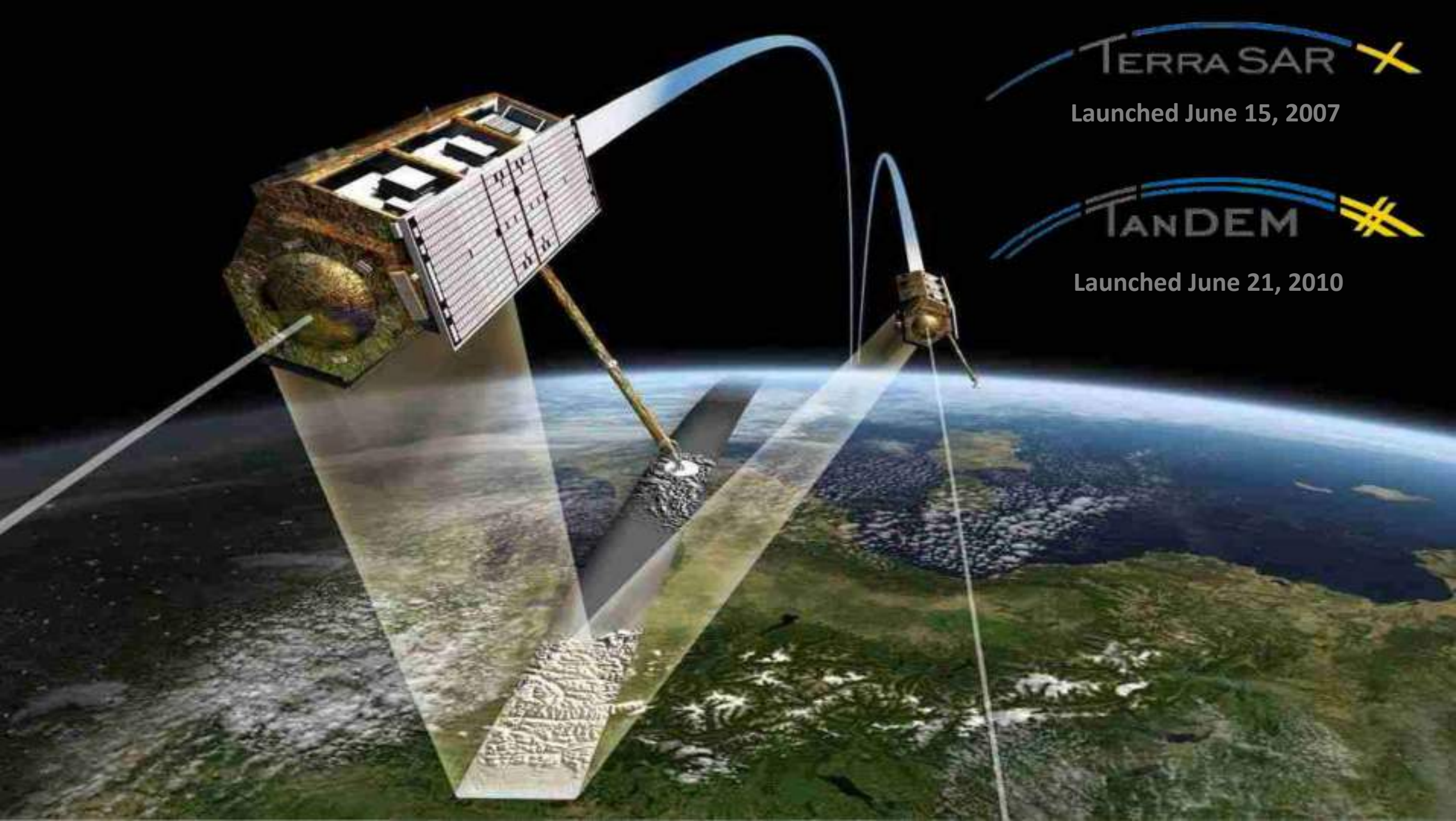
Future SAR Technologies and Mission Concepts

Alberto Moreira

German Aerospace Center

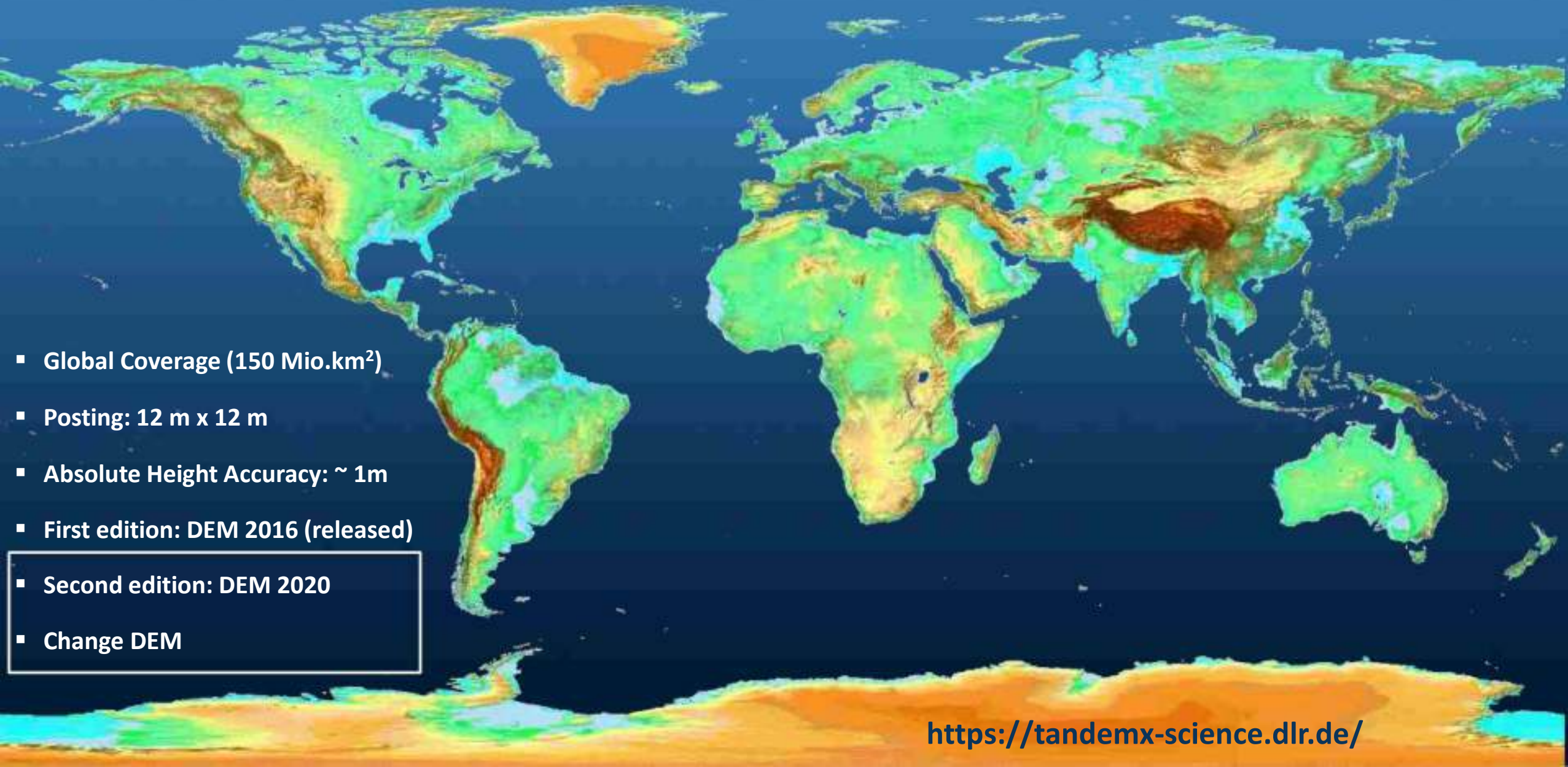
Microwaves and Radar Institute

Oberpfaffenhofen


TERRASAR
Launched June 15, 2007
TANDEM
Launched June 21, 2010


TanDEM

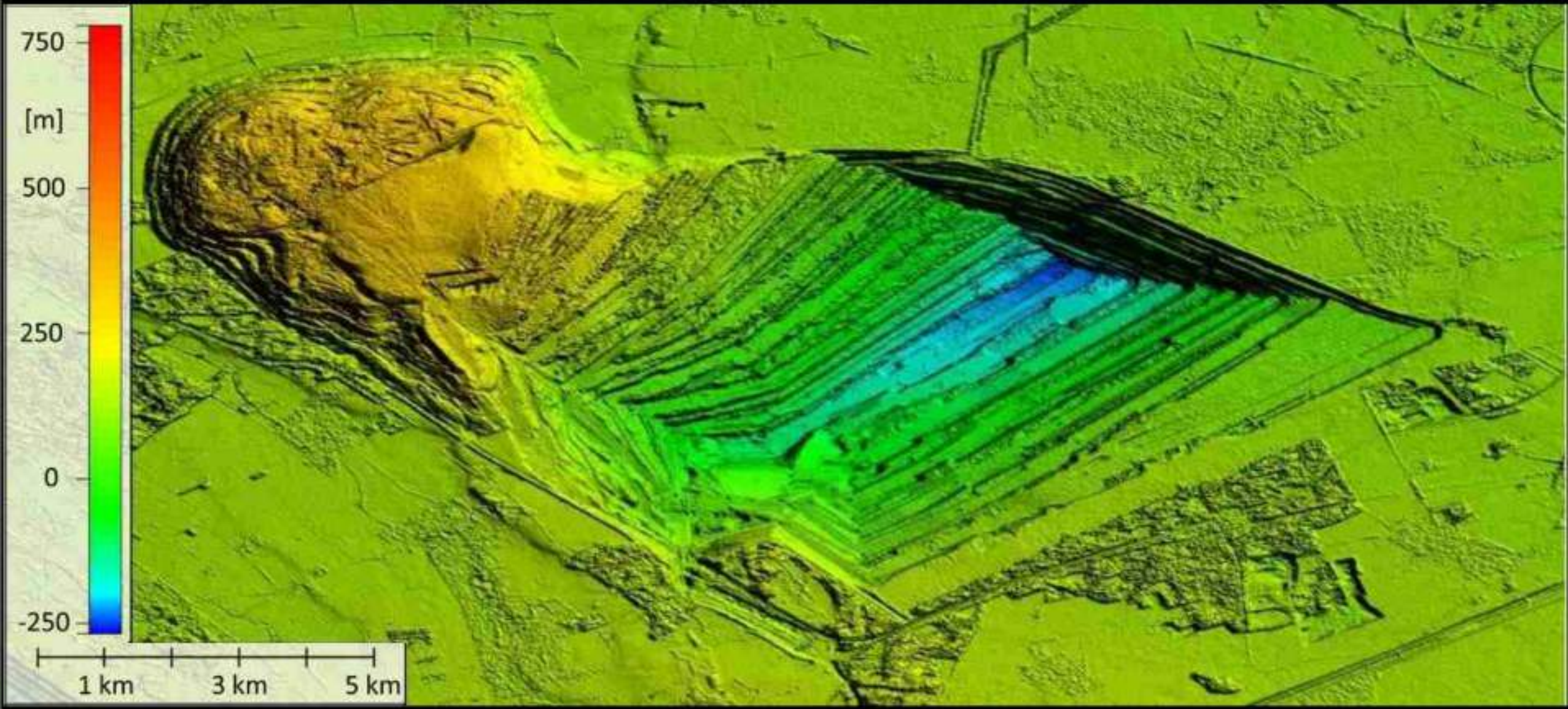
TanDEM-X Global Digital Elevation Model



- Global Coverage (150 Mio.km²)
- Posting: 12 m x 12 m
- Absolute Height Accuracy: ~ 1m
- First edition: DEM 2016 (released)
- Second edition: DEM 2020
- Change DEM

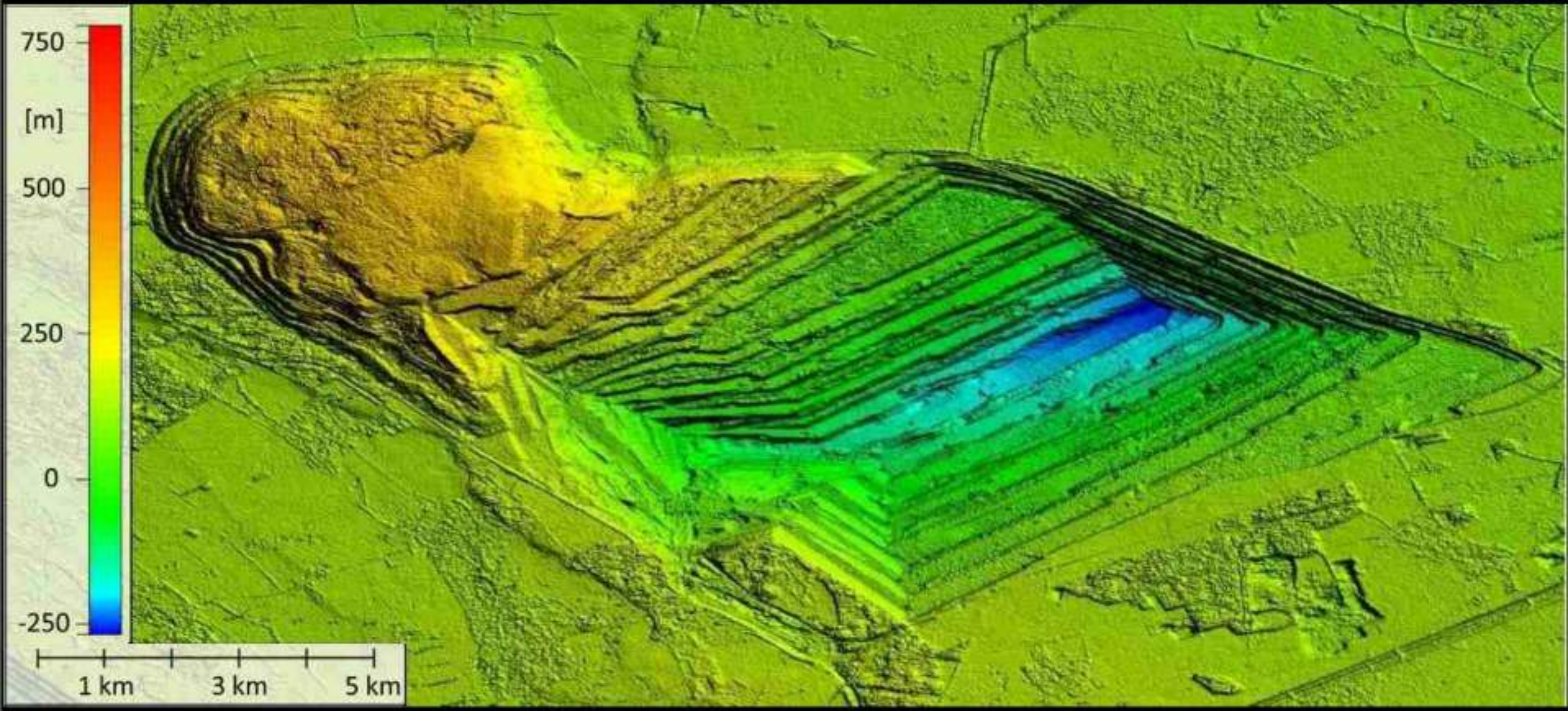
https://tandemx-science.dlr.de/

TanDEM-X DEM 2016



Open Pit Mine, Hambach, Germany

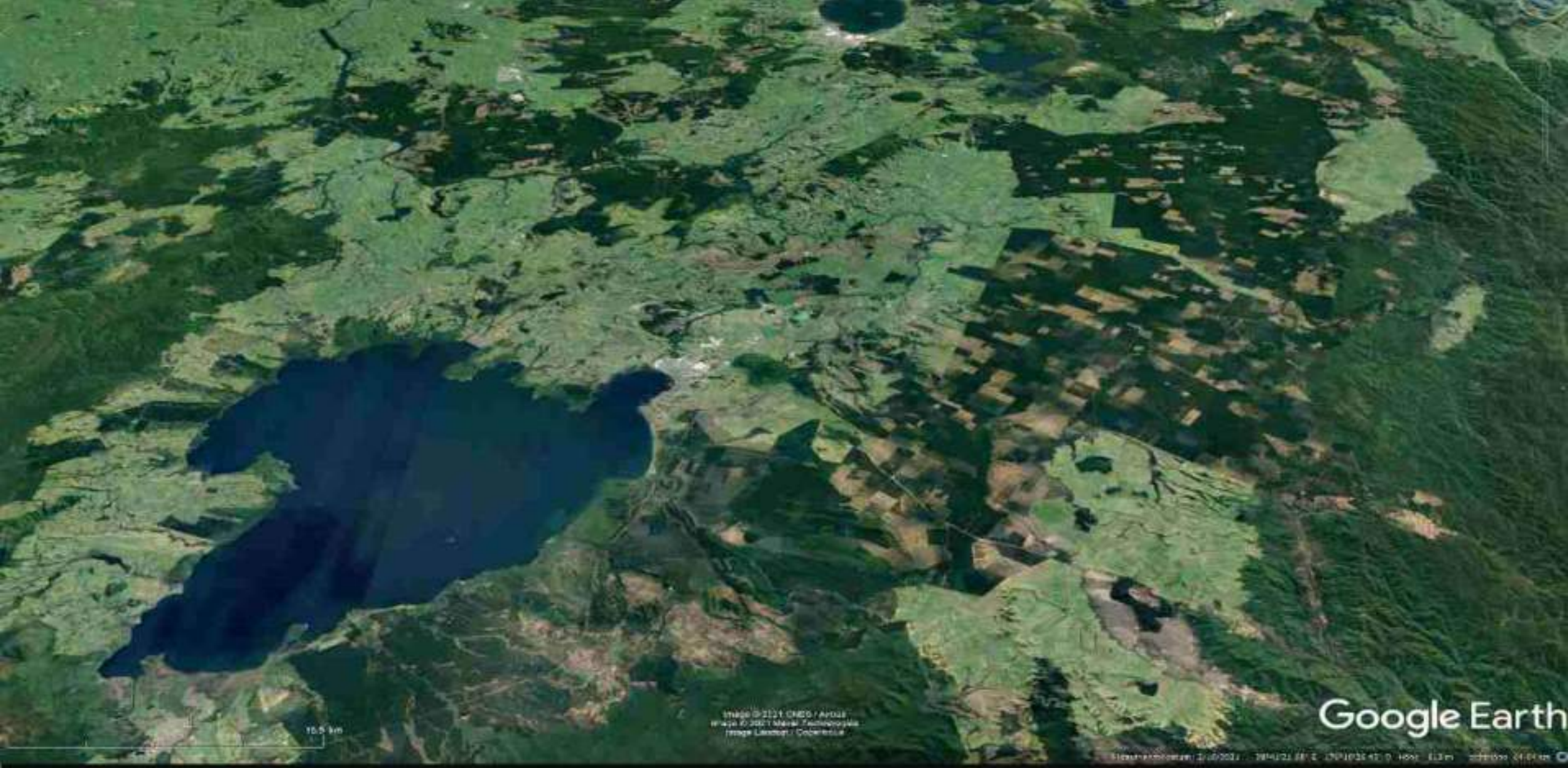
TanDEM-X DEM 2020



Open Pit Mine, Hambach, Germany

DLR

TanDEM

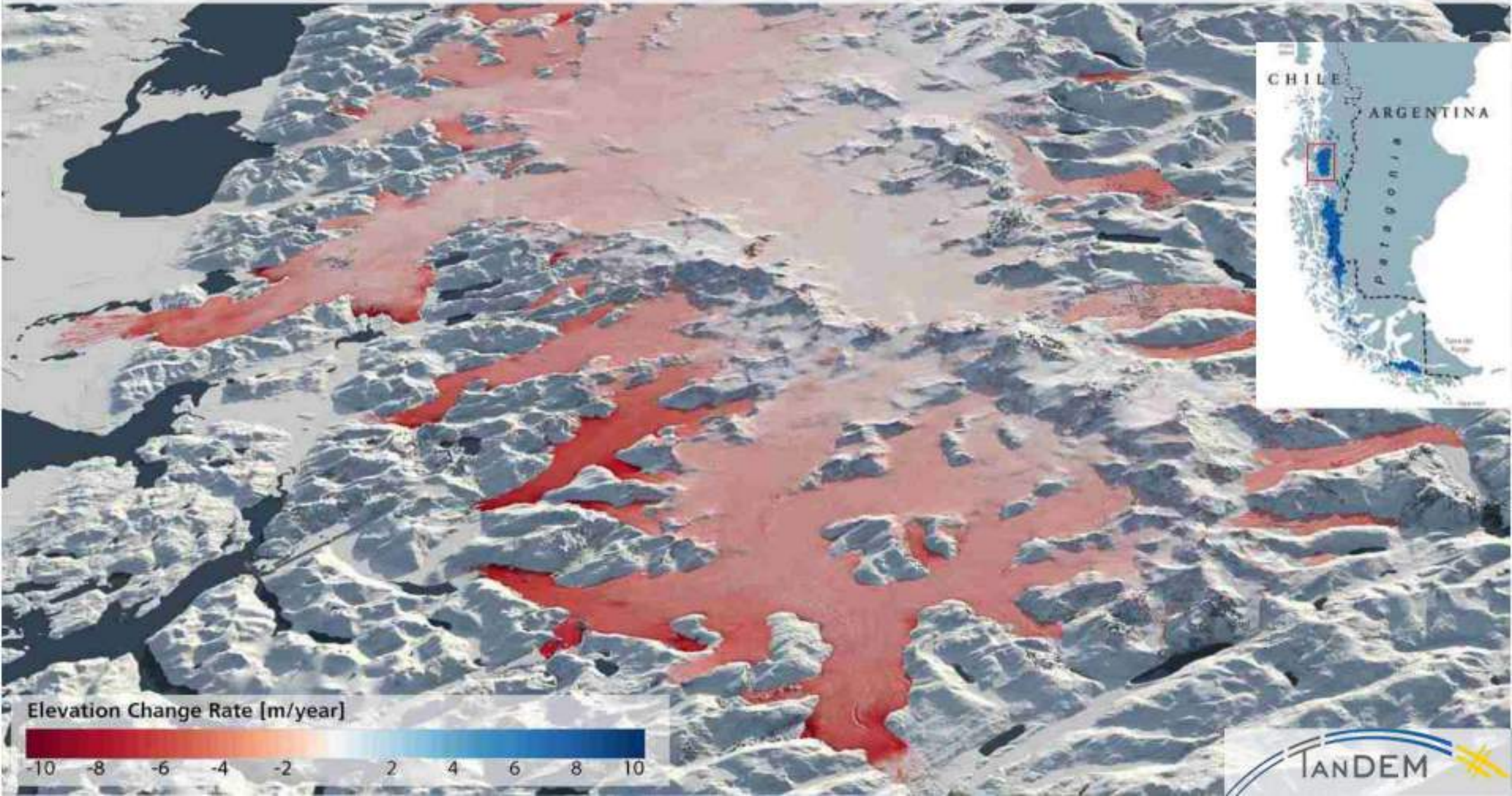


Lake Taupo, New Zealand

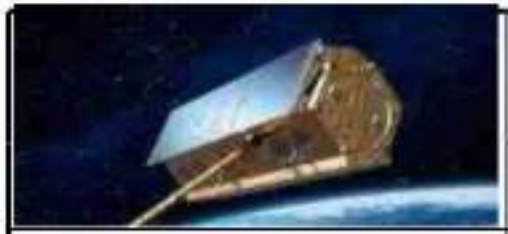
Lake Taupo, New Zealand, Change DEM

Rain Forest, Rondonia, Brazil (Change DEM)

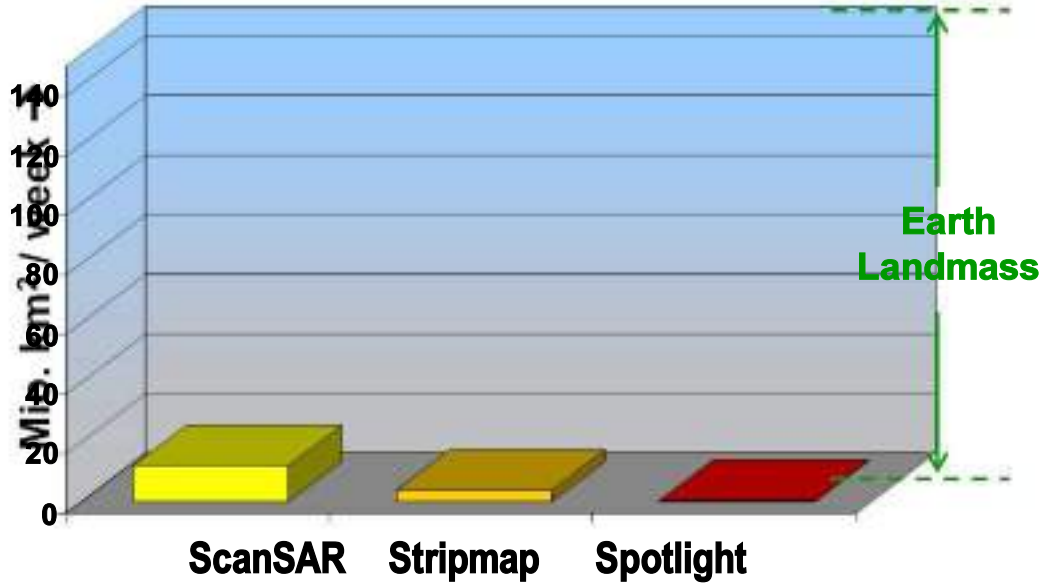
Melting of the North-Patagonian Ice Field



Mapping Capacity of TerraSAR-X / TanDEM-X



	Imaging Mode			
	Wide ScanSAR	ScanSAR	Stripmap	Spotlight
Resolution	40 m	16 m	3 m	1 m
Swath Width	270 km	100 km	30 km	10 km
Duty Cycle	3-5 minutes / orbit			

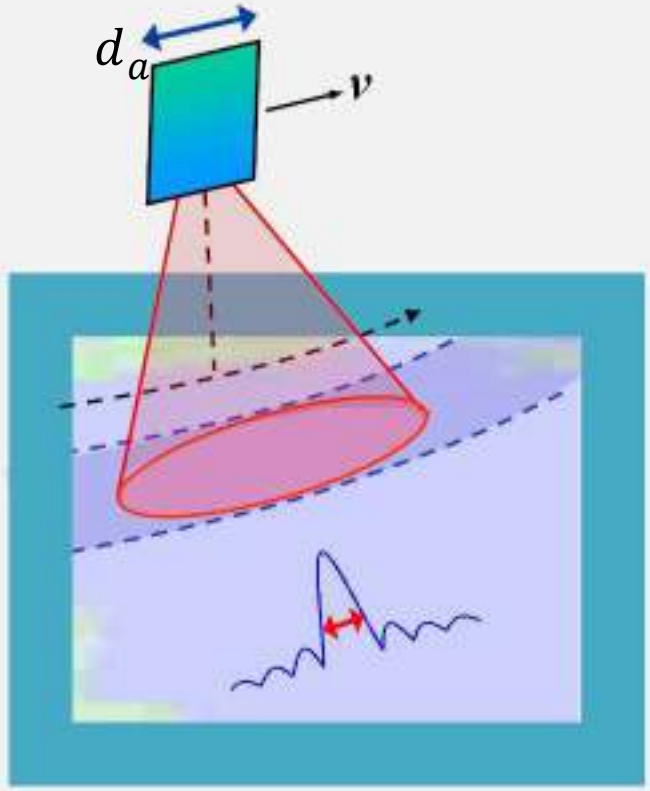


1 Day

DLR

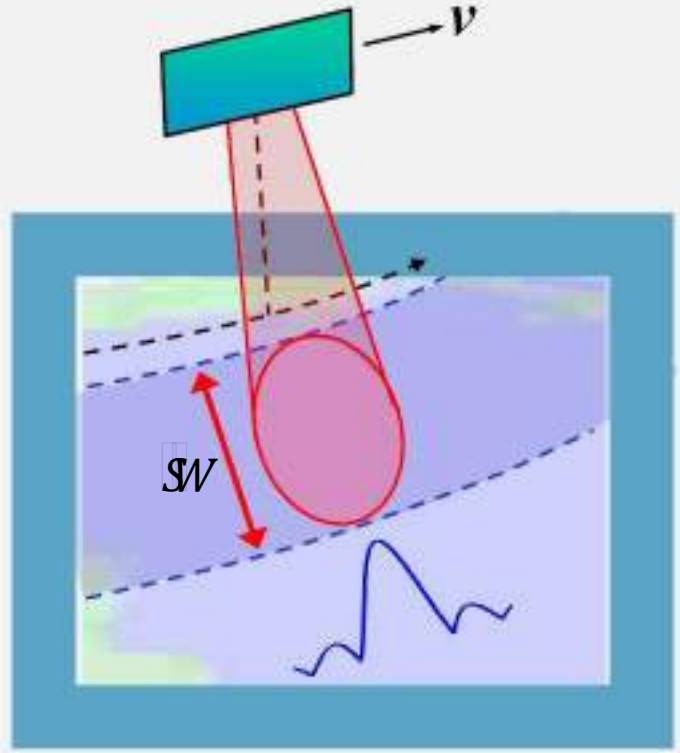
Limitations of conventional SAR

Case 1: High azimuth resolution



$$PRF > \frac{2.v}{d_a}$$

Case 2: Large swath width



$$PRF < \frac{c}{2.SW.\sin\theta_i}$$

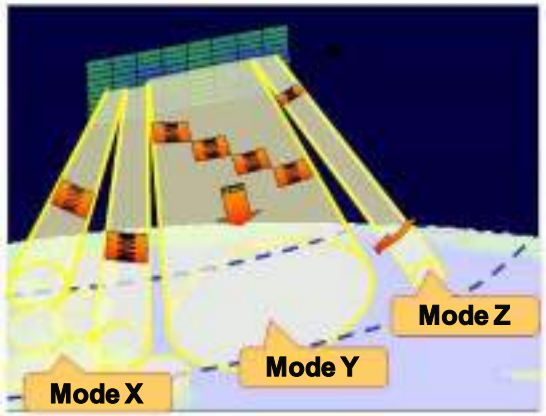
PRF = Pulse Repetition Rate

DLR

SAR Systems: State of the Art and Future Requirements

State of the Art (Sentinel-1)	Imaging Mode (**single/dual pol.**)		
	EW	IW	SM
Resolution	**40 m**	**20 m**	**5 m**
Swath Width	**400 km**	**250 km**	**80 km**
Orbit Duty Cycle	**25 minutes per orbit**		

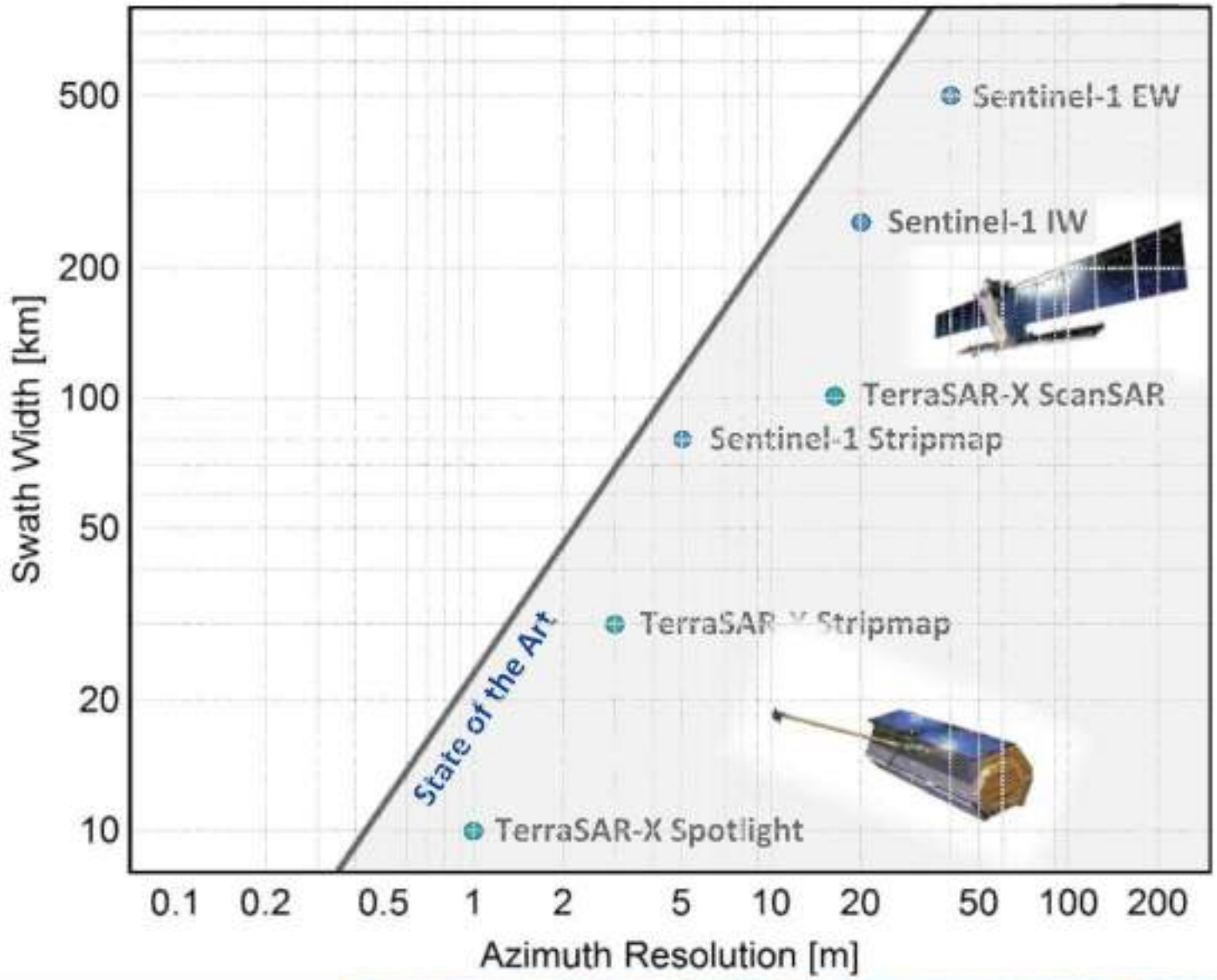
Resolution ⟷ **Swath Width** ⟷ **Repeat Cycle**



Future Requirements	Imaging Mode (**quad pol.**)		
	Mode X	Mode Y	Mode Z
Resolution	**5 m**	**2 m**	**1 m**
Swath Width	**500 km**	**200 km**	**100 km**
Orbit Duty Cycle	**> 50 minutes per orbit**		

DLR

A Constraint of the Spaceborne SAR Systems

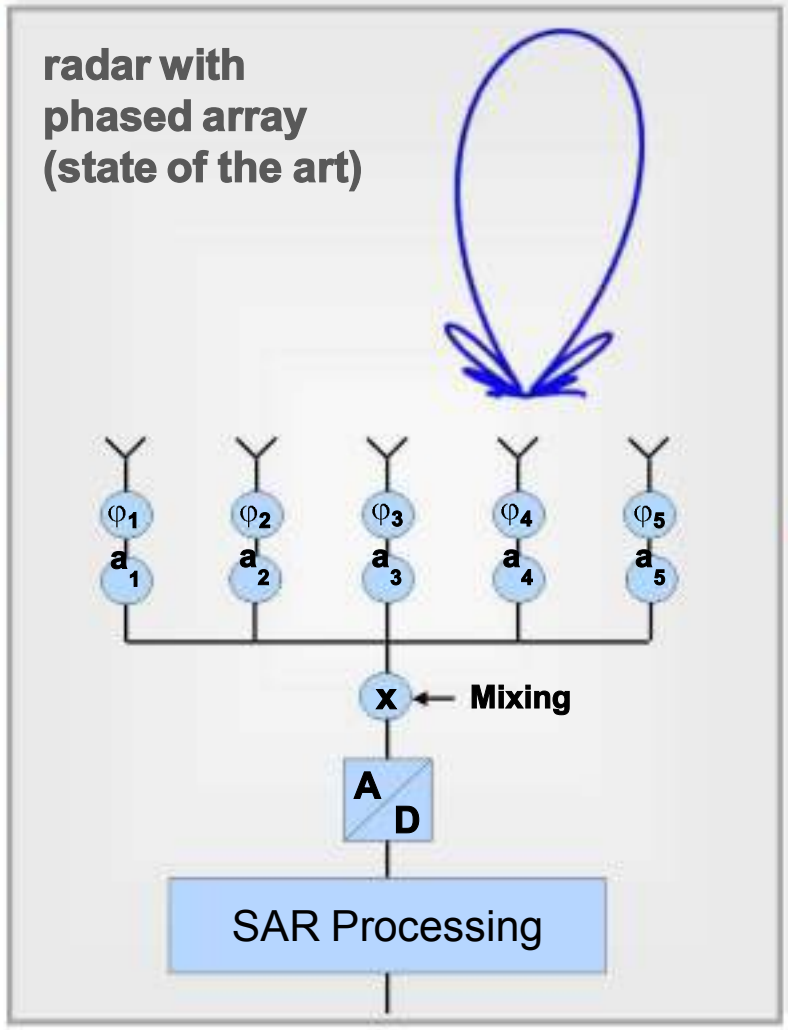


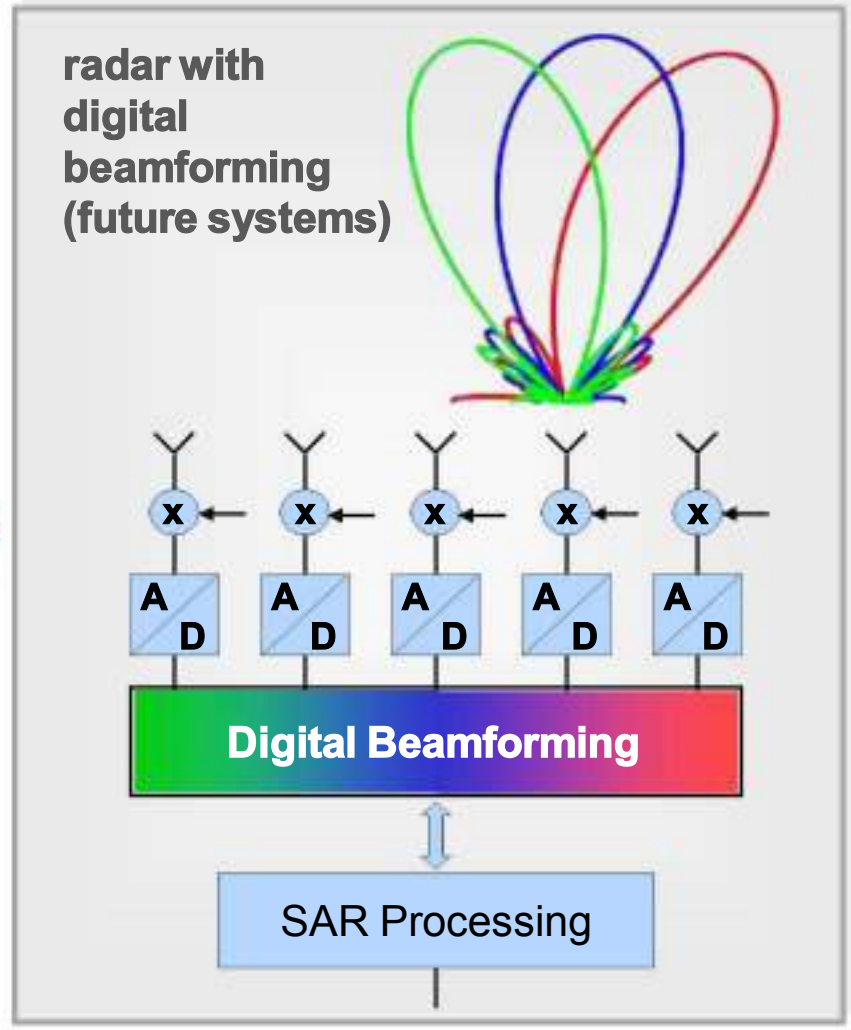
The Future of Synthetic Aperture Radar…

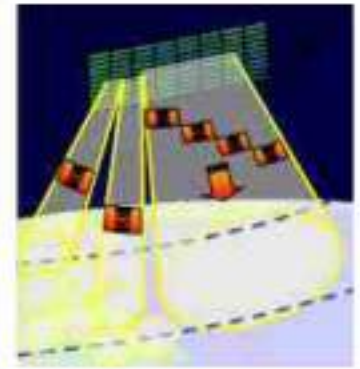
…Digital Beamforming: A Paradigm Shift!

Digital Beamforming / Multichannel SAR

Sentinel-1,
TerraSAR-X,
ALOS-2,
Radarsat-2,
RCM, etc.



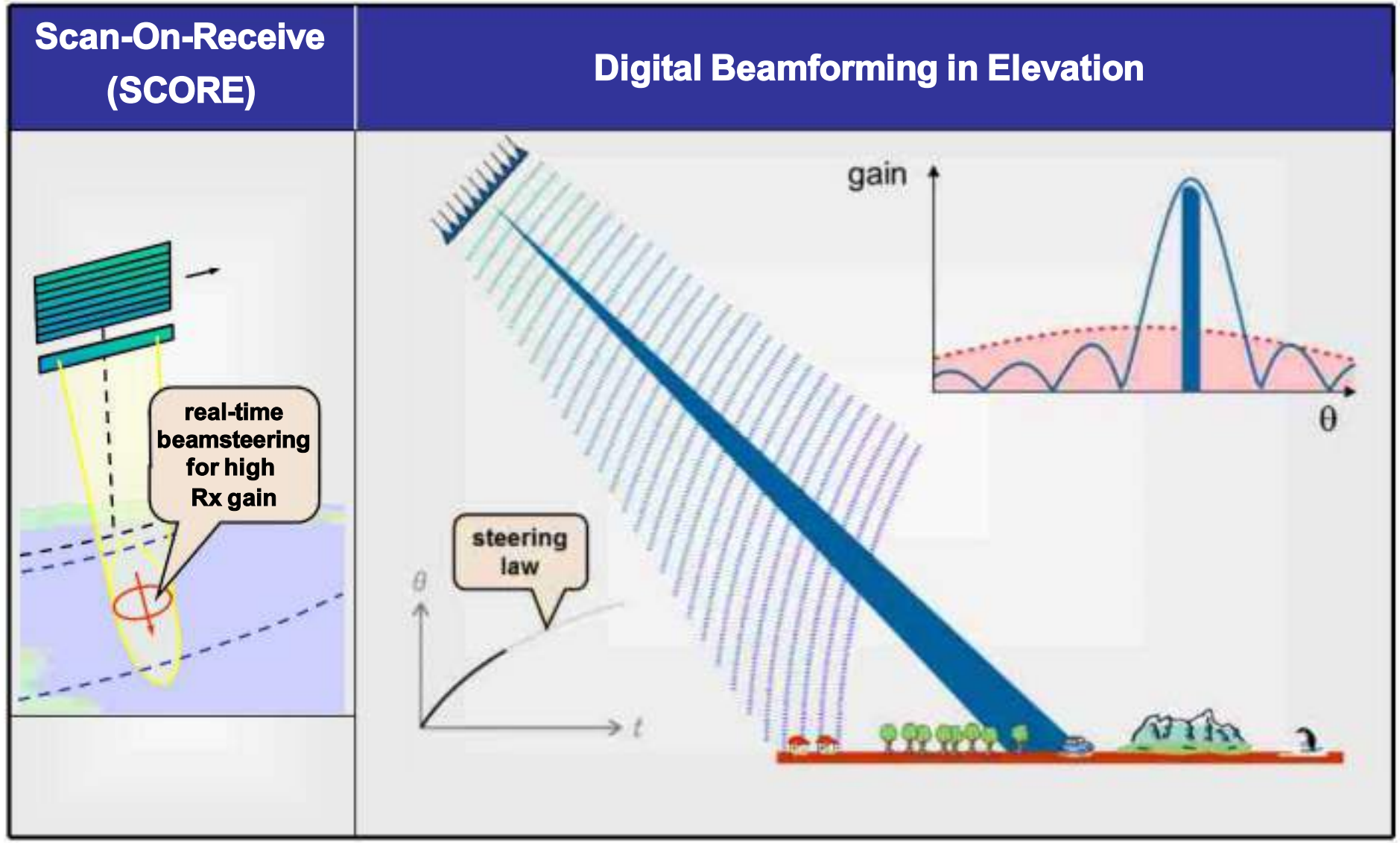




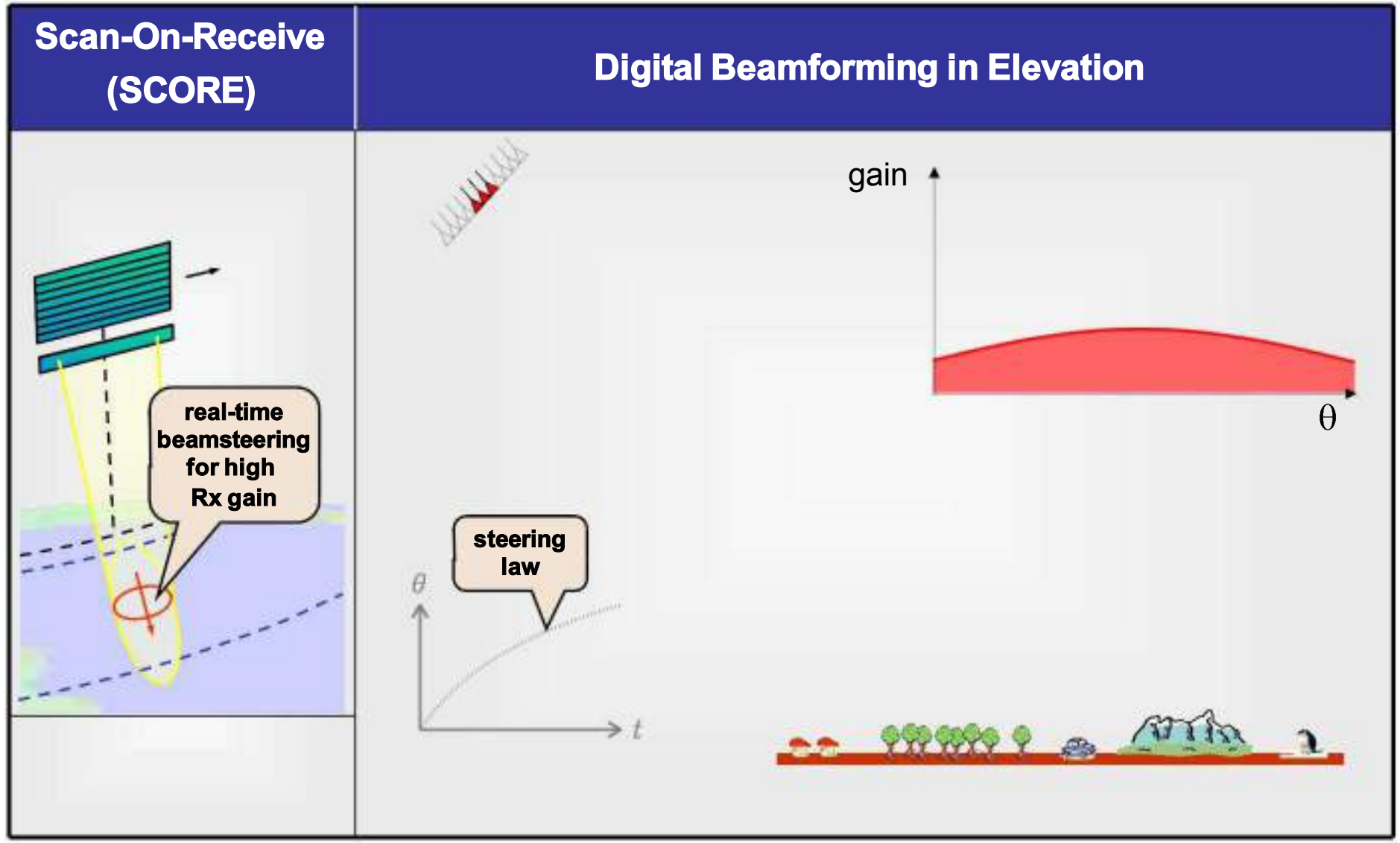
ALOS-4, NISAR,
ROSE-L,
Sentinel-1NG,
Tandem-L, etc.

DLR

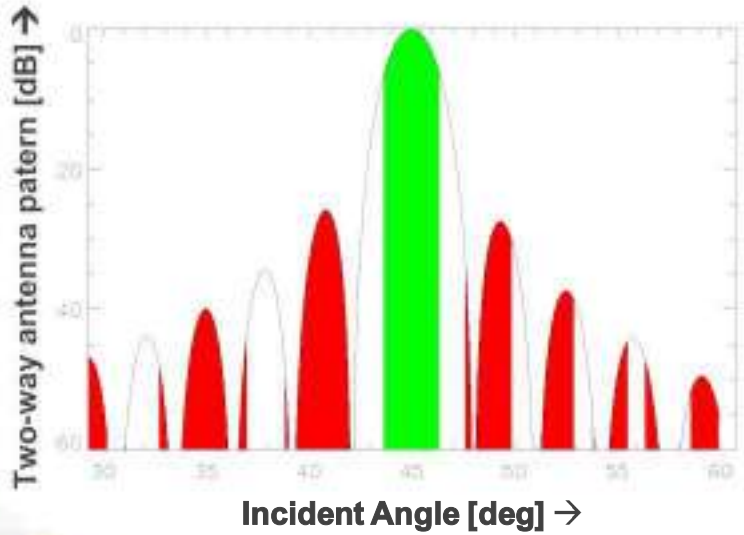
Digital Beamforming in Elevation

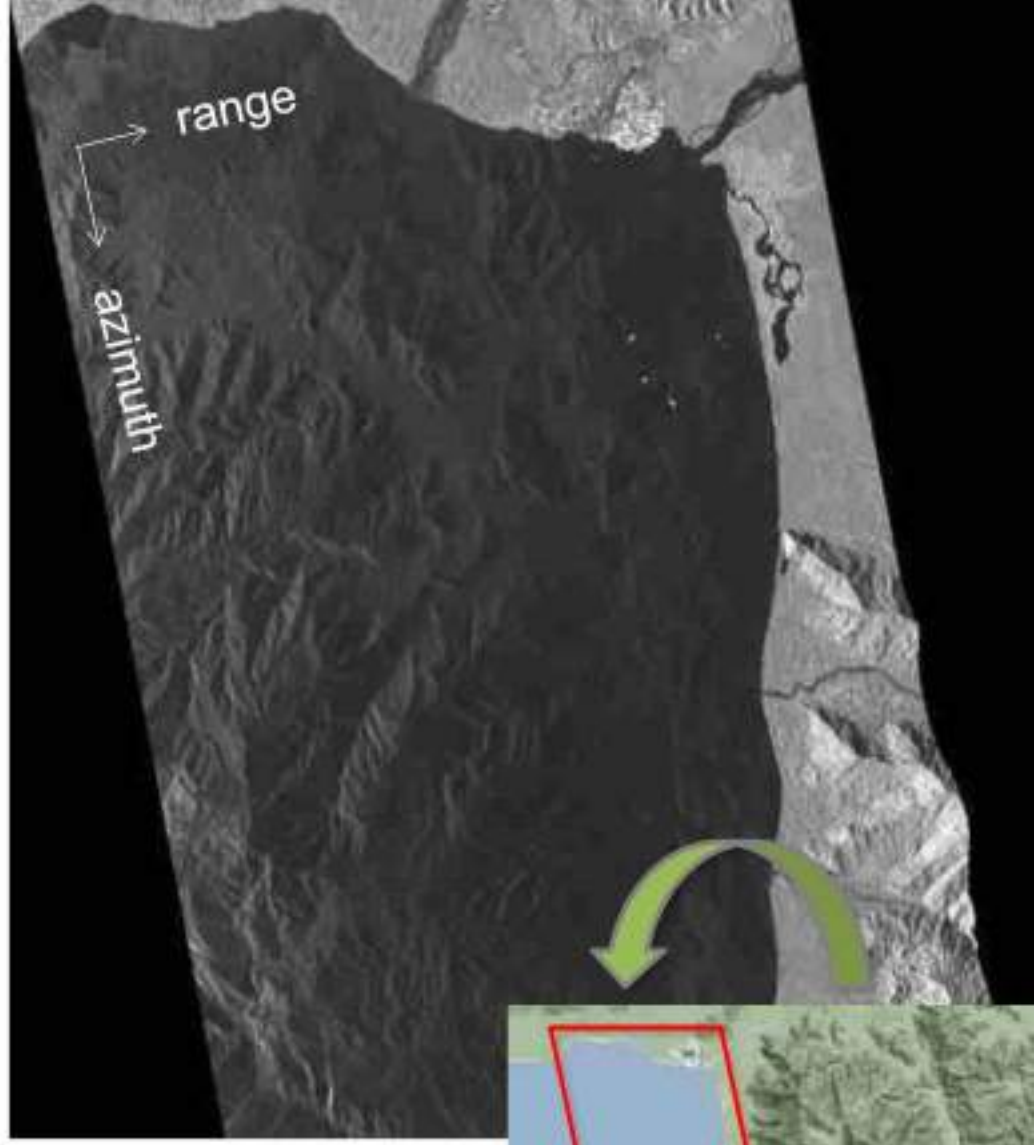


Digital Beamforming in Elevation



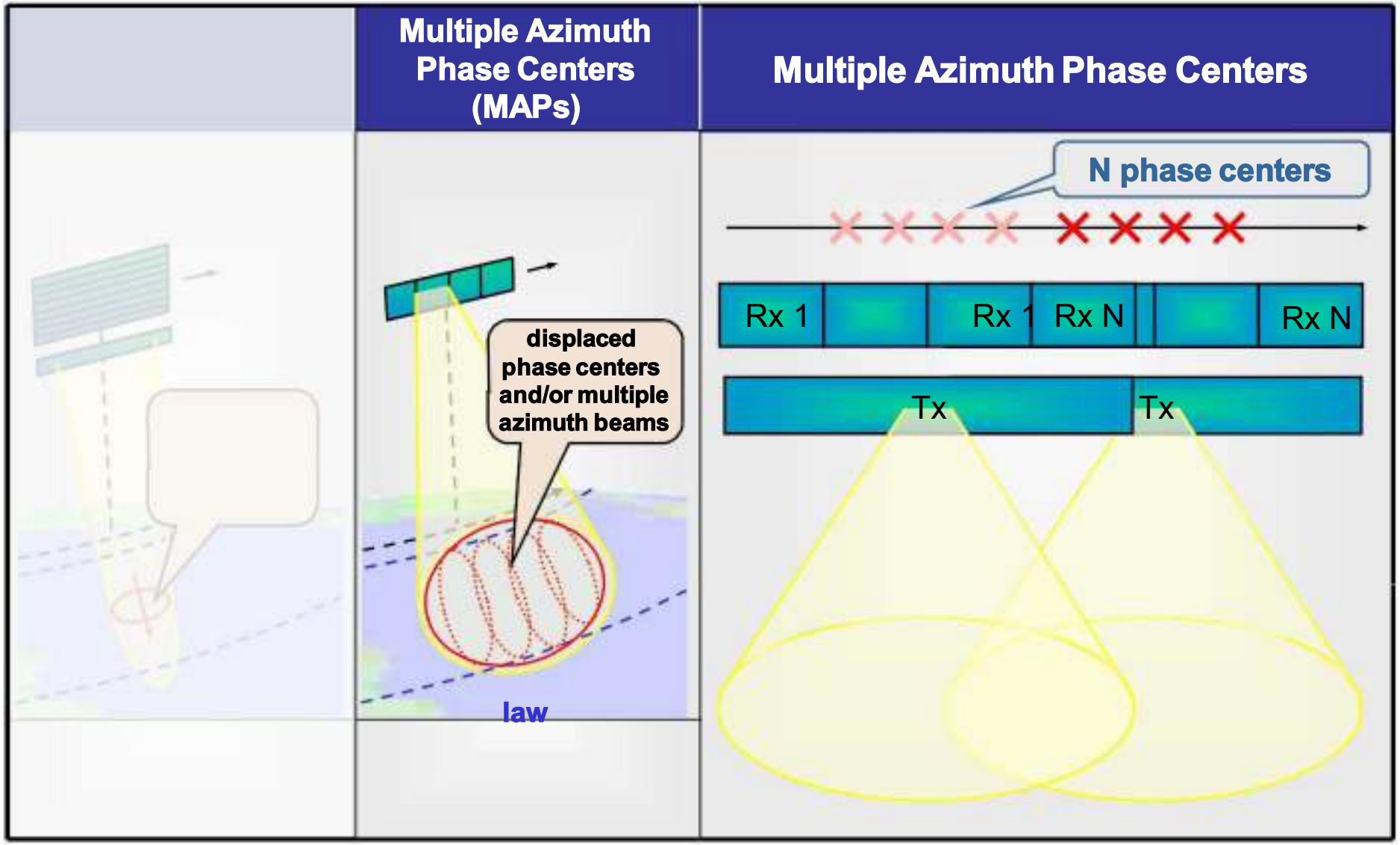
Range Ambiguities in SAR Systems





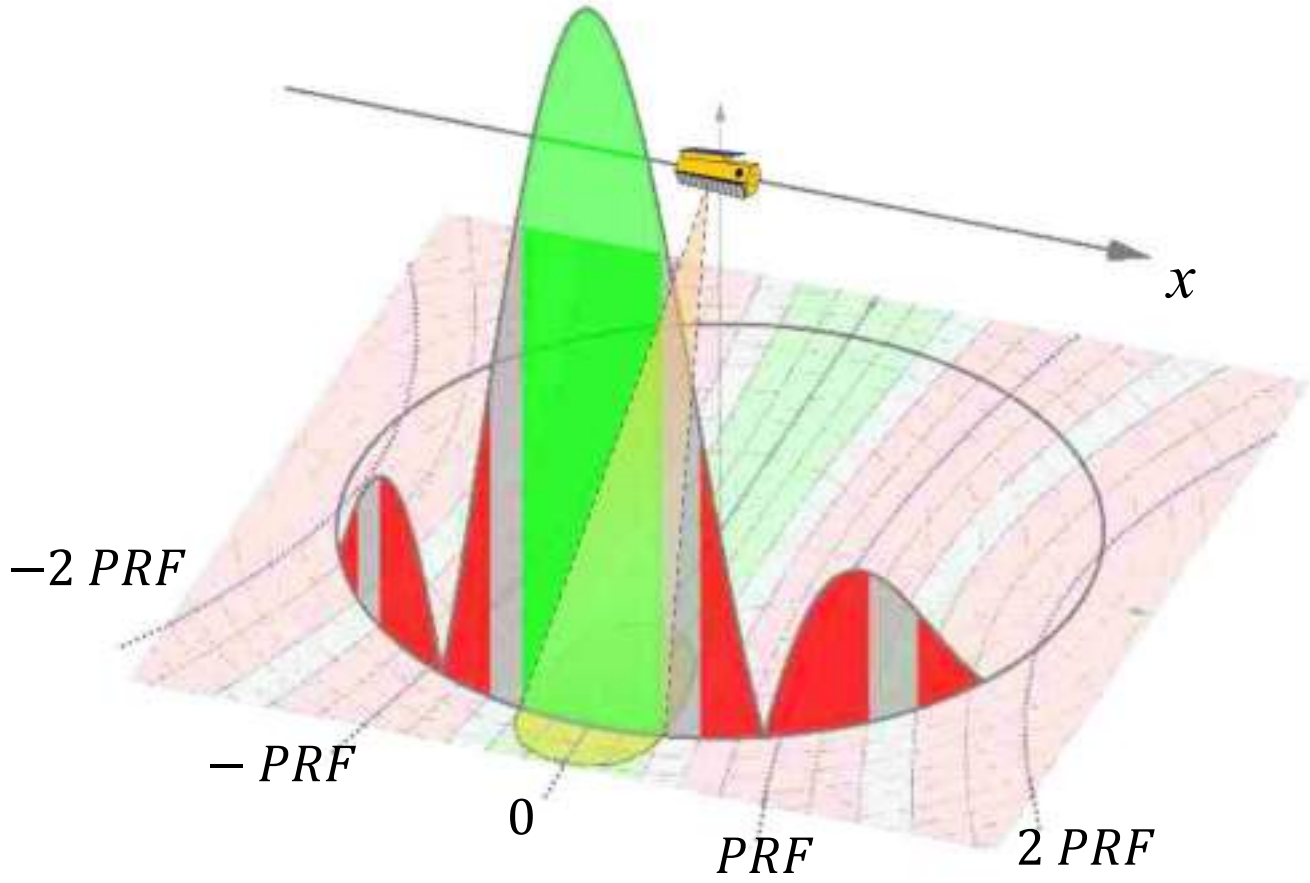
DLR

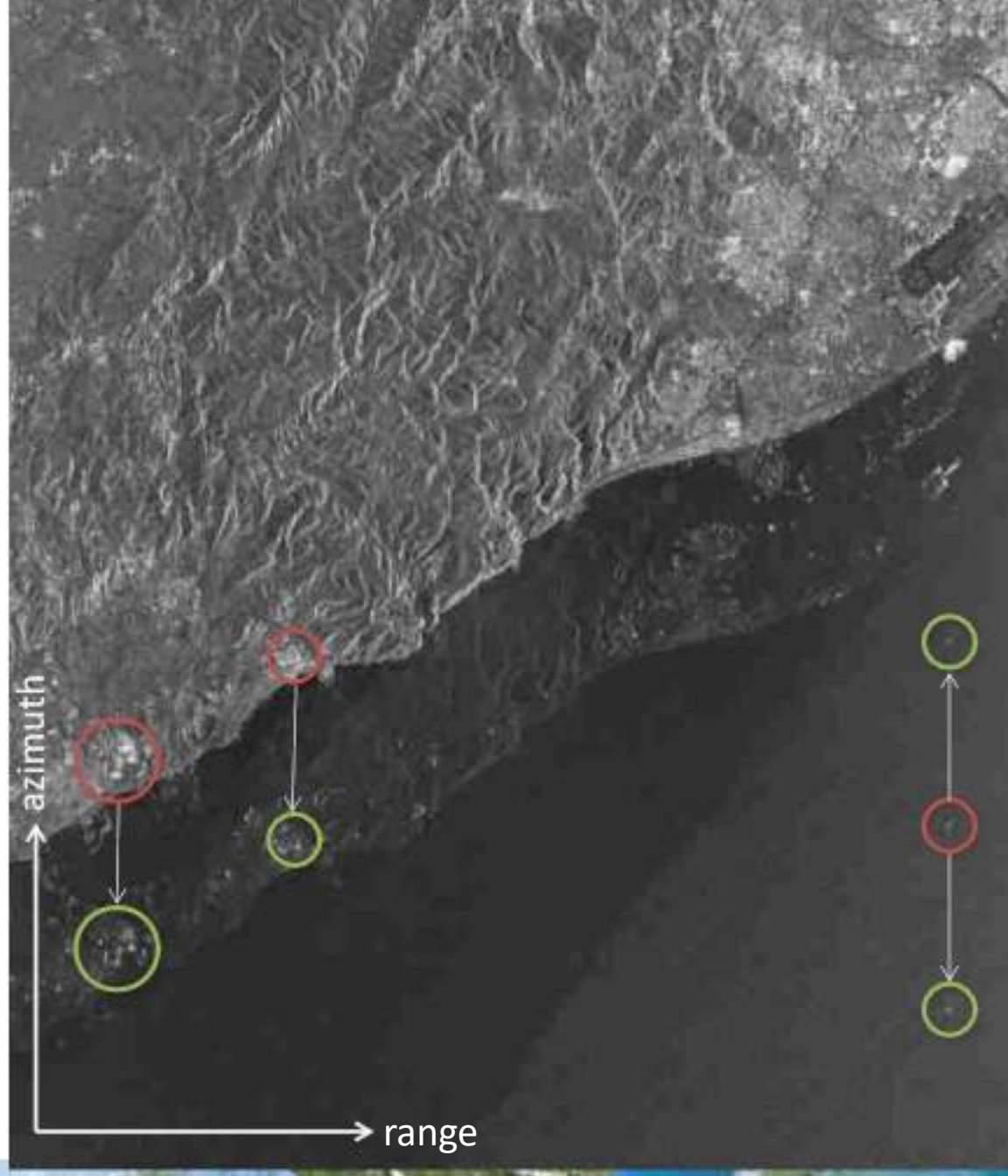
Digital Beamforming in Azimuth



DLR

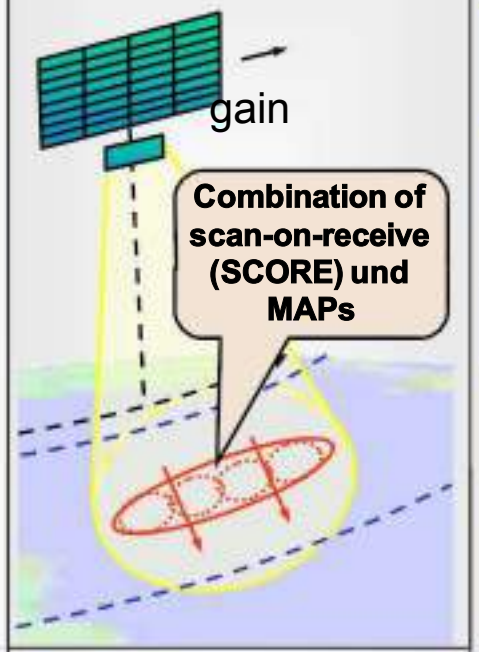
Azimuth Ambiguities in SAR Systems





DLR

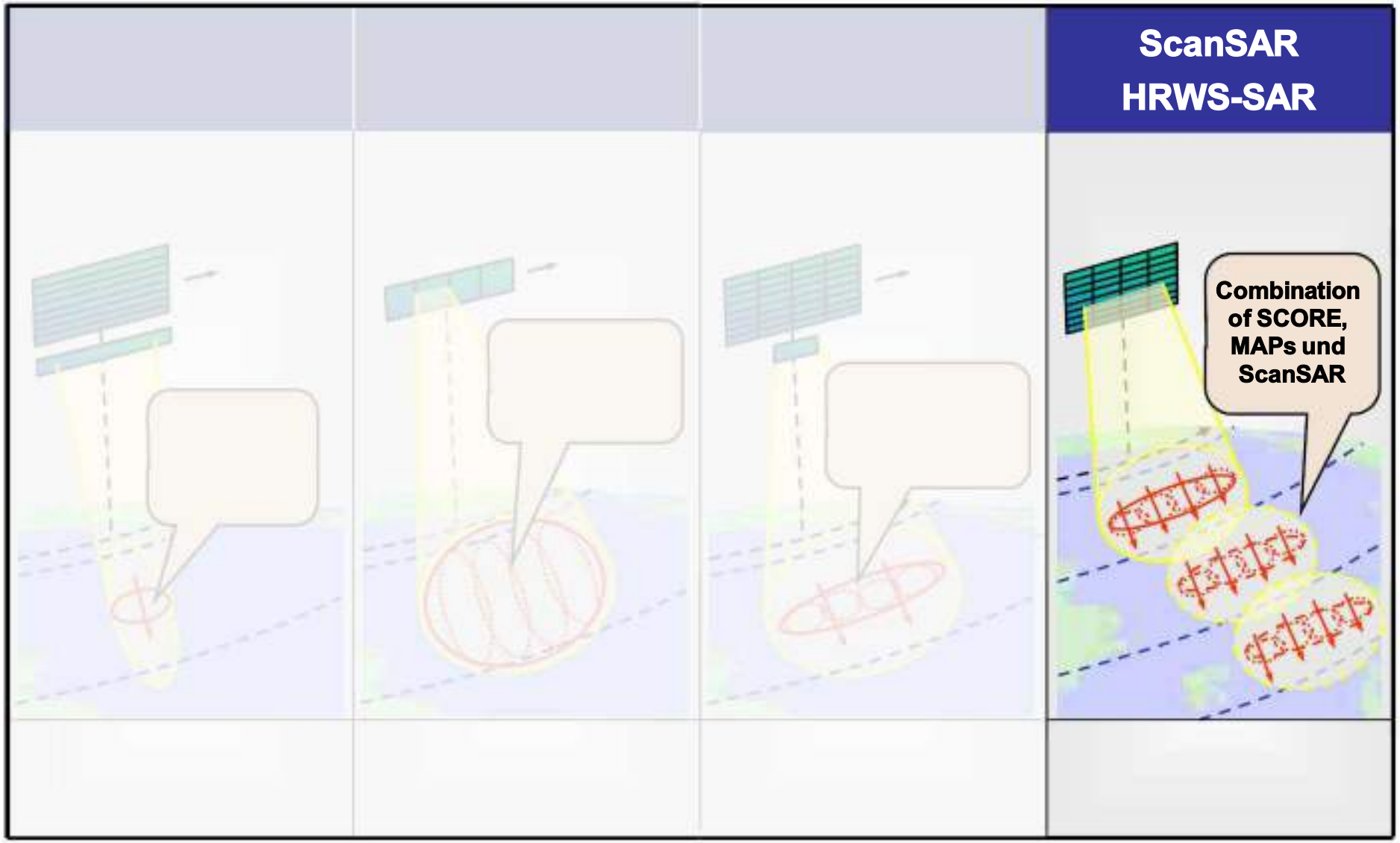
Digital Beamforming in Elevation and Azimuth

		High Resolution Wide Swath (HRWS)	System Concept Examples
			

swath [km]	PRF [Hz]	d_{ant} [m]
100	1600	≳10
200	800	≳20
400	400	≳40

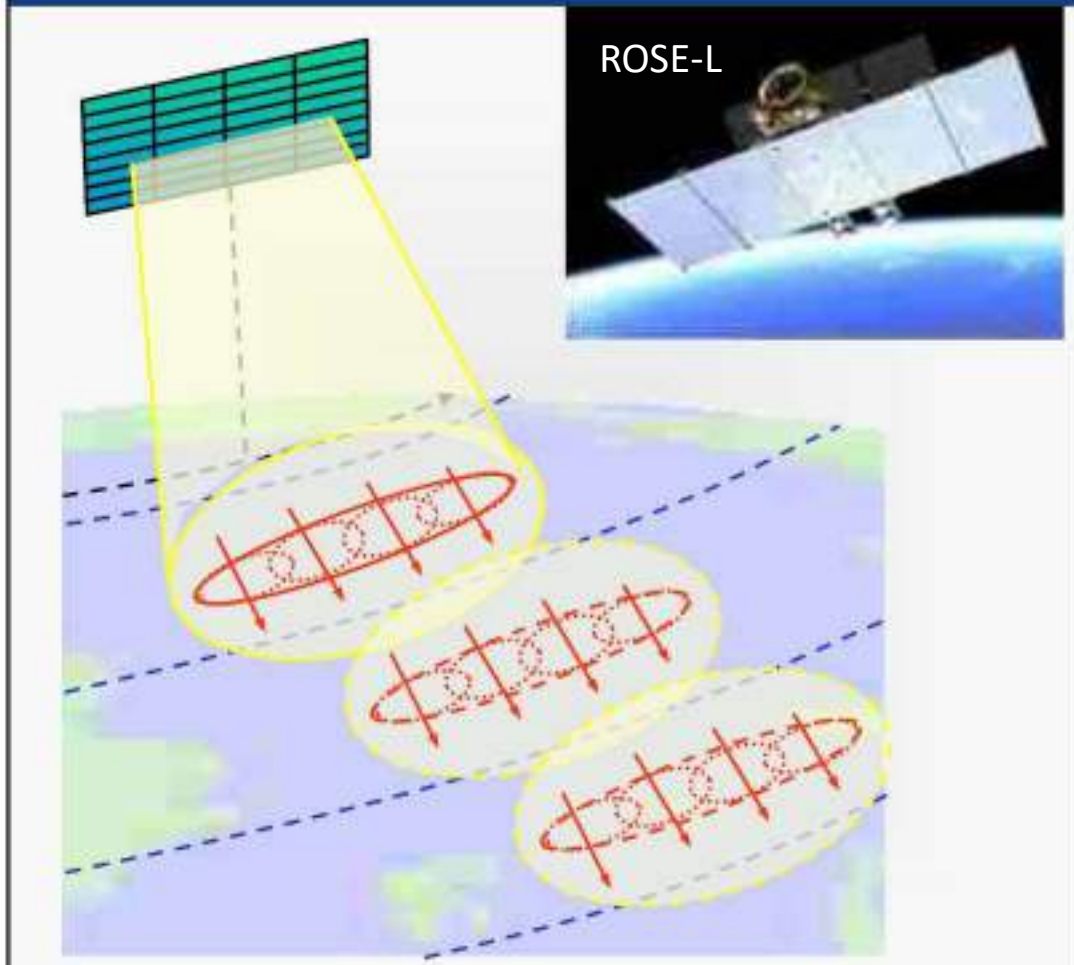
DLR

Digital Beamforming in Azimuth and Elevation with ScanSAR

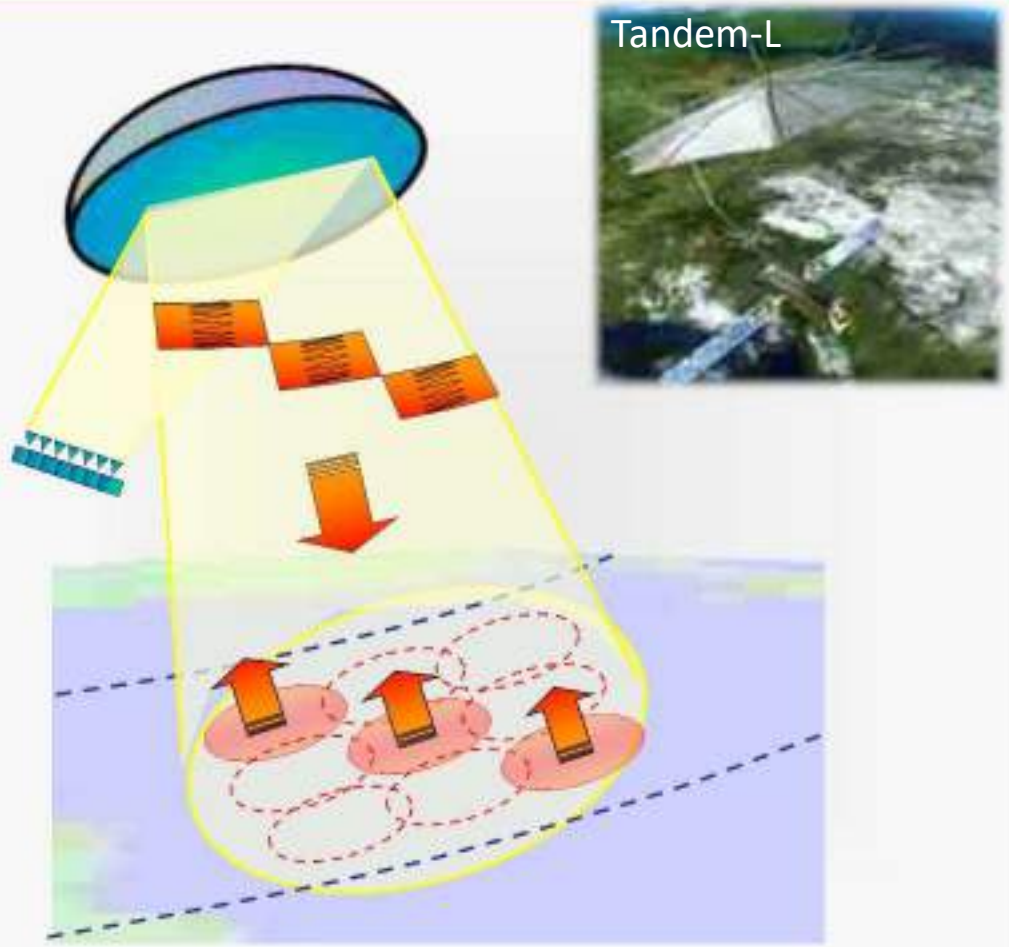


Digital Beamforming @ Future Spaceborne SAR Systems

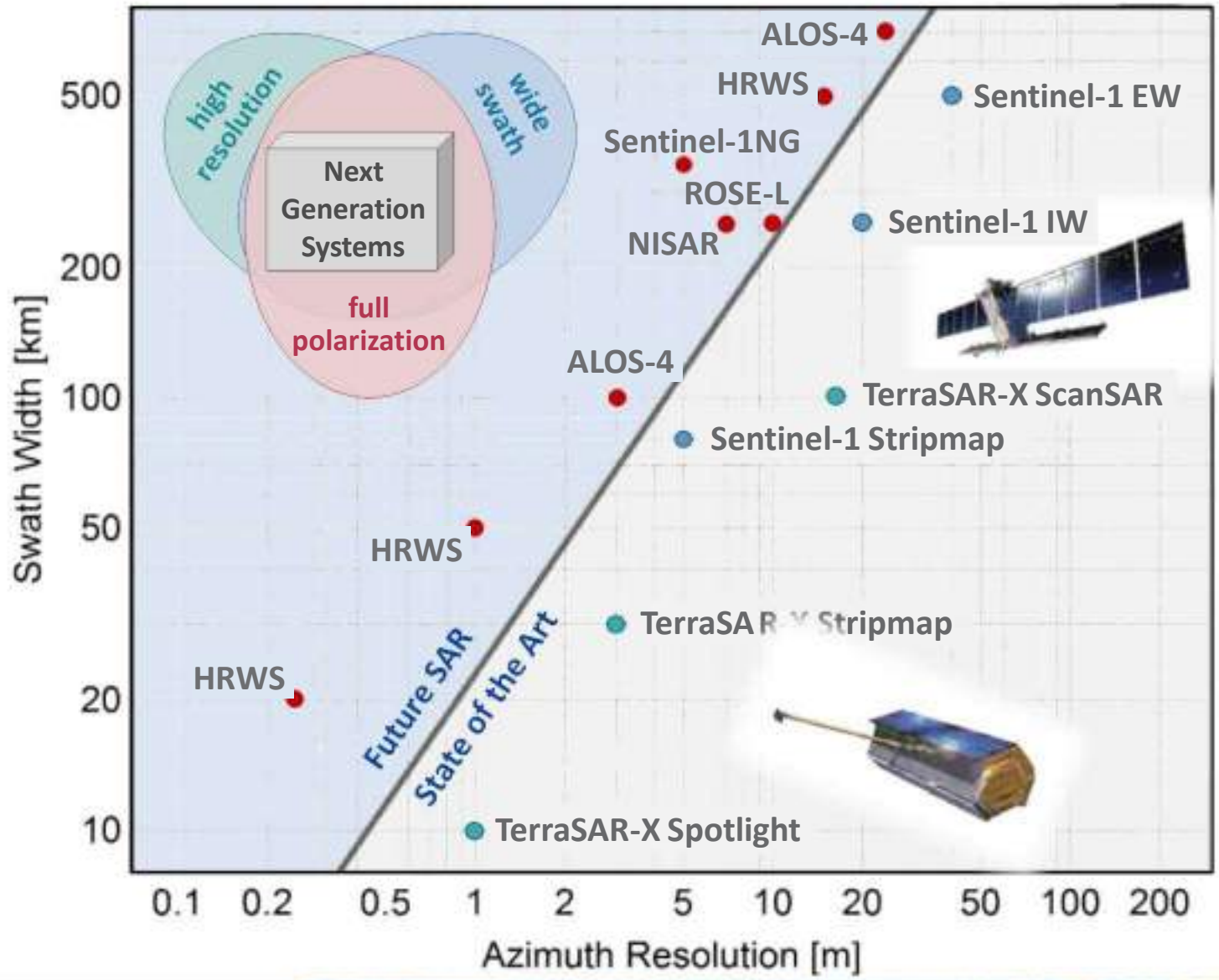
Direct Radiating Arrays



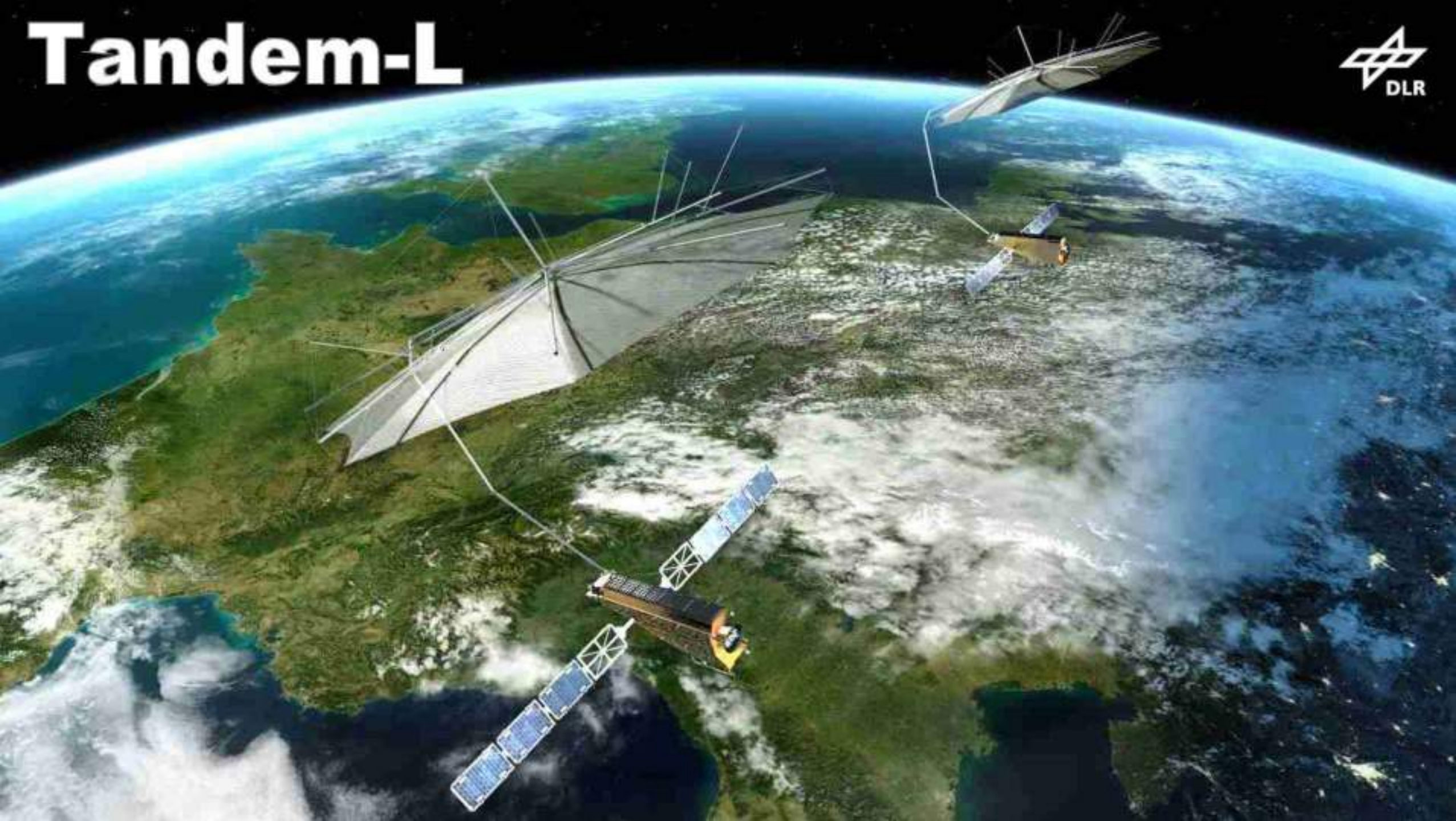
Reflectors with Digital Feed Array



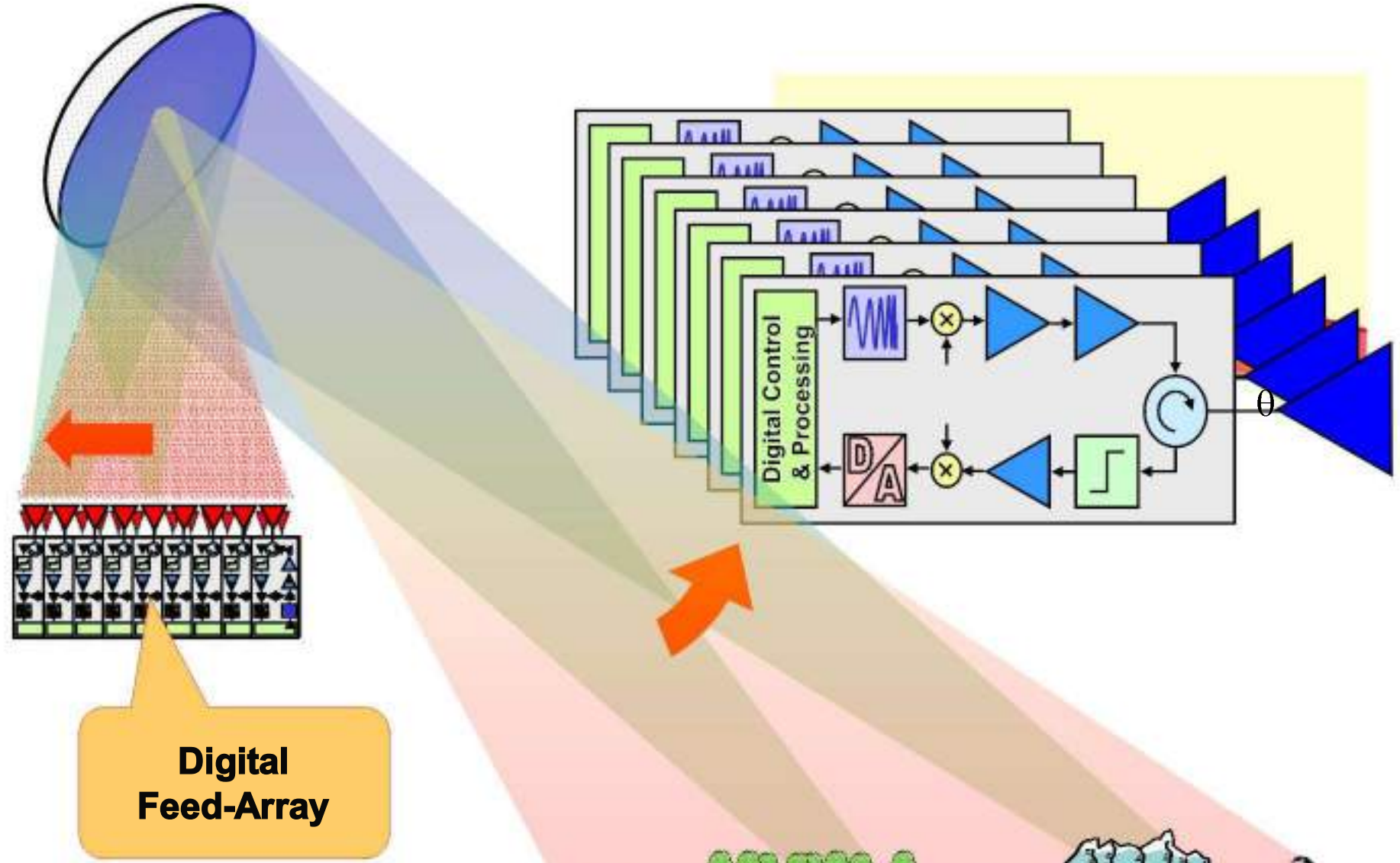
Digital Beamforming @ Future Spaceborne SAR Systems



Tandem-L

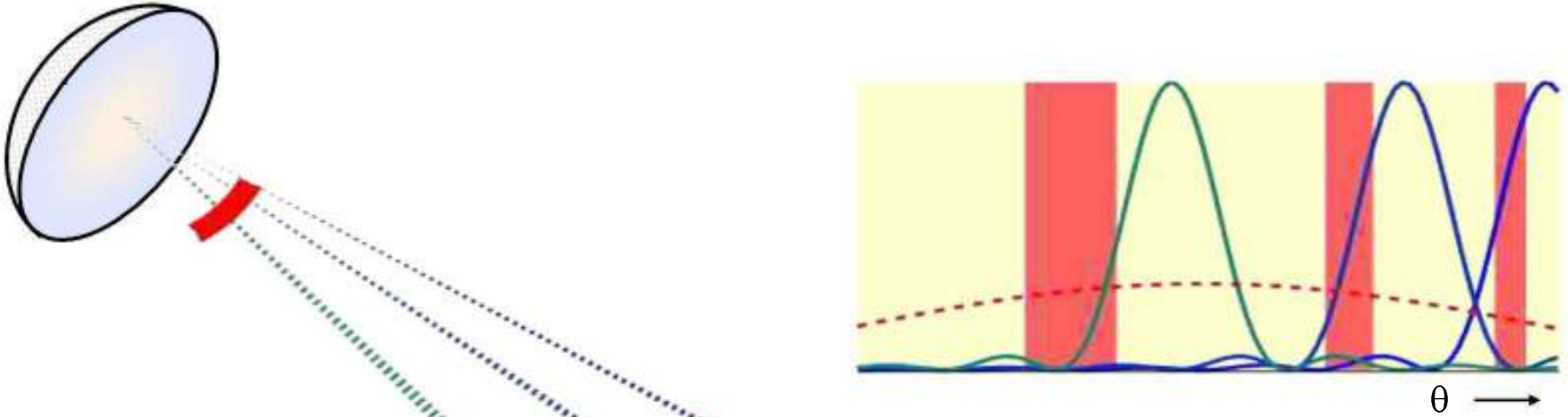


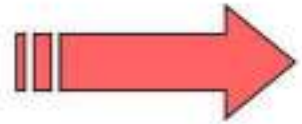
Digital Beamforming with Large Reflector Antenna



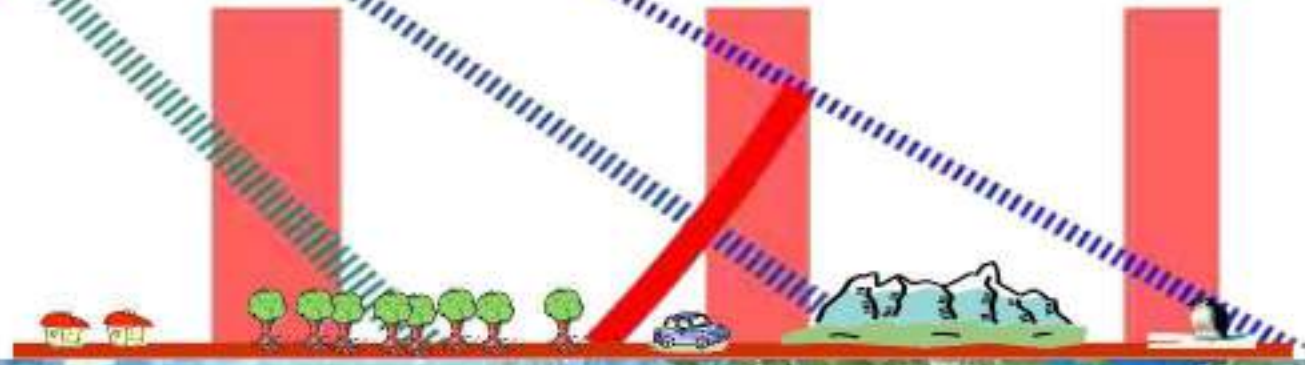
DLR

Digital Beamforming with Large Reflector Antenna





blind ranges



DLR

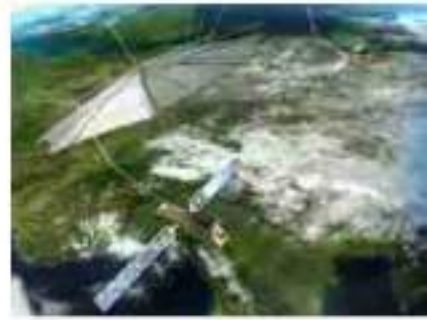
Comparison of Imaging Capacity

TerraSAR-X/TanDEM-X

1 global coverage / year

Digital Beamforming (Tandem-L)

2 global coverages / week



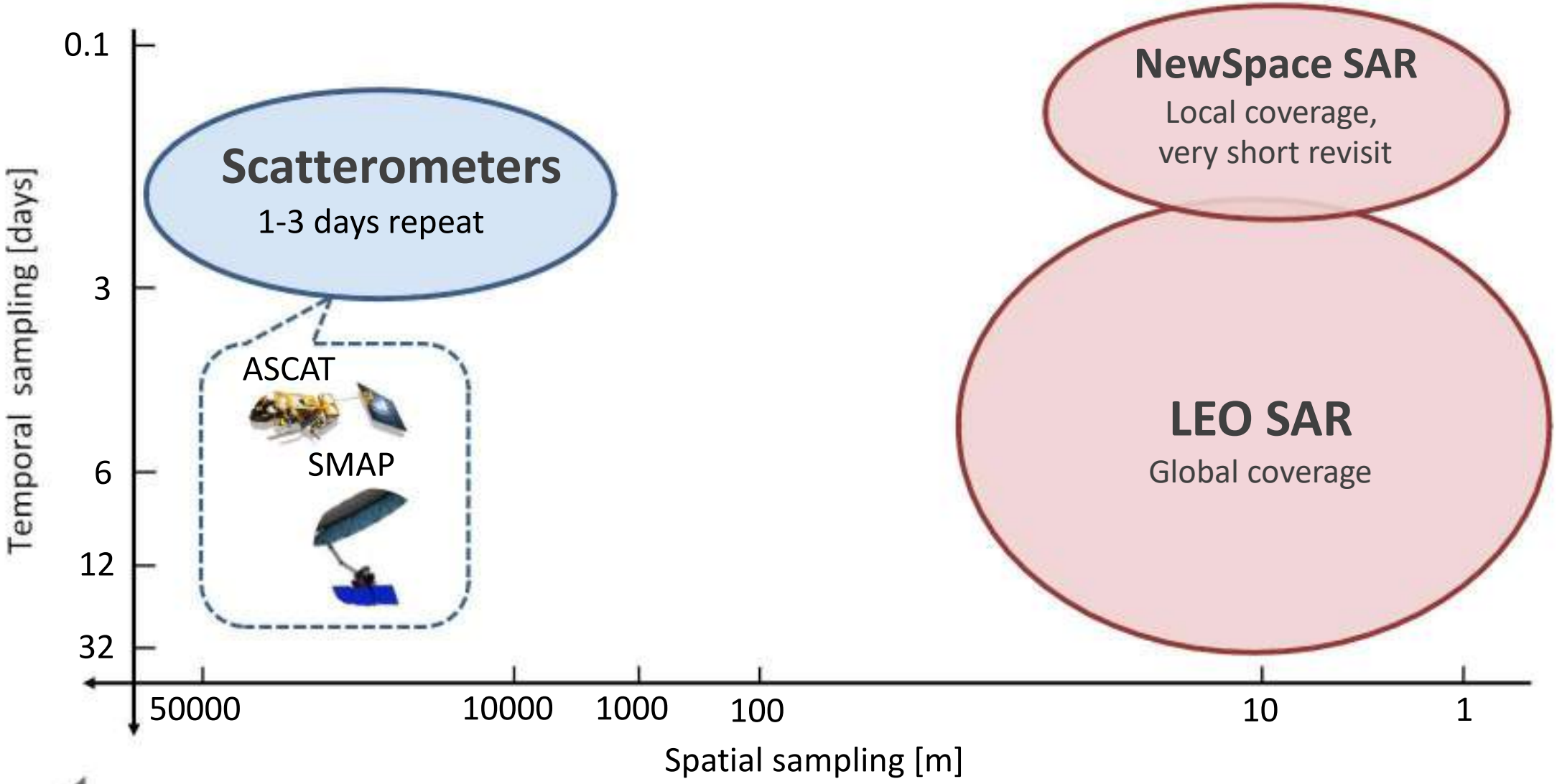
1

Days

DLR

NewSpace @ SAR Remote Sensing

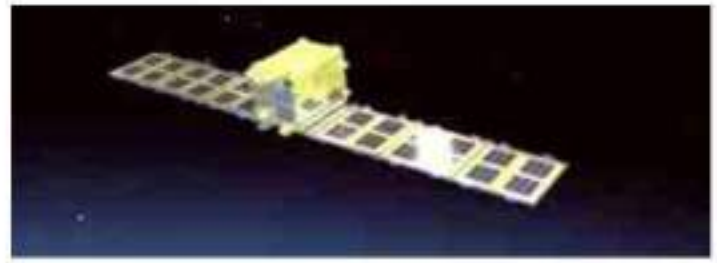
Spaceborne Radar for Earth Observation



NewSpace @ SAR Remote Sensing

ICEYE, Finland
30+ (20) Satellites

Capella, USA
36 (7) Satellites



Synspective, Japan
30 (3) Satellites

Xpress SAR, USA
3/4 Satellites

iQPS Inc., Japan
36 (2) Satellite

HRWS MirrorSAR, Germany
3 - 4 Small Satellites

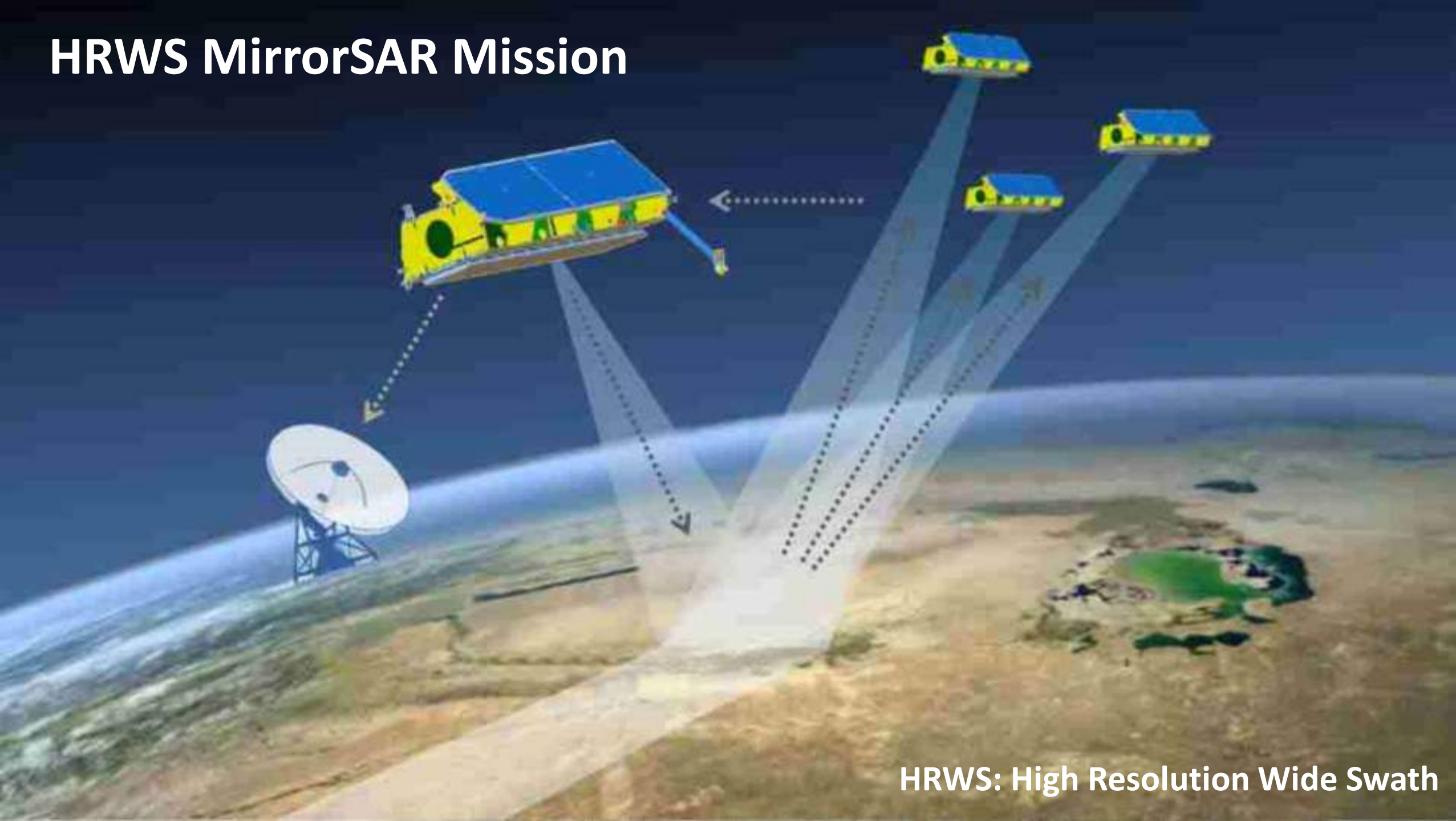
Spacety, China/Luxembourg
C- and X-band, 56 (1) Satellites

Umbra SAR, USA
24 (1) Satellites

PredaSAR, USA
96 Satellites

DLR

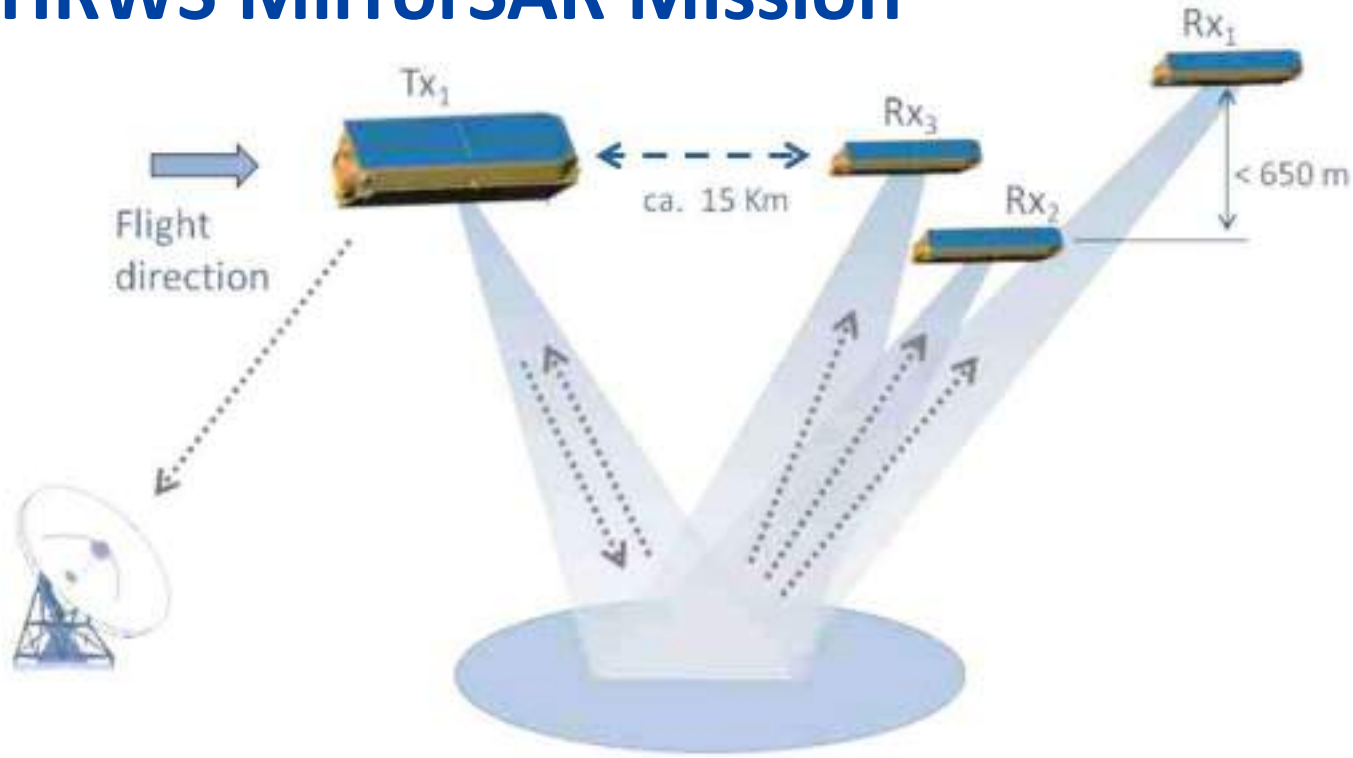
HRWS MirrorSAR Mission

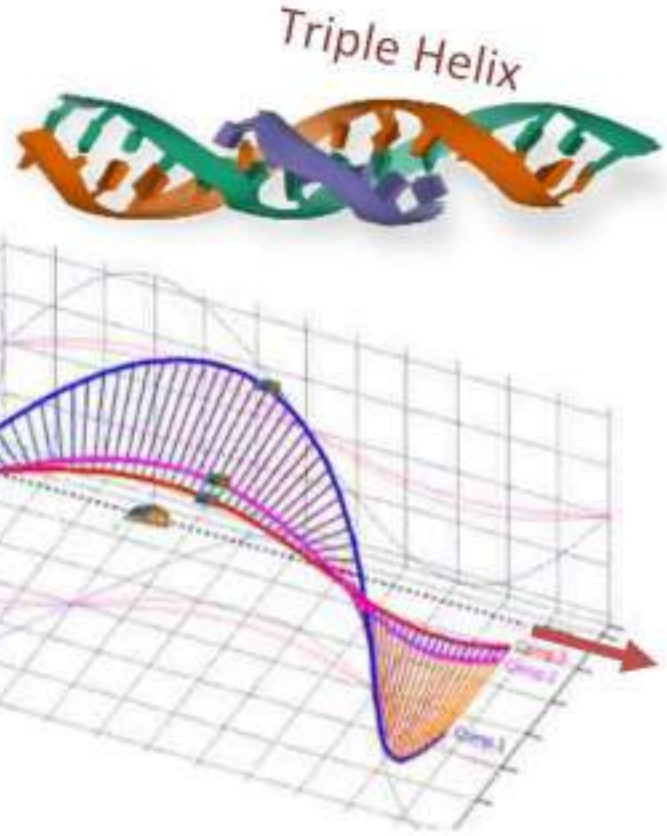


HRWS: High Resolution Wide Swath


Kaufbeuren (Germany)
DBFSAR, X Band quadpol
0.25 m x 0.25 m resolution

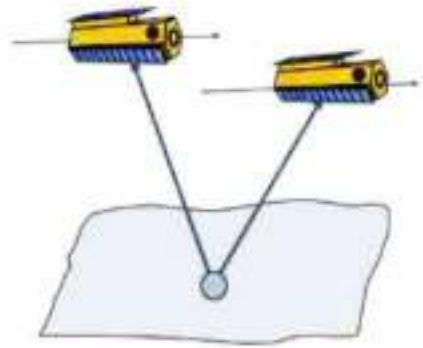
HRWS MirrorSAR Mission

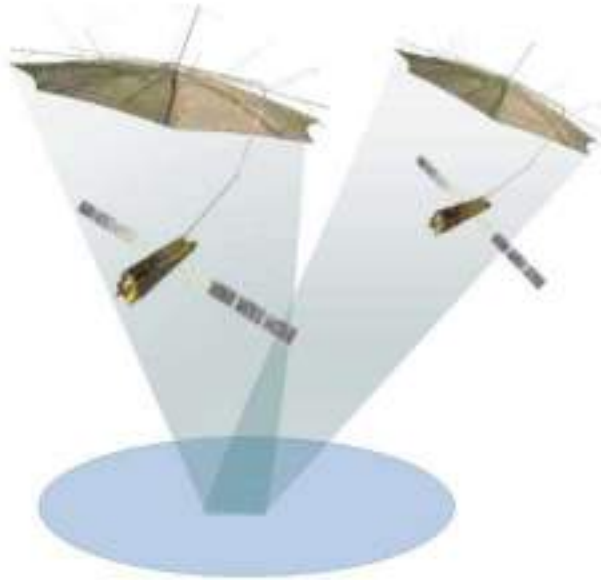




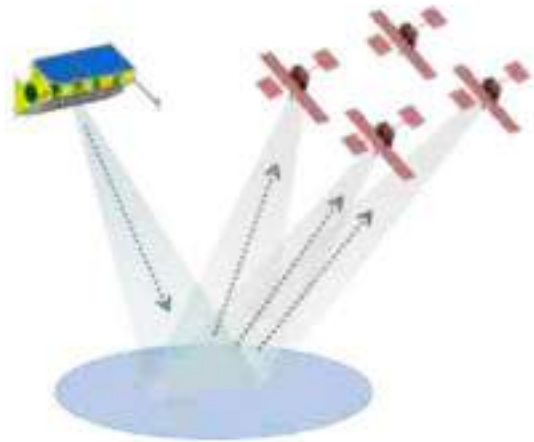
Imaging mode	HRWS MirrorSAR	TerraSAR-X TanDEM-X	Benchmark
Spotlight	0.25 m x 0.25 m @ 400 km²	0.25 m x 1 m @ 15 km²	106
Stripmap Single Pol	1 m x 1 m @ 80 km	3 m x 3 m @ 30 km	24
Stripmap Quad Pol	2 m x 2m @ 50 km	3 m x 6 m @ 15 km	15
3D Imaging	4 m x 4 m x 2 m	12 m x 12 m x 2 m	9

Trends for SAR Remote Sensing





- High-performance SAR systems
  - High resolution (< 5 m), wide swath (> 400 km)
  - Global coverage, short revisit
  - Digital beamforming (planar or large reflector antenna)
  - Bistatic/multistatic SAR systems with enhanced capabilities (e.g. polarimetry, interferometry and tomography)
- Small satellites (e.g., NewSpace)
  - Low costs (small swath, but high resolution)
  - Focused applications, small coverage, but very short revisit
  - Combination with high performance SAR systems
  - Distributed SAR systems



DLR

Spaceborne Radar for Earth Observation