PSU High Altitude Launch Vehicle Project

Abstract

We propose to design, construct, and launch a high altitude, solid fuel sounding rocket with a microcontroller-based payload that has both a scientific and educational component. Our multidisciplinary team, composed of electrical and mechanical engineering, computer science and atmospheric science majors, will construct the launch vehicle and payload to conduct atmospheric sampling, flight dynamics data acquisition, flight sequencing and color video imaging. A RF downlink will relay data to a ground station for real-time data processing. We will present our project and data to local schools and media through educational presentations, stressing the importance of science and engineering education.

PSU High Altitude Launch Vehicle Project Proposal

Background

The Portland State University student chapter of the AESS (Aerospace and Electronics System Society) was started in October of 1997 after more than a dozen engineering students expressed a strong interest both academically and pre-professionally in aerospace technology. Not just wanting to be another aerospace "glee club", our chapter decided to develop a project that was as close to a real-world aerospace project as possible. After a few months of discussions and project brainstorming, we decided to design, build and launch a high altitude sounding rocket. This combines all of the desired interdisciplinary aspects of a typical aerospace project: launch vehicle dynamics and control, payload design and integration, and wireless communication and data processing.

The High Altitude Launch Vehicle Project Specifications

We decided to embark on this project as the beginning of a 3 - 4 year long series of projects, starting with a very simple launch and payload system and moving on to greater complexity as our experience increases. This first project, and the focus of this proposal, is a single stage, solid fuel, passively guided sounding rocket with a scientific and imaging payload designed to reach 20,000ft.

Launch Vehicle:
· Airfraime: 1.9 meter Carbon Fiber - Kevlar composite (Total weight: 17lbs)
· Solid Fuel motor: Ammonium Perchlorate / Aluminum Class "M" motor (6,000 Ns impulse)
· Recovery system: Pyrotechnically deployed drogue and main chute

Scientific Payload:
· Microcontroller: PIC 17CXX 16bit RISC microcontroller for data acquisition and flight sequencing
· Backup controller: PIC 16CXX 12bit RISC microcontroller for backup of critical functions
· Scientific Sensors: Temperature, pressure, radiation, particulate count (currently - more TBD)
· Inertial Sensors: (Prototype for future Inertial Guidance System) 3 axis accelerometers, 3 axis gyroscopes
· Imaging: 256bit color 640x480 CCD imager with full speed NTSC output, coupled with a microphone

Communications:
· Imaging transmitter: 1W Amateur TV imaging transmitter (420-450MHz) for full speed NTSC throughput
· Telemetry Trans.: 14.4kbps data channel on audio signal or separate transmitter (TBD)

Ground Station:
· Data/Image receivers: Receiver and demodulator circuits for imaging and data transmissions
· Computer: 166MHz Pentium Notebook for real-time data processing and storage
· Misc.: Tracking equipment for launch vehicle recovery, protection against motor/launch failure, etc.

For more technical project information, including detailed system descriptions, flight simulations and preliminary microcontroller code, please feel free to contact us at `aess@ee.pdx.edu'.

Project Implementation

Immediately after choosing our preliminary specifications, we divided ourselves into project teams: Launch Vehicle (3 students), Imaging (3 students), Sensors (3 students), Communications (4 students), Data Processing (2 students) and Community outreach (2 students). Each team formed its own goals and timelines (see the enclosed timeline, page 5) in the context of a planned June 14th, 1998 launch.

Since the main purpose of our project is to gain the experience of systems-level design for an aerospace, a major part of our project is learning to effectively work in teams. Each of our six teams is working independently, but with close ties to the overall group. We are using mailing lists, direct emails, bi-weekly group meetings and a soon-to-be constructed web page to facilitate inter-group communication. Each team is expected to meet at least twice between general meetings to accomplish goals outlined at the group meeting.

We are fortunate to also have many local resources to rely on for this project. The NW section of the AESS has lent its support to us through advising and technical help. Perhaps more importantly, we have gotten strong support from all of PSU's engineering departments to go ahead with this project as well as from PSU's Center for Science Education. Some engineering departments (EE and ME) are even arranging to have this project be acceptable as graduate school credits.

Finally, our team is not starting from scratch. Our launch vehicle has already been built and is currently undergoing stress and stability testing. We have already tested 2 motors on our computerized thrust stand to obtain accurate thrust-time curves; we are planning on building a series of motors to prove their performance and reliability. Perhaps most importantly, many of our team members are experienced in our different technologies: the construction and testing of composite materials, amateur communication systems and microcontroller design. Two of our members are even experienced in high power rocket launches and have access to a high altitude launch area sanctioned by the FAA in Sheridan, Oregon, close to the Portland Metro area.

Professional Development

"You can't buy experience on the easy payment plan" read one of our team member's fortune cookies. Aerospace engineering requires a systems approach to design not found in all domains of engineering. We have found that the distinctions between disciplines disappear as the specifications of the project start to become clear. For example, the printed circuit boards designed by our EEs to hold the payload components must be modeled by the MEs to make sure that they can withstand acceleration forces of up to 20g. And the real-time data processing software written by the CS majors must acquire and process the differentiated signals of the inertial guidance data to make heads and tales of the rocket's position. There are few shortcuts to accomplishing our goals, but we recognize that working together and applying our different strengths will make our jobs easier. We are proud of the diversity of our project team, and we hope to inspire other cross disciplinary student teams through our example.
An important part of our engineering education is exposure to different technologies. The project specifications were chosen to hit as many technologies as possible. A few examples are:

- The flight dynamics data acquisition will be used to apply feedback control to a future active guidance system,
- Our microcontroller and sensors will have a modular, hot-swappable, common-bus architecture,
- The color CCD camera requires a high bandwidth (~6MHz) communications system,
- The ground station computer will perform real-time data processing and display to let us carefully track the rockets launch.

Not only will this project teach us new technical skills, but we hope to design it to teach us the necessary skills required to succeed in today's engineering jobs. Most engineering industries seem to be moving towards a "project" based development cycle which we have tried to model. We are also applying the engineering methodologies taught to us in design classes towards the efficient implementation of our project. We strongly believe that this project will be a proud addition to the resumes of our team members, and we hope that it will be successful enough to catch the eye of local high-tech industries and the general public.

Community Impact

As engineering students, we obviously value our engineering education. However, we feel that engineering does not always get the best press; the stereotype of the computer nerd has put a dull coffee stain on the excitement and challenge of engineering. We would like to bring a little more fun and excitement into the perception of engineering by presenting our project to local middle and high schools. We have found that younger students have a fascination with rockets and space; we'd like to kindle this fascination and direct it towards engineering. We are specifically designing the on-board color CCD camera and microphone to help us capture the excitement of the launch; we feel the tape could be quite spectacular.

We are already in contact with a few local schools in Portland and are arranging presentations. We are currently planning on a pre and post launch presentation; on the pre-launch presentation we'll introduce building rockets, space and our project. On the post-launch presentation we'll play our launch video and talk about what happened and how we accomplished it using engineering. If possible, we'd like to invite some classes out to the launch itself, although safety concerns may not make this possible.

We are also in touch with our local science museum, the Oregon Museum of Science and Industry (OMSI). OMSI is very interested in showing our tape and displaying our rocket as a part of their space sciences display. We hope to coordinate the launch with them as a public relations event.

And finally, we'll bring our flight video to the local news media to broadcast on the nightly news. Not only will it make a great short segment they can bait their audience with throughout their new show, but we'll get a chance to plug science and engineering education at our school as important and worthwhile. Finally, after having added some video shorts on building and launching the rocket, we will offer the video tape to other organizations such as public broadcasting stations and programs, school libraries and amateur rocketry clubs. We hope that this possible wide spread media attention to the project will bolster the reputation of Portland State University's engineering program. PSU has seen a significant revamping of its engineering programs; we would like to demonstrate how far PSU has come by using our project as a public example of the integration and success of our engineering and science programs.

Further down the road, we hope that the scientific data we acquire from our higher altitude flights may benefit the community as well. Pollution and radiation counts from the local upper atmosphere may help explain local weather and pollution patterns not easily identified using weather balloons or radar.

Future Projects

After the completion of our project outlined in this proposal in June of 1998, we will start "Phase 2" as we affectionately call it. The completion of our first project will have proved the launch vehicle and payload design in real flight conditions; the next step will be to increase the maximum altitude. By adding the already constructed second stage, two stage flight could boost our ceiling to higher than 50,000ft. At this altitude (roughly 10 miles straight up), the horizon should be curved, and stars should be visible even during daylight. To capture such imagery on video would be spectacular and inspiring. Adding a second CCD camera would capture stereoscopic images of the flight; using a VR headset, watching the videos would be as close as you could get to actually sitting on the rocket during flight. And at these altitudes, not only can real atmospheric science could be done, but the long descent could be used for microgravity research.

After launching the two-stage, we plan to construct a more complex launch vehicle. By this time, we should have enough data to integrate our inertial sensors into a active guidance system. An active guidance systems makes vectored thrust technology practical and will allow us to move on to new fuel systems such as liquid and hybrid fuels. New fuel systems will allow us to reach higher ceilings. While it would be incredibly difficult to make orbit with anything less than a few orders of magnitude larger budget, by pushing the envelope of our launch vehicle and payload, we can push ourselves into the realm of real aerospace engineering and science.