AS MAN EVOLVED ... SO DID THE TECHNOLOGIES THAT HE USED

1940s

Evolution of Avionics

Architecture & Data Buses

2000s

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AVIONICS

DEFINITION

Avionics : Aviation Electronics

Avionics : All electronic and electromechanical systems and subsystems (hardware and software) installed in an aircraft or attached to it. (MIL-1553A-HDBK)

Avionics has become an equal partner and is surpassing aircraft structures and propulsion in terms of cost and its mission effectiveness of modern aircraft
Establishing the basic architecture is the first and the most fundamental challenge faced by the designer.

The architecture must conform to the overall aircraft mission and design while ensuring that the avionics system meets its performance requirements.

These architectures rely on the data buses for intra- and intersystem communications.

The optimum architecture can only be selected after a series of exhaustive design tradeoffs that address the evaluation factors.
AVIONICS ARCHITECTURE

First Generation Architecture (1940’s –1950’s)
- Disjoint or Independent Architecture (MiG-21)
- Centralized Architecture (F-111)

Second Generation Architecture (1960’s –1970’s)
- Federated Architecture (F-16 A/B)
- Distributed Architecture (DAIS)
- Hierarchical Architecture (F-16 C/D, EAP)

Third Generation Architecture (1980’s –1990’s)
- Pave Pillar Architecture (F-22)

Fourth Generation Architecture (Post 2005)
- Pave Pace Architecture- JSF
- Open System Architecture
FGA - DISJOINT ARCHITECTURE

The early avionics systems were stand alone black boxes where each functional area had separate, dedicated sensors, processors and displays and the interconnect media is point to point wiring.

The system was integrated by the air-crew who had to look at various dials and displays connected to disjoint sensors correlate the data provided by them, apply error corrections, orchestrate the functions of the sensors and perform mode and failure management in addition to flying the aircraft.

This was feasible due to the simple nature of tasks to be performed and due to the availability of time.
FGA - DISJOINT ARCHITECTURE

- Pilot
  - Navigation Computer
    - Navigation Panel
    - Inertial Measurement Unit
    - Altitude Sensor
  - Radar Processor
    - Display
    - Control Panel
    - RF
FGA - CENTRALIZED ARCHITECTURE

• As the digital technology evolved, a central computer was added to integrate the information from the sensors and subsystems.

• The central computing complex is connected to other subsystems and sensors through analog, digital, synchro and other interfaces.

• When interfacing with computer a variety of different transmission methods, some of which required signal conversion (A/D) when interfacing with computer.

• Signal conditioning and computation take place in one or more computers in a LRU located in an avionics bay, with signals transmitted over one way data bus.

• Data are transmitted from the systems to the central computer and the DATA CONVERSION TAKES PLACE AT THE CENTRAL COMPUTER.
FGA - CENTRALIZED ARCHITECTURE

ADVANTAGES

- Simple Design
- Software can be written easily
- Computers are located in readily accessible bay

DISADVANTAGES

- Requirement of long data buses
- Low flexibility in software
- Increased vulnerability to change
- Different conversion techniques needed at Central Computer

Motivated to develop a COMMON STANDARD INTERFACE for interfacing the different avionics systems.
FGA - CENTRALIZED ARCHITECTURE

- Tape
- GNC
- WDC
- HSI
- FCS
- Multiplexer Converter
- Terrain Following Radar
- SMS
- RADALT
- TACAN
- Doppler Radar
- Integrated Display Set
- Maintenance Control Unit
- HSD
- Attack Radar
- Inertial Navigator Set
- Nav Data Display Panel
- Nav Data Entry Panel
Federated: Join together, Become partners
Each system acts independently but united (Loosely Coupled)

Unlike FGA – CA, Data conversion occurs at the system level and the datas are send as digital form – called Digital Avionics Information Systems (DAIS)

Several standard data processors are often used to perform a variety of Low – Bandwidth functions such as navigation, weapon delivery, stores management and flight control

Systems are connected in a Time – Shared Multiplex Highway

Resource sharing occurs at the last link in the information chain – via controls and displays

Programmability and versatility of the data processors
SGA – FEDERATED ARCHITECTURE

ADVANTAGES
- Contrast to analog avionics – DDP provide precise solutions over long range of flight, weapon and sensor conditions
- Sharing of Resources
- Use of TDMA saves hundreds of pounds of wiring
- Standardization of protocol makes the interchangeability of equipments easier
- Allows Independent system design and optimization of major systems
- Changes in system software and hardware are easy to make
- Fault containment – Failure is not propagated

DISADVANTAGES: Profligate of resources
SGA - DAIS HARDWARE ARCHITECTURE

Processor 1
  Bus Control Interface
    Remote Terminal 1
      Sensor Equipment

Processor 2
  Bus Control Interface
    Remote Terminal 2
      Sensor Equipment

Processor M
  Bus Control Interface
    Remote Terminal N
      Control & Display Equipment

Data bus A

Data bus B
SGA - DISTRIBUTED ARCHITECTURE

- It has multiple processors throughout the aircraft that are designed for computing takes on a real-time basis as a function of mission phase and/or system status

- Processing is performed in the sensors and actuators

ADVANTAGES

- Fewer, Shorter buses
- Faster program execution
- Intrinsic Partitioning

DISADVANTAGES

- Potentially greater diversity in processor types which aggravates software generation and validation
SGA – HIERARCHICAL ARCHITECTURE

- This architecture is derived from the federated architecture
- It is based on the TREE Topology

ADVANTAGES

- Critical functions are placed in a separate bus and Non-Critical functions are placed in another bus
- Failure in non-critical parts of networks do not generate hazards to the critical parts of network
- The communication between the subsystems of a particular group are confined to their particular group
- The overload of data in the main bus is reduced

Most of the military avionics flying today based on HIERARCHICAL ARCHITECTURE
Pave Pillar is a USAF program to define the requirements and avionics architecture for fighter aircraft of the 1990s.

**The Program Emphasizes**

- Increased Information Fusion
- Higher levels and complexity of software
- Standardization for maintenance simplification
- Lower costs
- Backward and growth capability while making use of emerging technology – VHSIC, Voice Recognition /synthesis and Artificial Intelligence

Contd…
TGA - WHY PAVE PILLAR

- Provides capability for rapid flow of data in, through and from the system as well as between and within the system.
- Higher levels of avionics integration and resource sharing of sensor and computational capabilities.
- Pilot plays the role of a WEAPON SYSTEM MANAGER as opposed to subsystem operator/information integrator.
- Able to sustain operations with minimal support, fly successful mission day and night in any type of weather.
- Face a numerically and technologically advanced enemy aircraft and defensive systems.
TGA – PAVE PILLAR ARCHITECTURE

- Component reliability gains
- Use of redundancy and resource sharing
- Application of fault tolerance
- Reduction of maintenance test and repair time
- Increasing crew station automation
- Enhancing stealth operation
- Wide use of common modules (HW & SW)
- Ability to perform in-aircraft test and maintenance of avionics
- Use of VHSIC technology and
- Capability to operate over extended periods of time at austere, deployed locations and be maintainable without the Avionics Intermediate Shop
FTGA - WHY PAVE PACE

Modularity concepts cuts down the cost of the avionics related to VMS, Mission Processing, PVI and SMS

- The sensor costs accounts for 70% of the avionics cost
- USAF initiated a study project to cut down the cost of sensors used in the fighter aircraft
- In 1990, Wright Laboratory – McDonnell Aircraft, Boeing aircraft company and Lockheed launched the Pave Pace Program
- Come with the Concept of Integrated Sensor System (IS$^2$)
- Pave Pace takes Pave Pillar as a base line standard
- The integration concept extends to the skin of the aircraft – Integration of the RF & EO sensors
- Originally designed for Joint Strike Fighter (JSF)
AVIONICS SYSTEM EVOLUTION

Independent Avionics (40's - 50's)

Federated Avionics (60's - 70's)

Integrated Avionics (80's - 90's)

Advanced Integrated Avionics (Post 2000)
KEY OBSERVATIONS

AVIONICS ARCHITECTURAL EVOLUTION

- Increased Digitization of Functions
- Increased sharing and modularization of functions
- Integration/sharing concepts increased to the skin of the aircraft
- Functionality has increasingly obtained through software
- Complex hardware architecture modules
- Complex software modules
- Increased network complexity and speed
Data Bus

- It provides a medium for the exchange of data and information between various Avionics subsystems

- Integration of Avionics subsystems in military or civil aircraft and spacecraft.
set of formal rules and conventions governing the flow of information among the systems

Low level protocols define the electrical and physical standards

High level protocols deal with the data formatting, including the syntax of messages and its format
TYPES OF PROTOCOLS

Command/Response : Centralized Control Method

Token Passing : Decentralized Control Method
               (Free token)

CSMA/CA : Random Access Method
How the systems are interconnected in a particular fashion

LINEAR NETWORK

Linear Cable

All the systems are connected in across the Cable

RING NETWORK

Point to Point interconnection

Datas flow through the next system from previous system

SWITCHED NETWORK

Similar to telephone network

Provides communications paths between terminals
History of the MIL-STD-1553B

- Developed at Wright Patterson Air Force Base in 1970s
- Published First Version 1553A in 1975
- Introduced in service on F-15 Programme
- Published Second version 1553B in 1978
MIL-STD-1553, *Command / Response Aircraft Internal Time Division Multiplex Data Bus* is a Military standard (presently in revision B), which has become one of the basic tools being used today for integration of Avionics subsystems.

This standard describes the method of communication and the electrical interface requirements for the subsystems connected in the data bus.
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<td>Transmission Mode</td>
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</table>
ELEMENTS OF MIL-STD-1553B

- BUS CONTROLLER (BC)
- REMOTE TERMINAL (RT)
- MONITORING TERMINAL (MT)
- TRANSMISSION MEDIA
COUPLING METHODS
ARINC 429
Single point failure in 1553B leads to certificability problem in civil aircraft

Addition of remote terminal requires changes in BC software which requires frequent certification

Standard adopted in the year 1977

Made its appearance in the C-17 transport aircraft

Point to Point Protocol
ARINC SPECIFICATION 429

- It is a specification that defines a local area network for transfer of digital data between avionics system elements in civil aircraft.

- It is simplex data bus using one transmitter but no more than twenty receivers for each bus implementation.

- There are no physical addressing. But the data are sent with proper identifier or label.

Contd…
ARINC 429 is viewed as a permanent as a broadcast or multicast operation.

Two alternative data rates of 100kbps and 12-14 Kbps.

There is no bus control in the data buses as found in MIL-STD 1553B.

It has direct coupling of transmitter and receiving terminals.
ARINC 429 ARCHITECTURE

ARINC 429 TRANSMITTER

ARINC 429 DATABUS

ARINC 429 RECEIVER

ARINC 429 RECEIVER

ARINC 429 RECEIVER

UPTO 20 RECEIVERS TOTAL
1977 => Boeing began to work on “DATAC” project

1977 - 85 => DATAC Emerged as ARINC 629

1989 => ARINC 629 was adopted by AEEC

1990 => ARINC 629 was first implemented in BOEING-777
ARINC 629 DATA BUS

- Time Division Multiplex
- Linear Bus
- Multiple Transmitter Access
- 2 Mbps Data Rate
- Current Mode Coupling
  (Present implementation)
<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
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<tr>
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<td>2 Mbps</td>
</tr>
<tr>
<td>Word Length</td>
<td>20 Bits</td>
</tr>
<tr>
<td>Message Length</td>
<td>31 Word Strings (maximum)</td>
</tr>
<tr>
<td>Data Bits per Word</td>
<td>16 Bits</td>
</tr>
<tr>
<td>Transmission Technique</td>
<td>Half - Duplex</td>
</tr>
<tr>
<td>Encoding</td>
<td>Manchester II Bi-phase</td>
</tr>
<tr>
<td>Protocol</td>
<td>Carrier Sense Multiple Access Collision avoidance</td>
</tr>
<tr>
<td>Transmission Mode</td>
<td>Voltage Mode, Current Mode, Fiber Optic Mode</td>
</tr>
</tbody>
</table>
ARNIC 629 ARCHITECTURE

ARINC 629 DATABUS

ARINC 629 TERMINAL

UPTO 120 SUBSCRIBER TERMINALS

ARINC 629 TERMINAL

ARINC 629 TERMINAL
Avionics Fully Duplex Switched Ethernet is an advanced Protocol Standard to interconnect avionics subsystems.

- It can accommodate future system bandwidth demands.
- Increase flexibility in Avionics design.
- Reduce aircraft wire counts, thus lowering aircraft weight and cost.
- Its first major use in A3xx.
• Since the Ethernet is a switched architecture rather than a point-point link, aircraft designers can create redundant sub networks

• Faults can be isolated and analysed without impacting the system as a whole

• ARINC 429 data bus may still be used but the main Avionics data pipe will be Ethernet (AFDX) of 100 Mbps
• Used in F-22 Advanced tactical fighter
• Generic version SAE Aerospace Standard 4074.1
• 50 Mbps - linear bus
• for optical medium implementation – star topology
• HSDB uses distributed control in which each terminal is permitted to transmit only when it receives the token frame.
SCI
IEEE –STD-1596-1992

SCI is an interconnect system for both backplane and LAN usage.

It is a system of rings and switches in its basic format

Operates at 1 Gbps

Electrical links upto 30m and optical links upto several kms.

Same Bandwidth as today’s 155Mbits/sec ATM links, 32 times that of today’s fiber optic channel and 800 times that of Ethernet.
<table>
<thead>
<tr>
<th>Standard</th>
<th>1553B</th>
<th>ARINC629</th>
<th>ARINC 429</th>
<th>ETHERNET</th>
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<tr>
<td>Def-Stan STANAG 3838</td>
<td>Published</td>
<td>ARINC</td>
<td>ARINC</td>
<td>IEEE 802.3 ISO 8802.3</td>
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<tr>
<td>Status</td>
<td></td>
<td>Published</td>
<td>Published</td>
<td>Published</td>
</tr>
<tr>
<td>Primary Support</td>
<td>USAF US DOD</td>
<td>Boeing</td>
<td>Civil Airlines</td>
<td>INTEL</td>
</tr>
</tbody>
</table>


**Performance**

**Signaling Rate**

- **1553B**: 1Mbps
- **Ethernet (AFDX)**: 100Mbps
- **ARINC 429**: 100Kbps or 12-14.5Kbps
- **ARINC 629**: 2Mbps
BUS ACCESS

- 1553B: Predetermined
- Ethernet: Not Determined
- ARINC 429: Fixed
- ARINC 629: Multitransmitter
Coupling

1553B - Transformer
Ethernet - Transformer
ARINC 429 - Direct
ARINC 629 - Transformer
Access Method

1553B - Time Division

Ethernet - CSMA/CD

ARINC 429 - Fixed (Single Transmitter)

ARINC 629 - CSMA/CA
Hierachy

1553B  -  Master/Slave
Ethernet  -  No Master
ARINC 429  -  No Master
ARINC 629  -  No Master
NUMBER OF NODES

1553B - 31(RT) + BM + BC
Ethernet - 100 +
ARINC 429 - 20
ARINC 629 - 120
MIL-STD 1773
WHY OPTICAL FIBER?

Though 1553B is used in various modern aircraft, it is recognised that buses operate in extremely severe environment like:

- EMI from intersystem and intrasystem
- Lightning
- Electrostatic discharge
- High Altitude Electromagnetic pulse
Fiber-optic version of 1553B

It also operates at the rate of 1Mbps

It also have the same 20 bit word and three words such as command word, status word and data word

stronger immunity to radiation-induced electromagnetic interference
Motivation of the STANAG 3910

- Draft Created in Germany during 1987
- Draft Submission on 1988
- A Project EFA Bus was issued on 1989
- Selected by the Euro fighter consortium in 1989
To meet the Demands of Avionics requirements for Highly Sophisticated fighter aircraft

Allow Evolution from MIL-STD-1553B Bus to “Higher Speed” Avionics Bus System

Stay with a Deterministic Master/Slave Protocol

“Low Risk” approach to EF2000 Prototypes using MIL-STD-1553B only
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<td>1 Mbps (LS), 20Mbps (HS)</td>
</tr>
<tr>
<td>Word Length</td>
<td>16 Bits</td>
</tr>
<tr>
<td>Message Length</td>
<td>32 Word (LS), 4096 Word (HS)</td>
</tr>
<tr>
<td>Max No. of Stations</td>
<td>32</td>
</tr>
<tr>
<td>Transmission Technique</td>
<td>Half - Duplex</td>
</tr>
<tr>
<td>Access Protocol</td>
<td>Command /Response</td>
</tr>
</tbody>
</table>
MIL-STD-1773 is same as the 1553B with Fiber-Optic Media

- STANAG 3910 operates under the control of STANAG 3838 (1553)

- The data rate in 1773 is 1Mbps

- The STANAG 3910 has 2 data rates
  - 1 Mbps in 3838
  - 20 Mbps in Optical bus
CAN BUS
Controller Area Network (CAN) is the network established among microcontrollers.

CSMA/CA Protocol

Two wire high speed network system which was firstly established to overcome the problems (wire harness, communication) faced in automobiles.

Linked up to 2032 devices (assuming one node with one identifier) on a single network.

CAN offers high speed communication up to 1Mbps, thus allowing real-time control.
Digibus

• Originally **Ginabus (Gestion des Informations Numeriques Aeroportees – Airborne Digital Data Management)**

• Designed jointly by Electronique Serge Dassault (ESD) and Avions Marcel Dassault- Breguet Aviation (AMD-BA) and SAGEM between 1973 and 76

• Digibus is now standard for all branches of French Military is defined in the Specification GAM-T-101
Digibus operates at 1 Mbits /sec.

Uses two twisted cable pairs shielded with two mesh screens, one cable pair conveys data and the other carries protocol messages.

The protocol messages are similar to MIL-STD-1553.

Maximum bus length is 100meters. But active repeaters allow extension up to 300 meters plus sub-bus couplers that can be used to connect sub buses (each up to 100 meters long) on to the main bus.
DATA BUSES
IN
SPACE APPLICATIONS
IEEE 1393
SPACEBORNE
FIBER OPTIC
DATA BUS

NASDA
• ON Board Data Handling networks

• High Speed payloads

• SFODB is 1 Gbps, support real time and On Board Data handling requirement of Remote Sensing satellites

• Highly reliable, fault tolerant, and capable of withstanding the rigors of launch and the harsh space environment.
- Small size, light weight, and low power

- Architecture: Redundant, Cross-Strapped Fiber Optic Ring with Passive Bypass


- Node Capacity: 127 Transmit & Receive Nodes
In Space shuttles

Two commonly used data buses

1. Multiplex interface adapter (MIA)

2. Multiplex/demultiplexer data bus (MDM)
• Command/response protocol

• 24 bit words (plus sync & parity)

• Same as to 1553 data bus in speed and biphase Manchester encoding

• Words are 24 bits long while in 1553 20 bits long
MDM DATA BUS

- Serial point to point communication between space shuttle payload general support computer and various subsystems.
- MDM interface consists of a serial data bus and three discretes (Message in, Message out, and word).
- Discrete contains the timing, direction, and No. of words on the serial data bus.
• Serial data bus is bi-directional

• Discrete are driven by bus controller (the PGSC) and received by the remote Terminal

• Speed is 1 Mbps

• Words have 16 bits, messages upto 32 words
CAN BUS
In Space Applications

- FASat-ALPHA(Chile) will carry an advanced OBDH system
- In this, Controller Area Network (CAN) bus is used to connect all processing nodes
• ROMER-a DANISH satellite, ACS will be implemented on an on-board connected to a CANBUS in order to communicate with sensors and actuators of the ACS.
• CANBUS network is used for connecting all components via an interface, within the body in TG-A launch vehicles.
MIL-Std 1553 Data Bus in Space Applications
• TAOS-Technology for Autonomous Operational survivability

• In TAOS Satellite 1553 is used for intersatellite communications

• Two MIL-Std 1750A(Processor) are used for spacecraft control and payload operation
MIL-Std 1553 Data Buses are used for a common data link between all segments of U.S. laboratory Module, Russian Service Module and functional Cargo block, the European Columbus Orbital facility and the Japanese Experimental Module.
In SWAS, NASA’s UBMILLIMETER WAVE ASTRONOMY SATELLITE use 1553 data bus for On-Board Data Handling system.

In TRACE, NASA TRANSITION REGION AND CORNAL EXPLORER employ 1553 to connect subsystems.
• Microstar Satellite platform uses 1553 Or 1773 Buses for payload data interface To accommodate high level interfaces.

• NASA’s Goddard Space Flight Center use a common bus for several satellites Which is attained by 1553 and 1773 buses

• Globstar system consider 1553 as a common reference design
THANK YOU