Jet Propulsion Laboratory
California Institute of Technology

USC University of Southern California

Jane Wyngaard, PhD
NASA Jet Propulsion Laboratory
University of Southern California
wyngaard@jpl.nasa.gov
@jrwyngaard
r4space

The University of Vermont

Lindsay Barbieri, Msc
University of Vermont
lkbar@uvm.edu
@barbieriiv

HJA H.J. Andrews Experimental Forest

Fox Peterson, PhD
H.J. Andrews Experimental Forest

USABLE BY DESIGN

For SSEDD to be an enabler for drones in science it must be two things.

- Easy to use by non-engineers
- Adaptable to a wide range of UAS platforms and sensor suits

SSEDD achieves both by making heavy use of standards, the open source community, and good packaging, but faces challenges given the nascent state of the broader industry.

DATA MANAGEMENT

Good data stewardship principles are essential, if drone data is to be useful. First, in order for the data to be transformed into information its provenance must be reliable and available. Second, for such contextualised information to contribute knowledge, and be of use in decision making, its relation to other data must be equally accessible.

Providing the first, especially for small, disparate, and distributed sensors, is unfortunately a largely unsolved problem. However, again due to recent technological advances, the bourgeoning – but still fragmented, chaotic, and lacking in standards – Internet of Things (IOT) industry, is spurring on work towards fixing this. With relevance to the earth-science domain there are three notable projects currently underway.

Nexos[2], is an EU funded project with one focus on marine instruments and specifically underwater gliders. OGC's IMIS[3] is a US based pilot program tasked with testing and developing OGC's Sensor Web Enablement (SWE)[4] suite of standards for data dissemination and analysis in disaster relief situations. Finally, as part of the NSF funded EarthCube, X-DOME[5] is seeking to develop OGC and W3C compatible tools for extracting sensor metadata.

There is an abundance of parallels between these projects foci and the needs of UASs for science. However, until these projects release their work, SSEDD must be developed in an even more flexible and adaptable manner. As such, for ensuring data provenance, SSEDD is being designed to operate with both SensorML[6] and the IEEE 1451 TEDS, sensor metadata mechanisms (both are OGC recognised standards).

For enabling interoperability between data sets, the solution is more complicated. While OGC's SWE currently contains standards for data schemas and transfer protocols, some are incomplete or stale, and all are largely xml based, which incurs a heavy burden in embedded systems. For now, therefore, SSEDD will utilise a Geojson[7] adhering schema that, within reason, mimics the SWE standards. It will rely on the Robot Operating System's (ROS)[8] publish/subscribe messaging and services infrastructure.

A further consideration for ensuring both provenance and interoperability is the data store. Apache's MongoDB[9] was selected, as SSEDD's integrated data store, given its tolerance for dynamic data models, it being a document store enabling direct search and retrieval, its guarantees of consistency and persistence, and its deign being NoSQL based which is a better fit for complex multi-sensor geospatial data.

PACKAGING

Snappy Ubuntu[10] is a customised minimal rendition of the server Ubuntu operating system (OS). Targeted specifically at embedded connected devices, it offers strong security, a rapid, reliable, and simple application deployment mechanism (Snappy instead of apt-get), and a minimal OS footprint.

These features, together with the much wider linux support base, mean customised (or pre-configured) instances of SSEDD can be easily downloaded and installed as the binary onto any Snappy supporting hardware (Rasberry Pi, BeagleBone, more coming fast). Only those libraries that are required need be incorporated. Together with ROS and sensor self identification, plug-and-play sensor integration is possible. Hardware support for various capabilities can be rolled in or left out simply by editing a single snapcraft yaml (configuration) file.

CONCLUSIONS

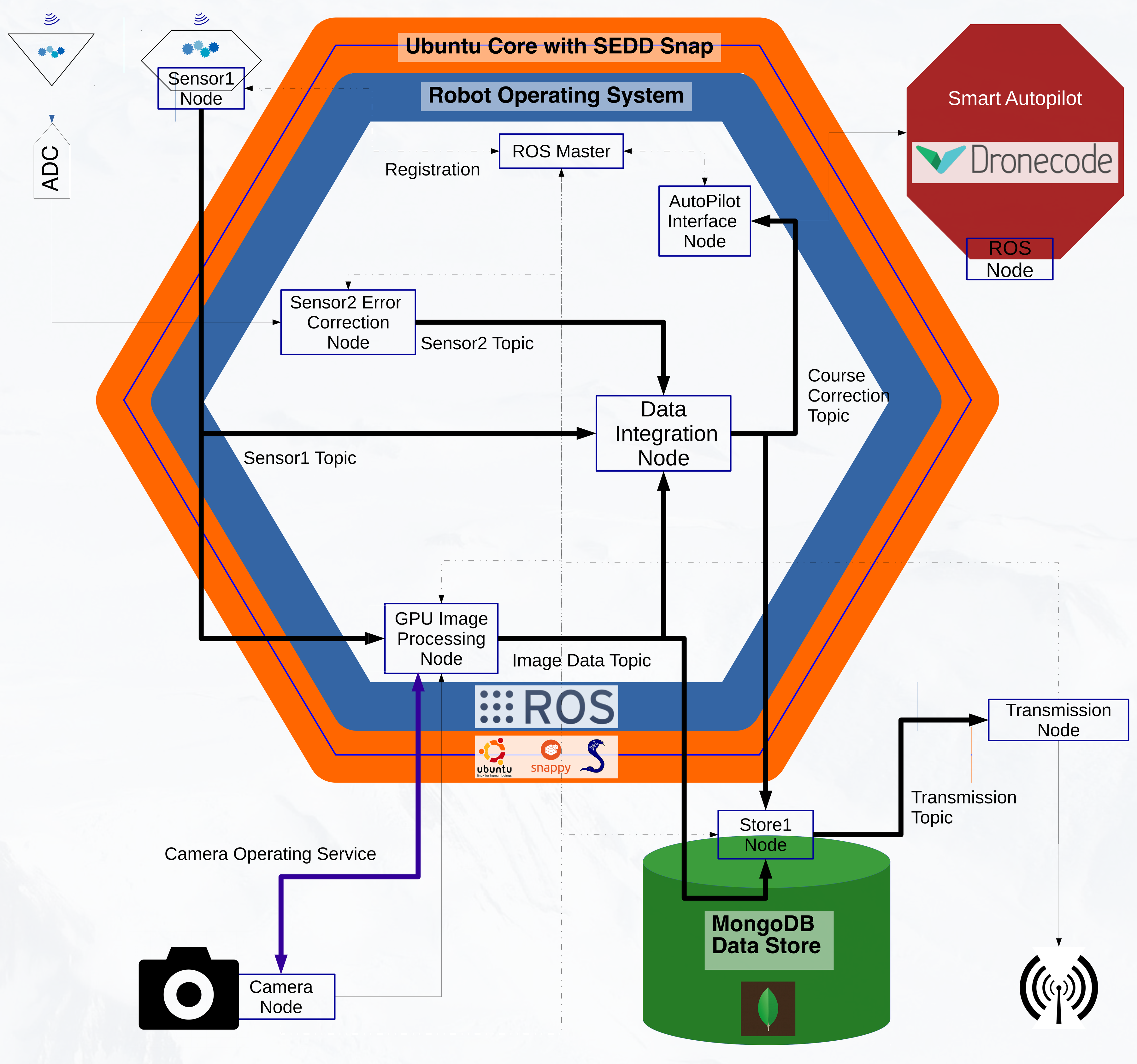
The presented approach leverages existing support for the features desired within target drone APIs (such as DroneKit[11]), the wide ROS, Apache, and Ubuntu communities, and abundant support in all spheres for Geojson.

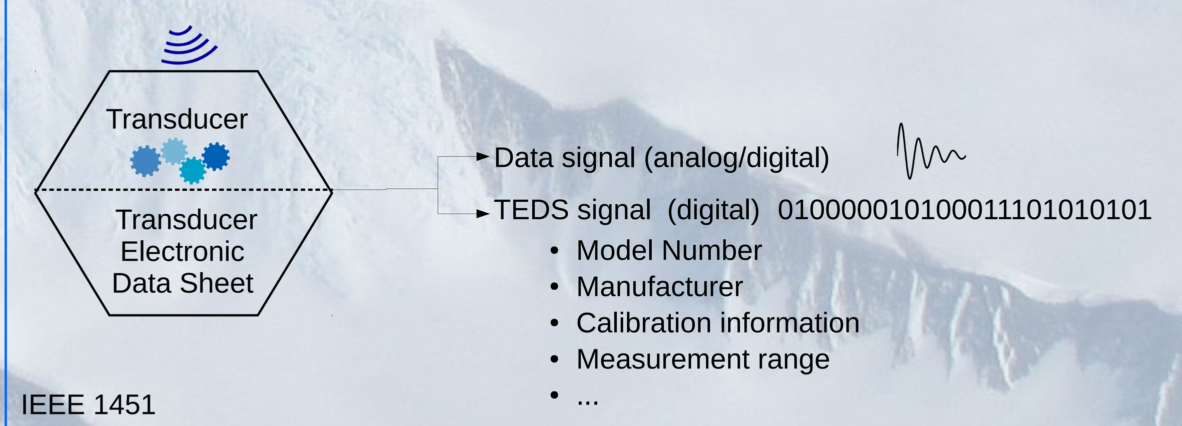
If the above mentioned research projects release standards or tools that provide very good reason for SSEDD to deviate from the above, then there is also a built in path to adaption.

Given the domain overlap it is highly unlikely that ROS would not integrate some degree of such, and as an open community any user could do so themselves. Further, as indicated MongoDB tolerates changing data models. Finally Ubuntu Snappy is designed specifically to provide seamless remote updating of software.

If you look closely, therefore, SSEDD is simply offering the necessary engineering glue, to plug together the now wide array of existing powerful tools available, to enable the scientific community to begin taking full advantage of UASs.

IN-FLIGHT COMPUTE





SEDD

Standardised Science Embedded Data ecosystem for Drones

GROUND STATION AND THE CLOUD

A LIBRARY OF CLOUD RESOURCES PROVIDING DATA-

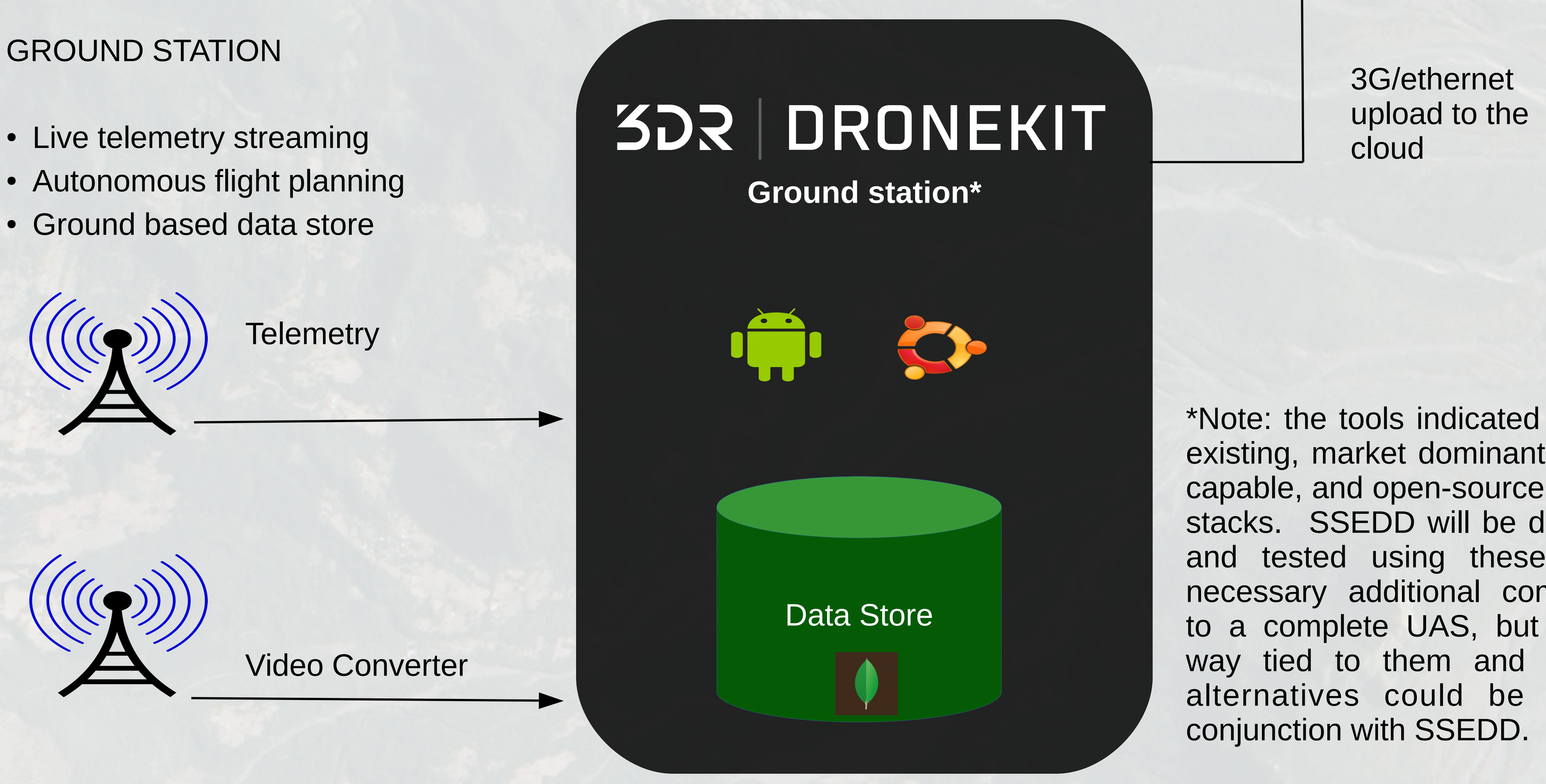
- Analytics
- Accessibility
- Usability
- Quality Monitoring and Assessment
- Provenance

Depending on the application, a range of cloud (or even non-cloud) resources will be most appropriate for the short and longer term stewardship of collected data. By using the relevant data standards within SSEDD, it will be possible to develop the appropriate APIs to interface with these tools (and others should they come into existence).

Being such an immature field the tools listed here are at best an informed guess, as to what interfaces scientists using drones might want to utilise. As an open and standards adhering tool, however, SSEDD will be flexible enough to adjust to the domain's changing landscape.

GROUND STATION

- Live telemetry streaming
- Autonomous flight planning
- Ground based data store



*Note: the tools indicated here are existing, market dominant, science capable, and open-source software stacks. SSEDD will be developed and tested using these as the necessary additional components to a complete UAS, but is in no way tied to them and therefore alternatives could be used in conjunction with SSEDD.

ABSTRACT

THE SCIENCE OPPORTUNITY

Unmanned Aircraft Systems (UAS)s for science are not new - the USGS UAS National Project Office opened in 2008[1] - however, the recent drop in their component costs, together with the maturing and newly gained accessibility of a number of enabling technologies (such as open source autopilots and controllers), now presents the scientific community with a remarkable opportunity.

While not a panacea for all challenging environments, UASs offer many advantages to a range of scenarios. From simple cost savings, safety gains, and a lowered impact on the environment being monitored, through to providing access to inaccessible areas, and better resolution sampling (<2.5cm resolution imagery, vertical profiling). However, perhaps one of the most significant advantages is that of increasing the ease with which measurements can be taken over much wider area, without radically increasing the cost. This ease of sampling also leads to improved data currency and increased repeat measurements

THE REMAINING BARRIER

However, while these advances are opening this door of opportunity, science-specific sensors, and the software required to operate and appropriately manage the data for such on UASs, remains a nascent domain. Within industry, companies are developing their own proprietary in-house solutions, primarily for non-science applications. In academia institutions are doing the same and only for their specific science use-case. Understandably, their solutions are generally developed to enable the goals of their single institute or research group, customised to their specific platform and sensor pairing, and requiring a full in-house engineering team. The result is many scientist reinventing the proverbial wheel at great cost, or being simply unable to take advantage of UAS due to a lack of engineering support.

SSEDD SOLUTION ++

SSEDD is our proposed solution to the above, a software stack designed for science (in it standards and sensor support), to be usable without extensive engineering support, and to be UAS platform independent. Looking further ahead, SSEDD will also provide the backend infrastructure necessary to not only log sample data, but process and triage it on board the drone as it arrives. This will enable both greater sampling automation (for instance auto navigation to revisit a sensor reading hot spot for a finer granularity sampling survey), and ensure only relevant data need be transmitted down the remote link and stored on board consuming space.

We designed SSEDD with community backing, and start-up funds from the Earth Science Information Partners (ESIP) 2015 winter 'FundingFriday'. Still in an early implementation phase, we would welcome comments and input on the design, especially from the scientific community. Its first test case will be the subject of one authors doctoral work, see AGU poster *"Utilizing In-Situ Static Chamber Measurements and UAV Imagery for Integrated Greenhouse Gas Emissions Estimations: Assessing Environmental and Management Impacts on Agricultural Emissions for Two Paired-Watershed Sites in Vermont*" - Lindsay Barberi.

1 Hutt ME (2010) U.S. Geological survey, Unmanned Aircraft Systems Project Office, Lessons Learned and opportunities. USGS presentation http://rmgsc.cr.usgs.gov/UAS/pdf/LessonsLearnedandOpportunities2010Hutt.pdf
2 http://nexosproject.eu/
3 http://www.opengeospatial.org/blog/2209
4 ttp://www.opengeospatial.org/ogc/markets-technologies/swe
5 http://earthcube.org/content/cross-domain-observational-metadata-environmental-sensing-network-x-domes
6 http://www.opengeospatial.org/standards/sensorml
7 http://geojson.org
8 www.ros.org
9 https://www.mongodb.org/
10 http://developer.ubuntu.com/en/snappy/
11 http://dronekit.io/

Hardware sponsored by
Federation of Earth Science Information Partners: Drone Cluster

Background Image: Composite of NSIDC Alaskan Snow, and NASA Villarrica Volcano