

# Eclipse-Ballooning 2017: The U of MN – Twin Cities Experience

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**The stratospheric ballooning team at the U of MN – Twin Cities started working on eclipse-ballooning in the fall of 2013, even before the Montana Space Grant announced their plan to organize a national Eclipse Ballooning Project. Our team promptly signed up to assist their effort, and have been heavily involved ever since. This presentation will discuss our eclipse-ballooning efforts and progress over the past 4 years. Our experiences include experimenting with a GoPro-based video-telemetry system (which ultimately was not as successful as Montana's Raspberry-Pi-based system), adopting (then helping test, modify, and teach other teams to learn to use) the Montana telemetry system, practicing with up-**

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**range and down-range ground station placement, developing and testing passive anti-rotation devices and active camera-pointing devices to improve video quality, landing two eclipse-telemetry systems in Minnesota lakes one week before the eclipse (ouch!), flying five balloon stacks during the eclipse from near Grand Island, NE, and organizing/hosting AHAC 2017. We will also discuss ways in which we have already begun to use the telemetry equipment for non-eclipse balloon missions. The eclipse project has greatly expanded our HAB network and ballooning capabilities in multiple different directions, and will continue to strongly influence our stratospheric ballooning program for years to come.**

## **I. Introduction**

**T**HE Minnesota Space Grant Consortium (MnSGC) has sponsored an active stratospheric ballooning team at the University of Minnesota – Twin Cities (UMTC) since 2007 with over 100 launches, most involving more than one balloon, as of fall 2017. This team, advised by MnSGC Associate Director James Flaten, has engaged well over 100 U of MN students in ballooning freshman seminars, extracurricular projects, and summer-time internships, and has also offered “Learn to do stratospheric ballooning” workshops that have helped start eight ballooning teams (so far) at other institutions around Minnesota.

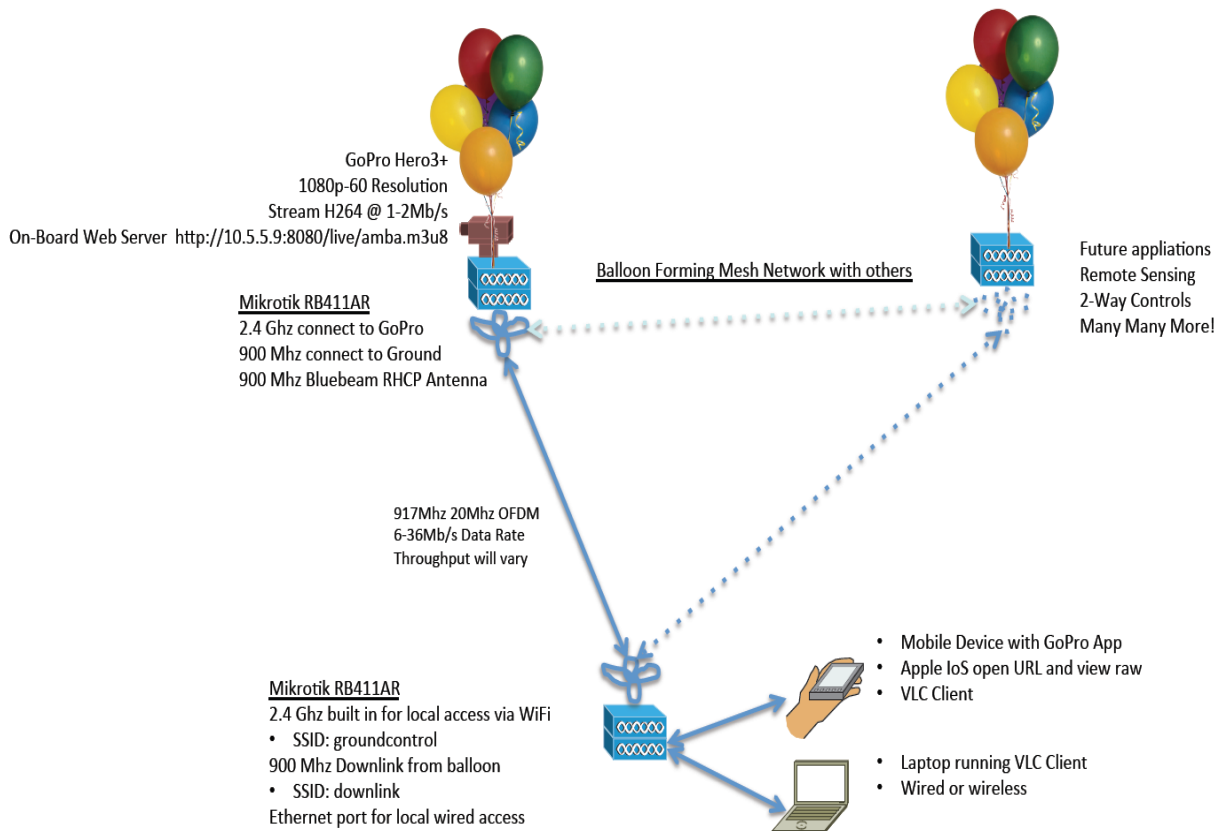
Eclipse-ballooning has been a focus for the UMTC stratospheric ballooning team since the fall of 2013, with activities culminating in the launching of five balloons into the path of totality near Grand Island, Nebraska, on August 21, 2017, followed by hosting the post-eclipse Academic High-Altitude (Ballooning) Conference (AHAC 2017) on October 27-28, 2017. This article describes, in mostly-chronological order, eclipse-related ballooning activities at the UMTC over the past 4 years.

## **II. Early Developments**

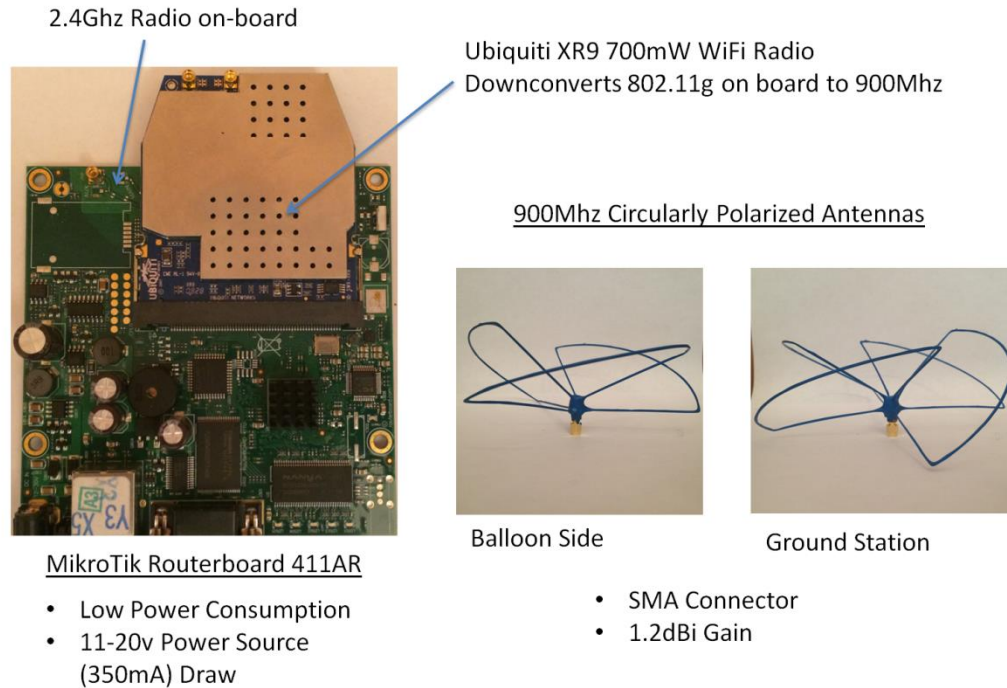
The total solar eclipse of August 2017 was mentioned during the National Space Grant Directors Meeting in Charleston, SC, in October of 2013 as an event around which Space Grants might want to plan activities. Coincidentally, that same fall the Louisiana Space Grant newsletter mentioned a SKY & TELESCOPE article about a project that involved one of their alumni to observe a solar eclipse from a stratospheric balloon flying over Australia [1]. By November 2013 the ballooning team at the UMTC was already corresponding with the ballooning

team at Louisiana State University (LSU) in Baton Rouge about organizing a nationwide weather-ballooning campaign to observe the eclipse. Independently, balloonists from the Montana Space Grant and the Colorado Space Grant started talking about a similar idea – only with even bigger goals. They announced their ideas for a national “Space Grant Eclipse Ballooning Project” (see <http://eclipse.montana.edu>) at the Spring 2014 National Space Grant Directors Meeting in Washington D.C., both the UMTC and the LSU teams signed on as “early adopters” (AKA “leadership” teams), and “the rest is history!”

Once video-telemetry was selected as a central emphasis of the Eclipse Ballooning Project, leadership teams from Montana, Louisiana, Minnesota, and Iowa began to work in parallel on low-cost video-telemetry hardware solutions with adequate range to meet this challenge. The UMTC team worked with ham radio operator Chandler Heath (NOTOR) to build and test a Heath design in which video from a GoPro Hero3+ camera was sent to a Mikrotik Routerboard 411AR by wifi, then to the ground using a Ubiquiti XR9 “XtremeRange” 900 MHz radio module and circularly polarized “BlueBeam” omni-directional antennas usually used for FPV (first-person view) radio-control flying applications. Figure 1 shows the overall system and Figure 2 shows some hardware details.



**Fig. 1 Design for streaming data and video over 900 MHz wifi link by Chandler Heath, August 2014.**



**Fig. 2 Some hardware used in the Heath design for streaming data and video from balloons.**

Unfortunately, despite many ground tests and two high-altitude balloon flights, this video telemetry system never lived up to its potential. Late in the summer of 2015 testing of the Heath system was halted in favor of the Montana Raspberry-Pi-based design which was farther along in development. Now that the eclipse is behind us, we may return to working on the Heath design because it has a lot of nice features, at least on paper.

### **III. Working with the Montana Space Grant (and Other Eclipse Teams)**

As a “leadership” team for the Eclipse Ballooning Project, the UMTC team sent representatives to Fort Sumner, New Mexico, in late August 2015 to help LSU and MSU prepare test eclipse equipment to fly on the HASP 2015 flight and to see the Montana video-telemetry flight and ground station hardware in person. Following this trip the UMTC team sent representatives to Bozeman, Montana, on three separate occasions to work with the ballooning team at Montana State University. The first trip to Bozeman, in January of 2016, was to practice assembling the Montana ground and flight hardware, in preparation for additional in-Minnesota testing and for the two summer 2016 training workshops. The UMTC then sent representatives to both the May 2016 and the much-larger July 2016 training workshops in Bozeman and helped with instruction and handling questions. In addition to these in-person training activities, the UMTC team also participated in regular “leadership” team telecons and “all-team” telecons

and also helped field technical questions on the phone calls and on ProBoards. In May of 2017 members of the UMTC team joined the MSU team for one final in-person pre-eclipse event – a demonstration balloon flight for the FAA (and others) at the Raven Industries facility in Sioux Falls, South Dakota.

#### **IV. Classes, Testing, and Results in Minnesota**

Payload development and testing for eclipse ballooning took place in Minnesota over the course of four summers and also was incorporated into two different freshman seminars at the UMTC. Eclipse-related payload development during the summer of 2014 and the summer of 2015 centered around building and testing the Heath video-telemetry system as well as continued work on a venting system, in hopes that we might have a robust capability to “float” balloons during the eclipse and not be so pressed to get the launch and ascent timing right. We learned a lot during both these summers but ultimately most of the hardware under development was superceded by eclipse time.

The pre-workshop build in Bozeman in January 2016 was particularly timely because Professor Flaten offered a freshman seminar at the UMTC during the spring of 2016 on the topic “Eclipse Ballooning.” In that 11-person class students with no prior knowledge of ballooning furthered development of a “multi-cut” payload for use to sever multiple lines on command in flight (a capability useful for eclipse-ballooning missions and beyond) and also built and test-flew a second Montana-style video-telemetry stack. (We ultimately purchased a third system and deployed all three during the actual eclipse.) Challenges that arose during that class, including attempting a class launch in the rain which waterlogged the payloads and wreaked havoc with our lift calculations, steered further summer development work and prepared students to be even more effective instructors during the summer 2016 training workshops in Bozeman.

Besides helping with training workshops, the summer of 2016 included multiple test flights in which the team became much better at operating the flight and ground telemetry equipment and also made preliminary strides towards turning the still-photo telemetry payload into a communications relay (Ref. [2]). That allowed our ground stations to receive direct gps transmissions every 3 seconds, which improved pointing accuracy. The team also developed techniques for operating ground stations “down-range” (i.e. close to the burst location) rather than “up-range” (i.e. at the launch site), which made telemetry distances smaller and more predictable – another big improvement. Details about these hardware/software modifications were shared with other ballooning teams.

During the spring of 2017 Professor Flaten offered a “CubeSat Ballooning” freshman seminar in which eclipse telemetry equipment was repackaged into a 2U CubeSat form factor (hard!) and ground station equipment was used

to communicate with CubeSat-shaped payloads deployed (in tethered mode) at altitude (also hard!). That project was our first attempt to use eclipse-ballooning hardware for other types of ballooning missions, an on-going interest.

Summer 2017 saw many new team members and multiple practice flights of video-telemetry stacks. One thrust of the summer was to get comfortable inflating, tending, then launching more and more balloons at one time. During that summer we did three-balloon launches, one four-balloon launch, and then five balloons on eclipse day (see Fig. 3). In preparation for possibly needing to deal with balloons in windy launch conditions, we developed a balloon “corral” (see Fig. 3), though we did not end up using it on eclipse day. We finalized a passive anti-rotation device design and integrated it with the OCCAMS cut-down system from MSU (Ref. [3]). The team also continued work on testing/improving the active-pointing “CHAD” device, first announced at AHAC 2016 (Ref. [4]). We started flying non-telemetry multi-camera payloads plus 360° virtual reality (VR) cameras such as a Garmin VIRB camera. The Garmin is hard to keep running for an entire balloon flight, but the resulting stabilized footage is stunning!

The last test flight exactly one week before the eclipse – four balloons, including all three of our video-telemetry units – was a near-disaster. Flight predictions let us down and two of the four stacks landed in lakes (see Fig. 3). Although the payloads floated, most of the contents including many lithium battery packs, two Iridium modems, two still photo systems, and two video-telemetry systems, got at least somewhat wet. Bags of rice and warm ovens (and warm window sills) were used to dry things out, extra batteries were purchased, and all available spare components were brought into play. One Iridium modem could not be salvaged, but MSU graciously provided a spare, and we were able to acquire enough additional lithium battery packs on short notice that we did not have to try reusing the ones that got wet. By eclipse day all three stacks were functioning again, at least on the ground. Whew!

Additional details about these and additional eclipse-related balloon payload development projects are posted at <http://www.aem.umn.edu/people/faculty/flaten/EclipseBallooningWebsite/>.

## **V. The Eclipse “Expedition”**

On August 19, 2017, Professor Flaten and 16 ballooning team members plus one ballooning team alumnus traveled to Grand Island, Nebraska, to prepare to fly stratospheric balloon missions during totality. We were met there by two other ballooning team alumni, four other helpers, plus two other Minnesota-based ballooning teams from St. Catherine University and U of MN – Morris with whom we collaborated throughout the eclipse project, though they were not involved in the video-telemetry project.



**Fig. 3 Testing images (left to right then top to bottom): (a) manual pointing of a video-telemetry antenna, (b) a balloon-tether “corral”, (c) a video-telemetry system attached to an active-pointing CHAD device, (d) a down-range ground station, and (e) setting out on a lake-recovery one week before the eclipse.**

On eclipse day ground stations were set up (and staffed by students) at the Stuhr Museum of the Pioneer Pioneer in Grand Island and at The Leadership Center (where the team was staying) in Aurora, about 20 miles farther east. Five balloons, three with video-telemetry stacks, were inflated and launched between 90 and 60 minutes prior to totality from Kenesaw (to the southwest) so as to be visible from both Grand Island and Aurora and ascending between 60,000 and 90,000 feet when totality arrived at 1 p.m. local time (see Fig. 4). Winds were light and cloud cover was intermittent right up to totality but, in fact, all team members on the ground did ultimately get a clear view of totality, albeit from about a half-dozen locations scattered around the Grand Island/Aurora area. Kenesaw was near the edge of the path of totality, so the launch crew did not stay there once the balloons were in flight.



**Fig. 4 Images from eclipse trip (left to right then top to bottom): (a) passive anti-rotation device, (b) line of balloons, ready to release, (c) view of receding eclipse shadow from 66,000 feet above Grand Island, Nebraska, and (d) UMTC team (most of it) at Strategic Air Command (SAC) museum on return trip to MN.**

The balloon inflations, tethers, then timed launches went very smoothly, especially considering the fact that our team had never tried a five-balloon launch and about half the people at the launch site were not actually on the summer 2017 ballooning team (though most did have past experience with ballooning). One balloon – the very last one to be launched – looked distorted even during inflation and ultimately popped early at 49,000 feet, about 15 minutes before totality. Prior to burst that balloon had a good video feed to the ground station in Grand Island.

The other two video-telemetry balloon stacks were monitored by two ground stations in Aurora. Both balloons had good video feeds to the ground and were at 66,000 and 92,000 feet respectively when totality arrived. Unfortunately the internet provider in Aurora was unable to deliver adequate bandwidth to stream the video to the



internet during totality, so we collected great on-board footage but were unable to consistently share it live on-line. See video clips at [http://www.aem.umn.edu/people/faculty/flaten/EclipseBallooningWebsite/eclipse\\_trip.html](http://www.aem.umn.edu/people/faculty/flaten/EclipseBallooningWebsite/eclipse_trip.html).

The other two stacks carried virtual reality (VR) cameras and multi-camera payload boxes. One stack was at 60,000 feet when totality arrived and recorded exceptional 360° video of the whole event. The final stack was at 89,000 feet during totality but its VR camera became detached during post-burst chaos, so that footage was lost. That final stack also happened to land on a power line so it was not recovered until several days later, by a power company. The science payloads onboard did fine (Ref. [5]), as did the tracking payloads. The other four payload stacks all landed in corn or soybean fields and were recovered, undamaged, without incident later the same day.

The UMTC team returned to Minnesota the day after the eclipse, stopping to visit the Strategic Air Command (SAC) Museum between Lincoln and Omaha (see Fig. 4) and thus coincidentally avoiding the traffic jams that plagued people who tried to leave central Nebraska immediately after the eclipse was over.

## **VI. Post-Eclipse Activities**

Since the eclipse, the UMTC ballooning team has been processing video and science data and putting things on display, including spending August 24, 2017, just 3 days after the eclipse, at the Minnesota State Fair. In late September 2017 the team put hardware on display at a section meeting of the American Society of Engineering Educators (ASEE). Professor Flaten has been invited to give talks about eclipse ballooning to the MN Science Teachers Association (MnSTA) Conference on Science Education (MnCOSE) and to the MN Astronomical Society. The UMTC is also hosting the annual Academic High-Altitude Conference – AHAC 2017 – on Oct. 27 and 28, 2017, and team members are presenting results on several of the projects mentioned above (Ref. [2-5]).

## **VII. Conclusions**

The Eclipse Ballooning Project has had a profound and lasting impact on the UMTC ballooning team. This project greatly expanded our ballooning contacts and capabilities in multiple ways, not just video-telemetry. We have already made use of communications-relay capabilities for balloon flights in three classes unrelated to eclipse ballooning. We are pleased with our new passive anti-rotation/cut-down device and expect to keep working on active pointing devices for cameras on balloon flights, as well as expanding our use of 360° VR cameras. Eclipse ballooning was a lot of work, and used a lot of resources, we benefited greatly by actively participating and are looking forward to whatever nationwide ballooning activities might come next (before the 2024 eclipse!).

## Funding Sources

Our eclipse ballooning activities were funded by the MnSGC and by the U of MN's College of Science and Engineering (CSE) Dean's office. We received, and appreciated, material (and logistical) support from the Montana Space Grant, provided in part with funding from their sponsors.

## Acknowledgments

We appreciate the support of the MnSGC and the AEM Department at the U of MN – Twin Cities, many additional ballooning students over the past 4 years not listed as authors on this paper, and Chandler Heath for his innovative GoPro video telemetry system design (which we still hope to get working some day). We are also thankful for support from the other “leadership” teams, sponsored by the Louisiana and Colorado Space Grants, and also for the hospitality shown us during our eclipse trip to Nebraska by staff at The Leadership Center and the Edgerton Explorit Center in Aurora, the Stuhr Museum of the Prairie Pioneer in Grand Island, and the Kenesaw Public School in Kenesaw. And special thanks to the landowners in whose fields our payloads landed.

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