HYBRID AEROCAPTURE USING LOW L/D AEROSHELLS FOR ICE GIANT MISSIONS

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Athul Pradeepkumar Girija
A. Arora, and S. J. Saikia
School of Aeronautics and Astronautics, Purdue University, IN, USA
J. A. Cutts
NASA Jet Propulsion Laboratory, California Institute of Technology, CA, USA

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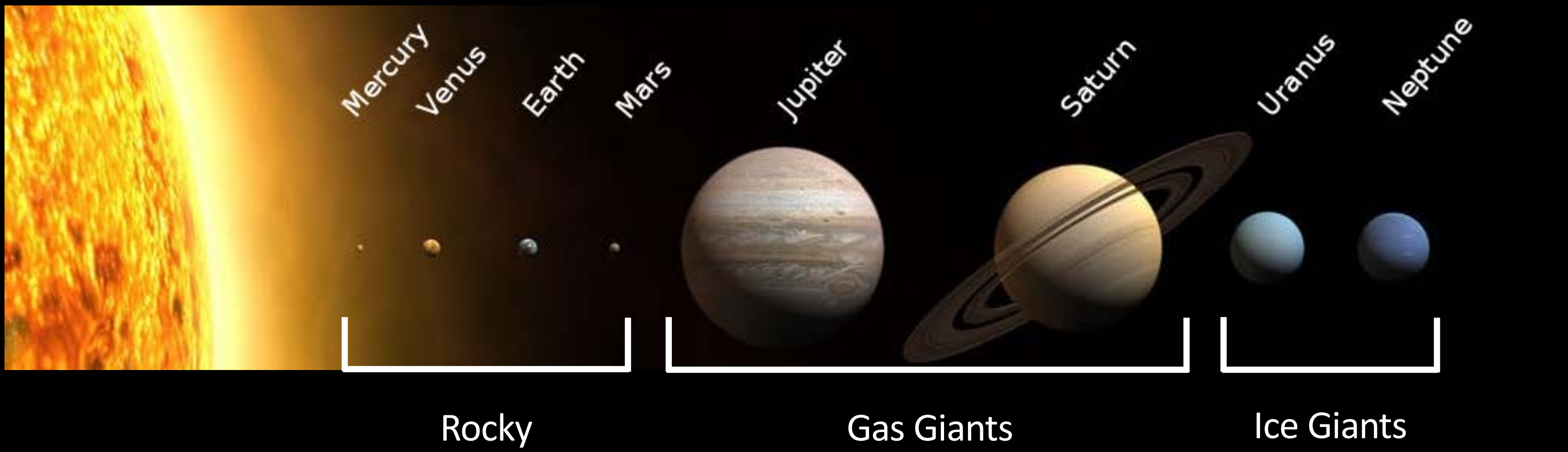
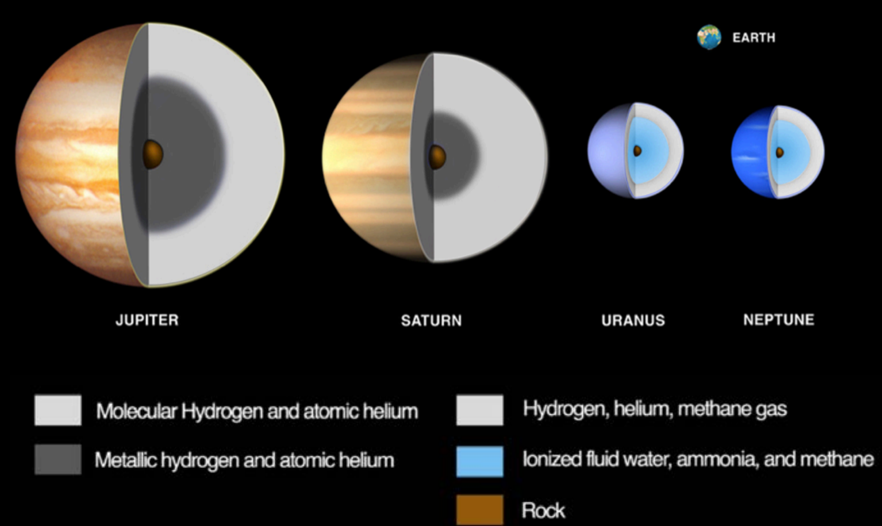
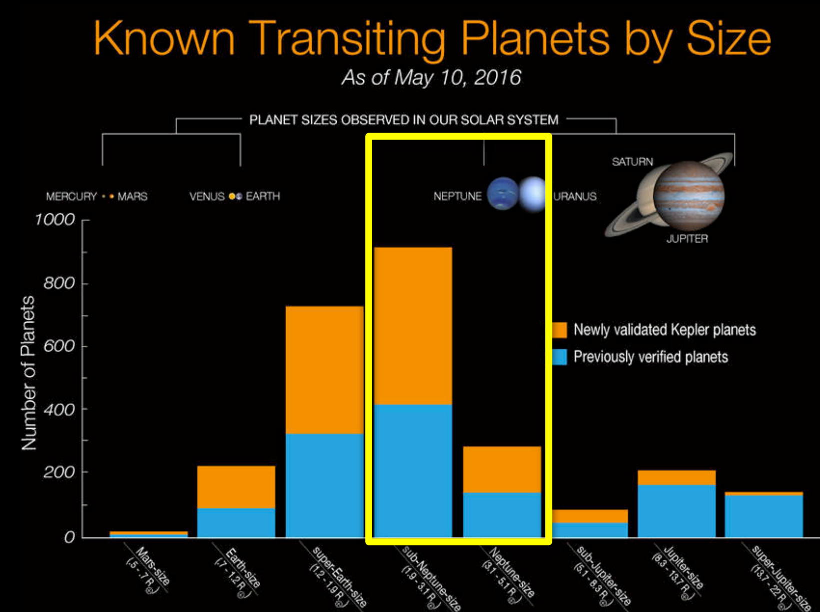
Artist's concept of a low L/D aeroshell used for aerocapture at the Ice Giants. MSL entry vehicle used for representative purpose only, credit: NASA/JPL.

Ice Giants – Uranus and Neptune







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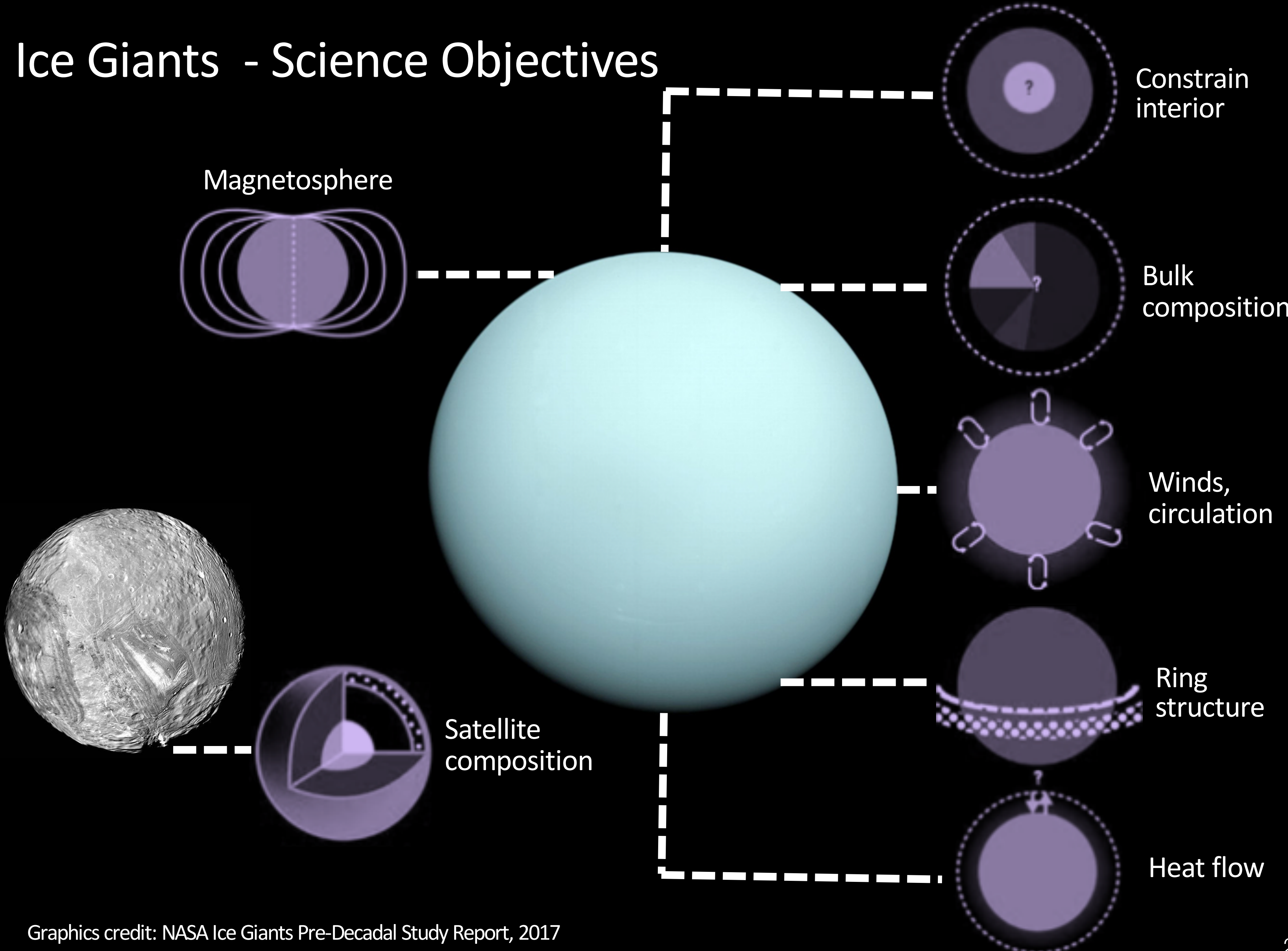
Ice Giants - Science Objectives

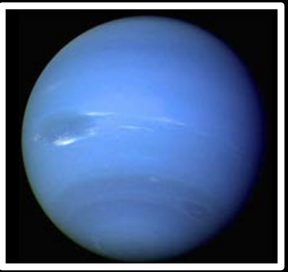


Graphics credit: NASA Ice Giants Pre-Decadal Study Report, 2017

NASA Ice Giants Pre-Decadal Study, 2017

Uranus Orbiter with probe and ~50 kg payload, no SEP

Launch	TOF (y.)	Arrival V∞	Arrival Mass	OI ΔV	Mass in Orbit
2031	12.0	8.5 km/s	3582 kg	1.7 km/s	1913 kg



Neptune Orbiter with probe and ~50 kg payload, with SEP stage

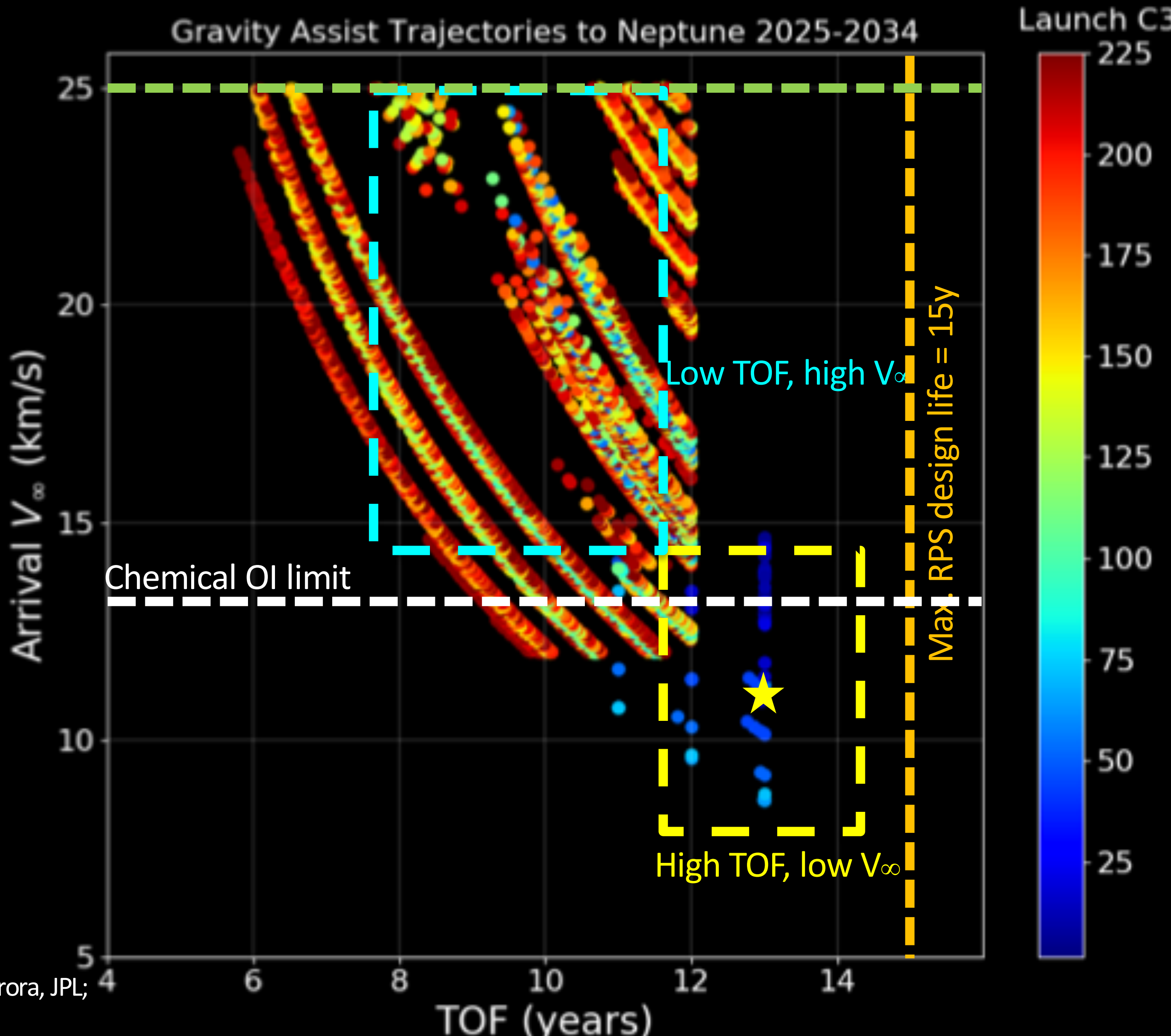
Launch	TOF (y.)	Arrival V∞	Arrival Mass	OI ΔV	Mass in Orbit
2030	13.0	11.5 km/s	5033 kg	2.7 km/s	2012 kg

Source: NASA Ice Giants Pre-Decadal Study Report, JPL D-100520

Mission Design Challenges

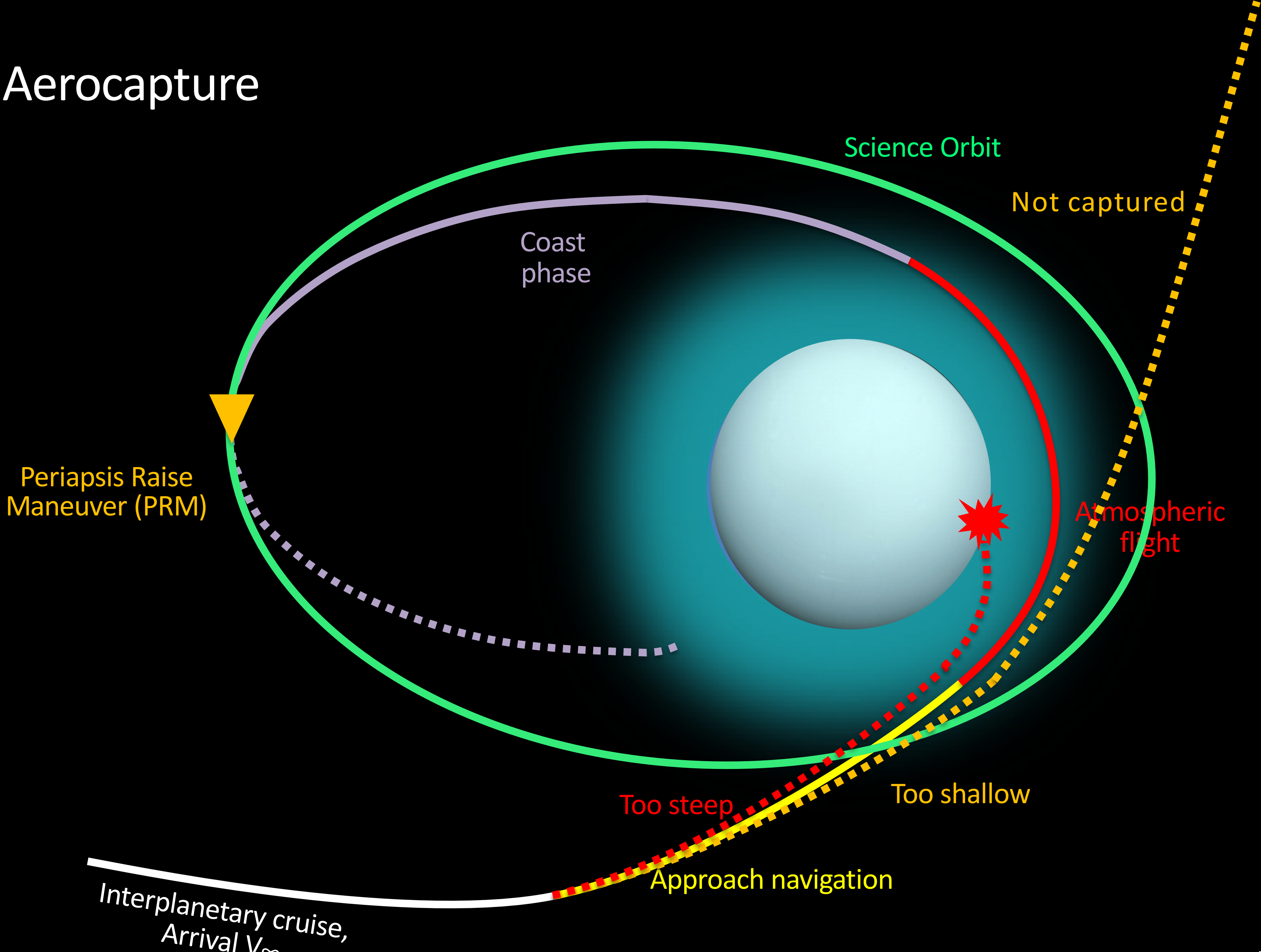
Chemical OI limit is the major design constraint.

Aerocapture uses atmospheric drag to perform orbit insertion.



Acknowledgement: A. Petropoulos, N. Arora, JPL; K. Hughes, A. Mudek, Purdue University

Aerocapture

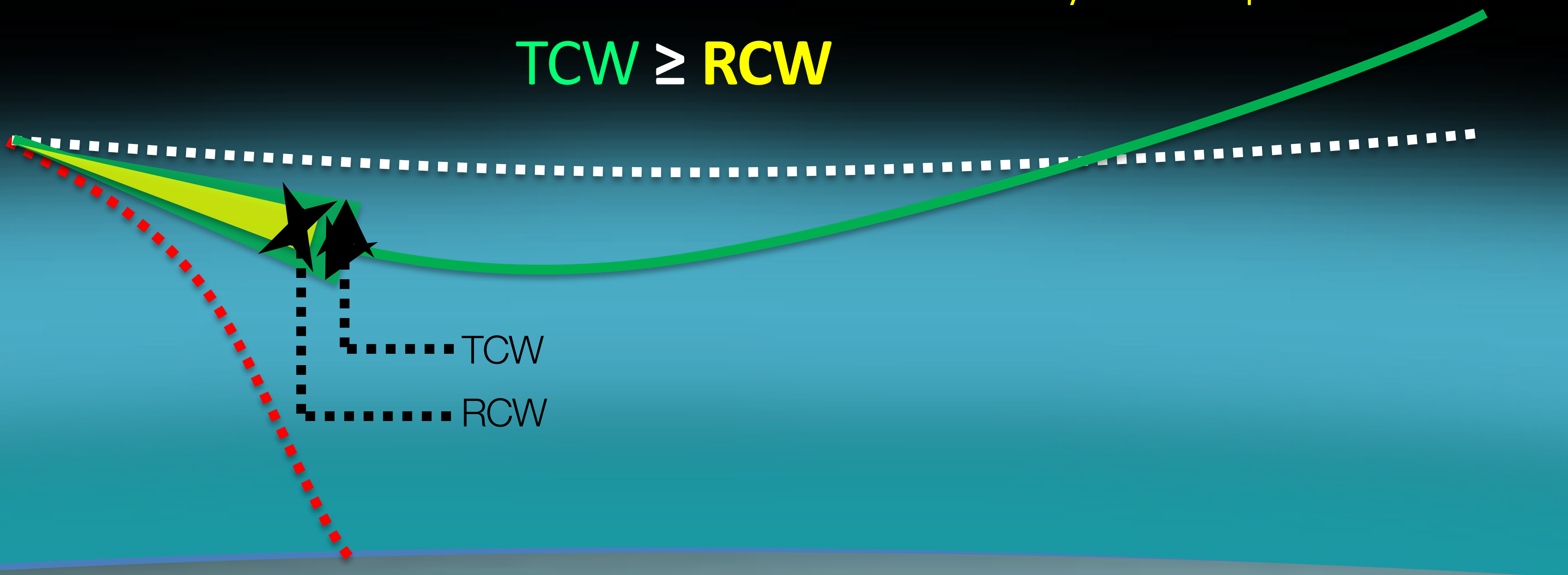


Corridor Width

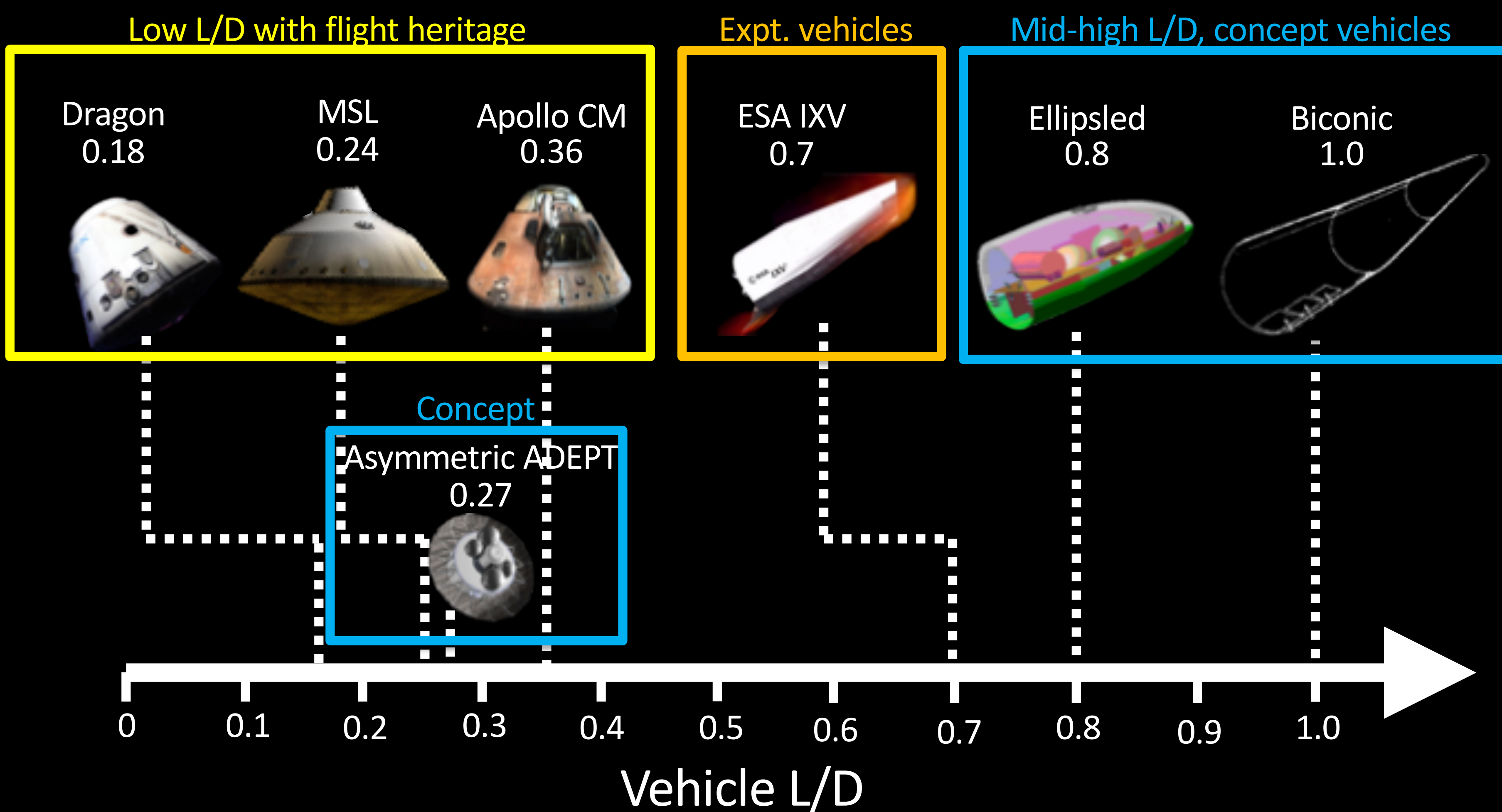
1. Theoretical Corridor Width (TCW)
   - Vehicle $(L/D)_{max}$
   - Arrival V_∞

2. Required Corridor Width (RCW)
   - Navigation errors
   - Atmospheric uncertainties
   - Aerodynamic dispersions

TCW ≥ RCW



Aerocapture Vehicles



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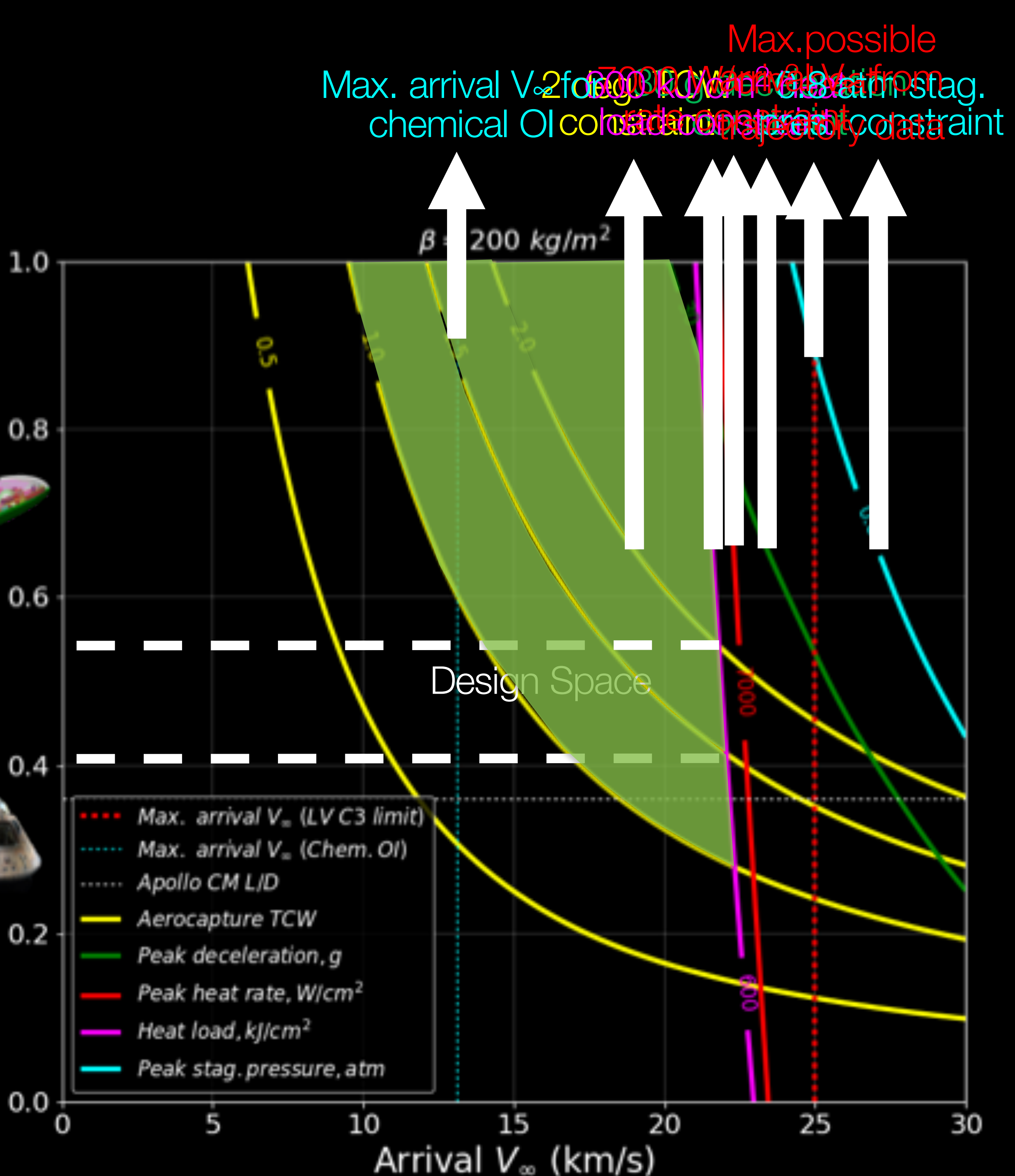
Neptune Aerocapture

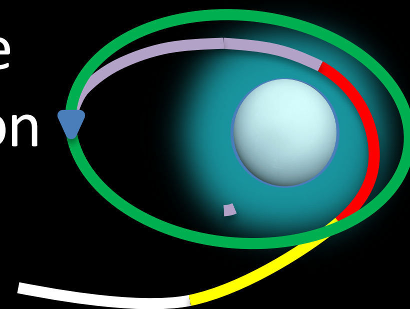
- Which vehicle do we need?
  - Mid L/D aeroshell

- Implications
  - Cost
  - Risk
- Can we lower the L/D?
  - Reduce uncertainties
  - Hybrid aerocapture

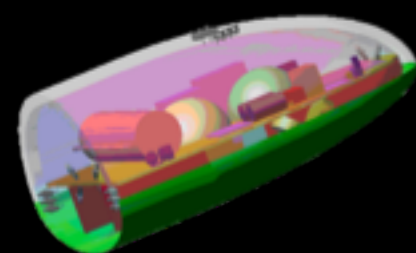


Hybrid Aerocapture

- Aerodynamic and propulsive forces used for orbit insertion
  - How?
  - Feasibility

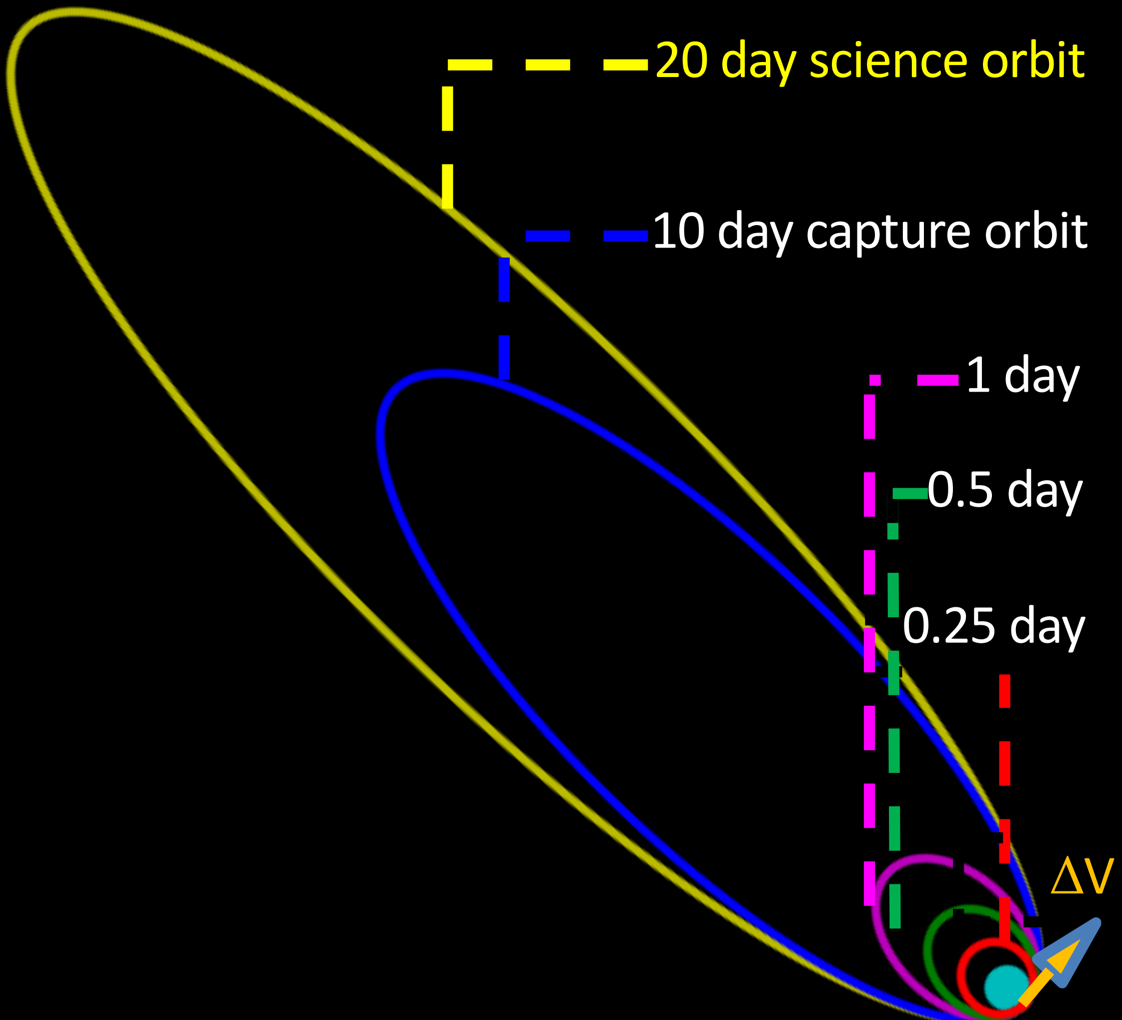


- Can we use low L/D aeroshells?
  - ΔV
  - Risk vs. Benefit



Hybrid Aerocapture – Approach #1: Small capture orbits

- Benefits
  - Increases TCW
  - Reduces risk of accidental escape
- Cost
  - ΔV
  - G-load, heating
- Risks
  - Ring plane crossing hazard
  - Autonomous navigation



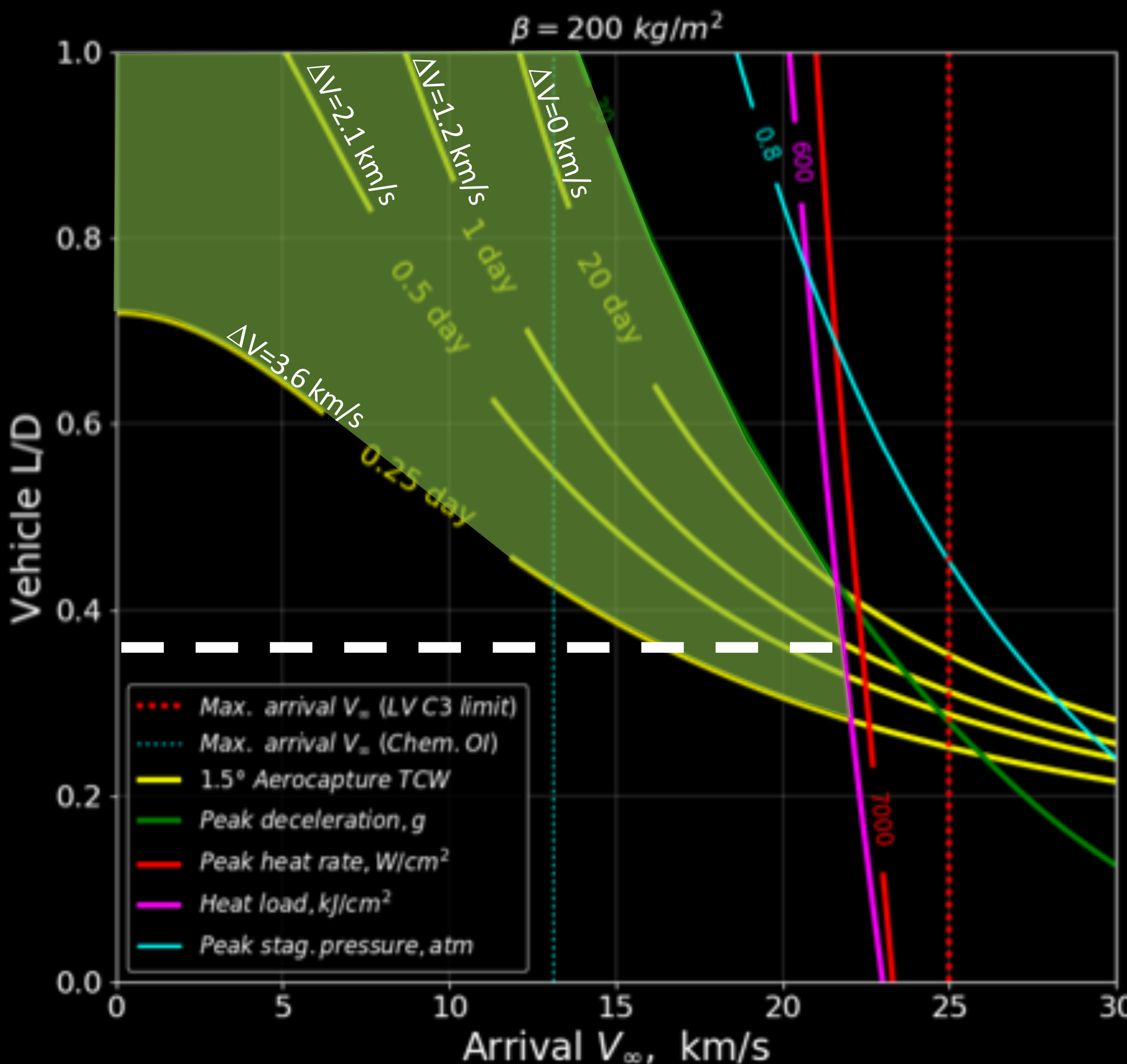
Hybrid Aerocapture – Approach #1: Cost-Benefit Analysis

RCW = 2.0°

RCW = 1.5°

Capture Orbit = 1 day
Prop. ΔV = 1.2 km/s

RCW	L/D	V_∞ (km/s)
2.0°	0.47	21.9
1.5°	0.36	22.1
1.0°	0.24	22.4



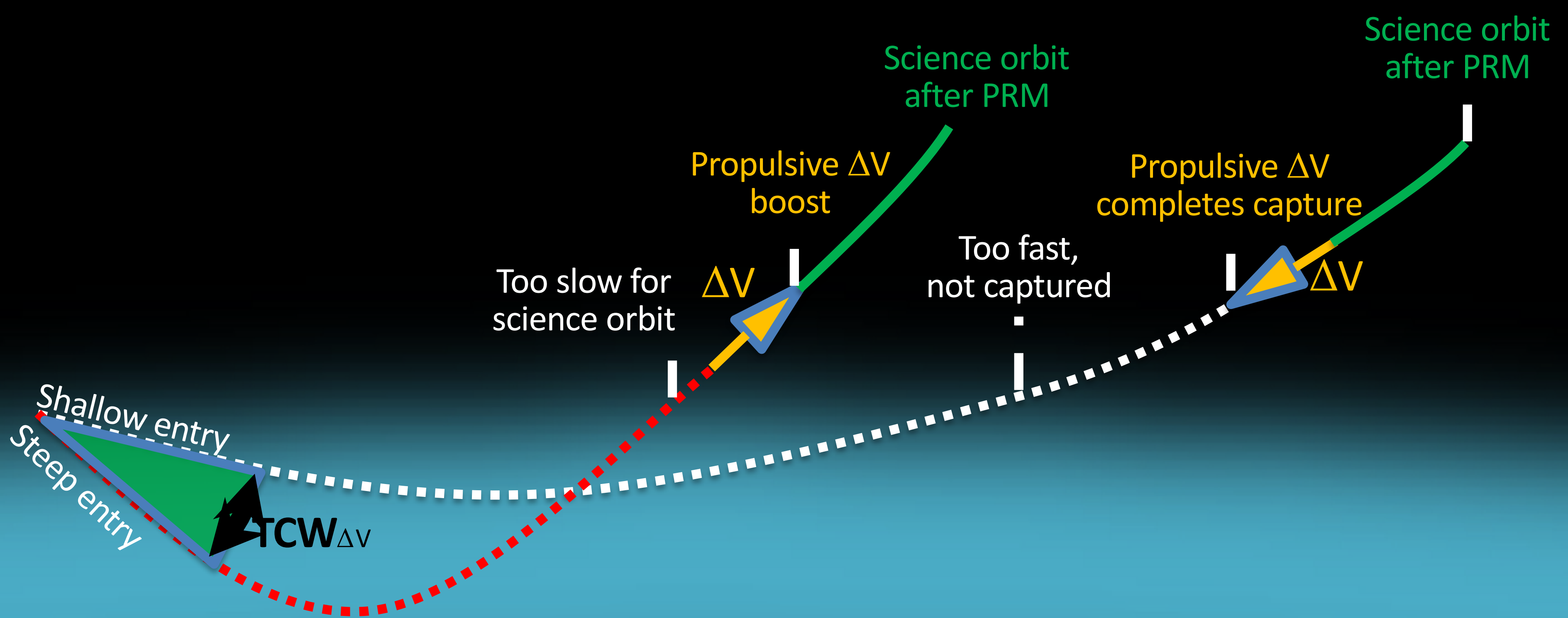
Hybrid Aerocapture – Approach #2: Exit speed targeting

Benefits

- Allow a wide range of exit speeds
- Increased TCW
- Reduced ring plane crossing hazard

Cost and Risk

- ΔV
- Possible escape



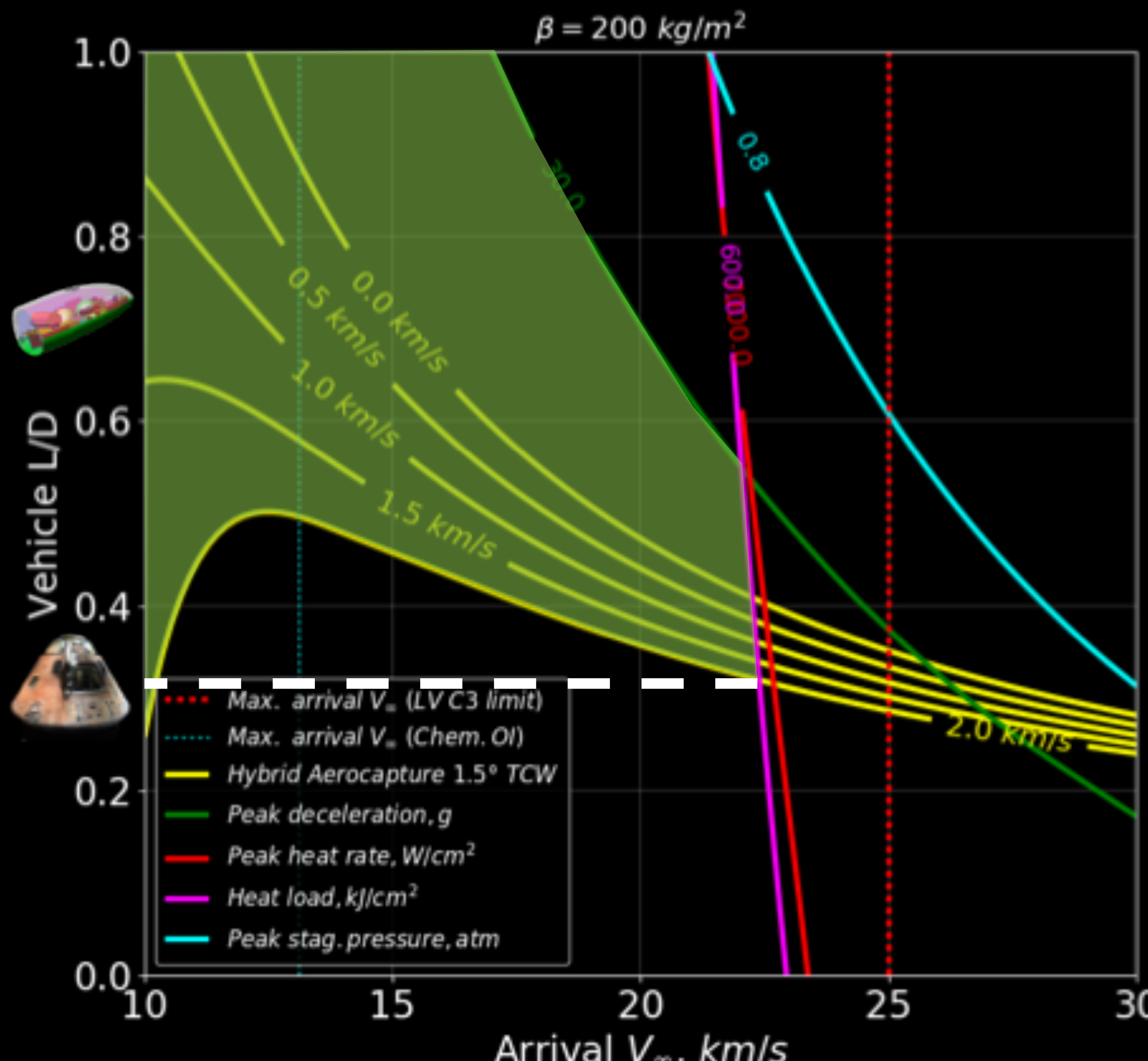
Hybrid Aerocapture – Approach #2: Cost-Benefit Analysis

RCW = 2.0°

RCW = 1.5°

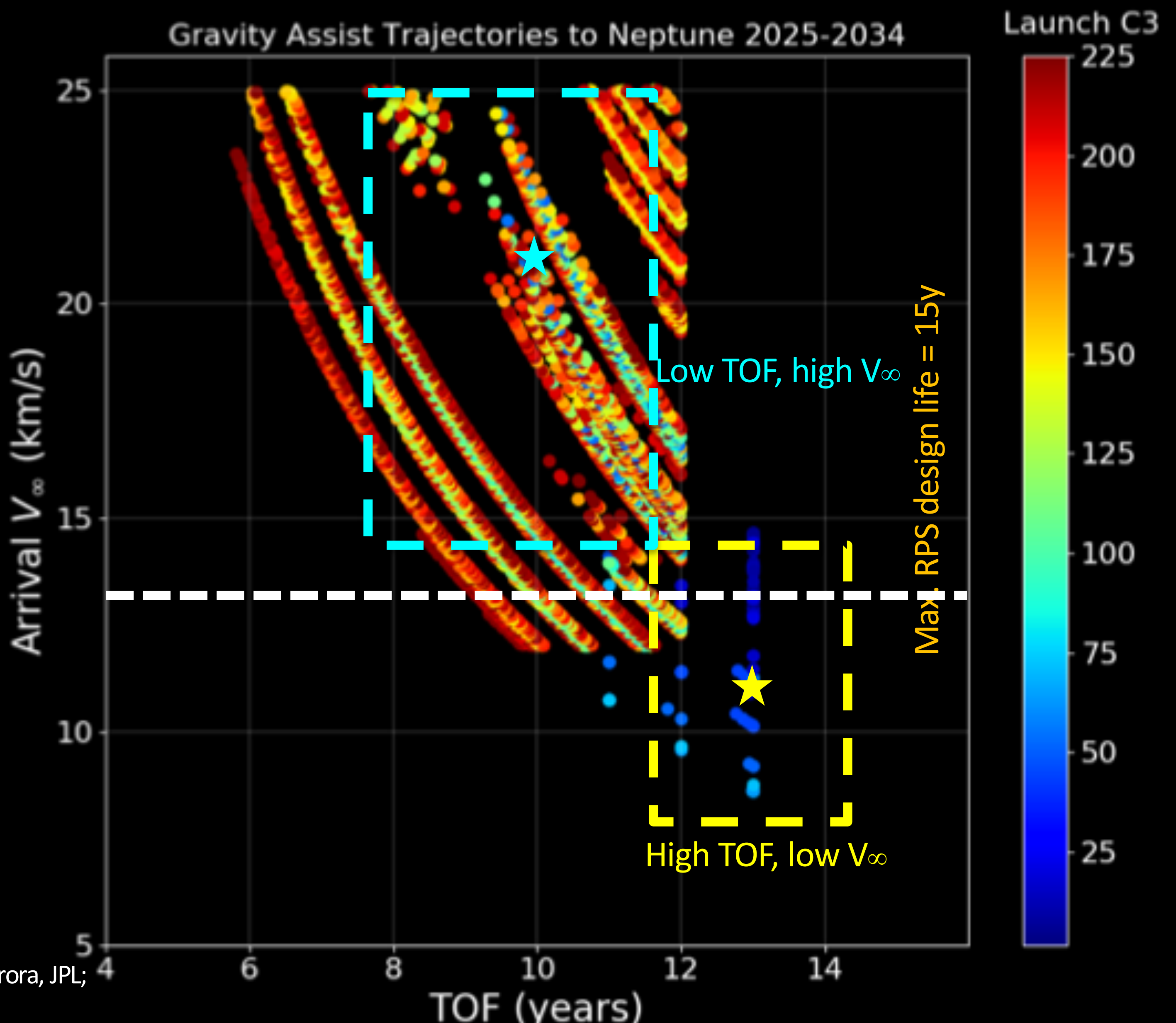
ΔV budget = 2.0 km/s

RCW	L/D	V_∞ (km/s)
2.0°	0.42	22.1
1.5°	0.32	22.3
1.0°	0.21	22.5



Hybrid Aerocapture Mission Concept

- TOF < 10y
- L/D: 0.2 – 0.4
- ΔV < 2 km/s



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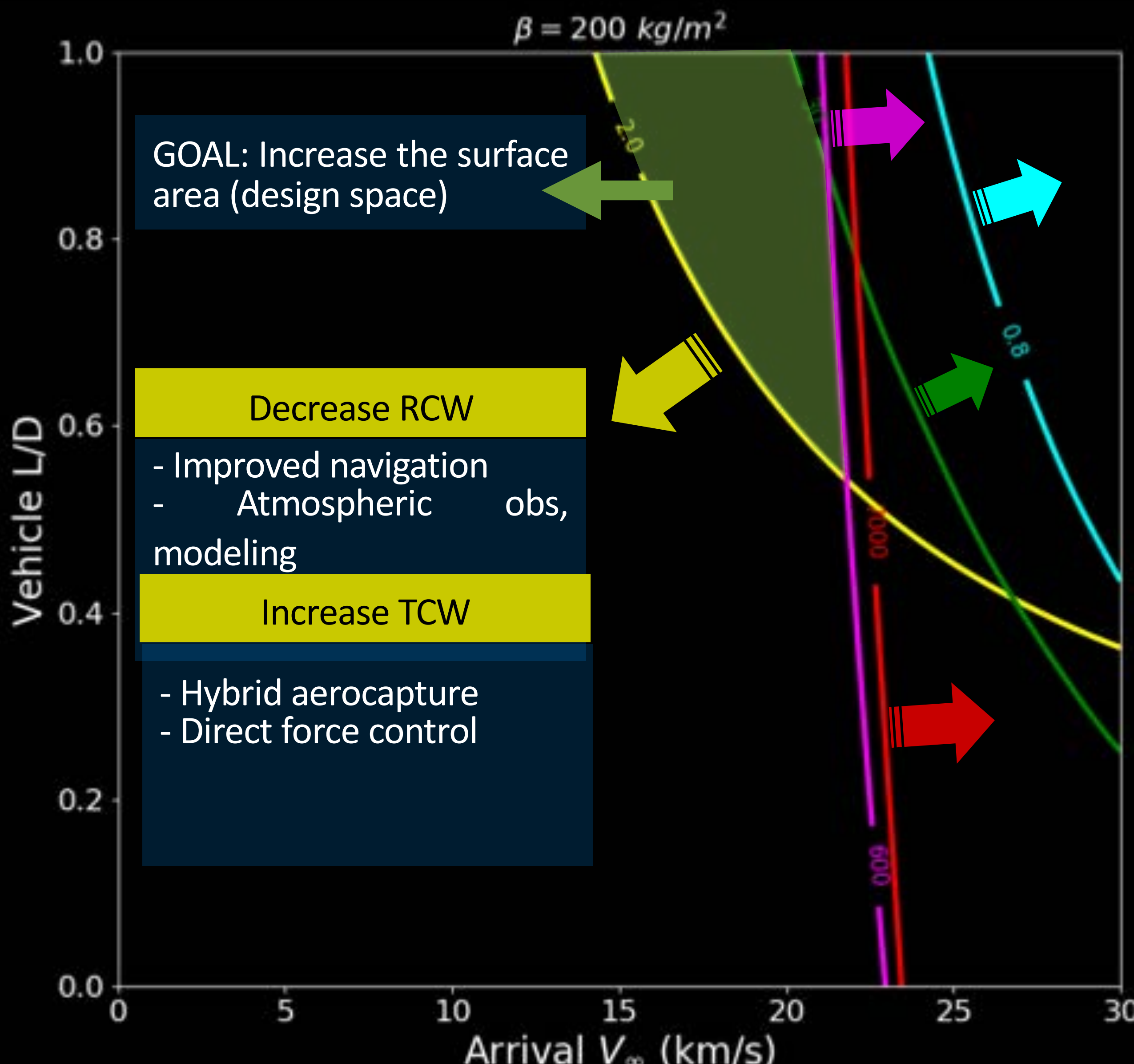
Summary of Options and Impact on Investment



GOAL: Increase the surface area (design space)

Decrease RCW

- Improved navigation
- Atmospheric obs, modeling

Increase TCW

- Hybrid aerocapture
- Direct force control

G-load

More Structural Mass
More Instrument Mass

Heat-Rate | **Stag. Press**

- New TPS Material Dev.
- Significant Investment

Heat-Load

More TPS material (more mass)

Large Launch Vehicle to deliver high V∞

Questions?

Crescents of Neptune and Triton acquired by Voyager 2 on its outbound journey from the Neptune system, Aug. 28, 1989.

Credits: NASA/JPL