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UAV ATTITUDE AND HEADING HOLD SYSTEM

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ME5643: Mechatronics

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Introduction

- **Goal:** To create a Low Cost Plug and Play UAV
- UAV Classification
    - Large Scale
    - Medium Scale
    - Micro
- Poly UAV: Smaller than Medium Scale UAV's, larger than Micro sized.
- Ability to carry small payloads
- Plug-n-Play
- Open Platform for testing control algorithms

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Hardware & Software

- Hardware Components
  - Airframe
  - Flight Computer
  - Inertial Measurement Unit (IMU)
  - Global Positioning System (GPS)*
  - Servo Controller
  - Airspeed Sensor*
  - Flight Radio
  - Radio Modem*
  - Safety Switch

*Not present in current configuration

- Software Components
  - Flight and Control Software
    - Hardware Modules
    - Controller Module
    - Integration Architecture
  - Operating System

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Budgets/Costs

- Project funded through NASA Space Grant (Prof. Kapila in Poly)
- Support from Ames Research Center

Component	Description	Poly	NASA
Airframe	Hangar 9 1/4 Scale J3 Piper Cub	$630	
Engine	Fuji Imvac BT43		$512
Hardware	Servos, Props,connecters etc.	$800	
Aircraft Radio	JR XP662		
Flight Computer	Fit PC2	$315	
GPS Sensor	Garmin 18x USB		$90
IMU	Microstrain 3DM-GX3	$2000	
Servo Controller	Propeller Servo Control Unit	$40	
Safety Switch	NASA Custom UAV safety switch		
Airspeed Sensor	MPXV500 Diff. Pressure Sensor	$20	
Telemetry Radio	MaxStream OEM 900 Mhz		
Control Software	Reflection		
Operating System	Microsoft Windows XP Embedded SDK		$1000
	Approximate Total	$3805	$1602

Table 1: Cost Description

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Hardware

- Flight Computer: Fit PC2
  - Intel Atom Z530 1.6GHz
  - 1GB DDR2-533 on-board
  - 6 USB 2.0 High Speed ports
  - 802.11g WLAN
  - 16Gb Solid State Hard Drive

- Advantages
  - Smallest form factor
  - Rugged and Robust
  - Quick Deployment : No assembly Required

Hardware

- Airframe: 1/4th scale Piper J3 Cub
    - Well instrumented aircraft
    - Available in Almost Ready to Fly Kit
    - Large wing area allows for higher payload capacity
    - Slow response
    - Gasoline Engine (Fuji-Imvac BT-43i) improves range
    - Individually actuated control surfaces can simulate damage

Hardware

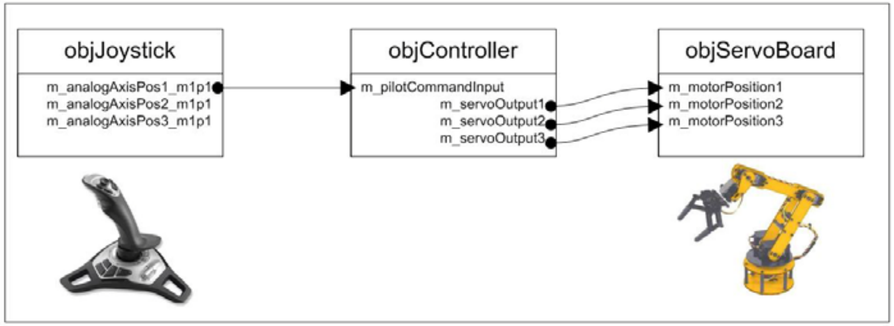
- Inertial Measurement Unit : Microstrain 3DM-GX3 25
  - Smallest and Lightest AHRS
  - Calibrated for sensor misalignment, gyro G-sensitivity, magnetometer hard-iron effects.
  - On board filtering
  - USB 2.0 and serial TTL communication
  - Sampling rate between 100Hz and 1000 Hz

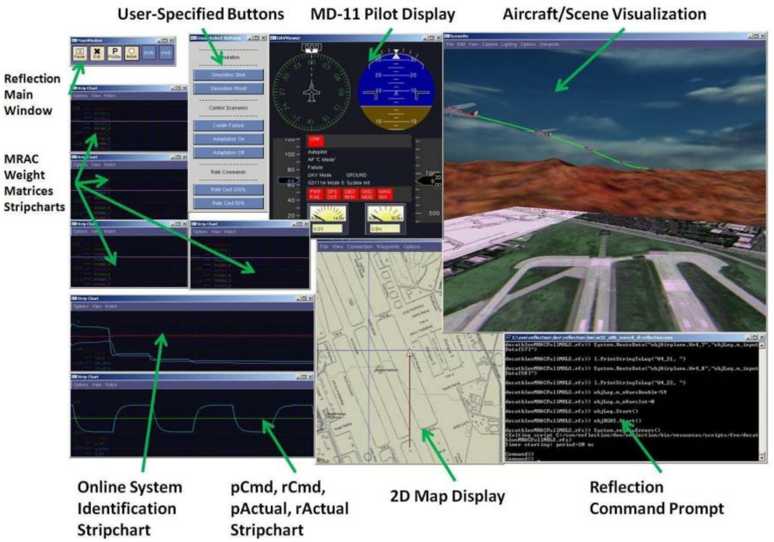
Hardware

- Servo Controller: Propeller Servo Control Board
    - P8X32A-M44 Propeller chip on-board
    - 16 Servos
    - Servo Ramping
    - Baud Rate 38.4 kbps
    - USB 2.0 serial TTL
- Safety Switch: NASA Custom
    - Optically Isolates Manual Radio System from Autopilot

Software

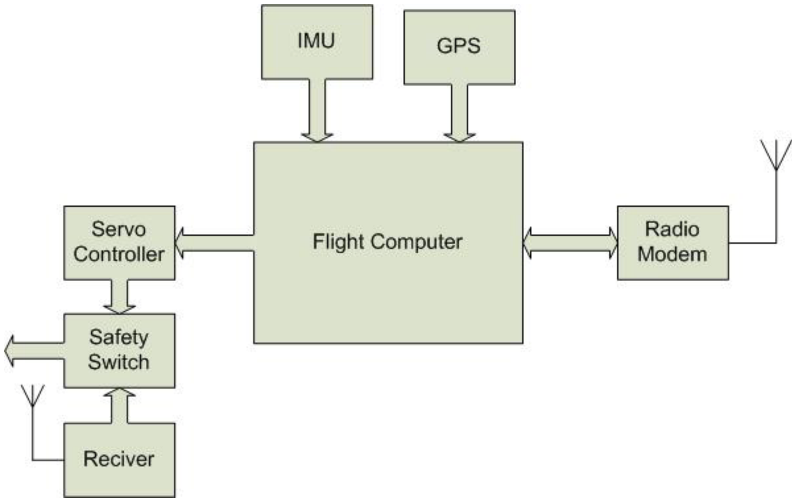
- Reflection Architecture
  - UAV built around Plug-n-Play architecture
  - Visual Studio based (C++)
  - Modular Architecture
  - Provides various functionalities like Module swapping in run-time
  - Simulation Environment provides rapid development and testing





Avionics System

- System Powered by two separate batteries
  - 4200 mAh NiMH servo power
  - 2450 mAh LiPo Computer Power
  - Voltage regulator



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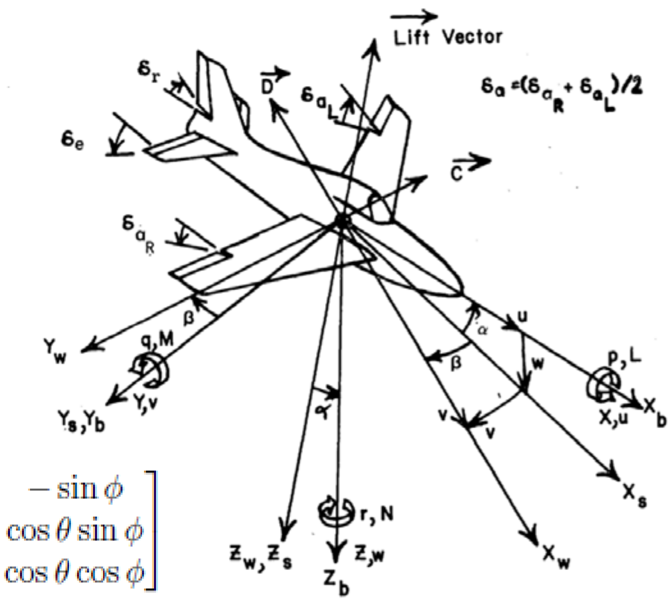
Software Modules

- objPSCU:
  - Communicates with the PSCU
  - Sends 8 byte commands
  - Servo position is set by sending a number between 1250 and 250
  - Accepts Scaled inputs between 1.0 and -1.0
- objMicrostrain
  - Communicates with the IMU
  - Sends single byte binary commands
  - Recieves fixed length binary replies
  - Outputs Acceleration Vector, Angular Rate Vector and Orientation Matrix

Background

- North East Down Body fixed co-ordinate System
- Rotation Matrix from World axis to Body Axis Defined by



$$M = \begin{bmatrix} \cos\phi\cos\theta & \sin\phi\cos\theta & -\sin\phi \\ \cos\psi\sin\theta\sin\phi - \sin\psi\cos\phi & \sin\psi\sin\theta\sin\phi + \cos\psi\cos\phi & \cos\theta\sin\phi \\ \cos\psi\sin\theta\cos\phi + \sin\psi\sin\theta & \sin\psi\sin\theta\cos\phi - \cos\psi\sin\theta & \cos\theta\cos\phi \end{bmatrix}$$

- Euler Angles

  pitch = arcsin(-M13)

  roll = arctan(M23/M33)

  yaw = arctan(M12/M11)

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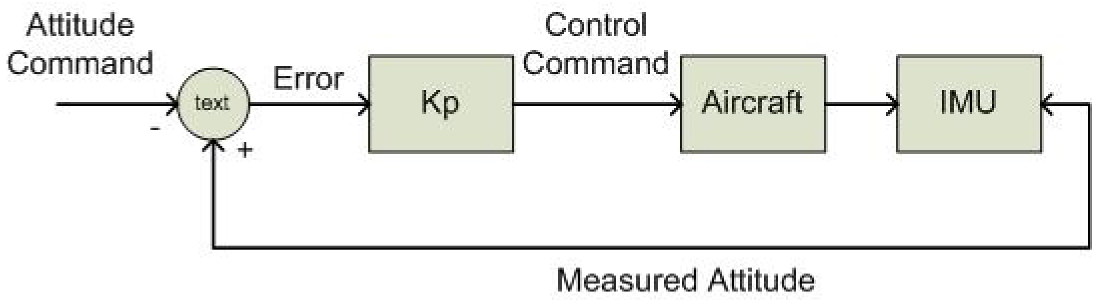
Controller

- Heading and Attitude Hold system
  - Proportional controller to hold and correct Roll, Pitch, Yaw commands
  - Input parameters: Euler Angles (Roll Pitch and Yaw)
  - North East Down Co-ordinate System
  - Input parameters: Euler angle Commands, Aircraft states
  - Output Parameters: Scaled Control Surface Command



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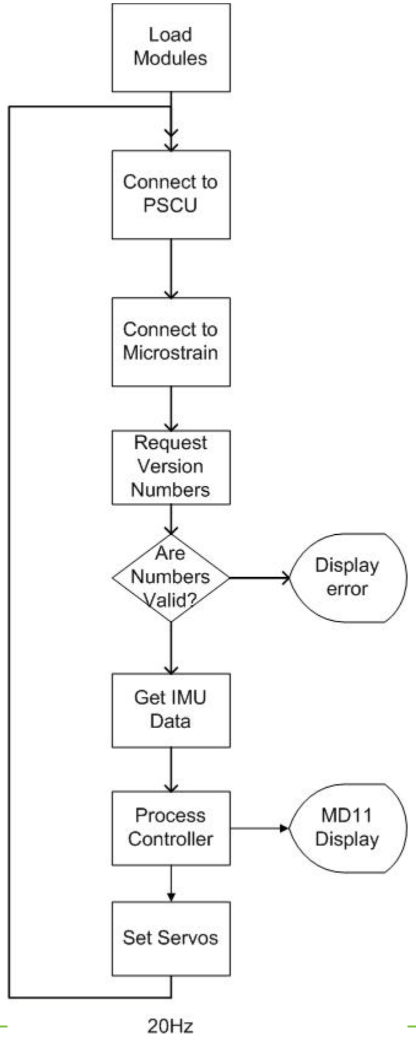
Flowchart



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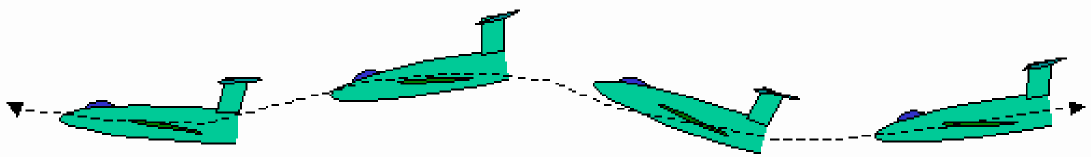
Applications & Future Work

- Application current system
  - Oscillation reducer. Example Phugoid damper.



  - Inner Loop control for system identification
    - Outer Loop program for constant control doublets

- Future Work
  - Integrate GPS: Sensor Fusion
  - Airspeed Indicator
  - Radio Modem to beam telemetry data