UNVEILING THE EVOLUTION AND FORMATION OF ICY GIANTS

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1 INTRODUCTION

The planet Uranus is one of two ice giants in the solar system, both of which have only been visited only once by the Voyager 2 spacecraft. Ice giants represent a fundamental class of planet, and in fact, it is believed that most exoplanets are ice giants. Therefore, a dedicated mission to an ice giant is crucial to deepen our understanding of the formation, evolution and current characteristics of such planetary and exoplanetary systems. Here we present results of a detailed study of a mission to investigate the Uranus system as an archetype for ice giants.

Our detailed trade-off study has resulted in a mission configuration consisting of an orbiter with a deep atmospheric probe and an extensive orbital tour of the Uranus system, including its rings and major moons.

2 SCIENCE OBJECTIVES

Answer fundamental questions about the formation and evolution of the icy giants and place them in the planetary system formation models.

- **ATMOSPHERE**: What is the composition of the atmosphere? What are the drivers of atmospheric chemistry? What are the atmosphere dynamics?
- **INTERIOR**: Why is the heat flux lower than expected? What are the implications for the interior and thermal evolution of the planet? Why does Uranus have such a strong intrinsic magnetic field? How do its characteristics constrain the interior? Is there a rocky silicate core?
- **URANIAN SYSTEM**: What is the origin and evolution of the Uranian moons? What is the internal structure, composition and current thermal state of the moons? How have the Uranian rings formed and evolved? What governs the dynamics of the Uranian rings?
- **MAGNETOSPHERE**: How is plasma produced and transported in the magnetosphere? What are the dynamics of the uniquely configured Uranian magnetosphere and its interaction with the Solar Wind?

3 PAYLOAD

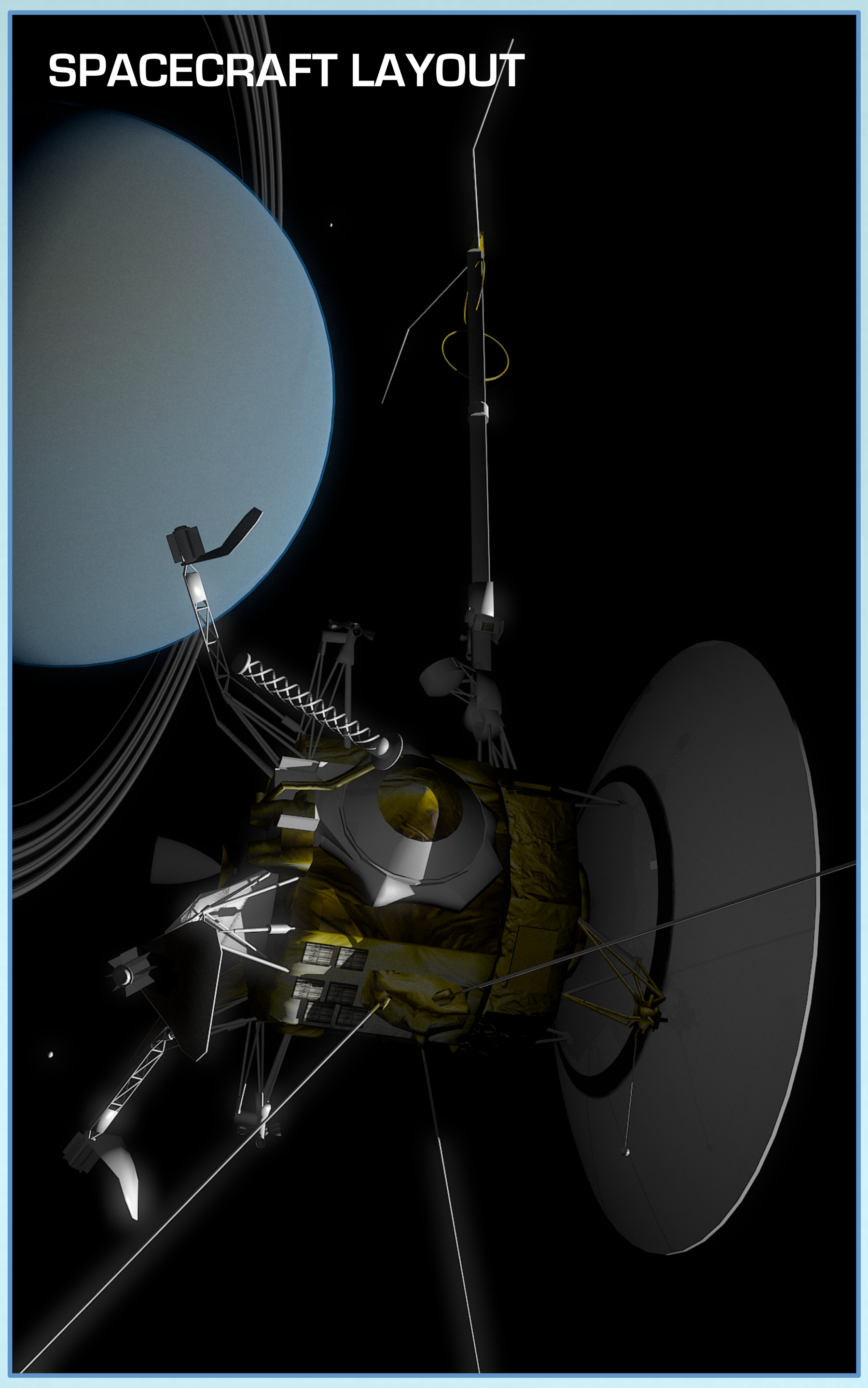
Orbiter Payload (97.9 kg)

Remote
- Narrow Angle Camera (NAC)
- Visible and IR Spectrometer (VINIR)
- Thermal IR Spectrometer (IRS)
- Microwave Radiometer (MWR)
- Extremely Low Freq. Antenna (ELF)

In situ
- Electron and ion sensor (EIS)
- Fluxgate Magnetometer (MAG)
- Energetic Particle Detector (EPD)
- Radio and Plasma Wave Ins. (RPW)
- Ion composition instrument (ICI)

Atmospheric Probe 312kg
- Aerosol Sampling System (ASS)
- Nephelometer (NEP)
- Doppler wind instrument (DWI)
- Atmosphere Physical Properties Package (AP3)
- Gas Chromatograph and Mass Spectrometer (GCMS)

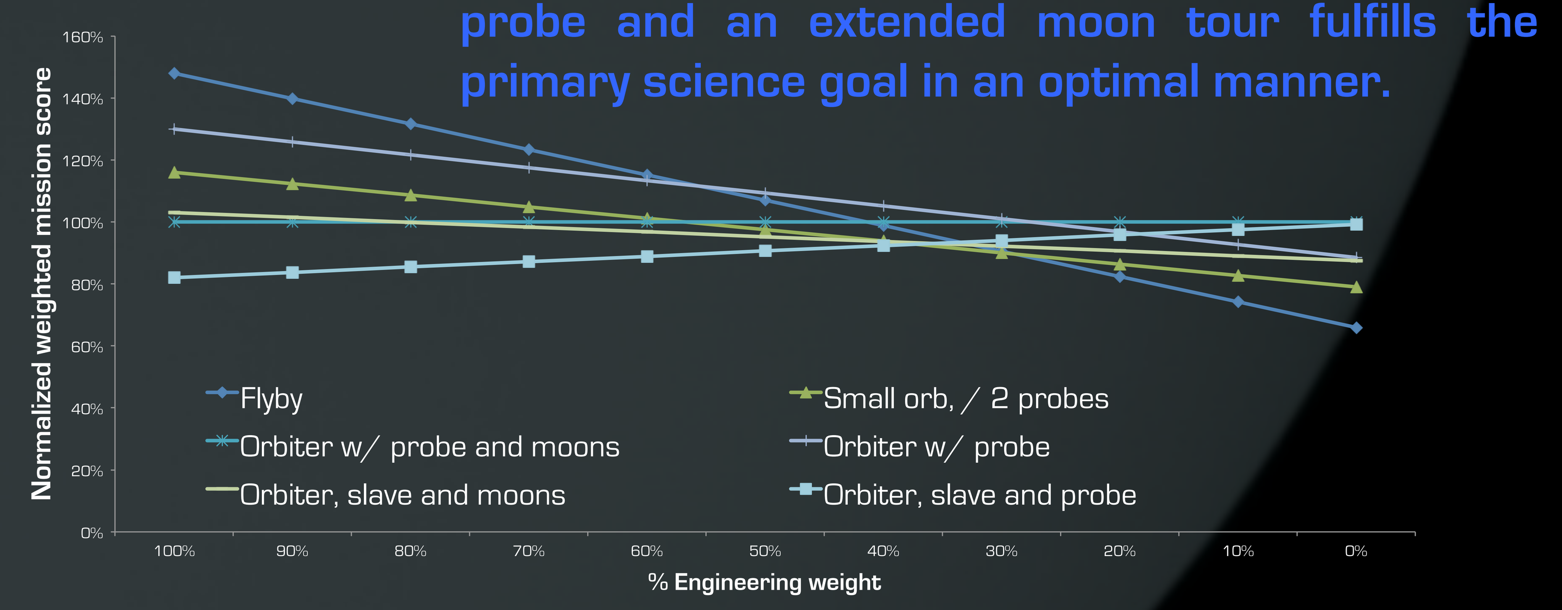
SPACECRAFT LAYOUT



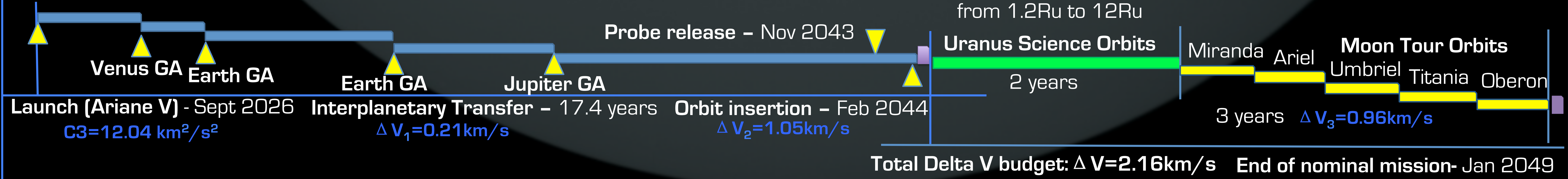
4 MISSION ARCHITECTURE TRADES

A detailed trade-off between several mission architectures was performed. In this process, parameters such as the relative importance of the scientific objectives, the science payload's capability to answer the scientific objectives and the spacecraft configuration was traded off. Similarly, the feasibility of each concept from an engineering point-of-view was assessed (complexity, cost, risk, etc.) The results are presented as a function of relative engineering and science score weights.

We conclude that a Uranus orbiter with an entry probe and an extended moon tour fulfills the primary science goal in an optimal manner.

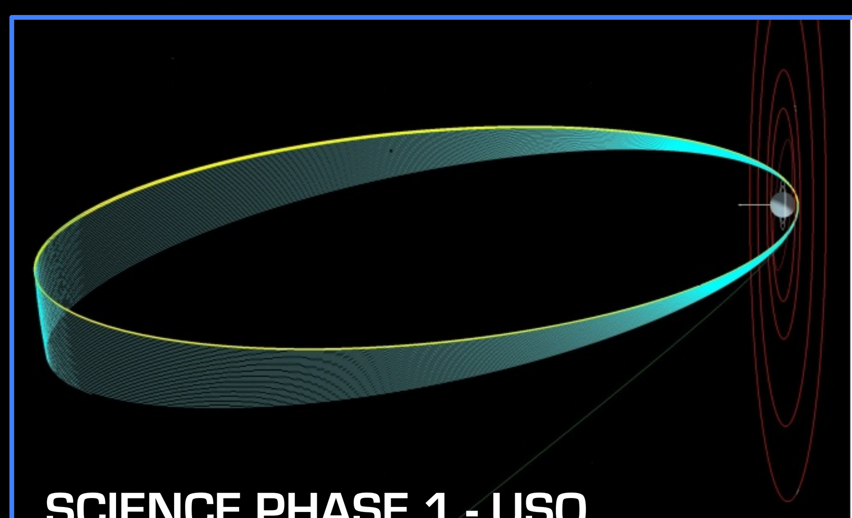


5 MISSION ANALYSIS

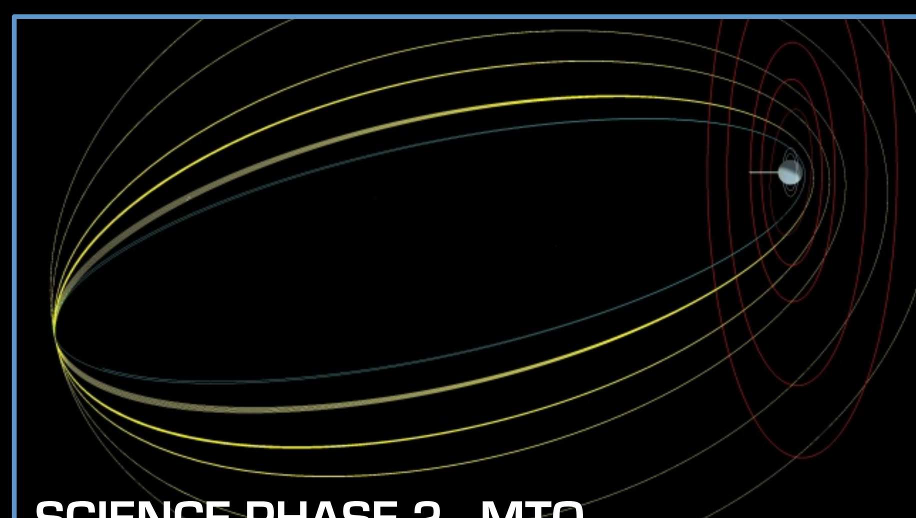


Mass Budget	Mass [kg]
Total dry mass	2952
Propellant mass	2167
Ariane 5 ECA performance	4300
Excess launch capac.	81 (2%)

Power Components	Power after 23yrs (EOM)	Peak power needs covered
4 ASRGs	436 W	120%
3 ASRFs (fail)	327 W	90%
40kg Lithium battery	3374 Wh	12%



SCIENCE PHASE 1 - USO



SCIENCE PHASE 2 - MTO

6 SYSTEM DESIGN

The spacecraft design is strongly driven by the unique operational profile of the mission. The design drivers are; the low solar flux at Uranus which dictates the use of a radioactive power source, the large thermal discrepancy between a Venus flyby and the final Uranus science orbit, the 20AU distance to the Earth, which requires a powerful communications system and the long interplanetary cruise to Uranus. The design of the atmospheric entry probe is based on ESA's Planetary Entry Probe (PEP) study. The spacecraft will be powered by four ASRGs, which are currently under development. A set of batteries is included, capable of covering the loss of one ASRG through the peak power phase. There will be a 100 Gbit data storage capacity for optimizing the science return through careful selection of transmitted data. Data transmission is performed by a 3.5 m high gain antenna transmitting in X-band for communications and Ka-band for tracking. An additional UHF-Band antenna is used for communications with the probe.

7 SUMMARY

A dedicated mission to Uranus represents a unique opportunity to study an ice giant system 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 further address a significant gap in the current understanding of Solar System formation.
Our detailed trade-off study has resulted in a mission configuration consisting of an orbiter with a deep atmospheric probe and an extensive orbital tour of the Uranus system, including its rings and major moons.

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