JUICE: a European mission to Jupiter and its icy moons

The JUICE Science Working Team and the JUICE Project Team
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Juice science themes

The focus of JUICE is to characterise the conditions that may have led to the emergence of habitable environments among the Jovian icy satellites, with special emphasis on the three ocean-bearing worlds, Ganymede, Europa, and Callisto. Ganymede is identified for detailed investigation since it provides a natural laboratory for analysis of the nature, evolution and potential habitability of icy worlds in general, but also because of the role it plays within the system of Galilean satellites, and its unique magnetic and plasma interactions with the surrounding Jovian environment. JUICE will determine the characteristics of liquid-water oceans below the icy surfaces of the moons. This will lead to an understanding of the possible sources and cycling of chemical and thermal energy, allow an investigation of the evolution and chemical composition of the surfaces and of the subsurface oceans, and enable an evaluation of the processes that have affected the satellites and their environments through time. The study of the diversity of the satellite system will be enhanced with additional information gathered remotely on Io and the smaller moons. The mission will also characterise the diversity of processes in the Jupiter system that may be required in order to provide a stable environment at the icy moons on geologic time scales, including gravitational coupling between the Galilean satellites and their long term tidal influence on the system as a whole. JUICE will carry out extensive new studies of Jupiter's atmosphere , magnetosphere and their interaction with the satellites to further enhance our understanding of the evolution and dynamics of the Jovian system. Source: red book

1. Emergence of habitable worlds around gas giants

Ganymede as a planetary object and possible habitat
- Largest satellite in the solar system
- Ocean between icy layers
- Internal dynamo
- Richest crater morphologies
- Archetype of waterworlds

Europa's recently active zones
- An active world?
- Ocean in contact with silicates

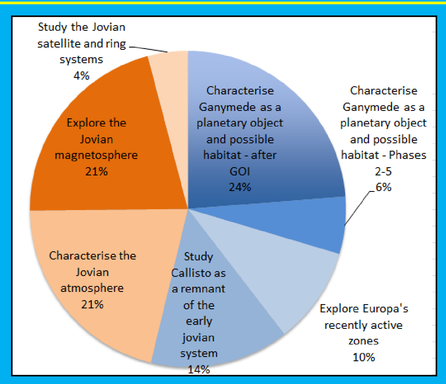
Callisto as a remnant of the early Jovian system
- Impactor history
- Enigmatic differentiation
- Witness of early ages

2. Jupiter system as an archetype for gas giants

Jovian atmosphere
- Archetype for giant planets
- Fluid dynamics, chemistry, meteorology,...
- Formational history of planetary system

Jovian magnetosphere
- Largest object in our Solar System
- Astrophysical mechanisms at work
- Giant particle accelerator

Jovian satellite and ring systems
- Tidal forces: Laplace resonance
- Electromagnetic interactions to magnetosphere and upper atmosphere of Jupiter



Overall data volume share amongst science objectives

10 instruments and 1 experiment

JANUS: Visible Camera System
PI: Pasquale Palumbo, Parthenope University, Italy.
Co-PI: Ralf Jaumann, DLR, Germany
- ≥7.5m/pixel
- Multiband imaging, 380 – 1080 nm
- Icy moon geology
- Io activity monitoring and other moons observations
- Jovian atmosphere dynamics

SWI: Sub-mm Wave Instrument
PI: Paul Hartogh, MPS, Germany
- 600 GHz /1280 GHz
- Jovian Stratosphere
- Moon atmosphere and surface
- Atmospheric isotopes

MAJIS: Imaging VIS-NIR/IR Spectrograph
PI: Yves Langevin, IAS, France
Co-PI: Guiseppe Piccioni, INAF, Italy
- 0.9-1.9 μm and 1.5-5.7 μm
- ≥62.5 m/pixel
- Surface composition
- Jovian atmosphere

GALA: Laser Altimeter
PI: Hauke Hussmann, DLR, Germany
- ≥40 m spot size
- ≥0.1 m accuracy
- Shape and rotational state
- Tidal deformation
- Slopes, roughness, albedo

UVS: UV Imaging Spectrograph
PI: Randy Gladstone, SwRI, USA
- 55-210 nm
- 0.04°-0.16°
- Aurora and Airglow
- Surface albedos
- Stellar and Solar Occultation

RIME: Ice Penetrating Radar
PI: Lorenzo Bruzzone, Trento, Italy
Co-PI: Jeff Plaut, JPL, USA
- 9 MHz
- Penetration ~9 km
- Vertical resolution 50 m
- Subsurface investigations

JMAG: JUICE Magnetometer
PI: Michele Dougherty, Imperial, UK
- Dual Fluxgate and Scalar mag
- ±8000 nT range, 0.2 nT accuracy
- Moon interior through induction
- Dynamical plasma processes

3GM: Gravity, Geophysics, Galilean Moons
PI: Luciano Iess, Rome, Italy
Co-PI: David J. Stevenson, CalTech, USA
- Ranging by radio tracking
- 2 μm/s range rate
- 20 cm range accuracy
- Gravity fields and tidal deformation
- Ephemerides
- Bi-static and radio occultation experiments

PEP: Particle Environment Package
PI: Stas Barabash, IRF-K, Sweden
Co-PI: Peter Wurz, UBe, Switzerland
- Six sensor suite
- Ions, electrons, neutral gas (in-situ)
- Remote ENA imaging of plasma and torus

PRIDE: Planetary Radio Interferometer & Doppler Experiment
PI: Leonid Gurvits, JIVE, EU/The Netherlands
- S/C state vector
- Ephemerides
- Bi-static and radio occultation experiments

RPWI: Radio and Plasma Wave Investigation
PI: Jan-Erik Wahlund, IRF-U, Sweden
- Langmuir Probes
- Search Coil Magnetometer
- Tri-axial dipole antenna
- E and B-fields
- Ion, electron and charged dust parameters

Spacecraft

- **3-axis stabilised**
- **Mass:**
  - **Launch mass: ~5300 kg**
  - **Instruments: ~220 kg**
  - **Propellant: ~2800 kg**
- **Radiation monitor**
- **Solar array 97 m² (power ~850 W at Jupiter)**
- **Fixed High Gain Antenna and Steerable Medium Gain Antenna (X- and Ka-Bands)**
- **Data Volume ~ 1.4 Gb per day**

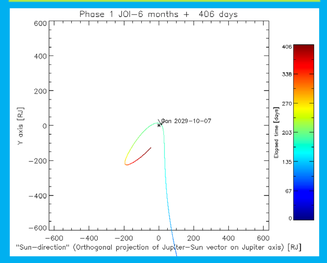
Mission trajectory and phases

Cruise phase

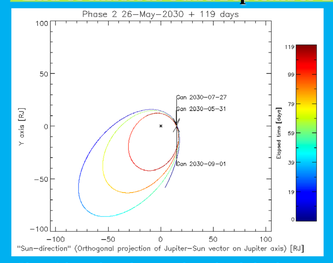
06/2022: Launch
05/2023: Earth flyby
10/2023: Venus flyby
09/2024: Earth flyby
02/2025: Mars flyby
11/2026: Earth flyby
10/2029: Jupiter orbit insertion

JUICE in the Jupiter system

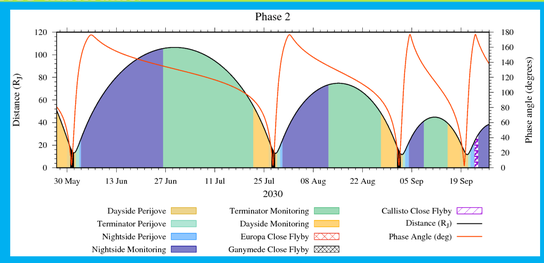
Phase 1: Orbit insertion-6 months and 1st orbit
Phase 2: Orbits# 2, 3, 4; three Ganymede and one Callisto flybys
Phase 3: Two Europa flybys (October 2030)
Phase 4: Jupiter inclined phase; ten Callisto flybys (~ October 2030 – August 2031)
Phase 5: Transfer to Ganymede; 8-9 Ganymede and 3 Callisto flybys
Ganymede orbit insertion (in the timeframe July-December 2032); Ganymede phases (in the timeframe July 2032-September 2033) : elliptical orbit (GEO) / 5000 km circular orbit (GCO5000) / 500 km circular orbit (GCO500)
End of mission: June/September 2033 timeframe.



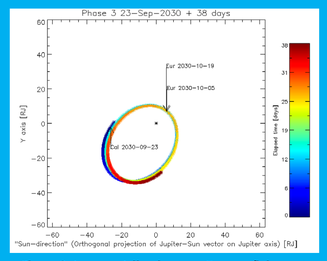
Phase 1 includes:(1) the approach to Jupiter; the nominal science mission starts 6 months before the orbit insertion, planned in October 2019. (2) the capture orbit, where the commissioning and the first observations in orbit take place



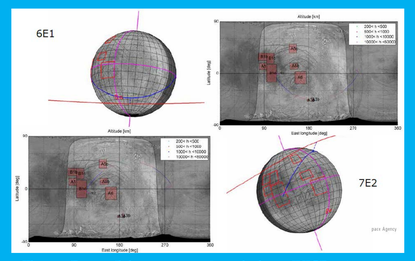
Phase 2 lasts about four months and includes the next three orbits, three Ganymede (300-1400 km) and one Callisto (2200 km) flybys.



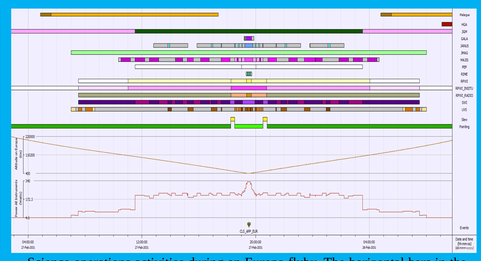
A geometry-driven segmentation plan for Phase 2, from the Jupiter Working Group. Distance to Jupiter is given in RJ, the phase angle is given as the red line. Perijoves are defined as ±50 hours either side of the pericentre, with colour coding for illumination conditions. Dayside is defined as 0-90 degrees, terminator as 90-135 degrees, nightside as 135-180 degrees.



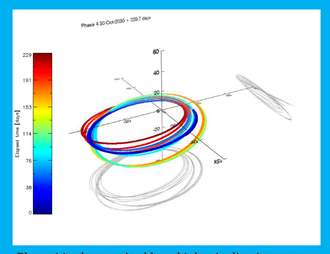
Phase 3 is essentially the two Europa flybys, at a closet approach of 400 km, on the dayside.



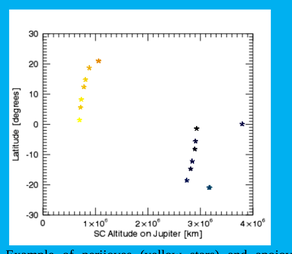
The two Europa flybys geometry, from the latest JUICE trajectory. The two flybys are separated by 14 days. Flyby velocity is ~ 3.8 km/s, closest approach at ~ 400 km.



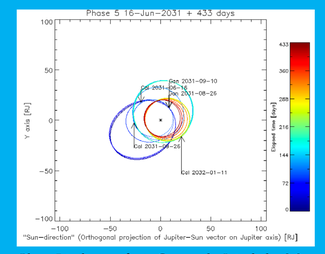
Science operations activities during an Europa flyby. The horizontal bars in the top indicate the payload activities as a function of time. The middle panel displays the altitude, and the bottom panel shows the power profile. During each flyby all instruments are operating, generating about 75 Gb of data.



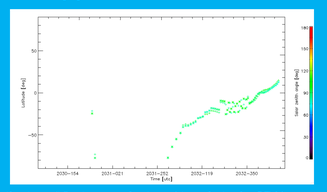
Phase 4 is characterised by a higher inclination – up to 28 degrees - of the orbital plane with respect to the Jupiter equatorial plane. During this phase, higher latitudes regions of Jupiter will be studied in detail. The change of inclination is performed with ~8-10 Callisto flybys at 200 km distance.



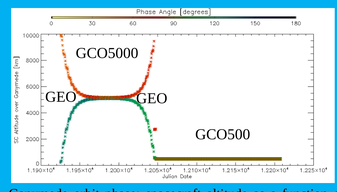
Example of perijoves (yellow stars) and apojoves (black stars) as a function of altitude and latitudes, during the inclined phase (phase 4). In this illustration, the inclination is up to 23 degrees.



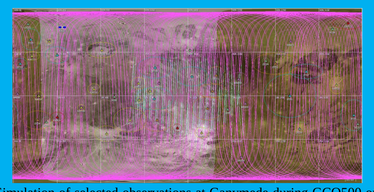
Phase 5 is the transfer to Ganymede. It includes 8-9 Ganymede flybys and 3 Callisto flybys at large distances (closest approach above 800 km).



Distribution of Jupiter occultations (time, latitude, SZA), during which the Jupiter's atmosphere and ionosphere will be sounded. The occultations will mainly occur during phase 5.



Ganymede orbit phase: spacecraft altitude as a function of time. The different orbits can be identified: GEO, GCO5000, GEO again, and finally GCO500.



Simulation of selected observations at Ganymede during GCO500 orbit. Pink lines indicate ground tracks of GALA. Light blue swaths are the observations of the RIME instrument. Source: red book.