



"Technology: Advancing Precision"
20-23 April 2009 Salt Lake City, Utah

Support Systems Associates, Inc.

800 Park Drive

Warner Robins, GA 31088

Software Acquisition Management Practical Experience



James E. Jones

Enabling organizations to achieve mission success through best practices and domain expertise

22 April 2009 – Track 6, Topic: Competitive Modeling



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- Key Acquisition Elements
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 - ❑ The Acquisition Environment
 - ❑ Requirements Management
 - ❑ Risk Management
 - ❑ Technical Performance Assessments
 - ❑ Software Test Evaluation
 - ❑ Performance Measurements
- Summary



Objectives

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- Provide **Key Acquisition Elements** for enabling delivery of quality software within cost and schedule
 - ▣ The Contract, The Acquisition Environment, Requirements Management, Risk Management, Technical Performance Assessment, Software Test Evaluation, and Performance Measurements

- Provide detailed **Practical Examples** from major military and commercial programs

- Illustrate how **Software Engineering Advisory and Assistance Services** help organizations achieve their objectives and advance the practice of software development

Knowledge of failure helps lead to success



Programs Overview

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- U.S. Air Force C-130 Avionics Modernization Program (AMP)
- Lockheed Martin C-130J Hercules Program
- U.S. Federal Aviation Administration (FAA) National Airspace System (NAS) Plan Programs



U.S. Air Force C-130 AMP

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➤ Contract

- ❑ July 2001 (F33657-01-C-0047) Engineering and Manufacturing Development (EMD) (\$485 million **Cost-Plus-Award Fee [CPAF]**)
- ❑ The Boeing Company
- ❑ Acquisition Category (ACAT-1D)

➤ Statement of Work

- ❑ Design, development, test, and installation of a modern glass cockpit and new avionics systems for US Air Force's **519** C-130 fleet of 15 different Mission Design Series (e.g., Combat Delivery, Tanker, Combat Talon, Gunship H, Gunship U, etc.)



U.S. AIR FORCE



Source: Global Security.org

➤ Key Features

- ❑ Six digital displays, proven Flight Management System, avionics systems which meets Communications Navigation Surveillance/Air Traffic Management (CNS/ATM)
- ❑ Two fully redundant Mission Processors to provide system control, system monitoring, data bus and discrete control, and integrated diagnostics



Examples of Contract Changes

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EMD Engineering Change Proposals (ECP) Examples

- ECP 1302 \$200 million Cost-Plus Award Fee Restructure due to funding reduction in FYs 03/04 resulting in two year delay
<http://www.dtic.mil/descriptivesum/Y2007/AirForce/0401115F.pdf>
- ECP 0303 \$58 million Cost-Plus Award Fee, Special Operations Forces (SOF) accelerated, two Talons NLT CY08 <http://www.defenselink.mil/contracts/contract.aspx?contractid=2753>

EMD Contract – Statement of Work Changes Examples

- Software Integration
 - Conduct supplier design review [*Software Specification Review (SSR)*, *Preliminary Design Review (PDR)*, and *Critical Design Review (CDR)*]
 - Prepare *interface design description (IDD)* in accordance with Contract Data Requirements List (CDRL) No. A015
 - Contractor shall perform both static and dynamic analysis for each flight critical CSCI in the AMP C-130 aircraft flight management system



Examples of Activities¹

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- Sep 19, 2006, C-130H2 (89-09101) **AMP1** successfully completed first C-130 AMP flight with Combat Delivery/Tanker Capability Block software
- 2007, AF instructed Boeing to stop work on SOF aircraft (1/10/07 Dow Jones Newswires)
- Jan 12, 2007, AF notified Congress of a Nunn-McCurdy breach
- June 6, 2007, DoD recertified C-130 AMP to continue upgrading **222** C-130H (H2, H2.5, H3)
- Aug 18, 2008, **successful flight test of AMP2 (H2.5 91-01239)** with Core Complete 2.2 software (Combat Delivery Product Baseline)



C-130 AMP First Flight

Sep 05, 2008, Boeing announced it has **completed** software development for **Combat Delivery Mission Design Series** aircraft



Lockheed Martin C-130J Hercules Program

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- Sep 1992, Lockheed Aeronautical Systems Company (Now **Lockheed Martin Aeronautical System-LMAS**) started with Lockheed 382J to achieve FAA Order 8110.4A Type Certification
 - ▣ The C-130J was an initiated improvement of the C-130H3
- In 1994, LMAS received the launch order from the United Kingdom (UK) Ministry of Defense for the Royal Air Force (RAF) for 25 C-130J
- Department of Defense (DoD) created a C-130J acquisition program (ACAT 1C) to provide the Air Force oversight of the development.



- In Oct 1995, Air Force contracted for two (2) C-130J under a **commercial acquisition strategy**. – LMAS identified only minor modifications needed



C-130J Key Avionics Features

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- Four multifunctional heads-down displays
 - ❑ Aircraft Flight Control
 - ❑ Operating Internal Systems
 - ❑ Navigation
- Two heads-up displays (HUD)
- Integrated Digital Avionics Systems
- Two Mission Computers (MCs) and two backup Bus Interface Units (BIUs)
 - ❑ Provide dual-redundant aircraft control with integrated diagnostics
- More than 50 Operational Flight Program (OFP) Computer Software Configuration Items (CSCIs)
 - ❑ Development, Modified Commercial Off-The-Shelf (COTS), and COTS



C-130J Glass Cockpits



Examples of Activities¹

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- Initial UKRAF delivery Aug 24, 1998
- Plan USAF delivery – July 1997, Actual Feb 1999
- First flight – April 1996 minimum OFP software
- Air Force agreed to a contractor-initiated, three-phase, block upgrade program (Blocks 5.1, 5.2, and 5.3) in Jan 1999
 - **C-130J problems meeting its advertised capabilities**
- FAA granted FAA Type Certification for commercial variant C-130J-30 (382J) in Sep 1999
- C-130J flew with a complete mission OFP software suite in Mar 2001
- **Air Force Air Mobility Command declared Initial Operation Capability on October 16, 2006**

¹ All timeline information is from: Department of Defense: Office of the Inspector General. Acquisition: Contracting for and Performance of the C-130J Aircraft (D-2004-102), July 23, 2004.

Available online at: <http://www.dodig.osd.mil/audit/reports/fy04/04-102.pdf>



FAA NAS Plan

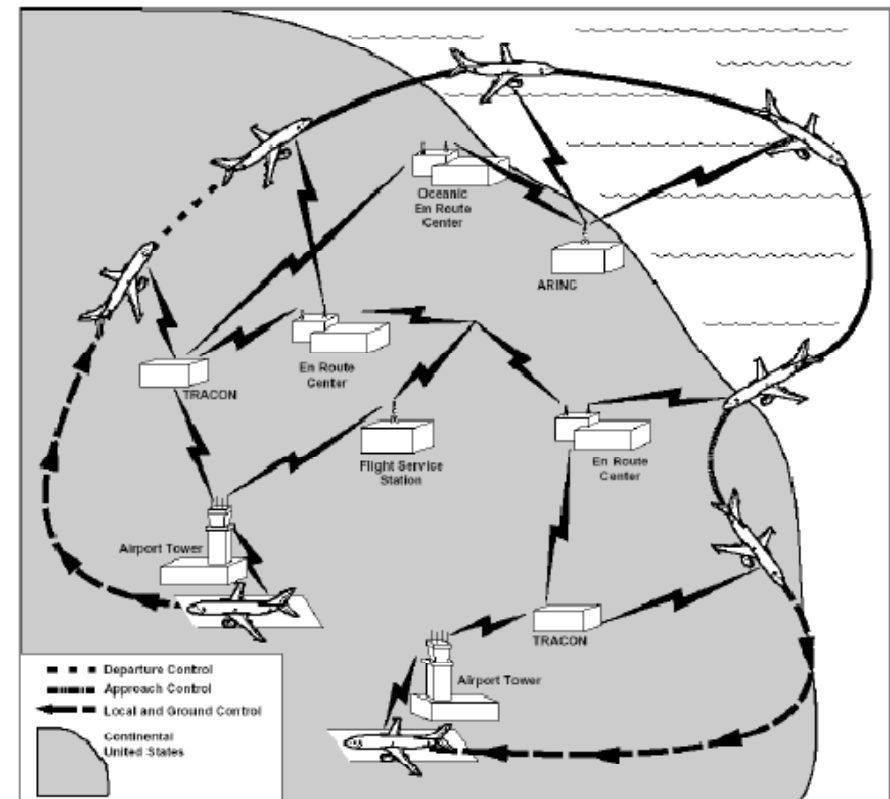
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- FAA NAS Plan (now **Capital Investment Plan-CIP**) released in 1982
 - ❑ Modernize Air Traffic Control (ATC) facilities and equipment for improvement in capacity, safety, and timelines
 - ❑ ATC Facilities – Flight Service Stations, Air Traffic Control Towers, Terminal Radar Approach Control (TRACON), and Air Route Control Centers
 - ❑ ATC permits air traffic controllers to view key information, communicate with pilots, display, communication, navigation, surveillance, and weather resources

Figure 1: Overview of U.S. Air Traffic Control System



Overview of U.S. Air Traffic Control System



Activity Summary

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- FAA NAS Plan is a **multi-billion-dollar** investment comprising over 200 separate programs
 - Between 1982 and 1998, Congress appropriated over **\$25 billion** (GAO/T-RCED/AIMD-98-93, February 26, 1998)
- In 2004, the GAO reported that since 1982, **the FAA's ATC modernization programs have consistently experienced cost, schedule, and performance problems - attributed to systemic management issues**
- Initially, the FAA estimated that its ATC modernization efforts would cost **\$12 billion** and could be completed over 10 years
- As of October 30, 2003, two decades and **\$35 billion** later, the FAA expects to need another **\$16 billion** through 2007 to complete key programs, for a total cost of **\$51 billion** [GAO-04-227T (www.gao.gov/cgi-bin/getrpt?GAO-04-227T)].



Examples of FAA NAS Programs

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<p>Advanced Automation System (AAS)</p> <p><i>Cornerstone of the NAS Plan</i></p>	<ul style="list-style-type: none">◦ 1984, \$276.7 million Competitive Design Phase Contract – <i>IBM Federal Systems and Hughes Aircraft</i>◦ 1988, \$3.6 billion Fixed-Price, – <i>IBM Federal Systems Statement of Work</i>◦ Replace computer hardware and software at ATC facilities-Airport Towers, Terminal Facilities, and En-Route Centers, 99.99999% Reliability.
<p>Microwave Landing System (MLS)</p>	<ul style="list-style-type: none">◦ 1984, \$90.6 million Fixed-Price First Production – <i>Hazeltine Corporation System Overview</i>◦ Landing aid to enable planes to fly a wide variety of approach paths to airport runways.
<p>Radio Control Equipment (RCE)</p>	<ul style="list-style-type: none">◦ 1986, Fixed-Price Contract (DTFA01-86-C-00034) - <i>AT&T Company Federal Systems Advanced Technologies System Overview</i>◦ Provides pilots communications links with air traffic controllers.



Examples of FAA NAS Programs

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Voice Switching and Control System (VSCS) Upgrade



- 1992-Contract Award-**\$1.3 billion**, *Harris Corporation*
System Overview
 - Allows air traffic controllers to communicate with pilots and other air traffic controllers at 23 Air Route Traffic Control Centers (ARTCC)
 - Independent distributed processors and voice switches, fault-tolerant databases, redundant high-speed bus interconnections, **operational availability – 0.9999999**

Terminal Doppler Weather Radar (TDWR)



- 1988, **Firm Fixed-Price Incentive contract** – *Raytheon Systems Company*
Develop, produce, and install 47 TDWR at 45 airport sites
System Overview
 - Detects and reports hazardous weather in and around airport terminal approach and departure zones
 - Identifies and warns air traffic controllers of low altitude wind shear hazards caused by micro-burst and gust fronts
 - Reports on precipitation intensities
 - Provides early warning of wind shifts



Software Acquisition Experience

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Programs

C-130 AMP

**Software Engineering Advisory
and Assistance Services**

- 7 years

C-130J Hercules

**Software Subcontract
Management**

- 4 years

FAA NAS Plan Programs

**Software Engineering Advisory
and Assistance Services**

- 10 years

Roles

Integrated Product Teams Support

Systems Integration Facility (SIF)

**Operational Flight Program (OFP) Software
Systems Requirements, Design & Test**

Supplier Manager

Review and approve SDRL items

Monitor supplier activities

Witness acceptance testing

Coordinate with FAA DER

System Development Manager (AAS)

SPO Software Lead (TDWR)

**Software Subject Matter Expert (e.g., VSCS,
MLS, RCE, NADIN II, MCCP/MCC)**

Deposed by AT&T (RCE), GAO Audit (MLS)

21-years Software Acquisition Management Practical Experience

Plus a foundation of 19-years Software Development and Process Improvement

United States Patents #4451702, #4479034



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Software Acquisition Challenges

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- **Why is Software Acquisition a Challenge?**
 - For **Software Intensive Systems** studies have shown that *technical performance, cost, and schedule risks* are inherent in delivering quality software products within cost and schedule constraints [GAO 1999]
 - **75% of all large scale software systems fail**
 - [Software's Chronic Crisis, W Wyatt Gibbs, 1994]
 - **Design constraints** make software acquisition and development extremely critical
 - **Examples of design constraints**
 - Application domain (real-time embedded systems of systems),
 - Software size
 - Complexity
 - High-integrity
 - Reliability
 - Safety-critical

The Software Crisis Is Still With Us!



Software Acquisition Challenges

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- Why is Software Acquisition a Challenge?
 - ❑ Software size is the critical factor in determining cost, schedule, and effort [Jones 2004][Jones 1999]
 - Software size typically driven by the supplier's agreement terms –
 - contract vehicle (Fixed-Price, Cost-Reimbursement)
 - statement of work
 - deliverables (Contract Data Requirements List-CDRL)
 - technical requirements (safety-critical),
 - supplier's software development capability/maturity
 - ❑ Software Acquisition Team – Inability to successfully manage the acquisition

“Acquirers must recognize quality work before they can require and accept it”

----Watts Humphrey, 2009



Examples of Acquisition Problems

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o C-130 AMP

- o Increase in cost
- o Nunn-McCurdy breach in FY07

“The government and industry both underestimated the complexity of the technology insertion”

“...use of commercial-off-the-shelf technologies to replace the navigator proved more difficult than anticipated...lines-of-code increased from 60,000 to 900,000”

-- The Honorable Sue C. Payton – Assistant Secretary of the AF for Acquisition, Defense Daily, Jan 12, 2007

o C-130J

- o Cost and Schedule overruns
- o Software performance issues
- o Source lines-of-code increased by 56%

“The C-130J aircraft does not meet contract specification and therefore cannot perform its operational mission”

-- Office of the Inspection General --Audit



Examples of Acquisition Problems

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FAA NAS Programs

- o AAS
 - o Inadequate requirement baseline control
 - o Cost and Schedule Overruns
 - o Restructured in 1994
 - **contract cost increased from \$3.6 billion to \$7.6 billion**
- o NADIN II
 - o Cost and Schedule Overruns
- o MCCP/MMC
 - o ***Termination for Convenience***
- o MLS
 - o ***Termination for Default***
- o RCE
 - o ***Termination for Default (DOT BCA No. 2479) (FAR 52.249-8)***



Success in Acquisition

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C-130 AMP

Boeing” program has stayed on schedule since 2005” <http://www.beurs.nl/nieuws/artikel.php?id=198658&taal=US>

o The Boeing Company¹

Three weeks
ahead of
schedule

- o Sep 19, 2006 – **First C-130 AMP aircraft (H2, 89-09101)** successfully completed its maiden flight
- o Mar 25, 2007 – **First C-130 AMP aircraft (H2.5, 91-01239)** successfully completed its maiden flight
- o Aug 18, 2008 – Successful flight test of H2.5
- o Sep 5, 2008 – **Completed software development**
- o Jan 17, 2009 – **First C-130 AMP aircraft (H3, 94-6704)** successfully completed its maiden flight

o System Program Office (SPO)

- o Ensure compliance with processes, product quality, and technical requirements: Examples of Activities
 - o **Participate at weekly meetings and technical reviews**
 - o **Identify process compliance**
 - o **Identify product discrepancies and provide recommendations**
 - o **Witness all formal qualification testing**

¹ Source: <http://www.boeing.com/ids/news>



Success in Acquisition

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FAA NAS Programs

- o TDWR¹
 - o Delivered First Production Unit six months early
 - o Received IEEE Computer Society award
 - o Operational at 45 Airports
 - o 1991, software process evaluated a SEI CMM® Level 3

® CMM registered in the U.S. Patent and Trademark Office by Carnegie Mellon University

Acquirer and supplier capability / maturity levels matched

- o VSCS Upgrade
 - o Production completed
 - o 100% on-time system delivery of all 23 systems
 - o FAA Contractor of the Year Award
 - o Human Factors Engineering Society Award

1 Successful Acquisition of FAA Terminal Doppler Weather Radar, Third Annual Conference on the Acquisition of Software-Intensive Systems (Experience Track, 26 January 2004). [Jones 2004-1]

<http://www.sei.cmu.edu/programs/acquisition-support/conf/2004-presentations/jones.pdf>



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The Contract

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- Contract Administration
- Contract Types
 - ❑ Fixed-Price
 - ❑ Cost-Reimbursable
- Contact Data
 - ❑ Statement of Work (SOW)/Statement of Objective (SOO)
 - ❑ Contract Data Requirements List (CDRL)
 - ❑ System Specification
 - ❑ Data Rights

The Contract is the foundation for acquisition success



Contract Administration

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- The **Contract** is a mutually binding legal relationship obligating the seller (supplier) to furnish products or services and the buyer (acquirer) to pay for them.
- **Acquisition management** involves obtaining products or services through a contractual agreement.
- **Contractual authority** – delegated to an Administrative Contracting Officer (ACO)/procuring contracting officer (PCO)

The **acquirer** specifies

- What the system requires
- When the system is needed
- How the system will be accepted

Concerns

- ❖ cost
- ❖ schedule
- ❖ technical

The **supplier** determines

- How the system will be produced
- The resources required (examples)
 - people, equipment
 - facilities

The degree of interaction depends on the nature of the development effort and the type of contract



Contract Types

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➤ Basic Compensation Schemes used in Contracts

❑ ***Fixed-Price***

- Acquirer pays the supplier a fixed sum
- The supplier assumes the risk
- Profit is a direct function of supplier's ability to deliver the product or service

❑ ***Cost-Reimbursement***

- Acquirer agrees to reimburse the supplier's allowable costs plus profit
- The risk is shared

The degree of acquirer/supplier relationship depends upon the contract type



Examples of Contract Types

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➤ Fixed-Price Contract

- ❑ Firm Fixed-Price (FFP) – contract requires firm requirements/design and adequate competition exist (**MCCP/MCC¹, MLS², RCE²**)
- ❑ Fixed-Priced with Price Adjustment
- ❑ Firm Fixed-Price Incentive (FFPI) - acquirer pays the supplier a fixed sum plus an incentive. (**TDWR**)
 - Raytheon earned \$9 million for delivery of TDWR 6 month early
- ❑ Firm Fixed-Price Redetermination (FPR) - a realistic price cannot be estimated at start

1 Terminated for Convenience of the Government

2 Terminated for Default



Examples of Contract Types

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➤ Cost-Reimbursable Contract

- ❑ Cost and Cost-Sharing
- ❑ Cost-Plus Incentive Fee
- ❑ Cost-Plus Award Fee
 - **C-130 AMP** - provide Boeing financial incentives for those areas deemed critical to the C-130 AMP EMD program
 - Award Fee Criteria established
- ❑ Cost-Plus Fixed Fee

➤ Cost-Reimbursable-Attributes

- ❑ Supplier's Advantage (Supplier reimburse allowable costs)
- ❑ Acquirer **must** assess and determine fees, costs, and progress
- ❑ Fee structure **must** be established



Contract Data

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- **Why have Contract Data?**
 - ❑ Management requirements **must** be communicated to the supplier
 - ❑ Contract vehicle **must** clearly express a vision of the final product and the development effort
 - ❑ Software acquisition issues **must** be addressed in the Request-For-Proposal (RFP)
 - ❑ The acquisition team **must** have software expertise in the RFP preparation
 - ❑ Software expertise **must** be in the application domain, acquisition, and project management

Success of an acquisition is directly linked to the quality of the RFP
--- (Army 2007)



Contract Data

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➤ Key *Software-Related* Contract Data in the RFP

- ❑ Statement of Work (SOW)/Statement of Objective (SOO)
- ❑ Contract Data Requirements List (CDRL) items
- ❑ System Specification
- ❑ Data Rights



SOW/SOO

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➤ What is the SOW/SOO?

- ❑ SOW defines specific tasks, SOO defines objectives
- ❑ Primary document for translating management requirements into contractual tasks
- ❑ Basis for communicating acquirer requirements to the supplier
- ❑ Sufficient detail **must** be provided to allow the supplier to scope the effort, cost it, and provide a responsive technical solution
- ❑ Tasking information **must** be defined for the preparation of deliverable artifact
 - Each tasking statement reference applicable **Contract Data Requirements List** (CDRL) item which will be delivered by that task.



SOW/SOO

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➤ Examples of Key SOW Software Tasking

- ❑ **Software development process** - **TDWR SOW** specified software development in accordance with DOD-STD-2167A
- ❑ **Software management** - **C-130 AMP SOW** specified the development and maintenance of the SDP for each CSCI
- ❑ **Software engineering** - **C-130 AMP SOW** specified the software engineering to perform the following tasks: software requirements analysis, preliminary design, detailed design, code and unit test, and integration. Safety verification was specified for safety critical CSCI.
- ❑ **Software tools and environment**
- ❑ **Risk management**
- ❑ **Technical reviews** – **TDWR SOW**: SSR, PDR, CDR, TRR
- ❑ **Direct technical visibility**

The SOW/SOO **must not** tell the supplier how to do the required work
The SOW/SOO **must not** specify selection of major software components



Contract Data Requirements List (CDRL)

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- Software products (artifacts)
 - ❑ Absolutely essential for managing the development process
 - ❑ A natural by-product of the development effort to capture results of each activity
- Contract Data Requirements List (CDRL)
 - ❑ Primary vehicle for acquiring software data products
 - ❑ A list of authorized data requirements for a specific procurement that forms a part of the contract.
 - ❑ Defense Federal Acquisition Regulation Supplement (DFARS) **Subpart 215.470 Estimated Data Prices** requires a CDRL (DD Form 1423) when delivery of data is required
 - ❑ **CDRL must** be referenced in the Statement of Work (SOW) describing the development effort
 - ❑ **Language must** be consistent with the SOW



CDRL Item Key Blocks

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➤ CDRL Item Key Blocks

Block	Description
4	Authority (Data acquisition Documentation No.) Data Item Description (DID¹) – Defines format and content preparation instructions for data product generated by task requirements Assist-Quick Search used to access the current DID 1 Should be tailored to meet contract requirements (Block 16)
5	Contract Reference - Reference Statement of Work paragraphs
6	Requiring Office – Organization have primary responsibility for reviewing the data and recommending acceptance/rejection of the data
8	Approval Code - (A) Approved by the Contracting Officer Should specify approval at each milestones (e.g., SSR, PDR, CDR, etc.)
10, 11, 12, 13	Delivery Requirements Should be associated with milestones(e.g., SSR, PDR, CDR, etc.)



CDRL

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➤ Lessons Learned

- ❑ CDRL items should be delivered to allow the acquirer significant time (30 – 45 days) to perform a detailed review and time to disposition supplier responses prior to the technical design reviews,
 - ***Software Specification Review (SSR), Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR)***

- ❑ **Software-related CDRL** items should be prepared by the software team, reviewed by all applicable distribution addressee organization, and approved by either the appropriate Chief Engineer, Program Manager or Data Requirements Review Board

- ❑ Typical software CDRL items include:
 - ***Software Requirements Specification (SRS)***
 - ***Interface Requirements Specification (IRS), may be appendix to SRS***
 - ***Software Design Description (SDD)***
 - ***Interface Design Description (IDD), may be appendix to SDD***
 - ***Software Test Plan (STP)***
 - ***Software Test Description (STD) (Test Cases and Test Procedures)***
 - ***Software Test Results (STR)***
 - ***Software Version Description (SVD)***



System Specification

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➤ What is the System Specification?

- ❑ Establish top-level technical performance, design, development, integration, and verification requirements
- ❑ Examples of requirement statements
 - All AMP aircraft software related to operation in civil airspace **shall** be modified or developed in accordance with the requirements of RTCA DO-178B or equivalent level of safety.
 - All newly developed software **shall** be written in a higher order language (HOL).
 - Meteorological algorithms **shall** be implemented in high order language (HOL)
 - Use of commercial software **shall** be approved by the FAA



Data Rights

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➤ Data Rights

- ❑ Enable the use, maintenance, and replication of the software data

➤ Data Rights Categories

- **Unlimited rights** - right to use, modify, reproduce, release, in whole or in part, in any manner and for any purpose whatsoever, and to have or authorize others to do so. **Associated with computer software developed exclusively with acquirer funds.**
- ❑ **Acquirer Purpose rights** - rights to use, modify, reproduce, release, within the acquirer's organization/company without restriction. **Software development with mixed acquirer and supplier funding.**
- ❑ **Restricted data rights** apply only to noncommercial computer software and mean that the acquirer's rights are as set forth in a Restricted Rights Notice. **Supplier funds all development.**

Secretary of the Air Force Memo - Data Rights and Acquisition Strategy (3 May 06) - directing the acquisition of technical data and associated rights to be addressed specifically in all Acquisition Strategy Plans, reviews, and associated planning documents for Acquisition Categories (ACAT) programs – software intensive systems and subsequent source selections.



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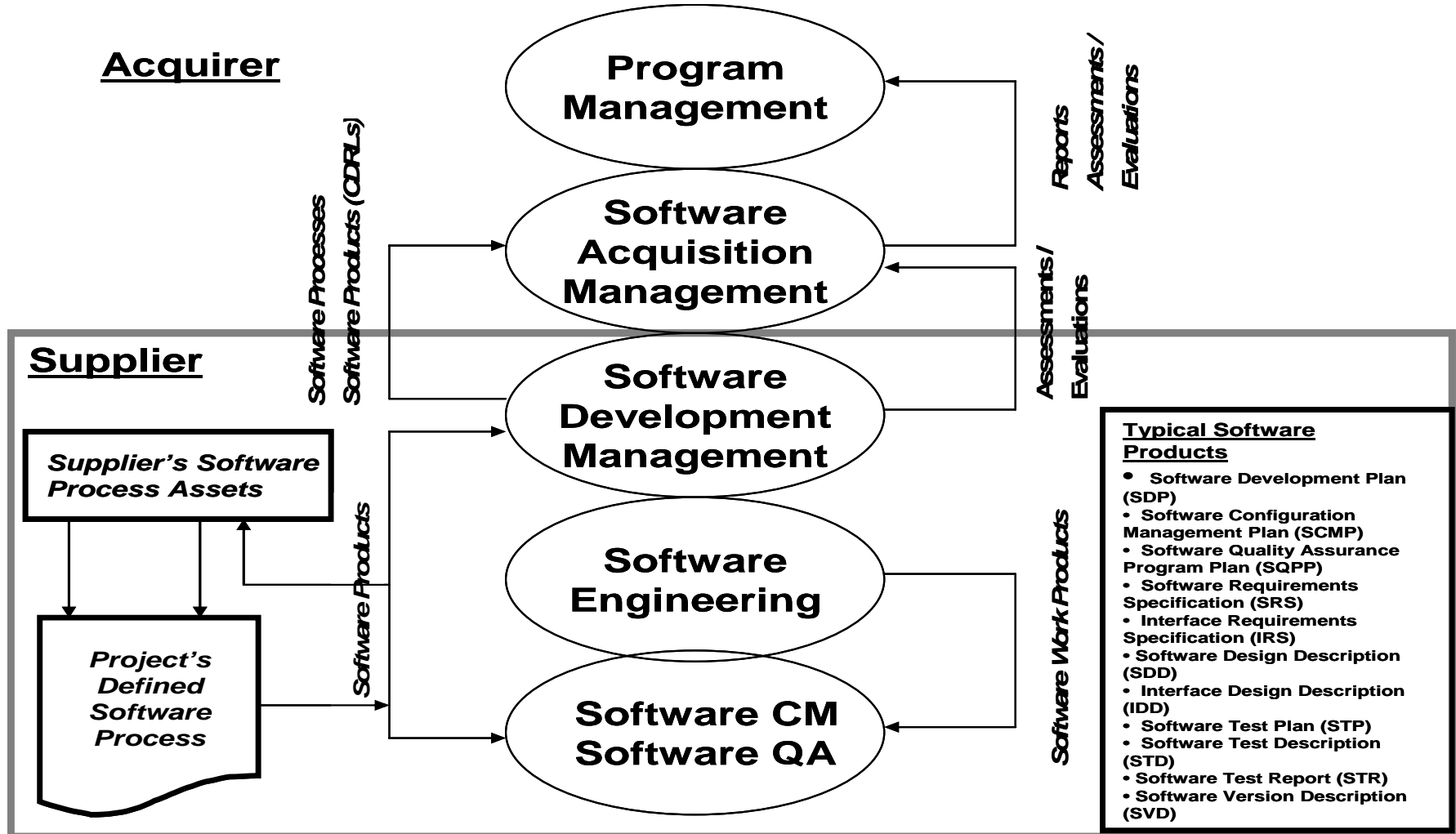


The Acquisition Environment

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Best Practices: Better Matching of Needs and Resources, will lead to Better Weapon Systems Outcomes...GAO 2001



The Acquisition Environment

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➤ Acquirer

- ❑ Acquisition of software-intensive systems involves a number of organizations, including the customer or user of the systems, the contracting agency, and the supplier
- ❑ During the agreement phase, the acquisition team **must** have software expertise in application domain, acquisition, process, project management, engineering, and safety, as needed
- ❑ A software lead **must** be designated to be responsible for establishment and managing the software acquisition activities
- ❑ The software acquisition team **must** have adequate resources and funding to perform the acquisition activities
- ❑ The software acquisition team **must** be trained (Examples)
 - *Software Acquisition Management*
 - *Application domain (Radar, Communications Systems, etc)*
 - *Processes, Procedures, Standards being used*
 - *Technologies, Tools, Methodology being used*

“Acquirers must recognize quality work before they can require and accept it”

----Watts Humphrey



The Acquisition Environment

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➤ Supplier

- ❑ A set of software process assets **must** be established and maintained
- ❑ The project **must** develop a defined software process by tailoring the organization's standard processes
- ❑ Software plans (**software development plan (SDP), software configuration management plan, and software quality assurance plan**) **must** be documented and institutionalized
- ❑ The SDP **must** provide the acquirer with:
 - Insight into the processes, procedures
 - Tools and Methods used
 - Procedures for performing software development activities
- ❑ Development environment **must** be augmented by management practices
 - Measuring and monitoring progress
 - Judging the quality of the product
 - Validating the deliverable
 - Conducting technical reviews



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Requirements Management

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- Requirements change for variety of reasons
 - ▣ Additional requirements are derived or changes made to the existing requirements
- **Requirements Management** involves establishing and maintaining bidirectional traceability of requirements, design, source code, and test to ensure the right product is being built
- Bidirectional traceability is required by CDRL item DID
- Bidirectional traceability is essential for Safety Critical
- Supplier **must** manage changes and identify any inconsistencies
- Supplier **must** track measures of requirements volatility

Requirements management is fundamental to a controlled and disciplined engineering design process [CMMI 2006]



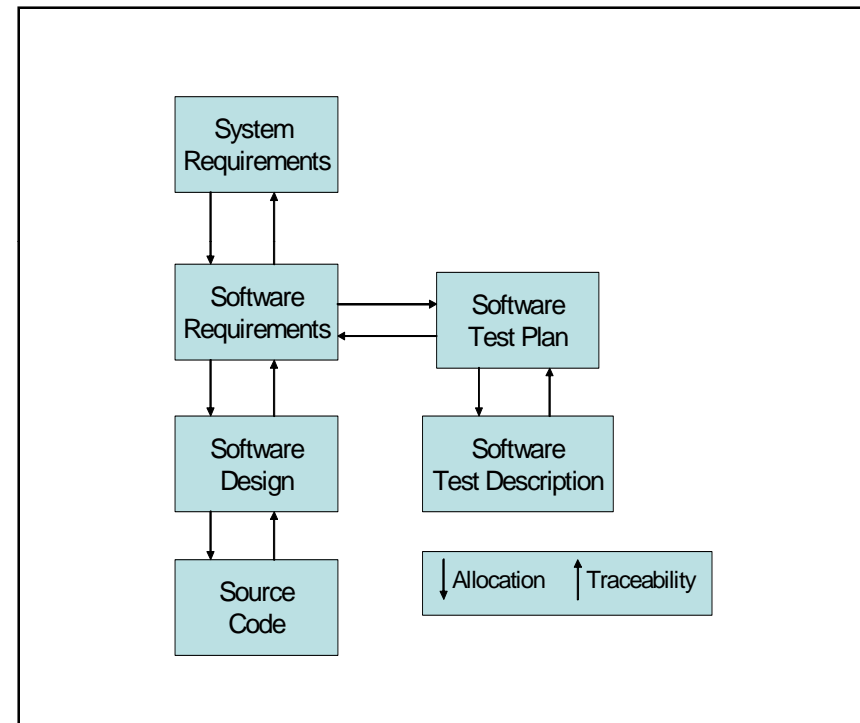
Bidirectional Traceability

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- Required by the CDRL item DID
- Allocation ensures the right products been built
- Reduce effort required to determine change impact
- Traceability ensures the evolving product is not expanding the scope
- Should be Documented in a requirements database
 - ❑ DOORS®, RTM



Bidirectional traceability



Practical Examples

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C-130 AMP

Contract

- Traceability specified in CDRL item DID

Boeing

- IAW CDRL item DID
- Requirements Management Database

SPO

- Provide review comments

FAA TDWR

Contract

- Traceability specified in CDRL item DID

Raytheon

- IAW CDRL item DID

SPO

- Provide review comments
-



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Risk Management

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➤ Why Manage Risks?

- ❑ Risk is like fire: if controlled it will help you; if uncontrolled it will rise up and destroy you...
 - Theodore Roosevelt
- ❑ Technical performance, cost, and schedule risks are inherent in software intensive systems development [GAO 1999]
- ❑ One key obstacle is the inability to see cost and schedule issues as symptoms of unforeseen problems
 - Software size growth, requirements growth, complexity, ability to perform
- ❑ Air Force expects the acquisition communities to address **Risk Management** throughout the life cycle of the acquisition program [DoD 2004]
 - Continuously identify and manage risks
 - Ensure the risks, impact, and mitigation plans are appropriately addressed during program reviews.
- ❑ **Risk Management** is a process element of the 10 Life cycle Processes of Operational Safety Suitability and Effectiveness [AFMC 63-1201]
 - 1) Risk Management Planning, 2) Risk Identification, 3) Risk Assessment, 4) Identification of Risk Options, 5) Decision Analysis, 6) Implementation, and 7) Risk Monitoring



Risk Management

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➤ Managing Risks

- ❑ Establish a **Risk Management Model** to define a systematic process
- ❑ Establish consistent **Risk Statement** to allow recognition of the impact or consequence
- ❑ Establish a **Risk Information System** for identifying, analyzing, planning, tracking, and controlling risk.
- ❑ **Risk Information System** should include - storage media, the procedures, and the tools for accessing the risk system



Example of Risk Management Model ---[Van Scoy 1992],

Tools

- **MITRE**
 - Risk Matrix
 - Risk Management Toolkit
- **AFMC [AMC 2007]**
 - Probability of Program Success (PoPS)



Practical Examples

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- **C-130 AMP**
 - **Contract SOW**
 - Establishment and implementation of a Risk Management Program
 - Tasks
 - Conducting risk identification working meetings
 - Documenting identified risks, including the owner
 - Rating, based upon the likelihood/consequences, with categorization as technical, cost or schedule
 - Identifying potential mitigations for each risk rated medium or higher
 - Ongoing tracking and status of risks and mitigations
 - **Boeing**
 - Compliance with Contract SOW
 - Risk Management System established and maintained including process, storage media, and tool
 - Risks managed at three levels:
 - 1) Program/USAF SPO (Quarterly)
 - 2) Integrated Product Team (IPT) Risk Coordinators (Monthly)
 - 3) Program/IPT (Monthly/Bi-Weekly).



Practical Examples

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➤ FAA NAS TDWR

- **Contract SOW - Software Development Plan (CDRL B021)**
 - **Tasks**
 - Establish and maintain documentation and implementation procedures for risk management
 - Identify, analyze, prioritize, and monitor areas involving potential technical, cost or schedule risks

- **Raytheon**
 - Contract Compliance
 - Documented procedures established and maintained to identify, analyze, prioritize, and monitor risk items
 - Managed risks at the Program Management Review (Quarterly) and at Technical Interchange Meetings



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Technical Performance Assessment

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- How to Reduce the Risks, Increase the Reliability and Quality, and Ensure Compliance with Requirements
 - ❑ Software work products (artifacts) are **absolutely** essential for managing the development process
 - ❑ Gaining adequate visibility into the suppliers' process, plans, and software products is key to technical performance assessments
 - ❑ Assessment techniques provide **visibility** into the process, quality and reliability of the software products.
 - ❑ **Technical Performance Assessment** provides feedback to improve the software process
 - ❑ **Technical Performance Assessment** ensures compliance with requirements
 - ❑ **Key technical performance assessments**
 - **Process**
 - **Progress**
 - **Software Product**

Acquirers **must** recognize quality work before they can require and accept it

----Watts Humphrey, 2009



Technical Performance Assessment

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- **Process Assessment** - Ensure software management, engineering, configuration management, and quality assurance activities compliance with contractual requirements and supplier's defined software process and plans

Process Assessment key focus is “what is done and the product being built”

- **Examples of Software Plans**
 - ❑ Software Development Plan (SDP)
 - ❑ Software Configuration Management Plan (SCMP)
 - ❑ Software Quality Assurance Plan (SQAP)

The Contract **must** provide mechanism to gain access to process and plans



Practical Examples

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➤ C-130 AMP Contract SOW

- ❑ Maintaining the C-130 AMP software development process configuration, training, software process navigator, and SDP
- ❑ Process remain up to date with the current development activities, and the SDP remains consistent with the actual activities being performed.
- ❑ Implementation of software configuration management in accordance with the approved configuration management and software development plans using IEEE/EIA 12207.0, 12207.1 and 12207.2 as guides
- ❑ Development and maintenance of a SDP for each supplier furnished avionics Operational Flight Program (OFP) Computer Software Configuration Item (CSCI)

➤ C-130 AMP SPO Activities

- ❑ Ensure management, engineering, configuration management, and quality assurance activities and products compliance with the C-130 AMP Standard Software Process, SDP, SCMP, and SQAP
- ❑ SDP, SCMP, and SQAP for the Program and SIF were available in the Software Process Assets Library. **These documents are not deliverable CDRL items**



Practical Examples

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➤ C-130J Supplier SOW

- ❑ Perform software development and engineering in accordance with the supplier's SDP, SCMP, and SQAPP.
- ❑ Supplier SDP, SCMP, and SQPP specified as [Supplier Data Requirements List \(SDRL\)](#) items.

➤ Examples of Supplier Management Activities

- ❑ Provide review comments and approval of SDRL items
- ❑ Monitor supplier management and engineering activities in accordance with supplier's SDP
- ❑ Conduct periodic reviews and/or audits of the supplier's software configuration management and software quality assurance products and activities
- ❑ Provide review comments and/or audit reports to the suppliers
- ❑ Report on a periodic basis to LMAS C-130J senior management:
 - Activities for managing the supplier
 - Results of the review comments
 - Results of reviews and/or audits



Practical Examples

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➤ **FAA NAS Plan (TDWR) SOW**

- ❑ Software development management and engineering to be conducted in accordance with **DOD-STD-2167A-Defense System Software Development**, 29 February 1988 (now *cancelled*).
- ❑ Software Development Plan (SDP) as a CDRL item (B021) in accordance with DID DI-MCCR-80030A
 - **Preliminary version delivered two MACA**
 - **Final version delivered at the System Design Review (SDR)**
- ❑ Software Configuration Management (SCM) in accordance with FAA-STD-021A
- ❑ Software Quality Assurance (SQA) was specified in accordance with FAA-STD-018A
 - **SCM and SQA not specified as deliverables.**
 - **Raytheon provided access to the SQA records**

➤ **TDWR Software Acquisition Team Activities**

- ❑ Ensure management, engineering, configuration management, and quality assurance activities and products compliance with the SDP, SCM, and SQA
- ❑ Witness SQA audits
- ❑ Provide periodic reports to FAA TDWR Senior Management



Technical Performance Assessment

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- **Progress Assessment** conducted to determine what is done
 - ❑ Contract SOW **must** specify **Technical Reviews** and **Design Reviews** to be held to determine progress, status, surface issues, and provide feedback. Examples:
 - **Technical Reviews (Examples)**
 - Program Management Review
 - Program Configuration Control Boards
 - Technical Interchange Meeting
 - In-Process
 - **Design Reviews** – used as quality gates (progress and quality)
 - (e.g., *Software Specification Review (SSR)*, *Preliminary Design Review (PDR)*, *Critical Design Review (CDR)*, etc)
 - ❑ Supplier **must** conduct informal reviews such as Peer Reviews in accordance with supplier's defined process
 - ❑ Acquirer **must** participate in Technical Reviews and Design Reviews to
 - Gain visibility into the progress and status
 - Discuss issues/candidate risks
 - Provide feedback



Practical Examples

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C-130 AMP

Weekly IPT Meetings

Bi-Weekly Boeing/SPO Engineering VTC

Technical Reviews (SSR, PDR, CDR, TRR)

IAW the Contract Integrated Master Plan

Technical Interchange Meets

disposition of CDRL review comments

Periodically PMRs

FAA NAS (TDWR)

Monthly PMRs

Technical Reviews (SSR, PDR, CDR, TRR)

IAW MIL-STD-1521B (canceled without replacement)

Technical Interchange Meetings

disposition of CDRL review comments

In-Process Reviews

Source code compliance



Technical Performance Assessment

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➤ Software Products Assessment

- ❑ Supplier **must** evaluate CDRL items prior to delivery and place under configuration control
- ❑ Supplier should deliver CDRL items (30 - 45 days) prior to the design review to allow significant time for detailed review and disposition of review comments
 - CDRL delivery and review comments disposition **must** be the entrance criteria for the design review
- ❑ Acquirer **must** establish a CDRL review process
- ❑ Acquirer **must** complete the review within an agreed upon time after receipt of the CDRL items



Software Product Assessment

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- Acquirer typical review process
 - ❑ Evaluation CDRL using evaluation criteria
 - ❑ Evaluation criteria examples
 - Compliance with DID format and content
 - Completeness (e.g., missing requirements, testing, interfaces, etc.)
 - Traceability (e.g., test traced to requirements, etc.)
 - Consistency with upper level documents
 - Internal consistency
 - Ambiguity of requirements (understandable, testable?)
 - Conflicting requirements
 - Test coverage of requirements
 - Appropriate analysis, design, and coding techniques used
 - ❑ Provide discrepancies and recommendations to supplier
 - ❑ Conduct meeting with supplier to disposition supplier responses.



Practical Examples

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➤ C-130 AMP Contract

- ❑ **8 Software-Related CDRL Items** specified by the SOW
 - *SRS (A012), IRS (A013), SDD (A014), IDD (A015), STP (A016), STD (A017), STR (A018), SPS (A019)*
 - Final submittal 60 days before EMD completion for the SIF nodes and final submittal 60 days after software FCA for other CSCIs.
 - **The CDRL noted :** *“Only final version of data/document to be formally delivered in accordance with the above stated milestone. Any initial, preliminary, draft, or other interim versions of the data/document referenced in the contractor’s IMP will be made available informally to the government.”*

➤ C-130 AMP SPO Activities

- ❑ Software IPT primarily responsible for MP OFP Software CSCIs
- ❑ SIF IPT primarily responsible for SIF Hardware (8-Nodes & SIL) and 3-Simulation Software CSCIs
- ❑ Document Comment Items (DCI)
 - SIF CD/TK CDR/TIM – **992 DCIs, 86% acceptance**
 - SIF CD/TK TRR - **598 DCIs, 90% acceptance**



Practical Examples

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- FAA NAS (TDWR) Contract
 - ❑ 16 CDRL Items specified by the SOW
 - ❑ Submittal (preliminary and final) linked to design review (e.g., SSR, PDR, etc)
 - ❑ Acquirer approval within 30-calendar days
- Raytheon
 - ❑ 45 Total CDRL Items delivered
- TDWR Software IPT
 - ❑ Over 4300 Review Items Discrepancies approved



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Software Test Evaluation

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➤ What is Software Testing?

- ❑ Software development involves a series of activities in which opportunities for human induced defects are enormous
 - 46% - 60% of all software defects originate in the software requirements analysis phase [Endves 1975] [Voges 1979]
- ❑ **Software Testing** is the quality assurance technique used to evaluate the “as-built” software product to **ensure the probability of failure** due to latent defects is low enough for acceptance
- ❑ Software testing typically consists of three levels of testing
 - *Unit Testing, Integration, and Formal Qualification Testing*

Software testing represents the ultimate evaluation of the software requirements, design, and coding activities [Jones 1993-1]

Software testing can make the software product more reliable and usable [Musa 1987] [Dunn1984]



Software Test Evaluation

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- What is required in the Contract?
 - ❑ Unit Testing, Integration, and Formal Qualification Testing (FQT) activities and artifacts **must** be documented in the supplier's defined software process and the Software Development Plan
 - ❑ FQT activities and artifacts **must** be specified in the SOW
 - Examples
 - Planning – **Software Test Plan** (CDRL item)
 - Test Description – **Software Test Description** (CDRL item)
 - Test Cases and Test Procedures
 - Test Results – **Software Test Report** (CDRL item)
 - ❑ Test Readiness Review (TRR) **must** be held prior to FQT execution to determine readiness
 - ❑ Software test artifact **must** be delivered at designated quality gates (i.e., PDR, CDR, TRR, and Product Release)
 - Acquirer and Supplier's Software Quality Assurance **must** witness all FQT execution



Software Test Evaluation

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➤ Problem Reporting/Tracking

- ❑ Supplier process **must** be institutionalized to:
 - Document problems identified during FQT and to track the problems to ensure closure
 - Determine the severity of all problems detected
 - Control changes to the software products under configuration control
 - Analyze the changes to determine impact to the work product, related work product, and schedule
 - Analyze the problem closure to determine the impact to the software release milestone

Change control system should be used to determine the aspects of process improvement and effectiveness of previous activities



Software Test Evaluation

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- **How much testing is enough?**
 - ❑ Complete test coverage is generally not possible [Jones 1993-1]
 - ❑ **Test Case** design methodology **must** be documented
 - ❑ Acquirer and supplier **must** mutually agree on completion criteria Examples
 - Completion of a number of test runs with no open priority 1 and 2 severity problems
 - ❑ Acquirer and supplier should establish a failure intensive objective (FIO) using a software reliability growth model: Examples
 - Time-Between-Failure Models
 - Error-Count Model

Acquirer and supplier face a difficult decision when to release the software product
Complete test coverage is generally not possible...[Jones 1993-1]



Practical Examples

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C-130
AMP

Contract SOW

- STP (A016), STD (A017), STR (A018)

Boeing

- Software testing IAW defined Software Test Processes
- *Problem/Issue Reporting/Tracking System* established and maintained

SPO/DCMA

- Test artifacts reviewed and comments disposition (**SIF CD/TK over 970 Review Items Discrepancies identified**)
- Witness all Formal Qualification Testing

FAA
TDWR

Contract SOW

- STP (B025), STD (B026), STR (B028)

Raytheon

- Software testing IAW defined Software Test Processes
- *Problem/Issue Reporting/Tracking System* established and maintained

SPO

- Test artifacts reviewed and comments disposition (**over 1510 Review Items Discrepancies identified**)
- Witness all Formal Qualification Testing



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Performance Measurement

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➤ Why Measure Performance?

- ❑ Software development is ***often out-of-control***. *You cannot control what you cannot measure...* [DeMarco 1982]
- ❑ **Performance Measurement** is key to managing and producing quality software and is an essential element of software process improvement [Humphrey 1989]
- ❑ National Defense Acquisition Act Section 804-2003 mandate
 - *Metrics for performance measurement and continual process improvement*



Performance Measurement

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➤ How to Measure Performance?

- ❑ *Software Measures* should be captured to document actual-versus-plan and to identify problems
- ❑ Software Measures should be selected that are directly measurable to evaluate progress and identify significant predictors [Jones 2004]
- ❑ Software Measures should be selected to provide insight into four key acquisition areas:
 - *Process* – insight into the software development process and how it is working
 - *Product* - insight into the quality of the product (frequency of requirement changes, number of problems, review comments)
 - *Project* - schedule attainment, CDRL delivery
 - *Productivity* - rate at which the work is progressing



Performance Measurement

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- **How to use Software Measures?**
 - ❑ Provide overview of development progress
 - ❑ Early-warning for detecting process and quality issues
 - ❑ Provide feedback to refine the process and contribute to positive control
- **Typical software measures**
 - ***Software size***
 - ***Cost/Schedule deviation***
 - ***Schedule progress***
 - ***Activity progress***
 - ***Requirements stability***
 - ***Resource utilization***
 - ***Documentation (Artifact) review item discrepancies***



Practical Examples

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<h2>C-130 AMP</h2>	<ul style="list-style-type: none">➤ <i>Software Size</i> – plan vs. actual Source Lines-of-Code➤ <i>Cost/Schedule Deviation</i> - Earned Value Management System (EVMS) (Cost and Schedule vs. Performance)➤ <i>Software Development Progress</i> – plan vs. actual➤ <i>Software Test Progress</i> – plan vs. actual➤ <i>Software Quality</i> – defects➤ <i>Technical</i> – throughput, memory utilization
<h2>FAA NAS Plan Programs</h2>	<ul style="list-style-type: none">➤ <i>Software Size</i> – plan vs. Actual Source Lines-of-Code➤ <i>Cost/Schedule Deviation</i> - Earned Value Management System (EVMS) (Cost and Schedule vs. Performance)➤ <i>Software Development Progress</i> – plan vs. actual➤ <i>Software Test Progress</i> – plan vs. actual➤ <i>Software Quality</i> – defects➤ <i>Technical</i> – throughput, memory utilization



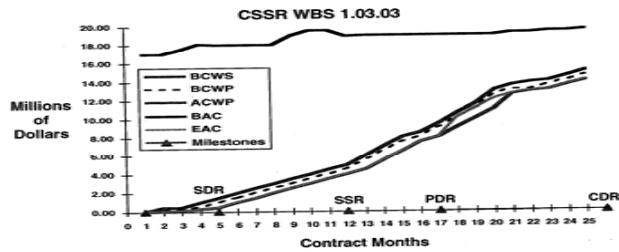
Practical Examples

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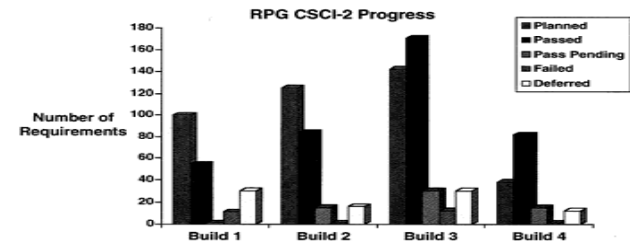
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TDWR System Software Design



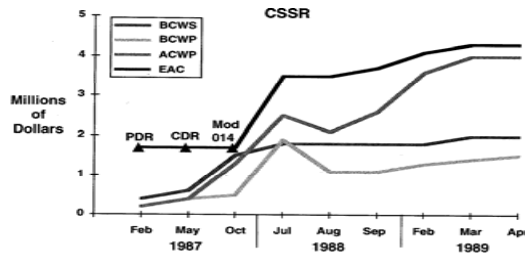
Cost/Schedule Deviation

TDWR Formal Qualification Testing



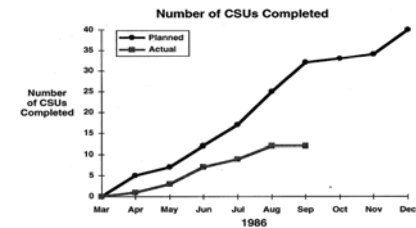
FQT Progress

RCE System Software Design

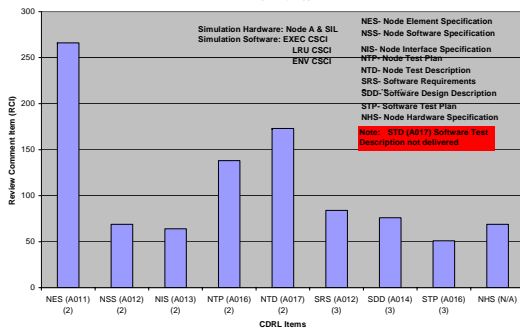


Development Progress

MLS Software Detailed Design

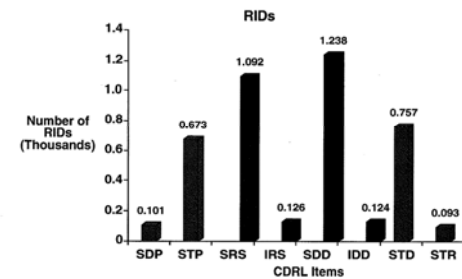


SIF CD/TK Critical Design TIM
3 - 4 Nov 2004



Document Review Item Discrepancies

TDWR Software Development Documentation





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The Software Crisis Is Still With Us!

- 75% of all large scale...software...systems fail
 - [Software's Chronic Crisis, W. Wyatt Gibbs, 1994]

➤ How to get quality software delivered on time?

- **THE CONTRACT** *must* specify what is required
- **THE ACQUISITION ENVIRONMENT** *must be* ability to perform
 - “Acquirers must recognize quality work before they can require and accept it” ----Watts Humphrey, 2009
 - The acquirer can negatively impact the supplier
- **RISK MANAGEMENT** *must be* performed to control the inherent risks
- **PERFORMANCE MEASUREMENTS** *must be* performed to control the development activities



Summary

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- How to reduce the risks, increase the reliability, and quality?
 - ❑ **TECHNICAL PERFORMANCE ASSESSMENTS** *must be* performed to gain insight into the process and product quality
 - Identify discrepancies in the process and products
 - Reduce the risks of software development
 - Increase the reliability and quality
 - Vehicle for process improvement
 - ❑ **SOFTWARE TEST EVALUATION** *must be* performed to ensure the “as-built” software meets requirements
 - ❑ **REQUIREMENT MANAGEMENT** *must be* performed to ensure the right product is being built at each phase throughout the lifecycle



Summary

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- **Improvements in Software Acquisition**
 - ❑ Public Law 107-314 Section 804 of the National Defense Authorization Act, released in December 2002 [Section 804-2003]
 - ❑ Clinger-Cohen Act: Initiatives such as Software Assurance and Open Architecture
 - ❑ The best practice model Capability Maturity Model® Integration (CMMI®) for Acquisition

The White House, Memorandum for the Heads of Executive Departments and Agencies, **Government Contracting**, 4 Mar 09

- [http://www.whitehouse.gov/the_press_office/Memorandum-for-the-Heads-of-Executive-Departments-and-Agencies-Subject-Government-Contracting/]



Questions ?

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Acronyms

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AAS	Advanced Automated System
ACAT	Acquisition Category
AMP	Avionics Modernization Program
ATC	Air Traffic Control
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CIP	Capital Investment Plan
CNS/ATM	Communications/Navigation Surveillance / Air Traffic Management
CO	Contracting Officer
COTS	Commercial Off-The-Shelf
CPAF	Cost-Plus Award Fee
CSCI	Computer Software Configuration Item
CY	Calendar Year
DCI	Document Comment Item
DER	Designated Engineering Representative
DFARS	Defense Federal Acquisition Regulation Supplement
DID	Data Item Description
DoD	Department of Defense
DOORS	Dynamic Object-Oriented Requirements Systems
ECP	Engineering Change Proposal
EMD	Engineering, Manufacturing and Development
FAA	Federal Aviation Administration
FFP	Firm Fixed-Price
FFPI	Firm Fixed-Price Incentive

FQT	Formal Qualification Testing
IDD	Interface Design Description
IRS	Interface Requirements Specification
MP	Mission Processor
NAS	National Airspace System
OFP	Operational Flight Program
OFP	Operational Flight Program
PCO	Procuring Contracting Officer
PDR	Preliminary Design Review
SCM	Software Configuration Management
SDD	Software Design Description
SOF	Special Operations Forces
SOO	Statement of Objective
SOW	Statement of Work
SPO	System Program Office
SQA	Software Quality Assurance
SRS	Software Requirements Specification
SSR	Software Specification Review
STD	Software Test Description
STP	Software Test Plan
STR	Software Test Report
SVD	Software Version Description
TRR	Test Readiness Review