Rocket University

R U Ready for the Future?

December 13, 2013/Volume 2, Edition 1

2013 Highlights

From top left, clockwise, Rocket Launch, High Altitude drop test of the Maraia capsule in Ft. Sumner, N.M., Unmanned Aerial Systems Design, Recovery image of small balloon payload.

Rocket University RU Ready

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Highlights of 2013

TRAINING

1

ZedBoard

2.

creo™ A PTC Product

3

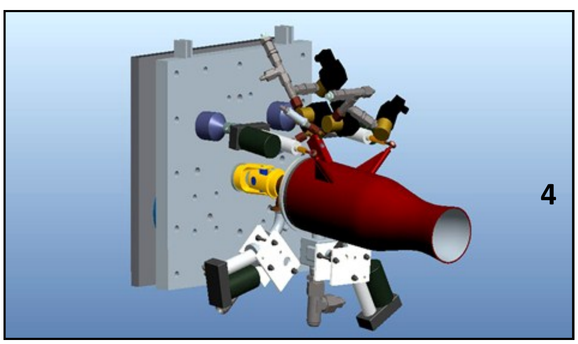
Rocket University (Rocket U) welcomed a variety of training opportunities in 2013, with lessons ranging from Introduction to Welding (1), to design manufacturing (3), to model-based systems engineering. Classes in Field Programmable Gate Array Basics (2) and propulsion were chosen to enhance the engineering skillset at Kennedy Space Center and directly impact our ability to support programs such as the Commercial Crew Program. Interested participants can sign up for classes in Satern, or contact one of the Rocket U team members for more details.

Highlights of 2013

PRODUCTION

1

2



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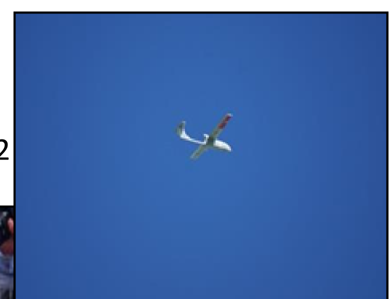
Rocket University uses hands-on applications for demonstrating the skills learned in the training courses. Between taking a class and executing a mission, engineers spend weeks (or months) designing, fabricating, testing and retesting hardware. UAS, Rockets, RUBICS, CubeSat, and Near-Space teams spent much of the past year at KSC's Prototype Shop, while the NEO team worked from their lab at the Shuttle Landing Facility. (1,3) For the UAS team, skills in composite manufacturing were acquired as engineers built the plane used for the UAS competition in October. (2) The water-tight aeroshell capsule, a mini version of the Maraia capsule, was designed by Rocket U participants and printed on a 3D printer . All of the Rocket U teams maintain drawings and specs for the hardware they build, such as the NEO engine graphic shown above (4). Readiness reviews before a test or flight ensure that each team is fully prepared for its mission.

Highlights of 2013

MISSIONS

1

Reaching new heights, Rocket U teams continued to push their limits by completing six missions in 2013. (1) The Space Coast Star Chaser Rocket team launched and recovered their rocket on September 30 from Launch Complex 39A. (2) In October, Rocket U welcomed teams from MSFC and JSC to participate in a UAS competition and knowledge sharing event, which paved the way for future collaborations on complex designs. (3) Members of the CubeSat team traveled to California to launch their payload, RUBICS, and supplied valuable data to the participating P-18 rocket team after a failure ended the flight early. (4) The Near Space Environments team launched multiple small scale weather balloons in Florida, and supported the large scale Maraia capsule drop test in Ft. Sumner, N.M. All of these missions contributed to one of Rocket U's most significant milestones in 2013: Collaboration with Range Safety and numerous other external stakeholders to perform launch and landing operations at Kennedy Space Center.



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Unmanned Aerial Systems

By Michael Dupuis and Michael Knutson

Figure 1: Genesis UAS render

The Unmanned Aerial Systems (UAS) discipline tract of Rocket U made incredible progress towards the deployment and fully-autonomous operation of the Genesis UAS (Figure 1) over the past few months.

Having successfully completed the Critical Design Review (CDR), UAS participants plunged into the fabrication of the molds required to build the Genesis airframe. Using newly-approved CAD designs, symmetrical plug halves were created as the first step towards the fabrication of the fuselage, tail boom and vertical stabilizer molds.

Figure 2: Luke Catella places parting plane template at KSC's Prototype Shop in June 2013.

UAS manufacturing engineers quickly determined that any variability between the plug halves imparted by the mill or our own sanding/finishing efforts would cause misalignment when the airframe half-shells were brought together. To overcome this potential problem the team decided to machine away the plug's base material and join the two halves together. This process improvement allowed the team to fair-out, or sand the plug across the center joining plane and ensure a smooth, continuous surface from one half to the other.

Under the direction of composite manufacturing experts from the KSC Prototype Shop like Luke Catella, project members prepared the plugs by joining, priming, filling and sanding its surfaces for molding. This initial process was completed by supporting the mold halves and installing a parting plane template (Figure 2).

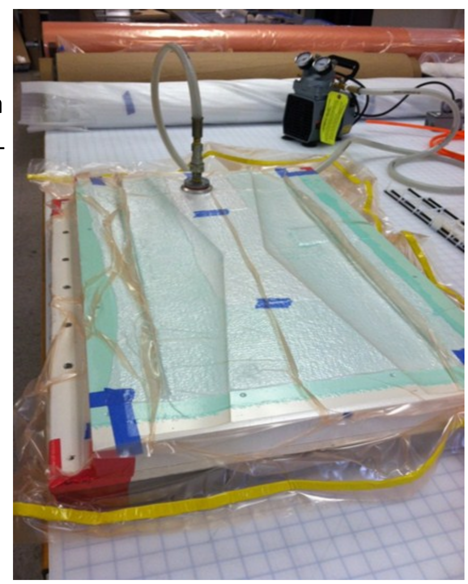

Figure 3: Curing the horizontal stabilizer

Students then covered the plugs with a releasing agent, tooling gel, and multiple layers of fiberglass to produce the mold halves.

With fuselage mold sets complete, participants practiced numerous processes for fabricating composite parts, including vacuum infusion and vacuum-cured wet layups. Unlike the fuselage and nose cone, the wing and horizontal stabilizer molds were fabricated by milling tooling board directly to a mold. As a proof of concept, the horizontal stabilizer molds (Figure 3) were machined first to test manufacturing processes needed on the larger scale wing fabrication.

To fabricate small, complex parts, the team learned how

Figure 4: Michael Dupuis inspects a fuselage bond seam at KSC's Prototype Shop in June 2013.

to employ additive manufacturing technologies like 3D polymer printing. Using a Stratasys Objet350 or a MakerBot Replicator 2X printer, the team printed 3D plastic parts that would be too difficult or expensive to make using conventional manufacturing techniques like milling or injection molding. Figure 5 shows the Genesis motor mount in the MakerWare™ interface with the actual 3D-printed part produced by the MakerBot.

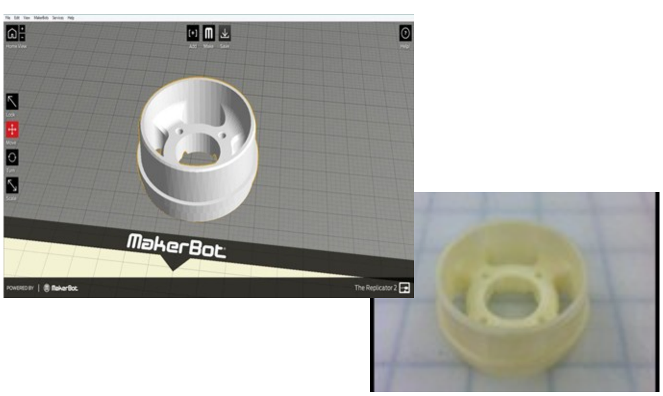

Figure 5: Motor mount in Maker Ware

The Prototype Shop utilized a new CNC Foam router to fabricate the wing's upper and lower skins and complete the mold assemblies. Once the tooling board was machined to shape, these new molds were covered with an adhesive-backed PTFE film to ensure parts would not stick to the mold surface. UAS project personnel next tackled the wing manufacturing using techniques learned during horizontal stabilizer test fabrications.

Led by participants Adam Dokos and Les Boatright, a launch system also was developed to meet customer requirements that Genesis must be capable of launching without a paved surface (i.e. cannot rely on landing gear). To this end the UAS team designed the all-aluminum rail launcher system shown in Figure 6. This system collapses down to meet transportability requirements and can easily be deployed by a two-person team. Following its assembly, the UAS team conducted extensive tension testing using a mass simulator to fine tune the system's acceleration to meet Genesis launch requirements.

Figure 6: UAS Genesis rail launcher

Another UAS project success story lies not with vehicle design and fabrication but with the headway made with training and certification of UAS pilots, as well as airspace access; a monumental task in its own right. In accordance with NPR 7900.3C (NASA Flight Operations Manual), the UAS project, in cooperation with the KSC Chief of Flight Operations, developed training syllabuses for UAS pilot operators (control station operators) and for UAS safety pilots/pilots-in-command (PICs). These syllabuses include formal training, physical exams, logged time requirements and proficiency demonstrations. For UAS pilot operators,

Figure 7: Edge 540 preparing for test flight north of Pad B.

flew three payload demonstration flights including the Piccolo™ autopilot and GoPro™ cameras. This added capability allowed the team to expand its experience in flight operations and gain vital imaging and inertial data needed for the upcoming inter-center UAS competition. Having finished construction of the mold assemblies and testing different manufacturing techniques, fabrication and integration of the Genesis Mark 1 airframe could begin in earnest. Leveraging the knowledge gleaned from Rocket U's composite manufacturing classes and workshops, participants constructed the composite airframe components necessary to assemble the Genesis airframe. This manufacturing process enhanced the finish and reduced the overall time and surface rework required. Rounding out the aircraft manufacturing process was the fabrication and installation of the 3-D-printed parts required to assemble the airframe and install internal components.

With the first flight date approaching and the airframe

logging hours and proficiency demonstrations are done on a ground station which has built-in flight simulation capability. Fantastic work also was done by UAS project Flight Ops Lead Mike Knutson and others to prepare the Currency Aircraft's KNPR 7900.2-compliant document and the formal presentation to KSC's Airworthiness and Flight Safety Review Board (AFSRB).

On March 25, the Rocket U UAS project, in conjunction with KSC Flight Operations, completed two successful checkout flights on the Edge 540 proficiency aircraft. Restricted Airspace R-2934 (Shuttle Landing Facility (SLF) area) was activated from 0800 – 0900 hrs and flights were conducted within this window. Preflight checklists were performed and safety/weather briefings were conducted prior to takeoff. Both takeoffs were nominal and the aircraft performed as expected.

Periodic flights of the Edge 540 were executed not only to maintain UAS piloting proficiency but, as part of the package approved by the AFSRB, the UAS project installed and

Figure 8: Genesis Pre-flight

“It has taken a concerted effort to get to where we are today, and countless individuals and organizations helped out along the way, for which we are exceedingly thankful.”
-Mike Dupuis, on the success of the UAS project

fabrication substantially complete, attention was turned to the integration of the vehicle's propulsion, servo-mechanical, avionics, electrical power and communication systems (subsystem testing discussed in previous news articles). One of the last functions to be performed before testing was the weight, balance and interface checks with the launcher's airframe adapter cradle.

On the morning of September 9, 2013, the team’s efforts were rewarded when the aircraft was packaged and transported to the UAS’s launch site north of Launch Pad B.

Placed on the launcher rail and following a preflight checkout, the aircraft took flight for the first of a series of test flights to demonstrate the vehicle’s stability, controllability and performance characteristics. Upon recovery, the pilot reported that the aircraft was very stable with adequate power, making it easy to fly.

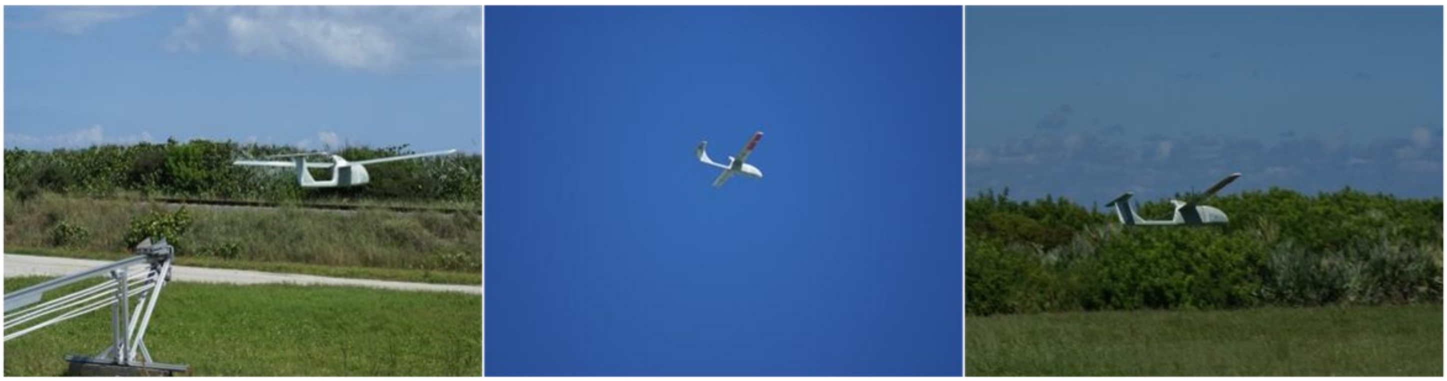

Figure 9 (above) : The KSC UAS during multiple phases of flight.

Figure 10 (left): An aerial image from the KSC UAS reveals the ‘casualty’ in orange on the ground. The competition required that the vehicles identified the figure.

UAS Looks to the Future

Having completed the Genesis airframe and demonstrated its airworthiness, the UAS team looks forward to the next series of labs to grow Genesis' capabilities.

- *Full integration and tuning of the autonomous flight control system.*
- *Integration of an onboard Fuel Cell power plant to increase the vehicle's flight duration and range.*
- *Hosting the DARPA NIMBUS project at KSC to expand our knowledge of lightning dynamics and increase our forecasting ability through electrical field measurements taken in and around thunderstorm clouds.*

Project NEO Updates

By Kyle Dixon

Project Neo is progressing well. The team has completed buildup of the fluid distribution frame and mounted it on the "skid" platform. Engine actuators are being characterized and cryogenic fuel and oxidizer lines are being routed. The team is reviewing the milestone schedule to determine if an end-of-the-calendar-year firing goal remains feasible.

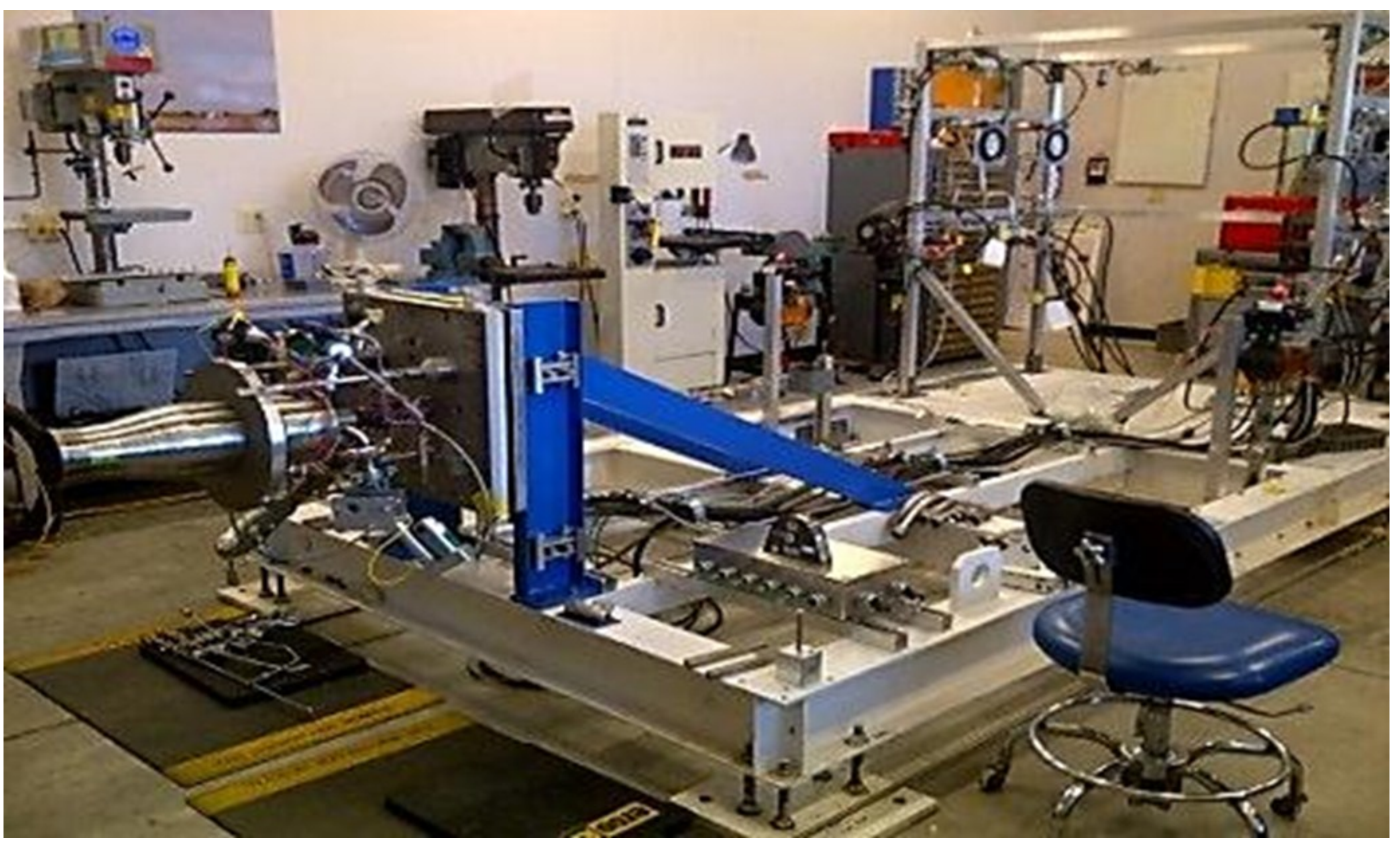

Figure 1: Project Neo

Maraia Capsule Drop Test

By Kelvin Ruiz

Rocket U team members Leandro James and Kelvin Ruiz traveled to a remote site of the Columbia Scientific Balloon Facility in Fort Sumner, N.M. with the objective of performing a drop test of the Maraia capsule built by a team comprised of Kennedy Space Center and Johnson Space Center (JSC) engineers.

Figure 1: **High Altitude Scientific Balloon prior to liftoff.**

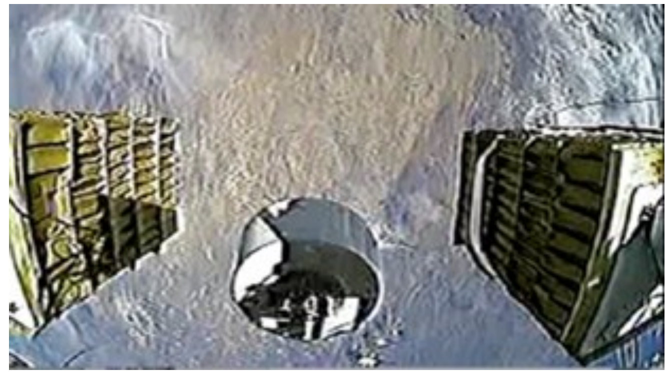

Figure 2: Maraia capsule release over New Mexico.

The objectives of the drop test were as follows:

- *Characterize the capsule's transonic and subsonic free-fall dynamic behavior and aerodynamics*
- *Execute full-scale autonomous pneumatic parachute deployment and recovery system*
- *Execute drogue-to-main-parachute transition*
- *Recover the payload*
- *Capture video and sensor data*

After a successful launch and hovering phases the capsule was released via a ground command at an altitude of more than 102,000 feet and more than three hours after launch. The capsule achieved a maximum speed of 562 mph (Mach 0.85), 45 seconds into free-fall. Upon reaching 60,000 feet the drogue parachute was released autonomously followed by main parachute deployment at 14,000 feet. Due to a problem with the camera's memory, only parts of the flight were recorded. However, all of the sensor data was recorded during the most important part of the test which was while the capsule was under free-fall. The data was received by the JSC team for analysis.

The recorded data from Maraia's drop test has provided JSC Engineering vital information about the behavior of various aeroshell shapes during reentry. As a result of Rocket U's contributions to the success of the drop test, JSC has asked Rocket U to collaborate on the second and third phases of this project, which include a Maraia drop from a sounding rocket and a

Field Programmable Gate Arrays and Rocket U

By Kelvin Ruiz

Rocket University participants have developed strong skills in the area of microcontrollers and embedded systems. So far our microcontroller projects have flown on high altitude balloons and rockets with a high rate of success. However, we have struggled in making the jump to Field Programmable Gate Arrays (FPGA), primarily when it concerns interfacing to multiple input/output peripheral just like we do in our microcontroller projects. So we were left with one question: Can we re-create the same type of projects that we have done with microcontrollers?

So we enlisted the help of Hardent Inc. and together we designed a Rocket U course that would focus on learning how to use FPGAs to communicate with multiple I/O peripherals through the most commonly used interfaces in Rocket U. For this course the ZedBoard Development Kit was selected as the target hardware for the hands-on labs (Figure 1). The processor on the ZedBoard is a Xilinx Zynq-7000 which is a very versatile architecture as it contains not only an FPGA but also a dual-core ARM processor. This architecture gives you the flexibility of using standard microcontroller projects in C/C++, running an embedded Linux operating system and also designing FPGA solutions on the same chip.

During the three-day course, there were several hands-on exercises where we interfaced an accelerometer to both the ARM cores and the FPGA. In doing so we covered I/O interfaces like UART for serial terminal communications and SPI to control an OLED display. The accelerometer data was received through both SPI and I^2C interfaces in separate exercises. This course was a step forward in developing the skills of an engineer who will participate in upcoming projects requiring the power of FPGAs.

One of those upcoming projects is the involvement in the National Science Foundation Center for High-Performance Reconfigurable Computing (CHREC). CHREC aims to use the power and flexibility of FPGAs to develop a reconfigurable computer for space applications. The CHREC community is comprised of members from academia, private companies and government entities like NASA. CHREC will be based on the same ZYNQ-7000 processor that our Rocket U participants were trained on.

Figure 1: Zed Board Development Kit

Rocket U Broad Initiatives CubeSat (RUBICS)-1

By Nicole Otermat

The purpose of RUBICS is to characterize nano-launchers and provide them with a usable low-cost avionics system design. The RUBICS-1 mission helped characterize the Garvey Spacecraft Prospector-18D (P-18D) rocket. This vehicle currently is deployed as a Suborbital Reusable Launch Vehicle (sRLV) for NASA's Launch Services Program (LSP) to conduct suborbital CubeSat launches under the High Altitude for Launch Service for Demonstration Nano-Satellites Program. RUBICS-1 consisted of a small avionics package that contained a microcontroller, GPS receiver, Inertial Navigation System (INS) and a Transceiver for radio frequency (RF) communication. The power system on RUBICS-1 is comprised of a Lithium-Ion Polymer (Li-Po) battery and a power charging circuit that allowed the battery to be charged while power was being provided to other RUBICS-1 electronics. The CubeSat external structure was purchased from a CubeSat vendor to ensure hardware integration since the RUBICS team had two months to design and ship the CubeSat. The NASA Prototype Shop designed and built the internal structure of the CubeSat which housed all of the electronics.

RUBICS-1 launched on the Garvey Spacecraft P-18 rocket on June 15, 2013. During ascent the Rocket experienced a failure which caused the parachute to deploy. RUBICS-1 incurred damage due to its position high up in the payload fairing. RUBICS-1 position in the payload fairing was chosen to allow the system to collect the most amount of data. Unfortunately, after the P-18 failure, the flight recorder (micro-SD card) onboard the CubeSat incurred irrecoverable damage and all of the recorded data was lost. To provide redundancy on RUBICS-1, a subset of the recorded data was telemetered to the ground live during the launch. All of the data that was telemetered during the launch was recovered with the exception of 11 seconds due to LOS issues. The other CubeSat payloads aboard the P-18 rocket either did not collect data or lost the majority of their data.

The RUBICS-1 team provided Garvey Spacecraft with all the data RUBICS-1 collected and they used this data during the investigation. The failure on the P-18 rocket launch provided invaluable data to the team on the performance of the CubeSat, and overall, RUBICS-1 met all of the mission goals and performed per design. Improvements for the next mission will be to improve the range of the onboard accelerometer, provide a more sensitive GPS system, and to upgrade the flight recorder.

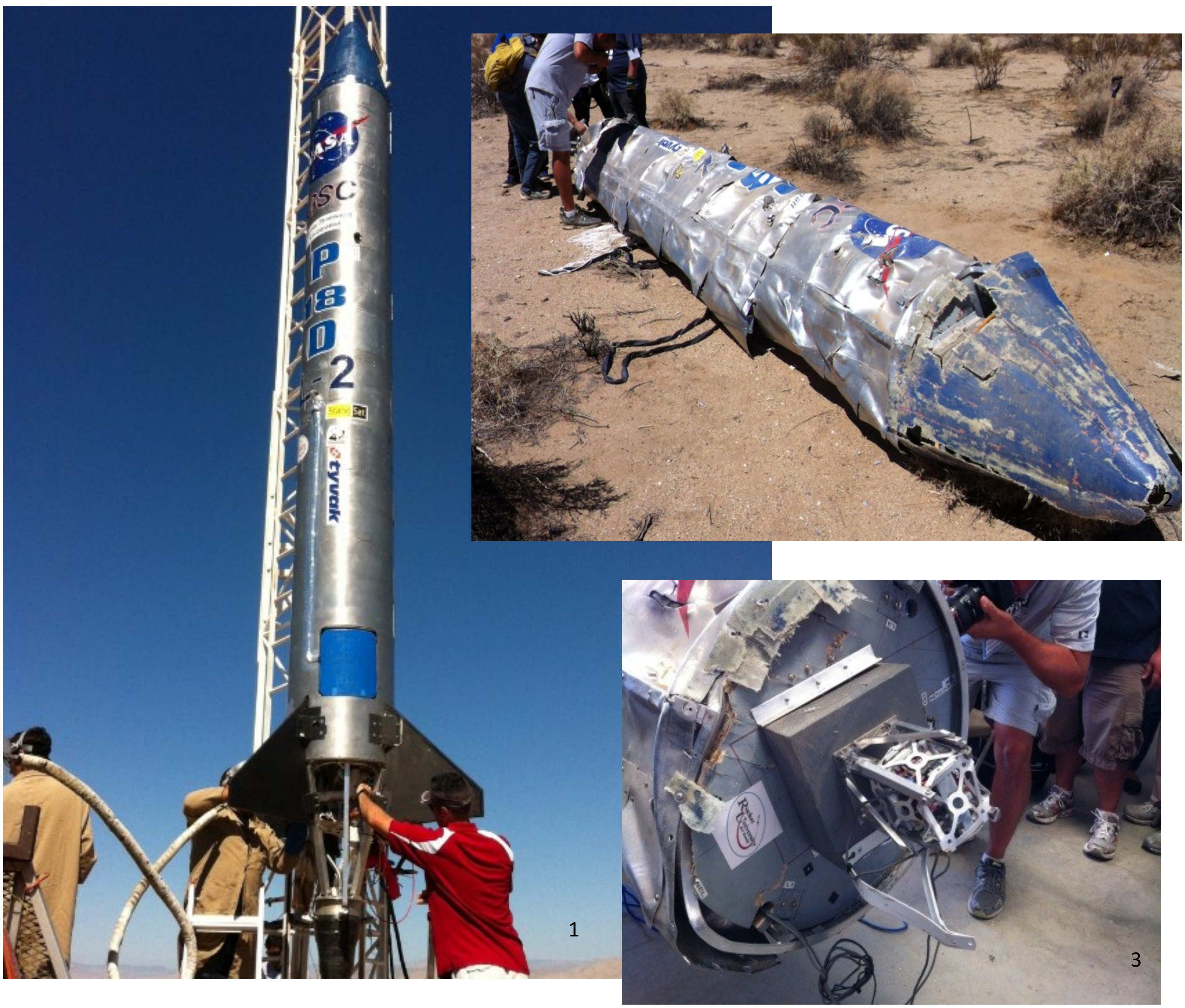

Figure 1: Leandro James performs prelaunch checks of RUBICS, 2) Image of Crash Site 3) View of RUBICS, post crash

Rocket Team Updates

By Kevin Vega

Space Coast Star Chasers

On May 24[t] 2013, the first Rocket Team launched on KSC property by the Space Coast Star Chaser team from Launch Pad A. This test flight marked a culmination of analysis, design, risk assessment, safety protocols, fabrication, test and checkout and launch ops coordination with more than 20 different departments, directorates and agencies. The successful launch also established a new baseline and capability at KSC not only for internal benefit but potentially also for external entities.

Figure 1: (from left) Julio Najarro, Leandro James, Morgan Simpson, Susan Danley, Kim Simpson and Myphi Tran

The launch occurred at 8:53 am and focused the test flight objectives to evaluate their flight dynamics modeling predictions and avionics system which was comprised of Commercial-Off-The-Shelf parts developed in a uniquely designed avionics system for high acceleration platforms. A microcontroller unit was programmed with logic to autonomously command critical mission events with data gathered from an inertial navigation system (accelerometers, gyroscopes and magnetometers) and an altimeter. The use of a wireless telemetry system allows for real-time downlink of data and uplink of commands. In addition to the avionics system, the design used a 3-D-printed avionics support structure, payload housing and camera fairing.

Figure 2: Space Coast Star Chaser Launch

Overall, the test went well and flushed out some configuration control lessons learned and software issues that ground testing couldn't expose.

Following the successful test flight, the team made a few avionics design, procedural and analytical changes as part of their CDR/FRR package in order to pursue their final three certification flights to complete this phase of training. On Sept. 30 the team successfully predicted, launched and recovered their vehicle. This final configuration of the certification vehicle fired on all cylinders starting with the redundant igniter, separation and recovery initiated systems, 3-D printed parts and assemblies and in-house designed avionics systems with real-time flight telemetry and ground initiated commanding to the vehicle to deploy a U.S. Flag from the payload bay. The first certification launch was capped off with the actual flight profile and recovery landing target matching up to the predicted models and simulations. The Space Coast Star Chasers, led by Chief Engineer Susan Danley, System Leads Leandro James (avionics), Morgan Simpson (flight dynamics/mechanical/pyro), Kimberly Simpson (mechanical/pyro/ops), Myphi Tran (telemetry) and Julio Najarro (mechanical/ops) is the first team to achieve this step in the training program and looks forward to wrapping up the final two certification flights Nov. 6.

Team X

Team X is developing alternate methods of vehicle power-up and safing to prevent transient voltages at avionics initialization and to allow for additional software safeguards to be demonstrated prior to final vehicle connections in a sub-scale version of their high-flying two-stage vehicle. Their in-house-designed avionics system will serve as the primary decision-making logic for all phases in flight with an additional facet of air braking the vehicle to limit the altitude to 10,000 ft. while achieving transonic speeds.

Team ACME

Team ACME is focusing on subsystem testing of their avionics and structural components to ensure their 12-foot-tall, two-stage vehicle performs as expected. The structural airframe and thrust ring bond line testing was determined to maintain a 45:1 (14,000 lbs.) and 17:1 (5,300 lbs.– yield at 8,000 lbs.) safety margins during compressive testing.

Figure 3: Kelvin Ruiz performs testing on the avionic subsystem.

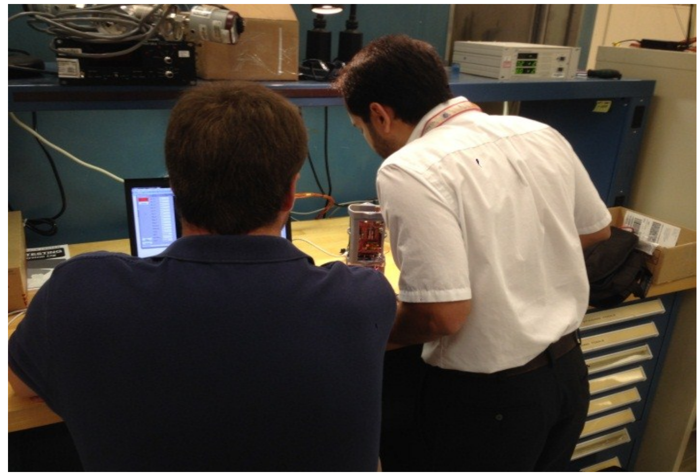

Figure 4: (from left) KSC Intern Benjamin Plotner and Kelvin Ruiz

Figure 5: Bond line

Figure 6: Airframe

In addition to the structural testing, the team proceeded with "flight like" random vibration tests on the avionics system from 20 – 2,000 Hz at 11 g RMS with a duration ten times more than each stage's expected burn time with great results.

The final segment of ACME tests included a Barometric test under vacuum of their avionics system. Since the avionics system receives real-time sensor feedback via barometric switch along with position sensors such as accelerometers, magnetometers and rate gyros to logically initiate separation events between stages as well as the recovery of both stages, this was a test method where the team could simulate the changing pressures during their flight regimes and ensure their avionics initiates events appropriately. The system demonstrated an average late reaction time (sensor measurement to command) of just 0.140 sec. The tests were successful in providing the team with assurances and risk reduction to move forward with CDR and final build of the vehicle.

"Test Like You Fly ... or at least understand the limits."

"Test Like You Fly ... or at least understand the limits."

Rockets Next Phase

As the current teams finalize their designs and fly their three certification flights to complete this phase of training, this is what we have in the works for next phase.

Sub-Orbital: High Altitude Launch System (Winter 2014)

- Use COTS "O" Level Motors on a three-stage vehicle to apply an advanced portion of curriculum

Orbital: Nano-Launcher Vehicle (Fall 2015) with Marshall Space Flight Center

- Orbital payload vehicle
- Full integration of the autopilot avionics
- Integration of an onboard Fuel Cell power plant to increase the vehicle's flight duration and range.

suc·cess [*suh* k-**ses**]

noun

1. the favorable or prosperous termination of attempts or endeavors; the accomplishment of one's goals.

Rocket U Courses

Topic/Name	Date	# Seats	Duration	NASA instructor or vendor
Introduction to Additive Manufacturing -- Desktop 3-D printing (Maker Bot familiarization)	12/5/2013	8	1 hour - Lunch and Learn (seminar)	Mike DuPuis
Introduction to Additive Manufacturing -- Desktop 3-D printing (Maker Bot familiarization)	1/14/2014	8	1 hour - Lunch and Learn (seminar)	Mike DuPuis
Prototype Design	1st quarter 2014	14	TBD -- 3 half days	Prototype Lab
Design and Fabrication Lab	1st quarter 2014	7	TBD -- 3-5 days	Prototype Lab
Introduction to Welding	1st quarter 2014	18	5 Fridays	Eastern Florida State College (formerly BCC)
CubeSat	1st quarter 2014	25	TBD	Pumpkin Works - Andrew Coleman
Rapid Prototype Familiarization	1st quarter 2014	30	2-3 days	Armadillo Aerospace
Advanced High Power Rockets	1st quarter 2014	20	4 days	Gary Dahlke
Introduction to Parachutes	1st quarter 2014	25	TBD	TBD

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