Thornburg Center for Space Exploration:
Background and Frequently Asked Questions

Our mission is to inspire students and improve STEM education through the design and implementation of an international multi-year elective or after-school program on Space Exploration. It is not enough to just learn STEM content; learners need to be aware of why there are people who choose to spend their lives working in these areas with passion and dedication. This program achieves these broad goals by promoting an environment that fosters innovation, creativity and the development of deep understanding and appreciation for science, technology, engineering and mathematics through the use of inquiry-driven projects done by students. These projects are conducted at school sites with the active guidance and support of highly-qualified educators from the students' schools, along with rich materials from international sources related to the topics of their inquiry.

What is the rationale behind this program?

Some of the founding ideas for this program emerged in *The New Basics: Education and the Future of Work in the Telematic Age,* published in 2002. This book identified a series of skills that research showed were essential for those who will be living and working in this century. Since that time, we have continued to think deeply about educational programs that address these needs.

Since the publication of that book, the challenge has increased significantly. According to the OECD (www.oecd.org) the United States ranks 24th worldwide in student understanding of science. In the domain of engineering, the US is not graduating enough engineers to fill current jobs, and the imminent retirement of "baby-boomers" is creating additional pressure on high tech corporations. For example, according to an article by Joelle Tessler for the Associated Press on 3/10/2008, 15% of Boeing's current high-tech employees are eligible for retirement now. Other countries (*e.g.*, Brazil) are experiencing challenges in finding qualified high-tech workers to feed their growing participation in the global economy. In short, there is a challenge in finding enough people in the STEM (science, technology, engineering and mathematics) areas to meet the needs of today, let alone the future. These challenges are addressed with clarity in the National Academies report, *Rising Above the Gathering Storm* (http://www.nap.edu), and our program is a direct response to the world's needs in the areas of STEM education. According to the Partnership for 21st Century Skills (www.21stcenturyskills.org), all students must have STEM education to acquire 21st century skills. Toward that end, our program addresses some of the skills and habits of mind needed for students to thrive in the world outside the classroom.

What makes this program unique?

Our program is unique in two ways. First, it seamlessly addresses science, technology, engineering and mathematics at the same time. This merger is not found in traditional programs that retain traditional academic boundaries between these subjects. This blending is especially important given that Science and Mathematics are typically the focus of academic schools, and Engineering and Technology are emphasised in vo-tech or career academy facilities. The interdisciplinary approach also embraces the arts, which is essential in obtaining a well-rounded education.

Second, while the projects involve depth in the STEM subject areas, students also develop an appreciation for why people may choose to enter careers in these fields. This is essential because some students may score very high in, for example, Science, but have no idea why anyone would want to work in a scientific field. Our underlying pedagogical model addresses this challenge from the very beginning.

Why is the focus on space exploration and STEM?

The world changed in October, 1957. The launch of Sputnik marked the beginning of international efforts to launch rockets and satellites into space. It also marked the start of a movement to strongly improve science, technology, engineering and math (STEM) education in the United States. One result of that effort was the education of the talent that later brought us many of the technological and scientific discoveries we take for granted today. Many of the modern inventions we take for granted were created by "children of the October sky," and these talented people are soon approaching retirement age. There are currently not enough qualified people to take their place, let alone enough to foster the continued growth of the increasingly high-tech economy.

It is clear that we need to revitalize STEM education in the United States for the current generation and beyond, what better platform can one imagine than space exploration? This highly interdisciplinary topic embodies all the STEM subjects and requires creative thinking and problem solving: all attributes of what we call 21st century thinking skills.

What is this program about?

We have developed a three year curriculum on space exploration designed for middle and high school-level students as an elective or after-school program. This program is project-based, constructionist in design, and largely driven by student inquiry. Each year progresses outward from the previous year's explorations – from the Earth to the Galaxies. During these projects students will develop skills in the areas of science, technology, engineering and mathematics (the STEM skills), and develop their own creative projects related to the subject areas. Furthermore, they will move beyond content to developing an understanding and appreciation for the fact that many people joyously explore these topics through the mechanism of their careers in the related fields.

The following is a brief description of the three year program:

Year One: From the Earth to the Moon

The first year explores the desire, strategies, and techniques needed to build a craft that can leave the Earth and travel to other locations in space. The curriculum starts with Science Fiction and early dreams of space travel, and moves on to the transition from dreams to reality, including the International Space Station, voyages to the moon, satellites, and other rich topics dealing with our own "neighborhood".

Year Two: Exploring the Solar System

Ancient Greeks noticed celestial objects that, unlike the stars, could be tracked as they moved through space. They called these objects "wanderers," or "planets," and they continue to fascinate us today. Some planets are built with rocky cores (like the Earth) and others are gaseous balls, having more in common with the sun than they do with the Earth. These planets and their moons are the subject of rich and ongoing research, with new discoveries being made all the time. The curriculum will start with the exploration of the planets themselves, and then move to strategies that allow these planets and their moons to be explored. Building on the history of planetary exploration, the course moves to future research areas where students are encouraged to design their own planetary research projects.

Year Three: Exploring Stars and Galaxies

Once we have explored our own solar system, we are ready to move into other parts of our galaxy, to explore other galaxies, and to examine the vastness of the Universe This curriculum will be based on the most recent discoveries and provide students will the opportunity to continue their explorations on their own. At this point, students will be expected to develop (and answer) questions of their own based on their knowledge and ability to conduct research in this area. The teacher's role in this year of the course will be largely advisory.

Why is the underlying pedagogy based on inquiry-driven project-based learning?

There are several reasons the program is based on inquiry-driven PBL. As reported in the National Academies report, *Rising Above the Gathering Storm* (http://www.nap.edu), inquiry-driven PBL is one of the few pedagogical models in existence today that strongly supports the development of STEM skills. This is also the pedagogical model used with great effect in statewide specialty high schools such as the Illinois Math and Science Academy. It prepares students to be inquisitive learners and problem-solvers in ways that traditional classroom models do not. In fact, the inquiry methods used by students in this program mirror those they will use should they seek careers in these fields.

What about standards?

Our curriculum is standards based, but not standards driven. Each activity is correlated with benchmarks developed by AAAS Project 2061 (http://www.project2061.org/publications/bsl/). On completion of each activity, teachers can readily identify the portions of their own State standards related to the student's work. This allows great flexibility in student projects, and also meets the needs of those concerned with school or State-based academic standards.

How are projects assessed?

Faculty members are provided with the resources needed to develop their own rubrics for student projects so that student work can be assessed.

How does the program work?

Students and their program educators will meet at least twice a week or more to share information and work on projects. Along the year, some directed instruction is required, but the main effort is devoted to having students work on chosen projects related to the topic being explored in each period. The product of these projects will synthesize student learning and will reflect both individual and team work. On completion of a topic area, students will share their projects with their peers and, hopefully, with a broader audience through presentations, models, interactive media, or other expressions suitable to the project. The overall theme for each year is designed to move students from the Earth to the Solar System, and from there to an exploration of stars and galaxies.

Why is it designed as an elective or after school program?

The interdisciplinary nature of the curriculum does not always lend itself to fitting into a traditional school calendar as a replacement for existing courses. It does, however, make for a very powerful elective course for those students interested in developing deeper understandings of academic work they may have studied elsewhere. We acknowledge that, in some cases, the school day is filled with so many required subjects that an elective interdisciplinary topic of this depth is hard to incorporate into a regular high school curriculum. Students attending after school can do some of their work in a school setting, and can continue their efforts from home.

What do educators need to know to lead the program at their schools?

Site educators in this program may have primary degrees in one of the STEM subjects, although a willingness to support inquiry-driven PBL is far more important. In this way, their own enthusiasm for the subject will be obvious to the students who, in many cases, may need some words of encouragement or help when getting stuck on a project. Educators need to be chosen in ways that will support the success of the program.

All educators in this program will attend two full weeks of staff development (one week per semester) which not only explores the curriculum, but the underlying pedagogy in depth, along with other requisite skills in the technology and engineering domains. We believe that the role of co-learner is important during staff development, as well as when working with students. We also recognize that site educators should have support throughout this program. For this reason, they will be provided with a mixture of online resources, individual/group conference chats, and site visits to secure help from the Center staff and each other.

Each site will be visited at least once a year for a program review where the identified successes and challenges can be explored. Some sites will be studied in greater depth so we can monitor the efficacy of our design, and make corrections if needed.

What will students be able to do when they are done?

We expect students who complete any year of this program will have come to see the STEM subjects as having tremendous relevance and application. Instead of learning *about* these subjects, they will be conducting their own work *in* the STEM fields. This will give them an advantage in post-secondary education, and may encourage more students to pursue deeper education and careers in the STEM fields. Given the shortage of STEM workers in the United States today, this result would be of great value to the country.

Why did this program start internationally?

Imagine looking at the Earth rising over the Moon.

Our beautiful blue ball is teeming with life, and with powerful ideas. From space, one does not see national boundaries, only a place called "home." Any worthy program that is involved with space exploration must, in our view, be international in scope. Each of us knows something, but none of us knows everything. The Center is devoted to finding and developing the best resources we can, no matter where in the world they originated.

A second (and more pragmatic) reason for designing this as an international program is that student teams from various countries can have a better grasp of cultural diversity when collaborating on projects, thus adding richness to their experiences.

Where do NASA and other relevant agencies fit in?

We are in constant contact and collaboration with people from NASA, as well as other agencies, organizations and resources who have amazingly high quality materials we can use in support of our curriculum. While the Center is not part of NASA, we have enthusiastic NASA team members who are helping us on a regular basis. In Brazil, the relevant agency is AEB (Brazilian Space Agency) who also has rich educational resources. Other groups are providing us with wonderful materials we are evaluating for relevance and building into our curricular objectives.

What if we don't have the room or available technology resources at our site?

In the event that schools have the space, but not the technology, we will arrange special pricing for the computers needed to implement the program. In the case that there is neither the space nor the technology, the Center will work with you to find other solutions.

Is this program available to students in elementary school?

As a result of early conversations with educational leaders, we launched this project at both the Middle School and High School level. We are now migrating the program to lower grades as well, perhaps to third grade where student attitudes toward science are first being formed.

Why does this program make extensive use of free open-source software (FOSS)?

We recognize that different schools use different computing platforms; Windows, Macintosh, and Linux. Because of this, we have designed the program to make use of excellent free open-source software that works equally well on any the these platforms. This is also of benefit to students continuing their work at home, since they can use the same software they are using at school, no matter what kind of computer they own. Also, many of the space-related programs are developed as FOSS projects for which there are no commercial counterparts.

What are our qualifications?

David Thornburg, Ph.D. (Executive Director)
David is the Founder and Director of Global Operations for the Thornburg Center. He is an award-winning futurist, author and consultant whose clients range across the public and private sector throughout the planet. His razor-sharp focus on the fast-paced world of modern computing and communication media, project-based learning, 21^{st} century skills, and open source software has placed him in constant demand as a keynote speaker and workshop leader for schools, foundations, and governments.

As a child of the October Sky, David was strongly influenced by the early work in space exploration, and was the beneficiary of changes in the US educational system that promoted and developed interest in STEM (science, technology, engineering, and math) skills. He now is engaged in helping a new generation of students and their teachers infuse these skills through the mechanism of inquiry-driven project-based learning.

His educational philosophy is based on the idea that students learn best when they are constructors of their own knowledge. He also believes that students who are taught in ways that honor their learning styles and dominant intelligences retain the native engagement with learning with which they entered school. A central theme of his work is that we must prepare students for their future, not for our past.

David splits his time between the United States and Brazil. His work in Brazil also is focused on education, and he has spoken at conferences and consulted for firms and educational institutions throughout that country.

Norma Thornburg, MA (Pedagogical Director)
Norma is currently the director of emerging technologies for the Thornburg Center where she shares her insights on trends relating to tools that help students learn more effectively. She has been a classroom teacher, a principal, a technology coordinator, and an educational consultant. Her work brings her all over the world.

While too young to have been caught in the Sputnik frenzy herself, she still developed a strong interest in technology, and has worked for years on projects where students designed and built computer-controlled robots themselves.

Norma's work in support of constructivist learning led her to write the first book on the Logo programming language in Brazil. She has many years experience working in the field of inquiry-driven project-based learning (PBL) and was the lead designer of a five-year PBL program that, at its peak, reached over 15,000 students throughout Brazil.

Sara Armstrong, PhD (Pedagogy and Assessment)
Sara Armstrong, Ph.D. has been an educator for over 35 years – as a classroom teacher, principal, and professional developer. She is recognized for her dedication to project-based learning and the benefits that accrue to students and teachers through this practice, particularly in the elementary grades. She conducts workshops in developing effective projects across the country, and has also led workshops in Nairobi, Kenya, Gabarone, Botswana, and Monterrey, Mexico. She is a firm believer in meaningful assessment, and presents workshops on developing effective rubrics for all aspects of project work. Sara is also interested in the power

of story and storytelling, and infuses it into her presentations and workshops. Her latest book, Information Literacy: Navigating and Evaluating Today's Media (Shell Education, 2008) helps students and adults think critically about the deluge of daily information we all experience. Sara is a recipient of both the Gold and Platinum Disks from Computer-Using Educators.

Additional active members of the program bring a variety of expertise in areas like PBL and rubric development.

How will the efficacy of the program be measured?

We have formed an alliance with Ruthmary and John Cradler from ESS (Educational Support Systems, San Mateo, California) to provide an external evaluation of this program as it is implemented in schools throughout the world. Their extensive background in program design and measurement will help insure the high quality of our efforts, and provide solid measures of the benefits of this program over the long term.

How do we get this program funded?

The Thornburg Center for Space Exploration will work with you on choosing the most effective implementation of the program. Our price sheet shows a few ways the program can be brought to your school or district.

How do we get started?

Contact David Thornburg directly at dthornburg@aol.com or by telephone at 847-277-7695 to schedule a conversation about your interest in this exciting program.