BOEING

DEFENSE & SPACE GROUP

Scaleable Optical Real-Time Interconnect (SORTI)

Open Systems-Joint Task Force

WALCOFF AUDITORIUM

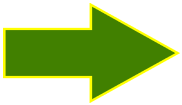
29 May 1996

FAIRFAX VA

Michael Dorsett
NAWC AD
Michael S. Foster
Boeing Defense & Space, Project Lead

BOEING
DEFENSE & SPACE GROUP

OUTLINE



BACKGROUND

- **TECHNICAL DETAILS**
- **FY97 RECOMMENDATIONS**
- **SUMMARY**

BOEING
DEFENSE & SPACE GROUP

BACKGROUND

GENERAL PROBLEM:

- Avionics Life-Cycle costs are rising exponentially as funds decrease
- Current architectures fail to meet future performance, real-time, scalability, and reliability rqmts
- Existing electrical technolgies require proprietary, complex, high power solutions with high module I/O densities and little scalability

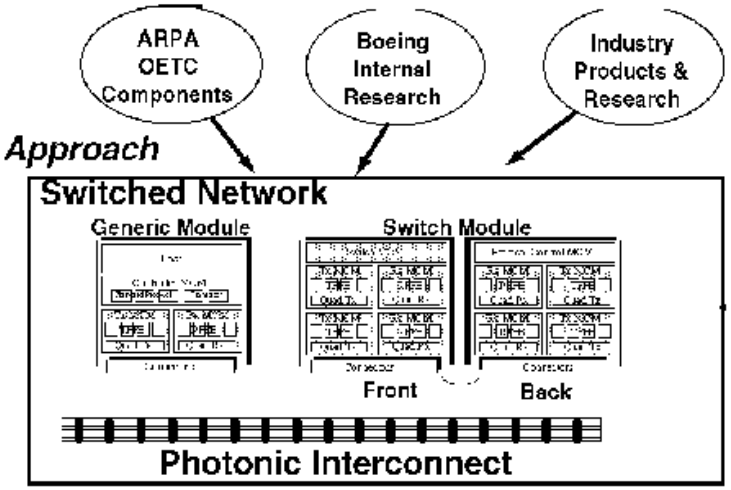
SOLUTION:

Boeing Defense and Space will:

- design, assemble, test, and demonstrate a Fibre Channel based connection-oriented switch fabric
- demonstrate real-time scheduling using H/W based priority and preemption
- demonstrate processor to/from memory transactions

BENEFICIARIES:

- F/A-18
- F-15
- AH-64
- Joint Strike Fighter
- Joint Airborne Sigint System (JASS)
- Joint Airborne Sigint Arch (JASA)
- Guardrail System II
- SHARP



BOEING
DEFENSE & SPACE GROUP

WHY FIBRE CHANNEL?

- Good Potential for Large Market Base from which to Leverage COTS Products.
- Base Standard can Still be influenced
- Core Features/Functions In-Line with Basic Avionics Requirements
  - Extensions for Avionics are minor
  - Compatibility/Interoperability between Avionics and Commercial Derivatives

BOEING
DEFENSE & SPACE GROUP

FIBRE CHANNEL MARKET

Fibre Channel Market Size Estimate ($B)
(1994 and 1995 data actual sales)

Year	1994	1995	1996	1997	1998	1999	2000
Low	-	-	0.75	1	2	4	5
Probable	0.4	0.5	0.9	2	4	7	10
High	-	-	1.25	3.5	8	12	18

Data provided by Edward M. Frymoyer of emf Associates

BOEING
DEFENSE & SPACE GROUP

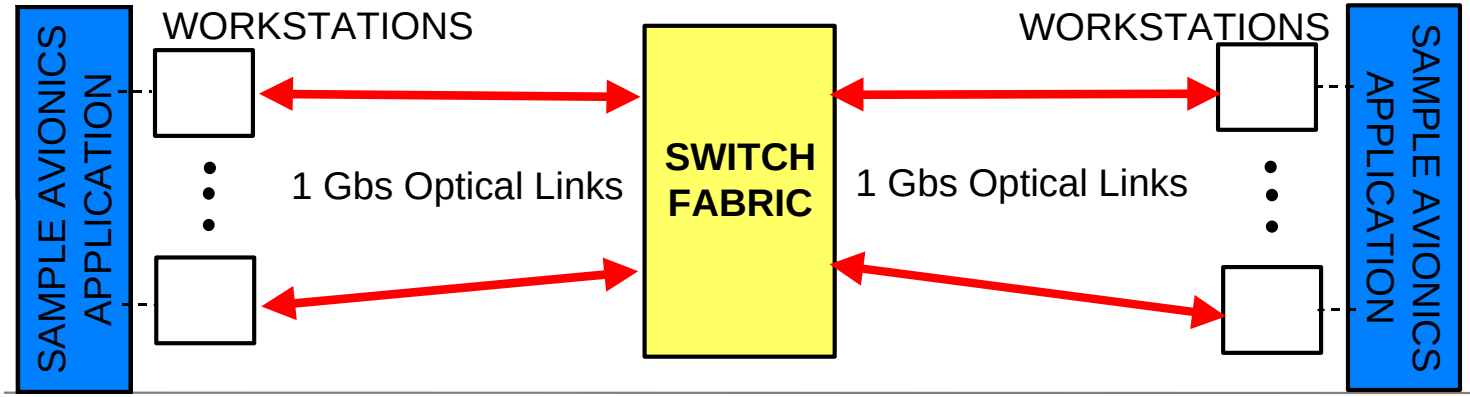
WHAT IS FIBRE CHANNEL?

- Bi-directional point-to-point serial data channel
- High performance
  - 1.06 Gbaud per direction now
  - 2.12, 4.24, 8.48 Gbaud specified in FC-PH-2, 3
- Loosely coupled (but can support shared memory)
- Scaleable (>16 million nodes, distances >10 km)
- Reliable (hardware error detection, recovery)
- Optical or electrical (coax, twisted pair)
- Topology-independent

BOEING
DEFENSE & SPACE GROUP

PROJECT OVERVIEW

OPEN SYSTEMS DEMONSTRATION



OPEN SYSTEMS STANDARDIZATION

- **ANSI X3T11 FIBRE CHANNEL AVIONICS ENVIRONMENT (FC-AE) WORKING GROUP**
- **FEATURES TO SUPPORT REAL-TIME COMMUNICATION**

PRIORITY	SECURE KEY EXCHANGE
PREEMPTION	ERROR PROCESS POLICY
MULTICAST	AVIONICS PROFILES
CLOCK SYNCHRONIZATION	

BOEING
DEFENSE & SPACE GROUP

OUTLINE

- BACKGROUND
- TECHNICAL DETAILS
- FY97 RECOMMENDATIONS
- SUMMARY

BOEING
DEFENSE & SPACE GROUP

DEVELOPMENT APPROACH

NAWC
NAVAL AIR WARFARE CENTER

Avionics Bottlenecks

Problem

Communications Limitations Driving Complex, Non-scalable, High Costs Architectures

Electrical Interconnect Limitations

Objective

LEAPFROG ELECTRICAL AVIONICS SYSTEMS TO REDUCE COSTS AND INCREASE PERFORMANCE

MAXIMIZE INTEGRATED MODULAR AVIONICS CONCEPT

Approach

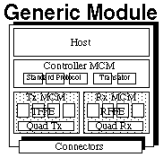
ARPA OETC Components

Boeing Internal Research

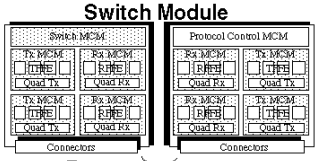
Industry Products & Research

Switched Network

Generic Module



Switch Module

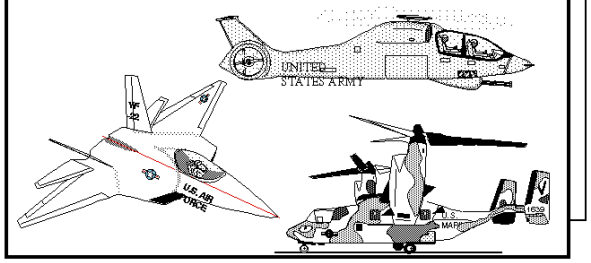


Photonic Interconnect

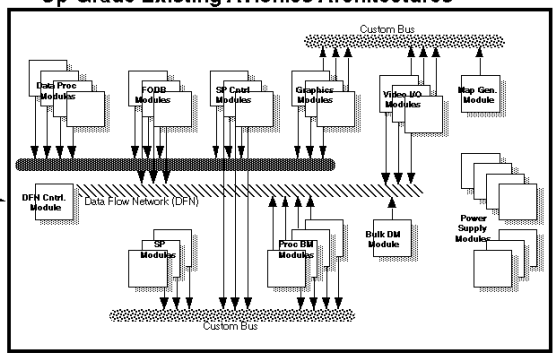
Dual-Use Next Generation Avionics

Commercial Avionics

Military Integrated Avionics



Up-Grade Existing Avionics Architectures



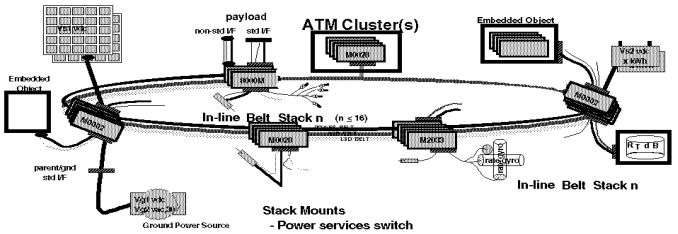
Scalable Photonic Interconnect Achieves Reduction in Avionics Size, Weight and Power with Increased Performance and Reliability

BOEING
DEFENSE & SPACE GROUP

INTEGRATED AVIONICS APPLICATIONS

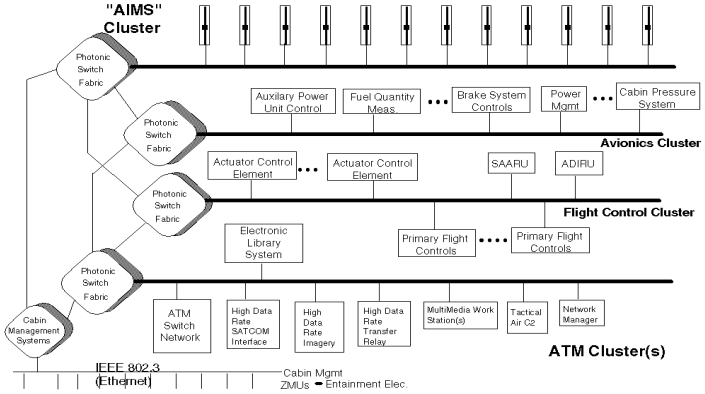
NAWC
NAVAL AIR WARFARE CENTER

Space Vehicles Garrison Belt

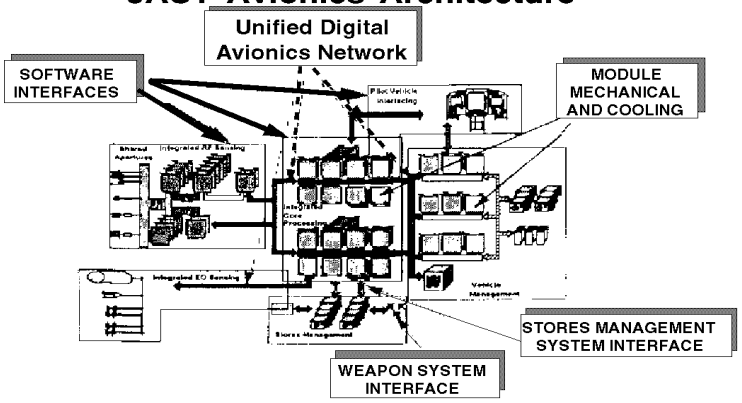


Stack Mounts
- Power services switch
- HSD BOIS (Tx, Rx, controller, switch, protocol control)
- LSD Serial digital (485, DR1773)
- Pool processor (general digital w/SVC, special)
- Memory array (RAM, ROM)
- A/DI (ADDAC, LoDI/O, HiDI/O, ref signal)
- Flight/Safety Critical A/DI (PVE DI/O Sequencer)
- ATM Cluster(s) (Communications)

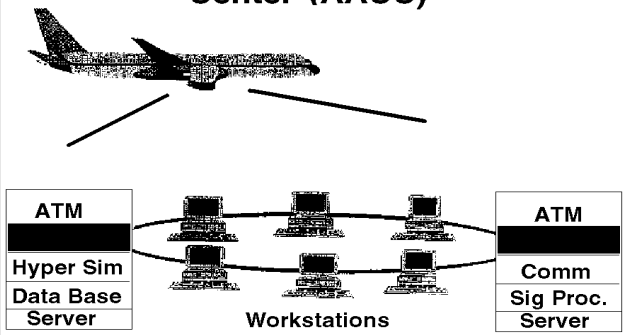
Distributed Commercial Avionics Architecture (777)



JAST Avionics Architecture

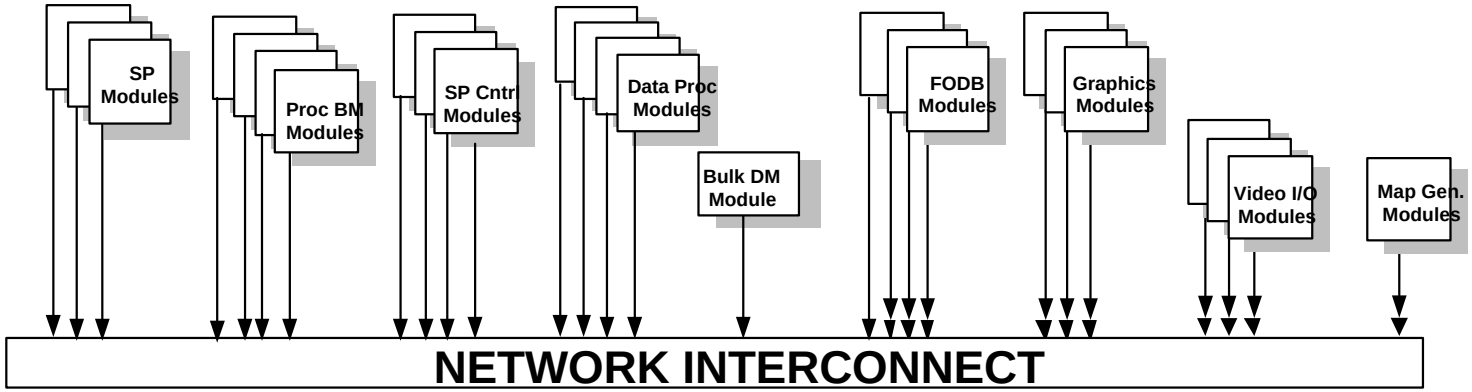


Advanced Airborne Command Center (AACC)



BOEING
DEFENSE & SPACE GROUP

SCALEABLE AVIONICS NETWORKS



Customer Goals:

- Lower Cost, Higher Performance
- Reduced Maintenance
- Increased Reliability
- Scaleable Architecture
- Open Architecture
- Standard Interconnect

Significant Improvements:

- Simpler Bus Interconnect
- Reduced I/O Connector Pin Count
- Reduced Interconnect Failure (~1% of all LRU failures)
- Up to 100 Meters Backplane Length
- 16 to 32 Gigabits/Second Bandwidth +
- Lower EMI Susceptibility

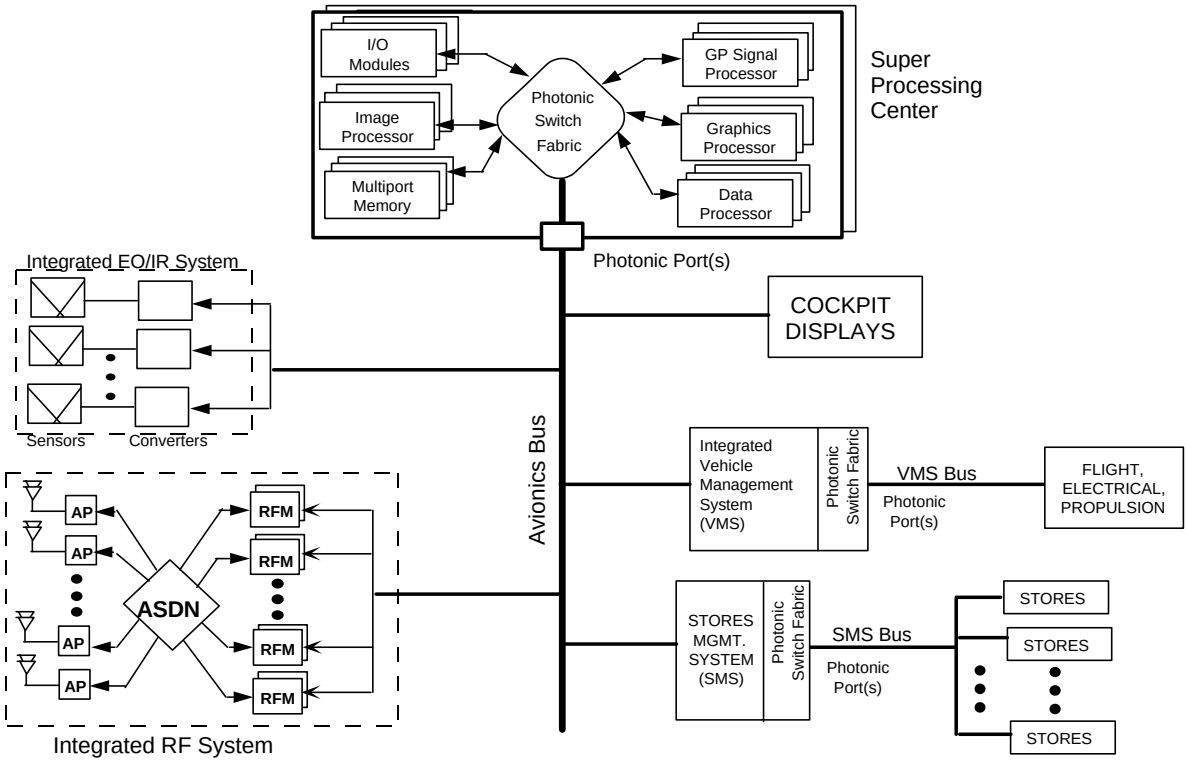
	Present Arch.	Network Arch.
Size, Wt, Pwr/ Unit Bandwidth	2*	1*
I/O Density	400	<60
Reliability/ Failure Rate	~24%**	~1%
Bus Length	0.5M	100M
Performance	100MBps	1000+ MBps
EMI	Susceptible	Immune

*- Normalized
**- % of all LRU Failures

Low Maintenance, High Performance LRUs.
Scaleable Open Architecture

BOEING
DEFENSE & SPACE GROUP

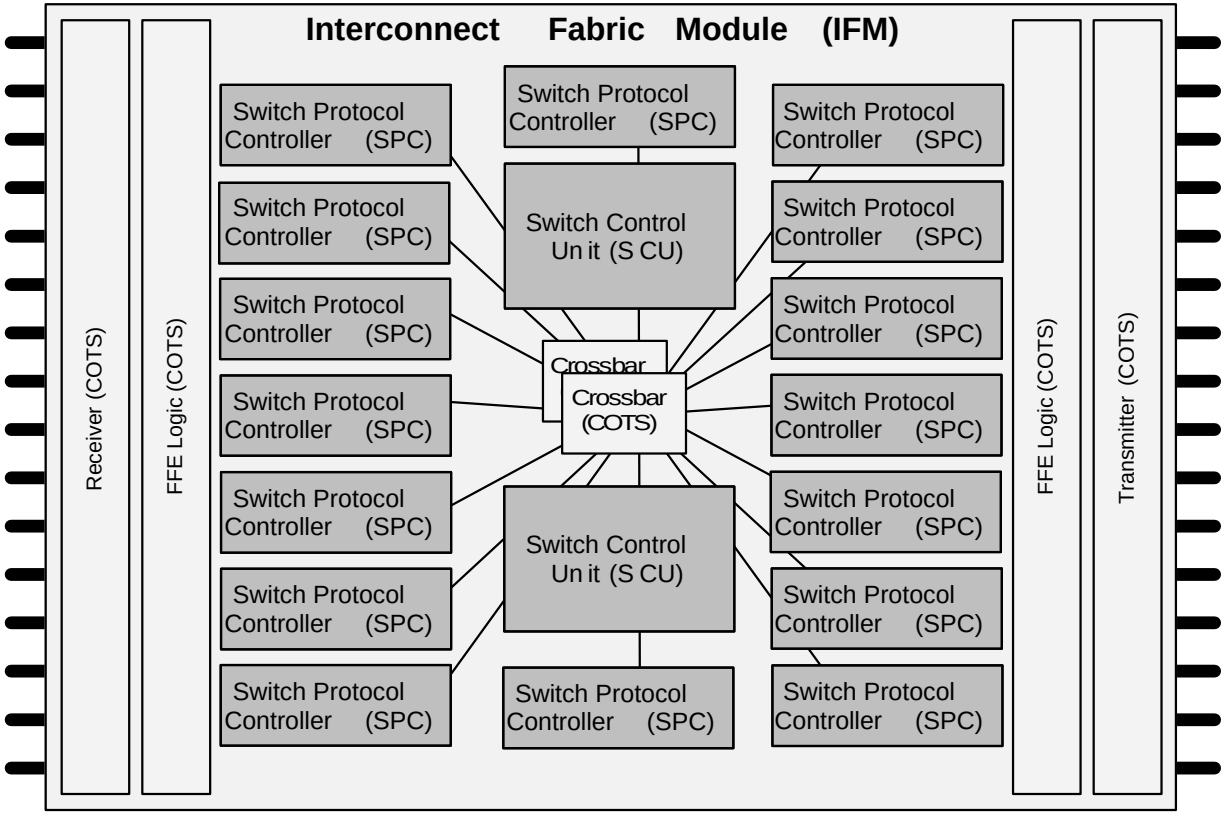
AVIONICS NETWORK SYSTEM



Scalable Photonic Interconnect Achieves Reduction in Avionics Size, Weight and Power with Increased Performance and Reliability

BOEING
DEFENSE & SPACE GROUP

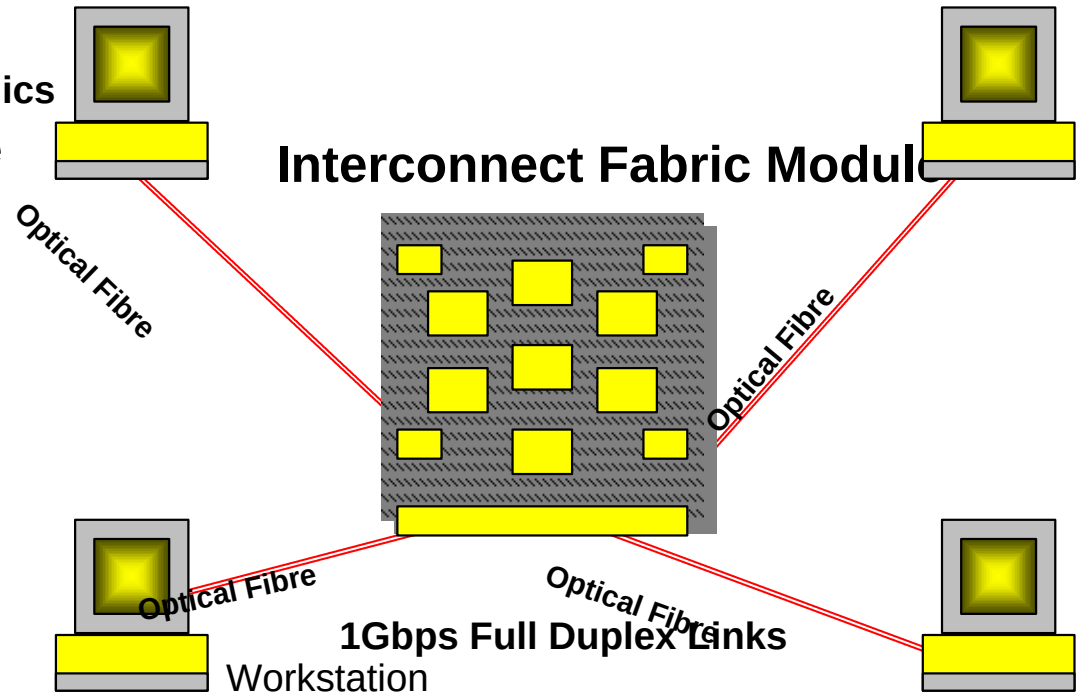
INTERCONNECT FABRIC MODULE



BOEING
DEFENSE & SPACE GROUP

SORTI TESTBED

- **Program Goals**
  - **Simulated Avionics**
  - **Demo Real-Time**
  - **Perf. Evaluation**
- **Approach**
  - **Implement IFM**
    - **4x4 Subset**
  - **Use Available Resources**
    - **Supporting IR&D**
    - **COTS**
    - **Appl. S/W**



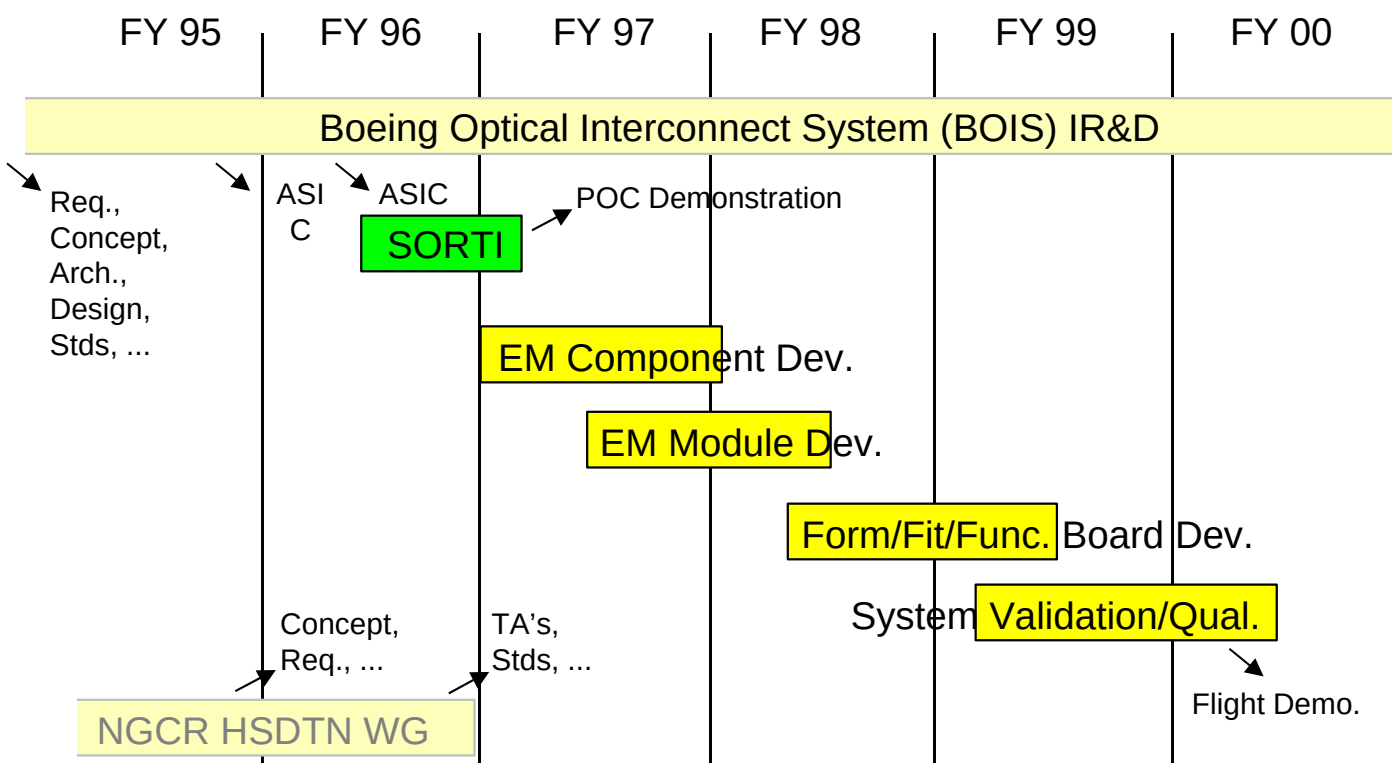
BOEING
DEFENSE & SPACE GROUP

OUTLINE

- BACKGROUND
- TECHNICAL DETAILS
- FY97 RECOMMENDATIONS
- SUMMARY

BOEING
DEFENSE & SPACE GROUP

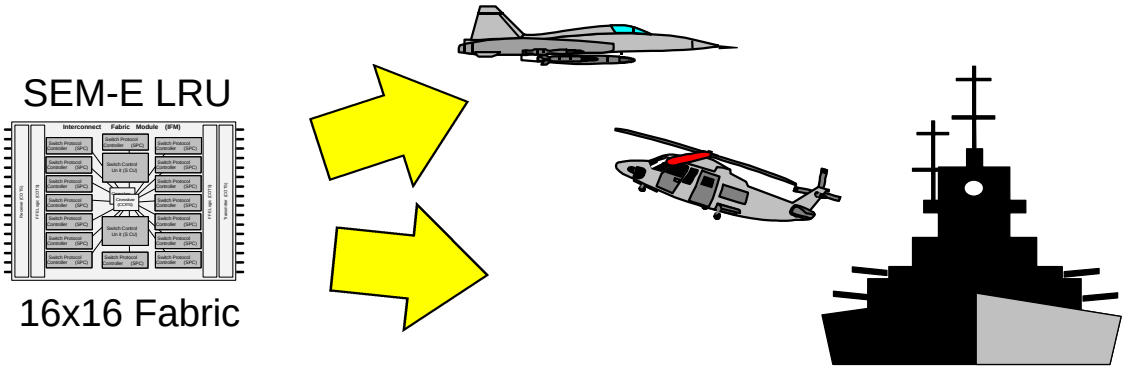
PROJECT SCHEDULE



BOEING
DEFENSE & SPACE GROUP

FY97 RECOMMENDATIONS (1)

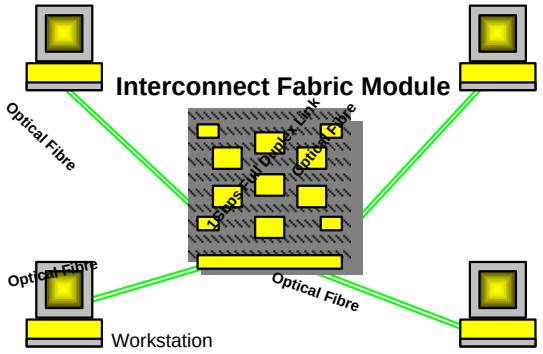
- **Build on Proof-of-Concept Designs for Engineering Model (EM) Interconnect System Development**
- **Phased Approach:**
  - **Identify COTS & Update ASICs for Form/Fit/Function**
  - **Leverage Advanced Packaging, Develop Modules (MCM, Hybrids, etc.) for Format E SEM Implementation.**
  - **Implement Format E SEM 16x16 Fabric Module**
  - **Validate and Qualify Design for Demonstration Flight Test**



BOEING
DEFENSE & SPACE GROUP

FY97 RECOMMENDATIONS (2)

- **Continue Standards Support/Interaction**
  - **Complete X3T11 Fibre Channel FC-PH-3 Review Process**
  - **Develop Fibre Channel Avionics Environment Profiles**
  - **Continue Consensus Building Process within FC-AE**
- **Demonstrate Avionics Applications**
  - **Utilize SORTI Testbed**
  - **Investigate Computational Networking Concepts**
    - **Unified Network (JSF)**
    - **Network of Workstations (C4I)**



BOEING
DEFENSE & SPACE GROUP

OUTLINE

- BACKGROUND
- TECHNICAL DETAILS
- FY97 RECOMMENDATIONS
- SUMMARY

BOEING
DEFENSE & SPACE GROUP

SUMMARY

- **Boeing has Experience in Developing and Implementing Open Standards for Avionics**
  - **1553, 1773, HSDB, Futurebus+, ARINC, Fibre Channel, ...**
- **Proof-of-concept Prototype Demonstration Development will Reduce Risk for Application to Systems.**
- **Consistent and Aggressive Funding Through 2000 will Prepare Networking Technology and Designs for Avionics Program Insertion.**
- **Standard, Open System, Scaleable Network Architecture can Achieve Higher Performance and Reliability while Reducing System Complexity, Size, Weight, Maintenance, and Costs.**

BACKUPS

BOEING
DEFENSE & SPACE GROUP

FC-AE APPROACH

- Work within the X3T11 Fibre Channel Community
- Influence existing specifications under development (not creating new standards)
- Define basic features and functions that enable compliance with widest range of avionics requirements.

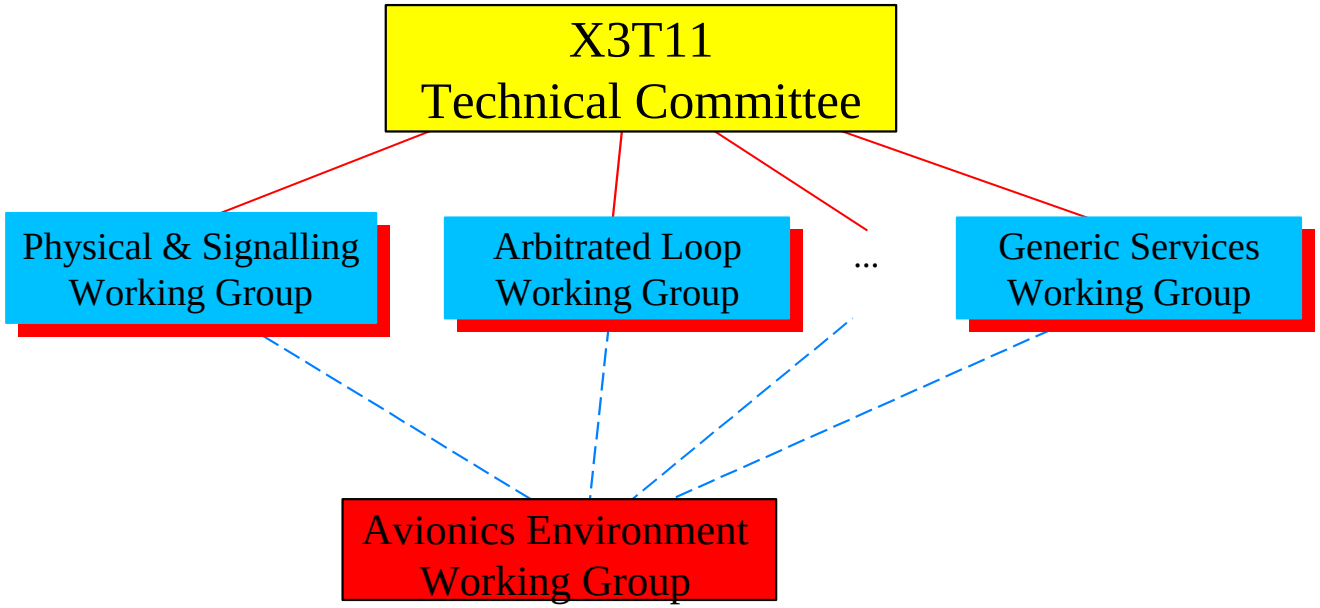
BOEING
DEFENSE & SPACE GROUP

FIBRE CHANNEL SUPPORTS OPEN ARCHITECTURES

- Through -
  - Standard Interface & Protocol
  - Commercially Supported Technologies & Toolsets
- Which Provides -
  - Minimized Development & Integration Costs
  - Simplified System Upgrades
  - Minimized Impact of Technology Obsolescence
  - Interoperable Multi-sourced Products
  - Improved Product Verification through Widespread Use
  - COTS Tools which Minimize Cost of Tool Development & Maintenance
  - Minimized Sustaining Engineering Costs

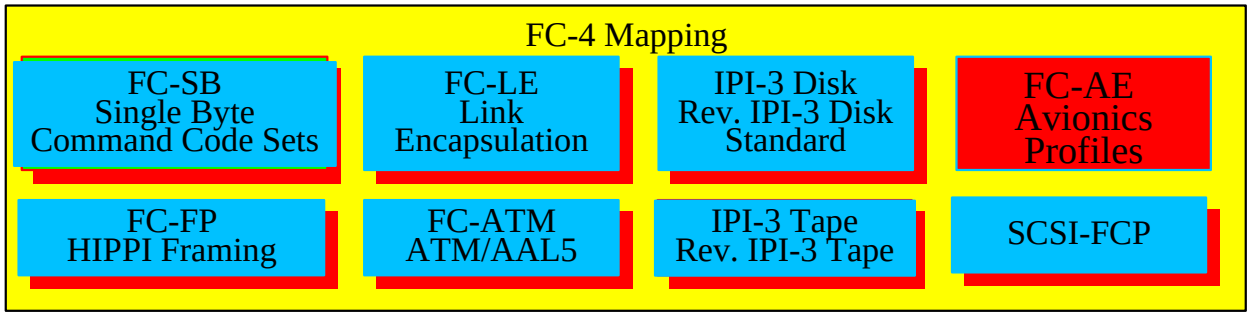
BOEING
DEFENSE & SPACE GROUP

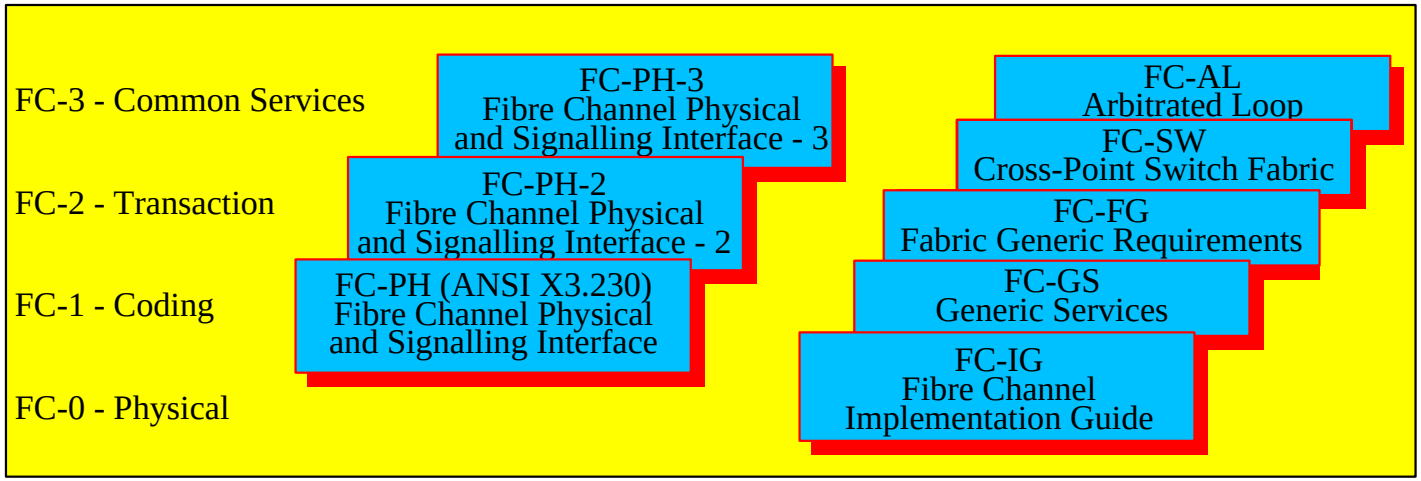
FIBRE CHANNEL
WORKING GROUP STRUCTURE



BOEING
DEFENSE & SPACE GROUP

FIBRE CHANNEL DOCUMENT RELATIONSHIPS





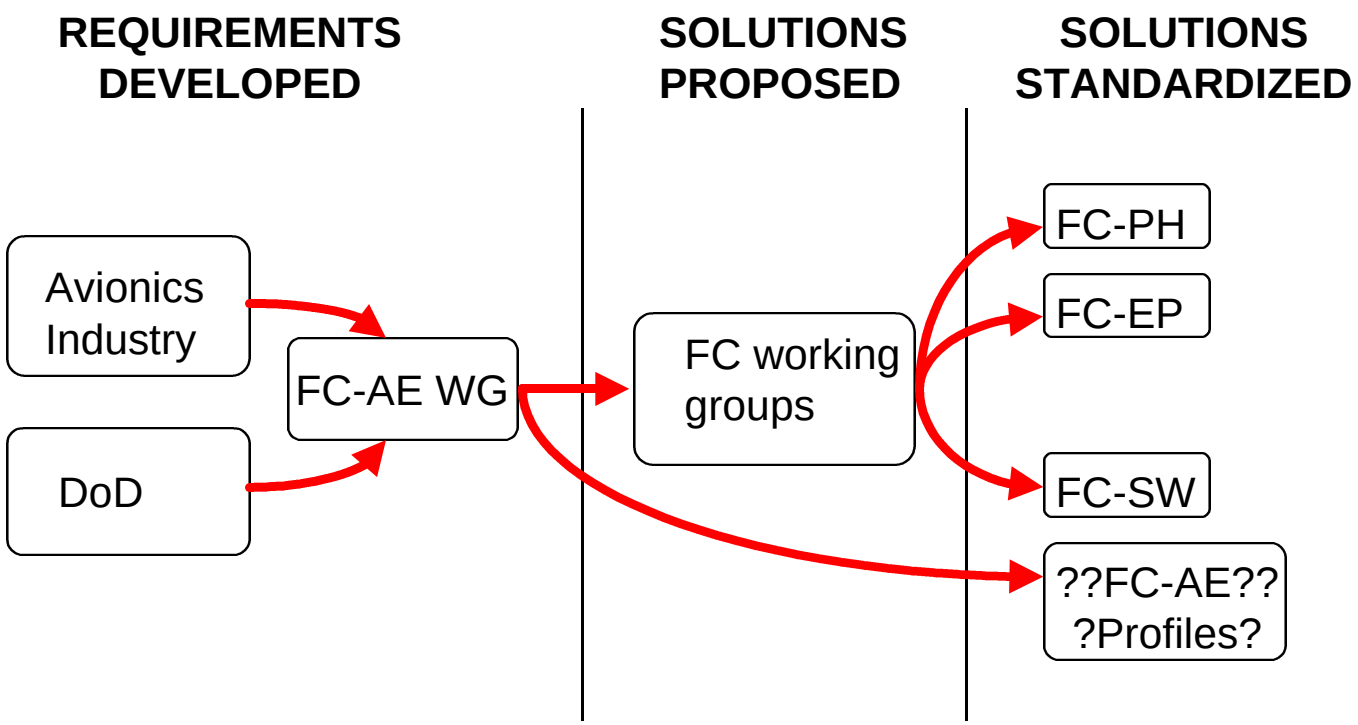
BOEING
DEFENSE & SPACE GROUP

FC-AE PARTICIPANTS

- Boeing Defense & Space
- CDInt
- Cypress Semiconductor
- E-Systems
- Emulex
- ENDL
- ESL Inc.
- Harris GASD
- HP
- HP Canada
- Hughes Aircraft Co.
- IBM
- Intel
- Johns Hopkins Applied Physics Lab
- McDonnell Douglas Aerospace
- MITRE
- Raytheon Equipment Div.
- Storageteck
- Systran
- Texas Instruments
- Technitrol
- US Navy

BOEING
DEFENSE & SPACE GROUP

FC-AE PROCESS



FC-AE ACCOMPLISHMENTS

- Proposals Developed/Submitted and Included in Draft FC Specifications Defining Functions For:
  - Protocols
  - Real-Time Support
  - Fault Tolerance & Security Support
  - Clock Distribution/Synchronization

BOEING
DEFENSE & SPACE GROUP

PROTOCOLS

- Multicast (Datagram)
  - Class 3 Connectionless
- Reliable Multicast
  - Class 6 Connected
- Low Latency Interconnect
  - Processor/Processor, Processor/Memory

BOEING
DEFENSE & SPACE GROUP

REAL-TIME FEATURES

- Priority
  - For All Classes of Service
  - 8-Bit Parameter in Header
    - Supports RT Scheduling Algorithms
- Preemption
  - Connection Oriented (Class 1 or 4)
  - Priority Based

BOEING
DEFENSE & SPACE GROUP

FAULT TOLERNACE

- Hunt Groups
  - Redundant Ports with Automatic Rerouting
- Multicast Groups
  - Server Manages Groups
- Time-outs
  - Option for Nanosecond Resolution

BOEING
DEFENSE & SPACE GROUP

SECURITY

- Key Exchange & Distribution
  - Distribution and Secret Key Exchange Protocol
- Cryptographic Algorithm
  - RC4 Recommended, Specific Algorithm Not Required
- Data Transfer
  - Utilizes Secret Key

BOEING
DEFENSE & SPACE GROUP

CLOCK SYNCHRONIZATION

- Synchronization Mechanisms
  - Synchronization Primitive
    - Fabric Based Capable of Nanosecond Accuracy
  - Extended Link Service (ELS)
    - Node Based
- Fabric Synchronization
  - All Nodes Synchronized to Fabric
  - Supports Segmented Fabric
- Synchronization Protocol
  - Based on Accurate Propagation Delay Calc.

BOEING
DEFENSE & SPACE GROUP

FC-AE PLANS FOR '96/97

- Support Standards Approval Process
- Develop Avionics Profile
  - Specify Minimum Set of Required Functions for Avionics Applications
    - FC-0 Through FC-4
  - Two Application Types Identified
    - Class 1 Connected Service
    - Class 3 Connectionless Service

BOEING
DEFENSE & SPACE GROUP

FC-AE STATUS

FC-AE Activity	Document	1995	1996	1997
Fault tolerance				
Hunt Group	FC-PH-2	▼ * ⊗	⊕	♠
Time-Out	FC-PH-3	▼ *	⊗ ⊕	♠
Protocol				
Multi-cast	FC-PH-2	▼ * ⊗	⊕	♠
Reliable Multi-cast	FC-PH-3	▼	* ⊗ ⊕	♠
Low Latency Protocol	FCA	▼ *	⊗ ⊕	♠
Real-Time				
Priority	FC-PH-3	▼ * ⊗	⊕	♠
Preemption	FC-PH-3	▼ * ⊗	⊕	♠
Clock Synchronization	FC-PH-3	▼ * ⊗	⊕	♠
Security	FC-GS-2	▼	* ⊗ ⊕	♠
Avionics	NGCR-TA	▼	* ⊗ ⊕ ♠	

▼ - Proposal
* - Draft Specification
⊗ - Working Group Review
⊕ - Public Review
♠ - Published

BOEING
DEFENSE & SPACE GROUP

FIBRE CHANNEL PRODUCT

- **Mass Storage Interconnect**
  - **PCs and Workstations to Disk (Sun, Digital, Compaq)**
- **General Networking**
  - **PCs and Workstations to each other (HP, IBM)**
- **Backbone Network**
  - **Server-to-Server (Ancor, Emulex, Radway)**
- **Information Servers**
  - **http://www.cern.ch/HSI/fcs**
  - **http://www-atp.llnl.gov/atp/telcom.html**

BOEING
DEFENSE & SPACE GROUP

CURRENT FIBRE CHANNEL USE IN DoD

- Lockheed Martin Astronautics
  - 1 Gb/s point-to-point link on classified satellite
- McDonnell Douglass Aerospace
  - AH-64 Apache Helicopter video link
  - F-15 Avionics upgrades
  - F/A-18 High-speed box-to-box interconnect
- E-Systems
  - Isochronous Slotted-Loop for USAF
  - Point-to-point network terminal link
- Open Systems Joint Task Force Demonstration

BOEING
DEFENSE & SPACE GROUP

FIBRE CHANNEL ASSOCIATION (FCA)

- **Mission:**

  Promote industry awareness, acceptance, and advancement of Fibre Channel, accelerating the use of Fibre Channel products and services, worldwide.

  http://www.amdahl.com/ext/CARP/FCA/FCA.html

- **60+ Members**
  - **Principal:** **Adaptec, AMCC, Amdahl, Ancor, AT&T, Compaq, Cypress, DEC, Dynatek, Emulex, ESL, Fujikura, HP (3), IBM (4), Intel, Interphase, Methode, Panasonic, Power I/O, Seagate, Siemens, Storage Tek, Sun, TriQuint, Unisys, Western Digital**
  - **Associate:** **Ancot, Ciprico, Computer Network Technology, Data General, Data Switch, EMC, GEC, IBM, Jaycor, LSI, Motorola, NSG, Radway, RHK, Samsung, Seastar Optics, Sequent, Sony, Storage Computer, Vitesse, VLSI**
  - **Educational:** **Argonne, AHPCRC, Battelle, CERN, Colorado State, ETRI, JHU/APL, LLNL, University of Minnesota**

BOEING
DEFENSE & SPACE GROUP

SUMMARY

- Avionics industry sees need to move to open, commercial standards
- Fibre Channel seen as best candidate by many avionics developers/integrators
- FC-AE WG incorporating avionics requirements into standards and profiles
- Significant benefit to commercial and military avionics through development and life cycle costs reduction

BOEING
DEFENSE & SPACE GROUP

SUGGESTED READING

- What Is Fibre Channel?, by Jan Dedek, Ancot and Gary Stephens, FSI Consulting
- Fibre Channel, Volume 1, The Basics, by Jan Dedek, Ancot and Gary Stephens, FSI Consulting
- The Fibre Channel Bench Reference, by Jeffrey D. Stai, ENDL Publications ISBN 1-879936-17-8, contact dal_allan@mcimail.com
- Fibre Channel, by Alan F. Benner, McGraw Hill ISBN 0-07-005669-2

BOEING
DEFENSE & SPACE GROUP

SUGGESTED READING CONT'D

- Anderson, T.M.; Cornelius, R.S., "High-performance Switching with Fibre Channel", Digest of Papers, COMPCON Spring 1992, IEEE Computer Society Press.
- Dal Allen, I.; Frymoyer, E., "Fibre Channel Can Break the Datacom Gridlock", Electronic Design, vol. 41, no. 9, p. 87-90, 92, 94-5.
- Fahey, Michael, "From Local to Global: Surveying the Fiber Landscape", Telecommunications, vol. 27, no. 11, p. 33(4).
- Frymoyer, E., "Fibre Channel Application Profiles, FCSI and FCA", Proceedings of COMPCON '94, IEEE Computer Society Press.

BOEING
DEFENSE & SPACE GROUP

SEMINARS/TRAINING

- FCA Seminar Handouts
  - http://www.amdahl.com/ext/CARP/FCA/FCA.html#education
- Fibre Channel Group
  - 6 Training Tracks Covering Business, Architecture, Technical Details, S/W Drivers, Physical Layer, & Real-Time
  - http://www.fcgroup.com
- Solution Technology
  - Courses on Introduction to Fibre Channel, FC Arbitrated Loop, and FC-4 Mapping
  - http://www.webventure.com/st/courses.html