The Vital Role of ICESat Data Products

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Land Ice

Sea Ice

Vegetation

Why Do We Need ICESat-2?

"Earth Science and Applications from Space: National Imperatives for the next Decade and Beyond " (National Research Council, 2007)
http://www.nap.edu

ICESat-2 is one of four first-tier missions recommended by the 2007 NRC Earth Science Decadal Survey

Tier 1	
	SMAP
	ICESat-2
	DESDynI
	CLARREO
Tier 2	
	SWOT
	HYSPIRI
	ASCENDS
	GEO-CAPE
	ACE
Tier 3	
	LIST
	PATH
	GRACE-II
	SCLP
	GACM
	3D-WINDS

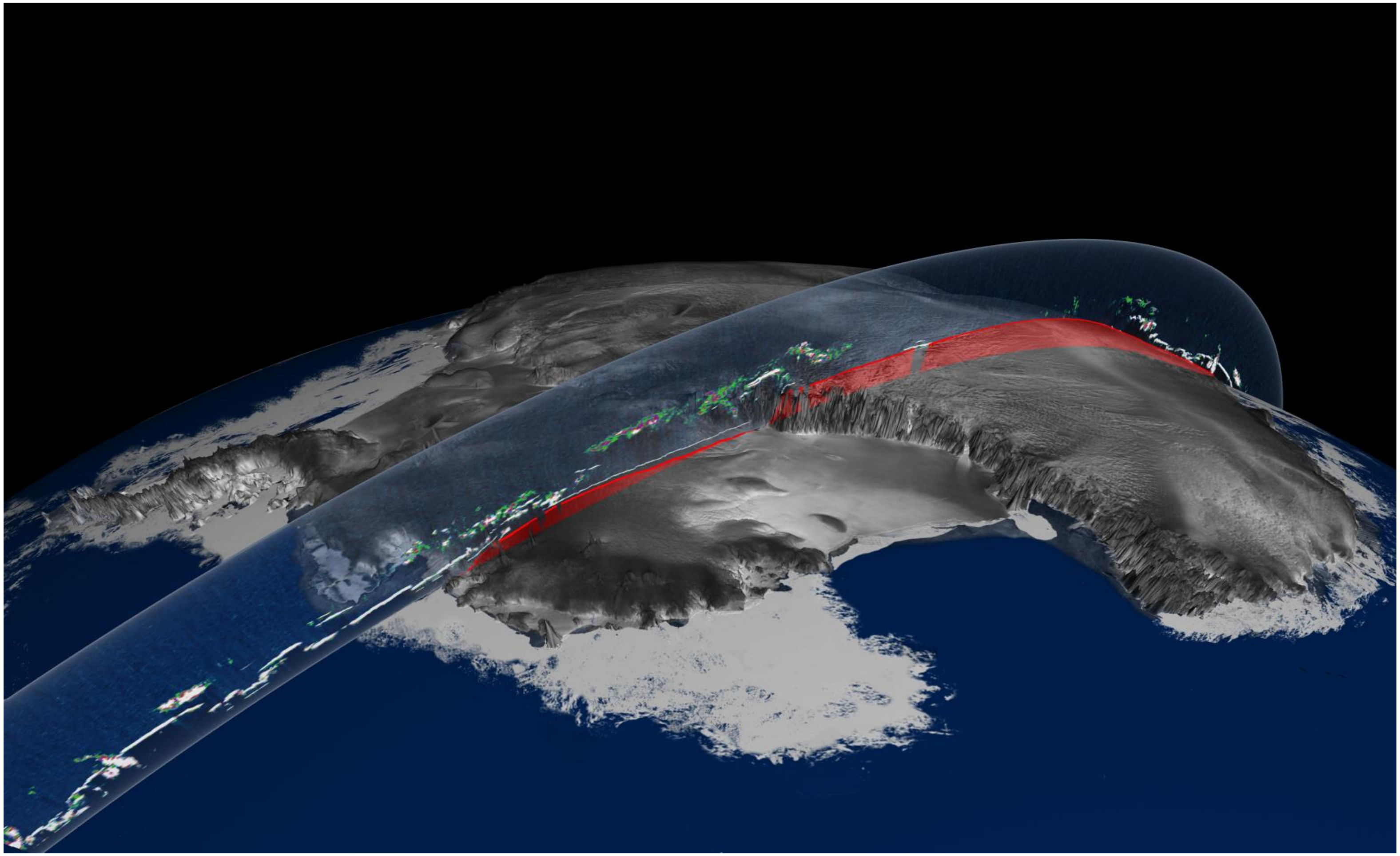
On February 14, 2008 NASA announced the selection of ICESat-2 Project

The First ICESat Mission

- Launched in 2003 as a three-year mission with a goal of returning data for five-years
- Deployed a space-based laser altimeter – Geoscience Laser Altimeter System (GLAS)
- Laser lifetime issues mandated change in operational approach
- Significant Contribution to Earth Science
    - Multi-year elevation data used to determine ice sheet mass balance and cloud properties
    - Topography and vegetation around the globe
    - Polar-specific coverage over Greenland and Antarctic ice sheets
- Mission ended in 2009 after seven years in orbit and 15 laser-operation campaigns

ICESat Data Swath of Antarctica

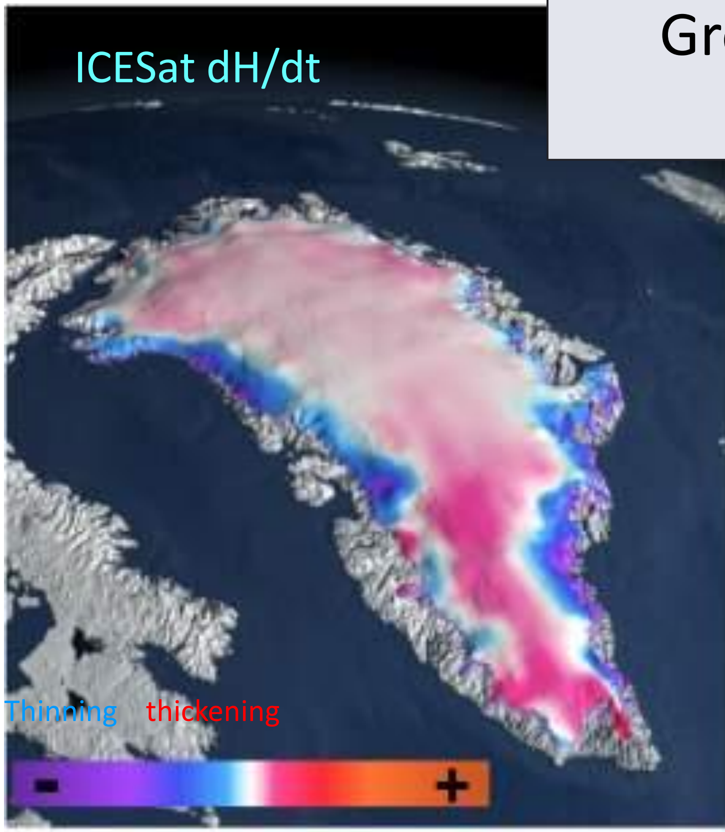
Image shows Ice Sheet Elevation and Clouds

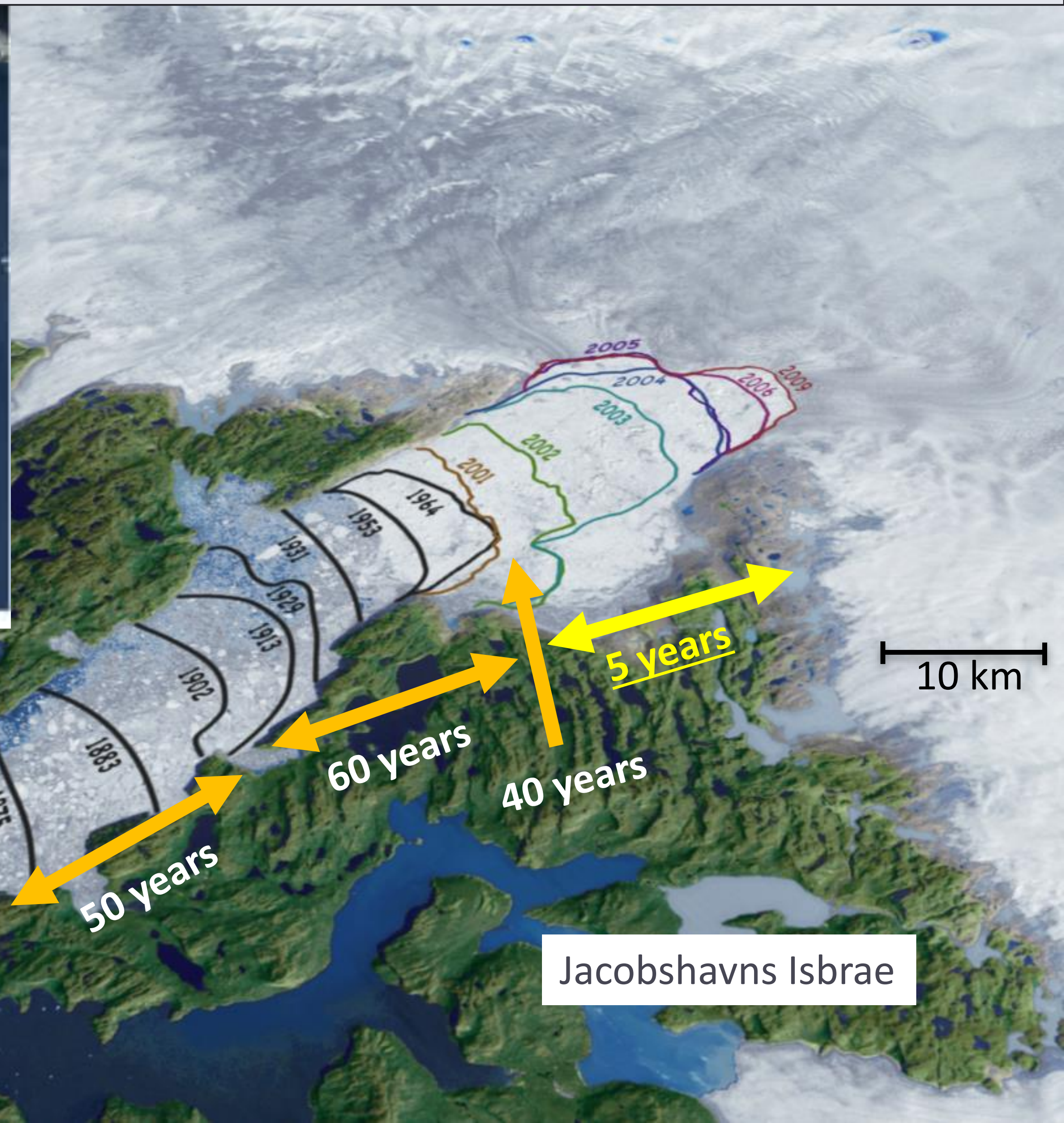


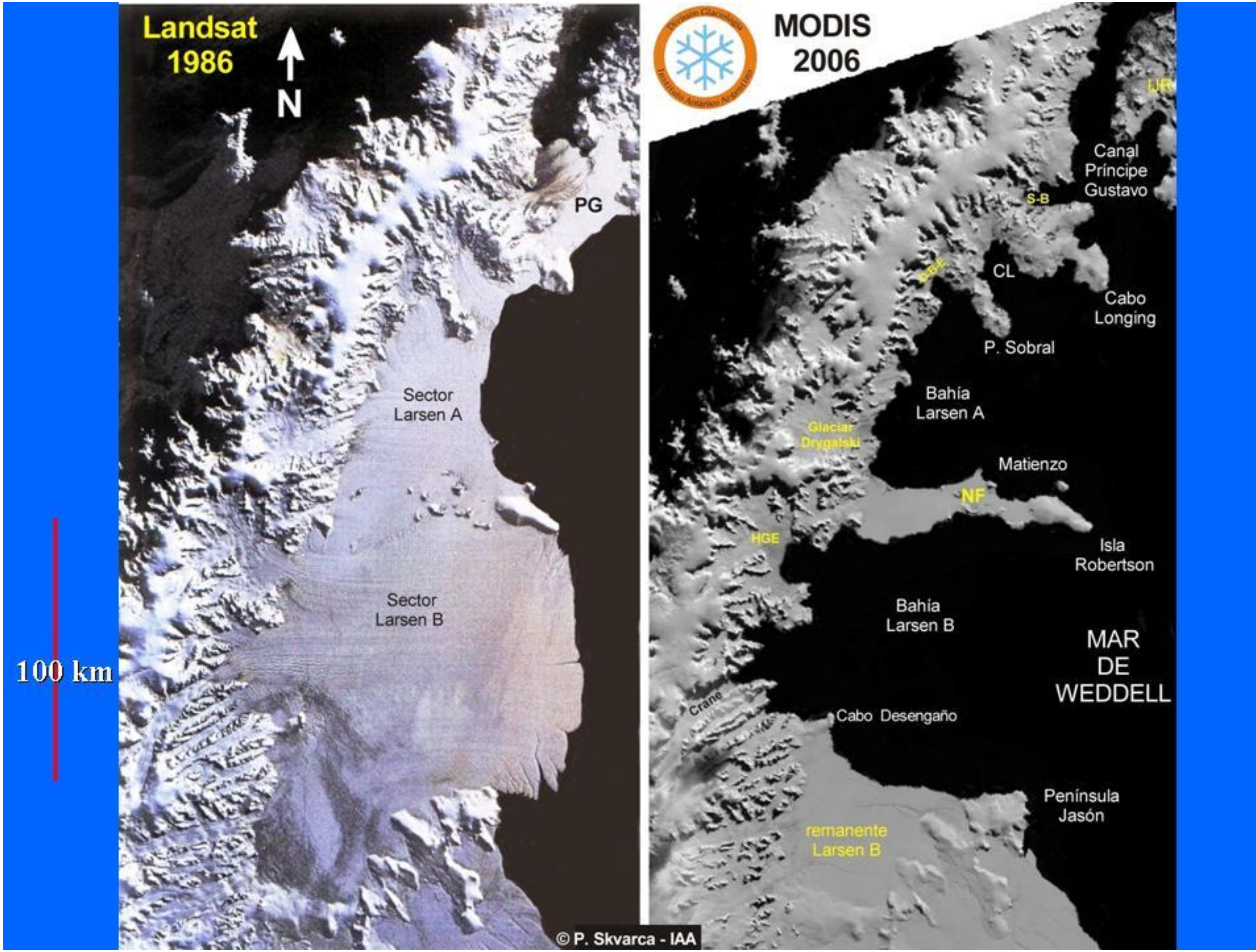
Next ICESat Mission

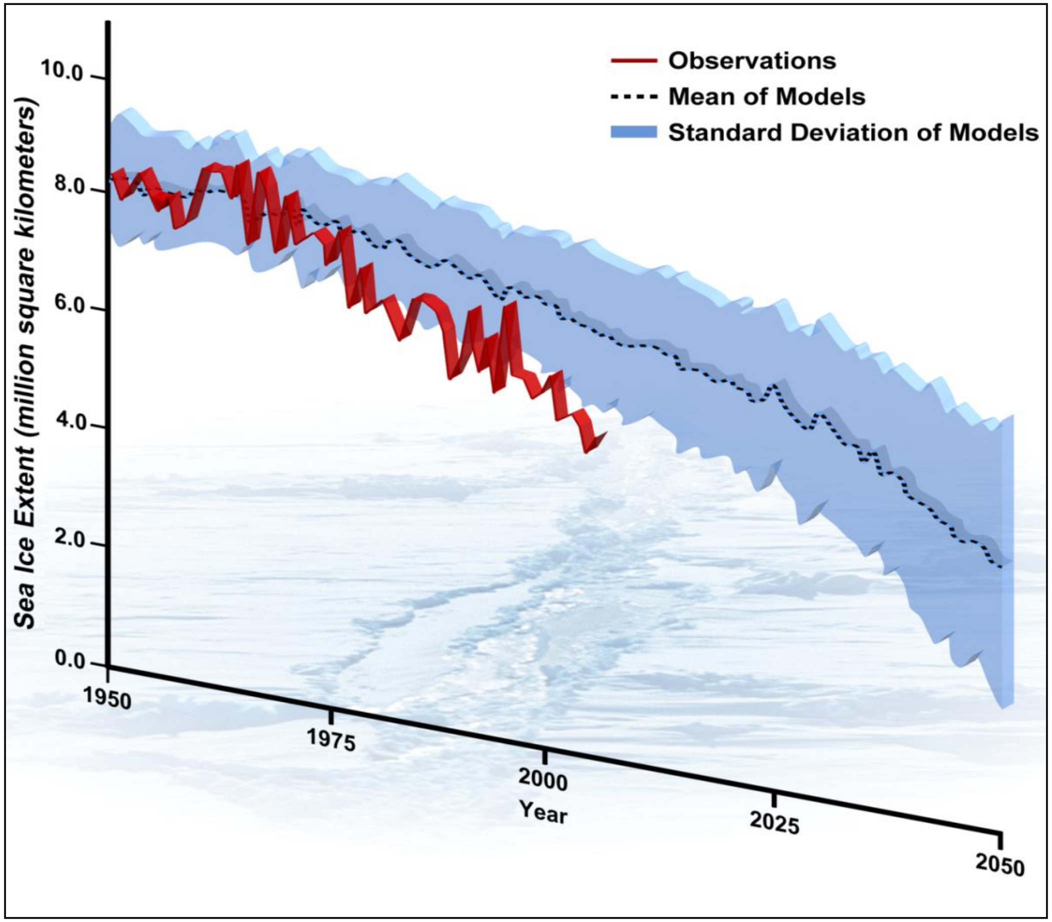
- Decadal Survey identified the next ICESat satellite as one of NASA's top priorities
- In 2003, ICESat-2 Mission award to Goddard Space Flight Center (GSFC)
- Observatory will use a micro-pulse multi-beam approach
  - Provide dense cross-track sampling
  - High pulse repetition rate producing dense along-track sampling
- Improved elevation estimates over high slope areas and rough areas
- Improved lead detection of sea ice freeboard estimates

Greenland and Antarctica are losing mass... especially in the outlet glaciers





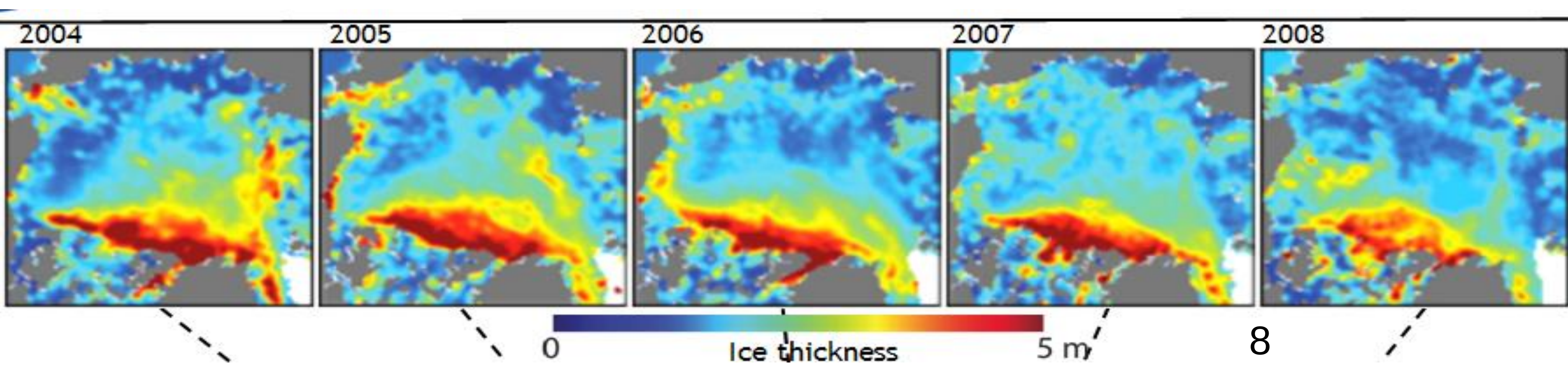

Landsat
1986
N
PG
Sector
Larsen A
Sector
Larsen B
100 km
© P. Skvarca - IAA
MODIS
2006
Canal
Príncipe
Gustavo
S-B
CL
Cabo
Longing
P. Sobral
Bahía
Larsen A
Glaciar
Drygalski
Matienzo
NF
HGE
Isla
Robertson
Bahía
Larsen B
MAR
DE
WEDDELL
Crane
Cabo Desengaño
Península
Jasón
remanente
Larsen B



Summer sea ice extent is decreasing faster than predicted by IPCC models

From ICESat

- Sea ice thickness has decreased by about 2.2 ft
- Area of thick, multiyear ice has decreased by 42%



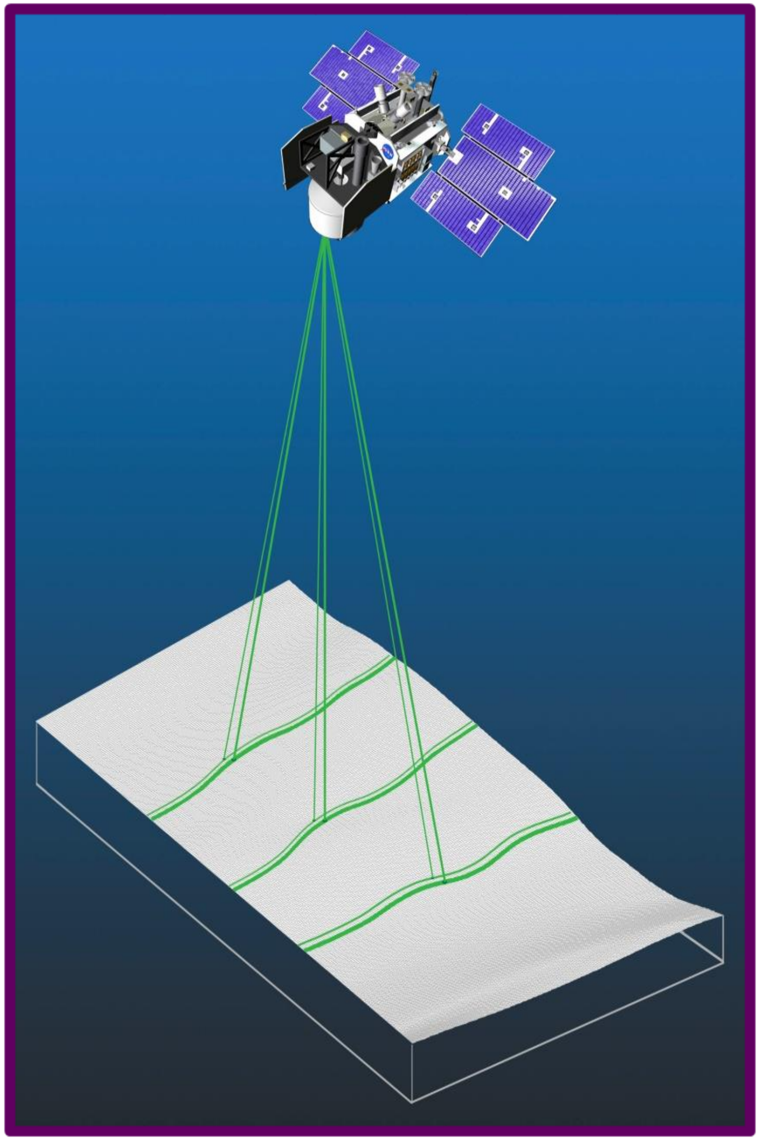
ICESat-2 Science Objectives

- Quantifying polar ice-sheet contributions to current and recent sea-level change and the linkages to climate conditions
- Quantifying regional signatures of ice-sheet changes to assess mechanisms driving those changes and improve predictive ice sheet models
- Estimating sea-ice thickness to examine ice/ocean/atmosphere exchanges of energy, mass and moisture
- Measuring vegetation canopy height as a basis for estimating large-scale biomass and biomass change
- Enhancing the utility of other Earth observation systems through supporting measurements

ICESat-2 Measurement Concept

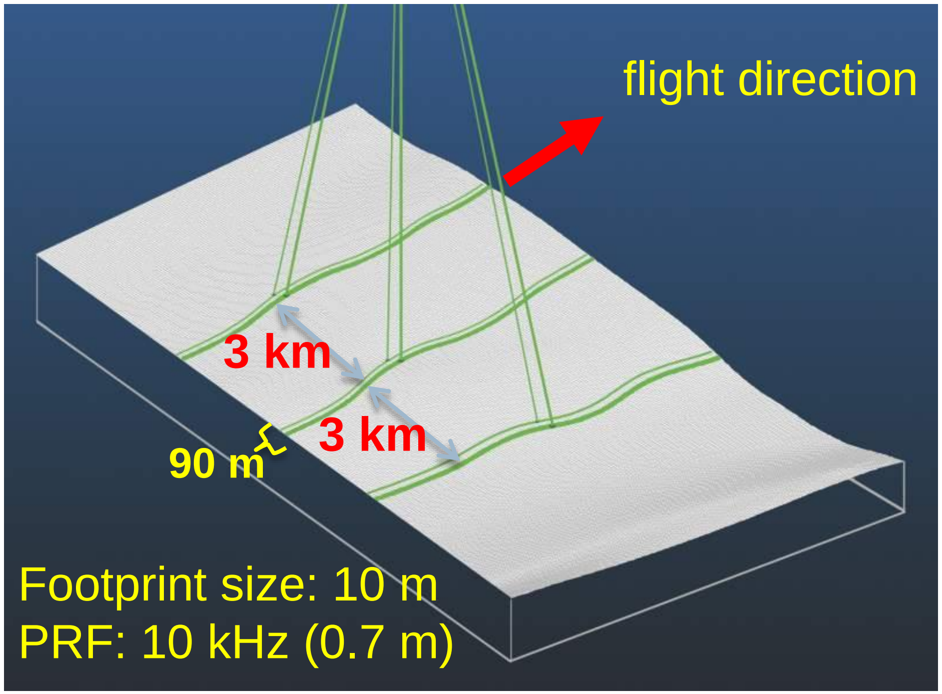
In contrast to the first ICESat mission, ICESat-2 will use *micro-pulse multi-beam photon counting* approach

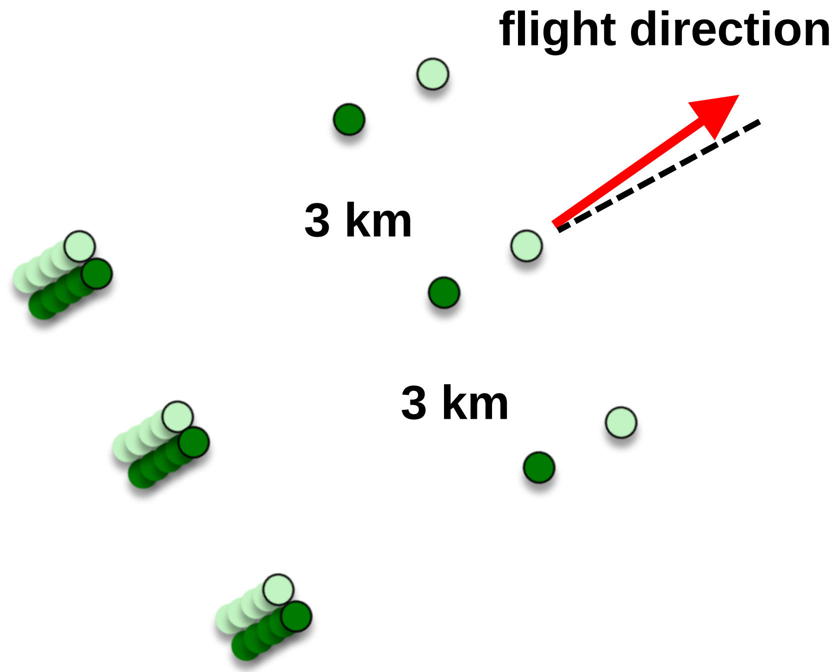
- **Provides:**
  - ➢ Dense cross-track sampling to resolve surface slope on an orbit basis
  - ➢ High repetition rate (10 kHz) generates dense along-track sampling (~70 cm)
  - ➢ Different beam energies to provide necessary dynamic range (bright / dark surfaces)
- **Advantages:**
  - ➢ Improved elevation estimates over high slope areas and very rough (e.g. crevassed) areas
  - ➢ Improved lead detection for sea ice freeboard



ICESat-2 Measurement Concept

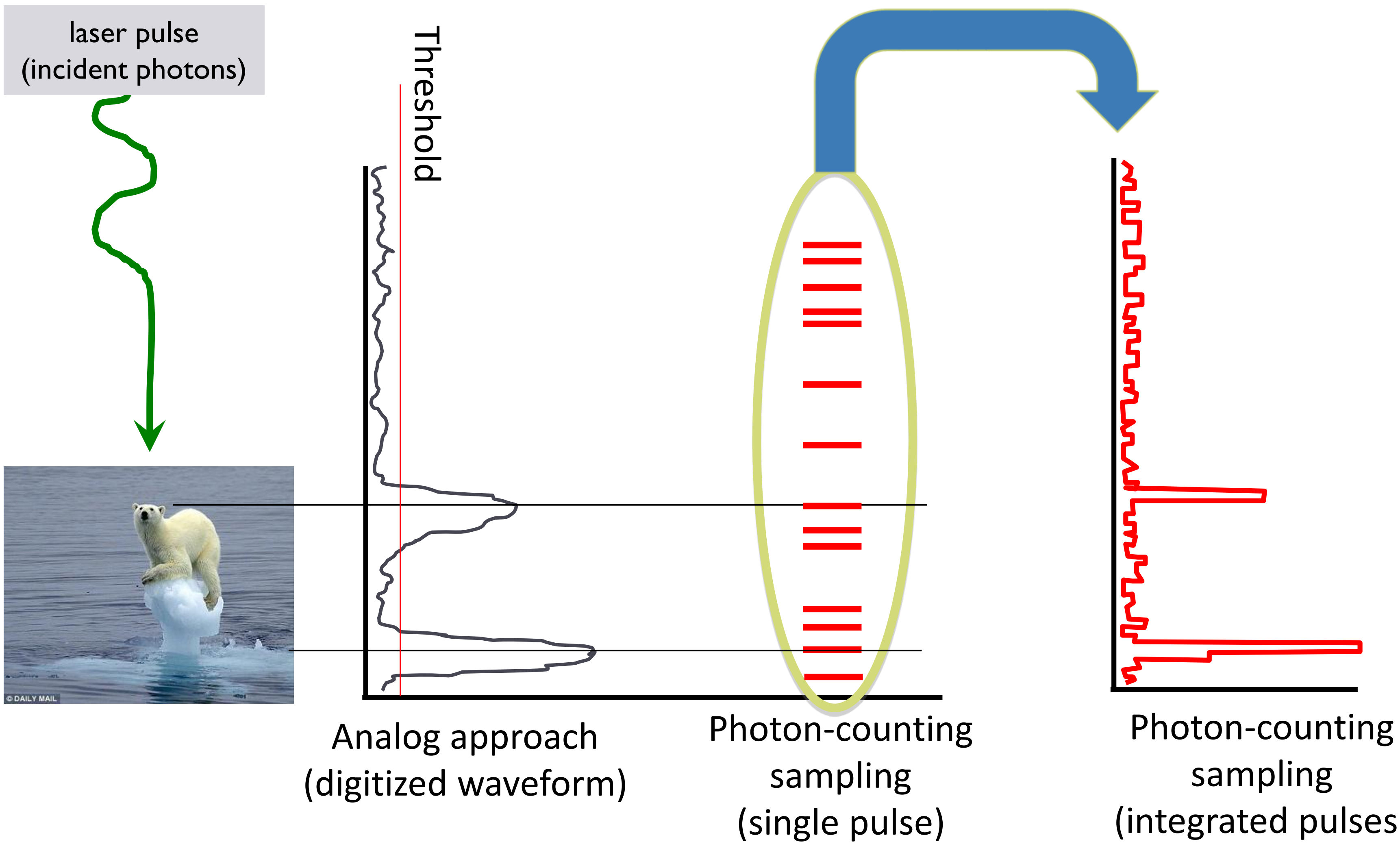
Single laser pulse, split into 6 beams. Redundant lasers, Redundant detectors.





3 km spacing between pairs provides spatial coverage
90 m pair spacing for *slope determination* (2 degrees of yaw)
high-energy beams (4x) for better performance over low-reflectivity targets

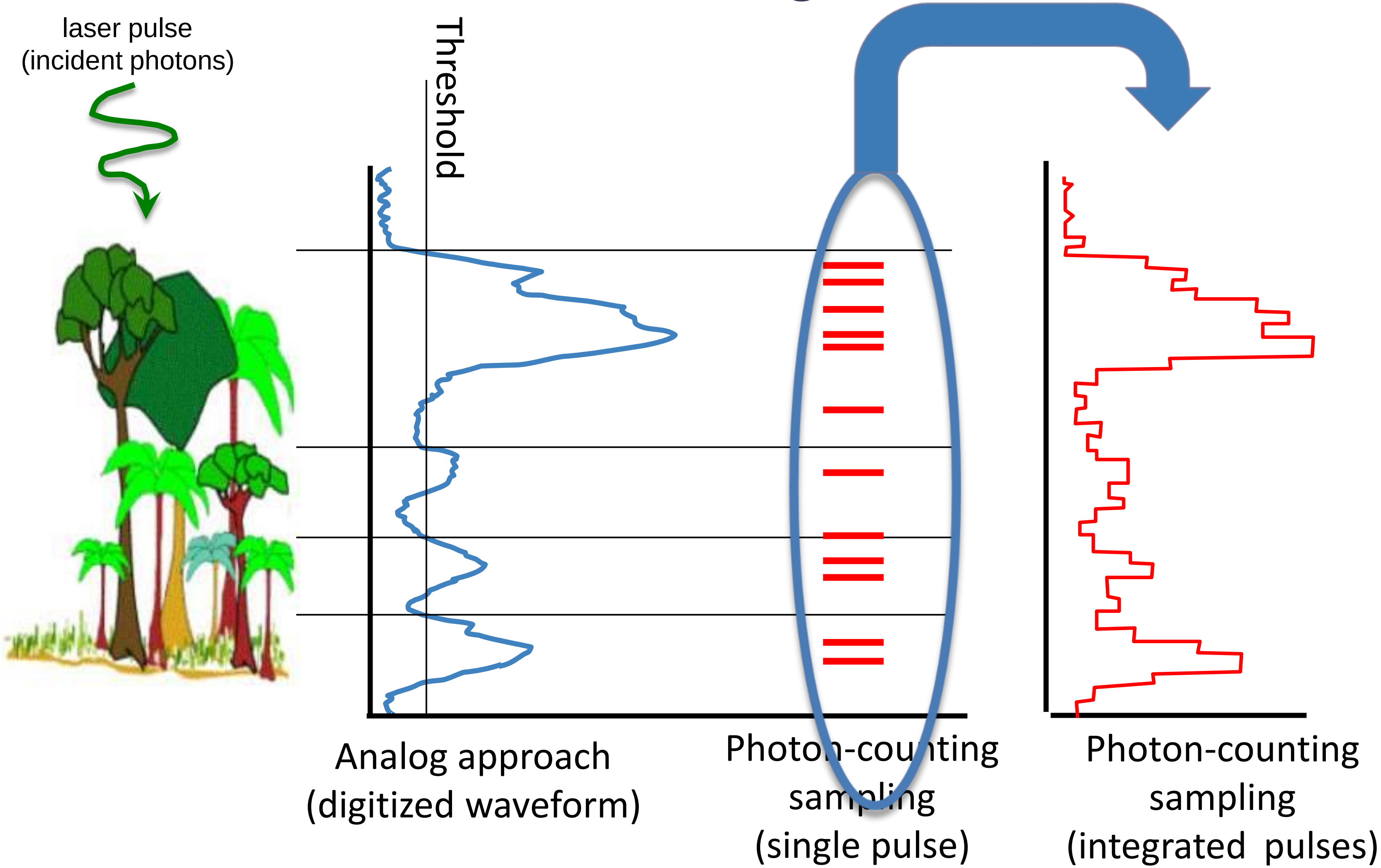
Analog vs. Photon-Counting



IMPORTANT: the integrated photon-counting sample ("histogram") _looks_ like the analog wave for but _it is not_ – the information content is different, and the method of analyzing the data is different

Analog vs. Photon-Counting

can also do it for vegetation



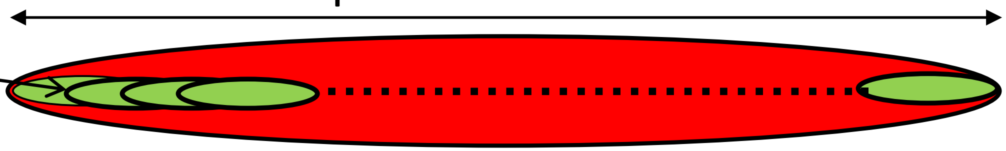
IMPORTANT: the integrated photon-counting sample ("histogram") *looks* like the analog waveform, but *it is not* – the information content is different, and the method of analyzing the data is different.

Find the Surface Return?

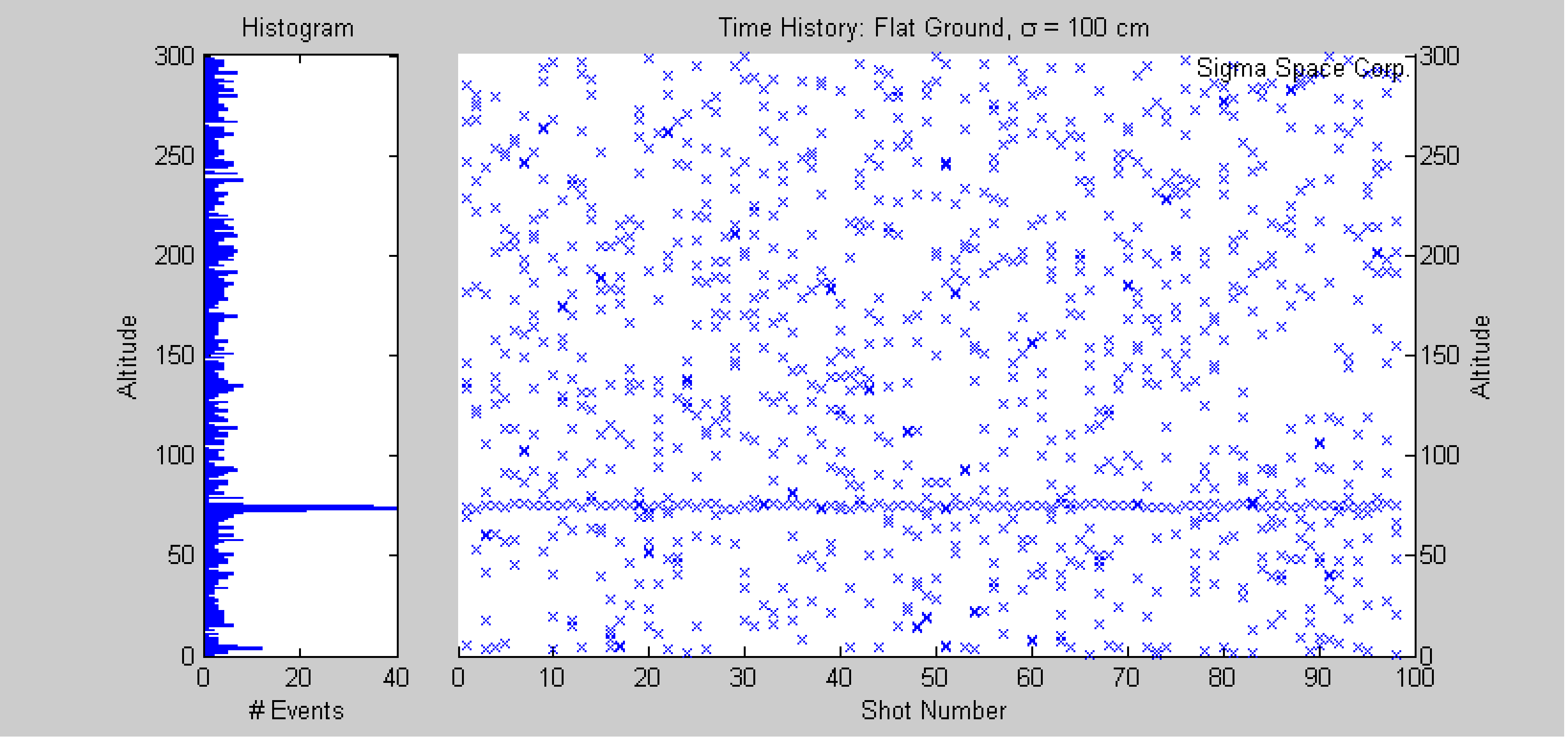
- Simulation assumes horizontal surface (zero slope)
- 10 noise photons and 1 surface signal photon per pulse
- Averages 100 Micropulse pulses (equivalent to 1 GLAS footprint)

GLAS spot = 70 meters

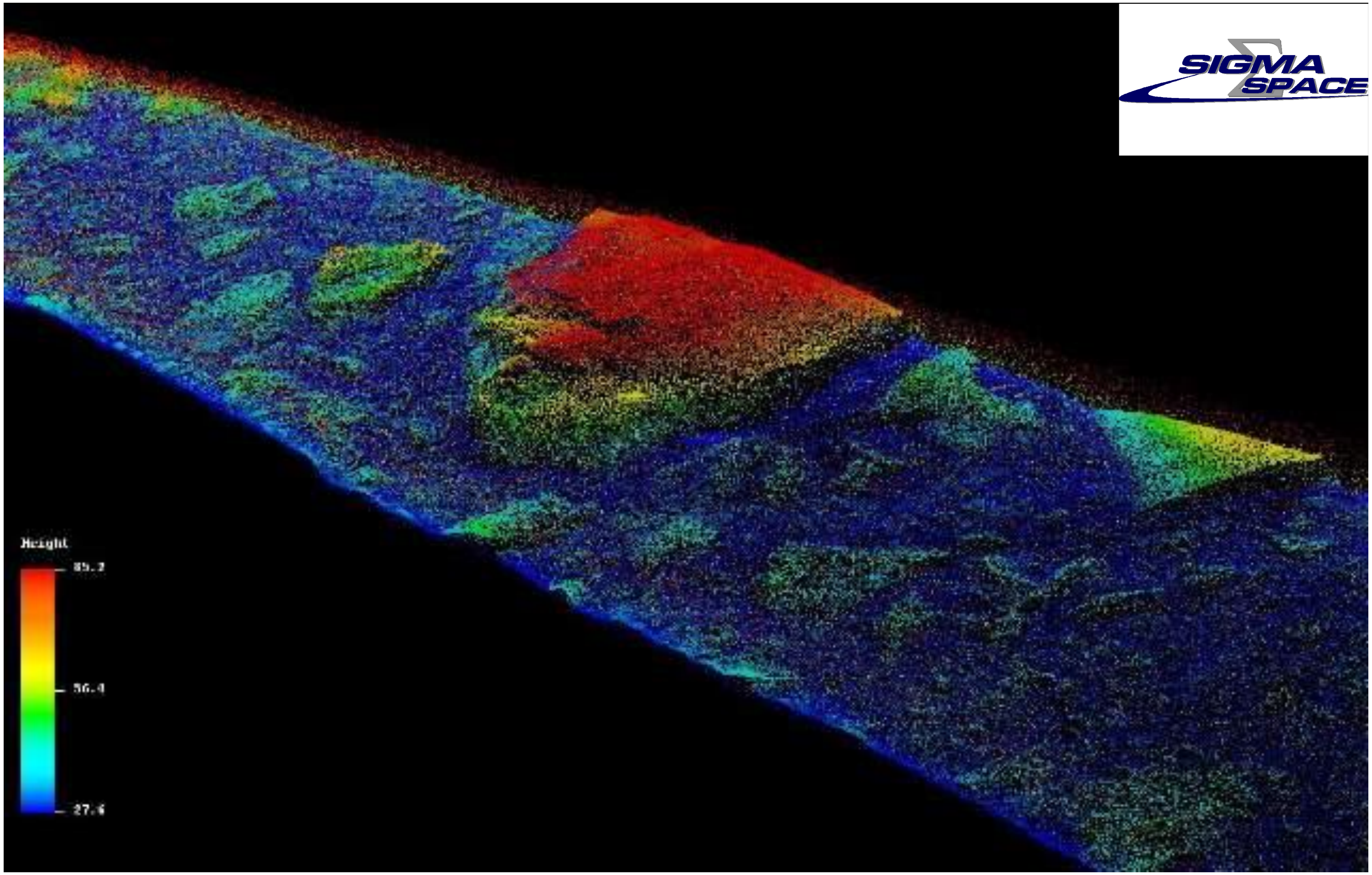
Micropulse spots are
10 m with 0.7 m spacing



300 m Range Window

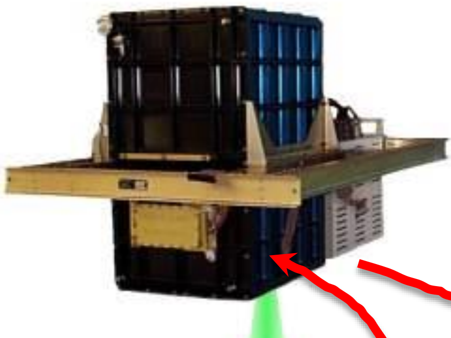


Data Example from P-C Altimeter

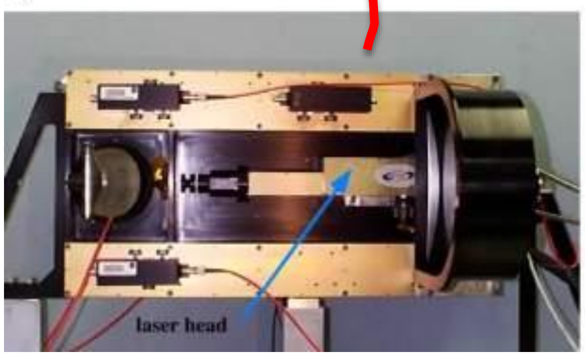


Example of a 3-D “image” of an ice chunk in Greenland from a photon-counting laser altimeter using 100 beams and scanning

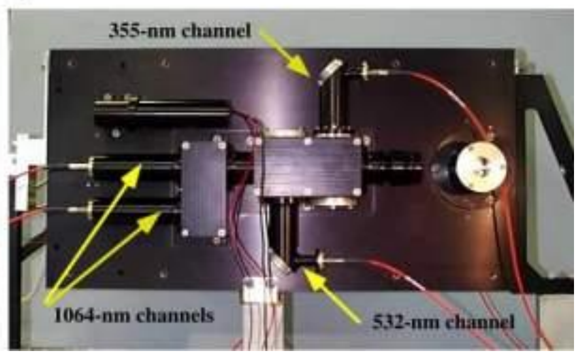
Atmospheric example of photon-counting
Cloud Physics Lidar



a)

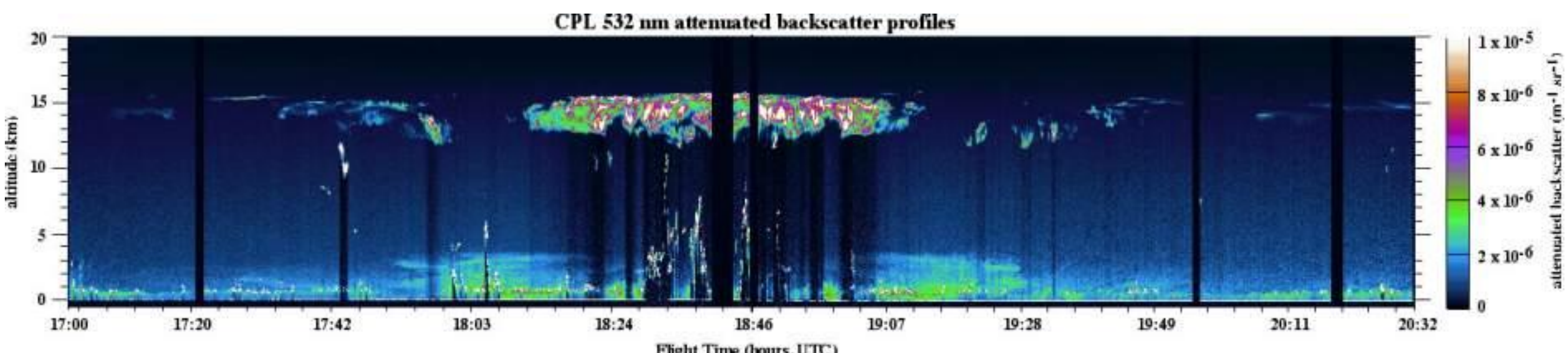


b)



Originally developed for the ER-2 aircraft, CPL is an autonomous, 3-wavelength, high-altitude backscatter lidar.

Use of a high rep-rate laser enables photon-counting detection, which in turn enables fast turn-around for data processing.



ICESat-2 Mission Overview

- Single instrument mission
    - Advanced Topographic Laser Altimeter System (ATLAS)
    - Multi-beam micro-pulse laser based instrument – utilizing photon counting
    - Design assembly and test at Goddard
- Spacecraft
    - Six vendors have shown interest
    - RSDO Spacecraft Procurement
- Launch Vehicle
    - Selection prior to S/C Preliminary Design Review (PDR)
- Mission Operations
    - Performed at Mission Operations Center (MOC) location
    - Instrument Support Terminal at GSFC
- Space Communications
    - NASA Ground Network
- Project Implementation and Management performed by GSFC

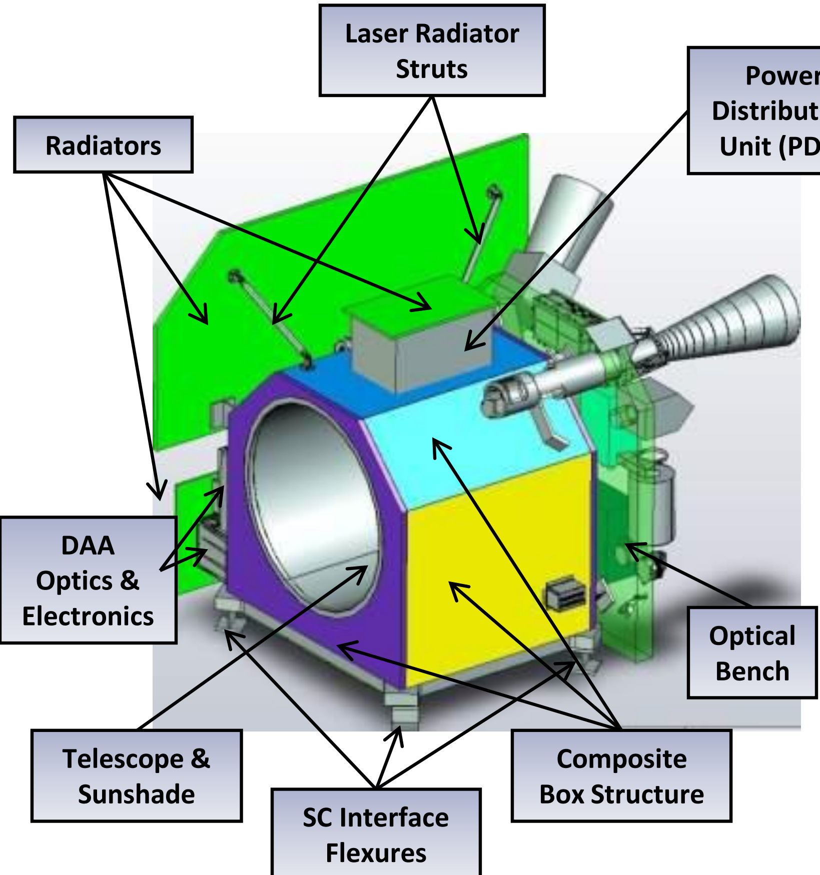
Mission Development Schedule

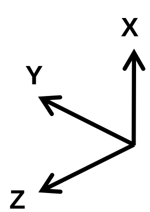
- Phase A start	December 2009
- SRR/MDR	May 2011
- PDR:	March 2012
- CDR:	March 2013
- MOR:	April 2014
- PSR:	December 2015
- LRD:	April 2016

Mission Class	ICESat-2 Mission Specified as Class C i
Launch	April 2016
Orbit	Orbit: 600 km, circ, 94 inclination, 91-day repeat
Life	3 years
Payload	Dedicated multi-beam lidar Instrument
Spacecraft	Dedicated Spacecraft

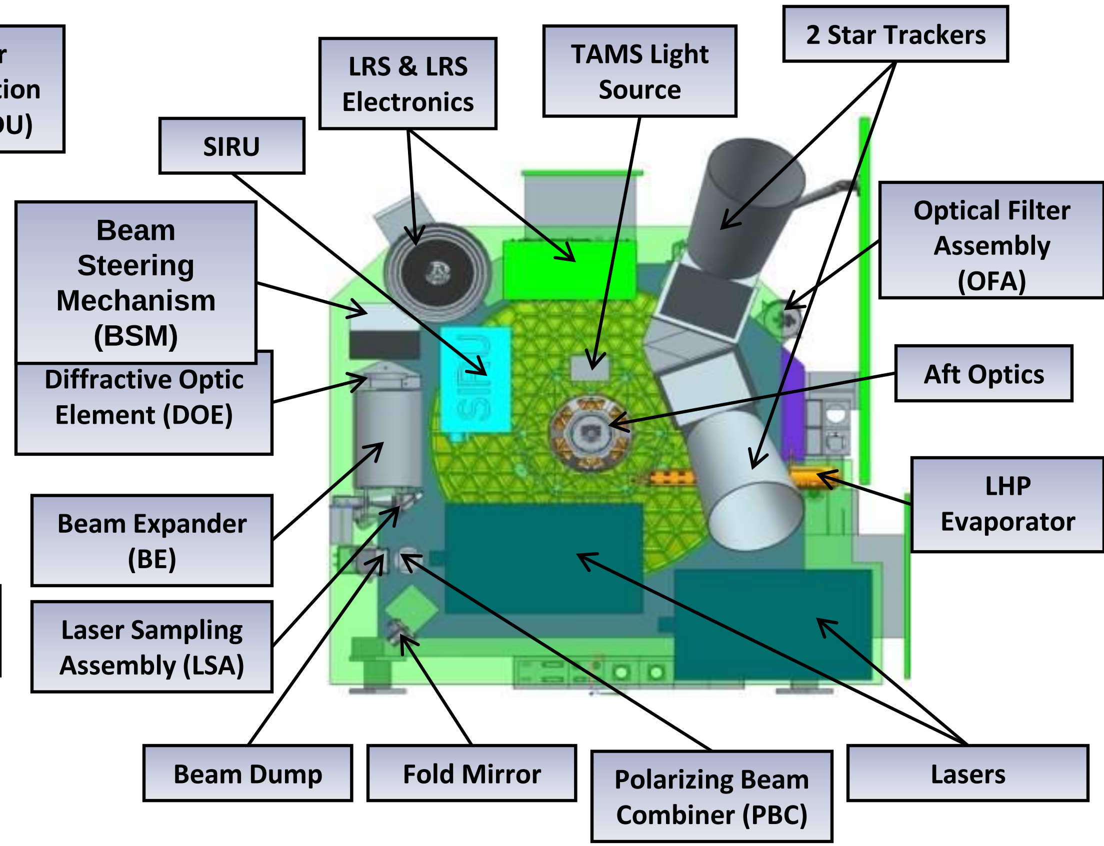
ATLAS Instrument Overview

A key function of the structure is to provide component & subsystem layout

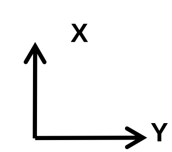




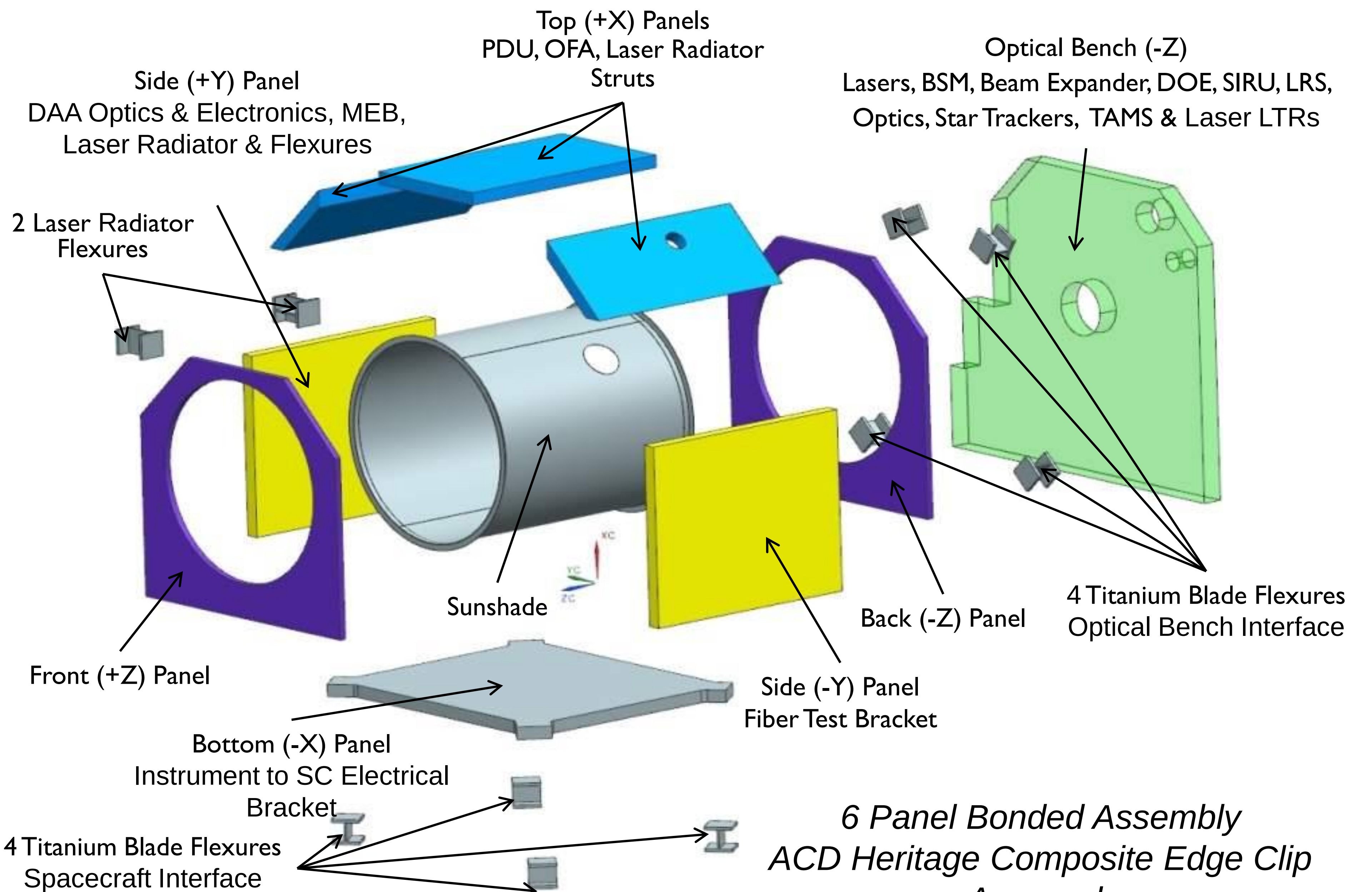
Isometric View



Optical Bench

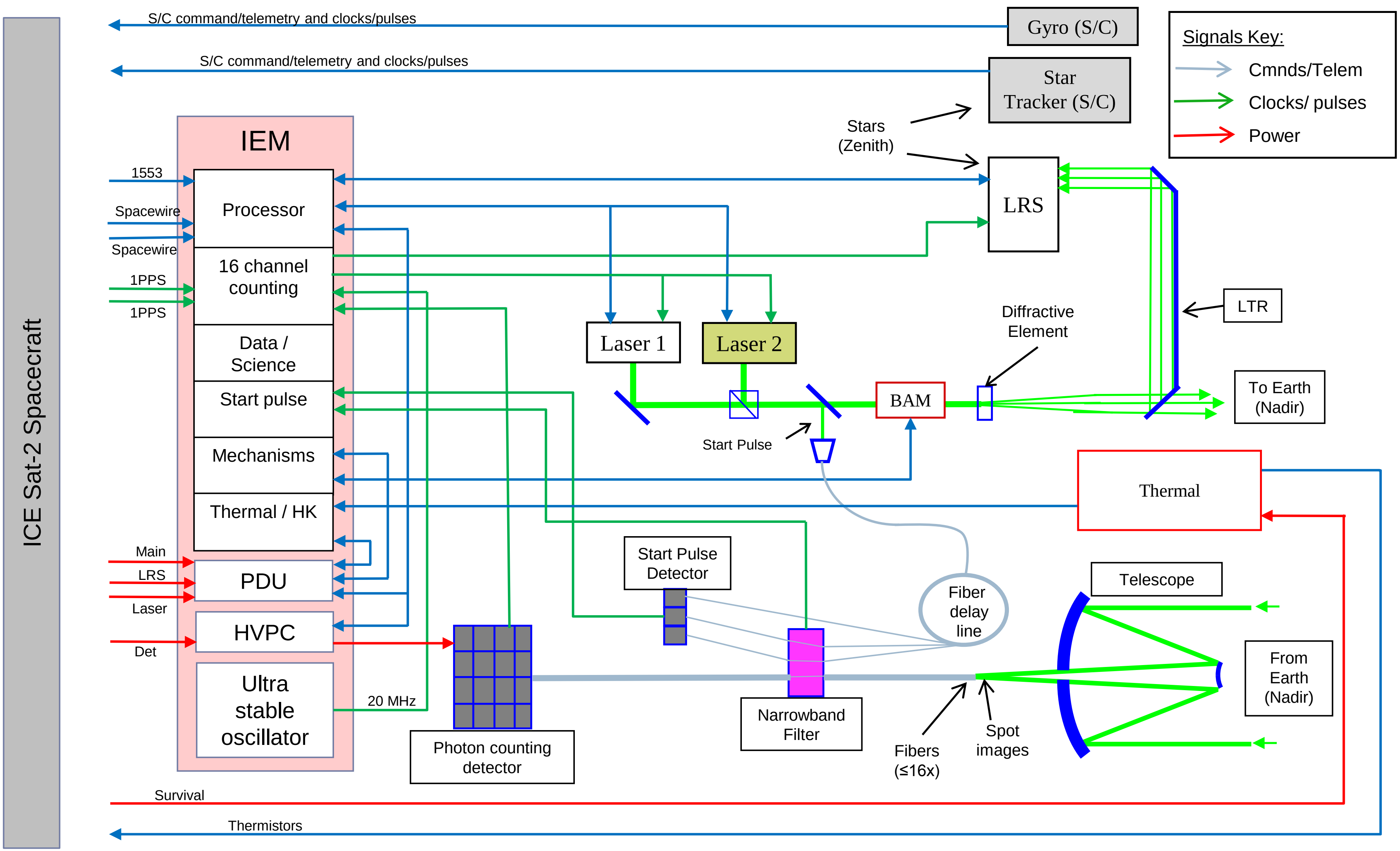


Structure Assembly - Exploded Model

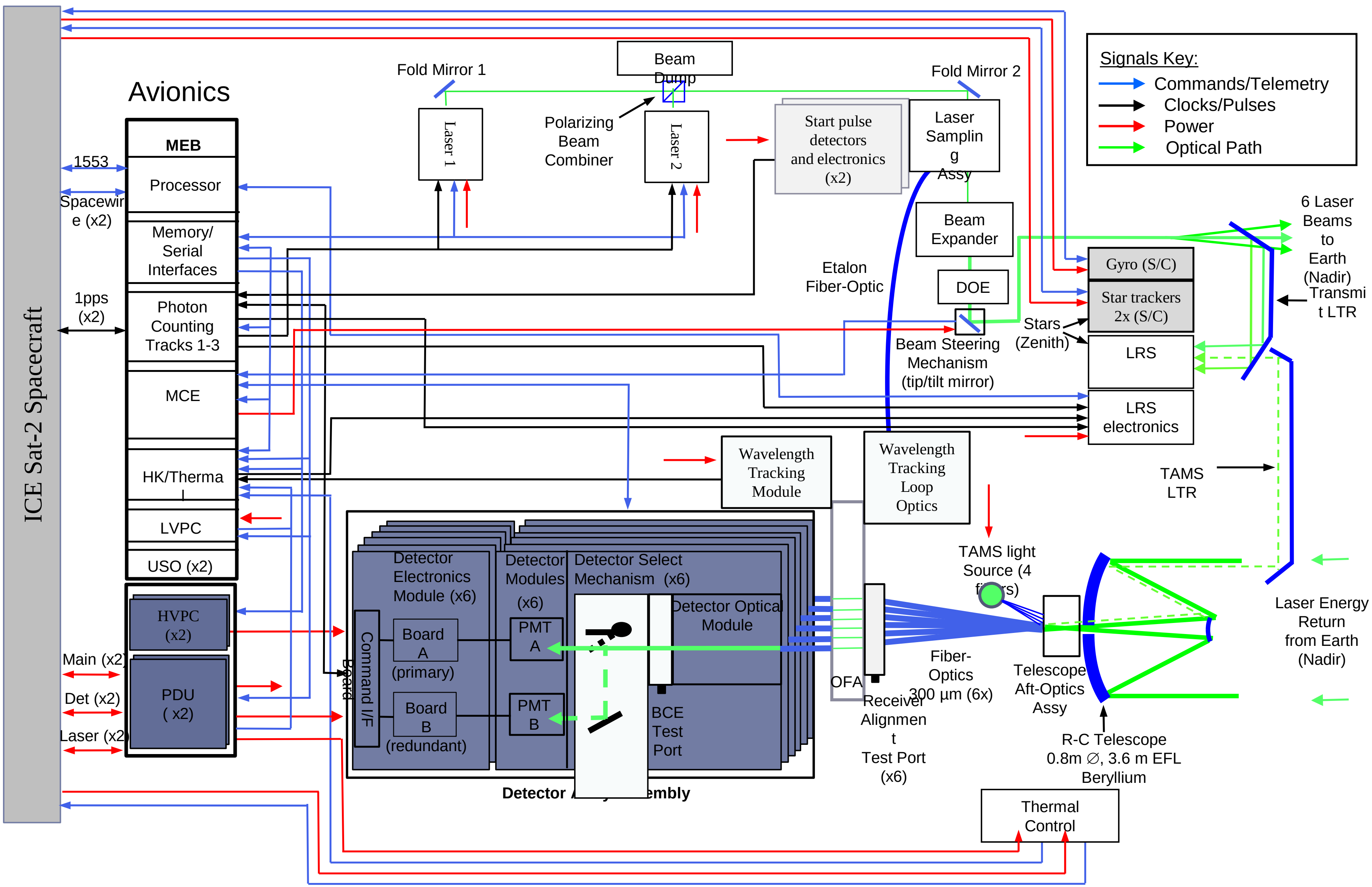


6 Panel Bonded Assembly
ACD Heritage Composite Edge Clip Approach

Instrument Block Diagram

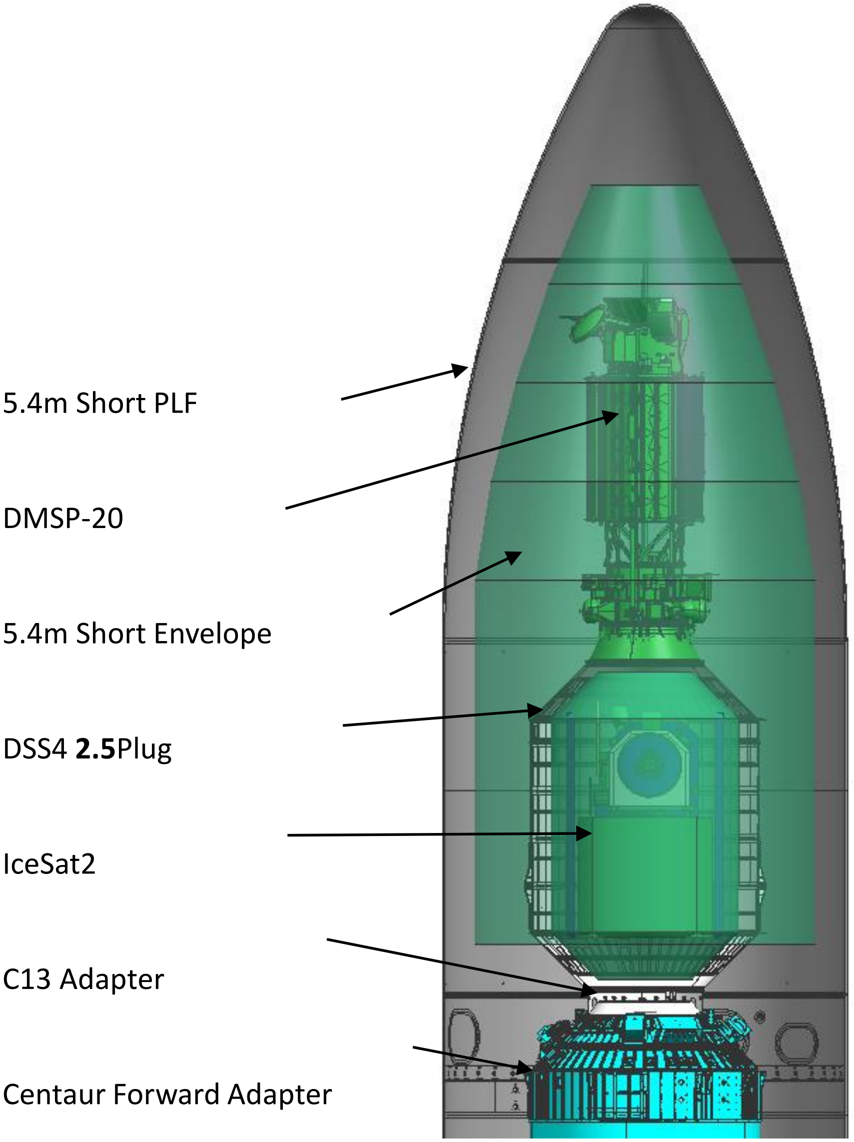


ATLAS Functional Block Diagram



Access to Space

- ICESat-2 is baselined as a co-manifest dual-payload launch
- Working several options – DMSP-20 is the primary opportunity
- This approach is mandated because of the lack of qualified medium-class launch vehicles
- There are several challenges and risks associated with this approach that must be "managed"
    - ➢ Schedule issues complicated this process
    - ➢ Engineering design issues overlay a added level of complexity
    - ➢ Challenges associated with interactions between NASA and partner – at all levels of management



ICESat-2 Operational Concept

- ICESat-2 is a 3-year mission divided into five phases:

  - Pre-Launch Phase - The Pre-Launch Phase consists of all design, development, test, and integration activities for the spacecraft, instrument, ground system, and launch vehicle through launch readiness

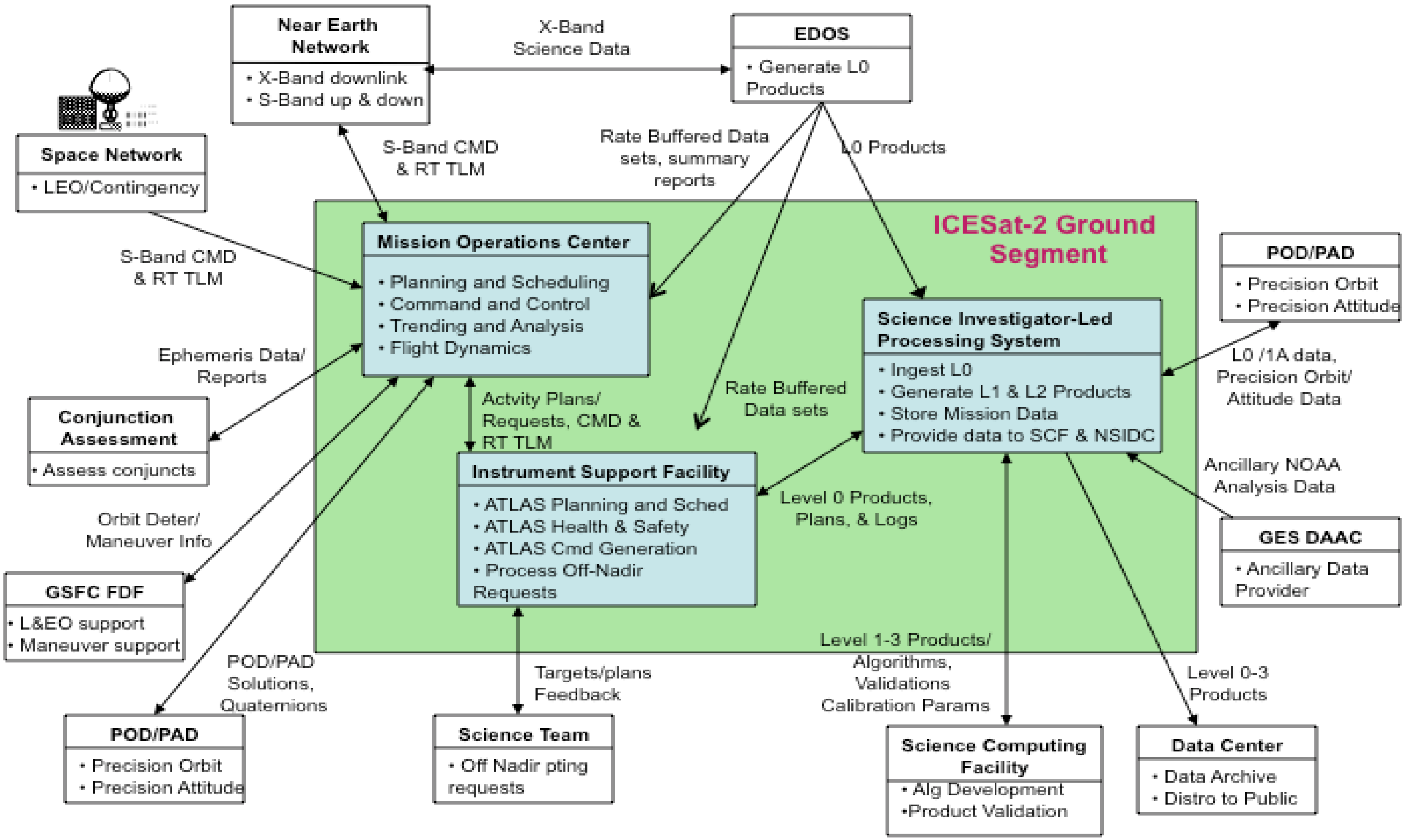
  - Launch and Early Orbit - The Launch and Early Orbit (LEO) Phase begins with the final launch countdown through the observatory attaining the initial orbit

  - Commissioning - The Commissioning Phase begins after the initial orbit is attained and lasts for no more than 60 days. During the Commissioning Phase, spacecraft and instrument checkout and initial calibration will be completed

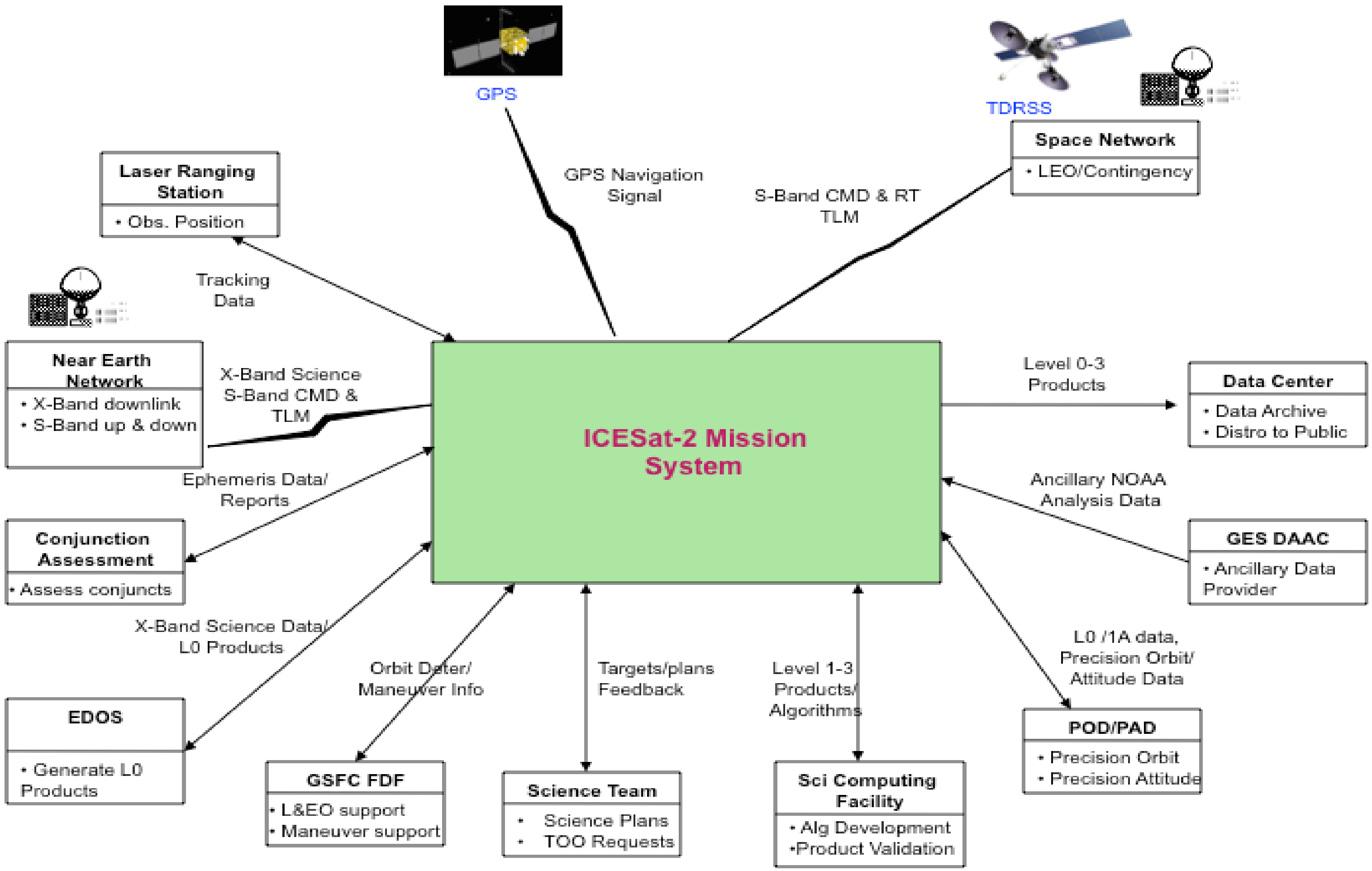
  - Operations - The Operations Phase begins at the completion of the Commissioning Phase and will last for 3 years during which time science data will be collected on the observatory, dumped to the ground for processing and distributed for science use

  - Decommissioning - The Decommissioning Phase begins at the completion of the Operations Phase and at the direction of NASA. It includes all the planning and activities required to passivate the observatory, concluding with the successful de-orbit of the observatory

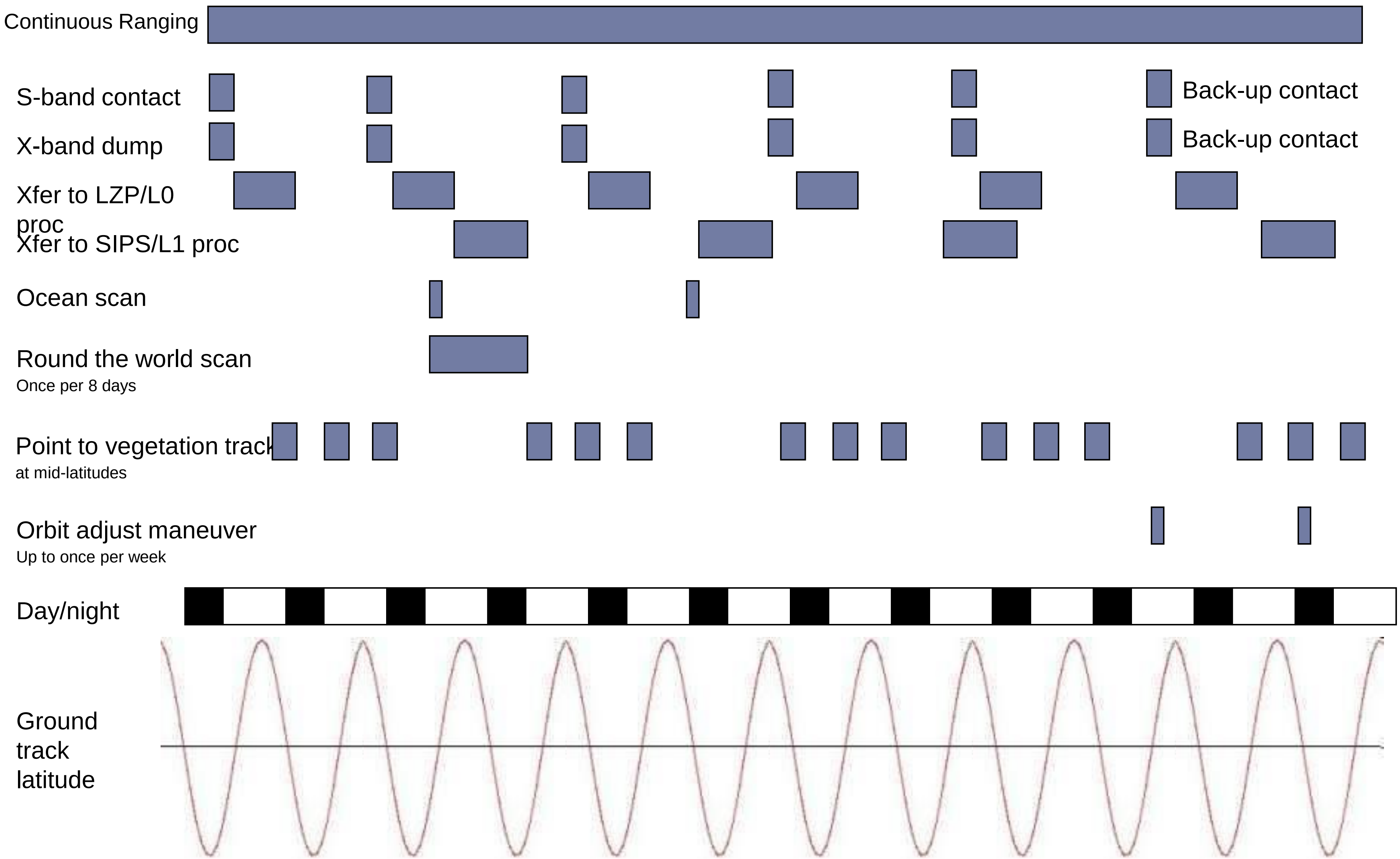
Ground Segment



External Interfaces



A Day in the Life of ICESat-2



Typical Day in the Life Data Processing (Year 2)

Process	Local Hour Data Day
Receive Level 0	N
Process L1A	N
Distribute L1A to SCF/POD	N
Receive POD/PAD v1	N-3
Process L1B,L2	N-3
Distribute L1B,L2 to SCF	N-3
Receive POD/PAD v2	N-60
Process L1B,L2	N-60
Distribute L1B,L2 to SCF	N-60
Receive POD/PAD v3	N-360
Process L1,L2	N-360
Distribute L1,L2 to SCF/POD	N-360
Distribute L1,L2 to NSIDC	N-90
Distribute L1,L2 to NSIDC	N-390
Process L3	N-90to180
Distribute L3 to SCF	N-90to180

L1A – Reformatted Telemetry

- Parsed, reformatted, time ordered telemetry remaining in downlink units
- Conversions of selected parameters of data ordering and monitoring

L1B – Science Unit Converted Telemetry

- Science unit converted time ordered telemetry. Reference Range/Elevations determined by ATBD Algorithm using Predict Orbit and s/c pointing. All photon events per channel per shot.
- L1B is a per-event product –Contains all data.
- Will not contain precise geolocation, only uses predict orbits or coarse location is available in the telemetry.
- L1B provides all of the telemetry pieces that go into the ground finding and geolocation:
  - For a given shot: times of photon events; retains beam information, channel information, etc…

L2A – High Rate Geophysical

- Reference Range/Elevations determined by ATBD Algorithm using POD and PPD. All photon events per shot per beam. Includes POD and PPD vectors.
- The conversion from L1B to L2A is where the Science algorithms take over.
- Geolocation provided on a per-shot, per beam basis.
- Geolocation requires finding the surface, as such an algorithm will need to aggregate many photon events and many consecutive shots.
- L2A will report the reference range used in the geolocation calculationfor the reported lat, lon of a each shot. This range need not be the highest-accuracy range possible, but should be correct to < ~100m.
- Recall: downlinked data will have limited telemetry range window(0.5 to 6 km), per flight algorithm use of DEM and DRM. Therefore it will not contain photon events from high in the atmosphere. It will be subject to false alarm and contain noise within the telemetry range window.
- L2A provides all of the pieces needed for alternate/refined/selective algorithm ground finding, surface characterization and geolocation for higher level products or research:
    - For a given shot: times of photon events; retains beam information, components of POD, PPD analyses at natural rates; rotation matrix, etc…

L2A- Reference Range

- How to decide which photons to use to find ground? Algorithm TBD, but will require many shots. This could be done many ways, but one approach needs to be selected to produce a reference range.
- Once a reference range is determined, then a geolocate a center of each illuminated footprint, on a per-shot per-beam basis will be computed.
- Process requires interpolation of both POD and PPD and a combination of many along-track shots. For some shots, we may not have any surface-reflected photons, but will still report a geolocation center for that shot.

What's Next

- Spacecraft contract in place this summer
- Instrument PDR in late fall
- Detailed design underway in late 2011
- Mission PDR in early 2012
- Mission CDR in early 2013
- Launch from Vandenberg Air Force Base April 2016