A UAS Facility for the US Academic Research Fleet

- White Paper for a Phased Vision to explore the desire and feasibility for a UAS facility as part of an Implementation Plan

- Overall idea here was to develop a longer-term plan to build out a UAS facility (UNOLS or otherwise) for all stakeholders. This could be imagined as something UNOLS oversees (or not), that a specific institution runs or a number of institutions run. All options would support NSF-type research. And RVTECs would be integral to this.

- An initial effort to develop our longer-term plan would be for SCOAR to hold a workshop with stakeholders and interested folks, both users and those interested in running a facility. This is something that we could write an EAGER grant to NSF to get funds to do this.

- We also discussed the possibility of writing a small grant to get some coordinated UAS operations going on UNOLS vessels. This could be an EAGER, or other funding avenues.

- Multi-Institution is key for moving forward
    - Potential for aircraft specialist institution, payload specialist institution, algorithm development institution… could be covered over many institutions.

- Training and best practices would be part of this Facility

- Based on the community input from all stakeholders, we decide whether to move forward:
    - Go directly to Kandy at NSF OTIC for a starter grant
    - MRIs are in varying size and target. The classic MRI program is institution specific for equipment or instrument development up to $4 million.
    - Mid-scale Research Infrastructure-1 (Mid-scale RI-2; up to $20 million) and -2 (Mid-scale RI-2; $20 million to $100 million) which could be teams of institutions.

Executive Summary for an Unoccupied Aerial Systems (UAS) Facility

Oceanographic and atmospheric research is poised for an observational transformation following a decade-long development of Unoccupied Aerial System (UAS) capabilities by my lab at Lamont-Doherty Earth Observatory of Columbia University. This effort has provided a unique research facility that will enable state-of-the-art oceanographic and atmospheric research by means of integrated ship- and aerial-based observations targeted to answer many of the critical questions facing us today.

In 2010, we launched a program at Lamont-Doherty Earth Observatory (LDEO) of Columbia University to develop scientific instrument payloads for moderate-size unoccupied aerial systems (UAS). The overarching goal for developing these payloads is to establish a facility for performing a variety of global in-situ measurements currently unavailable to the scientific and educational communities. For over a decade, we have worked to develop an infrastructure design of and laid the foundation for a revolutionary new UAS platform and sensor payload capability to support state-of-the-art oceanographic and atmospheric research [*Zappa et al.*, 2020]. The ship-based Remote Aerial Vehicle Exploration Network (RAVEN) consists of five components: (1) a fleet of three fixed-wing high-endurance (>12 hour) UASs with a fully-autonomous Vertical Take-Off and Landing (VTOL) capability; (2) a high-bandwidth (100 Mbps at 50 nautical miles), networked real-time communication system, (3) interchangeable scientific payloads, (4) advanced mission planning software, and (5) a streamlined data archiving pipeline. VTOL UASs utilize hybrid quadrotor technology that is ideal for ship-based operations, because they can take off and land from the moving deck of a research vessel like helicopters before transitioning into a fixed-wing flight mode that enables high-endurance (>12 hour) flights. Each UAS is equipped with a high-bandwidth (100 Mbps) communications system to enable network formation flight and coordinated observations to a distance of 93 km (50 nautical miles); communications with other systems, such as autonomous underwater vehicles (AUVs); and real-time mission control from the parent research vessel. The UASs can be flown in a variety of configurations, either to provide simultaneous measurements at multiple locations, or to perform continuous surveillance over a designated target. Furthermore, UAS operations can be tightly coordinated with other assets in the field in ways that occupied aircraft missions, staged from far-off airfields, cannot manage. To conduct scientific research, the UASs can be equipped with one of seven modular payloads that can be rapidly swapped into the UAS airframe using a “plug and play” system. These seven payloads are intended to form the basis of the workflow of the overall RAVEN system, but they can be expanded on the basis of oceanographic community feedback. To facilitate flight planning and optimization of multi-agent scientific surveys, we also developed and tested software tools for mission design and established a data archiving pipeline. The fully matured RAVEN is ready to make available to the broader geophysics research community through an implementation project to transform traditional research vessels into advanced scientific aircraft carriers.

This novel ship-based RAVEN facility infrastructure enables novel scientific research, meets the diverse needs of the oceanographic community by filling an important gap in existing oceanographic infrastructure, and provides LDEO with a global leadership position in integrated ship and aerial science. Furthermore, the RAVEN architecture, which includes high-bandwidth communications between UASs in the network as well as with the home ship, generates a novel platform for research in data science. For example, the large volume of data collected with the instruments onboard the UASs are ideal for developing training sets to enable data-driven discovery. Computer vision and machine-learning methods can also be developed and tested using the RAVENs to enable real-time optimization in search and optimized data acquisition, using high-bandwidth communication in combination with high-performance computing onboard the parent ship. The RAVEN facility will provide the next generation of instrumentation capability for ship-based UAS research. The RAVEN system is a transformational step to the critical charge of the Scientific Committee for Oceanographic Aircraft Research (SCOAR) to promote the coordinated use of aircraft facilities, including UASs, designated by the University–National Oceanographic Laboratory System (UNOLS), with research vessel operations and facilitating the scheduling of joint research vessel and aircraft experiments. Ultimately, my goal is to make UAS technology and observations as routine onboard research vessels as rosette samplers that collect water samples using Niskin bottles along with conductivity, temperature, and depth (CTD) measurements. Rosette samplers and LADCPs are a vital part of oceanographic research, but like RAVENs the limits of their utility are as boundless as the imagination of the instrument's users. The vision is for a UAS Center to be the beginning of a national facility that will eventually lead to a RAVEN-type system (of varying UAV size, capability, and payloads) tailored for each UNOLS vessel and science objective, with the ultimate goal of a potential UAV-craft carrier for oceanography.