NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences –2019
NNH19ZDA001N-AITT
A.30 The Airborne Instrument Technology Transition

The National Aeronautics and Space Administration (NASA) solicited proposals to integrate existing instruments, developed under the NASA Instrument Incubator Program (IIP) or other similar development programs, onto platforms supported by the NASA Airborne Science Program. The major goal of the Airborne Instrument Technology Transition (AITT) program is to provide campaign ready airborne instrumentation that can support the objectives of the Research and Analysis Program. This solicitation provides the opportunity to convert an IIP instrument end product into a useful suborbital instrument that can participate in field experiments, evaluate new satellite instrument concepts, and/or provide calibration and validation of satellite instruments. This opportunity was only for existing instruments, not development of new instrumentation. As projects would deal with data collection activities, proposed activities were to include specific attention enabling data availability of instrument products.

This solicitation specifically requested proposals that would support the objectives of one or more of the Earth science Focus Areas: Atmospheric Composition, Carbon Cycle and Ecosystems, Climate Variability and Change, Earth Surface and Interior, Water and Energy Cycle, and Weather. NASA advertised that four million dollars would be available over the next two years to fund approximately three to four projects.

NASA received a total of fourteen proposals, and four have been selected for either full or partial funding. The total funding awarded is $4.8M over the next twenty-four months.

The selected projects will enhance four different instruments to be fully campaign ready and able to serve the NASA community. The projects involve remote sensing using a wide variety of remote sensing techniques and in various push the envelope to make new observation capabilities available to the scientific community. The instruments to be made campaign-ready will be useable in both satellite mission calibration and validation (as well as collecting data instrumental for planning and refining states of the near future. Collectively the projects selected and described below will address objectives of all six of the NASA Earth science Focus Areas.

Ian Adams/Goddard Space Flight Center
Operationalizing CoSSIR for the Aerosol, Clouds, Convection, and Precipitation Era

19-AITT19-0005

The Compact Scanning Submillimeter-wave Imaging Radiometer (CoSSIR) is a collection of subsystems built at GSFC that has demonstrated the utility of submillimeter-wave radiometry for observing ice clouds and frozen precipitation. However, CoSSIR has never been a fully-integrated sensor as it shares resources with its millimeter-wave sibling the Conical Scanning Millimeter-wave Imaging Radiometer (CoSMIR). This project will make CoSSIR a stand-alone sensor that is readily available to do research flights. Moreover, we will exploit this sensor's unique, configurable scanning architecture to probe the vertical structure of clouds and snowfall by applying computed tomography (CT) algorithms to multi-angle observations. The cloud and precipitation products produced by this sensor will be relevant to the Weather, Climate Variability and Change, and Energy and Water Cycle Focus Areas. Finally, with the imminent launch of the European Organization for the Exploitation of Meteorological Satellites' (EUMETSAT) Ice Cloud Imager (ICI) and the strong consideration of submillimeter-wave sensors in the Aerosol, Clouds, Convection, and Precipitation (ACCP) architecture study, this work will ensure that CoSSIR is ready to support calibration/validation efforts and ACCP-related suborbital campaigns.

Submillimeter-wave brightness temperatures contain significant information content from ice clouds and frozen precipitation, and this portion of the electromagnetic spectrum complements microwave and millimeter-wave bands for a comprehensive understanding of clouds and precipitation. CoSSIR offers these capabilities, but it lacks the infrastructure to operate as a stand-alone instrument. This presents two challenges: one, CoSMIR must be partially disassembled to allow CoSSIR to fly, creating risk for both sensors, and, two, CoSSIR and CoSMIR cannot fly concurrently. By transitioning to a dedicated airborne sensor, CoSSIR will become the singular, premier NASA submillimeter-wave radiometer for observing ice clouds and frozen precipitation. Moreover, we will rename CoSSIR the Configurable Scanning Submillimeter-wave Instrument/Radiometer (retaining the same acronym) to fully reflect its scanning capability which includes conical, across- and along-track geometries. The proposed along-track scan pattern will facilitate multi-angle views of clouds for employing CT to discern cloud and precipitation vertical structure. Along-track data taken collected by CoSSIR will provide a comprehensive demonstration of the CT algorithms and help to interpret along-track data from the Temporal Experiment for Storms and Tropical Systems – Demonstration (TEMPEST-D). And, of course, CoSSIR will be ready to support ACCP-related suborbital campaigns, as well as NASA's interests with respect to ICI.

Specific work for this AITT project includes environmental testing of CoSSIR, electrical and mechanical work to interface with the ER-2, and modification and transition of flight and ground data processing software, including CT algorithms, and test/engineering flights to demonstrate CoSSIR. Data acquired during flights will be processed, analyzed, and made publily available. Work is projected to begin May 2020, with test/engineering flights in October 2021. Potential IMPACTS flights would occur in January and February 2022, overlapping with ground processing and analysis of test/engineering flight data.

Ken Cooper/Jet Propulsion Laboratory
Upgrading VIPR for Routine Pressurized Aircraft Deployment in Science Field Campaigns
19-AITT19-0004

The Vapor In-cloud Profiling Radar (VIPR) is the first in a new class of millimeter-wave cloud radars operating above 100 GHz, and is designed to remotely measure range-resolved absolute humidity inside of clouds and precipitation. VIPR also measures 170 GHz (G-band) cloud reflectivity and column-integrated water vapor, and addresses the Earth Science Decadal Survey (DS) objectives of understanding the thermodynamics of the Planetary Boundary Layer (PBL), as well as Cloud, Convection, and Precipitation (CCP) processes. The DS has highlighted the PBL as a Targeted Observable for technology incubation and CCP as a Designated Observable.

Matured to TRL 6 under the IIP-16 program, VIPR operates in atmospheric conditions that confound existing humidity profiling techniques of lidar and passive microwave/infrared radiometry. VIPR has been successfully validated in ground testing against radiosondes, and it will be demonstrated in the winter of 2019/2020 for airborne compatibility in engineering test flights in an unpressurized, open-viewport Twin Otter aircraft.

The objective of this AITT effort (May 2020 through April 2022) is to transition VIPR for regular airborne deployment in a higher flying, pressurized aircraft so that the instrument can participate in science field campaigns that include multiple atmospheric remote sensing instruments operating simultaneously. For example, several other candidate PBL instruments fly on NASA's DC-8 and P-3 airborne platform including the High Altitude Lidar Observatory (HALO) water vapor lidar, the Airborne Vertical Atmospheric Profiling System (AVAPS) dropsonde system, the Airborne Precipitation Radar 3rd generation (APR-3), the High Spectral Resolution Lidar (HSRL2), and various passive infrared and microwave sounding instruments.

To accomplish this objective, VIPR's radar optics and its G-band waveguide components will be separated from the radar's back-end electronics by a bulkhead seal between the pressurized aircraft cabin or cargo volume and the unpressurized nadir-viewing port. To increase VIPR's compatibility with multiple aircraft and in different weather environments, a protective and aerodynamic radome will be developed to cover the viewport. The radome will inevitably reflect a small portion of the transmit beam back into the waveguide feed port. This necessitates a physical separation of VIPR's transmit and receive ports, which are currently duplexed to share a single primary antenna, into a bistatic, dual antenna configuration with the two antennas separated by an RF-blocking barrier. In addition to this mechanical improvement, VIPR's absolute calibration will be refined in two ways. First, a heater and thermal control system will be built to stabilize the temperature of, and prevent moisture condensation on, VIPR's front-end components that are exposed to cold ambient air. Second, we will develop models of G-band ocean

reflectivity to compare with airborne measurements so that in-flight radar calibration can be done for VIPR as it is in other airborne radar systems such as APR-3. Our effort will culminate in a few hours of VIPR test flights in the winter of 2021/2022, with possible augmented deployments if an opportunity arises to join other airborne science missions. In this proposal we assume that VIPR will be designed for accommodation in either the NASA-Armstrong DC-8 or the NASA-Wallops P-3 aircraft as a specific deployment platform, but in VIPR's upgrade we will strive to keep the specific aircraft interfaces modular and interchangeable.

Nathaniel Livesey/Jet Propulsion Laboratory
The Airborne Scanning Microwave Limb Sounder (A-SMLS)
19-AITT19-0003

The Airborne Scanning Microwave Limb Sounder (A-SMLS) makes wide-swath vertical profile observations of the composition of the upper troposphere and lower stratosphere (the atmospheric region from ~10–20km altitude). A-SMLS measurements are well suited to studies of convective outflow, long-range pollution transport, and exchange of air between the troposphere and stratosphere. These atmospheric processes have strong impacts on climate and air quality but are currently incompletely understood. Improved understanding of these issues is one of the main goals of NASA's atmospheric composition Earth science focus area. A-SMLS airborne observations reflect the priority spaceborne "Ozone and Trace Gas" observables identified in the recent Decadal Survey.

A-SMLS was initially developed and flown on the WB-57 under the NASA Instrument Incubator Program (IIP), following which, it was adapted to the ER-2 platform. Subsequent work, funded under an additional IIP, has improved the receivers to ones that require cooling to only 70K rather than the previously needed 4K, and to use newer technology digital spectrometers. Test flights for A-SMLS in this new configuration are planned, but further work, proposed here, is needed to make the instrument fully "campaign ready".

A-SMLS observes a ~300km-wide swath ~300km ahead of the aircraft in a 2D raster scan (azimuth and elevation), with ~10x10km horizontal sampling (across and along-track). As typically configured, A-SMLS measures water vapor, ozone, and carbon monoxide. Retuning of the instrument (including in flight) can provide measurements of other species (including N2O, HCN, CH3CN, HCHO, and others).

The instrument would be a particularly valuable addition to multi-aircraft campaigns. The broad swath A-SMLS observations from the ER-2 could be used in near-real-time to help guide lower altitude aircraft carrying in situ sensors to regions of interest.

We propose two years of further work (May 2020 to April 2022) that will cement A-SMLS's suitability for campaign-mode operations, specifically:

- Addition of a liquid cooling loop to transfer waste heat from the existing ~70K cryocooler to the outer skin of the ER-2 wing pod.

- Development of an “intelligent scan” system that accounts for aircraft orientation etc. when performing the 2D raster limb scan on the atmosphere.

- Completion of a thorough ground-based instrument calibration.

- Development of an on-board radiance compression scheme that will enable key data to be transferred to the ground for use in real-time flight planning as described above.

- Updates to the analysis algorithms software used for Aura MLS, enabling their application to A-SMLS observations.

A set of three test flights is planned, deploying out of the NASA AFRC Palmdale facility where the ER-2 is based.

John Paden/University of Kansas Center for Research
Operational Multichannel Snow Radar for Swath Mapping of Snow Layers on Ice Sheets, Sea Ice, and Land
19-AITT19-0012

The Multichannel Snow Radar (MSR) was built under a previous NASA call associated with Operation IceBridge (OIB). The multichannel 2-18 GHz capability enables tomographic techniques that will generate 3D maps of snow distribution with unprecedented detail and coverage on sea ice and reliable direct sounding of snow on land. Over land ice, the additional antenna directivity will increase signal penetration and reduce off-nadir clutter which will improve detectability of deeper layers and precise mapping of interfaces. The current single-channel snow radar has been operated successfully on 25 missions as a part of NASA OIB since 2009. Where the surface layering is sufficiently flat, the snow radar does an excellent job of mapping snow thickness. However, over deformed sea ice and over moderately rough land snow, the current snow radar’s broad antenna footprint is not able to unambiguously resolve the top and bottom snow interfaces. The cross-track resolving capability of the MSR will refine snow thickness estimates and increase coverage over deformed and rough snow surfaces.

This proposed effort supports NASA’s Water and Energy Cycle and Climate Variability and Change focus areas by providing an all-weather 3D view of the snow distribution on sea ice and land and by improving snow accumulation measurements on ice sheets and glaciers. The enhanced snow thickness product will help significantly improve ICESat-2 sea ice thickness retrievals since uncertainties in snow depth are currently the largest source of uncertainty in the conversion from freeboard to sea ice thickness. Though the snow depth observations are spatially and temporally limited, they could be combined with existing model or climatology estimates through data assimilation techniques to improve the regional representation of snow used for sea ice thickness retrievals. The

MSR data could also improve weather models of snow accumulation that are used for input-output mass balance estimates of the ice sheets and in firn compaction models that will be used by ICESat-2 dH/dt mass balance estimates of the ice sheets. Snow thickness on land can also be used to calibrate and validate ICESat-2 land snow measurements. All three of these measurements are Decadal Survey Targeted Observables. The MSR will also contribute to improved understanding of various snow processes on sea ice by providing, for the first time, accurate 2D snow thickness maps over a wide area.

Currently, the only known instrument to be capable of providing accurate wide area coverage of snow thickness on sea ice is the snow radar or similar airborne radar modality – a spaceborne capability is not currently considered feasible because of the aperture size required from orbit. Therefore, deployment of a snow-radar-type instrument on long range NASA aircraft, such as the P-3, is the only way to make these observations. The MSR represents a transformative advance in the capabilities of the already successful snow radar.

The proposed work will span 24 months and is divided into four major tasks:
1) Design and manufacture mount for the MSR antenna array and cases for components residing in the unpressurized/uncontrolled environment of the P-3 bomb bay.
2) Integration of components into a compact chassis for simplified maintenance and installation. Acquisition of critical spares to minimize downtime during deployment.
3) Radar control features to a) automate operation of the system to minimize operator errors and allow faster response times to changing terrain conditions, and b) improve real time remote command/control/status.
4) Two test flights over land snow, sea ice, and land ice from Thule, Greenland in Spring 2021 to demonstrate operational readiness and exercise all steps of the process from installation and calibration to data product delivery and validation.