Annual Progress Report Template-Year 3

NASA Science Mission Directorate Science Activation Program

Cooperative Agreement

Annual Progress Report - 2018

NASA Science Mission Directorate Science Education

Cooperative Agreement Notice (CAN)

Solicitation: NNH15ZDA004C

I. Administrative

- **Name and address of the recipient's institution & Cooperative Agreement Number**: Wayne RESA -- Cooperative Agreement Number: NNX16AB95A
- **II. Name of the Principal Investigator**: David Bydlowski
- **III. Cooperative Agreement Title**: *AEROKATS and ROVER Education Network (AREN)*
- **IV. Type of Report**: Annual
- **V. Period covered by the report**: January, 2018 - December, 2018

II. Accomplishments/Metrics of Success

In AREN, we….. Strive to understand our changing Earth in order to make informed decisions. NASA helps us do that globally; AREN helps us do that locally.

In AREN, we….. Follow protocols and procedures that help answer a science mission question, including collecting baseline data

In AREN we...

- Plan and prepare for a launch
- Launch kites
- Attach payloads
- Collect data
- Conduct post-mission debrief
- Analyze and share our data

The AEROKATS and ROVER Education Network (AREN) introduces NASA technologies and practices in authentic, experiential learning environments. Low-cost instrumented systems for in-situ and remotely sensed Earth observations include kite-based “AEROKATS”, and remotely controlled aquatic and land-based “ROVERS”.

AREN technologies and lesson development are NGSS aligned and provide necessary science literacy skills. Data capture and visualization tools, designed to integrate with the GLOBE Program, enable the expansion of GLOBE study sites with transects and vertical profiles. Engineering Design concepts are embedded in student development of platform and instrument systems. Training, safety practices, and STEM challenges are a focus of the AREN Team, concurrently advancing student research projects investigating Earth science related phenomena.

The Goal of AEROKATS and ROVER Education Network (AREN) is to train the next generation of scientists, engineers, and other professionals to observe and understand our planet Earth through experiential learning using NASA technology and data in real-world settings.

Towards this goal, the five-year AREN objectives are to:

1. Apply NASA remote sensing and in-situ observation concepts, technology, and data in formal and informal learning settings for all ages and socioeconomic backgrounds.
2. Apply NASA operations, NASA AEROKATS and ROVER technologies, and Earth Science concepts into a wide range of formal and informal STEM learning for educators, students and citizen scientists.
3. Affordably implement AREN approaches, learning plans, and specific tools into the GLOBE Program.

4. Increase participation in the GLOBE Program through involvement in the AREN Project and new AREN measurement protocols.
5. Make affordably licensed AEROKATS and ROVER technologies and learning materials to the public through a distribution network.

The AREN objectives are consistent with those of the NASA Science Mission Directorate (SMD).

The four-fold Objectives of the NASA SMD Science Education (SE) Award are:

1. Enable STEM Education (evaluated through the AREN Project),
2. Improve U.S. Scientific Literacy,
3. Advance National Education Goals, and
4. Leverage Efforts Through Partnerships (evaluated through the AREN Project).

Program Reach 2018

Status of Project - Defined Metrics for SMD's Top Level Goals

Goal 1 -- Enabling STEM Education

Project Outcome: Increased the number of STEM experiences to 6000 through 2018 with the project goal of over 10,000 by 2020. There were approximately 100 learners in 2016, 4000 in 2017 and 2000 in 2018 to total the 6000 through 2018.

Over 2000 Learners participated in the AREN Project at various levels of instruction and participation in 2018.

- Wayne RESA -- 1260 Students and 200 Adult Learners
- University of Maryland Eastern Shore -- 15 Undergraduate Learners ENGE 150
- Goddard Space Flight Center -- 60 Adult Learners
- Chesapeake Bay Environmental Center -- Over 120 Student and Adult Learners
- Montana State University -- 110 Adult Learners and approximately 200 Student Learners
- University of South Florida -- 200 Undergraduate and 6th Grade Learners

Goal 4 -- Leverage Through Partnerships

Project Outcome: Partner with three organizations by 2020.

By the end 2017, the AREN Project had anticipated developing 20 partnerships by the end of 2020. During meetings with NASA Headquarters, the definition of a partnership started becoming more clearly defined. As partnerships became more clearly defined the AREN Project now anticipates developing three partnerships by 2020. At this time, work on partnerships is taking place with Earth Force, MI STEM, BSCS (FieldScope), American Kitefliers Association and the National Park Service.

Contributions from Co-Investigator Institutions

The following pages provide a summary of the contributions of the Co-Investigator team members and their Institutions:

- Anasphere, Inc. - John Bognar
- Chesapeake Bay Environmental Center - Vicki Paulas, Alissa Quinton, and Judy Wink
- Goddard Space Flight Center -- Geoff Bland, Brian Campbell, Patrick Coronado, Ted Miles, Kay Rufty, Sallie Smith
- Montana State University -- Kelly Boyce, Jamie Cornish, Kim Obbink, Suzi Taylor
- Public Lab -- Margie Cohen, Shannon Dosemagen, Jeffrey Warren
- University of Maryland Eastern Shore -- Willie Brown, Christopher Hartman, Xavier Henry, Abhijit Nagchaudhuri
- University of South Florida -- Jonathan Gaines
- Washington College -- Jemima Clark, Doug Levin
- Wayne RESA -- David Bydlowski, Andy Henry

Overview of 2018 Accomplishments:

Team Training and Capacity Building

- Weekly Team Meeting Phone Conferences -- Each Wednesday from 3:30 pm to 5:30 pm (ET)
- AREN Team meeting in conjunction with the GLOBE Northwest Regional Student Research Symposium at Montana State University in Bozeman, MT; May 31 - June 4, 2018
- Ongoing Field Practice Sessions

Anasphere, Inc.

- New license-free AM-band transmitter for the AnaSonde
- Beginning assistance with the development of ThermoPod - the infrared Aeropod
- Collaborative meeting with Dr. Tony Berthelote fro Salish-Kootenai College, tribal college in Ronan, MT

Chesapeake Bay Environmental Center

- Citizen Science Workshops

- Collaboration with Hawk Mountain Sanctuary (Scranton, PA) -- atmospheric profiling/bird migration
- AREN at Colina Azul in Costa Rica

Goddard Space Flight Center

- Monocam, MiniPod, Profiler and VideoPod prototypes and production
- Evaluation of 3D printers, instrumentation, and sensors
- Tri-folds and FlipBooks for MonoPod, Profiler, Aeropods, MiniPods and ROVERs
- Development of Mini-Kites for indoor use and simple Barometers for weather exploration
- ROVER development and testing of X-5, X-7 and X-8
- Multiple student workshops
- Collaboration with Tennessee State University
- Collaboration with Southwest Community College
- Partnership exploration with the National Park Service
- Development and Design of the GLOBE/AREN Engineering Design Challenge

Montana State University

- Hosted AREN Team Meeting May 31 - June 5
- Judged the GLOBE Northwest Student Research Symposium
- Collaboration with BOREALIS (Balloon Outreach, Research, Exploration, and Landscape Imaging System) of the Montana Space Grant Consortium
- Collaboration with Chief Dull Knife College
- Family Science Day
- Multiple AREN Presentations

Public Lab

- Development of materials packs for those requesting AREN supplies
- Multispectral platforms expanded with Raspberry Pi
- Development of a dual-camera system and low-cost webcam system
- Infragram and Image Sequencer software architectural work

University of Maryland Eastern Shore

- Course ENGE 150 - Modern Engineering Design -- Integration of AREN

- Wind Tunnel Design, Development, and Testing -- wind-tunnel design for system modeling -- Integration of Project Based Learning

University of South Florida

- Bulls-EYE Robotics Outreach Program for rising 6th graders -- Tera development (ROVER Ground Vehicles)
- Foundations of Engineering Lab for first-year undergraduate students -- Semester long engineering design projects
- Participants planned their design, acted upon the plan, fabricating the actual hardware, and then evaluated the effectiveness of their actions. The work culminated with fully functional prototypes and field testing.

Washington College

- Buoy system launched
- AquaRover development
- Integration of AREN with the Standards of Learning
- Kite systems developed for distribution
- Field testing of GLOBE resources
- International AREN presentations

Wayne RESA

- Hosted the GLOBE Midwest Regional Student Research Symposium at Wayne State University School of Medicine in Detroit, MI
- Named local host for the GLOBE Annual Meeting in July, 2019
- Presentations at the 2018 GLOBE GLE in Ireland
- Hosted a visit to local Metro Detroit schools for Tony Murphy
- Development and Design of the GLOBE/AREN Engineering Design Challenge
- Partnership with multiple GLOBE Student Research Projects
- Multiple AREN presentations at National, State and local conferences
- AREN workshops for over 1000 students in Metropolitan Detroit
- Collaboration with Mission Earth at the GLOBE Mission Earth PD Institute
- Partnership discussions with Earth Force, BSCS (FieldScope) and MI STEM
- Series of Podcasts developed on the Maker Movement
- Ongoing design and production and distribution of Aeropod and ROVER technologies
- Development of data collection and online visualization tools

AREN Management Team

The AREN management team is composed of Geoff Bland, David Bydlowski and Andy Henry. The team's primary purpose is to make decisions that guide the project's operations. The management team meets regularly and coordinates weekly teleconferences with the co-investigators and their team members. Members of the management team participated in:

- Monthly Phone conferences with NASA Headquarters
- Attendance at NASA annual meeting
- Coordination of Cross-Collaboration with other NASA CAN Awardees
- Writing of annual report and other required documentation
- Weekly team telecons
- Coordination of the full AREN team meeting at Montana State University
- Review of the AREN Project timeline
- Other issues impacting the AREN Project
- Purchasing and distribution of supplies and materials to partners and schools
- Coordination and development of training and curricular materials

Anasphere, Inc.
Accomplishments

A major hardware accomplishment was the demonstration of a new license-free AM-band transmitter for the AnaSonde, which will enable students to do low-altitude meteorological soundings, make temperature and humidity measurements in classrooms, and to do these activities while demonstrating principles of radio telemetry and Morse Code.

A second major hardware accomplishment was beginning to assist with the development of ThermoPod, which is the the imaging infrared Aeropod. Anasphere is working on overall hardware integration, software development, and alternative power supplies.

A major collaborative development was an initial meeting with a faculty member, Dr. Tony Berthelote, from Salish-Kootenai College, a 4-year tribal college in Ronan, MT. During this meeting, we identified areas of overlap between AREN activities and SKC degree and certificate programs, with aerial imaging and its integration with ARC-GIS being particularly relevant. An initial field study plan – one already underway at SKC related to identifying previously unknown burial sites on tribal land – was identified as a prime starting point for introducing AREN hardware to the college.

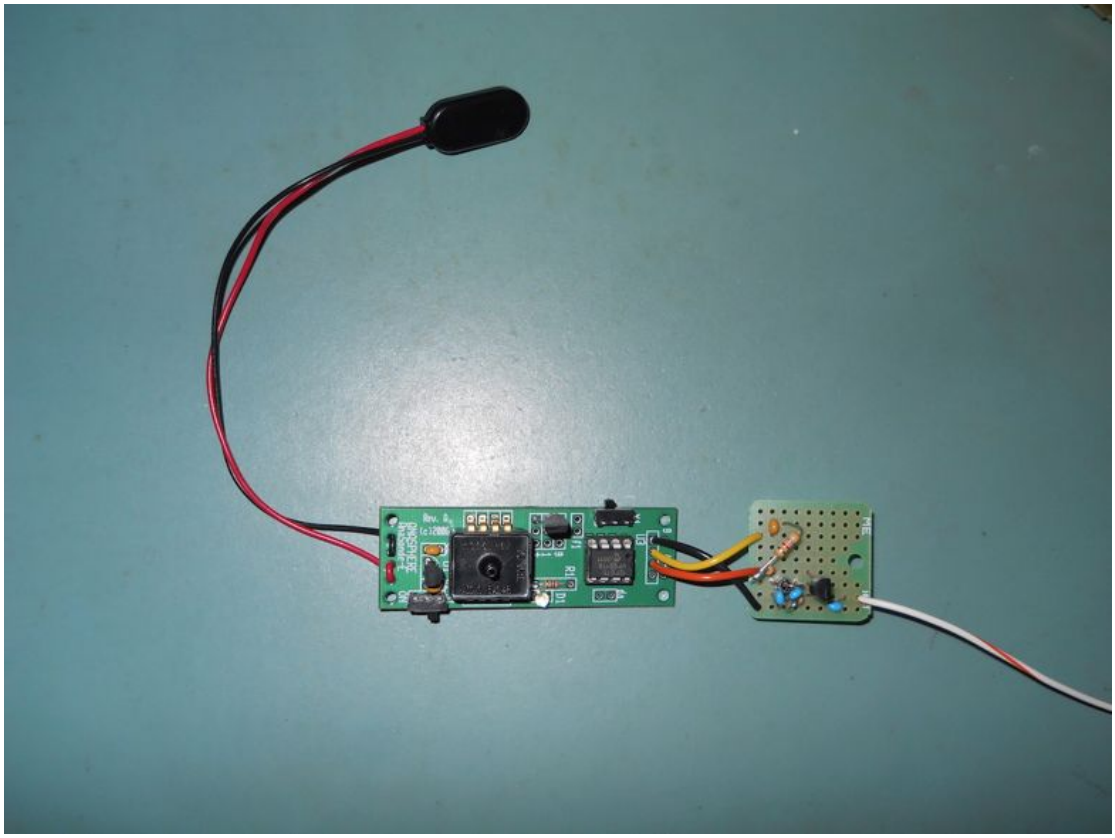


Figure 1. AnaSonde-E radiosonde (left) attached to new license-free AM-band transmitter (right).

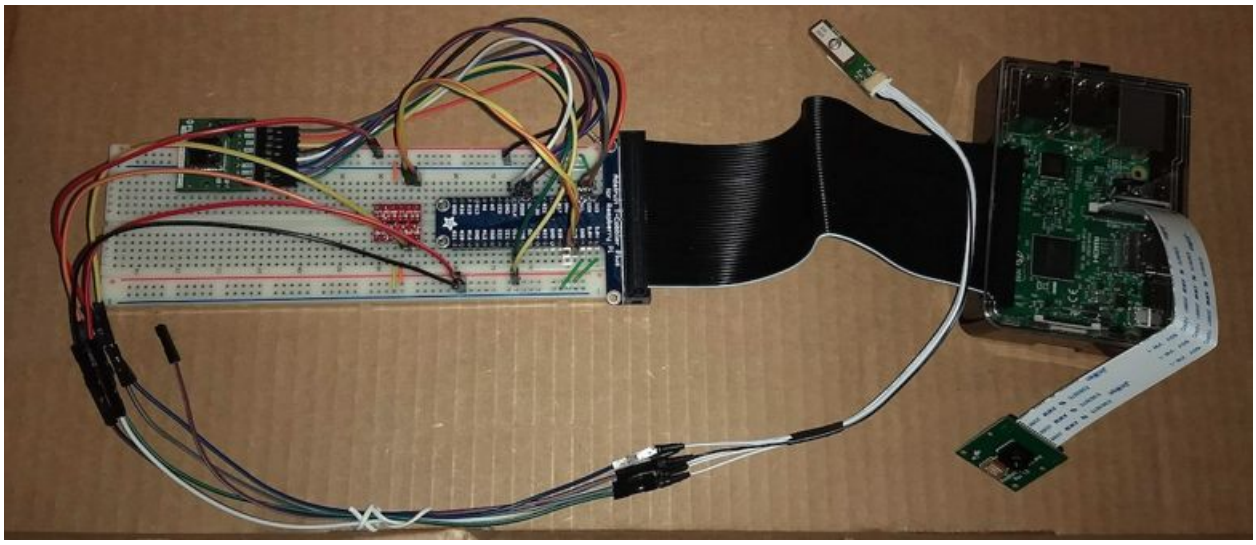


Figure 2. ThermoPod hardware as being used for system development at Anasphere.

Present Status

ThermoPod work is on track to conclude over the next month, culminating in a flight demonstration of the hardware. This hardware will be housed in a proof-of-concept housing fabricated by Anasphere.

Collaborative work with SKC will resume as their quarter begins late in September; once the student working on the burial site survey project is back up to speed on the project, we will work with Dr. Berthelote and the student to teach them how to apply AREN hardware (MonoCam and possibly ThermoPod) in support of their activities.

Any Changes That Took Place

The Anasphere work plan was amended partway through the year to make better use of Anasphere's capabilities in hardware development and connections with Montana educational institutions. The major hardware shifts were to reduce emphasis on Anasphere's development of a new Profiler, since there is no major cost advantage to be gained with that, and in turn increase emphasis on Anasphere's participation in the development of ThermoPod, which brings a new capability to the AREN project. Anasphere also took a lead role in developing a connection between AREN and Salish-Kootenai College.

Issues -- None at this time.

Dissemination Activities -- None at this time; they are outside of our scope of work.

Challenges -- None at this time.

Collaborations -- As noted above, Anasphere is working to establish a connection between AREN and Salish-Kootenai College.

Future Plans -- Anasphere will be further developing and refining ThermoPod hardware and software. Anasphere will also arrange supporting visits to SKC to support their adoption of AREN hardware and procedures.

Chesapeake Bay Environmental Center

Chesapeake Bay Environmental Center's (CBEC) mission is sustainability through education, restoration and research, and the AREN project parallels the mission in education and research. CBEC services approximately 8000 students in K-12 annually in providing environmental educational opportunities in the field to supplement their "in class curriculum." The AREN project is a welcome "hands-on" opportunity for students to experience atmospheric and water monitoring activities.

Although CBEC has presented the AREN project the past three years to school students engaged in atmospheric and water monitoring activities CBEC is now expanding the program into local research projects and data collecting for GLOBE. During the early months of 2018 CBEC hosted several Citizen-Scientist Workshops for adults interested in collecting local weather and water monitoring data for submission to GLOBE. CBEC is also collaborating with Hawk Mountain Sanctuary (Kempton, PA) with atmospheric monitoring as it correlates with bird migration. Also, a partnership with a school in Costa Rica, Colina Azul, is established with an introduction to the AREN curriculum.

Hawk Mountain Sanctuary monitors atmospheric components on a daily basis throughout the migratory season for birds of prey. In working with the education staff CBEC will demonstrate the importance of the use of kites/monopods/profiler to collect data for correlation regarding the volume of bird passage over a lookout/counting point on Kittatinny Ridge. The Hawk Mountain education staff will also extend the AREN project (particularly the use of the AEROKATS) to school students who visit Hawk Mountain to learn about the migration of birds.

Colina Azul is a private school in Atenas, Costa Rica encompassing grades 1-6. The partnership with CBEC will cross all grades with the younger students learning about clouds and reporting the data to the GLOBE website. The older students will engage in water monitoring (ROVER) and atmospheric monitoring (AEROKATS) for data collection which will be reported to the Globe database. A curriculum for clouds, water and atmospheric monitoring was developed during 2018.

Both the Hawk Mountain and Colina Azul projects will be ongoing in 2019 with additional expansion of the curriculum and outreach.

Presently, CBEC is contacting head teachers in the database of all schools that have participated in the educational programs in general at CBEC and introducing the AREN project as an additional option for class field activities. A flyer has been produced to advertise the offering and posted on CBEC's website and FB pages. The biggest issue that CBEC faces in promoting AREN is to entice the teachers that bring their students to CBEC for environmental education classes is to "try something new", such as, the AEROKAT or ROVER activities. It seems that the teachers who have used CBEC's site/curriculum in the past are satisfied with the programs/activities they have done in the past and are in a "comfortable rut" with their selection of topics. Also, due to space, equipment and personnel with each group of students engaging in

the AEROKAT curriculum…only small classes may be accommodated.

CBEC is making an effort to promote the AREN project at the local community colleges and with civic organizations to involve more people in data collection for recording on the GLOBE site.

Embedded is a list of activities CBEC has executed/administered since November 2017.
2017-2018

November 2017

- Tested all kites (8 different types) and related equipment.
- Conducted three missions each with kites and rovers.
- Outlined a plan for a school group visit (2 hrs. AEROKATS)
- Set Up Internship Program

December

- Conducted 1 AEROKAT and 1 ROVER mission with 8 STEM Students from Chesapeake College; 12 participants
- Started planning for Citizen-Science Workshops; prepared an outline for the workshop.
- 2 missions AEROKATS

January 2018

- Planned specific details for Citizen-Science Workshops in February and March.
- Continued work on curriculum for high school on both ROVERS & AEROKATS
- Set Up Scope of Work for Marsh Research year-round.

February

- 2 Citizen-Scientist Workshops; total for both workshops 21 participants.
- Prepared Cloud Curriculum for Colina Azul in CR; elementary school level
- Established a partnership w/Colina Azul in CR for AEROKAT program
- Assisted Colina Azul in registering/sending data to GLOBE

March

- Conducted 1 Citizen-Scientist Workshop; 10 participants
- Conducted 1 Teacher Workshop w/AEROKATS; 12 participants

April

- Started outline/syllabus for community college; Chesapeake College
- Tested 5 new kites and monopods
- 3 AEROKAT Missions
- 1 Homeschool Group w/AEROKAT activities; 18 participants

May

- 3 missions each AEROKATS & ROVERS
- 1 school group; Providence School; 18 participants, ROVER activities
- 1 school group; Homeschool Queen Anne's County; 15 participants, AEROKATS
- 1 meeting w/Colina Azul Principal to plan for teacher workshop in November 2018

June

- Attended NASA AEROKAT training in Montana
- 3 AEROKAT missions
- Inventoried equipment
- 1 school group; Homeschool Queen Anne's County- 15 participants; ROVER activities
- Planned 1 day of 4 day workshop w/Colina Azul teachers.
- 1 meeting w/Hawk Mt. Sanctuary Education Director for workshop plans in November 2018.

July

- 3 AEROKAT missions
- 1 ROVER mission; equipment failure

August

- Continued drafting syllabus for course @ Chesapeake College (ongoing)
- 3 AEROKAT missions
- 2 GLOBE modules (refresher)
- Outline for Hawk Mt. Sanctuary workshop
- Contacted county schools regarding availability of classes: AEROKATS

September

- Finalized plan/agenda for Hawk Mt. Sanctuary workshop
- 1 meeting w/Colina Azul Principal for details on trip/workshop in Atenas, CR.
- 3 AEROKAT missions; photographing marsh

October

- Working on curriculum development for middle school students; AEROKATS
- Working on syllabus for course; Chesapeake College (~80% completed)
- Developed a PowerPoint for CBEC board regarding AREN

November (projected)

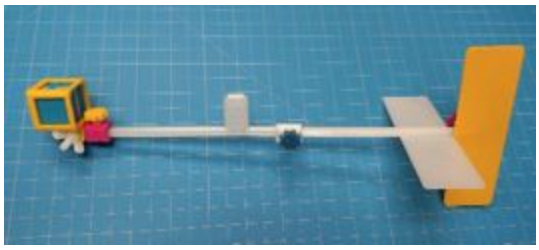
- Hawk Mt. Sanctuary Workshop- AEROKATS
- Colina Azul, CR Workshop (Nov 12-16, 2018)

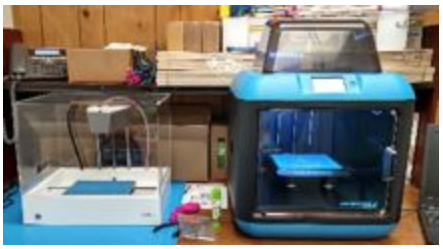
Goddard Space Flight Center

Accomplishments

Development:

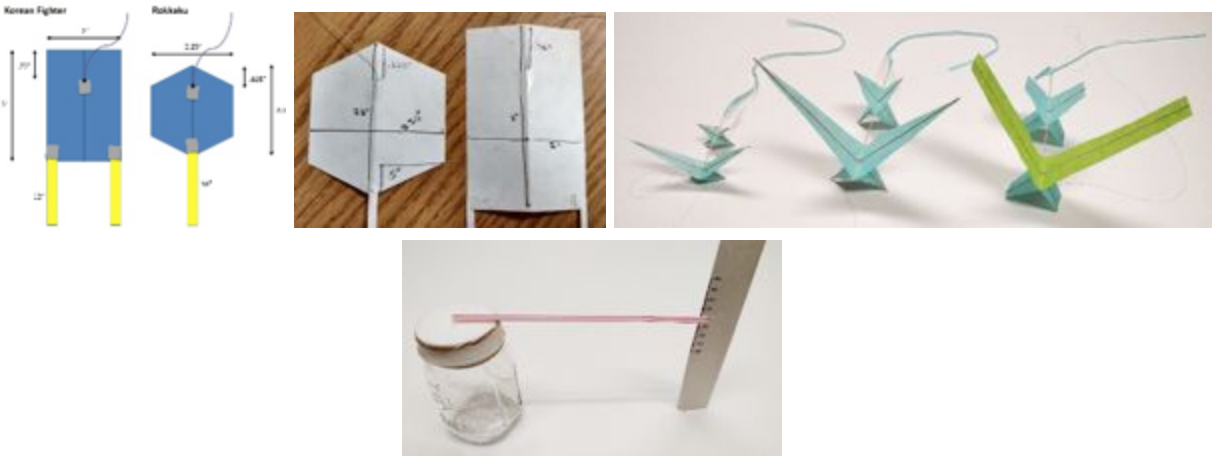
Aeropods – MonoCam, MiniPod, Profiler, VideoPod prototypes and production, evaluation of alternative 3D printers, instrumentation and sensors (Rufty, Miles)



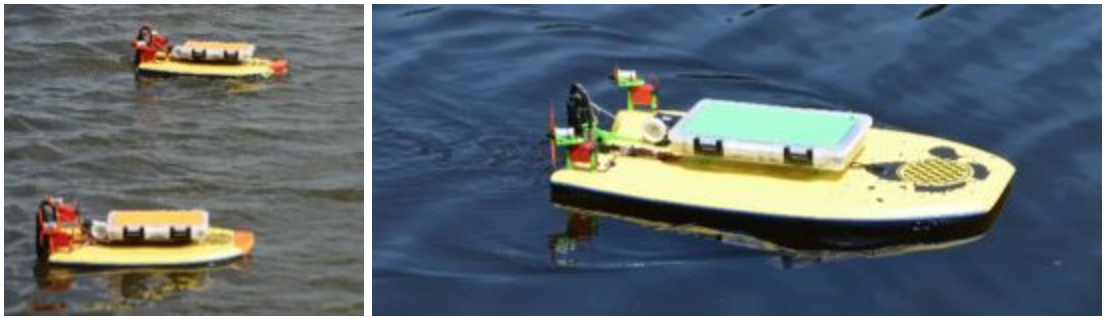


Instructional Materials – Trifolds and FlipBooks for MonoPod, Profiler, Aeropods, MiniPods, and (draft) instructions for ROVERs (Rufty, Smith)


Low Cost Kites and Materials: Mini-Kites for indoor use; simple Barometers for exploring atmospheric characteristics, weather investigations, and team-building and (Rufty)



ROVER development and testing of X-5, X-7, and X-8 (Miles)



Present Status

GSFC team is at full speed.

NASA was awarded US Patent No. 10059418, Aug. 28, 2018 for "Advanced remotely operated vehicle for education and research" – ROVERS are now considered a "NASA Technology" and AREN will incorporate licensing similarly to the newly developed and implemented Aeropod education license – thanks to the efforts of the GSFC Strategic Partnerships Office (Mitchell).

Changes

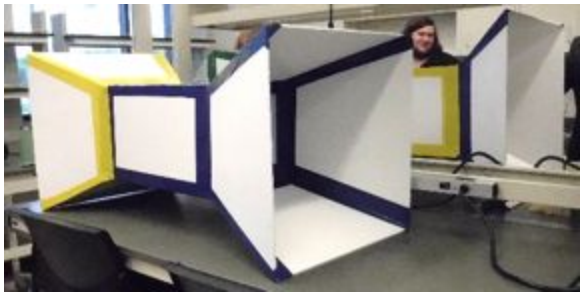
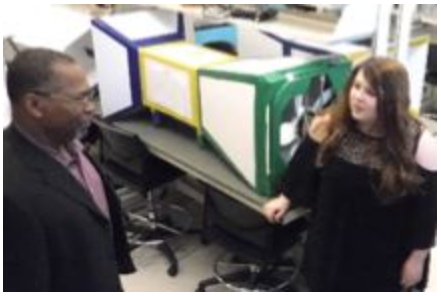
Addition of Kay Rufty and Brian Campbell to GSFC/Wallops based team.

Issues

Dissemination Activities

<u>Classroom, Workshops, and Community Outreach</u>

A second semester of the UMES ENGR150 “Intro to Engineering Design” students have created low cost Wind Tunnels for Aeropod experiments and instrumentation development using standardized materials intended to be easily replicable system for classroom use.

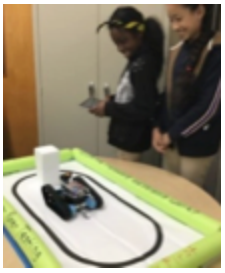



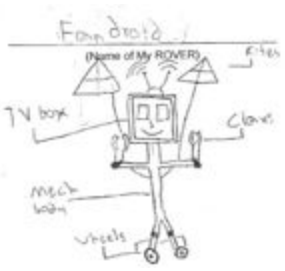
Howard B. Owens Science Center Community AREN Family Science Night (Smith)




Howard B Owens Science Center 5th grade Mars Kite-Flying ROVER challenge (Smith)







Kite Month (April) Celebration Community Flights in Greenbelt and Baltimore (Smith)

ERC workshops for local community and Wallops "Steminest" programs (Rufty)

Wallops Island flights with Morehouse College students (Bonsteel, Mitchell)

Combined AREN Team Meeting and workshops for the GLOBE Regional Student Research Symposium, and MSGC Borealis Team at Montana State University (Bozeman MT)

Challenges

Collaborations

<u>Partnership Development:</u>

Initiation of GLOBE Engineering Challenge for Wind Measurement (Campbell)

Tennessee State University Weather and Climate class workshop leading to a GIS focused curriculum using AEROKATS for spring semester 2019 (w/David Padgett – “Mission Earth”). Geoff Bland conducted a two day seminar and training event for Mission Earth's David Padgett's GEO3500 Weather and Climate class at Tennessee State University May 9-10.


Southwest Community College Physics Class support (Cass)

American Kitefliers Association - invitation to present at National Convention (October)

National Park Service – received NPS approval to pursue collaborative work with National Park Service at Assateague MD for outreach and coastal research

Future Plans

Future activities at Tennessee State University will expand on the AEROKATS theme in GIS and/or Agriculture classes, as well as service learning opportunities in the Nashville TN community (Kids and Kites Day for example).

Develop plan for sustainment phase.

Montana State University

Accomplishments
NATIONAL TEAM MEETING
The MSU team hosted the AREN team for a multi-day meeting May 31- June 5 in partnership with the GLOBE regional meeting. The meeting included several days of indoor and outdoor training for AREN team members, including flying kites and aeropods at Missouri Headwaters State Park near Three Forks, Montana. AREN team members served as judges for the GLOBE student poster competition.

During the meeting, AREN team members also hosted an informational presentation and kite-flying demonstration for MSU faculty and student interns associated with the BOREALIS program. BOREALIS (the Balloon Outreach, Research, Exploration and Landscape Imaging System) is a high-altitude ballooning program of the Montana Space Grant Consortium.

MSU continues to maintain contact with students and faculty at Chief Dull Knife College, who have flown several types of kites and aeropods. CDKC team members attended some of the AREN annual team meeting in Bozeman.

OTHER EVENTS

The MSU AREN team hosted a **miniature kites booth at MSU Family Science Day** on March 1, 2018. The event reached more than 500 people, including fifth graders from two local Title 1 schools (high percentage of free and reduced lunch) who visited the event for a field trip, and many parents with their children who attended as a family.

At our AREN station, kids (and sometimes their parents) used tissue paper, mylar, silk thread and 20-inch straws to build one of two different miniature kites based on the designs and resources of Glenn Davison. AREN team members assisted with the construction process while sharing an overview of the NASA AREN project and words of encouragement for our country's future scientists and engineers. The miniature kites featured blue and gold materials to celebrate Montana State University's 125th birthday.

An article on the event, including instructions for hosting a similar activity, were published on the national blog of AREN partner Public Lab.
https://publiclab.org/notes/SuziT9/03-08-2018/building-miniature-kites-at-a-family-science-night

AREN was also included in an article posted on the National Informal Science Education Network (NISENet) site:
http://www.nisenet.org/blog/post/partner-highlight-nanodays-transforms-msu-family-science-night-montana-state-university

MSU AREN scheduled a kite flying demonstration on April 23 in honor of **National Kite Flying Month**. However, Bozeman received several inches of snow that day, and the event was canceled.

PRESENTATIONS AND PARTNERSHIPS

Information about AREN at MSU was included in several presentations and lectures on the MSU campus:

- Grant-funded Outreach at MSU (Guest lecture, microbiology graduate students), November 2017, 12 students
- Science Communications and Outreach (Guest lecture, Geography graduate class), November 2017, 15 students
- Grant-writing Boot Camp, November 2017, 15 university faculty members
- Communicating Science (Guest lecture for Earth Science class), April 2018, 40 students
- MSU Outreach Projects (Guest lecture for Agricultural Education students), April 2018, 10 students
- College of Engineering Graduate Student Seminar, September 2018, 30 students

AREN team members are long-standing members of several national consortia and continue to investigate potential collaborations and synergies. Networks include the **National Girls Collaborative Project**, which advances STEM education for girls and other underserved youth; **Science Action Club**, a citizen science program for youth which utilizes GLOBE Observer for some activities; and the **National Informal STEM Education Network** (NISENet), a community of informal educators and scientists dedicated to supporting learning about STEM across the U.S. NISENet was a CAN award winner and developed the Explore Science: Earth and Space kit. MSU applied for and received one of these kits, which is used frequently in outreach programming.

FUTURE PLANS

MSU AREN team members will continue flying kites and payloads to better understand the technologies and operations. This year, we will begin developing a series of short, self-paced online modules to help educators (and the public) understand the kite-flying aspects of AREN. These modules will be disseminated via the National Teachers Enhancement Network (NTEN), a Montana State University program that has offered online professional development to more than 25,000 teachers around the world. We will continue to pursue potential partnerships with local, regional and national networks.

Public Lab

Public Lab work in Q (Quarter) 1 progressed faster in some areas (datalogging, site documentation and integration, multispectral platform options expansion) and slower in others (open source letter drafting, Image Sequencer back-end re-architecting). With solid capacity growth in this quarter from Google fellows and volunteers, we set up for a faster-than-planned development pace in Q2 and Q3.

Q2 was a fast-moving quarter after a period of back-end programming work from Q1; after publishing a new major version of Image Sequencer with completed base functionality for single-camera and dual-camera image processing, the Montana GLOBE meeting was a great opportunity to introduce these new tools to the rest of the AREN team, try them with new field-collected data, test multiple filter techniques, and present a brief tutorial on the use of these tools. Feedback from fellow AREN team members was invaluable in planning our next steps to further refine the UI of the tools, continue development of support resources, and plan out a blog series introducing these for classroom use.

Finally, a growing number of projects around the world are adopting these new tools and beginning to use them in the field, not only in aerial image processing but also in microscopic image analysis and other areas; following the Montana meeting, we see excellent opportunities for broader collaborative partnerships around airborne sensor data collection and microscopic imaging of air pollution particles.

In Q3, much input and feedback from the Montana meeting was integrated into different projects and tasks, and in part based on that input, a number of different software projects were completed in their first major release, including Image Sequencer, Leaflet Environmental Layers, Image Builder Pi, and more. Lots of groundwork was laid for upcoming airborne sensing work as both thorough documentation and technical advances came together, as well as some planned Providence-based local work that may provide a means to prove out these technologies.

Work from previous quarters enabled us to begin a cross-site blog series which will be an ongoing space for reporting in new progress, as well as a venue for onboarding newcomers into these exciting projects. Our letter making a case for the public benefit of open sourcing NASA technologies is almost complete, with much useful input from fellow AREN team members; it ended up being far more comprehensive and longer than originally conceived, but very exciting. The completion of this task opens up time and capacity for other activities as well.

Coordinated progress on many fronts is converging this fall and winter, with many moving pieces that had been deep in development now coming together in a way that the broader AREN team and public are able to participate. Initial feedback from AREN team members on various software projects, from our lens distortion program to Image Sequencer, has been very positive, and in particular, feedback on the user interface of Image Sequencer has been very good. In addition, the combination of software and hardware advances has opened up several new possibilities for lower-barrier, lower-cost NDVI work, bringing it well under the $50 price point for a starter kit.

We look forward to relying on these now-more-mature[1] and stable systems in doing more outreach and public promotion of the work, and supporting a larger group of participants in getting into this work.

Hardware Accomplishments

Q1: Initial letter research collection and framing work; letter outlining and drafting was delayed but anticipate working on this with AREN team in Q2.

Materials packs are sourced and pricing determined and ready for soft-launch: spruce, Tyvek in stock in store, and kite building support materials are built out and ready.

Multispectral platforms much expanded with Raspberry Pi work; more than one PL community member working to ensure compatibility of Image Sequencer code on RPi platform. Partnerships begun to build out tutorial material and ensure well-supported newcomer experience.

Q2: Planning for a lightweight Raspberry-Pi-based kit begun, with key input from Public Lab community members in the U.S. and Spain. Design and planning for a dual-camera system also begun with input from Spanish community; low-cost webcam versions tested but quality deemed insufficient. Power management testing begun with lightweight batteries for Raspberry Pi cameras. Public Lab partners at AS220/Modern Device released a “crash cage” for aerial use of wind sensors; prototyping of simple airborne sensor packages for classroom use continues.

Software accomplishments

Q1: Back-end systems saw much architectural work, with Infragram now modularized for reuse in various platforms, and Image Sequencer now expanded with new progress monitoring system, “meta module” system for easier extensibility, and Raspberry Pi compatibility. Worked to complete back-end work and refocus on user interface redesign.

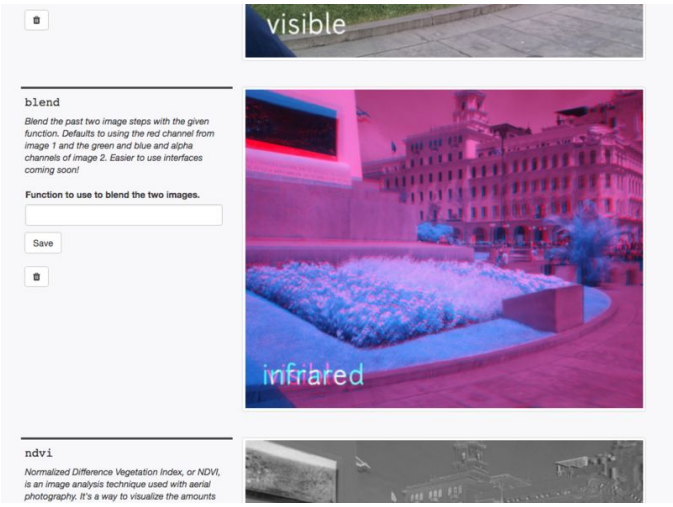
Q2: Software for web-based sequential image processing is complete in basic form and was demonstrated and used at the Montana GLOBE meeting. Color and filter testing of GitUp cameras and integration of initial two-camera image processing workflow also complete. Walk-through and training of fellow AREN team members on new tool set completed at Montana meeting, with follow-ups planned as team begins use of the new tools. Major user interface improvements completed and “headless” auto-run system is now in development for in-flight image processing.

Present Status

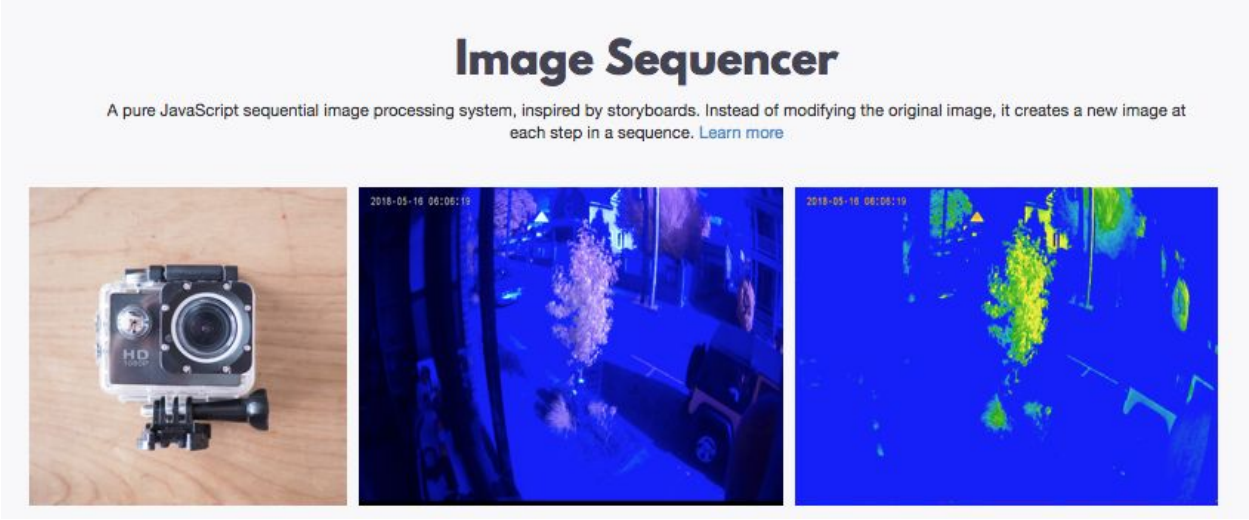
Hardware: Possibilities with Raspberry Pi hardware have opened up via software development of plug-and-play-ready imaging systems in the Image Builder Pi project, making high-resolution

and high-fidelity imaging more accessible at both low cost and low weight for airborne use. (see below, “Software”)

Additional progress on low-barrier, low-cost DIY NDVI has been documented in tutorials on using sub-$50 action cams with Infragram single-camera filters in Image Sequencer, with some feedback from community members already showing this in use in the field.



Software: Image Sequencer is reaching maturity, with additional code contributors adding new modules such as histogram, matrix math, and others, also refining the user interface, and adapting it for offline use.



The “Image-Builder-Pi” project, allowing for automatically generated Raspberry Pi memory cards based on preset “recipes” was mostly completed, and is now in testing. Integration with Image Sequencer will allow for lightweight Raspberry-Pi-based high resolution cameras with little configuration at low cost; <$50 ideally. The Leaflet Environmental Layers library was developed to display relevant environmental issues near a flight site.

Any Changes That Took Place

Some schedule changes occurred around the drafting of a letter about NASA open source technologies, and some reprioritizations occurred around the growing work on new low-cost camera platforms and low-cost sensor platforms. However, overall, we stuck to our original schedule as planned.

One change is that the scope of collaboration through the Public Lab network has grown considerably, with many new volunteer contributors helping to advance both software and hardware systems, explore new use cases, and refine and expand the capabilities of the tools.

Issues

Some software work took longer to get to an initial demonstration state, but part of this was offset by the expanded capacity that better project planning brought, through recruitment of community volunteer and fellowship time.

Dissemination Activities (aligned to 2018 calendar)

Q1: AREN presence on PublicLab.org expanded rapidly around the PublicLab.org/AREN page, including activities, challenges, and guides around a range of topics.

Q2: Video tutorials, FAQs, and diagrams for filter swapping, lens adjustment, and NDVI processing posted, and materials in development for a blog series introducing the project. Documentation for kite-making posted and kite-making materials now available in Public Lab store.

Q3: Initial technical documentation was published for Leaflet Environmental Layers, Image Sequencer, Image-Builder-Pi, and more, but documentation for a more general audience will come in Q4 as bugs are ironed out and the software packages stabilize and mature.

Blog posting across both PublicLab.org and Globe.gov was prototyped with an initial post which demonstrates a format usable for additional more in-depth posts in the coming quarter. Tutorials on NDVI using action cams was posted and is now in use after kits were shipped, including to a pilot library program.

A large amount of documentation and guidance on calibrating, using, and comparing particulate air quality sensing data was published by Ufuoma Ovienmhada, our Autodesk summer Student Expert. We anticipate this being useful in airborne measurements as well.

Challenges

We have continued to work on the problem of people across our broad community having different communication and sharing habits; while many people do amazing projects with our work, they share on platforms and channels ranging from Twitter to personal blogs to YouTube videos. Having recently hired a communications team member at Public Lab, we are now situated to better address the challenge of cross-channel collaboration and communication.

Collaborations

Q1: Progress on a range of projects, from easy-to-use dataloggers for aerial sensors, data visualization, and kite making support materials. Several cross-project posts and collaborations have laid solid groundwork for expanded collaboration and successfully piloted cross-community, cross-website collaborative model.

Q2: Montana meeting complete and regular calls have helped scaffold a range of collaborations, including image processing, lens distortion removal, and other workflows prototyped by PL staff. Of note is an upcoming collaboration around a new low-cost microscope kit developed by Public Lab with potential for imaging air pollution particles, to be used in the first-year program by Professor Jonathan Gaines' students. The Montana meeting was also an opportunity to brainstorm and prototype new bolt designs for 3D printing with NASA's Wallops team.

Q3: Low-cost air sensor materials and prototypes expanded upon for eventual airborne and plug-and-play usage through Autodesk fellowship. Further development of Image Sequencer through fellowship with Google Summer of Code. Planning for local Providence kite/sensor/wetlands project with intent to coordinate with some AREN goals. New tutorials on simple camera conversion and PublicLab.org/Globe.gov cross-site blog posts with plans for additional posts.

Future Plans

We have lots of project plans upcoming, from more accessible airborne sensor packages to more curricula and guidance around our NDVI software and hardware; much will start to go out over our coordinated blogging on Globe.gov and PublicLab.org. Many of our projects are now coming to fruition and are ready for broader adoption, or nearly so. We look forward to a much larger group of people beginning to work on NDVI, DIY aerial imaging, and AREN priority topics through the work done to date, and to have fewer barriers to good quality, accessible science learning through Public Lab contributions within the AREN project.

University of Maryland Eastern Shore

UMES - 2018 Annual Report for AREN Project

The University of Maryland Eastern Shore (UMES) - annual report submission highlights the ability to develop, integrate and explore training opportunities that could support engineering and aviation education using AREN's specific project design methods. Previously in 2017 annual report, UMES was successful in developing and offering a three (3) credit hour course titled: AVSC 310 – Aerial Operations in Remote Sensing (within the aviation science curriculum). The course development and implementation were successful in engaging students and exploring training methods for system-proficiency, data collection strategies, and STEM opportunities within the user community. Based on the findings, the AREN community recognized that STEM practices and the importance of higher education training standards using curriculum learning-outcomes could also align with specific course objectives proposed by UMES. Therefore, UMES explored the need to integrate specific projects using AREN's technology into existing courses within the Department of Engineering and Aviation Sciences at UMES. This development could also provide a baseline for aligning training efforts to address STEM practice at various teaching environments to allow students engage in active learning for potential college credits. As a result, starting in Fall of 2017, we were able to identify an engineering course taught every semester to first year undergraduate engineering students that could promote and support retention efforts based on the completion rates in STEM disciplines. This approach will engage engineering students' in-group projects sponsored by the AREN user community for project based learning. The approach mapped to the goals and objectives proposed by UMES to support the AREN community and the teacher experience in higher education. UMES efforts using the course ENGE 150 Modern Engineering Design involved Fall 2017, Spring 2018 and Fall 2018 (coordinated by Mr. Geoff Bland; Dr. Willie L. Brown, Jr.; Mr. Chris Hartman; and Dr. I. K. Dabipi).

Starting in Fall of 2017, the project title was "Wind Tunnel Design, Development, and Testing" and the students had to explore the practice of wind-tunnel design for system modeling. The description was provided to the students as follow:

> *In exploring engineering concepts, an approach for framing a system design is a fundamental requirement. To capture the intent for system development and testing, a baseline requirement specification is a critical first step. The Wind-Tunnel project introduces engineering concepts by exploring the various ways to analyze, design, development, monitor, test, and evaluate the system behaviors within a control environment using test models. This project will enable students to demonstrate and interpret these aspects of data collection needed for system modeling of performance and stability. The project will explore innovative measures and educational outcomes through a comprehensive study of wind-tunnel designs and requirements. The educational outcomes will be identified using a theoretical approach known as project-based learning (PBL) to model engineering practices, technology and science application. The PBL theory has been recognized as a way for students to investigate and discover meaningful solutions in the field of study through design and industry*

requirements. Therefore, this design approach will serve for the advancement of NASA's "Aeropod" technology – the results is intended to identify innovative efforts tailored to the requirement specification in order to meet emerging Earth-science research and industry needs. The engineering students in ENGE 150 - Modern Engineering Design will be tasked to develop and design a wind-tunnel system that will support the mission objectives for system testing and performance evaluation with regard to the specific test models identified as NASA's technology and their requirements specification in this project.

The outcome had identified the need of PBL with support of the AREN community encouraging an iterative process for student learning and engagement. To address the iterative process, in Spring of 2018, we introduced the project title: "Instructional Learning in STEM Education for Wind Tunnel Development" to encourage and engage both teachers and students in the AREN community to consider the design process based on the previous findings through student interactions. Hence, the AREN team created a project description in Spring of 2018, which included:

In Fall 2017, the ENGE 150 Modern Engineering Design course had an opportunity to design, test and develop engineering concepts that explored the various approaches required to deliver a wind tunnel system design and implementation. The cohort in Fall 2017 semester was able to capture the intent for system development and testing while identifying specific baseline's needed to understand wind tunnel requirements and specification. This was critical in the first steps needed in the initial introduction of Wind-Tunnel projects for STEM education. Since the concepts are introduced using engineering concepts, the (AEROKATS and ROVER Education Network) AREN engineers aim to streamline concepts for instructional learning in STEM Education using Wind-tunnel development. The evaluation process of the system behavior will have to demonstrate specific aspects used in system modeling based on performance and stability. The AREN team is using NASA's "Aeropod" kite-borne instrumentation technology and the results are intended to identify innovative efforts tailored to the requirement specifications for instructional learning in order to meet emerging Earth-science research and industry needs in STEM education. Wind instrumentation calibration is key objective. The engineering students in ENGE 150 - Modern Engineering Design will need to identify five (5) groups of four (4) members with the challenge, which support the team building the largest suitable test section with the best aerodynamic effectiveness (i.e., a minimum of turbulence and loss of air velocity) and instructional supportive documentation (e.g., step by step instructions with manuals, videos and any other preferred forms of documentations).

Our findings indicated that standardizing the materials could create a pedagogy in the student designs by providing curriculum requirements needed for STEM based-practices involving the overall education experiences. This approach also supported AREN mission proposed by UMES for curriculum integration in education. We had modified the project title to understand project-based learning and the user community to evaluation the student experience for project

design and testing. The project title is as follow: "The Evaluation of Engineering Practices for Quality Enhancement in Wind Tunnel Design and Testing." This will require students to research on the topic: Wind Tunnel Development Practices with Project-Based Learning for First Year Engineering Students. The description for Fall 2018 to the students included:

> *The client and stakeholders for the ENGE 150 Modern Engineering Design course have proposed to revisit a Wind Tunnel project for Fall 2018. Starting in Fall 2017, the ENGE 150 Modern Engineering Design course had an opportunity to design, test and develop engineering concepts that explored the various approaches required to deliver a wind tunnel system design and implementation. The cohort in both Fall 2017 and Spring 2018 semesters were able to capture the intent for system development and testing while identifying specific baseline's needed to understand wind tunnel requirements and specification. Whereas, they failed to meet the requirement of airspeed within the test section of 10 mph with the various wind tunnel designs. We have again been requested by the NASA AEROKATS and ROVER Education Network project (AREN - https://www.globe.gov/web/aren-project/overview) to create a Wind-Tunnel Project for STEM education. The evaluation process of the system behavior will have to demonstrate specific aspects used in system modeling based on performance and stability. The AREN team is using NASA's "Aeropod" kite-borne instrumentation technology and the results are intended to identify innovative efforts tailored to the required specifications for instructional learning in order to meet emerging Earth-science research and industry needs in STEM education. Wind speed measurement instrumentation calibration is key objective. The engineering students in ENGE 150 - Modern Engineering Design students are challenged with building the largest suitable test section and achieving the best aerodynamic effectiveness (i.e., a minimum of turbulence and loss of air velocity). Engineering students must create instructional supportive documentation (e.g., step by step instructions with manuals, videos and/or any other preferred forms of documentations).*

All of the project designs required students to consider the following system specification in the engineering practices and supported course integration within the Department of Engineering and Aviation Sciences, ENGE 150 Modern Engineering Design course at UMES. The Engineering Program is an accredited by the Accreditation Board of Engineering and Technology and the learning requirements mapped to the mandatory learning objectives. The requirements were:

- Requirement 1: Wind-tunnel design must be able to support the test model and flow conditions using a sub-scale *Aeropod*.
- Requirement 2: Wind-tunnel design must be able to display airspeed measurements within the test sections.
- Requirement 3: Wind-tunnel design must be modeled with an understanding of Bernoulli's Principle based on the flow of air through a Venturi tube (according to requirement one).
- Requirement 4: Wind-tunnel design should have a system mount with a configuration adjustment for the *Aeropod*.

- Requirement 5: Wind-tunnel design must have a minimum speed of 10 mph in the test section.
- Requirement 6: Wind-tunnel design must be built using foam core or cardboard with a 20-inch fan and other materials identified for standardization purposes in the matrix below.

The figures below also provide moments the students were engaged with the AREN project, their engineering redesigns to test Aeropod configurations, and the wind tunnel development at the University of Maryland Eastern Shore.

Figure 1. 3D Printed Aeropod for Engineering and Aviation Development

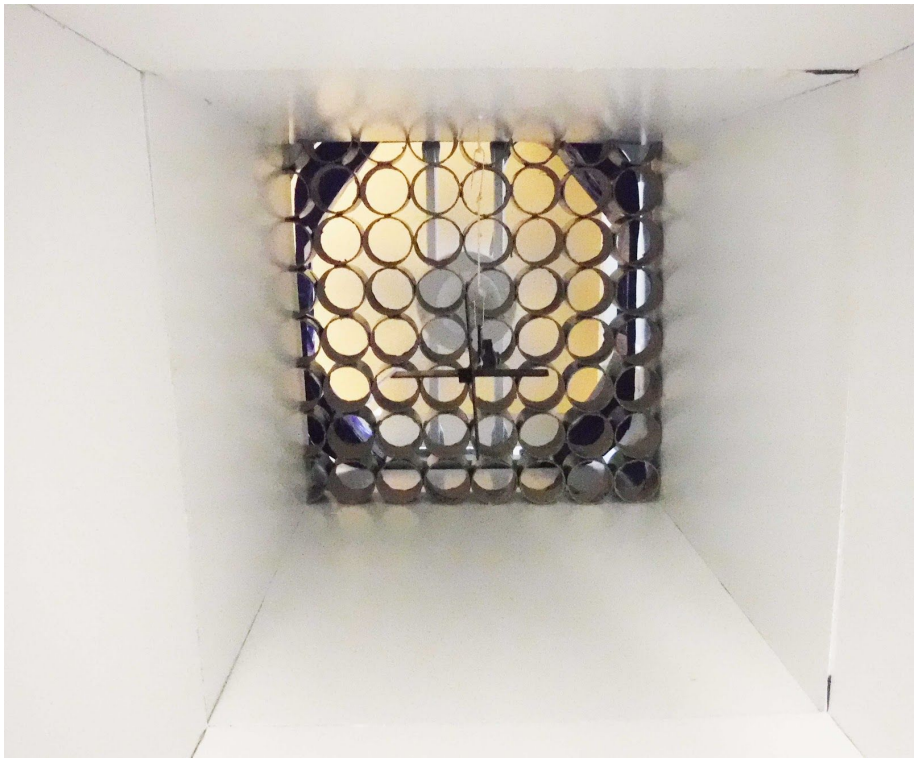


Figure 2. Aeropod and the testing development stages of the design prototype at UMES.

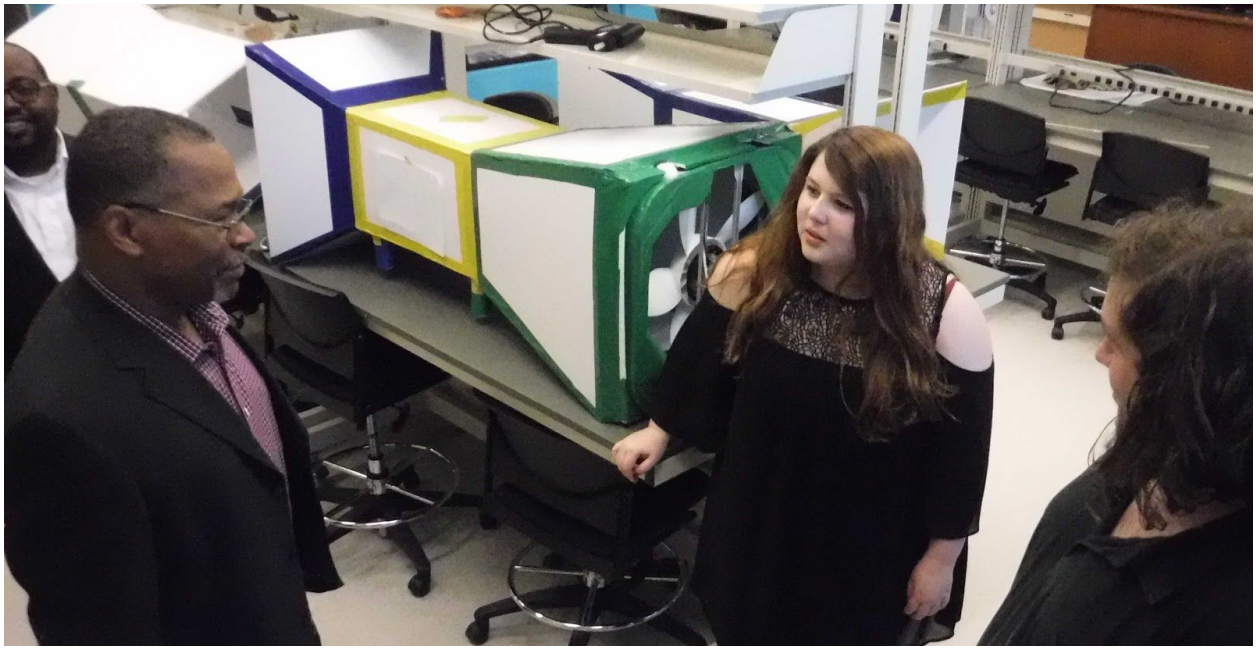


Figure 3. NASA visit to discuss the AREN's wind tunnel design with Engineering and Aviation Students at UMES.

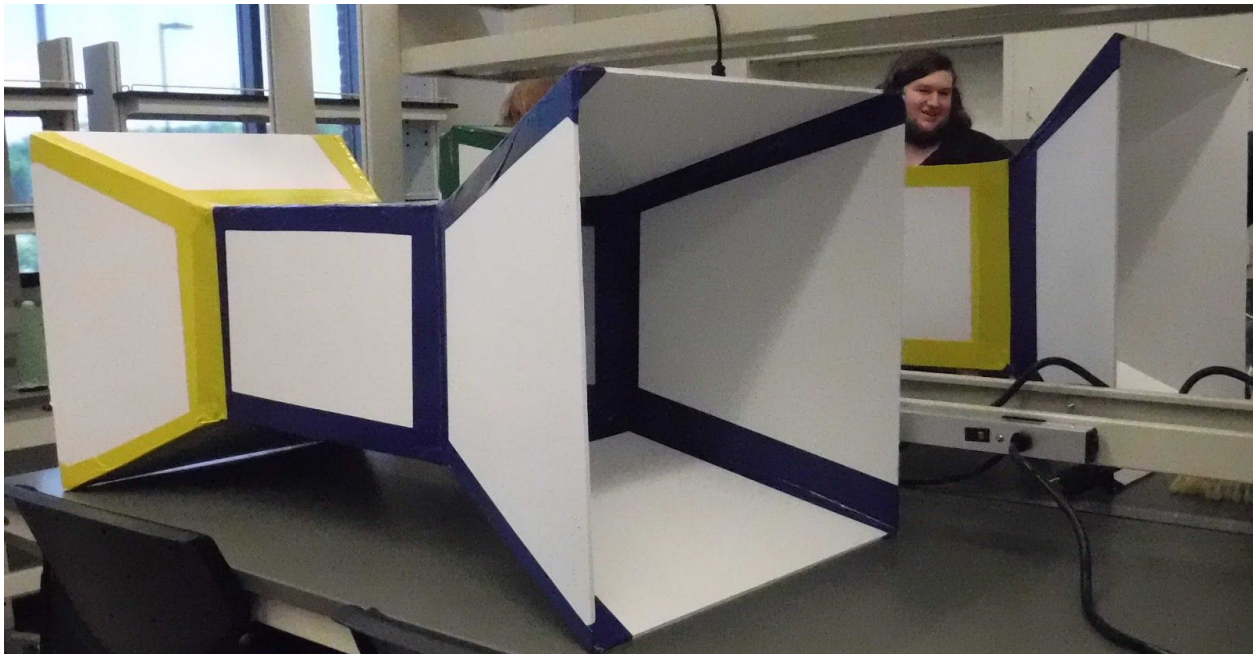


Figure 4. An example of a wind tunnel design model with regard to the AREN Project.

Our future efforts will continue to engage students in the various multidisciplinary areas in STEM practices. The AREN community has identified student researchers at UMES for the Summer of 2018 to embark in discovering the methods learned from previous classroom practices and promote innovation of kite-designs and development, data management, analysis and techniques to engage the AREN user community for partnership. The student researchers were successful and UMES submitted a publication for acceptance to the broader community addressing project-based learning and the integration of data analytics to assess multi-complex environments in engineering education for research to practice. The authors will present their findings at the 48th Annual Frontiers in Education (FIE) Conference sponsored by the American Society for Engineering Education (ASEE) and the Institute of Electrical and Electronics Engineers (IEEE).

University of South Florida

Summary of accomplishments for the reporting period

The USF partnership in the third year focused on two primary initiatives. Bulls-EYE Robotics which is an outreach program for rising 6th graders and Foundations of Engineering Lab which is a design class for first year undergraduate students. Both initiatives were successful in that Bulls-EYE Robotics engaged approximately 30 rising 6th graders during a 5 week summer academy and Foundations of Engineering Lab engaged approximately 100 undergraduate students in redesign activities around the Aeropod and kite based data acquisition. The strength of the USF partnership is in the breadth of the types of engagement around the NASA technologies that are central to the AREN project. Over the two years of the project, USF students or Tampa Bay youth have developed ROVERs, Tera – ROVERs, and Aeropods for educational purposes. USF has also bridged the gap between the unique NASA technologies and the engineering design process. Engineering design is central to the hands-on activities that lead to the development of the technology. For both Bulls-EYE Robotics and Foundations of Engineering Lab a similar design process was used. Participants planned their design, acted upon the plan, fabricating the actual hardware, and then evaluated the effectiveness of their actions. The work culminated with fully functional prototypes and field testing. In addition, both initiatives indirectly served an even broader group of people. For Bulls-EYE Robotics, approximately 20 undergraduate mentors helped to facilitate design activities, bringing the sum total of those impacted by the initiative to about 50 total counting mentors and mentees. For Foundations of Engineering Lab, undergraduate students presented their designs to approximately 50 middle school kids, raising the grand total of those affected to approximately 200 counting undergraduates and middle school youth. USF is effective at connecting college students to middle school aged youth supporting both informal environments (Bulls-EYE Robotics) and formal environments (Foundations of Engineering Lab).

For Bulls-EYE Robotics, the format was similar to what was done the previous year for Bulls-EYE Environment. The main difference was instead of developing ROVER platforms meant for data acquisition in the water, students developed Tera – ROVER ground vehicles for data acquisition on land. The robotic platforms that were developed in the third year still used the National Instruments myRIO platform for data acquisition. Students learned about sensors and actuation and built their robotic prototypes around the Pitsco Tetrix PRIME build system. This build system was used just because it is useful for quick and easy prototyping. Many of the activities done for Bulls-EYE Robotics could be replicated with a cheaper platform. Bulls-EYE Robotics also promoted NASA protocols because youth flew kites on multiple days and applied newly developed protocols established by the AREN team. Unlike last year where youth flew multiple days each week, kite flying was used this year to just reinforce concepts around data acquisition protocols and teamwork. Considering the Bulls-EYE structure has now been used to support ROVERs (Bulls-EYE Environment), Aeropods (Bulls-EYE Aerospace), and Tera-ROVERS (Bulls-EYE Robotics), the team has developed a pretty comprehensive understanding of the NASA technology in AREN and its usefulness in informal settings.

For Foundations of Engineering Lab, engineering undergraduates opt into a semester long engineering design project for educational purposes. Approximately 100 students opted into the

remote sensing project which resulted in their redesign of the Aeropod platform. Students were given all previous files used to make Aeropods and were asked to go through the design process and produce an iteration on the current design. During the last month of the Fall semester, students will collect data with their redesigned Aeropods and analyze that data using the image processing tools made available by Public Lab. To refine their ideas, design groups met with middle school youth to help inform the direction of their designs. A strength of the university partnerships in the AREN project is their access to undergraduate students that continue to contribute to new designs. This makes the partnership useful in formal settings.

Figure 1: Redesign of an Aeropod camera mount done by students in Foundations of Engineering Lab using new and previous parts.

Figure 2: Image of a design review conducted with middle school and undergraduate youth in support of Foundation of Engineering Lab

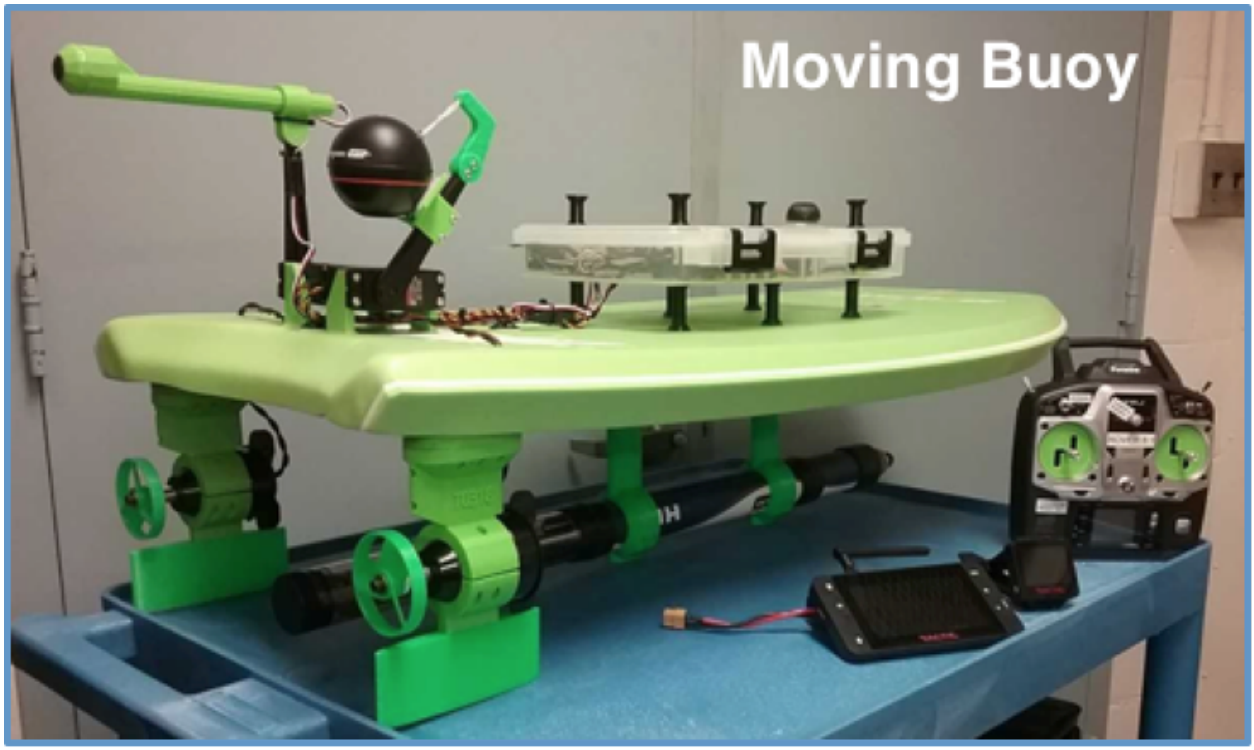
Figure 3: Image at orientation for Bulls-EYE Robotics showing mentors in the front, mentees in the middle of the crowd, and parents in the back

Figure 4: Image of a mentor and a mentee building a Tera-ROVER during Bulls-EYE Robotics

Washington College

The buoy system funded by this program in year 1 was launched in the spring. The buoy data is posted on the Data Fountain (http://data-fountain.washcoll.edu/) as Radcliffe Creek.

AquaRover (Rover 8) was designed and built (Ted Miles) that collects water quality data remotely using the Hydrolab HL4. This is the same WQ system as is in the buoy. The AquaRover is being used to collect water quality data. Procedures are being developed for Operations and Data Visualization. By next year it is anticipated that the AquaRover will be collecting data remotely by students from their classrooms. GPS tagged depth measuring capabilities were added to the AquaRover so that students can create maps of local ponds or waterways. Controlling the system remotely is on the "drawing board" and will use the same system developed for VideoRay ROVs. The Rover data will be measured against the Buoy system.



As schedule allows, Levin and/or Clark participated in weekly program tele-cons.

CES Staff (Jemima Clark) is working with local county partners to create/adapt lesson plans/activities with kites that are aligned with Standards of Learning that will allow Maryland

educators to use them in their classrooms, in addition to extracurricular activities. We are especially keen on figuring out how to get Kites into the Maryland SOL matrices.

A shared system of 20 kite systems was assembled in support of the AREN program. These systems represent a shared resource that can be shipped nationwide for AREN partner use in Kites in Technology Education (KITE) programs. The kites are being used in the Kent and Queen Anne's Counties school systems. Jemima and Doug periodically go to schools and help educators with their flying and data collection.

A set of kites, cameras, atmospheric profilers were delivered to NASA Goddard for teacher trainings. Including; 7' kites for young (down to elementary) flying demonstrations, 10' kites for advanced flying and data acquisition, VTech recording aerial video cameras, Kestrel 5500 Bluetooth atmospheric profiler and Strike Alerts.

Levin completed all 47 GLOBE e-Training Protocols and provided errata and evaluations of the protocols.

Levin has been using/evaluating the utility of GLOBE Observer Land Cover, Atmosphere, Clouds, and Mosquito Habitat Mapper. They are good for ground truthing NASA data gathering systems, but difficult to adapt for classroom use.

Levin developed a field sample station on the Choptank River to test and evaluate the data entry protocol. He contributed several evaluations of GLOBE data entry protocol to GLOBE. Used GLOBE recommended LaMotte Estuary & Marine Monitoring Kit – to collect data and add it to the GLOBE database.

Levin proposed use of GLOBE as a data portal for atmospheric and water quality data in **Bologna and Venice Italy**. GLOBE was also proposed for the New Arctic Observation System. Am also working with GLOBE for weather and water quality observation for **5 Gulf Coast States** with the Gulf Coast Ocean Observation System.

Wayne RESA

Wayne RESA is the fiscal agent for the AREN Project. As such, regular meetings are held with the Finance Department at Wayne RESA. Partner specific activities include:

- Coordination with the GLOBE Program
- Alignment of AREN with the Next Generation Science Standards
- AEROKAT and ROVER development, testing, and training.
- Training and supporting local middle and high school teachers and students
- Website design and development

The PI attended the North American Regional Meeting for GLOBE in West Lafayette, Indiana and the GLOBE Global Learning Expedition in Killarney, Ireland. The PI worked with GLOBE to help arrange the upcoming 2019 Annual GLOBE Conference to be held in Detroit, Michigan, the week of July 14, 2019. The Wayne RESA team, along with Evaluator, Anil Aranha, worked with GLOBE to host the 2018 GLOBE Midwest Regional Student Research Symposium.

AREN educator professional development, through Wayne RESA, was provided for educators:

- Metropolitan Detroit Science Teachers Association Conference
- GLOBE Student Research Symposium Teacher Webinar
- Returning Teacher Workshop for the Rouge Education Project
- Michigan Science Teachers Association Conference
- Rouge Education Project Teacher Training
- National Science Teachers Association
- Cooper Upper Elementary School Teacher Training and Student Field Days.
- GLOBE Midwest Regional Student Research Symposium
- GLOBE Mission Earth Professional Development Institute
- GLOBE Global Learning Expedition
- Detroit Kite Festival
- GLOBE and AREN Training Workshop at Madonna University

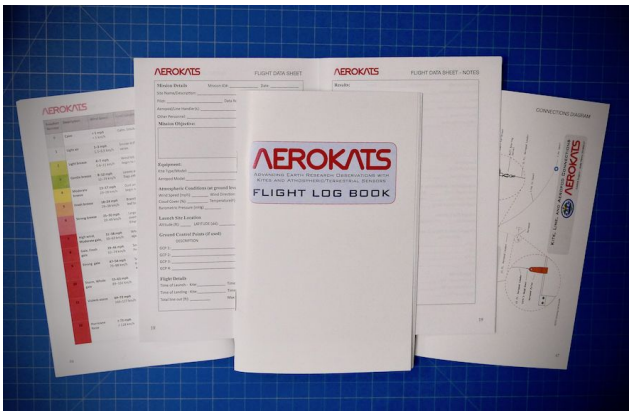
AREN student demonstrations impacted over 120 upper elementary students in the Livonia Public Schools at Cooper Upper Elementary, over 1200 7th graders in the Troy Public Schools at all four of the district's middle schools and over 60 middle and high school students who attended the GLOBE Midwest Regional Student Research Symposium. Each student built, decorated and flew a frustrationless flyer kite, and had the experience of flying and participating in Aeropod missions. Students were introduced to operational concepts, such as safety, protocols, teamwork, communication, and mission data recording. Scientific concepts included remote sensing, in situ observation, and atmospheric features including boundary layer, turbulence, lapse rate, and impacts of atmospheric variables on kite flying.

The AREN Project continues to work with the Rouge Education Project. The purpose of working with the Rouge Education Project is to support their work in water quality testing and integrating GLOBE and the AREN Project into their defined work. The AREN Project and the Rouge Education Project are working together with Earth Force to help students "take action" on their research. The Rouge Education Project and Earth Force are in a partnership, at this time. It

is hoped that AREN and Earth Force can form a partnership. Schools in the Rouge Education Project have also been introduced to a ROVER and it is anticipated that they will be able to use the ROVER during their work in 2019.
Wayne RESA distributed 50 Earth Science Week Toolkit packets to Earth Science Educators throughout Michigan.

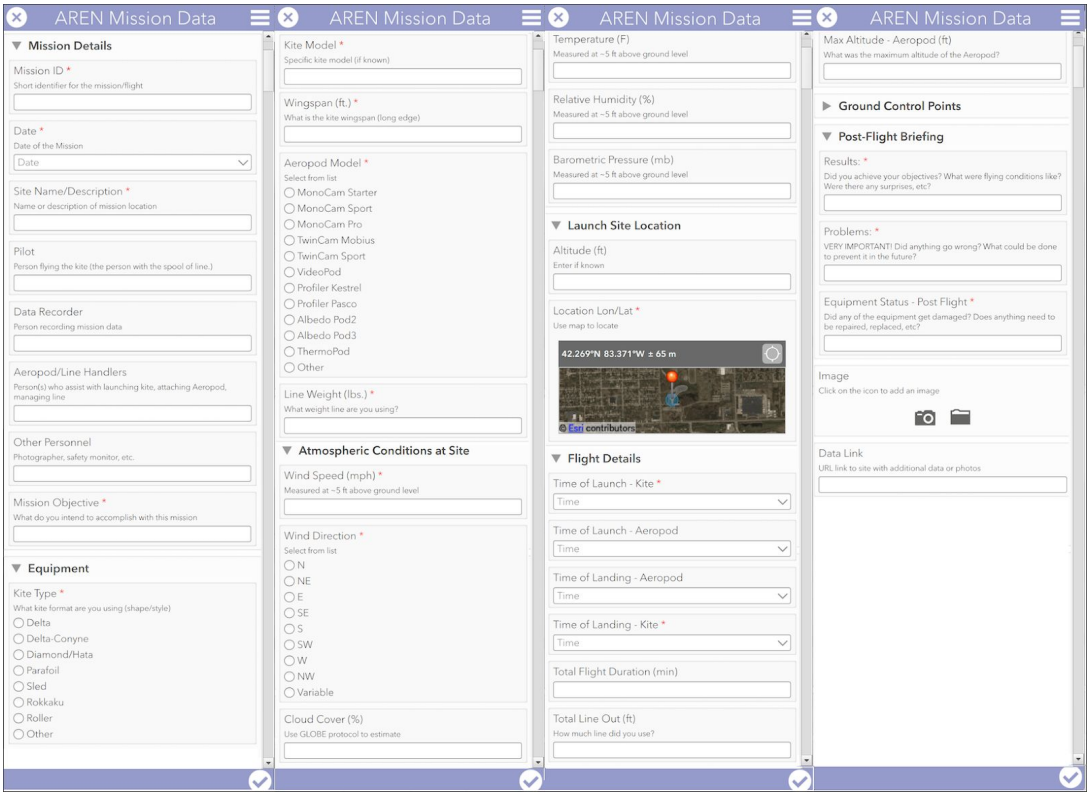
Wayne RESA produced multiple podcasts on a variety of subjects supporting the technology work of the AREN Project. These podcasts were done in conjunction with the podcast series "Middle School Matters" and were a feature of the podcast. All of the podcasts centered on "Maker" topics including:

- Illuminating Food Webs: A Maker Jigsaw
- Reinventing STEM Through the Maker Movement
- 7 part series on -- Lifelong Kindergarten

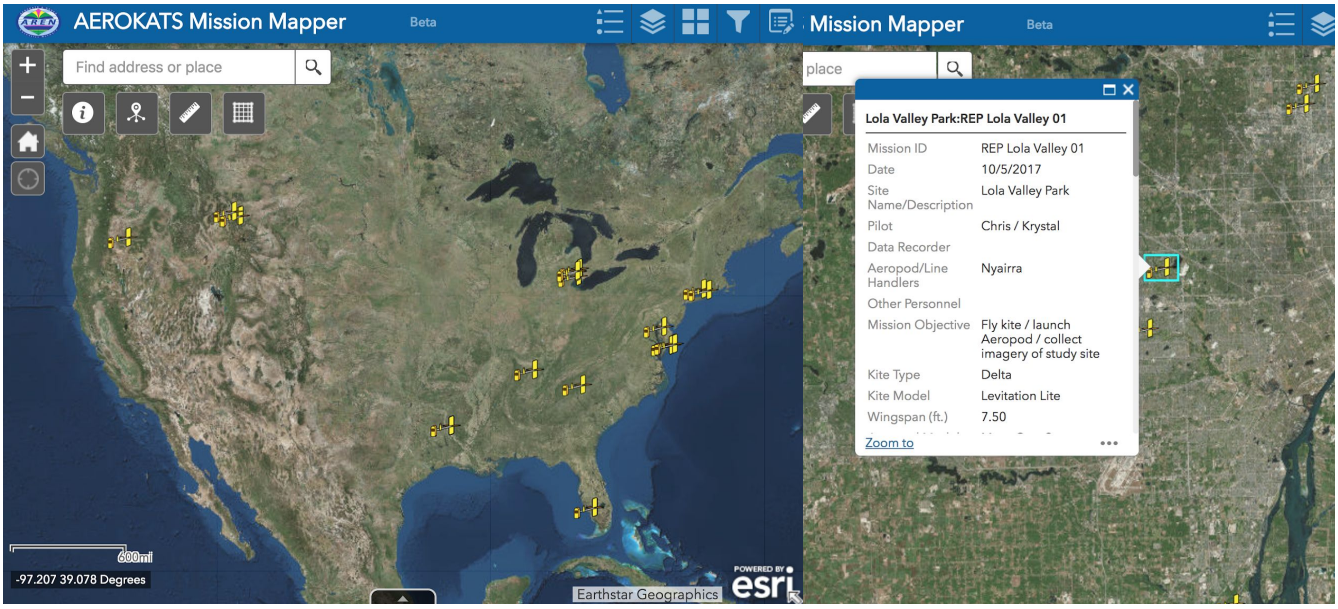


A new AEROKATS Flight Log Book has been developed for recording mission data in the field and is in use by schools.

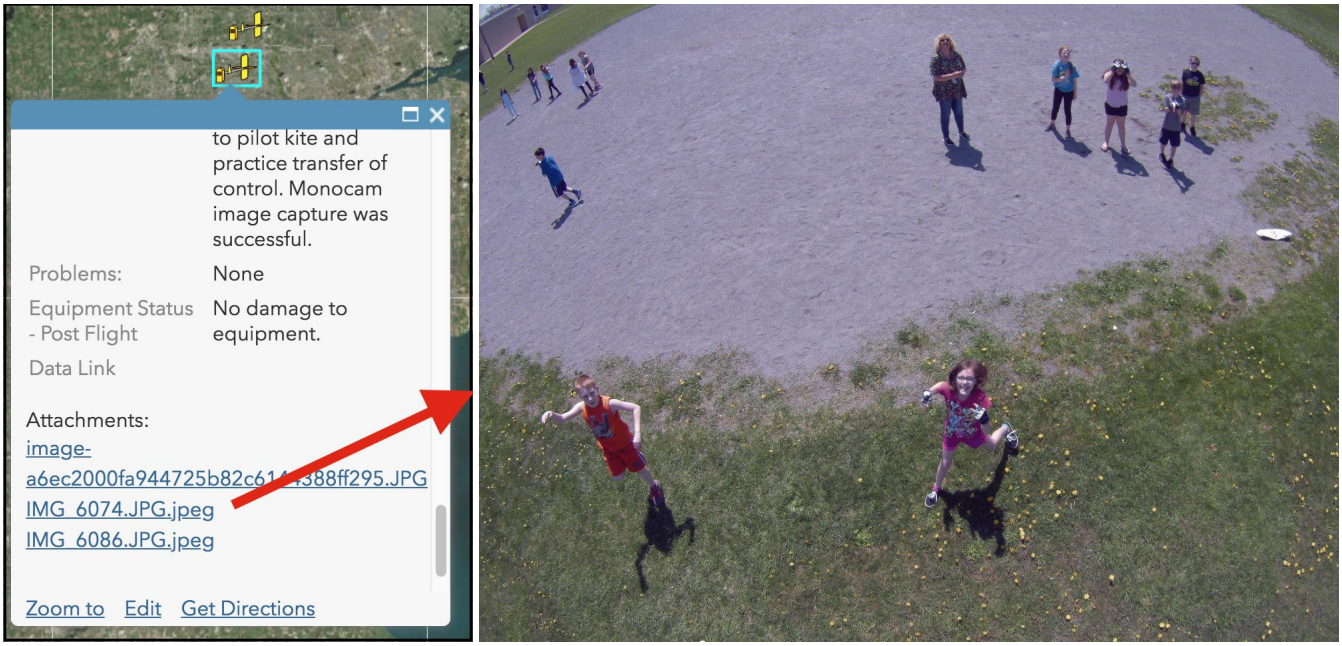
A corresponding app has been developed which allows data to be collected in the field and uploaded directly to a mapping database. (App link: https://arcg.is/1TeDGy)



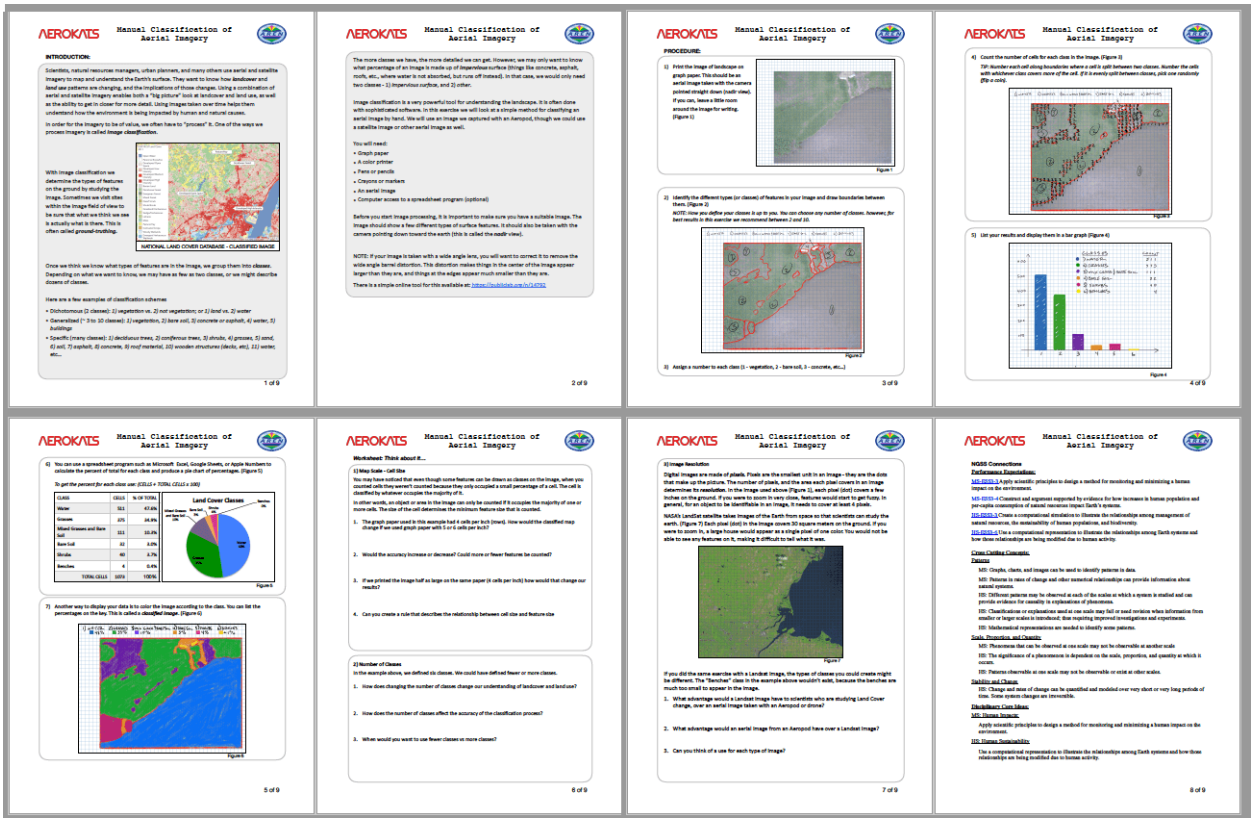
After uploading their data, AREN participants can now view, edit and share their mission data on the AEROKATS Mission Mapper https://tinyurl.com/ybfw5xsw.



The Mission Mapper allows the participants to not only upload their mission data, but they can share images and files, and link to shared folders of their work.



NGSS activities and lessons are being developed and field tested, including low tech methods for doing data analysis, as in this example of manual image classification of Aeropod imagery.



Work is nearly complete on the AEROKATS Field Guide, which will enable users to engage in AREN activities even without direct access to the AREN team for training. This piece is essential to moving forward with the extended national and international distribution and impact of AREN in year four. We anticipate this to be completed in November of this year.

We continue to produce and distribute Aeropods, and handle the purchasing and distribution of all related materials for the project. R&D into improved designs and expanded instrumentation options and processing tools is ongoing as well.

We have also engaged in a distribution arrangement with Into the Wind, our major supplier of kites. Into the Wind will take over direct shipment of AREN starter kite packages to schools, clubs, universities, citizen science groups around the country. This will significantly impact our ability to efficiently serve more end users and grow our community.

We working with other members of the Wayne RESA Instructional Technology and Educational Services department to leverage the new MI-STEM initiative, especially in the areas of design engineering and Making. We are developing a local lending library for 3D printers and materials, and will be hosting a MI-STEM Maker day in April of 2019 featuring AREN materials.

Contributions from the AREN User Community

Users are actively involved in the AREN Project throughout the United States and throughout the world.

Wayne RESA Affiliated

Wayne RESA is the fiscal agent for the AREN Project and also supports the Principal Investigator for the Project. Wayne RESA is a regional educational service agency that provides a broad spectrum of services and support to Wayne County's 33 school districts aimed at improving student achievement and maximizing economies of scale in staff development, purchasing, and administrative services.

- Advanced Technology Academy -- The Advanced Technology Academy (ATA), is a Michigan public charter school district located in Dearborn, Michigan that offers a rigorous Pre K-12 educational program. ATA is an NCA accredited Academy that has met Michigan's standard of Adequate Yearly Progress (AYP). The 2018 - 2019 goals for ATA within the AREN Project are:
  - Students become proficient at flying kites.
  - Students learn the different roles involved with flying kites and instrument packages.
  - Student practice roles by cross-training the different roles.
  - Students fly the instrument packages and collect data.
  - Students upload data to the GLOBE website.
- Cooper Elementary -- Cooper Upper Elementary School is a 5th and 6th grade school in Westland, MI and is part of the Livonia Public Schools District. Three-fifth and three-sixth grade classes at Cooper are participating in the AREN Project with a focus on engineering, especially in the area of developing a MakerSpace. They are particularly interested in flying and making kites.
- Rouge Education Project -- The AREN Project is currently working with teachers in the Rouge Education Project. The purpose of this cohort is to support their current work in water quality testing and integrate GLOBE and the AREN Project into their defined work. The timeline for the project is 2017 -2020. It is aligned to coincide with the Rouge River Water Testing Week. Additional teachers from the Rouge Education Project will be added to this cohort during the timeline. Schools participating in the project include:
  - Garden City High School
  - Huron Valley Lutheran High School
  - Inter-City Baptist Middle and High School
  - Crescent International Academy
  - Crestwood High School
  - Clippert Multicultural Honors Academy

    - Chandler Park Academy High School
    - Pierce Middle School
    - Tyrone Elementary, Harper Woods
- Gibraltar Public Schools -- Jeff Bouwman at Shumate MS in Gibraltar recently was approved to teach an advisory class focusing on the GLOBE Project. Here is the information that was given to students to help them prepare for this opportunity:
    - *"We are proud to significantly increase the number of students that will take part in The Global Learning and Observations to Benefit the Environment (GLOBE) Program, from 5 students in 2017/18 to 25 for 2018/19. The increased access to GLOBE is in direct response to the amazing success attained by our citizen scientists last year, along with the unmatched, deep learning opportunities the GLOBE Program will continue to afford our students.*
    - *All Shumate Students are eligible to apply for The GLOBE Program this year. Students will work in teams as they collaborate with experts from Wayne RESA and NASA as they conduct research toward their final project.*
    - *Teams will compete in this year's GLOBE International Virtual Science Symposium (IVSS), along with next year's GLOBE SRS.*
    - *Students that wish to take part in this year's GLOBE Program will need to see Mr. Bouwman and listen to announcements during the first week of school for further details regarding the application process."*

Troy Public Schools

The AREN Project is currently working with teachers from the Middle schools in the Troy School District. The purpose of this cohort is to support their current work in water quality testing and integrate GLOBE and the AREN Project into their defined work. GLOBE protocols used by this cohort include those dealing with the Atmosphere and Hydrosphere. Teachers and schools participating in the project include:

Baker Middle School

Boulan Middle School

Larson Middle School

Smith Middle School

AREN goals for these middle schools are:

- All teachers become certified GLOBE teachers through Protocol eTraining.
- Smith Middle School participates in the Rouge Education Project and shares data collected. (2018+)
- All students build and fly a Frustrationless Flyer kite, in the classroom. (2018)

- Each school successfully flies a Delta Kite with an attached Aeropod to do aerial imaging of their water and school study sites. (2018+)
- Each school successfully collects atmospheric data during kite launches.
- Students use AREN and GLOBE for Student Research Projects that can be shared at the GLOBE Virtual Science Fair and/or the GLOBE Regional Student Research Symposium.

Mission Earth Educators

Mission Earth Educators participated in AREN training during the summer of 2018 or are associated with Mission Earth in some other way. Schools include:

- Main Street Intermediate School -- Norwalk, OH
- Clay High School -- Oregon, OH
- Ottawa Hills Jr/Sr High School -- Ottawa Hills, OH
- Perkins High School -- Sandusky, OH
- Byrnedale Elementary School -- Toledo, OH
- St. Andrew Catholic School -- Cape Coral, FL
- Leverette Elementary School -- Toledo, OH
- Waite High School -- Toledo, OH
- Ottawa Hills Jr/Sr High School -- Toledo, OH
- Langston University -- Langston, OK
- Waite High School -- Toledo, OH
- Pioneer Career and Technology Center -- Shelby, OH
- St. John's Jesuit High School and Academy -- Toledo, OH

Arctic and Earth SIGNs

Katie Spellman, Josh Jones and Elena Sparrow represent the Arctic and Earth SIGNs Project, a NASA CAN Award. They participated in a June, 2018 AREN training at Montana State University. Josh and Elena are with the AAOKH (Alaska Arctic Observing Knowledge Hub). Hence AREN is a good facilitator of this working relationship building. Josh and Elena are planning to work with a North Slope Borough School District teacher to do kite training, where AREN will eventually be used. They are exploring the use of AREN in doing GLOBE investigations and possibly sea ice and/or tundra surface characterization; taking temperature and

barometric pressure readings. Arctic and Earth SIGNs may need additional AREN training in Alaska, to help train the AAOKH community members and/or GLOBE effort to use AREN tool(s) for environmental monitoring efforts and science investigations.

STEM Literacy Community of Practice

Betsy Stefany participates in the AREN Project by researching the use of AEROKATS to collect data on Albedo and atmospheric light conditions responding to land cover, soil and water conditions. Co-PI Andy Henry designed several custom “FlyPods" for that work with the cameras to research small site conditions. Betsy works with the SABENS Group, a New Hampshire based consulting firm, aiding entities to bridge from traditional to emerging learning systems.

Betsy Stefany Coordinator, STEM Literacy Community of Practice

Mike Jabot

Mike Jabot is a Science Education Professor and Director of the Institute for Research in Science Teaching at State University of New York at Fredonia. He is also a US GLOBE Partner, as well as a NASA Earth Ambassador. He is using AREN as a teaching tool to help develop the understanding of GLOBE and Remote Sensing in preservice and inservice teachers. His work has centered around how we can develop the skills presented in AREN in students as young as early middle school and have found AREN to be an incredible tool.

Mike's goals for 2018 - 2019 are to use AREN to establish baseline imagery and analysis in the Fall to use with GLOBE ground truthing with hopes that students will then use these data paired with imagery that we will collect using AREN in the Spring.

PASCO

Mike Blasberg is the Biology Product Manager for PASCO. PASCO has been supportive of the AREN Project and has made PASCO Weather Sensors, to the AREN team.

Smoky Mountains STEM Collaborative -- Southwestern Community College is an AREN cross-collaborator within the NASA Science Activation Team. Their NASA Can Award is the

"Smoky Mountains STEM Collaborative: Bridging the Gaps in the K-12 to Post-Secondary Education Pathway." Though the work of Matt Cass, the collaborative has worked with the AREN Project to produce a poster on the dynamic analysis of kite flight.

Bulgaria

Lachezar Hristov Filchev is an Associate Professor in the Space Research and Technology Institute at the Bulgarian Academy of Sciences. As a remote sensing scientist, he is interested in helping non-experts understand aerial observations. He is also interested in making this a more affordable experience. He is in contact with Bulgarian teachers to reach AREN goals.

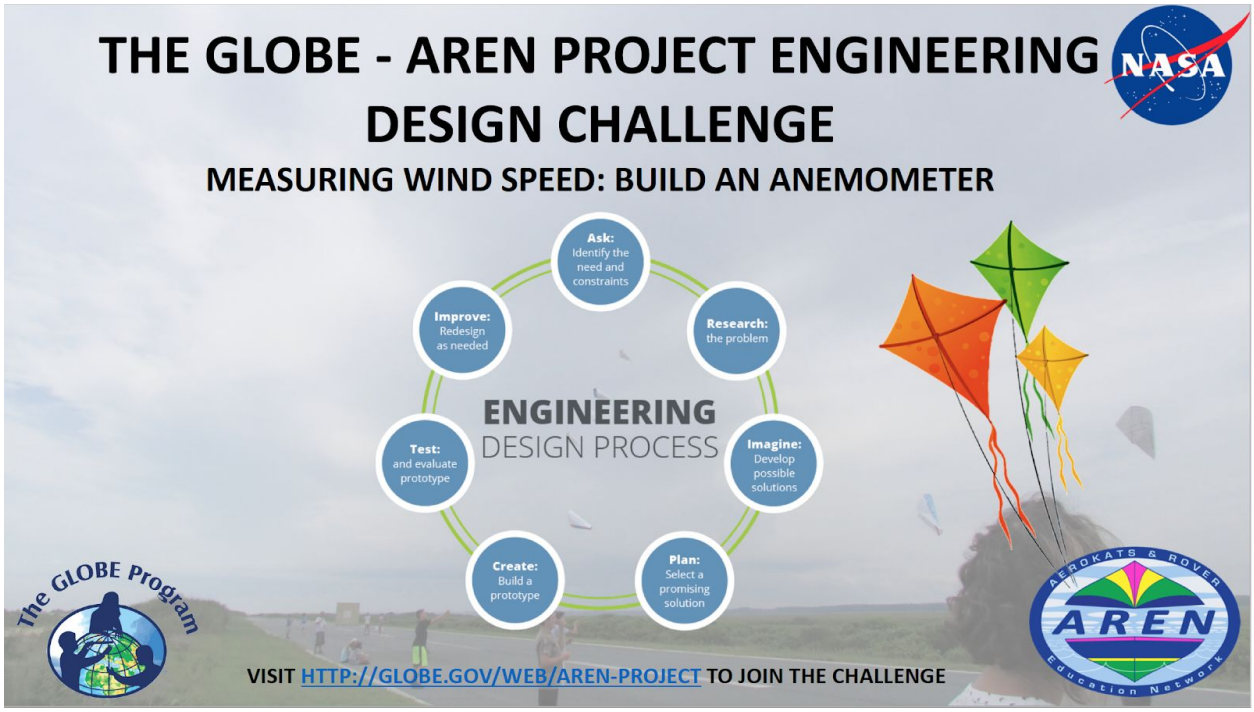
Bulls - EYE

The University of South Florida continues to incorporate NASA technologies in informal and formal educational settings. The collaborative relationship has always focused on impactful initiatives that involve middle school youth and the framing of activities through GLOBE protocols. One other aspect of USF's work has been a focus on engineering design to improve the educational technology. Work has been completed to use NASA technology informal and informal settings again this year with a novel approach to engineering design for new Aeropods. The design component has focused on developing the project's rapid prototyping capability and framing design activities within a service learning context. The two major initiatives discussed in this report that have been a focus of the USF collaboration are its Bulls-EYE Mentoring outreach program and AEROPOD use in its freshman level design course. The accomplishments of each initiative will be discussed along with ties to the goal of the project.

Palmyra Cove

John Moore and Peter Dorofy from the Institute for Earth Observations at Palmyra Cove are participating in the AREN Project.

Progress made toward a GLOBE / AREN Engineering Challenge in Conjunction with the Engineering Team from Mission Earth -- Submission to GLOBE Science Working Team



GLOBE/AREN Project Engineering Design Challenge
"Measuring Wind Speed: Build an Anemometer"
http://globe.gov/web/aren-project

Goal
Engineer a low-cost electronic or non-electronic anemometer (tool for measuring the speed of wind).

Driving Question
How can you *engineer* a tool for measuring wind speed?

Timeframe
December 2018 – January 2019

GLOBE Alignment
The GLOBE Program does not have a protocol for determining wind speed. The GLOBE Program supports the AREN Project, which utilizes kites to collect data. In order to safely fly a kite, it is important to determine wind speed. Whether you are flying alone or in a busy park, it

is good to remember the three C's of kite safety – Caution, Courtesy, and Common Sense. This challenge provides the opportunity for the community to *engineer* a low cost (less than $30) method of determining wind speed that could be used throughout the world.

Challenge Procedural Steps
1. Select an age appropriate category – Grades K-5; Middle School; High School; Undergraduate School; Citizen Science

2. Select a product category – Electronic; Non-Electronic
Note – Non-Electronic means that the measuring device is not electronic. It is understood that a timer or video camera may be required to calculate data.

3. Visit the GLOBE Project and learn about Wind
(https://www.globe.gov/do-globe/globe-teachers-guide/atmosphere)

4. Visit the AREN Project to learn about the role of kites and safety requirements when flying kites.
https://www.globe.gov/web/aren-project/overview/aerokats

5. Construct a low-cost (less than $30) for measuring wind speed.
Please note, wind speed should be determined at 1.5 meters above ground level. Comparison to a known wind speed measurement tool may help support your conclusions on your tools measurements precision and accuracy.

6. Accuracy and Force Range – Please keep in mind that GLOBE emphasizes accuracy in measurements and that units are standard throughout the world. The range should complement the Beaufort Force Scale:

Force	km/h	Description
0	<1	Calm, smoke rises vertically
1	1 – 5	Direction of smoke shown by drift, wind vanes don't move
2	6 - 11	Wind felt on face, leaves rustle, wind vanes move
3	12 – 19	Leaves and small twigs in constant motion, light flags extended
4	20 – 28	Raises dust and loose paper, small branches move
5	29 – 38	Small trees with leaves sway, crested wavelets on inland waters

Product
Submit a *storyline*:
· Written Word
· Video
· Audio
explaining how you and/or your team engineered a low-cost tool for measuring wind speed. Include information about you/your team, design materials, data, evidence of failure/success, cost, photos, and final product, the *engineering design process*!
Standards Alignment
Grades 3-5 Engineering, Technology and Society: 3-5-ETS1-1
DCI-Possible solutions to a problem are limited by available materials and resources. The success of a designed solution is determined by considering the desired features of a solution. Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

Middle School Engineering, Technology, and Society: MS-ETS1-1; MS-ETS1-4
DCI-The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful.

High School Engineering, Technology, and Society: HS-ETS 1-3
When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Undergraduate Engineering, Technology and Society:
An ability to design and conduct experiments, as well as to analyze and interpret data; an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; an ability to function on multidisciplinary teams; and an ability to identify, formulate, and solve engineering problems.

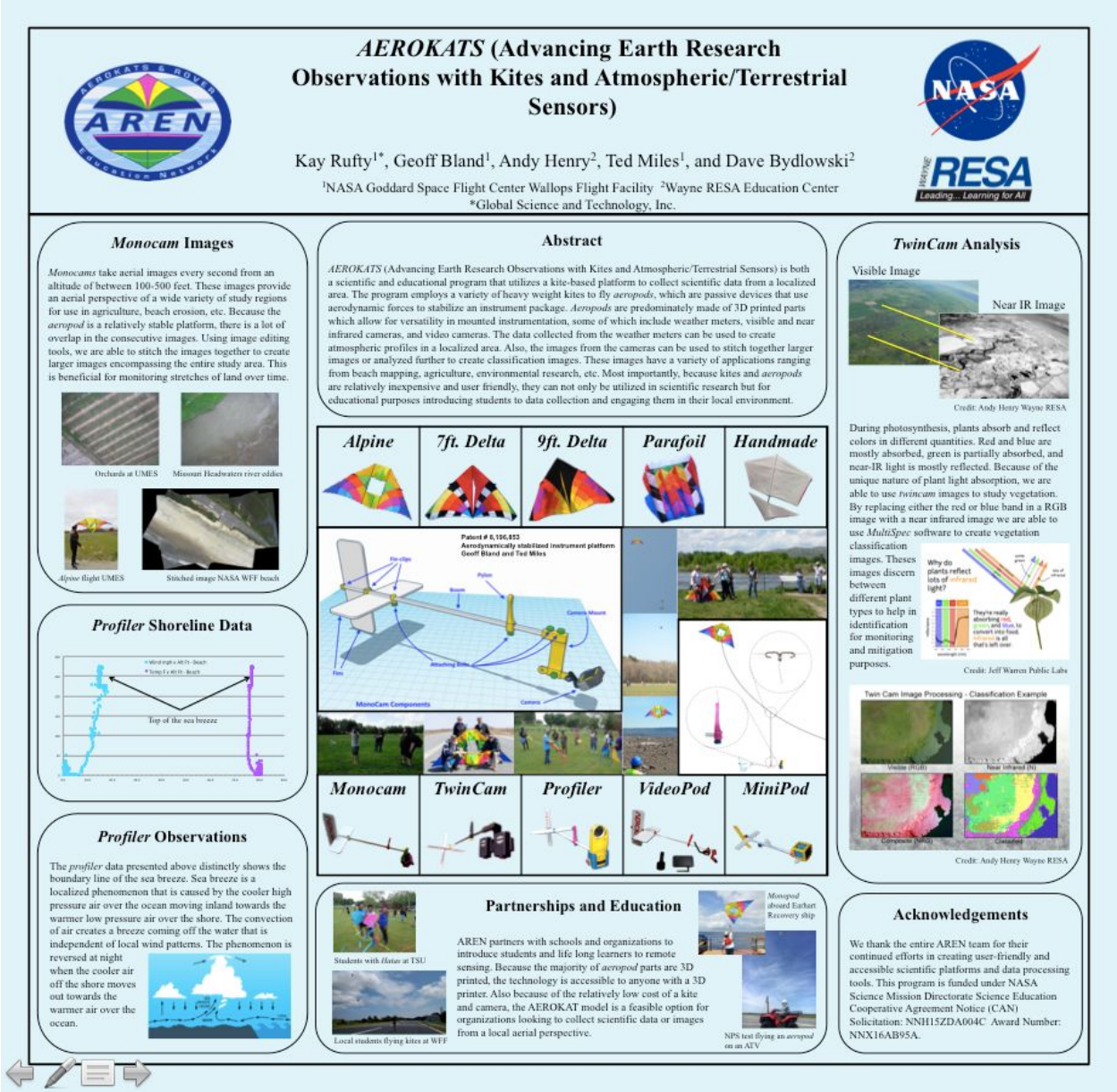
Awards
10 (5-USA and 5-World) successfully engineered products will randomly be selected to be the recipients of an AREN Kite package. The package includes a kite, kite string, Aeropod (an aerodynamically stabilized instrument platform for kites), and more.

III. Status/Changes/ Issues

The major change taking place in the AREN Project is a change in evaluator. Dr. Anil Aranha has been our evaluator since the beginning of the project. Thanks to Anil for his hard work and dedication to the AREN Project. Anil not only did the evaluation for the AREN Project, but he also served as the logistics person for the 2018 GLOBE Midwest Student Research Symposium, held at Wayne State University School of Medicine, in Detroit MI. The success of the symposium is due in large part to the work of Dr Anil Aranha. Unfortunately the AREN team is looking for a different direction in evaluating the project. The new evaluator/team will be selected by the end of 2018.

IV. Dissemination Activities

Poster by Kay Rufty (GSFC) for AGU Presentations



NASA Spinoff Publication -- 2018

NASA Kite Invention Spurs Ever-Growing Educational Program

https://spinoff.nasa.gov/Spinoff2018/ee_8.html

The Investigating Climate Change and Remote Sensing project, which came to involve schools and organizations across the country, began with one educational agency serving a county in Michigan and its interest in aerial imaging to monitor conditions at ponds and streams where water samples were being collected.

When an educational agency contacted NASA engineer Geoff Bland in 2010, wondering about a way to monitor ponds and streams where water samples were being collected, he gave what may have seemed an unconventional answer: "I said, 'Would you be interested in flying kites?'" he recalls.

Wayne Regional Educational Service Agency (RESA), which supports schools in Wayne County, just outside Detroit, had students comparing water quality in Michigan's Upper Peninsula with the rest of the state. It had occurred to someone, though, that conditions at the water collection sites weren't being monitored. "We wondered, is there some way to put up cameras and take pictures of the study sites?" says David Bydlowski, science consultant for Wayne RESA.

So the group had applied for and been granted a small NASA Cooperative Agreement Notice (CAN) award to explore options. Organizers had no idea Wayne RESA was about to be at the center of a project involving a multitude of organizations across the country, from Fairbanks, Alaska, to the Chesapeake Bay.

Through a series of contacts, the group ended up in touch with Bland, who works in the Earth Science Field Support Office at Goddard Space Flight Center's Wallops Flight Facility. Bland had worked on other educational programs that incorporated remote sensing and Earth-observation data, and he had also recently invented a new, low-cost, easy-to-use device for keeping cameras and other sensors in the air.

Bland has been involved with aerial imaging since the 1990s, when he led the creation of the first small electrically propelled drone to be outfitted with scientific research sensors. Interested in simpler, cheaper solutions, he looked to kites but found that the traditional tool to stabilize a camera on a windblown kite didn't provide the stability he needed and tended to get tangled. So he and NASA technician Ted Miles built something better.

Their AeroPod device is aerodynamically stabilized and is not attached directly to the kite but to a line that hangs from a ring suspended between ball bearing swivels on two segments of kite

string. It was patented in 2012.

AeroPods can be equipped with the same sensors commonly flown on drones and require far less training. “You can take somebody who’s never flown anything and have them taking data with a set of sensors after a day of training,” Bland says. They also never run out of power.

Wayne RESA’s leadership, with Bland’s collaboration, ultimately came up with the Investigating Climate Change and Remote Sensing (ICCARS) Project, which was piloted in 2010. It was much more ambitious than the original plan to monitor water quality test sites.

The team developed 60 lesson plans for middle and high school students, some intended as classroom course material and some as extracurricular activities. The program uses AeroPod-gathered Earth-imaging data to understand the science of climate change and its relationship to changes in land use and land cover.

To license the AeroPod technology at no cost, the Goddard Strategic Partnerships Office created a new educational license that requires feedback rather than monetary payment. “If end users want to develop their own AeroPod, that’s absolutely all right, as long as they tell us what they like and don’t like about it,” Bland says. Licensers also must share any data that’s of interest to NASA and any of their own advancements to the technology.

Bydlowski, who became the science lead for ICCARS, says organizers wanted students to understand the parallel between what they were doing with imagers on kites and what NASA does with its many Earth-imaging satellites. “We’re collecting data from the ground, and if we collect data day after day like a satellite does, we can start to draw some conclusions,” he says.

Aerial images taken in the visible and near-infrared spectra indicate the health of crops, so participants might analyze imagery collected in their community with AeroPods to determine biomass and predict crop yields. They could then look for relationships between crop growth and factors like temperature changes.

Hanging from a ring suspended between ball bearing swivels on two segments of kite string, an AeroPod is a more effective means of stabilizing a kite-borne imager than previous methods such as Picavet mounts.

The program provides customized handheld field data collectors with a software package for processing images, pinpointing locations with GPS, and transmitting data back to the classroom. Students share data with the ICCARS community through the project’s online portal, and they share it with the world through the Global Learning and Observations to Benefit the Environment (GLOBE) Program, an international school-based science and education program.

After the two-year CAN funding expired, Wayne RESA continued its ICCARS work, and in 2016, NASA granted the agency a five-year CAN award to expand the program into what’s now known as the AEROKATS and ROVER Education Network (AREN). AEROKATS, or

Advanced Earth Research Observation Kites and Atmospheric and Terrestrial Sensors, refers mainly to the kite-based AeroPod portion of the program, while ROVER introduces the Remotely Operated Vehicle for Education and Research, a remote-controlled watercraft for collecting water data. The ROVER series of in-water measurement systems were also developed at Wallops by Bland and Miles, in collaboration with the University of Maryland Eastern Shore (UMES).

Along the way, several partners have joined in as co-investigators or collaborators on AREN, with Wayne RESA as the lead institution. The University of South Florida has developed an engineering mentoring program for middle school students, designing and building ROVERs, while the University of Alaska, Fairbanks, is rolling aspects of the project into an educational program studying the warming Arctic. The Chesapeake Bay Environmental Center is helping to develop equipment and operations. Goddard and UMES continue to work together on developing and implementing these educational tools, and new partnerships also include Anasphere Inc., Montana State University, Public Lab, and Washington College.

What has made ICCARS and now AREN so popular and effective is that students are getting out in the field, collecting real-world data, and coming up with their own questions to answer with that data, rather than having information and questions fed to them in the classroom, Bydlowski says.

All the while, Bland says, he's made sure the Space Agency's rigorous operations procedures are part of the curriculum. Like a rocket launch, each flight or mission is a team effort in which all participants have specific roles, checklists are developed and followed, risks are assessed and mitigated, and operations are preceded and followed by comprehensive briefings.

Bland says students who participate in the programs end up better equipped to work with aviation and develop scientific research projects.

Project leaders are still gathering data to quantify the programs' success, but Bydlowski notes that first and second place in the 2016 Midwest Regional Science Fair went to students who had participated in ICCARS, as did first place in the 2013 international GLOBE Student Research Exhibition.

It's impossible to know how many students have learned new skills from the programs, but 31 schools in Wayne County participate, while countless students and teachers from coast to coast have also gotten involved.

Bland says he wants the program to improve the quality of future science and bolster NASA's ranks. "I hope the young people participating today turn into the next generation of NASA engineers, scientists, professionals, and support staff, people who will help us continue to understand our own planet and explore the universe," he says.

"And, hopefully, the program is fun, too."

GLOBE Blog

"For GLOBE teacher Diana Johns, every day is Earth Day"

July 24, 2018

In the spring of 2017, The GLOBE Program, an international science and education program sponsored by NASA, and supported by the National Oceanographic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and the U.S. Department of State (DoS), held six regional Student Research Symposia (SRS) where GLOBE data-collection protocols were used.

In this series of feature stories, we are able to see some of the teacher/student teams who were present at these symposia.

It's hard to believe that in the early 1970s, the environmental movement was strong and popular—and largely unchallenged, except by corporations responsible for air, ground, and water pollution. John Denver's anthems to the mountains and the skies were chart-topping hits. And the very first Earth Day, on April 20, 1970, became a perennial day of celebration and activism.

"What put me on the path to where I am today," said Diana Johns, science teacher at Crestwood High School in Michigan, "was that first Earth Day. About ten of us, high school juniors, organized activities for it. We saw something we could do. We got them to shut down the whole school in terms of regular academics for the day to do something environmentally related. That day led to my major in college," and, she would add, 43 years of teaching science.

However, some would counter that Diana's close ties to the natural world—which led her to become associated with GLOBE as a teacher and advocate in its earliest days—go back further. David Bydlowski, who has worked with Diana for decades as a GLOBE Partner and liaison, notes that she has a powerful connection to nature. Even outside the classroom, she helps her students understand natural cycles and the lives of animals in rural Michigan.

"She's always been a teacher who gets her kids outside," said David. "She gets them to do hands-on science not just in her school but in the community. Students would do projects where they might need to find a particular animal and study its characteristics." Diana, he said, knows just where to find what they need.

Not that Crestwood High sits in an environmental wonderland. "We're a suburban high school that's grown a lot in recent years, with 1,400 students designed for 1,200," Diana said. "It's a good thing we like each other!" As a suburb of Detroit, Dearborn Heights has "more houses than trees…open, flat, with no bodies of water." That requires Diana—who primarily teaches advanced placement environmental science—to get creative about connecting students with nature to employ GLOBE protocols and equipment.

"Our kids built a pond inside one of our courtyards, turning it into a living laboratory," she said. "They're making pollinator plants and edible gardening, some of which get dispersed out into the community."

"We've been doing GLOBE for quite a few years," said Diana. "For kids who couldn't

make a connection strictly with content, once they had a chance to go out and make observations, collect data…it helps them think a lot, plan, and coordinate." Diana treats GLOBE not as a separate add-on project—it's integrated into her existing curricula and standards. "A strength is the association with NASA. It's a real draw for kids. They see it as not just some silly reason to go out and collect data…it has a bigger purpose."

While Diana and her students have done some work with the GLOBE hydrology protocols, it's difficult because the closest water is a river five miles away, "and kids don't drive like they used to." She has focused more on GLOBE's atmospheric and aerosol protocols, preferring study that "is a little more rigorous…at the high school level, it has to feel more meaningful."

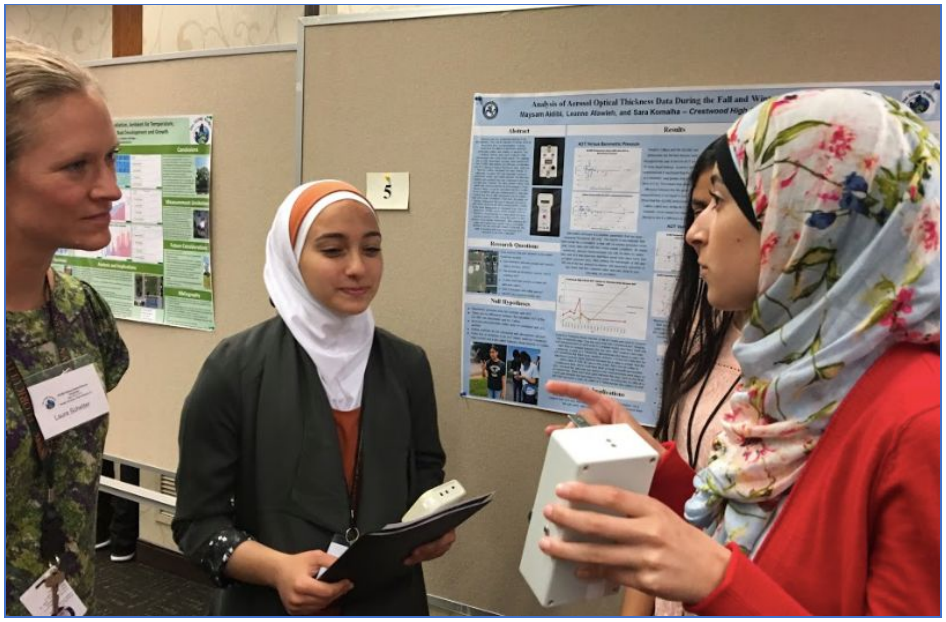
The aerosol work has given her students a chance to talk with other scientists around the United States. "One of my students got to be a representative down at NASA to discuss aerosol data. Another talked about this work with admissions officers at Stanford and MIT…that's how much GLOBE has really resonated with these kids. It's part of their DNA. All of our students participate by collecting data, but for some at the higher levels, GLOBE is the keystone of their science experience in high school."

Students feel excited when they realize some of the data they collect and analyze could be shared with Michigan's Department of Natural Resources. "They see that what they're collecting can be useful to people in the seats making decisions," Diana said.

Real environmental events have given Diana a chance to make science study even more concrete. "Using photometers, students measured aerosol particles of soot in the atmosphere from forest fires burning out west. We're just beginning to learn how fires impact climate change. When we were overseas at a GLOBE event in India a few years ago, we got a chance to see the instrumentation they use in Europe, so we ordered a photometer from France to use in our school."

Last summer's eclipse, which put Diana's school in the 80 percent totality band, resulted in a project her students submitted this spring to the International Virtual Science Symposium. "We have all this data collected during the eclipse on surface temperature, air temperature, observations on binder plants and weeds as they opened and closed in response to the light."

Taking their projects on the road



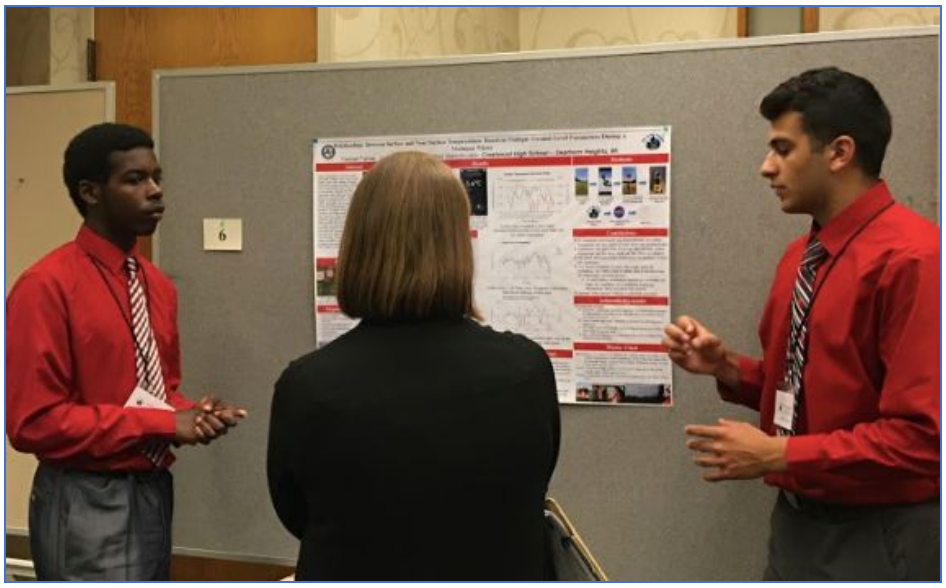
Crestwood students explain their research at the 2017 Midwest SRS.

Nine students accompanied Diana to the GLOBE Midwest Research Symposium at Purdue University last spring. "I had never been before…Purdue is like space central in terms of astronauts who went there." In addition to getting the "college experience"—a full tour, eating college food, visiting the bookstore, sitting in a lecture hall—the nine students, in three teams, got a chance to present their GLOBE projects to scientists, local teachers, and students from other schools. "It was so much fun for them," Diana said. "At meals, scientists came and sat to talk with the kids. The students could show their enthusiasm, be articulate, poised, and confident…to show off something you spent months on and give their 'elevator talk' in just a few seconds."

For their effort and excellence, the Crestwood students came home with recognition from the symposium. Two of those students, Ali and Sara, both 16 years old, explained how their presentation focused on aerosol data that examined the correlation between barometric pressure and sulfate particles. "We decided to find out how our data compared with a school at a similar latitude in Croatia," Sara said. So, online, they researched other schools who were collecting particulate data and incorporated it into their analysis.

"We brought a poster with us to show the reviewers how we came to our conclusions," said Ali, "and also brought a graph of a fire in Canada a year before to see how it affected aerosols."

As Sara and Ali enter their senior year, Ali is looking at STEM study (probably engineering or chemistry) at the University of Michigan and Sara is considering mathematics ("but after GLOBE, I want to make sure I incorporate science into it…GLOBE changed my mind about that," she said).


Crestwood students presenting at the 2017 SRS.

Diana explained that Crestwood has capstone projects for their seniors, who invariably choose environmental topics. "It's in the forefront of their minds, a theme that follows them all through high school and into college. Kids email me when a college teacher mentions something about hands-on science. Because of GLOBE, a lot of my students have chosen related pathways in college."

Their longer concerns are also in view: Said Ali, "I think that more needs to be done to stop rising temperatures. Our current leaders are not doing enough." Sara agreed: "We just researched aerosols and it shows a need to call attention to serious problems. We have to do something. We have one planet."

Before college, though, GLOBE has plenty more to offer Diana and her students. Teams will be attending this year's symposium (the midwestern event for 2018 is happening in Detroit), and Diana will be taking a small group this July to Killarney, Ireland for the GLOBE Learning Expedition. "The school administration had turned down two other international trips requested by other groups this year, but when we presented our GLOBE work, and they heard how the kids spoke about their GLOBE experience, the school board couldn't wait to tell them they could go," Diana said.

Partnership and friendship

As one of the first educators to be trained by GLOBE in the mid-90s, Diana has benefited from, and greatly enjoyed, her partnership with David Bydlowski, who works as a science consultant at the Wayne RESA (a regional educational service agency that provides support in the sciences). David also locally leads two exciting NASA-projects (the AREN Project). One relates to aeropods—kites and weather instruments that carry sensors and cameras up to 1,000 feet to study

the atmosphere. The second involves rovers, or remote-controlled boats, carrying sensors and cameras that give students the opportunity to study lakes and rivers beyond the shoreline.

GLOBE pairs every teacher with a representative like David from a college/university or other local or regional science organization as a means of support and bridge-building. "When I first started out, we had to string wires through the ceilings for the phones and modems to work," Diana recalled. David has worked with her from those very early days, helping her acquire grants and equipment, providing guidance and advice on how to access resources, and being a good friend to both teacher and students as they work to integrate GLOBE thinking and protocols into daily learning.

"Diana and I go back a long time," said David. Beginning with a water quality monitoring program and the Rouge River education program, the connection with Diana has been "a natural."

"We just celebrated our 25th year with the Rouge River project, but we've known each other 40-some years. As a teacher, she's exemplary, just outstanding. One thing that really impresses me is that when we get older, a lot of people take the easy track in life. With Diana, her enthusiasm is as great as it ever was. Her rapport with students is exceptional and she is a very, very caring person."

One of the characteristics of GLOBE, David said, is caring about both the environment and the people who are in it. "It's a kind of laid back sort of trait," which absolutely describes Diana. David states that the culture at Crestwood High School has changed over the years and the school is steadily moving to exemplary status academically. "Diana has had a lot to do with that.

It's impressive to see a person who's gone through a change like this in a school district. She's a rock, really accepting of change."

He adds that Diana has become an enthusiastic leader in the broader GLOBE community as well. "She's a real leader, bringing a lot of leadership skills to help others get involved in GLOBE."

Said Diana about David, "He's phenomenal, always able to provide resources to collect data…and some of this equipment is very expensive. He goes above and beyond for us. He takes the time and effort to make the kids a real priority and it makes a world of difference.

'He gets everybody fired up—students and teachers both."

—C. Ralph Adler

The GLOBE Program sponsored six 2018 Student Research Symposia funded by NASA Grant No. 80NSC18K0135. For information on these, visit the 2018 Symposia pages. Bookmark the SRS webpage to stay updated on dates, locations, and application procedures for 2019.

The 2017 Regional Research Symposia were funded by National Science Foundation Grant No. 1546713. Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors(s) and do not necessarily reflect the views of the National Science Foundation.

Publications and Articles from Montana State University

An article on the event, including instructions for hosting a similar activity, were published on the national blog of AREN partner Public Lab.
https://publiclab.org/notes/SuziT9/03-08-2018/building-miniature-kites-at-a-family-science-night

Building miniature kites at a family science night

by SuziT9 | March 08, 2018 22:00 | 318 views | 4 comments | #15900

SuziT9 was awarded the Basic Barnstar by xose for their work in this research note.

On March 1, 2018, several members of our Montana State University team (Academic Technology and Outreach)

shared a hands-on engineering activity with hundreds of kids and adults at MSU's annual Family Science Night on March 1.

We are all part of the NASA AEROKATS and ROVERs Education Network (AREN), and our goal was to engage and excite kids of all ages by helping them build miniature kites (see supplies, equipment and observations below). AREN is a program supported by NASA Science Mission Directorate Science Education that designs and uses low-cost instrumented systems for in-situ and remotely sensed Earth observations including kite-based "AEROKATS" and remotely controlled aquatic and land-based "ROVERS."

In the morning, the event hosted 150 fifth graders from local Title 1 schools (high percentage of free and reduced lunch). The evening saw 385 members of the community - mainly families with children, some as young as 2 or 3 years old.

To say it was controlled chaos is putting it mildly!

At our AREN station, kids (and sometimes their parents) used tissue paper, mylar, silk thread and 20-inch straws to build one of two different miniature kites based on the excellent designs and resources of Glenn Davison. AREN team members assisted with the construction process while sharing an overview of the NASA AREN project and words of encouragement for our country's future scientists and engineers. The miniature kites featured blue and gold materials to celebrate Montana State University's 125th birthday.

Overall, kids and adults really enjoyed this activity, and -- if they followed the instructions -- the kites really flew!

Below are the materials and equipment we used, preparation, observations and possible extensions.

Enjoy!

Materials

* Tissue paper (*Experimented with copy paper and plastic tablecloths; tissue worked best)*

* Mylar (roll of 24" x 8 feet) *(Experimented with audio cassette tape; mylar worked best)*

* Silk thread

* 20" straws (bought in packs of 200 for about $20 on Amazon)

Equipment

* Tape dispensers (many)

* Scissors (several)

Other

* Signs /banners publicizing the activity/project

* Signs or laminated sheets with step-by-step instructions *(This was really helpful because we had so many kids at once and one-on-one help was not possible)*

* Cardboard template(s) if kids will be cutting their own tissue paper (We pre-cut the tissue)

* Large surface area for construction plus chairs

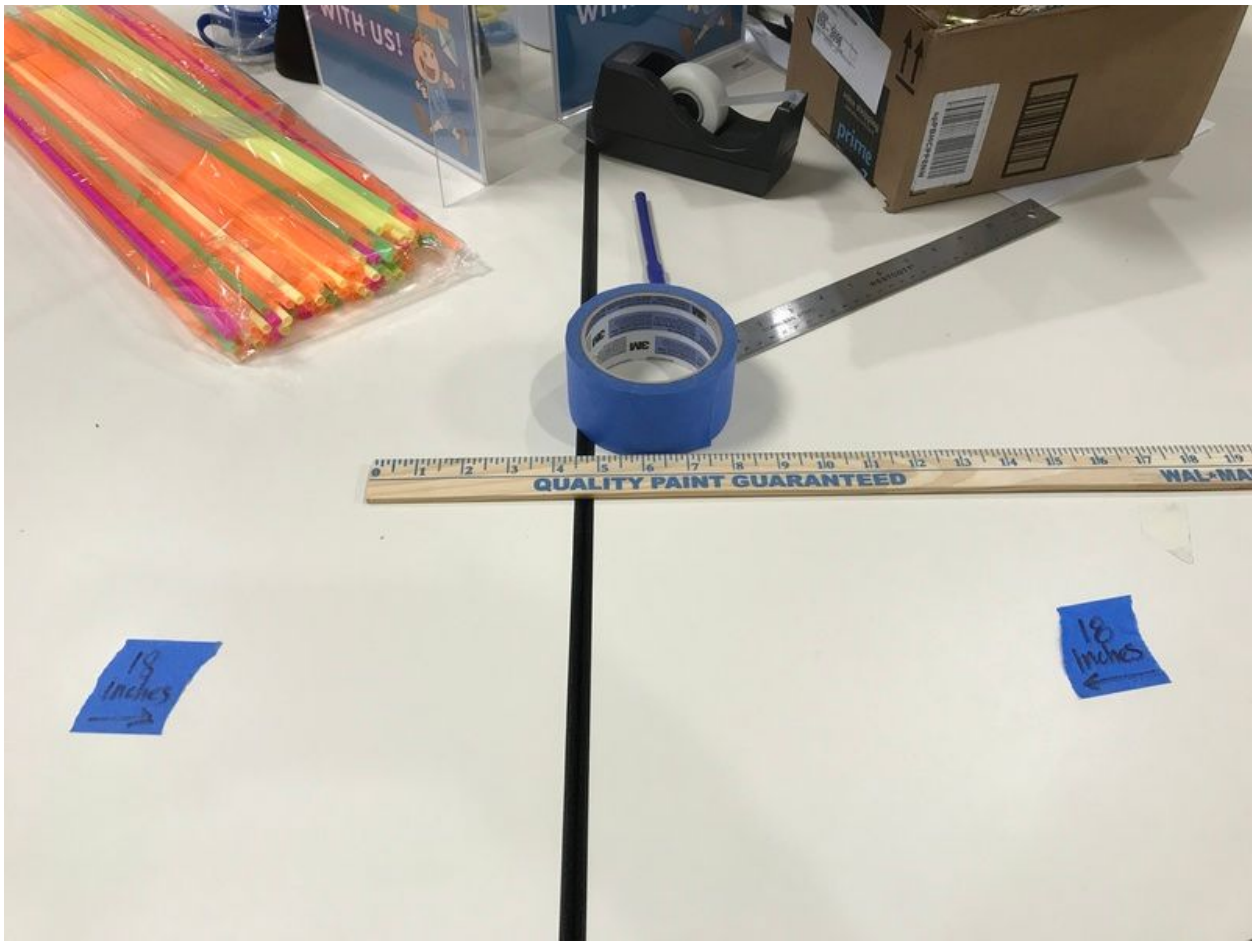
Preparation

* Pre-cut tissue paper for Rokkoku and Koren Fighter Kite designs (*or kids can do it themselves if you have more time and less chaos)*

* Pre-cut gold mylar tails (The mylar is fairly expensive and a bit hard to cut so allow enough time. Best if

kids don't do it)

* Marked off 18-inch spans with painter's tape on table (for thread) (Kids tended to cut the thread way too long, thinking longer is better)



Observations

* Kids under about fifth grade require parent's help

* Kids (and parents) want to experiment with the design ("be creative"), but those kites do not fly. Need a gentle way of telling people to follow the instructions

* "Being creative" can also use up your materials supply

* Kids will try to take a big straw (because they're fun) without making a kite

* Need to find the balance between "helping" and "doing it for them."

Possible extensions

* Make a list of questions we as facilitators could ask (either orally or on a sign) that encourage kids to think about the design process

* If lots of time and small group, could experiment with various designs before "unveiling" the field-tested

design that really flies.

For more information, feel free to contact me! It was super fun and educational, too.

Suzi Taylor - taylor@montana.edu

ARENA was also included in an article posted on the National Informal Science Education Network (NISENet) site:
http://www.nisenet.org/blog/post/partner-highlight-nanodays-transforms-msu-family-science-night-montana-state-university

Partner Highlight: NanoDays Transforms into MSU Family Science Night at Montana State University

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March 6, 2018
Suzi Taylor, MSU Academic Technology and Outreach
Partner Highlights

What started as a six-station gathering in the lobby of a Montana State University academic building has grown into a university-wide event that fills the student union ballrooms and reaches more than 500 members of the community.

Montana's first NanoDays launched in 2008 as a partnership between MSU Extended University, Montana NSF EPSCoR and MSU's Center for Bio-Inspired Nanomaterials (CBIN). In 2015, the event was renamed NanoDays/MicroDays to accommodate the many small-but-not-quite-nano scientists and engineers who wanted to participate. Demand grew further still, and in 2018, the event was re-christened MSU Family Science Night (featuring NanoLand) to host all the university faculty and students who wanted to take part. This year's event was held March 1.

Photo credit: Adrian Sanchez Gonazlez, MSU

In addition to NanoDays activity classics such as Gummy Capsules, and Invisibility, this year's event featured activities from the Explore Science: Earth & Space Toolkit like Filtered Light and Magnetic Fields. MSU Family Science Night also showcased other projects such as NASA's Aerokats and Rovers Education Network (AREN), which built miniature kites and WAFERx – an NSF-funded effort on the water-energy-food nexus, which featured an algae biofertilization demonstration. Also featured was "Bobcat Birthday Science" to celebrate MSU's 125th birthday.

Photo credit: Adrian Sanchez Gonazlez, MSU

Dr. Wataru Nakagawa of MSU's Electrical and Computer Engineering Department has participated in NanoDays since 2010 and estimates more than 40 students from his lab have honed their nano communications skills in "NanoLand" by donning clean suits, demonstrating Nano Gold and helping kids crawl through a scale model of a human hair.

The 2018 Family Science Night event reached 150 fifth-graders from local Title 1 schools (high percentage of free and reduced lunch) and 385 members of the community. An additional 50 MSU students, staff and faculty volunteered, including many pre-service teachers from MSU's College of Education.

Family Science Night is hosted by MSU Academic Technology and Outreach. For more information, visit http://ato.montana.edu/familyscience.

Calendar for Training and Professional Development

2017 Calendar -- November - December

November 11 -- "Grade 3 Weather and Climate with Elementary GLOBE Resources" (David Bydlowski) at the Metropolitan Detroit Science Teachers Association Conference in Warren, Michigan

November 11 -- "Aerial Exploration of Environmental Study Sites Using Kites, Cameras and Other Sensors" (David Bydlowski and Andy Henry) at the Metropolitan Detroit Science Teachers Association Conference in Warren, Michigan

November 13 - 17 -- "NASA SMD Science Activation Annual Meeting" (Anil Aranha, Geoff Bland, David Bydlowski, and Andy Henry) at the Lansdowne Resort and Conference Center in Leesburg, VA.

December 11 -- "A New Dimension for Earth Science Learning" (Geoff Bland) at the AGU Conference in New Orleans, Louisiana. (Approximately 25 people in attendance)

2018 Calendar -- January -- October

January 24 -- GLOBE Student Research Symposium Teacher Webinar: Writing Conclusions using the CER Framework (David Bydlowski) (9 Educators participated in the broadcast. It is available on YouTube and Viewers are recorded.)

January 25 -- AREN Project presentation on "AREN and the REP" and "Why Teachers Should Join the SRS" (David Bydlowski) at the Returning Teacher Refresher Workshop for the Rouge Education Project at the University of Michigan Interpretive Education Center in Dearborn, MI (8 Teachers Participated)

February 1 -- UMES Team Tag-Up (Bland, Quinton, Bonsteel, Brown, Campbell, Dabipi, Levin, Hartman, Clark, Wink, Mitchell, Nagchaudhuri, Rufty, Miles, Xavier and Zhang) at University of Maryland Eastern Shore in Princess Anne, MD

February 14 -- "Observe the Earth and Visualize the Future: Brining Geovisualization into the Precollege Classroom" (Please note, this presentation begins at the 16 minute mark) which includes an AREOKATS Presentation (John Moore and Peter Dorofy) at the Goddard Space Flight Center in Greenbelt, MD

February 18 - 24 -- Engineers Week

February 20 -- "Come Fly With Us" a citizen science adult education workshop involving the use of AREN equipment (Judy Wink, Vicki Paulas, Alissa Quinton) at the Chesapeake Bay Environmental Center in Grasonville, MD (10 Educators Participating)

February 27 -- "Come Fly With Us" a citizen science adult education workshop involving the use of AREN equipment (Judy Wink, Vicki Paulas, Alissa Quinton) at the Chesapeake Bay Environmental Center in Grasonville, MD (4 Educators Participated)

March 1 -- Deadline for Students to submit their research for participation in the GLOBE International Virtual Science Symposium

March 1 -- Family Science Night (Kelly Boyce and Suzi Taylor) a Free Community Outreach Event for All Ages, Featuring the AREN Project at Montana State University in Bozeman, MT

March 2 -- "#GettingScienceDone" presentation (Jeff Bouwman, David Bydlowski, and Andy Henry) at the Michigan Science Teachers Association Conference in Lansing, MI (18 Educators Participated)

March 3 -- "Citizen Scientists Needed! Students Collecting Data for the GLOBE Urban Heat Island Effect Campaign" presentation (David Bydlowski and Janet Struble) at the Michigan Science Teachers Association Conference in Lansing, MI (4 Educators Participated)

March 10 -- Rouge Education Project Teacher Training and AREN Training (David Bydlowski) at Detroit Country Day Middle School in Birmingham, MI

March 13 -- "Come Fly With Us" a citizen science adult education workshop involving the use of AREN equipment (Judy Wink, Vicki Paulas, Alissa Quinton) at the Chesapeake Bay Environmental Center in Grasonville, MD (10 Educators Participating)

March 17 -- "Aerial Exploration of Environmental Study Sites, Using Kites, Cameras and Other Sensors" presentation (David Bydlowski and Andy Henry) at the National Science Teachers Association Annual Meeting in Atlanta, GA

March 26 -- "AREN at Cooper Upper Elementary" workshop (Andy Henry) at Cooper Upper Elementary in Westland, MI (7 Educators Participated)

March 28-29 -- North American Regional Meeting for GLOBE (David Bydlowski) at Purdue University in Lafayette, IN

March 30 -- First Time Kite Fliers (Sallie Smith) at Aberdeen Baseball Field in Baltimore, MD (7 Participants)

April -- National Kite Month

April 16 -- "AREN at Smith Middle School" workshop (David Bydlowski and Andy Henry) in Troy, MI (240 Students and 2 Teachers)

April 19 -- "AREN at Baker Middle School" workshop (David Bydlowski and Andy Henry) in Troy, MI (260 Students and 2 Teachers)

April 22 - Earth Day

April 23 -- "AREN at Larson Middle School" workshop (David Bydlowski and Andy Henry) in Troy, MI (260 Students and 2 Teachers)

April 30 -- "AREN at Boulan Middle School" workshop (David Bydlowski and Andy Henry) in Troy, MI (300 Students and 2 Teachers)

May 8 - AEROKATS Monocam and Profiler Flights (Geoff Bland) -- Mission Earth/Tennessee State University Climate and Weather Class (GEO3500) with David Padgett.

May 8 -- "AREN Training and Field Day" (Andy Henry) at Cooper Upper Elementary in Westland, MI (5 Educators and 120 Students Participated)

May 18-19 - GLOBE Midwest Regional Student Research Symposium (Anil Aranha, David Bydlowski, Brian Campbell, and Andy Henry) at Wayne State University School of Medicine, Detroit, MI (60 Students and 22 Adults Participating)

May 23 -- Kite Basics, Flying Kites, Introduction to Equipment and Cloud Formation Workshop (Judy Wink) at Providence Academy in Providence VA (15 High School Students Participated)

May 30 - June 5 -- AREN Team Meeting in Conjunction with the GLOBE Northwest SRS and Arctic SIGNS Team Training at Montana State University, Bozeman, MT

June 1-2 - GLOBE Northwest Regional Student Research Symposium at Montana State University, Bozeman, MT

June 5 -- Presentation and kite demonstration on NASA AREN for BOREALIS team at Montana State University, Bozeman, MT. BOREALIS is a high-altitude balloon launching program organized under the Montana Space Grant Consortium, which includes several Montana schools and is one of 52 consortiums in the national Space Grant network. (15 Learners Participated)

June 11-15 -- GLOBE Mission Earth Professional Development Institute (David Bydlowski and Andy Henry) at University of Toledo, Toledo, Ohio (20 Participants Attended)

June 15 -- GIS Workshop with AEROKATS Training (Geoff Bland, Mike Bonsteel, Joel Mitchell, and Kay Rufty) by/with National Park Service Personnel at NASA GSFC WFF, Wallops Island, VA (15 Participants Attended)

June 18 -- "AEROKATS Systems Supporting Coastal Observations (Mike Bonsteel and Joel Mitchell) with visiting students from Morehouse College at NASA Wallops Flight Facility, Wallops Island, VA (19 Participants Including Students, Educators and NASA Professionals)

June 26-27 -- Junior Naturalist Camp on Kite Flying Basics, Cloud Cover and From Payload to Download (Judy Winks) (20 Middle School Students Participated)

July 1-6 - GLOBE Learning Expedition (David Bydlowski and Brian Campbell) in Killarney, Ireland

July 1 -- "Engaging College Students (Pre-Service, Science, and Engineering) in GLOBE Through Undergraduate Classes" (David Bydlowski, Kevin Czajkowski, Contributions from Willie Brown-UMES and Others) at the GLOBE GLE in Killarney, Ireland (25 Participants)

July 5 -- "Establishing an Engineering Focus for GLOBE" (David Bydlowski, Kevin Czajkowski, and Others) at the GLOBE GLE in Killarney, Ireland (25 Participants)

July 13 -- Meeting (Geoff Bland) with Personnel from "Into the Wind" (George Emmons, Mary Ann McCoy, and Sean Horan) to discuss creations of "packages" for AEROKATS hardware distribution in Boulder, CO.

July 13 -- Meeting (Geoff Bland) with National Park Service Personnel (Tim Smith and Seshu Vaddey) to Explore Partnership Opportunities in Denver, CO.

July 15 -- Detroit Kite Festival (David Bydlowski and Matthew Lippincott) on Belle Isle in Detroit, MI (Shared AREN Project with at least 30 Individuals)

July 20 -- ROVER X5 Stability and Performance Parametric Test (Geoff Bland and Ted Miles) at Guard Shore, VA

July 23 -- "Middle School Workshop on AEROKATS Program, Frustrationless Flyers, and Kite Flying" (Kay Rufty) at the NASA WFF Educator Resource Center (21 Students Participating)

August 13 -- "Middle School Workshop on AEROKATS Program, Frustrationless Flyers, and Kite Flying" (Kay Rufty) at the NASA WFF Educator Resource Center (13 Students Participating)
August 15-16 -- Airborne Remote Sensing Seminar (Maciej Stachura from BlackSwift Technologies) at the UMES Engineering and Aviation Sciences Complex in Salisbury, MD (16 Educators Participated)

October 4-10 -- World Space Week

October 10 -- AREN Flight and Data Collection Workshop (David Bydlowski) at Huron Valley Lutheran High School in Westland, MI (24 students)

October 14-20 -- Earth Science Week

October 15-20 -- American Kitefliers Association National Convention in Shreveport, LA

October 16 -- GLOBE Training for Pre-Service Teachers (David Bydlowski) at Madonna University, Livonia, MI (12 pre-service teachers).

V. Evaluation, Collaborators and Cross-Collaboration Agreements Activities

AREN Project Evaluation

AREN Project Evaluation 2018 - *Anil Aranha, PhD***,** AREN Project Evaluator
The AREN Project has been operational for a total of 30 months. Over this period of implementation of the project, the stated project goals were reduced from the initial 4 goals to 2 goals - enabling STEM education and leverage through partnerships - to permit an improved focus of the project and also provide achievable outcomes. During 2018, the year being evaluated, the Project Leadership Team has attempted to direct and align the efforts of the 9 Co-Investigator Institutions towards the reduced project goals. The accomplishments of the AREN Project for the year towards these two goals are summarized below:

Goal 1: Enabling STEM Education
The AREN project had an impact on a total of 2,165 learners at different age and education levels. The break-down of learners by co-investigator institutions is: Wayne RESA (1,460 Students/Adult), University of Maryland Eastern Shore (15 Undergraduate), Goddard Space Flight Center (60 Adult), Chesapeake Bay Environmental Center (120 Student/Adult), Montana State University (310 Adult/Student), University of South Florida (200 Undergraduate/6th Grade).

The total number of STEM education learners impacted shows a disproportionate contribution by Wayne RESA, 67.4% of the total achieved for the year or 24.3% of the stated 2020 project goal. The next closest performer, Montana State University provided 5.2% towards the stated goal. Consequently, either the annual performance expectations/goals for the future may have to be significantly reduced, or else, all the co-investigator institutions, especially the lower performing, may have to significantly increase performance towards achieving the annual goal. Of note, is the fact that during the unusual - solar eclipse - year of 2017, the overall performance of the AREN project towards the STEM enabling goal was higher than in 2018. Thus, may call into question the sustainability of the project using this outcomes measure.

Goal 4: Leverage Through Partnerships
The year 2018 may be considered a transition year as regards this goal, due the fact that 'partner' and 'partnership' has been discussed at various organizational levels through greater part of the year and has only recently been better understood. Nonetheless, the AREN project has made significant progress towards the 3 (or 20) project goal with agreements in the works with 5 organizations: 1) Earth Force, 2) MI STEM, 3) American Kitefliers Association 4) BSCS (FieldScope) and 5) National Park Service.

Finally, although not stated as a performance indicator for the AREN project, during the year 2018, the co-investigator institutions made significant strides in activities related to Team Training and Capacity Building. Especially of note, is the organization of the GLOBE Regional Student Research Symposium by two of the co-investigator institutions, publications of a few ($\leq$ 6) articles/blogs and the collaboration of AREN co-investigator institutions in technology development of numerous ($\geq$ 12) components that enhance the technologies of AEROKATS and ROVERS. Data on use of these components and technologies is said to be forthcoming.

Case Study -- *Betsy Stefany -- STEM Literacy Community of Practice*

In August 2017, The SABENS Group formalized their connection with NASA's Aeropod by a license through their Transfer of Technology Program. This enabled further tool development and research by SABENS to connect with the digital tools used in the former NH Math and Science Partnership Project, "STEM Literacy Community of Practice" and existing projects that led to student engagement. NH MSP member/teachers were tested by Harvard's MOSART test, identifying areas of public misconceptions in science and teachers developed projects to improve their knowledge of light, heat transfer and analysis of dual factor measurement analysis. The license enabled the sites that built contrasting data for NH comparison to explore the sensors to continue to contribute data on ground conditions beyond the classroom as remote sensing information.

The MSP partners, JASON Learning, Annenberg Learner, UNH Cooperative Extension and US Green Building Council continue to extend the project-based content to both teachers and to students, engaging them to explore phenomenon and document their experience with digital technology. The recent partnership with USGBC and their LEED awards aids the connection between sensor types and award areas

NH's new education laws enables students to obtain credits by demonstrating competencies through Extended Learning Opportunities (ELO), the MSP process of project-based learning is a natural transfer from engaging teachers in developing their own learning to applying the option to their high school students.

Further NGSS integration changed the approach to topics. The 2017 Eclipse presented an option to capture and develop a nationally experienced phenomenon which The SABENS Group worked with partners, friends and a student intern in 8 states across the total pathway and 5 partial sites extending from Maine to Florida. The intern continued to explore her options for an ELO in the fall of 2017 forming an informal high school team at a new school.

Present Policy
The SABENS work is set to aid the integration of STEM in rural locations and engaging community in STEM through activities that focus on energy as a sustainable use of natural resources. We are building the supporting STEM learning progressions by a collaboration with existing projects, programs and digital systems. and integrating them through connecting with other Communities of Practice, NESEA and Cape Cod STEM Network.

Preparing for Educational integration as a Learning Progression-
Accomplishments:

- Expanded use of Aeropod with "Flypod" additions to capture simultaneous atmosphere, land cover, soil and water levels with light/temp and motion data
- Piloted classroom- to- field sequencing of data-driven activities
- Increased career roles and applications to existing sensor industry use
- Expanded NGSS Phenomenon focus with sensor application models
- Developing critical thinking skill process at levels of visual interest (update from science to STEM, Moriarty's Writing Science through Critical Thinking)
- Collaborating with existing partners and sites to offer content access to support sensor topics
- Providing privacy guidelines and best practices for local systems to document student evidence for future Extended Learning Opportunities (ELO) options

Present Status: Developing digital extension Atmosphere to Water tool applications. Collecting Growing Season sensors for Fall testing stream activities at 6-8 grade level. Preparing to offer teacher online Classroom for mentoring online moderator practice.

Any Changes That Took Place-Increased span of use from field to water locations. Discovered a change in the light intensity absorbed by ground level materials this year.

Issues: Pacing the school schedule changes for the implementation of ESSA from NCLB was in its first implementation year last year. Also, the NH ELO option is new causing a refocusing from high school back to support 6-8 entry to remote sensing and will further be extended in 2018-19 to 3rd grade level for English Language Arts practices that build access to necessary underlying experiences and information.

Dissemination Activities -These involve multiple types of connections from casual explaining Remote Sensing using the Aeropod to how the digital tools' output aids various professions and sites improve and meet varied goals. They take place in classrooms, at existing events on site and while collecting data collection. In November 2017, the Aeropod was presented at the NHSTA as a workshop. Ten teachers from new districts signed up for the Community of Practice.

NASA Co-Collaborations

The AREN Project continues it partnerships with SMD co-collaborators. They include:
The institutions and projects within this cross-collaboration are:

American Museum of Natural History -- "OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Education and Beyond"

Institute for Global Environmental Strategies -- "NASA Earth Science Education Collaborative"

Maine / Gulf of Maine Research Institute -- "Real World, Real Science: Using NASA Data to Explore Weather and Climate"

NSO / Association of Universities for Research in Astronomy, Inc. -- "TE 2017: Geographically Distributed Citizen Scientist Training for the 2017 Citizen CATE Experiment"

Southwestern Community College -- "TE: Smokey Mountains STEM Collaborative: Bridging the Gaps in the K-12 to Post-Secondary Education Pathway"

University of Alaska, Fairbanks -- "Arctic and Earth Signs"

University of Colorado, Boulder -- "Enhancement of Astronomy and Earth Science Teaching Using High Resolution Immersive Environments"

University of Toledo -- "Mission Earth: Fusing GLOBE with NASA Assets to Build Systemic Innovation in STEM Education"

University of Washington, Seattle -- "Northwest Earth and Space Sciences Pipeline" (NESSP)

Cross-Collaboration Activities have included:

- Mission Earth/Tennessee State University workshop with Dave Padgett
- Warming Arctic/GLOBE Student Research Symposium exchange with Elena Sparrow and Katie Spellman
- Smoky Mountain STEM Collaborative with Matt Cass
- NESSP with Winglee
- Joint Presentation with “Mission Earth” at the Michigan Science Teachers Association Conference
- Mission Earth – Engineering Team Meeting and cross-collaboration at the GLOBE NARM meeting
- US GLOBE and Mission Earth – GLOBE Midwest Student Research Symposium
- Planning for AREN Team Meeting and GLOBE Northwest Student Research Symposium at Montana State University (MSU) in June, 2018. Reports being developed by team partners on successes, challenges and future plans.
- GLOBE and the Midwest Student Research Symposium -- Kite Flying
- AEROKATS Monocam and Profiler Flights as part of Mission Earth/Tennessee State University Climate and Weather Class (GEO3500) with David Padgett

- AREN Training for Arctic SIGNS Team in Bozeman, MT
- GLOBE Mission Earth Professional Development Institute with AREN Training in Toledo, OH in Partnership with Palmyra Cove
- Multiple Presentations at the GLOBE GLE in Killarney, Ireland, with Mission Earth and Various Universities
- Arctic SIGNS has joined in weekly AREN Phone Conference
- Update Work with Mission Earth
- Flying Practice in Alaska with Arctic and Earth SIGNs
- NISE Network was instrumental in setting up partnership meeting with the Michigan Science Center
- Meeting with Matt Cass from Smoky Mountain on project poster
- AREN attends meetings with GLOBE LIaisons and has regular phone meetings
- AREN participates in monthly “Earthlings” phone conferences, which include all of the Earth Science and GLOBE collaborating CAN Awardees
- AREN is part of the SMD MakerSpace and Data Literacy groups

VI. Known Future plans

The AREN Project is looking forward to the future in 2019. Below is a list of the major plans for 2019:

- GLOBE / AREN Engineering Campaign Implementation
- GLOBE / AREN Field Campaign
- Hosting the 2019 GLOBE Annual Conference in Detroit, MI
- Anasphere will be further developing and refining ThermoPod hardware and software. Anasphere will also arrange supporting visits to SKC to support their adoption of AREN hardware and procedures.
- Develop plan for sustainment phase.
- Montana State University will begin developing a series of short, self-paced online modules to help educators (and the public) understand the kite-flying aspects of AREN.
- Continue to pursue potential partnerships with local, regional and national networks.
- More accessible airborne sensor packages to more curricula and guidance around NDVI software and hardware with a larger group of people beginning to work on NDVI, DIY aerial imaging, and AREN priority topics.
- Have fewer barriers to good quality, accessible science learning through Public Lab contributions within the AREN project.
- Future efforts will continue to engage students in the various multidisciplinary areas in STEM practices.
- The AREN community has identified student researchers at UMES for the Summer of 2018 to embark in discovering the methods learned from previous classroom practices and promote innovation of kite-designs and development, data management, analysis and techniques to engage the AREN user community for partnership.
- AEROKATS hopefully will be incorporated into another course at Tennessee State University in spring semester 2019 or 2020.