Onboard Radar Processing Concepts for the DESDynI Mission

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We are developing onboard processor (OBP) technology to streamline data acquisition on-demand and reduce the downlink data volume of the L-band SAR instrument onboard the DESDynI mission for three science objectives: 1) measure crustal deformation to determine the likelihood of earthquakes, volcanic eruptions, and landslides; 2) characterize vegetation structure for ecosystem health; and 3) measure surface and ice sheet deformation for understanding climate change. Our approach is to determine the types of data processing suitable for implementation onboard the spacecraft to achieve the highest data compression gain without sacrificing the science objectives in each of these areas. The appropriate data processing algorithms and image compression techniques will be prototyped with the UAVSAR onboard processor that is currently under development. We will leverage the onboard autonomous flight planning software developed for the Earth Observation-1 mission and planned for the HysPIRI mission to enable data acquisition on-demand for specific science objectives. The onboard processor technology will enable the observation and use of surface deformation data and surface change data over rapidly evolving natural hazards, both as an aid to scientific understanding and to provide timely data to agencies responsible for the management and mitigation of natural disasters.

Background and Processing Architecture for UAVSAR and DESDynI

The onboard processor consists of four major functions:

1. Control processor – ingest ephemeris data, generate processor parameters, retrieve reference data set if needed for repeat-pass product generation such as change detection.
2. SAR image formation – form single look compressed (SLC) image and interferogram with reference SLC image if requested.
3. Image compression – compress SLC image or interferogram with traditional image compression algorithms.
4. Product generation – generate geophysical products such as forest biomass, flood scene map, sea ice classification, and change detection.

The processor architecture, as shown in Figure 1, is based on the OBP developed for the airborne repeat-pass interferometric SAR testbed, UAVSAR [Lou, et al.] We chose a hybrid architecture where we use a general purpose microprocessor for data-dependent calculations that are performed occasionally and all other arithmetic operations that operate on every pixel in the FPGA. We have demonstrated real-time SAR image formation with the custom FPGA processor board. Two FPGA processor boards are built to process data from two polarization channels or two interferometric channels at the same time. The availability of dual-polarized data and repeat-pass interferometric data enable us to generate quicklock science products based on unsupervised classification of polarimetric data and change detection respectively. In this paper, we present example data products that can be generated onboard the spacecraft for rapid response applications.

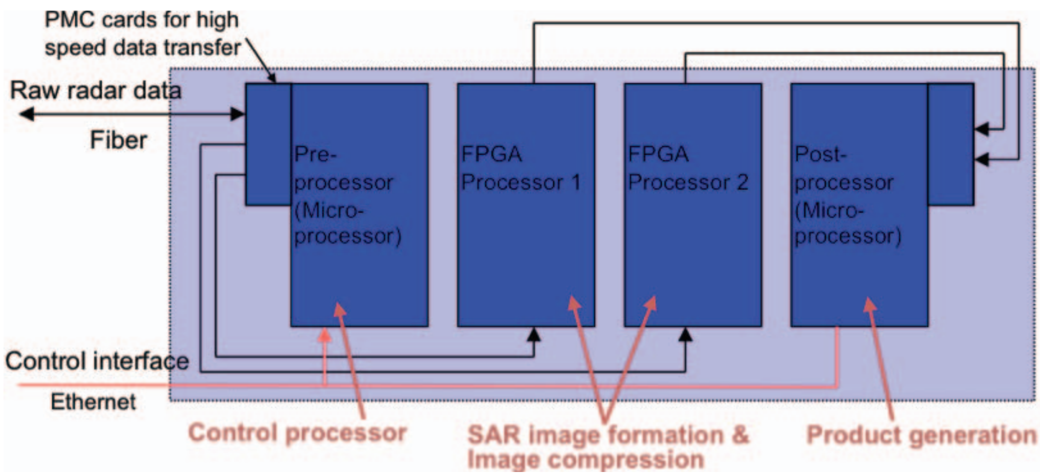


Figure 1. UAVSAR OBP hardware architecture, where general purpose microprocessors are used for control processing and product generation and custom FPGA processor boards are used for SAR image formation and image compression.

Rapid Response Applications

Surface water mapping / Flood detection

Calm water surfaces can be clearly distinguished from most land backgrounds based on a single SAR channel due to its low backscatter values [Martinis, et al.] Analysis of an HV L-band backscatter image shows dramatic attenuation from open bodies of water, or flooded areas. Thresholding of backscatter magnitude – tuned either from calibration parameters of the radar, or via normalization of the image – followed by a number of Gaussian filters would reliably filter out small point attenuations, and coalesce larger expanses. These larger expanses could then be clustered by a continuity sieve and geolocated by a centroid of the cluster. This algorithm relies on masking the input image towards flood prone areas and against false positives from high attenuation features such as rough topography that can cause "shadowing" effects. This algorithm, tested with UAVSAR data, successfully detected large ponds formed in the bottom of large rock quarries in the San Gabriel Valley following heavy rains.

Ice vs. Land/Water Detection for Glacier Monitoring and Sea Ice Tracking

Polarimetric SAR data have been used for sea ice detection and classification since this was first demonstrated with SIR-C data acquired in 1994 [Scheuchl, et al.] HV-intensity and HH/VV ratio and anisotropy have been used for sea ice edge/open water detection. Change detection techniques have been used to monitor glacier recession with satellite SAR data since the ERS-1 mission [Rignot]. Figure 2 shows a UAVSAR image acquired over Greenland's Kangerlugssuaq glacier in May 2009. The grounding line is clearly visible in the image. These products would be high value rapid response products for use in glacier monitoring and in tracking sea ice.

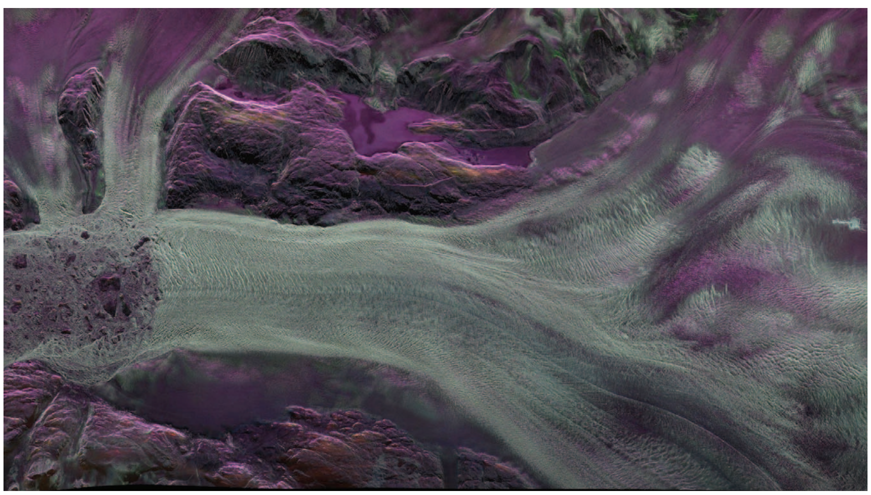
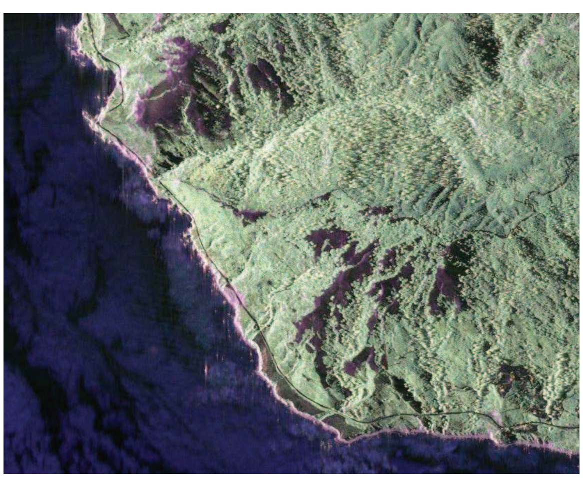


Figure 2. Three-polarization overlay of Kangerlugssuaq glacier where LHH, LHV, and LVV are represented in red, green, and blue respectively. The grounding line is clearly visible.

Forest Fire Detection – Crown Weight Difference

Another rapid response application is tracking of forest fires via biomass measurements. A number of algorithms exist based on canopy/crown biomass weight estimation [Saatchi]. We have been evaluating such algorithms to monitor forest fire progression during actual fire events, delivering products for assistance in fighting and mitigating fires. Such products can also be used in rehabilitation efforts by providing valuable information on burn extent and severity. Figure 3 is a Three-polarization overlay UAVSAR image of the Big Sur fire acquired in July 2008, showing the fire scars (purple) from June 2008.



UAVSAR and DESDynI Autonomous Response

With the ability to generate real-time data products, UAVSAR attains the potential of a reactionary or smart agent with self-acquired data as closed loop stimulus. Together with real-time planning software, the agent can safely modify its planned operations to further investigate observed phenomena, or act on other information provided from other systems, contingent upon operating within the constraints of the system platform. This project adopted and integrated ASPEN/CASPER [Chien et al.] to generate new flight-plans on-board for UAVSAR to execute in response to real-time data. Availability of onboard planning would also allow DESDynI to replan future observations similar to the Autonomous Sciencecraft on EO-1 [Chien et al.]

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The work reported here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.