Spaceward Bound 2006 Expedition: Chile Final Report

Christopher P. McKay, PI
Lizabeth K. Coe, Co-PI

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L. Conrad

"As I prepare for the first day of school, my mind is racing with anticipation of sharing my experiences of the Atacama expedition. I am so eager to be returning to school so that my excitement can be related to my fellow teachers and most importantly, my students. There have been other experiences I've enjoyed that have increased my enthusiasm for teaching science, but never anything of the magnitude of this summer's expedition."

- *Cherlyn Anderson, Sandhills Middle School, Gaston, South Carolina*

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Introduction

Program Description

"Tell me and I will forget.
Show me and I may remember.
Involve me and I will understand."
- Chinese Proverb

Spaceward Bound is an education program developed at NASA Ames (Codes SST and EN) in partnership with The Mars Society, and funded by the Exploration Systems Mission Directorate (ESMD) at NASA Headquarters. 2006 was the pilot year of the program.

The mission of Spaceward Bound is:

> *To train the next generation of space explorers by having students and teachers participate in the exploration of scientifically interesting remote and extreme environments on Earth, as analogs for human exploration of the Moon and Mars.*

The program is comprised of two expeditions per year. The focus of one expedition is to involve K-12 teachers in authentic field work so they can bring the experience back to their classrooms and assist in the development of pedagogy related to human exploration of remote and extreme environments. The focus of the second expedition is to enable students at the upper undergraduate and graduate level (and teachers) to participate as crew members in two-week long immersive full-scale simulations of living and working on the Moon and Mars at the Mars Desert Research Station (MDRS), established and operated by The Mars Society.

In June 2006, seven middle school teachers from around the U.S. teamed with seven teachers from Antofagasta, Chile to work alongside scientists exploring the Mars-like soils of the Atacama Desert in Northern Chile.

Five Spaceward Bound 2006 student/scientist crew rotations at MDRS will take place between November 2006 and April 2007.

This report will discuss the first expedition to the Atacama Desert.

Expedition: Chile

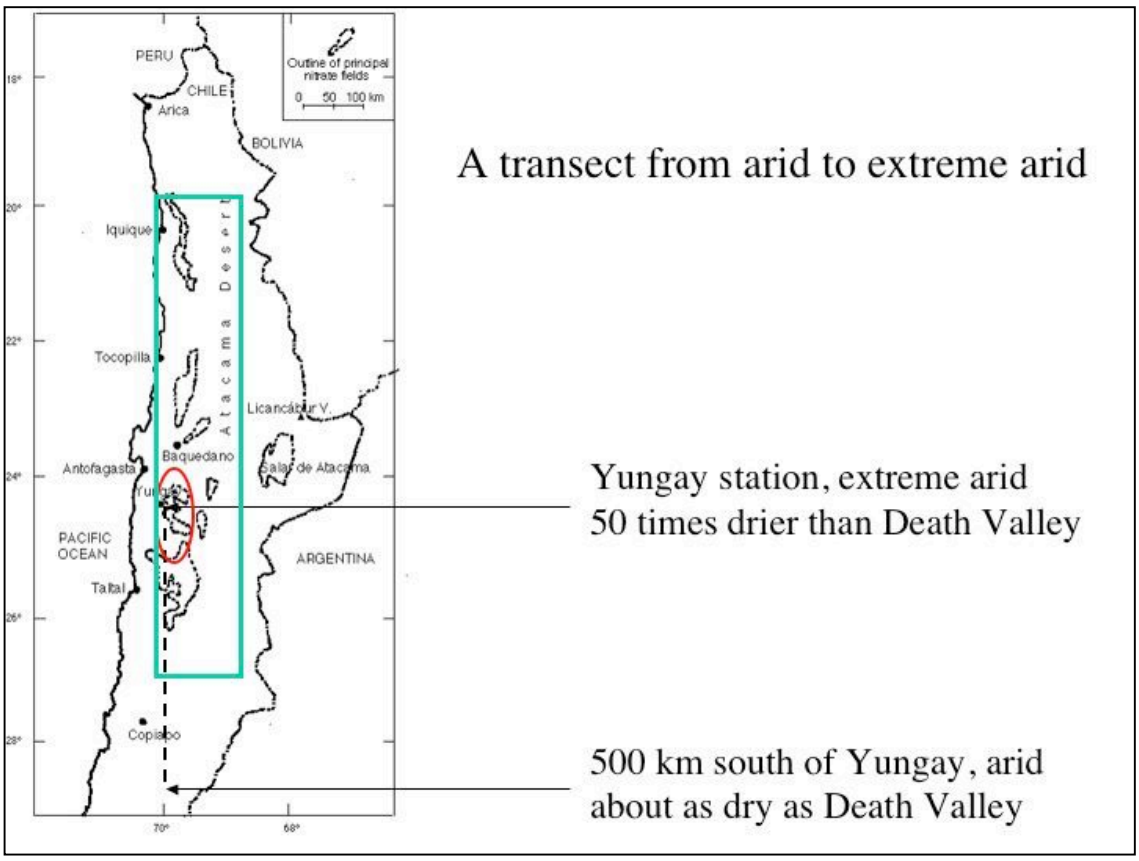
The first Spaceward Bound expedition took place from June 19 – June 30, 2006. The Atacama Desert was chosen as the site for this expedition because it is one of the oldest and driest deserts on Earth and provides an analog for life in dry conditions on early and present Mars. Our biological and chemical results suggest that if the Viking lander had landed in the arid core region of the Atacama, it would have been unable to detect any evidence of life. Indeed, the lander instruments would have produced results similar to what they produced on Mars.

"The Atacama desert has been found to be the driest place on earth. In fact, it is forty times drier than our own Death Valley. There can be literally decades between periods of rain fall. The only water to be found in this region of Chile, sandwiched between the coastal mountains on the west and the mighty Andes to the east, is underground. There are also a few rivers fed by the Andes that flow through the parched land in route to the sea. In the Yungay Region of this desert NASA has set up a Mars Analog Research Station. The landscape is similar to Mars and so devoid of life NASA uses this station to test techniques and equipment that could be used to explore the Martian planet or other extra terrestrial surfaces in the near future. Just to play a small part in something like this is an awesome experience in itself."

- Geoffrey Hammond, Lake View Elementary School, Huntington Beach, CA

There were also pragmatic reasons for selecting the Atacama Desert for this expedition:

1) it is accessible in the northern hemisphere summer when teachers are available,
2) the PI has worked in the Atacama Desert for over 10 years and has extensive knowledge of the area,
3) there is an existing letter of agreement between NASA and the universities in Chile for such activities,
4) several other groups had expressed interest in partnering with us for an Atacama expedition and the opportunity existed for synergy between these activities,
5) an established (yet rudimentary) research station exists at Yungay (see Figures 1 and 2), approximately 60 miles from the nearest city, Antofagasta.



Chris McKay

Figure 1: Location of Yungay Research Station

The research station at Yungay is best described by one of the teachers in his journal:

> *Thursday, June 22*
> *"The teachers 'americanos' woke up from a shivery night (it got down to negative two degrees Celsius) at a leisurely hour today since we got in late last night and were waiting for the Chilean teachers due to arrive at 10:00. This was our first look at "home" for the next week and a half. Camp last night was pitched in the dark next to the only trees in the area.*
>
> *The first images our eyes took in was a sea of sand and rock as far as you could see. Huge barren mountains ringed our horizon. The Yungay Station itself consists of one building with six rooms straddled on both sides of a courtyard. The south east corner of the building is the kitchen, complete with apartment sized propane stove, sink (Cold water), and small gas refrigerator.*
>
> *The northeast corner is the lab room, already full of equipment analyzing samples taken on the transect. Across the way is the bathroom with toilet, sink, and shower—cold water only. There are three rooms surrounding the bathroom that are sleeping quarters, at least one reserved for tech purposes when more equipment comes in on the weekend. Everything is simple and put together to work, not necessarily to look good."*
>
> *Koby Van Beest, Mascoma Valley Regional High School, Canaan NH*

C. McKay

Figure 2: Yungay Research Station

Expedition Timeline

June 19 – Teachers and scientists rendezvous at Dallas-Ft. Worth airport for overnight flight to Santiago.

June 20 – Teachers and scientists arrive in Santiago and begin transect; spend night in Vallenar;

June 21 – Teachers and scientists begin data collection portion of transect; make five data collection stops along the way and arrive at Yungay Research Station around 10 p.m.; greeted by more scientists from the U.S., Spain, and Peru.

June 22 – Chilean teachers and scientists arrive; introductory lecture at the Rock Garden; all teachers and scientists begin forays into the desert for data collection (field work); some are able to analyze samples at the Station.

June 23 – similar to June 22

June 24 – Field work on the way to San Pedro de Atacama; had flat tire in the desert and were delayed long enough to require spending the night in San Pedro

June 25 – Field work on the way through Valle de Luna and return to Yungay

June 26 – Broadcast crew arrives; Preparation and rehearsal for webcasts; continued field work

June 27 – Webcast in Spanish featuring Chilean teachers; Chilean teachers leave for home; continued field work

June 28 – Webcast in English featuring American teachers; continued field work

June 29 – Break down and pack up Station; drive to Vallenar collecting samples along the way

June 30 – Continue drive to Santiago and begin the journey home.

Program Overview

This expedition was comprised of three components:

1) Education
2) Science
3) Technology

The overarching theme that united the three components was *exploration*. Scientific activities were approached from the perspective of how similar activities would be performed on the Moon or Mars, how findings here on Earth could assist the identification and analysis of those from the Moon/Mars, and what infrastructure was needed to support the research which will, in turn, need to be provided on the Moon/Mars surface. The technology component was approached similarly.

Education activities were guided by the motivation to train students to be the next generation of explorers. The next generation will be the one from which the first inhabitants of a lunar research station will come, and will be the first to step foot on Mars. While *exploration* is often presented in classrooms as a motivational supplement to existing curriculum, and components of *exploration* are taught, no pedagogy[1] of *exploration* itself exists.

A true pedagogy of *exploration* would provide unparalleled experience in affective and cognitive motivations such as curiosity, discovery, bravery, disappointment, tenacity, flexibility, etc. Unfortunately, it also requires a synthesis of currently segregated academic disciplines, i.e. "hard" science, "soft" science, and non-science. Modern schools, curriculum and pedagogy are ill-equipped to embrace this synthesis, much less develop content, concepts and skills to teach it.

The goals and outcomes of the expedition for the individual teachers and their respective education communities will be discussed below. In a broader sense, however, the contribution of this expedition to the education community as a whole (including research) and to NASA is the creation of a program which enables the amalgamation of the expertise and experience of Master teachers with the knowledge, practice and experience of today's explorers to begin the conceptualization and development of a pedagogy of exploration.

Analysis of the teacher's final reports (see below) reveals how this new pedagogy may look – the best of current practice re-shaped and re-directed to reflect the actuality of *exploration*. It also provides clear evidence of the intrinsic power of authentic *exploration* to motivate, engage, frustrate and thrill.

Mission and Goal Alignment

As an experiential and immersive professional development program that takes place in an authentic science research context, Spaceward Bound is clearly aligned to NASA Education goals as well as the guidelines for effective professional development from respected science education research organizations.

- *NASA Goal 1: Strengthen NASA and the nation's future workforce*

The generation of students who will become the first astronauts to return to the Moon and step foot on Mars are currently in middle school. In order to fulfill NASA's mission, students will have to be trained in exploration science. This training consists of both STEM education as well as education that leads to understanding of exploration concepts and skills. In order to provide the latter, teachers must be trained not only in exploration science content and skills, but also pedagogy and pedagogical content knowledge – a primary focus of Spaceward Bound.

In addition, the Spaceward Bound program specifically targets traditionally underserved and underrepresented communities by recruiting teacher participants from the NES Explorer Schools Program which selects schools from these same populations.

[1] The science or profession of teaching

- *NASA Goal 2: Attract and retain students in STEM disciplines*

In order to engage and retain students in STEM education programs, students must perceive that these programs are engaging, fascinating, challenging and rewarding. Exploration science, particularly field research analogous to work that will be done on the Moon and Mars, is unparalleled in its capacity to inspire and intrigue students. The singular most important conduit for exploration science to reach students is through teachers – teachers who themselves are inspired and captivated by the science and well-trained in its concepts and skills.

- *NASA Goal 3: Engage Americans in NASA's mission*

The list of partners participating in this expedition is extensive:

- The Mars Society
- NASA Explorer Schools
- New Mexico Tech
- Desert Research Institute
- University of Nevada
- Valdosta State University
- Utah State University
- SETI
- USGS
- University of Antofagasta
- Catholic University of Chile, Santiago

In addition, through utilization of state-of-the-art web-based technology, Spaceward Bound is inherently able to reach a world-wide audience of formal and informal educators, students and the public. In addition, Spaceward Bound alumni are expected to disseminate their knowledge and experiences to both educational and public audiences. The interest of national and international press in Spaceward Bound provides clear evidence of its ability to engage the public in understanding exploration science.

Spaceward Bound also clearly fulfills the goals of the ESMD Education mission as below, by enabling teachers to understand the capabilities and technologies that currently exist to sustain exploration, and challenging them to engage themselves and their students in consideration of what will be needed in the future.

> *"ESMD is developing the next generation of spacecraft, including capabilities and technologies that enable sustained and affordable human and robotic exploration of space as outlined in the Vision for Space Exploration. ESMD research also ensures the health and performance of crews during long-duration missions. The ESMD education portfolio supports the broad agency education goals and is specifically tailored to meet NASA's long-term workforce requirements."*[2]

[2] http://education.nasa.gov/about/factsheet/index.html

The National Research Council goal for professional development is "*To enhance teachers' abilities to improve student learning"*. The following table lists the NRC objectives and explains how Spaceward Bound meets them.

NRC Objective	Spaceward Bound Element
To increase teachers' knowledge about subject matter, current issues and practices in science exploration	Through the extensive resources provided on the Spaceward Bound website and mentoring by world-renowned scientists, teachers were provided quality opportunities to learn all aspects of science exploration.
To offer field opportunities to participate in scientific research and exploration so that teachers will understand more about the process of science	Given that over 20 scientists participated in this field expedition, teachers were able to participate in an extremely wide variety of science exploration techniques and practices.
To build discipline-based scientific collaboration between teachers and scientists	As evidenced by the teacher's journals and final reports, collegial relationships were formed that exist to the present. In some cases, teacher and scientists are collaborating on long-term projects, such as the self-sustainability of the Yungay research station.
To prepare teacher mentors to train other teachers in subject matter, teaching strategies, and ways to adapt teaching strategies to the curriculum	Spaceward Bound is designed using a "train the trainer" model. Teachers are expected to bring their knowledge and experiences to their colleagues, schools, communities and a national audience. They are encouraged to utilize the NASA Explorer School Distance Learning Network for such activities.

Table 1: NRC Objectives and Responsive Elements of Spaceward Bound

Teacher Catherine Campbell wrote extensively in her final report about how Spaceward Bound followed, met and exceeded the requirements for training in experiential science as established by the Association of Experiential Education[3]:

> *"Experiential science is defined by the Association of Experiential Education (AEE) as, "…a philosophy and methodology in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills and clarify values." Key words that translate Spaceward Bound into science inquiry classrooms are "purposefully engage, direct experience and focused reflection".*
>
> *How were the Spaceward Bound teachers purposefully engaged? There were a number of activities performed by teachers that prepared them for the trip, starting with a rigorous essay application process that required*

[3] http://www.aee.org/customer/pages.php?pageid=28

applicants to reflect on specific prior experiences and personal qualities necessary to make an expedition such as Spaceward Bound meaningful. Teachers also researched various Mars analogs and became familiar with the science done at those sites along with the logistics of doing science while living in extreme environments. Teachers were placed in teams to write about the components of a Spaceward Bound type of expedition, which allowed them to begin to communicate with each other and work towards common goals. Videoconferencing provided both content and introduced the teachers to some of the scientists that would be part of Spaceward Bound and allowed everyone to put faces to names. By the time it came to travel to Chile, the group was fairly cohesive and looked forward to meeting each other in person.

That sense of purpose continued during the expedition itself with daily meetings between teachers concerning the outcome of the project and the DLN broadcast, which was scheduled for the ninth day of the trip. Connections were also made between scientists and teachers. The fieldwork proved fascinating and the scientists were engaged and eager to share their expertise. Teachers shared the scientists' enthusiasm and curiosity throughout the journey and worked alongside them to learn more about the research and the process for doing the research. Scientists also worked with one another, comparing and discussing results in order to verify information. Many soil and rock samples were checked using different equipment and methods with much debate regarding results obtained. Instruments were calibrated and recalibrated and anomalous findings provided more opportunities to troubleshoot techniques.

The broadcasts were another opportunity to observe troubleshooting at its finest and proved to be a highlight of the expedition. The technology necessary to do a broadcast from the middle of the desert along with the number of technicians and support staff was amazing. The Chilean teachers went first with a fairly formal broadcast. The majority of the broadcast consisted of Dr. Benito Gomez from the University of Antofagasta discussing the science being done at the station and the station itself. The American broadcast was much less formal with each teacher discussing the experience and how the experience would be taken back to schools and to other teachers. The viewers included people from teachers' families, schools, the 2006 cohort from Glenn Research Center in Ohio and teachers attending the Astrobiology workshop at Ames in California. The broadcasts definitely provided purposeful engagement to the Spaceward Bound experience.

The second component of experiential education is "direct experience". It is obvious Spaceward Bound met the direct experience component as the entire expedition from the planning stage through the Atacama stage was direct (and directed) experience. It was mentioned more than once during the trip that this was the best field trip ever, one which included all aspects of science, including collection of samples, running of tests, learning about process and discussing next steps. Having Chilean teachers and professor/scientists from the University of Antofagasta, Chile, and other

countries such as France and Italy, expanded the expedition to include elements of geography and culture, which incorporated the concept of global science into the experience. Language barriers, translation and different accents created interesting problems with communication as the ever increasing group size created problems with logistics, transportation and the use of resources such as bathroom facilities and electrical outlets. Although those types of problems were to be expected, they served to focus group problem solving and provided more opportunities for direct experience that could be brought back to classrooms and schools.

There are many connections and experiences that this participant will be translating into content and activities for the classroom. The main one is the connection made with Dr. Henry Sun, a research scientist at the Desert Research Institute in Nevada. Dr. Sun was in the Atacama looking for endolithic microbes and field-testing apparatus used to detect organic respiration. Through discussion and observation of his work, it became apparent that the basis of his work could be translated for seventh grade students studying life science and scientific process by simulating the transect between Santiago and Yungay Station in a classroom or greenhouse environment. Students and Dr. Sun would be able to interface through the DLN thereby providing an authentic experience and an enthusiastic audience for the students' experiments and results. Using the same type of experiential science that was used to prepare for Spaceward Bound should create a viable framework for the collaborative work. Protocol and lessons are currently in the development phase, but when completed and documented could be presented at national science conventions or through the NASA DLN. This is an example of how the second component of experiential education, direct experience, contributes to the advancement of experiential education for other educators and students as well.

Directed reflection is the third component of experiential education. It is during this phase that the learner understands the purpose of the experience and connects it to the real world. It is also at this time that the content is clarified, and assessment can take place. If the Spaceward Bound programs qualified as true experiential education, this all -important component needed to be present.

Throughout the Spaceward Bound experience teachers were required to journal thoughts, ideas and events. The journal became the basis for the narratives that were to be written and provided a means to document the trip, along with becoming a record of ideas that would be used to translate the experiences when we returned. Directed reflection was the vital piece of the educational experience, for it was through the reflection that the individual pieces of the expedition combined into a complete picture.

- Catherine Campbell, Scarlett Middle School, Ann Arbor, MI

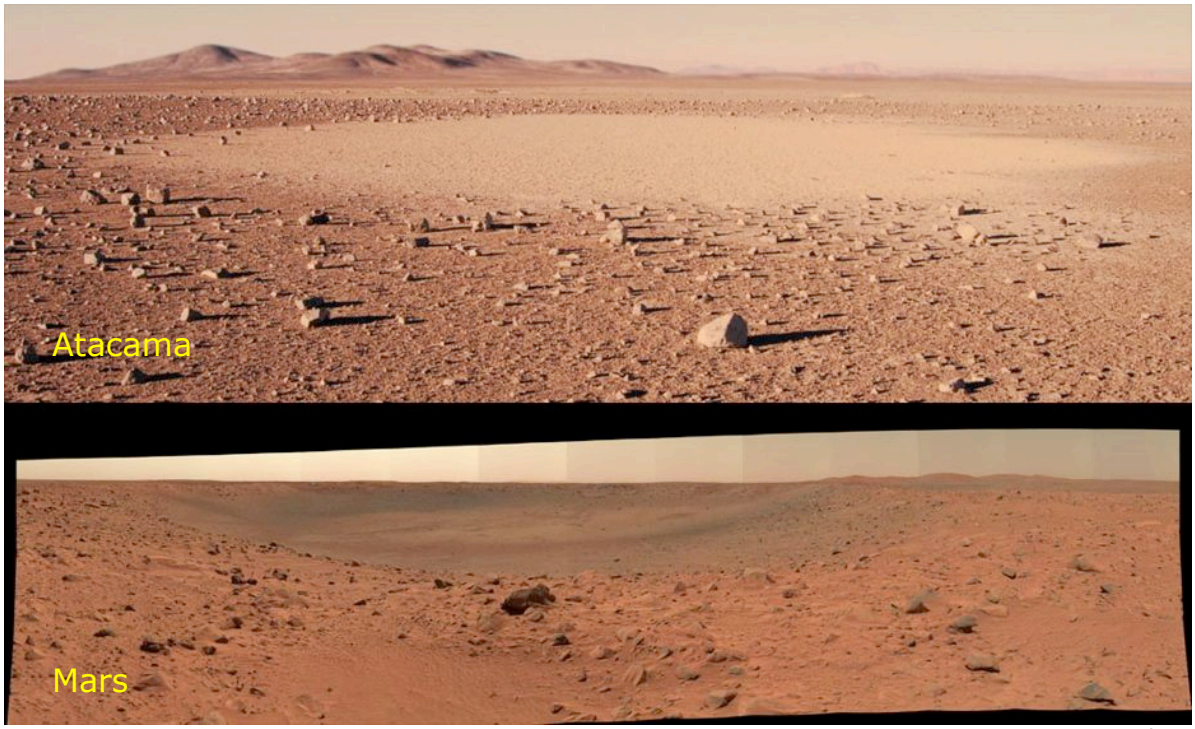
Science Component

Atacama Background

Within the driest part of the Atacama desert there exists a region with "Mars-like" soils (see Figure 3) (Navarro-Gonzalez et al. 2003). There are three characteristics that make these soils Mars-like:

1. There are very low levels of organic material and the organics that are present are refractory. They do not decompose at the temperatures reached by the Viking GCMS (5000C).
2. There are virtually no detectable soil bacteria either by culture or DNA amplification (Navarro-Gonzalez et al 2003) or by Limulus Amebocyte Lysate (LAL) (M. Turnbull private communication).
3. There is present in the soil an oxidizing agent that equally oxidizes L and D amino acids and L and D sugars.

Soils to the south of the arid core region do not show these characteristics. We think that these Mars-like characteristics result from the extreme aridity of the core region of the Atacama. The entire Atacama is arid and receives very little rain. However many locations in the desert receive marine fog providing sufficient moisture for hypolithic algae, lichens and even cacti (Rundel et al. 1991, Warren-Rhodes et al. 2006). However in the region south of Antofagasta the coastal range blocks the marine fog. (See Figure 4)

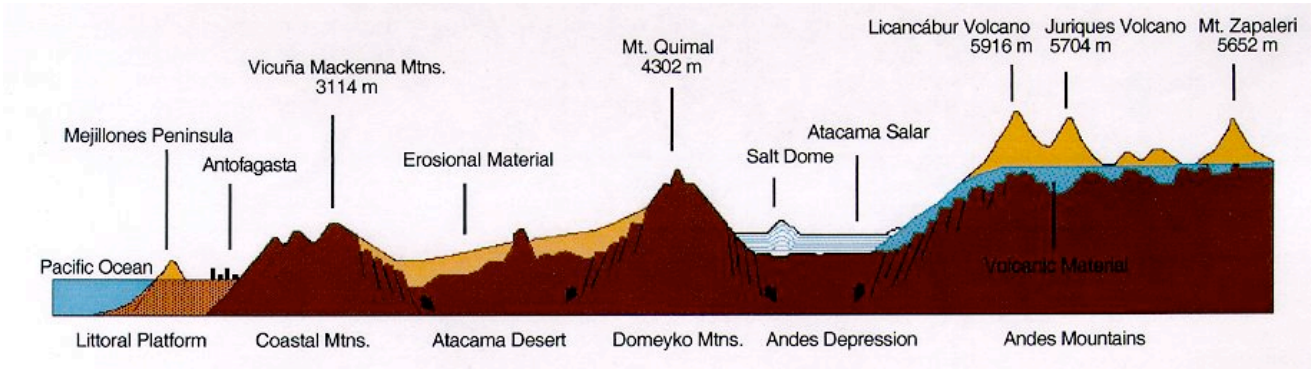


J. Wierzchos

Figure 3: Mars-like soils of the Atacama Desert visually compared to actual Mars soils

The crest-line of the coastal range averages 2500 m for about 100 km south of Antofagasta. The region that is in the "fog shadow" of this high coastal crest-line is the region that contains the Mars-like soils. Reich et al. (2001) have used sulfur isotopes to

trace out the areas affected by marine input. Their results are consistent with the coastal range blocking the marine fog in the region of Mars-like soils.



Chris McKay

Figure 4: Latitudinal cross section of Chile demonstrating that the Atacama Desert is shielded from moisture on both it's east and west sides resulting in extreme aridity

The transition between bacteria-rich soils and the Mars-like soils is not yet understood. Preliminary data suggests that the transition is patchy. In the extreme arid core the soil is dominated by Mars-like conditions with isolated islands of bacteria-rich soil. Moving toward wetter regions, these isolated islands presumably become more numerous and eventually merge for form the continuously habitable soils we observe in the regions of the Atacama the receive >25 mm/yr of rain. The arid core area the patchiness could follow geological patterns in the soils, or could follow subtle environmental patterns of water availability, or the patchiness could be an intrinsic response of the microbial ecosystem.

Science Program

The leads for the expedition science research activities were Chris McKay (NASA Ames) and Penny Boston (New Mexico Tech).

Scientist	Affiliation	Subject
Chris McKay	NASA Ames	Astrobiology
Penny Boston	New Mexico Institute of Mining and Technology	Microbiology
Linda Powers	Utah State University	UV Fluorescence
Jim Nienow	Valdosta State University	Cyanobacteria
Henry Sun	Desert Research Institute, University of Nevada	Soil microbiology
Kelly Snook	NASA GSFC	Soil electrostatics
Cassie Conley	NASA Ames	Desert invertebrates

Table 2: Scientists participating in Transect

In addition to the seven science "faculty" listed in Table 1, many other scientists joined the team at the Yungay Station for various lengths of time. The project had a open door policy and any scientist who was interested was invited to come to the station during the dates that the station was being operated for this expedition. By participating as part of the expedition these scientists benefited from the hospitality and infrastructure at the station and could conduct their work under the auspices of the NASA letter of agreement. The expedition benefited from the expertise they brought to the expedition.

In addition to the seven expedition science faculty, a graduate student and 14 scientists participated in station activities during the expedition. This included two scientists from Chile and two from Peru.

Graduate Student
Pierre-Yves Cousteau, International Space University, nematode distribution

Scientists
Rosalba Bonaccorsi, NASA Ames, soil organic content
Sasha Tsapin, JPL, culturable microorganisms
Alfonso Davila, NASA Ames, magnetotectic bacteria
Jacek Wierzchos, Spain, electron microscopy
J. Judson Wynne, USGS Flagstaff, evaporite cave detection and invertebrates
Jim Thompson, thermal detection of caves
Richard Quinn, SETI/ARC, soil oxidant chemistry
Cindy Taylor, SETI/ARC, soil oxidant chemistry
Lauren Fletcher, ARC/Stanford, Soil: DNA, microbiology, organics, mechanical properties
Shayne Rich, Engineer, Spectre Engineering Support

Scientists (South America)
Benito Gomez, University of Antofagasta, Director Yungay Research Station
Armando Azua Bustos, Catholic University Santiago, microbiology
Renee Apaza, Peru, soil microbiology, DNA
H. Saul Perez Montano, ARC, Chemist & Soil Researcher

The field research consisted of two parts: 1) a transect from the relatively wet southern border of the Atacama near the town of Vallenar to the Yungay station in the extreme dry core of the Atacama and 2) fieldwork performed at various locations based out of the Yungay Research Station. During both parts, the teachers worked alongside the scientists and participated in the in situ experiments and the collection of samples for analysis.

The distance of about 600 km (from Vallenar to Yungay) covers a range of rainfall rate from about 50 mm/year to less than 0.5 mm/year. Although the rain varies by a factor of 100, other environmental factors, temperature, elevation, UV, etc are essentially constant. Thus the transect provides a way to investigate the effects of moisture limitation in a direct way.

> *"As we continued north and turned inland towards our destination in the Yungay the terrain quickly began to change. Vegetation became less and less until there was none left at all for as far as the eye could see. No little*

shrubs, cactus, lichen, nothing. It was just sand, dirt and rock. The area was very desolate and seemingly very lifeless."

- Geoffrey Hammond

Our previous work (Navarro-Gonzalez et al. 2003) has shown that there is a dramatic change in the concentration of life in the soil over this transect with soil bacteria concentrations decreasing by a factor of 10,000 from the wet to the dry end. One goal for this year was to collect a set of samples over a wider range than before and to do a battery of tests on the samples comparing organic material and soil microorganisms. (See Appendix 1: Transect Samples for list of transect locations). A short description of some of the key science conducted on the transect and from Yungay can be found in the following paragraphs.

Hypolithic cyanobacteria: led by Jim Nienow, we investigated the distribution of diaphanous (translucent) rocks colonized with cyanobacteria. In the wet end of the transect there is sufficient rain that many of the diaphanous rocks are colonized. As we moved further north into dry environments the colonization became less and less and eventually disappeared. Along the coast, colonization was pronounced. The dry core of the Atacama desert is the only desert known in which hypolithic algae are not found.

Rock varnish: led by Penny Boson, we investigated the distribution of rock varnish across the moisture gradient. It is known that in deserts varnish-like material builds up on rock surfaces. This varnish is typically rich in Manganese and contains entrapped microorganisms. The role that microorganisms play in the formation of desert varnish is controversial. In the Atacama desert there appears to be less rock varnish in the arid core than in the wetter southern regions.

UV fluorescence: led by Linda Powers. Linda Powers' group at Utah State has developed a UV fluorescence instrument that can detect bacteria on surfaces without contacting the surface. The instrument is portable and we used it to measure soil bacteria during the transect. Soil samples were collected and placed in a tray beneath the unit. The highest concentration detected by the instrument was 10^6 and the lowest (near Yungay) was 10^2 - roughly equal to counts per gram.

Soil chemistry and organics: Samples were collected by Rosalba Bonaccorsi along the transect for analysis for PLFA (phospholipid fatty acid), ATP (adenosine tri-phosphate), TOM (total organic matter), and C/N (carbon/nitrogen) ratio. This analysis will help us understand the nature of the gradient in soil properties in response to changes in moisture.

Nematodes: led by Cassie Conley, we collected samples to search for nematodes. There are two interesting questions related to nematodes in the Atacama. First the distribution of nematodes in response to the moisture gradient. Second, recent results have shown that nematodes are poisoned by nitrates. The Atacama desert is high in nitrates and thus, there may be nitrate resistant strains of nematodes present there, or the presence of nematodes may be greatly suppressed beyond that expected due only to low water availability.

Samples for chiral uptake: led by Henry Sun. We collected samples for analysis at the station for the rate of CO_2 release after wetting. These wetting experiments are similar to the Viking biology experiments and we compare our results for the Atacama to the results obtained from Mars. The ongoing work, as well as previous work, indicates that in the extreme arid region of the Atacama the soil consumes organic material independent of chirality. This is indicative of a non-biological oxidant. Soils in the wetter south end of the transect preferentially consume organics that are compatible with biological processes.

One science investigation was performed only at the Yungay Research Station. It was aimed at understanding the effect of humans in the Mars-like soils.

Coliform: led by Cassie Conley and Penny Boston, we collected surface soil samples from the station, around the station and the soils nearby the station. We incubated these samples for the presence of human coliform bacteria. Our results indicated that contamination by human coliform bacteria was limited to the area of the station itself and did not extend beyond into the desert.
Final science results will be submitted to Journals for publication.

Technology Component

The technology component addressed issues of remote communications and control of robots and featured several sessions of students in California driving rover robots in Chile.

The technology crew included:
Mark Leon, NASA Ames, Lead
Corey Ippolito, Carnegie Mellon University, Director of Engineering
Steve Patterson, NASA Ames, Communications Engineer
Maite Trujillo San Martin, NASA Ames, Research Engineer

In addition, the technology demonstration afforded the utilization of satellites to broadcast a webcast/webchat using the NASA Quest infrastructure, to education audiences in both English and Spanish.

John Conley

Figure 5: Setting up the dish

Education Component

The primary focal point for Spaceward Bound is teachers and, as shown above, responds in full to the charges of leadership organizations in the science education community. Spaceward Bound also seeks to involve students directly through the utilization of the NASA Quest Program infrastructure – specifically through Quest Challenges and associated webchats and webcasts. In order to test the capabilities of our webchat/webcast technologies to broadcast from a remote and extreme environment, two webchat/webcasts were broadcast from the Atacama desert – one in Spanish, one in English. Information on these broadcasts can also be found below.

Research Background

The research basis for the design of the Spaceward Bound professional development program can be found in the literature involving teacher professional development in STEM subjects, experiential education and learning, immersion in authentic science, STEM pedagogy and constructivist approaches. In 1995, with funding from NSF, SRI lead a study of federally funded teacher enhancement programs in science and technology[4]. Their study concluded that the effective programs identified in the study had much to offer teachers as individual professionals and much to contribute to education reform efforts. They described these programs thusly:

> *"As a group, the institutes promoted and modeled a hands-on/minds-on, constructivist approach to instruction, immersed teachers in the practice of science, and facilitated transfer of learning with follow-up support throughout the school year." (abstract)*

An exhaustive analysis of a "hands-on/minds-on constructivist approach to instruction" is outside the scope of this report. However, it is intuitively obvious that through the mentoring of scientists and hands-on participation in science processes within an authentic research context, teachers are enabled to construct their own knowledge of exploration as well as design a like-minded pedagogy.

Susan Loucks-Horsley et al strongly endorse immersion of teachers in the world of scientists[5]:

> *"The vast majority of science and mathematics teachers have never had an opportunity to actually 'do' science or mathematics in a real-world setting. This situation perpetuates certain myths about the nature of science and mathematics because most teachers do not have practical experience in the fields they are teaching. Immersion in the world of scientists and mathematicians is one way to resolve this and provides an opportunity for teachers to strengthen their knowledge base in content areas by becoming active participants in a mathematics or science community." (p. 198-199)*

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[4] Ruskus, J. and John Luczak (1995). *Best Practice in Action: A Descriptive Analysis of Exemplary Teacher Enhancement Institutes in Science and Technology*. National Science Foundation.

[5] Loucks-Horsely, S. et al. *Designing Professional Development for Teachers of Science and Mathematics, 2nd edition.* Thousand Oaks, CA: Corwin Press, Inc..

Hence, the need for Spaceward Bound and similar immersive programs is clear. They go on to discuss key elements and implementation requirements of effective immersion programs – all of which are strongly reflected in the design and conduct of Spaceward Bound.

Teacher Recruitment and Selection

Early in the program design it was decided by the PI's to utilize the NASA Explorer Schools (NES) as the pool from which to recruit teachers for Spaceward Bound. This was done for several reasons:

1) The PI had participated in several NES events and was impressed with the enthusiasm and interest of the teachers that he met.
2) Teachers from NES have been introduced to NASA and NASA Education, are versed in NASA's Mission and Goals and culture, and are familiar with how NASA works – making the requirement for extensive introductory training in these regards unnecessary.
3) We anticipated that the administration of NES schools would be supportive of their teachers participating in Spaceward Bound. Even though the expedition took place in late June when school was out, the training sessions took place while school was in session. Depending on the time zone, some teachers had to be released from class to attend the sessions
4) We anticipated that the school culture and attitudes and beliefs of fellow faculty members would provide an environment conducive to Spaceward Bound teacher's ability to return to their schools and implement new practices and disseminate what they had learned to their colleagues
5) We anticipated that the infrastructure and information network residing in the NES program would prove to be helpful during recruiting and establishing communication with the selected teachers.

The NASA Explorer Schools program, under the lead of Peg Steffen with support from John Entwistle, Leah Bug-Townsend and the NES Coordinators, readily agreed to collaborate with Spaceward Bound. They were immensely helpful in two particular areas: marketing the opportunity and teacher selection. Once the Spaceward Bound website was up, the NES program leaders spread the word throughout the program, via "email blasts" and newsletters. The application can be found in Appendix 2.

The PI's and the NES administration performed parallel review and analysis of the applications and each created a ranked list of candidates, which we compared and then came to consensus on a final selection. The NES analysis incorporated the first-hand knowledge the NES coordinators had of the teacher candidates which proved to be invaluable. Our confidence in the NES coordinators input was well-founded – the group of teachers selected far surpassed our expectations.

Teachers pointed out that the infrastructure and previous NASA project participation provided valuable experiences that enhanced their ability to get the most out of the expedition. They also strongly believed that the student demographic represented in the Explorer School population are most in need of teachers with unique experience that they then leverage in the classroom.

"With all of the teachers on the expedition being from NES, we did share a common bond. Also, being from a NES school we have students that are in dire need of the experiences we can bring back to them. We can use our enthusiasm gained from these experiences to motivate our students to perhaps achieve a better life for themselves, following their passions for the love of science, math, or technology."

- Cherlyn Anderson

"I don't know specifically that being a part of an NES school made us better prepared for the trip. However, having videoconferencing equipment, prior NASA workshop experiences, NASA curriculum training, and exposure to inside NASA resources will definitely make our follow-up to this experience a success."

- Matthew Allner, West Middle School, Sioux City, IA

The following table provides a brief summary of information about the selected teachers. Their biographies can be found at http://quest.nasa.gov/projects/spacewardbound/atacama2006/info.html.

Name	School & Location	Subjects	Grades
Matthew Allner	West Middle School Sioux City, IA	Physical Science, Physics, Earth Science, Environmental Science, Biology, Health, Social Studies/Geography	Grade 8
Cherlyn Anderson	Sandhills Middle School Gaston, SC	Science, Technology, Language arts, World geography/history	Grades 5-8
Catherine Campbell	Scarlett Middle School Ann Arbor, MI	Biology, Math, General Science	Grades 7-12
Geoffrey Hammond	Lake View Elementary School Huntington Beach, CA	Science, Math, Reading, Writing, Social Studies	Grade 5
Phyllis Isbell	Key Peninsula Middle School Lakebay, WA	Science, Math, Language Arts, Social Studies	Grades 7-8
Karie Trupka	Circle of Nations School Wahpeton, ND	Science, Math, self-contained	Grades 7-8
Koby Van Beest	Mascoma Valley Regional High School Canaan, NH	Biology, Environmental Science, Physical Science, English	Grades 9-12

Table 3: Spaceward Bound Teachers

Pre-Expedition Training

Given the challenging nature of the expedition, the PI's decided to utilize the Distance Learning Network (DLN) to broadcast five hour-long pre-expedition training sessions. In addition the training sessions were broadcast through the internet. The training sessions were held on March 20, April 11, May 2, May 16 and June 12. The fifth training session was presented in both English and Spanish, with the Chilean teachers looking on. The following table lists the content of each of the training sessions.

Session	Content
1	Program introduction; mission and objectives; learning content; journaling; logistics (Coe); Introduction to science in the Atacama (McKay); Unknown Organisms (Boston); Q&A
2	Homework review; Review of world analog sites and concepts of analog and simulation (Coe); Group discussion on exploration processes (McKay); Q&A
3	Homework review (Coe); Human exploration of the Moon and Mars (McKay); Yungay station travel primer (Fletcher); Q&A
4	Biosignatures: Linking Life and the Geosphere (Boston); DNA Extraction in Atacama Soils (Fletcher); Q&A
5	Atacama Life/Vida en Atacama (McKay, Trujillo); Final logistics and planning, journaling (Coe); Q&A

Table 4: Teacher Training Session Content

Attendance by the teachers was 100% - to the extent that when one of the sessions was scheduled during the spring break of two schools, the teachers logged into the simultaneous webcast and communicated by webchat. All sessions were archived on the website for later review and all presentation materials were made available on the website for download.
(See http://quest.arc.nasa.gov/projects/spacewardbound/atacama/).

The training broadcasts were very successful in several ways:

1) They enabled the teachers to get to know the Spaceward Bound staff and scientists;
2) They provided the opportunity for a substantive introduction to the exploration and science components of the program. While the sessions were broadcast from Ames, scientists from around the country were "patched in" and gave presentations on their work;
3) They enabled presentation and discussion of the (complex) logistics;
4) Teachers were able to ask questions and voice concerns in a collaborative atmosphere.

In order to provide a scaffold within which teachers could build their learning, four focus areas were established:

1) Human factors
2) EVA and exploration
3) Logistics and Transportation
4) Life Support

Each teacher was assigned to two groups. The assignments were made based on their application essays which described their interests and what topics within exploration they found intriguing. At the conclusion of three of the five broadcasts, homework was assigned with the intent to build the teachers' relevant body of knowledge, challenge them to search for and find relevant resources and collaborate with their peers. With the exception of the first assignment, completion required collaboration between the members of the group and preparation of a short joint paper. The teachers found this particularly challenging given their busy end-of-year schedules, the fact that they barely knew one another and communication was only possible through email and phone.

Many admitted to complaining about the assignments while doing them, but realized that they were indeed quite helpful. The following homework assignments were given.

Homework 1

- Write and send biography as well as photo(s)
- Pick your first and second choice of an Exploration Process to focus on. Send your choices and a paragraph about what intrigues you about your choices
- Find five other Mars analog sites (anywhere on our planet). List the characteristics of each place that make them good analogs. Give an example of Lunar or Mars research that is done at each place

Homework 2

- Study the analog sites developed by the Mars Society
    - MDRS – Hanksville, UT
    - MARS-Oz – Arkaroola, Australia
    - Euro-MARS – Iceland
    - Flashline MARS – Devon Island
- Write four brief essays on how each of the Exploration Processes is simulated at each of the sites
    - Logistics and transportation
    - Energy and life support
    - Human factors
    - Exploration and EVA activities
- Write two brief essays that compare and contrast the differences between the sites with respect to the Exploration Processes simulated, for example …
    - Why one site simulates a process and another doesn't
    - What are the strengths and weaknesses of each site with respect to simulation fidelity
- Summarize all the above with an essay on what we can do on our expedition to as effectively as possible to simulate the Processes in your focus area
- Everyone must do the first three parts of this assignment individually. For the fourth, submit one essay from your team

Homework 3

Learn more about the McMurdo Station (Antarctica) using Chris McKay's talk as a basis, particularly with respect to the Exploration Processes: logistics and transportation, human factors, exploration and EVA, energy and life support. How are these processes supported and facilitated by the design and features of the McMurdo Station. Examples may be:

- logistics and transportation - a shuttle vehicle service between sites in and around McMurdo
- human factors - movies!
- exploration and EVA - equipment storage and rental, labs
- energy and life support - water (and restrictions thereon!)

Each group should provide one medium-sized essay on what they've found for their exploration process. Also, for each of the examples that you find discuss briefly whether they will be "doable" on the Moon or Mars and what the trade-off is between the need for it on the Moon or Mars and the difficulty and expense of getting it there or building it there.

In addition to all the above, a significant number of scientific and technical papers were posted on the website as well as references to other websites. These were used as background resources for the teachers.

In their final reflective writings, teachers commented on the pre-expedition activities:

> *"The pre-trip videoconferencing sessions that Liza, Chris, Lauren, Penny, and Maite conducted were great."*
>
> - *Matthew Allner*

> *"The presentations and papers teachers saw before leaving for Chile helped prepare us for what would be going on once there."*
>
> *- Koby Van Beest*

Journaling

The teachers were asked to begin journaling their Spaceward Bound experiences during the first pre-expedition training session. This emphasis on journaling was maintained throughout the expedition for two reasons:

1) Journaling is the most often-used and effective method of encouraging reflection on an experience and enabling cognitive and affective processing and alignment of the experience with individual history, knowledge, and background. Given the unique and novel nature of this expedition, taking quiet time to journal was critical to effective processing – particularly in this case where teachers are not only being asked to individually learn and understand content, but also create opportunities to leverage the content in their classrooms.
2) Journaling is an integral skill within the practice of science. The teachers observed scientists journaling and began to understand the importance of documenting what may, to the untrained eye, appear to be just miniscule details. As part of the goal to have teachers immerse in authentic science practice, journaling was essential.

The teachers worked together to provide a day-by-day journal of their experiences on the website. This set of journals was posted on the website during the expedition. The teachers also relied heavily on their journals to create their final reports (see http://quest.nasa.gov/projects/spacewardbound/atacama2006/journals.html).

> *"Throughout the Spaceward Bound experience teachers were required to journal thoughts, ideas and events. The journal became the basis for the narratives that were to be written and provided a means to document the trip, along with becoming a record of ideas that would be used to translate the experiences when we returned. Directed reflection was the vital piece of the educational experience, for it was through the reflection that the individual pieces of the expedition combined into a complete picture.*
>
> *It was also through reflection on the part of everyone involved in the Spaceward Bound program that the program would evolve into a sustainable one."*
>
> *- Catherine Campbell*

"One of the events witnessed on the transect, and during the work with the scientists, is the importance of journaling. I have stressed with my students for years (and other science teachers) that a scientist's journal means everything to their research. I have often used the example of Sean Connery in the movie "Medicine Man." He had found a cure for cancer, but didn't have the formula because he had lost his journals. It was awesome to see the scientists on the expedition writing in their journals. Penny Boston also related the importance of her journals. She mentioned that although she has transcripts saved on computers, she has had to go back into her actual journals to verify data for colleagues working on similar projects."

- Cherlyn Anderson

Transect

In retrospect, the transect had the most impact in terms of an immersion into the culture and practices of an exploration expedition. It tested the patience and resilience of all participants – teachers and scientists alike: getting off an all-night flight, squeezing 18 people, luggage and scientific gear into four vehicles, driving for two days straight, not stopping except for sample collection, tailgate lunches and pit-stops, finally arriving at their destination (Yungay) at 10 p.m. and setting up camp as temperatures plummeted on their way to 0°C.

However, even with the hardship, many teachers commented that they enjoyed the transect and found that it provided valuable experiential learning. They were able to, for the first time, observe and participate in true science field work.

"The most effective part of the expedition was the transect from Santiago. Although after two days of driving, I questioned the idea. It would have been much easier for us to fly to Antofagasta. I also questioned why Chris assigned us to cars at first. However, in both cases, that would have defeated the purpose of the entire expedition. It was necessary to collect samples along the 800+km route. More importantly, we would not have had time to bond with our fellow travelers (you learn a lot about someone after driving two days + in a car) and would not have been able to see the changes in landscapes along the way. How awesome it was to actually see plate tectonics in action!"

- Cherlyn Anderson

The first transect stop merited several mentions in the teacher's writing, after that partnering with scientists, listening, learning and honing fieldwork practices became (almost) routine.

"We drove a half hour out of town to the first transect site. The teachers separated and went with different scientists to collect samples of the rocks and soil. Our sampling tools consisted of sterile spoons, plastic gloves and zip-lock baggies."

Web Journal 6/21

"About thirty km north of Copiapo we pulled over for our tailgate lunch. Penny went off to look for varnish, Henry and Jim to look for translucent rocks, Linda and Rosalba to gather soil samples. Chris was intent on getting us to the camp by 5:00 pm so we tried to head out as soon as people had their food. He tried."

- Phyllis Isbell, Key Peninusula Middle School, Lakebay, WA

"We stopped twice to "get our feet wet" and do some sampling of the soils. This was to look for life at a microscopic level. Penny Boston and a scientist named Linda Powers gave us a quick introduction on sampling techniques and what we were looking for. We quickly got to work."

- Geoffrey Hammond

John Conley

Figure 6: Getting oriented at first transect stop

As the drive progressed, an alignment of teachers and scientists began to occur based on mutual interests and compatibility. While in hindsight, this natural alignment made perfect sense, it had not been anticipated. The expectation was that assignments would be made upon arrival at the station. The reality turned out to be much more positive and conducive to collaboration.

"The structure of Chilean and American teachers interacting with scientists working on their own research was highly effective in both engendering teamwork and fostering greater scientific understanding. Allowing collaborations to grow organically rather than being predetermined was highly beneficial and increased investment from both teachers and scientists."

- Koby Van Beest

It is highly doubtful that this alignment would have taken place so naturally and been so successful if teachers and scientists had met for the first time in the relatively unconstrained atmosphere of the station. Certainly, the alignments were more "informed" in that the teachers and scientists knew much more about each other and the science involved before the alignments were made.

This is not to say that all went entirely smoothly –

"The scientists are all passionate about their work here and the teachers are excited to be doing real science along side the scientists. We were still working out the kinks of cooperation and communication. We kept hearing the term "herding cats", which was a good description of the progress of our group."

- Web Journal 6/21

- or that teachers were entirely comfortable in their new roles as research assistants:

"Each of us was outgoing enough to attach ourselves to various individuals, but at times it felt as if we might be intruding on the scientists' work (thoughts) and their progress as they each had a specific objective to get accomplished while there."

- Matthew Allner

Neither the scientists nor the teachers had any appreciable understanding of the other's culture. As the expedition progressed, teachers' observations of scientists revealed an increased realization that even world-renowned scientists are, indeed, human.

"It was certainly energizing to see the "real" scientists get as excited about this work as we teachers."

- Web Journal 6/23

"Lots of good stuff…it was hard to pull away for dinner, but even scientists get hungry."

- Web Journal 6/23

"With no scheduled sampling stops, Rosalba couldn't resist as we caught her sampling near a palm tree at one of the Copec gas stations along the way."

- Web Journal 6/30

Finally, one teacher, always on the lookout for an opportunity to apply his experiences to the broader concept of exploration, wrote:

"The transect was also a very integral part of the experience as it did several things: it allowed us all quality time to get to know one another on a personal level; it allowed us an opportunity to see and experience the landscapes and some culture of Chile; it also allowed us an opportunity to experience being enclosed in a very small space (the transect) for a long time (similar to Russian space flight on the Soyuz) so that now we understand more the difficulties astronauts experience in a two-day orbit before docking with the ISS."

- Matthew Allner

The transect also provided an important conceptual framework within which to understand the exploration and science goals of the expedition. In effect, it was a lengthy immersive introduction which provided teachers both the time and experience to process the bigger picture of the expedition. In most professional development for

teachers that occurs in the field this lengthy, gradual, experiential introduction does not occur. It appears that such introductions are clearly necessary, if not critical, for effective learning in field work situations. By the time the teachers reached Yungay, they had a firm grasp on the exploration mission, goals and science:

> *"One of the reasons for the long drive was to view the changing landscape as we drove north from relatively arid to extremely arid environment. This was the first time a transect was done along this route for the primary purpose of determining the minimum water requirements for the threshold of life."*
>
> *- Web Journal 6/21*

Scientists – The Way They Are

Teachers are consummate observers. In fact, their very effectiveness as teachers relies on their ability to observe [their students], analyze [student needs], and act [create and implement effective teaching]. During this expedition, the teachers focused their observational skills on scientists – an entirely different "breed of cat" from their perspective. As mentioned above, early on they dispelled common notions about the humanity of scientists. As the expedition progressed, their understanding of scientists' motivations, their relational skills and techniques, how they approach their work – in short, "what makes them tick and turns them on" as one teacher remarked – was revealed in their observations and comments. This newfound understanding is largely a result of the context, i.e. the two groups lived and worked alongside each other in a relatively isolated environment, with aligned goals, sharing everything from scientific instruments to toilet facilities.

In some cases, teachers observed what scientists used or did which students could use or do in order to make their classroom science experiences more authentic and effective.

> *"Each scientist also carried with them a mini composition notebook where they noted the same information as well as any other variables that might be important. The notebooks don't take up much room, fit into any shirt or pants pocket, and are sturdy enough for the field. I need some for my students."*
>
> *- Phyllis Isbell*

> *"I also liked to see the scientists collaborating and asking each other questions about their specific work. Science needs more of this! This also supports my persistence of having my students continually ask questions about the activities and research they are doing in class."*
>
> *- Cherlyn Anderson*

Jim Thompson

Figure 7: Chris McKay and Jim Nienow conferring

Teachers noted the spirit of collaboration between the scientists, which dispelled another common stereotype – that of hyper-competitive scientists hiding results, guarding their methods, etc.

> *"The conversations among the scientists were exciting and enlightening. They were the kind of discussions I would hope for my students and triggered ideas for connecting with classes with the other Spaceward Bound teachers. The scientists discussed their work among themselves, sharing purposes and methods. They discovered commonalities, and I heard more than once, 'Will you keep me posted with your results? Your work ties in with what I am doing and can be useful.' "*
>
> *- Phyllis Isbell*

> *"Connections were also made between scientists and teachers. The fieldwork proved fascinating and the scientists were engaged and eager to share their expertise. Teachers shared the scientists' enthusiasm and curiosity throughout the journey and worked alongside them to learn more about the research and the process for doing the research. Scientists also worked with one another, comparing and discussing results in order to verify information. Many soil and rock samples were checked using different equipment and methods with much debate regarding results obtained. Instruments were calibrated and recalibrated and anomalous findings provided more opportunities to troubleshoot techniques."*
>
> *- Catherine Campbell*

While stereotypes generally are rooted (just a little bit) in reality, teachers recognize and respect effective leadership and the ability to generate an environment where collaboration is a norm – they aspire to these in their classrooms. Manifestation of these same characteristics in the science context were noted and applauded:

> *"Chris had assembled the scientists, each one searching for signs of life, each using their own unique method. Chris was the linchpin. Chris conferenced continually with each one, listening, conferring, analyzing, and*

suggesting, in a remarkably respectful and positive manner. ***That*** *is what I call a good teacher, and good teaching."*

Phyllis Isbell

In addition, teachers also recognize and appreciate the ability to communicate understanding to a diverse and uninformed audience:

"During this leg of the trip Linda was the star attraction on our little bus. She explained our NASA expedition and her role and my role as a teacher on the trip. She went into detail about what we were looking for and how this work relays to space travel and searching for life on other planets, and places, such as Mars. Everyone on board was fascinated and asked many questions which I was glad I didn't have to answer. Instead, Linda handled them easily and eloquently. She explained that if extra-terrestrial life does exist in our Solar System it is going to be found in or under the soil, rock, or ice and will most likely be on the microscopic level. The techniques for looking for life in this kind of environment that we practice and perfect here on Earth will be used by robots and humans in space in exploration."

- Geoffrey Hammond

Some observations were humorous and reflected a developing "esprit de corps" between teachers and scientists.

"As we headed off Koby mentioned he had seen the prettiest flower all by itself on the side of the road. I could see Pierre was stunned and speechless for a moment. In playful? exaggeration he said, 'Could you TELL the BIOLOGIST when you see a FRIGGIN FLOWER in the DESERT!?!'"

- Phyllis Isbell

Matthew Allner

Figure 8: The flower in the desert

"Kelly Snook, aerospace engineer, planetary scientist, technological gadget junkie and cement truck specialist …"

- Geoffrey Hammond

"Accommodations and food seem to be an afterthought for the science-minded."

- Geoffrey Hammond

"I helped Shayne with more sampling with his machine and chuckled at the scientists getting so excited over some potholes in the rocks that appear to have been filled with water at times."

- Geoffrey Hammond

"Bonding" (defined as the development of a close emotional tie) is often very important teachers. Over and above creation of a collaborative and mutually respectful environment, they seek to develop a closer, almost familial and decidedly mutually supportive feeling between themselves and their students, and between students. Similarly, bonding with their fellow teachers and scientists was an important aspect for some of the teachers on the expedition. The development and strengthening of bonds and the eventual separation at the end of the expedition were found in teacher's writings.

"Our team skills were unpracticed and it took three hours to eat, pack the vans, pile into our assigned vehicles, and leave Santiago. We ate breakfast and lunch off the tailgate of one of the trucks. The close quarters and chatter in the vans helped us bond. At lunch we were asked to mix up the vans again and we were reluctant to separate so early from our new friends. [next day] We were already coming together as a group and the packing of the vehicles took much less time.

- Web Journal 6/20-21

"Also, the San Pedro trip (an expedition in itself) was another opportunity to bond with not only the researchers and grad students, but with our Chilean friends."

- Cherlyn Anderson

"The transect and complementary car ride was also prime opportunity for the American teachers to investigate different research activities and establish connections."

- Koby Van Beest

The influence of the bonding process is reflected in this comment about the tradition of writing names on the kitchen wall of the station – the Yungay guest book, and the separation at the end of the expedition.

"Matt had drawn the Spaceward Bound patch on the white kitchen wall where people over the last three years had signed their names and date. Around the edge of the patch he left room for each of us to write our names. Cathy, Cherlyn and I worked on putting the color in and adding some extra graphics. We put Kari, Geoff, Liza and Chris's name up with all of ours. My extra picture is supposed to be a volcano, Mt. St. Helen, and a fir tree. Cherlyn drew a palm tree because she is from the palm tree state".

- Phyllis Isbell

Liza Coe

Figure 9: Yungay "guest book"

"Our group began to fragment and break up into smaller and smaller parts as people began heading to individual gates for their flights back to our own corners of the United States. Dallas International is a huge airport and I ended up taking a shuttle tram towards my gate with Matt, Koby and Karie. Coincidentally, Karie was the last person I said goodbye to as I headed toward my own flight back to Orange County."

- Geoffrey Hammond

Fieldwork

The first "official" activity at Yungay was an introductory lecture (in both Spanish and English) by the PI and Dr. Benito Gomez, from the University of Antofagasta. The lecture was held in the "rock garden", a research site located on top of a hill. The teachers received a small introduction to hiking a steep hill in a desert at altitude.

"After the Chilean's arrival and set up, Chris McKay, the chief investigator from the US, and Benito Gomez Silva, his Chilean counterpart, took us up to the infamous "rock garden." At over 10,000 [sic, should be 3000 ft.] feet we got quite a view with an introductory lecture."

- Web Journal 6/22

"Overlooking the pueblo ruins from the mining operation some hundred years ago, Chris and Benito explained why the area made so much sense as an analog study site. Essentially it is dryer than a "bone." Scientists come here to look for life surviving at the extremes, both because of the lack of water and the chemical composition of the so called soil."

- Web Journal 6/22

"To get to the rock garden is quite the climb! My heart was pounding. Only 4 wheel drives can make it even half way up and since I was in the van I was one of the ones walking all the way. The last halfway up is quite steep. Then we stood under the hot sun for an hour in the middle of the desert, the desert that is the driest place on earth, fifty times drier than the Mohave Desert. (Am I whining already? Ron knows I am loving every minute of it!)"

- Phyllis Isbell

Liza Coe

Figure 12: Hiking to the Rock Garden

The rhythm of the field work days settled into morning field work, followed by lunch and lab work or journaling during the heat of the day (siesta), late afternoon field work, followed by late dinner, campfire and bed. Given that it was winter in the southern hemisphere, activities were limited by light availability and were also influenced by cold temperatures (as mentioned below).

Renee Condori Apaza

Figure 10: Teachers and Scientist in the lab

Teachers met in a group with the Co-PI during siesta. Topics of discussion included

1) The days activities
2) Ideas for leveraging
3) Plans for integrating journal and experiences into final reports
4) Plans for the broadcast (later in the expedition)

> *"Our education lead (Co-PI) gathered all the teachers together and we did a formal introduction into the work that we were getting into. A list of the scientists and the work they were doing was gone over so that teachers could attach themselves to work they could bring back into the classroom. We discussed all sorts of ways to use what we were being exposed to and*

how it could stimulate interest in science, technology, engineering, mathematics, and geology. Lots of good ideas took us nearly to sunset. As it got cooler and we scattered to get warmer clothes, our heads were swimming with information and ideas."

- Web Journal 6/22

"This evening we had a teacher meeting and learned about our case study we are going to write about."

- Geoffrey Hammond

John Conley

Figure 11: Siesta meeting

For most of the meetings we were joined by the Chilean teachers with interpretation by either Chilean scientists or Spaceward Bound staff who are bi-lingual. Bringing small gifts from where you live to share with the group is a tradition honored in many teacher institutes. During these meetings the American teachers distributed small items unique to their areas to each of the other teachers. The teacher from Washington brought small vials of Mt. St. Helen's ash, for example. In addition, each American teacher picked the name of a Chilean teacher, and each Chilean teacher of an American teacher and a small gift was brought for the person's whose name was picked. Examples of these gifts were t-shirts, books, photos, etc.

"We had our gift exchange during the teacher meeting and talked about our days. We decided to use Lewis and Clark's expedition as a back drop for this program instead of New World Explorers. Matt already has some good information and ideas about the Lewis & Clark expedition and this is also part of Fifth Grade U.S. history."

- Geoffrey Hammond

"Again, we got back to the station long after noon. After eating a bit the teachers all gathered again for an exchange of scientific interests and ideas. We continued the sharing, by exchanging gifts from our home states with the Chileans. Lots of laughs and great feelings later it was again starting to get dark and a barbeque was being started to feed us."

- Web Journal 6/23

Below are a few representative examples of the work that teachers did in conjunction with the scientists. Of note are the fact that they were an integral part of the data collection process and the understanding of the science they gained from the experience.

"A few questions later we split into groups, teachers teamed up with several of the scientists. Folks went this way and that looking for areas to sample. Using sterile techniques, at least six groups were spooning in samples into whirl packs or small vials, recording GPS positions, or using equipment to read the relative level of organic matter in the soil."

- Web Journal 6/22

Matthew Allner

Figure 13: Taking a sterile sample

"Not long after everyone was regrouped and fed, we went back out, just east of the station to an ancient lake bed, consisting now of a field of miniature weird salt formations. Jacek Wierzchos and his assistant Alfonso Davila led us deep into the salt bed and invited us to hunt for the camouflaged probes, imbedded in a salt pile, measuring surface condensation, photosynthetic light, surface and internal relative humidity and temperature. What was amazing about this environment, was the tiny difference in outside humidity to internal, from about one to six percent, allowed for growth of Cyanobacteria to grow inside the salt bodies. When we broke open pieces of salt we could see green stripes of bacterial colonies. The salt attracted enough moisture to support life…wow! Back at the station, we unloaded the days samples and started work on analysis in the lab".

- Web Journal 6/22

"After breakfast, the scientists gathered their teacher assistants together and we all went back to the area of the rock garden to gather more samples. As we were up in the field, several ideas came up that led to several new experiments. One had us gathering samples and readings from a rock outwash both next to and underneath large boulders. This took a lot of time and everybody available pitched in.

While we were over in the wash, Penny Boston, one of the other lead scientists from the US, started jumping around and shouting… She had found a bowl-like depression in one of the lager boulders. The area around where water clearly had collected, was stained with what she identified as manganese waste product of living organisms. A second mini-pothole was located a bit later, and we thought of an experiment to hydrate these bowls and take life readings before and after the watering."

- Web Journal 6/23

"A group of us went up into the rock garden for some experiments involving equipment that liked cooler temperatures and darkness. Armed with headlamps and assorted sample collection paraphernalia, we spent an hour or so huddled around the two rocks (the ones with the depressions mentioned earlier) we had dubbed 'Penny's and Linda's potholes." As the temps fell and the wind rose, Rosalba, our resident sedimentologist from Italy, started to shiver in her native language…"

- Koby Van Beest

"Linda and Shayne were excited about some of the results from samples we took yesterday and wanted to head back early. Matt and I, along with our Chilean partners, Ivan and Marcos, were sent up on the hill to relocate our digs from the previous day and get GPS readings and photographs of the sites. We were successful and brought data back to the main group."

- Geoffrey Hammond

"We then worked with Penny Boston and Karie Trupka taking samples of top soil for bacteria growth purposes. Karie and I took samples of soil and placed it in four vials containing nutrient rich gel and moisture to try and grow any bacteria that might be present. This process can take from four days to three or four years to produce bacteria. We sterilized our equipment with alcohol and fire. Next we filled one vial that contained a solution that acted as formaldehyde to kill, preserve and dehydrate anything living for viewing under an electron microscope. Finally, we filled a large bulk sample and then did the whole thing over again."

- Geoffrey Hammond

Exploration Science

A significant example of the teacher's growing engagement with exploration science involved the idea of implementating self-sustaining technology at the station, similar to what would be required on the Moon and Mars.

I, Koby, personally spent the whole time gathering information on a possible project that Chris McKay and I were discussing about developing a self-supporting station here at Yungay. My original thoughts sprang from having spent nearly a week here and not once seen a cloud overhead. I mentioned to Chris that it would be so easy to use solar power in a place like this. From that he arranged for interviews with two Chilean scientists, Luís Cáceres from the Universidad de Antofagasta and Armando Azúa Bustos from the Universidad in Santiago.

Luis was a wealth of information and the tour of the Yungay station, which he had helped plan from the beginning, yielded interesting and detailed insights. We looked at the structures and dreamed of future ones. He talked about the agricultural experiments in the past, and we theorized how they might be changed for the better. The issue of water and energy was discussed in detail. We even climbed down into the waste trench and planned out how things could be better used, reused, and recycled. At each step I was most taken by Luis's enthusiasm for this experiment in desert research. Nowhere was that more evident than when we looked at the surviving trees from the original plantings. The dozen or more that were thriving were doing it on their own—"Nobody is watering these, " Luis delightedly exclaimed.

The conversation with Armando, though much shorter, was equally spirited. Mainly, we talked of the collaboration between Chile and the US. Armando has been working with Chris and the Chilean government trying to get some funding to improve the Yungay station's facilities. We discussed structure options, and I sketched some plans that I said I would finalize and send to him to aid in his presentation to the government officials involved. It all seemed very hopeful.

Speaking of which, I also cornered Penny Boston and had an encouraging discussion drawing on her extensive work on and in the Mars Habitat in the Utah desert. Right from the start she stressed the notion of prioritization and preparation. Her special concerns, noting her past experiences, focused on energy and communications. She recounted several disasters where scientists totally over taxed the always limited energy supplies as well as suffered countless headaches dealing with both internal and external communication problems. We bounced around ideas that would not only help my planning a new Yungay research station but could also be used to develop a "virtual" classroom station that could be used to study research station life from a systems stand point. All very exciting…if not overwhelming."

- Web Journal 6/26

This effort is still continuing and Koby's classes are fully involved.

The idea that understanding of challenging concepts is only achieved over time is indicated in the following comment:

"His instrument measures metabolism of algae by measuring its natural fluorescence because electrons are moving from phase one of photosyn to phase two. Then he blasts it with light and measures the fluorescence. The system gets overloaded by the light blast and shuts down. The important number is the ratio between the two measurements. If you think this is hard you should hear it in science talk. This was my third time with it and I think I am getting it."

- Web Journal 6/22

It was evident that the teachers always had leveraging in the back of their minds:

> *"That chunk of halite was surrounded by desert air with 1% relative humidity—that will be a challenge for New England students to imagine—while probes within the salt, recorded about 6%--again, itself an opportunity to raise questions. This dramatic increase attracts and supports the bacteria living within. Whenever I relate this I get animated "wow" responses, exactly what I felt when I was working with the scientist who first reported this."*
>
> *- Koby Van Beest*

Many written comments were made about the excitement of new discoveries and new understanding. Invariably these comments were followed by statements about bringing this excitement to their students.

> *"Obviously I will never admit to previously being a dull or boring teacher, totally changed by the expedition to the North of Chile. Still, the enthusiasm of new and unique experiences can only help to engage students in the world of science and stimulate learning.*
>
> *That chunk of halite was surrounded by desert air with 1% relative humidity—that will be a challenge for New England students to imagine—while probes within the salt, recorded about 6%--again, itself an opportunity to raise questions. This dramatic increase attracts and supports the bacteria living within. Whenever I relate this I get animated "wow" responses, exactly what I felt when I was working with the scientist who first reported this.*
>
> *Being in the Atacama was indeed amazing and being able to bring some of the experience back for the students makes it even more extraordinary and keeps the excitement going."*
>
> *- Koby Van Beest*

The Chilean Connection

Through the University of Antofagasta, seven Chilean teachers were selected from area schools to partner with the Spaceward Bound teachers.

The Chilean teachers included:
Marco Antonio Cáceres Torres, Biology
Iván Castillo Rubina, Chemistry and Biology
Juana García Delgado, Biology and Science
Alejandro Enrique Garrido Iribarren, Biology
Johana del Carmen Orellana Villazón, Mathematics and Computer Science
Claudia Vega, Biology and Natural Science
Drina Herrera, Science

The Chilean teachers camped at the station and participated in the same activities as did the American teachers. Having the opportunity to learn about life (and teaching!) in a different country was definitely informative for the American teachers:

"The Chilean teachers told us that they live their lives never leaving their town, and that this is quite an opportunity for them."

- Web Journal 6/22

"I drove with the Chilean teachers and they sang all the way home. They sang pop songs, movie songs, Disney songs and children's songs. They also wanted to know about my family, my home, my salary and shared the same information about themselves with me. They let me teach them "Little Bunny Frou Frou". It has been delightful to use what little Spanish I know and work on the communication with them. They are very kind and patient, and they want to practice their English."

- Phyllis Isbell

"They next had us drive to a National Monument, the Tres Marias. Only two are still standing, one has fallen over. The Chileans were unhappy that a woman was sitting on the monument for the longest time and wouldn't get down. They decided she was crazy, no one should be on the monument."

- Phyllis Isbell

The initial goals of this collaboration initially were to:

1) Incorporate a broader understanding of the context in which Spaceward Bound took place, i.e. culture, people, traditions, lifestyles;
2) Encourage greater knowledge of how science is taught in countries outside of the U.S.; what is emphasized, what are their challenges and areas of success;
3) "Give back" to the host country by affording this opportunity to it's teachers;
4) Increase international knowledge of NASA and its mission;
5) Enable collaboration between two groups of teachers.

Inevitably, language was an issue since only a couple of Chilean teachers had a rudimentary knowledge of English and only a couple of American teachers knew any Spanish. However, unique and effective methods for communication were devised, over and above calling on someone to translate. In all, the bilingual environment brought issues of communication forward and, again, consideration of how this element of the expedition could be incorporated into classrooms:

"… the issue of language, which was at once limiting but also inspiring. My inadequate Spanish and the Chileans' lack of English hampered me but I can imagine relating to my students the importance of communication."

- Koby Van Beest

"My plans are to slowly establish a sister-city/school relationship with Antofagasta with a possible future trip there someday with students. With so many Spanish-speaking students at our middle school, the language barrier would be easily overcome, and we could move right to cultural and scientific collaboration with these students."

- Matthew Allner

Plans were made to continue communication and sharing of ideas:

"Interacting with the Chilean teachers was an integral part of the expedition. I plan to stay involved with some of them and share data collected on field expeditions with our students, via e-mail, or even more effectively video-conferencing. We could discuss field research logistics prior to the study. We could establish a "pen-pal student scientists" web-site, allowing our students to post and share data, and most importantly interact socially."

- Cherlyn Anderson

"I also feel compelled to develop a pen-pal relationship between some of our 6, 7, and 8th graders (a pilot group) and a select group of Chilean students. In doing so I hope to incorporate more global awareness (geographical, linguistic, cultural, and scientific) for my students as they see global involvement as a key to evolution of science.

In the classroom I plan on developing pen-pal communication with a small pilot group of students. I have been in continual contact with several of the Chilean teachers and plan on continuing this in the future."

- Matthew Allner

Many teachers wrote about the impact the Chilean teachers had on the expedition and several also suggested that a trip to see the Chilean classrooms would have been interesting and informative.

"Having Chilean teachers and professor/scientists from the University of Antofagasta, Chile, and other countries such as France and Italy, expanded the expedition to include elements of geography and culture, which incorporated the concept of global science into the experience. Language barriers, translation and different accents created interesting problems with communication as the ever increasing group size created problems with logistics, transportation and the use of resources such as bathroom facilities and electrical outlets. Although those types of problems were to be expected, they served to focus group problem solving and provided more opportunities for direct experience that could be brought back to classrooms and schools."

- Catherine Campbell

"A visit from us to their schools and classrooms might stimulate creative curriculum ideas."

- Koby Van Beest

"The cross-cultural experience with the Chileans was awesome! I personally felt that this part added a whole other dimension to the experience, which was both enjoyable and challenging at the same time. Learning about their culture, history, and experiences was really amazing."

- Matthew Allner

Indication of the strong connections forged between the American and Chilean teachers can be found in their reluctance to say goodbye:

When it came time for the Chilean teachers to return to Antofagasta, scientists and teachers alike were sad to see them go. It was striking how many close friendships had been forged in a little under two weeks.

Afterwards [broadcast] we took pictures of each other and then went back to camp for the Chileans to pack up and head for home. We had made new friends and it was a happy and sad farewell.

The energy level was noticeably down with the Chileans gone."

- Phyllis Isbell

"Following the broadcast we loaded back up into the vans to head back to the station. The American teachers were meeting with Liza, to script out our broadcast for the next day. As we met, the Chilean teachers began packing up their tents and belongings. The bus from the University was there to take them back to Antofagasta. It was with great sadness to see them packing up to leave us. We had all bonded over the two day experience to San Pedro."

- Web Journal 6/27

Liza Coe

Figure 13: Saying goodbye to the Chilean teachers

Power(s) Trip

Early in the expedition, an opportunity arose for two of the teachers to accompany one of the scientists, Dr. Linda Powers and her assistant Shayne Rich, on a multi-day trip high into the Andes for data collection on volcanic slopes. Four of the teachers wanted to go and it was decided by Dr. Powers and the Co-PI to let the teachers decide among themselves who would go. After an afternoon and evening of discussion, the teachers came to a consensus on who should go.

"Linda and Shayne packed one of the trucks for their trip to the Andes. Kari and Geoff were the ones going with them. They will go to San Pedro with us then inland through Bolivia to meet their guide near Licancabur. It will take two days to ascend the 19,000 feet to the top so they will spend the night on the mountain which is an active volcano."

- Phyllis Isbell

Linda Powers

Figure 15: Collecting samples high in the Andes

The trip was indeed grueling with many challenges – not the least of which was intense cold at altitude accompanied by altitude sickness. However, exploration was successful – samples collected and data taken.

> *"I awoke early, yet was reluctant to leave the warmth of my sleeping bag and enter the chilly mountain air. Linda and I both waited until the sun was shining through the window to actually get up and start the day. My head was still pounding and my stomach was still turning but I decided to have a cup of tea and then go for a walk to explore the area around the Refugio. It was still very cold; in fact the INDOOR toilets were frozen solid. I looked in the back of one of the toilets and that water was also frozen solid. When you hit the flush lever you would hear the "kink, kink" of metal on ice and that was it.*
>
> *After very strenuous, steep climbing, being buffeted around by the wind and straining for oxygen we finally came upon the rim of the volcano. We were at 18,025 feet and could peer into the active volcano's abyss! The cul we were standing on was a low point on the rim and looking at the crater was pretty awesome. It is still venting and steaming sulphur and fumes from many different areas. The scale of the crater was much bigger than I had imagined and looking out over the edge you could see that the crater dropped straight down into steam and emptiness. You could not see the bottom. The smell was pretty potent and Linda and I both began to cough from the fumes.*
>
> *We collected our samples from the rim. One sample was even over the rim a bit (still makes me nervous thinking about this at night). Another we took about 10 meters from the rim and the last about 100 meters from it. The hike down took about an hour and a half and I felt pretty good until I sat in the van completely spent. A wave of nausea hit me and we couldn't have driven down that mountain fast enough. It was dark by now and the guides navigated our way down a maze of tracks and trails in pitch blackness. I was*

very happy to get back to San Pedro and tried to get food in my belly for energy for tomorrow's climb."

- Geoffrey Hammond

Linda Powers

Figure 16: Taking more samples very high in the Andes

While two teachers were afforded an experience in truly extreme exploration, the drawback was that they left the group for the majority of the expedition. This effected both the teachers that went and the teachers that stayed.

"One of the drawbacks of going with Linda and crew was that I didn't get to know the rest of the group as well as I would have liked to. This was unfortunate but there are pros and cons to every choice we make, and I wouldn't change this one at all."

- Geoffrey Hammond

While at the airport waiting for the flight back to Dallas, the teachers were sharing stories and the issue came up of whether or not it was a good idea for two of the teachers to break off from the rest of the group – even if the opportunity was extraordinary. One person brought up the idea that similar situations could arise on the Moon or Mars. An opportunity may arise that only a small number of astronauts are able to take advantage of – how is a decision made? By Mission Control? (analogous to the PI and Co-PI) or the astronauts (teachers) themselves?

Further, how is information about the parallel activities shared? In this expedition there was only little over an hour to share both experiences which was clearly not adequate. Much information was not exchanged which, on an interplanetary expedition, may prove to be important or even critical for any number of reasons.

Leveraging

The desired outcome of any professional development program is that a teacher will utilize what they've learned to the benefit of their students. For an experiential immersive program, the desired outcome is expanded to include leveraging – the utilization of the experience in contexts outside of the classroom to provide opportunities

to learn in both the cognitive and affective domains within the subject matter of the experience. Leveraging essentially serves to identify the difference between attending a program in a generic location (e.g. classroom, conference center) and attending one which is presented in a wholistic manner – i.e. within the context of the subject matter.

"Subject matter" in the case of Spaceward Bound includes concepts, content and skills of two fundamental paradigms of exploration: the use of analogs and the use of simulation in order to perform scientific and technological research. These two paradigms are inherent to the vast majority of exploration research – including that performed by NASA. They are not presented in traditional school curriculum at any depth, if at all, yet are key to student understanding of exploration and, to a large extent, the understanding of science itself. It is for these reasons that Spaceward Bound seeks to inject these paradigms into teachers' repertoire of concepts, content and skills and to develop with them the pedagogical content knowledge needed for leveraging their own knowledge and experience into opportunities to learn for their students.

Without extensive classroom observation, measurement of leveraging is performed mostly via anecdotal data provided by the teachers themselves as well as sundry artifacts and documentation. The teacher's journals and final reports were replete with intentions to leverage. It remains to be seen whether the intentions turn into reality.

Previous research done by the Co-PI has demonstrated that experiences such as these are indeed leveraged quite extensively. Differences in amount, quality, and methodology of leveraging, and what is leveraged, are dependent on several factors – some within the teacher's control and some not. Forces that work against leveraging are standardized curriculum, the fact that it is difficult to integrate new material into an already over-packed curriculum and the day-to-day urgencies of teaching which can overshadow even the strongest of intentions. Forces that work to promote leveraging include continued support by the program, support of school administration and colleagues, personal dedication, and continued collaboration with fellow expedition participants.

Spaceward Bound is dedicated to strengthening the forces that support leveraging to the greatest extent possible. Inhibitors are primarily funding issues associated with continued program support of the teachers. However, given the NES structure and DLN technology, continued support is much more inexpensive and cost-effective than it has been in the past. As time goes on, updates to this report will be provided that will detail program support activities as well as evidence of leveraging of the expedition by the teachers.

Below are a few examples of intended leveraging cited by the teachers.

> *"There are so many activities and opportunities that I want to bring to my students that will enhance my curriculum and build upon other resources that I already use. For example, the rovers that Corey worked with will be an excellent addition to my robotics class I will be teaching, as well as supplement my space exploration activities used during my space science unit. I plan to arrange a video-conference with Corey so that my students will see a young scientist at work. I would also like to incorporate the radio*

controlled airplanes we utilized at Goddard during the Remote Sensing Earth Science Teachers' Project. I developed a remote-sensing unit around the equipment used on the planes. I feel that I could incorporate Jim Nienow and Linda Powers' research into this unit in regards to spectroscopy and bio-signatures. I also plan to stay in touch with Penny Boston. She will be a tremendous asset during my Earth Science unit, having volunteered to share her collection of photos of rocks and minerals. I am also extremely interested in developing a unit of activities involving caves."

- Cherlyn Anderson

"I feel this experience has given me three main insights of reflection for my teaching this fall:

1. *How to more effectively collaborate an interdisciplinary science approach (grades 6, 7, 8) to a general science topic theme.*
2. *Integrate more of the cross-cultural aspect of science collaboration (language, culture, food, history, etc.)*
3. *Have students journal more on what they are experiencing both scientifically and personally (using the writing process)*

In regards to our staff, I plan to further increase my level of collaboration with interdisciplinary style approaches to learning/sharing science information. This will be done by sharing videoconferencing opportunities as well as developing meaningful interdisciplinary lessons and unit lesson plans.

I feel that a focus I would like to have as far as teaching science and how to do research (both in the classroom and outside of it) is to allow student inquiry to be more teacher led and student driven (as opposed to having me tell them everything step along the way in the scientific process).

I also would like them to learn to be aware of human factors as they work in groups with labs and activities. In doing so I would like them to develop self-awareness as to how their own human factors are either +/- affecting and contributing to the group development and dynamics."

- Matthew Allner

"I also plan on using sections of the archive along with other sources, i.e. pictures and related web sites, in a presentation within the classroom, throughout the district, and beyond. There will be ample occasions to spread the word on work done in the Atacama and raise the opportunity for doing more science."

- Koby Van Beest

"There are many connections and experiences that this participant will be translating into content and activities for the classroom. The main one is the connection made with Dr. Henry Sun, a research scientist at the Desert Research Institute in Nevada. Dr. Sun was in the Atacama looking for endolithic microbes and field-testing apparatus used to detect organic respiration. Through discussion and observation of his work, it became apparent that the basis of his work could be translated for seventh grade

students studying life science and scientific process by simulating the transect between Santiago and Yungay Station in a classroom or greenhouse environment.

Students and Dr. Sun would be able to interface through the DLN thereby providing an authentic experience and an enthusiastic audience for the students' experiments and results. Using the same type of experiential science that was used to prepare for Spaceward Bound should create a viable framework for the collaborative work. Protocol and lessons are currently in the development phase, but when completed and documented could be presented at national science conventions or through the NASA DLN. This is an example of how the second component of experiential education, direct experience, contributes to the advancement of experiential education for other educators and students as well."

- Catherine Campbell

"In the classroom I plan on developing pen-pal communication with a small pilot group of students. I have been in continual contact with several of the Chilean teachers and plan on continuing this in the future. My plans are to slowly establish a sister-city/school relationship with Antofagasta with a possible future trip there someday with students. With so many Spanish-speaking students at our middle school, the language barrier would be easily overcome, and we could move right to cultural and scientific collaboration with these students."

- Matthew Allner

Website and Webcasts

The website/webcast crew included:
Brian Day, NASA Ames, Education Technology Team
Linda Conrad, NASA Ames, Education Technology Team
Whitney Brown, Former JASON Argonaut, Broadcast Assistant

The Spaceward Bound website was a critical component of the program. It served logistical functions such as providing a "go to" resource for interested teachers when they received information about the program via email, presentations, or word of mouth. In addition, instructions for application and forms were provided on the website.

Most importantly, however, the website provided an extensive source of information for the teachers selected for the expedition. Biographies of teachers, scientists and Spaceward Bound staff were posted, along with relevant research papers by the scientists. Journal articles and papers about the Atacama Desert as well as NASA's Exploration Mission were also provided. Homework assignments were posted as well as archives of the training sessions, and logistical information about the travel to and from Chile.

After the expedition, photos taken by scientists and teachers, journals and final reports were posted. This report will be posted as well as links to scientific results. Further "meetings" via DLN among the teachers, scientists and staff will also be archived on the site.

In all, given that participants in Spaceward Bound are spread throughout the U.S. and in other countries, having a central point for information is critical. The website fulfilled this requirement for Spaceward Bound and also supported the effort to develop team relationships prior to the expedition and maintain them afterward.

As noted above, two webcasts were broadcast from the Atacama Desert – one in English and one in Spanish. There were two purposes for this effort. One was for technology demonstration – that is, production of a full-featured webcast complete with webchat and b-roll integration from a truly remote site that did not have satellite or other communication infrastructure available. For this expedition, satellite communications were provided by the Robotics Alliance Project – leaders of the communication component of the expedition.

The second, though no less important, purpose was to connect the expedition to schools and other interested groups back in the U.S. (the English broadcast) and in South America (the Spanish broadcast). The Spanish broadcast was more effective at accessing schools simply because school was in session – it was summer vacation for most schools in the U.S.. However, the teachers and the NES program advertised the webcast through their networks and both webcasts were very well attended.

> *"Broadcast day for the Chilean teachers. Following breakfast, the Chilean teachers went back over their broadcast plans. We all headed to the broadcast site which was about 1 kilometer away and where Corey had his rovers set up. Maite was the host for the broadcast and Benito Gomez was the primary scientist. Local Antofagasta newspaper and television reporters were present as well. One at a time, all seven teachers told their Atacama experiences working with the scientists. They also answered questions presented to them via the web cast chat room. It all went beautifully, especially when Corey rolled out the rovers. That was the fascination of the television and newspapers! Several of the teachers were interviewed personally, Juana by the television reporters."*
>
> *- Phyllis Isbell*

Liza Coe

Figure 17: Set of the Chilean broadcast

Simply preparing the webcast was a learning experience for the teachers as they were each required to describe their science exploration work and summarize what they learned. They also combed through their own and their colleagues photos to find the "perfect one" to accompany their talks.

> *"Liza met with the US teachers and we planned our webcast as well. Whitney was the emcee and would introduce the program and direct the flow of people. First, Chris would talk about the science, then Liza would talk about the goals of the Spaceward Bound program. We decided that I would follow and describe the transects and the science. Kobe would then discuss his idea about creating a station model to use at his school. Cathy would talk about Henry's work, the Viking expedition, and ideas for the classroom. Matt discussed Human Factors that arise from working with a group in close quarters. Whitney would then explain why Kari and Geoff were not present. We would end with Cherlyn talking about Penny's work as well as the use of robotics. Toby would send in rover and then talk on camera about the robotics program. We were asked to work with Geoff the photographer to select two photos each that could be shown during the webcast."*
>
> *- Phyllis Isbell*

Tensions ran high prior to both broadcasts but both succeeded without a hitch. Several teachers mentioned that they will use the archived broadcasts for presentations in the classroom, throughout their districts and beyond.

Teachers had the following comments about the broadcasts:

> *"The broadcasts were another opportunity to observe troubleshooting at its finest and proved to be a highlight of the expedition. The technology necessary to do a broadcast from the middle of the desert along with the number of technicians and support staff was amazing."*
>
> *- Phyllis Isbell*

> *"The broadcasts definitely provided purposeful engagement to the Spaceward Bound experience."*
>
> *- Catherine Campbell*

Press Coverage

As mentioned above, the Chilean press covered the Chilean teacher's broadcast. In fact, Corey Ippolito and the rover made the front cover of the Antofagasta newspaper. Various representatives of the Chilean press visited the station during the expedition.

Ames distributed two press releases in June 2006 on Spaceward Bound – June 12 "Spaceward Bound program in Atacama Desert", June 20 "NASA Sends Teachers 'Spaceward Bound'". Local newspapers in Los Angeles, Washington, Iowa, North Dakota and South Carolina picked up the releases and ran stories about the teacher from their area who participated in the expedition.

Two professional photographers (John Conley, Henry Bortman) and a freelance writer (David L. Chandler) also joined the expedition.

Lessons Learned

Much was learned from this pilot year, not the least of which was the opportunity for the Co-PI to observe the group dynamics and understand more fully what the potentials are for furthering the goals of a pedagogy of exploration and the establishment of a cohort of teachers trained and experienced in teaching exploration science.

While reflective data is still being collected from scientists concerning their interactions with the teachers, impact on their work, and perceptions of benefits to the teachers, one of the scientists wrote:

> *"Our effort had several teachers work closely with us [3 Chileans, 8 Americans] and 2 joined us on our long trek across the Atacama and to the top of two volcanoes. Both in the field and at Yungyi, they participated in all aspects of sample/data collection, data organization and recording, data integration/analysis, and discussions. They helped identify places to measure/sample and made sure we had all the equipment we needed for the tasks. In all, they were a tremendous addition to our efforts and we collected considerably more samples and data then we could possibly have without them. In addition, they were eager to learn and that makes even not so exciting [boring] tasks fun. We had several long discussions about underlying theory, possibilities, and applications and I sent them information about our technology after I returned. Two of those who worked with us have contacted me to see if they could work with us during the summers and I am working on that possibility.*
>
> *I believe the benefit to them was great and for us as well, but even greater for their students. First, they were fired up to learn something new and this attitude spreads like wild fire when they are in contact with students. Second, they were introduced to the excitement of discovery – a very addicting potion. The long trek up two volcans [I view it as quite godly] and hours of riding in a crowded 4X4 across the desert with no help available for possibly days [could be viewed as ungodly, I guess] should there have been a problem made them appreciate the commitment it takes and rewarded them with the satisfaction of having accomplished it. These are just the ingredients we want to convey to students! One of the teachers who went with me [up both volcans] is writing a book for his students on his experiences. This multiplies the investment by an unimaginable factor!"*
>
> *- Dr. Linda Powers, written communication*

Based on personal observations, the Co-PI would strongly agree with Dr. Nienow's comment below that the teachers effected the camp atmosphere. Teachers tend to be quite verbal, socially inquisitive and outgoing. Oftentimes scientists are quite the opposite. Studying the dynamics of a situation where two dissimilar groups are sequestered in close quarters, isolated from the rest of the world, is probably quite analogous to the environment interplanetary crews of the future will face. Indications from this expedition are that careful selection of the individuals in both groups can lead to a mutually productive and enjoyable expedition.

"During the drive to Yungay, the teachers were very helpful in looking for hypolithic growths at each of the stops on the transect. We didn't work as closely at Yungay, but they did help set up one of the data-loggers. We also had several conversations concerning the use of fluorescence to monitor photosynthesis. I also discussed simpler ways some of the physiology-humidity connection could be investigated in middle grades science classes with some of them. Even though my contacts were not extensive, I would rate having the teachers along as a big plus. It changes the atmosphere in camp to have a group interested in learning what everyone is doing and asking lots of questions. With luck they will be able to translate some of what they learned into classroom activities which they can pass on to other teachers. Even if that doesn't work out, anything that keeps science teachers energized and invigorated should improve teaching."

- Dr. Jim Nienow, email communication

In addition, the importance of the transect to the success of this expedition cannot be understated. Essentially (as pointed out by one of the teachers) the transect was analogous to a multi-day journey to the Moon in a cramped space vehicle. In typical professional development involving scientists and teachers, the introductory exchange of information between the two groups is mostly uni-directional (from scientist to teacher in the form of lectures), in an unrestrained setting, with bi-directional conversation limited to the "Are there any questions?" part of the lecture.

In the case of the transect, bi-directional conversations took place over a significant amount of time and there were opportunities to share individual information about family, interests, hobbies, etc. More importantly, however, the scientists most likely learned as much about teachers and teaching as the teachers learned about science and science processes. Thus, by the time the group reached the research station, where the scientists dispersed into their own research areas, alignment of teachers with scientists had taken place and there was mutual understanding at an introductory level of motivations, goals and interests. Essentially there was a critical "group knowledge" that had been created and built throughout the transect.

While transects similar to this one are not practical or even possible on all expeditions, the lesson to be taken from this experience is the importance of the development of a "group knowledge" on an expedition (be it terrestrial or not). The challenge will be to figure out how to develop that knowledge on future expeditions that don't lend themselves to transects.

Finally, as in most life situations, the absorptive nature of the activities at hand, make it difficult to separate oneself to the point that serious reflection can be done on larger issues. This was certainly the case for the teachers as they became fully immersed in the daily routine of the expedition. The Co-PI purposefully let some elements of program structure remain inexplicit (e.g. the content of the final paper, the links back to the four Exploration Processes) for two reasons:

1) Since this expedition was unique and programs that are similar generally do not contribute to the research literature, how the teachers would react to the situation,

what their focus would naturally be, what their concerns and motivations would be, were largely unknown. Thus, designing a strong pedagogical structure for this pilot expedition would most likely have resulted in an over-constrained design with inappropriate foci.

2) It was hoped that these elements might flow in a constructivist sense from the teachers themselves. While some of this did occur (e.g. questioning of how we were going relate the expedition to the Processes) it did not provide enough impetus to counteract the immediacy of the activities at hand.

There are probably a number of reasons for this – possibly the Co-PI should have simply provided more structure to help the teachers navigate the complexity of the issues, particularly the number of levels that must be traversed in order to realize the stated goals of the program.

These levels can be thought of as a multi-layered cake, where one has to "eat through" all the layers to get to the bottom – or realize the goal. The layers of the cake are levels of experience within the expedition context. The top layer (1) is simply "being there", observing the activities, but not immersing oneself in the culture and work of the expedition. The next layer (2) is immersion of oneself in the actualities of the expedition, learning the science content, skills and processes to the point of becoming an active participant in the activities of the expedition. The next layer (3) is consideration of how the actualities of the expedition can be brought into the classroom, essentially a reflective exercise. The next layer (4) is disassociation from the daily routine to consider how the daily activities fit into the larger questions of exploration, e.g. How would someone set up a data-logger on the Moon or utilize fluorescent technology on Mars? The next level (5) is figuring out how to bring students through the layers that one has just traversed. This level would most likely involve a lot of trial and error development of teaching methodologies and techniques hopefully resulting in descent to the final layer (6) - development of a codified pedagogy of exploration.

The teachers in this expedition easily traversed the first three layers and nibbled at the fourth. It is the sense of the Co-PI that in order to successfully attempt to traverse the fourth layer, more structure and interventional guidance will be necessary to help teachers apply their experience in the broader sense. However, this must be done using methods of guided constructivism, as teachers will have to build their own meaning of exploration and develop their own conceptual scaffolding. The programmatic goal for the education component of the next Spaceward Bound expedition (now scheduled for March, 2007) will be the development and implementation of an approach to facilitate teacher's traversal of the fourth layer and further refinement of the 5th layer.

Jim Thompson

Figure 18: Teachers and Scientists

Appendices

Appendix 1: Transect Samples

Date	*Site*	*GPS coordinates*	*Sample size*	*Depth (cm)*	*Description*	*Notes*
21-Jun-06	1A	S 28º28.668', W 70º42.699', Alt. 646m	~1 kg	0-1	light brown sand with gravel atop	Very sparse vegetation (1%). colonial cactus
21-Jun-06	1A	S 28º28.668', W 70º42.699', Alt. 646m	~1 kg	2-6	brown sandy silt	Very sparse vegetation (1%). colonial cactus
21-Jun-06	1B	S 28º28.668', W 70º42.699', Alt. 646m	~1 kg	0-1	light brown sand with gravel atop	sampled ~100 m away from Site 1A, no vegetation
21-Jun-06	1B	S 28º28.668', W 70º42.699', Alt. 646m	~1 kg	1-5	Brown sandy-silt	as above
21-Jun-06	1B	S 28º28.668', W 70º42.699', Alt. 646m	20 g	8-10	Reddish brown clay-silt.	as above
21-Jun-06	2	S 28º28.647', W 70º42.709', Alt. 645m			Plutonic rock outcrop, desert varnish	Some lichens, no plants.
21-Jun-06	3	S 27º20.200', W 70º42.373', Alt. 246m	~1 kg	0-1	Light brown silty-sand.	no plants
21-Jun-06	3	S 27º20.200', W 70º42.373', Alt. 246m	~1 kg	1-4	Light brown silty-sand.	no plants
21-Jun-06	3	S 27º20.200', W 70º42.373', Alt. 246m	10 gr	10-12	Reddish brown coarse sand.	no plants
21-Jun-06	4A	S 25º56.881', W 70º27.628', Alt. 769m	~1 kg	0-1	Brown coarse sand with gravel cover.	Desert pavement. No plants. r
21-Jun-06	4B	S 25º56.881', W 70º27.628', Alt. 769m	~1 kg	0-1	Light olive gray clay.	Surface patches of finer material above the gravel cover
21-Jun-06	4B	S 25º56.881', W 70º27.628', Alt. 769m	10 g	10-1	Reddish fine-to-coarse sand.	
29-Jun-06	5	S 25º5???', W 70º2???', Alt. 7?? m	~1 kg	0-3	Light brown silty-sand.	
29-Jun-06	6	S 25º5???', W 70º2???', Alt. 1229 m	400 g	0-3	0.5 cm-thick layer covering fine pale orange silty-sand.	Foothill site. Light orange colored surface;
29-Jun-06	7A	S 25º56.954', W 70º27.765', Alt. 777m	20 g	0-1	1cm-thick gravel cover. Red color.	Nearby Site 4..
29-Jun-06	7A	S 25º56.954', W 70º27.765', Alt. 777m	10 g	1-3	Yellow-brown silty-sand.	No plants.
29-Jun-06	7B	S 25º56.954', W 70º27.765', Alt. 777m	10 g	0-1	Patches of very light brown clay.	The patches consist of very well sorted clay material.
29-Jun-	8	S 26º21.361',	20 g	0-1	Light brown silty	Sparse

06		W 70º29.157', Alt. 188 m			sand w/plant debris.	vegetation. Sample stream bed. At km 990.
30-Jun-06	9	S 29º11.355', W 71º01.281', Alt. 777m	20 g	0-3	Light brown silty-sand w/plant debris.	Sparse vegetation. ~90km from La Serena.
30-Jun-06	10	S 29º50.211', W 71º15.572', Alt. 15m	20 g	0-3	Brown silty-sand.	Dense vegetation: La Serena.
30-Jun-06	11	S 31º53.452', W 71º29.698', Alt. 0m	50 g	0-2	Light gray sand w/ plant debris.	Beach sand dunes with plant cover

Appendix 2: Application

Spaceward Bound Pilot Program 2006 for Teachers
Application Directions

Dear Applicant,

Below are the instructions for preparing and submitting your application to Spaceward Bound 2006. If you have any questions, please contact:

Liza Coe
lcoe@mail.arc.nasa.gov
650-604-0883

Submission Process

- All application materials must be received through USPS mail no later than February 24, 2006.
- Please send an email to lcoe@mail.arc.nasa.gov when you have mailed your materials – we will then know to watch for them. If we don't see them in a few days, we will contact you.
- Mail completed application materials to:

  Liza Coe
  Education Division
  MS 226-8
  NASA Ames Research Center
  Moffett Field, CA 94035
- Do not use any mail services such as return receipt, express mail, etc. That will only slow down our receipt of your application as it winds its way through the NASA mail system!
- You will receive an email confirming receipt of your materials.

The following are the required components of your application:

1. Applicant Information Form filled out and signed by Applicant.
2. Essays – please write four essays, one on each of the following topics. There is no upper or lower bound on essay length, however please give complete and thoughtful responses
   - Essay 1: Why are you interested in participating in Spaceward Bound?
   - Essay 2: What experiences have you had that have prepared you for the Spaceward Bound expedition? (See requirements list for relevant experience not covered in the Applicant Information Form)
   - Essay 3: What NASA Explorer School activities have you directly participated in?
   - Essay 4: How do you envision leveraging the Spaceward Bound experience in your classroom, school, and throughout the NASA Explorer School System?
3. Letter of Recommendation and Commitment signed by Principal.
   - This letter should include the following:
     - A statement that the Applicant is a highly qualified candidate for the Spaceward Bound expedition with specific qualities that support this statement

- A clear commitment that the Principal and the school will support and honor the Applicant's commitment to the Expedition and the associated Expedition requirements to the best of their ability. This includes, but is not limited to, access to the DLN system for the five interactive training sessions.

4. **Spaceward Bound Pilot Program 2006 for Teachers Release and Consent Form** signed by Applicant