THE PHOENIX PROJECT

Coordinated Flight of Multiple Unmanned Vehicles

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Goals

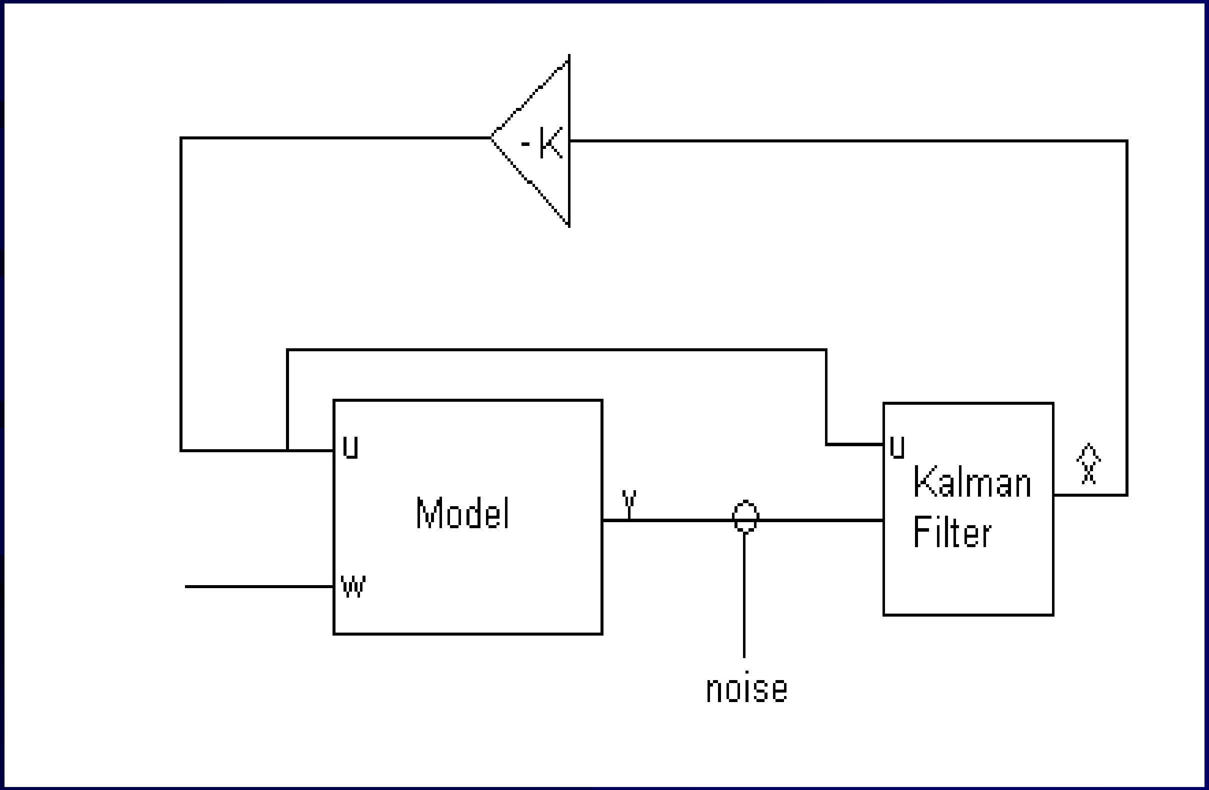
- Long Term
  - Fleet of 4 Aircraft
  - Way Point Navigation
  - Coordinated Aerobatic Maneuvers
- Short Term
  - Derivation of Longitudinal Controller
  - Refine Lateral Controller
  - Integrate System and Flight Test

The Hobbico Hobbistar 60

- Advantages
  - Remote Pilot
  - Inexpensive
  - Almost Ready to Fly
- Disadvantages
  - Small Payload

Phoenix 1 [1]

Lateral Control System



Lateral Control System

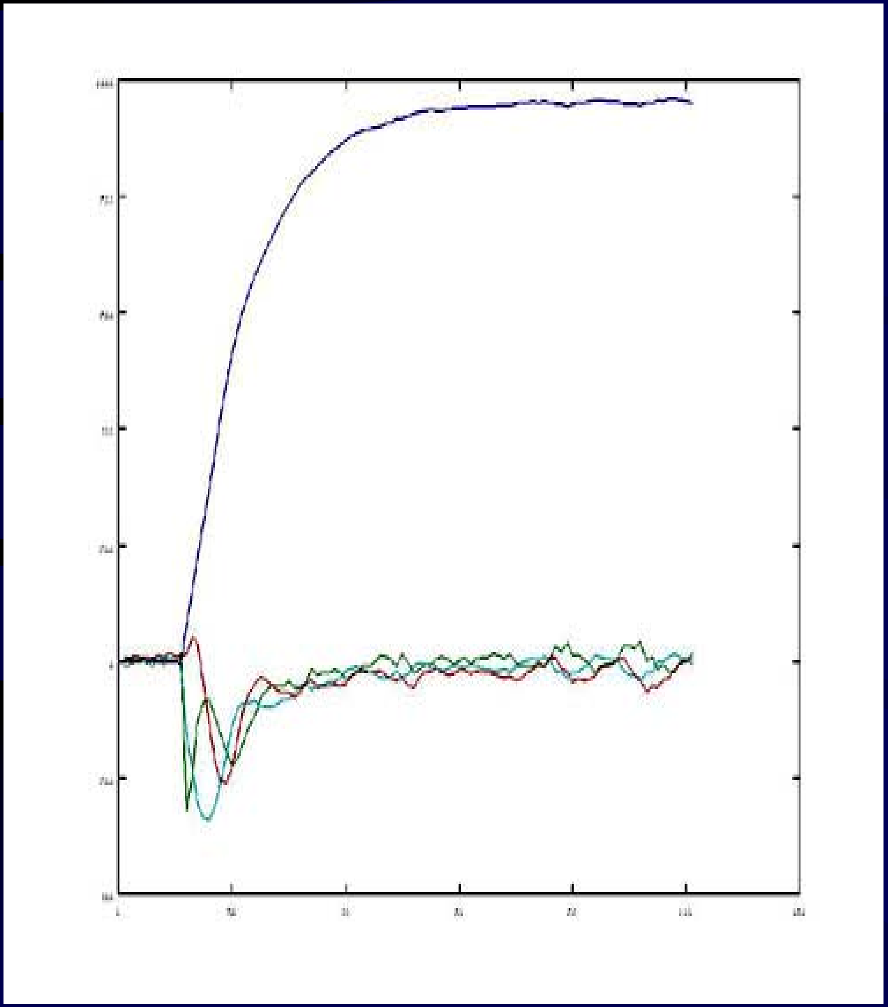
$$\dot{\vec{x}}_{lat_{n+1}} = A_{lat}\vec{x}_{lat_n} + B_{lat}\vec{u}_{lat_n}$$

$$\vec{x}_{lat} = \begin{bmatrix} v \\ r \\ p \\ \Phi \end{bmatrix}$$

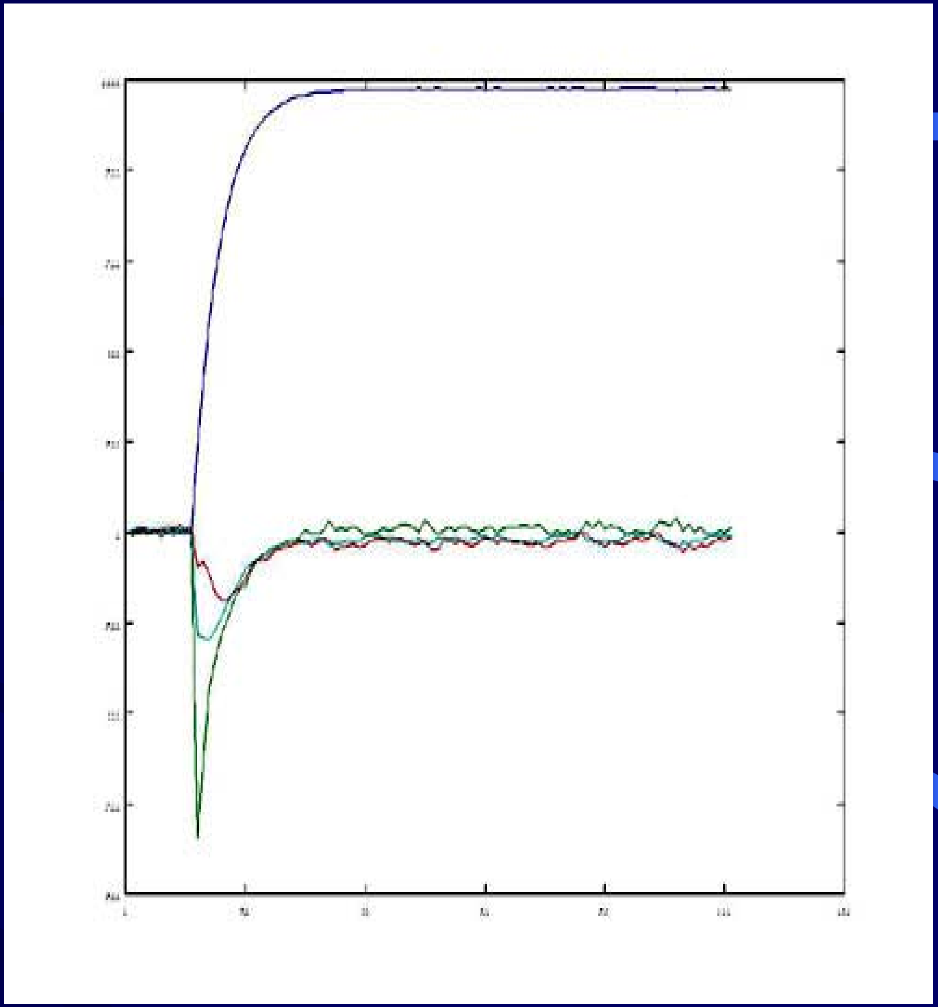
$$\vec{u}_{lat} = \begin{bmatrix} \delta_a \\ \delta_r \end{bmatrix}$$

- Refinement of Control System
  - Correction of Simulink Simulation
  - Alteration of LQR Control Cost

Simulink Analysis of LQR



•State Estimate with $R=30*I_2$



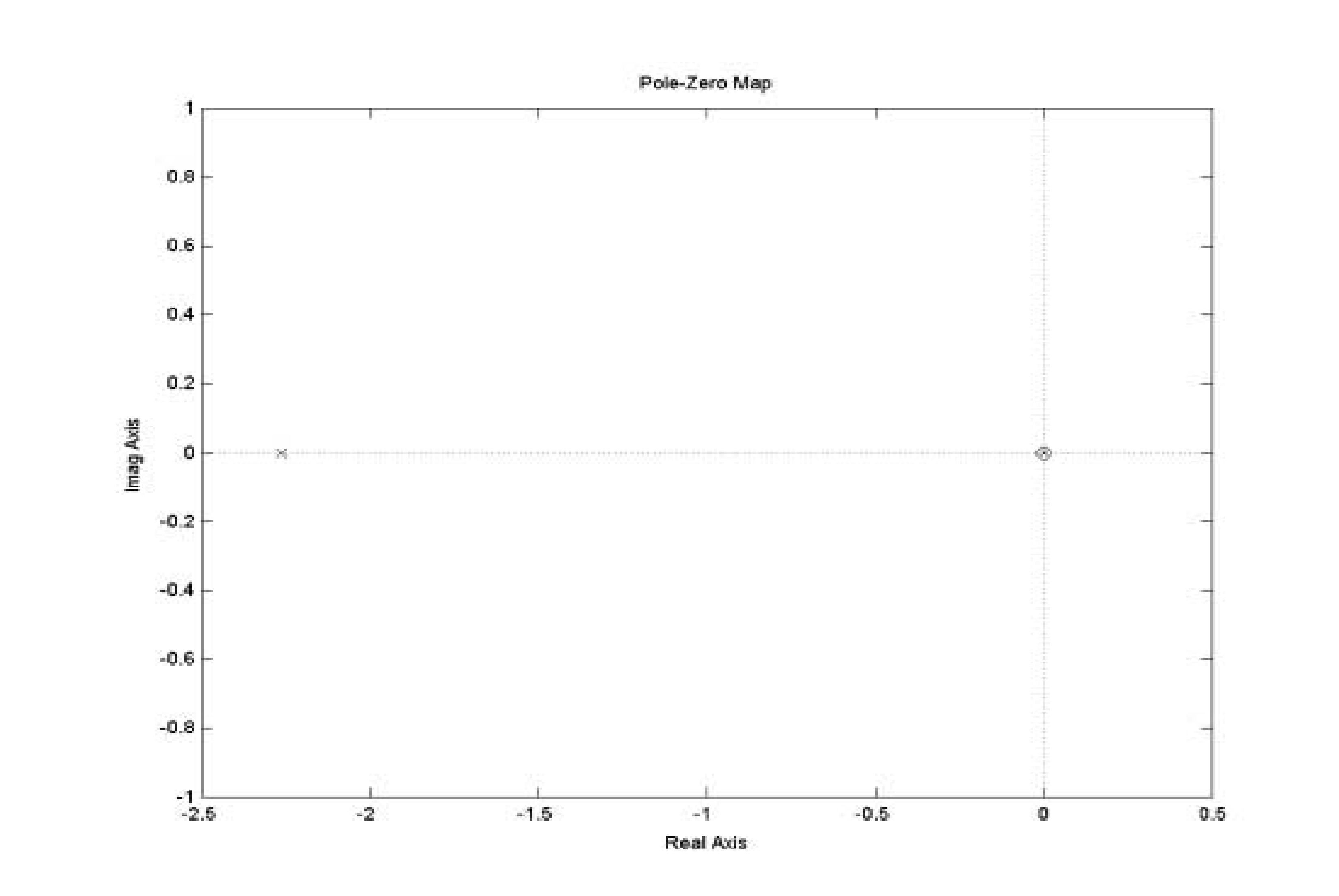
•State Estimate with $R=I_2$

Longitudinal Control System

$$P = \frac{0.7121 \cdot s - 0.0002239}{s^2 + 2.26 \cdot s - 0.004299}$$

- Derivation of Control System
  - Plant Model (*P* above)
  - Control Block (*C*)

Longitudinal Plant Pole/Zero Map



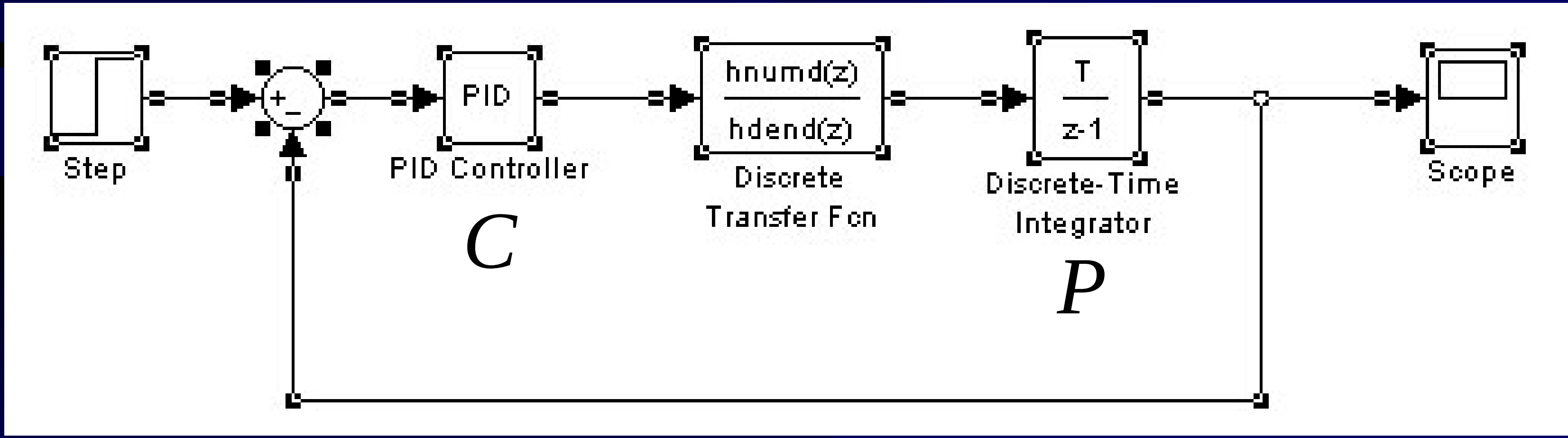
•Pole/Zero Map showing Poles of Longitudinal Plant Model

PD Control Derivation

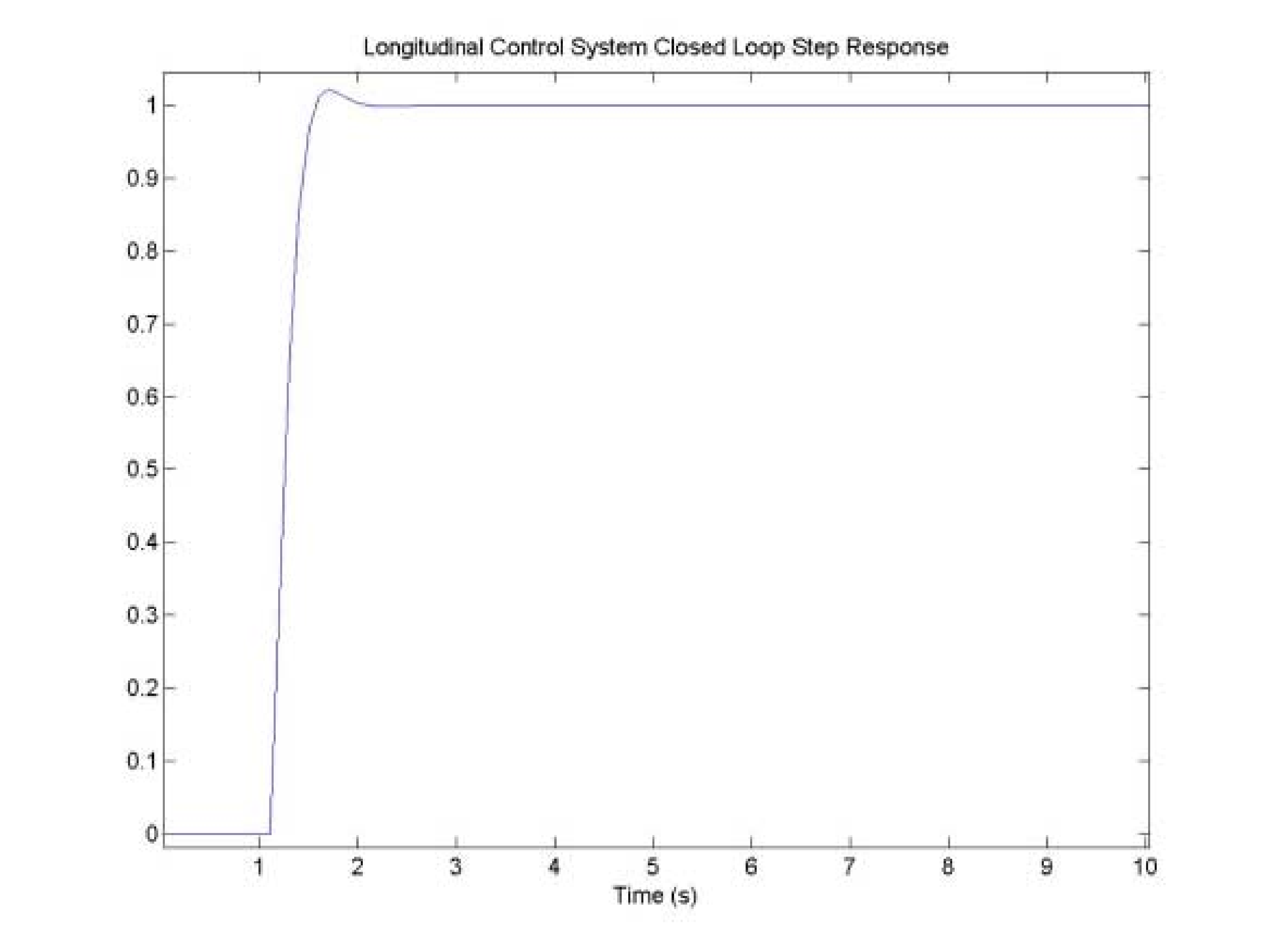
- PD Controller (*C*)
  - Proportional to control rise time
  - Derivative to control damping
  - Elimination of Integral Control
    - No need for 0 steady state error
    - Integral Control usually slows transient response
  - Non-computationally heavy, easier to maintain real-time

Longitudinal Control System

$$C = 10 + 4 \cdot s$$

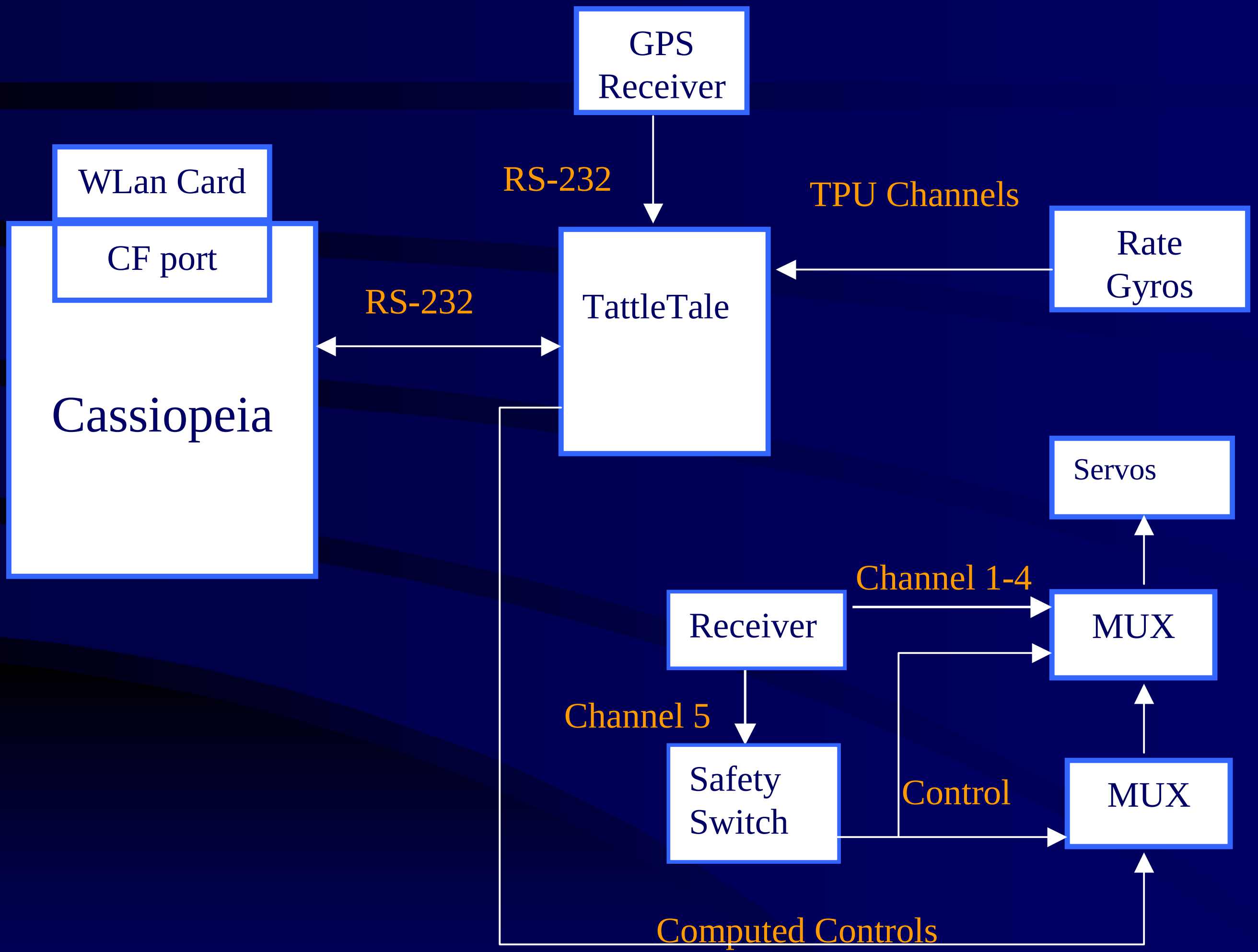


Closed Loop Step Response



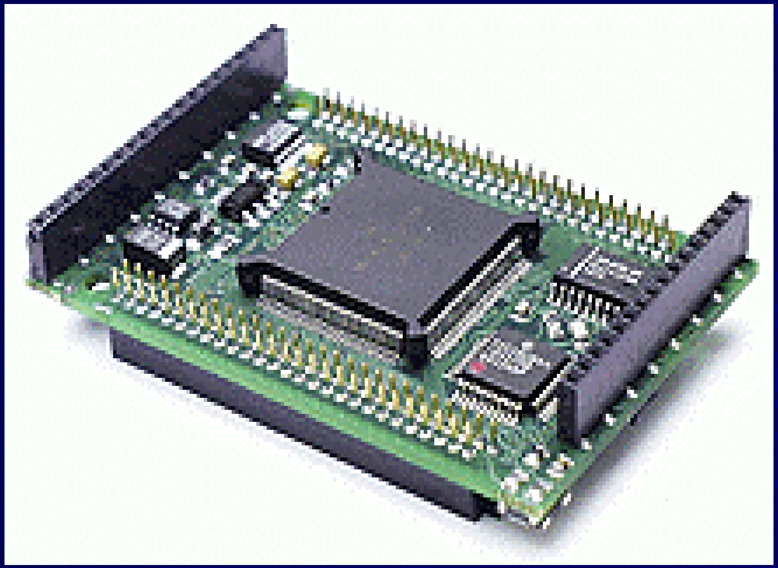
The Cassiopeia Payload Bay

Onboard System



Tattletale

- Data Logger from Onset Computers
- Acts as Data Acquisition Board
  - Reads Gyro data Pulses
  - Transmits Gyro data to Cassiopeia
  - Receives Servo data from Cassiopeia
  - Controls Servos via TPU Channels
- Sampling Time: 10Hz



TattleTale Model 8 [2]

Casio Cassiopeia

- Main Processor
  – Lateral Control
  – Longitudinal Control
- Wireless LAN
  – 2-way communication with ground laptop

Cassiopeia E-125 [3]

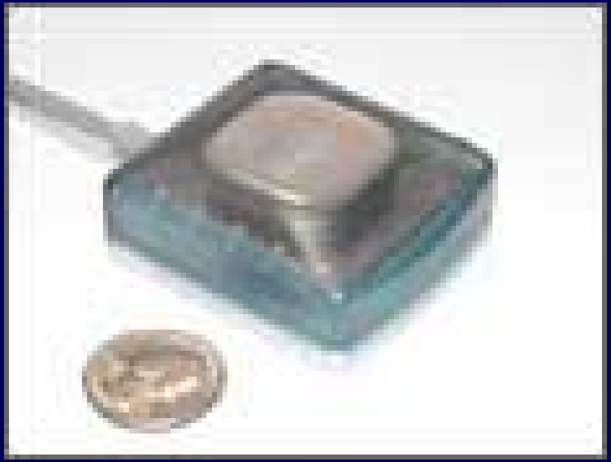
Wireless LAN

- Symbol 802.11 Wireless LAN
  - Designed for PDAs
  - Dynamically adjusts speed to increase range
  - Communicates with Ground Laptop

Symbol CF WLan Card [4]

GPS

- Pharos iGPS Receiver
- Read by TattleTale
  - 1Hz Sampling
  - RS-232 Protocol
- Data Sent to Cassiopeia
- Data Transmitted to Laptop
- Data plotted by Laptop

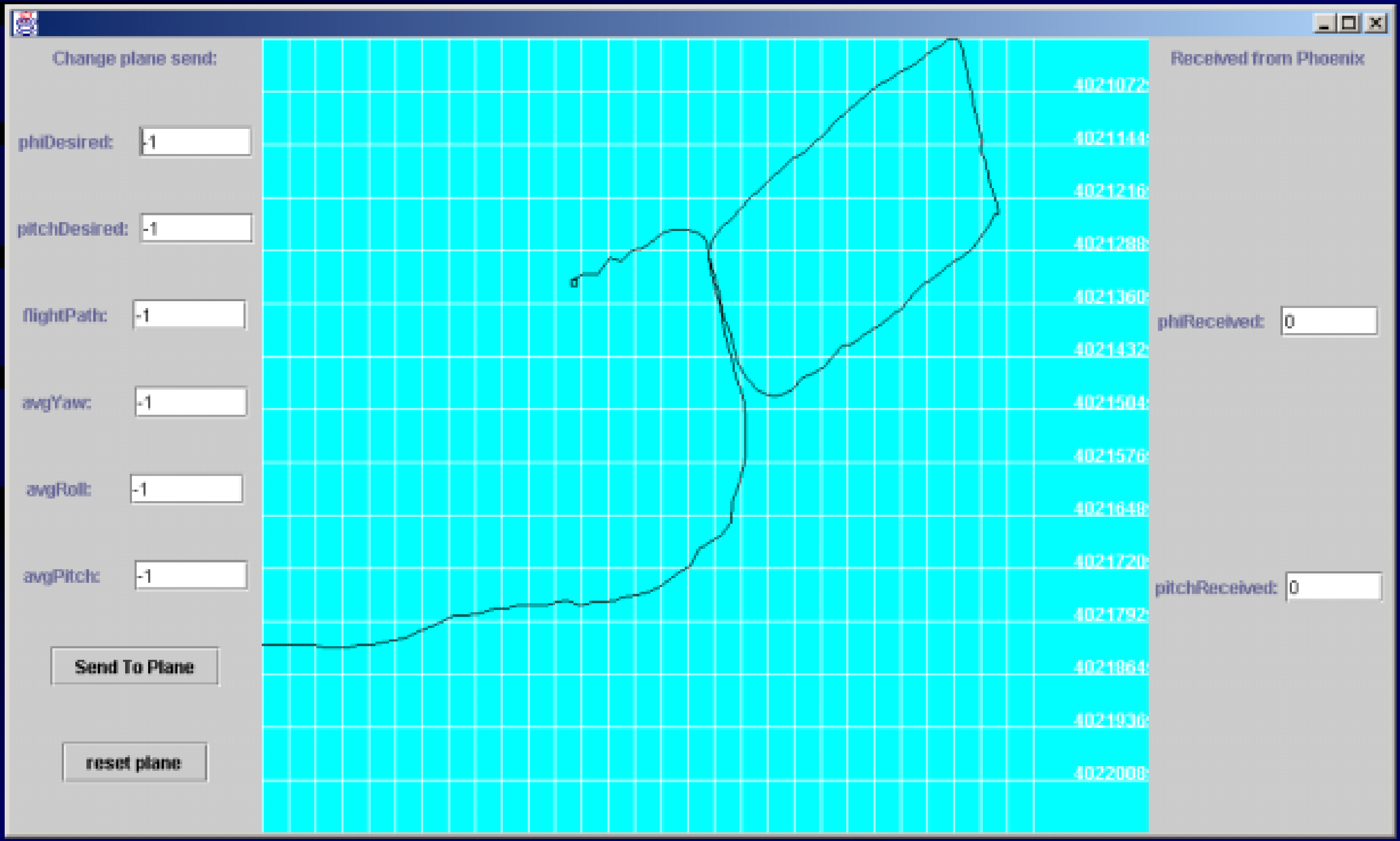


Pharos iGPS [5]

Ground-Based Laptop

- Receives Data from Cassiopeia
  - Φ and θ
    - Ensures Onboard System is functioning
  - GPS Data
- Transmits Data to Cassiopeia:
  - Φ and θ (desired)
  - ‘Enter Flight Path’ Command
  - ‘RESET’ Controls
  - Adjusts assumed Average Rate Gyro Values

Control System Interface



Ground Tests

- What Worked:
  - Safety Switch
  - System remained in Real-time
  - Reliable Network Software
    - System reestablishes communications
  - Controllers reacted to Disturbances
- What Didn’t:
  - Integration of GPS prevented system from remaining in real-time

Flight Test

When it Rains, It Pours

Conclusions

- Controller Flight Test was Inconclusive
  – Failure before Automated Control Test
  – Controller Performance known only to the extent of simulations
- What did Work
  – Wireless Communications
  – Tattletale/Casio Communications
  – Sensors and Integration

Changes Next Semester

- New PDA
  - Smaller PDA's exist that would fit in the Aircraft
  - Alternative OS's exist for PDA's with the Intel StrongARM
  - PDA and Laptop will log all data
- GPS: Direct Communication with PDA
  - Avoids GPS / TattleTale Interaction
  - Would allow system to remain in real-time
- Control to the TattleTale
  - More modular Design
  - Avoids excess communications

Special Thanks

- Professor Stengel: for allowing our involvement in this project
- Professor Littman: for his advice and counsel
- Professor Leonard’s Dynamics Lab: for their assistance
- George Miller: for generously donating his time to fly our airplane

References

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