

Vermont Space Grant Consortium
University of Vermont, Lead Institution
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PROGRAM DESCRIPTION

The National Space Grant College and Fellowship Program consists of 52 state-based, university-led Space Grant Consortia in each of the 50 states plus the District of Columbia and the Commonwealth of Puerto Rico. Annually, each consortium receives funds to develop and implement student fellowships and scholarships programs; interdisciplinary space-related research infrastructure, education, and public service programs; and cooperative initiatives with industry, research laboratories, and state, local, and other governments. Space Grant operates at the intersection of NASA's interest as implemented by alignment with the Mission Directorates and the state's interests. Although it is primarily a higher education program, Space Grant programs encompass the entire length of the education pipeline, including elementary/secondary and informal education. The Vermont Space Grant Consortium is a Capability Enhancement Consortium funded at a level of \$430,000 for fiscal year 2011.

PROGRAM GOALS

Goals of the Vermont Space Grant Consortium (VTSGC) during the second year of our current five-year award included continuing to develop our network of colleges and universities, industries, and other organizations interested in strengthening mathematics and science so as to increase interest and capabilities in aeronautics, space and related fields in the State of Vermont. The VTSGC has sought to encourage students at all levels from K-12 through university and graduate school to take more mathematics and science, to make connections with NASA, and to consider careers in scientific and technical fields. Through our Undergraduate Scholarship, Graduate Fellowship, and Higher Education Programs, the VTSGC has addressed critical pipeline issues, helped train the next generation of professionals, and has especially encouraged women, members of underrepresented groups, and persons with disabilities. As a Capability Enhancement Consortium, a priority for the VTSGC during the period of this award has been to enhance research infrastructure in Vermont, especially the capability to engage in research of an interdisciplinary nature. These goals and objectives, as well as the methods to be used to achieve them, are detailed in the VTSGC's Strategic Plan. A copy of the VTSGC's Vision Statement, Mission Statement and Strategic Plan can be seen on the VTSGC's website at the URL given above.

PROGRAM/PROJECT BENEFIT TO OUTCOME (1,2, OR 3)

Several illustrations will highlight the contributions made by VTSGC programs to the three outcomes that guide NASA's Education Portfolio. As a first illustration, after an extensive university-wide review and evaluation of existing research activity, the University of Vermont (UVM), the Lead Institution in the VTSGC, is currently in the process of implementing a Transdisciplinary Research Initiative (TRI). Within this initiative, UVM's initial strategic goal is to develop a small number of "Spires of Excellence" to expand, coordinate, and leverage research capability in areas at the intersection of important State and National interest where UVM already has significant research assets. Of particular relevance to NASA research priorities is the new TRI Spire in Complex Systems. Prof. Chris Danforth, an applied mathematician with strong links to NASA collaborators at NASA Goddard whose research involves reducing uncertainty in weather and climate model forecasts, is Associate Director of the UVM Complex Systems Center and is playing a leading role in the development of the Complex Systems TRI Spire. To continue our support of this new opportunity for both research and human resource development, the VTSGC awarded a Graduate Research Fellowship to Prof. Danforth's Ph.D. student, Nicholas Allgaier, in our 2011 Graduate Fellowship Competition. This graduate research support has allowed Mr. Allgaier to continue his thesis research on a topic for which Prof. Danforth was awarded a Research Minigrant in our 2010 Faculty Research Competition. This Minigrant included funding for travel to NASA Goddard to visit Dr. Robert Cahalan, Head of the Climate and Radiation Branch at GSEC. Previous VTSGC seed funding awarded to Prof. Danforth allowed this faculty researcher to obtain preliminary research results that have now led to a large NSF grant. At this stage, Prof. Danforth himself has "graduated" from our seed funding competitions and will be securing follow-on funding for his research program through regular competitive channels. However, by providing this support for this graduate student, the VTSGC has not only been able to further support state research infrastructure development, but we have contributed to the development of the STEM workforce in a discipline needed to achieve NASA's strategic goals (Outcome 1, *Employ and Educate*), and have facilitated the development of new NASA-relevant STEM educational opportunities for students and faculty (Outcome 2, *Educate and Engage*).

A second illustration of how VTSGC programs benefit NASA's Education Outcomes comes from our Higher Education Programs and involves continuing support for the Autonomous Underwater Vehicle (AUV) Project at Norwich University, a VTSGC affiliate. The student engineering team for this project, which during the current reporting period consisted of two undergraduate electrical engineering majors at Norwich, is developing a robot vehicle that will be 100% self-controlled and capable of navigating through a series of predefined tasks without human intervention. This project, which was initially supported using ESMD Higher Education funding awarded to the VTSGC, was so popular and successful that the VTSGC has provided follow-on funding from our main NASA award in FY 2011. This past year, the team pursued additional developments, such as waterproofing the vehicle's camera vision system, which will allow navigation in the harsh environment under the ice crust in Lake Champlain in support of NASA's mission of autonomous navigation for harsh environments in space. This development may be applicable to a future NASA mission planned to seek signs of

life below a 3 to 5 kilometer thick ice sheet on the surface of the Jovian moon Europa. The team also strengthened contacts with NASA researchers. Indeed, as a result of the enhanced NASA links, one former student team member (male, person with a disability) participated in the “Engineering Boot Camp “ Program at NASA Goddard during the summer of 2011. This effort has now led to a new hands-on educational opportunity for Norwich undergraduates. GreenSea Systems of Richmond, VT has become very interested in offering summer internships to Norwich students in the area of unmanned sea vehicles. An additional crosscutting feature of this project is an interaction of team members with 7th graders and their parents at the U32 School in Norwich, Vermont. This interaction not only has encouraged the 7th grade students to take more mathematics and science but also has promoted an increased awareness of NASA and its mission in the larger Norwich community (Outcome 3, *Engage and Inspire*).

A final illustration of the benefit to NASA Education Outcomes of our programs involves the VTSGC Awards Night Ceremony held in October last year. Students, their parents, and representatives of VTSGC affiliates, local school boards, and the State of Vermont attended this yearly ceremony, which honors students supported by the VTSGC’s Fellowship/Scholarship, Higher Education, and Research Infrastructure programs. The 2011 Awards Night program included presentations by two Vermont students who participated in VTSGC-supported NASA Summer Internships and mentored undergraduate research projects as well as demonstrations by supported student teams, such as the UVM Alternative Energy Racing Organization (AERO) Team. The Keynote Speaker was David Rosage of the University Affairs Office at NASA Goddard. Prof. Carl Brandon of Vermont Technical College also spoke on recent developments in the Vermont CubeSat Lunar Lander Project, which involves all of the VTSGC’s academic affiliates and is currently working to prepare a one-unit CubeSat for a July 2013 launch date that will test the navigation system for the full three-unit Lunar Lander CubeSat package in Earth orbit. Our Awards Night generated considerable publicity for both the VTSGC and NASA in local media across the entire state and helped to highlight strategic partnerships with formal and informal STEM education providers, promote our efforts to advance STEM literacy, and raise awareness of NASA’s mission among both Vermont’s education community and the General Public (Outcome 3).

PROGRAM ACCOMPLISHMENTS

Outcome 1: Contribute to the development of the STEM workforce in disciplines needed to achieve NASA’s strategic goals (Employ and Educate)

In order to provide NASA related competency-building education and research opportunities for students and faculty researchers, the VTSGC has strived to make significant achievements and progress in our Research Infrastructure, Fellowship/Scholarship and Higher Education programs. These are described in detail under the following three sub-headings:

1.1 Research Infrastructure:

As a Capability Enhancement Consortium, a priority goal of the VTSGC is increasing Vermont's Research Infrastructure in areas aligned with new and continuing NASA research priorities. Vermont's NASA EPSCoR Program shares this goal. There is close cooperation and coordination between the VTSGC and VT-NASA EPSCoR in this area. Several of our local faculty research awards are jointly funded by the VTSGC and VT-NASA EPSCoR, resources for local VT-NASA EPSCoR projects have been augmented by VTSGC Graduate Research Fellowship awards, and several Science PI's for VT-NASA EPSCoR's research team projects that are currently funded by National NASA EPSCoR Research Competition awards initiated their research projects using VTSGC Minigrants.

The primary program used by the VTSGC to promote the development of Vermont's research infrastructure is our yearly Faculty Research Proposal Competition. This competition is open to all full-time Vermont researchers at any Vermont college or university. Research Minigrants grants of up to \$5,000 to initiate research projects and collaborations with NASA colleagues and Small-Scale Grants of up to \$30,000 for more mature research projects, particularly those where a NASA contact has already been established, are available to faculty researchers through this competition. Potential uses of Research Minigrants include seed money to explore initiating NASA-related research projects, travel to a NASA Center to establish contact or collaborate with an appropriate NASA colleague, bringing a distinguished visitor or research collaborator to Vermont for a short visit, and summer support of an undergraduate or graduate student. The more extensive Small-Scale Research Grants may contain summer faculty research salary or research support for a graduate student. Small-Scale Grants typically contain travel funds to visit a NASA Center to establish or strengthen NASA collaboration, and a further expectation is the submission of a research proposal for follow-on funding from non-Space Grant and non-EPSCoR sources. For both Minigrants and Small-Scale Grants, significant cost share is required from the PI's home department or institution to demonstrate support for and a commitment to the research project.

Six new faculty research grants were awarded by the VTSGC during the past year as a result of our 2011 Faculty Research Competition. Four of these awards were Small-Scale Grants, and two were Research Minigrants.

Funded Small-Scale Grants in FY 2011 included awards to Prof. George Pinder and Prof. Jeffery Marshall, both of the UVM School of Engineering (SoE). Prof. Pinder is working to develop a hybridization of applied mathematical, operations research, and risk-based methods that will be capable of determining optimal solutions to subsurface contamination problems. His research is addressing the practical questions of how to optimally (at least cost) identify a groundwater contaminant source from measurements of water quality, how to determine under what field circumstances the contaminant source cannot be identified, and if it can be identified, at what cost. The mathematical tools required to address these questions involve numerical modeling, random fields, optimization, fuzzy sets and fuzzy logic and the Kalman filter. The bulk of the funding in

this small-scale grant will support the research efforts of Ms. Kate Johnson, a PhD student in UVM's School of Engineering. Prof. Marshall is using his small-scale grant to develop a new generation of computational models to predict the effect of turbulent mixing on the growth rate of suspended micro-algae. In his previous work in this area, algae cells in computer simulations were treated as passive scalars, which move with the local fluid velocity. However, real algae cells can adhere to other cells, forming larger cell agglomerates that disperse relative to the fluid flow. Dispersive particles are known to preferentially collect in the region in-between the energetic eddies of a turbulent flow. The objective of the supported work is to improve previous models by implementing a stochastic Lagrangian method that can correctly account for the action of large eddies in excluding the particles (cells). Since particle dispersion is directly proportional to the fluid acceleration, this research has focused on acceleration-based stochastic Lagrangian methods, which offer an improved approximation of the turbulence acceleration field over velocity-based models. In common with Prof. Pinder's small-scale grant, the bulk of the funding in this award is being used to support the research effort of a graduate student, Mr. Kyle Sala. Mr. Sala is working toward his MS degree in Mechanical Engineering at UVM, and he plans to graduate in October of 2012.

A third Small-Scale Grant was awarded to Prof. Mary Dunlop in UVM's School of Engineering. Prof. Dunlop's research involves characterizing microbial antibiotic resistance mechanisms in microgravity environments. Microbes can evolve strategies to resist antimicrobial drugs, limiting the number of antibiotics that can be used to counter infection. This is of particular concern for long-duration human space flight missions where conditions may compromise astronauts' immune systems and treatment options are limited. Previous studies have shown that microbes can acquire increased levels of antibiotic resistance and increase their virulence in space. The cause of the increased resistance remains unclear, but may be due to physiological changes to cells growing in microgravity, increased radiation levels, or other effects. Prof. Dunlop is studying two classes of antibiotic resistance mechanisms with the ultimate goal of understanding how their effects differ in normal and microgravity environments. This small-scale grant is supporting bacterial strain construction, characterization, and assay development, in addition to initiating work on mathematical modeling of persistence. The project involves an undergraduate research assistant (female). In January, Prof. Dunlop visited NASA Johnson to meet with Dr. Duane Pierson, Dr. Mark Ott, and other scientists working on the effects of microgravity on microbes.

The fourth small-scale grant from the VTSGC's 2011 Faculty Research Competition was awarded to Prof. Walter Varhue of the Materials Science Program at UVM. The goal of this investigation is to develop the technology required to efficiently and safely produce breathable oxygen for manned space missions. The production of breathable oxygen is currently accomplished via the electrolysis of waste stream liquid water in a proton exchange membrane (PEM) based electrolyzer. In the present project, the objective is to design a complete PEM electrolyzer system that operates in the vapor phase and is able to achieve greater energy efficiency. The working hypothesis of this investigation is that if the electrode surface is suitably designed, the electrolysis process can be performed in the vapor state at low applied voltages and operate with higher efficiency. The device that is

being designed operates with the aid of nano-material covered electrode surfaces, which are beneficial because the crystalline RuO₂ nanorods-decorated catalyst material provides a large surface area. In addition, the engineered electrode material with sharp geometric features produces a high electric field at its surface, which lowers the required activation energy of the chemical reaction, and the predicted high temperature of the electrode body, which results from plasmon resonance adsorption and an inability to radiate to its surroundings, further decreases the activation energy required the chemical reaction. Dr. Thomas Valdez at NASA JPL is an active collaborator in this project. This award includes funding to partially support the training of a Postdoctoral Fellow, Dr. Michael Cross

The first of two research minigrants from the VTSGC's 2011 Faculty Research Competition was awarded to Prof. Danner Friend of Norwich University's David Crawford School of Engineering. This minigrant allowed Prof. Friend to purchase an EyasSat system for his laboratory. The EyasSat is a fully functional nanosatellite designed for hands-on learning about how satellite systems work, and for teaching spacecraft systems engineering in the classroom and laboratory. A better understanding of how satellite systems work will help Prof. Friend and his students in the research and development of the autonomous navigation system for the Vermont CubeSat Lunar Lander Project. Furthermore, since there is not currently an Aerospace Engineering Program at Norwich, Prof. Friend intends to distribute the EyasSat laboratory experiences as course modules throughout several required courses in Norwich's Electrical and Computer Engineering and Mechanical Engineering program curriculums to expose as many students as possible to CubeSat technology and space applications. Five courses in EE and ECE and one course in ME have been identified as appropriate homes for these modules. Prof. Friend plans to start developing these modules during the summer of 2012 and to begin implementing the modules in the target courses starting in Fall 2012. The longer-term plan includes developing a program technical elective course at Norwich based on EyasSat. Thirteen Norwich undergraduate engineering students (4 female, 9 male) participated in this project during the current reporting period.

The second research minigrant from the VTSGC's 2011 Faculty Research Competition was jointly awarded to Prof. Jeff Frolik of UVM's School of Engineering and Prof. Josh Bongard of UVM's Department of Computer Science. In September, Prof. Bongard was named as one of 94 researchers who are the 2011 recipients of the Presidential Early Career Awards for Scientists and Engineers, the highest honor bestowed by the United States government on science and engineering professionals in the early stages of their independent research careers. The object of this VTSGC-funded research project is to develop a strategy by control algorithms for autonomous vehicles, such as MAVs (micro-aerial vehicles), that can be readily developed using evolutionary algorithms in conjunction with data collected using human-controlled flight. This minigrant provided operating funds for supplies to augment a Graduate Research Assistantship awarded by Vermont Space Grant to Mr. Gregg Carpenter, an MS student in Computer Science at UVM. Mr. Carpenter's research is under the joint supervision of Professor Frolik and Prof. Bongard. He has been successful in developing a strategy for the collection of the human-controlled flight data required in this project. Mr. Carpenter will be receiving his

MSEE degree in March 2012, and he has decided to accept an engineering position with IBM in Essex Junction, VT.

It should be noted that all six of the projects funded in our 2011 Faculty research Competition include the participation of undergraduate students researchers, graduate students, or a Postdoctoral Fellow. Promoting Human Resource Development by creating additional opportunities for students to work one-on-one with faculty researchers on projects that are strongly aligned with NASA research priorities or technical needs is a major objective of the VTSGC.

Vermont's NASA EPSCoR Program currently supports much of Vermont's academic faculty research in areas of interest to NASA. However, as indicated by the above awards, the VTSGC remains an active participant in efforts to expand and enhance Vermont's NASA-related research infrastructure and build further research ties between Vermont's academic faculty and NASA.

A comparison of the progress reported above with the SMART goals and objectives described in the VTSGC's FY 2010 proposal package for the current funding cycle shows that targets for the current reporting period have mostly been met. The target range for faculty awards in our FY 2010 proposal included four Small-Scale Grants and two Research Minigrants. As noted above, this is the distribution of local faculty research awards supported by the VTSGC during the current reporting period. As was pointed out earlier, these Research Grants will help to build and strengthen research ties between Vermont's academic faculty and NASA. Of the seven Faculty Investigators involved in these locally funded research projects, one is a woman. This does not meet our target of 40% in this area. However, we would note that two other female faculty researchers, Prof. Beverley Wemple and Prof. Jennifer Portius, both of UVM, are working with Prof. Frolik on a related aspect of his funded minigrant. These researchers were not counted toward meeting target as they are not formally Co-I's for the VTSGC funding. We exceeded our target for participation by female faculty researchers in the last reporting period for this grant, and we fully expect to meet our overall target over the five-year period of this funding cycle. None of the Faculty Investigators supported this year are members of a minority group that is underrepresented in STEM disciplines. However, because statistics show that Vermont has an exceedingly small number of STEM faculty members from underrepresented groups, our goal in this area is a five-year, rather than a year-to year, target.

1.2 Undergraduate Scholarship and Graduate Research Fellowship Competitions:

Results of the seventeenth Vermont Space Grant Undergraduate Scholarship Competition were announced in June 2011 with undergraduate scholarships awarded for the 2011-2012 academic year. In the general competition, five merit-based scholarships were awarded to outstanding Vermont students who will be attending Vermont institutions of higher learning throughout the state. Through a Memorandum of Understanding with the Abenaki Tribal Council of Vermont, four additional VTSGC Native American Undergraduate Scholarships were also awarded to outstanding scholars of Abenaki

heritage. Four of these nine scholars were women. Thus, our target of 40% undergraduate scholarships awarded to women contained in our FY 2010 proposal was met and our target of 25% awarded to members of underrepresented groups was significantly exceeded. All supported undergraduate students appear to be making excellent progress toward their baccalaureate degrees.

Three additional special scholarships of \$2,500 each were awarded during the current reporting period to students in the Aviation Technology School of the Burlington Technical Center, a VTSGC affiliate. One of these scholars is a woman, and a second scholar was a Silver Medalist in the 2011 National Skill's USA Competition. The BTC Aviation Technology School has a 100% employment record, and graduates of its program, which is one of the premier programs in North America that train certified aviation and powerframe technicians, are usually offered employment either before or within hours of graduation. Because the school calendar for this program differs significantly from the usual academic year, students in this program cannot reasonably compete in the VTSGC's normal Undergraduate Scholarship Competition. To address the special needs of this affiliate, these scholarships were first authorized by the VTSGC's Board of Advisor in 2003 as part of our efforts to develop and expand the scientific and technical workforce needed in the future by NASA and aerospace companies in the private sector.

Two VTSGC special scholarships were awarded in this reporting period to support student summer internships at NASA Centers. In the first of these internships, Andrew Lutz, a Mechanical Engineering student at UVM, worked in the Advanced Sensing and Optical Measurement Branch at NASA Langley under the supervision of Dr. Paul Danahey. The research focus of Mr. Lutz's project was the development and application of advanced laser-based measurement techniques to transonic, supersonic, and hypersonic flows. In the second supported internship, Douglas Bowman, an undergraduate engineer at Norwich University, participated in the summer "Engineering Boot Camp" at NASA Goddard organized by Michael Combariate, a Systems Manager in the Robotics Division. Mr. Bowman is a person with a disability. His research involved aspects of the development of an autonomous robot tractor that will be used by NASA scientists to take measurements on the Greenland Ice Shelf.

In terms of graduate fellowships, the University of Vermont is the only comprehensive institution in the entire State granting graduate degrees in mathematics, science and engineering. This fact explains why the VTSGC Graduate Research Fellowships have been for graduate study at UVM. Fortunately, UVM's graduate programs in mathematics, science and engineering are strong and thriving, especially in the biomedical and remote sensing areas that form the research focus of NASA-related research in Vermont. It is important to note that our graduate awards have a strong research component and are not simply pure fellowships. Recipients work with UVM researchers who have, or are developing links to NASA, and the awards usually contain a summer research stipend as a component.

Six Graduate Research Fellowships that fully supported graduate students for a 12-month period including the 2011-2012 academic year were competitively awarded in the VTSGC's 2010 Graduate Research Competition. This exceeds the target of four full-time awards stated in our FY 2010 base budget proposal. Only one of the six supported students is a women. Consequently, the results for women awarded VTSGC Graduate Fellowships during the present reporting period are under our goal of at least 40% awarded to female graduate students. However, based on experience in prior reporting periods, we are confident that we will be able to meet our goal for participation by women in this program over the full five-year period. Unfortunately, the same confidence cannot be expressed about meeting our target of awarding two Graduate Fellowships to members of an underrepresented group during the 5-year period of our Space Grant award. Potential faculty mentors are always strongly encouraged to propose GRA funding for women, members of underrepresented groups, and persons with disabilities in our yearly Graduate Research Competitions. However, despite this encouragement, UVM has few graduate students from recognized underrepresented groups in STEM, and none of the graduate students supported in FY 2011 from our base budget funding is a member of an underrepresented group.

Our graduate fellowship program is producing excellent outcomes. All graduate students awarded VTSGC Graduate fellowships during the present reporting period are making excellent progress toward earning their degrees.

1.3 Higher Education Programs:

In 1996, the VTSGC initiated a category of awards called Undergraduate Program Projects to fund many of our efforts in Higher Education. In the current reporting period, two supported activities in this category were the UVM Alternative Energy Racing Organization (AERO) Student Team and Norwich University's Autonomous Underwater Robotic Vehicle (AUV).

Professors Danner Friend and Jacques Beneat of Norwich University's Departments of Mechanical Engineering and Electrical and Computer Engineering are the faculty advisors for the Norwich AUV Student Teams. The 2011 Program Project Grants for this engineering design team provided additional follow-on funding for design efforts that were initiated with earlier ESMD-Space Grant awards. Prototype vehicles designed, built, and tested by this student team have successfully competed in national engineering competitions. The efforts of the Norwich AUV team have already been noted at the start of this progress report as one example of how the VTSGC's Higher Education programs benefit NASA's Education Outcomes.

The achievements of the UVM AERO Team provide an additional example of how VTSGC Higher Education efforts benefit NASA Education Outcomes. Prof. Jeff Frolik of UVM's Department of Electrical and Computer Engineering is the faculty advisor for this undergraduate student engineering team. To date, fifty active student members have participated in this team's various vehicle development projects. Participation in team activities has provided a pathway to professional employment in Green Energy areas.

Recent AERO alumni now work for GM's hybrid drivetrain division, Vermont alternative energy developers, and hybrid vehicle startup companies in New England. The club participates in the SAE/IEEE-sponsored Formula Hybrid International Competition (FHIC) with a unique, all-wheel-drive parallel hybrid racecar. VTSGC funding this reporting period has primarily been used to support the purchase and/or fabrication of the high-voltage electrical accumulator (i.e., battery packs) as the team prepares its 3rd generation vehicle for a May 2012 competition. The club has utilized nanophosphate lithium ion systems and more recently lithium iron phosphate systems.

Other Higher Education activities supported by the VTSGC during the present reporting period enhanced the baccalaureate experience of undergraduate students at Vermont colleges and universities through funding faculty-mentored undergraduate research projects while strengthening faculty research efforts and building ties to NASA. Of the seven undergraduate students participating in these research projects, three were women. Of the nine faculty mentors involved in these research projects, six were women.

At St. Michael's College (SMC) in Colchester, VT, Prof. Zsusanna Kadas has coordinated mentored undergraduate research projects on topics of interest to NASA involving students in STEM disciplines during the academic year or the summer. Prof. Kadas is the SMC representative to the VTSGC's Board of Advisors. During the current reporting period, five mentored undergraduate research projects were active at SMC. These projects involved faculty mentors and students in SMC's Departments of Physics, Biology, Mathematics, Computer Science, and Psychology. Prof. James Byrne coordinates a similar program of mentored undergraduate research at Norwich University. Prof. Byrne is a Vice Provost at Norwich and Norwich's representative to the VTSGC Board of Advisors. Because of scheduling problems, the Norwich program did not have an active mentored undergraduate project during the current reporting period. However, Norwich has notified us of plans to mount a project in this coming summer, and recruitment of students for this project is about to begin.

During the current reporting period, the VTSGC also supported two mentored undergraduate research projects in the UVM Ureca! Program, coordinated by the Dean of the UVM Honors College. The aim of this program is to provide undergraduate students in all disciplines at UVM an opportunity to engage in a mentored research experience that is "over and above" the research component of a course taken for academic credit. The Ureca! Competition is structured so as to model a real life grant cycle and involves a student-written research proposal, evaluation of proposals by panels of experts, panel review reports, announcement of awards, work on the actual research project with a faculty mentor, and writing a final report detailing research results. The two Ureca! projects funded by the VTSGC both involved research topics that are aligned with NASA research priorities. The topic of the first project, conducted by UVM Electrical Engineering student Chris Tardie, was "Determining water content in snow-packs through gamma radiation measurements." The second project, conducted by UVM Engineering student Meghan Thompson, was titled "Flume Experiment of Effects of Variable Shapes of Engineered Log Jams on River Morphology and Erosion."

Because of the importance of tracking the outcomes of VTSGC support to students, we have contracted with the National Space Grant Foundation to conduct our Longitudinal Tracking of students. Detailed longitudinal tracking data provided by the Foundation for 2011 is presented in the section of this report that gives Program Contributions to PART Measures. However, comments collected from students during the course of compiling the VTSGC's 2011 Longitudinal Tracking data indicate that our Higher Education programs appear to have had a significant impact in encouraging supported students to pursue STEM careers. Answers to the question "How did participation in these programs impact your education and life?" included:

"It had a significant impact on my life. I would not be where I am today if it wasn't for that grant. I can't thank you enough the opportunity. I hope you continue to provide these grants to the hard working and deserving engineer undergrads at Norwich University." (Benjamin DiMiero - on 01/30/12, 2008 ESMD Internship, Altair Engineering - Applications Engineer)

"It (a NASA Summer Internship) complemented the work that I was performing as a graduate student at UVM. It furthered my knowledge base in an area that I had much interest and motivated me to continue working in the field." (Andrew Lutz - on 03/21/12, 2011 Vermont Space Grant Scholarship, Suss Microtec - Mechanical Engineer),

"It certainly helped land me this awesome job! It was a great experience learning about research and experimental studies." (Evan Malina - on 03/02/12, 2009 Vermont Space Grant Scholarship, The Boeing Co - Structures Design Engineer)

A further indicator of Program Accomplishments contributing to Outcome 1 is also given in data provided by the National Space Grant Foundation. This tracking indicates that 10 students whose participation in our programs was significantly supported by the VTSGC in FY 2006 to FY 2010 took a "next step" during the current reporting period. In particular, in the FY 2011 program year, 2 of these students are now pursuing an advanced degree in a STEM discipline, 1 has accepted a position with a NASA contractor, and 7 have accepted STEM positions in industry.

Outcome 2: Attract and retain students in STEM disciplines through a progression of educational opportunities for students, teachers, and faculty (Educate and Engage)

VTSGC activities this past year in our Higher Education and Precollege programs that contributed to this outcome are described in the following two sub-headings:

2.1 Higher Education Programs:

Components of several of the VTSGC programs described above give undergraduate students in STEM disciplines a greater appreciation for the breadth and depth of NASA's mission as well as an appreciation for the challenges presented by NASA-related

research. In particular, as mentioned previously, faculty investigators in several of our FY 2011 Faculty Research Awards have actively engaged their undergraduate students by involving them in significant ways in their funded research projects. VTSGC research support thus provides new educational opportunities for these students and strengthens both the desire to pursue a career in a STEM discipline and, in some cases, the desire to go on to earn an advanced degree. The mentored undergraduate research projects described in the section above also directly educate and engage students at both a research university and two primarily undergraduate institutions in a way that would not be possible without VTSGC sponsorship.

In FY 2011, the VTSGC was instrumental in providing multiple avenues for Vermont students to explore a progression of educational opportunities that could lead to a career in a STEM discipline. In particular, during the current reporting period, the VTSGC provided support for two Capstone Senior Engineering Design Projects in the School of Engineering at UVM. The first of these had as its objective the “Design of a miniaturized ‘moving-liquid’ gyroscope for small spacecraft.” The student team assembled for this project, which consisted of three (male) senior undergraduate mechanical engineering students, was posed the challenge of designing, constructing, and testing a miniaturized “moving liquid gyroscope” prototype capable of demonstrating classic gyroscopic motion and behavior. For the practical purposes of this project, the size of the miniaturized gyroscope was constrained to no more than a few inches in diameter. Prof. Darren Hitt of UVM’s School of Engineering is the faculty coordinator for this design project, and Dr. George Williams, Jr. of NASA Glenn is acting as the NASA advisor. Dr. Williams is also the NASA point-of-contact for ongoing discussions exploring the potential use of the NASA GRC drop-tower facility for the prototype design testing. The second Capstone Senior Engineering Design Project, coordinated by Prof. Jeff Frolik of UVM’s School of Engineering is designing a “Zero-emissions vehicle for Frozen Landscape scientific studies.” The goal of this project is to develop aspects of a zero emission vehicle for NASA scientists that can be used for transporting scientific payloads across the frozen landscape of Greenland. This area has been declared an emissions-free zone due to the need to preserve scientific data. Currently, the only method of transportation is skiing, which is physically demanding, and makes carrying equipment difficult. The new vehicle must be capable of safely handling a 25Kg load with a size of 0.5m x 0.5m x 0.5m without sinking into the snow. It must also maintain traction on ice, and its energy accumulator must be readily converted to accommodate a 50Km range over a 24-hour period. In addition, it must also incorporate autonomous navigation so it can meet scientists at their study destination. This includes both the ability to follow a pre-programmed route, and the capability of avoiding any obstacles it may come across. The vehicle must be compact in size so that it can be loaded onto a cargo plane for transportation to Greenland. It must also be designed to travel across ice and windblown snow with a density of 250/400 kg/m³, and a depth of 20cm. Operation temperatures can reach a minimum of -20 °C, and it must be able to handle the grades and harsh weather conditions of Greenland. The vehicle should also be easy to use and operate for scientists with little to no training. The controls must be designed for use while wearing gloves, and basic maintenance such as changing batteries and loading and unloading

should take into account the same considerations. Michael Combariate of NASA Goddard is the NASA point of contact for this project.

2.2 Precollege Programs:

Vermont is a small, predominantly rural state without a well-developed statewide research culture. There are only 82 high schools in the entire state, and, in many school districts, students are not fully aware of opportunities for scientific and technical careers. VTSGC precollege programs are able to access Vermont students at a key location in the pipeline leading to professional careers. Our data shows that the summer enrichment programs we have partially supported during the course of our training grant, particularly the Summer Mathematics Institute (which has now become a part of the Governor's Summer Institutes in Science and Mathematics) and an underrepresented minority component for the UVM College of Engineering and Mathematics Summer Enrichment Program in Science and Technology, have been successful in motivating precollege students from across the State. Further, the positive publicity in the press generated by these programs has increased the visibility of NASA throughout the State and facilitated our efforts at both the higher education and research infrastructure levels. The VTSGC is a founding member of the Vermont-NASA Educational Cooperative (VNEC), a group of organizations with ties to NASA and agendas that involve education at the K-12 level. We also helped to promote an interest in science among Vermont's Middle School students by our participation and support in the Junior Solar Sprint program, a project for students in grades 5 through 8 involving the design, building, and racing of mini solar/electric cars. Our Program Coordinator, Ms. Laurel Zeno has acted as Northern Vermont Area Coordinator for this program. VTSGC participation in this event includes donation of the Trophies and Certificates as well as help with the fundraising from the private sector that makes this event possible.

Two events coordinated by UVM's College of Engineering and Mathematical Sciences (CEMS) that involved the VTSGC occurred in 2011: Design Technology And Society Connection (TASC) and E-Week. Design TASC is held annually at UVM. The purpose of this competition is to give teams of high school students the challenge and satisfaction of designing, building, and testing a device to perform a specified task. The program begins in September and culminates in December when schools bring teams (maximum of five students per team) to UVM to display the devices they have created. The 2011 E-Week was held in February at the Vermont Air National Guard's Burlington facility with approximately 500 students from 35 elementary, middle and high schools in attendance. Activities included building a pasta bridge, an edible car, design of a hangar roof truss, and wind turbine and passive helicopter drop competitions. The VTSGC mounted an exhibit showcasing our programs at these events and also provided a small amount of funding support. Other precollege programs in which the VTSGC was involved during the present reporting period included the Governor's Youth Leadership Conference and the ACE Camp run by VT Department of Transportation and Aviation.

As a CAPENS Consortium, the VTSGC expends only a small percentage of our own funding on precollege activities. Our strategy in this area is to work whenever possible through affiliates such as the Vermont State Mathematics Coalition, the Fairbanks and Montshire Museums, and the Franklin Northwest Supervisory Union Indian Education Office. However, through the donated time of the Director and program staff and our collaboration with these affiliates, the VTSGC has been able to establish a strong presence in the state and region in the K-12 arena.

Outcome 3: Build strategic partnerships and linkages between STEM formal and informal education providers that promote STEM literacy and awareness of NASA's mission (Engage and Inspire)

3.1 General Public and External Relations Programs:

To give NASA programs prominent exposure in the state and help engage and inspire the next generation of STEM practitioners, the VTSGC invites special guests to Vermont to address local audiences. NASA representatives who visited Vermont in FY 2011 included Dr. David Rosage NASA Goddard. Dr. Rosage was a keynote speaker in the VTSGC's 2011 Awards Night Ceremonies. His participation in this event, as well as surrounding activities that included the VTSGC Student Poster Session and a seminar held the following day, helped to facilitate opportunities and interactions between GSFC and Vermont students, teachers, and academic researchers.

The VTSGC has been named a full member of the Vermont Academy of Science and Engineering (VASE), a component of the Vermont Technology Council that advises the State of Vermont on science and technology policy. Consortium Director William Lakin was invited to participate in the last VASE review and revision of Vermont's official Science and Technology Plan, and Program Coordinator Laurel Zeno represents the VTSGC at the quarterly meetings of the Council.

Additional outreach within the State has come from the VTSGC's interactions with civilian aviation interests and the Civil Air Patrol in Vermont. Vermont's former Lieutenant Governor, Brian Dubie, a commercial airline pilot and past National Chair of the Aerospace States Association, expressed a particular interest in this portion of the VTSGC's activities before leaving office in late 2010. The VTSGC's Program Coordinator, Ms. Laurel Zeno, is our point person for interactions in this area. Ms. Zeno is a member of the Aero Club of New England and serves as the VTSGC's representative on the Board of Burlington Technical Center's Aviation Technology School. The VTSGC has played a key role in promoting the expansion of the Aviation Technology School's facility at the Burlington Airport. Indeed, we are one of a group of stakeholders that submitted a successful proposal to the State for funds to support an expansion. The proposed new facilities will not only benefit the Aviation Technology School, but will also be used by students in Vermont Technical College's new Aerospace Engineering Technology major, a degree program that owes its existence to an interaction of VTC and BTC through the Vermont Space Grant network. The VTSGC has also interacted with the NASA Explorer School in Orleans, Vermont.

PROGRAM CONTRIBUTIONS TO PART MEASURES

- Student Data and Longitudinal Tracking: The data presented below for Total Awards to students during the FY 2011 program year indicates that a majority of these awards were made through our Fellowship and Scholarship programs. However, it should be noted that our Graduate Fellowships have a strong Research Infrastructure component. In particular, graduate students awarded VTSGC Fellowships work directly with their faculty advisors on research projects that are aligned with new and continuing NASA research priorities. VTSGC Graduate Fellowships thus support our mandate as a CAPENS Consortium to promote the development of Research Infrastructure. The VTSGC fully recognizes the importance of providing the National Program with accurate data that longitudinally tracks students supported by our programs. Therefore, we have contracted with the National Space Grant Foundation to longitudinally track students who have received significant awards in past program years..

Total awards = 25 (19 Undergraduate, 6 Graduate); Fellowship/Scholarship = 16, Higher Education/Research Infrastructure = 9; 4 of the total awards represent underrepresented minority F/S funding. 1 student has accepted a STEM position with an Aerospace Contractor, 7 have accepted STEM positions in industry, while 2 have graduated and are pursuing advanced STEM degrees.

- Diversity: Promoting diversity in all portions of our program is a key goal of the VTSGC. Solicitations and announcement of opportunities always contain a section that strongly encourages the participation of women, members of underrepresented groups, and persons with disabilities, and this formal encouragement is supplemented by the personal efforts of the VTSGC Director. Data has been presented in the sections above for each of the individual components of our program that compares outcomes during the current reporting period with the targets for diversity contained in our 2010 proposal. This data indicates significant successes in a number of areas of our program. For example, one of the two students we supported for a summer internship in 2011 at a NASA Center is a person with a disability. Targets for participation by women were exceeded in both our Undergraduate Scholarship and Mentored Undergraduate Research Projects. In the Undergraduate Scholarship Competition, four of nine awards went to women, and, in addition, 44% of the awardees were members of an underrepresented group. In the supported Mentored Undergraduate Research Projects, 43% of the participating students were women, while 67% of the faculty advisers were women. Despite these successes, data included in several of the sections above shows that targets for participation by women and members of underrepresented groups were not achieved in some components of our program. For example, only one woman was awarded a Faculty Research Grant during the current reporting period in our local 2011 Faculty Research Competition. However, it should be noted that our target for awarding faculty research grants to women was exceeded in our 2010 Faculty Research Competition. We are therefore confident that our overall target for faculty research

awards to women in this component of our program will be achieved over the full five-year duration of our current award.

- Minority-Serving Institutions: Vermont has an exceptionally homogeneous population. Demographic tables from the recent US Census show that only 2.3% of Vermont residents identify themselves as members of an underrepresented minority in STEM areas while data from the National Center of Education Statistics Digest indicates that only 2.5% of students enrolled in Vermont (in-state and out-of-state) are Black, Hispanic, or Native American. Vermont has no minority-serving higher educational institutions, or indeed any higher educational institutions with a significant percentage of minority student enrollment. As will be noted shortly in the Program Partners Section, one VTSGC strategy for promoting diversity in our programs involves a strong working relationship developed over the past ten years with the Franklin Northwest Supervisory Union Indian Education Office, the Education Arm of the Abenaki Tribal Council of Northern Vermont. The FNWSUIEO, which is now a VTSGC affiliate, cooperates closely with the VTSGC and each year helps us to attract talented students of Abenaki Heritage to our Undergraduate Scholarship application pool. Indeed, in our affiliate structure, the FNWSUIEO plays a role similar to a “Tribal College.” A second part of the VTSGC’s strategy for promoting diversity in our programs involves developing relations with minority-serving institutions out-of-state. In particular, the VTSGC has worked through the New York Space Grant Consortium to conduct joint weather balloon launches with Medgar Evers College, part of the City University of New York for the Central Brooklyn community. In joint CricketSat workshops for undergraduate students, Vermont and New York students work on the assembly and calibration of CricketSat temperature sensors as well as conducting flights.
- NASA 2010 Education Priorities: A number of the accomplishments detailed above are directly related to the “Current Areas of Emphasis” stated in the 2010 Space Grant solicitation. These include:

VTSGC support for two capstone undergraduate engineering design projects (Greenland Robot Tractor and Miniaturized Liquid Gyroscope) and two student engineering teams (AERO at UVM and AUV at Norwich) provided authentic, hands-on student experiences in science and engineering disciplines based on real-life NASA research and technology needs.

Our support for an underrepresented minority component for the UVM College of Engineering and Mathematics Summer Enrichment Program in Science and Technology provided a summer opportunity for secondary students on a college campus with the objective of increased enrollment in STEM disciplines or interest in STEM careers while simultaneously promoting VTSGC Diversity goals.

Continued VTSGC support for faculty and students (both undergraduate and graduate) involved in an “Analysis of Arctic Sea Ice Dynamics Using NASA Satellite Data,” the development of an “Arctic Sea Ice Monitoring Buoy,” and the “Vermont Frozen Landscape Monitoring Project” addressed the priority related to

Environmental Science and Global Climate Change by promoting research and activities to better understand Earth's environments.

Funding awarded to Vermont's NASA EPSCoR project in FY 2007 produced a significant advance in Vermont's research infrastructure with the development over the last few years of a 30 kW Inductively Coupled Plasma (ICP) facility at UVM to study the ablation of aerospace materials used in heat shields under atmospheric reentry conditions. As a result of the close cooperation and coordination of the VTSGC with VT-NASA EPSCoR, a Graduate Fellowship was awarded by the VTSGC to a student who is working with Prof. Yves Dubief, an Assistant Professor at UVM, on this ablation project. This VTSGC funding has helped enable this early career faculty researcher to focus his research program toward NASA priorities. Prof. Dubief is now the Science PI on Vermont's 2011 NASA EPSCoR Research Award that will use advanced numerical methods to continue studies of ablation. A small-scale grant awarded in 2011 by the VTSGC to Prof. Mary Dunlop, a new Ph.D. in Biomedical Engineering recently hired by UVM's SoE, will likewise allow an early career faculty member to explore the initiation of research aligned with new and continuing NASA research priorities.

IMPROVEMENTS MADE IN THE PAST YEAR

During the present reporting period, we have continued to implement an expanded strategy for assessing the impact and outcomes of our funding in program components that involve undergraduate and graduate student participation. In addition to gathering standard evaluation metrics, such as presentations given, degrees conferred, and papers written, a new aspect of our evaluation and assessment plan is seeking to determine the "delta" in both interest in NASA and the motivation to pursue an aerospace-related career created by interactions between the students and the VTSGC through our programs and projects. Quantitative methods alone are not adequate for this determination. Dr. Jeffrey Benay, a Partner in J & J Educational Consultants of Fairfax, Vermont and an internationally recognized expert in STEM program evaluation design and implementation, is carrying out this portion of our evaluation plan. Dr. Benay is also a member of the VTSGC Board of Advisors and a past Chair of the Governor's Commission on Native American Affairs.

The evaluation approach that Dr. Benay is employing is an integrated "systems" matrix that draws on a myriad of qualitative and quantitative methodologies (mixed method evaluation plan). Within this framework, the use of interviews with students will provide raw data that, when transcribed and analyzed, will yield measures of the efficacy of our programs in terms of our impacts on students, faculty, and the NASA-related community. In addition, site visits and material review are assisting in the formation of an ongoing, fluid evaluation process that is examining the overall planning, implementation, and outcomes of the SMART objectives for this project. Both formative and summative evaluation cycles will promote dynamic communication feedback loops that will keep all stakeholders abreast of the grant's progress.

Because of privacy constraints, Dr. Benay is prohibited from contacting students directly to arrange interviews for subsequent analysis. He is therefore working through both faculty mentors and VTSGC affiliate contacts, who are urging all participating students to initiate contact with Dr. Benay and arrange for interviews. Because of the multiple research sites involved in this project, many of these interviews will be done remotely, but face-to-face, using Skype.

In a related development, the VTSGC has now crossed the digital divide to take account of evolving student trends in social networking. Ms. Vanetta Darby, our website designer and IT consultant, put the VTSGC on Facebook to advertise our 2011 Undergraduate Scholarship Competition. We will also be using Twitter to encourage students to interact with us and have sent out Tweets as well as emails to announce our 2011 Competition.

PROGRAM PARTNERS AND ROLE OF PARTNERS IN PROJECT EXECUTION

The University of Vermont is the VTSGC's Lead Institution and Fiscal Agent, and we are based in UVM's College of Engineering and Mathematical Sciences. Academic affiliates include: St. Michael's College, a Liberal Arts college in Colchester, VT; Norwich University, a comprehensive school with engineering programs in Norwich, VT; Vermont Technical College (VTC), part of the Vermont State College System in Randolph, VT; and the Aviation Technology School of the Burlington Technical Center (BTC), one of this country's premier programs leading to FAA Airframe & Powerplant Certification. The VTSGC and NASA thus have a presence at academic institutions throughout the state.

Other educational organizations that are VTSGC affiliates are the Vermont State Mathematics Coalition, the Fairbanks Museum and Planetarium, the Montshire Museum, and the Franklin Northwest Supervisory Union Indian Education Office (FNWSUIEO). The Vermont State Mathematics Coalition is composed of teachers at all levels, school board members, representatives from state agencies, and private sector representatives who are concerned with advancing Vermont's STEM education base. The linkage of this coalition with the statewide Space Grant network allows the VTSGC to be a stakeholder in K-12 education with only a small outlay of our own funding. The Fairbanks Museum and Planetarium and the Montshire Museum are both informal education providers with highly successful, nationally acknowledged programs serving the general public. The FNWSUIEO promotes the educational objectives of the Abenaki Tribal Council of Northern Vermont. As Vermont has no Minority Serving Institutions, or indeed any Higher Educational institution with a significant percentage of students from underrepresented minorities, the active participation of the FNWSUIEO as a full affiliate in our network greatly enhances our goal to engage diverse populations in VTSGC programs. Industrial affiliates of the VTSGC include Triangle Metal Fabrications of Milton, VT and Microstrain, Inc. of Williston, VT. Both of these companies have provided significant support and training for VTSGC-supported student engineering teams.