JUPITER EUROPA ORBITER: TRACEABILITY MATRIX

Goal	Science Objective		Science Investigation	Measurement	Instrument
Explore Europa to investigate its habitability.	E. Jupiter System	**Understand Europa in the context of the Jupiter system**	Atmospheric Dynamics and Circulation	E16. **Investigate the dynamics of Jupiter's weather layer**; zonal and meridional wind speeds, eddy momentum fluxes and the redistribution of energy and momentum within the troposphere.	E16a. Dayside imaging with ~15-km/pixel resolution. Imaging should include repeated coverage of the same regions at ~2 hour intervals for cloud tracking (necessary to obtain winds, divergence and vorticity) with 2-m/s accuracy. Wavelengths should include visible and/or near-IR continuum (e.g., 3.7 micron) as well as one or more methane absorption band (e.g., 889 nm and another near-IR e.g. 2.3 micron). Imaging strategy must characterize behavior over a range of timescales, including short (1-3 days), medium (~1 month), and long (~1 year) variability. Global or near-global daily coverage for periods of weeks-to-months is desired.	E16a. NAC, MAC and WAC imagers
					E16b. Sub-mm spectroscopy to obtain Doppler broadening of molecular lines at a wide range of latitudes and times to derive 5- to 300-mbar temperatures and wind speeds with high vertical resolution (10- to 20-km/pixel, R>1E6 for line shape, 2-10 m/s accuracy)	E16b. Sub-mm spectrometer
					E16c. Global view of velocity fields at the cloud level through Doppler shift of reflected visible solar lines, with a precision of about 2 m/s and a resolution of 100 km/pixel.	E16c. Visible and near-IR spectrometer
					E16d. Visible imaging (15 to 100 km/pix) of lightning flashes on the nightside of Jupiter, combined with imaging of discrete thunderstorms on the dayside. Multiple views of all latitudes on the nightside with clear filter imaging combined with imaging of discrete thunderstorms on the dayside. Requires repeated imaging while tracking a feature (usually near 90° phase). Complementary plasma (PWS) and fields measurements to understand global distribution	E16d. NAC/WAC imager, Plasma Wave spectrometer
				E17. **Determine the thermodynamics of atmospheric phenomena**; global three-dimensional temperature structure and horizontal gradients, temperatures within discrete atmospheric features from the upper troposphere to the stratosphere.	E17a. Repeated global nadir thermal mapping to obtain 80- to 700-mbar (troposphere) and 0.5- to 20-mbar (stratosphere) temperatures to an absolute accuracy of 1.0 K, relative accuracy of 0.4 K. Spatial resolution of 100-km/pixel. Limb viewing geometry to achieve 10- to 20-km altitude resolution at a wide range of latitudes.	E17a. Thermal instrument
					E17b. Repeated radio occultations closely spaced in latitude and time (*e.g.*, at the same latitude +/-10 degrees, once every 2 weeks), retrieving pressure as a function of altitude and relating this to zonal winds. Radio package doppler tracking in one-way mode at X-band and Ka-band frequencies driven by the USO. The target Doppler link stability is ~1E-13 at 10- to 1000-seconds integration time.	E17b. Radio science
					E17c. Stellar and solar occultations in the near-IR and UV for high vertical resolution temperature (and methane profile) to sub-scale height resolution sounding over a wide range of latitudes in the upper stratosphere.	E17c. UV imaging spectrometer and Vis-IR imaging spectrometer
					E17d. Sub-mm determination of three-dimensional temperatures from selected atmospheric species between 400 mbars and 1 microbar (HCN, H2O and CH4).	E17d. Sub-mm spectrometer
				E18. **Quantify the roles of wave propagation and atmospheric coupling**; depth of the zonal wind field, coupling of the jet stream pattern with convection within the deep interior; coupling between the troposphere and the middle-atmosphere by vertical wave propagation and eddies, horizontal distribution and temporal evolution of wave phenomena, particularly the QQO.	E18a. Multi-spectral imaging in the visible andnear to mid-IR spectral range to determine shears on the zonal wind fields and the vertical structure of vortices and plumes between 2- to 3-bar and the 0.5- to 1.0-bar levels (50 to 200 km/pix). Multiple high-resolution images of cloud structure on a timescale of hours, days months, and years.	E18a. Visible and near-IR imaging spectrometer
					E18b. Repeated radio occultations closely spaced in space and time (e.g. at the same latitude +/-10 degrees, once every 2 weeks) to determine pressure, density and temperature profiles perturbed by the waves.	E18b. Radio Science
					E18c. High spatial resolution determinations of the vertical temperature structure between 1-microbar and 400-mbars from sub-mm sounding of molecular lineshapes (R>1E6). Limb observations in the thermal-IR to determine stratospheric temperature oscillations (20-km vertical resolution). Nadir thermal-IR imaging of thermal waves at regular (2 week) intervals. Global thermal-IR observations (yearly) of the tropospheric and stratospheric temperature fields	E18c. Sub-mm spectrometer, thermal IR spectrometer, Mid-IR imaging spectrometer
					E18d. Near-IR stellar and solar occultations to obtain high-resolution stratospheric temperatures. Near-IR imaging of multiple altitude levels to determine vertical structure of horizontally propagating waves. Observations of dayside and nightside including coverage of equatorial regions and polar vortices.	E18d. Visible and Near IR Imaging spectrometer
				E19. **Investigate auroral structure and energy transport**; three-dimensional morphology including internal structure and satellite footprints, mechanisms for energy transpor within the Jovian aurora.	E19a. Near-IR imaging and polar spectral scans (70-90 degrees lat, both hemispheres) of H3+ emission at regular intervals with 100 km/pix spatial resolution. Temporal sampling: from less than an hour (for solar flares) to days.	E19a. Near IR imaging spectrometer
					E19b. UV spectral imaging studies and scans of the polar H2 glow, morphology and the composition of the polar vortices (aerosols, exotic chemicals). Lyman alpha line profiles with milliAngstrom resolution. UV stellar and solar occultations over the poles in the upper atmosphere.	E19b. UV imaging spectrometer
					E19c. High spatial resolution (30-km vertical resolution) limb studies to determine the vertical distribution of the Jovian aurora (200- to 500-km/pixel spatial resolution), and the nature of energy deposition processes. UV and visible imaging with a resolution of 150 km/pixel of the polar regions, dayside and nightside.	E19c. UV imaging spaectrometer, NAC imager
				E20. **Understand the interrelationships of the ionosphere and thermosphere**; vertically propagating waves and heating mechanisms (the "energy crisis"), wave characteristics and persistence, temporal variability of ionospheric total electron densities and ionization processes, upper atmospheric circulation.	E20a. Repeated radio occultations as in E17b and E18b	E20a. Radio Science
					E20b. Stellar occultations in the UV and near-IR to measure the vertical structure of the thermosphere with 10- to 15-km vertical resolution.	E20b. UV Spectrometer, near IR spectrometer.
					E20c. Near-IR limb observations of H3+ ionic species and tracers, intensity modulation by gravity waves in the upper atmosphere (Resolution > 10,000). Vertical resolution of half a scale height, coverage of mid and low latitudes with 300 km/pixel spatial resolution. Short and continuous long-time coverage (1 rotation or more) is require	E20c. Near-IR imaging spectrometer
					E20d. Two-dimensional UV spectral-spatial images of the latitudinal morphology of the H bulge and H2 emissions (from nadir viewing).	E20d. UV imaging spectrometer
					E20e. In situ measurements of the electron distribution of energetic electrons from energies of a few eV to MeV to identify primary and secondary ionospheric photoelectrons, three-dimensional electron distribution function with 4π coverage	E20e. INMS, PLP
					E20f. Measure the thermospheric winds, both zonally and meridionally, and determine the importance of wave acceleration and ion drag at these altitudes from high spectral resolution near-IR, UV line Doppler shifts (H3+, Lyman alpha, etc).	E20f. UV spectrometer, Near IR spectrometer
					E20g. Sub-mm measurements of molecular lines to determine atmospheric temperatures, neutral density profiles and three-dimensional distribution of atmospheric species between 1-microbar and 400-mbars.	E20f. Sub-mm spectrometer
			Atmospheric Composition and Chemistry	E21. **Determine the bulk elemental abundances**; elemental enrichments in He, C, N, S, P, As and Ge, isotopic ratios (D/H, C, N, O)	E21a. Near-IR high spectral resolution observations (R>10000 at 5-microns) to determine bulk abundances of NH3, CH4, H2O, PH3, AsH3, GeH4 to 5-10% in the upper troposphere (1- to 6-bars).	E21a. Near-IR spectrometer
					E21b. Mid-IR and far-IR spectroscopy (R> 1000) for distributions of PH3, CH4, NH3 at 0.1- to 0.8-bar, D/H ratio at 1-mbar pressure level; (R>2500 to 10000 at 10-micron) for the 15N/14N ratio in the upper troposphere. Mid-IR limb observations of 13C/12C ratio. Near IR micron spectroscopy (R> 4000-10000) for D/H	E21b. Near-IR spectrometer, thermal IR spectrometer
					E21c. Near-simultaneous radio occultations and far-IR spectroscopy to obtain helium abundance; dual spacecraft radio occultations at low frequencies to probe to 40-bars.	E21c. Far-IR Spectrometer, radio science
					E21d. Sub-mm observations of H2O and CO (R> 10E6) for 18O/17O ratio	E21d. Sub-mm spectrometer
				E22. **Measure the three-dimensional distribution of stratospheric hydrocarbons and their long-term variability**; relation to photochemistry and haze production, distribution of water and other minor species of exogenic origin, response to seasonal insolation over short-term and decadal timescales, non-thermal loss mechanisms at high altitudes; has implications for origins and formation	E22a. UVS FUV spectroscopy to study the 1- to 1000-microbar pressure level distributions of methane, acetylene, ethylene and ethane. Additional UV occultation studies to detect stratospheric hydrocarbons in absorption and haze scattering properties.	E22a UV spectrometer.
					E22b. Mid-IR thermal spectroscopy to sample 1-mbar pressure level methane, ethane and acetylene distributions (R>2000), the D/H ratio in the stratosphere (1-mbar pressure level), and HCN. Limb and nadir viewing required. Identify new trace higher order hydrocarbons with R>>2000 and near IR limb spectroscopy.	E22b. Mid or Thermal IR Spectrometer, Near IR spectrometer.
					E22c. High spectral resolution sub-mm sounding of H2O lines with R>1E6, 1-mbar to 10- μbar and above, CO2, CO, HCN, and/or CS abundance. Mapping for spatial variations at 1000-km/pixel resolution, vertical resolution of 25-km, absolute abundances to within a factor of 2. Vertical profiles with approximate scale height resolution	E22c. Sub-mm spectrometer
					E22d. Far-IR spectroscopy (R>1000) for stratospheric emission lines or water, with simultaneous derivations of atmospheric temperature from line width. Mapping for spatial variations at 1000-km/pixel resolution, vertical resolution of 100-km or better.	E22d. Far IR spectrometer
					E22e. Repeated sub-mm sounding, thermal mapping, FUV Lyman alpha imaging, radio occultation studies of the same latitudes 6- to 12-months apart to study long term evolution of the stratospheric temperature structure in response to seasonal variations.	E22e. Radio Science, Sub-mm sounder, thermal mapper, UV imager
					E22f. In situ measurements of ion composition, including H3+, in nearby space	E22f. INMS
				E23. **Study localized and non-equilibrium composition**; composition and evolution within discrete atmospheric features (plumes, vortices, storms), three-dimensional distribution of disequilibrium species in the upper troposphere; has implications for origins and formation	E23a. UV spectroscopy at regular intervals of evolving and discrete features (e.g., Great Red Spot Wake) to determine the PH3 distribution at altitudes higher than p<400 mbar.	E23a. UV imaging spectrometer
					E23b. Near and mid-IR spectral imaging of lightning locations and discrete features (repeated 10-hour separation views to study ice feature lifetimes, regular intervals for other discrete features), spatial resolution of ~100-km/pixel (spectral resolutions R > 500 required to resolve lines of H2O, NH3 (ice and gas) and PH3; R>2000 for AsH3, GeH4 and CO). Both regional high-resolution hyperspectral maps, and low resolution global maps are required.	E23b. Near IR imaging spectrometer, mid-IR spectrometer
					E23c. Mid IR and thermal spectroscopy at 200-km/pixel spatial resolution to determine the distribution of PH3 in the 0.1- to 0.8-bar region. Far-IR spectroscopy/imaging to determine the ortho/para-H2 ratio, methane distribution.	E23c. Mid to Far IR spectrometer, Thermal IR spectrometer
				E24. **Understand the importance of moist convection in meteorology, cloud formation, and chemistry**; global distribution of water vapor humidity and gaseous ammonia, vertical distribution of radio/microwave opacity sources (NH3, H2S and H2O), spatial distribution and power of lightning in the troposphere; has implications for origins and formation	E24a. Near-IR Imaging spectroscopy (R> 400) (ammonia ice, cloud height, composition) with 100-km/pixel spatial resolution over short (hrs) and long (days and months) time scales for temporal evolution	E24a. Near IR imaging spectrometer
					E24b. Mid-IR and thermal spectroscopy (water ice, composition, temperatures) with 200-km/pixel spatial resolution.	E24b. Mid or Thermal IR Spectrometer
					E24c. UV spectroscopy of NH3 distribution in the photochemical depletion region (pressures less than 400 mbar).	E24c. UV Spectrometer
					E24d. Dual X/Ka-band radio occultations to probe upper atmosphere down to a minimum of 1-bar, preferably to 3-bars (S-band). Vertical resolution of 1- to 4-km. Modulated 3.6-cm (X-band) and 0.94-cm (Ka-band) source to probe to the 1-bar level.	E24d. Radio Science
					E24e. Passive microwave radiometry at 1- to 5-cm wavelength to probe to the 100-bar level	E24e. Microwave Radiometer
					E24f. Nightside imaging of lighting, as in E16d, above	see E16d, above
			Atmospheric Vertical Structure	E25. **Determine the three-dimensional structure of Jupiter's upper troposphere and stratosphere**; global properties of Jupiter's clouds, hazes and aerosols, vertical structure within discrete atmospheric features, temporal evolution and response to global and local events	E25a. Multispectral VIS-NIR mapping at 100-km/pixel resolution of the clouds composition and particle size distribution, both globally and regionally on the dayside and nightside. Multiple phase angle coverage to constrain scattering properties and cloud altitude. Strong and weak CH4 absorption band imaging to investigate the vertical cloud structure to a spatial resolution of 30 km/pixel.	E25a. NAC/WAC imager, Near IR imaging spectrometer
					E25b. Near UV imaging to study the distribution and densities of high altitude UV-absorbent hazes, 100-200 km/pix. Repeated latitude mapping with spatial resolution of 5- to 10-degrees of latitude. Requires multiple phase angle views	E25b. NAC/WAC imager, UV imaging spectrometer
					E25c. Thermal spectroscopy/imaging in the troposphere to study the physiochemical environment in which clouds and aerosols form, 200-km/pixel spatial resolution.	E25c. Thermal IR mapper/spectrometer
					E25d. High-resolution (15-km/pixel) feature tracks and latitudinal (center to limb) scans, time separations of hours over multiple rotations for storm evolution from UV to IR.	E25d. NAC/WAC imager, Vis to Near IR imaging spectrometer
					E25e. Multiple radio science occultations for vertical temperature, pressure and neutral density profiles, using RSS referenced to a USO.	E25e. Radio Science
				E26. **Explore atmospheric structure deep below the clouds**; oscillation modes as diagnostic of wave propagation within the bulk of the atmosphere, phase transitions of molecular and metallic hydrogen within the deep interior	E26a. 1. Doppler spectro-imager to measure of frequencies of the global acoustic modes of the planet (up to degree l=25 floor, up to degree l=50 desired goal) in the range 0.3- to 3-mHz. Global radial velocity maps monitored continuously for months (1 frame/mn). Duty cycle higher than 70% is required, separated in uninterrupted periods longer than 1 day. Spatial resolution 1000-km/pixel at 0.03 AU. Radial velocity noise level < 1 cm/s in a month. Precision on frequency measurement <0.3 μHz	E26a. Doppler imager