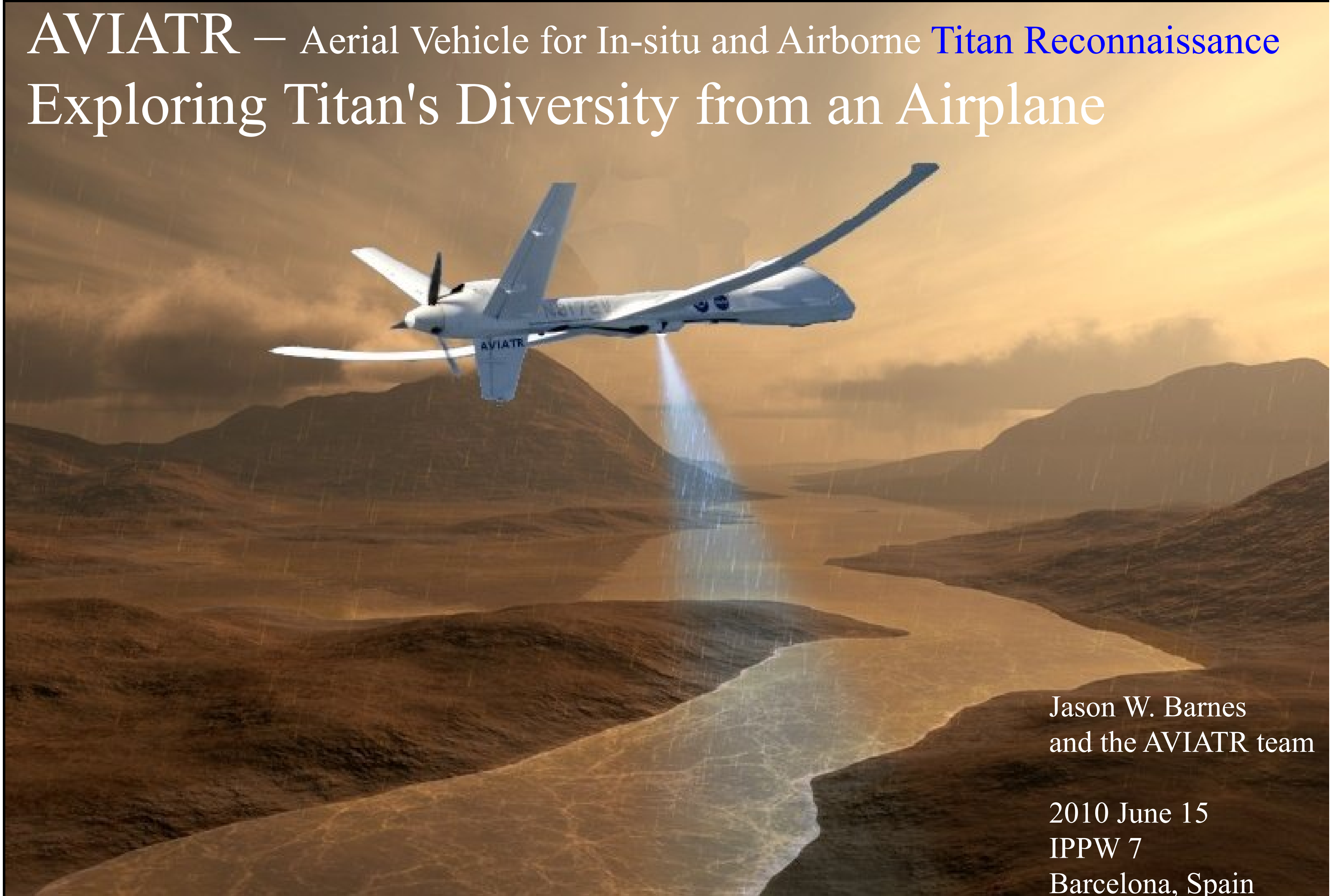
AVIATR – Aerial Vehicle for In-situ and Airborne Titan Reconnaissance

Exploring Titan's Diversity from an Airplane



Jason W. Barnes
and the AVIATR team

2010 June 15
IPPW 7
Barcelona, Spain

Mission Scope: Why not a balloon?

In general, either a balloon or an airplane is capable of achieving similar sets of scientific objectives. AVIATR is better suited to the task than a balloon:

BETTER SCIENCE: With go-to capability, stereo, repeat imaging, rapid altitude-change capability, remaining on the dayside, and direct-to-Earth communcations, a fixed-wing heavier-than-air plane can address more scientific objectives than a balloon and can be done on a Discovery budget.

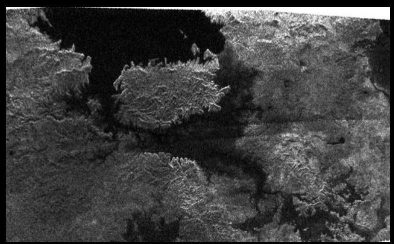
MORE EFFICIENT ^{238}Pu USAGE: Because a hot-air balloon uses MMRTG waste heat for buoyancy, it will not work with more efficient ASRGs. Conversely, MMRTG's are too inefficient in terms of Watts/kg to fly an airplane. Thus the ASRG is an enabling technology for a Titan Airplane.

Airplane vs. Balloon

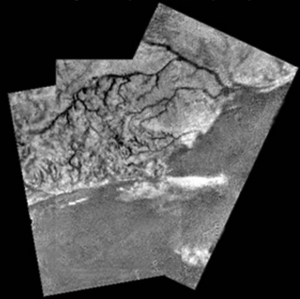
AVIATR Science Goals

Surface Geology: Ascertain, from above, the elements of Titan's geological processes and history, their relative levels of activity, and their global distributions and morphologies.

Lakes

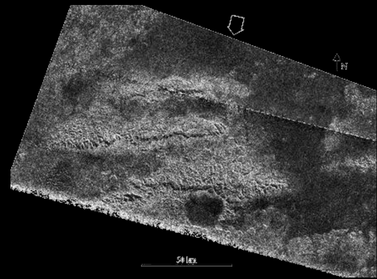


Channels

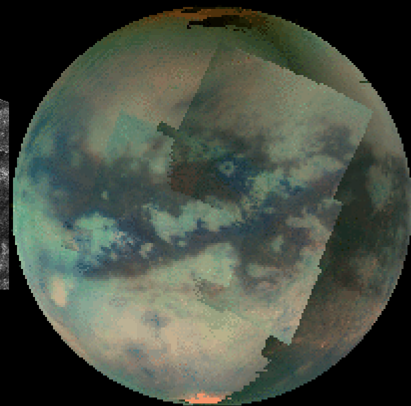


Dunes

Surface Activity

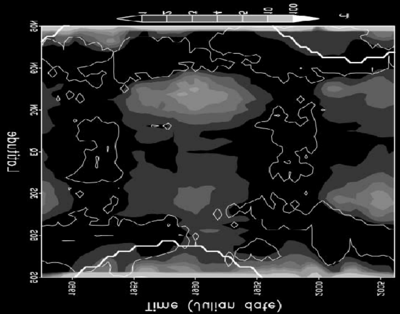


Exploration …

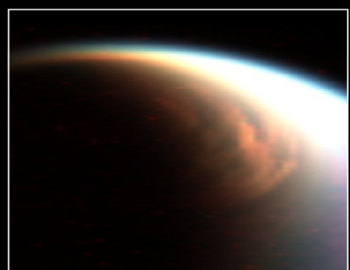


Atmospheric Science: Characterize, from within, the global diversity and local conditions of Titan's present-day atmosphere.

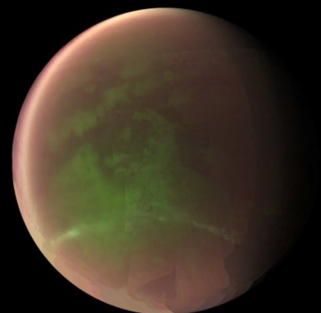
Winds



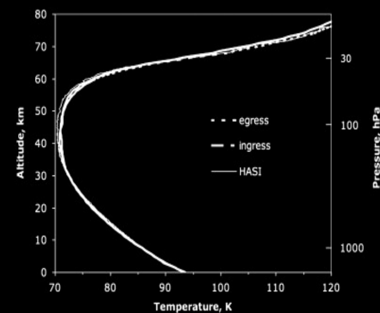
Clouds



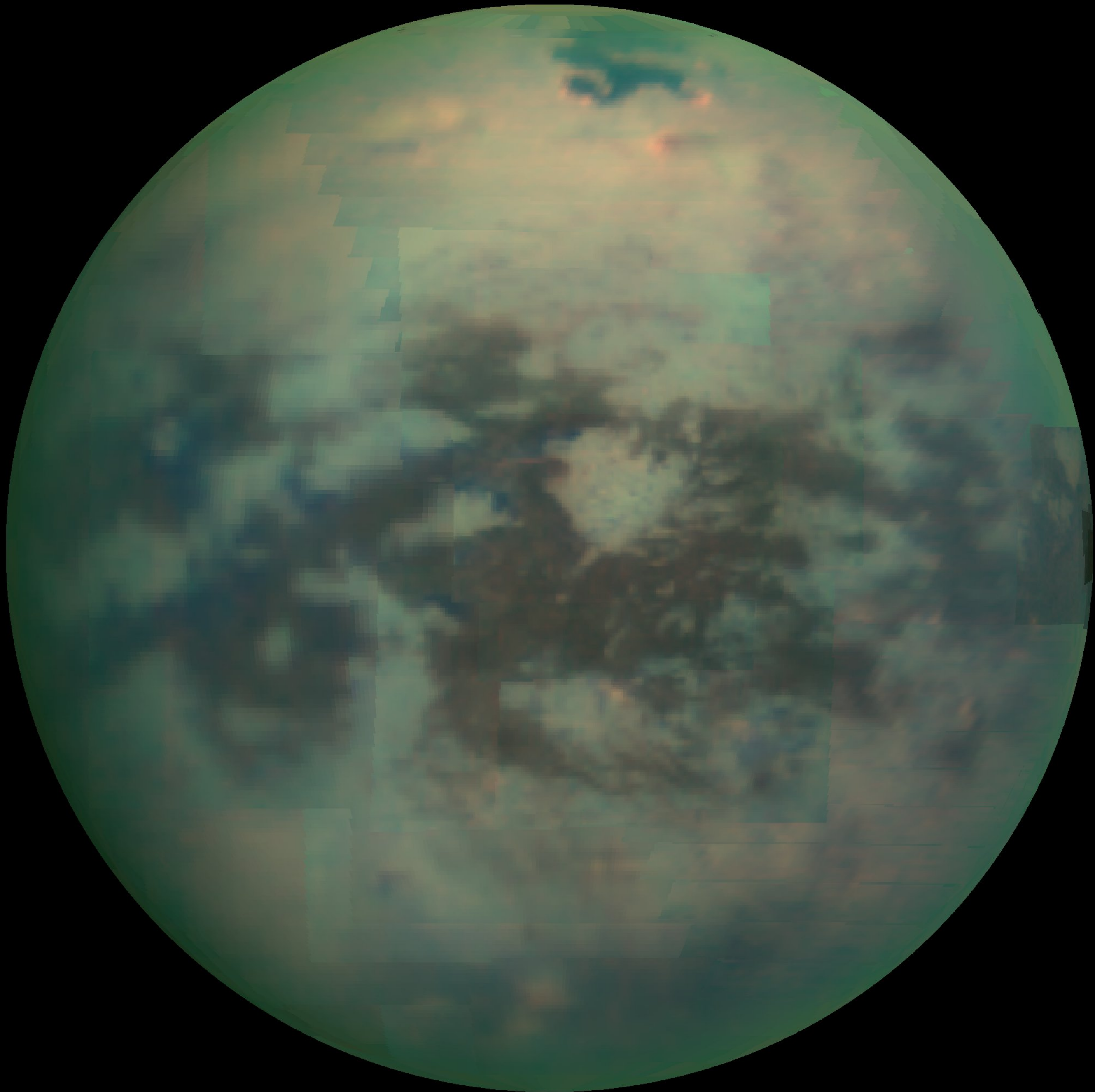
Haze



Structure



Titan's Diversity



UAV Design

Surface Gravity – 1.352 m/s^2 (0.138 x Earth)
Atmospheric Density – 3.9 kg/m^3 (at 10 km; E=1.2 kg/m^3)
Temperature – 85 K
Wind Speed at Flight Altitude – 0.0-3.0 m/s
Speed of Sound – 200 m/s
Specific Kinetic E for Flight – $^1/_{30}$*Earth, $^1/_{1200}$*Mars

With 3.25 times more air and 7 times less gravity than Earth (or 500 times more air and 2 times less gravity than Mars), along with a workable thermal environment, heavier-than-air flight makes more sense on Titan than anywhere else in the solar system.

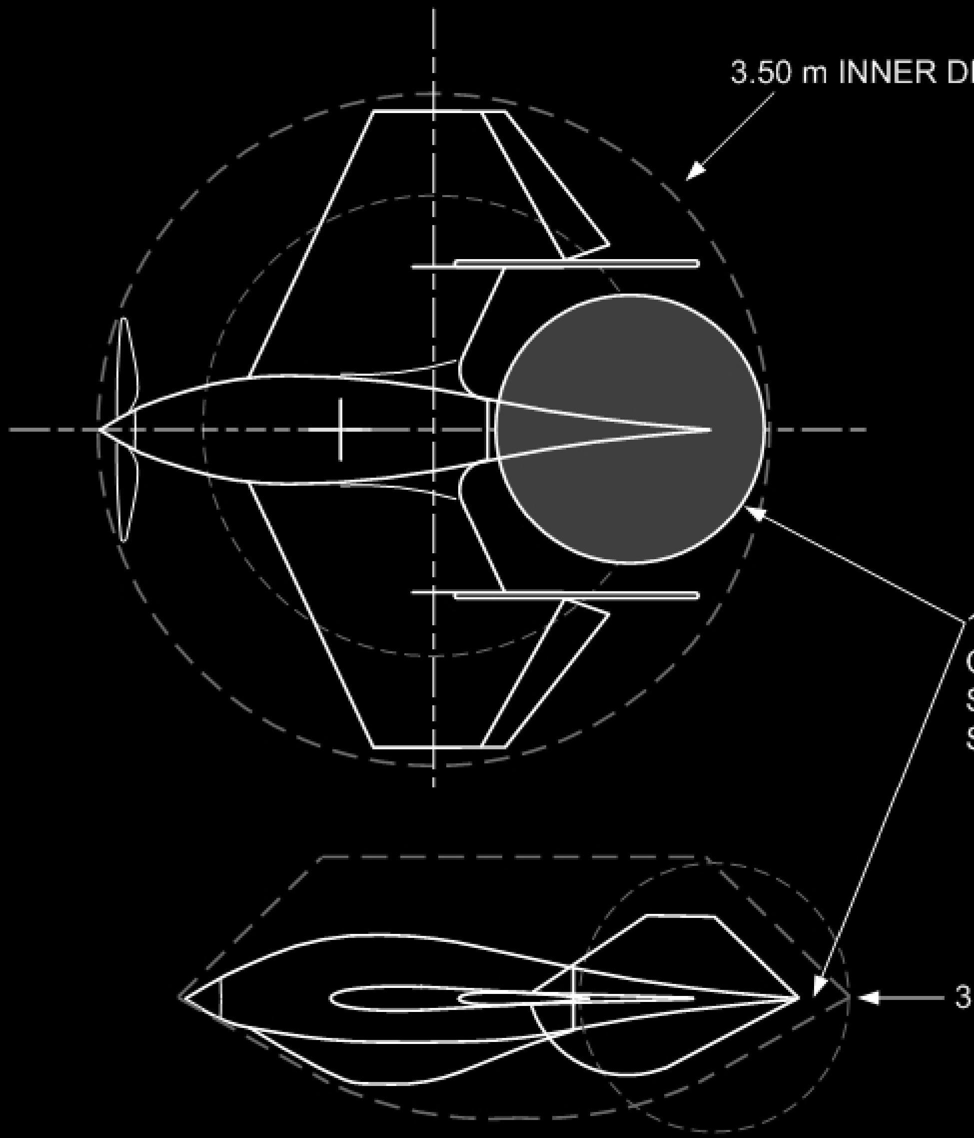
Titan Flight Parameters

UAV Design

Constraint	Derived requirement
No deployed elements – fits in 4-m rocket shroud	Max probe diameter ≤ 4 m, dia.
Atmospheric Entry and Heating Profile Similar to Huygens	60 deg half-angle conical entry vehicle, ≥ 3 m, dia.
Single Mission Element	Direct-to-Earth Communications
UAV Mission Duration ≈ 1 yr.	RPS for prime power

Mission Constraints

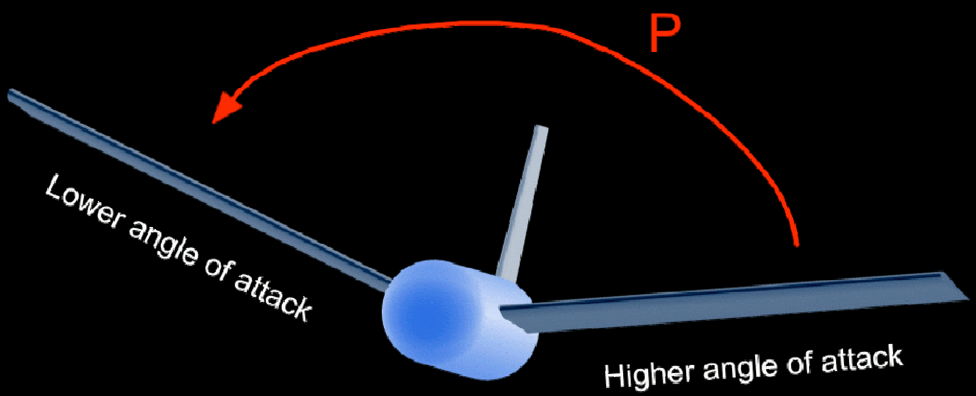
UAV Design



Wing Span	3.30 m (10.82 ft)
Wing Area	3.30 sq m (35.50 sq ft)
Aspect Ratio	3.3
.40c Sweep	20.0 deg
Fuselage Length	3.50 m (11.48 ft)
Mass	110.0 kg (slug)
Cruise Airspeed	8.5 m/sec (28 ft/sec)
Total Power Avail	300 Watts
Cruise Power	145 Watts

Airframe & Thermal Control

UAV Design



- With wing dihedral angle (left), stable and consistent weight and balance without consuming fuel, and proper trim, the aerial vehicle is inherently stable. Without control inputs, will return to straight and level flight. Long-wavelength oscillations can build up over many hour timescales.

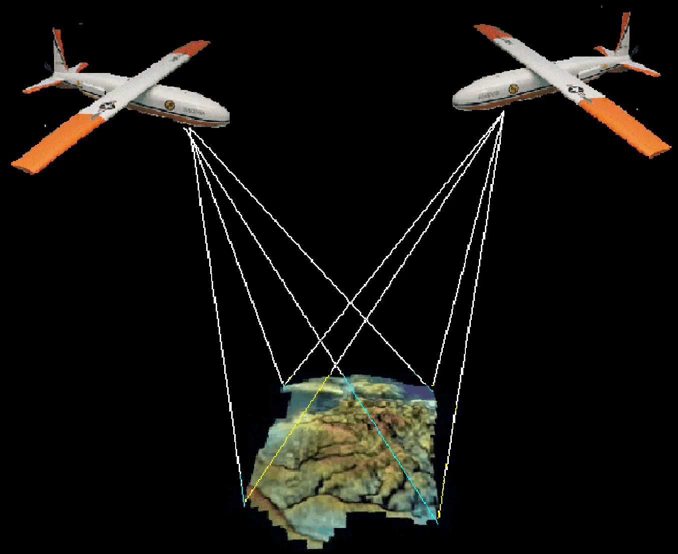
- AVIATR will have a built-in safe mode, just like any other modern interplanetary spacecraft. In safe mode the vehicle will fly so as to keep the solar zenith angle below a given value (say, 45^{o}), and point the antenna toward the Sun for communication with Earth to wait for further instruction.

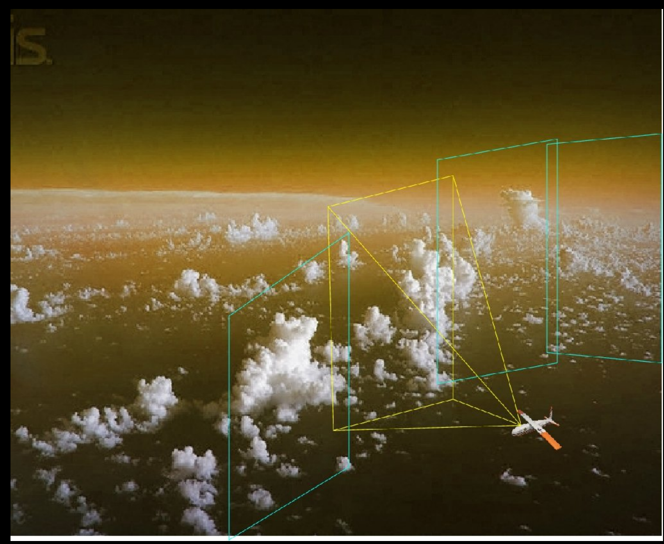
- Like safe mode for a vehicle in space: the AVIATR safe mode requires no prior knowledge of the vehicle's position or orientation.

Safe Mode

Science Instruments: Optical Remote Sensing Suite

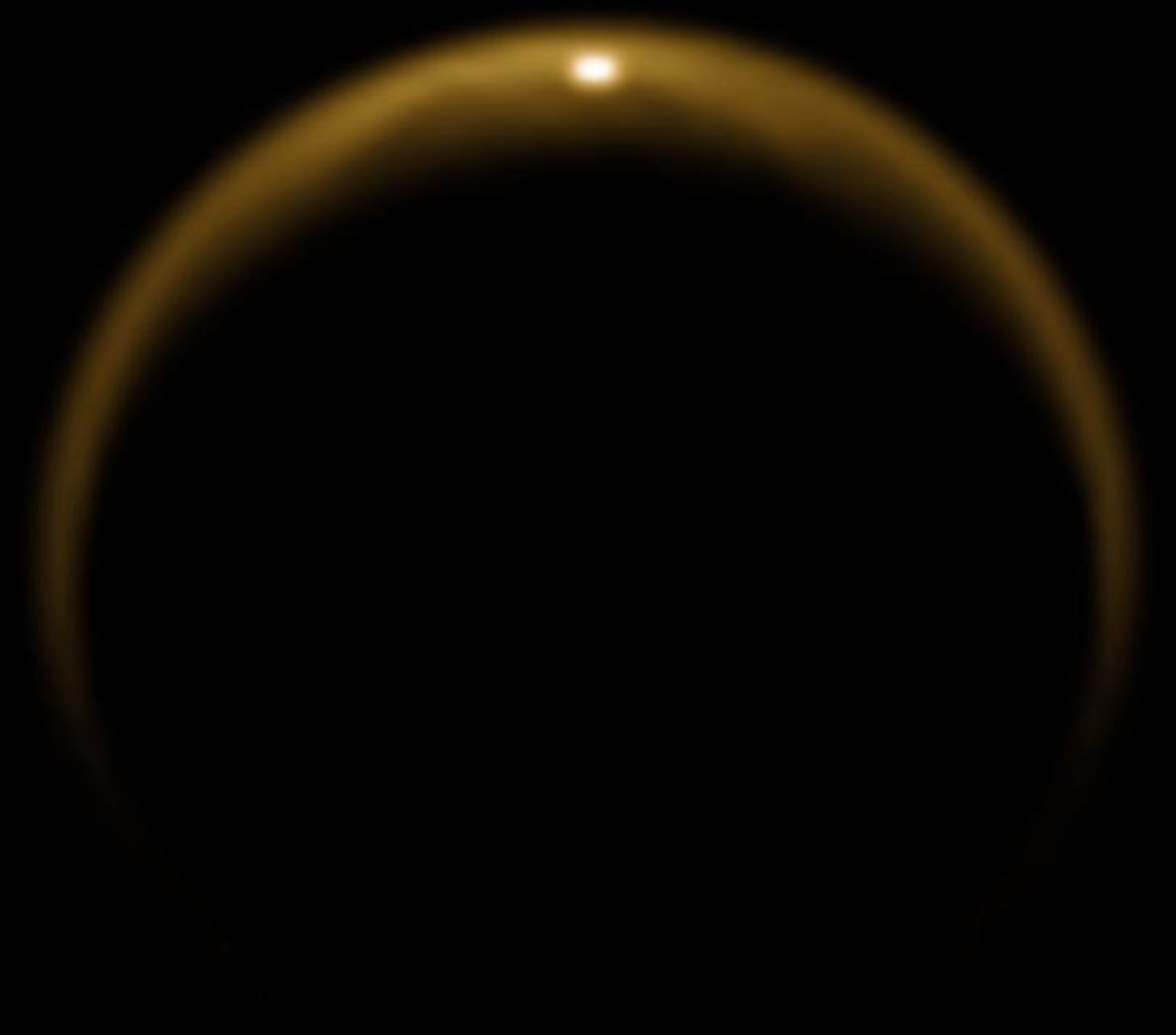
	High-Resolution Imager	Horizon-Looking Imager	Near-Infrared Spectrometer
Wavelength:	1.97 – 2.09 µm (2 micron methane window)	4.87 to 5.15 µm (5 micron methane window)	1.05 to 5.4 µm (with >=400 channels across this range)
Ground Scale:	0.25 to 0.5 m/pix at 3.5 km altitude (~2 m/pix at 15 km)	~15 to 34 m/pixel	3.5 to 8 m/pixel at 3.5 km alt (~15 to 34 m/pixel at 15 km)





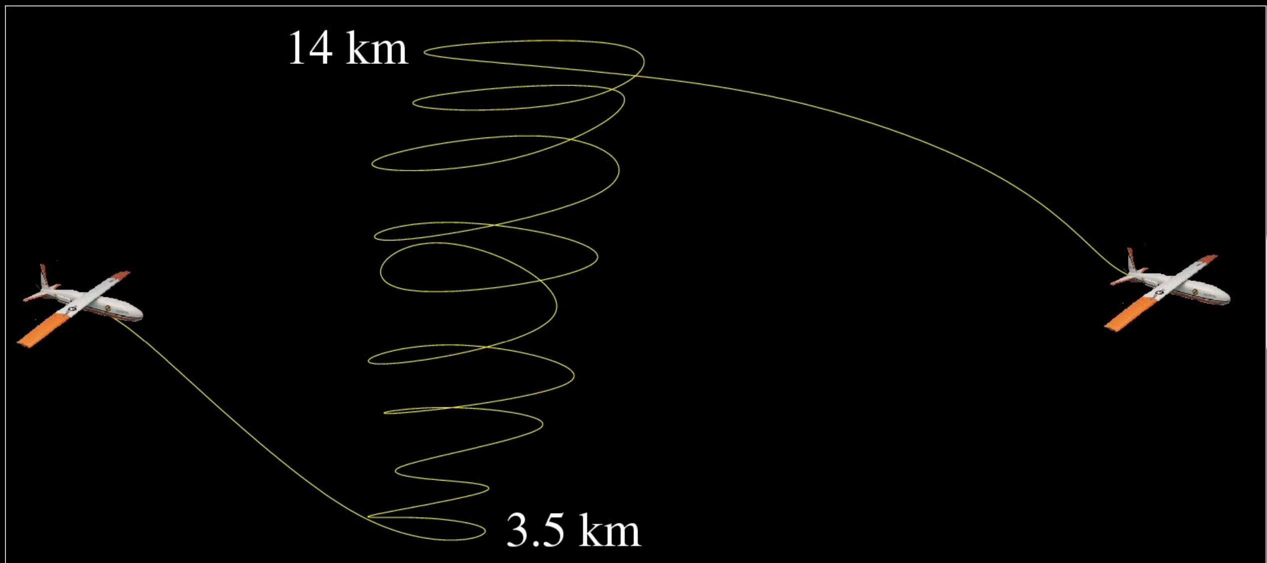
ORS Instrumentation

Specular Reflections

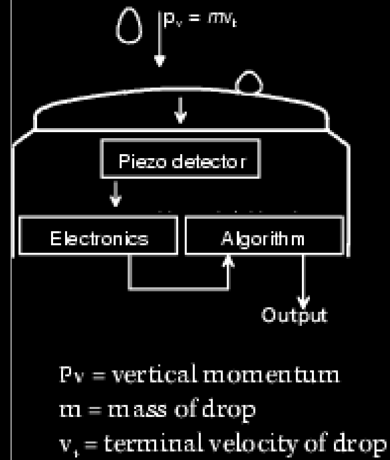


Science Instruments: Atmospheric Suite

Atmospheric Structure: P, T, humidity

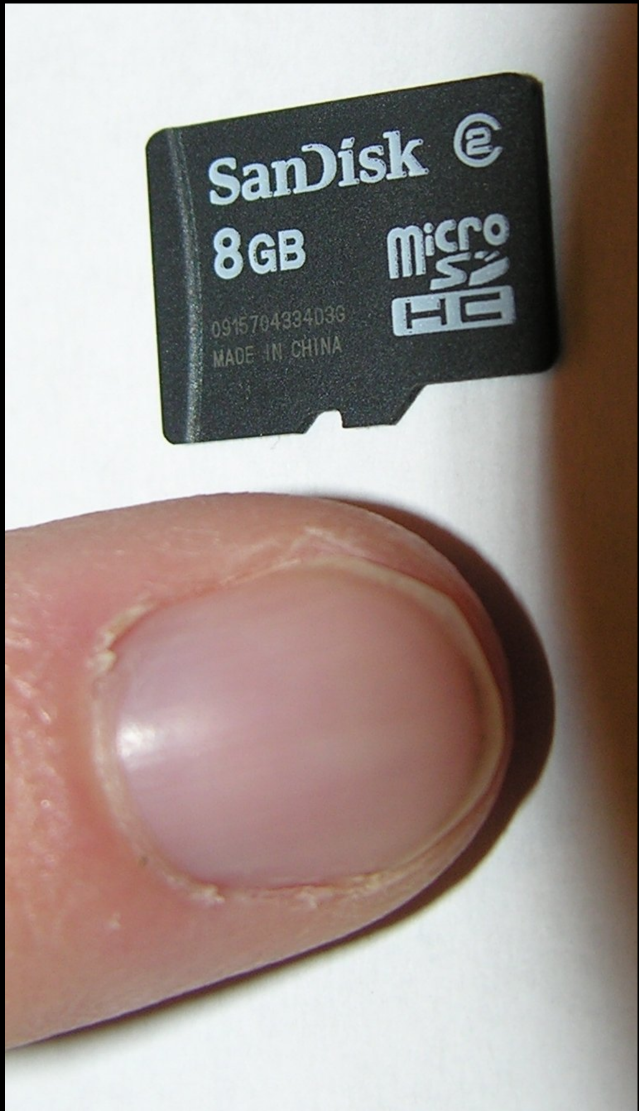


Nephelometer and Raindrop Sensor



Atmospheric Instrumentation

Operations



Bandwidth is limited; storage is cheap, small, & low-mass. We will build in far more onboard storage than we will be able to return to Earth.

Downlink only those data thought highest priority, but keep the others. Download them from the aircraft if and when a request is made for them.

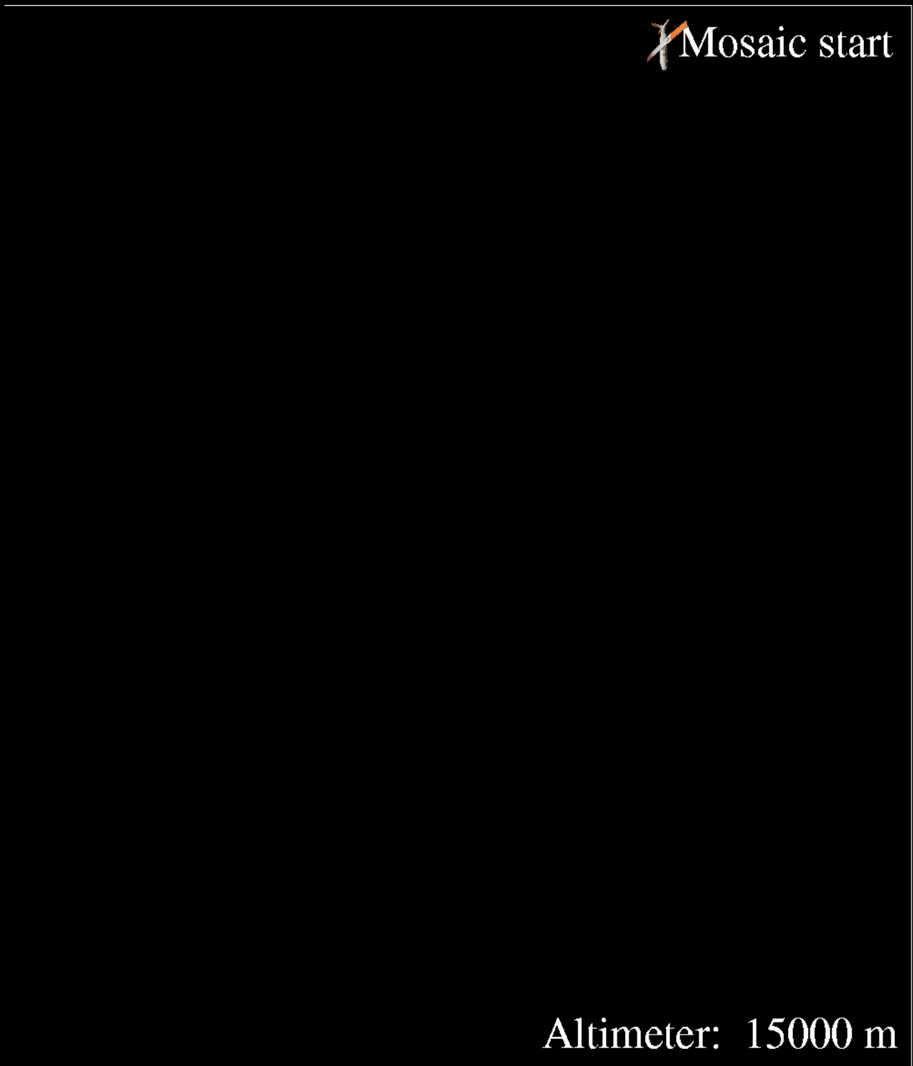
Send back meta-data and thumbnail-sized initial versions of images so that the science team can select which to return at full resolution

Both lossless and lossy compression available for science team to select on a per-image basis.

This approach and these abilities allow us to be highly efficient users of our limited bandwidth, in order to maximize the science return.

Data Management Strategy

Operations

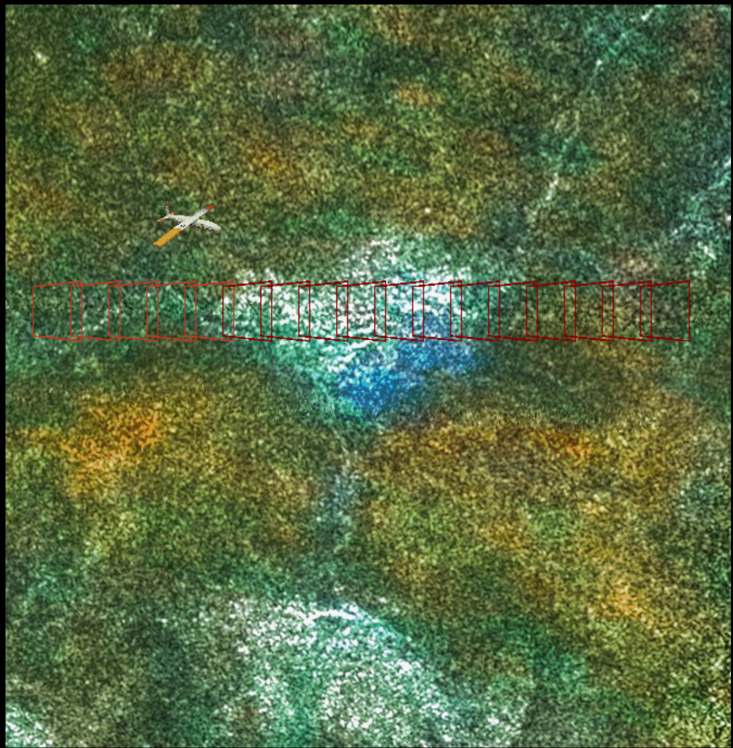


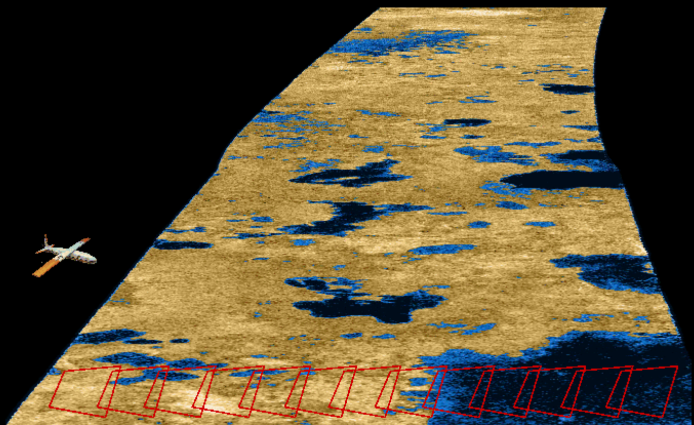
- On important targets we will execute large image mosaics, not individual frames.
- Mosaics will take most of the mission's bandwidth.
- Mosaics will (in general) have 4 components:

  1. Full surface scan just below the horizon
  2. Low resolution (4 m) mosaic from 14 km
  3. Stereo observations at either 4-m or 1-m res
  4. High resolution (1 m) mosaic from 3.5 km

Mosaics

Operations

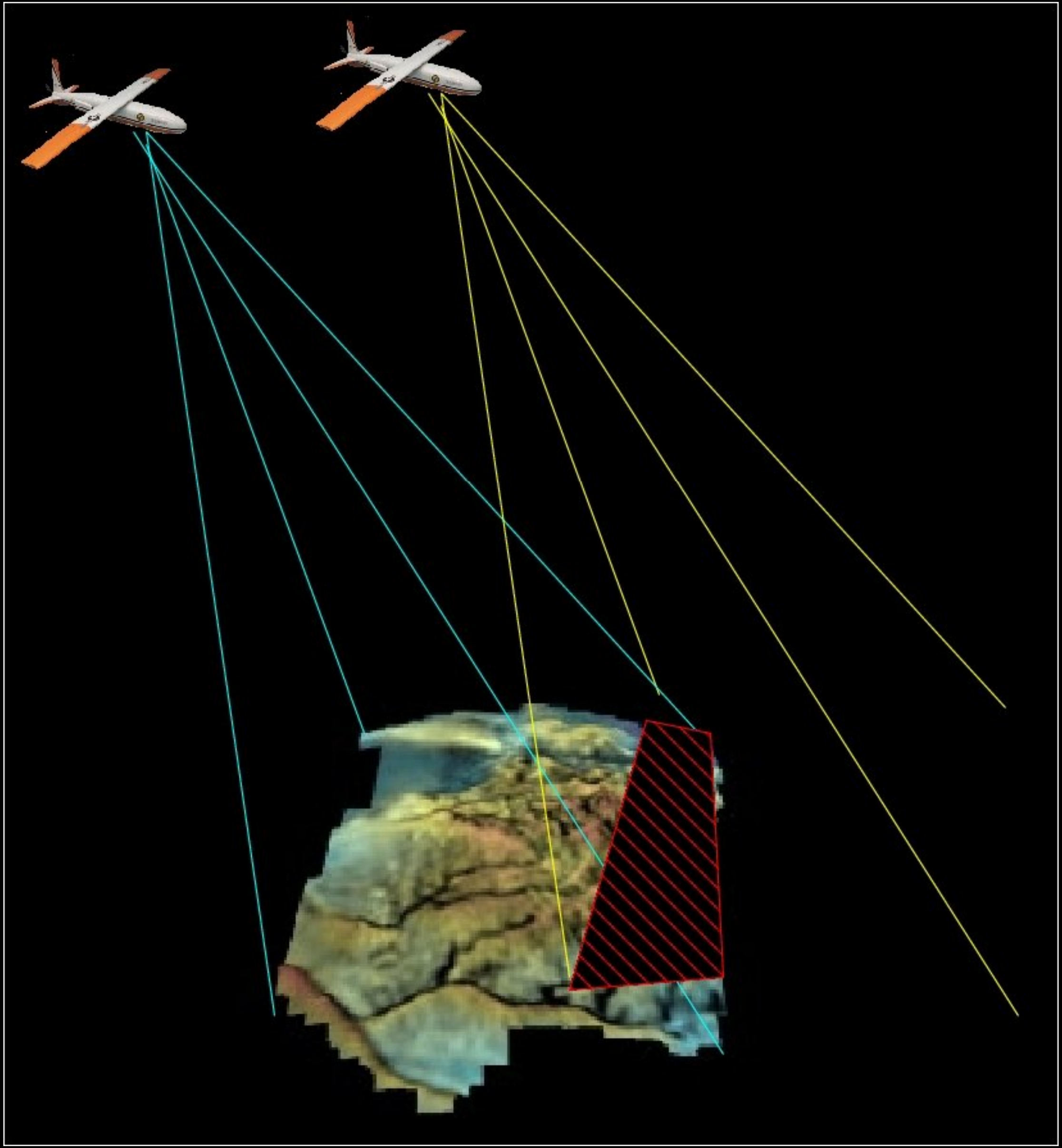




- Some targets will be better observed in noodle mode, or profile mode.
- For mountains, shorelines, etc, we will take a continuous strip of images across the target.
- Instead of sending all of the data back, send just, say, the altimetry for mountains, or the average I/F in each image for the shorelines. Then command the aircraft to downlink just the most interesting images

Profile

Operations



- Doppler wind not viable for long-duration mission with low-power signal
- Reuse tools already at our disposal:

1. Acquire two images separated in time
2. Compare the overlap region of the two images via minimum absolute difference (or more sophisticated algorithm) – necessary shift tells you ground speed
3. Subtract airspeed acquired from engineering instruments

Winds

Conclusion:

- Enabled by the ASRG, an airplane is a competitive architecture for an atmospheric in-situ Titan element
  - Runs on ASRG, not MMRTG
  - Go-to capability
  - Robust airframe
  - Flexible operations (mosaic, profile, structure)
  - Direct communications allows 1-element mission

- AVIATR would focus on exploring Titan's diversity, both surface and atmospheric

- Allows for a new programmatic strategy for Titan exploration more like the Mars Exploration Program