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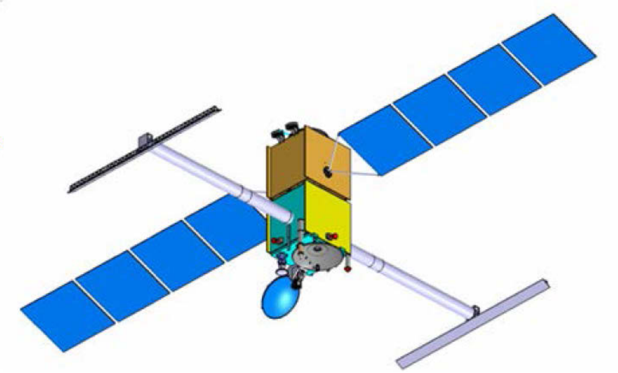
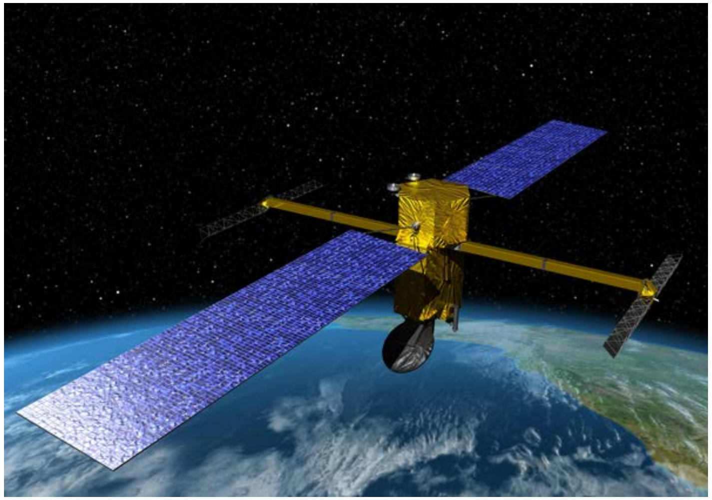
CENTRE NATIONAL D'ÉTUDES SPATIALES
NASA
Jet Propulsion Laboratory
California Institute of Technology

http://swot.jpl.nasa.gov





SWOT
Ground System

IGARSS – August 2011

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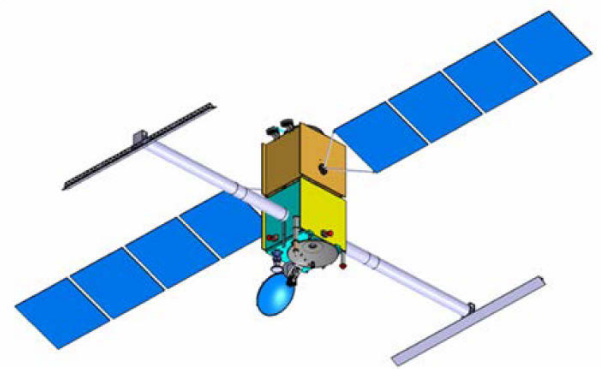
Outline



- 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

SWOT Mission

- 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)

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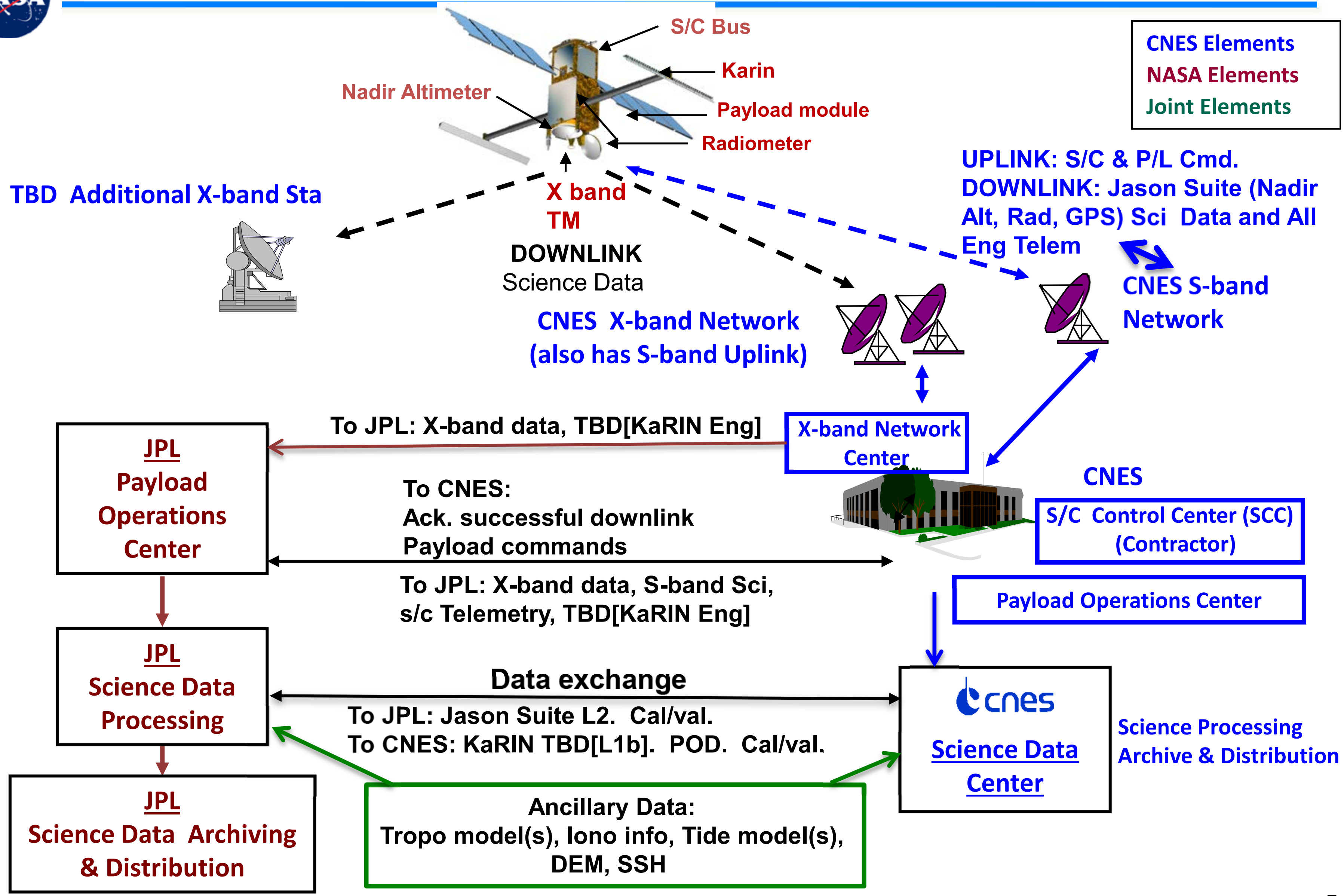
Architecture Diagram



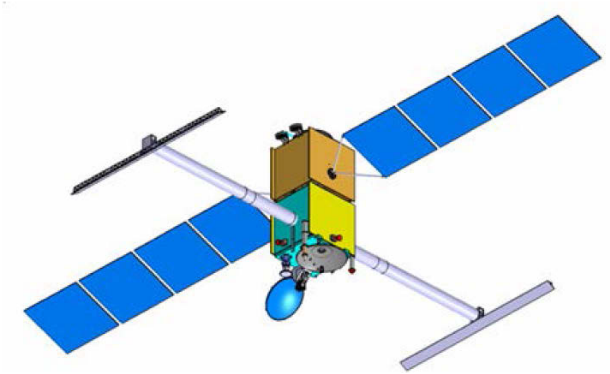
Ground System Elements (1 of 2)

- Tracking Stations
  - CNES S-band stations: Downlink for Nadir Alt, Radiometer, DORIS, GPS ("Jason Altimeter Suite", JAS). Uplink commanding
  - 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

Ground System Elements (2 of 2)

- Payload Operations Centers (POC)
  - JPL: Near Real Time health monitoring of KaRIN, GPS, Radiometer. Determine X-band data quality, need for replay.
  - 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

Outline



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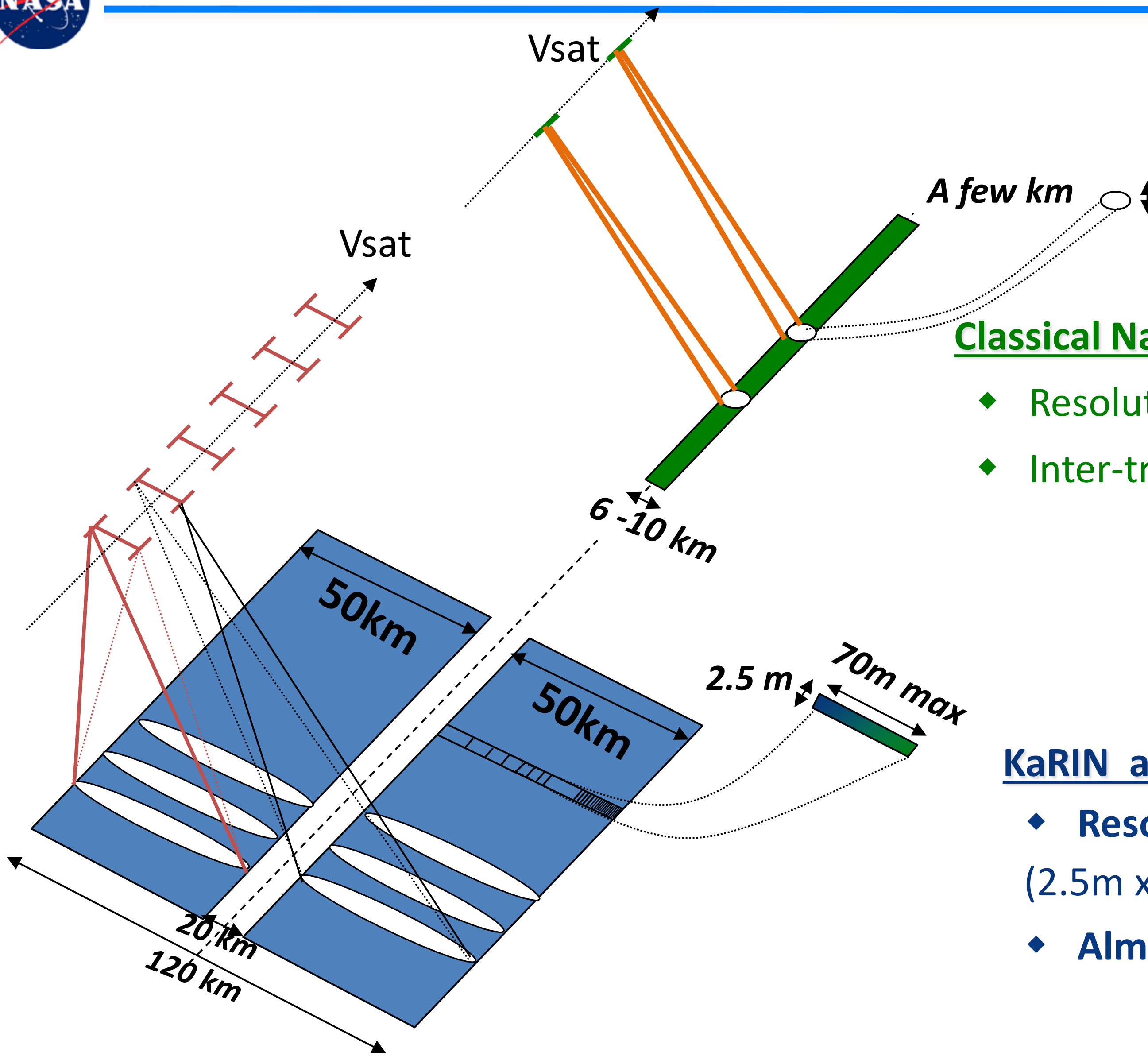
KaRIN Data Acquisition



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)

High Level Data Products (3 of 4)

- 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 (4 of 4)

- 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”

Sizing Considerations

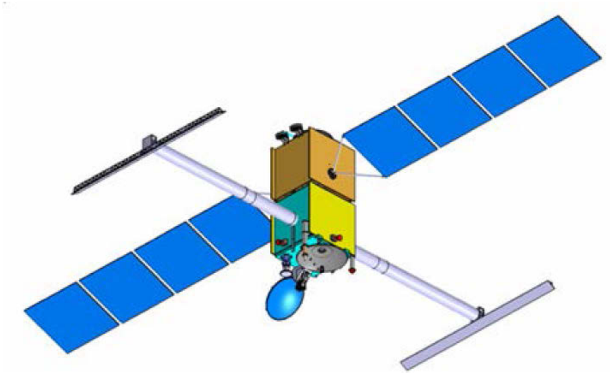
- Global coverage, continuous acquisition
- Acquisition hypothesis
  - Sea 70% and Land 30% =>

  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)

Outline



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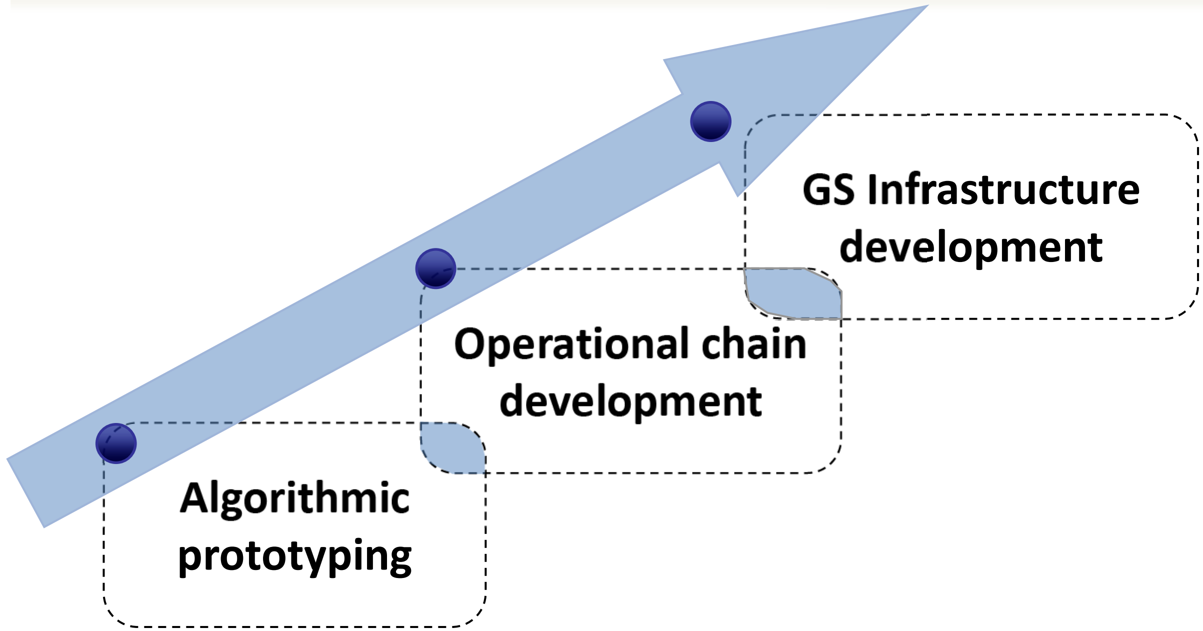
General Levels of Commonality

- 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

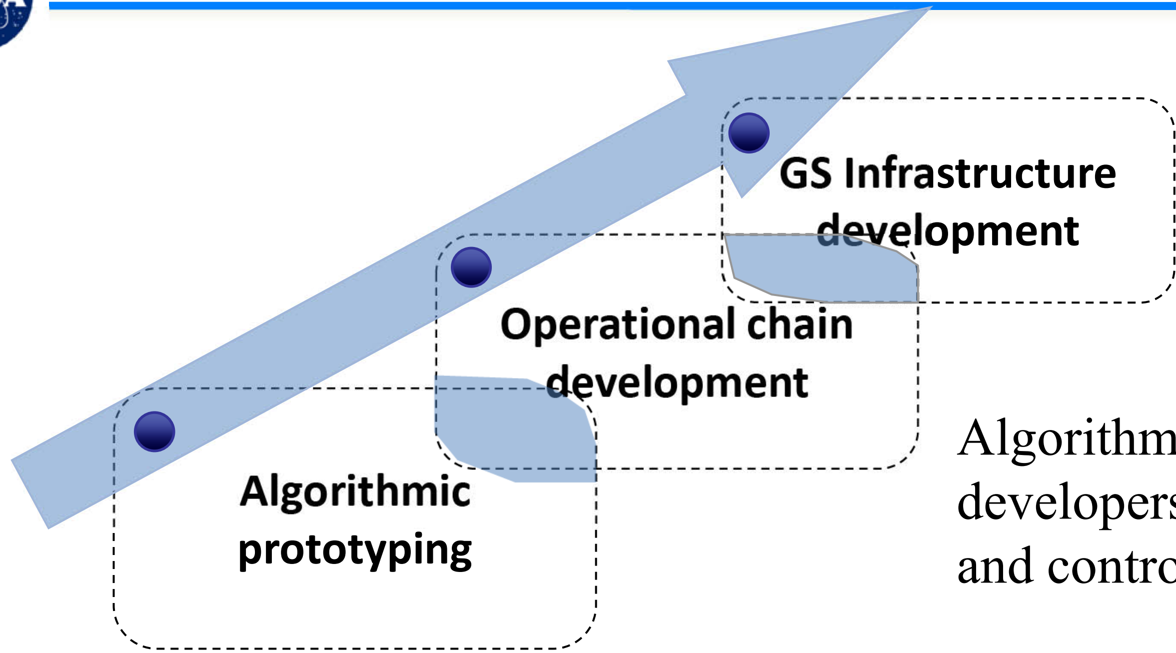
- Science processing algorithms will be developed primarily by supplier of each instrument
- Algorithm flow will be iterated within entire development team
- Data product definitions will be iterated with Science Team
- Algorithm testbed will be set up and prototype processing developed
  - Testbed will 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

CNES Usual Development Approach



- 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



Processing framework from previous projects will be leveraged

Algorithm and framework developers will agree on interfaces and control mechanisms

- 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

BACKUP

SWOT 40 month Mission Timeline

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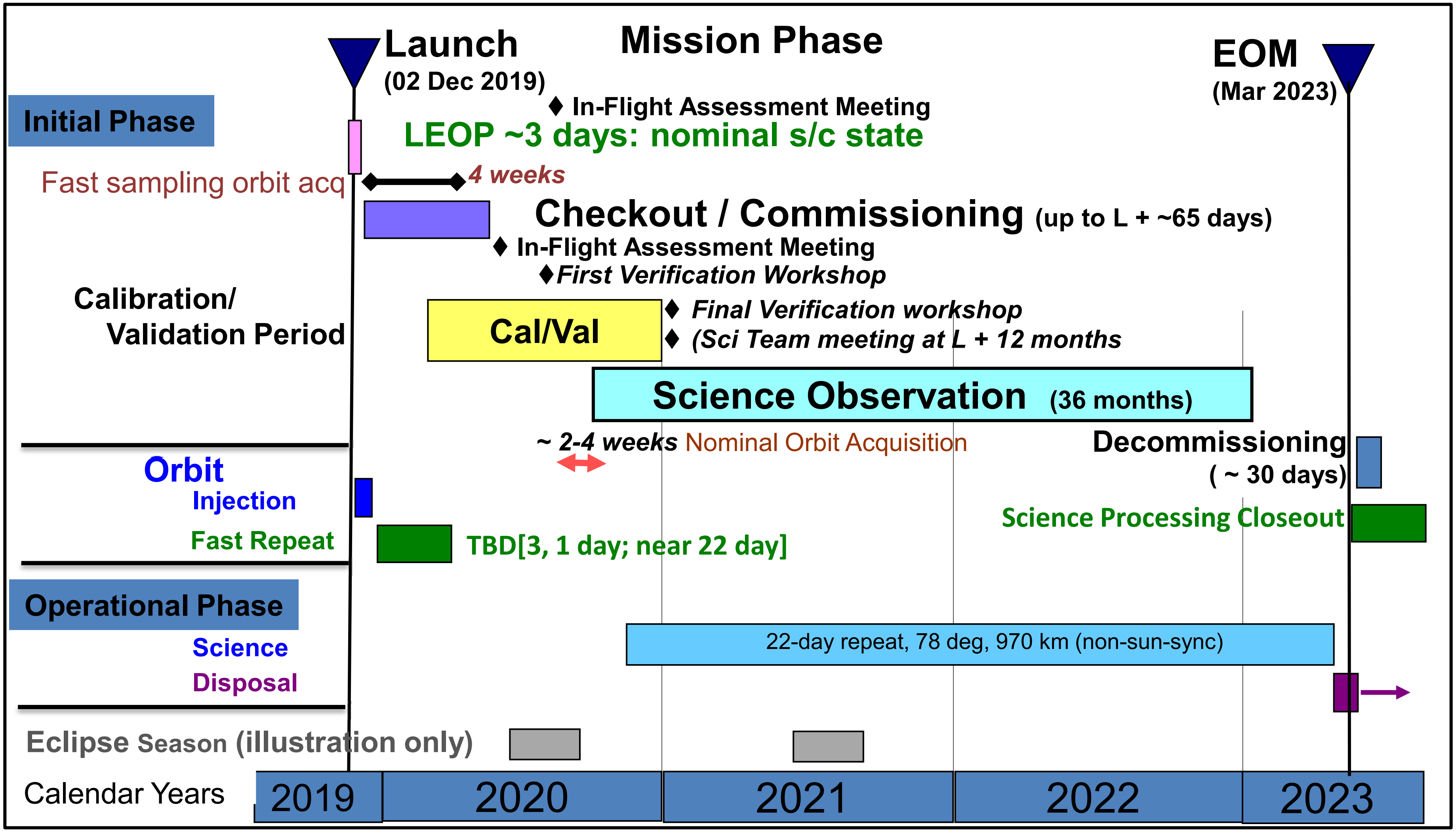
Backup or here ?



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])