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# Successful Acquisition of FAA Terminal Doppler Weather Radar

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**Third Annual Conference on the Acquisition of Software-Intensive  
Systems – Track: Experience Reports**  
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# Agenda

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- **Introduction**
- **Background**
- **Contract Requirements**
- **Software Development**
- **Acquisition Team**
- **Software Acquisition Process**
- **Metrics**
- **Conclusion**



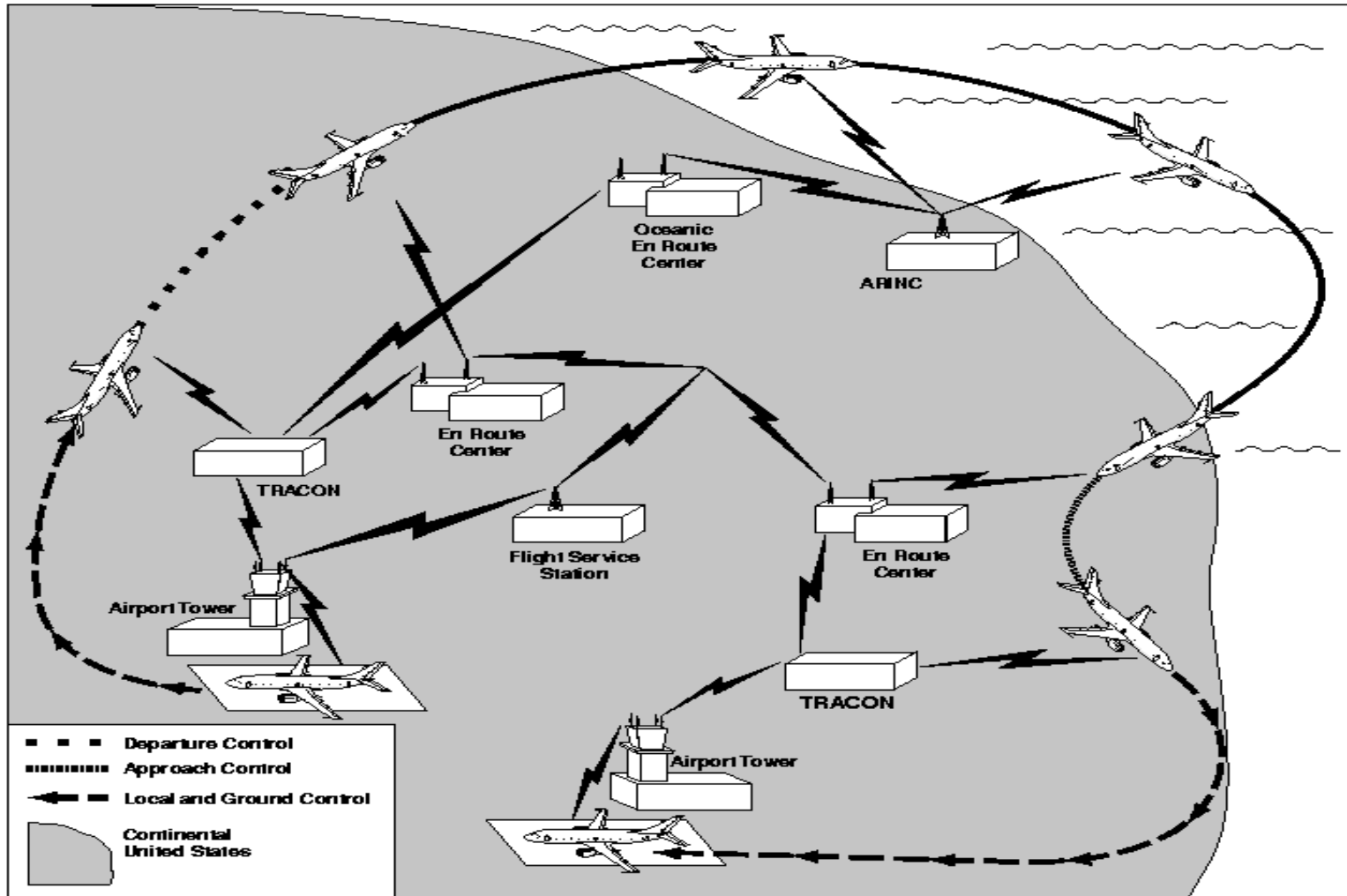
# Introduction

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- **Air Traffic Control System Overview**
- **Capital Investment Plan (CIP)**
- **CIP Projects Cost and Schedule Problems**
- **Examples of CIP Projects**
- **Terminal Doppler Weather Radar (TDWR) System**
- **Key Elements for Successful Software Acquisition and Development**



# Air Traffic Control System Overview





# Capital Investment Plan (CIP)

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- The Federal Aviation Administration (FAA) **Capital Investment Plan (CIP) [National Airspace System –(NAS) Plan]** was established in late 1981.
- The purpose of the CIP is to modernize the nation's air traffic control system for improvement in capacity, safety, and delays through the use of new technology.
- Currently, the CIP is a multibillion dollar investment comprising over 200 separate projects.



# CIP Projects Cost and Schedule Problems




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- **Between 1982 and 1998 Congress has appropriated over \$25 billion<sup>1</sup>**
  - \$5.3 billion on 81 completed projects
  - \$15.7 billion on about 130 ongoing projects
  - **\$2.8 billion on projects that have been cancelled or restructured**
  - **\$1.6 billion for personnel-related expenses associated systems acquisition**

1 GAO/T-RCED/AIMD-98-93, February 26, 1998



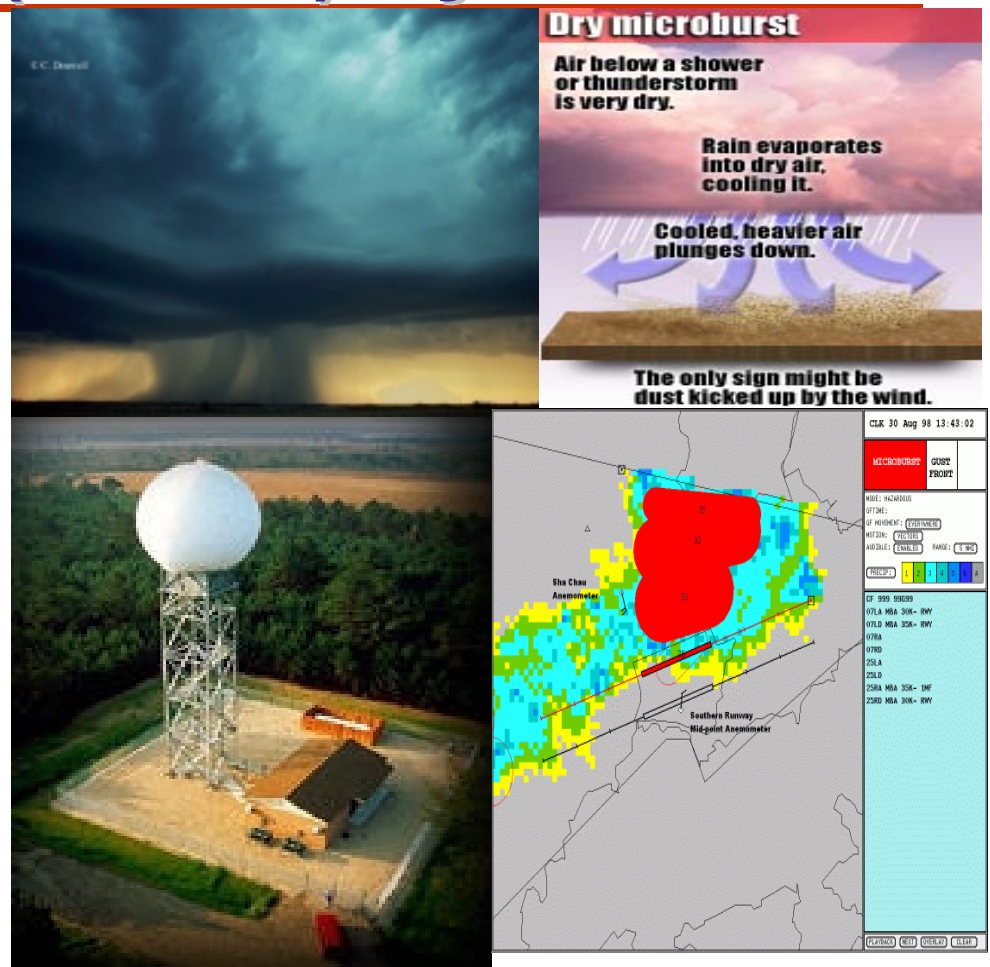
# Examples of CIP Projects

Example Project	Current Status	
<ul style="list-style-type: none"><li>Microwave Landing System</li></ul>	<ul style="list-style-type: none"><li>Terminated for Default (T4D)</li></ul>	
<ul style="list-style-type: none"><li>Radio Control Equipment</li></ul>	<ul style="list-style-type: none"><li>Terminated for Default (T4D)</li></ul>	
<ul style="list-style-type: none"><li>Maintenance Control Center Processor / Maintenance Monitor Console</li></ul>	<ul style="list-style-type: none"><li>Terminated for Convenience (T4C)</li></ul>	
<ul style="list-style-type: none"><li>Advanced Automation System</li></ul>	<ul style="list-style-type: none"><li>Restructured in 1994 after estimated costs tripled from \$2.5 billion to \$7.6 billion</li></ul>	
<ul style="list-style-type: none"><li>Voice Switching and Control System</li></ul>	<ul style="list-style-type: none"><li>Contract award – \$1.3 billion; Production completed</li><li>100% on-time system delivery</li><li>Contractor of the Year award</li></ul>	
<ul style="list-style-type: none"><li>Terminal Doppler Weather Radar</li></ul>	<ul style="list-style-type: none"><li>Delivered 6 months early</li><li>IEEE Computer Society Award</li></ul>	



# Terminal Doppler Weather Radar (TDWR) System

- The TDWR system enhance the safety of air travel through the timely detection and reporting of **hazardous wind shear** in the terminal area.
- Hazardous wind shears detected are **microburst** and **gust fronts**.
- TDWR displays **areas of wind shear** and **gust fronts** to enable tower controllers to warn pilots of wind shear conditions.



Weather is a primary factor in more than 35% of commercial aviation fatal accidents





## **Key Elements for Successful Software Acquisition and Development**

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- **Success in software acquisition and development depends on five key elements**
  - The contract
  - The development process
  - The acquisition team
  - The acquisition process
  - Metrics
- **To gain a better understanding of the key elements of success, it helps to:**
  - Understand the detailed requirements for each element of success



# Background

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- **Software Acquisition Management**
- **Key Software Acquisition Standards**



# Software Acquisition Management

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- **Software** was involved in essentially every CIP project to resolve existing systems limitations.
- Effective management of **software acquisition and development** is unquestionably one of the greatest challenges in the application of new technology.
- Software size, complexity, and diversity in air traffic control systems applications make proper **software acquisition management** extremely critical.

The history of software acquisition and development has been plagued with problems – many CIP projects have exceeded cost and schedule.



# Software Acquisition Management (cont'd)

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- Quality of software is the result of
  - Development management techniques, controls, processes, and tools
- Techniques, controls, and processes can be managed, measured, and progressively improved
- ***Software Acquisition Management methods and techniques*** can be used to ensure compliance with techniques, controls, and processes
- ***Software Acquisition Management methods and techniques*** can also be used to verify software quality



# Key Software Acquisition Standards

- Standards allow organizations to communicate in common terms – **Backbone of a Successful Acquisition**

<b>Key Process Area</b>	<b>Standard</b>
Software development	<b>DOD-STD-2167A</b> – Defense System Software Development, February 29, 1988
Technical reviews and audits	<b>MIL-STD-1521B</b> – Technical Reviews and Audits for Systems, Equipments, and Computer Software, June 4, 1985
Software quality assurance	<b>FAA-STD-018A</b> - Computer Software Quality Program Requirements, September 30, 1987
Software configuration management	<b>FAA-STD-021A</b> – Configuration Management, August 17, 1987

**Standards are essential....Key to acquisition and development success**



# **Contract Requirements**

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- **Contract Summary**
- **Statement of Work (SOW)**
- **Software Documentation**
- **Software Contract Data Requirements List  
Description**
- **System Specification**
- **Key Contract Modifications**



# Contract Summary

<b>Contract Type</b>	<b>Firm Fixed Price Incentive (<i>FFPI</i>)</b>	
<b>Contract Award</b>	<b>Raytheon Systems Company</b>	<b>Nov 88</b>
	<ul style="list-style-type: none"> <li>- Develop, produce, and install 47 systems</li> <li>- 45 airports sites</li> </ul>	
<b>Schedule Incentives</b>	<b>Final Acceptance of the 1st System Testing</b>	
	- <b>Contract Schedule Date</b>	<b>Aug 93</b>
	- <b><i>Incentive Target Date (at IAH) MEM</i></b>	<b><i>Feb 93</i></b>
	<b>Final Acceptance of the 4<sup>th</sup> site</b>	
	- <b>Contract Schedule Date</b>	<b>Oct 93</b>
	- <b><i>Incentive Target Date (at FLL)</i></b>	<b><i>Apr 93</i></b>
<b>Cost</b>	<b>Total F &amp; E cost</b>	<b>\$322.2 M</b>

An example of an FFPI contract type used to motivate the contractor to increase efficiency



# Statement of Work (SOW)

<i>Examples of Tasks</i>	<i>Standard</i>
<b>Perform software development management</b> Planning, process, formal reviews/audits, risk management, subcontract management	<b>DOD-STD-2167A</b>
<b>Perform software development engineering</b> Software requirements analysis, preliminary design, detail design, code and unit testing, and testing	<b>DOD-STD-2167A</b>
<b>Prepare software documentation</b> Software requirements specification, software design document, software test plan, etc.	<b>Contract Data Requirements List (CDRL)</b>
<b>Perform software configuration management</b>	<b>FAA-STD-021A</b>
<b>Perform software quality assurance</b>	<b>FAA-STD-018A</b>

SOW – Basis for communicating management requirements  
Describes the tasks and how the project should be managed





## Statement of Work (SOW) (cont'd)

<i>Examples of Tasks</i>	<i>Standard</i>
<b>Conduct technical reviews and audits</b> System Design Review (SDR) Software Specification Review (SSR) Preliminary Design Review (PDR) Critical Design Review (CDR) Test Readiness Review (TRR) Functional and Physical Configuration Audits (FCA/PCA)	<b>MIL-STD-1521B</b>
<b>Develop meteorology algorithms</b>	<b>Government provided algorithms</b>
<b>Perform sizing and timing analysis</b>	
<b>Provide Program Support Facility (PSF) software</b>	



# Software Documentation

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- ***Software documentation*** is essential for managing the development process.
- Software documentation is a natural by-product of the development effort to capture results for each software development activity.
- Software documentation was provided by the ***Contract Data Requirements List (CDRL)***.
- CDRL items were referenced in the paragraphs of the SOW describing the development efforts.



# Software Documentation (cont'd)

- **16** Software **CDRL** items were defined:
- CDRL Item key blocks

Block	Description
4	Authority (Data Acquisition Document No) <b><i>Data Item Description (DID)<sup>1</sup></i></b> – Defines format and content preparation instructions for the data product generated by task requirements as delineated in the contract. <b><i>1 Tailored to meet TDWR requirements</i></b>
5	Contract Reference <b><i>Reference Statement of Work paragraphs</i></b>
8	Approval Code – (A) Approved by the Contracting Officer
10, 11, 12, and 13	Delivery Requirements <b><i>Delivery Requirements associated with Design Reviews</i></b>

**CDRLs used to capture the results of software development activities**

<b>SOFTWARE CONTRACT DATA REQUIREMENTS LIST (CDRL) ITEMS DESCRIPTION</b>			
<b>CDRL</b>	<b>Description</b>	<b>DID</b>	<b>DATE OF SUBMISSION</b> <b>P – Preliminary F - Final</b>
	<b>Development Management</b>		
<b>B021</b>	<b>Software Development Plan (SDP)</b>	<b>DI-MCCR-80030A</b>	<b>P at CA+2, F at SDR</b>
	<b>Products</b>		
<b>B022</b>	<b>Commercial Product Software Documentation</b>	<b>DI-MCCR-80030A/T</b>	<b>P at SDR, F at SSR</b>
<b>B022</b>	<b>Software Requirements Specification (SRS)</b>	<b>DI-MCCR-80025A</b>	<b>P at SDR, F at SSR</b>
<b>B036</b>	<b>Interface Requirements Specification (IRS)</b>	<b>DI-MCCR-80026A</b>	<b>P at SDR, F at SSR</b>
<b>B023</b>	<b>Software Design Document (SDD)</b>	<b>DI-MCCR-80012A</b>	<b>P at PDR-1, F at CDR-1</b>
<b>B037</b>	<b>Interface Design Document (IDD)</b>	<b>DI-MCCR-80027A</b>	<b>P at PDR-1, F at CDR-1</b>
<b>B025</b>	<b>Software Test Plan (STP)</b>	<b>DI-MCCR-80014A</b>	<b>P at PDR-1, F at CDR</b>
<b>B026</b>	<b>Software Test Description (STD) – Test Cases and Procedures</b>	<b>DI-MCCR-80015A</b>	<b>Cases: P at CDR-3, F at CDR Procedures: P at 90 DPT, F at DPT</b>
<b>B028</b>	<b>Software Test Report (STR)</b>	<b>DI-MCCR-80017A</b>	<b>P at 5 DATC, F at 30 DARC</b>
<b>B029</b>	<b>Version Description Document (VDD)</b>	<b>DI-MCCR-80013A</b>	<b>5 days after new version</b>
	<b>Support</b>		
<b>B030</b>	<b>Software User's Manual</b>	<b>DI-MCCR-80019A</b>	<b>P at CDR+8, F at PCA+4</b>
<b>B031</b>	<b>Software Programmer's Manual</b>	<b>DI-MCCR-80021A</b>	<b>P at CDR+8, F at PCA+4</b>
<b>B032</b>	<b>Computer System Operator's Manual</b>	<b>DI-MCCR-80018A</b>	<b>P at CDR+8, F at PCA+4</b>
<b>B033</b>	<b>Firmware Support Manual</b>	<b>DI-MCCR-80022A</b>	<b>P at CDR+8, F at PCA+4</b>
<b>B034</b>	<b>Software Product Specification (SPS)</b>	<b>DI-MCCR-80029</b>	<b>F at PCA+1</b>
<b>B053</b>	<b>Computer Resources Integrated Support Document</b>	<b>DI-MCCR-80024A/T</b>	<b>P at PDR, F at CDR</b>



# System Specification

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- **Meteorological algorithms implemented in high order language (HOL)**
- **Use of commercial software approved by the FAA**
- **Programming Language (s)**
  - Use of a single higher order language (HOL)
  - Lower order language approved by Government
  - Programming language approved by Government
- **Software Reliability**

Software Error Category	Maximum NBR of Unresolved Errors
1	Zero
2	1/70 K SLOC
3	1/35 K SLOC



# Key Contract Modifications

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- **Modification 0004: June 14, 1989**

- System specification
- Microburst Detection Algorithm
- Gust Front Detection Algorithm
- TDWR Product Output Formats

*Key Modifications –  
Microburst and Gust  
Front Algorithm  
changes*

- **Modification 0010: June 25, 1990**

- Statement of work: Software documentation
- Microburst Detection Algorithm
- TDWR Product Output Formats

- **Modification 0015: October 24, 1990**

- Microburst Detection Algorithm
- Gust Front Detection Algorithm

- **Modification 0020**

- Equitable adjustment under Mod 0004, 0010, 0015
- FCA From 42 to 48 MACA (Nov 92)
- PCA From 40 to 46 MACA (Sep 92)



# Software Development

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- **System Software Description**
- **Software Development Environment**
- **Software Development Life Cycle Models**
- **Software Development Methodology**



# System Software Description

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- **11 Computer Software Configuration Items (CSCI)**
  - Allocated to 6 Hardware Configuration Items (HWCI)
- **6 Applications**
  - Digital Signal Processing, Radar Product Generation, Remote Monitoring, Display, Antenna Control, Transmitter Control
- **Distributed Microprocessors**
  - 68020 SBC, Harris 3803 Nighthawk, 68030, Array Processor
- **Multiple Operating Systems**
  - Sun OS, Unix, VRTX32, CRT/RT
- **Multiple Programming Languages**
  - C, Assembly, Fortran, Microcode
- **304.2K - Source Lines of Code**
- **4,416 - Software Requirements**

TDWR – Real-Time Software-Intensive System





# Application CSCIs

CSCI No	Title	Processor	OS	Programming Language (s)	SLOC K	NRB of Rqmts	Description
1	Digital Signal Processor (DSP)	<ul style="list-style-type: none"> <li>• 68020 SBC</li> <li>• Micro Processors</li> </ul>	VRT32	C Assembly Microcode	25	564	<b>DEVELOPMENT STATUS: NEW CODE</b> Controls the basic radar timing function, performs clutter filtering and clutter filter selection, and implements the pulse-pair processing to generate the zeroth and first moment data.
2	Radar Product Generation (RPG)	<ul style="list-style-type: none"> <li>• HARRIS 3803</li> <li>• Array Processor</li> </ul>	CX/RT	C	90	788	<b>DEVELOPMENT STATUS: NEW CODE</b> <ul style="list-style-type: none"> <li>• Base data estimation/data conditioning</li> <li>• Weather product generation</li> </ul>
3	Remote Monitoring Subsystem (RMS)	<ul style="list-style-type: none"> <li>• HARRIS 3803</li> <li>• Array Processor</li> </ul>	CX/RT	C	80	1760	<b>DEVELOPMENT STATUS: NEW CODE</b> Performs performance monitoring and maintenance alarm/alert generation.
4	Display Computer (DPL)	Sun 386i	SUN OS UNIX	C	30	778	<b>DEVELOPMENT STATUS: NEW CODE</b> Manages all graphic and alphanumeric display functions for display of radar product and status information.
8	Antenna Control	68020 SBC	None	C Assembly	2.5K	124	<b>DEVELOPMENT STATUS: NEW CODE</b> Command and control the pedestal.
9	Transmitter Control (XMT)	68020 SBC	None	C Assembly	2.7K	175	<b>DEVELOPMENT STATUS: NEW CODE</b> <ul style="list-style-type: none"> <li>• Command and control the transmitter</li> <li>• Performs performance fault monitoring function</li> </ul>



# Support CSCIs

CSCI No	Title	Processor	OS	Programming Language (s)	SLOC	NRB of Rqmts	Description
5	Software Development Tools (SDV)	SUN 386i	N/A	N/A	7.5K	N/A	DEVELOPMENT STATUS: COTS/NEW CODE Tools used for Sun workstations, data processor system, and 68020 SBCs. All CSCE tools, and programming utilities.
6	Test Tools Library (TTL)	<ul style="list-style-type: none"> <li>• HARRIS 3803 (NIGHTHAWK) 68030 CPUs</li> <li>• Sun 386i</li> </ul>	CX/RT CX/UN (Unix) SunOS Unix	C FORTRAN	59k	227	DEVELOPMENT STATUS: NEW CODE, EXISTING, MODIFIED Software to generate simulated base data and moment data and to simulate external interfaces.
7	VRTX-32 Operating System (VTX)	• 68020 SBC	N/A	N/A	N/A	N/A	DEVELOPMENT STATUS: COTS All multi-tasking operating system services and related boots strap and diagnostic function for the 68020SBC.
10	Data Processing Operating System (DPO)	•HARRIS 3803 (NIGHTHAWK) 68030 CPUs	CX/RT (Unix)	N/A	7.5K	N/A	DEVELOPMENT STATUS: COTS The RPG/RMS Data Processing Operating System for CSCI-2 and 3.
11	Display System Operating System (Unix)	Sun 386i	Sun OS	N/A	N/A	N/A	DEVELOPMENT STATUS: COTS The Display System Operating System for CSCI-4



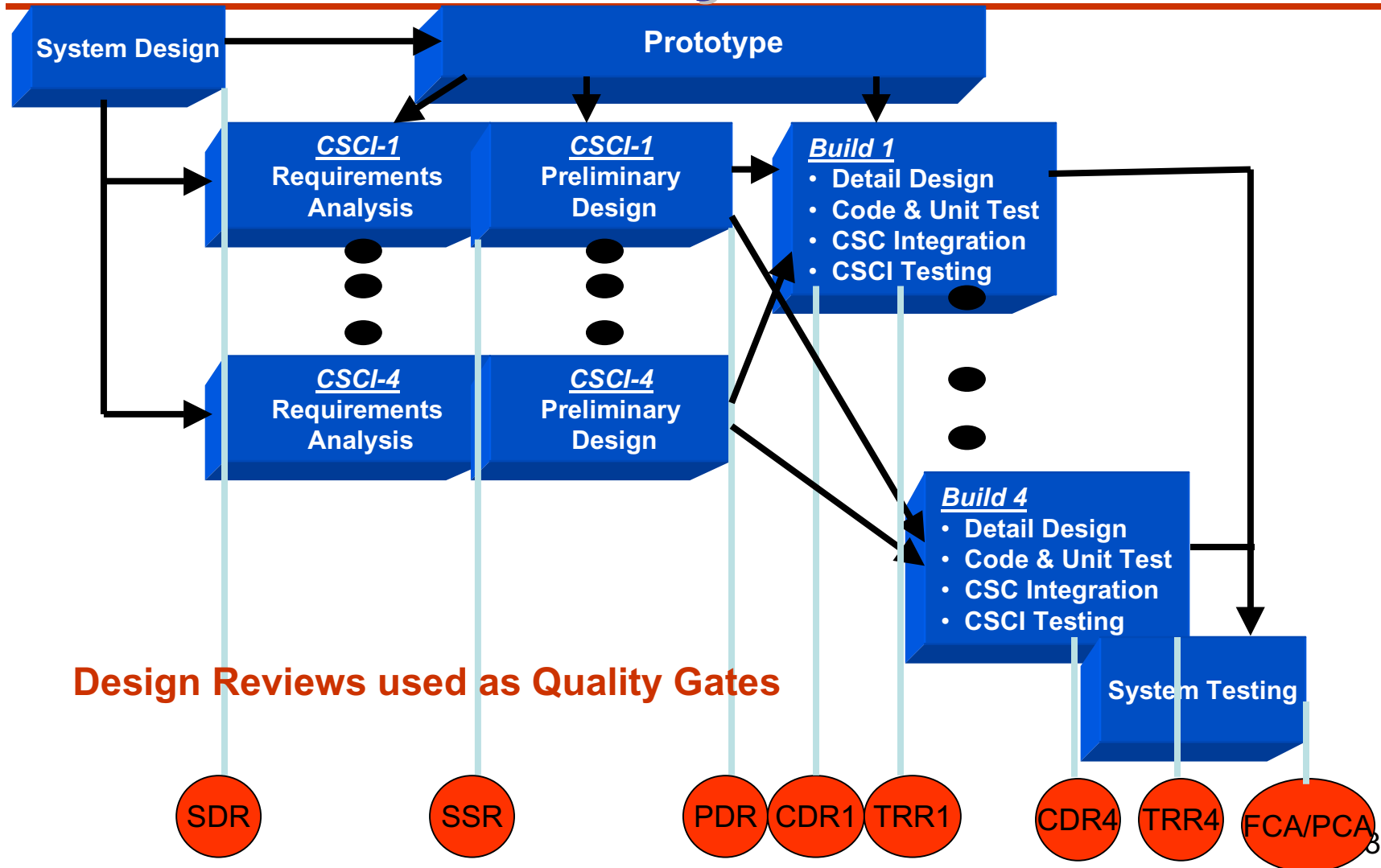
# Software Development Environment (SDE)

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- Established to support the software engineering process and provide production capability for the ***Software Requirements Specification (SRS)*** and ***Software Design Document (SDD)*** CDRL Items
- Computer-aided software engineering (CASE) tool (***IDE Software Through Picture***) used for structured analysis and design
- SDE augmented by management methods and practices (i.e., measurements/metrics and monitoring progress, judging the quality of the CDRL items)



# Software Development Life Cycle Models





# Software Development Methodology

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- Structured analysis and design performed during software requirements analysis and preliminary design.
  - **Data flow diagrams** used to model the software requirements
    - Software requirements documented IAW DID (DI-MCCR-80025A)
  - **Control flow diagrams** used to model the preliminary design
    - Software design documented IAW DID (DI-MCCR-80012A)



# Acquisition Team

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- **Program Management**
- **Technical Office**
- **Technical Support**



# Program Management

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- **Program Management**

- Program Manager
- Business Manager
- Associate Program Manager
  - Contracts
  - Logistics
  - Systems Engineering
  - Test and Evaluation
  - Flight Standards
  - Quality Assurance
  - General Counsel
  - Maintenance

**Federal Aviation Administration**  
***Program Manager for Weather Radar,***  
***ANR-500***

Identified high-risk development efforts and structured the management process accordingly – to provide control of the development and to gain timely and accurate insight into its progress



# Technical Office

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- **Technical Office**
    - **System Design**
    - **System Hardware Design**
    - **System Software Design**
    - **Test and Evaluation**
    - **Logistics**
    - **Configuration Management**
    - **Planning**
    - **Data Management**
    - **Integration**
- Martin Marietta Aerospace Air Traffic Control Division**  
***Systems Engineering Integration Contractor***

Ensure system requirements can be implemented within schedule and cost constraints





# Technical Support

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- **Technical Support**
  - **Meteorological Algorithm**
    - *Massachusetts Institute of Technology (MIT) Lincoln Laboratory*
  - **Products Output Display**
    - *National Center for Atmospheric Research (NCAR)*
  - **Weather Verification Tests**
    - *National Severe Storm Laboratory (NSSL)*
  - **Engineering Support**
    - *NYMA, Inc.*

Ensure accuracy of Meteorology Algorithm and Products Output Display



# Software Acquisition Process

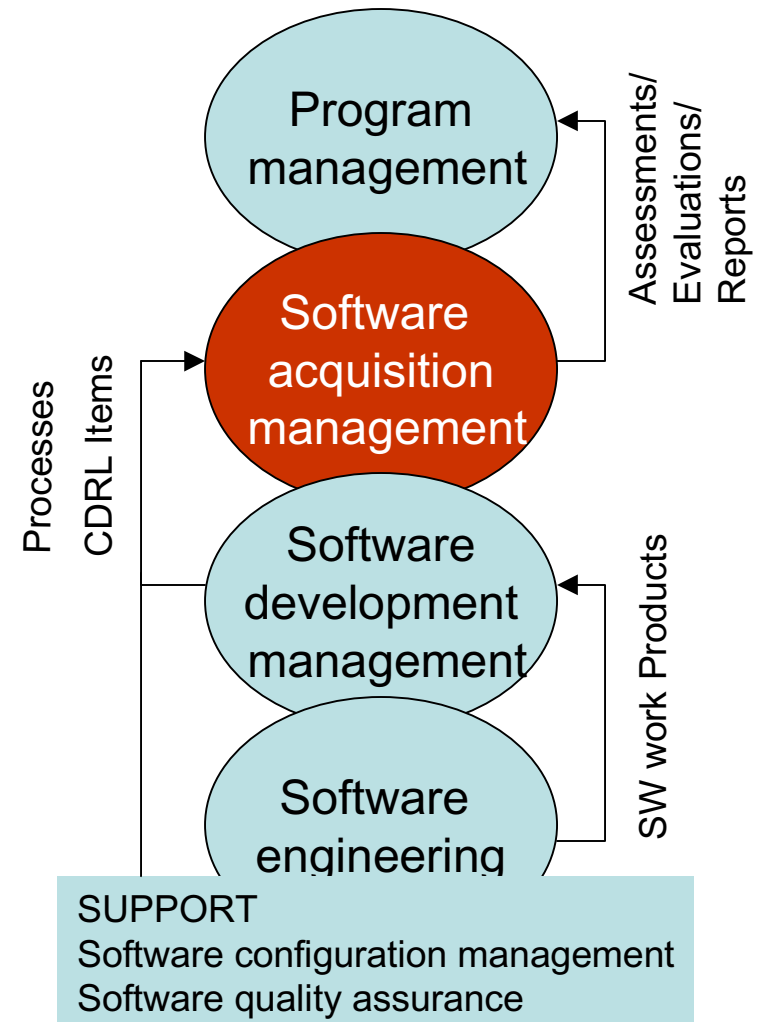
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- **Software Acquisition Management Relationships**
- **Software Acquisition Expertise**
- **Standards Applied**
- **Activities**



# Software Acquisition Management Relationships

- **Software Acquisition Management**
  - Supported the assemble of the contract requirements
  - Provided visibility to program management
- **Software development management**
  - Managed the engineering process
  - Provided processes and CDRL items for evaluation
- **Software engineering**
  - Built the software product
  - Provided software work products for evaluation





# Software Acquisition Expertise

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- **(6) Software engineering expertise**
  - Software acquisition management
  - Software development process
  - Software development methods and techniques using Government standards
  - Software design – mission critical, embedded, real time, and distributed
  - Application of programming languages
  - Software test methods and techniques
- **(8) Application Domain expertise**
  - Microburst, Gust Fronts, Precipitation, Base Data Processing, and Clutter Suppression

The focus is on *what is done* and the *product* being built



# Standards Applied

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***Standards* are essential....Key to acquisition and development success**

***Government standards* were applied to establish a uniform set of requirements and implementation practices.**

**Government standards also provided insight into the development management, engineering, testing, software configuration management, and software quality assurance processes and products**



# Standards Applied

- Government standards**

<b>FAA-STD-005D</b>	<b>Preparation of Specification Documents</b>
<b>FAA-STD-018A</b>	<b>Computer Software Quality Program Requirements</b>
<b>FAA-STD-021A</b>	<b>Configuration Management Plan</b>
<b>FAA-STD-031A</b>	<b>Statement of Work Preparation</b>
<b>MIL-STD-881A</b>	<b>Work Breakdown Structure for Defense Material Items</b>
<b>MIL-STD-490A</b>	<b>Specification Practices</b>
<b>MIL-STD-1521B</b>	<b>Technical Reviews and Audits for Systems, Equipment and Computer Software</b>
<b>DOD-STD-2167A</b>	<b>Defense System Software Development</b>
<b>MIL-HDBK-245B</b>	<b>Preparation of Statement of Work</b>



# Activities

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- **Software Acquisition Planning**
- **Request for Proposal Support**
- **Management Assessments**
- **Reviews / Meetings Participation**
- **CDRL Items Evaluation**
- **Software Test Evaluation**
- **Requirements Accountability**

***Software Acquisition Management activities used to ensure compliance to standards and delivery of a quality software product***



# Software Acquisition Planning

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- **Defined plans for performing software acquisition management**
- **Content of detailed plan:**
  - **Defined organizational structure, responsibilities, and required resources**
  - **Identified development risk and described criteria for risk assessment**
  - **Defined Interfacing with the prime contractor's**
    - **Program Office Software Manager**
    - **Software Quality Assurance**
    - **Software Configuration Management**
  - **Defined technical evaluation method and technique**
  - **CDRL item preparation standards and acceptance criteria**





# Software Acquisition Planning (cont'd)

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- **Content of detailed plan (cont'd)**
  - **Established procedures for:**
    - **Conducting management assessments**
    - **Evaluating CDRL items**
    - **Participating at reviews and meetings**
    - **Action items tracking and closure**
    - **Review Item Discrepancies (RID) processing**
  - **Detailed schedule for CDRL item reviews**
  - **Established metrics for:**
    - **Process, Product, Project, and Productivity**

Procedures and metrics established to gain insight into the software development activities, to verify compliance, and to verify product quality.



# Software Acquisition Planning (concl)

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- **Review Item Discrepancy (RID) form**
  - **Use to capture CDRL items and work products evaluations**
    - Documentation Identification
    - Comment Location (Page, Paragraph, Figure, Table)
    - Comment (i.e., consistency, missing information, correctness, ambiguous)
    - Recommendation / proposed solution
  - **Use to disposition review comments**
    - Concur/non-concur
    - Action
  - **Track review comments closure**
    - Date closed
    - Comment



# Request for Proposal (RFP) Support

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- **Provided RFP support to assemble:**
  - Solicitation package
  - Contract
  - Contract modifications
- **Solicitation package included**
  - Statement of Work
  - CDRL Items and DIDs
  - System Specification
  - Work Breakdown Structure (WBS)

Solicitation package -- Foundation of a successful software acquisition



# Management Assessments

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- Management assessments were conducted to verify compliance with contractual requirements.
- Management assessment were also conducted to ensure that the development activities and products were in accordance with the documented development processes *documented in the plans*.
- Management assessments conducted for:
  - Software development management
  - Software configuration management
  - Software quality assurance



# Software Development Management

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- Verified the ***Software Development Plan (SDP) (CDRL B021)*** complied with ***DID DI-MCCR-80030A***
- Verified software development management activities conducted for: 1) planning the software engineering, 2) managing the software project, 3) monitoring and controlling the development, 4) risk management, and 5) subcontract management
- **Examples of activities verified**
  - Software development activities IAW DOD-STD-2167A
  - Design reviews IAW MIL-STD-1521B
  - Schedule consistent with the Program Master Schedule and Contract Work Breakdown Structure



# Software Configuration Management

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- Verified the ***Configuration Management Plan (CMP) (CDRL A005)*** compiled with ***FAA-STD-021A***
- Verified software configuration management activities conducted for establishing and maintaining the integrity of the software products
- Examples of activities verified
  - Configuration identification is performed
  - Configuration control is established and performed
  - Configuration status accounting report generated on all CDRL items comprising the Baselines (Allocated, Developmental Configuration, and Product)
  - A software baseline library is established



# Software Quality Assurance (SQA)

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- Verified the **Computer Software Quality Program Plan (CSQPP)** complied with FAA-STD-018A
- Verified software quality assurance activities conducted to provide management with visibility into the process being used and the products being built
  - Examples of activities verified
    - Software development activities IAW SDP
    - Software configuration management IAW SCMP
    - CDRL items internally evaluated prior to delivery
    - SQA audits are performed
    - Records maintained and presented at the design reviews
- SQA audits witnessed during preliminary and detail design phases



# Reviews / Meetings Participation

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- Program Management Reviews
- Design Reviews
- In-Process Reviews
- Technical Interchange Meetings

Participated in reviews and meetings to gain insight and to provide feedback

**Key focus --- *What is done and the product being built***





# Program Management Reviews (PMR)

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- **39** PMRs conducted
- **Examples of items verified**
  - Status of work accomplished
  - Problems and impacts
  - Technical performance consistency with the *Program Status Report (CDRL item)*



# Design Reviews

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- **57** informal (28) and formal (29) design reviews held
  - Determine visibility and status, measure progress, and assess the integrity of the development processes and products
- Co-chaired all formal design reviews
- Associated CDRL items **RID** provided prior to the design review
- Verified compliance with the SDP and MIL-STD-1521B
- Verified technical presentations
- At the post review, attested to the **Action Items**
- Monitored Action Items until closure

***Design reviews used as quality gates***



# In-Process Reviews

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- **14** In-Process Reviews (IPR) held to evaluate work products and provide feedback
  - **95** products (examples)
    - Computer Software Unit (CSU) source code, Test cases, Test procedures, Test reports
    - Software Trouble Reports (STR)
    - Software development folder procedures
    - Program support library (PDL)
    - Cost/Schedule Status Report
- RIDs generated and disposition at the post review
- SQA ensured action items were prepared and tracked until closure

IPRs used to improve the process, product quality and content



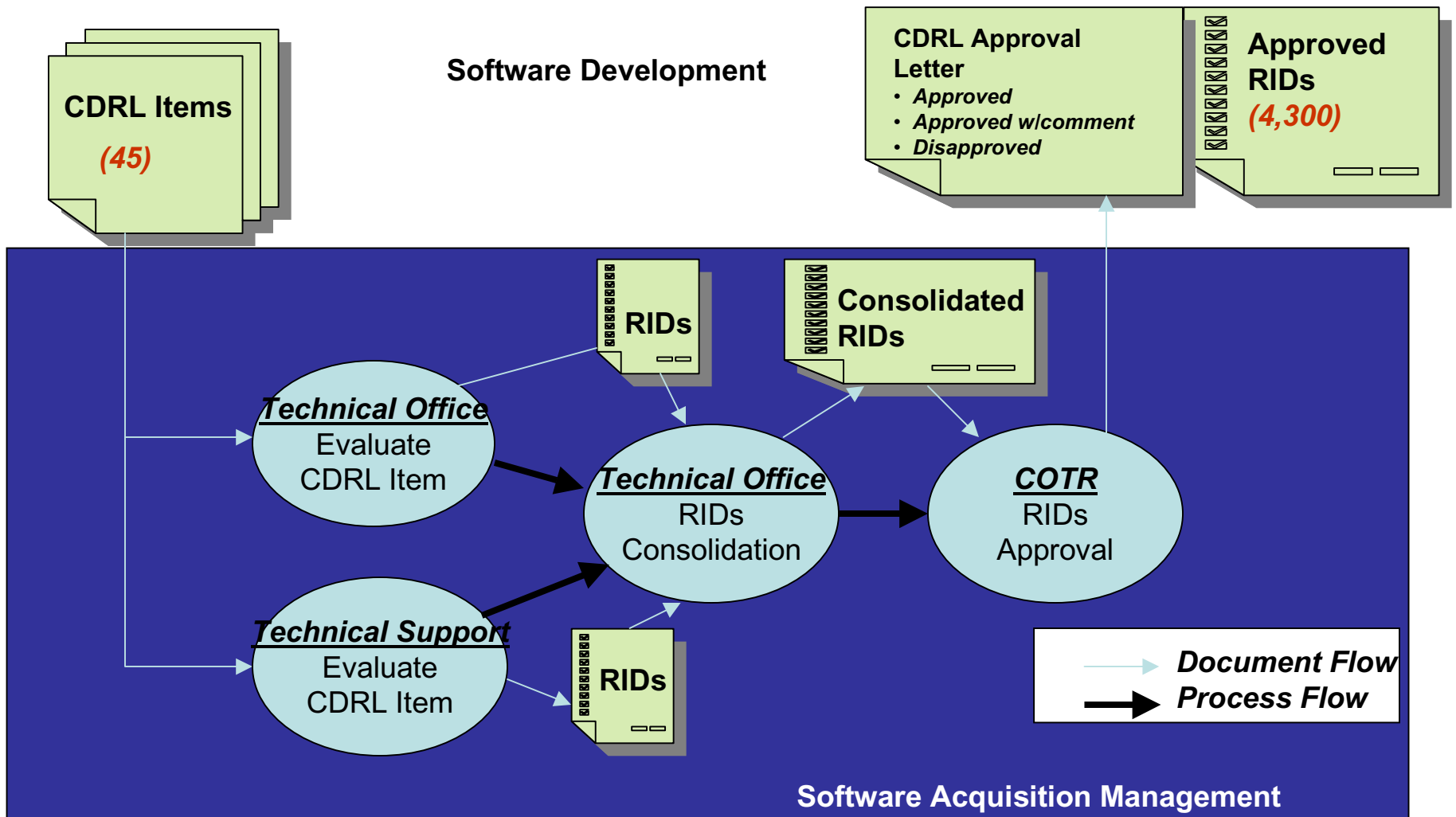
# Technical Interchange Meetings (TIM)

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- **52** TIMs conducted to resolve issues, RIDs resolution, and action items
- **Examples of TIMs**
  - Software development process
  - CDRL preparation (i.e., SRS, SDD, and STD)
  - SDF procedures
  - Meteorological algorithm changes
  - CX/RT Operating system argumentation



# CDRL Item Evaluation





# CDRL Item Evaluation

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- **Techniques**
  - ***Static analysis***
    - Detect errors through examination of the CDRL item
    - Focus -- form, structure, completeness, and consistency
  - ***Dynamic analysis***
    - Detect errors by studying the response to a set of input data
    - Focus -- functional processing, performance, interfaces, and design constraints
    - Test coverage analysis
  - ***Formal analysis***
    - Processing accuracy, efficiency, and correctness of algorithm
  - ***DOD-STD-2167A evaluation criteria***
  - ***Requirements traceability***
    - System specification, software requirements specification, design, code, and test cases

Proper use of CDRL evaluation techniques provided visibility into the development effort.



# Software Test Evaluation

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- **Designated by the COTR as the Software Test Director**
- **Evaluated software test CDRL Items**
  - Software Test Plan, B025
  - Software Test Description (Test Cases and Procedures, B023)
  - Software Test Report, B028
- **Participated at Test Readiness Reviews (TRR)**
  - Updates for SDDs, source code, and Software Development Folders (SDF)
  - CSU and CSC testing status
  - Source code in the Program Support Library (PSL)
  - Approved Engineering Change Proposals (ECP)
- **Witnessed CSCI Formal Qualification Testing (FQT)**
  - Ensured CSCI FQT conducted IAW approved STP and STD

**Participation validated the “as-built” software.**



# Requirements Accountability

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- **Requirements database** established during the CDRL Item and Software Test evaluation to capture requirements allocation and traceability
- Requirements database also used to capture Test Case results (example)
  - Success
  - Failure/Error (Test Procedure Step)
  - Software Problem Report Number
  - Comment (e.g., not critical, needs immediate attention)

Requirements accountability database provided means for:

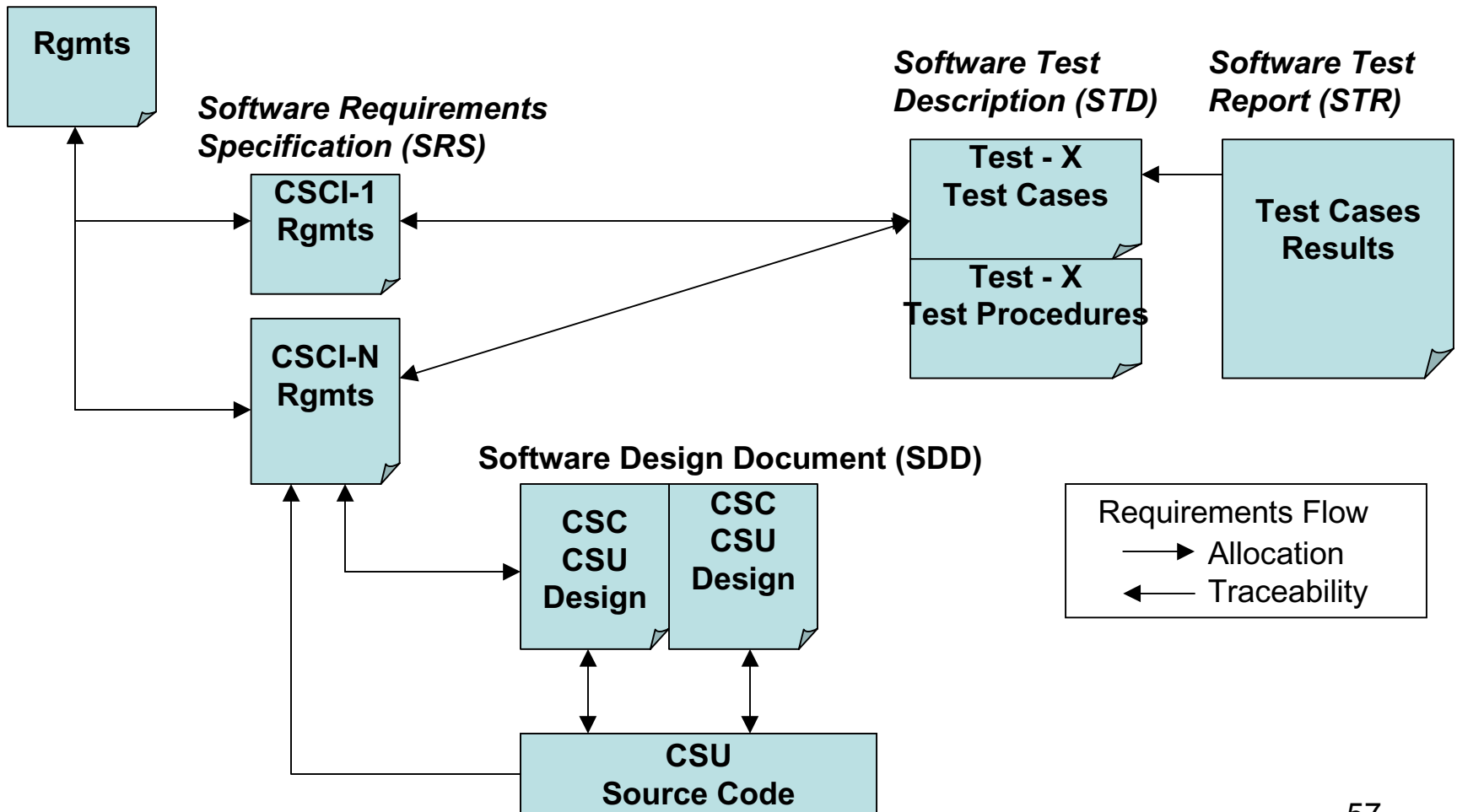
- Validating the CSCI implementation of allocated system requirements
- Validating “as-built” software satisfied the CSCI requirements





# Requirements Accountability

## System Specification





# Metrics

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- **45 Metrics** provided insight into four Key Acquisition Areas:
  - **Process**
    - Provided insight into the software development process and how it was working
  - **Product**
    - Measured the quality of the product (e.g., frequency of requirement changes, number of STRs, number of RIDs)
  - **Project**
    - Provided progress-oriented measures (e.g. schedule attainment, CDRL delivery)
  - **Productivity**
    - Measured the rate at which the work was progressing
- Metrics reported to **ALL** to encourage performance.

Metrics provided feedback to refine the software development process 3

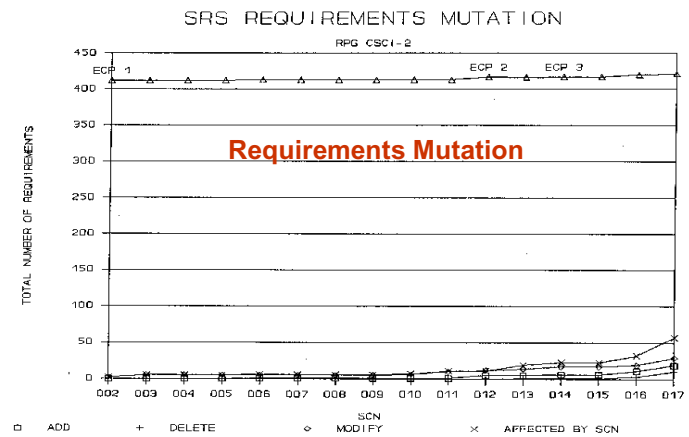
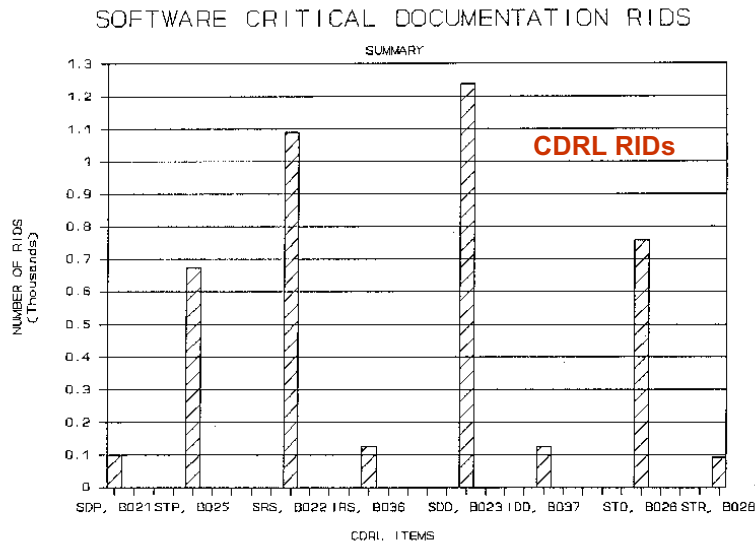
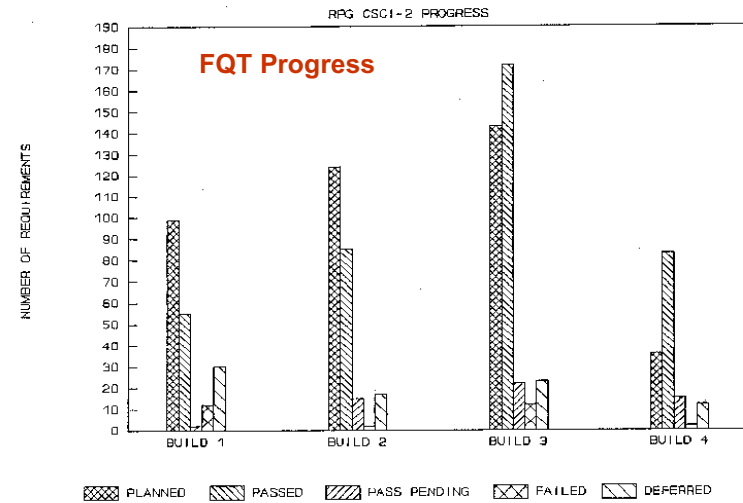
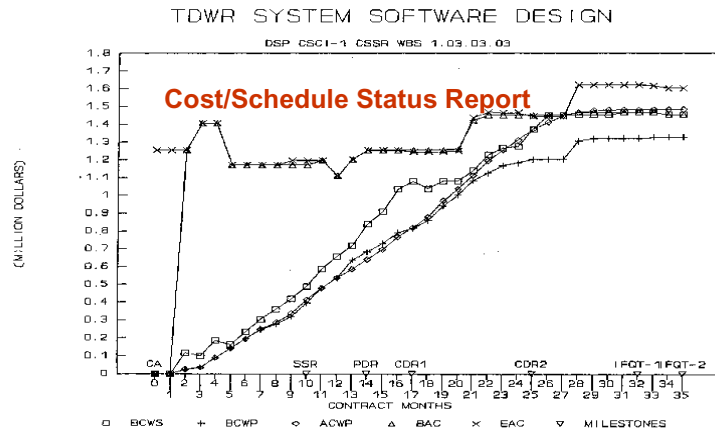


# Metrics Mapping to Key Acquisition Areas

<i>Examples of Metrics</i>	<i>Process</i>	<i>Product</i>	<i>Project</i>	<i>Productivity</i>
<b>Cost/Schedule Status Report</b>	X		X	X
<b>Development Progress</b>	X		X	
<b>FQT RPG CSCI-2 Progress</b>	X		X	
<b>CDRL Item Status</b>	X			X
<b>RPG/RMS HWCI-5 Resource Utilization</b>	X			
<b>Software Trouble Reports (Source Code)</b>	X	X		X
<b>CDRL Item RIDs</b>	X	X		
<b>Management Assessments</b>	X	X		
<b>In-Process Reviews RIDS</b>	X	X	X	
<b>Requirements Mutation</b>	X	X		



# Samples of Metrics





# Conclusion

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- **Key Elements for Success**
- **TDWR Success Attributes**



# Key Elements For Success

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- **Success in software acquisition and development depends on five key elements**
  - ***The Contract***
    - Statement of Work, Contract Data Requirements List, System Specification
  - ***The Development Process***
    - Software Development Plan, Software Configuration Management Plan, Software Quality Assurance Plan
  - ***The Acquisition Team***
    - Software engineering and application domain expertise
  - ***The Acquisition Process***
    - Activities used documented procedures and standards
  - ***Metrics***
    - Provided insight into four Key Acquisition Areas:
      - Process, Progress, Product, and Productivity



# TDWR Success Attributes

- **Software Completion**
  - Build 2/3 FQT Completed June 6, 1991
  - Build 4 FQT Completed December 18, 1991
- **Software Development Effort<sup>1</sup>**
  - Cost \$17 million
  - 300,000 lines of code
  - 70 software and test engineers
- **First Production**
  - (MEM) Memphis, TN November 1992<sup>1</sup> (*Schedule Incentive Target Date December 1992*)



<sup>1</sup> Source: Aviation Week & Space Technology, January 27, 1992  
“TDWR Installation Begins; Sizable Fuel Savings Expected



# TDWR Success Attributes

## Actual Key Performance Measurements

<b>SRS #</b>	<b>EVENT</b>	<b>RQMT</b>	<b>ACTUAL MEASUREMENT</b>
<b>Radar Product Generation (RPG) CSCI-2</b>			
02.3_6.01	Microburst	5 sec	.9 sec
02.3_6.02	Gust Front	5 sec	.9 sec
02.3_6.03	Precipitation	5 sec	1.9 sec
02.3_6.08	Archive Request	60 sec	.5 sec
02.3_6.09	Base Data Display	5 sec	4.68 sec
02.3_6.10	Error Report	3 sec	.5 sec
02.3_6.11	Active Runway Response	5 sec	1.2 sec





# TDWR Success Attributes

## Ocean Engineering

FROM: JAC OWEN

*applied research • instrumentation • marine electronics • offshore construction*

### IEEE Names Raytheon Leader In Software Industry

Raytheon Electronic Systems (Lexington, Massachusetts) recently received one of the most prestigious

This award recognizes Raytheon as a world-class leader in software development. In 1991, Raytheon's software process was evaluated at level three against the SEI Capability

According to Thomas J. Haley, manager of Raytheon's Software Engineering Laboratory and chairman of its SEPG, virtually all projects are now finished on or ahead of schedule

**Raytheon Electronic Systems received IEEE Computer Society Award for outstanding achievement in improving software processes**

**In 1991, Raytheon's software process was evaluated at level three against the SEI Capability Maturity Model (CMM)...**

have saved the company millions of dollars and have ensured that complex projects are delivered on sche-

software engineers are now seeing productivity increases of 170 percent and rework cost reductions of over

burst detection. That's just one of many examples of Raytheon's leadership in the software process arena."

**"One notable project is the terminal doppler weather radar (TDWR) project we recently accomplished for the Federal Aviation Administration (FAA)," said Haley . "Software development played a key role in achieving TDWR delivery to the FAA six months ahead of schedule, an objective set to reflect a growing national urgency for microburst detection . "**



# TDWR Success Attributes

**TDWR Currently Operational at 45 Airports<sup>1</sup>**



353149\_5

1 Source: Aviation Week & Space Technology, January 27, 1992  
"TDWR Installation Begins; Sizable Fuel Savings Expected"



# Questions??

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