum depends on the state of technology to support it. The technology task ahead is to push the operating point forward; the systems engineering job is to select the appropriate operating point for any given time.

Notional Detection/Surveillance Aggregation



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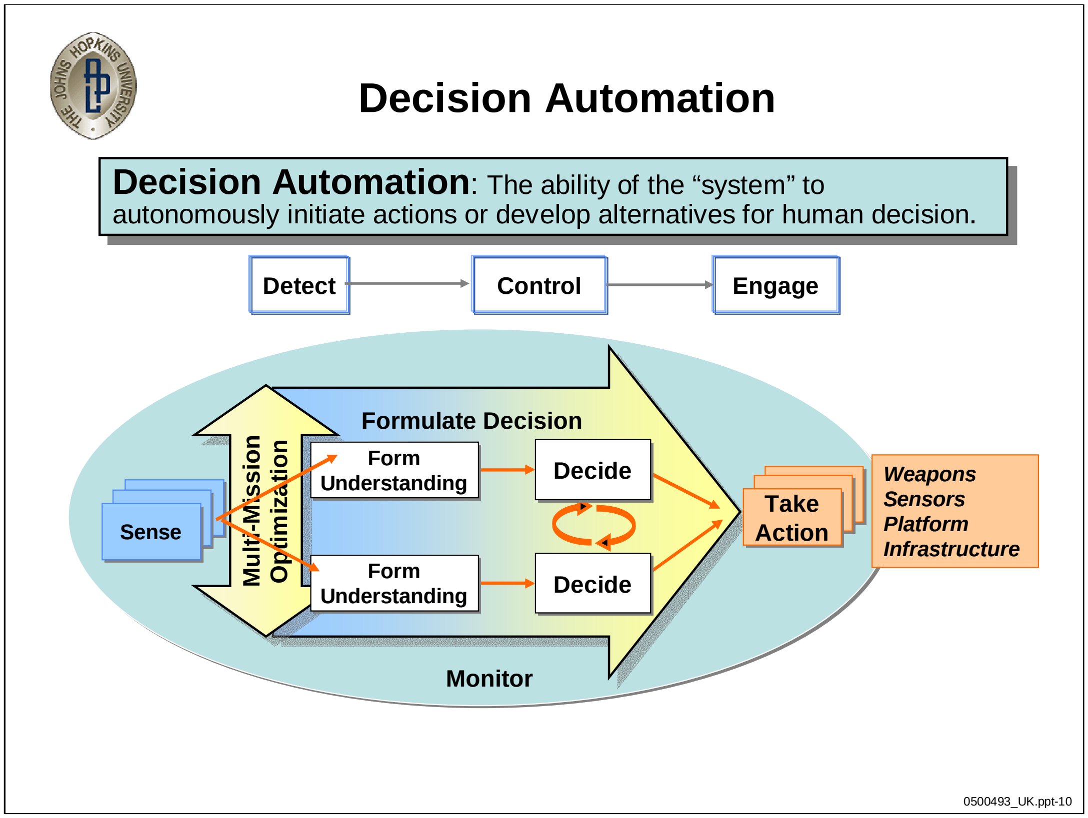
Throughout the paper, we examine the application of these concepts to the BMD domain. In this extremely challenging technical problem, we find multiple sensors of varying types that can be applied to the detection and tracking problem, multiple weapons that have varying ranges, and hosts that vary in mobility and command structure. The slide above depicts a notional case in which a land-based sensor, two ship sensors, and a satellite are available to support detection and tracking of ballistic missile launches in the region. To help raise the likelihood of detection, the land- and sea-based sensors focus their detection energy on areas determined by combinations of launch and impact points. The satellite has a broader field of view for detection, but lacks precision for tracking and may suffer from time-varying characteristics: It may not always be in place and does not always have a clear view (due to atmospheric interference). The problem, very simply, is to use these assets to the best of their abilities, in combination, to provide the most reliable and accurate detection and tracking of ballistic missiles possible (with those assets). The changing nature of the environment, intelligence (anticipated launch points), the resources themselves (satellite and ship locations), etc., establish a dynamic environment in which this optimization is performed.

To support the aggregation concept in a general way, capabilities must be established that allow resources from independent units to be grouped for optimized application to a mission. Mechanisms must be established to do the following:

- Create a pool of resources (in this case, the sensors).
- Nominate resources to the pool, i.e., give approval for the nominated resource to be used (as determined by the resource manager). It also seems likely that a mechanism for (optional) final approval be established to allow the resource owner final say on how a resource might be used.
- Express a mission objective in a way that allows a resource manager to discover a “good” (ideally optimal) resource allocation to fulfill it. Mechanisms for feedback to human decisionmakers and thresholds for acceptability are needed to provide the resource manager the needed guidance on when “best effort” is suitable and when decisionmakers must enter the picture to consider the problem (with additional options not available to the resource manager).
- Provide a mechanism for managing the resources in a pool, allocating them to specific responsibilities that collectively fulfill a mission objective. (This includes the “optimization” function that here must provide best-effort solutions to prioritized objectives under any collection of resources and objectives.)



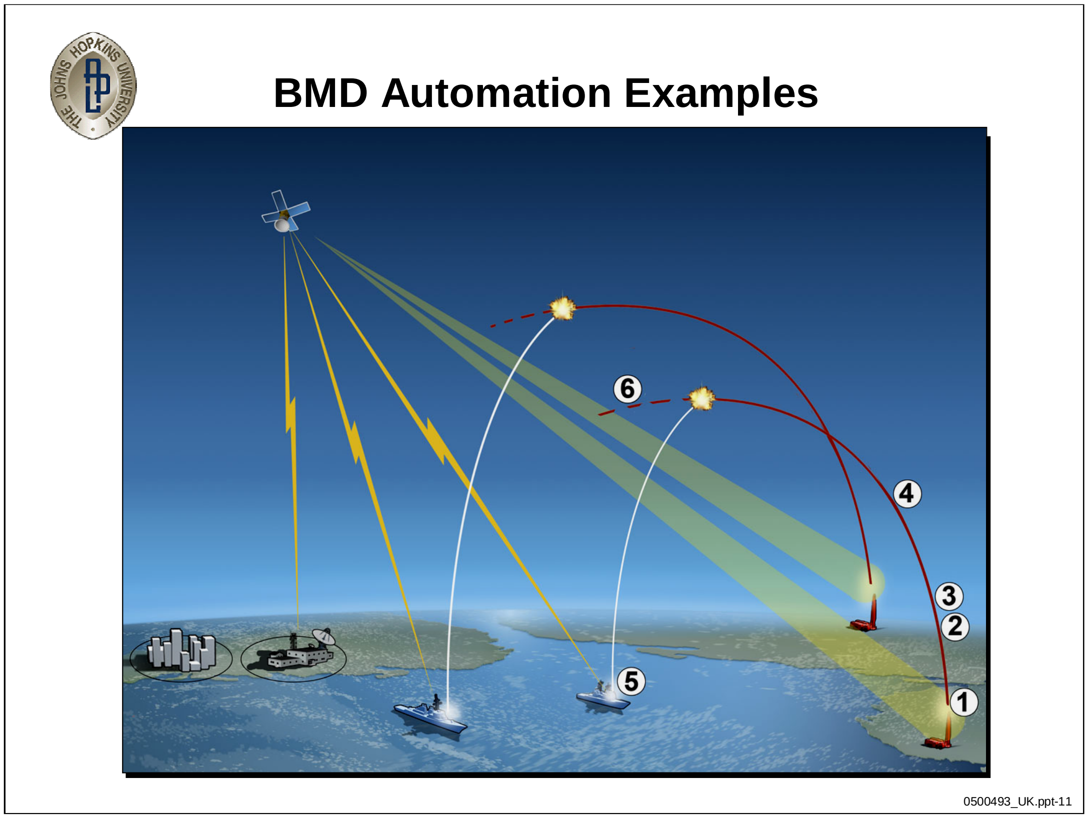
Automation

Automation is a broad term. In Aegis as well as in many other combat systems, a set of automated capabilities already exists, including automated detection and tracking, automated status reporting, and readiness assessments. The focus here is decision automation, which also has an existing set of capabilities supporting automated and human-supported decisions involved in object identification, threat engagement, and radar control. Automation joins our list of key concepts due to its continuing importance.

The current operational context includes large collections of sensors, weapons, systems, rules for use, preferred application techniques, etc. While these provide capability (and options), they substantially complicate decisions about what to do and when. The intended extension of automation we seek is the significant broadening of all aspects of the capability: the input set that is applied to the decision process, the richness of the language that is used to express desired automated actions, and the set of actions that may be taken as a result of automation. Moreover, it is desired that these extensions take a form that can be applied in a regular fashion to all the component systems (and their associated controls) that comprise the combat system "system of systems."

In the development of Aegis, the simple model "detect, control, engage" was used to provide a high level characterization of its overall architecture and automation approach. In considering the growth of automation for the future combat system context, a more apropos model is "sense, decide, act," where the growth in domain of all three steps is generalized to the broader mission context. In this model, automation and human decision must collaborate effectively and efficiently to address the staggering number of options that are afforded by increasingly capable and flexible systems. In its simplest form, sensed data and information are used to decide when and under what conditions various system capable actions are initiated.

An important principle in these systems, however, must continue to be the ability of the human decisionmakers to exercise supervisory control. This really requires two things": first, that appropriate control mechanisms exist, and second, that the behavior of the system be comprehensible to the decisionmaker. As more automation is established, both of these become more difficult to achieve and new techniques may well be required.



Automation in a ballistic missile defense scenario should assist in many of the operational decisions that may occur. The slide above depicts a complex situation involving multiple ballistic missiles, multiple sensors, multiple defensive firing units, and multiple defended areas. It is annotated with some of the decision points listed below, where we would expect that broad automation capabilities would play a major role in collecting relevant information and either making decisions outright or providing recommendations or option summaries for human decision.

1. For any initial detection (especially one that is the “first” in an actual military exchange), there are significant decisions that must be made on whether the observation is indeed a real object and whether it is one of interest, e.g., a ballistic missile of some sort.
2. Given that a real missile has been detected, the next set of questions pertains to whether it is something that warrants engagement. Is it perhaps just a test? If it is indeed a hostile action, is it of sufficient concern that we should attempt engagement? (An answer to this question varies considerably depending on prior events and weapon stores.)
3. On the event of a verified first hostile launch, there may be many actions (changes to automation settings, for example) that might need to be altered to establish a more active, faster response to further hostilities.
4. A ballistic missile in flight may be trackable by multiple assets. Which ones should be used? Are there sensor resource loading issues to address if there are multiple missiles in flight? Are different sensors better equipped to address different phases of tracking and discrimination? (Clearly, this ties into the aggregation concept quite directly.)
5. For a missile that is to be engaged, selection of the engaging unit and weapon must be made. What strategy should be applied to the engagement: salvo, shoot-look-shoot, single-shot?
6. For an engaged target complex, an assessment must be done to determine whether the warhead has been neutralized. This may also lead to a decision on whether to reengage, with criteria for reengagement changing as a result of the tactical situation and number of remaining defensive missiles. Again, a choice of engaging unit and weapon must be made (when more than one option remains).

Adaptation

Adaptation: The ability of the combat system to respond rapidly to changes in asset participation, environment, mission, or threat.

Aspect

- Focuses on the infrastructure required to adapt to or to institute change at various levels of the aggregated combat systems.
  - **Asset participation**: protocol for adjusting to the entry/exit of a unit or its resources from participation in one or more aggregate resource pools
  - **Operational doctrine modification**: ability for unit personnel to adjust or select automation rules in response to an operational situation
  - **Engineering doctrine modification**: ability to adjust combat system parameters and automation rules and forward them for ship use

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Adaptation

A century ago, German strategist Field Marshal Helmuth von Molke warned, “No plan survives the first engagement with the enemy’s main force.”[1] The creativity and innovation shown by current enemies seem to bear this out as a continuing principle. The risk in creating more complex collaborative and automated approaches to warfare and defense is that we may create capabilities that are overly rigid and vulnerable to unanticipated innovation.

Our focus on adaptation concepts is pointedly aimed at avoiding that problem. We envision three types of adaptation (as shown above):

• Changes in resources/participation – previously discussed as an element of aggregation (and indeed it is) in which the overall force must adapt in real time to the presence of different resource sets under a continuing fixed set of mission objectives. A broad interpretation of this also encompasses the evolution of systems: one may see an airborne warning and control system (AWACS) aircraft depart and a new one arrive on station with significantly different capabilities.

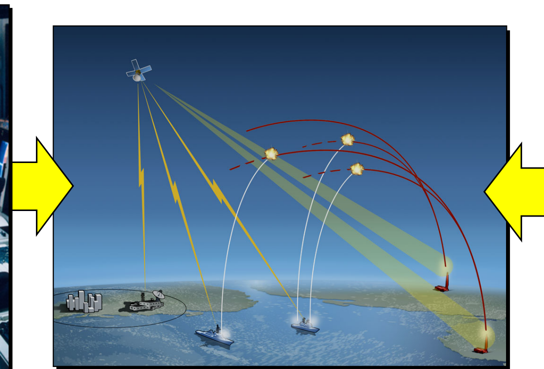
• Field modification of automation – With suitable support for entering and validating new automation rules, we wish to enable the warfighter community to tailor automated responses to the demands of their particular environment and operational guidelines. Achieving this requires a balance between flexibility and complexity, hopefully elevated by effective human interface design.

• Engineering station modification of automation – There are elements of automation control that may be beyond the expected proficiency of the warfighter. These areas can still be addressed as adaptable functions but with the support of an engineering community at a base or command installation. In addition to personnel with additional training, such a site might also have considerably greater assets for the determination of optimal automation settings and for the validation of what might be a large set of interrelated adjustments.

[1] cited in “Transforming military improvisation into strategy,” The Lawton Constitution.com, Richard Hart Sinnreich, http://www.lawton-constitution.com/sinnreich/archives/Transforming%20military%20improvisation%20into%20a%20strategy.htm.

Adaptation in BMD Scenario

Warfighter | **Engineering Center**



Adaptation capitalizes on the assets of the deployed fleet and its engineering support centers to rapidly react to changes in the threat and enemy tactics.

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Adaptation in a ballistic missile defense scenario might follow many paths. First, as discussed initially under aggregation, the set of resources to be applied to the detection and tracking problem should be seen as a set under the constant potential of change due to environment, system availability, and even pressing needs in another mission area. Second, on the event of the first confirmed tactical ballistic missile (TBM) launch, it is very likely that many identification (ID), tracking, and engagement controls might be altered to operate more aggressively (and with less command level confirmation) to allow weapons and systems to be used to their greatest effectiveness. Third, the experience of engaging the enemy might, for example, reveal an unexpected decoy approach. With the support of remote engineering analysis fueled by detailed field sensor data, the algorithm for identifying the ballistic missile warhead might be adapted to yield a lower susceptibility to deception. A network-based delivery of the new parameters for identification automation would be provided and installed with as quick a turn around as possible.

GIG Definition and Objectives

- Definition:
  Global Information Grid: "The globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters, policy makers, and support personnel."
- Needs
  - "The GIG shall support all DoD missions with information technology…"
  - "The GIG assets shall be interoperable …"
  - "The GIG shall be based on a common, or enterprise level, communications and computing architecture to provide a full range of information services at all major security classifications…"
- Vision
  "U.S. forces must leverage information technology and innovative network-centric concepts of operations to develop increasingly capable joint forces. Our ability to leverage the power of information and networks will be key to our success in the 21st century. We must make information available on a network that people will be willing to depend on and trust. We must populate that network with new types of information needed to defeat future enemies and make existing information more readily available. And we must deny enemies' information advantages against us."

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Key Concepts and the GIG

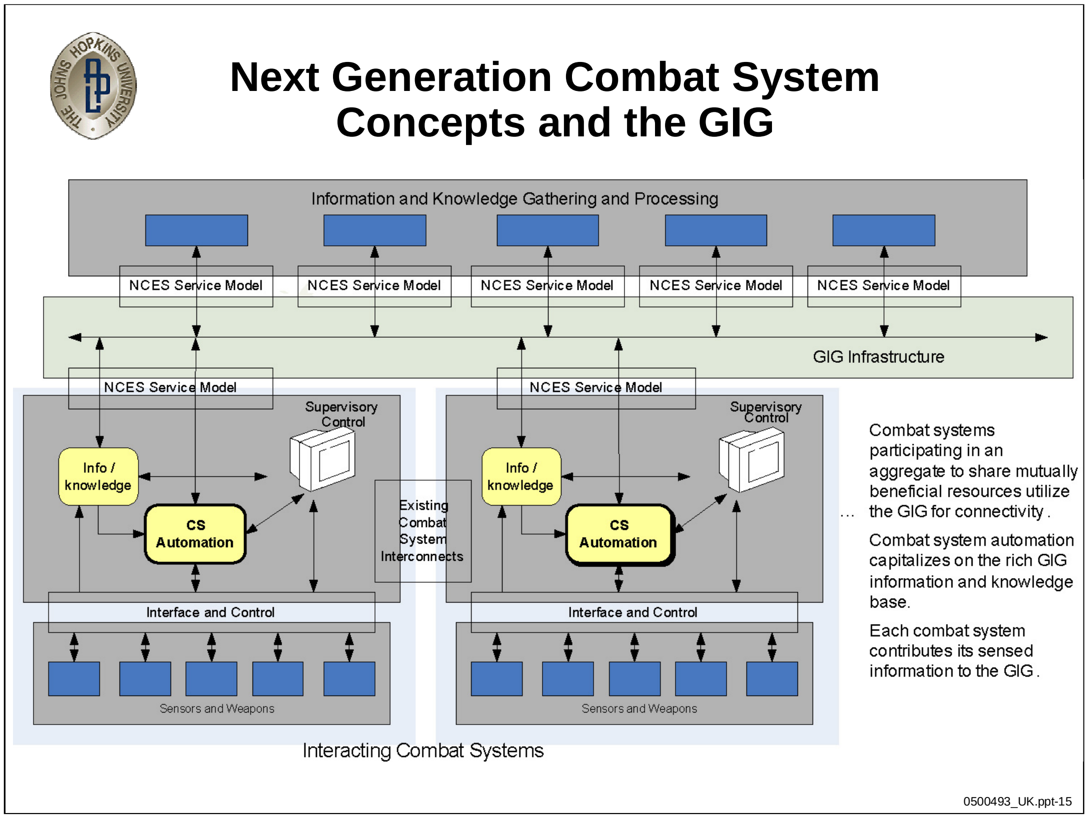
Policy for the GIG[1] aims for a future in which virtually all information systems (and those that employ or provide information to them) are crafted to operate in a common information exchange environment. With standards guiding interoperability, enterprise-level services providing common and efficient base capability, and a greatly extended communications infrastructure, the GIG promises to be "transformational" in the truest sense of the word. It is critical then to consider how this much-elevated capability for delivering and processing information may influence the combat systems of the future.

The Navy has established a specific initiative for pursuit of GIG objectives, called FORCEnet, which specializes the requirements of the GIG to the Navy environment and provides a first-level view of a planned architecture[2]. Interestingly, the future combat system concepts we espouse most certainly fit under the GIG umbrella of a system that "transmits information to, receives information from, routes information among, or interchanges information among other equipment, software, and services."[1] However, historic differences in requirements and the ability of technology to meet them have fueled two independent development communities: the combat system and information system (sometimes known as command, control, communications, computers, and intelligence [C4I] communities).

The convergence of these two futures seems inevitable. The true "value" of the the GIG and its Navy FORCEnet manifestation is not so much its ever more powerful knowledge base but, rather, what can be done with the knowledge it creates. A favorite term in the intelligence community (which is a major player in the information system environment of the GIG) is "actionable intelligence." The future combat systems will be primary providers of that "action."

[1] "Global Information Grid (GIG) Overarching Policy," DoD Directive 8100.1, Deputy Secretary of Defense Paul Wolfowitz, 19 September, 2002.

[2] "FORCEnet Architecture Vision," Version 1.2, Office of the SPAWAR Chief Engineer SPAWAR 05, 18 July 2003.



On the combat system side is a continuing quest for more and higher quality information that can be used to guide battle decisions. Our combat system concepts strive toward adaptable, automated capability, optimized across a collection of cooperating joint assets can only realize their potential with the type of adaptable, ubiquitous, and improved communications infrastructure promised by the GIG. Expanded automation capability appears to takes a central position in connecting these two objectives, as suggested above.

The richness of information made available ***(***and readily usable***)*** by the GIG will elevate the capabilities possible in a generalized automation scheme. No longer constrained to base decisions on own unit information, generalized decision automation will be free to identify and apply best sources, to incorporate information on other units' status and intent, and to utilize the real-time evolving experience base of its peers. But to achieve this integrated vision, the combat systems must be able to acquire information with the accuracy, reliability, and timeliness required for making real-time warfighting decisions. Bridging these two simultaneously evolving communities will take concerted effort, but with potentially high payoff.

The development of our NGCS key concepts may also contribute to the GIG's NCES. The development of components that support aggregation, automation, and adaptation might well be candidates for an extension of the current nine core enterprise services of the NCES[1]. In particular, the implementation of aggregation must employ a standard form across the participating systems to reap the desired advantages.

[1] "Global Information Grid (GIG) Enterprise Services (GIG ES) Capability Development Document," in ***Defense Acquisition Guidebook***, V1.0 Section 7.2.4.7, 17 October 2004.

Summary

- Drivers for change:
  - Threat, new missions, new environment, cost, complexity
- Concepts for the future:
  - Aggregation, automation, adaptation
  - Operational control, enhanced awareness/understanding, communications infrastructure
- Relationship to the GIG
  - GIG provides:
    - More information for better decisions
    - Infrastructure for force level collaboration
  - NGCS provides:
    - An “actor” environment for the GIG information/knowledge
    - Aggregation concepts and service definitions

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Summary

The authors have assembled a summary of factors driving Navy combat systems to change. A synthesis of drivers and operational vision led to a collection of primary and secondary concepts that establish general system capabilities that can be applied across a wide variety of military systems and missions. The primary concepts of aggregation, automation, and adaptation are discussed in moderate detail and applied in “thought exercise” form to the BMD mission. While these concepts have emerged from a Navy context, they should be equally appropriate to the combat systems of the other services. Indeed, without adoption of compatible (if not identical) concepts by the developers of all joint future combat systems, the complex collaborative system behavior envisioned will not occur. Because a broad set of systems would be integrated and controlled through these combat systems, it seems highly beneficial to address these concepts with general implementations that can be universally applied.

The development of the GIG is a highly relevant effort to the evolution of combat systems and specifically, to the described concepts. While it will require time to align objectives, requirements, and communities, it would seem inevitable that the significant capabilities present in current combat systems must eventually benefit from the rich information environment that will be assembled in the GIG

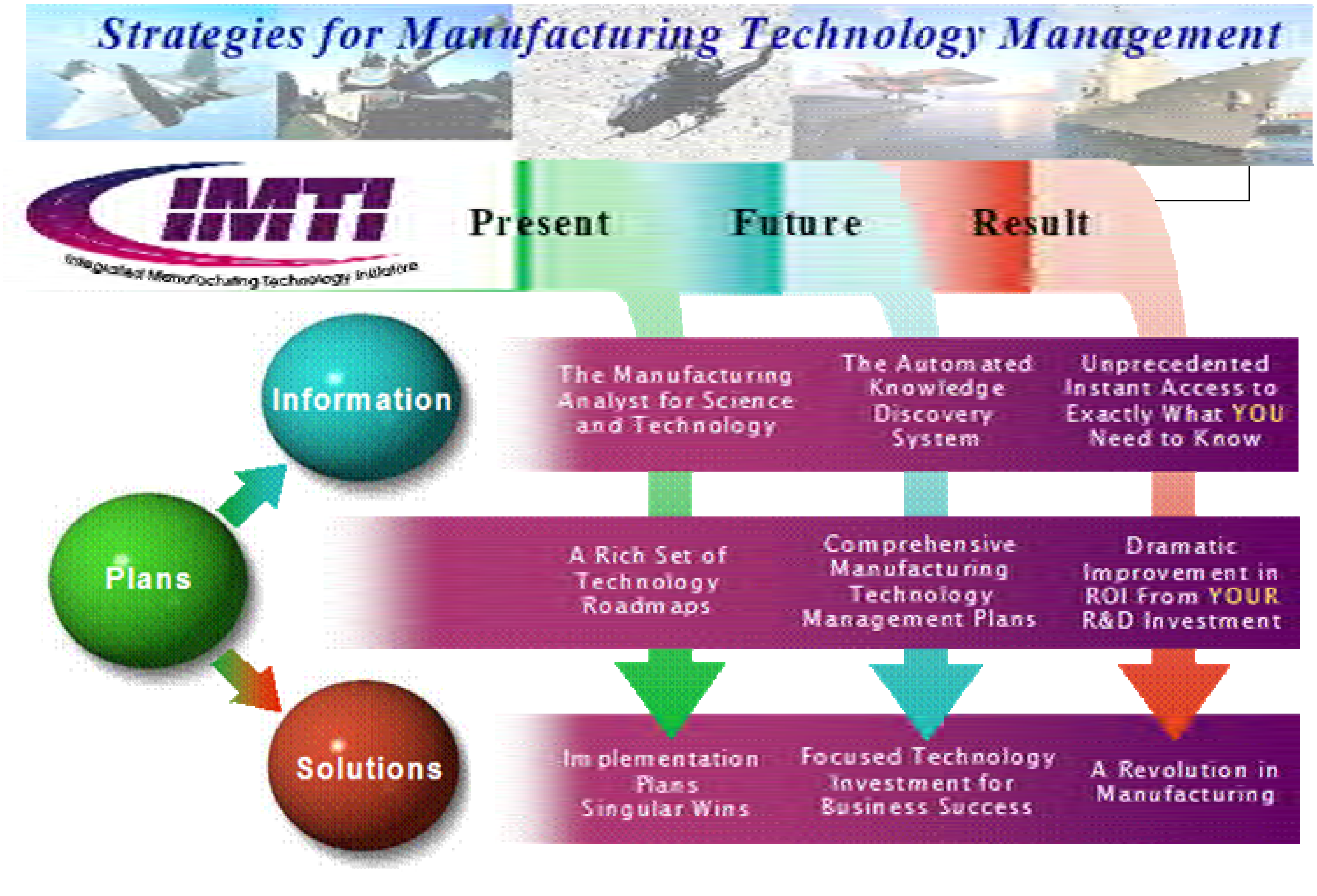
Acronyms

6-DoF	Six-Degree of Freedom
AAW	Anti-Air Warfare
BMC3	Battle Management Command, Control and Communications
BMCS	Battle Management Control System
BMD	Ballistic Missile Defense
C2	Command and Control
C2BM	Command and Control/Battle Management
CS	Combat System
GBI	Ground-Based Interceptor
GIG	Global Information Grid
GWOT	Global War on Terrorism
HLS	Homeland Security
IR	Infrared
NCES	Net-Centric Enterprise Services
NGCS	Next Generation Combat System

Next Generation Manufacturing Technology Initiative and the Model-Based Enterprise

NDIA Systems Engineering Conference
San Diego, California
October 26, 2005

Richard Neal - IMTI
Gerry Graves - ATI
Leo Reddy - NACFAM


Strategies for Manufacturing Technology Management
IMTI
Integrated Manufacturing Technology Initiative
Present
Future
Result
Information
Plans
Solutions
The Manufacturing Analyst for Science and Technology
The Automated Knowledge Discovery System
Unprecedented Instant Access to Exactly What YOU Need to Know
A Rich Set of Technology Roadmaps
Comprehensive Manufacturing Technology Management Plans
Dramatic Improvement in ROI From YOUR R&D Investment
Implementation Plans Singular Wins
Focused Technology Investment for Business Success
A Revolution in Manufacturing

The NGMTI Team

***Three non-profit organizations with strong expertise and experience in facilitating collaborations*.**

- **IMTI: a technology/research management organization with a mission to support the nation's manufacturing infrastructure**
- **NACFAM: a long-term builder of leadership-level, nationwide manufacturing technology public-private partnerships**
- **ATI: a deeply experienced manager of advanced manufacturing technology research collaborations.**

“NGMTI is dedicated to transforming the U.S. manufacturing base through technology driven innovation”

Importance of Manufacturing to Innovation

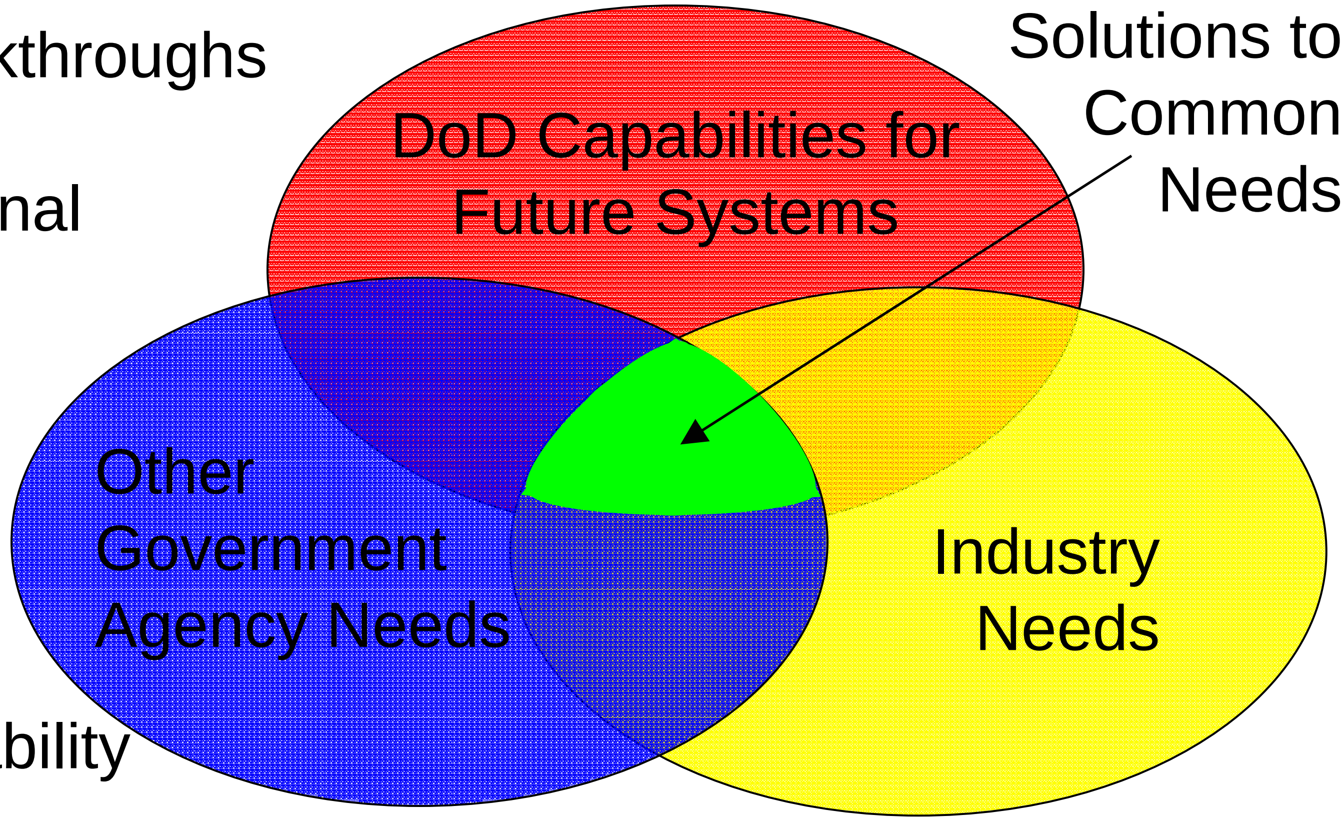
- **Drives innovation: Manufacturers invest $135 billion annually in R&D, which is 70% of industry R&D investment and more than all federal R&D**
- **Innovative mfg process technologies are <u>*the most effective means*</u> to reduce China's low-wage advantage**
- **Yet industry gives low priority to process technologies and is moving R&D offshore**
- **Only 2% of federal $132 billion R&D budget spent on basic and applied manufacturing tech**
- **Manufacturing R&D has never been a White House "Grand Challenge"**

The NGMTI Solution

- Provides a mechanism for building and executing an innovative manufacturing R&D strategy for both economic growth and national security goals
- Represents a sustainable organization meeting critical success factors: strategic planning, industry-government collaboration, national tools
- Coordinates research and development projects focused by strategic investment plans
- Leverages university, federal, industrial labs, and research consortia nation-wide

NGMTI Provides for Future Common Needs

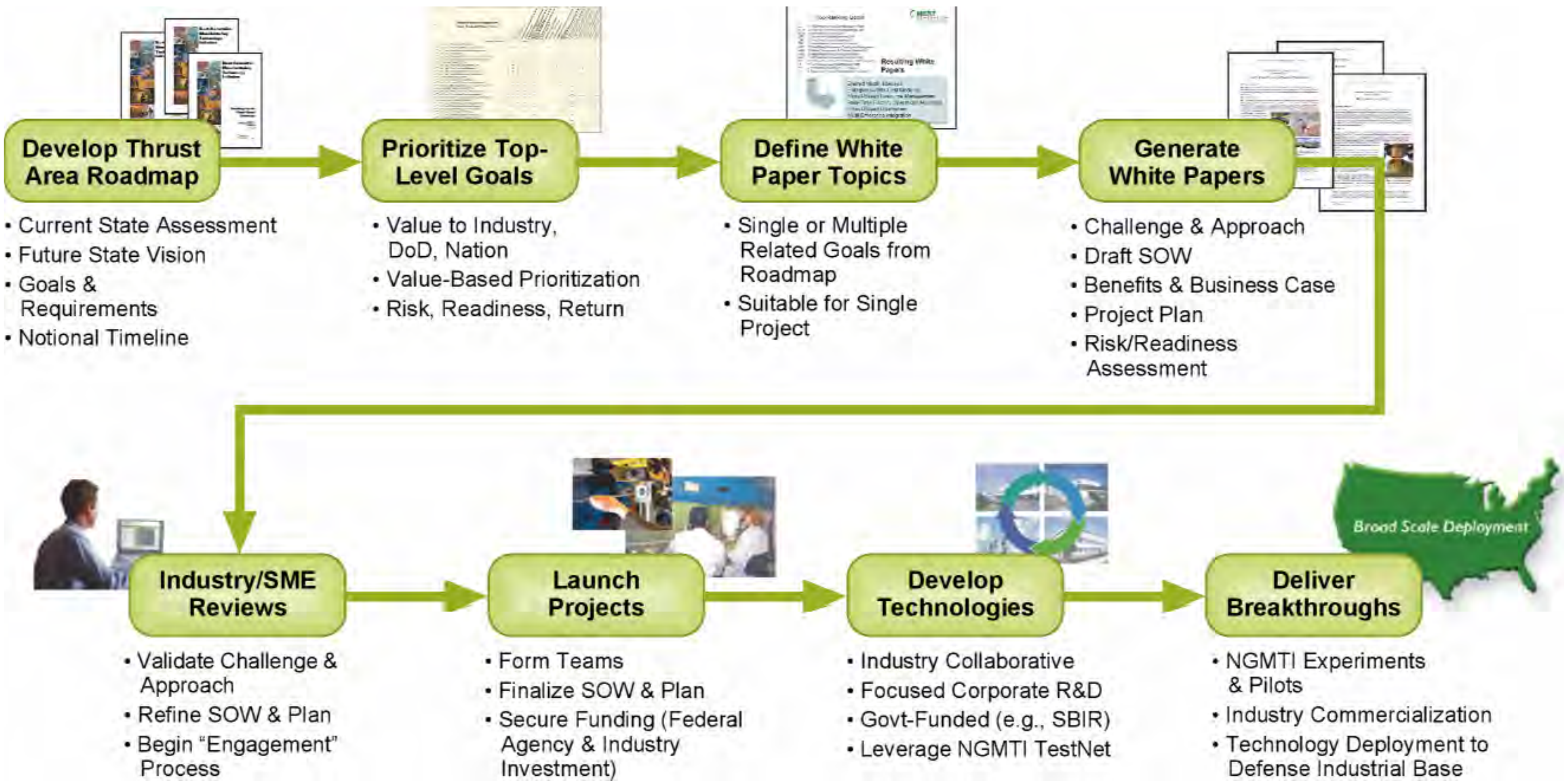
- Provide breakthroughs that produce transformational technologies
- Provide technologies that improve affordability and sustainability



- Create innovative opportunities for fast response manufacturing of new products

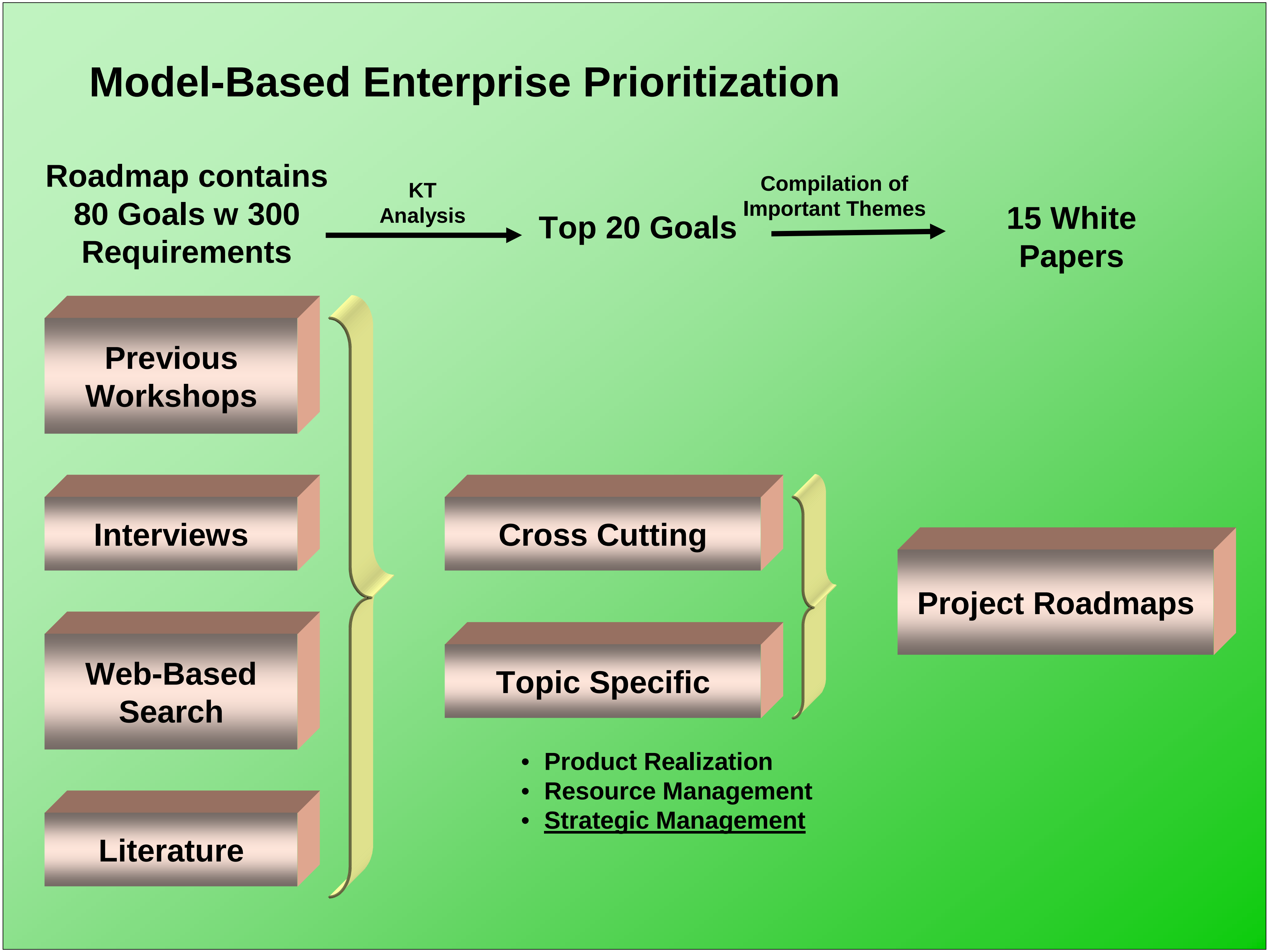
NEXT GENERATION MANUFACTURING TECHNOLOGY INITIATIVE℠

Implementation/Transition Plan



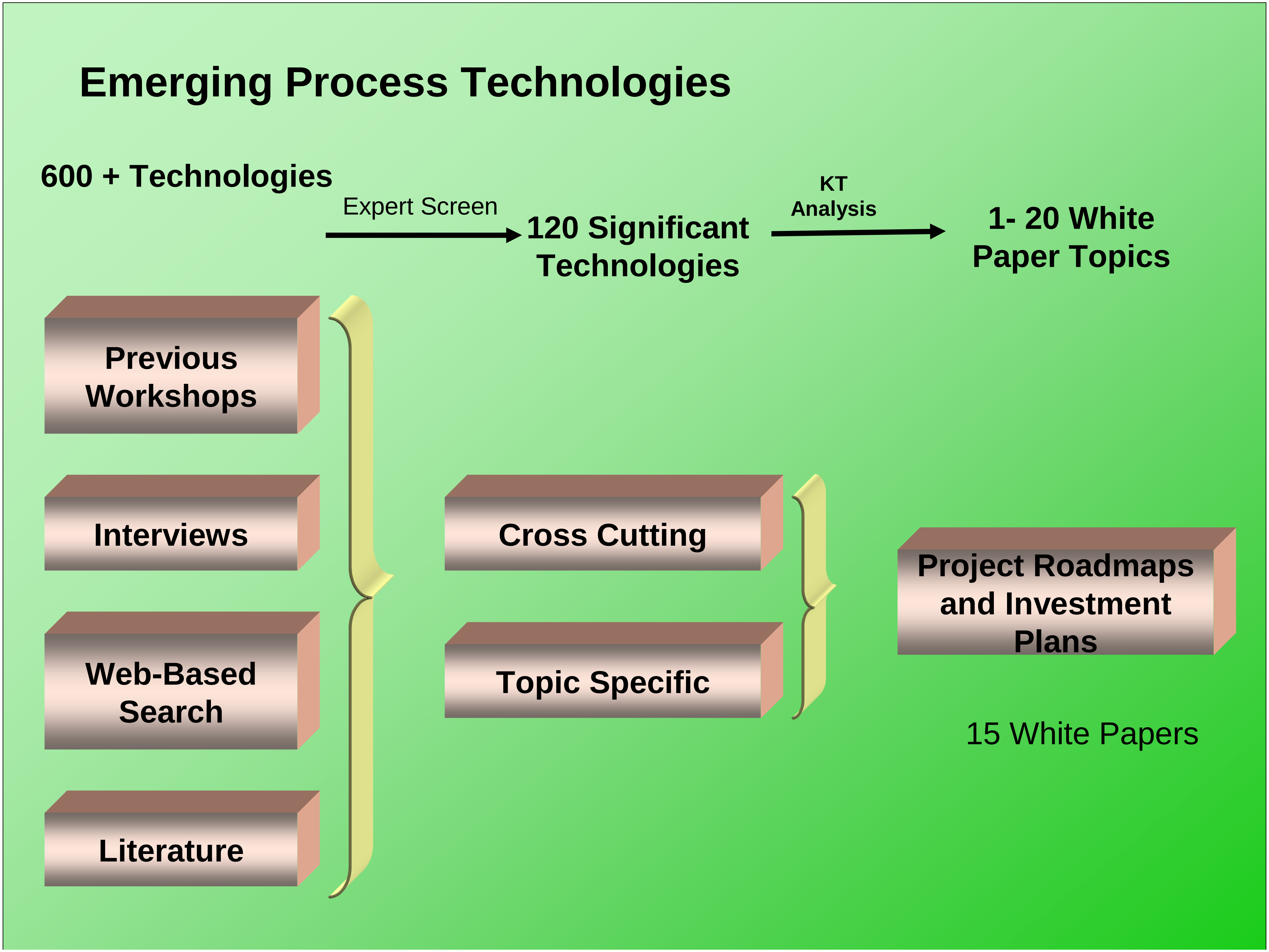
NGMTI Thrust Areas

- Emerging Process Technologies
- Model-Based Enterprise
- Safe, Secure, & Reliable Manufacturing Operations
- Enterprise Integration
- Intelligent Systems
- Knowledge Management


Model-Based Enterprise Prioritization
Roadmap contains 80 Goals w 300 Requirements
KT Analysis
Top 20 Goals
Compilation of Important Themes
15 White Papers
Previous Workshops
Interviews
Web-Based Search
Literature
Cross Cutting
Topic Specific
Project Roadmaps
• Product Realization
• Resource Management
• Strategic Management

Model-Based Enterprise White Papers

- Flexible Representation of Complex Models
- Shared Model Libraries
- System-of-Systems Modeling for the Model-Based Enterprise
- Enterprise-Wide Cost Modeling
- Intelligent Models
- Configuration Management for the Model-Based Enterprise
- Product-Driven Product & Process Design
- Model-Based Product Life-Cycle Management
- Model-Based, Real-Time Factory Operations
- Model-Based Distribution
- Multi-Enterprise Collaboration
- Model-Based Resource Management
- Information Delivery to Point of Use


Emerging Process Technologies
600 + Technologies
Expert Screen
120 Significant Technologies
KT Analysis
1- 20 White Paper Topics
Previous Workshops
Interviews
Web-Based Search
Literature
Cross Cutting
Topic Specific
Project Roadmaps and Investment Plans
15 White Papers

EPT White Papers

- Low-Cost Titanium Powder Production
- High-Frequency Laser Machining
- Friction Stir Joining Technologies
- Improved Thin-Film Processes for Semiconductor Fabrication
- Microreactors & Processing Methods
- Digital Direct Manufacturing
- Affordable, Lightweight Large Structural Composites Manufacturing
- Nanomaterials for Glass Coatings
- Smart, Reconfigurable Multifunction Machine Tools
- Thin-Film Coatings for Paint Elimination
- Manufacturing Applications for Carbon Nanotubes
- Advanced Aerospace Casting Processes
- Precision Optical Finishing
- Hybrid Bearing Manufacture
- Military Fuel Cell Technology

NGMTI Current Status

- 28 project plans developed for MBE and EPT, with “High-interest” from both defense and commercial firms
- Project teams now being formed for 13 of the White Paper topics
- MBE Forum being planned for the fall

The NGMTI Thrust Areas

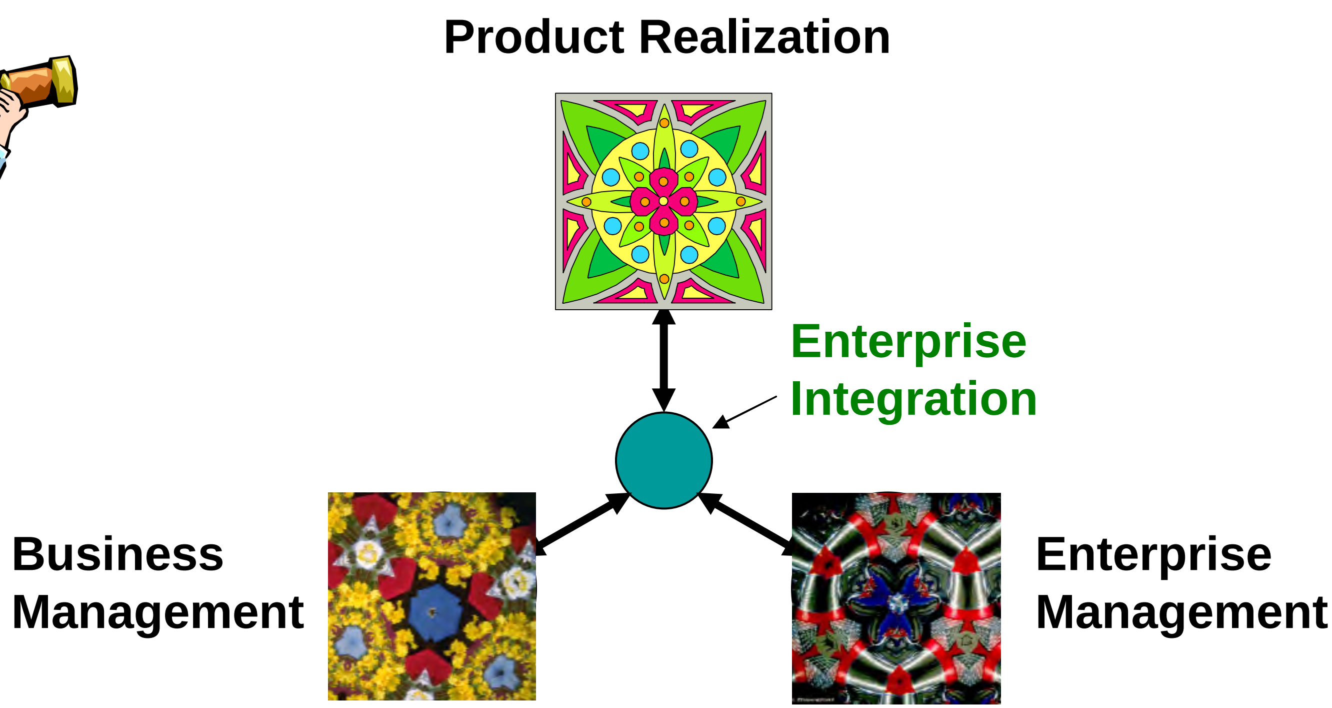
- Model-Based Enterprise
- Emerging Process Technologies
- Safe, Secure, Reliable, and Sustainable Manufacturing Operations
- Enterprise Integration
- Intelligent Systems
- Knowledge Applications

Model-Based Enterprise: A Single Objective

- MBE - an integrated digital environment for addressing all aspects of the enterprise
- Requires total sharing of information between all elements of the enterprise.
- New approaches and toolsets are required

Prioritization to Establish What to Do, When

Model-Based Enterprise: The Views



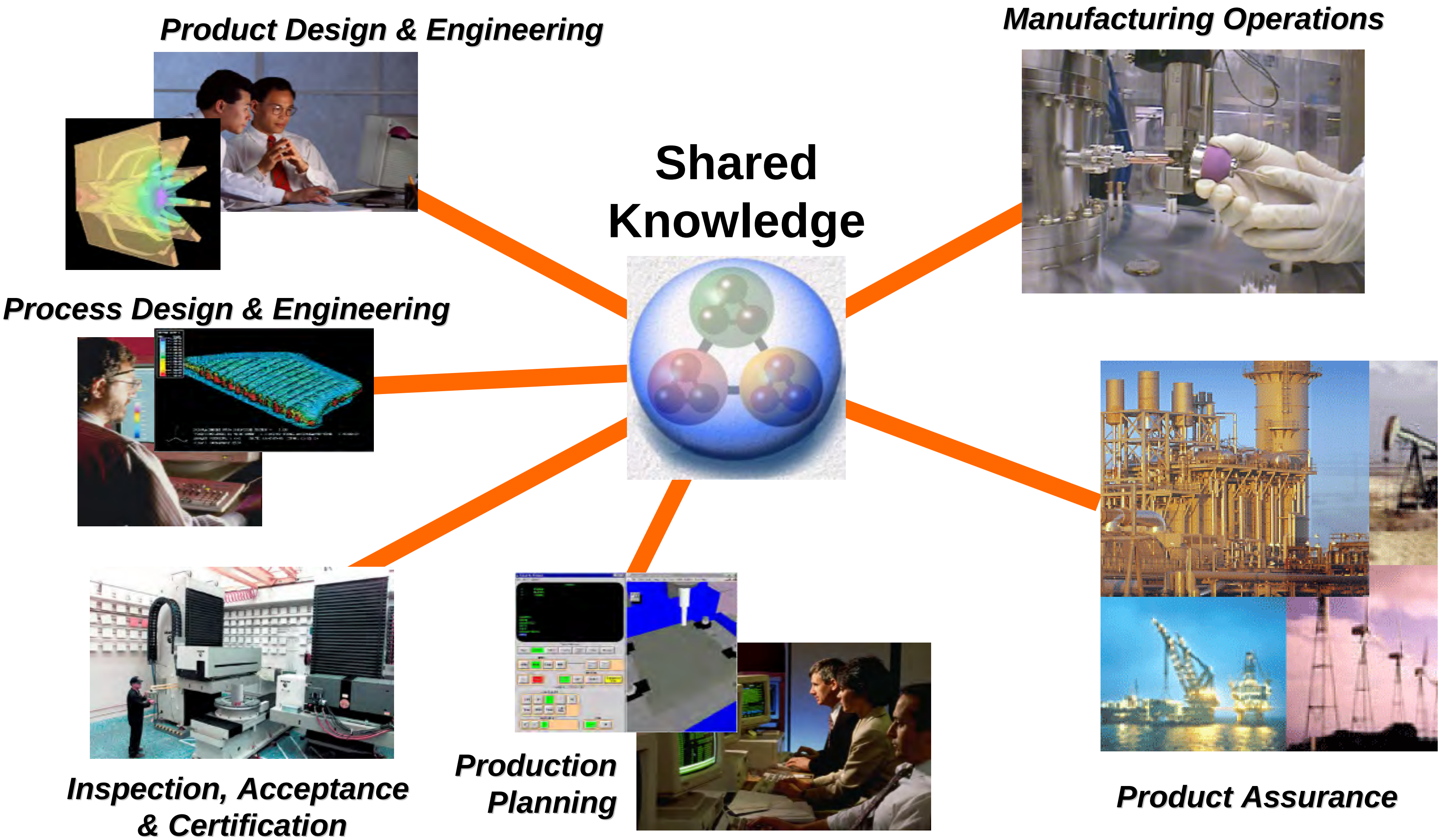
Such an Enterprise Will Be. . .

Thanks to the NNSA for sharing jointly developed visuals and concepts!

Totally Connected

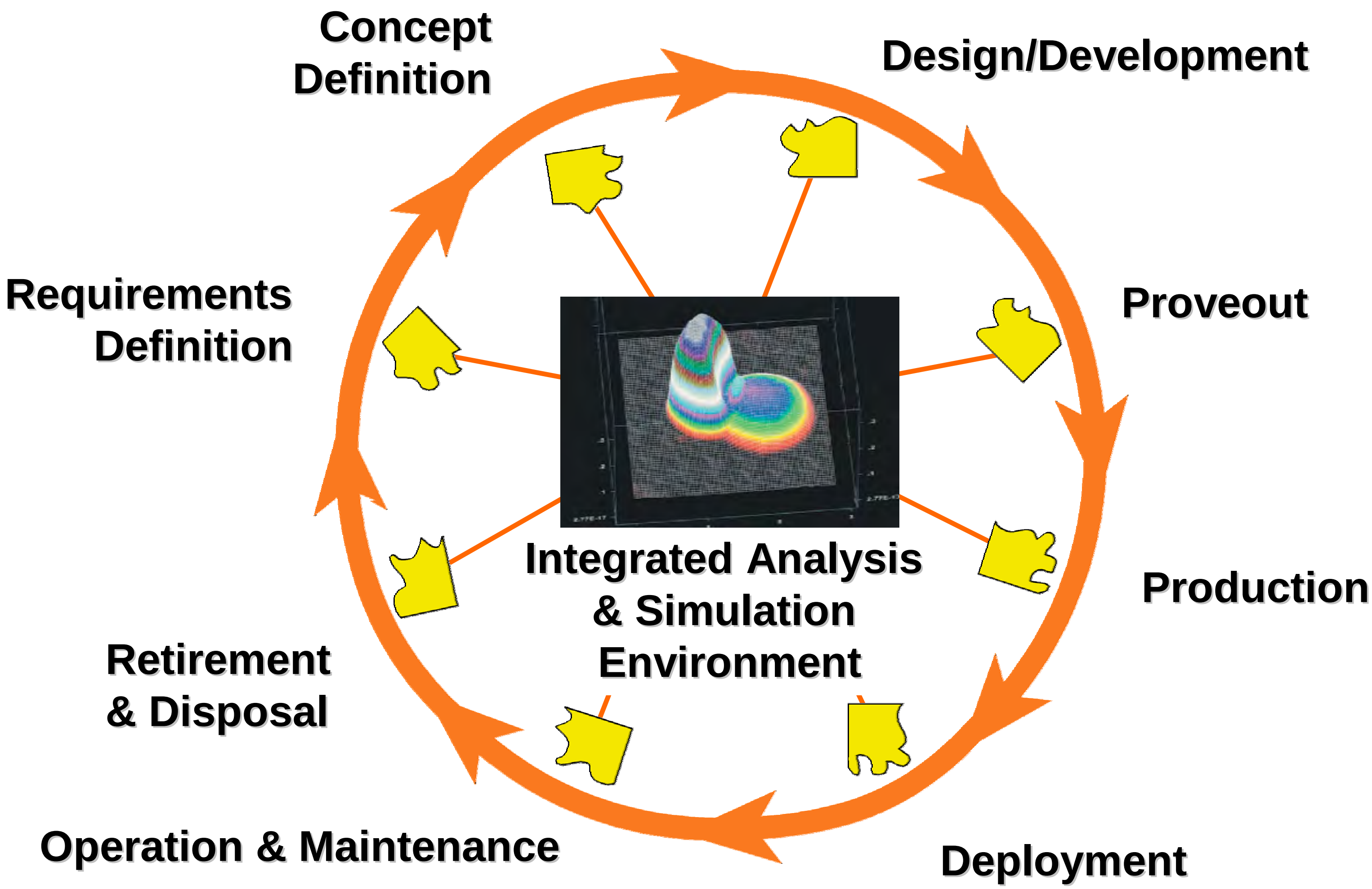
An Integrated Seamless Flow of Information and Knowledge

Knowledge Rich



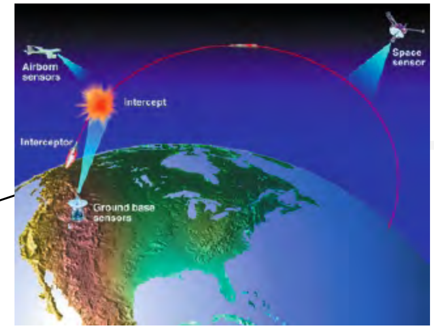
Continuous feedback and enrichment of information across the life cycle

Simulation Based



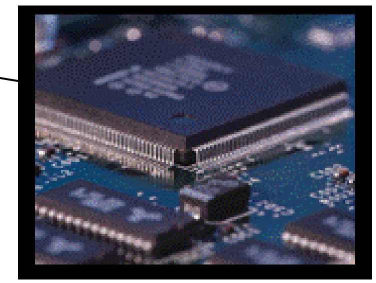
Science-based analysis supporting every aspect of the life cycle

Instantly Responsive with . . .

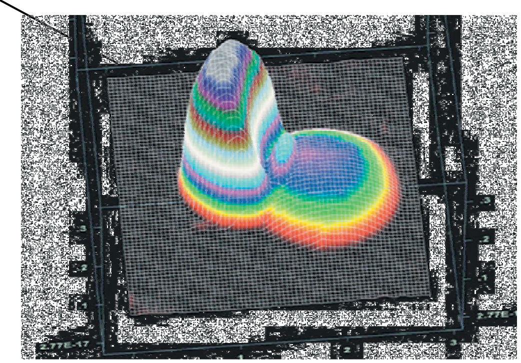


Requirements Analysis

Performance Assessment



Producibility



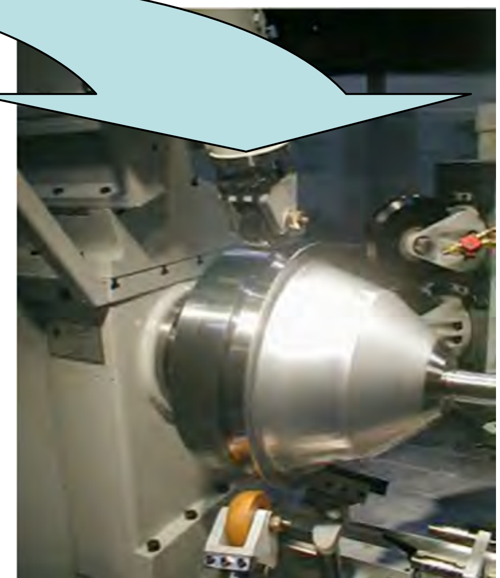
Material Behavior

One-click access to all needed analysis capabilities

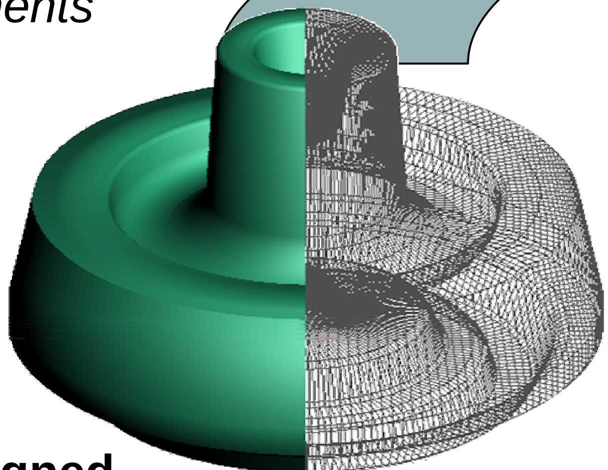
Capable of Supporting Closed-Loop Operation

- *Product & process definition*
- *Specs & control parameters*
- *Resource & schedule requirements*

As-Built



As-Designed



- *As-built configuration & properties*
- *Process performance & material behaviors*

Digital feedback deepens the knowledge base for future products

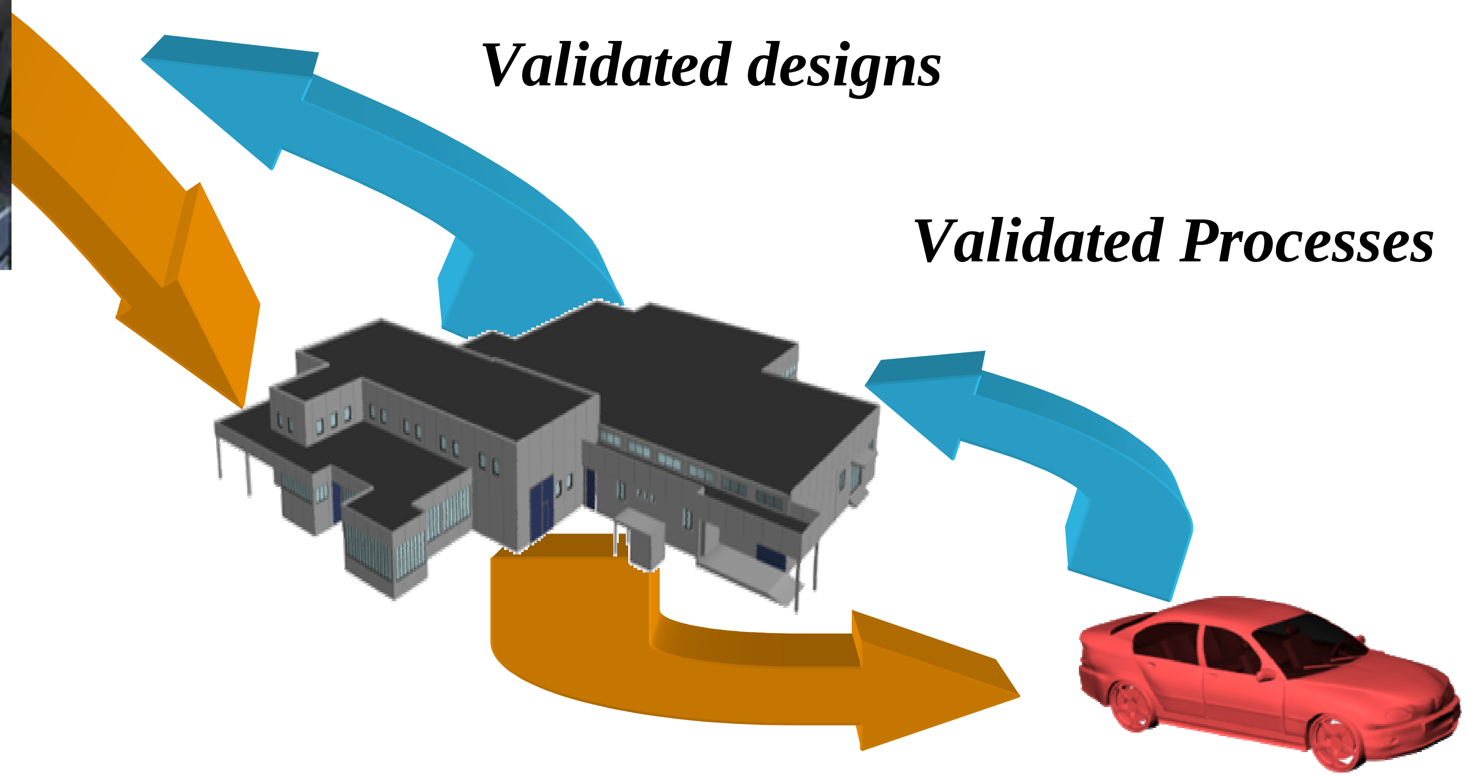
Bottom Line . . .

NEXT GENERATION
MANUFACTURING TECHNOLOGY INITIATIVE

Validated Models

Validated designs

Validated Processes



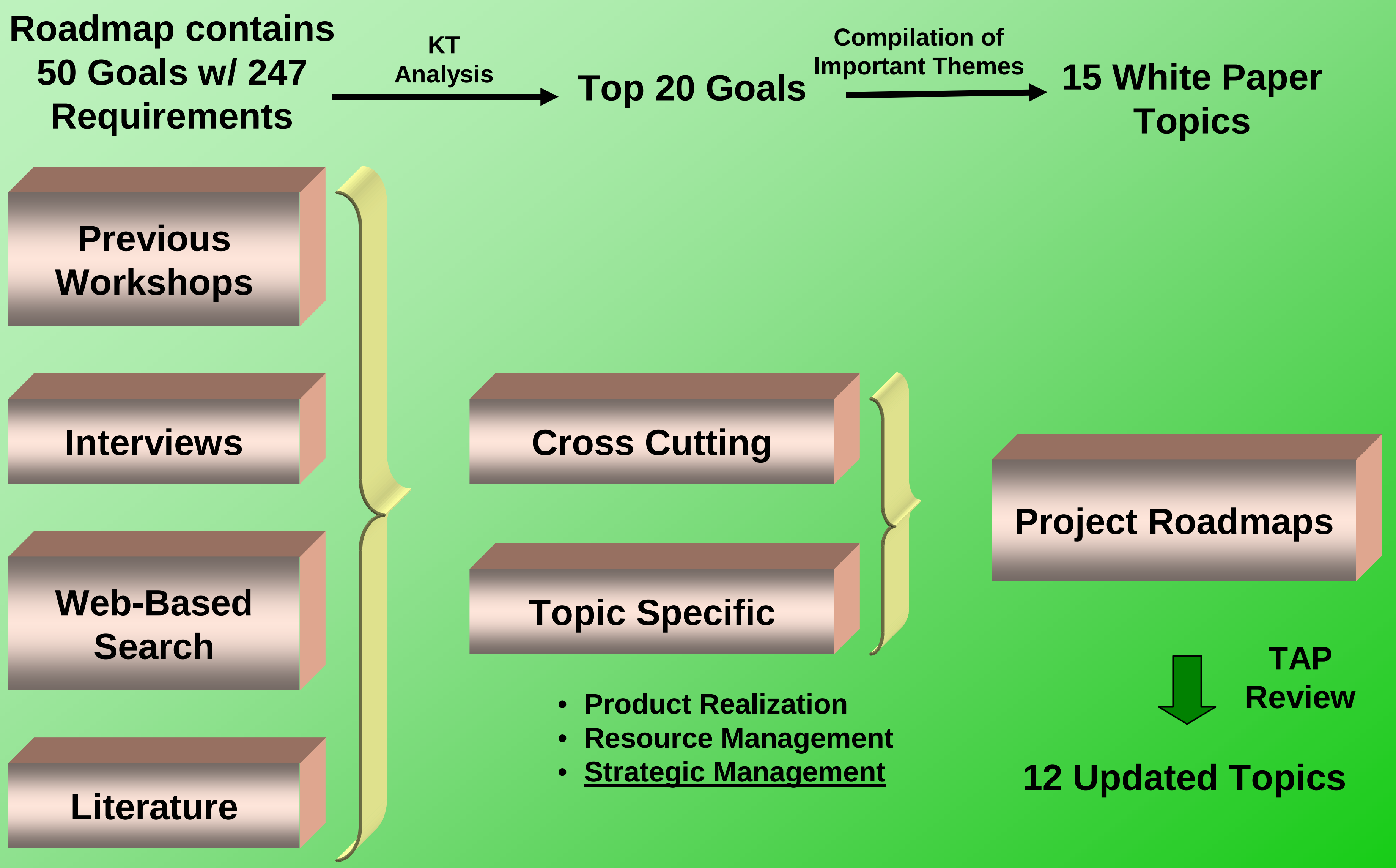
In a totally managed enterprise

Validated Products

MBE Roadmap Process

- Define the current state of MBE capabilities
- Develop MBE vision
- Express vision, goals & requirements in strategic investment roadmap document
- Establish priorities
  - "Readiness, risk & return"
  - "Scope, magnitude, vital to US competitiveness"
- Prioritize with Kepner-Tregoe decision-making tool
- Write white papers on critical topics
- Review and validation by TAP
- Refine white papers

Narrowing MBE Focus



Configuration Management for the Model-Based Enterprise

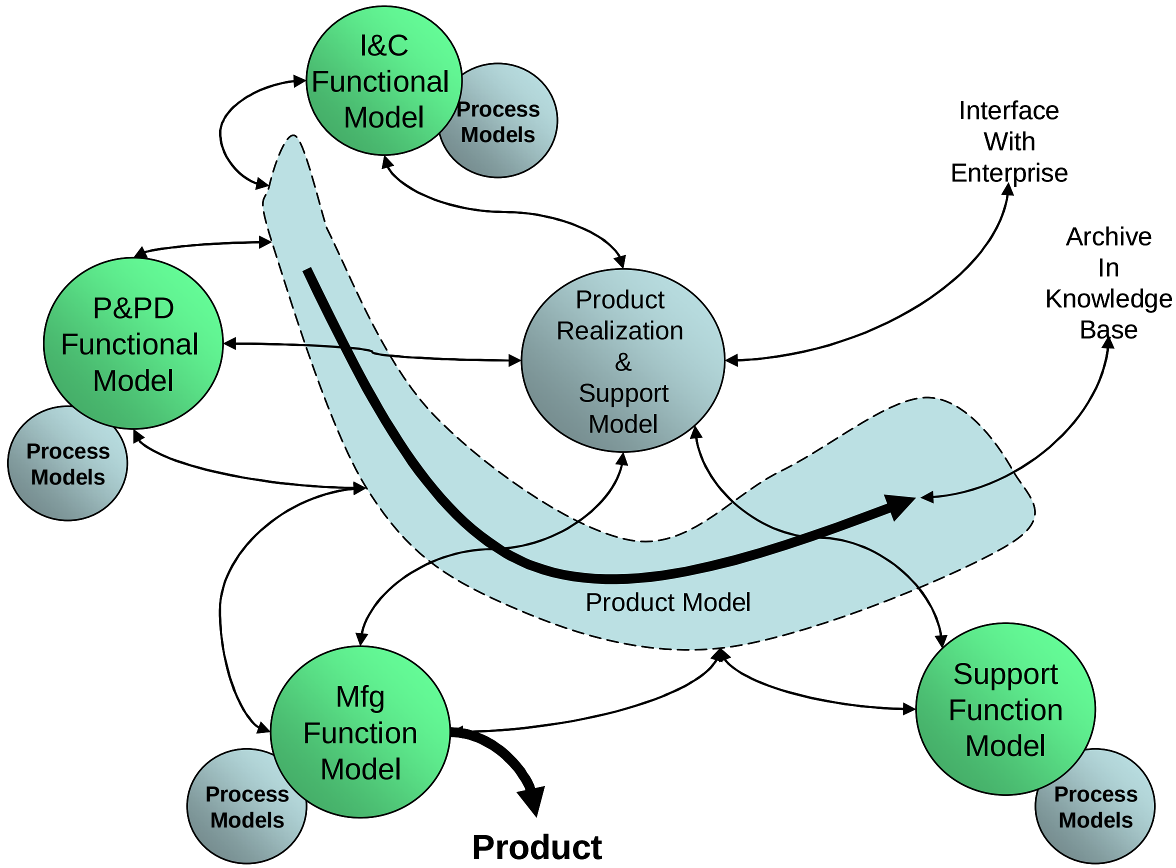
Objective: Develop an integrated system that assures association of the right information with any product or process throughout its life cycle.

Benefits:

- Association of correct info with each version of each product or process in the enterprise
- Feedback loop, which enables continuous product improvement.
- Assured ability to reproduce

Flexible Representation of Complex Models

Objective: Develop capability to create collaborative models rich enough to support all MBE functions.



Benefits:

- Enables full evaluation of any decision
- Procurement cost savings in the billions of dollars
- Reduced time to market
- Reduced costs
- Better quality products

System-of-Systems Modeling for Model-Based Enterprises

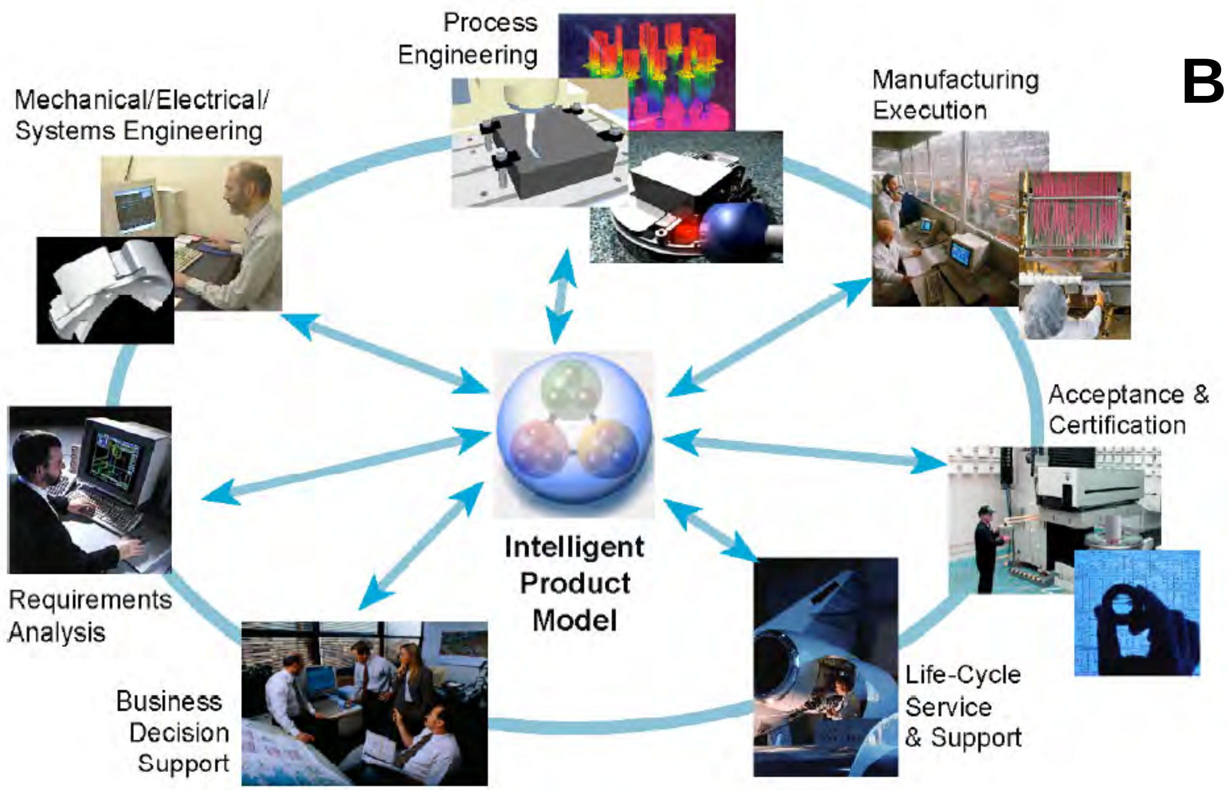
Objective: To develop capabilities, approaches, and tools for integrated multi-level, multi-system modeling of products, processes, and life-cycle functions.

Benefits:

- Composable and decomposable models enable evaluation of total system performance within its operational context
- Extends SoS philosophy to manufacturing enterprise
- Enhanced ability to simulate, with high fidelity, the effects of wear and tear on complex systems in combat and training

Intelligent Models for Manufacturing

Objective: Develop intelligent models that understand, seek out, acquire knowledge needed to execute their functions.



Benefits:

- Dramatic cost savings through elimination of design iterations
- Improved logistics support for weapons systems
- Significant reduction of design cycle times

Model-Driven Product and Process Development

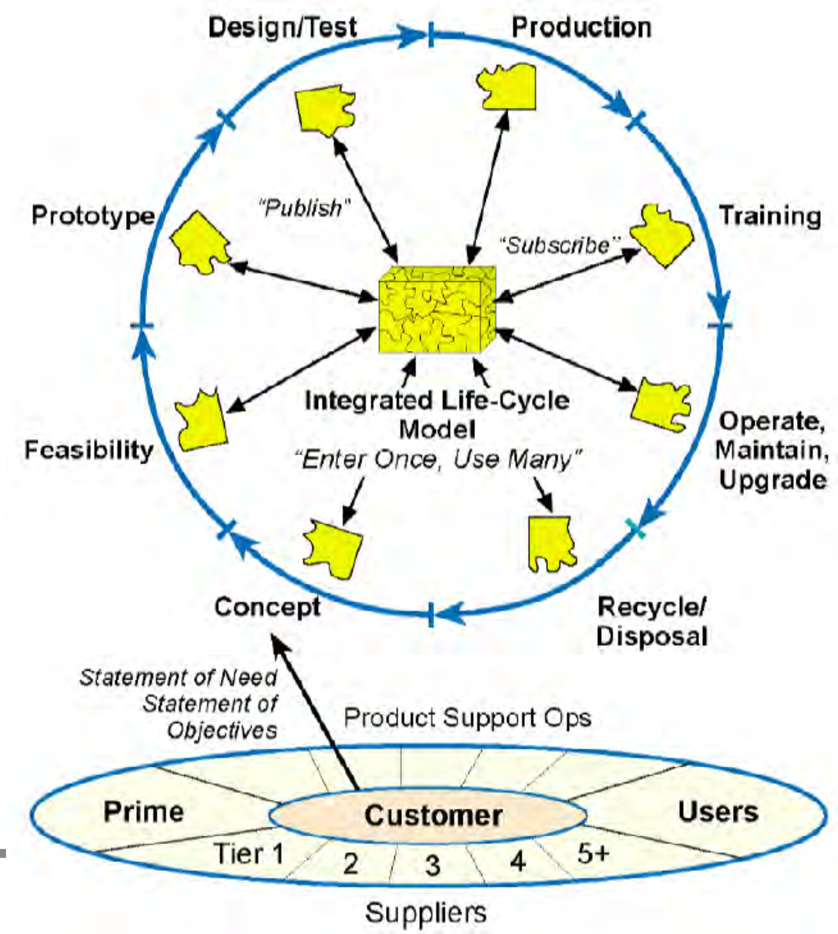
Objective: **Develop simulation capabilities enabling the product model to fully support down stream operations.**

Benefits:

- Saves money and assures product quality
- Optimizes use of product and process capabilities
- Reduces the extent and level of design changes
- Enhances risk analysis and mitigation

Model-Based Product Life-Cycle Management

Objective: Provide the capability to create and apply hi-fidelity, scaleable product life-cycle models.



Benefits:

- Provides a toolset for modeling and understanding life-cycle cost and supportability impacts .
- Enables feed back from down-stream experience to improve up-stream functions.
- Improved speed and accuracy of technical and business decisions over the life cycle,
- Ability to analyze and reverse-engineer "as-worn" parts to predict failure

Information Delivery to Point of Use

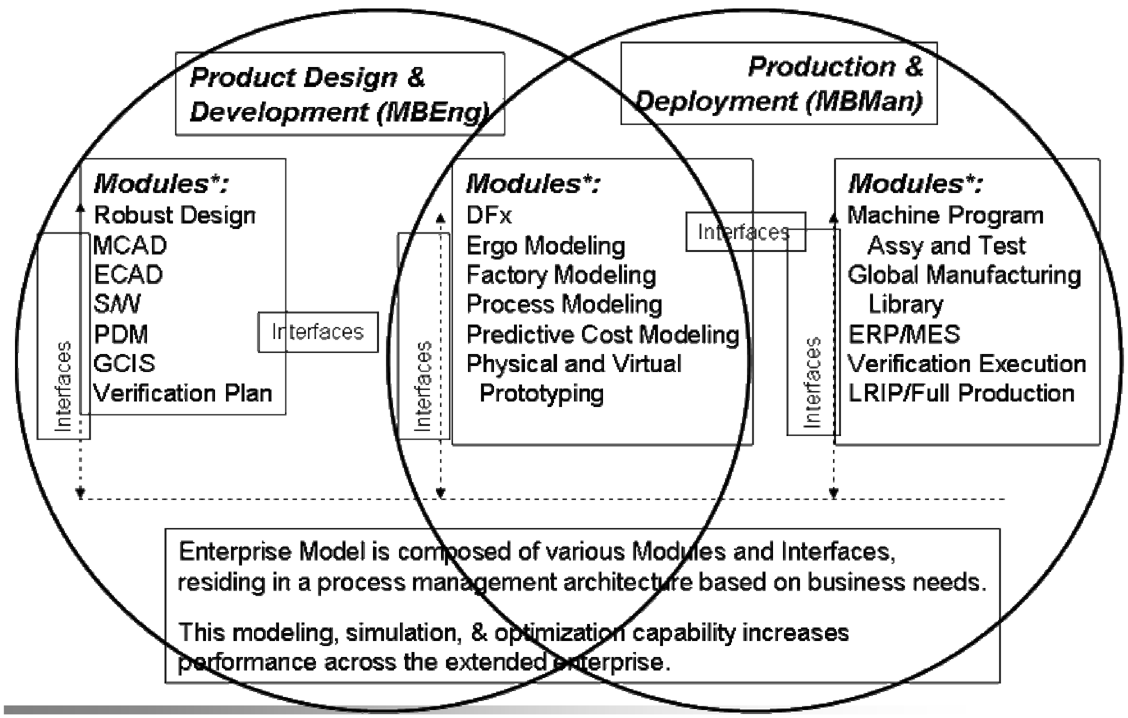
Objective: Deliver information to any location in support of any enterprise function

Benefits:

- Largely graphical information delivery
- Job compatible delivery
- Graphical format saves money in multi-lingual support
- Reduced warrantee cost for returns due to fewer mistakes

MBE Enablers for the Electro-Mechanical Industry

Objective: To apply product and process models to define and manage all enterprise processes, and by applying science-based analytical tools to make optimal decisions at every step of the product life-cycle.

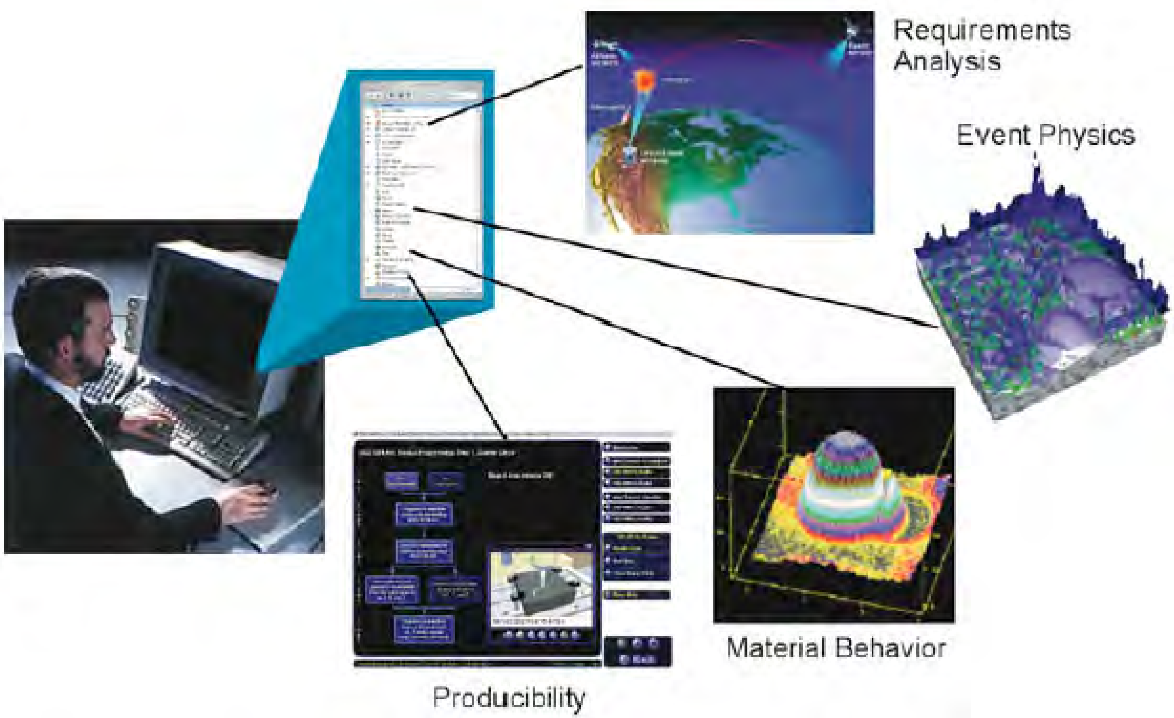


Benefits:

- **Model-Based testing offers development time savings of 50%**
- **Elimination of the "disconnect" between development and production**
- **Rapid response to customer demands**

Shared Model Libraries

Objective: Enable centralized access to modular components to support all MBE functions and optimize enterprise decisions

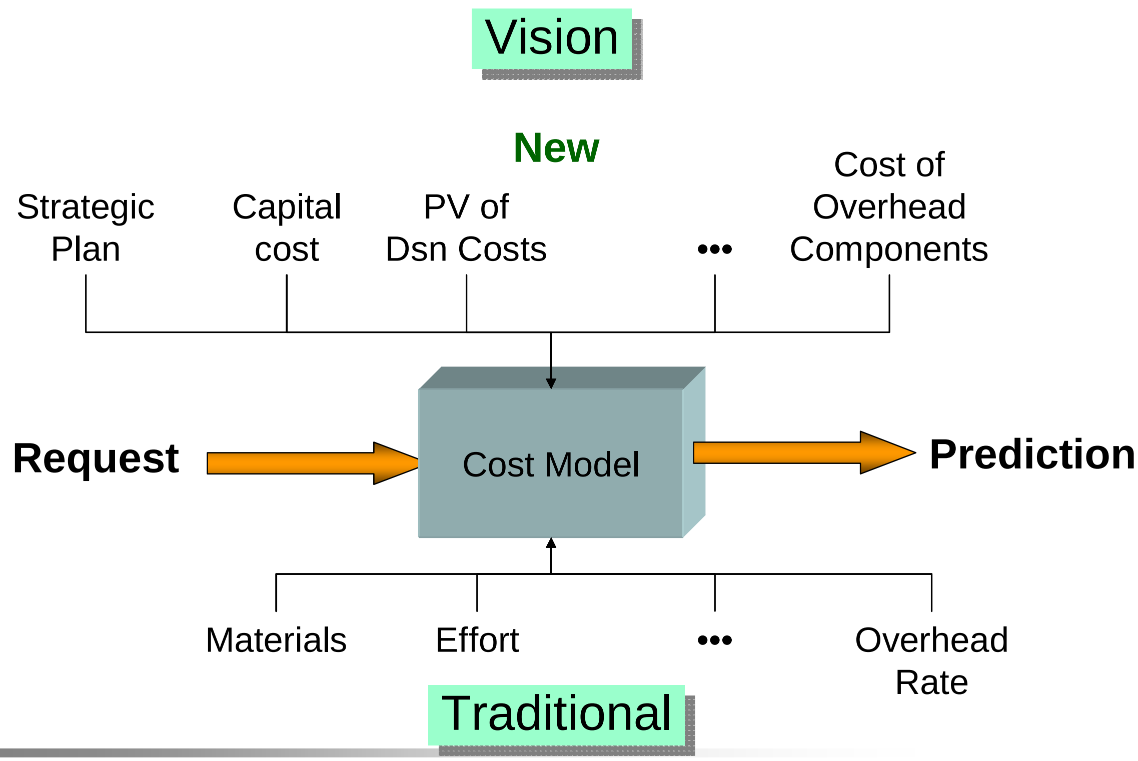


Benefits:

- Provides a core set of models affordable and available.
- Reduction in cycle time and cost by up to 40%
- Rapid integration and virtual testing of complex weapon systems
- Elimination/Reduction of redesign/rework costs and time

Enterprise-Wide Cost Modeling

Objective: Provide the ability to model and predict cost for every element and from every source in the enterprise, including uncertainty and risk.

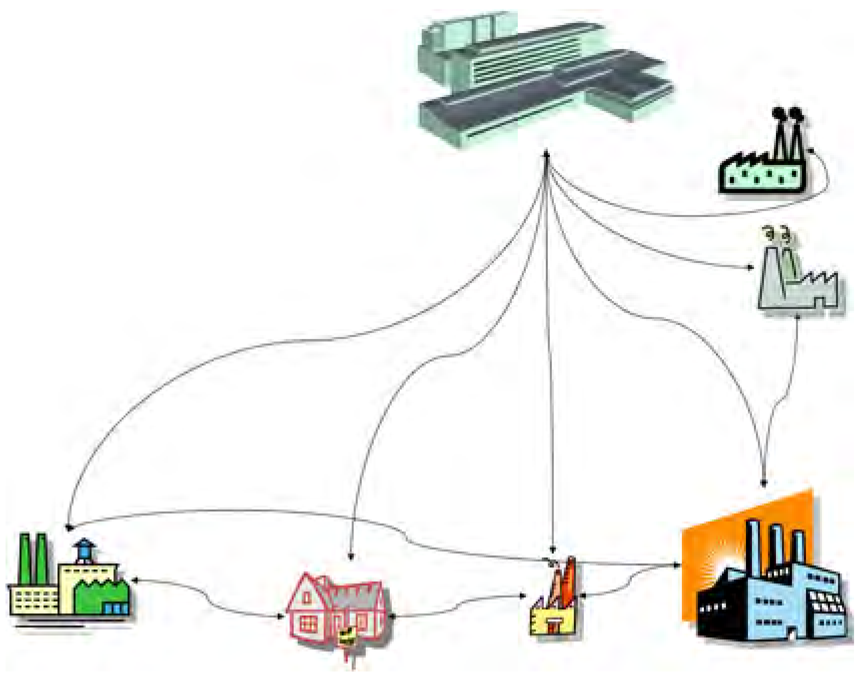


Benefits:

- Visibility of the cost impacts of design changes
- Eliminating low-ball estimates with directly traceable sources
- Significant areas of cost and expense can be easily identified
- Enables evaluation of Strategic options

Model-Based Real-Time Factory Operations

Objective: To develop enabling technologies for real time, model-based control of factory operations.

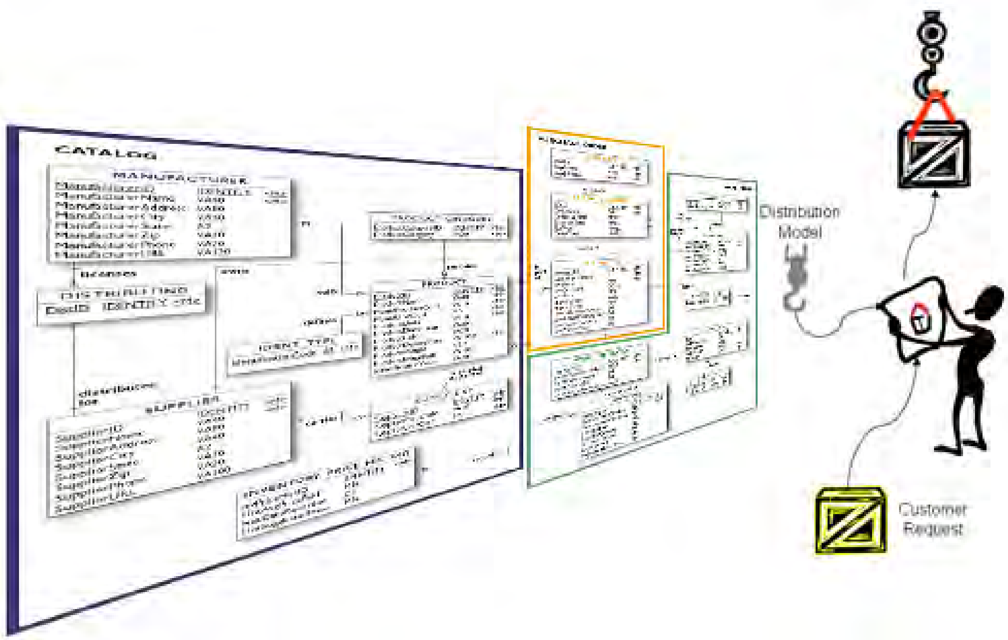


Benefits:

- First and every product correct due to process control.
- Maximum use of production capability
- More efficient, responsive, flexible, and capable manufacturing base
- Shortened timelines to ramp up production

Model-Based Distribution

Objective: **Provides a framework for supporting design for distribution planning, execution, and re-planning.**

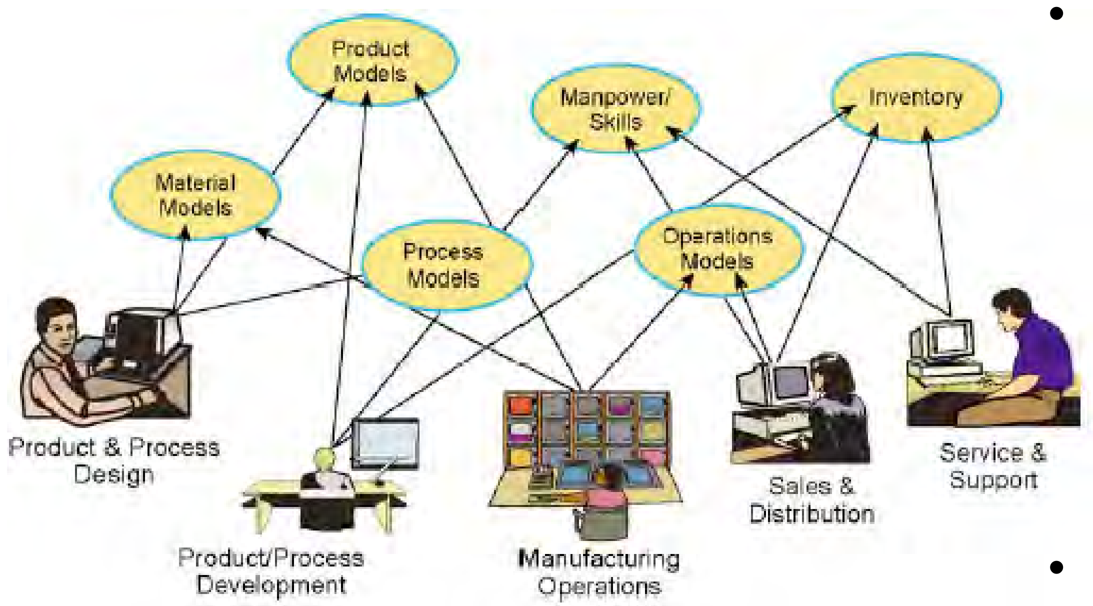


Benefits:

- "Engineer out" problems in new products rollout
- Accommodates far more variables in distribution planning
- Improved downstream life-cycle management
- Enables definitive information about where it should be
- Focuses for closing the loop on where it is

Model-Based Resource Management

Objective: **Create a cost effective, integrated capability for evaluating options and directing control over all manufacturing resources. Modular and easily integrated are key attributes.**

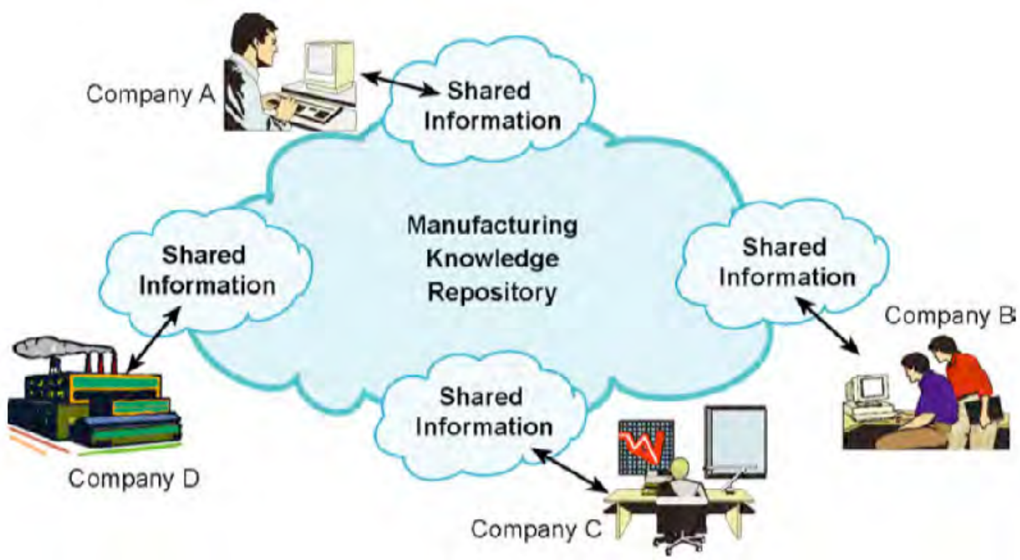


Benefits:

- Provision of model-based resource management capabilities that:
  - Greatly reduce the cost of acquiring, deploying and maintaining a resource management system
  - Enable far greater accuracy and efficiency in managing resources
- Enhanced ability of smaller suppliers to choose resource management tools, and to interface with prime manufacturers

Multi-Enterprise Collaboration

Objective: Provide a tool set to support multi-enterprise collaboration



Benefits:

- Mitigates the cost of transferring or recreating design definitions shared among different members of the supply chain.
- Enables ability to objectively evaluate potential suppliers
- Reduces contract administration costs by 50% through integrated reporting and management

Summary

- NGMTI is an important program to the nation
- We are off to a fast start and making great progress
- Project formation is in full swing – opportunity knocks

Ngmti.org

A Practical Application of the Non-Advocate Review

Bruce Nishime

C-17: A High Performance Program

MEETING OUR COMMITMENTS

- Excellent Quality
- Ahead of Schedule
- On Price
- 180 Aircraft Program

MEETING OUR COMMITMENTS

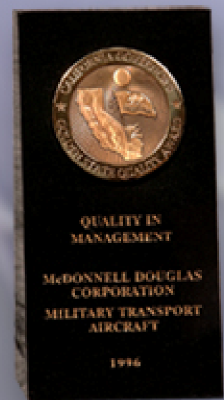
- 138 USAF Aircraft - 6 Bases
- Worldwide Operations
- Best Fleet Reliability
- 4 UK C-17s Delivered

Over 898,750 Flight Hours!

USAF Fleet – 872,885   UK Fleet – 23,085

C-17 Awards

1994
Collier Award



1996 California
Quality Award

1998 Malcolm
Baldrige National
Quality Award

Ministry of Defence

SA SMART ACQUISITION

2001 UK MOD Smart
Acquisition Award

2003 Missouri State
Quality Award

2001 ISO9001-2000 /
AS9100A Certification

CMMI

SEI
Standard
Level 5

2002 IW Winner:
Top 10 Best Plants

GEORGIA • OGLETHORPE Award

2003 Georgia
Oglethorpe
Award

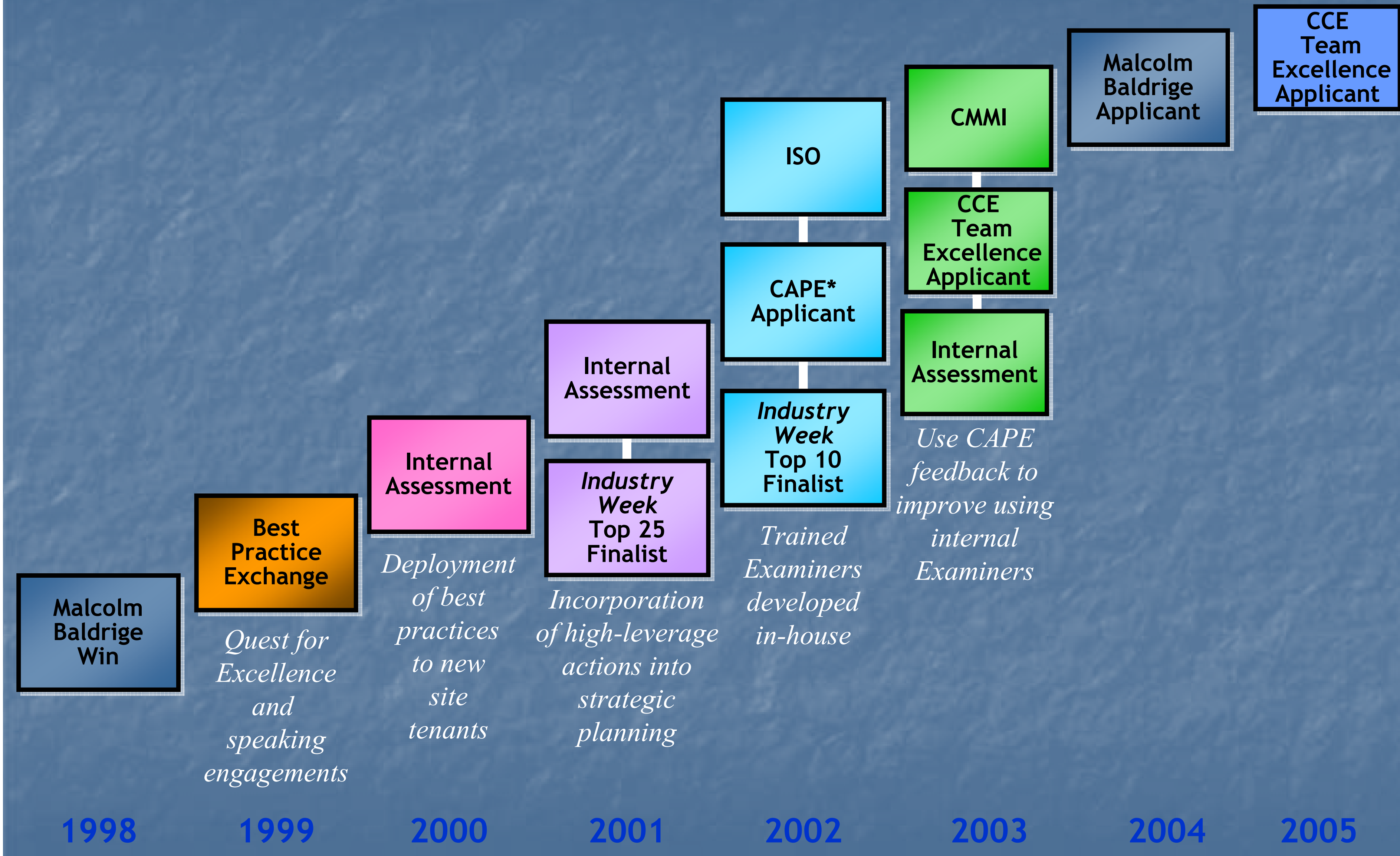
CALIFORNIA AWARDS FOR PERFORMANCE EXCELLENCE

2002 California Awards
for Performance Excellence
(Gold & Silver)

2003 Governor's Award For
Performance Excellence

BOEING

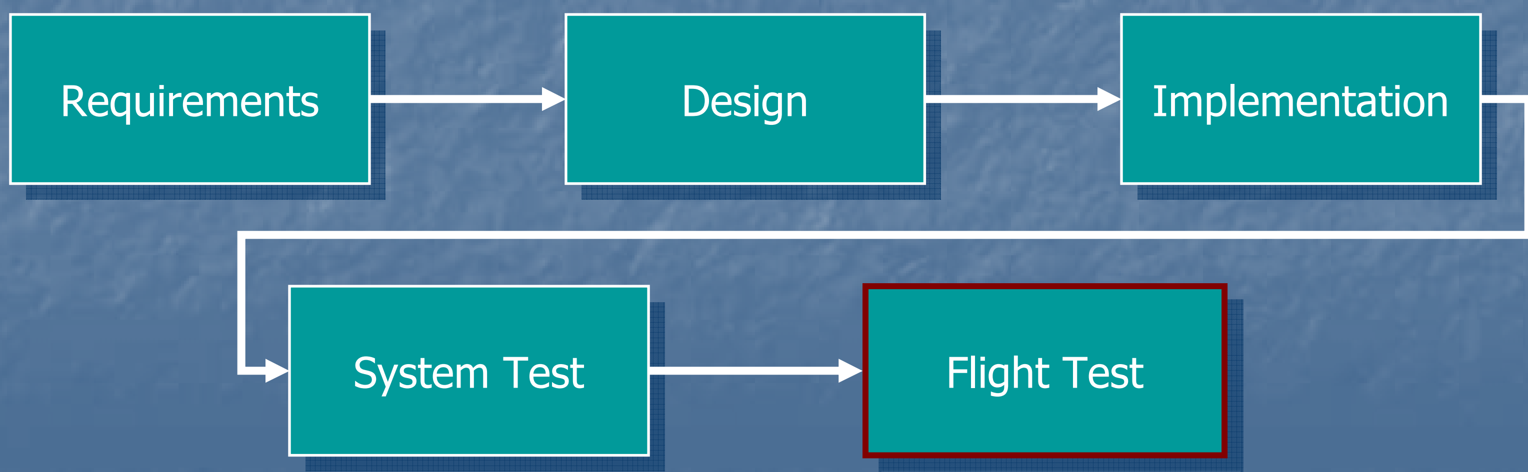
Quality Journey



*CAPE = California Awards for Performance Excellence

Issue

- Requirements verification/validation occurring late in development life cycle
  - Higher costs
  - Schedule delays



Solution

- Utilize Non-advocate Review Team to:
  - Perform root cause
  - Identify areas for improvement
  - Make recommendations based on diverse corporate knowledge from multiple programs

Definitions

- Independent Assessment - An impartial and in-depth analysis of a major issue or key milestone event performed by an Independent Assessment Review Team

- Non-Advocates: Subject Matter Experts (SMEs) from any of the following groups
  - Boeing non-program employees
  - Outside consultants
  - Industry SME
  - Fellows
  - Non-program related customers
  - Third party examiners

NAR Process

- Identify non-advocate team
- Define scope of review
- Data collection
- Analyze data
- Develop final report/outbrief

C-17 Application of NAR Process

Identify Non-advocate Team

- Selected from local site tenents
  - B-1B, C-130 AMP, C-17
- Utilized pool of Technical Fellows
  - Boeing recognized technical experts in various skills (i.e. Systems Engineering, Communications)
- Select chairperson
  - B-1B Chief Engineer

Define Scope of Review

- Software Development process
- Systems Engineering process
- Validation and Verification process
- Project Management

Expectations

- Identified expectations of upper management
  - Process issues
  - Improvement opportunities
  - Lessons learned
  - Recommendations

Resources Required

- Data
- Access to project personnel
- War Room - Facilities
- NAR Team availability and schedule

Data Collection

- Documentation
  - Deliverable
  - Non-deliverable (Engineering Notes)
  - Software Development Folders (SDF)
- Interviews
  - Engineers, Managers, Project managers
  - Customers
  - Suppliers

Analyze Data

- Lack of process compliance
- Lessons learned
- Process improvement
- Lean engineering opportunity

Develop Final Report/Outbrief

- Summarize issues
- Provide recommendations
  - Near-term
  - Long-term

AFRL Systems Engineering Initiative

Risk Management for Science and Technology

October 24 - 27, 2005

Bill Nolte

Electronics Engineer

Col Norman Anderson

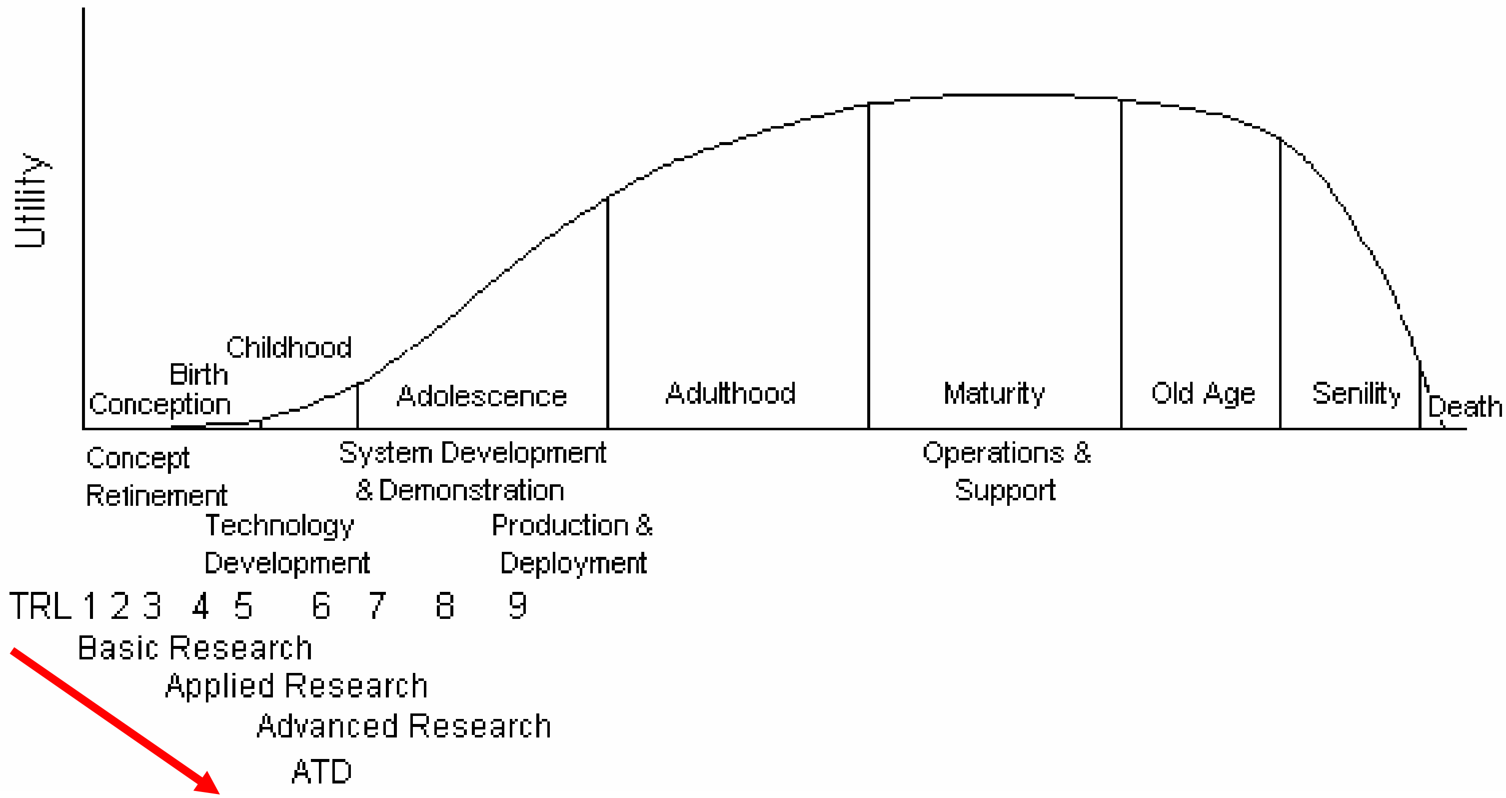
Chief Engineer, Space Vehicles

Bob McCarty

Systems Engineering Lead

Air Force Research Laboratory

Technology Life Cycle
The Whale Chart



- **The Whale Chart maps the Life Cycle to the Readiness Levels and R&D Stages**
- **A technology's usefulness changes over time**
  - Utility increases as a technology matures
  - Utility decreases as a technology becomes obsolete

Knowledge Growth

Technology Life Cycle

AFRL SE Initiative

Risk Management

Interim Conclusion

Tools

Conclusion

Key Question	Basic Research	Applied Research	Advanced Research	ATD	Man Tech
1. Who is your customer?	Partial	Nearly Complete	Complete	Complete	Complete
2. What are customer's requirements?	Partial	Partial	Nearly Complete	Complete	Complete
3. How will you demonstrate you have met the requirements?	Partial	Partial	Nearly Complete	Complete	Complete
4. What are the technology options?	Extremely Limited	Nearly Complete	Complete	Complete	Complete
5. Which is the best approach?	Extremely Limited	Nearly Complete	Complete	Complete	Complete
6. What are the risks to developing the selected technology?	Partial	Partial	Nearly Complete	Complete	Complete
7. How will you structure your program to meet requirements and manage risk?	Partial	Nearly Complete	Complete	Complete	Complete
8. What is your business-based transition plan that meets customer approval?	Extremely Limited	Partial	Nearly Complete	Complete	Complete

Key Questions and Systems Engineering

Technology Life Cycle

AFRL SE Initiative

Risk Management

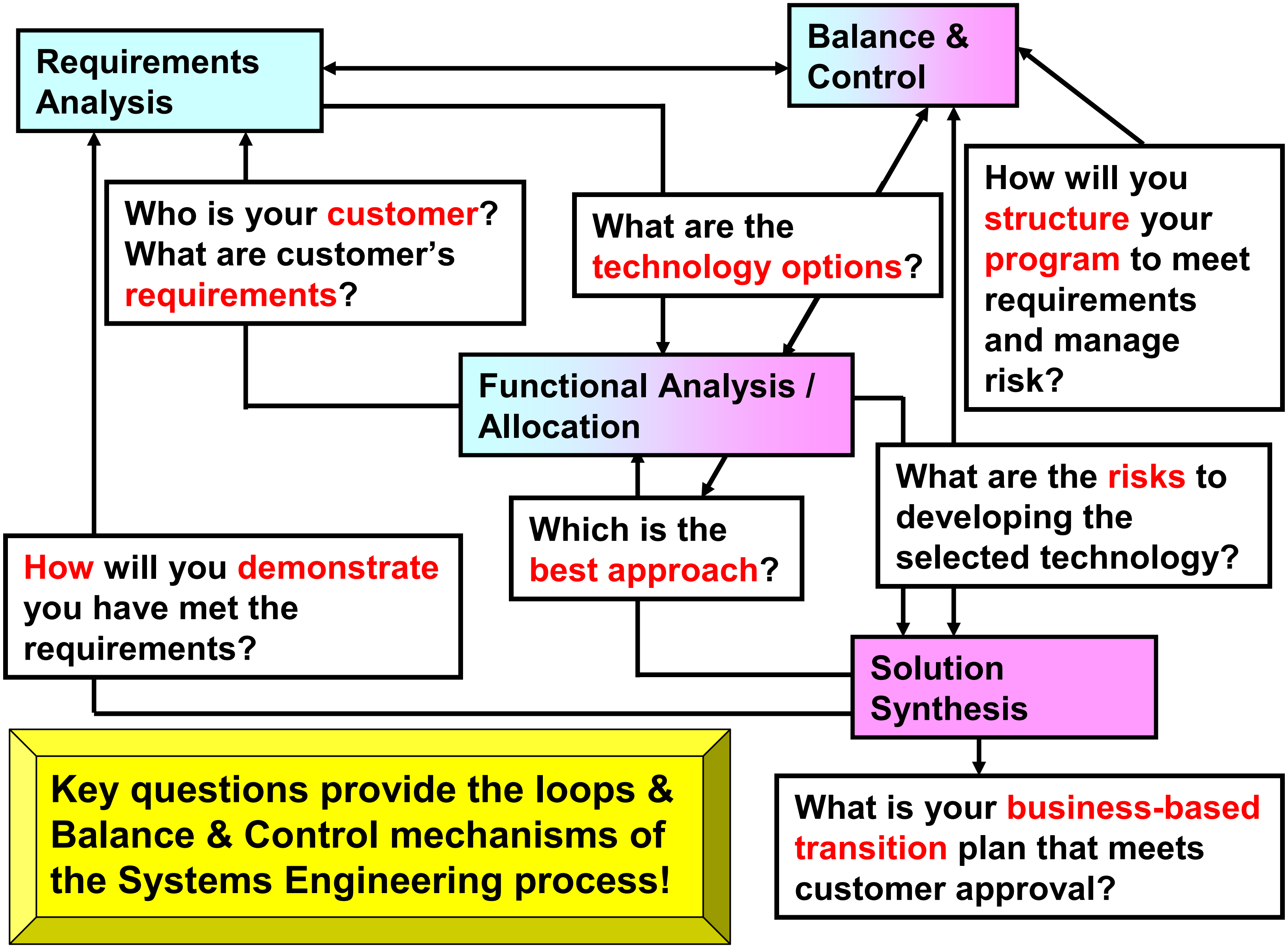
Interim Conclusion

Tools

Conclusion

Gov't Lead

Industry Lead



R&D Focus on Risk

Technology Life Cycle

AFRL SE Initiative

Risk Management

Interim Conclusion

Tools

Conclusion

Two of the Key Questions Focus on Risk in R&D

What are the risks to developing the selected technology?

How will you structure your program to meet requirements and manage risk?

RM Tailored to R&D Goals

Technology Life Cycle

AFRL SE Initiative

Risk Management

Interim Conclusion

Tools

Conclusion

- **Three Distinct Levels of Research and Development**
  - Basic Research – develop a fundamental understanding of selected physical properties
  - Applied Research – investigate application of physical properties to selected technical needs
  - Advanced Technology Development – explore application of technology to assess military relevance

Philosophy of RM in Basic Research

What

- Develop cost estimates for advancement of technology to useful level
- Identify development options and relative difficulty of options
- Maintain budget within pre-defined boundaries

How

- Establish knowledge incremental goals
- Estimate cost/time needed to achieve
- Determine risks associated with maintaining cost/schedule
- Track variances for periodic cost/schedule replan

Primary purpose of RM in Basic Research is to refine development roadmap

Philosophy of RM in Applied Research

What

- Develop technology into a repeatable engineering capability
- Identify extent of applicability of technology to military needs
- Determine the cost/benefit parameters of this new caapability

How

- Explore range of application of technology
- Refine development roadmap for specific applications
- Determine risks associated with achieving required performance at known cost/schedule
- Identify issues of repeatability and define mitigation approaches

Primary purpose of RM in Applied Research is to balance cost & performance

Philosophy of RM in Advanced Technology Development

What

- Apply engineering capability to specific military need
- Identify issues causing uncertainty in application
- Refine cost/performance relationship.

How

- Manage to cost/schedule
- Provide mitigation options and go/nogo gates
- Determine risks early, maintain constant awareness
- Identify potential of cost/schedule failure early (precursors), manage proactively

Primary purpose of RM in ATD is to balance cost, performance, schedule

Risk Management Summary

Key Questions 6 and 7 provide the basis of the AFRL Risk Management process

Questions apply to R&D programs at all stages of maturity

Knowledge available to the program manager changes with program maturity

Risk Management philosophy changes with program maturity

Risk Management Tools

Disclaimer:

This is a partial listing of risk management tools that have proved to be useful in the science and technology environment

The presence of a tool's name and description in this presentation does not constitute an endorsement by the US Air Force or any of its officers or personnel

The absence of a tool's name and description from this presentation does not constitute a finding of unsuitability or a criticism of the product by the US Air Force or any of its officers or personnel

Risk Management Tools

Technology Life Cycle

AFRL SE Initiative

Risk Management

Interim Conclusion

Tools

Conclusion

AFMC/TRIP Risk Mgmt
Active Risk Manager (ARM)
IPPD Control Suite
Probability /Consequence Screening (P/CS)
Risk Matrix
RiskNav

Risk Management Tools

Risk Radar
Risk Radar Enterprise
Technical Risk Identification & Mitigation System (TRIMS)
@Risk
Consolidated Risk Assessment Methodology (CORAM)
Risk Matrix

Risk Management Tools

Pertmaster
Risk +
Crystall Ball
Dynamic Insight
Active Risk Manager
Risk Nav

Microsoft Excel user created applications can also be useful

- RiskHammer
- TRL Calculator
- FMEA

Summary

- Technology Life Cycle
- AFRL SE Initiative
- Risk Management
- Interim Conclusion
- Tools
- Conclusion

The AFRL Systems Engineering Initiative is a method of managing risk in Science and Technology

- **Applicable early in the technology life cycle**
- **Key questions test risk management during program reviews**

A variety of risk management tools exists

- **COTS**
- **User created applications**

Discussion / Questions

Technology Life Cycle

AFRL SE Initiative

Risk Management

Interim Conclusion

Tools

Conclusion

BAE SYSTEMS

Technical Performance Measures

Jim Oakes, Rick Botta and Terry Bahill
BAE SYSTEMS
San Diego, CA
james.oakes@baesystems.com

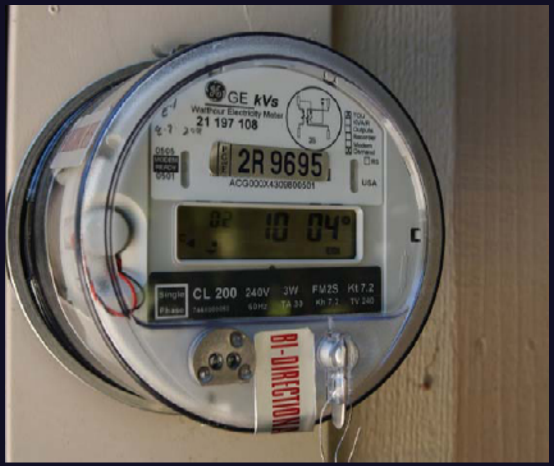
Definition

BAE SYSTEMS

- Technical performance measures (TPMs) are tools that show how well a system is satisfying its requirements or meeting its goals
- TPMs provide assessments of the product and the process through design, implementation and test
- TPMs are used to:
  - forecast values to be achieved through planned technical effort
  - Provide visibility of actual versus planned performance
  - Provide early detection/prediction of problems requiring management attention
  - Support assessment of the impact of proposed changes
    - determine the impact of these differences
    - trigger optional design reviews

TPM examples

- Reliability
- Power required
- Weight
- Throughput
- Human Factors
- Response time
- Complexity
- Availability
- Accuracy
- Speed



Requirements Criteria for TPMs creation

- High priority requirements that have an impact on
  - mission accomplishment
  - customer satisfaction
  - cost
  - system usefulness
- High risk requirements or those where the desired performance is not currently being met
  - the system uses new technology
  - new constraints have been added
  - the performance goal has been increased
  - but the performance is expected to improve with time
- Requirements where performance can be controlled
- Requirements where the program manager is able to rebalance cost, schedule and performance
- TPMs should meet all of these characteristics
- Less than 1% of requirements should have TPMs

BAE SYSTEMS

TPM Characteristics

- Should be important and relevant
- Should be relatively easy to measure
- Performance should be expected to improve with time
- If the measure crosses its threshold, corrective action should be known
- The measured parameter should be controllable
- Management should be able to tradeoff cost, schedule and performance
- Should be documented
- Should be tailored for the project

Collecting, Reporting and Displaying TPM data

•Systems Engineering Manager is responsible for collecting, analyzing, reporting and responding to TPM data

•TPMs should be presented to the person who can do something about it. Often this is the Chief Engineer

•Program Manager has oversight

•Measures Analysis Group might use them for process improvement suggestions

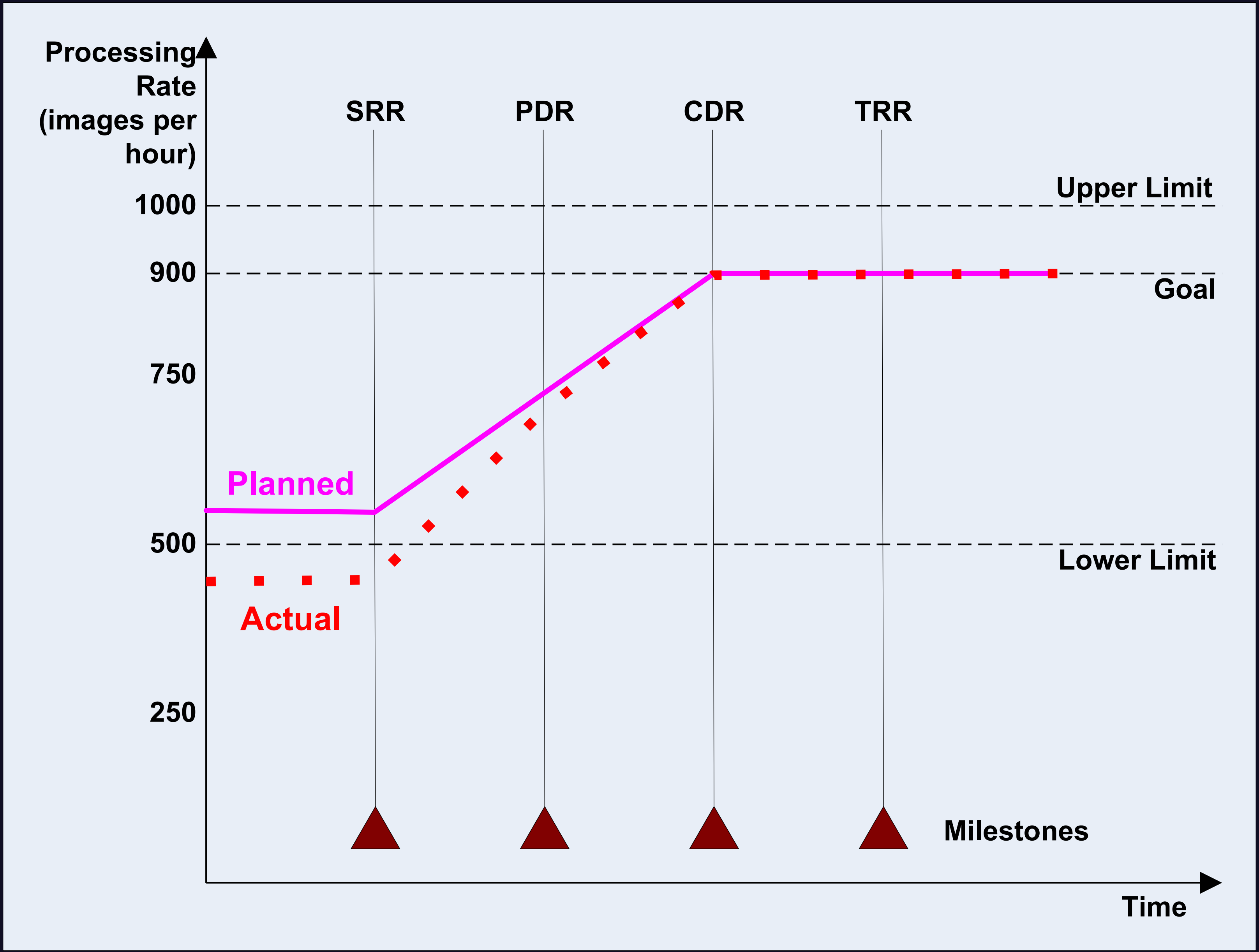
•TPM measures can be displayed with graphs, charts, diagrams, figures or frames

- e. g. Statistical Process Control Charts, Run Charts, Flow Charts, Histograms, Pareto Diagrams, Scatter Diagrams, Check Sheets, PERT Charts, Gantt Charts, Line Graphs, Process Capability Charts and Pie Charts

TPM Measurement

- The measuring method will vary with life-cycle phase
- Start with legacy systems, blue sky guesses and approximations
- Derive data from models and simulations
- Collect data from prototypes
- Measure data on rudiments of the real system

Typical TPM tracking chart



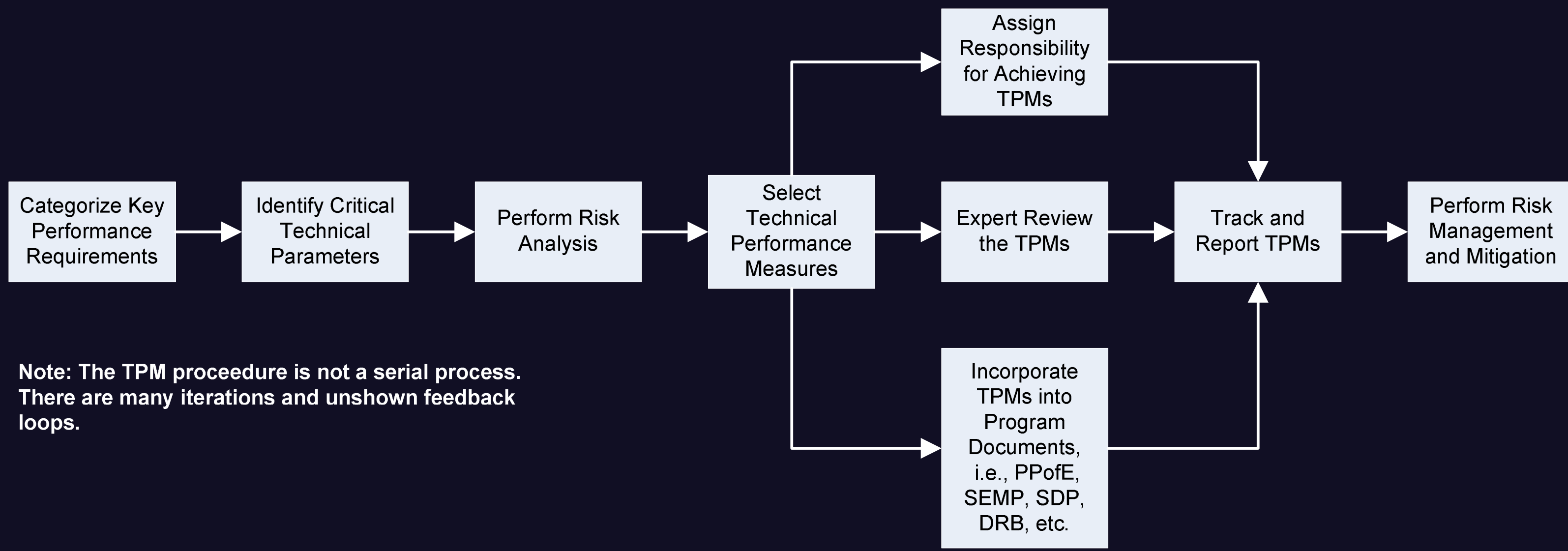
BAE NSS TPM Proceedure

BAE SYSTEMS

- TPMs are established during the proposal process by the Chief Engineer for:
  - Key Requirements
    - Customer's main requirement drivers
    - System requirements important to the Business
  - Key Functions
    - System level functions essential to the performance of the system
  - Critical Design Features
    - Represent uncertainty with respect to confidence in the design approach
    - Represent technical risk that is manifest as borderline performance
- TPMs are approved as a part of the Engineering Estimate Approval process
- TPMs are maintained in the program's risk register
- The TPM Proceedure is PD0644

BAE SYSTEMS

The BAE TPM Proceedure



Note: The TPM proceedure is not a serial process. There are many iterations and unshown feedback loops.

- **CMMI Requirements Development (RD) process area (SP 3.3-1) covers TPMs**
- **Related CMMI areas include Project Monitoring and Control (PMC) and Risk Management (RSKM)**

ID number	Process Step
1	Identify key performance requirements (refer to the Requirements Analysis process output). These are candidate TPMs.
2	Categorize key requirements within the requirements management tool (e.g., DOORS). Add TPM attributes as needed.
3	Identify critical technical parameters.
4	Perform risk analysis.
5	Select TPMs to be tracked throughout applicable program phase(s). Determine frequency of reporting.
6	Conduct expert review of selected TPMs. Feedback results and update.
7	For each TPM, establish upper and lower limits and performance growth values for discrete reporting points.
8	Assign responsibility for meeting TPMs.
9	Incorporate TPMs into appropriate program documents (e.g., PPofE, SEMP, SDP, DRB, etc.).
10	Use the project risk management process to track TPMs.
11	Schedule, collect and report TPM measurements.
12	Perform corrective action and risk mitigation on TPMs that do not meet performance growth values.

TPM Collection

- TPMs require quantitative data to evaluate the likelihood of satisfying the system requirements
- Gathering such data can be expensive
- Because of the expense, not all requirements have TPMs, just the high priority requirements. As a rule of thumb, less than 1% of requirements should have TPMs.
- A TPM's values change with time, hopefully getting closer and closer to the goal
- TPMs are linked to a requirement, have quantitative values and a risk level

BAE SYSTEMS

Typical TPM ranking table

Technical Performance Measure (TPM)	Source Requirement	Quantitative Performance Requirement	Current TPM Value	Risk of Not Meeting TPM*
Image processing time (minutes)	ID # 123	Less than 5 minutes from time of request	10 minutes	1
MTBF of system	ID # 321	Greater than 1000 hours	750 hours	3
Availability (operational)	ID # 456	98% (minimum)	95%	2

*1= Very High
2= High
3= Moderate
4= Low
5= None

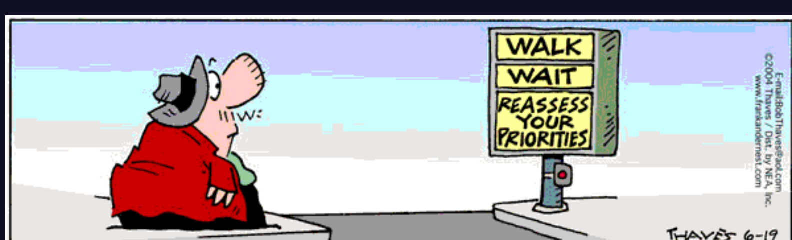
Prioritization

- Requirements are prioritized
- In addition, TPMs should be prioritized with relative importance to the customer
- BAE Systems NSS RF.PrioritizeRequirements documents process for requirements prioritization criteria and methods

BAE SYSTEMS

TPM prioritization

TPM	Planned value	Current value	Relative importance
Image processing time (sec.)	30 sec. max	45 sec. for an SES simulation	10
Power required	10 KV max. UPS 2 hr. backup	12 KV UPS 1.5 hr. Vendor data	8
Weight	600 lbs. max man portable modules	625 lbs. six-modules CAD mockup	7



1 = least important
10 = most important

TPMs can be organized hierarchically

For example

- System lifetime
  - mechanical lifetime
  - electrical lifetime
    - power consumption
    - battery capacity
- The lower level TPMs (or measures) are used to derive values of higher level TPMs
- The top-level TPMs may be reported to Senior Management

BAE SYSTEMS

Tracking TPMs

- The DOORS requirements module should have an attribute named TPM
- The name of each TPM should be entered in the attribute field of the appropriate DOORS requirement and this should be linked to the TPM module
- Each TPM should also be referenced in the project's Risk Register and be evaluated monthly

BAE SYSTEMS

Optional Independent Design Reviews

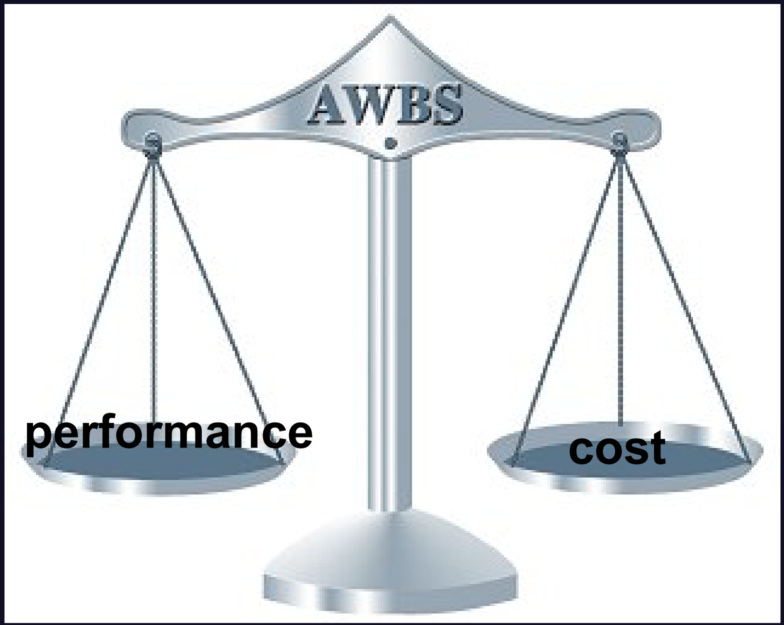
- TPMs can also be used to trigger optional independent design reviews
- Only eight design reviews are mandated
- If a TPM exceeds its thresholds, then an optional independent design review (IDR) will be added to the Engineering Plan

- PS0366 Plan and Conduct Independent Design Reviews
- PD0602 Plan Independent Design Reviews
- PD0603 Conduct Independent Design Reviews

BAE SYSTEMS

The big picture

- Program managers tradeoff cost, schedule and technical performance of a system
- Cost and schedule are often tracked with an earned value system
- TPMs give managers a way to track technical performance
- Managers can adjust cost and schedule per TPM forecasts



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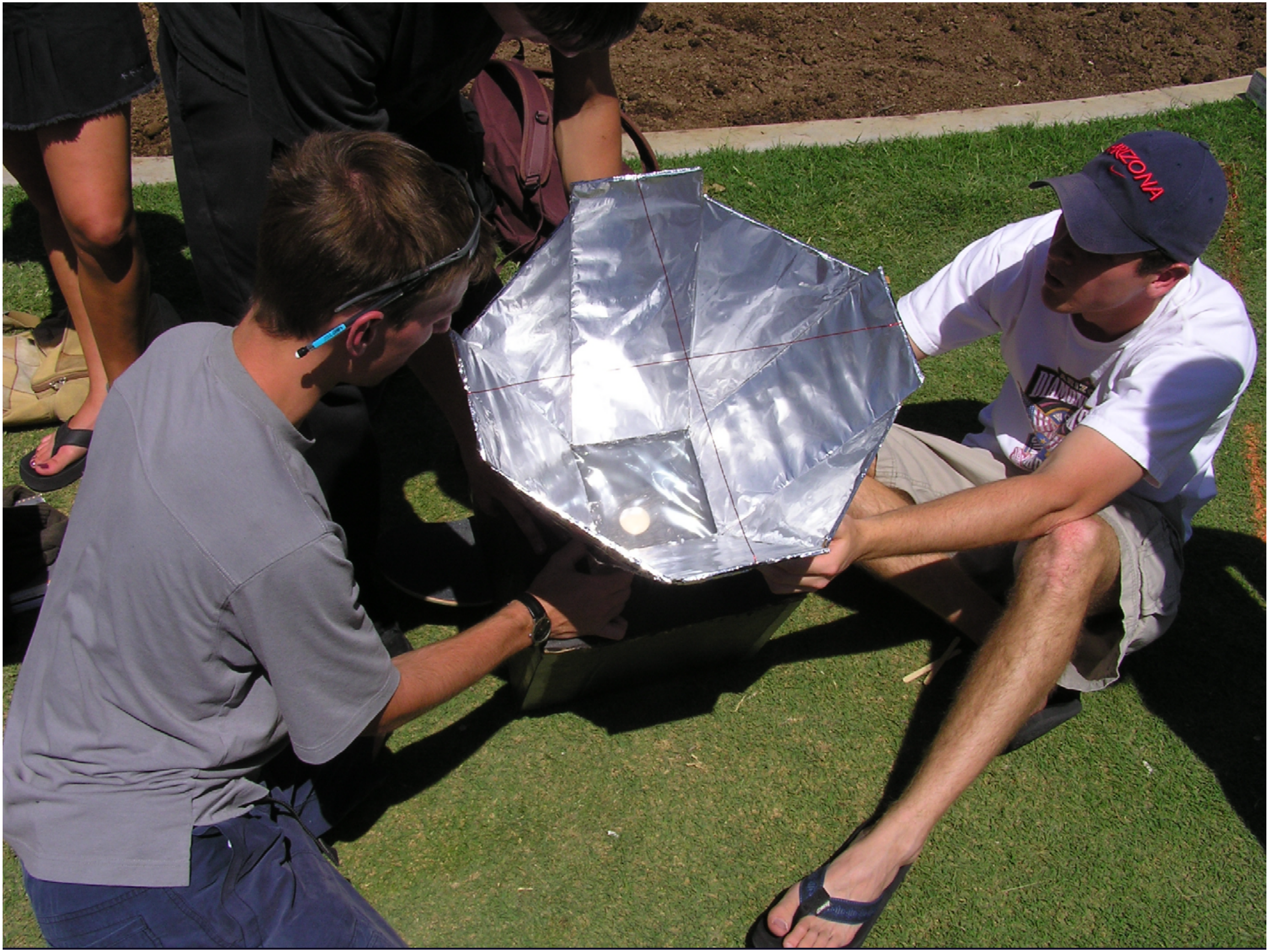
Solar Oven Case Study

- As an example of using a TPM, let us consider the design and manufacture of solar ovens
- In many societies people spend as much as 50% of their time acquiring wood for their cooking fires
- To address this, people have been designing and building solar ovens
- Let us examine the solar oven design and manufacturing process that we followed in a Freshman Engineering Design class (Engr-102) at the University of Arizona


ARIZONA

Risk analysis$_1$

For each identified risk, students recorded the Risk Name, description, impact, probability, type and risk mitigation plan

For the solar oven project three risks were identified

Risk One

Name: High Cost

Description: Material for the ovens is provided. But some students paid $100 for special materials and told their parents that was required

Impact: medium

Probability: low

Type: monitor

Plan: Compute cost for every design

Risk analysis of solar oven$_2$

Risk Two

Name: Failure to Have Oven Ready for Testing

Description: Everyone must test at the same time on the same day. If a team is not ready, they cannot be tested fairly.

Impact: high

Probability: low

Type: manage

Plan: Require final design 7 days before scheduled test date and require preproduction unit 3 days in advance

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Risk analysis of solar oven 3

Risk Three

Name: Insufficient Internal Oven Temperature

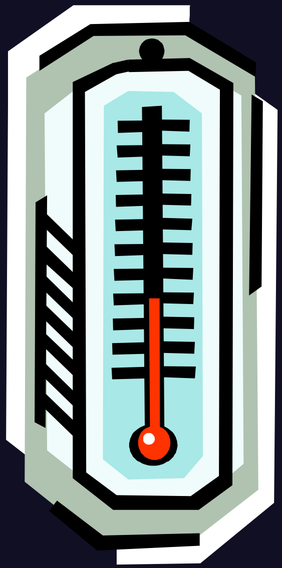
Description: The ovens must get hot enough to bake bread.

Impact: high

Probability: high

Type: resolve

Plan: Make it a technical performance measure



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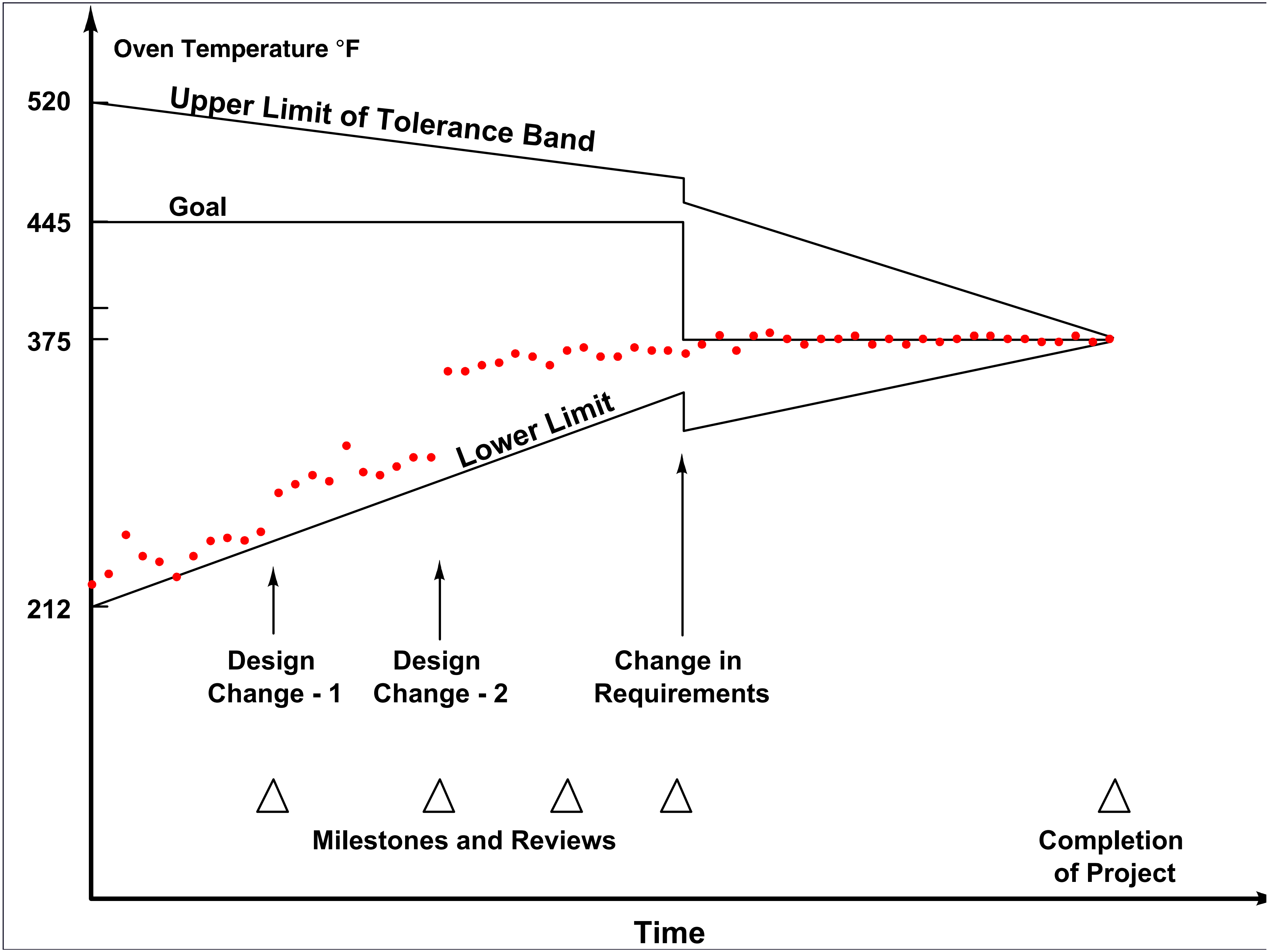
Design the TPM

- When a loaf of bread is finished baking, its internal temperature should be 200°F
- To reach this internal temperature, commercial bakeries bake the loaf at 445°F
- As initial values for our oven temperature TPM, we chose a lower limit of 212°F, a goal of 445°F, and an upper limit of 520°F
- The tolerance band shrinks with time as shown in the upcoming figure

TPM template

- **Name:** Internal Oven Temperature
- **Purpose:** ensure that most ovens pass the scheduled test
- **Source requirement:** assignment for Engr-102
- **Risk level:** resolve
- **What should be measured?** internal oven temperature in degrees Fahrenheit
- **How should it be measured?** test
- **How often should it be measured?** daily
- **During which project phases should it be measured?** all
- **How should it be displayed?** see figure
- **To whom should it be presented?** Engr-102 instructor
- **Threshold above or below which action is necessary:** the lower limit shown in the figure
- **What action should be performed?** suggest new design or negotiate with the customer to relax the requirements
- **Who should perform this action?** Engr-102 instructor



Oven Temperature °F
520
445
375
212
Upper Limit of Tolerance Band
Goal
Lower Limit
Design Change - 1
Design Change - 2
Change in Requirements
Milestones and Reviews
Completion of Project
Time

BAE SYSTEMS

Improvement$_1$

- In the beginning our day-by-day measurement values increased because of:
  - finding better insulators,
  - finding better glazing materials (e.g., glass and Mylar),
  - sealing the cardboard box better,
  - aiming at the sun better, etc.
- At the time labeled “Design Change-1,” there was a jump in performance caused by adding a second layer of glazing to the window in the top of the oven
- This was followed by another period of gradual improvement as we learned to stabilize the two pieces of glazing material

Improvement$_2$

- At the time labeled “Design Change-2,” there was another jump in performance caused incorporating reflectors to reflect sunlight onto the window in the oven top
- This was followed by another period of gradual improvement as we found better shapes and positions for the reflectors

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Study the requirement

- We might not attain our goal
- We reevaluated the process and requirements
- *Consequences of insufficient oven temperature:
  - Enzymes are not deactivated soon enough, and excessive gas expansion causes coarse grain and harsh texture
  - The crust is too thick, because of drying caused by the longer duration of baking
  - The bread becomes dry, because prolonged baking causes evaporation of moisture and volatile substances
  - Low temperatures cannot produce carmelization, and crust color lacks an appealing bloom

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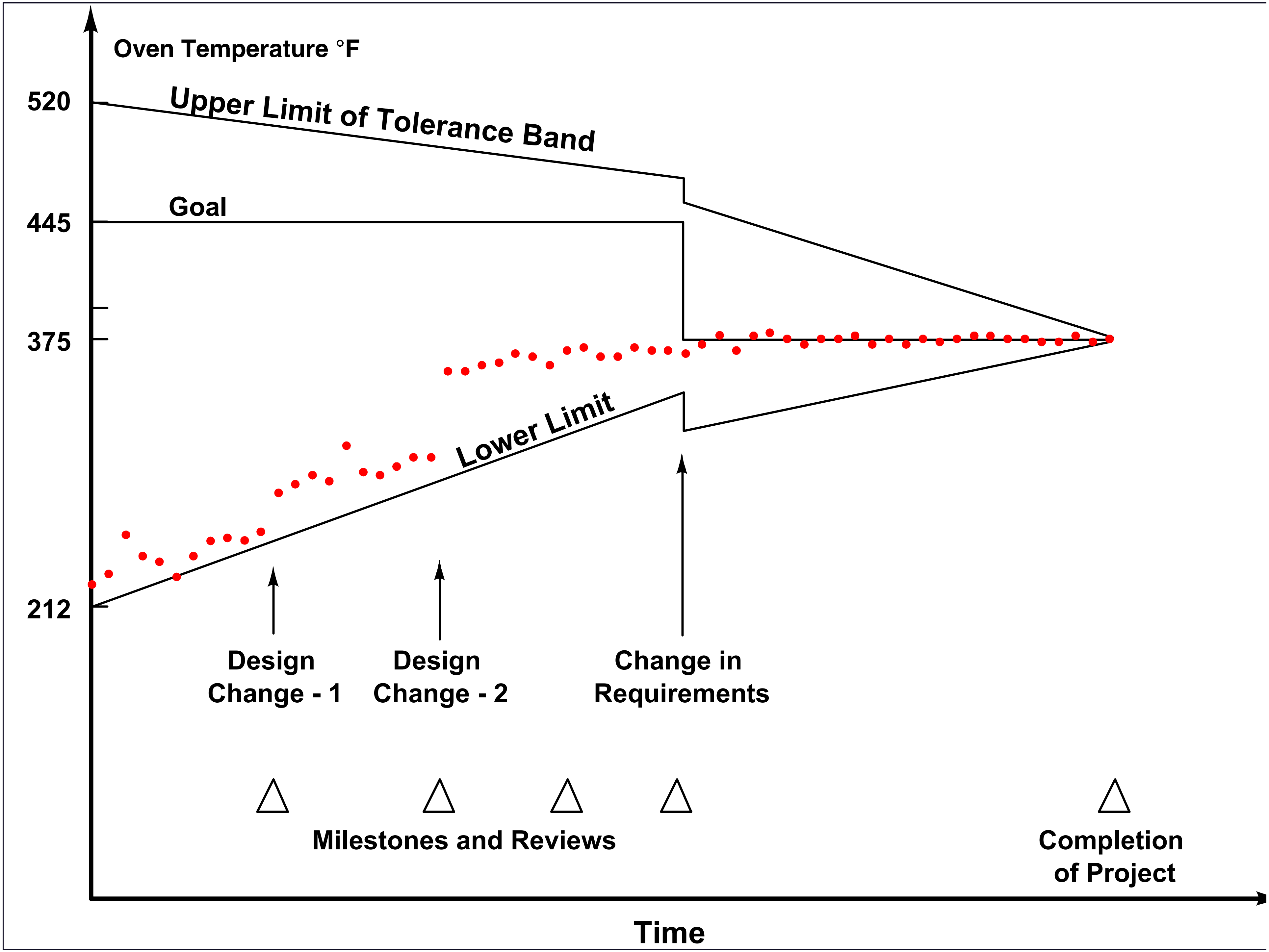
Alternatives

- If the dough were made richer by adding sugar, eggs, butter and milk, we could get away with temperatures as low as 350°F
- But we decided to design our ovens to match the needs of our customers, rather than try to change our customers to match our ovens

Change the requirement

- After consulting some bakers, our managers decided that 375°F would be sufficient to avoid the above problems
- Therefore, the requirements were changed at the indicated spot and our design was able to meet the goal of the TPM
- Of course, this change in requirements forced a review of ***all*** other requirements and a change in many other facets of the design
- For example, the baking duration versus weight tables had to be recomputed


Oven Temperature °F
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Goal
Lower Limit
Design Change - 1
Design Change - 2
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Completion of Project
Time

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Pilot at BAE Systems

- In 2005, a mature Archive and Dissemination development program piloted our TPM process
- This program has been running for seven years
- We used it on a new spiral that was to last seven months from funding to delivery
- TPMs were selected for less than 1% of the program's 7000+ system requirements
- The selected TPMs were related to image processing and data export (dissemination) rates
- Simulations done for the TPM process showed that dissemination of near-line data (information from tapes in a robot) and off-line data (information from tapes on a shelf) were significant risks
- The program continues to monitor these TPMs
- Modifications to the system/hardware design and architecture may be necessary to ensure satisfaction of the near-line and off-line dissemination requirements

What might change?

- Only create TPMs for requirements where you can change something
- In the solar oven example the design was changed twice and the goal was also changed
- Obviously, cost and schedule can be changed to improve performance
- TPMs can be used to choose between alternative concepts. The alternatives that can be used to reduce blood pressure include drugs, exercise, diet and reducing alcohol consumption. If one technique is not working, then you can add or switch to another.

Subtleties

Quantifying System Performance

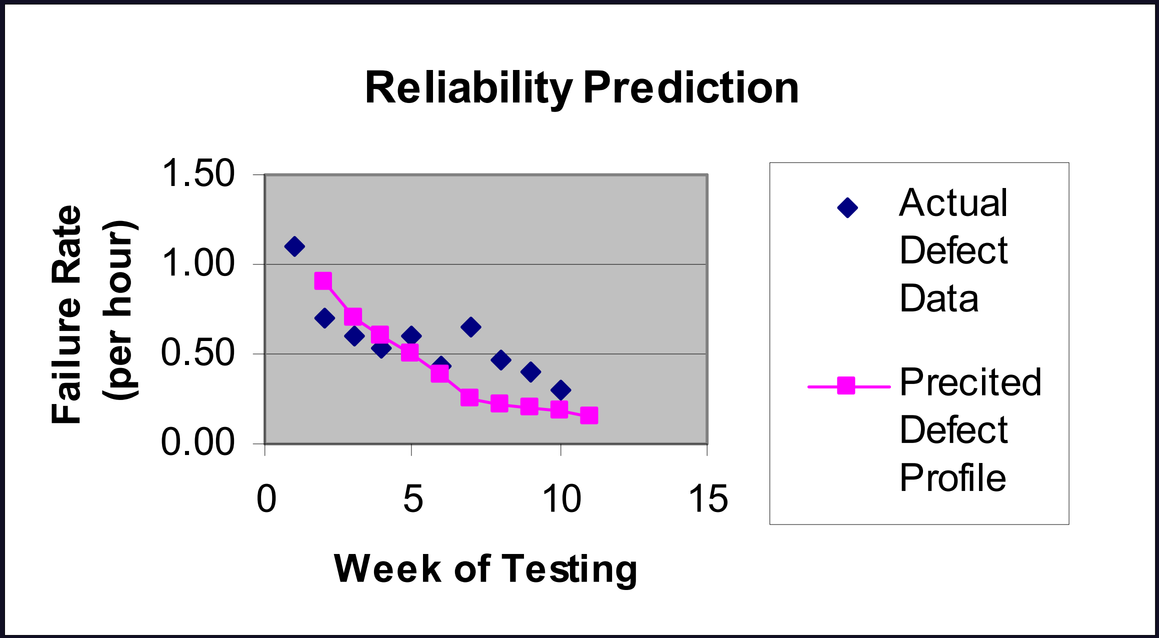
- Evaluation criteria (which are also called figures of merit and measures of effectiveness) are used to quantify requirements and to help select amongst alternative designs in tradeoff studies
- Measures (which used to be called metrics) are used to help manage a company's processes
- Technical performance measures are used to mitigate risk during design and manufacturing

Examples of Measures, not TPMs

- Number of features implemented
- *Components designed
- Components implemented
- Components integrated and tested
- Requirements allocated
- Requirements tested
- Test cases completed
- Paths tested
- Problem reports resolved
- Reviews completed
- Changes implemented
- Hours between failures
- Failure Rate a.k.a. Failure Intensity

Most of these are process, not product related

Failure Rate



From David N. Card, Software Productivity Consortium

In this case the planned values are given with an equation

$$\lambda = \lambda_0 e^{-\theta t}$$

where λ is the failure rate, λ_0 is the initial failure rate, θ is the decay rate and t is time. This is the equation for a Poisson distribution

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Preventing deterioration

- We use TPMs for requirements where the desired performance is expect to improve with time
- Another use of TPMs would be to prevent unacceptable decreases in performance
- In the design and development process, adding bells and whistles might reduce processing time or increase weight
- TPMs could warn of such unwanted behavior

TPM Summary[1]

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- TPMs are used to identify and track performance requirements that are program critical
- TPMs are used to establish the appropriate design emphasis, design criteria and identify levels of technical risk
- TPM measurements are collected and tracked against project design objectives in the project's risk register

TPM Summary$_2$

Create TPMs for high priority requirements

- that impact
  - mission accomplishment
  - customer satisfaction
  - system usefulness
- where performance improves with time
- where performance can be controlled
- where management can tradeoff cost, schedule and performance

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UNMANNED AERIAL VEHICLE SURVIVABILITY INFLUENCE ON SYSTEM LIFE CYCLE COST

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OBJECTIVE

To present a methodology for use in the Systems Engineering process that assists decision makers in identifying the unmanned aerial vehicle survivability alternative that provides the lowest life cycle cost while meeting the operational need.

OUTLINE

- BACKGROUND
  - Systems Engineering
  - Survivability
  - Unmanned Aerial Systems
- METHODOLOGY DESCRIPTION
  - Basic Premise
  - Characteristics
  - Description
- EXAMPLE
  - Scenario Description
  - Vignette Snapshot
  - Results
- CONTRIBUTORS

BACKGROUND
SYSTEMS ENGINEERING

DoD Directive 5000.1

Systems Engineering.Acquisition programs shall be managed through the application of a systems engineering approach that optimizes total system performance and minimized total ownership costs.

DoD Instruction 5000.2

Effective sustainment of weapon systems begins with the design and development of reliable and maintainable systems through the continuous application of a robust systems engineering methodology

Defense Acquisition Guidebook

Chapter 4 describes the systems engineering processes and the fundamentals of their Application to DOD acquisition.

THE METHODOLOGY DESCRIBED IN THIS PRESENTATION WAS CONCEIVED TO ASSIST SURVIVABILITY EVALUATIONS WITHIN THIS PROCESS

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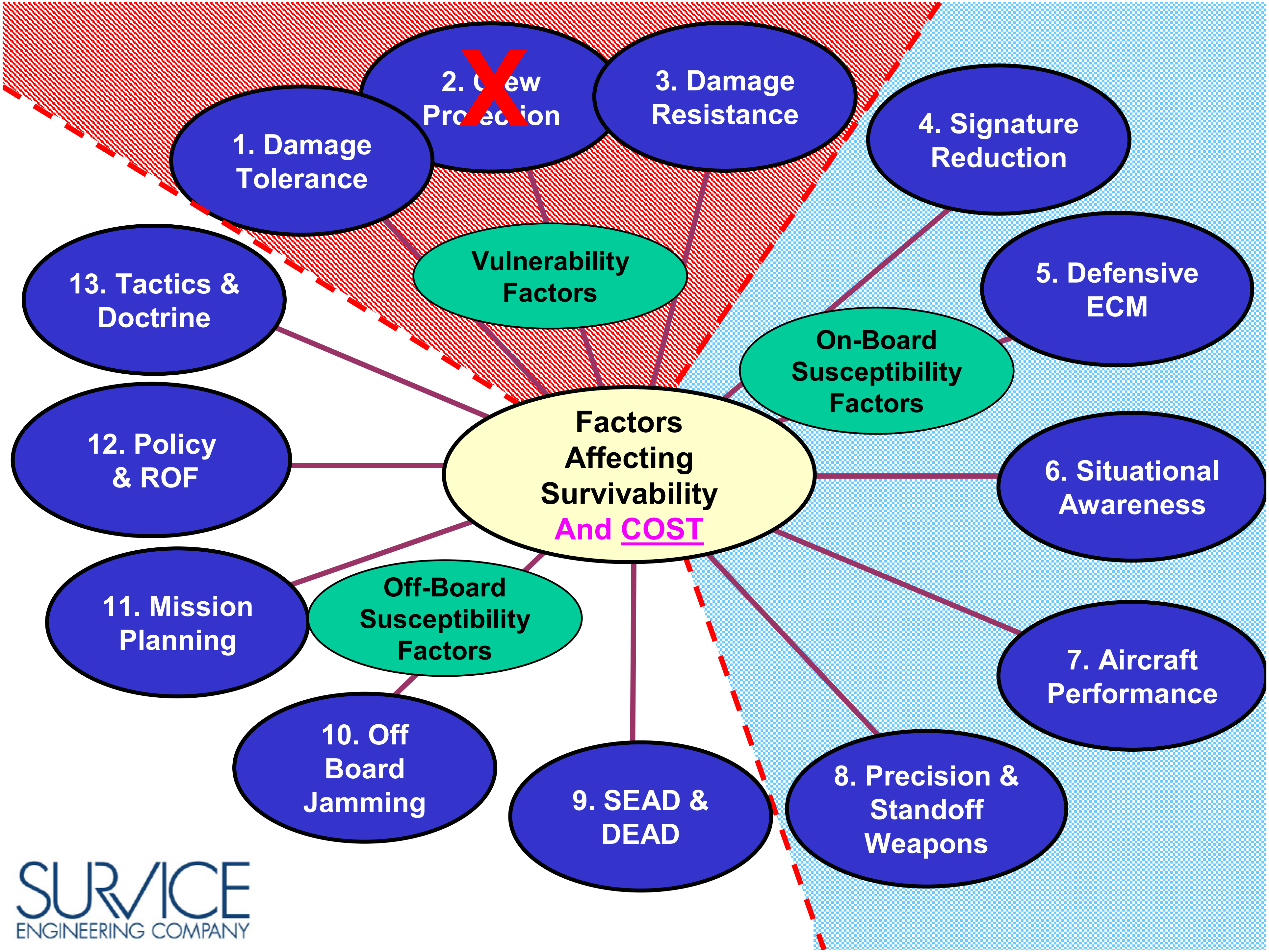
BACKGROUND
WHAT IS SURVIVABILITY ?

- Survivability is the capability of a system/platform to avoid and/or withstand a man-made hostile environment. Survivability is broken down into two subsets, susceptibility and vulnerability.
  - Susceptibility is the inability of an aircraft to avoid being hit by one or more damage mechanisms.
  - Vulnerability is the inability of an aircraft to withstand the damage sustained from man-made threats.

$$\text{Probability of Survival} = 1 - \left(\text{Probability of Being Hit}\right)\left(\text{Probability of Being Killed Given a Hit}\right)$$



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BACKGROUND
SURVIVABILITY

- Every combat system has survivability characteristics
  - Influenced by mission/threat - system design/configuration - relationships to other systems

- Survivability characteristics have a strong influence on Total System Cost
  - Not enough survivability - lose assets and cannot complete mission
  - Unnecessary survivability - creates affordability issues

- Survivability is important to any warfighting system

  It must survive to perform the mission
  It protects the operator from harm
  It keeps the system affordable

ANY SYSTEMS LEVEL EVALUATION OF UAVs SHOULD INCLUDE A STRUCTURED, INTEGRATED ASSESSMENT OF SURVIVABILITY TO IDENTIFY AND DEVELOP THE BEST OVERALL CONFIGURATION

BACKGROUND
UNMANNED AERIAL SYSTEMS

Source: DoD UAS Roadmap 2005 - 2030

Dragon Eye/BAI Aerosystems; AeroVironment/Marine Corps

Weight:	4.5 lb
Length:	2.4 ft
Wingspan:	3.8 ft
Payload:	1 lb
Ceiling:	1000 ft
Radius:	2.5 nm
Endurance:	45-60 min

RQ-4 Global Hawk/Northrop Grumman/Air Force

Weight:	26,750 lb
Length:	44.4 ft
Wingspan:	116.2 ft
Payload:	1950 lb
Ceiling:	65,000 ft
Radius:	5400 nm
Endurance:	32 hr

THE TRADE SPACE FOR SURVIVABILITY IS LARGE AND GROWING

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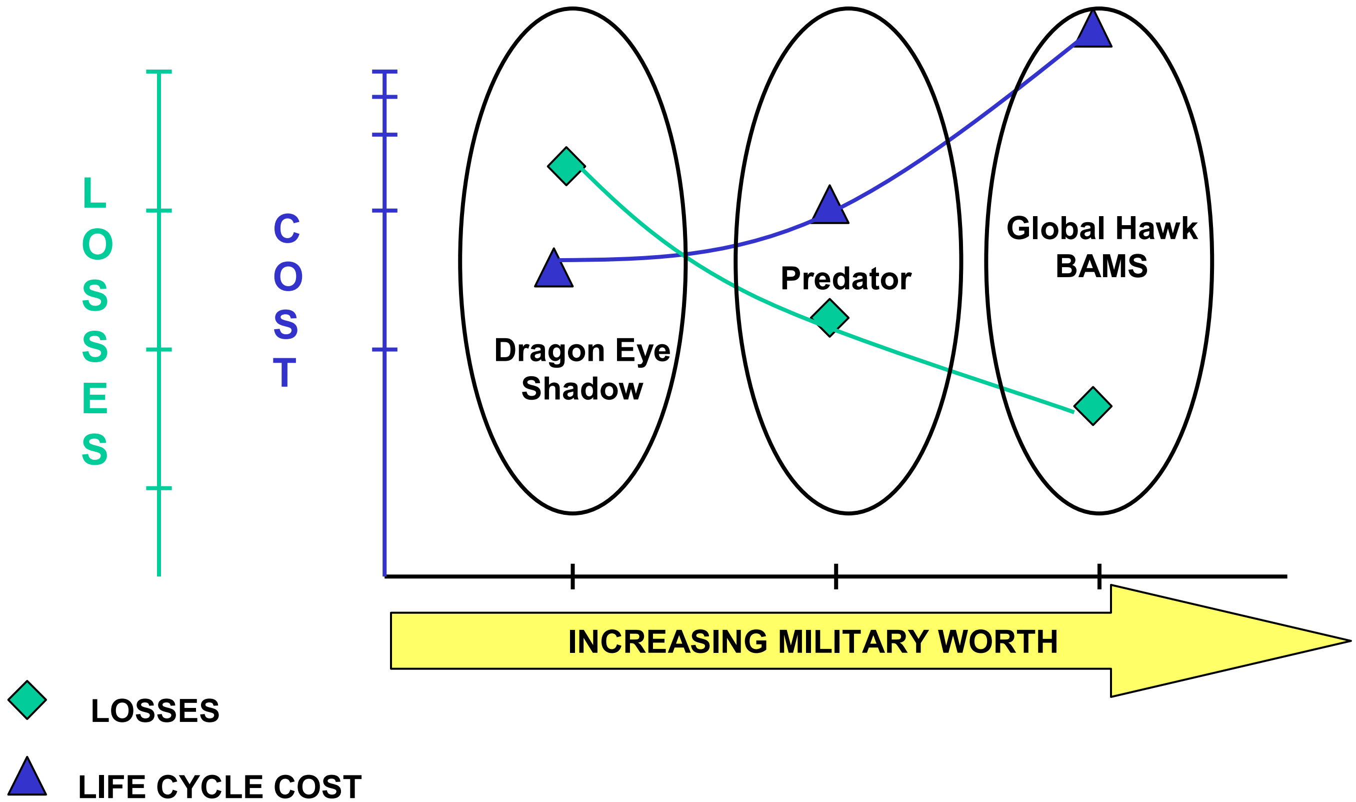
BACKGROUND
UNMANNED AERIAL SYSTEMS

Source: DoD UAS Roadmap 2005 - 2030

System	Aircraft Cost,FY04$*	Aircraft Weight, Lb*	Payload Capacity, Lb	System Cost FY04$	Number Acft/System
Dragon Eye	$28.5K	3.5	1	$130.3K	3
RQ-7A Shadow	$0.39M	216	60	$12.7M	4
RQ-2B Pioneer	$0.65M	307	75	$17.2M	5
RQ-8B Fire Scout	$4.1M	1765	600	$21.9M	4
RQ-5A Hunter	$1.2M	1170	200	$26.5M	8
MQ-1B Predator	$2.7M	1680	450**	$24.7M	4
MQ-9A Predator	$5.2M	3050	750**	$45.1M	4
RQ-4(Block 10) Global Hawk	$19.0M	9200	1950	$57.7M	1
RQ-4(Block 10) Global Hawk	$26.5M	15400	3000	$62.2M	1

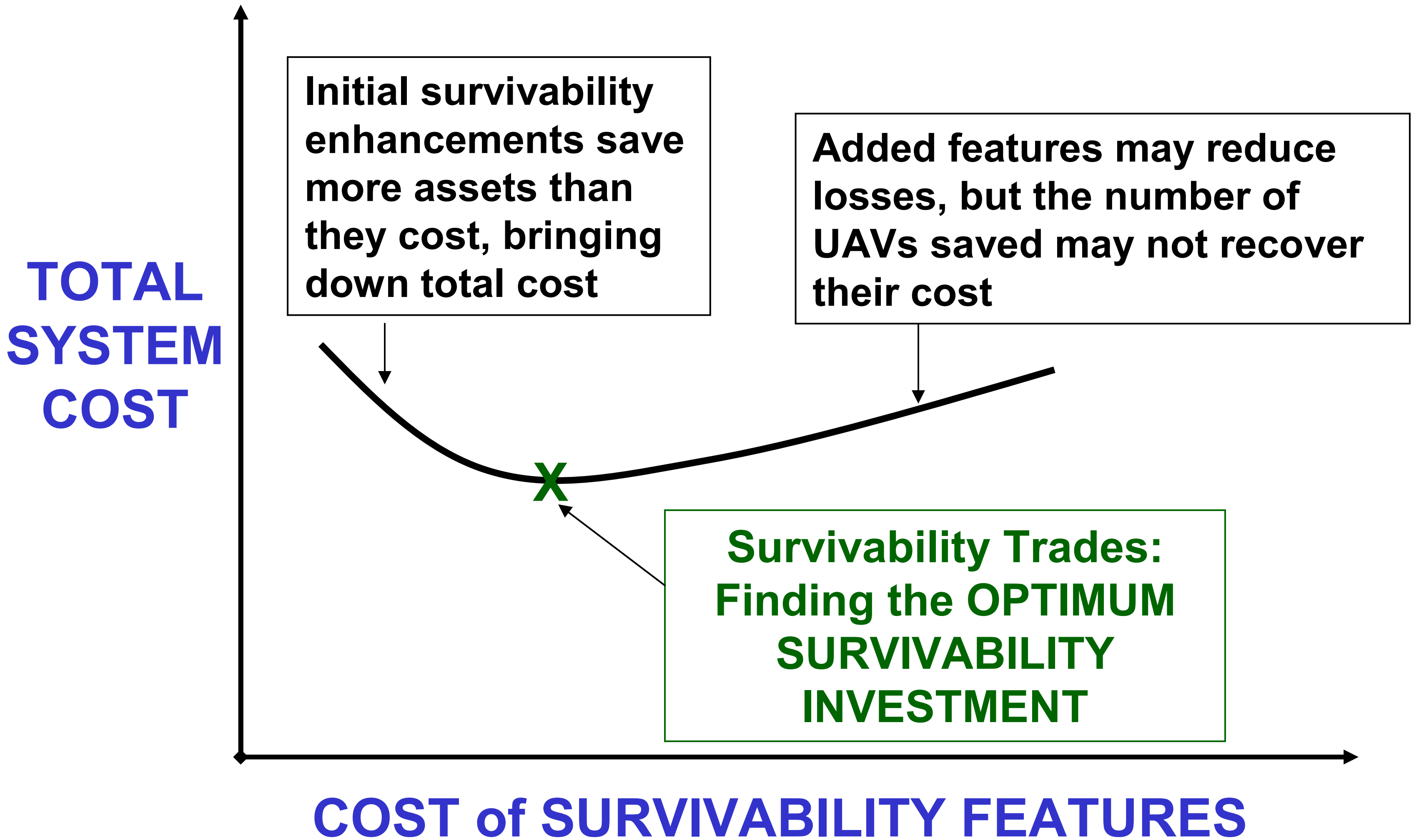
*Aircraft costs are minus sensor cost, and aircraft weights are minus fuel and payload capacities
** Internal payload weight capacity only

BACKGROUND
UNMANNED AERIAL SYSTEMS



- As cost and military worth go up, reducing losses becomes key
- Cost AND military worth must be quantified to support survivability goals

METHODOLOGY
BASIC PREMISE

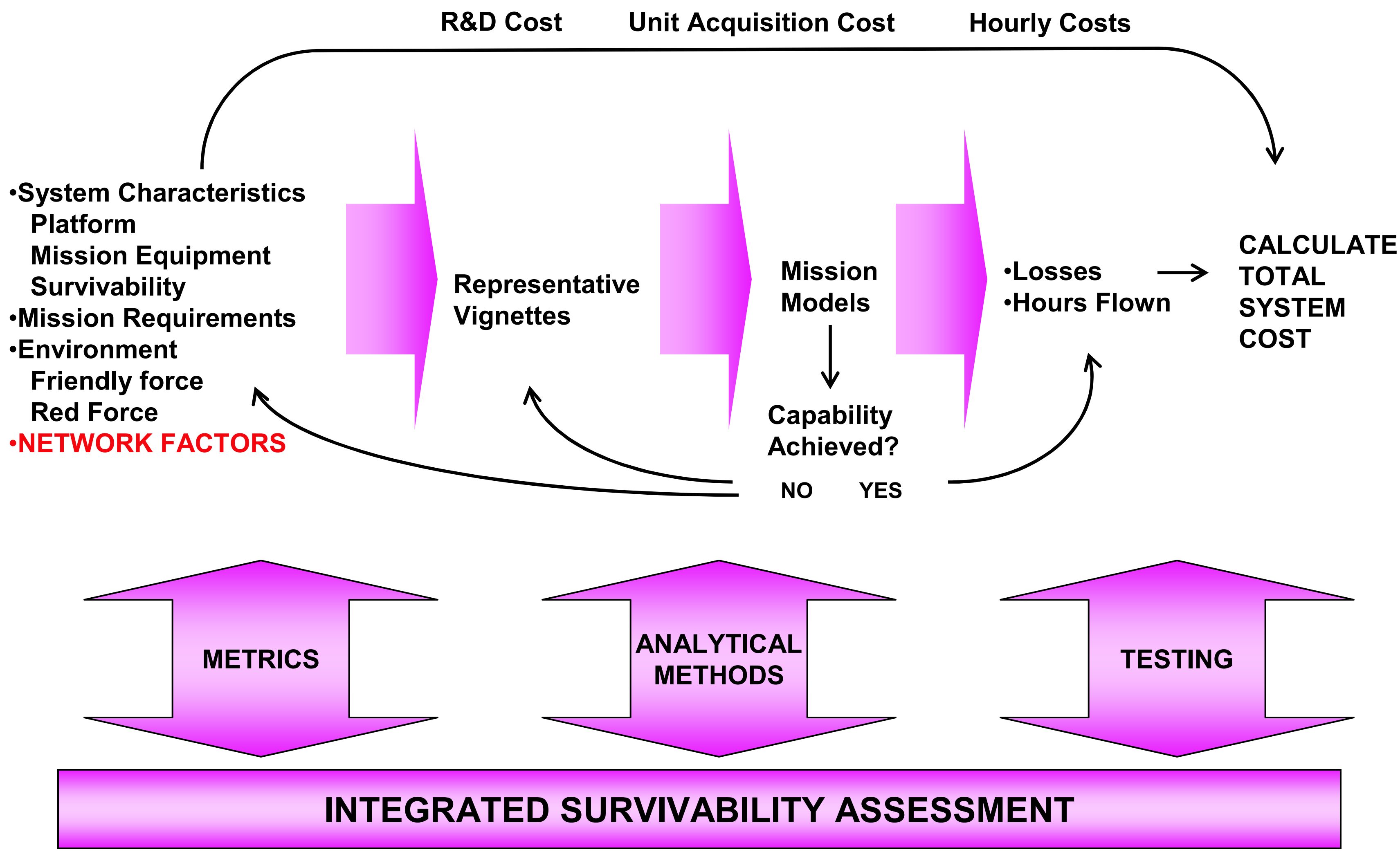


METHODOLOGY CHARACTERISTICS

- Encompass consideration of all aspects of survivability
  - Threat, Mission, Performance, Mission Equipment, Survivability Enhancements, Network Functions
- Executable within available time and resources.
- Account for cost implications during normal and combat conditions.
- Methodology supports decision-making even when little is known or when changes are encountered
  - Potential use as a capability evaluation tool
  - Parametric analysis around inputs that are “soft”
- Analysis allows building block approach
  - Build on what we have without starting over
  - Improve fidelity by evolution
  - What we know/don’t know is always transparent

ARRIVE AT THE BEST TOTAL COST ESTIMATE POSSIBLE COMMENSURATE WITH THE INFORMATION, RESOURCES, AND TIME AVAILABLE.

METHODOLOGY DESCRIPTION



EXAMPLE
SCENARIO DESCRIPTION

The sample analysis involves VTUAVs on a surveillance mission to locate threat RF missile sites.

Threat - Three batteries of short range RF missiles

Each battery has three TELARs and a C2 vehicle. Batteries operate under strict control of the commander

One squad of three soldiers with each of the nine TELARs and C2 vehicles for a total of 36 MANPADS. Operate autonomously.

Friendly - Three VTUAV systems, each with three VTUAVs and a ground control station. The UAVs fly at 100kts at an altitude of 1050m. Each has an EO/IR sensor and an LDRF. When the ground target is detected, the info is transmitted to the ground station which sends an attack aircraft. The RF signature was held a 10 Sqm and the IR signature was varied from 500W/sr to 1 W/sr. A degrade to the missile pk of 25%, 50% and 75% was applied to simulate an IRCM.

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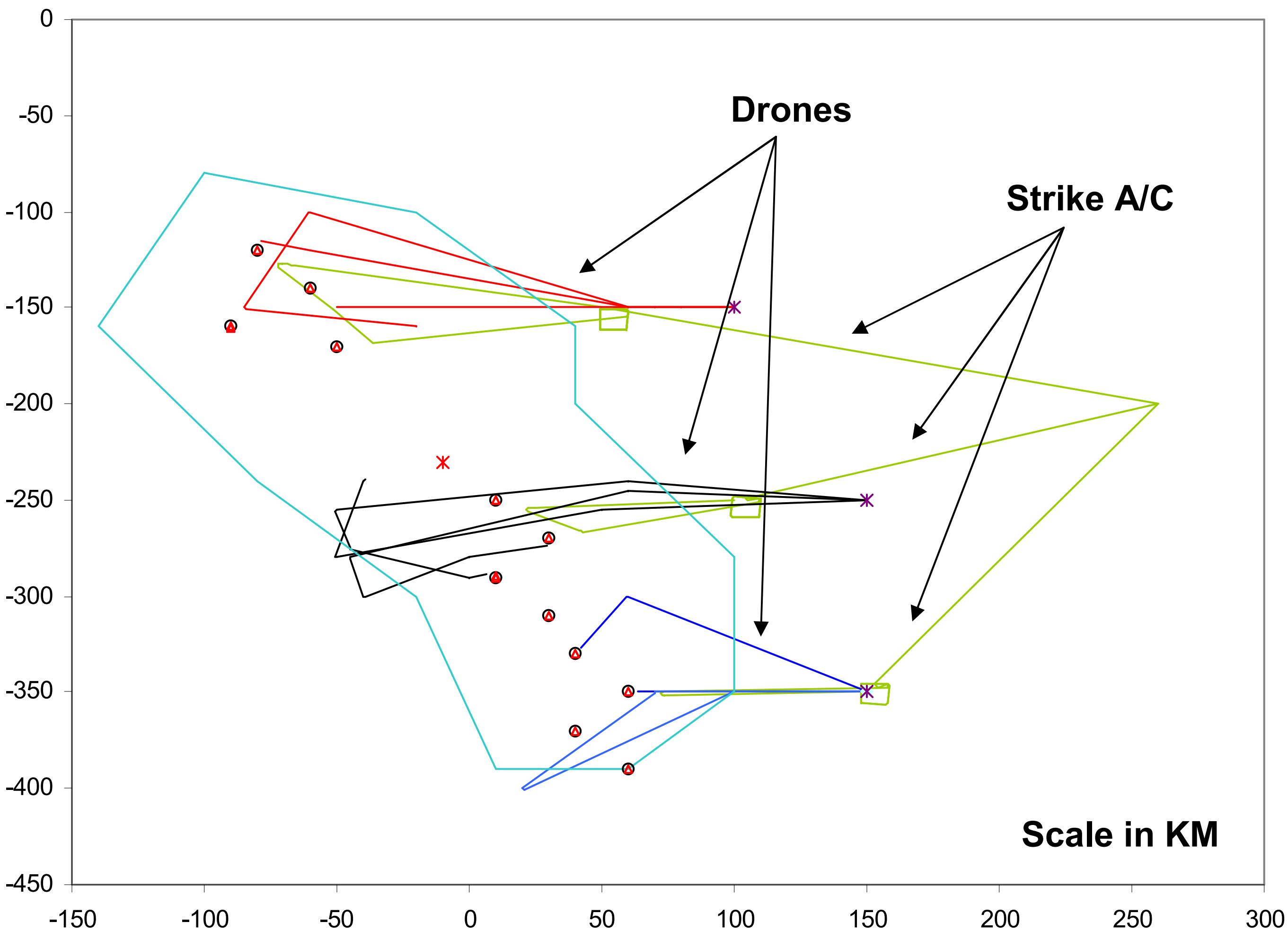
EXAMPLE
VIGNETTE SNAPSHOT



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EXAMPLE
OVERALL RESULTS

Attrition results as a function of signature

SIGNATURE	RF Shots	IR Shots	RF hits	IR hits
500W/sr	2.43	17.10	0.93	4.33
50W/sr	2.80	16.50	0.87	4.50
5W/sr	2.33	16.87	1.00	4.63
1W/sr	1.93	6.43	1.00	1.73

Attrition results as a function of IRCM effectiveness

Pk Degrade	RF Shots	IR Shots	RF hits	IR hits
No Degrade	2.43	17.10	0.93	4.33
25%	2.57	18.50	0.93	3.87
50%	2.13	19.70	1.00	3.30
75%	1.97	21.70	0.97	2.00

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EXAMPLE
IRCM IMPROVEMENTS

	BASIC	ALQ-144	ADV JAMMERS	DIR ENERGY
Original Number of Mission Aircraft	9	9	9	9
Number of Mission Aircraft Lost	5.26	4.8	4.3	2.97
Mission Probability of Survival	0.41556	0.46667	0.52222	0.67000
Fleet Size	100	100	100	100
Number of Missions	90	90	90	90
Number of Losses	52.6	48	43	29.7
Number of Flight Hours/Mission	6	6	6	6
Development Cost ($)				
Basic Platform	8,000,000	8,000,000	8,200,000	8,400,000
Mission Package	2,000,000	2,000,000	2,000,000	2,000,000
Survivability Enhancements	0	500,000	1,000,000	1,500,000
Sub Total	10,000,000	10,500,000	11,200,000	11,900,000
	0			
Unit Acquisition Cost ($)				
Basic Platform	3,000,000	3,000,000	3,000,000	3,200,000
Mission Package	1,000,000	1,000,000	1,000,000	1,000,000
Survivability Enhancements	0	100,000	200,000	500,000
Sub-Total	610,400,000	606,800,000	600,600,000	609,590,000
Hourly Operational Cost ($)				
Basic Platform	300	300	300	300
Mission Package	50	50	50	50
Survivability Enhancements	0	10	10	10
Sub Total	189,000	194,400	194,400	194,400
TOTAL SYSTEM COST ($)	620,589,000	617,494,400	611,994,400	621,684,400

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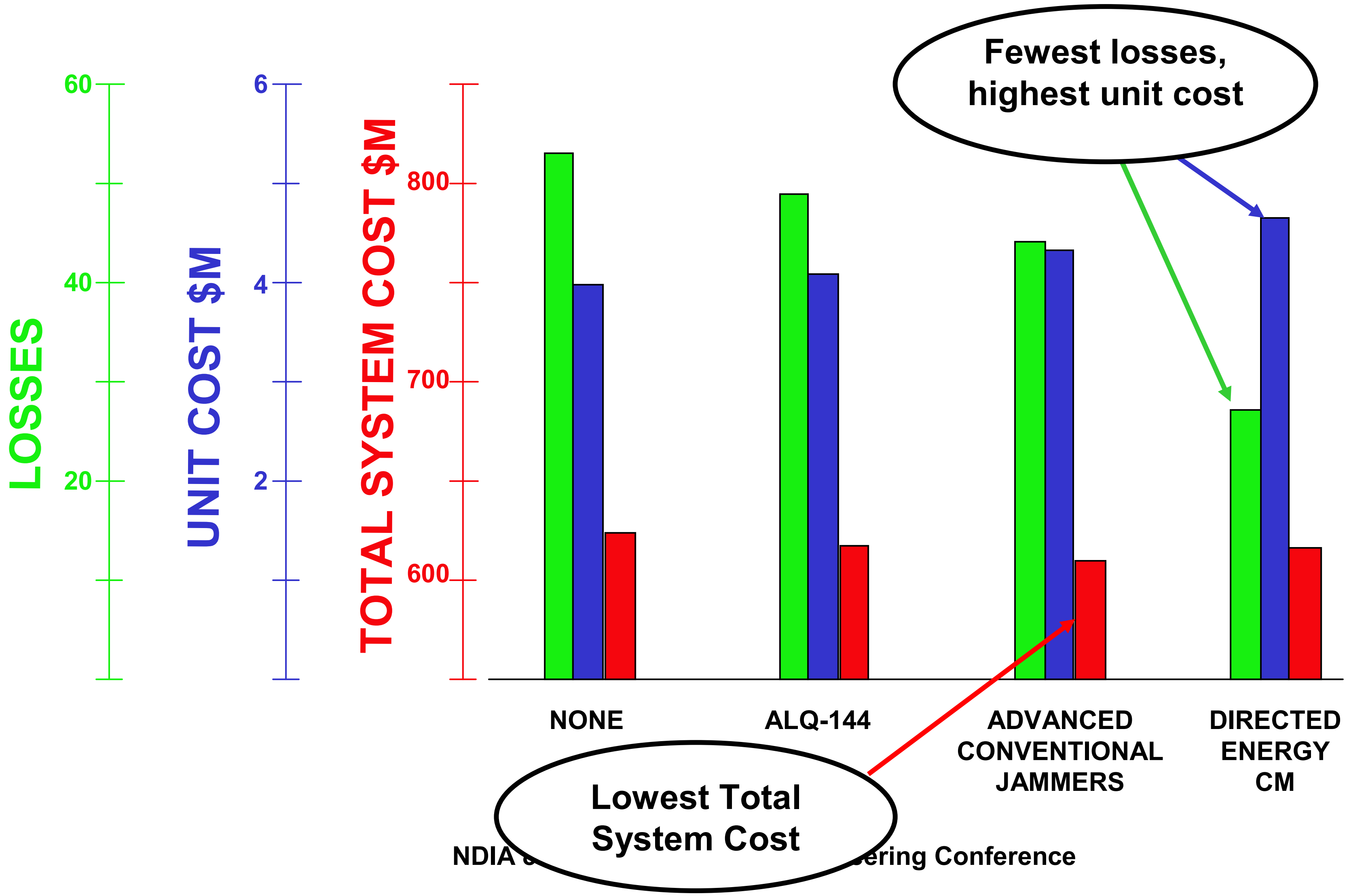
EXAMPLE
EFFECTS OF IRCM IMPROVEMENTS



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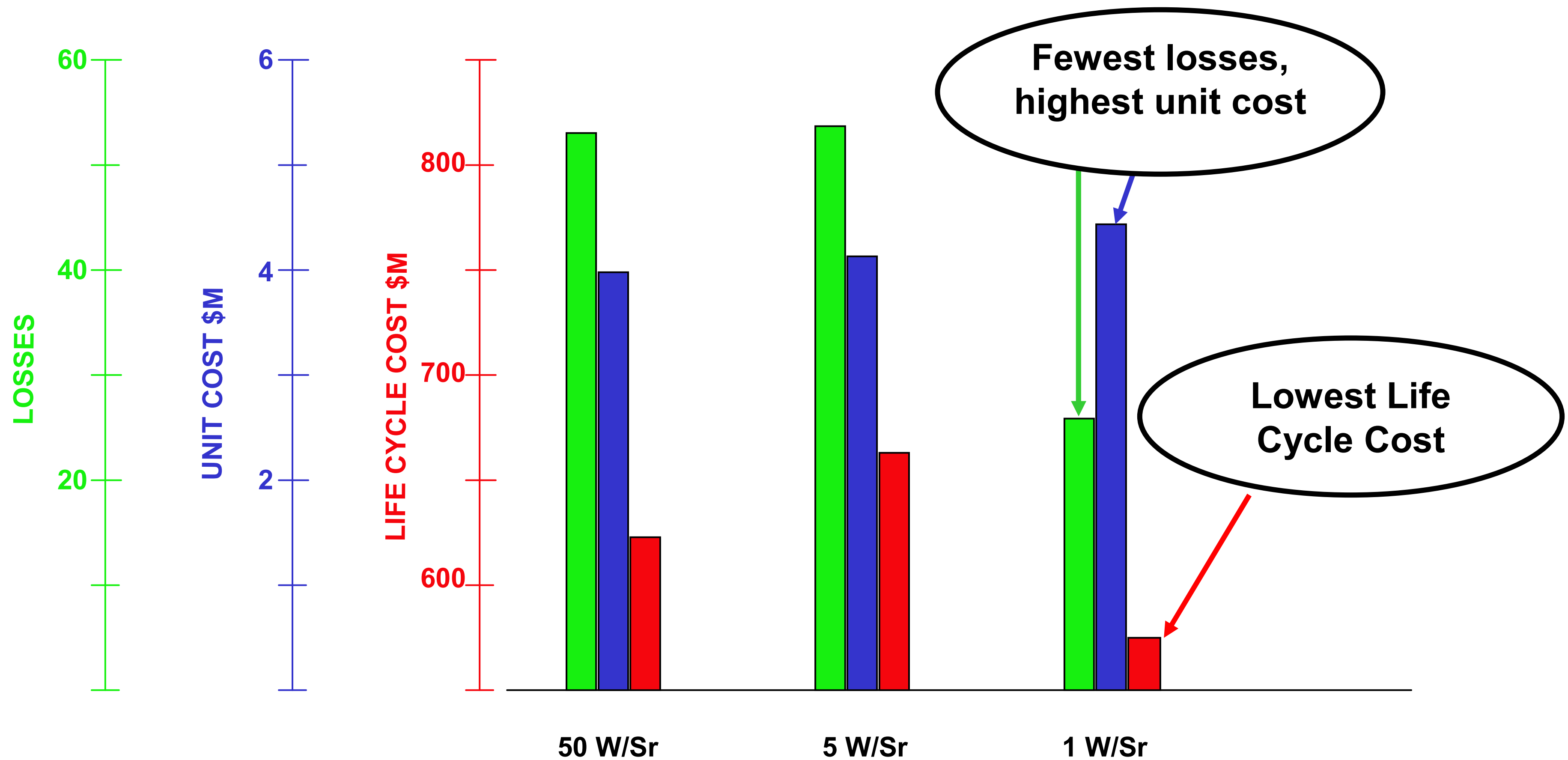
EXAMPLE
SIGNATURE REDUCTION

	50 W/Sr	5 W/Sr	1 W/Sr
Original Number of Mission Aircraft	9	9	9
Number of Mission Aircraft Lost	5.37	5.63	2.73
Mission Probability of Survival	0.40333	0.37444	0.69667
Fleet Size	100	100	100
Number of Missions	90	90	90
Number of Losses	53.7	56.3	27.3
Number of Flight Hours/Mission	6	6	6
<u>Development Cost ($)</u>			
Basic Platform	8,000,000	8,500,000	10,000,000
Mission Package	2,000,000	2,000,000	2,000,000
Survivability Enhancements	0	500,000	2,500,000
Sub Total	10,000,000	11,000,000	14,500,000
<u>Unit Acquisition Cost ($)</u>			
Basic Platform	3,000,000	3,000,000	3,200,000
Mission Package	1,000,000	1,000,000	1,000,000
Survivability Enhancements	0	100,000	200,000
Sub-Total	614,800,000	640,830,000	560,120,000
<u>Hourly Operational Cost ($)</u>			
Basic Platform	300	300	300
Mission Package	50	50	50
Survivability Enhancements	0	0	10
Sub Total	189,000	189,000	194,400
TOTAL SYSTEM COST ($)	624,989,000	652,019,000	574,814,400

EXAMPLE
EFFECTS OF IR SIGNATURE REDUCTION



NOTE: EXAMPLE ONLY

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QUESTIONS?

NDIA 8th Annual Systems Engineering Conference

“Requirements Management Tips and Tricks”

October 27, 2005

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Outline

- Requirements Elicitation
- Requirements Capture and Management
- Requirements Traceability
- Requirements Control
- Reaching Consensus
- Eliciting Verifications
- Communicating Requirements
- Metrics

Requirements Elicitation

How do you gather the requirements?

- Interviews
- QFD Workshops
- Web Based Surveys
- Vignettes and Scenarios
- Questionnaires
- Brainstorming and Mind Mapping
- Analysis/Derivation
  - ✓ Hazard
  - ✓ Fault Tree
  - ✓ Sensitivity
  - ✓ Trade Studies
- Existing Documentation and or Policies
- Quality Assurance Provisions

It involves a lot of research and is evolutionary!

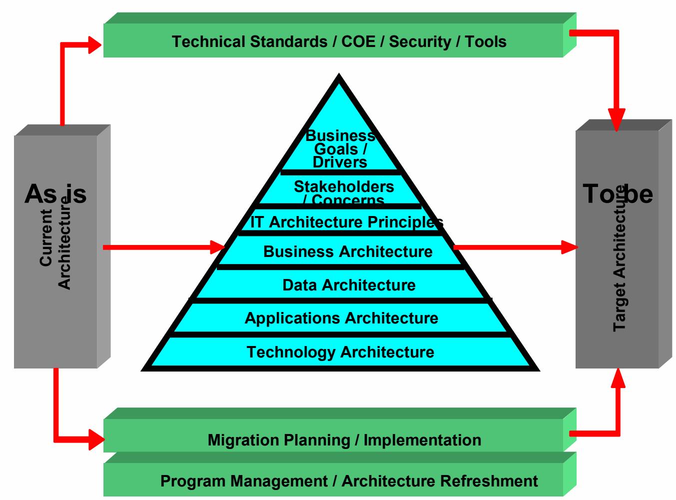
Don't forget to Document Rational. It will save you time latter when you will need to defend the requirements.

Interview Based Elicitation

Using and Enterprise Architecture approach one can first probe into Business Goals and Architecture Principles buy asking questions to understand:

- ❑ **Mission and Values of your organization**
- ❑ **Understand importance (PM Level)**
- ❑ **Understand organization structure**
- ❑ **Understand Products**
- ❑ **Understand Customers and Stakeholders**
- ❑ **Understand Daily Activities**

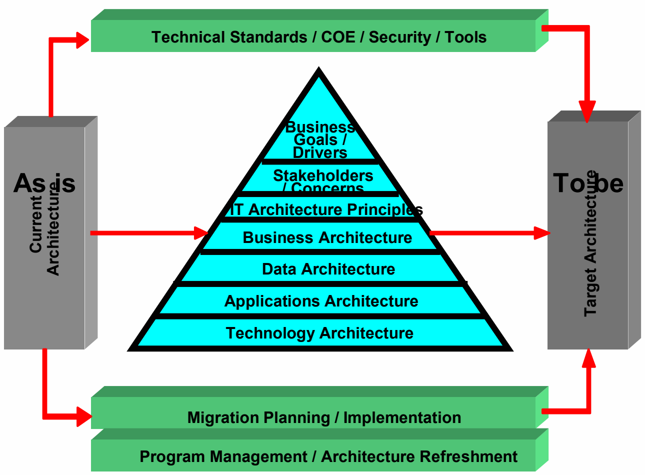
Mostly used for Business Systems



Interview Based Elicitation

Project and Product Data can be understood by asking these leading questions

- What are the Projects/Products that PM Mortars manages?
- Who do you interact with?
- What data types do you manage?
- How do you organize your data?
- What data do you view as being most important?
- Who are the Customers for each product?
- Who are the stakeholders for each product?
- What are the day to day activities that go on for the projects you choose?



QFD Based Elicitation

USER NEEDS	User Needs	Engineering Metrics: Engineering Measure 1	Engineering Measure 2	Engineering Measure 3	Engineering Measure 4	Engineering Measure 5	Engineering Measure 6	Engineering Measure 7	Engineering Measure 8	Engineering Measure 9	Engineering Measure 10	Engineering Measure 11	Customer Importance	Relative Importance
	Customer Need 1.0	9	9	0	0	0	9	9	9	0	0	9	5.00	26%
	Customer Need 2.0	0	0	9	9	9	9	9	3	0	0	9	3.00	16%
	Customer Need 3.0	0	0	0	0	0	3	9	1	9	0	3	5.00	26%
	Customer Need 4.0	0	0	0	0	0	1	3	9	0	0	1	4.00	21%
	Customer Need 5.0	0	0	0	0	0	1	1	1	0	5	1	2.00	11%

USER RATING	Absolute Score: Concept A	Concept B	Concept C	Concept D	Concept E	Relative Score: Concept A	Concept B	Concept C	Concept D	Concept E
Customer Need 1.0	3	5	1	3	2	0.79	1.3	0.3	0.8	0.5
Customer Need 2.0	3	2	3	3	3	0.47	0.3	0.5	0.5	0.5
Customer Need 3.0	3	5	5	3	4	0.79	1.3	1.3	0.8	1.1
Customer Need 4.0	3	2	5	3	5	0.63	0.4	1.1	0.6	1.1
Customer Need 5.0	3	1	5	3	4	0.32	0.1	0.5	0.3	0.4
	57	66	69	57	67	3	3	4	3	4

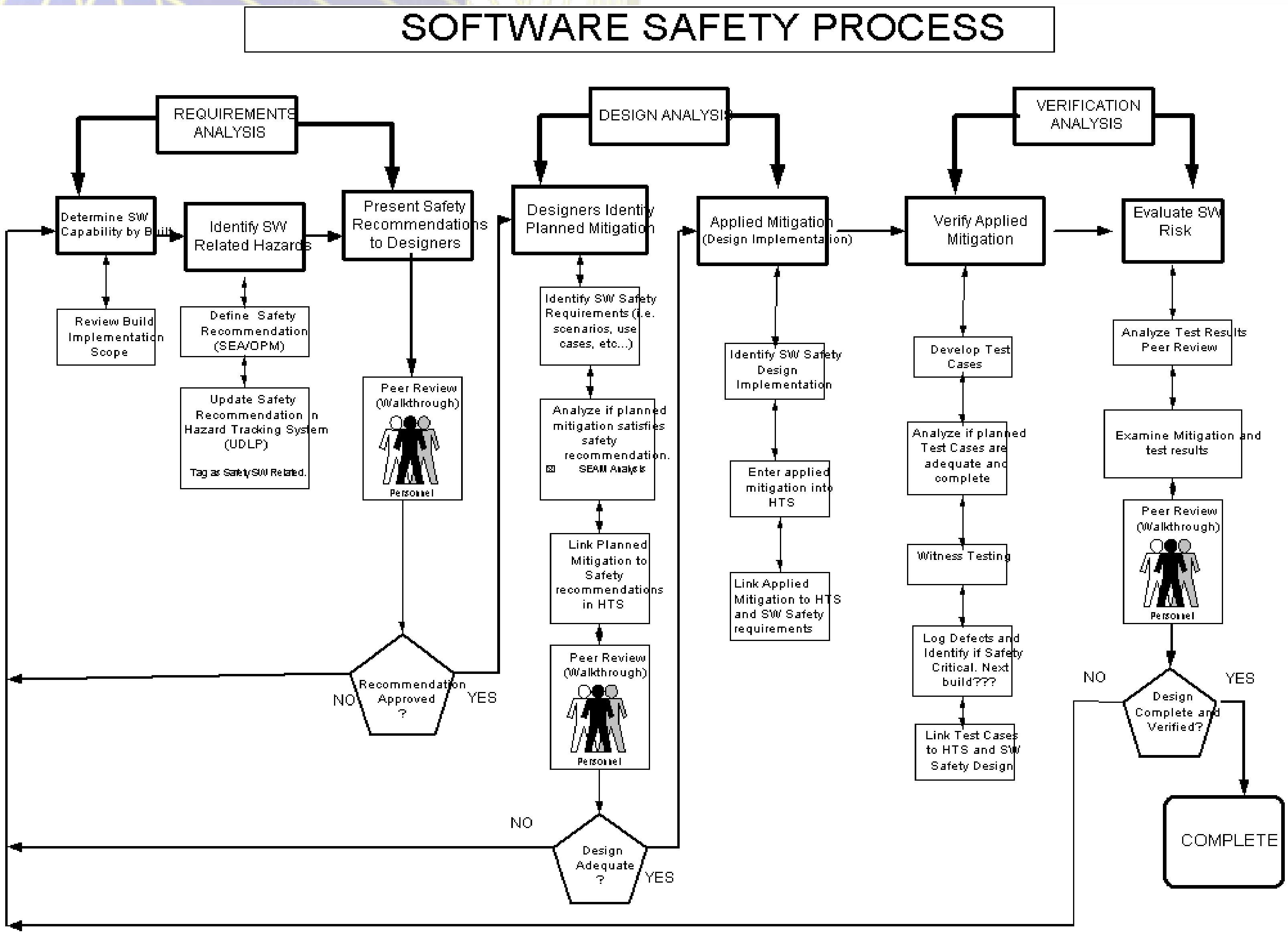
	EM 1	EM 2	EM 3	EM 4	EM 5	EM 6	EM 7	EM 8	EM 9	EM 10	EM 11
Organizational Difficulty											
Absolute importance	45	45	27	27	27	93	131	97	45	10	93
Relative Importance	7%	7%	4%	4%	4%	15%	20%	15%	7%	2%	15%

ENGINEERING RATING		EM 1	EM 2	EM 3	EM 4	EM 5	EM 6	EM 7	EM 8	EM 9	EM 10	EM 11	Total
Raw Score	Concept A	3	3	3	3	3	3	3	3	3	3	3	
	Concept B	4	3	2	4	3	5	3	2	1	3	3	
	Concept C	4	3	3	4	5	4	1	2	4	3	2	
	Concept D	3	3	3	3	3	3	3	3	3	3	3	
	Concept E	2	5	3	4	5	5	5	4	3	3	4	
Weigthed Score	Concept A	135	135	81	81	81	279	393	291	135	30	279	1920
	Concept B	180	135	54	108	81	465	393	194	45	30	279	1964
	Concept C	180	135	81	108	135	372	131	194	180	30	186	1732
	Concept D	135	135	81	81	81	279	393	291	135	30	279	1920
	Concept E	90	225	81	108	135	465	655	388	135	30	372	2684

RISK	EM 1	EM 2	EM 3	EM 4	EM 5	EM 6	EM 7	EM 8	EM 9	EM 10	EM 11
Technical											
Schedule											
Cost											

Also helps to Build Consensus and Understanding of complex relationships as well as importance.

Requirements are Discovered Thru The SW Safety Process



Eliciting Verification Methods

Similar to Requirements. Stakeholders are different. Methods are typically thru Analysis, Test, Inspection, Measurement.

- ❑ Use Interview
- ❑ Use Questionnaires
- ❑ Include Stakeholders Early and Often.
- ❑ Have Stakeholders Peer Review Requirements
- ❑ Use a JCCB

File Edit Insert Records Window Help

graph: Interface Definition

TRL: TRL5 TRL6 TRL7

IPT Name: Ammo Handling

Module Name AHR

ion: 3.1.2.0-1

uirements: The Ammo Handling Subsystem will interface with the Turret Structure, Gun Assembly, Fire Control, Ammo Suite and Secondary Armament.

ATD/Objective Force:

This enables and disables the required field warning:

Switch to View Mode

RL 5 Verification Method: ~~Please Select a Method~~

Analysis
Inspection
Measurement
Test
N/A
~~Please Select a Method~~

Responsibility: (e.g.: IPT Name, Subcontractor, System Integrartor)

Critical Test: ~~Please Select a Test~~

Location of Verif: (e.g.: Picatinny, Contractor Facility, Proving Ground)

Verification Procedure: Briefly ... d at this TRL level to validate or confirm the requirement.
If the requirement will not be v...

Data Collected:

Clear

Reset

L 6 Verification Method: ~~Please Select a Method~~

Responsibility: (e.g.: IPT Name, Subcontractor, System Integrartor)

Critical Test: ~~Please Select a Test~~

Location of Verif: (e.g.: Picatinny, Contractor Facility, Proving Ground)

Verification Procedure: Briefly describe the procedure you recommend at this TRL level to validate or confirm the requirement.
If the requirement will not be verified at this time please indicate so:

Data Collected:

Clear

Reset

RL 7 Verification Method: ~~Please Select a Method~~

|< <-- --> >| Record of Exit

Requirements Capture and Management

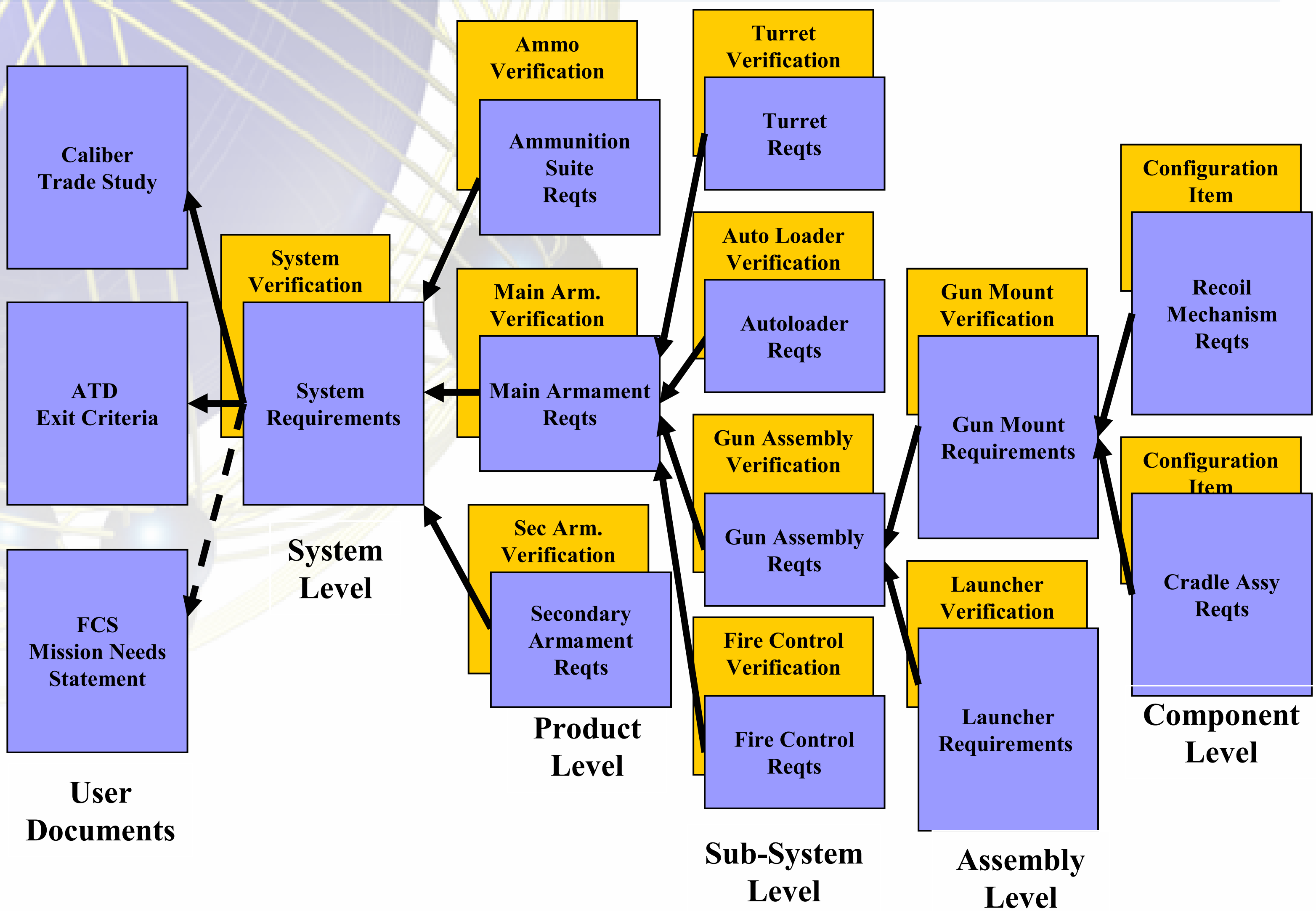
How and where do you store the requirements?

Word Documents are standard. Tools are useful and can Help. But try to get everyone to use them consistently!!!!!

- Access
- Excel
- DOORS
- RTM
- Requisite Pro
- RM Calibre
- etc….

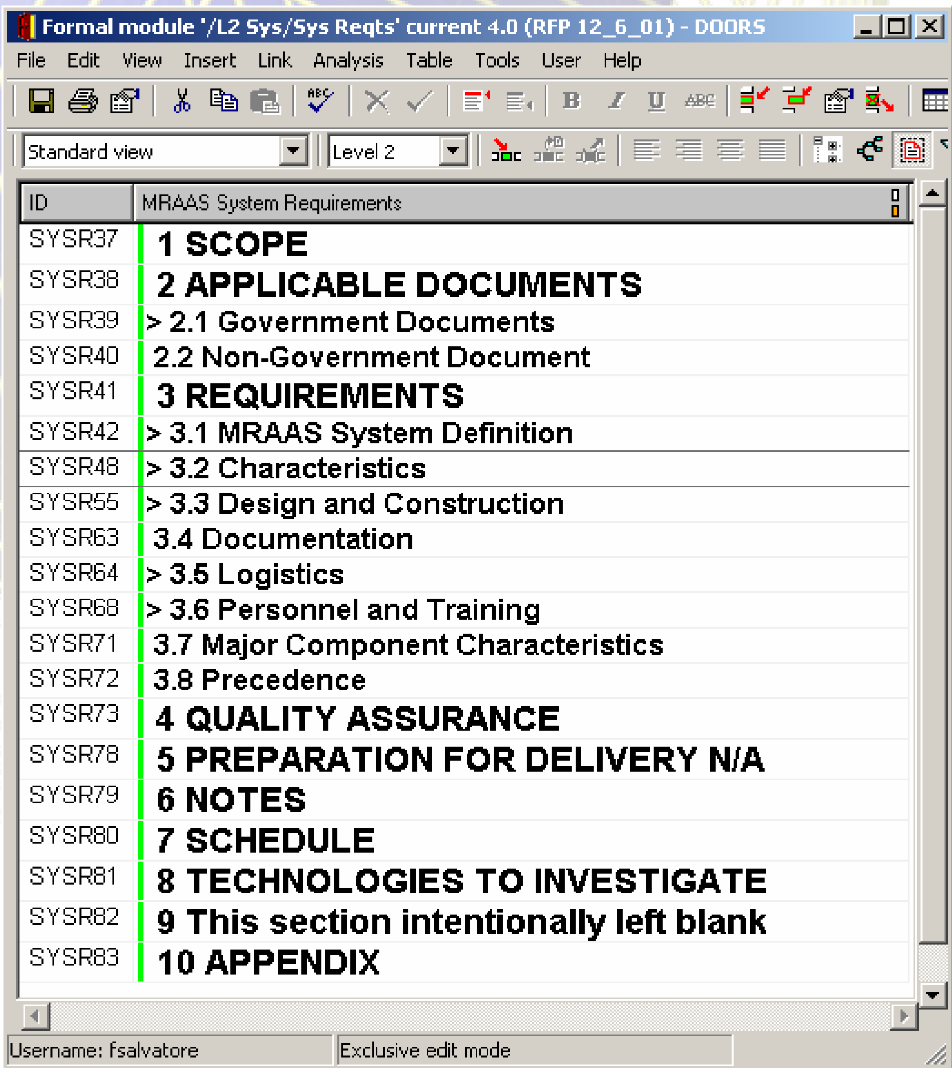
Use Document Templates Based On Standards. Also IM is Important for Efficiency.

Requirements Management Specification Hierarchy



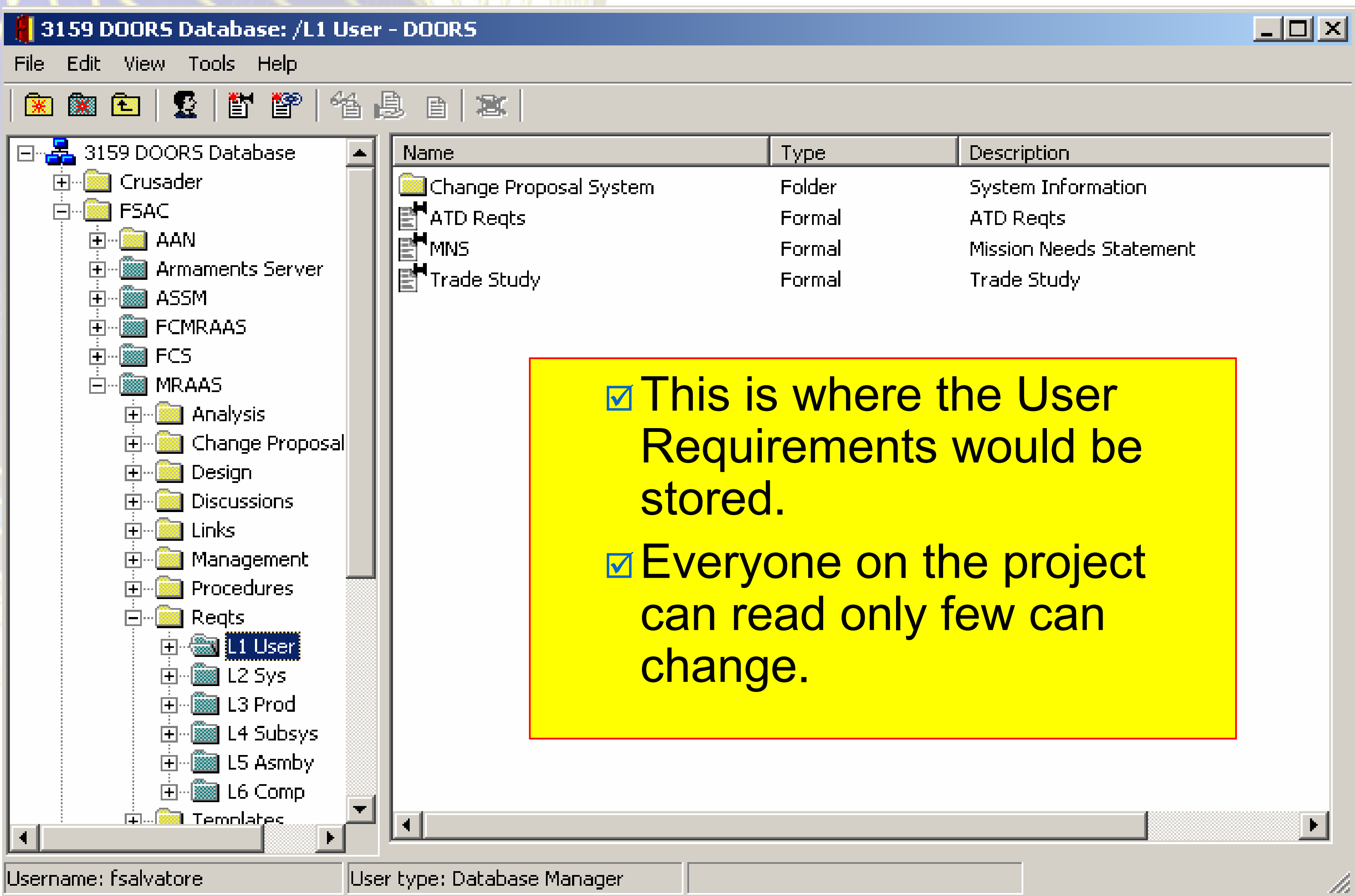
Follows IEEE Commercial Standards

Document Outline is Standard Throughout Project.



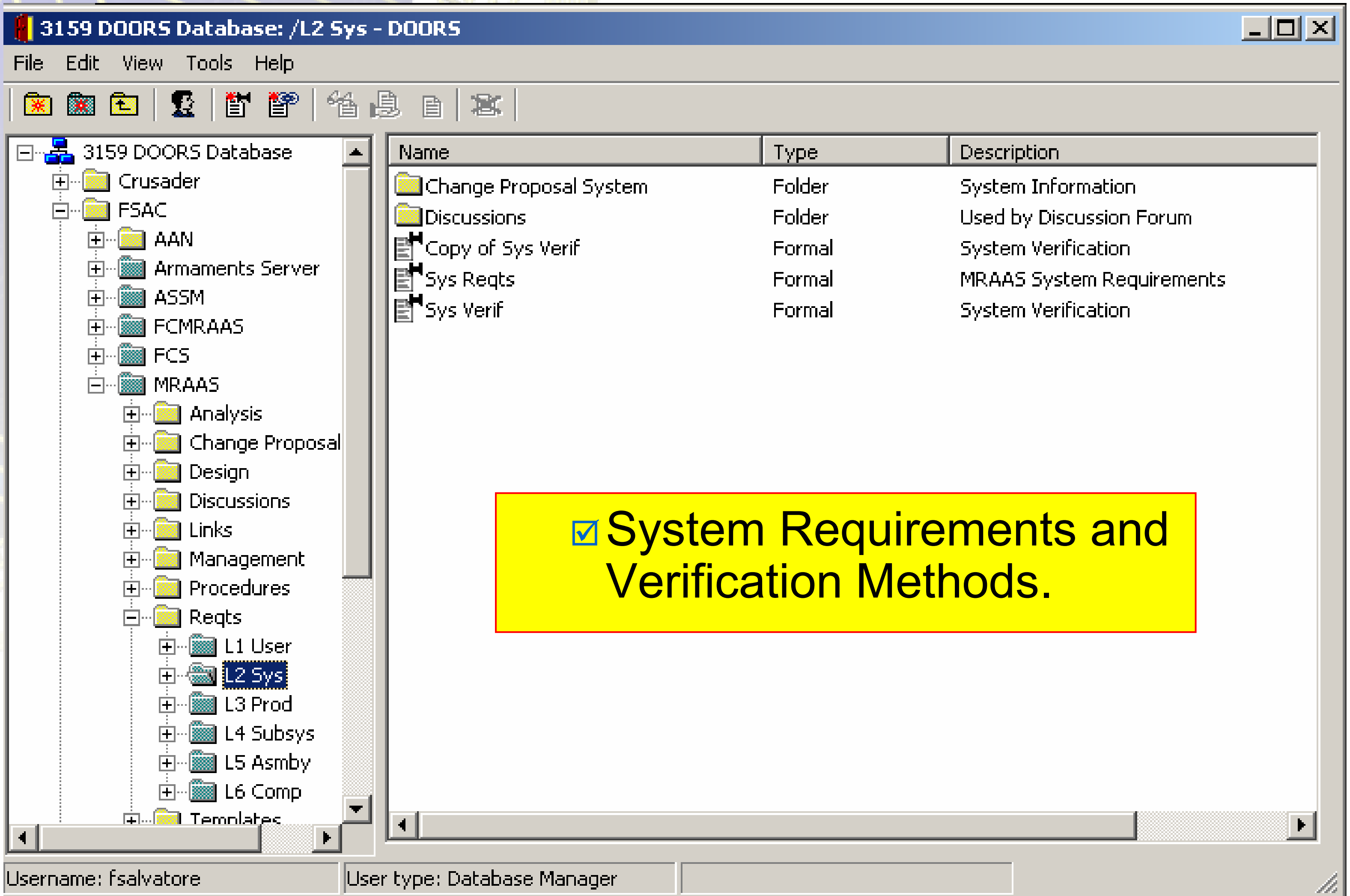
- ☑ Using Mil-STD-490 standard template
- ☑ Standardized Documentation format makes it easier to find what you are looking for

Level 1 User Requirements



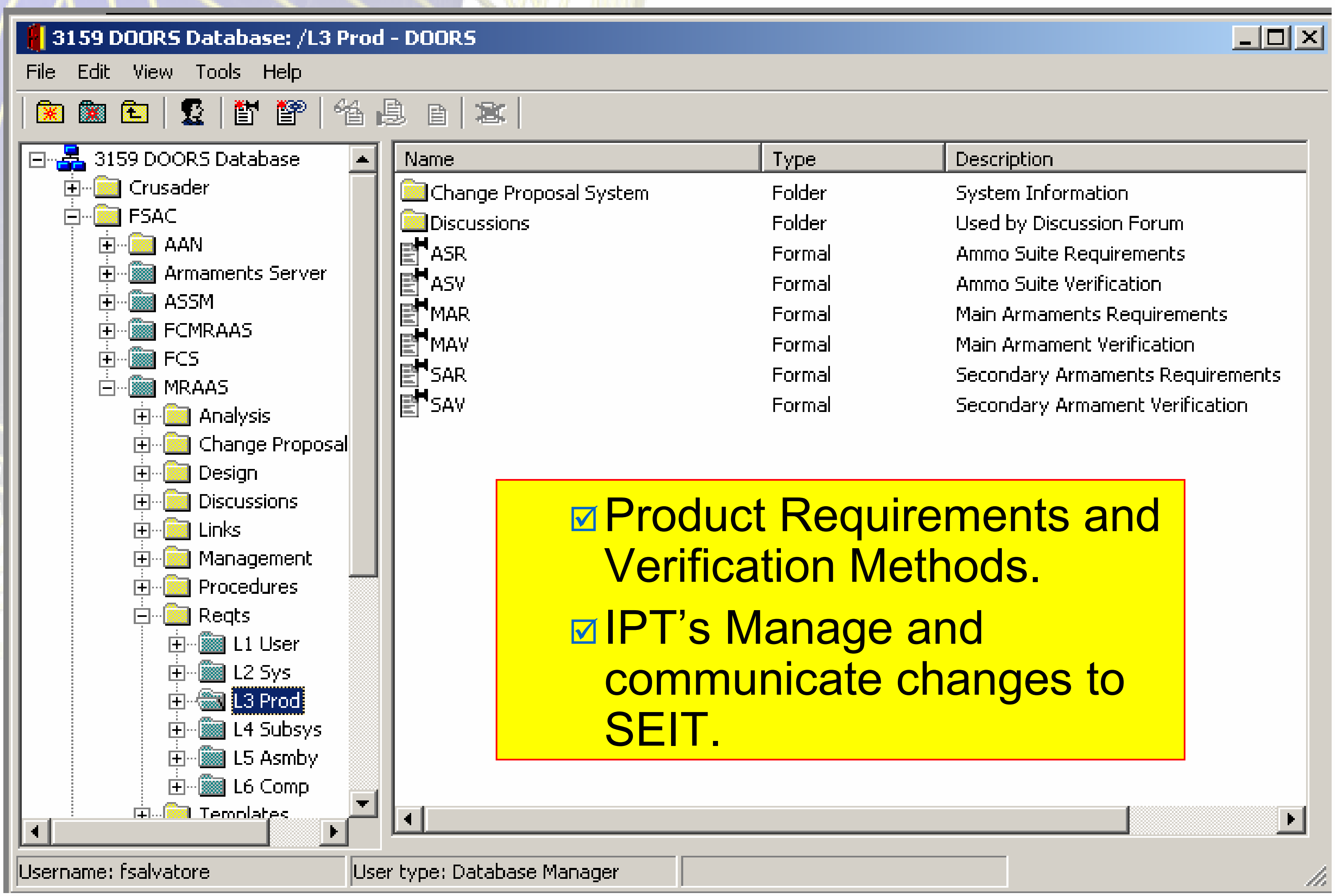
- ☑ This is where the User Requirements would be stored.
- ☑ Everyone on the project can read only few can change.

Level 2 System Requirements



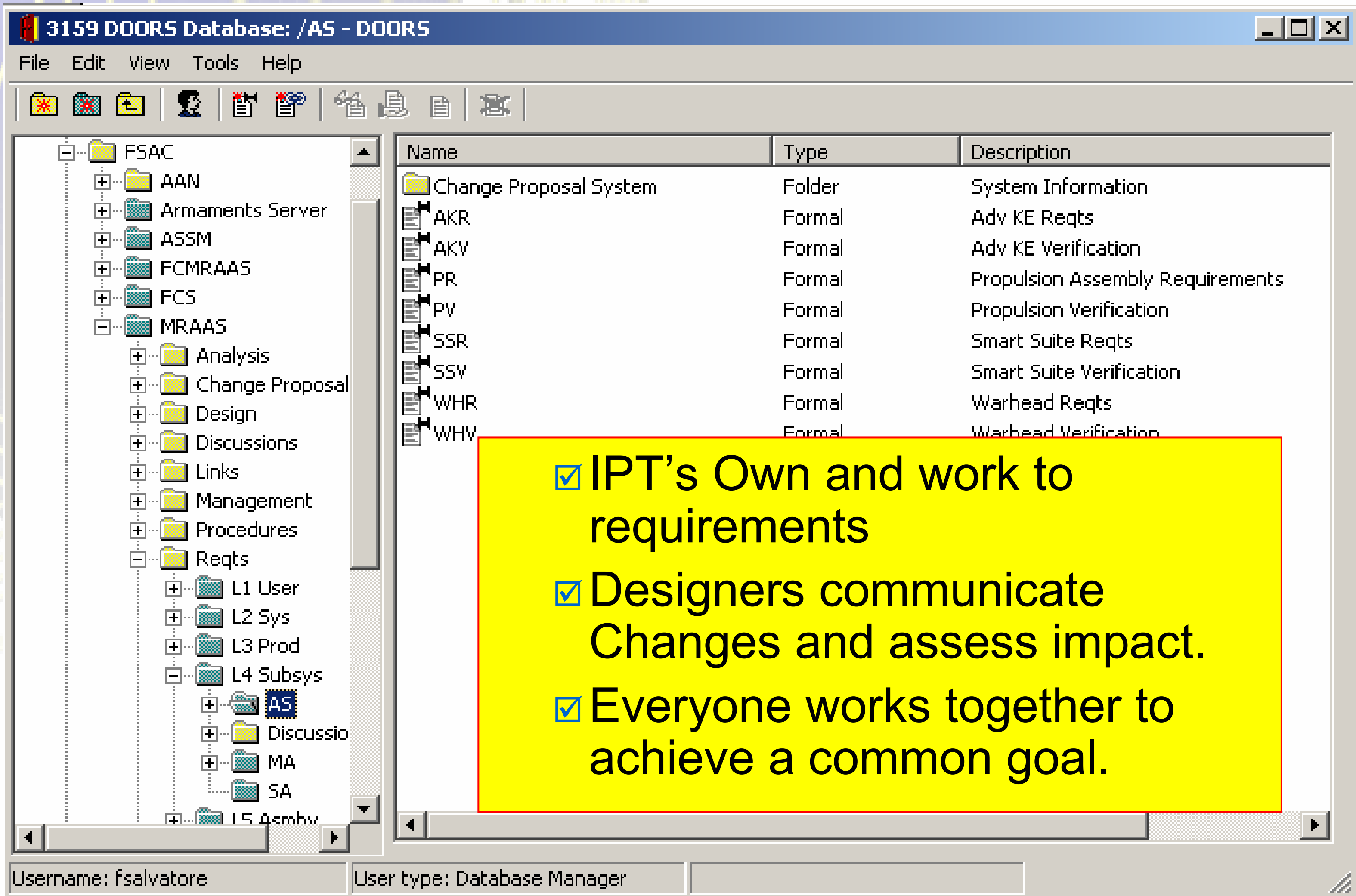
☑ System Requirements and Verification Methods.

Level 3 Product Requirements



- ☑ Product Requirements and Verification Methods.
- ☑ IPT's Manage and communicate changes to SEIT.

Level 4-6 Subassembly to Component Requirements



- ☑ IPT's Own and work to requirements
- ☑ Designers communicate Changes and assess impact.
- ☑ Everyone works together to achieve a common goal.

Requirements Traceability

How do you understand how the requirements are being satisfied, are complete, are accurate, etc…….

- ❑ **Trace Matrices are Typical and require constant care and feeding to maintain.**
- ❑ **Use a tool to manage your requirements and capture traceability so you can search and query when doing impact analysis.**
  - ✓ **More accurate**
  - ✓ **More efficient**
  - ✓ **More complete**

No tool will automatically generate but they will preserve it once you do it the first time.

If a requirement isn't traceable to anything it doesn't belong!!!

This is Important when performing Impact Analysis, doing FCA and PCA, etc….

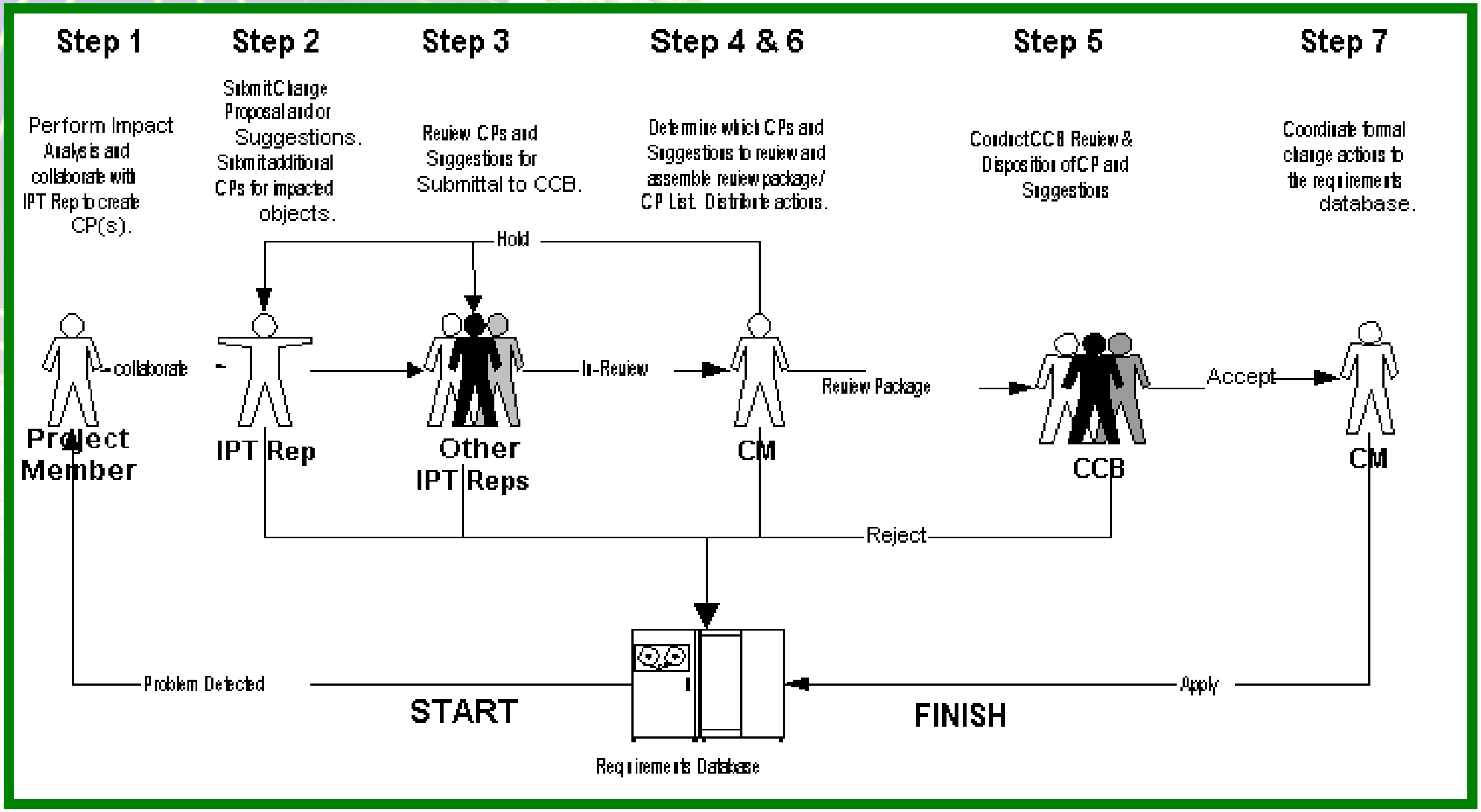
Requirements Change Control

If a Requirement is changed, how do we determine effects on other Requirements, Verifications or Schedule Events?

- ❑ **Use Inter-IPT Coordination**
- ❑ **Use Impact Analysis & Visualization Tools**
- ❑ **Use Formal Change Control Procedures**
- ❑ **Attributes**

With a tool you have better and more efficient ways of controlling the requirements.

Follow a Change Proposal Process



Starting the Change Process

IPT Member brings an issue to attention of IPT Lead

IPT Lead makes an initial determination:

- PURSUE – Proposed change has merit and is worth further investigation
- DISCARD – Proposed change does not have merit or is not worth further investigation at this time

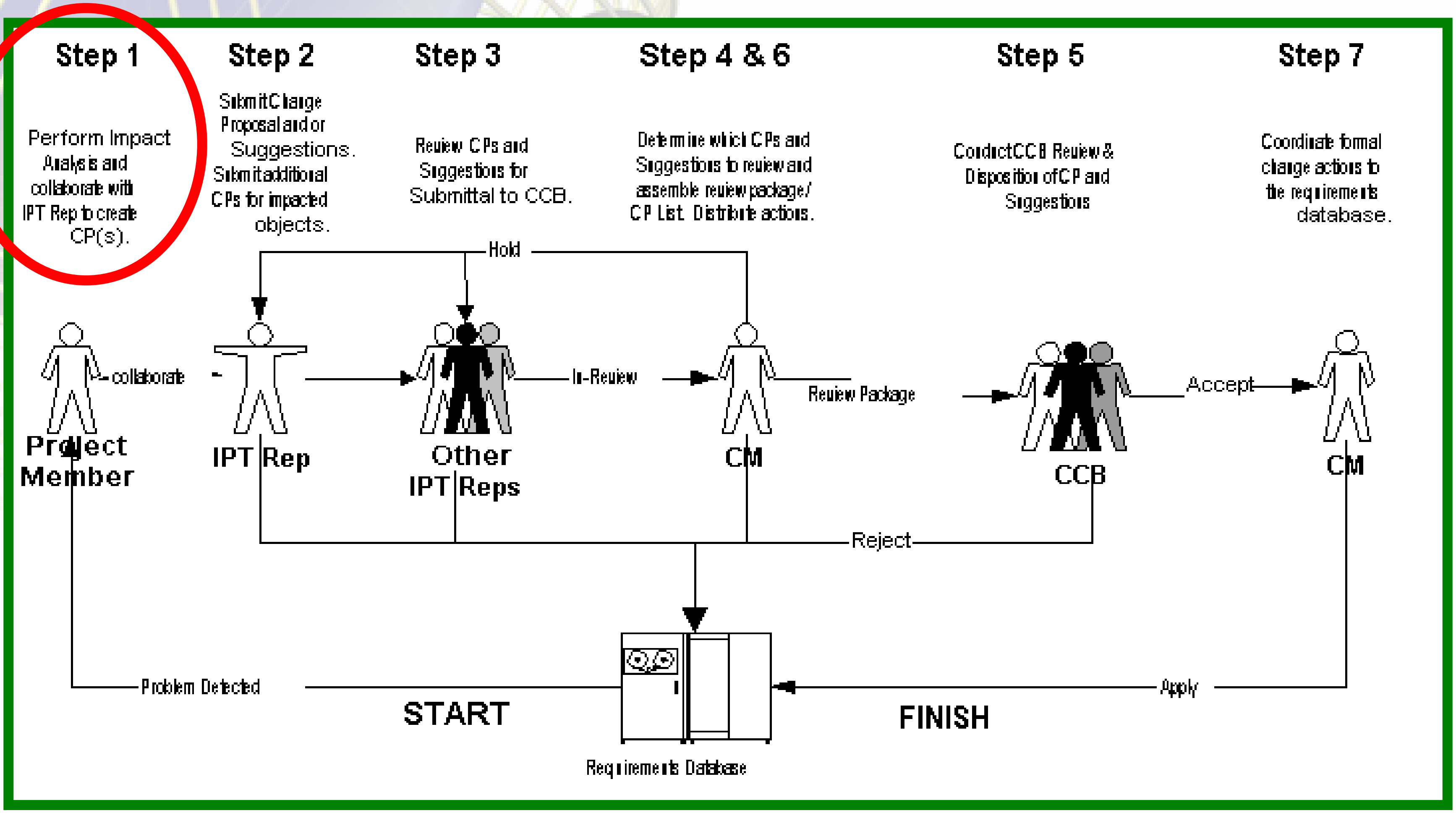
If you choose to PURSUE the potential change:

1. Coordinate with other IPT's to discuss
2. Initiate working group(s) as needed

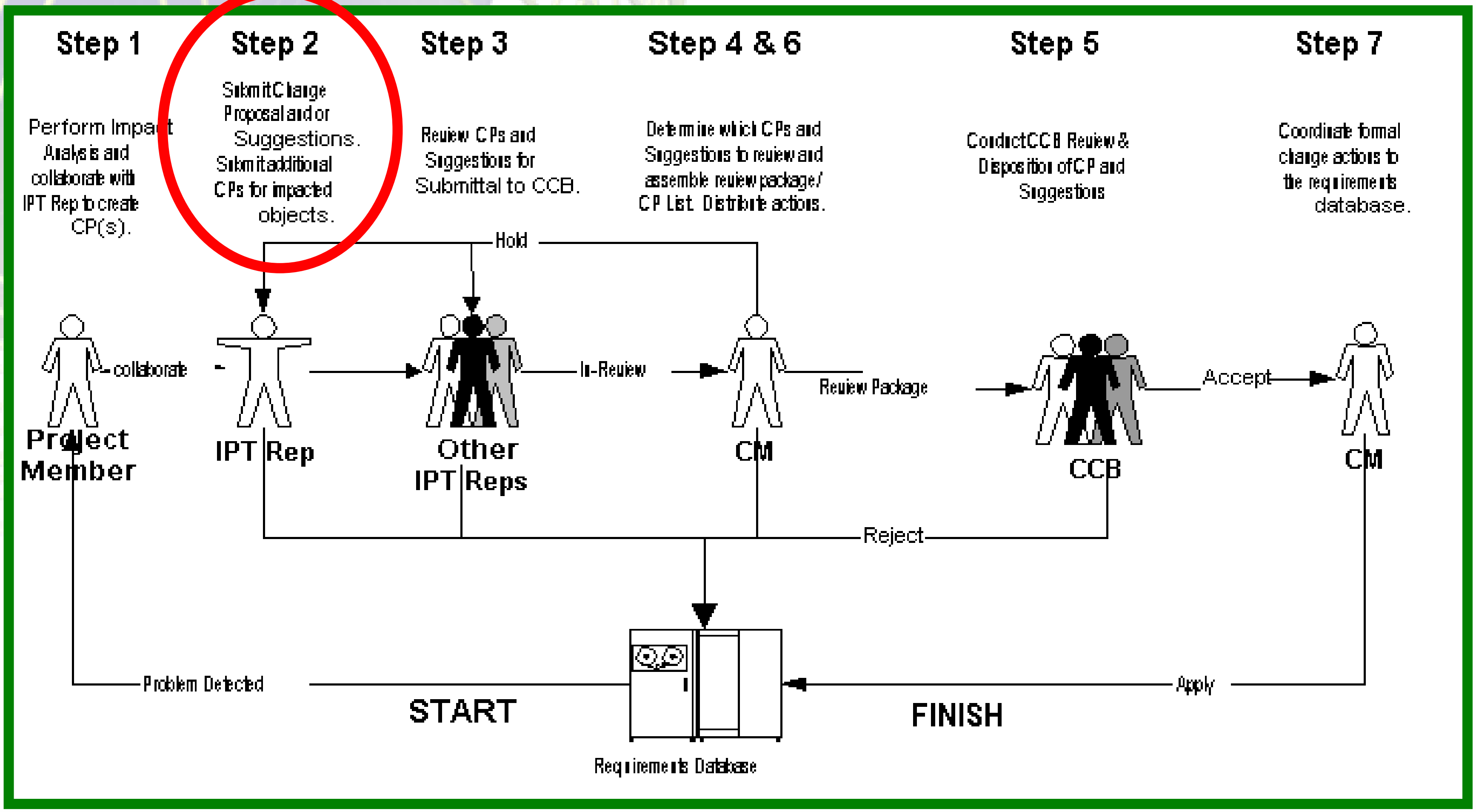
COMMUNICATE !!!

Starting the Change Process

Still think a change is needed? Perform an "Impact Analysis"

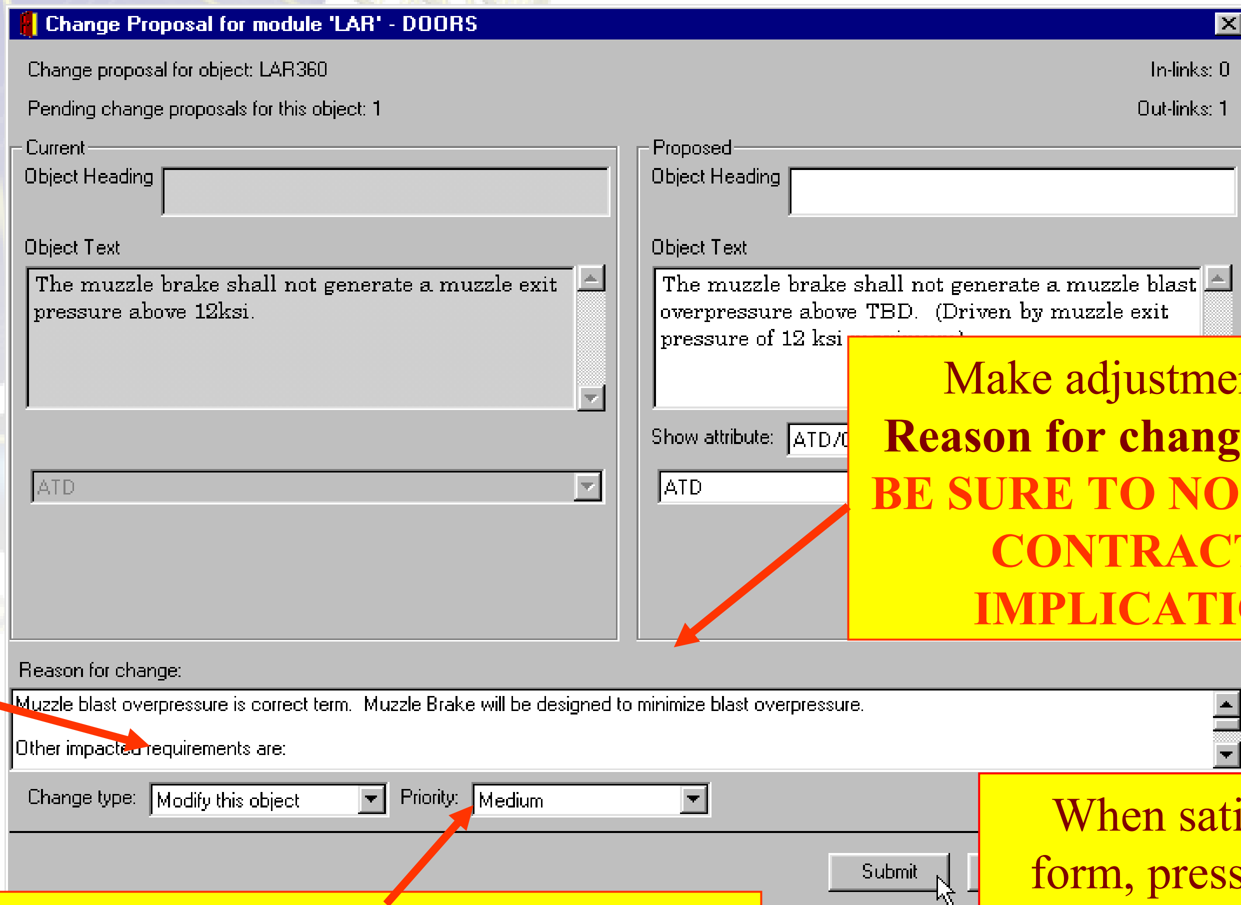


Impact Analysis Complete… Submit a Change Proposal



Submit Change Proposal

Fill out appropriate fields in the 'Proposed' half of the Change proposal Form. Remember to address any affected attributes.



Make adjustments to the **Reason for change** as needed. **BE SURE TO NOTATE ANY CONTRACTUAL IMPLICATIONS!!!**

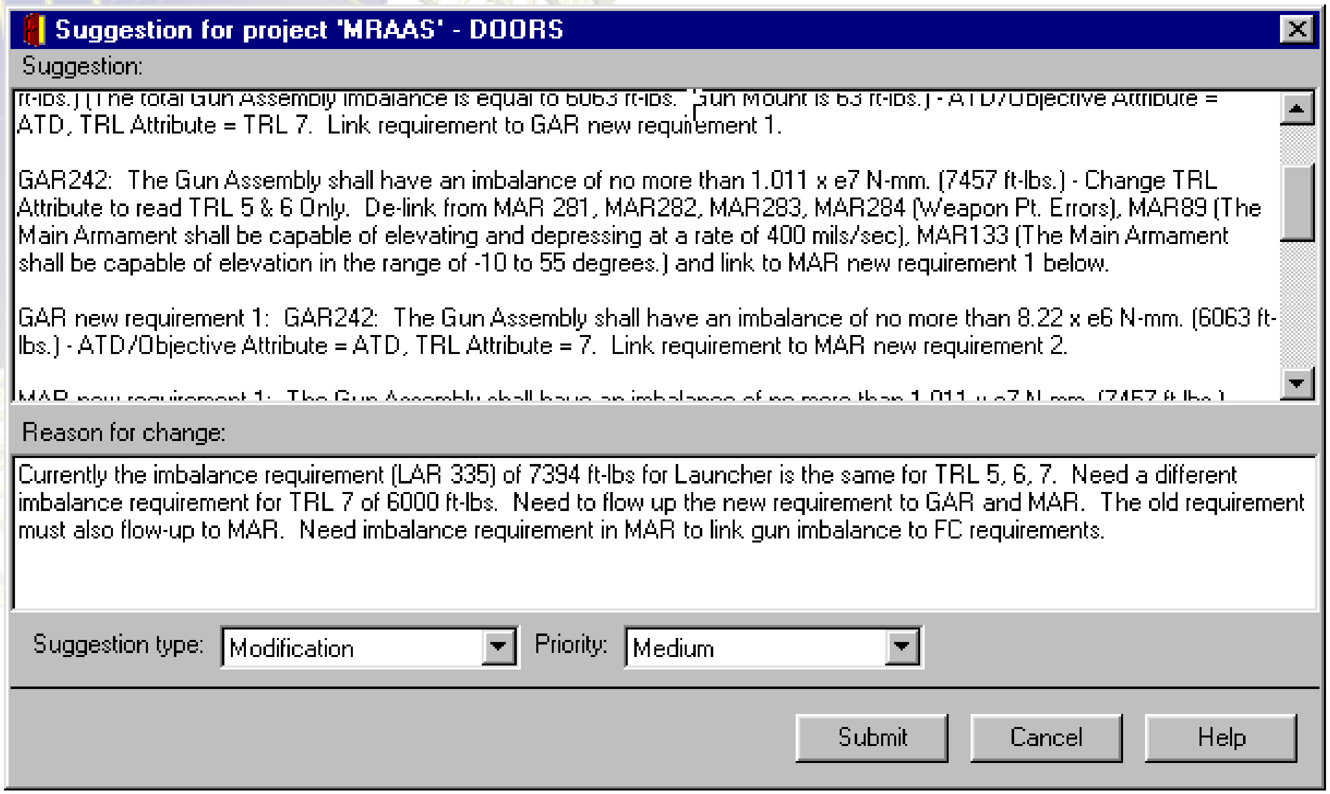
Select Change Type

Select Very High, High, Medium or Low (refer to CPP Document for details)

When satisfied with form, press **Submit** to create the new Change proposal

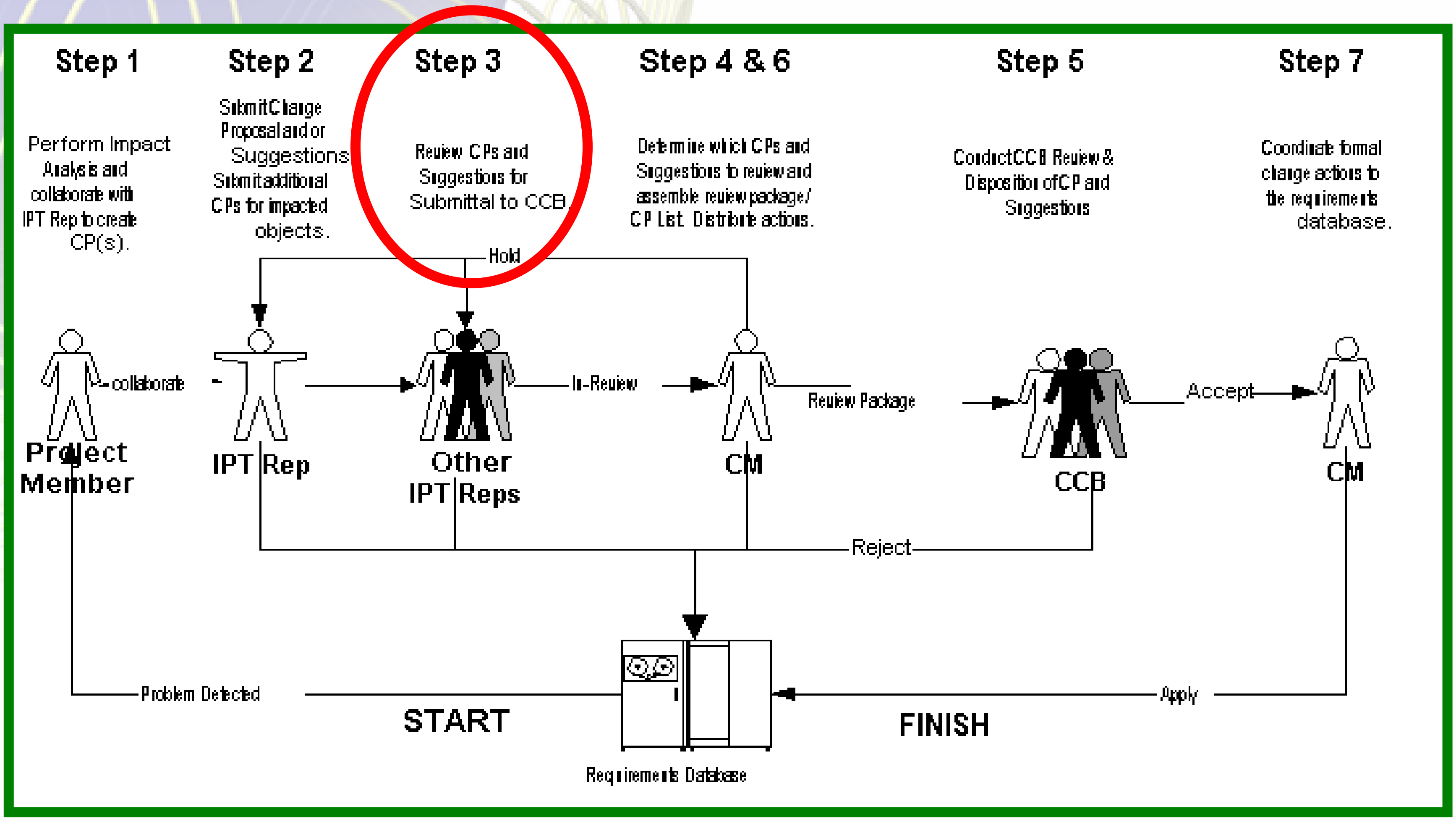
Submit Change Suggestion

When 5 or more actions need to occur (I.e., Change proposals) in order to fully satisfy a Change Proposal, a Change Suggestion should be created instead of a change proposal.

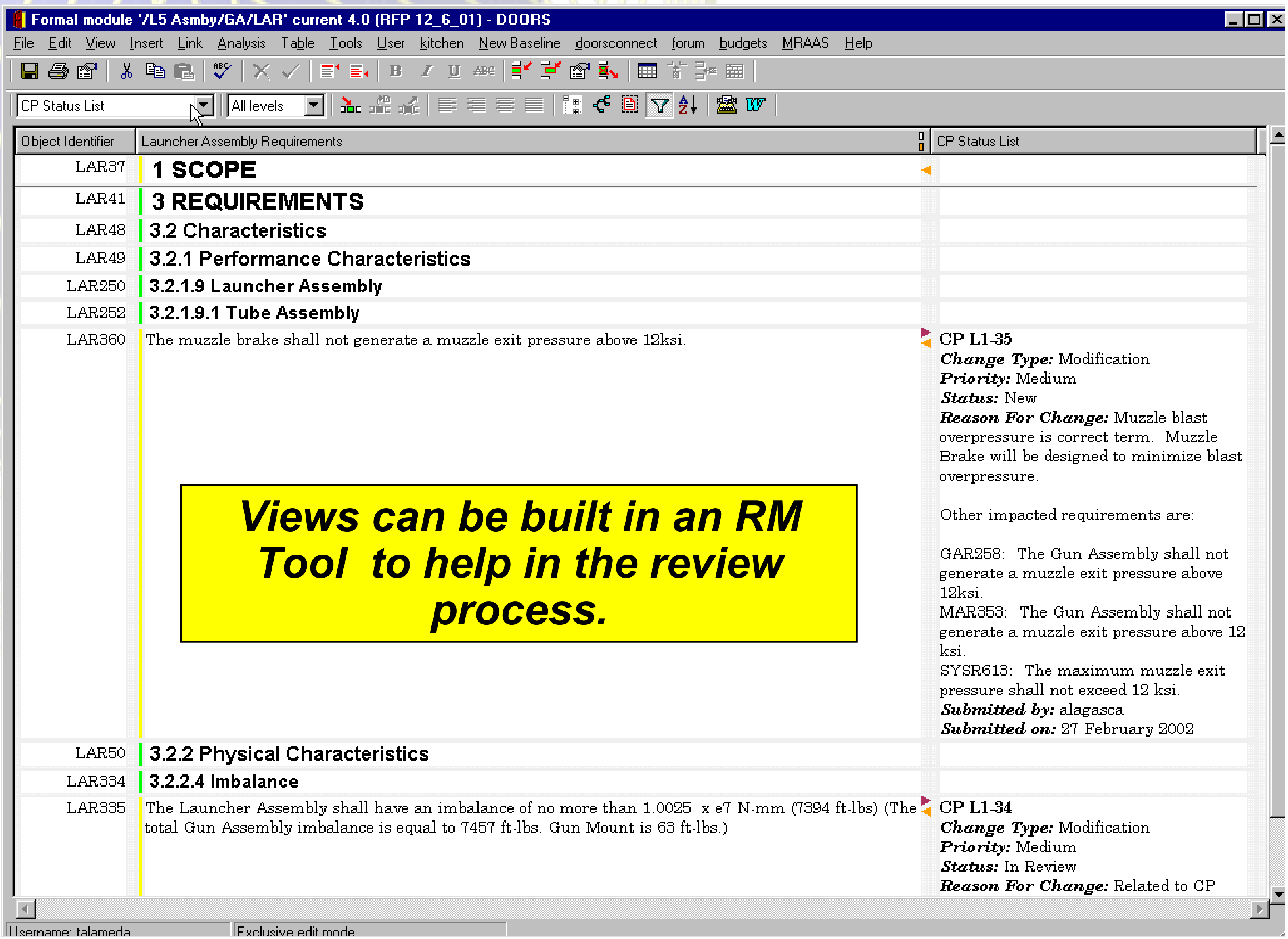


Fill out fields as needed and press **Submit** to create a new suggestion. The JCCB will approve and apply suggestions via the Change Proposal System.

Review CP's and Suggestion

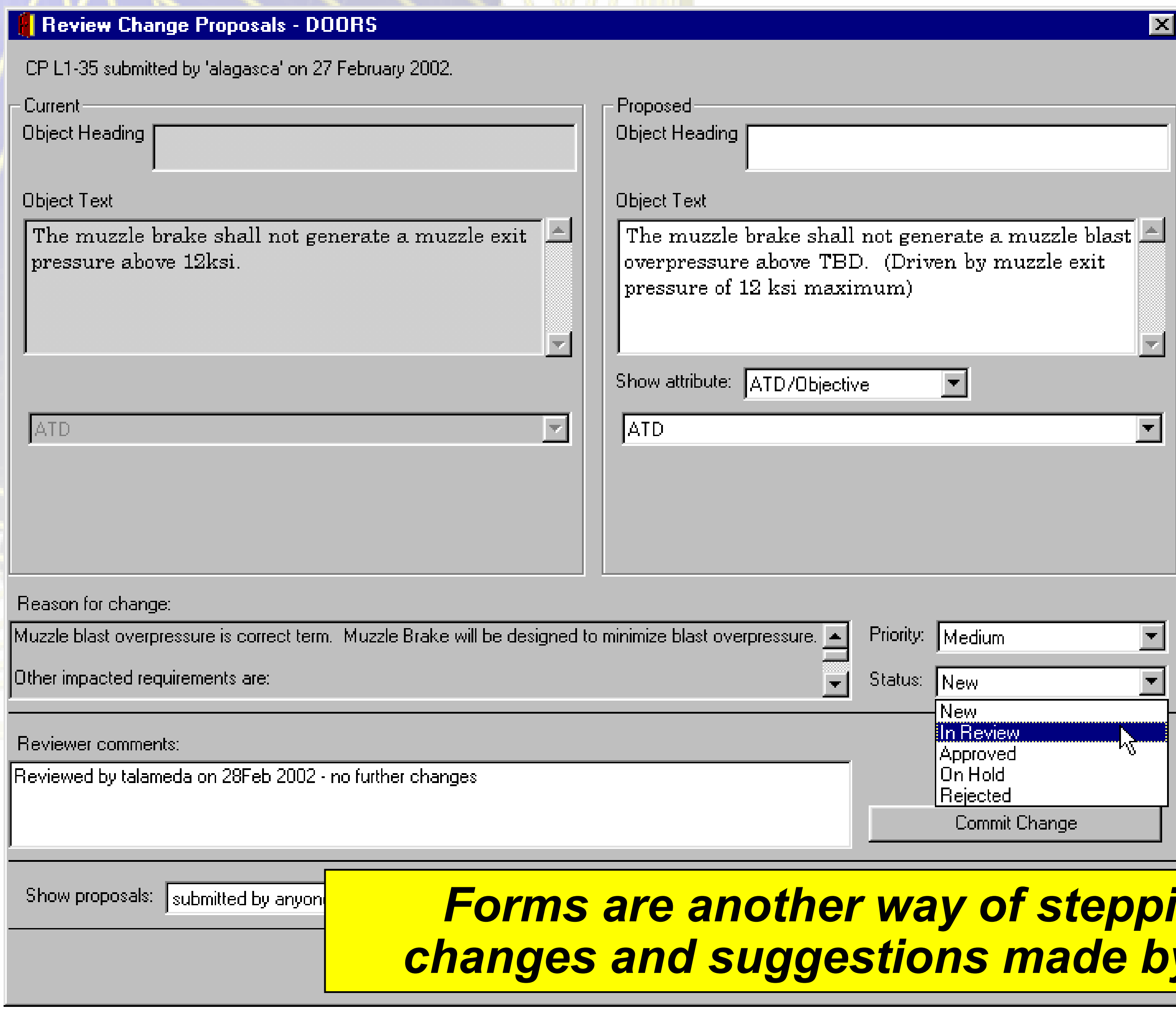


Predefined Views Can Help



Views can be built in an RM Tool to help in the review process.

Forms Can Also Help


Review Change Proposals - DOORS

CP L1-35 submitted by 'alagasca' on 27 February 2002.

Current

Object Heading

Object Text

The muzzle brake shall not generate a muzzle exit pressure above 12ksi.

ATD

Proposed

Object Heading

Object Text

The muzzle brake shall not generate a muzzle blast overpressure above TBD. (Driven by muzzle exit pressure of 12 ksi maximum)

Show attribute: ATD/Objective

ATD

Reason for change:

Muzzle blast overpressure is correct term. Muzzle Brake will be designed to minimize blast overpressure.

Other impacted requirements are:

Priority: Medium

Status: New

New
In Review
Approved
On Hold
Rejected

Reviewer comments:

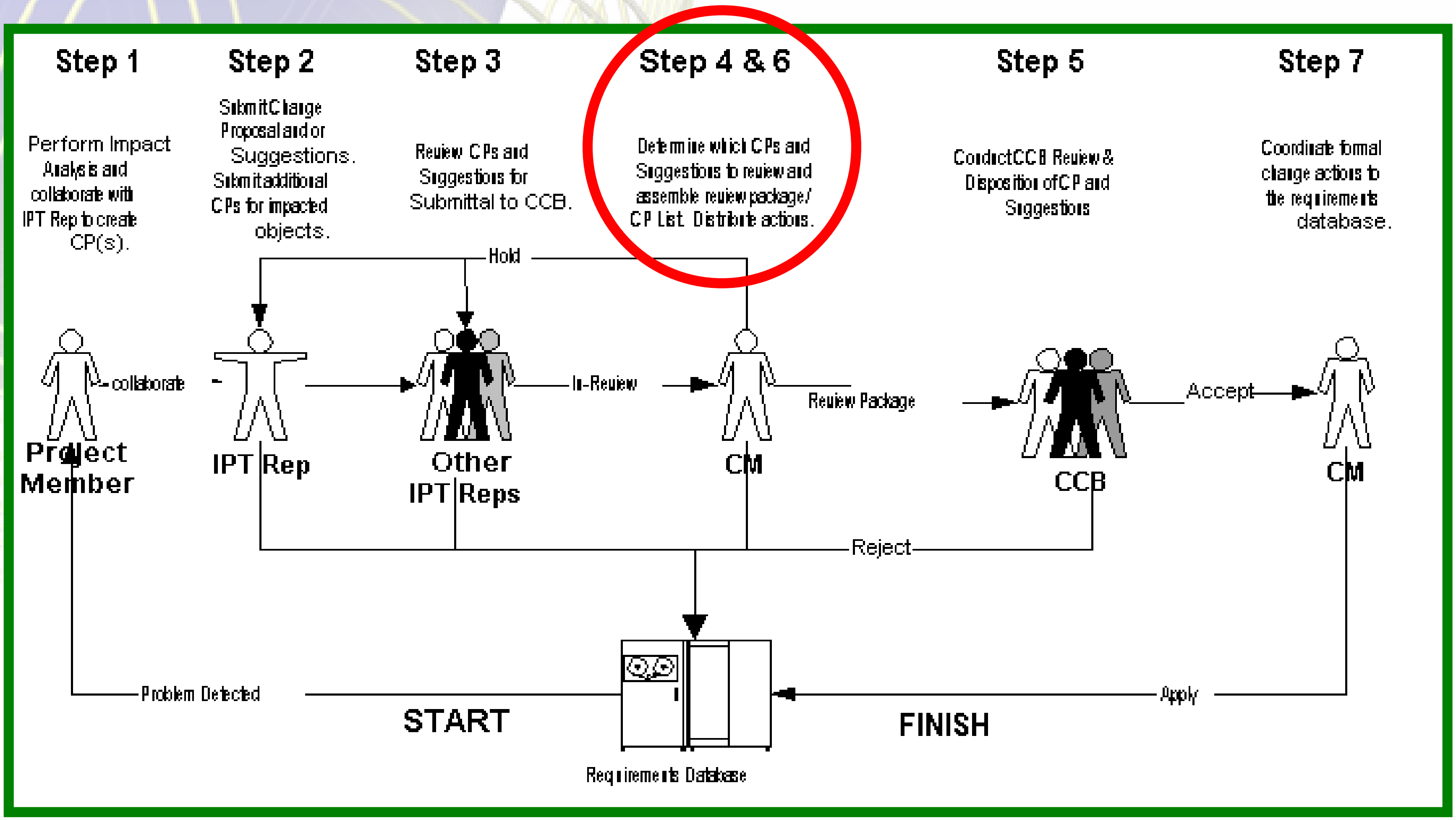
Reviewed by talameda on 28Feb 2002 - no further changes

Commit Change

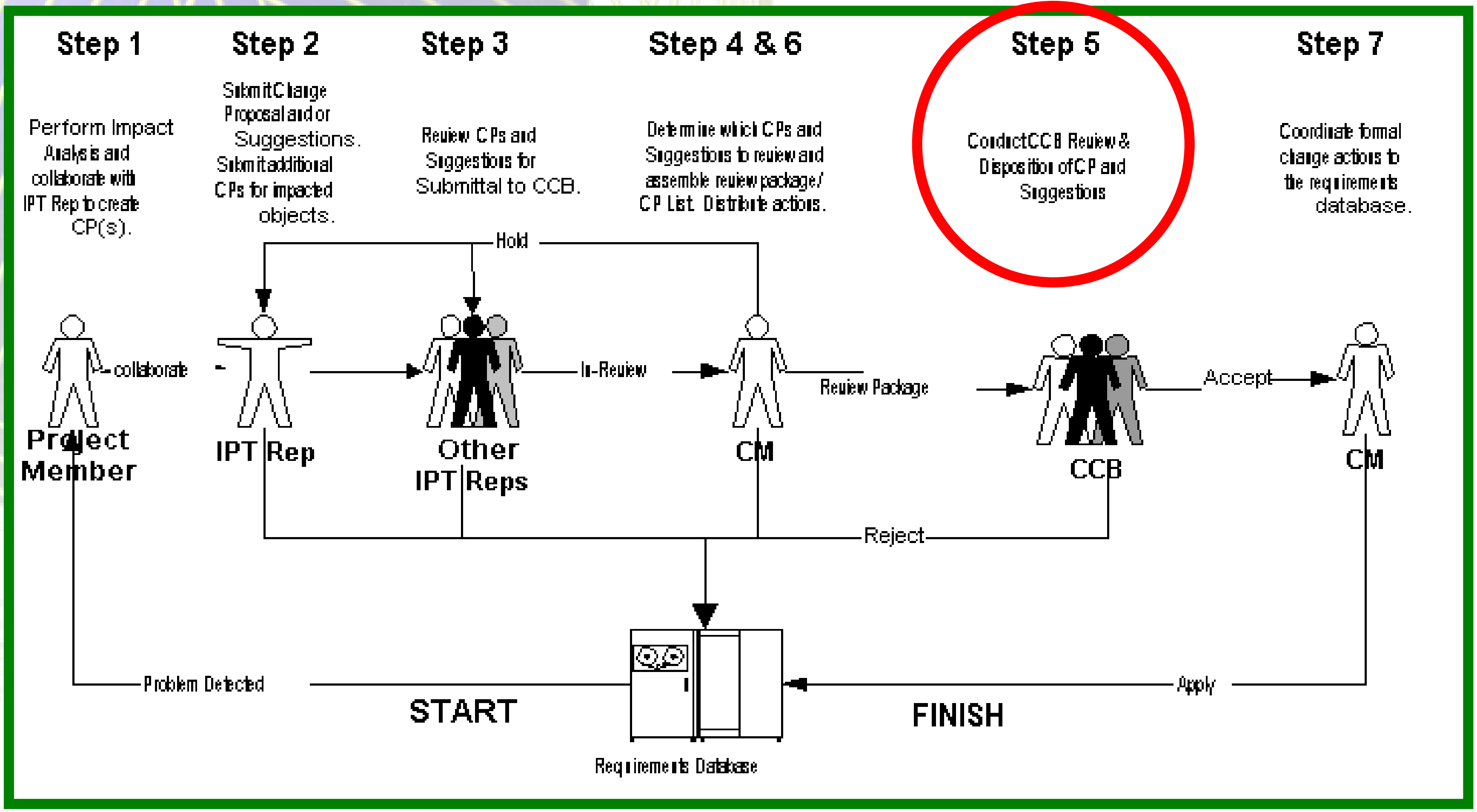
Show proposals: submitted by anyon

Forms are another way of stepping thru changes and suggestions made by the IPT.

ID CP's and Suggestions and Schedule JCCB



Perform JCCB and Update dB with Results.



Approved (ready for implementation)

On-Hold (further investigation needed)

Rejected (requested change discarded)

Reaching Consensus

Use IPT forum to Elicit Requirements.

- ❑ Include Stakeholders Early and Often.
- ❑ Have Stakeholders Peer Review Requirements
- ❑ Document Rational. It will save you time latter when you will need to defend the requirements.
- ❑ Use a JCCB
- ❑ Try using QFD Method to Build Consensus

Communicating Requirements

Use of DOORS has helped BUT!!

- Culture shock is hard to overcome.
- Revert back to WORD and EXCEL documents.
  - Not so efficient and may introduce errors.
- May need to hold hands
- Provide Training and Tailor it to the project.
- Need to pay close attention to Permission and database administration details.
- JCCB has forced communication to happen and has made it mandatory.
- Will need good IT support to reach remote locations when using a tool.

Requirements Metrics

Select metrics you will use.

Don’t try to many or they won’t be managed.

You can build them into an RM tool.

Some Examples Include:

- **Volatility**
- **# Requirements**
- **# TBD**
- **# Verified**

Using a tool will produce metrics naturally.

Requirements Attributes

Attributes are <u>additional defined characteristics</u> of a requirement and they provide <u>essential information</u> in addition to requirement text

Source	Who specified this requirement?
Priority	What is the priority of this requirement?
Verifiability	Is the requirement verifiable?
Accepted	Has this requirement been accepted by the developers?
Review	Review status of this requirement
Safety	Is this a safety-critical requirement?
Comments	Any comments on the requirement to clarify its meaning
Questions	Any questions that must be clarified with the source

You can define attributes that will support your process and make your database more productive for you

Summary

The use of an RM tool is an enabling technology to achieve greater accuracy and efficiency when engineering requirements.

There are definite skills and disciplines required to do requirements engineering

Not only will One need to understand how to:

- Elicit Requirements
- Capture and Control Them
- Establish and maintain Traceability
- Reach Consensus
- Elicit Verification Methods
- Communicate Requirements
- Defined some Metrics and Attributes

They will also need to be proficient in using and tailoring an RM Tool

Questions?


OUT OF CHAOS COMES:
CONVERGENCE!

Defense Logistics as a Chaos Theory…

- Chaos Theory is the name science has come up with to describe the very complex way the world works.
  - Much of mathematics is "linear", or related to a line, making equations and figuring out the answer fairly straight forward.
- But there are some things that just can't be explained so easily, like weather patterns, ocean currents, and defense logistics. There are too many things going on to keep track of: It almost seems as if they are random, or "chaotic".
  - Chaos theory is a way describe and predict these types of events.
- As a Chaos Theory, defense logistics process streamlining is next to impossible without reference modeling, as End-to-End Logistics spans the Galaxy!
  - Reference models visualize the "Best of Breed" across the National Technology Industrial Base
    - Reference Models feed off of logistics data: better data, better results
- As a Chaos Theory, defense logistics data analysis requires a common logistics data schema, as data files are so huge and tedious.
  - A common data schema is tantamount to logistics data linkage

Topics of Discussion

- Operations Reference Models – what are they?
- A Perspective On Life Cycle Logistics
- What is Industry Using for operations modeling?
  - Supply Chain Operations Reference model
  - Design Chain Operations Reference model
- The Need for Information
  - Common Logistics Data Schema
- Bringing it All Together (a Notional Concept)
- A parting Shot

What is a Reference Model?

- Process reference models integrate the well-known concepts of business process reengineering, benchmarking, and process measurement into a cross-functional framework

Business Process Reengineering

Capture the "as-is" state of a process and derive the desired "to-be" future state

Benchmarking

Quantify the operational performance of similar companies and establish internal targets based on "best-in-class" results

Best Practices Analysis

Characterize the management practices and software solutions that result in "best-in-class" performance

Process Reference Model

Capture the "as-is" state of a process and derive the desired "to-be" future state

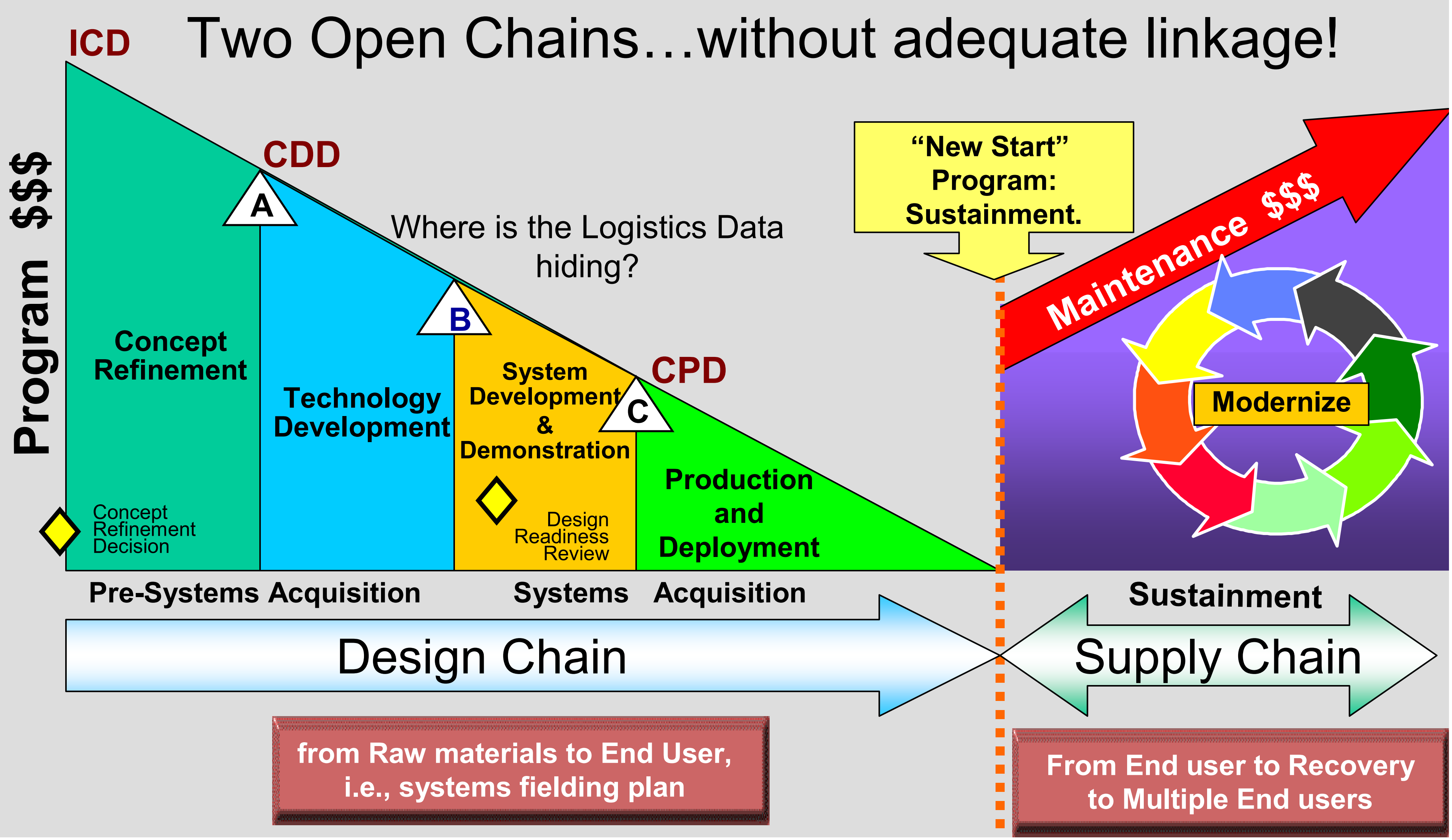
Quantify the operational performance of similar companies and establish internal targets based on "best-in-class" results

Characterize the management practices and software solutions that result in "best-in-class" performance

Data **is the fuel for reference models**

SCOR Supply-Chain Council

What does Life Cycle Logsitics Look Like Today?



Is There a Reference Model Available?

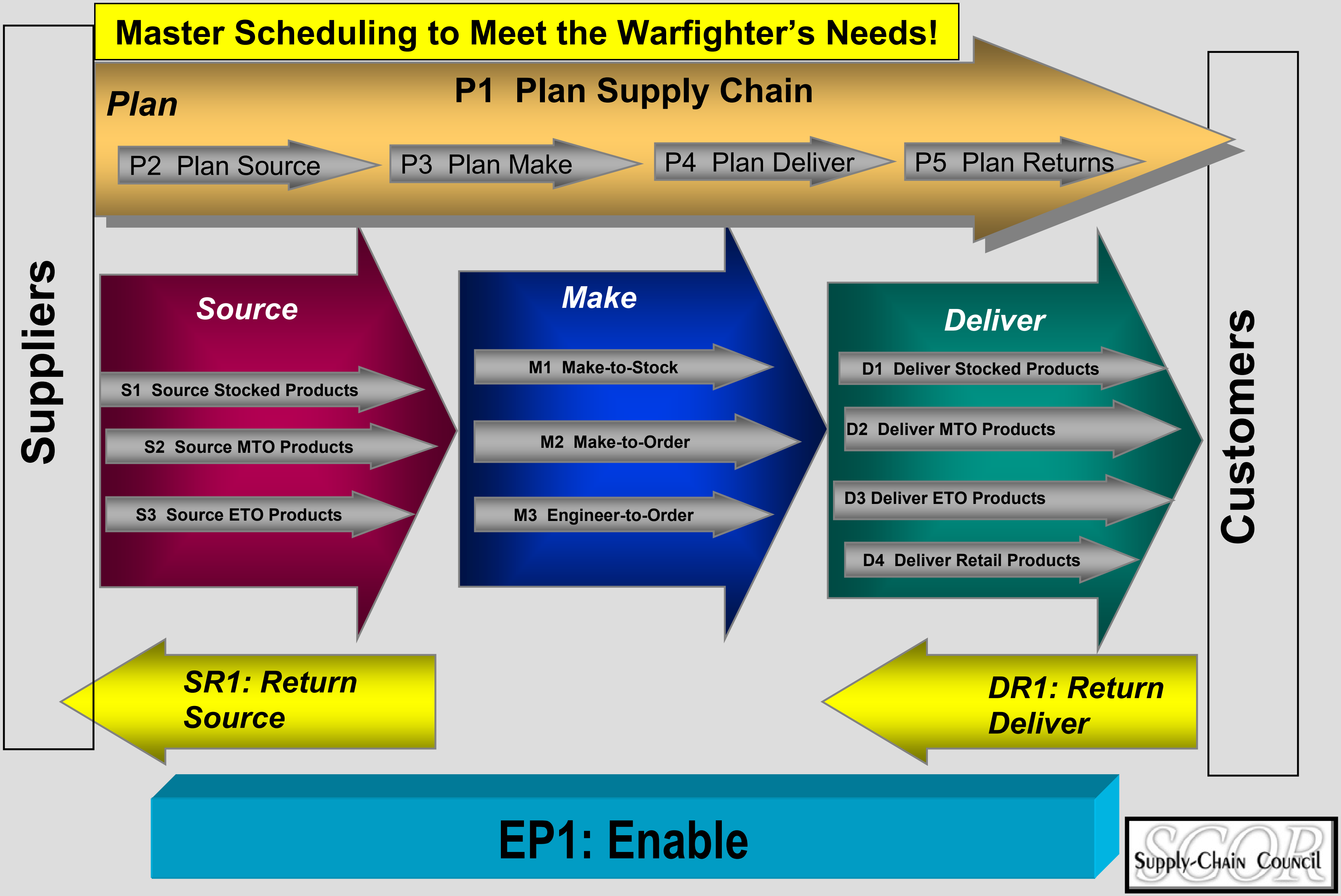
The Supply-Chain Operations Reference-model (SCOR)

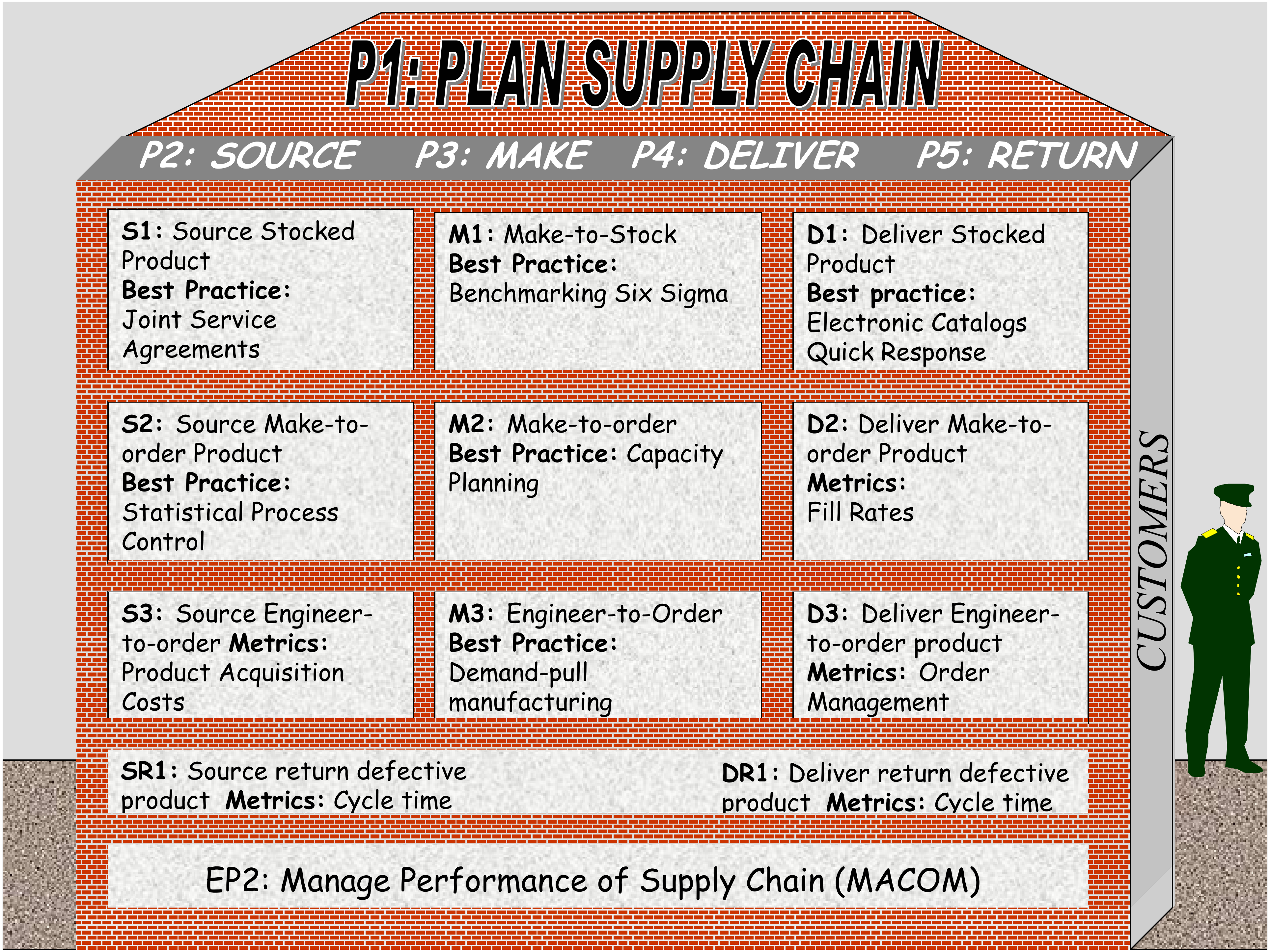
- SCOR is a management tool that has been developed by the Supply-Chain Council as the standard diagnostic tool for supply-chain management, enabling users to address, improve, and communicate supply-chain management practices.

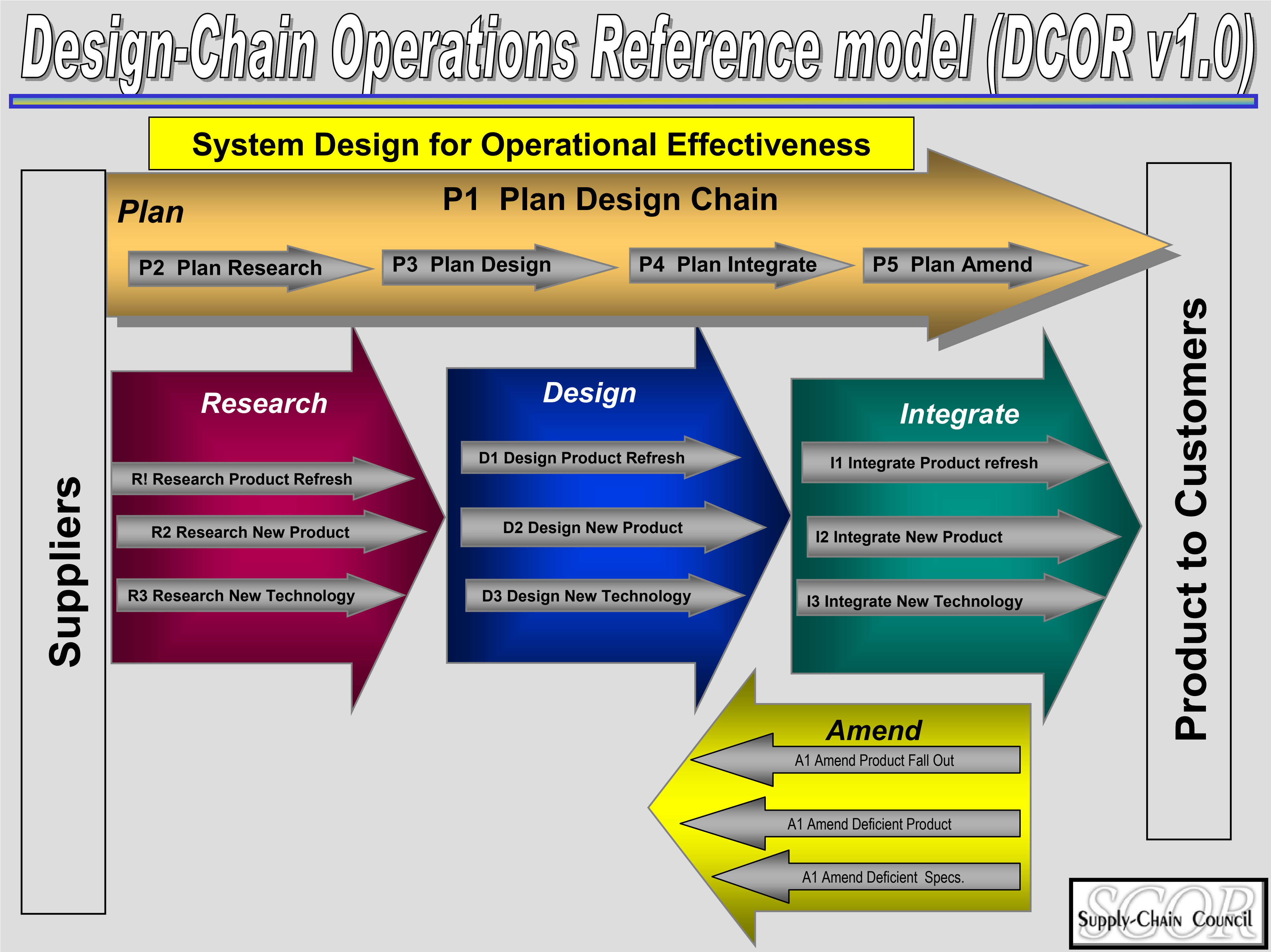
- The SCOR-model:
  - Describes the business activities associated with all phases of satisfying a demand.
  - Utilizes process building blocks.
  - Identifies metrics.
  - Uses a common set of definitions.
  - Links virtually any supply chain within Government and Industry.

SCOR Supply-Chain Council

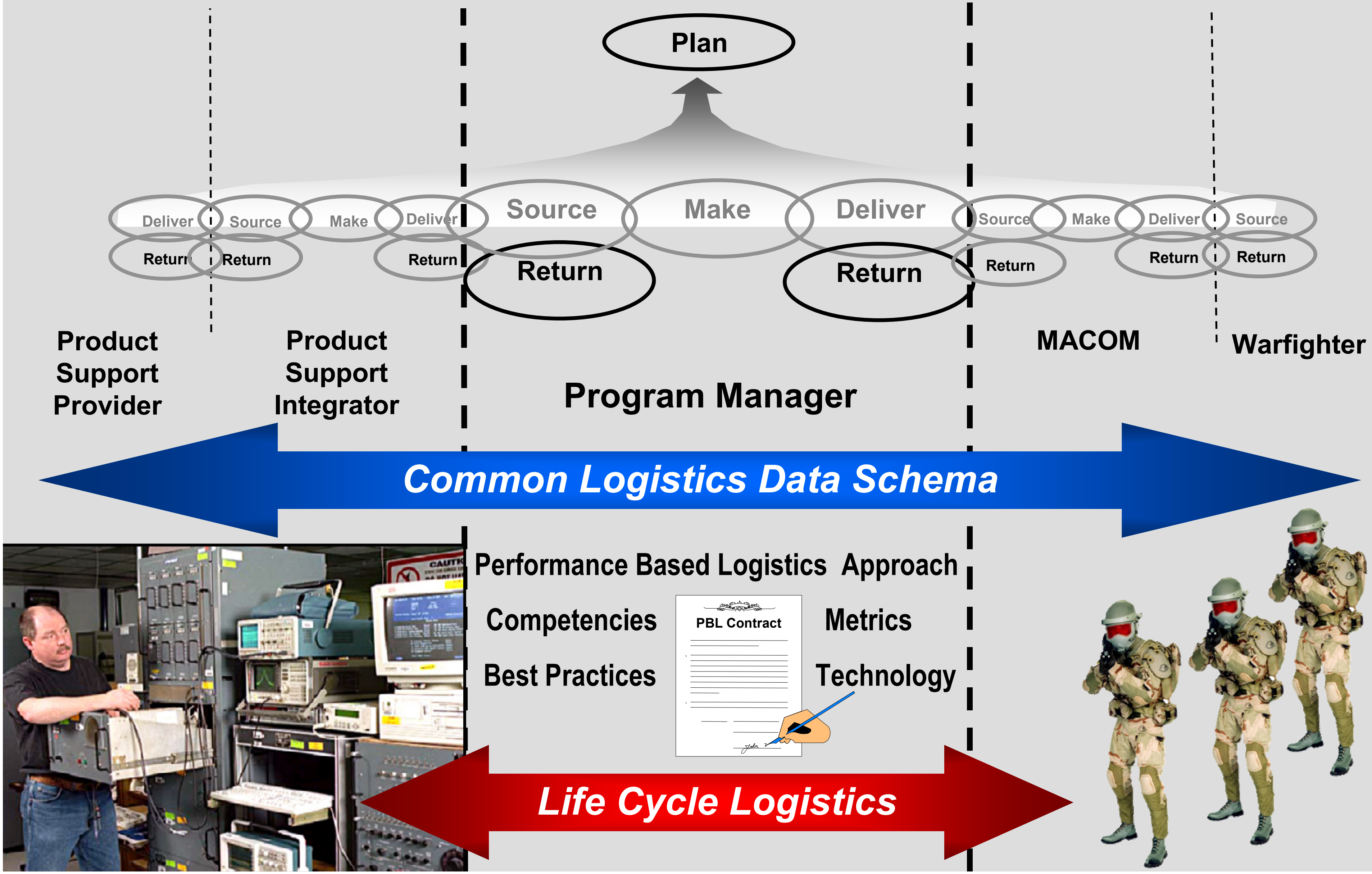
Supply-Chain Operations Reference model (SCOR v7.0)




P1: PLAN SUPPLY CHAIN
P2: SOURCE
P3: MAKE
P4: DELIVER
P5: RETURN
S1: Source Stocked Product Best Practice: Joint Service Agreements
M1: Make-to-Stock Best Practice: Benchmarking Six Sigma
D1: Deliver Stocked Product Best practice: Electronic Catalogs Quick Response
S2: Source Make-to-order Product Best Practice: Statistical Process Control
M2: Make-to-order Best Practice: Capacity Planning
D2: Deliver Make-to-order Product Metrics: Fill Rates
S3: Source Engineer-to-order Metrics: Product Acquisition Costs
M3: Engineer-to-Order Best Practice: Demand-pull manufacturing
D3: Deliver Engineer-to-order product Metrics: Order Management
SR1: Source return defective product Metrics: Cycle time
DR1: Deliver return defective product Metrics: Cycle time
EP2: Manage Performance of Supply Chain (MACOM)
CUSTOMERS


Design-Chain Operations Reference model (DCOR v1.0)
System Design for Operational Effectiveness
Plan
P1 Plan Design Chain
P2 Plan Research
P3 Plan Design
P4 Plan Integrate
P5 Plan Amend
Suppliers
Research
R! Research Product Refresh
R2 Research New Product
R3 Research New Technology
Design
D1 Design Product Refresh
D2 Design New Product
D3 Design New Technology
Integrate
I1 Integrate Product refresh
I2 Integrate New Product
I3 Integrate New Technology
Amend
A1 Amend Product Fall Out
A1 Amend Deficient Product
A1 Amend Deficient Specs.
Product to Customers
SCOR
Supply-Chain Council

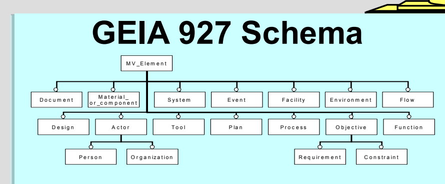
Sustaining Performance Requires Information



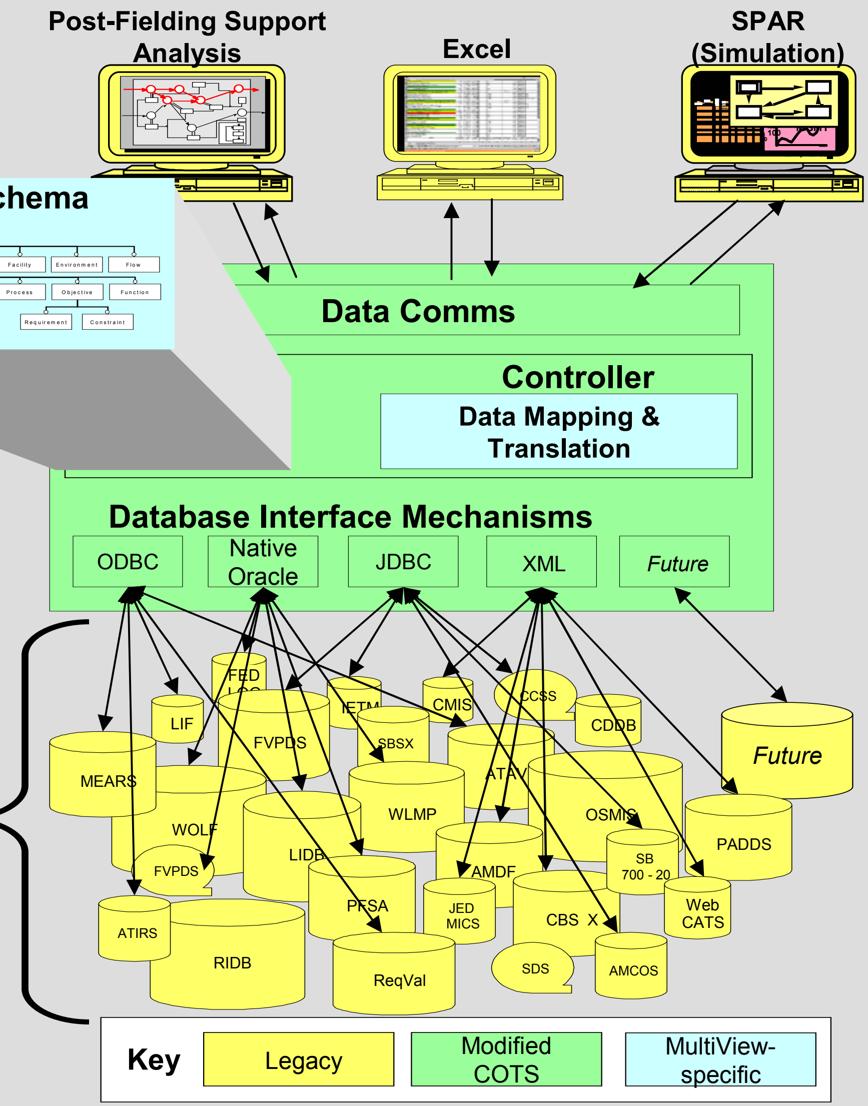
What is Common Logistics Data Schema?

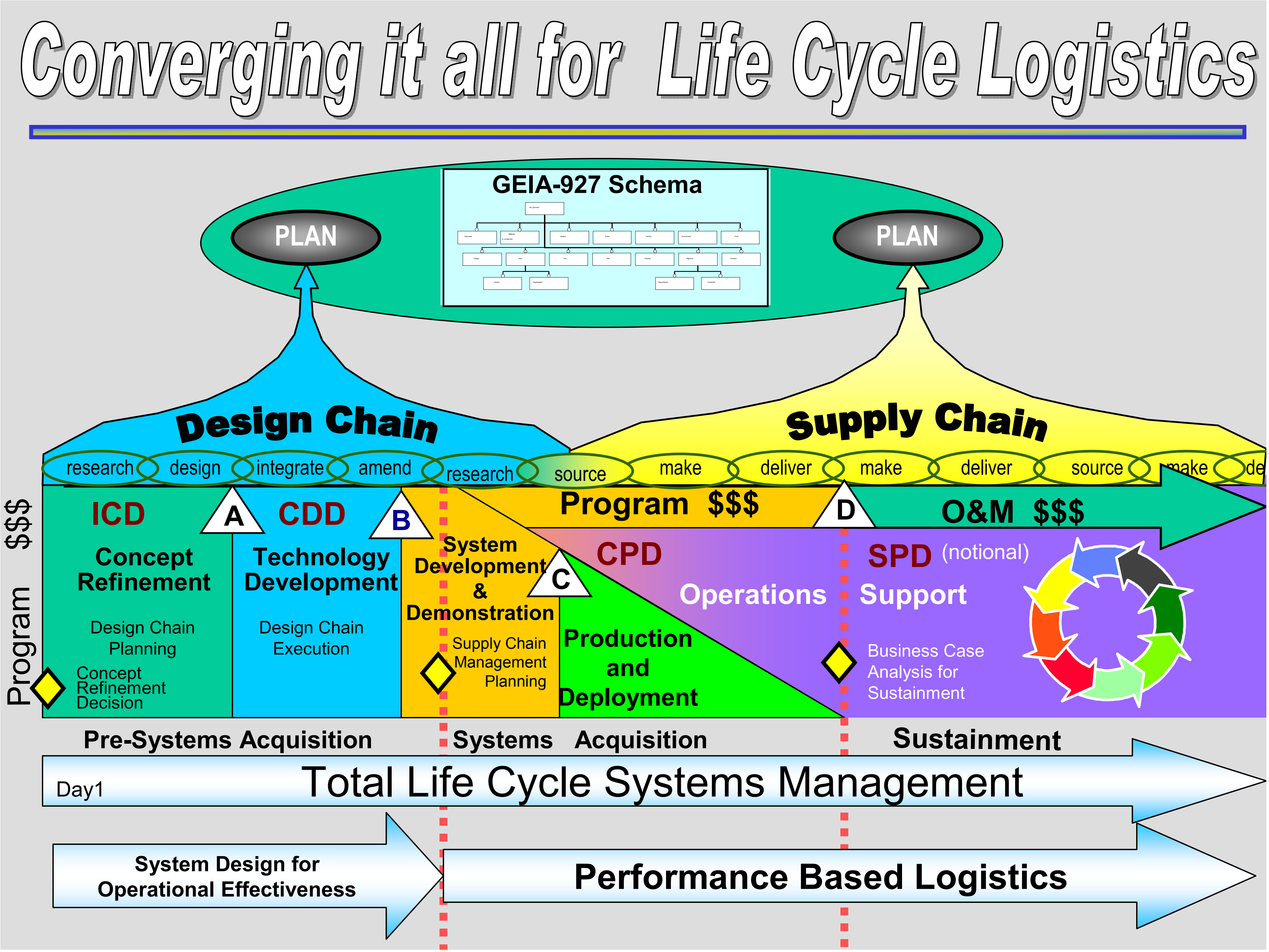
Example – the Government Electronics and Information Technology Association (GEIA) standard 927 – ***Multiview***

Multiview **- an integrated multi-domain data schema for representing system product and process data.**



The data schema is the organization and interrelationships of system data essential for developing an advanced integrated environment





Converging it all for Life Cycle Logistics
GEIA-927 Schema
PLAN
PLAN
Design Chain
Supply Chain
research
design
integrate
amend
research
source
make
deliver
make
deliver
source
make
de
Program $$$
ICD
A
CDD
B
Program $$$
O&M $$$
D
Concept Refinement
Design Chain Planning
Concept Refinement Decision
Technology Development
Design Chain Execution
System Development & Demonstration
Supply Chain Management Planning
C
CPD
Production and Deployment
Operations
SPD (notional)
Support
Business Case Analysis for Sustainment
Pre-Systems Acquisition
Systems Acquisition
Sustainment
Day1
Total Life Cycle Systems Management
System Design for Operational Effectiveness
Performance Based Logistics

ONE LAST SHOT:

just an opinion...

- A Milestone "D", with exit criteria and a Sustaining Performance Document (notional) could be the conduit between Acquisition and Sustainment.
  - Presently, the biggest life cycle event has no criteria
    - Cost, Schedule, Performance, & Supportability under one focal point across the Life Cycle
- Sustainment currently relies too heavily on forensics to determine plan of action
  - Need to map the requirements from Technology Development to operations & support
    - Move beyond "respond and fix"
  - Needs to become a value added service
- Presently "Data Rich and Information Poor"
  - A Common Data Schema would interact all facets of logistics and engineering
    - The "tie that binds" between engineers and logisticians!

For further information and discussion:

TOBYHANNA ARMY DEPOT Excellence in Electronics

John Sells
570-895-7585
John.sells@us.army.mil

Thanks!

- Louis A. Kratz, Assistant Deputy Under Secretary of Defense (Logistics Plans and Programs)
- Edward T. Bair, Program Executive Officer, Intelligence, Electronic Warfare & Sensors
- Randy Fowler, Director, Center for Logistics and Sustainment Curriculum Development, Defense Acquisition University
- Jerry Cothran, Program Director, Performance Based Logistics, Defense Acquisition University
- Jerry Beck, Senior Program Analyst, Office of the Assistant Deputy Under Secretary of Defense (Logistics Plans & Programs)
- Joe Burak, Senior Supply Chain Analyst, Chairman - Supply Chain Council, Aerospace & Defense Special Interest Group
- Veronica Allen, Associate Director, operations

Systems Modeling Language (SysML) Overview & Update

NDIA Systems Engineering Conference
October 27, 2004

Rick Steiner
SysML Submission Team
Raytheon
(858) 522-2008
fsteiner@raytheon.com

Caveat

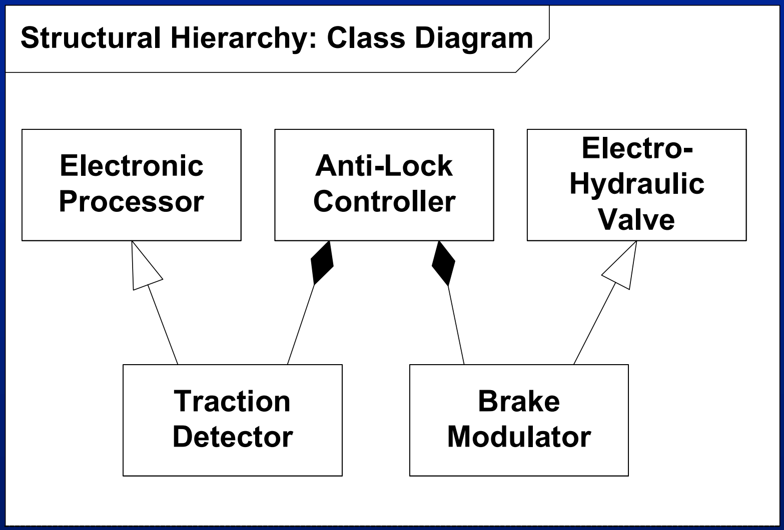
- Current baseline for SysML is v0.9 submitted to OMG in January 05
- SysML Submission Team and SysML Partners are two competing teams working to finalize the specification and submit for adoption to the OMG in February 2006
- This material is based on current status of the SysML Submission Team

Need for SysML:

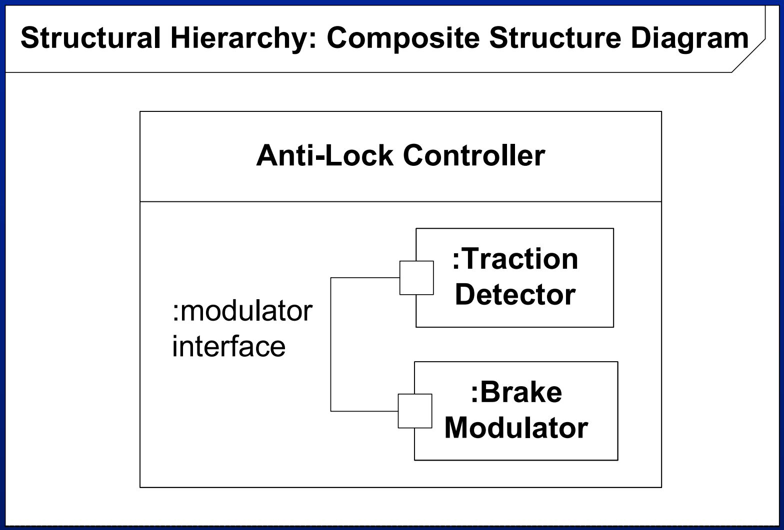
- Systems Engineers need a robust language for analyzing, specifying, designing, verifying and validating systems
- Many different modeling techniques
  - Behavior diagrams, IDEF0, N2 charts, …
- General purpose language must:
  - satisfy broad set of modeling requirements integrate with other disciplines (SW, HW, ..)
  - be scalable, adaptable to different SE domains, supported by multiple tools
  - A Systems Engineering Modeling Language based on UML 2 has a good chance of meeting these objectives!
- Joint INCOSE / Object Management Group (OMG) Initiative to extend UML to SE
  - Systems Engineering Domain Special Interest Group (SE DSIG) kickoff in Sept '01
    - Aligned with ISO AP-233 Systems Engineering data interchange standard to support tool interoperability
  - UML for SE RFI issued in 2002
  - UML for SE RFP (ad/03-03-41) issued March 28, 2003

Structure in UML 2 – A Useful Concept for Systems Engineers

Definition
(Class Diagram)



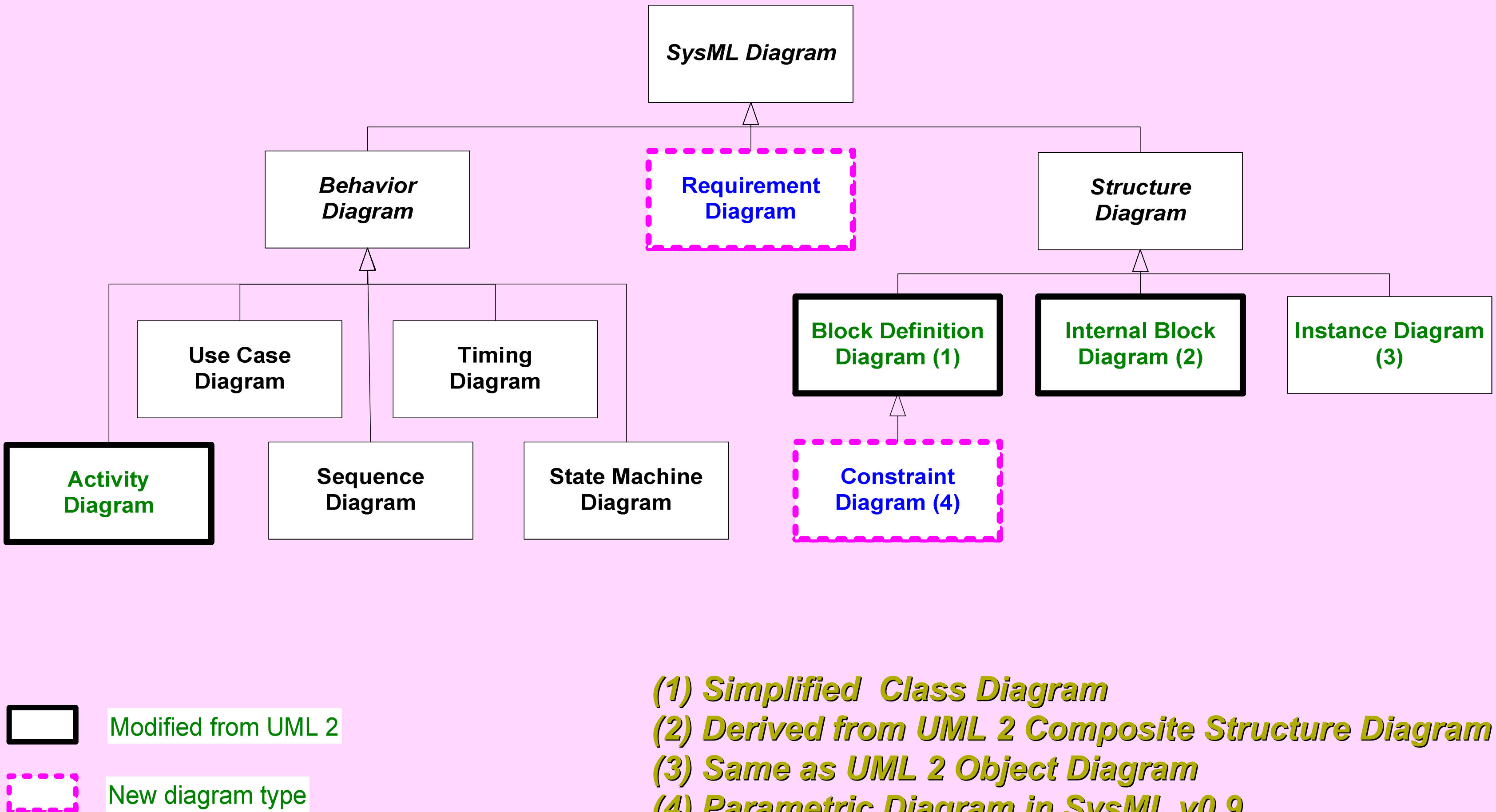
Use
(Composite Structure Diagram)



SysML Submission Status

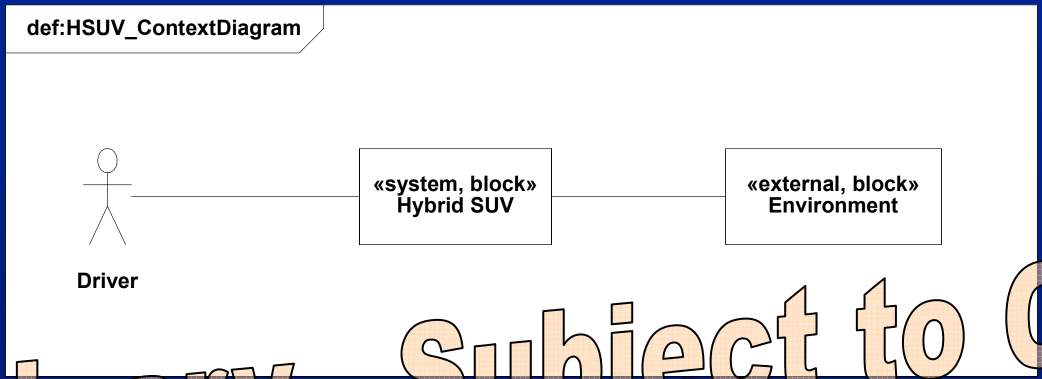
- SysML Partners formed in March, 2003
  - SysML V0.9 submitted to OMG on Jan 10, 2005
    - Profiles chapter addendum submitted May 30
  - 4 tool vendors piloted use of SysML 0.9 in their tools, and presented at INCOSE 2005 symposium in Rochester
    - Artisan, EmbeddedPlus, iLogix, and Telelogic
  - Missed goal for revised submission update in May and August ’05
- SysML Submission Team announced split from SysML Partners on August 30, 2005 to finalize spec
  - Goal to submit Final Revised Submission for presentation at December ‘05 OMG meeting
  - Request vote to recommend adoption at February ‘05 OMG meeting
- SysML 1.0 should be ready for use early in 2006
  - Already appearing in tools (0.9x version)

SysML Diagram Taxonomy

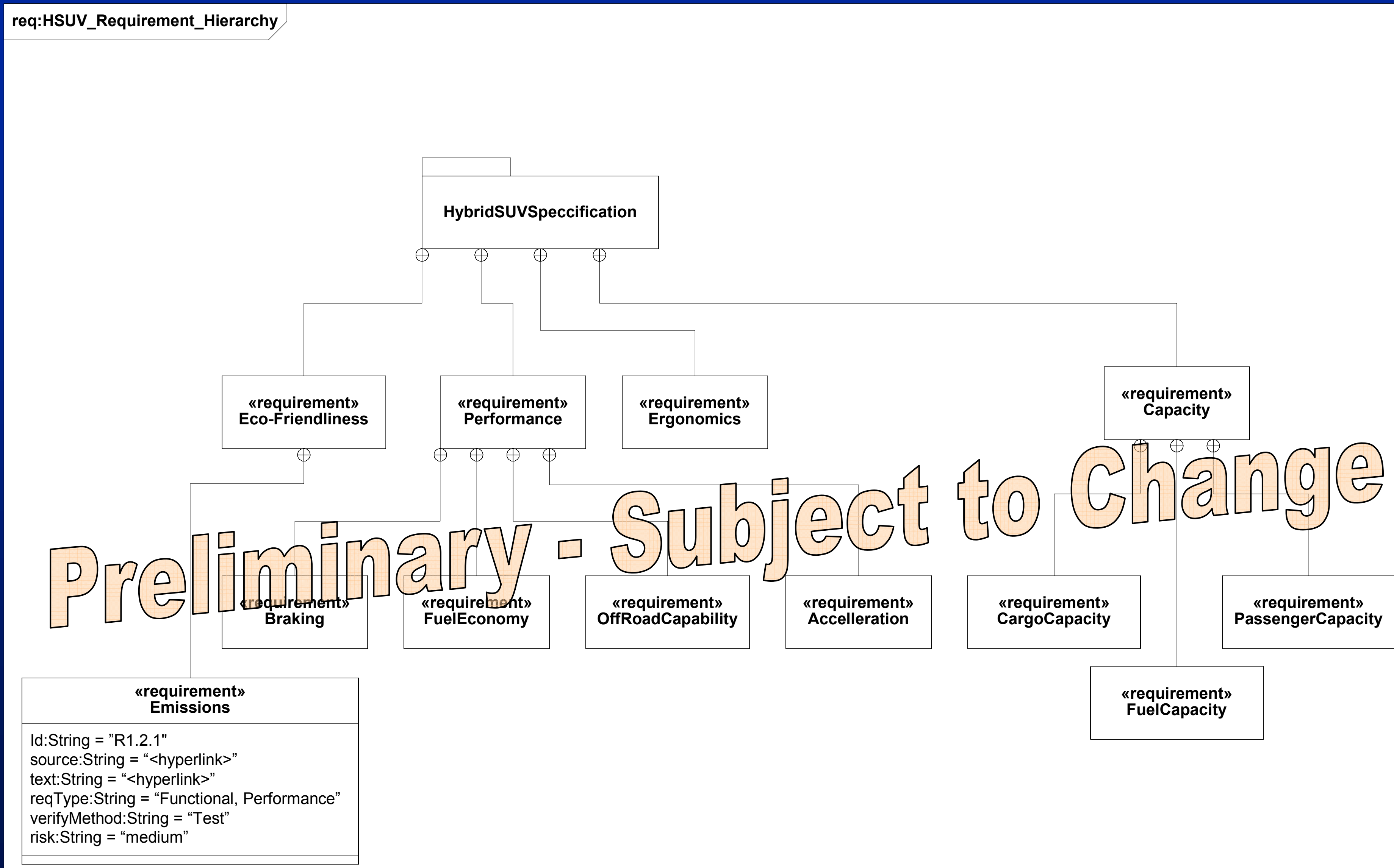


(1) Simplified Class Diagram
(2) Derived from UML 2 Composite Structure Diagram
(3) Same as UML 2 Object Diagram
(4) Parametric Diagram in SysML v0.9

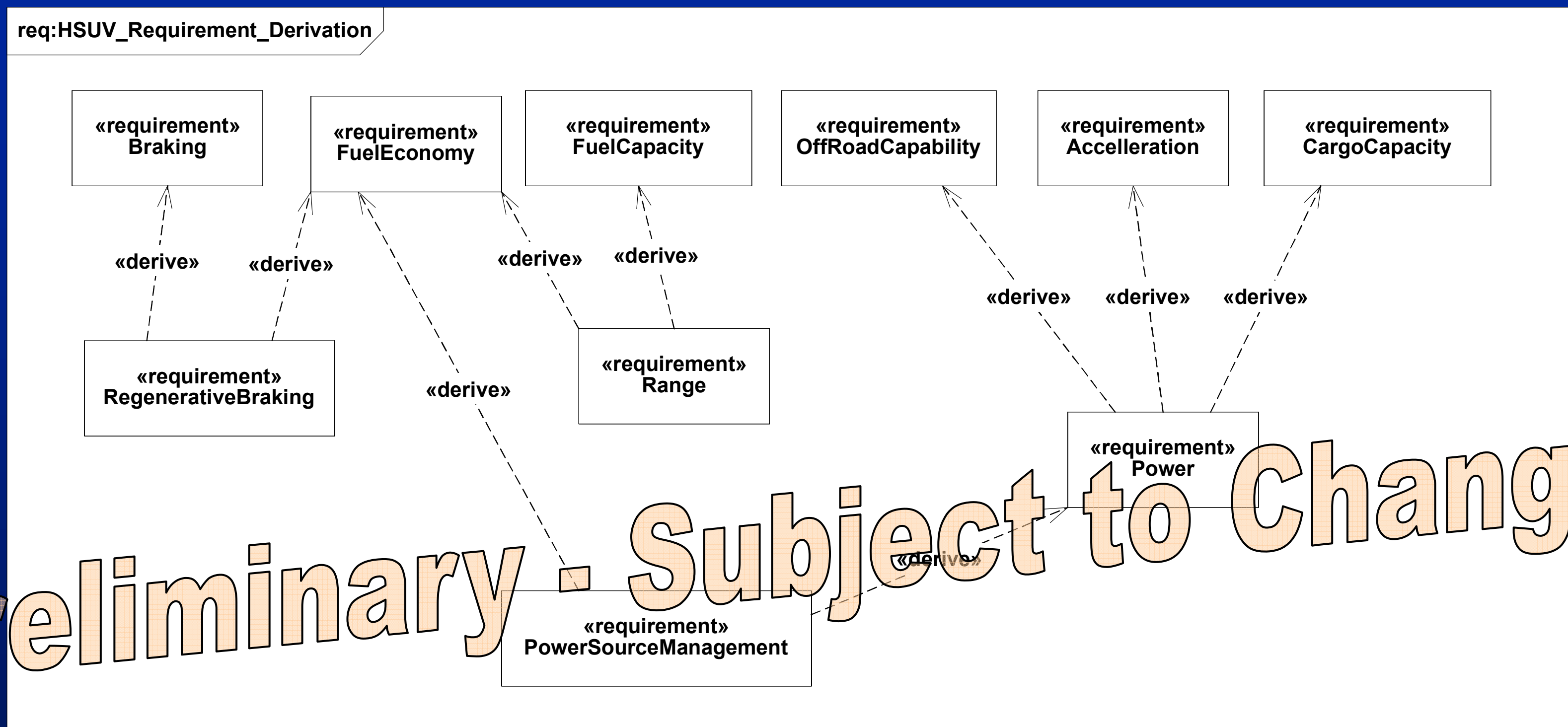
Hybrid SUV Example – Context Diagram



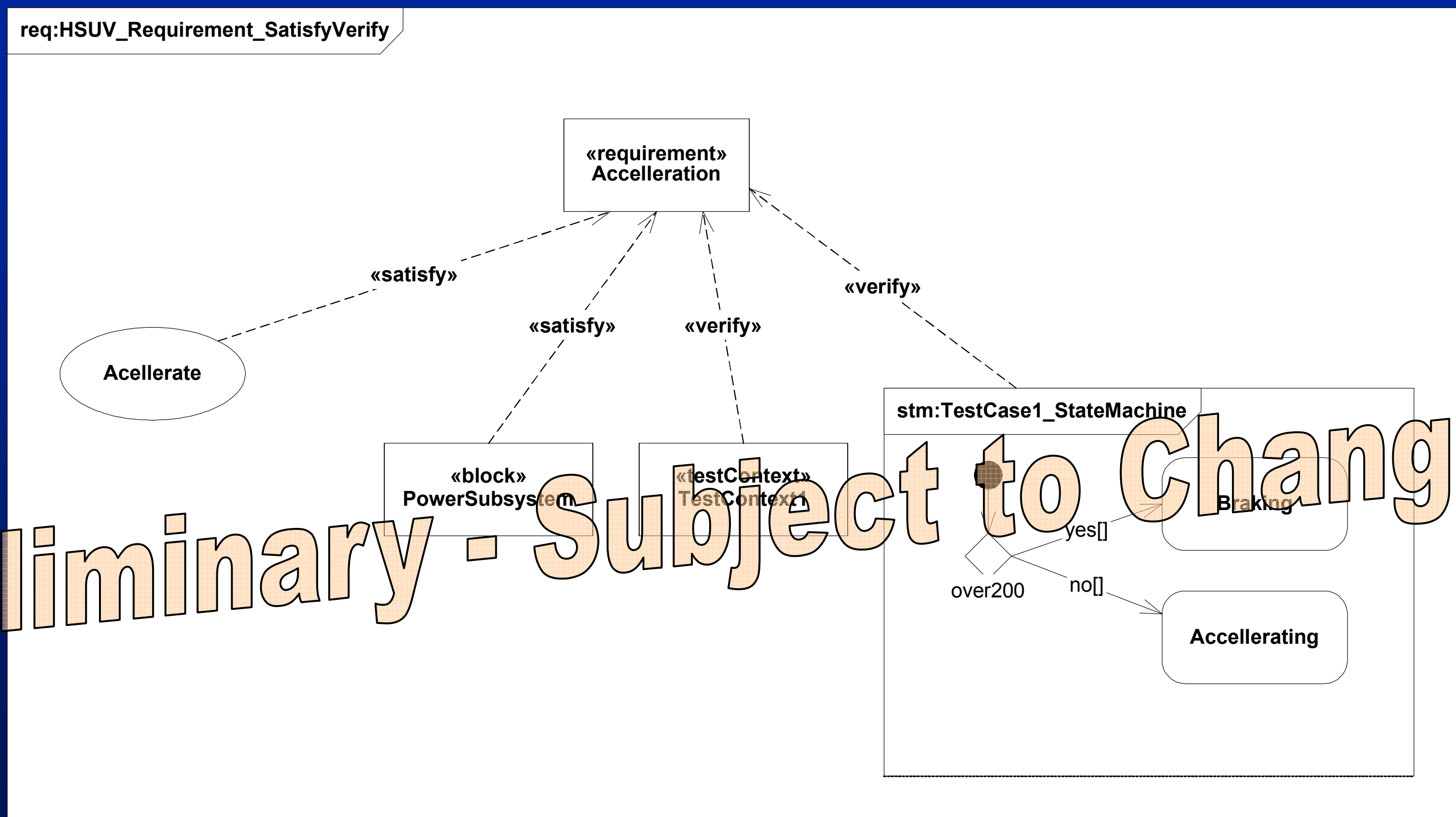
Hybrid SUV Example – Requirements Hierarchy



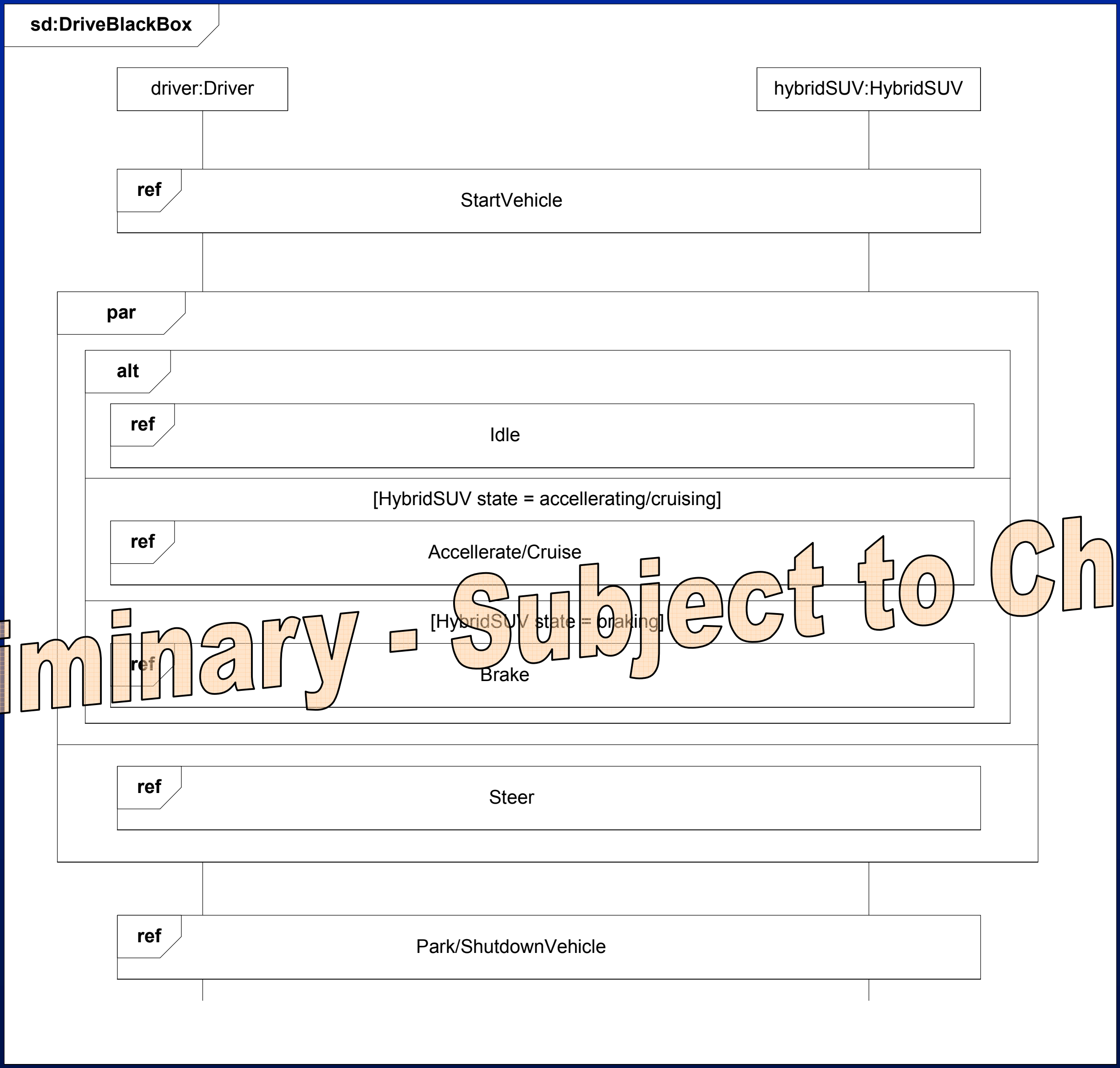
Hybrid SUV – Requirements Derivation



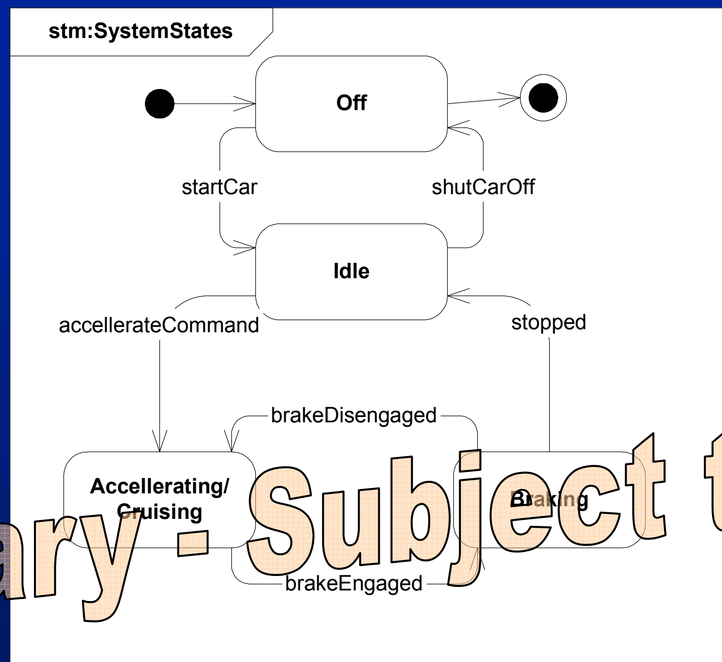
Hybrid SUV – Satisfy/Verify Requirements



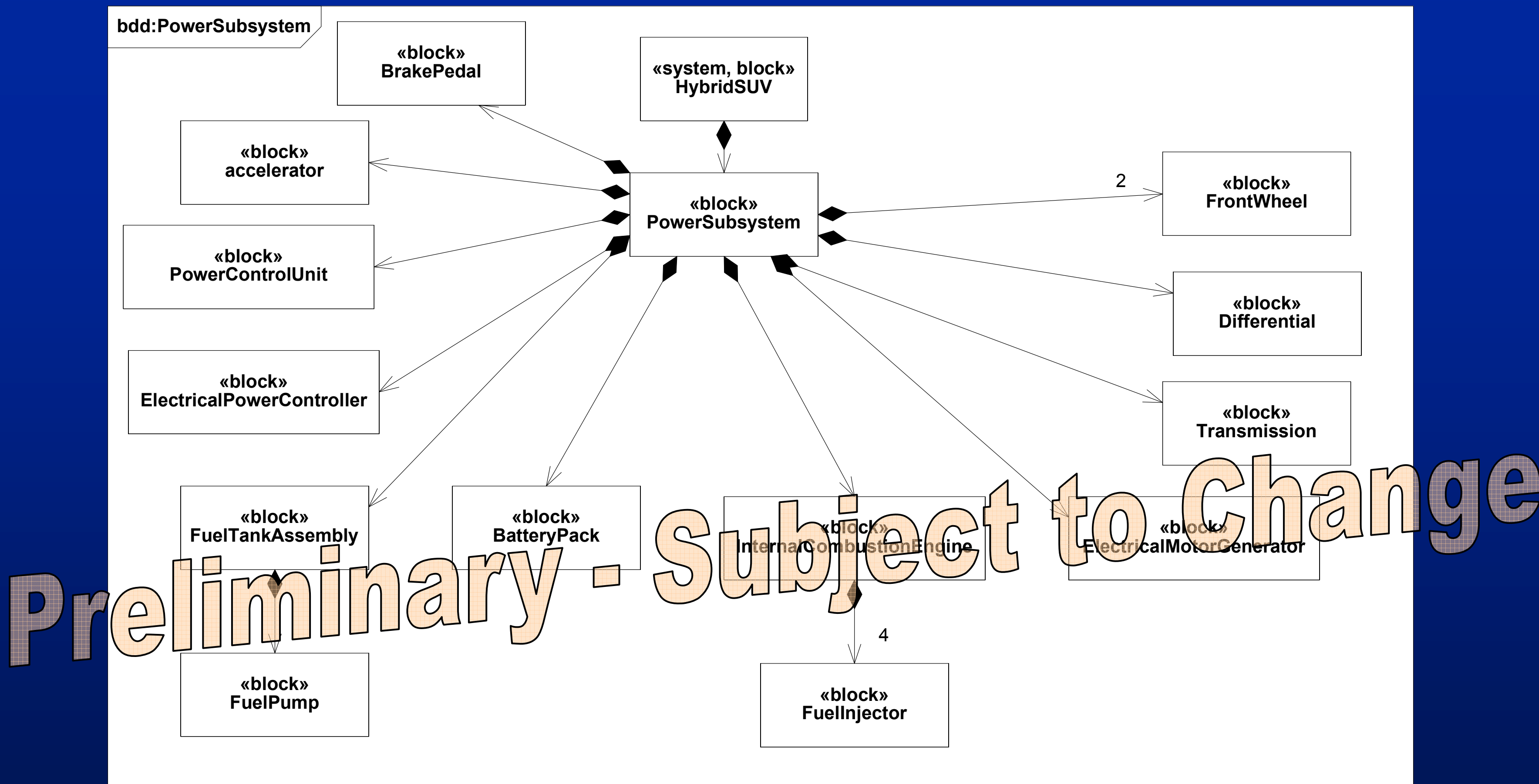
Hybrid SUV – black box Sequence Diagram



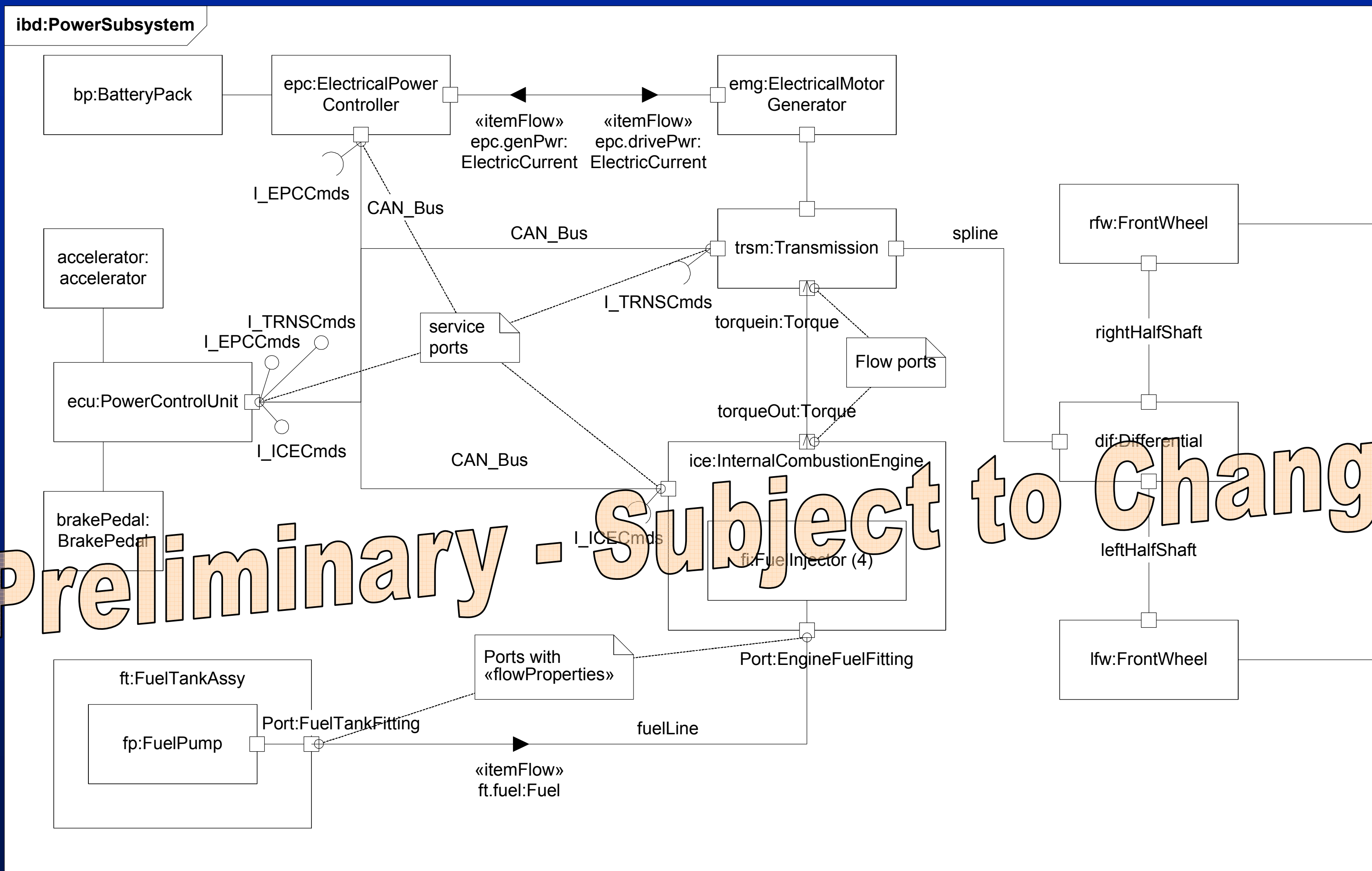
Hybrid SUV – Top Level State Machine



Hybrid SUV– Power System Block Definition Diagram

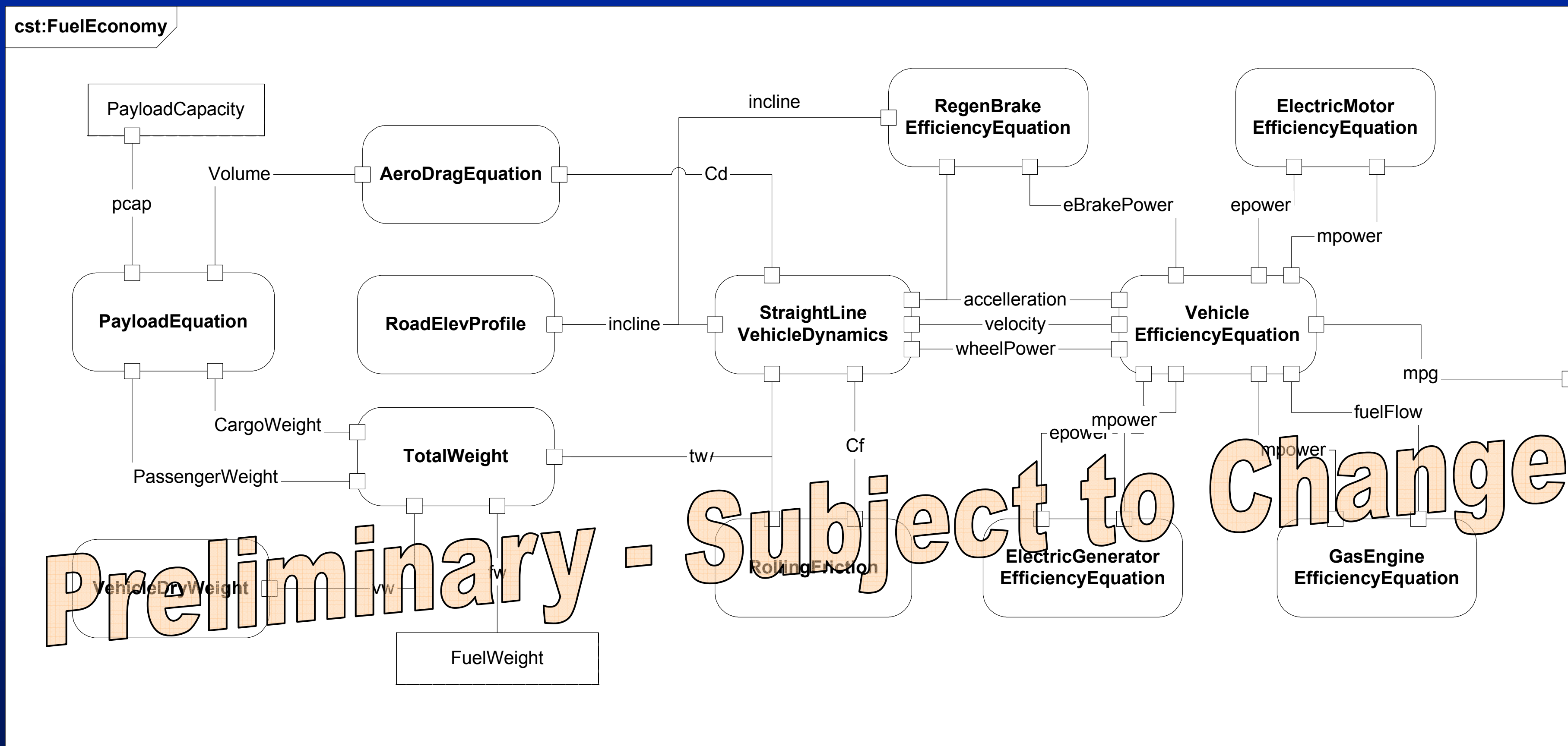


Hybrid SUV – Power System Internal Block Diagram

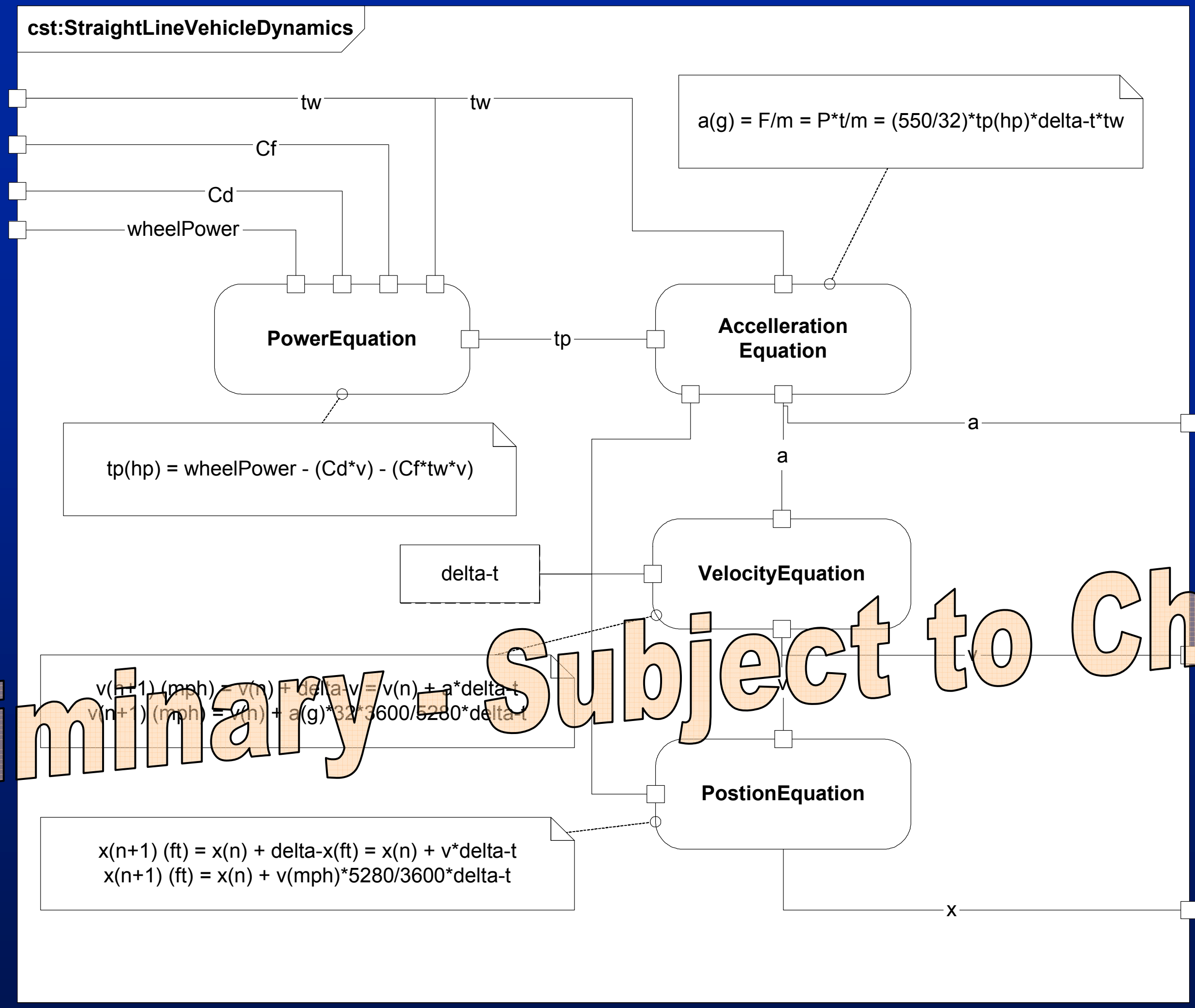


Preliminary - Subject to Change

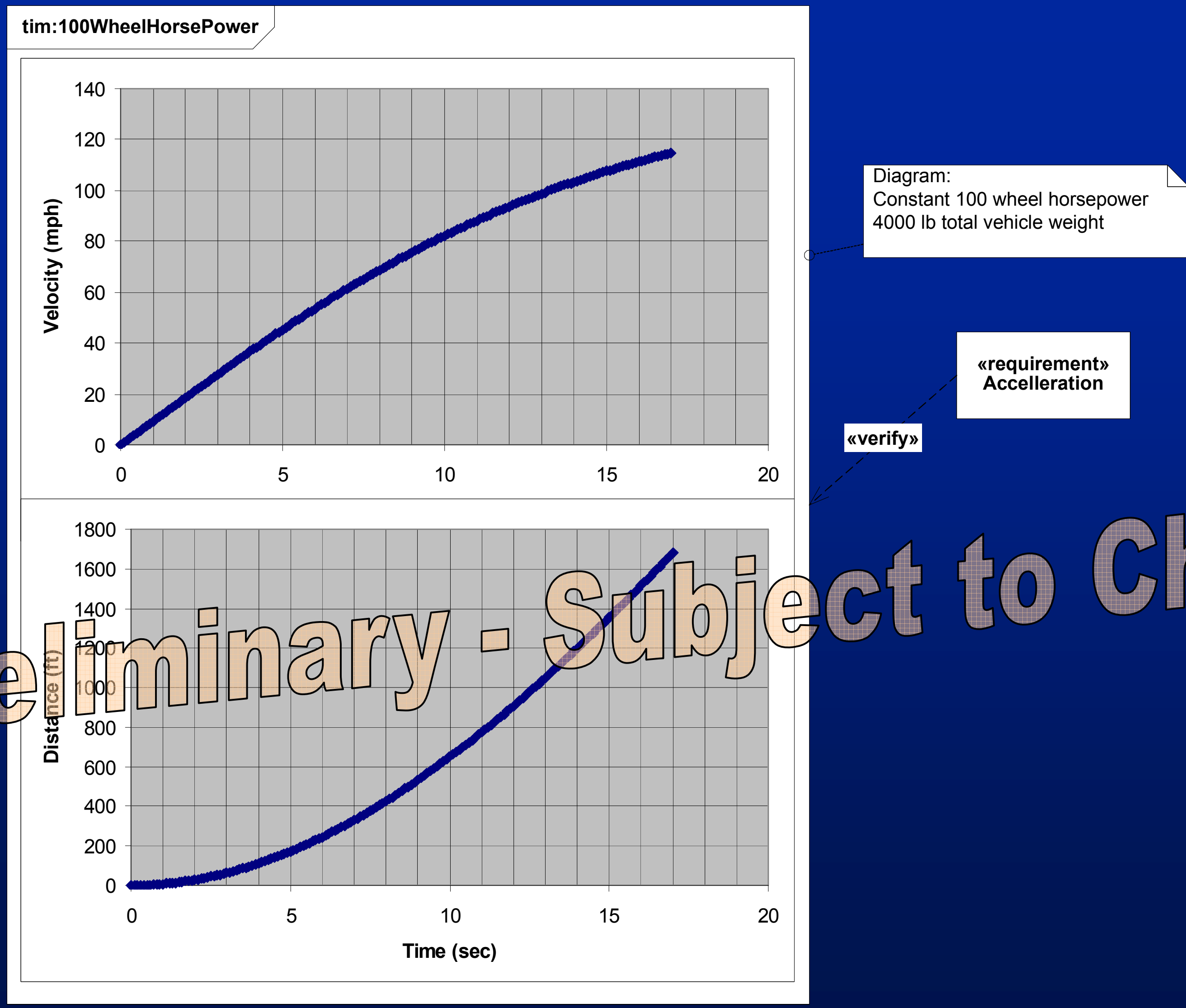
Hybrid SUV – Fuel Economy Equation Constraint Diagram



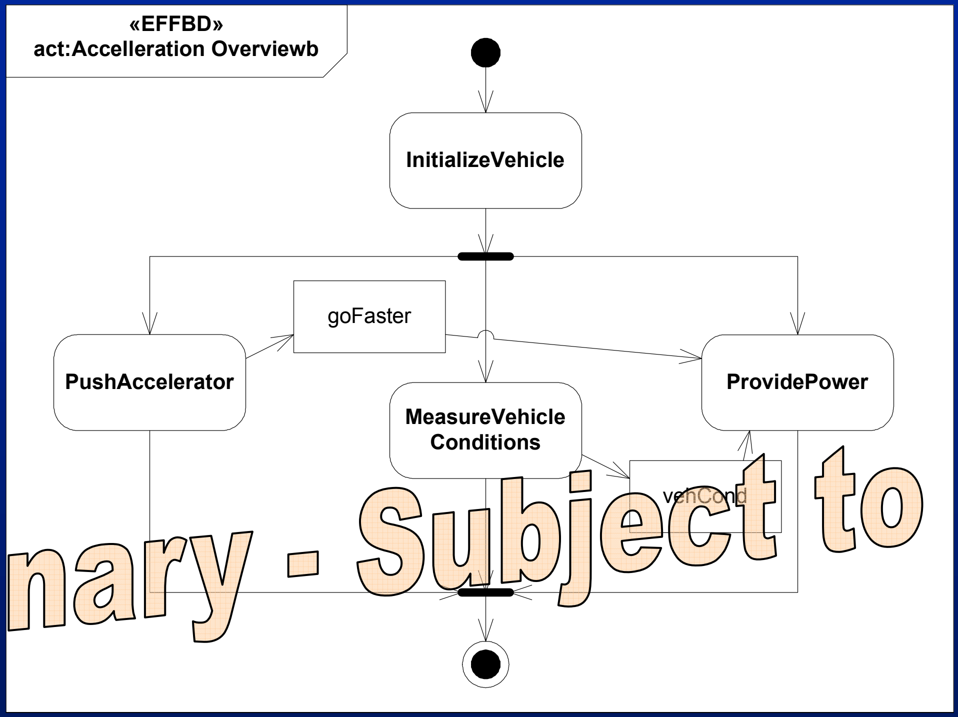
Hybrid SUV – Vehicle Dynamics Constraint Diagram



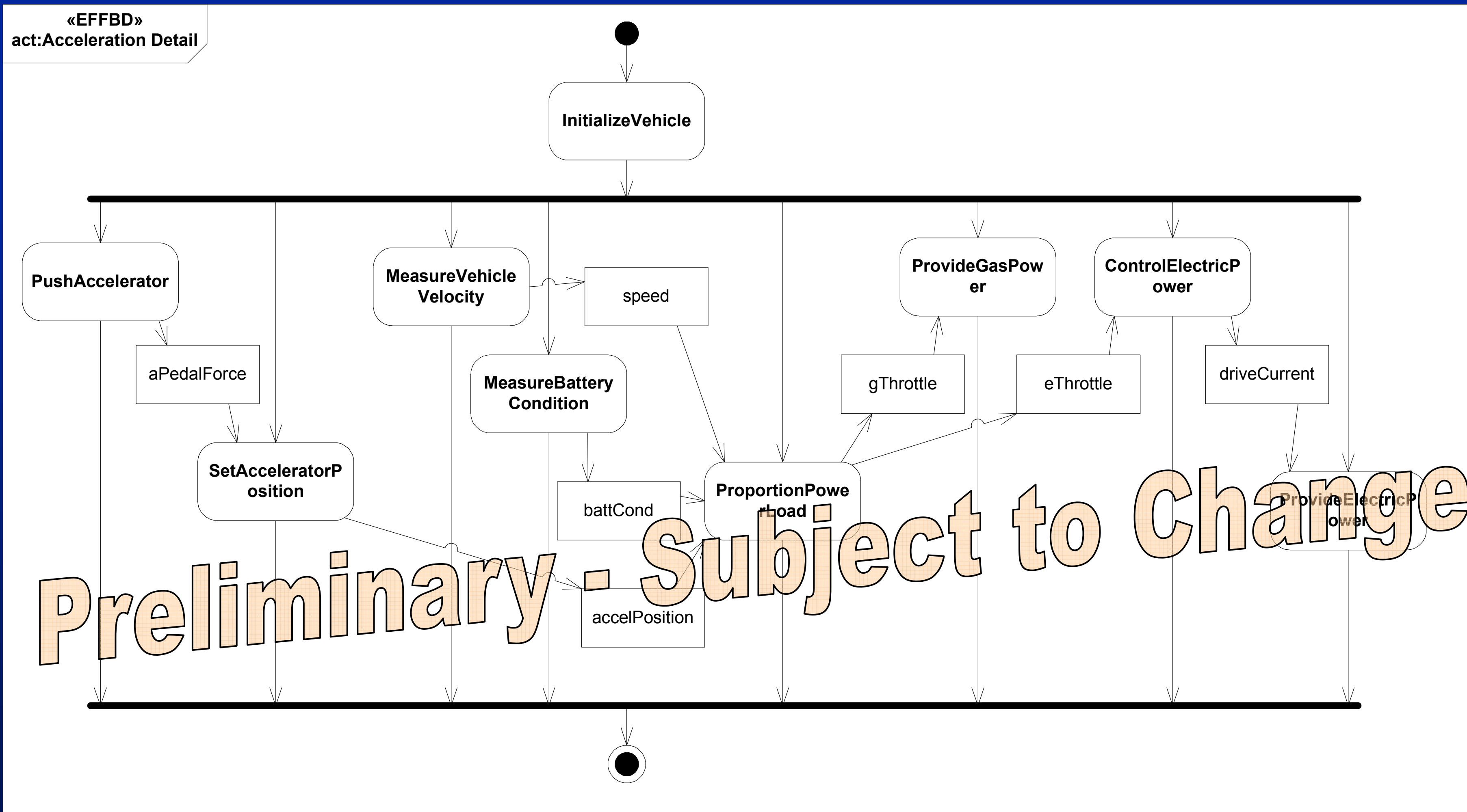
Hybrid SUV – Acceleration Timing Diagram



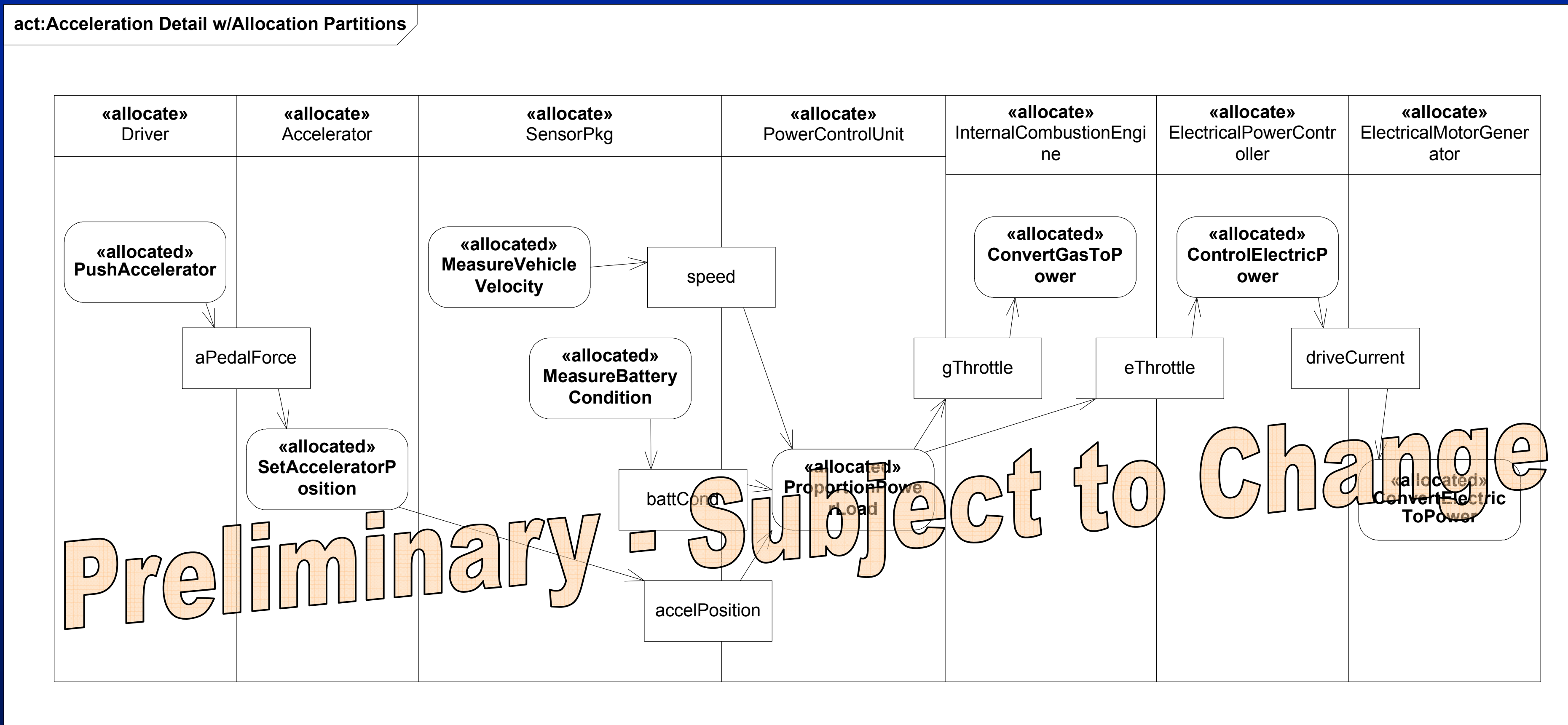
Hybrid SUV – Acceleration Activity Diagram (EFFBD - 1)



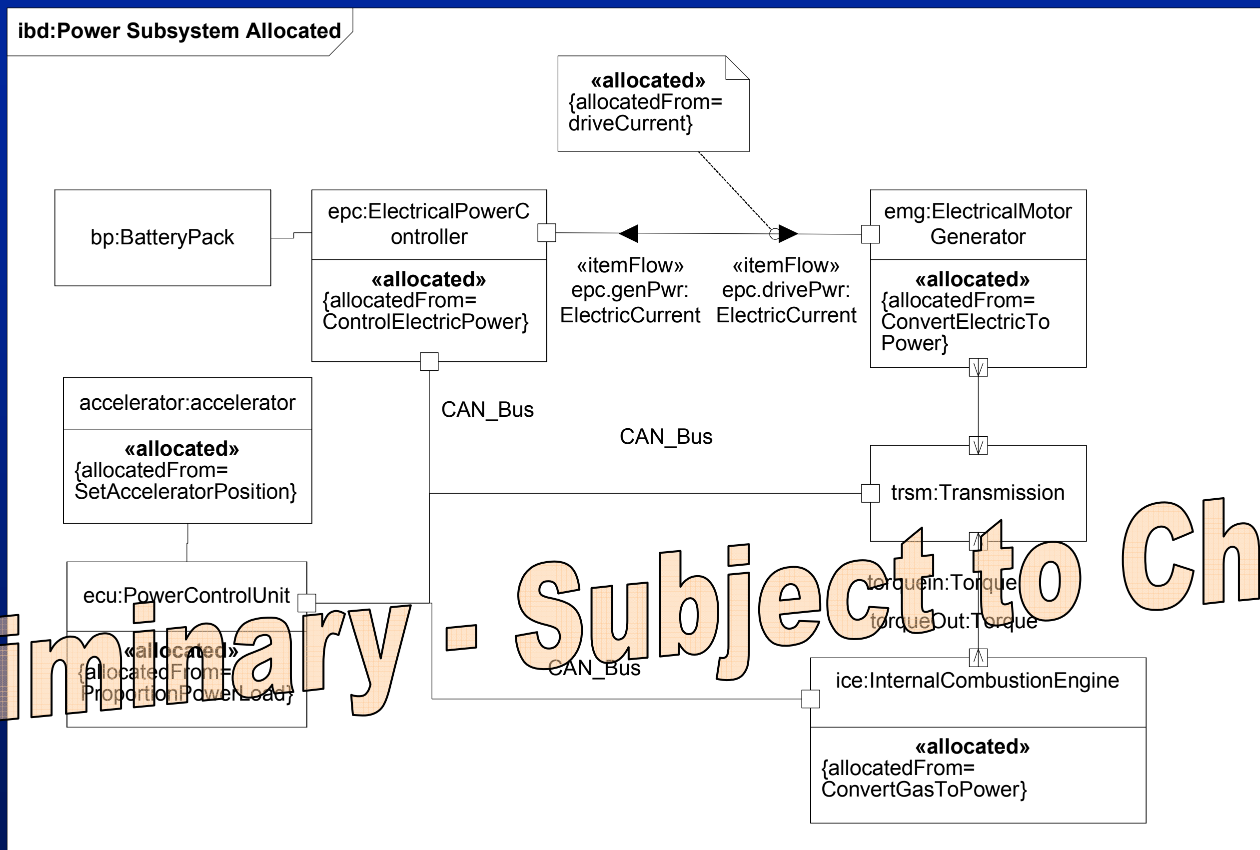
Hybrid SUV – Acceleration Activity Diagram (EFFBD - 2)



Hybrid SUV – Acceleration Activity Diagram (Allocation)



Hybrid SUV – Internal Block Diagram with Allocation



Backup Charts

SysML Submission Team

- Members
  - Industry & Government
    - American Systems, BAE SYSTEMS, Boeing, Lockheed Martin, NIST, oose.de, Raytheon, THALES, Eurostep, EADS Astrium
  - Vendors
    - Artisan, EmbeddedPlus, IBM, I-Logix, Mentor Graphics, Sparx Systems
- Collaborations
  - Deere & Company
  - Georgia Institute of Technology
  - INCOSE, AP-233

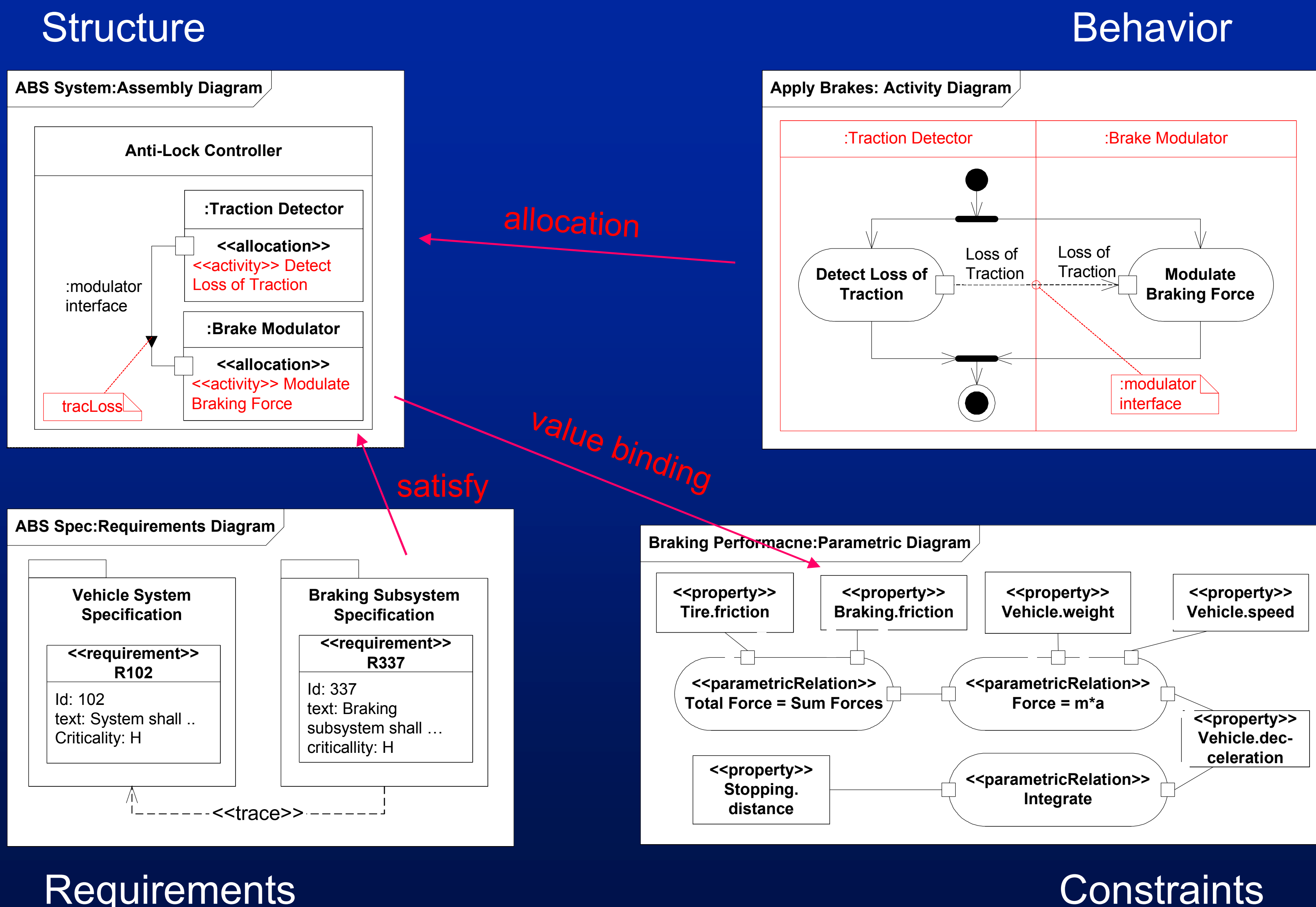
SysML Milestones

- UML for SE RFP issued – March 28, 2003
- Kickoff meeting – May 6, 2003
- Overview presentation to OMG ADTF – Oct 27, 2003
- Initial draft submitted to OMG – Jan 12, 2004
- INCOSE Review – January 25-26, 2004
- INCOSE Review – May 25, 2004
- Revised draft submitted to OMG – Aug 2
- 2nd Revised submission to OMG – October 11
- OMG technology adoption – Q1 2005 (Goal)

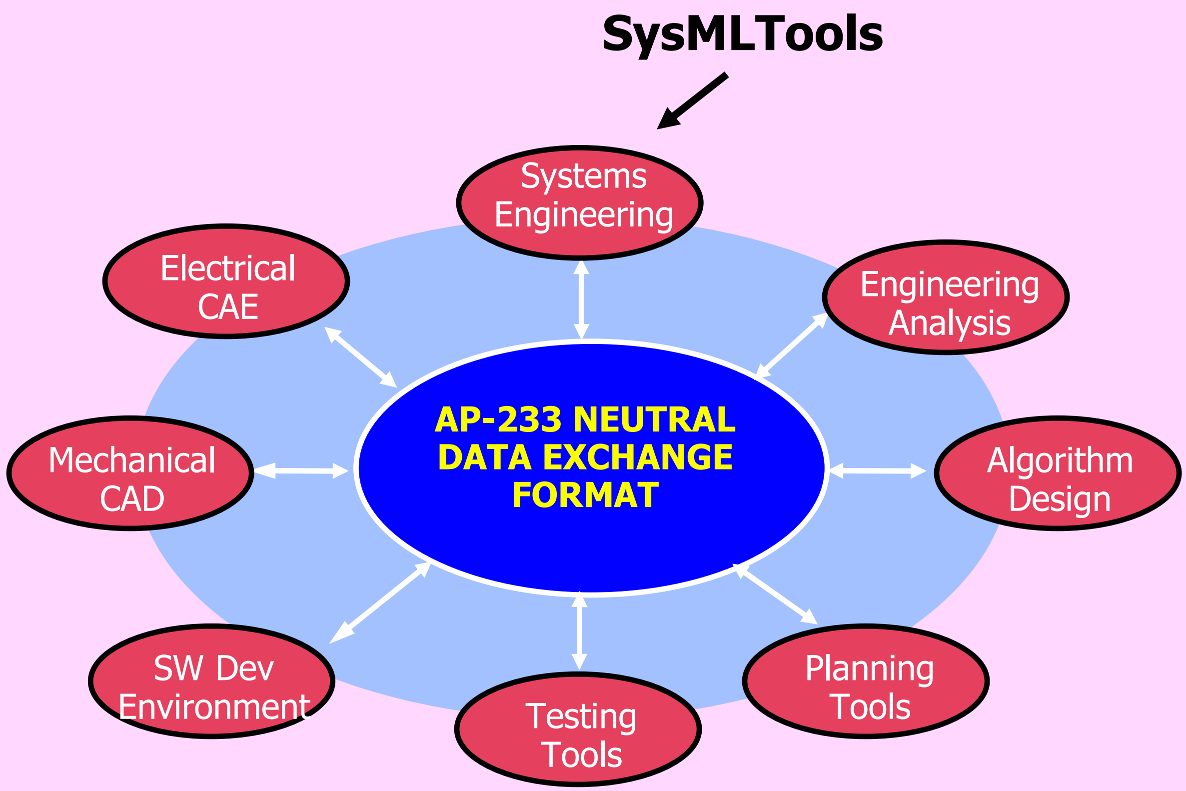
Modeling Language Requirements Refer to UML for SE RFP

- **Structure**
  - **e.g., system hierarchy, interconnection**
- **Behavior**
  - **e.g., function-based behavior, state-based behavior**
- **Properties**
  - **e.g., parametric models, time property**
- **Requirements**
  - **e.g., requirements hierarchy, traceability**
- **Verification**
  - **e.g., test cases, verification results**
- **Other**
  - **e.g., trade studies**

4 Pillars of SysML



SysML / AP-233 Alignment



References

- UML for SE RFP
  - OMG doc# ad/03-03-41
- UML 2 Superstructure
  - OMG doc# formal/05-07-04
- UML 2 Infrastructure
  - OMG doc# ptc/04-10-14
- INCOSE 2004 Symposium Paper “Extending UML to Support a Systems Modeling Language” – S. Friedenthal, C. Kobryn
- INCOSE 2003 Symposium Paper “Extending UML from Software to Systems” – S. Friedenthal, R. Burkhart
- INCOSE Insight (June 2004)
- [Bock 2003] "UML 2 Activity Model Support for Systems Engineering Functional Flow Diagrams," Journal of INCOSE Systems Engineering, vol. 6, no. 4, October 2003 – C. Bock

System Safety
in
Systems Engineering Process

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Ray C. Terry, Ph.D.
ray.terry@survice.com

NDIA 8th Annual Systems Engineering Conference

Overview

- The Big Question
  - System Safety
  - Systems Engineering
- Classic System Safety Model
- OSD(AT&L) Life Cycle Management Framework
- Systems Engineering V-model
- "Integrated" System Safety Model
- Summary

The Big Question

- **Have you ever wondered:**
  - **Why is it that it's _**Systems**_ Engineering,**
  - **But it's _**System**_ Safety?**
  - **What happened to the "s"?**
  - **Have you asked yourself this same question?**
  - **And, it's been used inconsistently at this conference!!**
- **Let's explore this for a few minutes**

What is System Safety?

- Engineering of Safe Systems or Safety of Systems
- Systems Safety – the discipline
- System Safety – the application of the discipline of systems safety to a specific system or a system of systems
- and…

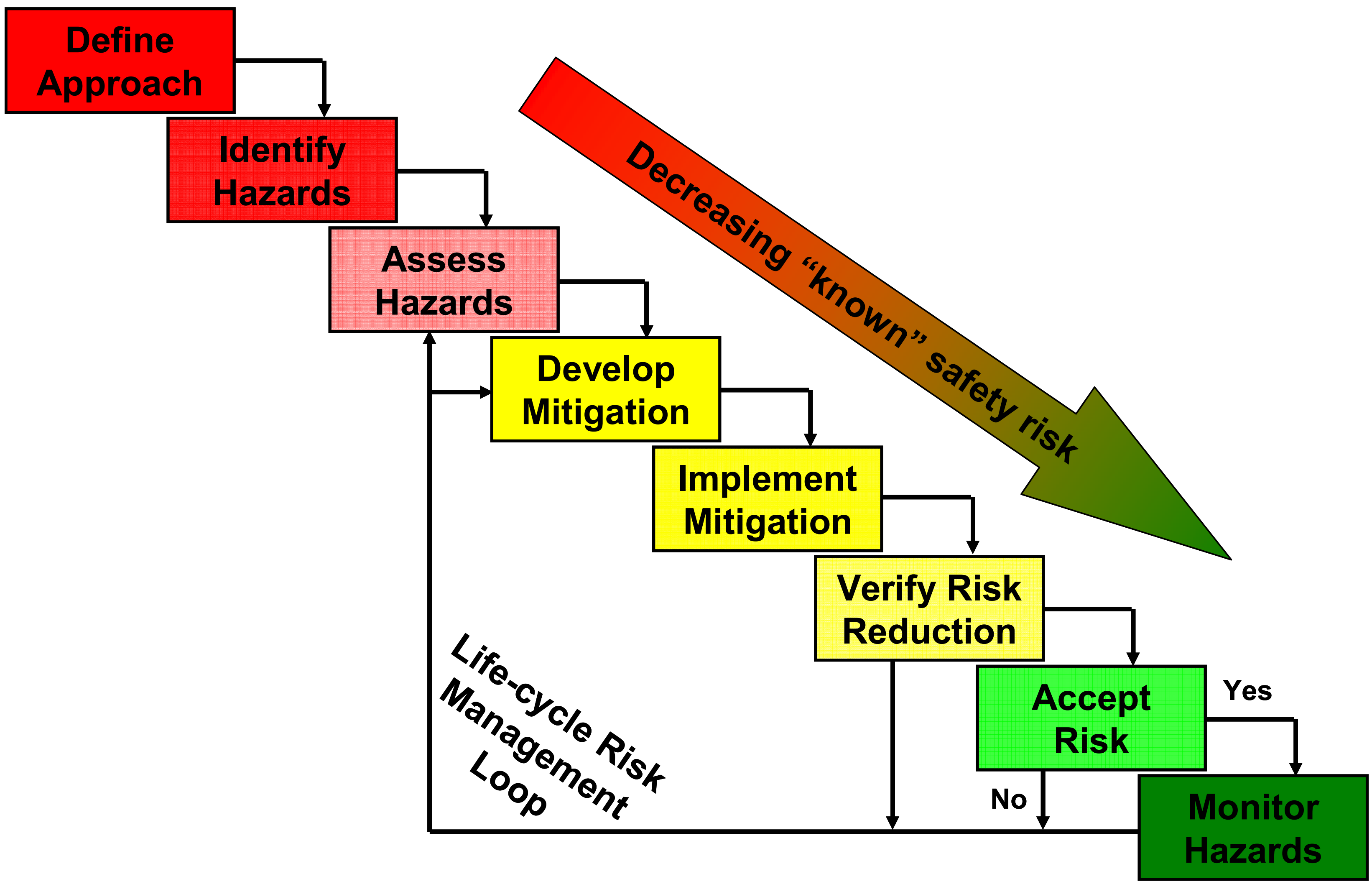
What is Systems Engineering?

- Engineering of Systems
- Systems Engineering – the discipline
- System Engineering – the application of the discipline of systems engineering to a specific system or a system of systems
- One Air Force Program Office used the terminology Director of "System Engineering" because according to the Director, they were working on only one system (contextually-based)
- But what it points to…

System Safety versus Systems Engineering

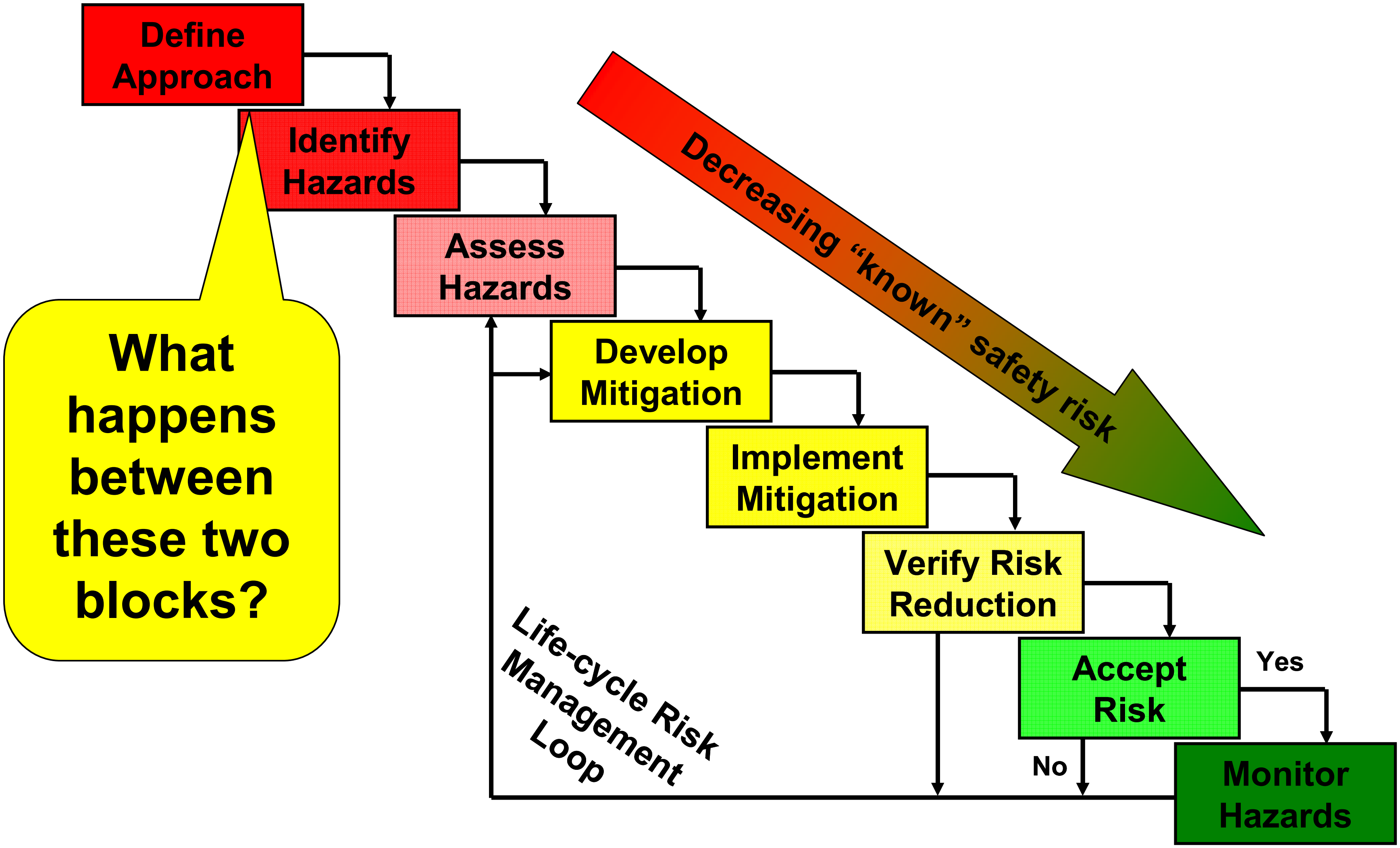
- Lack of effective integration of Systems Safety within Systems Engineering (or System Safety within System Engineering at the project level)
- Real issue is System Safety Requirements and ensuring System Safety is effectively integrated into product realization
- So…what do we do?
- First, we might use a standard definition of system
- But keep that question in mind while we discuss some other ideas

Classic System Safety Model
(MIL-STD-882D)



Classic System Safety Model

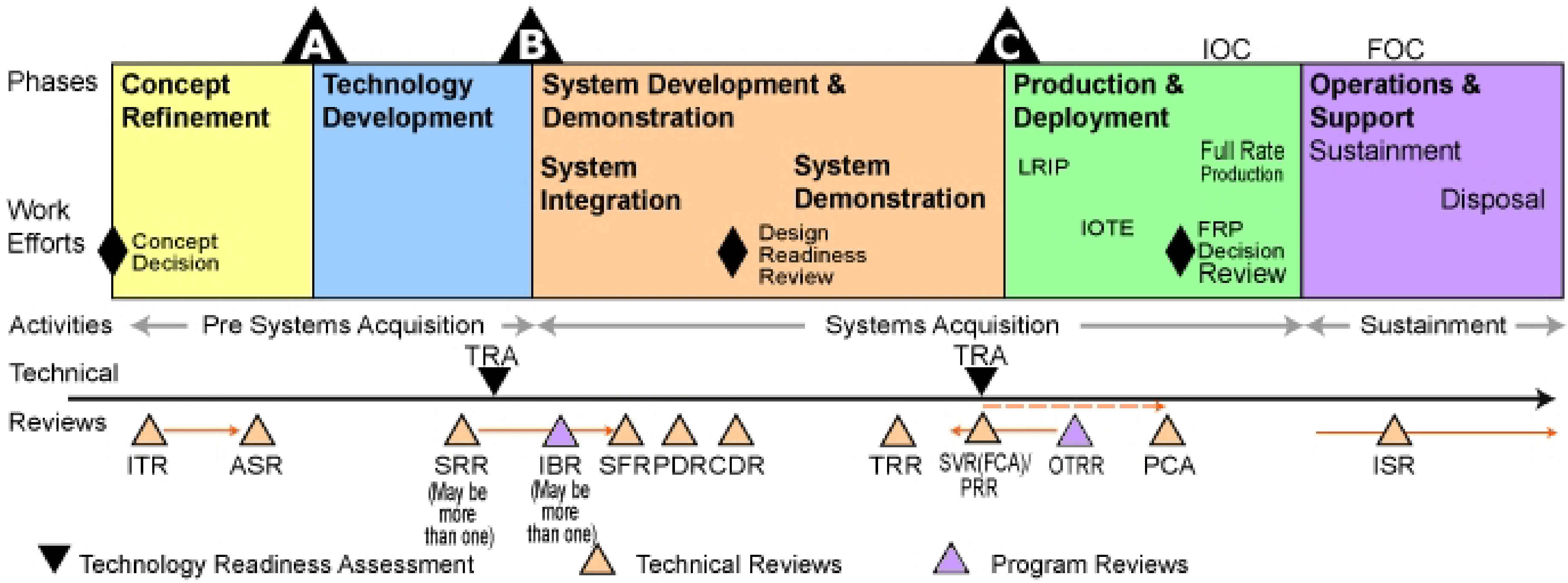
(MIL-STD-882D)



DoD 5000.1 Acquisition Phases

- **Major System Acquisition Phases**
  - Concept Refinement
  - Technology Development
  - System Development & Demonstration
    - System Integration
    - System Demonstration
  - Production & Deployment
    - Low-rate Initial Production
  - Operations & Support
    - Full-Rate Production and Deployment
    - Sustainment
    - Disposal (Recycle/Reuse, Reprocessing or Disposal)

DoD 5000.1 Acquisition Phases



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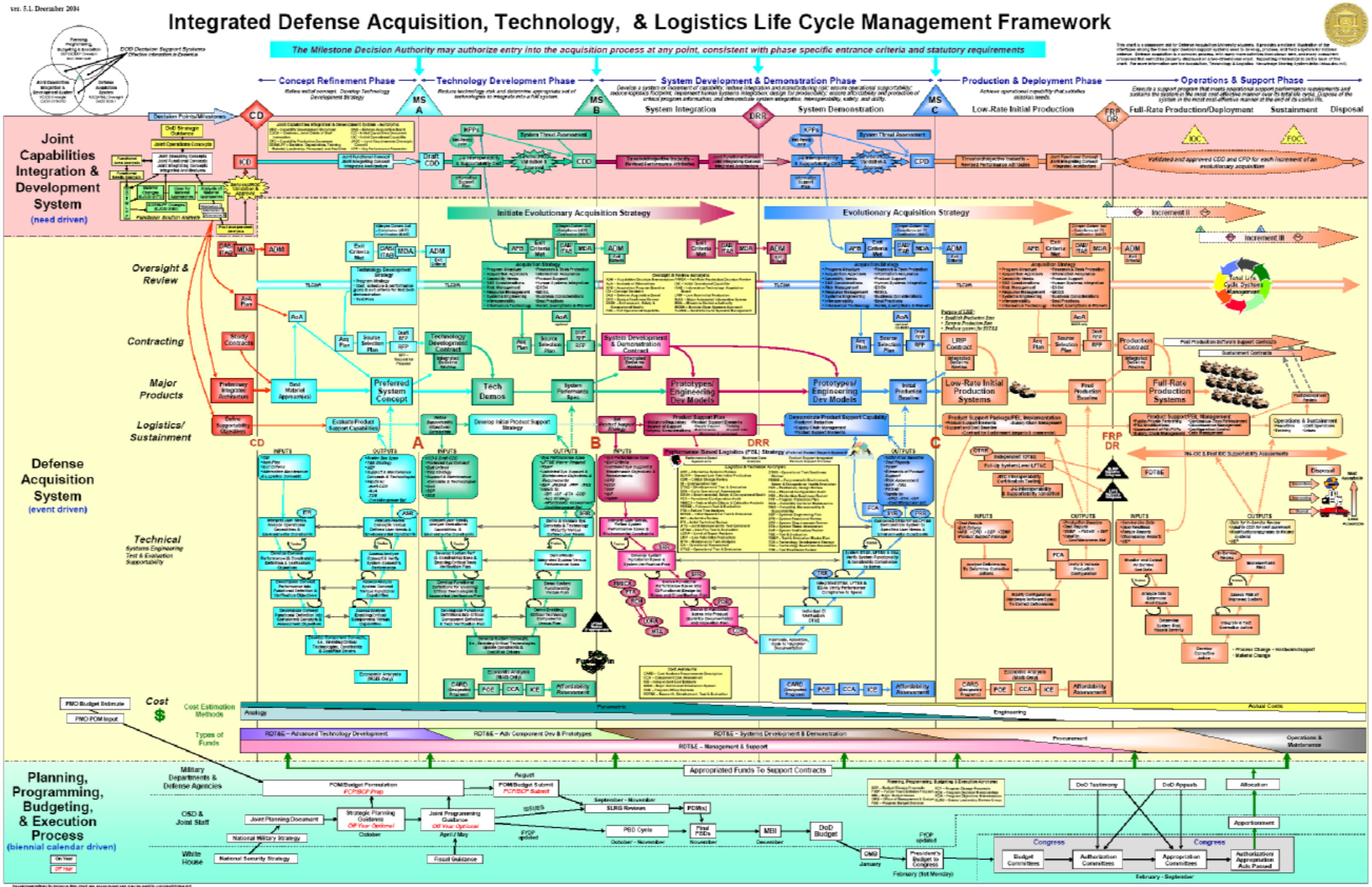
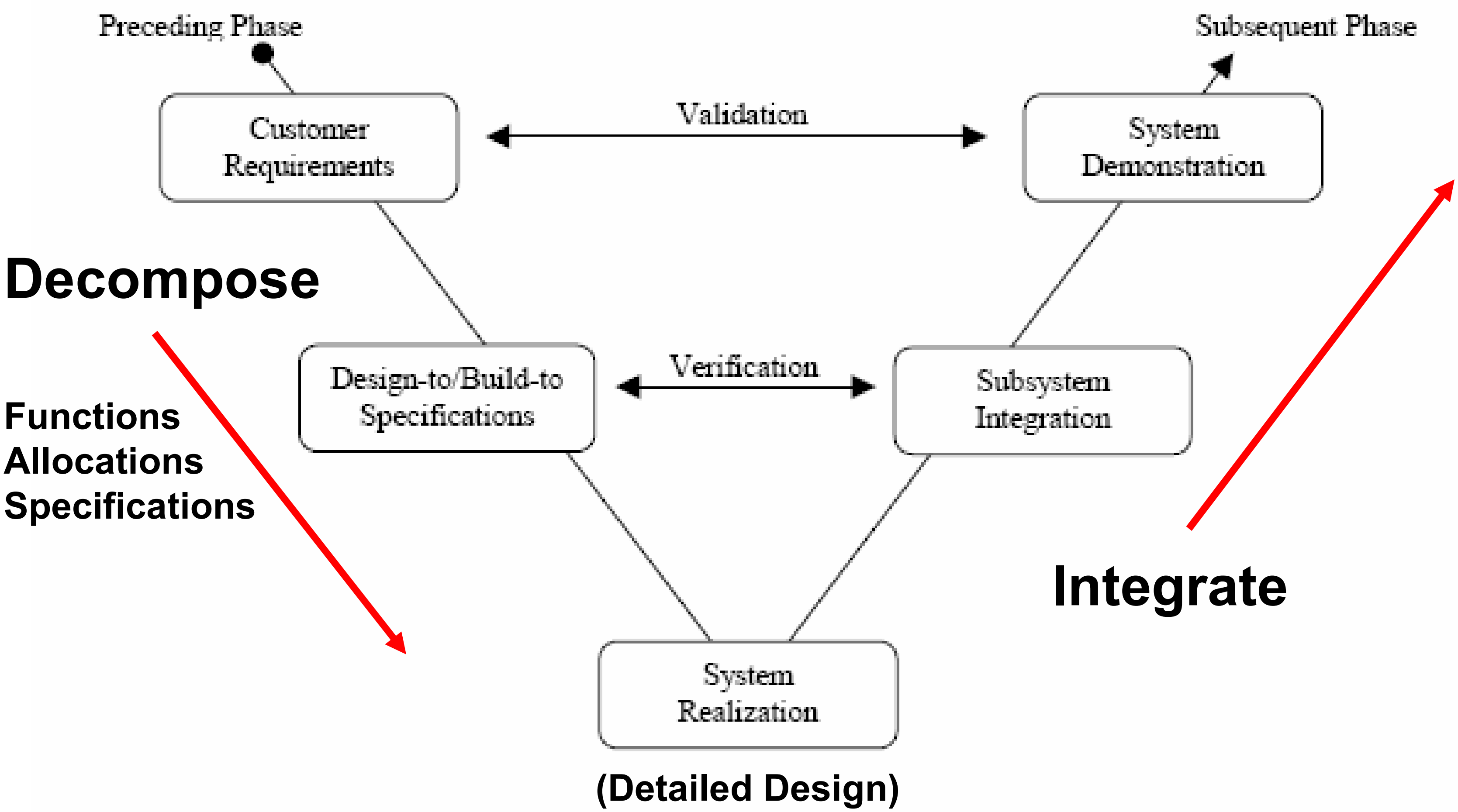
Integrated Systems Engineering
"The Wall Chart"



Phase Characteristics

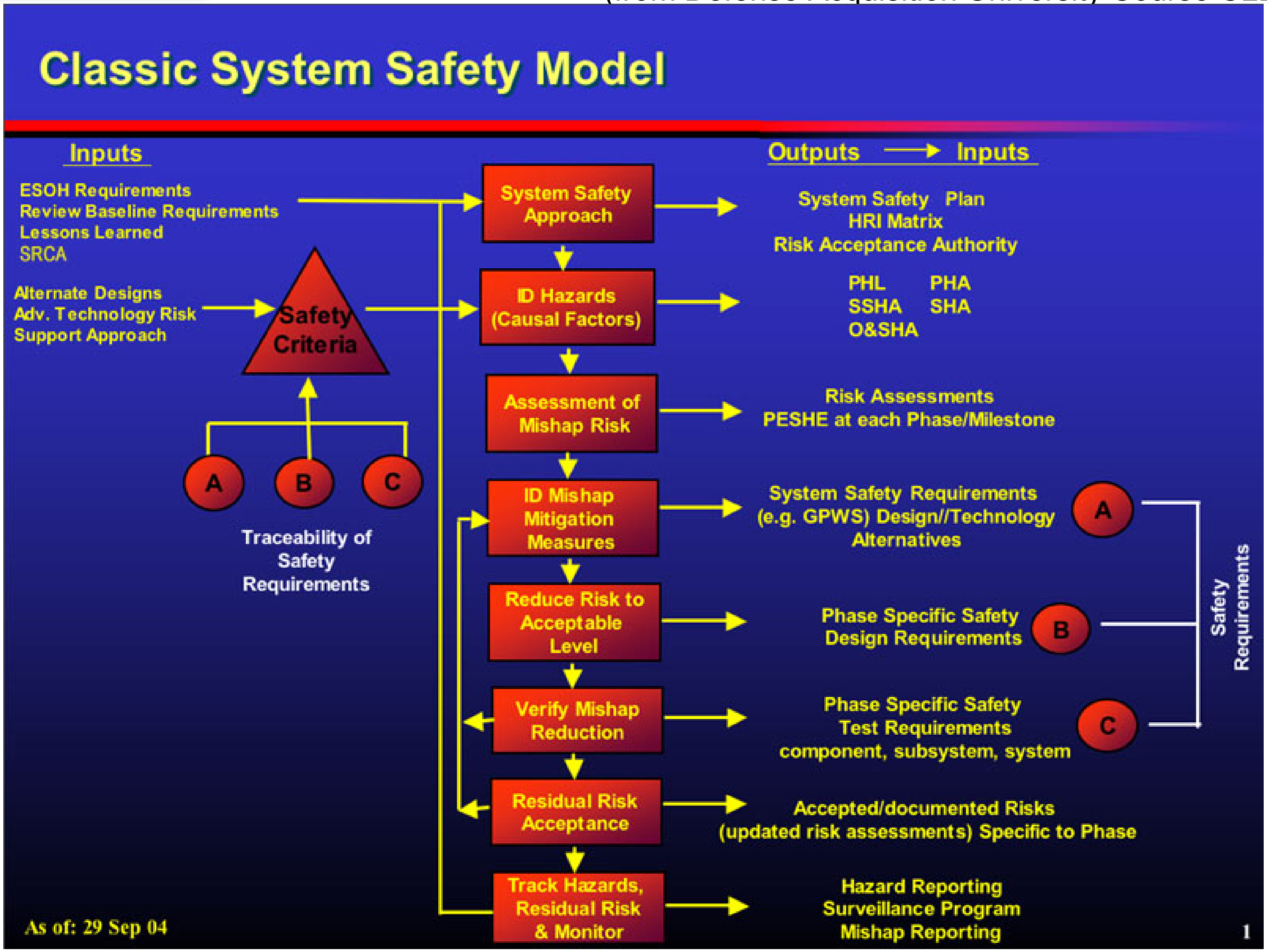
- Phase-specific Technical Baseline
- Phase-specific “Requirements” Review including “Derived” Requirements
- Requirements Analysis
- Functional Decomposition
- Functional and Physical Allocations
- Subsystem and Component Specifications
- Component, Subsystem & System Integration
- Verification and Validation Activities

Systems Engineering V-model
(generalized)

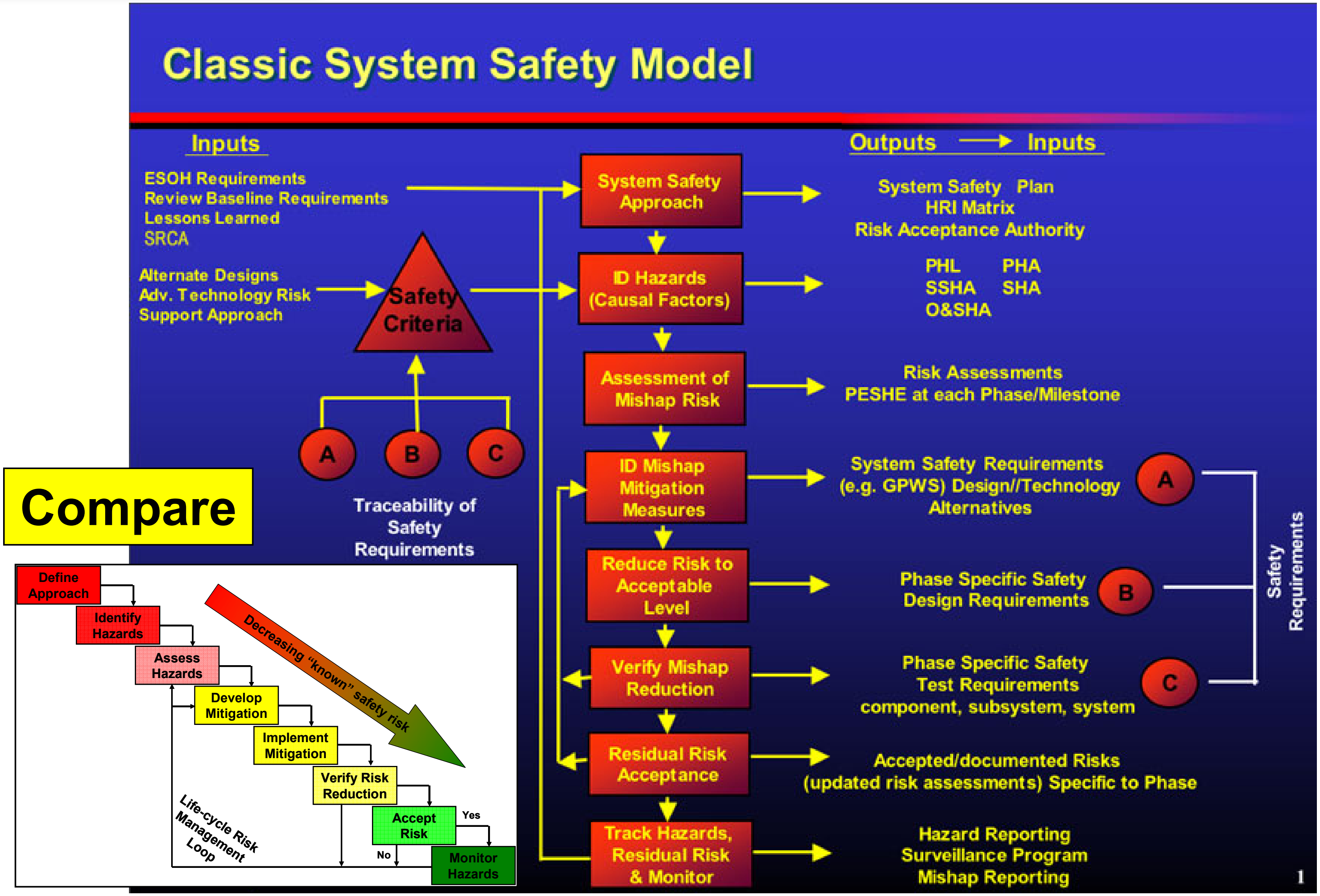


“Integrated” System Safety Model

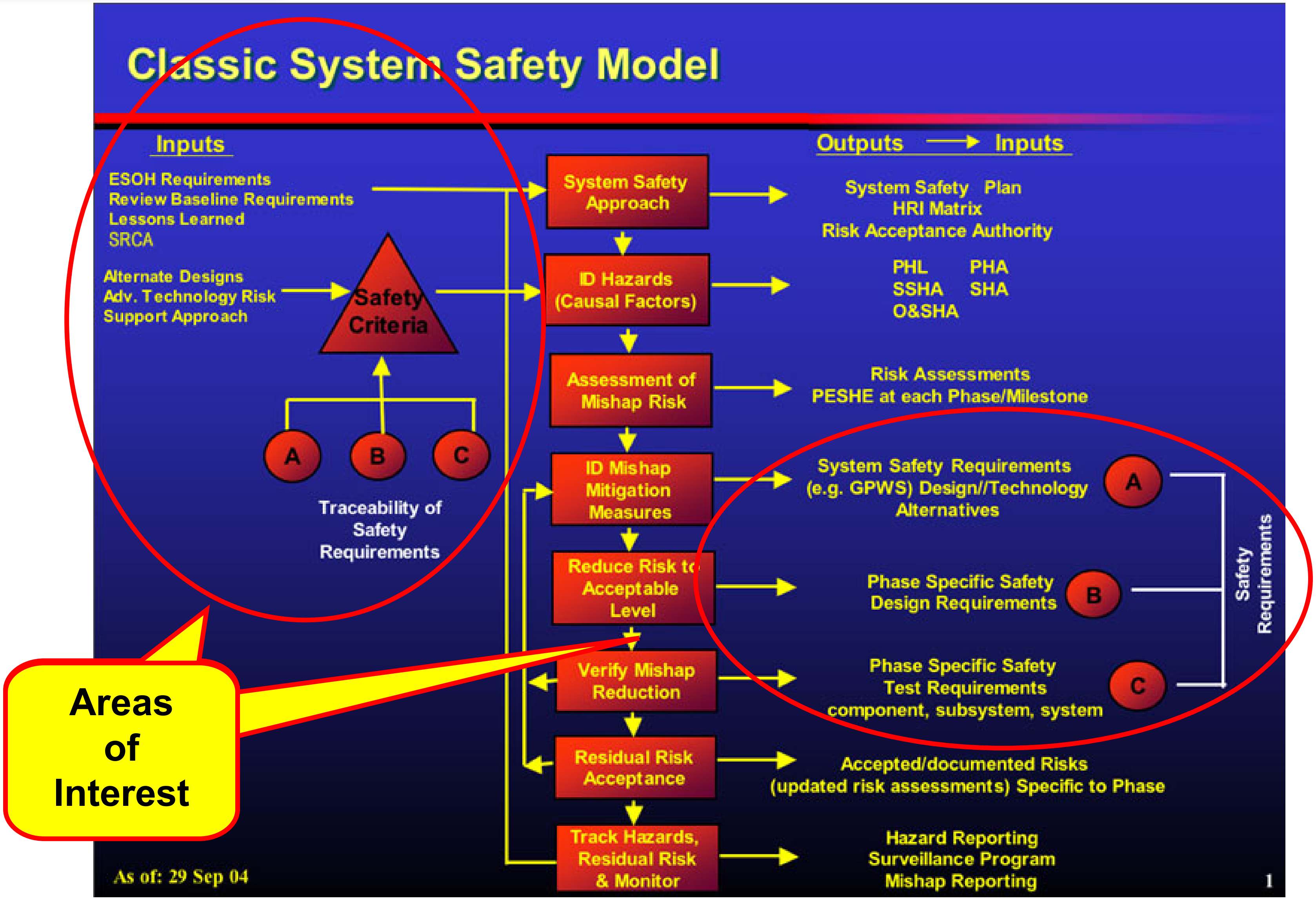
(from Defense Acquisition University Course CLE009)



“Integrated” System Safety Model



"Integrated" System Safety Model



System Safety Requirements

- **Phase Specific**
- **Managed with Other System Engineering Artifacts**
  - Requirements Traceability (requirements tool)
  - CONOPS, Conceptual Design & System Architecture
  - Verification and Validation Tests (e.g., TEMP)
- **Part of Technical Baseline for Each Phase**
  - Alternative System Review
  - System Functional Review
  - System Requirements Review
  - Preliminary Design Review
  - Critical Design Review
  - Test Readiness Review

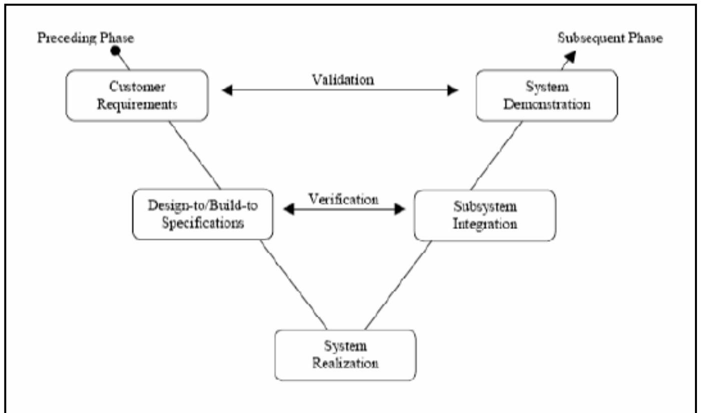


Figure 3 – System Engineering V-model[4]

System Safety Requirements

- Phase Specific
- Managed with Other System Engineering Artifacts
  - Requirements Traceability Matrix
  - CONOPS, Conceptual Design & System Architecture
  - Verification and Validation Tests (e.g., TEMP)
- Part of Technical Baseline for Each Phase
  - Alternative System Review
  - System Functional Review
  - System Requirements Review
  - <u>Preliminary Design Review</u>
  - Critical Des n Review
  - Test Read Review

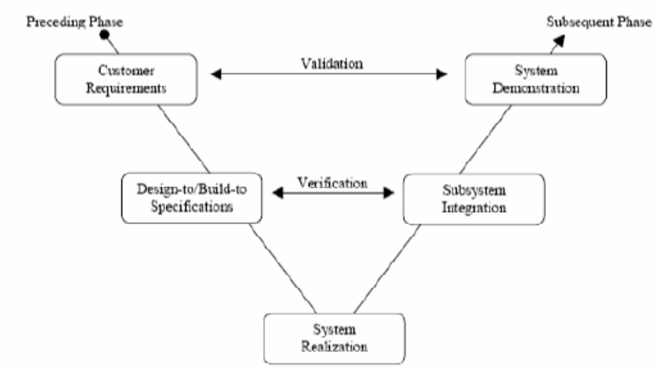


Figure 3 – System Engineering V-model[4]

Somewhere just before here is typical entry point!!

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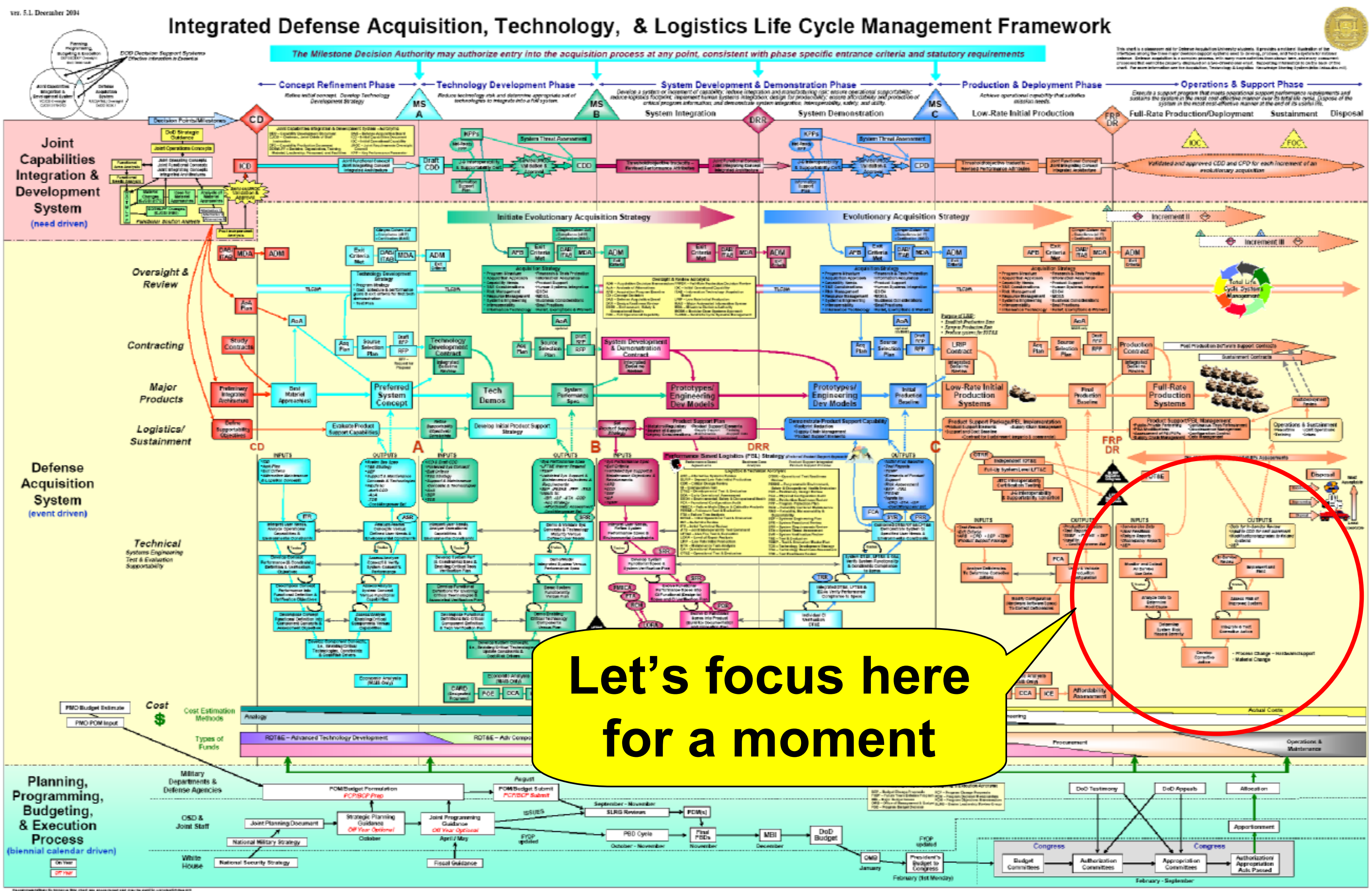
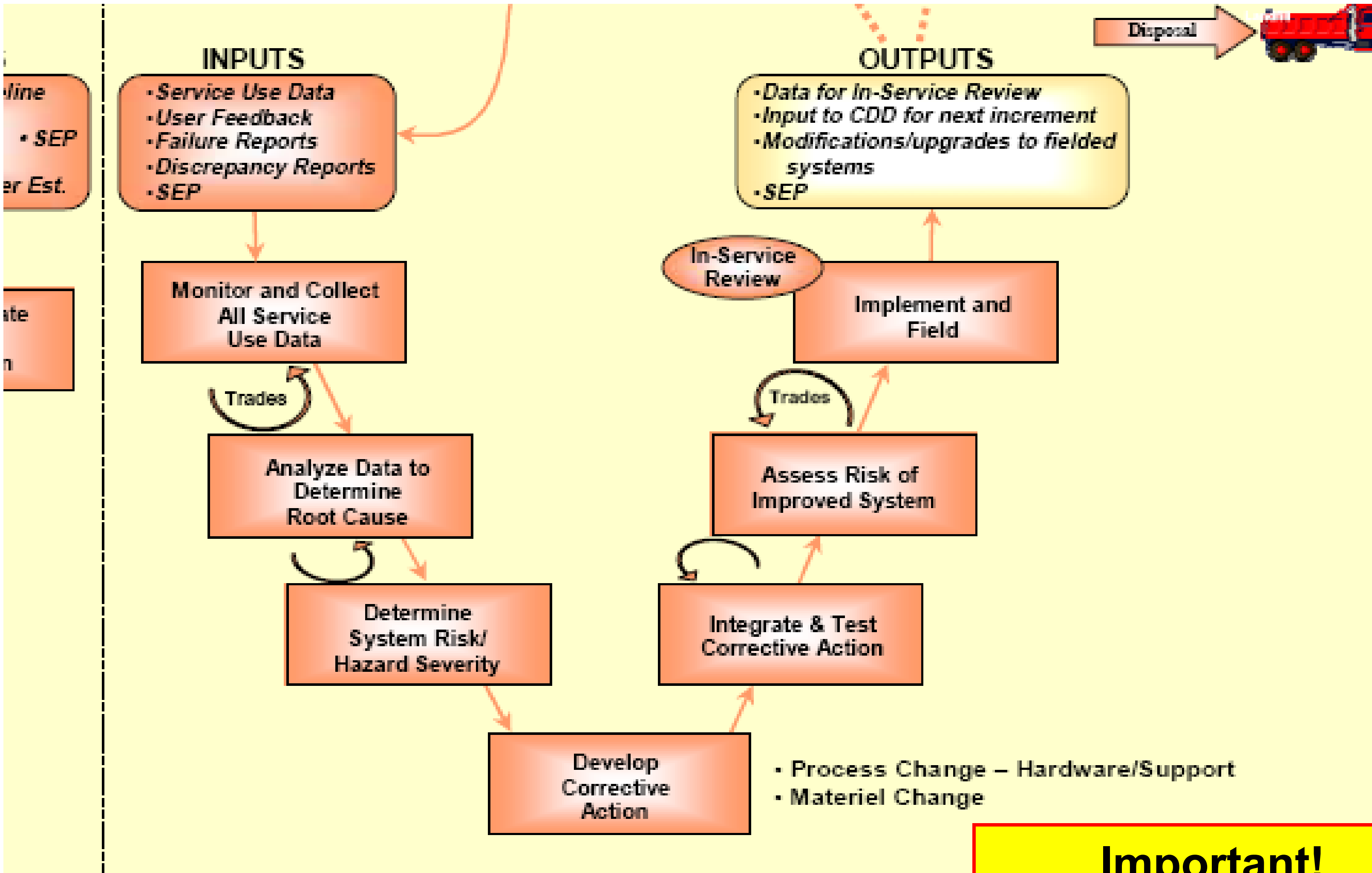
Integrated Systems Engineering "The Wall Chart"



Let's focus here for a moment

Life Cycle Framework In-service System Safety Requirements



Important!

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Conclusions

- Requirements, Requirements, Requirements
  - The language of the systems & design engineers
- Integration of System Safety into System Engineering Framework is Critical
- Framework is the Key
- Conditions are Right (OSD is an Advocate)
- Must Understand and Spread the Word

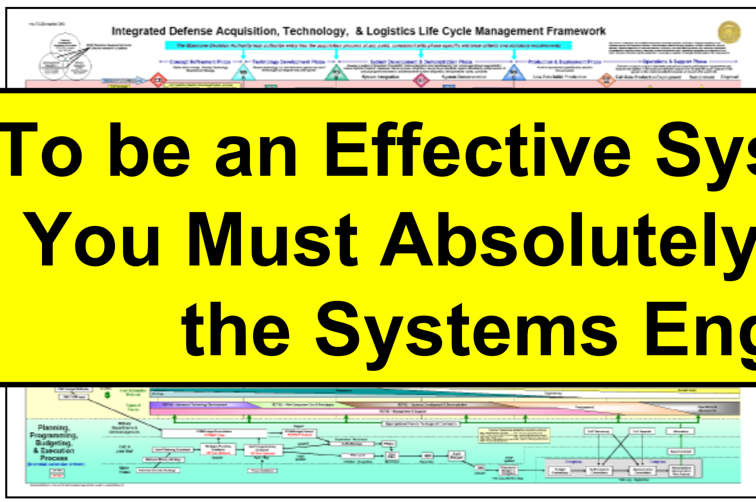

Figure 3 – System Engineering V-model[4]

To be an Effective System Safety Practitioner, You Must Absolutely Understand and Speak the Systems Engineering Process!!

The Return of Discipline

From Operational Safety, Suitability and Effectiveness (OSS&E)
To
Systems Engineering Implementation at Air Force Materiel Command

Presented By: Jackie Townsend
HQ AFMC/ENP
Wright-Patterson AFB, OH

Overview

- OSS&E Policy History
- Policy Execution
- OSS&E Implementation Efforts
- Three "R"'s of Systems Engineering
- Way Forward

Overview

- OSS&E Policy History
- Policy Execution
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- Way Forward

OSS&E Policy History

- Series of aircraft mishaps/ incidents

- Loss of Discipline
  – Loss of Configuration Control
  – Incomplete or outdated Technical Data
  – Unqualified People or Organizations making modifications/changes
  – Unauthorized changes
  – Lack of or incomplete testing
  – Improper procedures/procedures not followed
  – Lack of interface controls
  – Improper integration

OSS&E Policy History

- AFMC Response
  - Discussed with CSAF / SecAF and Subsequent Direction
  - Established Policies for Preserving Operational Safety, Suitability & Effectiveness (OSS&E)
    - Published AFPD 63-12, AFI 63-1201 & AFMCI 63-1201
      - Preserve Established Baseline Characteristics Throughout Operational Life of a System or End-Item
      - Designate Responsibility and Authority
      - Use Disciplined Processes
      - Maintain Baselines Throughout Operational Life

Essentially…Systems Engineering +

Overview

- OSS&E Policy History
- Policy Execution
- OSS&E Implementation Efforts
- Three "R"'s of Systems Engineering
- Way Forward

Policy Execution

Assure OSS&E … employ disciplined processes and effective procedures

OBJECTIVES

- Deliver systems/ end-items with OSS&E baseline
- Preserve the baseline over system life
- Update baseline when making modifications or changes

REQUIRED PROCESSES/PROCEDURES

- Disciplined systems management
- Disciplined systems engineering
  - ORM
  - Systems safety
  - Config mgmt
- Certifications
- Effective ops procedures
- Effective training
- Effective supply, inspection, and maintenance procedures
- Quality sources of supply, maintenance, and repair

Policy Execution

The policies require the preservation of operational safety, suitability, and effectiveness baseline characteristics of delivered systems and end-items over their operational life

Policy Execution

The policies require the preservation of operational safety, suitability, and effectiveness baseline characteristics of delivered systems and end-items over their operational life

Became an "engineering" focus…and at times…an engineering *sustainment* focus

Single Manager/Chief Engineer must know the answers to the tough questions…

What parts are going obsolete?

What are the Operational Requirements?

How is the threat changing?

What are the certification requirements?

Who is making replacement decisions in my supply chain?

What is the fielded configuration of my system/end-item?

Who buys my Spares and what change authority has been delegated to them?

What T.O.s are fielded and are they current?

How is my system aging? How is it performing?

What modifications are being made? How do they impact my systems?

Who does my maintenance? What change authority has been delegated to them?

How many of what type is fielded (Serial # & Tail #)

Overview

- OSS&E Policy History
- Policy Execution
- OSS&E Implementation Efforts
- Three "R'"s of Systems Engineering
- Way Forward

HQ AFMC OSS&E Implementation Levels

- Level 1 - Chief Engineer Assigned
- Level 2 - Configuration Control Processes Established
- Level 3 - Plan to Assure and Preserve OSS&E Documented
- Level 4 - OSS&E Baselines Developed and Coordinated with User
- Level 5 - OSS&E Assessment of Fielded Systems and/or End Items
- Level 6 - Full OSS&E Policy Compliance

Driving the wrong behavior…change is needed

Overview

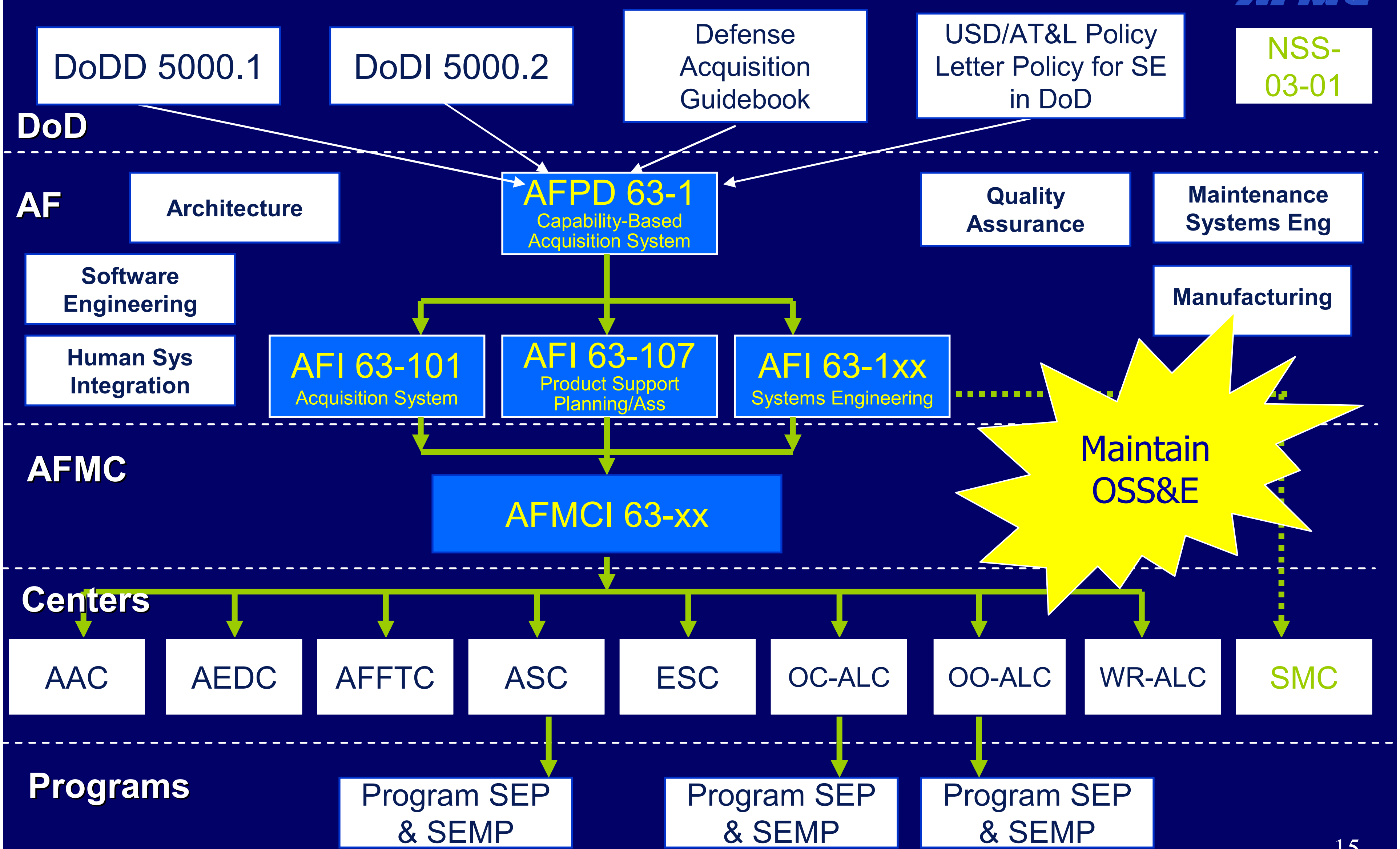
- OSS&E Policy History
- Policy Execution
- OSS&E Implementation Efforts
- Three “R”’s of Systems Engineering
- Way Forward

Three “R”’s of Systems Engineering

- Revitalize Processes/Policies
- Restore Technical Rigor
- Review Strategy

Revitalize Processes/Policies

Systems Engineering Policy-Vision



Restore Technical Rigor

- ✓ Development of technical integrity handbook/training
- ✓ Requirement for Systems Engineering Plan
- ✓ Publishing of key criteria for engineers
- Establishment of clear standards/metrics
- Alignment of SE and OSS&E

Review Strategy

- Establishment of clear standards/metrics
- Alignment of SE and OSS&E
    - •SE AFI (The Role of Systems Engineering)
    - •OSS&E (SE Process Assurance Standard)
    - •Standardized Reporting
    - •Training

Overview

- OSS&E Policy History
- Policy Execution
- OSS&E Implementation Efforts
- Three “R”’s of Systems Engineering
- Way Forward

Integrated Approach

Top-level policy

SE AFI – *The Role Of System Engrg*

Core Elements
- Requirements
- Planning
- CM
- Risk/Safety
- Interop
- Sys Mgmt
- Ops Procs
- Quality Sources
- Software
-

APP
- Other elements

OSS&E
Assurance Standards

Standards
- Requirements
- Planning
- CM
- Risk/Safety
- Interop
- Sys Mgmt
- Ops Procs
- Quality Sources
- Software
- ~~RTOC~~
- Standards for OSS&E baselines & reporting

APP
- Stds for other elements

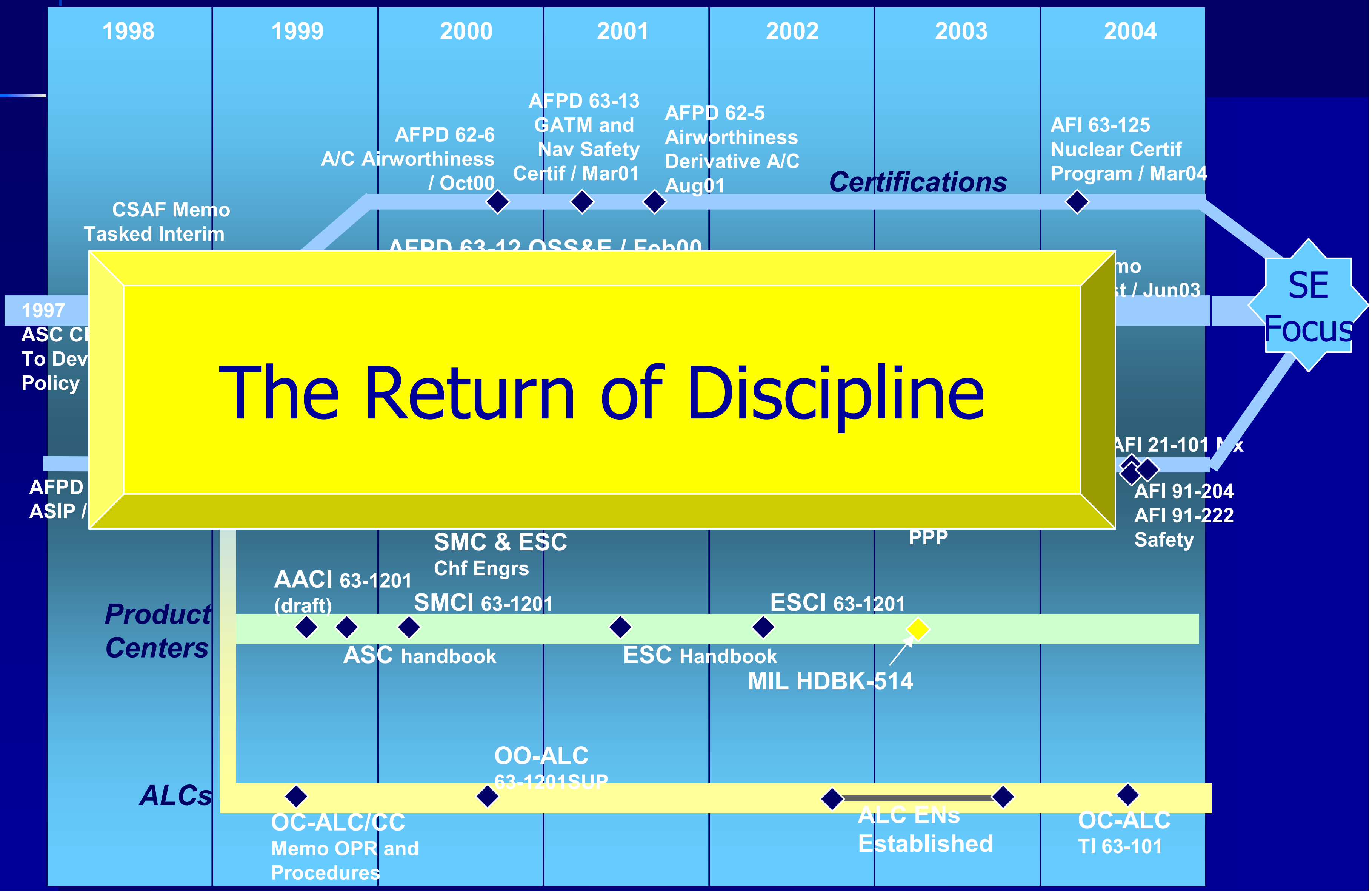
Standards for OSS&E

Update core elements based on SE AFI, Key elements…

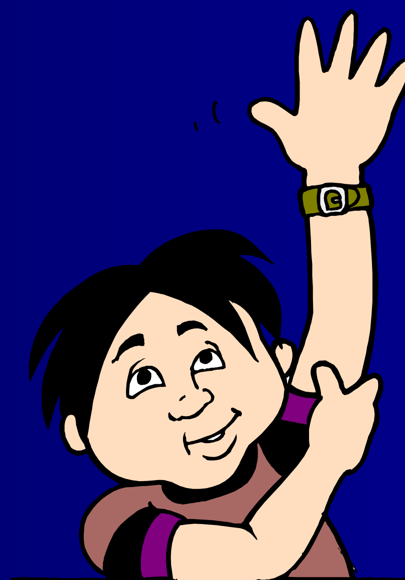
Integrated Approach

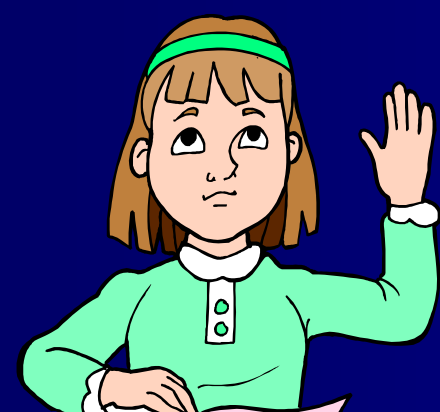
SE AFI – *The Role Of System Engrg*	**OSS&E** *Assurance Standards*	**Training –** *Systems Engineering & OSS&E*
Core Elements	**Standards**	**Core Elements**
• Requirements	• Requirements	• Requirements
• Planning	• Planning	• Planning
• CM	• CM	• CM
• Risk/Safety	• Risk/Safety	• Risk/Safety
• Interop	• Interop	• Interop
• Sys Mgmt	• Sys Mgmt	• Sys Mgmt
• Ops Procs	• Ops Procs	• Ops Procs
• Quality Sources	• Quality Sources	• Quality Sources
• Software	• Software	• Software
•	• ~~RTOC~~	
	• Standards for reporting OSS&E	• Standards for reporting OSS&E

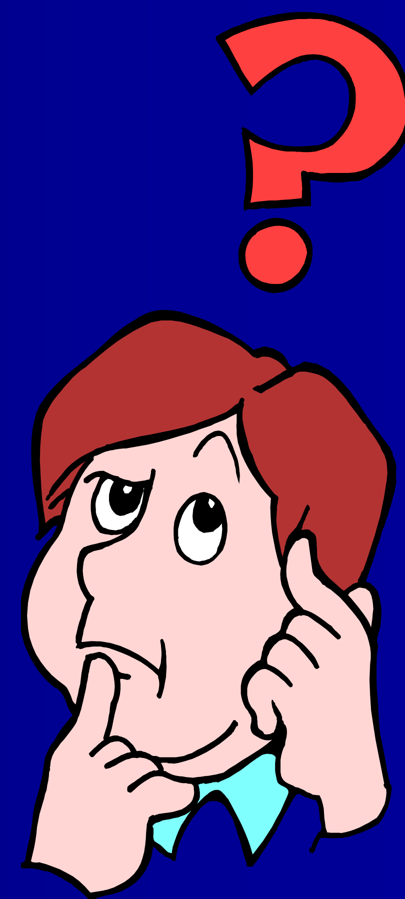
Where we're headed



Questions







Back-ups

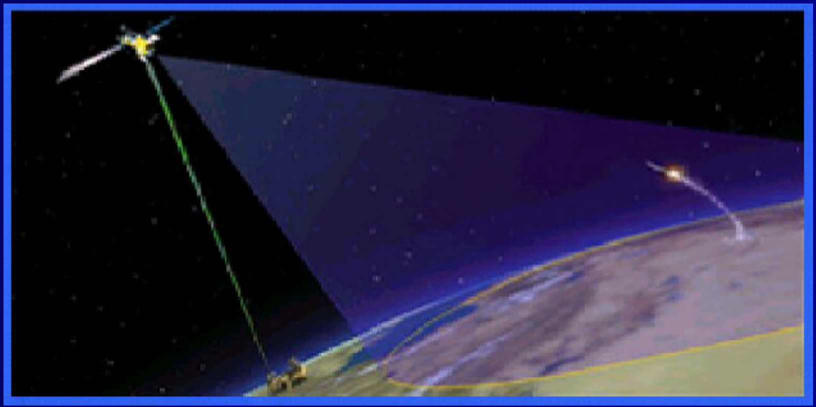
Safety

Operational Safety metrics:

- Air Worthiness
- Certification,
- Mishap Risk, Loss Rate...

With the operational life of weapon systems often extending 50-70 years, preservation of combat capability is essential. The policy aims to ensure the same low level of safety risk we boast at fielding is maintained across the operational life.

Suitability



Operational Suitability metrics:
Mission Capability Rate,
MTBF, MTBF, MTTR, …

The policy ensures that as the "systems of systems" architecture changes, the weapon system will remain equally suited to the task

Effectiveness

Operational Effectiveness metrics:

Range, Payload, Cargo Capability, …

It also ensures the effectiveness of the system as far as accuracy, endurance, etc., remains constant over the years. To accomplish these ends, clear responsibilities are established both for the single manager, AFMC and the using commands.

Decision Analysis and Resolution

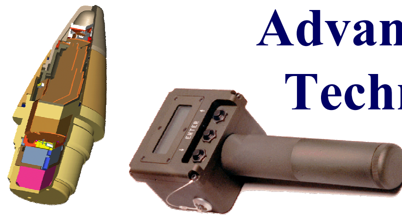
Tailorable Decision Analysis & Resolution process and tools for enterprise wide application

Outline

- Introduction
- ARDEC Systems Engineering
- Decision Analysis and Resolution (DAR)
- DAR Process
- Tailored application of DAR to Technical Trade Study
- Benefits

ARDEC Background

Artillery & Mortar Systems

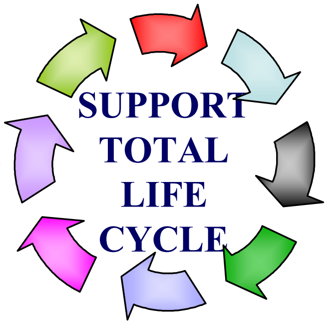


Advanced Fuze Technologies

R&D

Special Operations Weapons & Demolitions

DEMIL



PROD

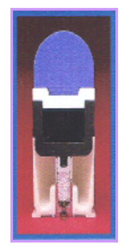
FIELD SUPPORT

Smart Munitions

Advanced Explosives & Warhead Development

Combat Vehicle Armaments & Fire Control

Logistics R&D



Non-Lethal Technologies

Future Small Arms

PROVIDING OVER 90% OF THE ARMY'S LETHALITY...

Introduction

- ARDEC Systems Engineering (SE) Division
  - Established from ARDEC re-organization to focus on disciplined systems engineering

> "System Engineering objectives provides the integrating technical process to define and balance system performance, cost, schedule, and risk."
>
> -Michael W. Wynne
>
> *Acting Under Secretary Of Defense*
> *20 Feb. 2004*

- System Engineering (SE) Process needed a consistent and effective process for making fact based decisions.

Decision Analysis and Resolution Definition

- Analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.

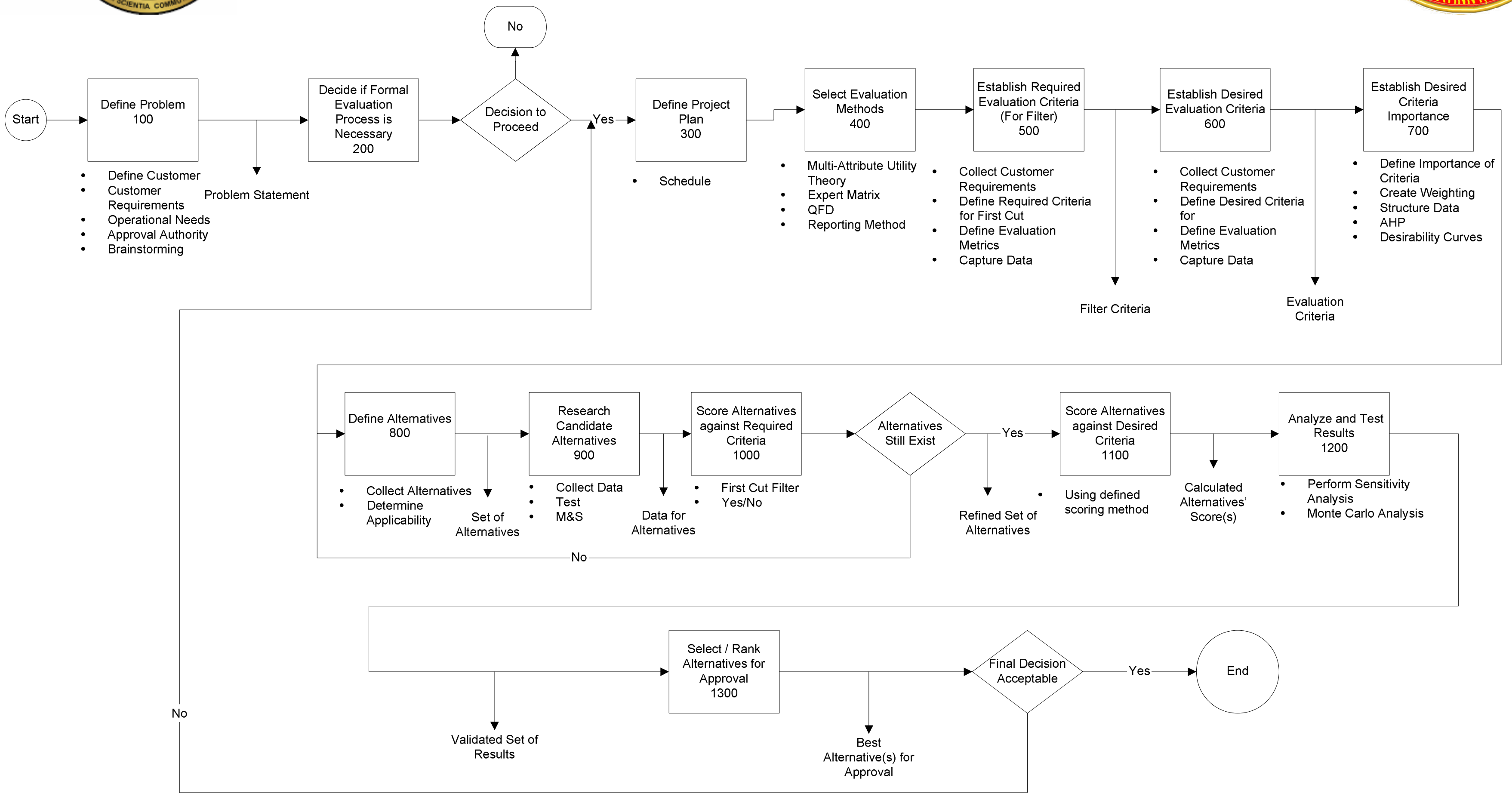
Decision Analysis and Resolution Impact

- Inconsistent DAR processes may…
  - Cause delays/bottlenecks when reviewers inquire how the decision came to being.
  - Raise the learning curve of new IPTs (must agree on common ones).
  - Not reach the best achievable solution.

Approach

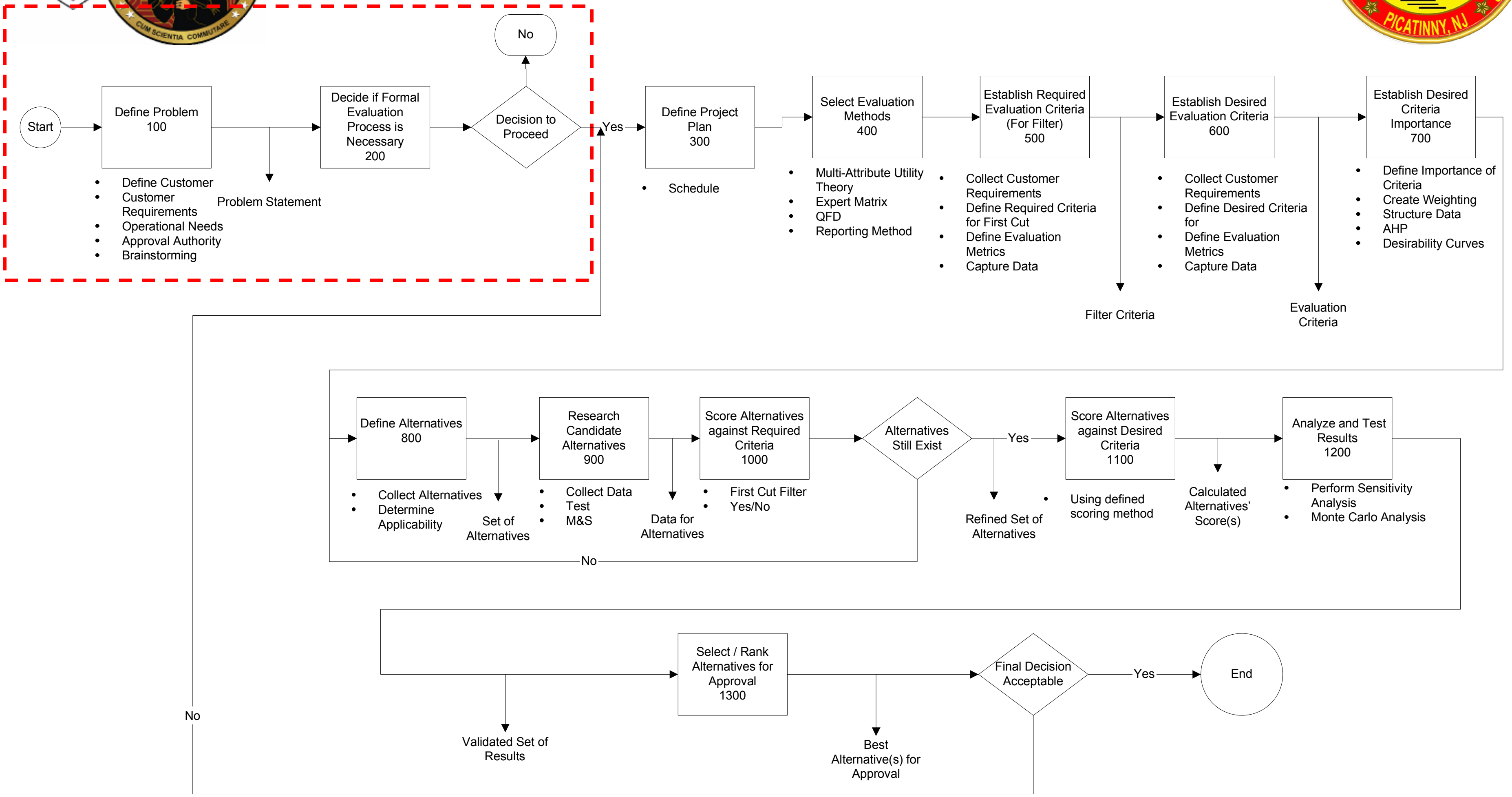
- Used as Six-Sigma Green Belt Project – Major Initiative at ARDEC to use Lean/6-Sigma
- Methodologies/Tools Used
  - Brainstorming
  - Process Map
  - Voice of the Customer
  - FMEA
  - Quality Function Deployment
  - Product Selection Matrix

Level 1 Decision Analysis and Resolution Process

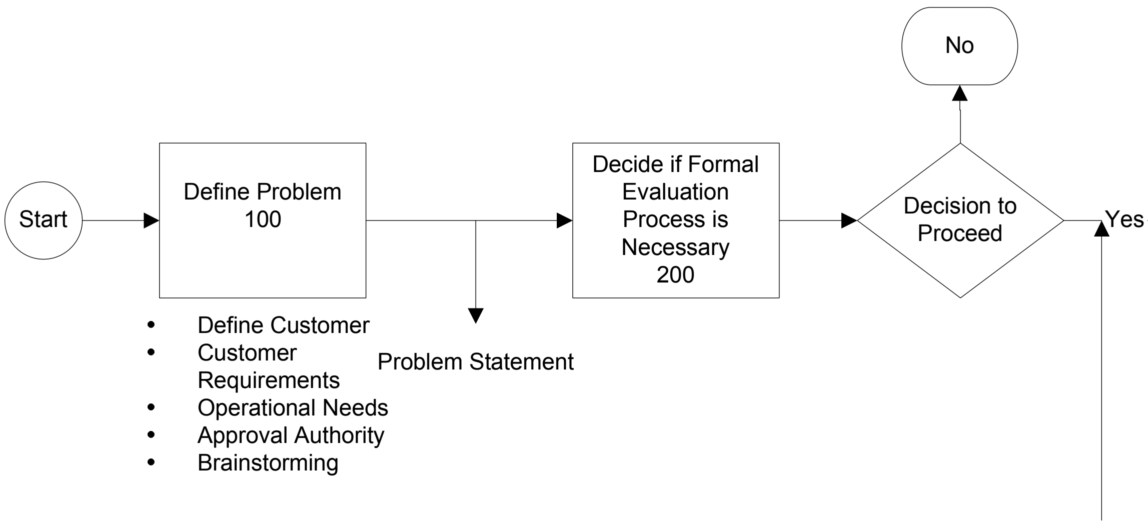


Enabling the American Warfighter to Dominate the Battlefield!

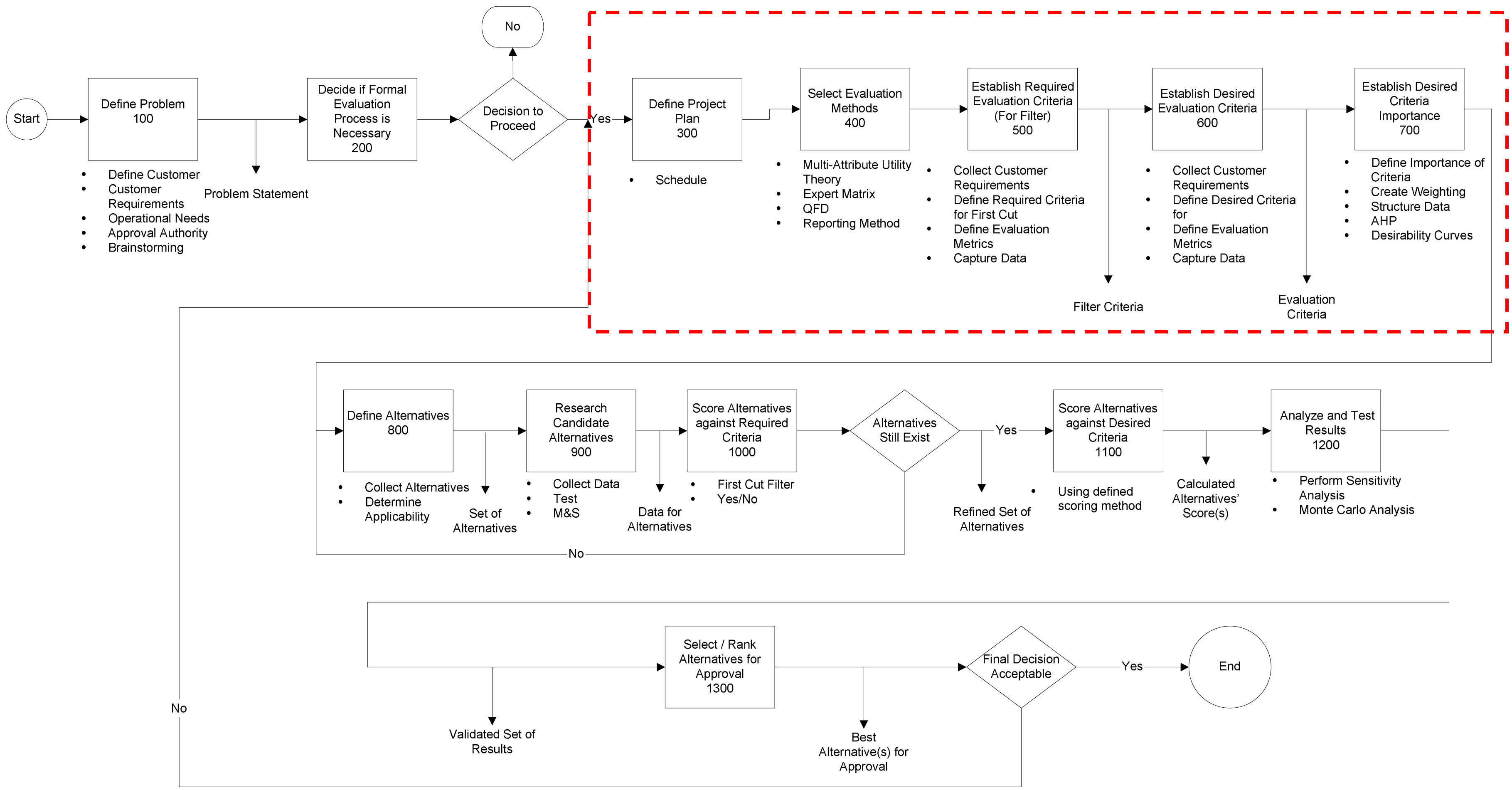
Level 1 Decision Analysis and Resolution Process



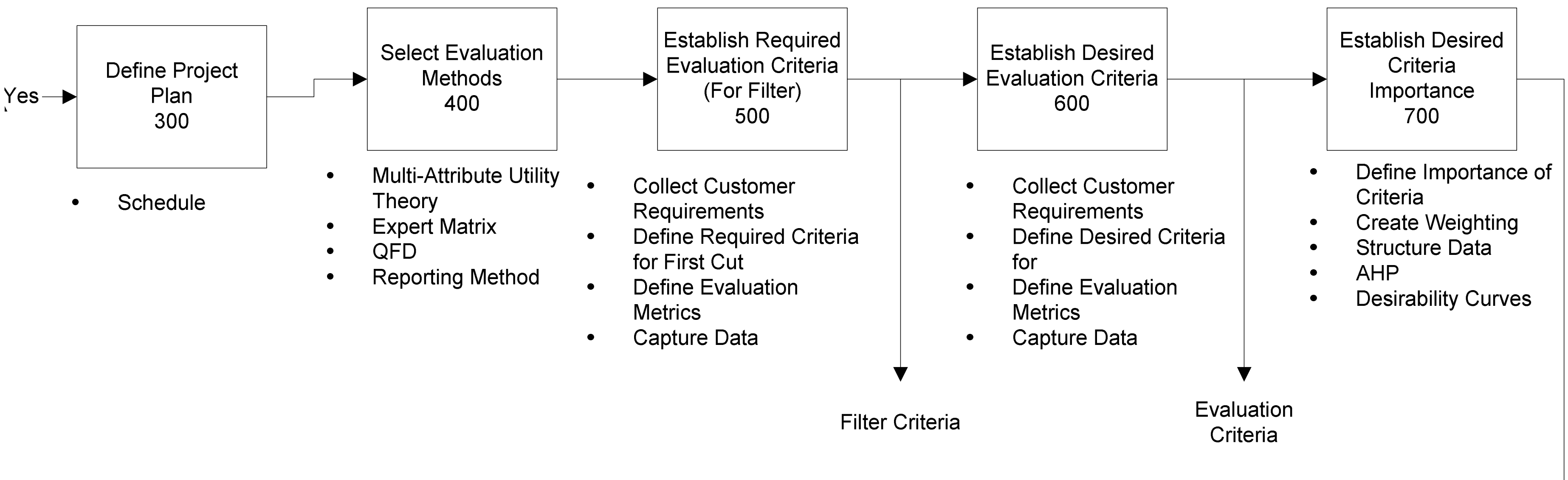
Enabling the American Warfighter to Dominate the Battlefield!


No
Start
Define Problem
100
Decide if Formal
Evaluation
Process is
Necessary
200
Decision to
Proceed
Yes
Problem Statement
• Define Customer
• Customer
Requirements
• Operational Needs
• Approval Authority
• Brainstorming

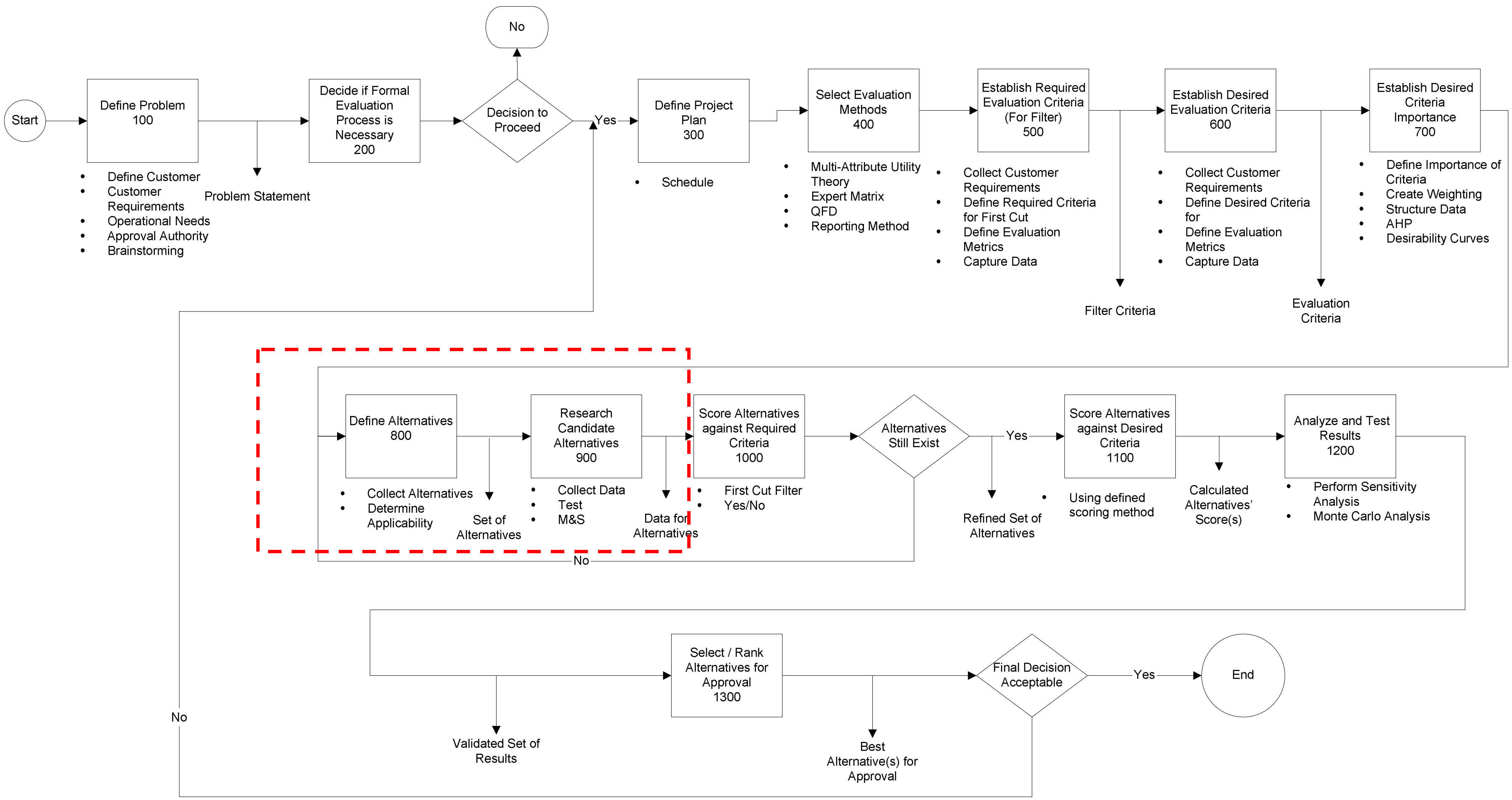
Level 1 Decision Analysis and Resolution Process



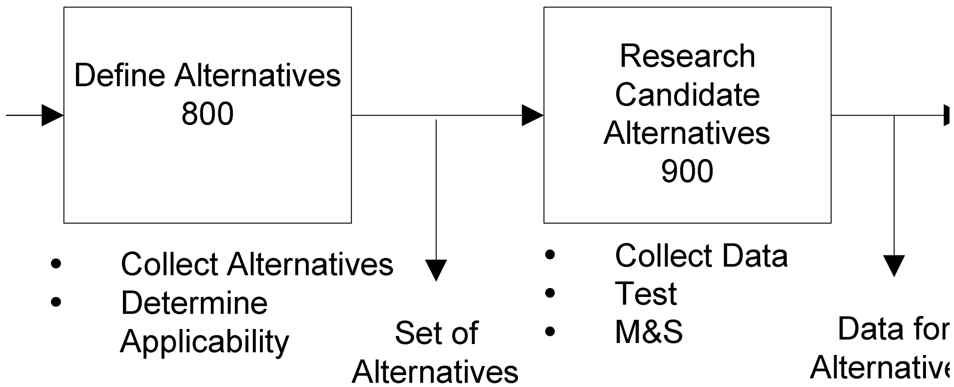
Enabling the American Warfighter to Dominate the Battlefield!


Yes
Define Project Plan 300
• Schedule
Select Evaluation Methods 400
• Multi-Attribute Utility Theory
• Expert Matrix
• QFD
• Reporting Method
Establish Required Evaluation Criteria (For Filter) 500
• Collect Customer Requirements
• Define Required Criteria for First Cut
• Define Evaluation Metrics
• Capture Data
Filter Criteria
Establish Desired Evaluation Criteria 600
• Collect Customer Requirements
• Define Desired Criteria for
• Define Evaluation Metrics
• Capture Data
Evaluation Criteria
Establish Desired Criteria Importance 700
• Define Importance of Criteria
• Create Weighting
• Structure Data
• AHP
• Desirability Curves

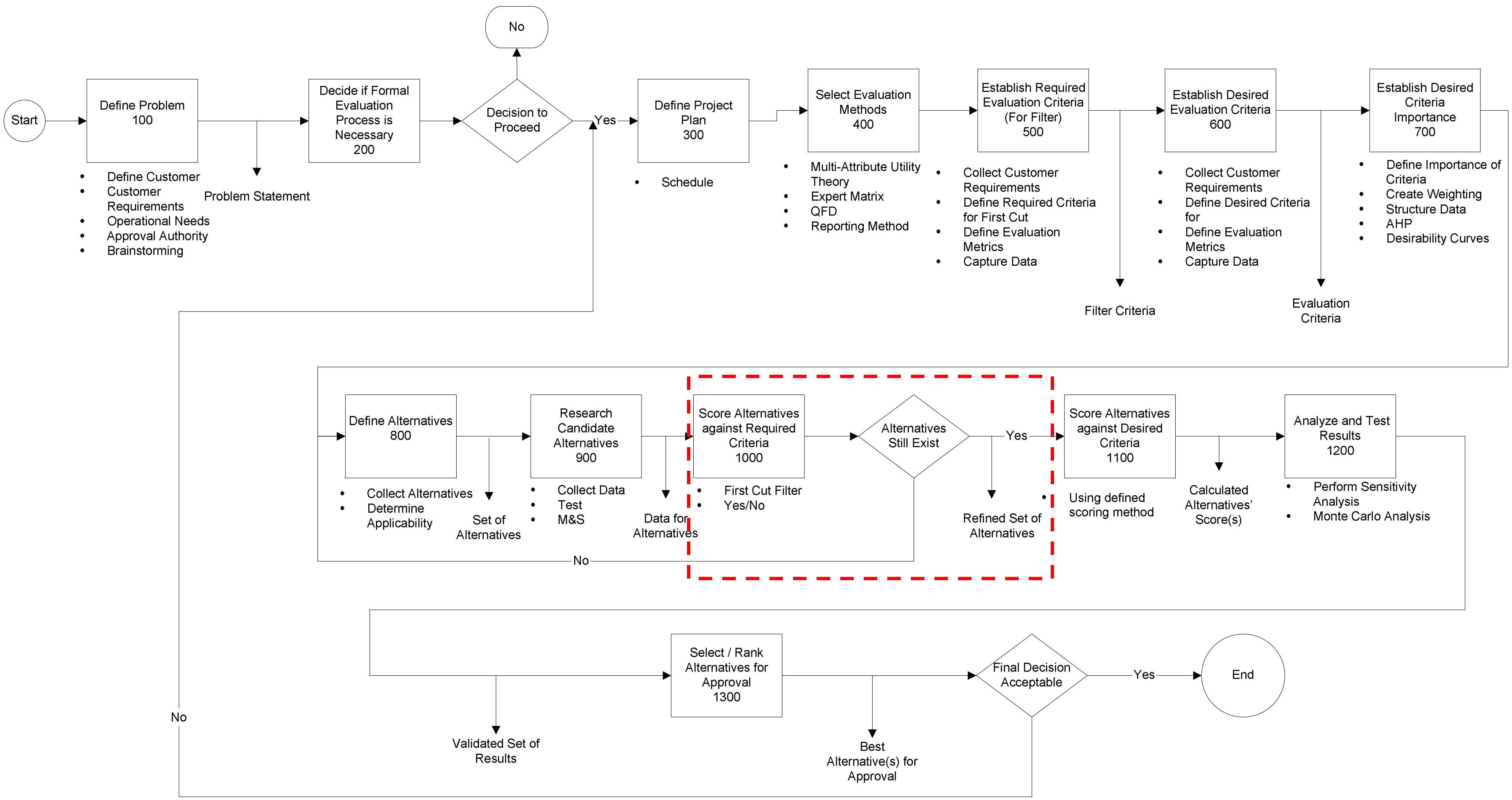
Level 1 Decision Analysis and Resolution Process



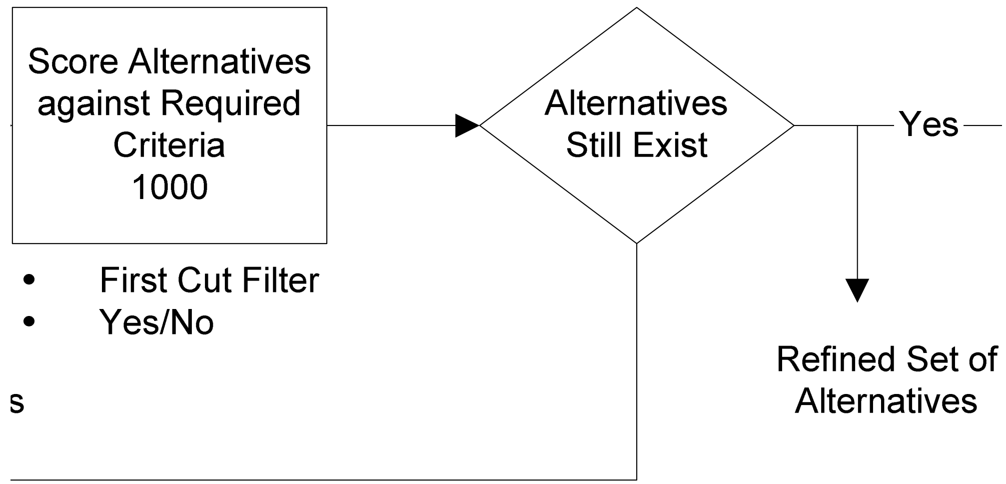
Enabling the American Warfighter to Dominate the Battlefield!


Define Alternatives
800
Research
Candidate
Alternatives
900
Collect Alternatives
Determine
Applicability
Set of
Alternatives
Collect Data
Test
M&S
Data for
Alternative

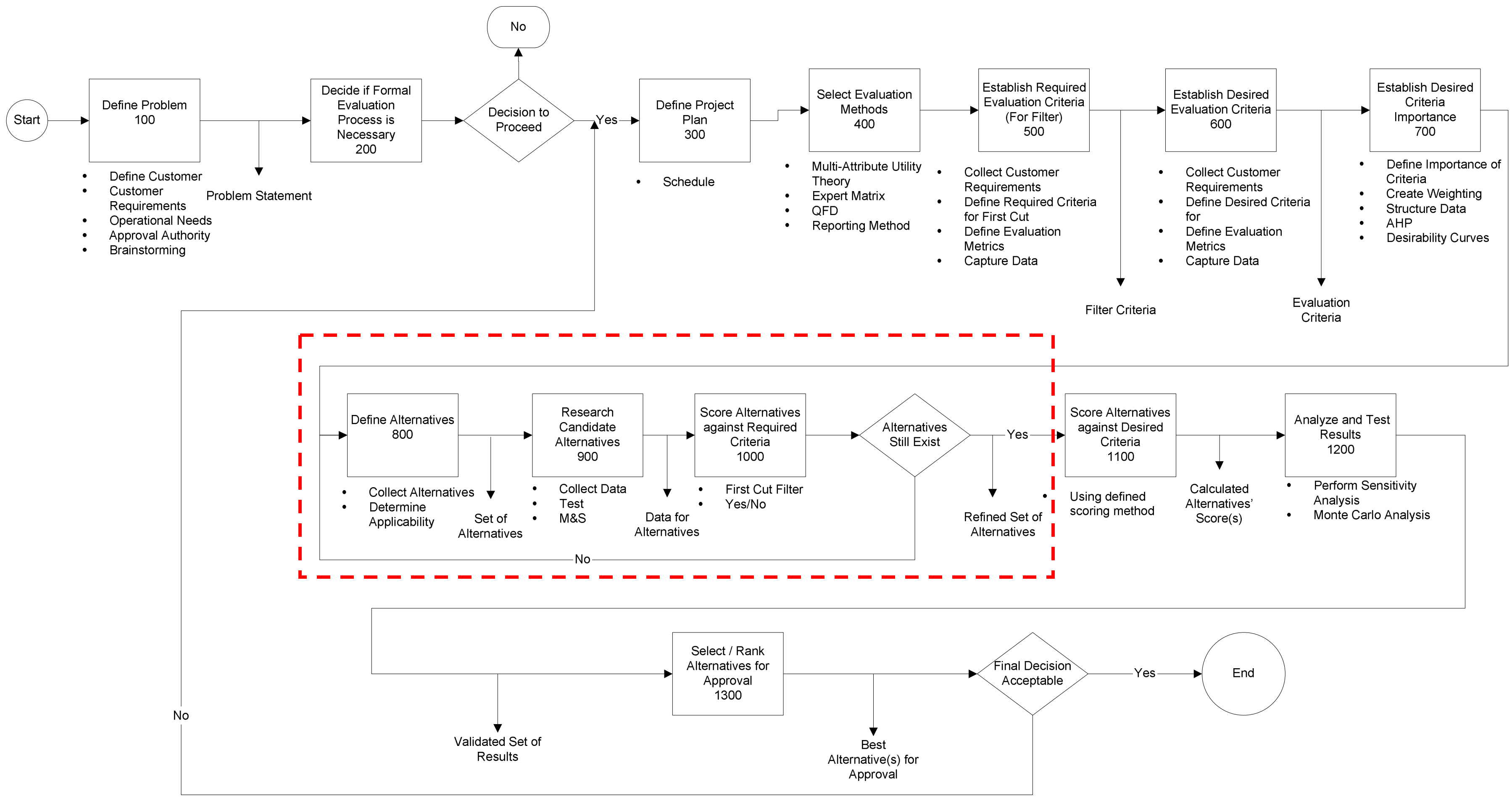
Level 1 Decision Analysis and Resolution Process



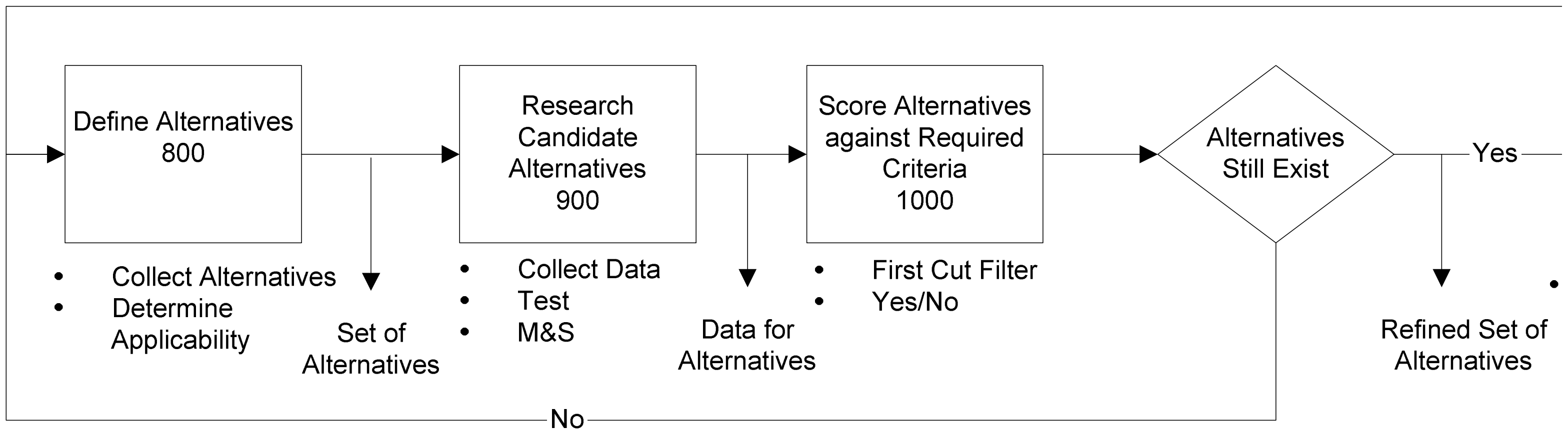
Enabling the American Warfighter to Dominate the Battlefield!


Score Alternatives against Required Criteria 1000
Alternatives Still Exist
Yes
First Cut Filter
Yes/No
s
Refined Set of Alternatives

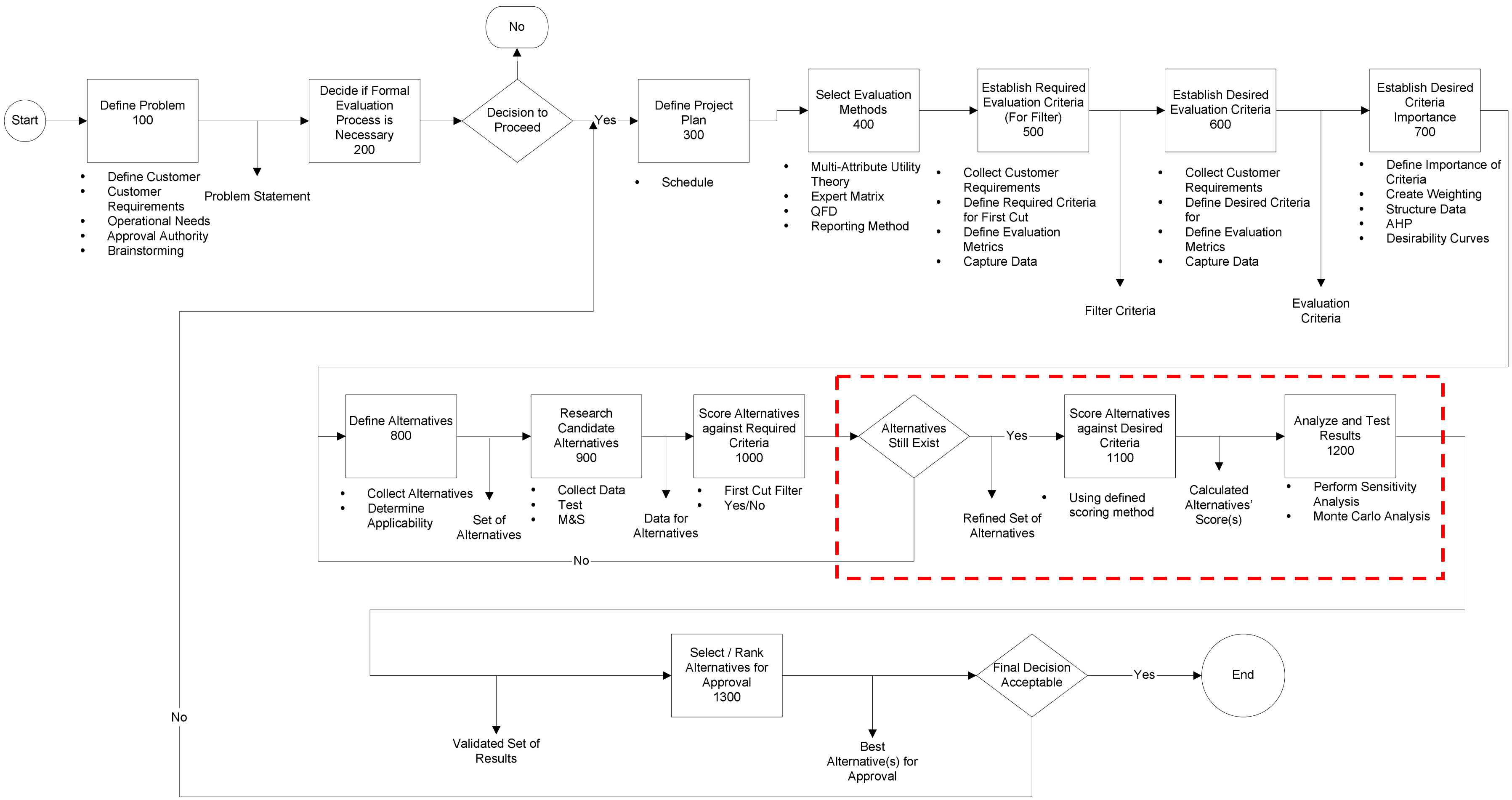
Level 1 Decision Analysis and Resolution Process



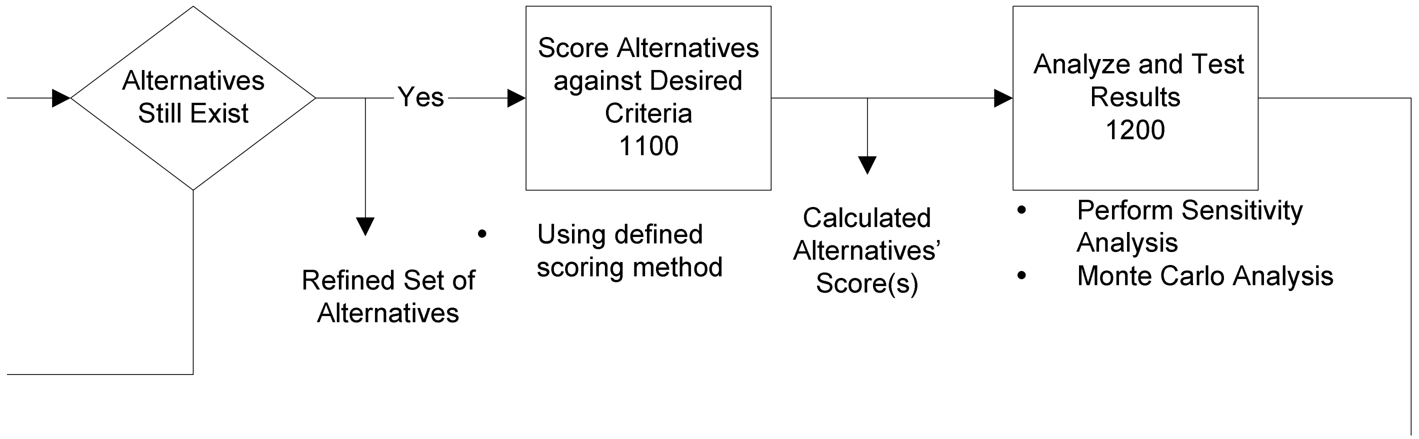
Enabling the American Warfighter to Dominate the Battlefield!


Define Alternatives
800
Collect Alternatives
Determine Applicability
Set of Alternatives
Research Candidate Alternatives
900
Collect Data
Test
M&S
Data for Alternatives
Score Alternatives against Required Criteria
1000
First Cut Filter
Yes/No
Alternatives Still Exist
Yes
No
Refined Set of Alternatives

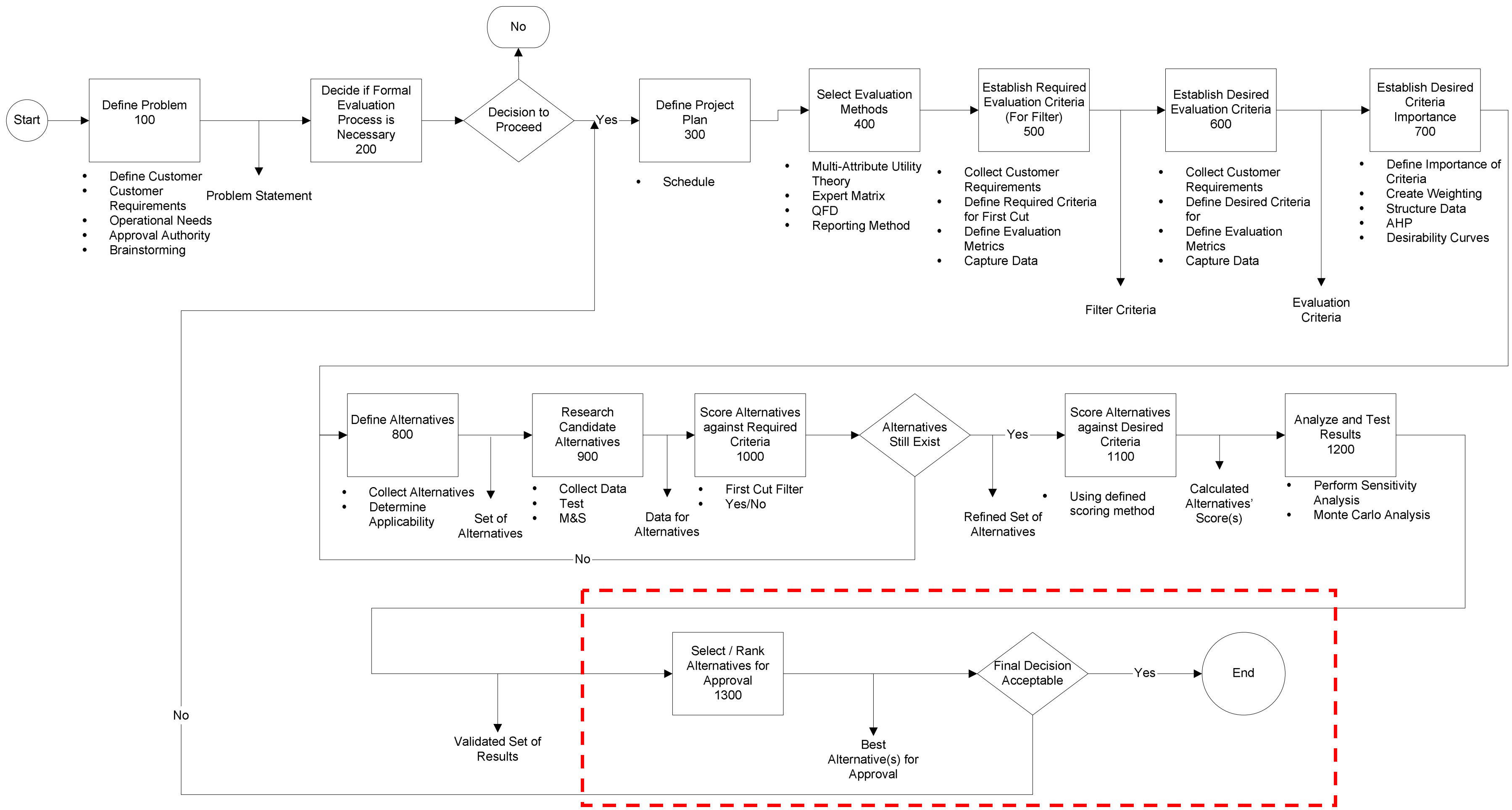
Level 1 Decision Analysis and Resolution Process

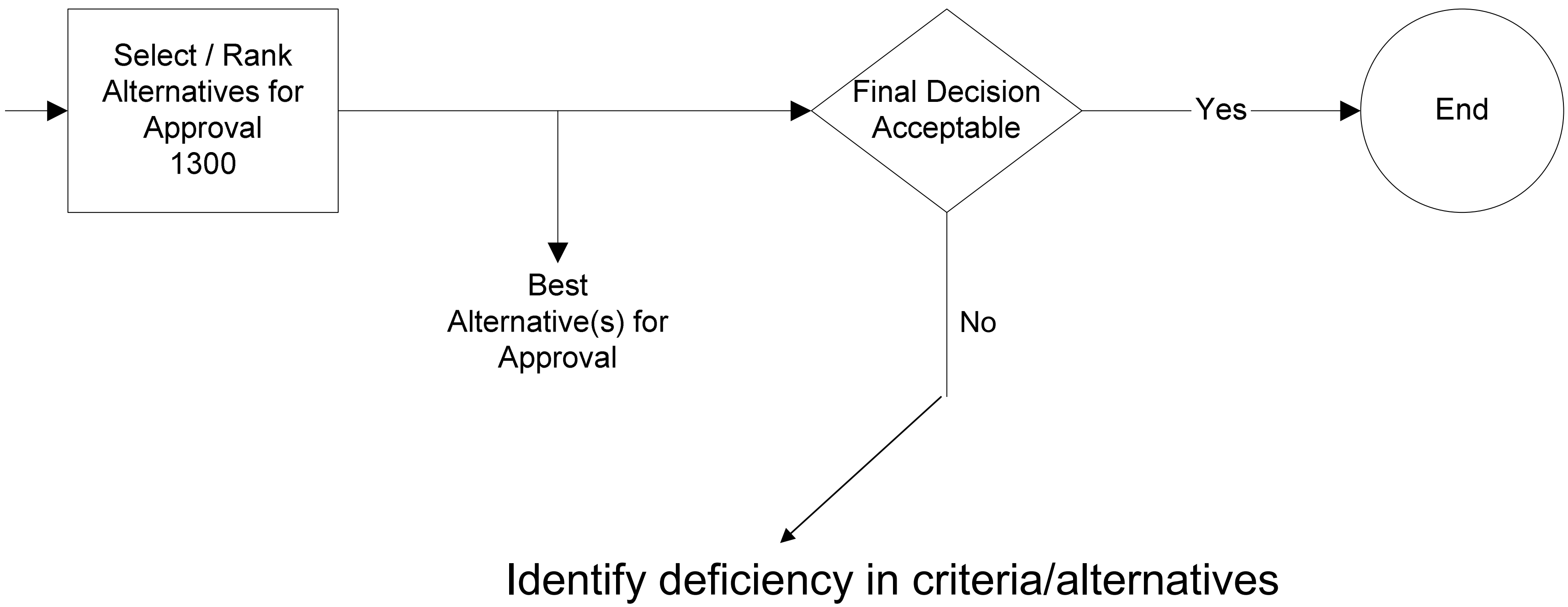


Enabling the American Warfighter to Dominate the Battlefield!


Alternatives Still Exist
Yes
Score Alternatives against Desired Criteria
1100
Analyze and Test Results
1200
Refined Set of Alternatives
• Using defined scoring method
Calculated Alternatives' Score(s)
• Perform Sensitivity Analysis
• Monte Carlo Analysis

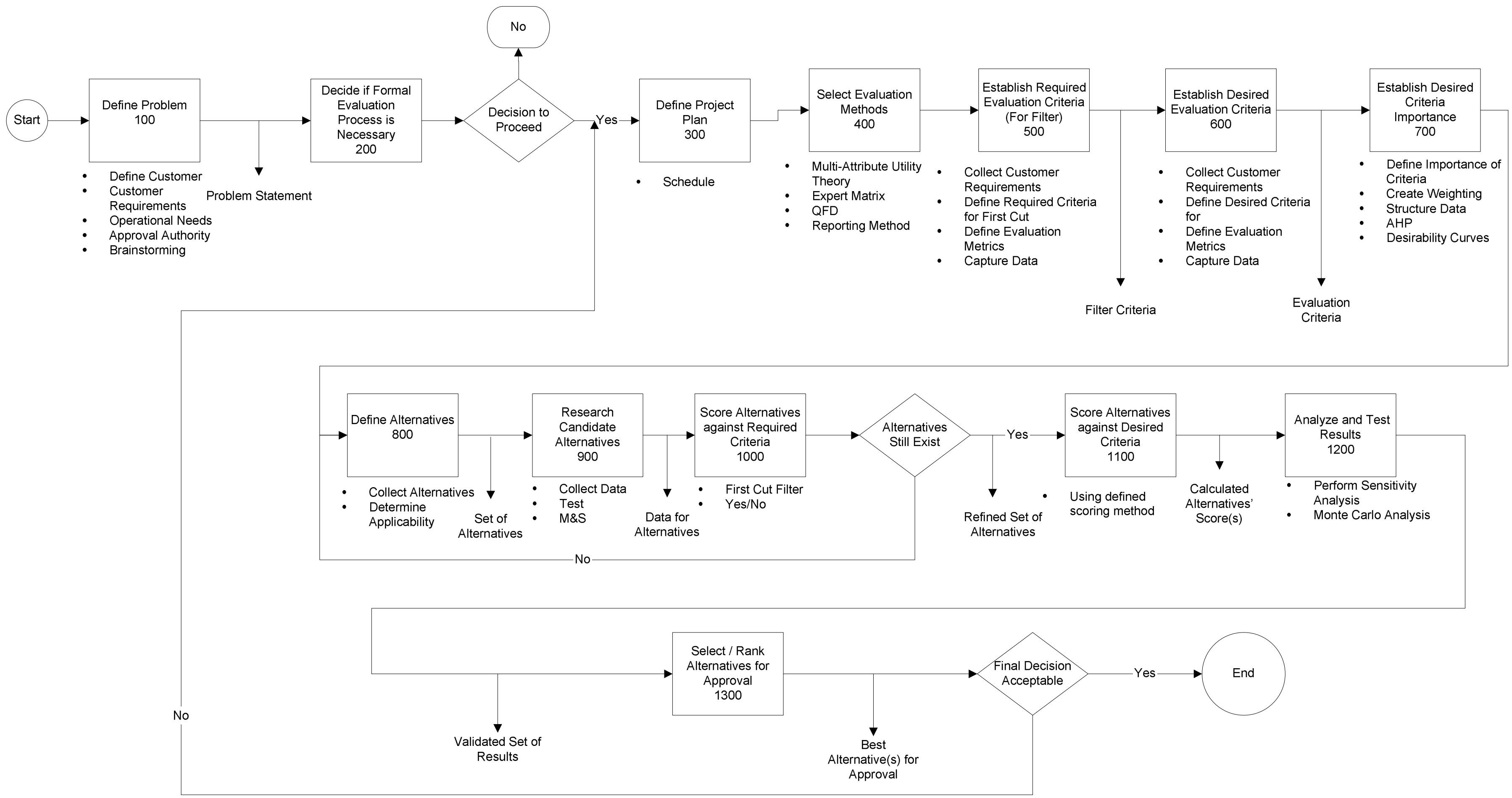
Level 1 Decision Analysis and Resolution Process





Enabling the American Warfighter to Dominate the Battlefield!

Level 1 Decision Analysis and Resolution Process



Enabling the American Warfighter to Dominate the Battlefield!

ARDEC Enterprise Application

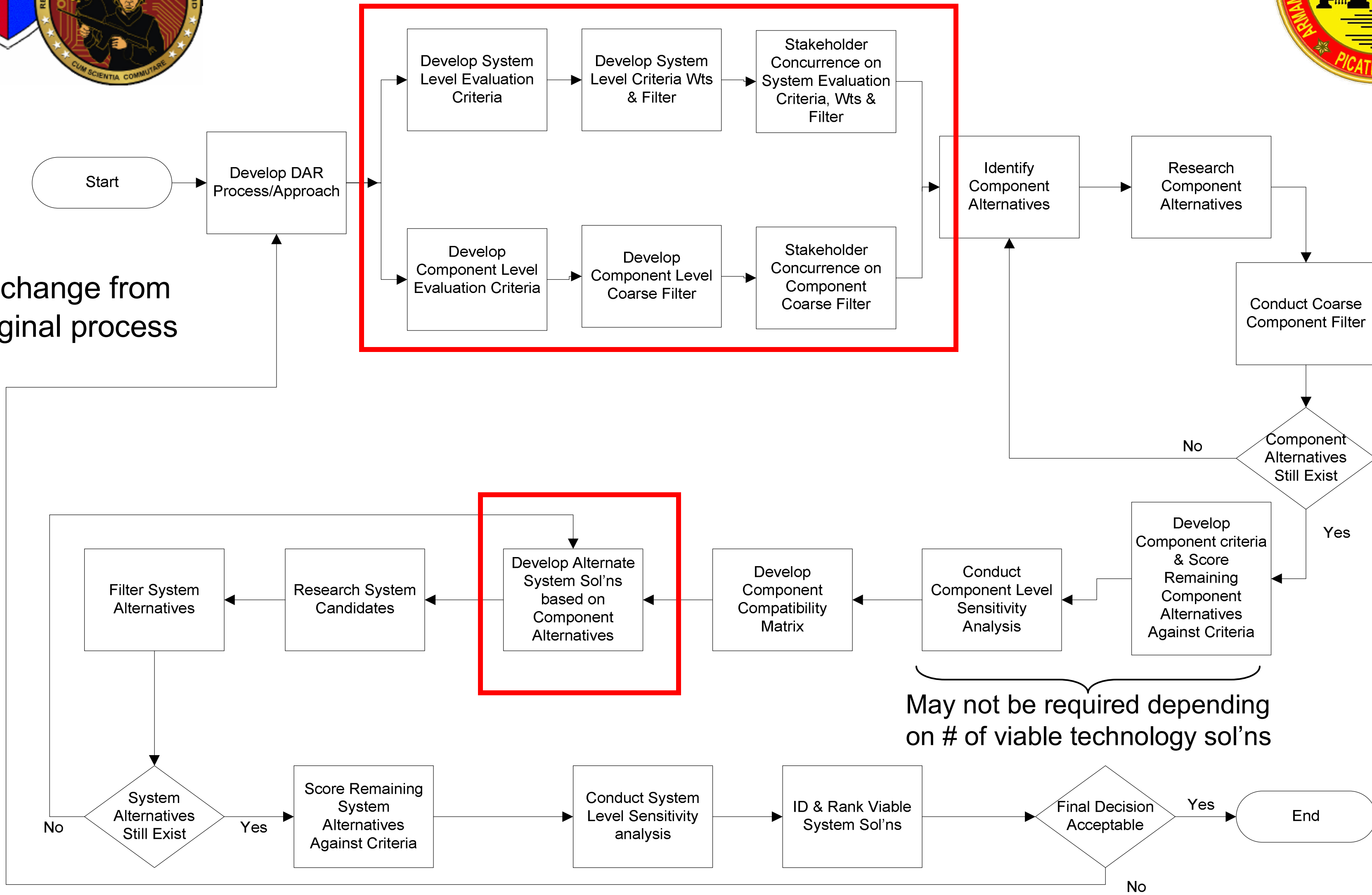
- DAR process to be approved as part of formal ARDEC SE Standard Process
- Projects are required to tailor and use process for their application
- Identified methodologies/tools for each process step to facilitate process execution

Tailored DAR Process

- Application for FCS Active Protection System (APS) Technical Trade Study for RDECOM.
  - Identify Science and Technology Investments needed to get to an objective APS system.

- ARDEC DAR process focused competing organizations' efforts to determine path-forward for the APS technical trade study

Tailored DAR Process



= change from original process

Enabling the American Warfighter to Dominate the Battlefield!

DAR Benefits

- Project risk will be reduced by applying the defined DAR process.
- Fact-based decision will be made rather than subjective decisions.
- Increased quality decisions
  - Defendable
  - Stakeholder buy-in
  - Flexible
  - Valid

Return on Investment

Quality or Customer Satisfaction	*Co$t*
•DAR Process created to enhance the ARDEC capability to deliver quality products to the Warfighter. •Tools capability to support ARDEC project execution	Savings from… •Reuse •Standardization •Best Practice application • Savings: $11.3K/use
•Defined DAR process provides for better time and resources scheduling needed to execute. •Lowers the learning curve DAR application	•Defined DAR process reduces risk by providing a tailorable framework for making decisions
Schedule	*Risk*

- Questions?

Effective SE Metrics Tailored to the Acquisition Life Cycle

Armament Research, Development & Engineering Center
Armament System Integration Center
Systems Engineering Division

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Systems Engineering Advisor
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(973) 724-6296

AGENDA

- ARDEC Background
- Measurement Approaches
  - Systems Engineering Plan
  - Level of Effort Assessment
- Tracking & Reporting
- Benefits
- Next Steps

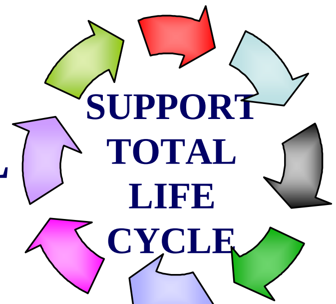
ARDEC Background

Artillery & Mortar Systems

Advanced Fuze Technologies

Special Operations Weapons & Demolitions

Smart Munitions



Advanced Explosives & Warhead Development

Combat Vehicle Armaments & Fire Control

Logistics R&D

Non-Lethal Technologies

Future Small Arms

PROVIDING OVER 90% OF THE ARMY'S LETHALITY...

Planned versus Actual
Metric: SE Planning

- Purpose
  - Living Document for Planning
  - Drive Technical Execution
- Rolling Wave Concept
- Tailoring
  - Based on Acquisition Phase
  - Project Specific Technical Activities
    - Level of Risk Acceptance
  - Programmatic Factors to Consider
    - Resources
    - Complexity
    - Customer & Stakeholders Needs
    - Schedule

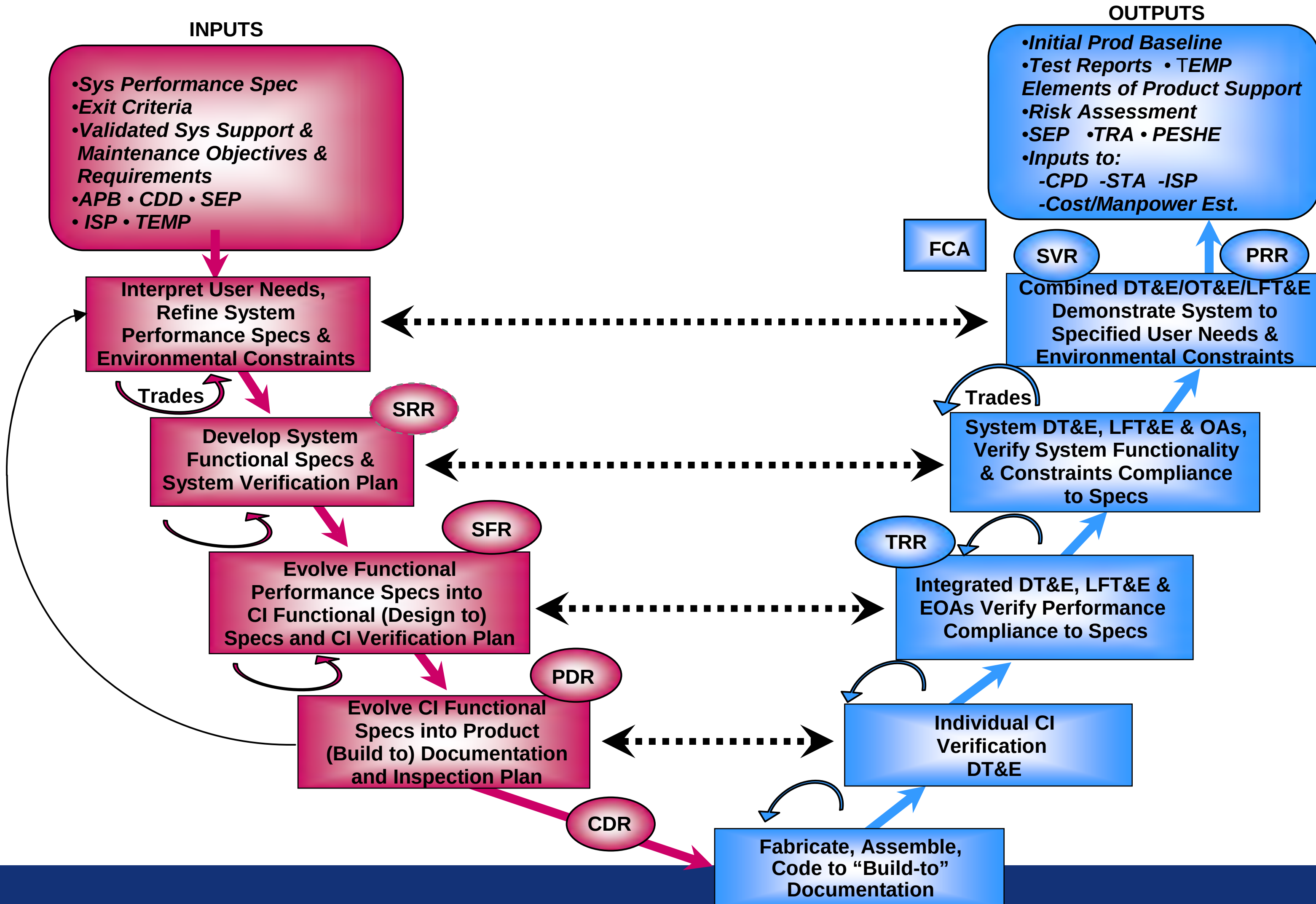
Metric: Level of Effort Assessment

- Based on Acquisition Phase
- Define Project SE status in Key Areas
  - Requirements
  - Functional Analysis & Allocation
  - Design Synthesis
  - Verification & Validation
  - System Analysis & Control
- Quantifies Remaining SE Work on Project
- Traced to OSD & ARDEC Guidance
  - Defense Acquisition Guide
  - Policies, Process, Procedures, Templates
- Validated with Other Factors to Consider
- Used to Develop SE Plans and Budgets

Other Factors to Consider

- Funding
- Customer
- Stakeholders & End User
- In-house Work Versus Outsourced
- ARDEC Priorities and Visibility
- Percent Complete
- Resources and IPT Members
- Technology Complexity & Domain
- Other Factors the Rater Wants SE to Consider

System Development and Demonstration Phase



System Development & Demonstration : Pre-Milestone C

SEL	Project Name	Type of Program (A-F)

		1	2	3	N/A & Rationale
Key Areas	System Engineering Plan	Drafted Updated Plan	Submitted Updated Plan	Approved Updated Plan	
Requirements	Interpret User Needs	Do not have defined requirements	Develop requirements from lifecycle considerations; use prototypes for stakeholder buy-in	Manage system requirements; address and characterize risk associated with requirements; conduct SRR if necessary	
		Requirements not yet decomposed; RM started	Utilized RM Tool	Requirements traced in database/tool	
	Refine System Performance Specs	Fundamental understand performance specs	Documented Performance Specs	Refined Performance Specs	
Functional Analysis & Allocation	Develop System Functional Specs & System Verification Plan	Have not yet developed subsystems	Partition the system into subsystems; define subsystem interfaces and integration	Developed subsystem integration, verification and validation plan/process	
Design Synthesis	Evolve Function Performance Specs into CI Functional Specs & CI Verification Plan	Have not allocated specs or defined CI performance/ functional requirements	Allocate system functional/performance specs; functional/ performance requirements defined for CI	Create test plan for verification of CI for f[illegible]nctionality/ [illegible]formance	
	Evolve CI Functional Specs into Product Documentation & Inspection Plan	Have not begun documentation for "building" components	Complete [illegible]rawings/[illegible] [illegible]ing" t[illegible]	[illegible]lized detailed [illegible]gn; Completed CDR	
Verification & Validation	Success/Fail Criteria	Su[illegible] no[illegible]	[illegible]	[illegible]umented/Approved [illegible]cess/fail criteria	
	Fabricate, Assemble, Code to "Built-to" Documentation	H[illegible] sy[illegible] co[illegible] re[illegible]	[illegible]ents; [illegible]e action; [illegible]est [illegible]ernative [illegible]gy if needed	Created prototypes/engineering development models	
	Individual CI Verification DT&E	H[illegible] v[illegible]idation p[illegible]	Assess technical progress against critical technical parameters	Demonstrate characteristics of components to be integrated	
	Integrated DT&E, LFT&E, EOAs Verify Performance Compliance to Specs	Have not planned for TRR, verification & validation	Conduct test and evaluation at subsystem level; Plan for TRR	Verified subsystem performance against defined subsystem design requirements; Validated intended subsystem use in environment	
	System DT&E, LFT&E, Oas, Verify System Functionality & Constraints Compliance to Specs	Have not worked to resolve interface/integration issues; do not monitor integration performance risks	Resolve interface and integration issues; monitor and analyze risks for performance of integrated system	Demonstrate integrated system under operational environment constraints	
	Combined DT&E/OT&E/LFT&E Demonstrate System to Specified User Needs & Environmental Constraints	Do not understand interface and interoperability issues; have not defined test environments/ scenarios	Defined developmental and operational test environments/scenarios	Resolve interface/interoperability issues; confirm operational supportability and manufacturing process control; assess technical risk and mitigate	
System Analysis & Control	DM & CM Requirements	Identify DM & CM Requirements	Develop & Maintain DM & CM Requirements	Maintain DM & CM Requirements	
	DM/CM Tool(s) that meet the DM/CM Requirements	Identify DM/CM Tool(s) that meet the DM/CM Requirements	Develop DM/CM Tool(s) that meet the DM/CM Requirements	Maintain DM/CM Tool(s) that meet the DM/CM Requirements	
	Create Risk Plan	Identified Risks (probabilities & consequences/impact)	Documented Risk Plan with Mitigation Strategy & Corrective Action Plan	Tracked Risk Plan with Mitigation Strategy & Corrective Action Plan	

Metric Tool

System Development & Demonstration

Requirements Metrics

Key Areas		1	2	3	N/A & Rationale
Requirements	Interpret User Needs	Do not have defined requirements	Develop requirements from lifecycle considerations; use prototypes for stakeholder buy-in	Manage system requirements; address and characterize risk associated with requirements; conduct SRR if necessary	
		Requirements not yet decomposed; RM started	Utilized RM Tool	Requirements traced in database/tool	
	Refine System Performance Specs	Fundamental understand performance specs	Documented Performance Specs	Refined Performance Specs	

System Development & Demonstration

Requirements Metrics

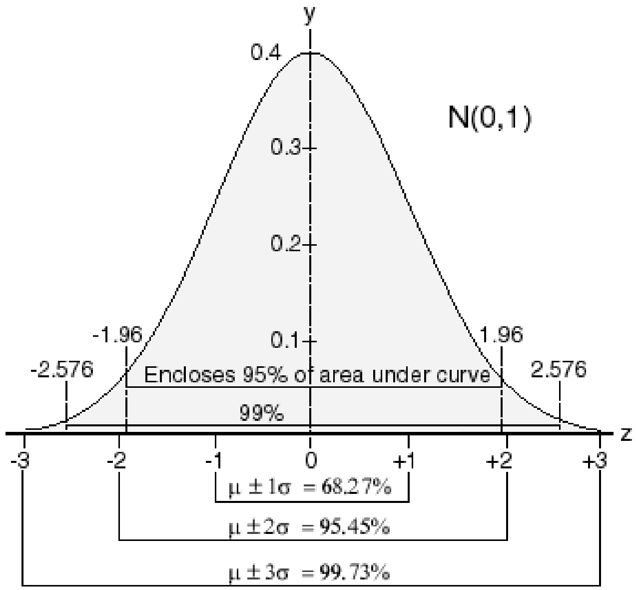
EXAMPLE

Key Areas		1	2	3	N/A & Rationale
Requirements	Interpret User Needs	Do not have defined requirements	Develop requirements from lifecycle considerations; use prototypes for stakeholder buy-in	Manage system requirements; address and characterize risk associated with requirements; conduct SRR if necessary	Documented plan for system availability, supportability, logistics footprint, developmental and operational test environments and scenarios, and disposal in SEP; present prototype to stakeholders Sept 05
		Requirements not yet decomposed; RM started	Utilized RM Tool	Requirements traced in database/tool	System Requirements Linked to user Requirements in DOORS Database
	Refine System Performance Specs	Fundamental understand performance specs	Documented Performance Specs	Refined Performance Specs	KPPs traced in database; translated requirements into performance specs

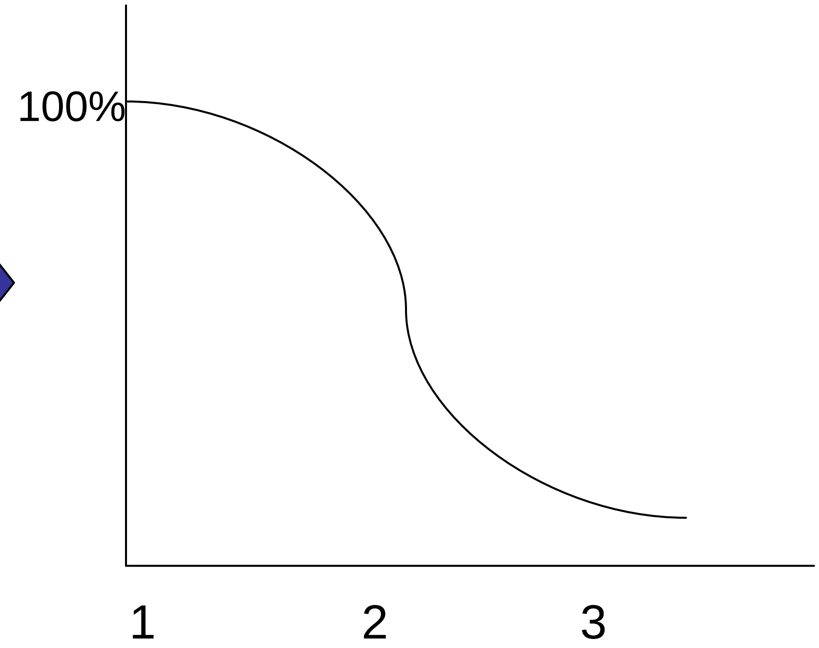
Calculations

- LOE: Translate Value to Percent out of 100

Normalized Gaussian



Remaining Work



Traceability & Budgeting

- Traced to OSD & ARDEC Guidance
  - Defense Acquisition Guide “Vee” Models
  - Policies, Process, Procedures, Templates
  - Linked on the SE Website for Ease

- Used to Develop SE Plans and Budgets

System Development & Demonstration : Pre-Milestone C

Key Areas	Defense AT&L "V" Model	DAG	ARDEC	INPUTS	OUTPUTS
System Engineering Plan	Approved SEP		102 ,115	All SE Activities	SEP
Requirements	Interpret User Needs	4.3.3.3.1	304	System Spec	SRR
	Refine System Performance Specs	4.3.3.3.1	305-308	System ICD	RTM to Functional/Physical Architectures
			309	System OCD	Environmental & Design Constraints
			310	Prelim. Development Spec	MOE/MOP
			802	Prelim CI ICD	
Functional Analysis & Allocation	Develop System Functional Specs & System Verification Plan	4.3.3.3.2	403, 404, 406-409 601	System Constraints	SFR RAS FMEA/FMECA ICD
Design Synthesis	Evolve Function Performance Spe... CI Functional Specs & C...				PDR
	Evolve CI Functional ... Documentation & Ins...				CDR
Verification & Validation	Fabricate, Assemble ... Documentation	4.3.3.3.5	509-510	Specs, TEMP, MOE/MOP, ICD, etc.	IV&V Plan
	Individual CI Verification DT&E	4.3.3.8.1	803-913		Verification Procedures
	Integrated DT&E, LFT&E, EOAs Verify Performance Compliance to Specs	4.3.3.8.2			TRR
	System DT&E, LFT&E, Oas, Verify System Functionality & Constraints Compliance to Specs	4.3.3.8.3			Facility Request Staffing Request Data Request Equipment Request
	Combined DT&E/OT&E/LFT&E Demonstrate System to Specified User Needs & Environmental Constraints	4.3.3.8.4			PRR SVR
System Analysis & Control	DM Tool(s) & Architectures		111, 115 202, 205, 206	Team with NWA	WBS
	CM Tool(s) & Architectures			Milestones, Allotted Time, etc.	Project Schedule with Decision Points
	Track major risks and execute risk strategy		405 507-508	ECP, CR, etc.	CM Plan ICD
			603	Risk Analysis Reports Risk Mgmt Plan	Risk Assessment Report Risk Status Report

Traceability Example

System Development & Demonstration : Pre-Milestone C					
Key Areas	**Defense AT&L "V" Model**	**DAG**	**ARDEC**	**INPUTS**	**OUTPUTS**
Requirements	Interpret User Needs	4.3.3.1	304	System Spec	SRR
	Refine System Performance Specs	4.3.3.2	305-308	System ICD	RTM to Functional/Physical Architectures
			309	System OCD	Environmental & Design Constraints
			310	Prelim. Development Spec	MOE/MOP
			802	Prelim CI ICD	

SE Resources Required

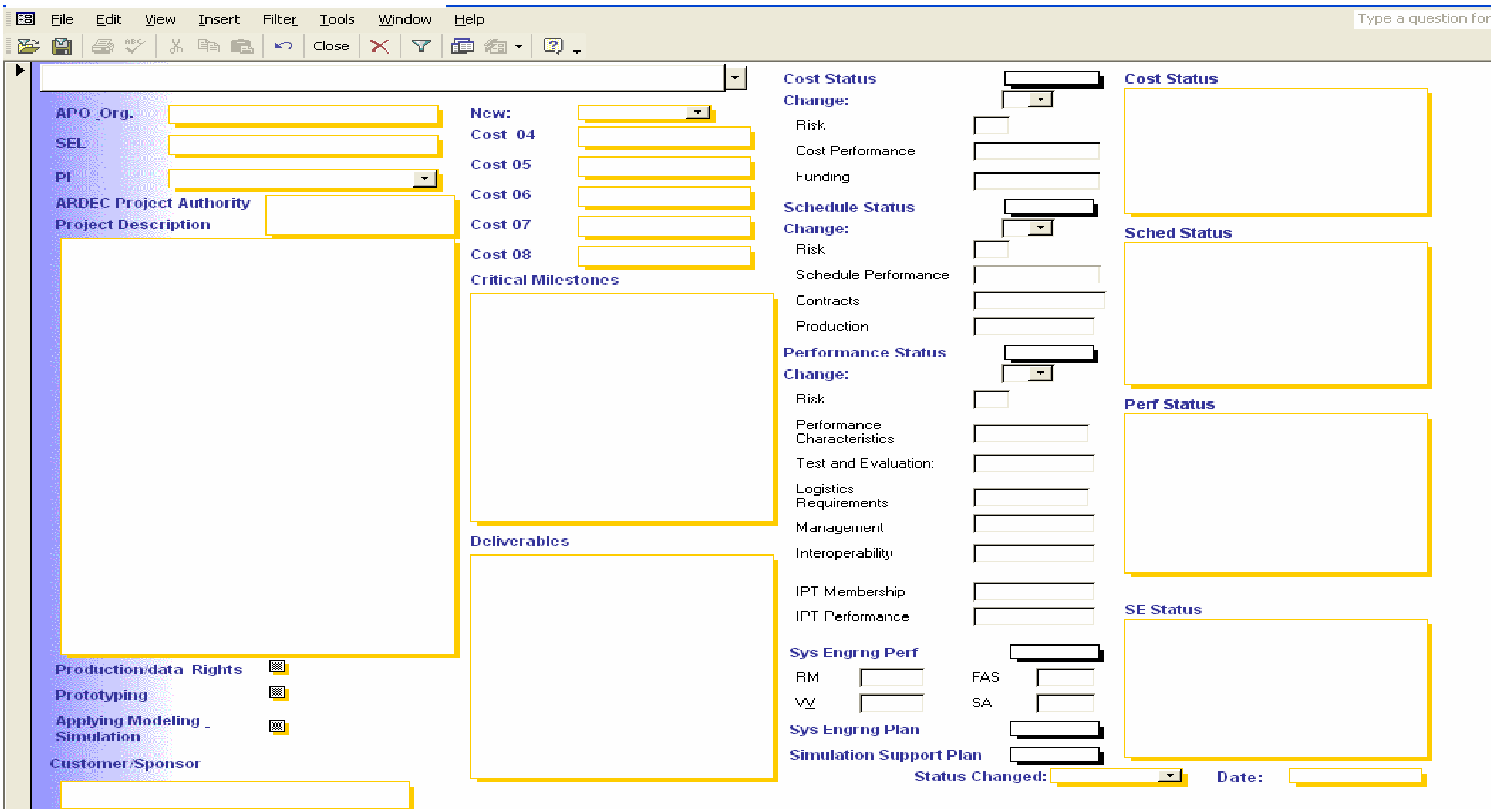
- Project SE WBS
  - Includes LOE Key Areas
  - Metrics to Obtain Actual Data
- Top Down Method
  - Step 1: Use Industry "Rules of Thumb" For Initial Estimate
  - Step 2: Refine Initial Estimates Using the LOE Assessment Tool

FY06 SE Resources ($) = Project FY06 Budget ($) X Rule of Thumb (%) X LOE (%)

Metric Tracking & Reporting

- Tracked Major ARDEC Priority Project Database
  - Status and Performance of LOE Key Areas
  - Note Significant Events and Changes
  - Projects Evaluated Monthly During Reviews
- Reported at Senior Leadership and Other Management Reviews Quarterly

Priority Project Database Snapshot



SE Status & Performance Summary

IPT Membership

IPT Performance

SE Status

Sys Engrng Perf

RM

FAS

VV

SA

Sys Engrng Plan

Simulation Support Plan

Status Changed:

Date:

Reporting on Metrics

SE Process STATUS - Project XYZ

SEL: Name

SEP Status: (Not Started, Drafted, Submitted, Approved)

(MM/DD/YYYY)

Baseline SE Level of Effort (BLOE): XX%, (MM/DD/YYYY)

Previous SE Level of Effort (PLOE): XX%, (MM/DD/YYYY)

Current SE Level of Effort (CLOE): XX%, (MM/DD/YYYY)

Phase/TRL

Process Area	Perf.	Rationale
Requirements		
Functional Analysis		
Design Synthesis		
Verification & Validation		
System Analysis & Control		

Benefits

- Consistent Documentation and Tools for Evaluation
- Quantified and Comparable Results
- Collect Historical Data for Parametric Modeling
- Provides Senior Leadership Visibility to Technical Issues for ARDEC Projects
- Enforced Implementation Through Reporting
- Training the Workforce on SE
- Tailored to Provide Just Enough SE; Avoid “Process Paralysis” (too much SE)
- Allows Project Manager to Focus on Important Issues

BOTTOM LINE: Implementing Systems Engineering on Projects Brings Better Products to the Warfighter!

Next Steps

- Transition LOE from Pilot to Full Scale Implementation
- Estimate SE Resource for FY06 WBS
- Track Status and Performance at Major ARDEC Project Reviews and Management Reviews
- Gather and Incorporate Voice of the Customer Feedback
- Refine and Improve LOE Procedure and Training

Questions/Comments

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Strength through Industry & Technology

NDIA Home < 6870 Abstract Submission

8th Annual Systems Engineering Conference

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					No

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Biographies

Mr. Tritsch is currently a Senior Systems Engineer for the Vitech Corporation. He was a certified acquisition professio Air Systems Command, where his responsibilities included developing forward-deployed information systems, Aircraft and DoD Policy for Logistics Support Analysis. He has also worked as an engineer in the polymer industry and has be lecturer at the Stevens Institute of Technology. Mr. Tritsch has a M.S. degree in Systems Management from Capitol C degree in Industrial Engineering from Lehigh University.

Abstract

Title

Ensuring Accomplishment of Performance Based Logistics Objectives Using Model-Based Systems Engineering

Text

Department of Defense Instruction 5000.2, dated May 12, 2003 set forth the policy that logistics requirements for sy
“Performance Based.” This requires logistics programs to place a priority on anticipated bottom-line results instead of
inflexible and at times inappropriate policies and standards. This paper will demonstrate how Model-Based Systems E
used to establish, track, and maintain performance-based logistics objectives and to use system models to predict life
performance as measured against the established supportability goals.

Make Changes Finish

INTEGRATED IN-SERVICE RELIABILITY PROGRAM

Naval Air Systems Command Integrated In-Service Reliability Program (IISRP)

Mr. Les Wetherington, Program Manager

Brief to the NDIA Systems Engineering Conference

San Diego, Ca.

25 October, 2005

INTEGRATED IN-SERVICE RELIABILITY PROGRAM

Agenda

- Mission
- Vocabulary
- Overview
- IISRP Background
- IISRP & Cost Wise Readiness
- IISRP Process
- Results
- Examples
- Summary

Mission

SUPPORT THE WARFIGHTER BY IMPROVING RELIABILITY

"The nation needs a Navy that can provide homeland defense and be both forward *and* ready to surge forward with overwhelming and decisive combat power … As leaders, we must create readiness from the resources given to us and recognize that readiness at any cost is not acceptable. "

ADM Vern Clark
Chief of Naval Operations
CNO Guidance for 2004, Accelerating Our Advantages

Vocabulary

- AERMIP – Aircraft Equipment Reliability and Maintainability Program
- AMSR – Aviation Maint. and Supply Report
- AVDLR – Aviation Depot Level Repairable
- BCM – Beyond Capability of Maintenance
- CA – Cost Avoidance
- DLA – Defense Logistics Agency
- FST – Fleet Support Team
- IISRP – Integrated In-Service Reliability Program
- MMH/FH – Maint. Man-Hour per Flight Hour
- NAVICP – Naval Inventory Control Point
- PMA – Program Manager Air
- ROI – Return on Investment
- TOW – Time on Wing

INTEGRATED IN-SERVICE RELIABILITY PROGRAM

Overview

- NAVAIR Integrated In-Service Reliability Program
  - A means to sustain aging weapon systems components while controlling operations and maintenance costs
  - An integral element of NAVAIR's global strategy to meet the Chief of Naval Operation's readiness and cost objectives
- A key component of Cost Wise Readiness

IISRP Background

- AMSR report identified poor AVDLR component reliability as a major cost driver
- NAVAIR BPR 3-3: Component Reliability Improvement Project initiated 1st qtr FY99
  - AIR-6.0 (Industrial) leadership, TYCOMs, NAVICP, AIR-3.0/4.0 (Logistics/Engineering) participation
  - Integrated teams in work at 3 depot sites since 1999
- Transitioned to an institutionalized program May 2002
  - AIR 6.0/4.0/3.0 (Industrial/Engineering/Logistics) Team

IISRP & Cost Wise Readiness

Focus mainly on high value AVDLRs:

- Identify poor performers
- Optimize support practices
- Balance increased reliability vs. cost

Objectives

- Improve component reliability
  - increase TOW by enhancing fielded reliability
- Reduce Weapon System life-cycle costs
  - reduce component demand, lower MMH/FH, optimize O/I/D capabilities, increase readiness

IISRP & Cost Wise Readiness

- Involves all stakeholders:
  - Fleet O- and I-Level Maintainers
  - PMA/FSTs
  - Depot Managers and Artisans
  - NAVICP and DLA
- Every aspect of support scrutinized
- “Fix” recommendations linked to root cause analysis
- Implementation assistance and tracking

IISRP & Cost Wise Readiness

- Analyzes components worked in organic depots
  - Primary focus on improving process <u>effectiveness</u>
  - Achieve goals by maximizing component Time on Wing (TOW)
  - Ensure support processes restore component resistance to failure

IISRP Process

iiSRP
INTEGRATED IN-SERVICE RELIABILITY PROGRAM

IISRP Process

Key enablers:
- Stakeholder buy-in
- Integrated systems and tools
- Training and expertise

Select
Top 500 List
Top T/M/S Degraders

Measure
BCM/kFH
TOW

Reach Inherent Reliability

Analyze
Process Audits

Fix
Follow the process
Consensus mtng w/stakeholders

Processes

SNT

Process Maturity

Training

Tools

Select
Automated Triggers

Measure
Automated LCC Models

Optimized Reliability

Analyze
On-line Models & Tools

Fix
Targeted Changes

Cost Wise Readiness

IISRP Process

PHASE THREE
- INSTITUTIONALIZED CAPABILITIES
- PERFORMANCE BASED INDUSTRIAL FOCUS
- FORMAL LIFE CYCLE MODELING

PHASE TWO
- EXPANDED FOCUS TO DESIGN / PERFORMANCE
- EXPANDED KNOWLEDGE OF FAILURE MODE / MECHANISM
- BEGIN FORMAL MODELING

Where we are…

PHASE ONE
- TARGET TOP COST DRIVERS
- REACH INHERENT RELIABILITY
- INDUSTRIAL PROCESS FOCUS

		Select	Analyze	Fix	Measure
Capability pending enabling tools and processes: SNT, depot data, etc.	Hi-tech	Automated trigger tools using SNTS (w/failure modes and depot data)	Formal statistical reliability modeling tools: Weibull, NHPP, Laplace	Design/operation change based on complete reliability analysis	Automated LCC/ reliability measurements using predictive techniques
Capability to partially perform with high manual effort		LMDSS/ CMIS analysis 3M/NALDA analysis/SRC w/manual links to failure modes	FMEA/FTAs (depends on program) Rogue Analysis	Design/operation change based on partial data	Manually combined reports
Capability exists to perform fully	Lo-tech	Summary listings (AMSR/Top 10s) Informal discussion with depot/fleet	Process walk through	Process change Adherence to proper procedure	

Results

Results as of 3rd Qtr FY05

INTEGRATED IN-SERVICE RELIABILITY PROGRAM

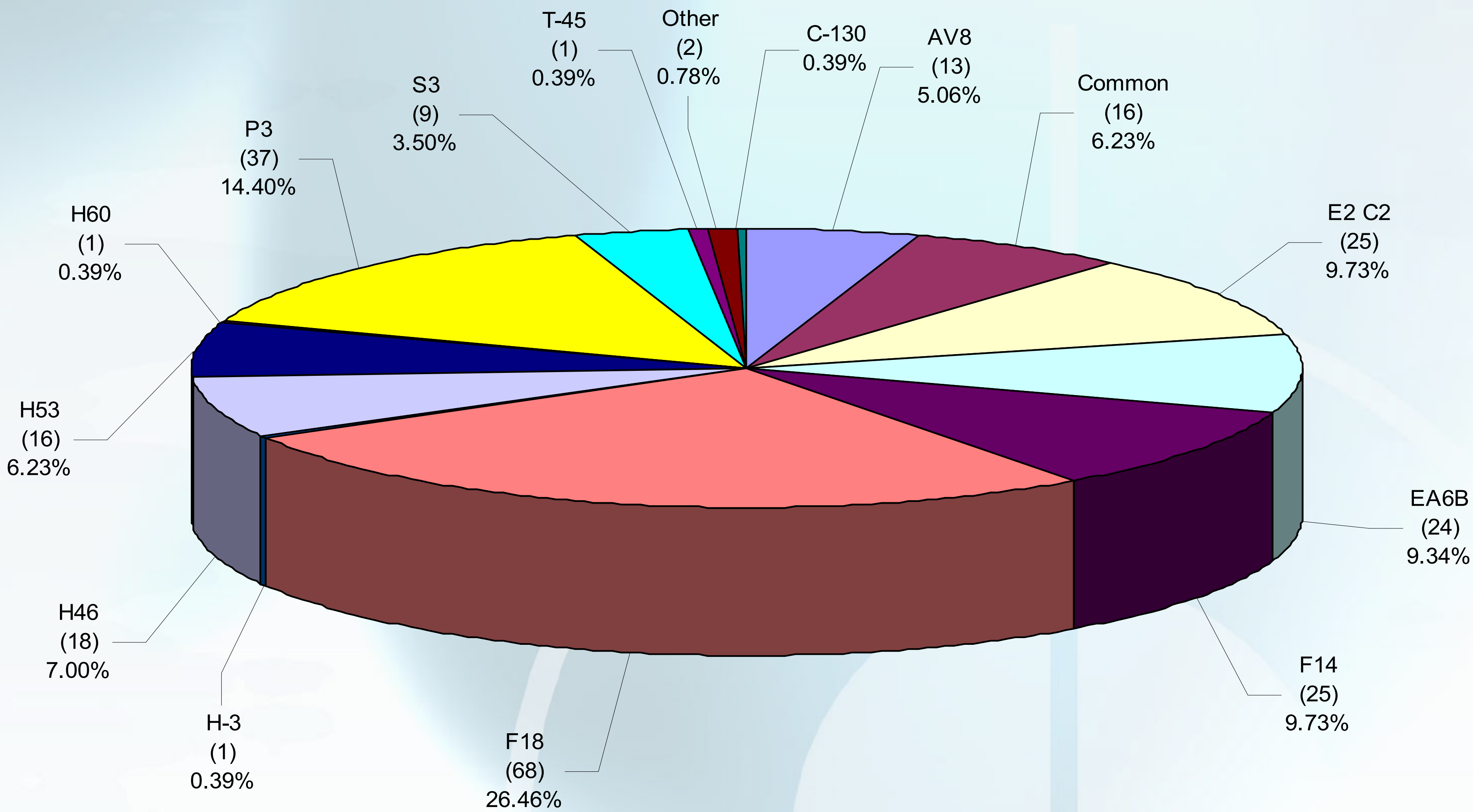
- Delivered 257 Reliability Studies
  - 110 Components studied from the AFAST Top 500 AVDLR Cost Driver List
- Other Sources include AMSR, OI, FST, IWST, others
- Generated 1383 Actions

Action Funding		
	Total #	Funded #
Internal to Depot	1307	1292
External to Depot	70	53
*Combined	6	6
TOTALS	**1383**	**1351**

*Combined = Actions with both Internal and External requirements.

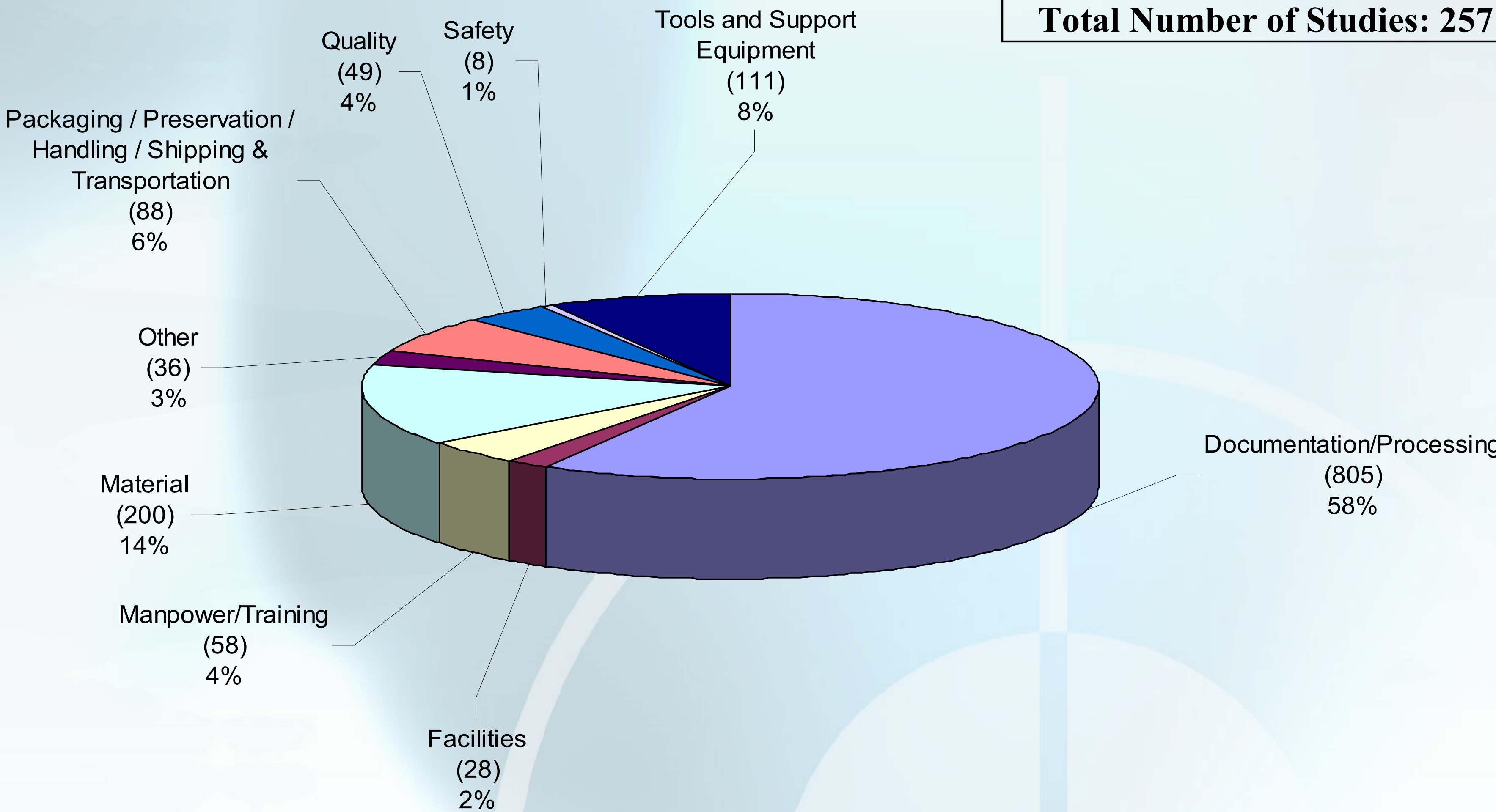
Studies by Platform

Total Number of Studies: 257



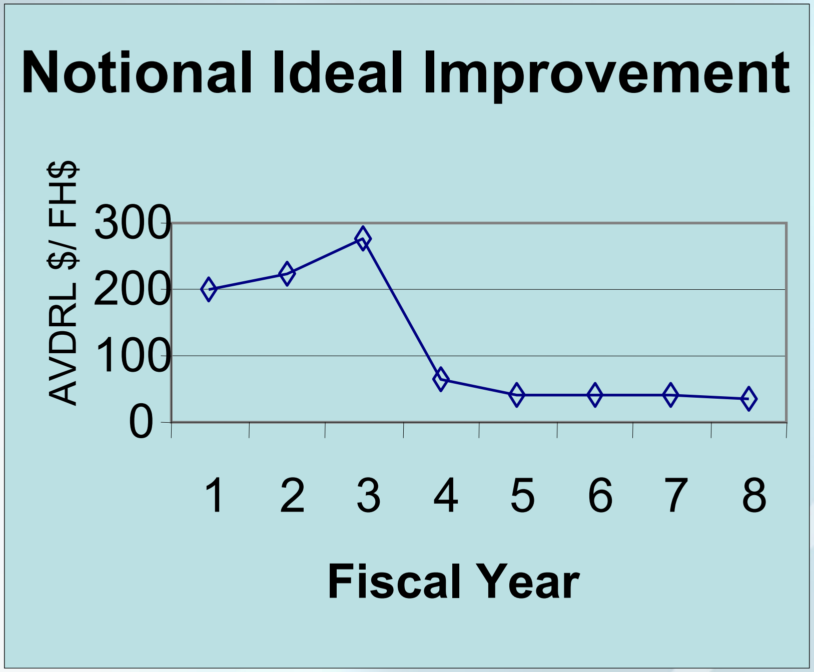
Actions By Category

Total Number of Studies: 257



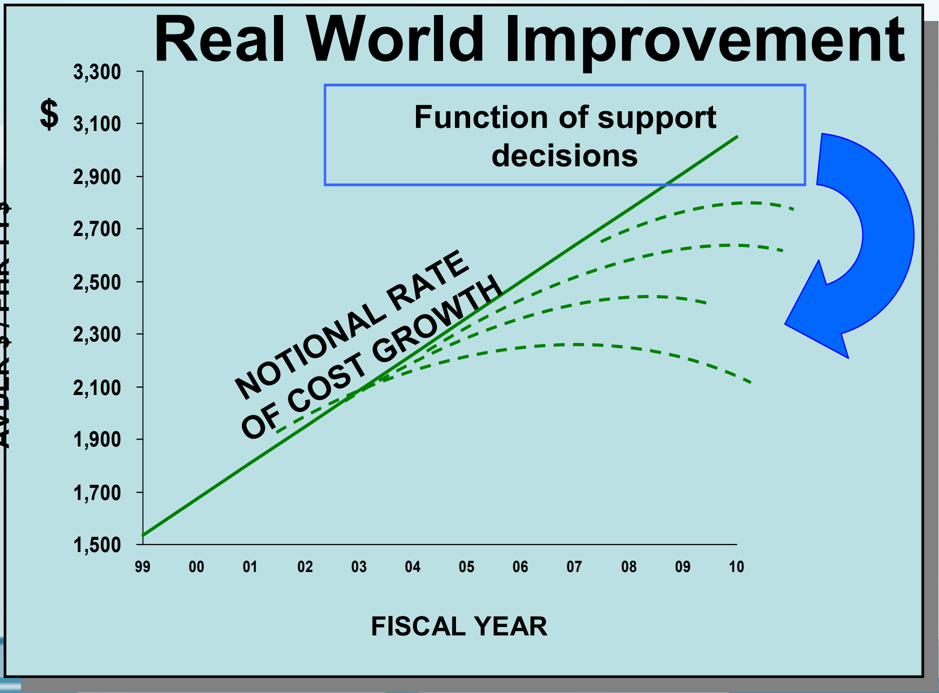
Improvement Takes Time

Effective Reliability Investments Reverse or Slow Cost Growth.. Over Time

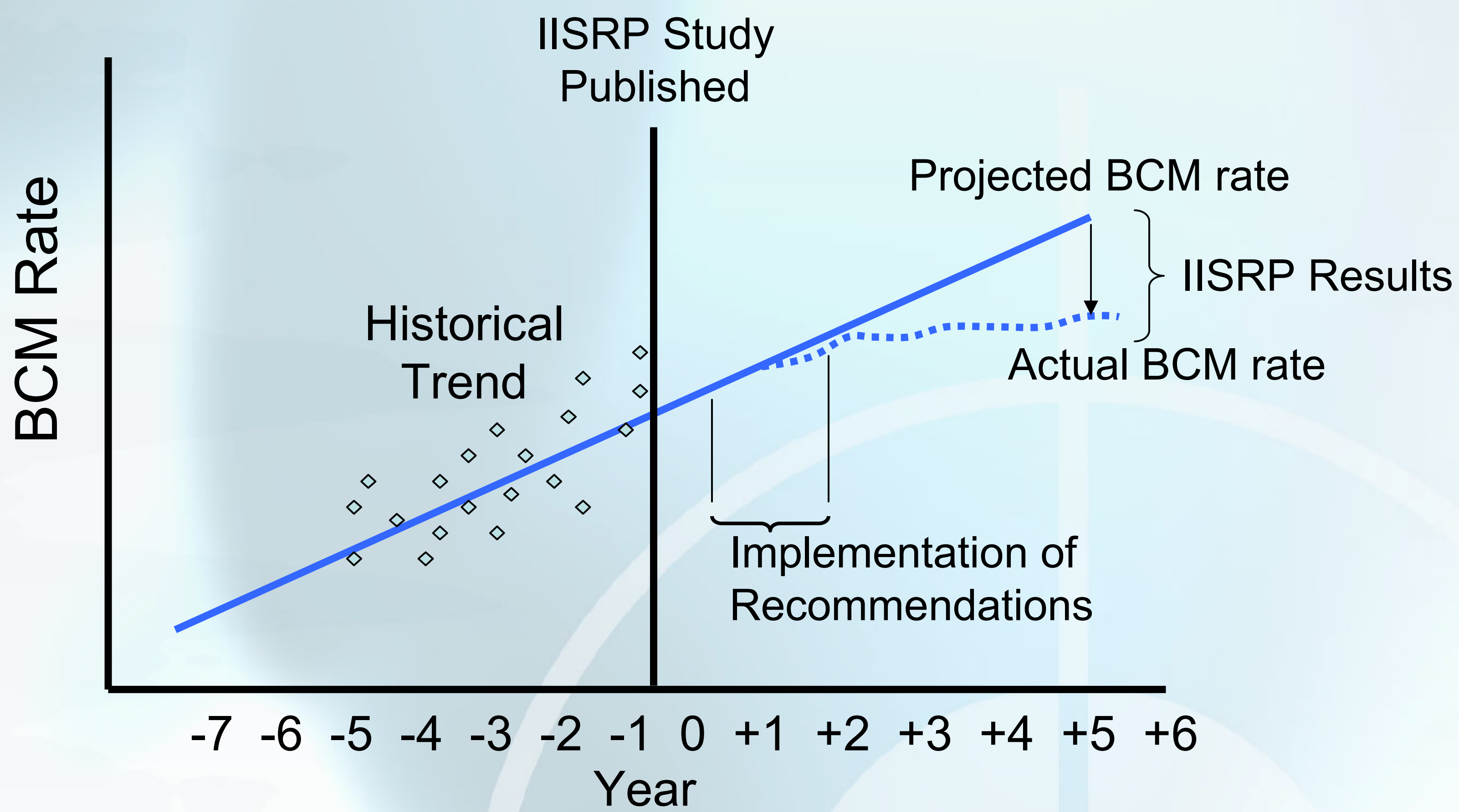


Instantaneous Implementation

Implementation by Attrition

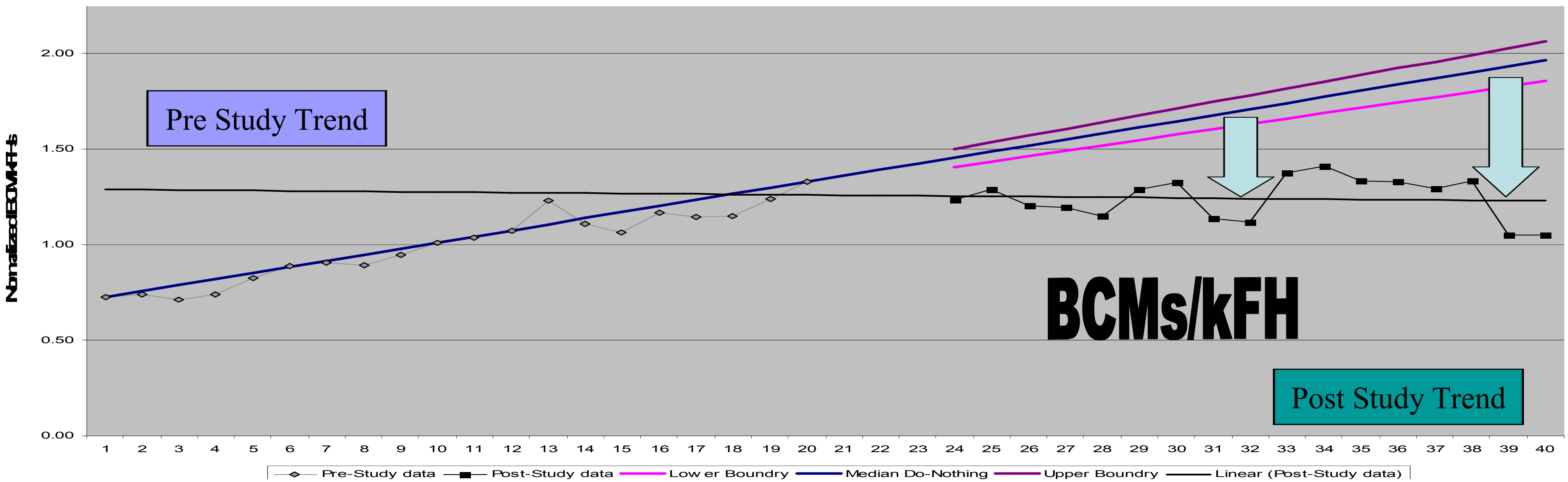


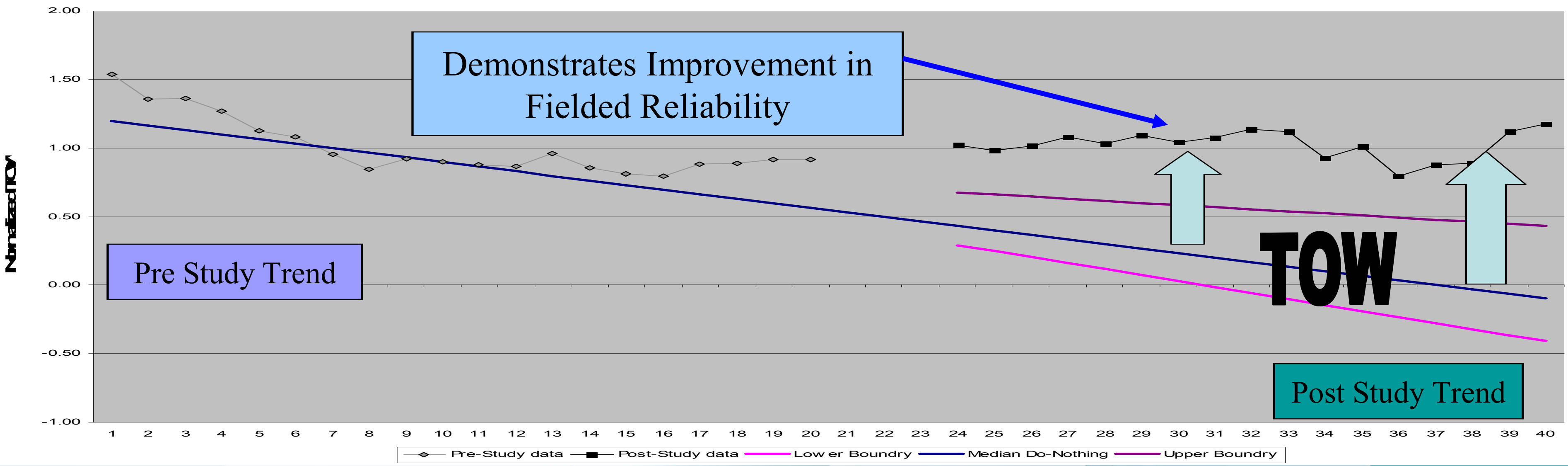
Measuring Results



- It takes time to see initial results
- ROI grows over time

Turning The Tide





Examples

- The following studies were completed by local IISRP Teams at the Naval Air Depots
- These IISRP Teams coordinated with local FSTs, Fleet Maintainers, Depot production managers, and artisans to complete the analyses

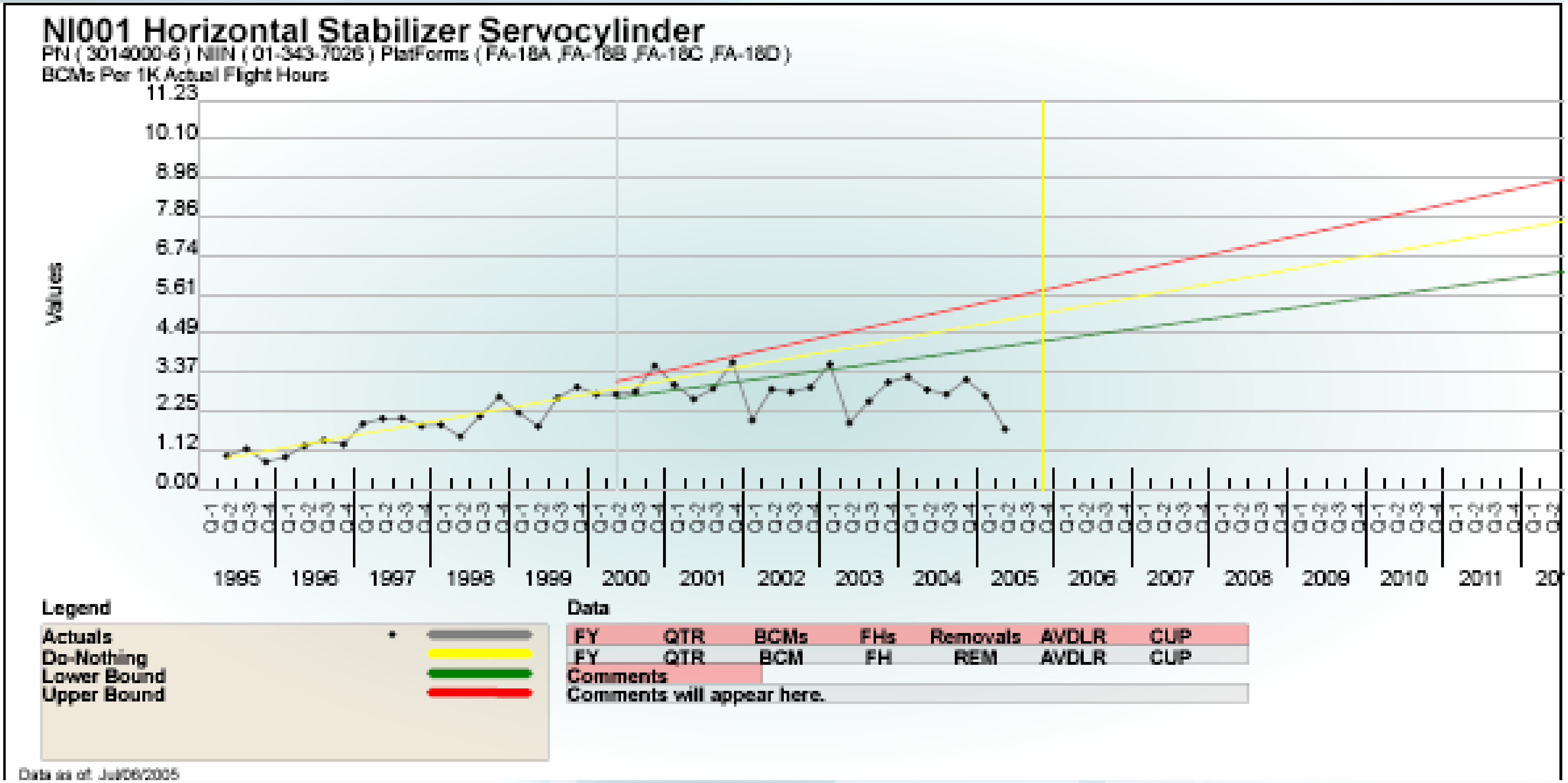
F/A-18 Horizontal Servo-cylinder

- **Drivers:**
  - Ranked number 20 on AMSR List of Top 100 AVDLR Cost Drivers
  - High on NAVICP 350/360 and Opportunity Index Reports
  - In CY98, 922 BCMs
  - From 1994 to 1999, BCM/kFH rate increased 486%
- **Findings/Actions:**
  - Majority of D-level repairs involve leaking/replacing seals
    - Developed engineering change to replace dynamic seals
    - Issued LES directing 100% replacement of seals in manifold and valve assembly if compromised seals or rings are discovered
    - Reactivated Hydraulic Action Team to train Fleet and reduce unnecessary removals
  - On Servo-cylinders inducted into depot, 50% of the Electro-Hydraulic Servo Valves had failed
    - LES issued requiring 100% inspection of EHSV Shuttle Spool
    - Implemented heating and cooling cycling during testing

F/A-18 Horizontal Servo-cylinder

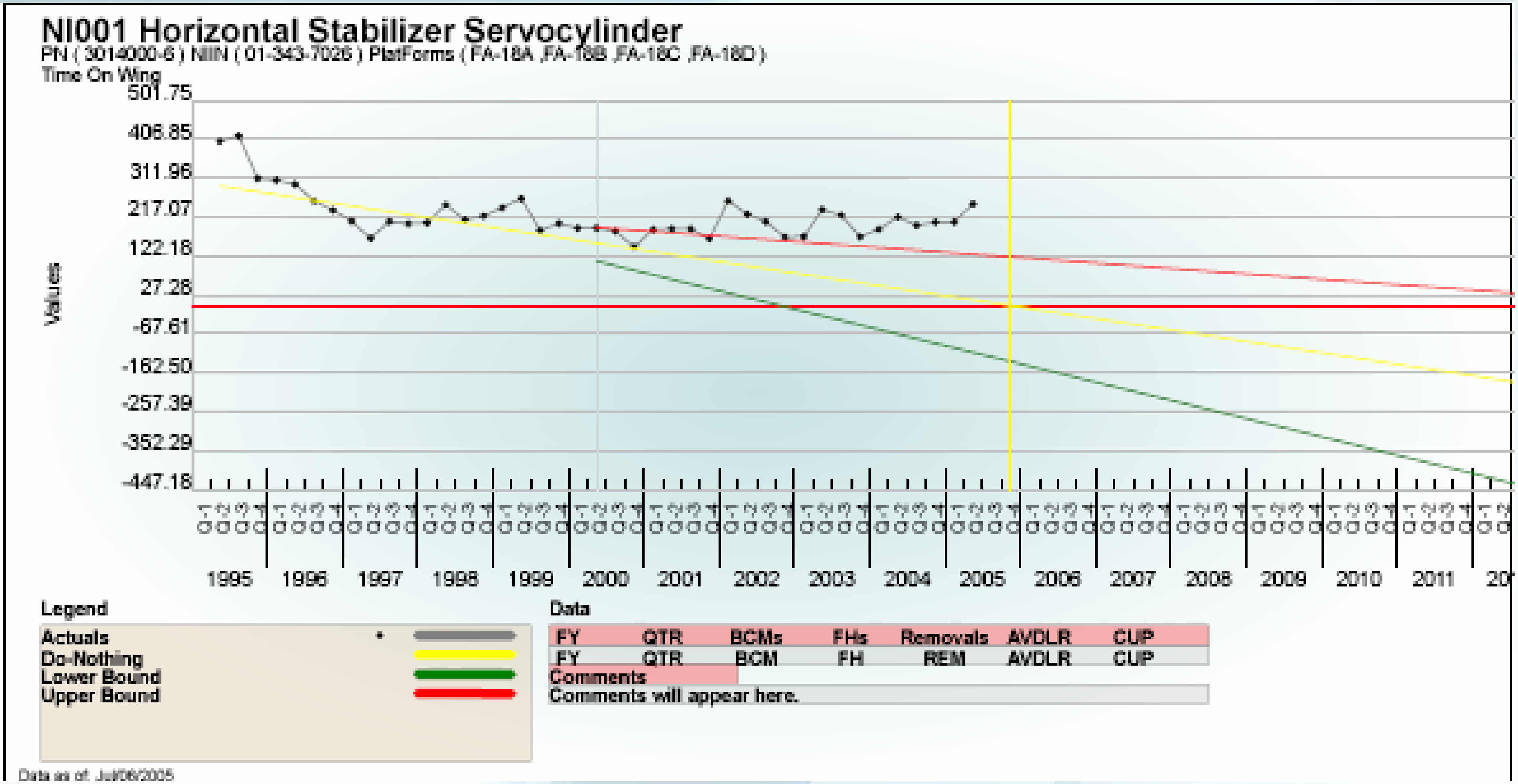
- **Results/Impact:**
  - **BCM/kFH rate decreased by 21% from existing trend since 3Q FY00**
  - **Additional BCM reduction expected after new seals are installed**

F/A-18 Horizontal Servo-cylinder



BCM/kFH

F/A-18 Horizontal Servo-cylinder



TOW

INTEGRATED IN-SERVICE RELIABILITY PROGRAM

P-3 Engine Driven Compressor

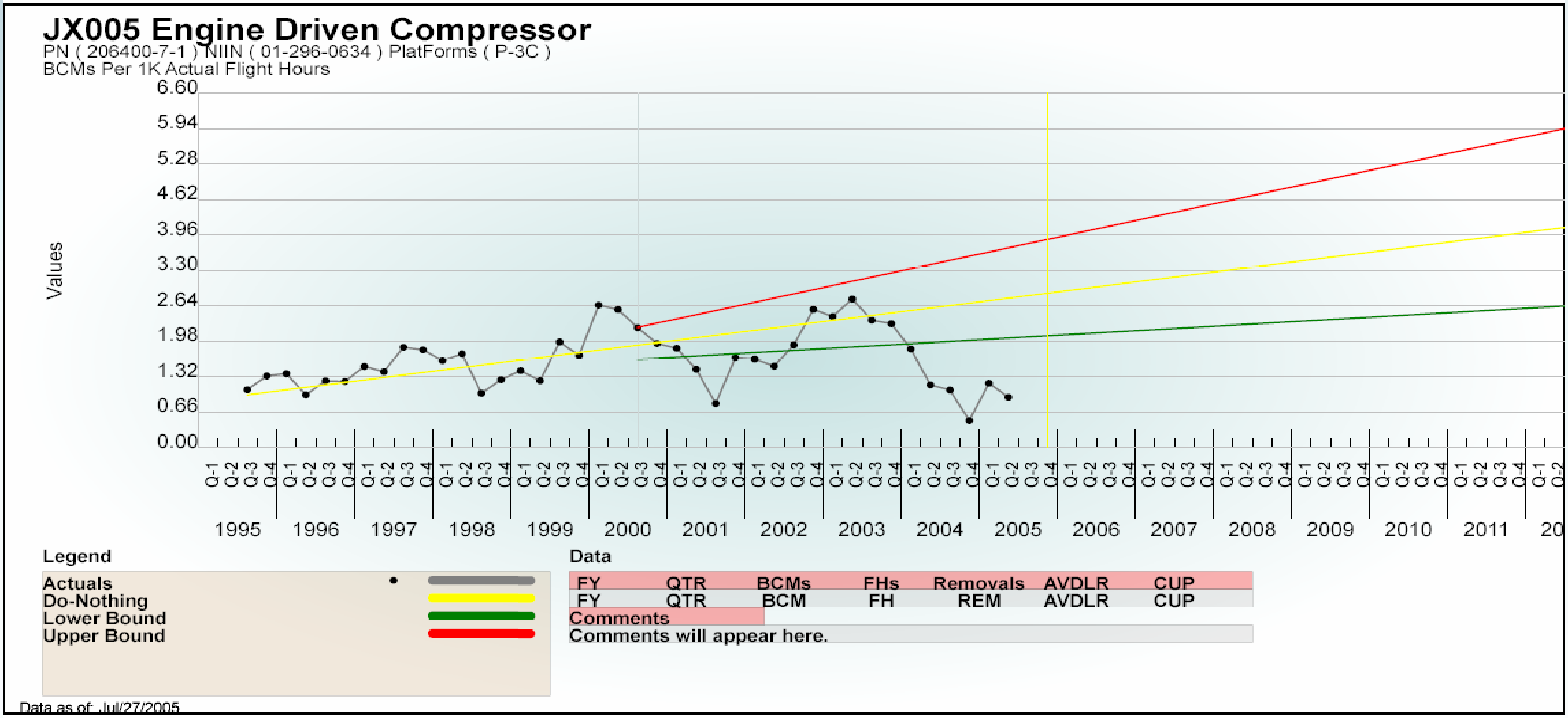
- **Driver(s):**
  - Ranked number 30 on the AMSR degrader list
  - In FY99 there were 141 EDC BCMs

- **Findings/Actions:**
  - Findings:
    - SM&R code in the O-level pubs was incorrect and did not reflect the maintenance plan
  - Action:
    - FST issued guidance to fleet to send EDC's to specialized Intermediate Maintenance locations

P-3 Engine Driven Compressor

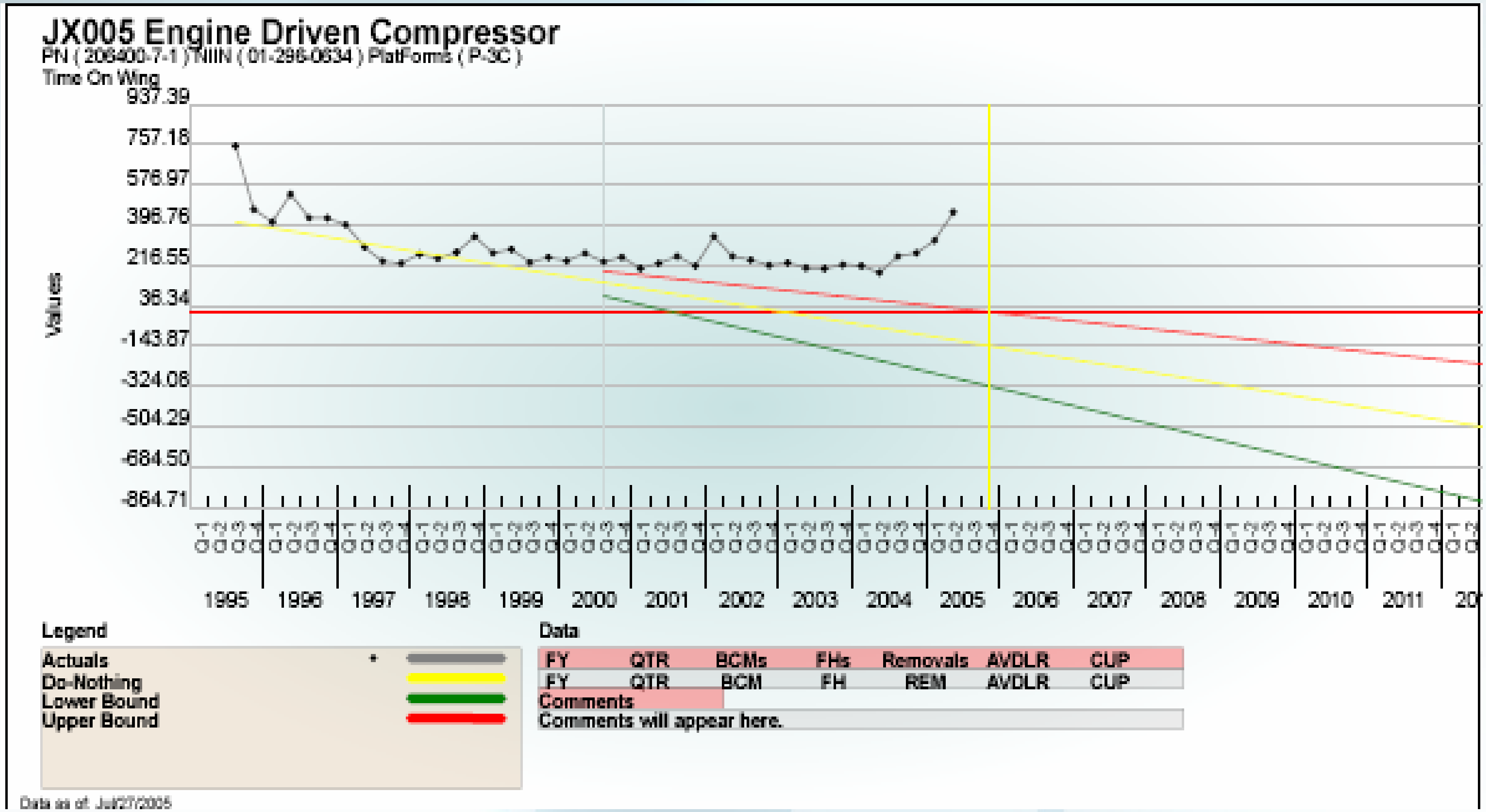
- **Results/Benefits:**
  - **BCM/kFH rate decreased by 40% from existing trend since 1Q FY01**
  - **TOW increased by over 50% from existing trend since 4Q FY02**

P-3 Engine Driven Compressor



BCM/kFH

P-3 Engine Driven Compressor



TOW

AV-8B Stab Servo-cylinder

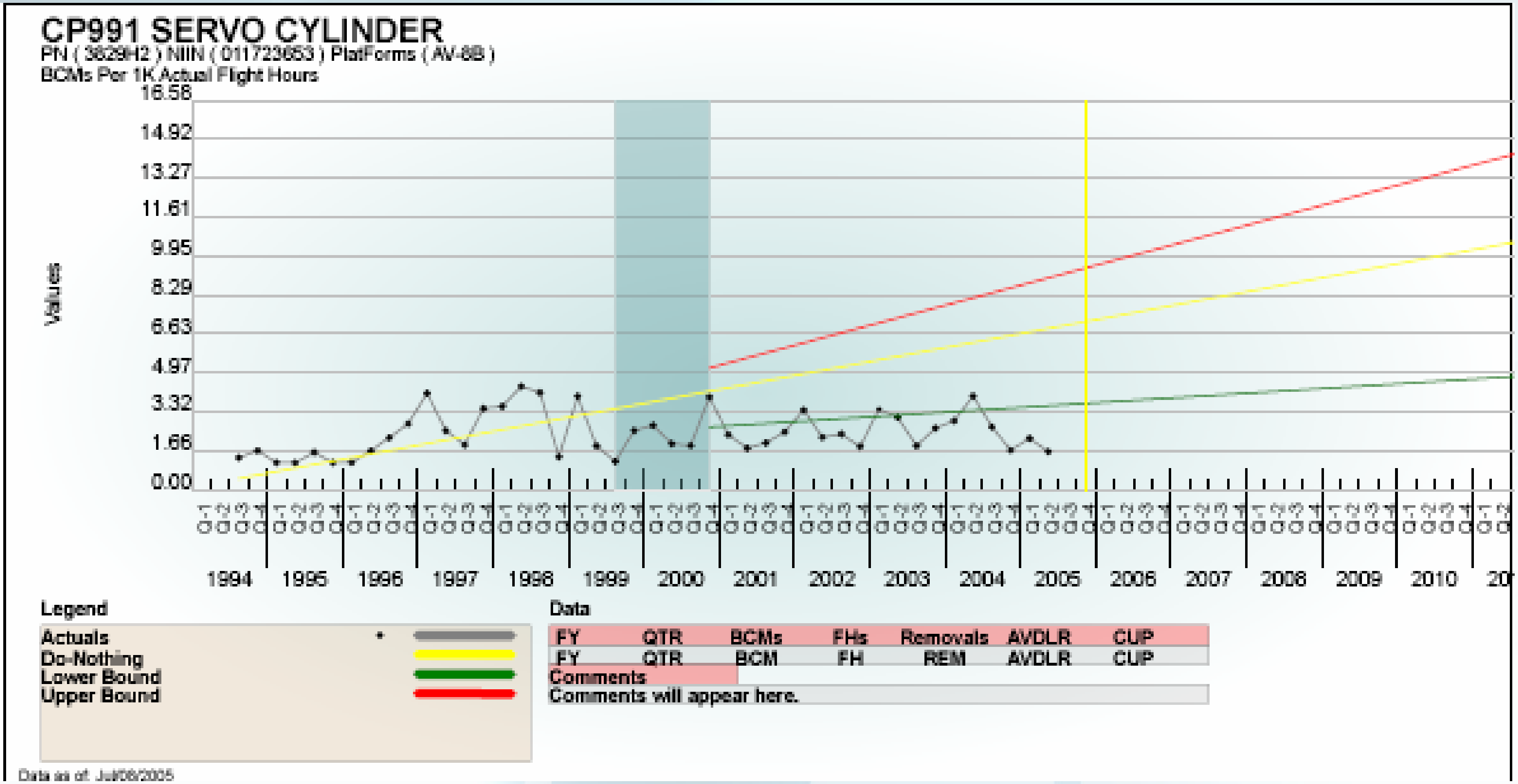
- **Drivers:**
  - First prototype IISRP candidate
  - In CY98, 114 BCMs
  - From 1994 to 1999, BCM/kFH rate increased 215%

- **Findings/Actions:**
  - Initially, majority of D-level repairs involve leaking/replacing seals
    - **MCR released identifying wedge-pack seals from Shamban Aerospace as preferable substitute. Total of 8 seals per units were impacted**
  - "A/C" pickoff testing procedures were inaccurate
    - **Procedures corrected and 26 AWP units were retested, made RFI and placed back into supply**
  - Sustainment review revealed new failure mode: SAAHS-6 failures (electrical)
    - **IISRP sponsored OEM site visit, which revealed modifications not being performed at depot level. Noted modification addressed electrical discrepancies**

AV-8B Stab Servo-cylinder

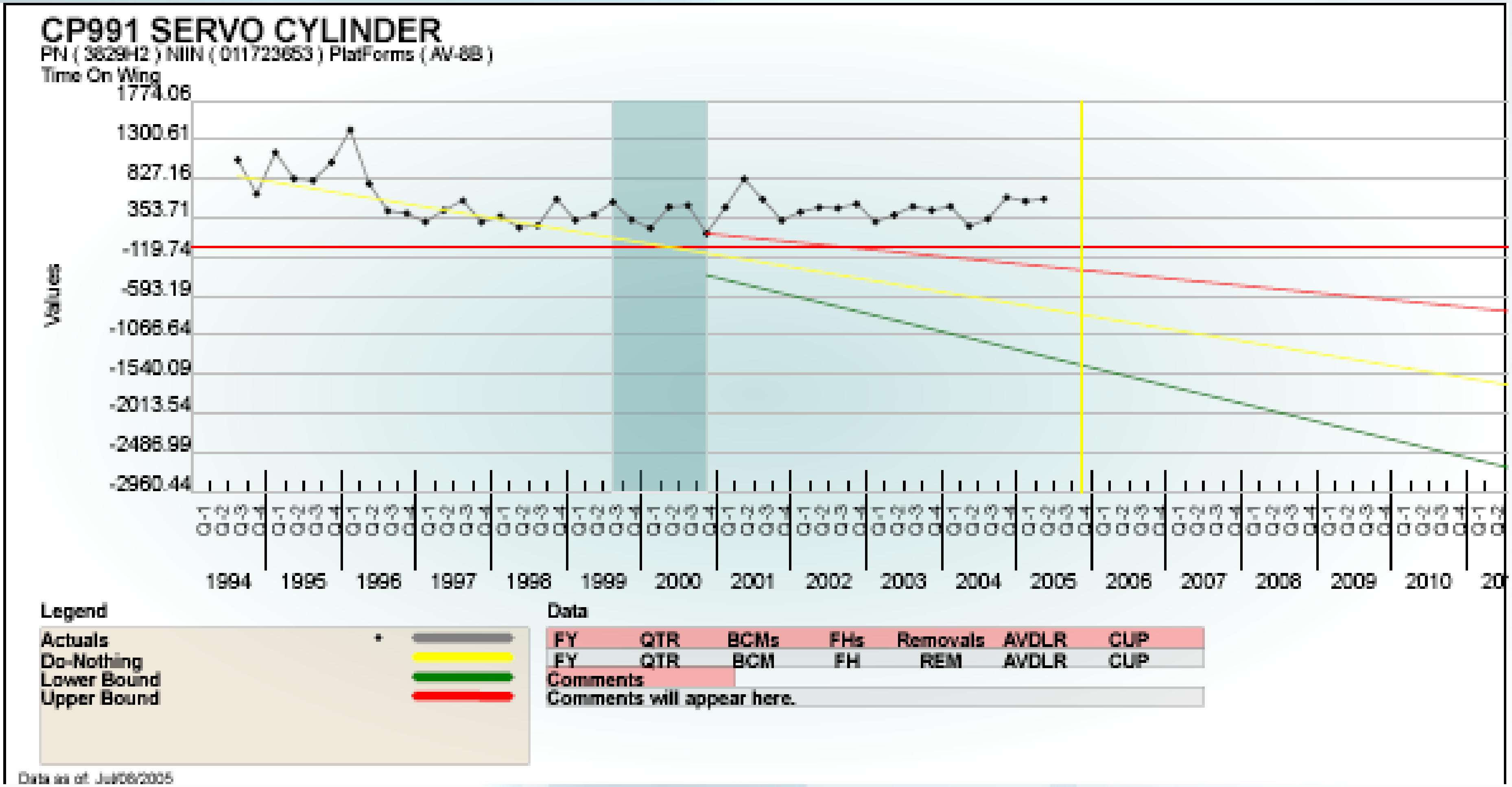
- **Results/Impact:**
  - **Resolved immediate readiness issue**
  - **Avoided a planned buy of new servo-cylinders**
  - **BCM//kFH rate decreased by 55% from existing trend since 2Q FY00**

AV-8B Stab Servo-cylinder



BCM/kFH

AV-8B Stab Servo-cylinder



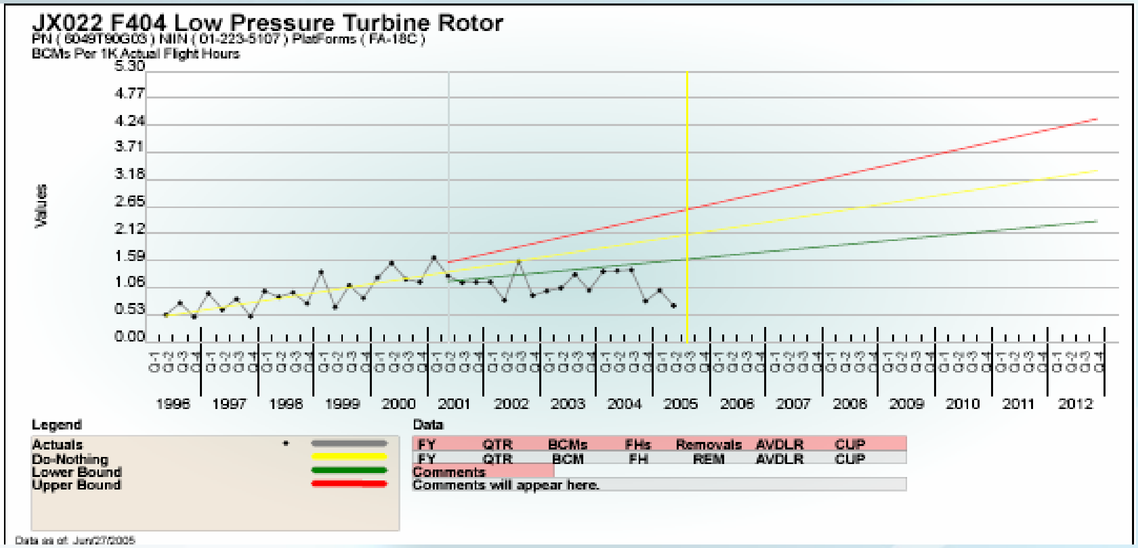
TOW

Summary

- **IISRP**
  - **is a key element of Cost Wise Readiness**
  - **is a credible process**
  - **has demonstrated results:**
    - **BCM Rates - reducing or slowing the increase**
    - **TOW - improving or holding steady**
  - **continues to work with all stakeholders to improve readiness and control cost**

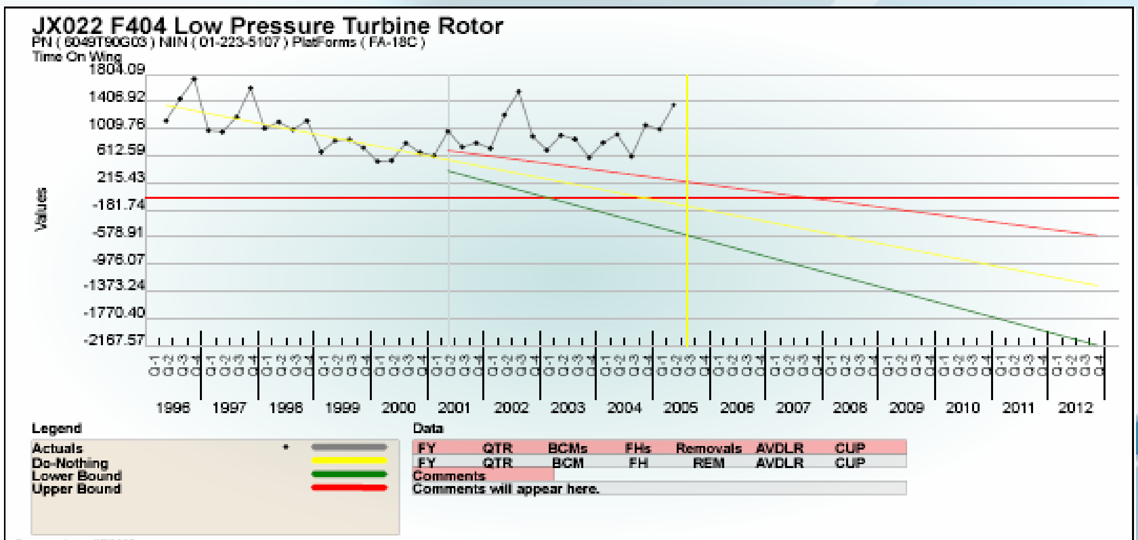
Back ups

F404-400 Low Pressure Turbine Rotor



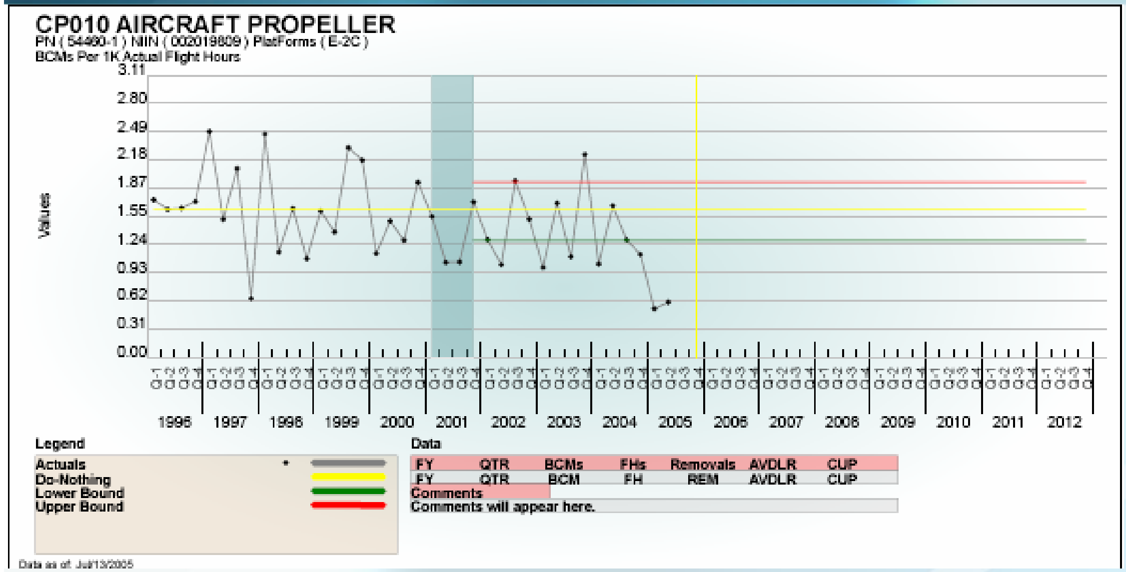
Solution:
Added precision measurement tooling to I-level
Provided O-level training on proper FH computation method

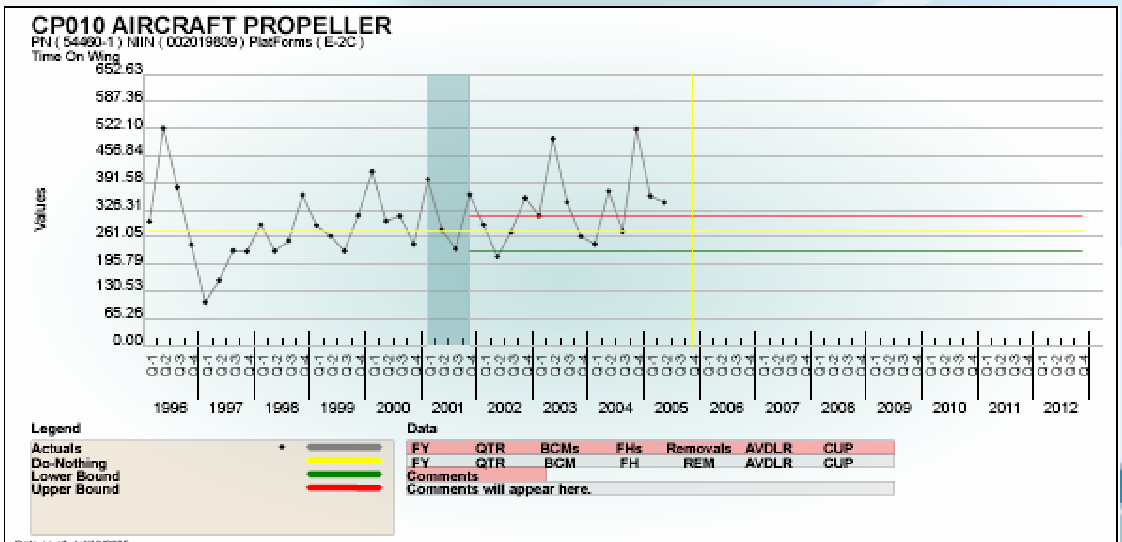
Immediate Impact:
Near immediate arrestment in increasing BCM trend



Long Term Results/Benefits:
- ✓ BCM/kFH rate decreased by 34% from existing trend since 3rd quarter FY01
- ✓ TOW increased by 44% from existing trend since 3rd quarter FY01

E-2/C-2 Propeller





Solution:
Added automated foam pouring capability at depot

Immediate impact:
RFI'ed 85 blades vice scrapping due to foam damage

Long Term Results/Benefits:

- ✓ BCM/kFH rate decreased by 21% from existing trend since 1Q FY03
- ✓ Significant Cost Avoidance since implementation of study actions.

A Complementary Approach to Enterprise Systems Engineering

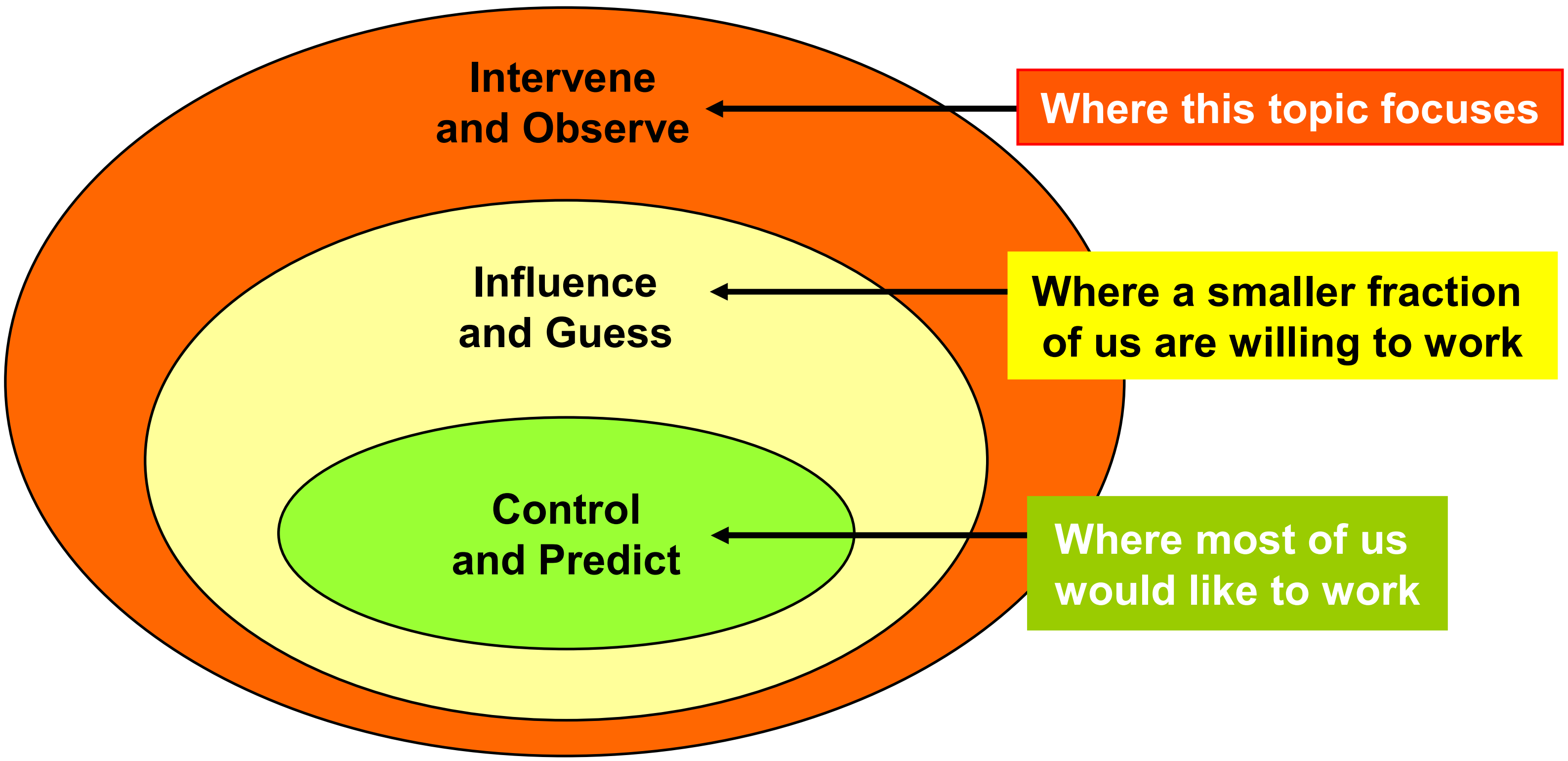
B. E. White, Ph.D.
The MITRE Corporation
26 October 2005

National Defense Industrial Association
8th Annual
Systems Engineering Conference
October 24-27, 2005
Hyatt Regency Islandia, San Diego California

Outline of Talk

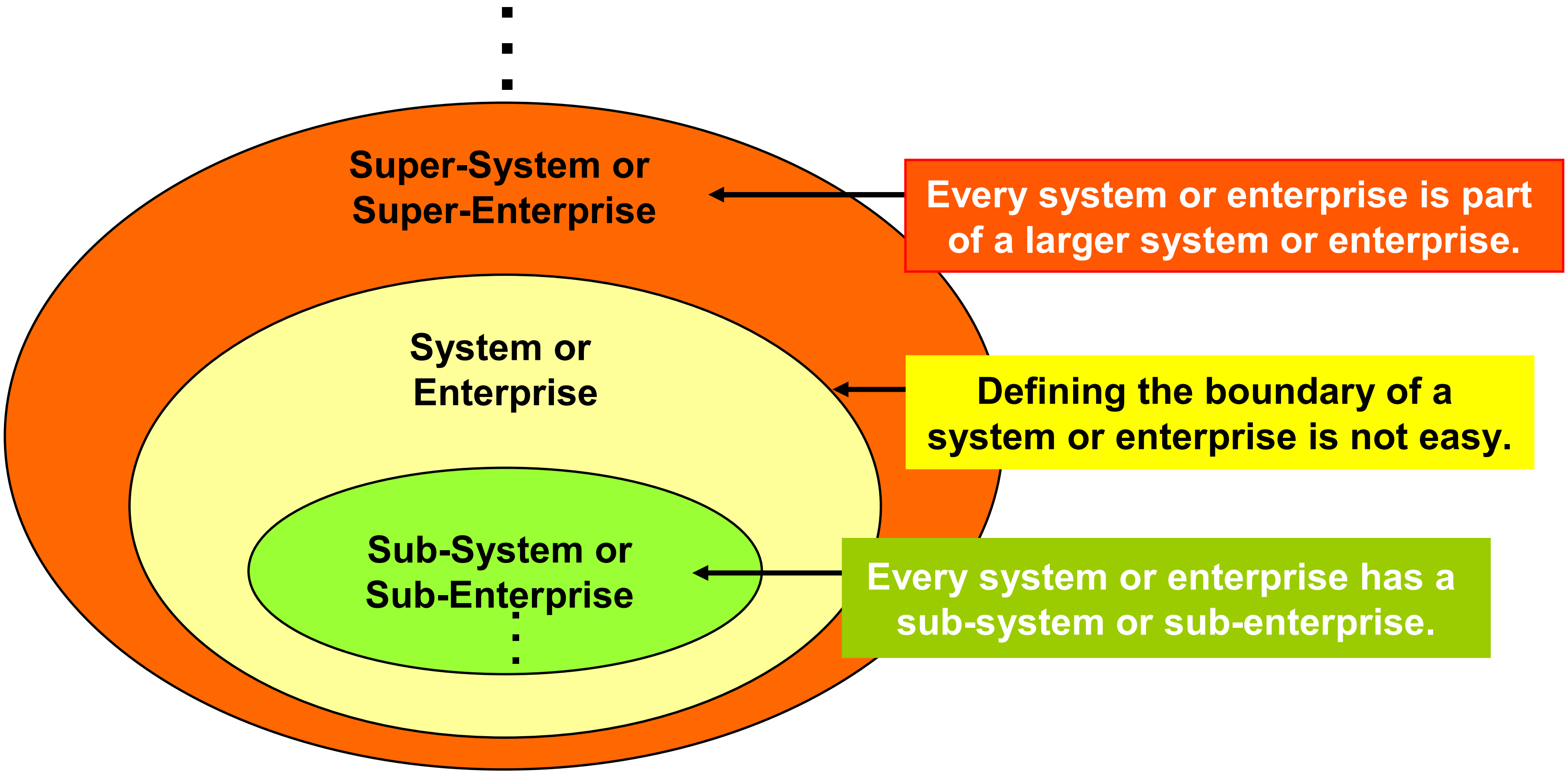
- Purpose
- Definition of systems engineering terms
  - Traditional Systems Engineering (TSE)
  - Enterprise Systems Engineering (ESE)
  - Complex-System Engineering (CSE)
- Characterizing enterprise environments
- A regimen for CSE
  - Explanation of activities
  - Preliminary evaluations
- Summary

Context of This Talk



After [Gharajedaghi, 1999, p. 31]

Systems and Enterprises Are Nested – and Changing Their Boundaries Can Be Illuminating



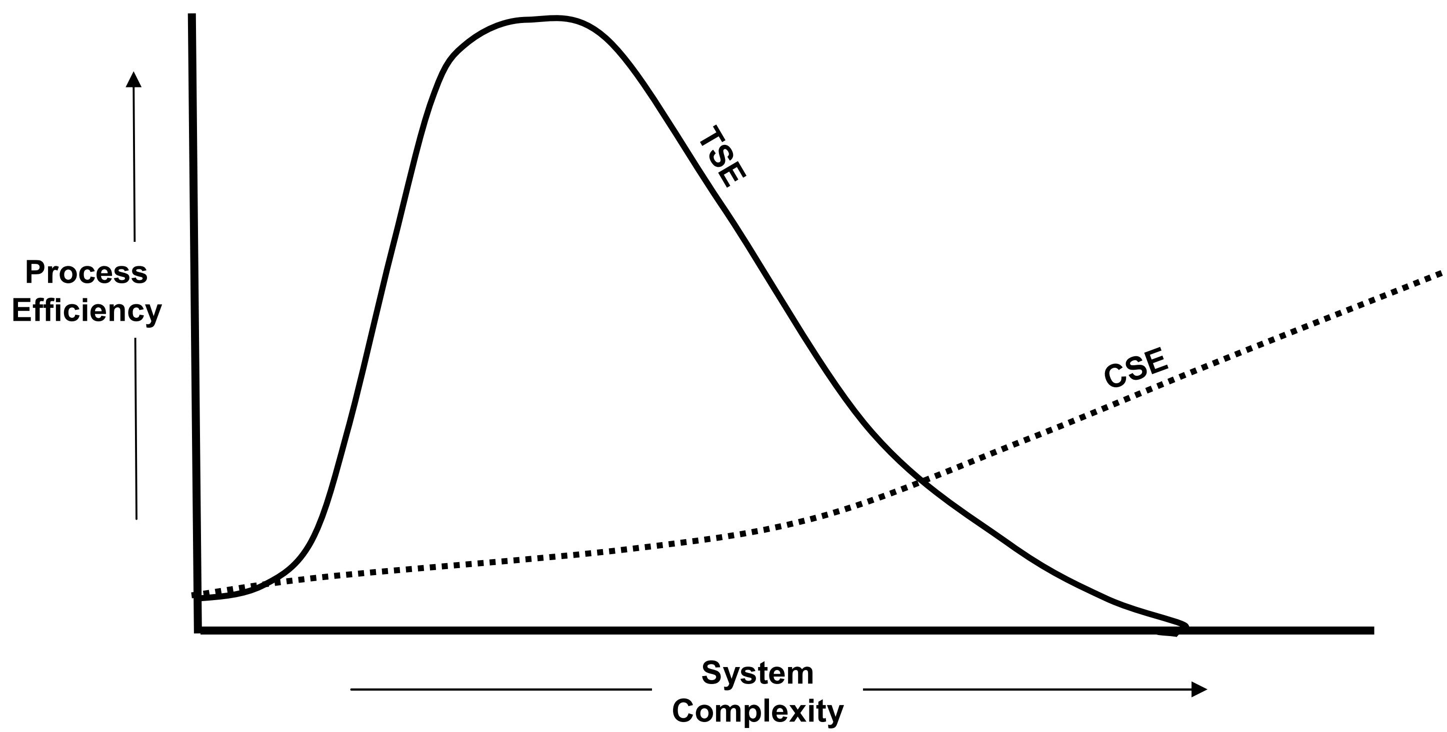
Some feel that no matter at what scale one is, in this nested structure, the same known SE techniques can be applied to effect good results.

Others say, no, depending on the scale in question, some radically different SE techniques may be needed.

See Notes Page

Notional View of Applicability of TSE and CSE

Just as some believe that traditional system engineering can be successfully applied to every system, there will be those who believe that complex-system engineering is appropriate for every system.



Source: Mike Kuras

Motivation

- Of course, there is a continuum in thinking about this.
  – There's a whole spectrum of individuals between those taking a traditionalist view and those searching for new ways of systems thinking.
- We think it is important to offer a different mindset (the regimen) to
  – "Capture the imagination" of those open to it
  – Provide "food for thought" for those wedded to more conventional views.
- During the following it may help to become a little more humble
  – Reverse (or suspend) the assumption* that one can always pre-specify, predict, and control system or enterprise behavior and performance
  – Broaden your definition of systems engineering to include the management of "complex" environments that include people, organizations, etc.

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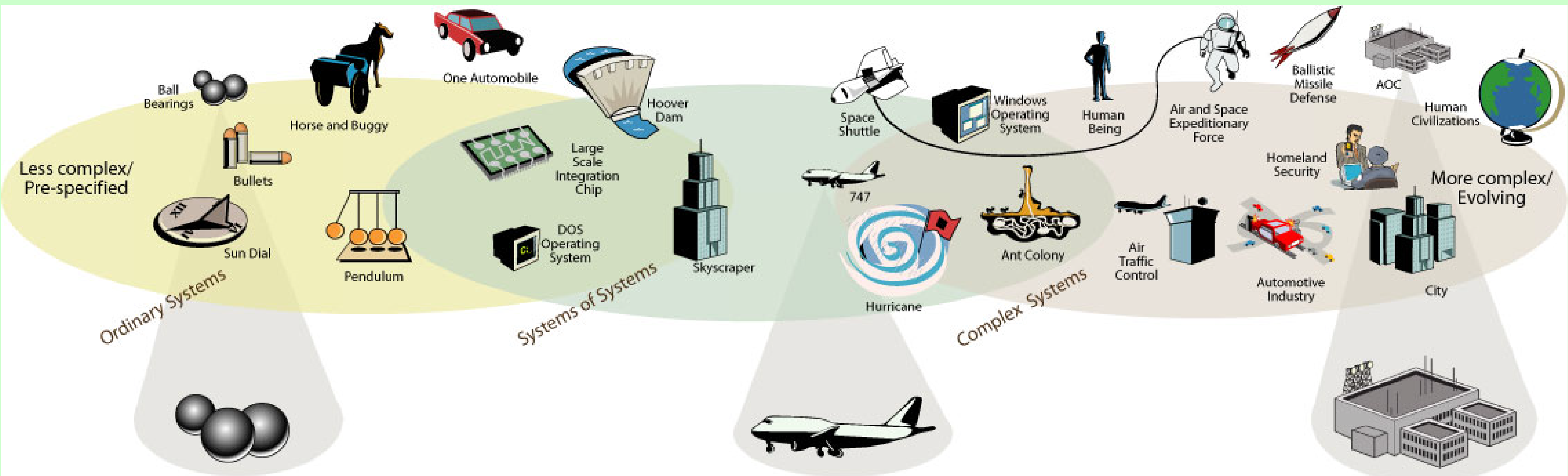
* [Johansson, 2004, pp. 53-57]

A Spectrum of Systems

System: An instance of a set of degrees of freedom* having relationships with one another sufficiently cohesive to distinguish the system from its environment.**

*Normally grouped into subsets or elements **This cohesion is also called system identity



Less complex
Pre-specified

More complex
Evolving

[Kuras and White, INCOSE, 2005]

Distinguishing Attributes of Two Classes of Systems

Complex-systems	Non-complex systems
Unique	Identical and reproducible
Development and operation concurrent and continuous	Development and operations are separate and distinct
Emergence: development and operation at multiple scales	One predominant scale amenable to reductionist analysis and synthesis
Stochastic, unpredictable	Predictable at its predominant scale
Always open	Treatable as closed or with completely specified inputs
Learning and memory of prior history alters behavior	Repeatable transients
Requires both cooperation and competition to function effectively	Competition (for resources), friction and so forth reduce effectiveness

[Kuras, 2005]

Distinguishing Attributes of Two Classes of Systems (Concluded)

Complex-systems	Non-complex systems
Robust and broadly inefficient	Can be optimized and made efficient
Ambiguous and shifting boundaries	Well-defined, distinct boundaries at its predominant scale
Explores and tests *new* possibilities	Development progressively removes *unwanted* possibilities
Self-integrating and re-integrating	Integrated by external agents in one or more configurations
Dominated by transient and short-range relationships	Dominated by uniform and permanent relationships
Can exhibit relational networks at $O(n)$, $O(n^2)$, and $O(\sim 2^n)$	Can exhibit relational networks at $O(n)$ and $O(n^2)$
Hierarchies are partial and transient	Hierarchies are important, extensive, and durable

Assertion: Complex-systems can only be engineered by intervention, not by specification and then development.

[Kuras, 2005]

See Notes Page

Complex-Systems and CSE vs. Non-Complex Systems and TSE

- Complex-systems evolve naturally
  - Non-complex systems do not.
- Many organizations are complex-system enterprises. (see next chart)
- CSE creates/shapes environmental conditions which focus and accelerate actions of people/organizations.
- CSE is complementary to TSE.
- TSE is applicable to some of the parts of an enterprise.
  - TSE techniques should still be applied when appropriate.
  - TSE is not to be abandoned.

[Kuras and White, MIT, 2005]

See Notes Page

Enterprises

- Enterprises are complex-systems functioning at multiple scales.
  - Scale: Combination of {field of view, resolution} plus {organizational, process, technical} aspects
  - Often "emergence" occurs & "patterns" appear when changing scales.
- Enterprises are characterized by *homeostatic** environments.
- Enterprise evolution is driven primarily by people/organizations acting autonomously but collectively.
- It is important and useful to characterize the enterprise's operational and developmental environment.

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* [Yates, 2002]

[Kuras and White, MIT, 2005]

ESE Environment Characterization Template

- **Typical program domain**
  - *Traditional systems engineering*
  - *Chief Engineer inside the program; reports to program manager*
- **Transitional domain**
  - *Systems engineering across boundaries*
  - *Work across system/program boundaries*
  - *Influence vs authority*
- **Messy frontier**
  - *Political engineering (power, control…)*
  - *High risk, potentially high reward*
  - *Foster cooperative behavior*

Source: Renee Stevens

MITRE

Regimen for CSE

- A regimen (not recipe) for CSE
  - Developed by SEPO's Mike Kuras
  - In paper presented at INCOSE's 2005 Symposium [Kuras-White, 2005]
- 8 CSE activities are advocated
  - Emphasize the Developmental Environment.
  - Shape Development During Operations.
  - Identify Outcome Spaces.
  - Establish Rewards (and Penalties).
  - Judge Actual Results.
  - Apply Developmental Stimulants.
  - Characterize Continuously.
  - Enforce Safety Regulations.
- The above activities are <u>not</u> independent of one another.

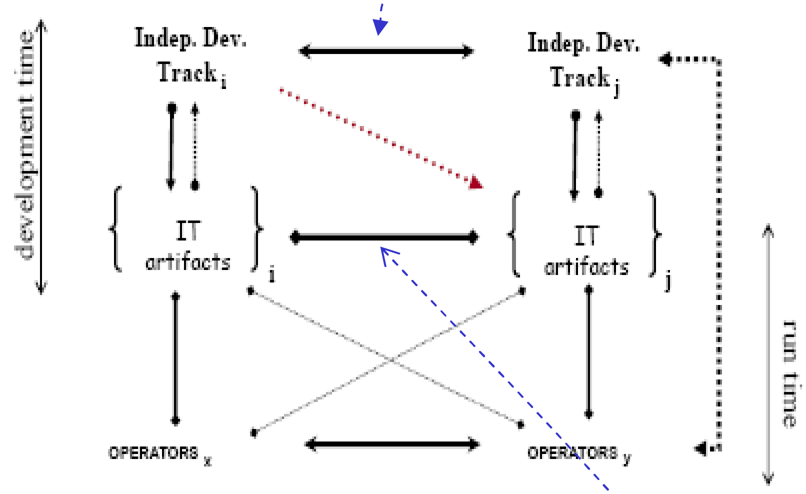
Emphasize the Developmental Environment

- Define, augment, and shape enterprise environment to be
  - Conducive to change/evolution
  - Supportive of both cooperation and competition.
- Don't try to "build" the complex-system; it builds itself.
  - Heed "the gardener" (not "the watchmaker") metaphor.
    - If it doesn't rain…
    - If rabbits are eating the plants…
  - Understand "the shopping mall" metaphor.
- Methods for engineering environments are inherently open ended, e.g.,
  - Modulate the flux of developers, e.g.,
    - Establish stipends for participation
    - Ensure unfettered information exchange
  - Manage towards stability in the face of changes like people joining or leaving the environment.
  - Divert funds from contract awards to performance rewards.
  - Use both *in situ* environments and partially artificial extensions.

Shape Development During Operations

- Development and operation overlap and occur simultaneously in a complex system. The life cycle is not development *and then* operations.
- Engineering should be applied to operations as well as to development.
- Interoperability at different scales requires different mechanisms.
- Provide mechanisms for developmental collaboration across the enterprise.
- Examples
  - Involve operators in development (JEFX, JWID, ADOCS, etc.)
  - Involve developers in operations (Joint STARS in '91)

Developmental collaboration mechanisms are focused here.



Things like Service Oriented Architectures (SoAs) are focused here.

See Notes Page

Identify Outcome Spaces

- Identify and formulate broad Outcome Spaces that appeal to many enterprise participants, not narrow and specific outcomes.
- Focus and shape evolution while focusing on goals; do not try to pre-specify an end-state.
  - Operational Outcome Spaces do not always directly inform development.
  - Developmental Outcome Spaces do not directly determine operations.
  - If specific desired outcomes can be achieved directly by individual entities, then encourage competition.
  - If collective action is required to achieve outcomes, then encourage cooperation.
- Examples of "good" Outcome Spaces
  - U.S. Army's "Own the Night"
    - Not: Detailed specifications for night-vision goggles
  - The "X-Prize"
    - Take a passenger into space, return to earth, and then repeat within a week with the same method.
  - 2005 DARPA "Grand Challenge"
    - Advance technologies that will save the lives of our uniformed men and women on the battlefield.
  - Neutralize hostile cruise and ballistic missile threats to the U.S.
    - Destroy any/all incoming cruise and ballistic missiles before impact.

See Notes Page

Establish Rewards (and Penalties)

- It is assumed that each autonomous agent of an enterprise
  - Makes decisions and takes actions to achieve what they perceive as desired outcomes
  - Is motivated by externally applied rewards and penalties
- These actions determine enterprise change/evolution.
- Rewards should link specific populations of operators and/or developers to Outcome Spaces.
  - Create financial and other types of incentive opportunities for <u>groups</u> of independent contractors, not for individual programs.
- Rewards
  - Influence, but do <u>not</u> specify, decision making outcomes
  - Can accelerate enterprise change/evolution
- Achievement Rewards are <u>not</u> contract awards.
  - Typically contracts are awarded <u>before</u> outcomes are achieved.
  - Rewards are for <u>performance</u> and <u>not</u> the plausibility of promises.
- Example of a “good” Reward
  - $10 million and a plaque for the X-prize

See Notes Page

Judge Actual Results

- Judging is the explicit assignment of Rewards to appropriate autonomous agents for actual outcomes achieved.
- The Judging activity of the CSE regimen
  - Ties Rewards to actual outcomes
  - Provides opportunities to "weed the garden"
  - Completes Outcome Space–to–Rewards–to–autonomous agents linkage
  - Is tightly coupled to Development Environment and Rewards
- When change occurs in an enterprise, the acceptability of the change needs to be determined.
  - For example, change should not inhibit future change and should not prevent the enterprise from continuing to operate successfully.
  - A "healthy" enterprise does <u>not</u> become less "complex" as it evolves.
- Rewards for positive change should be allocated to those responsible for its achievement.
- Rewards modulate resource flows from the environment to the enterprise.
- Examples
  - X-Prize
  - DARPA Grand Challenges

Apply Developmental Stimulants

- Accelerate desired outcomes by stimulating autonomous agents to interact appropriately.
  - "Stir the pot" and/or "change the rules".
  - This is the most significant factor in accelerating enterprise evolution.
- Outside agents may be able to facilitate the necessary interactions, so inject additional autonomous agents as facilitators and brokers.
  - Example: MITRE as facilitator of "Cursor on Target (CoT)".
- Autonomous agents should be making "informed" decisions.
  - Endeavor to increase the frequency, intensity, and persistence of autonomous agent interactions.
- Developmental Stimulants are not outcomes.
  - They encourage autonomous agents to create outcomes for which they are <u>mutually</u> and <u>not</u> individually accountable.
- Pay for <u>collective</u> results; for example
  - Modify DD-250 Form to Reward a working, integrated system.
  - No autonomous agent (contractor team) gets paid for delivering a component system that is not successfully integrated.

See Notes Page

Characterize Continuously

- Capture and publish current "features" of the enterprise and its environment that seem to matter (e.g., Outcome Spaces and actual outcomes achieved, Rewards, and Judging results).
  - Help autonomous agents to "think globally but to act locally".
  - Focus on "now" and do not try to pre-specify the distant future.
  - Continuously refine these features to gain consistency in agent actions.
  - Ensure that accurate evaluation criteria and metrics are developed and publicized for refined levels of the features.
  - Avoid too much detail (refinement) because metrics and efforts may become localized and not support overall enterprise performance improvement.
  - Balance the continuing characterization of existing features with initiating the characterization of new features.
- Analogical examples
  - The daily stock market report
  - Highway traffic reports
  - Best/most recent Time Critical Targeting (TCT) times

See Notes Page

Enforce Safety Regulations

- Safety Regulations focus on ensuring the continuous operation of the complex-system or enterprise – not on what it does or does not do.
  - Formulate and enforce rules that keep the enterprise functioning.
  - Develop and monitor measures of
    - "Fitness"
    - Measures of the rate of change
- Guard against complex-system failure modes: stagnation, disintegration, or collapse.
  - Absence of change may signal the potential death of the enterprise.
  - Ensure change can occur without destabilizing or destroying the enterprise.
- Examples
  - Criteria for vetting or training new autonomous agents as well as "weeding out" dysfunctional ones
  - Enforcing contractual obligations among autonomous agents
  - Managed redundancy/retirement
    - Microsoft's File Manager and Explorer
  - MIT Lincoln Laboratory's "off-line, in-line, on-line"

In Summary, Who Does All This?

- People have asked
  - Who is responsible for making all this happen?!
  - Who actually "engineers the environment" of the enterprise to accelerate its evolution?
- These are good questions beyond the present scope.
- The CSE regimen is akin to enterprise "governance".
- This role of exercising the regimen can be taken by people with respect, authority, power, and "purposeful cohesion".
- It seems likely that this "governing body" would be external to the enterprise.

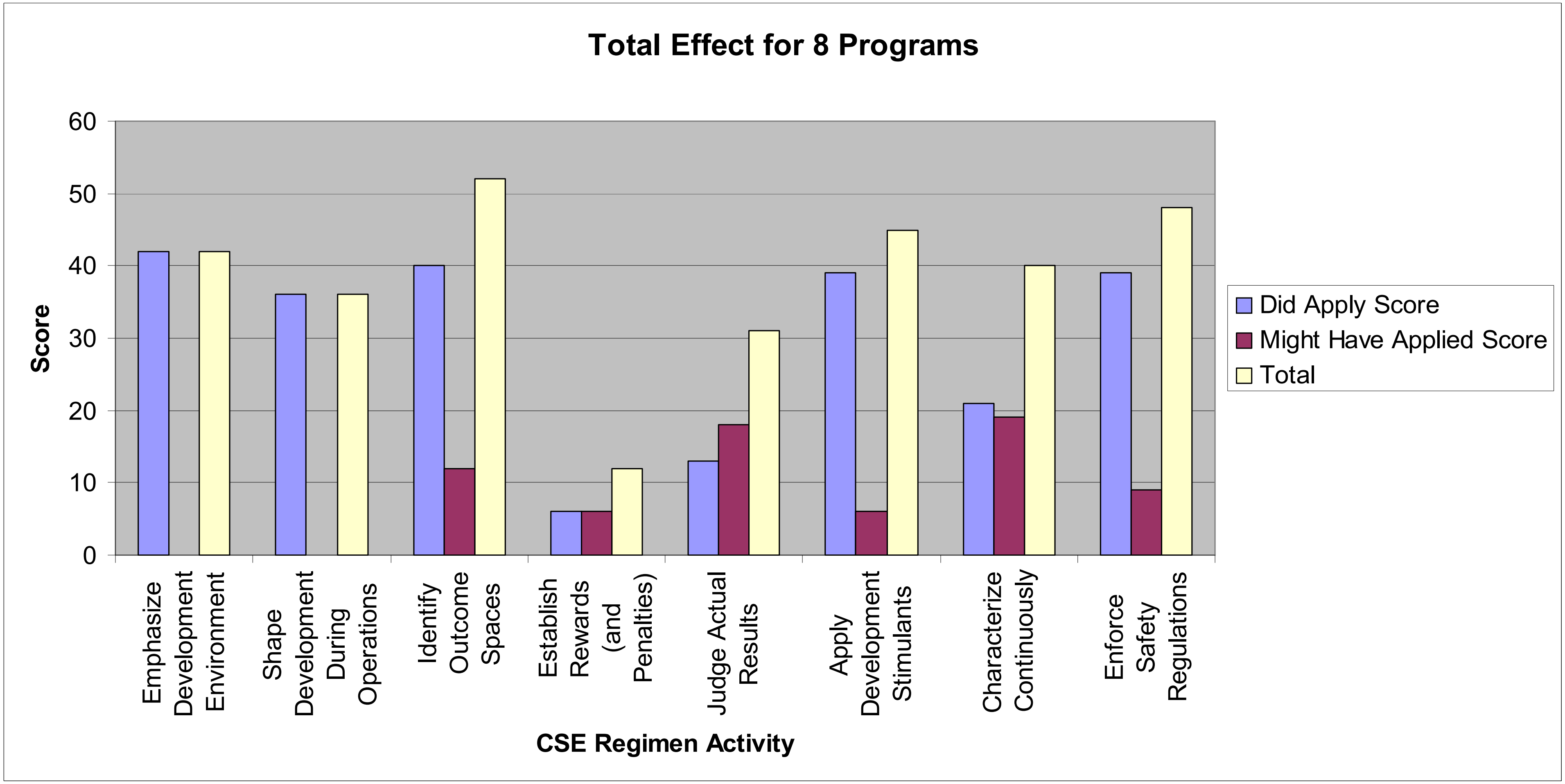
MITRE-Only 18-Feb CSE Workshop

- Purpose: Determine to what extent the CSE regimen applied to programs
- Methodology
  - Program experts provided basic information in advance
    - Program profile: program name, objective, sponsor, funding, years involved, type and number of contractors, etc.
    - Ratings on positive/negative impact of each regimen activity
  - Two hours were spent explaining/discussing the regimen.
  - Each expert briefed their program for about 30 minutes, focusing on "stories" about selected regimen activities.
  - The wrap-up discussion summarized overall impressions about applicability of regimen to programs.
  - Each expert revisited and revised their pre-meeting ratings afterwards based on what they learned during the meeting.
- Conclusions
  - The regimen applied (or could have applied) to most programs.
  - With few exceptions, the regimen had a positive impact.

MITRE Programs Involved

- Department of Defense Intelligence Information System
- National Airspace System Communications Modernization
- Air Operations Center Weapons System
- Americas Shield Initiative
- United States Visitor and Immigrant Status Indicator Technology
- Net Centric Enterprise Services
- Theater Battle Management Core System

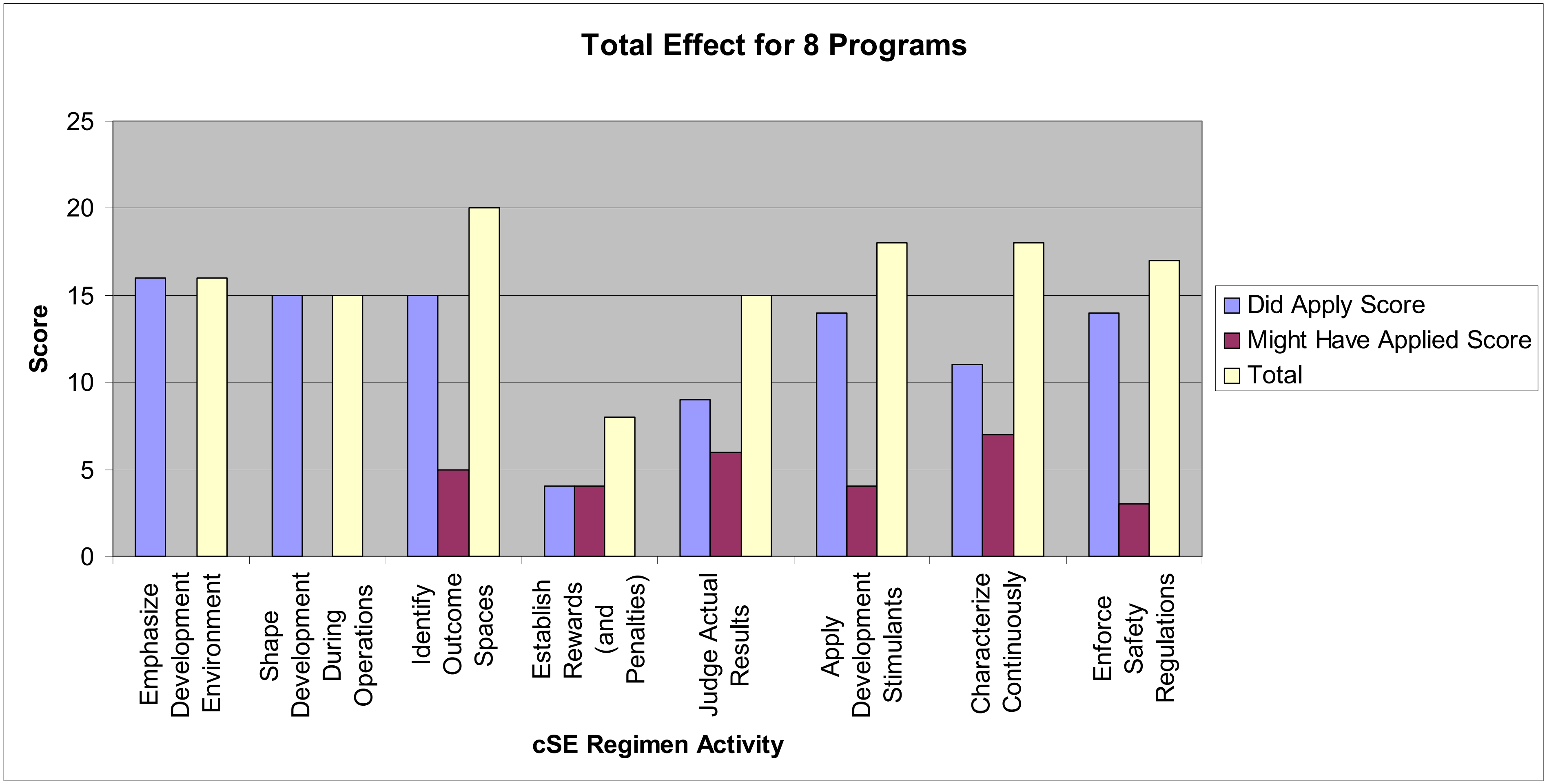
Numerical Results



<u>**Note on Individual Program *Impact Value* (whether positive or negative)**</u>

Major = 9
Significant = 3
Minor = 1

Numerical Results (Concluded)



Note on Individual Program *Impact Value* (whether positive or negative)

Major = 3
Significant = 2
Minor = 1

Summary

- A distinct mind-set for approaching CSE has been offered.
  - Concentrate on engineering the whole enterprise environment.
  - Continue to apply traditional SE techniques to individual systems.
- Terminology related to traditional and enterprise SE was gathered.
  - Definitions were crafted in an attempt to foster better understanding.
- A template for characterizing ESE environments was suggested.
- A CSE regimen for intervening in enterprise environments to achieve better outcomes was introduced.
  - Further work is needed to improve and validate the regimen.

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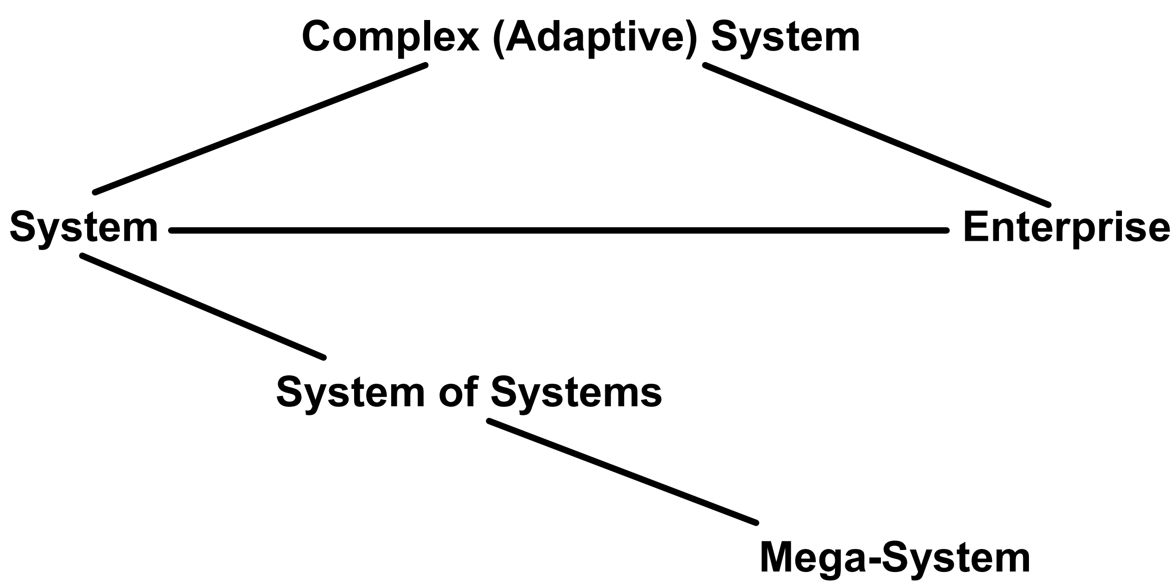
Backup Charts

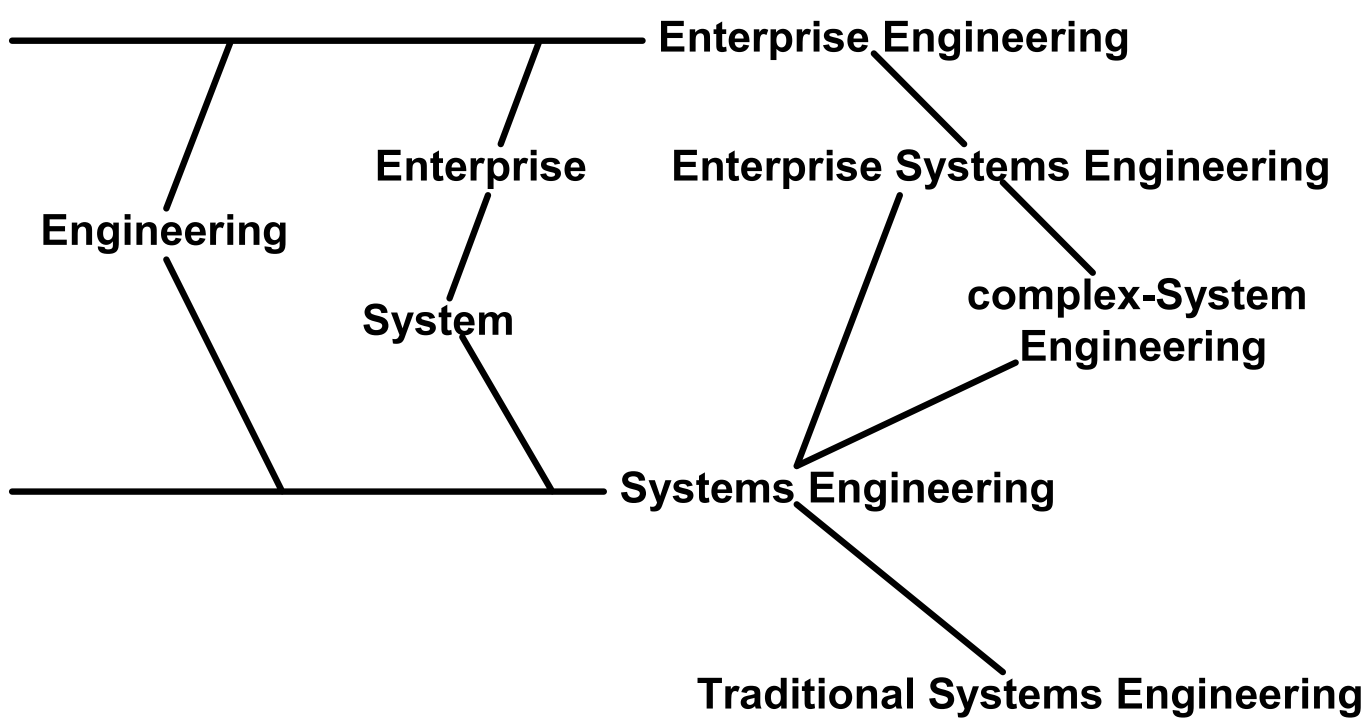
Definitions

System Definitions Diagram



Definitions (Continued)

Engineering Definitions Diagram



Definitions (Continued)

System: **An interacting mix of elements forming a whole greater than the sum of its parts.**

Features: These elements may include people, cultures, organizations, policies, services, techniques, technologies, information/data, facilities, products, procedures, processes, and other human-made or natural) entities. The whole is sufficiently cohesive to have an identity distinct from its environment.

Note: In this definition a system does not necessarily have to be fully understood, have a defined goal/objective, or have to be designed or orchestrated to perform an activity.

System of Systems (SoS): **A collection of systems that functions to achieve a purpose not generally achievable by the individual systems acting independently.**

Features: Each system can operate independently and is managed primarily to accomplish its own separate purpose. A SoS can be geographically distributed, and can exhibit evolutionary development and/or emergent behavior.

Complex System: **An open system with continually cooperating and competing elements.**

Features: This type system continually evolves, changing its behavior in response to itself and its external environment (often in unexpected ways). Changes between states of order and chaotic flux are possible. The relationships of the elements are imperfectly known, and are difficult to describe, understand, predict, manage, control, design, and/or change.

Notes: Here "open" means free, unobstructed by artificial means, and with unlimited participation by independent agents and interactions with the system's environment. Also, a complex system that is entirely natural is not an enterprise (see below).

Enterprise: **A complex system exhibiting a relatively stable equilibrium among many interdependent component systems in a shared human endeavor.**

Features: An enterprise may be embedded in a more inclusive complex system. External dependencies may impose environmental, political, legal, operational, economic, legacy, technical, and other constraints.

Notes: According to this definition, an enterprise need not include an agreed-to or defined scope/mission and/or set of goals/objectives. In addition, there is no attempt to include what is necessary to embody a successful enterprise; that is a different topic, i.e., enterprise engineering and enterprise systems engineering (see below).

Definitions (Continued)

Engineering: **Methodically conceiving and implementing solutions to real problems, with something that is meant to work.**

Note: This definition does not imply that the problems are always solved.

Enterprise Engineering: **Application of engineering efforts to the enterprise with emphasis on enhancing capabilities of the whole and understanding the relationships and interactive effects among the components.**

Note: This definition does not necessarily imply that the "best" efforts are applied. (See enterprise systems engineering on next chart.)

Systems Engineering: **An iterative and interdisciplinary management and development process that defines and transforms requirements into an operational system.**

Features: Typically, this process involves environmental, economic, political, and social aspects. Activities include conceiving, researching, architecting, utilizing, designing, developing, fabricating, producing, integrating, testing, deploying, operating, sustaining, and retiring system elements.

Notes: The customer for or user of the system usually states the initial version of the requirements. The systems engineering process is used to help better define and refine these requirements. Further, often the requirements change as further decisions are made as a result of systems engineering. Hence, for conciseness, the use of the single word "defines". This definition does not imply that a successful system is always realized. The word "integrated" is not included in this definition because systems engineering efforts may not be that well integrated.

Definitions (Concluded)

Traditional Systems Engineering (TSE): **Systems engineering but with limited attention to the non-technical and/or complex system aspects of the system.**

Features: In TSE there is emphasis is on the process of selecting and synthesizing the application of the appropriate scientific and technical knowledge in order to translate system requirements into a system design. Here it is normally assumed and assured that the behavior of the system is completely predictable. Traditional engineering [not just TSE] typically is directed at the removal of unwanted possibilities.

Note: Here it is assumed that TSE is identical to "classical" systems engineering, i.e., customary and accepted methods of doing system engineering.

Enterprise Systems Engineering (ESE): **A regimen for engineering "successful" enterprises.**

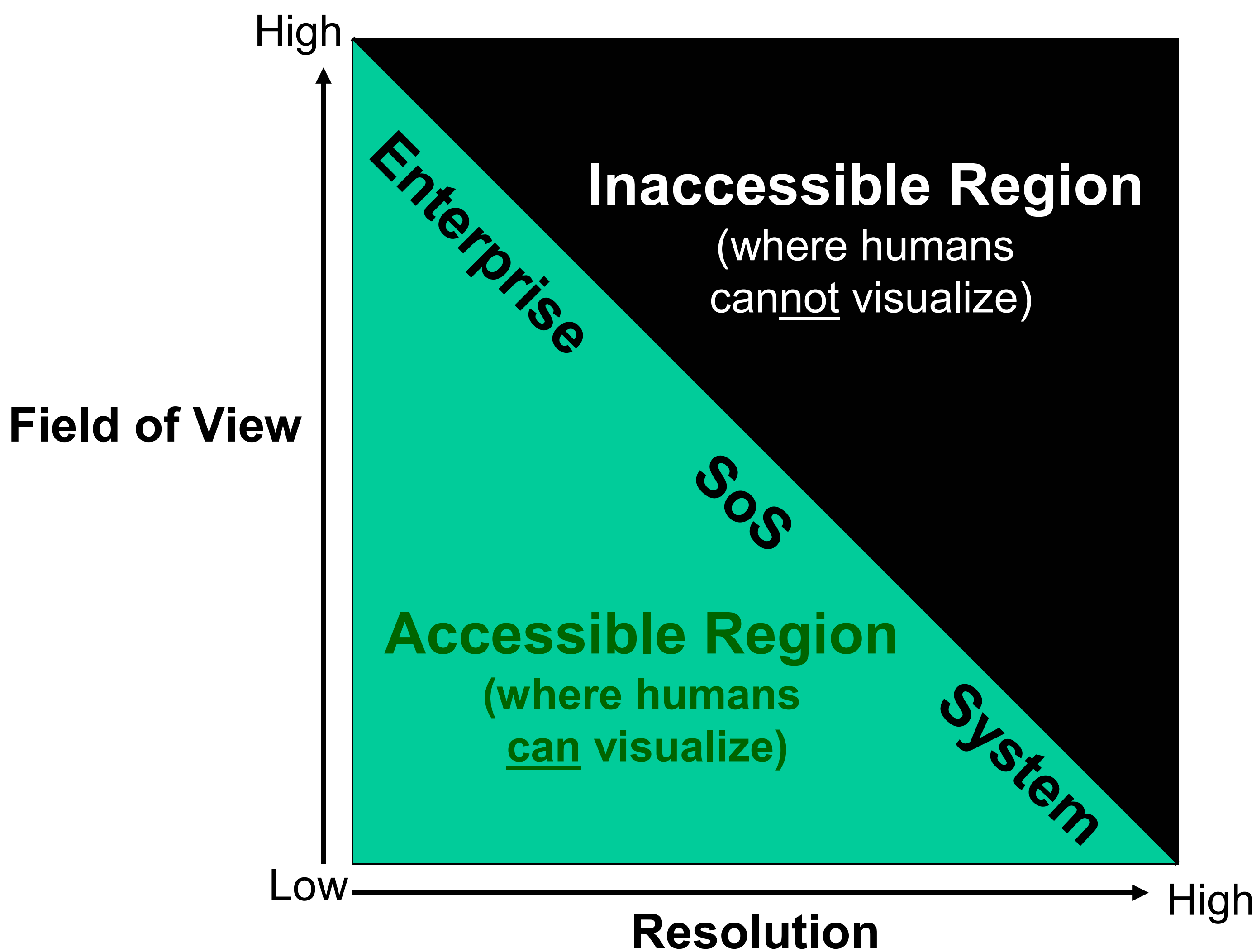
Features: ESE is systems engineering but with emphasis on that body of knowledge, tenets, principles, and precepts, having to do with the analysis, design, implementation, operation, and performance of an enterprise. The enterprise systems engineer concentrates on the whole as distinct from the parts, and its design, application, and interaction with its environment. Some potentially detrimental aspects of TSE are given up, i.e., not applied, in ESE.

Notes: Here "regimen" means a prescribed course of engineering for the promotion of enterprise success.

Complex-System Engineering (CSE): **ESE but with additional conscious attempts to further open the enterprise to create a less stable equilibrium among many interdependent component systems.**

Features: In CSE, special attention is paid to emergent behavior, especially due to the openness quality, which can either be desirable or undesirable. One tries to instill the deliberate and accelerated management of the natural processes that shape the development of complex systems.

Multiscale View of Complexity

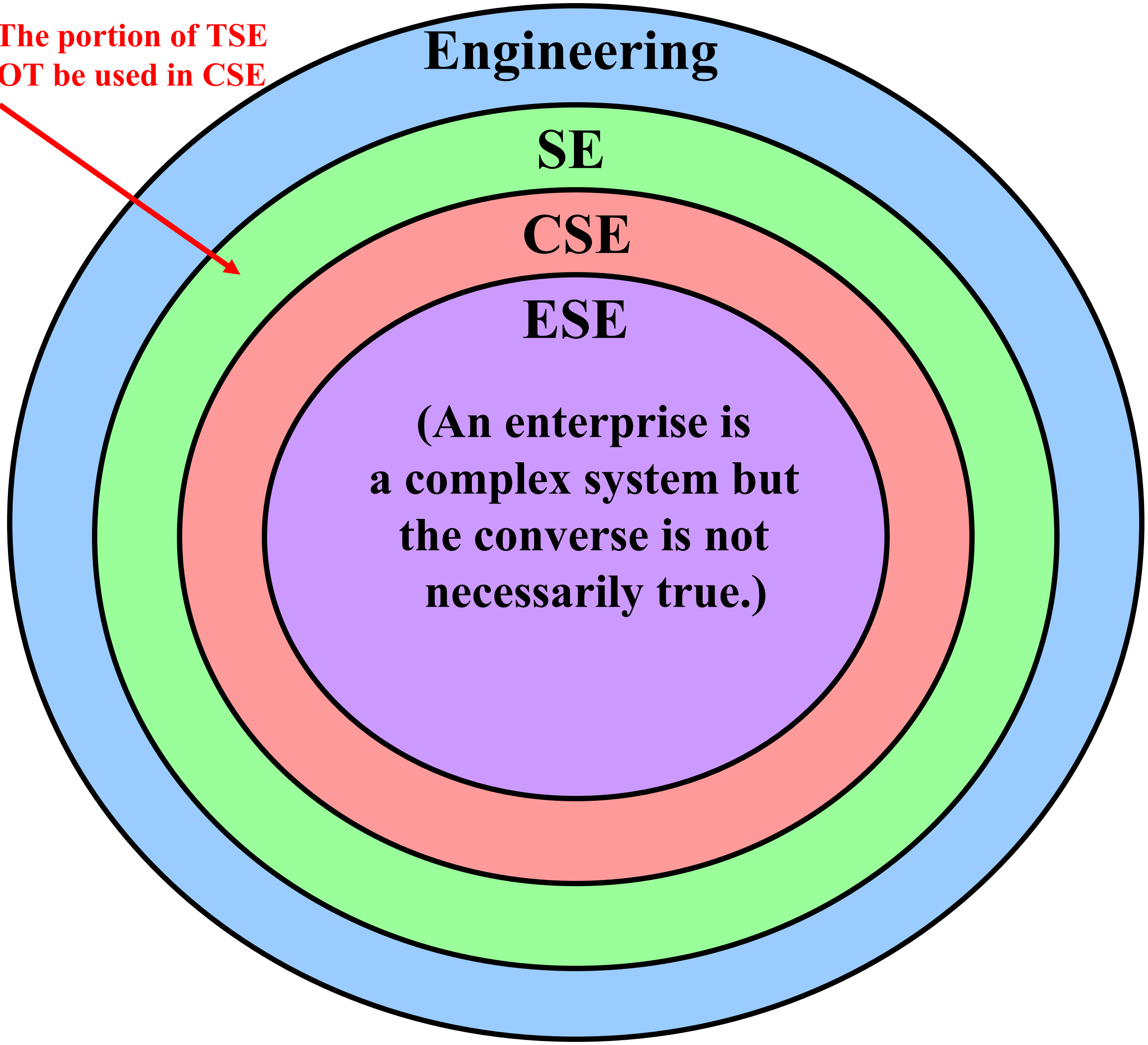


From: Kuras, M. L., and B. E. White, "Engineering Enterprises Using Complex-System Engineering," Paper for INCOSE 10-14 July 2005 Symposium, Rochester, NY

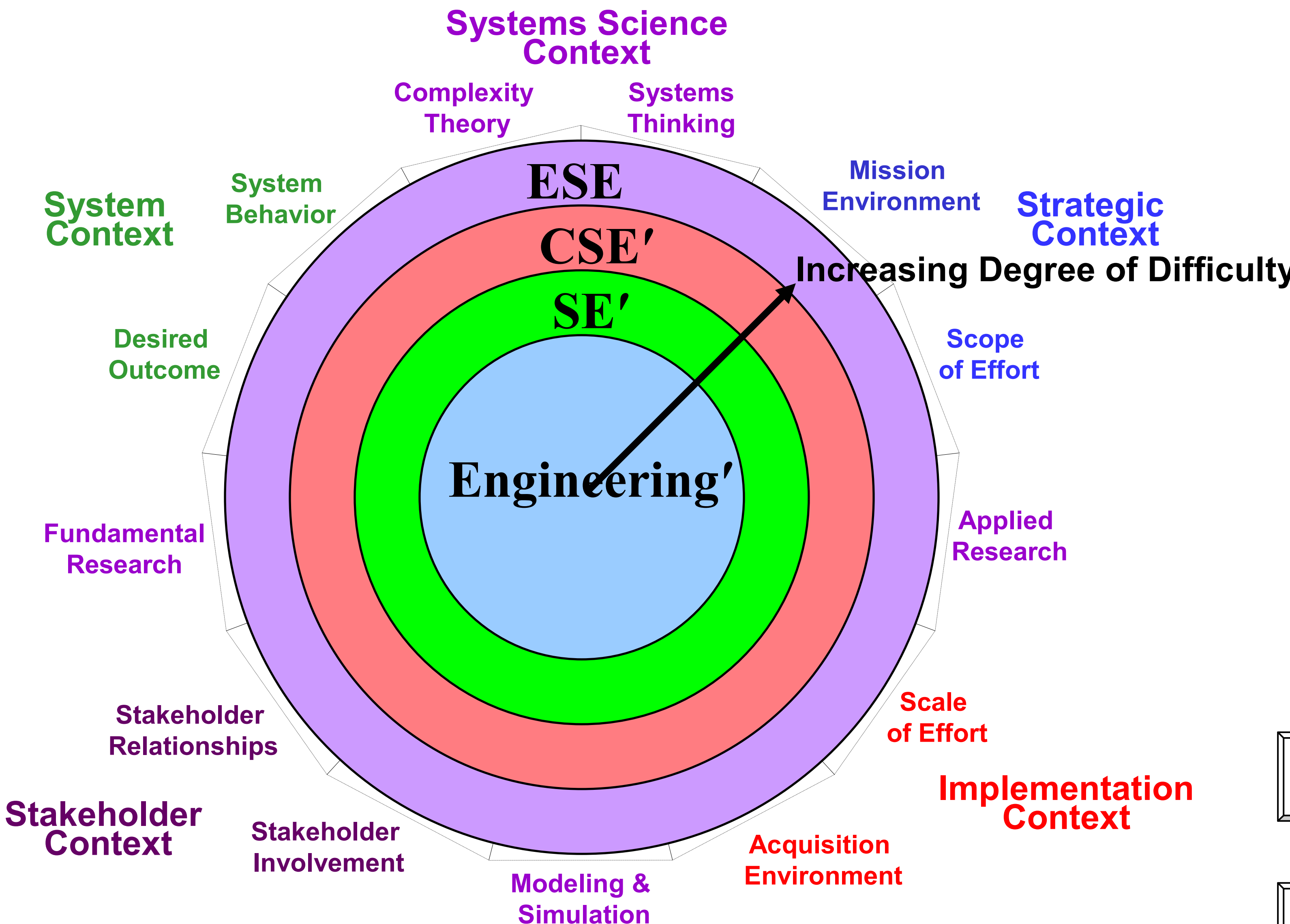
See Notes Page

Set Theory View of Engineering Disciplines

“SE – CSE”= The portion of TSE that should NOT be used in CSE



Degree of Difficulty View of Engineering Disciplines*



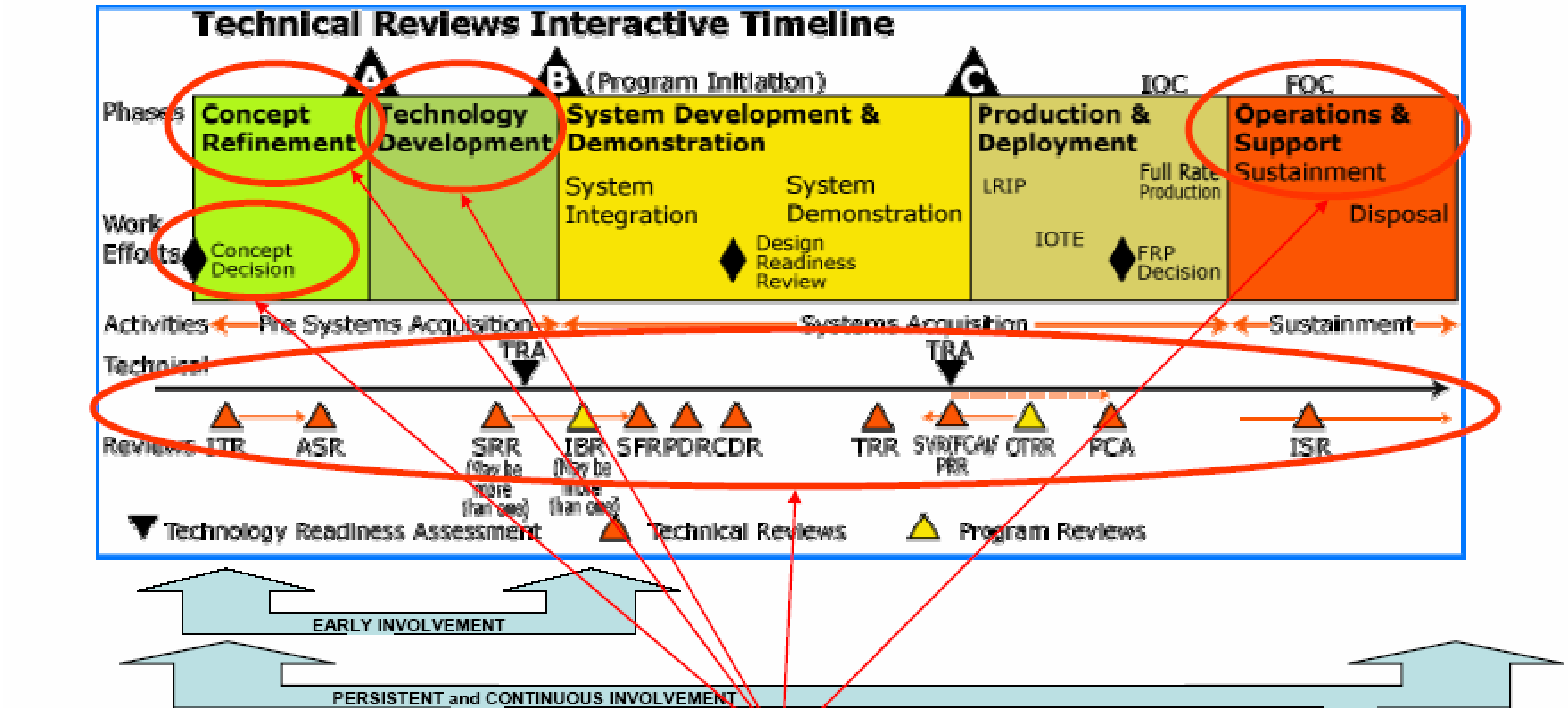
Notes:
Derived from Renee Stevens' template (see Chart 8)
These "rings" should be interpreted as "partitioned" versions of the rings of Chart 32, e.g., Engineering′ above is that portion of The whole Engineering set that is not included in the SE set, etc.

Traditional System Engineering

- Underpinnings of classical linear system analysis
- Hierarchical composition of separately engineered subsystems is common
- Addresses the form, fit, and function of a solution for a problem in two basic steps
  - First, functionality
  - Then, implementation
- Starts with “specifications”
  - Specifications are predictions that are made to come true.
  - Systems are built to “stand alone”.
- Predictions carry a lot of weight.
  - Plans, roadmaps, schedules, etc.
  - Developmental tests are planned independently of implementation.
  - When there is divergence, one tries to restore the validity of the predictions.
- Many detailed tools and procedures
  - Requirements analysis, allocation, and traceability
  - Functional analysis/synthesis, tradeoffs, abstractions, structuring and layering
  - WBSs, PERT and Gantt charts, etc.
  - Developmental processes (waterfall and spiral models, etc.), developmental and quality metrics, configuration control, etc.
  - Modeling/simulation, OSS&E, C4ISPs, ICDs
  - Technology surveys and risk management
  - Unit & integration testing, OT&E, MTPs, etc.
  - System architecting (operational views, employment views, technology views, materiel views, acquisition views, etc.)
- Many techniques are applied and refined successfully at the product level
  - Linearize non-linear problems (externalize memory; employ feedback).
  - More detail is always beneficial.
  - Iterate when possible.
  - Bottom-up and top-down convergence also helps.

Abridged from: Kuras, M. L., 12 Jan 05, “Introduction to Complex-system Engineering,” for the Air Force (AF) Scientific Advisory Board (SAB); Skip Saunders’ subcommittee on System of Systems (SoS) Study.

Driving SE Back Into Programs
[Good Systems Engineering Plans (SEPs) Are Key]



Increased use of disciplined SE, including formal technical reviews, to effectively address all technical issues

17

From: "Driving Systems Engineering into Programs," Mark D. Schaeffer, Principal Deputy Director, Defense Systems, Director, Systems Engineering, Office of the Under Secretary of Defense (AT&L), 23 March 2005, Keynote for CSER, Stevens Institute of Technology

Abbreviations and Acronyms

ADOCS = Air Defense Operations Center System
AF = Air Force
AOC = Air Operations Center
ASR = Acquisition Strategy Report
AT&L = Acquisition, Technology, and Logistics
C4ISP = Command, Control, Communications, Computers, and Intelligence Support Plan
CCRP = Command and Control Research Program
CDR = Critical Design Review
CoT = Cursor on Target
CSE = Complex-System Engineering (or cSE)
CSER = Conference on Systems Engineering Research
CTC = Concurrent Technologies Corporation
DARPA = Defense Advanced Research Projects Agency
DoD = Department of Defense
DOS = Disk Operating System
ESD = Engineering Systems Division
ESE = Enterprise Systems Engineering
FOC = Full Operational Capability
FoV = field of view
FRP = Full Rate Production
IBR = Initial Baseline Review
ICD = Interface Control Document
INCOSE = International Council on Systems Engineering
IOC = Interim Operational Capability
IOTE = Initial Operational Test & Evaluation
ISR = Independent Safety Review
IT = information technology
ITR = Independent Technical Review
JEFX = Joint Expeditionary Force Experiment
Joint STARS = Joint Surveillance & Target Attack Radar System
JPDO = Joint Planning and Development Office
JWID = Joint Warfighter Interoperability Demonstration
MIT = Massachusetts Institute of Technology

Abbreviations and Acronyms (Concluded)

MTP = Maintenance Test Plan [or Package]
NDIA = National Defense Industrial Association
NECSI = New England Complex Systems Institute
O = order
OOS&E = Operational Safety, Suitability and Effectiveness
OT&E = Operational Test and Evaluation
OTRR = Operational Test Readiness Review
OUSD = Office of the Under Secretary of Defense
PCA = Physical Configuration Audit
PDR = Preliminary Design Review
SAB = Scientific Advisory Board
SE = systems engineering
SEP = Systems Engineering Plan
SEPO = Systems Engineering Process Office
SFR = System Functional Review
SoA = Service Oriented Architecture
SoS = System of Systems
SoSECE = System of Systems Engineering Center of Excellence
SRR = System Requirements Review
TCT = Time Critical Targeting
TRA = Technical Readiness Assessment
TRR = Technical Readiness Review
TSE = Traditional Systems Engineering (or System)

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FUTURE COMBAT SYSTEMS

One Team-The Army/Defense/Industry

System of Systems Analysis of Future Combat Systems Sustainment Requirements

Ivan W. Wolnek

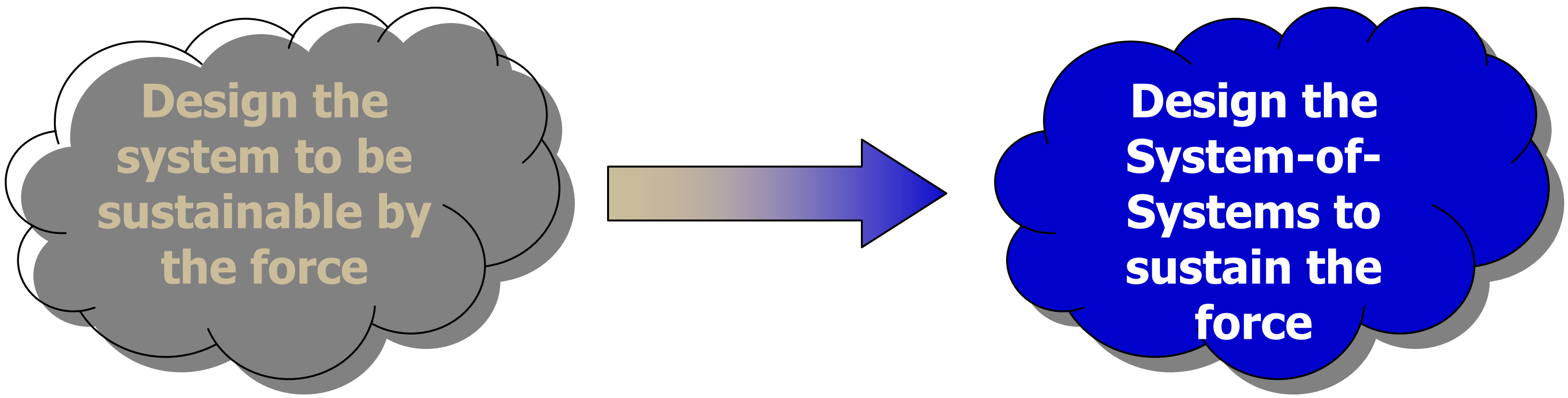
Associate Technical Fellow

The Boeing Company

8Th Annual NDIA Systems Engineering Conference

October 2005

FCS Sustainment



Development of an individual system → **Development of a System-of-Systems**
Current Army force structure → **Future Force – Unit of Action**

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Agenda

- FCS and Army Transformation
- Supportability Performance
- Analysis Process and Examples
- Process Enablers
- Lessons Learned
- Questions

Leading Transformation

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

- **The US Army "At War and Transforming"**
  - 781,000 to 480,000 active duty since 1990
  - Forces currently deployed in 120 countries
  - Army's transformation effort announced in Oct 1999
  - Leading implementation of network-centric operations
  - Driving Joint interdependency and standards

General Peter J. Schoomaker
Chief of Staff, U.S. Army

- **FCS: Transformation in Multiple Dimensions**
  - Warfighting, logistics, technology, business

FCS is a Complex System of Systems in a Transformational Warfighting Context

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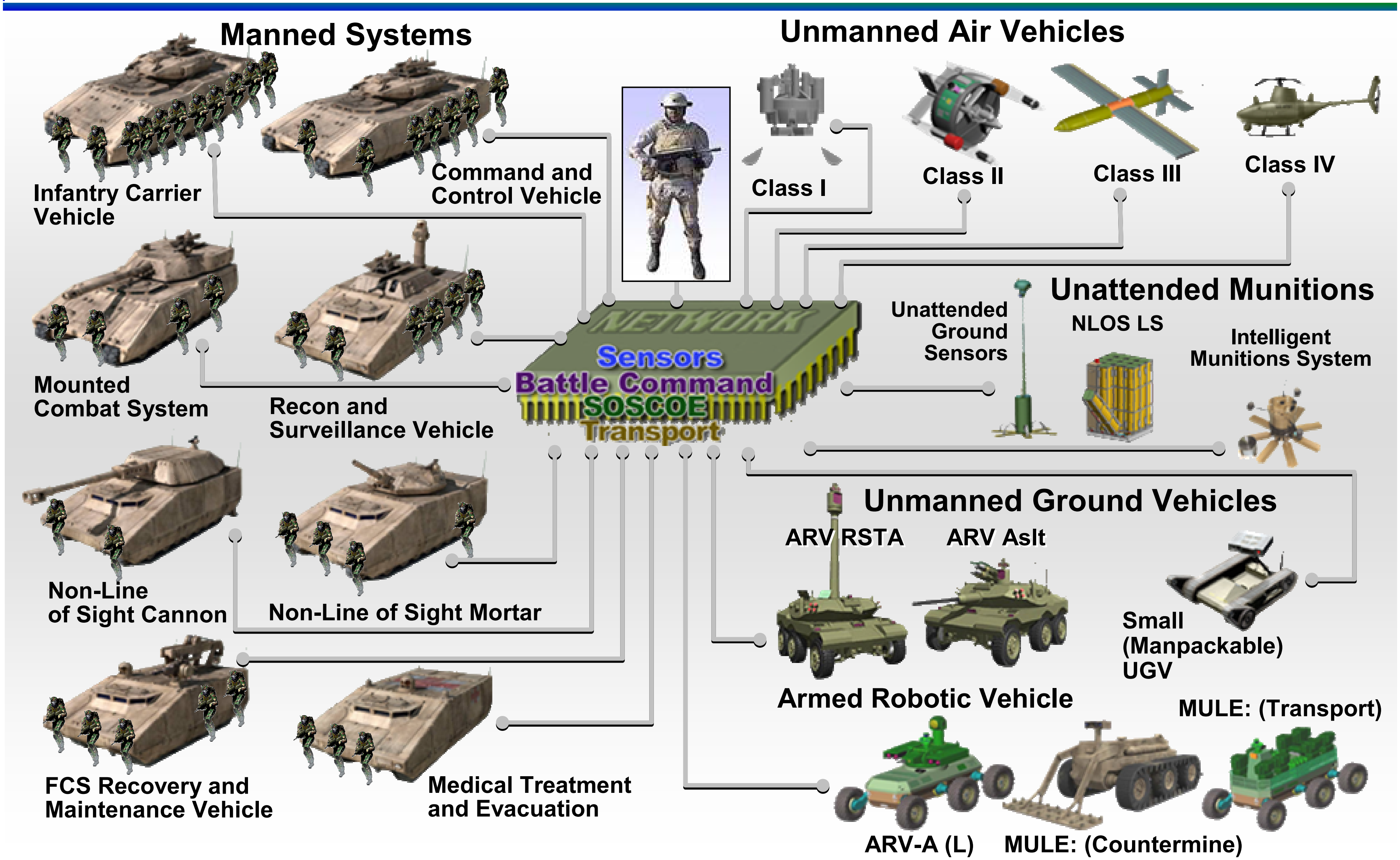
Reaffirming the Government's Key Program Tenets

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

- Create opportunity for **Best of Industry** to participate
- Leverage government **Technology** base to maximum extent
- **Associate** on-going enabling efforts with LSI-Led activity
- **Collaborative Environment** from design through life cycle
- As a minimum, **Commonality** at subsystem/component level
- Design/plan for **Technology Integration and Insertion**
- Maintain and shape the **Industrial Base** for the future
- Retain **Competition** throughout future force acquisition
- Appropriate **Government Involvement** in procurement processes
- Consistent and continuous **Definition of Requirements**
- Maintain and shape government acquisition community
- Program **Affordability - Balance** performance and sustainment
- One team operating with **Partnership and Teamwork**

The tenets remain constant: Applying them to the Current and Future Force

Future Combat Systems



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Supportability Performance

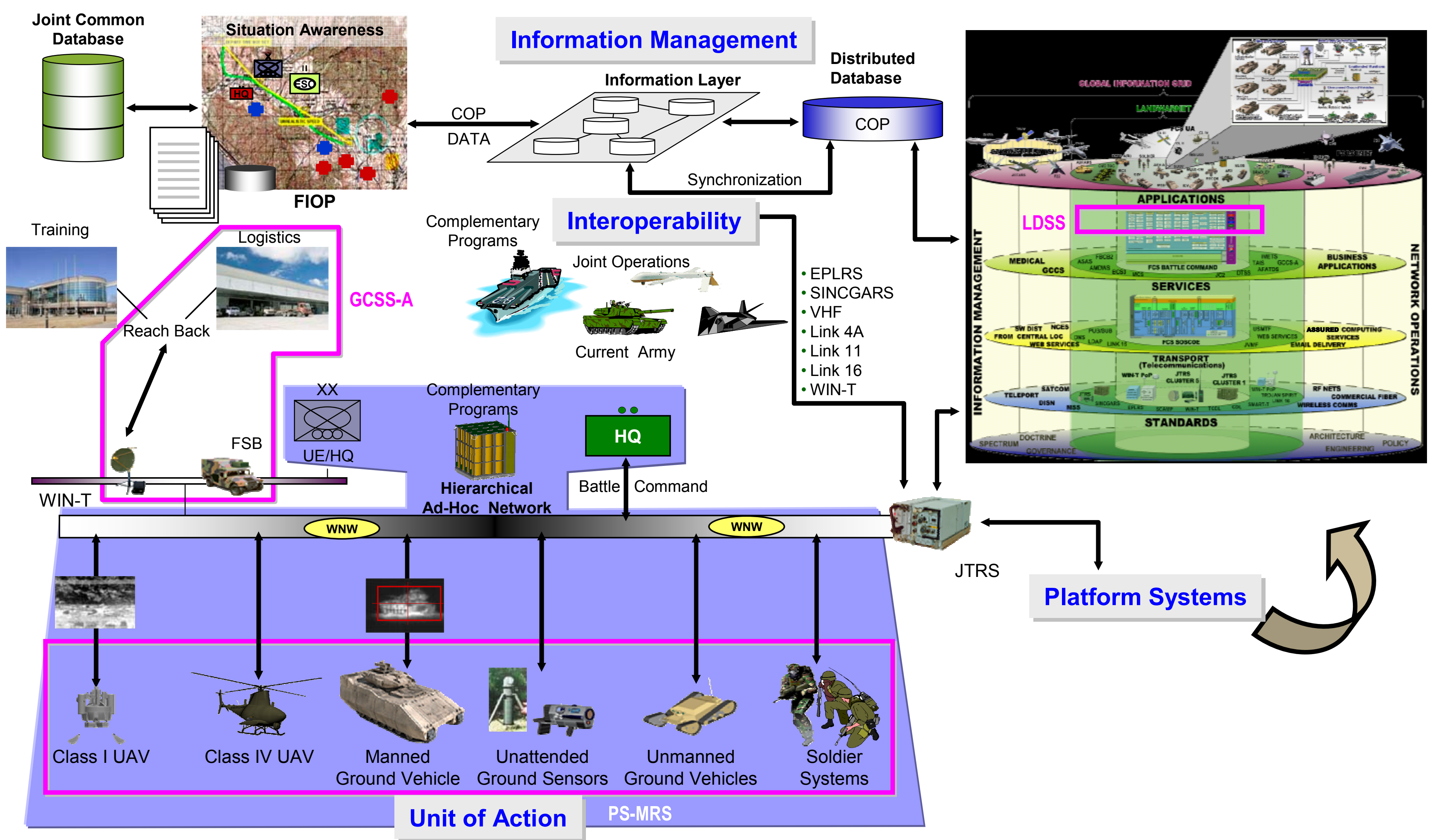
FUTURE COMBAT SYSTEMS
FCS
One Team-The Army/Defense/Industry

- **Supportability Performance Objectives**
  - Reduced Logistics Footprint
  - Reduced Demand for Maintenance
  - Reduced Demand for Supply

- **Enabled by**
  - Personnel Efficiencies
  - Improved Reliability/Availability
  - Lower Maintenance Ratio
  - Increase in Crew-performed Maintenance
  - Lower Consumption Rates
  - Part and supply Commonality
  - Self-Sustainment
  - Networked Sustainment

The Integrated - Interoperable UA

Network-Centric Warfighting - Supportability



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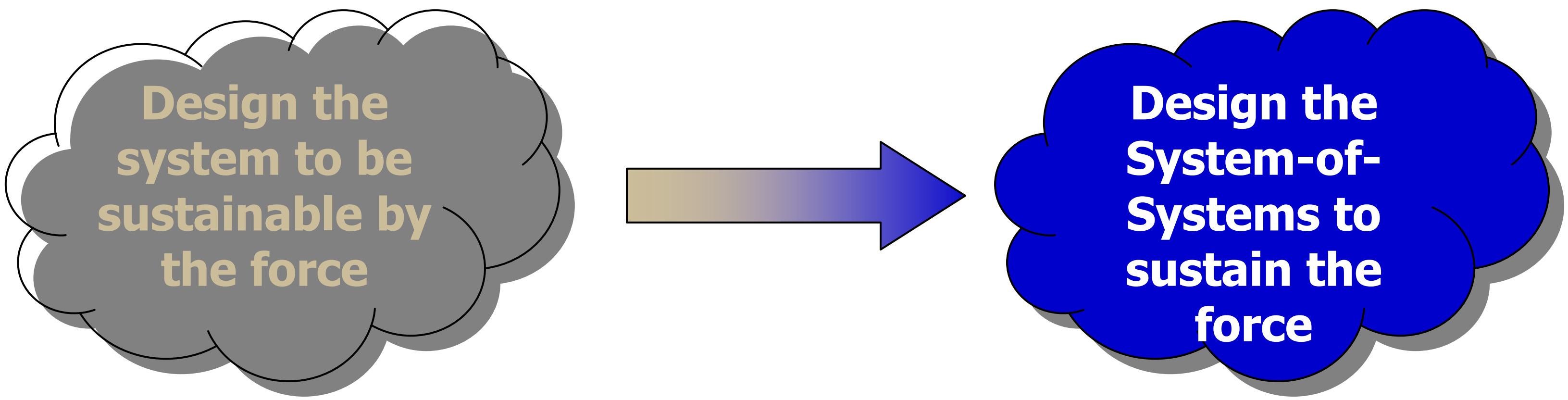
Supportability as a Quality of Firsts

- **See First**
  - The Networked Sustainment system “sees” supportability concerns before the warfighter
- **Understand First**
  - Networked Sustainment system understands the impact/influence of supportability concerns on the force
- **Act First**
  - Networked Sustainment system automatically presents Courses of Action (COAs) to the User to resolve supportability concerns
  - Automated initiation of COAs
- **Finish Decisively**
  - Networked Sustainment enables resolution of supportability concerns with minimal impact to force operation
- **Sustainment Concerns = need for and status of:**
  - Resupply
  - Maintenance
  - Combat Health Support
  - Human Resource Support

Sustainment Performance Analysis

- Integrate Army doctrine for supportability functionality into the FCS requirements baseline
- Apply FCS Networked Sustainment concept to the accomplishment of supportability functions in the UA



Development of an individual system → **Development of a System-of-Systems**
Current Army force structure → **Future Force – Unit of Action**

Agenda

- FCS and Army Transformation
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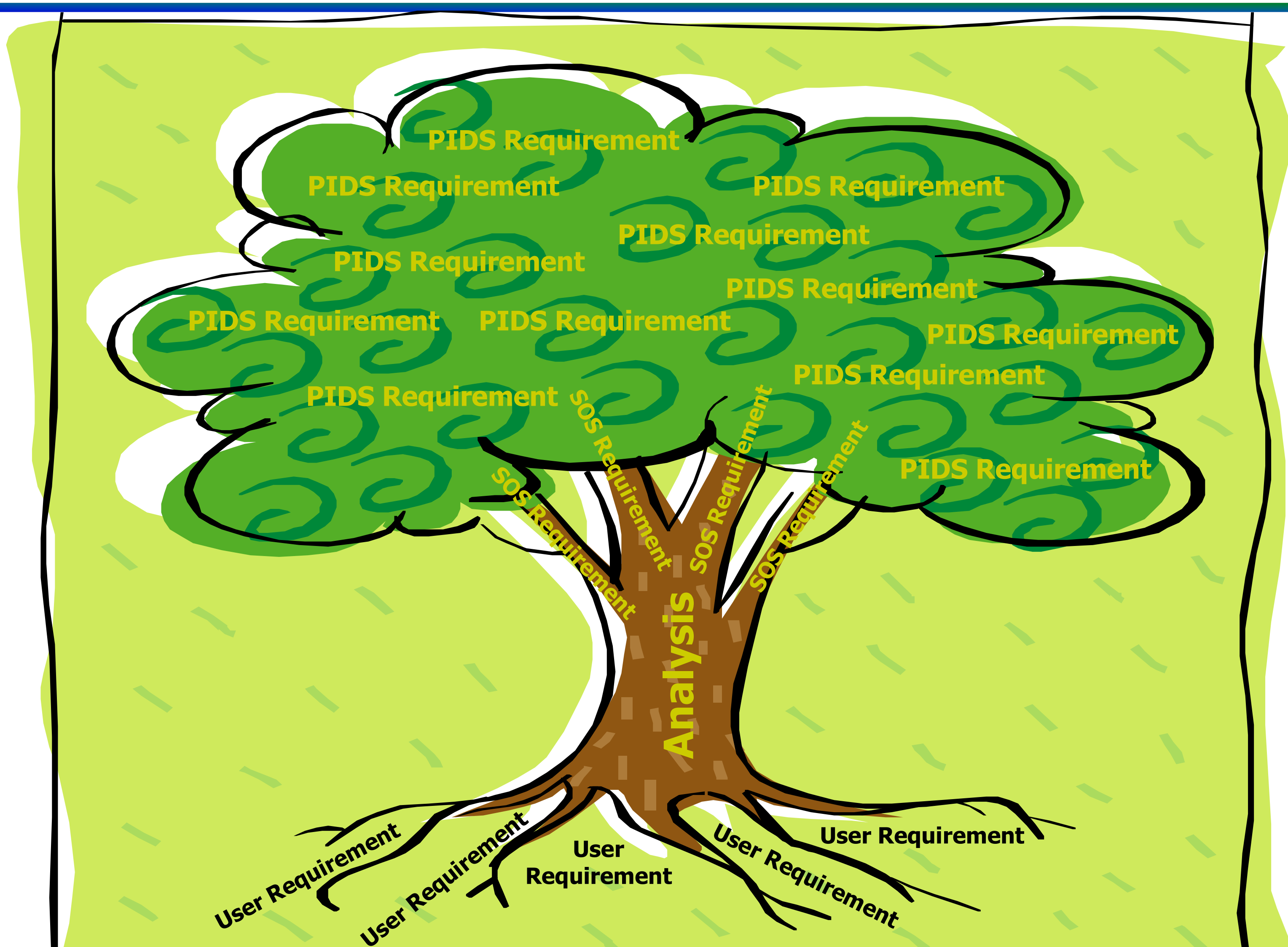
Requirements Tree

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry



Analysis establishes a strong foundation to support requirements development

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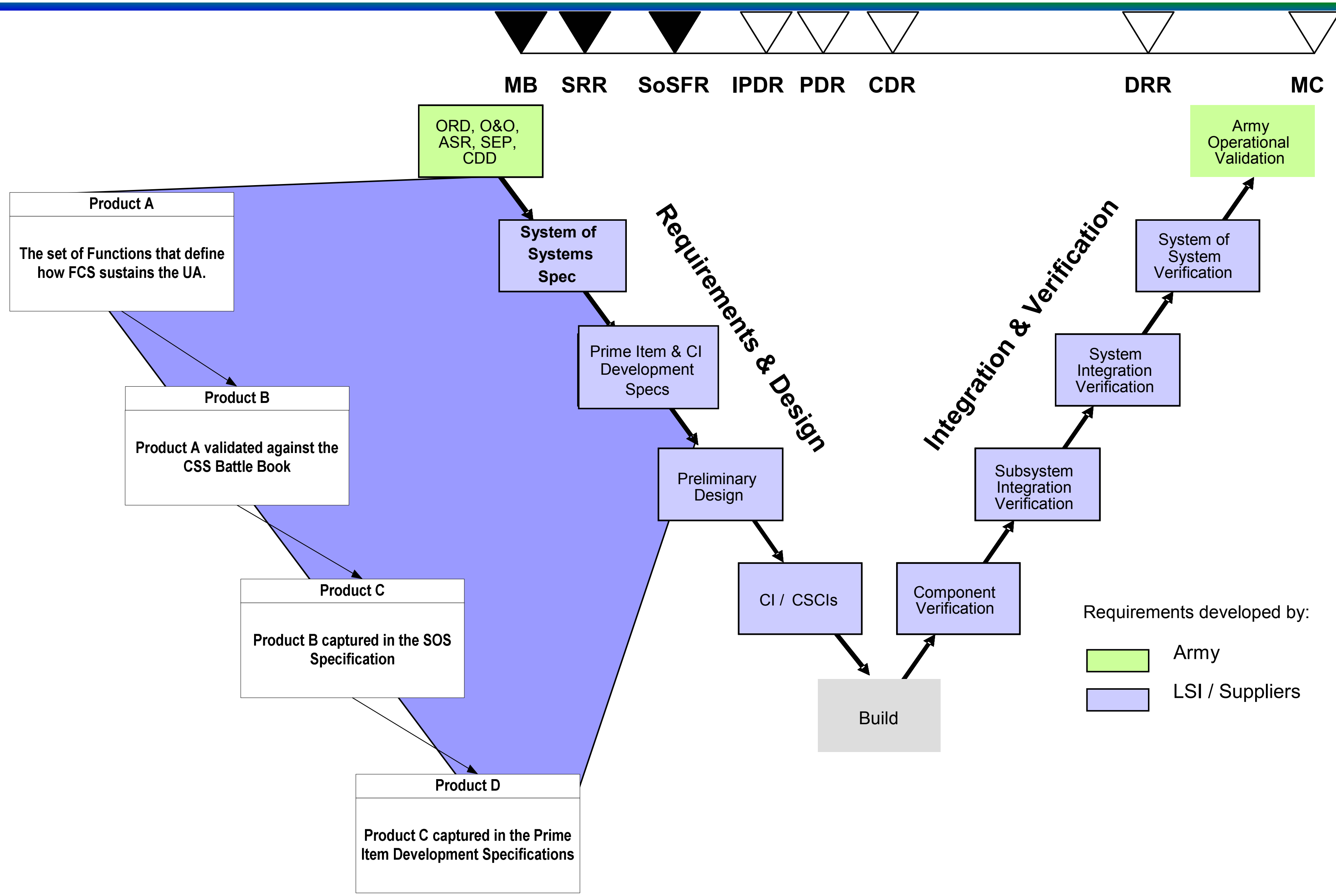
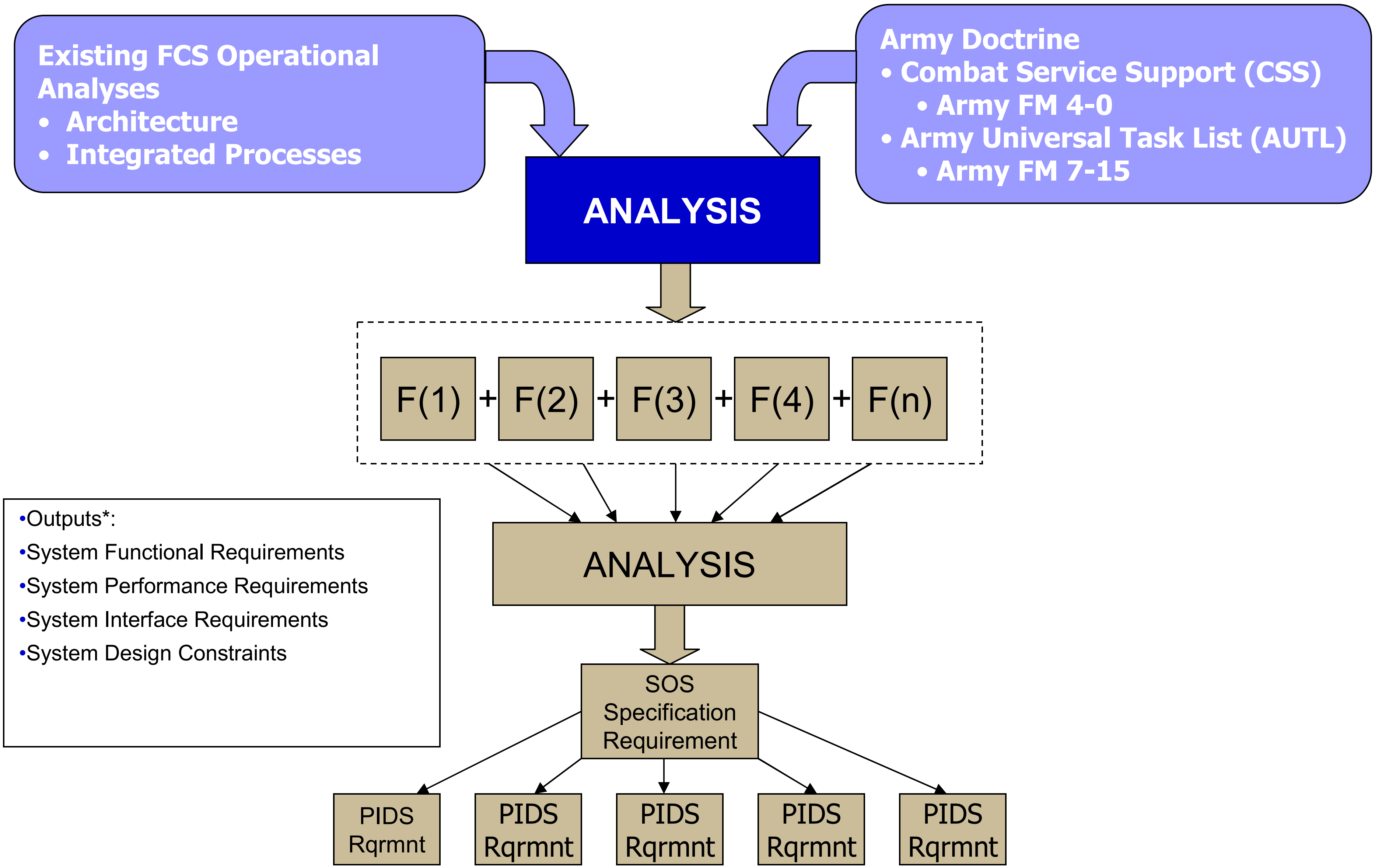
Analysis Focus



Requirement Decomposition Process



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Example – Human Resources Support

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

Combat Services Support		Army Universal Task List
Human Resources Support	....	Provide Human Resources Support
Manning the Force	....	Man the Force
Personnel Readiness Management	....	Conduct Personnel Readiness Management
Replacement Operations Management	....	Conduct Replacement Operations
Personnel Accounting		
		Provide Career Management
Personnel Information Management	....	Provide Personnel Information Management
		Manage DOD/DA Civilian Personnel
Personnel Services		
Personnel Support		

Distribute soldiers to subordinate commands based on documented manpower authorizations and the commander's priorities. ART 6.6.1.1 involves the critical manning tasks of predict, resource, monitor, assess, and adjust.

- Upon prediction of a critical personnel manning vacancy based upon …. the FCS Networked System shall identify the vacancy to the Commander.
- Upon notification of a vacancy … the FCS Networked System shall recommend assignments to fill critical personnel manning requirements.
- The FCS Networked System shall prioritize critical personnel manning data for the Commander's assessment.
- The FCS Networked System shall collect critical personnel manning data in accordance with AR 220-1.
- The FCS Networked System shall recommend adjustment of critical personnel to distribute soldiers to subordinate UA commands.

Example – Dental Support

FUTURE COMBAT SYSTEMS

One Team-The Army/Defense/Industry

Combat Services Support

- Health Service Support
  - Functional Areas
    - Medical Evacuation & Regulation
    - Hospitalization
    - Health Service Logistics
    - Dental Services
      - Operational Care
        - Emergency Dental Care
        - Essential Dental Care
      - Comprehensive Care
    - Veterinary Support
    - Preventive Medicine

Army Universal Task List

- Provide Force Health Protection
  - Provide Combat Casualty Care
    - Provide Medical Treatment
    - Provide Hospitalization
    - Provide Dental Services
      - Operational Dental Care
        - Emergency Dental Care
        - Essential Dental Care
      - Comprehensive Dental Care
    - Provide Clinical Laboratory Services
    - Provide Mental Health Treatment
  - Provide Medical Evacuation
  - Provide Medical Logistics
  - Provide Casualty Prevention
    - ...
    - ...
    - ...
    - Provide Preventive Dentistry Support

Out of Scope For Unit of Action

Example – Dental Support (page 2)

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

Combat Services Support	Army Universal Task List
Dental Services	Provide Dental Services
Operational Care	Operational Dental Care
Emergency Dental Care	Emergency Dental Care
Essential Dental Care	Essential Dental Care
Comprehensive Care	Comprehensive Dental Care

Prevent and treat dental disease and injury. ART 6.5.1.3 includes providing operational dental care, which consists of emergency dental care and essential dental care, and comprehensive care which is normally only performed in fixed facilities in CONUS or in at least a Level III facility.

- Provide Emergency Dental Treatment
  - Collect Emergency Dental data
  - Communicate Emergency Dental Data to MC4
- Provide Preventive Dental Support
  - Collect preventive Dental data
  - Communicate preventive Dental Data to MC4

Out of Scope For Unit of Action

Analysis Summary and Results

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

- **Original Sustainment requirements analysis based only on the ORD resulted in approximately 1100 requirements**
- **Incorporation of CSS and AUTL field manuals into the analysis process**
- **CSS/AUTL analysis clarified functionality not obvious in original ORD analysis**
  - Human Resources
  - Information Management
    - Medical Support
    - Resupply
    - Maintenance
  - Planning functions
    - Resupply
    - Maintenance
- **CSS/AUTL analysis derived an additional 950 SoS requirements**
  - Represents 1/3 of the Sustainment Requirements in the specification

Agenda

- FCS and Army Transformation
- Supportability Performance
- Analysis Process and Examples
- Process Enablers
- Lessons Learned
- Questions

Key Factors to a Successful Analysis

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

- **The right mix of people … and personalities**
  - Systems Engineers
  - System Designers
  - Logisticians
  - Soldiers
  - Facilitators
- **Leadership commitment to a common set of goals**
- **Adequate planning and schedule**
- **Participants want to do the job and appreciate the value**
- **Maintain tangible results in-sight**

Agenda

- FCS and Army Transformation
- Supportability Performance
- Analysis Process and Examples
- Process Enablers
- Lessons Learned
- Questions

Lessons Learned

- **It pays off when the time is taken to do the job right**
- **Indications the job was done right**
  - Endures the "test of time"
- **Sustainment analysis at the front end of the program as a major influence**
  - Historically unusual for this level of Sustainment requirements analysis this early in a program
  - Sustainment requirements constitutes ~30% of System-of-System requirements on FCS
- **Culture change within the Sustainment community … bigger culture change outside the Sustainment community**

Agenda

- FCS and Army Transformation
- Supportability Performance
- Analysis Process and Examples
- Process Enablers
- Lessons Learned
- Questions

System Safety in Systems Engineering DAU Continuous Learning Module

NDIA Systems Engineering Conference

October 26, 2005

Amanda Zarecky
Booz Allen Hamilton
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Course Context - Drivers

- **Increased DoD emphasis on safety**
  - **May 2003 SECDEF Memo**
  - **July 2003 Defense Safety Oversight Council**
    - **Joint Chiefs of Staff & Undersecretaries of the Services**
    - **Eight Task Forces**
- **April 2004 Acquisition and Technology Programs Task Force**
  - **Chair: Mr. Mark Schaeffer, USD (AT&L) Director of Systems Engineering**
  - **Focused on improving System Safety implementation**
  - **Linked efforts to Systems Engineering revitalization initiatives**
  - **23 Sep 04 USD(AT&L) Memo "Defense Acquisition System Safety"**

Course Context - DoD Policy

- **23 May 03 DoDI 5000.2 E7, Environment, Safety, and Occupational Health (ESOH)**
  - **Strategy for integrating ESOH into Systems Engineering**
  - **Identification of ESOH risks**
  - **Acceptance of ESOH risks per "industry standard for system safety"**
  - **NEPA/E.O. 12114 Compliance Schedule**
- **23 Sep 04 USD (AT&L) Defense Acquisition System Safety memo**
  - **Mandates integration of System Safety into Systems Engineering**
  - **Mandates use of MIL-STD-882D**
- **Oct 04 Defense Acquisition Guidebook**
  - **Chapter 4, Systems Engineering**
  - **Section 4.4.11, ESOH: "industry standard" = MIL-STD-882D**

Course Development Team Effort

- USD (AT&L)/Systems Engineering
  - Col Warren Anderson, Program Manager
  - Ann Marie Choephel, Program Manager Support
  - DAU Course Developer contractors: MTC & CTC
- Subject Matter Experts from each Component and DAU
  - Trish Huheey, DUSD(I&E) (Team Lead)
  - Sherman Forbes, SAF/AQRE
  - Ben Mack, USMC (AOT, Inc.)
  - George Murnyak, US Army CHPPM
  - Paige Ripani, DUSD(I&E) (Booz Allen Hamilton)
  - Amanda Zarecky, CNO N45 (Booz Allen Hamilton)

Course Description

- **Course developed**
  - **In response to need for training depicting how System Safety fits into the overall DoD Systems Engineering process throughout a system's life cycle**
  - **To teach the learning objectives and encourage active participation and coordination between System Safety Engineers and Systems Engineers**
- **Top Level Outcomes**
  - **Recognize the Defense Acquisition policy and guidance on System Safety in Systems Engineering**
  - **Recognize System Safety methodology as the Systems Engineering approach for eliminating Environment, Safety, and Occupational Health (ESOH) hazards or minimizing ESOH risks across the system's life cycle**

Course Description (cont)

- Target Audience
  - Primary: Systems Engineers, Chief Engineers
  - Secondary: Program Managers, System Safety Engineers
- DAU Systems Engineering Elective - not required; no pre-requisites
- Counts towards 80 hours of DAWIA certified continual learning
- 3 ½ hours web-based training

Course Description (cont)

- Built around the Systems Engineering (SE) Process V-Model
- Identifies System Safety activities supporting each of the Systems Engineering activities in each phase of a systems life cycle
- Enables Systems Engineers and System Safety Engineers to understand what to expect, what to provide, and when
- Not intended to teach details of System Safety
- Assumes an understanding of Systems Engineering

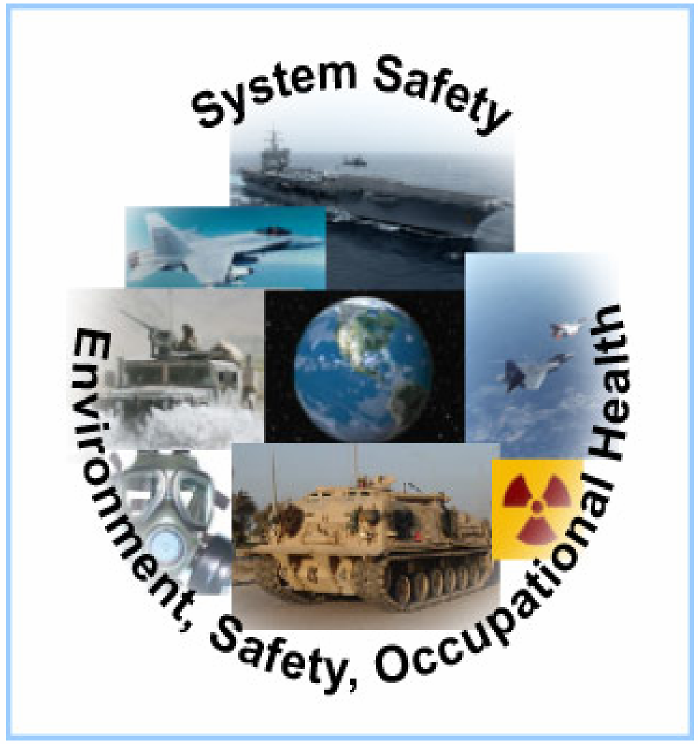
Course Outline

- System Safety Overview
- System Safety Terminology
- Eight Mandatory Steps of System Safety
- Risk Assessment
- System Safety Order of Precedence
- Typical System Safety Tasks
- System Safety Throughout the System's Life Cycle
- Module Summary

System Safety Overview - Explains MIL-STD-882D methodology is DoD's SE approach for eliminating ESOH hazards or minimizing ESOH risks across the system's life cycle

Why Implement System Safety?

- Protects military and civilian personnel by reducing hazards/risk to personnel and equipment
- Reduces accidents proactively
- Improves warfighting capability and combat readiness
- Reduces total ownership costs
- Lowers the risk of environmental damage
- Prioritizes hazards for corrective action
- Reduces need for system retrofits
- Required by DoDI 5000.2 (May 2003) and USD(AT&L) Memo (Sep 23, 2004)



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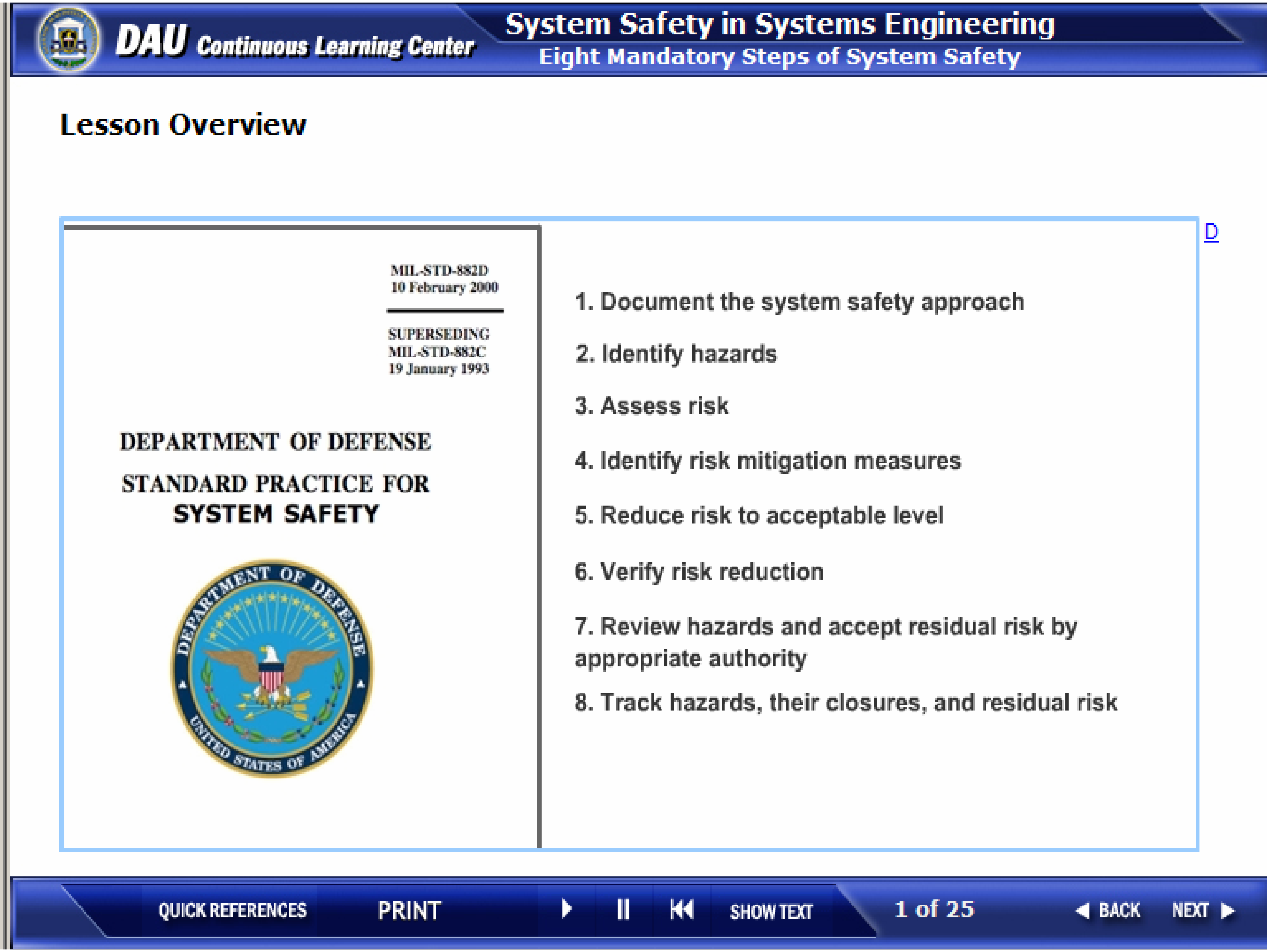
System Safety Terminology - Defines terms pertinent to use of system safety in the SE process

System Safety Terms		
System	System Life Cycle	Systems Engineering
System Safety	System Safety Engineering	Environment, Safety, and Occupational Health (ESOH)
Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE)	Human Systems Integration (HSI)	Hazard
Causal Factor	Mishap	Risk
Mitigation Measure	Residual Risk	

Eight Mandatory Steps of System Safety - Describes application of each of the steps in the system safety process outlined in MIL-STD-882D



Eight Mandatory Steps of System Safety – Knowledge Review

Drag-and-Drop Challenge

Directions: The following are the steps taken by the (fictitious) Marauder Howitzer Program Office team to mitigate the risk of extreme temperatures causing the gun barrel to warp, a round to jam in the barrel, followed by an in-bore explosion that severely injures or kills the operators and destroys the Howitzer. Arrange the activities in the order that accurately reflects the system safety process. Then click the Submit button. The Next button will return to the navigation bar when the answer is correct. Click here if you require a text-based version of this challenge.

D

- Discover potential round jamming hazard.
- Install LBDD to detect gun barrel warping.
- Document the system safety approach.
- Track rounds jamming in the gun barrel.
- Document PM acceptance of residual risk.
- Assign initial risk category as high.
- Verify residual risk following installation of LBDD.
- Identify alternatives for eliminating hazard or reducing risk.

Submit

Risk Assessment - Provides a systematic process for assessing risk and determining appropriate risk acceptance authority

Overview of Mishap Assessment, Cont.

The following pages provide further details of each of these steps along with the three sample tables:

1. Severity Categories
2. Probability Levels
3. Risk Assessment and Acceptance Matrix (shown here)

MIL-STD-882D provides definitions for severity categories, probability levels, risk assessment values and risk assessment categories that will be used unless otherwise documented by the Program Office in the system safety approach.

Components of Step 1

D

Risk Assessment and Acceptance Matrix

PROBABILITY LEVEL	SEVERITY CATEGORY: I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) Frequent	1 (IA)	3 (IIA)	7 (IIIA)	13 (IVA)
(B) Probable	2 (IB)	5 (IIB)	9 (IIIB)	16 (IVB)
(C) Occasional	4 (IC)	6 (IIC)	11 (IIIC)	18 (IVC)
(D) Remote	8 (ID)	10 (IID)	14 (IIID)	19 (IVD)
(E) Improbable	12 (IE)	15 (IIE)	17 (IIIE)	20 (IVE)

Values	Category	Acceptance Authority
1, 2, 3, 4, 5	HIGH	Component Acquisition Executive
6, 7, 8, 9	SERIOUS	Program Executive Officer
10, 11, 12, 13, 14, 15, 16, 17	MEDIUM	Program Manager
18, 19, 20	LOW	Program Manager

Risk Assessment – Knowledge Review

Risk Acceptance Authority, Cont.

Directions: Use the Risk Assessment and Acceptance Matrix to answer each of the following challenges.

Challenge: Who is the acceptance authority if the severity category is marginal and the probability level is frequent? Answer

Challenge: Who is the acceptance authority if the severity category is catastrophic and the probability level is improbable? Answer

D

Risk Assessment and Acceptance Matrix

PROBABILITY LEVEL	SEVERITY CATEGORY			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) Frequent	1 (IA)	3 (IIA)	7 (IIIA)	13 (IVA)
(B) Probable	2 (IB)	5 (IIB)	9 (IIIB)	16 (IVB)
(C) Occasional	4 (IC)	6 (IIC)	11 (IIIC)	18 (IVC)
(D) Remote	8 (ID)	10 (IID)	14 (IIID)	19 (IVD)
(E) Improbable	12 (IE)	15 (IIE)	17 (IIIE)	20 (IVE)

Values	Category	Acceptance Authority
1, 2, 3, 4, 5	HIGH	Component Acquisition Executive
6, 7, 8, 9	SERIOUS	Program Executive Officer
10, 11, 12, 13, 14, 15, 16, 17	MEDIUM	Program Manager
18, 19, 20	LOW	Program Manager

System Safety Order of Precedence - Identifies and explains application of DoD's system safety order of precedence for eliminating ESOH hazards or minimizing ESOH risks

System Safety Order of Precedence

When comparing potential alternatives for eliminating the hazard or reducing the risk, the system developer should apply the MIL-STD-882D system safety design order of precedence. The following are listed in order from the most to the least preferred risk mitigation methods:

Most to Least Preferred Risk Mitigation Measures		
1.	Eliminate hazards through design selection	If unable to eliminate an identified hazard, reduce the associated risk to an acceptable level through design selection.
2.	Incorporate safety devices	If unable to eliminate the hazard through design selection, reduce the risk to an acceptable level using protective safety features or devices.
3.	Provide warning devices	If safety devices do not adequately lower the risk of the hazard, include a detection and warning system to alert personnel to the particular hazard.
4.	Develop procedures and training	Where it is impractical to eliminate hazards through design selection or to reduce the associated risk to an acceptable level with safety and warning devices, incorporate special procedures and training. Procedures may include the use of personal protective equipment. **Note:** For catastrophic or critical hazards, avoid using warning, caution, or other written advisory as the **only** risk reduction method.

System Safety Order of Precedence (cont)

Marauder Howitzer SHA
Risk Mitigation Measure 1b

EXAMPLE ONLY

Example - Marauder Howitzer System Hazard Analysis Worksheet - Risk Mitigation Measure 1b													
Hazard	**Hazardous Effects**	**Causal Factors**	**IS**	**IP**	**IRV**	**IRC**	**Risk Mitigation**	**FS**	**FP**	**FRV**	**FRC**	**Status**
Round jams in barrel when fired	Round initiates causing in-bore explosion resulting in personnel death and weapon destruction	Warped gun barrel from a combination of extreme external temperature, e.g., in Desert Warfare, and high fire rate	I	B	2	High	Develop new barrel design using new technology composite material that will contain blast over pressure. New barrel design will minimize warping and is a line replaceable unit that costs $50K to minimize downtime in the event of an in-bore explosion. This design change allows only minor system damage and no injury to personnel.	III	D	14	Medium	Closed. The Program verified that new barrel design using the new technology composite material reduced the probability of warping (causal factor) and reduced the severity of the mishap occurring by being able to contain and dissipate the blast over pressure. The Program Manager formally accepted the FRC.

IS = Initial Risk Severity Category
FS = Final Risk Severity Category
CAE = Component Acquisition Executive

IP = Initial Risk Probability Level
FP = Final Risk Probability Level
PEO = Program Executive Officer

IRV = Initial Risk Value
FRV = Final Risk Value
PM = Program Manager

IRC = Initial Risk Category
FRC = Final Risk Category

D

Close

System Safety Order of Precedence (cont)

Marauder Howitzer Risk Matrix
Risk Mitigation Measure 1b

EXAMPLE ONLY

D

Risk Mitigation Measures (RMM) Examples

PROBABILITY LEVEL	SEVERITY CATEGORY			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) Frequent	1	3	7	13
(B) Probable	2 △	5	9	16
(C) Occasional	4	6	11	18
(D) Remote	8	10	14 ▲ RMM 1b	19
(E) Improbable	12	15	17	20

High Risk
Serious Risk
Medium Risk
Low Risk
△ Initial Risk
▲ Residual Risk

System Safety Order of Precedence – Knowledge Review

DAU Continuous Learning Center

System Safety in Systems Engineering

System Safety Order of Precedence

Drag-and-Drop Challenge

You are leading the Program Office team of the (fictitious) Marauder Howitzer. Please click round jamming hazard to review critical background information before completing the following challenge.

Directions: Listed below are four alternative measures to mitigate the round jamming hazard. Based on the system safety design order of precedence, indicate the order in which each alternative should be applied by placing the Number 1 beside the most preferred; the Number 2 beside the second preferred; etc. Then click the Submit button. The Next button will return to the navigation bar when the answer is correct. Click here if you require a text-based version of this challenge.

D

1		Train operators to routinely check for barrel warping.
2		Install alarm to alert operators to gun barrel warping.
3		Install safety interlock that prevents firing if the barrel is warped.
4		Change the design to preclude a round jamming in the barrel.

Submit

QUICK REFERENCES PRINT 12 of 13 BACK

Typical System Safety Tasks - Provides detailed descriptions of several widely-used system safety analytical and assessment tools

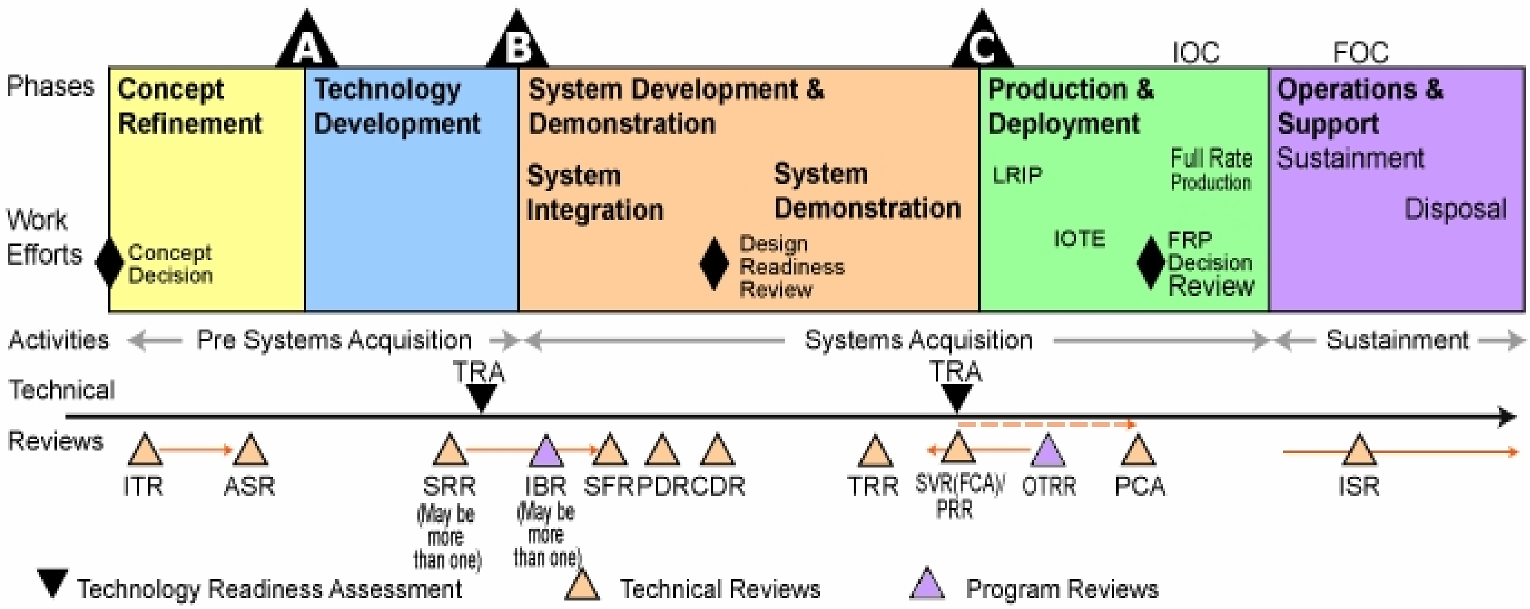
Typical System Safety Tasks, Cont.

Typical System Safety Tasks		
Safety Requirements/Criteria Analysis (SRCA)	Health Hazard Assessment (HHA)	Safety Assessment Report (SAR)
Preliminary Hazard List (PHL)	Preliminary Hazard Analysis (PHA)	Subsystem Hazard Analysis (SSHA)
System Hazard Analysis (SHA)	Operating & Support Hazard Analysis (O&SHA)	Sneak Circuit Analysis (SCA)
Fault Tree Analysis (FTA)	Failure Modes and Effects Analysis (FMEA) Failure Modes, Effects, and Criticality Analysis (FMECA)	Operational Trend Analysis
Threat Hazard Assessment (THA)	System Safety Program Plan (SSPP)	

System Safety Throughout the System's Life Cycle - Provides an overview of key system safety activities completed during each phase of the system life cycle

System Safety Activities Throughout the System Life Cycle

Directions: Please click each of the five phases of the System Life Cycle to discover key safety activities completed by the system safety staff during that phase. After you have clicked each of the five phases, please click the Next button to continue.



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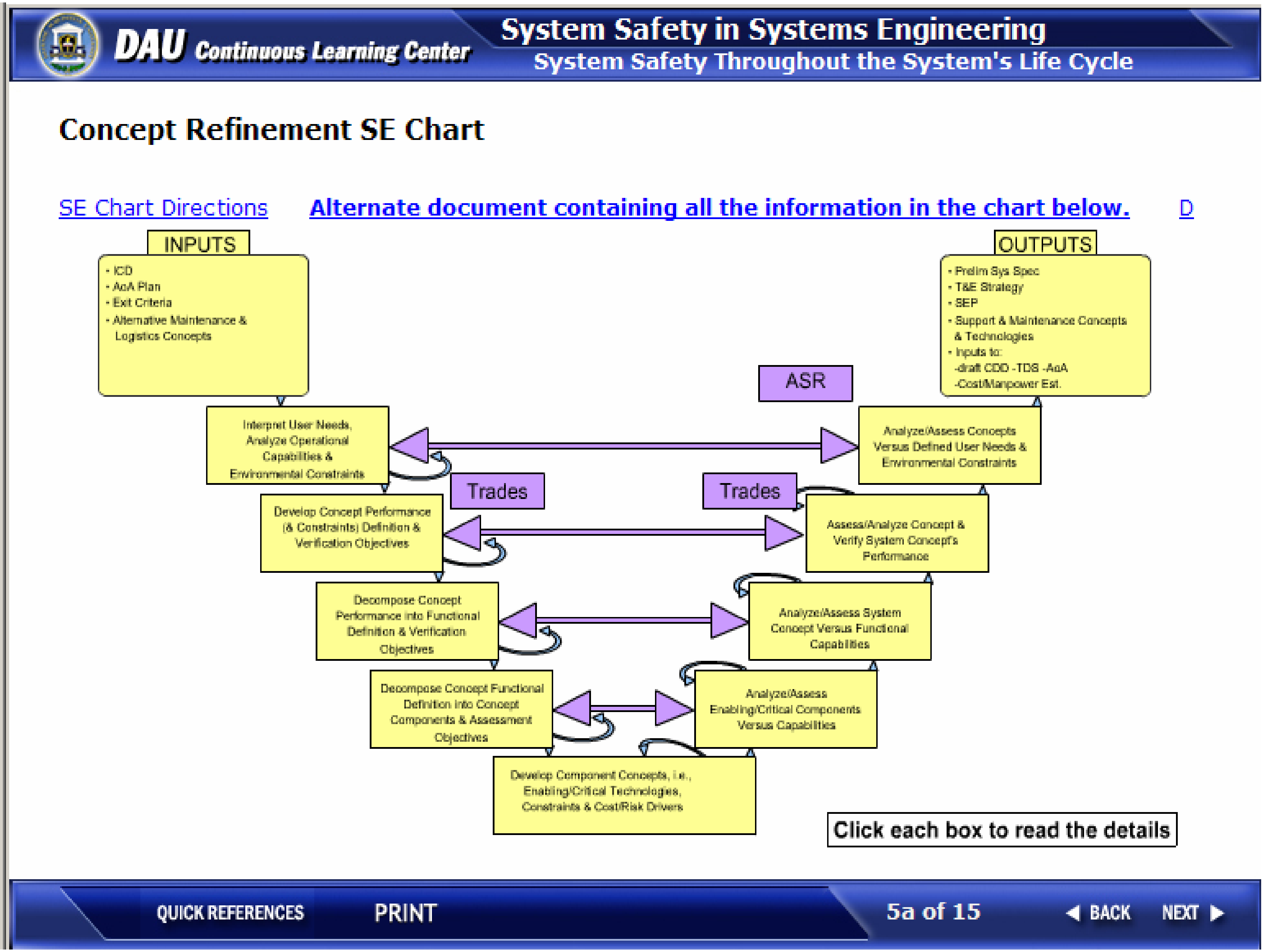
System Safety Throughout the System's Life Cycle (cont)



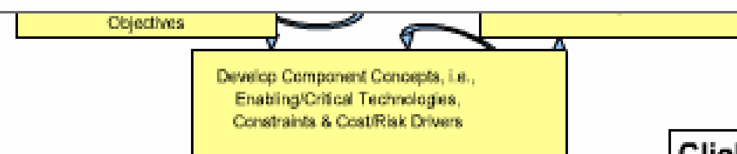
System Safety Throughout the System's Life Cycle (cont)

Concept Refinement SE Chart

SE Chart Directions   **Alternate document containing all the information in the chart below.**   D

X Close Window

Inputs	System Safety Should:
Initial Capabilities Document (ICD)	Provide inputs as requested
Analysis of Alternatives (AoA) Plan	Participate in AoA development
Exit Criteria	Provide the following exit criteria: 1. Preliminary Hazard List (PHL) 2. Strategy for integrating Environment, Safety, and Occupational Health (ESOH) risk management into the Systems Engineering Plan (SEP)
Alternative Maintenance and Logistics Concepts	Provide inputs as requested



Click each box to read the details

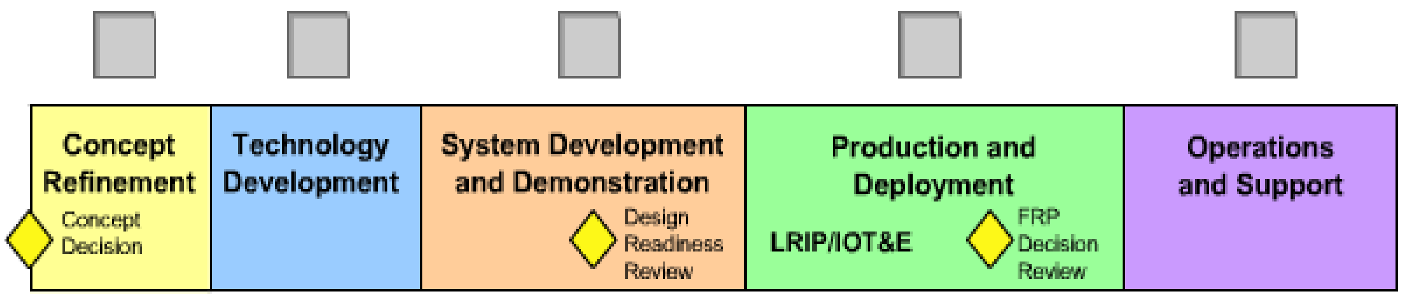
System Safety Throughout the System's Life Cycle – Knowledge Review

Drag-and-Drop Challenge

Directions: Drag each of the system safety activities to the corresponding phase of the System Life Cycle. Then click the Submit button. The Next button will return to the navigation bar when the answer is correct. Click here if you require a text-based version of this challenge.

A	B	C	D	E
Evaluate each change to a fielded system for hazards	Review PCA for potential safety impacts	Present safety info at the SRR, SFR, PDR, CDR, TRR	Prepare the PESHE for Milestone B	Document the system safety approach

D



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Module Summary - Recaps essential information to reinforce attainment of the learning objectives of each lesson

Module Summary Organization

The module summary is organized by lesson. It presents the following for each lesson:

- Learning goal(s) of the lesson
- Summary of the key learning points needed to attain each learning goal

The Module Summary includes only the following lessons:

- System Safety Overview
- System Safety Terminology
- Eight Mandatory Steps of System Safety
- Risk Assessment
- System Safety Order of Precedence
- Typical System Safety Tasks
- System Safety Throughout the System's Life Cycle

Conclusion

- **Continuous Learning Course helps students**
  - **Recognize the Defense Acquisition policy and guidance on System Safety in Systems Engineering**
  - **Recognize System Safety as the Systems Engineering approach for eliminating ESOH hazards or minimizing ESOH risks across the system life cycle**
- **Course (CLE009) available for registration at DAU's website http://www.dau.mil/basedocs/continuouslearning.asp**