Instrument Concept for the Proposed DESDynI SAR Instrument

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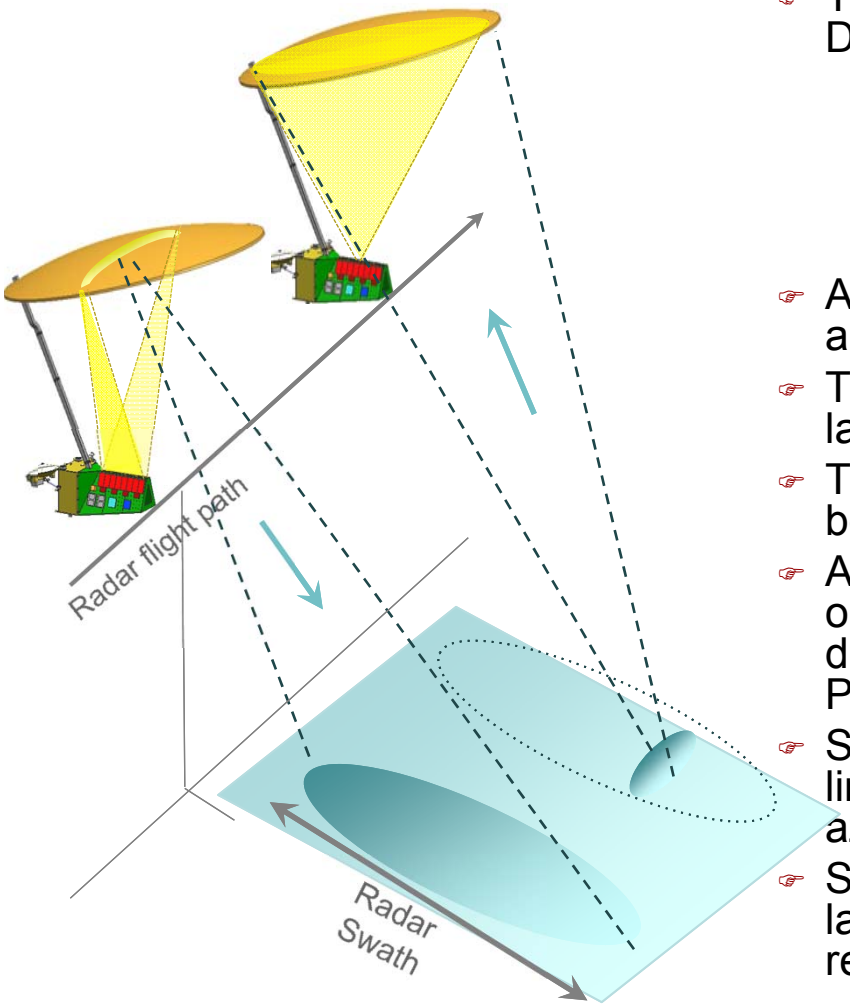
Science Objectives of the Proposed DESDynI Mission

- The proposed DESDynI mission would contribute to our understanding of processes that drive changes in three science disciplines: Solid Earth **D**eformation, **E**cosystems **S**tructure and **Dyn**amics of **I**ce.
- The key science objectives are:
  - *Determine the likelihood of earthquakes, volcanic eruptions, and landslides (measures deformation)*
  - *Predict the response of ice sheets to climate change and the impact on sea level (measures velocity)*
  - *Characterize the effects of changing climate and land use on species habitats and the Earth's carbon budget (measures biomass)*
  - *Monitor the migration of the fluids associated with hydrocarbon production and groundwater resources*

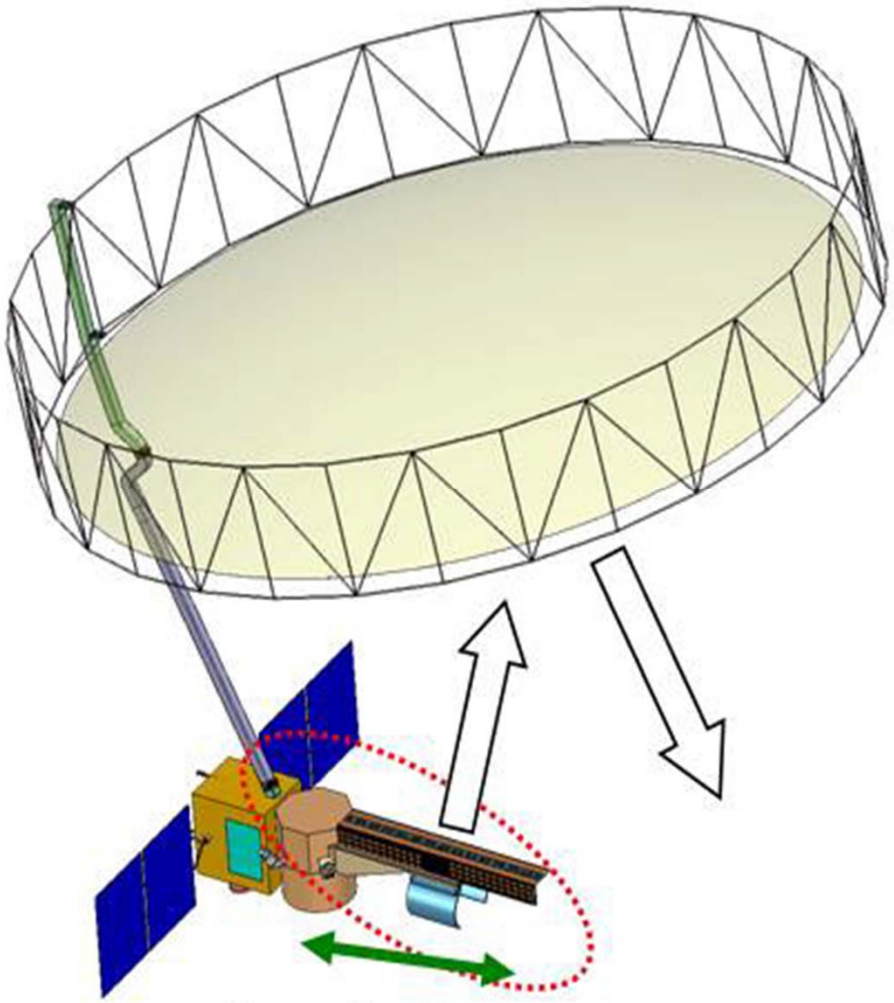
Proposed DESDynI SAR Instrument Concept



- To satisfy the science objectives the proposed DESDynI SAR Instrument (DSI) would need to:
  - *Repeat its measurements regularly and preferably at short intervals (8-24 days)*
  - *Use polarimetric measurements (biomass)*
  - *Be stable and accurate enough to measure deformation at rates of 1mm/yr*
- A stringent deformation measurement would require a repeat pass SAR instrument
- To satisfy coverage and relatively short repeat time a large swath would be required (~ 200 km)
- To satisfy polarimetry, a fully polarimetric radar would be required.
- Achieving large swath width, particularly when operating in fully polarimetric modes, is challenging due to increasing range ambiguity levels at the larger PRFs.
- ScanSARs present a traditional solution to above limitations, however they come at a price of reduced azimuth resolution.
- SweepSAR* technique enables data collection over large swaths with high resolution by tracking the received echo in elevation dimension.
  - *Pros: Large swath, high resolution*
  - *Cons: Multiple transmit/receive modules and digital real-time on-board beamforming*

* A. Freeman, G. Krieger, P. Rosen, M. Younis, W. Johnson, S. Huber, R. Jordan, A. Moreira, "SweepSAR: Beam-forming on receive using a reflector-phased array feed combination for spaceborne SAR", Proc. Radar Conference, Pasadena, CA (2009).

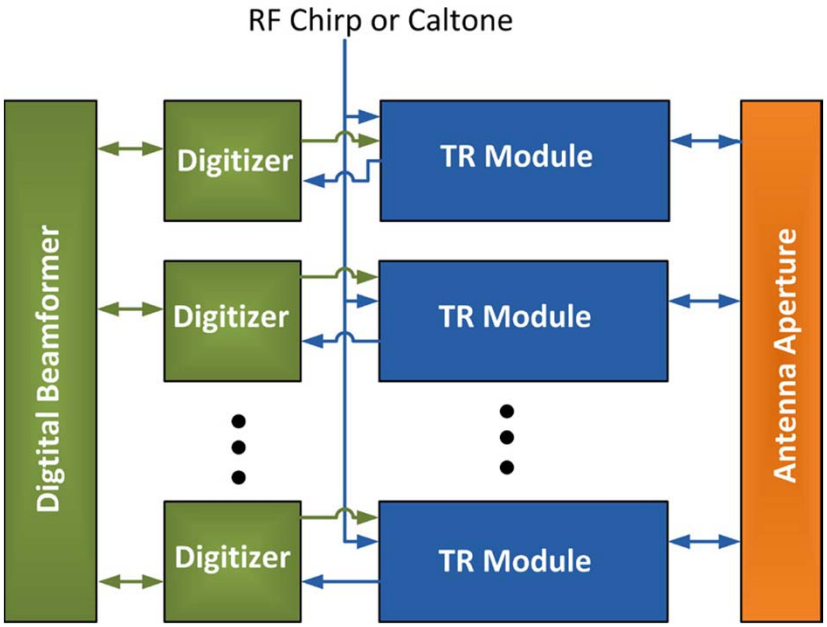
DSI* Array-Fed reflector Subsystem



- Limiting factor for a traditional SAR system is the large antenna used for high resolution.
- Digital beamforming (DBF) SAR techniques have been developed to overcome this issue.
- At low frequencies such as L-band (suitable for canopy penetration) the traditional DBF SAR arrays are too large to be deployed from space.
- A unique adaptation of the DBF SAR antenna system for longer wavelengths is a reflector antenna fed by a one-dimensional feed array.

*Proposed - Pre-decisional – for Planning and Discussion Purposes Only

DSI* Transmit Receive Modules

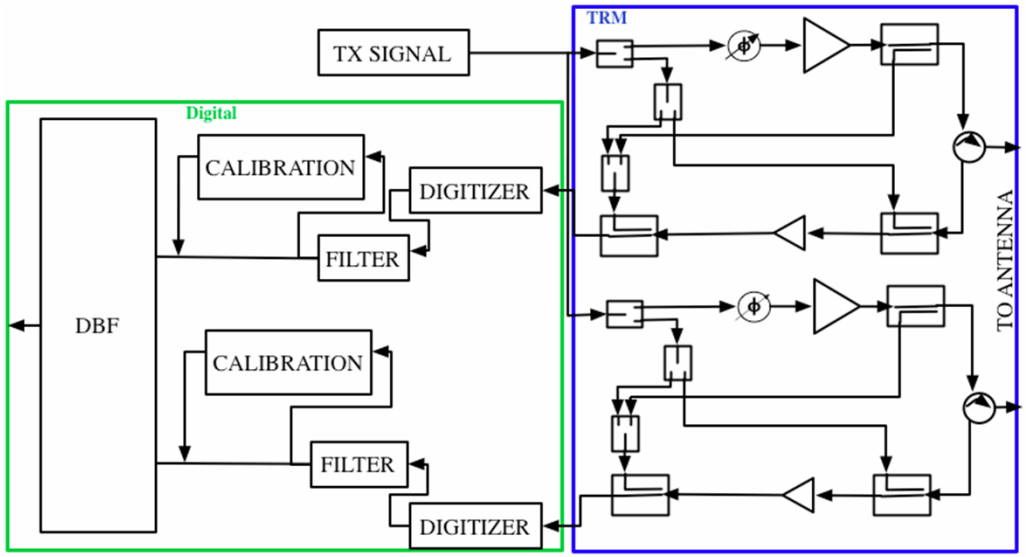


- The antenna feed elements are fed by Transmit Receive Modules (TRMs) that distribute and amplify the L-band signal to form the transmit beam. On receive the backscattered echoes are filtered, amplified and digitized independently.

- The signals exiting TRMs are coherently combined and form a transmit pattern – TRMs must have stable and precisely known phase and amplitude.

DSI* Digital Calibration

- Traditional calibration-loops require high isolation between transmit and calibration paths while calibration techniques based solely on the temperature sensors' measurements require prohibitively large numbers of sensors in a multiple TRM system and are unable to track system changes due to ageing.
- Digitally calibrated systems enable systems' flexibility and tracking of system characteristics over their lifetime.
- Splitting traditional calibration-loop into three independent paths allows:
  - *Digital alignment of TRM channels*
  - *Receive gain and phase tracking while receiving echoes*
  - *Transmit closed-loop phase alignment*



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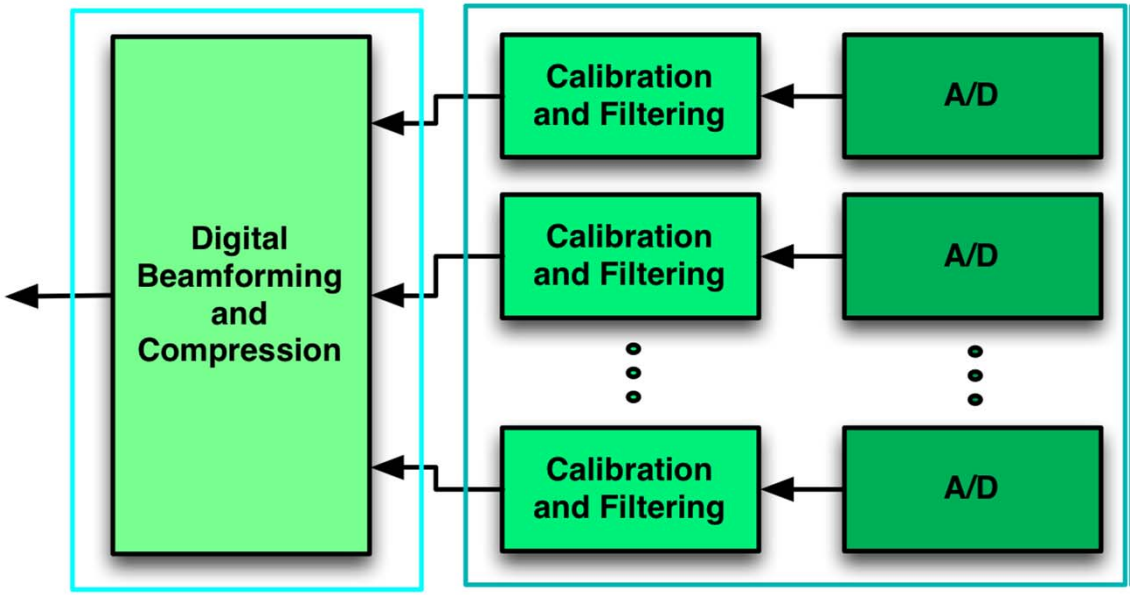
DSI* Digital Subsystem and On-board Processor

- The DSI* digital subsystem would have a dual role:
  - *Controls the system's timing and its operations and processes science data to reduce the necessary downlink rate*
  - *Assesses the performance of analog TRMs in real-time (updates estimates of system's performance on millisecond time scale)*
- DSI* digital subsystem would have a distributed design due to heavy data processing of multiple channels and high data rates.



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SweepSAR Airborne Technology Demonstration

- As part of the proposed DESDynI risk reduction studies we conducted the first airborne demonstration of SweepSAR technique[1].
- Ka-band airborne SweepSAR using array-fed reflector and digital beamforming:
  - *8 simultaneous receive beams generated by offset-fed reflector an 8-element active array feed*
  - *8 digital receiver channels, all raw data recorded*
  - *Receive antenna system is approximately 1/28th scale of proposed DESDynI*
- Supports radar instrument development and risk mitigation for DESDynI*:
  - *Demonstrates first-of-it's-kind, real-world performance of SweepSAR with array-fed reflector*
  - *Reduces risk by exposing engineering issues that are not predicted by simulation*
  - *Demonstrates performance of critical beamforming and calibration techniques in post-processing*
    - Identify, quantify and mitigate error sources
    - Trade algorithm performance vs. computational resource consumption

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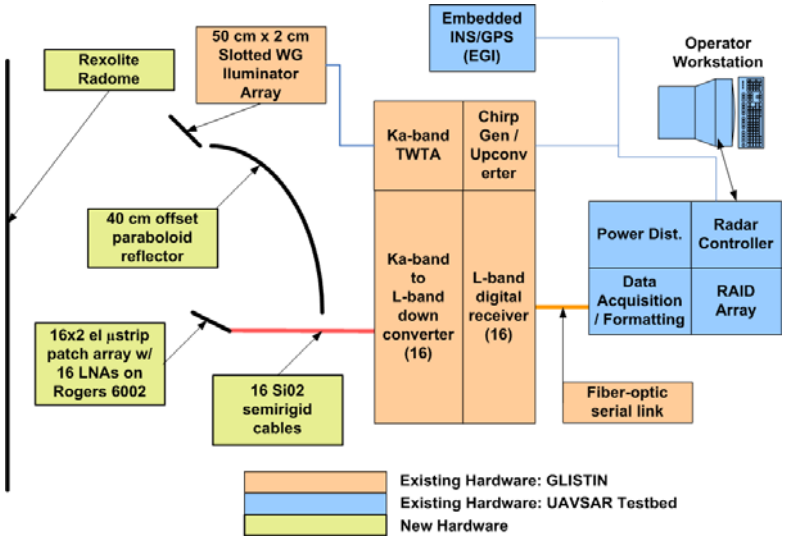
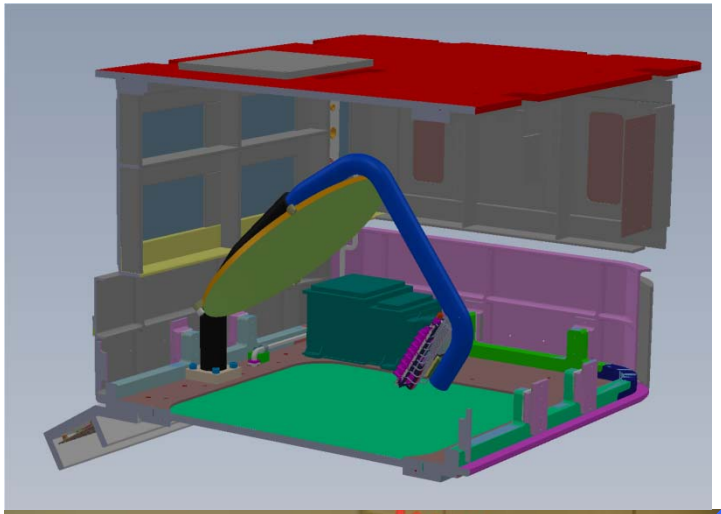
SweepSAR Demo Block Diagram



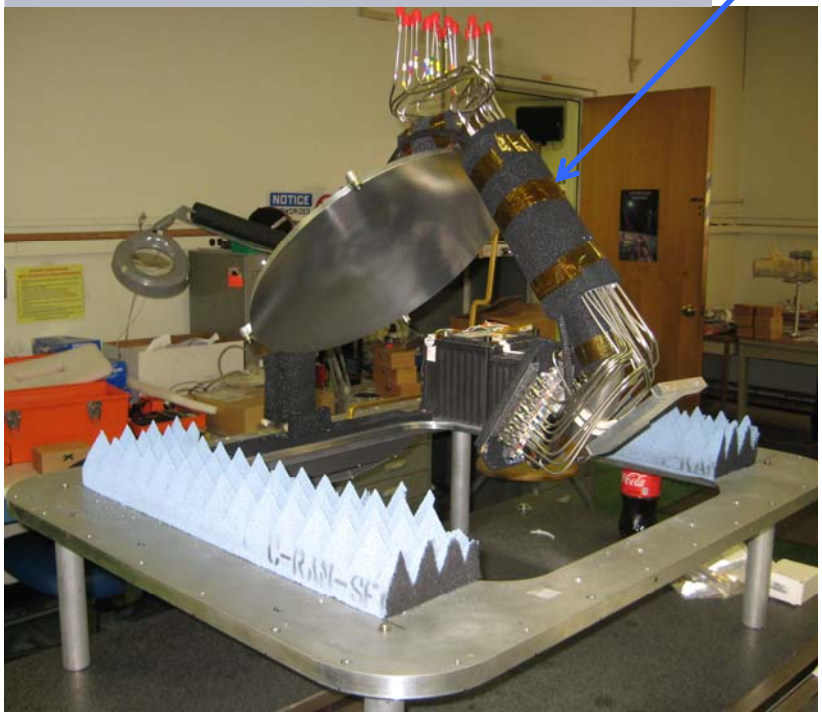
[1]G. Sadowy, H. Ghaemi, S. Hensley, "First results from an airborne Ka-band SAR using SweepSAR and digital beamforming", 9th European conference on Synthetic Aperture Radar Program, EUSAR 2012, Nuremberg, Germany, (April 2012).

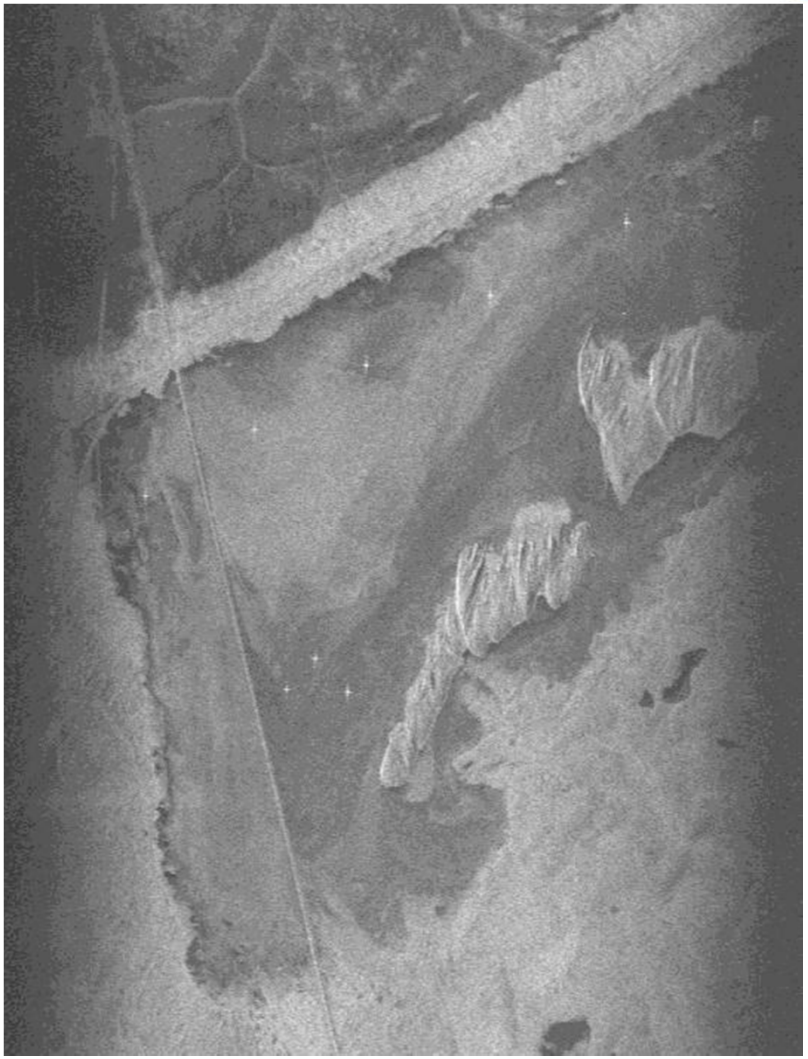
SweepSAR Airborne Technology Demonstration



Receive antenna

Array-fed reflector





Beamformed SweepSAR image in Rosamond, CA

Summary

- The proposed DESDynI SAR Instrument would expand the trade-space of radar instrument concepts and push the boundaries of high-level integration of digital and RF subsystems in order to achieve very precise assessments of system's behavior.

- DESDynI mission concept would provide continuous science measurements that would greatly enhance understanding of geophysical and anthropological effects in three science disciplines.

- Trades in instrument architecture implementations and partnership discussions are producing a set of options for science community and NASA to evaluate and consider implementing late in the decade.

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Thank You