ESS 265
Instrumentation, Data Processing and Data Analysis in Space Physics

Lecture 3: Past, Present and Future Missions

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April 6, 2008

Early Space Physics Missions

• Explorer 10	1961	Battery operated; first measurements across magnetopause (in near tail)
• Explorer 12	1961	Measured magnetopause from noon to dawn in eccentric orbit
• IMP 1	1963	Mapped location of magnetopause, bow shock and studied near Earth tail
• 1963-38C	1963	Discovered field-aligned currents
• OGO-1	1964	First high resolution measurements at magnetopause and bow shock
• OGO-3	1966	Discovered ELF hiss and chorus in magnetopause
• OGO-5	1968	Discovered erosion of the magnetopause. Led to near-Earth neutral line model for substorms

Important Recent Space Physics Missions

• IMP 7 and 8	1972, 1973 – 2001
• GEOS 1,2	1977, 1978
• ISEE 1,2	1977 – 1987
• ISEE 3	1978 – 1985
• DE 1,2	1982 – 1989
• AMPTE (UKS, IRM, CCE)	1984 – 1986
• SAMPEX (SMEX)	1992 – ?
• Geotail (ISTP)	1992 – present
• FAST (SMEX)	1994 – present
• Wind (GGS, ISTP)	1995 – present
• Polar (GGS, ISTP)	1996 – 2008
• Cluster (4 S/C)	1996 – present
• IMAGE (MidEx)	2000 – 2006
• TIMED (MidEx)	2001 – 2007
• THEMIS (MidEx)	2007 – present

Important Recent Heliospheric and Solar Missions

- Voyager 1, 2 1977 – present
- Ulysses 1990 – 2008
- SOHO (ISTP) 1995 – present
- ACE 1997 – present
- TRACE (SMEX) 1998 – present
- RHESSI (SMEX) 2002 – present
- Hinode 2007 - present

Missions in Development and Planning

- Twins
- Solar Dynamics Observatory
- Magnetosphere Multiscale
- Radiation Belt Storm Probes
- Solar Orbiter
- Solar Probe

Important Planetary Space Physics Missions

• Pioneer Venus Orbiter	1978 – 1992
• Galileo	1989 – 2002
• Cassini	1997 – present
• NEAR	1996 – 2001
• Mars Express	2003 – present
• Venus Express	2005 – present
• Messenger	2004 - present

Types of Particle and Fields Investigations

- Fields:
  - Magnetic – Fluxgate
    - Vector Helium
    - Proton Precession
  - Electric – Dipole – wires
    - Dipole – Spheres
    - Electron guns
- Plasma:

  Langmuir Probe
  Retarding Potential Analyzer
  Faraday Cup
  Electrostatic Analyzers
  Mass Spectrometer
  Time-of-Flight Analyzers
  Linear Electric Field Analyzer
- Energetic Charged Particle Detectors
- Energetic Neutral Particle Detectors
- Imagers

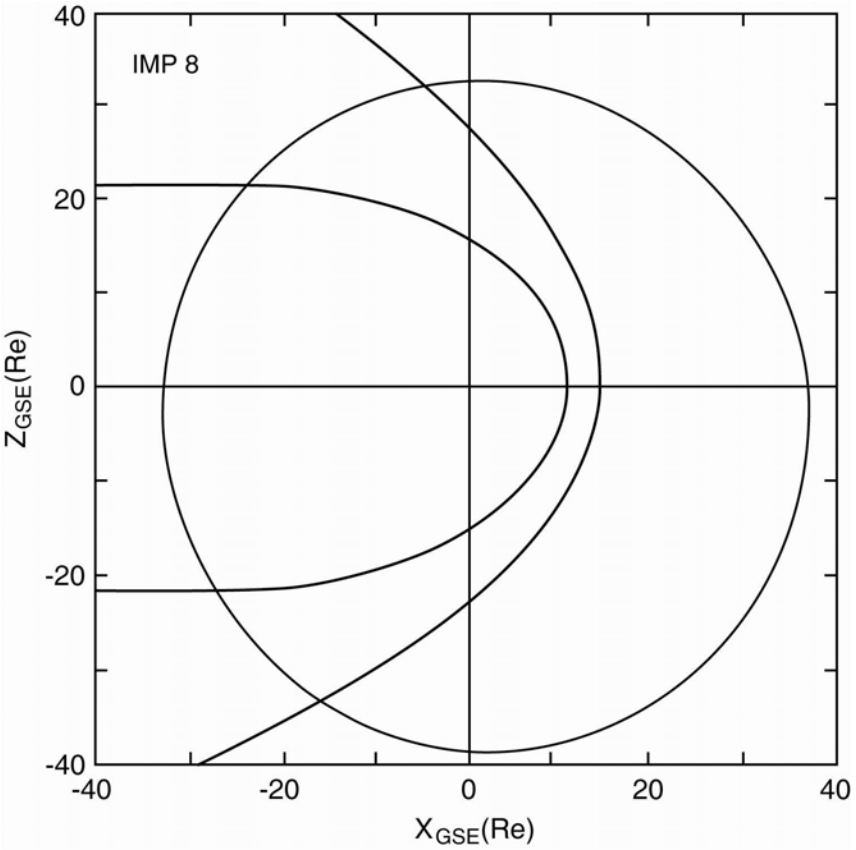
Interplanetary Monitoring Platforms: IMP 7 and 8

	IMP 7	IMP 8
Apogee	30-40 R_e	37-45 R_e
Perigee	30-34 R_e	35-33 R_e
Inclination	10-44°	20-55°
Spin Rate	46 rpm	22 rpm
Launch	9/23/72*	10/26/73
End of Operation	1978	2001

Payload: Magnetometer, D.C. electric field, plasma waves MIT and LANL solar wind, Iowa LEPEDEA, energetic particles (Williams, Gloeckler, Krimigis, McDonald, Stone, Simpson)

Reference: J.H. King in IMS Source Book, AGU, 1982.

*Magnetometer failed shortly after launch



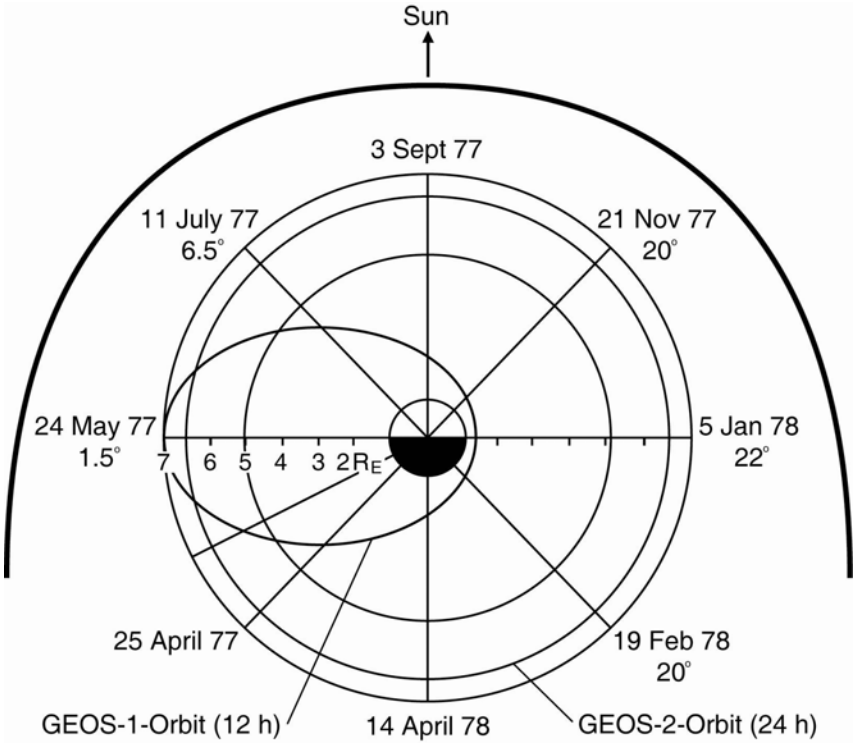
Geosynchronous Spacecraft: GEOS 1 and 2

	GEOS 1	GEOS 2
Apogee	38,000	42,000
Perigee	2,050	42,000
Inclination	0°	0°
Period	12h	24h
Launch	4/20/77	6/15/78
End of Operation	1979	1981^+

Payload: Magnetometer*, D.C. electric field with electron beam, AC magnetic fields and DC/AC electric fields with wire booms, thermal plasma, composition, low energy plasma, energetic particles.

Reference: K. Knott in IMS Source Book, p43, AGU, 1982.

*Magnetometer failed early

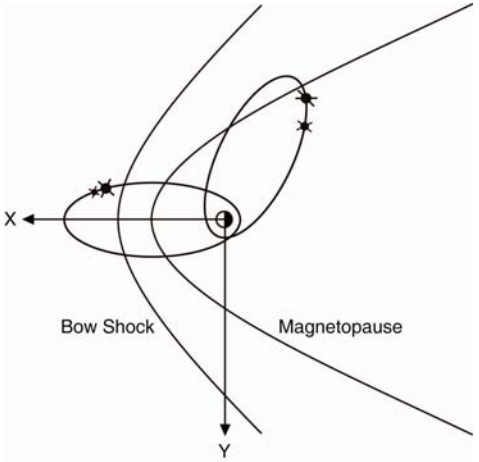


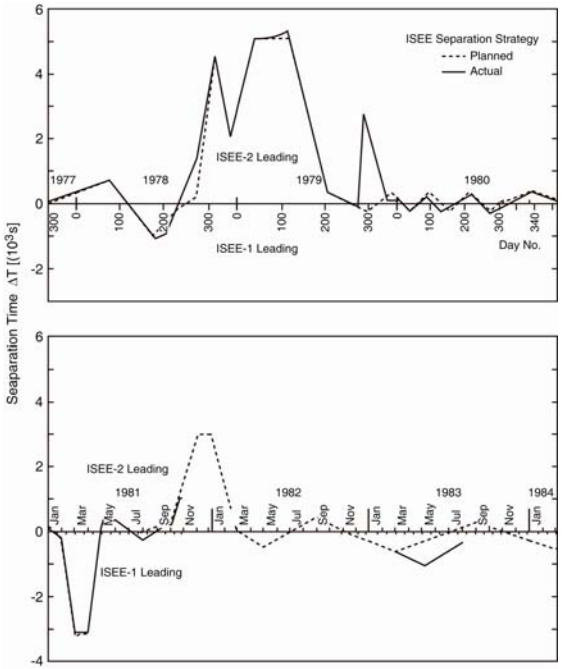
ISEE 1 and 2 Co-orbiting Spacecraft

Apogee	23 R_e
Perigee	1000km
Inclination	23°
Period	57.2h
Launch	10/22/77
Reentry	10/87
Separation	Up to ~ 2 R_e

Payload: Magnetometer, plasma (LANL, Iowa, Goddard) energetic particles, AC/DC electric fields, AC magnetic fields, propagation and sounder experiments composition

Reference: IEEE Transactions on Geoscience Electronics, GE-16, 1978.





Solar Wind Monitor: ISEE-3

Location: Potato chip-like orbit 130x90 R_e around forward (L1) Lagrangian point.

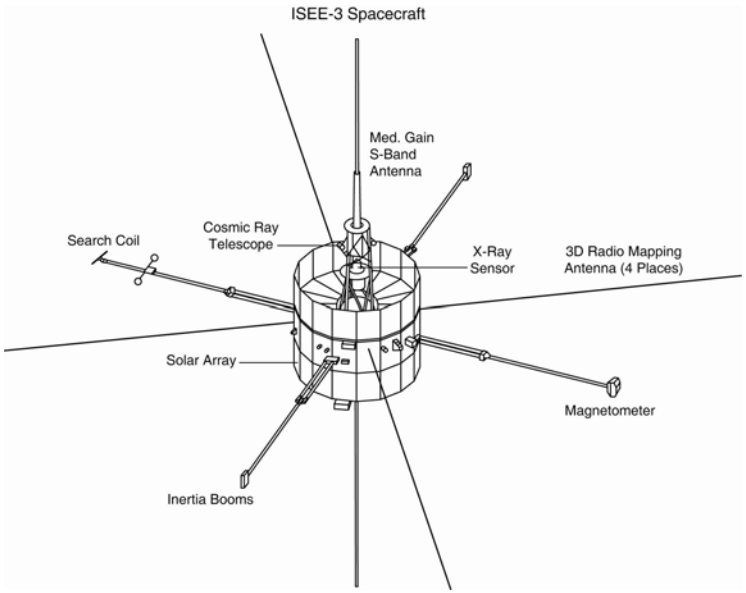
Launch: 8/12/78

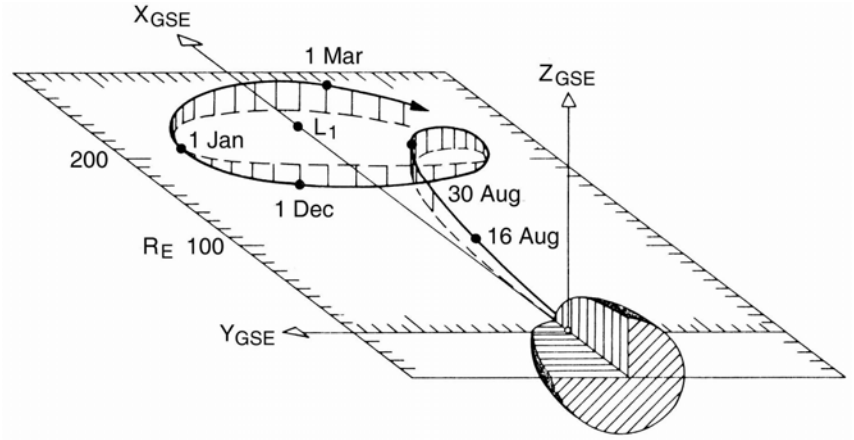
Significant Events: 1983-4 tail study
1985- comet Giacobini-Zinner

Payload: Magnetometer, solar wind plasma*, composition, energetic particles, AC electric and magnetic waves, radio waves, cosmic rays

Reference: IEEE Transactions on Geoscience Electronics GE-16 1978

*Proton measurements failed on 2/80





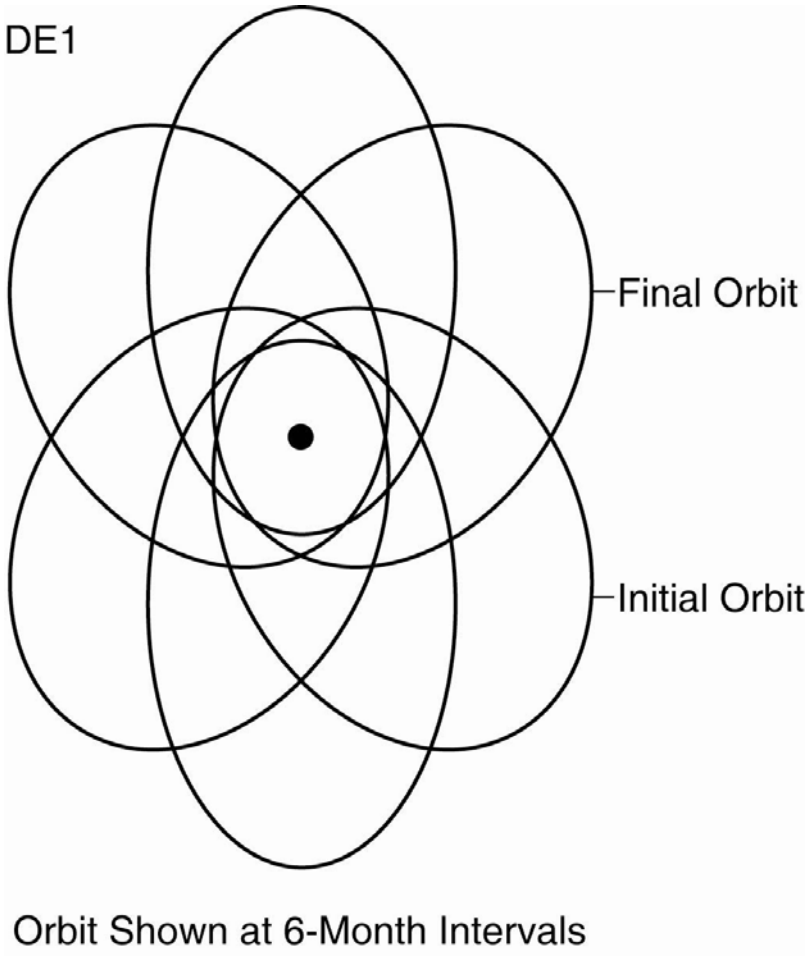
Dynamics Explorer DE1 and DE2

Two coplanar orbits to obtain measurements along the same field line

One moderate altitude polar, DE-1, and one low altitude polar

Innovation: Moderately high altitude auroral imaging

Most notable failure: Centralized data system



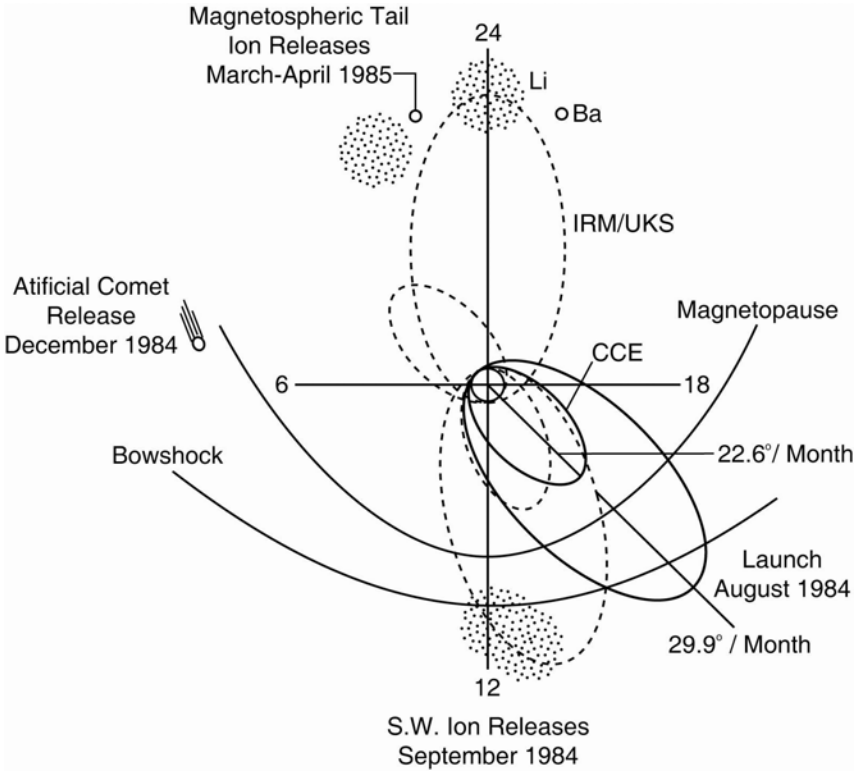
Active Magnetosphere Particle Tracer Explorer: AMPTE

Three spacecraft mission
- -Ion Release Module (IRM)
- -United Kingdom Subsatellite (UKS)
- -Charged Composition Explorer (CCE)

	CCE	IRM	UKS
Apogee	18.7 R_e	18.8 R_e	8.8 R_e
Period	44.3h	44.3h	15.6h
Inclination	28.8^o	28.8^o	<5°
Launch	8/16/84		

Purpose of mission: To release lithium and barium ions in the solar wind, magnetosheath and magnetotail

See IEEE Transactions on Geoscience and Remote Sensing GE-23(3) May 1985

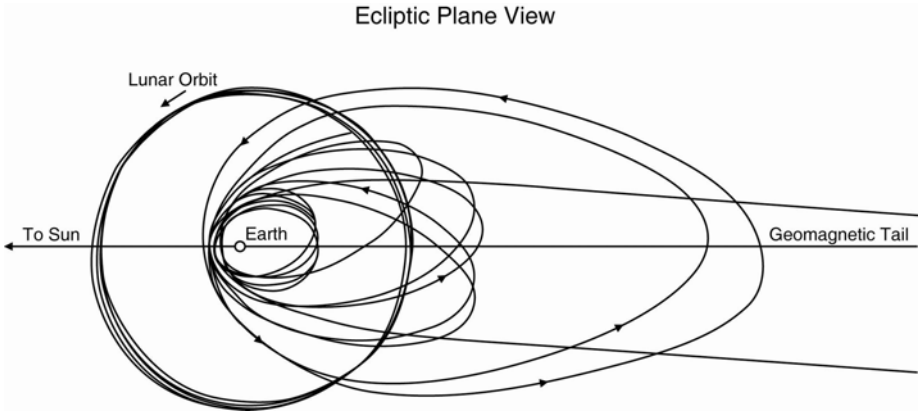


Geotail

- Geotail was Japan's contribution to the ISTP program. It stayed on schedule and was launched in 1992. The rest of ISTP was launched in 1995 (Wind) and 1996 (Polar). The fourth spacecraft, Equator, was never launched but rather sacrificed to pay for budget overruns.

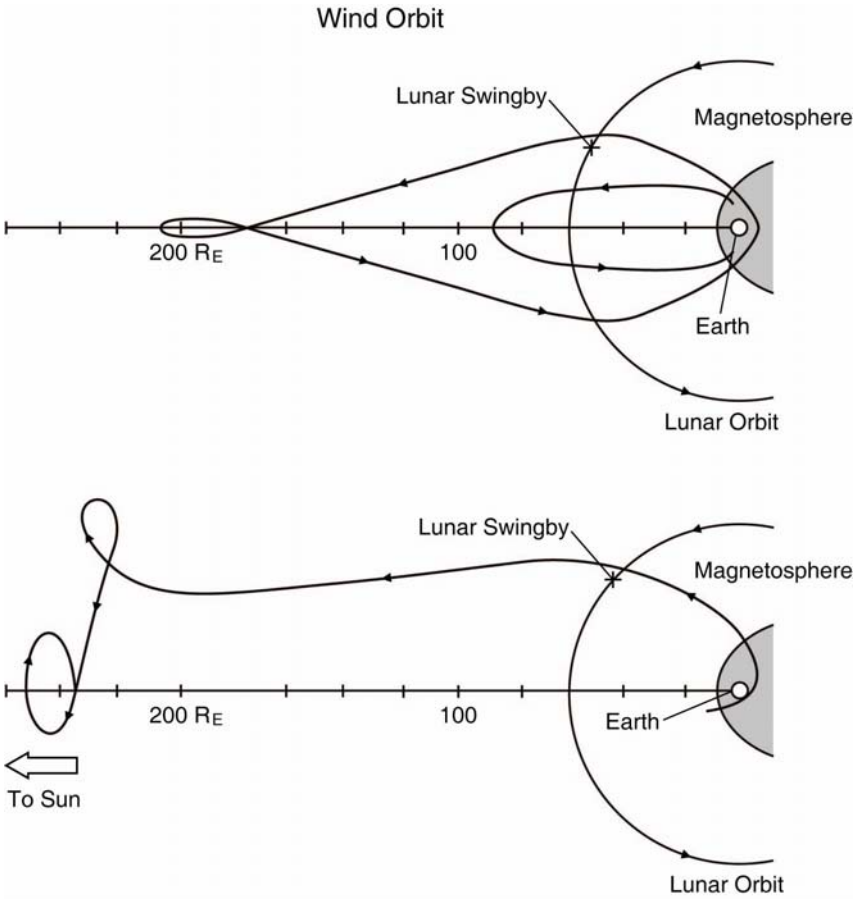
- Geotail had three operational phases
  - Distant tail with apogee kept inside the tail using lunar gravity assists
  - Near tail with lunar gravity assists
  - Near-Earth tail, magnetopause and solar wind

- Geotail is an extraordinarily good mission with a wealth of scientific return.



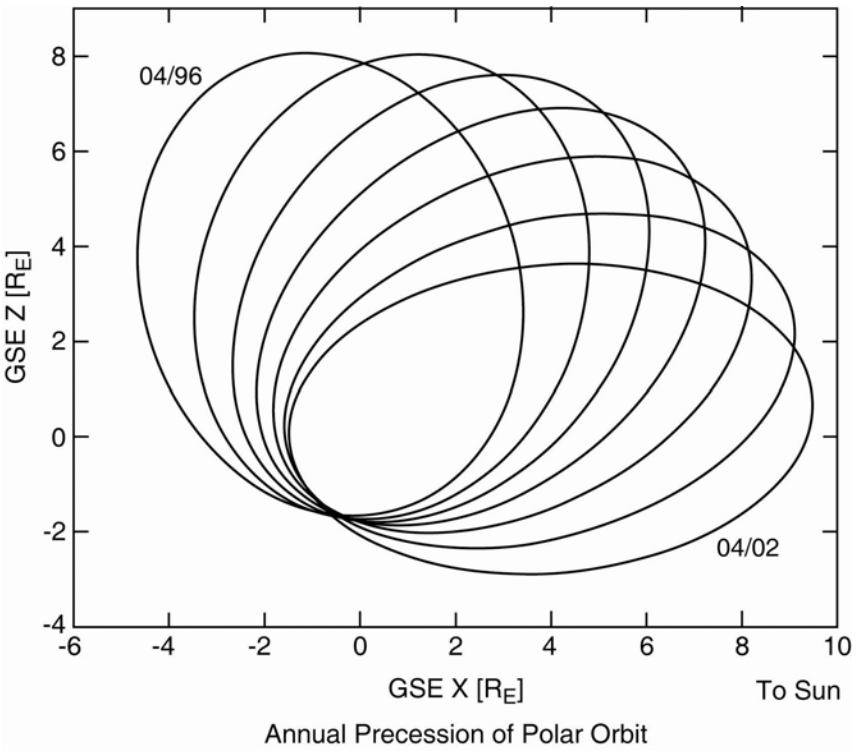
Wind

- The Wind spacecraft was designed to monitor the solar wind impinging directly on the Earth's magnetosphere.
- To do this, Wind used lunar gravity assists to keep apogee along the solar wind stream line directly in front of the Earth.
- Wind may have been too well instrumented for just monitoring, so when ACE was launched, Wind started looking for other things to do.
- For a while it was in a very broad looping orbit going from the leading to trailing edge of a ±200 R_E ellipse around the Earth.
- Its present long-term fate is uncertain.



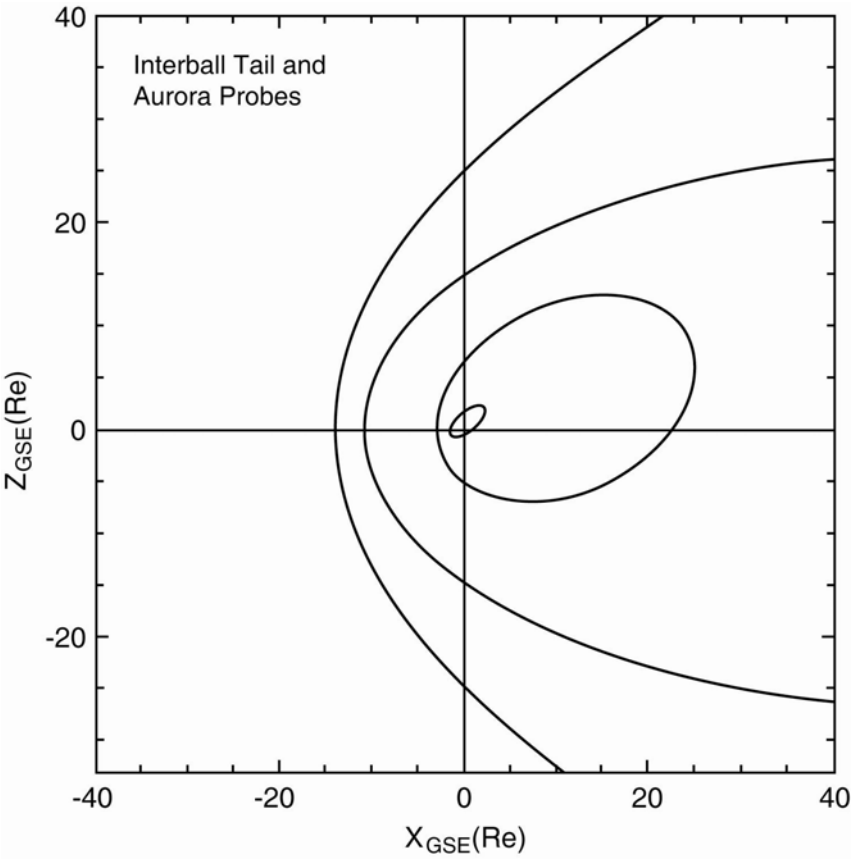
Polar

- The Polar spacecraft was launched in 1996 to explore the polar magnetosphere including the polar cusp.
- Polar mapped out the northern polar cusp and northern lobe in its first three years and then continued to precess down to the equator and then to the Southern polar regions by 2008.
- It explored the entire volume of the magnetosphere.
- In 2008, it ran out of control gas and will be decommissioned immediately for safety reasons.



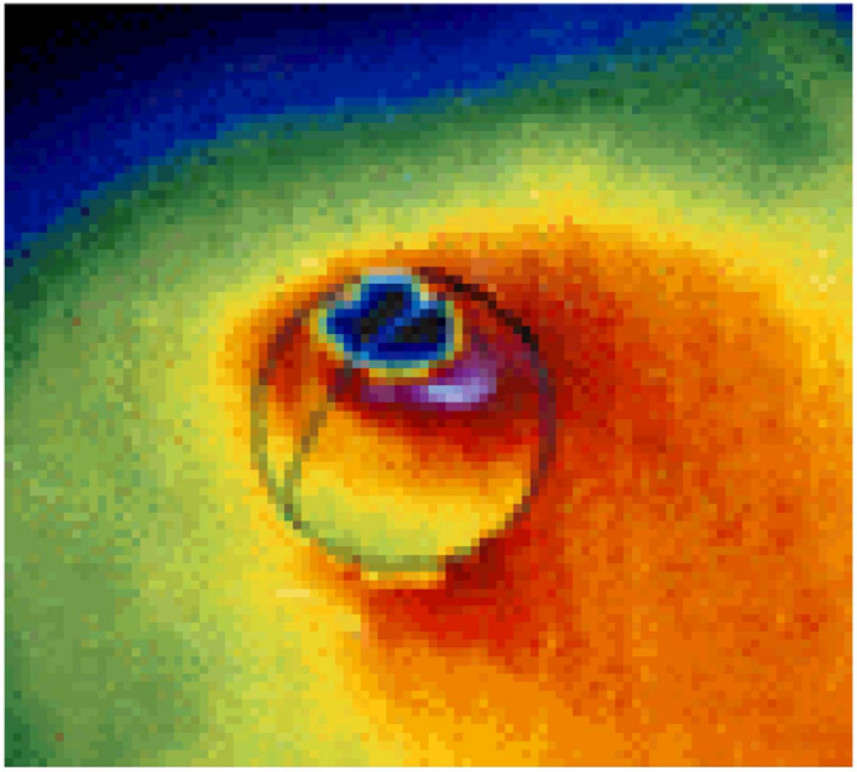
Interball: Tail and Auroral Probes

- The Interball program was a very ambitious Russian program in cooperation with Czechoslovakia.
- There were two launches, each with a main spacecraft and a subsatellite. One pair went into the distant equatorial magnetosphere and the other went into a polar orbit in the inner magnetosphere.
- At first only the high altitude subsatellite worked. Later, after the first one died, the low altitude subsatellite came to life.



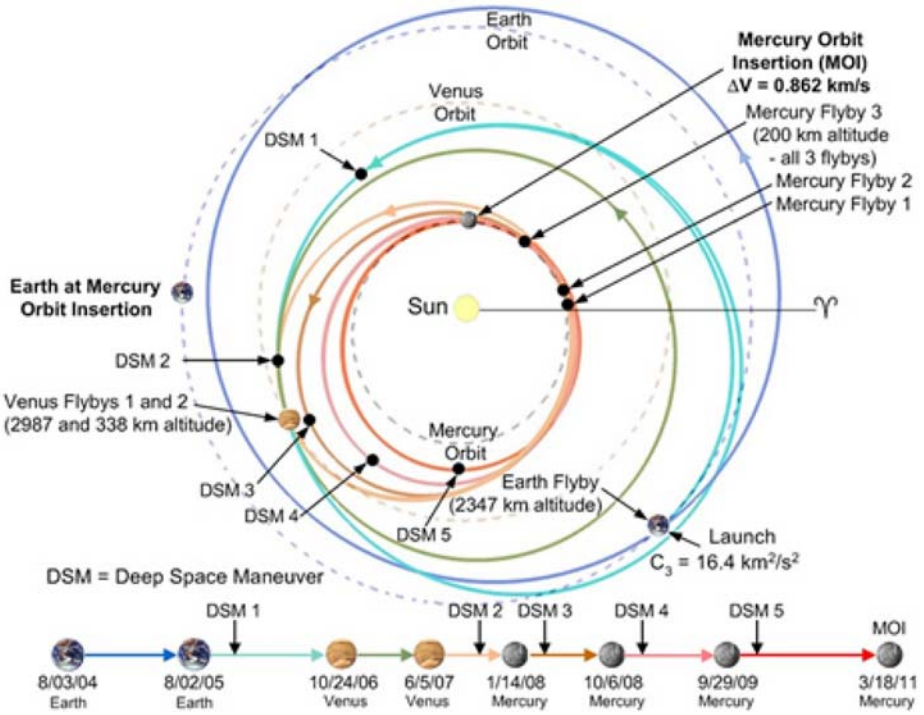
IMAGE

- IMAGE was the first MidEx mission. It was under the direction of a Principal Investigator, Jim Burch and was launched in 2000.
- It had a theme of remote sensing the magnetospheric plasma.
- It had cameras for the auroras, for the EUV emission from the plasmasphere, for measuring fast neutral particles from charge exchange between various energy range ions and the neutrals in the exosphere. It also tried remote sensing of the magnetopause and the plasmaspause with radio waves.
- It did a fairly good job of remote sensing the plasmasphere and imaging the aurora but it is very difficult to interpret fast neutral data and the remote sensing using radio waves did not work to image the magnetopause and plasmapause.
- The spacecraft died unexpectedly in 2006.



Space Physics at Mercury

- Mariner 10 made these passes by Mercury in 1974 and 1975. Passes 1 and 3 were close and on the night side and pass 2 at some distance on the day side.
- A bow shock and mini-magnetosphere were found. The ion spectrometer did not work because of a failed door. The electron instrument and the magnetometer worked fairly well.
- ULF waves and flux transfer events were seen.
- MESSENGER has just made its first pass by Mercury. It will later go into orbit once it slows down via gravity assists.
- Bepi Colombo is under development by ESA and JAXA to fly a two-spacecraft mission to orbit Mercury.

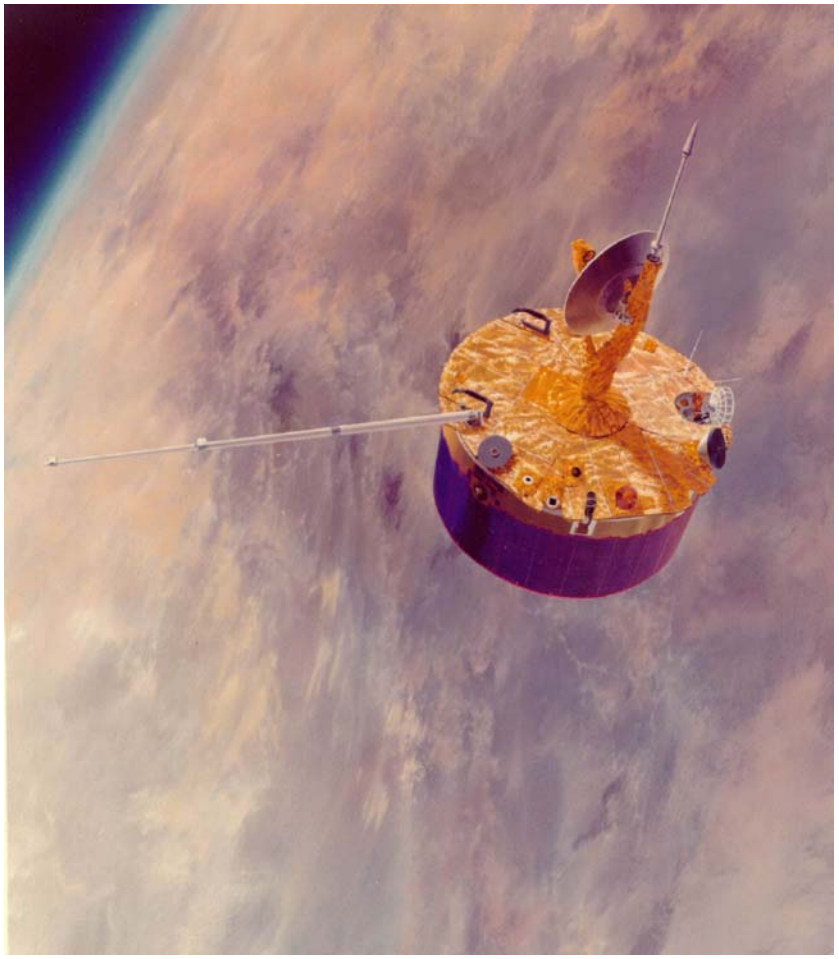


Space Physics at Venus: Venera and Pioneer Venus Orbiter

- The USSR supported a very vigorous program of Venus Exploration in the 1970's and 1980's. There were a series of atmospheric probes up to Venera 8. Then there were two orbiters Venera 9 and 10. Then there were sophisticated landers Venera 11-14. They took the first radar pictures of the surface and the VEGA mission on its way to Halley dropped off two balloon missions.

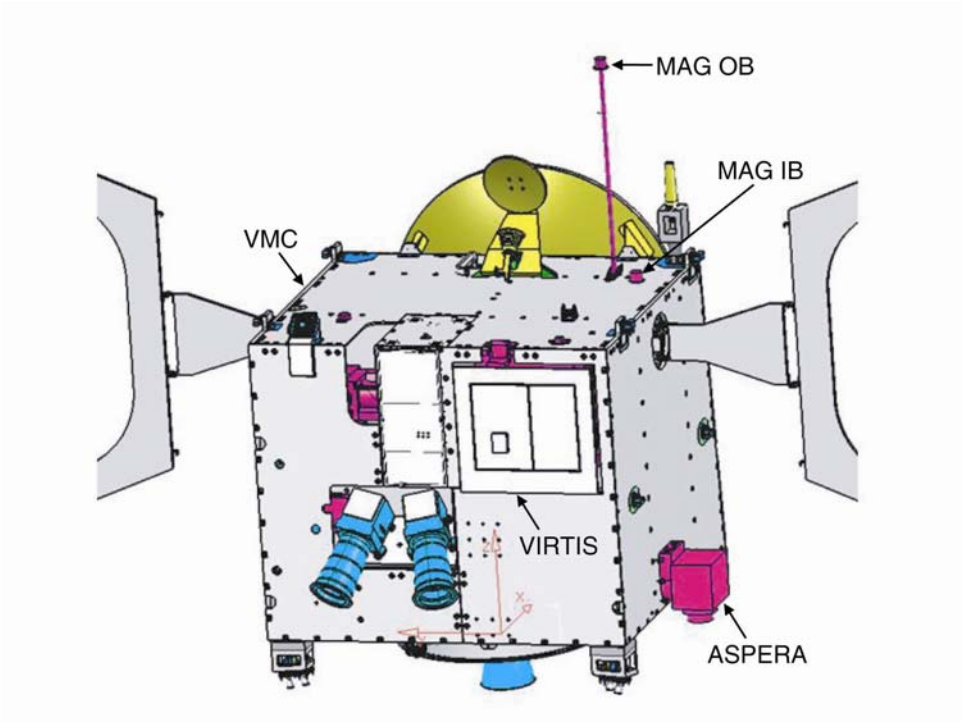
- The US was far less ambitious at Venus and as yet has still not attempted a lander mission or a balloon mission despite the potential high payoff of such data.

- One important (and low-cost) mission was Pioneer Venus that dropped four probes into the atmosphere and left an orbiter that operated for 14 years. We understand the solar wind interaction with Venus quite well because of these data.



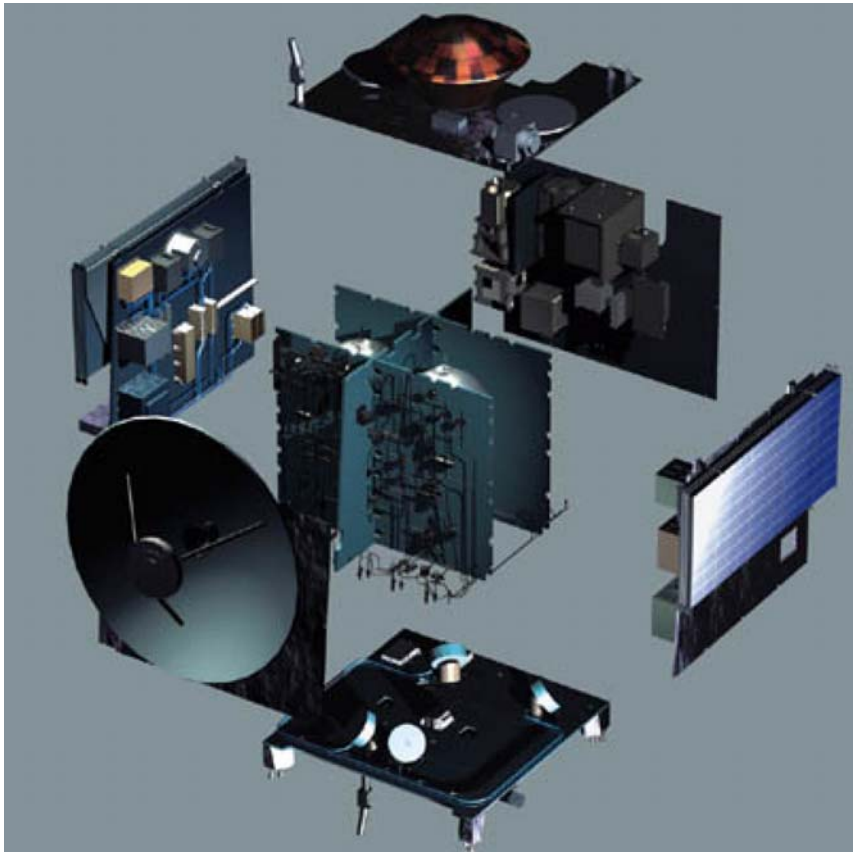
Space Physics at Venus: Venus Express

- In late 2005, ESA launched the Venus Express to Venus after close to 20 years of neglect by the world's space faring nations.
- The mission is largely remote sensing but it includes a magnetometer and a sophisticated plasma spectrometer capable of measuring neutral particles. The ionosphere is measured by radio wave propagation.
- The mission is not magnetically clean and has a short boom, but two sensors allow it to detect spacecraft contributions to the field via a gradiometer technique. This has worked fairly well but a clean spacecraft with a long boom would have been better.
- The magnetometer can sample up to 128 Hz, which is high enough to detect lightning.



Space Physics at Mars

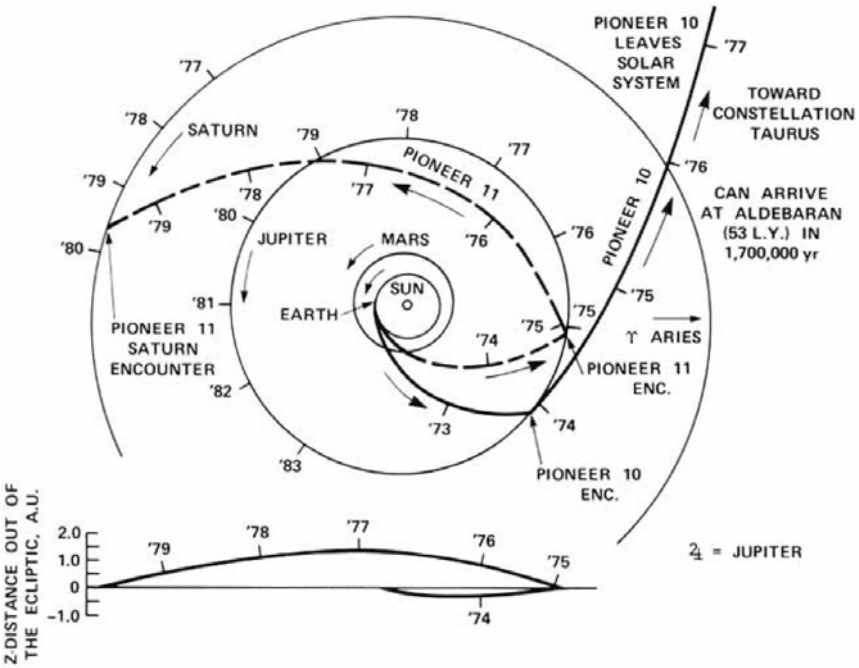
- Mariner 4 flew by Mars in 1984 and detected a planetary bow shock.
- The first orbiters were the Soviet Mars 2, 3, and 5 missions. They mapped the bow shock and detected ion loss to the solar wind.
- The next orbiter of importance to space physics was the Phobos mission in 1989 that showed the global martian field was very weak.
- This was followed by the Mars global Surveyor mission that found strong crustal remanent magnetism.
- In 2003, the ESA's Mars Express arrived with a comprehensive plasma package but no magnetometer. Mars Express also has a combined radar and ionospheric sounder.



Pioneer 10, 11 Ulysses

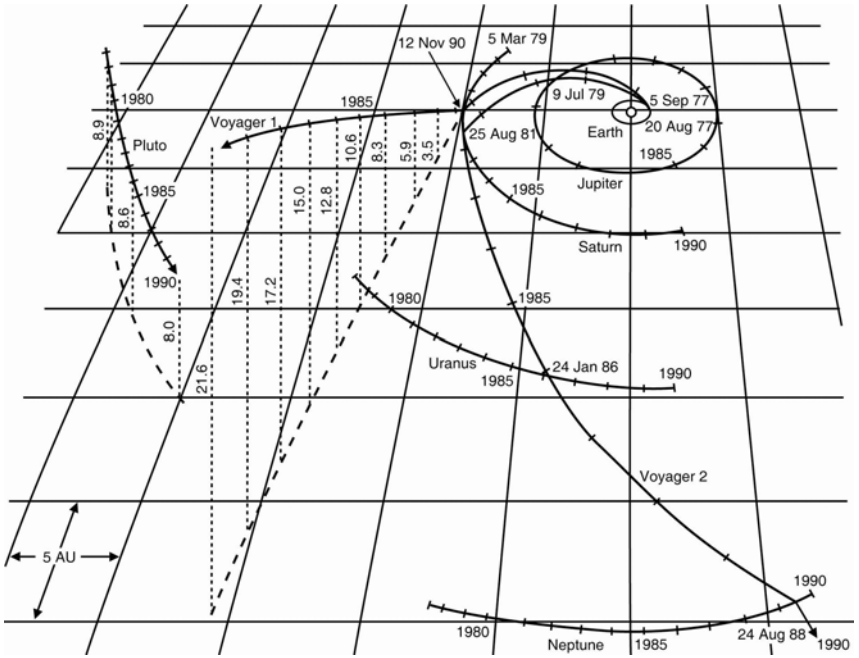
- Pioneer 10 and 11 were launched in 1972 and 1973 to fly by Jupiter where they arrived in 1973 and 1974. Pioneer 10 then went on to explore interplanetary space while Pioneer 11 headed for Saturn arriving in 1979. These probes found two very large magnetospheres, Jupiter's being the largest and most rotationally dominated due to the tremendous mass loading by the moon Io.

- Ulysses was a joint ESA-NASA mission originally involving 2 spacecraft that would use the gravitational field of Jupiter to bend their trajectories out of the ecliptic plane and over the two poles of the sun. NASA cancelled its spacecraft but supported launch and telemetry gathering. Ulysses was launched in 1990 and arrived in 1992, basically confirming the results of Pioneer and Voyager. The mission ended in 2008 when a transmitter failed.



Voyager 1 and 2

- Voyager 1 and 2 were launched in 1979 first flying by Jupiter and then Saturn.
- These missions include a flyby of Io at Jupiter and Titan at Saturn.
- Voyager 2 continued to Uranus (1986) and Neptune (1989) and eventually crossed the termination shock that slows the solar wind before it interacts with the interstellar medium.
- Voyager 1 and 2 are both still operating on their RTGs.



Galileo and Cassini

- While flyby missions are fine for a first exploratory look at a planet, an orbiter is essential for detail knowledge and understanding.

- Galileo was a sophisticated flagship mission sent to Jupiter in 1989, after much delay arriving in 1995. Unfortunately, the communications antenna did not open and science was limited by the low bandwidth. Nevertheless, much was learned about the planet and its magnetosphere.

- Cassini was launched in 1997 with two Venus gravity assists and one Earth gravity assist and arrived at Saturn in 2004. This orbiter worked very well and has provided spectacular data about Saturn and its moons.

Future Planetary Missions

- Juno, a mission to probe Jupiter's planetary magnetic and gravitational fields is currently under development as a New Frontiers PI-led mission.
- Two aeronomy missions are in competition to orbit Mars in the latest Scout competition.
- The New Horizons PI-led mission is on its way to Pluto without a magnetometer but with particle instruments.
- Study groups are examining several options for flagship outer planet missions.
- Lunar missions are under way as well. The Lunar Reconnaissance Orbiter will soon be launched. A call for ideas for a LADEE (Lunar Atmosphere) mission has been announced.
- Rosetta is on its way to comet 67P Churyumov-Gerasimenko.