Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-438

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 an autonomous drone swarm system equipped with advanced sensors to enhance wildfire detection and monitor prescribed burns to improve air quality management and wildfire response strategies.

ENRTF Funds Requested: $749,000

Proposed Project Completion: June 30, 2028

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 ecosystems, air quality, and public health, intensified by climate-driven droughts and human activities. Historically, Minnesota experiences roughly 1,000 wildfires annually, burning approximately 25,000 acres; notably, 2021 saw over 2,000 wildfires consuming around 69,400 acres due to severe drought conditions. Current wildfire detection in Minnesota primarily relies on indirect public reports and manual aerial surveillance, which in 2024 identified only about 12% of wildfires, involving approximately 663 hours of flight observation. These conventional methods often delay critical responses, allowing fires to grow significantly and escalate their environmental and public health impacts. Additionally, prescribed burns are essential management tools that help reduce wildfire risks and maintain healthy ecosystems but require precise real-time monitoring to ensure safety and efficacy. Current monitoring systems fail to adequately capture detailed smoke dispersion patterns, limiting effective management and creating health risks from smoke exposure. Minnesota agencies have recognized these gaps through previous LCCMR-funded initiatives that address various aspects of wildfire and prescribed burning practices (e.g, LCCMR projects 2020-052, 2021-08e, 2022-190, 2023-152, 2024-173), emphasizing the urgent need for advanced, autonomous, high-resolution detection technologies to enhance early wildfire detection and provide comprehensive real-time mapping of prescribed burn smoke dispersion.

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.

We propose to develop an advanced drone swarm system composed of four fixed-wing Vertical Take-off and Landing (VTOL) drones, each equipped with centralized GPU-based machine learning processors and a suite of specialized sensors for early wildfire detection and prescribed burn monitoring. These include high-resolution optical cameras for real-time smoke plume identification, infrared and thermal sensors for heat anomaly detection, and gas and particulate sensors for identifying fire-related emissions such as carbon monoxide and fine particulates. Our system will also integrate novel Digital Inline Holography (DIH) sensors for enhanced particle characterization. Operating autonomously in a coordinated manner, the drone swarm will survey up to 150 miles per mission, with each drone capable of 5-hour flights. The system will serve dual purposes: (1) Wildfire Early Detection – enabling rapid response by identifying emerging fires through thermal, optical, and chemical signatures, and integrating with Minnesota's existing wildfire detection infrastructure, including DNR aerial patrols and satellite data; (2) Prescribed Burn Monitoring – providing real-time 3D mapping of smoke dispersion to assess air quality impacts and optimize burn management. Our multidisciplinary team ensures a comprehensive approach to system development, field deployment, and community engagement for wildfire resilience.

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 drone swarm system with advanced sensing and AI-driven solutions will be integrated with existing wildfire detection infrastructure and enhance statewide fire surveillance and resource management. Its real-time monitoring capability will enable faster air quality alerts, helping communities adopt protective measures and mitigating the long-term health impacts of wildfire smoke exposure. The system also enables detailed 3D smoke mapping during prescribed burns that will optimize burn strategies, ensuring safer air quality management. Our education and outreach will result in Firewise community initiatives, fostering a culture of resilience among young Minnesotans.

Activities and Milestones

Activity 1: Drone Swarm System Development

Activity Budget: $360,000

Activity Description:
This activity will involve the detailed design, construction, and initial validation of an advanced drone swarm system specifically tailored for wildfire early detection and prescribed burn monitoring. A swarm of four fixed-wing VTOL drones will be developed, each incorporating GPU-based processing units to enable sophisticated autonomous navigation, collision avoidance, coordinated swarm behavior, and efficient real-time data processing and communication. The primary focus of this activity will include finalizing drone aerodynamic designs and system architecture, optimizing payload configurations, and developing robust autonomous flight algorithms to ensure extensive and precise area coverage. Prototypes of drone components will undergo bench tests including structural integrity, propulsion systems, battery efficiency, and communication protocols, to ensure reliability and operational effectiveness. Flight trials will systematically assess critical drone flight dynamics under various environmental conditions, validate control precision in both manual and autonomous modes, rigorously evaluate communication latency and reliability between drones and ground stations, and thoroughly test swarm coordination capabilities to ensure precise synchronization and efficient area coverage. Data from these initial tests will be analyzed rigorously to refine drone hardware and software, addressing any identified operational limitations or mechanical deficiencies. Successful completion of this activity will ensure drone readiness for subsequent sensor integration and real-world operation.

Activity Milestones:

Description	Approximate Completion Date
Design Finalization: Complete drone system architecture, sensor layout, and flight algorithms	December 31, 2026
Prototype Development: Build and conduct bench tests on drone prototypes	May 31, 2027
Initial Flight Testing: Perform basic autonomous flight trials to validate flight stability and control	June 30, 2027

Activity 2: Sensor Integration and Calibration

Activity Budget: $228,000

Activity Description:
This activity will focus specifically on the integration, calibration, and validation of the drone sensor payloads, distinct from the drone system hardware and flight algorithm development. The integrated sensors will encompass optical cameras optimized for early visual detection of smoke plumes, thermal and infrared imaging sensors specifically calibrated for detecting subtle heat anomalies, gas sensors designed to identify combustion-related chemical signatures, air quality sensors for quantifying particulate matter concentrations, and advanced Digital Inline Holography (DIH) sensors for detailed particle characterization. Initial sensor integration efforts will ensure seamless data interface, efficient signal processing, and minimal interference across the drone platforms. Rigorous laboratory-based calibration tests will be performed under controlled conditions simulating environmental variations expected during wildfire scenarios to assess sensor accuracy, sensitivity, response time, and stability. Following laboratory validation, controlled field calibration trials will utilize artificially generated smoke, thermal sources, and particulate emissions to replicate real-world operational conditions. Comprehensive data analyses from both laboratory and field calibrations will verify sensor performance, inform necessary adjustments, and finalize sensor configurations for effective deployment. Leveraging Yang and Hong's expertise in advanced sensor technologies and modeling, this activity ensures accurate, reliable, and operationally robust sensor performance critical for wildfire detection and smoke dispersion modeling.

Activity Milestones:

Description	Approximate Completion Date
Sensor Integration: Complete hardware and software integration of sensors into drones	September 30, 2027
Calibration Testing: Conduct lab and controlled environment field calibration	December 31, 2027
Data Validation: Verify real-world sensor and model performance before operational deployment	March 31, 2028

Activity 3: Field Deployment and Testing

Activity Budget: $141,000

Activity Description:
This activity focuses on rigorous real-world deployment and comprehensive evaluation of the drone swarm system under actual wildfire detection scenarios and prescribed burn conditions. Initial efforts will include developing detailed operational protocols, securing necessary permissions, and coordinating closely with the Minnesota Department of Natural Resources (DNR) for targeted deployments. Field testing of prescribed burn will occur during the spring and fall prescribed burning seasons, focusing on assessing the system's capability to accurately map smoke dispersion patterns in real-time, evaluate burn conditions, and inform operational strategies. During these tests, detailed data on smoke plume movement, air quality impacts, and drone system performance under controlled burn scenarios will be collected and analyzed. Wildfire early detection deployment in collaboration with the DNR will also be executed during the summer wildfire season, targeting high-risk forested areas. The drone swarm system will perform autonomous patrols, systematically scanning large, forested areas, identifying potential fires quickly, and transmitting validated fire data directly to DNR dispatch. Results from these deployments will inform further system refinements, optimize detection strategies, and ensure effective integration with Minnesota's existing wildfire management practices.

Activity Milestones:

Description	Approximate Completion Date
Deployment Planning: Develop operational protocols and secure permissions for testing	March 31, 2028
Prescribed Burn Monitoring (Spring): Deploy drones during prescribed burn practices	April 30, 2028
Wildfire Early Detection Testing (Summer): Conduct field deployment in high-risk wildfire areas	June 30, 2028

Activity 4: Education and Outreach

Activity Budget: $20,000

Activity Description:
This activity will develop and implement comprehensive educational and community engagement programs focused on wildfire prevention and drone-based environmental monitoring. As a high-school science educator with extensive experience in STEM education, Princesa has recommended high school students to Yang and Hong's labs on various STEM projects. Leveraging Princesa's expertise in fostering STEM engagement and environmental stewardship, the team will develop tailored STEM curriculum and community outreach materials highlighting wildfire science, drone technologies, and best practices for community resilience. Interactive workshops and public demonstrations will be conducted to showcase drone swarm operations, sensor capabilities, and real-time data interpretation for wildfire detection and management. Additionally, hands-on training sessions aim to empower local stakeholders, fire management professionals, and community members to effectively utilize drone-generated information in fire preparedness strategies. Collaboration with Firewise initiatives will further promote community-level adoption of fire safety practices and encourage proactive risk mitigation behaviors. Feedback from participants, educators, and community partners will be systematically collected and evaluated to continually refine outreach effectiveness, improve community engagement strategies, and sustainably enhance wildfire preparedness across Minnesota.

Activity Milestones:

Description	Approximate Completion Date
Program Development: Create educational materials and outreach plans	March 31, 2028
Community Workshops: Conduct demonstrations and interactive training sessions	June 30, 2028
Feedback Evaluation: Assess outreach effectiveness and document findings for future initiatives	June 30, 2028

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
Pranay Junare	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 provide supervision and expertise in field testing of the drone swarm.	Yes

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?

Implementation will be sustained through integration with wildfire response infrastructure, such as DNR aerial patrols, and ongoing data contributions to fire behavior and air quality modeling. Particle4X, a key startup partner, will drive the long-term adoption by enhancing drone systems for wildfire and prescribed-burn practitioners. As part of its commitment, Particle4X will contribute additional systems (~$120K) to the DNR for wildfire and prescribed-fire. Future funding is expected through the DOD SERDP Wildfire Initiative, which has engaged with us multiple times and shown strong interest. SERDP's anticipated December 2027 funding call presents an avenue to continued support to advance this effort.

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 MnDRIVE Robotics, Sensors, and Advanced Manufacturing initiative at the University of Minnesota (UMN), where she leads a research program at the intersection of remote sensing, agricultural robotics, and environmental sustainability. With over a decade of experience, Dr. Yang has pioneered the development

and deployment of drone-based sensing technologies for precision agriculture and high-throughput phenotyping, with a particular focus on detecting abiotic and biotic stressors in crops and natural ecosystems.
Dr. Yang's research harnesses advanced drone-based remote sensing techniques to monitor nutrient deficiencies, disease outbreaks, and environmental stressors in Minnesota's agricultural landscapes. Her work aims to optimize chemical inputs, mitigate runoff contamination, and promote sustainable farming practices. She has developed novel drone imaging methodologies that integrate machine vision, multispectral, hyperspectral, and LiDAR technologies to capture high-resolution crop health data, enabling real-time decision-making for farmers and land managers.
Beyond precision agriculture, Dr. Yang's research extends to regenerative farming, where she employs drone-based remote sensing to study carbon sequestration in soil and its impact on climate resilience. Her 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.
At the UMN, Dr. Yang directs the Agricultural Robotics Laboratory, a multidisciplinary research hub housed within the College of Food, Agricultural and Natural Resource Sciences and the College of Science and Engineering. Her team oversees the entire research pipeline, from experimental design and field data collection to advanced data analytics and dissemination of findings through scientific publications, stakeholder workshops, and K-12 outreach initiatives. Through these efforts, Dr. Yang continues to push the boundaries of drone technology for next-generation agricultural and ecological monitoring.

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		Project manager, overseeing the progress and the research, development and application activities.			36.6%	0.16		$34,795
Professor		Co-I, leading the drone swarm system development, including autonomous navigation, drone hardware integration, and flight operations.			36.6%	0.04		$9,801
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		$117,890
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%	0.12		$13,660
							Sub Total	**$176,146**
Contracts and Services								
Engineer and Science Educator	Service Contract	High school educator will provide field experiments and lead education and outreach activities.				0.4		$20,000
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	**$420,000**
Equipment, Tools, and Supplies								
	Equipment	Jetson Orin Nano Controller Kits	Micro Processor for AI and controls in drones					$1,494
	Equipment	Cameras with gimbals	Ultra HD 6X Digital Zoom Gimbal Camera with AI Smart Identify and					$1,614

			Tracking HDR Starlight Night Vision for UGV USV RC Plane FPV Drones Robot					
	Tools and Supplies	Radio Transmitters	Remote controllers for the drone swarm system					$1,200
	Tools and Supplies	Cube Orange (ADS-B) w/ Here3 & RFD900x Telemetry Set	Here3 RTK gps telemetry set for telemetry					$4,854
	Tools and Supplies	Anti-Vibration Damping Plate	reducing vibrations in flight controllers					$48
	Equipment	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	VTOL drone frames with basic electronic systems	The base frame and basic electronics of the drone swarm system					$37,000
	Equipment	LIDAR	Real time reconstruction of smoke for prescribed burning					$18,150
	Tools and Supplies	Concentration Laser Sensor	Digital Particle monitoring using laser					$200
	Equipment	Blackfly® S, Monochrome Camera	Monochrome cameras for perception					$2,620
	Tools and Supplies	Laser diodes	For range sensing					$50
	Tools and Supplies	LORA modules with 4G and WIFI support	For long range communication and swarm operation					$695
	Tools and Supplies	Parts including spare propellers, batteries, connectors, wires, dongles, wifi router, data storage for drones	Consumables for the drone swarm system					$12,927
	Equipment	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	**$113,854**
Capital Expenditures								
							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 5-6 people with meals and some trips with lodging. Average $1500 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	**$749,000**

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: $869,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 86ef8a21-8c5.pdf

Alternate Text for Visual Component

Visual demonstration of wildfire early detection and prescribed burn management using autonomous drone swarms. There are four activities proposed: drone swarm development; sensor integration; swarm deployment, sensor data collection, analysis and mapping; education and outreach plan....

Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	88564247-ae5.pdf
Audit	1b867ea2-6e8.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?

Yes, Sponsored Projects Administration

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")?

No

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