Systems Engineering Best Practices

Air Launched Tactical Weapons Quick Reaction Capability Programs

J. Frank Robbins Panel Co-Chair
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"Acquisition Excellence through Effective Systems Engineering"

Introduction

Rapidly evolving, urgent needs of our warfighters throughout the world place new challenges in front of our acquisition community to meet these needs in very time constrained conditions.

Numerous studies and reports from OSD, GAO, the Defense Science Board and others have indicated that Quick Reaction Capability Programs are critical to on-going operations.

Massive Ordnance Air Blast

Rapid Delivery of a Complete System Requires a Focus on System Engineering Fundamentals

NDIA Gulf Coast Chapter Acknowledgements

Current Quick Reaction Program Panel

- Follow-on to Previous Systems Engineering Panel
- Core Group Developing Findings and Recommendations:
  Raytheon (chair), Boeing (co-chair), Lockheed Martin (co-chair), GC Chapter-Advisor (co-chair), Northrup-Grumman, Wyle, Mustang, ATK, Jacobs and many others
  Supported by 15+ other companies on Sys. Eng. Panel

Previous Studies:

- Systems Engineering for Air Delivered Weapons
- Urban and Complex Terrain Close Air Support
- Weapon Fuzing
- High Speed Weapons
- Weapon Networking and Data Links
- Universal Armament Interface
- And Others

Special Thanks to AAC/EN, AAC/XR and AFRL for their support and contributions to the study!

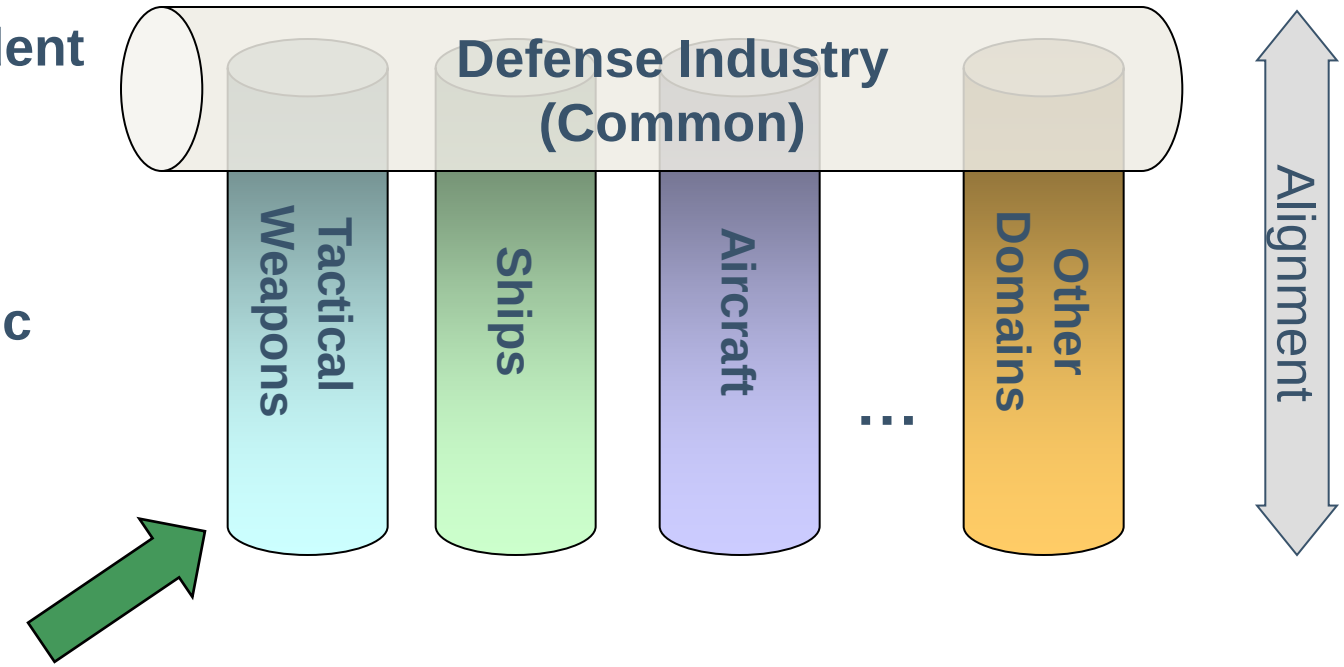
NDIA's Gulf Coast Chapter
Unique Challenge and Perspective

Tactical Weapons Non Redundant Designs Require Unique Practices

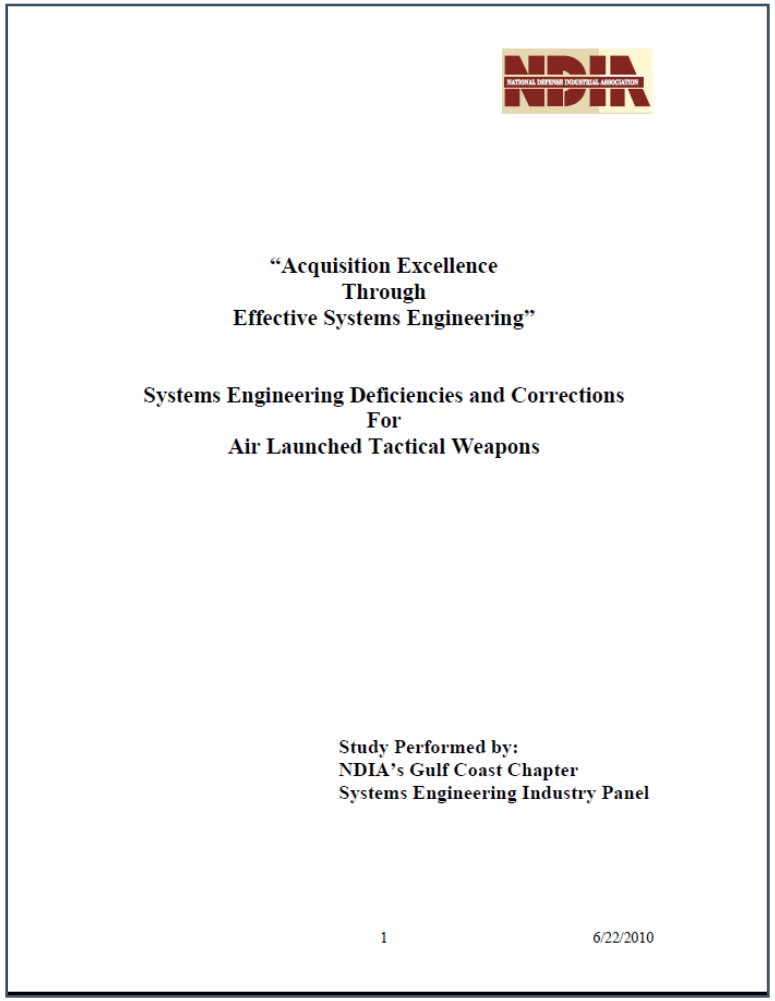
- NDIA Top 5 SE Issues
- NDIA Top SW Issues
- Systemic Root Cause Analysis (SRCA)
- SE Effectiveness Survey

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

Domain-Specific
(NDIA Chapters, Commands, Centers)



Foundational Principles (2010 SE Study)



"Acquisition Excellence
Through
Effective Systems Engineering"

Systems Engineering Deficiencies and Corrections
For
Air Launched Tactical Weapons

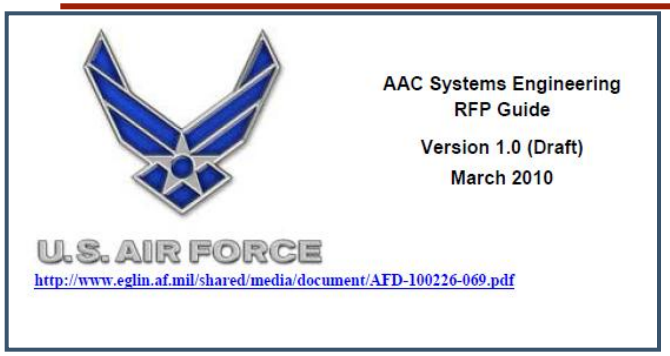
Study Performed by:
NDIA's Gulf Coast Chapter
Systems Engineering Industry Panel

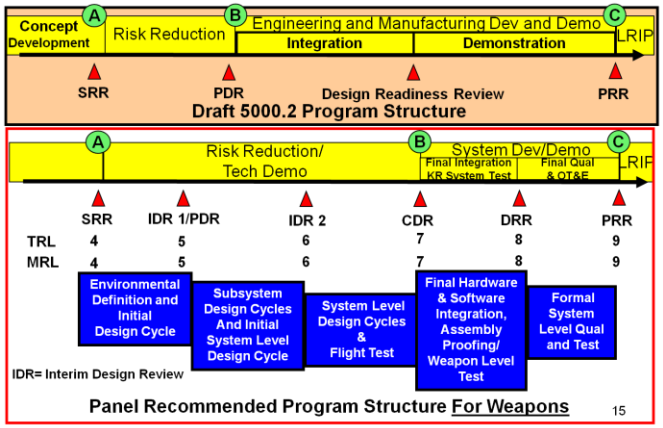
1 6/22/2010

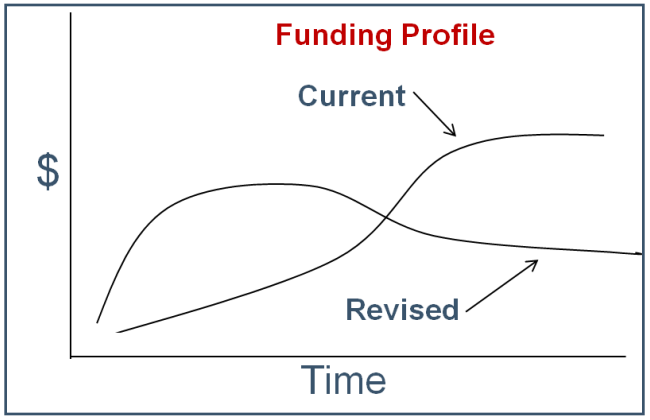
Findings:

- Generally Sound Principles Utilized
- Program Problems Generally Result of Missing Fundamentals
  a. Price-based Competition without Standards
  b. Lack of Requirements Analysis
  c. Lack of Design Characterization
  d. Configuration Control
  e. Program Plans
  f. Use of COTS

Foundational Principles (2010 SE Study)







Recommendations:

- RFP Enhancements to Require Inclusion of Missing Fundamentals in Proposed Program
- Revised Program Structure to Foster Sound Systems Engineering Fundamentals
- Revised Funding Profile

What Is A QRC?

Quick Reaction Capability (QRC)

Program Definition:

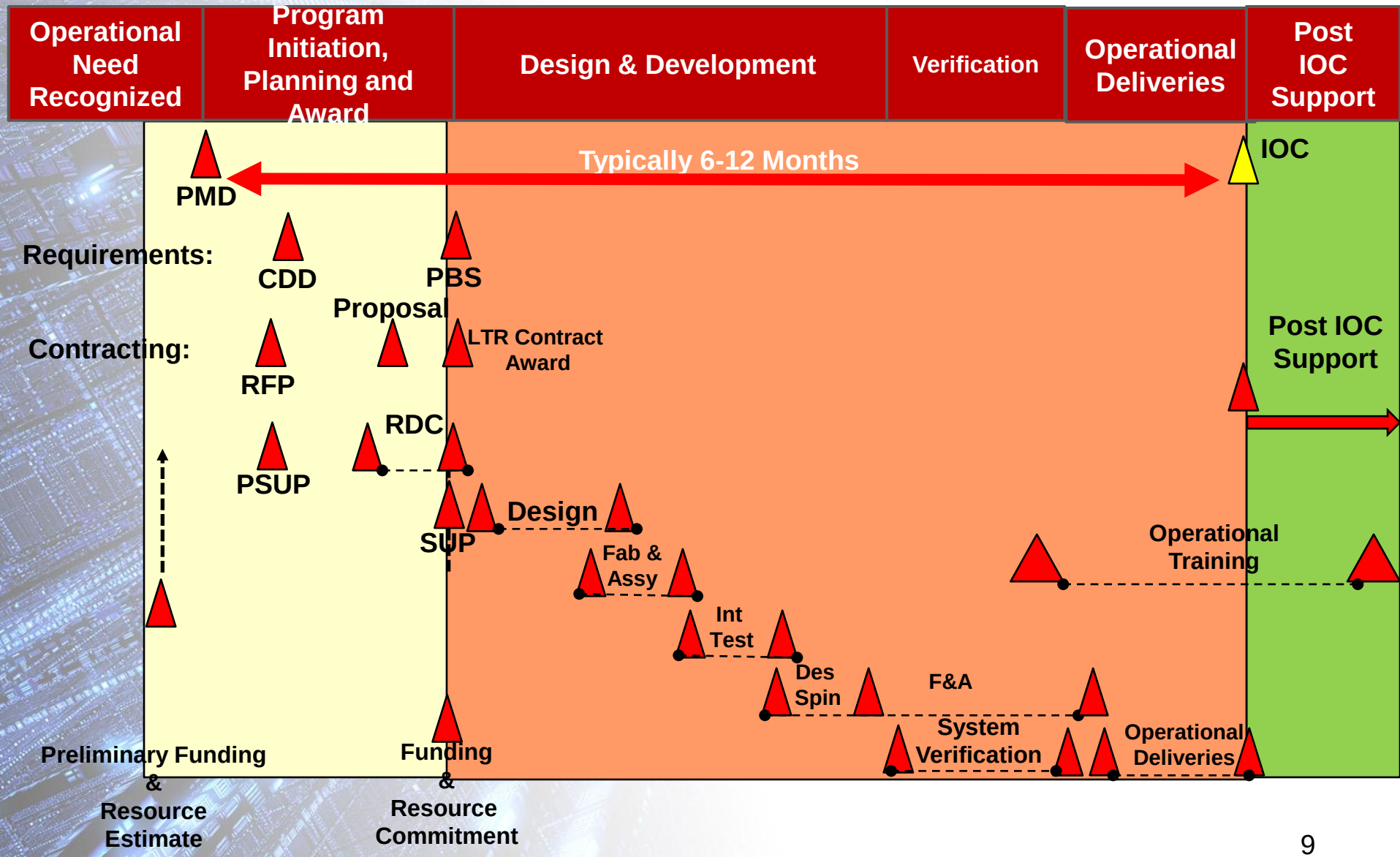
- Design, Build, Integrate, Test And Fielding Of A Time-critical, High-priority Capability Needed By Operational Forces That Meets System KPP's
  - Operationally Suitable For Initial Employment
    - Mature And Reliable
  - Includes Required Documentation, Support Equipment And Training

What is Expected in QRC's

- **Expectations:**
  - **QRC Programs Must Be Executed On Schedule And Provide Identified Critical Capabilities**
  - **Delivered Capability Must Include All System Elements Necessary for Warfighting Operations:**
    - **Performing Weapons in Required Quantities**
    - **Delivery Platform Modifications (if required)**
    - **Test and Support Equipment**
    - **Tech Orders**
    - **Trained Air Crews, Load Crews, Ammo Crews, EOD, etc.**
    - **Initial Spares**
    - **Mission Planning Tools**
    - **Seek Eagle and Safety Clearances**
    - **Field Support to Continue and Expand Training, Expedite Resolution of Issues, etc.**

QRC Systems Engineering Results In Initial Operational Capability Of A Complete System

Quick Reaction Program Phasing



Government Program Office Roles In QRC(s)

- **Prepare Acquisition/Fielding Strategy**
  - Includes Approved, Requested or Planned Statutory Waivers/Deviations
  - Identify Documentation Deferred Until Capability Transition Review
  - Estimate and Secure Required Funding
- **Define and Coordinate Requirements**
  - System Requirements, KPPs, Service Use Profile (PBS)
  - Tech Data Requirements, Drawings and Tech Orders
  - Top Level Schedule Requirements and Fielding
- **Contract for Capability**
  - Prepare Request for Proposal
  - Expedite Required Government Support (Test Range Equipment & Platforms, Gov't Furnished Equipment, Operational Utility Eval Support)
  - Support Development of Associate Contractor Agreements where needed
  - Delivery Instructions

Government Program Office Roles In QRC's (cont)

- **Support Execution**
  - Expedite Delivery of Required Intelligence (Threat and Target Characteristics) Support
  - Expedite Government Review of Required Certification Packages
  - Participate in Risk Identification and Management
  - Support Platform Integration Activities (SEEK Eagle, Systems Integration Lab, System Level DT/OT)
  - Validate Tech Orders and Support Training
- **Prepare for Capability Transition Review**
  - Plan additional test and analysis to prepare for Enduring Capability, System Sustainment or Disposal

Example Weapon QRC Programs

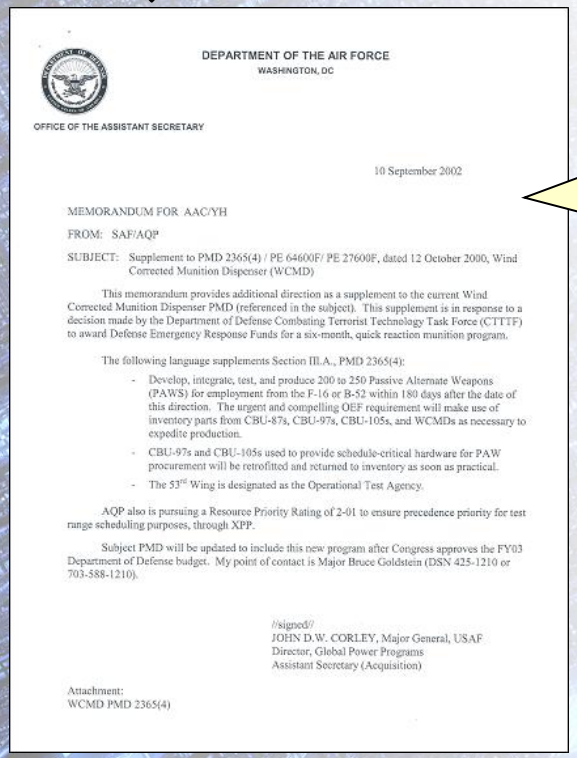
- GBU-28 “Bunker Buster” – Desert Storm
- EGBU-15 – OAF (2000) and JCTD (2005)
- Thermobaric Bomb – OEF
- GBU-43 MOAB – OIF
- CBU-107 Passive Attack Weapon – OIF
- F-16 Block 30/40/+/GBU-38 (JDAM)
- Massive Ordnance Penetrator (Current)
- Adaptive Carriage Environment (ACE)
- Active Denial System (ADS)
- BLU-122 (Eglin Steel)
- BLU-109 - QRC - ~1980-1985
- BLU-113 – 1991 and Later BLU-122-2006
- BLU-121 - ACTD – 2006
- FLM - ACTD – 2007
- Griffin (2008)
- Viper Strike (2008)
- Laser JDAM (2009)
- BLU-129/B (Precision Lethality MK-82 (Current)

Typical QRC Structure

Outline of QRC Critical Activities

- Program Direction
- Capabilities Development Document
- Service Use Profile
- RFP Content
- QRC Early Program Coordination Requirements
- Proposal
- Risk Management
- Contract Award
- Design and Development
- Test and Integration
- System Integration
- Platform Integration
- System Verification
- Manufacturing Considerations
- Initial Operations Capability (IOC)
- Post IOC Support

QRC Program Direction



DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

OFFICE OF THE ASSISTANT SECRETARY

10 September 2002

MEMORANDUM FOR AAC/YH

FROM: SAF/AQP

SUBJECT: Supplement to PMD 2365(4) / PE 64600F/ PE 27600F, dated 12 October 2000, Wind Corrected Munition Dispenser (WCMD)

This memorandum provides additional direction as a supplement to the current Wind Corrected Munition Dispenser PMD (referenced in the subject). This supplement is in response to a decision made by the Department of Defense Combating Terrorist Technology Task Force (CTTTF) to award Defense Emergency Response Funds for a six-month, quick reaction munition program.

The following language supplements Section III.A., PMD 2365(4):

- Develop, integrate, test, and produce 200 to 250 Passive Alternate Weapons (PAWS) for employment from the F-16 or B-52 within 180 days after the date of this direction. The urgent and compelling OEF requirement will make use of inventory parts from CBU-87s, CBU-97s, CBU-105s, and WCMDs as necessary to expedite production.
- CBU-97s and CBU-105s used to provide schedule-critical hardware for PAW procurement will be retrofitted and returned to inventory as soon as practical.
- The 53rd Wing is designated as the Operational Test Agency.

AQP also is pursuing a Resource Priority Rating of 2-01 to ensure precedence priority for test range scheduling purposes, through XPP.

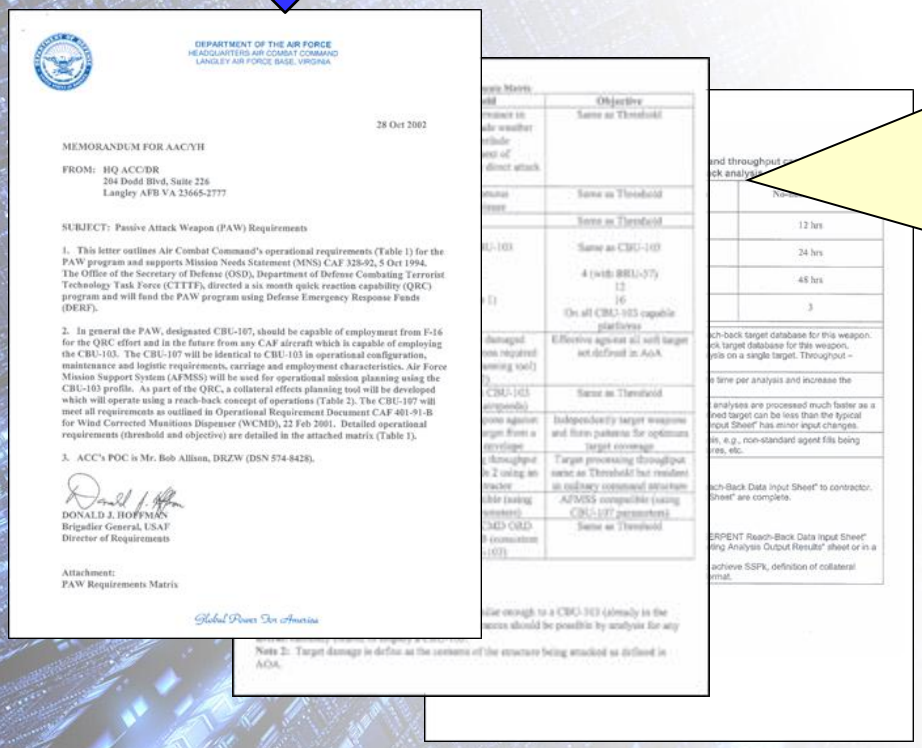
Subject PMD will be updated to include this new program after Congress approves the FY03 Department of Defense budget. My point of contact is Major Bruce Goldstein (DSN 425-1210 or 703-588-1210).

//signed//
JOHN D.W. CORLEY, Major General, USAF
Director, Global Power Programs
Assistant Secretary (Acquisition)

Attachment:
WCMD PMD 2365(4)

- **Identifies Urgent Operational Need**
- **IOC Date**
- **IOC Quantity**
- **Program Precedence Rating**
- **Authority to use inventory assets**
- **Designates Operational Test Agency (OTA)**
- **Formally Directs Program Initiation**

Capabilities Development Document



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR COMBAT COMMAND
LANGLEY AIR FORCE BASE, VIRGINIA

28 Oct 2002

MEMORANDUM FOR AAC/YH

FROM: HQ ACC/DR
204 Dodd Blvd, Suite 226
Langley AFB VA 23665-2777

SUBJECT: Passive Attack Weapon (PAW) Requirements

1. This letter outlines Air Combat Command's operational requirements (Table 1) for the PAW program and supports Mission Needs Statement (MNS) CAF 328-92, 5 Oct 1994. The Office of the Secretary of Defense (OSD), Department of Defense Combating Terrorist Technology Task Force (CTTTF), directed a six month quick reaction capability (QRC) program and will fund the PAW program using Defense Emergency Response Funds (DERF).

2. In general the PAW, designated CBU-107, should be capable of employment from F-16 for the QRC effort and in the future from any CAF aircraft which is capable of employing the CBU-103. The CBU-107 will be identical to CBU-103 in operational configuration, maintenance and logistic requirements, carriage and employment characteristics. Air Force Mission Support System (AFMSS) will be used for operational mission planning using the CBU-103 profile. As part of the QRC, a collateral effects planning tool will be developed which will operate using a reach-back concept of operations (Table 2). The CBU-107 will meet all requirements as outlined in Operational Requirement Document CAF 401-91-B for Wind Corrected Munitions Dispenser (WCMD), 22 Feb 2001. Detailed operational requirements (threshold and objective) are detailed in the attached matrix (Table 1).

3. ACC's POC is Mr. Bob Allison, DRZW (DSN 574-8428).

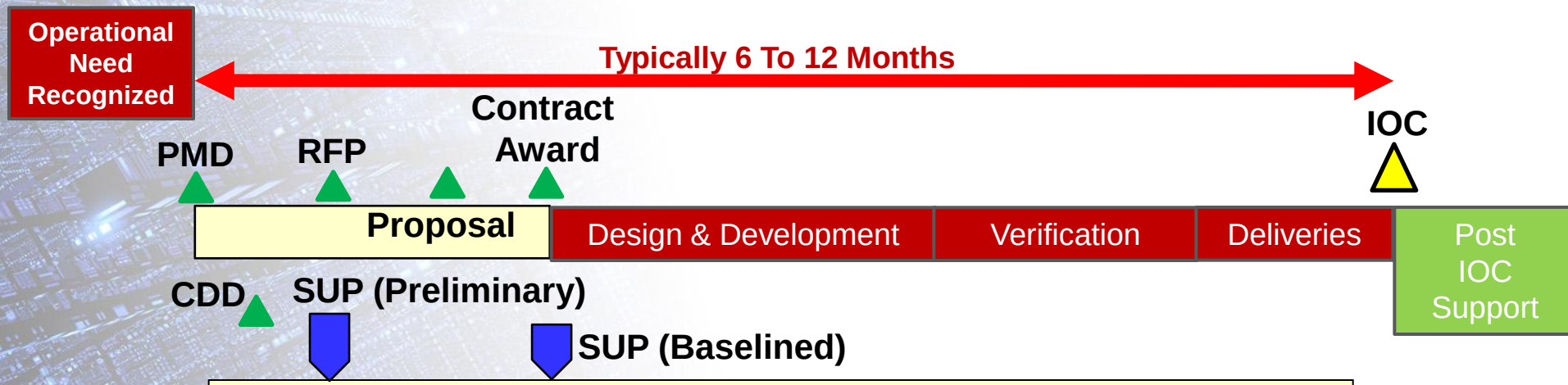
DONALD J. HOFFMAN
Brigadier General, USAF
Director of Requirements

Attachment:
PAW Requirements Matrix

Global Power For America

- **Identifies Critical Thresholds and Objective Requirements**
  - **Includes Platform Requirements**
- **Needed at RFP Release**
- **Recommend CDD Be Supplemented With A Preliminary Service Use Profile (SUP)**

Service Use Profile



Service Use Profile

- Expands on KPPs Identified Within the CDD
- Developed by Operational User and Coordinated With Government Program Office/Industry Team
- Preliminary Available At RFP Release
- Baselined At Contract Award
- Living Document With Changes Coordinated Through Configuration Control Board Post Contract Award
- Carry Over From Previous Panel Recommendations

Service Use Profile- Typical Content

- Begins with Weapon Delivery to Government and Continues through Entire Weapon Life Cycle
- Service Use Profile is the Description of the following:
  - 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-Arching System Architecture, CONOPS and Employment Concept

Developed By User-Chaired Working Group With GPO And Industry Participation

QRC RFP Content

Assumptions And Limitations
How The Contractor Will:

- **Define Requirements Including Environments**
- **Insure That Existing And New Subsystems Have Margins Against The Operational Environments**
- **Develop The System With HW&SW Performance Margins**
- **Verify How The System Meets Requirements (HW&SW)**
- **Structure An Integration And Test Strategy To Include "Sell Off" Criteria**
- **Manage GFE**
- **Perform Configuration Management**
- **Support Associate Contractors**
- **Create Source Materials For TO Revisions**

QRC Early Program Coordination Requirements

- Safety
  - System Safety
    - Safety Board Coordination
    - Explosive Hazard Classification
  - Range Safety
    - Especially Flight Termination Requirements
- Security (All Aspects)
- Test Range Requirements
  - Especially Telemetry Requirements
- GFE Availability and Government Facilities
  - Wind Tunnel
- Special Program Intel Requirements
- These Requirements Continue Throughout the Program

The QRC Proposal

- Proposed "Point Of Departure" Design
  - Pedigrees At Subsystem And System Levels
  - Mapping Of New Requirements To The Design
  - Includes All System Elements- Not Just The Tactical Round
  - Performance Limitations
- Integrated Master Plan and Schedule
  - Proposed Verification Plan
    - Methods Mapped to Asset Requirements and Verification Method: Subsystem Tests, System Tests, Analysis, Simulation, Analogy, etc.
    - Developmental and Operational Verification Proposal
  - Hardware Manufacturing Schedules
  - Software Development Plan
  - Platform Integration Plan
  - GFE Requirements
- Risk Management Plan

QRC Risk Management

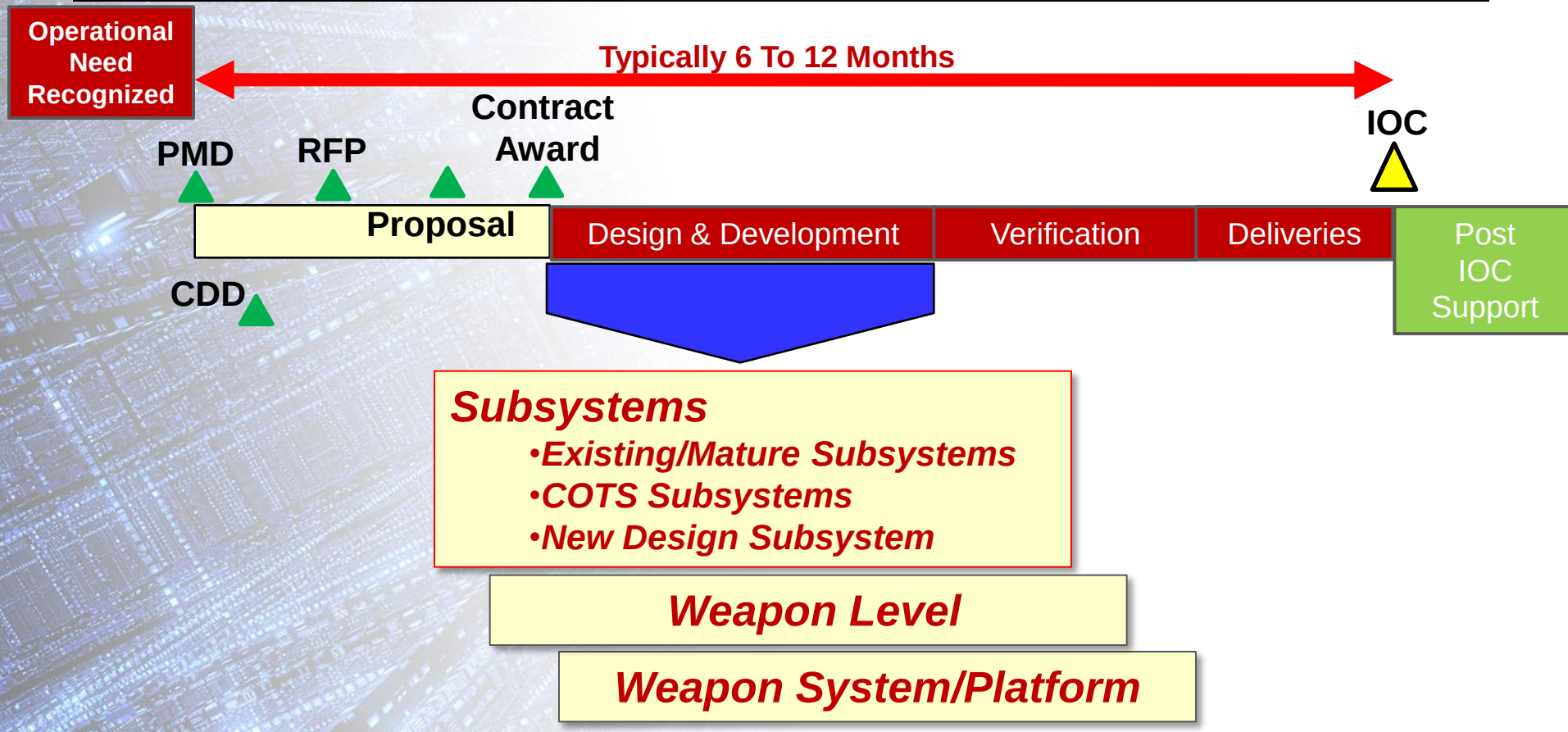
Risk Management Plan

- Time Based Risk Retirement Plan
  - Close tracking of Risk driven by concurrency
  - Program backup plan for high concurrency risk items (Design Cycle Interaction, parallel path, or alternate source)
- Risk Management is CRITICAL to successful QRC
- Adequacy of Design, Characterization, Maturation, and Verification Resources
- Sufficiency of Resources to support activities
- COTS Integration Approach
- System First's in Test
- Zero Margin Design Features
- FMECA Required for New Designs and System Level Design
- Platform Integration
- Close coordination on Failure Review Boards and Corrective Actions
- QRC Program Risks
  - Range Availability
  - Government Furnished Equipment (GFE) Availability
  - Qualified Flight Termination System

QRC Contract Award

- Service Use Profile Baselined
- Performance Based Specification Baselined
- Point of Departure Design
  - Bi-Directional traceable Requirements to Design Map
  - Functional Decomposition
- Established Test and Integration Strategy
- Platform Integration Program Defined and Coordinated
- Integrated Characterization, Maturation, and Verification Plan (ICMVP) for new equipments and capabilities
- Streamlined Data Items Requirements
  - Earned Value Measurement System (EVMS)
- Risk Assessment and Risk Management Plan
  - Focus on Asset Availability and Schedule Margin
- Supply Chain – Identified and Vertically Integrated

QRC Design and Development

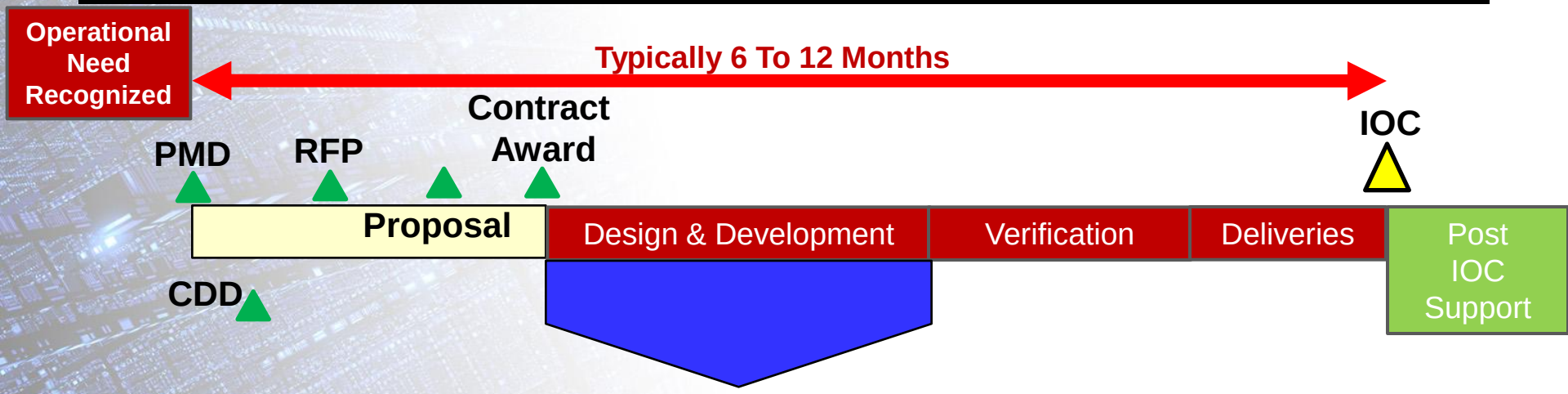


Design and Development Activities Need to be Addressed at the Subsystem, Weapon, and Weapon System/Platform Level

QRC Subsystem
Test and Integration Strategy

- *Existing/Mature Subsystem*
  - In Lieu of Fully Characterizing Margins
    - Survey Pedigree (Factory Yields, Field Functional Reports, Warranty, Depot)
    - Comparative Analysis of Anticipated Service Use against original Subsystem Requirements
    - Analysis of Critical Performance Related Features
- *COTS Subsystem*
  - Stability of COTS configuration is NOT assured
  - Buy from a single Lot/Date Source (minimize configuration variation)
  - Acceptance Testing
    - Test/Characterize Key Performance Features to Verify Margin
    - Reliability Testing
      - Series of Highly Accelerated Lifetime Tests (HALT)
      - Determine the Useful Life Curve
      - Develop Screening Acceptance Test that eliminates Infant Mortality
- *New Design Subsystem*
  - Use of New Design for Subsystems should be minimized
  - Design should be fully characterized with margin defined
  - Manufacturing margin consistent with QRC quantity requirements

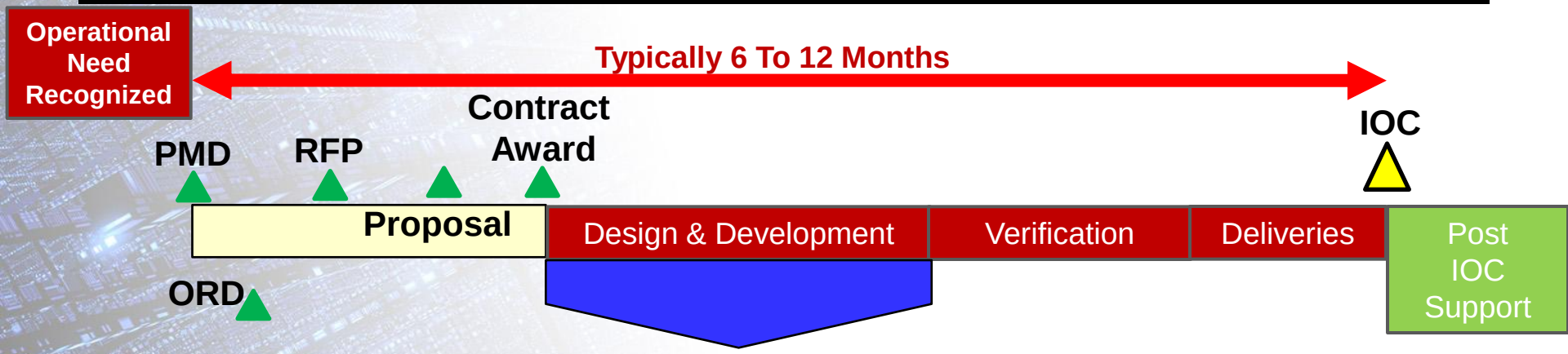
QRC System Integration



System Integration

- **Interface compatibility (internal and external)**
- **Verification of ALL Mode State Transitions**
- **Utilize Component and Subsystem Integration Tests to Reduce Risk in Final System Verification**
  - **Minimize "System Firsts" in formal tests**
- **Demonstration Tests in accordance with the ICMVP**
  - **Fully Characterize Design interfaces understanding Margins where verification by analysis is planned**

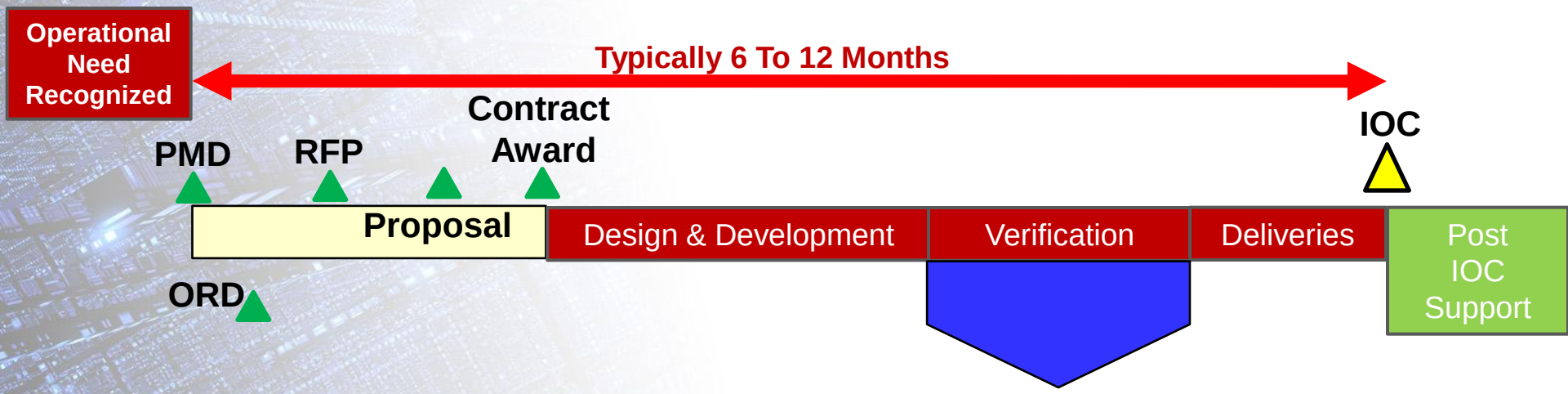
QRC Platform Integration



Platform Integration

- **Design to Known External Profiles and Mass Limits**
- **Use of Established Electrical and Functional Interfaces to the Degree Practicable**
- **Quantification of Service Use Captive and Release Environments through Previously Obtained or New Test Activities (Preference to Digital Measurement Vehicles for Vibration; Wind Tunnel and Actual Test Releases for Performance Baselining, etc.)**
- **Demonstration Tests for entire system under Operation Use Profile conditions**
- **Closely Coordinated Weapon/Platform Verification Activities (SIL, Flight Test, ICWG, etc.)**

QRC System Verification



- System Verification on a QRC includes the following:
  - Simulation and Analysis mapped to KPPs
  - System Integration Test Results Mapped to KPP's
  - Environmental Qualification Test Results Mapped to KPPs
  - Software Formal Qualification Results
  - Flight tests to verify KPP's
  - Technical Order (TO) Verification and Validation
  - Software FQT
- Operational Test Authority (OTA) actively involved in the System Verification Process

Manufacturing Considerations for QRC Operational Deliveries

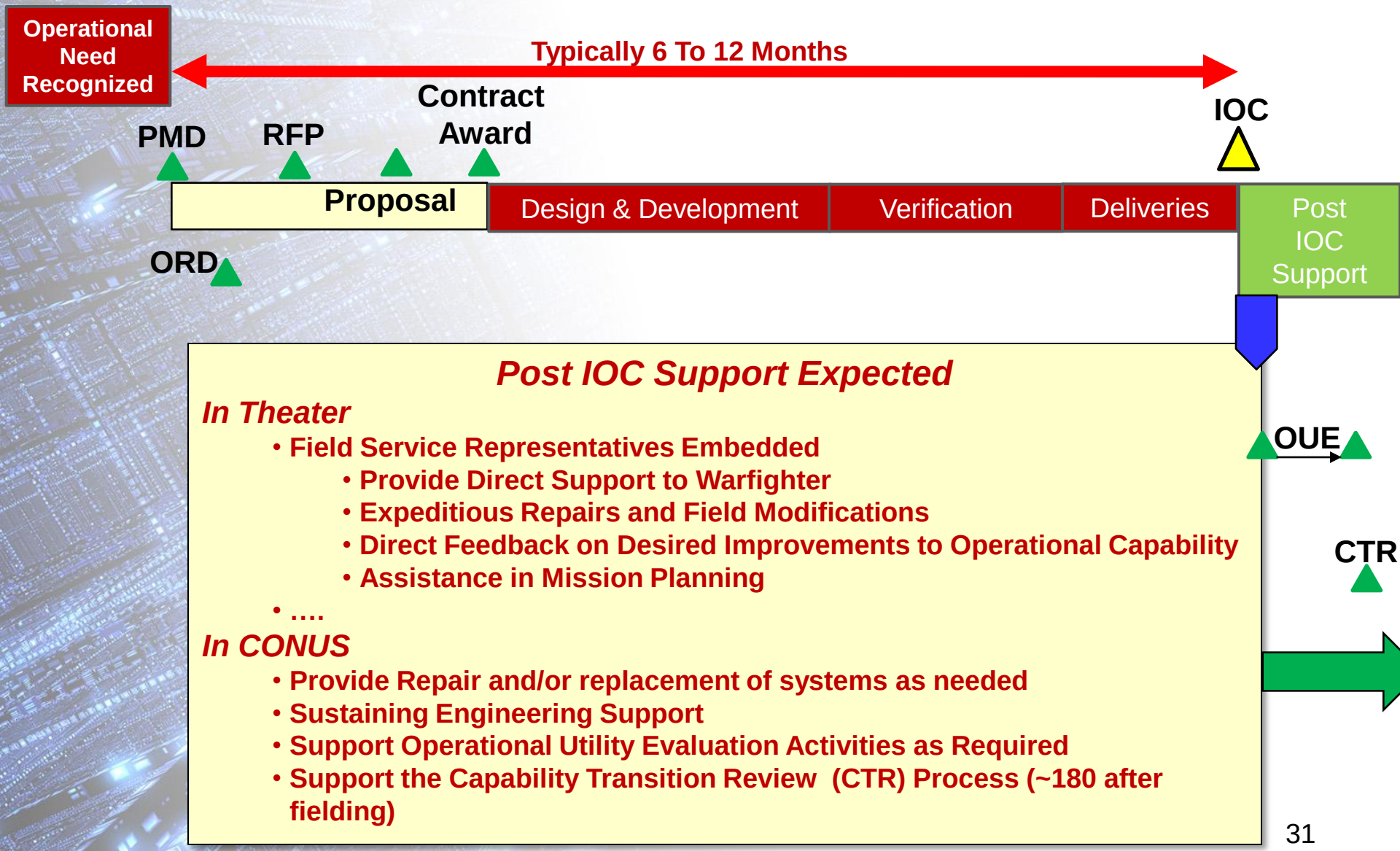
- Deliveries
  - Development/Production Concurrency Constitutes Risk
  - Criticality of GFE availability to schedule
  - Government acceptance of operational deliveries per approved Acceptance Test Plan
  - Early planning and coordination of all delivery details, i.e. packaging and shipping, required documentation per contract
  - Point of Acceptance and Delivery

QRC Initial Operational Capability

Initial Operational Capability Achievement Criteria:

- Design and Verification of the Tactical System has been accepted by the Government
- Operational Test Authority Has Certified that System is ready for Operational Use
- Required Technical Data and Training has been provided to the Operators
- Required Operational Assets have been delivered to the operator
  - Weapons
  - Launch Equipment
  - Support Equipment
  - Required Spares
  - Modified Platforms as Required
  - Mission Planning Tools
  - Etc…
- Required Field Support In Place In Theater

QRC Post IOC Support



Post IOC Support Expected

In Theater

- Field Service Representatives Embedded
  - Provide Direct Support to Warfighter
  - Expeditious Repairs and Field Modifications
  - Direct Feedback on Desired Improvements to Operational Capability
  - Assistance in Mission Planning
- ….

In CONUS

- Provide Repair and/or replacement of systems as needed
- Sustaining Engineering Support
- Support Operational Utility Evaluation Activities as Required
- Support the Capability Transition Review (CTR) Process (~180 after fielding)

Observations

Shared Characteristics Successful QRC Programs

- "Joint Pursuit of Success" Permeated Gov't/Contractor Team To Achieve Urgently Needed Capability
  - Cohesive Team Behavior and Alignment on Objectives
  - GPO worked as a Proactive Integrator With All Program Participants
  - Co-Operative environment with user as customer
  - Access to user provides ability to understand and rapidly explore trade space
- Program Ground Rules and Assumptions Were Baselined and Maintained from the Beginning to Prevent Req'ts and Scope Creep
- New capability provided by upgrade or technical insertion into an existing and mature system, with subsystem Technical Readiness Level not less than TRL 6
  - New capability derived from subsystems with carefully selected TRL and MRL assessments
- System Engineering Discipline/Rigor was not traded for schedule or cost considerations----in favor of greater performance from less mature or COTS sub-systems.

Observations (cont)

Shared Characteristics of Successful QRC Programs

- GPO, User and Contractor Defined Requirements (JRWG) and Associated Verification Products
  - Environmental requirements established by parent system extension to new system elements
  - Trade space explored and where possible, verification scope was decreased by limiting initial operational capability (ie launch envelop and conditions)
  - GPO Engineering and Test participants in verification test planning
  - System Integration infrastructure exists and available
  - Range Safety and Instrumentation Kits Qualified and Available
  - Contracts incorporate “force majeure” provisions
  - Logistics Products and Verification Methods
- Both the GPO and Contractor teams staffed with Experienced, Senior Level talent.
- GPO established streamlined reporting requirements to reduce administrative burden.
- GPO utilizes Review, Discuss, & Concur (RDC) will all participants to achieve alignment and manage expectations

Recommendations

Successful QRC Program Observations Should Be Considered For Use in Future Weapon QRC's

Previous Panel Recommendations for Normal Acquisitions Are Applicable to Quick Reaction Capability Programs

- **Cooperatively developed Service Use Profile to Complement the CDD**
- **Bi-directional Mapping of Requirements to Design Features**
- **Carefully Selected Subsystems Based on TRL and MRL Maturity**
- **Comprehensive Pre-planning to included ICMVP and Asset Utilization Matrices**
- **Comprehensive Risk Mitigation Plan**
- **Minimization of "System Firsts" in Flight Testing**
- **Supplier Management and Alignment**

Additional areas for future success

- **Treatment of COTS---Useful Life Margin and Screening Approach**
- **System Integration to examination of all mode/mode state transitions**
- **Emphasis on platform integration**

Thanks to Each Company and Every Panel Member!…

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
NDIA
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

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BOEING

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Missile Systems

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Rockwell Collins

NORTHROP GRUMMAN

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Ordnance and Tactical Systems

KAMAN FUZING

ATK

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Honeywell