POLITECNICO DI MILANO
DEPARTMENT OF AEROSPACE ENGINEERING

Space Systems Engineering and Operations

AA 2023-2024

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OSTM/Jason-2 Mission

Assignment 1: System Overview and Mission Analysis

Group 25

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July 30, 2024

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Acronyms

ADCS Attitude Dynamics and Control System. 4

AMR Advanced Microwave Radiometer. 7, 9

CARMEN-2 Environment Characterization and Modelisation 2. 7, 8

CNES Centre National d'Études Spatiales. 4, 7

ConOps Concept of Operations. 2, 5, 9

DIODE Détermination Immédiate d'Orbite par Doris Embarqué. 7

DORIS Doppler Orbitography and Radiopositioning Integrated by Satellite. 7–9

ESA Electronics Structure Assembly. 7

GPS Global Positioning System. 8

GPSP Global Positioning System Payload. 7–9

iLRO Interleaved Long Repeat Orbit. 6, 9

JASON Joint Altimetry Satellite Oceanography Network. 4–6, 9

JAXA Japan Aerospace Exploration Agency. 7, 8

JMR Jason Microwave Radiometer. 7

JPL Jet Propulsion Laboratory. 7

LPT Light Particle Telescope. 7, 8

LPT-E Light Particle Telescope Electronics. 8

LPT-S Light Particle Telescope Sensors. 8

LRA Laser Retroreflector Array. 7–9

LRO Long Repeat Orbit. 6, 9, 10

MEX Experiment Module. 8

NASA The National Aeronautics and Space Administration. 4–6

OSCAR Observing Systems Capability Analysis and Review Tool. 7

OSTM Ocean Surface Topography Mission. 4, 5, 9

POD Precise Orbit Determination. 7, 8

POSEIDON Positioning,Ocean,Solid Earth, Ice Dynamics, Orbital Navigator. 4, 7, 9

RSA Reflector Structure Assembly. 7

SHM Safe Hold Modes. 6

SLR Satellite Laser Ranging. 8

T2L2 Time Transfer by Laser Link. 7, 8

TOPEX Topography Experiment. 4, 9

TRSR-2 Turbo Rogue Space Receiver-2. 7

WMO World Meteorological Organization. 7

1 Mission Overview

The Ocean Surface Topography Mission (OSTM), more precisely the JASON-2 satellite, is an international satellite mission that planned to carry on the precise sea surface height measurements that were initiated in 1992 by the joint mission composed by NASA and CNES: the TOPEX-POSEIDON; continued in 2001 by the NASA/CNES Jason-1 mission, into the next decade.
Researchers wanted to monitor changes in the global sea level and gain a better understanding of the relationship between climate change and circulation of the oceans through the use of information collected from the mission. This data has been helpful in many fields, such as operational oceanography, seasonal forecasting, climate monitoring, marine meteorology, and ocean, Earth system, and climate research. The mission functioned as a link for transferring future measurement collection to international weather and climate forecasting organisations. This information has been used by such organisations to forecast weather and climate across short, seasonal, and long time periods.
The OSTM/JASON-2 took up the previous spacecraft's near-circular orbit at a height of 1,336 kilometres (830 miles) above the equator, using the same ground track as Jason-1. It has a period of 112 minutes and a repeating gound track every ten days. Thanks to its inclination of 66 degrees it was able provide ocean topography data for 95 percent of Earth's ice-free waters. [6]

2 Mission Main Goals

The main high level goal of OSTM/JASON-2 is the continuance of the missions Jason-1 and TOPEX-POSEIDON. In more detail, high level goals of OSTM/JASON-2 can be divided in two main categories as shown in Table 1.

Science Goals	**Engineering Goals**
Continue ocean surface topography measurements	Reach and maintain the same orbit of Jason-1
Investigate ocean circulations	Improve Jason-1 measurement accuracy
Measure global sea level change and its relation to climate change	Maintain stability of measurements accuracy
Improve ocean, costal tides models and waves measurements	Operate for a minimum period of 3 years

Table 1: Science and Engineering goals [6]

3 Mission Drivers

Through our analysis of the mission we have identified two drivers:

1. **Continuity with Jason-1 data.** This is the main driver of the mission. This driver influences the design of most subsystems and the selection of the instruments as the data accuracy shall be the same or better with respect to the previous mission and the number of sensors shall remain at the least the same.

2. **Accurate nadir pointing.** This driver influences the design of many subsystems: the Attitude Dynamics and Control System (ADCS); the sensor types and positioning on the satellite; the power supply, as the solar panels shall provide a certain minimum amount of power at all times. It is noted that this driver may be considered a consequence of the first, but this driver is also due to the improved measurements accuracy goal of which the first driver is not a consequence.

4 Functional Analysis

Starting from the requirements, it is possible to outline the functions necessary for the completion of the mission, as shown in Figure 1.

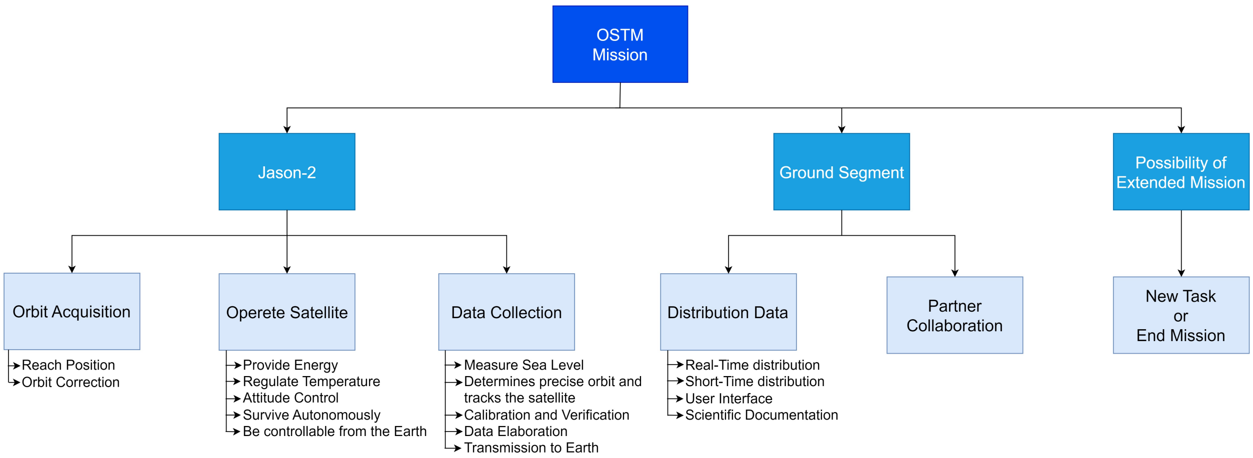

Fig. 1: Functional Tree Analysis

5 Mission Phases & ConOps

NASA's Press Kit before the launch [6] of the OSTM/JASON-2 mission outlines 6 main phases, which define distinct stages of the mission, each serving a specific purpose:

1. **Launch and Early Orbit Phase (3 days):** This phase involves the launch of the satellite and its maneuvering into its initial orbit. During this time, satellite and instrument systems are activated and thoroughly checked.
2. **Orbit Acquisition Phase (about 1 month):** In this phase, the satellite is maneuvered into its operational orbit. This phase overlaps with the first half of the Assessment Phase.
3. **Assessment Phase (2 months):** This phase begins after the Launch and Early Orbit Phase and concludes when the satellite and instrument systems are certified to be fully functional. It also marks the readiness of the ground system for routine operations.
4. **Verification Phase (at least 6 months):** Overlapping with the Assessment Phase, this phase starts when Jason-2 reaches its operational orbit and flies in tandem with Jason-1. It continues until the received data from the satellite, its instruments, and data processing algorithms are satisfactorily calibrated and validated. During this phase ground data and laser ranging data are collected for verification purposes, furthermore workshops between agencies are held to assess and authorize the delivery of products to final users.
5. **Initial Routine Operations Phase:** Starting after the Assessment Phase and ending three years after launch, this phase involves the continuous collection and monitoring of instrument data. Science data products from the Verification Phase are reprocessed at the end of this phase.
6. **Extended Routine Operations Phase:** If useful data is still being collected, this phase extends the mission by an additional two years or as agreed upon by mission partners.

Within each phase, workshops among partners and reports are also scheduled.

In Figure 2, we summarize the main phases inside a broader context containing the Jason-1 and Jason-3 missions as well.

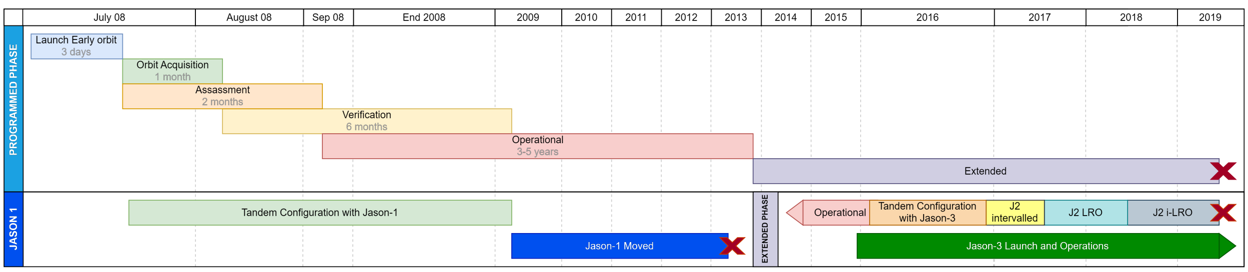

Fig. 2: Mission Phase & ConOps

5.1 Launch Sequence

The satellite was launched on June 20^{th}, 2008, by a Delta-2 Rocket from the Vandenberg launch site in California, USA. Jason-2's launch timing was meticulously planned to meet its scientific goals, ensuring that the satellite is placed in the correct orbit relatively to the Jason-1 satellite. The launch date was determined by satellite readiness, Delta vehicle availability, and atmospheric conditions at Vandenberg Air Force Base. The launch window was set from June 15^{th} to August 15^{th}, with a nine-minute slot each day, which is brought forward everyday by about 12 minutes. The launch sequence can be summarized in Figure 3, which was released by NASA in their pre-launch press kit[6]. In Figure 3 a brief overview of the launch sequence is presented.

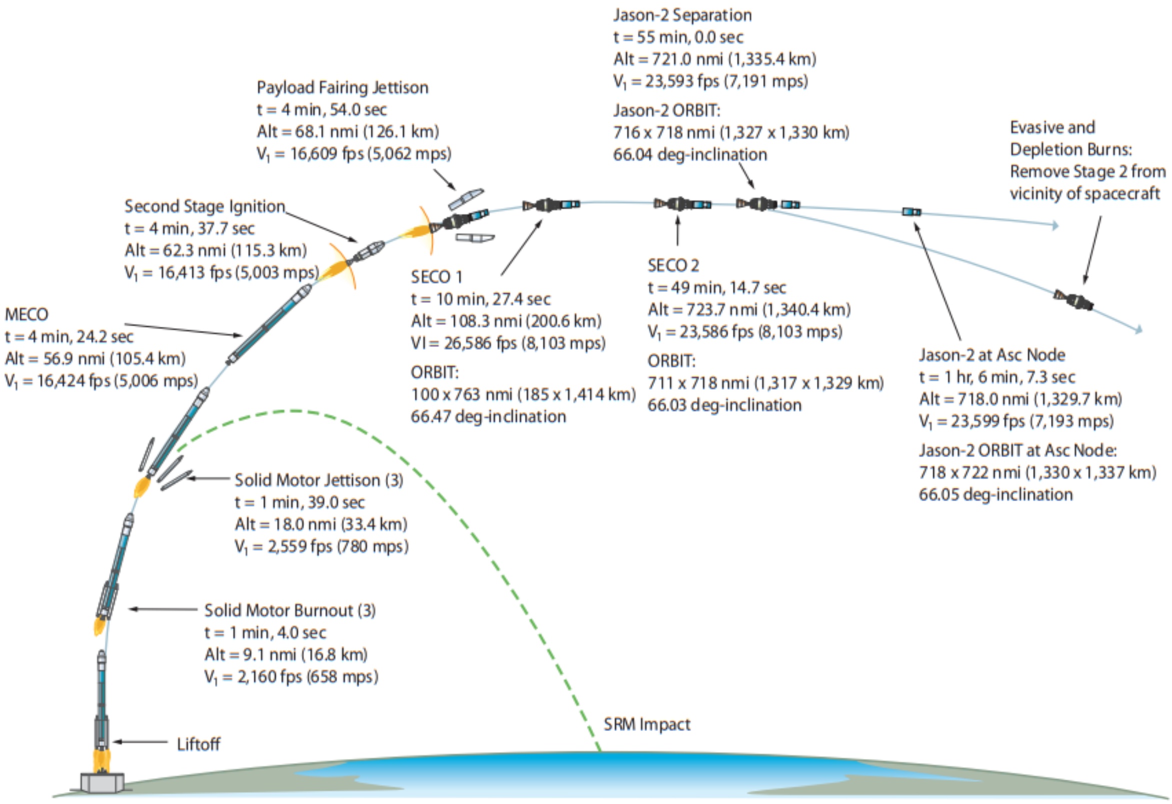

Fig. 3: Jason-2 Official Launch Sequence

5.2 Extended Phase

The satellite was initially planned to last for 3 to 5 years. However, given the successful outcomes of the Jason-1 mission and the actual lifetime of the Jason-2 satellite, the mission was extended further than the initial estimated lifespan. In the pre-launch documentation [6] the possibility of an "extended mission" is briefly mentioned.

In this section, we will discuss the end-of-life scenario for the Jason-2 mission, referring to the historical report [3] and the executive report [5] of the mission. The satellite's end-of-life plan closely followed the approach used for its predecessor, Jason-1 [2], ensuring a smooth transition between missions. Jason-2 would operate on its reference orbit until the launch of its successor, Jason-3 [4]. This involved an initial tandem configuration for calibrating and verifying the successor satellite's strumentation, followed by a transition to other orbits. However, there was also the possibility of cancelling the JASON program and terminating the mission. The program's confirmation occurred with the launch of Jason-3 on January 17^{th}, 2016. Following the pattern set by the Jason-1 mission, Jason-2 was then moved to an interleaved orbit at the same altitude in October 2016.

However, due to multiple gyro anomalies and the occurrence of the Safe Hold Modes (SHM), Jason-2 was subsequently moved to a Long Repeat Orbit (LRO) with an 8 km resolution grid in July 2017. This orbit is approximately 27 km below the previous orbit, still utilized by Jason-3. On July 16^{th}, 2018, Jason-2 was relocated to a new Interleaved Long Repeat Orbit (iLRO) to achieve 4 km grid measurements. This increased measurement density was chosen for its advantages in marine geodesy, such as the enhancement of bathymetry and mean sea surface models. On October 1^{st}, 2019, The Jason-2 concluded its science mission after detecting deterioration in the spacecraft's power system [3].

6 Scientific Instruments

6.1 Overview

In order to accomplish the mission goal, a total of five primary science instruments were carried on board. Three of them are attitude determination systems, to accurately estimate the satellite and position, while the other two were used for sea surface topography measurements. Moreover, three more instruments were carried on board of the spacecraft with their own objectives to fulfill. The data presented in the following section was retrived from the WMO's OSCAR Website [7] and Dr. Kramer's eoPortal [3]. A brief overview of the scientific instrumentation of the Jason-2 satellite is presented in Table 2.

Name	Mass	Power Consumption	Developer
POSEIDON-3	70 kg	78 W	Thales Alenia Space
AMR	27 kg	31 W	JPL/ ATK Space Systems
DORIS	91 kg	42 W	CNES/Thomson
GPSP/TRSR-2	10 kg	17.5 W	Spectrum Astro Inc.
LRA	2.2 kg	-	ITE Inc.
CARMEN-2	4.2 kg	10 W	CNES
LPT	7 kg	15 W	JAXA
T2L2	12 kg	48 W	CNES

Table 2: Instrumentation Overview

6.2 Payload Description

- **POSEIDON-3**
  Positioning,Ocean,Solid Earth, Ice Dynamics, Orbital Navigator (POSEIDON), is a radar altimeter and the main instrument onboard of the spacecraft. Its principal function is measuring the satellite's distance from Earth's surface by emitting radio waves at two different frequencies, 13.575 and 5.3 GHz, towards the sea and measuring the time delay between the return of a signal and the other. Additionally to its main function, POSEIDON-3 can be used to calculate ocean surface current velocity and to measure ocean wave height and wind speed.
  POSEIDON-3 features an experimental mode to support measurements closer to coastal zones. This will be achieved by an open loop tracker as the satellite to surface distance will be estimated by the altimeter using the real-time orbit position predicted by DIODE (on board navigator based on DORIS receiver).
- **DORIS**
  Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) is a Precise Orbit Determination (POD) system providing position and ionospheric correction for POSEIDON-2. The DORIS flight segment consists of a two-channel, two-frequency (401.25 MHz and 2036.25 MHz) Doppler receiver capable of tracking signals from a worldwide network of about 50 ground beacons.
- **AMR**
  The Advanced Microwave Radiometer (AMR) is a JPL-developed instrument, which derives from its predecessor: the Jason Microwave Radiometer (JMR), positioned on the Jason-1 satellite. The AMR is divided in two subsystems: the Electronics Structure Assembly (ESA) and the Reflector Structure Assembly (RSA).
  The AMR is a passive microwave radiometer measuring the brightness temperatures in the nadir column at frequencies of 18.7, 23.8, and 34 GHz, providing path delay correction for the altimeter. The 23.8 GHz channel is the primary water vapor sensor, the 34 GHz channel provides a correction for non-raining clouds, and the 18.7 GHz channel provides the correction for effects of wind-induced enhancements in the sea surface background emission.
- **GPSP/TRSR-2**
  The Global Positioning System Payload (GPSP), which is also referred to as Turbo Rogue Space

Receiver-2 (TRSR-2), is a 16-channel GPS receiver with the objective to provide supplementary positioning data to DORIS in support of the POD function.
The GPSP is fully redundant and divided in two independent receivers operating in cold redundancy. Each unit is composed of an omnidirectional antenna, a low-noise amplifier, a crystal oscillator, sampling down-converter, and a baseband digital processor assembly.

- **LRA**
  The Laser Retroreflector Array (LRA), provides a reference target for Satellite Laser Ranging (SLR) measurements, which are necessary to calibrate the POD system and the altimeter throughout the mission. The LRA is a totally passive unit placed on the nadir face of the satellite and is composed by nine quartz corner cubes arrayed as a truncated cone with one in the center and the other eight distributed around the cone. The small number of ground stations and the sensitivity of laser beams to weather conditions make it impossible to track the satellite continuously using only this instrument, for this reason other onboard location systems are needed.
- **CARMEN-2**
  The Environment Characterization and Modelisation 2 (CARMEN-2) is an instrumentation dedicated to study the influence of space radiation on advanced components to measure high-energy particle flux of electrons (e-) and protons (p+), and ion fluxes.
  The instrument is composed of a spectrometer and an Experiment Module (MEX).The MEX includes three types of dosimeters to measure accurately the exposed dose and monitor several components under test.
- **T2L2**
  The main function of the Time Transfer by Laser Link (T2L2) instrument is to allow comparison and follow-up of distant clocks, either of an embarked clock relative to a ground clock or of two (or more) ground clocks. The means used to establish a link between these clocks is the transmission and the dating of laser pulses.
  The T2L2 satellite payload is composed of two subsystems:
  * The optical subsystem that ensures the functions of electronic activation and collection of the laser pulse for the dating.
  * The electronic subsystem that ensures the functions of non-linear detection, dating, instrument management and interfacing with the satellite.
- **LPT**
  The Light Particle Telescope (LPT) is a detection unit developed by JAXA. LPT is composed by two units:
  * LPT-E provides functions of the electrical interface with the satellite system. It receives primary power supply from the satellite system and provides sensors and electrical circuits with secondary power. It also receives prompts and sends telemetry data to the ground segment.
  * LPT-S consists of four sensors. Each sensor counts a number of interesting particles irradiated from inside of the view angle with the specific energy of each channel every second.

Fig. 4: Payloads on board of Jason-2

Figure 4 shows the position of the sensors on the spacecraft.

6.3 Main Goals - P/L correlations

Mission Goal	Payload
Measurement of sea level	POSEIDON-3
Precise orbit determination and tracking the satellite	DORIS, GPSP, LRA

Table 3: Correlation between mission main goals and payloads

6.4 ConOps - P/L correlations

Mission phase	Payload
Launch and Early Orbit Phase	Activation of positioning systems DORIS, GPSP, LRA
Orbit Acquisition Phase	DORIS, GPSP, LRA
Assessment Phase	Testing and calibration of POSEIDON-3 and AMR
Initial Routine Operations Phase	Employement and manteinance of all scientific payloads
Extended Operations Phase	-

Table 4: Correlation between mission phases and payloads

7 Mission Analysis

7.1 Nominal Orbit

Jason-2's nominal orbit is identical to that of Jason-1, its high altitude (1336 kilometers) reduces interactions with the Earth's atmosphere and gravity field to a minimum, thus making orbit determination easier and more precise. The orbit inclination of 66 degrees enables the satellite to cover most of the globe's unfrozen oceans. The orbit's repeat cycle is just under 10 days. This cycle is a trade-off between spatial and temporal resolution designed for the study of large-scale ocean variability.

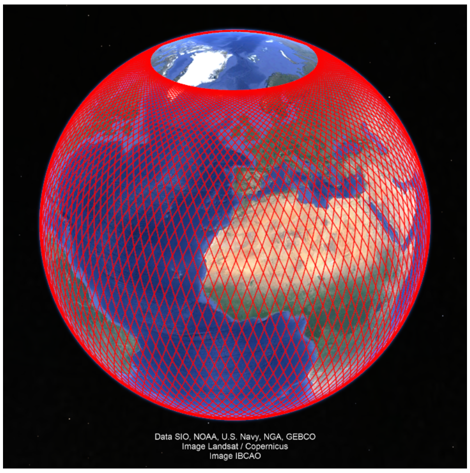

Fig. 5: 3D Ground Track for a 10-day cycle [1]

Furthermore, using the same orbit as TOPEX-POSEIDON will ensure better intercalibration and data continuity. The orbit is also designed to pass over two dedicated ground calibration sites : Cap Senetosa in Corsica and the Harvest oil rig platform in California, USA.

7.2 Orbits History & Phase Correlation

After launch, the satellite finds itself in a parking orbit, from which is moved to the nominal orbit thanks to the propulsive system on board, during the "Orbit Acquisition Phase".
During the first six months of the mission,period known as the "Verification Phase", the OSTM/JASON-2 and Jason-1 satellites were flying in formation along the same groundtrack, separated in time by only 55 seconds. This tandem configuration allows in-depth intercalibration of the two altimeter missions. During "Verification" and "Operational" phases Jason-2 was located on its nominal orbit.
From Oct.2016, after more than 8 years of service, Jason-2 shifted to the interleaved orbit that was used by TOPEX-POSEIDON from 2002-2005 and Jason-1 from 2009-2012. This interleaved orbit has a groundtrack in-between the nominal groundtrack. The Jason-3 satellite continued the long term climate data record on the nominal ground track.
From July 2017, Jason-2 operates on a new Long Repeat Orbit (LRO) at roughly 1309.5 km altitude.
From July 2018, Jason-2 operates on an Interleaved Long Repeat Orbit (iLRO), with a ground track in the

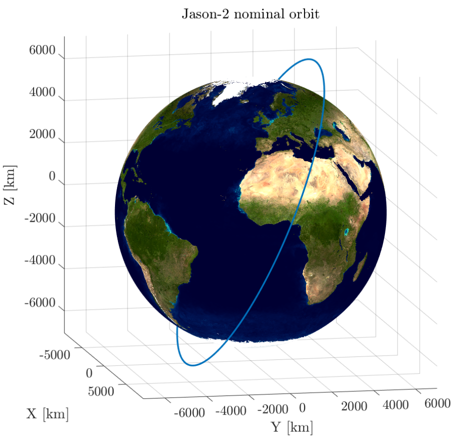

Fig. 6: Single Orbit Plot

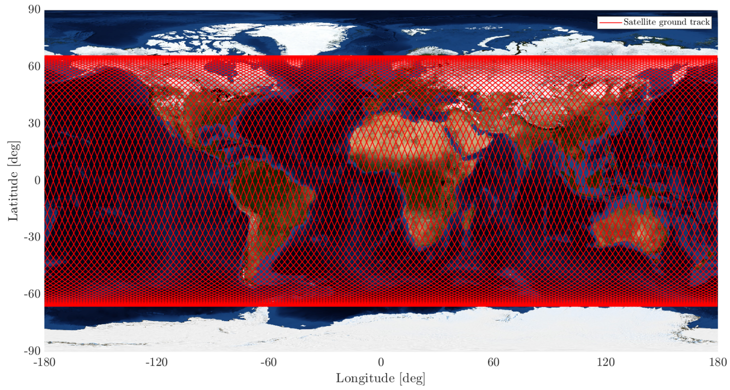

Fig. 7: 2D Ground Track for a 10 day cycle

middle of the grid defined by the LRO. (For more details on LRO look at Section 5.2)
The satellite decommissioning operations were completed on the 10^{th} of October, 2019, and deorbiting is expected to happen throughout hundreds of years due to passive atmospheric drag.

7.3 Orbit maintenance

A satellite's orbit parameters tend to change over time as a result of atmospheric drag. In the long term, more or less periodic variations also occur due to instabilities in the Earth's gravity field, solar radiation pressure, and other forces of smaller magnitude.

Orbit manoeuvers are performed every 40 to 200 days. Intervals between maneuvers depend mainly on solar flux and each manoeuver lasts 20 to 60 minutes. Where possible, they are performed at the end of the orbit cycle and above solid earth, so that lost data acquisition time is reduced to a minimum.

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