DRAGONFLY

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

The Dragonfly Entry and Descent System

Summer Intern Presentation

June 30, 2021

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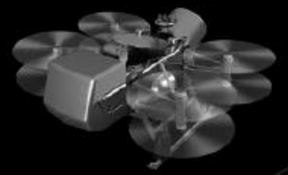
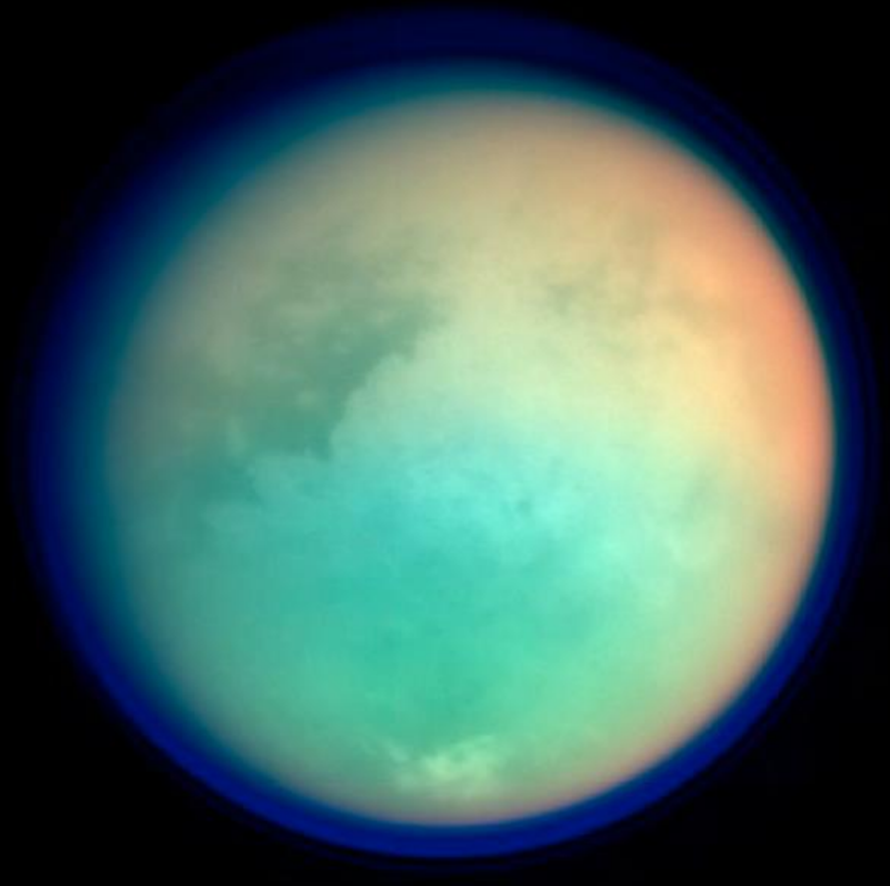
Titan : Largest of Saturn's Moons



- Diameter = 5150 km
- Surface gravity = 1.35 m/s2 = 0.14 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 (4× density)
- Surface temperature = 94 K = –290°F
  - Bedrock composition = water ice
  - Atmospheric composition = nitrogen, few % methane

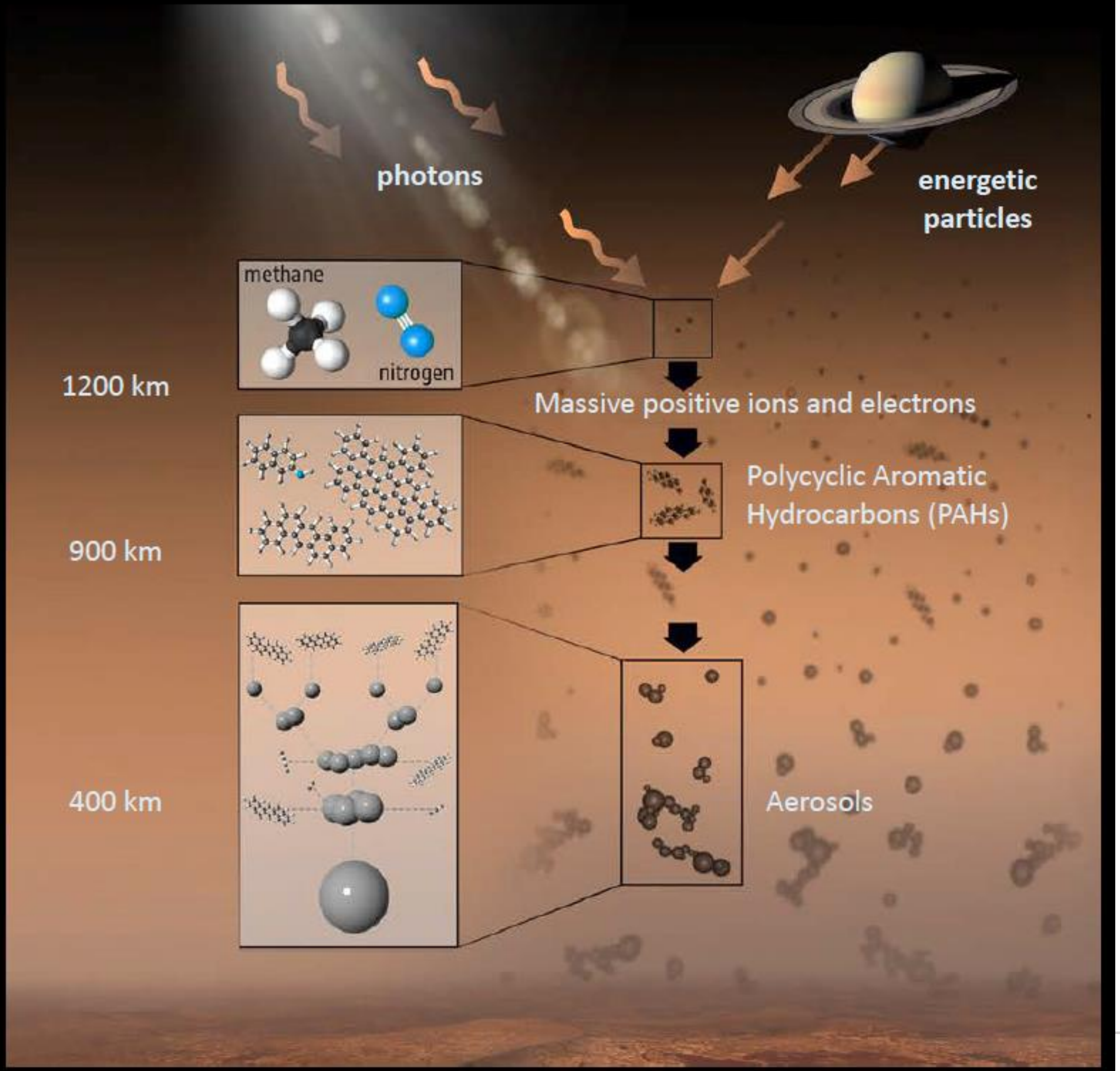


Why Titan?

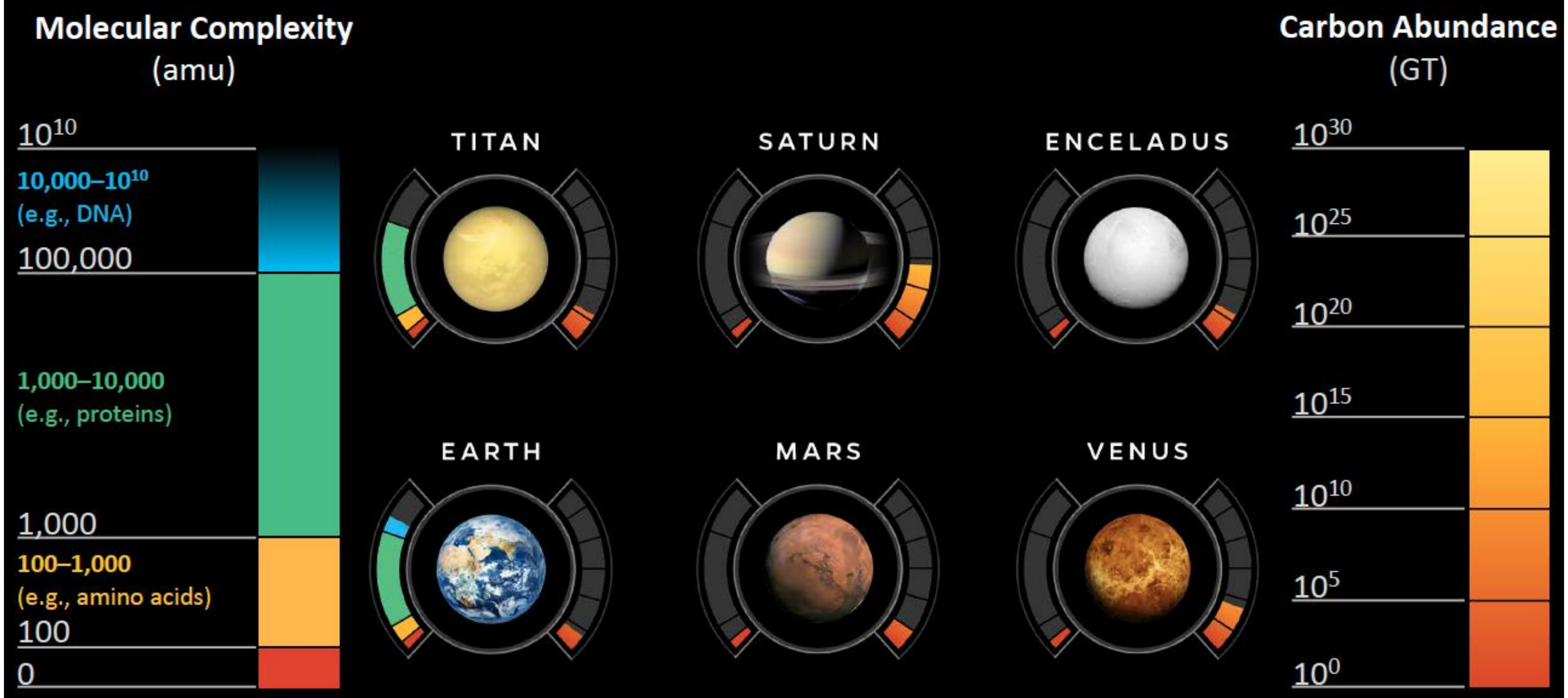
Complex organic chemistry

- 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



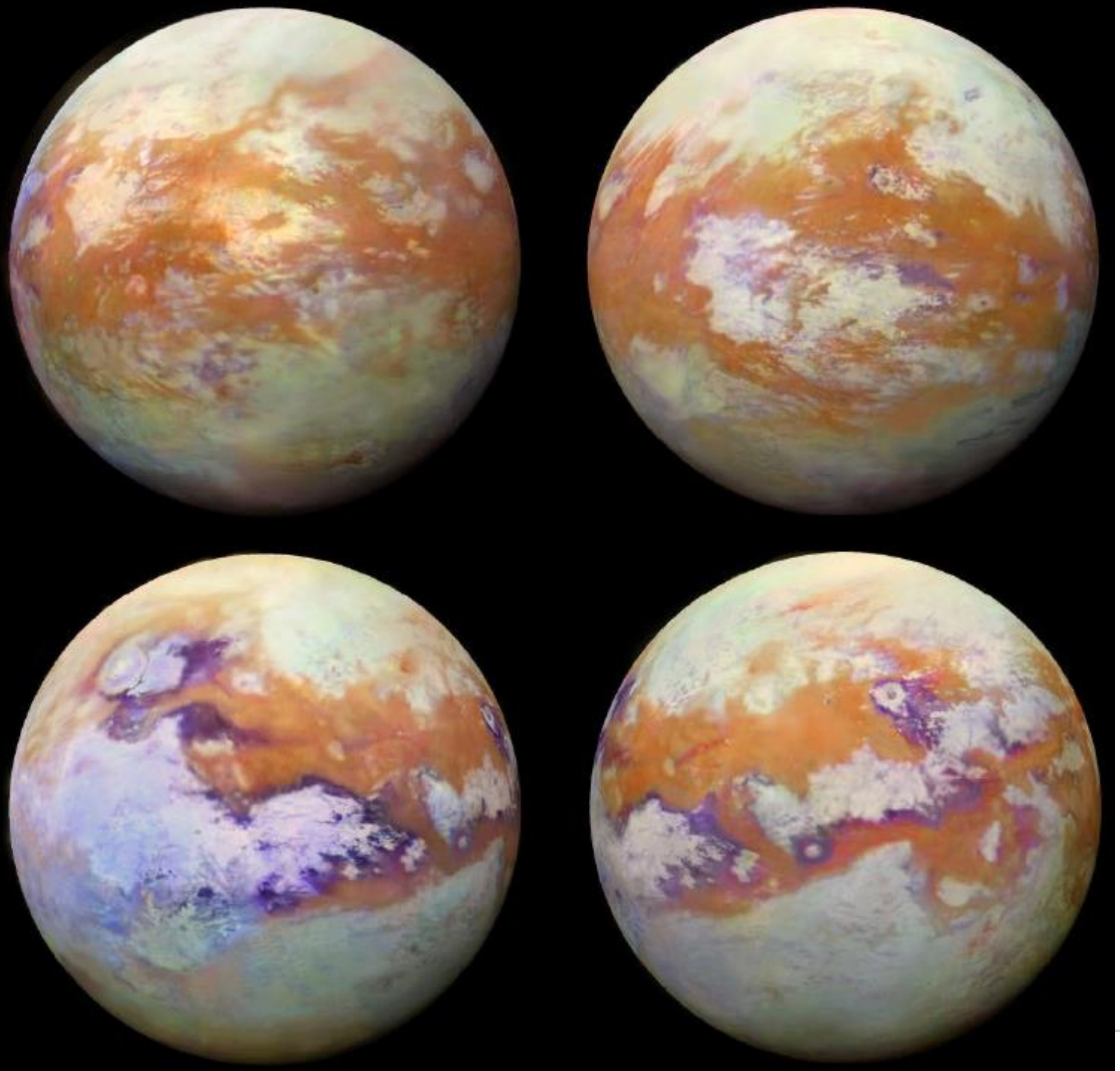
Why a Relocatable Lander?

DRAGONFLY

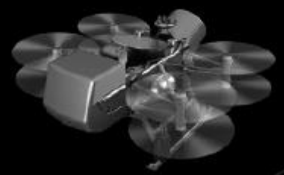
Cassini-Huygens has revealed where to look for answers

- 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

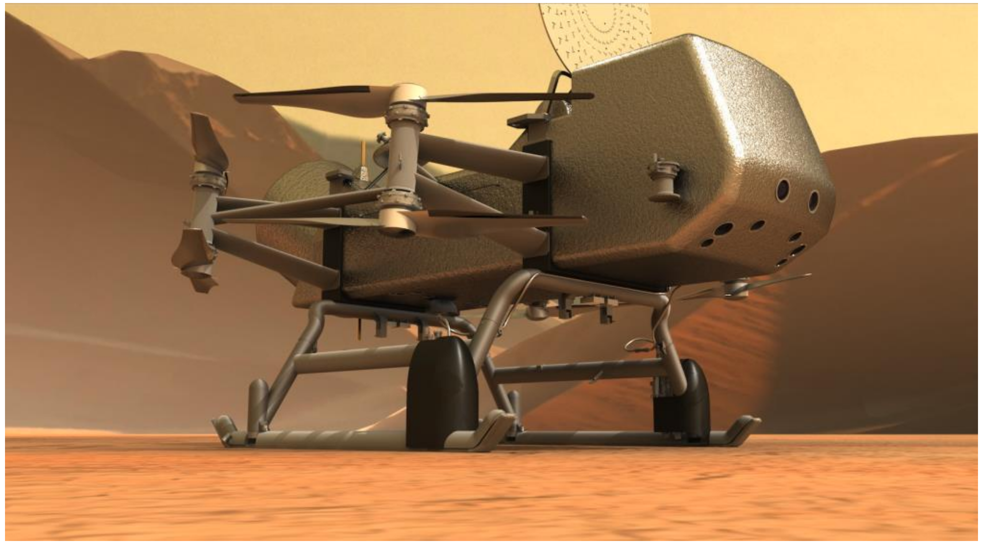
A Note on Scale

Ingenuity

Key Dimensions:

Fuselage: 13.6x19.5x16.3 cm
Rotor Diameter: 1.2 m
Total Mass: 1.8 kg

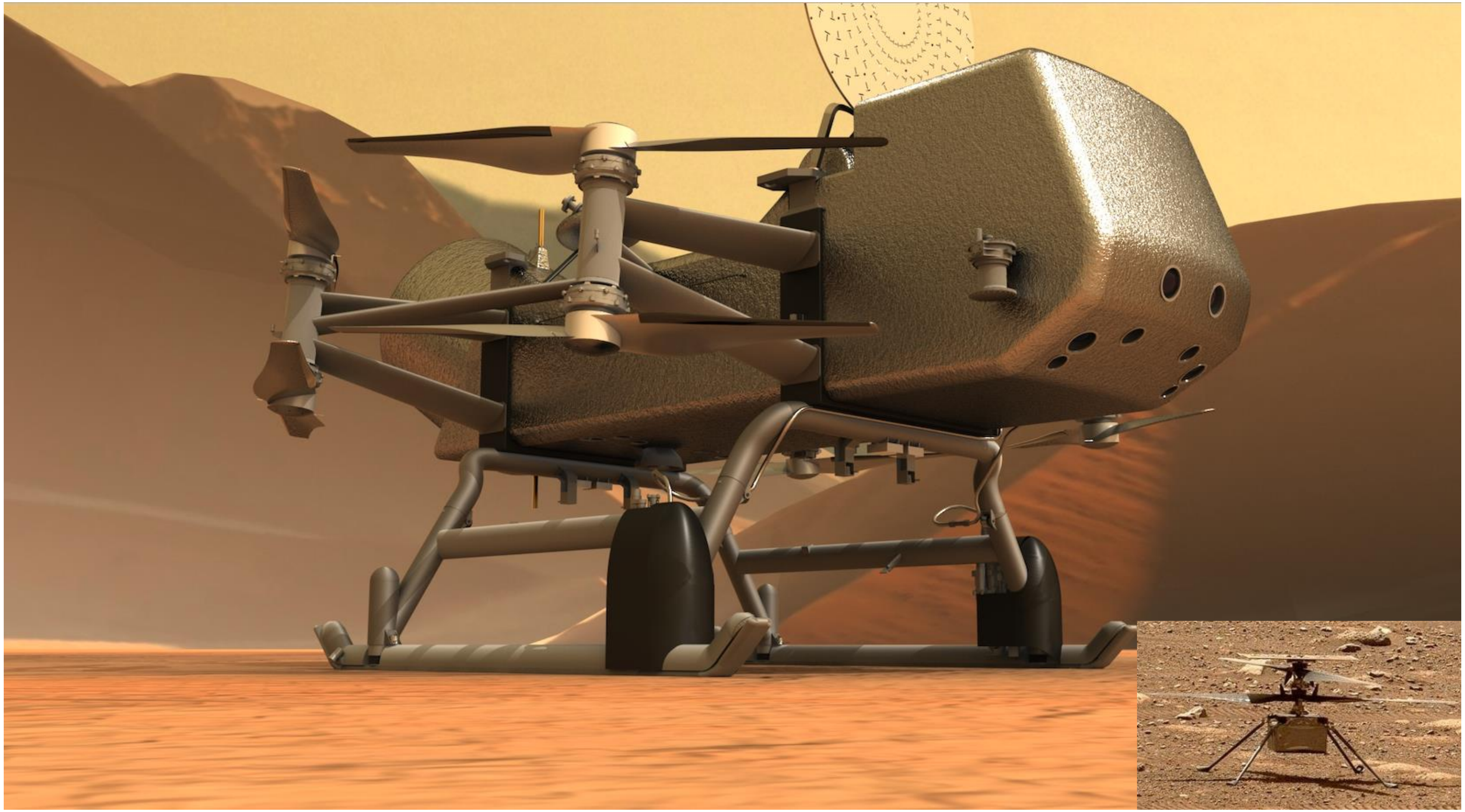
Dragonfly



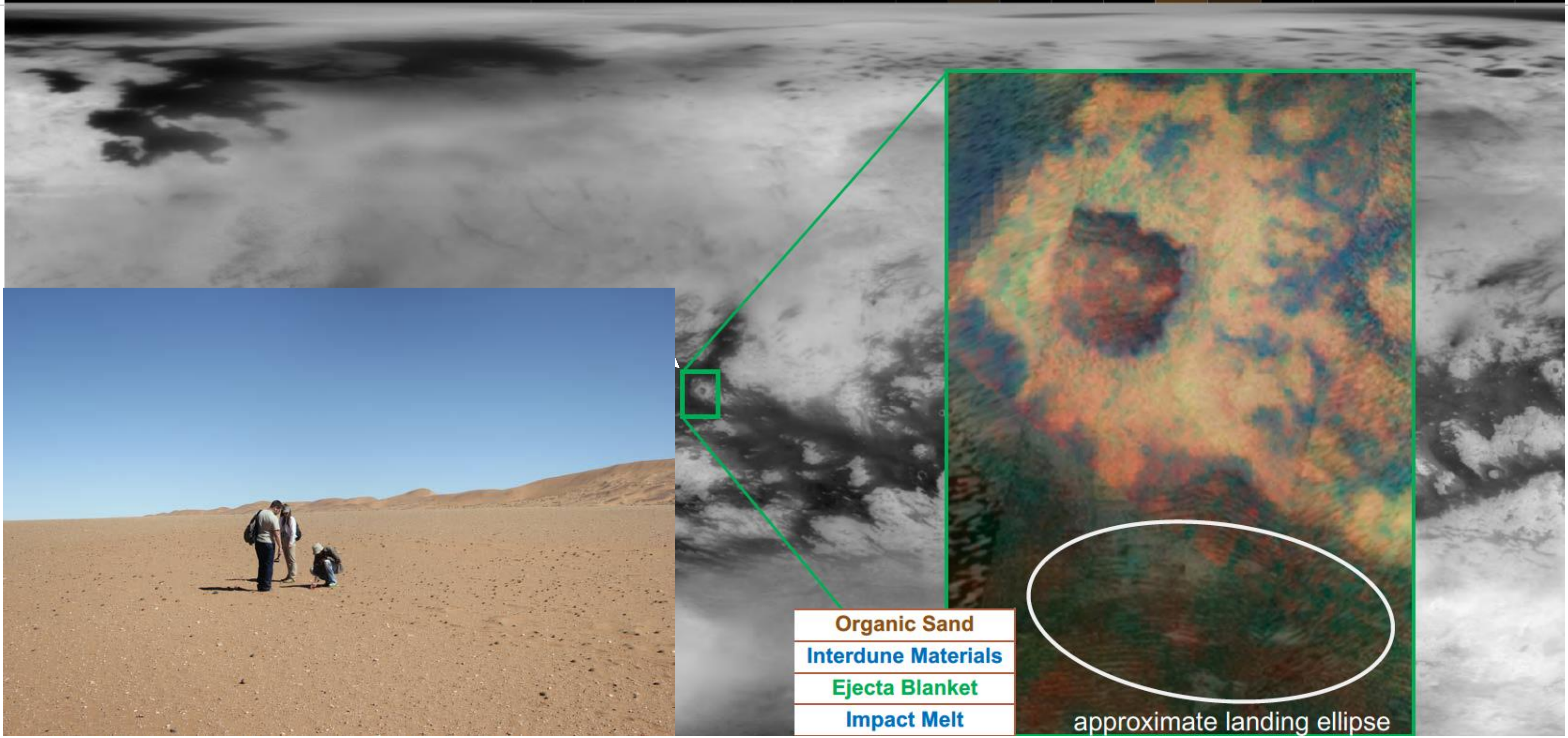
Key Dimensions:

Fuselage: ~3.85 m long
Rotor Diameter: ~1.35 m
Total Mass: ~900 kg

A Note on Scale

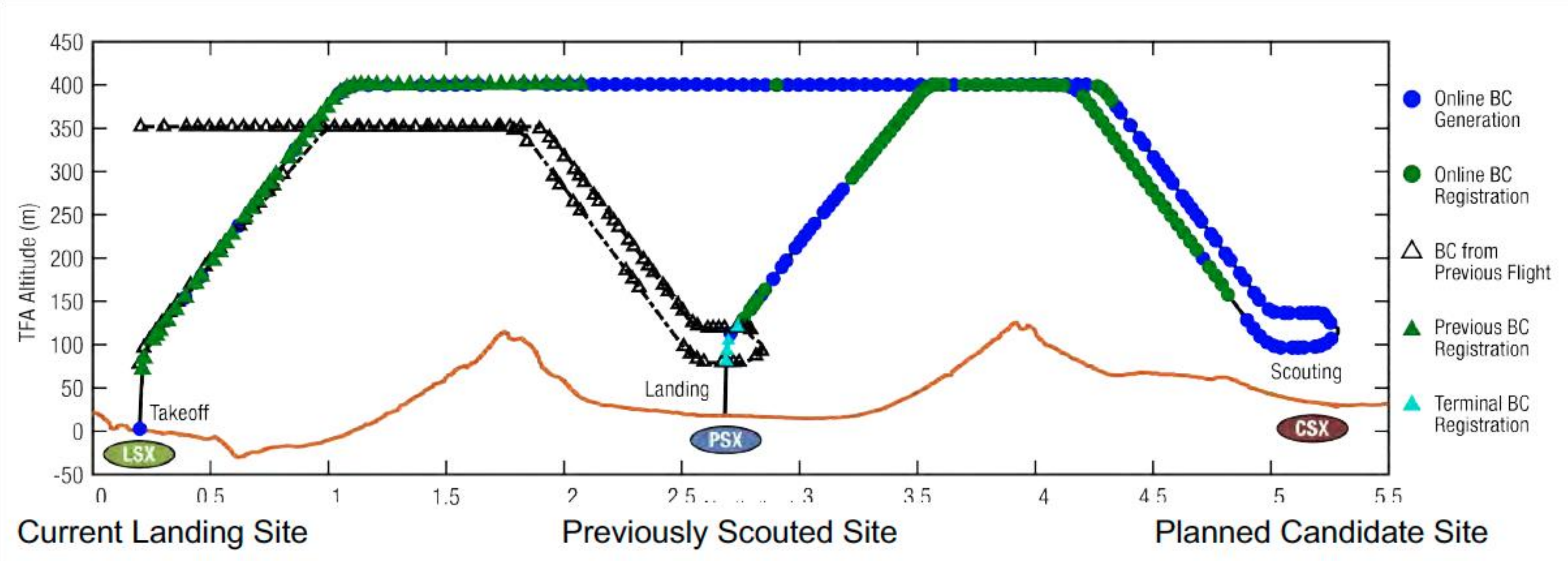


Organic sediments and materials with a water-ice component: dunes, interdunes, impact crater deposits



Dragonfly exploration strategy

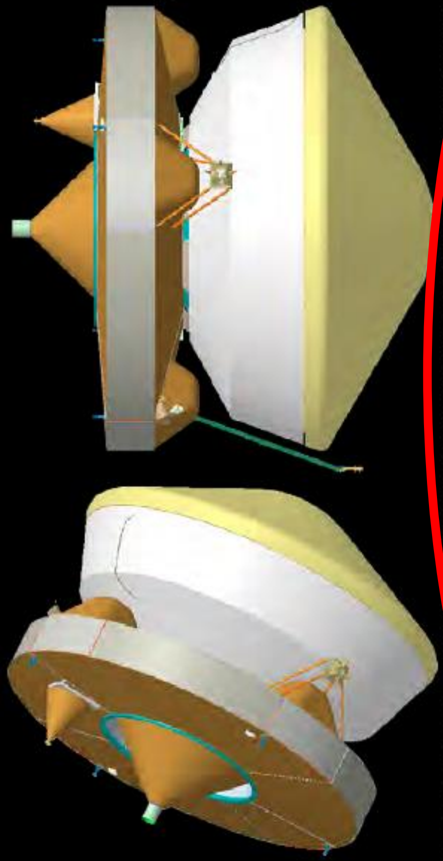
- "Leapfrog" exploration strategy to scout future landing sites
- 16-day Titan sols → relaxed operations schedule
  - Nominal flight schedule is once per 2 Tsols (~1 flight / Earth month)
  - Most of time is spent on the surface making science measurements



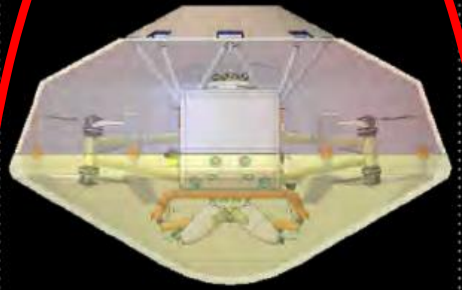
How Will We Get it There?

Dragonfly mission elements

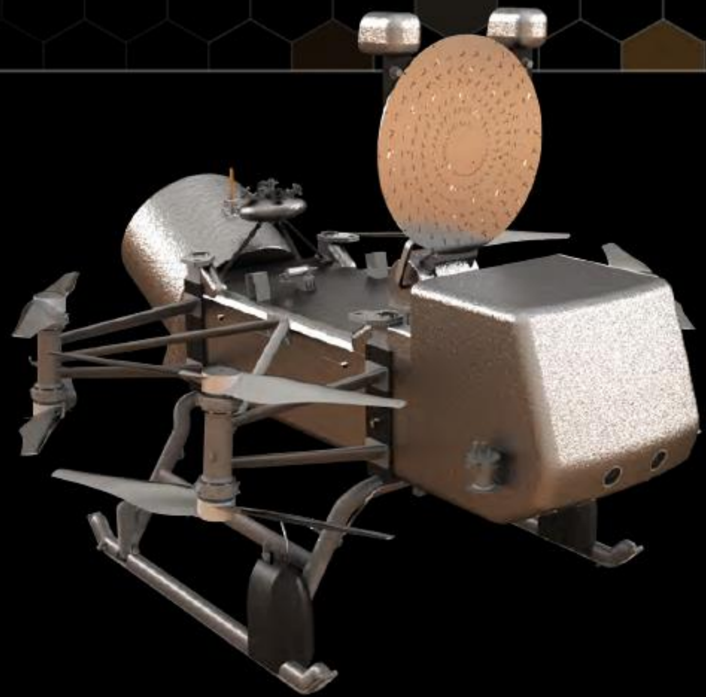
Spacecraft =
Cruise Stage + Entry Vehicle



Entry Vehicle =
EDL Assembly + Lander



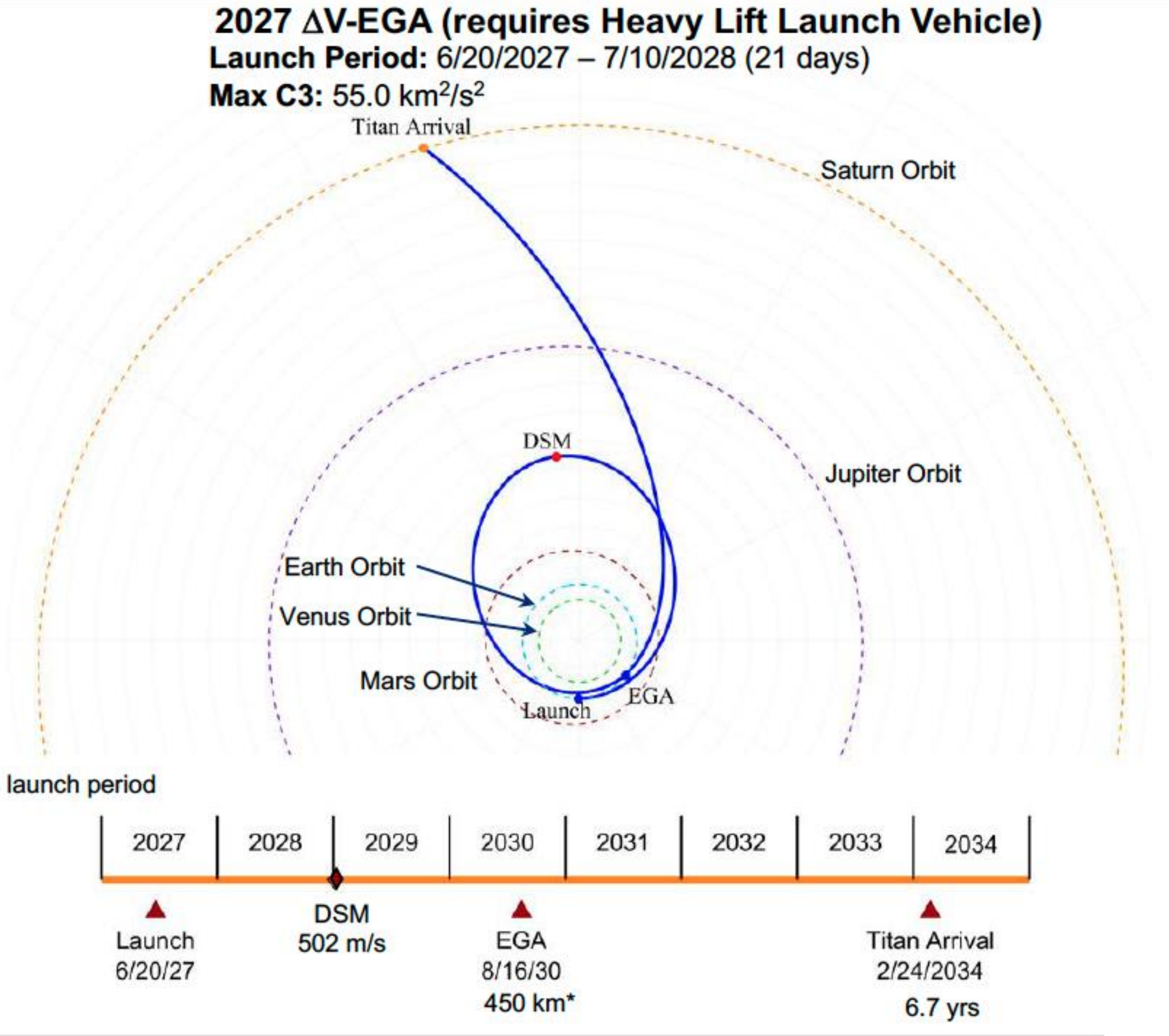
EDL assembly includes aeroshell (heatshield and backshell), parachutes, ESI, and support equipment.



Rotorcraft Lander
Surface configuration with HGA deployed

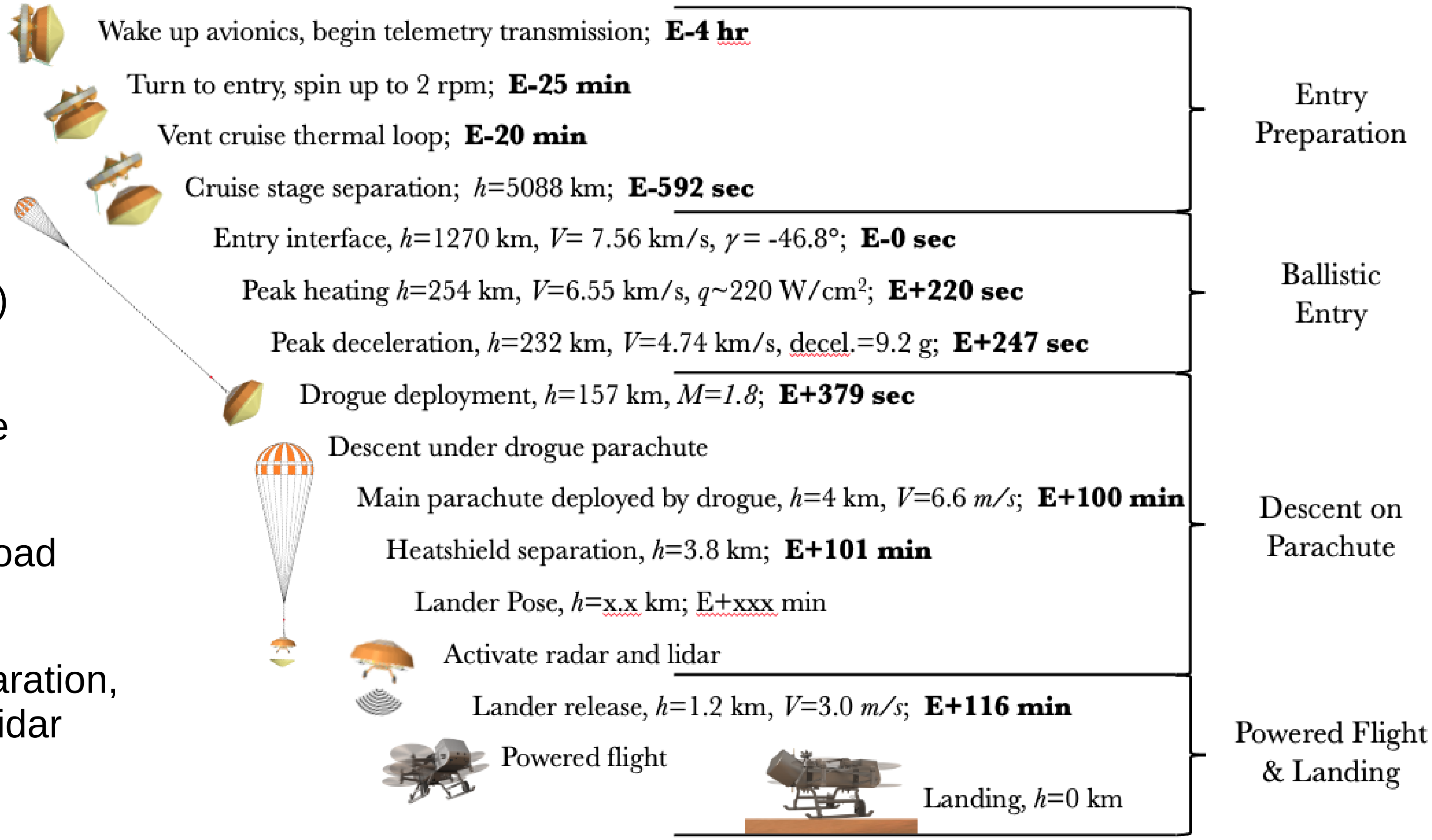
- MMRTG
  - Charges battery to power flight and science activities
  - Waste heat maintains nominal thermal environment in lander
- Direct-to-Earth communication
  - HGA articulation used to target cameras for panoramas of surrounding terrain
- Measurements on surface and in flight
  - Aerial imaging
  - Atmospheric profiles

Interplanetary trajectory



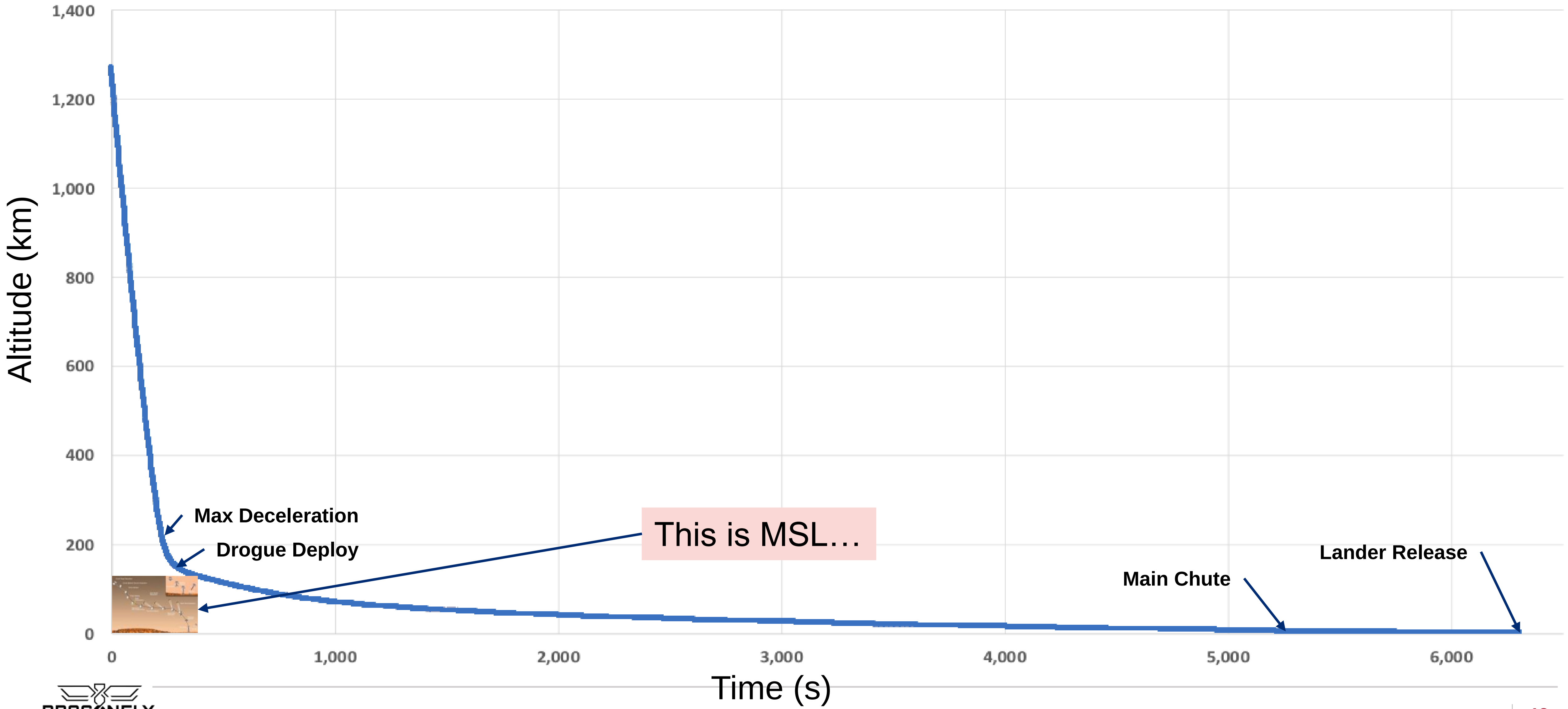
EDL Concept of Operations

- Entry Interface 1270 km
  - Spin-stabilized to 2 rpm
- Entry heat pulse: 260 sec.
  - Peak heat flux >250 W/cm^2 (margined)
- Drogue deploy E+6 min, ~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



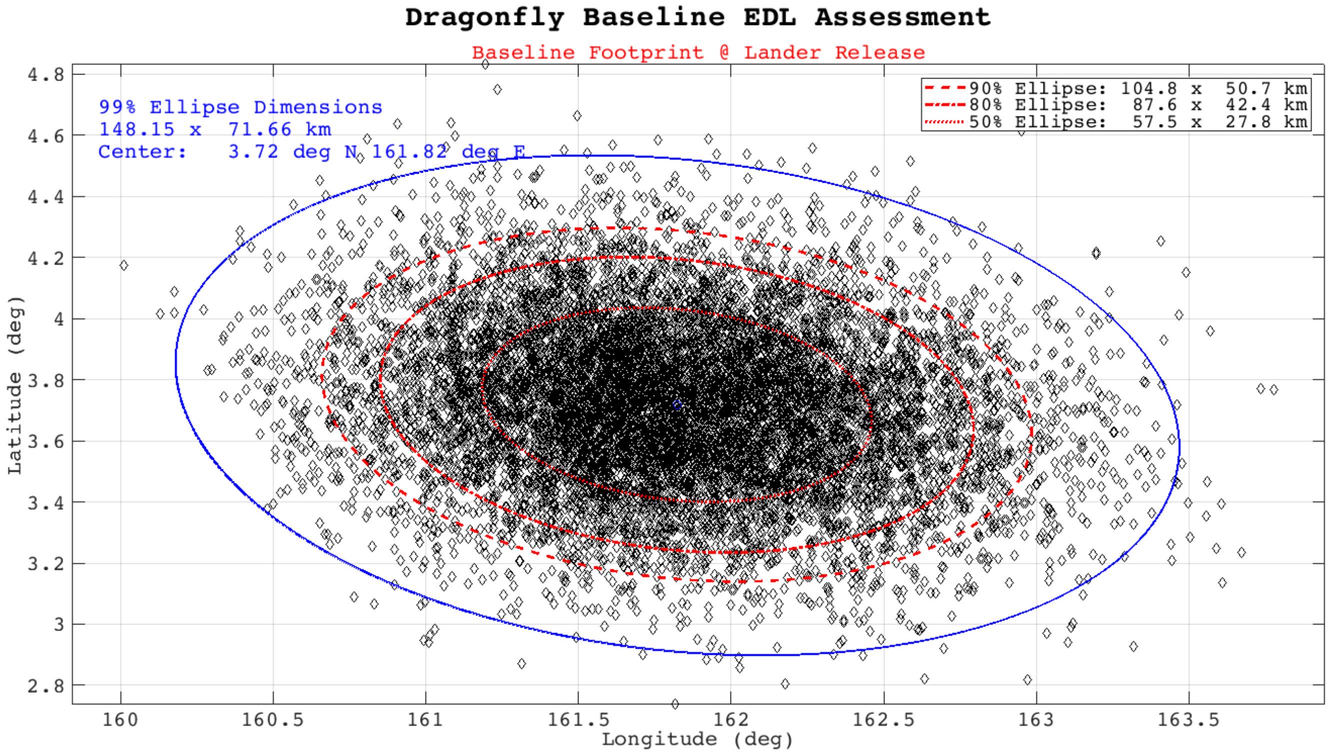
EDL Video

EDL Timeline Comparison



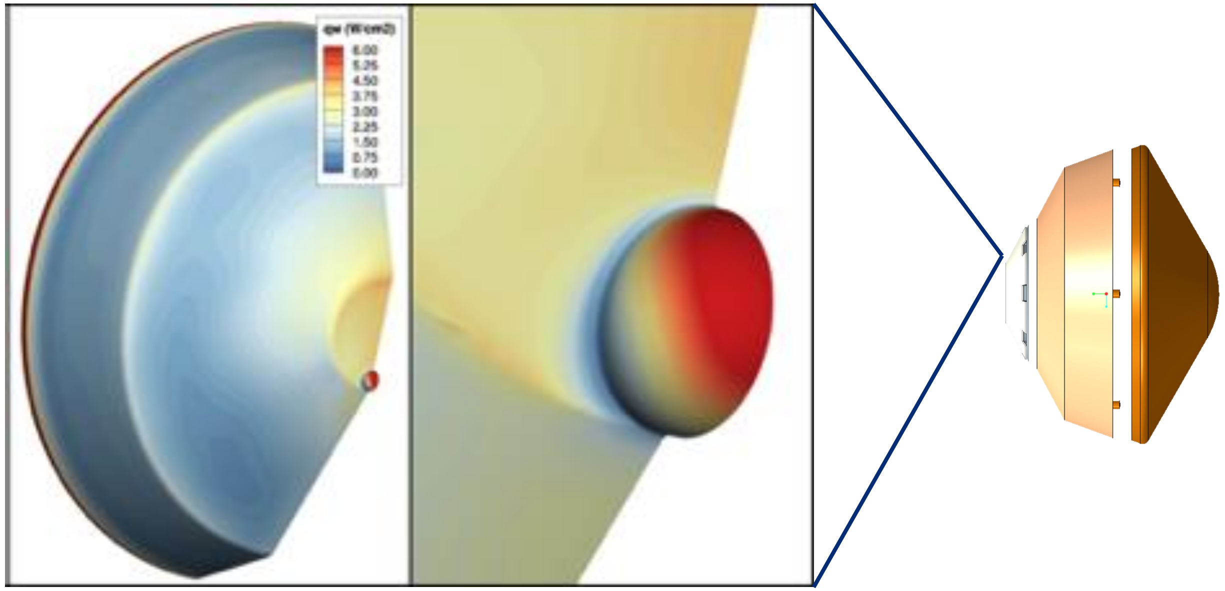
EDL Monte Carlo Analysis

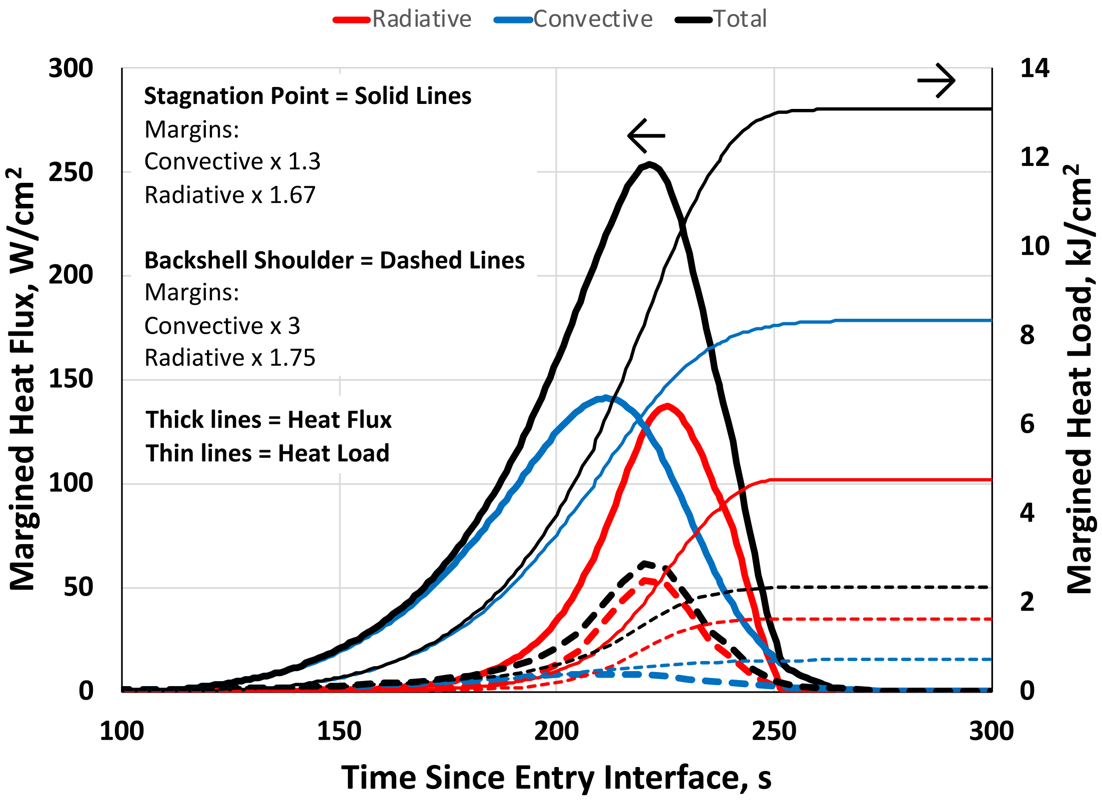
- Full analysis in POST2 from entry interface to lander release
- Delivery accuracy ~149x72 km at release
  - Affords lander sufficient accuracy to navigate to selected landing zone
- Dispersions sources
  - Latitude: arrival navigation errors
  - Longitude: on-chute winds



Aerothermodynamics

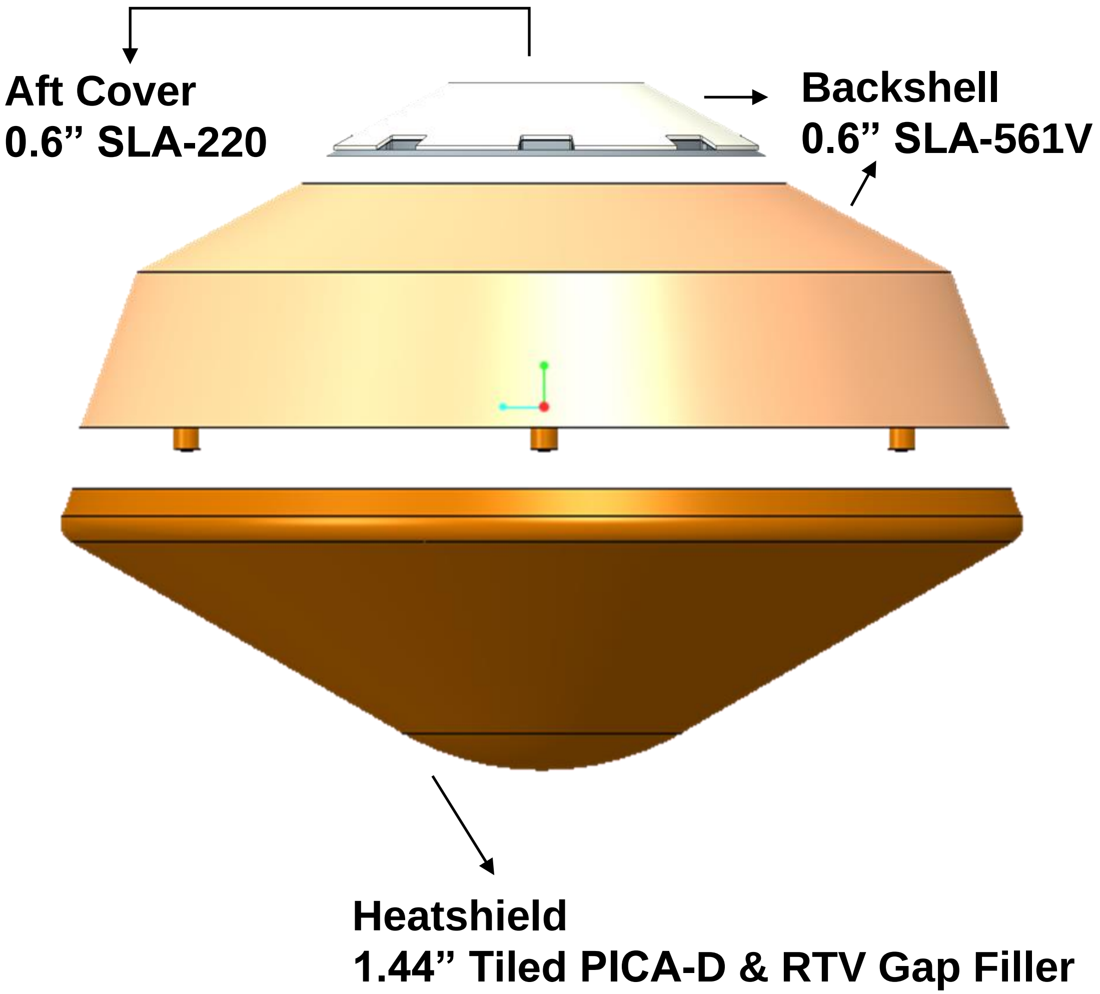
- NASA standard aerothermal models tuned for Titan entry conditions
  - Much of the heating comes from radiation due to methane
- Total heating calculated over entire aeroshell
  - Conservative margins applied
  - Margined values within tested limits for chosen TPS





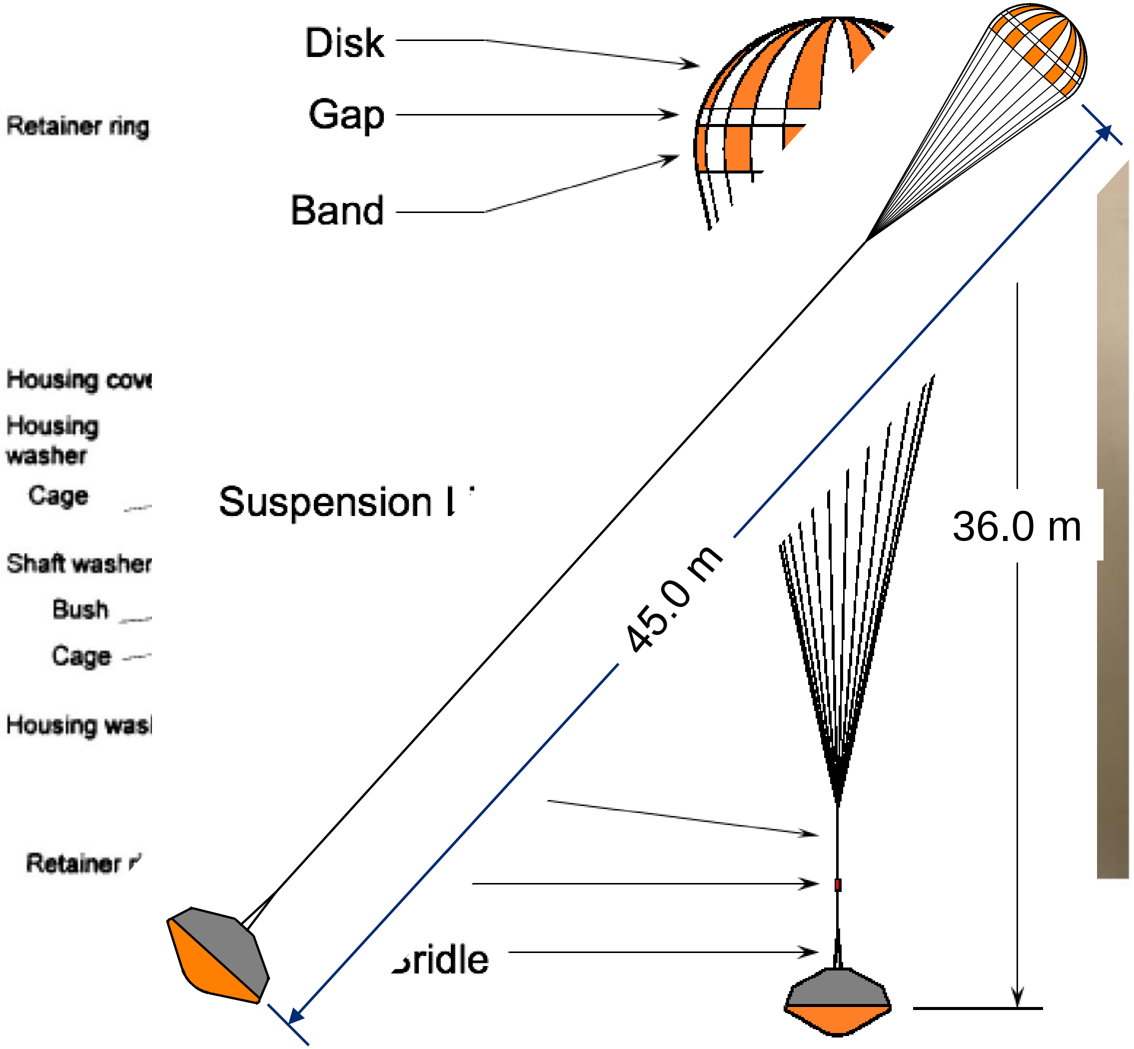
Thermal Protection System

- 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

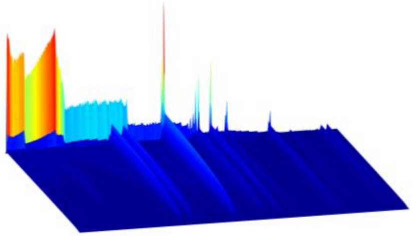
- Drogue Parachute (5.4 m DGB)
  - Mortar deploy via trigger at Mach 1.5
  - Functions: stabilize capsule, decelerate through atmosphere, extract main chute
- Main Parachute (13.44 m DGB)
  - Low speed subsonic deploy
  - Possible anti-inversion netting
- Huygens heritage swivels prevent line twisting



Key EDL Challenges (time sequence order)

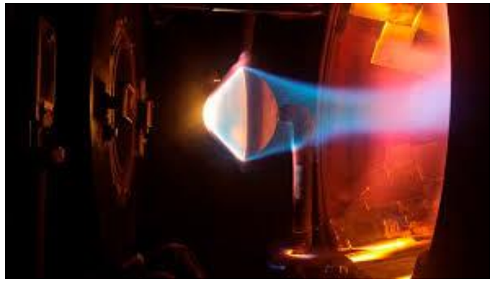
- **Quantifying heating due to shock layer radiation**
  - dominated by CN-red and violet emission
  - Less validated than air or CO_2
- **TPS material qualification**
  - Non-oxidizing environment, radiation dominated heating
- **EDL Phase thermal analysis**
  - Long descent time, cryogenic exterior, 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

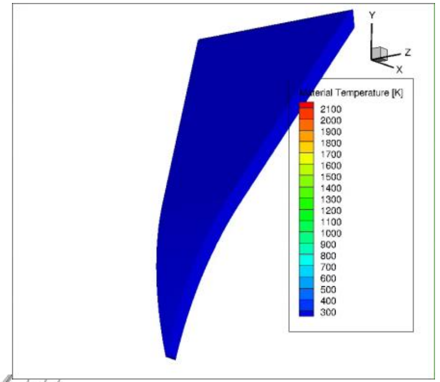
EAST Testing*



VST/TDT Testing

Arc Jet / Lamp Testing

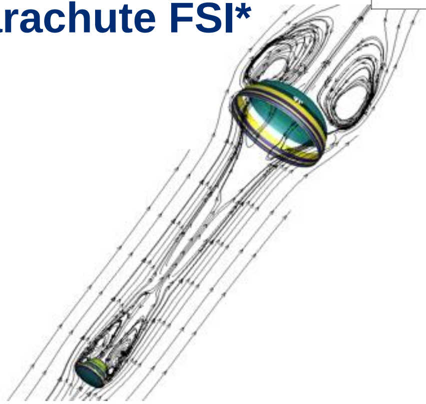




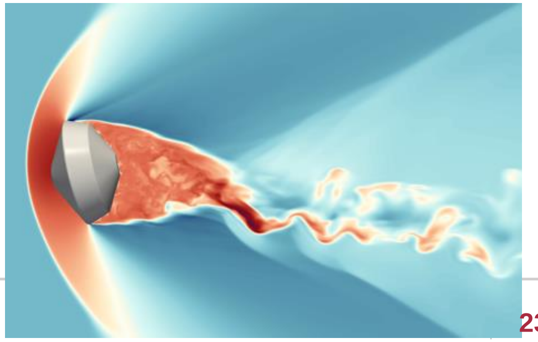
3D Material Response*

Drop Test

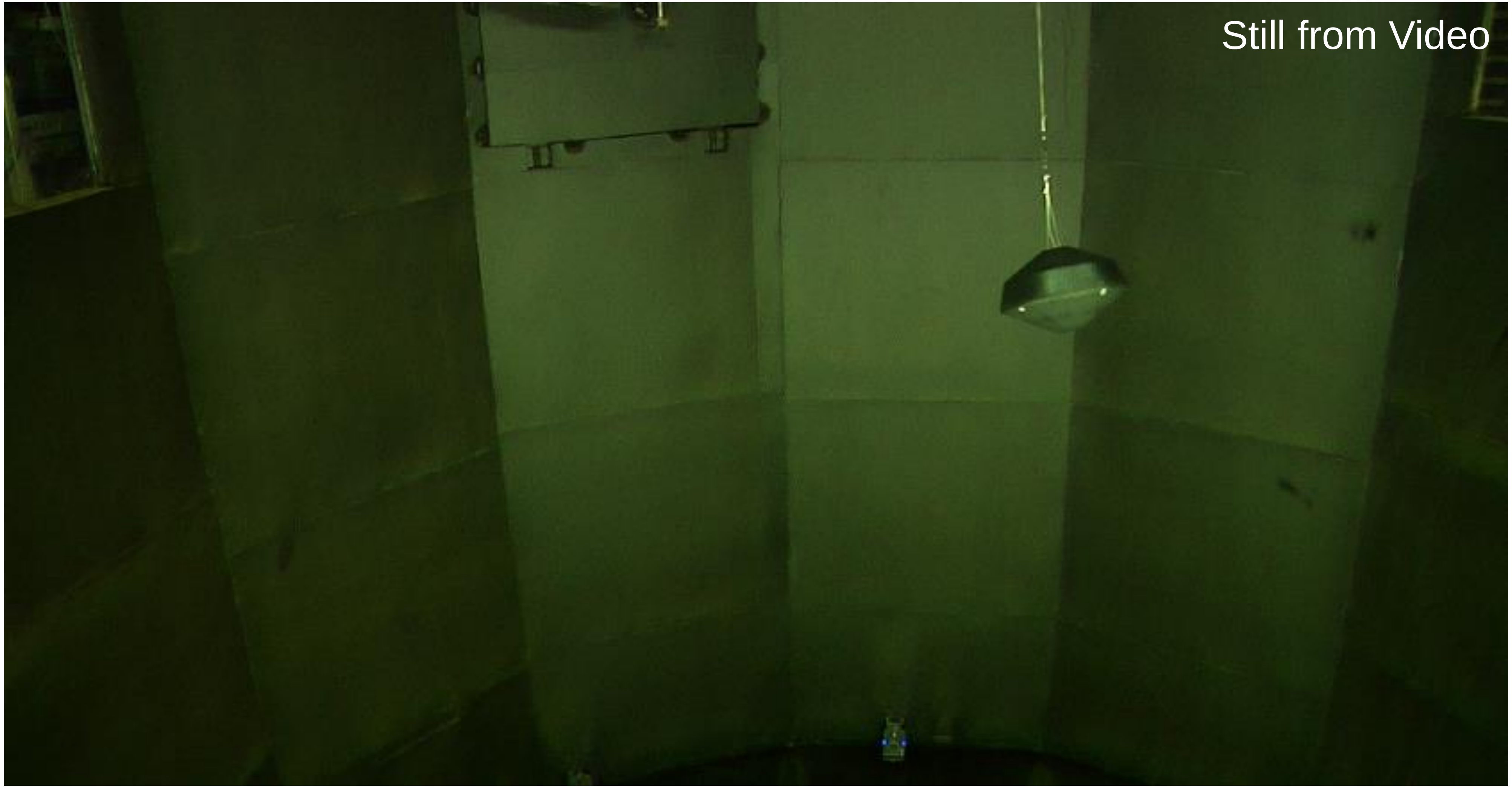
Parachute FSI*



Free Flight CFD*



Vertical Spin Testing – Drogue Chute Dynamics



Oh, and by the way, its instrumented!

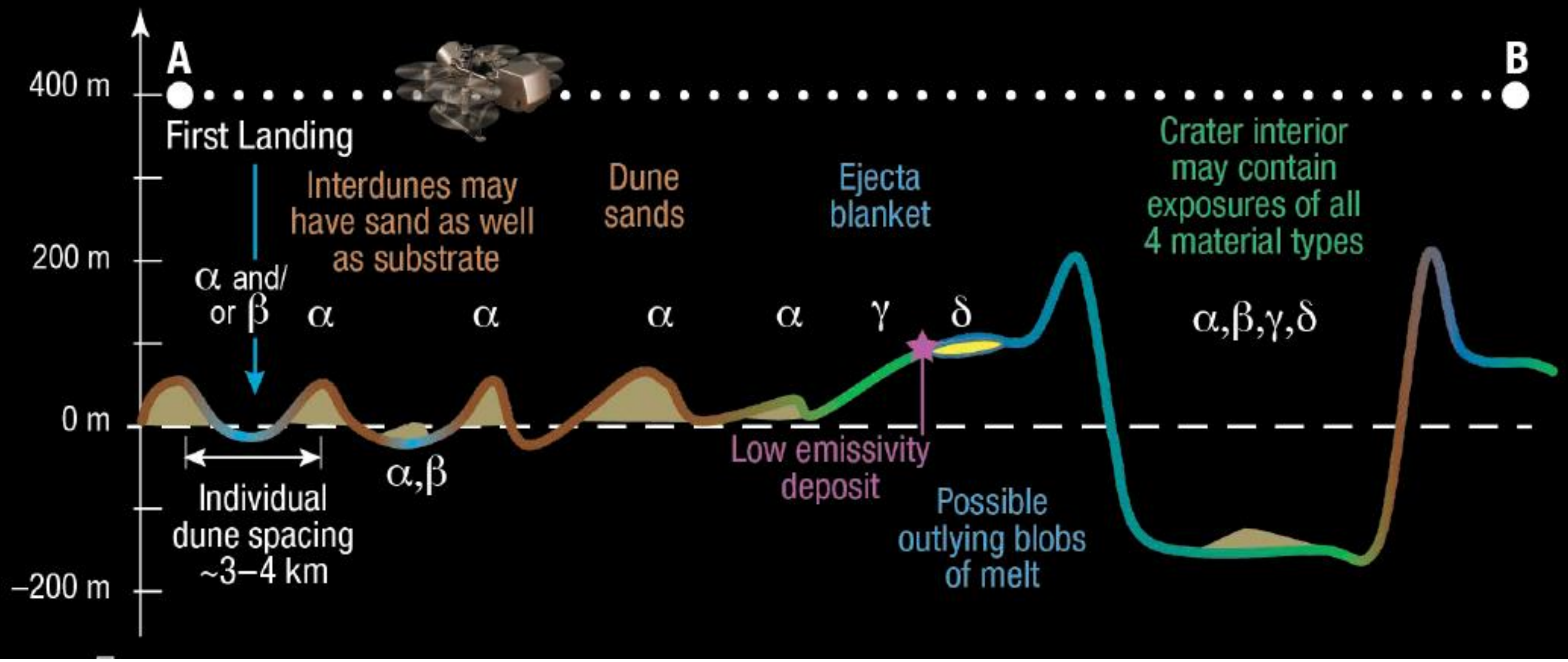
Any questions before Aaron tells you about DrEAM?

DRAGONFLY

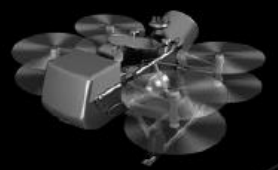
Backup

Exploration strategy

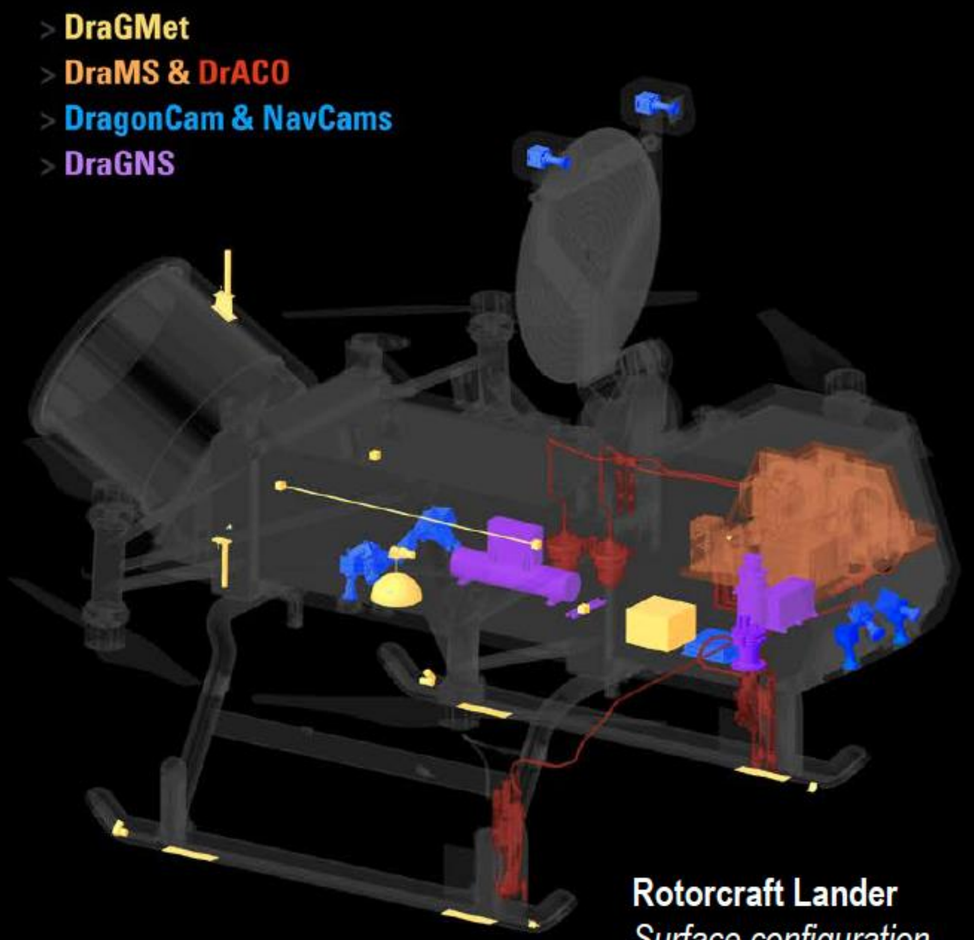
- ~3.25 years of exploration
  - 74 Tsols (Titan days) of science operations
  - Traverse distance up to ~180 km
  - Exploration of ~25-30 unique sites



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



Rotorcraft Lander
Surface configuration with HGA deployed