The Uranus System Explorer (USE) – Unveiling the evolution and formation of icy giants

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1. Introduction

Many fundamental aspects of the Uranian system remain unknown or poorly constrained as no in-depth study of this system has been carried out thus far. Our knowledge of Uranus relies mainly on the Voyager 2 flyby in 1986, as well as remote sensing from Earth orbit by the Hubble Space Telescope. Studying the Uranian system would allow a better understanding of how the icy giant planets formed, provide an archetype for similar exoplanets, and better constrain current solar system formation models [1]. Uranus System Explorer (USE) will investigate the Uranian planetary system and gain new insight into the formation and evolution of icy giants. This mission will perform highly accurate measurements of the Uranian System gravity and magnetic fields as well as a number of in-situ and remote sensing investigations.

The mission concept presented here is the result of a student exercise during the Alpbach Summer School in 2012 [2].

2. Scientific Objectives

The scientific objectives of the USE mission will address the following topics: the Uranian interior, the atmosphere and the magnetosphere. To understand the interior structure and dynamics of the planet, we will use gravity and magnetic field measurements. To reconstruct the potential of both fields, it is essential to have global coverage at low altitudes. The atmospheric dynamics can ideally be studied if global coverage on both the day-and night side are available. Remote sensing instruments are used to probe the upper layers of the atmosphere. However a probe penetrating down to the tropopause will be required to investigate the deeper layers of the atmosphere [3].

To study the magnetosphere and its interaction with the solar wind, the instrumentation should be able to cover plasma particle energies up to at least 4 MeV. In addition, the payload shall be able to investigate high-frequency electromagnetic fields and magnetic fields down to the magnetic field intensity of the solar wind at 0.1 nT. As the magnetopause at the sub-solar point extends to approximately 20 Uranian radii (R_u), the orbit design should be such that we can sample regions at least that far away from the planet in order to globally characterize the magnetosphere.

3. Mission Overview

In order to meet the scientific requirements, USE will consist consist of an orbiter and a deep atmospheric probe. The selected scientific payload for the orbiter is illustrated in Table 1 and the top level mass budget can be seen in Table 2.

Launch is planned to be on Oct 2029, the trajectory will be composed of four gravity assists (Venus-Earth-Earth-Jupiter) with a 20 year long interplanetary cruise. Orbit insertion (polar orbit with 90^o of inclination) is expected in November 2049. Figure 1 depicts the three science phases that the mission will cover and Table 3 the Delta-V budget of the mission.

4. System design

The USE spacecraft design, depicted in Figure 2, was strongly driven by the unique operational profile of the mission. In order to achieve acceptable telemetry rates at Uranus, the spacecraft carries a 4m High

Gain Antenna for Ka-band downlink and X-band uplink. Electrical power is provided by three Advanced Stirling Radioisotope Generators, providing 140 W of electrical power at beginning of life. The two large side panels of the spacecraft house the remote sensing instruments and the atmospheric probe, respectively, while the smaller side panels house the plasma instrument package. The magnetometer payload is housed at the end of a deployable 10m boom to minimize the influence of spacecraft fields. Primary propulsion is provided by an NTO-Hydrazine bipropellant main engine, providing a specific impulse of 318s and a nominal thrust of 645N.

Table 1: Orbiter model payload

Instrument	Energy/Wavelength
Radio and plasma wave instrument	E: 1 kHz-10 MHz B: 0.1Hz –20 kHz
Fluxgate magnetometer	B: 0.1nT–120000 nT
Electron and Ion Spectrometer	e, i: 1 eV-40keV
Energetic Particle Detector	e, p: 15 keV-10MeV
Ion composition instrument	i: 25-4 keV
Imaging camera	λ=0.35-0.85 μm
VIS & IR Spectrometer	λ: 0.25-5.0 μm
UV Spectrometer	λ=52-187 nm
Microwave Radiometer	λ: 1.3-50 cm, 6 bands
Thermal Infrared Spectrometer	λ: 7.16-1000 μm

Table 2: Communications Overview

Link	Frequency	Bandwidth [kbps]
Orbiter-Earth downlink	Ka-band	6.00 (at Uranus)
Orbiter-Earth uplink	X-band	0.07 (at Uranus)
Orbiter-Probe uplink	UHF	2.32 (at 100 bar)

Table 3: Delta-V budget

Maneuver	ΔV [km/s]	
Escape from Earth	3.56	
Deep space manoeuvres	0.21	
Orbit insertion at Uranus	0.63	**TOTAL**
Orbit transfers and de-orbit	0.60	**1.44 km/s**

Table 4: Top level Mass budget

Allocation	Mass [kg]	
Total dry mass	2115	
Propellant before orbit insertion	935	
Propellant for in orbit operations	949	**TOTAL:**
Adaptator	186	**4185 kg**

Figure 1: Schematic view of all science phase orbits.

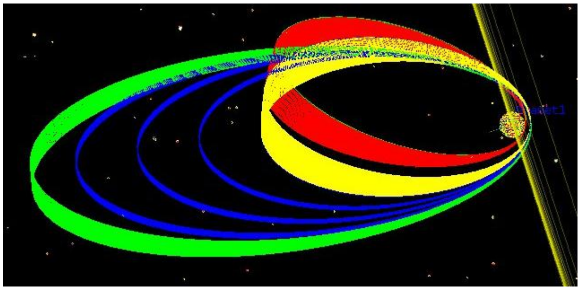
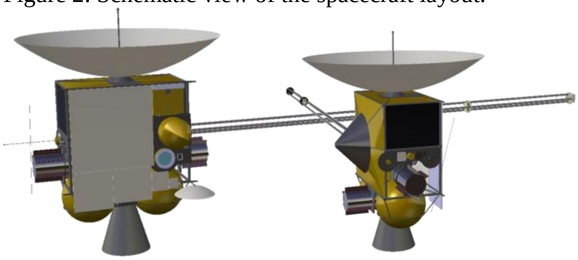


Figure 2: Schematic view of the spacecraft layout.



5. Summary

The USE mission represents a unique opportunity to study the Uranian system in unprecedented detail and to gain new insights into the formation and evolution of icy giant systems. The knowledge gained from this investigation would provide crucial constraints to current models for planetary formation and evolution, and would address a significant gap in current understanding of Solar System formation.

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