SWOT

Ground System

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http://swot.jpl.nasa.gov
Outline

• Introduction
  – SWOT mission
  – Mission phases
  – SWOT ground segment overview

• KaRIN acquisition and products
  – Acquisition characteristics
  – SWOT Karin processing
  – Products
  – Sizing considerations

• Commonality levels and approach for the processing development
• Mission
  – Extraction of water surface heights over ocean and continental water bodies
  – The principal instrument is KaRIN, a Ka-band interferometric SAR system.
  – Other instruments are a nadir altimeter, radiometer, and precision tracking systems (classical Jason Altimeter suite)

• Main scientific requirements
  – Oceanography: Global coverage (< 78°) of oceans, sea surface height precision < 2 cm at approximately 1 km resolution ⇒ LR mode
  – Hydrology: Global inventory of rivers > 100 m (50 m) and lakes > (250 m)^2, water surface height precision of the order of 10 cm (averaged over 1 km^2), slope precision 1 cm/km (averaged over 10 km); average posting 50 m ⇒ HR mode
Mission Phases

• Launch and Early Orbit Operations (~ 3 days)
  — Launch planned for late 2019

• Checkout / Commissioning (~ 30 - 45 days)

• Calibration / Validation (Cal/Val) (~ 90 days)
  — Fast repeat orbit at 3 (or 1) days

• Transition to Science Orbit, Operations (~ 15 days)
  — Non-sun-synchronous, 22 day exact repeat, 970 km altitude, 78 deg inclination

• Science Observations (= 3 years, starts ~4.5 months after launch)

• Disposal and Ground System Closeout (= 3 months)
• Tracking Stations
  – X-band network (620 Mbps (nominal, min)): Downlink for high rate science (KaRIN), and associated Engineering data

• Front End Networks
  – Network from X-band Data Center(s) to JPL and CNES operation centers. Minimum data rate to return all downlink within approximately 20 mins is >~ 300 Mbps (similar to downlink)
  – Network from CNES to JPL for S-band science and engineering data

• Spacecraft Control Center (SCC, CNES/Contractor)
  – Real time monitoring of s/c and p/l via S-band housekeeping telemetry
• **Payload Operations Centers (POC)**
  - CNES: Near Real Time health monitoring of Jason Altimeter Suite

• **Science Processing Centers**
  - JPL: Processing of KaRIN, POD
  - CNES: Jason Suite, POD

• **Data Archiving and Distribution Centers**
  - JPL: PODAAC
  - CNES: AVISO

• **Project Data Distribution Networks**
  - JPL-CNES link
  - Science Processing Centers to Archiving/Distribution Centers
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KaRIN Data Acquisition

**Classical Nadir Altimetry**
- Resolution = Swath (~10km)
- Inter-track at equator ~100km

**KaRIN altimetry**
- Resolution << Swath: (2.5m x 10m to 70m) << ~100km
- Almost full coverage
KaRIN Processing Steps

• SAR processing (range and azimuth compression)

• Interferometric processing (co-registration, computation of interferometric phase and coherence)

• Application of “acquisition geometry” in a wide sense (geolocation, precise orbit determination, correction of roll, baseline variations, tropospheric delay, …)

• Estimation of geophysical parameters (water surface detection (HR only), computation of water surface heights, slopes etc.)

• Establish/refine floodplain DEM (yearly or whole mission)

• High-level and multi-temporal processing is a science teams activity
High Level Data Products (1 of 4)

• Level 0 (~ 1 TB/day)
  – Ocean KaRIN: raw data (L1 (partial interferograms) processing onboard)
  – Hydro KaRIN: raw data
  – Nadir altimeter and Radiometer data: instruments raw data
  – GPSP and DORIS data: POD raw data

• Level 1: Nadir Alt, Radiometer, KaRIN (~ 12 TB/day)
  – L1a: Engineering unit conversion, calibration data separated for additional processing
  – L1b: Final instrument level data with calibrations appended
    • Ocean: 9-11 onboard interferograms (1km x 1 km), correlations, amplitudes with instrument calibrations and phase variations corrected combined
    • Hydro (HR): KaRIN phase flattened Interferograms
    • Altimeter, radiometer compliant with Jason-2 Science Data record processing (SGDR)
High Level Data Products  (2 of 4)

• **L2A**
  – Ocean KaRIN : As L1B + Geophysical corrections. Nadir data merged for cross calibration.
  – Ocean Crossover Attitude Correction: Estimate attitude errors from ocean crossovers for correcting both ocean and land data.
  – Intermediate Hydro: L1B + water mask detection; rain, snow, ice/frozen detections

• **L2B** (standard distributed products)
  Remark: Every field will be associated with an uncertainty estimate
  – Ocean:
    • Sea surface (SS) heights in latitude/longitude grid
    • SS slope at each point of the grid
    • Sigma 0
    • Wind speed
    • Ocean Sea Wave Height on same grid (goal)
• L2B (standard distributed products) (continued)
  Remark: Every field will be associated with an uncertainty estimate
  – Hydro:
    • Geo-localized water mask (lakes > 250 m², rivers >100 m)
    • Estimated water elevations (same sampling as mask) -> Triangular interpolated network (+ uncertainties)
    • Topographic map of the flood plain surrounding the water surface and channel cross sections (requirement to be produced by the end of the mission)
  – Ocean Nadir: Similar to current Jason-2 SGDR

• NRT (goal)
  – Ocean: as Level 2 products but with lower accuracy (degraded orbit and calibration using past cross-overs)
  – Hydro: Level 1 products (SLC + interferogram), no calibration data, use of ancillary DEM for phase flattening
  – Nadir products: OGDR/ IGDR products (see Jason-2 OSS)
High Level Data Products

- POD – determined from GPS and DORIS

- Ancillary Data – updated daily
  - Atmospheric models: Dry Tropo (surface pressure), Wet Tropo (water vapor)
  - Input to ionospheric model

- Geophysical Models – updated infrequently
  - Mean Sea Surface, Geoid
  - DEM, Water mask (a priori, then self derived)
  - Elastic Ocean Tides, Earth Tides, “Pole Tide”
• Global coverage, continuous acquisition

• Acquisition hypothesis
  – Sea 70% and Land 30% =>
  In the average orbit, KaRIN will acquire 67 GB of data to be transmitted
to ground => ~1 TB /day (~ 99% HR data)

• Archive Plan
  – Nominal mission duration: 3 years
  – Long term archive of (main contributors in terms of volume) Raw HR +
  SLC (L1A) + Interferograms + masks (L2A) + geo-localized hydro
  products (L2B) => ~10 000TBytes

• Comparison to other missions
  – CNES: more than 5 times Pleiades satellite archive (dual
civilian/defense optical imagery, to be launched soon)
  – NASA: similar to proposed DESDynI (Earth deformation and sea ice
  from L-band Radar repeat pass interderometer)
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General Levels of Commonality

- Commonality between two processing systems may be achieved at different levels:
  - Commonality of the **full production system** (clone, e.g. Jason)
    - Prevents existing systems reuse. Not necessary for SWOT development
  - Commonality of the **algorithms, software, and products**
    - Products are guaranteed 100% similar. May be the right level.
  - Commonality of **specification and reference data**
    - Independent developments. Risky because reference data does not cover all cases so products will not be 100% similar.
General Algorithm Development Approach

- Science processing algorithms will be developed primarily by supplier of each instrument
- Algorithm flow will be iterated within entire development team
- Data product definitions will be iterated with Science Team
- Algorithm testbed will be set up and prototype processing developed
  - Testbed will read and write specified products
  - Test data will be (or emulate) specified products
- After initial development cycle, algorithm specifications will be written for review by System Engineering team and selected subset of Science Team
• Algorithms prototyping activities and operational chain development are relatively independent
  ▶ The scope of prototype development may be larger than scope of operational system development
  ▶ But not true the other way: prototypes are needed to build the reference data for the validation of the operational chain
JPL Usual Development Approach

- Testbed prototype will incorporate as much of the processing framework as possible

- **Notes:**
  - NRT processing will be based on standard algorithms but may not use the processing framework
  - Existing POD processing will be implemented in project environment
Commonality Approach for SWOT

- Complementary prototyping activities will be conducted by JPL and CNES

- The order and nature of the processing steps of the operational LR and HR processing chains will be discussed and agreed on by JPL/NASA and CNES

- The detailed work share is not yet defined, but the operational algorithms and related binary code will be common
SWOT 40 month Mission Timeline

Initial Phase
- Launch: 02 Dec 2019
- LEOP ~3 days: nominal s/c state
- Checkout / Commissioning: (up to L + ~65 days)
  - In-Flight Assessment Meeting
  - First Verification Workshop
  - Cal/Val

Mission Phase
- Calibration/Validation Period
- Calibration/Validation Period
- Science Observation: (36 months)
  - ~2-4 weeks Nominal Orbit Acquisition
- Operational Phase:
  - Science
  - Fast Repeat
- Eclipse Season (illustration only)

Calendar Years
- 2019
- 2020
- 2021
- 2022
- 2023

EOM: (Mar 2023)
- Decommissioning (~30 days)
- Science Processing Closeout
- TBD[3, 1 day; near 22 day]
- 22-day repeat, 78 deg, 970 km (non-sun-sync)

Backup or here?
Science Operations (1 of 1)

• Science data collection phase starts ~ 4.5 months after launch. Collect data for 3 full years in observational orbit

• Full validation period: 6 months of data in science orbit + 2 months processing, internal review
  – Science Team meeting to assess initial data products ~ 12 months after launch
  – Processing update based on Science Team assessment implemented ~ 2 months after meeting

• Ready to reprocess all data with updated system ~ 16 months after launch.

• Science Requirements on Reprocessing (assume “caught up” at 24 months) puts requirements on total Processing Center throughput (Suggest project aggregate > 5x). Budget/scenario:
  – Cal/val data (~3 months) – as science phase starts
  – Initial science phase data (~12 months + 3 months cal/val) – within TBD [< 3] months. Result: at ~20 months after launch version 2 of all usable data available. Support Science Team meeting at ~24 months to validate data
  – End of nominal mission: Reprocess all data a second time with SDS update done from ~ 30 – 36 months after launch; takes 6 – 8 months (runs until 3 months after end of mission [assumes no extended mission])