Advanced Integrated Concepts
for the IlliniSat-2 Bus

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ADACS Problem

• Implementing science missions on the IlliniSat-2 bus requires precise pointing and attitude knowledge within one degree on each axis

• Limited power, mass, volume and computation make this a challenge to implement on board
Solution

• Use an array of small, cheap sensors to capture attitude knowledge
  – Magnetometer
  – Photo-diode Sun sensor
  – Rate gyros

• Use a linear Kalman filter to remove sensor noise
  – Filter only the attitude to reduce computational complexity
  – Smooth angular rate data using a moving average filter
Determination Architecture

[Diagram showing the Attitude Determination Architecture, including boxes labeled Control Attitude, Rate Gyros, Sun Sensor, Magnetometer, Data Smoothing-Moving Average, TRIAD Algorithm, Kalman Filter, and paths labeled $w_{meas}$ and $q_{meas}$]
Kalman Filter Theory

• A Kalman filter provides a minimum variance linear estimate
• States are propagated using system dynamics, then adjusted using measurement data
• Filter may be tuned to reject varying amounts of sensor noise
Simulation Results

- Nadir point scenario modeled using reasonable sensor noise estimates
Simulation Results Cont.

Error v Time: Roll

Abs Error [Degrees]

X: 5400  Y: 0.5611
Control Simulation Results
Conclusions

• A linear Kalman filter may be used to filter attitude data
• Filter uses less complex calculations at the expense of using more sensors
• Attitude knowledge within 1 degree possible
Outline

ADACS Problem
• Problem Statement
• AD Architecture
• Kalman Filter Theory
• Simulation Results
• Conclusions

Solar Panel/Magnetorquer
• Problem Statement
• Conceptual Design
• Design Synthesis
• Manufacturing
• Integration
• Conclusions
Solar Panel/Magnetorquer

- Create a strong, lightweight solar panel substrate that is easy to manufacture with reproducible quality
- Develop an integrated component to take the place of magnetorquers, and solar panel terminals
Conceptual Design

• The conceptual design consisted of:
  – Carbon fiber solar panel substrate
  – Aluminum backing
  – Flexible PCB to include magnetorquer and solar panel terminals.
• The design needs to be lightweight (<75g single panel w/ solar cells) and easy to connect
Design Synthesis

Carbon Fiber Substrate

• Constructed of unidirectional carbon fiber prepreg stacked up in an orthogonal balanced layup
• Original idea of using aluminum backing for easy machining of mechanical connections was abandoned due to warping
• After many iterations, we arrived at a balanced stack up which is currently in material testing
Design Synthesis

Flexible PCB Magnetorquer

- The design of the flexible PCB went through many iterations
- In addition to solar panel terminals at the outside edges and a magnetorquer, pyro channels were added along with data connections
- The design also allows for the magnetorquer to be separated from the circuit and used on its own for the z-axis torquer
Manufacturing

Solar Panel Substrate
• The substrate layup is done in-house and cured in-house using an autoclave
• The substrate is machined externally using a water jet
• Total mass of carbon fiber substrate 21g

Flexible PCB
• The flexible PCB was designed in-house and manufactured externally
• Total mass of flexible PCB 25g

Total Mass of Single Panel Assembly
< 65g
Integration

• Solar cells (mounted to the solar substrate) and the solar panel terminals (which is part of the flexible PCB) both need to be external to the satellite
• Therefore, at some point, one must pass through the other
• Holes are cut through the substrate to allow the fingered terminals of the flexible PCB to pass through
• The substrate/flexible PCB assembly is connected via one electrical connection to a power board, and mechanically attached to the upper and lower faces, and a center plate located near the middle of the satellite
Conclusions

- In a small package, a robust, lightweight solar panel substrate was manufactured using carbon fiber.
- An integrated flexible PCB was designed and produced which includes a magnetorquer, pyro channel, solar panel terminals, and thermocouple connections.
- The designs are scalable.
- The two are currently under individual testing to evaluate performance for use in the IlliniSat-2 bus.
Questions
Appendix – Kalman Filter Theory

• Predict

\[ \hat{x}_{k+1}^- = \Phi \hat{x}_k \]

\[ P^- = \Phi P \Phi^T + Q \]

• Measurement Update

\[ z_k = Hx_k \]

\[ K = P^- H^T \left( H P^- H^T + R \right)^{-1} \]

\[ \hat{x} = \hat{x}^- + K \left( z - H \hat{x}^- \right) \]

\[ P = (I - KH) P^- \]
Error v Time

- $E_{RMS}$
- $E_{1-|q|}$
Appendix – Assembly
Appendix – Flex Cable Functionality

- 6 Solar Panel terminals
- 3 Pyro channels
- 4 surface mount data terminals
- Magnetorquer
- Primary data and power connection
- Torque-only secondary tail