The 12th Annual Systems Engineering Conference

"Acquisition Excellence through Effective Systems Engineering"

Systems Engineering Deficiencies and Corrections for Air Launched Tactical Weapons

28 October 2009

Marvin Ebbert----Industry Panel Chair

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)

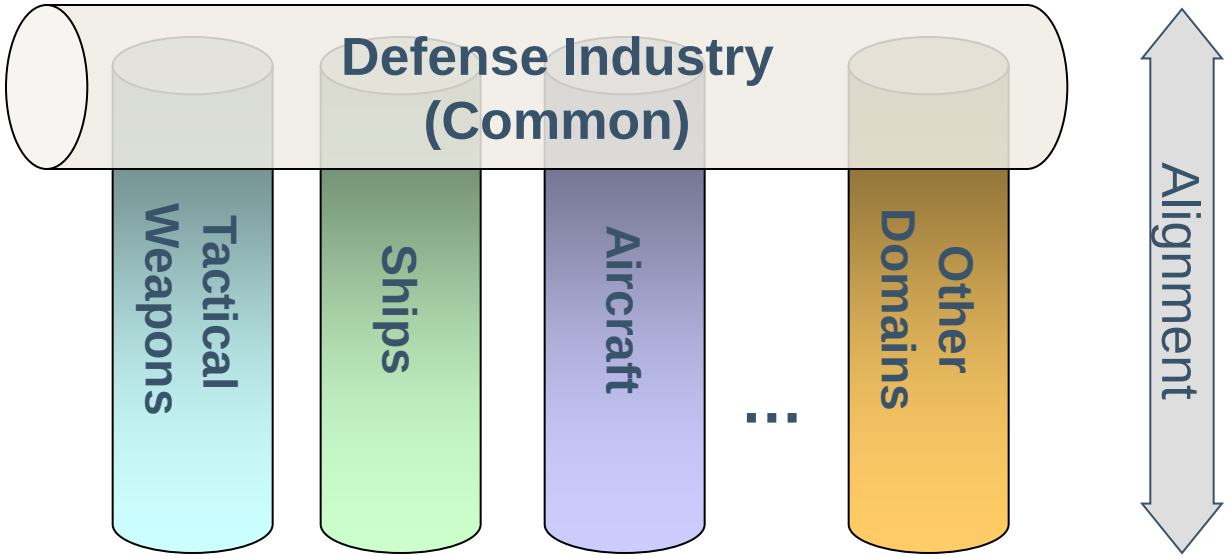
Integrating SE Findings and Recommendations

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

- NDIA Top 5 SE Issues
- NDIA Top SW Issues
- Systemic Root Cause Analysis (SRCA)
- SE Effectiveness Survey

Domain-Independent
(OUSD(AT&L), NDIA SE Division)

Domain-Specific
(NDIA Chapters, Commands, Centers)



- **SE of Tactical Air Launched Systems** ***(Gulf Coast Chapter)*** ***(Air Armament Center)***

Air Armament Symposium 2008

AEROSPACE PROFESSIONALS
AN RWB COMPANY

BOEING

MUSTANG TECHNOLOGY GROUP

SYSTEMS ENGINEERING OF
TACTICAL AIR-LAUNCHED WEAPONS
AN INDUSTRY EXAMINATION

Raytheon Missile Systems

LOCKHEED MARTIN

NORTHROP GRUMMAN

Georgia Tech Research Institute

Rockwell Collins

L3 communications
KDI Precision Products, Inc.

GENERAL DYNAMICS
Ordnance and Tactical Systems

KAMAN FUZING

ATK

wyle

Honeywell

And others…..

USAF Weapons
The Most Capable in the World

Challenge and Charter

AAC Challenge To Industry:

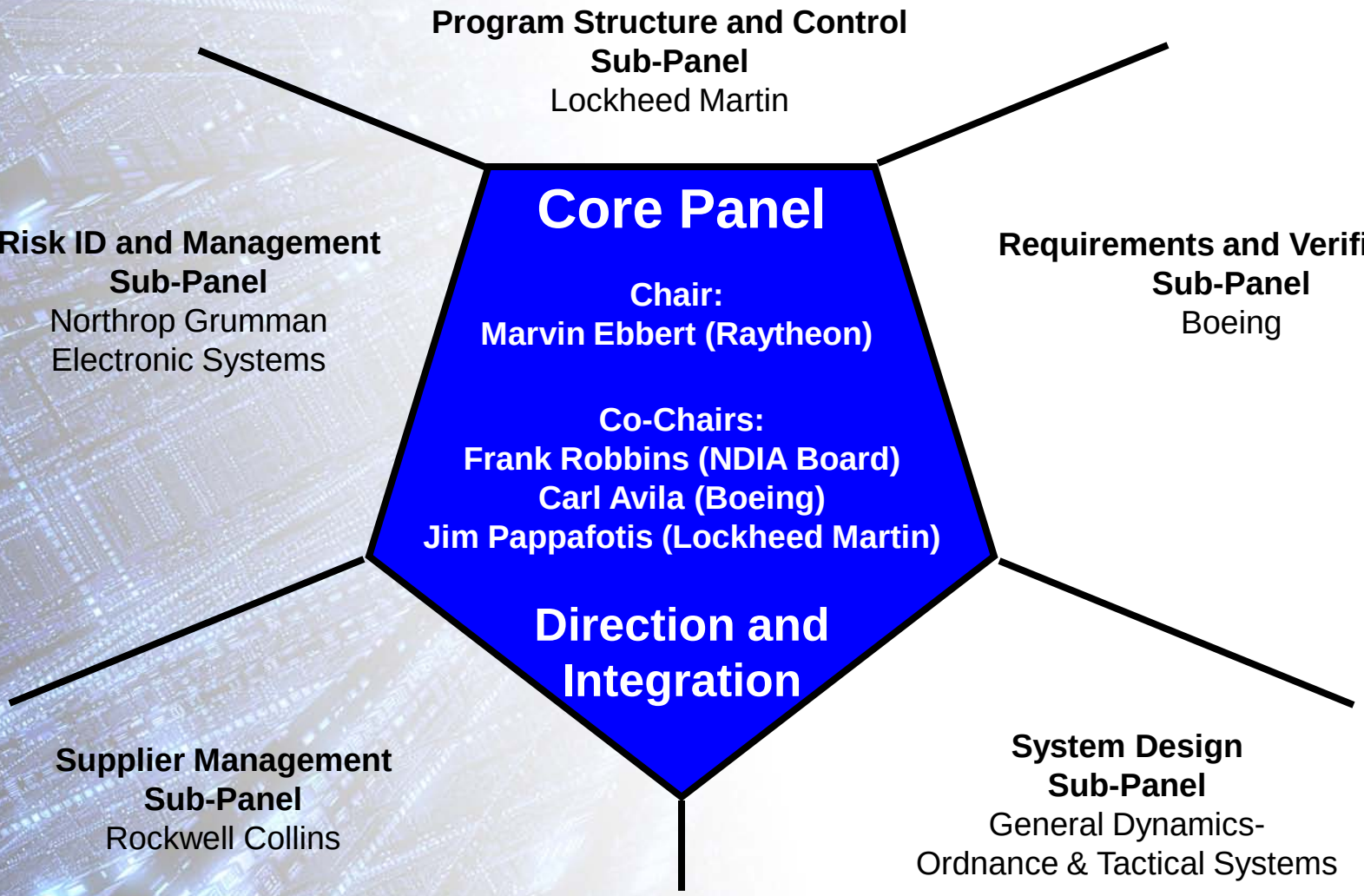
Identify Weapon Systems Engineering Best Practice Improvements That Will Provide:

- **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

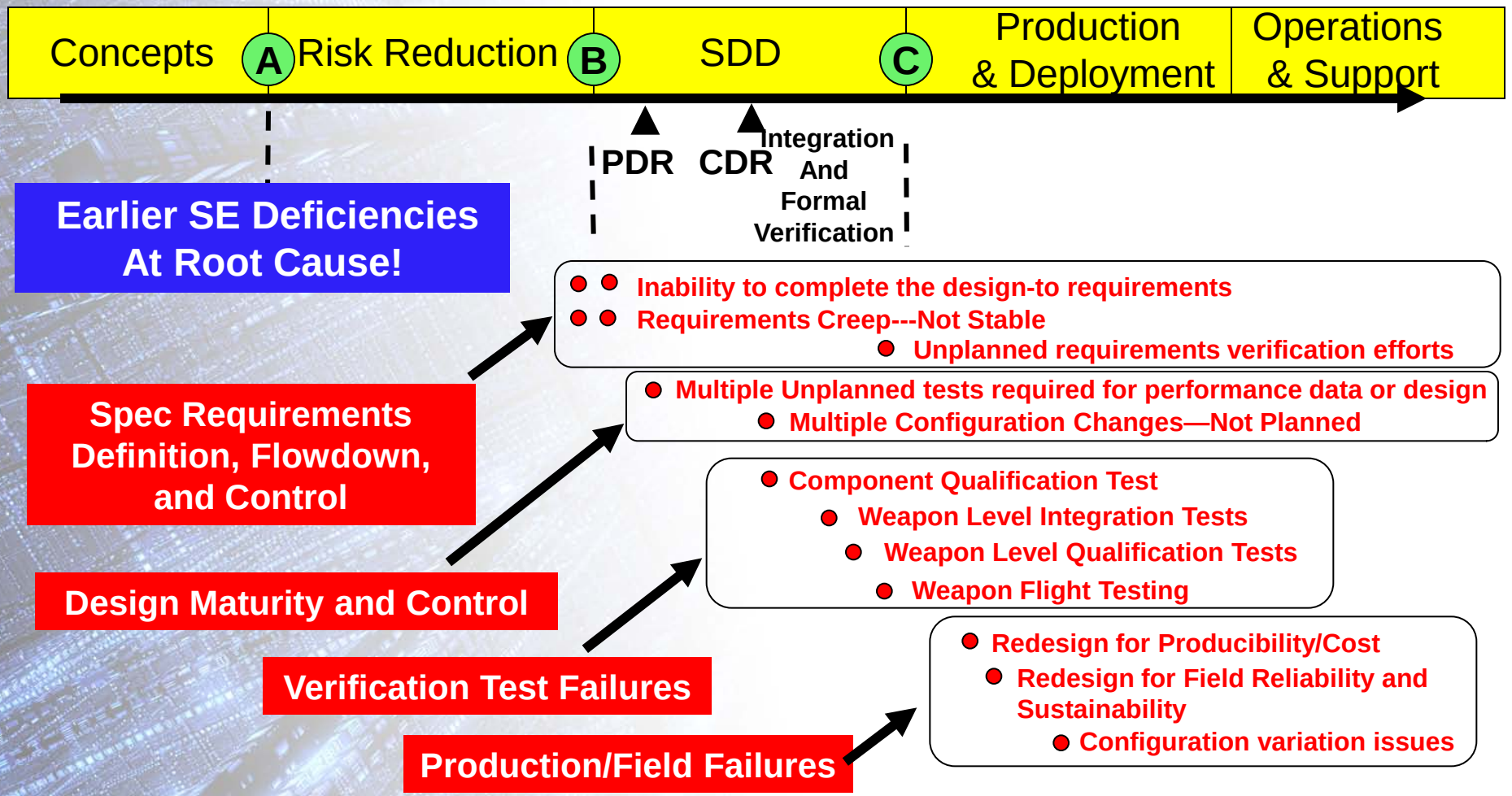
AAC Expectations
Recent Program Structure

- **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



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 (F^3M)

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 Margin And Sensitivity Development
  - Critical Manufacture And Assembly Process ID / Control
- Miss-Use Of "Production Representative" Configuration For Verification

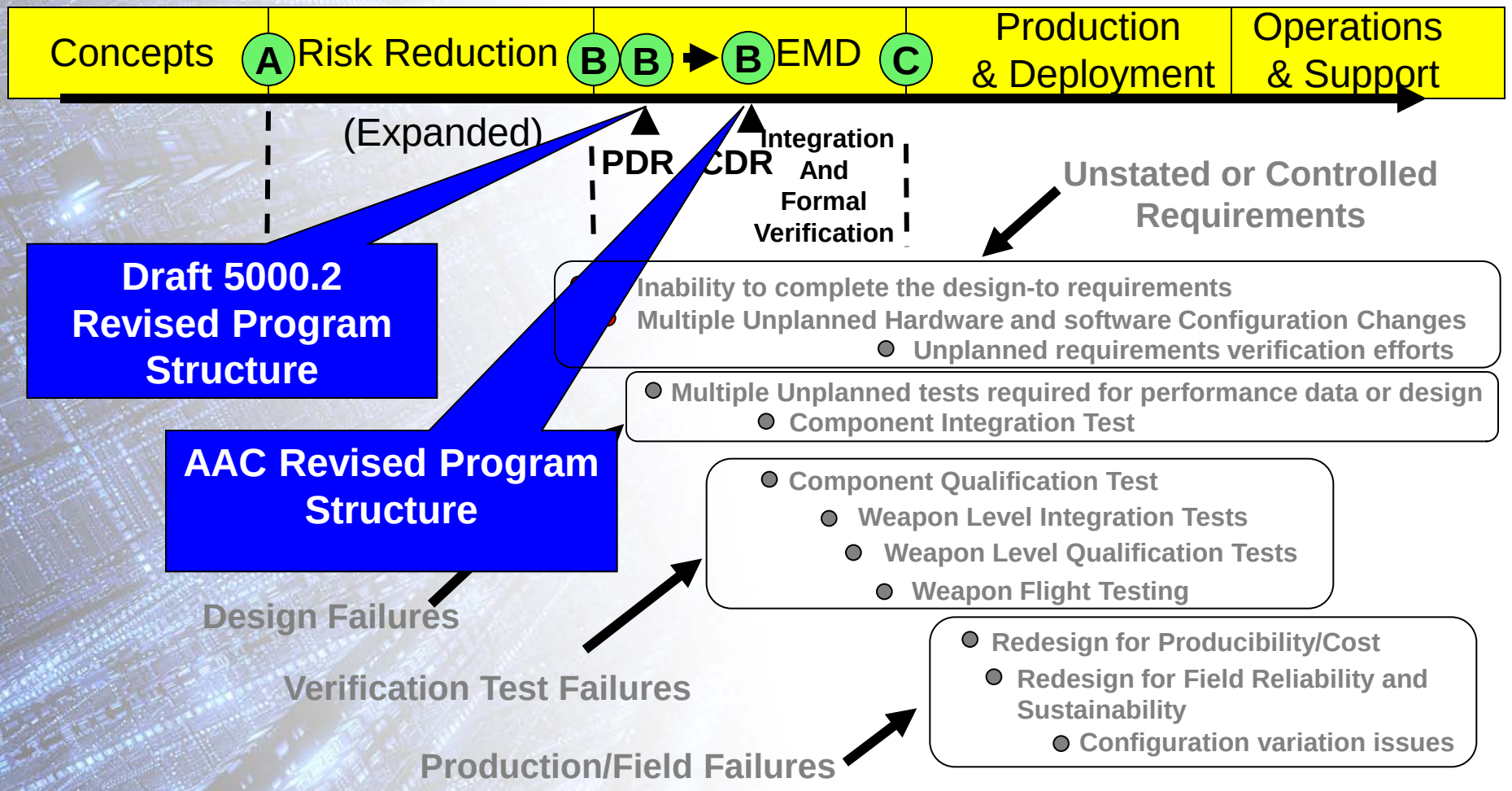
Risk Identification And Management: (Deficiency)

- Inadequate Relationship To "Knowledge" Of Design

Supply Chain Practices: (Deficiency)

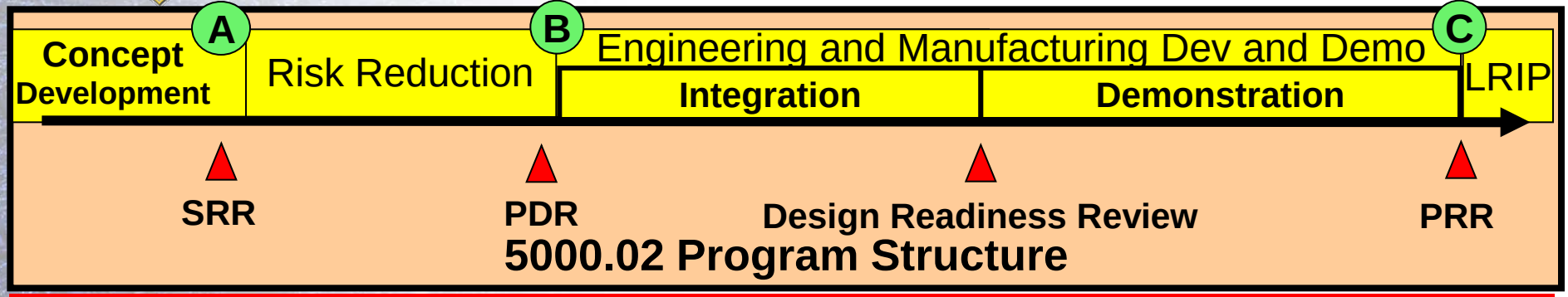
- Inconsistent Approaches To Design Characterization

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

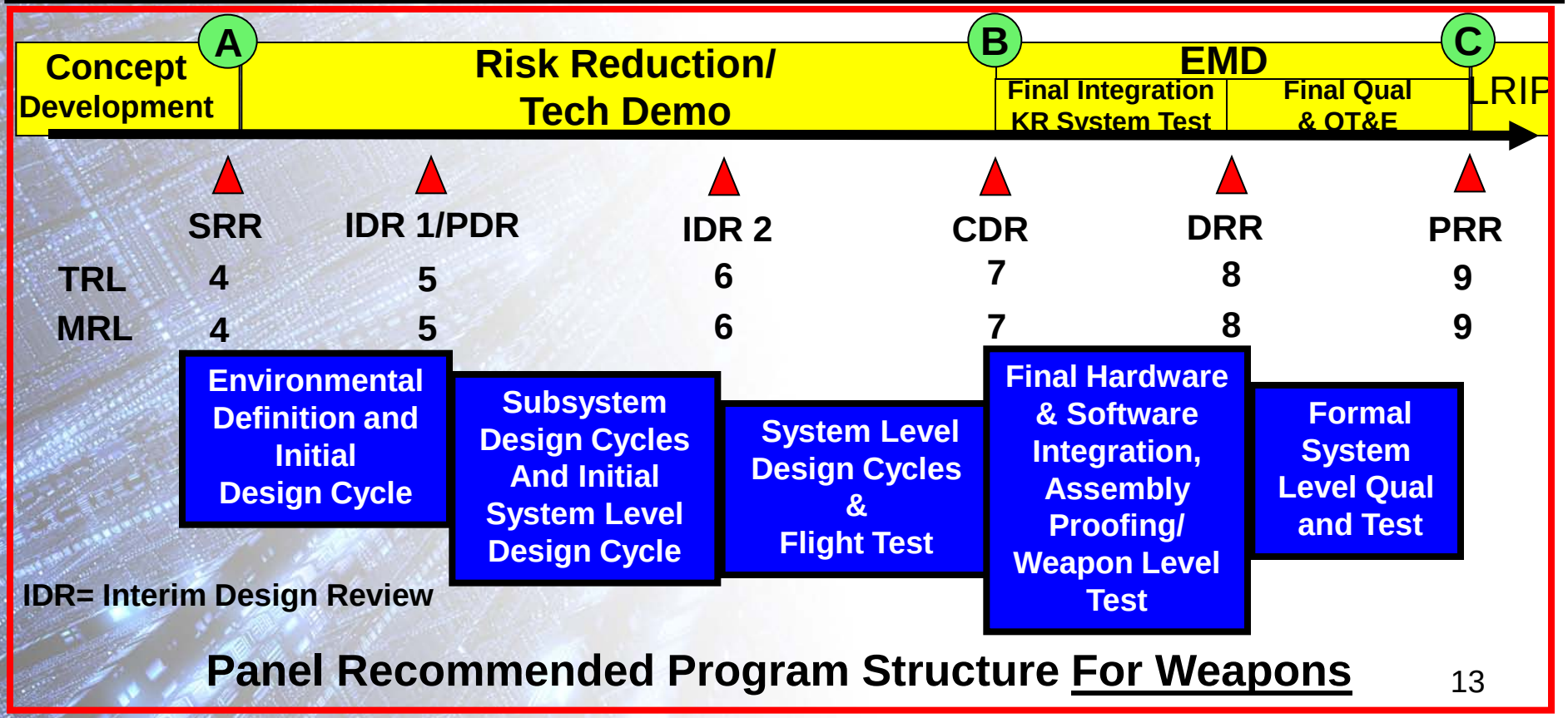


Greater Maturity at EMD Entry Provides Improvement
Improved Best Practices Ensure the Solution

5000.02 Tailored For Weapons



5000.02 Program Structure



Panel Recommended Program Structure <u>For Weapons</u>

Recommendations and Benefits:
Program Structure and Control

Adopt the Expanded Risk Reduction Model 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 (F^3M)
- Establish Culture That Accepts "Press to Failure" Approaches
- Downselect To Single Source When No Longer Cost Effective To Maintain Competition

Benefits: (When Combined with other Recommendations)

1. Shortens EMD and Total Program Timelines—Reduces Verification Test Failures
2. Earlier Maturation and Reliability
3. Reduced Weapon Costs---Less Costly Production Testing and Rework
4. Reduced Need to Create Changes in Early Production Phases

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

Recommendations and Benefits: Requirements and Verification

Recommendations

- Provide a Complete/Coordinated Service Use Profile (Pre-MS A)
- Initiate Joint Requirements Working Group
- Initiate Joint Interface Control Working Group
- Establish Overarching Test Strategy (including Acceptance) and Requirements at MS A
- Develop and Control an Asset Utilization Matrix
  - Define the Configuration and Number of Every Test Article
  - Map Testing to Assure Minimum “System Firsts” in Testing

Benefits

- Reduced Total Program Timeline
  - Reduced Level of Requirements Interpretation Issues
  - Increased Probability of Verification Test Success---”Test Mature System”
- Reduced Weapon Cost
  - Demonstrated Maturity and Reliability --- Lot Sample Acceptance Test

Recommendations and Benefits: 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 And Manufacturing Sensitivity
  - Design And Manufacturing Process Margin Summary
  - Critical Manufacturing And Assembly Process ID And Controls
- Treat COTS As Military Equipment
  - Must Be Isolated, Or
  - Subject Of Design Characterization And Configuration Control

Benefits

- Reduction In Total Program Timeline And Cost
  - Reduced Verification Test Failures
- Earlier Weapon Maturity
- Reduced Weapon Cost
  - Reduced Production Phase Changes And Acceptance Test Costs
  - Reduced Cost of Sustainment

These Recommendations Should Be Contained In Risk Reduction RFP's

Recommendations and Benefits:
Risk Identification and Management

Recommendations

- Continue Risk Identification And Management Practices
- 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

Benefits

- Reduced Total Program Timeline---Fewer Failures
- Knowledge Based Sufficiency Reviews---Cost Certainty

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

Recommendations and Benefits:
Supply Chain

Recommendations

- **Weapon Development And Production Practices Should Be Vertically Consistent**
  - **For Design Characterization/Maturation,**
  - **For Development Test, And Production ATP Philosophy,**
  - **For Risk ID And Management, And**
  - **For The Use Of COTS.**

Benefits

- **Fact: Typically 50% To 80% Of Design And Manufacturing Detail Resides Below The Prime Contractor Level**
- **Full Benefit Of Enhanced System Engineering Practices Can Only Be Realized With Inclusion Of The Supplier Chain Within Engineering Reform**

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

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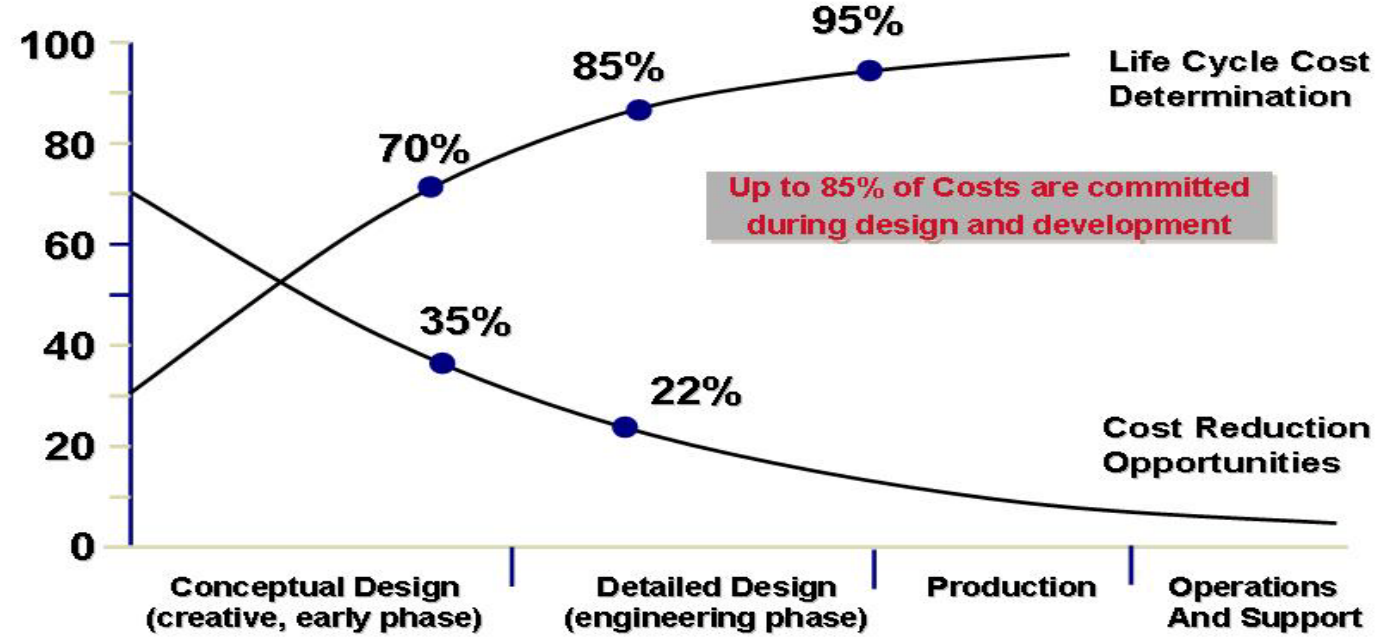
Backups

Systems Engineering
Addresses Costs of Decision Timeliness



Source: DARPA Rapid Design Exploration and Optimization Project

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
  - Etc.
- Must be Consistent with Over-Arching 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 Environments/Conditions Outside Specified Requirements.**
- **Design Margin:**
  - **Capability Of A Product Design In Excess Of "Design-to" Requirements**
    - **Includes The Extremes Of Variation In Manufacture/Assembly Processes**
- **Design Sensitivities:**
  - **Susceptibility Of Product Design Performance When Exposed To Specified <u>And Non-specified</u> Environments.**

Definitions (cont'd)

- **Configuration Management: Form, Fit, Function and Margin (F^3M)**
  - **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.**