DESDynI – Deformation, Ecosystem Structure and Dynamics of Ice

MAKING THE MOST OF DESDYNI – AN OVERVIEW OF THE PROPOSED MISSION

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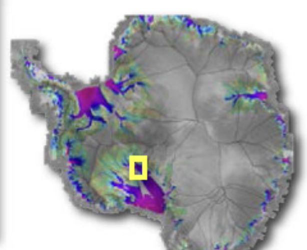
IGARSS 2011, Vancouver, Canada

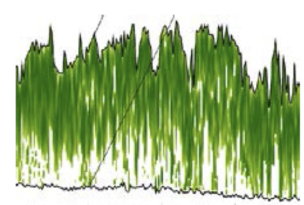
July 27, 2011

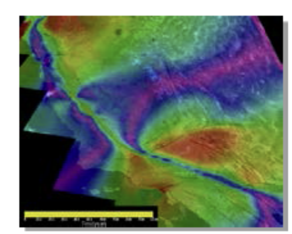
DESDynI Science

- Recommended by the NRC Decadal Survey for near-term launch to address important scientific questions of high societal impact:
  - *What drives the changes in ice masses and how does it relate to the climate?*
  - *How are Earth's carbon cycle and ecosystems changing, and what are the consequences?*
  - *How do we manage the changing landscape caused by the massive release of energy of earthquakes and volcanoes?*
- Planned by NASA as one of the following 4 Decadal Survey TIER 1 Missions
  - *SMAP*
  - *ICESat-II*
  - *DESDynI*
  - *CLARREO*

- **Ice sheets and sea level**
  - *Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur?*
  - *What will be the time patterns of sea level rise as a result?*
- **Changes in ecosystem structure and biomass**
  - *How does climate change affect the carbon cycle?*
  - *How does land use affect the carbon cycle and biodiversity?*
  - *What are the effects of disturbance on productivity, carbon, and other ecosystem functions and services?*
  - *What are the management opportunities for minimizing disruption in the carbon cycle?*
- **Extreme events, including earthquakes and volcanic eruptions**
  - *Are major fault systems nearing release of stress via strong earthquakes?*
  - *Can we predict the future eruptions of volcanoes?*

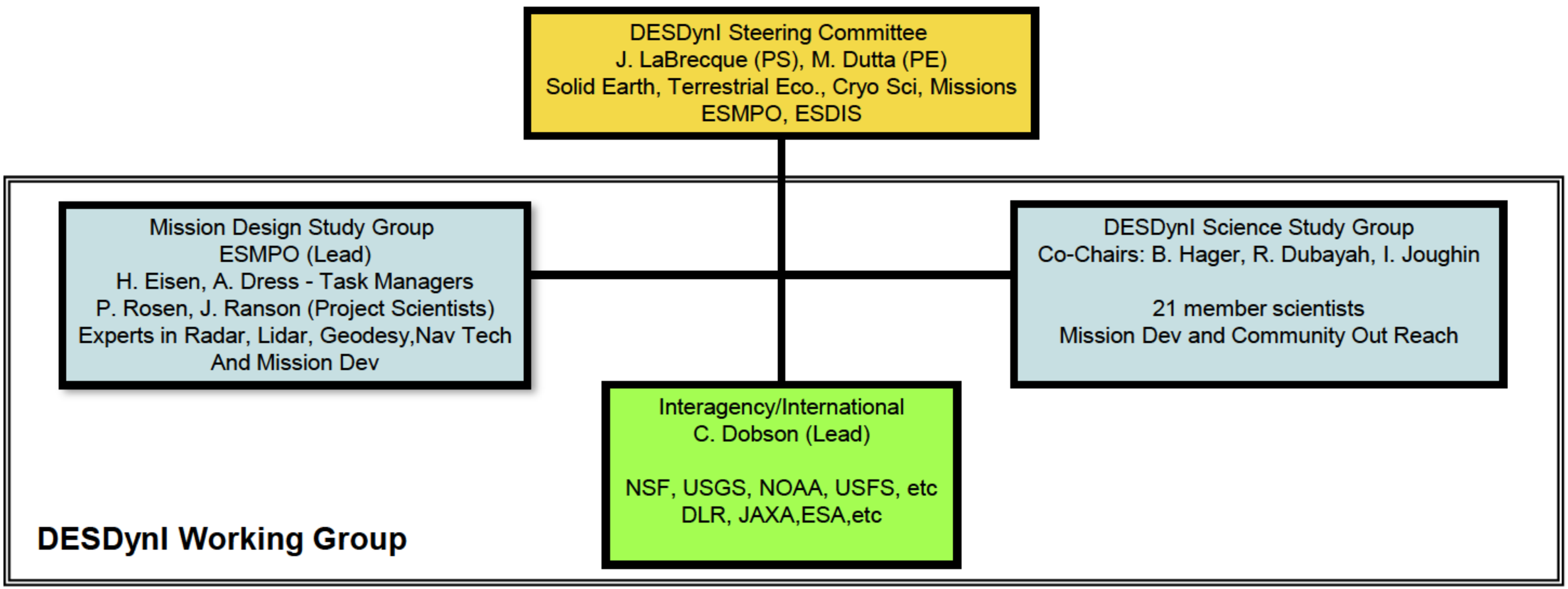

Ice Dynamics


Biomass


Deformation

Pre-formulation DESDynI Working Group

- The DESDynI Working Group is managed by the DESDynI Steering Committee representing the three principal disciplines identified by the Decadal Survey – Solid Earth, Ecosystem Structure, Cryospheric Science – and ESDIS, ESMPO
  - The Steering Committee oversees and coordinates the activities of three groups.
  - Mission Design Study Group – Includes but not limited to center design and project scientists.
  - Interagency/International Coordination Group – Develops potential partnerships that could benefit DESDynI.
  - DESDynI Science Study Group – Three Co-chairs provide scientific guidance and coordination.

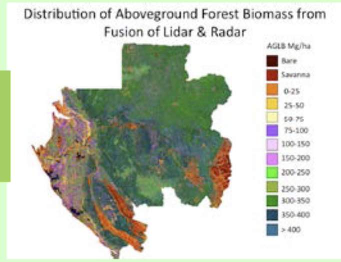


DESDynI Science Study Group Membership

- Ian Joughin, Applied Physics Lab, U Washington (Dynamics of Ice)
  - Anthony Arendt, Geophysical Institute, U Alaska
  - Mark Fahnestock, U New Hampshire
  - Ronald Kwok, JPL
  - Eric Rignot, UC Irvine
  - Christopher Shuman, U Maryland-Baltimore County
  - Ben Smith, Applied Physics Lab, U Washington
- Ralph Dubayah, U Maryland (Ecosystem Structure)
  - Kathleen Bergen, U Michigan
  - Richard Houghton, Woods Hole Research Center
  - Josef Kellndorfer, Woods Hole Research Center
  - Jon Ranson, GSFC
  - Sassan Saatchi, JPL
  - Hank Shugart, U Virginia
- Bradford H. Hager, MIT (Deformation/Solid Earth)
  - Tim Dixon, U Miami
  - Andrea Donnellan, JPL
  - David Harding, GSFC
  - Rowena Lohman, Cornell University
  - Jeanne Sauber, GSFC
  - Howard Zebker, Stanford University

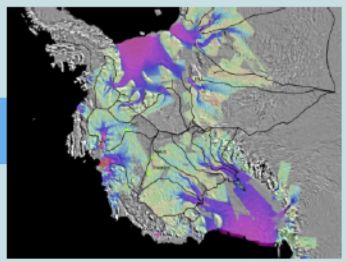
Proposed DESDynI Science to Implementation

Ecosystem Structure



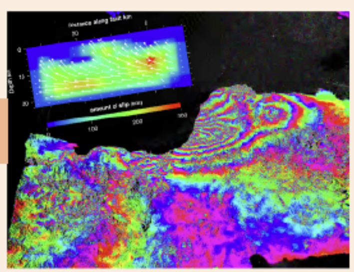
Biomass, Vegetation Structure, Effects of changing climate on habitats and CO_2, disturbance

Cryosphere



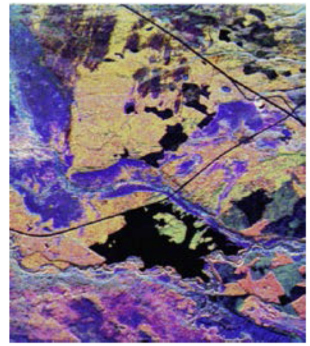
Ice velocity, thickness
Response of ice sheets to climate change & sea level rise

Solid Earth

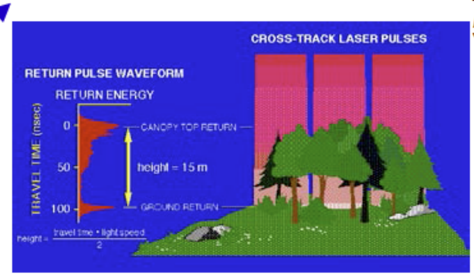


Surface Deformation
Geo-Hazards
Water Resource Management

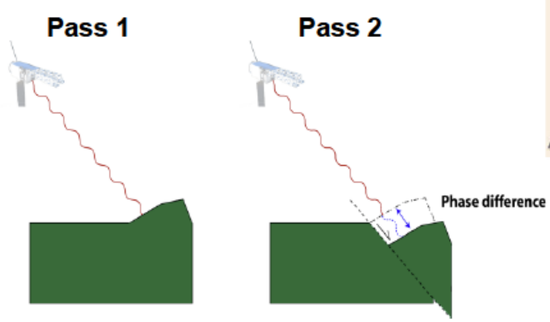
L-band Polarimetric SAR

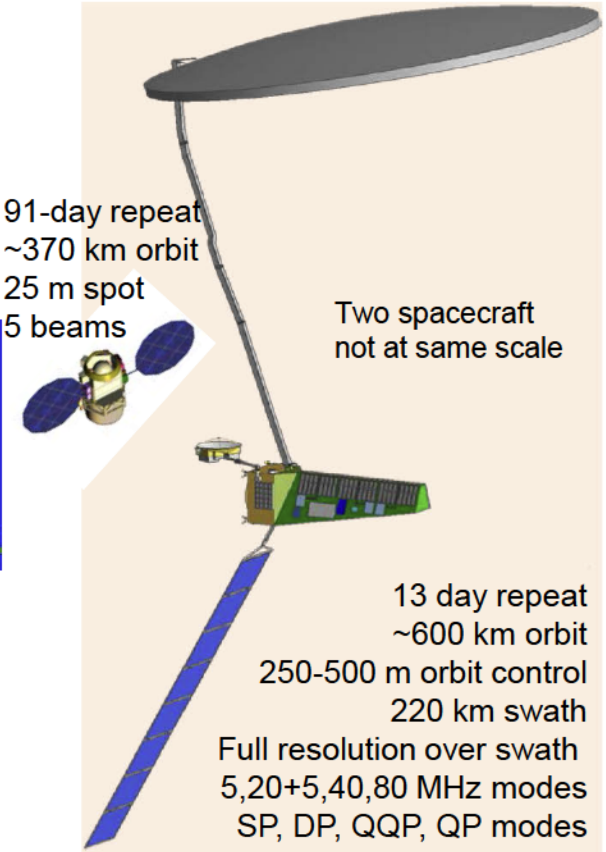


Multibeam Profiling LIDAR



L-band Repeat Pass InSAR



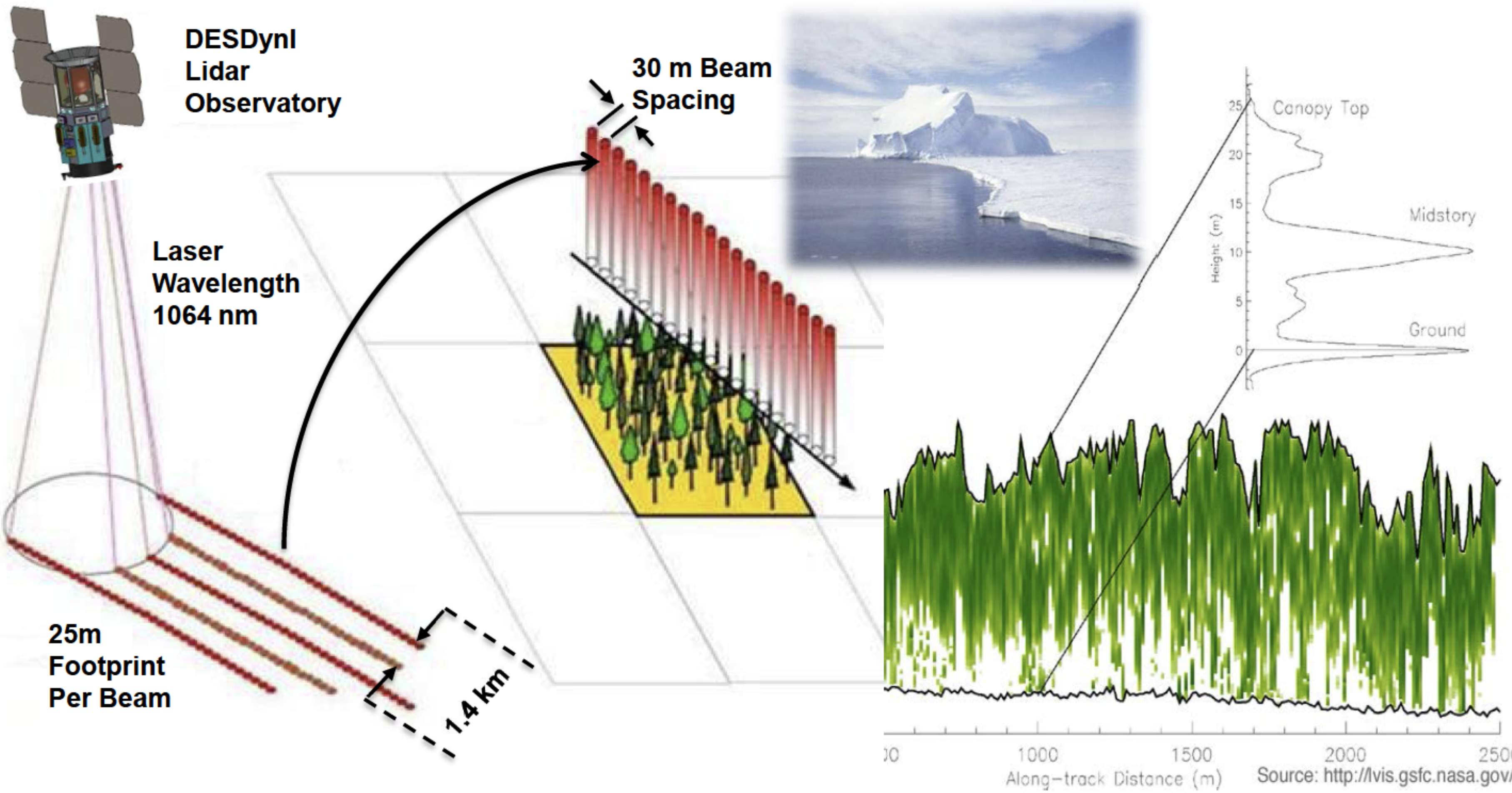


91-day repeat
~370 km orbit
25 m spot
5 beams

Two spacecraft
not at same scale

13 day repeat
~600 km orbit
250-500 m orbit control
220 km swath
Full resolution over swath
5,20+5,40,80 MHz modes
SP, DP, QQP, QP modes

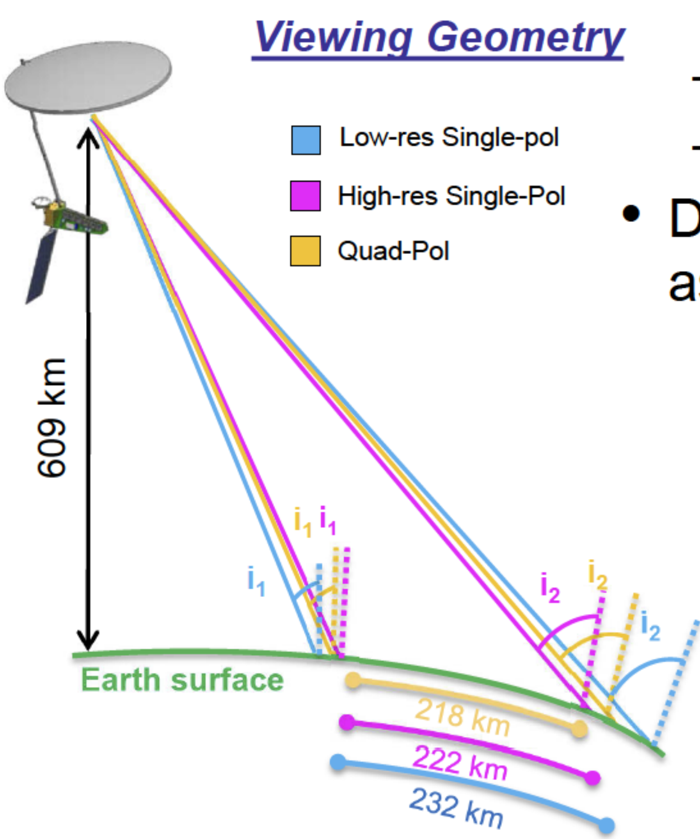
Proposed DESDynI Lidar Mission



- **Lidar Multi-Beam Sampling Provides:**
  - **Global, direct measurements of vegetation structure**
  - **Surface topography of land, water, and ice.**

Proposed DESDynI SAR Concept

- 3 primary modes:
  - Solid earth deformation, ice sheets and glaciers: Single pol (H or V)
  - Ecosystem Structure: Quad pol
  - Sea-ice: Low BW single pol
- Data acquired Left or Right of spacecraft track, ascending and descending



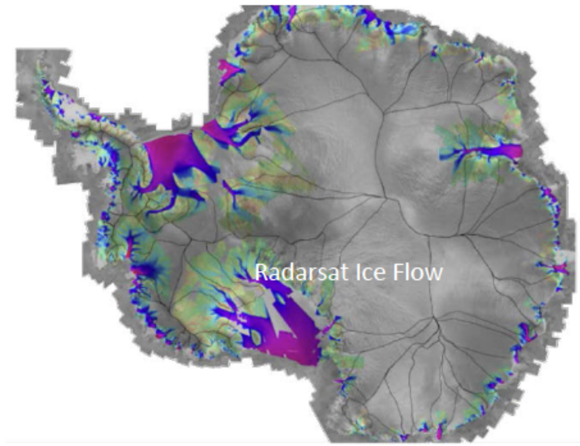
- Wide swath in all modes allows for 13 day repeat with overlap at equator (2-5 passes over a site depending upon latitude)
- Coverage is limited by downlink bandwidth and selection of mode

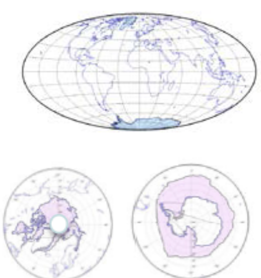
Dynamics of Ice: Primary Goal and Science Objectives

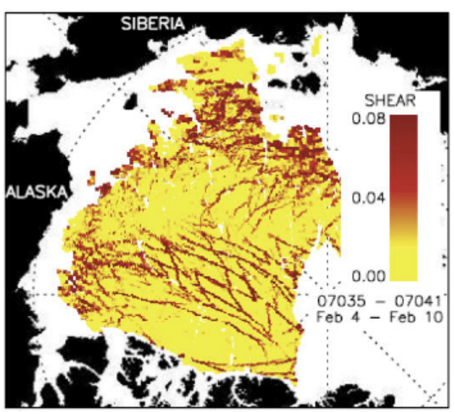
Characterize response of polar ice sheets to climate change

Ice dynamics: predictive models of sea level rise

- flow processes and rheology
- grounding line change
- flux gates
- boundary conditions



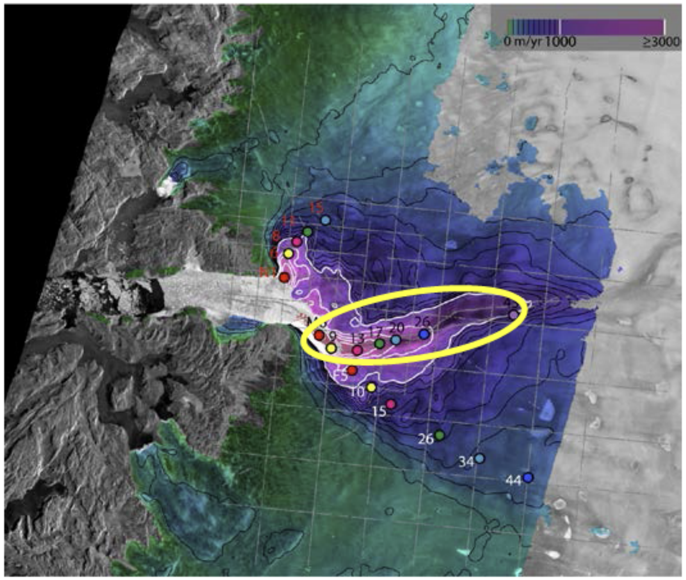




Sea ice dynamics: coupling to ocean and atmosphere

- motion and export
- thickness and volume
- inputs to GCM/ocean models

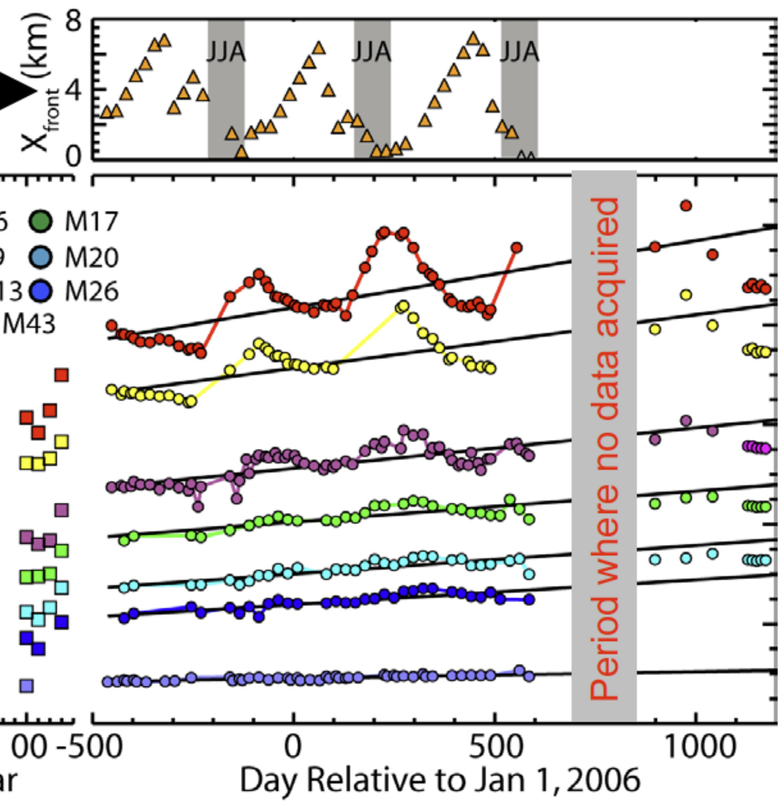
Speed on Jakobshavn Isbrae Highly Variable in Time



Jakobshavn Isbrae is one of the few glaciers where frequent InSAR observations are available.

~5%/yr velocity increase

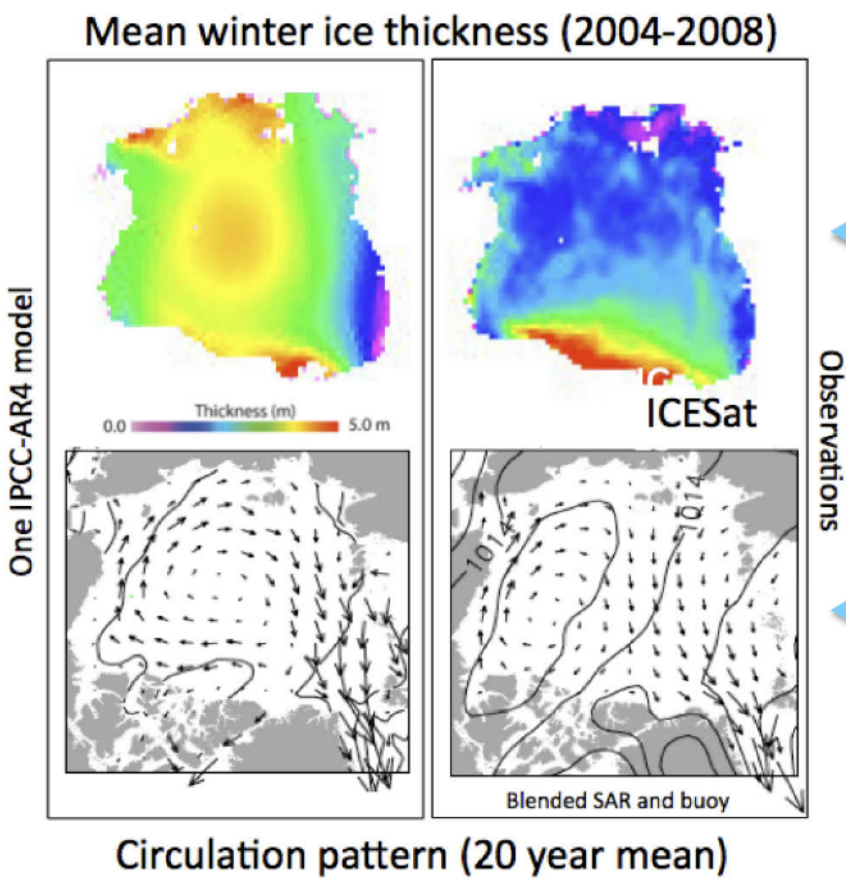
Position of Ice Front



Despite spare spatial and sporadic temporal sampling, existing SAR data reveal large variations in glacier flow.

DESDynI would provide fine temporal sampling of all rapidly evolving outlet glaciers and ice streams.

DESDynI and Sea Ice



Lidar
Sea Ice Thickness from Freeboard

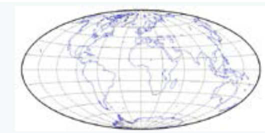
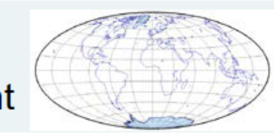
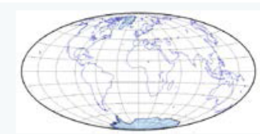
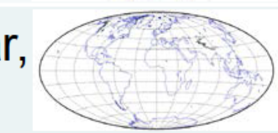
- Monitor thickness and volume changes along with changes in ice extent
- Multi-decadal record for understanding response to atmospheric and oceanic changes
- Model validation and data assimilation

SAR
Sea Ice Motion and Deformation

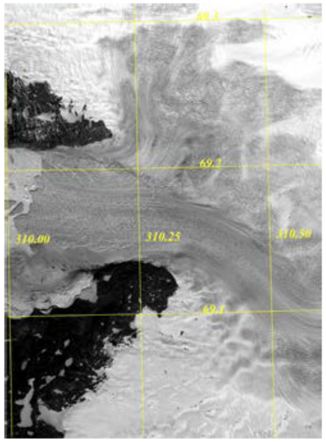
- Circulation changes, export and regional redistribution of sea ice
- Small-scale motion for quantifying deformation-induced ice production
- Volume storage due to ridging
- Model validation and data assimilation

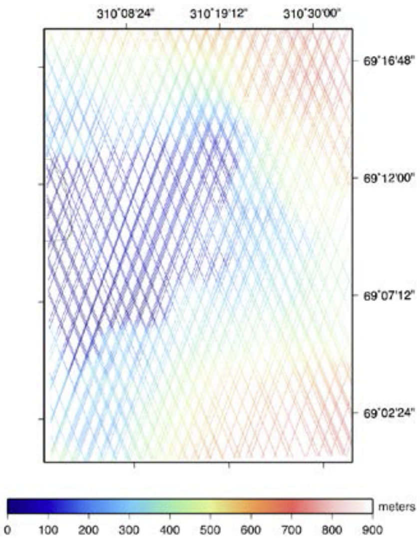
Near simultaneous observations of thickness (lidar) and ice deformation (SAR) would resolve the contribution of dynamics and thermodynamics to the distribution of ice thickness - needed inputs for global model initialization and validation

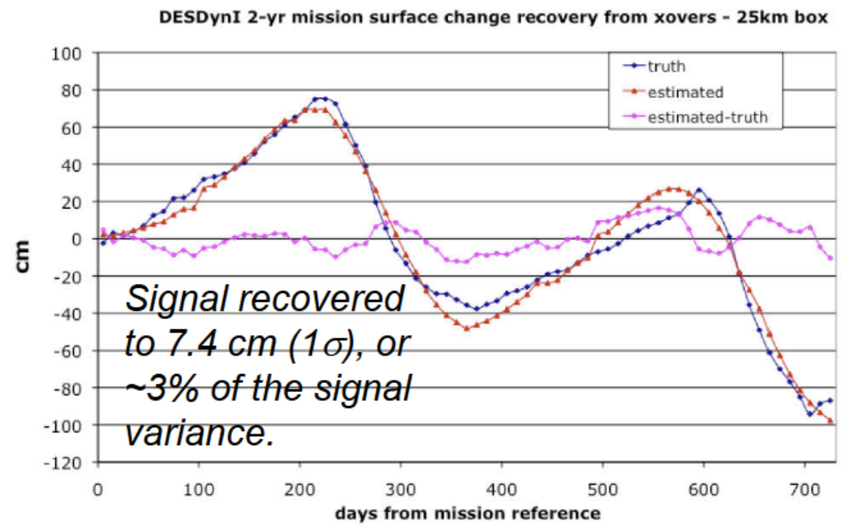
Dynamics of Ice Baseline Requirements at MCR

Measurement	Requirements	Coverage
Greenland/Antarctic Ice Sheet *velocities* (Winter)	Slow ice: 1 m/yr, 100 m res Fast ice: 5 m/yr, 500 m res	Radar, In winter, 3-D 
Grounded margins Ice Sheet *velocities*	5 m/yr, 500 m res	Radar, All year, 3-D 
Greenland/Antarctic Ice Sheet *elevations*	1 m, 1000 m res	Lidar, All year, height 
Greenland/Antarctic Ice Sheet *elevation change*	1 m/yr, 2500 m res	Lidar, All year, dh/dt 
Mountain Glaciers *velocities and elevation*	As observation resources permit	Radar/Lidar, Opportunistic 
Arctic and Antarctic Sea Ice *thickness*	0.6 m, 25 km res	Lidar 
Arctic and ***Antarctic*** Sea Ice *velocities*	100 m/day, 5 km res	Radar, All year, 2-D 

Lidar 2-yr mission surface elevation & change requirements







1σ Error in Recovered Signal (ABS(truth-estimated))

Mission Configuration and data used 1. 50% random pass loss from clouds unless otherwise noted. 2. 30 m along-track sampling unless otherwise noted.	Spatial Resolution (km X km)	2 Year Trends (cm/yr)	1 Year Trends (cm/yr)	6 month change (cm)	No. of Obs.	Post-fit Obs. Residual (m)
Data acquired from a 2-yr mission. Can further optimize sampling with pointing control.	**2.5**	**71.2**			**27**	**1.18**
	5	21.4	54.9		83	1.61
	10	4.3	11.7	16.8	482	1.66
	25	3.9	8.9	12.4	2447	1.48

Ice sheet / Glacier Velocity Error Model

- Interferometrically derived displacement, with errors:

$$d_{LOS} = \frac{\lambda}{4\pi}\left(\Delta\phi_{\text{flat}} + B_{\perp}\frac{z}{\rho_0 \sin\theta_0}\right) + n_{SNR} + n_{tropo} + n_{iono} + n_{surf}$$

including topography and baseline errors, propagation and surface effects

- Errors are broken out in the requirements flow
  - SNR/MNR
  - Phase error
  - Geometric Correlation
  - Temporal Correlation
  - Volumetric Correlation
  - Geolocation Error
  - Digital Elevation Error
  - Ionosphere
  - Troposphere
  - Surface changes
  - Baseline knowledge
  - Rotational Correlation

DESDynI is proposed to reduce these errors to meet challenging measurement requirements

- Small baselines to minimize topographic error and geometric decorrelation effects
- L-band wavelength to minimize temporal decorrelation effects
- Many samples over time to minimize propagation media effects

Meeting Ice Sheet/Glacier Velocity Requirements

Assumptions	
Radar Mode	Single-Pol 20+5MHz
Interferogram	13 days
Observations	Asc & Des; Winter
Wavelength	24 cm
Correlation+	0.6 (fast) 0.4 (slow)
Atmosphere	5 mm
Product Resolution	100 m x 100 m - slow 500 m x 500 m - fast
Pointing	Left & right
Number of obs	4 per direction
Matching resolution	100

+ Includes SNR, Temp, Geom,Vol Correlations

- For slow ice, use interferometry
- For fast ice, use speckle tracking
- Under fairly conservative assumptions given, and previous formulas, requirements can be met:
  - Fast ice (Req: 5 m/yr or greater)
    - ✓ 1.3 m/yr
  - Slow ice (Req: 1 m/yr or greater)
    - ✓ 0.9 m/yr

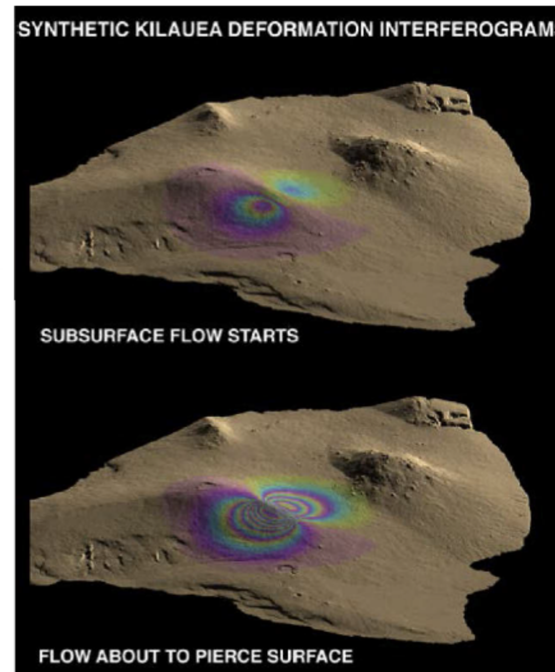
✓ Vector measurements through ascending/descending, right/left in winter

- To be confirmed:
  - That correlations are supported in over 80% of ice regions (fastest moving and dark areas)

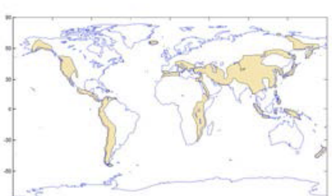
Deformation/Solid Earth: Primary Goal and Science Objectives

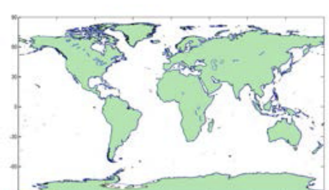
Understand the physics of earthquakes and volcanoes, apply to mitigation of natural hazards, monitor/manage water and hydrocarbon extraction and use

- Tectonic/fault processes
- Magmatic processes
- Manage water use/storage and hydrocarbon extraction, CO_2 sequestration, landslides

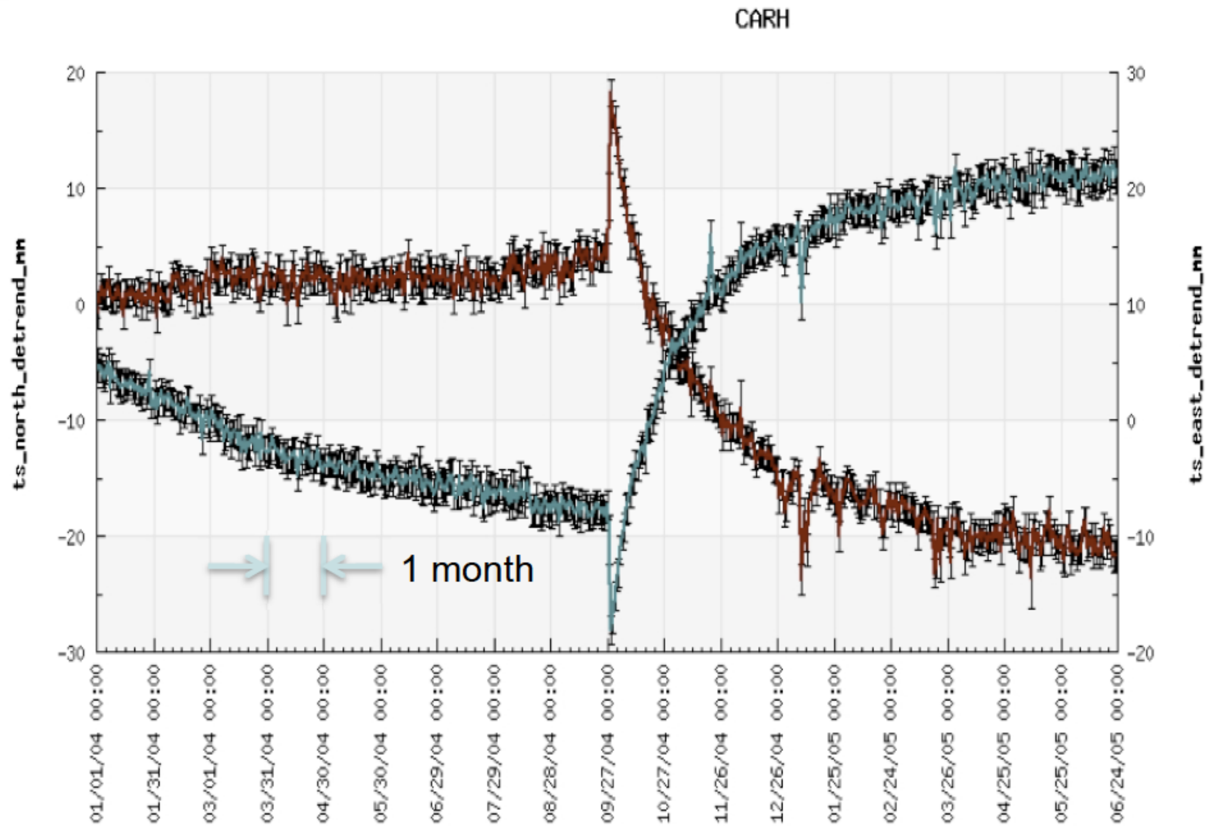


Time series interferograms show onset of activity and how it progresses toward eruption





Frequent Temporal Sampling to Understand Earthquake Mechanisms



GPS East (red) and North (blue) position time series at continuously operating site CARH centered on the time of the September, 2004 Mw 6.0 Parkfield earthquake. A linear trend has been subtracted from each component.

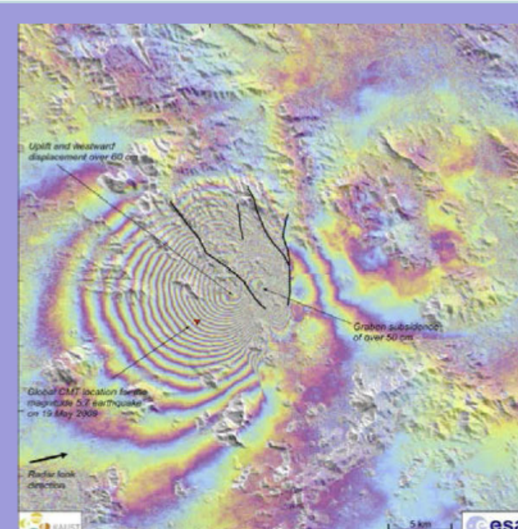
- Variations in interseismic, coseismic, and postseismic displacements are visible on a wide range of time scales. Disentangling coseismic from postseismic displacements, and observing postseismic deformation requires frequent temporal sampling.

DESDynI would greatly spatial and temporal coverage of deformation globally

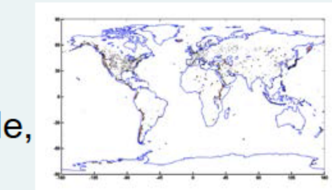
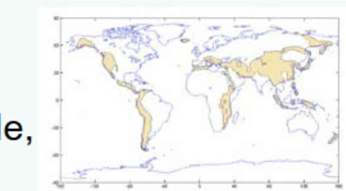
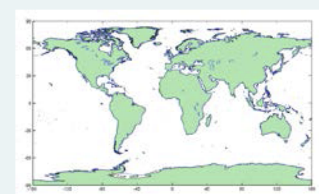
- EarthScope covers the Western US with ~1000 GPS stations at km to 10's of km spacing
- Most detailed study of a plate boundary to date
- Map at left shows PBO Western US permanent stations

- But DESDynI would cover the globe with $\sim 10^{11}$ pixels at 10's of m spacing
  - Temporal evolution with nearly contiguous coverage at fine resolution
- Would improve our models of earthquakes/volcanoes/hazards many-fold

A typical event interferogram rich with information about the subsurface



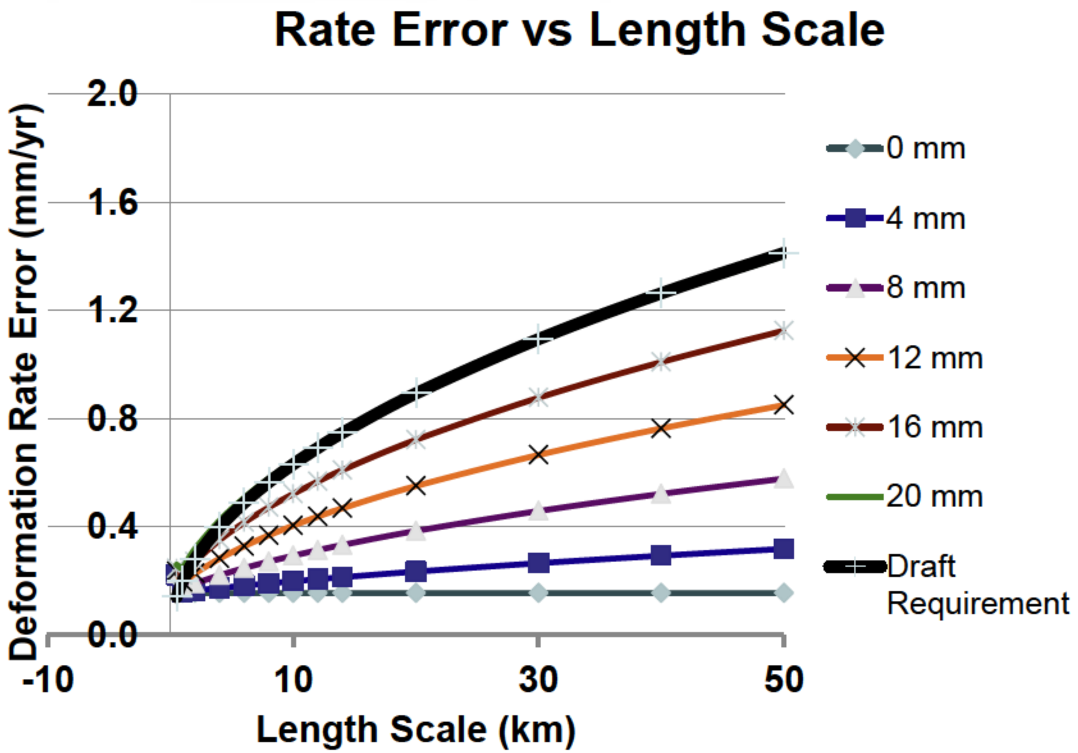
Deformation Baseline Requirements at MCR

Measurement	Requirements	Coverage
Deformation of Events (co-seismic, post-seismic, volcanoes, landslide, aquifers, etc)	Near weekly: $\leq 2 \sqrt{L}$ mm Yearly: $\leq 0.5 \sqrt{L}$ mm, 0.5 km < L < 50 km, L = length scale in km. Resolution: 10-20 m	Radar, Every Cycle, 2-D 
Deformation Rates (interseismic velocities)	$\leq 0.2 \sqrt{L}$ mm/yr, 0.5 km < L < 50 km, L = length scale in km. Resolution $\leq$ 1000 m	Radar, Every cycle, 2-D,  ***All high strain rate areas shown***
Global Co-seismic Deformation (ensures capture of significant events outside expected areas)	***$< 5 \sqrt{L}$ mm,*** ***0.5 km < L < 50 km,*** ***L = length scale in km.*** ***Resolutions $\leq$ 100 m*** ***Applies for earthquakes of magnitude > 7 at depths < 50 km.***	***Radar,*** ***2 per year,*** ***2-D*** 

Interseismic Requirements over Scale

Assumptions	
Radar Mode	Single-Pol 20+5MHz
Interferogram (plus stacking)	600 days
Observations	Asc & Des
Wavelength	24 cm
Correlation+	$\gamma_0 e^{-t/T}$, T = 200 days (γ < 0.1 per interferogram)
Atmosphere	20 mm
Product Resolution	1000 m x 1000 m
Pointing	Left or Right
Stacking Period	3 years

+ γ_0 includes SNR, Geom, Vol Correlations



- ✓ 2-D vector measurements through ascending/descending, right or left
- Margin introduced through additional data not considered
  - Polarimetric data
  - Overlap due to orbit convergence

Meeting DESDynI Deformation Requirements

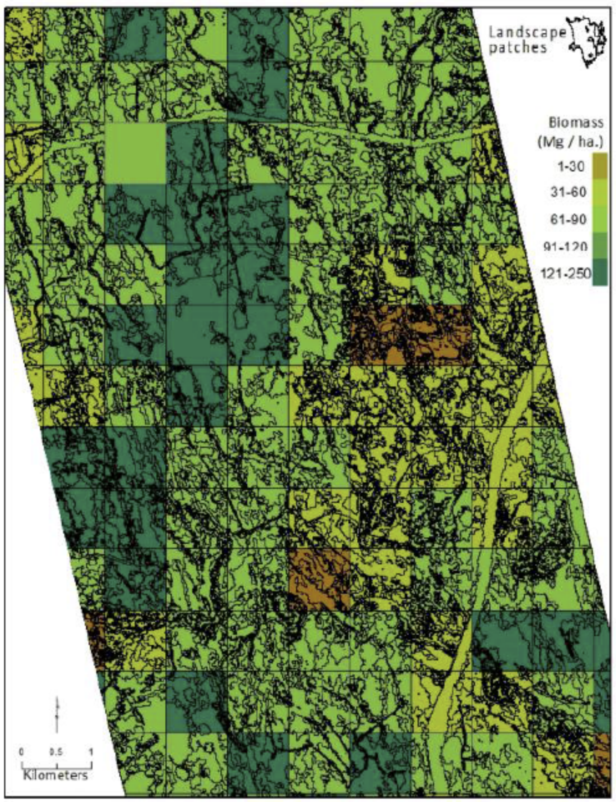
Assumptions	
Radar Mode	Single-Pol 20+5MHz
Interferogram (plus stacking)	L1.1: 13 days L1.2: 600 days
Observations	Asc & Des
Wavelength	24 cm
Correlation+	$\gamma_0 e^{-t/T}$, T = 200 days
Atmosphere	20 mm
Product Resolution	L1.1: 20 m x 20 m L1.2: 1000 m x 1000 m
Pointing	Left or Right
Stacking Period	L1.1: 1 year L1.2: 3 years

+ γ_0 includes SNR, Geom, Vol Correlations

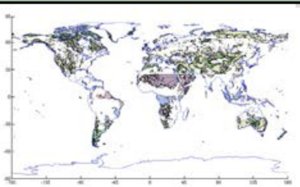
- For targeted phenomena (L1.1), use single or short period interferograms in short stacks
- For interseismic deformation (L1.2), use long period interferograms over mission duration in long stacks.
- Under stated assumptions given, and previous formulas, requirements can be met:
  - L1.1a (Req: 14 mm at 50 km scale)
    - ✓ 14 mm
  - L1.1b (Req: 3.5 mm at 50 km scale in 1 year)
    - ✓ 2.7 mm
  - L1.2 (Req: 1.4 mm/yr at 50 km scale)
    - ✓ 1.4 mm/yr
- To be confirmed in Phase A:
  - That accuracies are supported in over 80% of deformation regions (correlations and atmosphere model improvements)

Ecosystem Structure: Primary Goal and Science Objectives

Characterize the effects of changing climate and land use on terrestrial carbon cycle, atmospheric CO_2, and species habitats

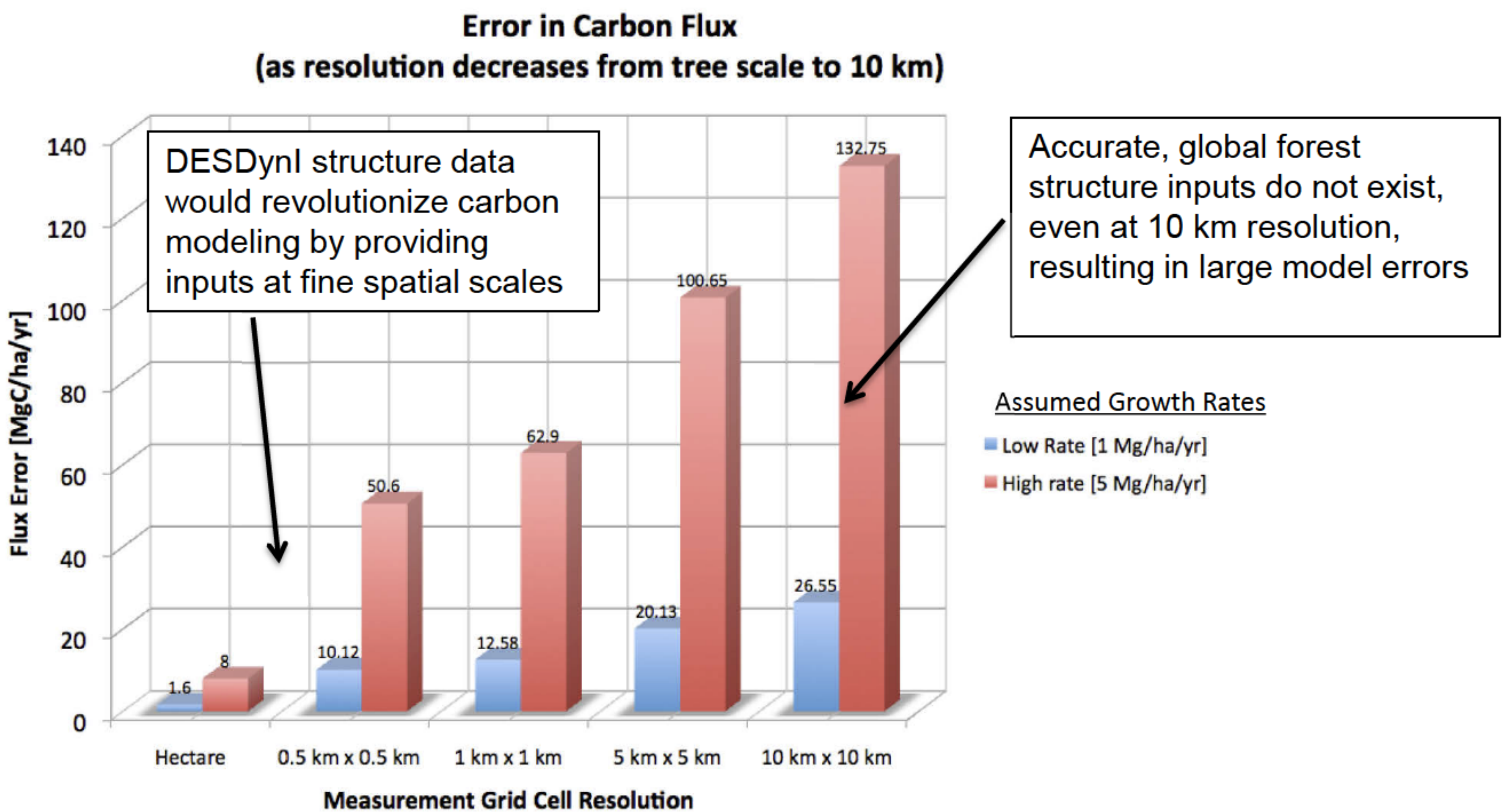


- Characterize global distribution of aboveground vegetation biomass and carbon
- Quantify changes in terrestrial biomass and carbon resulting from disturbance and recovery
- Characterize habitat structure for biodiversity assessments



Global Carbon Modeling

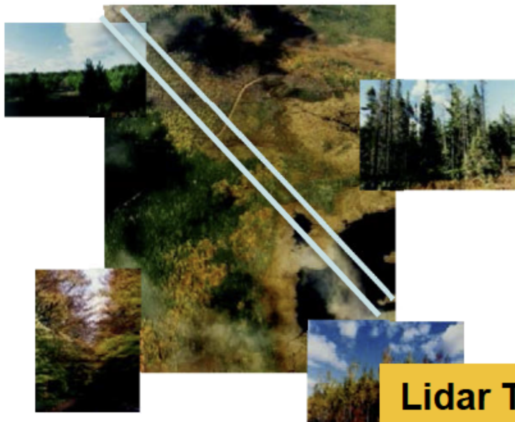
- Carbon model data and modeling scales must be near the scale of disturbance and environmental gradients (about 1 – 10 ha)
  - Coarse forest structure inputs in carbon models produce vastly inaccurate fluxes compared to proposed DESDynI measurement scales



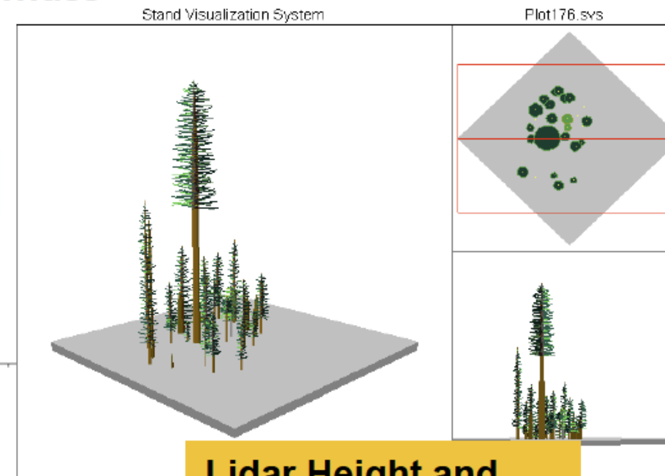
Characterization of Habitat Structure and Biodiversity

Radar & Lidar can map and measure landscape structure

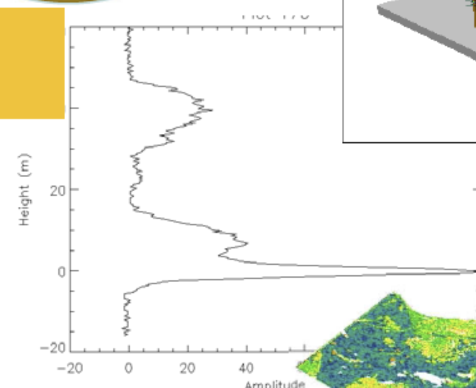
Lidar and Radar can map and measure vertical structure & biomass



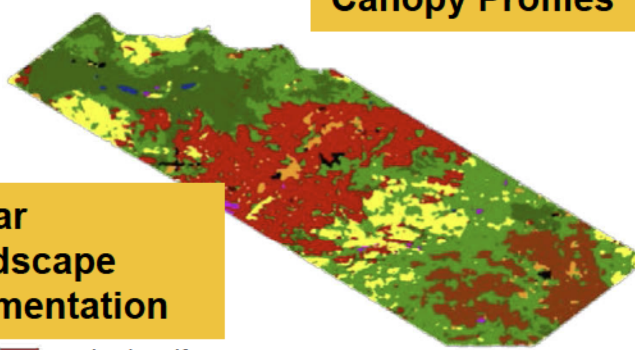
Vegetation 3D Structure : Radar and Lidar Fusion



Lidar Transect Canopy Profiles



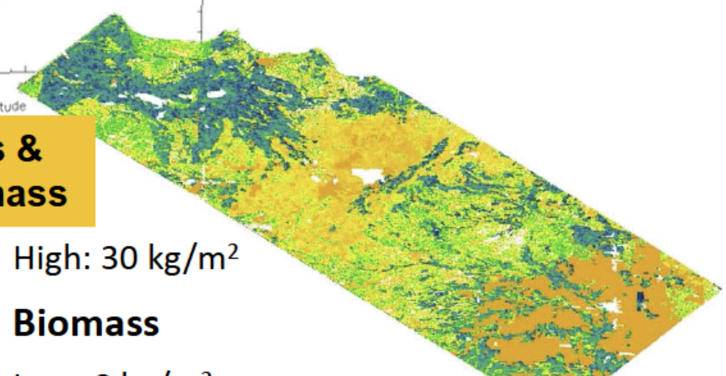
Lidar Height and Within-Canopy Vertical Structure



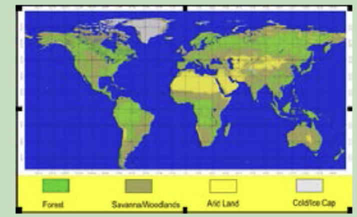
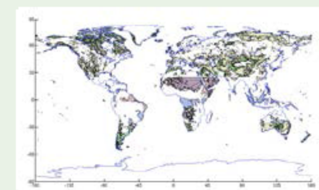
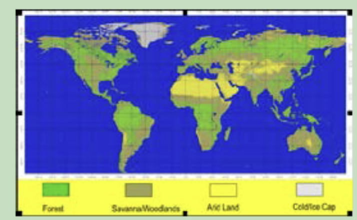
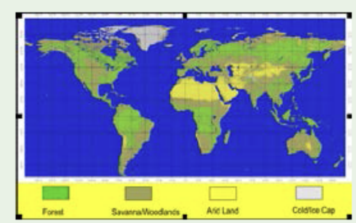
Radar Landscape Segmentation

- Upland conifer
- Lowland conifer
- Northern hardwoods
- Aspen/lowland deciduous
- Grassland
- Agriculture
- Wetlands
- Open water
- Urban/barren

Radar Bands & Derived Biomass

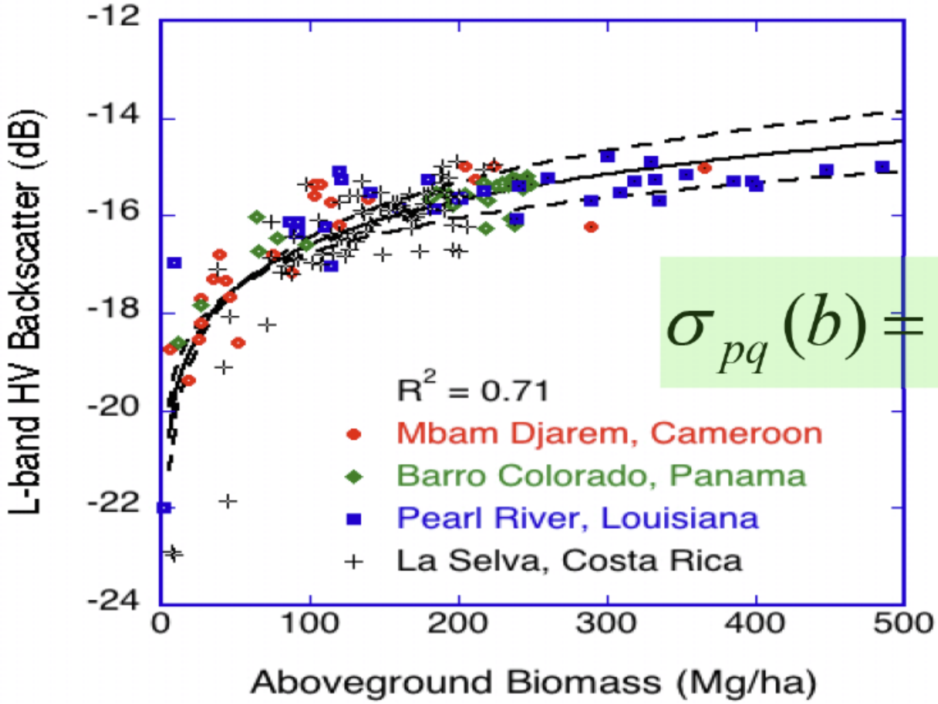


Ecosystem Structure Baseline Requirements at MCR

Measurement	Requirements	Coverage
Aboveground Woody Biomass (High Density)	< the greater of 10 MgC/ha or 20%, capped at 25 MgC/ha Resolution: 1 km resolution	Lidar, 1 map 
Aboveground Woody Biomass (Low Density)	< 10 MgC/ha, when biomass is < 40 MgC/ha Resolution: 100 m	Radar, Seasonally 
Aboveground Woody Biomass Disturbance	50% change in biomass	Radar, Quad-pol, Yearly 
Canopy Height Profiles	Resolution: 25 m Along-track Posting: 30 m Vertical resolution: 1 m	Lidar 98.5% canopy cover 

Radar Polarimetric Measurement

- Experiments over boreal, temperate, and tropical forests have shown that radar backscatter is related to the amount of live aboveground biomass of vegetation.
- L-band linearly cross-polarized (HV) backscatter has a strong sensitivity to biomass up to 100 Mg/ha.
- Backscatter sensitivity to biomass depends on radar incidence angle, environmental condition, and surface slope.
- Speckle noise, spatial variability of vegetation structure, and radar resolution cell are factors influencing biomass estimation accuracy from radar measurements.



Recommended algorithm for biomass estimation from radar measurements used only for radar design and performance analysis.

$$\sigma_{pq}(b) = A_{pq}(1 - e^{-B_{pq} b}) + C_{pq} b^{\alpha} e^{-B_{pq} b}$$

p,q: H or V polarization

b: Aboveground Live Biomass (Mg/ha)

A_{pq}, B_{pq}, C_{pq} are calibration coefficients

Error in σ_o Measurements

- The error/variability in the backscatter measurements, $\Delta\sigma_{pq}$ (*pq=hh,hv,vv*), are a function of speckle, thermal noise, temporal variability of the backscatter, calibration errors (which in turn depend on pointing DEM errors) and area projection correction terms as given by the following equation.

Speckle Noise | Thermal Noise | Backscatter Temporal Variability | Calibration Errors | Area Projection Errors

$$\Delta\sigma_{pq} = \left[\left(\frac{1}{\sqrt{N}}\frac{1}{\sqrt{N_{o_s}}} + \frac{1}{\sqrt{N}}\frac{1}{\sqrt{N_{o_t}}}\frac{1}{SNR}\right)\sigma_{pq} + \frac{1}{\sqrt{N_{o_t}}}\Delta\sigma_{pq_t}(b) + \frac{1}{\sqrt{N_{o_t}}}\Delta\sigma_c + \sqrt{\frac{A_{dem}}{A_{pix}}\frac{1}{\sqrt{N}}\frac{1}{\sqrt{N_{o_s}}}\Delta\sigma_a}\right]$$

Number of pixels to average per obs | Speckle-diverse observations | Total number of observations

- Since SAR uses a coherent imaging source, the image data is subject to speckle noise as well as thermal noise.
- Backscatter is also sensitive to weather, wind, vegetation health, ground cover, soil moisture and other factors.
  - Empirical data for several biomes and times ranging from 14 days to several years (restricted to the same season) show variability in the 0.5 – 0.75 dB range at L-band.
- In large slope area removing the area projection correction associated with the broadside imaging geometry can be a major source or error.

Key to reducing measurement error: good calibration, good topo knowledge, *number of pixels to average, and number of observations*

Meeting radar biomass requirements

Requirement: Accuracy < 10 MgC/ha, when biomass is < 40 MgC/ha, at 100 m resolution

Mode (Pol, BW)	Speckle Identical Obs.	Speckle Diverse Obs.	Total Obs.	Biomass Accuracy (%)	Biomass Accuracy (MgC/ha)
HH/HV/VV, 20 MHz	24	12	36	25	< 10
HH/HV/VV, 40 MHz	6	12	18	27	< 11
HH/HV, 20 MHz	60	12	72	27	< 11
HH/HV, 40 MHz	24	12	36	28	< 11
HV, 40 MHz	60	12	72	28	< 11
HV, 20 MHz	132	12	144	28	< 11
HH, 20 MHz	132	12	144	30	< 12

- Quasi-pol 20 mode with three observations per year in each season meets low biomass requirement
- Many modes come close to meeting the requirement


Season 1: Leaf On, Dry


Season 2: Leaf Off, Wet

Ecosystem Requirements Flow

ECOSYSTEM STRUCTURE

Global Biomass
+/-10 MgC/ha or 20% (but < 25MgC/ha)
1000 m resolution

Global Transects of Vertical Canopy
25 m resolution
30 m along-transect posting
1000 m across-transect posting
1 m vertical resolution
98.5% canopy cover

Global Biomass
+/-10 MgC/ha or 20% (but < 25MgC/ha)
100 m for areas < 40 MgC/ha annual

Global Disturbance
> 50% change, 100 m resolution annual

Measurement Method

Achieve biomass accuracy by measuring height metrics to 1 m in resolution cell -> 25-m spot profile

Measurement Method

This is a direct pass-through of lidar transect and coverage requirements

- 1 micron 15 mJ lidar
- 25 m spot / 30 m sampling
- 1 m receive aperture
- 5 beams / 5 m placement
- 1415 m cross-track spacing
- 371 km altitude orbit
- Uniform cross-track land/ice coverage over mission
- Minimum 2 years

Measurement Method

Biomass sensitivity -> L-band quad-pol radar reflectivity

225 looks +asc/des to beat down speckle/thermal noise -> 10 m res

Thermal noise relative to speckle noise -> NES0

Global coverage -> obs. Strategy

Multiple seasons over 3 years to minimize temporal variability

- L-band SAR
  - Quad-pol
  - 10 m resolution
  - -25 dB NES0
- 13-day repeat orbit
- ~240 km observable swath
- 609 km altitude orbit
- 250 m repeat orbit control
- 1/20 deg pointing control
- Left/right Observations
- Ascending/Descending Obs
- Seasonal Vegetation
- Winter ice sheets
- Every opportunity sea-ice
- Every-repeat deformation
- Minimum 3 years

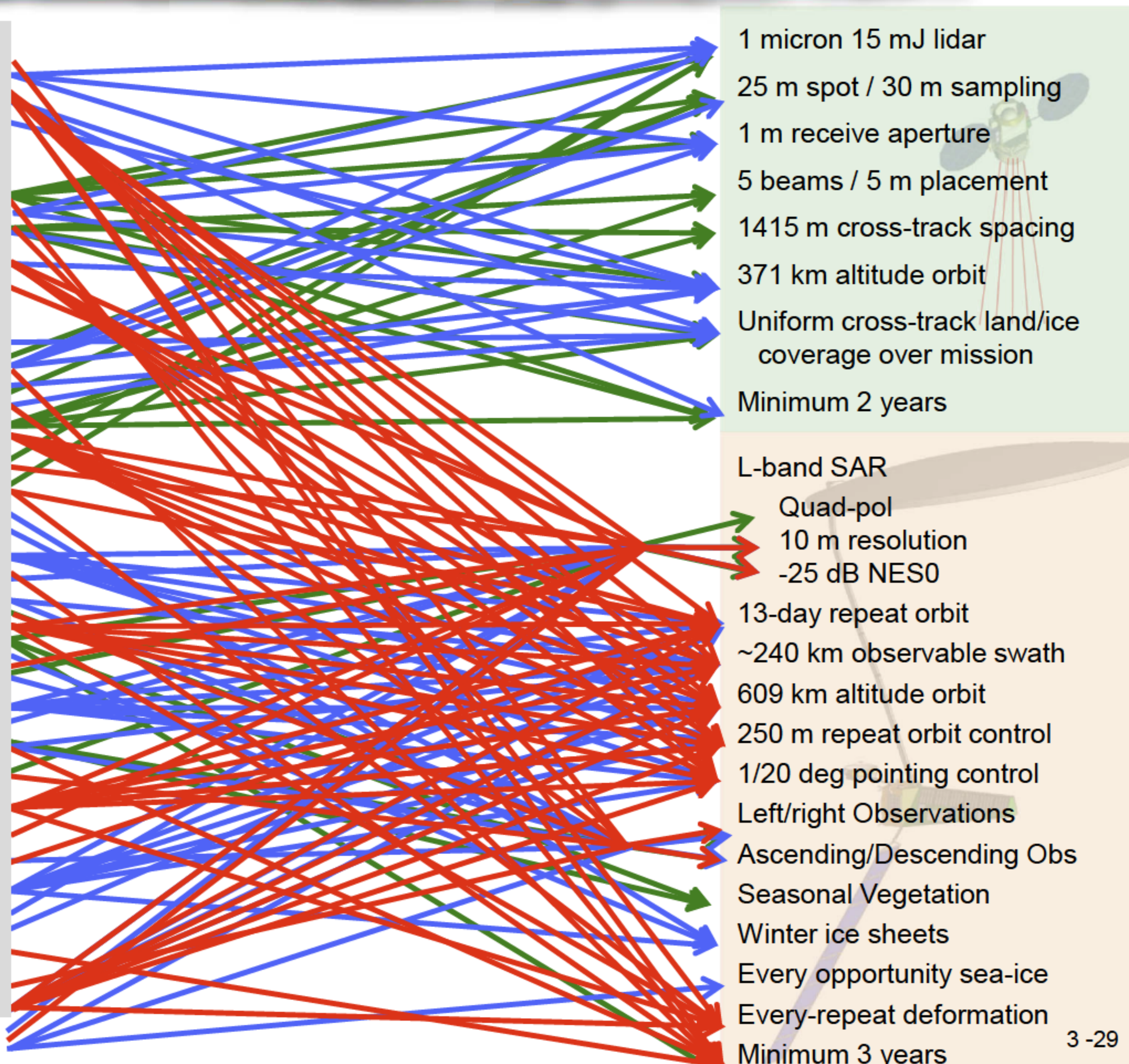
All System Requirements Traceable to Science

<u>All L1 Requirements collectively map to the mission concept</u>

Dynamics of Ice
- Ice sheet dynamics
- Glacier dynamics
- Sea ice dynamics

Ecosystem Structure
- Global Biomass/Carbon
- Changes in Global Biomass/Carbon and Disturbance
- Habitat and Biodiversity

Solid Earth Deformation
- Tectonic processes
- Magmatic processes
- Sequestration, land-slides, aquifer change



Proposed Key & Driving Radar Instrument Requirements

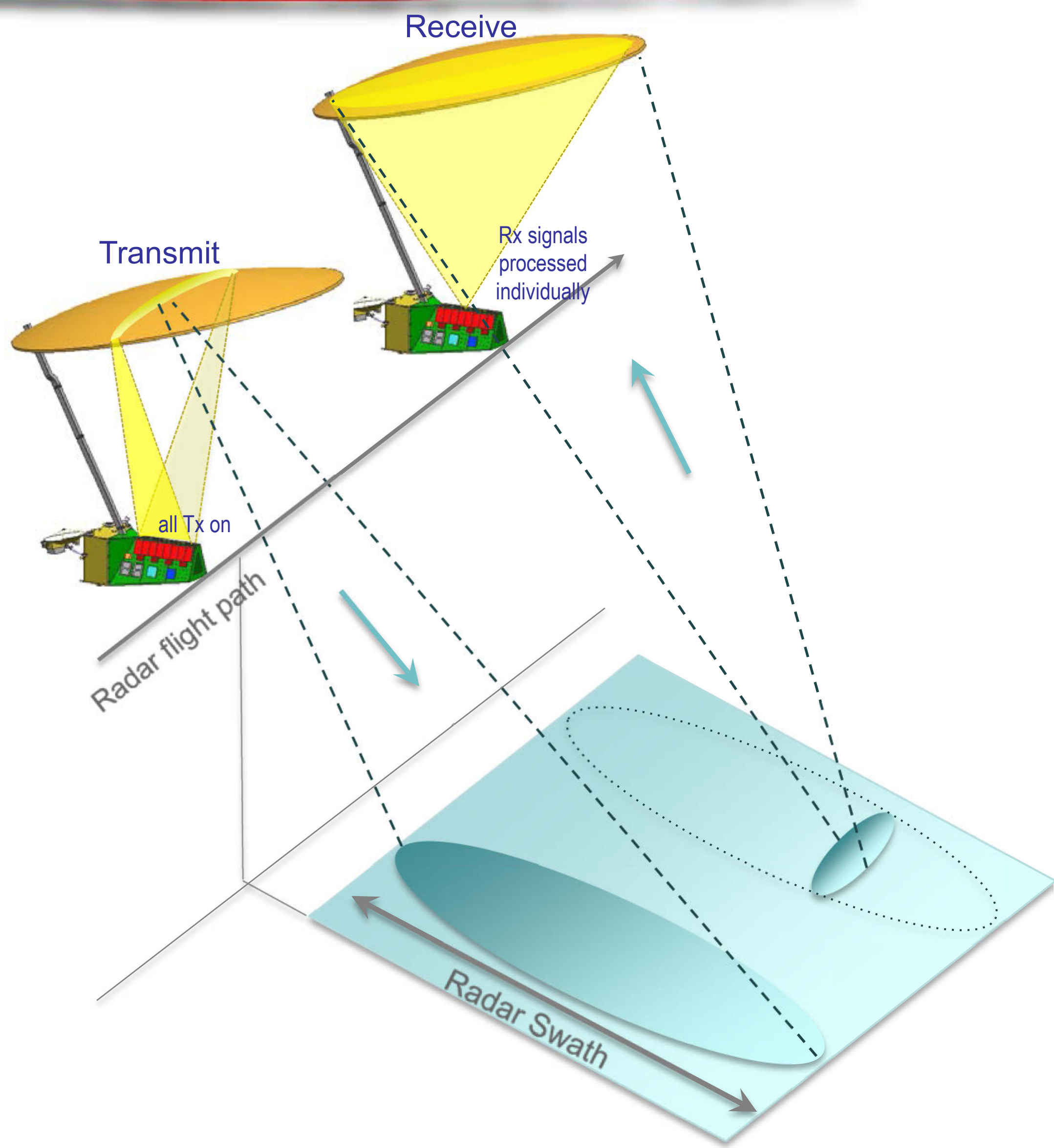
Requirement	Projected Performance	Key/Driven Radar Parameters
The Radar shall operate at L-Band (1215 to 1300 MHz)	L-Band Instrument, bandwidth consistent with NTIA constraints	• Antenna Size • System Bandwidth (constraint)

The Radar shall have a field of regard no smaller than the repeat-cycle ground track spacing at the equator including terrain effects	For 13-day repeat, ground track separation at the equator=208 km; 4 km reserved for terrain effects, 6 km for overlap; Predicted swath >218 km for primary science modes	• Antenna Config
		  • Reflector Diam & F/D
		  • Feed Length
		  • # of Elements

The Radar shall be capable of operating in Single, Dual, and (Quasi) Quad-Polarization modes	Radar supports single, dual, and quasi-quad linear polarization modes over full swath; full BW quad-pol over reduced swath	• On-Board Data Throughput • Co and Cross-Pol Rx Channels
The Radar shall operate with a Noise Equivalent Sigma Zero value of at most -25 dB from 30-46° incidence angle	$NE\sigma_0$ -33 to -25 dB over 30-46° for 20 MHz BW modes	• Antenna Size • Peak Tx Power • Pulsewidth • DC Pwr/Thermal
The total Radar Multiplicative Noise Ratio shall be less than -15 dB	Expect -15.2 dB total MNR -20 dB max Ambiguity Level -20 dB ISLR -20 dB QNR (4-bit BFPQ)	• Antenna Sidelobes • Timing Jitter • Data Quantization
The post-calibration Radar relative accuracy across the swath shall be: <0.1 dB Amplitude <1.5° Phase	Expect 0.091 dB, 0.44° total relative 0.01 dB, 0.34° Reflector/Feed misalignment 0.09 dB, 0.27° components outside Cal Loop 0.01 dB, 0.06° Cal Loop residual (exclusive of RFI effects)	• Built-In Calibration Performance • Antenna Pattern Knowledge/Stability

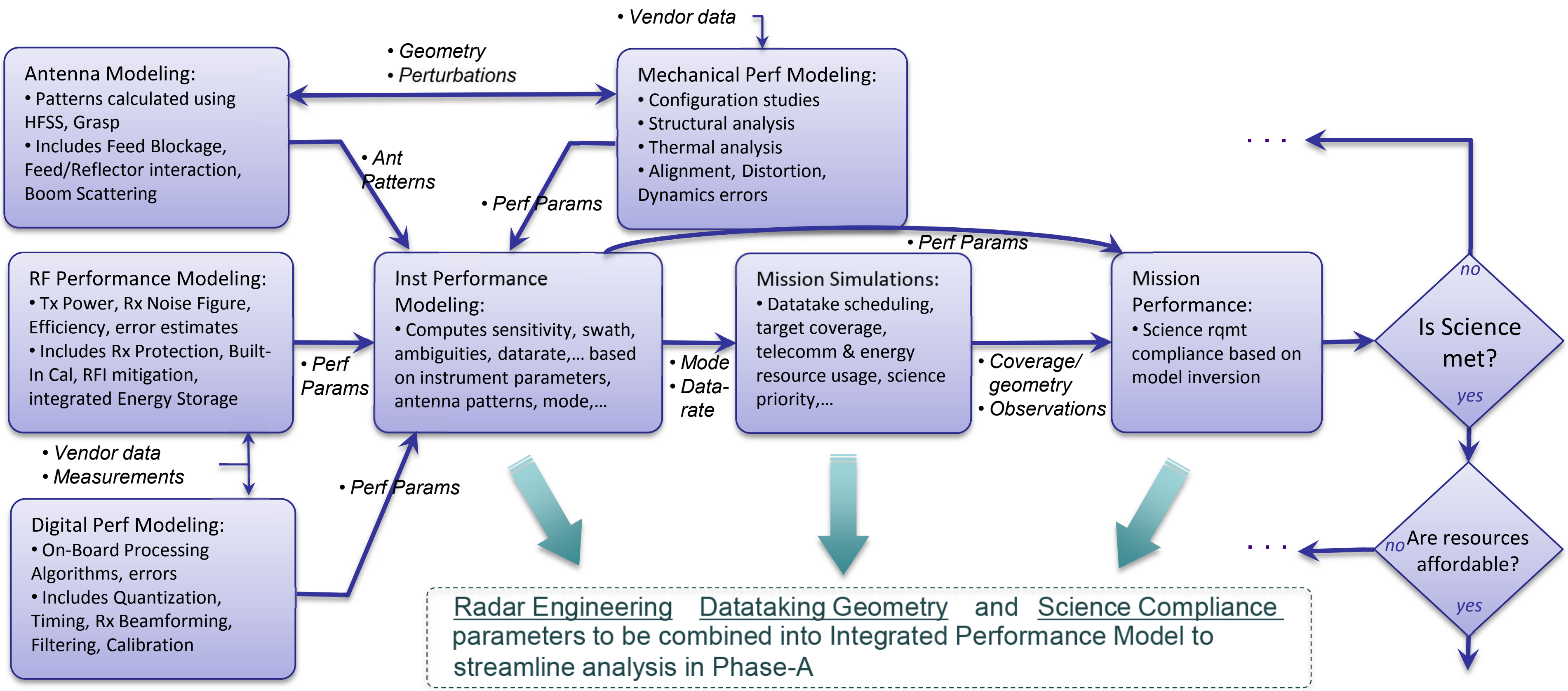
SweepSAR Implemented with Array-Fed Reflector

- Implementing the SweepSAR technique using an Array-Fed Reflector Antenna has these benefits:
  - On Transmit, all Feed Array elements are illuminated (*maximum Transmit Power*), creating the wide elevation beam
  - On Receive, the Feed Array element echo signals are processed individually, taking advantage of the full Reflector area (*maximum Antenna Gain*)



Radar Design Process

- SweepSAR with Array-Fed Reflector is a new type of Radar, requiring development of new tools for performance simulation and analysis
- During the course of the pre-A study phase, analyses have been performed for
  - Repeat Periods 8 to 16 days; Altitudes 540 to 761km
  - Reflector Diameters 6 to15 m; F/D 0.75 to 1.0; Feed Offset 0 to -2 m
  - Feed Lengths 2.5 to 5 m; Number of elements 8 to 32; Element Spacings 13 to 24 cm
  - Transmit Peak Power 800 W to 4.2 kW; Bandwidths 5 to 80 MHz; Pulsewidths 5 to 100μs



Radar System Parameters

- Instrument Parameters for selected point design
  - Repeat Period 13 days; Altitude 609 km
  - Reflector Diameter 12 m; F/D 0.75
  - Feed Length 3.25m; Number of Elements 16 x 2; Element Spacing 15cm el 13cm az
  - Fully Polarimetric; 8 Receive Beams per Polarization
  - Transmit Peak Power 1240W

- Mode-Dependent Command Parameter Settings and Resource Usage

	Commandable Parameters						*Performance*		*Resources*	
Primary Modes	**Polarization**	**Swath Start[1] (km)**	**Swath End[1] (km)**	**PRF[2] (Hz)**	**Band-width (MHz)**	**Pulse Width (µs)**	**Threshold NEσ_0 (dB)**	**-25 dB Swath (km)**	**DC Power (W)**	**Data Rate (Mbps)**
Dynamics of Ice - Glacier	VV	323.9	543.2	1955	20+5	20+5	-25	219.3	618	423.6
Dynamics of Ice - Sea Ice	VV	319.8	551.9	1955	5	20	-25	232.2	588	90.0
Ecosystem Structure - Low Biomass	HH, HV, VH, VV	323.9	546.1	1955	20	40	-25	222.2	984	1376.4
Ecosystem Structure - Forest Change	HH, HV	323.9	546.1	1955	20	40	-25	222.2	707	688.2
Deformation	HH	323.9	542.2	1955	20+5	20+5	-25	218.3	618	423.6

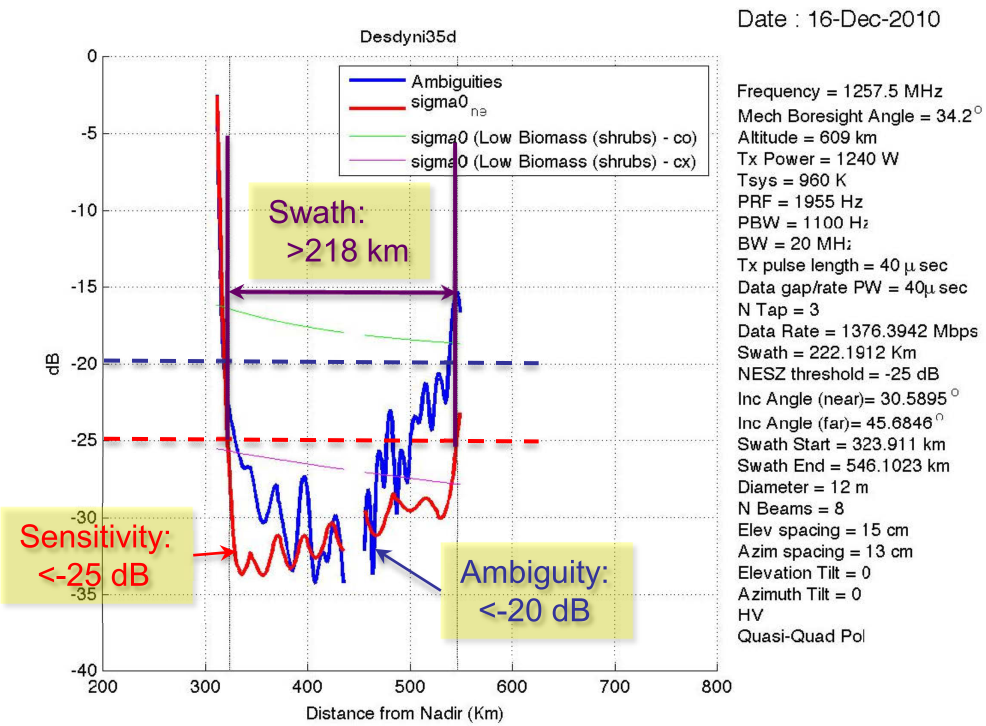
[1] Swath set to max available for analysis purposes
[2] PRF = Pulse Repetition Frequency

- S/C Attitude Control System is required to perform Zero-Doppler Steering (yaw and pitch steering to remove the variation in Doppler centroid along the orbit due to earth's rotation)

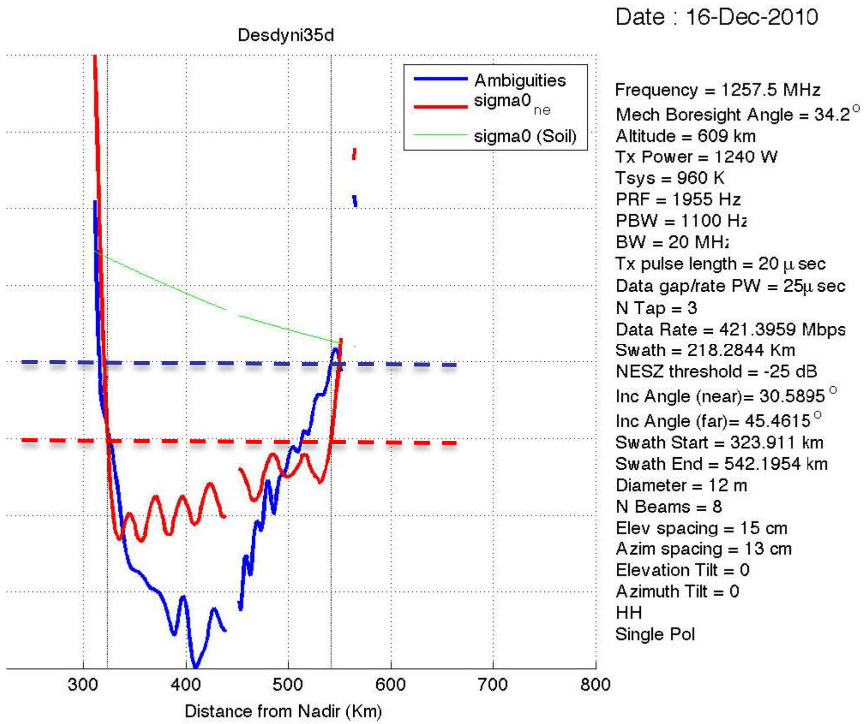
Some Radar System Performance Estimates

- Performance over the swath for the Primary Modes: Ecosystem Structure and Deformation

Ecosystem: Quasi-Quad-Pol (HH, HV, VH, VV) 20 MHz Bandwidth

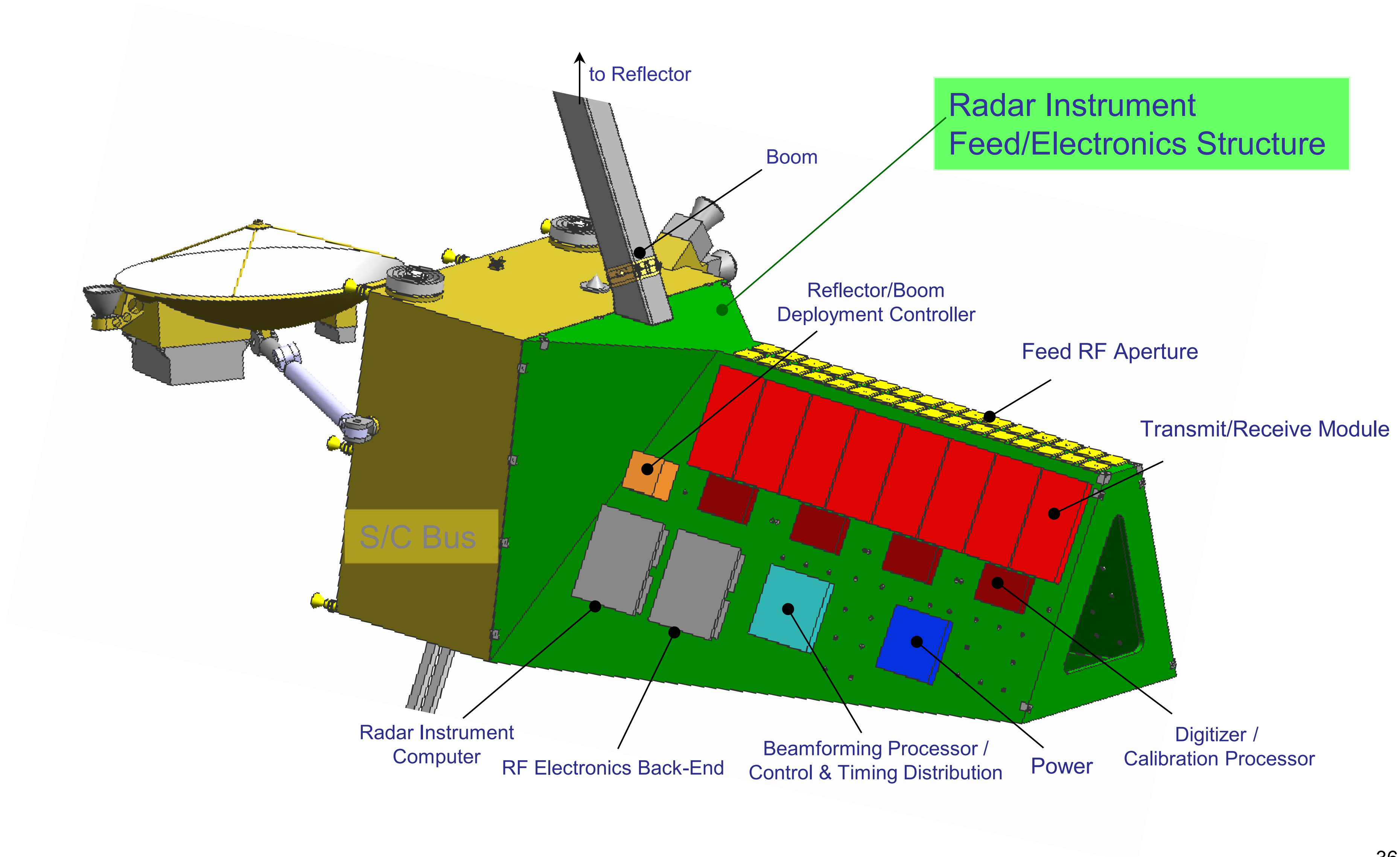


Deformation: Single-Pol (HH) 20 MHz Bandwidth



- The Quasi-Quad-Pol mode (simultaneous H & V Tx, multiplexed in frequency) is used rather than “True” conventional Quad-Pol (time-interleaved H & V Tx) to mitigate ambiguities and gaps

Radar Instrument Configuration



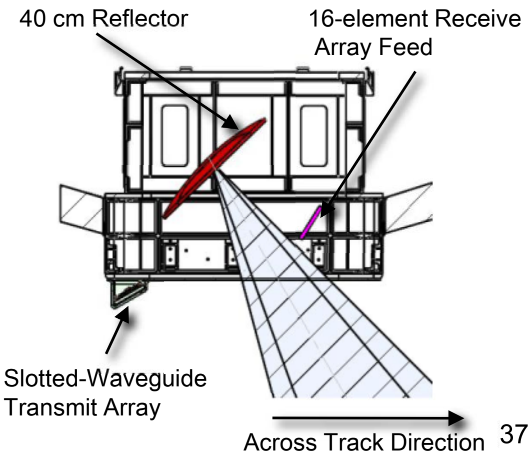
Technology Advancement Status

- V5 and On-Board Processing Implementation:
  - Xilinx Inc, NEPAG (NASA EEE Parts Assurance Group), and XRTC (Xilinx Radiation Test Consortium) are performing radiation and reliability qualification testing of Xilinx flight V5 FPGA (XQR5VFX130); flight part production is expected in June 2011
  - Prototype designs of the on-board processing algorithms and FPGA hardware using the Xilinx commercial V5 FPGA (XC5VFX130T-1FF1738C) are in progress; prototype design of the First-Stage Processor and Second-Stage Processor hardware, along with the timing circuits for implementation of on-board processing algorithms are underway

- GaN and TRM:
  - GaN amplifiers have been designed and tested to demonstrate >60% power added efficiency, enabling increased transmit power and reduced DC power (and thermal dissipation); several parts from 3 vendors are undergoing preliminary screening and radiation testing
  - Prototype designs for the TR module Transmit, Receive, Receive Protection, and Energy Storage subcircuits have been tested; fabrication and assembly of the full TR prototype is underway

- SweepSAR DES Algorithms and Airborne Demo:
  - The SweepSAR Demonstration is an airborne radar system using an array-fed reflector (Ka-Band) with digital beamforming to emulate the DESDynI SweepSAR measurement technique using scaled geometry and timing
  - The SweepSAR Airborne Demo is the first-ever demonstration of the SweepSAR technique, reducing DESDynI implementation risks by enabling evaluation of SweepSAR data collection in a real-world environment, to uncover issues and enable performance studies that cannot be done by simulation alone

SweepSAR Airborne Demo Antenna Installation In DC-8 Cargo Bay



Outlook for DESDynI

- DESDynI concept presented here passed its Mission Concept Review in January 2011
- President's FY12 Budget Proposal (February 2011) reset the go-forward plan for DESDynI
  - Lidar mission to be contributed, not funded by NASA
  - Radar mission to be implemented more affordably
- NASA continues to invest in DESDynI
  - Forming a Science Definition Team
  - Continuing trade studies at JPL
- NASA is currently exploring options for reducing cost
  - Reducing number and scope of science requirements levied on DESDynI
    - + DESDynI in combination with other satellites to approach DESDynI requirements
  - Find international partners interested in the science and technology
  - Find domestic partners that would increase utility of DESDynI data

Summary

- DESDynI as presented here would provide exciting scientific returns in three distinct science disciplines by exploiting the complementary power of wide-area mapping radar and vertically-profiling lidar
- DESDynI would provide direct benefits to society as its measurements are used to help forecast sea level rise and the likelihood of earthquakes or volcanic eruptions and to improve forest inventories and carbon monitoring
- DESDynI measurements would be unique and available to the world for scientific use
  - L-band full-resolution, full-swath, 13 day repeat capability would revolutionize our ability to characterize natural hazards, quantify ice dynamics, and monitor Earth's changing terrestrial carbon stocks
  - 5-beam 1-micron 25-m footprint profiling lidar in space was optimized to produce unprecedented estimates of terrestrial carbon storage and ice topography
  - Accuracy/resolution/coverage would be orders of magnitude improvement over existing scientifically available data
- DESDynI is still in pre-formulation!
- However, in light of recent budgetary direction, new ideas for implementing DESDynI more affordably must be explored vigorously