Don’t fear the BUS, It won’t run you over

Presenter: Nicholas Childs

Date: Friday, Aug 6th 1400-1425

Summary: **This talk is a basic introduction to aircraft avionics comm/nav bus systems and the expansion of the network to more vulnerable areas than have seen before. It is more of a primer and 101 for stepping into the larger world of aerospace networks**.

Don't fear the BUS

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Retiree

github.com/boxswapper
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Email nick@boxswappers.com

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C:\Users\1256369778>whoami
- Intern with FullCircle Communications LLC
- 20 years experience in communication navigation systems
- Aeronautical Engineering Degree
- Mechanical repair and servicing experience with 737, L10-11, DC-10, 747
- Proficient with multiple airframe avionics systems; C-17,C-5,C-141,KC-135,B-1
- 5 years experience Active Directory Administrator on DoD network
- Multiple cybersecurity certifications (all expired) ☹
- FCC Radiotelephone Operator License with Radar Endorsement

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Original Why?

Things are broken, Avionics bus systems were designed for use not for security, Like most legacy systems, the addition of new technologies has introduced vulnerabilities.

I need your help..or

WE'RE ALL GONNA DIE!!!

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New Why?

Avionics BUS systems and integrated flight management systems now seem to be the things of magic. Let's demystify and educate. I promise, we can easily learn things that high school educated Airmen know.

It's not as painful as you think

Additionally, input validation is not a thing!

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Viewers Like you…

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History Of Aircraft network systems

Communication along BUS systems

A few networks you should know about

Attack Vectors and Upgrades

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History of Aircraft Network Systems

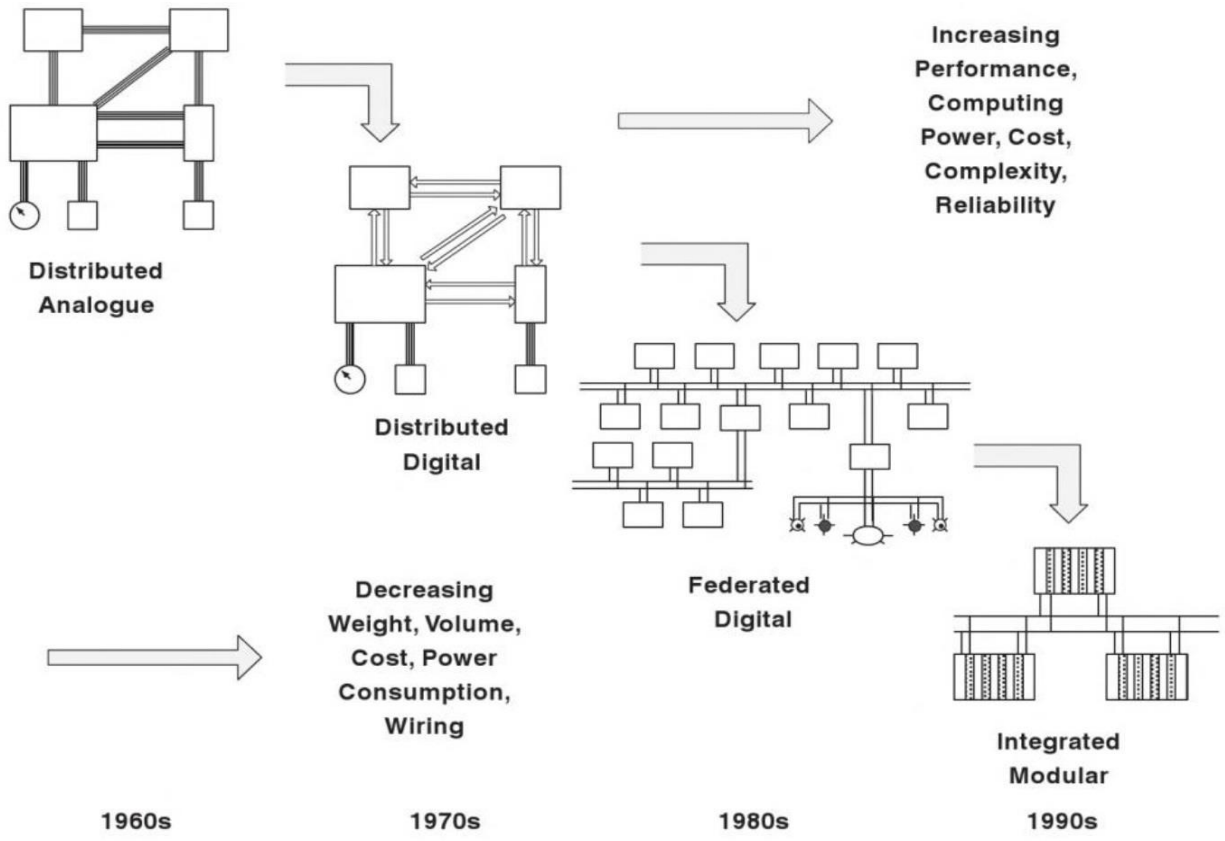

Figure 5.11 Evolution of avionics architectures.

Design and Development of Aircraft Systems Ref (a)

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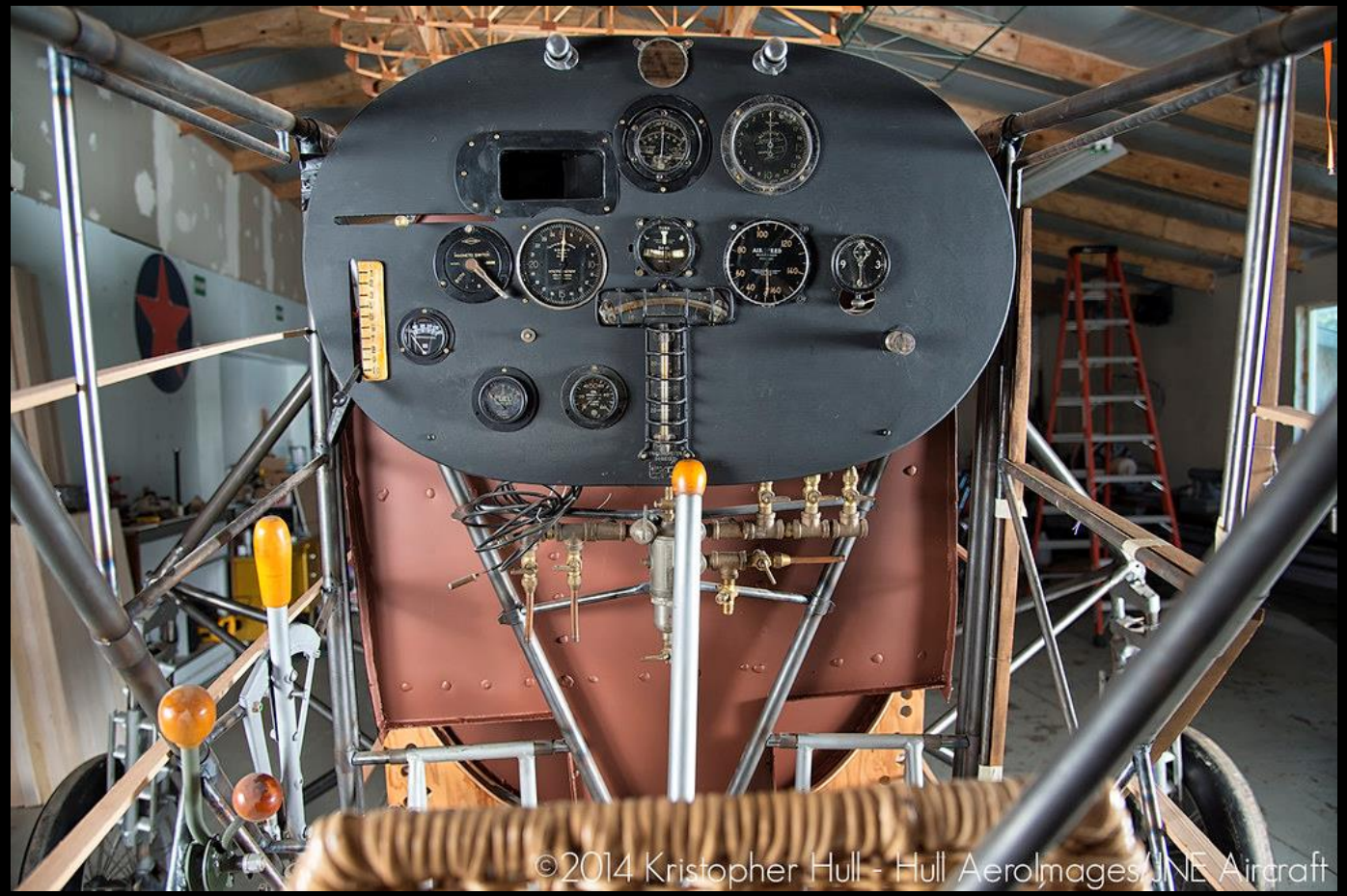
Distributed Analogue



Spirit of St. Louis Replica Cockpit
C/o Kristopher Hull

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Distributed Digital

DC-7 Cockpit
Ramey Logan Photographer

Don't fear the BUS

Federated Digital

C-5M Super Galaxy Cockpit

Paris- LeBourget
©Jonathan Zaniger

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Integrated Modular

A380 Airbus cockpit

Wallpaper Safari

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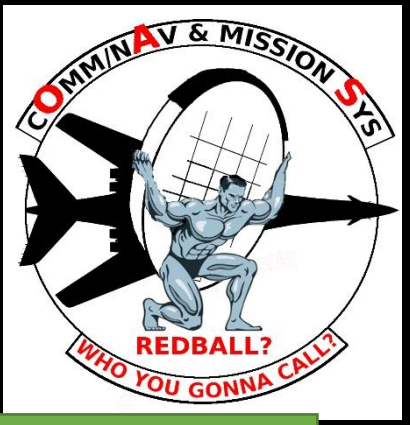
Federated Digital (Mil-STD-1553b & ARINC-429)



3. Interface Layer

Flight Management System

Data Loader

MX Computer

Emergency Comm Controller

2. LRU Layer

Radio set

BSIU

MFD controller

ADC

Trans-Ponder

TCAS

REMOTE TERM.

REMOTE TERM.

REMOTE TERM.

Controller

REMOTE TERM.

REMOTE TERM.

REMOTE TERM.

1. Network Layer

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B-1b CITS

CITS "Maintenance Computer"

B-1b Offensive Officer Position
Dyess AFB
c/o Defense.gov

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There are Many BUS'es

-MIL-STD-1553(B)	Federated Digital
-ARINC-429	Federated Digital
-AFDX® (ARINC-664)	Integrated Modular

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BUS - MIL-STD-1553(B) Coded Language

- -Manchester II Encoding
- -Binary Phase Shift Keying (BPSK)
- -1.0 mbps
- -Accuracy of .01% short term (100Hz)
- -Accuracy of .1% Long term (1000Hz)
- -each word is 16 bits plus sync wave and parity

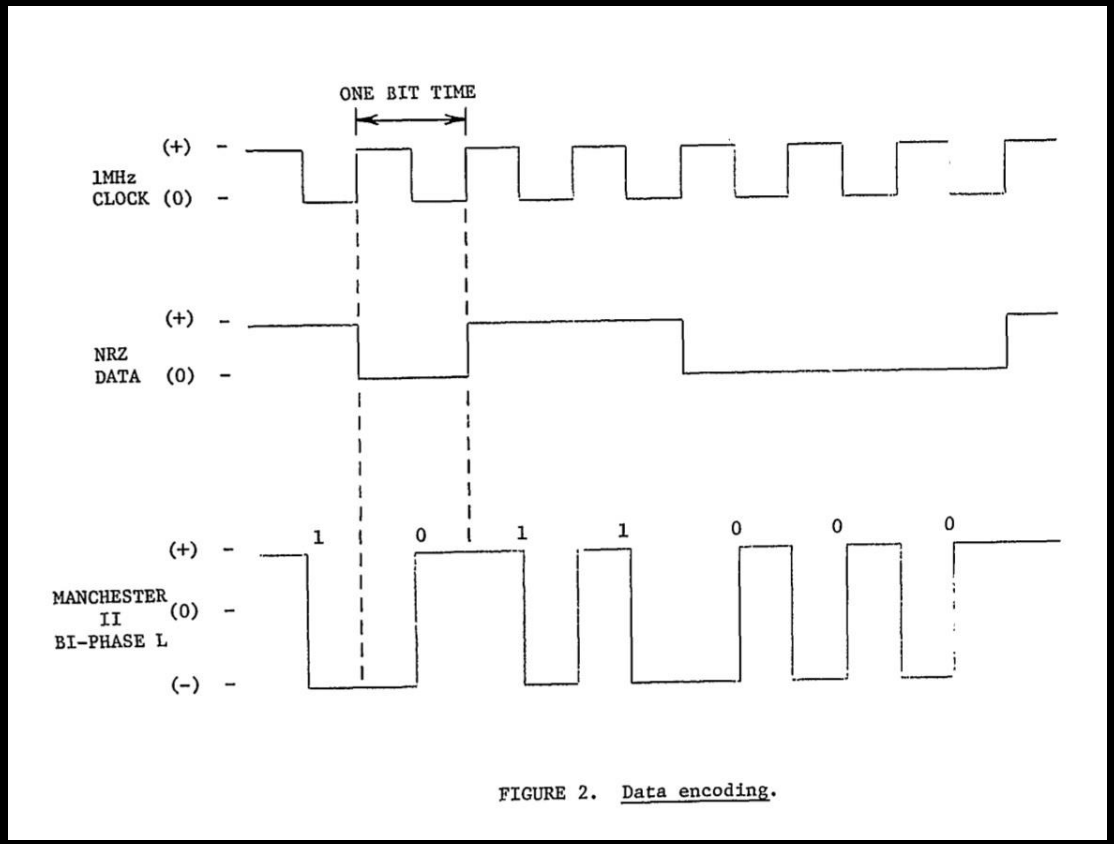

FIGURE 2. Data encoding.

MIL-STD-1553b Data bus Standard Ref(b)

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BUS - MIL-STD-1553(B) Word

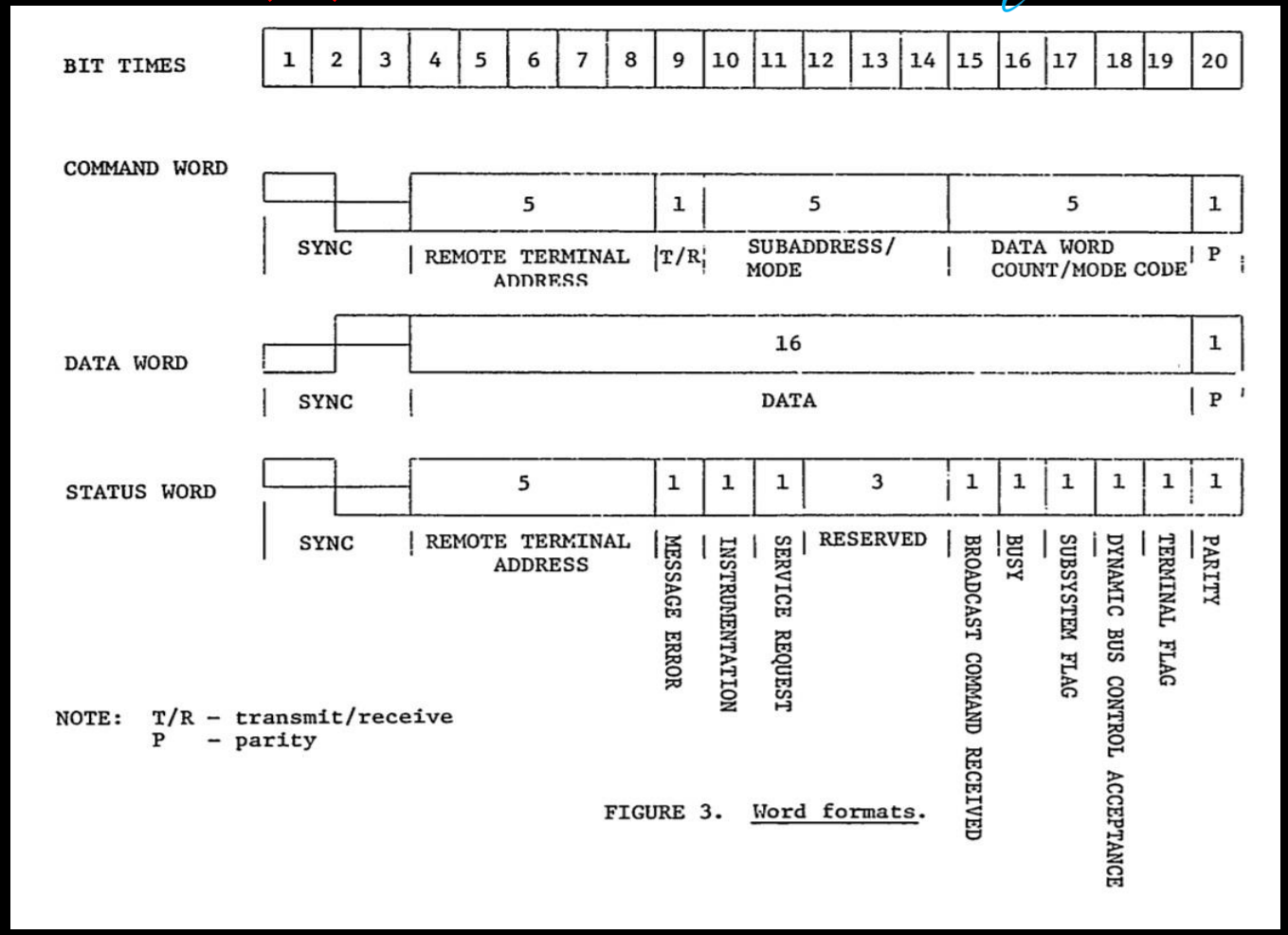

FIGURE 3. Word formats.

MIL-STD-1553b Data bus Standard Ref(b)

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BUS – ARINC-429 Coded Language

-BOEING Standard in legacy systems

-Each word is 32bits

-No more than 20 receivers on single wire

-Unidirectional (tx and rx are on different Ports)

-12.5, 50, or 100kbps

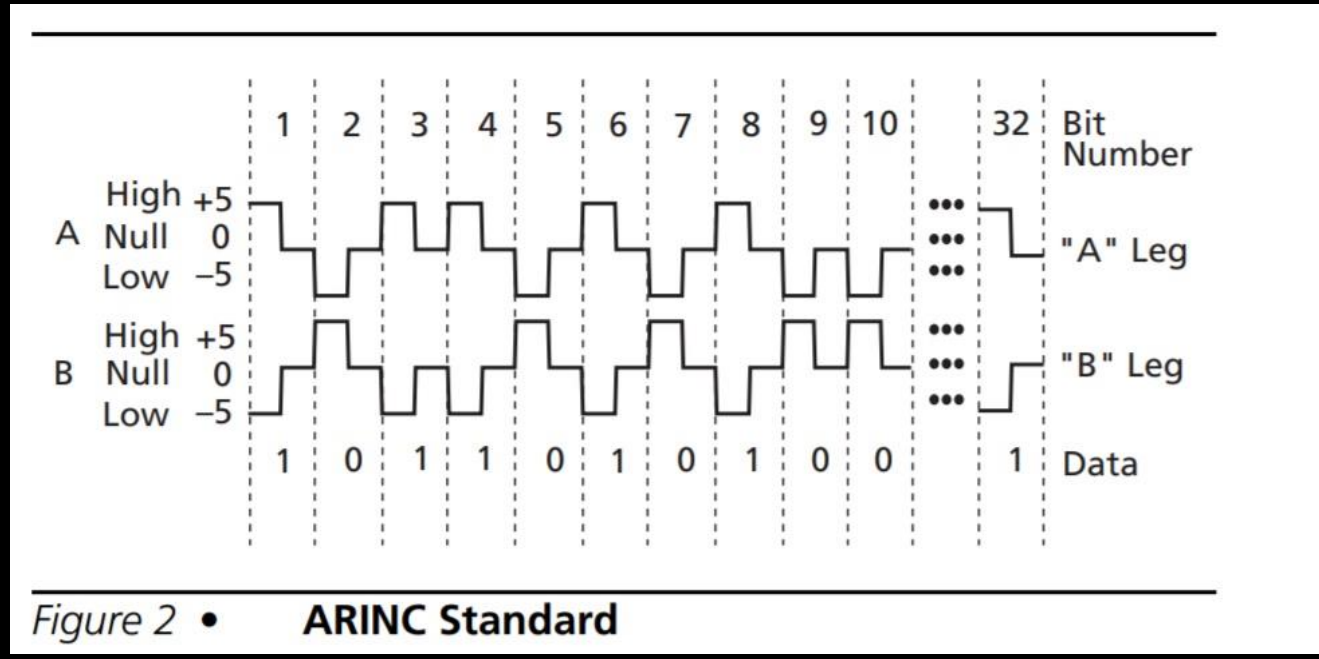

Figure 2 • **ARINC Standard**

ARINC-429 Bus Standard Ref(c)

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BUS - ARINC-429 Coded Word

-Contains five fields to every word: Parity Sign/Status Matrix Data Source/destination Label

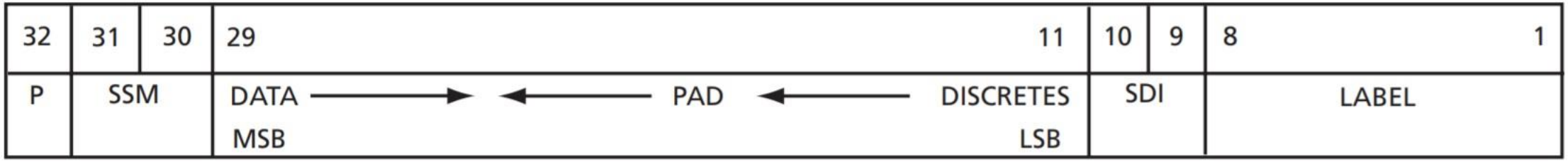

Figure 3 • **ARINC Data Bit Positions**

ARINC-429 Bus Standard Ref(c)

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BUS – Integrated Modular

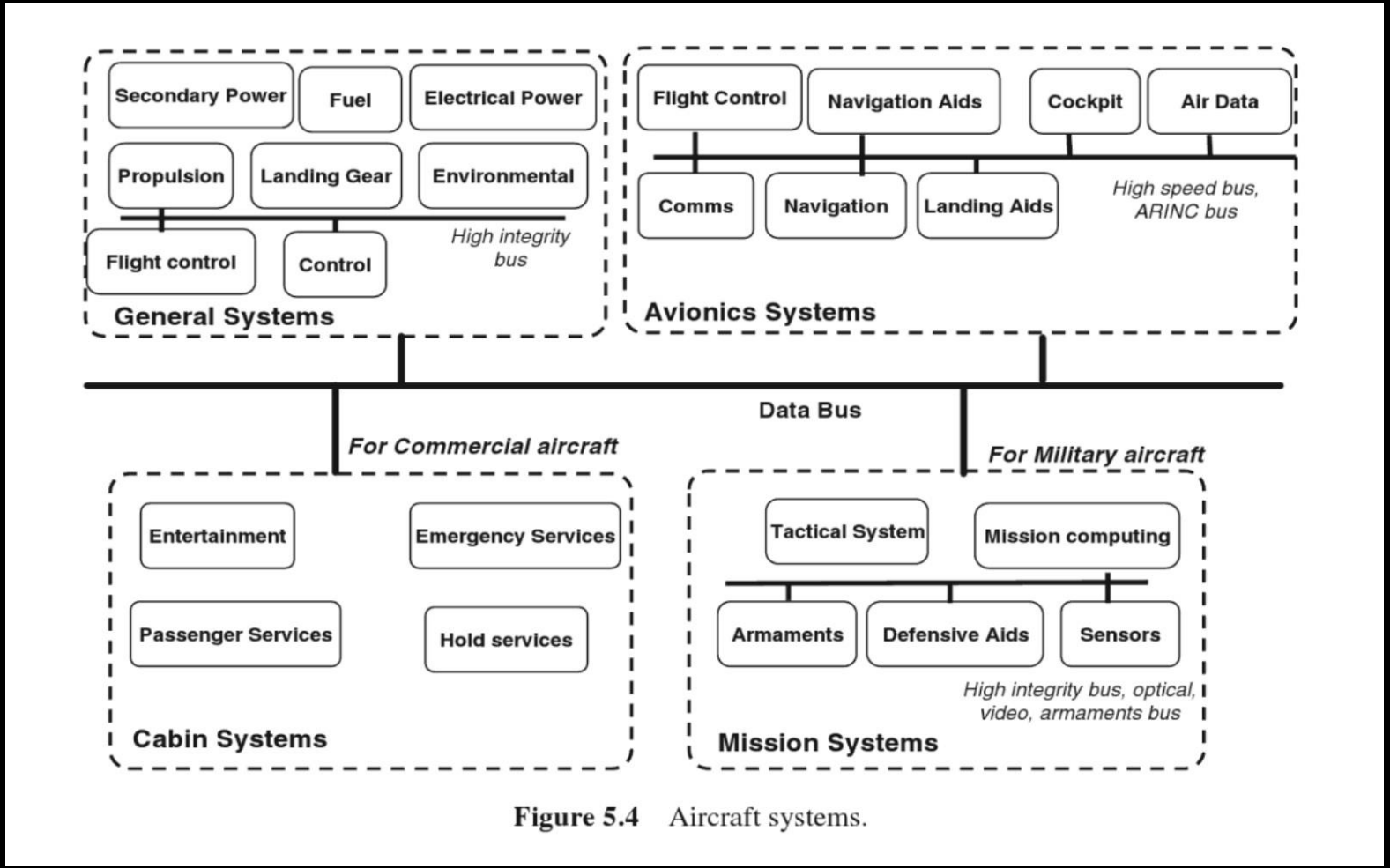

Figure 5.4 Aircraft systems.

Design and Development of Aircraft Systems Ref (a)

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BUS - AFDX® (ARINC-664))

Avionics Full-Duplex Ethernet Switching

-Airbus Standard

-Maximum 120 data terminals per controller

-2 Mbps

-Each word 32 bits

-COTS Integration

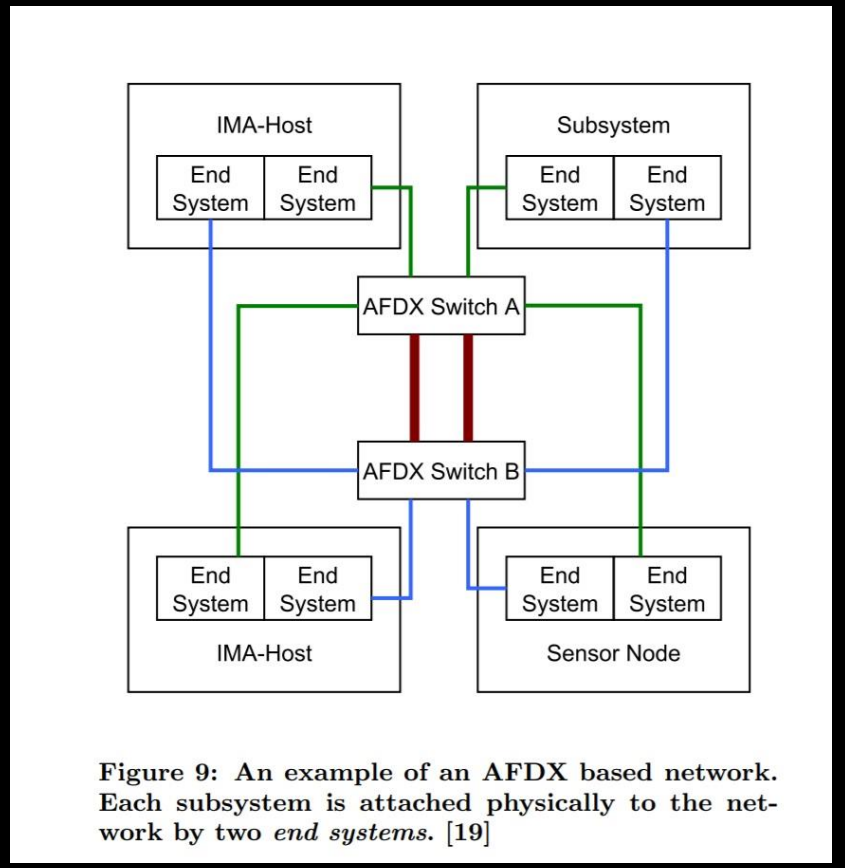

Figure 9: An example of an AFDX based network. Each subsystem is attached physically to the network by two *end systems*. [19]

ARINC-429 to AFDX ref(d)

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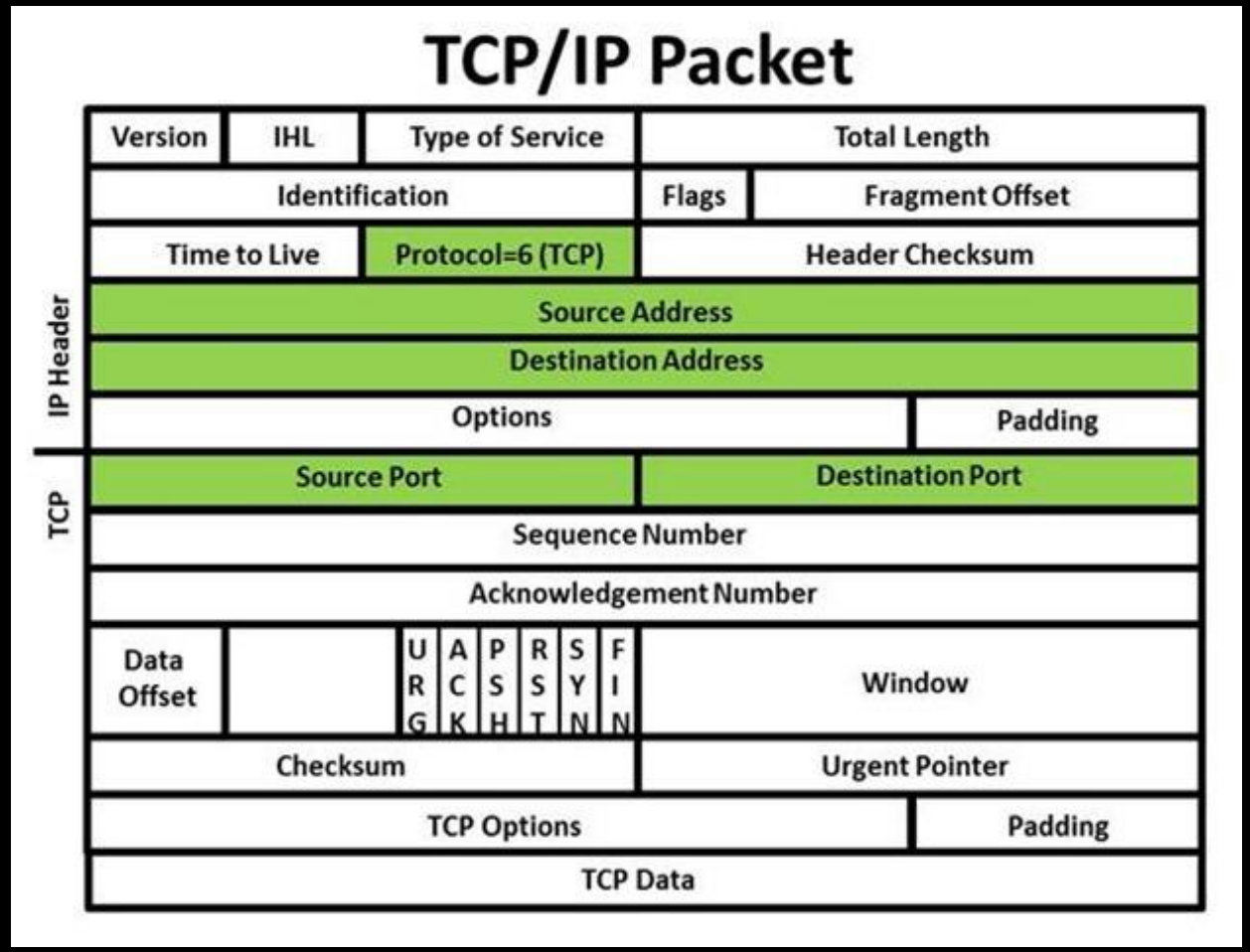
BUS - AFDX® (ARINC-664 upgraded)



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BUS - AFDX® (ARINC-664) FRAME

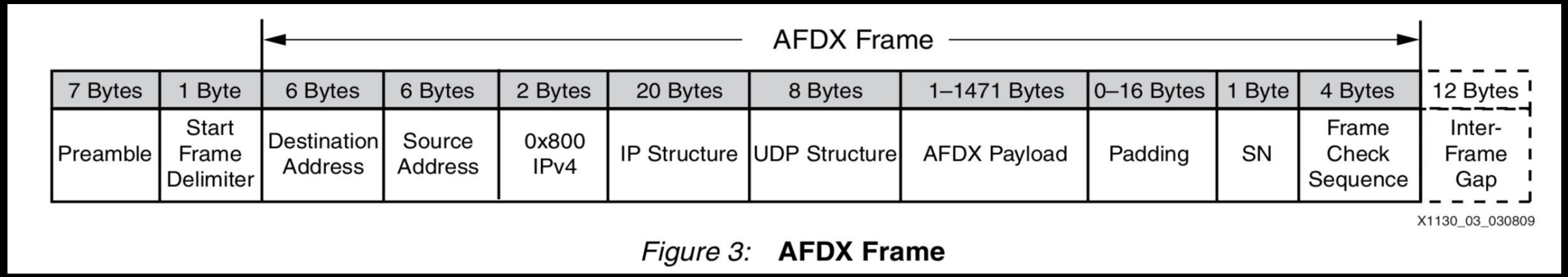

Figure 3: **AFDX Frame**

XILINX Architecting ARINC 664 Part 7 (ref da)

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Attack Vectors (If they existed)

-COTS (Commercial Off the shelf Devices)

-Local Data Connections

-External Data Connections

-People (always with the People)

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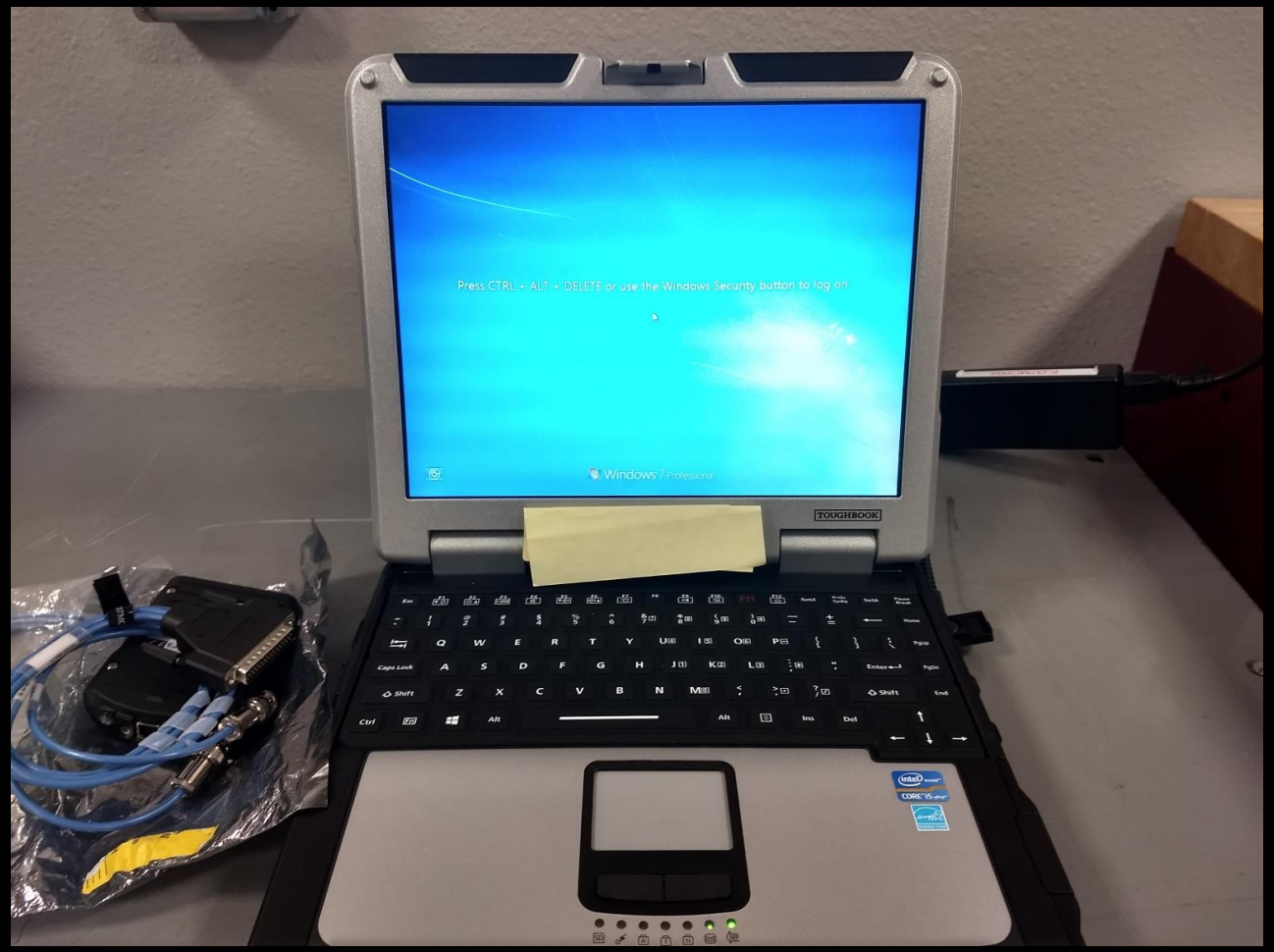
Vectors -COTS

-network hubs

-USB hubs

Literally, commercial Devices designed for IT infrastructure.

- Surprisingly enough, COTS protocols and Services as well.



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Vectors – Local Data Connections

-OFP Loading (1553 Coax shown)
- Using on A/C Data bus to load common Processors,
- EX:
- Primary Flight Computer OFP
- Air Data Computer OFP
- Inertial Navigation Units OFP
- More updates as tech advances

BYOD type MEDIA
- Electronic Flight Bag

-MX data Media
- Hot swappable HDD
- PCM/CIA Cards
- USB drive
- SD Cards

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Vectors –External Data Connections

-CPLDC (Controller Pilot Data Link)

-ACARS (Aircraft Communication, Addressing and reporting System)

-FANS (Future Air Navigation Systems)(VDL2)

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Vectors –External Data Connections

-CPLDC (Controller Pilot Data Link)

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Vectors –External Data Connections

-CPLDC (Controller Pilot Data Link)

-CPLDC is Application layer relying on VDL2
-Used for sending Clear text messages between the ATC and Pilot operators
-Is based off a network to include Iridium Commercial Satellites and ground stations
-VHF band in use for data

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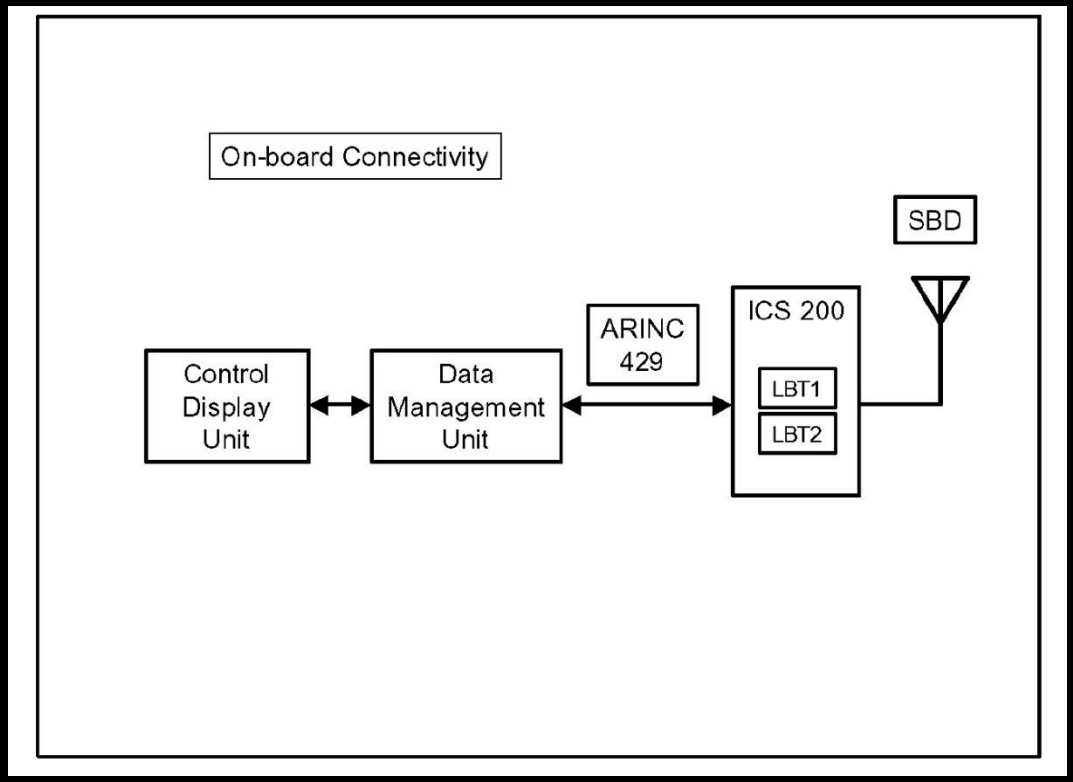
Vectors –External Data Connections

-ACARS (Aircraft Communication, Addressing and reporting System)

- VHF and HF
- Receive Data to print onto Thermal Paper
- Relies on Readily Available commercial networks
- Also a VDL2 product



ACARS ICS-200-1 ref(e)

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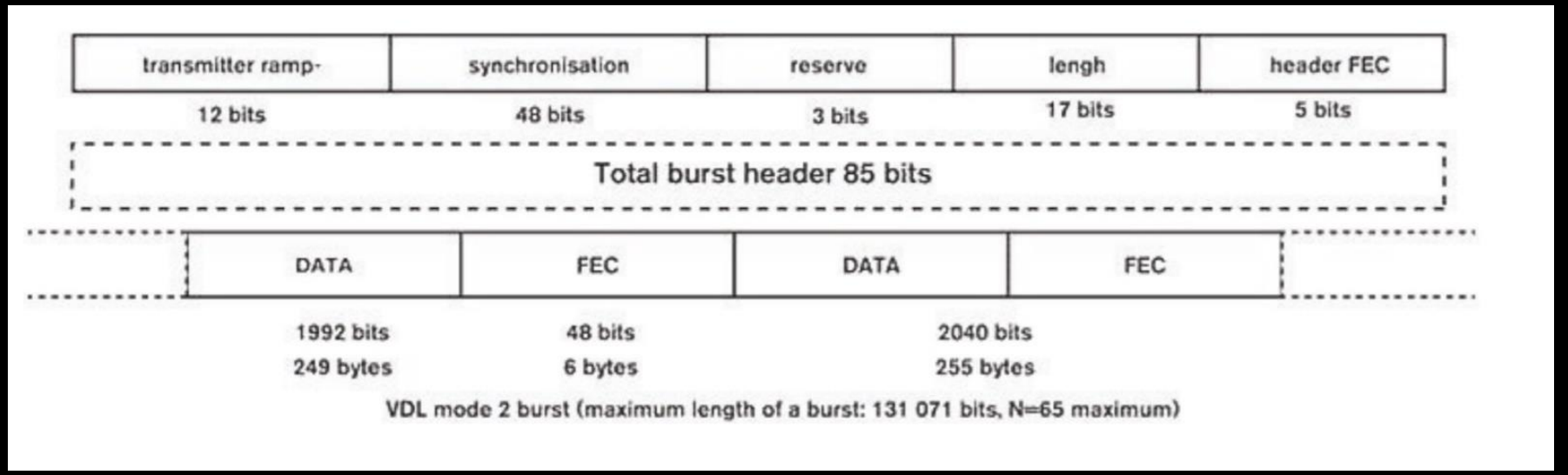
Vectors –External Data Connections

-FANS (Future Air Navigation System)

-VDL is a point-to-point communication technology
-VHF, limited to 200NM of the Aircraft 3k-4k feet
-SDR project Dumpvdl2 on Github



European Telecommunications Standards Institute Master Documentation for VDL
(Ref g)VDL Technical characteristics ETSI EN 301 841-1

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Vectors –External Data Connections

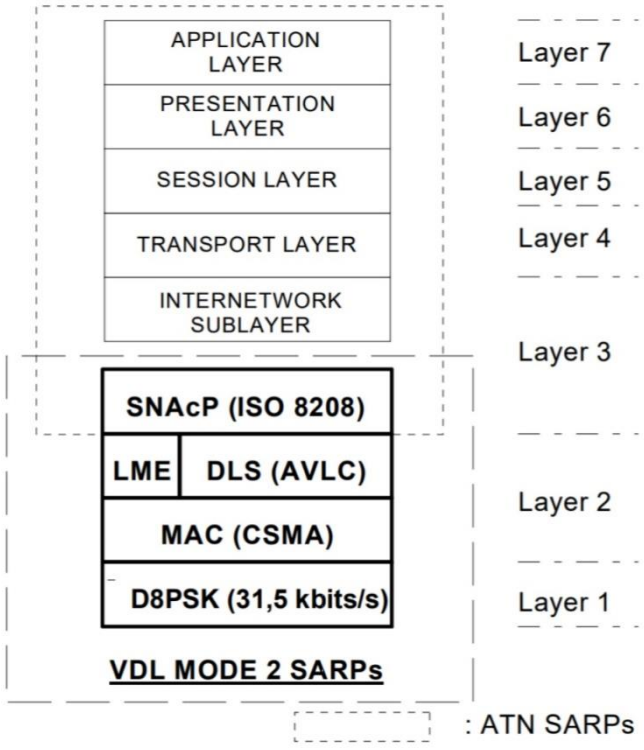
Very High Frequency Digital Link Mode 2 (VDL2)

118 - 136,975 MHz

Lager 1 – Physical layer
- Frequency control
- Encoding for bit errors

Lager 2 – Datalink layer
- Send data
- Framing
- Status
- Error detection

Lager 3 – Network layer
- Data-packet flow



LINKÖPING UNIVERSITY

Andrei Gurtov Air Traffic Seminar 2019 ref(f)

(h)Github DumpVDL2 from Tomasz Lemiech(szpajder)
https://github.com/szpajder/dumpvdl2

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Hacker Hurdles

-Understanding Aircraft Infrastructure

-Understanding Specific components Functions

-Physical Access to hardware

-Testing / Tabletop Access to Software & Hardware

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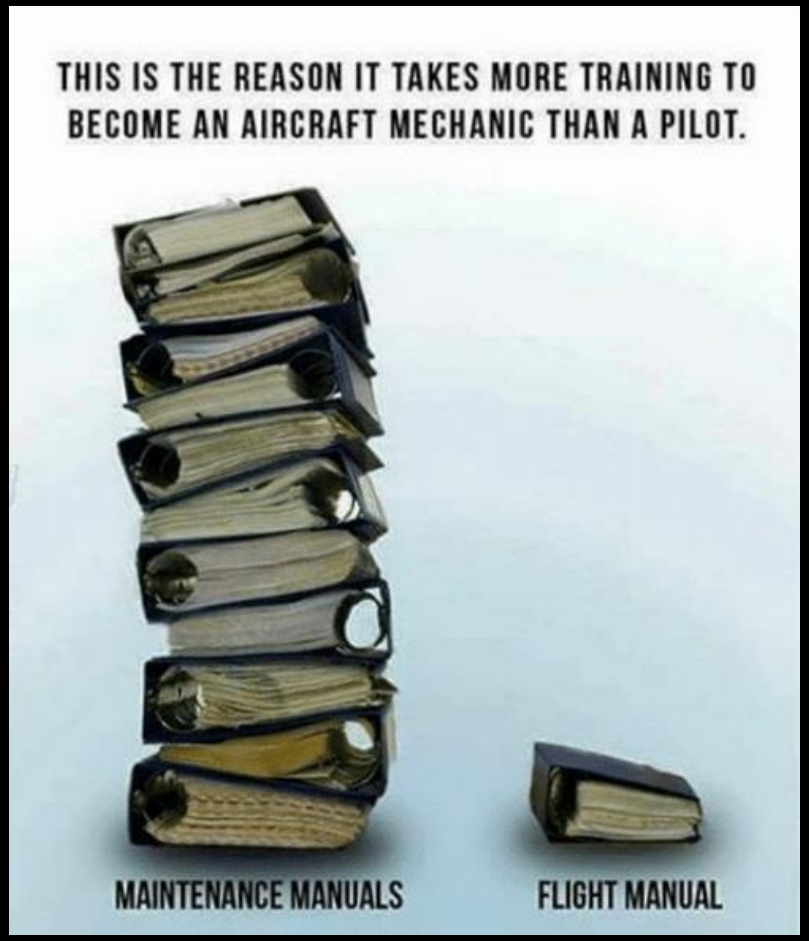
Addendum: Things are happening

- Bombardier Data Leak of CG information, RADAR and linkage
- Software Example, Boeing 737 MAX (OFP)
- US Government Probes A/C Vulns 'Only a Matter of time'



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RESOURCES

(a)Design and Development of Aircraft systems Google-book http://bit.ly/2k6kICx

(b)MIL-STD-1553b Data bus Standard 1979/01/22 PDF http://bit.ly/39QFmLu

(c)ARINC-429 Bus Standard PDF (Archive.org) http://bit.ly/2qtYb5f
Data Link Advisory Circular PDF http://bit.ly/2pGR5Ke
(d)Evolution of Avionics Networks from ARINC-429 to AFDX PDF http://bit.ly/2N4DGnm

IRIG-106 Aeronautical telemetry Open source 1553 Mil standard format 0 http://bit.ly/31AMUgu

Data Comm Systems with FANS 1/A+, CPDLC DCL and ATN B1 PDF http://bit.ly/2N1jR0h

(da)XILINX Architecting ARINC 664 https://bit.ly/36VM2s1

(e)ICAO International Introduction to ACARS ICS-200-PDF http://bit.ly/2Bvuhjp

SDRPlay Decoding ACARS Messages PDF http://bit.ly/2J9KMGf

(f)Andrei Gurtov Air Traffic Seminar 2019 http://bit.ly/2Na0pia

(g)VDL Technical characteristics ETSI EN 301 841-1 PDF http://bit.ly/2pl63Qj

Github DumpVDL2 from Tomasz Lemiech(szpajder) https://github.com/szpajder/dumpvdl2

*Evolution of Avionics Netoworks from ARINC-429 to AFDX https://bit.ly/3eSKOC7

Exploring the Vulns. Of TCAS through SDR PDF http://bit.ly/2Wcjzd6