Cassini Remote Terminal Interface Units as Part of Instrument Test Bed Operations During the Tour of Saturn

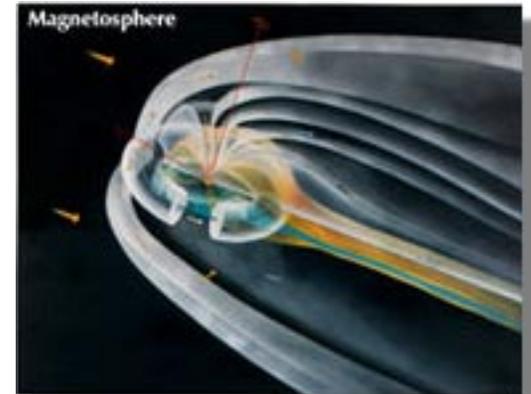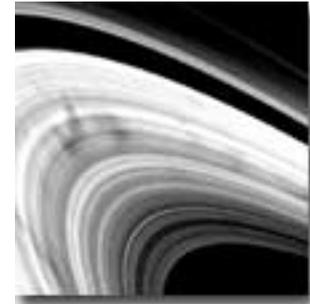M.A. Sarrel, S.C. Clancy, A.J. Runkle,

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Jet Propulsion Laboratory

California Institute of Technology

National Aeronautics and Space Administration

Cassini Science Objectives

- Saturn
- Rings
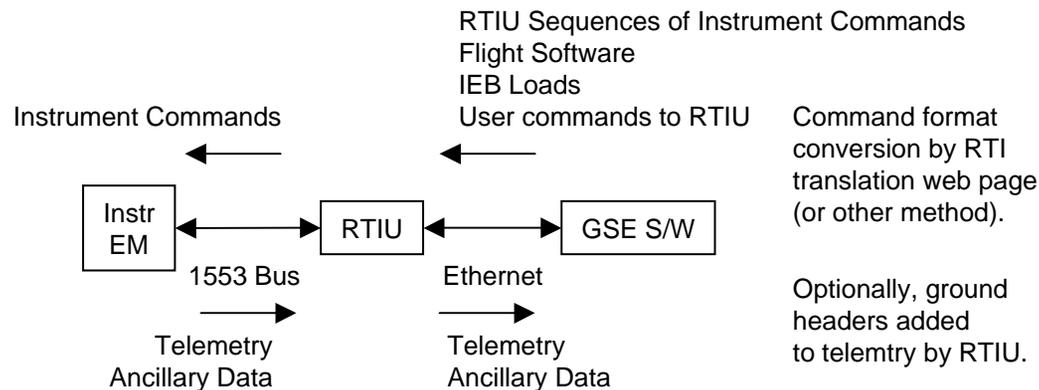- Titan
- Icy Satellites
- Magnetosphere

Cassini Mission

- Launched 15 October 1997
  - Venus, Venus, Earth, Jupiter gravity assist trajectory.
- Will arrive at Saturn 1 July 2004.
- Four-year primary mission.
  - Seventy-six orbits!
- Twelve Cassini science instruments.
- Cassini Principal Investigators and Team Leads located in seven US states and two European countries spanning nine time zones.
- Carries ESA Huygens Probe.
- Six Huygens science instruments.

What is an RTIU?

- Part of instrument test bed.

- Connects the instrument engineering model to the ground support equipment software
  - Talks to the EM over the 1553 bus.
  - Talks to the GSE s/w over Ethernet.

- Sends commands to the EM and returns telemetry.

RTIU Sequences of Instrument Commands
Flight Software
IEB Loads

Instrument Commands   User commands to RTIU   Command format
                                                                      conversion by RTI
        ◄──────   ◄──────   translation web page
                                                                      (or other method).
    ┌────────┐   ┌──────┐   ┌──────────┐
    │ Instr │◄──────►│ RTIU │◄────────►│ GSE S/W │
    │ EM   │   └──────┘   └──────────┘
    └────────┘   Optionally, ground
        1553 Bus   Ethernet   headers added
                                                                      to telemtry by RTIU.
        ──────►   ──────►
    Telemetry   Telemetry
    Ancillary Data   Ancillary Data

Components of the System

- Hardware
  - Motorola VME Chassis.
  - Motorola PPC Motherboard.
  - Systran 1553 Interface Card.

- Software
  - Custom RTIU software that runs on VME hardware.

- Web pages
  - Translate spacecraft sequences into hex-based sequences in RTIU format.
  - Translate spacecraft sequence into hex-based Instrument-Expanded Blocks in RTIU format.
  - Translate recorded bus-monitor data from Cassini Integration and Test Lab into hex-based RTIU sequence.

Reasons for Upgrade

- Before upgrade, we had three different implementations of RTIU
  - different capabilities and interfaces
- Cassini has a lengthy mission
  - 3-4 yr pre-launch, 7 yr cruise, 4 yr tour and TBD yr extended mission.
- No plan for hardware replenishment.
- No plan for hardware maintenance.
- No plan for software maintenance.

- Other benefits, like improved performance and capability came later.

Reasons for Improved Capability

- Pre-Launch
  - Build/test instrument hardware.
  - Integrate onto spacecraft.
  - Build/test instrument flight software.
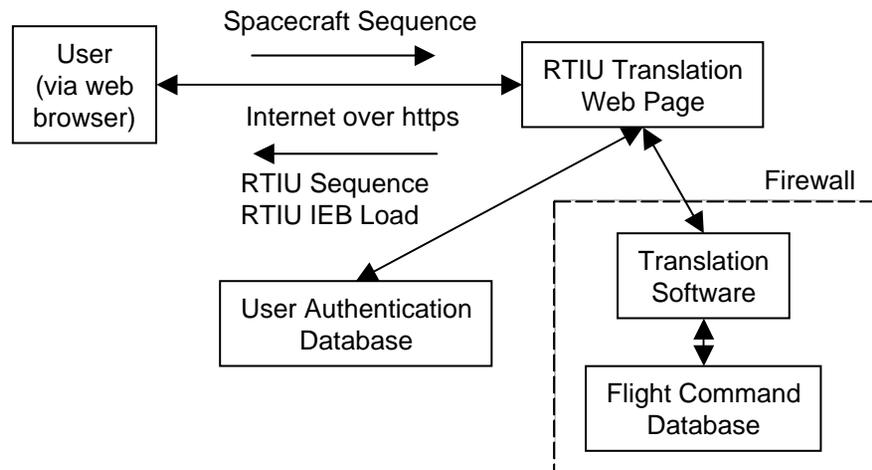 - Build/test instrument ground software.

- Post-Launch
  - Design/test sequences for flight.
  - Design/test sequence for science planning.
  - Design/test Instrument Expanded Blocks.
  - Resolve Instrument Anomalies.
 - Test changes to command database or telemetry modes.

RTIU Sequence Translation

- Lets users translate sequences of commands using the flight command database.

- Input format is the same as that used in flight sequence development.

- Output is either

  – A translated sequence to run from the RTIU.

  – A translated sequence to load an IEB into the simulated IEB library region in the RTIU (Cassini-unique feature.)

User
(via web browser)

Spacecraft Sequence

Internet over https

RTIU Sequence
RTIU IEB Load

RTIU Translation
Web Page

Firewall

User Authentication
Database

Translation
Software

Flight Command
Database

ITL Bus Monitor Translation

- Lets users translate commands recorded from the 1553 bus in ITL into an RTIU sequence.

- Two ways to get recorded 1553 bus traffic
    - Can be planned into a new ITL test.
    - Can be generated from historical data from a previous ITL test.

- Provides "Virtual ITL" connection.

- One-way only.

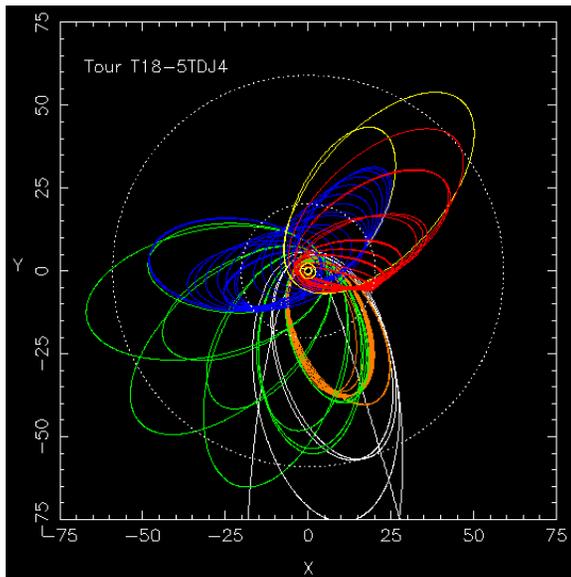May 2004   SpaceOps2004   9
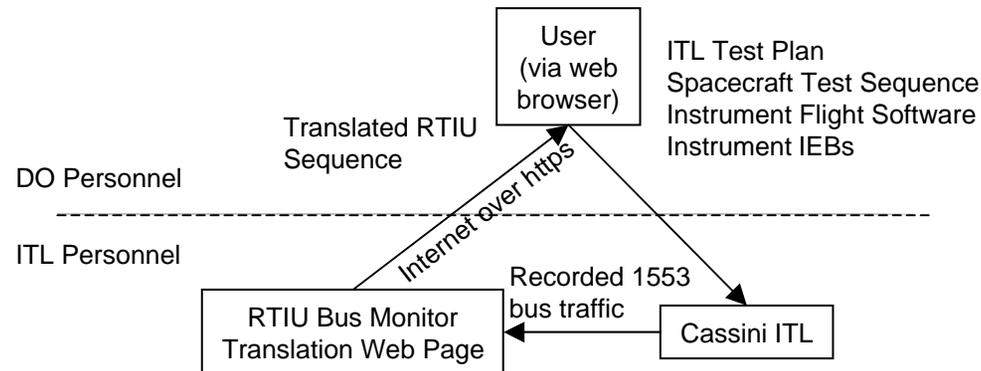
New Features for Tour

- Verify actual command sequences translated by the same software used for flight.

- Replay sequences of commands as run in the Cassini Integrated Test Laboratory with exactly the same content and timing.

- Simulated Instrument Expanded Block library region as on spacecraft.

- Load instrument flight software at flight rate.

- Collect and report ancillary data as broadcast by instrument engineering model.

- Allow multiple instruments simultaneously (useful for ISS which appears on the spacecraft bus as two instruments).

- Emulation modes for backward compatibility with instrument ground support software designed to work with one of the three previous implementations of RTIU.

New Features for Tour

- Optionally add ground headers to facilitate compatibility with instrument ground software.

- Windowing to allow parts of a sequence to either be repeated or skipped (good for long sequences).

- Allow simulation of timing jitter on 1553 bus.

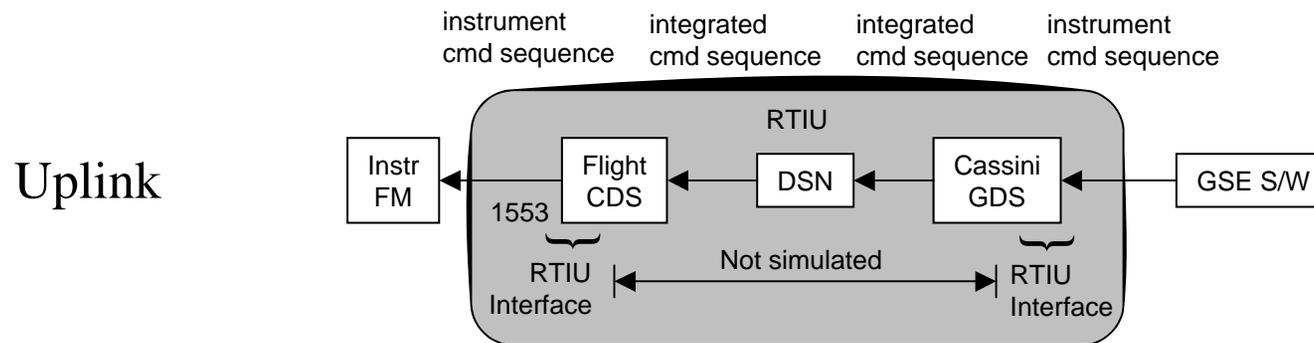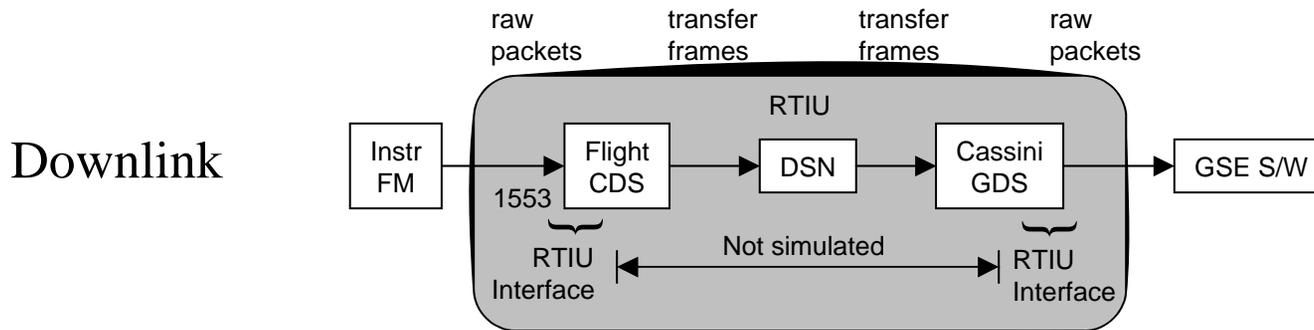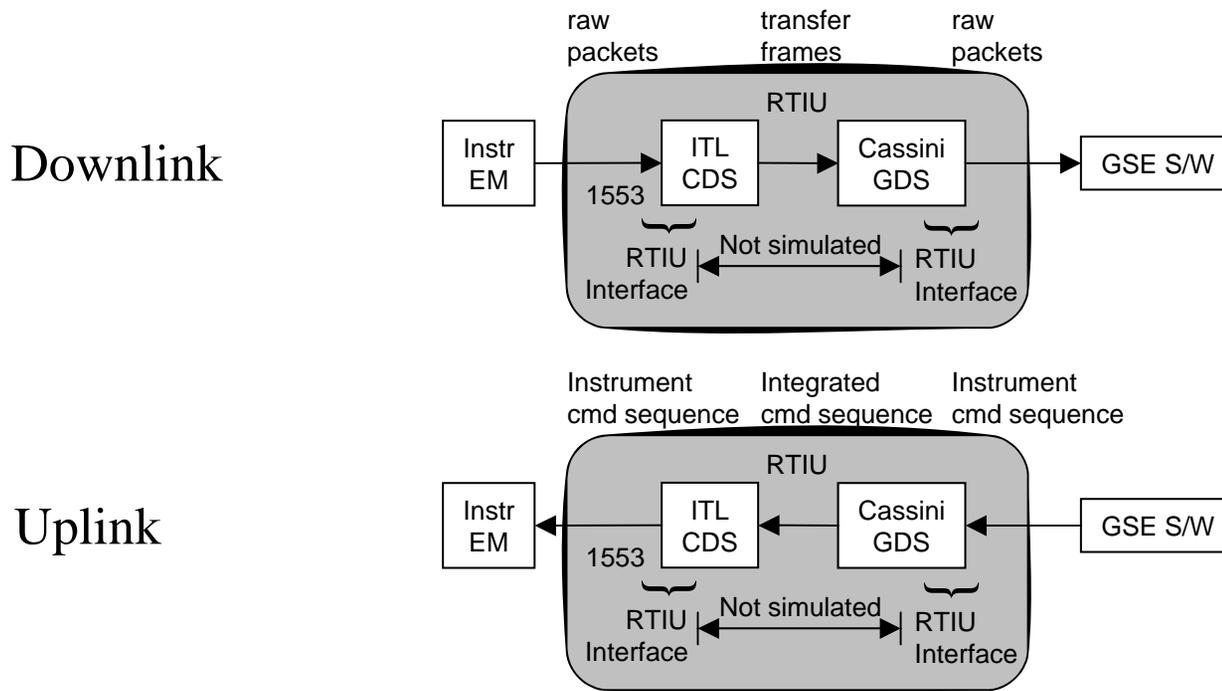- These petal plots show the Cassini tour trajectory.
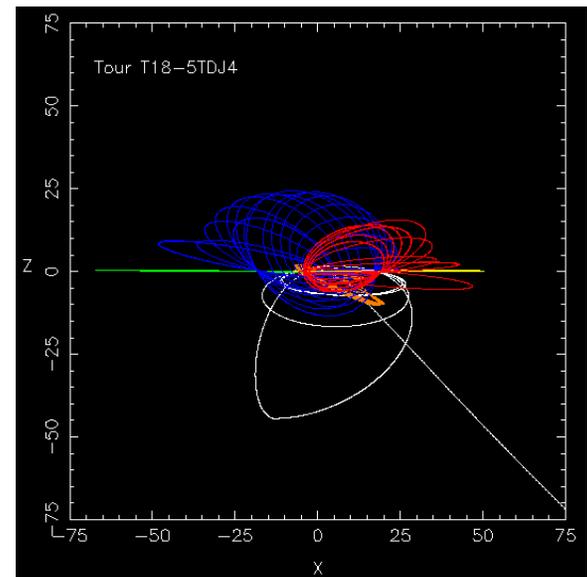
Cassini Flight Processes

- This shows how the RTIU compares to the Cassini downlink and uplink processes.
- The RTIU replaces, but does not simulate, everything contained in the dashed, rounded rectangle.
- It implements only enough to meet the interfaces at either end.

Downlink

| raw packets | transfer frames | transfer frames | raw packets |

RTIU

Instr FM → Flight CDS → DSN → Cassini GDS → GSE S/W

1553

RTIU Interface ← Not simulated → RTIU Interface

Uplink

| instrument cmd sequence | integrated cmd sequence | integrated cmd sequence | instrument cmd sequence |

RTIU

Instr FM ← Flight CDS ← DSN ← Cassini GDS ← GSE S/W

1553

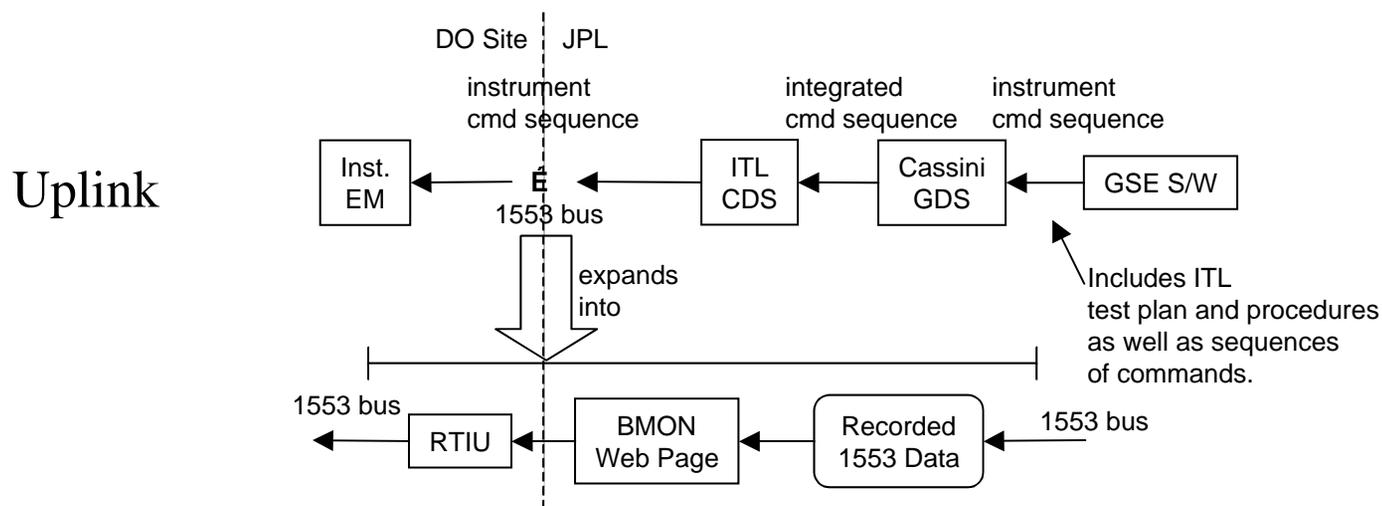RTIU Interface ← Not simulated → RTIU Interface

Cassini ITL Processes

- This shows the same information to compare the RTIU to the ITL downlink and uplink processes.

- This is almost identical to the flight downlink and uplink processes shown on previous page.

- But, there is an additional way to view the ITL uplink process.

Downlink

raw packets   transfer frames   raw packets

RTIU

Instr EM → 1553 → ITL CDS → Cassini GDS → GSE S/W

RTIU Interface ←— Not simulated —→ RTIU Interface

Uplink

Instrument cmd sequence   Integrated cmd sequence   Instrument cmd sequence

RTIU

Instr EM ← 1553 ← ITL CDS ← Cassini GDS ← GSE S/W

RTIU Interface ←— Not simulated —→ RTIU Interface

Cassini ITL Processes

- This diagram shows the use of the Bus Monitor Translation Web Page as described before.

- It uses that web page in conjunction with the RTIU to make a one-way, virtual 1553 connection between the ITL CDS and the Engineering Model of the instrument.

- Instrument telemetry not collected by ITL CDS in this scenario.

Uplink

DO Site | JPL

instrument
cmd sequence

integrated
cmd sequence

instrument
cmd sequence

Inst.
EM ← E ← ITL
CDS ← Cassini
GDS ← GSE S/W

1553 bus

Includes ITL
test plan and procedures
as well as sequences
of commands.

expands
into

1553 bus

RTIU ← BMON
Web Page ← Recorded
1553 Data ← 1553 bus

System Tradeoffs

- The Cassini RTIU is a special-purpose piece of hardware and software.
- It is Cassini-specific.
- Does a limited set of things:
  - Sends commands
  - Collects telemetry
  - Executes and manages sequences of commands
  - Simulates a few Cassini-unique CDS features
- Designed as drop-in replacement for existing RTIUs.
  - It emulates the old software interfaces.
- Does not attempt to do any telemetry display.
- Does not attempt to do any telemetry processing.
- Does not attempt to do any command generation.
- Requires instruments to have separate software for telemetry display and analysis.

Benefits

- Reduced need for instruments to request testing time in Cassini Integrated Test Laboratory.

- More efficient use of that ITL time.

- Easier regression testing of ITL tests.

- Better fidelity of translated sequences.

- Increased ability to diagnose or rule out instrument problems.

- Ability to simulate all spacecraft data rates.

- Allowed one instrument to get rid of a custom-built timing board along with their old RTIU.

- Several instruments took the opportunity to upgrade their ground support equipment software.

- System includes more than just RTIU software and hardware, but various web pages and integration with project processes.

Conclusions

- Don't build and forget
  - New requirements
  - Bug fixes
  - Changing operating systems
  - Changing security environments
  - Hardware replenishments
- On-going hardware and software maintenance is important
  - Even when primary development ends, must have enough funding to keep software development viable.
  - Need to stock spare hardware and have maintenance plan.
- Look at over-all system
  - External features like the web pages add great amounts of functionality.
  - Think of new uses to which your system can be put.
- Build these sort of features into the RTIUs early (pre-launch).
  - RTIUs will be more fully used by instrument teams.
  - RTIUs will be more fully integrated into Mission Operations processes.

Saturn and Enceladus

http://saturn.jpl.nasa.gov
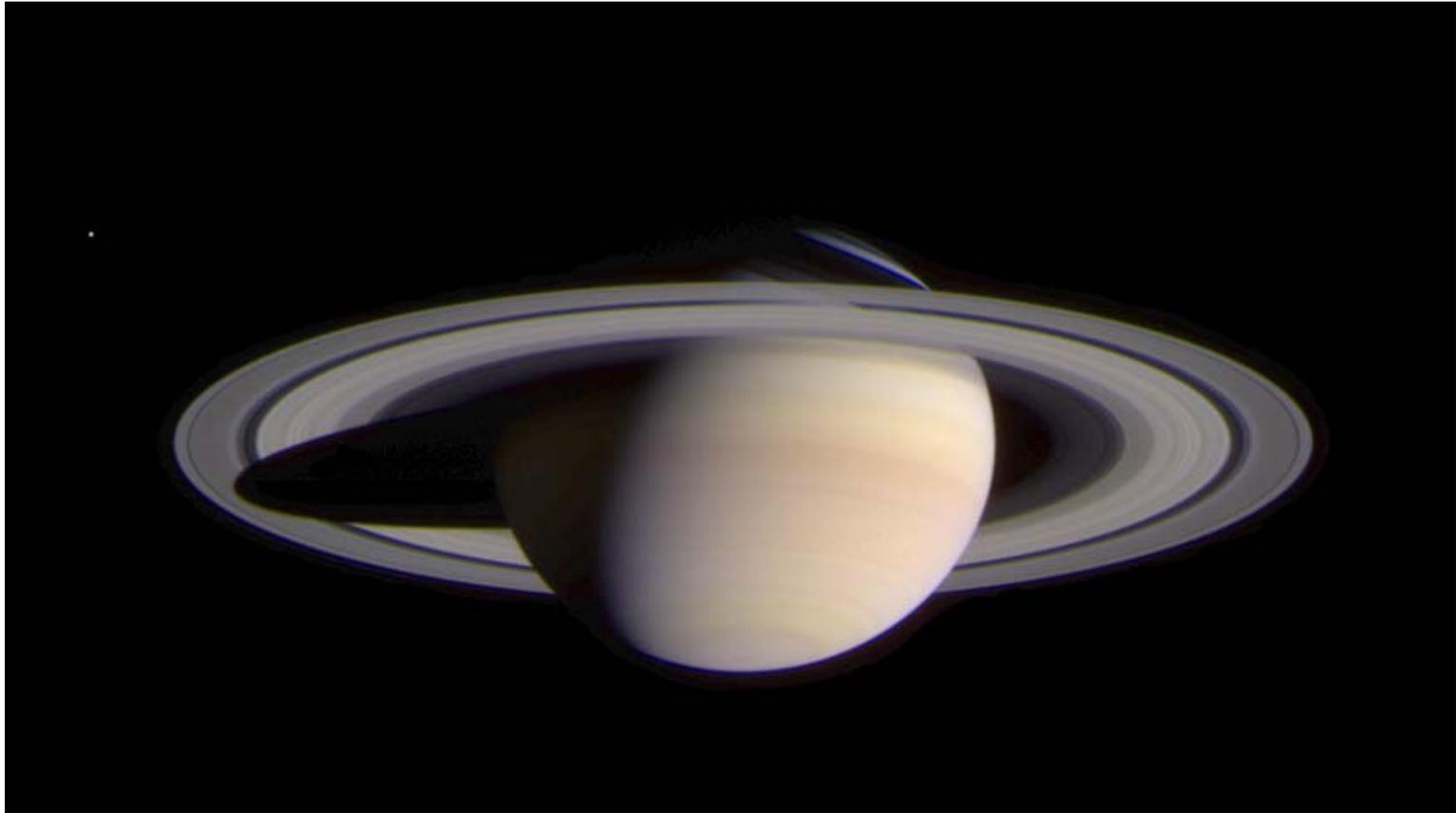
9 February 2004

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