Auburn University
UAV Initiatives
Aerospace Engineering

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COLLEGE OF ENGINEERING

Gil Crouse, PhD

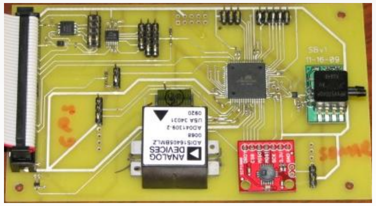
May 17th, 2010

Facilities

- 3’x4’ Wind Tunnel
- UAV Development Lab
  - Composite fabrication
  - Systems development and test
  - Full machine shop including CNC
- Flight Support
  - AUO Airport
  - RC Field
  - AU Field (in planning)

Resources

- Guidance/Comms Systems
  - Micropilot COTS autopilots
  - AU-developed autopilot
    - COTS sensor board with 3 axis accelerometer, rate gyros, magnetometer, and GPS
    - COTS Linux-based SBC
  - COTS wireless LAN and serial modems



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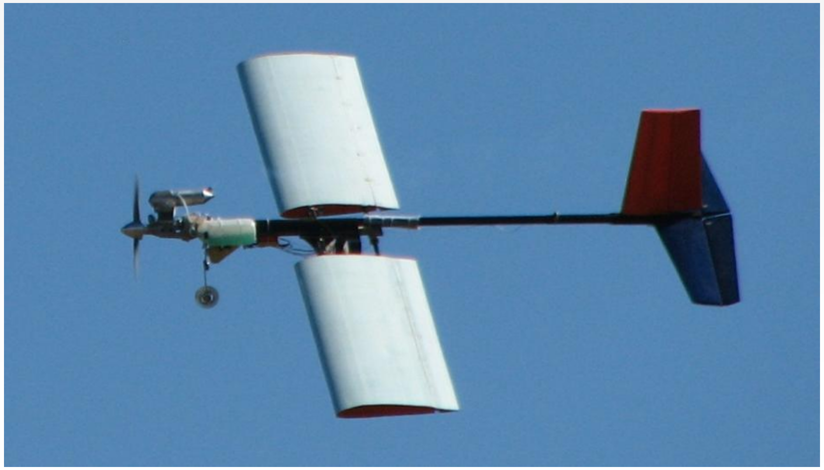
Resources

- Platforms
  - 3 RC trainer airplanes, park flyers, sport model
  - 9’ Wingspan, 30 lb GW, modular UAV

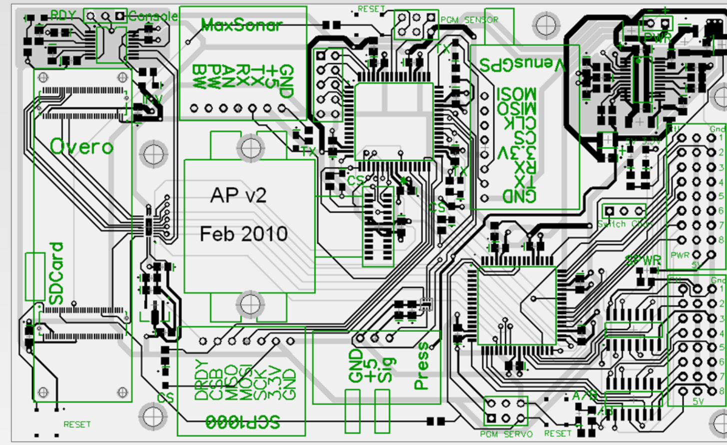


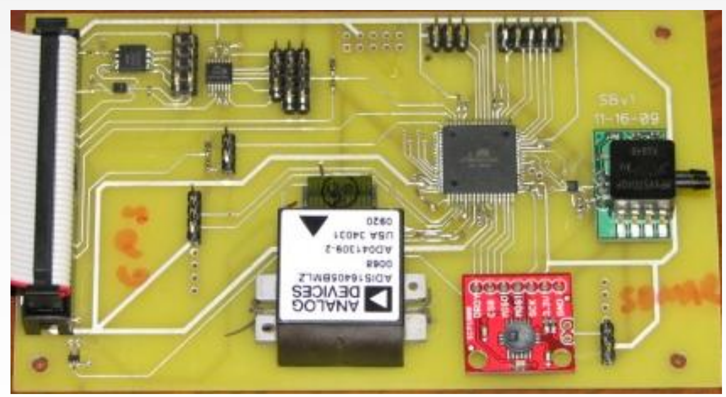
Research Areas

- Open architecture guidance and control system
- Conflict/collision avoidance
- Robust control & agile flight
- Flight in adverse environments

AU Open Architecture UAV Guidance and Control System

- AU-designed hardware and software using off-the-shelf sensors and a linux-based computer-on-module processor
- Sensor suite including GPS, IMU, magnetometer, static and dynamic pressure, and AGL altimeter
- 16 channels of A/D input available for future needs
- 8 channel servo controller with fail-safe for override by RC and lost-signal/lockup protection
- Object-oriented software suite provides attitude estimation, inner-loop control, and way-point navigation
- Simulation environment using open-source flight simulator for testing on Windows or Linux desktop computer





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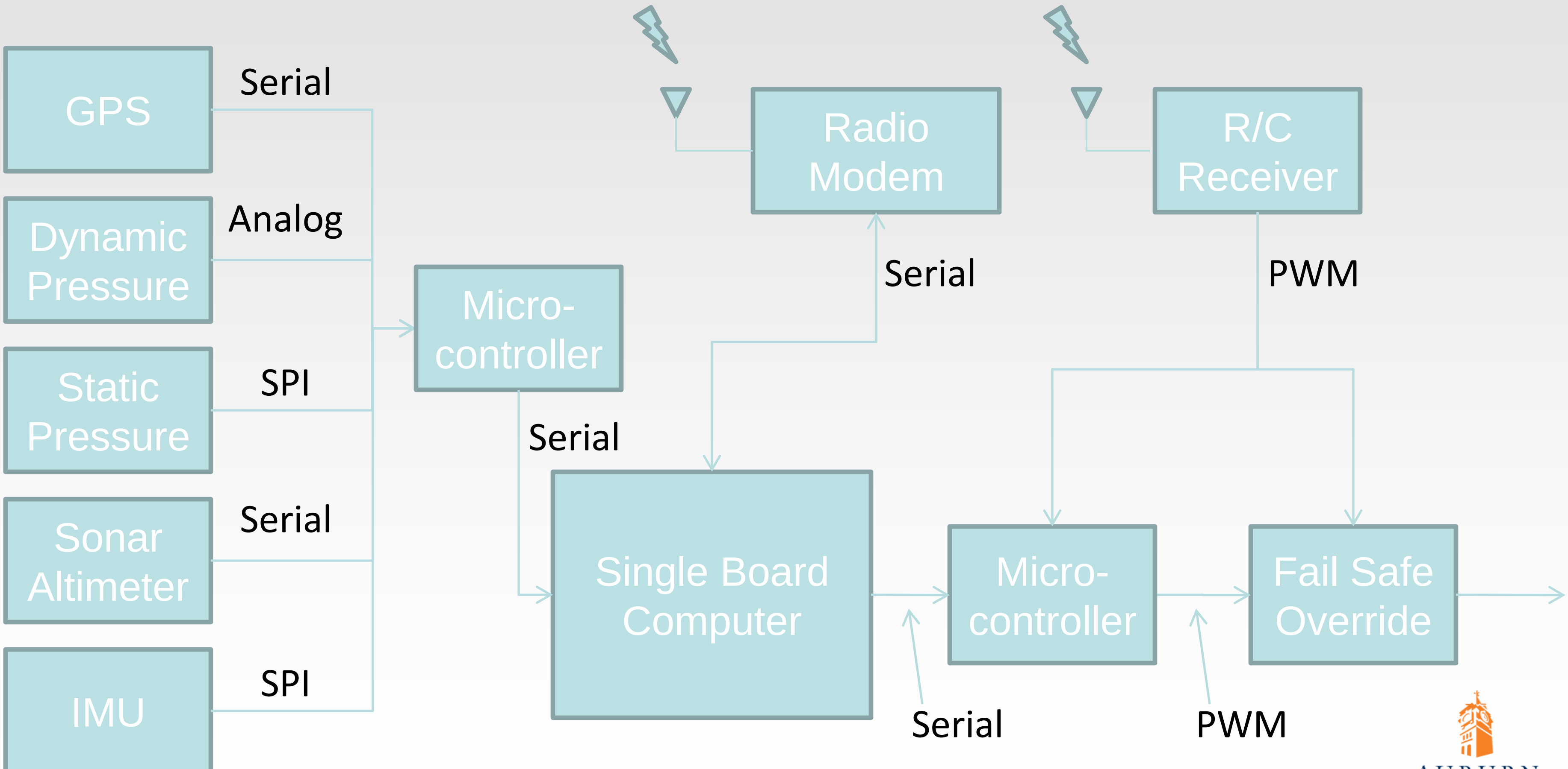
Block Diagram



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Single Board Computer

Gumstix Overo™ Earth

Processor:

- OMAP 3503 Application Processor with ARM Cortex-A8 CPU

Clock: 600 MHz

Performance:

- Up to 1200 Dhrystone MIPS

Memory:

- 256MB RAM
- 256MB Flash

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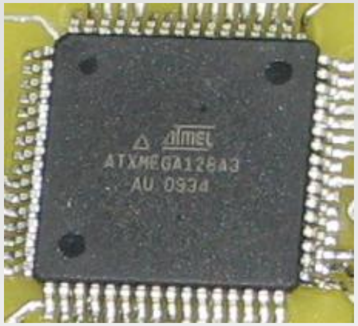
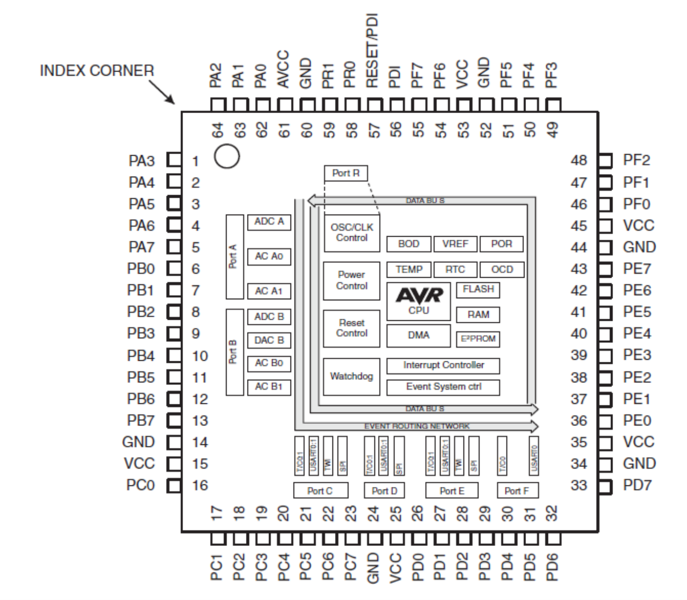
Microcontrollers

Atmel XMEGA Microcontrollers

- 32 MHz Clock
- 128 KB Flash
- 4 KB EEPROM
- 16 KB SRAM
- 16 12-bit A/D
- 2 12-bit D/A
- PWM Generation and Capture
- 50 Programmable I/O Lines
- Single 3.3V Supply

Control system uses one microcontroller for sensor data acquisition and one for PWM generation and fail safe





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GPS

Data Sheet SKYTRAQ

VENUS634FLPx 65 Channel Low Power GPS Receiver --- Flash

FEATURES

- GPS receiver in 10mm x 10mm x 1.1mm size
- Tests 8 million time-frequency hypothesis per sec
- Open sky cold start 29 second
- Signal detection better than -161dBm
- Accuracy 2.5m CEP
- ~28mA in tracking and navigation mode
- Multipath detection and suppression
- Data logging with external SPI serial Flash
- Supports active or passive antenna
- 1 SPI interface and 7 GPIO lines
- Flash-based, firmware customizable
- LGA44 package with 0.8 pitch
- Pb free RoHS compliant

The Venus634FLPx is a module-in-a-chip design targeting mobile consumer and cellular handset applications. It offers very low current consumption, high sensitivity, and best in class signal acquisition and time-to-first-fix performance.

The Venus634FLPx contains all the necessary components of a complete GPS receiver module, includes GPS RF front-end, GPS baseband signal processor, 0.5ppm TCXO, 32.768kHz RTC crystal, RTC LDO regulator, and passive components. It requires very low external component count and takes up only 100mm^2 PCB footprint.

Dedicated massive-correlator signal parameter search engine within the baseband enables rapid search of all the available satellites and acquisition of very weak signal. An advanced track engine allows weak signal tracking and positioning in harsh environments such as urban canyons and under deep foliage.

Programmable flash-based memory makes it ideal for applications requiring customized firmware.

Dynamic Pressure Sensor

Freescale Semiconductor

MPXV5004G
Rev 12, 09/2009

Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated

The MPxx5004 series piezoresistive transducer is a state-of-the-art monolithic silicon pressure sensor designed for a wide range of applications, but particularly those employing a microcontroller or microprocessor with A/D inputs. This sensor combines a highly sensitive implanted strain gauge with advanced micromachining techniques, thin-film metallization, and bipolar processing to provide an accurate, high level analog output signal that is proportional to the applied pressure.

MPXV5004
MPVZ5004
Series

0 to 3.92 kPa
(0 to 400 mm H_2O)
1.0 to 4.9 V Output

Features

- 1.5% Maximum Error for 0 to 100 mm H_2O over +10° to +60°C with Auto Zero
- 2.5% Maximum Error for 100 to 400 mm H_2O over +10° to +60°C with Auto Zero
- 6.25% Maximum Error for 0 to 400 mm H_2O over +10° to +60°C without Auto Zero
- Temperature Compensated over 10° to 60°C
- Available in Gauge Surface Mount (SMT) or Through-Hole (DIP) Configurations
- Durable Thermoplastic (PPS) Package

Application Examples

- Washing Machine Water Level
- Ideally Suited for Microprocessor or Microcontroller-Based Systems
- Appliance Liquid Level and Pressure Measurement
- Respiratory Equipment

Static Pressure Sensor

Data Sheet

SCP1000 SERIES (120 kPa) ABSOLUTE PRESSURE SENSOR

Features

- 30 kPa - 120 kPa measuring range
- Single +2.4 … 3.3 V supply
- Four measuring modes plus power down mode
- On-chip temperature measurement
- Fully calibrated and compensated component
- Standard digital output: SPI or I^{2}C [1]
- Small package size with optional [2] sealing gasket. Diameter 6.1 mm, height 1.7 mm
- Proof pressure 2.0 MPa
- Pb-free solderable component & RoHS-compatible

Applications

- Barometric pressure measurement and altimeter applications
- Home weather stations
- Advanced medical applications
- Level gauging

Benefits

- 1.5 Pa (~10cm at sea level) resolution with < 10 µA current consumption
- Altimeter/barometer function can be realized with minimum use of MCU
- Chemically and mechanically robust package

Sonar Altimeter

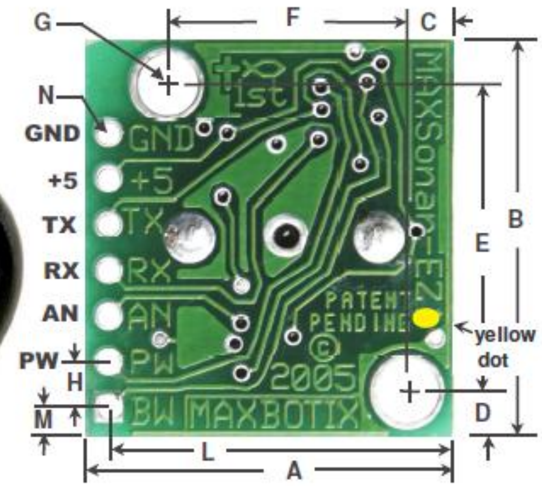
LV-MaxSonar®-EZ4™
Data Sheet

LV-MaxSonar®-EZ4™ High Performance Sonar Range Finder

RoHS COMPLIANT

With 2.5V - 5.5V power the LV-MaxSonar®-EZ4™ provides very short to long-range detection and ranging, in an incredibly small package. The LV-MaxSonar®-EZ4™ detects objects from 0-inches to 254-inches (6.45-meters) and provides sonar range information from 6-inches out to 254-inches with 1-inch resolution. Objects from 0-inches to 6-inches range as 6-inches. The interface output formats included are pulse width output, analog voltage output, and serial digital output.

approximately actual size



A	0.785"	19.9 mm
B	0.870"	22.1 mm
C	0.100"	2.54 mm
D	0.100"	2.54 mm
E	0.670"	17.0 mm
F	0.510"	12.6 mm
G	0.124" dia.	3.1 mm dia.

H	0.100"	2.54 mm
J	0.645"	16.4 mm
K	0.610"	15.5 mm
L	0.735"	18.7 mm
M	0.065"	1.7 mm
N	0.038" dia.	1.0 mm dia.
weight, 4.3 grams		

values are nominal

IMU

ANALOG DEVICES

Tri-Axis Inertial Sensor with Magnetometer

ADIS16405

FEATURES

- Tri-axis, digital gyroscope with digital range scaling
  - ±75°/sec, ±150°/sec, ±300°/sec settings
- Tri-axis, ±18 *g* digital accelerometer
- Tri-axis, ±2.5 gauss digital magnetometer
- 220 ms start-up time
- Factory-calibrated sensitivity, bias, and axial alignment
  - Calibration temperature range: −40°C to +85°C
- Digitally controlled bias calibration
- Digitally controlled sample rate, up to 819.2 SPS
  - External clock input enables sample rates up to 1200 SPS
- Digitally controlled filtering
- Programmable condition monitoring
- Auxiliary digital input/output
- Digitally activated self-test
- Programmable power management
- Embedded temperature sensor
- SPI-compatible serial interface
- Auxiliary, 12-bit ADC input and DAC output
- Single-supply operation: 4.75 V to 5.25 V
- 2000 *g* shock survivability
- Operating temperature range: −40°C to +105°C

APPLICATIONS

- Unmanned aerial vehicles
- Platform control
- Digital compassing
- Navigation

FUNCTIONAL BLOCK DIAGRAM

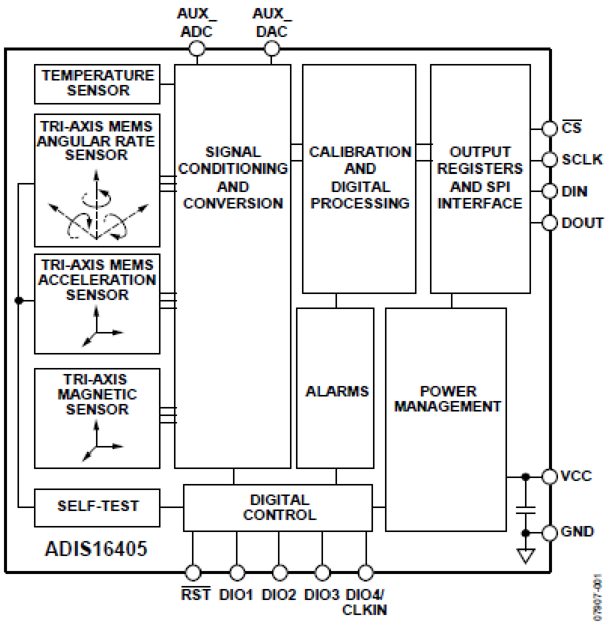


Figure 1.

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UAS Conflict Avoidance

- Assuring adequate separation between manned and unmanned aircraft is a key consideration for acceptance of unmanned aircraft into the national airspace system
- AU Thrust areas
  - Collaborative conflict avoidance
  - Radar / EO fusion for traffic detection and conflict avoidance
  - Statistical modeling
    - Estimating Time to Loss of Separation with Uncertain Position and Velocity Measurements
    - Estimating uncertainty of future motion

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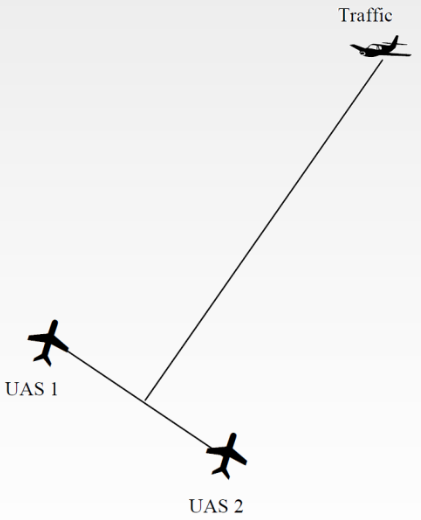
Conflict Avoidance Topics

Collaborative collision avoidance using passive sensors

- Use of passive sensors for collision avoidance is desirable from a size, weight, and power standpoint; however, passive sensors (e.g. electro optical, infrared) don't provide range information
- Using two unmanned aircraft cooperatively allows use of triangulation to fix position of potential conflicts
- Study evaluated concept and methods for dynamically positioning aircraft to minimize range error and improve position estimates of conflicts



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Conflict Avoidance Topics

Estimating Time to Loss of Separation with Uncertain Position and Velocity Measurements

- Maintaining separation between aircraft is paramount for air traffic control and time to loss of separation is one metric that can be used for determining whether two aircraft are a potential threat to each other
- Uncertainties in the position and velocity estimates of two potentially conflicting aircraft can corrupt the estimate of when and if those two aircraft will lose separation
- The uncertainties can arise from sensor limitations as well as uncertainty about possible future maneuvers of each aircraft
- This study evaluated the effects of uncertainty on predictions of time to loss of separation and evaluated several improved algorithms for improving estimation of time to loss of separation in the presence of uncertainty

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Robust Control/Agile Flight

GOALS

- Autonomous control through full flight envelope of aircraft
- Upset/stall/spin recovery
- Enhanced maneuverability
- Recovery maneuvers
  - Minimum speed landing
  - Perching

STATUS

- Testbed control system under development
  - Tightly coupled GPS/Inertial
  - Kalman-filter based multiple model algorithm

Source: flyingcirkus.com

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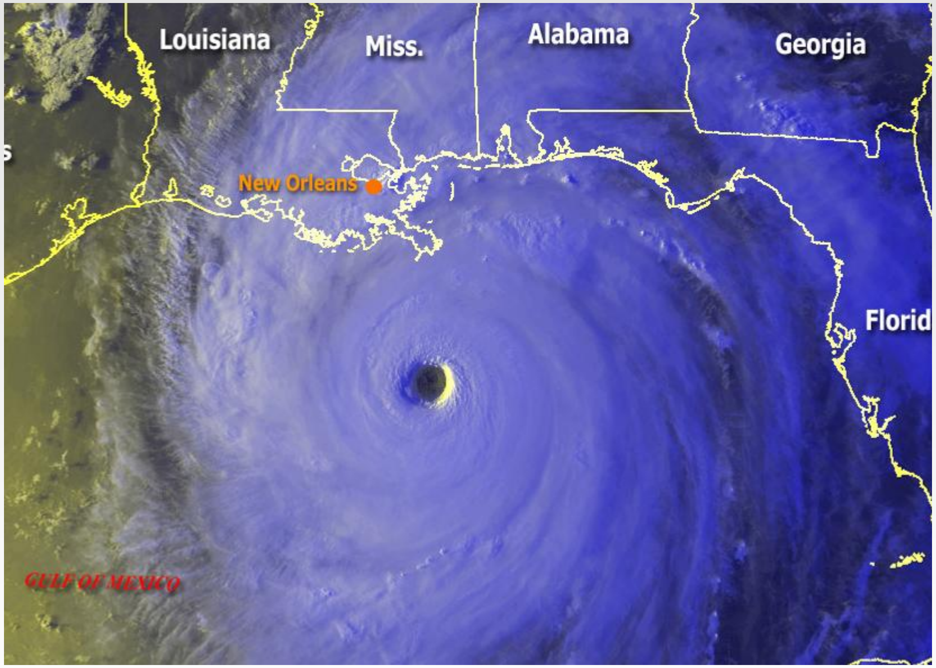
Design for Adverse Environments

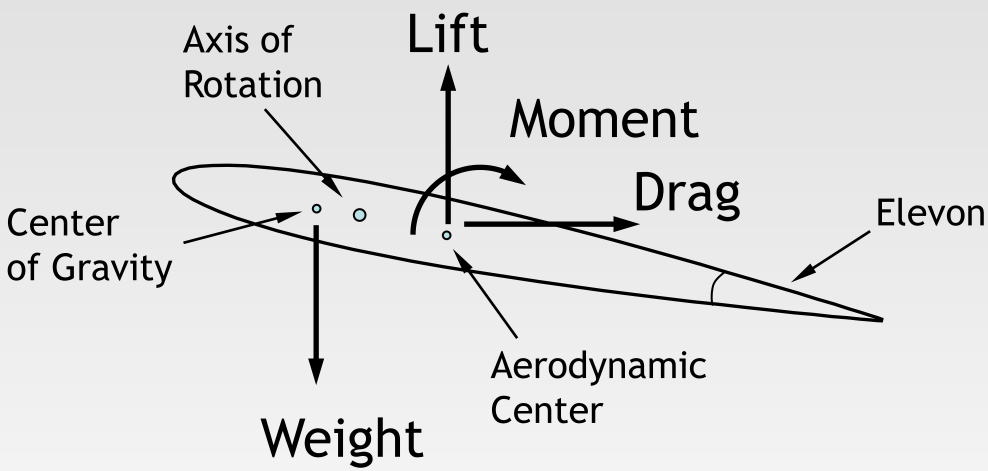
GOALS

- All weather operation
- Tropical storm monitoring
- Wake vortex safety



Source: NOAA

Freewing Concept



- Wing is free to pivot in pitch to maintain moment balance about the axis of rotation
- Because the aerodynamic center is aft of the axis of rotation, the wing angle of attack remains constant for a given elevon deflection
- Elevon deflection balances the airfoil pitching moment and CG moment about the center of rotation

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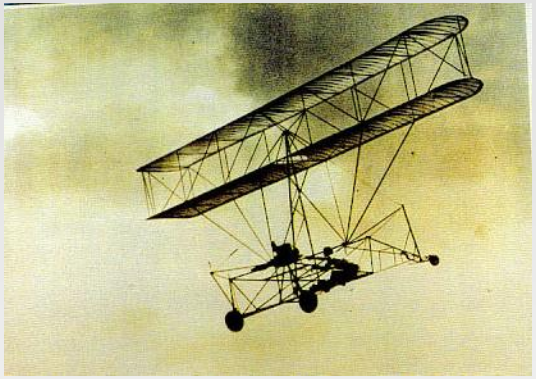
Freewing History



Early Spratt Controlwing (1912?)

Photo: Bill Wolfe, www.georgespratt.org

Hugh Schmittle and George G. Spratt

Photo: Freewing Aerial Robotics

Spratt Controlwing 1937

Photo: EAA Sport Aviation 1974

Scorpion UAV

Photo: Freewing Aerial Robotics

Freebird MK-IV

Photo: Freewing Aerial Robotics

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Advantages of Freewing Design

- Constant angle of attack ➔ constant lift ➔ reduced gust sensitivity ➔ much more stable sensor platform
- Up to 4-to-1 Reduction in Vertical Gust Sensitivity
- Freewing adjusts automatically during transition from hover to forward flight
- Reduced download on wing surfaces during hover
- Cannot stall or spin

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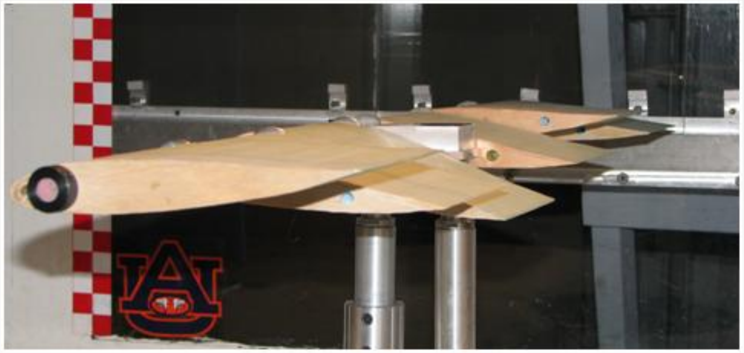
Segmented Free Wing

- For large-span aircraft, the gust field may vary along the span of the wing affecting the lift distribution / loads on the wing
- Segmented free wing divides the wing into multiple segments that can pitch independently equalizing the load over the span of the wing
- Wind tunnel and truck-mounted tests have been conducted to evaluate the concept and determine feasibility
- Initial wind tunnel tests showed dramatic reduction in rolling moment when operating in a spanwise velocity gradient



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