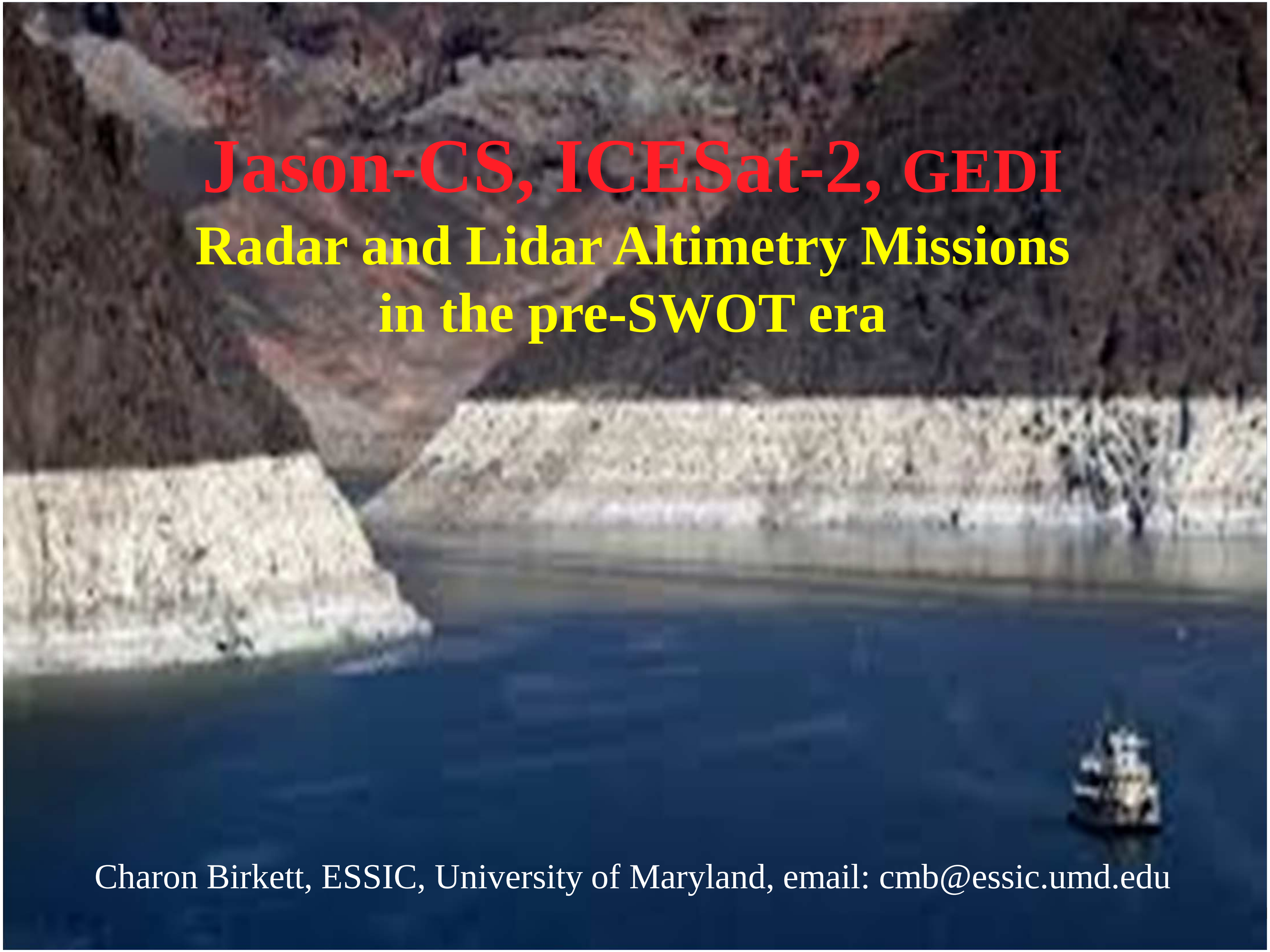
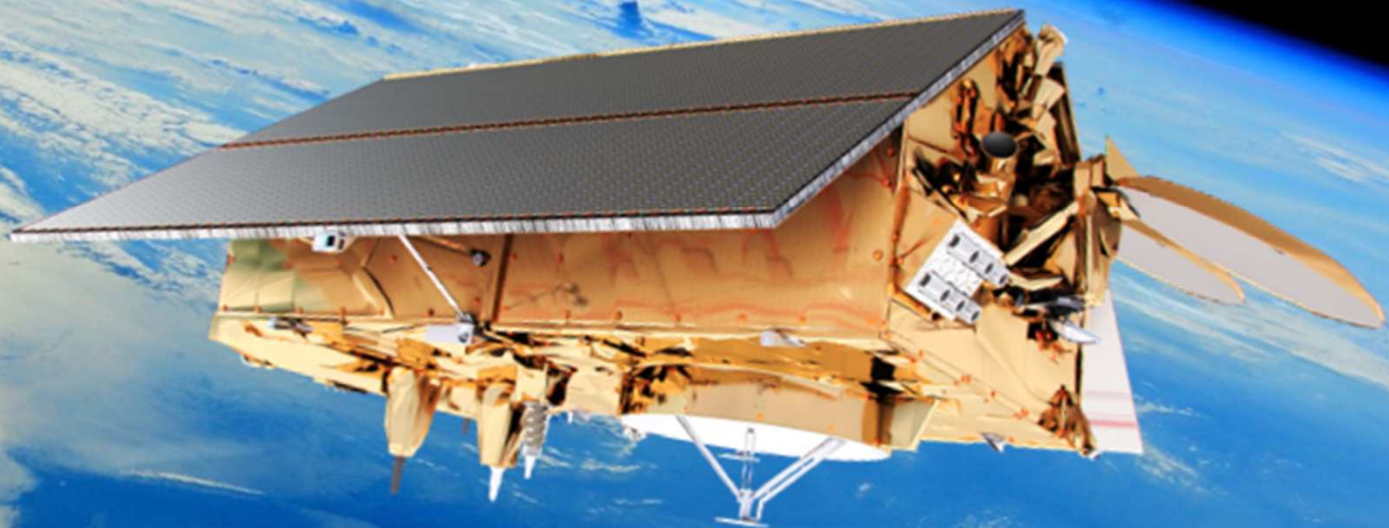

Jason-CS, ICESat-2, GEDI
Radar and Lidar Altimetry Missions
in the pre-SWOT era
Charon Birkett, ESSIC, University of Maryland, email: cmb@essic.umd.edu



Sentinel-6/Jason-CS
News & developments

Pierrik Vuilleumier & Parag Vaze

ESA/ESTEC (NASA-JPL)

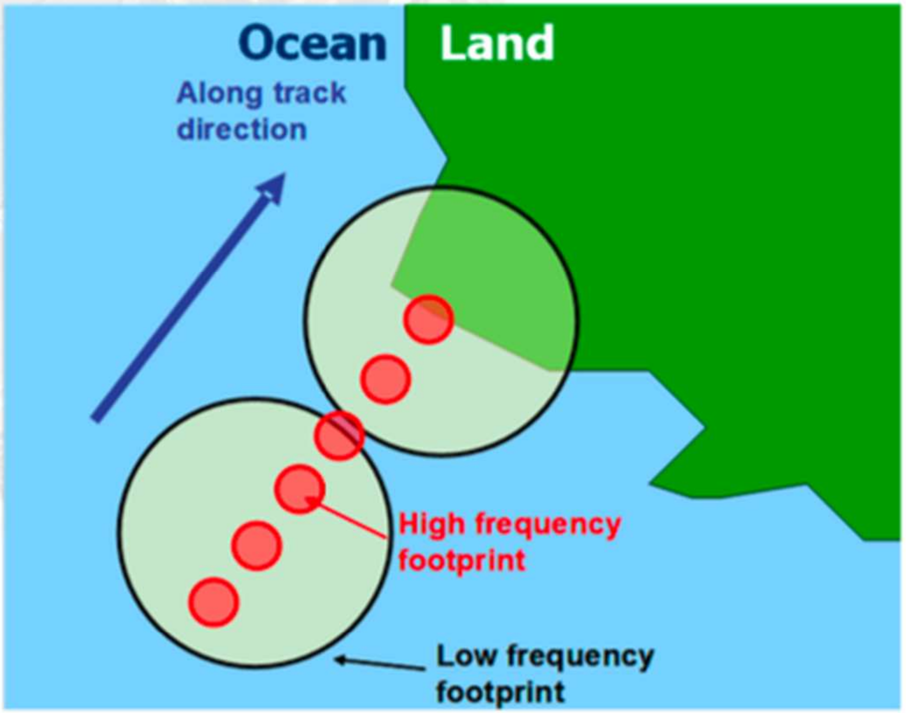
Programme status

- **Funding for two satellites**
  - ESA GSC-3 + EC MFF programmes already in place.
  - Entry into force of the EUMETSAT programme.
  - FY16 NASA budget approval (AMR-C, RO, LRA, Launcher).

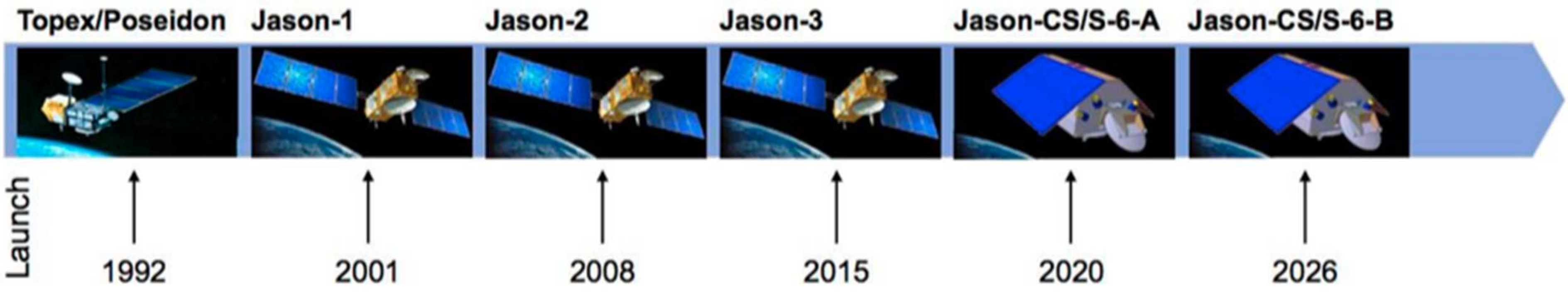
- **Launch date**
  - Agreed among the parties
  - November 2020 with two months of contingency
  - Satellite B model in 2025

High frequency radiometer add-on

- **Three additional channels: 90GHz, 130GHz and 166GHz**
  - Experimental, non redundant
- **Same reflector**
  - Dedicated feed
  - Offset footprint
- **Independent electronics**
  - Dedicated interfaces
- **Not part of the mission products**
  - At least at first
- **Opportunity for new science**



Sentinel-6/Jason-CS mission



- **Forms the Copernicus Altimetry Constellation together with Sentinel-3 SRAL**
- Maintains the **reference-orbit topography mission** - started in 1992 with Topex-Poseidon and subsequent Jason missions (Jason-3 launch in 2015).

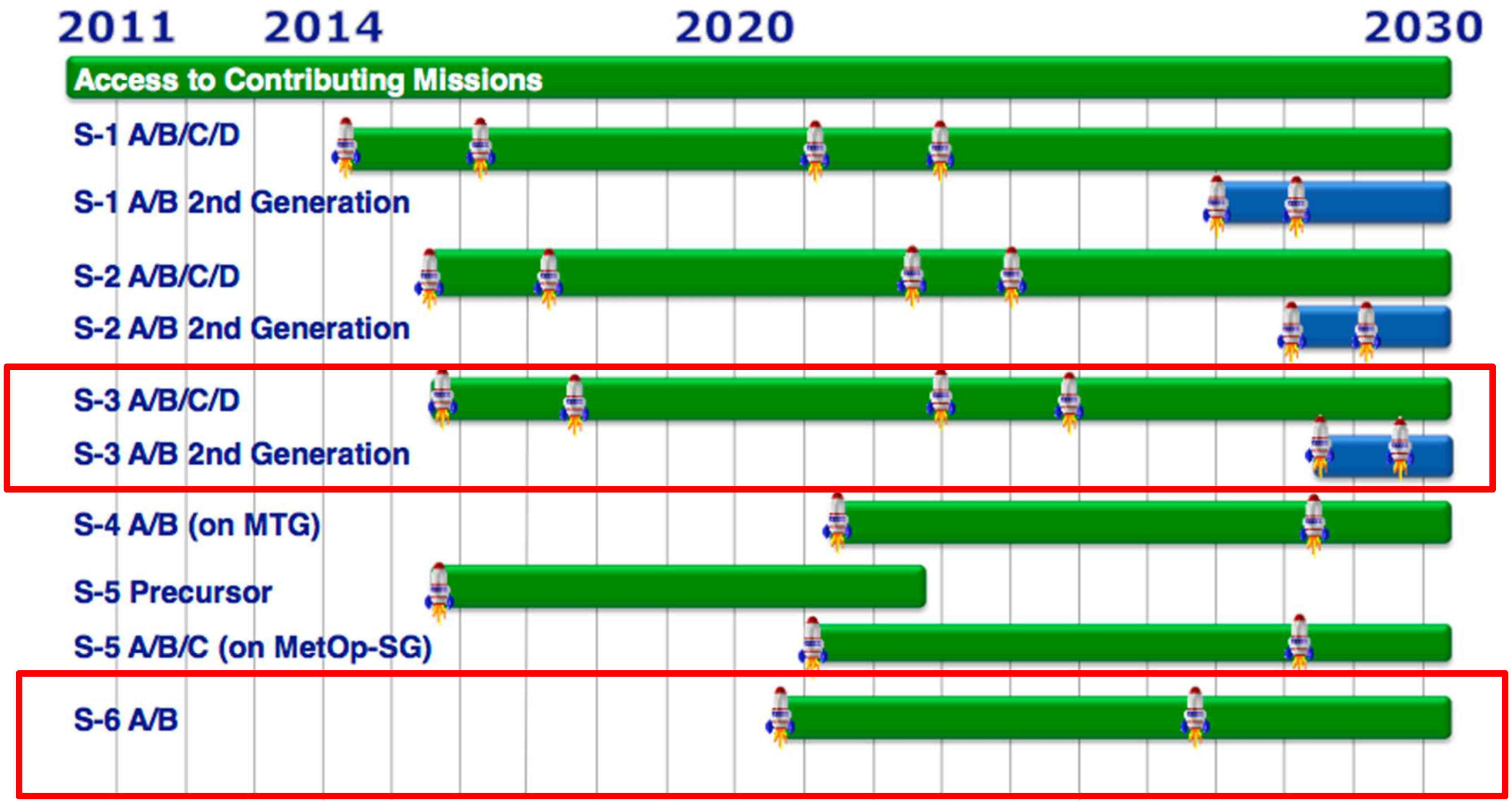
Copernicus Sentinel Satellites… Coordinated by ESA

esa

- **S1A/B/C/D:** Radar Mission (Launched and entering operations)
- **S2A/B/C/D:** High Resolution Optical Mission
- **S3A/B/C/D:** Medium Resolution Imaging and Altimetry Mission
- **S4A/B:** Geostationary Atmospheric Chemistry Mission
- **S5P:** Low Earth Orbit Atmospheric Chemistry Precursor Mission
- **S5A/B/C:** Low Earth Orbit Atmospheric Chemistry Mission
- **S6/Jason-CS A/B:** Reference Altimetry Mission

… with a long-term operational perspective

esa



300m x 1000m Along-Track SAR resolution

CryoSat (>2010, 369-day, LRM, SAR, SARIn)

Ku-band, SIRIL instrument, decomposes main beam into 64 along-track narrower beams

Mapping mission using mode-mask

Sentinel-3A/3B (>2016, 27-day, LRM, SAR)

SIRIL instrument heritage

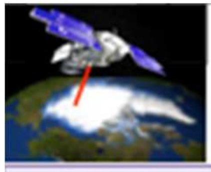
Onboard DEM for use in highly varying terrain

Global SAR coverage

3A/3B interleaved ground tracks, 52km separation at equator

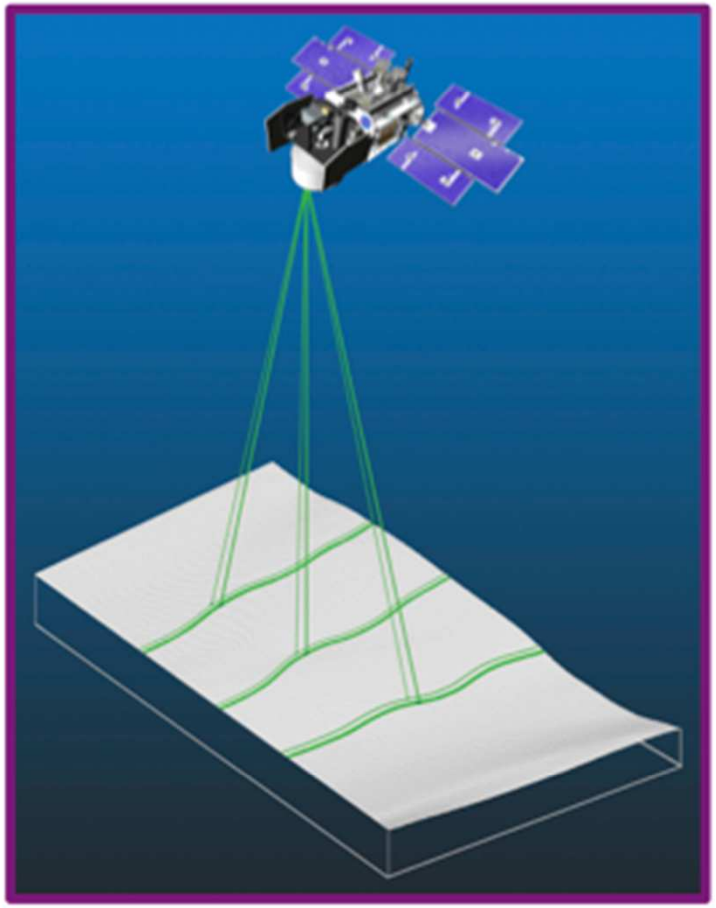
Sentinel-6/Jason-CS (launch 2020, LRM+SAR)

New Poseidon-4 “Open Burst Interleaved Mode altimeter” i.e., continuous transmission of pulses, so LRM and SAR mode can operate simultaneously



ICESat-2 Mission Concept

In contrast to ICESat design, ICESat-2 will use ***micro-pulse multi-beam photon counting*** approach.



Provides:

Dense cross-track sampling to resolve surface slope on an orbit basis.

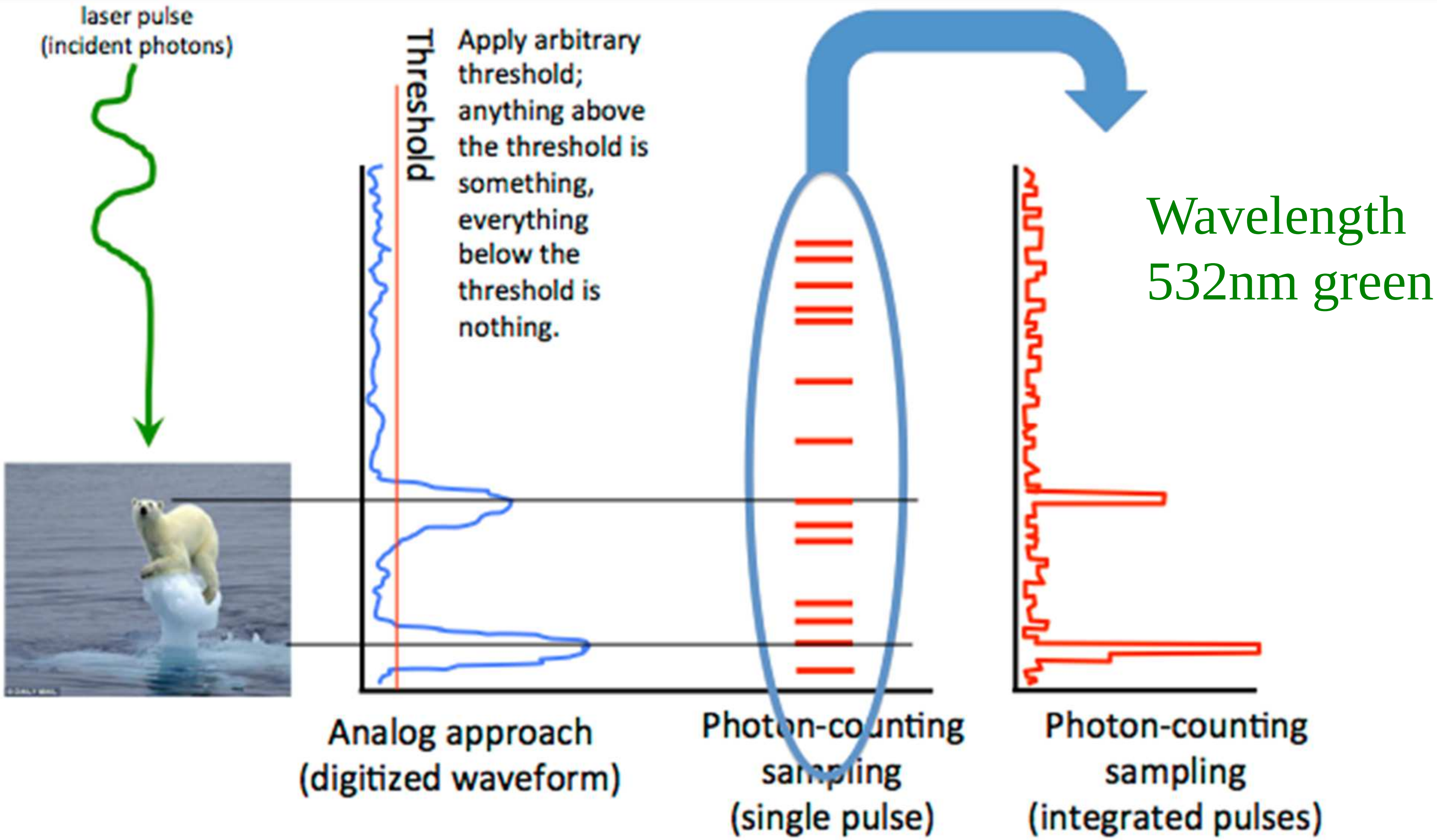
High repetition rate (**10 kHz**) generates dense along-track sampling (**~70 cm**).

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.

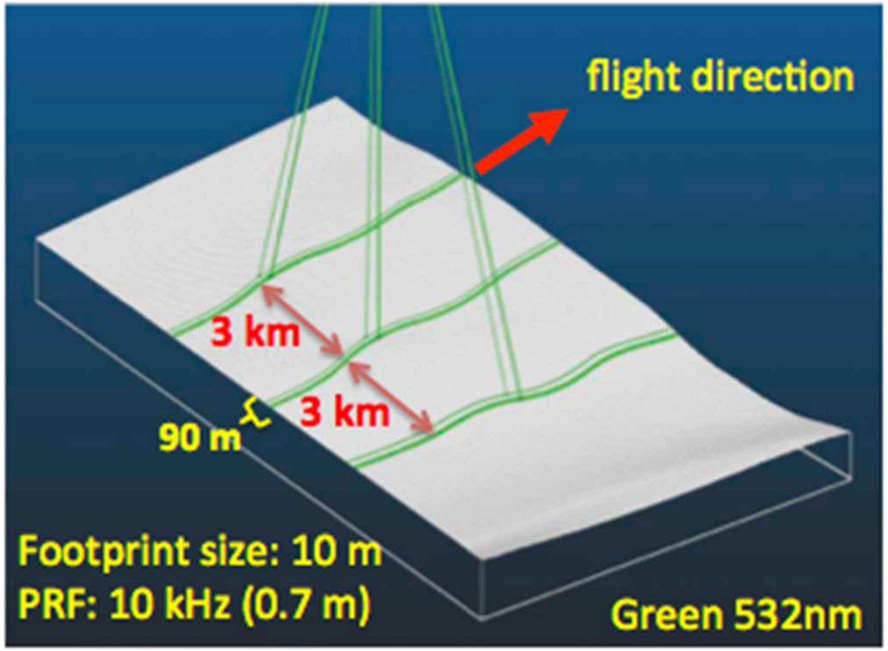
Analog –vs- Photon-Counting

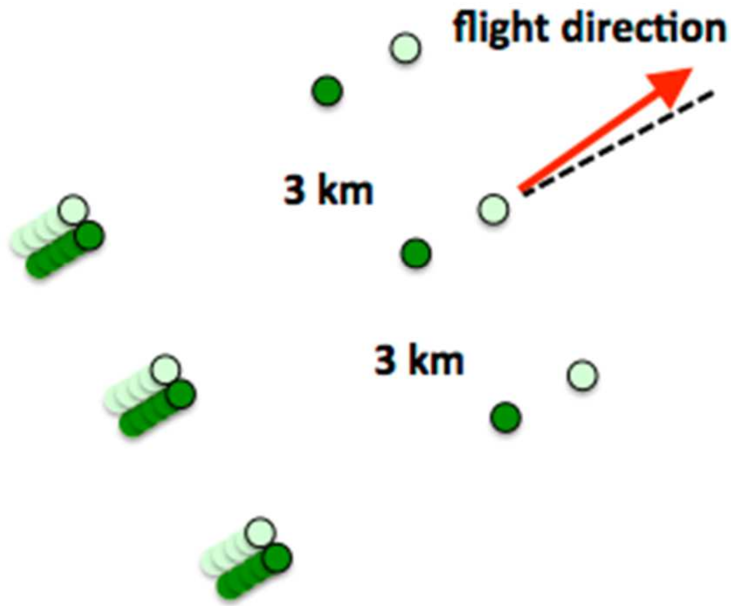


IMPORTANT: the integrated photon-counting sample ("histogram") *looks* like the analog waveform, but *it is not* – the information content is different, and the method of analyzing the data is different.

ATLAS – Advanced Topographic Laser Altimeter System

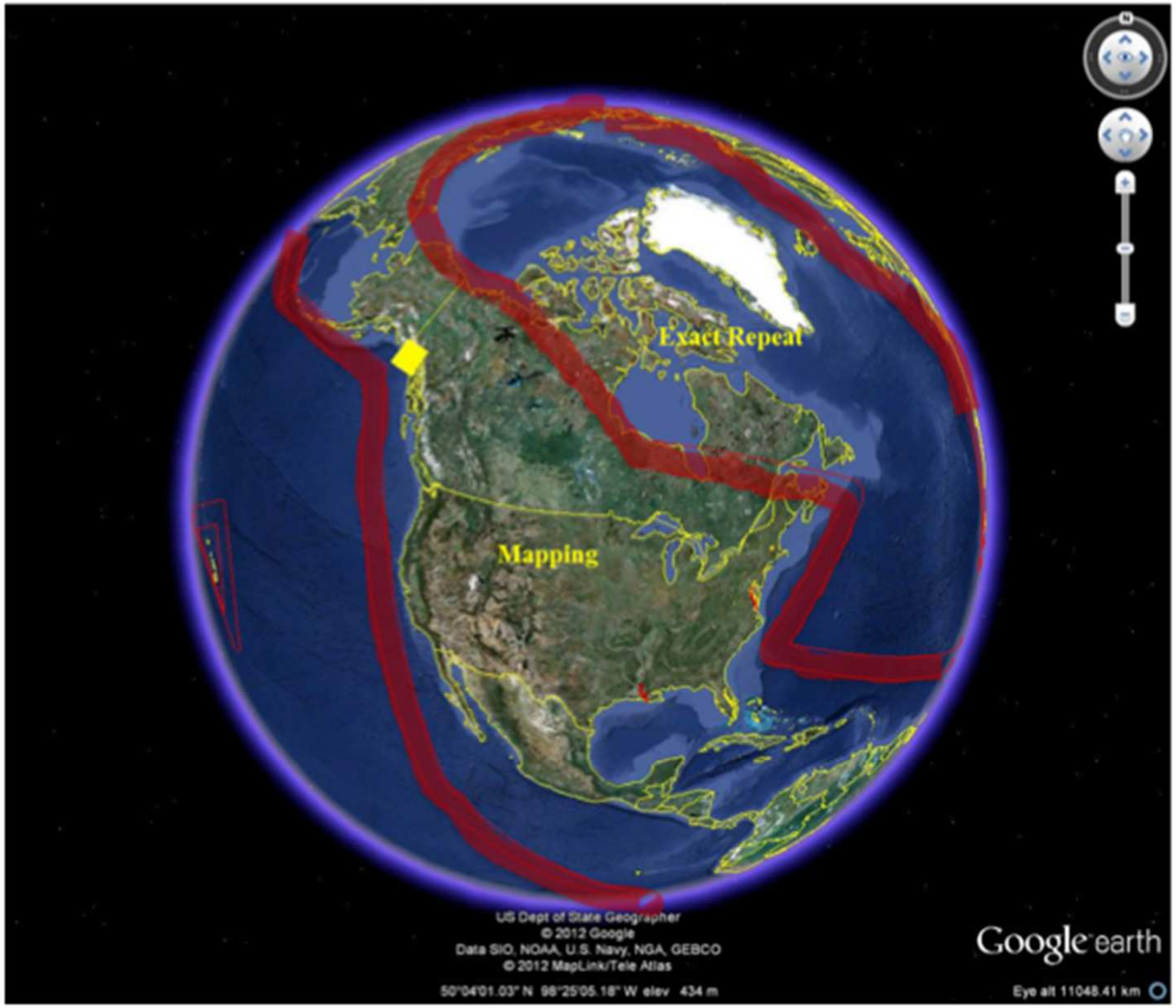
3. Number of beams.





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

ICESat-2 Observation Strategy: "Mapping" and "Repeat" Zones



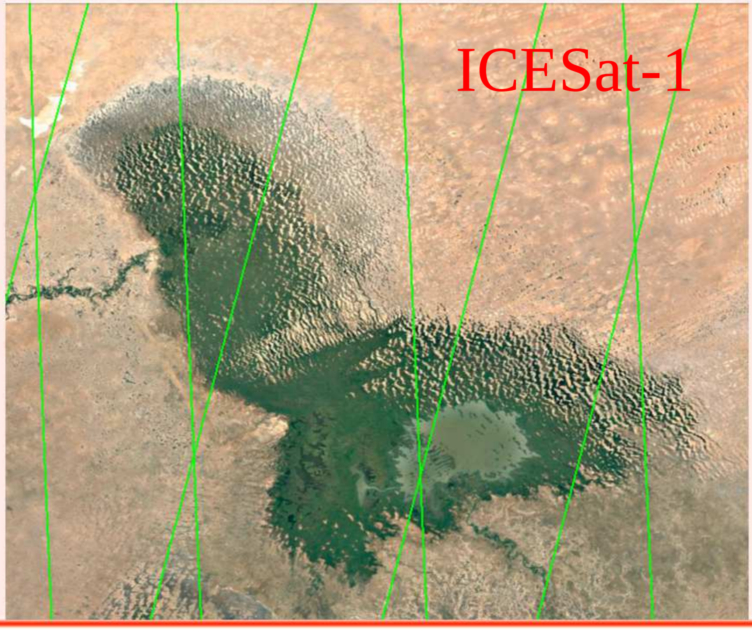
ICESat-2 latest developments

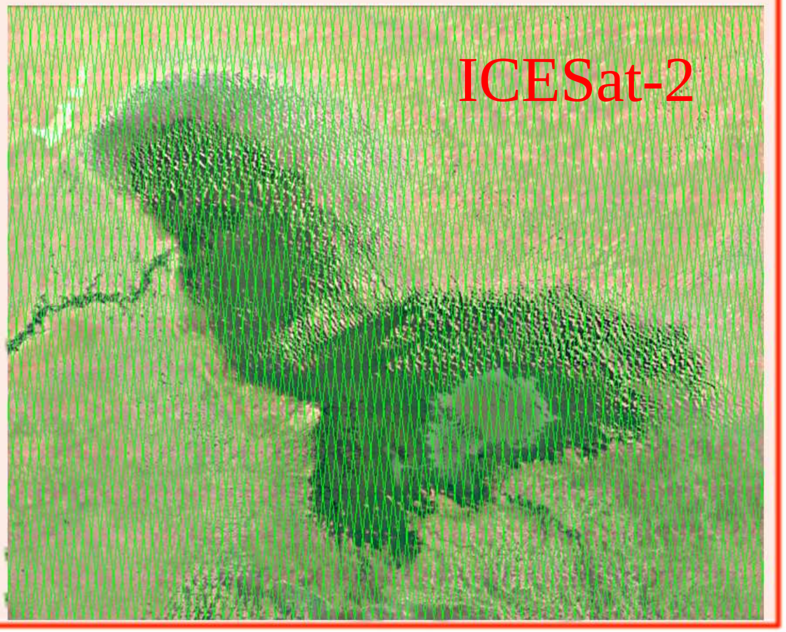
Launch September 2018, 3-7yr lifetime

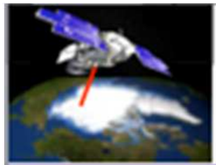
Nominal orbital altitude: 496 km, Inclination still under discussion 92 deg

91-day exact repeat, Subcycles: 29-29-33 days

1387 revolutions, coverage to 86deg lat, not sun synchronous







Science Requirements

LAND ICE: Ice-sheet elevation changes to 0.4 cm/yr accuracy on an annual basis.
Annual surface elevation change rates on outlet glaciers to better than 0.25 m/yr over areas 100 km^2 for year-to-year averages.
Surface elevation change rates to an accuracy of 0.4 m/yr along 1 km track segments for dynamic ice features that are intersected by the ICESat-2 set of repeated ground-tracks.
Resolution of winter (accumulation) and summer (ablation) ice-sheet elevation change to 10 cm at 25 km x 25 km spatial scales.

SEA ICE: Monthly surface elevation measurements with a track density of better than 30 km poleward of 70 degrees, to enable the determination of sea ice freeboard when sea surface references are available, under clear sky conditions, to an uncertainty of 3 cm along 25 km segments, for the Arctic Ocean and Southern Oceans.

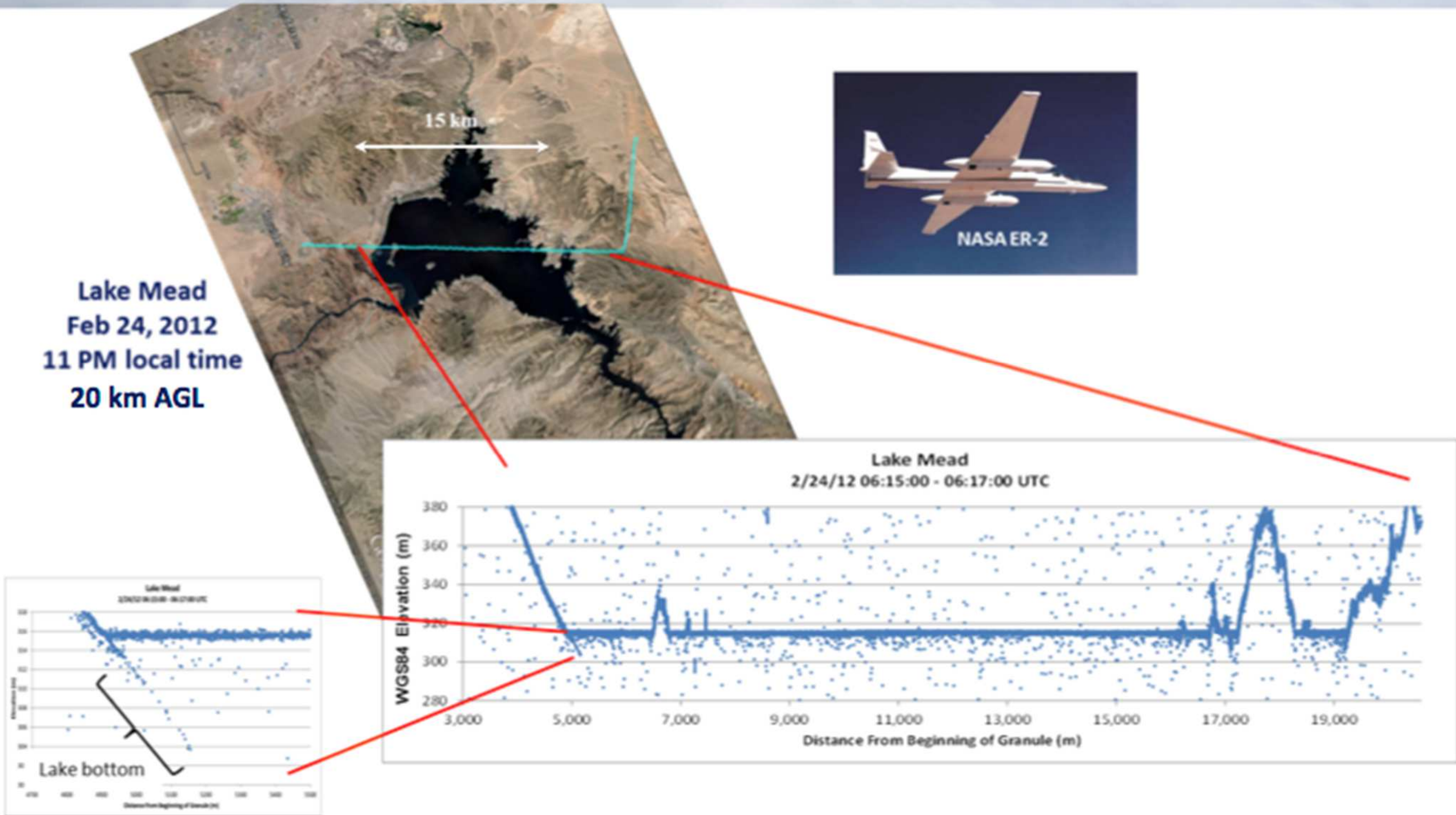
VEGETATION: ICESat-2 shall produce elevation measurements that enable determination of global vegetation height to 3-m accuracy at 1-km spatial resolution in vegetated area with canopy closures less than or equal to 75 percent under clear sky conditions.

SURFACE WATERS: No Science Requirements

Ocean conical scans considered for pointing accuracy studies (as per ICESat-1).
Design case studies considering the 5degree scans,0.25 optical depth, averaging 100 shots, suggest:
1.3cm/0.7cm stdev range (weak/strong beams with SWH 0.1m), -0.25cm range bias
22.3cm/13.6cm stdev range, (weak/strong beams with SWH 4m), 26cm range bias
Range precision improves with strong beam and calmer surfaces.

Satellite orbit 4cm (LRS, GPS), Atmosphere (Wet – model) 3cm, Range Precision 1-22cm
Expected Accuracy? 5-20cm, averaging 100shots (70m) along track. Expected improvement for near nadir shots.

Testing ICESat-2 Inland Water Product
w/Multiple Altimeter Beam Experimental Lidar (MABEL)



Jasinski et al., 2016. *Journal of Coastal Research*, 10.2112/SI76-005.

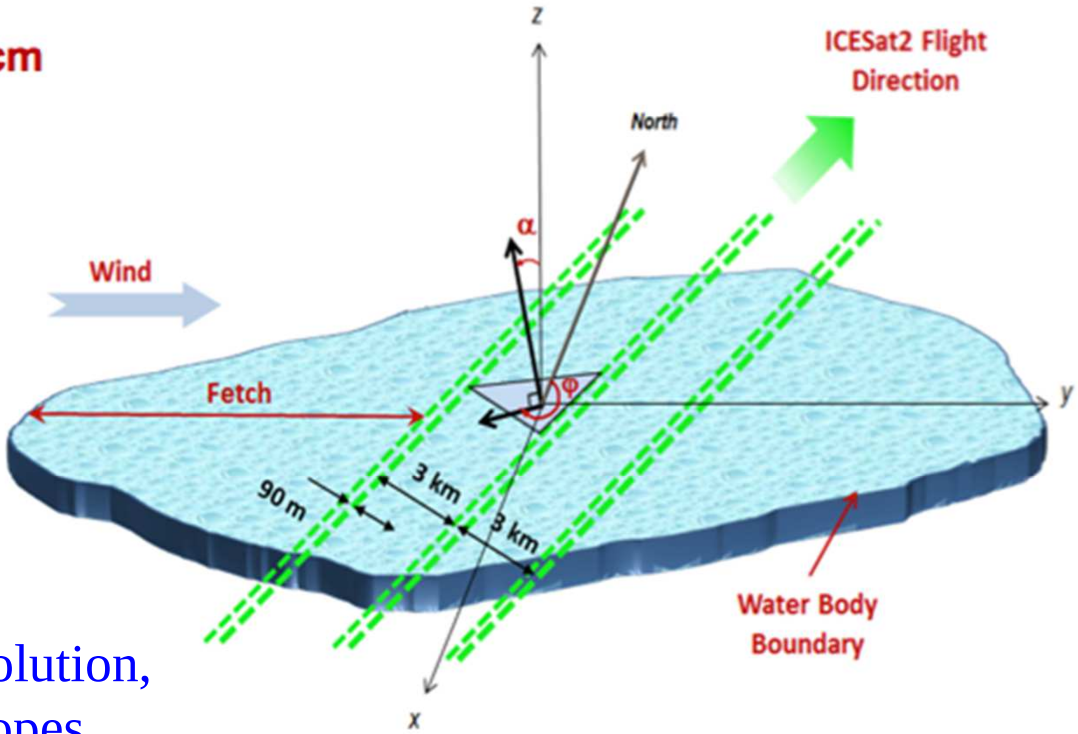
ICESat-2 Inland Water Data Product

Details:

- Operational (Product ATL13)
- Along track surface water mean height, SDev, max slope & aspect
- Coverage: Inland & near coast
- Segment length: ~100m
- Water bodies > ~ 5km^2
- Vertical precision: ~ 5-10 cm

Data Product Lead:

- Mike Jasinski, NASA GSFC
  (Michael.F.Jasinski@nasa.gov)



Dense cloud limitations

Small footprint, high spatial resolution, height and along/across track slopes, mapping/monitoring, global

Remote Sensing of Ecosystem Structure and Dynamics

GEDI LIDAR

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Ralph Dubayah
University of Maryland
Principal Investigator

The Importance of Ecosystem Structure

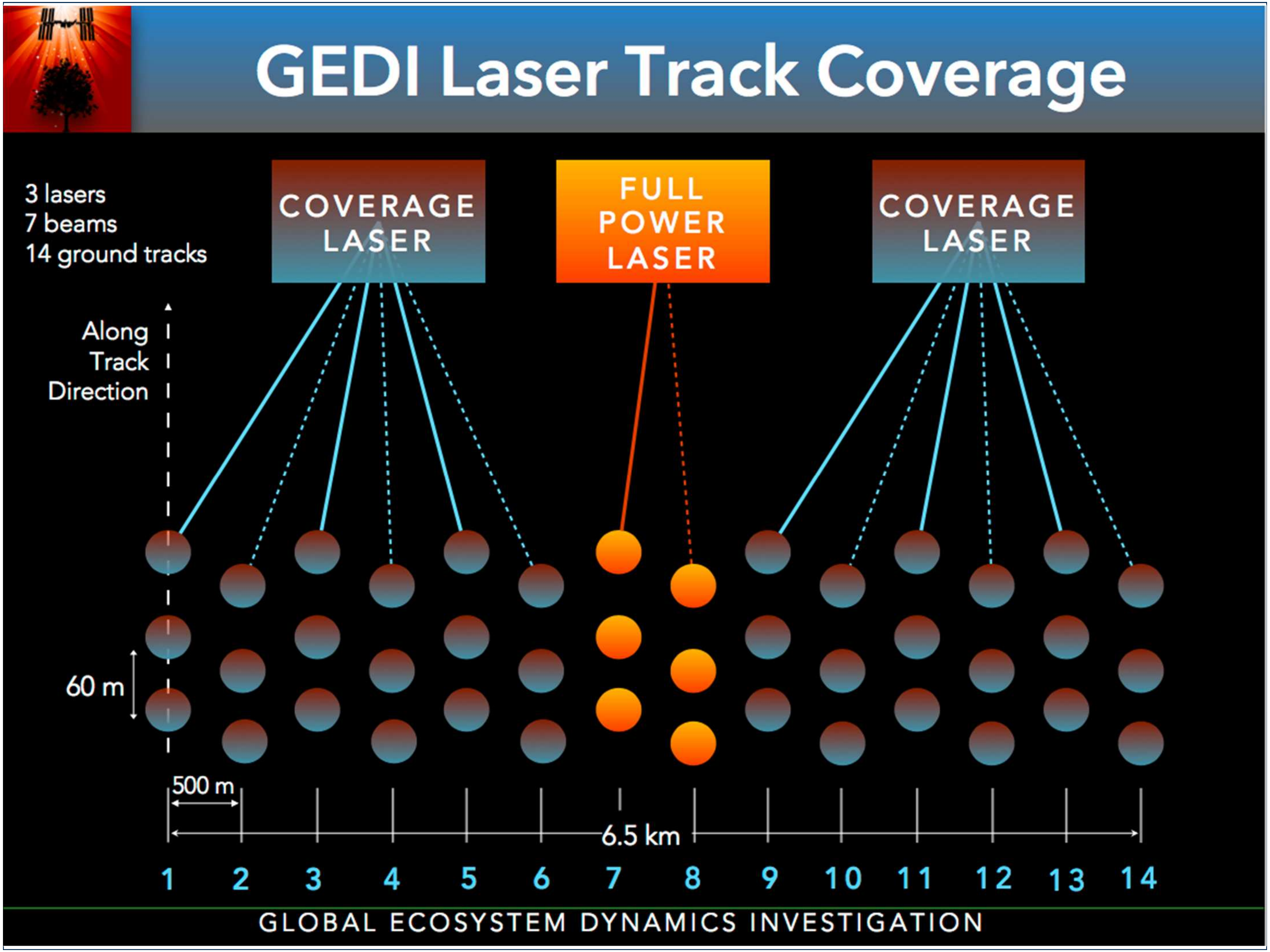
- Ecosystem structure key element of Earth System
  - Carbon and nutrient cycling
  - Habitat quality and biodiversity
  - Forest health and productivity
  - Fire modeling
  - Hydrological cycling
  - Policy needs (REDD++, and others)

Earth Ventures Instrument (EVI)

Deployed via the International Space Station 2018/19.

GEDI based on ICESat-1 heritage. Instrument can rotate to provide off-nadir tracking. GPS, IMU, Star Trackers for ranging, attitude and position. Geolocation to <10m.

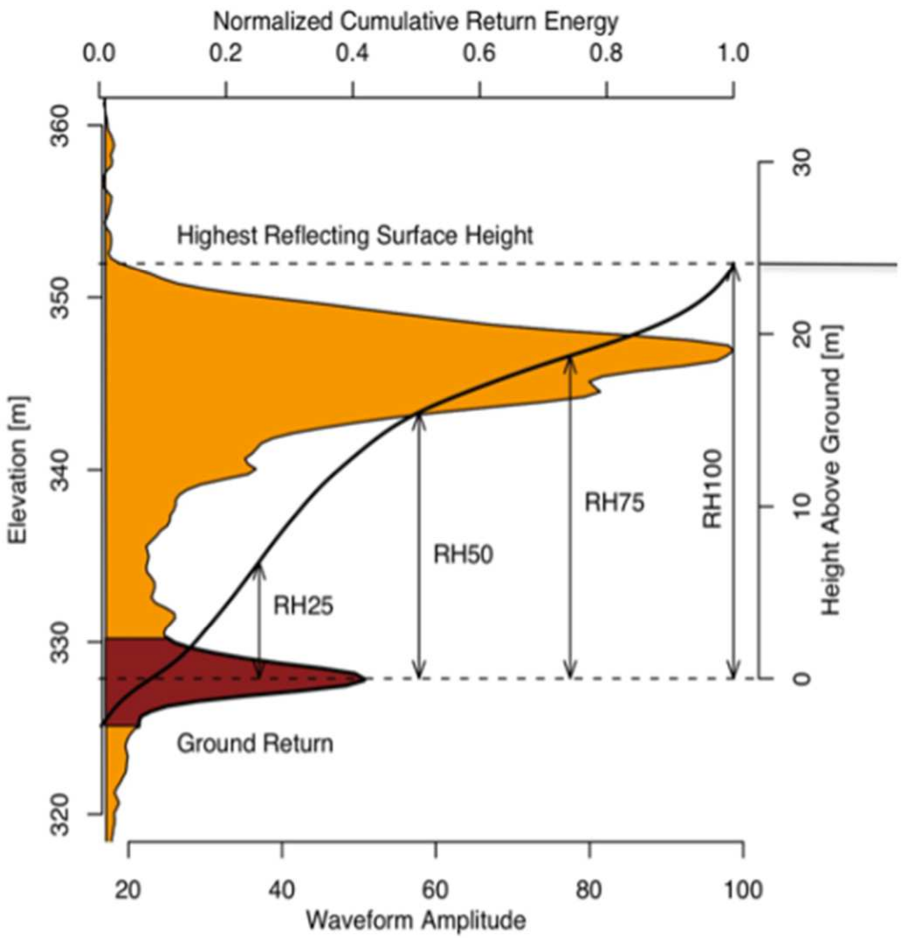
Canopy profile to 1m with <1km resolution, ±51.5deg latitude

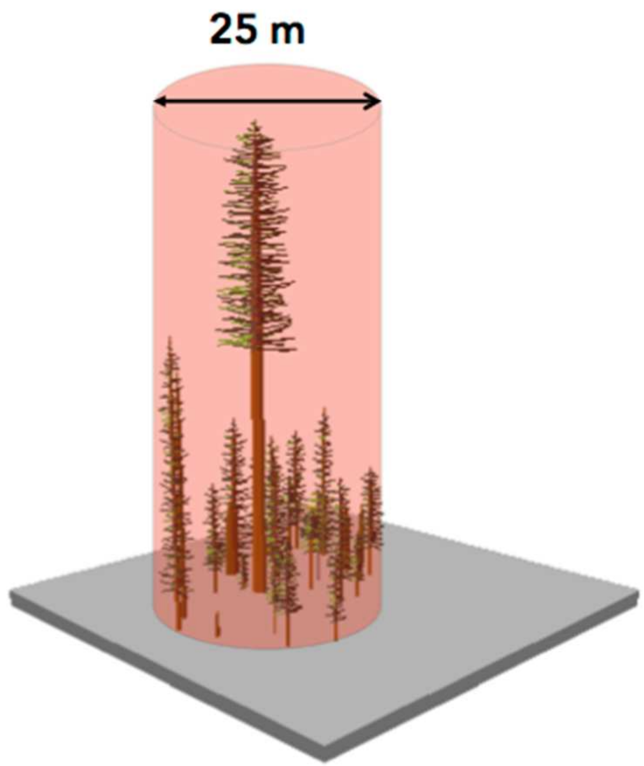

GEDI Laser Track Coverage
3 lasers
7 beams
14 ground tracks
COVERAGE LASER
FULL POWER LASER
COVERAGE LASER
Along Track Direction
60 m
500 m
6.5 km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Lidar Measurement

- Sole GEDI observable is the lidar waveform

1064nm near-infrared





Product	Description	Resolution
Level-1	Geolocated waveforms	22 m diameter
Level-2	Canopy height and profile metrics Relative height (RH) metrics Canopy top height Ground elevation Canopy cover and cover profile Leaf Area Index (LAI) and LAI profile	22 m horizontal; 0.5 m vertical
Level-3	Gridded Level-2 metrics	Nominal 1 km grid
Level-4	Above-ground biomass **Demonstration products:** Prognostic ecosystem model outputs Enhanced height/biomass using fusion with TanDEM X and Landsat Biodiversity/habitat model outputs	22 m footprint; 1 km grid Grid size(s) TBD* Grid size(s) TBD Grid size(s) TBD

All about geolocation error – knowledge of beam location to be 10m.
So, radial positioning has to be better than 20cm
Add on range and range correction errors, so radial accuracy ~25cm
Aiming for final radial error of 10-15cm