

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 Span4 Meters
 - Length2.9 Meters
 - Dry Weight10 Kg
 - Max Flying Weight20 Kg (with fuel and payload)
 - Top Speed90 mph – 144 km/h – 40m/s
 - Stall Speed36 mph – 58 km/h – 16.1m/s
 - Fuel Tank Capacity5.6 Litre
 - EngineMoki 180 (1.8 in³ - 30cc) 2-stroke gas
 - Fuel Consumption1.55 L /hr @ 6500 RPM (approx.)

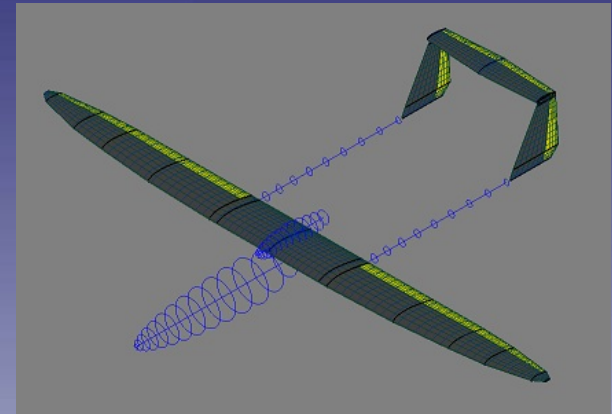
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UAV Development

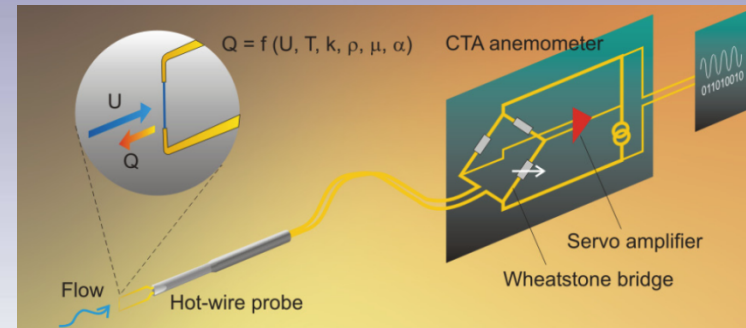
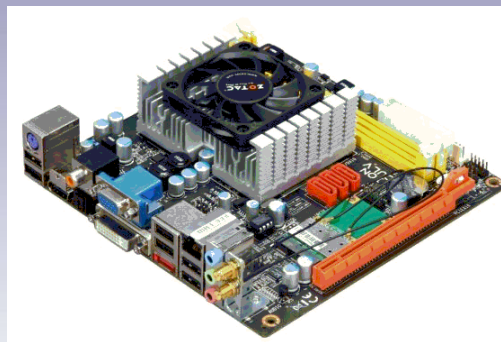
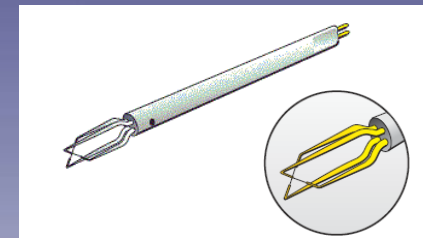
- Instrumentation
- 3D Modeling
- Simulation
- AutoPilot
- Programming
- Flight Planning



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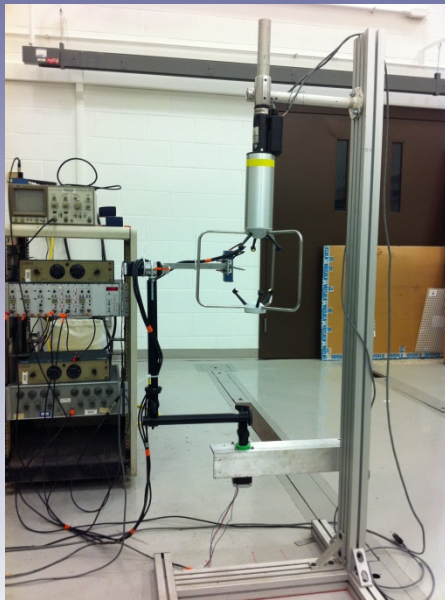
Instrumentation



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Instrumentation Goals



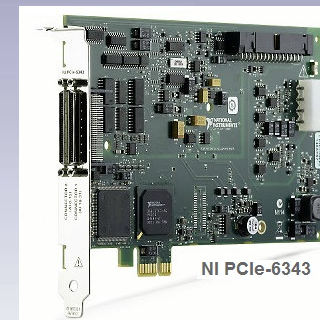
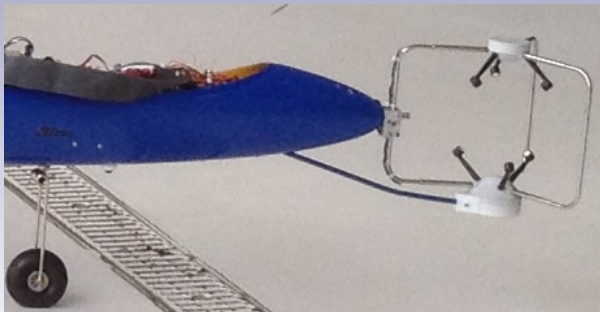
- Fit Hot film/Sonic Combo probe into nosecone of an of-the-shelf UAV
- Design data acq. system for 1-2 hrs of data collection with 16 channels of analog inputs @ 20kHz sample rate
- Design a power supply for above

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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 $\pm 25g$ 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

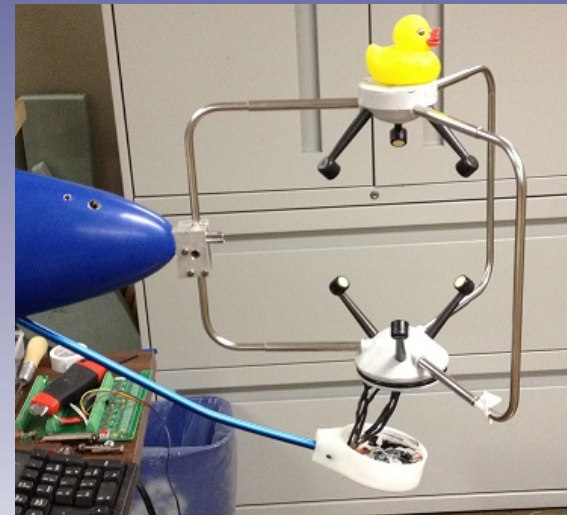
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Instrument Modifications



R.M. Young 81000

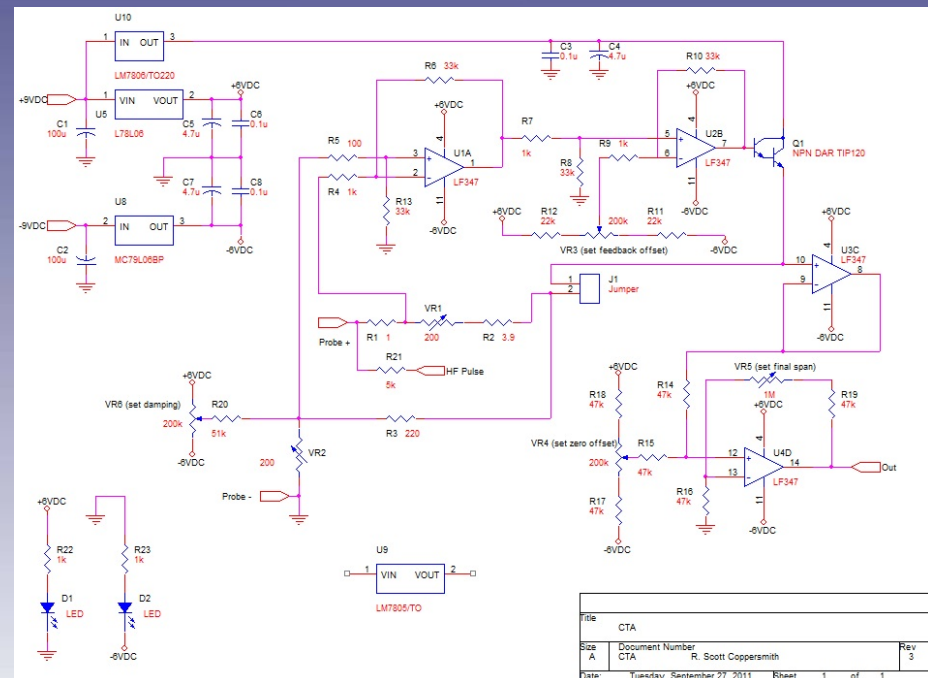
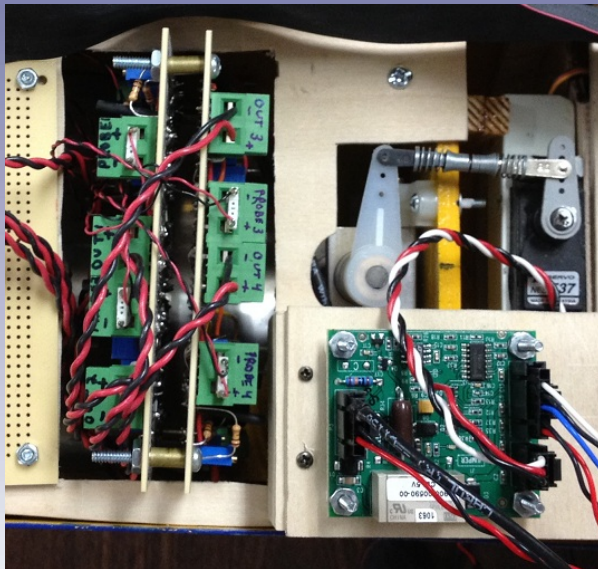


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Instrument Modifications

TSI Hot Film Signal Conditioning

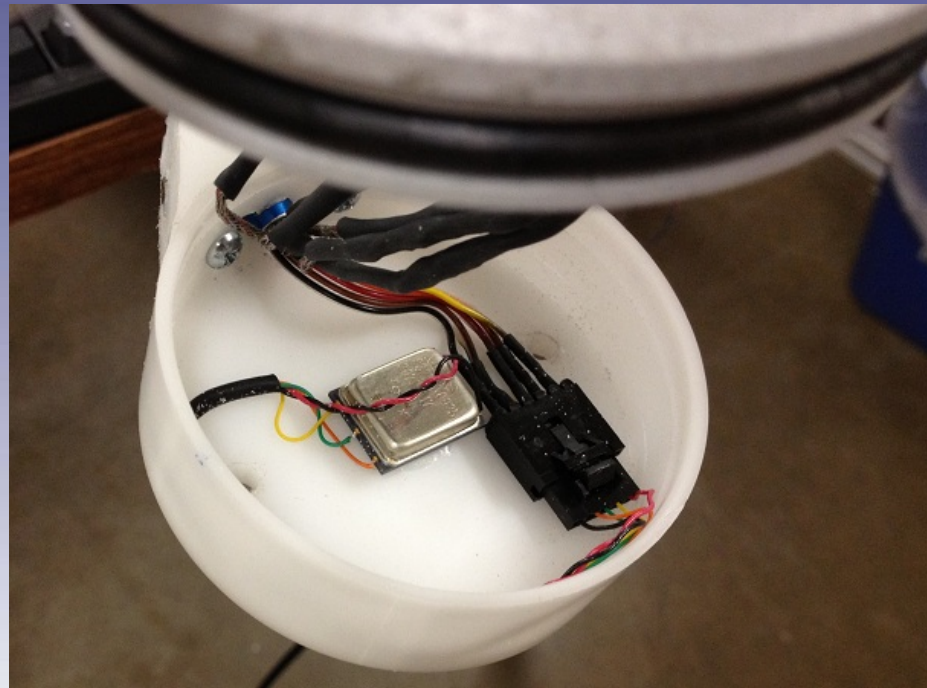


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Instrument Modifications

3-axis Accelerometer



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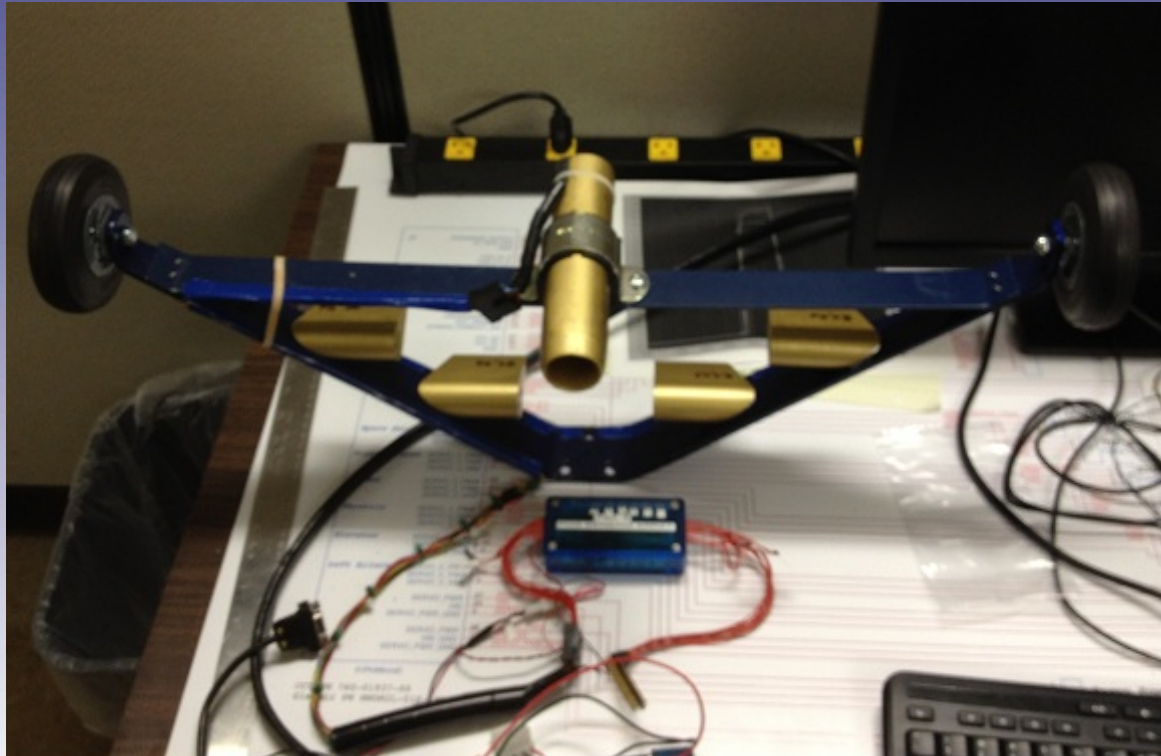
Instrument Testing

- 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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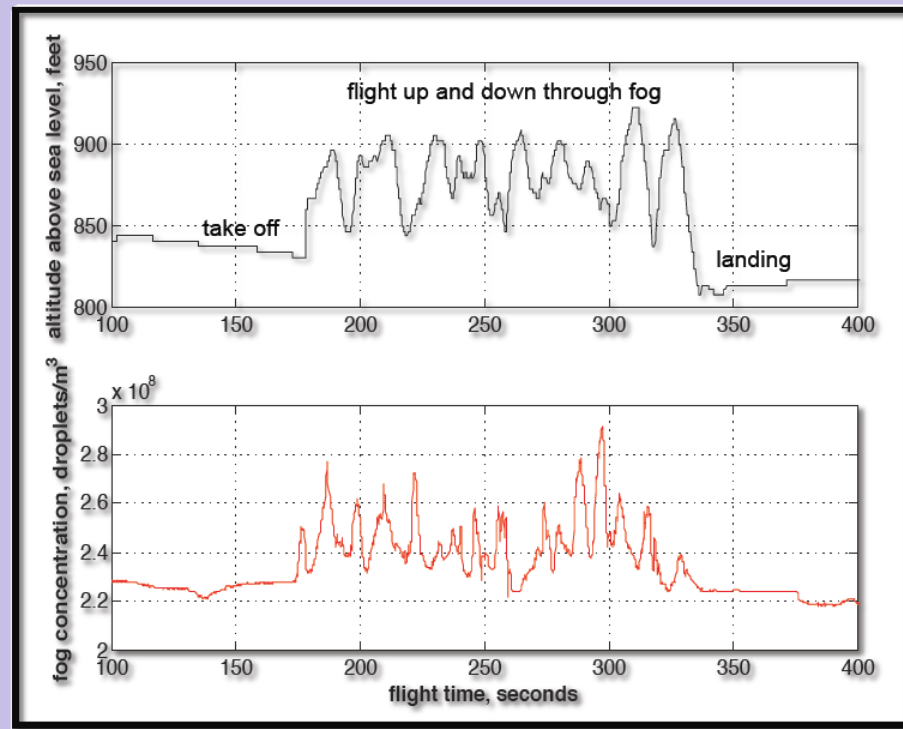
FASS



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FASS-RPV Flight Test Result

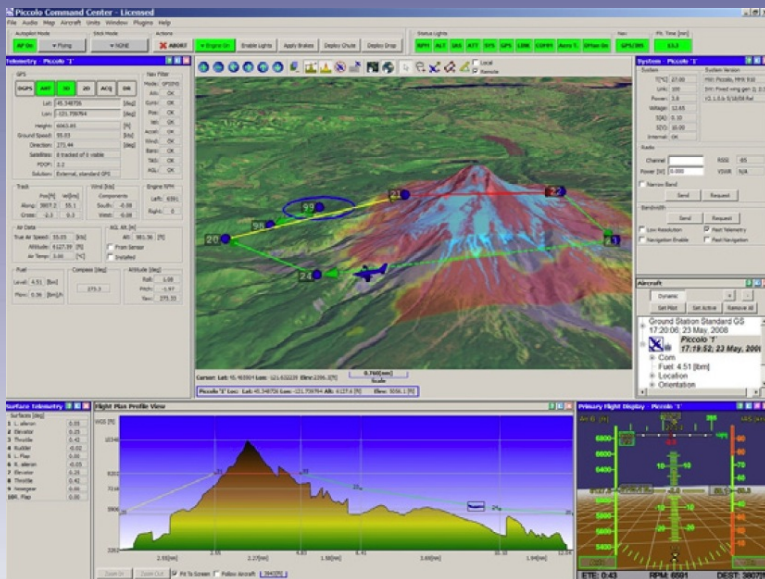


Flight altitude and fog concentration as RPV flies up and down through cloud of fog above runway.

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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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Telemetry Channels

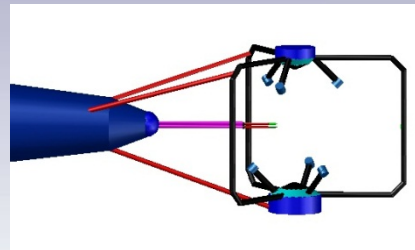
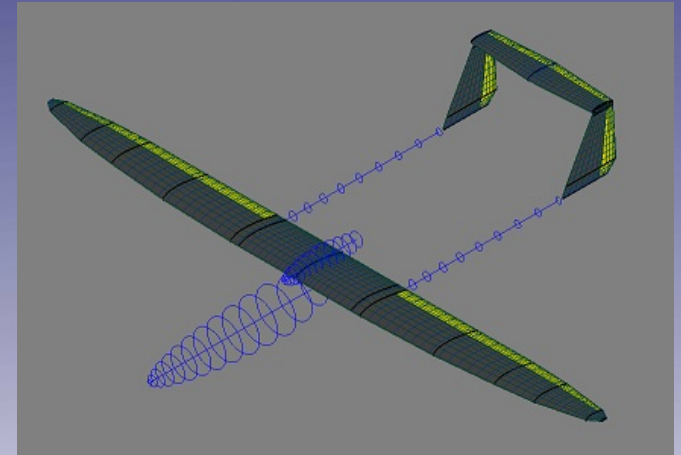
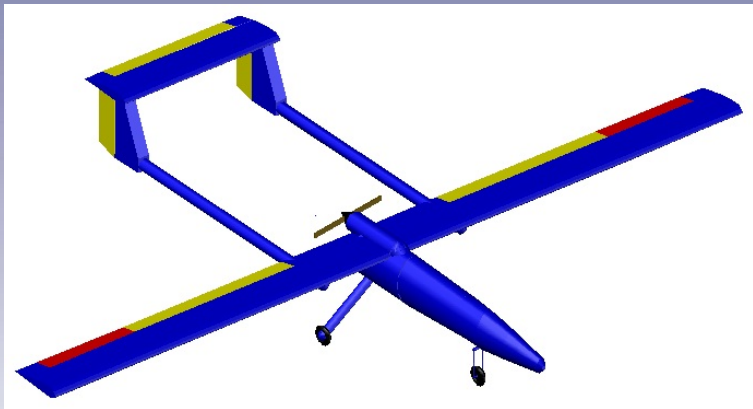
- GPS Lat/Lon
- Altitude [GPS and/ Barometric Pressure Calculated]
- Pitot Tube Static and Dynamic Pressure
- Roll, Pitch, Yaw Sensors
- X, Y, Z Accelerometers
- X, Y, Z, Magnetometer
- Engine RPM – Hall Effect
- Ground Speed, Vertical Speed [Calculated]
- Fuel Estimate
- Servo and Control Data
- + Analog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

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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

```
<?xml version="1.0"?>
- <Piccolo>
  - <Vehicle>
    <Auto_elevator_effect>0</Auto_elevator_effect>
    <Auto_aileron_effect>0</Auto_aileron_effect>
    <Auto_elevator_power>0</Auto_elevator_power>
    <Auto_aileron_power>0</Auto_aileron_power>
    <Auto_rudder_power>0</Auto_rudder_power>
    <Wing_area>1.181000</Wing_area>
    <Wing_span>4.052000</Wing_span>
    <Vertical_tail_arm>0.000000</Vertical_tail_arm>
    <Steering_arm>0.762000</Steering_arm>
    <Gross_Mass>20.000000</Gross_Mass>
    <Empty_Mass>10.000000</Empty_Mass>
    <X_Inertia>3.688300</X_Inertia>
    <Y_Inertia>4.829600</Y_Inertia>
    <Z_Inertia>8.109600</Z_Inertia>
    <Payload_Mass>0.000000</Payload_Mass>
    <Aileron_effect>0.369529</Aileron_effect>
    <Elevator_effect>-8.232607</Elevator_effect>
    <Rudder_effect>-0.000000</Rudder_effect>
    <Aileron_power>0.228152</Aileron_power>
    <Elevator_power>-2.109590</Elevator_power>
    <Rudder_power>-0.000000</Rudder_power>
    <Roll_damping>-0.617412</Roll_damping>
    <Pitch_damping>-36.530399</Pitch_damping>
    <Yaw_damping>-0.137437</Yaw_damping>
```

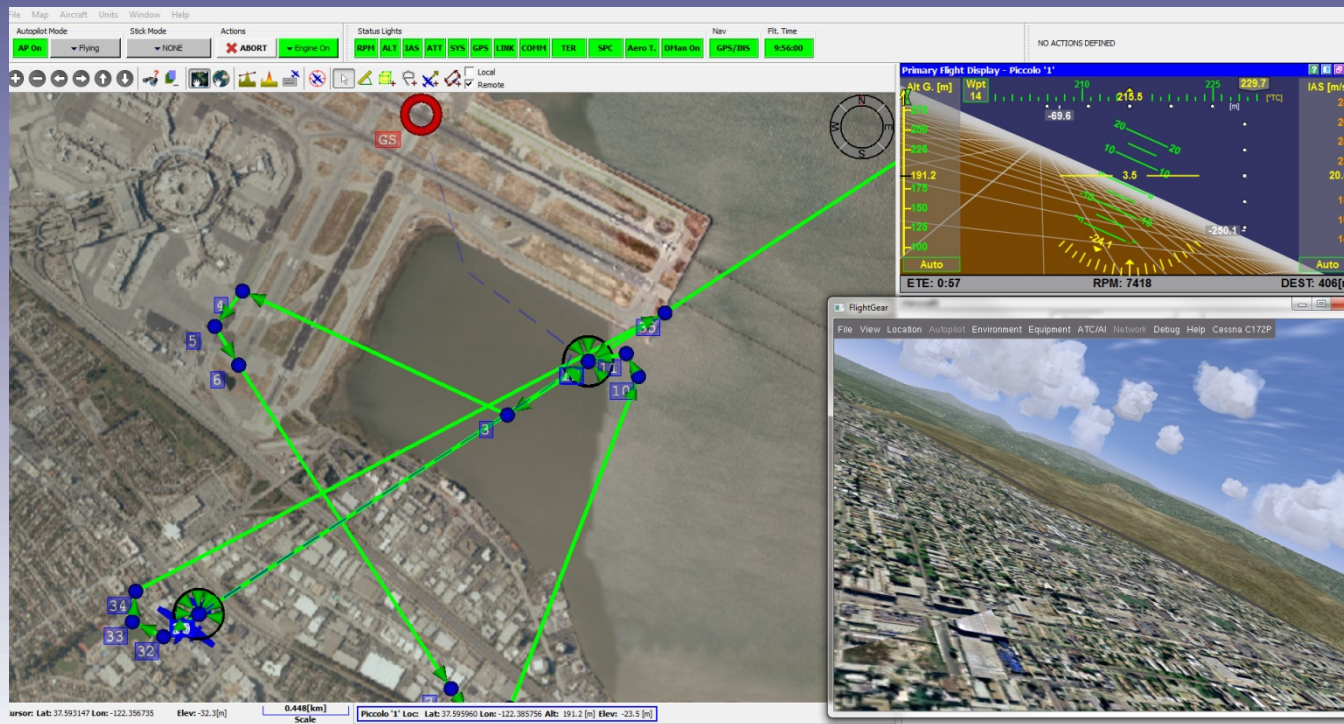
```
// Flamingo F-18 with MOKI piston e
// SIMULATOR MODEL
// UND Materhorn project, 5/1/2012
//----- AERODYNAMIC
// Aerodynamics data from AVL
Alpha_sweep_xml_file=Flamingo.xml
// Mapping of the channel numbers i
// Left Elevator
Channel_d1=8
// Right Elevator
Channel_d2=1
// Left Rudder
Channel_d3=3
// 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
```

```
<?xml version="1.0"?>
- <Piccolo>
  - <Surfaces>
    - <Surface_0>
      <Type>1</Type>
      <Angle_0>-0.174498</Angle_0>
      <Width_0>1103</Width_0>
      <Angle_1>-0.139591</Angle_1>
      <Width_1>1194</Width_1>
      <Angle_2>-0.104702</Angle_2>
      <Width_2>1295</Width_2>
      <Angle_3>-0.0697957</Angle_3>
      <Width_3>1360</Width_3>
      <Angle_4>-0.0349066</Angle_4>
      <Width_4>1480</Width_4>
      <Angle_5>0.0349066</Angle_5>
      <Width_5>1580</Width_5>
      <Angle_6>0.104702</Angle_6>
      <Width_6>1658</Width_6>
```

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The Technology Component (MATERHORN-T)

Autopilot Software



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The Technology Component (MATERHORN-T)

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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The Technology Component (MATERHORN-T)

The screenshot displays the MATERHORN-T software interface, which is used for configuring and simulating a vehicle's control system. It consists of several interconnected windows:

- Controller Configuration - Piccolo '1'**: This window is divided into tabs for Lat Gains, Lon Gains, Trims, Limits, Vehicle, Mixing, Landing, Launch, and Sensor Navigation. The 'Limits' tab is active, showing various parameters for Command and Actuator.

Parameter	Value	Unit
Bank max	30.00	[deg]
Roll rate max	30.00	[deg/s]
IAS min	16.00	[m/s]
IAS max	22.00	[m/s]
Descent max fraction	0.25	
Climb max fraction	0.25	
Load factor min	-0.60	[g]
Load factor max	1.60	[g]
RPM rate filter	0	[RPM/s]
Steering load max	0.200	[g]
RPM min	3000.0	[RPM]
RPM max	11000.0	[RPM]
- Surface Calibration - Piccolo '1'**: This window allows for calibrating various surfaces. It includes a 'Request All Data' and 'Send All Data' button, a 'Surfaces [deg]' list, and a 'Calibration' table.

Surface	Value
0 L. aileron	0.00
1 Elevator	-2.03
2 Left Throttle	0.94
3 Rudder	0.00
4 R. aileron	0.00
5 Rudder	0.00
6 no actuator	0.00
7 L. Flap	20.00
8 Elevator	-2.03
9 R. Flap	20.00
10 no actuator	0.00
11 no actuator	0.00
12 no actuator	0.00
13 no actuator	0.00
14 no actuator	0.00
15 no actuator	0.00
- Simulator - Flamingo/Flamingo_AVL.txt**: This window provides a comprehensive overview of the simulation's state. It includes buttons for 'Apply Slew', 'Clear Slew', 'GPS Enabled', 'Wind Profile OFF', 'Thermals OFF', and 'Turbulence OFF'. It also features a 'Reset', 'Start', 'Stop', 'Carry', and 'Launch' control panel.

Category	Parameter	Value
Position [deg]	Lat	37.619855
	Lon	-122.372124
	Alt [m]	-29.00
Altitudes [m]	MSL (geoid)	-31.77
	Ground	-29.27
Winds [m/s]	South	0.00
	West	0.00
Air Data	TAS [m/s]	0.00
	OAT [°C]	15.0
Angles [deg]	Alpha	0.000
	Beta	0.000
Aerodynamics	CL	0.000
	L/D	0.00
Engines	Power[W]	2959.1
	Thrust[N]	107.74
Autopilot Trim	Left	11216
	Right	0

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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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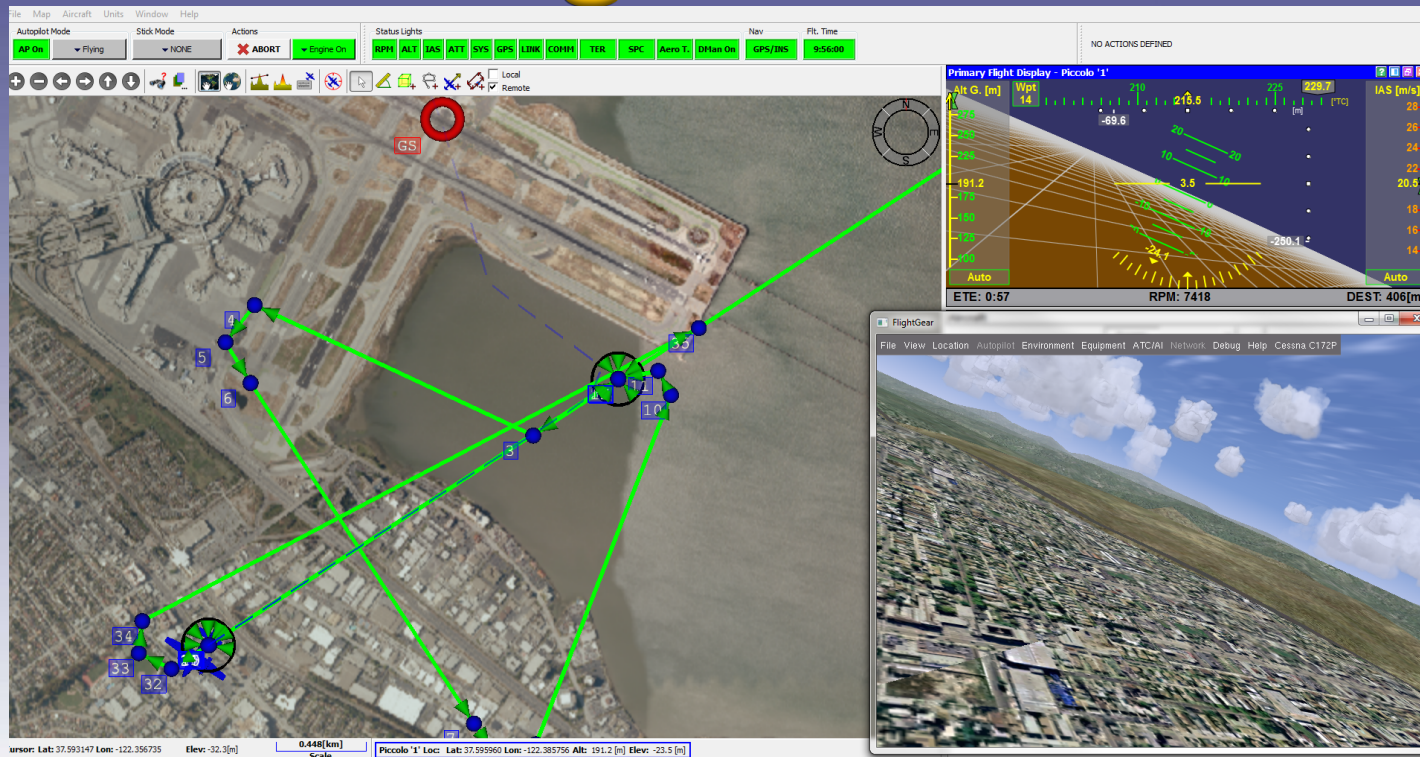
Flight Videos



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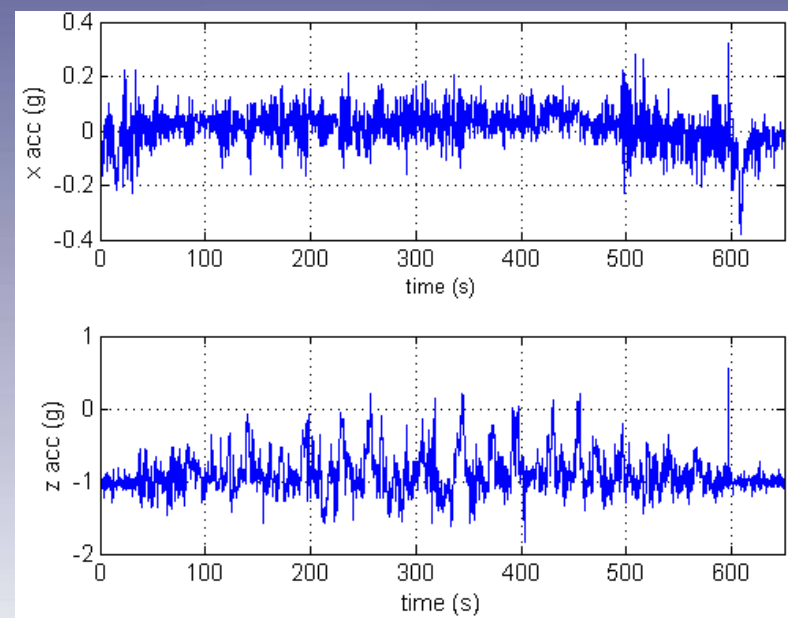
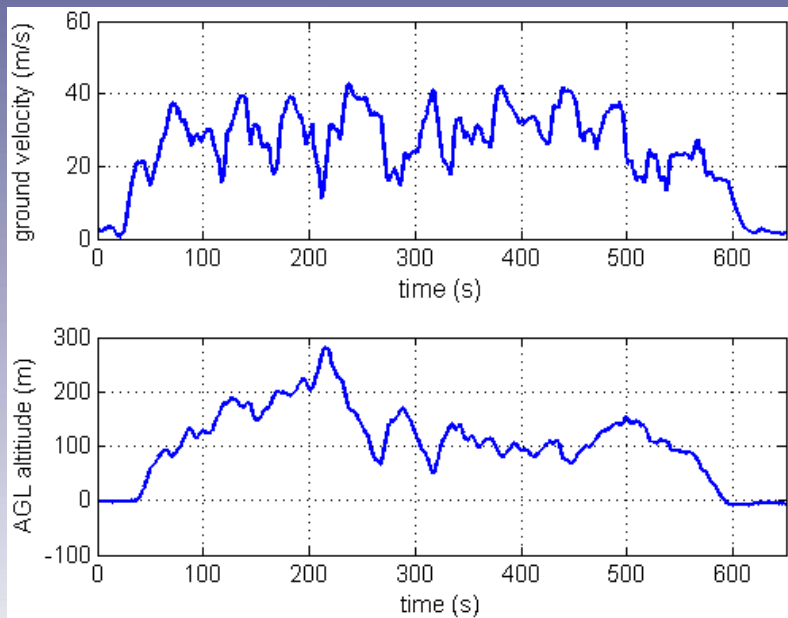
SimFlight Videos



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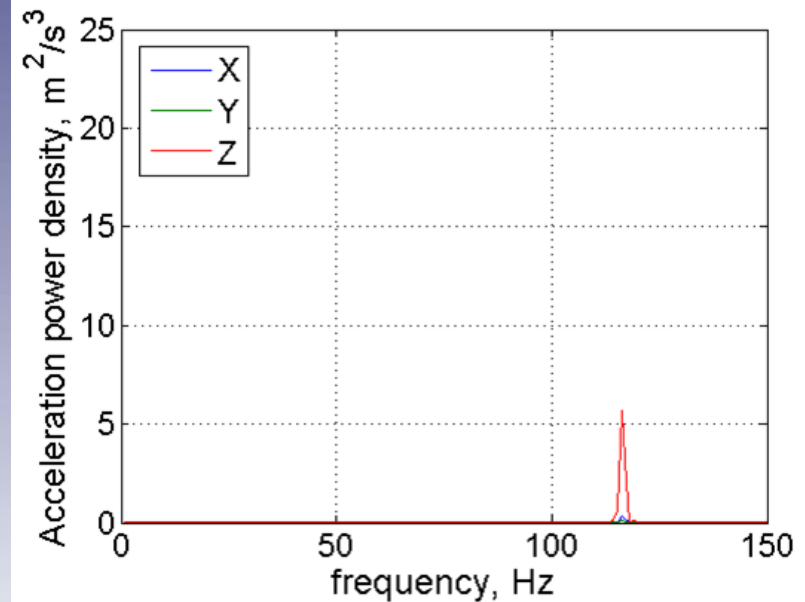
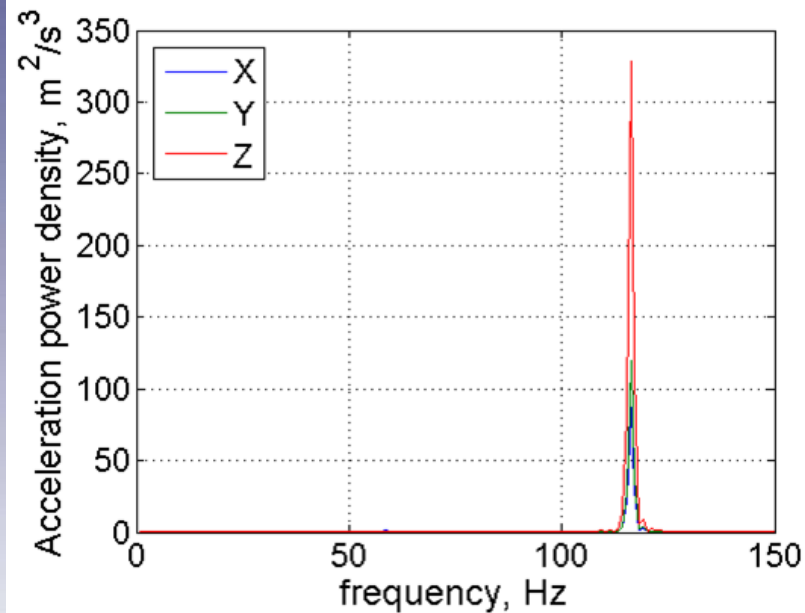
Flight Data



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Flight Data



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The Technology Component (MATERHORN-T)

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/>