Unveiling Earth's Waters and Conquering Martian Skies: The Innovations of SWOT and Ingenuity Technologies

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The Precursors to SWOT

1992 TOPEX/Poseidon

2001 Jason-1
2008 Jason-2
2016 Jason-3

2020 Sentinel-6
SWOT Will Monitor Sea-Level at Higher Resolution

DARE MIGHTY THINGS FOR THE EARTH
SWOT is a pathfinder mission addressing transformative questions on water and energy of the Earth System, with radar interferometry measuring the elevation of water surface of the world.

SWOT will cover the world every 21 days.
SWOT – Mission Description

Artist's Concept

courtesy CNES
SWOT – Mission Description

- Microwave Radiometer
- LRA
- KaRIn Reflectors
- Radiators
- Solar Arrays
- S-band Antennas (another on opposite side)
- Star Trackers
- Payload GPS (Inside bus)

5m

X-band Telecom
DORIS
Nadir Altimeter

Stowed Configuration
SWOT Deployment – 8 Days (Accelerated)
SWOT – **Unprecedented Challenges**

1. First 2,000 W Ka-band Interferometric SAR (KaRIn)
2. Thermal stability of less than 0.05 °C/minute while rejecting more than 1000W of waste heat
3. Largest deployable dual reflectarray antenna in space each 5m x 0.25 m
4. Deployable Antenna Assembly with a 0.004 Deg co-alignment stability, over a 10 m baseline
5. Precision alignment mechanisms capable of adjusting antenna pointing to 0.0001 Deg
6. First on board real-time interferometric processing
7. First Xband antenna transmitting high data rate (620 Mbps) without the use of a gimbal mechanism
8. Complex EMI/EMC environment requiring accurate modelling in near and far field early in the project phase
SWOT – Payload Qualification

Nadir Module

Payload Module

DAA

KaRIn Module
Deployable Antenna Assembly has 0.004 Deg co-alignment stability, over a 10 m baseline.

Deployable Antenna Assembly has a 0.0015 degree error budget across thermal and deployment.
SWOT – *Payload Qualification*

0.0015 degrees in context:

Each division below is 10x less than the previous step.

What is harder than building something to zero error? Measuring something to zero error at temperature.
With a requirement of 0.0015 degrees, we had to make a measurement at 0.0003 degrees, or 5x less. This is 1 arcsec.
SWOT – Payload Qualification

The 1 arc second measurement needed to be made at room temperature, -75°C, and +75°C.

Courtesy of SRI
SWOT – *Payload Qualification*

The thermal box with hardware installed.
SWOT – *Payload Qualification*

Measurements were made at -75C and 75C.

Results showed accuracy between 1 and 3 arc seconds for each deployment
Generated using E.U. Copernicus Marine Service information using sea surface height measurements from 7 active nadir altimeter missions.

Sea Surface Height Anomaly (m)

Surface Water and Ocean Topography (SWOT) nadir altimeter

SWOT Ka-band Radar Interferometer provides improved resolution by more than a factor of 10, resolving fine structures of ocean circulation.
SWOT Water Surface Elevations
Yukon-Kuskokwim Delta, Alaska
June 18, 2023
Tracking a cold eddy
SWOT Water Surface Elevations
Kakhovka dam breach, Ukraine
Tsunami caused by melting of iceberg
MARS HELICOPTER

INGENUITY
Satellites Orbiting Mars Provide Large Scale Maps of the Surface from an Altitude of 200 Miles, But Finer Features Are Not Detectable.
Cameras on the “Neck” of the Rover Provide More Detailed Ground Level Imagery …… But Are Limited to Unblocked Line of Sight.
Opportunity Rover
Spent 100 Days
Roaming the Perimeter
of this Crater in Search
of Safe and Interesting
Entry Point
Curiosity Rover …
Roving Over Terrain
that That Was Rockier
than Expected….. If
One Knew Ahead
Ingenuity – Fast Facts

1. First test of powered flight on another planet.

2. Built to be light and strong enough to stow away under the rover while on the way to Mars, and survive the harsh Martian environment after arriving on the surface. The helicopter weighs less than 4 pounds (1.8 kilograms).

3. Powerful enough to lift off in the thin Mars atmosphere. The atmosphere of Mars is very thin: less than 1% the density of Earth’s.

4. The helicopter may fly for up to 90 seconds, to distances of almost 980 feet (300 meters) at a time and about 10 to 15 feet from the ground. That’s no small feat compared to the first 12-second flight of the Wright Brothers’ airplane.

5. The helicopter flies on its own, without human control. It must take off, fly, and land, with minimal commands from Earth sent in advance.
Ingenuity – First Flight
Ingenuity – *Flight Sequence*
Ingenuity – *Flight Sequence*
Telecommunication heatmap showing the location of the Rover between Sol 755 and Sol 763 and the helicopter landing site. Note that according to the heat map, the Rover in location 4 can close the link with a nominal rover orientation. In location 5, communication is guaranteed independently of the Rover orientation.
Ingenuity – *The End of the Mission*

On Jan. 18th, Ingenuity took its last flight. Rotor blade damage was observed after the flight.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Achieved</th>
</tr>
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<tbody>
<tr>
<td># of Flights</td>
<td>5</td>
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<tr>
<td>72</td>
<td></td>
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<tr>
<td>Operational Time</td>
<td>30 days</td>
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<td>Almost 3 years</td>
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<tr>
<td>Distance Flown</td>
<td>1.25 km</td>
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<td>17.7 km</td>
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Dare Mighty Things Together

Some of the SWOT Team

Questions?
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Mars Helicopter Team

ASAT Conference
May 18th 2024

Pre-Decisional Information – For Planning and Discussion Purposes Only
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