Flight Test Instrumentation

Ryan Graves

Agenda

- Flight Test Articles
- Transducers
- Effectors/Actuators

Flight Test Articles

- Business jet flight test programs are typically based around four test aircraft and one production aircraft
  - T1: Aero envelope expansion bird
    - Stalls testing
    - Flutter
    - Ice Shapes
  - T2: Loads and performance bird
    - Aerodynamic loads
    - Field performance
  - T3: Systems bird
    - Avionics
    - Electrical
    - Anti-ice
  - T4: Cabin bird
    - Smoke evacuation
    - Water and waste
    - Lightweight handling
  - P1: Production bird
    - Victim-source testing
    - EMI
    - Function and reliability

T1: Aero Envelope Expansion

Nose Boom Instrumentation
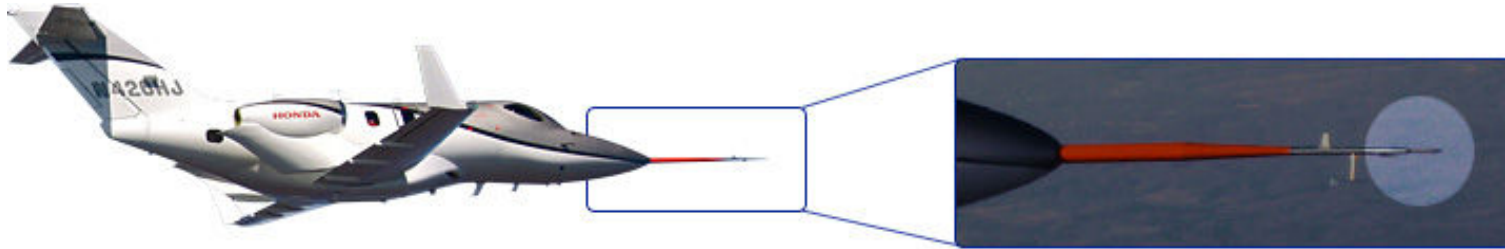
The pitot tube is attached to the front of the nose boom, where there is little interference to air streams.
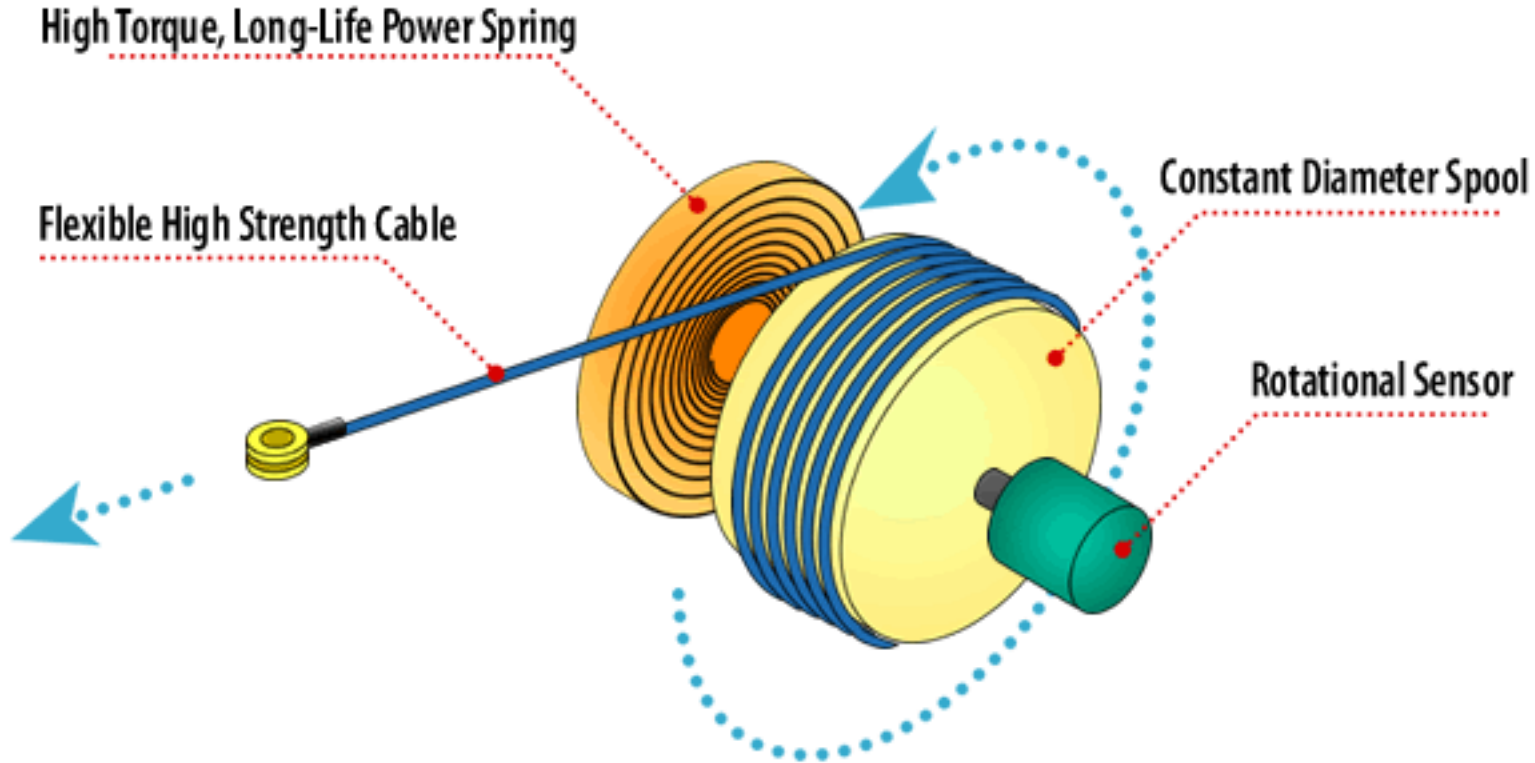
Trailing Cone

T2: Performance
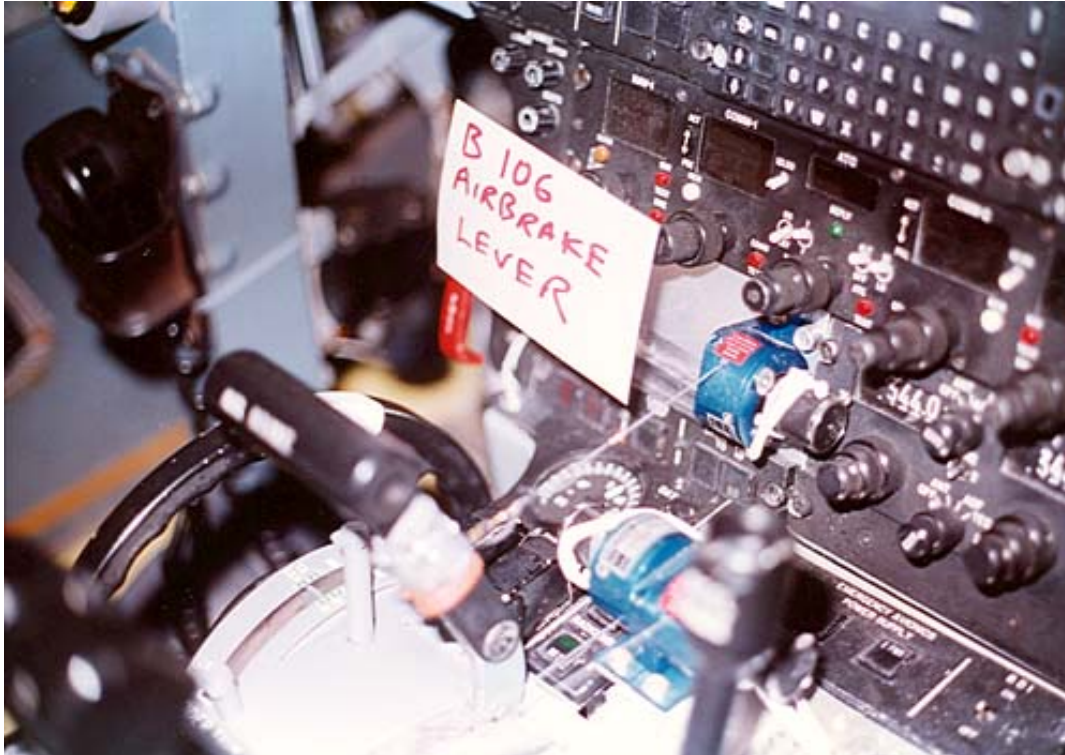
T3: Systems

T4: Cabin

Transducers

- String Pots
- Strain Gages
- Thermocouples
- Pressure Transducers
- Rotary Encoders
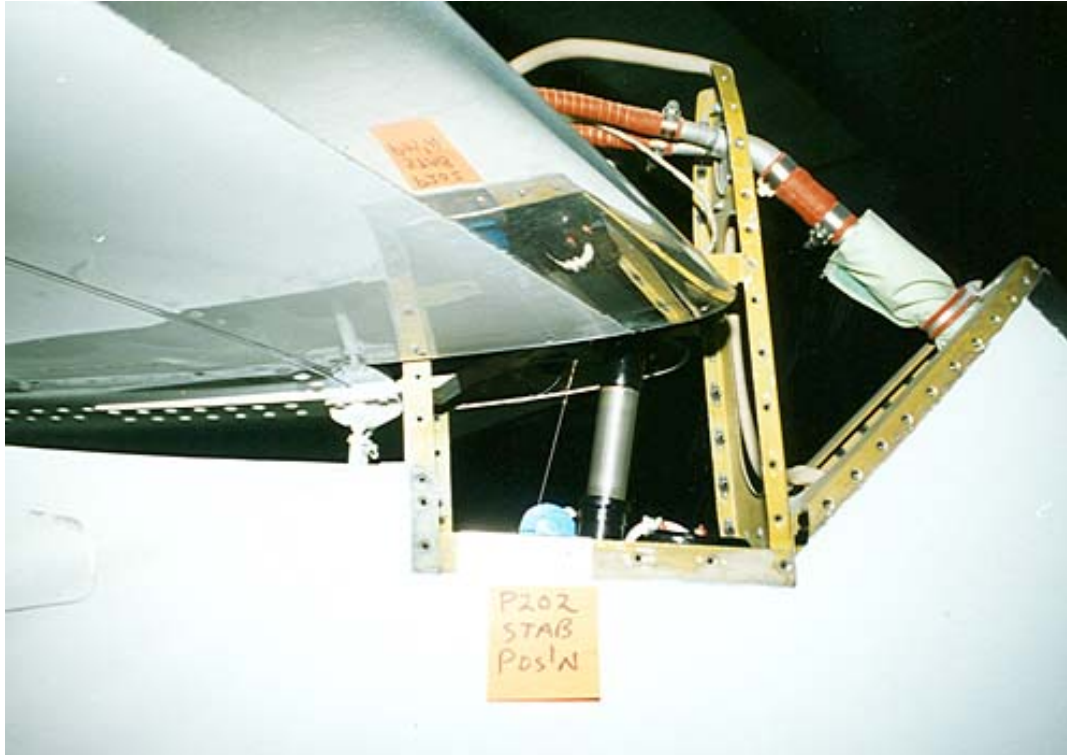- Electrical Sensors
- Serial Bus Sniffers
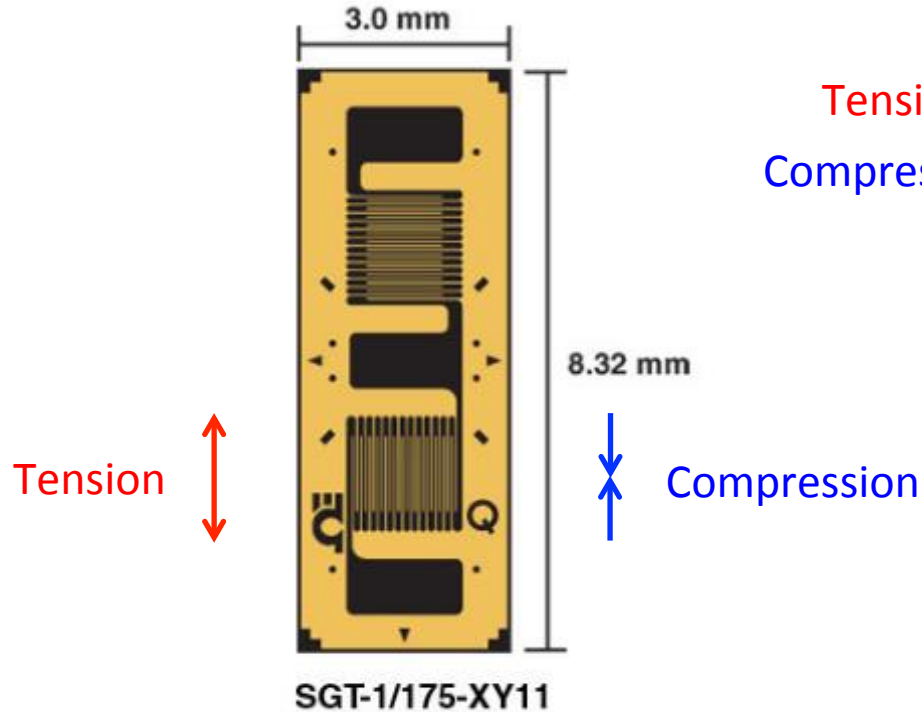
String Potentiometers

High Torque, Long-Life Power Spring

Flexible High Strength Cable

Constant Diameter Spool

Rotational Sensor

String Potentiometers
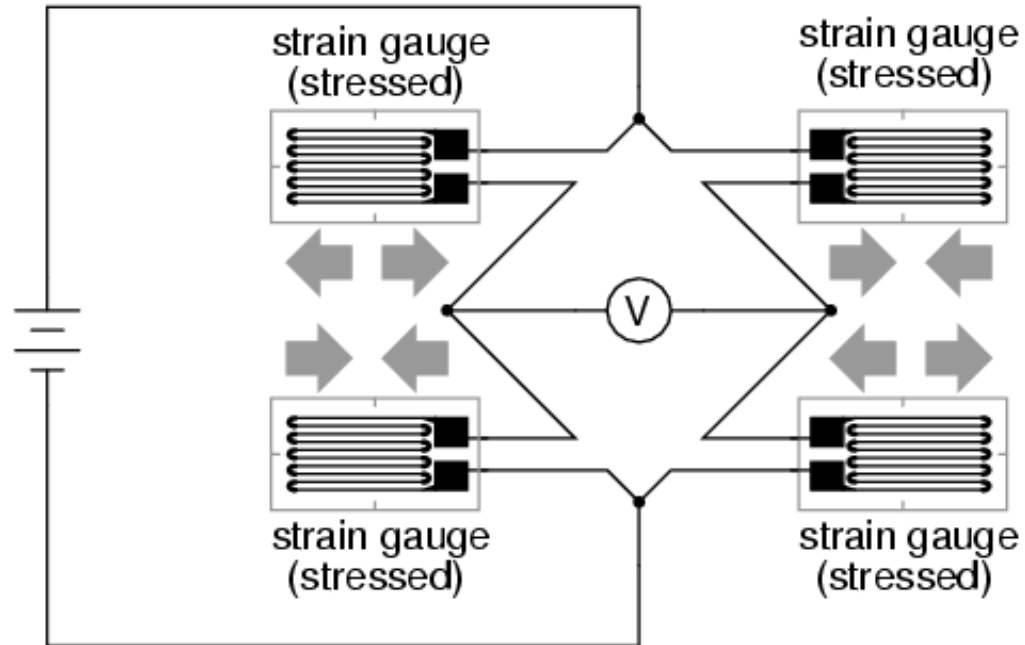

Lear 35

String Potentiometers

Lear 35

Strain Gauges

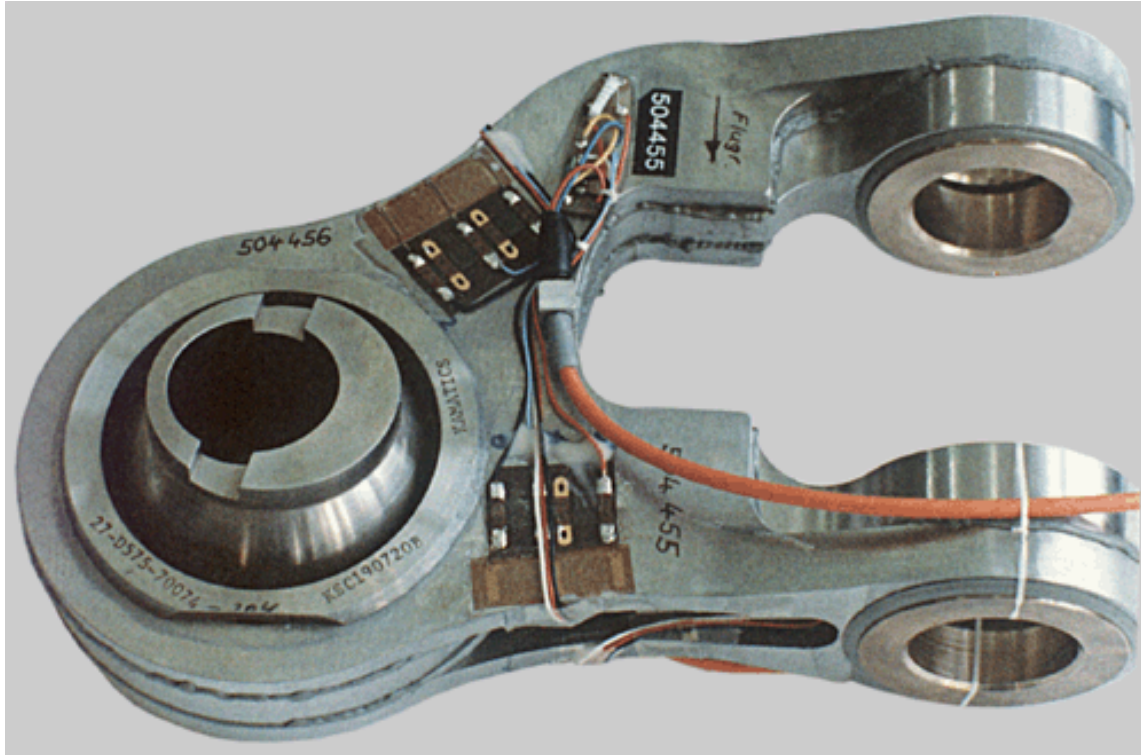
Tension = Increased Resistance

Compression = Decreased Resistance
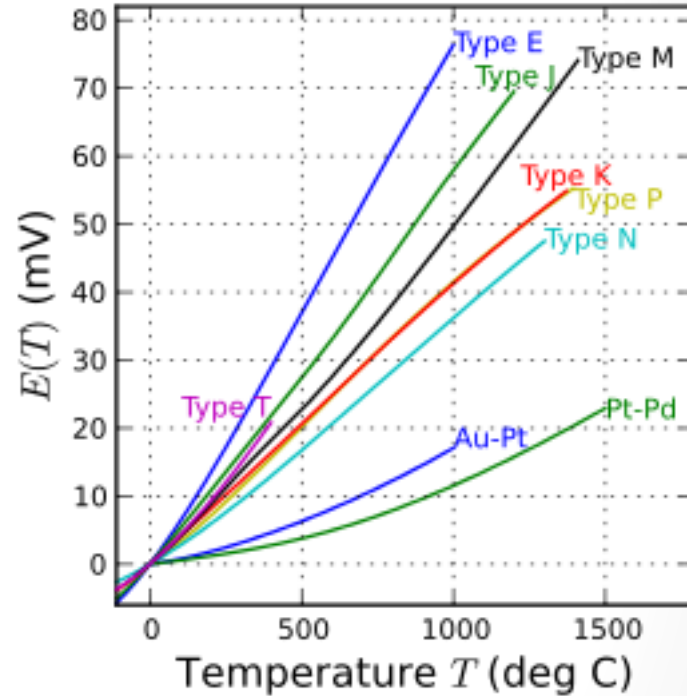
Strain Gauges
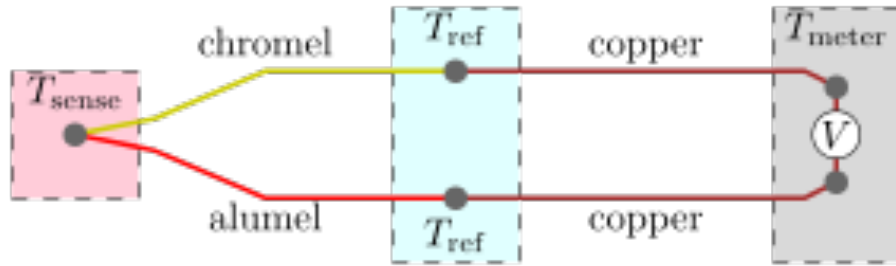

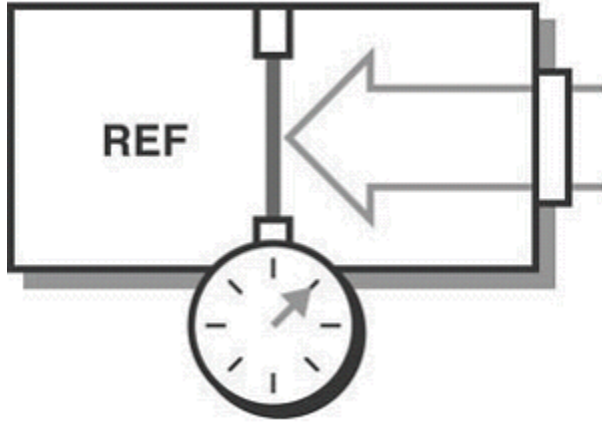
Full-bridge strain gauge circuit

Strain Gauges
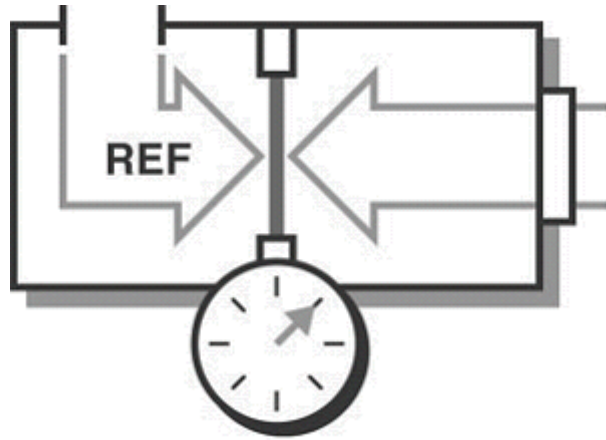
Thermocouples

Pressure Transducers

- Absolute pressure transducer
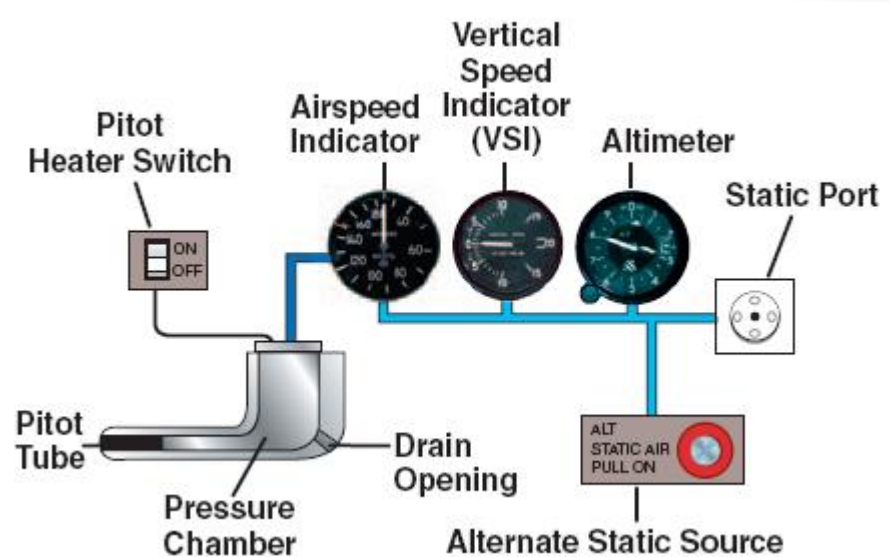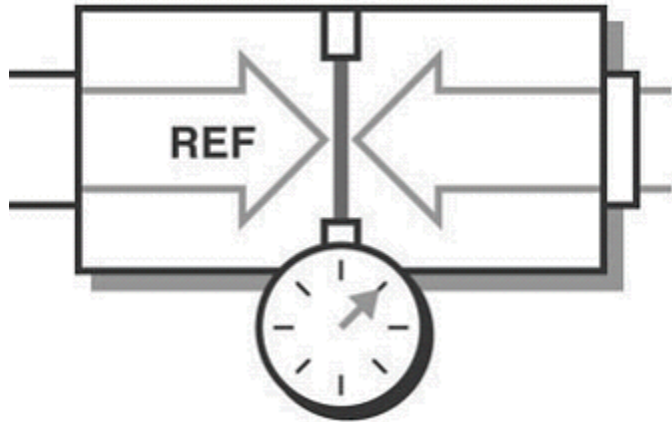- Reference to sealed pressure
  - Normally sealed to SSL

Pressure Transducers

- Gauge pressure transducer
- Reference to ambient pressure

Pressure Transducers

- Differential pressure transducer
- Two inputs measured differentially

Pressure Transducers

Rotary Encoders
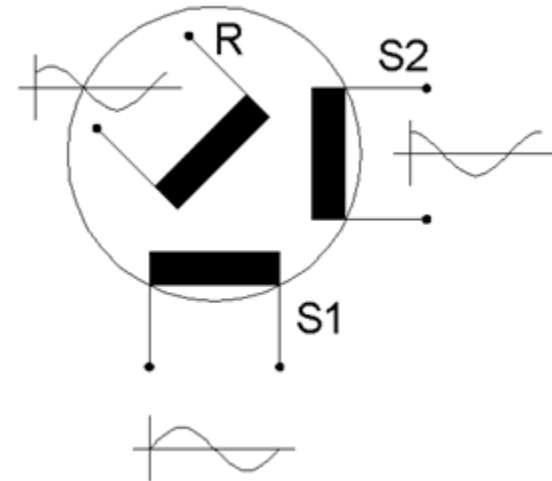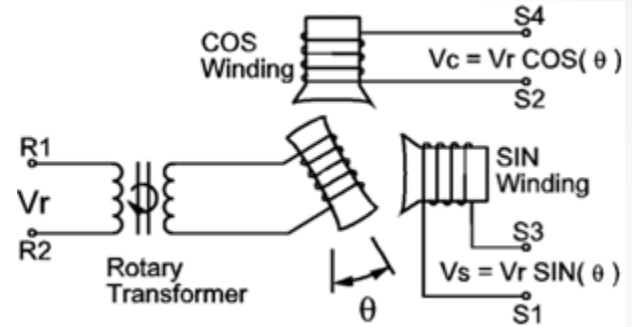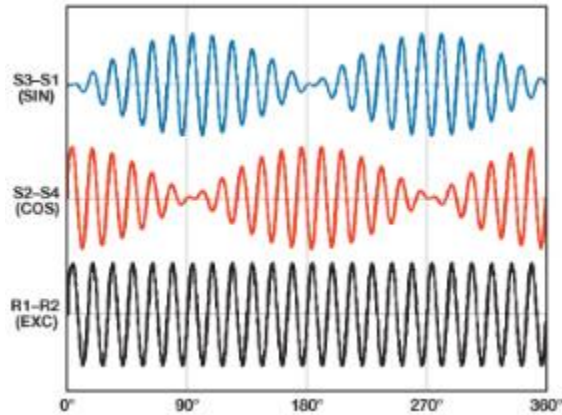
Electrical Sensors

OPEN CIRCUIT BEHAVIOR

BEHAVIOR UNDER LOAD

R_1

R_2

V_1

NO LOAD

V_{out}

R_1

R_2

V_1

WITH LOAD

V_{out}

R_L
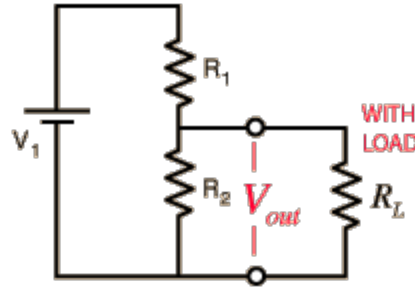
$$V_{out} = V_1 \frac{IR_2}{I(R_1 + R_2)} = \frac{V_1 R_2}{(R_1 + R_2)}$$

OUTPUT VOLTAGE UNDER "NO LOAD" CONDITION (open circuit)

OUTPUT VOLTAGE UNDER LOAD

$$V_{out} = V_1 \frac{IR_2}{I(R_1 + R_2)} = \frac{V_1 (R_2 \parallel R_L)}{(R_1 + R_2 \parallel R_L)}$$

Electrical Sensors
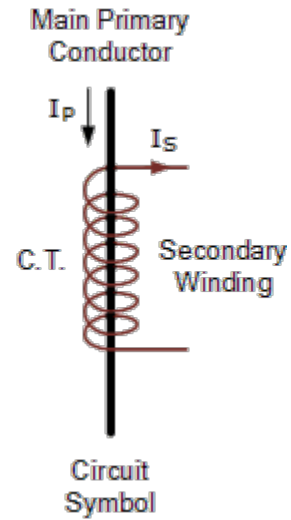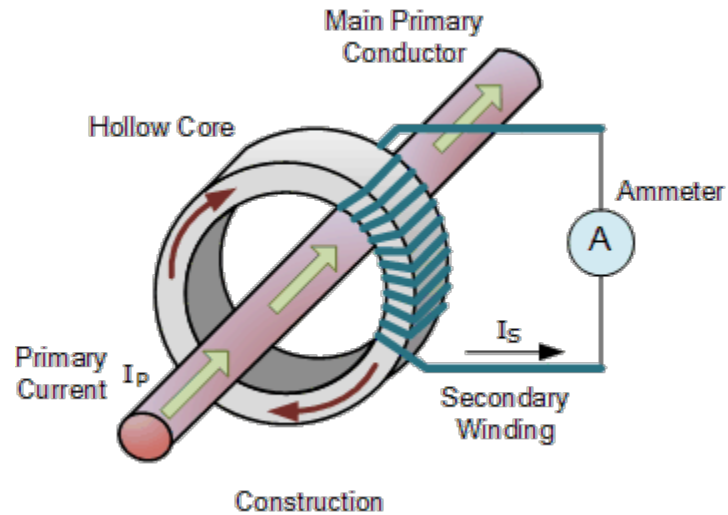
Other Sensors and Transducers

- Serial bus sniffers
  - Used to monitor avionics I/O
- Accelerometers
  - Engine vibration
  - Flutter
- Microphones
- Video

Data Sinks

- All data recorded to hard drives on-board
  - Solid-state hard drives preferred due to vibrations
- Critical data recorded to dedicated flash memory cards
- Mission select data telemetered to base station
  - Live data analysis can happen in-air or over telemetery to base station

Sample Rate

- Nyquist rule states:
  - The minimum sampling rate is two times the highest frequency component of interest of the input signal

- High sample rate:
  - Accelerometers
  - Pressure transducers
- Low sample rate:
  - Thermocouples

Camera
DAU
Camera
Ethernet Recorder
GPS Antenna
Engine mounted DAUs
Grandmaster
Camera
Chapter 10 Recorder
Rugged Switch
Camera
DAU with Ethernet to PCM Bridge
RF Transmitter
Blade Antenna
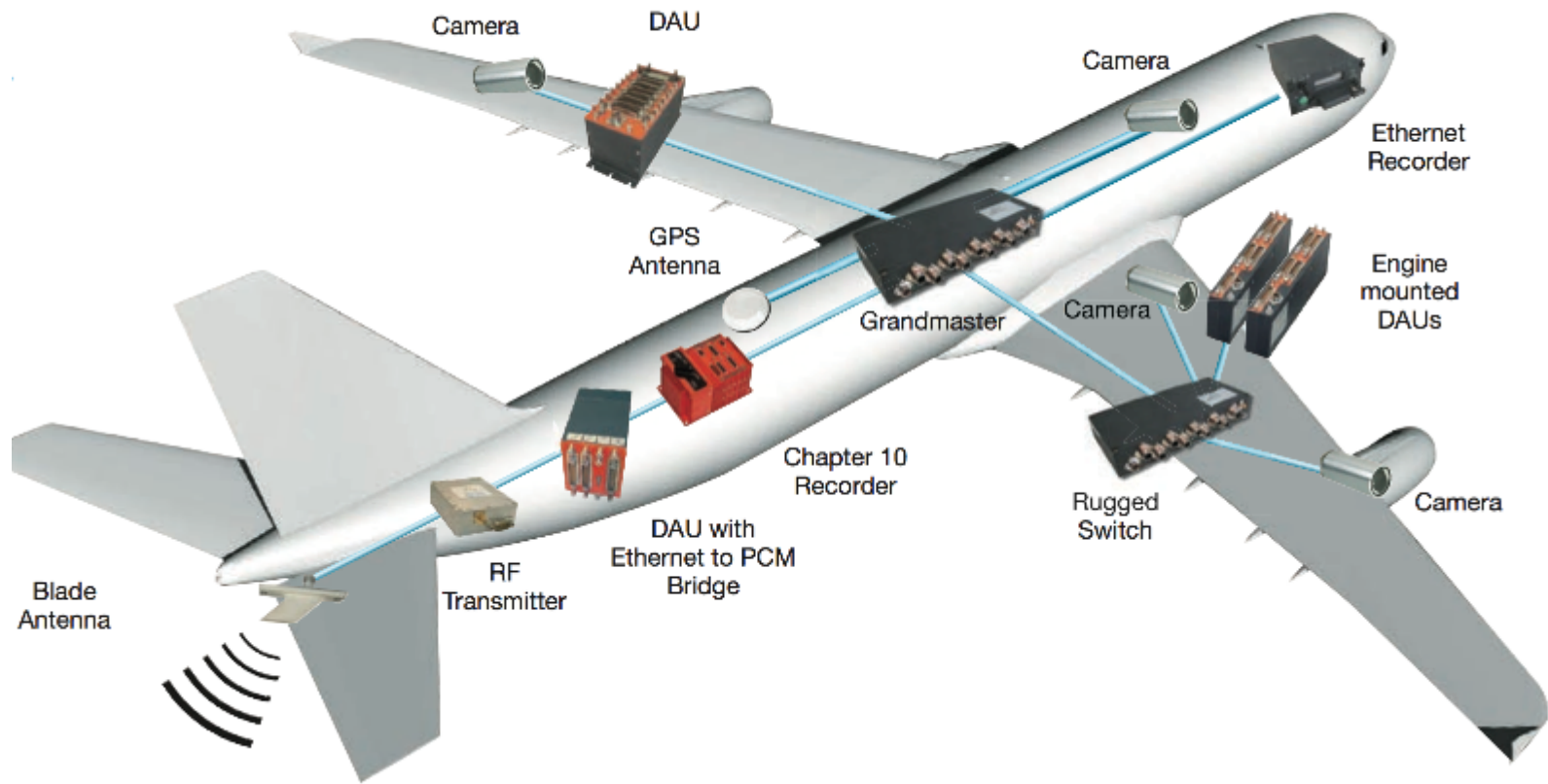
Actuators and Effectors

- Electrical Load Banks
- Smoke System
- Flam Fluids System
- Flutter System
- Attitude Recovery System
- Crew Egress Devices

Electrical Load Banks

- Simple load resistors
- Cooling system
- Crew control

Smoke System

- Fill the cabin with smoke
- Test flown into setting sun
- Crew control over system
- Test aircraft's smoke
  evacuation system

Flammable Fluids System

- Consists of a tank and pump assembly
- Many nozzles in various locations
  - Nose gear
  - Main gear
  - Hydraulic bay
  - Pylons
- Simulate flammable fluid leak

Flutter Actuators

- Apply low frequency high amplitude vibration to airframe
- Uses small airfoil on a servo motor to induce loads
- Applied to wingtip and tail
- Crew sweeps frequencies
- Responses recorded via accelerometers

Flutter Actuators

Attitude Recovery System

Attitude Recovery System

Crew Egress

- Used on high risk flights only
  - Aero stalls
  - Ice shapes
- Minimal crew
- Crew wears parachutes
- Explosive bolts in door latch mechanisms
- If required, door hinge pins removed by ground crew after crew board
- Air dams spring out into the airstream to allow safe exit from open door

Questions

References

1. http://www.gulfstream.com/gulfstreamnow
2. http://world.honda.com/HondaJet/
3. http://www.celesco.com/faq/cet.htm
4. http://www.airplanetest.com/bae.htm
5. http://www.omega.com
6. http://www.ni.com/white-paper/3642/en/
7. http://telemess.de/tm/ENG/MESSENG/mess6eng.htm
8. https://en.wikipedia.org/wiki/Thermocouple
9. http://www.ni.com/white-paper/13034/en/
10. http://www.paroscientific.com
11. http://www.all-electronics.de/praezisions-resolverdigital-wandler-misst-winkelposition-und-drehzahl/
12. http://www.amci.com/tutorials/tutorials-what-is-resolver.asp
13. https://en.wikipedia.org/wiki/Resolver_(electrical)
14. http://hyperphysics.phy-astr.gsu.edu/hbase/electric/voldiv.html
15. http://www.theelectricalportal.com/2015/07/what-is-current-transformer-working-of.html
16. http://www.esa.int/spaceinimages/Images/2016/02/Test_flight_instrumentation
17. http://www.simplexdirect.com/
18. http://www.visionsafe.com
19. https://spinoff.nasa.gov/spinoff1997/t8.html