2011–2012 USLI Post Launch Assessment Report

University Of Minnesota Team Artemis

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Post Launch Assessment prepared by University of Minnesota Team Artemis for 2011-2012 NASA University Student Launch Initiative.
2011-2012 University of Minnesota USLI Team

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Team Summary

Team Name: University of Minnesota Team Artemis
Project Name: Atmospheric Rover and Rocket Delivery System
Team Location: Department of Aerospace Engineering
107 Akerman Hall
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Minneapolis, Minnesota
Team Officials: Dr. William Garrard - Faculty Adviser
Gary Stroick - NAR/TRA Mentor

Launch Vehicle Summary

Vehicle Specifications

Vehicle Dimensions
- Height: 134 inches
- Diameter: 7.708 inches payload section
  6.170 inches booster section
- Empty Vehicle Weight: 41.0 pounds
- Loaded Weight: 50.2 pounds (with motor and payload)

Recovery: Dual Deployment, redundant black powder ejection
Rail Size: One and one-half inch button

Motor Specifications:

Manufacturer: Cesaroni Technology
Model: CTI Pro75 L2375-P
Type: Reloadable
Loaded Weight: 146.8 oz
Propellant Weight: 81.9 oz
Total Impulse: 4905 N sec
Maximum Thrust: 629 lb
Average Thrust: 551 lb
Burn Time: 2.1 sec
ISP: 214 sec
General Payload Description

The payload objective was to deploy a small, remotely controlled rover equipped with an array of sensors to collect temperature, relative humidity, and light intensity readings. The rover was also to be equipped with a wirelessly transmitting camera, allowing the pilot to control the rover without visual contact. The purpose of this project was to simulate and explore the possibility of deploying small, inexpensive probes to extraterrestrial bodies in order to scout potential landing zones for more complex, large-scale missions.

Vehicle Description

The 134 inch long vehicle had a total loaded weight of 50.2 lbs and was constructed of mainly phenolic tubes, fiberglass, and plywood. The nosecone, transition, and boat tail were made out of fiberglass. The fin mount, drogue parachute coupler, and main parachute tubes were made from phenolic tubes while the larger payload bay tube was constructed from pre-glassed phenolic tubing. All bulkheads and centering rings were machined from birch plywood.

The separate sections are as follows:

Nosecone

The nosecone housed a radio tracker as well as a bulkhead used for centering our ejected payload.

Payload Bay/Main Parachute

Our payload bay and main parachute tubes were attached with our front avionics bay separating them. Both payload bay and parachute tube housed pistons for ejection of payload and parachute. Pistons were constructed of phenolic tube and birch plywood bulkheads. Threaded rods were used to attach the payload section to the main parachute tube during flight.

Drogue Coupler

The drogue coupler housed our drogue parachute and kept the forward main parachute tube and aft fin mount section connected via 4-40 shear pins. It was constructed of phenolic tube and a birch plywood bulkhead.

Fin Mount Section

The fin mount section housed our removable motor mount system which comprised a total of four plywood centering rings. The motor mount tube could be removed by unscrewing three ¼-20 bolts from the lower centering ring. The fins were attached via
¼-20 bolts contained within the interior airframe. The fins were tapped so the bolts pulled the fins tight against the airframe. The fins were machined from G10 fiberglass.

Data Analysis & Vehicle Results

Due to an unfortunate manufacturer error, the payload did not operate under normal mission conditions. While the payload was flown in the rocket, an electronic failure the day before competition prevented the remote ejection of the rover from the rocket. The ejection of the rover was triggered by using an electronic switch via the RC control system, and it was the malfunctioning of this switch which prevented the payload from operating in the competition.

Altitude Reached

The rocket reached apogee at 19.12 seconds after launch, and the drogue chute was ejected and opened around 1.9 seconds later. The primary charge was set to go off at apogee and the secondary charge was set 1-second delay. Since the primary charge did not go off, secondary charge was the only charge, which pushed the drogue chute out of the rocket tube.

The primary charge for the main parachute was set to go off at 733ft altitude, but it did not go off even though a signal from the altimeter was sent to the charge. The secondary charge was to set to go off at 200 meters (656ft) and the main parachute was ejected at 186.7 meters (612 ft). The time difference between altitude 186.7m and 200.0m was 0.4 seconds.

The apogee altitude recorded by the front Featherweight Raven altimeter (barometric) was 5858ft while the rear Featherweight Raven altimeter (barometric) recorded an apogee altitude of 5850 feet. The altimeters were separated by approximately 4 feet within the vehicle leaving a 4 foot discrepancy (0.07% discrepancy).

The altimeter recorded the rocket falling from apogee at approximately 82ft/s, and the main chute opened at 612ft above the ground. The altimeter also recorded the descent speed of approximately 17.4ft/s from main deployment until landing.
Payload Summary

The payload consisted of a remote controlled vehicle capable of passively collecting data on local temperature, light intensity and relative humidity. The vehicle was equipped with two driving claws on either side of a center frame that housed all of the control and data acquisition electronics, as well as an outrigger arm that allowed for forward driving. When loaded in the rocket, the claws and outrigger folded inwards towards the frame which reduced the maximum dimensions of the vehicle so that it could fit inside the airframe. Upon deployment, which was intended to occur following a control input after touchdown, the claws and outrigger were spring-loaded to automatically unfold, which put the rover in drive configuration. At this point, the rover was ready to receive control inputs and was capable of driving several predetermined routes to explore its new environment. Unfortunately, during competition the electronic switch that was intended to trigger the black powder ejection charge was defective due to the manufacturer’s error, so the rover could not be deployed in the field. Upon recovery of the airframe, the rover was inspected and determined to be undamaged and fully operational, with the exception of the ejection switch.

Data Analysis & Payload Results

During the full scale test launch it was discovered that the electronic switch we initially ordered was not functioning properly. The RC-100 switch has two outputs, normally closed and normally open, the title of each signifying the state of the circuit when the switch is in the default position. For our purposes, the normally open position was desired. In this configuration the RC controller can be turned off during flight, mitigating the risk of an accidental ejection. In the normally closed position, depending on the RC system in use, the controller may or may not need to be powered on in order to keep the switch in the open configuration. During the full scale test, the RC-100 switch was successfully tested in the normally closed condition with the AR-600 receiver. With this system the switch remained in whatever orientation it was last commanded to, even after the RC transmitter was powered down.

The range on the AR-600 was found to be insufficient for our mission and we opted to switch to LRS Pro system. Unfortunately, in this configuration when the RC transmitter was powered down, the switch flipped into its default position, closing the circuit, thereby rendering the switch useless for competition due to safety concerns. The company, RCAT Systems, was contacted about a week and a half before competition, when the first switch was found to be faulty. Unfortunately, all of the workers at RCAT Systems were out of the office for the week following my attempt to contact. Due to this delay, RCAT Systems was not able to send a replacement switch until days before the competition, thus forcing them to send us the switch in Alabama.
On Friday the new switch finally arrived and was installed on the rover. When the system was powered up to be fully tested on Saturday the switch began to smoke and burn, completely destroying the circuitry. The electronic switches can withstand a maximum of 6V, and while we were using a 6V battery, at full charge we were supplying 7V to the switch. This problem had already been addressed months before the competition. RCAT Systems offered to modify the switch, by simply adding resistance to the circuitry, to allow for higher voltages. While this was done correctly on the first switch we ordered, we believe in their haste to replace the faulty switch, or by some miscommunication, the second switch was not modified. Without this modification, the replacement switch experienced current loads sufficient to melt the circuitry, leaving us without a working switch and without a means to eject the payload.

Due to the last minute failure of the switch the payload was flown essentially as ballast, and was not powered up to operate under normal mission parameters. Nevertheless, the rover did not receive any damage structurally or electronically during the flight. After the flight we did set the rover in the field to test how capable it was of driving. We confirmed that the rover was capable of navigating through the terrain, having enough torque and ground clearance to handle the field. Additionally the video feed worked well. Before competition the rover was tested at the hotel. We placed the rover in the hallway and controlled it from inside the hotel room, observing and recording the video feed on a laptop computer. The main problem that occurred with the drive tests was with the outrigger. As the soil was so loose and the reactive torque so large, the rover did have a tendency to push the outrigger into the ground.

In hindsight more time should have been spent on testing. If the switch and the full scale test had been conducted earlier in the year we would have had plenty of time to replace/fix all faulty components, despite the bad luck we encountered with the manufacturer. Additionally, more time should have been spent on the outrigger design to account for the possibility of it digging into the ground. Nevertheless, we consider the payload to be semi successful. It was capable of recording light intensity, temperature and relative humidity (we have no values to report from competition because the rover was not actually launched). Furthermore it was tested on the competition field and shown to be capable of driving and capable of transmitting video to the ground station. We feel confident that if the electronic switch had not failed so close to completion, the payload would have been a success.

Scientific Value

The purpose of the rover was to explore the potential value in sending an inexpensive probe to potential landing zones on extraterrestrial bodies in order to gain detailed scouting information. The information gained by the scouting rover may be used to mitigate risks for future large-scale operations. This project was intended to be a
simplified simulation of an actual mission and is intended simply to explore the potential of such a device.

Visual Data Observed

The vehicle traveled in a helix during ascent, which has never happened before. Due to this we thought the vehicle was below altitude, because in previous flights we had flown very close to 1280 feet. At apogee the drogue was successfully ejected, although very forcefully. This was due to only the backup drogue charge firing. The vehicle initially descended quickly because the drogue parachute was tangled in the shock cord, which has never happened in our four previous flights. The main opened as expected at 700 feet and at the time it looked very successful. Unfortunately we did not see that this charge was also the backup so it was very forceful and damaged our phenolic tube. Once the vehicle reached the ground the main parachute was large enough and the wind high enough so that the vehicle was dragged until the parachute got stuck in a tree.

Lessons Learned

- Assumptions often turn out to be wrong. Be sure you know everything you are assuming and check that the assumptions are valid.
- Start building early; construct the half scale in the first semester, most of the learning takes place during the building.
- The first piece of machining shouldn't be the final piece, build test pieces to practice technique.
- You will likely need more money than you think, so add at least 20% cost to your projected project total.
- Don't get too hung up on the design process, things will change as you try to build the rocket. Knowledge of building will help your design process more than anything.
- Leave room to de-scope your project if need be.
- Leave room in your design for potential changes during the build process or other parts of the design cycle.
- TEST EVERYTHING!
- Designs are never complete; there is always room for optimization. It is important that at some point you call the design good enough and move on.
• Communication is very important; make sure sub-teams are communicating effectively.
• This project involves a lot of machining, so people with a lot of machining experience are invaluable. If you don’t have any experience, practice making pieces fall semester, even if they aren’t going to be used later.
• Make sure every system has been fully and independently tested before testing all systems together.
• Construct a team with a diverse background. It is beneficial to have students from electrical and mechanical engineering to help with electronics and machining.
• Keep the design as simple as possible. The simpler it is, the easier it will be to construct and to simulate, ultimately increasing the chances of success.
• Don’t assume RockSim (or any other simulation) is right, check with other sources. Compare and validate with flight tests.
• Always get a second opinion about design ideas, construction, etc. It’s effective to have somebody else double check your work.
• Test your components/systems early. Make sure all components you order work as soon as you receive them.
• Double-check all electronics before launching to mitigate risk of electronic failure.
• Parts may take longer to come than you think. Many parts have long lead times: Motors are 3 weeks and parachutes are 3-5 weeks. Make sure to order parts early
• If you are waiting for parts to arrive, you are kidding yourself; there is always something to do… go do it.
• Don’t get stressed out if part of the design isn’t working, there is almost always a way to solve the problem. Step back, look at the big picture, and consult with others.
• Always save your scraps, they may be very useful later on. It is always nice to have spare components.
• Make the design modular. The ability to replace one faulty piece, rather than a whole section, can be the difference between success and failure. The ability to remove parts easily makes construction and repair much easier.
• Keep a good inventory of all your parts, supplies, tools, etc. and stay as organized as possible.

• If you use airbrakes, make sure they open upwards. With this design, if they fail the wind will push them closed rather than rip them off.

• Finish writing reports a week before they are due, you will need that last week for proofing and formatting.

• You may not feel comfortable with your design as a major milestone like PDR approaches. At some point, at least a week before you begin writing, you need to implement a design freeze and write the report on what you have. Make sure you write where you are, not where you think you will be.

Summary of Overall Experience
(what you attempted to do versus the results and how you felt your results were; how valuable you felt the experience was) Everyone (add bullets)

Since our primary experiment was to deploy and operate our rover successfully after the flight, and we were unable to do so for technical and safety reasons, there was no way to gage the success of our mission.

With regards to the rocket vehicle flight, we consider it a partial success despite structural failure of the main parachute tube, and misfiring of our charges. Our previous flight tests were less successful, ending in major structural failures, although our vehicle performance in our flight tests was better overall, achieving altitudes close to one mile, and maintaining complete stability in high winds.

Overall, the experience to compete in the NASA University Student Launch Initiative was amazing. The team learned a lot along the way, and gained many skills and insight into teamwork and complete project design cycle.

University of Minnesota hopes to compete in the USLI in future years, and this is a good start for future rocket team work at our school.
Educational Engagement

Community Outreach is not only important to our success in this competition, but for the future of the aerospace industry. The goals of all of our community events were to inspire those younger than us to not only become interested in aerospace, but math, science and engineering as a whole.

We performed six events. The first event was an Urban 4H kickoff on October 29th, 2011. This event was smaller with 15 children and 6 parents present. In the first half of this event we had the children make CD hovercraft and straw rockets to emulate fluid power and fin design of rockets. In the second half of the event we went outside to shoot off 3 in. water propelled rockets as well as larger foot-long rubber rocket. With these rockets we were able to show how the difference in the propellant (water or air) affects how much power is generated, as well as how compressed air can be used. This allowed the kids to apply the lessons learned from the indoor activities on rockets.

The second event was the Math & Science Family Fun Fair on November 19th, 2011. This event was six hours and had a total of 2,200 attendees including the children and adults. The event is for children from K-12, with majority of them being in 4th-8th. We had our own room and used the CD hovercraft and straw rockets again, along with the air pneumatic circuit kit, and used a LCD screen attached to a laptop to show videos of previous launches. A rocket used last year by a student organization was on for display and our Team Lead answered questions about it. An estimated 250 kids, with an equal amount of parents visited our room. The number is an estimate because, although we kept a tally as people walked through the door, the event was fairly busy the entire six hours.

The third and fourth events were science nights at Galtier Elementary, a K-6 school which had 47 attendees and Lincoln Center Elementary, another K-6 which had 200 attendees. For both had a booth or table and had our half-scale rocket on for display. There was also a pasteboard demonstrating how rocket’s fins and propulsion works. We had kids make straw rockets, as they are perfect for these types of events because they are easy to make and the kids can take them home with them after they make it.

With these events we are projected to meet with 883 people total, with approximately 550 of them being middle school students.

The fifth and sixth were hour long classroom events with 40 kids from Marcy Open Elementary about rockets. The first half was a PowerPoint presentation/questionnaire
about how rockets’ work and the future of rocketry because many students thought nobody built rockets anymore. The second half we built straw rockets. The straw rockets were used continuously throughout all outreach events because they are fun for all ages and the kids are able to take it home with them.

Budget Summary

The overall project budget post competition flight is summarized in the following tables:

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<td>Senior Design Class Funds</td>
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<td>Minnesota Space Grant Consortium</td>
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<td><strong>TOTAL ALLOCATED FUNDS</strong></td>
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<th>Project System</th>
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<td>Full Scale Subtotal</td>
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<td>Payload Subtotal</td>
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<tr>
<td>Testing and Supplies Subtotal</td>
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<tr>
<td>Travel Subtotal</td>
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<td><strong>TOTAL EXPENDITURES</strong></td>
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