Hyperion Flying Wing Aircraft Technology

Poster Presentation

Jean Koster, Scott Balaban, Andrew Brewer, Chelsea Goodman, Derek Hillery, Cody Humbargar, Mark Johnson, Mikhail Kosyan, Derek Nasso, Julie Price, Eric Serani, Alec Velazco, Tom Wiley, and Richard Zhao

University of Colorado, USA

Martin Arenz, Holger Kurz, David Pfeifer & Matthias Seitz, Claus-Dieter Munz, Ewald Krämer

University of Stuttgart, Germany

Kai Lehmkuehler, KC Wong, Dries Verstraete

University of Sydney, Australia

ABSTRACT

Student engineering teams develop a 3m scale model inspired after the NASA-Boeing X-48B blended wing body to use as a test bed for advanced technical studies. The design concept, named Hyperion, implements a novel hybrid gas/electric power train as a green aircraft technology. The aircraft serves as a test-bed for research and development in the following focus areas: aerodynamics, structures and materials, weights and mass properties, handling and control, flight mechanics, and efficiency improvements on performance. The University of Colorado's collaboration with the University of Stuttgart, Germany, and the University of Sydney, Australia, allows the global project team to work full 24-hour days on the project by transitioning every 8 hours. Thus, the project teaches essential global industry skills in project management and systems engineering through long-distance design collaboration with multidisciplinary and multicultural teams of graduate and undergraduate students located around the world. Lessons learned will be valuable for the students and industry.

KEYWORDS

Global design, international teamwork, aircraft design, green aviation

INTRODUCTION

The goal of the Hyperion project is to conceive, design, implement, and operate an aerial platform to investigate new technologies for improvements in capabilities and efficiencies. The growing UAV and commercial airline industries are forcing improvements to be made in order for the growth to be sustainable. A second goal of the Hyperion project is practice international collaboration in academia by providing an industry simulated working environment. Improving the educational experience of the next generation of engineers is paramount to providing the workforce necessary to achieve the challenges ahead in industry. The newly designed aircraft offers efficiency improvements over conventional designs and serves as a platform for hybrid engine development. This paper will merely highlight the foundational design aspects of the Hyperion aircraft, which has been completely designed and built in the span of 9 months.

AERODYNAMIC DESIGN

The Hyperion aircraft is a test platform for a variety of high-efficiency and cutting edge aircraft design ideas. In order to maximize aerodynamic performance parameters, a flying wing was designed using the NASA/Boeing X-48 as inspiration. The result is a new aircraft entirely, seamlessly blending different two different airfoil sections to maximize the lift to drag ratio, while still maintaining correct trim, shown in Figure 1.

$C_{L_{max}}$	~0.85
L/D_{max}	~18
V_{stall}	15.2 m/s (34 mph)
V_{TO}	18.24 m/s (40.8 mph)
V_{CR}	27 m/s (60 mph)
S	1.536 m^2 (16.53 ft^2)
b	3 m (9.84 ft)
W	16 kg (35 lb)
W/S	10.4 kg/m^2 (2.1 lb/ft^2)

Figure 1. The Hyperion Aircraft and Performance Specifications

The aircraft has a 3 meter wingspan, will cruise at speeds of approximately 30 m/s, and is controlled by a single rear elevator, two ailerons, and two rudders. An automated, iterative script was developed in XFoil, Athena Vortex Lattice (AVL), and MATLAB to optimize winglet design. The final design employs raked wingtips, which achieve increased span efficiency and L/D without the risk of stall at low Reynolds numbers. An H-tail was selected using similar methodology, while considering directional stability and piloting simplicity.

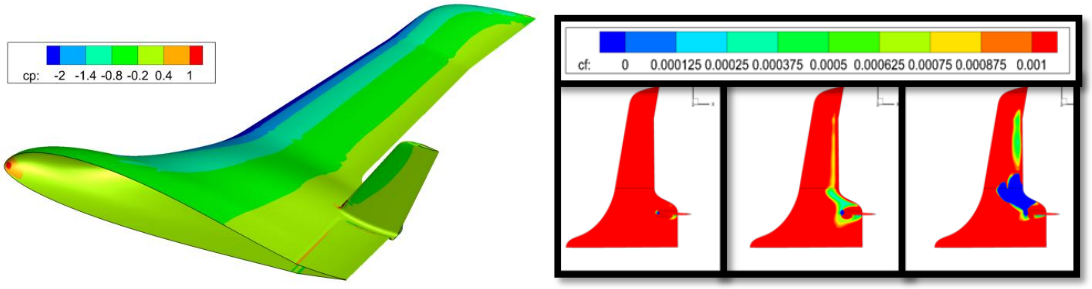

Figure 2. University of Stuttgart CFD Results

In addition, the University of Stuttgart, Germany has performed a 3-D computational fluid dynamics (CFD) analysis of the airframe to better predict performance using a proprietary CFD code. The CFD, pictures shown in Figure 2, employs the implicit backward Euler method, and is used to refine lift and drag predictions, and to quantify stability derivatives required by the flight control system. Furthermore, CFD has been performed to quantify the influence of the engine propeller on the flow field and the lift and drag curves of the aircraft. The CFD analysis was compared to the wind tunnel tests performed at the University of Sydney, shown in Figure 3.

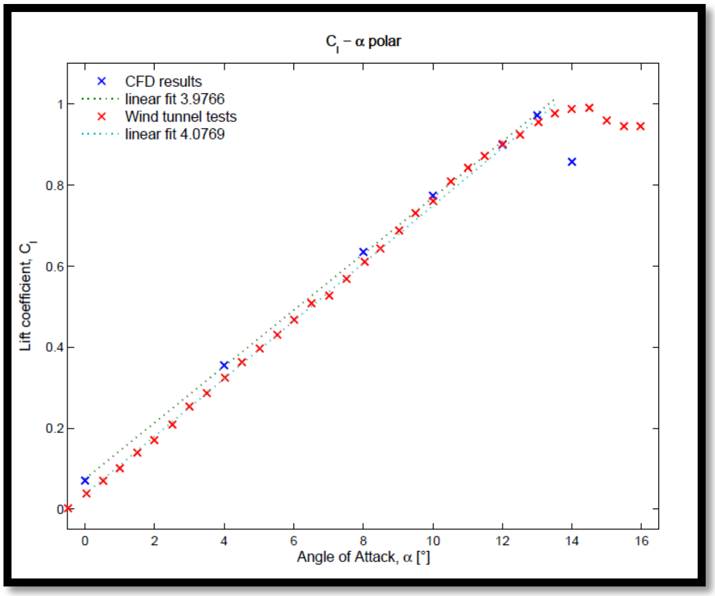

Figure 3. CFD and Wind Tunnel Results Comparison

STRUCTURAL DESIGN

In order to minimize the mass of the aircraft, the vast majority of Hyperion is constructed from composite materials. Two carbon-fiber spars bear the loads in each wing, and transfer stress to four carbon-fiber foam-core ribs, shown in Figure 4. These ribs also serve to maintain the aerodynamic shape of the skin. Finite element analysis (FEM) was performed to validate rib and spar integrity with safety margins against expected loads. This structure was manufactured by a team at the University of Colorado, while University of Stuttgart students were simultaneously working on the molds to complete the fiberglass skin layup, which is constructed from a layered fiberglass with a foam core.

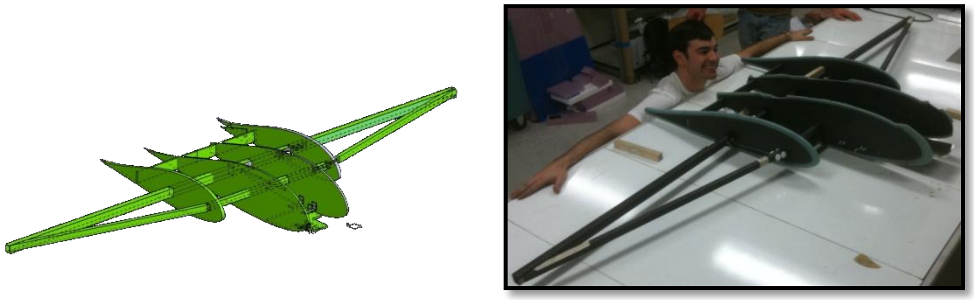

Figure 4. Internal Design & Structure

Classical laminate theory was used to predict material properties of the skin laminate, while a Bernoulli beam theory approach yielded the occurring bending stresses in the skin shell as can be seen in Figure 5. This analysis establishes confidence in skin defence against buckling under aerodynamic loads.

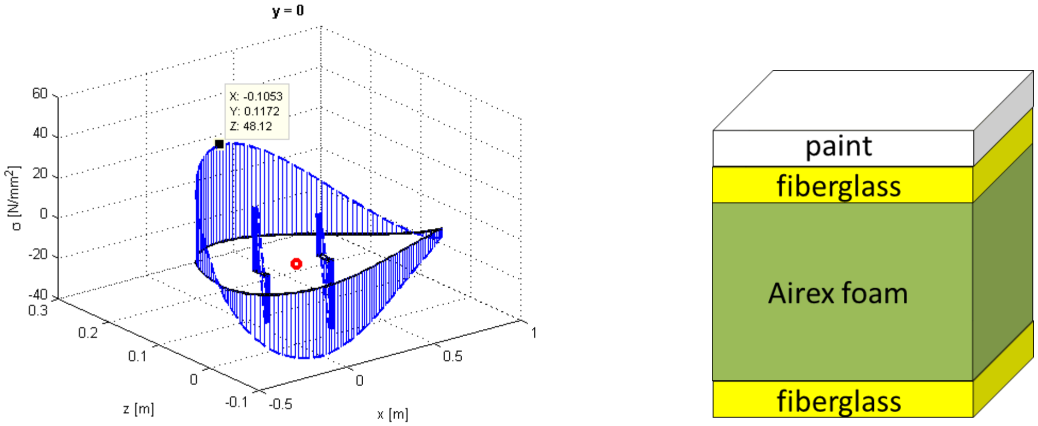

Figure 5: Skin stiffness analysis and composition.

PROPULSION

The Hyperion is powered by a one-of-a-kind hybrid gas-electric engine based on a proprietary design developed at the University of Colorado in 2009-2010, now licensed by Tigon Enertec, Inc. A patented gearing system seamlessly blends the torque from an internal combustion engine and an electric motor, which are arranged in an in-line configuration to maintain aircraft-friendly symmetry.

Figure 6. Hybrid Propulsion System

This propulsion system, Figure 6, allows for the aircraft to fulfill concepts of operations of both long-endurance and quiet loiter UAV platforms without sacrificing performance. Furthermore, the engine has demonstrated fuel savings of approximately 15%.

ELECTRONICS AND FLIGHT CONTROL

The Hyperion flight control system is designed to combine pilot control input with onboard guidance, navigation, and control data to successfully fly the aircraft. Two onboard batteries and a consumer off-the-shelf (COTS) R/C communication and data logging system support this function. The control system architecture is modeled in the Matlab/Simulink environment for simulation and development. As flight control code matures and hardware is acquired, hardware-in-loop (HIL) tests are performed to verify and improve models, optimize controller performance, and to identify and debug integration issues. Upon successful integration of the flight code and hardware on a test bench, the code will be recompiled into an embedded format and loaded onto the aircraft for additional testing and flight.

The flight controller performs stability augmentation using state variable feedback (SVF), where the aircraft states are monitored by two onboard sensors. This control scheme allows for the computer to make updates to aircraft attitude rapidly in order to more accurately track pilot input commands. Parameters for the plant matrix of the state-space controller are determined using computational fluid dynamics from the German team, empirically from University of Sydney wind tunnel data, and experimentally using aircraft geometry. A block diagram illustrating the control system architecture is presented in Figure 7.

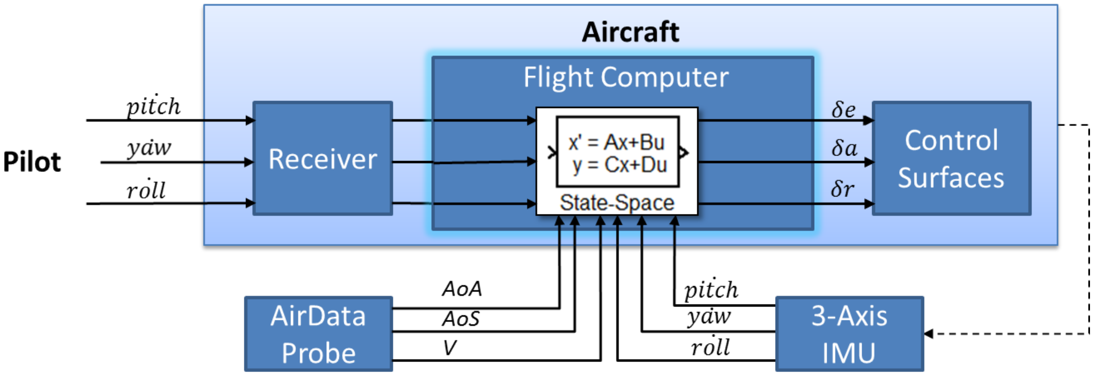

Figure 7. Left: Hyperion State-Space controller

INTEGRATION AND TEST

For a project of this complexity and low tolerance for failure, high-fidelity simulation and hardware-in-loop (HIL) testing is required to ensure success. Several "flat-sat" integration models have been constructed, to aid in electronics integration and test, as well as internal layout design and mass balance. Furthermore, using the MATLAB simulation/flight software package outlined previously, a test platform can be constructed to simulate aircraft performance with the controller and sensors engaged. A block diagram of the Hyperion Test Platform is presented in Figure 8. In order to facilitate international testing and collaboration, the test bench can be operated over the internet by the Australian and German teams using a remote desktop tool. The operator then configures the simulation to test a particular behaviour or set of behaviours and engages the bench.

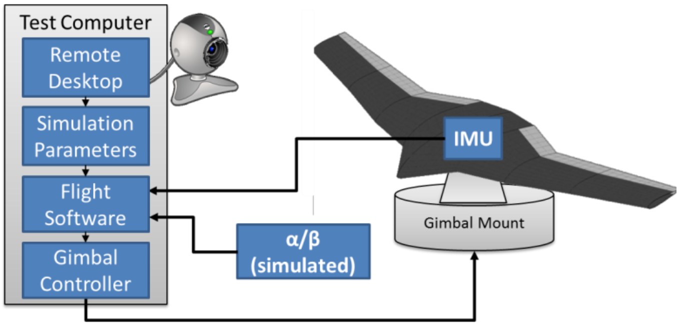

Figure 8. Hyperion Test Platform

This HIL testing scheme allows for a majority of hardware integration problems to be detected and eliminated prior to flight, greatly increasing chances of success. Furthermore, the Hyperion Test Platform allows for operators on all three international teams to perform statistical stability and performance analysis under a variety of highly configurable conditions around the clock. Large numbers of these simulations can be used to perform Monte-Carlo analysis, allowing the team to quantify confidence intervals and probabilities of failure during critical flight regimes.

Furthermore, a number of ½ scale prototype aircraft have been constructed for flight testing. These aircraft were created from foam blocks and carefully hand-sanded to achieve dynamic scaling of the Hyperion's geometry.

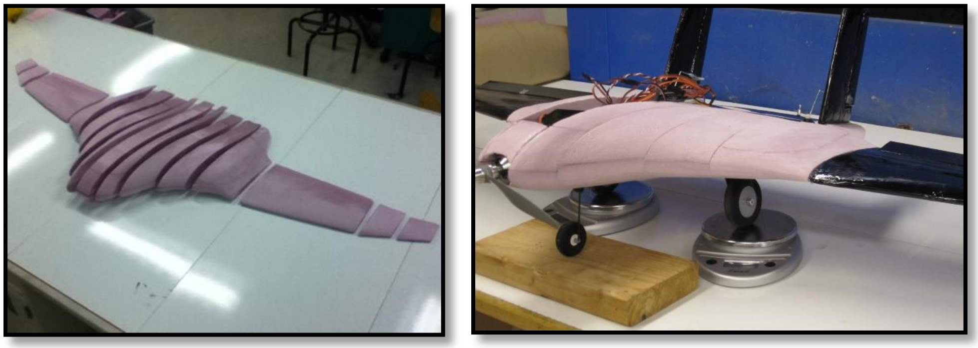

Figure 9: Half-scale flight test prototype.

These prototypes serve to acquaint the pilot with aircraft performance, mitigating inherent risks associated with flight testing the full aircraft in the Spring of 2011.

CONCLUSION

Hyperion is on schedule to complete construction and flight testing in April of 2011 in Colorado. The resulting aircraft will be the epitome of cutting edge aircraft design, and the result of an international collaboration designed to expose students to industry practices and a variety of engineering cultures.

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Biographical Information Lead Authors

Derek Hillery is a graduate student at the University of Colorado at Boulder, with an emphasis in aerodynamics, systems, and control, and a holder of an Engineering Entrepreneurship Certificate. Derek served as the Systems Engineer and Electronics Lead on the award-winning Remote Reconnaissance Rovers project in 2009/2010, in partnership with the Jet Propulsion Laboratory. He gained experience with hardware-in-loop satellite controls and flight software with Lockheed Martin Space Systems Company. Derek is also a founding member and Research and Development lead for TIGON EnerTec.

Cody Humbargar is a graduate student in Aerospace Engineering Sciences at the University of Colorado studying vehicle systems with a focus in fluids. Cody worked on the HELIOS project, designing an innovative hybrid propulsion system for aircraft becoming an expert in gearing systems for small engines. For this project he was the CFO as well as Assistant Project Manager and Software Lead and he continued his work with the engine for TIGON EnerTec, Inc.

Jean N. Koster is Professor of Aerospace Engineering Sciences at the University of Colorado, Boulder, Colorado and President of Tigon EnerTec, Inc., a start-up company for aerospace propulsion technologies. He is the CDIO representative from the University of Colorado and is the department course coordinator for the senior design projects courses. He is faculty adviser and PI of the Hyperion project funded by Boeing, eSpace, and NASA-CDIO-NAAP grant.

Eric Serani is a graduate student in Aerospace Engineering at the University of Colorado at Boulder and is getting his emphasis in vehicle systems and control. He was the lead systems engineer on the HELIOS Senior Design project that designed a hybrid-electric engine for use in RC aircraft. He continued with the hybrid technology and was a founding member of TIGON EnerTec, Inc. Outside of school you can find him flying or working on an experimental he and his father built while in high school.

Alec Velazco is a graduate student in Aerospace Engineering Sciences at the University of Colorado at Boulder, where he is focusing studies on hybrid vehicle systems and controls. As an undergraduate, Alec received a certificate in Engineering Entrepreneurship form Lockheed Martin, while also working on the Remote Reconnaissance Rovers project in AY2009/2010, a CU senior project partnership with the Jet Propulsions Laboratory. Alec is also a founding member of Tigon EnerTec, Inc.

Corresponding author

Prof. Jean N. Koster
University of Colorado
Dept. Aerospace Engineering Sciences
Boulder, Colorado 80309-0429, USA
303-492-6945
303-492-7881 (fax)
Jean.Koster@Colorado.edu