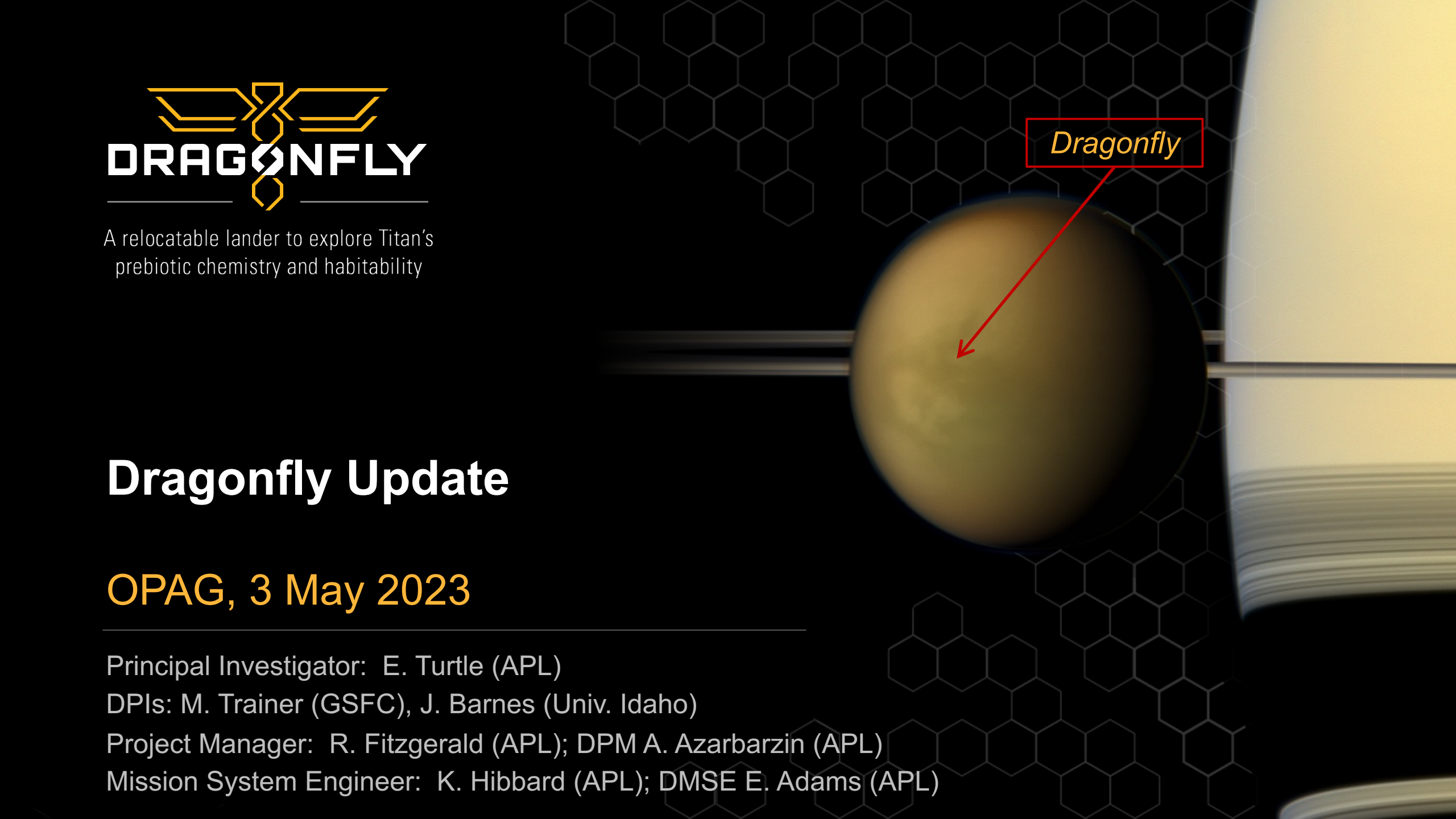
DRAGONFLY

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



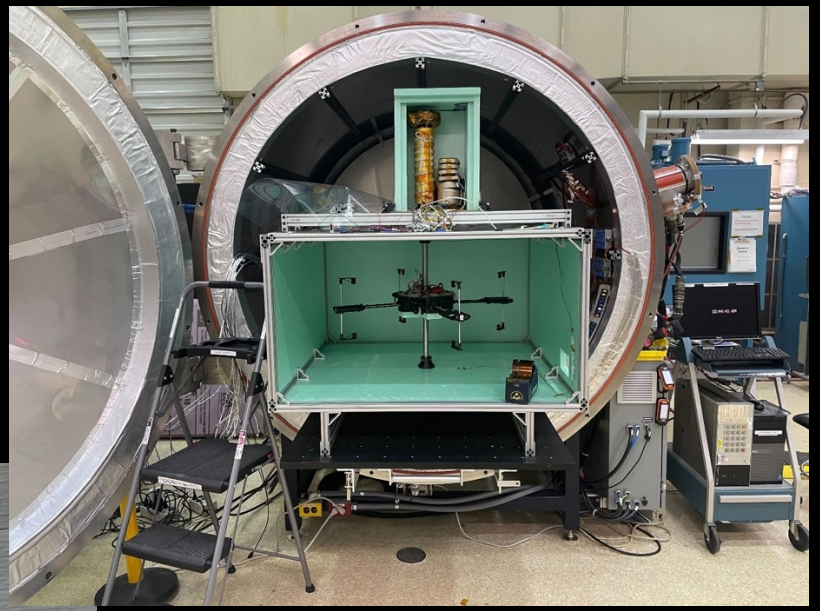
Dragonfly Update

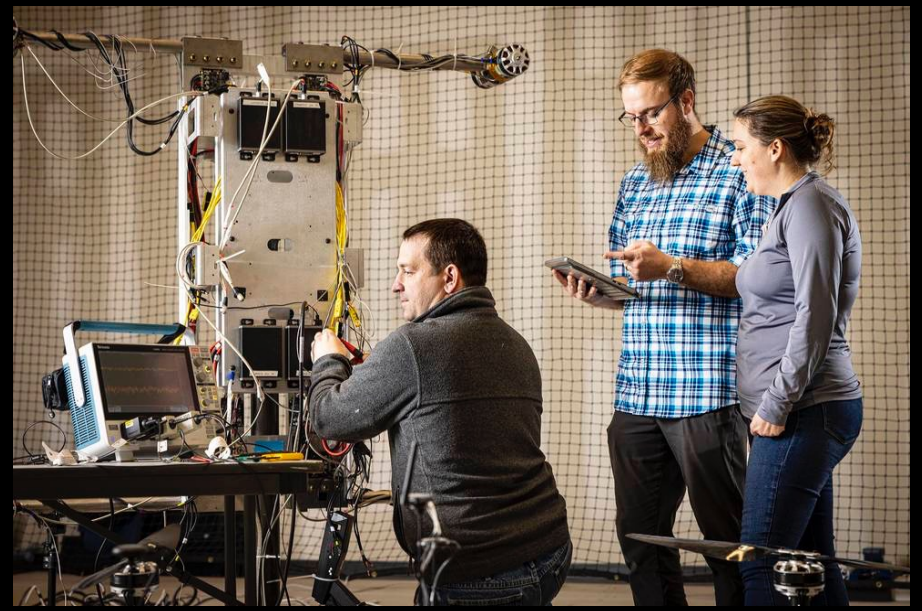
OPAG, 3 May 2023

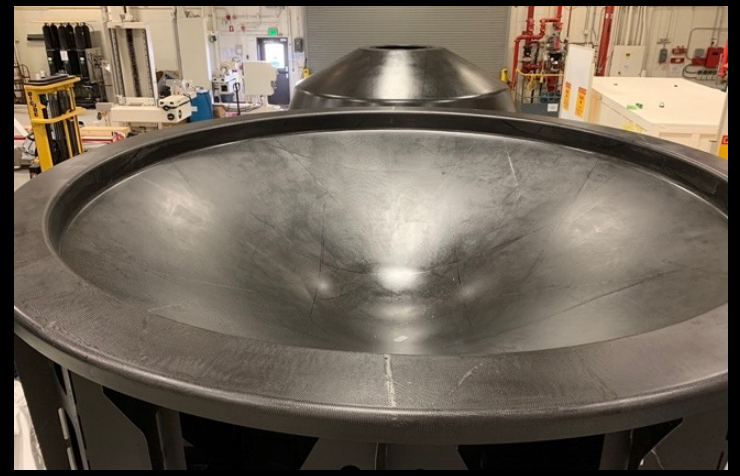
Principal Investigator: E. Turtle (APL)
DPIs: M. Trainer (GSFC), J. Barnes (Univ. Idaho)
Project Manager: R. Fitzgerald (APL); DPM A. Azarbarzin (APL)
Mission System Engineer: K. Hibbard (APL); DMSE E. Adams (APL)

Outline

- Mission science
- Project status and recent work





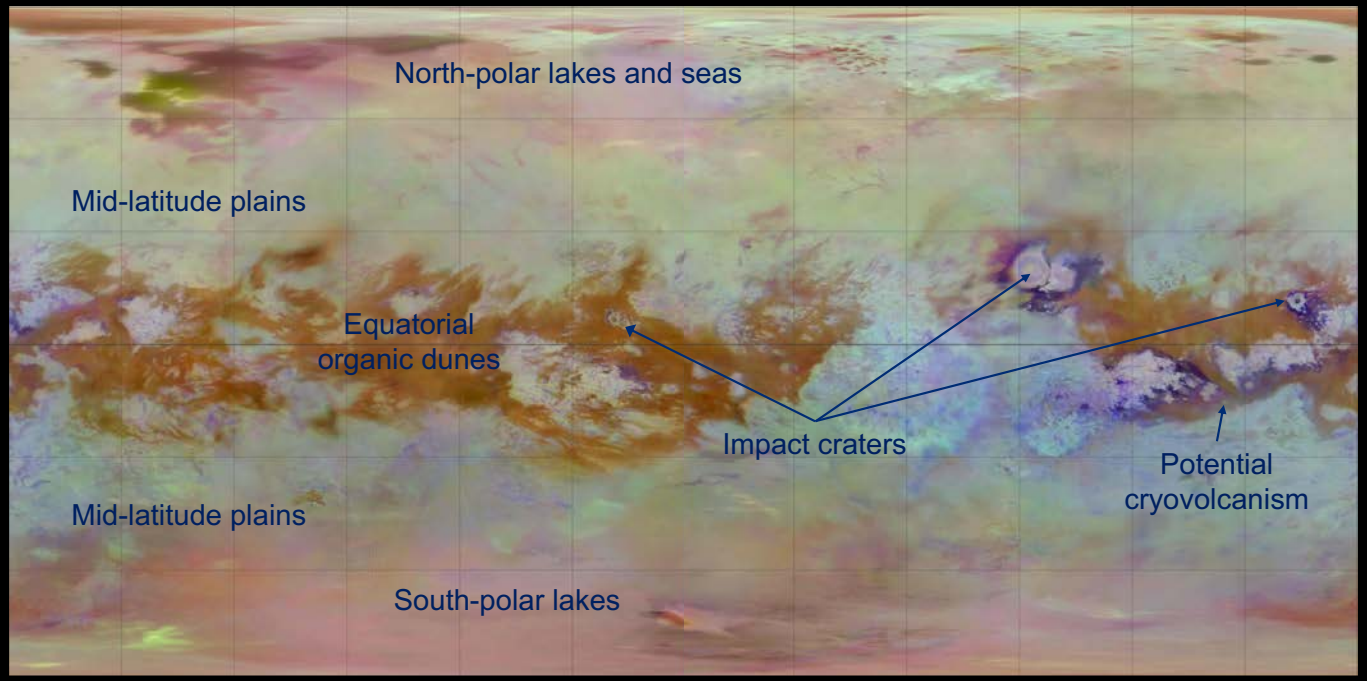


Opportunity to seek answers to fundamental astrobiology questions

What makes a world habitable?

What chemical processes led to the development of life?

Has life developed elsewhere in our solar system?



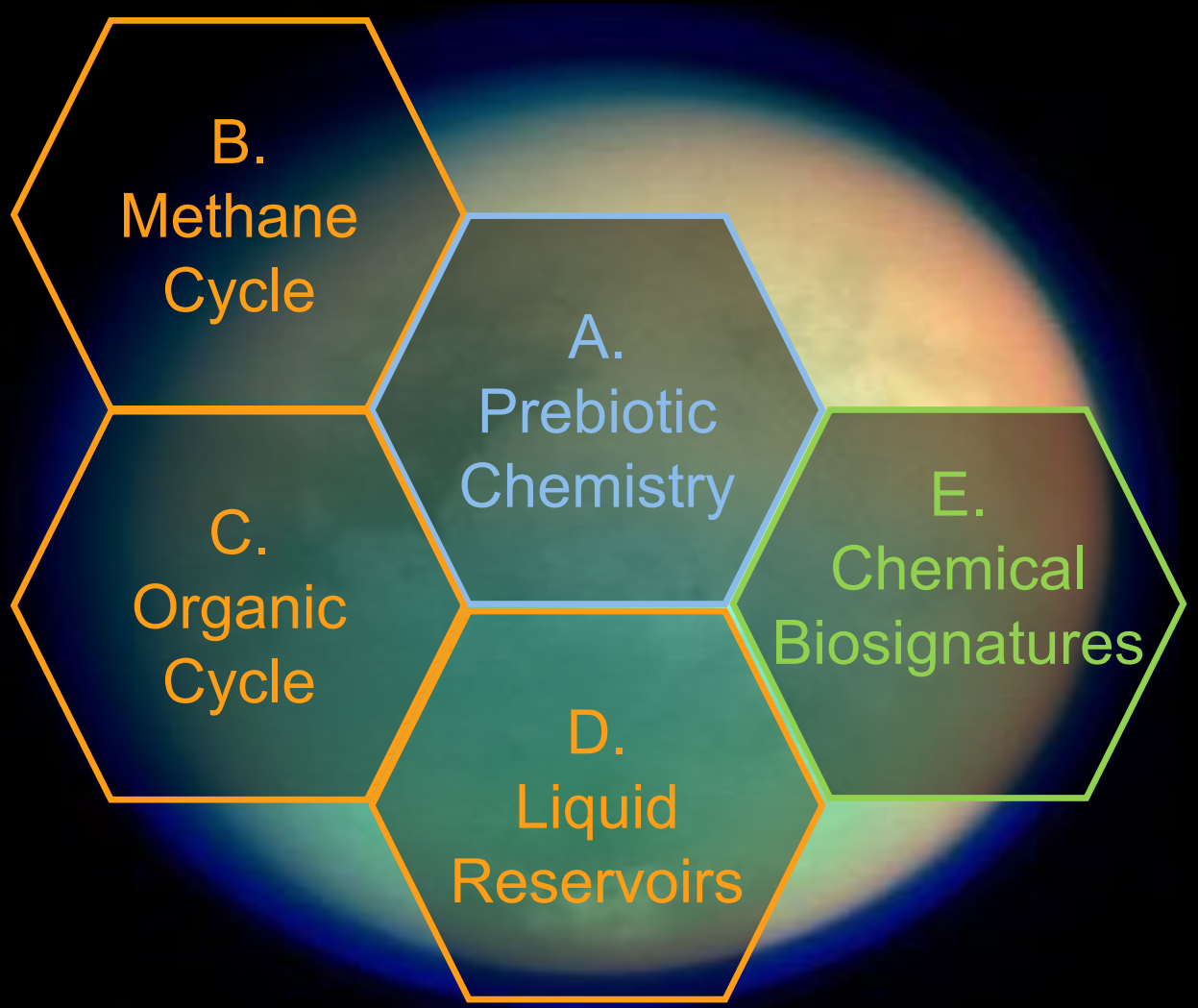
Cassini enhanced-color map of Titan's surface at near-infrared wavelengths (Seignovert et al. 2019)

On Titan, we can study prebiotic chemistry in the full context of a planetary environment with Earth-like surface processes

Dragonfly mission science

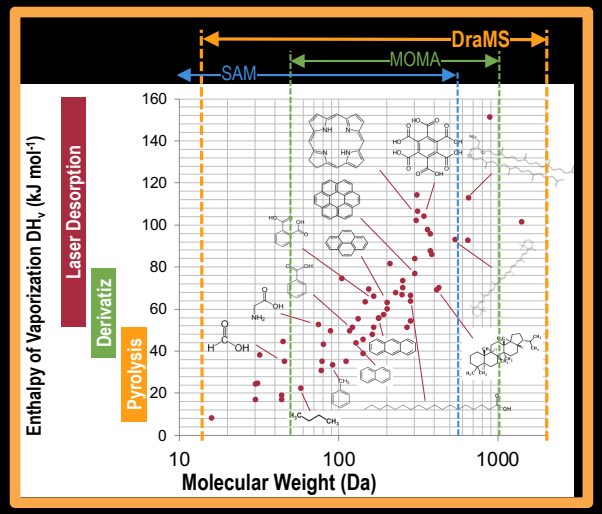
Barnes et al., *PSJ*, 2021
https://doi.org/10.3847/PSJ/abfdcf

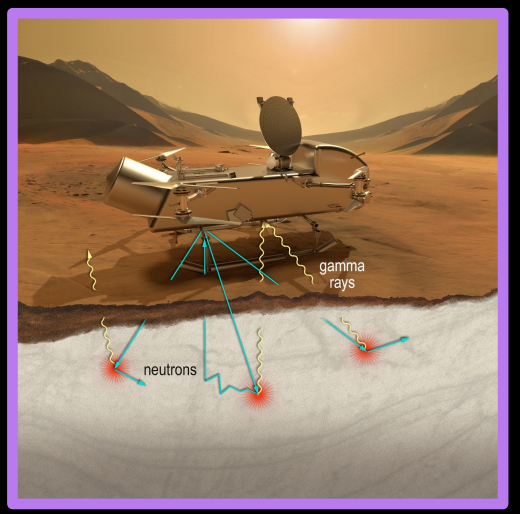
- Prebiotic chemistry
  - Analyze chemical components and processes at work that produce biologically relevant compounds
- Habitable environments
  - Measure atmospheric conditions, identify methane reservoirs, and determine transport rates
  - Constrain processes that mix organics with past surface liquid water reservoirs or subsurface ocean
- Search for biosignatures
  - Search for chemical evidence of water- or hydrocarbon-based life

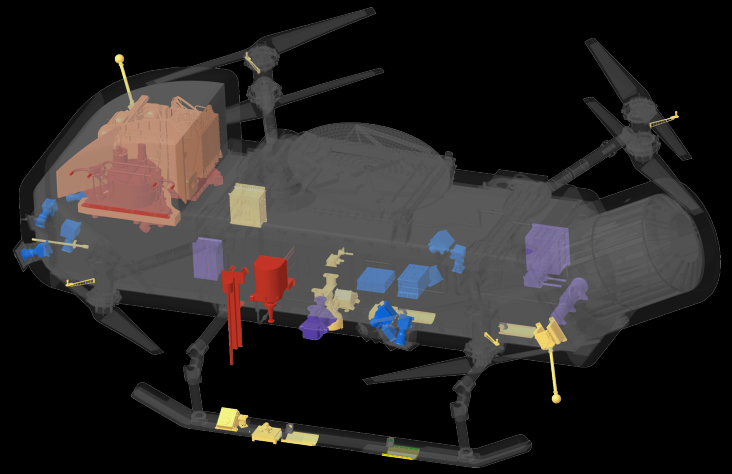


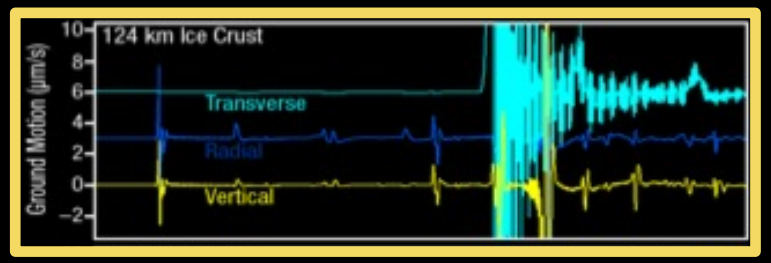
Multidisciplinary science measurements

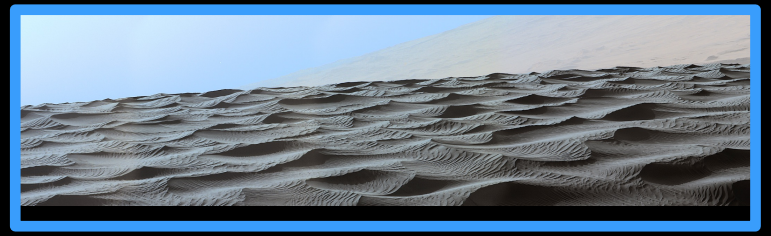
- **DraMS:** Mass Spectrometer
- **DrACO:** Drill for Acquisition of Complex Organics
- **DraGMet:** Geophysics & Meteorology Package
- **DragonCam:** Camera Suite
- **DraGNS:** Gamma-ray Neutron Spectrometer

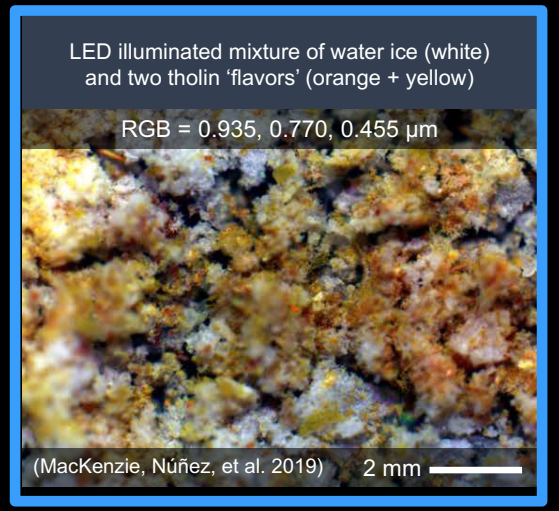






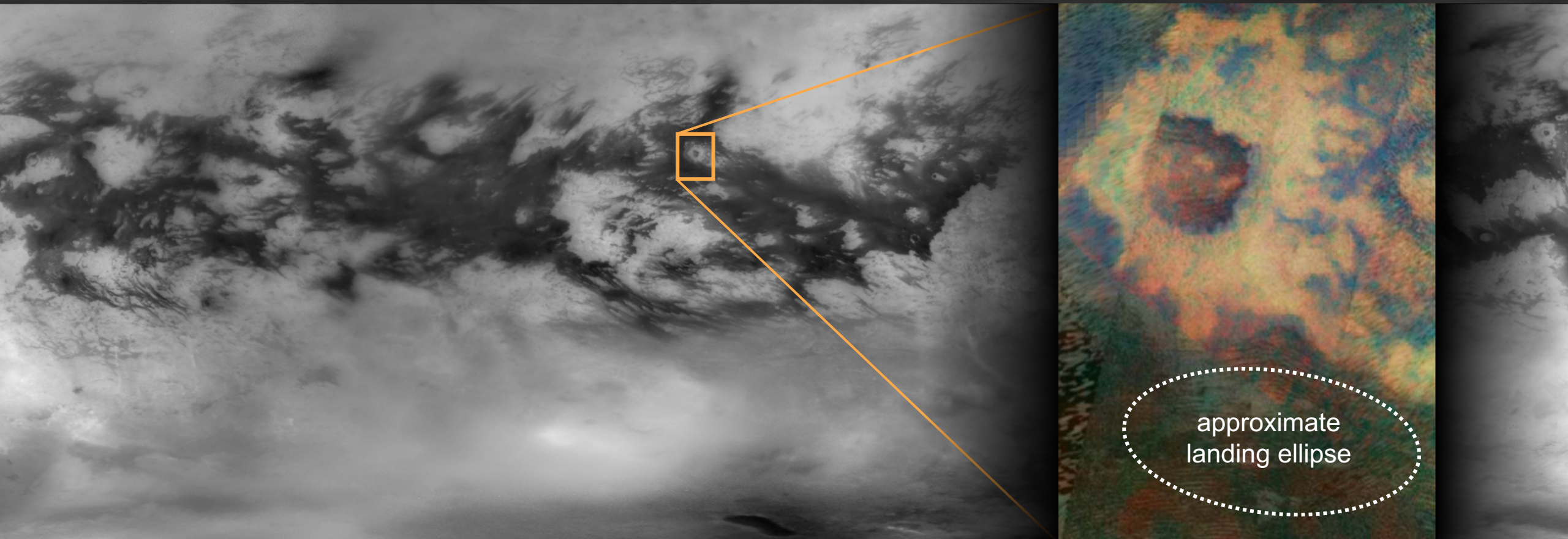






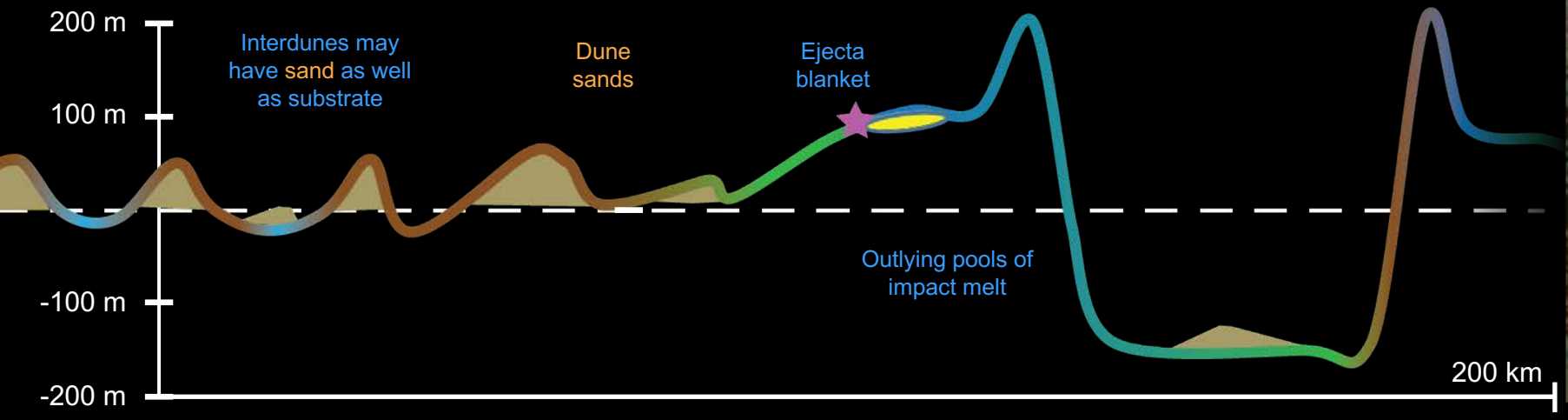
Dragonfly landing site provides access to organic sediments & materials with a water-ice component

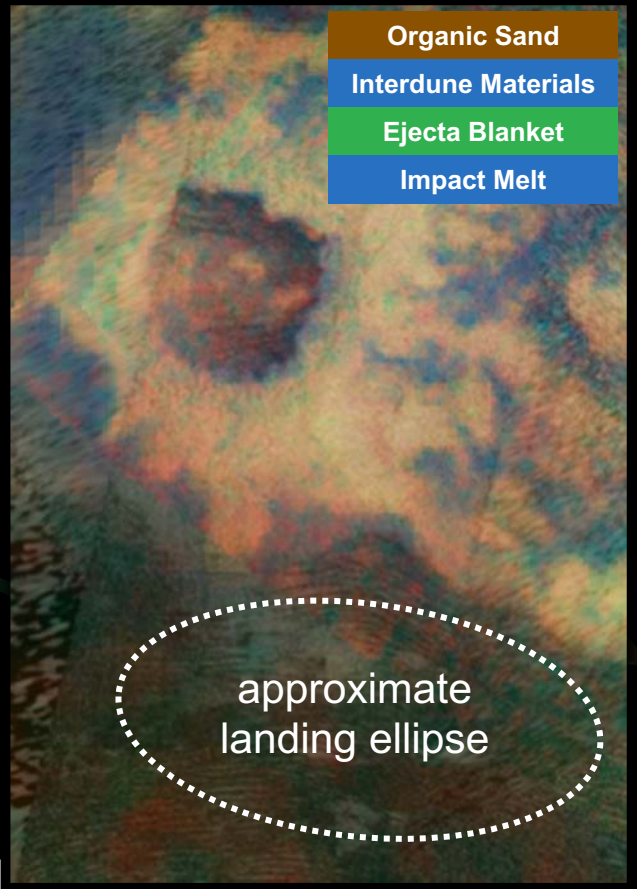
- **Sand dunes:** organic sediments
- **Interdune areas:** materials with a water-ice component
- **Selk impact crater:** materials where organics may have mixed with liquid water impact melt



Dragonfly exploration strategy

- **~3.3 years, ~74 Tsols (Titan days) of science operations**
  - Traverse distance several tens of km
  - Exploration of >30 unique sites
  - Aerial scouting of future landing sites
- **16-day Tsols**
  - Nominal flight schedule is once per 2 Tsols (~1 flight / Earth month)
  - Most of time (99.9%) is spent on the surface: science measurements; data downlink; ground-in-the-loop operations





Dragonfly Phase B activities

- Preliminary design phase focus on maturation of requirements, design, interface definitions, and risk reduction
  - Define element and subsystem requirements, Titan environment specifications and Environment Requirements Document (ERD)
  - Develop preliminary design for elements and subsystems that meets resource requirements and fits within mission concept of operations
  - Develop preliminary Interface Control Documents (ICDs) and Mission Level Verification & Validation (V&V) Plans
  - Demonstrate technology development items meet Technology Readiness Level 6 (TRL-6); two were eliminated through design trades
  - Mature Concept of Operations (ConOps)
- Document status
  - Rules of the Airways (RotA) developed as living document with annual review and acknowledgement by full Dragonfly Team
  - Planetary Protection Category II concurred with NASA Office of Planetary Protection
  - National Environmental Policy Act (NEPA) Finding of No Significant Impact (FONSI), Nuclear Launch Authorization Plan (NLAP), Project Protection Plan, and Risk Classification Memo all have been approved by NASA
  - Communications and Public Engagement Plan approved by NASA
  - NASA Standing Review Board (SRB) formally approved
  - Level 1 requirements reviewed with NASA, and Program Level Requirements Appendix (PLRA) signed
  - International agreements with CNES and DLR have been signed; JAXA letter in place, agreement in progress
- Dragonfly Student Guest Investigator Program Cohorts 1-3
- NASA H2O (Here to Observe) partnership with Virginia State University

Design updates through Phase B: Highlights

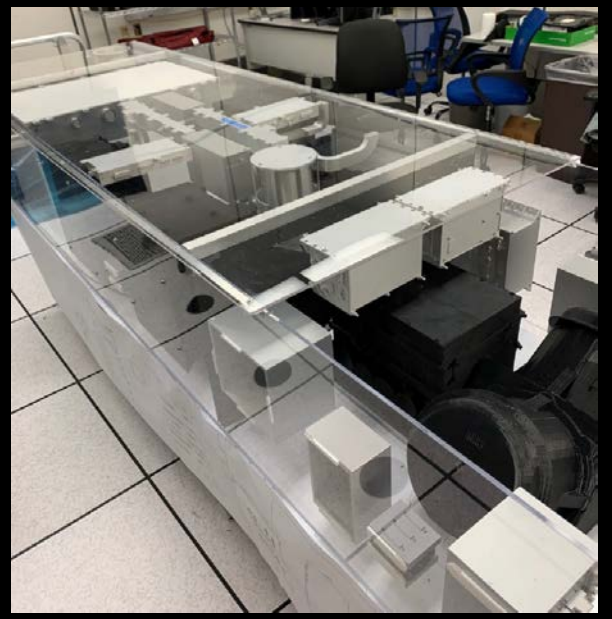
- External MMRTG (multi-mission radioisotope thermoelectric generator) modifications to reduce fin length and adjust thermal loops, reducing size and simplifying accommodations
- Replaced low-gain antenna (LGA) cluster with medium-gain antenna (MGA) and LGA
- Simplified Lander leg design from hinged deployment with dampers to fixed legs meeting landing loads without dampers
- Definition of Flight Reference Mission – flexible flight schedule facilitates energy management and response to contingencies
- Updated spacecraft and cruise for high-energy trajectory
- Trades to reduce complexity and risk and increase mass margin, while preserving Science Objectives
  - Leveraged use of Mg instead of Al in boxes for mass savings
  - Single drill mounted to Lander body instead of directly to skid reduces sampling risk; backup sampler design
  - Replaced cameras mounted on high-gain antenna (HGA) with Lander-mounted side-looking cameras to simplify thermal design, HGA gimbal design, and ConOps, as well as reduce mass
  - Balancing single-string and redundant elements and subsystems

Dragonfly Project status

- Technology maturation and preliminary design complete
- Successful Mission Preliminary Design Review, (MPDR) February-March 2023
  - 22 subsystem & instrument PDRs and >40 associated peer reviews leading up to MPDR
  - Working to close requests for action (RFAs) from Standing Review Board (SRB)
- Ongoing detailed design activities and preparation for NASA Confirmation Review in September 2023

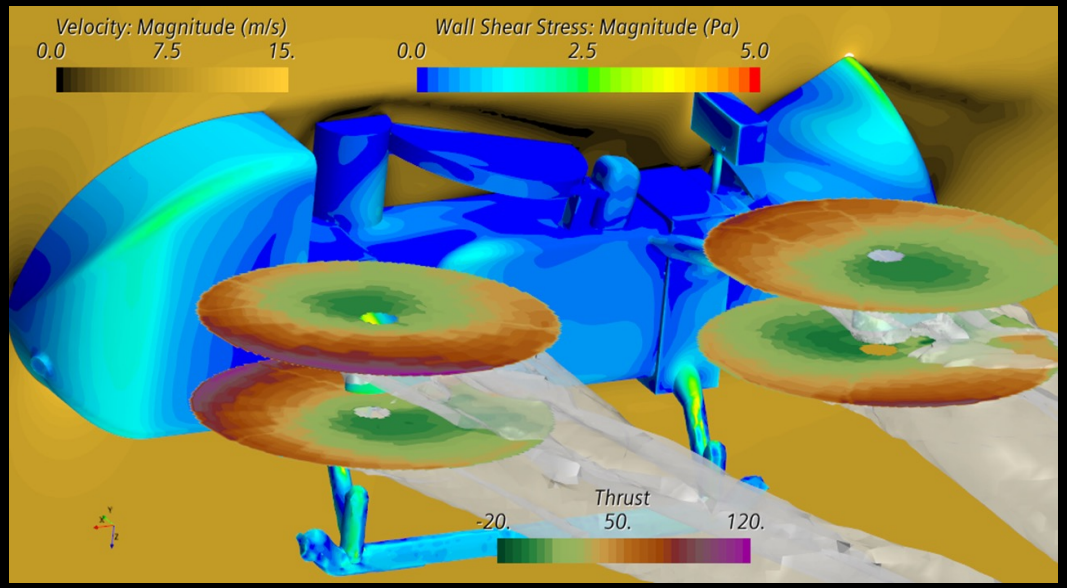
Phase B activities: Development and testing

- Completed mobility capstone test flights
  - Scout and linked Leapfrog flights, including autonomous navigation, takeoff, and landing
- Subsystem and instrument testing
  - Completed pre-PDR testing in LaRC Transonic Dynamics Tunnel (TDT)
- Full-scale lander body mock-up built to support harness, packaging, and I&T (Integration and Test) development
- Focus on thermal-mechanical-structural and mobility development
  - Assembly of development test module (DTM) underway – full-scale representation of Lander primary structure

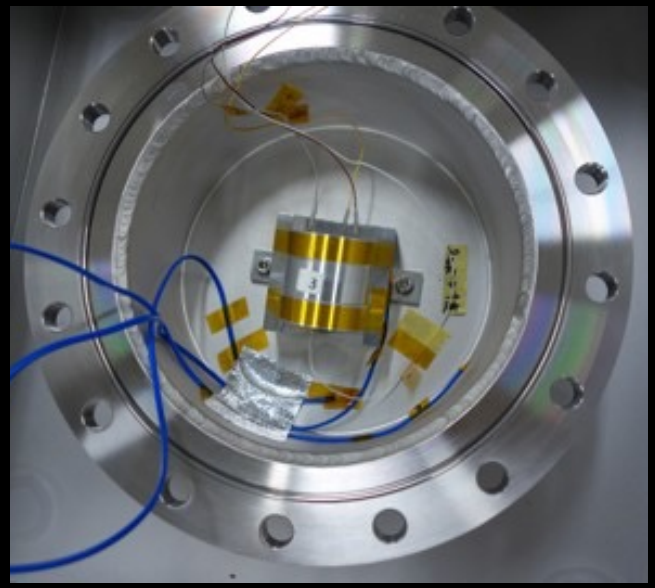


Phase B activities: Development and testing

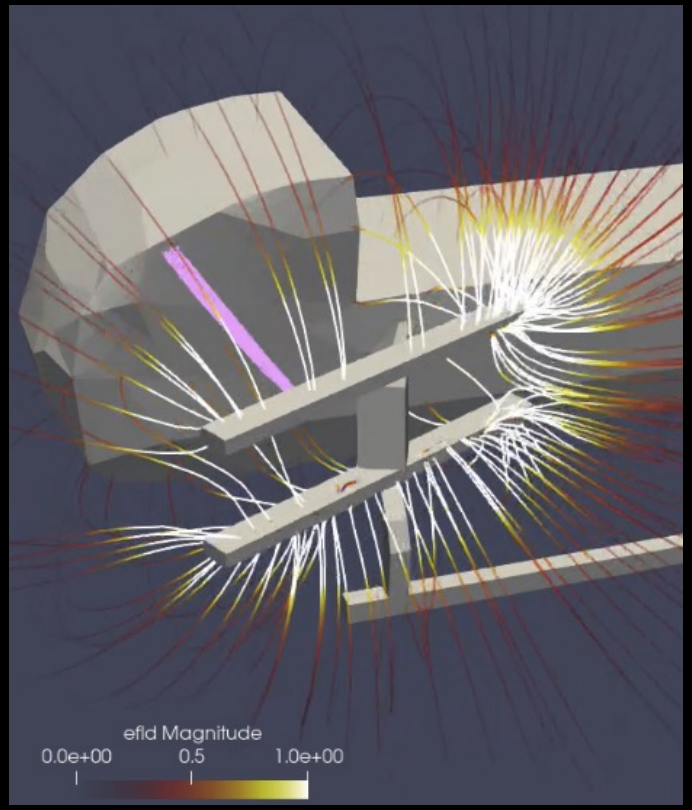
- Prototype and EM (engineering model) builds and environmental and life testing underway for various components, including DraMS miniature scroll pump (MSP) and ion-trap mass spectrometer (ITMS); DraGMet sensors; DragonCam windows; DraGNS pulsed neutron generator (PNG)
- Refinement of interfaces and mechanical interface documents (MICDs)



New iteration of CFD (computational fluid dynamic) tables for thrust/drag performance (M. Kinzel, U. Central Florida)



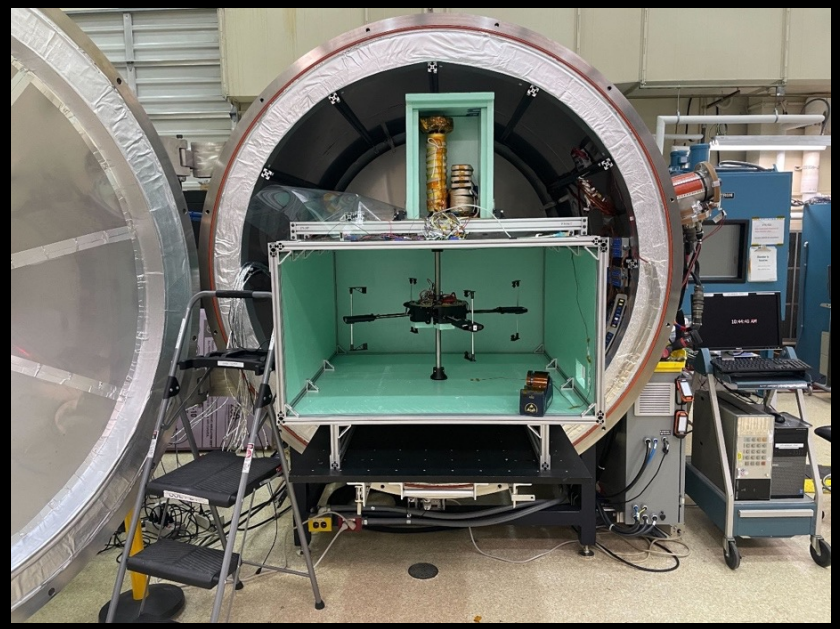
DraGMet seismometer cryo testing at JAXA; EM (engineering model) assembled for delivery to APL



Lander E-field modeling to calibrate antenna readings to ambient field given lander perturbation

Phase B activities: APL test facilities

Titan Pressure Environment Chamber (TPEC)



DraGMet wind sensor setup for testing at Titan's 94-K cryogenic temperature and at 1.5-bar surface pressure, so that gas flow conditions are fully representative of the Titan environment

DrACO ETU (engineering test unit) end-to-end testing of drilling and sample collection in APL TPEC with water ice sample (dyed purple) at -180°C

Titan

System power-on to check pumps and balance thermal systems scheduled week of 8 May 2023

Dragonfly Student and Early Career Guest Investigator Program: Broadening Mission Participation

Quick et al., 2021: https://www.hou.usra.edu/meetings/lpsc2021/pdf/2653.pdf

Cohort	Project	Dragonfly Team Mentors	Grad Student Guest Investigators
1 2021-23	Seismic investigation of Titan's interior using full waveform modeling	Mark Panning, JPL	**Andrea Bryant**, University of Chicago, Physics
	Spectral/compositional library for interpretation of DragonCam / DraGNS measurements	Shannon MacKenzie & Richard Miller, APL	**Karla Negrete**, University of Maryland Baltimore County (UMBC), Mechanical Eng.
	Development of the DragonCam microscopic imager multispectral LED arrays	Jorge Núñez, APL	**Brianna Wylie**, Florida Agricultural & Mechanical University (FAMU), Mechanical Eng.
2 2022-24	Tuning DraGNS' Interpretations to Titan's Surface	Ann Parsons, GSFC & Patrick Peplowski, APL	**Anna Engle**, Northern Arizona Univ. (NAU), Astronomy and Planetary Sci.
	Development of DraMS Instrument Operational Guidelines	Melissa Trainer, GSFC	**Will Suero Amparo**, New Jersey Institute of Tech., Biomedical Engineering
3 2022-24	Volatility of Titan-Relevant Compounds and Implications for Dragonfly Analyses	Morgan Cable & Rob Hodyss, JPL	**A'Laura Hines**, George Mason University, Chemistry
	Building a Library of Diagnostic Fracture Patterns and Erosional Morphologies for Interpretation of DragonCam Images	Ellen Stofan and Dr. Emily Martin, Smithsonian NASM	**Shahrose Khan**, Univ. of California San Diego, Aerospace Engineering
	Background Research for DrEAM Aeroscience Experiment	Aaron Brandis, NASA Ames	**Alyssa Vellucci**, Univ. of Texas Dallas, Mech. Eng.

- Goals of Program
  - Extend opportunities for graduate students to work with *Dragonfly* scientists and engineers
  - Encourage broader participation by making it easier for students who ***don't*** already have connections to *Dragonfly* or NASA spacecraft missions and/or who ***don't*** have a planetary science background
  - Provide networking opportunities and to expand training of the next generation of mission team members and leaders

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Applications for Guest Investigators cohort #4 are being accepted through 16 June 2023
https://dragonfly.jhuapl.edu/Student-Opportunities/

Cohort	Project	Dragonfly Team Mentors
4 2023-25	Data visualization library for Dragonfly science operations	Jake Strang, APL
	Dragonfly science planning tool development	Hari Nair, APL
	Characterizing sample morphology to interpret DragonCam images	Ellen Czaplinski, JPL; Shannon MacKenzie & Jorge Núñez, APL

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DRAGONFLY

http://dragonfly.jhuapl.edu