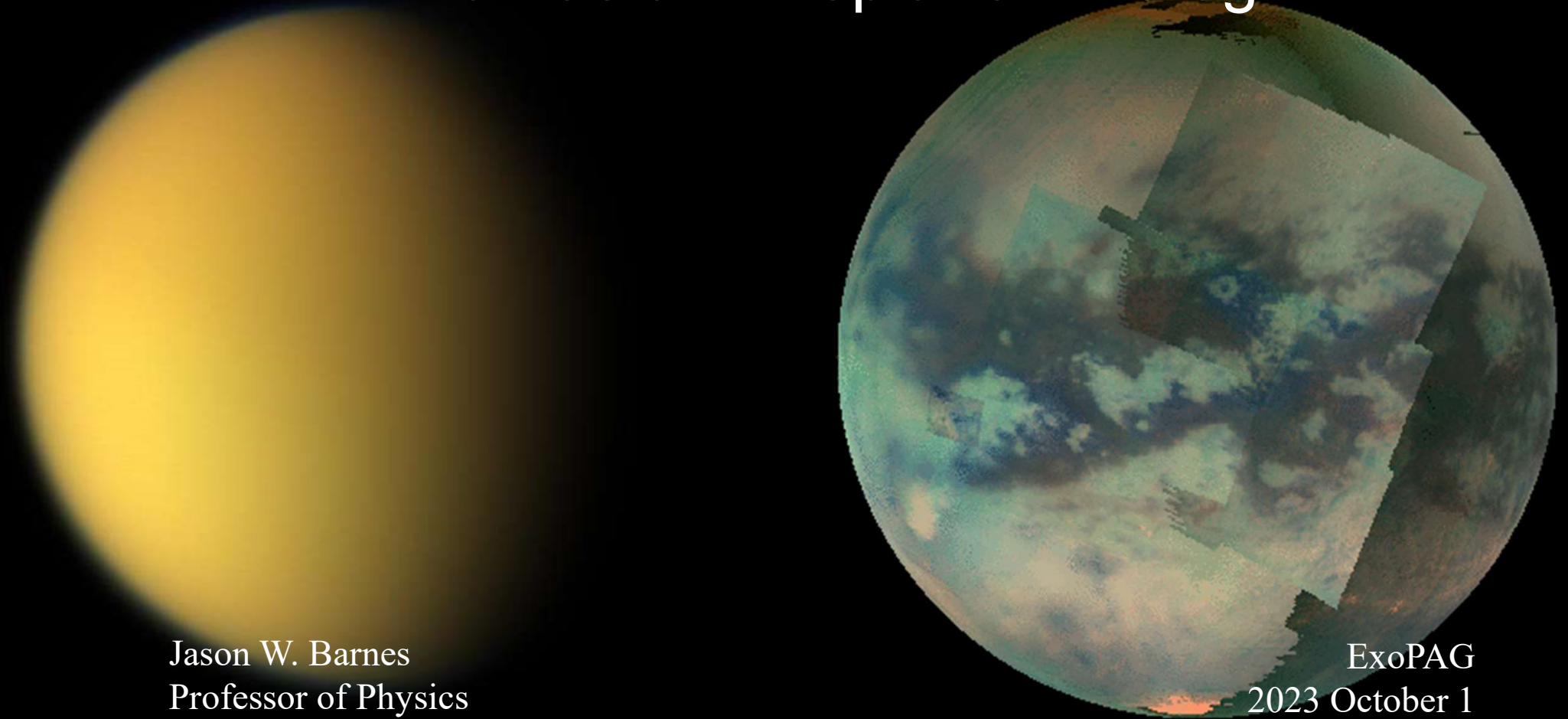


Titan as an Exoplanet Analog



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Professor of Physics
University of Idaho

ExoPAG
2023 October 1
San Antonio, Texas

Planets with Air and Solid Surfaces



Venus

Mass: $0.82 M_E$
Radius: $0.95 R_E$
Density: 5.24 g/cm^3
Atm Press: 92 bar
Atm Comp: CO_2
Surf Temp: 740K
Crust: rock
Clouds: $\text{SO}_2, \text{H}_2\text{SO}_4$



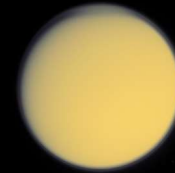
Earth

Mass: $1 M_E$
Radius: $1 R_E$
Density: 5.52 g/cm^3
Atm Press: 1 bar
Atm Comp: $\text{N}_2, \text{O}_2, \text{H}_2\text{O}$
Surf Temp: 288K
Crust: rock
Clouds: H_2O



Mars

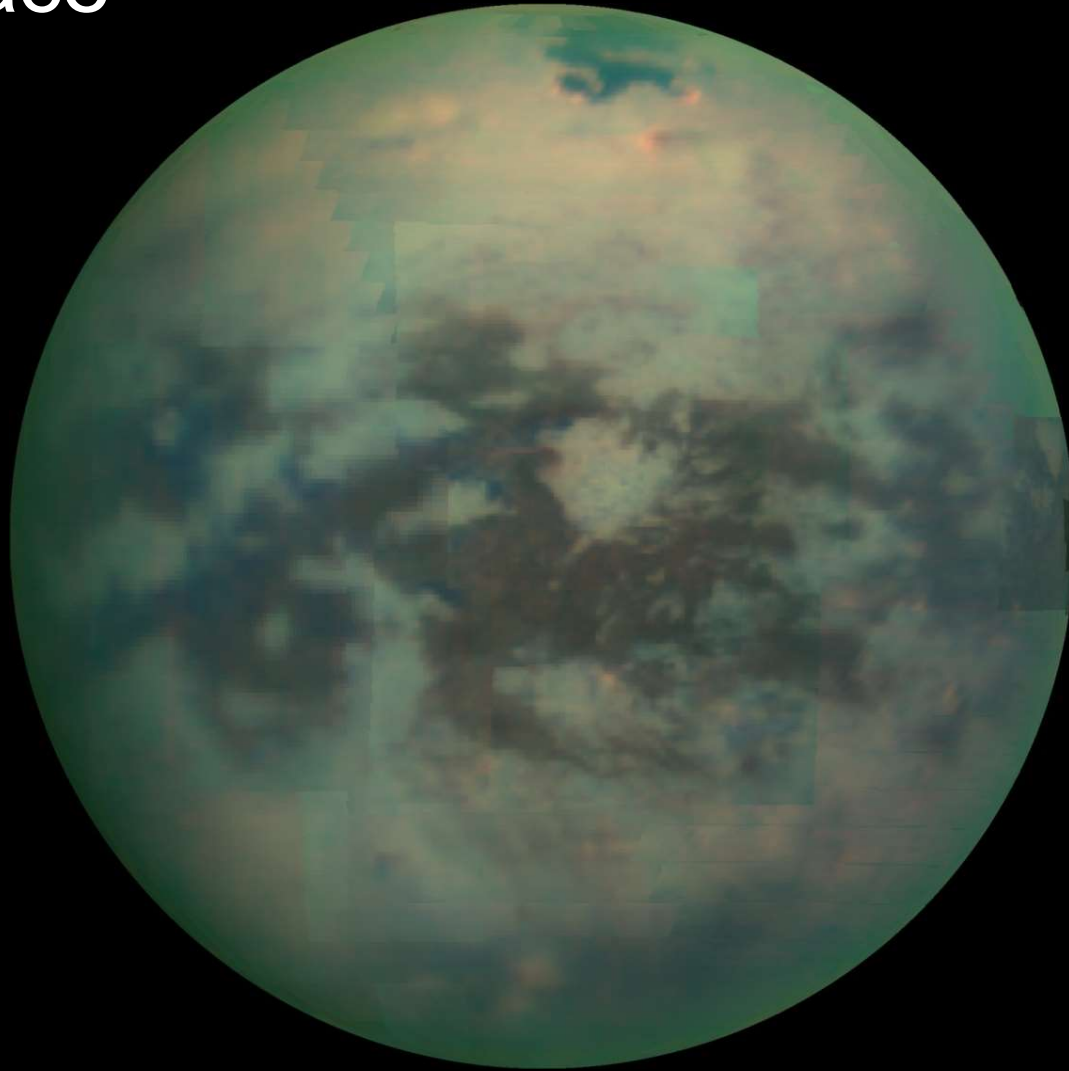
Mass: $0.11 M_E$
Radius: $0.53 R_E$
Density: 3.94 g/cm^3
Atm Press: 0.006 bar
Atm Comp: CO_2
Surf Temp: 210K
Crust: rock
Clouds: H_2O



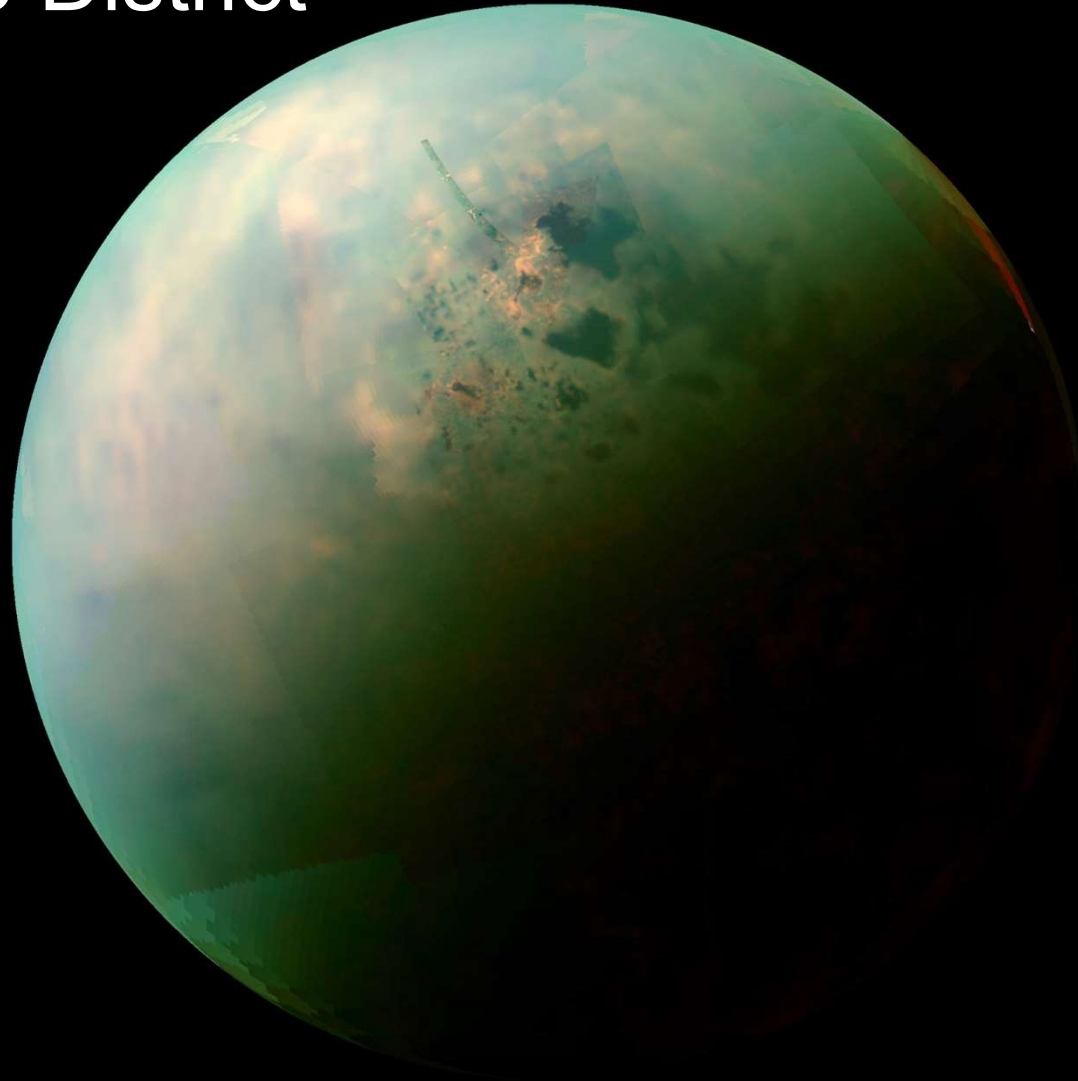
Titan

Mass: $0.023 M_E$
Radius: $0.40 R_E$
Density: 1.88 g/cm^3
Atm Press: 1.5 bar
Atm Comp: N_2, CH_4
Surf Temp: 94K
Crust: ice
Clouds: $\text{CH}_4, \text{C}_2\text{H}_6$

Titan's Surface



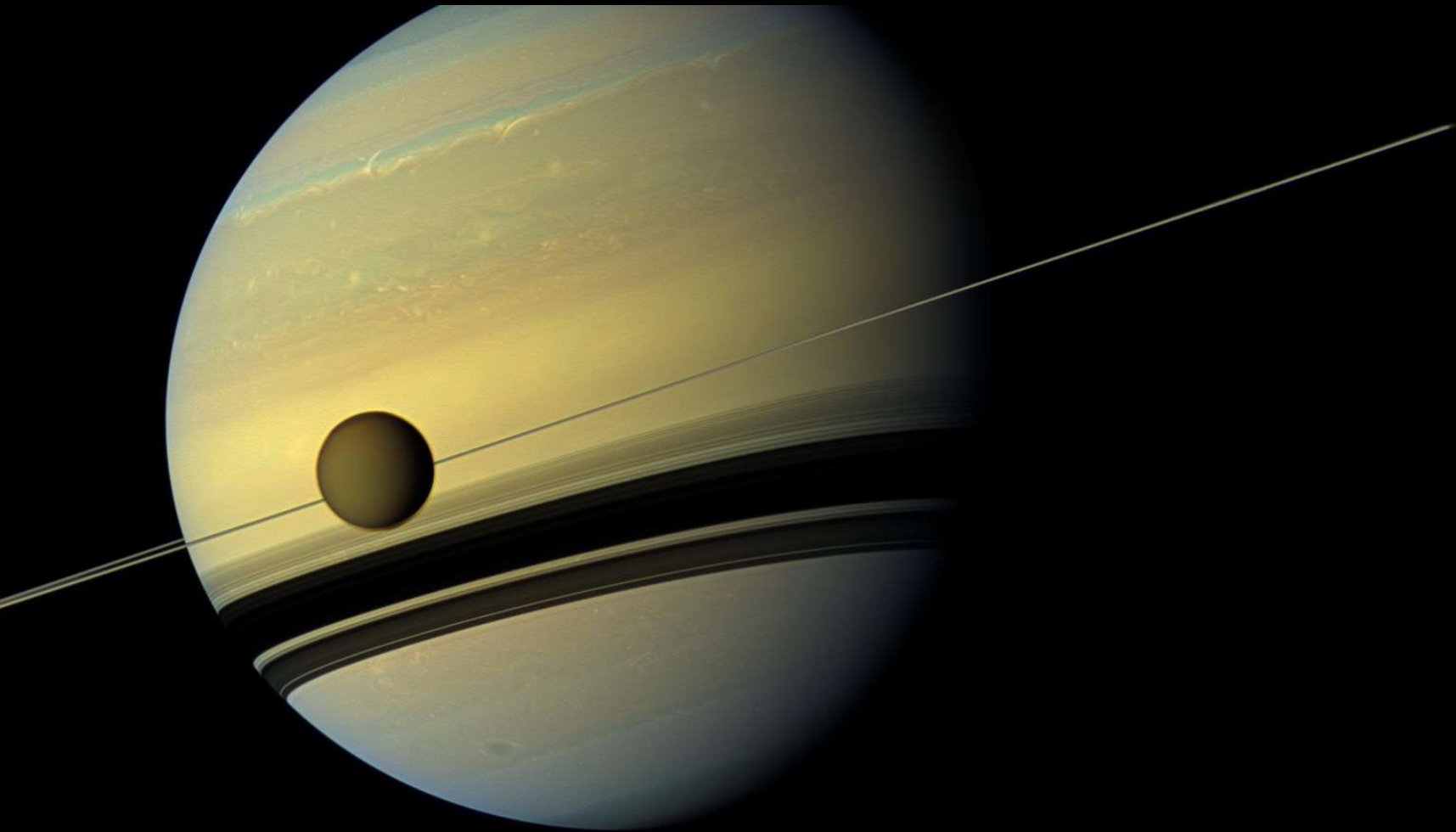
Titan's Lake District



Specular Reflections off of Titan's Seas



Also an Exomoon Analog



Local Waterworlds

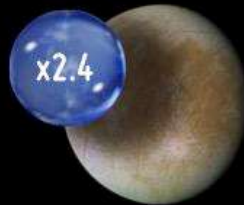
Oceans of the Solar System



x6.2

Ganymede

(5.4% Liquid Water)



x2.4

Europa

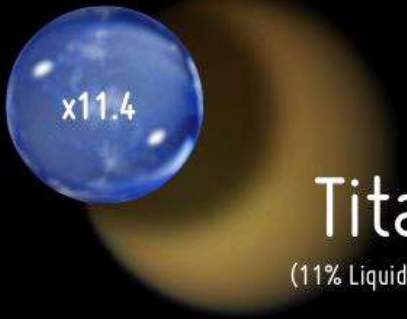
(6.4% Liquid Water)



x1

Earth

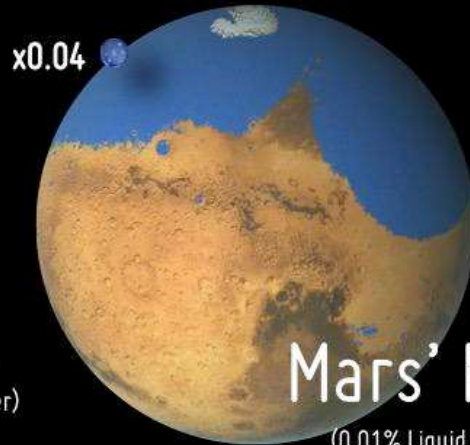
(0.02% Liquid Water)



x11.4

Titan

(11% Liquid Water)



x0.04

Mars' Past

(0.01% Liquid Water)

(estimated percent of liquid water by mass excluding ice)

Credit: PHL @ UPR Arcibo, NASA

The Dragonfly Octocopter



Dragonfly: A Relocatable Lander

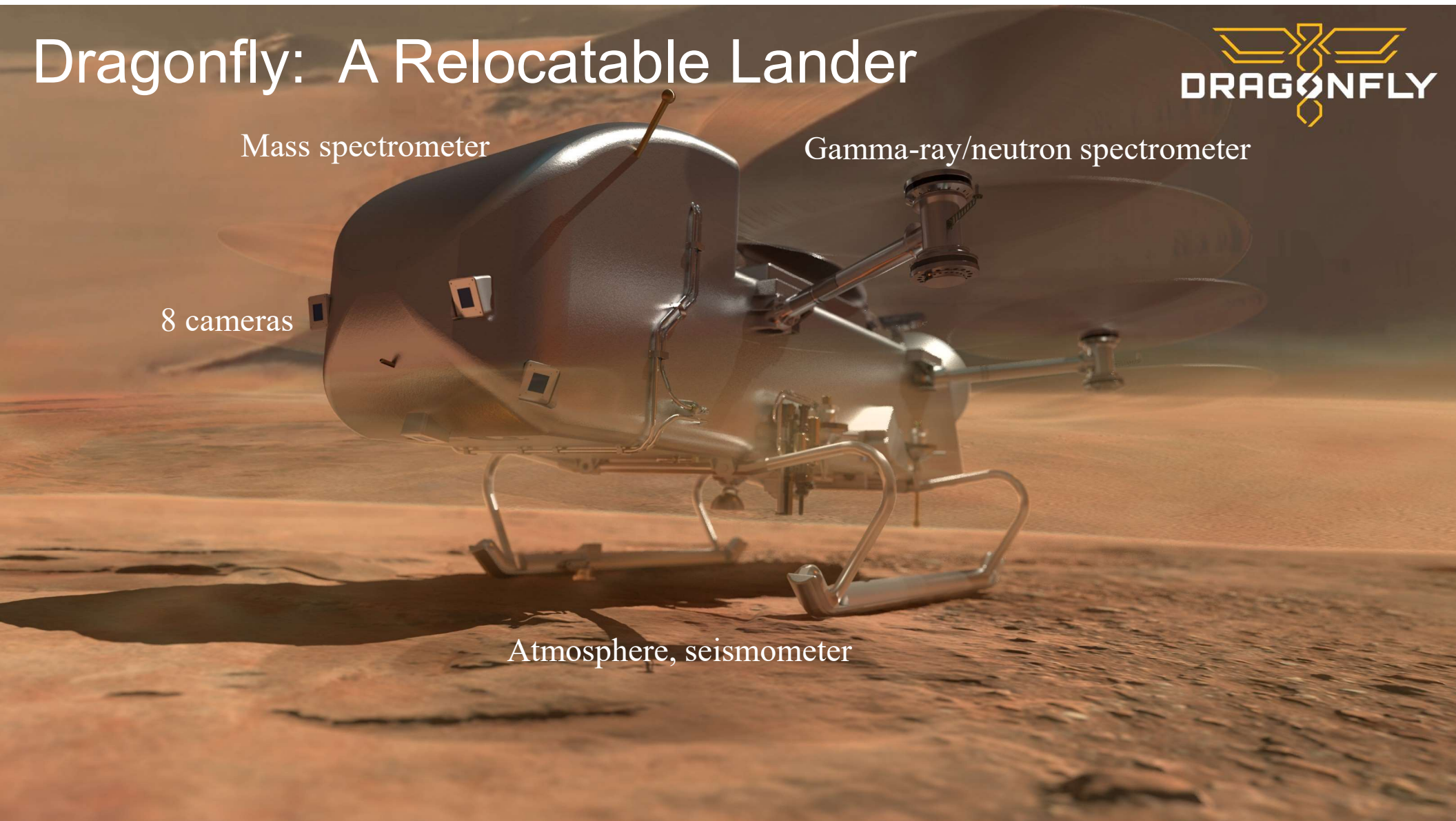


Mass spectrometer

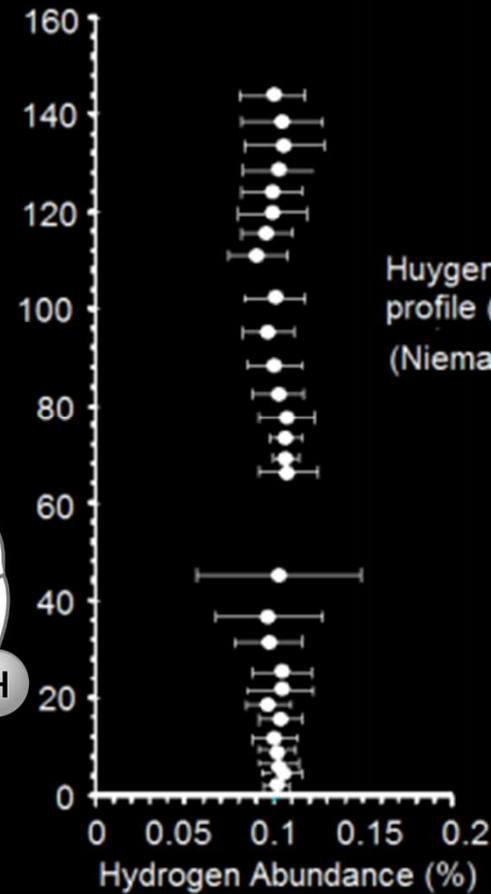
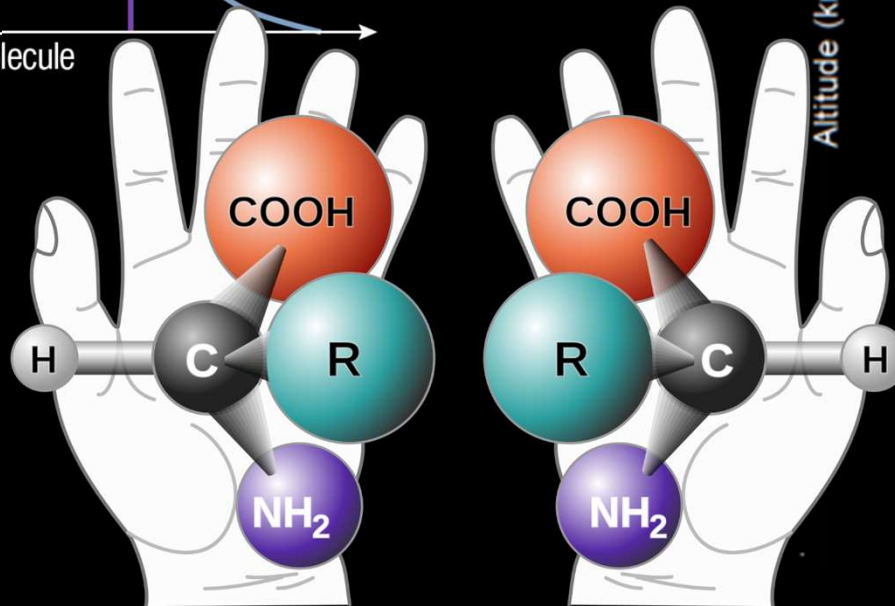
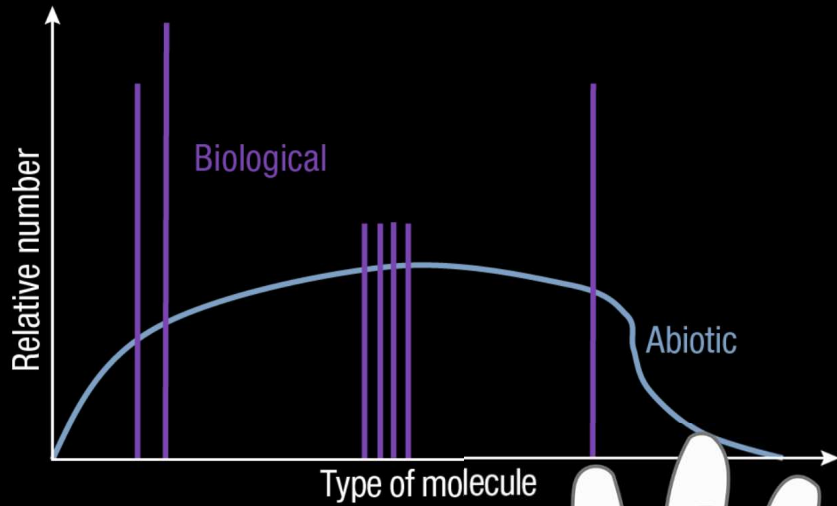
Gamma-ray/neutron spectrometer

8 cameras

Atmosphere, seismometer



Titan Astrobiology from Dragonfly



How is Titan an exoplanet analog?

- . Atmospheric transmission spectroscopy and photochemistry
- . Atmospheric circulation of a low-insolation slow rotator
- . Only other known hydrological system outside of Earth
- . Specular reflections
- . Dynamics and geophysics of an exomoon
- . Waterworld – a mini-mini-Neptune
- . Astrobiology and prebiotic chemistry



To Titan!

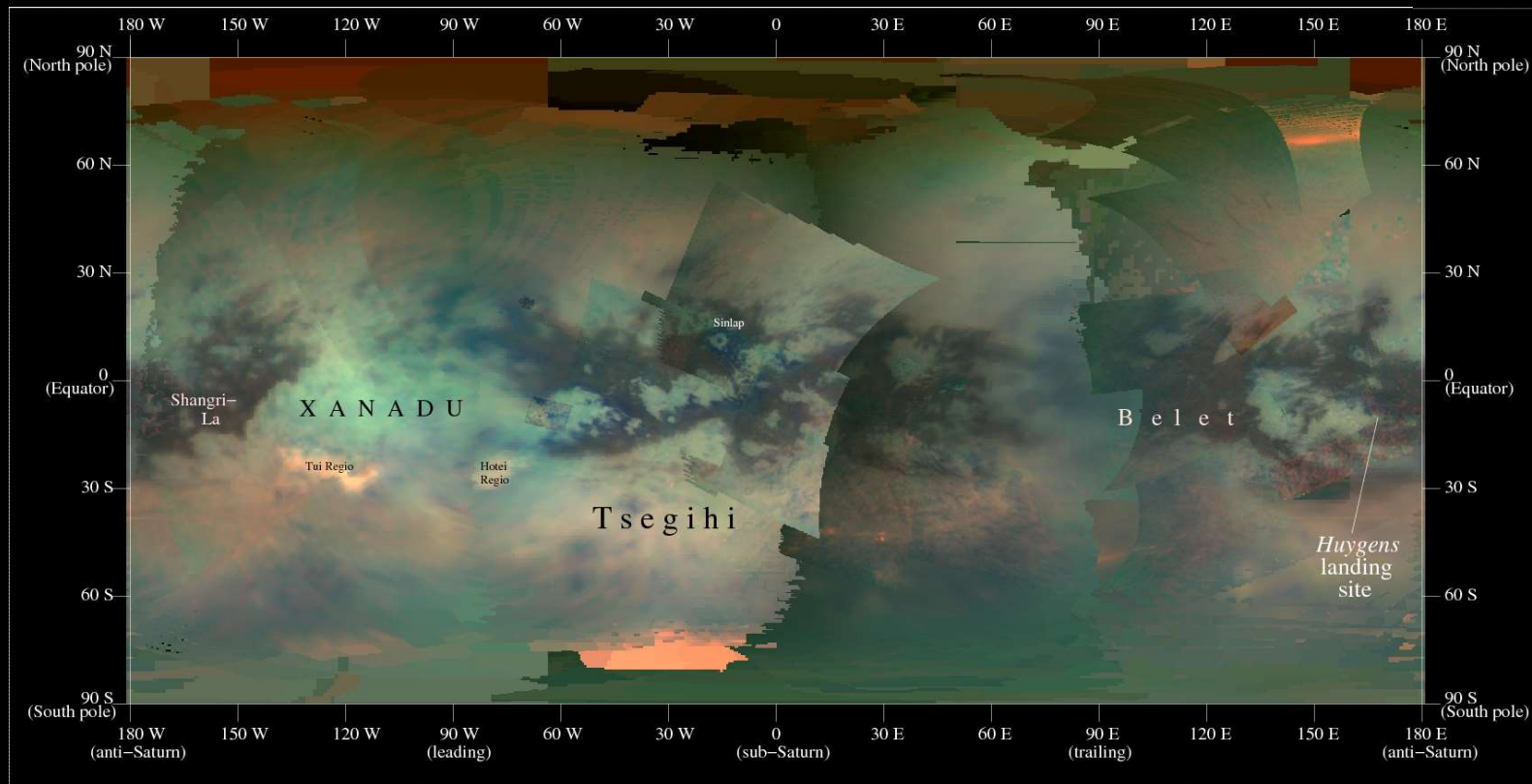



DRAGONFLY


DRAGONFLY



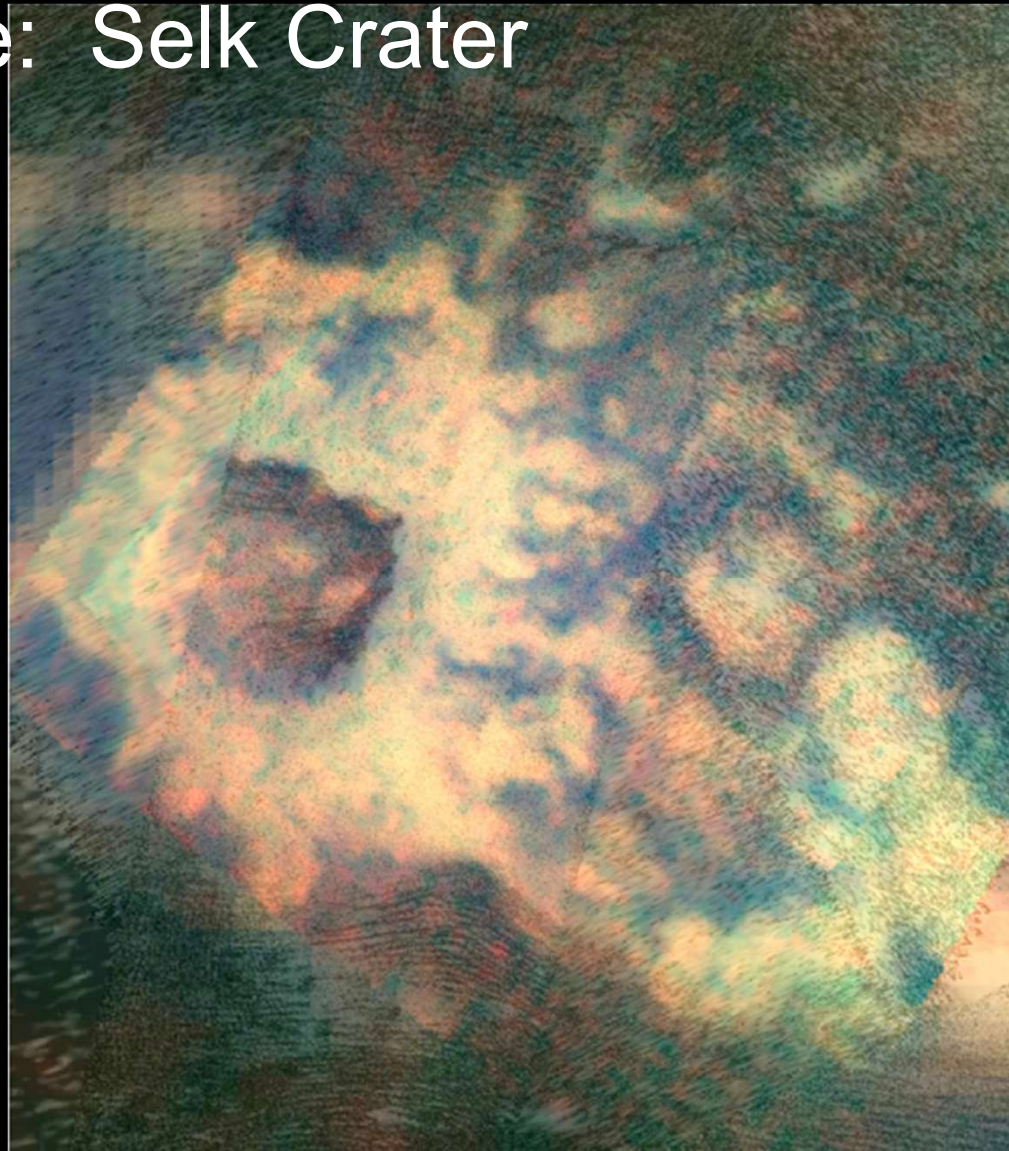
Where Should We Land?



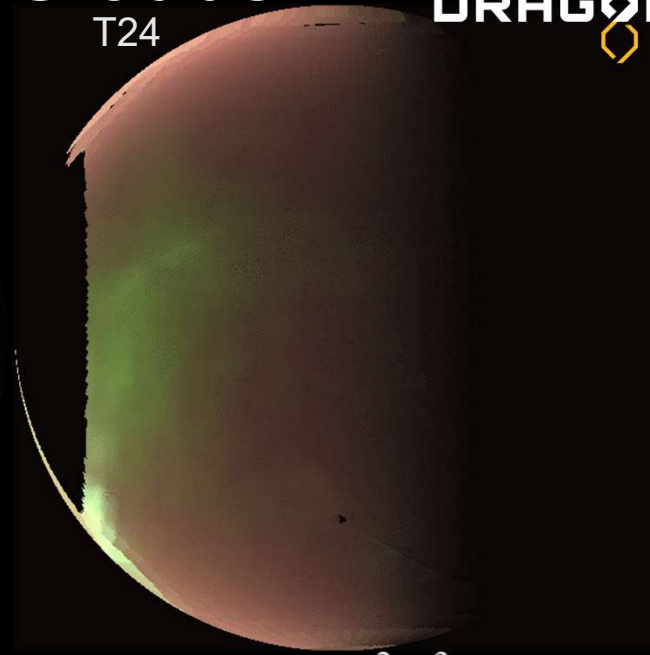
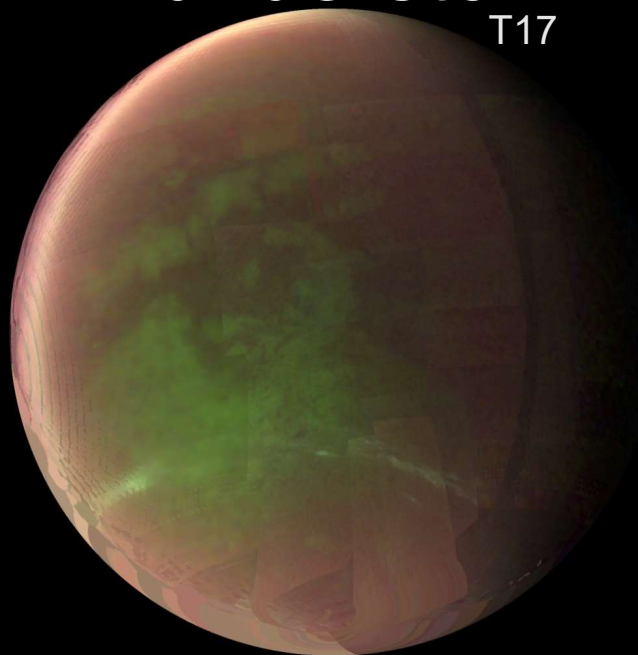
Cylindrical map – RED = 5 μm , GREEN = 2 μm , BLUE = 1.28 μm

Map from Cassini-VIMS
Visual and Infrared Mapping Spectrometer

Landing Site: Selk Crater

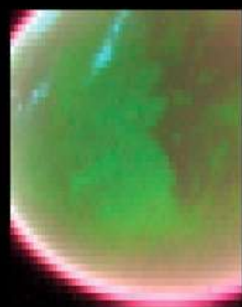


Methane “Thunderstorm” Clouds

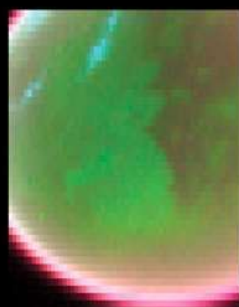


Obs 1

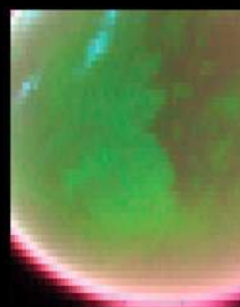
Tb



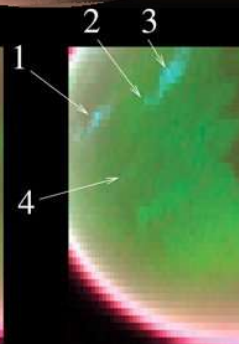
Obs 2



Obs 3



Obs 4

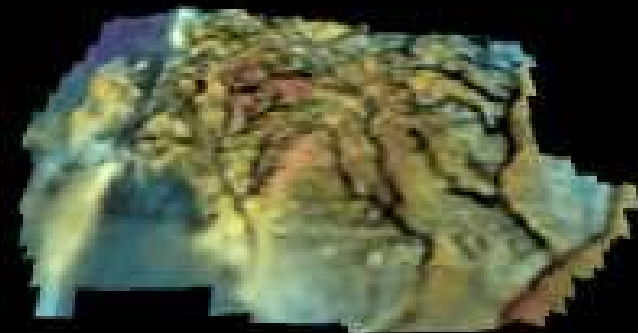
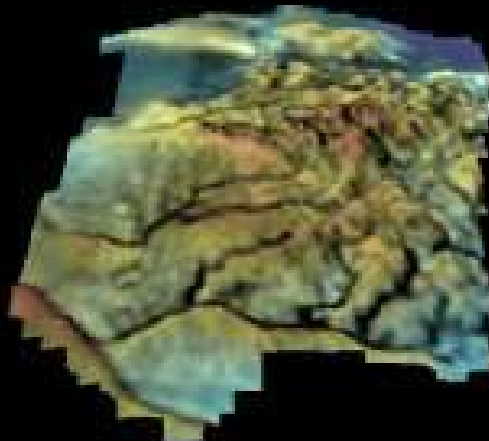
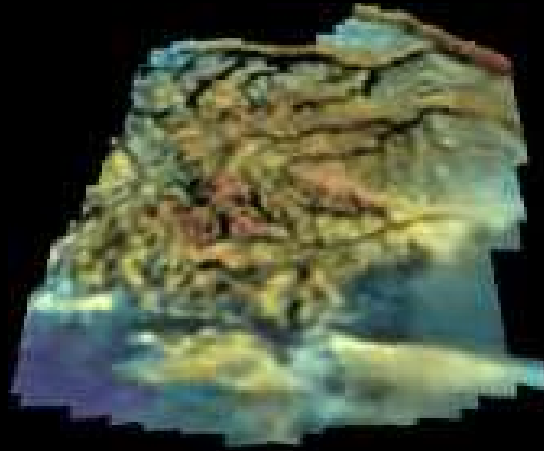


Obs 5



Obs 6

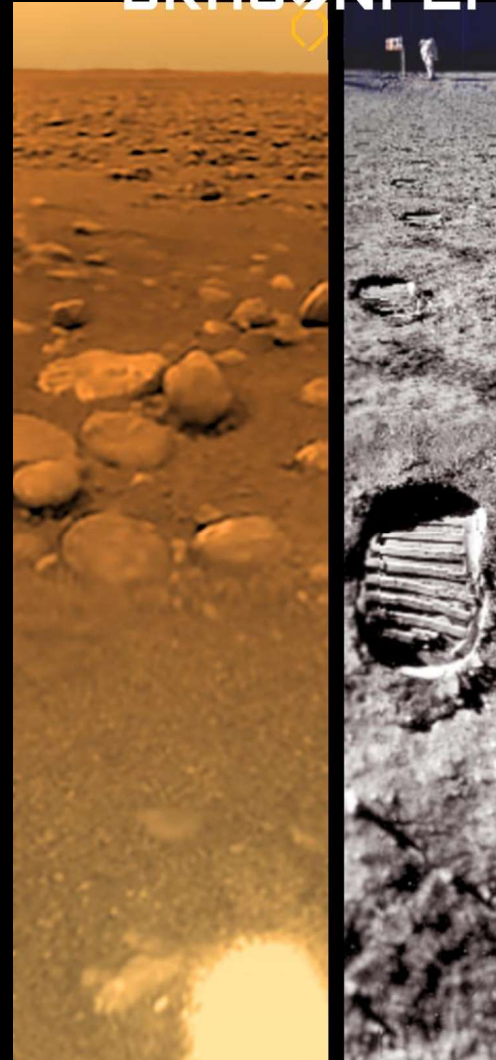
Channels Viewed from Huygens





Outflow Channel from the Surface!


DRAGONFLY



Titan's Organic Sand Dunes

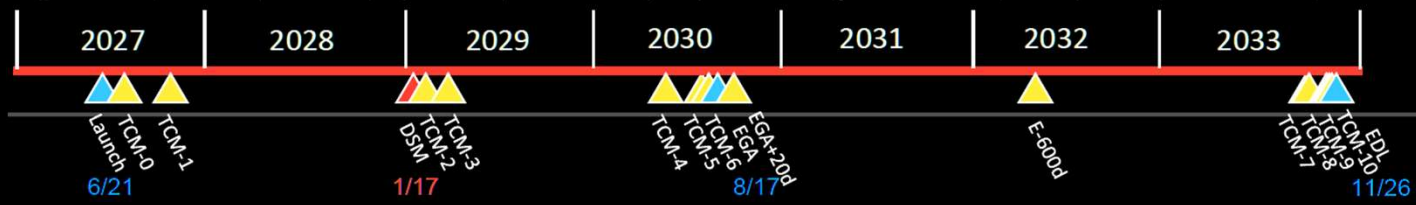
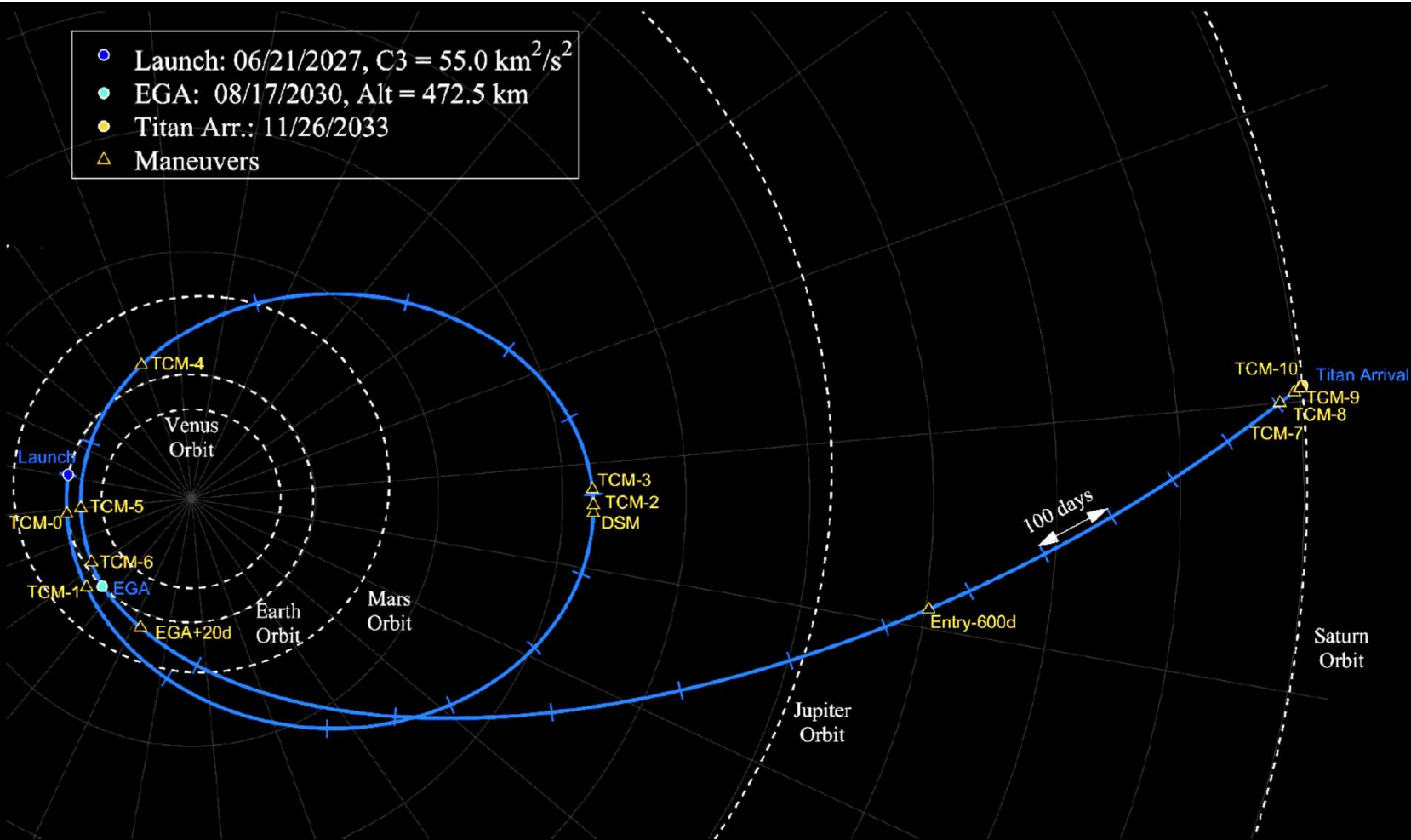


Titan Dune Analog: Namibia





- Launch: 06/21/2027, $C3 = 55.0 \text{ km}^2/\text{s}^2$
- EGA: 08/17/2030, Alt = 472.5 km
- Titan Arr.: 11/26/2033
- △ Maneuvers



Getting There