

# Constellation Program Design Challenges as Opportunities for Educational Outreach- Lessons Learned

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## Abstract

The Texas Space Grant Consortium (TSGC) and the NASA Exploration Systems Mission Directorate (ESMD) Education Office both have programs that present design challenges for university senior design classes that offer great opportunities for educational outreach and workforce development. These design challenges have been identified by NASA engineers and scientists as actual design problems faced by the Constellation Program in its exploration missions and architecture. Student teams formed in their senior design class select and then work on a design challenge for one or two semesters. The senior design class follows the requirements set by their university, but it must also comply with the Accreditation Board for Engineering and Technology (ABET) in order to meet the class academic requirements. Based on a one year fellowship at a TSGC university under the NASA Administrator's Fellowship Program (NAFP) and several years of experience, lessons learned are presented on the NASA Design Challenge Program.

## I. Introduction

NASA funded the National Space Grant College and Fellowship Program in 1989 with the mission of partnering with colleges and universities to enhance public understanding of science, technology, engineering, and mathematics (STEM). Currently it consists of 52 space grant consortiums and 850 affiliates nationwide. One of these 52 space grant consortiums is the Texas Space Grant Consortium (TSGC). The TSGC consists of 43 members that include universities, government agencies, industry, and non-profit organizations.

The mission of the TSGC is to ensure that the benefits of space research and technology are available to all in Texas. The TSGC sponsors many educational initiatives statewide that includes the following:

- Sharing of space related source materials among the academic institutions
- Development of multi-institutional space research efforts that team industry/academia
- Promoting high quality undergraduate/graduate-level space research
- Encouraging participation in science and math through space related topics
- Using the broad appeal of space to foster programs and curricula in public schools
- Increasing the pool of high school graduates- with an emphasis on under-represented minorities and women who enter college to study STEM

## II. Design Challenge Program

One of the main educational programs of the TSGC and the ESMD Education Office is the Design Challenge Program. The Design Challenge Program evolved from an earlier design program that was NASA sponsored, nationwide, and operated by the Universities Space Research Association (USRA) from 1985 to 1995. This earlier design program presented NASA focused design efforts at 40 universities across the country. Design projects were suggested by NASA engineers, NASA contractors, and university faculty.

The Design Challenge sponsored by TSGC is open only to colleges and universities located in Texas that are members of the TSGC. The Design Challenge sponsored by the ESMD Education Office is open to all colleges and universities where a design challenge program does not exist in their state. At the end of the academic year, each university team presented its design work in non-competitive conference held at a NASA center. Some of the design topics are the same between the TSGC and the ESMD Education Office.

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### **A. Design Challenge Program Goals and Objectives**

The TSGC Design Challenge Program has provided participating students with an opportunity to engage in meaningful research, invention, and design. One of the main features of this program is the promotion of hands-on project design as part of the course work required for graduation. The TSGC Design Challenge Program goals and objectives have to be aligned with those set by the State of Texas, NASA, and any other national goals. The following are the goals and objectives for the TSGC Design Challenge:

Goal: provide students with a meaningful classroom design experience via real world projects of interest

Objective: establish design teams at TSGC member institutions to work with projects proposed and offered by NASA

Goal: encourage institutions of higher learning to implement, improve, or expand design project curricula

Objective: offer design project opportunities that consider student interest, motivate a high level of performance, provide funding and work well within the framework of required courses

Goal: develop opportunities for substantive student research, training, and design

Objective: seek out mission relevant design project opportunities from NASA researchers that provide students with projects they can envision seeing in use

Goal: engage and partner students, faculty and mentors in the design process

Objective: pair mentors from NASA and industry with student's teams and faculty to work towards the common goal of engineering a relevant design project

Goal: retain student interest in academic pursuits in Science, Technology, Engineering, and Mathematics

Objective: offer challenging project opportunities to student teams that create excitement and interest in pursuing STEM related futures

Goal: advance diversity by promoting collaboration outside academia to include the community at large

Objective: bridge the diversity gap by encouraging teams to participate in far reaching and meaningful education and public outreach activities within K-12 communities, museums, and engineering day events, promote collaboration outside the academic nest and within a diverse professional community at large, reward participation in professional meeting and presentation

Goal: provide participation motivation to students and faculty through resources and rewards

Objective: provide access to opportunities that directly benefit individual students and faculty: career information, professional enhancement, extended learning opportunities, summer internships, and faculty appointments

Goal: facilitate bonds and foster high level teaming between academia and industry via student/mentor and faculty/mentor relationships

Objective: ensure as successful an experience as possible between faculty, team, and customer in order to secure and sustain opportunities for future faculty/mentor/student relationships and avenues for higher level learning

Another goal and objective of the TSGC and ESMD Education Office Design Challenge is contributing to the requirements for engineering accreditation. In order to maintain accreditation, a college of engineering must meet required outcomes set by the Accreditation Board for Engineering and Technology (ABET) where students must demonstrate knowledge and success. The ABET required outcomes (a) - (k) are listed below followed by a brief statement of how the TSGC Design Challenge Program addresses each outcome.

(a) An ability to apply knowledge of mathematics, science, and engineering

TDC participants apply knowledge of mathematics, science, and engineering in the development of the designs to meet NASA requirements

(b) An ability to design and conduct experiments, as well as to analyze and interpret data  
TDC participants must analyze and interpret data from their design trade studies in order to form design alternatives

(c) An ability to design systems, components, or processes to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability  
TDC is based on design and each design satisfies this requirement

(d) An ability to function on multidisciplinary teams  
Teaming is required in the Design challenge. Many TDC teams involve students from several engineering disciplines

(e) An ability to identify, formulate, and solve engineering problems  
All engineering design processes require students to identify, formulate and solve engineering problems

(f) an understanding of professional and ethical responsibility  
TDC provides materials and guidelines that serve to promote an understanding of professional and ethical responsibility. Whether these are used is up to the individual professor

(f) An ability to communicate effectively  
Student teams are required to submit written reports and make an end of year oral presentation to their NASA mentors

(g) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context  
TDC projects have an education and public outreach component. Teams go out and present their requirements to public school classes, make videos explaining their activities, deliver activities or demonstrations that relate STEM concepts to their design project

(h) A recognition of the need for and an ability to engage in life-long learning  
TDC presents learning challenges to participants. Whether this translates to recognition of the need for life-long learning is an open question.

(i) A knowledge of contemporary issues  
Program participants are working on contemporary design problems, presented by professionals in the field. They do learn about contemporary technical problems.

(j) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.  
Participants use many modern engineering tools in their design work. They use CAD programs, computer simulations, solid modeling systems, etc.

## **B. Design Challenge Process**

About a month before the start of academic semester, the TSGC and ESMD Design Challenge Program Managers solicit design challenge topics from NASA engineers and scientists. A NASA ESMD requirement was that the topics had to have relevancy to the Constellation Program. The TSGC and ESMD maintain a website where these design topics and the descriptions of the challenges are posted. This gives the professors that will be teaching the design classes at each university the opportunity to review the projects that align with their design classes. ESMD Education Office also funded a few faculty summer fellowships where the faculty member went to various NASA center and met with engineers and scientists to identify design projects that could be used the following semester.

During the 2008-09 academic year, 8 design projects were selected and posted for students and professors to review and select. Selection of a team name and patch is required as part of the project. The team name usually is related to the topic or the university. The team name and patch create team pride and helps the students to start thinking and working together as a team. It is up to the university whether the project is a one or two semester project. If it is a one semester project, then only the design process is taken to the concept development stage with a

mockup or prototype as an option. If the project is a two semester project, then the first semester is the design process up to concept selection. The second semester is the development of a prototype and testing of the prototype.

The university determines the team composition and the number of team members per team. Ideally, teams would be composed of students from several engineering disciplines in order to get a systems approach to the design challenge. From experience it is very difficult to form multidisciplinary teams due to the class schedules among the various engineering departments. The vast majority of the teams are from a single discipline. Again from experience, an ideal team would have 4-5 team members. Most professors agree that 3 is the minimum and 6 is the maximum for the type of projects under the TSGC Design Challenge Program. Table 1 shows the university, the team name, the composition of the team, the semester, and the project title for TSGC design projects for Academic Year 2008-09.

A typical design challenge write-up includes an objective, background information, the problem, and the team profile. As described earlier, the design challenge has to have relevance to the NASA exploration program. An example of a typical design challenge is the following:

**TOPIC # – TDC-17\_S10**  
**DESIGN OF DUST TOLERANT EVA**  
**COMPATIBLE CONNECTORS**

Design project topic offered by:

NASA Johnson Space Center  
Crew and Thermal Systems Division

**OBJECTIVE:**

In the dusty lunar environment, astronauts will be making and breaking various electrical and fluid connectors with their gloved hands. A goal is keep out dust when the electrical or fluid connector is exposed. Design an electrical or fluid connector for lunar exploration with EVA capability. The connector should include dust mitigation capabilities.

**BACKGROUND:**

America will send a new generation of explorers to the moon aboard NASA's Orion crew exploration vehicle and the Altair Lunar Lander. Orion is part of the Constellation Program to send human explorers back to the moon, and then onward to Mars and other destinations in the solar system. Altair will be capable of landing four astronauts on the moon, providing life support and a base for weeklong initial surface exploration missions, and returning the crew to the Orion spacecraft that will bring them home to Earth.

Once on the moon, astronauts will need to use vehicles, tools and scientific equipment to complete their missions. They will stay in pressurized habitats.

**PROBLEM:** The task would be to design an electrical or fluid connector for lunar exploration with EVA capability and keeps dust out. These connectors could be on the space suit for recharging the portable life support system or on lunar surface systems for assembly or maintenance. The goal would be to creatively design a connector that is easy to operate with a gloved hand while keeping dust out with minimum crew operations and complexity. The Advanced EVA Technology Group will provide information on concepts from previous studies.

**DESIGN TEAM PROFILE:**

☐ **Level:** Upper Division Undergraduate Team: JR, SR

☐ **Major:** ME majors

☐ **Teams:** Mentor may accept more than one team for this project.

Institution and Team Name	Team Composition, Semester, and <i>Project Title</i>
Lamar University Launders	All senior ME Design Team, Semester I of II (two semester project) Design of a Highly Efficient Horizontal-Axis Washing Washing Machine for Lunar Base
Texas A&M University, Kingsville HOGS	All senior ME Design Team, Semester I of II (two semester project) Wardroom Table for the International Space Station
Texas Tech University WORKOUT	All Senior ME Design Team, Semester I of II (two semester project) Exercise Device for the Crew Exploration Vehicle
University of Texas NKD Texas Design Team	All Senior ME Design Team, Semester I of I (one semester project)
Texas A&M University TEAM FIT	All Senior BMEN Design Team, Semester I of II (two-semester Project)
University of Texas, San Antonio VORTEX	All Senior ME Design Team, Semester II of II (two semester project) Design of Dust Tolerant EVA Compatible Connectors
Texas A & M University, Kingsville KOIOS	All Senior ME Design Team, Semester I of II (two semester project) Design of an Unpressurized Manned Rover for Use on the Moon or Mars
University of Texas, San Antonio No Boundaries	All Senior ME Design Team, Semester II of II (two semester project) Design of a Lunar Cargo and Equipment Utility Cart

Table 1 Academic Year 2008-09 Universities and Topics Selected for TSGC Design Challenge

### **III. Lessons Learned**

There are many lessons learned from several years of experience as a NASA engineer providing design topics and serving as a mentor to the student senior design teams. From a NASA mentor and design topic initiator's perspective, the following are key lessons learned for future NASA, industry, or academia mentors who wish to get involve in design challenges:

Become familiar with the TSGC and the ESMD Design Challenge websites and the schedule for participation

During day to day work in your engineering or science organization and during project or program reviews, be on the lookout for items that could serve as design topics

Be prepared with a few design topics when the request for design topics is made by TSGC and ESMD

When contacted by TSGC or ESMD that your design topic has been selected, verify that your schedule will accommodate an hour or two every few weeks to mentor and advise the student design teams.

If possible invite the student team for a visit to the NASA center for a review during the semester.

Meet with the student team prior to the end of the semester presentation to insure their project is complete and ready for a formal presentation.

The mentor should emphasis the need for a good prototype that communicates their design well.

The mentor should emphasis the need for testing and data collecting in order to present the results as part of the project

Finally, treat the students will respect and in a professional manner that instills pride in their work and in their chosen engineering profession.

### **IV. Conclusion**

The TSGC and the ESMD Education Office Design Challenge Programs have proven to an effective and productive initiative to engage students in NASA related design projects, to provide design topics for required senior design classes needed towards graduation, and to help meet the ABTE outcomes needed to maintain engineering accreditation. The focus of the design topics has changed in the past and will change again the future as NASA's space programs evolve. With the Constellation Program's cancellation, design topics will have to be reviewed and refocused on NASA's new missions. Working with NASA, academic institutions, and industry, TSGC and ESMD will have to adapt in order to continue to educate and train the future work force needed for space exploration.

### **Acknowledgments**

The author would like to thank the NASA Administrator's Fellowship Program and the United Negro College Fund, Special Projects Office for their support during my one year fellowship at the University of Texas in San Antonio and the TSGC, especially Ms. Debbie Mullins, the Design Challenge Program Manger, who has led and managed the Design Challenge for the past 8 years.

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