



University
of Victoria

Graduate Studies

PROGRAMME

The Final Oral Examination
for the Degree of

DOCTOR OF PHILOSOPHY
(Department of Mechanical Engineering)

Jenner Richards

2009
2005

University of Victoria
Camosun College

B. Eng
Dip Tech

**“An Experimental Investigation of a Joined Wing Aircraft
Configuration Using Flexible, Reduced Scale Flight Test
Vehicles”**

Thursday, July 17, 2014
10:00 a.m.

David Turpin Building, room A137

Supervisory Committee:

Dr. Afzal Suleman, Department of Mechanical Engineering, UVic
(Supervisor)

Dr Curran Crawford, Department of Mechanical Engineering, UVic
(Member)

Dr. Pan Agathoklis, Department of Electrical Engineering, UVic
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External Examiner:

Dr. Sergio Ricci, Department of Aerospace Science and Technology,
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Chair of Oral Examination:

Dr. Hao Zhang, P. B. Gustavson School of Business, UVic

Abstract

The United States Air Force has specified a need for the next generation, High Altitude, Long Endurance aircraft capable of carrying advanced sensor arrays over very large distances and at extreme altitudes. These extensive set of requirements has required a radical shift away from the conventional wing & tube configurations with a new focus placed on extremely light weight and unconventional structural and aerodynamic configurations. One such example is the Boeing Joined wing SensorCraft Concept.

The Joined wing concept has potential structural and sensor carrying benefits, but along with these potential benefits come several challenges. One of the primary concerns is the aeroelastic response of the aft wing, with potential adverse behaviours such as flutter and highly nonlinear structural behaviour of the aft wing under gust conditions. While nonlinear computation models have been developed to predict these responses, there exists a lack of experimental ground and flight test data for this unique joined wing configuration with which to benchmark the analytical predictions. The goal of this work is to develop a 5m, scaled version of the Boeing Joined Wing configuration and collect data, through a series of ground and flight based tests, which will allow designers to better understand the unique structural response of the configuration.

A computational framework was developed that is capable of linearly scaling the aeroelastic response of the full scale aircraft and optimize a reduced scale aircraft to exhibit equivalent scaled behaviour. A series of reduced complexity models was developed to further investigate the flying characteristics of the configuration, test avionics and instrumentation systems and the develop flight control laws to adequately control the marginally stable aircraft. Lessons learned were then applied the 5m flight test article that was designed and constructed by the author.

In the final stage of the project, the decision was made to relax the aeroelastically scaled constraint in order to allow additional softening of the structure to further investigate the nonlinear behaviour of the aircraft. Due to the added risk and complexity of flying this highly flexible aircraft the decision was made to produce the final aeroelastically scaled article at the 1.85m scale. This model was designed, developed and ground tested in the lead up to a follow on project which will see additional flight testing performed in conjunction with Boeing Inc.

Awards, Scholarships, Fellowships

2007 - Undergraduate Research Award, *University of Victoria*

2006 - University Entrance Scholarship, *University of Victoria*

2006 - Camosun Academic Achievement Award, *Camosun College*

Publications

1. Richards, J.G; and Suleman, A; "Design of a Scaled RPV for Investigation of Gust Response of Joined-Wing SensorCraft", American Institute of Aeronautics and Astronautics Structural Mechanics and Dynamics Conference, Palm Springs, USA, 2009
2. Richards, J.G; and Suleman, A; "Aeroelastic Scaling of Unconventional Joined Wing Concept for Exploration of Gust Response", International Forum on Aeroelasticity and Structural Dynamics, Seattle, USA, 2009
3. Richards, J.G; Suleman A; Aarons, T; Canfield R; "Multidisciplinary Design for Flight Test of a Scaled Joined Wing SensorCraft", American Institute of Aeronautics and Astronautics Multidisciplinary Analysis and Optimization Conference, Fort Worth, USA, 2010 (Best Student Paper)
4. Richards, J.G; Aarons T; Suleman A; Canfield R; Woolsey C; Lindsley N; Blair M; "Design for Flight Test of a Scaled Joined Wing SensorCraft", American Institute of Aeronautics and Astronautics Structural Mechanics and Dynamics Conference, Denver, USA 2010
5. Richards, J.G; Aarons T., Garnand J, Woolsey C., Canfield R., and Suleman A.; "Airworthiness Evaluation of a Scaled Joined-Wing Aircraft", American Institute of Aeronautics and Astronautics Structural Mechanics and Dynamics Conference, Honolulu, USA, 2012, Paper No. AIAA-2012-1721.
6. Richards, J.G and Suleman A.; "Advanced Aircraft Configuration Design and Testing", NATO Advanced Vehicle Technology Workshop, San Diego, USA, 2012

7. Richards, J.G.; Suleman A; Garnand J; Ricciardi A; Canfield R; "Design and Evaluation of and Aeroelastically Tuned Joined Wing SensorCraft Flight Test Article", American Institute of Aeronautics and Astronautics Structural Mechanics and Dynamics Conference, Boston, USA, 2013
8. Richards, J.G. and Suleman A.; "Flight Test Evaluation of the Boeing Joined Wing SensorCraft", Unmanned Vehicle Systems Canada Annual Conference, Vancouver, Canada, 2013 (Best Student Paper Award)
9. Richards, J.G. and Suleman A; "Airworthiness and Aeroelastic Evaluation of a Joined Wing SensorCraft", International Workshop on Energy Efficient Aircraft Configurations, Technologies and Concept of Operation, Sao Paulo, Brazil, 2013