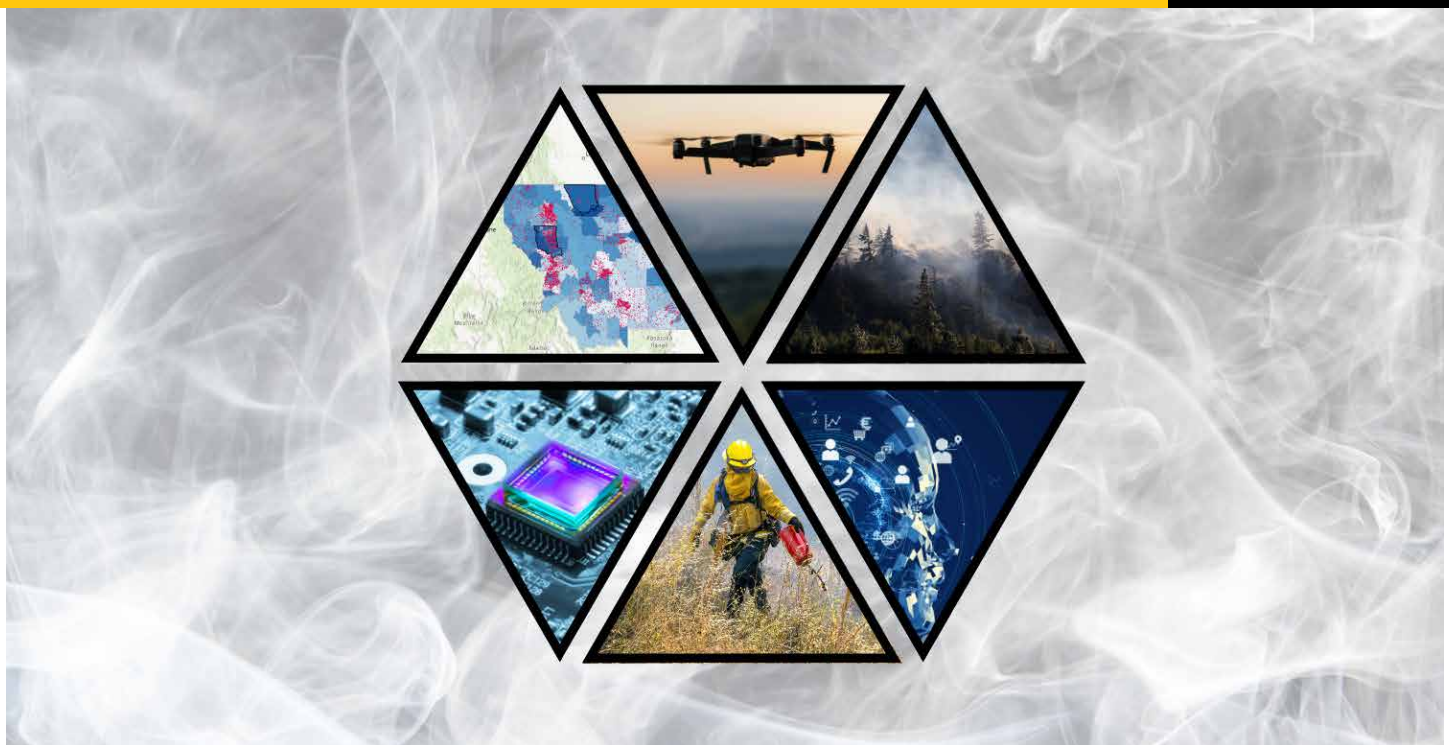
MONTANA NSF EPSCoR

NEWSLETTER

SMART FIRES
YEAR 2
HIGHLIGHTS
2025



DIRECTOR'S UPDATE

On August 1st, SMART FIRES began its third year. Evidence that the project is hitting its stride is everywhere—from the deployment of the mobile field laboratory to the development of new tools for detecting smoke plume dynamics, to continued community engagement and educational outreach. SMART FIRES is transforming how we think about prescribed fire's impacts on air quality, forest management, and community health.

The SMART FIRES team currently consists of more than 100 participants from seven institutions across the state. We're particularly excited to welcome two new members to the team: Prof. Jacob Downs and Ben Williamson.

- **Jacob** is the newest addition to UM's Computer Science faculty. He joins the team with an active interest in exploring how numerical modeling and machine learning methods can be used to predict prescribed fire evolution in real time.
- **Ben** came on board in April as our new project manager. With a background in ecosystem conservation and land management, Ben has quickly become a cornerstone of the SMART FIRES leadership team.

Looking ahead, there's a lot to be excited about. We're eagerly anticipating the SMART FIRES Year 3 All-Hands Meeting in Bozeman this September. The meeting will once again feature project updates, workshops, poster sessions, and opportunities to discuss cross-cutting, interdisciplinary research and educational initiatives. In addition, the Smart Optical Sensors group is preparing demonstrations to showcase the new technologies being developed to advance SMART FIRES science.

One final note: in early April, Todd Kipfer—a longtime EPSCoR veteran and the original SMART FIRES project manager—left to take on a new role as IT Senior Manager for the Open Space and Mountain Parks Department in Boulder, CO. While we were saddened to see Todd go, we wish him the best as he takes on new challenges managing 45,000 acres and over 155 miles of trails in and around Boulder.

Thanks again for your continued efforts. I'm looking forward to seeing everyone in Bozeman this September.

—Professor Rob Walker,
SMART FIRES Project Director
rawalker@montana.edu

SMART FIRES YEAR TWO

This special issue of the Montana NSF EPSCoR newsletter provides a summary of the Year 2 activities and progress for the RII Track-1 project: Sensors, Machine Learning, and Artificial Intelligence in Real Time Fire Science (SMART FIRES). SMART FIRES is a five-year, $20M collaborative scientific research project funded by the National Science Foundation under award OIA-2242802 with a focus on developing and deploying new technologies and research to better understand the behavior of prescribed fire and its impacts on decision makers and communities in Montana.

Project research is organized into four focus areas: Fire and Smoke Science (FSS), Smart Optical Sensors (SOS), Machine Learning and Artificial Intelligence (AIML), and Social Science, Economics and Ethics (SPEE).

32 Faculty

36 Post Docs & Graduate Students

37 Partners and Collaborators

28 Undergraduate Students

46 Total Publications

SMART FIRES BY THE NUMBERS

YEAR 2 OUTCOMES OF MONTANA'S NSF EPSCOR RII TRACK-1 PROJECT

A total of **32** faculty, **36** graduate students and postdocs, and **28** undergraduate students participated in the SMART FIRES project in Year 2.

46 PUBLICATIONS were produced by SMART FIRES researchers in Year 2

37 EXTERNAL PARTNERS AND INSTITUTIONS collaborated on SMART FIRES activities in Year 2.

SMART FIRES PARTNERS AND COLLABORATORS

- University of Montana Forest & Conservation Experiment Station
- Lubrecht Experimental Forest
- US Forest Service Missoula Fire Sciences Laboratory
- Northern Rockies Fire Science Network
- Montana Department of Natural Resources & Conservation (DNRC)
- Montana Department of Environmental Quality (DEQ)
- Blackfoot Challenge
- Climate Smart Missoula
- Missoula County Public Health Department
- NASA AERONET
- National Center for Atmospheric Research (NCAR)
- Resonon, Inc.
- Montana Photonics and Quantum Alliance (MPQA)
- Vision Aerial
- Missoula Public Library
- Bozeman Field School
- NRG Systems
- Council for American Indian Programs
- GLOBE Observer
- Northwestern Energy Inc.
- SelectHealth
- University of Arizona
- SciNation on the Flathead Reservation
- Montana Afterschool Alliance
- The Nature Conservancy

A prescribed burn in progress and the SuperVan in action.

NEXT STEPS IN FIRE AND SMOKE RESEARCH

In year two, the Fire and Smoke Science (FSS) team developed sampling procedures and conducted five prescribed fires. A repository was developed to hold data on fuels, moisture, area burned, and consumption, along with notes and images of ignition sequences, changes in weather, and observed fire behavior.

The FSS team completed necessary modifications to the smoke sampling van and deployed it as a mobile laboratory on several prescribed fires. The mobile lab's power system is built around a 600-amp hour, 48V, LiFePO4 battery bank, capable of running the core payload for more than 15 hours before recharging. The entire power system is controlled by a central computer that manages the power load and seamlessly switches between different charging sources and the battery bank to provide uninterrupted power to the payload.

In addition to the mobile lab's power capabilities, the interior boasts a flexible mounting system for the instrument payload, which allows the mobile lab to host instrumentation from other research groups as needed for current and future project needs. Drone-based Laser Scanning and RGB Imagery were collected for each of the burns on which the SuperVan was deployed, and these data have been processed into ground-normalized canopy height models and digital orthomosaics.

Additional year-two FSS work included the collection of hyperspectral and lidar imagery pre- and post-fire, as well as the development of a Cavity Enhanced Raman Spectrometer (CERS) for non-destructive, multicomponent detection in smoke conditions.

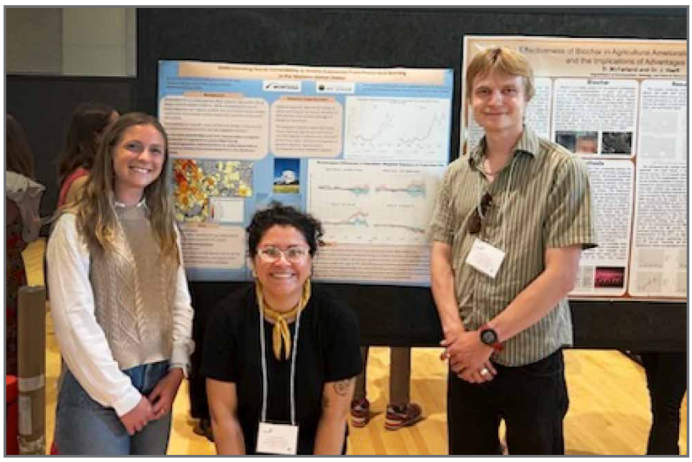
Smart Optical Sensors (SOS) Graduate student Morgan Hasenmyer (left) undergoing drone pilot training during a snow-sensing field experiment in the Gallatin Range near Bozeman. February, 2025.

FROM LAB TO FIELD: OPTICAL SENSOR DEVELOPMENTS

Project year two saw the Smart Optical Sensors (SOS) team generating novel optical systems that are moving steadily toward outdoor deployment in a prescribed fire environment.

The High Spectral Resolution Lidar (HSRL) instrument was developed and is operating properly in its all-weather enclosure. The All-Sky Polarization Imager (ASPI) was developed, and preliminary data are promising. The instrument is being repackaged and will be ready for engineering field testing alongside the HSRL instrument in summer 2025. In the likely event that wildfire smoke appears in the Bozeman sky this summer, the team will obtain the first-ever smoke measurements with a combined HSRL and ASPI. These two instruments have strong potential synergies and, following successful field tests, will be ready for prescribed fire field deployment in year three.

Additionally, the team is building a mounting system to enable RC-vehicle deployments of the smart hyperspectral imager. Beginning with an existing vehicle—including its frame, wheels, and motor—the team is integrating remote-controlled steering and speed regulation, braking systems, collision and tip-over alerts, and a retractable camera mount that will extend 4–5 feet above ground and retract when the vehicle is moving.



SPEE research associate Alison Monroe (far left) presents a poster at this year's International Association for Society & Natural Resources conference. Also pictured are SPEE students Jazzelle Elias (center), and Clemens Wilson (right).

THE HUMAN SIDE OF FIRE: Attitudes, Behaviors, Exposure, and Decisions

The Social Psychology, Economics, and Ethics (SPEE) team made progress in multiple research areas in year two. SPEE researchers developed a survey questionnaire to understand attitudes and behaviors related to prescribed burning and smoke exposure. The survey includes an economic non-market valuation module to examine the social value of prescribed burning. The survey will be launched in year three.

The team is exploring ways to assess and predict smoke exposure from prescribed burns as part of a vulnerability analysis. Researchers have collected smoke and other contextual data such as PM 2.5 datasets, fire activity datasets, burn permit data, weather and land cover datasets, and are analyzing whether gridded PM2.5 datasets are capturing smoke from prescribed fires, or only wildfire smoke. The team has also explored whether seasonality can be used to distinguish wildfire smoke from prescribed burn smoke and found that temporal factors are not enough to distinguish the two. Another effort is looking at PM2.5 time series from ground-based air quality sensors located near prescribed fires. These efforts will contribute to the smoke vulnerability analysis and will be incorporated into a risk-assessment tool, along with the GIS maps developed in year one.

The SPEE team is using qualitative methods to better understand how decisions are currently being made related to prescribed fire. In year two, researchers developed an interview guide and conducted 17 semi-structured interviews with prescribed fire managers. Researchers are beginning an iterative coding process and plan to conduct 8-10 more semi-structured interviews this fall.

BUILDING SMARTER MODELS: AIML PROGRESS AND COLLABORATION

Work for the Artificial Intelligence and Machine Learning (AIML) research thrust progressed on schedule, with ongoing collaboration in sentiment analysis between the AIML and SPEE teams.

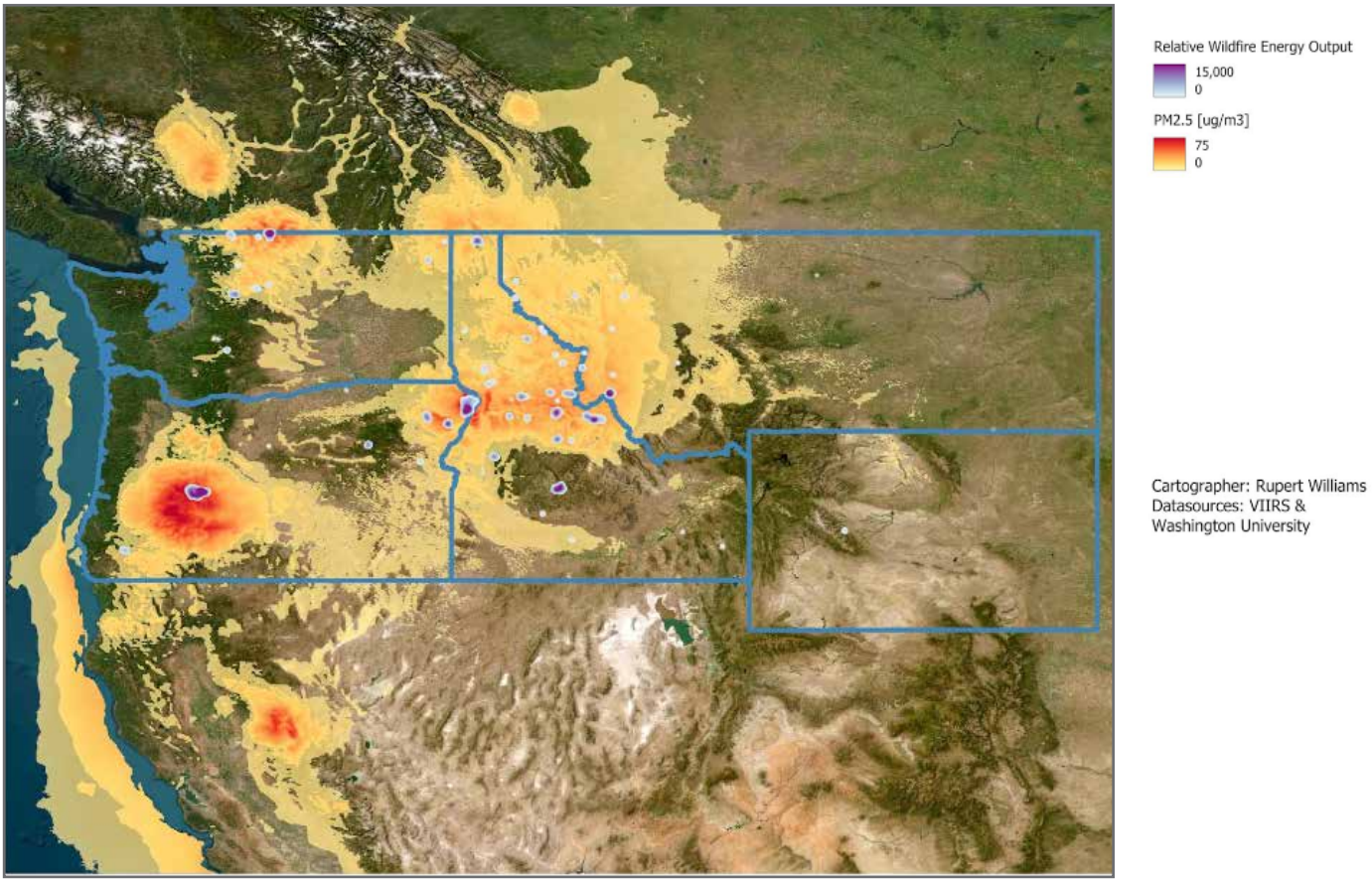
Multiple research products were produced, and new hires Lucy Owen and Michael Wojnowicz were further integrated into project activities.

Modeling processes have been developed based on prior work in risk-informed decision making within a Prognostics and Health Management (PHM) environment and the group has continued to aid in the development of an effective Continuous Time Bayesian Network (CTBN) library written in C/C++ with an automatic build pipeline to integrate the system with more accessible languages, such as JavaScript and Python.

This work has been done in cooperation with a parallel effort funded by the US Navy in developing risk-based PHM tools for aircraft prognostics. A common back-end code base is being developed with different front ends developed specific to the target application.

Additionally, progress has been made toward managing the data sets the team will be using to construct an emulator and on selecting a model architecture for the emulator itself. Some of the data used by the AIML team is proving useful to the other research thrusts and steps have been taken to share it.

September 2022 Wildfire Intensity and PM2.5 Concentrations



Fire intensity is shown in the purple colors, and air quality as measured by PM2.5 in orange to red. These values are both averaged over an entire month, which allows for visual assessment of the relation between wildfire location and declines in air quality. In the context of this objective, the AIML team seeks to use the wildfire output energy to fine-tune a foundational climate model to predict PM2.5.

STRENGTHENING CYBERINFRASTRUCTURE FOR SMART FIRES SUCCESS

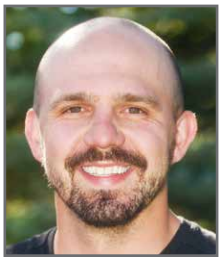
Year two advancements in high-performance computing (HPC), research concept development, network visualization, and boundary-spanning data storage and protection have positioned the Research and Data Cyberinfrastructure (CYBER) team to effectively support the SMART FIRES project as it evolves.

Cyberinfrastructure activities actively engage participants across research thrusts, emphasizing the importance of cross-disciplinary integration. Current efforts include collaboration with the AIML team to systematically address data reliability and accessibility. CYBER researchers are also leveraging Natural Language Processing (NLP), topic modeling, and network analysis for visualization of SMART FIRES research concepts and enhancing project visibility. In addition to supporting research, CYBER activities contribute to workforce development through team training in high-performance computing. The team has also expanded capacity for data storage and transfer via a streamlined resource known as the data lake. The research, experiences, and documentation generated over the past year have enabled the CYBER team to establish a scalable model that will support not only SMART FIRES but future projects as well.

EARLY CAREER DEVELOPMENT AWARDS

This Spring, as part of the SMART FIRES project, The University of Montana awarded six Early Career Development Grants to UM professors and post docs in SMART FIRES related fields.

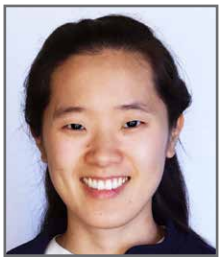
LUCIA WILLIAMS, Assistant Professor of Computer Science, used her award to continue a collaboration investigating the use of generative AI in aiding cross-disciplinary student teams.



JUSTIN GAY, Assistant Teaching Professor of Ecology and Environmental Science, used funds to support sample analysis and consumables for a collaborative project examining how prescribed fire affects understory plant communities and soil biogeochemistry.

LAUREN MCKEAGUE, Assistant Professor at the School of Public and Community Health Sciences, used this funding to partner with a data analyst at UM's Center for Population Health Research's Data and Modeling Core to complete an analysis of the relationship between exposure to wildfire smoke and increases in emergency department visits and hospital admissions, as well as exposure to prescribed fire smoke and negative health outcomes in Missoula County.

ANH NGUYEN, Assistant Professor of Computer Science, used this grant to support the development foundational ideas for a cognitive CPS-IoT platform that integrates wearable and distributed sensing with real-time AI analytics to enhance the safety and effectiveness of prescribed fire operations.



AVA ORR, a Postdoctoral Research Associate on a SMART FIRES seed project, used this additional support to purchase an expanded set of historical PurpleAir data allowing her to enhance her skills in working with large-scale, real-time environmental sensor data, and begin exploratory data processing and model calibration across a broader geographic region.

ALINA CANSLER, Assistant Professor at UM's Franke College of Forestry and Conservation, will use this grant funding to purchase equipment and software to develop her skills using bioacoustics monitoring devices for avian species detection, for long-term monitoring and research on the effects of fire and fuel treatments on avian species occupancy and community composition.

ERIC CASTRO – LITTLE BIG HORN COLLEGE PROJECT LIAISON

SMART FIRES is excited to welcome Eric Castro as Little Big Horn College's (LBHC) project liaison. Castro received his bachelor's degree in Environmental Studies at MSU-Billings and from there entered a post-baccalaureate program in Microbiology. He is currently a graduate student at MSU studying Land Resources & Environmental Sciences with a focus on Water Quality, advised by Mari Eggers.

For his graduate project, he will investigate the impact of PFAS contamination in smaller communities, aiming to raise awareness about the importance of water quality and how human activities are introducing these 'forever chemicals' into our water systems.

His plans as LBHC liaison for SMART FIRES are to help Native American communities prepare for the eventuality of wildfires and understand the importance of thinning forests of fallen trees and other fire fuels. This work will also allow him to use AI, R, and ArcGIS as tools in wildland fire management.

Once his master's degree is complete, Eric hopes to become an environmental instructor, and mentor, educating members of small communities, especially young adults and elders, to understand the meaning and importance of being an environmentalist.

MEET THE SMART FIRES EXTERNAL ADVISORY BOARD

KALYANMOY DEB is a Distinguished Professor in the Department of Electrical and Computer Engineering at Michigan State University. His research interests are in evolutionary optimization and their application in multi-criterion optimization, modeling, and machine learning. He was awarded IEEE Evolutionary Computation Pioneer Award for his sustained work in EMO, Infosys Prize, TWAS Prize in Engineering Sciences, CajAstur Mamdani Prize, Distinguished Alumni Award from IIT Kharagpur, Edgeworth-Pareto award, Bhatnagar Prize in Engineering Sciences, and Bessel Research award from Germany. He is fellow of ACM, IEEE, and ASME, and is on the editorial board of 10 major international journals.

SARAH MCCAFFREY received her PhD from the University of California at Berkeley where her dissertation examined Incline Village, Nevada homeowner views and actions in relation to defensible space and fuels. McCaffrey retired in 2022 after 20 years as a fire social scientist with the US Forest Service where her research focused on understanding the social dynamics of fire management. Her work examined the role of risk perception and risk attitudes, social acceptability of prescribed fire, homeowner mitigation and evacuation decisions, risk communication, and agency-community interactions during fires. Since retirement she has been involved with research and practitioner efforts to improve future fire outcomes including as an adviser to the Gordon and Betty Moore Foundation's Wildfire Resilience Initiative and Board member for Fire Adapted Colorado.

MEREDITH KUPINSKI joined the Wyant College of Optical Sciences at the University of Arizona (UA) in 2008 where she is an Associate Professor developing polarimetric instrumentation, polarized light scattering models, and polarization-aware computer vision and graphics capabilities. She earned a BS with Highest Honors in Imaging Technologies from the Rochester Institute of Technology and an MS and PhD in Optical Sciences from UA. In 2016, she was awarded a Jean d'Alembert visiting scholar position at École Polytechnic in France, and in 2024 she received an NSF CAREER award. Her career goals include leveraging academic resources to build new opportunities for underrepresented students. As both an optical engineer and an image scientist, her research considers every aspect of the imaging chain. Prof. Kupinski was the recipient of Science, Engineering, and Education for Sustainability (SEES) postdoctoral NSF fellowship and she values multi-disciplinary experiences and exposure to diverse perspectives.

WYATT FRAMPTON is the Deputy State Forester and Deputy Forestry Division Administrator at the Montana Department of Natural Resources & Conservation.

TEACHING FIRE SCIENCE: SMART FIRES WORKSHOP AT MSU FOR MONTANA EDUCATORS

The SMART FIRES broader impacts team with the MSU Science Math Resource Center recently hosted a two-day workshop equipping 12 Montana middle and high school teachers with tools to bring fire and smoke science and sensing technology into their classrooms.

Highlights from MSU SMART FIRES researchers included a behind-the-scenes tour of the optical sensor lab with Joseph Shaw, an exploration of prescribed fire ethics by Kristen Intemann and Mary Farina, and an overview of AI-driven wildfire modeling and decision support tools from John Sheppard. Tim Price, joining virtually from Flathead Valley CC, introduced educators to vegetation-focused citizen science. National guest speakers joined to share GIS mapping, air quality monitoring with Temtop sensors and using micro:bits for interactive learning.

Teachers represented schools in Bozeman, Chinook, CutBank, Hardin, Livingston, Manhattan, Poplar, Seeley Lake, Three Forks, The workshop showcased how science, technology, and place-based learning can empower educators to spark student curiosity and teachers left inspired.

On the roof of Norm Asbjornson Hall, teachers learn about optical sensor technology with Joseph Shaw during a two-day workshop.

"It was refreshing to connect with educators outside of Ag," said Tyler Noyes, agriculture teacher at Three Forks High.

"With air quality sensors like the Temtop, my students can explore wildfire impacts on our community," said Neria Manero, Poplar Middle School.

"This will help me open doors to STEM careers for my rural students," added Kari Hinkle, Cut Bank High School.

spectrUM'S SCIENCE LEARNING TENT POPS UP AT SUMMER POWWOWS

Over three days in July, spectrUM Discovery Area brought its Science Learning Tent to the Arlee Celebration and the Elmo Standing Arrow Powwow on the Flathead Reservation. Under the tent, 1,200 visitors to the powwows engaged with STEM exhibits and role models from the University of Montana, UM's Flathead Lake Biological Station, Missoula Public Library, Confederated Salish and Kootenai Tribal (CSKT) Health, CSKT Natural Resources, and Salish Kootenai College.

SMART FIRES research associate Ali Monroe was among the guest role models facilitating hands-on activities alongside spectrUM educators. Exhibit and activity themes included health care, environmental science, local ecosystems, engineering, and Indigenous traditional hide preparation methods.

The Science Learning Tent is an annual highlight of spectrUM's longstanding partnership with its SciNation advisory group on the Flathead Reservation, as well as a pillar of SMART FIRES's broader impacts efforts to foster STEM learning and workforce development for all.

AT LEFT: Kids explore STEM activities under the Science Learning Tent at the Arlee Celebration and Elmo Standing Arrow Powwow.

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