Ames Innovation Fair 2020

Section A

Title: Miniature biomimetic Swarms: A novel approach to remote sensing

Lead name: Lynn J. Rothschild

Lead org: SST

Implementation: S

Section B

INNOVATION AIM/OBJECTIVE

This project proposes two swarm-based biomimetic design solutions to remote atmospheric exploration, each with its own unique advantages. Our objective is to begin preliminary design of these miniature spacecraft and payloads.

BACKGROUND

A major focus of current and future planetary science is the measurement and modeling of terrestrial atmospheres. Our pursuit of a more comprehensive and detailed construction of the atmosphere is crucial to our understanding of the world around us and to learning more about the complex systems that sustain life on earth. Off earth, the atmosphere is also a key point of interest for learning more about the conditions on Earth-like planets, and the investigation of whether these planets were or are ever capable of sustaining life.

So how do we go about collecting data from the atmosphere in the first place? Atmospheric composition data are available from ground-based *in situ* and airborne measurements, including remote sensing in the form of dropsondes or aerostats. While these tools can offer a high degree of sophistication and temporal resolution, they have a limited representation of greater spatial ranges. Satellite remote sensing can provide the spatial variation of atmospheric variables, using the same sensor and technique to retrieve the desired information, over the whole planet, but with much less detail.

INNOVATION DESCRIPTION:

This project proposes two swarm-based biomimetic design solutions to remote atmospheric exploration, each with its own unique advantages. Our objective is to begin preliminary design, prototyping, and testing of these miniature spacecraft and payloads and explore potential payloads.

The first design is an origami interpretation of the structure and flying mechanism of the **maple seed**. Composed of a flat rectangle of paper that is cut and folded at multiple points, this biodegradable design can be transported compactly and easily prepared. Using a self-folding mechanism involving shape memory polymers that can be printed on the paper, the design can be stored flat and will self-fold upon entry into the atmosphere through heat or light activation, spinning as it descends. So the idea is that these little maple seed “helicopters” can be deployed in swarms by dropping these sheets into the air from a larger UAV. With microfluidic sensors placed on the wings of the vehicle, detection of the biological element could result in some sort of signal like a color readout, or heat emission, or even light. Then, the UAV, carrying some sort of accessible detection system like a camera or scanner, can scan the area for this signal, collect data, and then the drone itself can be collected and the readout analyzed.

The highlight of this design is that it delegates the task of *in situ* data collection to a more low-fidelity, high-output swarm of sensors--essentially adding another tier to the current model of remote sensing to address the limitations in data quality without compromising on quantity. To put it more simply, we're remote sensing the remote sensors. And because this one-sided data collection is happening on the next tier up, at the UAV level, there's no need for active communication from the paper vehicle itself, eliminating the need for batteries or transmitters, which greatly lowers the cost and difficulty of manufacturing.

The second design features the star of the show-- **the dandelion**! It's inspired by the dandelion plant's scaled-down, swarm-like approach to seed dispersion, and the specific mechanism they use to fly in the wind. Cummins et al. (2018, Nature 562, 414–418) found that even though they are really porous, they operate on drag-based flight (like a parachute) rather than lift-based flight (which we associate with most aerial vehicles with propellers like helicopters or drones). They found that the structure of the porous filaments which sit atop the dandelion seed result in a unique phenomenon: a separated vortex ring--essentially a pocket of air--above the seed itself. This design behaves similarly to a parachute, minimizing surface area while maximizing drag and stabilization in flight with a greater efficiency than winged, lift-based aircraft. Researchers were able to achieve proof-of-concept within the lab, by successfully recreating the flight mechanism (separated vortex ring) by making a tiny porous microfabricated disk out of silicon. As this flight mechanism is dependent on a smaller overall size, we envision this vehicle to be ~2 inches in diameter. The vehicle would include a nanosensor on the disk in the center, and a microtransmitter and/or battery would be located on the bottom of the "stem"; there's also the potential of including other nanotech like a tiny camera component. This allows it to transmit data from much further distances and in more turbulent conditions, when visual detection by the upper-level aircraft isn't possible. Lastly, this design would also be deployed as a swarm, in a range of space and space-adjacent applications that are either inefficient or impossible with current remote sensing techniques--from continuous vertical profiling of the transition from space to earth's upper atmosphere, to the detection of biological components and the modeling of wind patterns in off-earth atmospheres like Venus.

Cummins, C., Seale, M., Macente, A. et al. A separated vortex ring underlies the flight of the dandelion. Nature 562, 414–418 (2018). https://doi.org/10.1038/s41586-018-0604-2

PROPOSAL DELIVERABLES:

Design of both the maple seed and dandelion concepts
Prototype both concepts
Test flight of concepts and potential payload mass and distribution on Earth
List of potential payloads including COTS components
Iterative design as time/funding permits

INNOVATION STATEMENT

We propose to tackle the shortcomings of both approaches to atmospheric data collection with two novel designs that address the exploratory platform gap between the current models of *in situ* measurement and remote sensing, as well as the need for advances in atmospheric sensing, or more specifically, the need for *in situ* atmospheric sensing to catch up with advances in nanotechnology.

RELEVANCE AND VALUE TO AMES AND NASA:

The innovative miniaturized biomimetic swarms have the potential for novel low costs primary or secondary payloads, with the potential to contribute atmospheric data for both Astrobiology and Life sciences, as well as Earth and Space Science, thus providing Ames with an innovative solution that addresses 3 out of 8 core competencies. Similarly, they address many of NASA's strategic goals for exploration of the Earth and beyond. Although this proposal is pitched primarily as a science proposal, it has not escaped us that such a swarm can be used as a secondary payload to detect atmospheric anomalies to direct landing of human or other spacecraft, thus decreasing mission risk.