Active Flight Load Alleviation Using Segmented Trailing Edge Wings on a Small UAS

By
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Overview

• Introduction
  – Aeronautics Academy Team
  – Objectives
  – Technologies

• System Description
  – Aircraft
  – Fiber Optic Sensor System
  – Segmented Control Surfaces

• Testing
  – Analytical Modeling
  – Flight Test Preparations
  – Flight Tests

• Results
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- [California Space Grant Consortium]
Team Members

• Benjamin Martins
  – University of California, San Diego
  California Space Grant Consortium

• Nathan Suppanade
  – California State University, Los Angeles
  California Space Grant Consortium

• Corbin Graham
  – The University of Oklahoma
  Oklahoma Space Grant Consortium
Introduction
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current wing design

potential concept by 2015
Introduction

current wing design

potential concept by 2015

potential concept by 2020
Introduction
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Project Objectives

• Build small UAS platform to allow for experimentation in active control of segmented control surface (SCS) wings
• Utilize compact fiber optic strain sensing (cFOSS) system to measure in-flight structural response
• Develop models to predict aerodynamic loading and structural response
• Control in-flight wing deformations using real-time cFOSS data
Segmented Control Surfaces

- Current wing control surface configurations often produce unnecessary structural and aerodynamic loads.
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• Current wing control surface configurations often produce unnecessary structural and aerodynamic loads
• SCS allow for higher resolution of aircraft control input
• SCS can be optimized over the flight envelope
• Key step to implementation of conformal control surfaces/flexible wing concepts
Segmented Control Surfaces

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cFOSS System

- cFOSS system utilizes glass optical fibers as strain sensors
- Fiber Bragg gratings (FBG) distributed along fiber
- Laser interrogates fibers with incident light
- Straining fiber modifies FBG spacing and hence reflected wavelength
- Capable of ~4000 strain measurements at ~50Hz
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Aircraft (APV-3)

- Span: 12.33 ft
- Dihedral: 2.5 ° along hinge line
- Structure: Monocoque composite
- Original control surfaces: Flap and aileron on each wing, split elevator, rudder
- Weight (without cFOSS system): ~35lbs
- Weight (with cFOSS system): ~45lbs
- Max gross takeoff weight: 55lbs
- Fully autonomous capabilities (Piccolo II)
Fiber Optic Strain Sensors

- Continuous grated fiber with strain data measured every 0.5”
- 86ft of fiber provides over 2000 real-time strain measurements
- Fiber rosettes allow for shape, displacement, twist and principle strain calculations
Segmented Control Surfaces

- Wings modified to include 22 independent control surface segments/servos per wing
- Servo uniformly spaced to produce 3” SCS from existing control surfaces
Complete System
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Aerodynamic Analysis

- Utilized Athena Vortex Lattice (AVL) and XFLR5 programs
- Analytical model prepared for predicting aerodynamic loading of conventional and SCS configurations
- Aides in optimization of SCS configuration at various flight conditions
Structural Analysis

- Developed 32,000 element single wing model in FEMAP
- Wing loaded along quarter chord with load distributions predicted by AVL (40 nodes along span)
- Model solved with NX Nastran yielding strain and displacement predictions
- Used to study effects of SCS configuration on displacement and strain
Pre-Flight Requirements

- 4g static loading distribution on right wing

![4g Static Loading on Right Wing](image)

- 4g Static Loading on Right Wing
  - Root
  - Tip
  - Upper LE Axial
  - Upper TE Axial
  - Lower LE Axial
  - Lower TE Axial

![Out-of-Plane Displacement](image)
Complete Systems Test
Complete Systems Test Video
Test Flights

- Test flights conducted at Dryden Flight Research Center small UAS work area
- Same Flight Patterns flown with (mimicked) conventional and segmented control surface configurations
- Circuits Flown
  - Steady Level Flight
  - Pitch Doublets
  - Roll Doublets
  - High g Steady Turn
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Flight Results-Time History

Filtered Acceleration vs. Time

Filtered Wing Tip Deflection vs. Time
Flight Results-Time History

Filtered Acceleration and Wing Tip Deflection vs. Time

Normalized Wing Tip Deflection vs. Time

Control System On

Control System Off
Flight Results-Time History

- Pitch doublet (~30 sec) strain data for 3 sensors (25, 345, 355)
Flight Results - Conventional

Micro Strain

Displacement

Deflection Conventional

Top Strain Conventional

Bott Strain Conventional
Flight Results-SCS
Future Objectives

- Design and build high aspect ratio wings with SCS and FBG fibers to allow for wider range of wing displacements and SCS control

- Design advanced control architecture for controlling/monitoring of dynamic events
  - Gust Alleviation
  - Flutter Suppression
  - Structural Health Monitoring

- Transition to conformal trailing edge materials
Personal Reflection

- Aeronautics Academy was the experience of a lifetime:
  - Jump started my PhD research
  - Created valuable personal and profession contacts
  - One of a kind practical flight research experience

- California Space Grant Consortium:
  - Gave me research opportunities as an undergraduate with no experience
  - Influenced my decision to go to graduate school
  - Provided support so that I could pursue my research interest both through the Academy and at UCSD
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Questions?