Europa Geophysical Explorer

Science Traceability and Payload

Mission Objectives (equal priority)

Prioritized Science Objectives (part I)

A. Confirm the presence of a sub-surface ocean	B. Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid	C. Map the organic and inorganic surface compositions, especially as related to astrobiology	D. Characterize surface features and identify candidate sites for future exploration	E. Characterize the magnetic field and radiation environment	F. Understand the heatsource(s) & time history of Europa's Ocean
1. Determine the amplitude and phase of the gravitational tides	1. Search for shallow subsurface liquids	1. Relate compositions to geological and interior processes	1. Characterize magmatic and tectonic features	1. Characterize perturbations to the magnetic field from plasma	1. Determine the gravitational interactions between Europa and the Jovian system
2. Determine the amplitude and phase of the induced magnetic field at several frequencies	2. Determine possible correlation of surface features to subsurface structure	2. Characterize past and present "habitability	2. Search for areas indicative of surface-subsurface exchange	2. Determine the radiation effects on surface ice redox chemistry	2. Understand cratering/regolith formation in context of Callisto and Ganymede
3. Determine the amplitude and phase of the surface motion during a tidal cycle	3. Characterize the physical properties of the regolith and possible links to the interior	3. Search for indicators/constraints of past or present life	3. Search for areas of recent or current geological activity	3. Characterize exogenic material derived from the Jovian plasma	3. Determine micrometeoroid mass flux and composition in Europa's orbit

Mission -> Science -> Measurements -> Requirements -> Instruments

Summary

Mission Objective

	Techniques	Instruments	Remarks
A. **Confirm the presence of a sub-surface ocean**	**Geodesy, Induced fields, surface motion, Libration, Surface deformation**	**Precision tracking, Altimeter, Imager, Magnetometer, SAR [Seismometer] [Supporting measurements for magnetometer]**	SAR – **insufficient power to operate with other radars** Altimeter – **Topomapper desirable, Imager needed** Seismometer – **requires lander**
B. **Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid**	**Multi-frequency sounding, Altimetry, Mapping, Gravimetry**	**Sounder, Mapping altimeter, Imager, SAR, Precision tracking (@low altitude)**	**Single frequency** sounder **and and sub-sampled** altimetry **in baseline**
C. **Map the organic and inorganic surface compositions, especially as related to astrobiology**	**UV, VIS, IR spectroscopy, Neutral and Ion spectroscopy, X-ray spectroscopy**	**IR, mapping spectrometers, Neutral and Ion spectrometers for several energy ranges, X-ray spectrometer**	X-Ray **requres development, possible detector challenges** Neutral and Ion spectroscopy **and** Mapping spectroscopy **reduced in baseline**
D. **Characterize surface features and identify candidate sites for future exploration**	**Multi-band image mapping, topography, thermography, photometry**	**Multi-band VIS mapper, Altimeter, Radiometer**	Radiometer **and** Topomapper **not in the baseline** **Difficult to accommodate photometry**
E. **Characterize the magnetic field and radiation environment**	**Magnetic Fields, Electron, Ions and Neutrals**	**Magnetometer, Ion and Neutral spectrometers for low and high energy, UV and IR photometers**	**High energy resolution low in baseline** **Difficult to point into co-rotating plasma**
F. Understand the heatsource(s) & time history of Europa's Ocean	**Gravity fields, Mapping, Altimetry, Fields and Particles, Spectroscopy**	**Correlate measurements from objectives A, C, E** **Dust**	Dust **not in any payload configuration**

Mission -> Science -> Measurements -> Requirements -> Instruments

Two payload options beyond EO were studied

- **EO 27 kg, - (payload ~ 18 kg) ~30W, ~30kbps**
- **Baseline 150 kg - (payload ~ 100 kg), 150W, 340kbps**
- **Orbiter 300 kg - (payload ~ 240 kg), 300W, 680 kbps**
- **All mass numbers are payload + margin**

Study Orbit Characteristics

- Altitude 100 km (gravity, mag mapping, particles mapping)
- Track separation ~ 26 km
- Single repeat cycle in 30 days
- ~Sun synchronous, evening equator cross
- ~1.3 km/sec ground relative velocity
- ~ 2 hour period
- 80 degree inclination

DSN Upgrade

- **Planned (but not assured) DSN 12 meter Ka array provides ~ factor of 10 improvement – which greatly improves the mission with no mass or power impact**
- **The question is when…**

Observation	Number or rate	Data size Gbits	Mean kbps	Mission, rate, volume
100m global Mosaic, 100 m, 6:1, vis	7	25.7	16.9	EO = 34kbps, 53Gbit
10m global mosaic, 6:1, vis	0.1 coverage	36.7	24.1	Base = 340kbps, 530Gbit
316m global mosaic, 2:1, 300 λ, IR	0.1 coverage	55.1	36.2	Orbiter = 680kbps, 1Tbit
32m global mosaic, 2:1, 300 λ, IR	0.01 coverage	551	362/271	DSN = 6.8Mbps, 10Tbit
100 m altimeter trace, 10 hz	1 kbps	778	1.7	
1 km sounder trace, night time, radar	300 kbps	2.6	510/255	
F&P, mag, ions & electrons, neutrals	11 kbps	28.5	18.6	
200 m, global thermal map, LWIR	1`	7.8	5.1	
10x1 meter altimeter map	350 kbps	907	596/0	
		2390	1571/629	

300 Kg sizing payload

Subsystem	Daylight	Night	Average	Mass	Data Daylight	Data Night	Mean Data Rate
Instruments (w/o margin)	**185.71**	**291.85**	**238.8**	**238.4**	**753.0**	**553.0**	**653.0**
Instruments (w/ 30% margin)	**241.423**	**379.405**	**310.4**	**309.9**			
2-band Sounder	5	60	32.5	30.0	0	200	100
Topomapper	10	140	75.0	40.0	0.0	300	150
Laser Altimeter	20.8	0	10.4	7.3	0.5	0.5	0.5
Radiometer	15	15	15.0	24.0	30	30	30
WAC	1.88	1	1.4	3.0	100	0.0	50
NAC	1.88	1	1.4	3.0	100	0.0	50
Vis/NIR HiRes	21.3	1	11.2	37.5	150.0		75
UV Spec	8	1	4.5	6.0	50.0		25
VIS-MWIR Spec	30	1	15.5	30.0	300.0		150
CAPS	14.5	14.5	14.5	12.5	8.0	8.0	8
CDA	11.4	11.4	11.4	16.4	0.5	0.5	0.524
INMS	27.7	27.7	27.7	9.3	1.5	1.5	1.5
RPWS	7	7	7.0	6.8	10.0	10.0	10
EPD	10	10	10.0	11.0	1.0	1.0	1
Magnetometer	1.25	1.25	1.3	1.7	1.5	1.5	1.5

Other Instruments

- **X-Ray – high priority, low TRL, refining mass numbers**
- **SAR – great surface science, problematic power budget**
- **Plasma Sounder – Incompatible with available power**

150 Kg sizing payload

Subsystem	Daylight	Night	Average	Mass	Data Daylight	Data Night	Mean Data Rate
Instruments (w/o margin)	**129.33**	**65.65**	**97.5**	**99.7**	**512.5**	**111.0**	**311.8**
Instruments (w/ 30% margin)	**168.129**	**85.345**	**126.7**	**129.6**			
1-band Sounder	5	40	22.5	20.0	0	100	50
Laser Altimeter	20.8	0	10.4	12.0	0.5	0.5	0.5
WAC	1.88	1	1.4	7.0	100	0.0	50
Vis/NIR HiRes "HiRes Camera"	21.3	1	11.2	20.0	100.0		50
VIS-MWIR Spec "IR Spectrometer"	30	1	15.5	12.0	300.0		150
EPD (High energy)	10	10	10.0	10.0	1.0	1.0	1
PEPE (low energy)	11.4	11.4	11.4	7.0	8.0	8.0	8
INMS	27.7	0	13.9	10.0	1.5	0.0	0.75
Magnetometer	1.25	1.25	1.3	1.7	1.5	1.5	1.5

Payload Comparisons

30 Kg, 30 w	150 kg, 150 w	300 kg, 300 w
Gravity/Precision tracking	Gravity/Precision tracking	Gravity/Precision trackins
NAC	NAC, filters	NAC, filters
WAC, filters	WAC, filters	WAC, filters
IR mapper	IR mapper	IR mapper
Laser Altimeter	Laser Altimeter	Laser Altimeter
Mag	1-band Sounder	2-band Sounder
	Mag	Mag
	KEV e-, ions	KEV e-, ions
	MEV e-, ions	MEV e-, ions
	INMS	INMS
		Radiometer
•Well addressed: A	•Well addressed: A,B, D,E,F	UV spectrometer
•Partially addressed: D	•Partially addressed: C	MWIR spectrometer
•Poorly addressed: C, B, E, F	•Poorly addressed: D3	TopoMapper
•Aggressive mass reduction	•New instruments required	CDA
•High instrument risk	•Medium instrument risk	PWS
•High risk to objectives	•Almost all objectives met	•Known instruments

Mission Objectives (equal priority)

Prioritized Science Objectives (part I)

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Mission -> Science -> Measurements -> Requirements -> Instruments

Accommodation issues

- **Power is more precious than mass for the cases studied**
- **Without expanded DSN, large data reduction factors are required to support global maps. Radiation impacts compressibility**
- **Mapping instruments are not particularly compatible with the (greatly appealing) approach tour**
- **Difficult to look in ram direction (turntable needed)**
- **Difficult to meet photometry measurements**
- **Low altitude increases FOV (and distortion) of mappers**
- **Single map was used to size mission, multiple views required**
- **“Dipping” orbits to sample sputtered materials are achievable at EOM**

Backup slides - traceability

Mission Objectives (equal priority)

Prioritized Science Objectives (part II)

A. Confirm the presence of a sub-surface ocean	B. Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid	C. Map the organic and inorganic surface compositions, especially as related to astrobiology	D. Characterize surface features and identify candidate sites for future exploration	E. Characterize the magnetic field and radiation environment	F. Understand the heatsource(s) & time history of Europa's Ocean
4. Determine the amplitude of libration	N/A	N/A	4. Assess erosion and deposition processes (impact gardening, mass wasting, etc.)	4. Characterize magnetospheric sputtering interactions with the surface	4. Study Jupiter's atmosphere as input to the magnetosphere and its role in Europa's evolution
5. Search for active, tidally-induced crustal deformation features	N/A	N/A	5. Investigate local and global heat flow	5. Determine the structure and dynamics of the ionosphere and neutral atmosphere	5. Investigate Jovian aurora processes, links to the solar wind, and current flows
N/A	N/A	N/A	6. Assess surface ages and subsurface structure using impact craters	6. Characterize the deep interior of Europa	6. Characterize the Jovian rings and the relations to collisions with the moons

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurements related to science objective (part I)

Mission Objective

	Priority 1	Priority 2	Priority 3
A. **Confirm the presence of a sub-surface ocean**	a. **Spacecraft tracking via two- way Doppler** b. **Two-way tracking coverage resolve second degree gravity field time dependence** c. **Orbit altitude is constrained**	a. **Continuous magnetometry** b. **Plasma measurements to correct for non-ocean currents.**	a. **Crossing altimetry tracks throughout several tidal cycles in combination with Doppler tracking**
B. **Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid**	**a. Identify dielectric or physical interfaces related to the current or recent presence or water or brine diapirs,** **b. Determine the global gravity field of Europa to identify regions of density contrast,** **within the ice crust.**c. **Identify areas of recent resurfacing by cryo-volcanic processes.**	a. **Identify dielectric or physical interfaces related to faults or cracks formed in association with surface tectonic patterns,** b. **Measure surface topography**	a. **Characterize the Fresnel reflectivity of the surface layer**b. **Characterize the dielectric and physical properties of the ice regolith**
C. **Map the organic and inorganic surface compositions, especially as related to astrobiology**	**a. Global (NIRS) at improved spectral and spatial resolution to the identification of mpurities** **at the 1% level** **b. measurement of products from energetic particle bombardment of the surface to probe of the surface composition. Measure both** **organic and inorganic species**c. **Quantitatively assess the bombarding energetic particle** **input flux and ion productionrates**	a. **Determine presence of liquid water (mission objective A)** b**. Detect the presences of organics and brine salts (objectives 1 & 3)** c. **Determine the radiation environment (mission objective E)**	a. **Utilize surface emissions from the sputtering process to identify the existence of deposits of organic materials on the surface through the detection of x-rays emitted from the surface during the sputtering process... Anomalous ratios of C and N relative to other surface elements (O, S, Na, Mg, etc) provide a strong indicator for organics.**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurements related to science objective (part II)

Mission Objective

	Priority 1	Priority 2	Priority 3
D. **Characterize surface features and identify candidate sites for future exploration**	*Required*: a. **Topographic mapping of a representative 20% of the surface** b. **Global (>90%) monochromatic imaging** c. **Multispectral global mapping** ***Desired***: d. **As for a, with global coverage.** e. **As for b, higher resolution** f. **As for c, higher Resolution topomapper, laser altimeter, VIS camera, multi-band**	*Required:* a. **Same as 1a.** b. **Same as 1b.** c. **Same as 1c.** ***Desired:*** d. **Same as 1d.** e. **Same as 1f.**	a. **Obtain multispectral images of areas seen on previous missions (preferably with similar lighting geometry).**
E. **Characterize the magnetic field and radiation environment**	**Make continuous field, plasma, energetic charged particles flux measurements from spiral-in and circular orbits around the moons with the following measurement priority** a. **Measure the magnetic field** b. **Measure the plasma environment (ions and electrons)** c. **Measure energetic charged particles (ions and electrons)**	d. **charged particles and neutral atmospheres constituents** e. **atmosphere neutral species spectra** f. **Emission profiles above the limb for composition and temperature** g. **auroral emissions maps** h. **structure of dust cloud from regolith impacts** i. **Make radio plasma sounder measurements**	**See objectives 1&2**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurements related to science objective (part III)

Mission Objective

	Priority 1	Priority 2	Priority 3
F. Understand the heatsource(s) & time history of Europa's Ocean	*Required:* a. **Multi-frequency Doppler downlink radio science for gravity and related ionospheric measurements**	*Required:* a. **Low resolution multi-spectral imaging,** b. **high resolution imaging,** c. **high resolution altimetry (radar or laser),** ***Desired:*** d. **regolith radar (GHz).**	*Required:* a. **plasma/suprathermal (1 eV to 10 keV) composition spectrometer,** b. **high energy electron (10 keV to 10 MeV) and proton (10 keV to 100 MeV) spectrometer,** ***Desired:*** c. **low-energy (1 eV to 1 keV) neutral atom/molecule,** d. **high-energy neutral atom imager**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurements related to science objective (part I)

Mission Objective

	Priority 4	Priority 5	Priority 6
A. **Confirm the presence of a sub-surface ocean**	a. **Determine a time-dependent S22** b. **A control network based on imaging**	a. **Multiple imaging of selected locations to search for new fractures.** b. **Multiple stereo imaging of regions to look for topographic variation.** c. **inSAR observations to detect cm-scale deformations.** d. **Acoustic measurement of seismic activity in the crust.**	**N/A**
B. **Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid**	N/A	N/A	N/A
C. **Map the organic and inorganic surface compositions, especially as related to astrobiology**	N/A	N/A	N/A

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurements related to science objective (part II)

Mission Objective

	Priority 4	Priority 5	Priority 6
D. **Characterize surface features and identify candidate sites for future exploration**	*Required:* a. **Same as 1a.** ***Desired:*** b. **Same as 1a, but with global coverage.** c. **Map regolith photometric properties of the icy moons**	*Required* : a. **Conduct thermal mapping in the covering 90% of Europa and repeat the observations at several times of day and night.** b. **Map the bolometric albedo o Europa**	*Required* : a. **Same as 1a.** b. **Same as 1b.** c. **Same as 1c.** ***Desired:*** d. **Same as 1d, global coverage.** e. **Conduct targeted topographic mapping of craters and surrounding terrains** **f. As for 1b, but global** g. **As for 1f, but with selected areas at 30-m/pixel scale.**
E. **Characterize the magnetic field and radiation environment**	**See objectives 1&2**	**See objectives1&2**	**See objective 1**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurements related to science objective (part III)

Mission Objective

	Priority 4	Priority 5	6
F. Understand the heatsource(s) & time history of Europa's Ocean	*Required:* **a. multi-spectral remote imaging.**	*Required:* a. **Correlative in-situ (field & plasma) and multi-spectral remote imaging (VIS, UV, X-ray). Note: x-ray spectroscopic imager might be used at higher priority for moon surface composition.**	*Required:* a. **visible imaging and photometric measurements of Rings** b. **micrometeoroid mass flux**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part I)

Mission Objective

	Priority 1	Priority 2	Priority 3
A. **Confirm the presence of a sub-surface ocean**	a. **0.1 mm/s over 60s accuracy. Multi-frequency communication (e.g. Ka & X) would be ideal, but X is sufficient and Ka is better.** b. **k2 (at the orbital frequency) should be recovered to 0.001.** c. **Need for sufficient tracking opportunities during the course of the mission (<500km). No significant constraints on orbit geometry , though a low eccentricity is preferred. The accuracy of the gravity field recovery is roughly proportional to the period of time between impulsive maneuvers.**	a. **Several tidal cycles,1 nT accuracy observations** b. **Low energy plasma flux measurements (ions and electrons) between energy range of 1 eV-50 keV with an energy resolution deltaE/E ~ 0.1 and a temporal resolution of 10 sec or better. Energetic particle flux measurements between energy range of 20 keV and 10 MeV (ions and electrons) with an energy resolution of deltaE/E ~ 0.3 or better and temporal resolution of 10 sec or better. Optimal altitude may depend on plasma environment.**	a. **Radial orbit error must be reduced to ~1m. Horizontal position of altimetry points must be known to within 100 m, with 1 m vertical accuracy. h2 recovery to better than 0.002. Greater than 500 crossovers.**
B. **Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid**	a. **Probe the upper 5-10 km of the ice shell with spatial resolution of order 1 km, depth resolution of ~1% of the probing depth (50-100 m), and uniform global spatial sampling** b. **Horizontal scales of order 100 km** c. **global scale compositional imaging**	a. **Probe the upper 5-10 km of the ice shell, on global scales, with spatial resolution of order 1 km, depth resolution of ~1% of the probing depth, and uniform spatial sampling.** b. **100-m spatial scale for at least 10% of the surface.**	a. **on horizontal scales of order 10 km, with uniform sampling, on a global basis.** b. **to depths of at least 10 m, on 100-m horizontal scales, for at least 10% of the surface.**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part II)

Mission Objective

	Priority 1	Priority 2	Priority 3
C. **Map the organic and inorganic surface compositions, especially as related to astrobiology**	a. **Global maps in selectable bands @ 0.9-15 microns** b. **Mass range 400 Daltons (amu/charge), mass resolution of 800 to 1000. Angular resolution of 15 x 15 degrees and energy resolution of 10% . Large geometric factor for sensitivity. Low-altitude dipping orbits, if feasible, to aid in the sensitive indication of minor species and to allow correlation with NIRS** c. **ion mass spectrometry**	**See measurement description**	a. **Spatial resolution is 10s of meters. Spectral resolution is tbs**
D. **Characterize surface features and identify candidate sites for future exploration**	a. **better than 10-m/pixel scale and better than or equal to 1-m vertical accuracy.** b. **100-m/pixel scale with phase angles < 30º (except near poles).** c. **Minimum of 3 colors (violet, green, IR) at better than 100-m/pixel scale and phase angles less than 30º (as near as possible close to poles).**d. **global** e. **better than or equal to 10-m/pixel scale.** f. **selected areas at 30-m/pixel scale**	**See Objective 1**	**Mission planning requirement**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part III)

Mission Objective

	Priority 1	Priority 2	Priority 3
E. **Characterize the magnetic field and radiation environment**	a. **1.sampling of every 0.2 s and a sensitivity of 0.1-nT.** b. **energy (E) range of 1- to 50-keV with a resolution of DE/E ~ 0.10. For the atomic mass range of H+ through S+, a mass (M) resolution of M/DM ~ 10 is required. An angular resolution of ~10° over 4-pi steradians is need with a sampling rate of less than 2 minutes.**c. **energy (E) range of 10-keV to 10's of MeV per nucleon (10 MeV for electrons) with an energy resolution of DE/E ~ 0.1 to 0.3, dependent on energy and particle type, and an elemental compositional resolution up to 1 AMU for H to S. Observations are needed than 1 minute, with an angular resolution of ~10° over 4-pi steradians. Narrower angular and higher time resolution may be needed for surface loss cone measurements supporting magnetic field analyses.**	d. **mass range up to 300 amu m/Δm of 300, angular resolution: 5x5 degrees.** e. **Simultaneous multi-wavelength hyper-spectral imaging (UV- IR resolution > 2000; spatial scale 20-km/pixel), with solar/stellar/radio occultations where possible. For spectroscopy of solar and stellar occultations, wavelength range 50- to 320-nm, spectral resolution >2000, time resolution 1 second or better.** f. **wavelength and resolution requirements as in (e) above with altitude resolution ~5 km at the limb.** g **for the wavelength range 50-to 320-nm, at a spectral esolution > 2000, and an altitude resolution ~5 km at the limb. h. (tbs)** i. **resolution of 1 % for magnetic field magnitude near the spacecraft and resolutions TBD for the ionospheric electron density distributions and local field line geometries and composition at resolution TBD.**	**Mission planning requirement See objective 1, measurement c**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part IV)

Mission Objective

	Priority 1	Priority 2	Priority 3
F. Understand the heatsource(s) & time history of Europa's Ocean	**Dual band propagation, propagation error tbs**	**tbs**	**tbs**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part I)

Mission Objective

	Priority 4	Priority 5	Priority 6
A. **Confirm the presence of a sub-surface ocean**	a. **S22 could be detected by the gravity inversion (1).** b. **Position accuracy of 100 m.**	a. **High resolution (< 10m) imaging, multiple passes.** b. **Medium resolution (< 1km) imaging. Requires three or more imaging passes.** c. **Radar wavelength less than 26cm to reduce penetration. High altitude orbit is best to achieve baseline requirement, but power limitations may require lower orbit.** d. **Requires geophone with a dynamic range of 10^-5 micron/s to 10^3 micron/s and frequency range 0.01 to 100 Hz, lasting multiple tidal cycles. May also directly detect ice-ocean interface.**	N/A
B. **Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid**	N/A	N/A	N/A

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part II)

Mission Objective

	Priority 4	Priority 5	Priority 6
C. **Map the organic and inorganic surface compositions, especially as related to astrobiology**	N/A	N/A	N/A
D. **Characterize surface features and identify candidate sites for future exploration**	c. **wavelength range of 0.3- to 3-µm with a spectral resolution of 2; broad illumination geometry coverage, good absolute calibration.**	a. **Same as 1a.** b. **Same as 1b.** c. **Same as 1c.** ***Desired:*** d. **Same as 1d, global coverage.** e. **Conduct targeted topographic mapping of craters and surrounding terrains** f. **As for 1b, but global** g. **As for 1f, but with selected areas at 30-m/pixel scale.**	a-d. **See objective 1** e. **10-m pixel scale, and better than 1-m relative vertical accuracy.** f. **global mapping at better than or equal to 10-m/pixel scale.**

Mission -> Science -> Measurements -> Requirements -> Instruments

Measurement requirements related to science objective (part III)

Mission Objective

	Priority 4	Priority 5	Priority 6
E. **Characterize the magnetic field and radiation environment**	**See requirements 1&2**	**See requirements 1&2**	**See requirements 1&2**
F. Understand the heatsource(s) & time history of Europa's Ocean	**tbs**	**tbs**	**tbs**

Mission -> Science -> Measurements -> Requirements -> Instruments

Instruments related to science objective (part I)

Mission Objective

	Priority 1	Priority 2	Priority 3
A. Confirm the presence of a sub-surface ocean	Dual band telecom Momentum wheels Minimum Maneuvers KA, X bands	Dual Magnetometers, boom Low Energy Electrons/Ions High Energy Ions & Electrons MAG/PEPE/CAPS/EPD/EPADS	Altimeter [Laser/Radar] Visible Imager (mapper)
B. Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid	50 MHz radar sounder 5-10 Mhz radar sounder Line-of-sight gravity (radio). VNIR 10 meter res	+ Stereo photography, scanning laser altimeter, or dual-antenna topographic mapping synthetic aperture radar system	A synthetic aperture radar, operating in the 10-30 cm wavelength range to probe to depths of 10-30 m.
C. Map the organic and inorganic surface compositions, especially as related to astrobiology	NIR mapping spectrometer UV-VIS mapping spectrometer Ions and Neutrals spectrometer INMS, PEPE, EPD/EPADS	{Detect water Map compositions}	X-ray spectral imager
D. Characterize surface features and identify candidate sites for future exploration	topomapper, laser altimeter, VIS camera, multi-band	same	same
E. Characterize the magnetic field and radiation environment	Magnetometer PEPE/CAPS EPD,/EPAD	INMS UV,VIS,IR mapping spec. Dust detector Radio plasma sounder	Same
F. Understand the heatsource(s) & time history of Europa's Ocean	Telecom	Multi-spectral imager HiRes imager Altimeter (radar or laser Radar (GHz)	plasma/suprathermal spec. H.E. electron & proton spec. neutral species imager (LENA) H.E. neutral atom imager (MIMI)

Mission -> Science -> Measurements -> Requirements -> Instruments

Instruments related to science objective (part II)

Mission Objective

	Priority 4	Priority 5	Priority 6
A. **Confirm the presence of a sub-surface ocean**	**Same as 1&2**	**Visible imager** **SAR** **[Geophone – surface measurement]**	**N/A**
B. **Characterize the three-dimensional configuration of the icy crust, including possible zones of liquid**	**N/A**	**N/A**	**N/A**
C. **Map the organic and inorganic surface compositions, especially as related to astrobiology**	**N/A**	**N/A**	**N/A**
D. **Characterize surface features and identify candidate sites for future exploration**	**Same as (1)** **Spectrometer or photometer**	**mapping radiometer** **Same as (4)**	**Same as (1)** **Laser altimeter** **Topomapper**
E. **Characterize the magnetic field and radiation environment**	**Same as 1&2**	**Same as 1&2**	**Same as 1&2**
F. Understand the heatsource(s) & time history of Europa's Ocean	**Same as (2)**	**Correlate:** **Mission objective E** **Mission objective C**	**VIS imaging** **Photometric measurements** **Dust detector**

Mission -> Science -> Measurements -> Requirements -> Instruments