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Express Launch: A New Capability for NearSpace

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Developing an operational program for high-altitude ballooning can be a daunting experience or impractical due to perceived risk, start-up cost, limited time and lab resources, and poor landing location (trees, hills, water, and minimal access or roads). An objective of the current NSF CCLI/TUES grant is to streamline academic access to near space (at low risk and cost) while still fully developing classroom experiments and maintaining the real-time data and launch excitement. As a logical stepping stone to purchasing a full-up "turnkey" flight system (e.g. Stratostar LLC) or building your own system is to first obtain some flight experience with a "Launch for Hire" of your experiment. Launch success can be obtained with a nearby experienced launching group or a distant express mail service. Towards this end NearSpace Launch Inc. was started (NSL) to help investigate remote launch capability and includes express launching of payloads to/from Upland, IN and shopping-cart purchasing of flight sensor systems/kits. The NSL services include the support of launch, operations, recovery, data collection, and ancillary measurements (GPS, tracking, Temp/pressure/humidity, video cameras and accelerometers) for K-12, university, and research programs. In addition, engineering and science services are available to help the advancement of curriculum, technical designs, and research. NSL offers a simple/quick way to get started by catalog purchasing of proven sensors and parts with academic documentation to meet the needs of curriculum or research and then letting NSL take the responsibility for final launch and operations with the economics of numbers. Currently the Taylor University HARP program (and NSL experience) has launched over 300 balloons in the past decade with over a 99% success rate. Students can visit the launch site and ground station (Upland, IN) or the class can watch the live video of the launch, the balloon tracking map progress, and the streaming data in real time on a big screen. After flight, the recovered payload is photographed, the high speed solid state data logger, the real time data and the video files are copied and other documentation copied and expressed back to the customer. For advanced users more sophisticated balloon launch options are available. To further explore near space from the topside of the atmosphere NSL plans to provide services and parts for developing nanosatellites (CubeSats) for LEO orbits. Recent TSAT certification by the FCC and Globalstar should validate the satellite-to-satellite communication link and modem when scheduled for launch end of 2013 on a Space-X rocket to the International Space Station . The NSL Globalstar modem product will eliminate the need for expensive ground stations and significantly improve small sat communications and balloon recovery while adding global coverage for long missions.

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I. Introduction

High–altitude balloon launches provide low-cost access to near space and give general education and upper level students the opportunity to experience firsthand the excitement of real science in a relatively unexplored region of the stratosphere. Small balloons achieve heights of 32 km and can carry payloads up to 4 kgs without needing special FAA waivers. The flight passes through the troposphere, tropopause, most of the ozone layer, and up through 98-99% of the atmosphere. A balloon travels for about 2-6 hours and covers a horizontal distance of 0 to over 200 km. To date we have launched over 300 balloons and have recovered over 99% due to the reliable and redundant GPS flight computer transceiver system, the ideal launch conditions in Indiana (road access, few trees, flat farm land and good neighbors), and experienced recovery teams (Figures 1 and 2).

The use of balloons for real projects significantly invigorates and expedites development and teamwork, teaches problem solving and instructor mentoring, drives schedule and creativity, uncovers unexpected problems, permits end-to-end testing, helps student understand failure and workmanship principles, gives a real environmental check (significant thermal vacuum and free-fall vibration test), and forces completion and validation of the flight and ground station software. Figure 1 illustrates some of the program operational logistics.

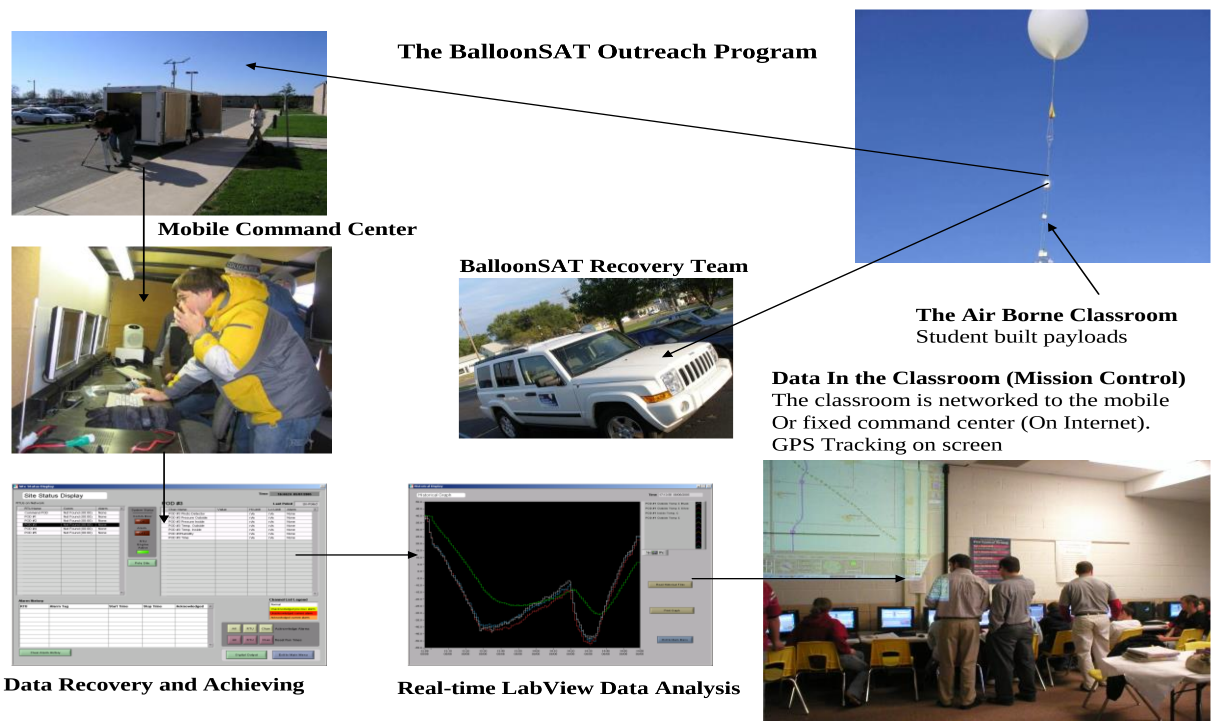

Figure 1. Real experience and real data as student sensors transmit their data in real time and student teams monitor data, track flight path, and chase for the GPS landing.

Specifically, the HARP balloon experiments helps students 1) learn the Scientific Method (hypothesis, test, observe, analyze, interpret, predict, repeat, document), 2) learn some hand-on technical skills (design, soldering, fabrication, electronics, assembly, and team work, 3) learn engineering principles (heat transfer, sensors, GPS, communication links, optics, remote imaging, and data processing), 4) learn atmospheric variables (pressure, temperature, wind, troposphere, stratosphere, humidity, dynamics, and others), 5) obtain physics knowledge (fundamental equations, radiation, acceleration, Archimedes principle, etc.), 6) apply data analysis skills (using Excel, handling noisy data, plotting profiles, creating log plots, and applying different plot formats), and 7) documentation (Wiki reports, team report, presentation, and resume). The objective is for students to have fun, efficiently learn, value science, improve in STEM, and advance in critical thinking skills[2].

High-altitude balloon training, hands-on experience, and quick turn-around are foundational to student advancement into more complex experiments such as aerospace and satellite system projects. Without experiencing real flight and some failure feedback it is hard for students to understand the importance of Requirements, sensor noise, workmanship and Quality Assurance, test fixtures, calibration, turn on procedures, clean documentation and configuration control, Concepts-of-Operations (Con-Ops), Program Management and schedule, and ground station software.

Figure 2. Flight paths now for 300 launches in Indiana over the past 10 years. Only half shown.

II NearSpace and Extremely Low Earth Orbit Defined

The official definition for the beginning of space is called the Karman Line defined to be 100 km (62 miles) altitude. At this altitude there is not enough wing lift to keep an object in flight with the atmospheric density less than 1 millionth the density at the surface. Weather balloons can routinely achieve altitudes of 32 km where they are over 99% of the earth's atmosphere and therefore make

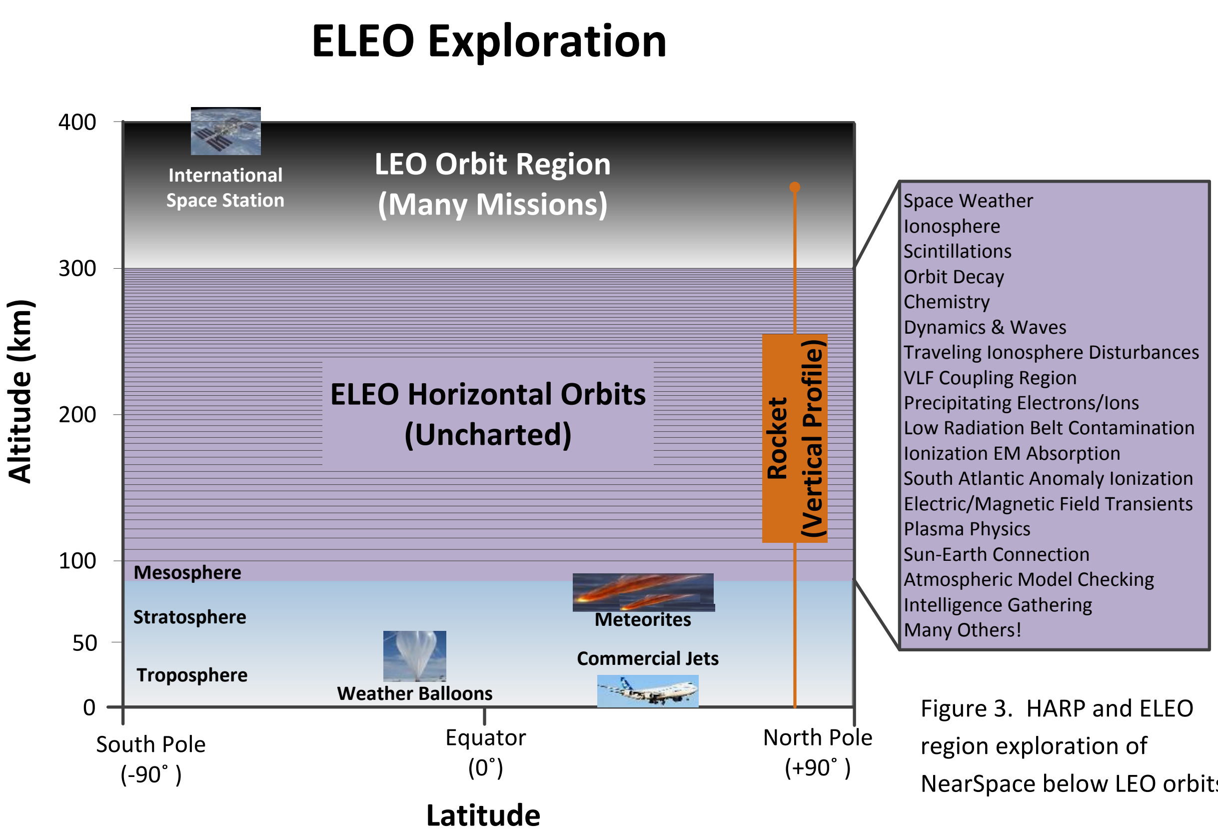

Figure 3. HARP and ELEO region exploration of NearSpace below LEO orbits

measurements in quote "Near Space".

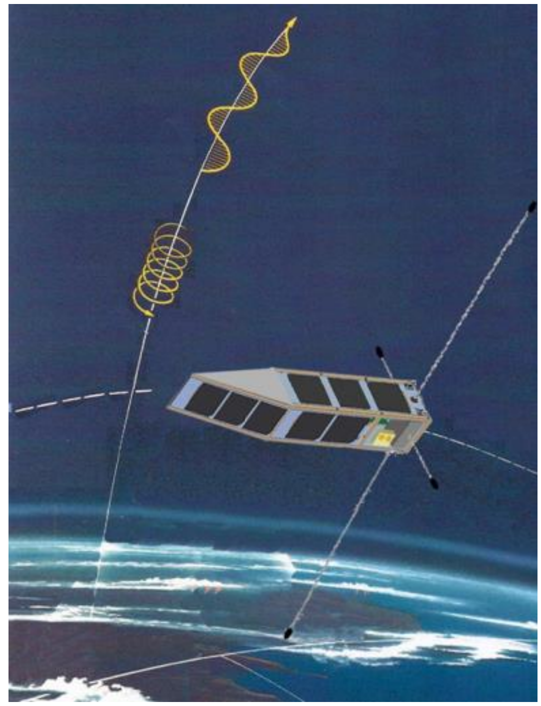

Figure 4. Aerodynamic ELEO Satellite making new measurements with waves and particles below 300km in NearSpace.

Although balloons are fundamental for efficient teaching, testing, and research they are limited in exploring the relatively unknown region between 40km up to 300km[1-5]. This region includes the upper stratosphere, mesosphere, and lower thermosphere. Above 300 km Low Earth Orbit (LEO) satellites have long enough lifetimes to permit higher altitude thermospheric measurements. The region below 300 km can also be considered "Near Space" since typical LEO satellites are unable to chart and communicate from below 300km. The region below 300 km is also very important for understanding global climate energy transfer and chemistry, the global electric circuit, Space Weather and many other interests as listed in Figure 3. Measurements in this region below 300km are also critical for discovery and testing mathematical models that have boundary conditions at lower balloon altitudes and at upper 300km altitude.

The new frontier of making measurements below 300 km can be conceptualized with a constellation of small and aerodynamic satellites (Figure 4) placed in the orbits near 325km that proceed to spiral slowly into the lower atmosphere. Solar operated ion engines may also cancel the drag forces above 200 km to maintain orbit. These Extremely Low Altitude (ELEO) satellites can make many horizontal and global cuts though the atmosphere down to about 100 km where friction forces begin to build up (see Figure 3). Short rocket flights (about 20 min) can take vertical measurements in this ELEO region but are limited to only one location and are very expensive. The new class of proposed ELEO satellites (like TSAT) is aerodynamic with a high mass ballistic coefficient so that they can make measurements down to 100 km and relay their data immediately to a satellite network like Globalstar. Ground stations are not required and for the first time small satellites can acquire near real-time data anywhere on the earth.

Some of the reasons now for opening this window into the earth's upper atmosphere include 1) ELEO orbit rides are very low cost and many are available through the NASA ELaNa program and Air Force University Nanosatellite Program (UNP)[3], 2) Climate and the Sun-Earth measurements and connection are critical to a better understanding of the 100-300km region, 3) being an unexplored region of space many new discoveries are expected, 4) current atmospheric and planetary models can be validated with real data from this region, and 5) the recent availability of a global communication network like Globalstar with real time data passage to the internet permits data collection above the "black-out" region anywhere on the earth.

In the future ELEO orbits could use high efficiency ion engines to add impulse to compensate for drag. Tether systems could help transform orbital energy into power at high altitudes when drag is low. Tethers can also reduce space time ambiguity of measurements by having two measurements at different locations or times. Furthermore, when the ELEO-SAT enters the deceleration region near 90 km a future design could allow for the heavy exoskeleton and batteries to be jettisoned while a stiff Kevlar chute with small POD would reenter and continue measurements as a dropsonde. In the future it is expected that many rides will become available to ELEO orbits because the lifetimes are relatively short and the supply to these orbits are high.

III Bridging the gap to launch experiments into NearSpace

The process for developing a full and robust balloon launch capability usually involves significant cost, time commitments, know how, experience, and suitable locations for flight and recovery. Risk management also is an important consideration with the unknowns of system electronic failures, losing GPS tracking and complete payloads, turbulence wrecking communication antennas, software glitches, landing in tall trees, lakes, or private facilities, liability issues, and safety.

For teachers or researchers who want to focus on the teaching part and develop their own experiment boxes and not worry about all of the logistics of the tracking, communication link, launch, software, chase, and recovery the idea of a "launch for hire" or "express launch" service may be a good alternative. At a fraction of the cost and time of developing your own system the economy of numbers, proven reliability, and experience may be a more effective way to get immediate results. By gracefully coming up to speed in near space flight a bridge is established to get your experiments flown reliably with little risk.

Collaboration is another advantage of a Launch for Hire or Express Launch option with the launch provider making baseline measurements of certified temperature, pressure, humidity, and accelerations in addition to providing routine upward and downward video camera support. There is also the likelihood of collaboration with outer experiment PODs from other institutions for comparison of data.

IV What is "Launch for Hire (LH)" or "Express Launch (EL)"?

Launch for Hire or Express Launch may be a good way for educators to efficiently conduct their own NearSpace experiments by letting a launch service provider assume the upfront cost, risk, insurance, and time commitment of the full launch system (Balloon, gas, parachute, command/telemetry link, GPS, data collection, ground station, and chase/recovery). Launch for hire is the concept of teaming with a local and experienced university or group that is willing to fly extra payload pods. Cost of a pod would be about $150 to $200/pound that includes all launch services or may be able to piggy back for free. Several flights per year would be typical and services would vary greatly between local providers.

Figure 5. Video camera frame of student twin balloon ascending while also showing the atmosphere, the curved limb-of- the- earth, and black heavens.

Express Launch is the same as Launch for Hire except it focuses on many flight opportunities and can be of international scope where institutions can express ship their instrument pods to the launch provider for regular service. The basic idea is to increase learning while reducing risk/cost by using the economy of numbers and improved yield (with a proven express launch service provider). The launch provider integrates the received PODS on a balloon with 5 or 6 other experiment PODS and also provides near real time internet launch video and streaming data. Upon recovery the institution PODS along with all data documents are immediacy sent back to the owners for further analysis. Potential benefits also include EL baseline control data (certified Temp., pressure, humidity, accelerations, video), standard data formats and plots, and the ability to collaborate with other institutions on the flight. Launch can still be viewed live with streaming data on the internet and local students can still visit the launch site and participate. Express launch also allows for campaigns (see Figure 5) and constellations of up to 20 flights, and ability to specify other supporting instrumentation. Also competitions between different universities and be managed with Express Launch Services. At this time the cost of an experiment POD would be about $150-$200/pound for beta testing that includes all launch services. Donated and reduced cost (for multi-balloons flights and special events) options are available.

V. Beta Testing Launch for Hire and Other Sustainability Options

One of the main goals of the NSF CCLI Balloon Grant is that the HARP program becomes sustainable on its own and continues to assist with workshops. In order to continue to grow the HARP program beyond the 50 universities participating in previous workshops an effort this summer is being made to beta test the Launch-for–Hire (LH) program. This summer small awards are being made to participants to encourage interested schools and universities to build a payload of interest and have a local or an Express Launch provider take care of the logistics of flight. Also a Questionnaire is available for obtaining meaningful information regarding the Launch for Hire program and is currently being distributed.

Small awards should help generate interest in order to better understanding the positive and negative issues regarding the start-up of a local Launch-for-Hire program. It is important to have experts in the field and potential users indicate their interest, improvements in the program and weaknesses in the program. In addition, the Taylor University program will be transferring much of its responsibility to a local company called NearSpace launch Inc. to make express access to near space for educational flights routine and streamlined as a One Stop launch provider.

This summer, 2013 an effort is also being made under the CCLI grant to improve and release the balloon software as Open Source, beta test a Virtual Workshop that will operate online with options for a kit of parts, and release documentation for understanding balloon flight, curriculum, and testing equipment that can be used in the classroom.

VI. NearSpace Launch, Inc.

To get started in ballooning you can 1) build your own system, 2) purchase a complete launch system from StratoStar Systems LLC, 3) contact a local amateur or professional group, if available (e.g. Edge of Space or local Launch for Hire Institution), or 4) mail your payload box (Figure 6) to NearSpace Launch and for a small fee you can remotely Express Launch and collect your live data online. A simple/quick way to get started (see Figure 7) is to purchase a payload kit, select sensors of interest, and let NearSpace Launch Inc. take responsibility for launch, recovery, returning, and collecting your data for a ride-for-hire (turnkey system, GPS tracking, supporting T, P, H sensors, video, near real time data to your classroom, liability insurance, regulations, safety, and more). After you experience a few low risk payload launches more sophisticated launch options are available or invest in your own launch system. NSL location is at 8702 E 825 S, Upland, IN 46989 and website is nearspacelaunch.com.

Figure 6. Express Launch service by shipping to Upland address for rapid launch, live video and streaming data, tracking, recovery, documentation and return shipping.

A main educational goal of NearSpace Launch Inc. is to give continuity to the Taylor University HARP Program by moving it to NSL and continuing to support new and established balloon programs and help them grow efficiently. Mr. Jeff Dailey who is now the lead engineer for the Taylor University balloon program will be going full time with NSL in June of 2014. Dr. Hank Voss will also be working part time at NearSpace Launch Inc. and was the Principle Investigator for the first Taylor University NSF Course Curriculum and Laboratory (CCLI) grant.

This year (June 2013-2014) NSL will be building its capability and launching a number of HARP payloads on 38 acres of private property in Upland IN. Currently NSL is now able to Express Launch your payload for beta testing. By next year we plan to have the full Express Launch service available so that we can maintain and increase our current rate of launching a balloon once per week on average. Mr. Jeff Dailey and Dr. Hank Voss with NSL have now launched over 300 Balloons in the past 10 years.

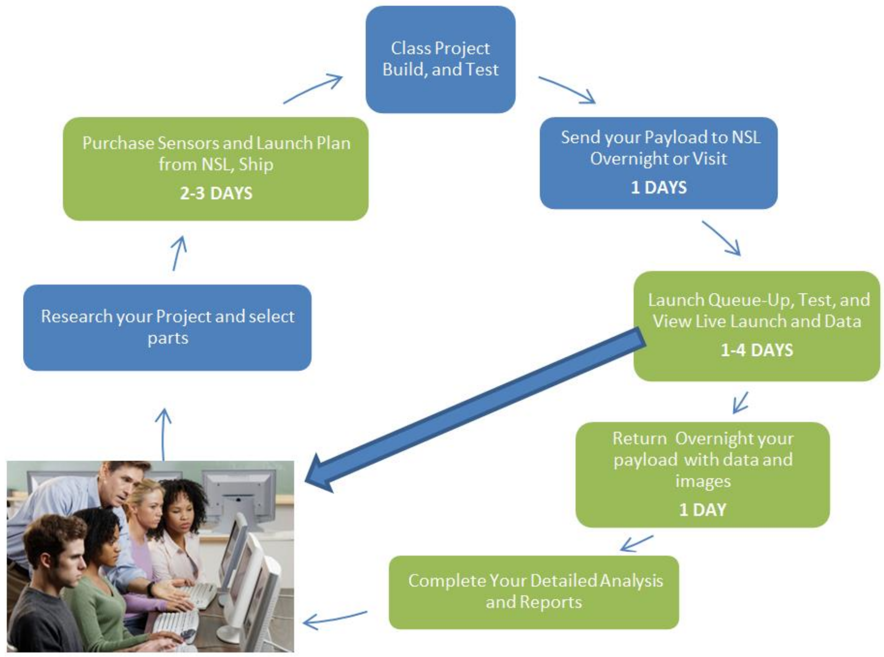

Figure 7. Standard Procedure for Express Launch service with live video web video and data transfer.

The main Objectives of NearSpace Launch Inc. are 1) to become a profitable small business, 2) expand STEM education internationally, 3) make discoveries and contribute to new science, technology and publications, and 4) donate external support.

VII. HARP Balloon Products for NSL

NearSpace Launch Inc. does not plan to market complete turnkey Balloon Launch Systems to avoid competing with StratoStar Systems LLC (which was previously spun off from Taylor University under the leadership of Mr. Jason Krueger).

Typical Balloon Products that we plan to have available this year include:
1) for Balloon Bus:, parachutes, mechanical pods, float valve, batteries, balloons, cameras, a GPS data logger module with Globalstar link[1], software, and antennas
2) for basic Sensors: Geiger counters, light sensor, IR, UV, Met unit, TPH, video cameras, VLF radio, Ion probe, electric field probe, solid state sensor, magnetometers, compass, accelerometers
4) for Certified Sensors and Systems: Globalstar link module[1], TPH Met units, Geiger counter
5) for testing: Simulators

VIII. NSL Small Satellite Products

Typical small satellite products that we plan to have available in two years include:
1) for Satellite Bus: Structure, Solar Arrays, Power Distribution Systems, Batteries, Globalstar communication link, boom deployment mechanism.
2) Globalstar Communication link module link
2) for Satellite Operations: Software, Ground Support Equipment, antennas, data management
3) Satellite sensors: Light sensors, IR, UV, VLF radio, Plasma Probe, E-Field Probe, Solid State Sensors, Geiger counter
4) Nano-satellite Basic Kits ready for flight

IX. NSL Express Launch Service (Education and Research)

Typical services that we plan to have available in one year include:
1) HARP Express Launch Service of experiments with real time video/ data links on web (section IV).
2) SAT Express Launch Service of experiments with real time video/ data links on web
3) Environmental Testing, Calibration, and software development
4) Satellite payload launch, Globalstar GPS[1], and tracking service
5) Multipoint constellations of balloons connected in a mesh network.
6) Joint proposals for advancing discovery, technology, operations, and publications

X. NSL Education Service

Typical materials and service we plan to have available in one year include:
1) Documentation on how to build experiments for Balloon flight
2) Curriculum for teaching STEM using the HARP Platform
3) Retainer for helping schools develop balloon related STEM education in labs and classroom.
4) Joint Proposals for advancing STEM education

XI. Final Thoughts

High Altitude Research Platforms (HARP) and Extremely Low Earth Orbit (ELEO) satellites are very important for STEM education and improving our fundamental understating of the near space environment below 300km. Balloon and satellite launch missions meet and exceed the ABET objectives by inspiring students to create missions within scope that can unlock secrets of the uncharted regions of near space. With the Express Launch service of NSL and other Launch for hire opportunities becoming available the efficiency of teaching and discovery is accelerated especially as experienced students move from localized HARP programs into global nano-satellite opportunities.

Acknowledgements

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