Environment and Natural Resources Trust Fund
2017 Request for Proposals (RFP)

Project Title: **ENRTF ID: 148-E**

Air Quality Network Sensing Aircraft Pollution Near MSP

Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 571,210

Proposed Project Time Period for the Funding Requested: 3 years, July 2017 - June 2020

Summary:

Design, build, and deploy an air quality sensor network to determine the impact of aircraft pollution in neighborhoods near MSP. Conclusions will inform decisions about changes needed in flight patterns.

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Sponsoring Organization: Minnesota State University, Mankato

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Location

Region: Metro

County Name: Hennepin

City / Township: Minneapolis, Richfield, Edina, Eagan

Alternate Text for Visual:

A map showing aircraft flight patterns and air quality instrument locations overlaid on maps of South Minneapolis. As illustrated routes change daily, which will allow their impact to be estimated.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Air Quality Network Sensing Aircraft Pollution Near MSP

I. PROJECT STATEMENT

Pollution from combustion engines (e.g. aircraft, on-road vehicles) adversely effects human health by increasing mortality rates, exacerbating respiratory problems for at risk populations such as the young and elderly, and possibly accelerating degenerative diseases like Alzheimer's and Parkinson's. There is no "zero threshold" for health effects; for example, adverse health effects from carbon monoxide (CO) exposure occur at levels far below the existing EPA mandates. The MSP airport operates thousands of commercial aircraft flights daily, with typical flight paths cutting through South Minneapolis, Edina, and Richfield neighborhoods, resulting in increased levels of noise and exhaust pollution for residents. While noise pollution mitigation techniques have been enacted in these neighborhoods, air pollution mitigation has been ignored. The Minnesota Pollution Control Agency (MPCA) currently operates 26 air quality monitoring sites in the metropolitan area but there is only one within five miles of the MSP airport. As such, predicting or measuring the effects of FAA proposed "superhighways" on local air quality is impossible. Meeting the general need of spatially and temporally resolved air quality has been hampered by the relatively high cost of a single instrument that can accurately measure these pollutants. This task is much more difficult than measuring noise. However, recent advances in sensor technology and relatively simple microcontrollers make the possibility of a high accuracy, relatively low-cost instrument now a reality. To date, "networks" of 10's to 100's of these relatively low-cost instruments have been deployed to help protect an important natural resource in communities of Zurich (Switzerland), MIT (Massachusetts), the Heathrow Airport (London, UK), and Los Angeles (California).

We seek to design, build, and deploy 200 air quality sensors to determine the impact of the densification of flight patterns and aircraft exhaust in communities surrounding the Minneapolis-St. Paul (MSP) airport. We will measure aircraft pollution such as CO, oxides of nitrogen (NO & NO_2), sulfur dioxide (SO_2), and ozone (O_3). All results will be made available online and in real-time using a website that is developed. "Citizen Scientists" will be engaged to help with sensor deployment and monitoring of local events that may affect air quality. In addition, results will be modeled with commercially available software that is already used by the MSP airport (but results are not widely disseminated). The primary outcome of this work is accurate, temporally and spatially resolved, air quality analyses that will provide much needed guidance on the advantages and consequences of the densification of aircraft take-off and landing routes. Analyses will provide insight into what changes should be implemented, if any, to preserve, protect, and improve local air quality. Appropriate actions would reduce the impact of air pollution on residents in South Minneapolis.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Design, build, and test 200 air quality instruments* **Budget: $378,066**

Finalize sensor design, purchase supplies to build instruments (1000 individual gas sensors, microcontrollers, batteries), manufacture instruments, insure each instrument is fully functional, run models to guide deployment locations

Outcome	Completion Date
1. 200 air quality instruments that are validated and ready to deploy	May, 2018
2. Laboratory and/or field results showing performance and accuracy of instruments	May 2018
3. Aircraft plume dispersion model that predicts influence of flight patterns on pollution concentrations - used to guide deployment locations	May, 2018

Activity 2: *Develop website and database that shows air quality online in real-time* **Budget: $123,066**

Software development efforts are required to consolidate all streaming data into a database and format that is suitable for online publishing.

Outcome	Completion Date
1. Website that shows all sensor locations and real-time data for public monitoring	September 2018

Activity 3: *Operate network of 200 sensors for a year and continuously collect data* **Budget: $70,079**
Analyze all results and present conclusions to the public in various forms.

Outcome	Completion Date
1. One year of air quality data online and in database form	May 2020
2. Presentation of results at community meetings; manuscripts submitted for publication	May 2020
3. Clear, meaningful conclusions related to current and proposed densification of flight patterns and aircraft exhaust in neighborhoods near MSP	May 2020

III. PROJECT STRATEGY

A. Project Team/Partners

The project will be led by Prof. Jacob Swanson of Minnesota State University, Mankato (MSU-M). Prof. Swanson is internationally recognized for his work on emissions from engine combustion engines, including those from gas turbines. His efforts are well supported by many collaborators as indicating in the following.

Participants *receiving* ENRTF funds

- MSU-Mankato engineering undergraduate research assistants appointed by Dr. Swanson will design, build, and install sensors; help with air quality analysis and modeling
- Co-PI Electrical Engineering Professor Robert Sleezer (MSU-M) will support the circuit design and build
- A software developer contractor and circuit design contractor will help ensure student work is "robust"

Participants *not receiving* ENRTF funds

- Adam Boies (UMN Civil Engineering Professor) will collaborate and share information from on-going similar projects related to understanding sensor design and operation best practices
- Monika Vadali (MPCA Scientist) will assist with sensor calibration and validation by providing access to MPCA air quality monitoring sites that are fully compliant with Federal regulations
- Jennifer Lansing and environmental scientists from the City of Minneapolis will support community involvement and sensor deployment efforts
- South Minneapolis "Citizen Scientists" will help with sensor deployment and monitoring of local events that may impact air quality and convolute sensor responses
- Logistical and electrical support from Xcel Energy is anticipated but there is no secured commitment yet

B. Project Impact and Long-Term Strategy

This proposal represents the final phase and columniation of two years of focused sensor design and development efforts. While this funding is critical to deployment of many (200) sensors, significant proof-of-concept work has already been completed. Faculty research funds (~$5,000) supported the first air quality sensor design, and a faculty research grant from MSU-Mankato (~$5,000) supported a sensor redesign and the work required to produce this proposal. These efforts demonstrated that a single fully functioning sensor could be built for $1,100 or less (this compares to a commercial cost of $10,000/each). The results from this project will be analyzed and disseminated to the local community, legislatures, and other stakeholders seamlessly using our real-time online data tool. The publically accessible data and conclusions resulting from this project will inform legislatures, scientists, and citizens on the environmental and health costs of operating an airport in a highly populated area. The sensors are not consumables, so it is expected that the sensor networks will be an economically tool that is deployable to other at-risk areas of the state at the conclusion of this work. This and future research would provide accurate raw data and statistics to validate air quality, plume dispersion, and climate change models, which could then be used to model the effects of other pollution sources in the state. All new findings will be submitted for publication in peer-reviewed academic journals.

C. Timeline Requirements

The expected timeline is three years: one year to build 200 sensors, one year to deploy all sensors and collect data, and one year of analysis and dissemination.

2017 Detailed Project Budget

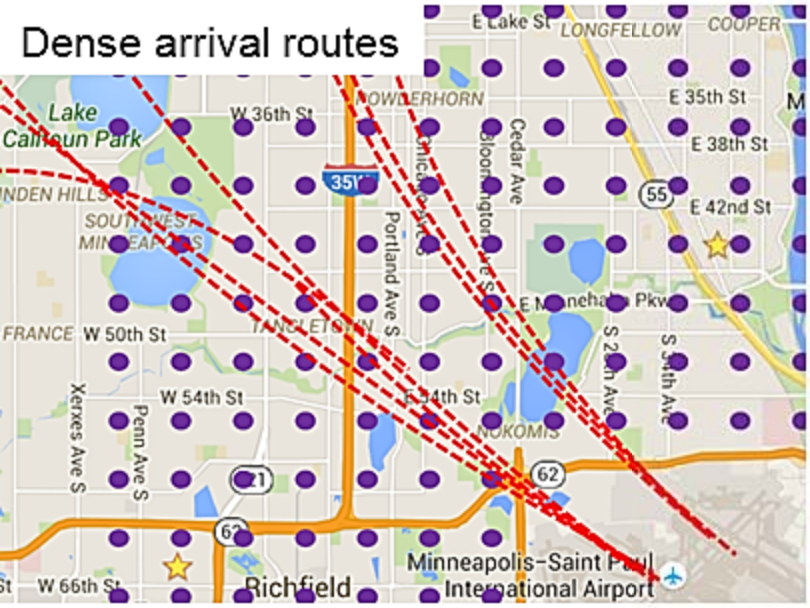
Project Title: Air quality network sensing aircraft pollution near MSP

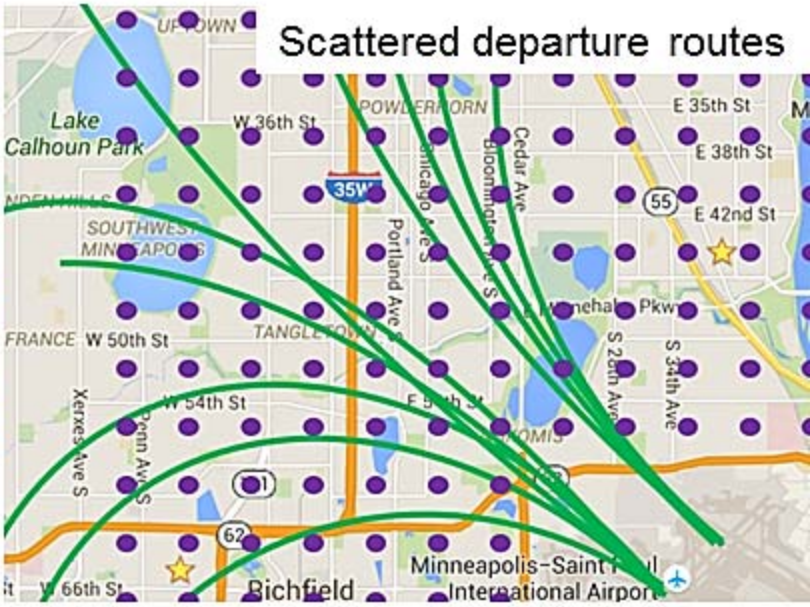
IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Prof. Jacob Swanson, Project Manager, (82% salary, 18% benefits); 19% FTE for 3 years	$ 86,199
Prof. Robert Sleezer, Electrical Engineer, (82% salary, 18% benefits); 15% FTE for 2 years	$ 45,973
5 Undergraduate Research Assistants (92% salary, 8% benefits, $10.45/hr); 1.25 FTE for 3 years	$ 86,338
Professional/Technical/Service Contracts:	
Software developer to facilitate website design and online data reporting (contractor TBD)	$ 30,000
Circuit engineer (contractor TBD)	$ 20,000
Equipment/Tools/Supplies:	
Supplies to build 200 instruments (boxes, batteries, electronics, 1,000 individual gas sensors @ about $200/each)	$ 220,000
Hardware for sensor mounting and fabrication, machining, 3D printing	$ 25,000
Gas analysis equipment (bottles, regulators, etc for calibration)	$ 20,000
Computer server, hosting fees, website fees, data storage, wireless fees, software	$ 35,000
Acquisition (Fee Title or Permanent Easements): n/a	
Travel:	$ -
Travel to 200 locations for sensor deployment, return trips for maintainence - est. 5000 miles over 3	$ 2,700
Additional Budget Items: n/a	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 571,210

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period		
Expected NSF proposal submission under "Citizen Science and Crowdsourcing - Public Participation in Engineering Research"	$ 100,000	Unsecured
Other State $ To Be Applied To Project During Project Period: *n/a*		
In-kind Services To Be Applied To Project During Project Period:		
Access to regulatory insturments to check calibration of instruments (MPCA)	$ 25,000	Secured
Assistance with sensor deployment from City of Minneapolis environmental services scientists	$ 10,000	Secured
Assistance with powering sensors (Xcel Energy) (depends on final decision of locations)	$ 20,000	Unsecured
Funding History:	$ -	
MNSCU leveraged funds for equipment purchases	$ 5,000	Secured
MSU-Mankato Faculty Research Grant (supported preliminary work for this proposal)	$ 4,995	Secured
Remaining $ From Current ENRTF Appropriation: *n/a*	$ -	





Help from local citizen scientists

Real-time data from 200 instruments

Available online

Known health effects of pollution and airborne contaminants

Analysis

Our aircraft pollution modeling results

Informed decisions about aircraft flight patterns that preserve, protect, or improve local air quality

I. PROJECT MANAGER QUALIFICATIONS

Dr. Jacob Swanson is an Assistant Professor of Engineering in the **Twin Cities Engineering Program** in the Department of Integrated Engineering at Minnesota State University Mankato. He is also an Adjunct Assistant Professor in the Department of Mechanical Engineering (ME) at the University of Minnesota. He was previously a Research Associate in the Department of Engineering at the University of Cambridge, UK and before that, a graduate of UMN's ME Department. Prof. Swanson is internationally recognized for his work on emissions from engine combustion engines, including those from gas turbines. He has published nearly 30 papers and given more than 60 conference presentations on these topics. He is currently advising about 25 students as part of his ENGR Design course. He has 3-4 other external projects supporting about eight undergraduate students. He annually supports, by co-advising, on average 1-2 graduate students in the Particle Technology Laboratory and Engine Research Labs at the University of Minnesota. His specific experience, as related to aircraft exhaust, includes a significant amount of real world, field experience measuring aircraft emissions all over the world:

- Participation on in UK "SAMPLE" campaigns in the United Kingdom (UK) and Switzerland aimed at determining a methodology for measuring aircraft gas turbine particulate matter
- Operation of the Cambridge Intermediate Pressure Gas Turbine Combustion (CIPCF) facility (supported by Rolls Royce) at the University of Cambridge
- Participation in US EPA "VARIAnTII" sample campaigns in Tennessee and Minnesota that were also aimed at determining a methodology for measured aircraft gas turbine particulate matter.

II. ORGANIZATIONAL DESCRIPTION

Twin Cities Engineering (TCE) is a program of the Department of Integrated Engineering of Minnesota State University, Mankato. TCE has the purpose of expanding the pool of qualified engineers in the Twin Cities Metro area by establishing an affordable, accessible, and unique option for the region's engineering students. TCE offers an inclusive and innovative learning experience that has attracted non-traditional students and veterans at a higher rate than traditional students. The BSE degree program includes several features that differentiates it from traditional engineering degree programs. TCE addresses the entire learning experience and not simply one component of the curriculum. Five features, designed to produce desired attributes in BSE graduates, are as follows.

- Trans-disciplinary thinking
- Industry-sponsored, project-based-learning
- Experiential learning in context
- Competency-based assessments
- Significant exposure to professionalism, design, creativity, and innovation