GNSS Reflectometry and Passive Radar at DLR

- ➤ ACES and FUTURE GNSS-Based EARTH OBSERVATION and NAVIGATION
- ➤ 26./27. May 2008, TU München
- ➤ Dr. Thomas Börner, Microwaves and Radar Institute, DLR

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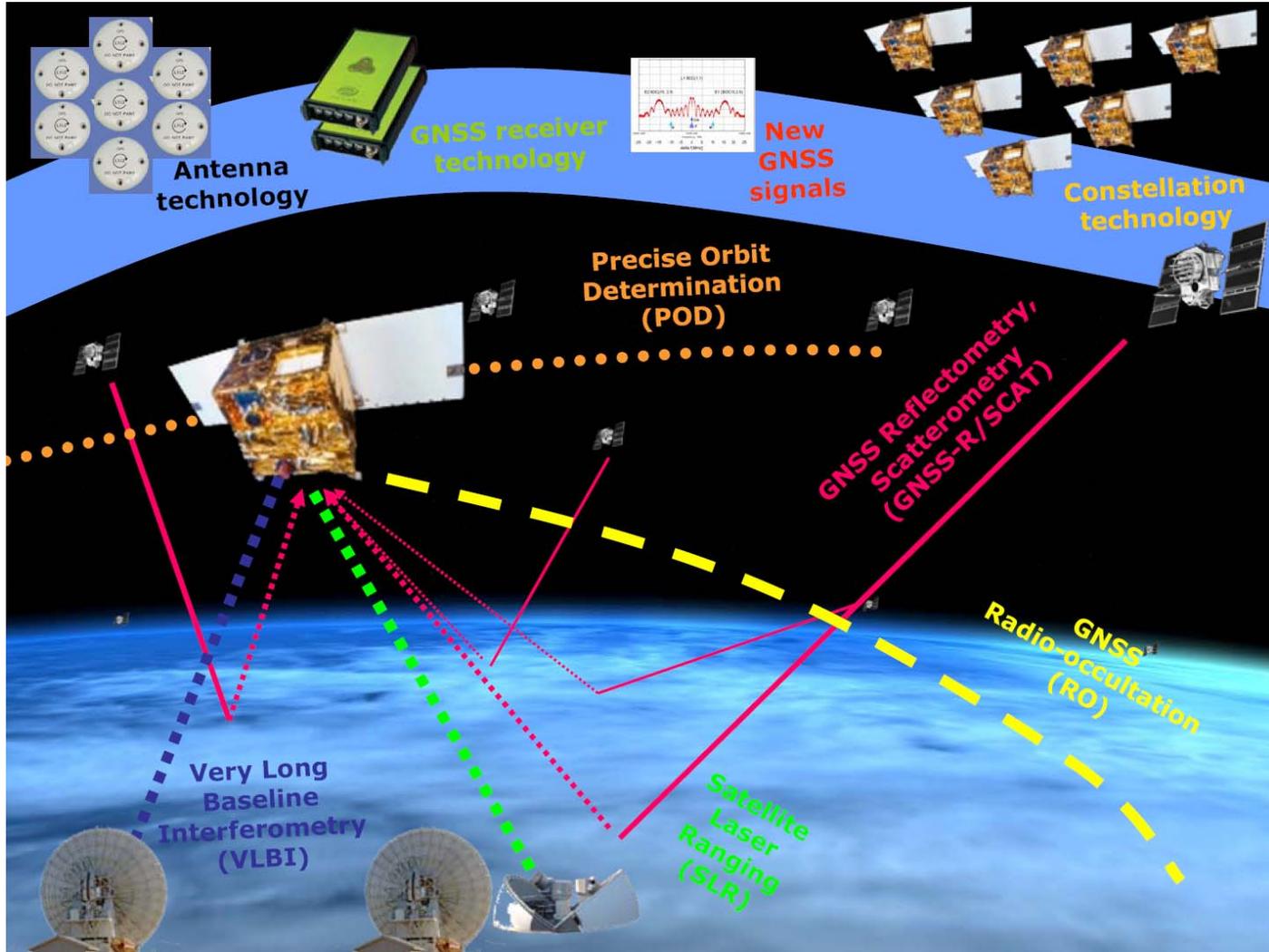in der Helmholtz-Gemeinschaft
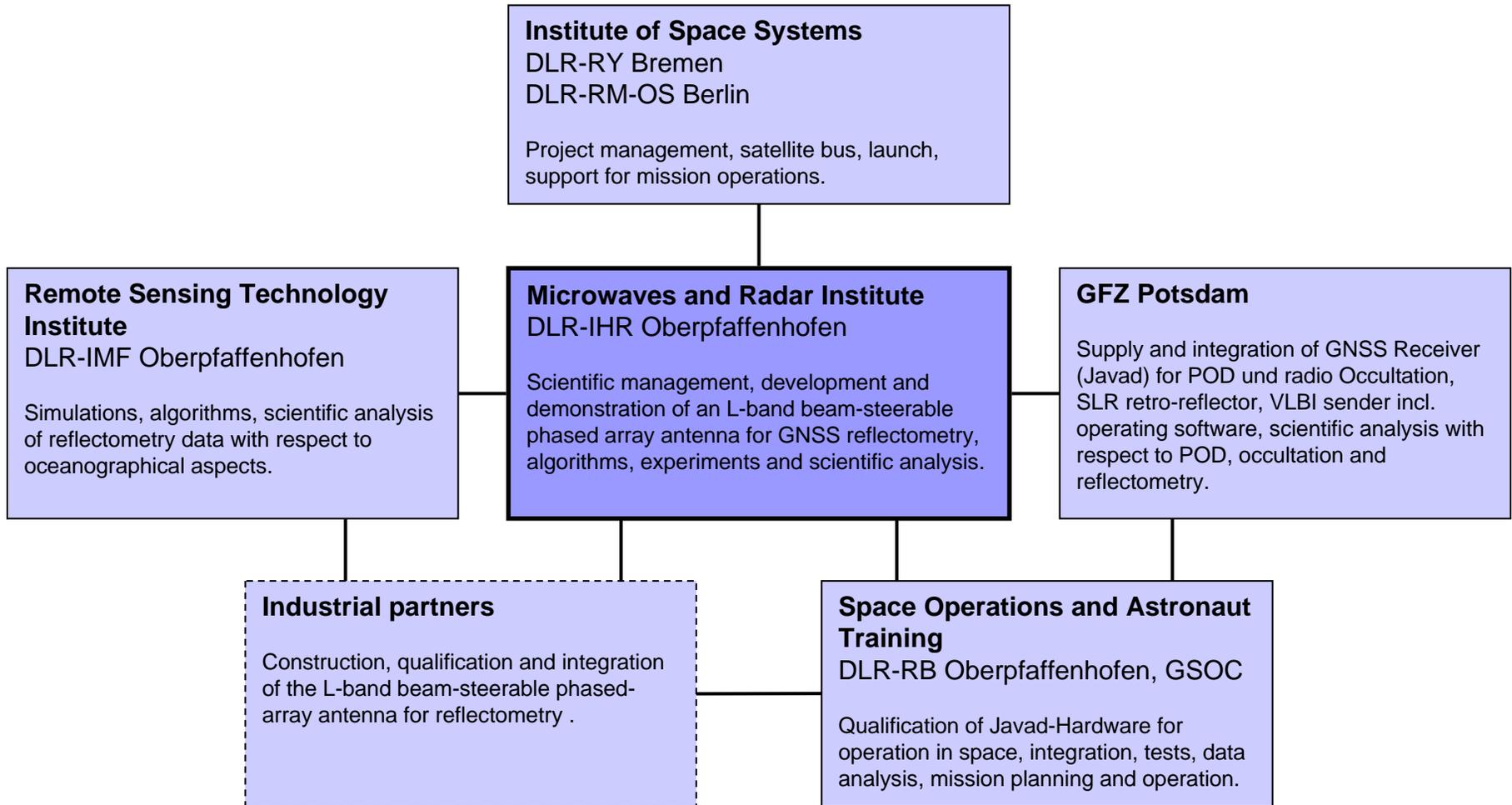
Overview

- GNSS Reflectometry – a joined proposal of DLR and GFZ Potsdam
  - Project Overview
  - Project Team
  - Satellite Bus
  - Instruments
  - Mission Requirements
  - Goals and Innovations
  - Applications and Experiments

- Tsunami detection from space
  - Using GNSS Reflectometry
  - NESTRAD

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GNSS Reflectometry – Project Overview

picture kindly provided by A. Helm, GFZ Potsdam

Project Team

Institute of Space Systems
DLR-RY Bremen
DLR-RM-OS Berlin

Project management, satellite bus, launch, support for mission operations.

Remote Sensing Technology Institute
DLR-IMF Oberpfaffenhofen

Simulations, algorithms, scientific analysis of reflectometry data with respect to oceanographical aspects.

Microwaves and Radar Institute
DLR-IHR Oberpfaffenhofen

Scientific management, development and demonstration of an L-band beam-steerable phased array antenna for GNSS reflectometry, algorithms, experiments and scientific analysis.

GFZ Potsdam

Supply and integration of GNSS Receiver (Javad) for POD und radio Occultation, SLR retro-reflector, VLBI sender incl. operating software, scientific analysis with respect to POD, occultation and reflectometry.

Industrial partners

Construction, qualification and integration of the L-band beam-steerable phased-array antenna for reflectometry .

Space Operations and Astronaut Training
DLR-RB Oberpfaffenhofen, GSOC

Qualification of Javad-Hardware for operation in space, integration, tests, data analysis, mission planning and operation.

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Platform – Satellite Bus: TET (similar to BIRD)
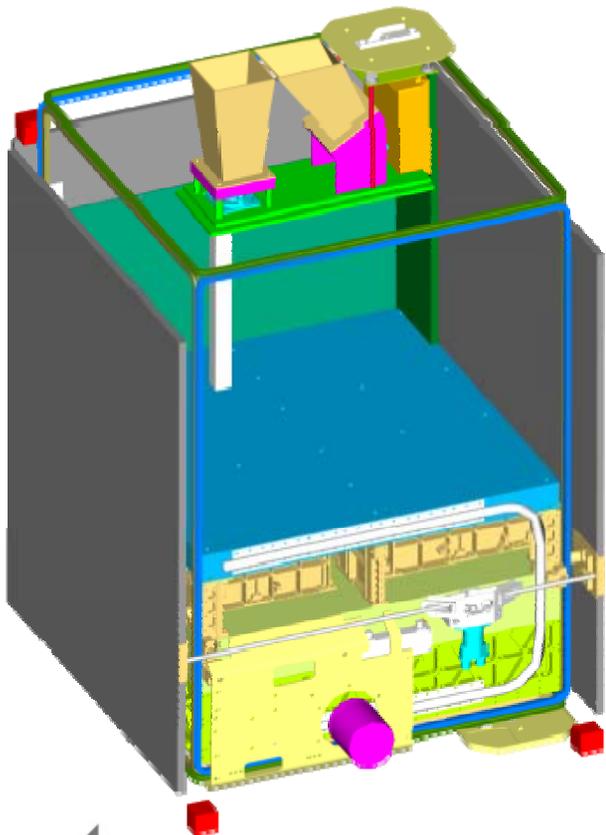
Orbit:	LEO, 450 - 850 km, 53° up to sun synch.
Attitude control:	3-axis stabilised
Precision of alignment:	5 arcmin
Jitter:	2 arcmin/s
Alignment of payload and solar panels:	
	sun, earth, nadir, zenith, heading, deep space

Payload power:	0 - 20 W (continuous)
Peak power:	$P_{POB\ max}$ = 160 W
Battery (nominal):	20 V (min. 18 V; max. 24 V), max. 8 A
Payload data rate:	2,2 Mbps
Data capacity:	TBD

TET-satellite (LxWxH):	639 mm x 546 mm x 821 mm
Envelope TET-satellite (LxWxH):	650 mm x 550 mm x 880 mm
Payload volume (LxWxH):	460 mm x 460 mm x 420 mm
	(incl. bus components)
TET bus mass:	ca. 68 kg
TET gross payload mass:	50 kg

Instruments

- Javad Global Navigation Satellite Systems (GNSS) Receiver (additional 2-3 receivers for redundancy)

- 1-Frequency Receiver (also 1-2 more for redundancy)

- GNSS antennas for precise orbit determination (POD), radio-occultation (RO) and coherent reflectometry incl. amplifier and software for onboard processing

- 1 Satellite Laser Ranging (SLR) Retro-Reflector for orbit determination and orbit validation

- 1 Very Long Baseline Interferometry (VLBI) Sender in S- und X-Band

- L-Band digitally-steered phased array antenna

- GNSS Receiver (Broadreach) + software for antenna beam steering and processing of reflections

Javad receiver board
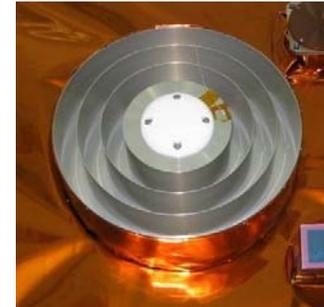
Choke-ring antenna

Helix antenna

Laser retro reflector

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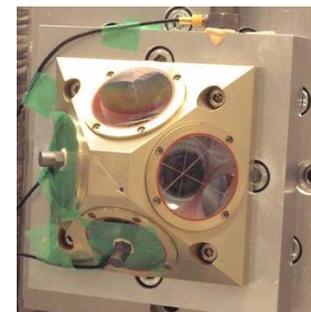
L-Band digitally-steered phased array antenna

➤ Requirements: "as light as possible"

"as much gain as possible"

➤ Size: ~ 0.5 m^2

➤ Gain: ~ 15 dB, strongly dependent on design

(most likely: microstrip)

➤ Weight: ~ 6 kg

➤ Power: ~ 5 W

NAVSYS HAGR antenna

➤ Why beam-steerable?

➤ point the beam to the specular return of the GNSS signal

➤ point the beam at a certain point of interest

➤ Simultaneous tracking of more than one GNSS signal
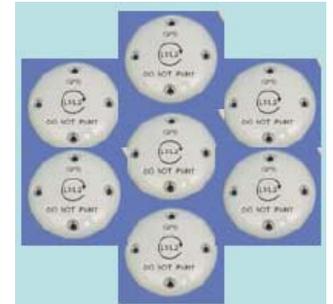
Mission Requirements

- Sun-synchronous orbit (for max. power supply)

- Orbit as low as possible for good SNR

- Attitude accuracy around 1° is sufficient

- Data rate: 2 MBit/s are sufficient, because several measurements can be processed on-board and do not have to be downlinked at full resolution.

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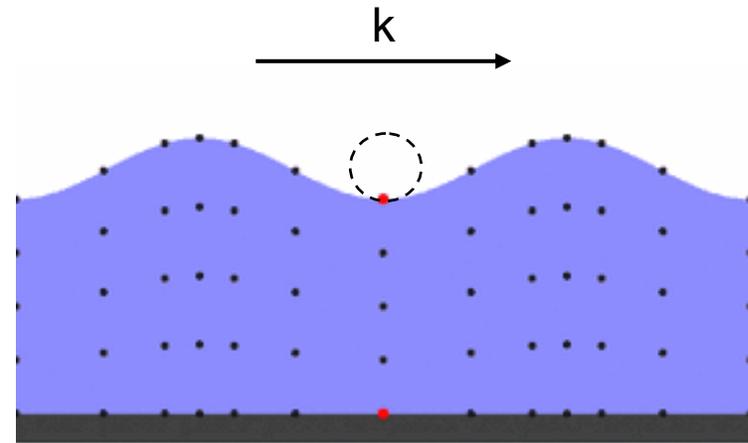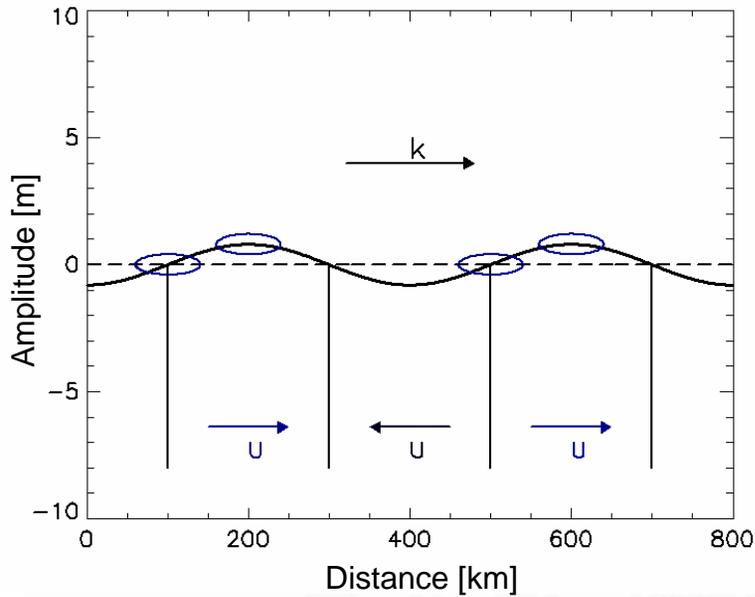
Goals and Innovations

- ⇘ GNSS-based remote sensing for atmosphere, ionosphere, oceans, ice, soil (moisture), etc. using radio occultation and reflectometry
- ⇘ Precise orbit determination (POD) and co-location of geodetic methods from space (reference systems, gravity field, etc.)
- ⇘ Development of technologies and know-how for future micro satellite constellations (formation flights) using GNSS
- ⇘ Passive radar for altimetry and scatterometry using a beam-steerable antenna
- ⇘ Antenna development for passive radar
- ⇘ Qualification of hardware for operation in space

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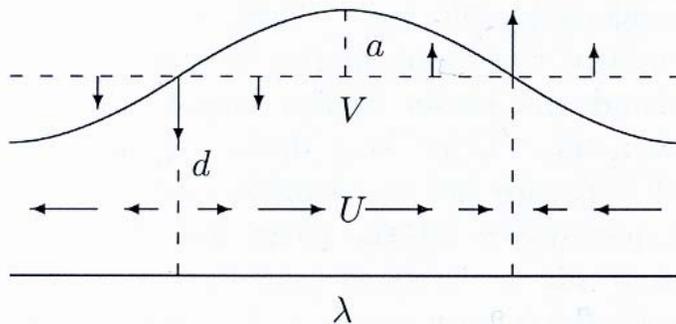ACES Workshop – TU München, Thomas Börner (thomas.boerner@dlr.de), 27.05.2008

Applications and Experiments

- Oceanography:
    - Sea level (altimetry)
    - Ocean wave spectra (2D), roughness, swells (scatterometry)
    - Retrieval of wind directions → not possible?
    - Retrieval of sea ice parameters
    - Estimation of orbital velocities
    - Tsunami detection (?)

- Possible additional applications:
    - Soil moisture extraction
    - Ionospheric and atmospheric effects (weather)
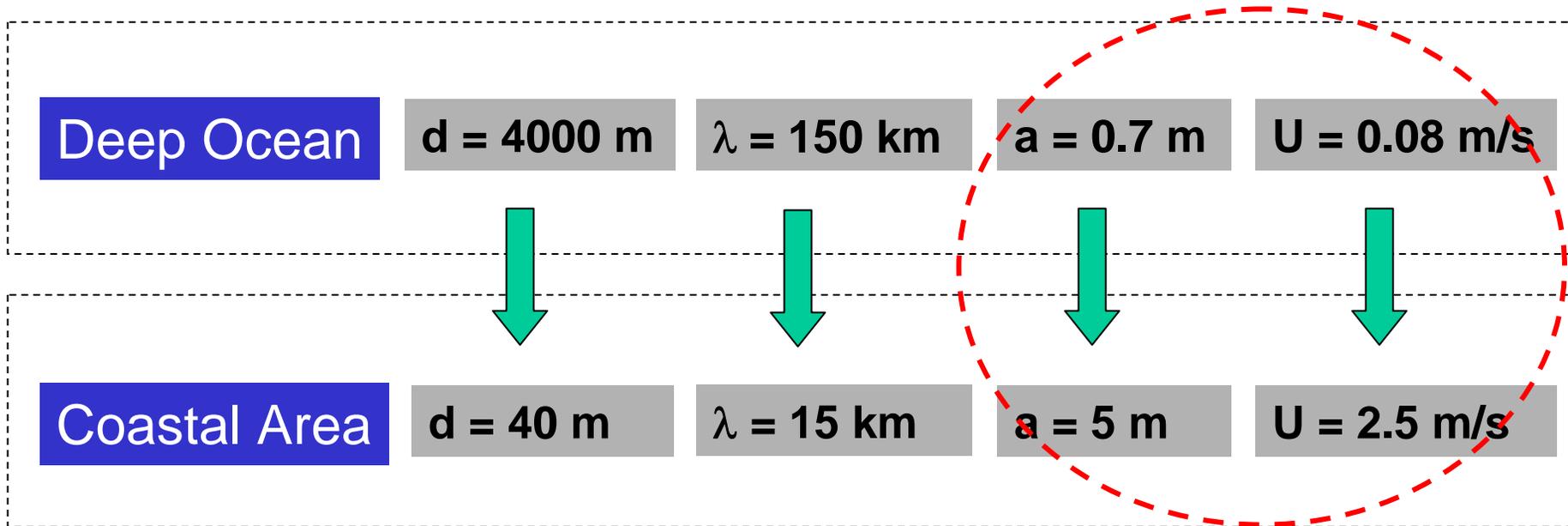   - Land mapping (clutter)

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Tsunami parameters

http://de.wikipedia.org/wiki/Tsunami

a	amplitude
d	water depth
U	horizontal velocity
V	vertical velocity
λ	wave length

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Tsunami Scale

Benny Lautrup, *Tsunami Physics*
Kvant, Jan 2005

Deep Ocean	d = 4000 m	λ = 150 km	a = 0.7 m	U = 0.08 m/s
Coastal Area	d = 40 m	λ = 15 km	a = 5 m	U = 2.5 m/s

Tsunamis are easier to detect in coastal areas

Tsunami Early-Warning: Far-field and Near-field

Tsunamigenic areas of the Indian Ocean

Makran Subduction Zone

Sunda trench
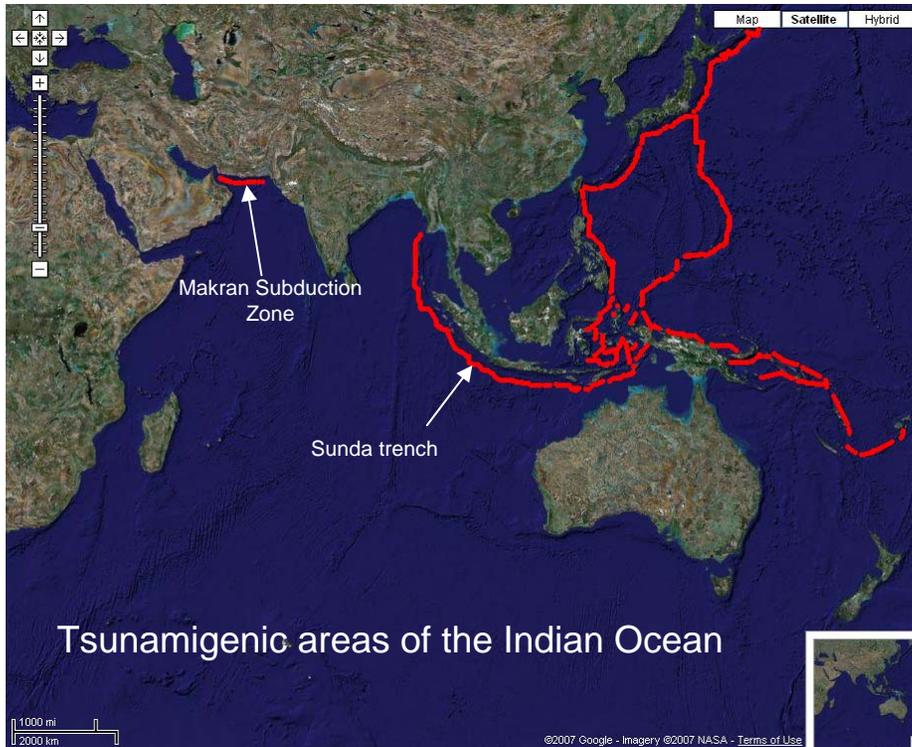
Under near-field tsunami threat in the world ocean: Indonesia, Makran Subduction zone (Iran, Pakistan), Japan, Mediterranean countries, Cascadia, Caribbean, etc.

FAR-FIELD TSUNAMI > 30 min

- Tsunami can happen anytime but trans-oceanic propagation can take hours!
- Far-field Tsunami Early-Warning is operational and effective.

NEAR-FIELD TSUNAMI < 30 min

- Indonesian government requires first warning to be issued within 5 min from the quake!
  → Temporal Coverage: 24/7, for immediate response.
- Spatial Coverage: dictated by plate tectonics.

Near-field tsunami early-warning is challenging. Sometimes the first direct measurements come from tide gauges.

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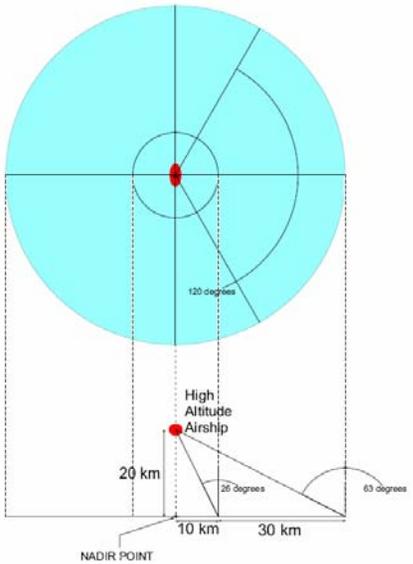ACES Workshop – TU München, Thomas Börner (thomas.boerner@dlr.de), 27.05.2008
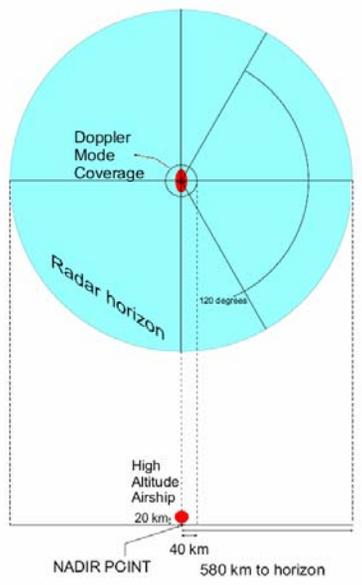
Tsunami detection using GNSS reflectometry → Requirements

- Tight temporal coverage is essential:
    - Constellation of satellites needed that ensures data takes over the same area at least (!) every 5-10 minutes.
    - Downlink of acquired data has to be permanently available for processing required results in (near) real time.

- Accuracy of measured ocean heights must be in the order of some cm!

- Assessment of accuracy, stability and robustness of GNSS-reflectometry from space has to be carried out → need for demonstrators!

- Tsunami events are rare: sensor constellation must serve various purposes. Tsunami detection "mode" shall only be triggered through seismic events.

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TOP VIEW

SIDE VIEW

120 degrees

High
Altitude
Airship

20 km

26 degrees

63 degrees

10 km   30 km

NADIR POINT

**DOPPLER MODE
ALTIMETER MODE**

DLR

NESTRAD

Wave Height at Nadir
Orbital Velocities
Tsunami Shadows
Tsunami-induced internal waves

TOP VIEW

SIDE VIEW

Doppler
Mode
Coverage

Radar horizon

120 degrees

High
Altitude
Airship

20 km

40 km

580 km to horizon

NADIR POINT

**RADAR CROSS
SECTION MODE**

NESTRAD coverage (NEAMTWS)

NESTRAD consists of a real aperture phased array radar accommodated inside a stationary stratospheric airship. It provides all-weather, day-and-night coverage.

Stratospheric Airships are unmanned, untethered, lighter-than-air vehicles expected to persist 12 months on station providing continuous, real-time info.

NESTRAD coverage (IOTEWS)