EXODUS: A mission to explore exoplanet evolution through understanding atmospheric escape

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Introduction

Understanding the variety of system architectures and formation histories of planetary systems remains a major challenge. Current detection methods are strongly biased towards short-period bodies, leaving a gap in the exoplanet population demographics [1], [2].

Scientific questions:

1. How does **atmospheric escape** shape the evolution of long orbital period exoplanets?
2. What proportion of the exoplanet population do planets with **long orbital periods represent**?
3. How does the **Solar System architecture** compare to that of exoplanet systems?

Exodus is a mission to study the largely unexplored population of sub-Neptune to Jupiter-sized exoplanets with orbital periods greater than 100 days, through new detections and characterisation of atmospheric escape [3-7].

Payload

UV monitoring of stellar activity
- Ritchey-Chrétien configuration
- Primary mirror diameter: 9.3 cm
- FOV: 40 arcmin

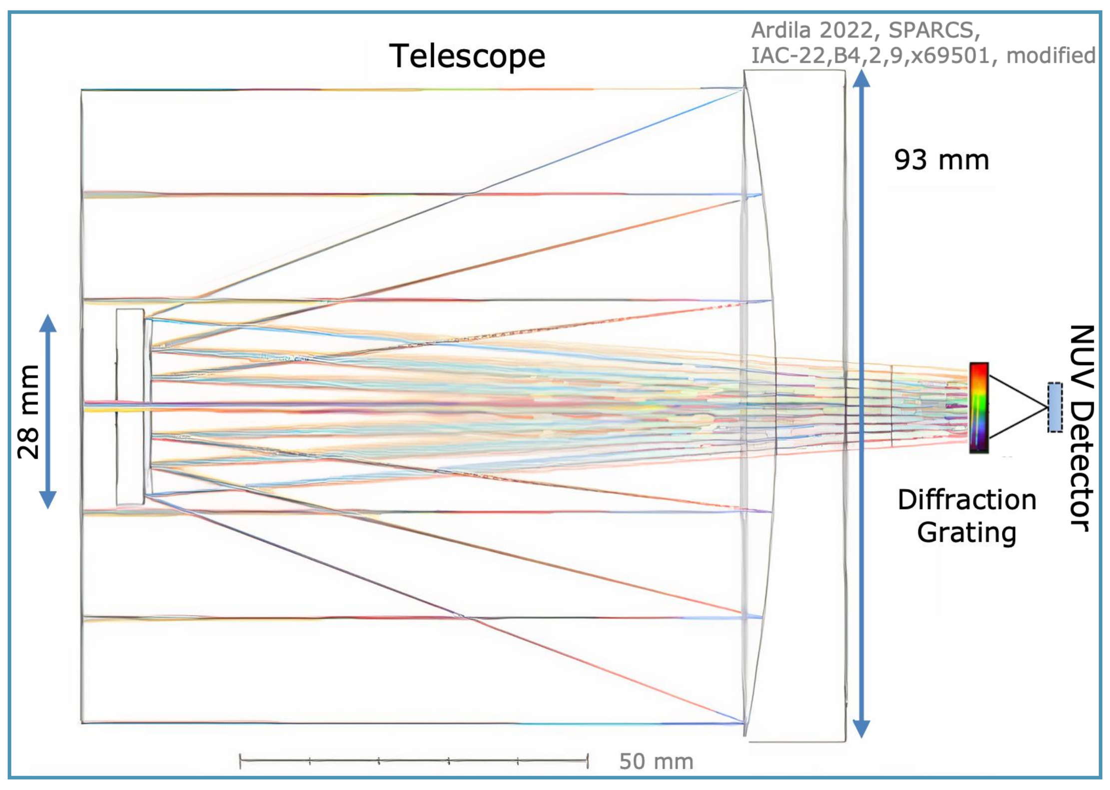
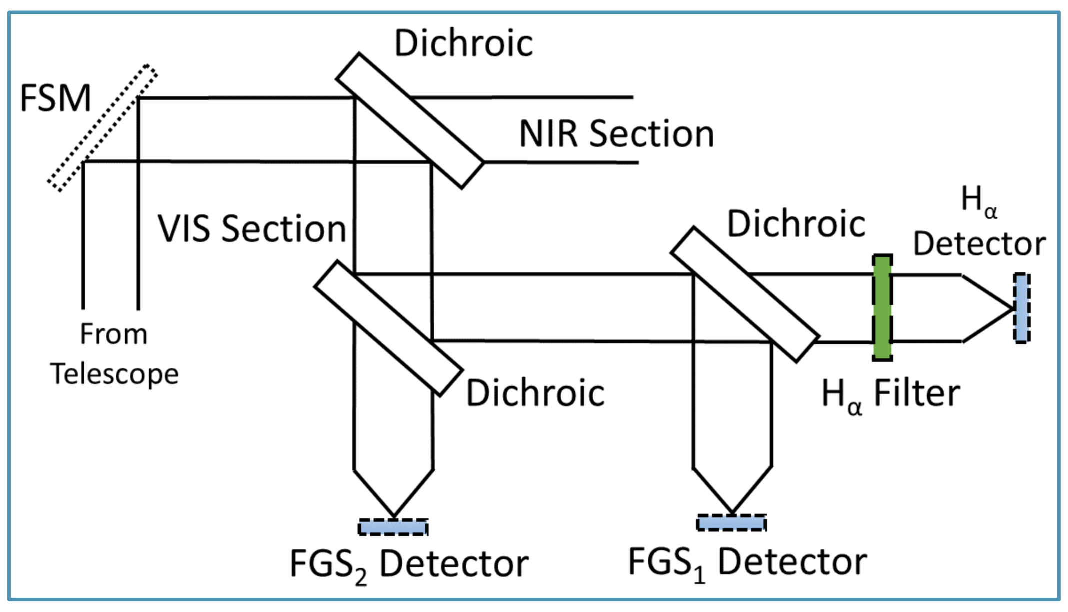


Figure 1: Optical path and configuration of the UV telescope based on the near-ultraviolet part of the SPARCS CubeSat mission payload [8].

UV target: Mg II H&K, Ca II H&K lines (stellar activity tracers).



NIR observations of the planet
- Cassegrain telescope
- Main mirror diameter: 2.4 m
- FOV: 10 arcsec
- Focal length: 12.6 m

Figure 2: VIS lightpath of the VIS-NIR telescope. The fast-steering mirror increases telescope pointing precision through fast tilt-shift corrections on the collimated beam.

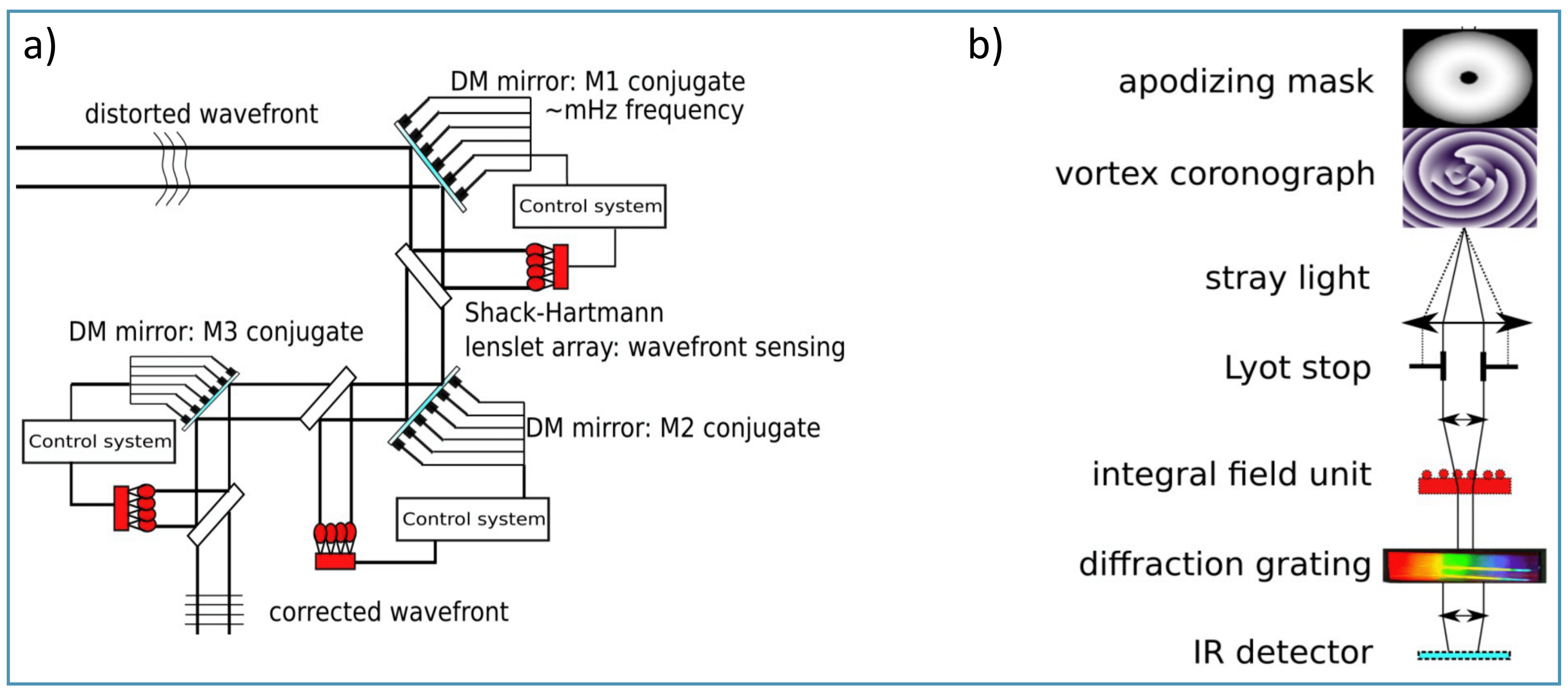
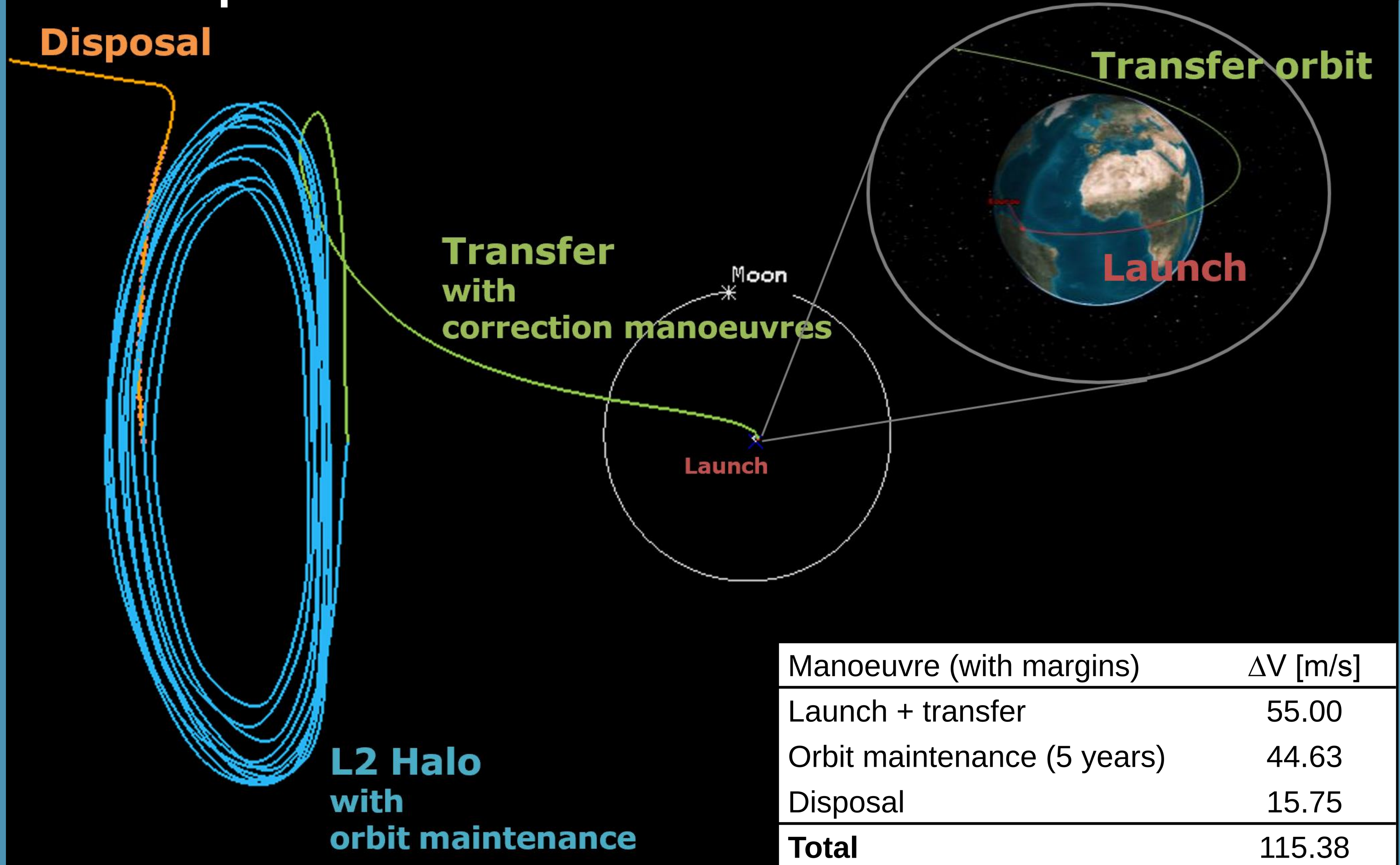


Figure 3: NIR lightpath of the VIS-NIR telescope. a) Adaptive optics system. b) MARY instrument.

NIR target: He 1083 nm line of planet's atmosphere (coronography to block out star light)
VIS target: H_α 656 nm line (trace stellar activity) + pointing corrections

Mission profile



Manoeuvre (with margins)	ΔV [m/s]
Launch + transfer	55.00
Orbit maintenance (5 years)	44.63
Disposal	15.75
Total	115.38

Spacecraft bus design

Overall dimensions:
- Length: 8.79 m
- Maximum width: 4.04 m
- Dry mass: 1599 kg
- Wet mass: 1783 kg

Main spacecraft bus design drivers:
- Instrument constraint: < 73 K
- Observation pointing precision: 50 mas performance drift error across 72 hours

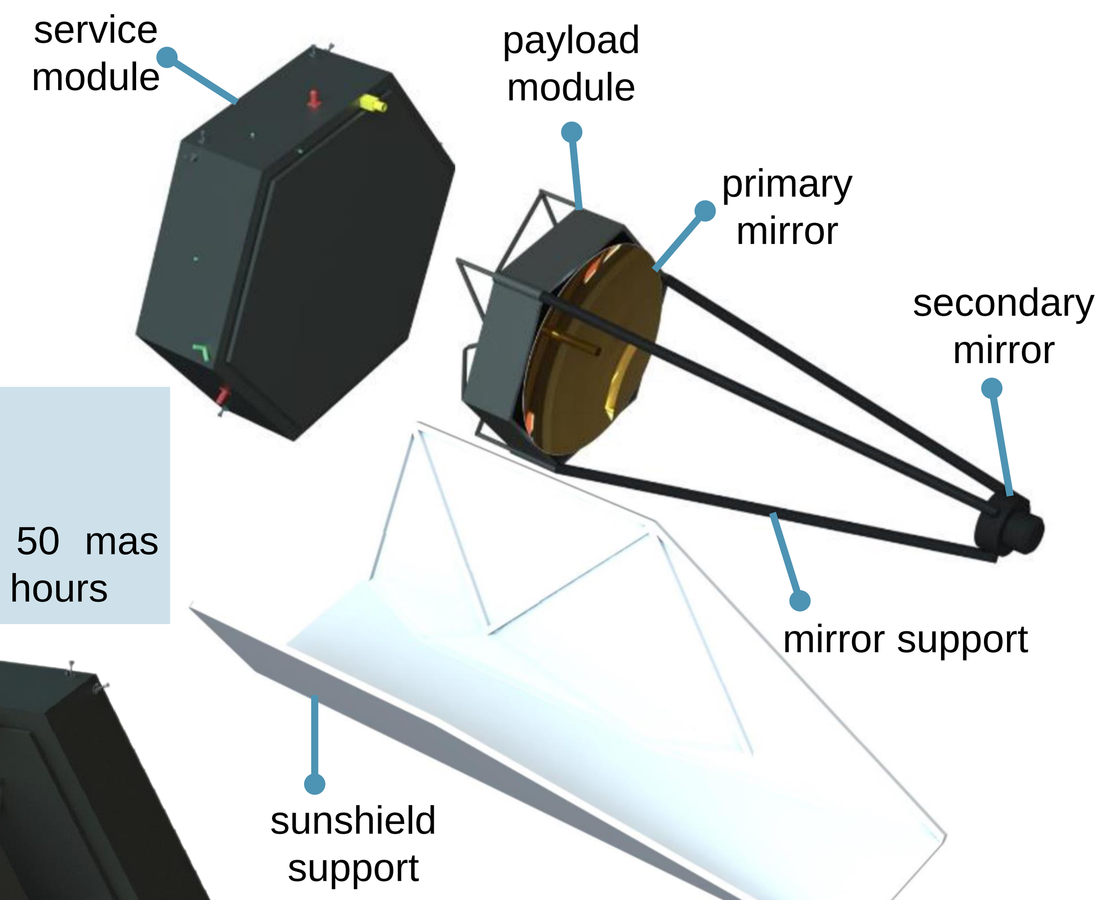


Figure 4: The payload module holds the optical parts, while the service module houses the subsystem components. The solar panels are attached to the sunshield support.

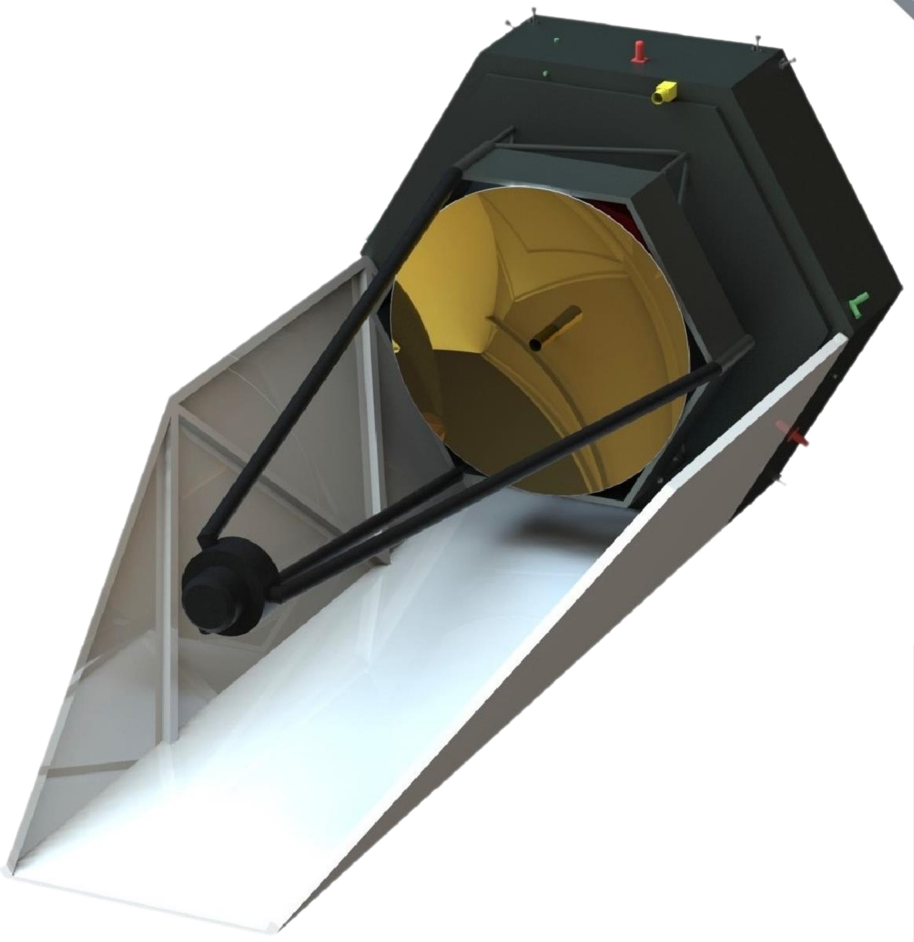


Figure 5: Overview of the Exodus spacecraft.

Communication
- High gain system (science downlink) with 1 dish antenna and 2 transceivers
- Low gain system (TM/TC) with 3 omni antennas and 2 transceivers
- Data volume: up to 250 Gbits/week

Propulsion
- 51 N thruster dimensioned for transfer burn into L2 orbit. (3 total for redundancy)
- Propellant: Monopropellant + hydrazine

Thermal
- 7-layer sunshield (213 K to 77.5 K)
- Thermal decoupling with heaters and radiators
- Surface coatings and insulators

ADCS
- Rough pointing: 6 sun sensors, gyroscope, 2 star trackers, 8 thrusters, 4 reaction wheels
- Fine pointing: Fine guidance sensor, fast steering mirror

Power
- Solar panel area: 5.72 m² (no eclipses during lifetime, driven by manoeuvre mode)
- Battery capacity: 2300 Wh (driven by launch mode)

Discussion and Conclusions

Iterations with the COMET tool at ESA Education Training Centre Concurrent Design Facility led to refinements of Exodus' subsystems.

- **Payload:** from a complex, low TRL single telescope design to two specialized telescopes — one for VIS-NIR observations and one for the UV spectral range.
- **FOV of MARY instrument:** changed from 3 to 10 arcsec, increasing the diversity and number of exoplanets observed.
- Simultaneous **observations** of **stellar activity and atmospheric loss** will reveal the impact of host stars on planetary systems.
- **High contrast** observations will **reduce technique biases** in new detections and enable comparisons with Solar System architecture.

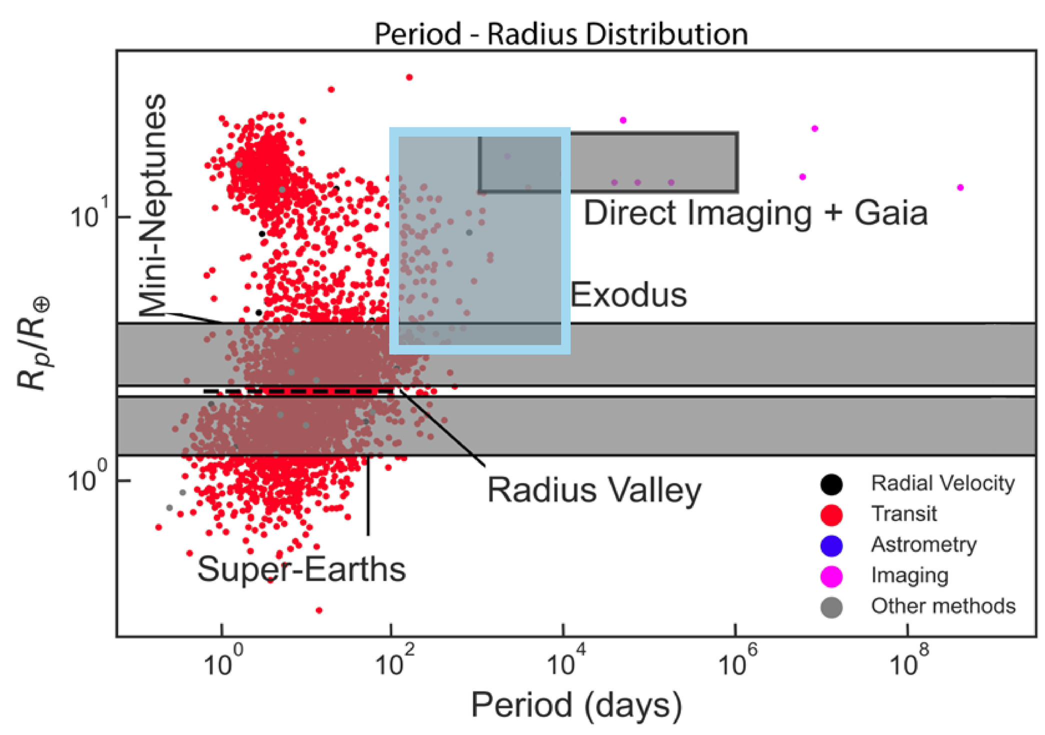


Figure 6: Exodus aims to monitor atmospheric escape in relation to stellar activity for over 5000 exoplanets, refining our understanding of exoplanet diversity and the conditions required for habitability.

Figure 7: Exodus spacecraft placed in Ariane 62 fairing.

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