Next Generation UAS Based Spectral Systems for Environmental Monitoring

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BACKGROUND

This investigation aims to bridge the gap in Earth observation between field and airborne measurements (**Figure 1**); and reduce the risk to NASA through development of methods to make well-characterized measurements from Unmanned Aerial Systems (UAS) for integration, calibration and validation of NASA satellite and airborne data. At present, UASs used in environmental monitoring collect mostly low spectral resolution imagery, capable of retrieving canopy greenness or properties related water stress. Because of the potential for rapid deployment, spatially explicit data from UASs can be acquired irrespective of many of the cost, scheduling and logistic limitations to satellite or piloted aircraft missions. Provided that the measurements are suitably calibrated and well characterized, this opens up opportunities for calibration/validation activities not currently available.

There is considerable interest in UASs from the agricultural and forestry industries but there is a need to identify a workflow that yields calibrated comparisons through space and time (**Fig. 2**). This will increase the likelihood that UASs are economically feasible for applied and basic science, as well as land management. This effort will develop a UAS based capacity for accurate measurement of spectral reflectance at high temporal frequencies and stability to depict diurnal/seasonal cycles in vegetation function. We target the consistent retrieval of calibrated surface reflectance, as well as biological parameters (BPs) including nutrient and chlorophyll content, specific leaf area and leaf area index, chlorophyll fluorescence, photosynthetic capacity - all important to vegetation monitoring and yield.

The deployment of UAS sensors at sites such as flux towers will facilitate more frequent (e.g. within-day) and spatially comprehensive assessment of the vegetation physiology and function within tower footprints than is possible by foot, from sensors fixed to the tower, or irregular aircraft missions. We will test our technology and protocols first using spatially-resolved discrete point measurements characterizing canopy VNIR reflectance and solar-induced fluorescence (**Fig. 3**) , followed by imaging spectroscopy. All spectral data will be uploaded to NASA's EcoSIS online spectral library.

We will implement a rapid data assimilation and delivery system based on past SensorWeb efforts to move calibrated reflectance data and derived retrievals directly from the UAS to users (**Fig. 4**). We will utilize SensorWeb functionalities to strategically run a data gathering campaign to optimize data yield. As well, we will develop a mission deployment system to optimize flight paths based on real-time in-flight data processing to enable effective data collection strategies. We will use a data delivery system in which products are rapidly distributed to users, providing spatially explicit data of vegetation traits at temporal and spatial scales not currently available. We enter the effort at Technology Readiness Level (TRL) 3 and will exit at TRL 5.

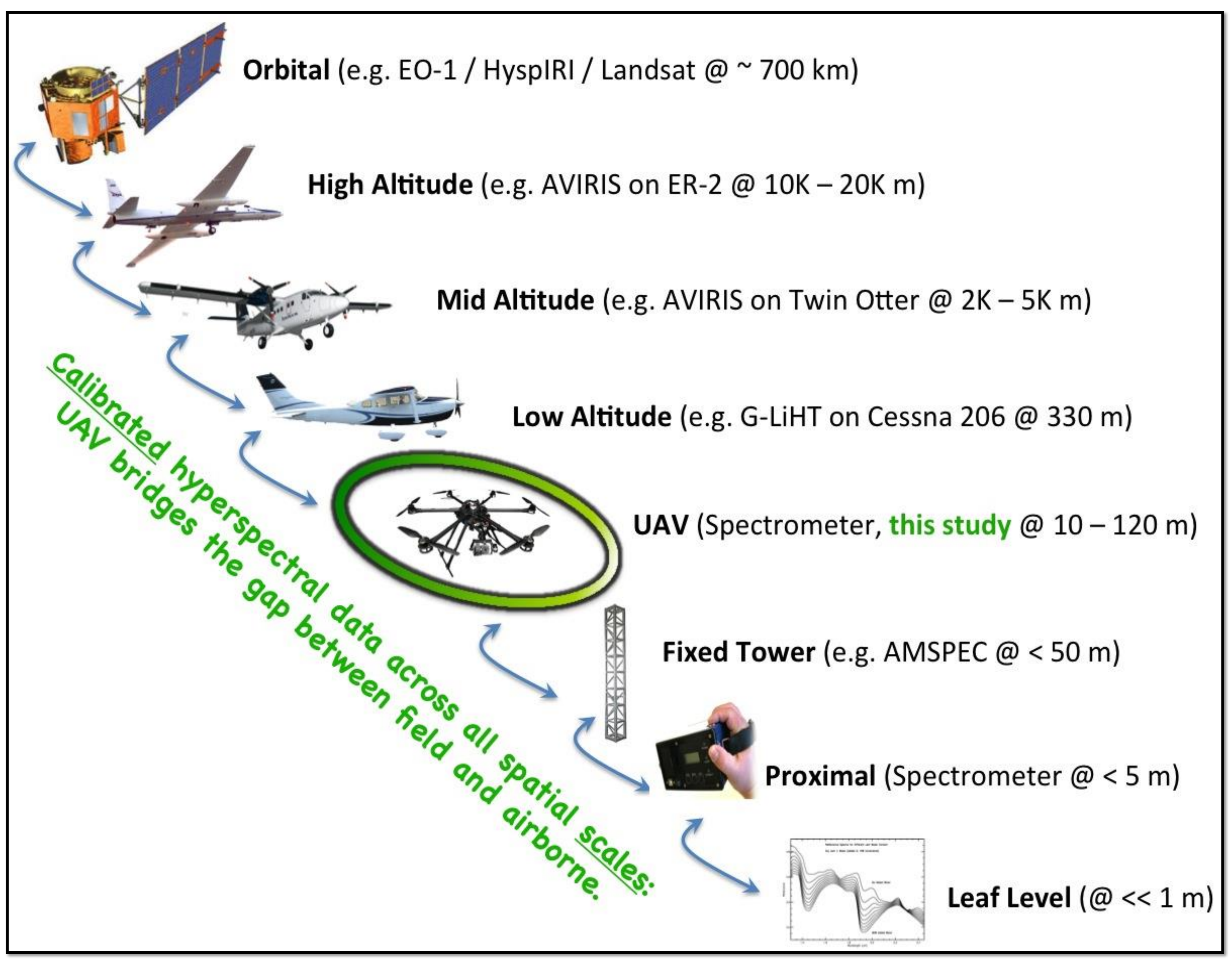

Figure 1. Scales at which remote sensing spectral measurements are currently made, with UAS sensors bridging the gap between ground and higher altitude aircraft data. Note that UASs offer the **potential** for much more rapid deployment and modification of spatially distributed acquisition plans than other technologies.

PROJECT GOALS

Our goal is to produce science-quality spectral data from UASs suitable for scaling ground measurements and comparison against airborne or satellite sensors. We will develop protocols and a workflow (Fig. 2) to ensure that VNIR measurements from UAS's are collected and processed in a fashion that allows ready integration or comparison to NASA satellite and airborne data and derived products (e.g. Landsat, AVIRIS EO-1 Hyperion and future HyspIRI, Fig. 1).

With this effort we will:

- Develop capability to: retrieve biochemical and physiological traits (BPs)from UASs, and depict diurnal and seasonal cycles in vegetation function (e.g. accurate measurements of vegetation reflectance at high spectral, spatial and temporal resolution, variability and stability);
- Optimize UAS spectral data acquisition and workflows, to develop a small UAS hyperspectral sensor-web (Fig. 4);
- Demonstrate the capability to produce science-quality spectral data and BPs from UASs suitable for scaling ground measurements and comparison to from-orbit data products.

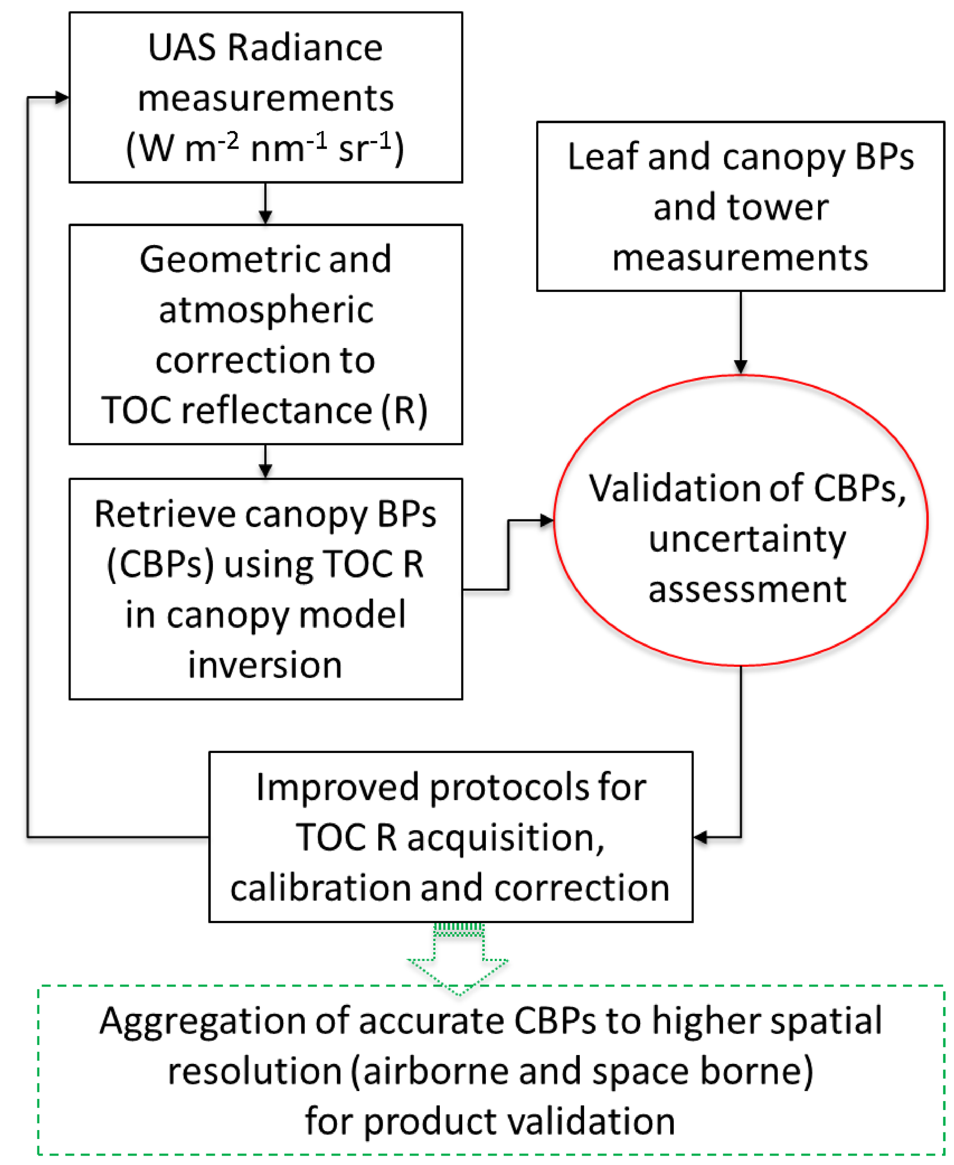

Figure 2. Workflow for retrieval of Biophysical Parameters (BPs), validation and improvement (after Vuolo et al. 2012).

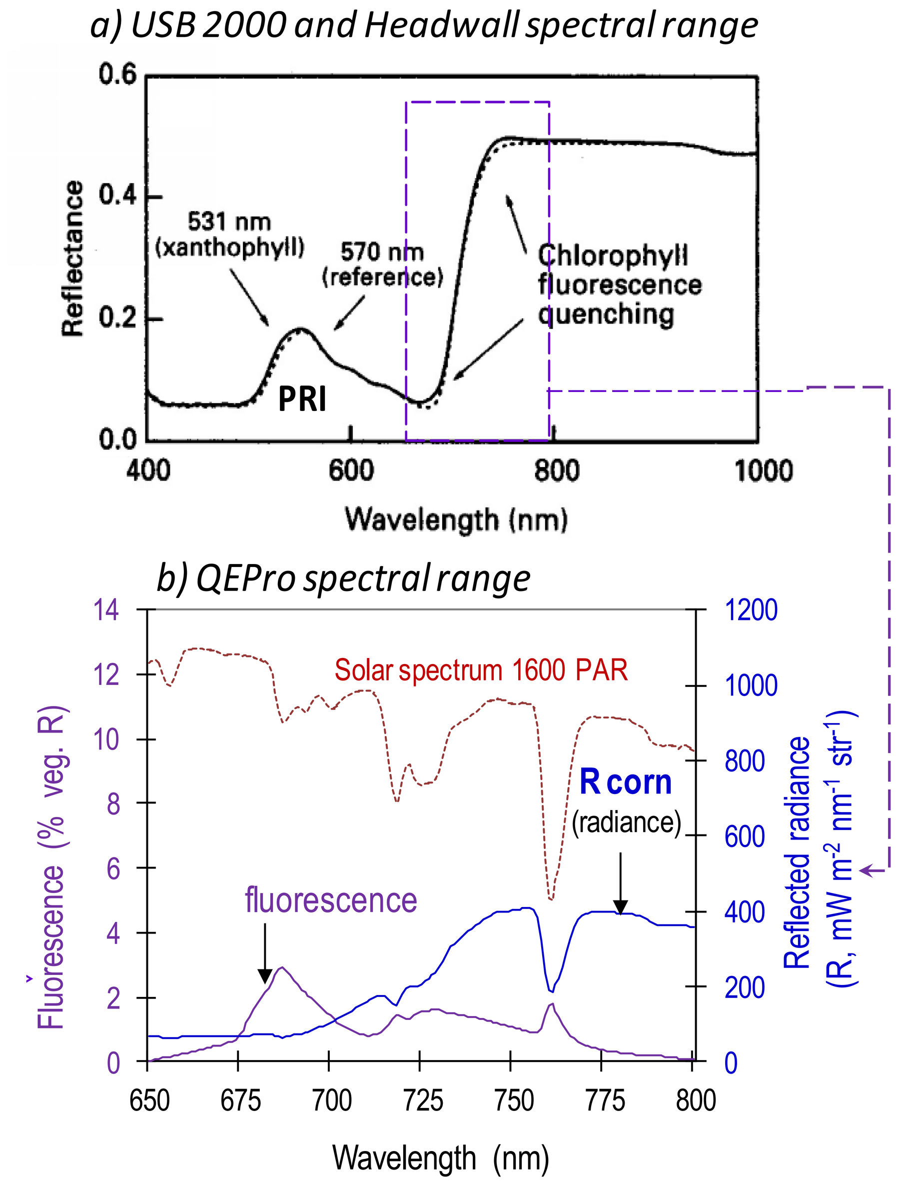

Figure 3. The technology/measurements to characterize canopy VNIR include: reflectance (a) and solar-induced fluorescence (b). We will use high spectral resolution discrete measurements and imaging spectroscopy.

KEY MILESTONES and TECHNICAL APPROACH

- Integrate and test Ocean Optics spectrometer and *Piccolo Doppio* upwelling/downwelling foreoptic onto UAS, and establish calibration protocols
- Parameter retrieval and validation of measurements at well-characterized sites
- Develop Rapid Data Assimilation and delivery system, based on SensorWeb Intelligent Payload Module high speed onboard processing developed under AIST-11 and other cloud based data processing chain functionality (http://sensorweb.nasa.gov);
- Develop data gathering campaign strategy to optimize data yield;
- Leverage EcoSIS online spectral library
- Integration of Headwall imaging spectrometer, inter-calibration to *Piccolo Doppio*
- Validate real-time computing capacity
- Parameter retrieval maps and validation against field data
- Data Production Pipeline Demo

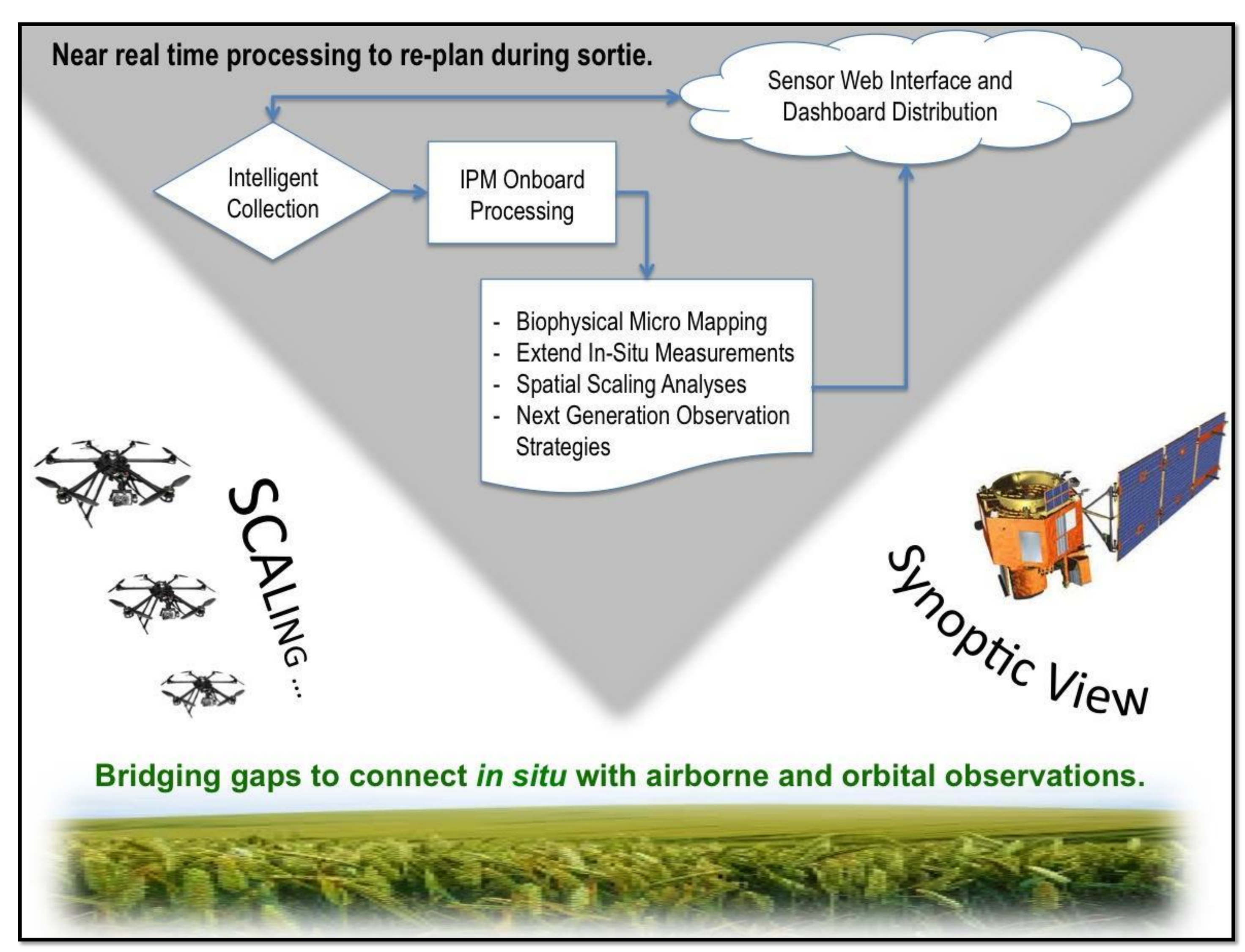

Figure 4. Small UASs augmented with SensorWeb capabilities will implement the rapid data assimilation and delivery system. A mission deployment system will optimize flight paths based on real-time in-flight data processing to enable effective data collection strategies.

ANTICIPATED OUTCOME

This research effort will enable the acquisition of science-grade spectral measurements from UASs. It will advance the use of UASs in remote sensing beyond current state of application, providing measurements of a quality comparable to those from handheld instruments or well-calibrated air- and space-borne systems. The UAS collections at 10-150m altitude would bridge the gap between ground/proximal and airborne measurements, typically acquired at 500m and higher, allowing better linkage of comparable measurements across the full range of scales from ground to satellites.

Reference: F. Vuolo, J. Dash, P. J. Curran, D. Lajas and E. Kwiatkowska (2012). Methodologies and Uncertainties in the Use of the Terrestrial Chlorophyll Index for the Sentinel-3 Mission. Remote Sens. **2012**, 4, 1112-1133; doi:10.3390/rs4051112

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