2006-449: INDUSTRIAL ENGINEERING APPLICATION IN SPACE MISSION

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INDUSTRIAL ENGINEERING COLLABORATION WITH NASA ST-5 PROJECT

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Abstract

The study of designing for cost-effective manufacturing is a critical development in any manufacturing process to promote profit. Due to the growing financial pressure, it also holds true in NASA's space missions, where it is imperative to consider mission requirements, reliability of the spacecraft, and mission success while attempting to maintain low cost. Since there is no direct monetary profit, the goal is to promote the success of future space missions. As a result, the success in a space mission would be defined as satisfying all mission requirements and decreasing the cost of future assignments. Morgan State University (MSU) Industrial, Manufacturing, and Information Engineering Department has collaborated with the Space Technology 5 (ST-5) Project Team of the National Aeronautics and Space Administration (NASA) at Goddard Space Flight Center in an effort to study the expenditures of creating three Nano-Satellites (Nanosats). The ST-5 nanosats are small but intelligent satellites with miniaturized subsystems and components. This type of nanosat can be used in specialist communications, remote sensing, rapid response science, military operations, and technology demonstrators. The three ST-5 satellites will be used to test several new technological components and simultaneously accomplish a science mission to collect the data of the Earth's magnetic field. This innovation is one of NASA's New Millennium Programs and is known as Space Technology 5.

1. Introduction and Background

For years now, space exploration has thrived and there is an ever growing interest in the realm of outer space. As a result, more and more critical information is being discovered as countries all over the world attempt to take their ambitions and explore outer space. Consequently, the National Aeronautics and Space Administration (NASA) have been at the head of a lot of the discoveries and in satellite development. Currently, the Goddard Space Flight Center, located in Greenbelt, Maryland, is developing three small satellites under NASA's New Millennium Program (NMP). The NMP is a program designed to test and validate flight technology. In more detail, the name of this New Millennium Project is called Space Technology 5 or ST-5. Other NMP Projects include *Deep Space 1*, *Deep Space 2*, *Earth Observing 1*, *Earth Observing 3*, and *Space Technology 6*, etc[1].

The three ST-5 spacecraft have been built and are undergone various deployment tests to assure a successful launch on March 11, 2006, being lifted by a Pegasus XL rocket from Vandenberg Air Force Base (Figure 1). In more detail, the ST-5 spacecraft is distinctly characterized from its lightweight structure (less than 25 kilograms), octagonal shape, and specific constellation objectives. The MSU research team is working closely with the ST-5 civil servants and the project manager. The MSU research team has participated by performing cost analysis, of the recurring and nonrecurring cost of building and testing these three elite spacecraft, through the use of interviewing and surveying subsystem technical leads. Also, from

the expenditure data the team will attempt to construct a learning curve by comparing the expenditures per unit. In more detail, NASA may use this information in consideration of building tens to hundreds of similar spacecraft in future constellation missions. Also, the team is constructing a non-functional mock-up of the ST-5 satellite, which will assist in their comprehension of its intricate mechanisms and evaluation of manufacturing strategies. Therefore, the mock-up can be useful in recommending manufacturing cost reduction methods. Some of the reduction processes that can be evaluated are technology, process changes, launch cost, spacecraft cost, and possibly mission operations cost. In summary, this research has provided the students with a real-life experience on NASA's space mission. It is important because of a possible contribution in significant cost reduction for the future manufacturing of multiple spacecraft production runs.

Figure 1: Three ST-5 Spacecraft on Pegasus XL launch vehicle, being lifted on March 11, 2006.

These three small satellites will assist in constellation and technology missions. To clarify, constellation missions are simply intelligent multi-spacecraft flight operations. One of the major benefits to a constellation mission, in contrast to a single spacecraft launch, is mission failure risk mitigation. Nano-satellites are often used in constellation missions because of their project objectives and capabilities. Moreover, this mission is also a technology based operation and not primarily a science mission, even though it does have some science objectives. The main science objective is to simply use the new technologies to get some useful information of the Earth's magnetic field and validate the constellation measurement concept for future SEC Geospace Science and Space Weather missions[1]. However, the foremost priority of NASA is to create a fully functional satellite under 25kg that has many of the same features a larger satellite has and use these three flight units to test specific component technologies[2]. For example, the New Millennium Program's technologies include a cold gas microthruster, CMOS Ultra-Low Power Radiation Tolerant Logic (CULPRiT), and a miniature communication X-band transponder[1]. In addition, some other technologies include a nutation damper, miniature magnetometer, and a miniature spinning sun sensor, etc. Many of the subsystems are constructed at Goddard, though some other partners or contractors also include Boeing, Northrop Grumman as well as Jet Propulsion Laboratory (JPL). However, after a successful launch, the concept may

be extended to the manufacturing of more satellites and the industrial partners may be contracted for multiple production runs of the spacecraft, instead of the in-house manufacturing. For example, the industrial engineering concepts in dealing with mass production of aerospace products will be useful for the future space constellation mission of flying tens or hundreds of similar spacecraft.

In addition, small satellite exploration is important, due to the interest in more economical space missions, and the increasing demands for timely access to space[3]. The ST-5 project team has gone through a successful concept review in May 2000, a successful preliminary design review (PDR) in September 2001, a successful critical design review (CDR) in June 2002, and another successful Delta CDR in July 2004. The Delta CDR was held as a result of mission requirements changes. One of the changes was a change in the orbit the ST-5 was designated to be in. The ST-5 is no longer going to be in an equatorial orbit but now is set to be in a polar orbit. Also, the launch vehicle has been changed and the interfaces had to be redesigned. Now that these three small spacecraft have been designed, NASA engineers are in the implementation phase and beginning the preparation of on-site testing, aimed at a launch date in early March 2006 from Vandenberg Air Force Base in California.

2. Main Focus of MSU Research Team

The focus of this project is to perform some cost analysis, of the recurring and nonrecurring cost of building and testing these three elite spacecraft, through the use of interviewing and surveying subsystem technical leads. The cost calculation will in turn allow us to predict the cost of producing tens to hundreds of spacecraft in the future.

Recurring cost and nonrecurring cost are the two main categories used to describe expenditures in this project. Costs that are repetitive and occur on a regular basis as a result of consistent production of a product are called recurring cost, which are also variable cost[4]. Furthermore, nonrecurring costs are the exact opposite of recurring cost. Nonrecurring costs are one-time cost and will often include the setup cost in a project at the beginning of the life cycle[4].

3. Engineering Education Application

Morgan State University's Industrial Manufacturing and Information Engineering program has provided the Undergraduate students and Graduate Student the scholastic foundation for accomplishing the objectives of the project. In addition, it was necessary for students to seek out the supplemental knowledge to complete the project and have high-quality results. Students acquired this information from GSFC spacecraft tests, and foundry managers, etc. Also, the students wanted to get a full comprehension of the spacecrafts intricate mechanisms by building a full-scale mockup model.

Networking at Goddard Space Flight Center

Numerous trips were made to the GSFC to observe some of the test being held on the actual flight units, including a vibration test, balance test, and spacecraft deployer test. All of the tests that we observed were fascinating and motivational. The tests usually were filmed by

multiple still cameras and sometimes video footage was recorded. There were many people in attendance and welcomed us to watch the test and offered some brief explanation of what we were seeing. Even though, students could not participate, they were welcome to observe, take pictures, and ask questions. The site visits to GSFC allowed the students the opportunity to see the project as it progressed along and also gave them the opportunity to ask for advice and speak with the project manager, Douglas McLennan. The students also had several meetings with NASA ST-5 Project Manager Dr. McLennan to discuss our objectives, ask for advice, and get current updates. Dr. McLennan also invited the students to attend the delta CDR, which was a design review for the change in mission requirements. The delta CDR attendees consisted of NASA civil servants, the Jet Propulsion Lab Scientists and Engineers, as well as NASA administrators, and a review board. These visits to GSFC provide an excellent opportunity for students to network and get an inside look at what engineers at NASA do.

Figure 2: Graduate Student Ricky Whittington at a vibration test

ST-5 Nano-Satellite Student Mockup

The student research assistants at Morgan are assigned to make a reasonable mock-up of the ST-5 spacecraft by casting techniques, rapid prototyping strategies, etc. to enhance the student's understanding of manufacturing techniques. The ST-5 engineering mock-up and the approximately half scale desktop model located in the ST-5 team facility in Greenbelt, MD at Goddard Space Flight Center was used as references for duplication, as well as standards of quality. The research team is working on the fabrication phase and making use of the laboratories at Morgan State University. The tentative date to have the mock up spacecraft completed is the end of January 2006, to keep a pace with the ST-5 launch preparation. The mockup is nearly completed, to keep pace with the ST-5 launch preparation.

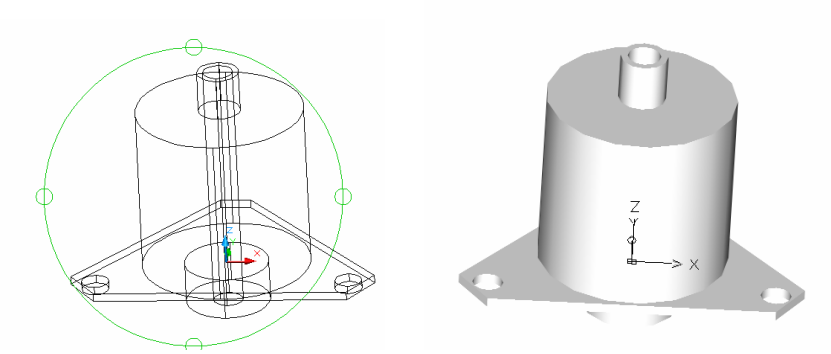

Figure 3: Microthruster Wire Frame and Micro Thruster Solid Model


Figure 4: Actual Microthruster

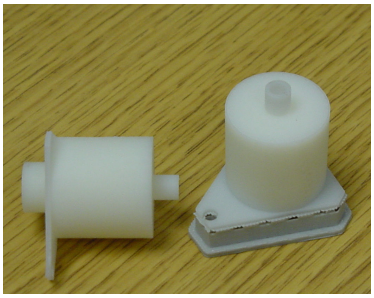
Figure 5: MSU Rapid Prototype

The mock-up is a great way for the students to be educated in the manufacturing effort involved in creating a satellite as well as the project management aspect of creating schedules, attending meetings, and meeting deadlines. Both of these tasks allow for the students to prepare for a career in engineering.

Foundry Tours and Casting Industry Acquaintances

One critical component of creating the mock-up was performing aluminum casting of top and bottom decks. Students have learned the basis for casting in their manufacturing processes class; however, to get more insight students took tours of several foundries and made some important contacts. The foundries include: New Arts Foundry, Swiss Foundry, Foundry Service and Supply, Danko Arlington, and Buck Company. All of these visits provided students with the familiarity of casting to determine what equipment and materials was necessary, what type of casting would best suit out project, and more in creating a quality cast. For the most part, foundries were cooperative and welcomed students.

Figure 6: Graduate Student Ricky Whittington and Undergraduate Edikan Bassey

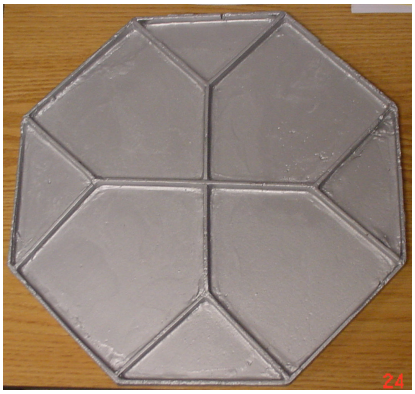

Figure 7: Top Deck Casting

One foundry owner actually visited MSU to assist in the first casting operation and give recommendations. This was beneficial and students were able to take several pictures and scrutinize the procedure. As a result, students made the recommendation to cast the top and bottom decks using a sand casting approach. After several unsuccessful castings, students were able to complete a full scale quality cast.

Figure 8: Visit to Swiss Foundry with Mr. Veljco

4. Future Works / Outreach

The future works that we are now looking to accomplish are the completion of the final assembly of the mock-up for outreach. The mock-up should serve as a great representation of the flight units for demonstration outreach purpose. Also, for the purpose of outreach, the team has developed a poster (Figure 9) serving as a general description of the project to individuals that are unfamiliar with the project. Furthermore, a 44" flat screen television that is currently in the lab will be used to perform presentations to visitors from any institution. The visitors could range from the governmental agencies to students at the local High Schools. Most recently, research associate Ricky Whittington represented ST5 and MSU at the Black Engineer of the year conference in Baltimore, MD. Another poster was created for display purposes at the conference and questions were answered concerning the research. Additionally, we are still working diligently on charts on Microsoft Excel and SPSS that will serve as great references for our cost analysis in the future. We have planned several meetings with the ST-5 project manager to discuss and plan how to complete all of the essential data needed to perform our duties.

Figure 9: Collaboration Project Poster

5. Conclusion

The cost accounting process for space mission is important. For multiple production runs of spacecraft, recurring costs are specifically important because they play a significant impact on total cost. It gives the general idea of how much money is being saved in comparison to a larger spacecraft mission. The involved MSU students have learned and experienced a great deal on space mission and project operation, as well as NASA's technologies, through their collaboration with NASA ST-5 project team and the project manager. Their interest in NASA related research and projects has significantly stimulated. Through working on the mockup, the students have significantly enhanced their understanding of various manufacturing technologies. The project PI, and NASA's ST-5 project manager as well as subsystem leads such as Peter Rossoni, are very encouraging. This research is a great learning experience as well as a great opportunity for the student team at Morgan State University and also proposes a great opportunity for our collaboration with NASA.

Acknowledgements

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