Open Systems Architecture for Legacy Aircraft (OSALA)

Open Systems Project Engineering Conference (OSPEC)

FY 98 Status Review

29 April - 1 May 1998

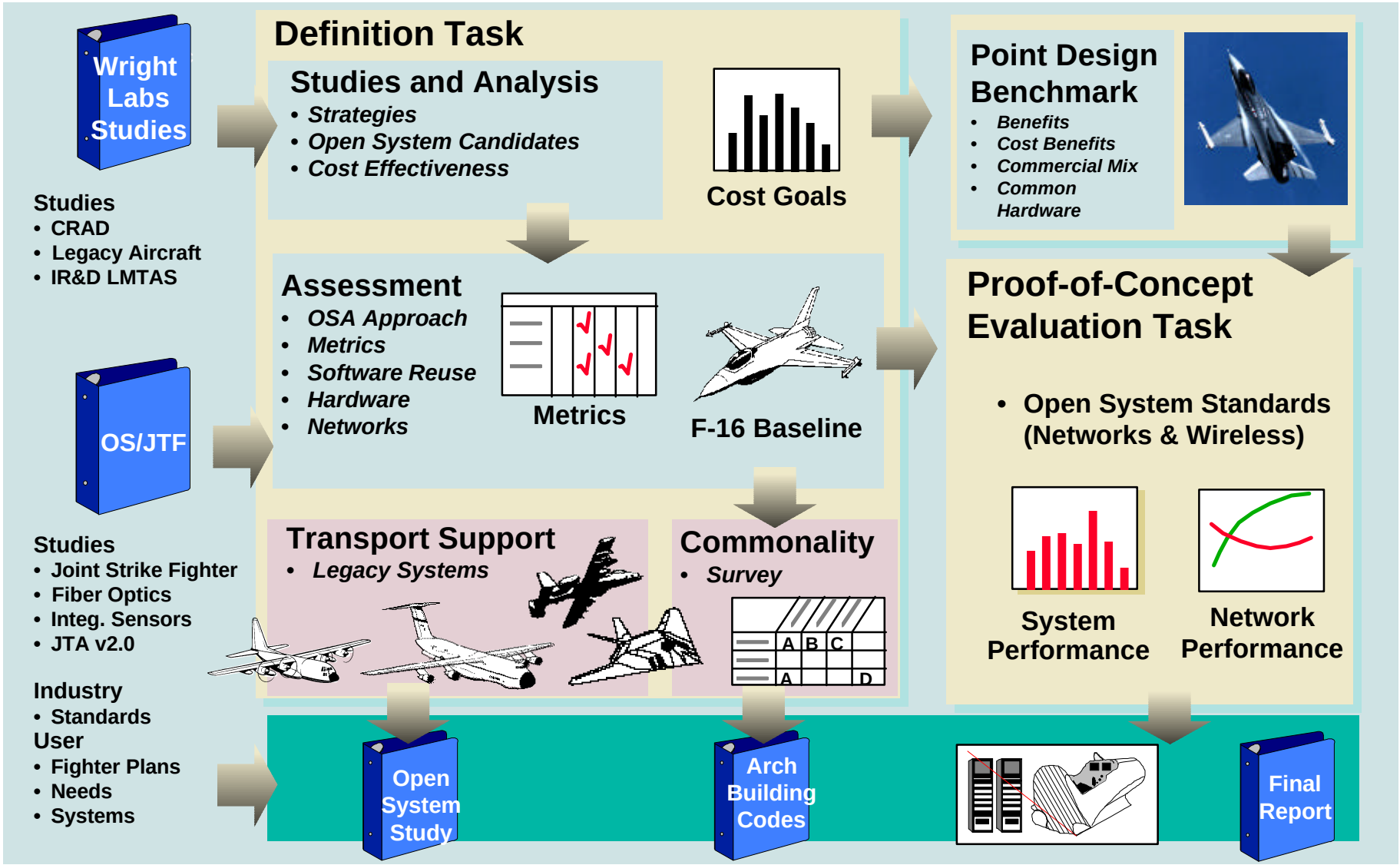
Mr. Juan M. Carbonell

AFRL/AAS, Project Manager

Mr. Mikel J. Harris

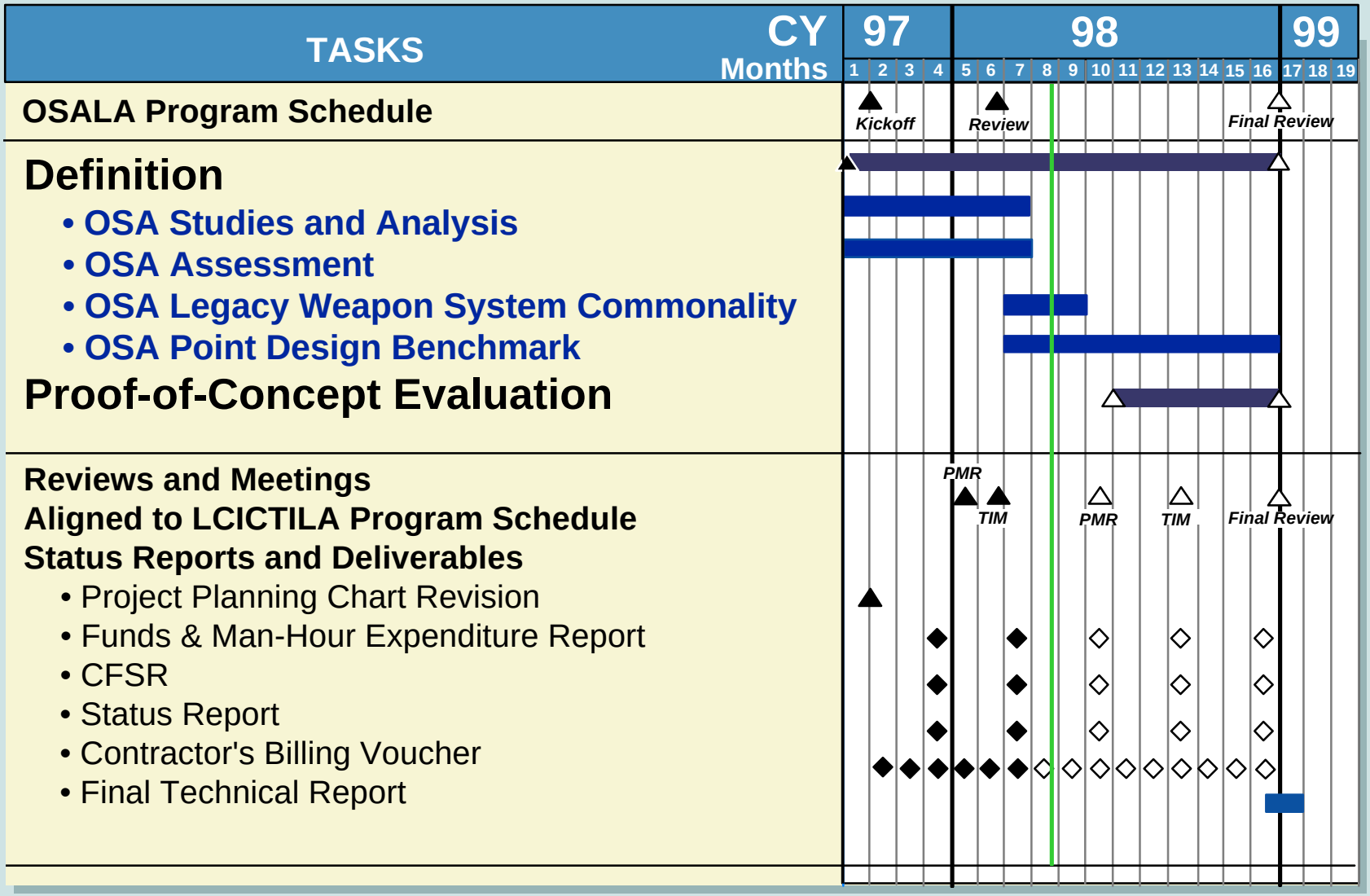
Lockheed Martin, Engineering Spec. Sr.

OSALA Program Overview



Based on Available Funding

Program Schedule



Project Organization

Lockheed Martin Tactical Aircraft Systems

Vice President
Product Engineering
W.B. Anderson

Director
Software
R. K. Moore

Project Team

USAF Program Manager
AFRL
Mr. Juan M. Carbonell
OS/JTF Program
Ltc. Glen T. Logan

Project Team Lead

Mr. Mikel J. Harris

Lockheed Martin Team

Jon Preston (Software Systems)
Tony Schiavone (Architecture and Hardware)
Michael DelPrincipe (Embedded Systems)

OSALA Progress Summary

- Completed Assessment of Open System Standards
- Completed Analysis of F-16 Avionics Open System Insertion Opportunities
- Initiated Wireless Ethernet Studies and Analysis
- OSALA Demonstration: Enhanced Diagnostics Software Integration Started Under Internal IR&D
- Benefits Analysis Task for Open System Standards to be Concurrent with F-16 RMS/LCC Analysis

Technical Progress Summary

- Roadmaps - Complete
- Technology Plans & Roadmaps - Complete
- System Baseline Planning Document - Complete
- Network Testing - Complete
- Wiring Study - Complete
- System Requirements Review - Sep. 11,‘97
- F-16 HSDB Insertion Team - Review, 13 Nov. 1997
- Packaging/Enclosure Studies - Complete
- Program Management Review No. 2 - 7 Jan. 1998
- Technical Interchange Meeting - 24 February 1998
- F-16 Production Planning and Transition - Complete

Technical Activity Forecast

- **Program Technical Report Documentation**
- **Briefing to F-16 SPO - May 1998**

Coordination With F-16 Production Planning...

- **Insertion of Open System COTS-based Solutions Into Aircraft Avionics**
- **ATM Modeling Tasks**
- **RMS/LCC Benefits Analysis**

Program Meetings and Reviews

Program Reviews	Date Oct 96 - Dec 99	Location
Kickoff Meeting	October 96	Dayton, OH
Program Management Review (PMR)	February 97	VTC
Technical Interchange Meeting (TIM)	April 97	Ft. Worth, TX
System Requirements Review (SRR)	September 97	Ft. Worth, TX
OSALA Kickoff	October 97	Ft. Worth, TX
PMR No. 2	January 98	VTC
TIM No. 2	February 98	Washington
System Design Review (SDR) and Lab Demonstration	May 98	Ft. Worth, TX
PMR No. 3	June 98	VTC
TIM No. 3	September 98	VTC
OSALA Final Review & Demo.	December 98	Ft. Worth, TX

** VTC - Video Teleconference*

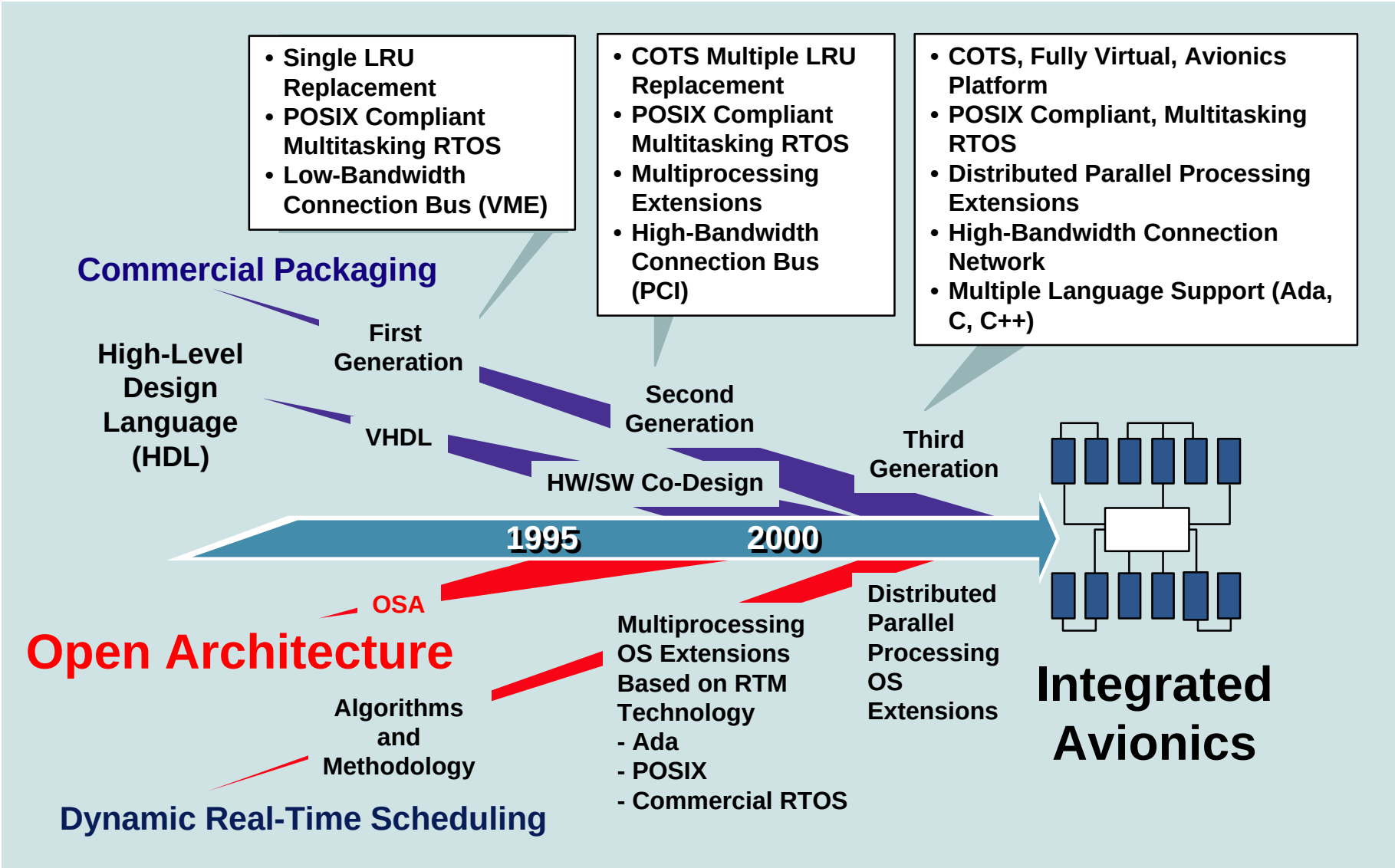
F-16 Network Study Completed

- **Purpose**
  - ✓ **Determine What Is the "Best" High Speed Bus/Network for the F-16**
- **Working Constraint**
  - ✓ **High Speed Network Is to Go On a "36 Month" Airplane With January 1998 Go-Ahead**
  - ✓ **Production Incorporation, Retrofit a Consideration**
    - ✈ *Harnesses Will Be Modified*
  - ✓ **Commercial Build and Procurement**

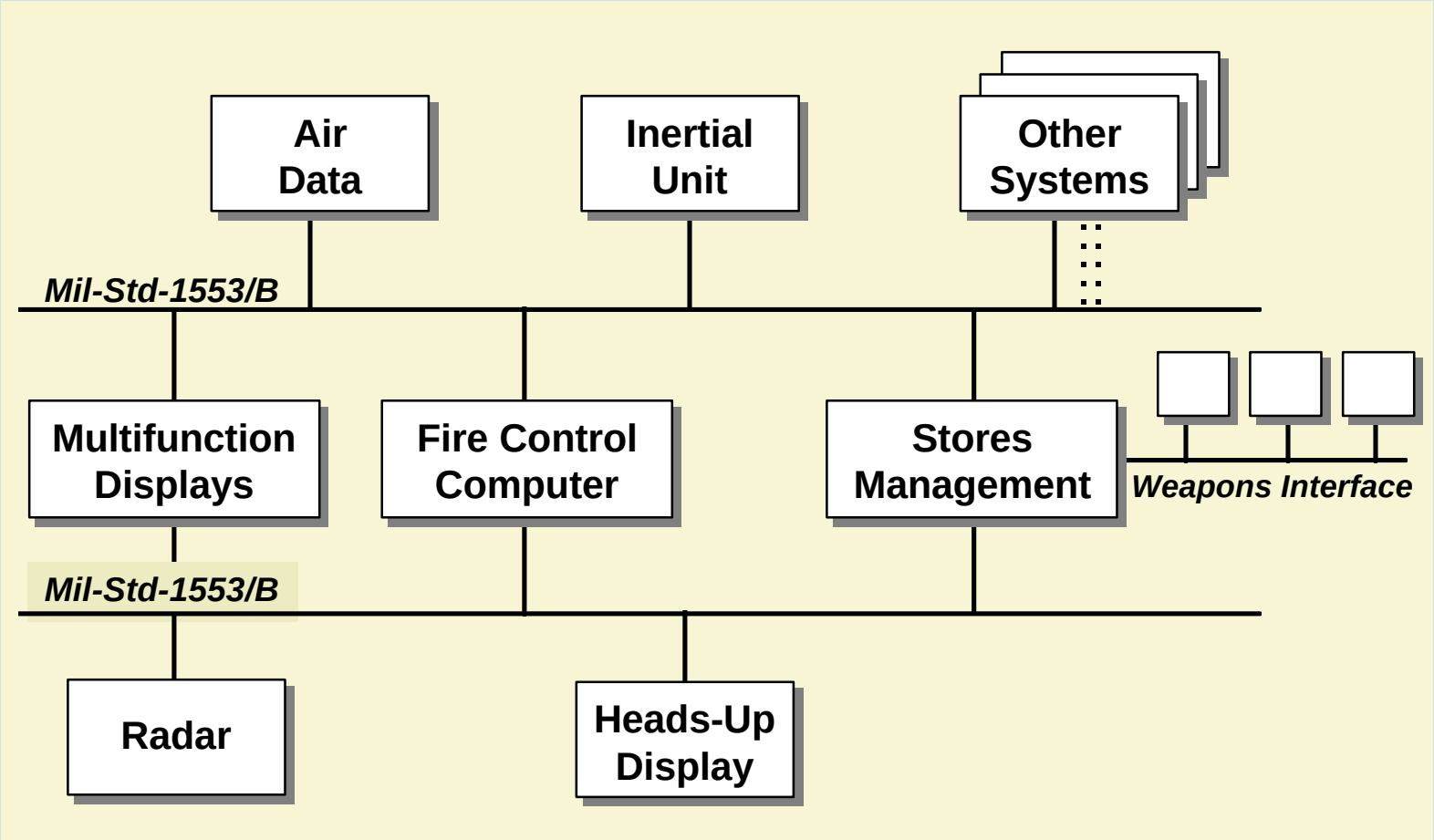
F-16 Study Summary

- **Generated List of Evaluation Criteria**
  - 29 Criteria Identified
  - 9 used for Down Select
- **Developed Reference and Achievable Near-Term Architectures**
- **Estimated Throughput Required of High Speed Network by Each Architecture**
- **Down Selected to 2 Candidates**
  - Asynchronous Transfer Mode (ATM)
  - Fibre Channel

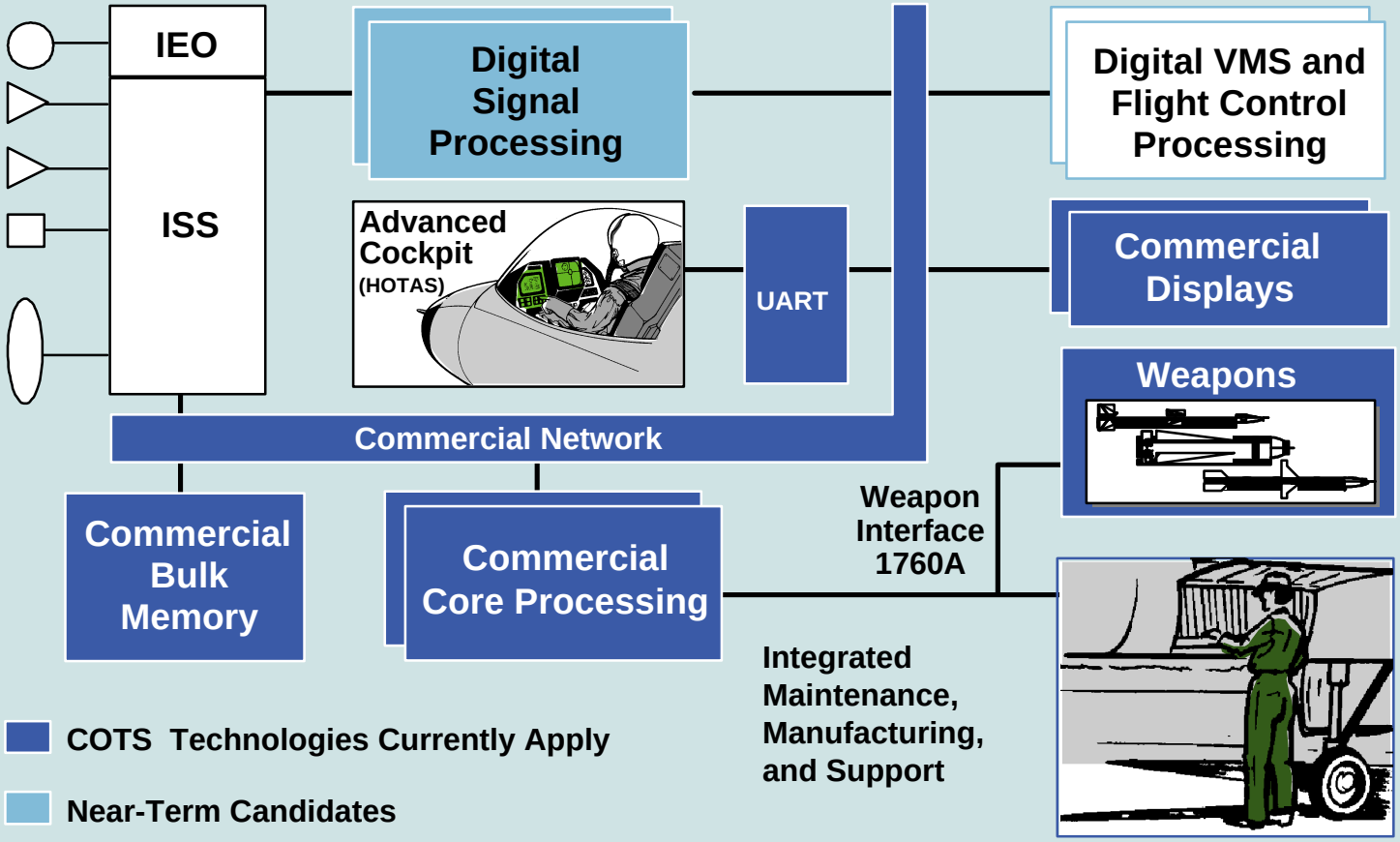
Virtually-Integrated Avionics Architecture



Typical Drawing of the F-16 Architecture



COTS Technologies Can Be Used To Produce A Low-Cost Open System Architecture



COTS Technologies Currently Apply

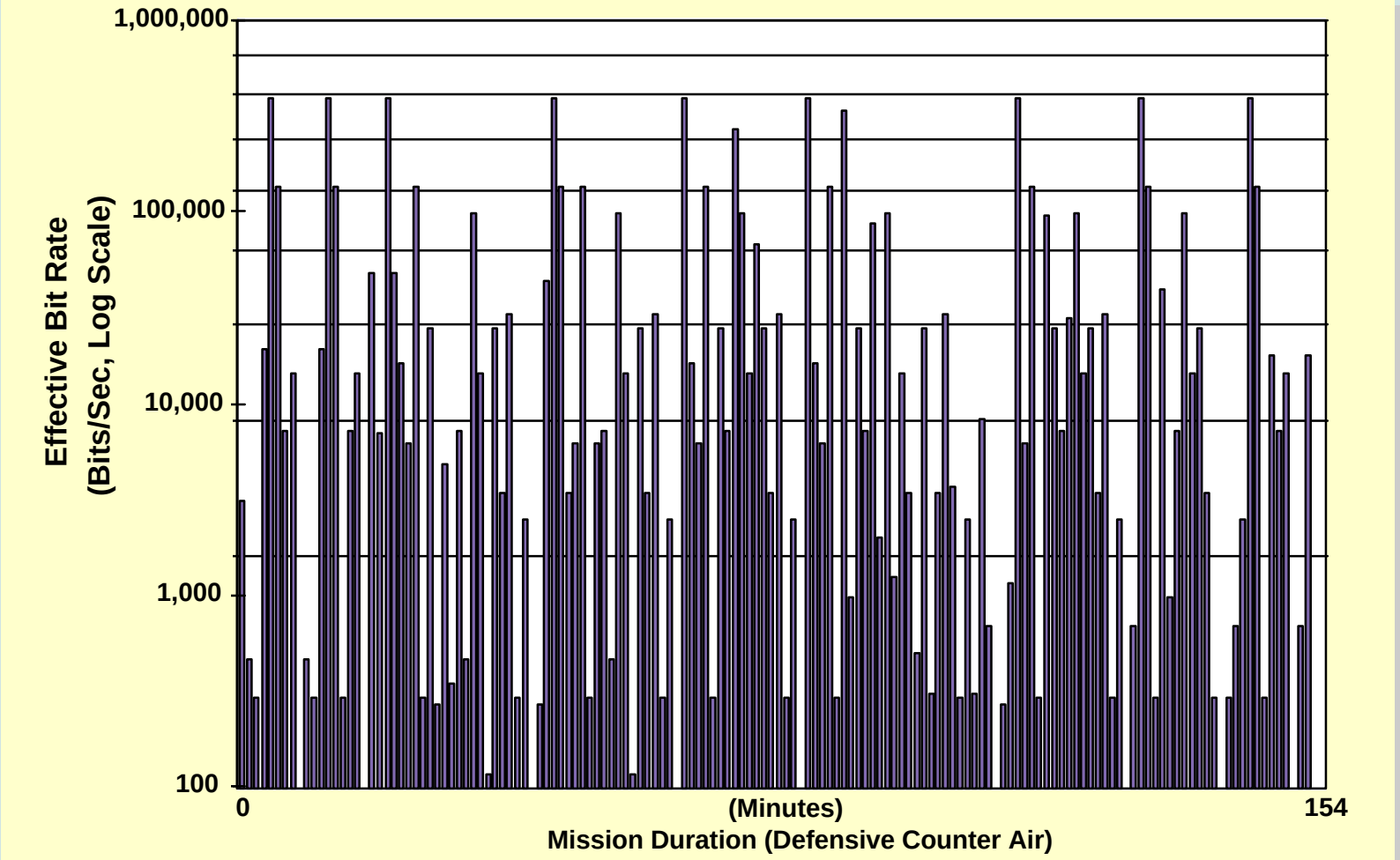
Near-Term Candidates

F-16 Bandwidth Requirements

F-16 Bandwidth Requirements…CY2000

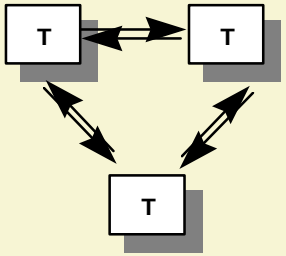
Category	Required Bit Rate Mbits/Sec		Quantity in Reference Arch	Total Bit Rate Required		Quantity in Near Term System	Total Bit Rate Required	
Basic F-16	5		1	5		0.2	1	
Download Picture to JASSM	7.4		1	7.4				
Change Map Scale	7.4		1	7.4		1	7.4	
Real-Time Video to Displays	45.3		6	271.8				
Air-to-Air Radar Improvements	0.09		1	0.09		1	0.09	
ESM Sensor	0.5		1	0.5				
Imaging Sensor (FLIR/SAR/GM)	45.3		3	135.9		3	135.9	
Air Vehicle Systems	1		1	1				
Data Link	0.5		1	0.5		1	0.5	
Helmet Mounted Display	0.2		2	0.4		1	0.2	
Cockpit I/O	0.25		1	0.25				
Video Recording (n R/T Videos)	45.3		7	317.1				
				747 Mb/sec			**145 Mb/sec**	

Mission Requirements Indicate A Need for Increased Network Bandwidth

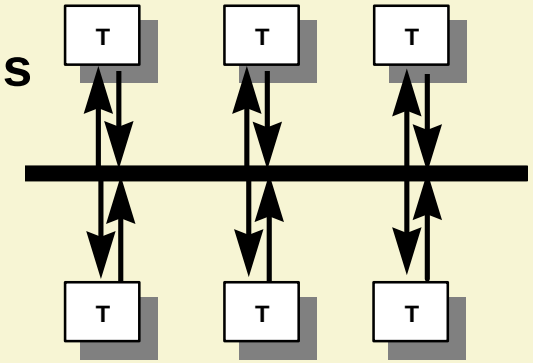


Network Topology

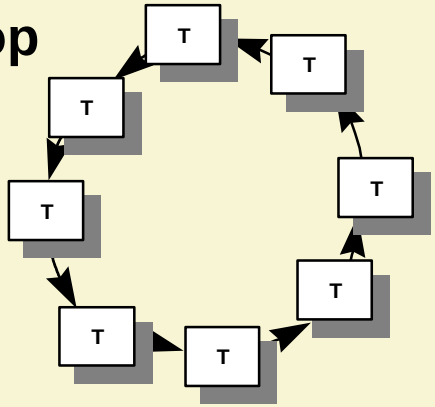
- Point-to-point or Mesh



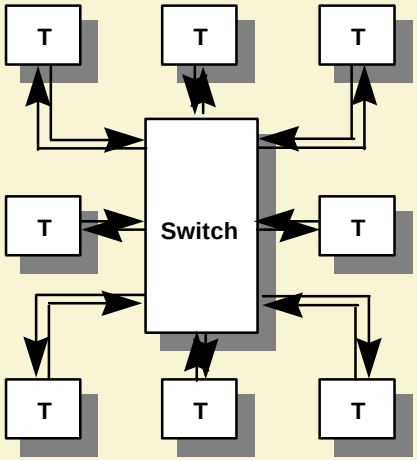
- Bus



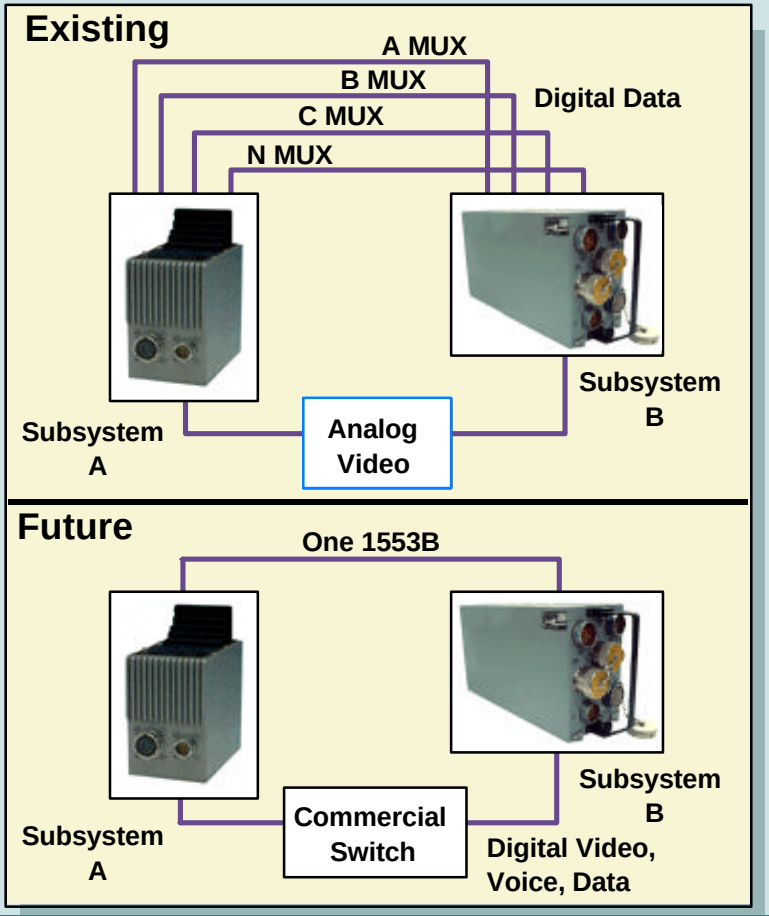
- Loop



- Switched



Increasing Network Bandwidth Is A Key Enabling Technology



Problem:

- Bandwidth Limited
- Linear Growth in Buses
- Exponential Growth in Memory and Throughput
- Limited by Physical Wiring
- Software Cost Prohibitive
- Multiple Unique Networks

Alternative:

- Mine Existing Wiring Bandwidth
- Insert Commercial Network
- Migrate Modified LRUs from 1553B to COTS Network Open Systems Architecture
- Define Process for COTS Insertion into Legacy LRUs
- Incrementally Upgrade SW/HW
- Single Common High Speed Net.

A "Cray-in-the-Box" Is No Good Unless The Data Can Be Moved Out

LRU	*Line Replaceable Unit*
COTS	*Commercial Off-the-Shelf*
SW/HW	*Software/Hardware*

Technology Comparison

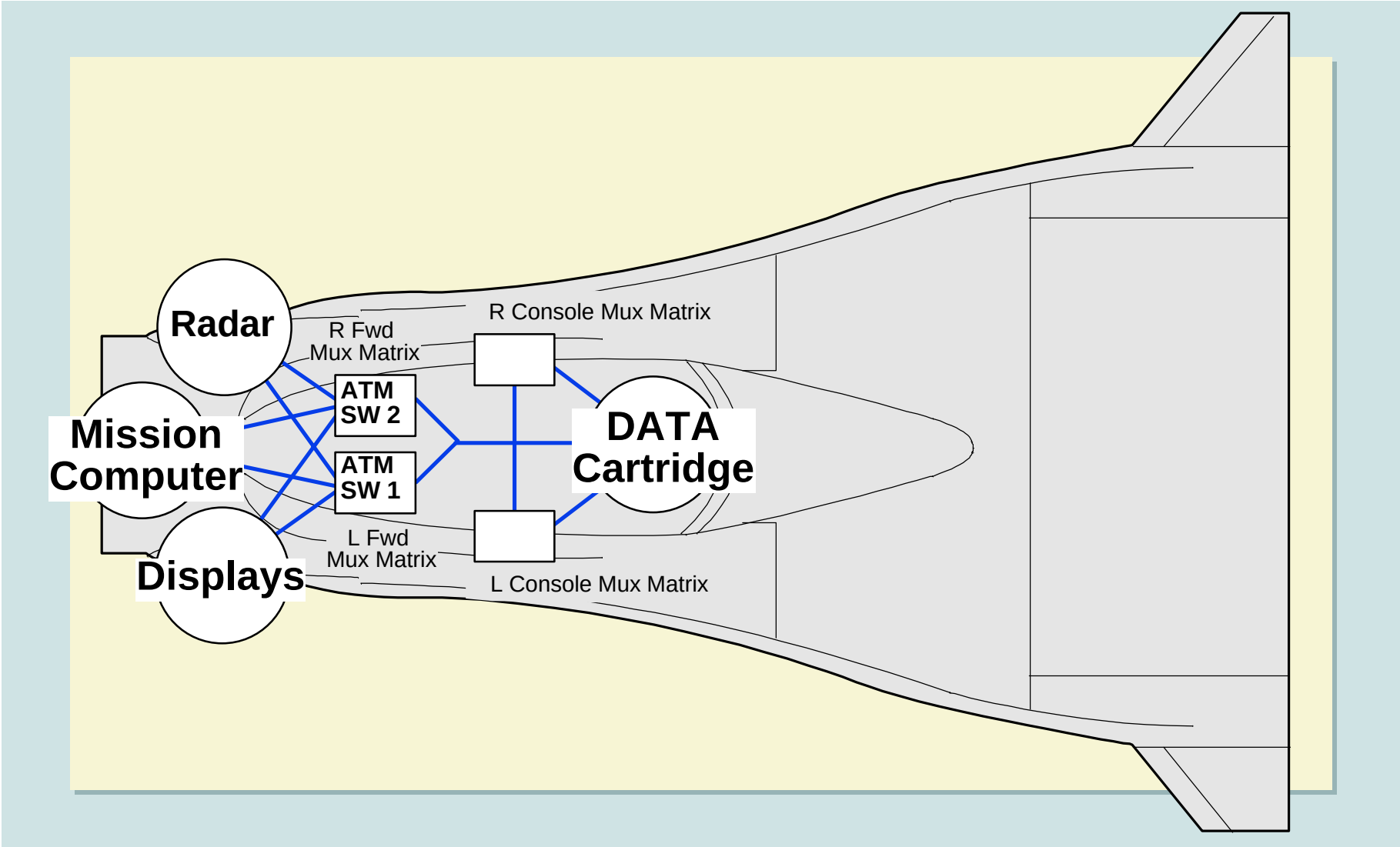
Measures	Availability (Yes/No)	Maturity of Standard (Used 1, Not Used 3)	Media Type (Fiber, Coax, STP)	Effective Bandwidth (bits/sec)	Predictability (Yes/No)	Topology Type	Cost Risk (Low, Med, High)	Producible (Yes/No)	Maintainable (Yes/No)	RTOS Software (Yes/No)	F-16 Aircraft Most Likely Protocol
	Protocol / Benchmark Metrics										
WDM	No	3	FO	FO >10 G	Yes	Bus+	High	Yes	No	No	Wave Division Multiplex (IRAD)
ATM	Yes	1	ALL	FO >10G Cu 60M	Yes	SW	Med	Yes	Yes	Yes	Asynchronous Transfer Mode OC-3c, 155Mbps (STS-3c)
FC	Yes	1	ALL	FO 800M Cu 30M	Yes	Loop	Med	Yes	Yes	Yes	Fibre Channel 1G FO Loop, STP CDDI
FW	Yes	2	STP+2	Cu 200M 4.5m limit 4+2pwr	Yes	Chain	Med	Yes	No	No	Firewire (IEEE 1394-200MB/s)
GbEth	Yes	2	All	FO 300M Cu 20M	No	SW	High	No	No	No	Gigabit Ethernet FO 1G or STP Fast Ethernet
1553B	Yes	1	Coax, STP	Cu 800M	Yes	Bus	Low	Yes	Yes	Yes	Mil-Std-1553/B

Assessment

- **Fibre Channel Is a Fairly New Standard and Its Persistence Is Unknown**
  - **Currently, Switches Are Not Available for Fibre Channel**
  - **Software Extensions Required for Real-Time Operations**
- **ATM Is Firmly Entrenched in the Telecommunications Industry**
  - **Provides Support and a Growth Path**
- **ATM Demonstrated on Existing 1553 Cable**
  - **Provides Retrofit Opportunities to Existing F-16s**
  - **Only Minimum Group A & B Changes Needed**

A Switched ATM Network Is the Baseline for Near-Term F-16 Programs

Production F-16



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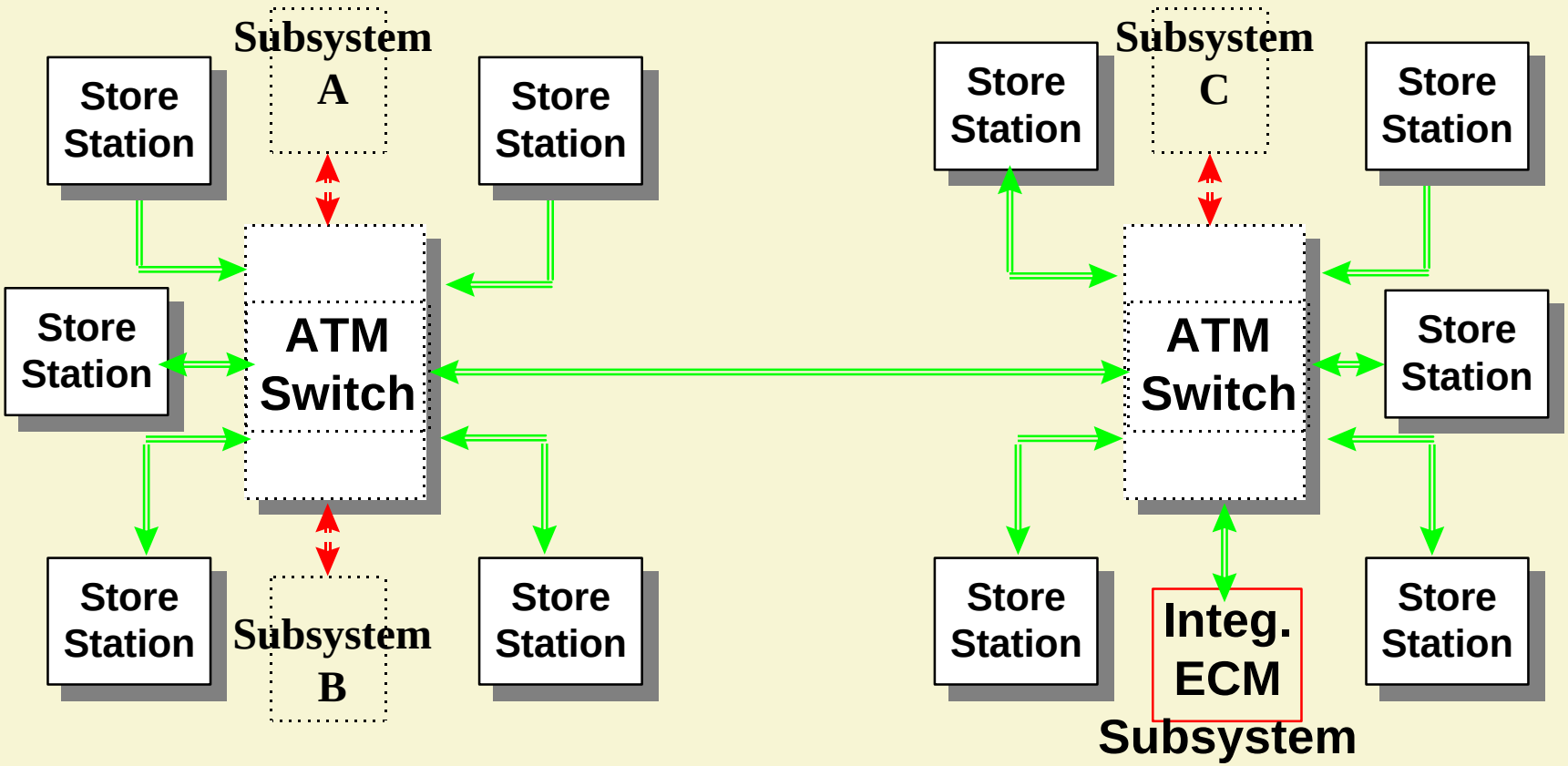
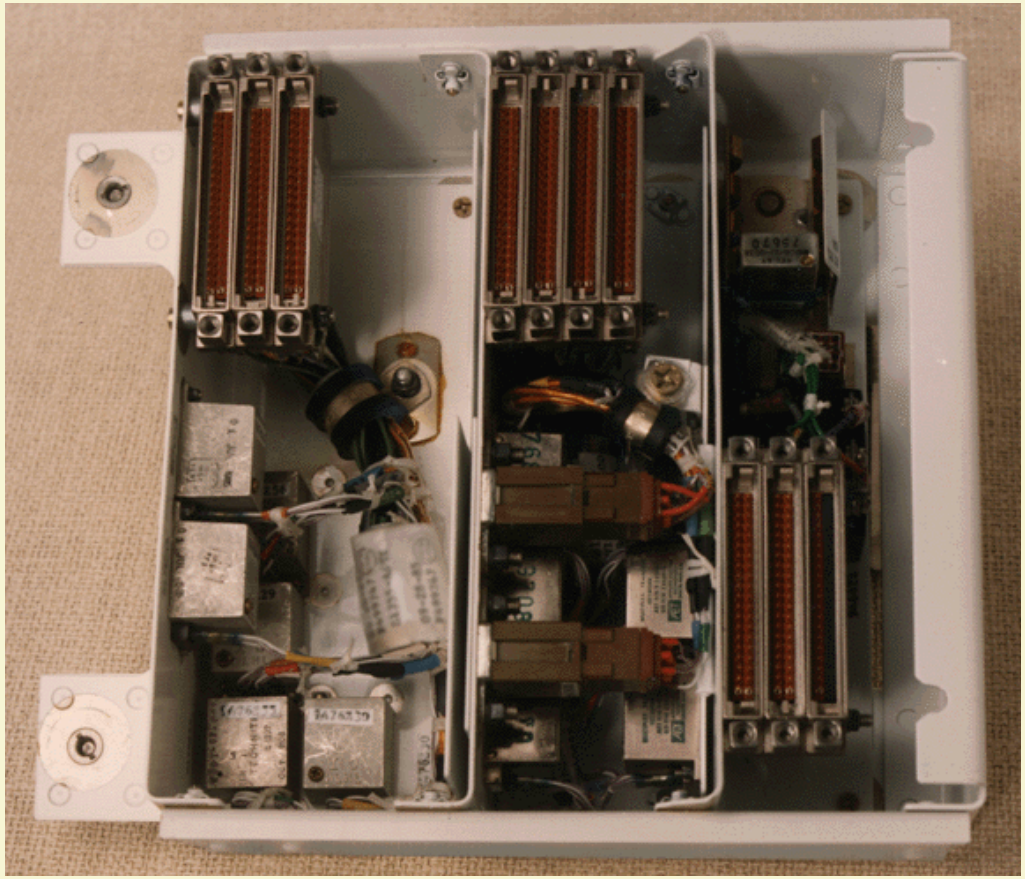
Proposed F-16 Weapons Interface

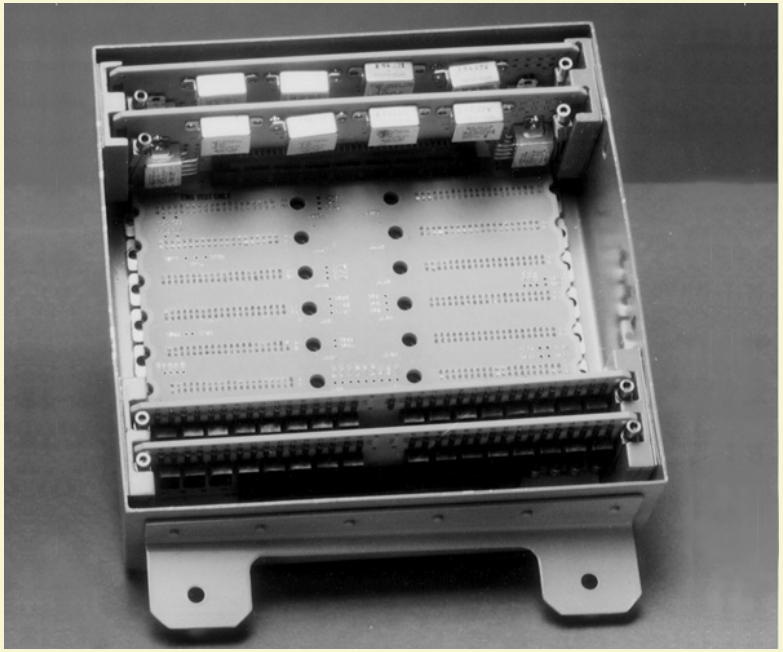
- Optical Fiber Added to All Store Stations
- Termination at Switch Location
- Network Terminals Added to Subsystems in Future Modifications
  …Switch to be Located in Mux Matrix Assemblies



Typical Block 30 MUX Matrix Assembly With MIL-STD-1553 Termination



Existing Multiplex Assembly Enclosure



Chassis: 8.2" x 8.1" x 3.0"

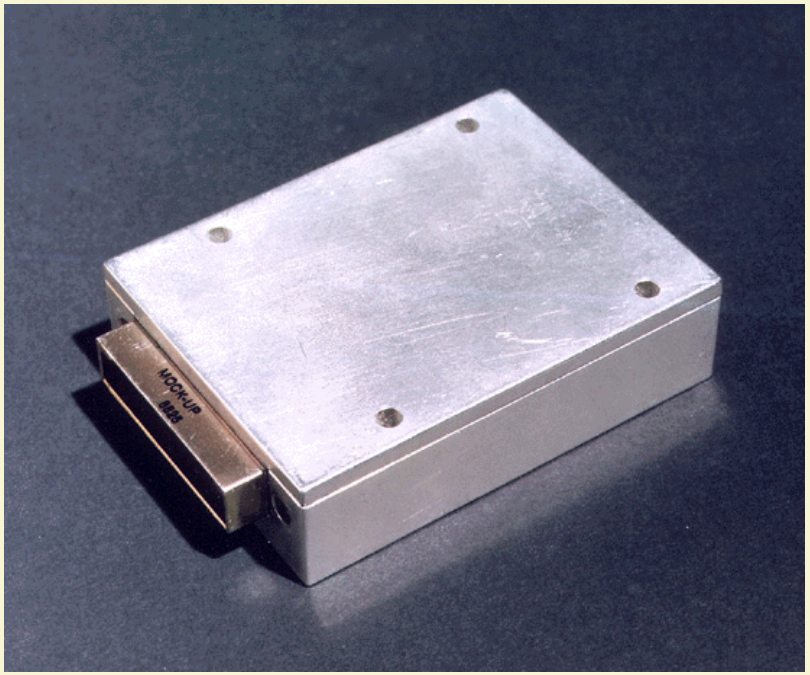
Equipment Description

Discrete Signal and Power Interface Switching Network

Functions/Features

- Mother Boards
  - 8 and 14 Layer
- 2 Relay Daughter Cards
  - 6 Relays Per Card
- 2 MUX Daughter Cards
  MIL-STD-1553 Studs for 4 Buses, 8 RTs
- Components
  - 16 Transformers
  - 33 Resistors
  - 4 Tranzorbs
- Interconnections (J-Box)
- Through Hole Technology PCBs

Existing Coupler Modules Are In Use In Legacy Aircraft



Chassis: 2.5" x 0.8" x 3.0"

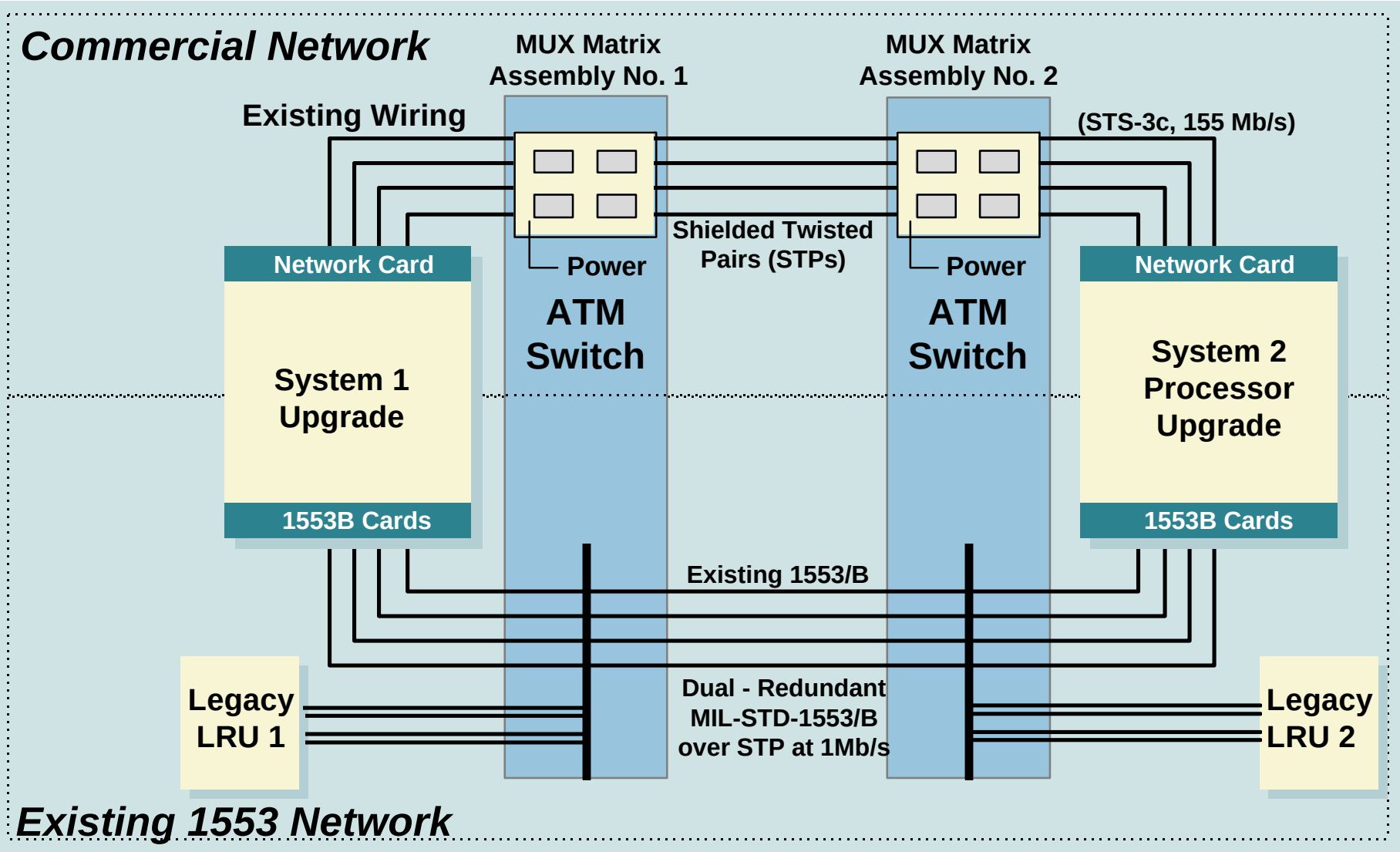
Equipment Description

Enclosure Provides Impedance Matching and Fault Isolation for the MIL-STD-1553 Data Bus, Can Be Housing for Network Switch

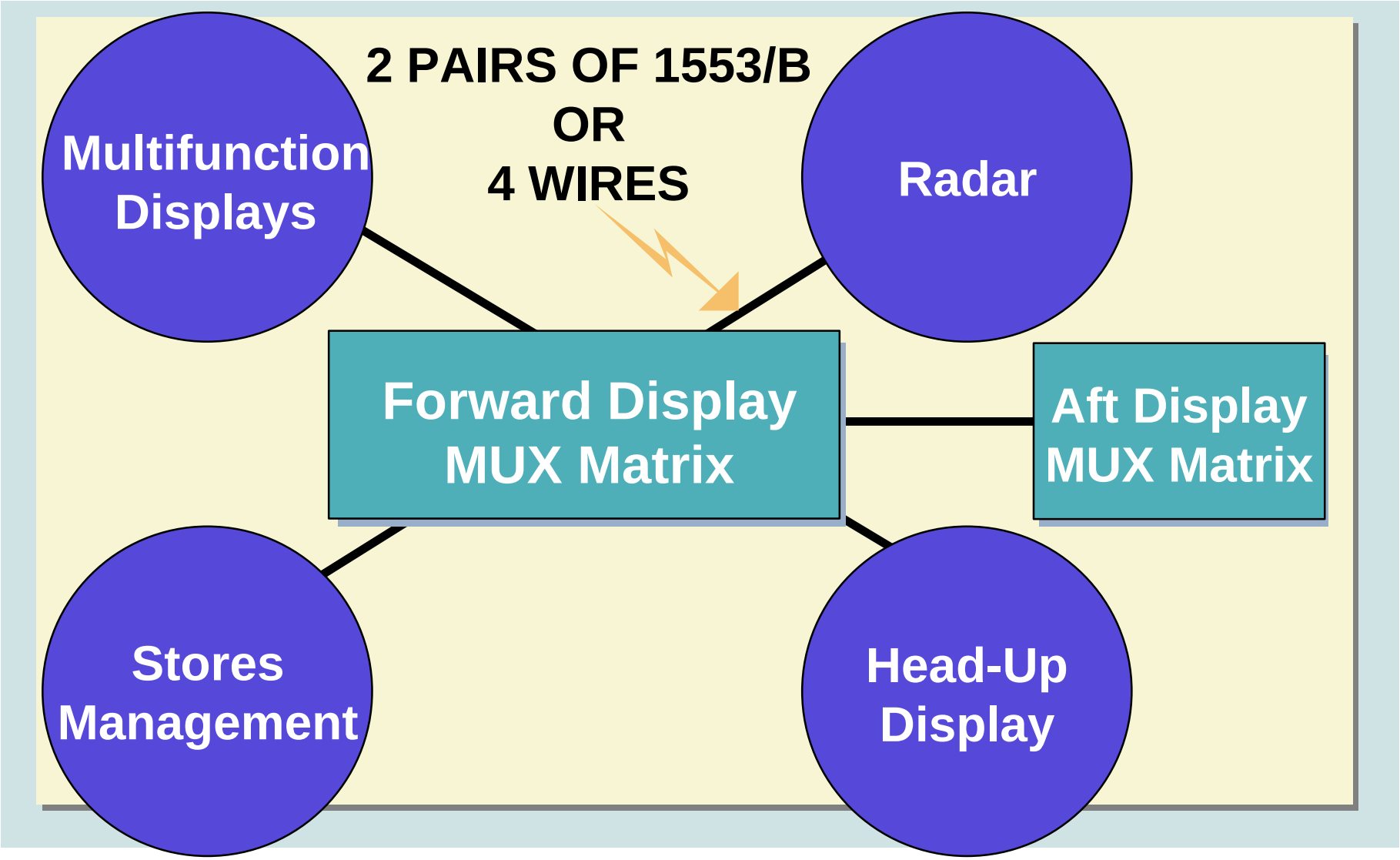
Functions/Features

- **High Voltage Protection for Media**
- **Thermoplastic Chassis**
- **Through-Hole Technology Printed Circuit Board**

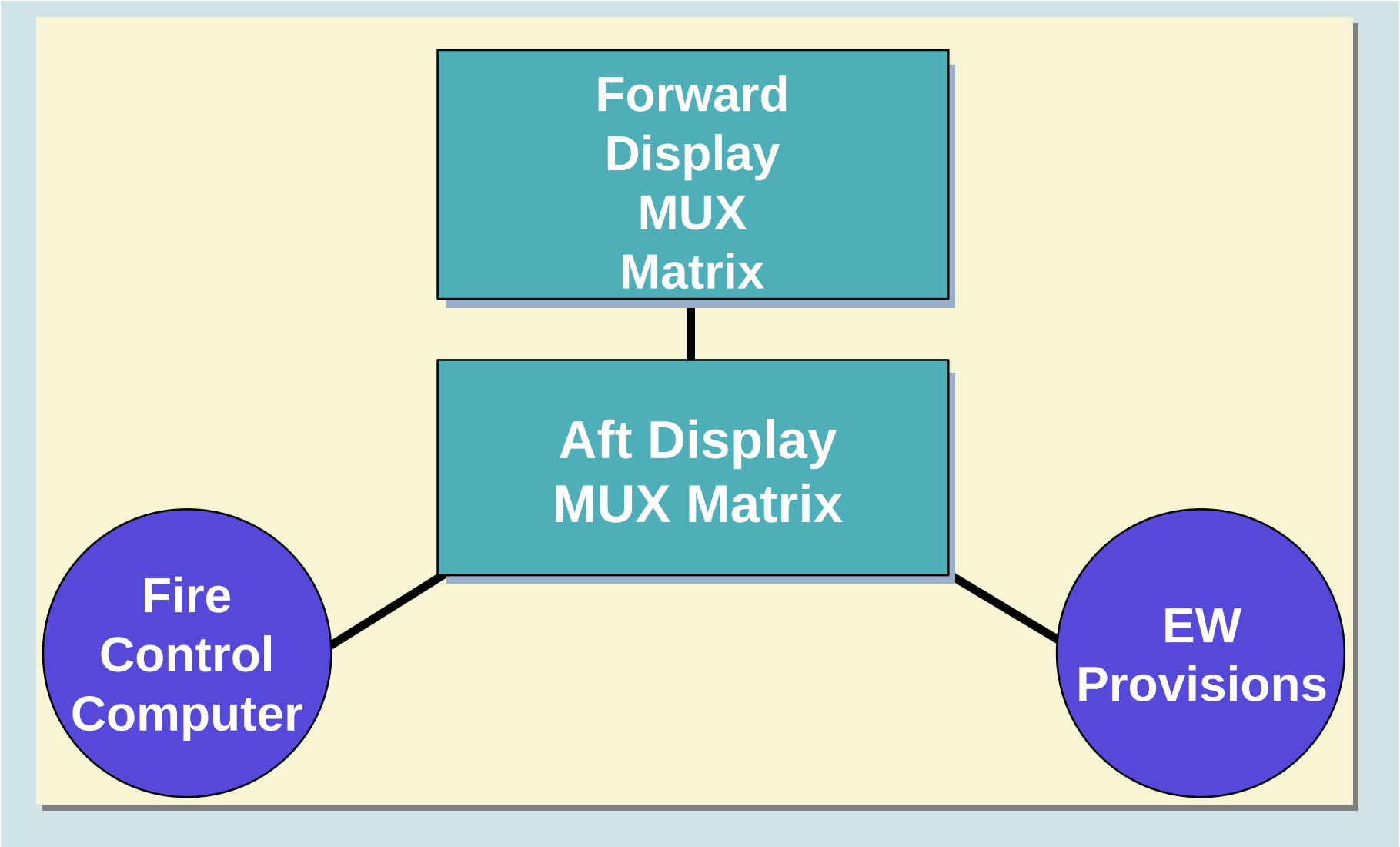
Existing Mil-Std-1553/B Wiring Can Be Used to Increase Network Bandwidth



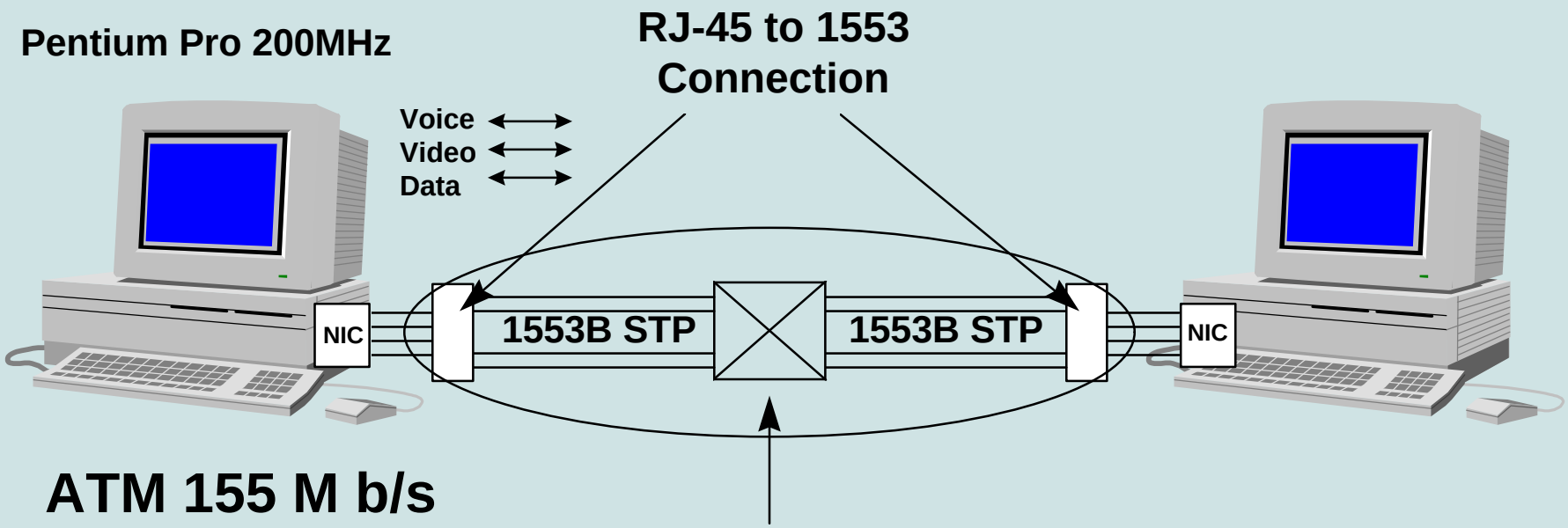
Display-MUX


2 PAIRS OF 1553/B
OR
4 WIRES
Multifunction Displays
Radar
Forward Display MUX Matrix
Aft Display MUX Matrix
Stores Management
Head-Up Display

Display-MUX AFT Assembly



Benchmark Configuration



ATM 155 M b/s

Fore Systems PCA-200E

or

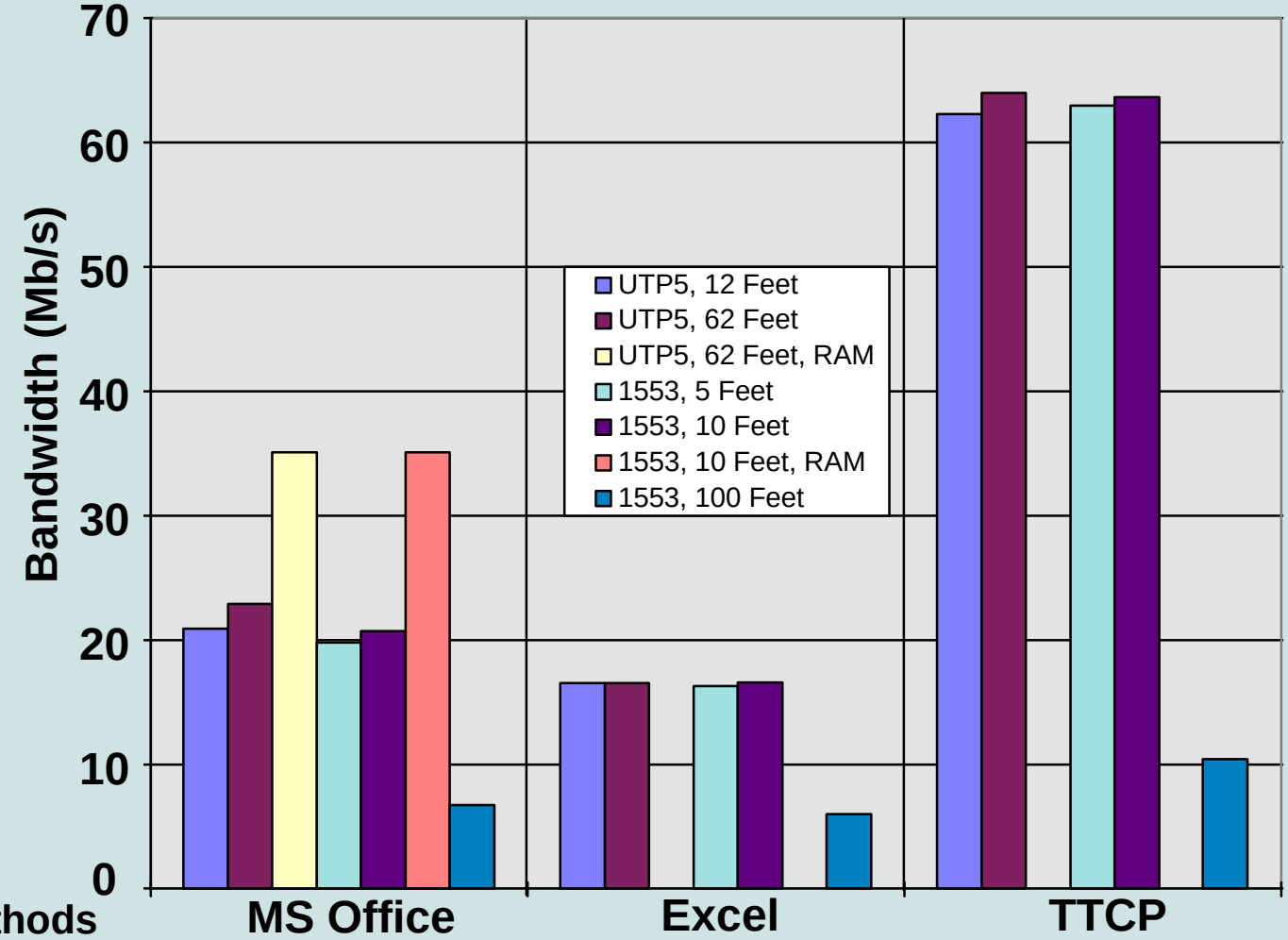
Fast Ethernet 100 Mb/s

3COM 10/100BT

1553 MUX Matrix Assembly (Cross Over Cable Optional)

NIC	*Network Interface Card*
ATM	*Asynchronous Transfer Mode*
MUX	*Multiplex*
STP	*Shielded Twisted Pair*

Benchmark 100 BaseTX Ethernet Over 1553 Cable

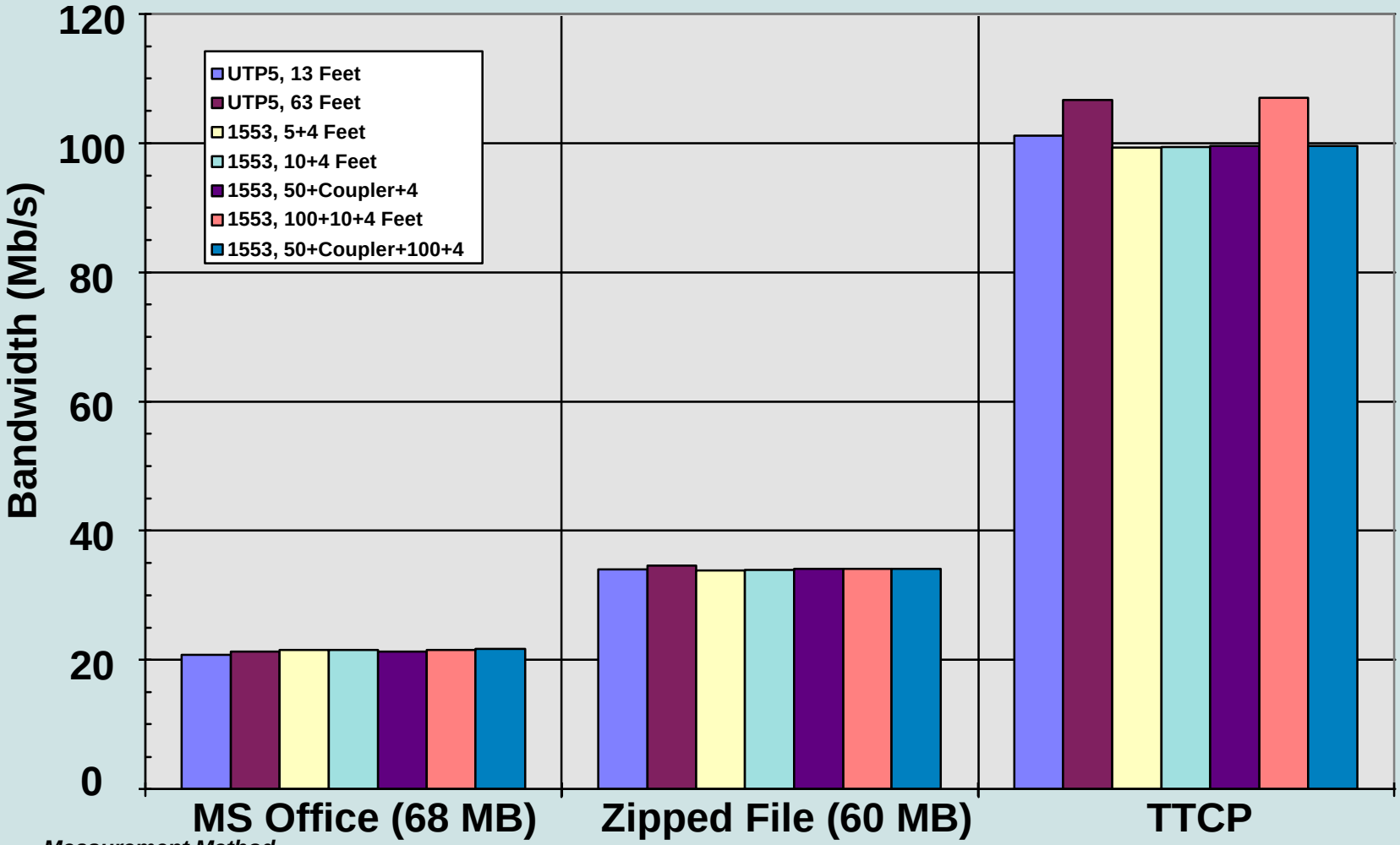


Test Methods

- *Measurement Method*
  - √ *Standard UTP Category 5 Cable Compared to 1553 Cable*
  - √ *Differing Cable Lengths*
    - –*UTP5 (12 and 62 Feet)*
    - –*1553 (5,10,100, and 200 Feet)*
  - √ *No Impedance Matching for 1553 Cable*
  - √ *Average of 5 Runs*
  - √ *Large Directory and Small File Transfers Under Windows NT*
    - – *MS Office Directory (68 MB / 32 MB)*
    - – *MS Excel Single File (5 MB)*
  - √ *TTCP Program, Standard Network Test*

UTP Unshielded Twisted Pair
TTCP Test Transmission Control Protocol

Benchmark 155 Mbps ATM Over 1553 Cable



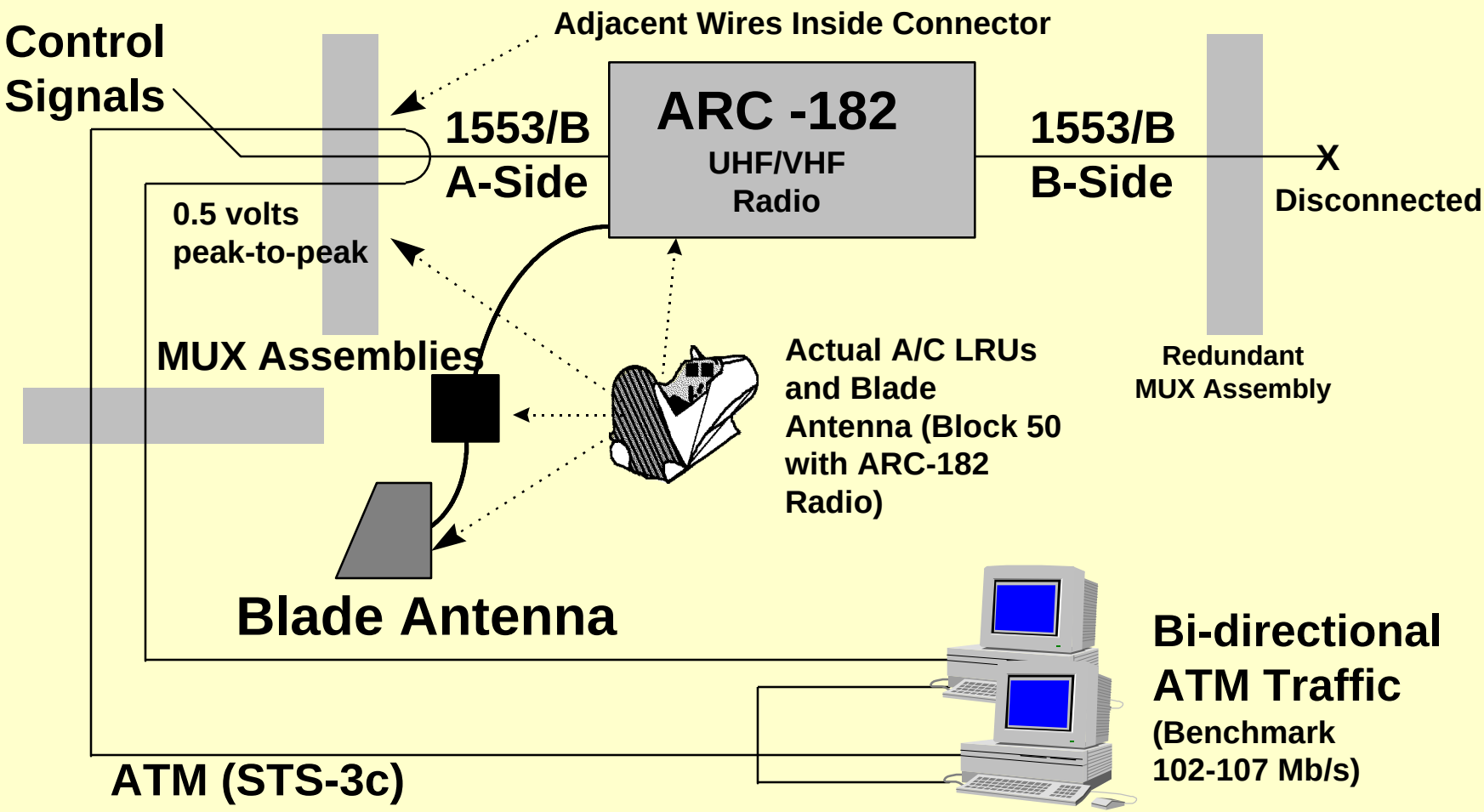
- *Measurement Method*
  - √ *Standard UTP Cat. 5 Cable Compared to 1553 Cable*
  - √ *Differing Cable Lengths*
    - *–UTP5 (13 and 63 Feet)*
    - *–1553 (5,10,50,110,150 + 4' for Converters) & Couplers where Applicable*
  - √ *No Impedance Matching for 1553 Cable*
  - √ *Average of 5 Runs*
  - √ *Large Directory and Single File Transfers Under Windows NT*
    - – *MS Office Directory (68 MB)*
    - – *Zipped Single File (60 MB)*
  - √ *TTCP Program, Standard Network Test*

Benchmark Conclusions

- **1553 Cable Works for Both ATM and Fast Ethernet**
  - **UTP5 and 1553 Cable Results Nearly Identical**
- **Limiting Factor for File Transfers is Operating System Overhead and Hard Disk Speed**
- **Impedance Matching is not a Factor Except for Long Cable Runs (Ethernet > 100 feet, ATM > 150 feet)**

Existing Cable is Not an Issue in the Design of a Faster Network

ATM Test Configuration



STS Synchronous Transfer Signaling

ATM Test Setup

- **Conduct Experiments Using Actual Hardware and Operational Equipment**
  - ✓ F-16 ITS Block 50 Station with ARC-182 UHF/VHF Radio
  - ✓ Actual Blade Antenna Configurations
  - ✓ Actual RFI/EMI Noise Environment (All other F-16 LRUs and MIL-STD-1553/B Traffic, Power, Controls, etc.)
- **Perform Functional Tests Using UHF/VHF Radio**
  - ✓ Receive / Transmit on Authorized Channels
    - ➡ UHF 284.1, 292.5 MHz, VHF 123.575, 123.4 MHz
  - ✓ Subjective Evaluation of Changes in Signal Quality
  - ✓ Monitor Multiple UHF/VHF Channels for Degradation
- **Load ATM Network with Maximum Traffic**
- **Measure Cross-Talk on Adjacent Wires**

ATM Test Results

- **Subjective Evaluations**
  - ✓ ***No Change in Signal Quality in VHF or UHF***
  - ✓ ***No Change at Cockpit or at Remote Site***
  - ✓ ***No Interference on Monitored Channels***

- **Objective Evaluations**
  - ✓ ***No Cell-Drops or Loss of Data on ATM Network***
  - ✓ ***Crosstalk Measurement - Peak-to-Peak Voltage***
    Average Signal Noise Increase: 18-20 mv
    Measured Noise (Before ATM Applied): 39-42 mv

RFI and EMI Can Be Managed

ATM Test: Post Analysis

- **Cable Noise On the Aircraft is Expected to Be Less Than the System Integration Lab (SIL) Test Station**
  - ✓ ***Shields of the 1553B Cables Inside the Test Station Were Ungrounded for Ease of Connection to the Station***
  - ✓ ***In the F-16, Both Ends of MUX Cable Shields Are Grounded***
  - ✓ ***In the F-16, MUX Cable is Grounded at the Backshell of Every Disconnect***
- **Actual F-16 vs the SIL Test Station:**
  - ✓ ***The Average Noise Measured on the F-16 Aircraft Could Be 1/3 Lower Than That Measured on STS***
  - ✓ ***The Resulting Average Crosstalk Noise is Expected to be 1/2 that Measured on the STS***

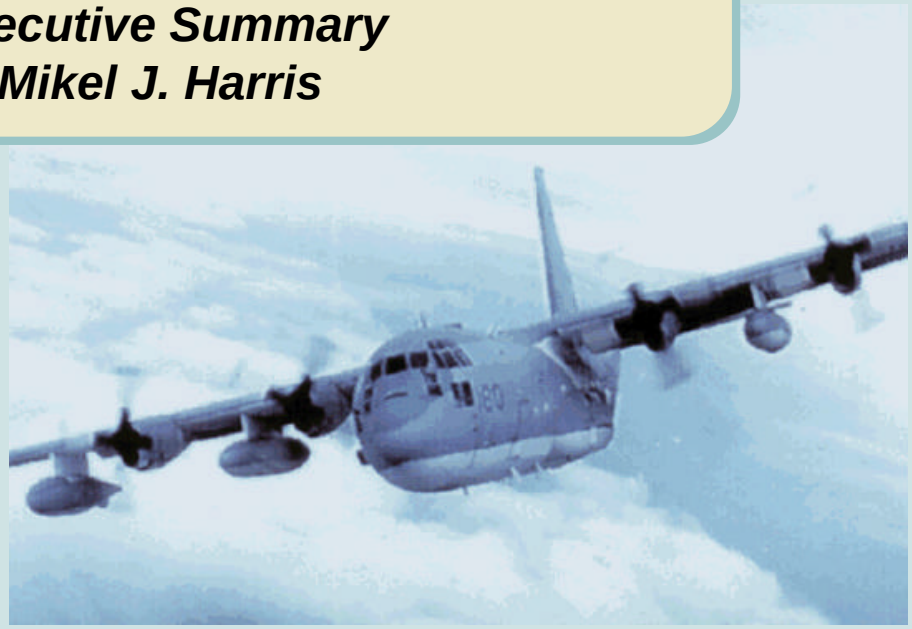
Summary

- **Legacy Aircraft Are Implementing Open System Standards**
  - ✓ Transition to Open System Standards for Legacy Aircraft Avionics has Started and Will Accelerate (LRUs, Networks)
  - ✓ DoD Acquisition Processes and Strategies Are Working on Legacy Aircraft Product Lines
- **Evolving Fielded Weapon Systems to Open System Approaches Is the Challenge**
  - ✓ Need Champions in the Logistics Support Communities
  - ✓ Need Sustained Development Funding for Aircraft Infrastructure Evolution (Flight Test, Tech Demos)

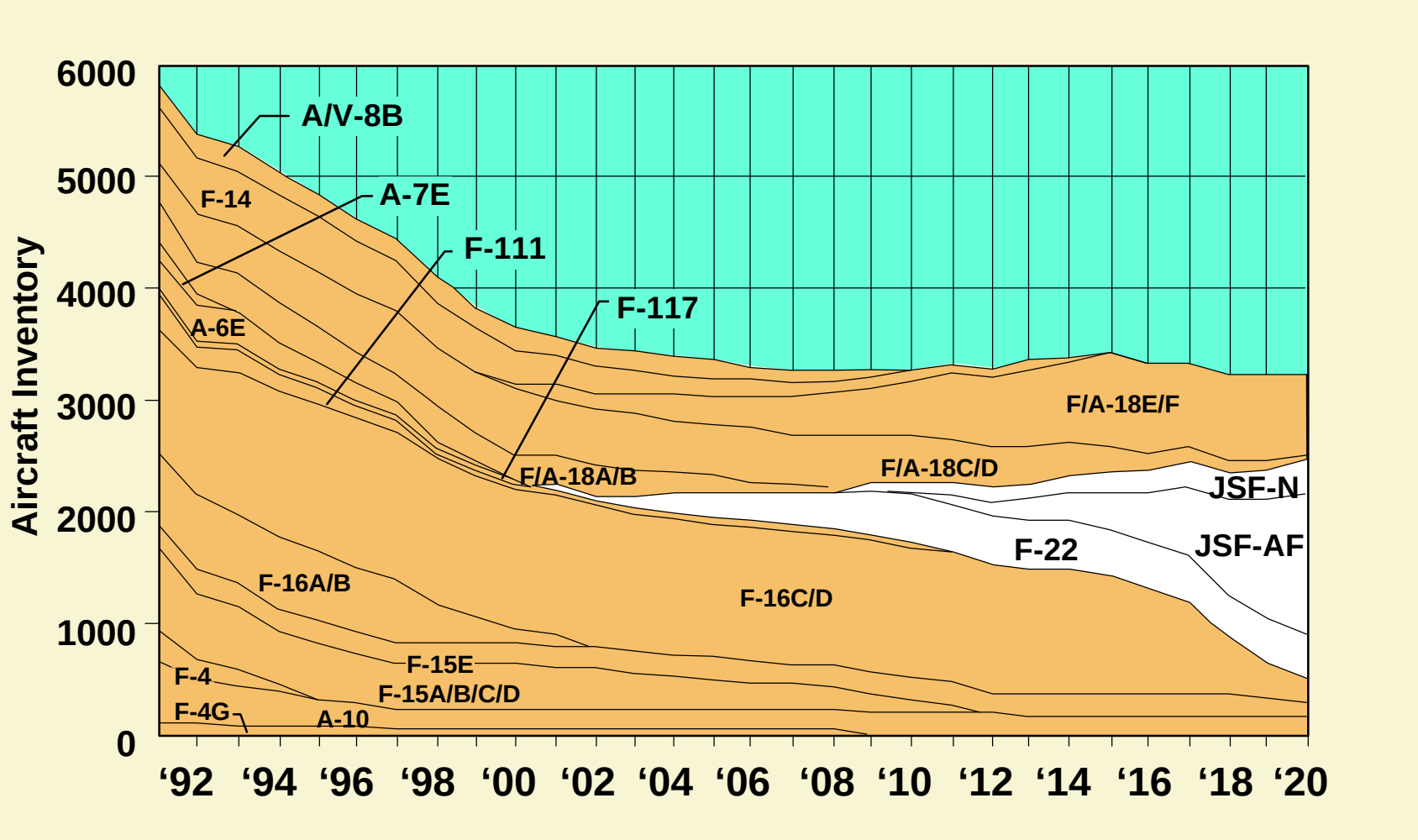
Open System Architecture for Legacy Aircraft

Executive Summary

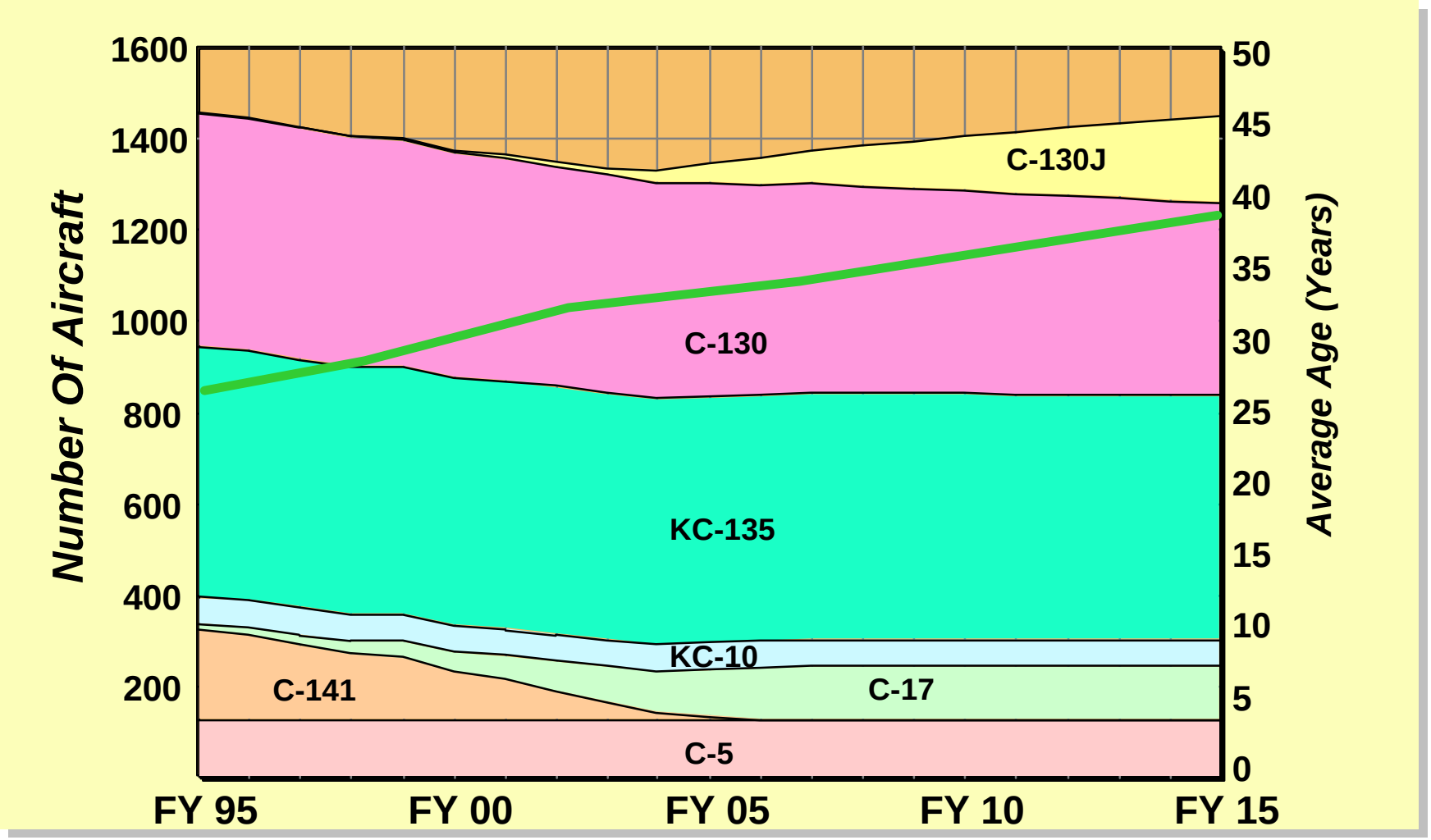
Mikel J. Harris



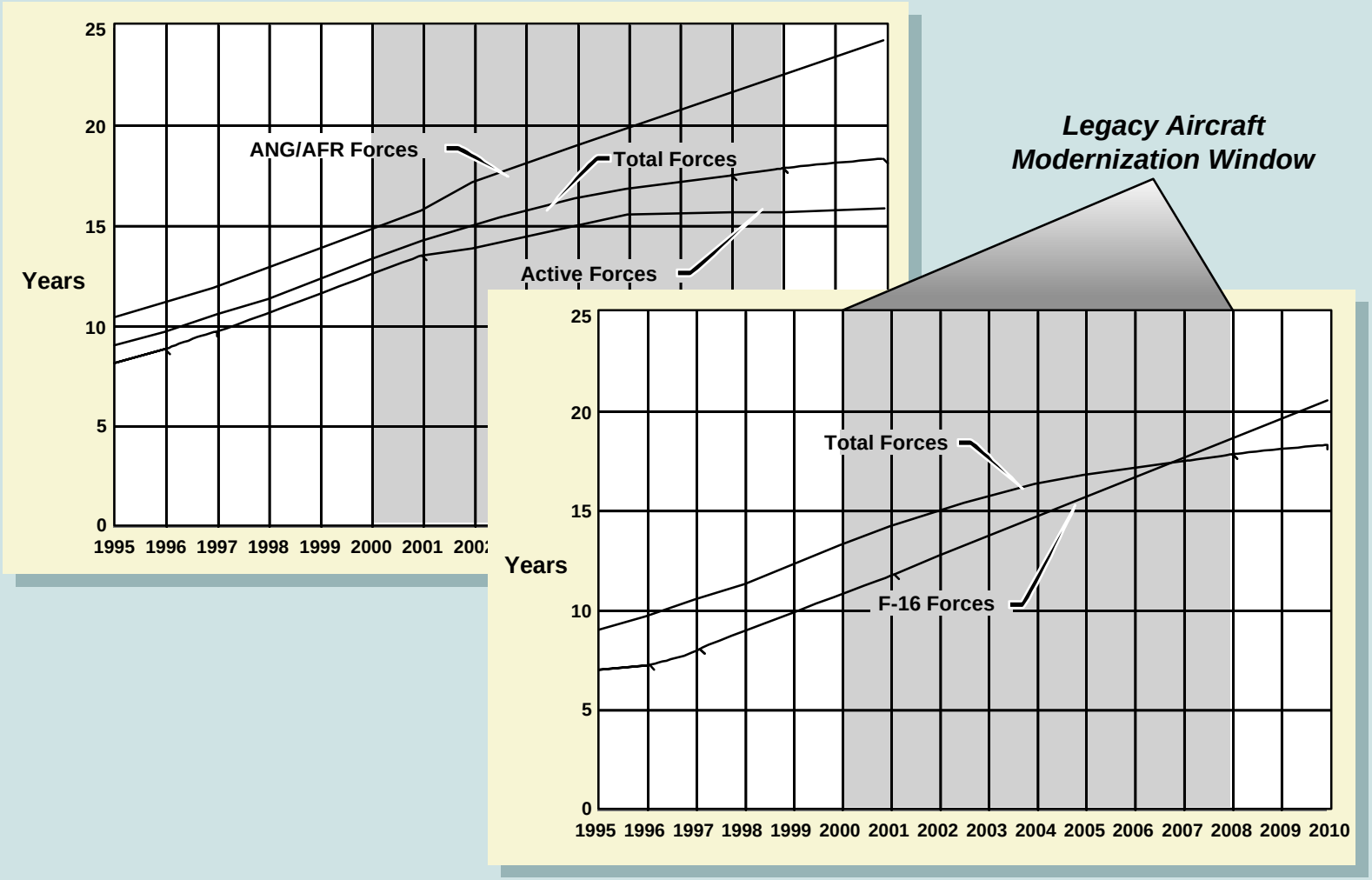
The Majority of Our Tactical Force Through 2020 Will Be Legacy Aircraft



Strategic & Tactical Airlift Inventory Projections



F-16 Dominates the USAF Force Structure Until JSF Introduction



Avionics Upgrade Environment

- The User Must Accomplish More With His Fleet of Existing Aircraft
  - Limited Funds and Aging Fleet (Average Age of All Fighters 18yrs @ 2010)
- Modifications Must be Incremental, Modular, and Rapid
  - Available Funding Profiles Will Not Allow Major Physical Upgrades
  - Politics are the Enemy of Long Programs
- We Must Work Within the Aircraft Physical Architecture (Wiring, Cooling, etc.)
  - Physical Changes Drive Mod Cost Exponential (Kills Program)
- No Software Modification is Minor
  - Test and Validation are the Cost Drivers (Not Design and Coding)
- Logistics Tail Plays Key Role in Upgrade/Mod Decisions (Have Final Vote)
  - The Cost Here Continues Throughout the Life Cycle (Key Words - 1 Level Maintenance)
- Commercial Market Drives the Electronics Industry (Not DoD)
  - We Must Work Within This Environment for Affordability
  - Key Element is Rapid Commercial Parts Obsolescence (Not Environmental)
- We Must Work Within the Avionics Vendor Chain of Capability
  - Vendors Must Protect Their Ownership of Functionality (i.e. CNI, EW, Radar, etc.)
  - DoD and Primes Must Prevent “Vendor Vanish”

Open System Studies

Studies Were Directed Towards Legacy Avionics Architecture…

Studies and Analyses	Summary of Preliminary Results
Global Reach Open Network	Aircraft Weapon Systems and Support Systems Should Be Directly to the Military Networks for Ground Operations Repair, Maintenance, and Support
Common Real Time Operating System Interface for Software	Commercial Real-Time Operating Systems Have Been and Can Be Adapted
Open Network Architecture Protocols	Asynchronous Transfer Mode and Fibre Channel Are Interim Network Solutions (Integrated Sensor System Program to Determine Radar Protocols)
Open Standards and Interface	Commercial Open Standards Are Available to Replace Existing LRUs

…to Evolve Aircraft Weapons Systems to Open Systems Standards.

Conclusions and Recommendations

- **The Big Pay-off Is in Opening the Federated Architecture**
- **DoD Investments Are Required**
  - Open Standard for Mil-Std-1553 Emulation on COTS Network
  - Open Interface Standard for Peer-to-Peer Military Protocols
  - Validation and Flight Test
- **The Driving Cost Factors Are Group A Aircraft Changes and the Software Impacts to Existing Avionics**
  - Must Address How to Minimize These Costs for Each Aircraft
  - Configuration
  - Develop an Upgrade Plan for Modernization