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Kentucky Space: A Multi-University Small Satellite Enterprise

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ABSTRACT

Kentucky Space is a consortium of universities located throughout the Commonwealth of Kentucky who have developed a collaboration with the goal of developing technologies and expertise in small satellites. In three years, Kentucky Space has progressed from concept to the launch of three sub-orbital sounding rocket payloads, the launch of a near-space high-altitude balloon mission, and the completion of its first satellite, KySat-1, which is scheduled to launch in 2010. To support these missions, Kentucky Space has established a network of VHF/UHF ground stations, adapted the 21-meter radio telescope at Morehead State University to support S-band communications for Low Earth Orbit satellites, and established fabrication and testing facilities to build and flight qualify small satellites; these include a dedicated cleanroom, thermal-vacuum facility, vibration facility, and communication test facilities. With students participating throughout the state, the team faces many of the challenges encountered in the aerospace industry today in terms of systems engineering, documentation, communication, scheduling, and management of a distributed team. This paper describes the past, present, and future projects of Kentucky Space and discusses the approaches used by the student team to overcome the challenges of operating a multi-university program.

INTRODUCTION

Kentucky Space is an ambitious non-profit enterprise involving a consortium of universities, public organizations, and private companies formed to design and lead innovative space missions with realistic budgets and objectives. Kentucky Space projects train students in the dynamics of spacecraft design, construction, testing and operation as a means of extending science and technology education, R&D, innovation and economic development in Kentucky. Kentucky Space projects involve an ongoing series of satellite missions – each with increasing scope and complexity. Partners in Kentucky Space include: University of Kentucky, University of Louisville, Morehead State University, Murray State University, Western Kentucky University, the Kentucky Community and Technical College System, Kentucky Space Grant Consortium, Kentucky Science and Engineering Foundation, Kentucky Council on Post-Secondary Education, Kentucky Science and Technology Corporation, and the Belcan Corporation.

All the missions undertaken by Kentucky Space are student-led and student-designed with guidance and expertise provided by mentors in both industry and academia. As these missions are inherently multi-disciplinary, students get to experience many different engineering fields while still facing challenges and gaining experience in their specialty. This multi-disciplinary atmosphere gives the student knowledge and experience in systems engineering as they are encouraged, and often required, to learn about all aspects of the design and not just their specific section. As these projects are also student-led, program management is a skill that the students acquire which is difficult to attain in a conventional academic environment.

This paper describes the history of Kentucky Space along with its purpose, mission statement, and goals. Additionally it discusses the projects both completed and in progress that were undertaken in order to achieve those goals as well as the infrastructure that was developed to complete the projects. Finally, it reviews some of the collaboration tools and program management methods that are employed to allow Kentucky Space to complete these projects while overcoming the geographic separation of the students involved.

BACKGROUND

The Kentucky Space (formerly KySat) consortium was formed in 2006 under the leadership of the Kentucky Science and Technology Corporation (KSTC) a private nonprofit corporation committed to the advancement of science, technology and innovative economic development in Kentucky. Through the KSTC Advanced Concepts Office at Moffett Field, the Kentucky Space consortium has established close ties with several divisions at the NASA Ames Research Center. For three summers Kentucky Space students spent time at that office immersing themselves in the aerospace world and learning what it takes to complete an aerospace mission. This experience included tours of and meetings with California Polytechnic University's CubeSat program and Stanford University's Space Systems Development Laboratory. Students took that knowledge and applied it to the projects undertaken by Kentucky Space, and they continue to apply it as they pass it on to new students and use it in order to achieve the goals set forth by the consortium.

Kentucky Space's ultimate goal is to design, build, launch and operate a small spacecraft every 12-18 months, giving the Commonwealth of Kentucky a permanent presence in space. The plan to accomplish this goal is to solicit public and private payloads for an on-going series of launches of near-space, sub-orbital and orbital missions.

A major goal of the consortium is the development of human infrastructure to support NASA's space initiatives by investing in the "talent pool" and laboratory facilities used to train the graduates at the partner institutions in Kentucky. Developing the capacity to design and fabricate spacecraft subsystems, along with the capacity to design and operate Earth station systems to support KySat and NASA missions, constitute a significant asset to the nation's future space missions.

MISSIONS

KySat-1

The flagship project of Kentucky Space is the KySat-1 orbital satellite.[1] KySat-1, Figure 1, is a 10x10x10 cm, 1-kg satellite following the CubeSat standard.[2] The primary mission of KySat-1 is educational outreach to both university students who are designing the satellite and to K-12 students and teachers, ultimately providing opportunities for hands-on learning in the Science, Technology, Engineering, and Math (STEM) disciplines. The outreach payload includes a low-resolution camera and a relatively high powered (for CubeSats) UHF/VHF radio to allow satellite communication from small portable ground stations that can be easily set up on a playground or parking lot of a school. KySat will also carry a communications payload, a commercial 2.4 GHz high-speed transceiver, which will be tested for feasibility of use in a space environment as well as the in-situ optimization of several parameters.

Figure 1: KySat-1 in a P-POD

The secondary mission of KySat-1 is that of technology development and process maturation. KySat-1 is the first satellite built in the Commonwealth of Kentucky and there was a steep learning curve for all those involved, students and mentors alike; therefore the focus of KySat-1 is on the satellite bus with the purpose of gaining confidence in the hardware that was used and our design and fabrication procedures; as well as becoming familiar with the management techniques needed when working with a complex system involving third party developers. KySat-1 is a combination of custom and commercial components with a focus on reproducibility with an end goal of combining the KySat-1 bus with third party payloads resulting in quick turn-around times.

In 2008, the KySat-1 CubeSat was down-selected by NASA in a competition among universities in the United States for a launch on NASA's first effort to carry student built satellites as secondary payloads. The project is now known as Educational Launch of Nanosatellites (ELaNa) Mission. KySat-1 is currently undergoing final flight model integration and environmental testing and will be ready to ship to the launch integrator in September of 2009.

KySat-1 was initiated in 2006 as the first project for Kentucky Space. As time went on, it was realized that there was a need for a mechanism to train new students, learn more about working with launch integrators and other third parties, and to test technologies and processes. With that in mind Kentucky Space embarked on smaller projects while still working to complete KySat-1 with the first of those being a sub-orbital sounding rocket mission called Space Express.

Space Express

Space Express was a sub-orbital sounding rocket mission launched from White Sands Missile Range on December 5, 2007.[3] The launch vehicle was a passive dart on top of a Super Loki, Figure 2, which was designed to reach an altitude of 127 km. Kentucky Space designed a mechanical structure that fit inside the passive dart which held a custom printed circuit board, batteries, and a radio. The circuit board contained a suite of temperature and pressure sensors distributed along the length of the dart in order to establish a profile of the dart during the launch and descent phases. It also made extensive use of technology developed for KySat-1 including hardware, software, and fabrication techniques while helping to develop new processes for Kentucky Space such as rapid prototyping and launch vehicle integration.

Figure 2: Space Express Launch

Figure 3: Student Team and Advisors At WSMR

Unfortunately the launch system suffered a failure which caused both the dart and booster to become unstable and break apart 2.1 seconds after launch at an altitude of 1.7 km. The mission was still considered a success however both because although the booster and dart broke apart, our ground stations received one radio packet 7.5 seconds after lift-off indicating that the payload survived the initial launch and breakup of the launch vehicle and operated nominally and because of the lessons learned from the experience. Those lessons include working toward a deadline, working with a launch integrator, and that it is, in fact, quite difficult to get to space. The next project taken on by Kentucky Space was not as literally high-reaching as Space Express but still offered all the experience as well as greater opportunity for outreach. The project was a high-altitude balloon called Balloon-1.

Balloon -1

As part of achieving the goal of providing quick and relatively inexpensive access to space and near-space environments, Kentucky Space began a high altitude balloon program with the first launch out of Bowling Green, Kentucky in July of 2008. Balloon-1 was primarily a learning experience for Kentucky Space and a training exercise for a new group of students that had just joined in May. The payload consisted of a sensor suite, a GPS tracking device, and a CW beacon as well as two digital cameras that were set to take pictures every ten seconds. The balloon also gave an opportunity for the Department of Homeland Security in Kentucky to test alternative communications technologies in the event of an emergency. The balloon reached ~93,000 feet and was successfully recovered.

The balloon offered an excellent outreach opportunity to people of all ages (Figure 4). There were multiple media outlets there and families were able to come out and learn about engineering and aerospace technologies. The children present had the opportunity

Figure 4: Balloon-1 Outreach

to participate in the launch. They were able to build and launch what are called "PearlSats"; ping pong balls that were cut in half and then filled with objects selected by the children and then attached to the flight string, resembling a string of pearls. PearlSat experiments were recovered and returned to the children.

The Kentucky Space balloon effort builds on the highly successful near-space program called BIG BLUE (Baseline Inflatable-Wing Glider Balloon Launched Unmanned Experiment). BIG BLUE was funded by the NASA workforce development program. From 2002-2007, BIG BLUE provided a comprehensive aerospace experience for over 300 students in ME, ECE and CS designing, developing, and testing high-altitude balloon systems to verify the feasibility of inflatable-wing

Figure 5: Students Holding the Flight String

technology for Mars exploration. To date, the five high-altitude flight experiments and hundreds of low altitude flight tests resulted in > 15% of the participating students entering the aerospace workforce.[4,5,6,7]

One of the major lessons learned during Balloon-1 was the importance of keeping detailed records of inventory, packing lists, and procedures in order to make the most efficient use of time particularly for field operations. This lesson is especially important for missions on short timelines such as the next project undertaken by Kentucky Space, a sub-space launch with the Garvey Spacecraft Corporation.

Garvey Prospector 12-A

The launch of Garvey Prospector 12-A took place out of the Mojave Desert in California in October of 2008 as part of the California Launch Vehicle Education Initiative supported by the California Space Authority. The launch vehicle was a Prospector-12A, a single stage reusable launch vehicle, provided by the Garvey Spacecraft Corporation. Kentucky Space provided a six-axis inertial measurement unit (IMU) as a payload with the intention of using the recovered data to reconstruct the flight path of the launch vehicle.

Figure 6: Student Team and Advisor at Mojave

This mission was accomplished on a very short timeline. From its beginning to delivery of the payload to the launch integrator was six weeks. This short timeline led to several lessons learned including the importance of documented procedures and test results as mentioned above and also that it is sometimes necessary to eliminate system performance in order to reach a deadline. Kentucky Space originally planned to include pitot tubes, magnetometers, and cameras as part of the payload, but all these systems had to be eliminated to deliver the payload on time.

Sub-Orbital CubeSat Experimental Mission

The latest project, as of August 2009, is a sub-orbital mission scheduled to launch out of NASA's Wallops Flight Facility in August of 2009. This mission is unique in that Kentucky Space is not only providing a payload but it is also integrating a third party payload and manufacturing the launch vehicle interface that will attach the payload to the launch vehicle. The mission is known as Sub Orbital CubeSat Experimental Mission (SOCEM), as both payloads follow the CubeSat standard and are being ejected out of the rocket using a similar mechanism that is used with orbital CubeSats, Figure 7. The mission is also unique in that this mission is the first whose primary goal is the testing of hardware that will be used on KySat-1. In previous missions the primary goal was personnel training and process development. The payload was developed jointly by members of Kentucky Space and as a class project at the University of Kentucky.

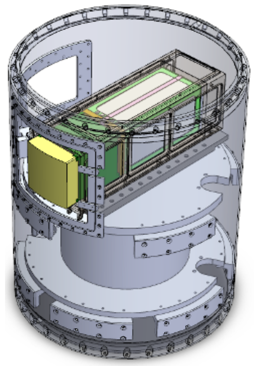

Figure 7: SOCEM Experimental Concept

The payload designed by Kentucky Space is known as ADAMASat and will test KySat-1's antenna deployment mechanism. The ejection system, shown in Figure 8, used for the SOCEM mission created several constraints typically not seen in CubeSat missions. Once the launch vehicle has reached altitude a side door will open via a pyrotechnic system allowing both payloads to be ejected into space. At ejection the vehicle will be spinning at approximately 4 Hz creating design constraints on both payloads concerning their centers of gravity. With this design consideration in mind Kentucky Space has designed ADAMASat with a center of gravity much closer to the spin axis of the launch vehicle to minimize the inertial force becoming greater than the ejection spring force and preventing a successful mission. Additional constraints were also placed on other hardware components used for the SOCEM mission including a pedestal that interfaced the launch vehicle bulkhead with the ejection system had to be specially machined to assure the entire payload was balanced as well as a specially machined interface between the leading payload and the rocket door.

Figure 8: Poly CubeSat Launcher With Mass Models Inside

This mission is the first time that Kentucky Space will reach space; the launch vehicle is designed to reach an altitude of 200 km. This mission is representative of the goals of Kentucky Space as it incorporates education, provides a launch opportunity for third parties, tests hardware that will be used in future missions, and provides an opportunity for students to manage ground operations. Kentucky Space is also involved in activities other than space missions in order to achieve the goals set forth at its inception such as researching topics relevant to small satellites and developing the necessary infrastructure for aerospace missions.[8]

INFRASTRUCTURE

One leading motivation when the Kentucky Space consortium began was to develop all necessary facilities for the development and testing for any missions undertaken. This infrastructure would include systems for environmental testing (vibration/thermal-vacuum), airframe fabrication (machine shop/surfacing), communications (anechoic chamber/far field range/ earth stations), and final construction (clean room) facilities. Within the last eighteen months facilities for each of the above systems have either come on line for use by Kentucky Space or will soon be ready.

Vibration

To achieve the rigorous vibration requirements lain out by launch providers and integrators, Kentucky Space has begun developing a comprehensive vibration testing system located at the University of Kentucky, Figure 9. Previous research focused on fatigue testing of automotive and agricultural equipment at low frequencies and amplitudes over large intervals of time. This is an extreme contrast to the relatively high frequencies and short duration testing needed during satellite environmental testing. To repurpose the existing facilities for their new uses Kentucky Space

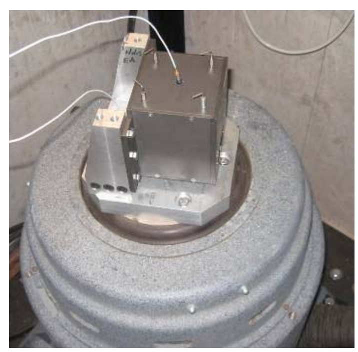

Figure 9: Vibration Facility

faced several challenges including the loss of several key faculty members with knowledge of the previous system along with the shaker itself being unused for the previous eight years.

The first concern addressed was to have the existing MB Dynamics C10E shaker serviced by a licensed technician to assure the system had not sustained degradation to any of the mechanical or electrical components during its dormancy. With the shaker checked out, Kentucky Space began designing a controlling software system with help from the Belcan Engineering Company and a university PhD student. The software was written in LabView with original capabilities including sine sweep and random vibration tests. Problems were encountered during initial qualification testing involving the added processing time needed in the beta version of the software along with uncertainty with the controlling ability of the code. To add to the problem, using an entirely different software platform than all other testing centers left Kentucky Space with a disadvantage as most reports use a consistent commercial software package instead of a one-of-a kind system. Currently, Kentucky Space is fielding proposals for a commercial grade software package that will broaden the range of testing that the system will be capable of as well as assuring consistency and confidence in all testing performed on the system.

Fixture design is one area where Kentucky Space has obtained consistent results while also gaining an understanding of the principles to be considered in minimizing fixture resonances, assuring payload safety, and reliability of testing. The initial design which was considered before the shaker system was running involved a clamping design in which a test pod, containing the satellite, was held in place by tightening down an aluminum beam to thus preventing the test pod from experiencing any unwanted movement. This design proved to be troublesome as the fixture caused the response of the satellite and test pod to be coupled with that of the shaker's armature and base plate; causing the control and experiment accelerometers to read similar outputs and resulting in the software shaking the fixture at a much lower level than needed.

With this in mind a new fixture was designed that ultimately de-coupled the response of the test pod from that of the base plate. This allowed the control accelerometer to shake at the specified test levels and allowed the experiment accelerometer to measure the satellites natural response. The new fixture, shown in Figure 9, does not use the clamping mechanism but affixes the test pod to a modified version of the previous design.

At this time Kentucky Space is considering several possible upgrades of the vibration facility to ultimately allow the system to be used for a variety of tests over a range of applications including aeronautical, automotive, biomedical, and structural tests. These updates include some cosmetic changes; currently the shaker is attached to the floor on a recessed platform that facilitated research involving tractor cabs. This positioning required additional time for all testing as a researcher must climb down into the recession for any maintenance which includes turning all power off for safety reasons. The current plan is to move the shaker to a new area at floor level that will allow for easier testing and reduce time along with allowing for better demonstrations during tours and labs.

Thermal Vacuum Chamber

Kentucky Space's environmental testing facilities also include an operational thermal vacuum chamber located at the University of Kentucky's Space Systems Lab. The chamber allows Kentucky Space to mimic the harsh atmospheric conditions and temperature fluctuations that the payloads will experience on orbit. The chamber, shown in Figure 10, has a volume of 3.3 ft^3 and uses both roughing and turbo pumps to achieve pressures as low as 10^{-7} torr when testing with a payload. The thermal testing is accomplished with four resistive patch heaters and a liquid nitrogen cooling system. The heaters have the capability to raise the test article up to 90° C; currently the cooling system is in the final stages of construction. Kentucky Space presently uses the chamber for outgassing and bake out procedures and will add thermal cycling within the coming year to provide full testing for all CubeSat standard payloads.

Figure 10: Thermal Vacuum Chamber

Prototyping, testing, and constructing all Kentucky Space payloads requires proper facilities with the ability to fabricate all parts in a short time frame while maintaining tight tolerances. Kentucky Space is fortunate to have multiple resources with knowledge of the processes used and access to the machinery necessary to fabricate these parts. Both Morehead State University and the University of Kentucky contain machine shops where quick, high-quality parts can be made in close proximity to Kentucky Space labs. This capability drastically cuts down on time required and allows for quality communication between the designer and the machinist. When extremely sensitive or complicated parts are needed, the University of Kentucky utilizes the College of Engineering's Center for Manufacturing which employs several CNC machines that can produce unique quality parts ready for testing and later flight. Along with the fabrication opportunities Kentucky space also has the ability to quickly anodize all spacecraft parts within a day; The Department of Chemistry at the University of Kentucky machine shop include glass making and surfacing capabilities which Kentucky Space uses for quick turnaround missions.

When all components have been designed, fabricated, and tested for Kentucky Space payloads their final assembly occurs in the consortium's clean room located in the Space Systems Lab at the University of Kentucky, Figure 11. The clean room is a class 10,000 18' x 12' area which assures that no foreign particles can interact with a key component and thus jeopardize a mission. All employees who enter the clean room must wear protective gowns, gloves, and hairnets to guarantee cleanliness. Two cabinets located in the clean area keep all integral components, tools, and flight hardware locked so that they are secure when not being worked on. The area contains its own set of tools and electronic test equipment so that all components are tested before being assembled into a flight model to guarantee readiness.

Figure 11: Clean Room at the Space Systems Lab

VHF/UHF Earth Stations

Kentucky Space is currently maintaining and operating two Earth stations consisting of VHF/UHF Yagi arrays used in conjunction with a motorized azimuth and elevation array rotators, back-end receivers, and tracking software to allow the antennas to track satellites during passes.

Figure 12: VHF/UHF Antennas

Each station uses an ICOM America IC-910H transceiver in conjunction with a 2 meter linear amplifier to boost the transmitted signal strength and an ICOM America AG-35 70cm preamplifier to boost the incoming signal. A 50 Amp/13 volt Astron power supply powers a PacComm PicoPacket terminal node controller (TNC) which is responsible for the formatting and unformatting of AX.25 packets. The satellite tracking hardware consists of a Yaesu Antenna rotator and a ZL2AMD rotator/radio controller which commands the rotator and commands the radio to account for doppler shifts.

Custom software is currently being developed by Kentucky Space to aid in commanding the KySat-1, reassembling the received data, and to allow for amateur radio enthusiasts and the public at large to receive and decode the telemetry sent back from the satellite.

21 M Space Tracking Antenna

The Space Science Center at Morehead State University has developed a full motion 21 m class antenna system which is engaged in a rigorous research program in radio astronomy and also serves as a ground station with the capabilities for tracking low earth orbiting (LEO) satellites and serving as a test bed for advanced RF systems. The instrument provides a unique educational tool that serves as an active laboratory for students to receive hands-on learning experiences with the intricacies of satellite telecommunications and radio astronomy. This major research instrument provides a state-of-the art laboratory for researchers and students in astrophysics, satellite telecommunications, engineering (including electrical, mechanical, and computer architecture), and software development. The 21 m antenna system became operational in the autumn

Figure 13: 21 Meter Antenna

of 2006 and is currently engaged in a rigorous scientific program in fundamental research (observational radio frequency astrophysics), applied research (satellite telemetry and antenna feed development) and satellite operations support.

The gain of the large 21-meter antenna combined with the sensitivity of receiver systems at L, S, and Ku bands together provide a powerful telescope for teaching and research in radio frequency astrophysics. Astrophysics research supported with the 21 m includes:

- long-term monitoring campaigns (of active galactic nuclei—AGNs)
- sky surveys (including kinematic maps of the Milky Way)
- transient phenomena (supernovae and gamma ray bursters-- GRBs)

In Earth station mode, the 21 m is capable of tracking a variety of satellites including LEOs, MEOs, GEOs, and lunar orbiting and fly-by spacecraft. The primary aspects of mission operation services for which the 21 m Earth station are utilized include satellite tracking and associated scheduling, command sequence generation, uplink and downlink commanding, science instrument control, satellite housekeeping, orbit tracking, management of downlinking activities including science and telemetry data acquisition. Scheduling and commanding of the satellites are carried out by ground station personnel that include a significant student workforce component. The 21 m will serve as the primary Earth station for the KySat-1 and -2 orbital missions, as an Education and Public Outreach (E/PO) Earth station for NASA's PharmaSat mission, and as an Earth station for future NASA (and potentially ESA) missions.

Electromagnetic Anechoic Chamber

The Kentucky Space electromagnetic anechoic chamber, located at Morehead State University, (Figure 14) is an experimental laboratory that simulates the electromagnetic environment of space to allow testing and measurement of antennas and communication devices. An anechoic chamber is essentially an experimental room lined with RF absorbent material and which contains an antenna positioner and controller that allows for a variety of empirical measurements of antenna performance. The facility will allow MSU to establish an antenna verification program, to characterize the RF performance of space-based and ground-based (Earth station) antenna systems. The anechoic chamber will allow empirical measurements of antenna parameters such as radiation patterns, gain, system temperature profiles, astronomical radio source gain-to-noise temperature ratio (G/T), cross-polarization isolation contours, and effective isotropically radiated power (EIRP) stability.

Figure 14: Anechoic Chamber

MSU acquired the anechoic chamber as part of a University-Industry partnership to relocate the COMSAT Clarksburg MD facility's anechoic chambers and antenna test range to Morehead State University. COMSAT, which is now Lockheed Martin Global Tele-communications, no longer had a requirement for this type of research facility, and gave the equipment to MSU. The COMSAT anechoic chamber is world-famous in the satellite antenna business, having been used to verify antennas that flew on the INMAST and INVARSAT series of satellites. The chamber will allow faculty and staff at MSU to focus on the development and characterization of space (and terrestrial) communication systems, and facilitate the testing of Kentucky Space Systems.

Antenna Test Range

Antenna design, fabrication, and performance verification is imperative to the success of Kentucky Space systems. To support these efforts, a free space antenna range capable of testing antennas from 100 MHz to 18 GHz (with range extension to 40 GHz planned) has been developed by the Space Science Center at Morehead State University. The antenna test range is used to measure performance characteristics of test antennas. Parameters such as gain, pattern, VSWR (return loss), cross-polarization rejection, among others will be measured to research-grade precision with the test range. This is accomplished by using a 3-axis pedestal for the antenna under test, to allow accurate movement in azimuth, elevation and polarization, under computer control. The receiver system uses a scalar analysis measurement system (based on a source and receiver, both under computer control). The range source consists of a remotely controlled synthesized generator, driven by IEEE-488, capable of covering the frequency range from 50 MHz to 18 GHz, with sufficient output power to drive power amplifiers. The receiver currently uses a spectrum analyzer (a scalar network analyzer is used for specific tests, such as VSWR). As the measurement system evolves, vector measurement capability (a vector network analyzer) will be added to permit array optimization through phase front measurement techniques. A broadband source antenna set, using horns and log spirals, remotely selectable, can be used to provide the measurement excitation.

The antenna test range is used to design and verify a variety of antennas and feeds for commercial and research purposes. The outdoor range is used to characterize feed systems for the 21 m antenna to provide high performance operation in both the telemetry/tracking missions and the radio astronomy roles. The range is also being used to validate and characterize the communication systems for the KySat series of Earth-orbiting satellites.

Morehead State University Space Science Facility

Morehead State University has completed construction of a \$15.4 million, 45,000 ft^2 state-of-the-art R&D and instructional facility for Space Sciences, artist rendering shown in Figure 15. Groundbreaking occurred in March, 2007 and construction was completed in May 2009. The facility will house a state-of-the-art control center for MSU's 21 m Space Tracking Antenna, RF and electronics laboratories, an anechoic chamber that mimics the electromagnetic environment of space, an advanced computing facility, a rooftop antenna test range, a Class 100/1000 clean room (which will include a micro-nano-laboratory and a space systems development laboratory), machine shop, offices and reception area, and a digital Star Theater. The facility serves as an R&D facility for fundamental and applied research.

Figure 15: Space Science Center

OUTREACH

Outreach to K-12 students in the state is a main priority of Kentucky Space. An important goal is the encouragement of students to take interest in Science, Technology, Engineering, and Math (STEM). Significant effort is devoted to including outreach opportunities on every mission undertaken by Kentucky Space and those efforts continue to evolve with the program. While Ballon-1 allowed students to fly PearlSats, KySat-1 will allow students to communicate with the satellite while on orbit along with the capability of taking pictures with the onboard camera. Kentucky Space is developing mobile ground stations that can be taken to schools and operated by students. Also under development is user-friendly software with which a student or teacher can log onto a server to communicate with KySat-1 without the hardware normally required.

Kentucky Space operates a website, located at www.kentuckyspace.com, which includes updates of current and upcoming missions and news concerning student space projects. Upon the launch of KySat-1 the website will provide orbital information as well as make available the telemetry received from KySat-1 in orbit. Kentucky Space also maintains a blog which provides daily posts about Kentucky Space missions and information about who Kentucky Space is, past missions undertaken and current news related to aerospace and space science.

In the future Kentucky Space will utilize Morehead State Universities brand new Star Theater for outreach and education. The Star Theatre is a 108 seat multi-function, state-of-the-art digital classroom. The auditorium includes a full dome (360 degree) projection system with 6 digital star projectors and surround sound systems. The Star Theater is as an instructional tool for space science students, K-12 student groups, and for general public programs. The Star Theater will host special events such as planetarium shows, NASA produced videos and commercial full dome movie features. The Star Theater will also be used to showcase movies and photos taken from cameras attached to Kentucky Space missions including future high altitude balloons and sub-orbital rockets.

MANAGEMENT

Managing multiple missions and projects while developing infrastructure, and especially with a geographically distributed team, requires a suite of collaboration tools that allow easy sharing of designs and the ability to track the changes that have been made to a design. Kentucky Space utilizes three different tools for design sharing and collaboration: a wiki, a source code management system, and a file server.

The wiki is used to track design decisions and system specifications. The ability to have access to the wiki from any internet connected computer and the ability for anybody, with the proper permissions, to edit the wiki allow it to be a living document that is easily accessible to an entire team and allow design changes to be documented in real time so everyone has access to the latest specifications. Finally the ability to track changes, revert to previous revisions, and take snapshot backups prevents any catastrophic loss of data to either user error or equipment failure.

The source code management system is used to allow multiple software developers to collaborate on the same software project from multiple locations with constant access to the latest code written by any of the developers. It is similar to the wiki in its accessibility and its ability to track changes, revert to previous revisions, and produce snapshot backups. It differs in the fact that it places actual files on the user's computer and will only update those files or commit changes made by the user on command. It also has the ability to do side by side comparisons of modified files and the ability to merge changes made by two different users on the same file. A source code management system of some kind is a near essential for any complex software development project.

The file server is used for actual files that do not contain code. It allows the sharing of large files and the accessibility necessary to work from remote locations. It does not have the ability to track or revert changes made but it does allow for robust backups using common RAID systems.

The key to making these collaboration tools work is a robust organizational structure. As with any tool, if it is not easy to use it will not be used. The structure needs to be at least two-tiered; a structure that specifies what data each individual tool will contain and a structure that specifies how that data will be organized within each tool. When implementing such a system it is very important to invest the time at the beginning in designing the organization of the structure and to enforce and maintain the organization continuously. It is a much more daunting task to reorganize a structure than to invest the time in the beginning to make it easy to use and maintain.

Beside the technology used, the actual management and delegation of responsibility, especially with students, is not a trivial task. The overall management organization and structure has to be a top down process for each project. Meetings and design reviews play an important role in managing a team especially at the beginning of a project. The first important step is developing well-defined requirements which will allow a team to work toward a goal and narrows focus onto completing a task. Not doing this will lead to confusion, frustration and apathy within the team which leads to an imbalanced work load between the team members. It is tempting to skip this step especially during rapid turn-around missions but the consequences are an inferior end product and unhappy students as a lack of clear goals will result in the estrangement of all but the most self-motivated students. A lack of clear goals also leads to a never ending spiral of additional features and capability which can delay full robust testing of the most important aspects of the mission. During the Garvey mission much time was wasted on working on aspects of the mission that did not end up in the final product because clear defined goals were not established at the beginning of the mission which also led to some oversights in the final product which led to the data collected not being as good as it could have been.

Weekly meetings and multiple design reviews are also very important but again are easily allowed to slip into obsolescence. But it is critical that these are sustained as they are vital in maintaining students' motivation and vision; if these meetings and reviews are allowed to falter crucial information will not be transmitted to the relevant parties which can result in incompatible designs. The nature of small aerospace projects lends itself to highly integrated systems where changes in one aspect of the design will ripple through the entire system impacting seemingly unrelated subsystems. This lesson was learned early during the KySat-1 mission. At the first integration attempt it was found that the system would not fit together and a major design change was required. By attempting integration early on this problem was discovered but could have been avoided with the use of meaningful meetings and design reviews.

CONCLUSION

Since its inception in 2006, Kentucky Space has established an active research program involving graduate and undergraduate students under the mentorship of partners from both industry and academia. It has developed the infrastructure necessary to complete multiple projects from near space missions with high altitude balloons to orbital satellites. While doing this it has also developed and refined the necessary collaboration tools and management techniques necessary to efficiently run a small satellite enterprise in spite of geographic separation. With the launch of SOCEM and KySat-1 in the near future Kentucky Space will be well along its way in establishing its permanent presence in space while developing a talent pool for Kentucky and for the aerospace industry as a whole.

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