Cassini Plasma Spectrometer (CAPS)

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Outline

- Saturn’s System
- Scientific Objectives
- The first man!
- Heritages and Innovations
- CAPS – Characteristics
- CAPS - Sensing Instruments
- How they work?
Outline - Continue

- Design Parameters
- Scientific Results – Statistics
- Scientific Results – Highlights
- After CAPS and Future
- Selected References
Saturn’s System

- as a Scaled Planetary System
  - Help to understand: Origin and Evolution

Artist's concept of a planetary system  Artist's close view of Saturn’s ring
Saturn’s System

- as an excellent Plasma Laboratory
  - Help to understand: Complex Interactions (surfaces and atmospheres)
  - Help to understand: Hypersonic Plasma
Scientific Objectives

- To measure the **composition** of ionised molecules originating from Saturn's ionosphere and Titan
- To investigate the **sources and sinks** of ionospheric plasma: ion inflow/outflow, particle precipitation
- To study the effect of magnetospheric/ionospheric **interaction** on ionospheric flows
- The sensors are designed to determine the composition, dynamics, and temperature of the plasma that surrounds the Saturn system, giving information that will help to **characterize the evolution of the Saturn system** over its 4.5 billion-year existence.
- To investigate auroral phenomena and Saturn Kilometric Radiation (SKR) generation
- To determine the configuration of Saturn's magnetic field
- To investigate auroral phenomena and Saturn Kilometric Radiation (SKR) generation
- To study the interaction of the magnetosphere with Titan's upper atmosphere and ionosphere
- To evaluate particle precipitation as a source of Titan's ionosphere
- To characterise plasma input to magnetosphere from the icy satellites
- To study the effects of satellite interaction on magnetospheric particle dynamics inside and around the satellite flux tube
Dr. David T. Young

Professional Chronology
- Royal Institute of Technology, Stockholm, Sweden: research scientist, 1971;
- University of Bern, Switzerland: senior research scientist, 1971-80;
- Physikalisches Institute: privat docent, 1980-1;
- Los Alamos National Laboratory: scientific staff member, 1981-7;
- Rice University: adjunct professor of Space Physics and Astronomy, 1996-9;
- Southwest Research Institute: institute scientist, 1988-9;
- University of Michigan, College of Engineering: professor of space science, 1999-2002;
- **Southwest Research Institute: 2002-[institute scientist, 2002-present].**
Heritages and Innovations

- Market Share
- Innovation Diffusion

1997

1989 PLS-Galileo
1985 RPA - Giotto
1978 ISEE-3
1977 ISEE-1
1978 Sun-Earth
1975 Comet
1977 Sun
1990 Sun-Earth
1990 SWOOPS - Ulysses
1997 Saturn
1997 CAPS
CAPS onboard
CAPS - Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>12.5 kg</td>
</tr>
<tr>
<td>Average operating power</td>
<td>14.5 W</td>
</tr>
<tr>
<td>Average data rate</td>
<td>8 kilobits/s</td>
</tr>
</tbody>
</table>

Table in front of you!
- Cell phone: ~1 W
- Laptop: ~100 W
- Cell phone: ~10 Mb/s
- Extremely Low Data Rate
CAPS - Sensing Instruments

- Ion Mass Spectrometer (IMS)
- Ion Beam Spectrometer (IBS)
- Electron Spectrometer (ELS)

High-voltage power supply: HVU 1 & 2
Actuator: ACT
Data Processing Unit: DPU
How it works? - ELS

- All three sensors are cylindrically symmetric and are based on curved-plate electrostatic analyzers (ESA)

Electron

Potential

Microchannel plate : MCP

ESA
How it works? - IMS

- Analogous to ELS
- with its HVUs, is the largest and most complex of the three sensors.
How it works? - IBS

- is dedicated to measuring the very narrow distributions of ions expected at Titan and in the solar wind and auroral zones.
Design Parameters

Different Objectives

Different measurements

For example:

C+ ($M/Q = 12$)
CH+ ($M/Q = 13$)
N+, CH+2 ($M/Q = 14$)
NH+, CH+3 ($M/Q = 15$)
O+, NH+2 ($M/Q = 16$)
OH+, NH+3 ($M/Q = 17$)
H2O+ ($M/Q = 18$)
H3O+ ($M/Q = 19$)
C+2 ($M/Q = 24$)
C2H+ ($M/Q = 25$)
CN+, C2H+2 ($M/Q = 26$)
CO+, N+2 ($M/Q = 28$)
Scientific Results - Statistics

- Number of papers
- Two Patents

VEX ~ 300

![Bar Chart](chart.png)

- X-axis: Year (2000-2010)
- Y-axis: Number of Papers (0-50)

The chart shows the increase in the number of papers from 2000 to 2010, with a significant increase in 2009 and 2010.
Some Scientific Results

- Discovery of an ionosphere over Saturn's rings.

- Recall some Objectives: Plasma Sinks and Sources; Composition, Boundaries
Some Scientific Results

- Discovery of large negatively charged molecules in Titan's upper atmosphere.
Some Scientific Results

- Discovery of charged water ice grains in plumes of gas escaping from Enceladus' south pole.
...smaller, less expensive missions to explore the solar system.

CAPS and PEPE
25 percent of the mass
12 percent of the volume

2005
IES - Rosetta

2006
SWAP - NH

2011
JADE-JUNO

Comet
1998
PEPE-DS1

Comet
2005
Pluto

Jupiter
2011

Sun
1990
SWOOPS - Ulysses

Saturn
1997
CAPS

Jupiter
1989
PLS-Galileo

Innovators
2.5%

Early Adopters
13.5%

Early Majority
34%

Late Majority
34%

Laggards
16%
Selected References

Questions or Comments?
Not a Technical Recommendation

But

Learn about Human resources as much as you learn about Instrument heritages and Technologies!
Remember the first man!

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## Collaborations (NASA & ESA)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>INSTITUTION</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>MSSL / RAL</td>
<td>ELS lead</td>
</tr>
<tr>
<td>Norway</td>
<td>NDRE</td>
<td>ELS (SMU, science)</td>
</tr>
<tr>
<td>USA</td>
<td>Los Alamos / GSFC / JPL / Rice University / U Virginia</td>
<td>IMS &amp; IBS hardware / Science</td>
</tr>
<tr>
<td>France</td>
<td>CETP / OMP</td>
<td>IMS hardware / Science</td>
</tr>
<tr>
<td>Finland</td>
<td>VTT / U Oulu</td>
<td>Actuator, IBS hardware / Science</td>
</tr>
<tr>
<td>Hungary</td>
<td>KFKI</td>
<td>EGSE</td>
</tr>
</tbody>
</table>
International Sun-Earth Explorer (ISEE-3) - 1978

(1) to investigate solar-terrestrial relationships at the outermost boundaries of the Earth's **magnetosphere**,

(2) to examine in detail the structure of the solar wind near the Earth and the shock wave that forms the interface between the solar wind and the Earth's magnetosphere,

(3) to investigate motions of and mechanisms operating in the plasma sheets,

(4) to continue the investigation of cosmic rays and solar flare effects in the interplanetary region near 1 AU.
Reme Plasma Analyser – Giotto - 1985

fly by and study Halley's Comet
Plasma Subsystem – Galileo - 1989
Solar Wind Observations Over the Poles of the Sun -SWOOPS - Ulysses - 1990

to study the Sun as a joint venture of NASA and the European Space Agency (ESA)
CAPS – Cassini - 1997

- Size and Complexity
Electron Spectrometer – Rosetta - 2004
SWAP – New Horizon - 2006
JADE – JUNO - 2011

Jovian Auroral Distributions Experiment (JADE)

JADE will measure the distribution of electrons and the velocity distribution and composition of ions.
Highlights: Atmospheric Escape Processes

- Examples:
  - Understanding the Escape of Water from Enceladus
  - Understanding the dynamics of Titan’s Ionosphere
Highlights: Plasma Sinks and Sources

- Examples:
  - Tethys and Dione as sources of outward-flowing plasma
  - Oxygen ions over optically thin parts of the rings and inside the "Cassini division"
Highlights: Astrobiological Potentials

- Examples:
  - The Composition of Titan’s Ionosphere: organic-rich aerosols (tholins)
  - Enceladus’ Oceans
Highlights: Magnetic Environment

- Examples:
  - Inceladus’ water ice jets influencing radio and auroral activity, and even causes changes in the rotation of the magnetic field itself.
  - Beams of electrons link Saturn with its moon Enceladus
Planetary System Evolution and Plasma: Connection

- Magneto-Rotational Instability (MRI)
- Atmosphere Interaction: Escaping
- Surface Interaction: Composition Determination
- ...

...