EJSM/Jupiter Ganymede Orbiter Design and Status

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EJSM Instrument Workshop
18 – 20 January 2010

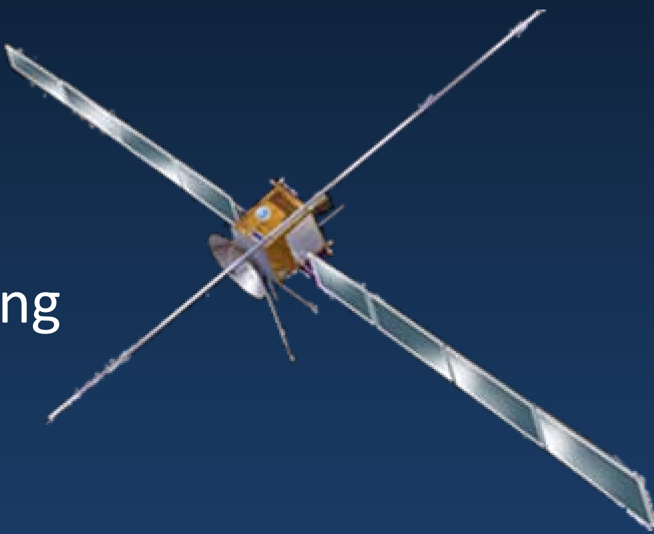
Industrial System Studies

- Three parallel industrial system studies
  - Astrium, OHB, Thales-Alenia in competition
  - Phase 0/A from July 2009 to July 2010
- Input from Joint Study Science Team
  - Specification of science requirements
  - Definition of Model Payload
  - Baseline instrument operations

- Due to the competitive nature, no detailed technical information can be given at this point in time
  - Described baseline is focused on ESA internal study
  - Updated with some common lessons learned from ongoing studies

EJSM/Laplace Spacecraft

- Dry mass ~1500 kg, propellant mass ~2900 kg
- Planning payload 104 kg, ~120–150 W
- 3-axis stabilized s/c
- 500 N main engine
- Power: GaAs LILT solar cells array (>60 m^2)
- HGA: ~3 m, fixed to body; Ka-band, switching data rate
- Challenges
  - Radiation environment; 150 krad (shielded)
  - Thermal: Venus flyby, Jovian system
  - Communication: large distance (signal turn around), data rate and power
  - Power: solar generators & battery
  - High Δv requirement, high mass amplification
  - Complex navigations



JGO Model Payload

Instrument	Acronym	High level description
High Resolution Camera	HRC	Spectral range: 350–1050 nm, 12 filters, IFOV: 0.005 mrad
Wide Angle Camera	WAC	Wide: 12 filters Framing, IFOV: 2 mrad
Plasma Package (includes part of INMS)	PLP	Plasma Analyzer Electrons: 1 eV – 20 keV, Ions: 1 eV – 50 keV Particle Analyzer: Electrons: 15 keV – 1 MeV Ions: 3 keV – 5 MeV, ENA: 10 eV – 10 keV Thermal plasma number density (Te < 10 eV)
Radio and Plasma Wave Instrument	RPWI	Plasma Wave: electrons, ions Electric & magnetic field vector, QTNS
Magnetometer	MAG	Dual tri-axial fluxgate sensors
Visible and infrared Hyperspectral Imaging spectrometer	VIRHIS	Pushbroom imaging spectrometer with two channels with scan system, Spec. range: 400–5200 nm, Spec. res: 2.8 - 5 nm
Submillimeter Wave Sounder	SWI	2 channels: Spec. range: 550–230 µm FOV: 0.15° – 0.065°
Radio Science Instrument plus Ultrastable Oscillator	JRST & USO	2-way Doppler with Ka-Band transponder & Ultra-stable Oscillator
Ultraviolet Imaging Spectrometer	UVIS	EUV and FUV + MUV grating spectrometers Spectral range: 50–320 nm
Laser Altimeter	LA	Single Beam @ 1064 nm, 10 m spot @ 200 km 175 Hz pulse rate
Subsurface Radar	SSR	Single frequency: 20–50 MHz, Dipole antenna: 10 m

EJSM/Laplace Mission Profile

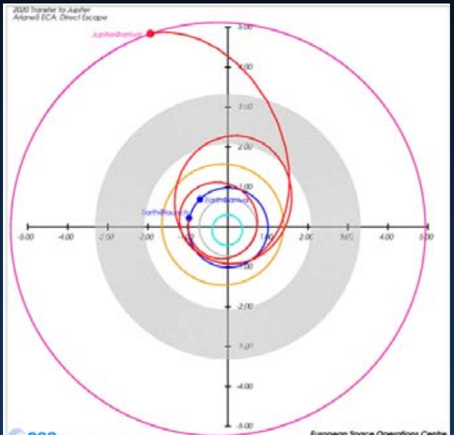
- Interplanetary transfer
  - Launch 2020
  - VEE Gravity Assist (Venus: 1 Jul 2020, Earth: 27 Apr 2021, Earth: 28 Jul 2023)
  - 5.9 years transfer
  - Jupiter arrival: 4 Feb 2026

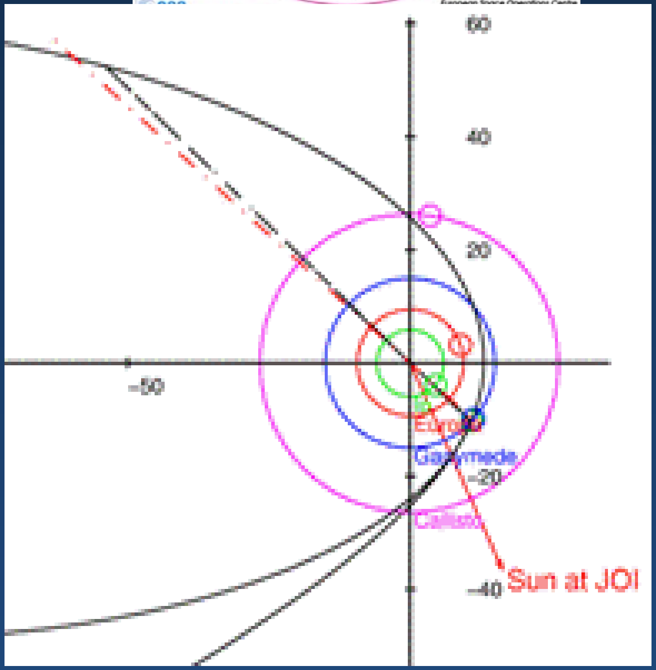
- Jupiter orbit insertion (230x13 R_J) and energy reduction (165 + 120 days; Δv = 887 m/s)

- Transfer to Callisto (57 days; Δv = 15 m/s)
- Callisto resonances: 400 days, 15 swing-bys

- Transfer to Ganymede polar orbit (85 days; Δv = 165 m/s)
- Ganymede elliptical phase (120 days)
- Ganymede circular phase (180 days)

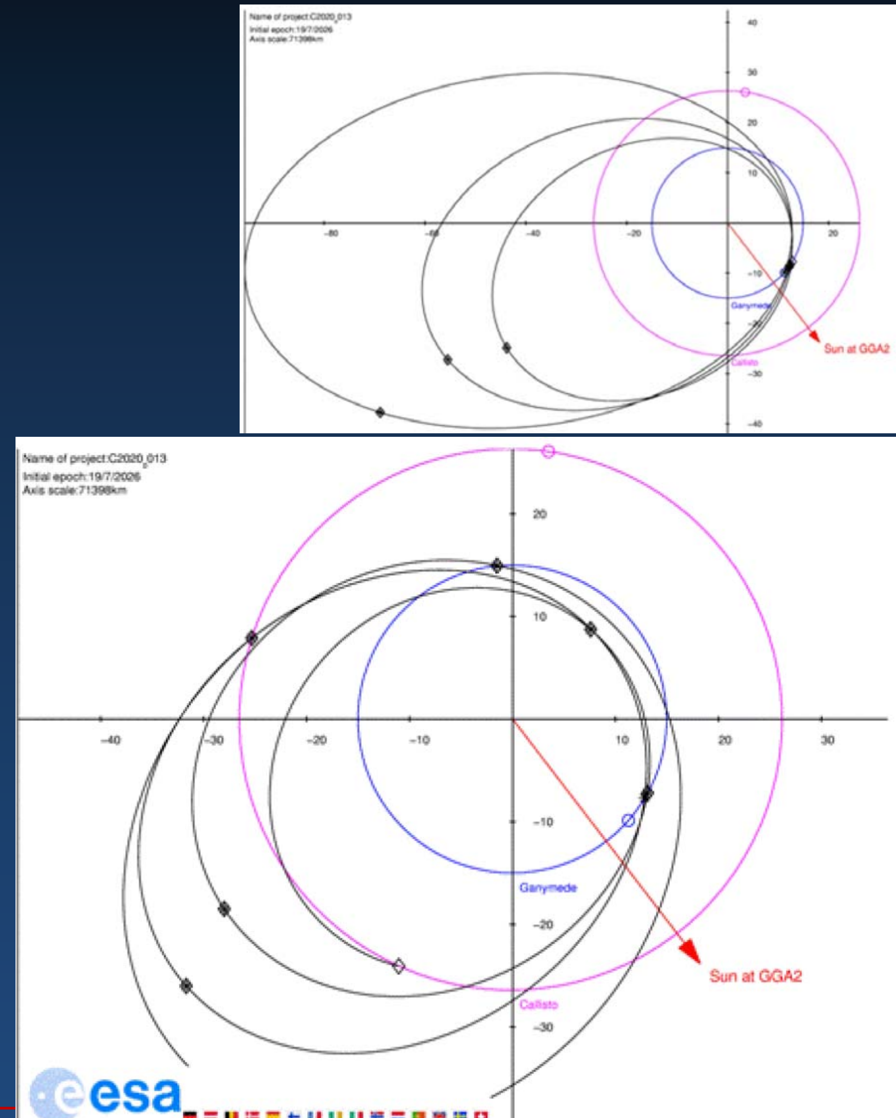
- Total mission duration: 8.4 years





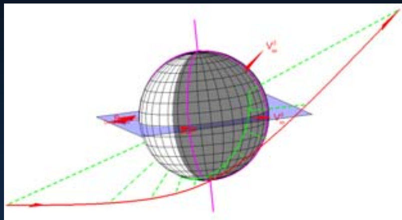
JGO Mission Profile – Transfer to Callisto

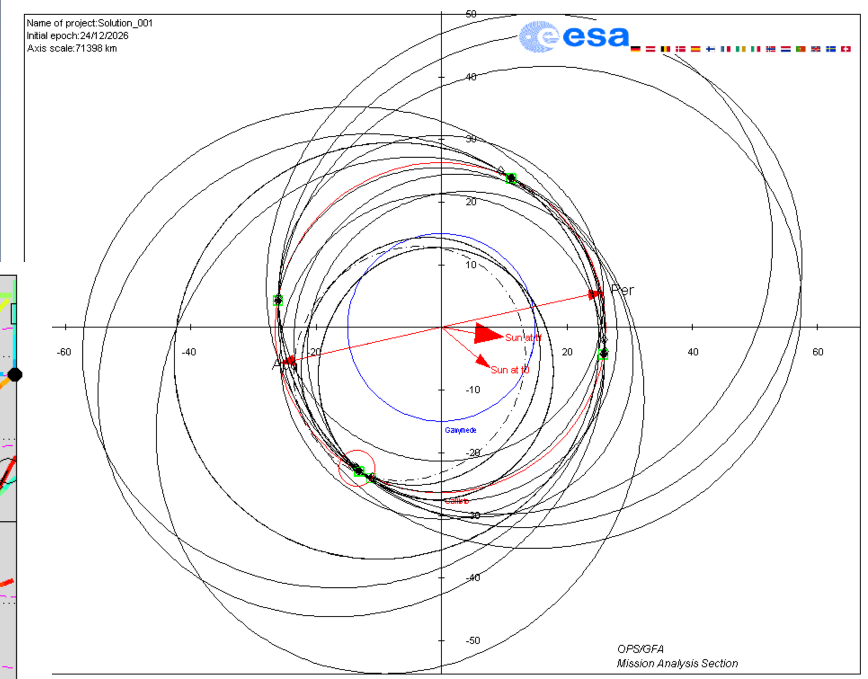
- Reduction of apocenter by three Ganymede swing-bys
  - Duration 120 days
  - Final orbit: 12.5x50 R_J
- Callisto and Ganymede flybys to synchronize orbit with Callisto
  - Duration: 57 days

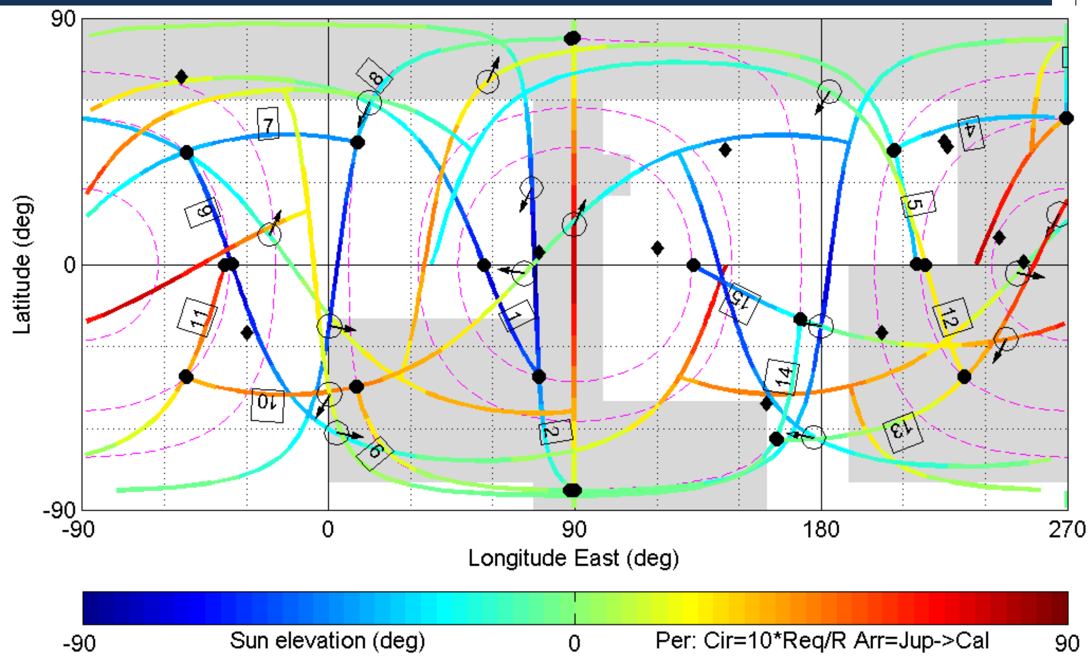


JGO Mission Profile – Callisto Phase

- Series of 15 resonant flybys
- Flybys covering both poles; ≥200 km, 2.5 – 2.6 km/s,
- Duration: 400 days



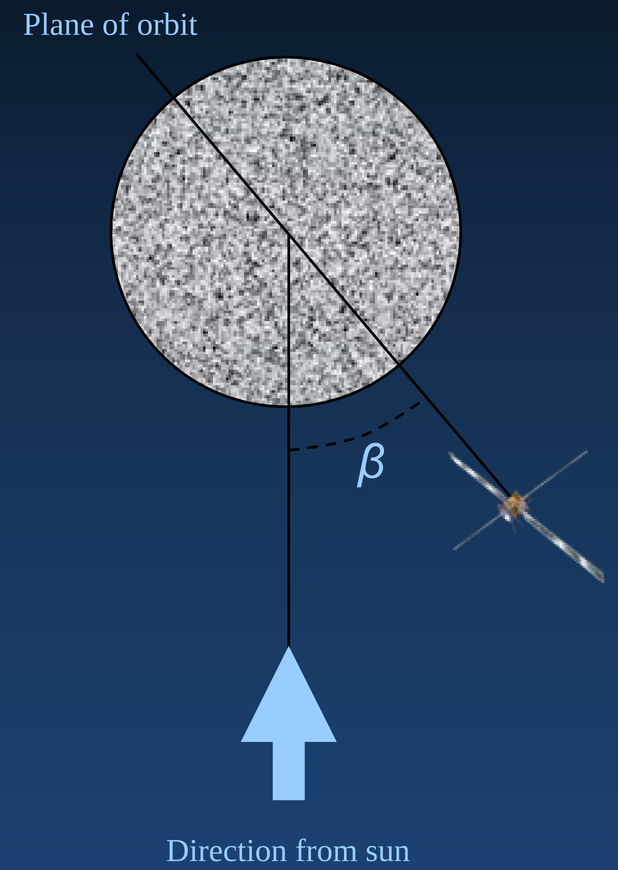




Flyby traces for altitudes <1000 km

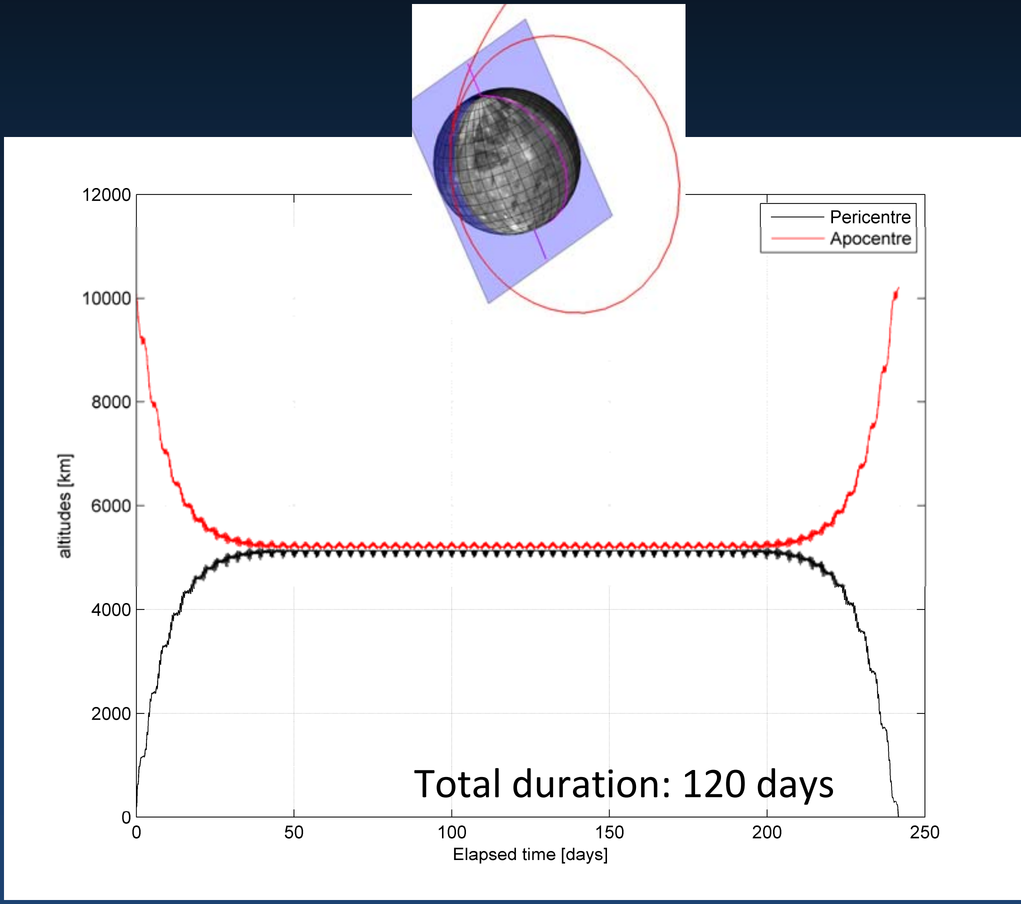
Ganymede: Illumination Conditions

- Angle β is between the orbital plane and the direction to the sun (declination)
- β=0: noon-midnight orbit
- At the equator β is also the sun elevation at the sub-nadir point
- For circular polar orbit 200 km, and β<68°: eclipses by Ganymede



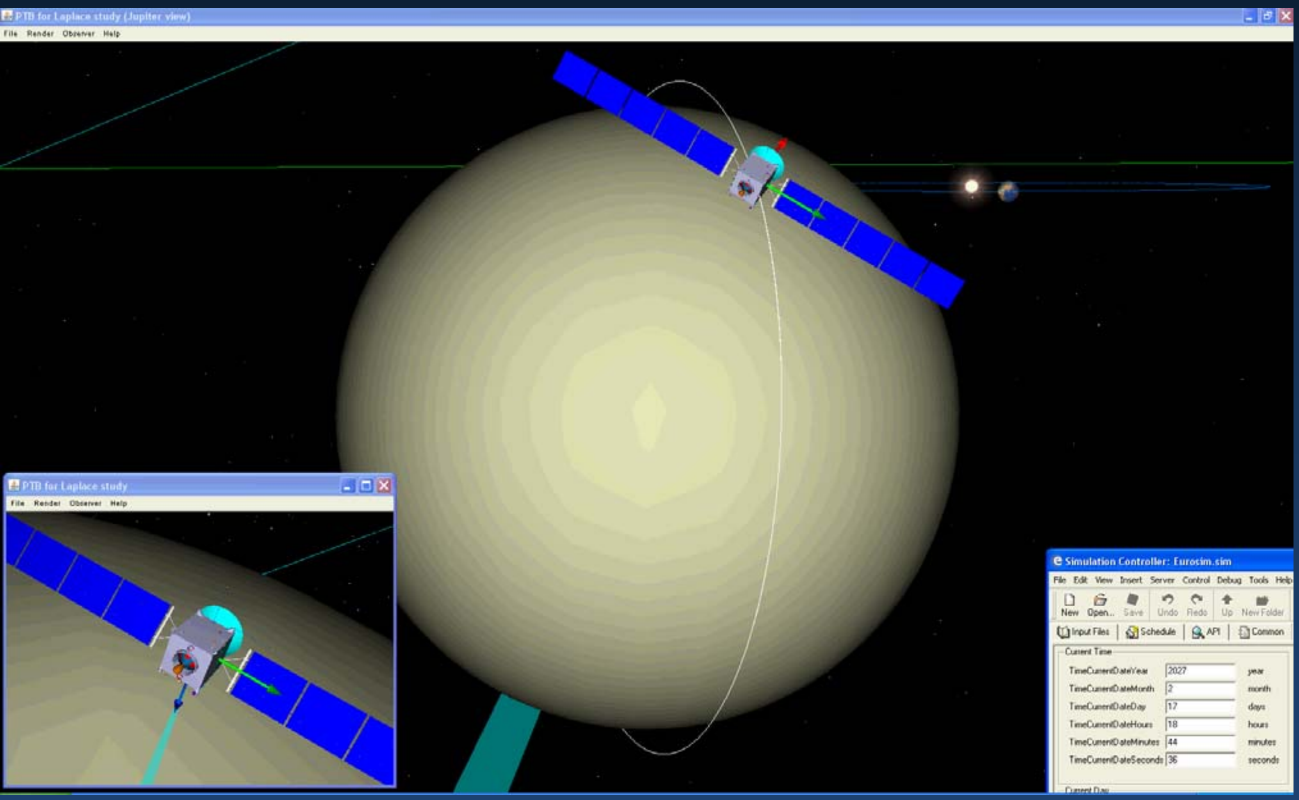
JGO Mission Profile – Ganymede Phase

- Polar orbit
- Elliptical phase
  - 200x10,000 km; 120 days
  - Declination of sun (β): 41 – 45°
  - Quickly circularizing at high altitude
- Circular phase
  - 200x200 km; 180 days
  - Declination of sun (β): 45 – 56°



- End of mission:
  Impact on Ganymede

Optimization of Power Generation: Yaw Rotation



- Baseline is continuous rotation
- Exceptionally stable pointing will be performed, with recovery period
- Stable Earth pointing will be performed (TM download)

Instrument Operations Scenarios
Power Budget & Science Return

- Ganymede circular phase is most constraining phase (sizing case)
- Callisto, and other phases are not driving the design
  - Sufficient time for telemetry download
  - Sufficient solar illumination
- Reference p/l operations was derived to determine the average power consumption needed

Operational Scenarios

Obs1 Remote Sensing	Obs2 In situ + WAC & LA	Obs3 Radar + in situ	Obs4 Radio Science & downlink	Obs5 Jupiter Monitoring
VIRHIS	WAC	SSR	JSRT	SWI
HRC	LA	RPWI	USO	VIRHIS
UVIS	MAG	MAG		HRC
MAG	RPWI	PP		WAC
LA	PP			UVIS

Orbit	Moon	Orbital time	Duration	observational scenario
1	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs2
2	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
3	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
4	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs2
5	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
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1	Ganymede	Eclipse	57	Obs3
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		Daylight	101	Obs2
5	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
6	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
7	Ganymede	Eclipse	57	Obs1
		Daylight	101	Obs3
8	Ganymede	Eclipse + Ground Station Access (partial)	57	**Obs4**
		Daylight + Ground Station Access	101	**Obs4**
9	Ganymede	Eclipse + Ground Station Access	57	**Obs4**
		Daylight + Ground Station Access	101	**Obs4**

Orbit	**Moon**	**Orbital time**	**Duration**	**Observational scenario**
10	Ganymede	Eclipse + Ground Station Access	57	**Obs4**
		Daylight + Ground Station Access (partial)	101	**Obs4**
11	Ganymede	Eclipse	57	Obs5
		Daylight	101	Obs1
12	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
13	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs2
14	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
15	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs1
16	Ganymede	Eclipse	57	Obs3
		Daylight	101	Obs3
17	Ganymede	Eclipse + Ground Station Access (partial)	57	**Obs4**
		Daylight + Ground Station Access	101	**Obs4**
18	Ganymede	Eclipse + Ground Station Access	57	**Obs4**
		Daylight + Ground Station Access	101	**Obs4**

Telemetry Budget

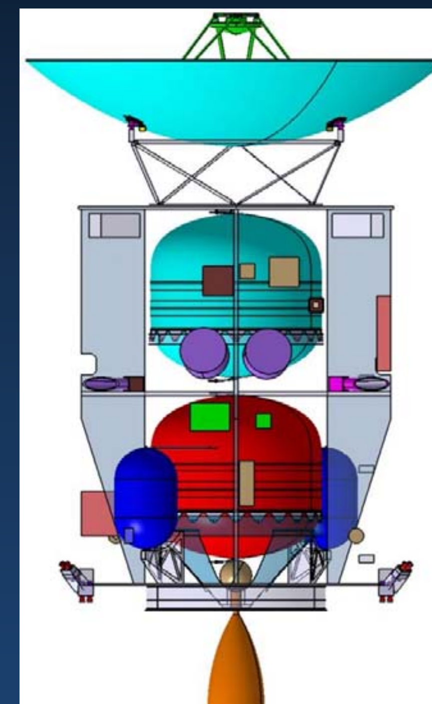
- Baseline is Ka-band, switching rate depending on elevation
- Assuming HGA of 3.2 – 3.4 m, 100 W into TWTA
- Downlink duration assumptions (Ganymede orbit):
  - Antenna visibility: 8 hours/day
  - Earth occultations: 27% – 32% (β from 46° to 56°)
  - Total duration: 5.3 – 5.5 h/day or >1 Gb/day (assuming no "radio-science only" mode)

Summary: Instrument Operations

- Spacecraft pointing
  - Baseline is continuous rotation of s/c around yaw
  - Exceptionally stable pointing will be performed, with recovery period Optimization of configuration for Ganymede remote sensing
- A preliminary instrument operation scenario was derived with the science team
  - Showed that all science objectives could be met
  - Showed that all data fit into available telemetry volume
- Operations of remote sensing and *in situ* separated in time
  - Instrument power during stand-by/switch off important
- No (or much reduced) instrument operations during telemetry downlink periods

JGO Radiation Mitigation

- Total ionizing dose ~85 krad behind 10 mm Al
- Additional shielding with alternative materials (Ta, W) should be investigated
- Design shall aim for 150 krad tolerance
- Shielding
  - Mostly box shielding, some spot shielding
  - 10 mm Al is conservative approach; tailored shielding material may be used
  - ESA study estimated ~80 kg shielding for 104 kg payload and avionics
  - Solar cell arrays currently designed to be covered with 70 µm cover glass
- Combined mitigation approach: shielding and radiation hardened components



JGO: Main engine, tanks, HGA

Planetary Protection

- Category II + additional requirements
  - Significant interest in processes of chemical evolution
  - Remote probability of contaminating future exploration
- Demonstrate probability of contaminating the Ganymede subsurface ocean $\leq 10^{-4}$
  - Investigating timescales and transport properties of surface processes
- Contamination of Europa ocean $\leq 10^{-4}$
  - Probability of accidental impact on Europa (reliability)
- Probability of impact launch vehicle on Mars $\leq 10^{-4}$ for 50 years after launch
  - Probability of accidental impact as a consequence of failure
- Planetary protection plan will be compiled and reviewed

EJSM – JGO Key Milestones

July 2009 – June 2010	Spacecraft Phase 0/A (3 parallel studies) – 12 months
Mid 2009 – mid 2010	Instrument Phase A (12 months) – DOI Studies
Early Nov 09	Updated PDD to system study
Mid 2010	Preparations of study report (*Yellow Book*)
End 2010/Beg 2011	Review & Down-selection (3 → 2)
Early 2011	Instrument AO
Mid 2011 – end 2012	Spacecraft Phase A/B1 (2 parallel studies) – 18 months
End 2011 – end 2012	Instrument Phase B1 (12 months)
End 2012	Preparations of study report
Early 2013	Review & Mission adoption (2 → 1) **TRL ≥ 5**
Mid 2013	Start of implementation Phase (B2/C/D)