Strengthening Balloon Programs: University and Business Collaborations, Research, Outreach, and Internal Support

Hank D. Voss[1]
hnvoss@taylor.edu, Taylor University, Upland, Indiana, 46989

Donald K. Takehara[2]
Consultant, Upland, Indiana, 46989

Over the past decade, Taylor University developed a high altitude balloon program from scratch because of the impact that it had on undergraduate STEM education and research. The result was a growing and significant increase in student learning and the ability to exceed many of the ABET (Accreditation Board for Engineering and Technology) student outcomes. Over 300 balloons have now been successfully launched with over a 99% success and recovery rate. In addition, over 70 other universities were trained on using ballooning in their STEM courses. A core group of 25 universities are now regularly using ballooning in their courses. This is a key foundation for the starting up on Statospheric Ballooning Association (SBA), a professional ballooning organization. Various student and faculty assessments validated the learning outcomes and impact of ballooning in undergraduate courses. This growth was aided by funding from the National Science Foundation (NSF), the NASA Indiana Space Grant Consortium (INSGC), Air Force University Nanosatellite Program (UNP) and internal funds. In addition, two start-up balloon companies were launched to help serve the community: Stratostar Systems LLC and very recently NearSpace Launch Inc.

This paper is written as a resource to help others start ballooning programs from scratch and to help others build and strengthen their existing high altitude ballooning programs. References and lessons learned over the last decade are shared: Why a balloon program, How to start-up and build a balloon program, and funding source examples. For those starting high altitude ballooning or wanting to upgrade their portfolio there are a number of new technology options based on recent miniaturization and communication innovations.

The most complex and demanding part of a balloon system is coming up with a reliable flight processor and communication system that has high performance. Eight options are compared in a tradeoff matrix table for balloon flight systems. Seven basic approaches are identified for design and operation of a balloon system depending on objectives: 1) Build your own system, 2) Buy a full working system, 3) Buy an All-in-one flight data and communication system, 4) Build only your payloads and let a Launch-for-Hire group launch your experiments (while you watch live or watch live on the internet), 5) Buy or build a simple tether balloon system for testing experiments and teaching, 6) Buy a low cost disposable data and tracking system (that you attach your experiments to and watch your launch live while your data streams live on the internet without the need to recover payloads because of difficult terrain), and finally 8) Fly a simple data logger attached to a SD card with a simple tracking device for chase and recovery. Collaborations with universities, government agencies (NASA, AF, NSF, NOAA), balloon associations, NASA Space Grant Consortiums, collaborations with industry, outreach to K-12 and internal support are all ways used to build the Taylor University program.

[1] Professor of Engineering and Physics, 236 West Reade Avenue, Upland, IN 46989, hnvoss@taylor.edu, AIAA Member, KB9ZNZ, Also acting president of NSL, 8702 E 825 S, Upland, IN 46989, Cell 765 618 3813
[2] Consultant, 236 West Reade Avenue, Upland, IN 46989

I. Introduction

Over the last decade, the authors helped develop one of the largest academic balloon programs for undergraduate education and research. In addition, with the help of two NSF grants, over 70 universities were trained to implement high altitude ballooning into their classes. There is currently a network of over 25 universities who are actively launching balloons and collaborating together through the start-up of the Academic High Altitude balloon Conference (AHAC) and the Stratospheric Balloon Association (SBA). In addition, two companies have started up as a result of this effort: StratoStar LLC and Near Space Launch Inc.

The purpose of this paper is to help others build and strengthen their ballooning programs and to assist those who have just started ballooning. This will be done through sharing lessons learned over the last decade in the following areas. First, why start a balloon program? This paper addresses the importance and benefits of balloon program implementation. This discussion continues by explaining how one can start up a program and the new technologies available to leap forward to a high quality balloon program. Finally, program development and building is explored through university and business collaboration, research application, outreach opportunities, and internal support. Though this paper is from a university perspective, the information is also applicable to K-12 schools and the general public.

II. Why a Balloon Program?

High Altitude Research balloon Platforms (HARP) have very high learning outcomes for advanced engineering education (Capstones) and STEM (Science, Technology, Engineering, Mathematics) education in general. Practically everyone who has experienced a high altitude balloon launch agrees that it is an exciting experience that captures the attention of people of all ages. As a result, it is an excellent tool for getting people interested in and teaching them about STEM areas. Throughout the world it is believed that economic success and high standard of living are dependent upon science and technology. Therefore, there is major emphasis on people being educated in STEM fields and improve upper lever senior classes. In the U.S., only four percent of the workforce is in science related positions, which causes concern that the U.S. is falling behind in science and engineering[1]. Thus, there is a major need to draw children into STEM fields and improve upper level education. High altitude ballooning shows much promise to be able to do this.

High altitude ballooning introduces a type of project-based or problem-based learning that has been studied much in the literature and implemented in the classroom. Project/problem-based learning helps develop the following in students:

- Problem solving
- Analysis
- Life long learning
- Teamwor
- Inspiring students, Intrinsic motivation
- Hands-on, real world skills
- Risk-benefit analysis
- Meeting deadlines
- Documentation and presentation skills

These are extremely important in the education and training of young minds that will be future world leaders.

In addition, student resumes are enhanced with HARP projects, student summer scholarships and internships are available for HARP work, and there

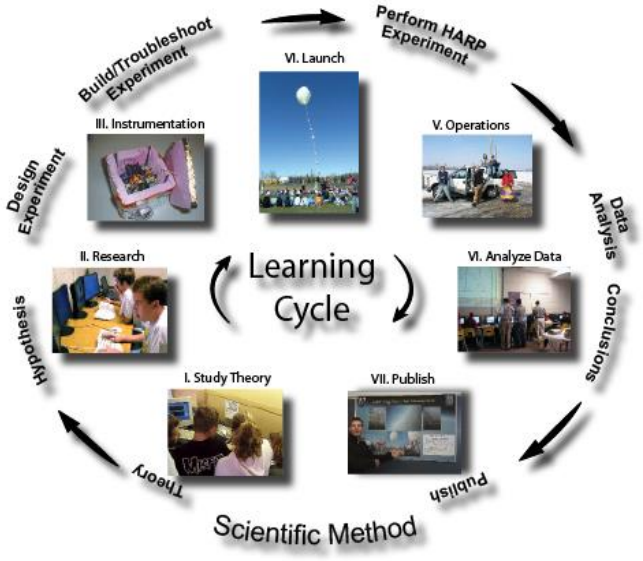

Fig.1: Scientific Method Applied to Ballooning

is much recruitment and public outreach associated with HARP. The student project work is many times at a Master's degree level. With low cost launches students can fail and rapidly flourish in learning the "right stuff" to build quality and integrated flight hardware products. The rigors and efficient learning of the balloon program prepare undergraduate students to be competitive in graduate level small satellite programs.

During 2013, Taylor engineering Capstone students competed and won a LEO launch opportunity for a student satellite, called TSAT, in the NASA ElaNa-5 program for launch on a Space-X rocket to the ISS. In April 2014, TSAT was successfully launched into space and the new EyeStar data and satellite link performed very well. Some summer intern students are working to analyze the on-orbit data and help publish the results in the August 2014 26th Small Sat Conference in Logon UT. This year Capstone students won an Air Force University Nanosatellite Program (UNP) grant to compete for a Phase 2 development effort and free launch into orbit. Our undergraduate students are competing with nine large graduate universities for the final competition. The learning in the HARP program is attributed to the success of the TSAT and wining the first round of competition in the UNP-8 competition. This year Capstone students had to launch four balloon flights to test their satellite designs and integration activities in the real world of a two hour balloon flight (testing, flight and ground software, calibration, communication links, vibration, temperature extremes, near vacuum conditions, UV and X-ray radiation and many other rigors). On the fourth launch, their system finally operated in near space.

Assessment of college students and professors who used high altitude ballooning in the STEM classrooms was completed. The results show that high altitude ballooning is successful in drawing students into STEM fields. Detailed information follows. A recent ABET (Accreditation Board for Engineering and Technology) 6-year program review listed Taylor University's balloon and satellite work as one of their top strengths.
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, gives a real environmental check (significant thermal vacuum and freefall vibration test), and forces completion and validation of the flight and ground station software.

Specifically, the HARP balloon experiment helps students:

1) Learn the Scientific Method (hypothesis, test, observe, analyze, interpret, predict, repeat, document –Fig. 1),
2) Learn some hands-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, windows, 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, 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.

Assessment of College Students

A study assessing the impact of high altitude ballooning on 1,470 students from 16 different universities and 51 classes was completed through Taylor University's two NSF grants. The study included students answering a series of self-assessment questions before and after ballooning projects in the classroom. The questions were shown to be reliable (reproducible) as well as valid (effectively meeting the objective of the study). Table 1 below discusses the areas where statistically significant increases in student learning occurred as a result of using ballooning in undergraduate classes.

Table 1: Areas where statistically significant increases occurred in undergraduate courses

Area	Description
Intrinsic Motivation	Motivation in curiosity, challenge, contextualization, challenge, control, and cooperation
Valuing Science	Valuing problem solving, calibration, the scientific method, reproducibility, data analysis, metacognitive planning, monitoring and assessing, teamwork, and meeting deadlines
Application Knowledge	How to use problem solving, prototyping, evaluating, calibrating, and documenting
Metacognitive Processes	Planning, monitoring, and assessing ones thought processes
Cognitive Skills	Application of the following to a complex problem at the appropriate time: problem solving, prototyping, evaluation & calibration, the scientific method, reproducibility, and data analysis
Content Knowledge	Knowledge of the scientific method and high altitude ballooning

Assessment of College Professors/Instructors

Thirty-two professors/instructors at universities using high altitude ballooning responded to a survey assessing how high altitude ballooning has impacted their ability to teach STEM courses. In general, the respondents felt that implementing high altitude ballooning into their courses had a significant impact on their ability to teach. A summary of the results are show in Table 2.

Table 2: Results from Assessment of College Professors/Instructors

(6-Strongly Agree, 5-Moderately Agree, 4-Mildly Agree, 3-Mildly Disagree, 2-Moderately Disagree, 1- Strongly Disagree)

Statement	Average Rating
I see the educational potential of high altitude ballooning	**5.8**
High altitude ballooning enhanced my ability to have students apply the concepts that they learned from my classes	**5.1**
High altitude ballooning enhanced my ability to inspire students to be creative with science and technology	**5.2**
High altitude ballooning enhanced my ability to stimulate an interest in students for science using a hands-on project	**5.4**
High altitude ballooning enhanced my ability to engage students in problem solving activities that are challenging	**5.5**
High altitude ballooning enhanced my ability to help students excel beyond what has been done before	**5.1**
High altitude ballooning enhanced my ability to enable students to have ownership in the learning process	**5.3**
High altitude ballooning enhanced my ability to have students learn how to work as a team	**5.5**
High altitude ballooning enhanced my ability to have students see that cooperation is needed in order to be successful	**5.4**
I see the value of ballooning in creating a learning environment where students monitor their thinking in order to accomplish the task	**5.3**
I see the value of ballooning in giving students freedom and control to take ownership of a research project	**5.6**
High altitude ballooning has enhanced my ability to have students select a strategy to accomplish the mission objective	**5.0**
High altitude ballooning has enhanced my ability to have students predict their results	**5.1**
High altitude ballooning has enhanced my ability to have students handle obstacles that are encountered	**5.4**
High altitude ballooning has enhanced my ability to teach students how to complete a specific task within a project timeline	**5.4**
High altitude ballooning has enhanced my ability to have students keep in mind possible obstacles and errors	**5.2**

III. Ways to Start-up a Balloon Program

A) Many Balloon Products and Organizations Available

Starting a Balloon program can be a difficult process since there are so many system choices, a myriad of parts, and risks associated with developing a sustainable program. The good news is that there has been much progress in the past few years in miniaturized electronics, communication technology, and groups that can now collaborate and help. For example many universities are now trained in balloon flight through workshops, a number of new companies have started to help make launching a balloon much easier, more excellent publications are available, and there are good professional and amateur organizations that also help. The AHAC conference encourages participation in Open Source information to contribute to growth.

In Figure 2 a time-zone map shows many of the organizations for HARP ballooning that can help in getting a program started effectively. Web URLs for these institutions are listed in the reference section.

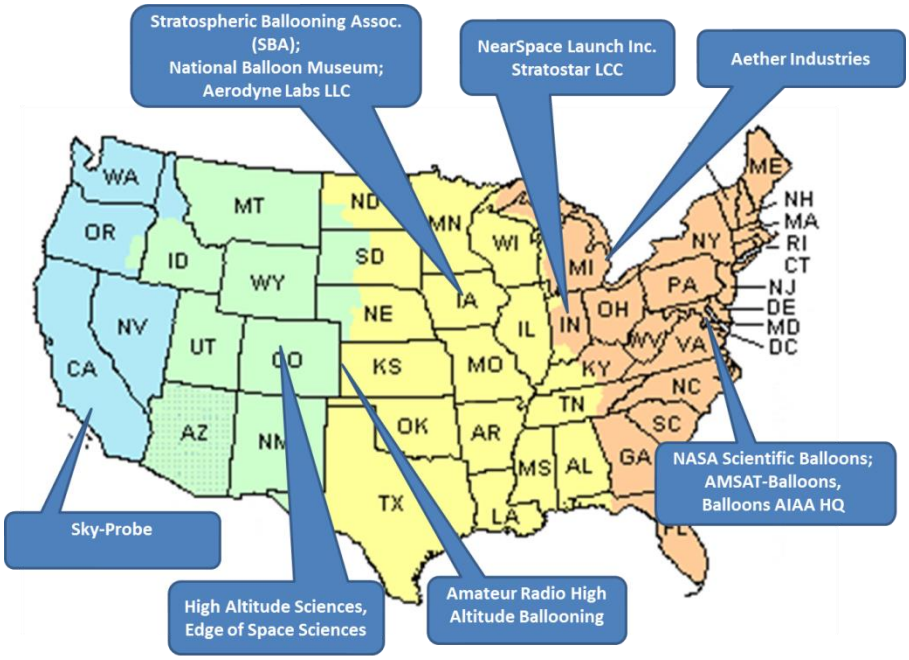

Fig. 2 There are more than 300 university, amateur, and club groups across the nation. Identified above are some balloon product distributors for flight systems and some of the national professional organizations. Many other organizations listed in references and websites listed in Figure.

B) Balloon Flight Options and Technology

For those starting high altitude ballooning or wanting to upgrade their portfolio there are a number of technology options. The most complex and demanding part of a balloon system is coming up with a reliable flight processor and communication system that has high performance. These are summarized in the following Table 3. Communication units include 1) using APRS ham radio tracking on the 2m band (whip antenna), 2) using spread spectrum on the commercial International (ISM) band at 900+MHz, 3) using a ground based Globalstar tracker device called SPOT (Slow rates) which can be purchased at many sport and electronics stores (also requires a data plan), and 4) using a high altitude and high data rate Globalstar modem operating near 1.6 GHz and using a 1 inch square patch antenna purchased from NearSpace Launch with HARP Value Added Reseller (VAR) License and FCC license included (also requires sharing on a NSL data plan).

From Table 3 it can also be seen that there are eight basic approaches to design and operation of your system depending on your objectives: Build your own system, buy a full working system, buy an All-in-one flight data and communication system, build only your payloads and let a Launch-for-Hire group launch your experiments while you watch live (in person) or watch live on the internet, buy or build a simple tether balloon system for testing experiments and teaching, buy a low cost disposable data and tracking system that you attach your experiments to and watch your launch live while your data streams live on the internet without the need to recover payloads because

of difficult terrain, and finally just fly a simple data logger to a SD card with a simple tracking device for chase and recovery.

Table 3: Technology Options for Starting Up a Balloon Program

Approach and Radio	Purchase	Performance	Initial Cost	Risk	Data Rate	Ground Station	Need for Training
1) Build from **Scratch** Ham Radio, ISM, SPOT Tracker	Study, design, develop, build	Team up with experienced group, Workshops, May need Ham License, Custom features	Very High	High	Variable	Yes	High
2) **Full Flight** Turnkey 1W ISM, Zigbee	StratoStar LLC	Real time data, GPS, sensors, Constellations, Service	High	Low	High	Yes	Medium
3) **All-in-one System** Globalstar VAR, ISM, and Zigbee	NearSpace Launch Inc. **Full EyePod**	Real-time data & SD Card, GPS, sensors, tree cut-down, options Constellations, Research Grade	Medium	Low	High <1 s sampling	No	Medium
4) **All-in-one System** SPOT Tracker	High Alt. Res. **Eagle Sky-Probe**	GPS, SD Card, sensors	Low	Low	Medium 10s sampling	No	Medium
5) **Launch for Hire**, Full flight system, sensors, Data Base	NSL & others **Full EyePod**	Globalstar and ISM, Real-time data, common data base, SD card Research Class	Very Low	Very Low	High <1 s sampling	No	Very Low
6) **Tether system** Low power ISM	NSL & others **EyePod-Lite**	Realtime data, SD Card, GPS, <1000ft height, no Chase	Very Low	Very Low	High <1 s sampling	Yes	Low
7) **One-use (**dispose) Globalstar VAR	NearSpace Launch Inc. **EyePod Lite**	No chase cost, GPS, fly over poor recovery terrain (water, trees, etc.) Common data base	Very Low	Very Low	Medium 1- 100s sampling	No	Low
8) **Data Loggers**	**HOBO EyePod-Lite**	Earth and flight support systems, Must add GPS and Radio	Very low	low	High	No	Very Low

Eight of the available options of the EyePod unit are shown in Table 3 above.

Option 1 is associated with building your own flight data system. It is better to team up with some nearby experienced group. Also extensive research and workshops will help ensure quality, performance, and success. Many processor systems are available using Arduino microcontrollers. Much cost can be spent building high reliability PCB electronics and flight software. This option may be good to do for advanced engineering student education while using a parallel proven radio and processor data and tracking package.

Option 2 is available from Stratostar LLC for those who want to purchase a full high reliable data and tracking system. This option allows customers to focus on building the payload portion.

Option 3 represents a full-up all-in-one data and tracking system from NearSpace Launch (NSL) that is Research Grade certified. It uses low power ISM spread spectrum radio and Globalstar links. High speed data is captured on a 2G memory stick. Also ideal for constellation arrays and international use.

Option 4 is also an all-in-one data and tracking system that employs the SPOT radio for tracking. It samples at lower rates but also cost less than option 3.

Option 5 represents a Launch-for-Hire or Express Launch service (Voss and Dailey, AHAC 2013). In this case the full-up research grade EyePod unit is included and all of the launch and chase is conducted at NSL and data and video are streamed to the internet for live viewing. This option is ideal for experimenters who just want to fly atmospheric instruments without worrying about flight platform and logistics or who

live in a launch area with difficult terrain (water, forest, mountains) or have other liability, insurance, and risk concerns. This option may also be good for international customers who find it difficult to launch in their local environment.

Option 6 above uses a low power high data rate modem to send student and research data down from a tethered balloon payload. In this option, the risk is low and the tether balloon can be retrieved without a chase and reused, students can test their experiments and collect real atmospheric data. Good photos and videos can also be obtained of the local surroundings.

In Option 7 (One Use or disposable) a low cost EyePod-lite can be used to fly instruments over great distances and over rugged terrain without worrying about recovery. Data and GPS tracking is transmitted in near real time over the Globalstar network for data analysis. The cost of the chase is eliminated and can be used to cover balloon system and data costs. This option may also be good for international customers.

Finally, Option 8 includes a stripped down EyePod-lite version for simple data acquisition with a SD card. For balloon flight, other Ham radio or SPOT tracking systems can be used. Also the included EyePod sensors provide redundant and certified measurements.

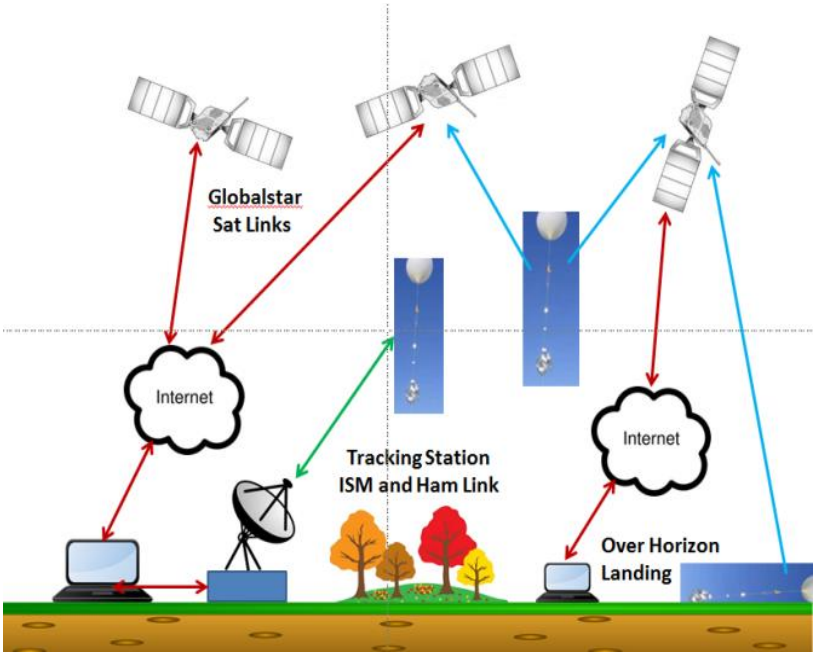

Fig.3 New paradigm in ground tracking using the commercial Globalstar communication network (No over horizon problem). No ground station is required with data available on internet server. Coverage is global for international and long duration flights and for multi-balloon/constellation flights and common database.

C) Savings with Balloon Flight Architectures

There are many decisions to be made in choosing a balloon architecture, configuration, and operation. For example, significant cost can be saved by using hydrogen gas instead of helium. The cost of hydrogen (sustainable) is about 25% that of helium (short supply). For college classes and research we use hydrogen but only have it handled by a qualified person. The balloon when filled with hydrogen can be connected to a long tether before it is tied to the parachute and payload giving more ground safety with students and improved balloon dynamics. We never have had a fire problem. We also intentionally exploded hydrogen filled balloons near the ground, videotaped, and made measurements of the flame process around the balloon. The fire was a burn and not an explosion with the hydrogen moving upward rapidly because of its high diffusivity. For all of our K-12 and public outreaches we use helium gas. There are a number of tradeoffs like this that can save considerable launch costs.

During descent the freefall can be violent with antennas and pods hitting and breaking. Also during descent the velocities are large and so data is very poor and hardly ever used. To eliminate the post-burst chaos and freefall and obtain good data on the downleg (double your data) we have found that a second lift balloon can have many

advantages. If the second balloon is smaller, under filled, and located above the parachute it can provide significant lift (20-40%). When the larger balloon burst at high altitude the second balloon gracefully lowers the payload through the thin atmosphere while the parachute is not yet deployed and the second balloon diameter is much larger than the parachute (more drag). On landing the second balloon can still be floating (if not in tree) and reused for another flight. A concern is that the balloon can be up a long time with the slower descent and time in the jet stream.

Many other considerations can be looked into for the a particular balloon mission objectives. Some options include the following: microgravity freefall drop (e.g. to test weightless tether release mechanism), de-spin platforms, float valves for long duration, release of gliders and dropsondes, airships, motherships, long tethers for Electric-field measurements, and many other platform operational capacities.

D) Workshops

Various methods for receiving training for doing high altitude balloon launches, tracking, and recovery were developed and tried over the last six years through funding from NSF. Table 4 summarizes the pros and cons of these methods. These methods were used for Option #1 and #2 in Table 3.

Table 4: Methods for Training – Pros and Cons

Training Method	Description	Pros	Cons
Workshop – at an expert's location	Workshop at an expert's site for 2 days	• Thorough hands-on training from an expert	• High cost • Timing may not be convenient
Workshop - Virtual/Hands-on	Half-day webinar training plus 1-2 day hands-on training at a location within driving distance	• Good hands-on training, • Develop network with regional partner	• Medium cost • Timing may not be convenient
Workshop – regional locations	Workshop is at a location within driving distance	• Good hands-on training • Develop network with regional partner(s)	• Medium-High Cost • Timing may not be convenient
On-line	Use web based resources only for training	• Low cost • Flexibility	• No hands-on training
Personal one on one	Expert comes to your location and trains you (StratoStar)	• Good hands-on training from an expert • Flexibility • Customized	• Very high cost

IV. Ways to Build a Balloon Program

A. Collaborations with Universities

One of the major ways to enhance an existing balloon program is to collaborate with universities. The synergistic effect of collaborations is being recognized in STEM fields as well as society. This has opened the door for opportunities to collaborate. Some specific examples are discussed below. Note that this is certainly not an exhaustive list, but it is a result of the learnings over the last decade by the authors.

NSF Grants

National Science Foundation has grant opportunities that those in High Altitude Ballooning can submit proposals. These grants can be used for many educational and research activities (atmosphere, remote sensing, instrumentation, biology, and many other opportunities)

Previous NSF Grants

The authors were Principle Investigators on two NSF grants in the CCLI (Course Curriculum Laboratory Improvement) Program that later became TUES (Transforming Undergraduate Education in STEM). Note that this program is now under the Improving Undergraduate STEM Education (IUSE) Program. The two grants covered the period from August 2007 through January 2014 and are as follows:

- "'New Heights' in STEM Undergraduate Learning" ($217,668 ID: 0717787)
- "High Altitude Ballooning in Undergraduate STEM Curriculum: Preparing for Widespread Implementation" ($533,797 ID: 1047577)

The major outcomes of these two grants are as follows:

- Developed a core group of faculy from over 25 universities who regularly use ballooning. This group is the backbone of a new professional organization, Stratospheric Ballooning Association (SBA).
- Assessment data from undergrad students using ballooning showed statistically significant increases in valuing science, application knowledge (including problem solving, prototyping, evaluating), metacognitive processes, cognitive skills, content knowledge (including scientific method, balloon technology), and learning motivation. A survey of 32 professors showed that, on average, they moderately to strongly agreed that ballooning enhanced their ability to apply concepts, inspire creativity, and help students excel. All strongly agreed that they see the educational potential of high altitude ballooning.
- Trained over 70 universities to implement ballooning in their undergraduate courses.
- Established the annual Academic High Altitude Conference now in its fifth year.
- Piloted best practices for training new universities in ballooning using various forms of workshops, an on-line website, launch for hire capability, etc.
- Universities collaborated to develop capabilities such as Cosmic Ray Sensor, High Precision/Gas Sensor Pod, Flight Prediction Software, Flight Dashboard Display, Laboratory Thermal-Vacuum Chamber, and Thunderstorm Analysis Equipment.
- Piloted the implementation of ballooning into Science Methods courses for education majors. Students developed curricula for middle school classes and tested them in 6^{th} and 8^{th} grade classes. Assessment of student learning for education majors showed statistically significant growth in metacognitive processes and content knowledge. The 6^{th} and 8th grade students showed statistically significant gains in valuing of science, metacognitive processes, and content knowledge. Ball State University developed the website "Teaching on the Edge: Using High Altitude Ballooning in the Classroom" (http://ilearn.bsu.edu/tote/) with lesson plans, supplementary material, and data from launches. Ball State also created the iBook, "Teaching on the Edge," (available at the Apple iBook store) - a textbook for middle school teachers and students on the atmosphere and ballooning. It includes interactive learning activities and animated time/geographically based launch simulations using real launch data.
- Piloted one day Space Camp for 70 Middle School students.

The outcomes from these two grants were highly successful in terms of transforming undergraduate STEM Education through high altitude ballooning – the goal of the TUES program. Assessments showed significant impact on student learning and faculty ability to teach. Many universities are now using ballooning in their undergraduate courses. In addition, resources to spread to additional universities are being put in place through Stratospheric Ballooning Association and companies like Near Space Launch.

NSF IUSE Program Opportunity

As a result of the success of the two NSF grants, there is good potential for a grant through the Improving Undergraduate STEM Education (IUSE) Program for the following reasons:

- The program officers in IUSE are familiar with the two grants since IUSE includes activity from the former CCLI/TUES program
- The previous grants showed that High Altitude Ballooning is significantly improving undergraduate STEM courses at multiple universities. In addition, a path is paved for dissemination to universities across the U.S.
- NSF desires to fund past successful projects in order to increase the impact of these projects.

Some important things to know about the IUSE Program are as follows:

- The program synopsis is on the NSF Website: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504976
- Note that there is not a solicitation but there are Frequently Asked Questions that should be reviewed.
- The program synopsis is intentionally left to be very vague so that it can cover a wide range of opportunities. This can make things difficult but actually enables one to entertain many different possibilities.
- Even though proposals can be submitted at any time, it is best to submit before a target date (if given) to have the best opportunity to be considered when funding is most available. The last target date was early in 2014. (As of June 5, 2014, a new target date is not in place. Consulting with a Program Officer may be a good idea.)
- A proposal that has very significant impact on undergraduate courses in STEM that can be implemented in many universities is very important.
- A proposal that is based on the existing body of knowledge and will fill a significant need in the body of knowledge is very important.
- A proposal where the effort is innovative and novel (has not been done before) is very important.

Other NSF Programs

In particular the NSF Directorate for Education and Human Resources (EHR) which has a particular focus on education is a promising area for grant opportunities. Under EHR is the Division on Undergraduate Education (DUE) and the Division on Research in Formal and Informal Settings (DRL). Here are particular programs under DUE and DRL that would be of interest.

DUE

- Improving Undergraduate STEM Education (IUSE)
- STEM-C Partnerships: MSP (STEM-CP: MSP)

DRL

- Discovery Research K-12 (DRK-12)
- Advancing Informal STEM Learning (AISL)
- Innovative Technology Experiences for Students and Teachers (ITEST)

Appendix A gives a list of steps for writing a successful NSF proposal. Proposals are usually improved if several groups can collaborate in a meaningful way to help spread the load and ensure success.

Space Grant Consortium

The Indiana Space Grant Consortium provided funding for the early and later years of the balloon program at Taylor University. Grants in the $5,000-$20,000 per year range were a great help to building Taylor University's program. Each state in the U.S. has a Space Grant Consortium. The website for the National Space Grant Consortium with links to each of the states is: http://www.nasa.gov/offices/education/programs/national/spacegrant/home/Space_Grant_Consortium_Websites.html . Since the Space Grant Consortium is focused on education and public outreach in Aerospace and STEM in general, this is a good match with those doing high altitude ballooning at universities, K-12 schools, and in the general public.

Stratospheric Ballooning Association (SBA) and Other Socities

The Stratospheric Ballooning Association (SBA) is a national professional organization with the following mission: to support those engaged in high altitude ballooning by promoting the field to others, empowering practitioners, and facilitating collaboration. The outcomes from the two NSF grants described earlier helped provide the foundation for SBA. Table 5 shows the benefits of being a member of SBA. The SBA membership and conference costs are relatively low to help smaller universities and researchers to participate.

Table 5: Stratospheric Balloon Association Member Benefits

Benefit	Description
Academic High Altitude Conference (AHAC)	This annual conference, now in its fifth year, is averaging 50 attendees and 20 papers. Attendees share cutting edge efforts in ballooning through presentations, keynote speakers, breakout discussion sessions, a poster session, networking time, and a balloon launch.
Mini/Virtual AHAC	2-3 hour conference over the internet including presentation and breakout session.
Website	Website includes resources for those engaged in high altitude ballooning including training videos, best practices, links to papers, curricula, info on capabilities for high altitude ballooning, etc.
Journal	Opportunity to publish a paper in a special ballooning issue of the Transactions of the Canadian Society for Mechanical Engineering during 2015.
Collaborative Grant Proposal	SBA will facilitate the collaboration of multiple organizations to submit a grant proposal for funding during 2014-2015.
Best Practices	SBA will facilitate a process to come up with a process for determining best practices for high altitude ballooning

The American Institute of Astronautics and Aeronautics (AIAA) also has a professional venue and has a Balloon Systems Technical Committee that supports a Balloon Systems conference each year at the annual AIAA meeting. Two professional Amateur Radio societies (AMSAT and ARHAB) are also active and promote balloon group advancement and conferences.

Grand Challenges

A number of universities, amateur and international groups are spontaneously coordinating challenges for long duration flights and global launches. Competitions and prize awards are a great ways to cultivate innovation and education. As more groups grow more coordination and organization is needed.

B. Collaborations with Business

StratoStar LLC was started up in 2005 as a spin off from Taylor University's balloon program. It was recognized that in order for other universities to implement high altitude ballooning into their classrooms, there would need to be a way to provide balloon systems to these universities. As a result, StratoStar LLC was founded. Over the last nine years, StratoStar has provided balloon systems to universities and K-12 schools after training these institutions to implement high altitude ballooning into their courses. In addition, StratoStar has collaborated with Taylor's Balloon Program to develop software, provide training videos, and provide marketing studies and business plans.

Near Space Launch Inc., was recently established to continue and expand the balloon program that began at Taylor University ten years ago. Its mission is Technology, Service and Education for High altitude balloons and LEO satellites. Near Space Launch has proven expertise and experience in designing, developing, and implementing state of the art instruments and sensors to enhance high altitude ballooning in the area of research and scientific discovery. Near Space Launch has additionally been successful at lowering cost and simplifying high altitude ballooning. Details of NearSpace Launch objectives and products were outlined last year in the AHAC conference (Voss and Dailey, 2013). In addition to the Balloon market, NearSpace launch is also heavily involved building satellites manufacturing Globalstar modems, and building communication infrastructure (EyePod and EyeStar products). NearSpace Launch is designed to complement Startostar LLC products. NSL also is involved in research grants and is open to teaming up with others to write successful proposals. More information NearSpace Launch can be found on the NSL Website.

Larger companies and industry many times will support student capstone and internship HARP projects with funding and donate equipment. ITT Aerospace (Exelis) donated over $100,000 in used testing equipment. Students completed design reviews with many large companies at their facilities. Companies that hire our graduates in aerospace and computer engineering give internships to students and play an active role in our curriculum and ABET judging reviews.

C) Research Stratosphere Platform Opportunities

Many government grants are available for pursuing research in the upper atmosphere from NOAA, NASA, AF, DARPA, NSF, EPA and other agencies. The outline below is a sampling of areas of NSL interest and collaboration.

Atmospheric Sensing

In Situ: thunderstorm multi probes, turbulence**,** humidity, winds, electric fields, O3, cosmic rays, solar proton events, gas sampling, spectrometers, and remote imaging, dropsondes, Biological functions and bacteria in stratosphere

Testing flight hardware systems

Nanosatellites: TSat, AFOSR-UNP Program (TEST and ELEO-Sat)**;** Link margin, ground station, deployable testing , scanning mechanisms, booms, imagers, gyros, sensors, …

Communication

Low Data Rates: Oil and gas, utilities, transportation, homeland security, Third World Assistance, Emergency Service, Wildlife management,…

High Bandwidth: Internet, Cell phones, Battlefield

Test New Networks out for global communication and data**:** Globalstar and Iridium

Remote Sensing

Earth Science: Spectral Images (Visible, IR, agriculture,), Penetrating Radar (geology), LIDAR, surveillance, sprites and lightning,

Space Science: Space Weather, VLF waves, airglow, aurora, e- x-ray precipitation,

Astronomy: Solar UV and X rays, Gamma ray bursts, Microwave Background Radiation

Biology: Agricultural and wildlife mapping on earth

Energy

Solar concentrators and Photovoltaic Arrays/Microwave-IR beam

Tethered balloon wind mega power generators

Cargo Moving and Passengers

Hybrid airship designs for large but slow transport:

Many defense applications

Understanding turbulence in stratosphere

D. Outreach

Using high altitude balloon launches to reach out to K-12 schools and the public has given Taylor University positive exposer to the community and to prospective students. It has opened the door to unexpected media coverage (local newspaper articles, radio interviews, etc.). In addition, the Indiana Academy of Sciences chose to highlight Taylor's High Altitude Ballooning in a video that is being aired on Public Television in Indianapolis. This was one of four areas chosen to inform the public about STEM education in the State of Indiana.

The following table shows the various outreach opportunities that Taylor University has had through its High Altitude Balloon Program.

Table 6: Outreach Opportunities for Taylor University's Balloon Program

Description of Outreach	Type of Outreach
Marion High School Science Classes – Marion, IN	K-12
Eastbrook South 6th Grade Class- Upland, IN	K-12
RJ Basket Middle School - Gas City, IN	K-12
Kings Academy High School – Jonesboro, IN	K-12
Science Central – Fort Wayne, IN	Public
Indiana State Fair – Indianapolis, IN	Public
Space Camp for 70 students – Upland, IN	Public
Indiana Astronomical Society	Public

E. Internal Support

Taylor University's Balloon Program received internal support from the Taylor University Center for Research and Innovation $(CR\&I)^2$. The different types of support received by the CR&I are shown in the table below.

Table 7: Support Received from Center for Research & Innovation

Type of Support	Description
Grant Support	Proposal writing, report writing, budget management, management of project
Find Opportunities for Balloon Launches	Network internally and externally to find opportunities for high altitude ballooning including demonstrations, outreach to the public, K-12 opportunities, university outreach
Public Relations	Created written and video PR material.
Facilitate Collaborations	Develop relationships with other universities, industry, government agencies, foundations, community, etc.
Project Management	Management of various ballooning projects including conceptualizing, implementing, monitoring, and finishing projects.

Internal support for balloon flights was also obtained from normal department class budgets and from other university funds.

V. Resources for Starting Up and Building a Balloon Program

Papers

Papers in the following areas may be of assistance for those starting up and building a balloon program.

2013 AHAC

Express Launch: A New Capability for NearSpace[3]
Cosmic Ray Measurement and Analysis[4]
High Altitude Research Platform (HARP) All Sky Camera[5]
HARP Visible and Ultraviolet Intensity Profile and Blackbody Spectrum with 2nm Spectra[6]
Over-The-Horizon Global High Altitude Balloon Communications System[7]

2012 AHAC

Taylor University High-Altitude Research Platform as a Research Tool[8]
High-Altitude Balloon Atmospheric Database[9]
Micro Gravity Balloon Drop: Tether Release[10]
High Altitude Ballooning in High School Science Classes[11]
High Altitude Ballooning into Undergraduate STEM Curriculum: Preparing for Widespread Implementation (Implementation into Undergraduate Education Curricula)[12]
High-Altitude Balloon Curriculum and Hands-On Sensors for Effective Student Learning in Astronomy and STEM[13]
Understanding High-Altitude Balloon Flight Fundamentals[14]

2011 AHAC

Extended flight time of latex balloons through the use of a buoyancy control system[15]
Developing High Altitude Balloon Curriculum for Undergraduate Courses – NSF Grant Impact and Example in General Education Chemistry[16]

Websites

The following websites may be of assistance for those starting up and building a balloon program.

Aerodyne Labs: http://www.aerodynelabs.com/
Aether Industries: http://www.projectaether.org/
Amateur Radio High Altitude Ballooning (arhab): http://www.arhab.org
Amateur Radio Satellites: http://www.amsat.org/amsat/balloons/balloon.htm
Edge of Space Sciences: http://www.eoss.org/
High Altitude Science: http://www.highaltitudescience.com/
Near Space Launch, Inc.: http://www.nearspacelaunch.com
Sky-Probe.com: http://www.sky-probe.com/ Stratostar LLC: http://www.stratostar.net/
Stratospheric Ballooning Association ; http://www.stratoballooning.org
Teaching on the Edge: http://ilearn.bsu.edu/tote/

VI. Conclusion

Studies have shown that there is significant advancement of upper level engineering programs with HARP. Studies also show statistically significant student learning when High Altitude Ballooning is implemented into undergraduate STEM courses. In addition, the results of a survey show that faculty believe that ballooning gives a very significant benefit in teaching their STEM courses. Therefore, there is much promise for high altitude ballooning to have significant impact on STEM learning for students of all ages. As a result of the authors' ten year experience of starting up and building a balloon program which includes over 300 balloon launches and training of over 70 universities, there are many lessons learned that can help organizations start-up and build a balloon program.

The outcomes from the authors' decade of experience at Taylor University will be sustained through the Stratospheric Ballooning Association (SBA) and Near Space Launch Inc. In addition, it should be noted that High Altitude Ballooning has been particularly successful at smaller teaching universities. There are many ways to enhance and strengthen existing HARP programs.

Appendix A Step procedure for NSF Grants

The following are some keys to writing a NSF proposal that has a good chance of being funded. These are based on the authors' experience.

1. Do your homework.
   - Read and understand the solicitation thoroughly.
   - Look at previous awards (available on the NSF website).
   - Attend free webinars explaining the solicitation and program (available on NSF website).
   - Read and understand the literature pertaining to the solicitation.
2. Brainstorm ideas/concepts for a proposal that fit the solicitation.
   - Competition is stiff so a concept that stands out above the rest is needed.
   - Be innovative with novel concepts.
   - Have compelling reasons why your concept will make a significant impact on the goals of the solicitation.
   - Base the proposal on the literature and fill a void in the literature. How does the idea fit in the body of knowledge in the field?
3. Take the time to evaluate and develop potential concepts.
   - Bounce ideas off colleagues within and external to your organization.
   - Begin thinking about others to collaborate with you on your proposal.
   - Start several months before the proposal due date.
   - Coming up with a great concept/idea for your proposal and fully developing it is essential.
4. Choose an idea or concept and develop it into a full proposal.
   - Contact a NSF Program Officer to get his/her input on your idea. This is very valuable. The Program Officers want to help, so take the time and be persistent to get his/her input.
   - Include partners early and have them be part of developing the proposal.
   - Develop a good plan including details on how the project will be executed, timeline and milestones, specific roles of personnel, etc.
   - Develop a detailed budget that accurately reflects what is needed to carry out the project. Be realistic. If the budget does not seem to have enough in it to cover the project, reviewers will think that you do not understand what is needed to carry out the project.
   - Assess and evaluate the outcomes of your project.
     - Assess as the project is executed to improve the project while it is active.
     - Evaluate at the end of the project to show the true impact.
     - Have assessment plans that are specific, well thought out, and based on best practices

    - Include an external evaluator (someone not involved in the project)
    - Consider consulting an expert in assessment and including funding in the budget for this person
  - Determine as many project details as possible. Having thought through and implemented these specifics shows the reviewers that you are well prepared and therefore have a high probability of success.
5. Follow the solicitation and proposal guidelines for NSF rigidly
  - Make sure all the general proposal guidelines for NSF proposals and specific guidelines from the solicitation are followed. Proposals can be rejected without review if it does not follow all the requirements.
  - Make sure to obtain approval within your organization early.
  - Make sure your organization has the appropriate personnel and NSF administrative items in place to submit proposals to NSF.
6. Write a proposal that will succeed in the NSF review process.
  - Proposals including both the Project Description (15 pages max) and Project Summary should be well written.
    - Write in a well-organized manner that easy to read.
    - Be concise, but still include all of the information needed for review.
    - Write without error. Grammar, spelling, sentence/paragraph structure should be flawless.
    - Use tables, figures, and pictures to convey information in a concise, easy to read fashion.
    - Thoroughly think through proposal organization and content.
    - Be willing to rewrite and reorganize the proposal to make it better.
    - Take the time to thoroughly edit and proof the proposal , and ask for second opinions.
  - Proposals should clearly address the two Merit Review Criteria – Intellectual Merit and Broad Impacts, which are the key evaluation criteria.
    - Make sure you clearly understand both criteria.
    - Within the context of the two criteria, make sure the proposal gives compelling arguments for a significant impact on the goals given in the solicitation and the overall goals of the NSF.
    - Within the context of the two criteria, make sure that the proposal stands out as being innovative and novel.
    - Within the context of the two criteria, make sure that the proposal is based on the existing body of knowledge and will significantly add to this body of knowledge
  - Review Panel
    - Typically there is a panel of three to five reviewers that the NSF brings on board to review proposals. They are people who are familiar with the field that the solicitation covers and have some experience with NSF grants. Many are professors.
    - The panel reviews 10-20 proposals, and each review individually rates each submission. The panel will then convene for a few days to discuss each proposal and develop a panel summary on the proposal. Individual reviewers can change their rating after discussion with the panel.
    - Each panel member gives each proposal one of the following ratings: Excellent, Very Good, Good, Fair, or Poor. Receiving Excellent and Very Good ratings from every reviewer is probably needed for a proposal to be funded.
    - The key criteria for evaluating proposals are the Merit Review Criteria (Intellectual Merit and Broad Impacts). **Make sure that your proposal addresses both of these criteria well and it is obvious to the reviewers.**
  - Program Officer
    - Program officers take the information from the review panel and rank them from highest to lowest recommendation on being funded. Note that there may be other factors involved other than the review panel input on this process.

- The Program Officer may have the ability to push a particular proposal to be funded or not to be funded.
- Final Decisions on funding occur at levels higher than the Program Officers. The Program Officers may have the ability to argue for or against funding of particular proposals.

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References

[1] Augustine, Norman R., et. al., *Rising Above the Gathering Storm, Revisited*, The National Academies Press, Washington, D.C., pp. 4-5.
[2] Bates, Michael J., Takehara, Donald Ken, and Voss, Hank D., "Engineers, Entrepreneurs and Innovation at a Liberal Arts University," *2014 Annual ASEE Conference Proceedings*, in press, 2014.
[3] Voss, Hank D. and Dailey, Jeff, "Express Launch: A New Capability for NearSpace," *Proceedings of the 4th Academic High Altitude Conference*, Taylor University, June 26-28, 2013.
[4] Melendez, Jordon A. and Smith, Caleb J., "Comic Ray Measurement and Analysis," *Proceedings of the 4th Academic High Altitude Conference*, Taylor University, June 26-28, 2013.
[5] Graves, Raquel I. and Yoshino, Kate A., "High Altitude Research Platform (HARP) All Sky Camera," *Proceedings of the 4th Academic High Altitude Conference*, Taylor University, June 26-28, 2013.
[6] Emison, Joseph T. and Straits, Stephen E., "HARP Visible and Ultraviolet Intensity Profile and Blackbody Spectrum with 2nm Spectra," *Proceedings of the 4th Academic High Altitude Conference*, Taylor University, June 26-28, 2013.
[7] Dailey, Jeffrey F., "Over-The-Horizon Global High Altitude Balloon Communications System," *Proceedings of the 4th Academic High Altitude Conference*, Taylor University, June 26-28, 2013.
[8] Dailey, Jeffrey F., "Taylor University High-Altitude Research Platform as a Research Tool," *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[9] Ramm, Natalie A. and Voss, Hank D., "High-Altitude Balloon Atmospheric Database" *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[10] Ramm, Natalie F., Solyst, Bill G., Fisher, Ben C., Dodge, Reid C., Pollina, Anthony J., and Kuehl, Paul G., "Micro Gravity Balloon Drop: Tether Release," *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[11] Takehara, Donald, Dailey, Jeffrey, Gavin, Susan, Snyder, Steven, and Smith, Bethany, "High Altitude Ballooning in High School Science Classes," *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[12] Takehara, Donald, Medows, Pamela, Gavin, Susan, Dailey, Jeffrey, Snyder, Steven, Smith, Bethany, and Tomasik, Rachel, "High Altitude Ballooning into Undergraduate STEM Curriculum: Preparing for Widespread Implementation." *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[13] Voss, Hank D. and Dailey, Jeff, "High-Altitude Balloon Curriculum and Hands-On Sensors for Effective Student Learning in Astronomy and STEM," *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[14] Voss, Hank D., Ramm, Natalie A., and Dailey, Jeff, "Understanding High-Altitude Balloon Flight Fundamentals," *Proceedings of the 3rd Academic High Altitude Conference*, 2012.
[15] Dailey, Jeffrey F., "Extended flight time of latex balloons through the use of a buoyancy control system," *Proceedings of the 2nd Academic High Altitude Conference*, 2011.
[16] Takehara, Donald, Snyder, Steven, Booth, Travis, Romines, Elise, Smith, Bethany, and Tomasik, Rachel, "Developing High Altitude Balloon Curriculum for Undergraduate Courses – NSF Grant Impact and Example in General Education Chemistry," *Proceedings of the 2nd Academic High Altitude Conference*, 2011.
[17] Dailey, Jeff, and Hank Voss, EyePod-3: An all-in-one Global Data & Tracking Module, 5th Annual Academic High Altitude Conference (AHAC), this proceeding