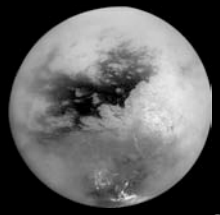
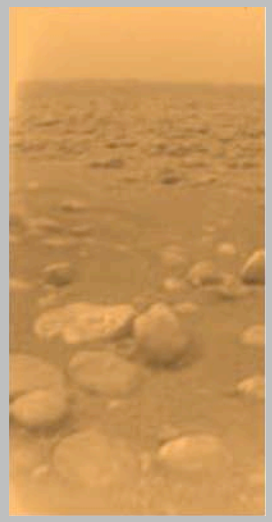


Titan and Saturn System Mission (TSSM) Joint Science Definition Team (JSDT)

Dennis Matson
Study Scientist

March 31, 2008
OPAG. Boulder, Colorado

Overview



- Study Organization
- Status
- Schedule

Recent History

- NASA and ESA have firm plans leading to an Outer Planet Flagship mission
  - The FY09 President's Budget includes an Outer Planet Flagship mission launching in 2016-2017
  - ESA is currently conducting Cosmic Vision study and selection process, which includes Outer Planet Flagship candidates
- NASA and ESA are collaborating on mission studies for *Europa and the Jupiter system* and *Titan and the Saturn System*
- Two Joint Science Definition Teams (JSDT) have been convened as part of those studies

Recent History

- The ongoing is a Phase 2 Study.
  - Science co-chairs Jonathan Lunine and Jean-Pierre Lebreton
- The phase I study led by APL
  - Ralph Lorenz and Hunter Waite were science co chairs
  - NASA only study which included an orbiter, lander and balloon.
  - The final report of that study is available on the OPAG website.
- The present Phase 2 Study is predicated on a collaboration between NASA and ESA

TSSM Objectives

- Produce breakthrough scientific advancement in understanding Titan, an Earth-like system
- Achieve major advance beyond Voyager and Cassini by carrying out focused Titan exploration initiatives
- Conduct dedicated remote sensing (orbiter) and *in situ* campaigns

Constraints and Opportunities for the Orbital Mission

- The constraint applied to the Phase 2 study that aerocapture cannot be used (because of its technological immaturity) has required a fundamental rethink of the mission-
  - Much more limited orbital payload because of mass limitations.
  - Opportunity to investigate other parts of the Saturn System including Enceladus because science is now possible prior to Titan orbit insertion.

Study Organization

The *Titan and the Saturn System Mission (TSSM)* study has three teams that work together:

- Joint Science Definition Team (JSDT)
- Mission Engineering Teams
  - Orbiter at JPL
  - *In Situ* Vehicle at ESTEC

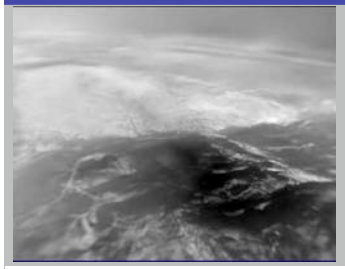
Joint Science Definition Team (JSDT) Charge

- Define the science content of the mission
- Work closely with the engineering teams to define a mission concept that optimizes science, cost, and risk.
- Define and defend the science value of the mission concept

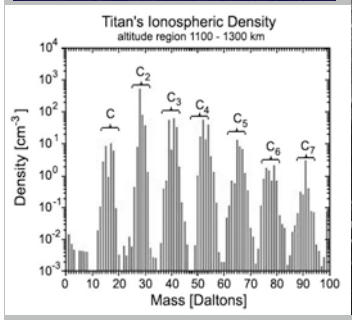
Joint Science Definition Team (JSDT) Specific Responsibilities Include:

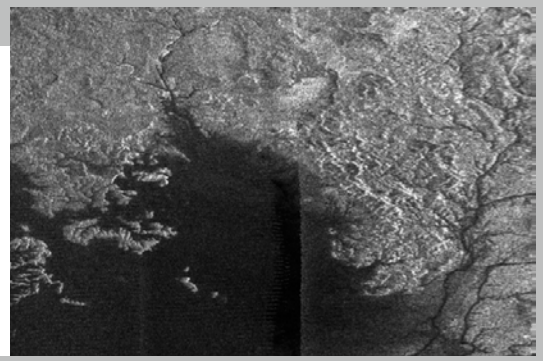
- Define Level 1 science requirements
- Link the mission science to strategic documents
- Define mission science investigation(s)
  - Establish a hierarchy for scientific goals, objectives and measurements
  - Prioritize to the extent possible
- Define strawman payload

What Cassini-Huygens Did



- Saw methane and ethane clouds that varied
- Imaged fluvial channels, lakes, seas
- Sniffed evaporating methane/ethane from ground
- Found evidence for cryovolcanism
- Detected surface deposits of carbon dioxide
- Detected unexpectedly complex molecules high up
- Measured non-synchronous spin: subsurface ocean?





Titan Is A Once And Future Earth

- Titan is an organic-rich world whose active processes most closely resembles the Earth's, but where ice plays the role of rock and methane the role of water.
- Earth of the past: Rich in organics and poor in oxygen, Titan's planetary environment is the solar system's only stage on which Earth's prebiotic organic chemistry is playing out today.
- Earth of the future: bereft of ocean but with methane lakes, seas, rain and clouds, Titan's planetary climate is the solar system's best analog to Earth of the future.

What We Now Seek to Know- Our Goals Are to Learn About:

- Titan: an Earth-like System
- Titan's Organic Inventory - A Path to Prebiological Molecules
- Enceladus and Saturn's magnetosphere

4

What we now seek to know

- ***Goal 1: Titan: an Earth-like System:*** How does Titan function as a system? How do we explain the similarities and differences between Titan and other solar system bodies in the context of the complex interplay of the geology, hydrology, meteorology, and aeronomy present in the Titan system?
- ***Goal 2: Titan's Organic Inventory - A Path to Prebiological Molecules:*** What is the complexity of Titan's organic chemistry in the atmosphere, within its lakes, on its surface, and in its putative subsurface water ocean. How does this inventory differ from known abiotic organic material in meteorites and therefore contribute to our understanding of the origin of life in the Solar System?
- ***Goal 3: Enceladus and Saturn's magnetosphere:*** clues to Titan's origin and evolution. What is the exchange of energy and material with the Saturn magnetosphere and solar wind? What is the geysering source? Does complex chemistry occur in the geyser source?

Goals ---> objectives (long list) -----> measurements (even longer list)

4

What we now seek to know

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What we now seek to know

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Science Objectives define Key Measurement Requirements (partial list)

- What are the lakes made of? What's flowing in the rivers?
  - 1-5 micron spectral images with resolving power 1000
  - Temperatures to 1 K over poles
- Is there active volcanism? What kinds of tectonics? How thin is the crust?
  - Global imaging to 50 m resolution
  - Global topography to 10 m precision over km spot size
- How are the polymers made in the atmosphere? What's the energy source?
  - Identification of species up to 1000 amu with resolving power of 1 amu
- When and how do the heavy rains occur?
  - Deep atmosphere temperature measurements to 1 K
  - Global imaging to 50 meters resolution

Science Objectives define Key Measurement Requirements (partial list) - Continued

- Is there a rock/metal core? How thin is the crust?
  - Magnetic measurements sensitive to "sub-Ganymede" fields
  - Global gravity mapping to 0.01 Titan's gravity
  - Global topography to 10 m precision over km spot size
- Is ammonia present and what is the loss rate of the major gases?
  - Detection of energetic particles from solar wind and magnetosphere
  - 1-5 micron spectral images with resolving power 1000
  - Rotational spectra of molecules in Titan's limb
- What are the organics at Titan's surface? What is the potential for life?
  - 1-5 micron spectral images with resolving power 1000

Study Teams at JPL and ESTEC

- Orbiter being studied at JPL
- In situ vehicle being studied at ESTEC
- JSDT works with both teams

The Study Teams at JPL and ESTEC:

- Derive mission requirements from the scientific:
  - Goals
  - Objectives
  - Desired Measurements
- Determine data return necessary for the scientific investigations
- Define mission architecture
- Conduct trade analyses
- Produce a System Requirements Document

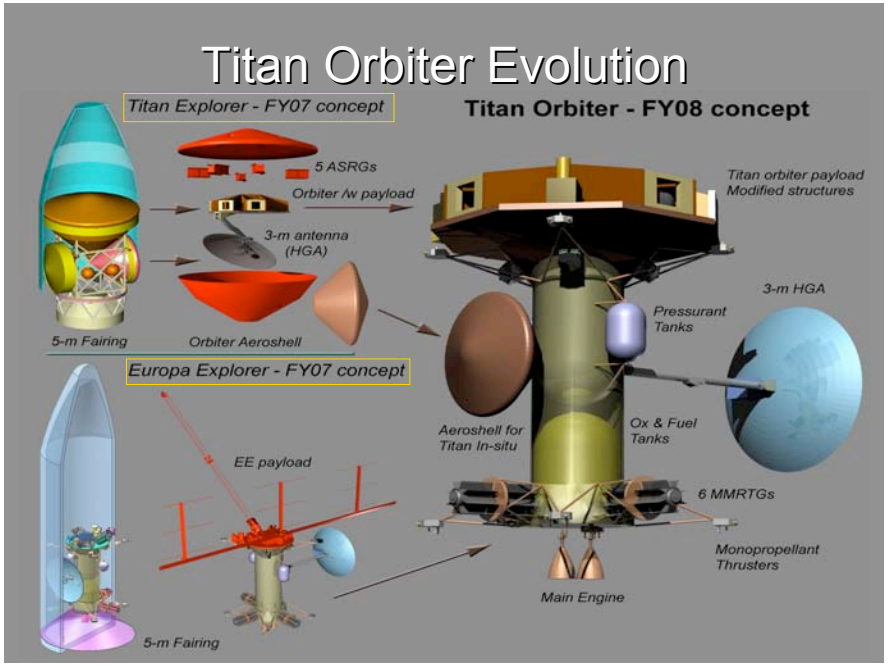
Status

- Teams formed and active
  - JSDT has had two meetings
  - Study teams now have weekly meetings
- First cut at scientific objectives and traceability matrix (JSDT)
- Key engineering aspects of the mission identified
- The pace is frenetic because of short schedule

Examples of Issues Being Worked

- Orbiter spacecraft definition
- Identification of instrument accommodation issues
  - Power, mass, data rate
  - Pointing, stability and operational requirements
- Nature of the in-situ payload: Balloon, Lander, Probe(s)
- In situ vehicule: delivery options, mass, data-link, …
  - Prior to Saturn Orbit Insertion
  - Between Saturn Orbit Insertion and Titan Orbit Insertion
  - After Titan Orbit Insertion

Titan Orbiter Evolution



Examples of Issues Being Worked

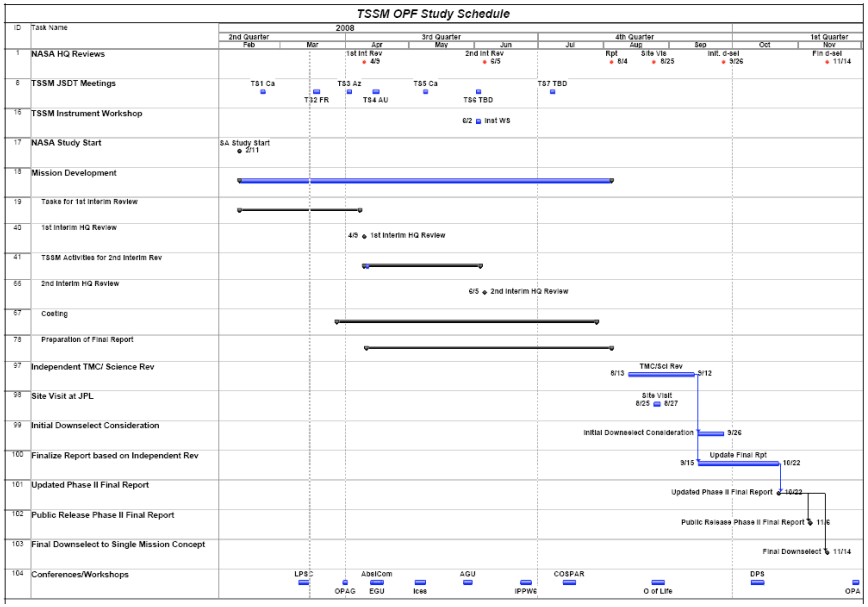
- Orbiter spacecraft - What does it do?
  - Titan global scientific objectives (e.g., mapping the surface and atmosphere)
  - Saturn System (e.g., Enceladus, magnetosphere, other)
  - In situ vehicle support
    - Navigation (e.g., where to go on Titan)
    - Commanding and systems status
    - Vehicle safety
    - Relay scientific and engineering data to Earth
    - Other TBD
- In situ vehicle - What is it?
  - Balloon (CNES, NASA)
  - Lander (ESA)
  - Probe(s)
  - Submarine !! (Suggested and discussed at Meudon Workshop)

Titan Submersible

- Power system MMRTG
- Glider - no propulsion
- Payload
  - Mass spectrometer
  - Sonar
  - Flow velocity
  - Temperature
  - Other?
- Mass 99 kg

Schedule

- ***Summer 2008:*** Preliminary mission study reports and independent TMC and Science review
- ***Fall 2008:*** Teams revise reports
- **Late Fall 2008:** HQ and ESA downselect to one Outer Planet Flagship mission



Outer Planet Flagship Mission Instrument Workshop

June 3-5 2008

Pasadena, California

Outer Planet Flagship Mission Instrument Workshop – Charter

- **The purpose of the workshop is to prepare the scientific community for an upcoming opportunity to propose instruments for the international Outer Planet Flagship mission that is planned for a new start in fiscal 2009.** NASA and ESA are planning to issue a joint Announcement of Opportunity for scientific experiments to fly on the mission. A decision is expected in November on whether the mission is a Europa Jupiter System Mission (EJSM) or a Titan Saturn System Mission (TSSM). The AO is expected to be issued in the late winter or early spring of 2009.
- **Each mission option involves distinct challenges.** EJSM includes two orbiters with instruments designed to operate in the severe radiation environment of the Jupiter system an many need to be sterilized to comply with planetary protection requirements for Europa. **TSSM includes both an orbiter and in situ vehicle(s) and the instruments must make the best use of the current capability (power and mass) to accommodate limited payload capability and survive and operate in the cryogenic environment of Titan.**
- **The workshop has been structured in two parts.** The first day will provide an overview of the outer planet flagship program, the two missions and the constraints placed on the instruments based on the unique environments of the Jupiter and Saturn systems. Two subsequent days will run parallel sessions, one for each mission. One track will address the radiation and planetary protection issues for the EJSM mission. Critical topics such as the environment and radiation effects on parts and materials, shielding, and other topics of importance to instrument development and operations will be presented. The second track will focus on the TSSM in situ payload including the challenges of operating in the cryogenic environment. In conjunction with the International partners the session will give an overview of the possible in situ payload envisaged for Titan. **There will also be an opportunity for poster presentations with a 5-min oral overview on instrument concepts at each session.**

Joint Titan-Saturn Science Definition Team

Lunine, Jonathan University of Arizona (Cochair)
Lebreton, Jean-Pierre ESTEC (Cochair and ESA Study Scientist)
Coustenis, Athena Observatoire de Paris-Meudon, France *(European Lead Scientist)*
Matson, Dennis JPL *(NASA Study Scientist)*
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Dougherty, Michele K. Imperial College London
Hansen, Candice JPL
Ingersoll, Andy Caltech
Jaumann, Ralf DLR Institute of Planetary Research, Berlin
Kurth, William University of Iowa
Lara, Luisa M. Instituto de Astrofisica de Andalucia, Granada
Lopes, Rosaly JPL

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Sittler, Ed GSFC
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Sotin, Christophe JPL
Stevenson, Dave Caltech
Stofan, Ellen Proxeny
Tobie, Gabriel Universitie de Nantes
Tokano, Tetsuya Universitie zu Koeln
Tortora, Paolo Universitie di Bologna
Turtle, Elizabeth JHU-APL
Waite, Hunter SWRI