Safety Considerations for Hybrid Motor Systems

Team 09 Project Technical Presentation to the 2018 IREC

Tyler McIrvin and Sabrina Tong
University of Washington Society for Advanced Rocket Propulsion, Seattle, WA, 98926, United States

Hybrid rockets are commonly chosen for teams moving to student researched and designed (SRAD) motors for their relative simplicity and safety when compared to solid or bipropellant motor designs. Nitrous oxide is a choice oxidizer for its self-pressurization properties and ease of handling, but despite this there are a number of considerations that must be made when working with this fluid. In this presentation, the University of Washington Society for Advanced Rocket Propulsion (SARP) will comment on improvements to oxidizer cleaning procedures, and fail-safe operation of it's injection and fill system aimed at assisting teams new to hybrid rocketry in undertaking these projects. SARP continues to make improvements to it's safety procedures and ensure the successful operations of all systems involved in the rocket. At the 2018 Spaceport America Cup, SARP intends to validate the newest developments of it's hybrid rocket system. SARP also plans to work to further improve safety in the undergraduate rocketry research community.

Integrated Flight Modeling: Trajectory Analysis & Hybrid Engine Performance

Team 12 Technical Presentation to the 2018 Spaceport America Cup

Ross B. Alexander, Jacob M. Caesar, Roshan C. Doddanavar and Jacob Q. Doll
Texas A&M University, College Station, Texas, 77840, United States

For the 2018 Intercollegiate Rocketry Engineering Competition, the Texas A&M University Sounding Rocketry Team (TAMU-SRT or SRT) will be launching its student-researched and -developed hybrid rocket, Theseus, to an apogee of 10,000 ft above ground level (AGL). In order to achieve this goal, the team must maintain the capability to accurately predict the trajectory of the rocket, given knowledge of the rocket's inertial and aerodynamic properties, as well as realistic assumptions of in-flight conditions. TAMU-SRT developed the SRT Flight Simulation (SRT FS). SRT FS is a flexible, easily-extensible, six-degree-of-freedom simulation suite implemented in MATLAB, which utilizes the MonteCarlo method to quantify the statistical uncertainty in the rocket's trajectory. SRT FS is supported by the SRT Hybrid Engine Model (SRT HEM), a robust simulation suite also implemented in MATLAB, which provides engine performance predictions for hybrid rocket engines. SRT FS has been validated with eight flight tests of solid rockets spanning multiple aerodynamic, inertial, and propulsive regimes, resulting in a mean apogee prediction error of only 1.72%. In the future and in order to further improve the accuracy of the simulation, the kinematic model must be extended to allow for the modeling of multi-stage vehicles and off-axis center-of-gravity shifts due to liquid sloshing in the oxidizer tank.

Non-Destructive Evaluation of Composite Materials

Team 20 Project Technical Presentation to the 2018 IREC

Nicholas Reiter
Iowa State University Ames, Iowa, 50010, United States

The necesity to validate and verify materials after the manufacturing and use of aerospace structures is of utmost importance to ensure the safety and stability of these structures and those who utilize them. The best way to validate materials is to use Non-Destructive Testing (NDT) as it is a non-invasive technique to test complex components and geometries for a number of material failures. The two advanced NDT methods used by Cyclone Rocketry were pulse thermography and air coupled ultrasonics. The team used these tests on the carbon fiber fuselages and nose cone to detect delaminations and manufacturing imperfections. The purpose of these nondestructive tests were to test the in-house manufactured materials on-board *INVICTUS I* for defects and to determine if these defects would threaten the structural integrity of *INVICTUS* during flight. The results showed that all components on-board would possess the ability to withstand the loads of lift-off, flight, and recovery. It is recommended that tests be completed on load bearing components for future rocket builds to validate the manufacturing processes and post launch structural integrity.

Design and Validation of a Solid Rocket Propulsion System

Team 21 Project Technical Presentation to the 2018 IREC

Nicholas Reit Devon E. Burson, Travis S. Fujimoto and Matthew W. Hoeper
Oregon State University, Corvallis, Oregon, 97330, United States

The development and validation of this year's Oregon State University 30k team's propulsion system is demonstrated. The product is a student researched and developed solid rocket propulsion system with notable aspects in propellant formulation and non-traditional motor diameter. The team selected a 5" internal diameter motor due to constraints from the rocket airframe diameter and length. Over the course of the project, the team tested several propellant formulations, and created two new propellants. With the successful static fire and several improvements to the overall flight rocket, the design and testing of the motor results in an expected altitude of just under 30,000 ft AGL at the Spaceport America Cup competition. The motor is significant to validate solid rockets at Oregon State University, and to demonstrate the ability to improve propellants and build odd sized motors.

Design and Analysis of Landing Legs for Reusable Rocket

Team 23 Project Technical Presentation to the 2018 IREC

Jeremy Browne and Travis Moleski
Ohio University, Athens, OH, 45701, United States

The Ohio University Rocket Design and Engineering Team (OURDET) will be launching project The Big One. This project will be competing in the 30,000 foot altitude category and will be fitted with a set of internally stored extending landing legs. Historically, the aerospace industry has exercised the use of non-reusable launch vehicles for rocketry. These launch vehicles return to Earth at speeds that can cause significant damage to the body's structure and result in added costs to fund further research and development. The addition of a landing leg system is a continuation of a similar project for the 2017 IREC by the Ohio University Team and is an attempt to improve on the previous design to increase reusability of sub-orbital launch vehicles. Initial design decisions were successful at satisfying the two goals originally laid out by the design team. Collectively the weight of the landing leg system is on par with only a single leg of the previous year's design, a significant improvement. After initial analysis it was determined that the landing leg system needed to be reinforced due to larger than desired deflections. To meet this need a new support structure using fiberglass "L" brackets was added to the leg design.

Application of Reefing to Rocket Recovery

Team 35 Project Technical Presentation to the 2018 IREC

Guilain Lang and Malo Goury du Roslan
Swiss Federal Institute of Technology, EPFL, Lausanne, Switzerland

The Matterhorn mission implements dual-event recovery using reefing technology. The work consisted of an analysis of the existing methods, system designs to implement a chosen method and a battery of tests to approve the concept. Instead of deploying a drogue parachute at apogee as it is done in traditional recovery concept of operation, the idea is to directly use the main parachute in reefed position. For the second phase, the canopy is fully deployed in order to reach a low descent rate for a soft landing. After studying different reefing techniques1, we decided to implement the method consisting of controlling the drag of the canopy by adjusting the length of the central line. Indeed, pulling on the central line reduces the dragging area and the drag coefficient of the parachute. At the release of the central line the canopy inflates quickly, and the maximum drag force is reached in a very short time. This results in strong forces during the reefing release. A detailed analytic work was performed to understand how those forces could be calculated and to obtain an idea of the accelerations that the launch vehicles would need to withstand. In parallel, a SRAD parachute was developed. We started from a basic toroidal design and added two main features. The first one consists of adding upper vents which decrease even more the drag in reefed position and have very low effects when the canopy is fully deployed. The second characteristic is the lower vents, helping to stabilize parasite effects such as strong swaying or squiding effects.

Tracking Nitrous Oxide Level with Differential Pressure

Team 37 Project Technical Presentation to the 2018 IREC

Cameron Buccellato
University of Michigan, Ann Arbor, MI, 48109, United States

Experimental liquid and hybrid rockets often utilize Nitrous Oxide. There is a need to track the liquid level during the fill process to ensure complete propellant loading, and during the engine burn to gather flow rate data.

The liquid level in the oxidizer tank can be determined by using the difference in pressure between the top and the bottom of the tank to calculate the height of the liquid column. The Michigan Aeronautical Science Association (MASA) has developed a bipropellant liquid rocket engine to fly at the 2018 IREC. The engine uses Nitrous Oxide for the oxidizer and 95% ethanol for the fuel, and has an ablative-cooled combustion chamber. Due to Nitrous Oxide being incompatible with many materials and its high vapor pressure at room temperature, it is difficult to use conventional liquid level sensing equipment. MASA has flown hybrid engines in previous years, and a vented dip-tube in the oxidizer tank was used to determine if the tank was full or not-full. However, it was not possible to track the exact liquid level during the fill process. For this reason, a differential pressure (DP) transducer was integrated with the liquid engine to enable continuous liquid level tracking. Although the transducer exhibits odd behavior when the tank is over-filled, it is repeatable, and is a clear indication that the maximum liquid level has been reached. This method is preferred over the vented dip-tube method because data can be gathered during the entire oxidizer fill process. With further testing and calibration, the DP transducer can be used for even more accurate liquid level tracking.

Remote Launch Control System for Hybrid Rockets

Team 38 Project Technical Presentation to the 2018 IREC

Jacob Deery
University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada

A design aspect particular to hybrid and liquid rocket development is the need for dedicated Ground Support Equipment (GSE) for propellant fill procedures. Due to the enormous design space of experimental rocketry, each rocket is developed with its own unique characteristics and GSE requirements. Consequently, it is very difficult to find a COTS system that is capable of performing all tasks required for execution of a given rocket's mission. Waterloo Rocketry has developed a Remote Launch Control System (RLCS) that provides capabilities for control of propellant load and rocket ignition procedures while maintaining the safety of all launch personnel and enabling the launch team to work much more efficiently. RLCS comprises fill, data acquisition, and engine control subsystems, along with a communication module that greatly increases operating range, enabling remote launch control from a distance of 3000 ft. At the 2017 IREC, RLCSv1 performed successfully, allowing the team to conduct a successful launch of Vidar III. Although the newest iteration of RLCS has not yet been used for a full launch, it has undergone comprehensive testing in static engine tests and operational dry runs, and all results indicate that the system will fulfill its design requirements in providing capabilities for safe, efficient remote launch control. Future development on RLCS will comprise both reliability improvements and functional upgrades. Additional functionality may include additional valves, which will be necessary if the team elects to develop a liquid engine in the future.

Design, Analysis, and Testing of Telemetry System Antennas

Team 42 Project Technical Presentation to the 2018 IREC

Vincent Rocheleau
Laval University, Quebec City, Quebec, Canada, G1V 0A6

When it comes to transmit real-time data from a rocket to a ground station, many different electrical components are required. It is necessary at least to proceed to the modulation and to the demodulation of the transmitted signal, and all of this require a communication channel. Some specific telemetry radios already exists and achieve such transmission in a very reliable way. Our team uses two RFD900+ designed and built by an Australian company. In another hand, one other important thing is to have at least one antenna on the emettor and another one on the receiver. Since there are many different types of antenna which have their own specific utility, it is required by the team to select the one that suits the best for the ground station and for the rocket, all of this regarding many different requirements and constraints. A Yagi-Uda type antenna was selected for the ground station. An inset-fed patch antenna was selected for the rocket. When taking the entire network itself, which is composed of two RFD900+, the Yagi-Uda antenna on one of them, and the inset-fed patch antenna attached to the other one, we were able to demonstrate that the telemetry radios were able to connect and send data from a point to the other one without any problem. The most challenging part of this project was really the design and testing of the inset-fed patch antenna. it would be interesting to study more the interaction of the emission pattern of the inset-fed patch antenna when the antenna is in a curved position. Indeed, it would be very interesting to analyse the comportment of the radiation pattern when changing the curvature of the antenna along the sides of the rocket.

Composite Overwrapped Pressure Vessel (COPV)

Team 43 Project Technical Presentation to the 2018 IREC

X. Cui, H. Stoldt, L. Alacoque, T. Messinger
University of Calgary, Calgary, AB, T2L 1B3, Canada

The University of Calgary Student Organization for Aerosapace Resarech (SOAR) previously had designed, tested, and used an all aluminum (6061-T6) vessel to store 42 L of Nitrous Oxide for our flight vehicle Atlantis I. The goal of the presented projet was to significantly reduce the weight of the tank, down from 50 lbs. The project originally designed a 1/16" walled liner with overwrap that was 17 pounds, but due to sourcing constraints, a 1/8" liner was purchased. The presented design still has a 25lb or 50% weight reduction. The project entails the vessel geometry, the physical attachments, fluid access, the model generation and results of initial analysis, and finite element analysis (FEA). The project entails the vessel geometry, the physical attachments, fluid access, the model generation and results of initial analysis, and finite element analysis (FEA). A composite overwrapped pressure vessel has been successfully created with a theoretical burst pressue of 3000 psi. The internal pressure forces are the strength determining requirement of the vessel, structural loads can be absorbed. The COPV should be manufactured and available for testing in time for this year's Spaceport America Cup, with reported tests of industry standard proof load and leak test. As a result of the weight savings achieved, SOAR should be able to compete in the 30,000 feet category this year. It is recommended when time and resources permit that the vessel should be burst tested to further validate the design.

Computational Design of a Modular Airbrake System

Team 54 Project Technical Presentation to the 2018 IREC

Andrew Walsh, Hunter Billen, Nicholas Rozell, Tim Runnels, Kyle Hickman
Oklahoma State University, Stillwater, OK, 74075, United States

Cowboy RocketWorks created a Controls Team for the Spaceport America Cup. This team was tasked with designing an airbrake system to control the ascent of the rocket intelligently. To do this, a series of prototype rough designs were created by the team. They were then evaluated for efficacy by a series of test and further refined until the best design emerged. From there, the airbrake was manufactured, tested, and programmed to perform optimally. The Controlls Team conducted a series of computational fluid dynamics (CFD) studies in Solidworks to generate custom Cd vs Mach number curves for evaluation in OpenRocket. Each parametric study consisted of running CFD with the rocket in the same position and changing only the Mach number of the air flowing over it. In total, five parametric studies were conducted at 0%%, 25%, 50%, 75%, and 100% fin deployment. A future test flight will show if the models described in this paper are accurate or not.

Model Predictive Control of Custom Airbrakes

Team 55 Project Technical Presentation to the 2018 IREC

Nikhil Peril, Andrew Zavorotny, and Manit Ginoya
University of Ottawa Student Team of Aeronautics and Rocketry, Ottawa, ON, Canada

It is necessary to implement some clever method to improve precision. For uOSTAR (University of Ottawa Student Team of Aeronautics and Rocketry), this clever method includes the airbrake system and the control schema dictating it. The idea is simple. Since the COTS solid rocket motor cannot be controlled effectively or with certainty, the rocket must be controlled by manipulating other major forces acting upon it: that is, the aerodynamic forces during coasting flight. These aerodynamic forces cannot be dynamically decreased. They can however be increased. With that line of reasoning, it was determined that actively controlled airbrakes would be implemented on the vehicle. Once the mechanical aspects of the airbrake system were completed and analyzed, a control schema was needed to drive the airbrake leaves. An immerging method of control with respect to trajectory manipulation is Model Predictive Control (MPC). This method allows for abstract control derivations for non-linear, high complexity plants. Additionally, this method is easily adapted (via software) to different rocket designs via generalized parameters such as vehicle mass and geometry. MPC schemes consist of maintaining a virtual simulation of the system on a computationally able device. This requires careful filtering and fusion of sensor values for the sake of accurate state estimation. Even though the completed work is comprehensive and extensive, the only indication of validity is high fidelity experimentation; In this case, that is a flight test at IREC 2018. The data collected from this flight will provide significant insight into the performance of the systems described in this abstract. This gained insight will inform future experimental projects regarding flight control.

Design of a Hybrid Rocket Engine with Swirling Oxidizer Injection

Team 59 Project Technical Presentation to the 2018 IREC

Olivier Jobin, Mathieu Chartray-Pronovost and Guillaume Villeneuve
École Polytechnique, Montréal, Québec, Canada, H3C 3A7

This presentation summarizes Oronos Polytechnique Montreal's Prometheus, the team's first hybrid rocket. Here will be briefly discussed the rocket's engine. Firstly, an engine overview is made to introduce the subject. Combustion mechanics related to this rocket's engine is then explained, mostly related to swirling flows and solid fuel mechanical propertities. The test bench and the data acquisition system is presented. Prometheus' engine uses paraffin wax and nitrous oxide and produces 2400 Newtons of thrust for around 7 seconds. The home made avionics module controls and ignites the solid fuel. Since the oxidizer is injected by a swirling injector, combustion mechanics for this flow was presented. Mechanical properties of the mixture of paraffin wax and alpha-olefin particules were obtained using Differential Scanning Calorimetry (DSC), rheology tests and static fire tests. This engine was only tested througt static ground fires. It is then possible that some factors such as rocket acceleration and vibration will affect engine behavior during the flight. This year's test flight will be a perfect opportunity to ascertain these as-of-yet unverified parameters.

Design of a Crawford Strand Burner

Team 65 Project Technical Presentation to the 2018 IREC

Michael Pekala, Patrick Begalowski, and barak Stolz
University of Illinois at Chicago, Chicago, Illinois, 60607, United States

Modern solid rocket propellant consists of an oxidizer and polymer binder - typically ammonium perchlorate and hydroxy terminated-polybutadiene along with the additions of powdered metals such as aluminum powder for increased temperatures. The combustion properties of the propellant determine the performance and success of a rocket motor. Understanding these properties will allow to tailor design structural components of the motor to operate close to their mechanical limits without failure. With the available information on burn rates, variables such as particle size, chemical additives, method of curing etc. present discrepancies from one source to another, thus predicting the actual behavior of the combustion process very difficult. Documented values for burn rates are subject to empirical verification and are critical for the success of the motor. To successfully describe the properties of this propellant, comparisons between known types of APCP mixtures will first be observed to calibrate our equipment. Once an established method and procedure is developed, further research into tailoring propellant properties for increased performance or specified constraints can begin. The addition of metals, catalysts, and or additives often present problems of high temperature gradients and mechanical stresses which bar structural efficiency. A good balance of propellant properties constrained by structural properties allow for an ideal type of motor. In order to safely research and develop these kinds of propellants, our team will construct a Crawford strand burner for the University of Illinois at Chicago as an efficient way to describe the properties of solid rocket propellant.

Wind Tunnel Study of an Experimental Sounding Rocket

Team 73 Project Technical Presentation to the 2018 IREC

G. D. Edwardo
Aeronautics Institute of Technology, São José dos Campos, SP-Brazil, 12228-900

The subsystem of aerodynamics used the dependencies of the Aeronautics Institute of Technology, the Feng Laboratory, to estimate experimentally the aerodynamic coefficients in a full size subsonic open circuit wind tunnel of 200 HP. We adapted our designed rocket on the wind tunnel`s six degrees of freedom load cell using a specific designed aluminium part. The test simulated, in the Reynolds number similar of flight, the entire flight packet by changing yaw and pitch angles of attack. As a result, we derived drag force coefficient, normal force coefficient, side force coefficient, roll moment coefficient, pitch moment coefficient and yaw moment coefficient. Since the body in flight reaches Mach number where compressible effects are relevant, we used the Prandlt-Glauert compressibility transformation to adapt experimental`s data to flight condition. Hence, we could compare and check our Datcom`s virtual model with our actual rocket`s coefficients. In the IREC 2017 Competition, ITA's team designed rocket RD-07 reached insufficient altitude to score in flight performance criterium. Flight apogee was less than calculated in our six degrees of freedom computational simulation. The team doubted the accuracy of Datcom's model drag coefficient and suspected that, because the rocket rolled considerably during flight, it drained energy from trajectory. Awind tunnel test was conducted to determine experimentally drag coefficient and roll moment coefficient. We conclude that the wind tunnel test results for our rocket elucidated better it flight dynamic, in special in terms of roll calculation.

Development of an SRAD Flight Computer

Team 83 Project Technical Presentation to the 2018 IREC

Owen P. Torres and Derek Bourabah
University at Buffalo, Buffalo, NY, 14260, United States

The goal of this first student researched and designed (SRAD) flight computer was to control parachute deployment events, measure and record altitude, track the rocket via GPS, transmit basic information back to the ground, and use a camera to record the flight. With a lot of ground to cover in the first year the flight computer was designed to utilize a number of commercial modules so as to facilitate reusability and easy prototyping. To achieve this goal both skills learned throughout various classes in the University at Buffalo's undergraduate curriculum and by independent study, a functioning flight computer was designed, tested, and proven to work. The result of this development was a working flight computer that is packed into a small footprint, has easily replaceable modules, and has all of the required functionality. In the future we are considering developing our own radio system based on a commercial IC instead of using the pre-assembled XBee modules. This may allow us to improve the range, reliability, and latency of our connection by taking advantage of options available to us through licensed radio bands. We will also optimize our design to reduce the number and size of components, and reduce the flight computer's cost.

Implementing Bolted Assemblies to Increase Rocket Reusability and Reconfigurability

Team 92 Project Technical Presentation to the 2018 IREC

Jeremy Palmer, Andre Sushchenko, and Saad Yousaf
Rice University, Houston, Texas, 77005, United States

Rice Eclipse is a four year old undergraduate rocketry club at Rice University. Due to the organizations young age, 2018 is the first year it has competed in the Spaceport America Cup. For the team's first year in the competition, the project goals were fairly conservative, seeking primarily to reach the target altitude and learn more about higher altitude rockets. As of May 2018, the highest altitude ever achieved by Rice Eclipse is just over 3700 feet, so the attempt for 10,000 feet in June will be a monumental step for the club. Along with reaching the target altitude, a primary goal for the year has been to create custom carbon fiber body tubes that can be reused on multiple rockets. In most cases, when a rocket is assembled the fins, motor mount, and other components are permanently affixed to the lower body tube of the vehicle. This renders the entire assembly unusable if the fin size or motor size were to change, forcing a team to roll another body tube from scratch. This can cost hundreds of dollars and take hours of work for roll, epoxy, sand, and polish all over again. For Eclipse's first carbon fiber flight vehicle, a primary goal has been to reuse the body tube on future rockets and develop completely removable motor mounts and fins. Rice Eclipse was successfully able to implement a removable motor mount and fin support system with the use of fin slots and bolts to secure centering rings. Moving forward the club will be able to easily experiment with various fin shapes, airfoils, and motor sizes by swapping the the motor mounting assembly. Since all testing can be performed on the same launch vehicle, reliable experiments can be set up where a single variable is manipulated(such as a particular airfoil) and compared to a baseline value for an accurate measure of differing performance.

Resin Infusion as a Meathod of Manufacturing Composite Rocket Airframes

Team 93 Project Technical Presentation to the 2018 IREC

Jonathan Lesage
McGill Rocket Team, Montreal, Quebec, H3A0E9, Canada

Vacuum assisted resin infusion (VARI) provides an opportunity to create aerospace grade composites with low costs and quick lead time. As such, it is a viable candidate for manufacturing a fully composite sounding rocket airframe. However, creating aerospace grade composites requires care to ensure reasonable part quality is obtained before bringing it into service. The properties of the composite may vary drastically due to slight processing differences and be significantly degraded compared to tested specimens. The study conducted by the McGill Rocket Team seeks to effectively implement the process for a full sounding rocket, while also investigating and evaluating the quality of the main body tube sections. This acts not as a recount of obtaining a manufacturing technique that works, but rather as a structured approach to implementing VARI in the main structure of a rocket properly.

Risk Constrained Dynamic Programing Control of Airbrakes

Team 100 Project Technical Presentation to the 2018 IREC

T. Lew, F. Lyck and G. Müller
ETH Zurich, ARIS, Switzerland

The goal is to precisely reach a target apogee using actuated airbrakes, which are surfaces generating drag forces during the flight. Our approach is verified on a rocket built by our team and flown for the Spaceport America Cup. We implemented a fourth order Runge-Kutta integration method of the Inertial-Measurement-Unit's gyroscope and accelerometer measurements which are fused with the barometer to yield a precise state estimate in real time. The drift induced when integrating the inertial measurements is limited and the barometer measurements reduce it further. Comparing the barometer altitude measurement at apogee with pure IMU integration on a previous flight, we found an error of less than 4 meters on our prototype rocket which reached 640 meters. Using the rocket's state estimate as described above, the following question lies in how to design optimal airbrakes positions and control them to reach the target altitude as precisely as possible. Successful algorithms for trajectory generation and control of rockets include Model -Predictive- Control (MPC) and successive convexification1. All these approaches required considerable on-board computing capabilities and their implementation on hardware itself constitutes a challenge. To enable a simple implementation on a rocket with limited memory and computing capabilities, we opt for a controller using optimal control and risk constrained Dynamic Programming to generate an offline look-up table with optimal airbrakes positions. Using previous flight data, we tuned our simulator, noise model and control parameters for optimal performance using the controller on the simulator. This control table can be generated during the competition using our simulator to account for measured wind. It is then saved into a SD card read by the avionics during the flight.

Design of the Ares IV Tribrid Liquid Propellant Engine

Team 104 Project Technical Presentation to the 2018 IREC

Colum Ashlin and Eric Lufkin
Colorado State University, Fort Collins, Colorado, 80521, United States

The Aries IV tribrid liquid propellant engine utilizes nitrous oxide oxidizer and ethanol fuel during the liquid phase of combustion to produce thrust. Nitrous oxide was selected as the oxidizer due to the pressure and temperature at which it vaporizes. This behavior means the entire system can be pressurized by the oxidizer itself and eliminates the need for turbopumps. This drives the oxidizer and, with the help of a piston, the fuel out of the propellant tanks, through a custom plumbing system, and into the combustion chamber. These tanks are mounted coaxially and are separate from the combustion chamber to dampen any vibrations experienced during flight and mitigate the risk of pogoing during flight. A hydroxyl-terminated polybutadiene combustion chamber liner serves to aid in ignition and maintain combustion early on in the ignition of the liquid propellants, as well as to act as a thermal liner to protect the combustion chamber walls. When ethanol runs out during an engine burn, this secondary fuel source can combust with the oxidizer in a hybrid burn mode. The hot gases produced from combustion of these three propellant sources are accelerated through the throat of a nozzle to produce thrust. The liquid propellants burn for approximately 10 seconds and produce an average thrust of approximately 425 lbs to propel the rocket to its 10,000 ft. apogee.

Design and Development of Self-Pressurized Feed System for Bi-Liquid Rocket Engines Using N2O

Team 105 Project Technical Presentation to the 2018 IREC

Tomasz Palacz
AGH Space Systems, AGH University of Science & Technology, 30-059, Krakow, Poland

The Turbulence rocket is propelled by bi-liquid rocket engine Zawisza Z3000. Since their humble beginnings with liquid propulsion people at AGH Space Systems has chosen N2O as their oxidizer mostly due to easy handling, availability and great experience with hybrid propulsion. As a result of work done by author in previous years, which based on research and development of Zawisza engines series, bi-liquid vapour pressurized (VaPak) feed system for the Zawisza 3000 rocket engine has been proposed. Preliminary results gathered through integration tests and cold-flows of the feed system with installed pressure vessel confirmed proper operation of the vessel. There are still a lot of tests to be performed as not much measured data have been acquired, but it seems that N2O bi-liquid vapak is a good candidate with great adventages for Zawisza 3000 rocket engine and the Turbulence rocket.

Long-Range SRAD Radio Telemetry System (SRADio)

Team 111 Project Technical Presentation to the 2018 IREC

S. Platt and S. Maldonado
Stanford University Dept. of Electrical Engineering, Stanford, CA, 94305, United States

SSI’s entry into the 2017 Spaceport America Cup carried an onboard radio telemetry system which used a commercially available XBee 900HP radio module. These modules are widespread amongst amateur rockets, as they are commodity hardware requiring no licensing and minimal knowledge of radio systems to use. The XBee module occupied a point in the optimization space which, while extremely suitable for our Spaceport America Cup rocket, was not particularly well suited to other proposed rocket and balloon projects in our organization. The XBee module had a minimum bit rate in excess of other systems’ requirements and a receive sensitivity that prevented use at distances greater than 10 km without replacing our nearly omnidirectional dipole antennas with directional antennas, which in turn introduce a need for pointing and other operational challenges. A first principles analysis of the link showed that a radio system built from the ground up but optimized for long range communications was readily achievable and could meet the needs of both our Spaceport America Cup rocket and prospective, higher-altitude rockets under development. Beyond ground testing, we have conducted several flight tests of the SRADio with promising results. As of this writing SRADio boards have flown successfully on two rocket test flights and two high altitude balloon test flights, with the latter experimentally validating the units’ ability to maintain a 500 bit/s link over 200 km. Additional software configuration improvements validated on the ground but not yet tested in flight promise to extend this usable distance to 400 km, at which point the range (for balloon flights) becomes limited by the curvature of the Earth.

Validation of a Detatchable Fin Design for a Supersonic Sounding Rocket

Team 117 Project Technical Presentation to the 2018 IREC

Sebastian Panchyrz and Aaron Latorre
UVIC Rocketry, University of Victoria, Victoria, BC, V8P 5C2, Canada

UVIC Rocketry has been participating at IREC / Spaceport America Cup since 2016. This year's rocket - Hyak-1 - will fly in the 30k COTS solid category. This step puts a significant amount of additional forces and stresses onto the rocket since the rocket's size, mass, and flight velocity must increase to reach the increased altitude. This rocket will pass through the transonic region and enter the supersonic domain, where the aeroelastic phenomena of flutter is common. In the past, the team has had 3D-printed PLA fins overwrapped with one layer of carbon fiber to increase strength and stiffness. These fins fastened from the outside of the fuselage into the fin mount structure that surrounded the motor casing. This feature allows for easier and faster interchanging of fins which increases the theoretical reusability of the rocket, making it a desirable feature to carry forward on the Hyak-1 rocket. Much experimental testing has been done to determine the fins' strength and stiffness with this design, which must exceed the calculated values as described in the NACA TN 4197 paper on fin flutter.

Design Analysis and Testing of a Reusable Airframe Separaion Mechanism

Team 124 Project Technical Presentation to the 2018 IREC

Stéphane Testé and Annika Torp
The Johns Hopkins University, Baltimore, Maryland, 21218, United States

Originally, a pyrotechnic event caused by gunpowder being ignited by the motor was employed to initiate separation and deploy a single parachute. Testing proved this method to be inconsistent and rudimentary. A compressed CO2 canister system was then created to remove the uncertainty associated with the combustion-based separation. Wanting to save resources, money, and preparation time, AstroJays began work on a reusable stage separation system. A 24 V 60 RPM DC motor was mounted on the upper stage of the rocket using six M3 screws and circular aluminum base plates epoxied to the rocket outer body. It is powered by two 2200 mAh LiPo battery packs. An input signal from the altimeter turns on the motor through our circuit which contains a MOSFET transistor. A ½"-8 ACME lead screw made of 1018 carbon steel was welded to a steel coupler which is attached to the motor pinion with a set screw. This interfaces with a precision ½"-8 ACME round nut attached to a 1" inner diameter PVC tube. This tube was mounted similarly to the motor with two base plates in the lower stage of the rocket. The rocket is assembled by screwing the upper stage onto the lower one. Separation is initiated at apogee by powering on the motor and allowing the screw to unscrew from the nut. The rotation of the lower half, caused by the torque of the motor, is prevented by using an interference fit between the upper and lower stage. The precision of the nut and screw also prevent motor torque from being transferred to the lower stage. The same drogue and main parachute setup is utilized with bolt cutters. This system proved a viable, reusable recovery method.

****

Non-competing Collegiate Rocket Engineering
Research, Design, Test, and Evaluation

****

Low Cost Sounding Rocket Design

Team 205 Project Technical Presentation to the 2018 IREC

Riley K. Meik and Alex R. Laraway
Brigham Young University, Provo, Utah, 84606, United States

The demand for vehicles that can carry small payloads to space is constantly growing. The purpose of this project is to explore a technique for reducing the cost of these launches by developing a simple and efficient method to manufacture composite filament wound solid rocket motor casings. Currently, sounding rockets are extremely costly and complicated, in part due to the tedious and expensive manufacturing processes used in solid rocket motor construction. This research targets optimization of the motor casing. The goal is to develop a more cost and time-effective method of manufacturing composite motor casings, making it cheaper and easier for consumers and universities to deliver their small space payloads. In order to measure the results of this project, Zap Pak, altitude was chosen as the given measure. High performance rocketry extends far beyond industry and university involvement. Some of the most impressive advancements in sounding rockets have been made by amateur rocketeers, or hobbiest. Two projects, one university and one hobby were chosen as standards for this project. The first was USC's Fathom II. Fathom II was a composite case solid propellant sounding rocket launched in March of 2017. Their Q-class motor powered the rocket to an altitude of 144,000 feet and velocities just under Mach 4. This was the first university project to pass 100,000 feet. The second project was Steve Heller's Sunday Silent. Sunday Silent is the current Tripoli record holder for the research motor O-class category. Sunday Silent reached an altitude of 68,606 feet. A goal of 100,000 feet was chosen to measure the effectiveness of this project. By reaching this altitude, this project would hold the record for the second highest flight of any university project (on a motor with one fourth the total impulse) and would break the current O-class record by almost 50%. Upon concluding the design and full scale test of the rocket motor, flight simulations were conducted to validate initial altitude calculations for the flight of Zap Pak. The rocket motor developed far surpassed preliminary motor calculations, thus increasing the simulated altitude for its flight. Zap Pak is simulated to reach an altitude of 115,000 feet and a maximum velocity of Mach 4.75 this June at the 2018 Spaceport America Cup. While designing and testing the motor, many innovative ideas emerged that will be implemented into future projects that will allow even further advancements in low-cost sounding rocket design.
