Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-347

Proposal Title: Wildfire Early Detection and Prescribed-Burn Management Using Drones

Project Manager Information

Name: Ce Yang

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: We propose to develop autonomous long-range drone swarm systems equipped with advanced sensors for wildfire early detection and safer prescribed burns to improve air quality and wildfire response strategies.

ENRTF Funds Requested: $856,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Resiliency (A)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Wildfires increasingly threaten Minnesota's forests, communities, and air quality. The state experiences roughly 1,000 wildfires each year, burning about 25,000 acres, with extreme years such as 2021 seeing more than 2,000 fires and nearly 69,400 acres burned during severe drought. At the same time, smoke from large Canadian fires frequently affects northern Minnesota and the North Shore, pushing fine particulate pollution (PM2.5) to unhealthy levels in communities including Duluth and Grand Marais and exposing Minnesota residents to prolonged air-quality alerts. Yet wildfire early detection and smoke monitoring remain limited. Current detection relies heavily on public reports and crewed aircraft flights, which required more than 600 flight hours in 2024 and identified only a limited portion of new ignitions. Detection delays allow fires and smoke plumes to grow before response. Prescribed burns are an essential tool for reducing wildfire risk and restoring ecosystems. However, they lack precise, real-time monitoring of smoke dispersion and impacts on nearby communities. Recent severe air pollution in Minnesota caused by fires highlights the need for faster, higher-resolution systems that can detect fires earlier and map smoke movement to support wildfire quick response, safe prescribed-burn management and protection of public health.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

This project provides a statewide public benefit by delivering an operational fire and smoke monitoring capability for Minnesota land managers and air-quality agencies, improving wildfire detection, smoke tracking, and protection of communities and natural resources. Rather than developing stand-alone technology, the project will conduct an operational pilot that integrates a coordinated fleet of long-endurance drones equipped with thermal, optical, and air-quality sensors into existing state wildfire detection and monitoring programs. Working directly with our partners, we will deploy the systems to monitor wildfire incidents and prescribed burns, providing near real-time information on heat anomalies and smoke dispersion that significantly improves situational awareness for fire and air-quality managers. Onboard machine-learning processing will enable rapid interpretation of sensor data, allowing the system to deliver actionable information while reducing operational risk and providing a cost-efficient capability that complements traditional aerial monitoring. The project will deliver lasting value by producing operational monitoring tools, validated deployment protocols, and publicly shareable data products that state agencies and land managers can continue using after the project concludes. By strengthening coordination among fire management, land stewardship, and air-quality programs, this collaborative pilot establishes scalable capabilities to protect Minnesota communities and natural resources while reducing fire and smoke pollution.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The project will deliver UAV-based fire and smoke monitoring solutions that support protection and stewardship of Minnesota's natural resources. Key outcomes include long-range drone systems shared with partners for detecting thermal hotspots and mapping smoke plumes, operational deployment protocols for DNR and land managers, and shareable geospatial data products documenting fire behavior and smoke dispersion. These tools will improve situational awareness during wildfire events and prescribed burns, enabling earlier detection of fires, safer prescribed burn management, and reduced smoke impacts on communities. With the validated drones and protocols, our partners can continue using the systems after the project concludes.

Activities and Milestones

Activity 1: Prototype Validation and Expansion of a Drone Monitoring System

Activity Budget: $360,000

Activity Description:
This activity will validate and expand an existing autonomous drone monitoring platform for wildfire detection and smoke plume tracking in Minnesota landscapes. The research team has already developed and field-tested a prototype system capable of autonomous smoke plume tracking, with results reported in a peer-reviewed IEEE conference paper and highlighted by Star Tribune. The project team will initially focus on evaluating the existing drone system in various environments in collaboration with wildfire specialists from the Minnesota DNR. These validation tests will assess flight reliability, navigation accuracy, communication stability, and the system's ability to support wildfire surveillance and smoke monitoring under conditions representative of Minnesota's forested landscapes. Collaboration with the DNR wildfire aviation supervisor will help refine system configuration, transferable operational flight procedures and monitoring coverage strategies to ensure compatibility with existing wildfire detection and aerial patrol practices. Following validation, the team will construct additional monitoring systems with fixed-wing vertical takeoff and landing (VTOL) drones for long-distance flight deployment. The expanded drone swarms will cover substantially larger regions and support more frequent patrols than manned aircraft and conventional drones, particularly in remote and high-risk areas of Minnesota, creating a practical pathway toward statewide wildfire detection and smoke surveillance.

Activity Milestones:

Description	Approximate Completion Date
Drone fleet prototype validation testing in various environments with DNR input	December 31, 2027
Construction and testing of additional VTOL drone systems based on validated design	May 31, 2028
Multi-drone coordination and operational flight testing for additional drone systems	June 30, 2028

Activity 2: Sensor Integration and Calibration

Activity Budget: $328,000

Activity Description:
This activity will integrate and validate advanced environmental sensors that enable the drone systems to detect wildfire activity early and characterize smoke impacts on Minnesota communities and ecosystems. A multi-sensor monitoring payload for heat detection, smoke plume identification, and air-quality measurement, including fine particulate matter (PM2.5), carbon monoxide (CO), and other measurements relevant to smoke exposure will be incorporated into the drone systems. Hardware integration will ensure stable sensor mounting, onboard processing and synchronized data transmission. Laboratory-calibration will quantify sensor sensitivity, accuracy, and response time under controlled conditions simulating wildfire and prescribed burn environments. Controlled field experiments will then focus on combustion heat spots, smoke plumes, and particulate emissions to validate detection capability and measurement accuracy. The project team will coordinate with DNR to ensure that sensor outputs and data products align with operational monitoring needs such as localized temperature anomalies, smoke concentration, PM2.5 exposure risk, and near-source air-quality conditions, so that the resulting information can directly support wildfire response and prescribed burn management strategies. Completion of this activity will produce calibrated airborne sensing systems capable of reliably detecting early fires and mapping smoke dispersion patterns and associated air-quality impacts relevant to Minnesota natural resource management and protection.

Activity Milestones:

Description	Approximate Completion Date
Sensor integration with drone monitoring platform	September 30, 2028
Laboratory and controlled field calibration testing	December 31, 2028
Validation of wildfire and smoke detection performance with DNR collaborator	February 28, 2029

Activity 3: Field Deployment and Testing

Activity Budget: $144,000

Activity Description:
This activity will deploy and evaluate the drone swarm system in real-world wildfire and prescribed-burn operations to deliver direct, measurable benefits to Minnesota's lands, ecosystems, and communities. One system will support Minnesota DNR wildfire detection and rapid situational awareness, and one will support prescribed-burn monitoring at Cedar Creek Ecosystem Science Reserve (CCESR). The team will establish transferable operational protocols, flight plans, and reporting procedures to ensure safe, regulatory-compliant deployment and seamless integration with agency workflows. During wildfire season, the DNR system will conduct autonomous patrols over high-risk areas to detect heat anomalies, smoke, and air-quality impacts and provide rapid geo-referenced information for earlier response and improved protection of forests, wildlife habitat, and nearby communities. During prescribed burns, the UMN system will monitor burn progression, smoke plume movement, and local meteorological conditions to generate actionable datasets for fire behavior interpretation and smoke-impact assessment. System performance will be evaluated based on operational effectiveness and usefulness to end users. The drone systems will remain long-term assets for wildfire response, prescribed-burn management, and public-health protection in Minnesota. The resulting datasets, deployment protocols, and best-practice guidance will form a transferable framework to support operational planning and guide future expansion of drone-based monitoring across the state.

Activity Milestones:

Description	Approximate Completion Date
Develop operational protocols and secure permissions for field deployment and testing	March 31, 2029
Wildfire Early Detection Testing: Conduct field deployment in high-risk wildfire areas	June 30, 2030
Prescribed Burn Monitoring: Deploy drones during prescribed burn practices	June 30, 2030

Activity 4: Education and Outreach

Activity Budget: $24,000

Activity Description:
This activity builds statewide capacity to safely apply drone-based wildfire detection and smoke monitoring through targeted training and education. While based in a single Minnesota school district, Princesa has developed collaborations with educators statewide through STEM programs and student research placements, enabling outreach to at least 10 school districts, including metro, rural, northern Minnesota, and Tribal communities, and aiming to engage at least 150 high school students annually in years 2 and 3 through curriculum modules developed from this project. The curriculum will focus on wildfire science, smoke impacts on public health, and drone-enabled monitoring, providing students exposure to environmental monitoring careers. To support real-world adoption, the project will deliver 4-5 targeted training sessions in year 3 for fire managers, local officials, and community stakeholders to interpret and apply drone-derived data for wildfire response and prescribed-burn planning. Training will emphasize that more frequent long-range drone deployments can serve as strong decision support within existing agency workflows. In addition, 6-8 regional workshops will be organized to guide participants in understanding real-time data on heat anomalies and

smoke dispersion for preparedness. Partnerships with Firewise and local organizations will promote community-level wildfire preparedness and fire risk reduction practices.

Activity Milestones:

Description	Approximate Completion Date
Curriculum development and pilot integration	June 30, 2028
Curriculum distribution and pilot classrooms, practitioner training sessions, regional workshops	June 30, 2029
Real-world data sharing and interpretation, application-focused classroom learning, workflow trainings, and community preparedness workshops	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Jiarong Hong	University of Minnesota	Co-Principal Investigator, leading the drone swarm system development, including autonomous navigation, drone hardware integration, and flight operations.	Yes
Nikil Krishinakumar	Particle4X	Leading drone software and hardware development, including autonomous flight control, real-time data processing, and system integration for wildfire detection.	Yes
Nicholas Bravo Frank	Particle4X	Developing drone-based sensor systems, including digital inline holography (DIH) imaging for air quality monitoring, and assisting in field testing.	Yes
Princesa Hansen	Intermediate District #287 high school instructor	Leading education and outreach efforts, developing materials, conducting workshops, and engaging communities in wildfire risk awareness and drone swarm applications.	Yes
Darren Neuman	DNR	Providing expertise in wildfire management, coordinating drone integration with existing fire response strategies, and facilitating field testing access.	No
Troy Mielke	University of Minnesota Cedar Creek Long Term Ecological Research	Coordinating prescribed burn activities and providing supervision and expertise in field testing of the drone swarm.	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.

1. Education and community outreach.

The project will conduct educational workshops (consistent with Activity 4) and public demonstrations to introduce students, educators, and community members to wildfire risk, smoke impacts, and drone-based environmental monitoring. Outreach materials and classroom resources will illustrate how emerging technologies support wildfire detection and prescribed burn monitoring. These activities will increase awareness of wildfire preparedness and environmental stewardship and help communities across Minnesota understand emerging tools for monitoring fire and smoke.

2. Agency collaboration and operational knowledge sharing.

The project will work closely with operational partners including the Minnesota Department of Natural Resources and the University of Minnesota Cedar Creek Ecosystem Science Reserve to share monitoring tools, transferable deployment procedures, and environmental data products. Practical deliverables will include a drone deployment guide, recommended monitoring workflows, and example geospatial datasets showing wildfire heat signatures and smoke plume movement. These materials will help agencies evaluate how drone monitoring can complement existing wildfire detection and prescribed burn management practices across Minnesota landscapes.

3. Field demonstrations for practitioners.

Drone monitoring capabilities will be demonstrated during field testing and prescribed burn activities so that wildfire managers, prescribed burn practitioners, and air-quality specialists can observe system operation and review resulting data products. These demonstrations will provide opportunities for practitioners from across the state to evaluate the technology, discuss operational needs, and consider how drone-based monitoring could support wildfire detection and smoke monitoring in different regions of Minnesota.

4. Research publications and technical dissemination.

Technical advances and project findings will be documented through open-access publications, conference presentations, and technical reports. Selected datasets, monitoring results, and project documentation will remain accessible to researchers, agencies, and educators interested in wildfire and smoke monitoring technologies.

All publications, presentations, outreach materials, and demonstrations will acknowledge support from the Environment and Natural Resources Trust Fund in accordance with ENRTF acknowledgment guidelines.
The above-mentioned dissemination related materials will be documented on a project webpage hosted by the University of Minnesota. All materials will be designed for reuse and adaptation to support continued education, outreach, and agency adoption beyond the project period. The webpage will report project progress in education/outreach in schools and workshops, partnership with MN DNR and Cedar Creek Ecosystem Science Reserve for training and workflow integration, field demonstrations with practitioners and videos of drone swarm deployment in real environments, validated downloadable materials, and publications record.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
This project will deliver drone monitoring systems that support wildfire and prescribed burn monitoring in Minnesota. The research team will work closely with partners to develop operational protocols and monitoring workflows that align with existing wildfire and prescribed fire practices. After project completion, the drone swarm systems and protocols will remain available to fire experts to support future monitoring efforts by MN DNR and UMN. Particle4X has committed to providing technical support for the drone systems operated by DNR and UMN, enabling operational use beyond the project. The results will also enable external funding to support broader fire monitoring efforts.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Remote Sensing And Super-Resolution Imaging Of Microplastics	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 08j	$309,000

Project Manager and Organization Qualifications

Project Manager Name: Ce Yang

Job Title: Associate Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Ce Yang is a faculty member in the Department of Bioproducts and Biosystems Engineering, hired through the MnDRIVE Robotics, Sensors, and Advanced Manufacturing initiative at the University of Minnesota (UMN). She leads the AgRobot Laboratory and is the Associate Director of the Center for Precision Agriculture. The AgRobot Lab is a multidisciplinary research hub housed within the College of Food, Agricultural and Natural Resource Sciences and the College of Science and Engineering. Dr. Yang's research is at the intersection of drone remote sensing, agricultural robotics, and environmental sustainability. With over a decade of experience, Dr. Yang has pioneered the development and deployment of drone- and ground- based sensing technologies for precision agriculture. She has developed novel sensing and imaging methodologies that integrate machine vision, multispectral, hyperspectral, and LiDAR technologies to capture high-resolution field data, enabling real-time decision-making for farmers and land managers. Her work aims to optimize chemical and water inputs, mitigate contamination, and promote sustainable practices. Dr. Yang's work has direct applications in sustainable land management and conservation efforts. She collaborates extensively with agronomists, ecologists, and industry partners to translate research findings into practical tools for improving crop productivity and environmental stewardship.
Dr. Yang will oversee the deployment pipeline of this project, from constructing long-range drone swarms to testing them both in lab and in the field, to deploying the drone swarms in forests and prescribed burn locations by

collaborating with MN DNR and the Cedar Creek Ecosystem Science Reserve, and to disseminating the project impacts through K-12 education and outreach initiatives, stakeholder workshops and scientific publications. By pushing the boundaries of long-range drone swarm technology for the next-generation fire monitoring and smoke characterization, the project will deliver statewide benefits on fire control, clean air and community health, and set a sustainable model for university-state-community partnerships.

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Organization Description:
The University of Minnesota-Twin Cities campus, spanning the East Bank, West Bank, and Saint Paul Campuses, is the flagship campus of the University of Minnesota system, with nearly 48,000 students and ~3,800 academic staff. Its educational and research programs in science and engineering consistently rank in the top 25 in nearly all disciplines. This project in particular will be housed within the Department of Bioproducts and Biosystems Engineering (BBE) in the College of Food, Agricultural and Natural Resource (CFANS), Department of Mechanical Engineering (ME) from the College of Science and Engineering (CSE) and industrial partner Particle4X. CFANS is at the core of tackling issues in environmental, agricultural and natural resources. The BBE department has very dynamic interdisciplinary research activities that connect with a wide range of researchers and industrial partners. The Aerosol and Particle measurement techniques, leveraged in this project, were originally developed in the ME Department in the 1950s, and leadership in aerosol and fluid mechanics measurement continues in the department. Particle4X is a pioneer in industry for airborne holographic sensing. Its technical team and facilities will be leveraged for the development of detection and monitoring technologies used in this project.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor Yang, PI, 9 month appointment, seeking summer salary		Project manager, overseeing the progress and the research, development and application activities.			36.6%	0.24		$51,477
Professor Hong, 9 month appointment, seeking summer salary		Co-I, leading the drone swarm system development, including autonomous navigation, drone hardware integration, and flight operations.			36.6%	0.12		$32,730
1 Graduate Research Assistant		Work with Particle4X engineers on integration of thermal and infrared sensors to the drone systems and data collection, cleaning, analysis and modeling.			60%	1.5		$188,327
Cedar Creek Research Supervisor		Coordinate and supervise prescribed burn in Cedar Creek Ecosystem Science Center Reserve and coordinate with DNR for other prescribed burn practices.			36.6%	0.18		$14,060
							Sub Total	**$286,594**
Contracts and Services								
Engineer and Science Educator	Service Contract	High school educator will provide field experiments and lead education and outreach activities.				0.4		$16,000
Particle4X	Subaward	Drone Engineer 1: Leading drone software and hardware development, including autonomous flight control, real-time data processing, and system integration for wildfire detection.				2		$240,000
Particle4X	Subaward	Drone Engineer 2: Developing drone-based sensor systems, including digital inline holography (DIH) imaging for air quality monitoring, and assisting in field testing.				2		$160,000

							Sub Total	**$416,000**
Equipment, Tools, and Supplies								
	Equipment	2 Jetson Orin Nano Controller Kits	Micro Processor for AI and controls in drones					$1,494
	Equipment	8 Cameras with gimbals	Ultra HD 6X Digital Zoom Gimbal Camera with AI Smart Identify and Tracking HDR Starlight Night Vision for UGV USV RC Plane FPV Drones Robot					$2,166
	Tools and Supplies	8 Radio Transmitters	Remote controllers for the drone swarm system					$1,200
	Tools and Supplies	2 Cube Orange (ADS-B) w/ Here3 & RFD900x Telemetry Set	Here3 RTK gps telemetry set for telemetry					$4,854
	Tools and Supplies	8 Anti-Vibration Damping Plate	reducing vibrations in flight controllers					$48
	Equipment	2 RTK base station	Sub-cm gps navigation to be used on the drone swarm					$725
	Tools and Supplies	Laptop with graphic card	For computation and test of the drone swarm system					$2,800
	Equipment	8 VTOL drone frames with basic electronic systems	The base frame and basic electronics of the drone swarm system					$37,000
	Equipment	8 drone LIDAR	Real time reconstruction of smoke for prescribed burning					$18,150
	Tools and Supplies	8 Concentration Laser Sensor	Digital Particle monitoring using laser					$200
	Equipment	8 Blackfly® S, Monochrome Camera	Monochrome cameras for perception					$2,620
	Tools and Supplies	8 Laser diodes	For range sensing					$50
	Tools and Supplies	2 LORA modules with 4G and WIFI support	For long range communication and swarm operation					$695
	Tools and Supplies	8 sets of parts including spare propellers, batteries, connectors, wires, dongles, wifi router, data storage for drones	Consumables for the drone swarm system					$12,927
	Equipment	2 Multispectral and thermal cameras	Enhance monitoring and mapping of fire with heat and spectral information and characterization of smokes from the fire					$26,000
	Tools and Supplies	Incidentals for safety of wildfire and prescribed burn flight tests.	Incidental safety gear and miscellaneous.					$3,477

							Sub Total	**$114,406**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	10 trips per year, 1 car and 1 Uhaul per trip, 300 miles per round trip with 2-3 people with meals and some trips with lodging. Average $1000 per trip.	This project requires multiple trips to remote areas for wildfire and prescribed fire monitoring.					$30,000
							Sub Total	**$30,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Three papers	Open access journal and IEEE conference paper publications					$9,000
							Sub Total	**$9,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$856,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Company in-kind support.	Particle4X will donate a drone swarm system and technical service to DNR for their future deployments beyond the duration of this project.	Potential	$120,000
			Non State Sub Total	**$120,000**
			Funds Total	**$120,000**

Total Project Cost: $976,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: b15e1ef5-278.pdf

Alternate Text for Visual Component

Visual demonstration of wildfire early detection and safer prescribed burn management using autonomous drone swarms. There are four activities proposed: validation of a smart drone swarm system and system expansion with long duration drones; sensor integration and calibration; swarm deployment in MN forests and prescribed burn locations; education and outreach....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Letter of Approval to Submit	4549cad4-398.pdf
StarTribune news article on drone deployment for wildfire smoke	bce0b5e4-ce2.pdf
Particle4X letter of support	123ae27d-a5b.pdf
DNR Darren letter of support	ae42268b-643.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

No

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

Yes

Do you certify that background checks are performed for background check crimes, as defined in Minnesota Statutes, section 299C.61, Subd. 2, on all employees, contractors, and volunteers who have or may have access to a child to whom children's services are provided by your organization?

Yes

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Jiarong Hong and Wendy Moylan, University of Minnesota

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

Yes, I understand