



A relocatable lander to explore Titan's
prebiotic chemistry and habitability

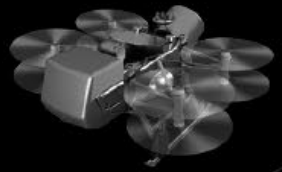
The Dragonfly Entry and Descent System

Summer Intern Presentation

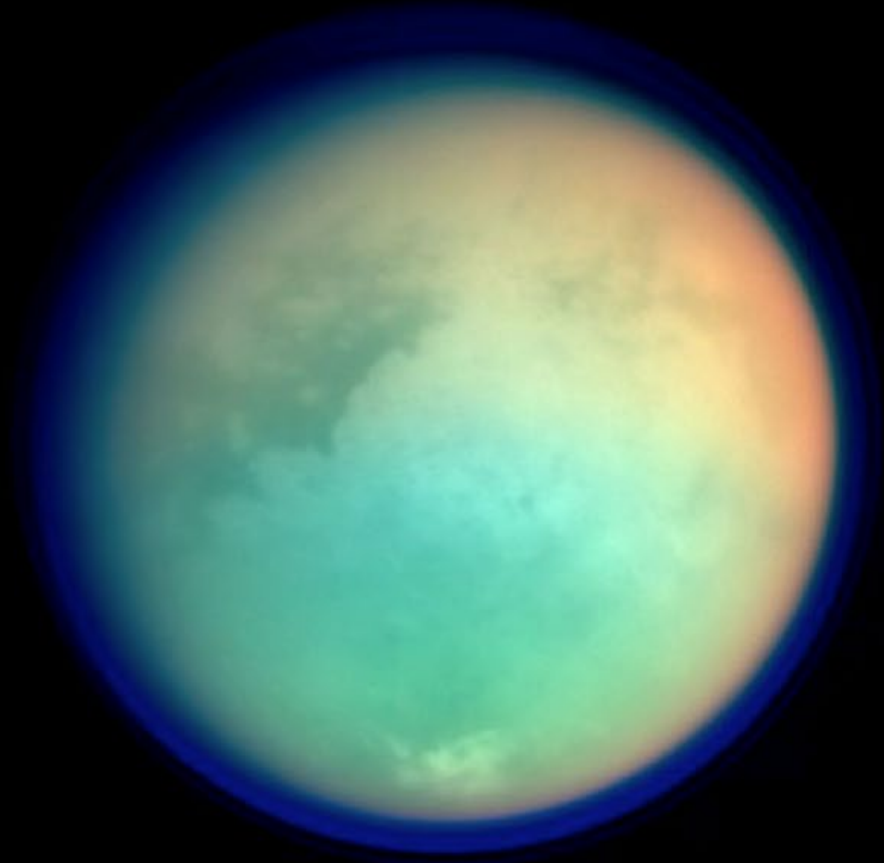
June 18, 2021

Michael Wright (Dragonfly EDL Phase Lead)

Titan : Largest of Saturn's Moons



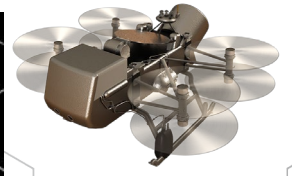
- Diameter = 5150 km
- Surface gravity = $1.35 \text{ m/s}^2 = 0.14 \text{ g}$
 - 14% of gravity at Earth's surface
 - 83% of gravity at Moon's surface
- Surface pressure = 1.5 bar
 - 1.5× pressure at Earth's surface
- Surface temperature = $94 \text{ K} = -290^\circ\text{F}$
 - Bedrock composition = water ice
 - Atmospheric composition = nitrogen, few % methane





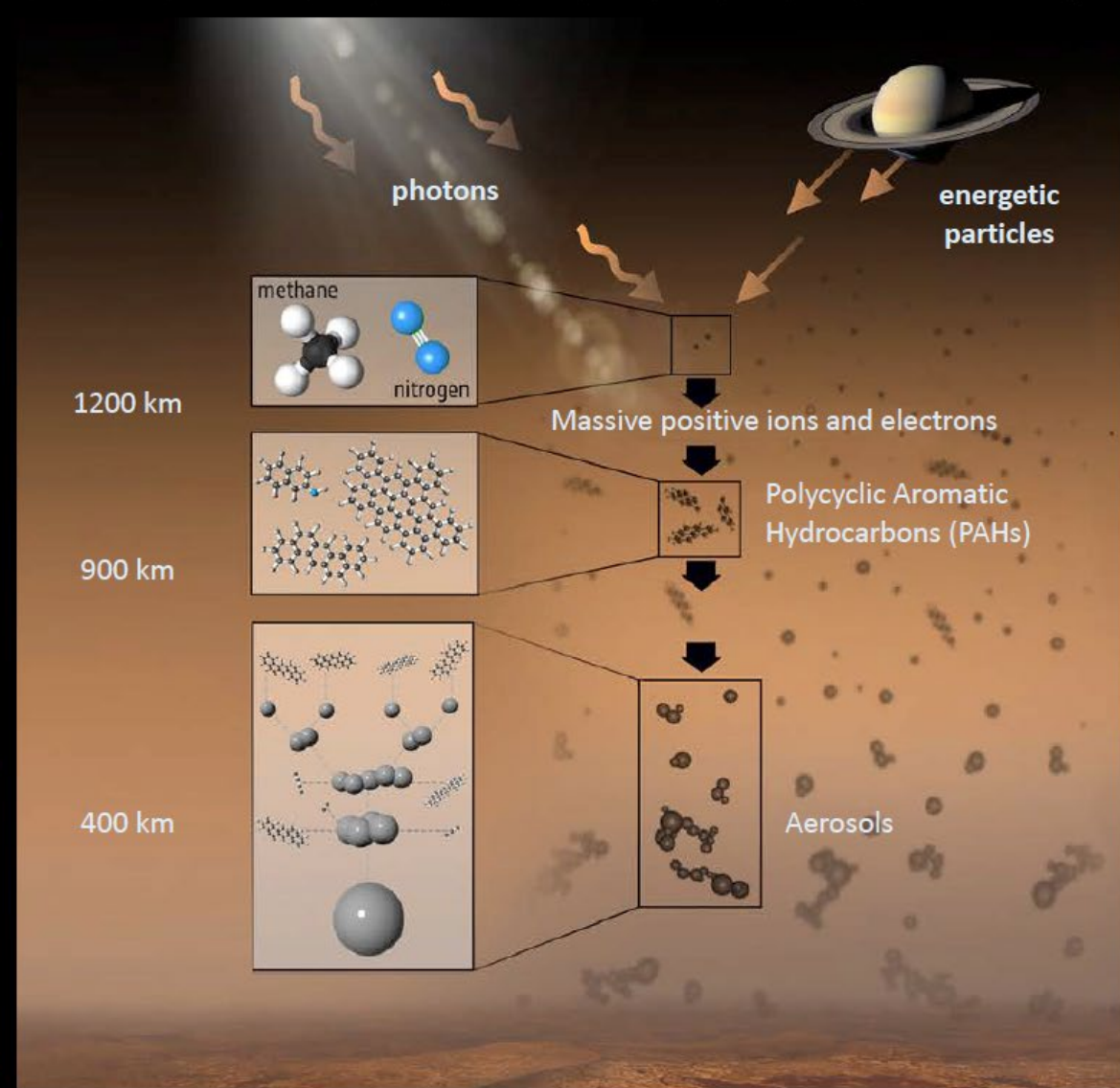
Why Titan?

Complex organic chemistry

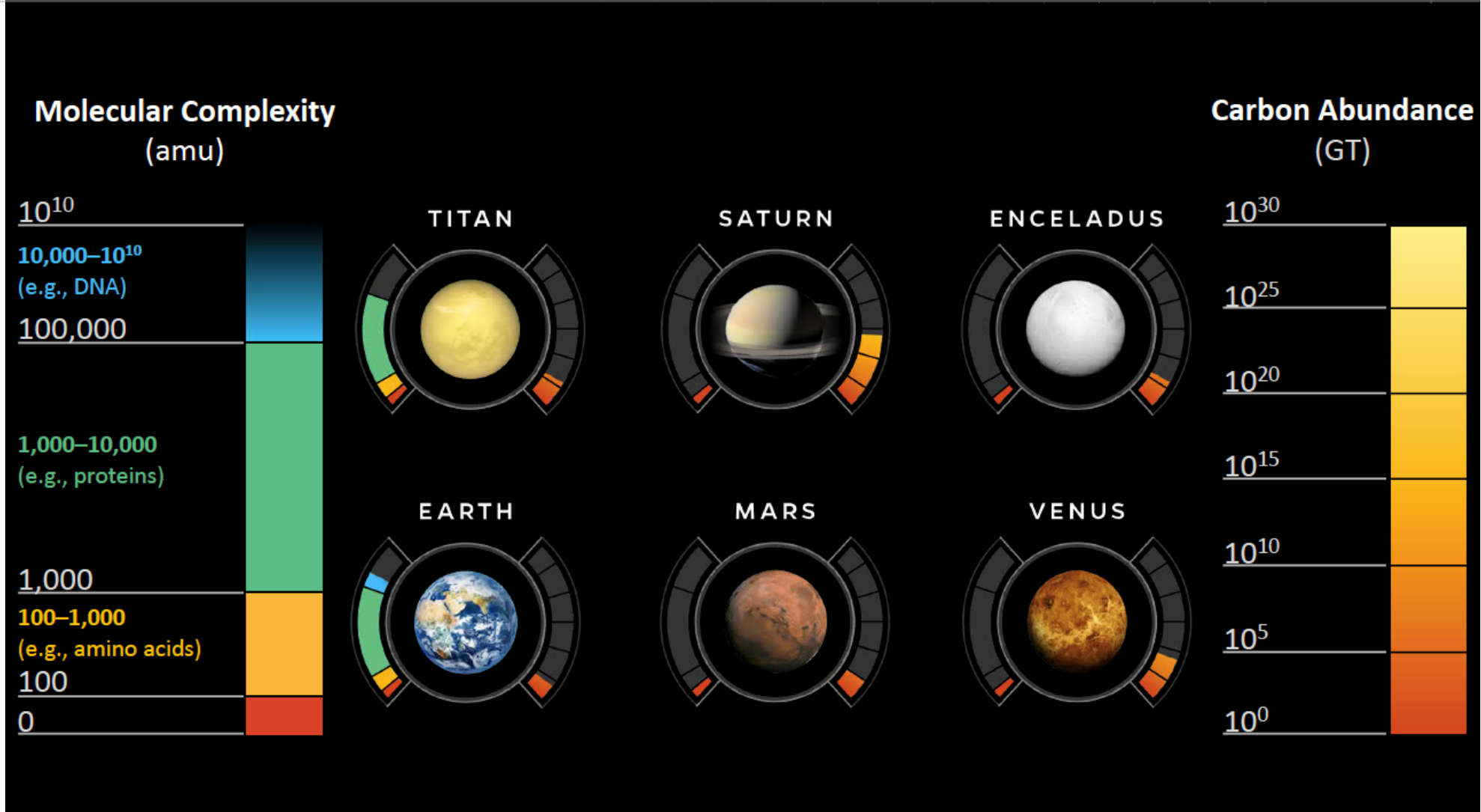
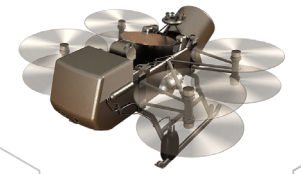


- Titan's unique atmosphere supports rich photochemistry
- Organic material produced in the atmosphere covers the surface
- Potential for organic compounds to have mixed with liquid water
- Materials are easily accessible on the surface

Titan is a singular destination for understanding the chemical processes on our own planet that supported the development of life



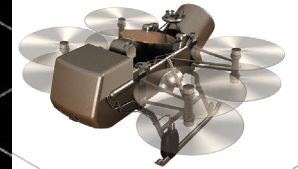
Titan's organic complexity approaches that on Earth



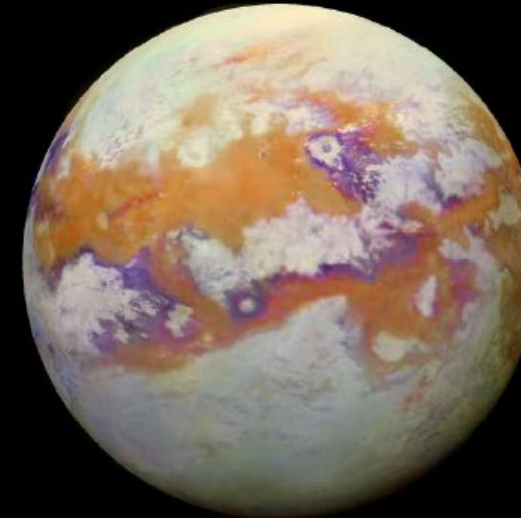
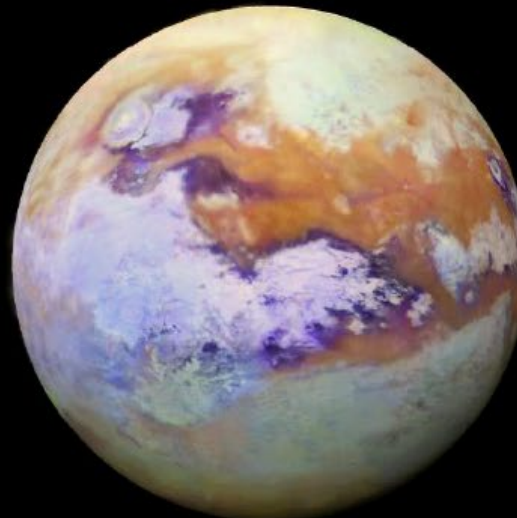
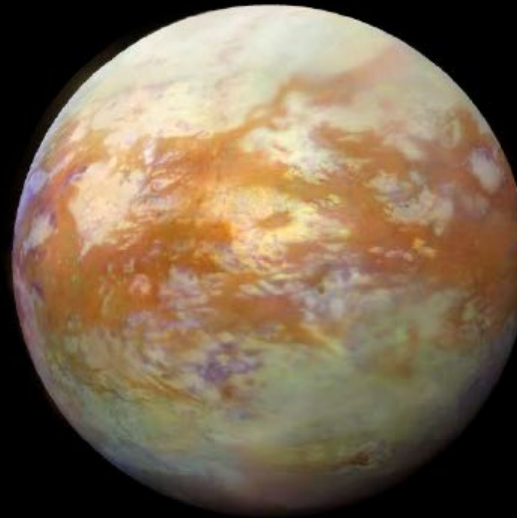


Why a Relocatable Lander?

Cassini-Huygens has revealed where to look for answers

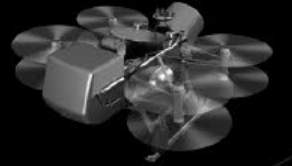


- Diverse surface materials and environments
- Earth-like variety of geologic processes
- Science challenge is to get instruments to multiple high-priority sites to sample materials and measure compositions



Mobility is key for science measurements

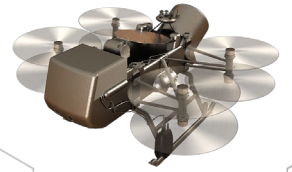
Lander with aerial mobility enables wide-ranging in situ exploration – key for science measurements



- Heavier-than-air mobility highly efficient at Titan
 - Atmospheric density 4x higher than Earth's reduces wing/rotor area required for lift
 - Gravity 1/7th Earth's → reduces power required



A Note on Scale



Ingenuity



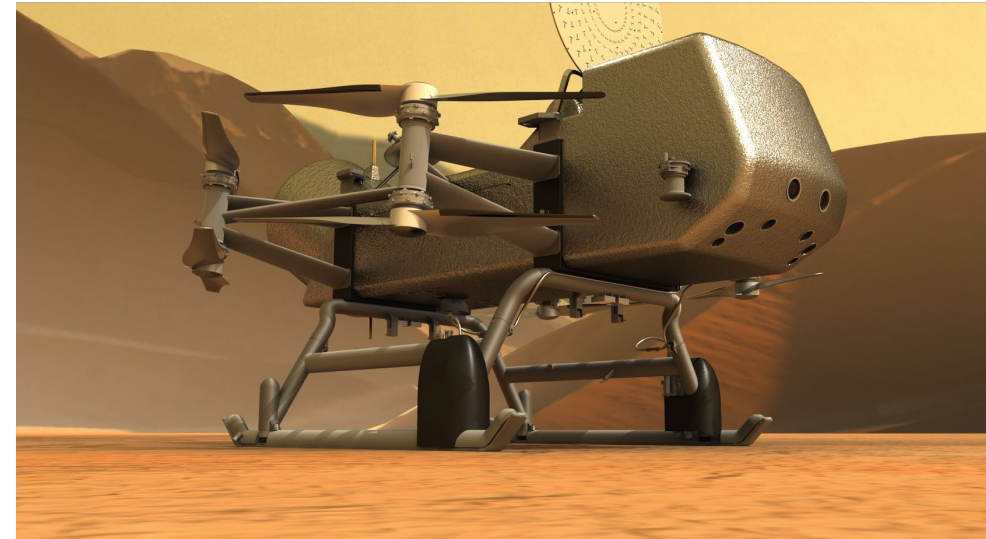
Key Dimensions:

Fuselage: 13.6x19.5x16.3 cm

Rotor Diameter: 1.2 m

Total Mass: 1.8 kg

Dragonfly



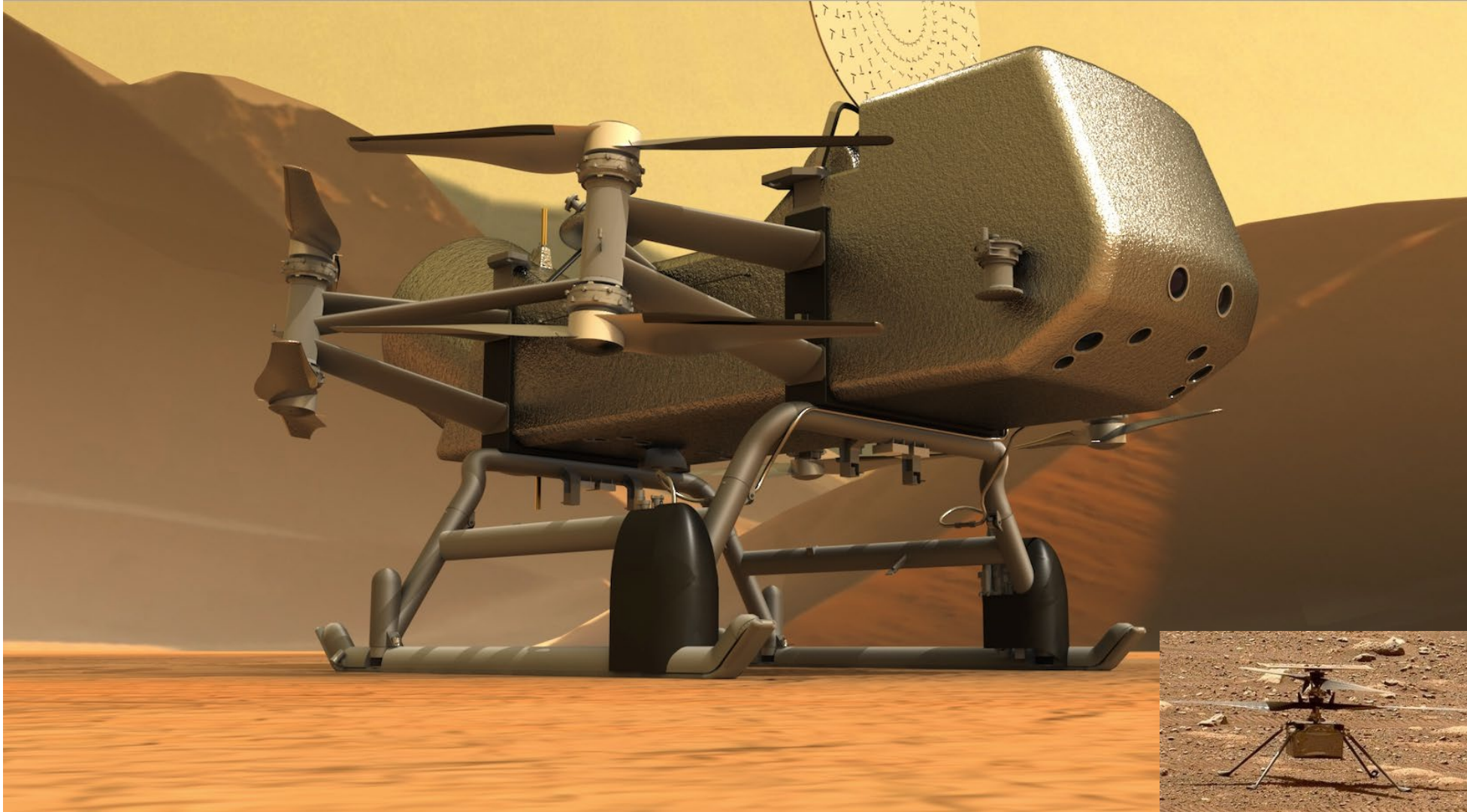
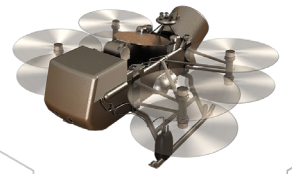
Key Dimensions:

Fuselage: ~4 m

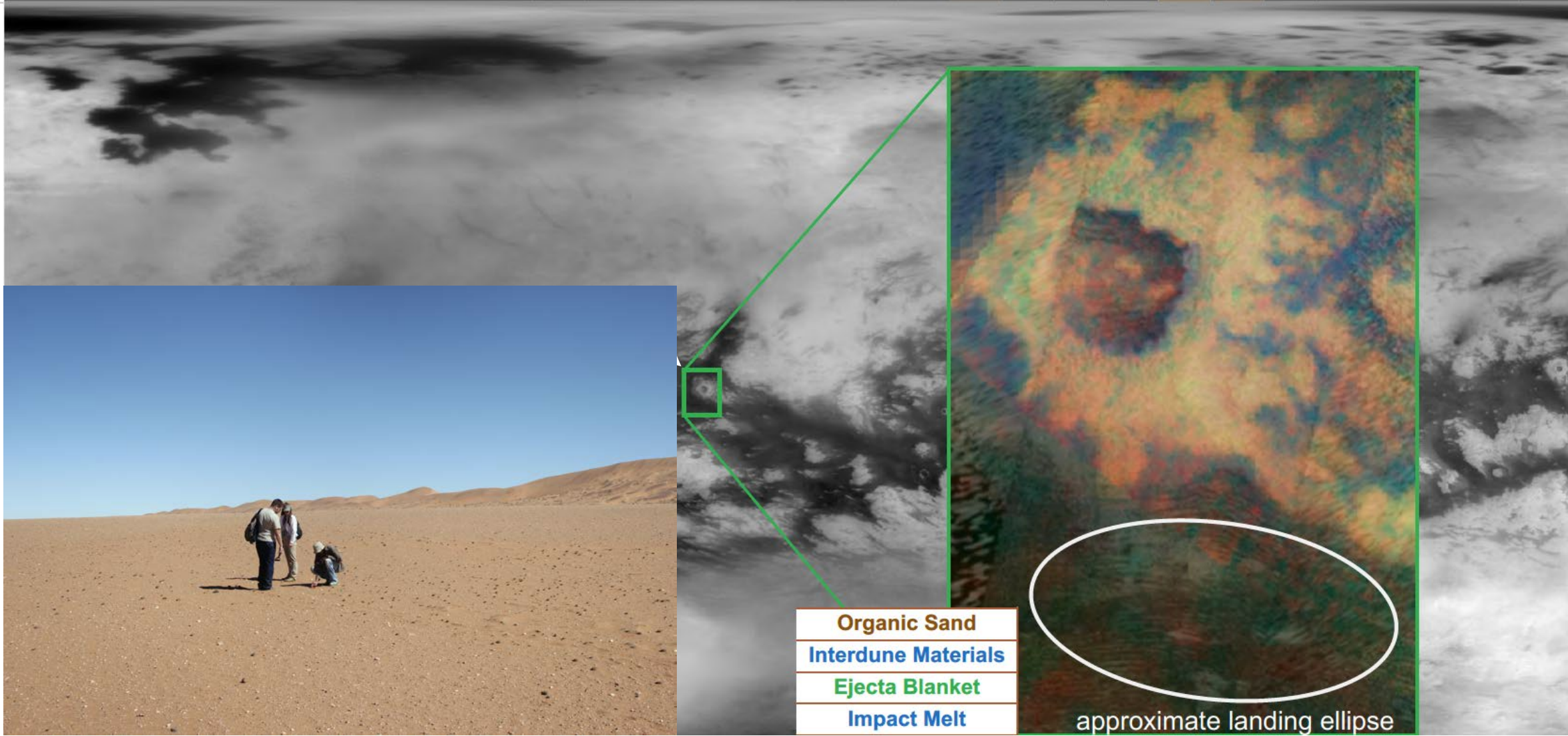
Rotor Diameter: ~80 cm

Total Mass: ~900 kg

A Note on Scale



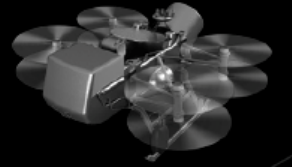
Organic sediments and materials with a water-ice component: dunes, interdunes, impact crater deposits



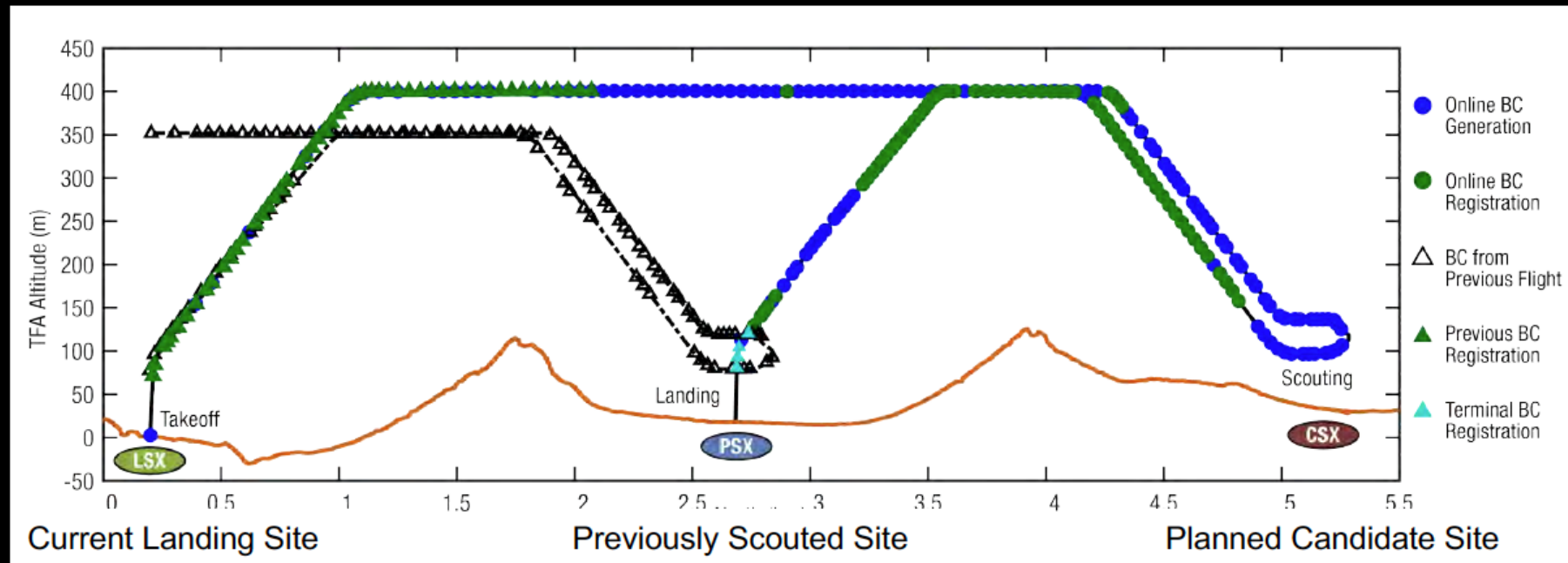
- Organic Sand
- Interdune Materials
- Ejecta Blanket
- Impact Melt

approximate landing ellipse

Dragonfly exploration strategy



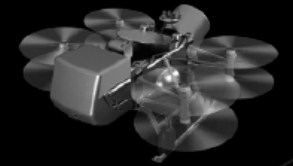
- “Leapfrog” exploration strategy to scout future landing sites
- 16-day Titan sols → relaxed operations schedule
 - Nominal flight schedule is once per 2 Tsols (~1 flight / Earth month)
 - Most of time is spent on the surface making science measurements





How Will We Get it There?

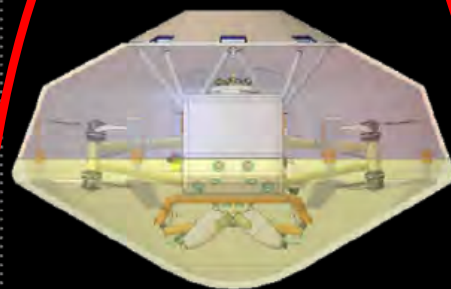
Dragonfly mission elements



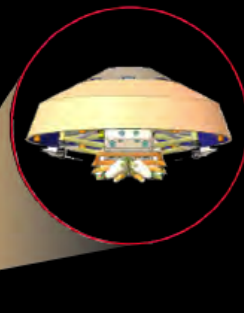
Spacecraft =
Cruise Stage + Entry Vehicle



Entry Vehicle =
EDL Assembly + Lander



EDL assembly includes aeroshell (heatshield and backshell), parachutes, ESI, and support equipment.



Rotorcraft Lander
Surface configuration with HGA deployed

MMRTG

- Charges battery to power flight and science activities
- Waste heat maintains nominal thermal environment in lander

Direct-to-Earth communication

- HGA articulation used to target cameras for panoramas of surrounding terrain

Measurements on surface and in flight

- Aerial imaging
- Atmospheric profiles

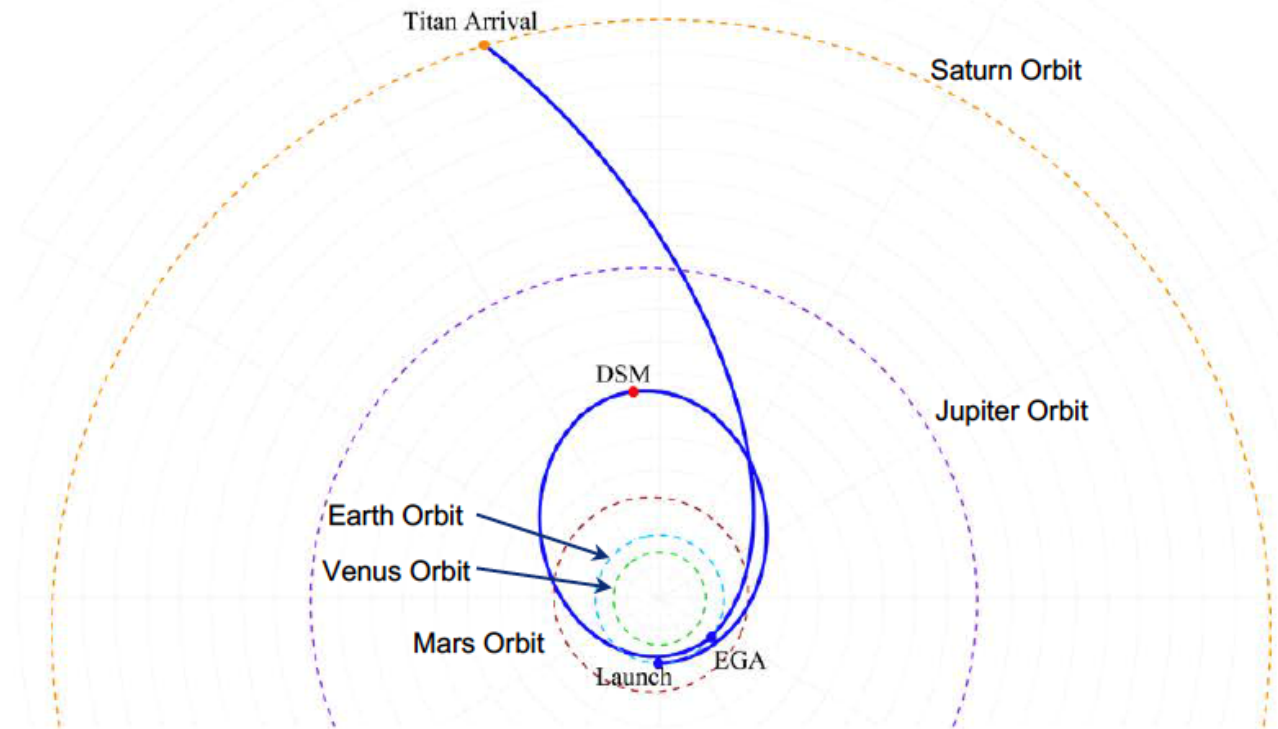
Interplanetary trajectory



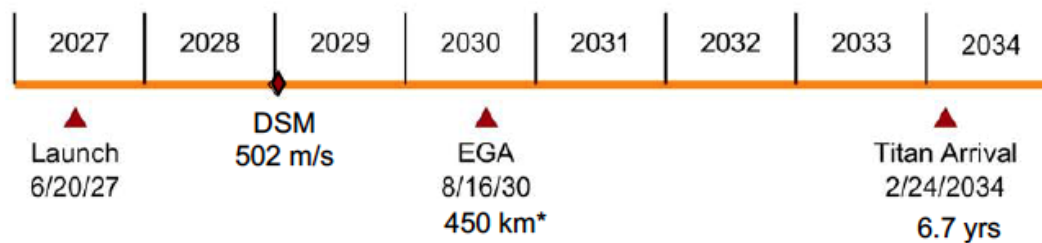
2027 ΔV -EGA (requires Heavy Lift Launch Vehicle)

Launch Period: 6/20/2027 – 7/10/2028 (21 days)

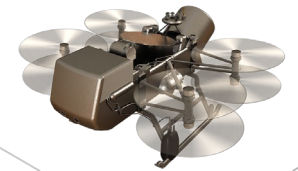
Max C3: 55.0 km²/s²



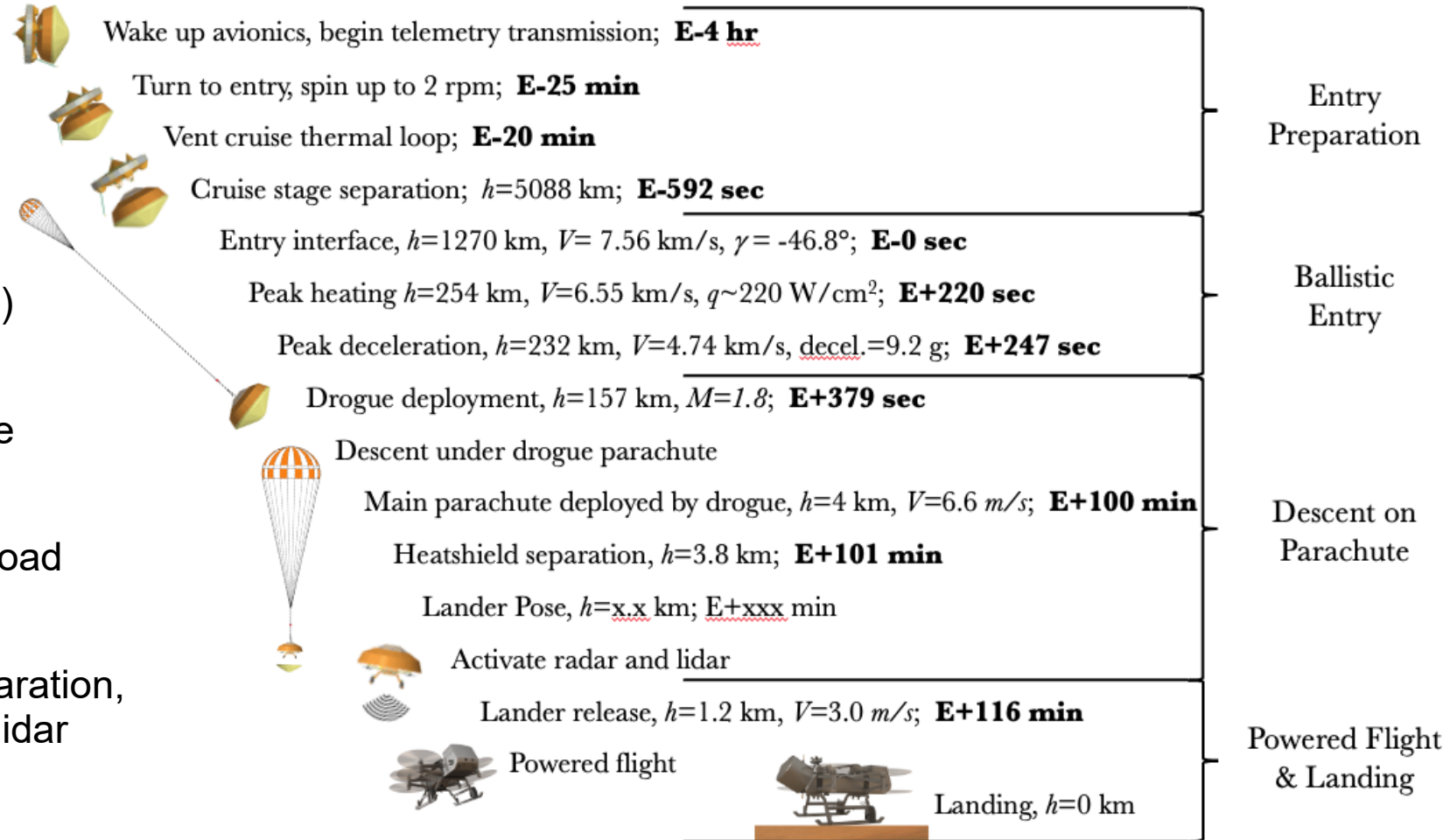
launch period



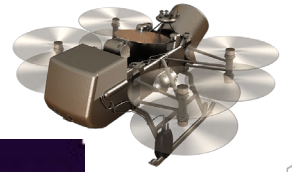
EDL Concept of Operations



- Entry Interface 1270 km
 - Spin-stabilized to 2 rpm
- Entry heat pulse: 260 sec.
 - Peak heat flux $>250 \text{ W/cm}^2$ (margined)
- Drogue deploy E+6 min, \sim Mach 1.5.
 - More than 90 minutes spent on drogue
- Main chute deploy E+100 min.
 - Low velocity (6.6 m/s) & low opening load
- Lander Release E+116 min.
 - Plenty of time to stage heatshield separation, pose the lander, and activate radar & lidar



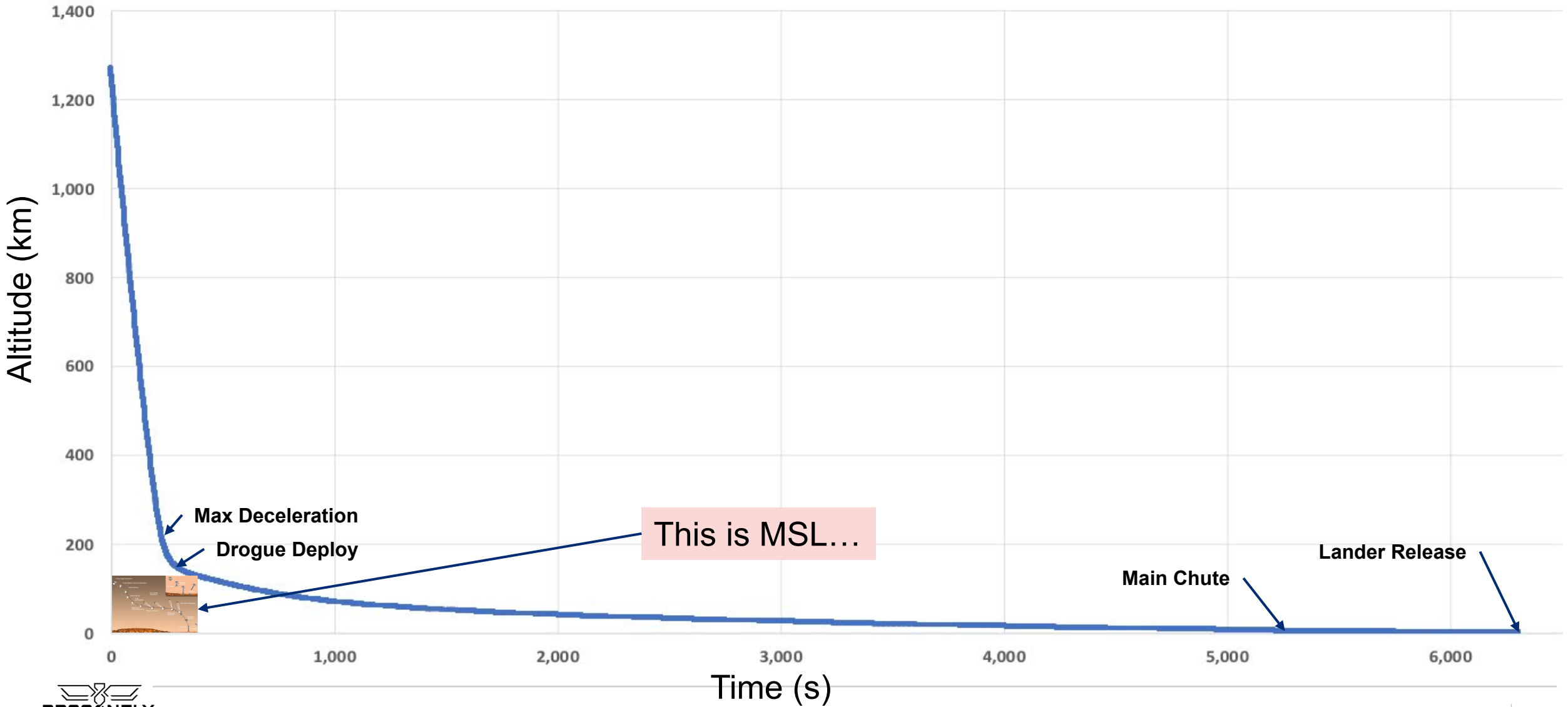
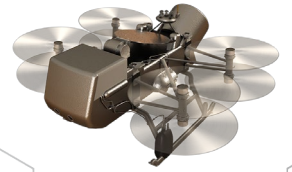
EDL Video



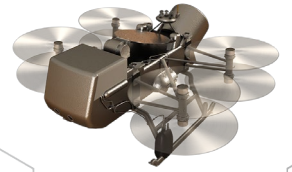
Still from Video

MAIN CHUTE DEPLOY
4 km | 7.3 m/s

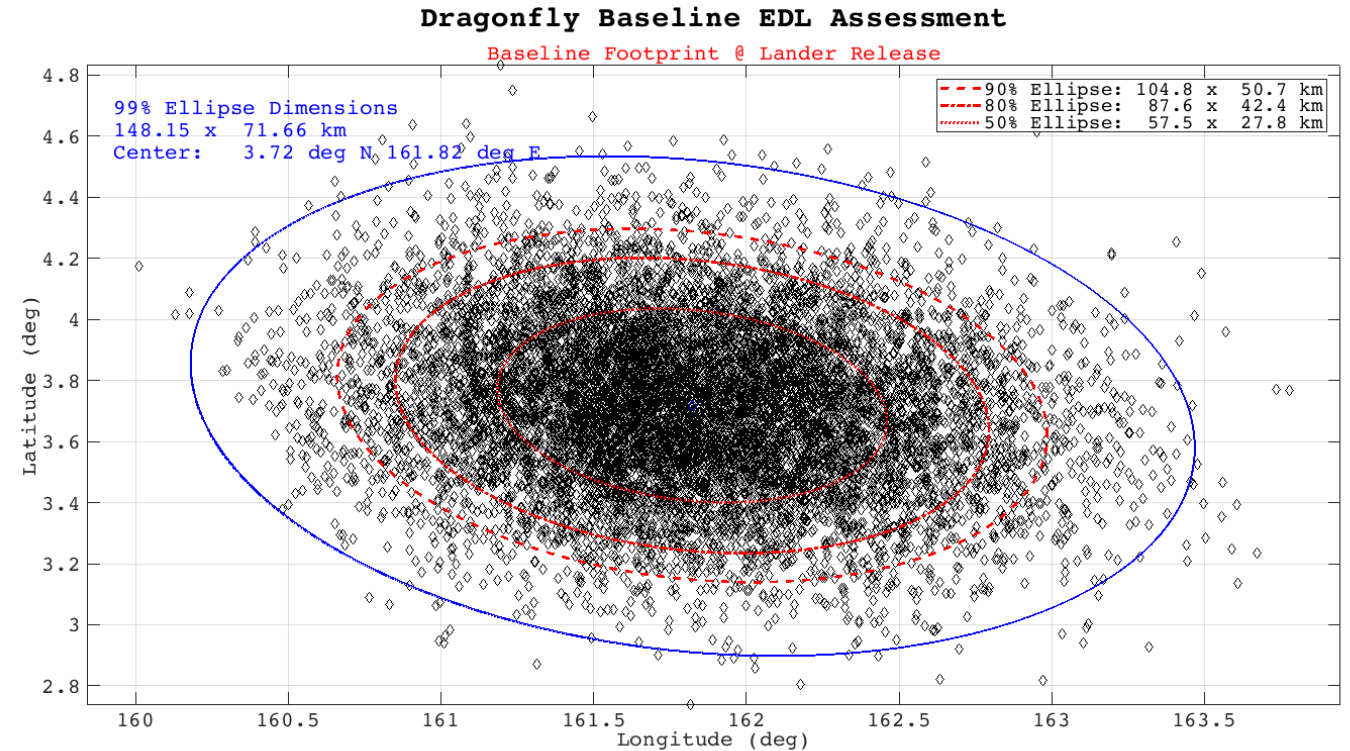
EDL Timeline Comparison



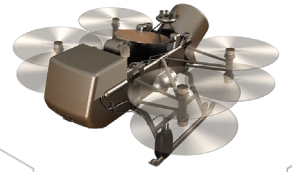
EDL Monte Carlo Analysis



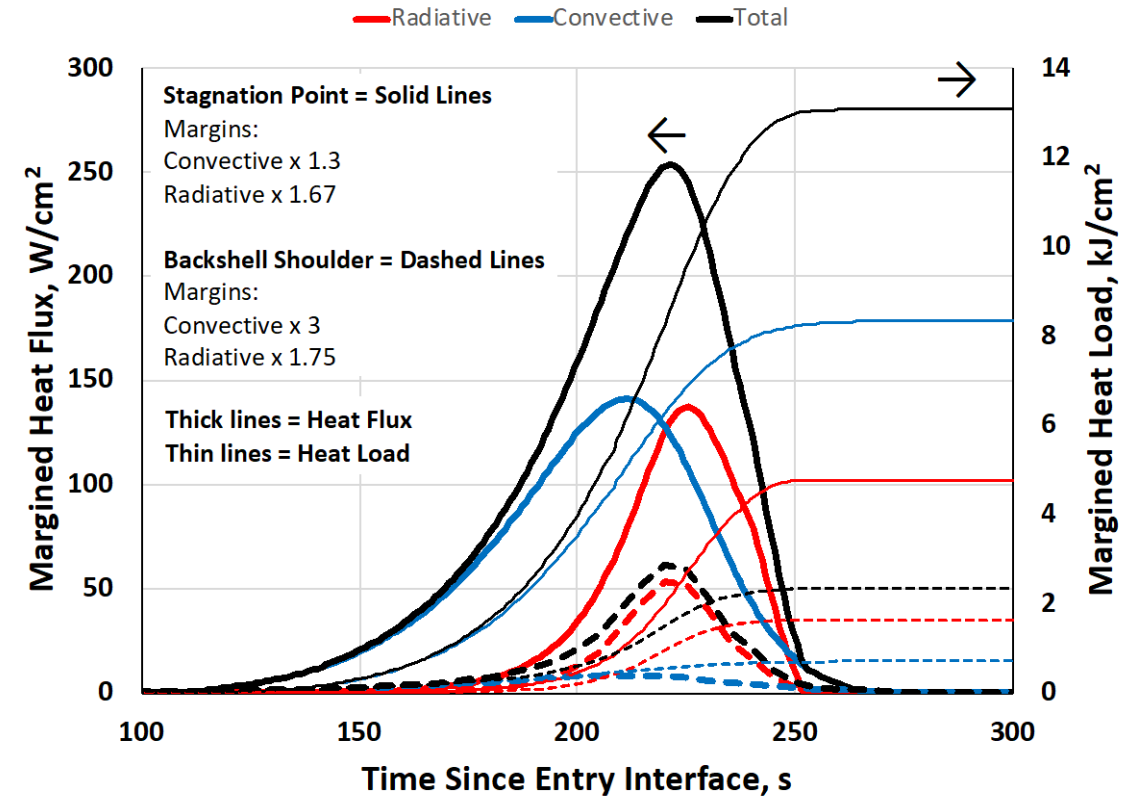
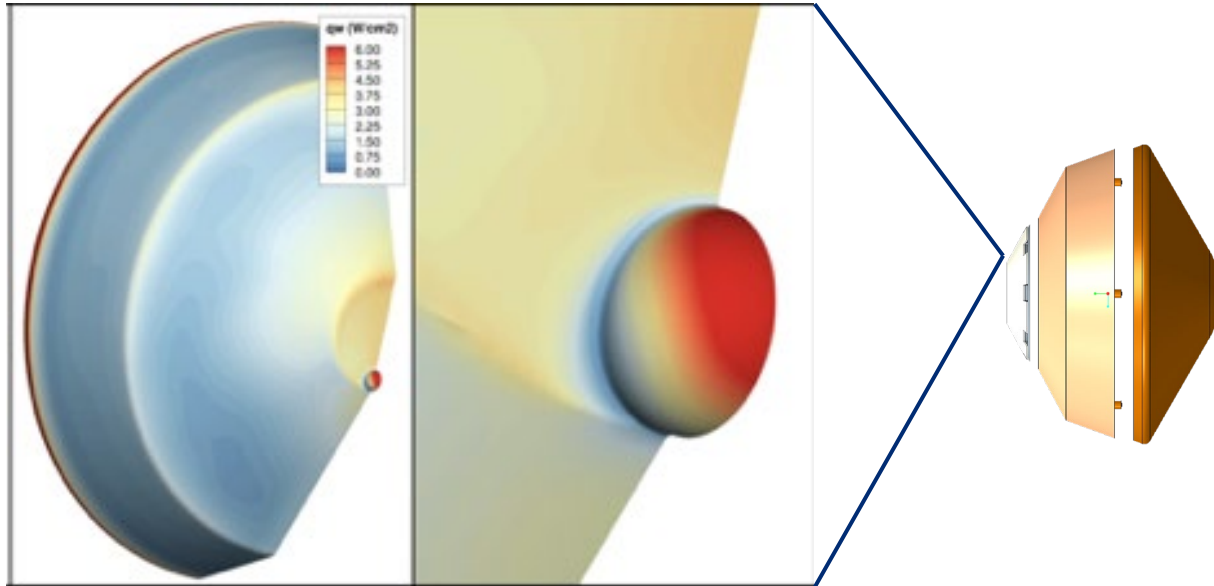
- Full analysis in POST2 from entry interface to lander release
- Delivery accuracy ~149x72 km at release
 - Affords lander sufficient accuracy to navigate to selected landing zone
- Dispersions sources
 - Latitude: arrival navigation errors
 - Longitude: on-chute winds



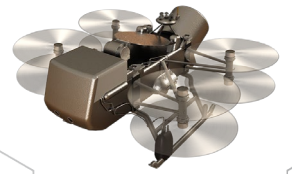
Aerothermodynamics



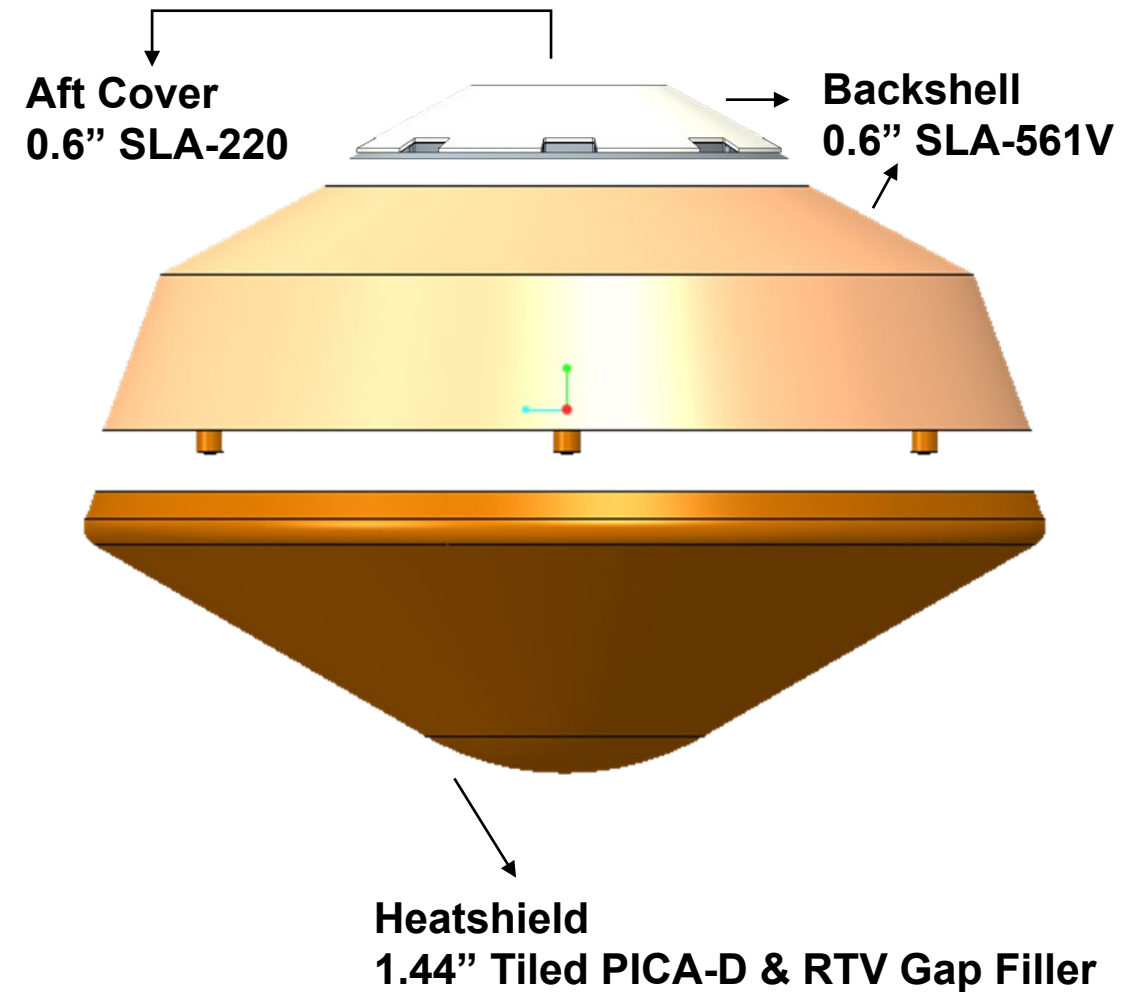
- NASA standard aerothermal (convective + radiative) models tuned for Titan entry conditions
- Total heating calculated over entire aeroshell
 - Conservative margins applied
 - Margined values within tested limits for chosen TPS



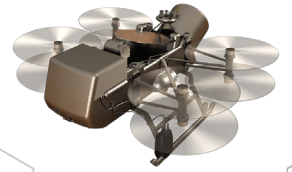
Thermal Protection System



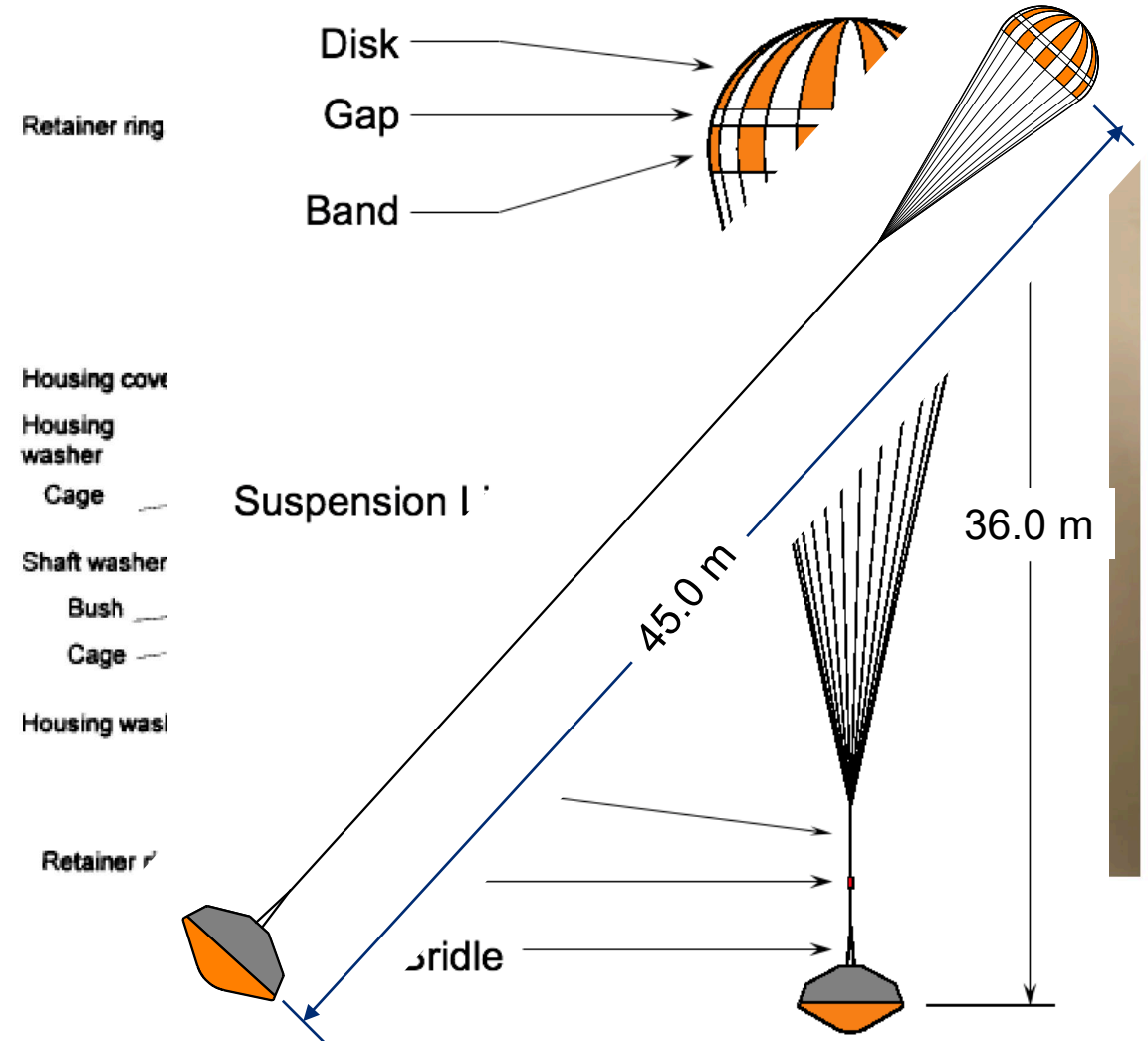
- Three TPS materials:
 - High TRL and used well within tested limits
 - Arc jet testing confirms performance
 - SMD funded PICA-D is a drop-in replacement for heritage PICA; fabrication of DF billets will start this year
- TPS sizing & margin analysis uses mature processes developed during MSL/Orion
 - Design thicknesses carry unallocated margin
- TPS manufacture, testing, qualification and assembly follow standard procedures developed at LM and NASA ARC



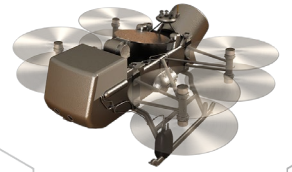
Parachute Deceleration System



- Drogue Parachute (5.4 m DGB)
 - Mortar deploy via trigger at Mach 1.5
 - Functions: stabilize capsule, decelerate through atmosphere, extract main chute
- Main Parachute (13.44 m DGB)
 - Low speed subsonic deploy
 - Possible anti-inversion netting
- Huygens heritage swivels prevent line twisting



Key EDL Challenges (time sequence order)



- **Quantifying heating due to shock layer radiation**

- dominated by CN-red and violet emission
- Less validated than air or CO2

- **TPS material qualification**

- Non-oxidizing environment, radiation dominated heating

- **EDL Phase thermal analysis**

- Long descent time, cryogenic exterior, internal heat source

- **Transonic-subsonic aerodynamics**

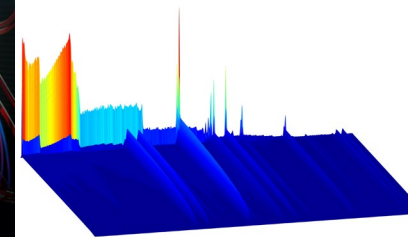
- Drogue chute is relatively smaller than that for Genesis
- Initial analysis shows that capsule dynamics dominates system dynamics
- Heritage ADB is not high fidelity in this speed regime

- **Very long inflation time and possible high angle of attack at deploy for main chute**

- Anti-inversion netting baselined
- Drop testing is planned



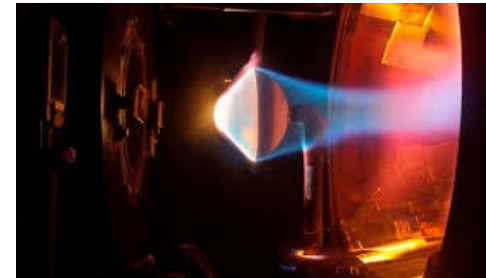
EAST Testing*



VST/TDT Testing



Arc Jet / Lamp Testing

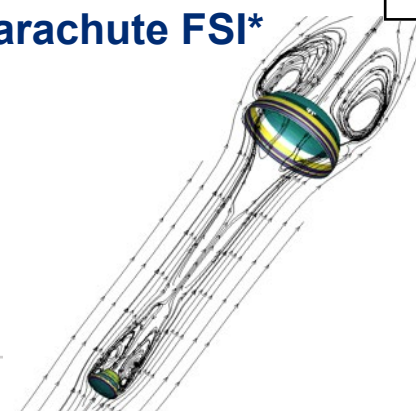


3D Material Response*

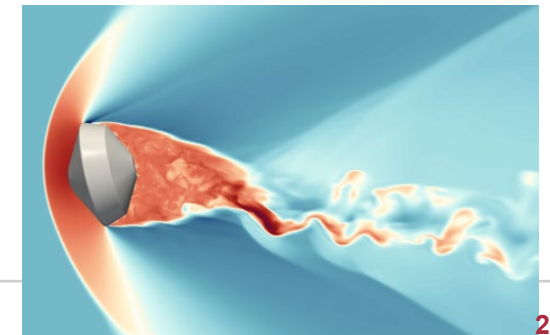


Drop Test

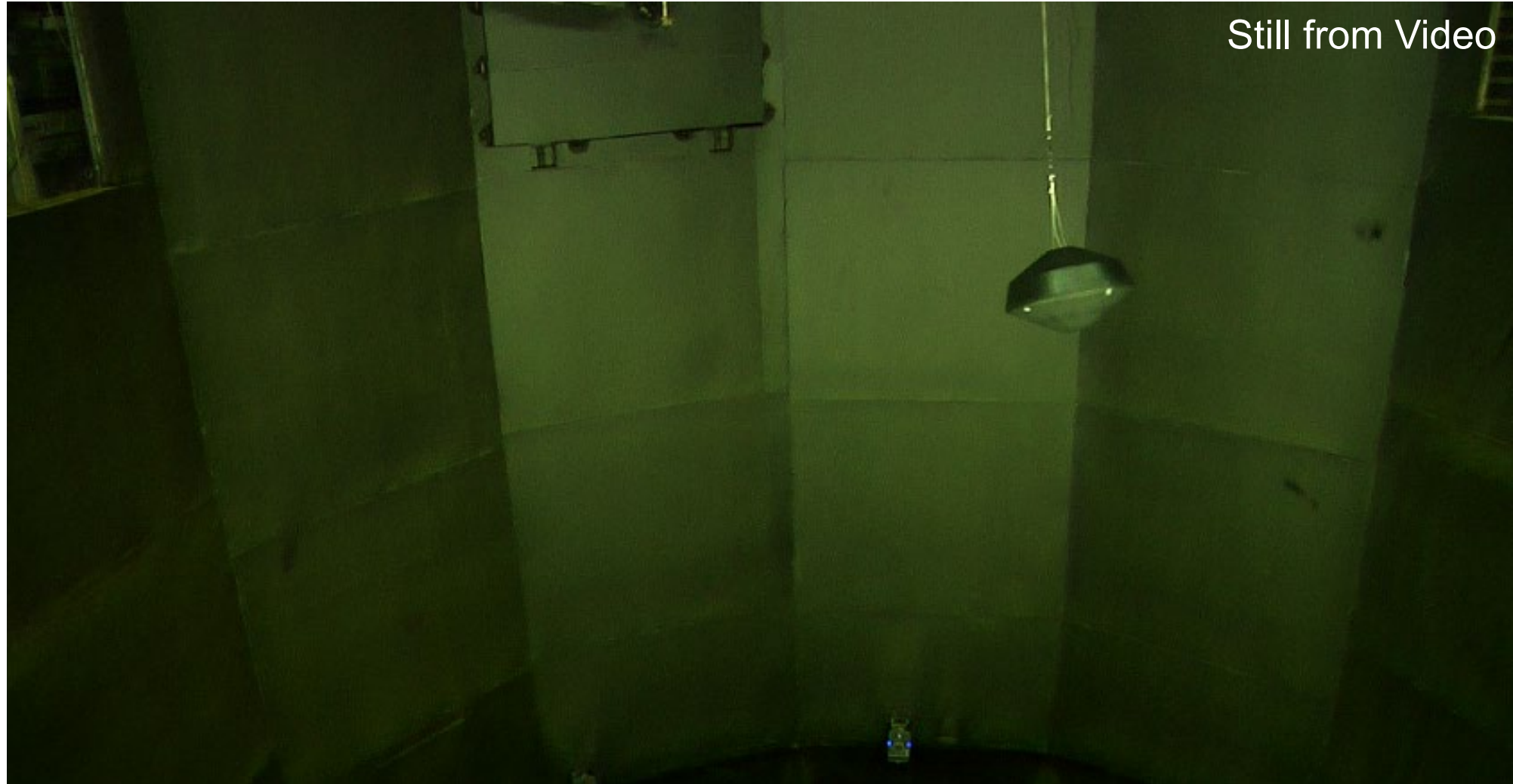
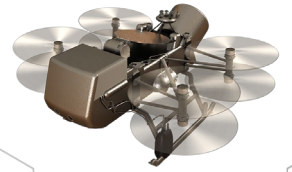
Parachute FSI*



Free Flight CFD*



Vertical Spin Testing – Drogue Chute Dynamics





Any Questions?

The logo features a stylized dragonfly in yellow, composed of multiple parallel lines that create a sense of depth and movement. The dragonfly is positioned centrally above the text.

DRAGONFLY

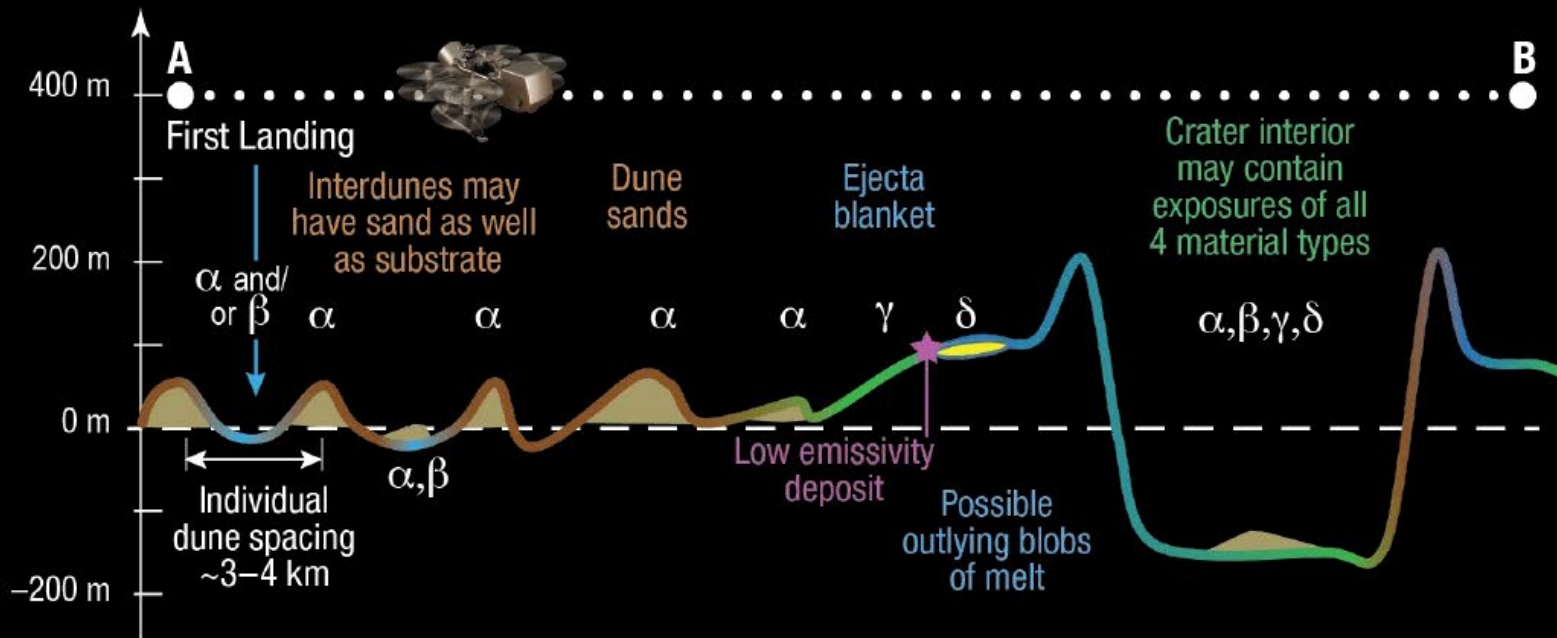


Backup

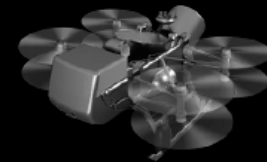
Exploration strategy



- ~3.25 years of exploration
 - 74 Tsols (Titan days) of science operations
 - Traverse distance up to ~180 km
 - Exploration of ~25-30 unique sites

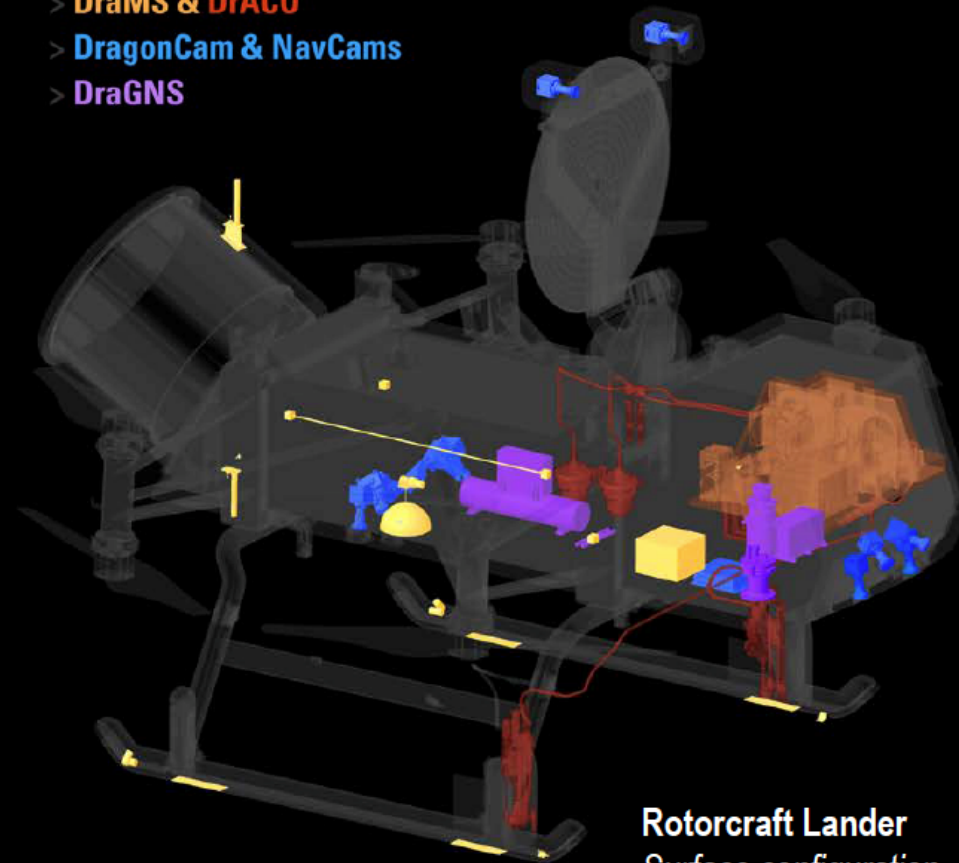


Multidisciplinary science measurements at dozens of potential landing sites



- DraMS: Mass Spectrometer
- DrACO: Drill for Acquisition of Complex Organics
 - GSFC, Honeybee – MSL SAM, ExoMars MOMA
- DraGNS: Gamma-ray Neutron Spectrometer
 - APL, LLNL – MESSENGER GRNS, Psyche GRNS
 - GSFC, Schlumberger – Pulsed Neutron Generator
- DraGMet: Geophysics & Meteorology Package
 - APL sensor suite + JAXA Lunar-A seismometer
- DragonCam: Camera Suite
 - MSSS – OSIRIS-REx ECAM, MSL Mastcam, Mars 2020 descent camera

- > DraGMet
- > DraMS & DrACO
- > DragonCam & NavCams
- > DraGNS



Rotorcraft Lander
Surface configuration
with HGA deployed