A Multidisciplinary University Research Initiative (MURI)

Sponsored by the Department of Defense

MATERHORN

The Technology Component (MATERHORN-T)

Notre Dame Flamingo UAV

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UAV

- Flamingo MK2 UAV manufactured in Australia by Silvertone Electronics
  - Wing Span ……4 Meters
  - Length ……2.9 Meters
  - Dry Weight ……..10 Kg
  - Max Flying Weight …….20 Kg (with fuel and payload)
  - Top Speed ……90 mph – 144 km/h – 40m/s
  - Stall Speed ……36 mph – 58 km/h – 16.1m/s
  - Fuel Tank Capacity ……5.6 Litre
  - Engine ……..Moki 180 (1.8 in^3 - 30cc) 2-stroke gas
  - Fuel Consumption ……1.55 L /hr @ 6500 RPM (approx.)

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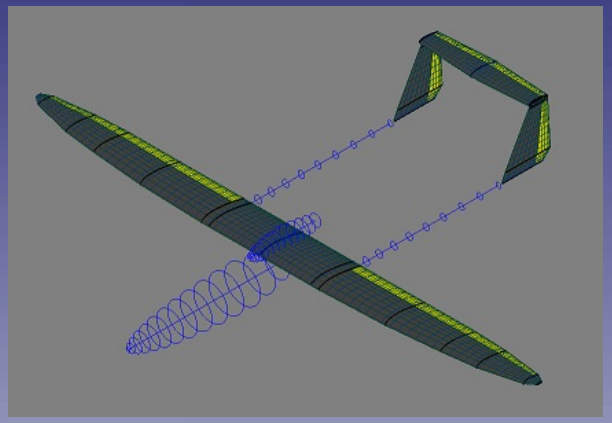
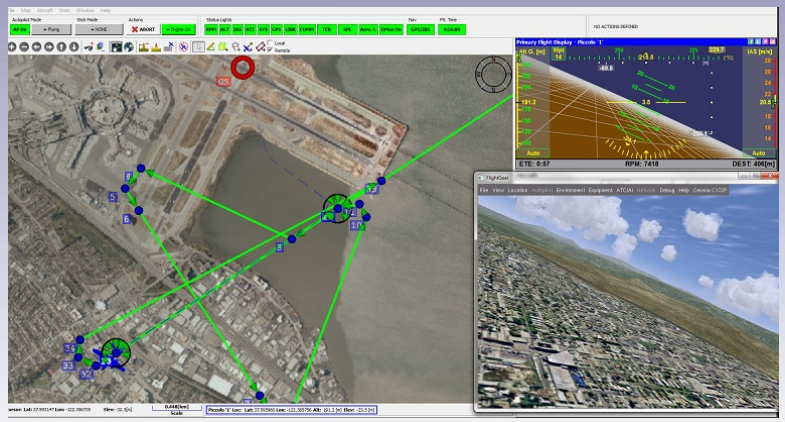
UAV Development

- Instrumentation
- 3D Modeling
- Simulation
- AutoPilot Programming
- Flight Planning





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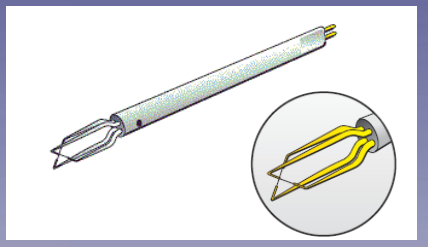
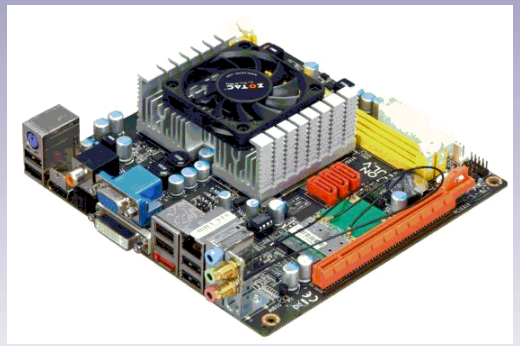
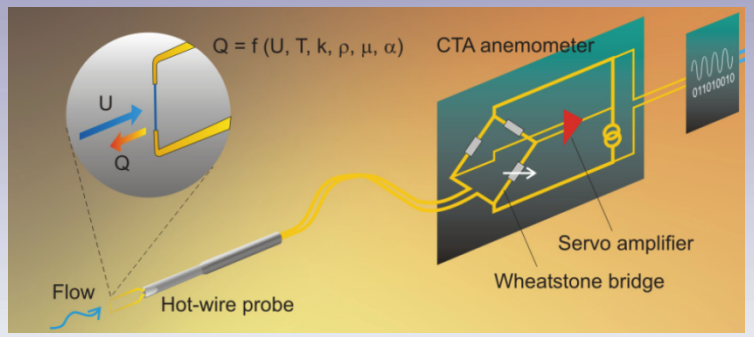
Instrumentation







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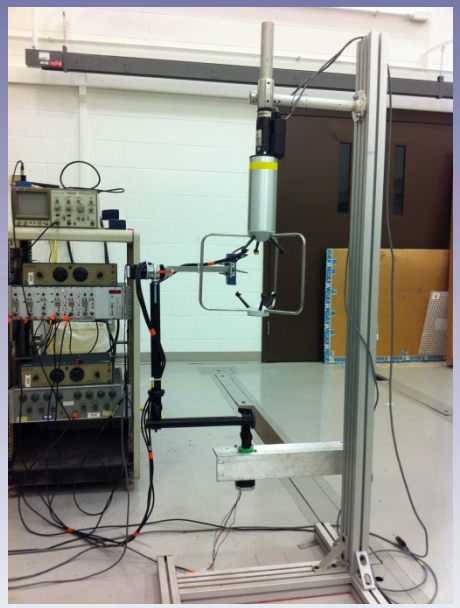
Instrumentation Goals



- Fit Hot film/Sonic Combo probe into nosecone of an of-the-shelf UAV
- Design data acq. system for 1-2 hrs of data collection with 16 channels of analog inputs @ 20khz sample rate
- Design a power supply for above

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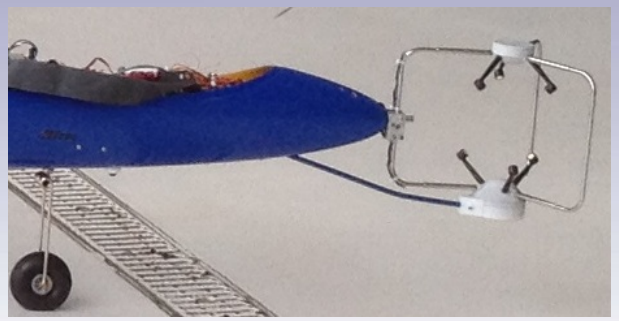
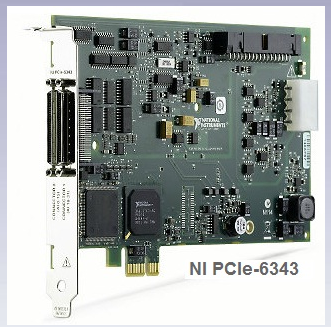
Instrumentation

- Zotac IONITX-P-E Celeron 1.2 GHz dual-core Mini ITX Motherboard
- National Instruments PCIe-6343, 32-ch 500 kS/s 16-bit Data Acq.
- RM Young 81000 Ultrasonic Anemometer with Dual X-Hot Film CTA
- Fog Aerosol Sampling System (FASS)
- OCZ 480 GB Solid State Hard Drive for Data Storage using LabView
- Custom CTA Bridges and Instrumentation Signal Conditioning for UAV
- LiPoly Battery Power Supply





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Instrument Channels

- Texas Instruments LM35 Precision Temperature Sensor
- Ultrasonic Anemometer Wind Vectors U V W
- Ultrasonic Anemometer Sonic Temperature
- 2 - TSI Model 1241-20W Hot Film Anemometer (CTA Mode)
- MSI/Schaevitz Model 832M1-0025 ±25g 3-axis Accelerometer
- 2 – GE Sensing Model MC65F103B 0.065" NTC 10k Ohm Thermistors
- MSI Model HM1500LF Capacitive Relative Humidity Sensor
- + 9 Analog Input Channels For FASS
- Fast Sample Rate – 10khz
- Data Storage on UAV Solid State Hard Drive

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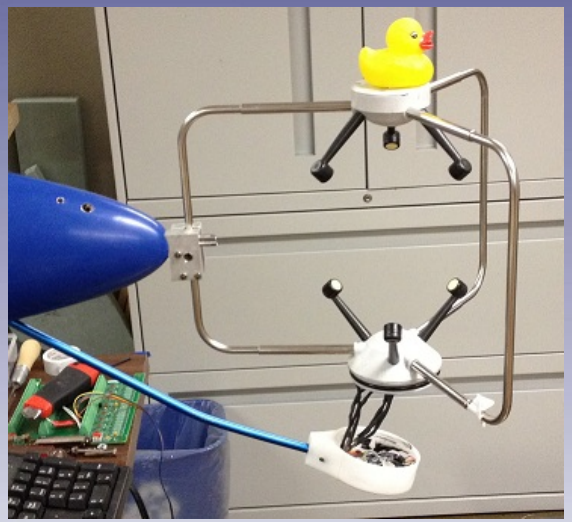
Instrument Modifications

R.M. Young 81000



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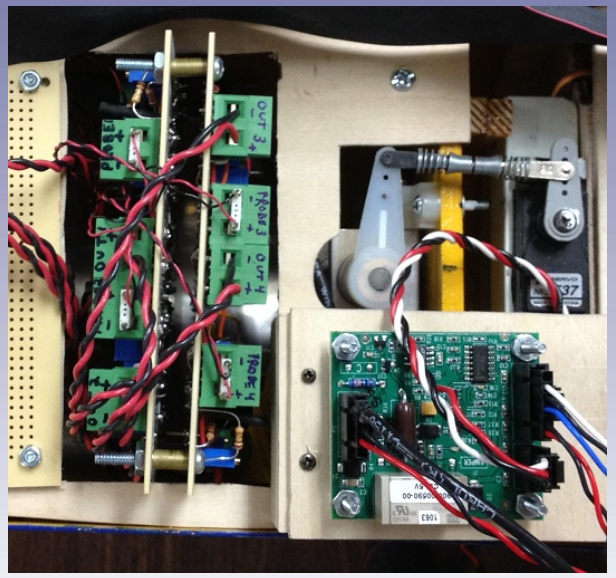
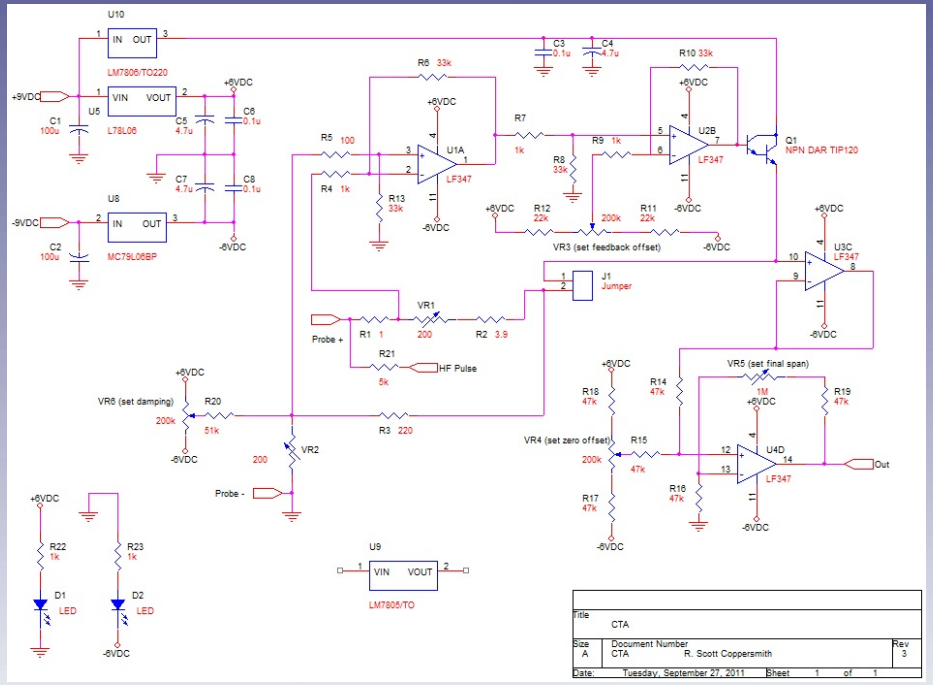
Instrument Modifications

TSI Hot Film Signal Conditioning





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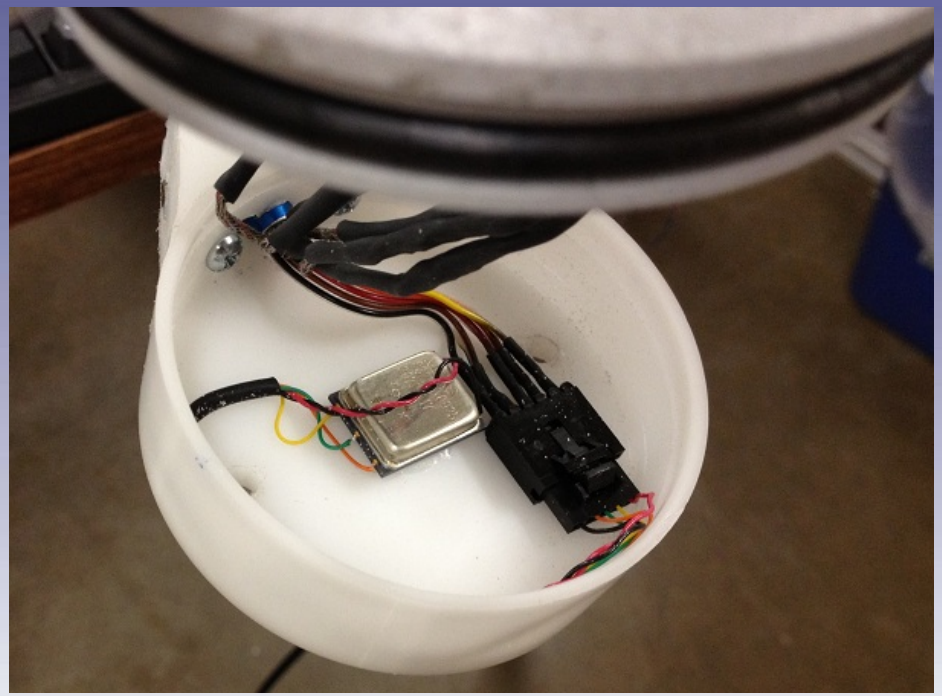
Instrument Modifications

3-axis Accelerometer



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Instrument Testing

- Cadence PSpice Simulations and high speed wind velocity testing
  - Resulted in power supply regulator changes
- Wind Tunnel Testing (low speed < 10m/s)
  - Showed combo probe vibration interactions
  - Resulted in probe configuration changes
- Pre-Flight tests
  - Showed motor vibrations and mechanical weak areas
  - Required complete review of all fasteners and servo connections
- Battery capacity and fuel capacity limits flight time
- Radio power (1w) limits flight range to a 8-10 mile radius from GS

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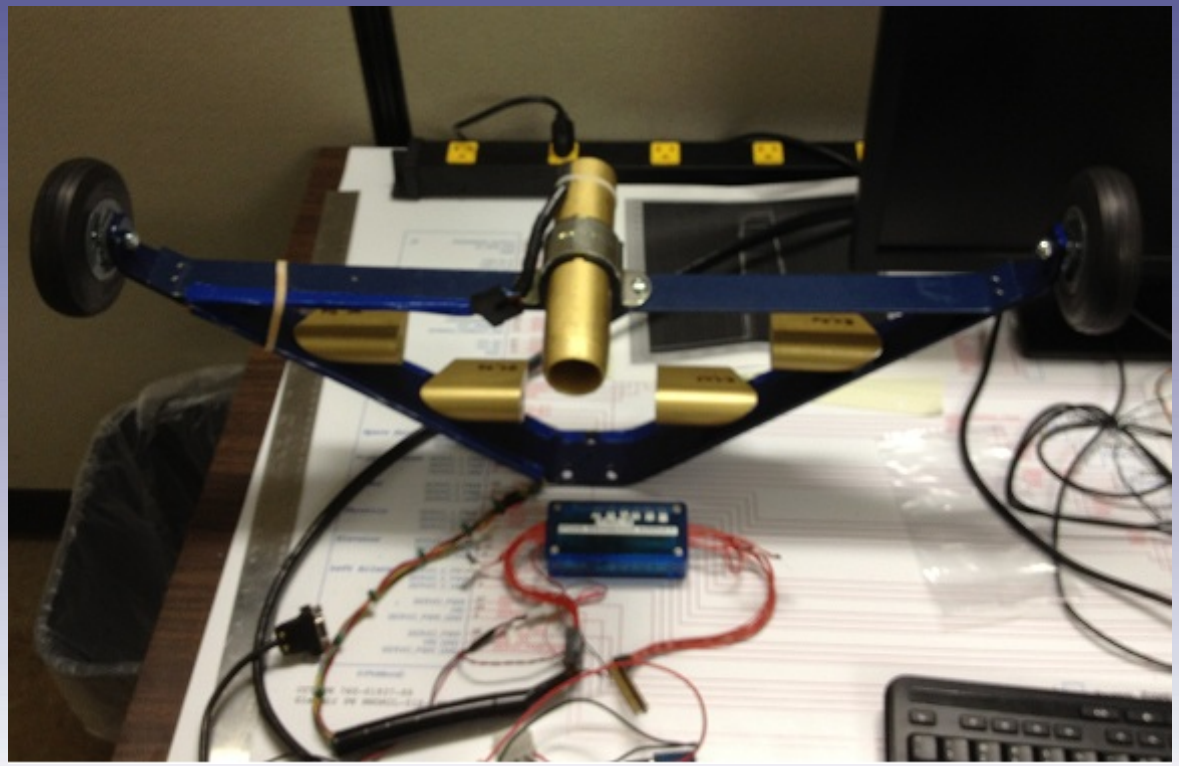
The Technology Component (MATERHORN-T)

FASS



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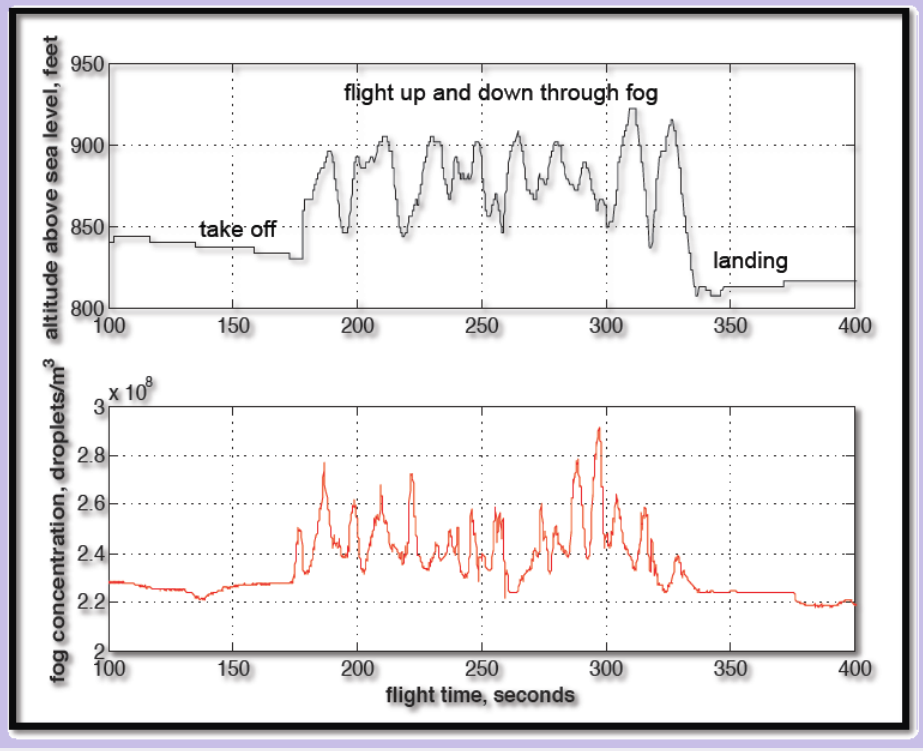
FASS-RPV Flight Test Result



Flight altitude and fog concentration as RPV flies up and down through cloud of fog above runway.

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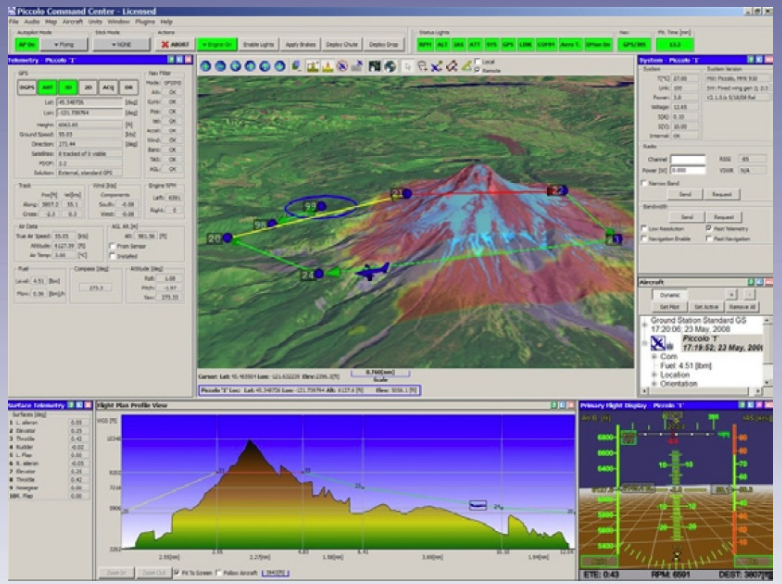
Autopilot



- Cloud Cap Technology – Piccolo SL
- 900 MHz Radio
- 4 Hz GPS, Analog/Digital/RS232 I/O
- Portable Ground Station

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The Technology Component (MATERHORN-T)

Telemetry Channels

- GPS Lat/Lon
- Altitude [GPS and/ Barometric Pressure Calculated]
- Pitot Tube Static and Dynamic Pressure
- Roll, Pitch, Yaw Sensors
- X, Y, Z Accelerometers
- X, Y, Z, Magnetometer
- Engine RPM – Hall Effect
- Ground Speed, Vertical Speed [Calculated]
- Fuel Estimate
- Servo and Control Data
- + Analog Inputs [Not Used]
- Up to 25 hz sample rate

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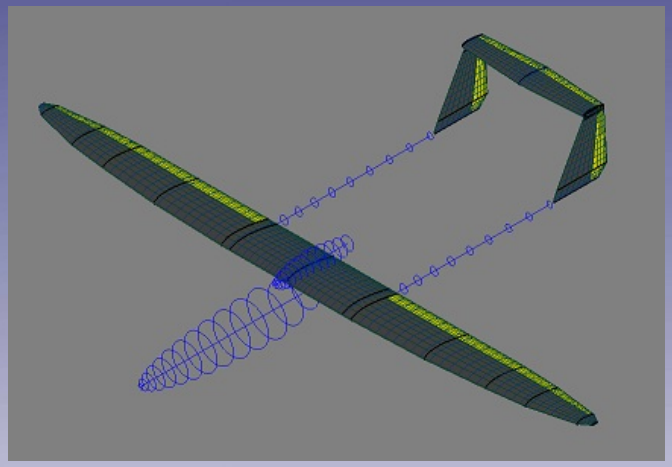
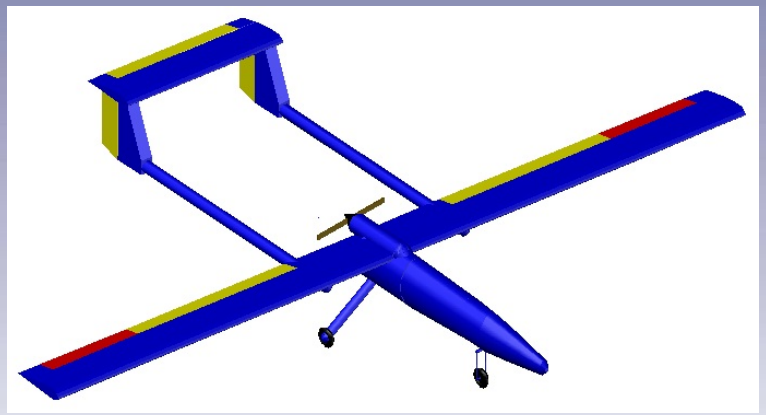
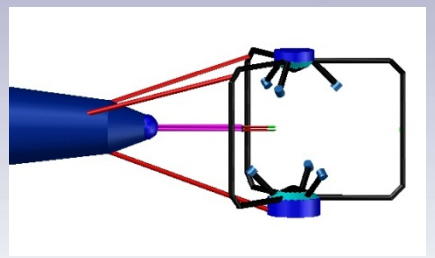
The Technology Component (MATERHORN-T)

Aircraft Models

- Required for Autopilot and Payload Planning
- Can be used in Flight Gear Simulator
- Cad Data Not Available From Manufacturer







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Aircraft Parameters

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- <Piccolo>
  - <Vehicle>
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```

```
// Flamingo F-18 with MOKI piston e
// SIMULATOR MODEL
// UND Materhorn project, 5/1/2012

//--------------------  AERODYNAMIC

// Aerodynamics data from AVL
Alpha_sweep_xml_file=Flamingo.xml

// Mapping of the channel numbers i
// Left Elevator
Channel_d1=8
// Right Elevator
Channel_d2=1
// Left Rudder
Channel_d3=3
// Right Rudder
Channel_d4=5
// Right flap
Channel_d5=9
// Right aileron
Channel_d6=4
// Left aileron
Channel_d7=0
// Left flap
Channel_d8=7

// Reference area, in m^2
Wing_Area=1.18

// Span, in m
Wing_Span=4.04


//--------------------  INERTIA  --

// Gross take-off mass of the aircr
Gross_Mass=20
// Mass of aircraft without fuel, i
Empty_Mass=18

// Moments of inertia
Roll_Inertia=3.6883
Pitch_Inertia=4.8296
Yaw_Inertia=8.1096
Roll_Yaw_Coupled_Inertia=0.5309
```

```
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- <Piccolo>
  - <Surfaces>
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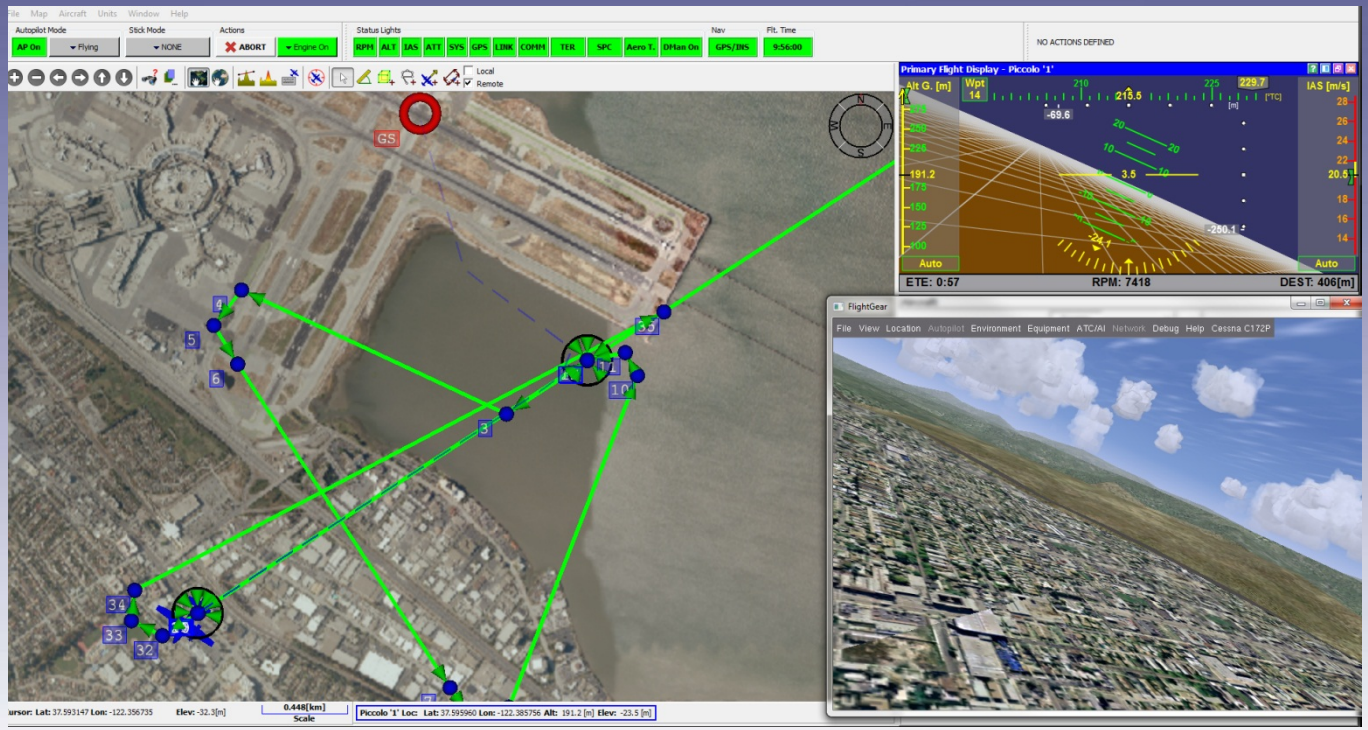
The Technology Component (MATERHORN-T)

Autopilot Software



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Autopilot Software

- Manual takeoff and landing with Futaba controller
- Real-time control of the aircraft based on GPS waypoints
- Failsafe control via flight plan for lost communication
- Tracking telemetry and visualization with Flight Gear simulator
- Additional I/O for control of ignition system, lights, etc.
- Flight termination parameters can be programmed
- Software and Hardware-in-the-loop modes available
- Storage and playback of flights (simulated and real)

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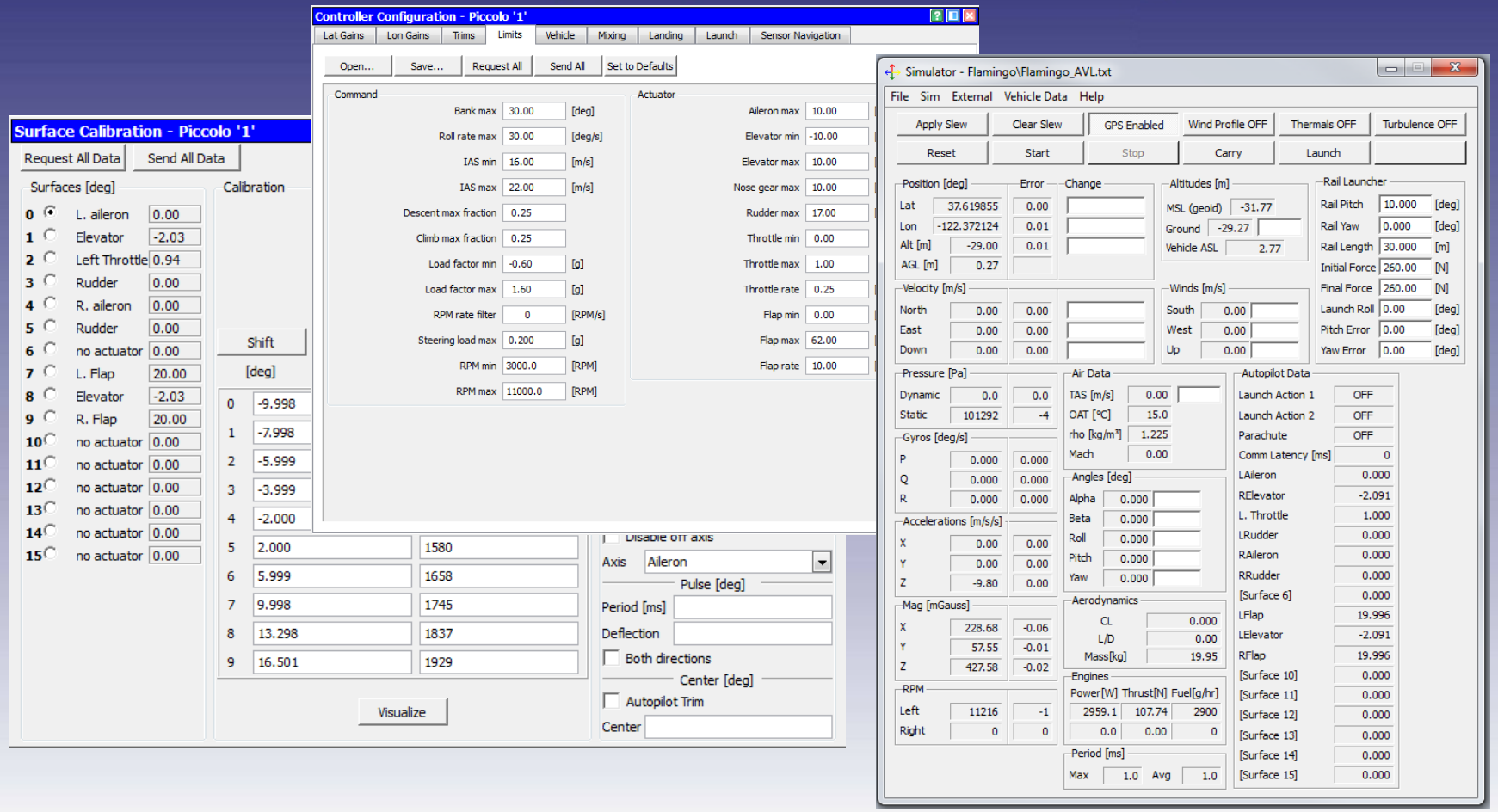

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Pilot training

- South Bend RC club members Brandon Herzog, Terry Rensberger, and Dave Schroeder trained ND personnel on basic RC aircraft

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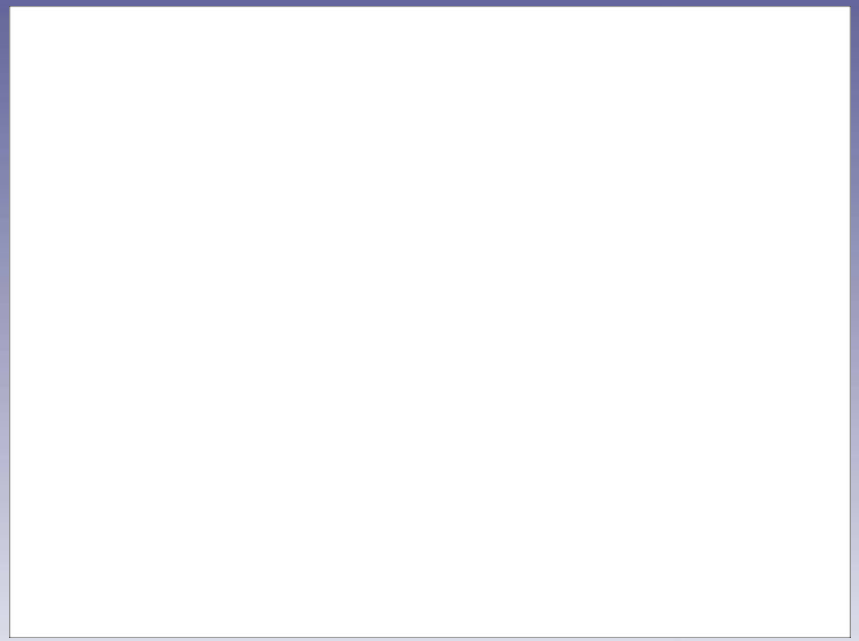
Flight Videos



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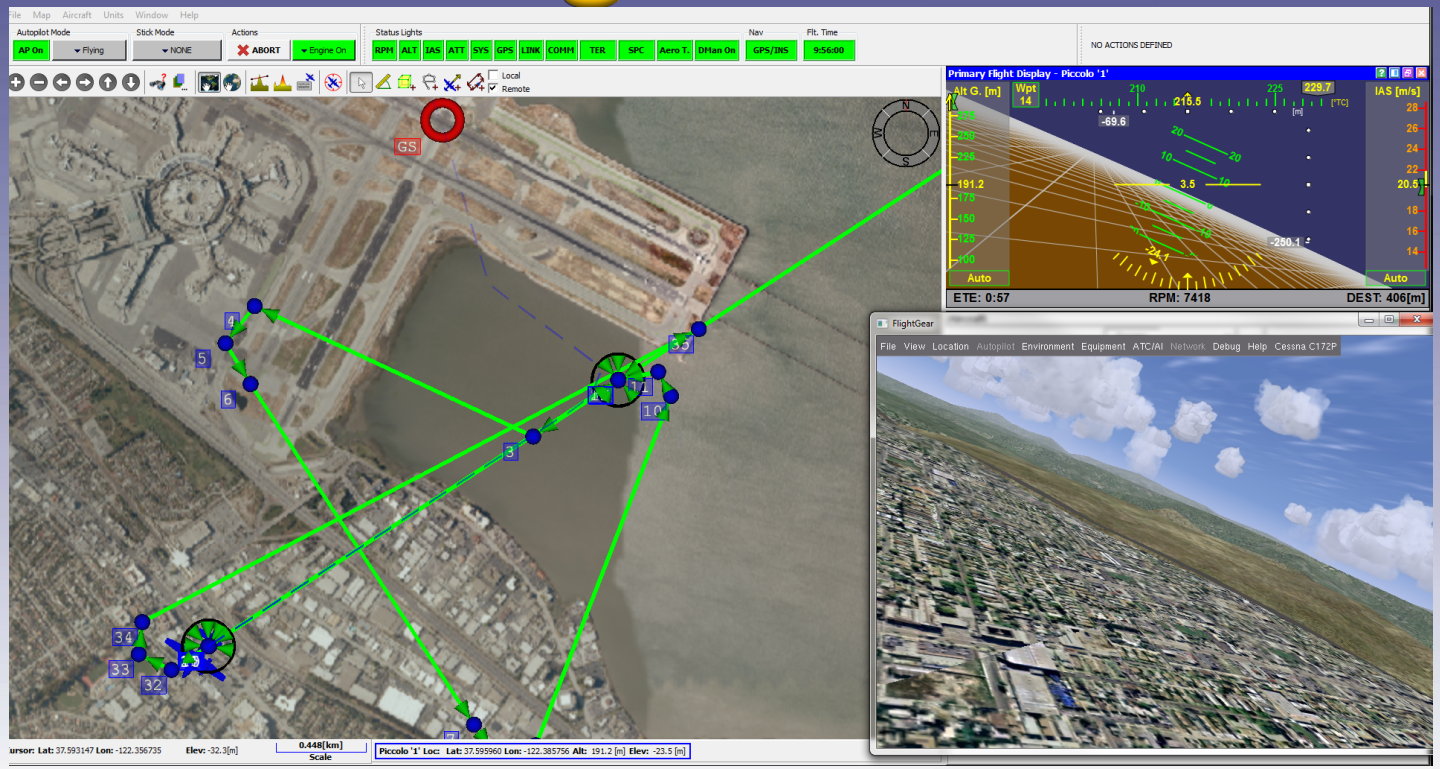
SimFlight Videos



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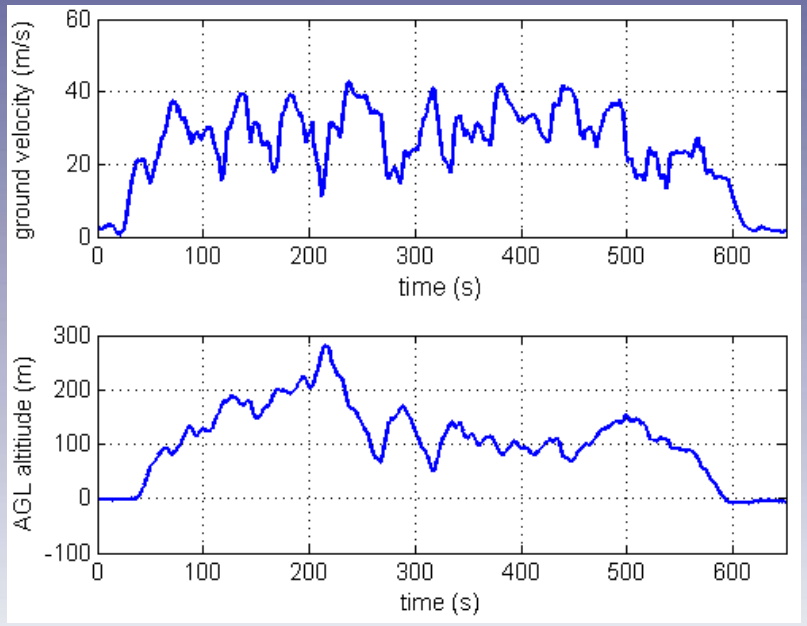
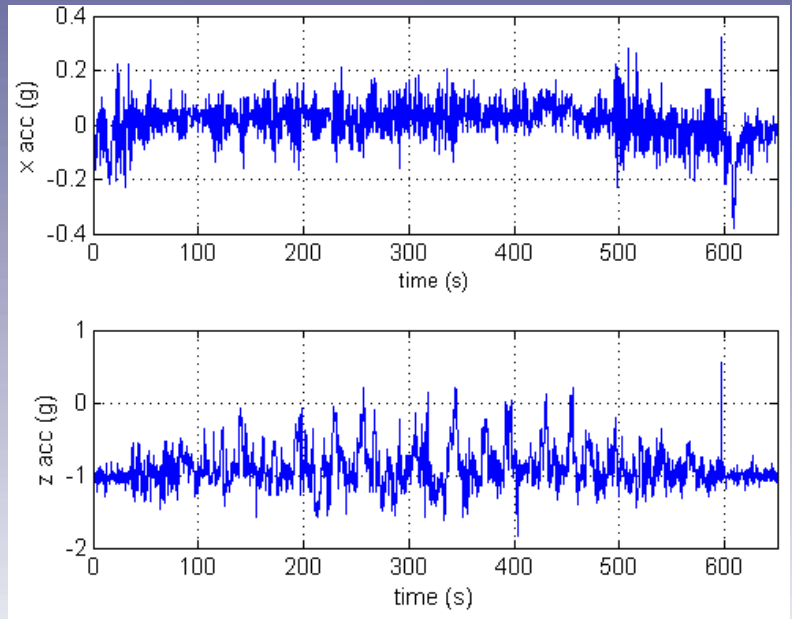
Flight Data





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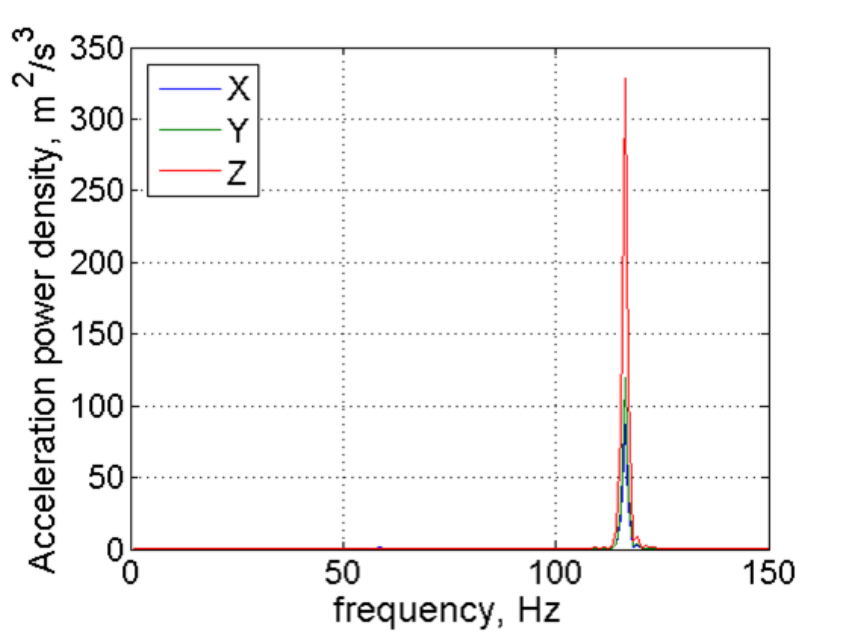

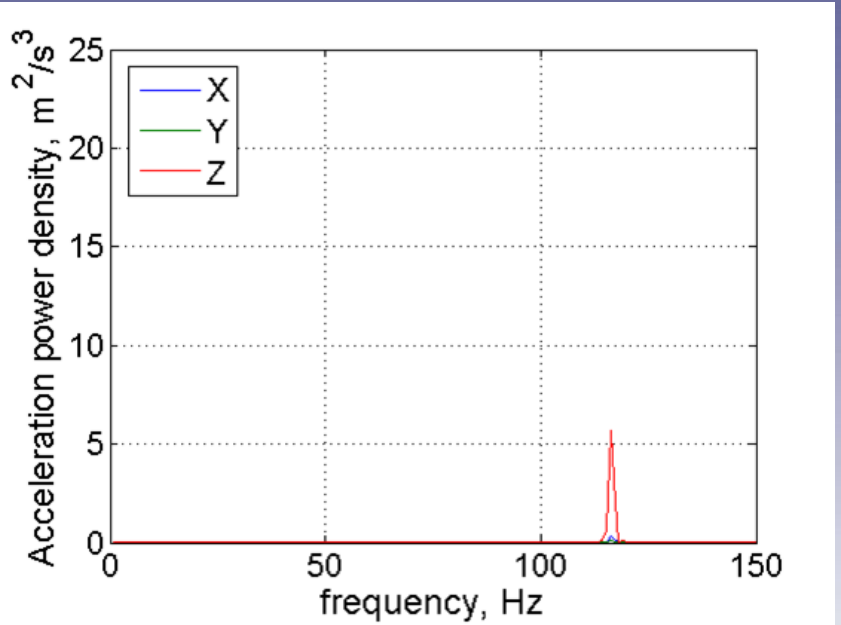

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Flight Team

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The Technology Component (MATERHORN-T)

Flight Team + Extras

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- Links:
  - Silvertone - http://www.silvertoneuav.com/new/index.php
  - Cloud Cap Technology - http://www.cloudcaptech.com/
  - National Instruments - http://www.ni.com/
  - ZOTAC Global - http://www.zotacusa.com/
  - TSI CTA Systems - http://www.tsi.com/en-1033/index.aspx
  - R.M. Young - http://www.youngusa.com/