Unsteady and Nonlinear System I.D. of Large Unmanned Aerial Systems

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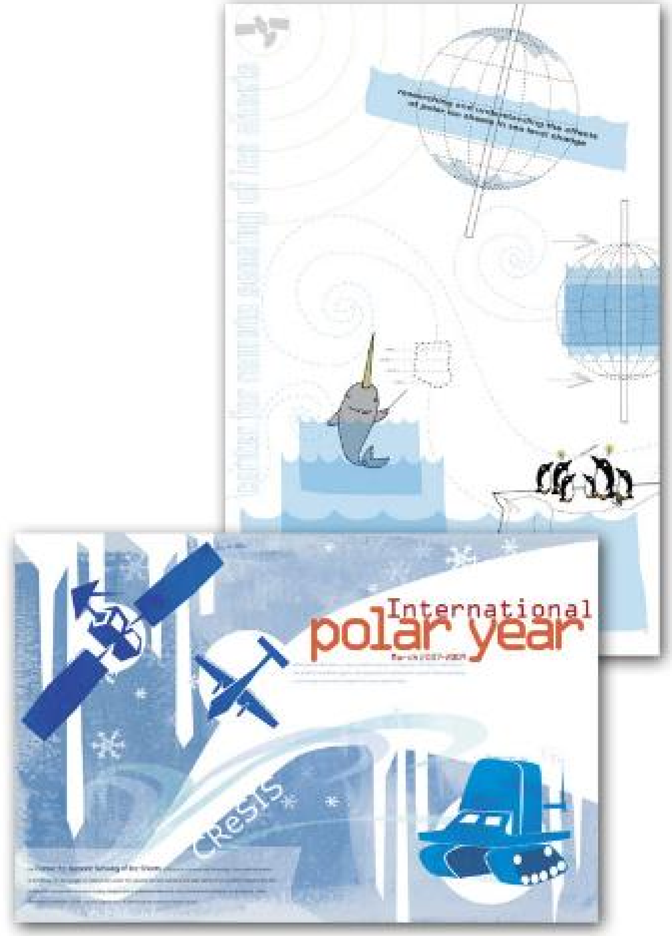
CReSIS

- The Center for Remote Sensing of Ice Sheets (CReSIS) is a NSF funded project.
- CReSIS is developing sophisticated sensors and long-duration uninhabited aerial systems (UAS) to carry them.
- Researchers from CReSIS are developing next generation radar technology to map internal layers near ice beds.
- These data sets are essential for developing improved ice sheet models to simulate how ice sheets will respond to a warming climate and predict their contribution to sea-level rise.



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NSF NASA KTEC

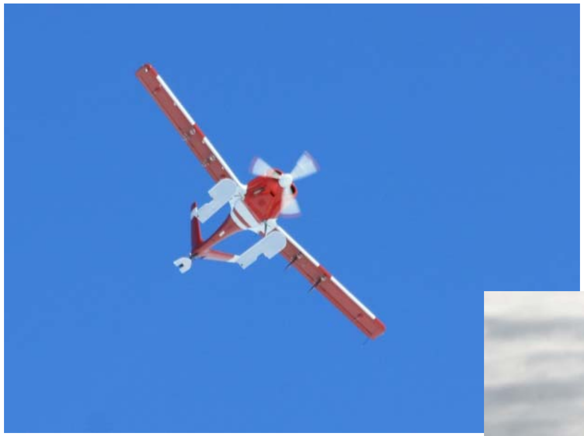
Core Research Focus Areas

1. **UAS Modeling and Flight Dynamics Analysis**
   I. System and Parameter Identification
   II. Collision Avoidance Algorithms
   III. Trajectory Optimization Methods
2. **UAS Flight Control**
   I. Nonlinear and Robust Controllers
      I. Collision Avoidance of Cooperative and Noncooperative Agents
3. **UAS Flight Testing**
   I. Small & Large UAS Flight tests
4. **Hardware & Software Development**
   I. KUASF Autopilot System
   II. See-Detect-Avoid Radar
   III. Autolanding Laser Based sensor

Airborne UAS Platform -- Performance Requirements for CReSIS Field Tests

- The UAS shall support the fine survey mission, defined as a 20km x 20km area with 1km grid line spacing and a 350km ingress/egress
  - Range: 945nm (1,750 km)
- Ground Speed: 180-220 km/hr
  - Driven by Sensors
- Cruise Speed: ~120kts (240 km/hr)
  - Driven by Wind speeds: 20-40 kts (35-75 km/hr)
- Operating Ceiling: 15,000 ft (4.6 km)
- Operating Altitude: < 4,900 ft AGL (1,500 m)
- Takeoff and Landing Distance: 1,500 ft (450 m)*
  - *(enables operation from field camp or remote base)
- Heavy Fuel Engines are Preferable

UAS Program @ KUAE



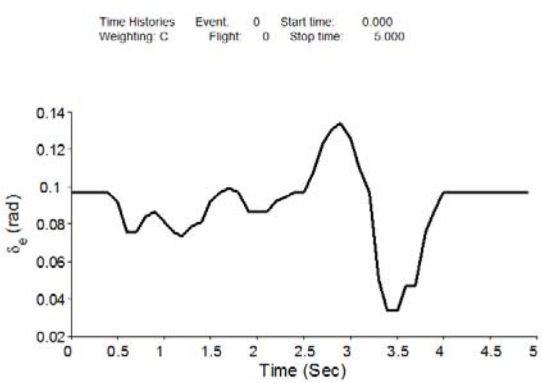


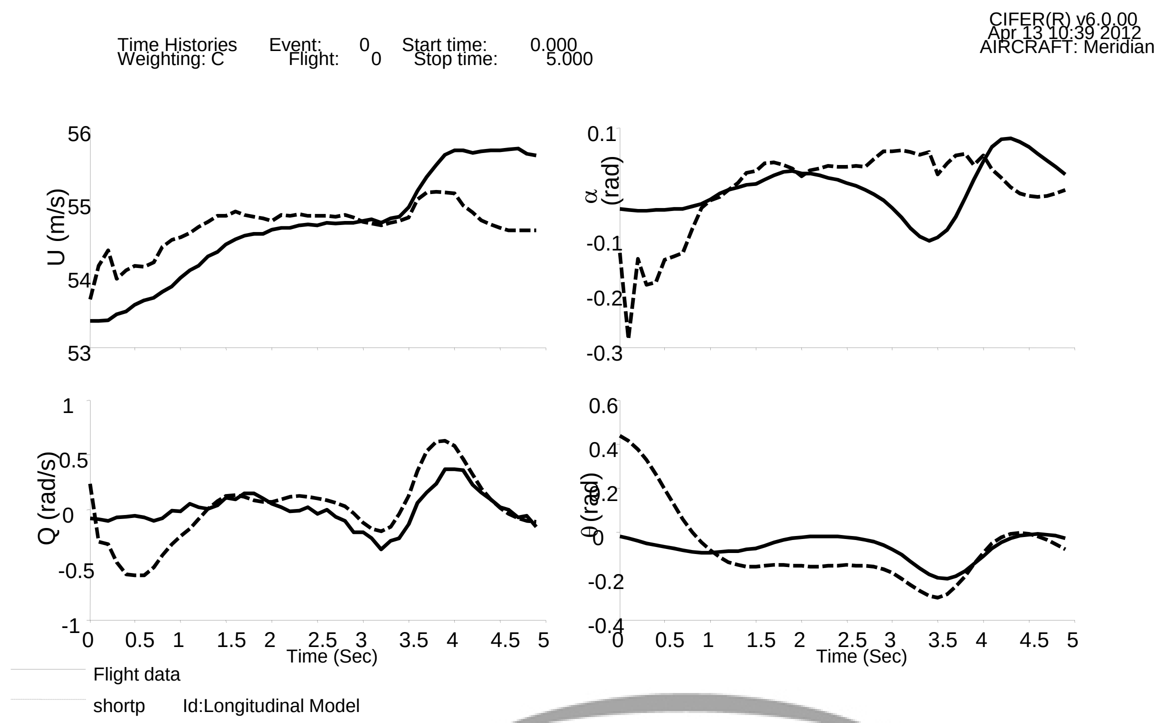
Comprehensive Identification from Frequency Response (CIFER)

- The Meridian UAS has a v-tail and because of that a strong coupling between the longitudinal and lateral-directional modes was observed.
- Using CIFER, the cross-coupled stability and control derivatives (i.e. Cnq, Cmr, and Clq) for the Meridian were identified, as these terms are normally neglected as the longitudinal and lateral modes are assumed decoupled in most cases.

CIFER State Estimation for Meridian UAS

- The following plots illustrate initial results for the Meridian's longitudinal mode, assuming decoupling.





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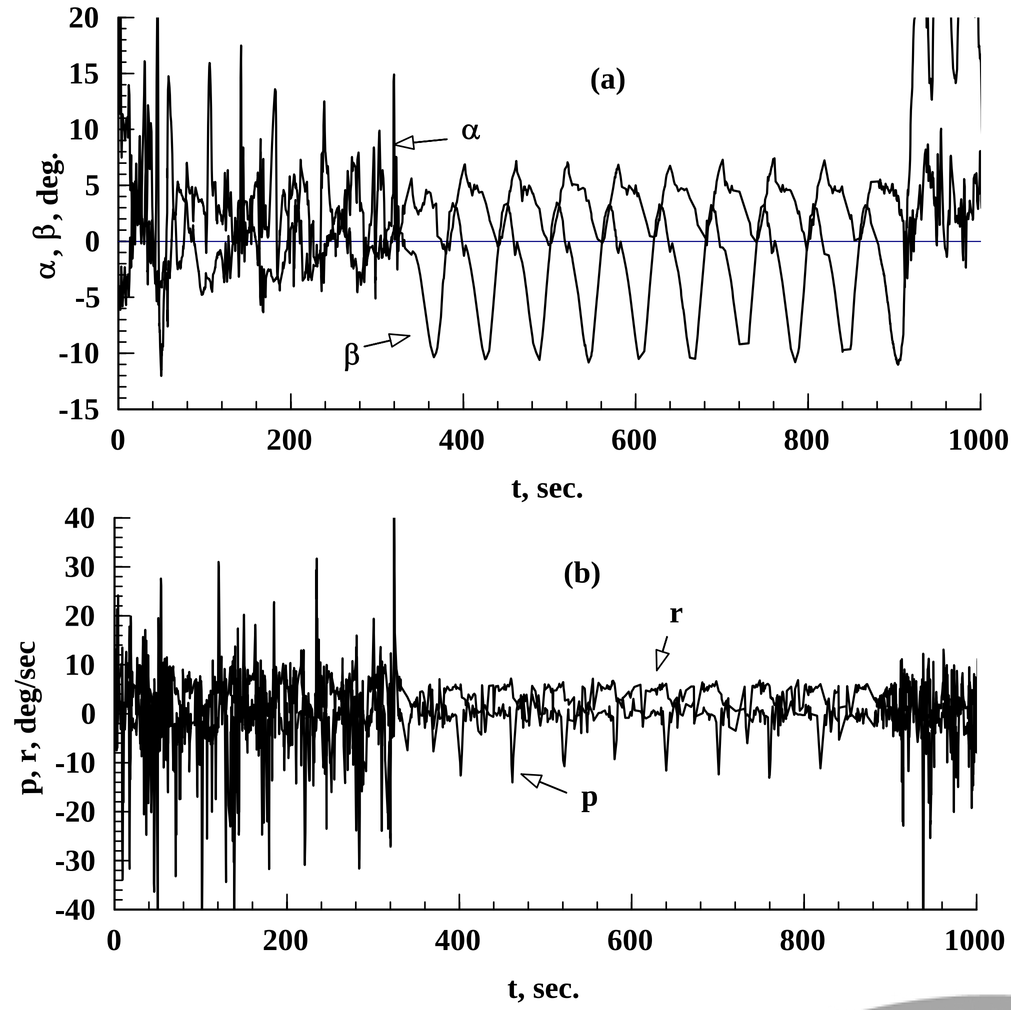
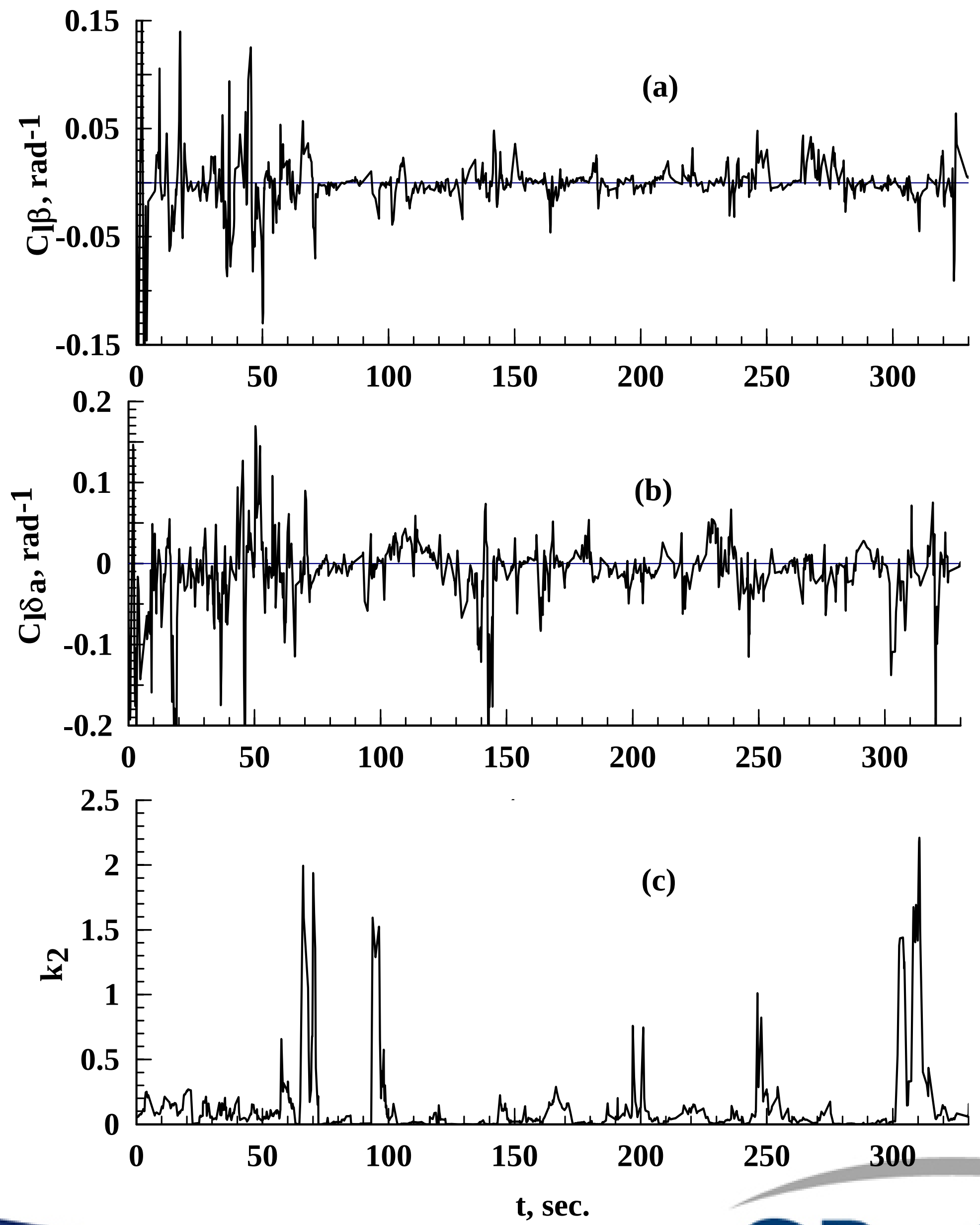
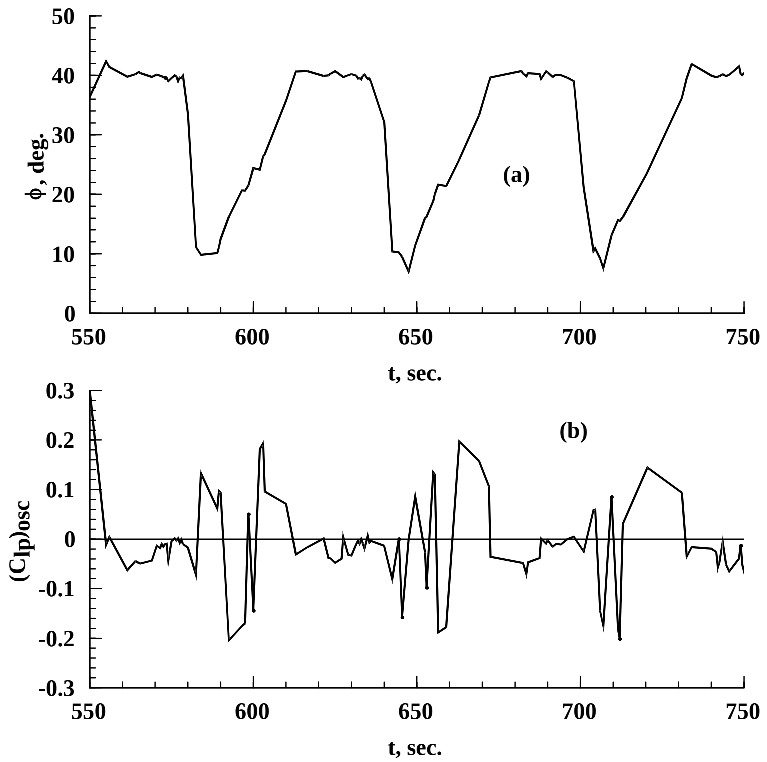
High Airflow Angles and Angular Velocity

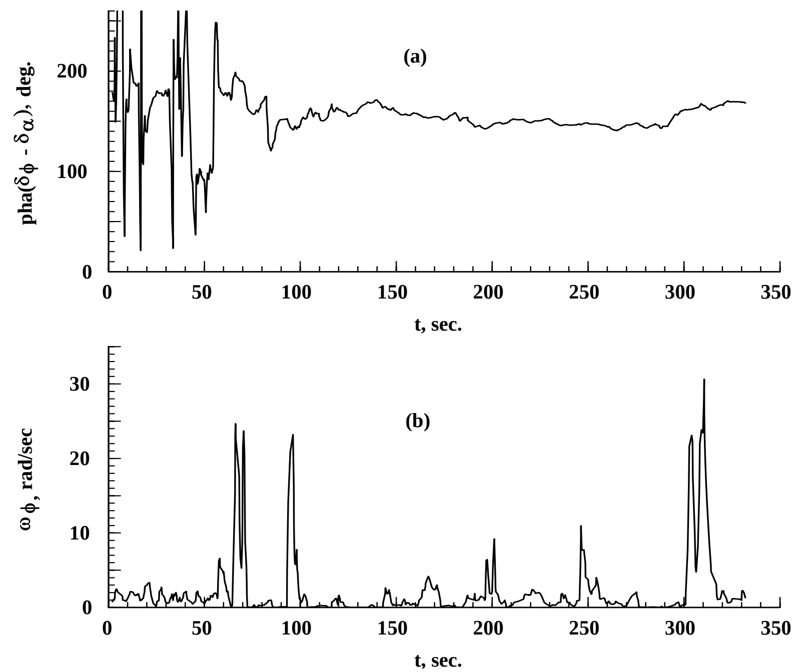




(a)
Clβ, rad-1
0.15
0.05
-0.05
-0.15
0
50
100
150
200
250
300
(b)
Clδa, rad-1
0.2
0.1
0
-0.1
-0.2
0
50
100
150
200
250
300
(c)
k2
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
t, sec.

PIO &Wing Rock Phenomenon in a Large UAS in Cross-Wind





The FLM technique was applied to identify the pilot induced oscillation (PIO) and the ensuing wing rock for the Meridian in Antarctica wind shear. The wing rock was shown to be sustained by the wake interference effect on the empennage for this V-tail low-speed configuration.

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Summary

- The unsteadiness of aerodynamic, and stability and control derivatives must be considered for the autopilot design.
- Classical system and parameter identification methods (e.g. ML and LSM) were found inadequate to identify nonlinearity and unsteadiness of aerodynamic characteristics including the complex effects of time-dependent boundary layer and vortex wake, dynamic stall, delayed edge-separated vortex, unsteady vortex bursting, coupled effects.
- Fuzzy Logic Modeling (FLM) was successfully employed for modal analysis, and for the first time in open literature, two nonlinear aerodynamic signatures including, PIO and Wing-Rock, were identified.

Questions?