Annual Progress Report Template-Year 4
NASA Science Mission Directorate Science Activation Program
Cooperative Agreement
Annual Progress Report - 2019
NASA Science Mission Directorate Science Education
Cooperative Agreement Notice (CAN)
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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.
4. Affordably implement AREN approaches, learning plans, and specific tools into the GLOBE Program.
5. Increase participation in the GLOBE Program through involvement in the AREN Project and new AREN measurement protocols.
6. 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 2019

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 9000 through 2019 with the project goal of over 10,000 by 2020. There were approximately 100 learners in 2016, 4000 in 2017, 2000 in 2018 and over 3,000 to total the 9000 through 2019.

Over 3000 Learners participated in the AREN Project at various levels of instruction and participation in 2019.

- Chesapeake Bay Environmental Center – 1350 Learners
- Montana State University – 730 Learners
- Wayne RESA – 580 Learners
- Goddard Space Flight Center – 110 Learners
- University of Maryland Eastern Shore – 80 Learners
- Washington College – 35 Learners
- AREN Groups -- 180

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 has become more clearly defined. As partnerships became more clearly defined the AREN Project now anticipates developing three partnerships by 2020.

Contributions from Co-Investigator Institutions

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

- 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 Bobbin, Suzi Taylor
- Public Lab -- Shannon Dose Magen, Mimi Spahn Sattler, 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 2019 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 at the Chesapeake Bay Environmental Center – September 17 – 19
- Ongoing Field Practice Sessions

Chesapeake Bay Environmental Center

- Teaching kite flying skills
- Learning instrumentation
- Data collection
- Use of data
- AREOKAT and ROVER mission conducted weekly
- Ongoing professional relationship with Colina Azul in Costa Rica
- Curriculum development
- Kites at the BoSox Expo in Bowie

Goddard Space Flight Center

- MD Association of Environmental and Outdoor Educators (MAEOE)
- Assateague Park (NPS)
- Puerto Rico teacher
- GLOBE North American Regional Meeting (NARM)
- Maryland Coastal Bays Program
- GLOBE Annual Meeting
- Michigan Science Center - ROVER
- Maury Project at Naval Academy
- STEMinist at Wallops
- Arlington Echo
- American Kitefliers Association (AKA)
- French Immersion School

Montana State University

- Community Engagement Events -- Heck Quaw Elementary School; Family Science Night; American Computer and Robotics Museum's Apollo 11 Outreach Celebration, YMCA STEM Week; Livingston Links for Learning Afterschool Program
- Classes and Presentations for Youth – Things That Fly-A STEM Event for Middle School Girls; Kites at Summer Camp with local artist; Western Scholars; Kite Day at STEM Camp; MSU Explore-Earth and Space Science Camp; Presentation with Northwest Earth and Space Science Pipeline
- Opportunities for Educators – Citizen Science and the Lewis and Clark Trail; Kites and Citizen Science with NASA at MSU Science Summer Institute; Montana Afterschool Alliance Conference and Science Summer Institute
- Other Audiences – Montana Library Association Fall Planning Meeting; Science Pub Talk
- Developing an online module for teachers called "Atmospheric Pressure and Wind"
- Hired Andrew Mullen as an Earth Science Intern

Public Lab

- Relaunch of MapKnitter 3.0
- 2 Leaflet web-mapping plugins for NDVI conversion
- Refinement and launch of Infragram Pi kit for easy multispectral imaging
- Live-streaming video NDVI software
- "Tech Tuesday" outreach series on social media
- Expanded tutorials and blog posts demonstrating AREN project outputs including software and kits

University of Maryland Eastern Shore

- AREN STEM Day Event with Upward Bound Students
- AREN's Teacher STEM Training Workshop with Upward Bound Program
- Spring 2019 – ENGE 150 Modern Engineering Design Course

University of South Florida

- Focus on Foundations of Engineering Lab course or first year undergrads at USF
- Approximately 100 Students focused on design questions around Aeropods
- Engaged with approximately 50 middle school students for design review of student projects. Students used feedback to inform design.
- Formed partnership with Society of Aeronautics and Rocketry to focus on testing protocols and procedures.

Washington College

- Upgrades to water quality system on Chester River buoy to match AquaRover (customized ROVER 10 platform).
- Maryland Association of Environmental Outdoor Educators, Towson, MD workshop with Geoff Bland and Brian Campbell
- Updates to AquaRover data acquisition system to allow better calibration with buoy and GPS integration
- Introduced AREN to Assateague Costal Trust
- Presented 'Bathy in a Box' to team at CBEC meeting
- Work on alignment of AREN based lessons/activities to Maryland Standards of Learning
- Middle school workshop, Kites, Monocams & Atmospheric Profilers at Washington College
- Introduced AREN to Undergraduate Applied Sciences Course at Washington College
- Introduced GLOBE program in several locations abroad
- Established Watershed Innovation Lab at Washington College, including kites and ROVERs.

Wayne RESA

- Co-Hosted, with Mission Earth, the 23rd GLOBE Annual Meeting in Detroit, MI
- Presentations at the 2019 GLOBE Annual Meeting
- Partnership with multiple GLOBE Student Research Projects
- Multiple AREN presentations at National, State and local conferences
- AREN workshops for over 500 students in Metropolitan Detroit
- Ongoing design and production and distribution of Aeropod and ROVER technologies
- Development of data collection and online visualization tools

- Participation in the GLOBE North American Regional Meeting at NASA Langley
- Provided support for teams participating in the GLOBE Midwest Student Research Symposium in Iowa
- Wayne RESA Maker-STEM Summit 2019 at the Henry Ford in Dearborn, MI
- Collaborated with Mission Earth at the GME Satellites Student Conference at the University of Toledo
- Planning and coordinating of AREN Project efforts
- Contracts for Public Lab, Washington College, Chesapeake Bay Environmental Center
- Coordination of Budget
- Collaboration with the Rouge Education Project for Water Quality Testing and Testing Sites
- Collaboration with NASA at the Odyssey of the Mind Event at Michigan State
- GLOBE Training for Pre-service teachers at Madonna University

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Co-I Yearly Reports

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 and planning for the AREN team meeting at Chesapeake Bay Environmental Center
- 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
- Coordination with new evaluation team

Chesapeake Bay Environmental Center

The 2018-2019 time frame involving the AREN Project focused on all ages and skill levels regarding kite flying skills, learning the instrumentation, data collection and use of data. Chesapeake Bay Environmental Center's (CBEC) staff of Alissa Quinton, Judy Wink and volunteer, Deane Horowitz conducted all activities.

One AEROKAT mission and one ROVER mission was conducted weekly. Each mission was 1.5 hrs. There were several weeks in July and August when there was insufficient wind to conduct the missions.

We continued our international relationship with Colina Azul in Costa Rica and in January and March Judy Wink visited the school and worked with the teachers/students in flying the kites, testing the equipment and collecting data. The teachers in the lower grades (1-3) were working with the students with the GLOBE cloud protocol. The upper grades (4-6) used the kites/equipment for the data collection. The students collect data twice a month, as they need to walk to an area distant from the school where it is safe to fly the kites.

Our staff worked on curriculum development for both the AEROKATS and ROVER throughout the year, and prepared lesson plans for each component of the programs. Attached is an example of a lesson plan for the ROVER activity.

In the Spring of 2019, our team completed 4 presentations of "how to make mini kites" and the background of the AREN program to students and teachers attending the BaySox Stem Expo in Bowie. This was an opportunity to expose 1000's of students to the kites, complete a hands-on activity (mini kites) and speak with teachers about GLOBE and the AREN program. We prepared handouts for the teachers promoting GLOBE and AREN including an app to be used at the site involving cloud data collection. We plan to participate in the Stem Expo in 2020 and will make improvements in our presentation to encourage the teachers to contact CBEC for site visits to participate in AREN activities.

Alissa Quinton planned and handled most of the administrative duties/logistics for an annual meeting of AREN project coordinators at CBEC in September.

In the Spring and Fall we conducted a one-day activity for children (2-5 yrs. old) focusing on different types of kites and kite flying. They were involved in making mini kites, decorating kites and flying 3 different types of kites. Each participant was accompanied by a parent. In the Spring 50 children participated and in the Fall there were 81 participants. We had ample space for preparing and flying kites, and it was most helpful to have the parental oversight for each child.

In the Spring and Fall of 2019 our staff worked with 6 school groups (Spring) and 4 school groups (Fall) that visited the site for AEROKATS and ROVER experiences. We are courting the Regional Homeschool organization to promote involvement of this audience in the AREN Project.

We continue refining the activities and recruiting schools, adult groups and volunteers to participate in the AREN Project.

Alissa Quinton and Judy Wink explaining the making of mini kites to student participants at the BaySox Science Expo.

Creepy Crawler kids flying the Frustrationless Flyers.

Judy Wink explaining the functions of the hand-held weather device to Colina Azul students.

Delta kite and monopod w/camera launched at CBEC.

Alissa Quinton and Judy Wink demonstrating kite flying skills to Colina Azul students.

Goddard Space Flight Center

AREN efforts at NASA GSFC focused on the implementation of AEROKATS tools and further development and user testing of ROVER aquatic systems. Key personnel include Kay Rufty (GST), Sallie Smith (SSAI), Ted Miles (Zinger Enterprizes), Brian Campbell (GST) Sandra Banks (610.W) and Geoff Bland (610.W). During the performance period, significant use of 3D printing tools had been used for fabrication, and numerous workshop and project materials have been created and presented during the year. The primary focus has been on AEROKATS distribution and training, combined with advanced development of ROVERs for future infusion into relevant settings.

GSFC continued to develop and disseminate multiple AEROKATS instrumented Aeropods, including MonoCams and Profilers. Fabrication and packaging for shipment (including kites and associated materials) for multiple users was the focus. Regular communication with Andy Henry (Wayne RESA) on production was critical. Numerous “MiniKites” were also created and distributed.

GSFC supported the preliminary development of the future AEROKATS.org website with Wayne RESA. A *GLOBE Wind Measurement Challenge* was also initiated at GSFC, and was enabled by Wayne RESA. This *Wind Measurement Challenge* formed the basis for a GLOBE Learning Activity now under development by the team. The *Wind Direction at Altitude* activity is a significant focus for next steps of the project.

Other efforts include a novel hands-on activity created to celebrate the 50th anniversary of the Apollo landing, prototype classroom activities, poster designs, presentations at AGU, and preparing for AREN workshops including the GLOBE Annual Meeting.

GSFC workshops, presentations, trainings and meetings of note:

- MD Association of Environmental and Outdoor Educators (MAEOE) - Feb
- Assateague Park (NPS) - March
- Puerto Rico teacher – April
- GLOBE North Am. Regional Meeting (NARM) – April
- MD Coastal Bays Program - June
- GLOBE Annual Meeting – July
- Michigan Science Center - July ROVER
- Maury Project at Naval Academy - Aug
- STEMinist at Wallops – Aug
- Arlington Echo - Aug
- American Kitefliers Association (AKA) - Oct
- French Immersion School - Oct

Puerto Rico Fliers in Training and AEROKATS Image from Remote Site

ROVER designs were further solidified trough testing of ROVER 7 and ROVER 10 variants. ROVER 7's are optimized for very shallow water, and ROVER 10's are designed for simplicity and low cost – with enhanced provisions for user-defined sensor system design and integration. Several examples of each were completed and are now being evaluated by team members within GSFC and Wayne RESA. Both ROVER 7 and 10 examples were provided for the AREN Team Meeting at CBEC, enabling detailed familiarity with the systems by the team members. A ROVER 10 is also now at LaRC for sensor integration and testing (Neilan – thanks to Jessica Taylor/LaRC for arranging this). A follow-on development, the ROVER 7B is under development incorporating lessons learned to further simplify this design.

Several lectures and visits to the University of MD Eastern Shore (UMES) supported the ENG150 *Introduction to Engineering Design* and AVSC390 *Introduction to Remote Sensing* classes. ENG150 is now in its fourth semester of an AEROKATS focused design and fabrication Wind Tunnel project, and AVSC390 completed its second semester. Both classes emphasize teamwork, planning and safety as critical elements in project execution.

GSFC personnel also coordinated and oversaw sub-agreements with the University of MD Eastern Shore (UMES), Montana State University (MSU), and the University of South Florida (USF).

Montana State University

Accomplishments and Dissemination Activities

The AREN team hosted and participated in several community engagement events, including:

- November 8 -- Heck Quaw Elementary School STEM Night in Belgrade, Montana. The AREN team made miniature kites with students in grades K-4 and exhibit an aeropod, Kestrel and full-scale kite.
- February 7 -- "Family Science Night" at Montana State University in Bozeman, MT. (175 Participants)
- July 20 – The AREN team shared the mini-Kites and Apollo 11 Drogue activities at the American Computer and Robotics Museum's Apollo 11 outreach celebration in Bozeman, MT
- August 12 – MSU shared the Apollo drogue capsule activity during Gallatin Valley YMCA's STEM Week (Bozeman, MT)
- Sept. 17 – Livingston Links for Learning afterschool program building miniature kites (Livingston, MT) (25 youth)

The AREN team hosted several classes and presentations for youth:

- March 30 – The AREN team hosted a workshop called "Things that Fly" at "Expanding Your Horizons - A STEM Event for Middle School Girls" at Montana State University in Bozeman, MT (300 Participants total; 15 girls in this workshop). The workshop included creating miniature kites as well as dissecting owl pellets, as part of the California Academy of Sciences' Science Action Club program.
- July 11 – Flew Frustrationless Flyers at Summer Camp with Artist Beth Kennedy in Bozeman, MT (15 Educators)
- June 25 -- Western Aerospace Scholars Presentation (a program of NESSP) at the Montana Learning Center, Canyon Ferry Lake, Montana
- July 11 – Kite Day at STEM Camp - Bridger Kids Summer Camp, Belgrade, Montana. Hands-on STEM for kids in grades K-5. https://www.bridgerkidscamp.com/ (26 Students)
- July 24 -- Kite Flight with MSU Explore: Earth and Space Science Camp at Montana State University in Bozeman, MT (15 People) [Partnership with Northwest Earth and Space Science Pipeline]

- July 25 -- Presentation on AREN + Frustrationless Flyer Kites at the Montana State University Explore Camp in Bozeman, MT (10 People) [Partnership with Northwest Earth and Space Science Pipeline]

The AREN team hosted the following opportunities for educators (informal and K-12)

- June 28 – Citizen Science and the Lewis & Clark Trail: Educator Workshop at Montana State University. Bring history, citizen science, NASA technologies and Montana water quality research to your classroom or out-of-school program as you meld the mystique of the Lewis & Clark National Historic Trail with modern tools for data collection. Bozeman, MT http://www.montana.edu/smrc/Educator_Workshop.html (11 Educators representing K-12 schools, museum, Boys and Girls Club, etc.)

- August 7 – The AREN team hosted a workshop called Kites and Citizen Science with NASA –at the Science Summer Institute, Montana State University. This is a summer institute for K-12 teachers and administrators. Workshop description:

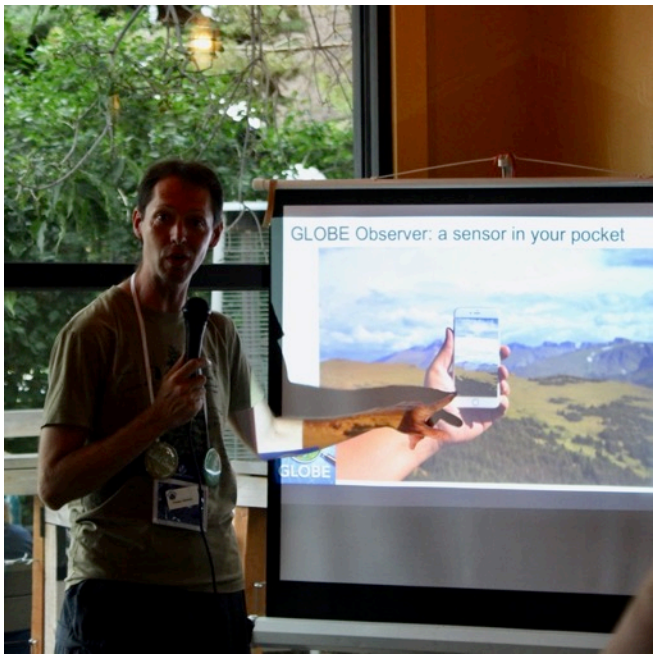
  The NASA Aerokats and Rovers Education Network provides hands-on experiences that bring a unique "aerial perspective" to learners of all ages using large kites, cameras and sensors. Learn about kite aerial photography (KAP), citizen science, and how AREN helps students experience NASA science missions, technology and operations. Decorate your own sled kite (putting Art into STEM to make STEAM!); build a miniature kite; and find out how you can bring NASA AREN to your students.

- https://www.swmss.coop/ssi2019.html (120 People at conference; approximately 25 at workshop (many tracks available)

- August 6-8 -- AREN hosted an exhibit table in partnership with the Montana Girls STEM Collaborative at the Montana Afterschool Alliance Annual Conference and Science Summer Institute in Bozeman, MT

Other audiences

- July 24 -- AREN Exhibition at the Montana Library Association Fall Planning Meeting in Bozeman, MT (30 Librarians)
- August 6 -- Science Pub Talk: GO on a trail to monitor changes on planet Earth (Suzi Taylor, MSU and Peder Nelson, Oregon State University) on the Lewis and Clark Trail in Bozeman, MT (30 adults)



Other Activities:

The Montana State AREN team is developing an online module for teachers called "Atmospheric Pressure and Wind." Written by an Earth Sciences faculty member at MSU, the module will provide basic information on weather and related topics for kite flyers. The module will be disseminated through MSU's National Teachers Enhancement Network, which has provided online learning to more than 25,000 teachers throughout the world.

The Montana State University AREN team hired MSU senior Andrew Mullen as an Earth Sciences intern. Andrew conducted kite flights; modified the existing camera mount file so it would work with the Campark Xtreme camera; collected and plotted weather data in Excel; took several GLOBE Observer observations in the area; and is creating a series of short videos on how to use the Kestrel.

Andrew is currently modifying a kite-mounted camera to see infrared. He will fly this over an astro-turf field and grass field. He is learning about how to use the infragram filters, and about different vegetation indices and what they tell us about plant health, water content, etc. He is working with Peder Nelson to write a blog post to the GLOBE Website.

Changes

- We hired a student intern to help with flying and other activities.
- Suzi Taylor, part of the Montana State University AREN team, moved to a different MSU department but remains part of the project.

Challenges

Long winters and short summers mean much of our kite-flying and outreach activities are concentrated into a short amount of time.

Collaborations

- GLOBE trainer Lynn Powers taught educators how to use the Clouds protocol at the educator Citizen Science workshop on June 28
- Contributed to Northwest Earth and Space Science Pipeline to present to Western Aerospace Scholars and at MSU Explore: Earth and Space Science Camp
- Montana Girls STEM Collaborative - co-hosted exhibitor booth
- GLOBE Observer – Oregon State - hosted guest speaker Peder Nelson in collaboration with Montana NSF EPSCoR
- Future: Montana School for the Deaf and Blind – working with teacher to make Frustrationless Flyers with students

Public Lab

Accomplishments (Summation)

- Relaunch of MapKnitter 3.0
- 2 Leaflet web-mapping plugins for NDVI conversion
- Refinement and launch of Infragram Pi kit for easy multispectral imaging
- Live-streaming video NDVI software
- “Tech Tuesday” outreach series on social media
- Expanded tutorials and blog posts demonstrating AREN project outputs including software and kits

Work plan for 2019

Collaborations:

Q1-4: Build on discussions and collaborations with AREN partners (including via weekly calls) and broader Globe community to promote AREN project outputs and integrate them into classrooms and fieldwork.

Q1-4: Collaborative outreach and co-authorship with fellow AREN partners.

Q3: Two Public Lab staff attend AREN meeting in Detroit.

Q1-4: Outreach to remote sensing community, web mapping community, educational community

Q1-2: Outreach to NASA GIBS team about Leaflet Multispectral, comparison of kite multispectral vs. LANDSAT/MODIS

Hardware:

Q1-2: Follow-up on letter to Goddard regarding public benefit of open licensing re: AEROPOD.

Q1-4: Develop and expand range of kits building on new PL/AREN multispectral camera development, including add-ons, intro/advanced kits, and build on Public Lab community projects and collaborative model to advance these projects. Develop additional derivative kits tailored for specific uses to demonstrate potential applications.

Q1-4: Continue exploration of additional kits across PL ecosystem to further AREN scope priorities, for example low cost sensors, data logging, etc.

Software:

Q1-2: Improved integration of Infragram, Image Sequencer, and MapKnitter to reduce barriers. Further refinement and expansion of Image Sequencer and Image Sequencer UI.

Q2 & Q3: Integration of multispectral processing with new cloud-based image processing workflows.

Q3+: Optimization of video-streaming multispectral modules.

Q3+: Implementation of improved data/image hosting/storage and annotation solutions to meet needs in sensor/datalogging, multispectral and other related data collection systems.

Documentation:

Q1-4: Develop and engage Public Lab and AREN community support materials, guidance, tutorials, and activities for multispectral image processing, building on new toolsets. Materials (illustration/photography/video + step-by-step guides, case studies) will focus on real-world and classroom use of software, kits, and methodologies with emphasis on growing the community.

Q1-4: Continued implementation of educational materials with focus on sensor/datalogging and other airborne/land-based platforms for data collection, kite building and flying resources and further multispectral image processing workflows and supporting materials featured across PublicLab.org and GLOBE websites.

Accomplishments (Elaboration)

Community members have been using Raspberry Pi Zero boards with cameras as aerial photography setups, supported by our new Raspberry-Pi-based Infragram Pi kit. Our Pi Builder software has made getting started really easy, and provides a WiFi connection, enabling live video transmissions during kite flights, with NDVI processing of the feed. Our goal of easier, faster, and more powerful software tools for multispectral imaging and image processing has borne fruit, and we've seen good progress on more efficient and maintainable software systems, expanded integration with other open source packages, more reliable and robust systems. Community contributor growth has underpinned these improvements, with a total of 75 people contributing to our Image Sequencer project alone.

Over the past six months, we've overhauled almost every part of the MapKnitter website, used by many kite and balloon mappers around the world, having raised additional funds; via our Google-funded MapKnitter code fellowships and our Google Summer of Code (#GSoC) fellows, we've had contributions from five continents and more than ten people, all coming together to build this complex system. You can read more about this enormous project at:

https://publiclab.org/notes/warren/07-26-2019/community-atlas-an-around-the-world-collaboration-on-mapknitter

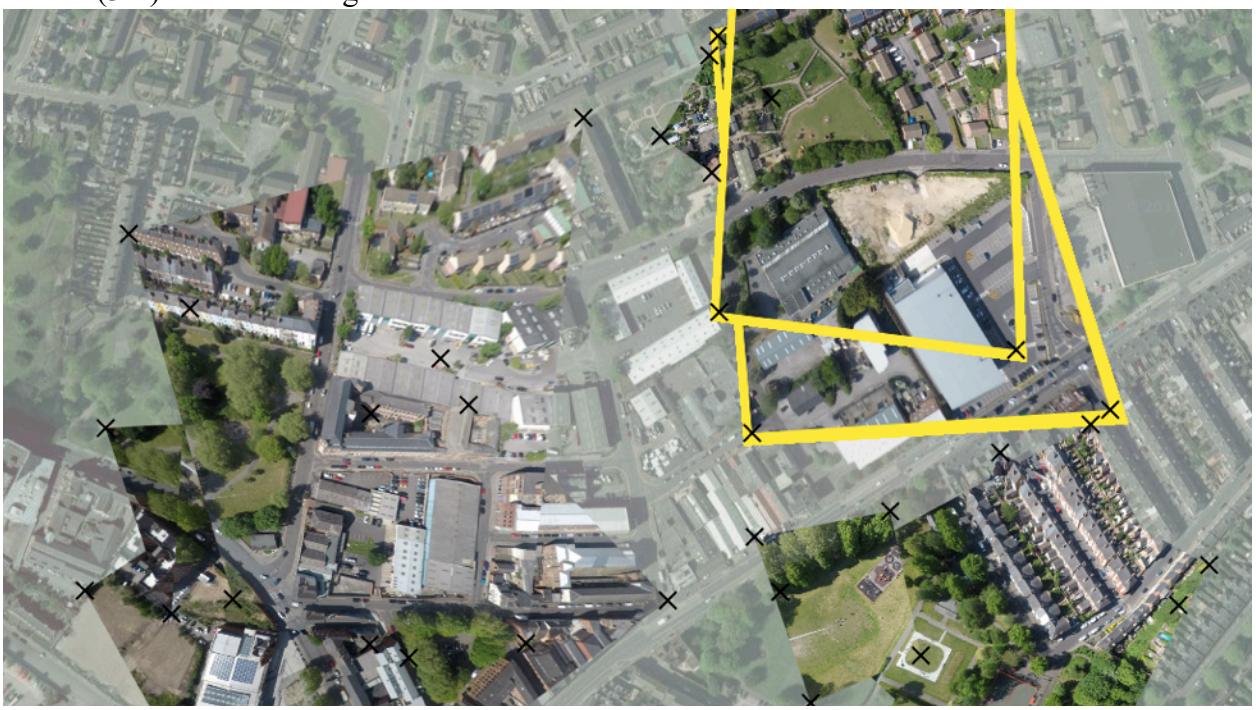
In March, we put out a call for Mapping Fellows to help lead mapping events in their communities and give feedback on their experiences using MapKnitter.org to stitch together their aerial images. We partnered with Mo Langmuir, who worked with youth asylum seekers and refugees to do balloon mapping in their new home in Nottingham. We also partnered with N. Sairam, who worked with community members in Bangalore to map local waste sites and analyze optimum sites for installing solar panels. Mo and Sairam provided detailed user interface feedback on MapKnitter's design, from the overall workflow to specific organization and styling of buttons and tabs.

Our project to develop a low-cost sensor platform has matured into the Simple Air Sensor project, which at very low cost (~$50 per kit, versus ~$250 for comparable kits from other vendors) aims to bring environmental monitoring into the classroom, and we are working on overall payload weight to make this system compatible with the Aeropod as well as other forms of aerial monitoring.

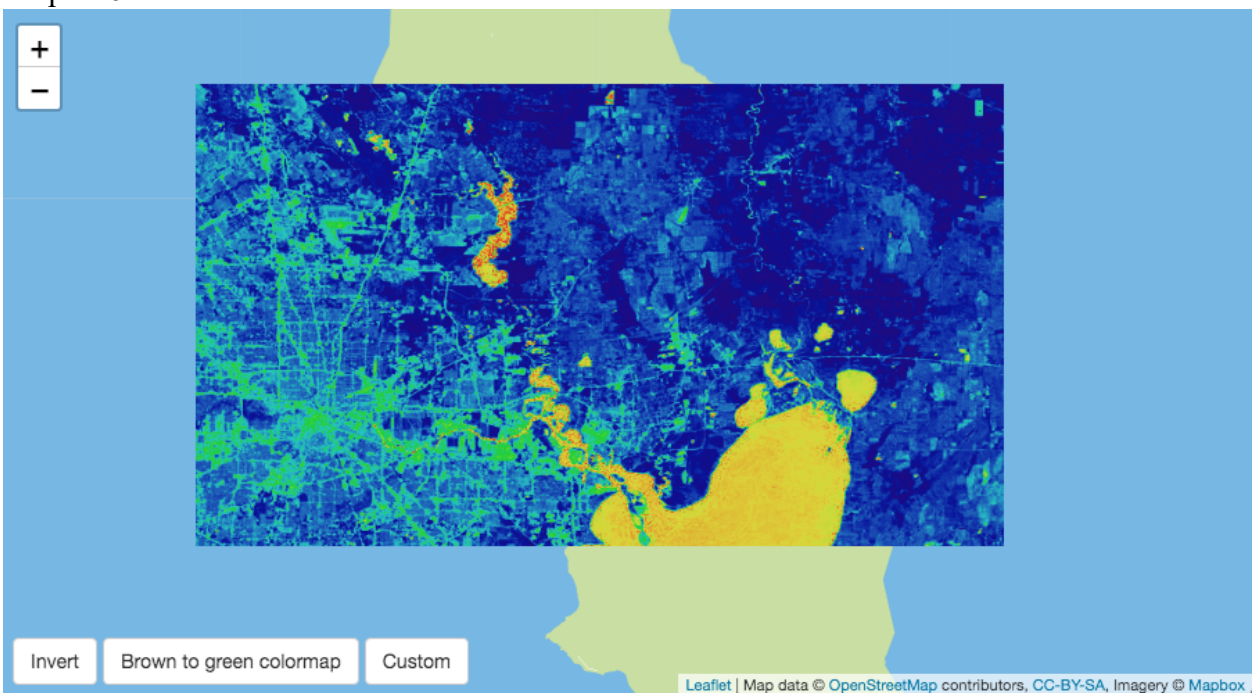
In concert with our new education program, we have also begun an overhaul of PublicLab.org educator resources, including handouts, guides, and curricular materials for a wide range of our kits — including those which have been useful to the AREN project. As part of this work, we've developed a classroom-based activity for modeling air flow in a small model "neighborhood," using affordable fans and mist generators to show how wind and weather can affect differential readings of particulate air pollutants. This was demoed at the Detroit GLOBE meeting as well as in concert with community partners in Wisconsin and Louisiana.

This year being primarily oriented towards outreach, we have a range of outreach efforts in progress or upcoming in the fall. A lot of preparation has gone into a series of videos (mentioned below) as well as improved and refined tutorials, which we are posting regularly on social media (Instagram, Twitter, Facebook) and these are seeing good engagement numbers.

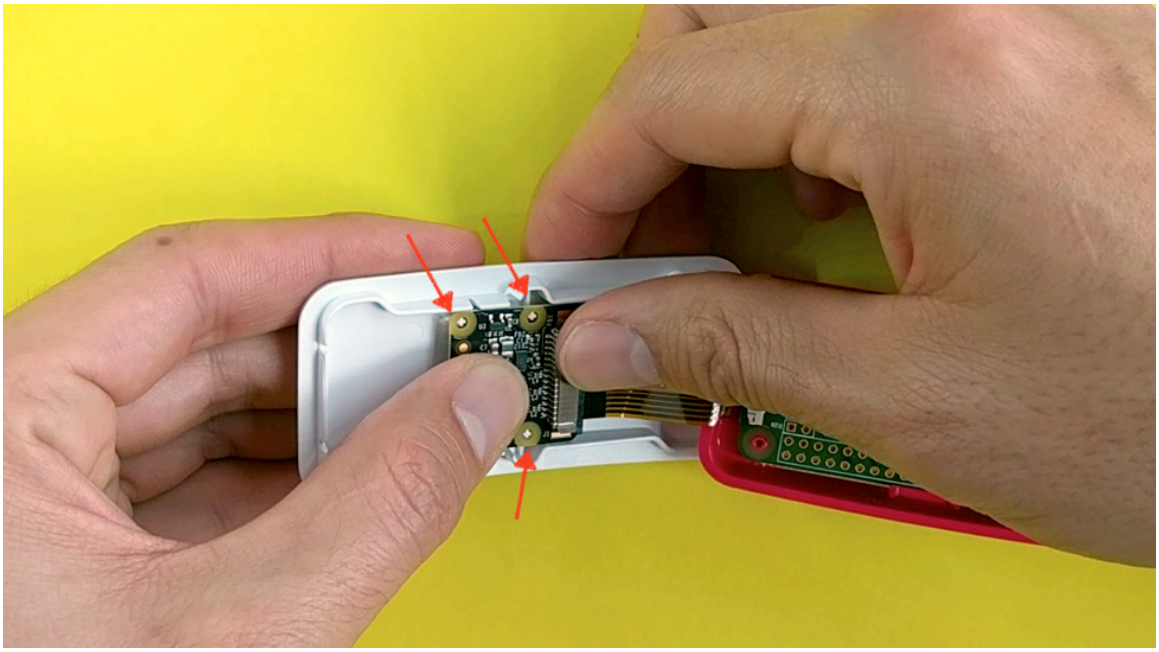
Photos (3-4) Demonstrating Work



A demo of the new multiple-image system for MapKnitter, just one of many improvements from the past 6 months.



Demo of Leaflet plugin integration of Infragram/Image Sequencer software: https://publiclab.org/notes/warren/08-27-2019/bringing-public-lab-s-multispectral-image-processing-to-leaflet-maps



Assembly instructions for the Infragram Pi kit: https://publiclab.org/notes/warren/05-20-2019/set-up-a-raspberry-pi-camera-with-pi-builder

Prototype aerial rig for the Infragram Pi kit: https://publiclab.org/notes/warren/06-05-2019/build-a-simple-aerial-photo-rig-for-a-raspberry-pi-camera

Present Status

Current work includes the development of simple datalogging capability on the Simple Air Sensor platform, and will be coordinated with our new Oil and Gas Accountability Fellows in the fall, as well as curricular development with our educational programs in the Gulf Coast region. We also plan to pilot airborne data collection at the September partner meeting as well as in October with Providence community arts organization AS220 as part of Open Hardware Month (in coordination with the Open Hardware Association).

We plan to continue to build on discussions and collaborations with AREN partners and broader GLOBE community to promote AREN project outputs and integrate them into classroom and fieldwork.

Changes That Took Place

Mimi Spahn-Sattler joined Public Lab's team at the Detroit annual meeting. Although Mimi is occupied with leading Public Lab's educational programs, she will be occasionally involved due to her work curricular efforts, educational kits, and classroom data analysis activities.

Issues

The exceptional growth of features and power of the Image Sequencer project, sustained in part by the Google Summer of Code program, is impressive (e.g. graphics card acceleration, additional modules, ability to handle larger images) but the added complexity has also brought some increase in bugs, especially with our UI. However, we are addressing this with a renewed push for automated UI testing and anticipate this stabilizing significantly in the coming weeks and months.

Dissemination Activities

Part of our outreach plan during the past quarter has been to develop simple, standard integrations with common existing web mapping technologies, with a focus on the extremely widely used Leaflet library. This culminated in the release of two Leaflet libraries, Leaflet.Multispectral and Leaflet.TileFilter, each demonstrating the capabilities of our web-based NDVI compositing engine in ImageSequencer:

https://github.com/publiclab/leaflet-multispectral
https://github.com/publiclab/leaflet-tile-filter

These both used MODIS imagery as an example dataset, and bring a common toolset to the processing of multispectral imagery from DIY collection methods and satellite imagery.

We are in the middle of a run of "Tech Tuesdays" posts on social media which highlight (using 60-second build videos) many of our kits, including those developed in collaboration with AREN, and have seen a great deal of interest from the public as a result. The coming months will see additional outreach and adoption building on this, as well as some print publications we have planned that we anticipate will see a very broad audience.

Challenges

We've struggled a bit with issues related to the Raspberry Pi sub-system we use to make the Infragram Pi kit possible. While the Pi Builder system is very powerful, there are lots of friction points related to accessing and staying connected to WiFi networks, getting very large numbers of images off of the Pi camera, and other issues which we continue to work on. However, we have been contacted by a range of community members interested in the capabilities of Pi Builder and are optimistic about it's long-term ability to solve these kinds of issues in a repeatable way suitable for kit distribution.

Collaborations

Q3: Two Public Lab staff attend AREN meeting in Detroit.

Kay Rufty developed a prototype Infragram Pi Aeropod adapter, carrying a lightweight battery and camera with onboard WiFi; this was tested in Detroit at the GLOBE meeting.

Upcoming possibilities for collaboration include the possibility of crossover between the particulate air pollution testing and wind tunnel development projects; this may be discussed during the September meeting.

Follow-up continues on the process of licensing AEROPOD under an open source license, with Public Lab finding support from Michael Weinberg of the Open Source Hardware Foundation, and an ongoing discussion on the license draft with Eric McGill.

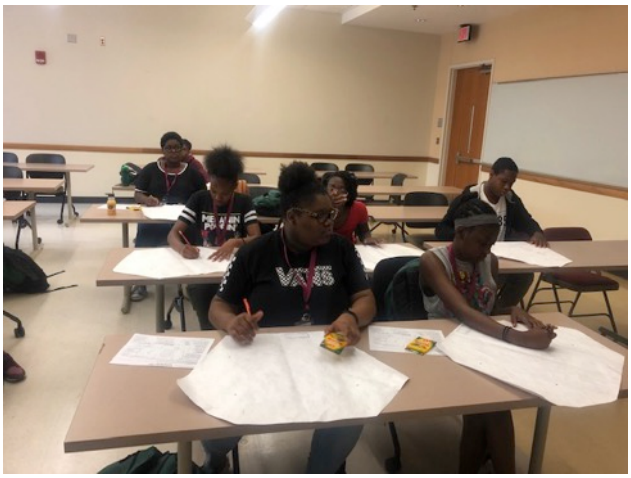
Future Plans

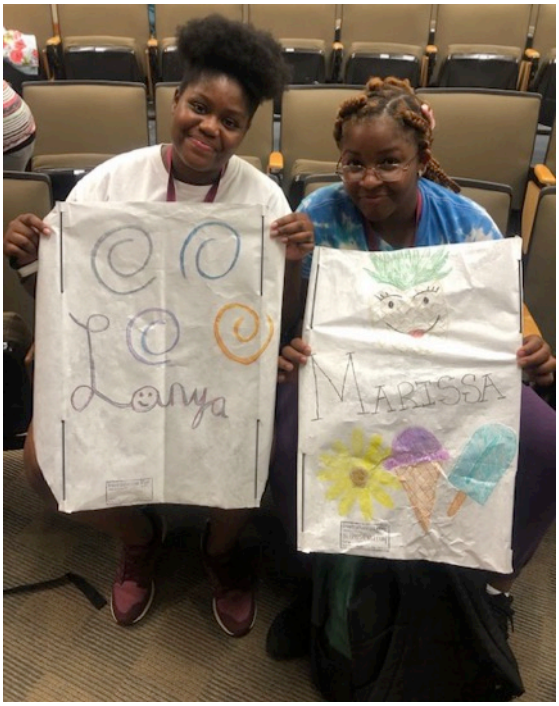
A number of refinements and improvements to MapKnitter are in the works due to the major infrastructural changes completed this summer. Among these are a synchronous editing project which will bring Google Docs-like real-time, multi-user features to MapKnitter. In addition, GPS auto-placement will see refinement, and a long-shot project to bring automated image matching to the project is being explored after a lot of successful work during the summer.

University of Maryland Eastern Shore

Accomplishments

- AREN STEM Day Event with Upward Bound
- 30 Upward Bound Students and 7 teachers supported by college mentors to partake in the first STEM Day event with AREN at UMES on July 11.
- The students were involved in a workshop introduction, design challenge and kite flying. From the results, the students were involved in a workshop introduction (1 1/2 hours), design challenge (1 1/2 hours) and kite flying (1 hour). The total time was 4 hours with a plan event time from 9 am to 1pm.
- There were three (3) teams with two (2) assigned teachers and one (1) college mentor in two (2) out of the (3) groups. One instructor had two (2) college mentors assigned to her team since she was the only assigned teacher.
- We had a ten (10) member team with the three groups and I was the rotating instructor. It was amazing to witness 30 students engaged- all who were flying the kites at one time as initiated in the pictures of this event with Dr. Nicole Gale and Dr. Willie Brown at UMES.




Lanya
MARISSA

AREN's Teacher STEM Training Workshop with Upward Bound Program (240 – Minute Workshop)

- The teacher workshop targeted 7 teachers in the local community
- The workshop was a one-day event with the teachers on May 25, 2019
- The workshop breakdown below:

Timeline/Schedule	**Workshop Outline**	**Instructor Lesson Plan**
30 minutes	Introductions, Presentation and Exercise: Benefits of Hands-on Science Learning	Brief overview of AREN; goals and objectives; and the introduction of technology with the naming of tools/parts and benefits to STEM education
30 minutes	Hands-On Exercise: The Practices of Safety: We are Aviators!	Sterile cockpit practice and the concept of safety using the preflight checklist and roles; activities includes, preflight checklist (e.g., inspection) with a group exercise
30 minutes	Presentation: Things you should know - Planning of the Activities	Determining the decision (Go –or- No Go)
90 minutes *	Hands-On Exercise: Instructional Learning and Demonstration	Instructor demonstration with groups based on the decision and activity requirements
30 minutes	De-Briefing and Summarize Key Points	Discussion, Survey (if provided), and Plan Next Steps
3:30	*The session could be modified to fit the selected components and scheduling needs of the workshop requirements	

Photo demonstrating the workshop and event

Spring 2019 - ENGE 150 Modern Engineering Design Course: The Integration of AREN Application to Understand Flow Characteristics and Capabilities with Monitoring the Wind Tunnel Environments

- The project description is provided below with the requirements:
- The AREN/NASA (AEROKATS and ROVER Education Network - https://www.globe.gov/web/aren-project/overview) community and ENGE 150 Modern Engineering Design course has received great interest with the wind tunnel project starting in Fall 2017. This year's project will continue the design, testing and development of the wind tunnels to deliver a not only the critical requirement of 10 mph, but also integrate a flow rate system as part of the implementation design. 2018. The cohorts for Fall 2017, Spring 2018, and Fall 2018 semesters were able to capture and advanced the wind tunnel systems each year; however, they all failed to meet the critical requirement of 10 mph with the wind tunnel design. This requirement is critical for the evaluation process of the system behavior using NASA's Aeropod" kite-borne instrumentation technology in specification testing and instructional learning with regard to emerging Earth-science research in STEM education. In addition, the Fall 2018 cohort was tasked to defined and evaluate wind instrumentation calibration as a key objective. As the previous years, 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). The students will also have the ability to install both a flow rate system and cameras in order to understand environmental conditions. Moreover, the engineering students must create instructional supportive documentation (e.g., step by step instructions with manuals, videos and/or any other preferred forms of documentations). The building materials will be standardized and the material items are included in part III below.

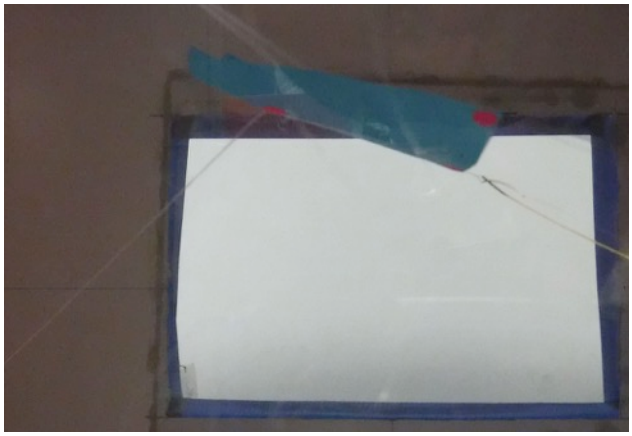
- System specification for engineering design and items required for the project: The following factors are identified to support the items in the project design:
    - Requirement 1: Wind-tunnel design must be able to support the test model and flow conditions using a full scale or sub-scale Aeropod.
    - Requirement 2: Wind-tunnel design must be able to display airspeed measurements at multiple points 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 Ventura 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.
    - Requirement 6: Wind-tunnel design must be built using foam core with a 20-inch fan and other materials identified for standardization purposes in the matrix below.
    - Requirement 7: Wind-tunnel design must have a built flow rate system and application attached to the structure
    - Requirement 8: Wind-tunnel design must have a built camera system to allow evaluation of the system environments and application characteristics.

Present Status

Fall 2019 - ENGE 150 Modern Engineering Design Course: Wind Tunnel Project – It is all About Testing

- The AREN/NASA (AEROKATS and ROVER Education Network - https://www.globe.gov/web/aren-project/overview) community is moving forward with the next objective for ENGE 150 Modern Engineering Design course and their interest will focus on testing. The Fall 2019 class will received an instructional manual design by a previous ENGE 150 student, Brandon Garner on the design requirements in developing wind tunnels. This year's class will adopt manual and identify any constrict(s) in the design process for continuous improvement with regard to the engineering practices; for instances, a) option to build the wind tunnel with foam core vs. poster board; b) graph of wind speed vs. fan speed measures; c) CAD files with templates of the actual wind tunnel design. The Fall 2017, Spring 2018, Fall 2018 and Spring 2019 semesters were active in capturing the project scope and requirements involving the STEM education component for ENGE 150. However, the testing and evaluation process of the system behavior using NASA's Aeropod" kite-borne instrumentation technology in specification testing and instructional learning were lacking due to time constricts of a semester period. The instructions and building materials will be standardized and videos must be produce highlighting the practices, which will include in the project requirements below.
- System specification for engineering design and items required for the project: The following factors are identified to support the items in the project design:
    - Requirement 1: Wind-tunnel design must be able to support the test model and flow conditions using a full scale or sub-scale Aeropod using the instructional manual.

- Requirement 2: Wind-tunnel design must be able to display airspeed measurements at multiple points within the test sections with measurements of wind speed as a comparison to fan speed.
- 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) with CAD files and templates.
- Requirement 4: Wind-tunnel test must have a system mount with a configuration adjustment for the Aeropod.
- Requirement 5: Wind-tunnel design must have the kestrel-based profilers to test the fan speed.
- Requirement 6: Wind-tunnel design must be built using foam core or poster board with a dual 20-inch fan and other materials identified for standardization purposes in the matrix below.
- Requirement 7: Wind-tunnel design must have a built flow visualization to evaluate system environment and application characteristics (e.g., video recording).



Collaborations/Future Plans

UMES will identify future plans and collaboration efforts with teachers to disseminate activities related to AREN projects in the classroom and engineering/aviation practices with regard to wind tunnel designs, global network and the science user community involving the Aerokats and Rover training.

University of South Florida

Summary of accomplishments for the reporting period

The USF partnership in the fourth year focused on the Foundations of Engineering Lab course which is a design class for first year undergraduate students. Last year, Foundations of Engineering Lab engaged approximately 100 undergraduate students in redesign activities around the Aeropod and kite based data acquisition. That work was continued this year as another 100 students were engaged. 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 also continues to bridge the gap between the unique NASA technologies and the engineering design process. 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. In addition, For Foundations of Engineering Lab, undergraduate students presented their designs to approximately 50 middle school kids, raising the grand total of those effected to approximately 200 counting undergraduates and middle school youth. Those that participated in Foundations of Engineering Lab also presented their ideas to their peers.

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. Over the last year, design ideas fell into one of four major categories. Some students focused on means of attachment of components. Others focused primarily on aesthetics. Performance was also a focus, creating a platform that was lighter and performed better in the air. Lastly, reliability was a design area that could be seen as a way to make the product more reliable in the air, upon a crash, and also more reliably created through means like rapid prototyping.

The second page of this report shows some of the ideas students have come up with to this point. 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.

Future plans for the USF partnership focuses on developing a design project for the Foundations of Engineering Lab course that focuses on the development of the ROVER platform. The same approach will be taken with the ROVER design that took place with the Aeropod design. Students will be provided with a base platform and will iterate upon that design to create something that is more useful in an educational setting. Currently, a team of 3 students is hired through the grant to work on development efforts towards this end. The students all have experience completing the Foundation of Engineering Lab course and will provide that understanding for the new project. The new project around ROVER will be kicked off during the spring semester. During that semester, we will create 20 groups of 4-5 students through those students that opt into the ROVER project. The Aerokats project also will continue during the future so some developmental effort will take place around improving that project so it can consistently be used during the fall semesters.

A partnership also was developed with a student organization called the Society of Aeronautics and Rocketry. This organization will be trained by Dr. Gaines with a focus on how to follow proper protocols and procedures when testing the Aeropod platform. This way, the testing

component of Foundations of Engineering Lab projects is expected to be more robust. Students will spend more time flying the Aeropod than ever before and testing their new ideas.

Here is an example of a written deliverable students created in Foundations of Engineering Lab (EGN3000L) last semester.

EGN3000L focused on students developing skills necessary which is why the course is structured in a way to introduce first-year engineering students to expect as an engineer or in future classes. The structure of the course is divided into three parts: Individual designs, group designs, and product manufacturing and presentation.

The first part is the individual designs which focus on improving individual skills in CAD as well as our creative thinking skills. In this group, there were three designs which included the tutorial, cosmetic design, and functional design. The tutorial is mainly served as a guide to introducing the students to the CAD software called Tinker CAD. Then, the cosmetic design assignment focused on putting our thoughts into turning them into an idea which is designing a rough model of the project using Tinker CAD. At last, we changed the cosmetic design into a design that can function meaning changing any extravagant parts. The focus of this last assignment is to design a product that could potentially work. This part of the course helps gather information as well as provide a direction that the course will be progressing towards.

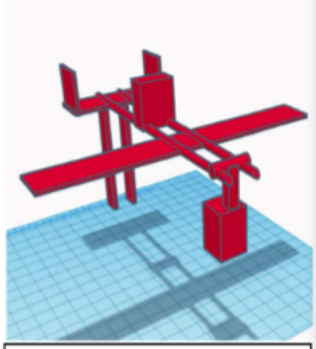


Figure 1: Functional Design rendered in Tinker CAD

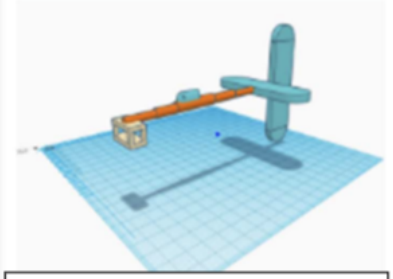


Figure 2: Final group design which shows incorporation of selfie stick and round fins for aesthetics.

Furthermore, the second part of the course focuses on group work which developed our communication skills. In this part, there is three assignment in this part which includes Design Review 1, Design Review 2, and first group design. Design Review 1 is our first interaction with the customer where each member of the group presented our ideas and better understood the customer's needs and wants. This served as a base for this part of the course as we used these ideas to format our first group design. Our first group design included the design that the customer liked the best and we incorporated some ideas that we thought that the customer might like. After we designed the product, there was another design review where we showed the customer how we incorporated his wants and needs in the type of design he liked. All in all, this part focused on interacting with the group and the partner to brainstorm and develop a design.

The last part of this course focused on developing the product which helped develop our problem-solving skills. This part is also divided into three assignments: Design review 3, fabrication, and showcase. Design review 3 diverged into each group roles. As I was the educational materials lead, I focused on building an outline of the educational materials as well as helped design the final group design. For the fabrication, I focused on developing an outline for the educational materials. Educational materials are used as a guide for the product as it describes

Figure 3: Final manufactured body with the fins attached.

Figure 1: Student written reflection about the ideation phase of the Foundations of Engineering Lab course. This figure shows individually crafted functional design, a group crafted group design

On this page and the next page are examples of project hardware that was developed. Both groups focused on aesthetics and means of deployment and attachment. One group focused on aesthetics primarily but then developed an innovative folding dowel for their final project deliverable. The other group focused on ease of assembly in the field and easy to deploy press fit components.

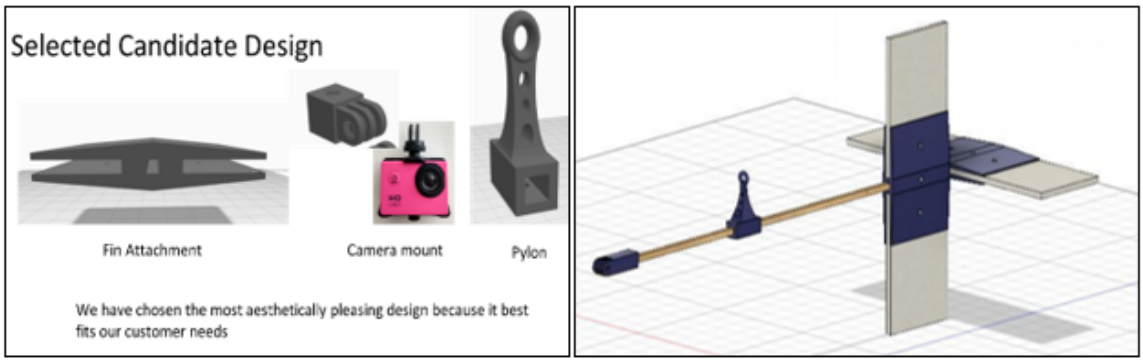


Figure 2: Images capturing the ideation phase for the Aeropod design project in collaboration with the middle school community partner. Insight from the partner was to make the design lighter and more aesthetically pleasing

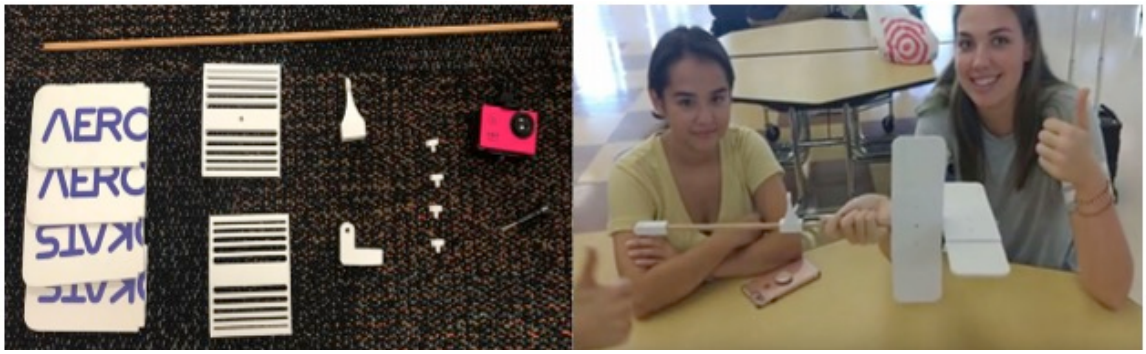


Figure 3: Summary of the fabrication phase for the project described in Figure 2. Leftmost figure shows the individually fabricated parts. Rightmost figure shows the undergraduate student present at the design review

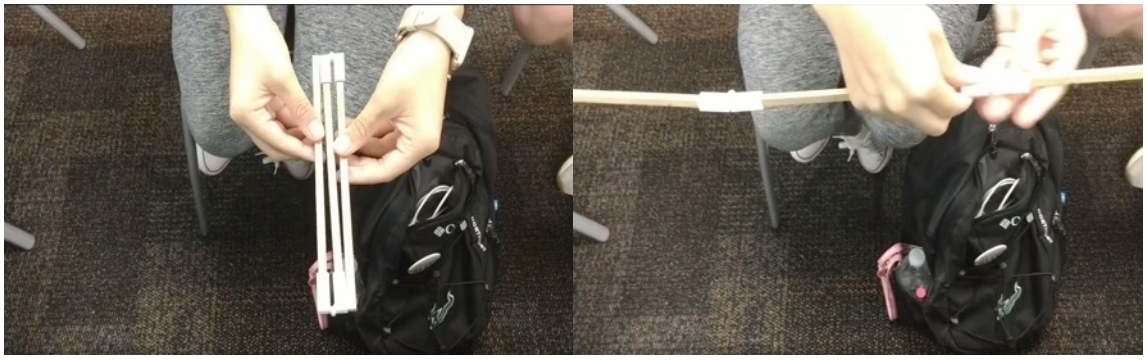


Figure 4: Close up of the foldable dowel developed for ease of assembly of the Aeropod

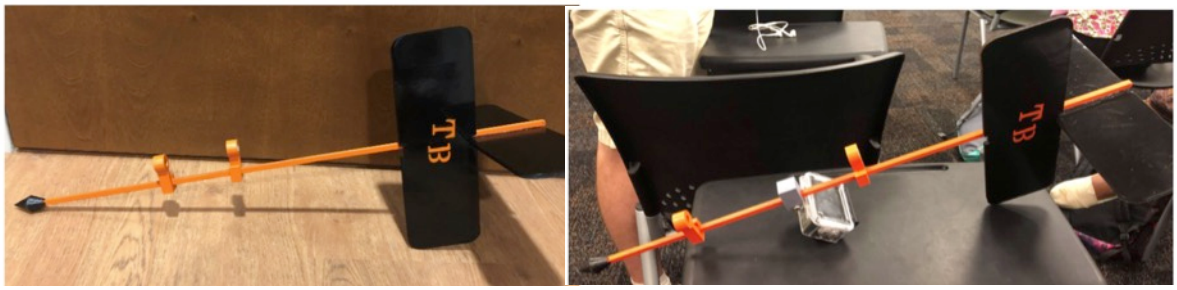


Figure 5: Aerpod design presented at Turner-Bartels where the students addressed the means of attachment for 3D printed parts and aesthetics

Figure 6: Close up of the slide attachment created by one of the groups to help with ease of assembly

Other groups focused on performance. Some made the payload smaller and lighter while others rethought passive stability. Examples are found on this page and the following pages

Figure 7: A smaller version of the Aeropod intended to help with performance, increased stability, and aesthetics

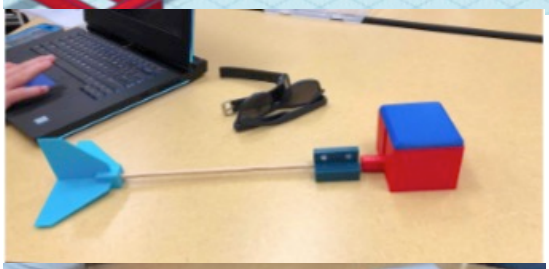


Figure 8: The final version of the project mentioned in Figure 7 where the attachment of the camera had to be adjusted during the fabrication process.

Figure 9: An additional project that was fabricated to reduce complexity and increase performance by reducing weight and size.

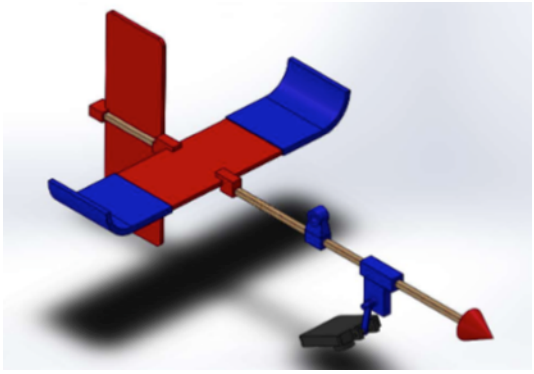


Figure 10: Redesigned Aeropod with the camera mounted towards the center in the ideation phase

Figure 11: Redesigned Aeropod for aesthetics. This design features camera center as opposed to the end of the Aeropod

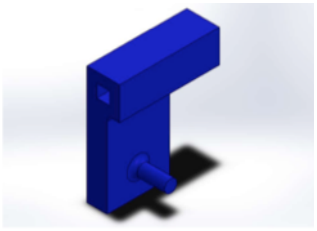
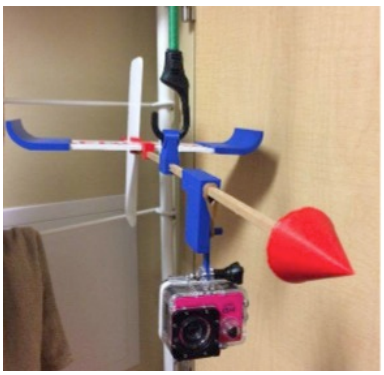


Figure 12: for the center Figure 11 and also addressed means of



performance and placement towards the

Camera attachment part mounted camera of 12 showing the group challenges with the attachment

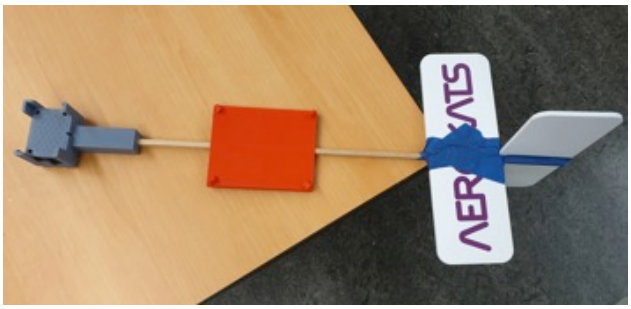
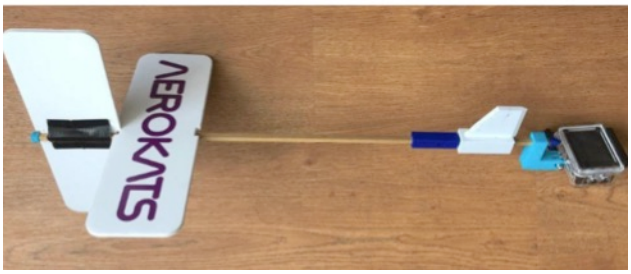


Figure 13: Design that focused on the means of attachment of the aeropod to the kite exploring ways to make the platform more stable by providing multiple anchor points as opposed to just one

Figure 14: Design that focused on using the waterproof casing and camera while also addressing the means of attachment. A shortened pylon was used with a fin attached to also address stability



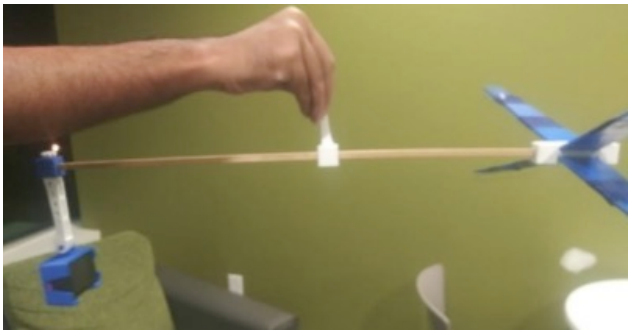


Figure 15: Redesigned Aeropod with adjustments to the tail in order to address issues with aesthetics and performance. The camera mount was also redesigned to provide for easy removal and reattachment for data collection

Washington College

1. The buoy system funded in program year 1 was deployed in March and removed from the water on, or about November 15th to prevent ice damage. (March/Spring 2019). The buoy was rebuilt and calibrated for the 2018 field season. The buoy data was posted on the OTT-Hydromet Cloud.

   A new water quality system is being installed on the buoy to match the system on AquaRover (see item 2). The AquaTROLL 500 and VuLink will be resident in the buoy for the coming program year (2020). The purchase of the 500 and Vu-Link was made outside of this program budget allotment.

2. In February of 2019 Levin presented with Geoff Bland & Brian Campbell at the Maryland Association of Environmental Outdoor Educators, Towson, MD – 3 hours with 25 educators – with G-Scale Trains, 4 species of Rovers, Kites, Remote Control Dump Truck, and Trees.

3. The AquaRover - Rover 10 was fitted with the Hydrolab HL4, the same WQ system in the buoy. However, the Hydroilab HL4 is to be replaced by an In-Situ AquaTROLL 500 and a new vu-link data logger. The new datalogger has an internal GPS and will replace the Canmore GPS presently onboard the Rover. The water quality data will be directly stamped with a GIS coordinate. The spatially collected water quality data will be easily imported into ArcGIS for map creation.

4. Participated in AREN Introduction to Assateague Coastal Trust.

5. As schedule allowed, Levin attended weekly program telecons and contribute as appropriate.

6. The CES Education Manage participated in the annual workshop at CBEC in Grasonville, MD. On September 17. Jemima presented “Bathy in a Box”.

7. CES continues to work with 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.

8. July 2019 – 15 Middle Schoolers explored remote sensing; Kites, Monocams & Atmospheric Profilers at Washington College.

9. Kites were introduced into an Undergraduate Applied Sciences Course taught by Dr. Jillian Bible with assistance from Jemima Clark (Education Manager for CES @ Washington College).

10. Additional connections between Citizen Science and GLOBE were identified and brought to the NASA GLOBE office attention, including phytoplankton monitoring. GLOBE protocols for clouds, water quality, and earth science. The GLOBE program was introduced in the UK, Morocco, Venice, Italy, the Azores, and Anchorage, Alaska –

11. Continue to investigate the inclusion of Aquabotz, an underwater engineering program where students design, build, operate working underwater robots in a little more than an hour.

12. Established Watershed Innovation Lab within the Center for Environment & Society in the new Semans Griswold Environmental Hall that includes Kites and ROVERS.

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 at the NASA Langley Research Center in Hampton, Virginia. The PI worked with GLOBE to help host the 2019 23rd Annual GLOBE Conference, held in Detroit, Michigan, the week of July 14, 2019. The PI worked with local Detroit area schools to support student work for the 2019 GLOBE Midwest Regional Student Research Symposium.

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

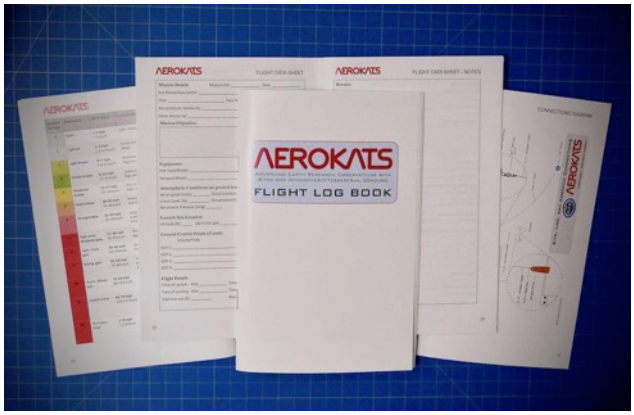
- Metropolitan Detroit Science Teachers Association Conference
- Teacher Workshops for the Rouge Education Project
- Student Training for the Rouge Education Project
- National Science Teachers Association
- Maker: Wayne RESA Maker-STEM Summit 2019
- GLOBE and AREN Training Workshop at Madonna University
- Collaboration with Mission Earth for the GME Satellites Student Conference
- Collaboration with NASA at the Odyssey of the Mind Event at Michigan State University

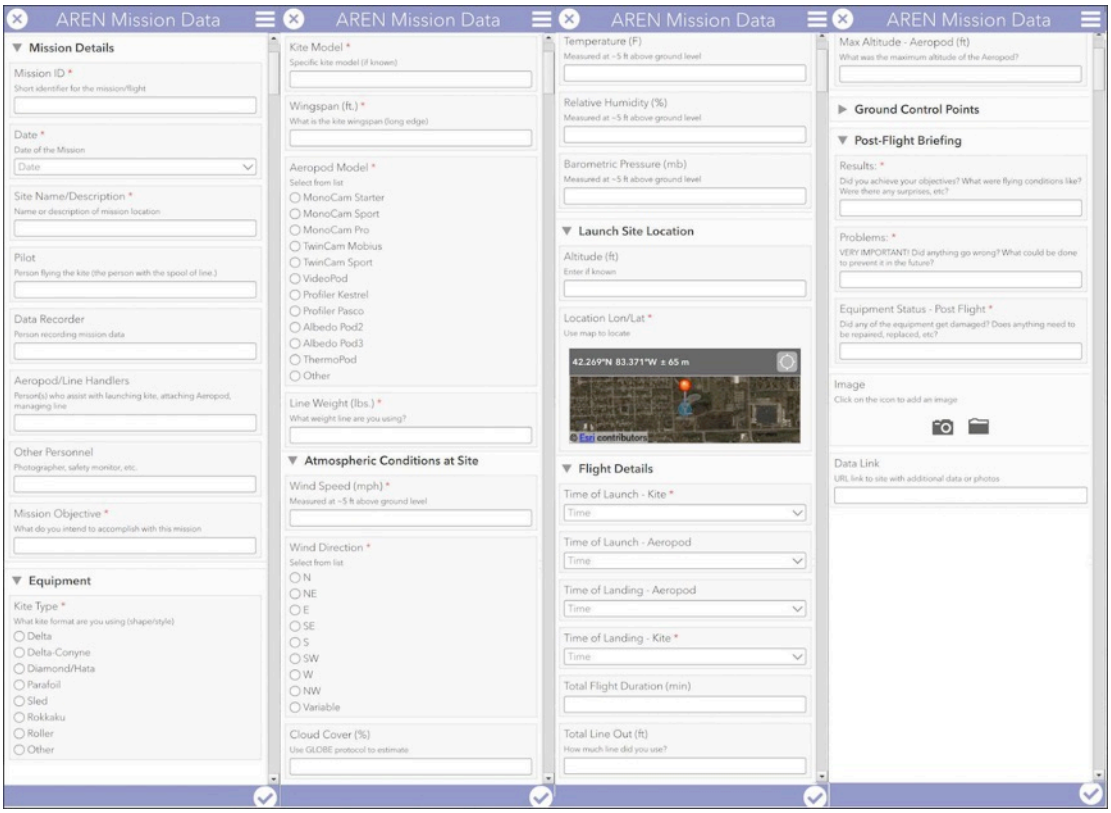
The AREN Project continues to work with the Rouge Education Project. The purpose of working with the Rouge Education Project is to support their work in water quality testing and integrating GLOBE and the AREN Project into their defined work. The AREN Project and the Rouge Education Project are working 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 2020.

Wayne RESA distributed 50 Earth Science Week Toolkit packets to Earth Science Educators throughout Michigan.

Mission Mapper tool – deployed beta for field-testing, including both app and web based data entry tools. User feedback is guiding design decisions for updated version. Planned release of version two is spring 2020. (App link: https://arcg.is/1TeDGy)

The AEROKATS Flight Log Book has been developed for recording mission data in the field and is in use by schools. The corresponding app allows data to be collected in the field and uploaded directly to the AEROKATS Mission Mapper database. Over 100 flight missions were added to the database in 2019.





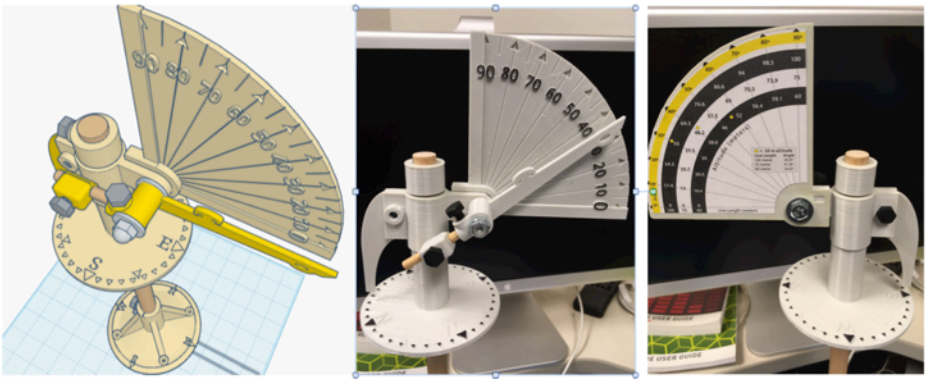
We continue to produce and distribute Aeropods, and handle the purchasing and distribution of all related materials for the project. R&D into improved designs and expanded instrumentation options and processing tools is ongoing as well.

Technician James Moon-Dupree joined the Wayne RESA team. James work has focused on fabrication, packaging and shipping of Aeropods and other materials; inventory control, support for educator training; and ROVER 10 Arduino based sensor kit development.

We have been working closely with Kay Rufty at GSFC on development of new AEROKATS.org website to serve as implementation resource portal for AEROKATS. Incorporating usability heuristics guidance from HRI to increase value of site to users, as well as formatting all materials for 508c compliance.

We conducted Annual Team Meeting at Chesapeake Bay Environmental Center in September. The team worked closely with evaluators to focus efforts and thinking. Prioritizing the incorporation of our work into GLOBE through specific learning activities was one outcome. To this end we identified and prioritized a limited set GLOBE learning activities for development.

One example of a potential GLOBE learning activity is capturing wind direction at various altitudes using small kites. Wind direction data at various altitudes are used by scientific community. However, these data are often difficult to obtain, and no current GLOBE protocol exists to support this work. While at the team meeting we developed and tested proof-of-concept prototype instruments A post-meeting outcome was the development of a printable version of an instrument for field-testing. Initial results are positive.



Wind direction measurement instrument prototype

Additional priority learning activities are Mission Operations Field Guide, Atmospheric Profiling, and Image Classification.

The team as a whole also trained on the ROVER platform for the first time at the team meeting in Maryland. ROVER 7.3 and ROVER 10.1 are beginning to be introduced in K-12 environments. Wayne RESA is collaborating with Geoff Bland and Ted Miles on the development of a kit-based ROVER with a DIY sensor package for broad distribution.

Working with Jeff Bouwman's class at Shumate, MS in Gibralter, MI, we deployed the first ROVER 7.3 in a public school setting. Two teams of students are using ROVER as part of their GLOBE student research projects this year.

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 RESAis 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.

- 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 Fall and Spring Rouge River Water Testing Weeks. Schools participating in the project include:

    - Garden City High School, Garden City
    - Huron Valley Lutheran High School, Westland
    - Inter-City Baptist Middle and High School, Allen Park
    - Crescent International Academy, Westland
    - Crestwood High School, Dearborn Heights
    - Clippert Multicultural Honors Academy, Detroit
    - Chandler Park Academy High School, Detroit
    - Pierce Middle School, Redford
    - Tyrone Elementary, Harper Woods

Gibraltar Public Schools -- Jeff Bouwman at Shumate MS in Gibraltar taught an advisory class focusing on the GLOBE Project. Here is the information that was given to students to help them prepare for this opportunity:

All Shumate Students are eligible to apply for The GLOBE Program advisory class this year. Students worked in teams as they collaborated with experts from Wayne RESA and NASA conducting research toward their final project.

Teams competed in this year's GLOBE International Virtual Science Symposium (IVSS), along with the GLOBE SRS.

GLOBE / AREN Engineering Challenge in Conjunction with the Engineering Team from Mission Earth

During the first quarter of 2019, the AREN Project promoted an engineering design challenge to engineer a tool for measuring wind speed. The challenge was promoted through the AREN Project and the GLOBE website. GLOBE does not have a protocol for determining wind speed, yet wind speed is very important for determining the success of a kite flight. Unfortunately, the challenge was not very successful. There was only one entrant for the challenge. The entry came from:
Luis Marcelo Paillali Araneda
International Preparatory School
Santiago, Chile

Status/Changes/ Issues

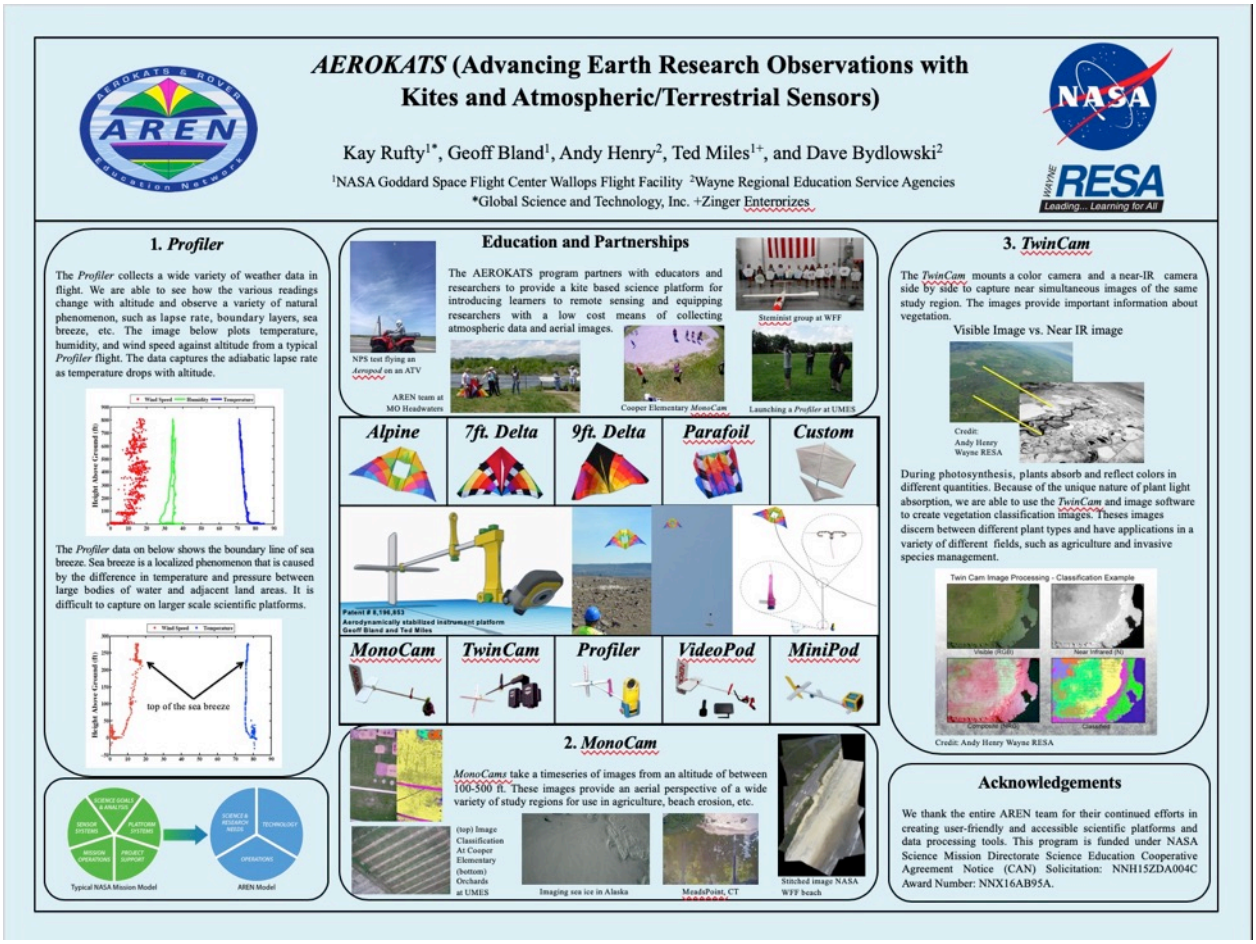
There were two major changes in the AREN Project, during 2019.

- Dr. Anil Aranha, our evaluator for the first three three years of the project was replaced by Horizon Research, Inc. led by Eric Banilower.
- One of our Co-I's, John Bognar from Anasphere, Inc. in Belgrade, Montana decided to leave the AREN Project.

There will be one major change taking place in 2020. The AREN Management Team has asked for David Bydlowski, PI of the AREN Project to be replaced by Andy Henry, presently a Co-I. David will take on the role of a Co-I and remain with the project as a GLOBE partner.

Dissemination Activities

Poster by Kay Rufty (GSFC) for GLOBE Annual Meeting Presentation



Pop-Up Science with NASA at the Michigan Science Center in Detroit, Michigan

By Charles Gibson, Director of Outreach

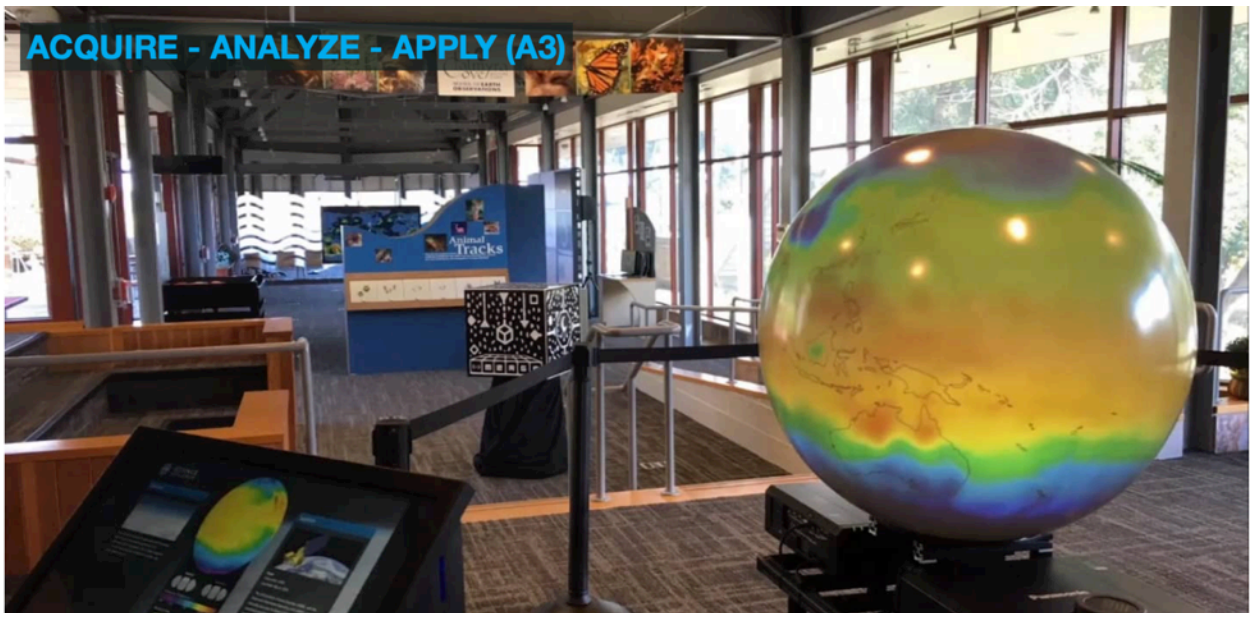
In July, the 23rd annual GLOBE Meeting took place in Detroit just down the road from Michigan Science Center (MiSci), which presented a new, collaborative opportunity for MiSci's planned Apollo 11 50th anniversary events taking place. NASA-funded educators and scientists attending the GLOBE Meeting worked together with MiSci on a special "pop-up science" event to share their work with the public as well as presented several live interactive presentations to visitors on MiSci's Science Stage discussing current NASA Earth science and technology. Through this collaboration with MiSci, it presented a first for the GLOBE Annual Meeting and was such a great experience that they hope to continue making these local community connections at future meetings. Read the full partner highlight to learn more about MiSci's Pop-Up Science with NASA events

https://www.nisenet.org/blog/post/partner-highlight-pop-science-nasa-michigan-science-center-detroit-mi

AREOKATS Highlighted in 2019 STEM for All Video Showcase

Acquire – Analyze – Apply (A3)

John Moore: Palymyra Cove, Institute for Earth Observations, Rowan University
https://stemforall2019.videohall.com/presentations/1443

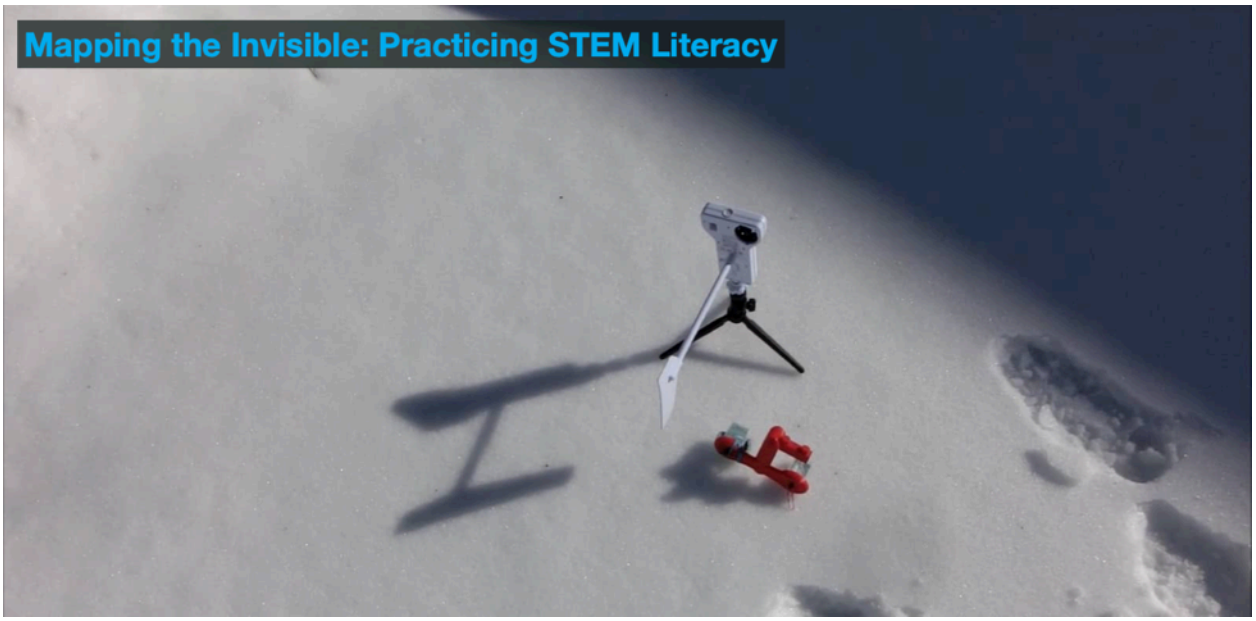


"Engaging in STEM Education with Big Data Analytics and Technologies: A Rowan-Cove Initiative" focuses on the large amounts of data have become available across fields in science, industry, government. Big data analytics and technologies hold tremendous promise to boost economic productivity, enhance national security and improve the quality of life.
ACQUIRE: Acquiring satellite imagery and data sets are often difficult for teachers, students, and citizen scientists. HoloGLOBE was envisioned to be a "mixed reality" node where participants post and share their interpretations of satellite imagery along with their own field observations with other participants worldwide. Through Augmented Reality current satellite imagery and data sets can be viewed and investigated.
ANAYLZE: Traditional field experiences of making observations and measurements following established science protocols are used to create a database, which provides "ground-truth" data that can be compared to data/imagery gathered from space platforms as in the GLOBE Program's Satellite Collaborations. The use of ImageJ and the creation of Geographic Information Systems (GIS) allowed for data to be viewed in a new way, and once again, developed transferable workforce readiness skills.
APPLY: STEM professionals are using satellite and remote sensing technologies to incorporate imagery, data, real-time observations, and modeling into daily decision making on a local to a global basis. GIS content is taught as a technical skill, and is used to develop "Geospatial Thinking" and the gathering of "Environmental Intelligence" to be used in problem-solving in

multiple communities, and has become an integral component of data analysis and communication.

Mapping the Invisible: Practicing STEM Literacies

Betsy Stefany: The SABENS Group



https://stemforall2019.videohall.com/presentations/1397

The NH-based MSP "STEM Literacy Community of Practice" educators and an ELO student share views of Project-based activities that advance ELA critical reasoning and documentation skills while supporting rural community relevancy to STEM. Their activities include the introduction of coding, applying ELA skills to extend the reasoning described as "cascade of Practices PBL Sequence" (from Bell et al., 2011) research to place-based practice.

The activities build on science literacy research (Moulding 2013), increasing critical reasoning support and increasing experiences. These additions ensure local relevancy and leverage from existing community programs. The video shares varied grouping from collecting evidence and model development to historical site data. This approach enables skills to be developmentally appropriate, formatively accessed and accessible while maintaining student privacy. Their middle students are preparing for changing high school "Extended Learning Opportunities" requiring progressive ELA support and communication skills.

Since NH is known for the "worst weather", this year's video focuses on the challenge to observe and document movement in a spatial context. The phenomenon of wind serves to focus

the varied projects from design to movement documentation and the complexity involving mapping invisible wind turbulence.

Since the MSP teacher/researchers use a variety of digital tools in projects, continuing to extend STEM projects beyond their classroom to informal program applications and model building that include engineering practices relevant to their geographic community.

The research as a Community of Practice enables partners to join and continue to update activities as evidence is published. Time is flexible to teaching and learning with activities providing the documentation through technology. Building on the findings, the teachers can adjust to changes and take advantage of micro-credentialing while students build skills to advance spatial literacy. The video invites interactive discussion.

Calendar for Training and Professional Development

2018 Calendar -- November - December

November 3 -- MDSTA / DACTM Fall Conference (Jeff Bouwman, David Bydlowski and Andy Henry) at Cousino High School in Warren, MI -- Presentation Sessions Include: "Foolproof Kites that are Easy and Fun for all Ages," "#GettingScienceDone," and "Aerial Exploration of Environmental Study Sites Using Kites, Cameras and Other Sensors" (33 Educators Participated)

November 5-9 -- "NASA SMD Science Activation Annual Meeting" (Geoff Bland, David Bydlowski, and Andy Henry) at the Lansdowne Resort and Conference Center in Leesburg, VA.

November 7 -- Career Day for 3rd - 5th Graders with AREN Kite-Building at the Ward Museum in Salisbury, MD (123 student learners)

November 8 -- "Teaching and Learning Symposium technology showcase at Montana State University". The AREN team will showcase miniature kites, full-scale kites, AREN-related remote sensing equipment and data collection apps at a technology-focused exhibition for MSU faculty, staff and graduate students.

November 8 -- Heck Quaw Elementary School STEM Night in Belgrade, Montana. The AREN team will make miniature kites with students in grades K-4 and exhibit an aeropod, Kestral and full-scale kite.

November 30 -- Ward Museum Rover Training and NPS Assateague Island Research and Training Flights (Kay Rufty, Ted Miles, Jenny Friedman, Neil Winn, Geoff Bland) on Assateague Island, Maryland.

December 8 -- "Rouge Education Project New Teacher Orientation" (David Bydlowski) at the PARC in Plymouth, MI.

December 10 -- "New Capabilities with Miniature Platform and Sensor Systems" (Geoff Bland) at the AGU Meeting in Washington, DC.

December 10 - "Addressing Equity and Student Self-Efficacy through Student Research Symposia" (David Bydlowski) at the AGU Meeting in Washington DC

December 11 -- "Infragram - A DIY Aerial Multispectral Photography and Analysis Platform for Classroom Use" (Jeffrey Warren) at the AGU Meeting in Washington, DC.

December 12 - "AEROKATS" (Advancing Earth Research Observations with Kites/Terrestrial Sensors) - (Kay Rufty, Geoff Bland, And Henry, Ted Miles, David Bydlowski) at the AGU Meeting in Washington DC.

December 12 -- "AEROKATS and ROVER Education Network - a Multidisciplinary Approach" -- (Geoff Bland, David Bydlowski, Andy Henry) at the AGU Meeting in Washington, DC.

December 12 -- "Tethered Aerosystems: Emerging Tools for a Variety of Observations / Posters" (Geoff Bland, David C. Pieri) at the AGU Meeting in Washington, DC.

December 19 -- AREN Participation (David Bydlowski) in Earth Force Training at the PARC in Plymouth, MI

2019 Calendar -- January -- October

February 7 -- "Family Science Night" (Suzi Taylor and Kelly Boyce) at Montana State University in Bozeman, MT. (175 Participants)

February 8 -- "NASA's Advanced Earth Research Observations with Kites & Atmospheric/ Terrestrial Sensors (AEROKATS) Program" (Doug Levin, Geoff Bland, and Brian Campbell) at the Maryland Association for Environmental and Outdoor Education Conference in Towson, MD (11 Participants)

March 4-8 -- GLOBE North American Regional Meeting at NASA Langley Research Center in Hampton, VA

March 28 -- "Washington College Flies Some Kites" (Jemima Clark and Doug Leven) at Washington College, Chestertown, MD (34 Undergraduate Students)

March 30 -- "Expanding Your Horizons - A STEM Event for Middle School Girls" (Suzi Taylor) at Montana State University in Bozeman, MT (300 Participants)

March 31 -- "Kite Day with the Creepy Crawlers" (Alissa Quinton and Judy Wink) at Chesapeake Bay Environmental Center in Grasonville, MD (47 Children and 40 Adults Participated)

April-May -- AREN GLOBE Wind Speed Challenge

April 1-30 -- National Kite Month

April 4-7 -- GLOBE Midwest Student Research Symposium at the University of Northern Iowa in Waterloo, IA

April 11 -- "Design Review for Wind Tunnels" - ENG 150-Engineering Design/Dabipi/Brown -- (Willie Brown, Geoff Bland and Chris Hartman) at University of Maryland Eastern Shore (15 undergraduate students participated)

April 11 -- "Mission Readiness Reviews for Student Project Flights - AVSC310 - Introduction to Remote Sensing/Henry (Xavier Henry, Geoff Bland, and Chris Hartman) at University of Maryland Eastern Shore (16 undergraduate students participated)

April 13 -- "#GettingScienceDone" (12 Educators) and "Aerial Exploration of Environmental Study Sites -- Using Kites, Cameras, and Other Sensors" (18 Educators) (David Bydlowski) at the National Science Teachers Association Conference in St. Louis, Missouri.

April 15-17 -- "Our Global Environment: AREN AEROKAT STEM Training" Workshop (Geoff Bland and Sallie Smith) in Puerto Rico. Participants and their Frustrationless Flyer Kites, the Full Group of Participants and Team Hawksbill.

April 15 -- Maker: Wayne RESA Maker - STEM Summit 2019 (Andy Henry, Judy Bowling, Kay Rufty, and David Bydlowski) at the Henry Ford in Dearborn, MI

May 1 -- Bay Sox STEM Expo (Alissa Quinton and Judy Wink) -- Bowie Bay Sox Field in Bowie, Maryland (1240 Students in Grades 1-12)

May 1 -- GME Satellites Student Conference at the University of Toledo.

May 3 - Water Quality Testing Day (David Bydlowski) at Farmington STEAM School in Farmington Hills, MI (84 Students)

May 8 -- Atmospheric Profiling and Aerial Imaging of the Rouge River (David Bydlowski) with Students from Clippert Multicultural Academy in Detroit, MI (35 Students Participated)

May 22 -- Bay Sox STEM Expo (Alissa Quinton and Judy Wink) -- Bowie Bay Sox Field in Bowie, Maryland

May 23 -- AREN Project Presentation and Kite Flying (David Bydlowski and Andy Henry) at the Odyssey of the Mind Event at Michigan State University in East Lansing, MI (83 Students)

May 24 -- AREN Project Presentation and Kite Flying (David Bydlowski) at STEAM School in Farmington Hills, MI (75 Students)

May 25 -- Upward Bound Teachers Training (Willie Brown) at University of Maryland Eastern Shore

May 30 -- Bay Sox STEM Expo (Alissa Quinton and Judy Wink) -- Bowie Bay Sox Field in Bowie, Maryland

June 3-4 -- AREN Project Presentation and Kite Flying (David Bydlowski) at Hillside Elementary School in Farmington Hills, MI (20 Students) Photo 1; Photo 2; Photo 3; Photo 4

June 3-21 -- Adventures in AERO Summer Camp (David Padgett) -- Hunters Lane High School in Nashville, TN (65 Students and 6 Teachers) Photo 1, Photo 2, Photo 3

June 19 and 24 -- AREN Project Presentation and Teacher Workshop (David Bydlowski) for Returning Rouge Education Project Teachers at the PARC in Plymouth, MI

June 25 -- Western Aerospace Scholars Presentation (Suzi Taylor with Support from NESSP) at the Montana Learning Center, Canyon Ferry Lake, Montana

June 28 – Citizen Science and the Lewis & Clark Trail: Educator Workshop at Montana State University. Bring history, citizen science, NASA technologies and Montana water quality research to your classroom or out-of-school program as you meld the mystique of the Lewis & Clark National Historic Trail with modern tools for data collection. Bozeman, MT http://www.montana.edu/smrc/Educator_Workshop.html (11 Educators)

July 10-11 -- "AEROKAT Kite Remote Sensing Training" (Sallie Smith) -- Goddard Education Resource Center, Greenbelt, MD

July 11 -- Upward Bound STEM Day with NASA/AREN (Willie Brown, Nicole Gale) -- University of Maryland Eastern Shore (30 Students and 7 Teachers)

July 11 – Kite Day at STEM Camp - Bridger Kids Summer Camp, Belgrade, Montana. Hands-on STEM for kids in grades K-5. https://www.bridgerkidscamp.com/ (26 Students)

July 11 -- Frustrationless Flyers at Summer Camp with Artist Beth Kennedy (Suzi Taylor) in Belgrade, MT (15 Educators)

July 14-19 -- GLOBE Annual Meeting in Detroit, Michigan (David Bydlowski, Andy Henry, Geoff Bland, Kay Rufty, Jeff Warren, Mimi Spahn Sattler) including "Let's Go Fly a Kite and Learn More About Our Earth" workshop on Belle Isle and “Pop Up Science” event at the Michigan Science Center

July 18-19 -- AREN AMS - Cal U. Maury Project Teacher Matapeake Beach ROVER Missions (Sallie Smith) (24 Teachers)

July 20 -- Mini-Kites and Apollo 11 Drogue (Suzi Taylor) at the American Computer and Robotics Museum in Bozeman, MT

July 24 -- AREN Exhibition (Suzi Taylor) at the Montana Library Association Fall Planning Meeting in Bozeman, MT (30 Educators)

July 24 -- Kite Flight with MSU Explore: Earth and Space Science Camp (Suzi Taylor) at Montana State University in Bozeman, MT (15 People)

July 25 -- Presentation on AREN + Frustrationless Flyer Kites (Suzi Taylor) at the Montana State University Explore Camp in Bozeman, MT (10 People)

August 1 -- GLOBE Presentation and Demonstration AEROKATS Flight (Sallie Smith, Judy Wink and Alissa Quinton) at the Arlington Echo Nature Center in Millersville, MD (24 Educators) Powerpoint Version of the Presentation

August 5 and 12 -- Rouge Education Project New Teacher Orientation (David Bydlowski) at PARC in Plymouth, MI (5 Educators)

August 6 -- AREN Exhibitor Table at the Science Summer Institute for K-12 teachers at Montana State University in Bozeman, MT.

August 6 -- Science Pub Talk: GO on a trail to monitor changes on planet Earth (Suzi Taylor, MSU and Peder Nelson, Oregon State University) on the Lewis and Clark Trail in Bozeman, MT (30 People)

August 7 - Kites and Citizen Science with NASA –Science Summer Institute, Montana State University. Summer institute for K-12 teachers and administrators. The NASA Aerokats and Rovers Education Network provides hands-on experiences that bring a unique "aerial perspective" to learners of all ages using large kites, cameras and sensors. Learn about kite aerial photography (KAP), citizen science, and how AREN helps students experience NASA science missions, technology and operations. Decorate your own sled kite (putting Art into STEM to make STEAM!); build a miniature kite; and find out how you can bring NASA AREN to your students. https://www.swmss.coop/ssi2019.html (120 People)

August 8 -- AREN Exhibit (Suzi Taylor) at the Montana Afterschool Alliance Annual Conference in Bozeman, MT

August 12 -- YMCA Camp Using Apollo Drogue (Suzi Taylor) at STEM Week in Bozeman, MT

August 20 -- Steminist Program (Kay Rufty) at the Wallops Flight Facility Visitor Center (14 Middle School Girls) Photo 1; Photo 2; Photo 3

August 20-21 -- Voyager Pocket Lab/Kestrel Bluetooth Data Collection Test Flights (Sallie Smith) at Greenbelt Lake, MD

August 29 -- The AREN Project Presentation (Kay Rufty) as part of the "What's Up at Wallops" Series at the NASA Wallops Visitor Center (20 participants)

September 17-19 -- AREN Annual Team Meeting at the Chesapeake Bay Environmental Center -- Photo 1; Photo 2; Photo 3

September 25 -- GLOBE Training for Pre-Service Teachers (David Bydlowski) at Madonna University, Livonia, MI (10 pre-service teachers).

September 27 and October 18 -- Prince George's County Public Schools French Immersion AREN Implementation Training (Sallie Smith) at the Dora Kennedy and Maya Angelou Schools

October 2 —AREN Training (David Bydlowski) for Students at Crestwood High School in Dearborn Heights, MI

October 9 -- AREN Flight (David Bydlowski) with Clippert Multicultural Magnet Honors Academy - Detroit Public Schools at Bell Creek Park in Redford, MI (30 Students -- Unfortunately No Wind -- Lots of Effort from Students)

October 11 -- Dissolved Oxygen Water Quality Analysis (David Bydlowski) at the STEAM School in Farmington Hills, MI. Photo 1; Photo 2; Photo 3; Photo 4 (88 Students)

October 11 – American Kitefliers Association Annual Meeting (Geoff Bland) in Seaside, Oregon

October 18 -- AREN Presentation (Suzi Taylor) at the Montana Educators Conference in Bozeman, MT

Evaluation, Collaborators and Cross-Collaboration Agreements Activities

AEROKATS and ROVER Education Network (AREN)

Year Four Evaluation Report

Kayla C. Wingard
Eric R. Banilower

October 2019

INTRODUCTION

Project Overview

The *AEROKATS and ROVER Education Network* (AREN) is a research and design project aimed at broadening authentic STEM experiences through a variety of pathways. The AREN project aims to implement widespread use of two low-cost technologies, AEROKATS and ROVER, with communities and formal and informal science education audiences. The AEROKATS technology consists of a kite with attachments for aerial imaging and sensors; the ROVER technology refers to a remote-controlled watercraft that can collect water quality and other data. The project is composed of several collaborating organizations developing and/or implementing the technologies and associated supports for their use: Chesapeake Bay Environmental Center (CBEC), Goddard Space Flight Center (GSFC), Montana State University (MSU), Public Lab, University of Maryland Eastern Shore (UMES), University of Southern Florida (USF), Washington College, and Wayne County Regional Educational Service Agency (Wayne RESA). The project's ultimate goals are to increase the scientific literacy and STEM capabilities of students and adults, and to encourage them to become part of the next generation of STEM professionals.

In Year Four, the project's work has focused on two areas: (1) testing the implementation of AEROKATS technology with a variety of audiences and (2) continuing development of the ROVER technology. The project has provided trainings for informal and formal educators, as well as offered outreach experiences for students, educators, and communities to generate interest and catalyze further engagement with the project or other NASA-funded experiences. The team plans to refine their offerings based on what they have learned from these experiences.

Description of the Evaluation

Horizon Research, Inc. (HRI) of Chapel Hill, NC is conducting the external evaluation of AREN. HRI joined the project near the beginning of its fourth year and developed an evaluation plan in collaboration with project leaders. The evaluation includes both formative and summative components intended to provide an independent perspective on the project's work and sustainability of its efforts. Questions guiding the evaluation are:

1. What supports would allow different audiences to use the AREN products successfully?

2. What is the quality of AREN's process for developing, testing, and revising supports for different audiences (in both formal and informal education settings)?

3. What are the impacts of the AREN products on the target audiences, including informal educators, K–12 teachers, students, and community members using the products?

4. What is the likelihood that the project's efforts will be sustained beyond the life of the grant?

The Year Four evaluation work mainly focused on deepening HRI's understanding of the project and assisting the project in thinking strategically about its work (addressing the first and second questions). HRI conducted the following evaluation activities between January 2019 and October 2019:

- Attended select weekly teleconference meetings;
- Attended the 3-day annual face-to-face project meeting;
- Conducted telephone interviews with representatives from the collaborating project organizations;[1]
- Assisted the project in unpacking its theory of action; and
- Reviewed the early plans for the project's new AEROKATS.org website.

In the remainder of Year Four, HRI will continue attending weekly calls with the project team and work with project leaders to prioritize the next set of evaluation activities (e.g., developing data collection systems for monitoring upcoming work). HRI will also attend the annual meeting of the Science Activation Collective. As AREN continues to implement its products with various audiences, HRI will provide feedback on the project's processes for developing, testing, and revising the resources it is creating, as well as begin to address the third and fourth evaluation questions.

The remainder of this report is organized in four sections. The first focuses on the project's theory of action. The second section reports the results of interviews with project team members, focusing on strengths of the project, lessons learned, and remaining challenges. The third provides feedback on the development of the new project website. The report concludes with HRI's reflections on the project work and recommendations for moving forward.

UNPACKING THE AREN THEORY OF ACTION

Much of HRI's early work with the project centered on unpacking the project's theory of action—a visual representation of how project activities are expected to lead to both short- and long-term impacts. Theories of action have multiple uses. One is that they make a project's thinking about its work explicit so that all stakeholders understand not only what the project is doing, but how each piece of the work contributes to its goals. They also can unearth assumptions or gaps in a project's thinking, which, if unaddressed, could make accomplishing its goals unlikely. A theory of action can also serve as a touchstone for a project, allowing it to reflect on what it has accomplished and what still needs attention. Along these lines, it can serve as a "map of the mall" for project stakeholders, allowing them to point to specific activities and outcomes in discussions with both internal and external audiences. Lastly, a theory of action can be used to focus the project's evaluation efforts as it helps identify the high-leverage project activities and provides guidance on what data would be most important to collect (evaluation can look at the quality of an activity as well as the extent to which it has the expected outcomes). In interviews with project team members, HRI asked a number of questions intended to help elicit information about the project's theory of action. One question asked team members what a press release they would write at the end of the project would highlight about its

[1] HRI attempted to interview 10 representatives from the collaborating organizations. Despite multiple email invitations, three team members did not respond to the requests. HRI interviewed seven team members representing six collaborating organizations.

accomplishments. Other questions focused on identifying key project activities, intermediate outcomes, and challenges the project has discovered so far in its work. After completing the interviews, HRI drafted an initial theory of action and discussed it with the project leadership. HRI made edits based on the leadership's feedback and continued to work with them until a version was ready to share with other project team members, who were also given opportunities to discuss, ask questions, and suggest edits.

The current version of the theory of action reflects the latest decisions by the project leadership regarding feedback from project team members.[2] Because the project has multiple components, targeting multiple audiences through different pathways, the first page, shown in Figure 1, provides an overview.[3] Much of the project's work up to this point has focused on technology and resource development (shown in purple), which feeds into each of the pathways for the different target audiences. This work includes the development and testing of the remote sensing technologies and techniques, data capture and visualization tools, and, more recently, supports for helping each target audience make use of the technologies in meaningful ways.

[2] It is important to note that a theory of action should be considered a living document—lessons the project learns as it carries out its work could lead to additions, deletions, or other modifications.

[3] Multi-colored elements signify aspects of the theory of action that apply to more than one pathway.

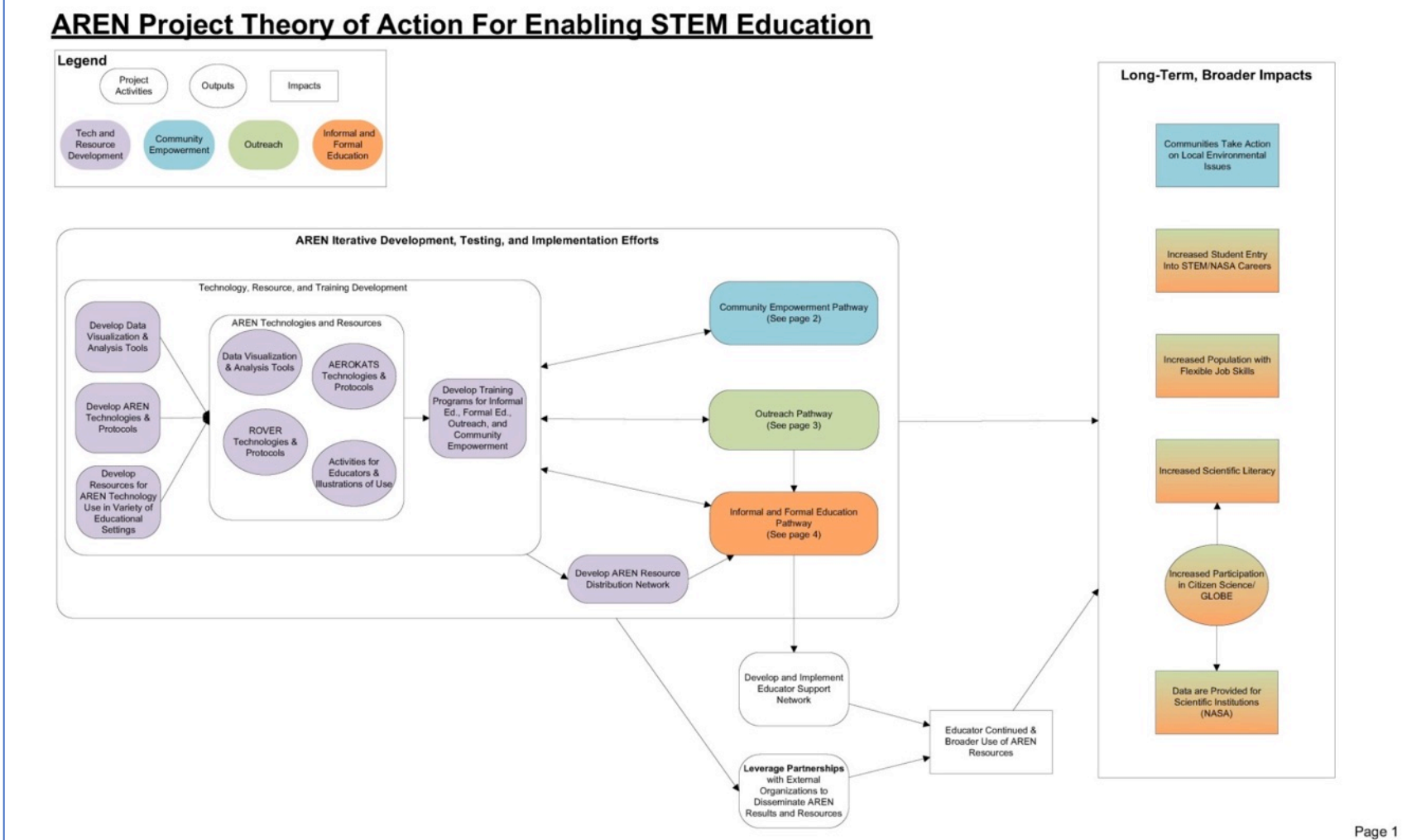

AREN Project Theory of Action For Enabling STEM Education
Legend
Project Activities
Outputs
Impacts
Tech and Resource Development
Community Empowerment
Outreach
Informal and Formal Education
AREN Iterative Development, Testing, and Implementation Efforts
Technology, Resource, and Training Development
Develop Data Visualization & Analysis Tools
Develop AREN Technologies & Protocols
Develop Resources for AREN Technology Use in Variety of Educational Settings
AREN Technologies and Resources
Data Visualization & Analysis Tools
AEROKATS Technologies & Protocols
ROVER Technologies & Protocols
Activities for Educators & Illustrations of Use
Develop Training Programs for Informal Ed., Formal Ed., Outreach, and Community Empowerment
Community Empowerment Pathway (See page 2)
Outreach Pathway (See page 3)
Informal and Formal Education Pathway (See page 4)
Develop AREN Resource Distribution Network
Develop and Implement Educator Support Network
Leverage Partnerships with External Organizations to Disseminate AREN Results and Resources
Educator Continued & Broader Use of AREN Resources
Long-Term, Broader Impacts
Communities Take Action on Local Environmental Issues
Increased Student Entry Into STEM/NASA Careers
Increased Population with Flexible Job Skills
Increased Scientific Literacy
Increased Participation in Citizen Science/ GLOBE
Data are Provided for Scientific Institutions (NASA)
Page 1

Figure 1

Details for each main audience (pathway) are shown the next three figures. Figure 2 illustrates the project's current thinking about the community empowerment pathway, which will be facilitated largely by Public Lab. The vision is that community members will be able to use AREN-based tools and resources to build teams of diverse expertise in order to investigate locally relevant environmental issues and help their communities take appropriate action (e.g., investigating water quality issues). The hope is that users will share their experiences in an online forum that allows a learning community to form and grow.

Figure 3 shows the outreach pathway of the project. Outreach events, typically short in duration, are intended to generate excitement and enthusiasm for NASA science, as well as spark interest in engaging further with NASA-sponsored projects. The project envisions outreach targeted at both students and educators. The project is already conducting a number of such events, for example, MSU has conducted several school-based science and STEM nights using AREN technologies, and GSFC has given presentations about AREN at environmental centers and hosted events where participants could try flying a kite with the AEROKATS program.

The last, and most complex, component of the project is the informal and formal education pathway (see Figure 4). It is through this pathway that the project envisions the most intensive work with target audiences, and the one that has the greatest potential to impact a large number of learners. The project envisions training educators on AREN-based technologies, protocols, and learning activities so that they develop the knowledge, skills, and confidence to engage learners in authentic STEAM (science, technology, engineering, arts, and mathemtics) experinces. In turn, these experiences would: (1) address important concepts and practices of the disciplines, (2) teach valuable job and life skills, and (3) motivate learners to pursue further education and careers in STEM fields. This work has been piloted by a number of partners, including GSFC and MSU. CBEC, GSFC, MSU, UMES, USF, and Washington College have all offered either formal or informal student experiences.

AREN Project Theory of Action: Community Empowerment Pathway

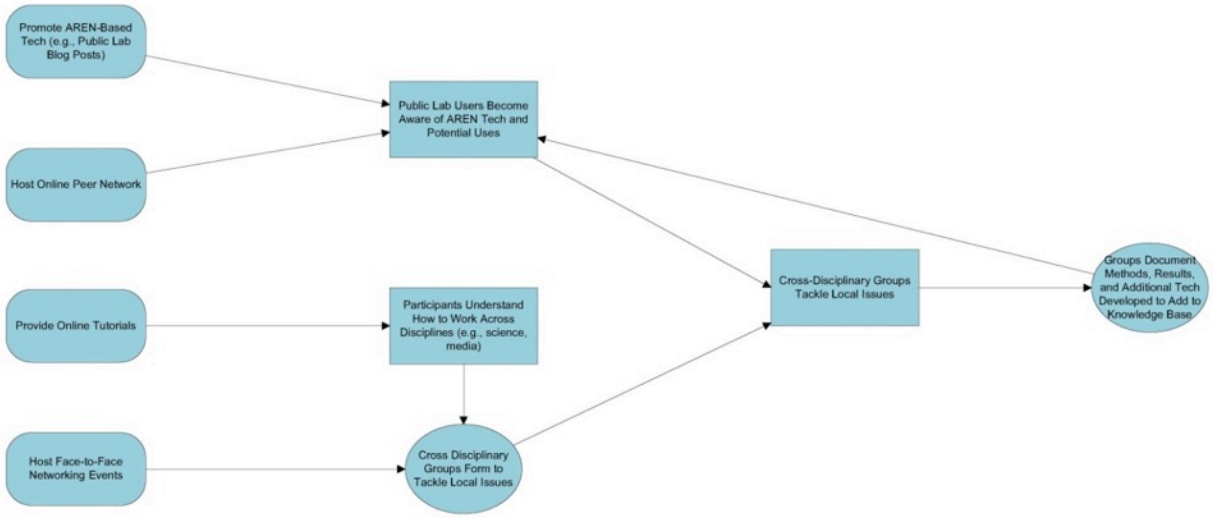


Figure 2

AREN Project Theory of Action: Outreach Pathway

Outreach: Informal, short (<1 hour per audience unit) events.

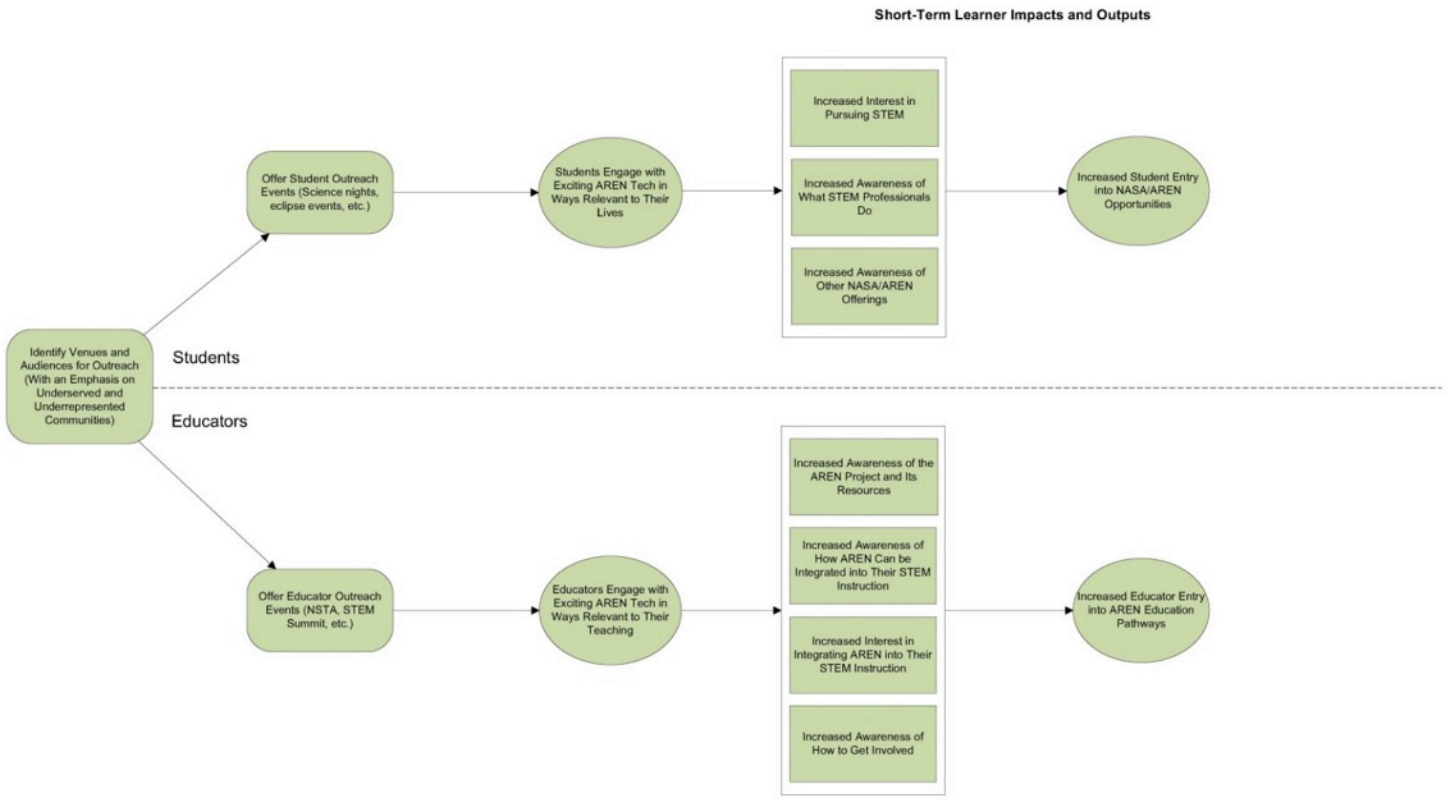


Figure 3

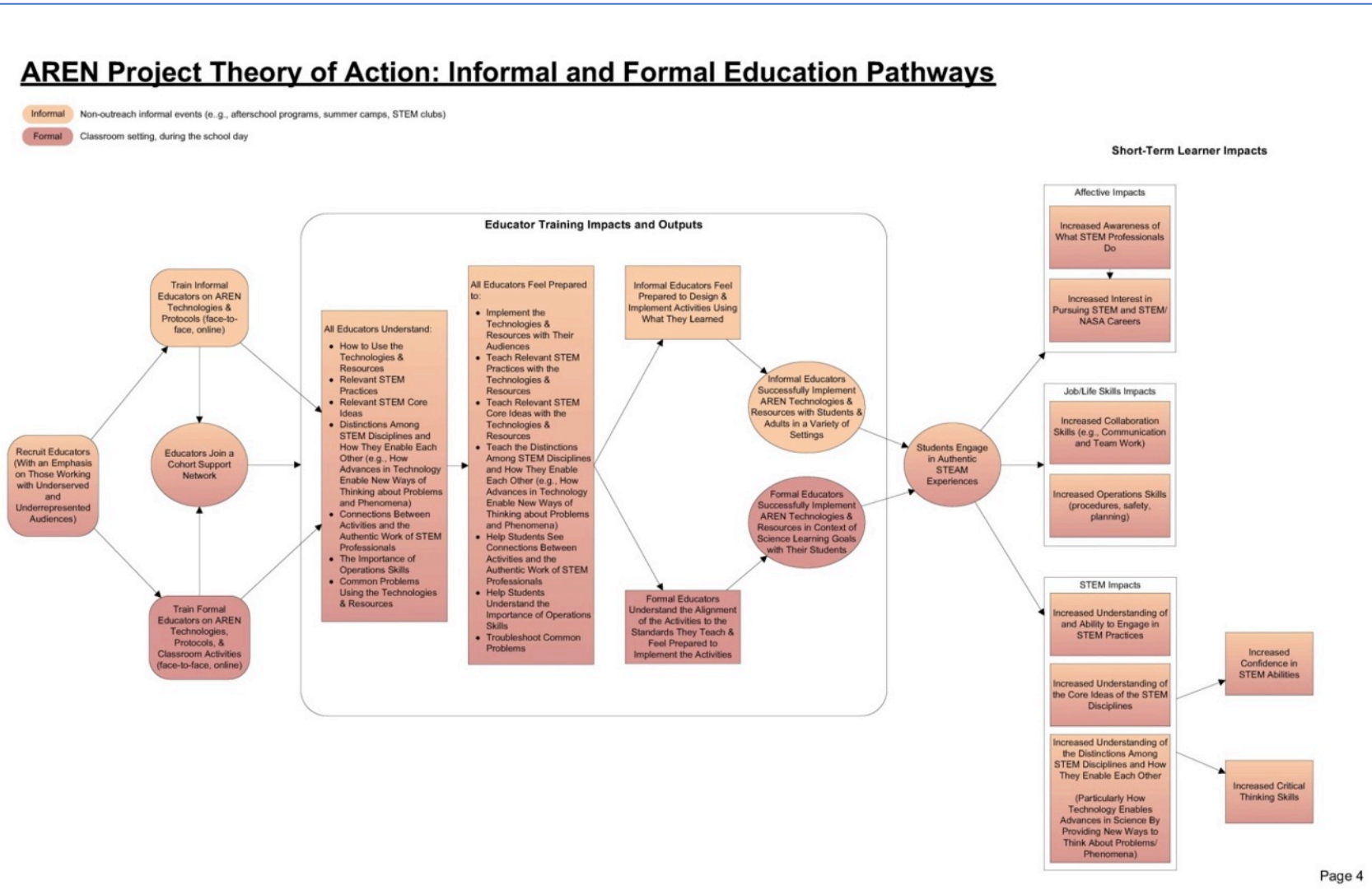

AREN Project Theory of Action: Informal and Formal Education Pathways
Informal
Non-outreach informal events (e..g., afterschool programs, summer camps, STEM clubs)
Formal
Classroom setting, during the school day
Short-Term Learner Impacts
Educator Training Impacts and Outputs
Recruit Educators (With an Emphasis on Those Working with Underserved and Underrepresented Audiences)
Train Informal Educators on AREN Technologies & Protocols (face-to-face, online)
Educators Join a Cohort Support Network
Train Formal Educators on AREN Technologies, Protocols, & Classroom Activities (face-to-face, online)
All Educators Understand:
How to Use the Technologies & Resources
Relevant STEM Practices
Relevant STEM Core Ideas
Distinctions Among STEM Disciplines and How They Enable Each Other (e.g., How Advances in Technology Enable New Ways of Thinking about Problems and Phenomena)
Connections Between Activities and the Authentic Work of STEM Professionals
The Importance of Operations Skills
Common Problems Using the Technologies & Resources
All Educators Feel Prepared to:
Implement the Technologies & Resources with Their Audiences
Teach Relevant STEM Practices with the Technologies & Resources
Teach Relevant STEM Core Ideas with the Technologies & Resources
Teach the Distinctions Among STEM Disciplines and How They Enable Each Other (e.g., How Advances in Technology Enable New Ways of Thinking about Problems and Phenomena)
Help Students See Connections Between Activities and the Authentic Work of STEM Professionals
Help Students Understand the Importance of Operations Skills
Troubleshoot Common Problems
Informal Educators Feel Prepared to Design & Implement Activities Using What They Learned
Formal Educators Understand the Alignment of the Activities to the Standards They Teach & Feel Prepared to Implement the Activities
Informal Educators Successfully Implement AREN Technologies & Resources with Students & Adults in a Variety of Settings
Formal Educators Successfully Implement AREN Technologies & Resources in Context of Science Learning Goals with Their Students
Students Engage in Authentic STEAM Experiences
Affective Impacts
Increased Awareness of What STEM Professionals Do
Increased Interest in Pursuing STEM and STEM/ NASA Careers
Job/Life Skills Impacts
Increased Collaboration Skills (e.g., Communication and Team Work)
Increased Operations Skills (procedures, safety, planning)
STEM Impacts
Increased Understanding of and Ability to Engage in STEM Practices
Increased Understanding of the Core Ideas of the STEM Disciplines
Increased Understanding of the Distinctions Among STEM Disciplines and How They Enable Each Other
(Particularly How Technology Enables Advances in Science By Providing New Ways to Think About Problems/ Phenomena)
Increased Confidence in STEM Abilities
Increased Critical Thinking Skills
Page 4

Figure 4

PROJECT STRENGTHS, LESSONS LEARNED, AND CHALLENGES

It is evident that the project is making progress in many aspects of its work. In the spring interviews, team members were asked to reflect on the project's work, specifically what is going well, what they have learned through their work thus far, and what challenges the project is facing and how it plans to address them. This section of the report highlights main findings from these data.

Strengths

In the interviews, team members described a number of strengths of the project. A main strength, mentioned across interviews, was the set of people and institutions collaborating on the work. Interviewees described those involved as talented, diverse, and dedicated. As one said:

> *I think we have, by and large, a really outstanding team. A lot of talented people, bright people doing interesting things. You know, our, if we go back to our initial proposal and our concept…we really wanted to see more of how does, how does this technology work in a variety of educational environments? …we have partners that work, you know, we have university partners. We have partners that are non-profit institutions, and, you know, a whole range of partners out there.*

Further, the relationships across team members and organizations are seen as positive and productive. Interviewees praised the work of other team members within and across institutions, and saw these relationships as facilitating development and early implementation. In the words of one:

> *People have begun to identify other people that they can regularly communicate with, and that's cool. I certainly like to know what's going on, you know, it's just my nature. But I encourage folks to develop full and loud and meaningful dialogues and activities based on their own interests and capabilities. So yeah, for the most part, I think there are some very, very, special relationships that are being very productive.*

A number of interviewees attributed the progress of the project to its leadership, which has been very supportive of the work of the various team members and organizations. These supports have been both financial and moral. As one said:

> *[Project leader] has been amazingly generous with his time in helping us, and me in particular, figure out just what's our best role for the project.*

The leadership was also praised for facilitating regular communication among all those involved, including disseminating progress updates, lessons learned, and suggestions for solving problems. In the words of one team member:

> *The weekly conference calls on Wednesdays have been terrific. I think leadership from NASA has been on point in terms of [project leader].*

Team members also cited multiple pieces of evidence of the project's progress, including an increase in interest and a resulting increase in project participation. These increases appear to be primarily due to the applicability of the AREN technologies across STEM topic areas and grade ranges in both formal and informal education settings. Interest has also grown from the ability to use some of the products recreationally and with very young children. Additional factors cited as influencing interest were the low price-point of AEROKATS as well as the project's efforts to promote the technologies at educator outreach events. In the words of one interviewee:

We got a bunch of teachers and from around the county to [educator outreach event]—180 teachers and administrators attended and got exposure to the project. And they're all looking at that sort of engineering component and STEM…the whole Maker Movement. And we feel we're really strongly positioned in that regard because engineering is a big component of AEROKATS and so that's, that was, I thought, a very successful event. And it's going to lead to more participation.

Team members also thought these efforts have been having positive outcomes for both educators and students who have participated in the project. Through the various project offerings, team members report witnessing educators who are excited to be teaching with these technologies and students who are excited to be learning with them. They also highlighted cases where participants have gone on to pursue STEM career opportunities after their AREN experiences. As one project member described:

Students from this program have already participated in, you know, in the professional world. We will be hiring at least two students this summer as interns here at [collaborating organization]. So we're getting output from the program in the form of our future workforce.

The project's progress in technology development and distribution is also seen as a strength. Interviewees described this area of work as one that has benefitted from cross-organization collaboration. As one interviewee stated:

I think the technology is working pretty well. Our AEROKATS side of the house, the kite flying side with the Aeropods, the 3-D printing work, is going well. The technology, the instrumentation keeps changing, but I think the team, there's several people on the team that particularly [team members] are doing a tremendous job as well as [team member] keeping up with the changes in the technologies that we have to incorporate into our Aeropod system.

Lastly, the team expressed gratitude for the enthusiasm and support the project has received from NASA headquarters. They recognize the importance and value of this support.

Lessons Learned

Interviewees acknowledged that many of the project's strengths came from lessons that they have learned over the course of doing the work. For example, they stated that the diverse experience each organization brings was something they grew to appreciate over time. Further, interviewees stated that they learned about the potential for reaching a broader audience (spanning topics and grade ranges) by team members trying things out with diverse participants. Interviewees also described several lessons learned about the AREN technologies. For example, the project has learned a great deal about how to deploy the AEROKATS and ROVER technologies safely, particularly related to weather conditions and technology retrieval. In addition, they learned about unanticipated costs associated with using the technologies, such as budgeting for gloves for flying the AEROKATS or parts needed for the ROVER. The project has also realized that it needs to be crystal clear in specifying data collection procedures for AEROKATS. As one interviewee stated:

Well, we've found that the AEROKATS piece is pretty easy to implement; ROVER is much more difficult in terms of technology. If we just dealt with the dollar issue, it's still quite expensive to produce a ROVER. We can make an Aeropod in the AEROKATS program for almost nothing, you know, 3-D printers, there's a lot of tools that allow you

to do it. But basically, you could make one at school. So maybe, so I guess if there was one piece that I wish would move faster, it would be the ROVER because I think there's a tremendous amount of interest in using remote control boats to collect data about a water system to complement schools in their water quality testing programs.

The project has also learned more specifically, how to best integrate the AEROKATS technology with particular audiences. For example, a team member at the university level has determined a sequence of lessons that fit in a first-year engineering curriculum and informal mentoring programming:

So my [informal education event], so in that context, it actually kind of really allowed us to develop some ideas around, okay, how do you get somebody acclimated to the technology and the platform and flying [kites]? And so that was a really good learning experience to kind of see how you could start out the first two weeks with really simple kites, and the next few weeks, you could have them flying large Deltas, and then by the last week of the program, we were flying the Aeropods. [They] learned also about 3-D printing, which I think is also one of the real highlights of the Aeropod, is being able to print it in a short amount of time. And then different aspects of engineering design we could tie to it to improve it.

The project has also learned that participants face a number of barriers to getting involved. One is the amount of time participants need to devote. The technologies require a substantial amount of training in the mechanics of their use and how to implement them with learners in a meaningful way. This issue can be especially problematic for formal K–12 educators who may have limited time for attending trainings. In addition, formal educators also may have limited classroom time to devote to AREN because of the amount of content they are expected to cover. Another pressure mentioned for formal educators was managing large class sizes, particularly in an outdoor setting.

Challenges

When asked about what could be going better in the project and challenges in achieving project outcomes, some interviewees echoed challenges related to the lessons learned and others raised additional concerns. Project identified challenges include roadblocks to participation, ensuring they reach underserved audiences, and staying on the same page with a large project team. Also related to the lessons learned, the project foresees a number of challenges to involving K–12 educators. These challenges include aligning the technology and activities to the standards teachers are expected to teach, finding appropriate outdoor locations, planning for weather, and finding the time to implement components of the activities that do not directly meet learning goals but are integral to the use of the technology (e.g., assigning roles and employing safety checklists). Project team members recognize that they need to bring additional expertise onto the project to help address the issues facing classroom teachers. The project is, however, thinking about methods of obtaining teacher feedback to ensure that project offerings are meeting their needs. One interviewee stated this challenge as follows:

The biggest challenge is helping with participation and making an easy avenue to enter the program…how can we make it so that it's easy enough that people are: (1) willing to

try it and (2) see a real importance in their classroom and can make the connections that they need for teaching kids…It's very difficult, you know, when you're in a classroom with, you know, 30 kids and you have five or six classes a day, it's really pretty difficult to take kids out and fly kites.

Another challenge mentioned by interviewees is ensuring that the project reaches students from groups historically underserved and underrepresented in STEM fields. To its credit, the project recognizes the difficulty of this component of its work and knows that it will take a deliberate and concerted effort to be successful in this regard. As one interviewee said:

I think always our goal is to reach people who aren't always served—so underserved and underrepresented audiences. And it's always challenging. So with any project, I think, that's going to be a challenge…making sure we're not just hitting the people who always participate in every STEM education project.

Although team members see benefits from having a large and diverse group of organizations involved in the project, they also know that this characteristic presents its own set of challenges. In particular, it can be difficult ensuring all team members stay on the same page about key aspects of the project. For example, although team members recognize the importance of GLOBE to the project, the degree of that importance appears to vary across project staff, with some team members thinking the relationship to GLOBE is a key project component and others thinking the relationship is not core to the project's success. Another area where staff may not share a common understanding is the roles and expectations of the collaborating organizations. These challenges can also be compounded by geographic separation. Although the project works to address these issues with weekly calls, accommodating everyone's schedules and availability, especially those working at academic institutions, is another challenge. One interviewee stated:

GLOBE, I think is part of the project, but I think some of the folks at the top of the project think it's like the most important thing about the project. And I think that kind of limits what the project can become. And so, you know, I think just a clear understanding of what our values are and our goals would be beneficial for the project.

Interviewees were also asked how they think the project can overcome these challenges. To address the challenges associated with having a large team, interviewees described the need for leadership to define project goals, set expectations, and strategically plan project meetings. Although team members may have similar visions for long-term project impacts, a clear definition and communication from project leadership would help ensure all organizations can productively coordinate their work. Interviewees also thought that the leadership continuing to work with each organization to help clarify roles would be helpful. Finally, interviewees suggested making sure weekly teleconferences and the more infrequent face-to-face meetings are used strategically to address issues best suited to the meeting format. Having a fleshed-out theory of action to refer to will likely also help, as it will allow team members to point to specific aspects of the project's work. In the words of one:

I think organizationally, maybe the leadership could put together an objective list or priority list of what they might want to accomplish. And then, what they can then do is vet that to the members of the project and see who's doing what, and do a checklist of progress.

The project plans to address the challenge of reducing barriers to participation, particularly with formal educators, first and foremost by making it a priority. The team has already begun devoting more time to discussing what types of educator supports it needs to offer and is taking advantage of the perspectives of team members who have the most expertise in this area. The project is also considering developing different types of supports that it can place on its website

such as how-to videos, example lessons, connections to existing curricula, and a clearer description of ways educators can participate in the project. As one interviewee described the vision for supporting educators through the website:

> *We have to help teachers meet those challenges. So, this AEROKATS.org site that we're putting together, we want to load up a lot of activities, a lot of different models of how this can be used so the teachers have, you know, and the public—whoever's using it—has ideas about how this could fit into what they do without it being a burdensome piece.*

WEBSITE REVIEW

It is clear that the project's websites will play an important role in the project's work. Thus, HRI reviewed both the existing site (www.globe.gov/web/aren-project) and an early version of the AEROKATS.org (https://sites.resa.net/aerokats/) site to help the project consider how the sites can be designed to best meet their purposes. HRI's review was based on a set of usability heuristics[4] (see Figure 5), and feedback is organized into three areas: usability, navigability, and readability.

Usability Heuristics

1. **Speak the users' language**. Use words, phrases, and concepts familiar to the user. Present information in a natural and logical order.
2. **Be consistent**. Indicate similar concepts through identical terminology and graphics. Adhere to uniform conventions for layout, formatting, typefaces, labeling, etc.
3. **Minimize the users' memory load.** Take advantage of recognition rather than recall. Do not force users to remember key information across documents.
4. **Build flexible and efficient systems**. Accommodate a range of user sophistication and diverse user goals. Provide instructions where useful. Lay out screens so that frequently accessed information is easily found.
5. **Design aesthetic and minimalist systems**. Create visually pleasing displays. Eliminate information which is irrelevant or distracting.
6. **Use chunking**. Write material so that documents are short and contain exactly one topic. Do not force the user to access multiple documents to complete a single thought.
7. **Provide progressive levels of detail**. Organize information hierarchically, with more general information appearing before more specific detail. Encourage the user to delve as deeply as needed, but to stop whenever sufficient information has been received.
8. **Give navigational feedback**. Facilitate jumping between related topics. Allow the user to determine her/his current position in the document structure. Make it easy to return to an initial state.
9. **Don't lie to the user.** Eliminate erroneous or misleading links. Do not refer to missing information.

Figure 5

[4] Levi, M. D. & Conrad, F. G. (1996). A heuristic evaluation of a World Wide Web prototype, *Interactions, 3*(4), p.50–61.

Usability

Usability refers to a user's ability to efficiently and effectively complete intended tasks. Designing a website to be usable requires having clearly defined purposes and audiences, clearly communicating these purposes to each potential user group, and making it easy to understand how to use the site for a specific purpose. Typically, a site's home page should make the main purposes and audiences of a site clear and should "sell" the site. In other words, the job of the home page is to tell the site's story and to let visitors know why they might want to explore further.

The existing project site appears to be attempting to serve a multitude of purposes for a variety of audiences. It has both a top menu and a relatively extensive side bar menu, which makes the home page somewhat overwhelming. It also does not provide an obvious path for different types of users. The site has a "participate" option on the side menu; however, this link takes users to a page that contains multiple links to other pages with different information about participation, which greatly raises the effort required by a user. In contrast, the AEROKATS site is more clearly aimed at providing educators with the tools needed to implement the AEROKATS program in their contexts and has a clear "participate" section, with step-by-step instructions for doing so. This clearer pathway for a user will make it much more likely that visitors to the website will both find what they are looking for and then act upon it.

Navigability

Navigability refers to how easy it is for users to move about the site and find the resources they are seeking. The review considered whether the design of the sites made content easy to find and if links and features functioned as expected. Organization of information should be hierarchical and logical, and should encourage the user to delve as deeply as needed. It also requires making clear to users where they are within the website and ensuring that links lead to what one would expect.

Within the current project site, the hierarchy and what one would expect to find in the different subsections is unclear and inconsistent. For example, the subsections for the two main technologies (AEROKATS and ROVER) are organized very differently and contain very different types of information. In contrast, there is a simpler and clearer organization of the AEROKATS site, which has the potential to make it more navigable by intended users. Building in easy ways for users to retrace their steps and understand where in the site they are will help ensure the new site is as easy to navigate as possible.

Readability

Readability refers to how the appearance of the information on the screen impacts a user's ability to read and understand what is being presented. A website should be designed to make it easy to make sense of what is on the screen, presenting information in a consistent way in terms of formatting (e.g., using different font styles and sizes to always signal a particular type of information) and using accessible language. Graphics should be used purposefully, and distracting or irrelevant features should not be included.

Many of the decisions that will go into the design of the new project website to increase readability will depend upon decisions made regarding intended users, anticipated purposes for their use of the site, and organization of the information within the site. Thinking about the site

from the perspective of each type of intended user will help the project in making these design decisions, and attending to these principles will make it more likely that the project will be effective in reaching larger numbers of users.

SUMMARY AND RECOMMENDATIONS

The AREN project brings together a diverse and dedicated team of collaborating organizations, each of which contributes unique expertise to the project's work. Team members range from NASA engineers to STEM educators to Earth scientists. Interviews with team members indicate they have a tremendous amount of enthusiasm to work cross-organizationally toward the project's goals.

The AREN project has accomplished a great deal in its first four years. Progress has been made in developing and refining the AREN technologies, gaining interest among a variety of audience types, and generating enthusiasm among participants. The project has also learned from its work, refining its vision and making adjustments as needed.

Given the project's ambitious goals, it is not surprising that there is still a great deal of work to do. Perhaps most pressing is further developing clear pathways for participation by the different intended audiences. In this context, and in the spirit of a critical friend, HRI offers the following recommendations to assist the project as it plans for the future.

- *Continue to use the theory of action to reflect on what the project has accomplished thus far, determine what still needs to be done, and prioritize future efforts.*

  Although having a large number of collaborating organizations and team members brings a great deal of expertise to the project, it also presents a number of challenges. One is avoiding divergent evolution of efforts. Another is making sure all involved understand their priorities and how those priorities fit into the overall success of the project. The recent unpacking of and discussions about the project's theory of action already appear to have helped get everyone on the same page. The project should continue to use the theory of action as a touchstone to reflect on where the project's work currently focuses and which components need more attention. These reflections should prove valuable in helping the project prioritize future efforts and help ensure it reaches each of its goals.

- *The project should be strategic about prioritizing which user supports to develop first.*

  The project's development work spans multiple technologies, data visualization tools, activities, and trainings, each of which requires its own cycle of development, testing, and revision. Given constraints on team members' time, the project should consider selecting a small number of audience-technology combinations to focus on as prototypes. Doing so would allow the project to best utilize team members' time and specific expertise, and create models of both the processes and the products that can guide future efforts. For example, the project has begun developing a wind direction learning activity that could be submitted to GLOBE. Focusing, at first, on the development of a single learning activity targeting specific science learning standards at a particular grade level will allow the project to test out and refine a process for activity development. Once the project completes development of the product, it can reflect on the process used, refine it, and apply it to other learning activities.

Strategically selecting a small number of development prototypes will also allow the project to take advantage of the diverse expertise of team members, dividing them into groups by area of expertise. Each subgroup could tackle the prototype process for a particular type of product then share their results with the larger team for feedback.

- *In developing its new website, the project should think carefully about the needs of each intended user audience and work to ensure there is a clear and intuitive path through the website for each.*

  The original AREN website has evolved over time and serves as a "catch all" for the project. Although there is value in having a central repository for the project's work, that website is not user friendly for people outside of the core project staff. The new website being developed provides an opportunity to tailor information for each intended audience, presenting only that information relevant to the audience in a way that facilitates, and does not frustrate, users. Thus, the project should carefully consider what purposes it expects the website to fulfill for each intended audience and how to organize the necessary information for each audience. The design heuristics described in this report provide some guidance for thinking about the structure and appearance of the website. The project should also consider conducting user testing with different types of audience to get feedback and make improvements to the site. Ideally, this testing would include think-aloud interviews with a small number of different types of users. In these interviews, a project staff member would watch a potential user explore the site and ask the subject to share his/her thoughts about the site. This type of feedback has great potential for uncovering aspects of the site that are confusing to users and help ensure the site does not act as a barrier to participation in the project.

NASA Cross-Collaborations

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

- Institute for Global Environmental Strategies (NESSC)
- Southwestern Community College
- University of Alaska, Fairbanks
- University of Colorado, Boulder
- University of Toledo
- University of Washington, Seattle
- WGBH
- GSFC Education
- JSC Astro Materials
- Earth to Sky NPS
- GLOBE

Cross-Collaboration Activities have included:

- Collaboration on Presentations for the AGU Conference
- Celebration of the 50th Anniversary of the Apollo Landing
- ROVERs at Langley Research Center
- Citizen Science and the Lewis and Clark Trail
- Workshops Implementing the GLOBE Observer App
- Consultation at Planning at GLOBE Annual Meeting and GLOBE NARM
- University of Toledo – GME Satellites Student Conference
- Odyssey of the Mind at Michigan State University
- Kite Flying at the University of Alaska, Fairbanks
- Smoky Mountain STEM Collaborative with Matt Cass
- University of Toledo – Engineering Team Meeting
- University of Alaska Participation in Weekly Phone Conferences
- Pop Up Science at the Michigan Science Center
- 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

Future Plans

The AREN Project is looking forward to the future in 2020. Below is a list of the major plans for 2020:

- Prioritizing the incorporation of AREN work into GLOBE through specific learning activities such as the capturing of wind direction at various altitudes
- Introduction of the AEROKATS.org website
- Increased ROVER implementation/ROVER 10.x kit with DIY sensor package
- Exploration of increased use of kites in cold weather climates
- Refinements and improvements to Mapknitter software
- Aeropod licensing agreement with UCAR/GIO
- Aeropod licensing agreements under a possible open source license
- Refinements and improvements to Infragram Pi kit
- Dissemination of activities and engineering practices to classrooms
- Continuation of wind tunnel design
- Development of a global network and science user community
- Continued expansion of AREN user community
- Additional flights added to the AREN Mission Mapper database
- Mission Mapper updates. Additional data types
- Continued work with GLOBE on three dimensional data integration
- Continue to pursue potential partnerships with local, regional and national networks