

# Titan - What Next ?

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A new beginning....

Artwork by Mark Robertson-Tessi and Ralph Lorenz, LPL,  
University of Arizona ( <http://www.lpl.arizona.edu/~rlorenz> )

## Titan - What Next ?

- The future on Titan - seasonal change
- Emerging Astronomical Capabilities
- Future Titan Exploration Instruments and Concepts

Titan's seasons 7.5x longer than Earth's, slightly stronger (higher obliquity), and asymmetric due to orbital eccentricity (c.f. Mars)

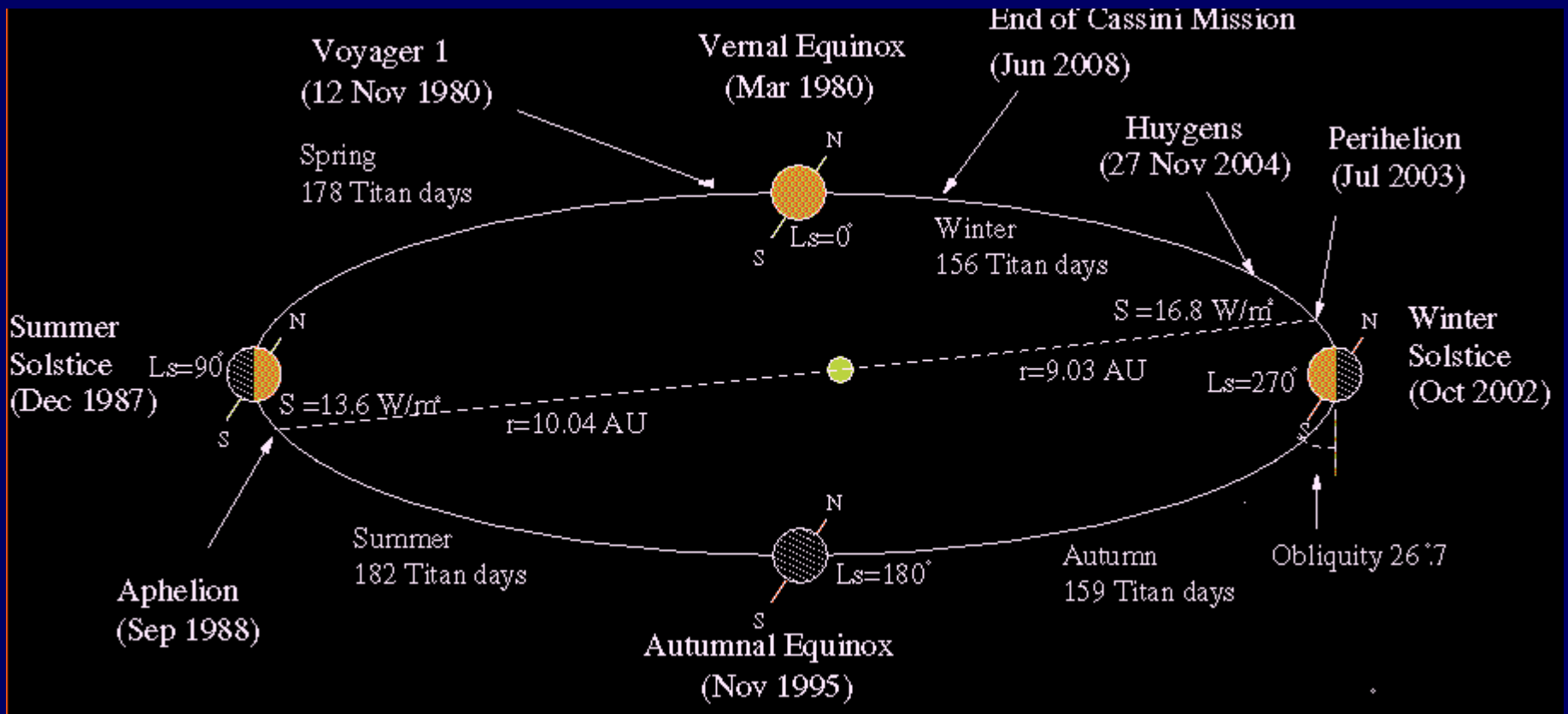
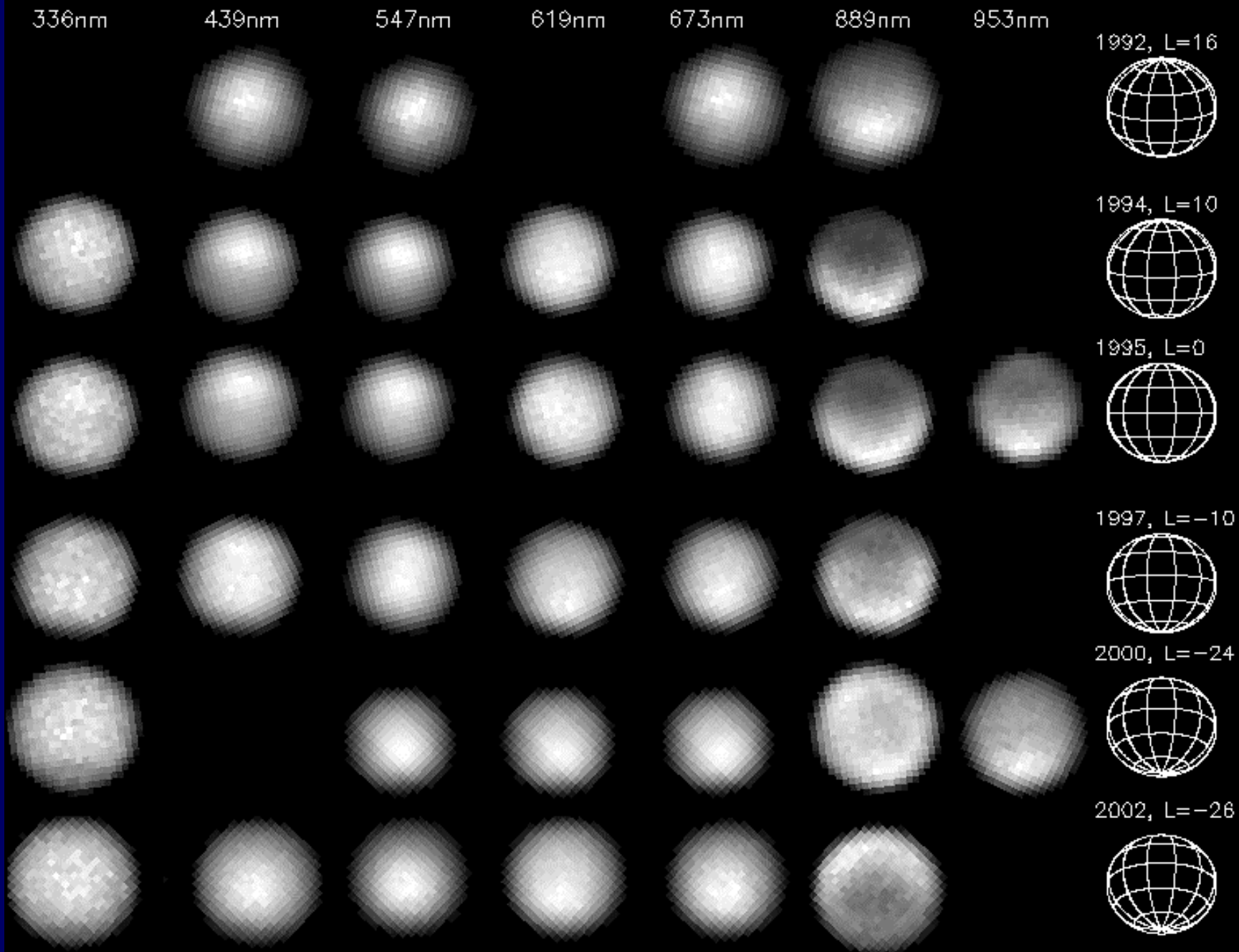


Figure courtesy of Tetsuya Tokano (Tokano et al 2000)



## Emerging Capabilities

AO imaging/spectrographs on 10m-class telescopes - cloud monitoring.

High-resolution spectrographs (Geballe HCN ; Roe - Propane etc.)

ALMA - Atacama Large Millimeter Array

Heterodyne IR spectroscopy on large telescopes (Kostiuk+)

HST ??

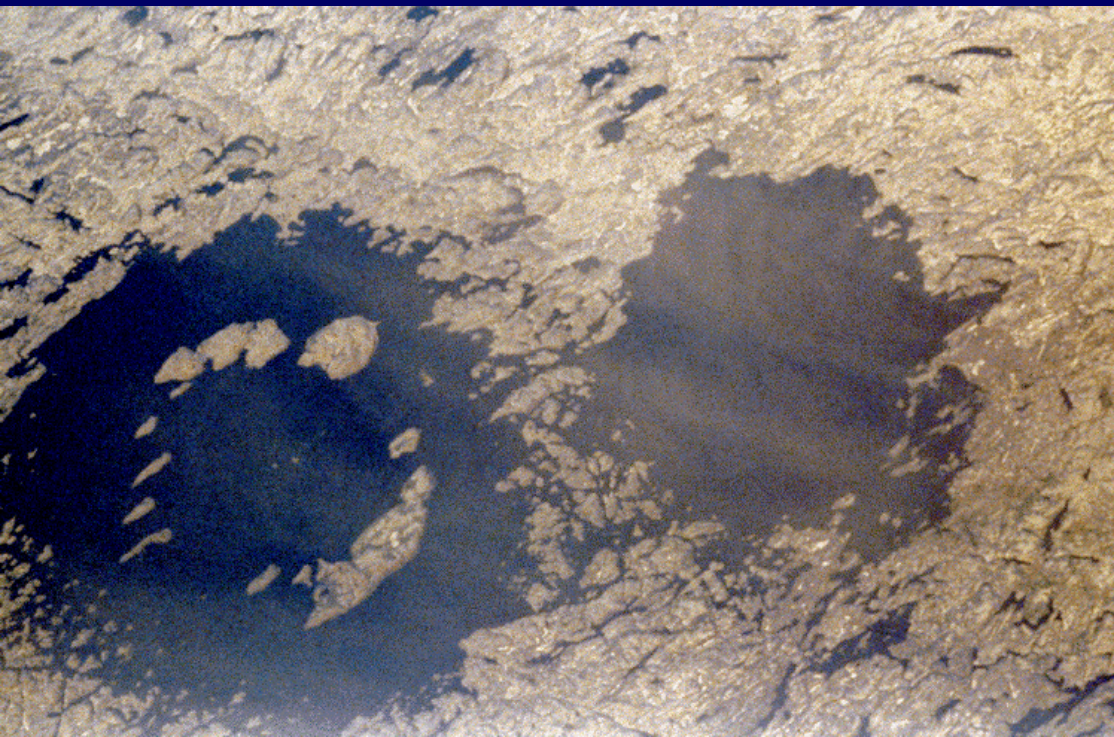
JWST



**Cratering** - interpolation among Saturnian satellites suggests  $\sim 200$  craters ( $D > 20\text{km}$ ) per million  $\text{km}^2$ .

$\sim 20,000$  total? (Atmospheric shielding cuts off population  $< 10\text{km}$ ) Craters fill with liquid? (all to the same level?)

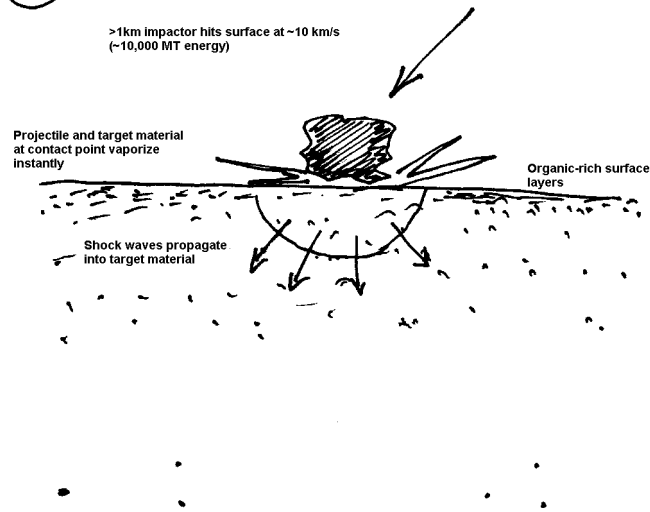
Canadian examples (Clearwater Lakes; 30,20km ;  
Manicouagan 70km)



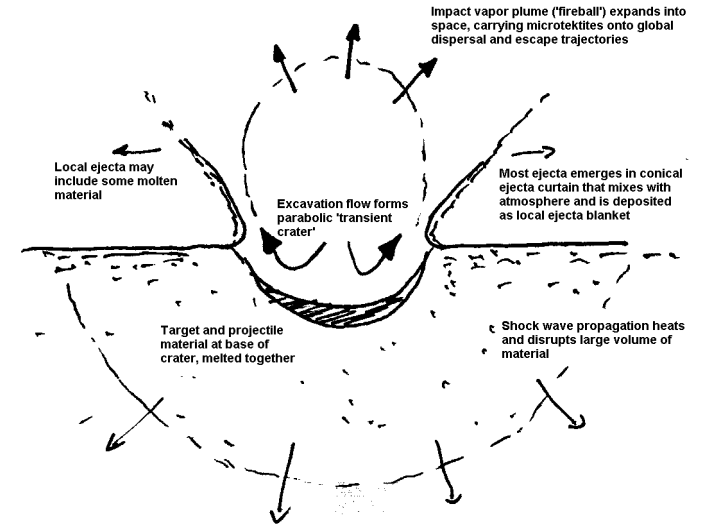
# Impact melt sheets are prime sites for organic synthesis on Titan - hydrolysis of tholin yields purines, amino acids etc...

①

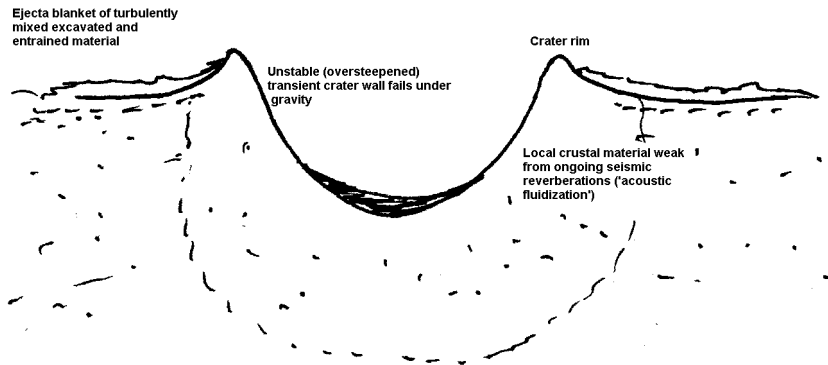
>1km impactor hits surface at ~10 km/s  
(~10,000 MT energy)



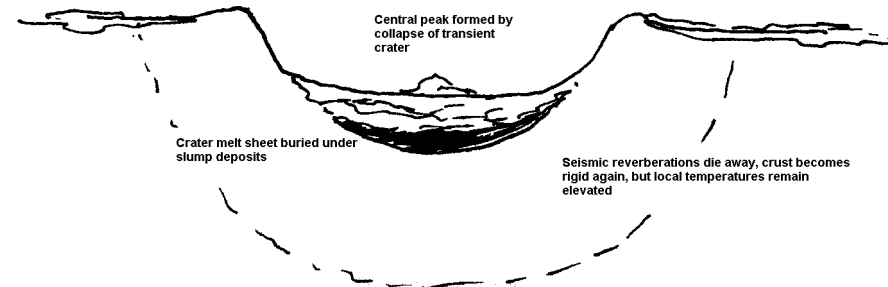
②



③



④





## Key Science Goals (mutatis mutandi post Cassini)

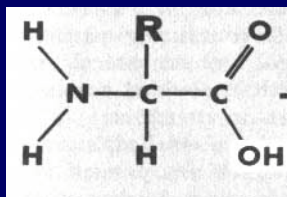
- Surface chemical sampling for Astrobiology - especially of frozen ice material in melt sheets etc ; contains water-tholin interaction products such as amino acids
- Subsurface profiling - presence of near-surface melt, depth of methane lakes
- High-Resolution geomorphological studies (esp. fluvial, aeolian phenomena at scales too small for Cassini)
- Meteorological Investigations

# Hotspot Chemistry

From atmospheric photochemistry

O'Brien, Lorenz, Lunine (2004)

Tholin Hydrolysis Products



Amino Acids

Urea

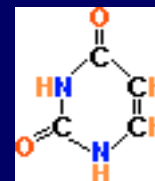
Tholin  
(R-CN etc)

HCN

HCN  
oligomers

Strecker  
Synthesis

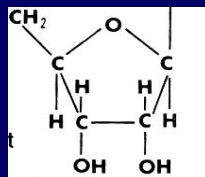
Purines,  
Pyrimidines



Sugars

Cometary Material

R-CHO



Impact Melt from Icy Crust

NH<sub>3</sub>

H<sub>2</sub>O

# Team “ $\chi$ MERA” (ChiMERA, or Chiral Measurements for Extraterrestrial Robotic Analyses)

## *A U of Arizona-Caltech-JPL Partnership*

**Team Lead:** Pat Beauchamp, Jet Propulsion Laboratory  
**University Lead:** Jonathan I. Lunine, Lunar and Planetary Laboratory,  
The University of Arizona

### Team

**Jack Beauchamp, Beckman Institute and Dept. of Chemistry, Caltech**

**Dennis Dougherty, Dept. of Chemistry, Caltech**

**Gene MacDonald, Jet Propulsion Laboratory**

**Mark Smith, Department of Chemistry, U of A**

**Chris Welch, Merck and Co.**



The Chimera of Arezzo, 1553  
(image of copy of original)

## 'Vision' Missions NRA - Proposals Selected Early 2004

Study mission concepts for 2010+ timeframe

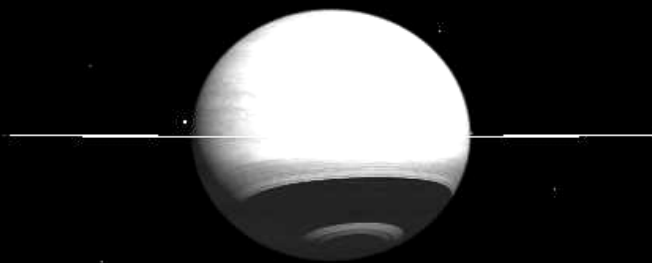
\$300K / 1 year study

- Joel Levine, NASA Langley. Titan Aeroplane?
- Jonathan Lunine (+Zimmerman/JPL, Lorenz) Titan concepts, especially Airship+deployable robot

Sun/Saturn position - autonomous location determination via near-IR imaging of sky (Earth always within ~6 degrees of sun)

Saturn visible too - provides additional navigation information via phase and ring shadow.

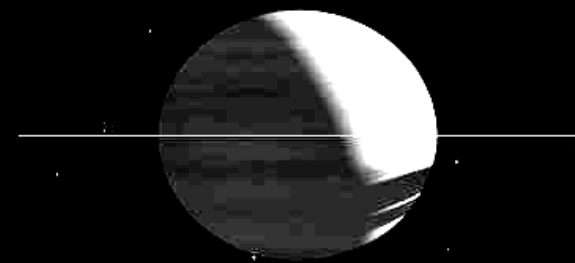
Saturn as seen from Titan  
09 Jan 2018 00:00 GMT  
18.86 deg field of view



	Saturn	
Range	1.221 mil	km
Phase	31.7	deg
Diameter	5.66 deg	arc

Solar System Simulator

Saturn as seen from Titan  
11 Jan 2021 00:00 GMT  
19.30 deg field of view



	Saturn	
Range	1.193 mil	km
Phase	104.8	deg
Diameter	5.80 deg	arc

Solar System Simulator



Airship concept - phased array antenna for direct-to-Earth communication. Deployable tethered sonde for surface sampling



Image by Mark Robertson-Tessi and Ralph Lorenz

## HCIPE - High Capability Instruments Program

- Study instrument concepts for post-JIMO Prometheus (nuclear) missions, to exploit high power and bandwidth capabilities, esp. leveraging on terrestrial experience

~ \$1.5M/3 year

Probably to include SARs, Subsurface Sounding Radars, Laser Ablation Spectrometers etc.

At least one Titan-specific proposal selected. Eastwood Im, Steve Durden (JPL) and Ralph Lorenz - Titan Cloud and Precipitation Radar / Altimeter

Ka-band radar for 3-D cloud structure

# Conclusions

Titan to change in next 6 years

Titan is on NASA's radar screen

Work ongoing esp. at JPL - other centers waking up.  
Instrument concepts evolving

Next New Frontiers AO to solicit Titan mission?

(\$700M+) N Polar mission circa 2015?

Prometheus mission (a la JIMO?)

ESA ???