

**“Acquisition Excellence
through
Effective Systems Engineering”**

**Systems Engineering
Deficiencies and Corrections
for
Air Launched Tactical Weapons**

OSD Systems Engineering Forum

15 June 2010

Introduction

Numerous studies and reports have indicated persistent performance issues in the development of defense programs

- GAO, NRC, NDIA, ...

Many issues relate to a lack of adherence to fundamental systems engineering (SE) principles

These SE issues are being considered and addressed at multiple levels of DoD and the defense industry

- DoD – OSD, services, commands, centers
- NDIA – divisions, chapters, committees

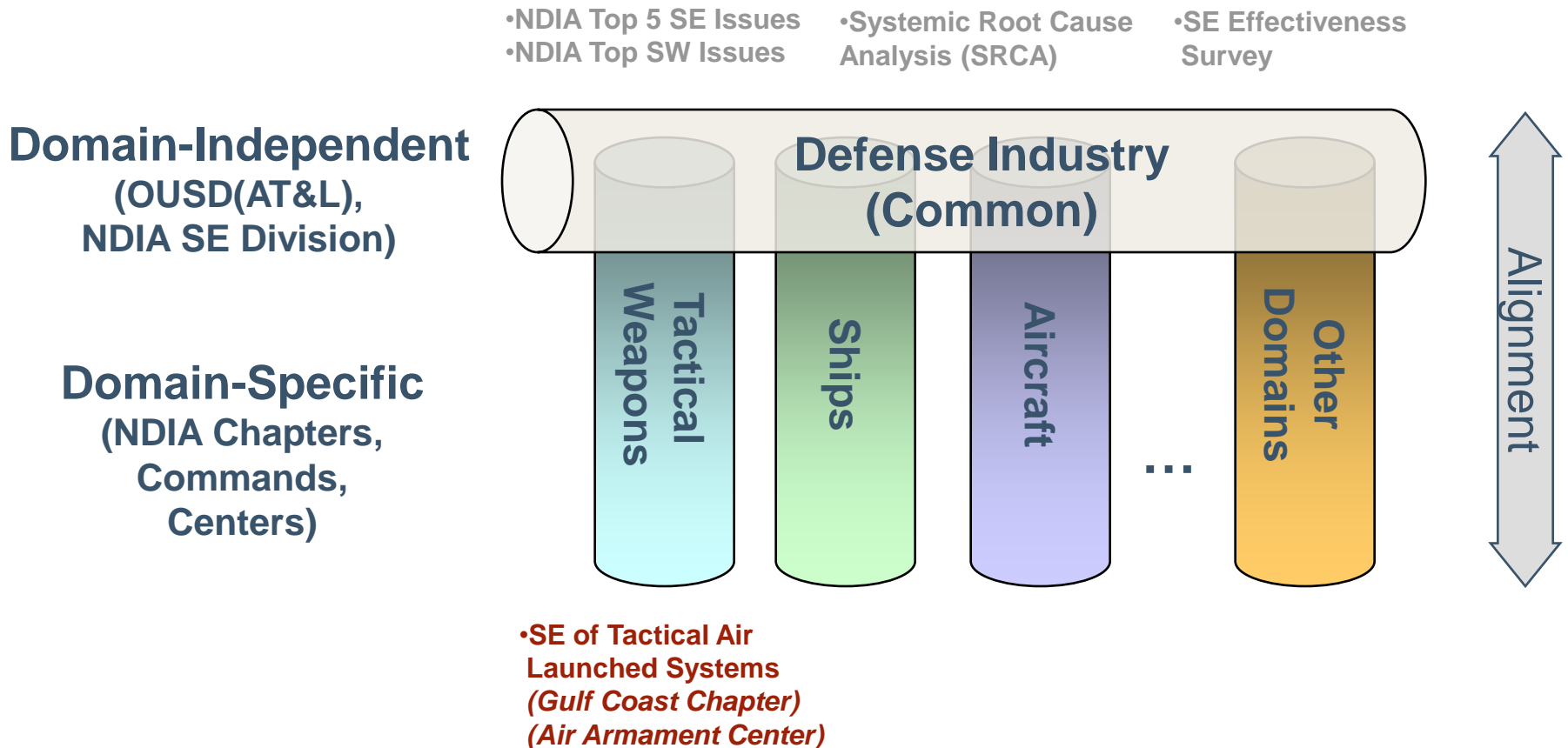
Issues and solutions may vary, depending on the context and situation

- Common (domain-independent)
- Unique (domain-dependent)



Integrating SE Findings and Recommendations

NDIA SE Division serves as integrating framework for coordinating SE issues with OSD, and sponsoring improvements across the enterprise





Air Armament Symposium 2008



SYSTEMS ENGINEERING OF TACTICAL AIR-LAUNCHED WEAPONS AN INDUSTRY EXAMINATION

Raytheon
Missile Systems



NORTHROP GRUMMAN



**Rockwell
Collins**



GENERAL DYNAMICS
Ordnance and Tactical Systems

KAMAN FUZING



wyle

Honeywell



USAF Weapons

The Most Capable in the World





Challenge and Charter



AAC Challenge To Industry:

Identify Weapon Systems Engineering Best Practice Improvements That Will Provide:

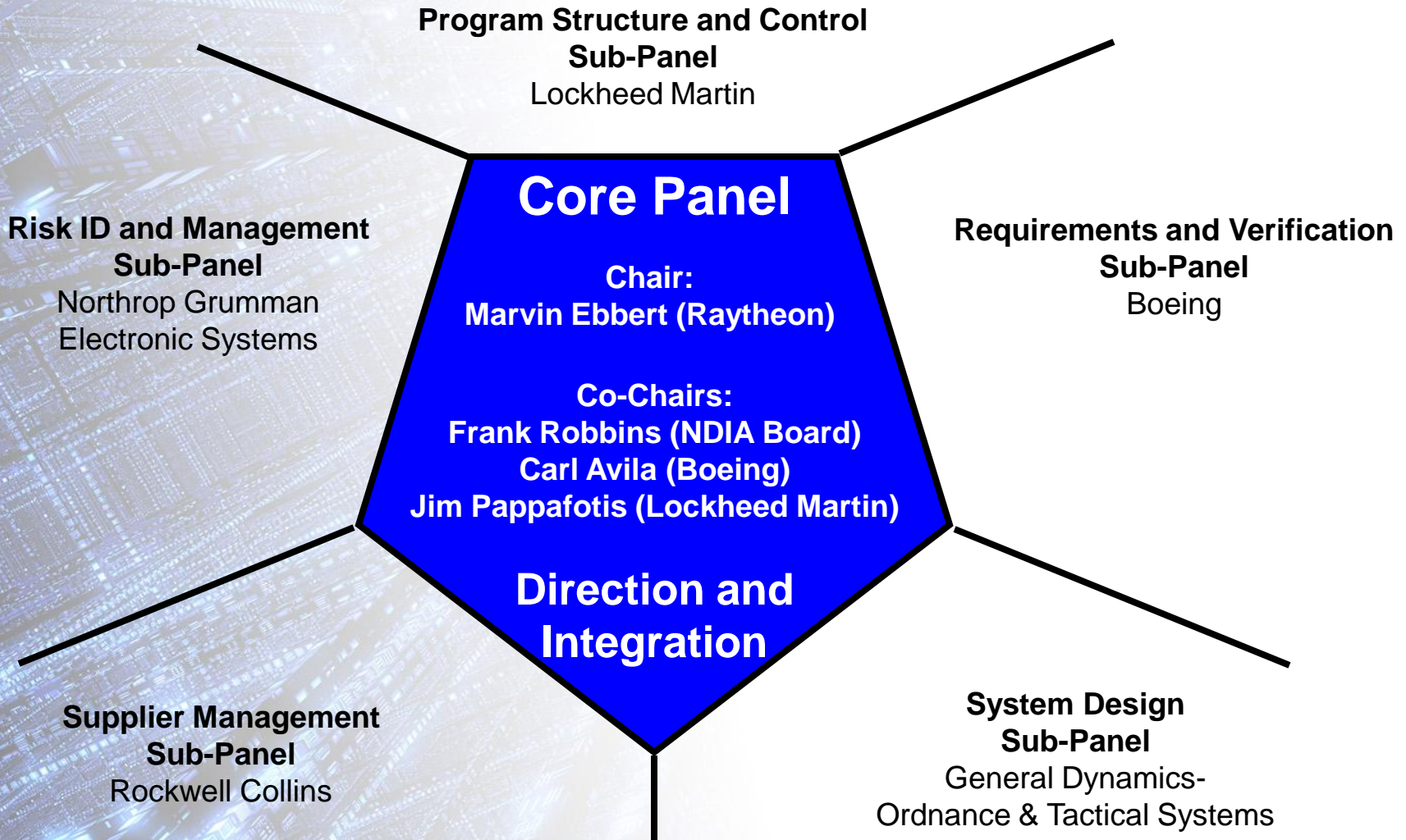
- **Improved Program Performance (Cost And Schedule)**
- **Earlier Weapon Maturity**
- **Reduced Weapon Acquisition and Sustainment Cost**

NDIA Response:

Chartered An Industry Expert Panel To Determine If Improvements In “Systems Engineering Best Practices” When Combined With Program Structure And Control Improvements, Could Provide The Desired Results.



System Engineering Industry Panel



**Panel Structured to Address
The “Root Causes” of Systemic Deficiencies**



AAC Expectations Recent Program Structure



- **AAC Objective And Customer Expectations:**
 - **EMD Programs Must Be Executed On Schedule And Within Budget!**
 - **Systems Fully Matured At Milestone C- Ready For Production And Deployment**
- **The Strategy: Increase The Level Of Achievement In Risk Reduction Phase (Pre Milestone B)**
 - Force EMD To Be **Production-configuration** Build, Integrate, And Formal Verification Tests---with Fielding Preparations
 - **Significant Reduction In Time And Cost Of SDD Program Expected**
 - **Move The CDR Milestone To Milestone B Position As An Entry Criteria**
 - **Use Competition To Ensure That The Highest Levels Of Risk Reduction Are Achieved**

**Achieve A Level Of Maturity Of The Product Baseline At MS B
Necessary To Accurately Predict Program And Product Performance
And Cost.**



COMMON SYMPTOMS



Earlier SE Deficiencies At Root Cause!



- ● Inability to complete the design-to requirements
- ● Requirements Creep---Not Stable
 - Unplanned requirements verification efforts

Spec Requirements Definition, Flowdown, and Control

- Multiple Unplanned tests required for performance data or design
- Multiple Configuration Changes—Not Planned

Design Maturity and Control

- Component Qualification Test
 - Weapon Level Integration Tests
 - Weapon Level Qualification Tests
 - Weapon Flight Testing

Verification Test Failures

- Redesign for Producibility/Cost
- Redesign for Field Reliability and Sustainability
 - Configuration variation issues

Production/Field Failures

Weapon Development And Production Programs Have Common "Symptoms Of Systems Engineering Deficiencies"



Deficiencies In Systems Engineering- Root Causes



Program Structure And Control: (Deficiencies)

- Insufficient Maturity Of Design At Critical Decision Points
- Insufficient Testing And Analysis Planned To Achieve Maturity
- Late Integration Of Production Critical Processes And Controls
- Program Funding Profiles Not Structured For Improved Practices
- Configuration Management: **Form, Fit, Function And Margin (F³M)**

Requirements And Verification: (Deficiencies)

- Lack Of Service Use Profile Leaves Interpretive Requirements
- Insufficient Mapping Of Requirements To Design
- Ineffective Maturation And Verification Planning



Deficiencies In Systems Engineering- Root Causes



Design Best Practices: (Deficiencies)

- Inadequate Design Analysis
 - Fault Tree Analysis On All Subsystems During Design
 - Single Point Failure Analysis During Design
 - Critical Parameter and Key Feature Identification
- Inadequate Maturation Analysis And Testing
 - COTS Integration
 - Design Sensitivity and Margin Development
 - Critical Manufacture And Assembly Process ID / Control
- Miss-Use Of “Production Representative” Configuration For Verification

Risk Identification And Management: (Deficiency)

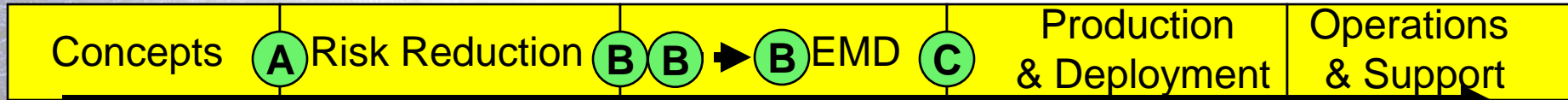
- Inadequate Relationship To “Knowledge” Of Design

Supply Chain Practices: (Deficiency)

- Inconsistent Approaches To Design Characterization



5000.02 and Recent AAC Program Structure Changes Improve EMD Performance, But...



Draft 5000.2 Revised Program Structure

AAC Revised Program Structure

- Integration And Formal Verification
- Unstated or Controlled Requirements
- Inability to complete the design-to requirements
 - Multiple Unplanned Hardware and software Configuration Changes
 - Unplanned requirements verification efforts
 - Multiple Unplanned tests required for performance data or design
 - Component Integration Test
 - Component Qualification Test
 - Weapon Level Integration Tests
 - Weapon Level Qualification Tests
 - Weapon Flight Testing
 - Redesign for Producibility/Cost
 - Redesign for Field Reliability and Sustainability
 - Configuration variation issues

Design Failures

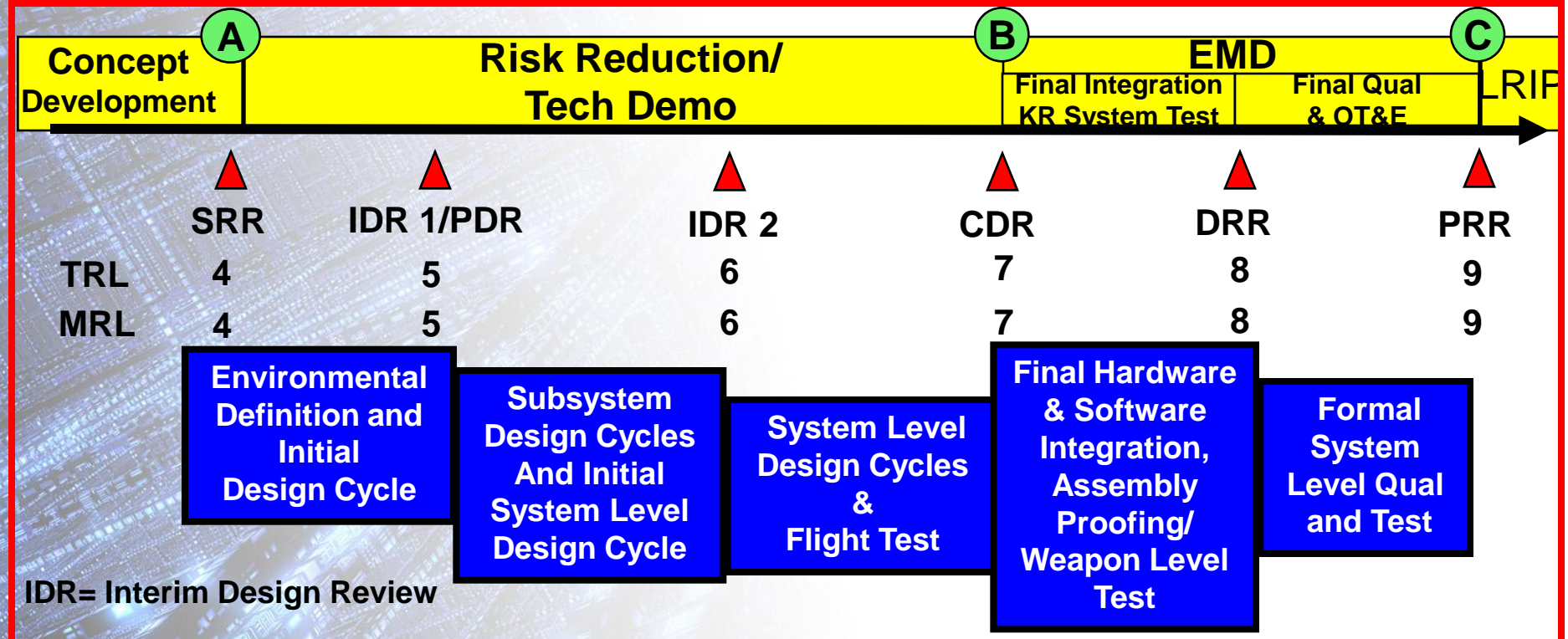
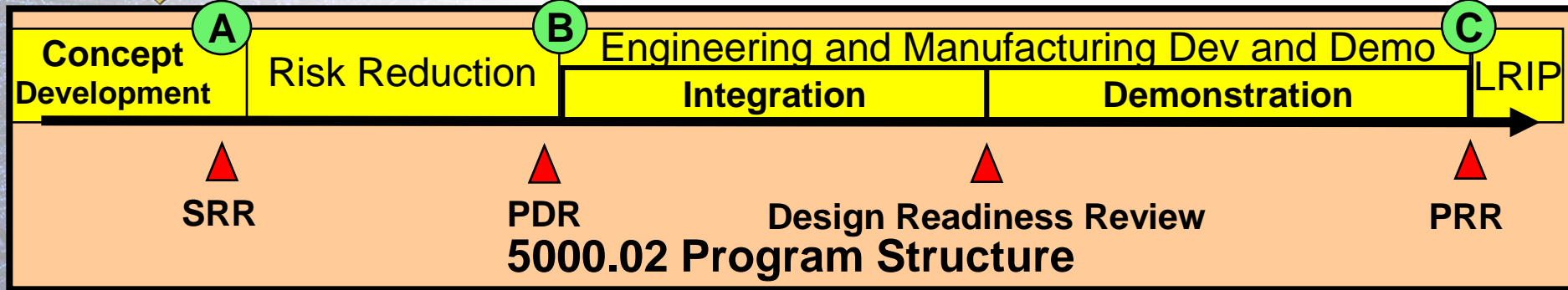
Verification Test Failures

Production/Field Failures

**Greater Maturity at EMD Entry Provides Improvement
Improved Best Practices Ensure the Solution**



5000.02 Tailored For Weapons



Panel Recommended Program Structure For Weapons



Recommendations: Program Structure and Control



Adopt the Expanded Risk Reduction Model (CDR Ready at MS B) for Acquisitions

- Incorporate Knowledge Based Decision Milestones (A, B & C)
- Provide For Variations In Milestone Attainment Timelines
 - Based On Contractor's Unique Design Maturity
- Funding Must Be Based On Design Characterization/Maturation
- Re-Establish Program Contractor Configuration Control Boards (CCBs):
 - **Form, Fit, Function and Margin (F³M)**
- Establish Culture That Accepts “Press to Failure” Approaches
- Select a Single Source When No Longer Cost Effective To Maintain Competition

**Recommendations Should Be Contained In Risk Reduction RFP
(EMD Planning Must Be Included)**



Recommendations: Requirements and Verification



A More Thorough Treatment of Requirements is Necessary:

- **Provide a Complete/Coordinated Service Use Profile (Pre MS-A)**
- **Requirements to Design Bi-Directionally Traceable Mapping**
- **Initiate Joint Requirements Working Group Pre MS-A**
 - **Verification Techniques Agreed Upon**
 - **Reliability Verification Approach---Characterization and Maturation**
- **Overarching Test Strategy from Parts Screening, BIT, Characterization, Qualification, Acceptance, to Performance Verification must be in place Pre MS-A**
- **Develop and Control an Asset Utilization Matrix Pre MS-A**
 - **Define the Configuration and Number of Every Test Article**
 - **Map Testing to Assure Minimum “System Firsts” in Testing**



Recommendations: System Design



Incorporate Design Characterization And Document

- Bi-directional Mapping Of Requirements To Design Features
- Critical Parameter and Key Feature Identification and Control
- Fault Tree And Single Point Failure Analyses (1629A)
 - Completed As The Design Process, Not As An After-thought
- Perform Design Characterization As Part Of Design
 - Design Manufacturing/Assembly Process Sensitivity
 - Design with Manufacturing/Assembly Process Margins
 - Critical Manufacturing And Assembly Process ID And Controls
- Treat COTS As Military Equipment
 - Must Be Isolated, Or
 - Subject Of Design Characterization And Configuration Control

**These Recommendations Should Be
Contained In Risk Reduction RFP's**



Recommendations : Risk Identification and Management



Continue Risk Identification And Management Practices and Add:

- **Implement Risk Rating Factors/Checklists To Assess:**
 - **Sufficiency Of Design Characterization**
 - **Program Resource Sufficiency To Support Design Characterization and Verification**
 - **Approach to Include COTS (Commercial Off the Shelf)**
- **Create Knowledge-Based Technology/Manufacturing Readiness Level (TRL/MRL) Definitions**

Incorporating Knowledge-based Risk Management Technique Will Improve Program Success.



Recommendations: Supply Chain



Development And Production Practices Vertically Consistent

- For Configuration Definition and Control,
 - To include Key Features and Critical Process Controls,
 - Bi-Directional Traceability of Requirements
- For all Testing:
 - Design Characterization and Maturation (Reliability),
 - Development and Qualification Testing, and
 - Production Acceptance Testing
- For Risk ID And Management, And
- For The Use Of COTS.

The Targeted Level To Which Practices Should Be Applied Will Vary From Program To Program.



Summary of Industry Panel Findings



- **Acquisition Reform, Competitive Pressures, and Industry Over-Reliance on Modeling/Analysis, parented a Loss of Critical Systems Engineering Fundamentals:**
 - Government Standards Lost to Acquisition Reform
 - Insufficiently Defined Requirements in Government RFP's to Assure Complete Design Maturation
 - Lack of Detailed Technical Planning Being Provided In Industry Proposals
 - For Government Technical Evaluation
 - For Program Funding Development and Contract Pricing
- **Consensus Opinion on SE**
 - If the Government Doesn't Require Definition of the Core Practices to Mature a Product Design.....then,
 - Technical Activities (ie Fundamental Systems Engineering Practices) Are Within Industry's "Trade Space" and Can Be Eliminated Unilaterally-
 - Very Likely to Occur With Pressures of Competition In Today's Acquisitions



Government Need- A New Level of Insight



- **The Government Needs A New Level of Insight into Contractor Planning for Development and Production**
 - To understand how the Desired Levels of Maturity will be Reached at Program Decision Milestones
 - To Select the Highest Probability of Success Contractors
 - To Establish Revised Funding Profile “Front Loaded” Necessary to Support “Robust Systems Engineering”
 - To Understand Sufficiency of Contractor Cost Proposals
- **Will Require Changes In RFP’s, Source Selection Emphasis, and Government/Contractor Education**



Recommended RFP Requirement



Volume 1 – System Performance Specification

Volume 2 – Risk Management Plan

Volume 3 – Integrated Characterization Maturation Verification Plan

Volume 4 – System Engineering Plan (Hardware and Software)

Volume 5 – Small Business Consideration Plan

Volume 6 – Supply Chain Management Plan

Volume 7 – Safety Program Plan

Volume 8 – Configuration Management Plan

Volume 9 – Manufacturing and Assembly Plan

Volume 10 – Logistics and Support Plan

Volume 11 – Reliability Growth Plan

Cost/Price/Schedule/Contract Data

Volume 1 – Integrated Master Plan (IMP)/Integrated Master Schedule (IMS)

Volume 2 – Model Contract

Volume 3 – Risk Reduction Program Cost/Price

Oral Presentation/Power Point Charts



Summary



- Thanks to USAF's AAC Challenge to Industry,

Fundamental Deficiencies in Systems Engineering Practices of Industry have Been Identified.

- Correction recommended through modification of :
 - 1. RFP Requirements --- Plans traceable to Bid
 - 2. Source Selection Criteria --- Affordable Maturation
 - 3. Revised Program Structure
 - 4. Revised Milestone Requirements

Recommendations for RFP requirements and assessment have been provided and are available.

Industry and Government Working Together Will Correct Current Deficiencies in Systems Engineering and Improve Program Performance

For Additional Information...



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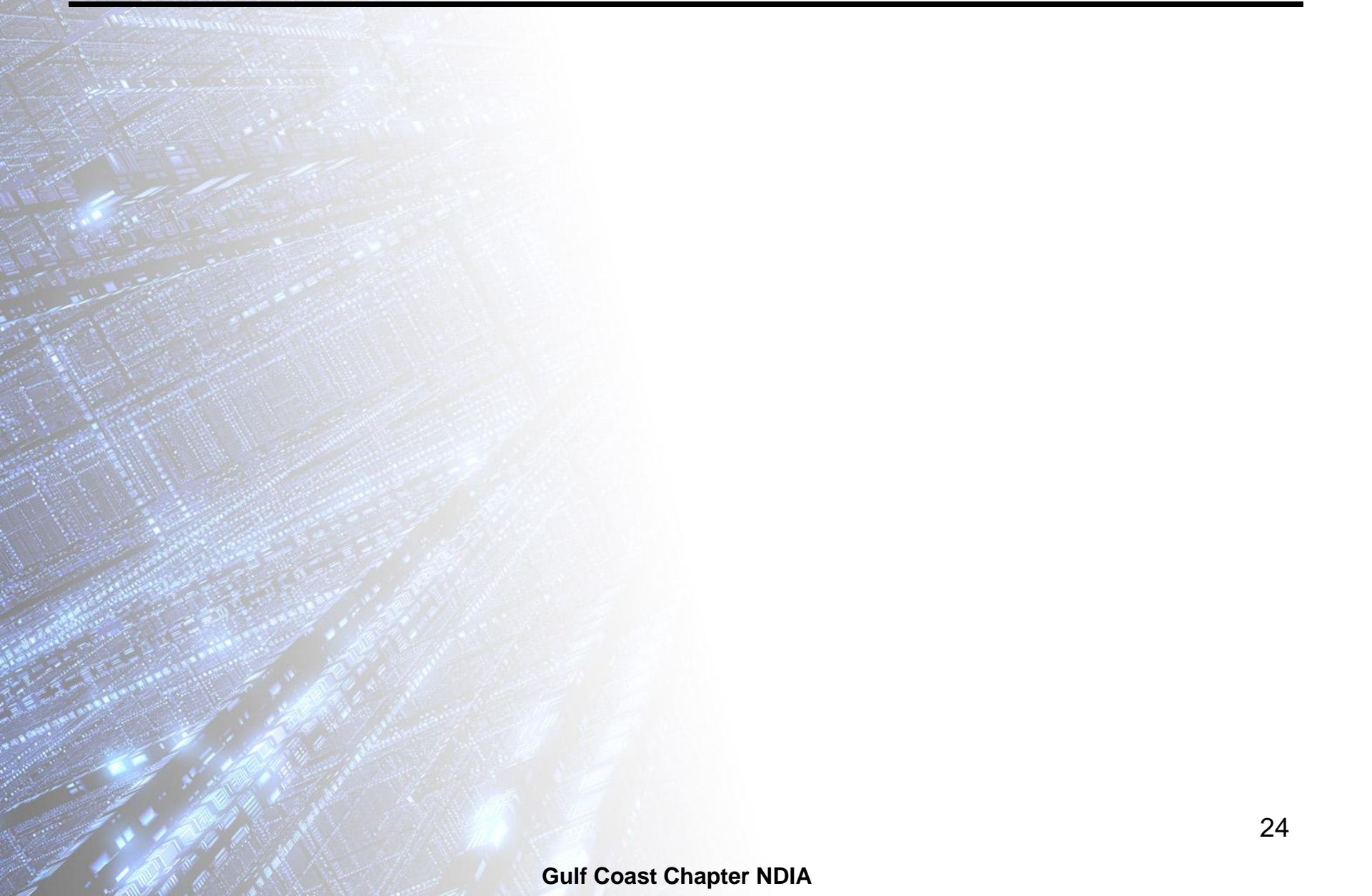
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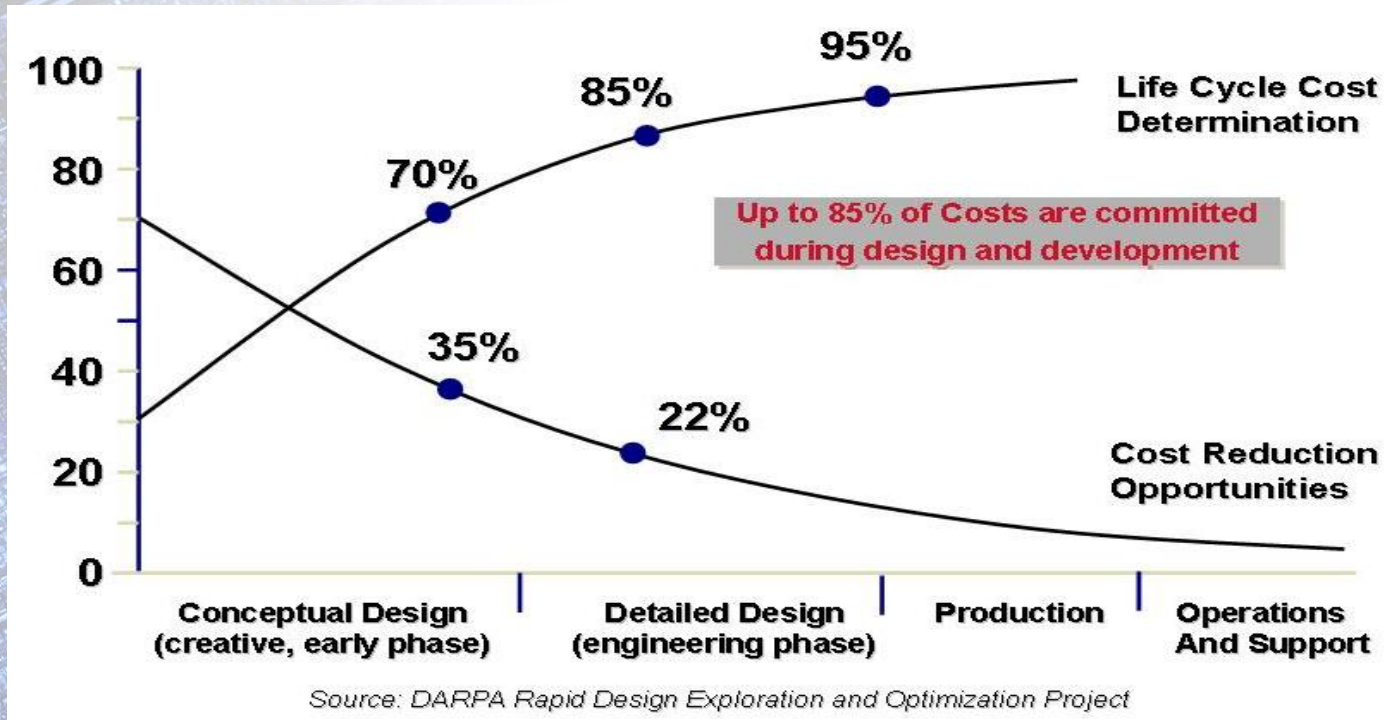


Backups





Systems Engineering Addresses Costs of Decision Timeliness





Service Use Profile Definition



- Begins with Weapon Delivery to the Government and Continues through the entire weapon life cycle
- Service Use Profile is the Description of the following with sufficient specificity to allow Weapon System Development and Qualification
 - Transportation Modes, Environments, Times, Distances, Packaging, Etc.
 - Storage, Handling, Packaging and Unpackaging, Assembly, Test, Etc.
 - Load Operations, Support Equipment Interfaces
 - Platforms, Load Outs with all Tactical and Test Configurations
 - Take Offs/Landings/Cats/Traps
 - Mission Planning Requirements
 - All Mission Profiles (to be platform specific)
 - Captive Carriage
 - Release Parameters (Range, Altitude, Air Speeds, etc.)
 - Special Considerations (Presence of Emitters, etc.)
 - Performance
 - Survivability
 - Lethality against Target Set (Including “Kill Criteria”
 - Special Timeline Requirements
 - Special Communication Requirements
 - Reliability (Transportation, Storage and Handling, Captive Carriage, Free-Flight, End Game Reliability, Testing, etc.)
 - Logistics Approach (O-Level, Depot, RETOK, etc.)
 - Decontamination, Cleaning, Recontainerization, EOD, DeMil
 - Special Security Requirements, etc.
- Must be Consistent with Over-Archiving System Architecture, CONOPS and Employment Concept



Definitions



- **Design Characterization:**
 - **Determining Capability Margins Through Analysis And Test**
 - **Integrated Performance**
 - **Physical, Logical, And Electrical**
 - **Against Specified Requirements**
 - **Including Sensitivities To Operational Environments as well as Manufacture and Assembly Practices**

- **Design Margin:**
 - **Capability Of A Product Design In Excess Of “Design-to” Requirements**
 - **Includes The Extremes Of Variation In Manufacture/Assembly Processes**

- **Design Sensitivity:**
 - **The quantification of performance change produced by variations in operational environments or manufacture/assembly practices.**



Definitions (cont'd)



- **Configuration Management: **Form, Fit, Function and Margin (F³M)****
 - **Margin Maintenance**
 - **System Engineering/Configuration Management Best Practice**
 - **Requires Fully Characterized Product Design (Baseline Record)**
 - **No Change Allowed Without Full Understanding Of Individual And Cumulative Effects Of Product Margins And Sensitivities.**
 - **Requires Evaluation Of All Potential Class I And Class II Changes**
- **Non-Redundant Design (NRD)**
 - **Design In Which Redundancy Not Available Due To Physical Or Cost Constraints**
 - **Typical Characteristic Of Tactical Weapons**
 - **Stressing Performance Requirements**
 - **High Reliability**
 - **Lengthy Storage And Use Times**
 - **Full Range Of Military Environments.**
 - **Challenge to Weapons: Reliability without Redundancy**



Definitions



- **Integrated Verification And Maturation Matrix**
 - **Matrix That Contains At All Levels Of The Configuration:**
 - **A Mapping Of Requirements To Verification Test(s), Engineering Analyses, And Basis Of Similarity Analyses Used To Verify Compliance Of The Design With Specification Requirements.**
 - **A Mapping Of All Testing And Analyses Required In Addition To The Requirements Verification Testing That Are Necessary To Fully Characterize And Mature The Product Design.**
- **Asset Utilization Matrix**
 - **Matrix That Contains The Configuration Definition (And Number Of) Each Of The Units-Under-Test Contained In The Integrated Characterization, Maturation, and Verification Matrix.**
- **Knowledge Of The Design**
 - **The Degree To Which The Design Is Characterized, Qualified, And Verified Against The Specified Requirements.**