The Delay-Doppler Altimeter

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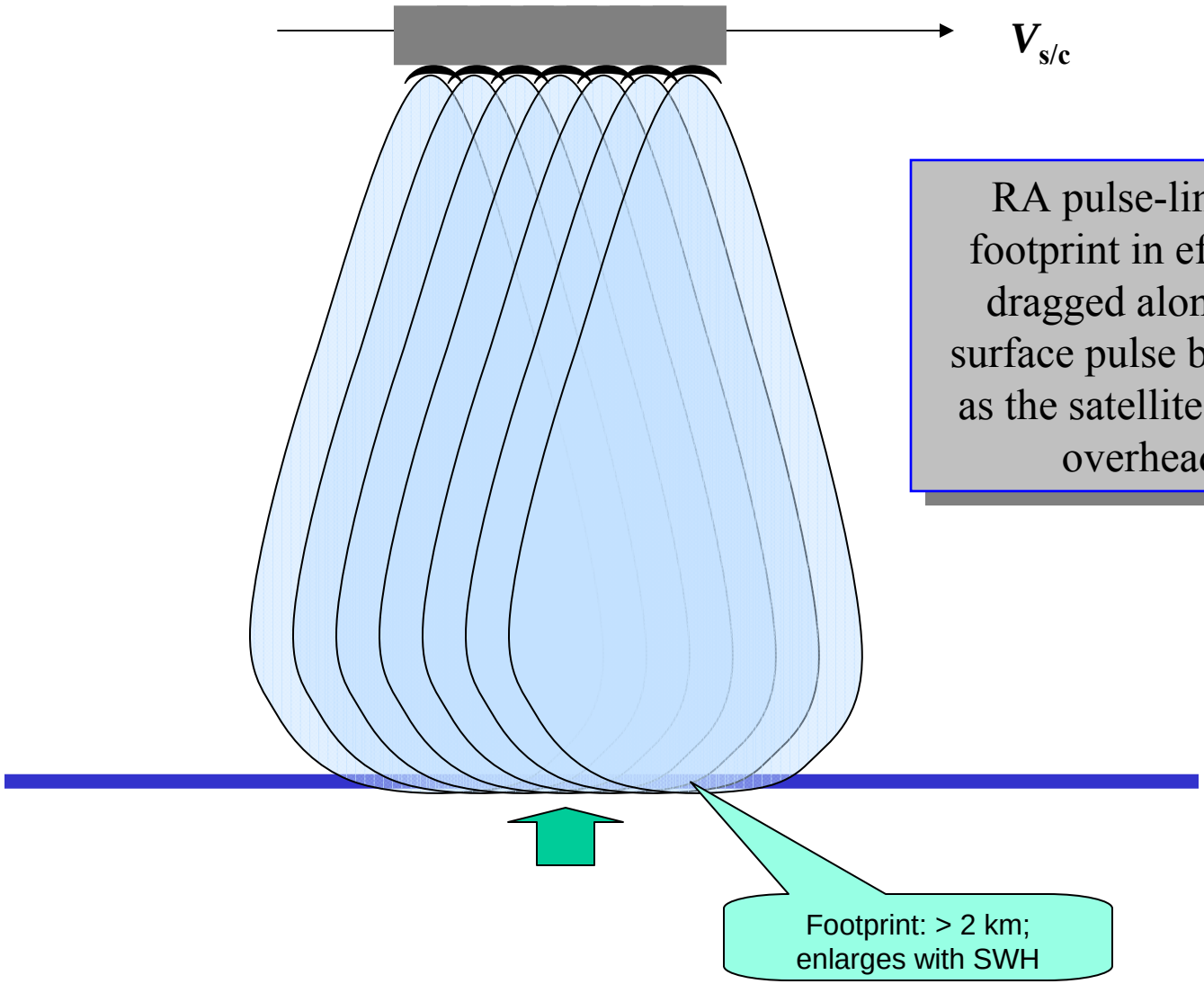
- **What is a Delay-Doppler altimeter?**
- **Precision**
- **Tracking**

(Resource material)

Conventional ALT footprint scan



Delay-Doppler (SAR mode*) Radar Altimetry

DDA: near-optimum partially coherent processing

N-pulse bursts

**** CryoSat (Alcatel) terminology for pulse-to-pulse coherent altimetry = "delay-Doppler"***

Range pulse compression

Sum range waveforms (incoherent)

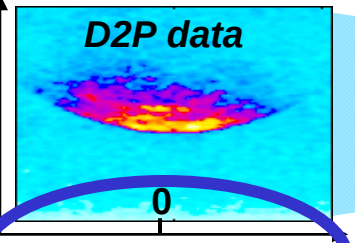
~ 2000 looks per second

Processing similar to that of Topex:

INCOHERENT

N-pulse bursts

Range



N Doppler bins

Along-track FFTs

COHERENT

Range curve correct

Doppler frequency is proportional to along-track angle

Range pulse compression

M bursts per along-track resolution (Doppler) cell

Sum M powers P_{Dop} at each Doppler

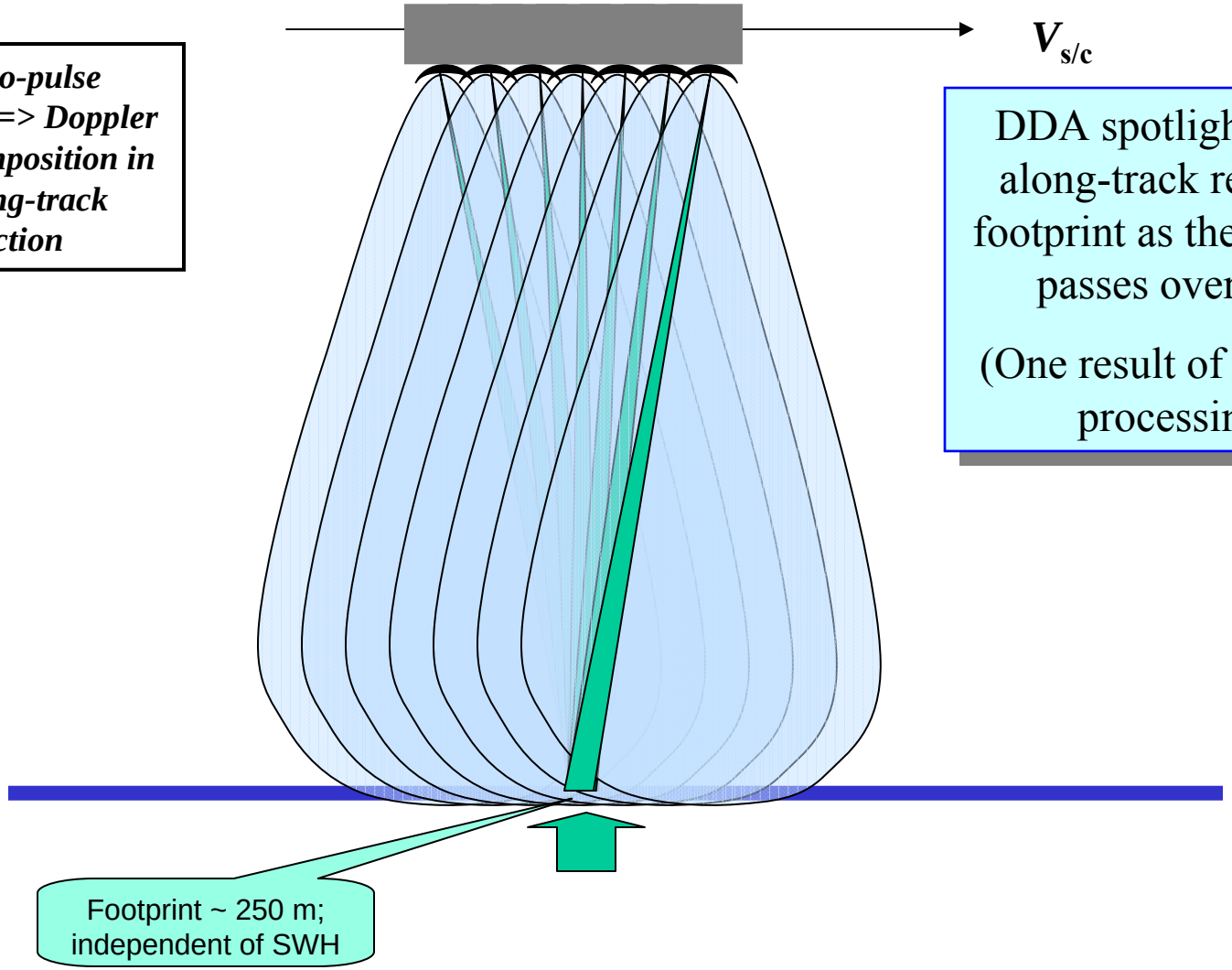
Sum N P_{Dop} at each x

> 6000 looks per second

INCOHERENT

DDA: a fundamentally different method

Pulse-to-pulse coherence => Doppler data decomposition in the along-track direction

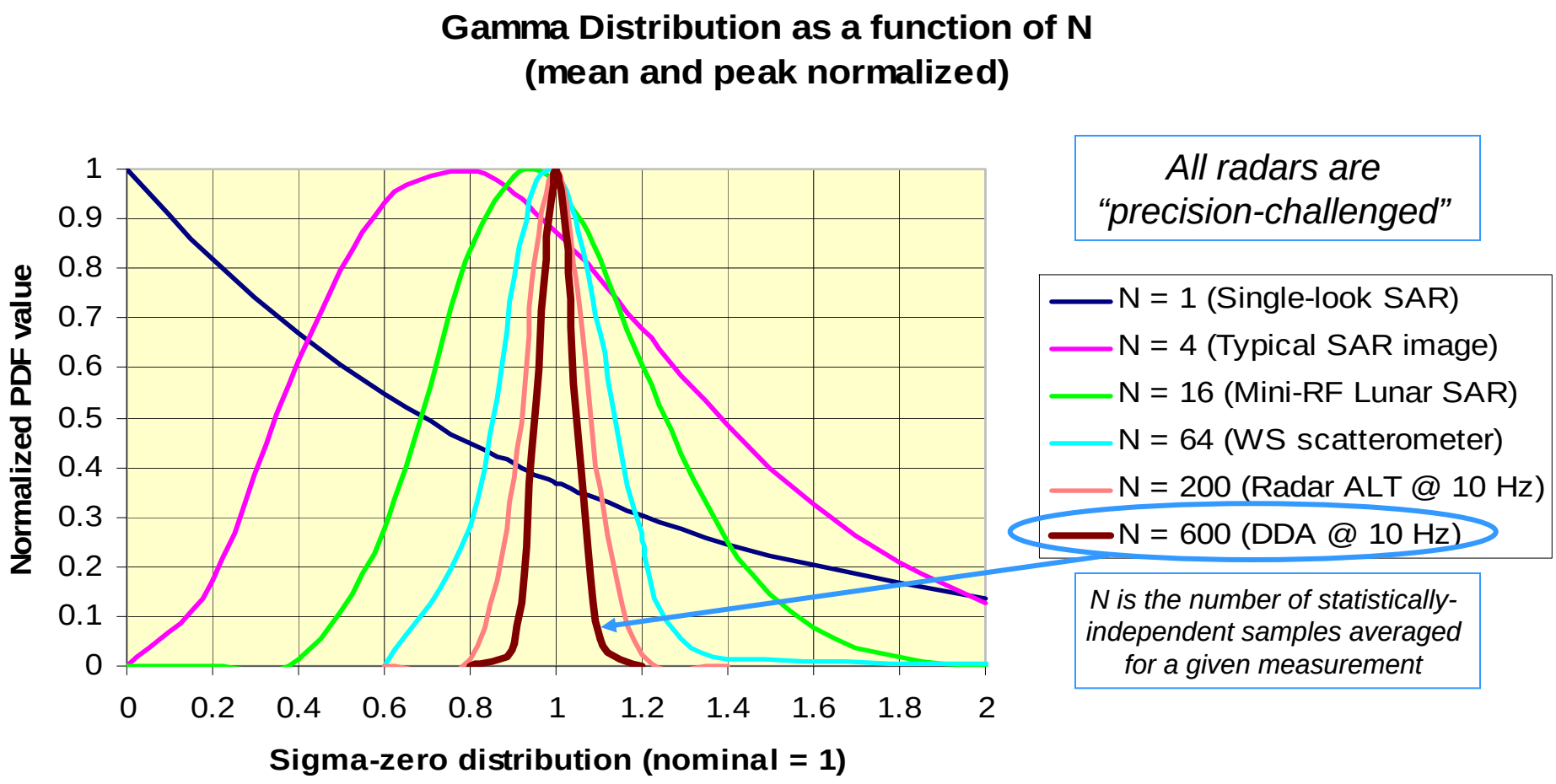


DDA spotlights each along-track resolved footprint as the satellite passes overhead

(One result of Doppler processing)

On Precision (*wrt* Radar Self-Noise)

Doppler spectral decomposition => more incoherent averaging

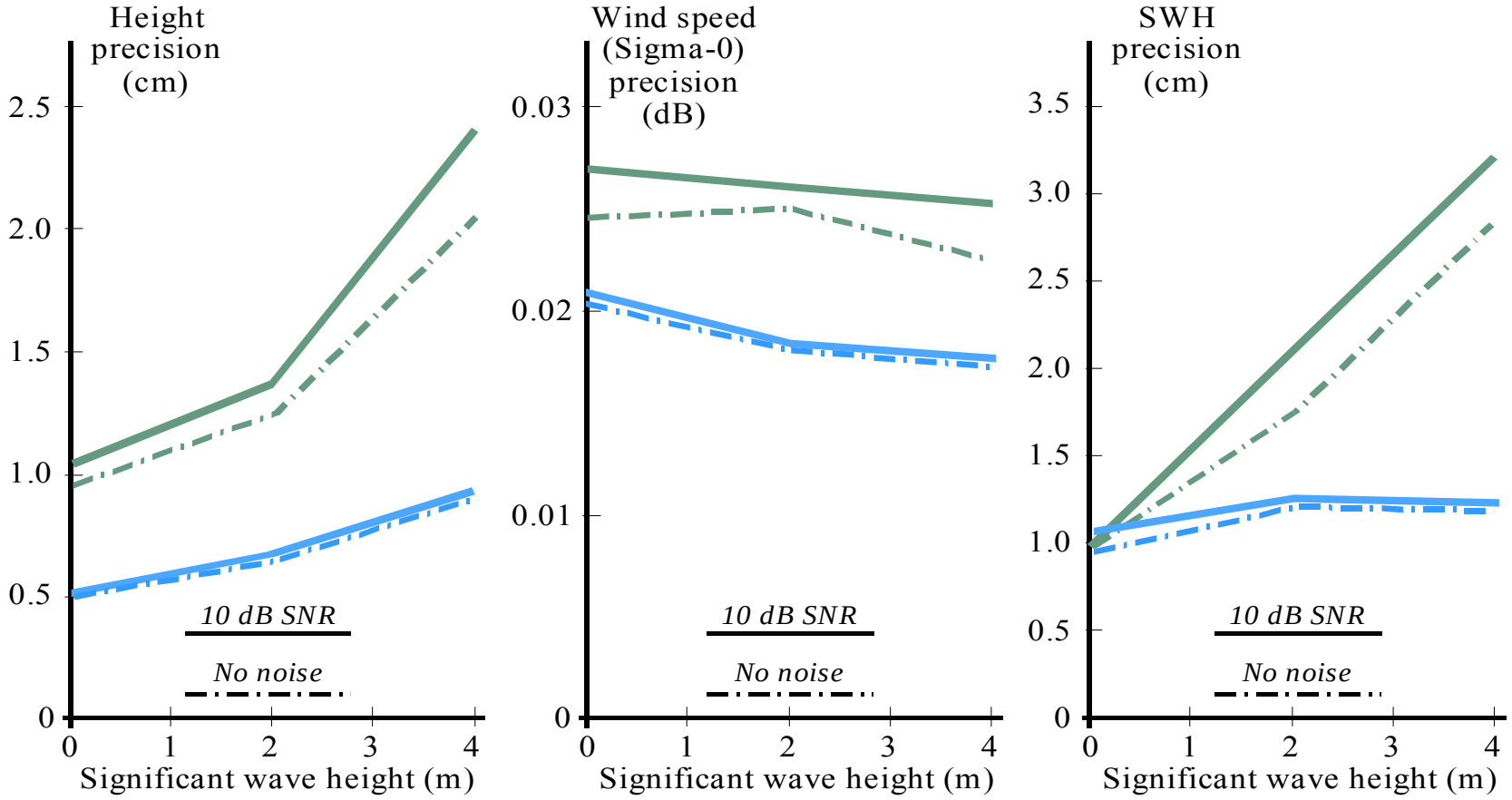


***Delay-Doppler (DDA) = CryoSat "SAR mode"**

Delay-Doppler Altimeter (DDA) vs Conventional:

Precision at 1 Hz Rate*

*Delay/Doppler ~ x2 **better** than conventional*

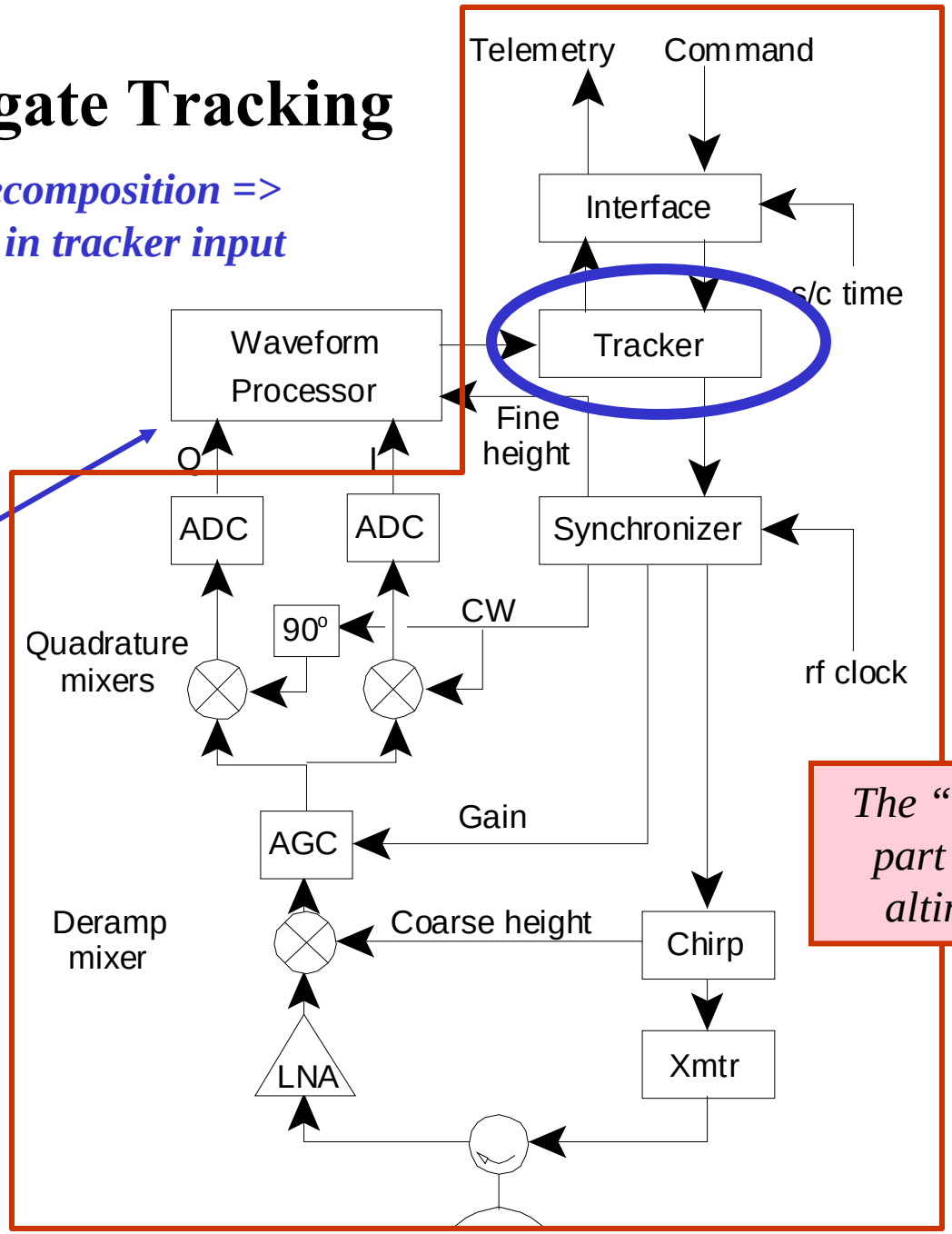


Courtesy: J. R. Jensen

* *Based on computer simulations*

On Range-gate Tracking

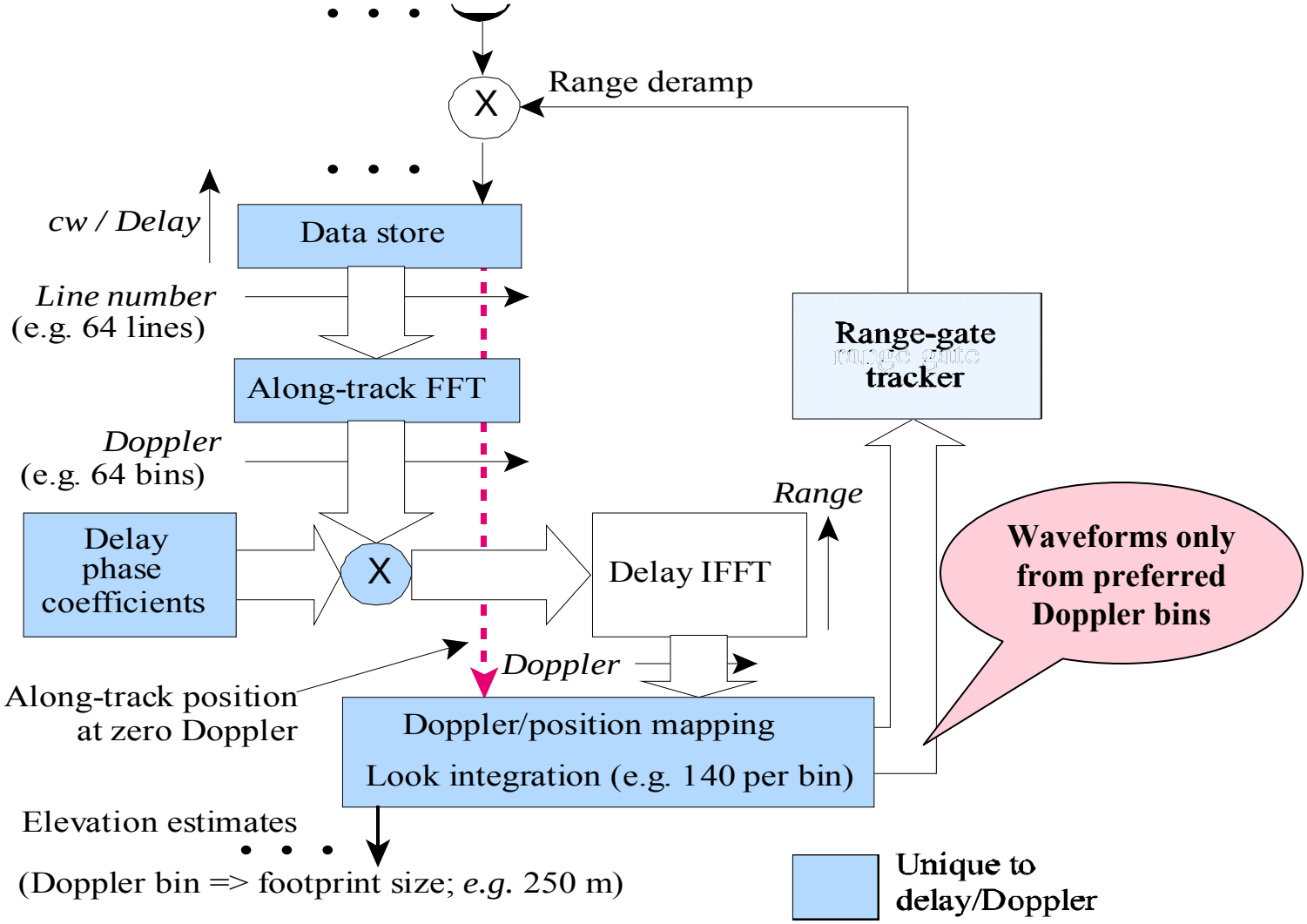
Doppler spectral decomposition => more selectivity in tracker input



The waveform processor is essentially the only difference between a conventional radar altimeter and a delay-Doppler instrument.

The "radar" part of the altimeter

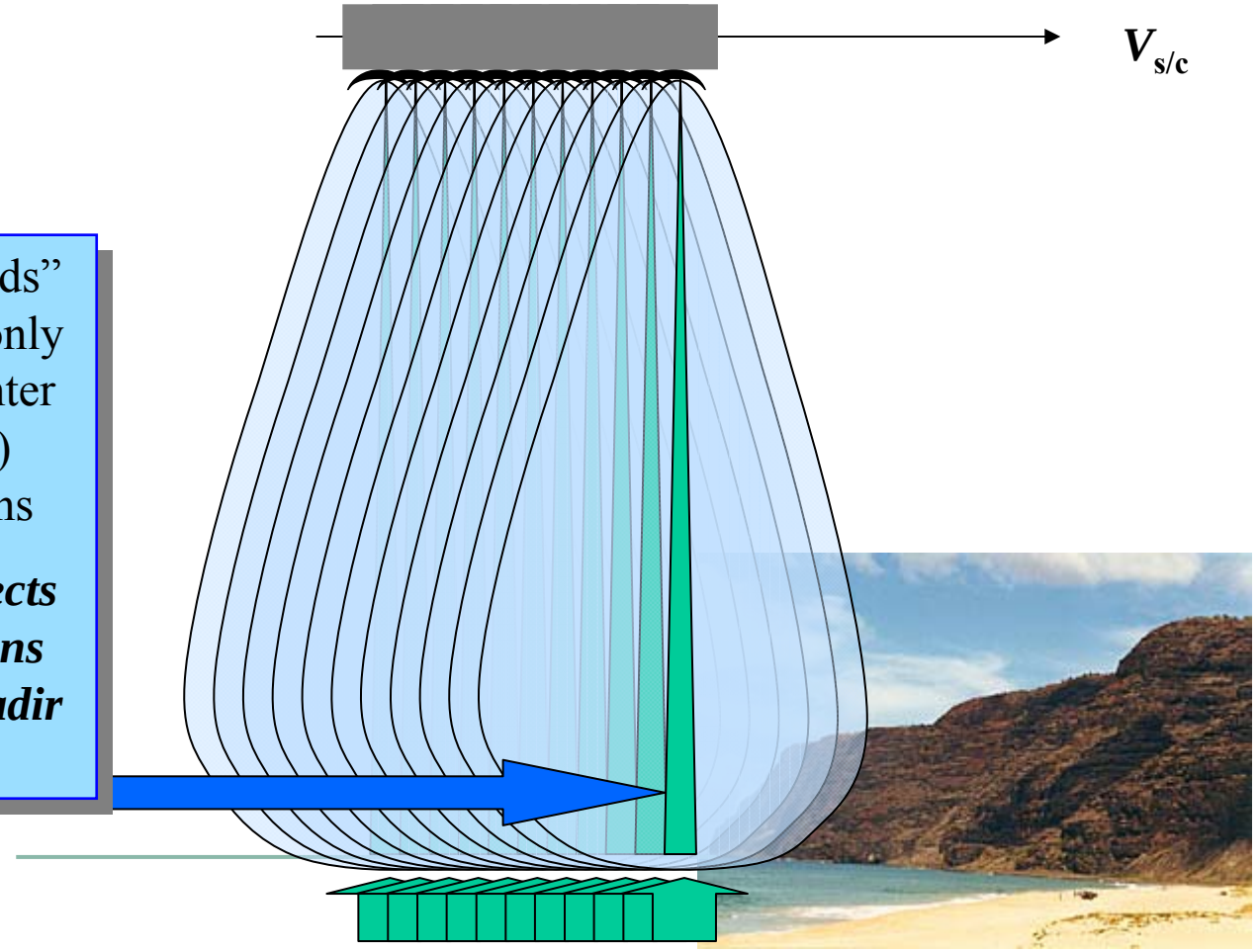
"Smart" Tracker: Doppler-Beam Limited



DDA Beam-Limited Tracker Algorithm

Tracker "reads" waveforms only from the center (1, 2, or 3) Doppler bins

Result? ***Rejects all reflections from non-nadir sources***



Delay-Doppler Altimeter Summary

- ***Precision:*** The standard deviation of the inherent radar self-noise is better by (approximately) a factor of 2, which reduces by a factor of 4 the extent of in-scene averaging required to get the same results => ***major advantage in near-shore applications***

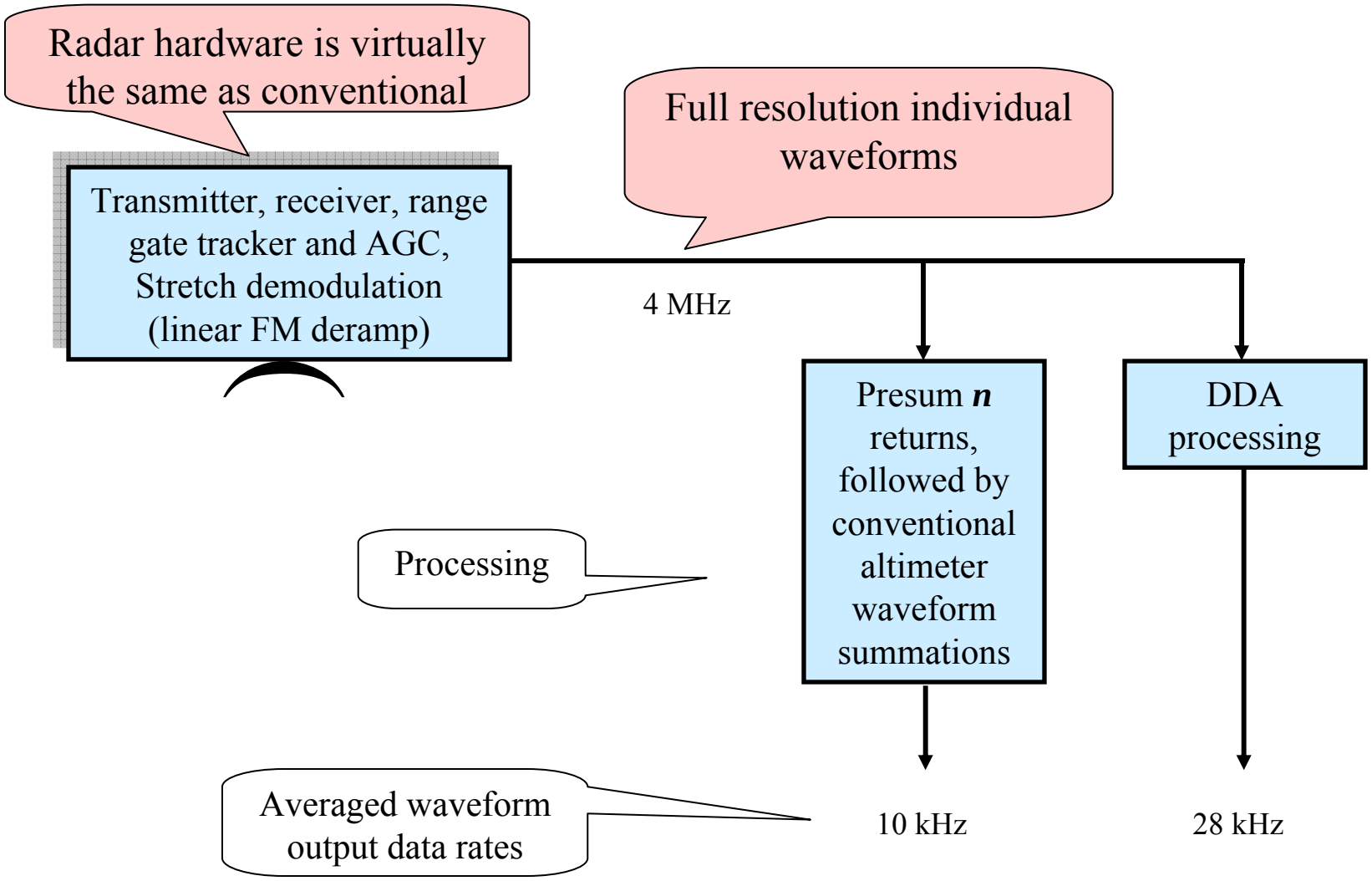
- ***Tracking:*** Decomposition of the received data into Doppler frequencies corresponds one-to-one to along-track beam-limited selectivity => ***a major advantage in near-shore applications***

- ***Other:*** the DDA altimeter is simple and low-risk, user can choose (along-track footprint) size (in multiples of 250 m); relies on extensive heritage in space and airborne prototypes; and compatible with well-established retrieval algorithms

Back-up/Resource Material

On Pseudo-conventional ALT waveforms

SAR mode => both DDA and conventional waveforms

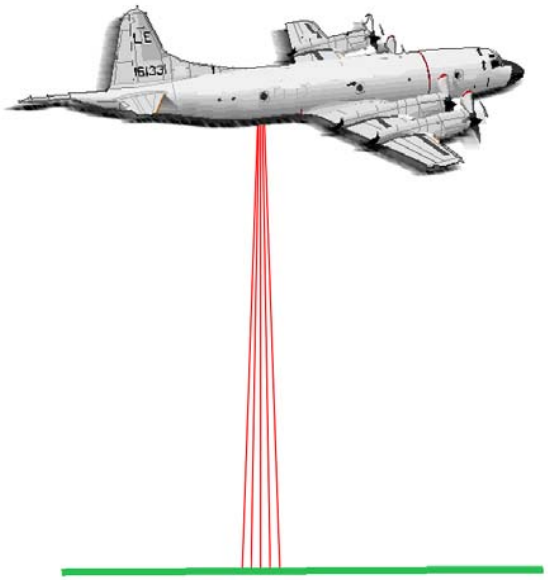


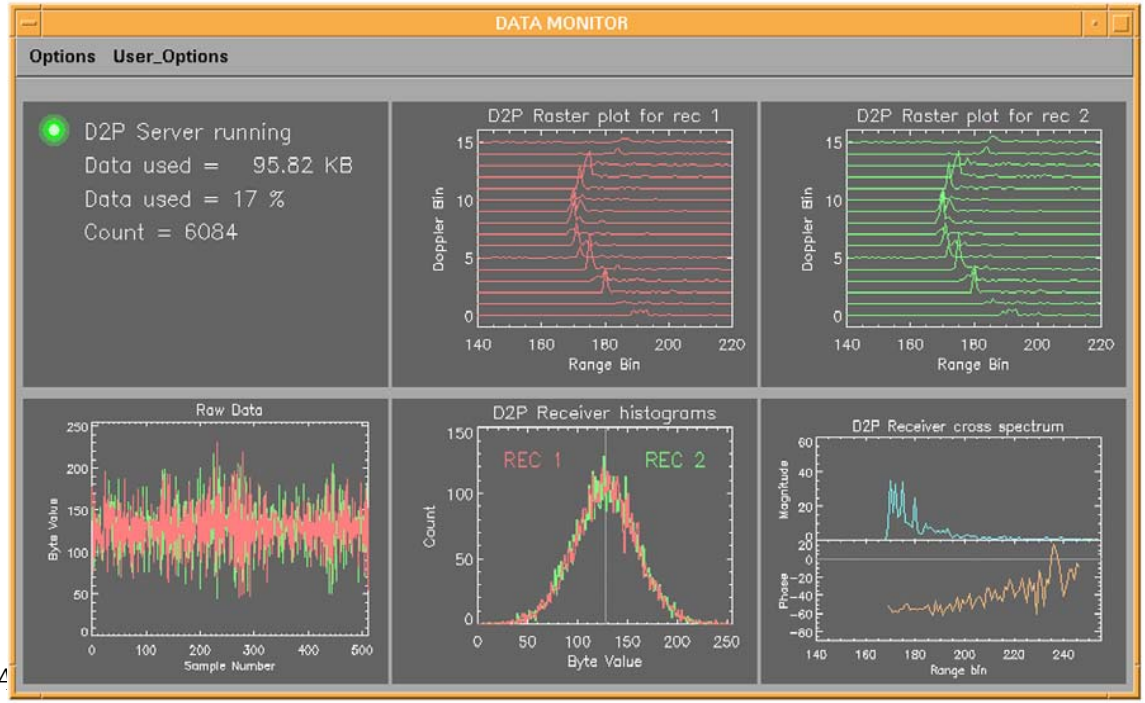
NASA-Funded proof-of-concept Aircraft Altimeter (D2P)

Field campaigns 2000, 2001, 2002, 2003, 2005

Johns Hopkins University
http://fermi.jhuapl.edu/d2p

Delay-Doppler



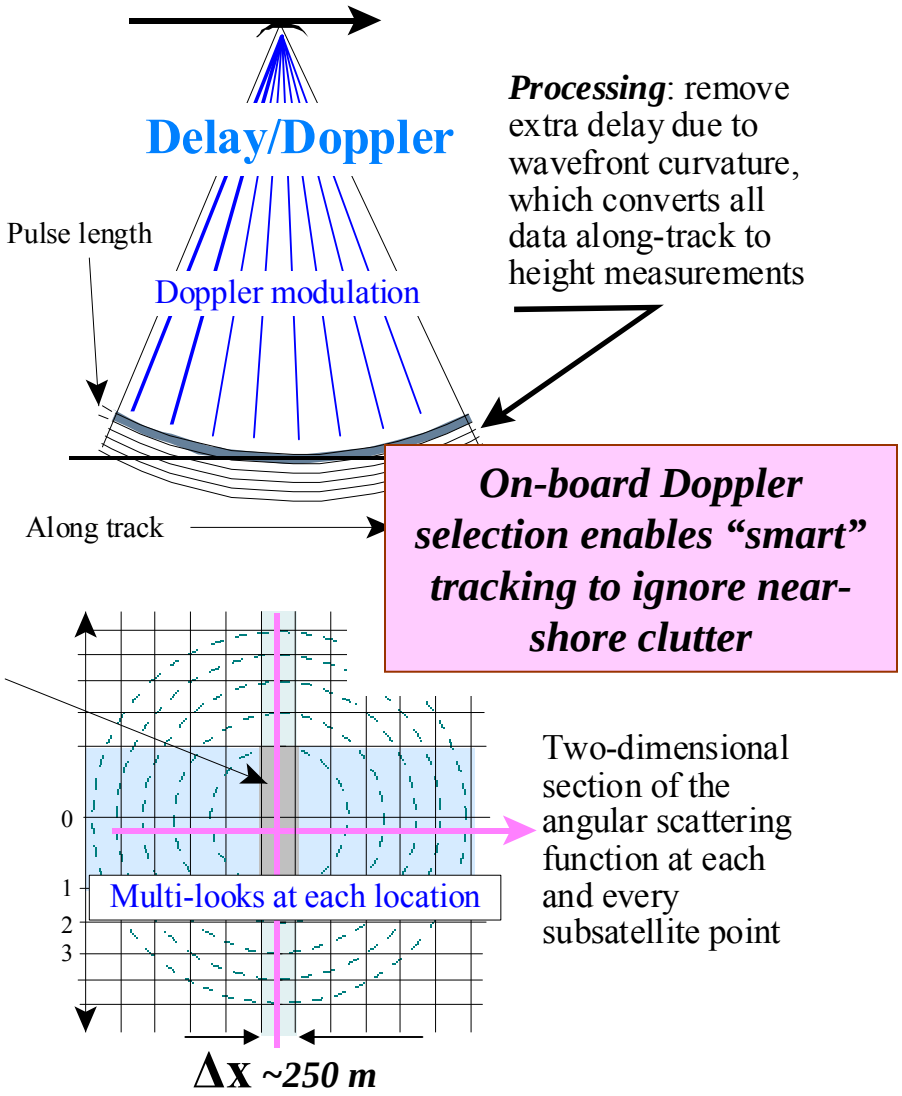


Unique Delay-Doppler Characteristics

- DDA paradigm retains advantages of a pulse-limited altimeter (pulse-limited across-track)
- SSH accuracy (to first order) does NOT depend on attitude control/knowledge of the s/c
- Instantaneous pulse-limited footprint along-track length Δx is constant with increasing SWH
- Sample posting rate @ ***n*** /km gives rise to a constant effective footprint along-track length

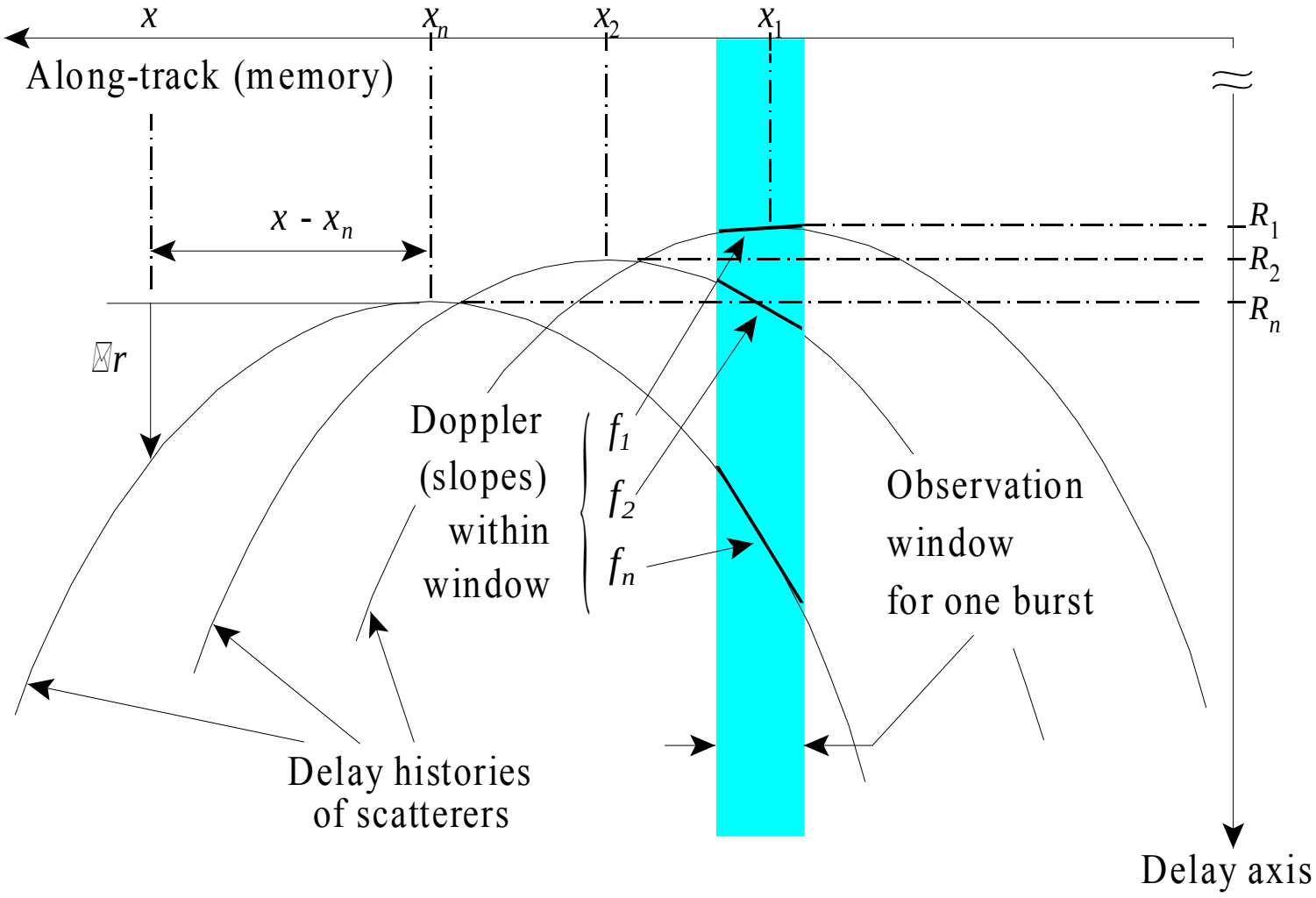
$$L_{eff} \approx (6.7/\boldsymbol{n}) \text{ km}$$

- Along-track posting rate 27 Hz for 250-m resolution



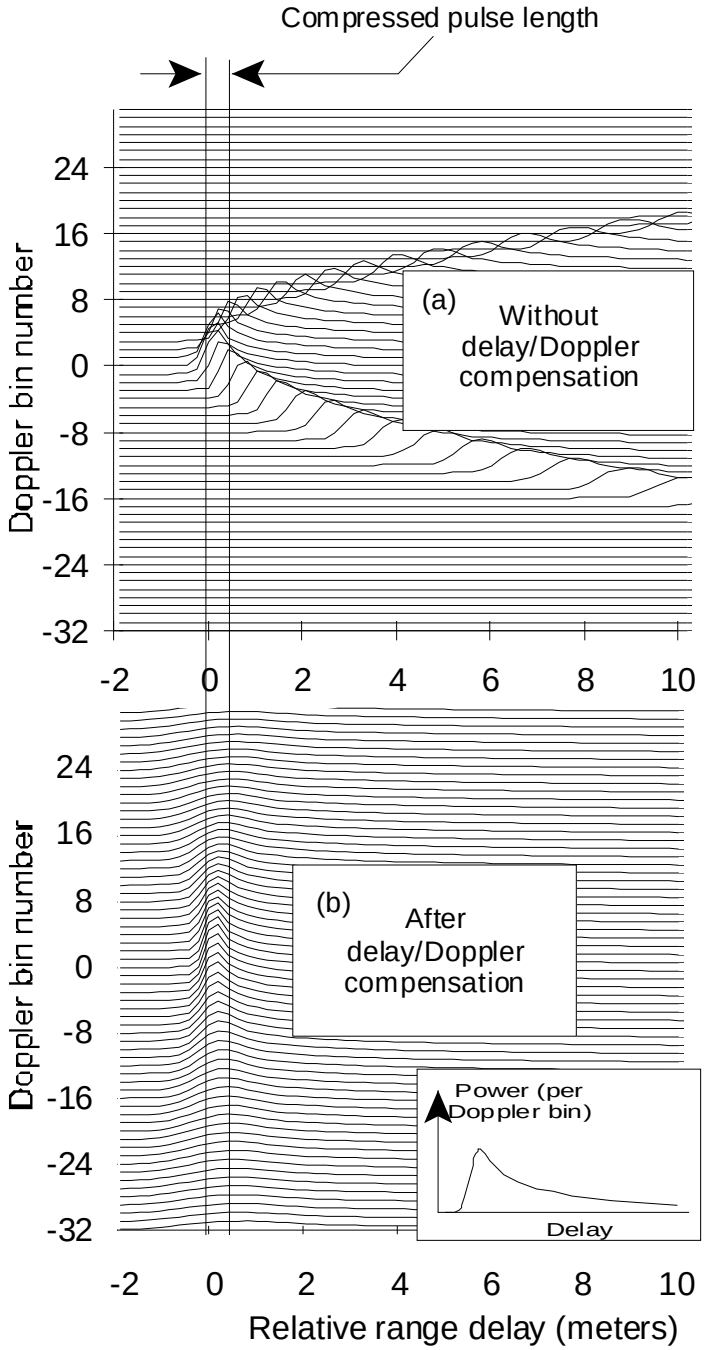
Curvature Delay *vs* Doppler

Before azimuth FFTs the curvature delays are multi-valued

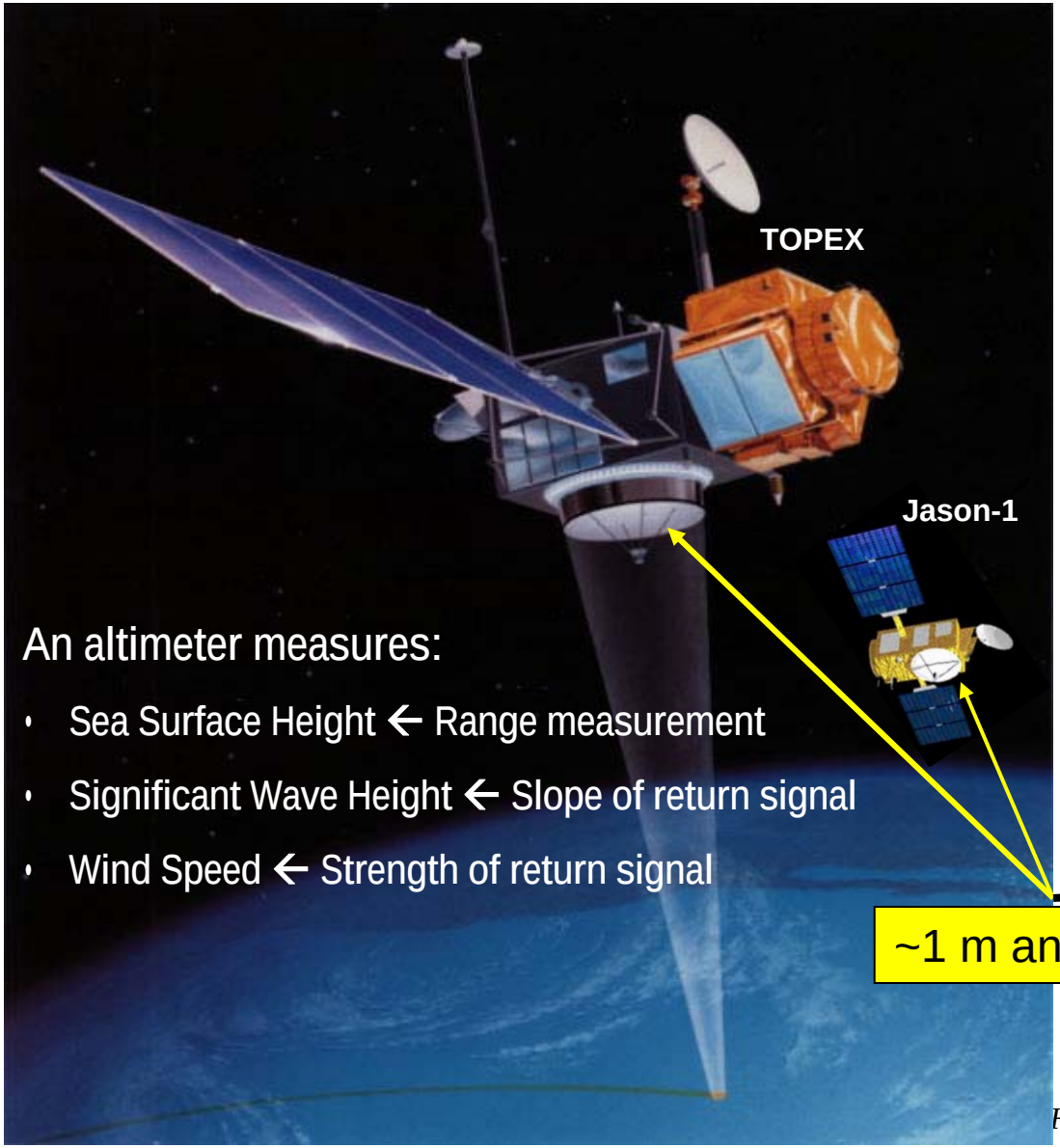


After Doppler decomposition range curvature is single-valued

Processing consists of an frequency/phase multiply in delay within each Doppler bin, one set of such operations per burst

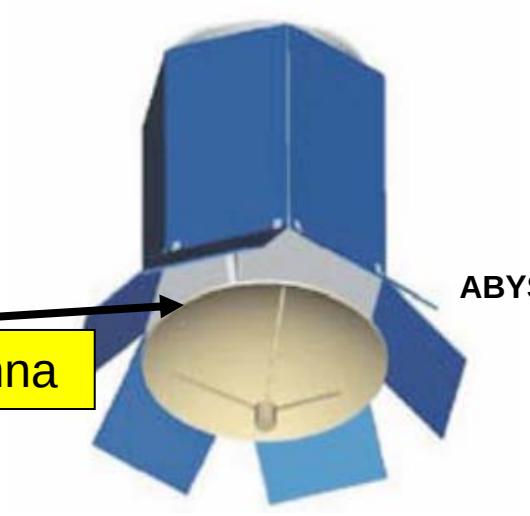


Conventional and Delay Doppler Altimeters (DDA) Measure the same Three Parameters



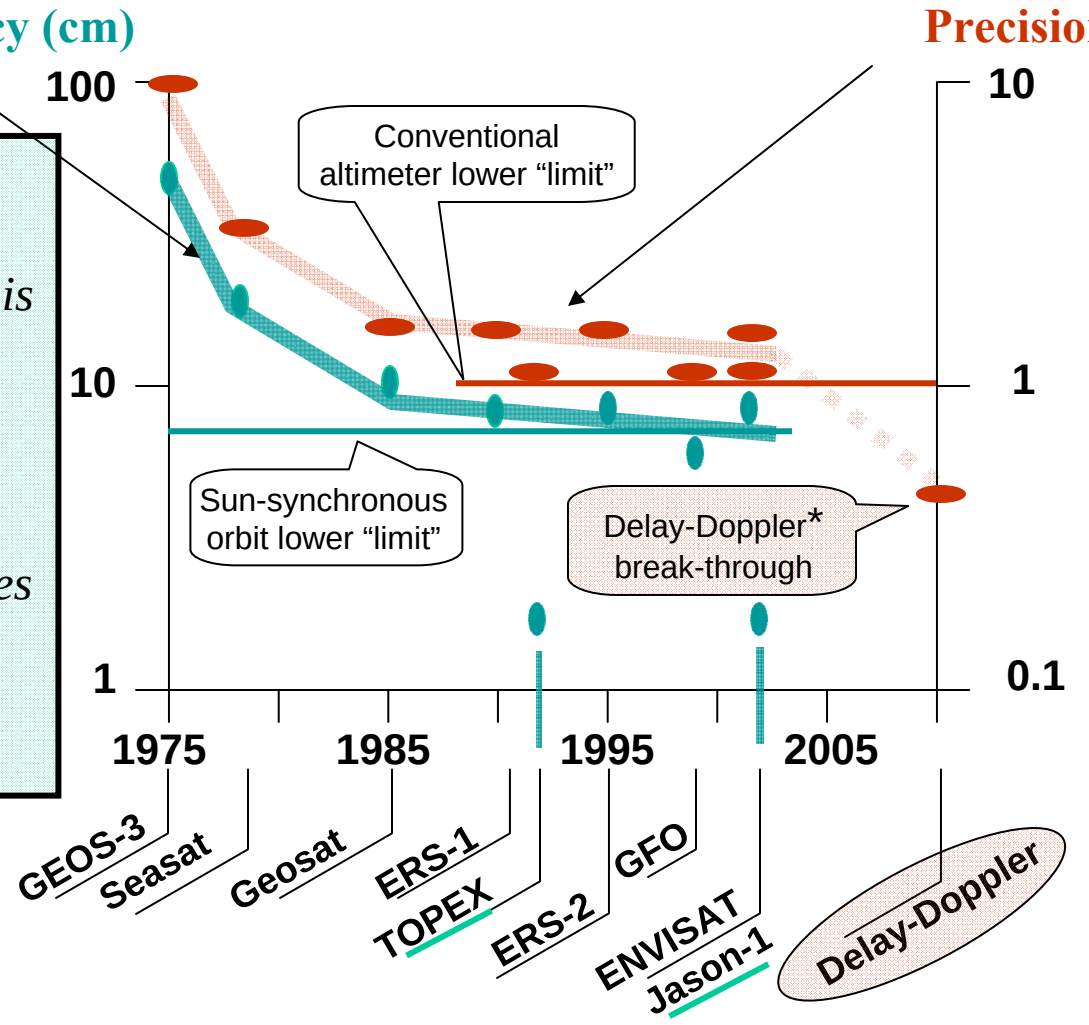
Delay Doppler Altimeter:

1. Low risk, low cost path to altimeter data continuity
2. Smaller footprint: 250m x 2 km
3. Measurement closer to shore: ~0.5 km (*vs ~40 km*)
4. Less s/c Mass and Power



Precision and Accuracy Trends

Height ***ACCURACY*** *(orbit-dependent) is the essential attribute of SSH measurements, thence global topographic studies and climatology (e.g annual sea level rise)*



Height ***PRECISION*** *(instrument dependent) is the essential measurement attribute for geodesy, bathymetry, and mesoscale oceanography, and enhances near-shore measurements*

Delay-Doppler (DDA) = CryoSat "SAR mode"