Operational Loads Monitoring: A Hands On Approach

ICAF 2009

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ACRA CONTROL

Overview

- Data Acquisition in Aerospace Applications
- COTS/Open Standards
  - Ethernet
  - Storage
- Case Studies
  - T-38
  - C-130
  - Tucano
  - E-3D Sentry
- Wrap up

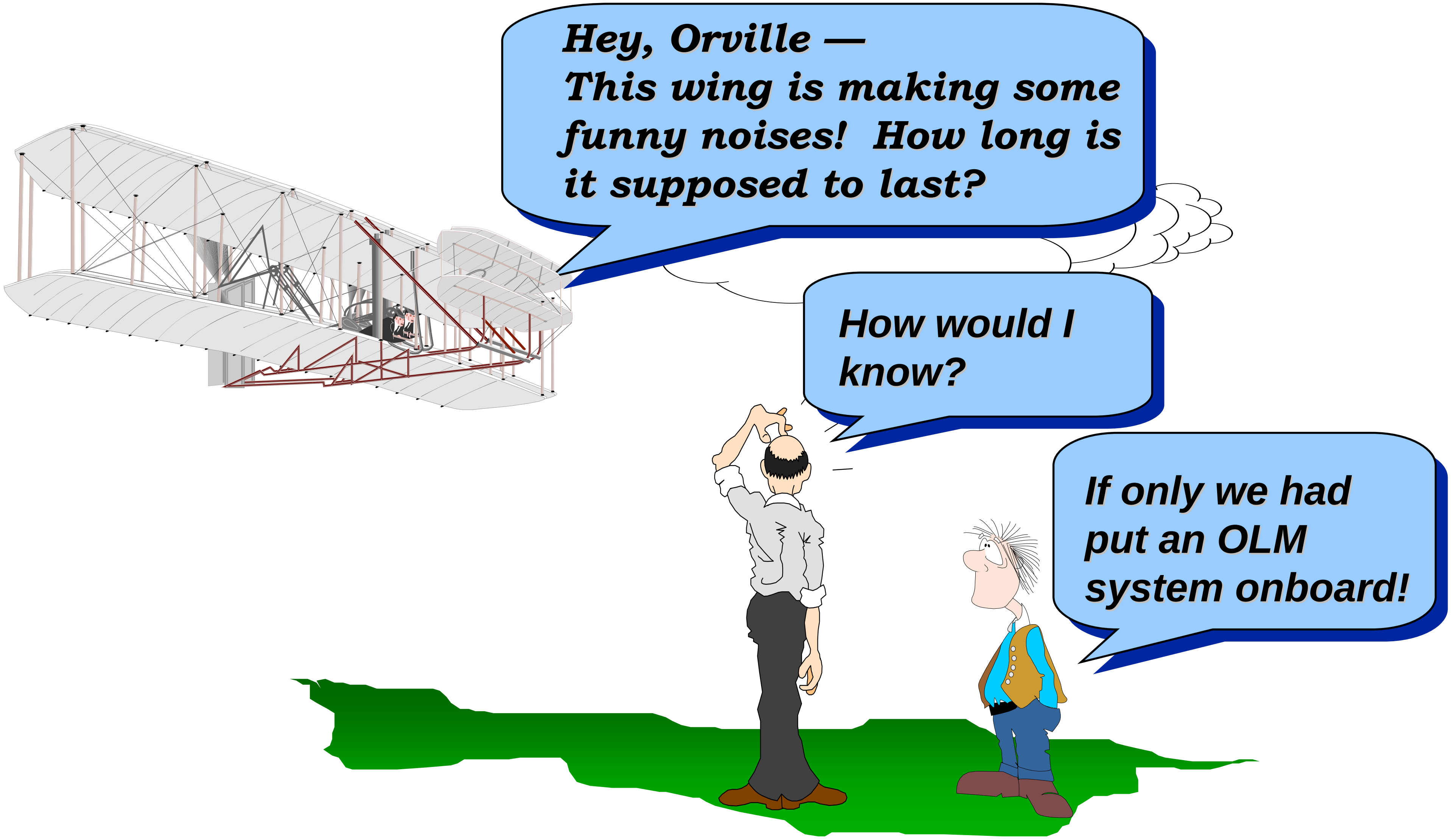
Data Acquisition in Aerospace Applications

- OLM often includes structures and shares similar data acquisition requirements and goals with other methodologies including:
  - CBM
  - L/ESS
  - IVHM
  - HUMS
  - ODR
  - PHM

	Flight Test	OLM	ODR	FDAU	HUMS
Number of Parameters	Thousands	Thousands	Hundreds	Tens	Tens
Data Rates	50K to >2M sps	1 – 100 sps	>10Ksps	1 –100sps	10sps – 10Ksps
Data Storage	Onboard and telemetered	Onboard	Onboard	Onboard	Onboard, sometimes preprocessed

Data only part of the puzzle

A long time ago in a Kitty Hawk ...



COTS and Open Standards

- Commercial Off The Shelf
  - ‘Commercially available products that can be purchased and integrated with little or no customization’
- Open Standards
  - Standards that are widely used, consensus based, published and maintained by recognized industry standards organizations.

Why COTS/ Open Standards?

COTS

- Reduced Cost
- More Future Proof
- Flexibility
- COTS software

Open Standards

- Freed from proprietary hardware and software
- Broad user base
- Suppliers maintain a continuous development plan, using state of the art programming techniques and languages

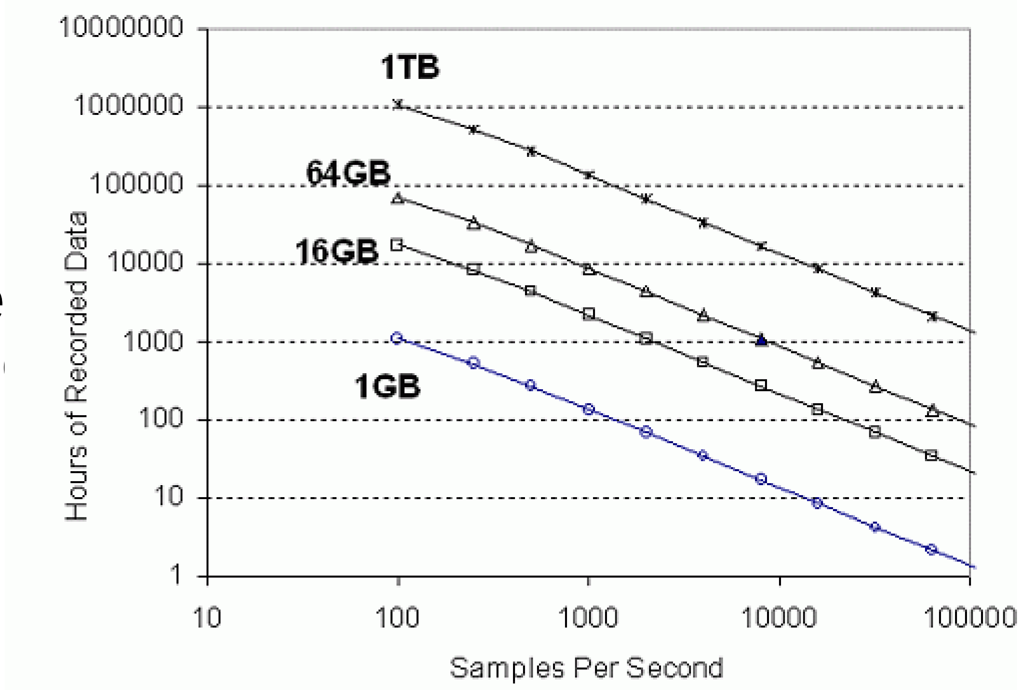
Ethernet

- Ethernet is a proven technology allowing *scalable*, *reliable*, and *flexible* network solutions
- Has a immense userbase
- Airborne networks are unique
  - Small, known
  - IEEE-1588 PTP
  - Dedicated airborne switches and recorders

- Support for hybrid networks
- Fast
- Protocols

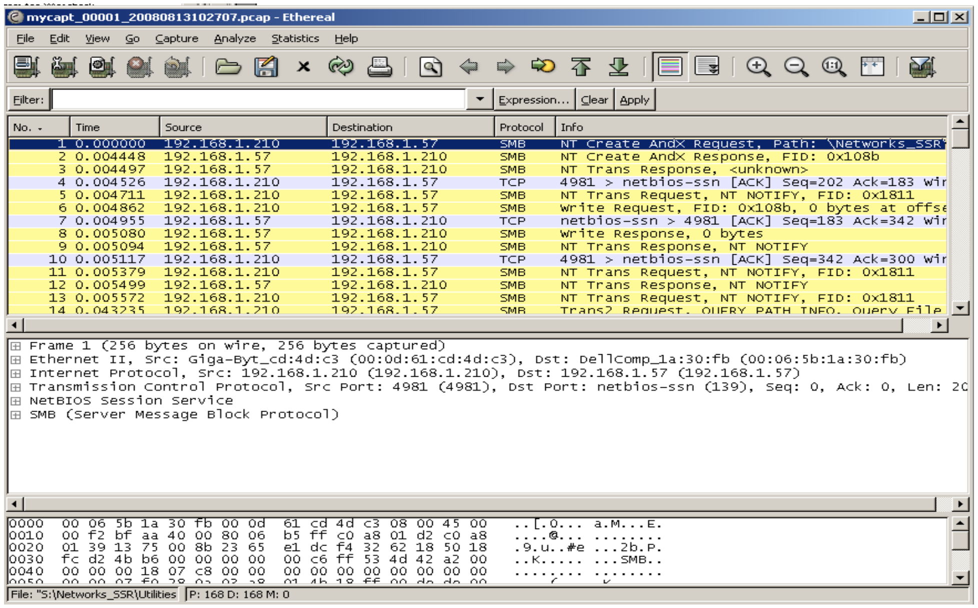
Storage (I)

- Datarates are typically low (5 Hz) except for vibration which can be 2000 Hz +
- Up to 6 years ago OLM syste used tape recorders – up to 4 of data
- Current technologies - CompactFlash and SATA



Storage (II)

- PCAP – Open and efficent Ethernet file format
- PCAP files are widely supported and viewable with free and proprietary software (e.g. Wireshark)
- Simple, easy to process file formats require no conversion



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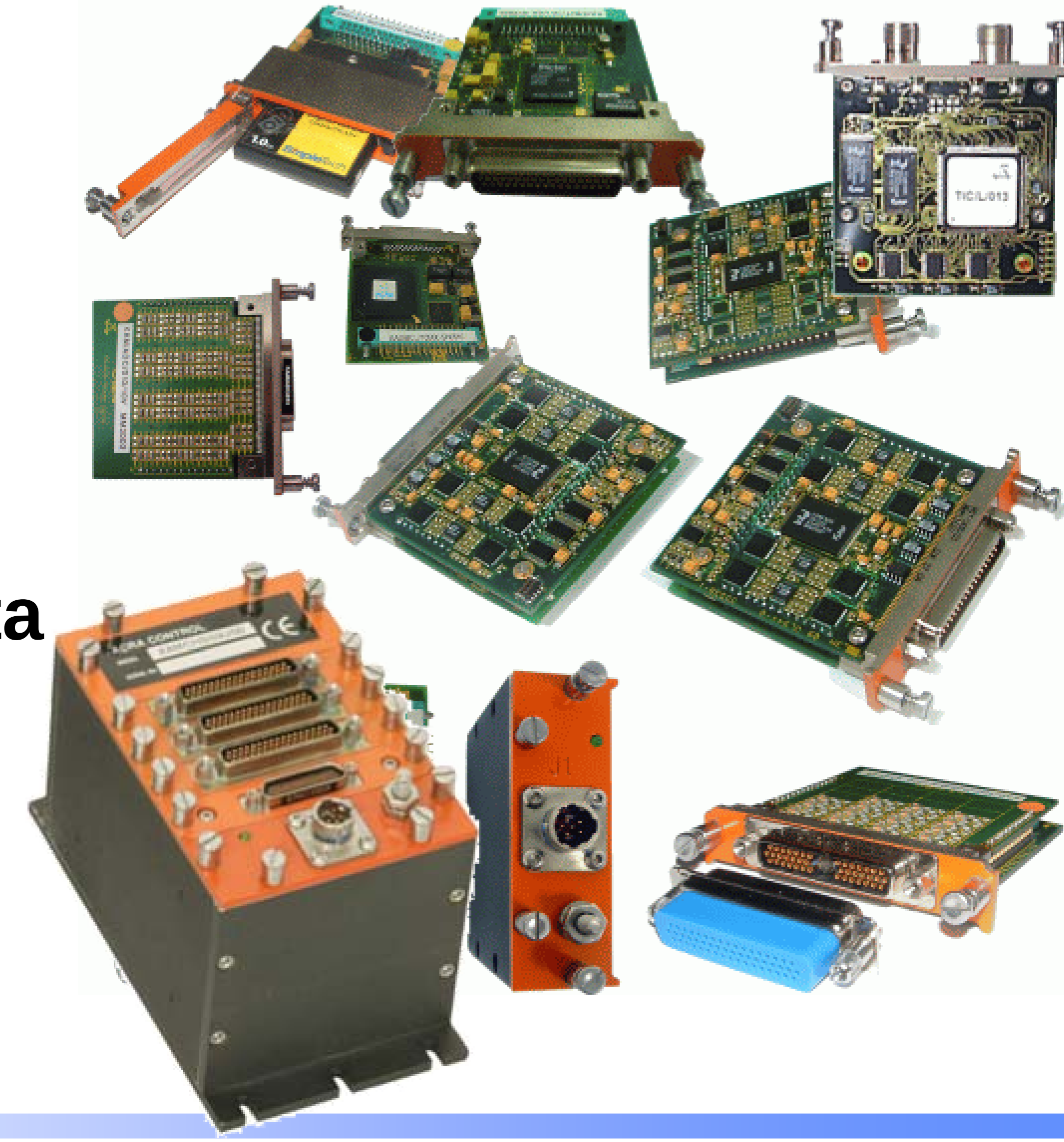
ACRA CONTROL Hardware

- COTS philosophy
  - CompactFlash
- Open Standards
  - Ethernet
  - PCAP
- Acquire the best data possible
  - Simple
  - Robust
  - No supercomputers



Case Studies

- T-38
- C-130
- Tucano
- E-3D Sentry

T-38

- **First and most produced supersonic trainer**
- **Flying for 50 years, talk of extending beyond 2017 to 2020**

Phase 1

- 1st testing phase: Recorded flight data for 6 months
- Measured parameters
  - Air Speed
  - Altitude
  - Vertical & Lateral Acceleration
  - Time Reference
- Onboard storage

Phase 2

- 2nd phase added strain gauge and serial data modules
- 'BIT'
- MatLab for analysis
- Expandable system

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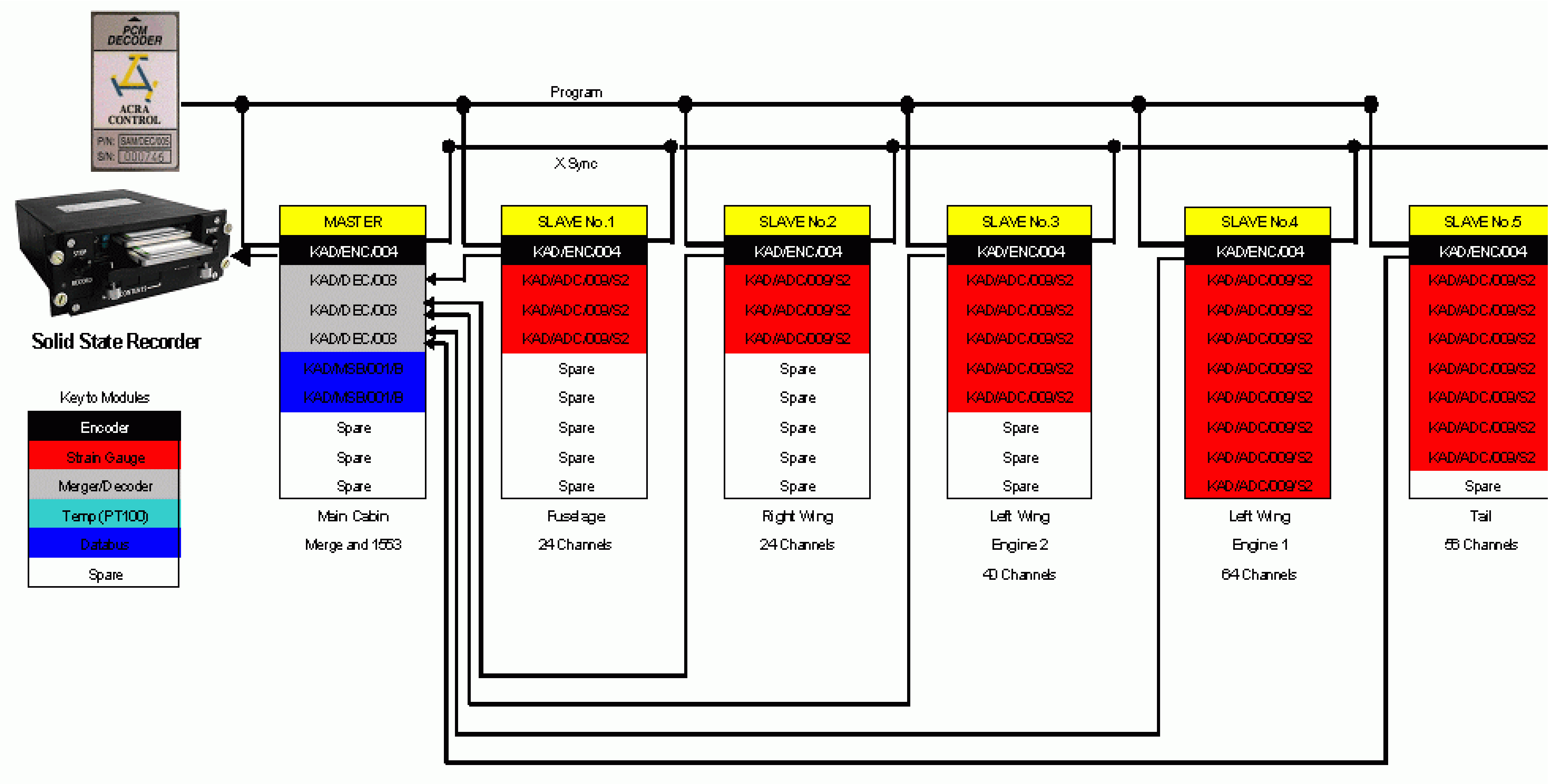
C-130

- In use around the world
  - Different roles
  - Different environments
  - Impact on fatigue by <u>aircraft use</u> not just flying time


Data Acquisition



208 Strain gauges **28 Other Aircraft parameters**

Parameters Measured by the C-130J DAS

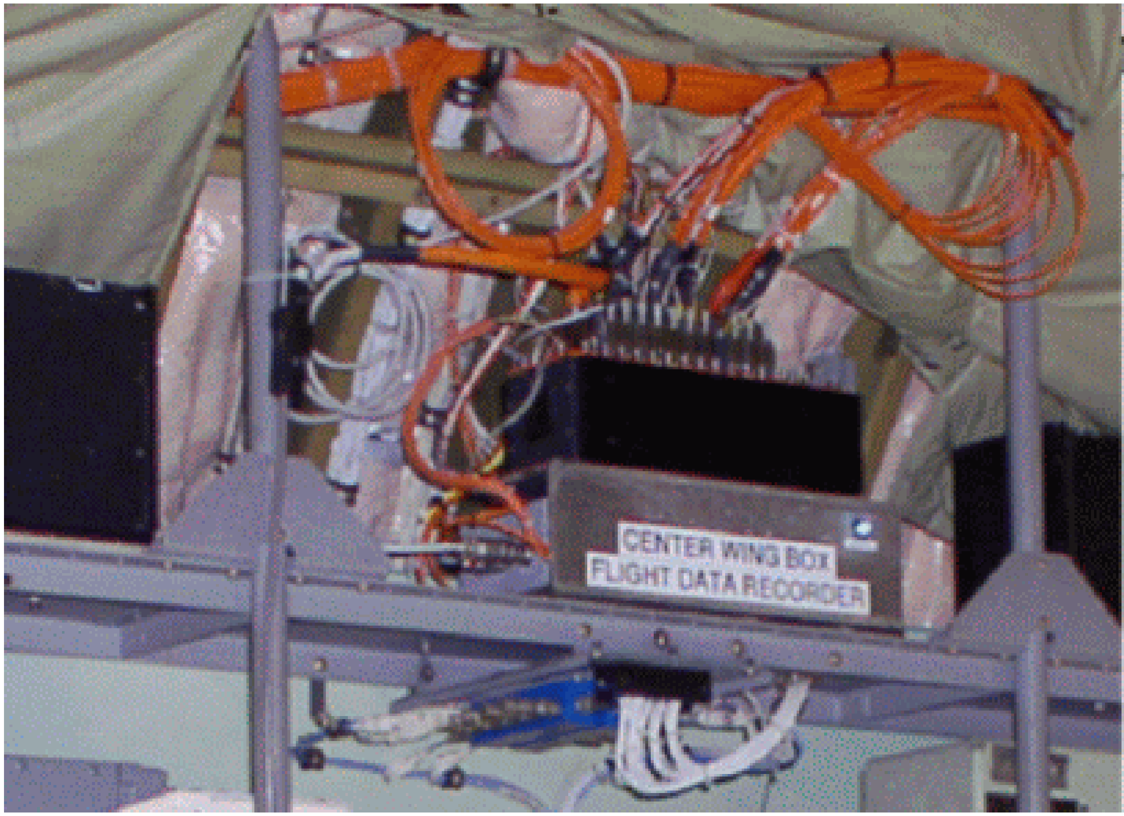
Airspeed	Cabin Differential Pressure	Engine Torque Number 1
Pressure Altitude Fine	Fuselage	Condition Lever Position
Radio altitude (Low Range)	Total Fuel Weight	Pitch Trim Deflection
Aileron (Left Hand)	Mach Number	Roll Attitude
Rudder Position	Climb/Descent Rate	Roll Rate
Fuel Flow Rate (4 Parameters)	Pressure Altitude Coarse	Normal Acceleration at Centre
Engine Torque Number 2	Radio Altitude (High Range)	Lateral Acceleration
Flap Position (Left Hand)	Elevator Position	Angle of Attack
Pitch Attitude	Aileron (Right Hand)	Ground Speed
Pitch Rate	Flap Position (Right Hand)	

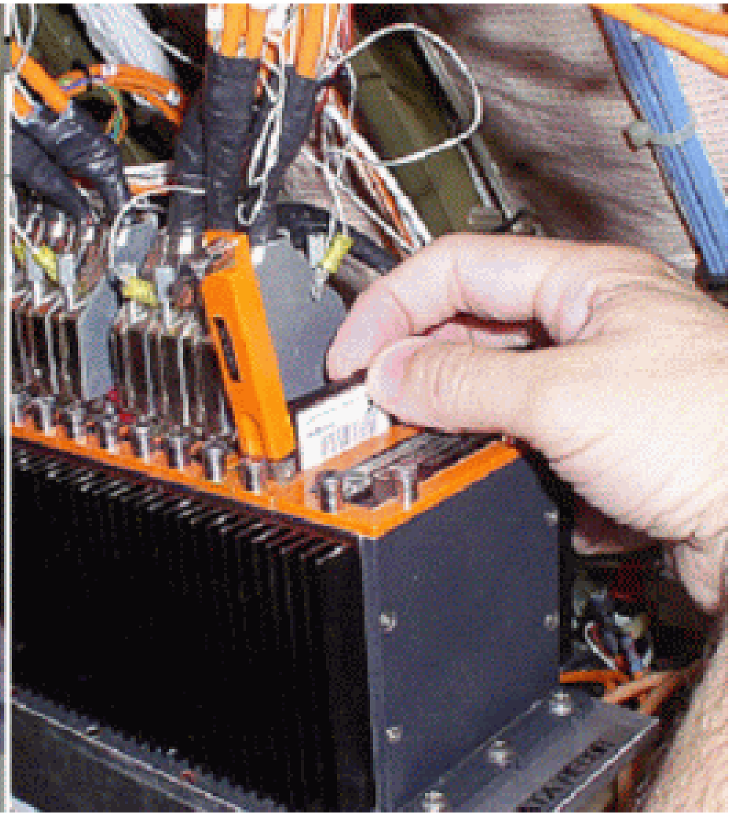
USCG HC-130H

- US Coast Guard
- Search and Rescue
- Patrol
- Environmental data for future comparison

Installation

- Digital and Analog signals
- Integrated CompactFlash recording





Tucano

- Originally fitted with only a ‘g’ counter
- Aims
  - More detailed data from actual flights
  - Over 1,200 instrumented flights
  - Create spectra for rig tests

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Parameters Acquired by the Trainer Aircraft DAS

Strains	Aircraft Parameters	Discrete Signals
12 on the wings	Airspeed	Undercarriage Position
6 on the tail-plane	Altitude	Air-brake
3 on the fin	Elevator Aileron, Rudder Angles	Weight on Wheels
4 on the fuselage	Tail, Port and Normal G, acceleration	Radio Transmit
9 on landing gear	Flap position	Compass Flag
	Compass heading	Pilot Event Switch
	Engine Torque	Start/Run/Stop Switch
	Fuel	Engine Speed
		Trend Switch

- **Battery back clock**
- **In built storage**

2nd Phase

- Ground rig
  - Simulate stresses
- About 200 ‘sorties’ per week
- Still running today
- Results emulating real flight phenomena - successful
- Same hardware still flying

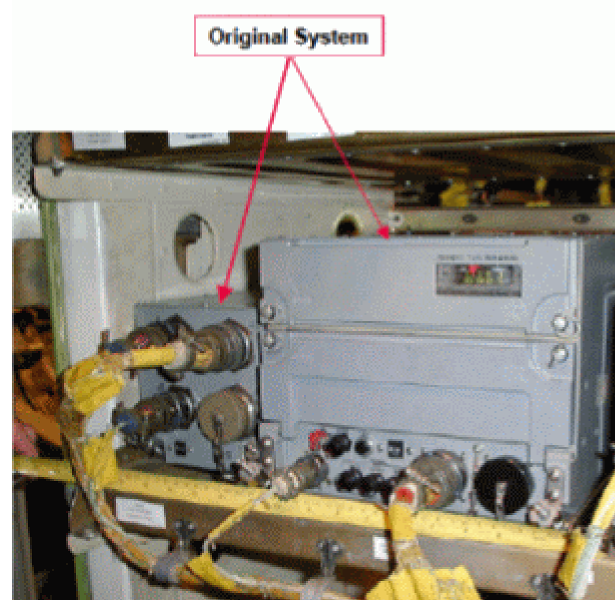
E-3D Sentry L/ESS

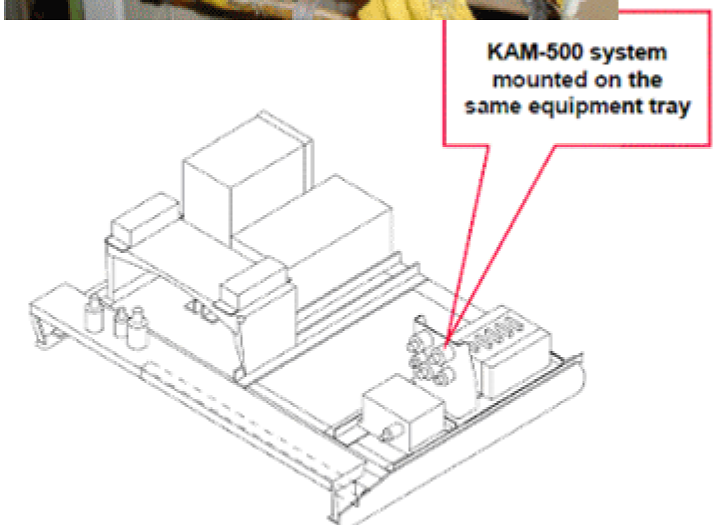
The Boeing E-3D Sentry is an Airborne Warning and Control System (AWACS) aircraft

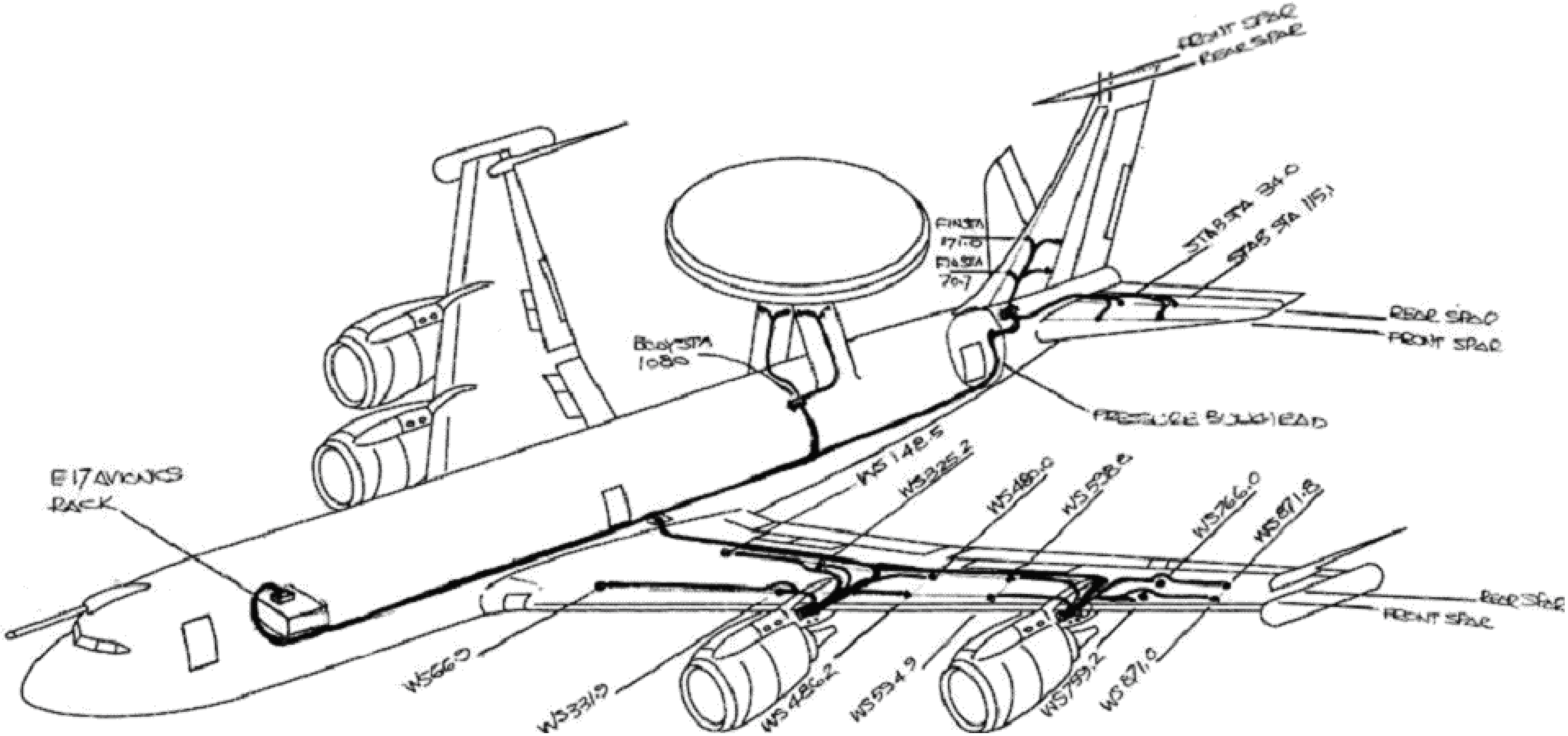
- Recorded airframe stress and other parameters on every flight
- The US collect data from other aircraft around the world
- Trend data indicates potential fatigue or maintenance problems well before they become critical

ACRA CONTROL & E-3D Sentry

- **ACRA CONTROL replaced the E-3D system**
- **Benefits included**
  - Weight – 15Kg lighter
  - Power – 50% lower
  - Space - < one quarter
  - Maintainability – standard product
  - Supportability – spares, new modules available

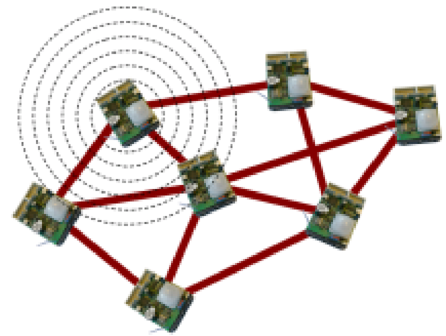


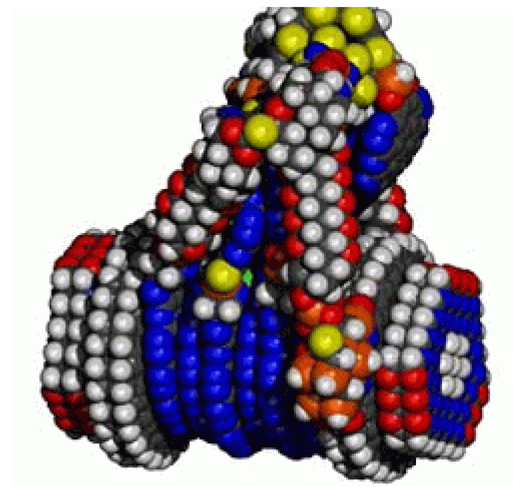




OLM – In the Future

- Bi-directional IP centric mobile wireless
  - Aircraft Condition Monitoring systems
  - RTP
- Smart sensors, Nanotechnology, MEMS, Artificial Intelligence and Distributed Computing could eventually lead to self repairing and ageless structures
- Become part of integrated electronics for future aircraft?
  - Likely, but that may take some time





In Conclusion

- Aging Aircraft may be placed into new roles/environments that requires a new fatigue profile
- Data Acquisition is only part of the puzzle
- Open standards/COTS have many advantages over proprietary systems
- Adaptable and expandable systems can evolve with the airframe and technology changes
- Interesting developments in the future, but may be a long time coming

THANK YOU