Surface Water and Ocean Topography Mission (SWOT)

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Mission Science

Science questions to be addressed by this mission concept

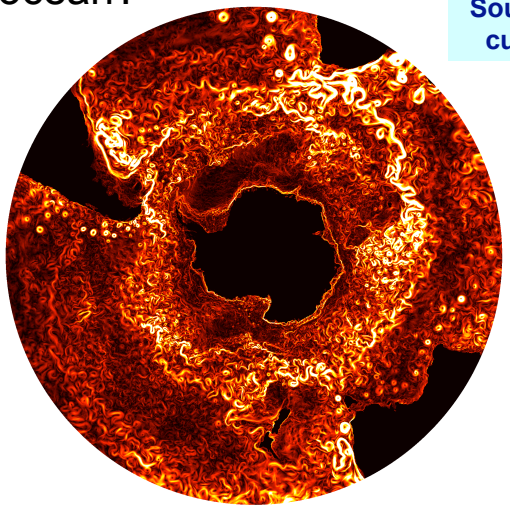
Hydrology

What is the spatial and temporal variability in the world's terrestrial surface water storage and how can we predict these variations more accurately?

Image credit: Larry Smith

Oceanography

Resolving the ocean sub-mesoscale and kinetic energy containing scales -- What is the small-scale (10-100 km) variability of ocean surface topography that determines the velocity of ocean currents, especially the effects of ocean current velocity on the vertical transfers of heat, carbon dioxide, and nutrients between the upper and deep ocean?



Southern Ocean near-surface current speed from ECCO2

Additional science applications:
Ocean bathymetry, sea-ice properties, coastal and internal tides

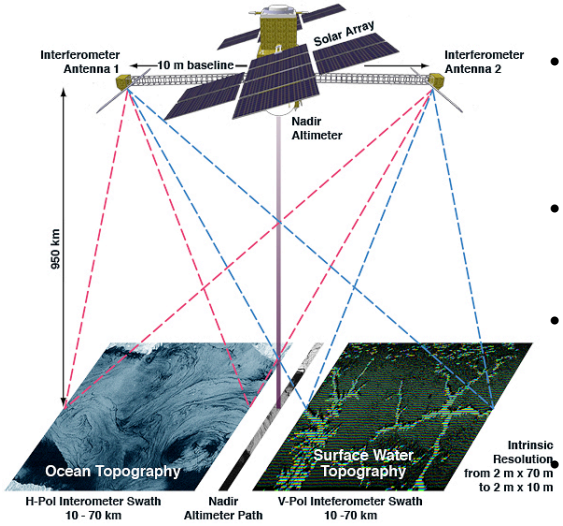
SWOT Overview

Mission Science

Oceanography: Characterize the ocean mesoscale and submesoscale circulation at spatial resolutions of 10 km and greater.

Hydrology: To provide a global inventory of all terrestrial water bodies whose surface area exceeds $(250m)^2$ (lakes, reservoirs, wetlands) and rivers whose width exceeds 100 m (requirement) (50 m goal) (rivers).

- To measure the global storage change in fresh water bodies at sub-monthly, seasonal, and annual time scales.
- To estimate the global change in river discharge at sub-monthly, seasonal, and annual time scales.



Mission Architecture

- Ka-band SAR interferometric (KARIN) system with 2 swaths, 65 km each
- Produces heights and co-registered all-weather imagery
- Use conventional Jason-class altimeter for nadir coverage and radiometer for wet-tropospheric delay.

Orbit: 970Km Alt, 78 Deg Incl, 22 day repeat

Mission Implementation Challenges

•Need to mature key KARIN instrument technologies (Antenna, On-Board Processor, Deployable structures, RF phase stability):
  - •IIP and ACT funded to mitigate risk
  - •Building on WSOA and SRTM heritage
  - •Maximize heritage on non-core instruments & S/C

•Demanding S/C requirements:
  - •Payload power, mass: ~1.1KW, ~300Kg
  - •Stringent Pointing knowledge requirements
  - •High Data Rate: ~272 GBytes of stored data / rev

•Two Science Communities: Formed international science working group to establish complementary science goals/ requirements

•Mission Cost: CNES partnership to contribute significant mission elements. Established plans for joint pre-phase A and phase A study.

FY 09 Plans

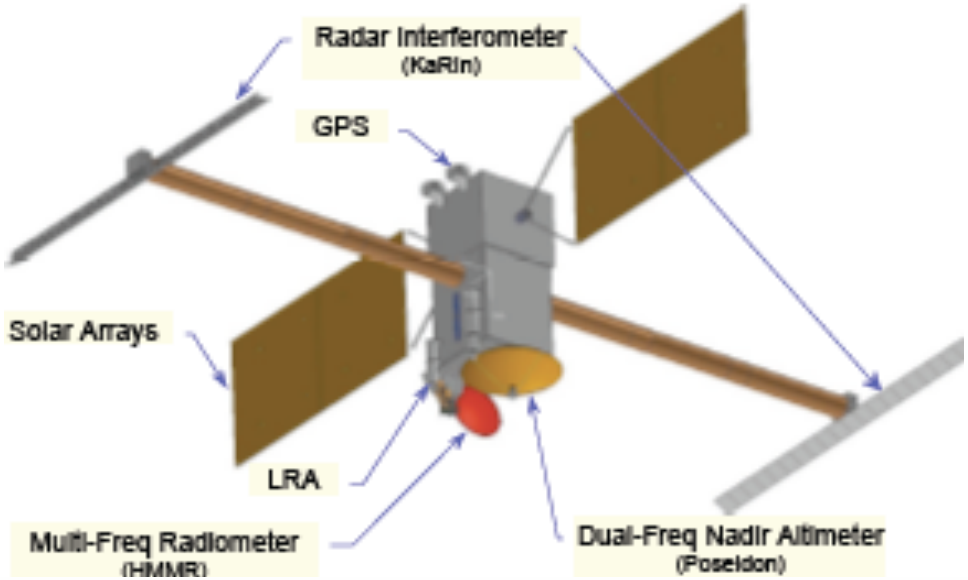
•Objective: Establish Science and Mission Requirements along with a baseline mission design/cost at sufficient maturity to support an MCR.
  - •Baseline science Req: Jan 2009, mission Req: April 2009
  - •Refine CNES partnerships: Feb 2009 – June 2009
  - •Mission Concept Report: Aug 2009
    - •Mission implementation plan, partnerships
    - •Risk reduction results (TRL maturity)
    - •Cost estimates
  - •Ready for MCR by Sep 2009

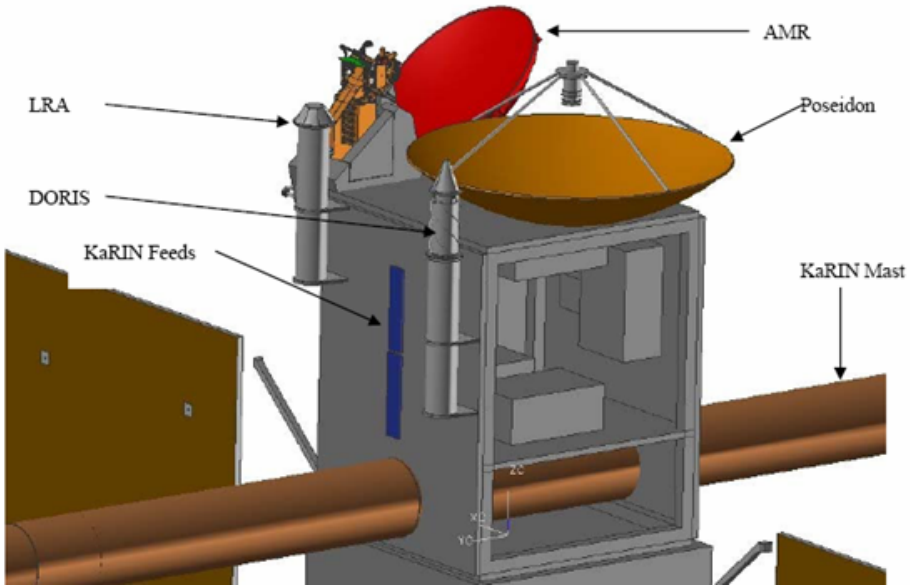
•Status:
  - •Held Oceanography and Hydrology science workshops
  - •Mission plan introduced at AGU townhall (Dec '08)
  - •Integrated Science Working Group baselined science requirements (Jan '09)
  - •S/C RFI released - received strong responses (Jan '09)

SWOT Mission Study Overview

- **Science Goals:**
  - Oceanography: First global determination of the ocean circulation, kinetic energy and dissipation at high resolution
  - Hydrology: First global inventory of fresh water storage change on a global basis
- **Differences between the communities are complementary, do not require compromise**
  - Oceanography: km-scale resolution with specific temporal sampling
  - Hydrology: m-scale resolution with general temporal sampling
  - Great scientific advances while avoiding technology & cost creep
- **SWOT is a combination of the WATER and Hydrosphere Mapper missions submitted to the NRC**
  - The WATER portion has well developed international cooperation with CNES
  - JPL and CNES have a rich history of strong collaborations in ocean altimetry
  - Key Payload (KARIN) builds upon the JPL designs for WSOA and SRTM
- **International (NASA, CNES) Science working group formed**
  - US (Fu & Alsdorf) & CNES (Mognard & Morrow) leaders identified
  - Conducted several focused (ocean, hydrology) science workshops to refine requirements
  - Prepared draft science requirements for science team review
  - AGU townhall (Dec 08) to get community feedback
  - Science working group has established baseline requirements (Jan 09)
- **CNES has strong partnership interest to contribute major system elements towards achieving common science objectives.**
  - SWOT ranked #1 for future Earth Science Missions
  - Next evaluation in March 2009 to establish future priorities and funding
- **JPL tasked to perform mission concept study in collaboration with CNES**
  - NASA/CNES Implementing Arrangement for (pre) and phase-A study in final review cycle

S/C Configuration

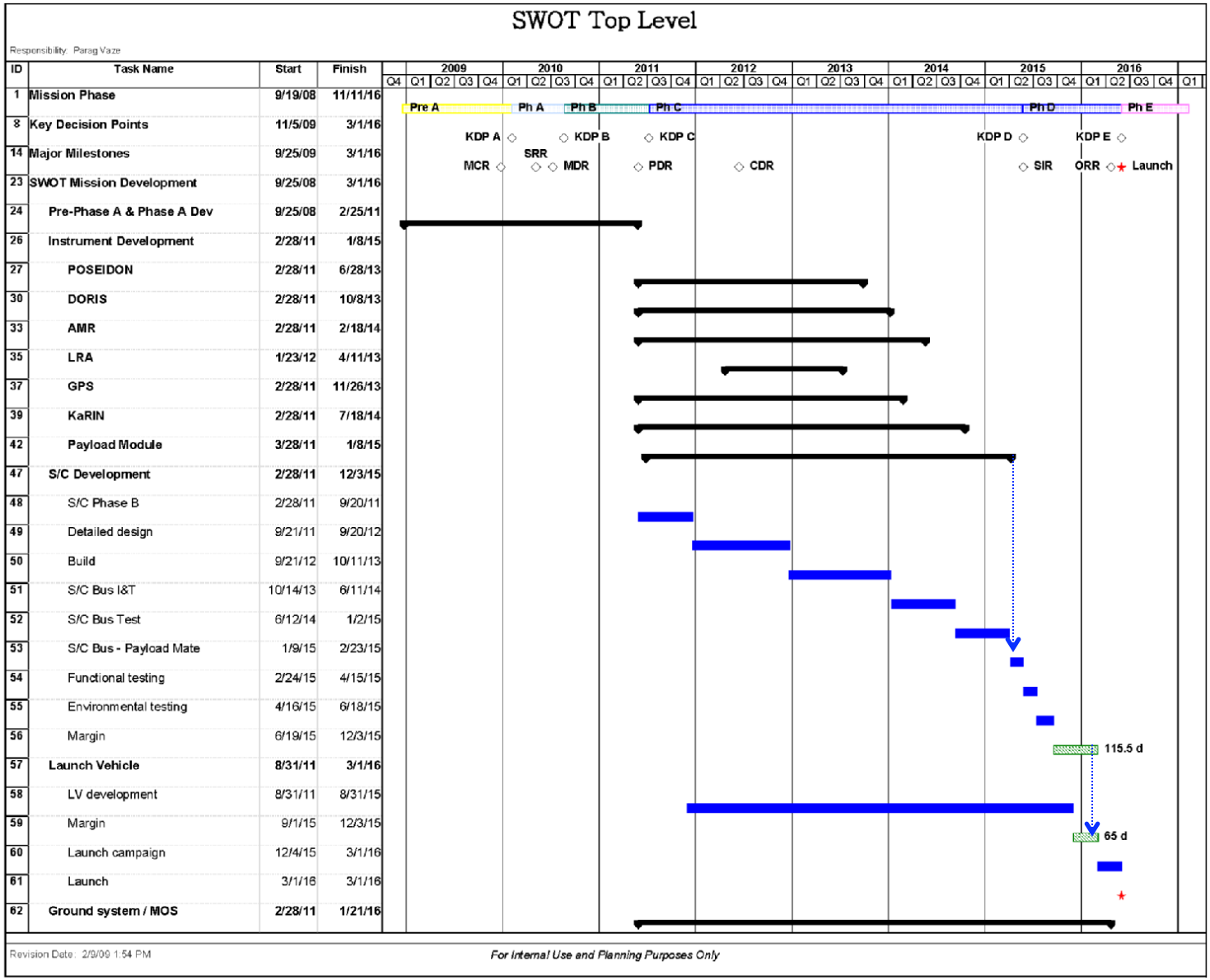




Payload

- KaRIN
  - Two 5-meter deployable masts on either side
  - 5 x 0.2 meter Deployable Reflectarray Antenna at each Mast tip
  - Antenna Feeds mounted at S/C to illuminate each Reflectarray
  - Mast axis (interferometer baseline) perpendicular to S/C velocity vector
- Dual-Frequency Nadir Altimeter (Ku/C)
  - 1.2-meter diameter nadir-pointing parabolic dish
- Multi-Frequency Microwave Radiometer (AMR)
  - 1-m diameter nadir-pointing offset-fed parabolic dish.
- GPS Receiver
  - Two small antennas with field of view to GPS satellites
- DORIS Receiver
  - Precision Orbit Determination using ground based radio beacons
- Laser Retroreflector Array
  - Field of view to nadir

SWOT Proposed Mission Schedule



SWOT FY08 Task Plan Summary

1. **Define Level 1 science requirements for the SWOT mission**: Oceanography and Hydrology workshops held, with preliminary level 1 science requirements developed. Wide community feedback at AGU townhall. Full science team has endorsed as baseline at Jan 09 meeting.
2. **Conduct a study to assess the measurement requirements for determining global fresh water storage and storage change**. Instrument measurement requirements developed jointly with virtual mission team and presented at hydrology workshop. Workshop report available on DS mission website
3. **Conduct a workshop to address the capabilities of the SWOT mission to measure ocean mesoscale and sub-mesoscale phenomena.** Completed workshop and updated Instrument measurement requirements. Workshop report released on DS mission websiteand published in Eos, AGU's weekly transactions
4. **Conduct a study to determine a family of orbits that will be used during the SWOT mission.**.Orbit candidates selected by ocean and hydrology community. Baseline orbit selected at full science team mtg (Jan 09)
5. **Determine implementation options for the SWOT instrument**. Instrument and mission design changed based on oceanography workshop inputs. Error budget in place, with calibration contribution being worked.
6. **Examine the impact of wet tropospheric errors across the swath, in coastal regions, and over land.** Tropospheric regional models being run. Initial results are very promising.
7. **Conduct studies to determine calibration schemes for correcting roll and systematic phase errors in the SWOT data.** Global measurement forward simulator completed. Calibration algorithms being developed. Completion (Feb '09)
8. **Generate simulated science data sets to be studied by the SWG to assess different mission scenarios and the science impacts of the SWOT mission**. Forward model completed. Completion (Mar '09)
9. **Derive the spacecraft requirements for the SWOT mission and prepare a Request for Information (RFI) to spacecraft vendors**. Requirements developed and draft RFI prepared. Released RFI (Nov 09)
10. **Derive mast requirements for the SWOT mission and start preparation of an RFI for mast vendors to assess the cost and feasibility of the SWOT mast.** Developed initial requirements and selected two implementations for further study. Submitted proposal for NASA ACT (selected). RFI planned for early '09 pending further analysis and results from S/C RFI.

FY09 Task Plan Summary - 1

- **Mission Science Definition:**
  - **Hydrology studies:** Conduct trade-off studies to determine optimal spatial resolution, height accuracy requirements, and size of rivers that need to be imaged.
  - **Oceanography studies:** Conduct studies on the spatial and temporal characteristics of the relation between submesoscale sea surface height and upper ocean circulation for the development of mission data products
  - **River scattering experiment:** This experiment complements earlier work funded under internal JPL funding to determine the scattering behavior of rivers, including the angular dependence of the cross section, and the temporal correlation of the radar returns. These results are required to determine the expected performance of the instrument.
- **Payload Definition:** The goal of this task is to refine the design of the NASA payload at a level sufficient for meeting the MCR requirements, including expected performance and technology assessment
  - **KaRIN design:** Refine the KaRIN interferometer design to a level consistent with MCR and SRR requirements. Generate resource tables, including mass, power, and technology readiness for all KaRIN susbsystems.
  - **Payload performance:** Conduct system analyses and simulations that will assess the end-to-end performance of the SWOT mission. Generate simulated data to support science studies (in collaboration with the ground system element).
  - **Technology assessment:** Provide technology assessment consistent with that required by the MCR and SRR.

FY09 Task Plan Summary - 2

- **Spacecraft Definition:** The goal of this task is to identify feasible spacecraft to accommodate the SWOT mission, and obtain ROM costs for all spacecraft options. In order to accomplish these goals, the following activities will be undertaken:
  - **Spacecraft requirements:** Interact with the NASA and CNES payload teams to derive spacecraft requirements, and document them.
  - **Spacecraft RFI:** Finalize the preliminary spacecraft requirements and write an RFI to spacecraft vendors. Assess the RFI responses and interact with vendors.
- **Ground System:** Define science data products, algorithms, and architecture at a level consistent with MCR
  - **Data product definition:** Define Level 0 Ð Level 2 data products. Interact with the science team to iterate data product definition.
  - **Ground system architecture:** Define the ground system architecture, determine interfaces, throughput and storage requirements.
  - **Processing algorithms:** Define required ground processing algorithms, prototype and test key algorithms, interact with system engineering to produce a prototype end-to-end simulator. Interact with the science team for the definition and implementation of key algorithms.
- **Cost Estimate:** Produce a mission cost consistent with MCR costing requirements.

SWOT FY09 Study Schedule

- Draft mission science requirements (OSTST mtg – Nov 14th Nov '08)
- S/C RFI released: Nov '08, Received S/C RFI responses from vendors: Jan '09
- AGU Townhall: Release preliminary science requirements, received broad science interest
- Science Team endorsed release of baseline mission science requirements: Jan '09
- Draft preliminary mission/system requirements: March 2009
- KaRIN technology development:
  - Antenna: Baseline design and small scale prototype development and test
  - On-Board Processor: Initial algorithm design and software model
  - RF sub-system: Design and prototype key elements to validate phase stability
  - Mast: Perform trade study to establish baseline configuration
  - Sys Eng – Cal/Val: Develop software simulators and analysis tools and field experiments to verify/validate performance requirements and develop initial calibration/validation plan
  - Establish ground data system architecture and initial algorithm design
- Produce conceptual designs for high-frequency radiometer
- Baseline initial mission concept architecture with credible options/trades: April 2009
  - S/C Bus, Payload Module, Launch Vehicle
  - Mission ops , data processing
- Generate preliminary costing for key system elements: May 2009
- Establish partnership framework with CNES: June 2009
- Develop framework/plan for Science Definition Team: June 2009
- Document baseline design and implementation plan (Mission Concept Report): Aug 2009

SWOT Complementary Measurements/Missions

- Coincident operation with SMAP and GPM presents a unique opportunity for global water budget studies
- GPS/Doris observations complement CLARREO
- For river phenomenology: CryoSat, airborne Ka-band measurements (Experiment of opportunity to better understand Ka-band phenomenology over inland water bodies and over the ocean)
  - A funded IPY experiment (D. Moller, PI) will collect Ka-band ice data over Greenland
  - Data could be collected during transit to reduce mission risk associated with the scattering characteristics of water at Ka-band
- Some useful lake/river data to be collected by OSTM, Jason-3, and IceSat2
- ALOS/PalSAR water body mask will be useful for planning and climatology
- For oceanography, complimentary data collected by Jason altimeter series

Cross Cutting Investments

- High data rate ground stations (>800Mbps)
- Direct broadcast or Near-Real Time downlink infrastructure
  - Enable/Engage significant near-real time user community (ex: monitoring storms coastal effects, inland river flooding, etc…)
- Airborne flight demonstration platforms
- Medium class / affordable Launch Vehicles

Issues and Challenges

- Technical:
  - Focus is on building upon WSOA experience and demonstrating significant risk reductions by early prototyping, experiments and modeling/analysis.
  - Limit technology creep: Keep it simple and maximize heritage
  - Limit requirements creep (work with science team to provide strong mission analysis to support early trades and establish feasible requirements, expectations)
- Programmatic:
  - Fostering continued partnership with CNES
  - CNES contributions will enable significant reductions for NASA total mission cost
- Science:
  - Developing a coordinated global validation plan, including in situ experiments, data assimilation and modeling