ADDING “MISSED” SCIENCE TO CASSINI’S OPS PLAN

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SpaceOps 2014
Extended Missions

- Main rings only 10m thick, with complex km-scale vertical structures
- Gravity binds ring particles into ephemeral streamers
- Titan has methane weather, subsurface water ocean
- Rare, Earth-sized storm wrapped around Saturn
- Saturn oscillations revealed by ring spiral waves
- Enceladus has subsurface water ocean; orbital tidal stress controls plume volume

Northern Summer Mission

- Saturn’s rotation rate
- Total mass of main rings
- Ring structures in 3D at high resolution
- Saturn gravity field sufficient to constrain formation theories
- Direct sampling of ring particles and Saturn’s upper atmosphere

Prime Mission

- European partnership for first outer-planet moon landing
- Methane clouds, rain, rivers, lakes, and seas on Titan
- Unexpected diversity among dozens of moons
- Enceladus salt-water plume creates E Ring
Science planned in discipline clusters: Discipline working Groups (i) **TOST** (Titan Orbiter Science Team) (ii) **SOST** (Satellite Orbiter Science Team) (iii) **Saturn TWT** (Saturn Target Working Teams); (iv) **MAPS TWT** (Magnetosphere and Plasma Science Target Working Team); (v) **RINGS TWT** (Rings Target Working Team) (vi) **XD TWT** (Cross Discipline Target Working Team)

This resulted in each segment focusing on their preferred target and so there were instances of “missed” science opportunities for other “out of discipline” targets.

- Working groups fully develop integrated timelines of the science, deliver to the science planning team which combines the discipline segments into sequences uplinked to the spacecraft at the end of the implementation process.
Restrictions in CSM operations

- **Workforce reduction** due to reduced funding necessitates prioritization of science and using templates to design science observations.

- **RBOT (RWA Bias Optimization Tool) restrictions** The health of the aging spacecraft reaction wheel assemblies (RWAs) is preserved using the RBOT, by which the most desirable state of the reaction wheels during a specified science collection period is decided; To minimize workload due to redesign, basic rules were developed which the science teams could use when developing their designs. This has further increased the number of missed scientific opportunities due to keeping with “RBOT-friendly” designs.
**TOST Science Planning lead to Missed Science**

- * Titan science planned only during the TOST segment during and around planned Titan Flyby 

- Weather pattern changes and sporadic cloud behavior study requires frequent observations.

- Persistent Titan detached haze altitude as observed by Cassini differed from Voyager results; regular monitoring needed for answer

- Frequent observations needed to monitor the evolution of UV-dark polar hood with Titan seasons.

- * Missed opportunity: huge tropical storm observed by ground based observers April 2008*

Images of Titan showing a huge low latitude cloud outbreak April 2008, (Schaller, et al)
How to mitigate missed Titan science?

- More regular Titan observations were needed instead of relying solely on data from (roughly) monthly Titan flybys. Titan scientists realized that it was necessary to at least capture “snapshots” to get a complete picture of the changing appearance of Titan.

- This lead to the birth of the TMCs (Titan Meteorology Campaigns) and TEA (Titan exploration at Apoapses) which would be outside the TOST segments spread across other disciplines.

- At least intrusive strategy was decided following a design template to not increase the workload of science planners.

- For TMCs ISS (Imaging Science Subsystem) would be the instrument controlling the pointing and CIRS (Cassini Infrared Spectrometer), UVIS (Ultraviolet Imaging Spectrometer) and VIMS (Visible and Infrared Mapping Spectrometer) “ride along”.
TMC requirements and planning

- TMCs are short 30 minute on Titan requests
- Split into 3 range bins <1Mkm, 1-2 Mkm, and >2Mkm
- Observations with phase < 90 degrees are cloud observations
- Observations with phase >90 degrees are haze observations
- Agreed upon observing requests are entered into Cassini Information Management System and then integrated into the sequences after discussion within the specific discipline
- RBOT protective restrictions impact the number of TMCs integrated.
- Ideally 6-8/month are required
TMCs met the geometric constraints and were subsequently dropped due to RBOT and other integration constraints ending with on many cases TMCs < 6-8/month
TMC status

- Realizing the great scientific value, efforts are continuous to try and increase the number of TMCs; negotiation is currently in works with the Spacecraft operations team for flexibility in the RBOT constraints.

- The extra importance of TMCs during conjunction periods (when Saturn can solely be observed by Cassini) has been noted by discipline leads.

- Titan methane cloud pattern changes are being monitored; a major success among others – large, low-latitude cloud system storm observed early in Titan’s northern Spring (2010) by a TMC. Titan’s haze and polar hood: Cassini observations match Voyager’s almost one seasonal cycle earlier; details of the evolution of the south polar haze and vortex formation and also changes in the detached haze at other latitudes observed
TEA (Titan Exploration at Apoapsis)

- TEA planned in the Cross Discipline segments over periods of days to weeks
- Low to moderate Phase; 1-2 opportunities a year
- CIRS (Cassini Infrared Spectrometer) controls pointing with ISS (Imaging Science Subsystem) and VIMS (Visible and Infrared Mapping Spectrometer) riding along
- Provided evidence that Titan seasonal change well underway
- Used to Calibrate Earth Based Titan observations
Number of days of planned and executed TEA from 2011-2014
Saturn Storm Watch Campaign

- In the CSM the Saturn Working group decided to do detailed Saturn observations about every six months.

- This hampered Cassini’s ability to see the birth and evolution of random storm systems often picked up by the amateur community.

- Saturn Storm Watch observations were introduced to fill the gap. Efforts are made to plan one every 24 hours. Added to the last two minutes of suitable ISS observations as riders in XD and MAPS segments.

- Using these scientists are learning much about the Saturn atmosphere; In Dec 2010 a giant planet encircling storm was observed (predicted to be once every 20-30 years).
A typical Cross-Discipline segment in CSM with TMC and Saturn watch campaigns

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Storm Watch riders planned at the end of all the observations shaded in yellow.

TMC with Storm watch at the end

4 TMCs
Future and conclusions

- The Titan Meteorology Campaigns have proved to be one of the most important vessels for Cassini Titan Science.

- These will continue as planned through the proximal orbits to end of mission.

- Both TMCs and Saturn Storm Watch campaigns have been instrumental in bringing forth phenomenal scientific results which would have been “missed” with regularly planned science operations.

- The nonintrusive way of how both these observations entered regular Cassini Mission plans should show the way to future missions.