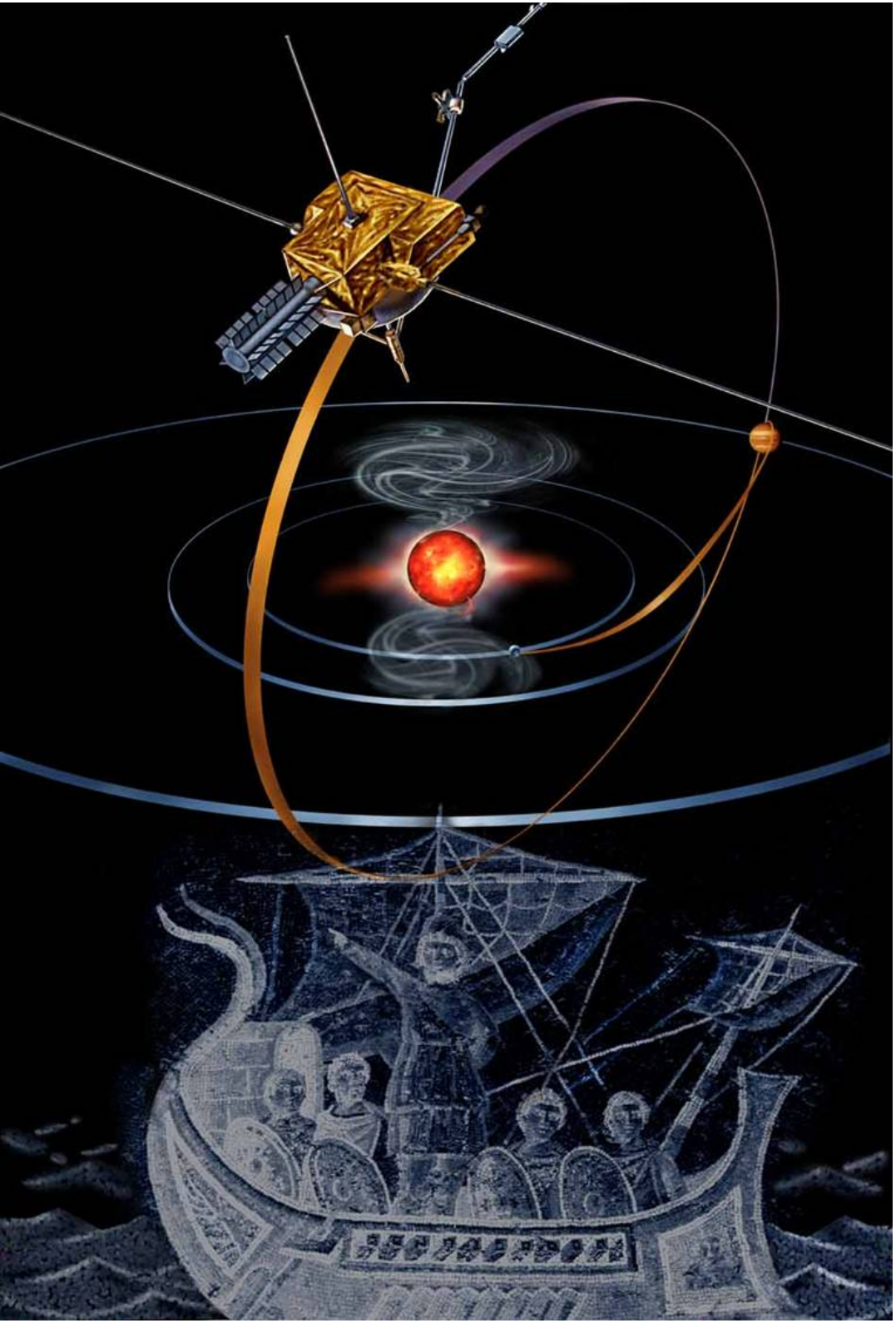

The Ulysses Mission: Over the Sun's Poles

Jet Propulsion Laboratory
Open House
19th & 20th May 2007

Presentation Material for the
Ulysses Booth

Ulysses Flight Control Team
European Space Agency
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Pasadena, CA 91109
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Outline of Presentation

- Ulysses mission overview & history
- The unique orbit of Ulysses
- Ground stations used by Ulysses
- The Ulysses spacecraft
- Ulysses science payload
- Some Ulysses science results
- Web sites
- Spacecraft sub-systems block diagrams
- Questions and answers

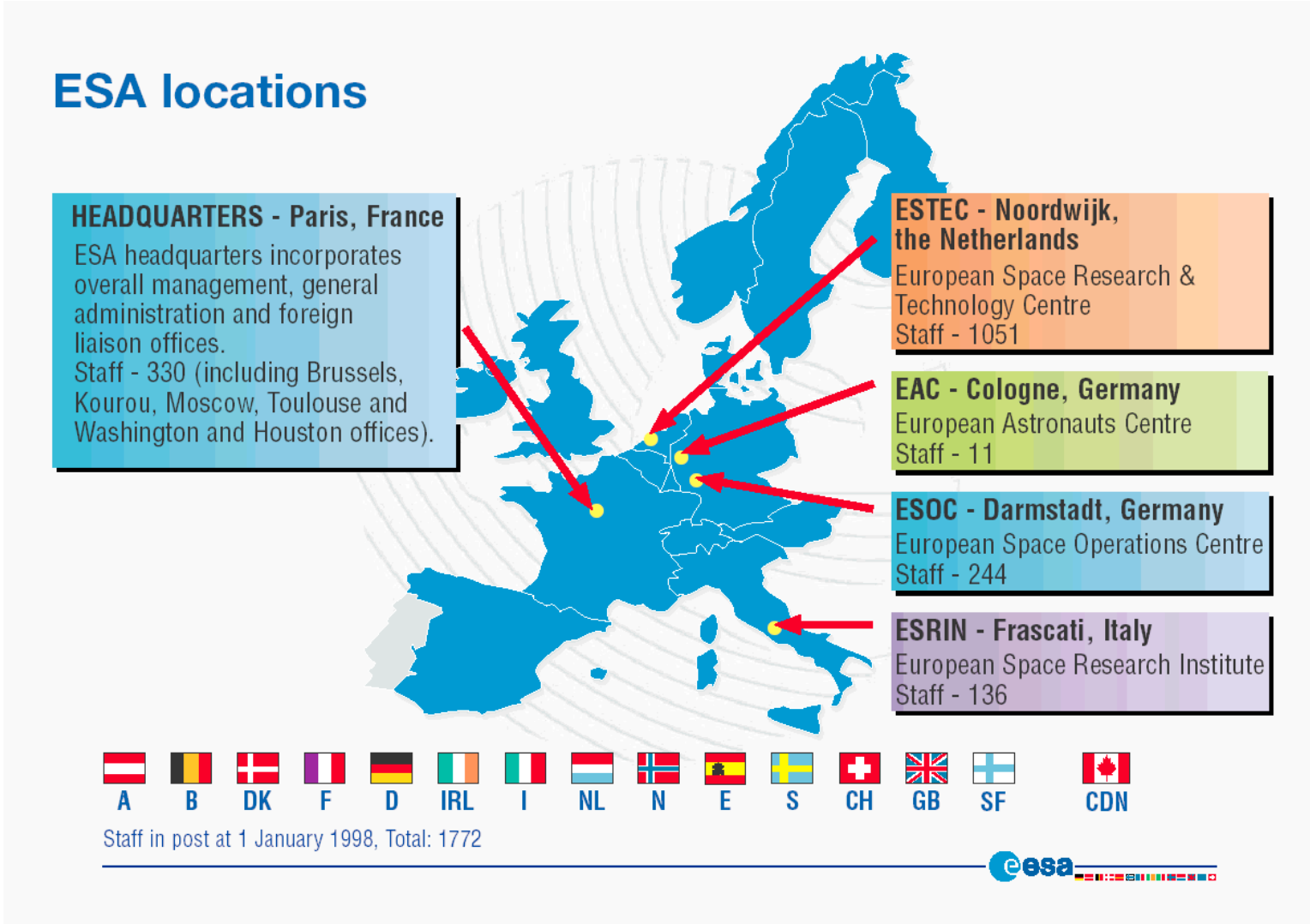
Mission Overview

- Joint ESA-NASA mission
  - *"… to make the first-ever measurements of the unexplored region of space above the Sun's poles."*
  - Launched on 6th October 1990
    - Delayed 4 years due to Challenger accident
  - Mission extended until March 2008
    - Completion of 3rd set of solar polar passes
    - Second set of solar minimum observations

International Cooperation

- ESA ~50% contribution:
  - Spacecraft design and construction
  - ~50% of science payload
  - Integration of science payloads to spacecraft
  - Flight control team at JPL
- NASA ~50% contribution
  - Launch
  - Radioisotope Thermoelectric Generator (RTG) power source
  - ~50% of science payload
  - Use of Deep Space Network (DSN) ground stations
  - Ground operations, navigation, data management teams
  - Facilities for ESA flight control team at JPL

European Space Agency



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Ulysses

NASA

Jet Propulsion Laboratory

Manages and/or operates ***most*** of NASA's deep space missions

Mission Development History

Year	Event
1959	Over-flight of solar poles first proposed.
1974	ESA/NASA joint mission study - mission named *Out of Ecliptic* (OOE).
1977	*Out of Ecliptic* project approved - launch set for 1983.
1978	Construction of ESA OOE spacecraft started.
1979	Name changed to *International Solar Polar Mission* (ISPM).
1980	ISPM launch postponed to 1985 due to space shuttle development problems.
1981	NASA ISPM spacecraft cancelled - numerous science instruments lost.
1983	ESA ISPM spacecraft completed and put in storage till 1985. Mission renamed *Ulysses.*

Year	Event
1984	*Ulysses* launch postponed to 1986.
1985	Spacecraft removed from storage for reintegration and recertification for launch in May 1986.
Jan 1986	*Challenger* accident. *Ulysses* launch campaign at Kennedy Space Center (KSC) halted.
mid 1986	Spacecraft shipped back to Europe for storage.
mid 1989	Spacecraft removed from storage for second round of reintegration and launch recertification.
early 1990	Spacecraft shipped to KSC for launch campaign. ESA engineering team relocated to KSC. ESA operations team relocated to JPL.

Reference: "The Ulysses Data Book", ESA-BR 65, June 1990, European Space Agency, ISBN 92-9092-039-4

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Mission Milestones

Date	Event
6 Oct 1990	Launch
8 Feb 1992	Jupiter Closest approach (6.3 Rj)
26 Jun 1994	Start of 1st south polar pass
13 Sep 1994	Maximum south solar latitude (-80.2°)
5 Nov 1994	End of 1st south polar pass
19 Jun 1995	Start of 1st north polar pass
31 Jul 1995	Maximum north solar latitude (+80.2°)
29 Sep 1995	End of 1st north polar pass
6 Sep 2000	Start of 2nd south polar pass
27 Nov 2000	Maximum south solar latitude (-80.2°)
16 Jan 2001	End of 2nd south polar pass

Date	Event
31 Aug 2001	Start of 2nd north polar pass
13 Oct 2001	Maximum north solar latitude (+80.2°)
10 Dec 2001	End of 2nd north polar pass
4 Feb 2004	Jupiter Distant Encounter (1684 Rj)
17 Nov 2006	Start of 3rd south polar pass
7 Feb 2007	Maximum south solar latitude (-79.7°)
3 Apr 2007	End of 3rd south polar pass
30 Nov 2007	Start of 3rd north polar pass
14 Jan 2008	Maximum north solar latitude (+79.8°)
15 Mar 2008	End of 3rd north polar pass
31 Mar 2008	*Planned* end of mission operations

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Mission Operations Team

- Joint ESA-NASA mission operations team located at the Jet Propulsion Laboratory
  - ESA
    - Flight control team
      - Mission operations manager (1)
      - Spacecraft operations manager (1)
      - Spacecraft systems engineers (3)
      - Spacecraft analysts (3)
      - Flight dynamics engineer (1)
      - Software support engineer (1)
      - Scheduler (1)
  - NASA/JPL
    - Ground operations team (4)
    - Navigation team (0.25)
    - Data management team (1)

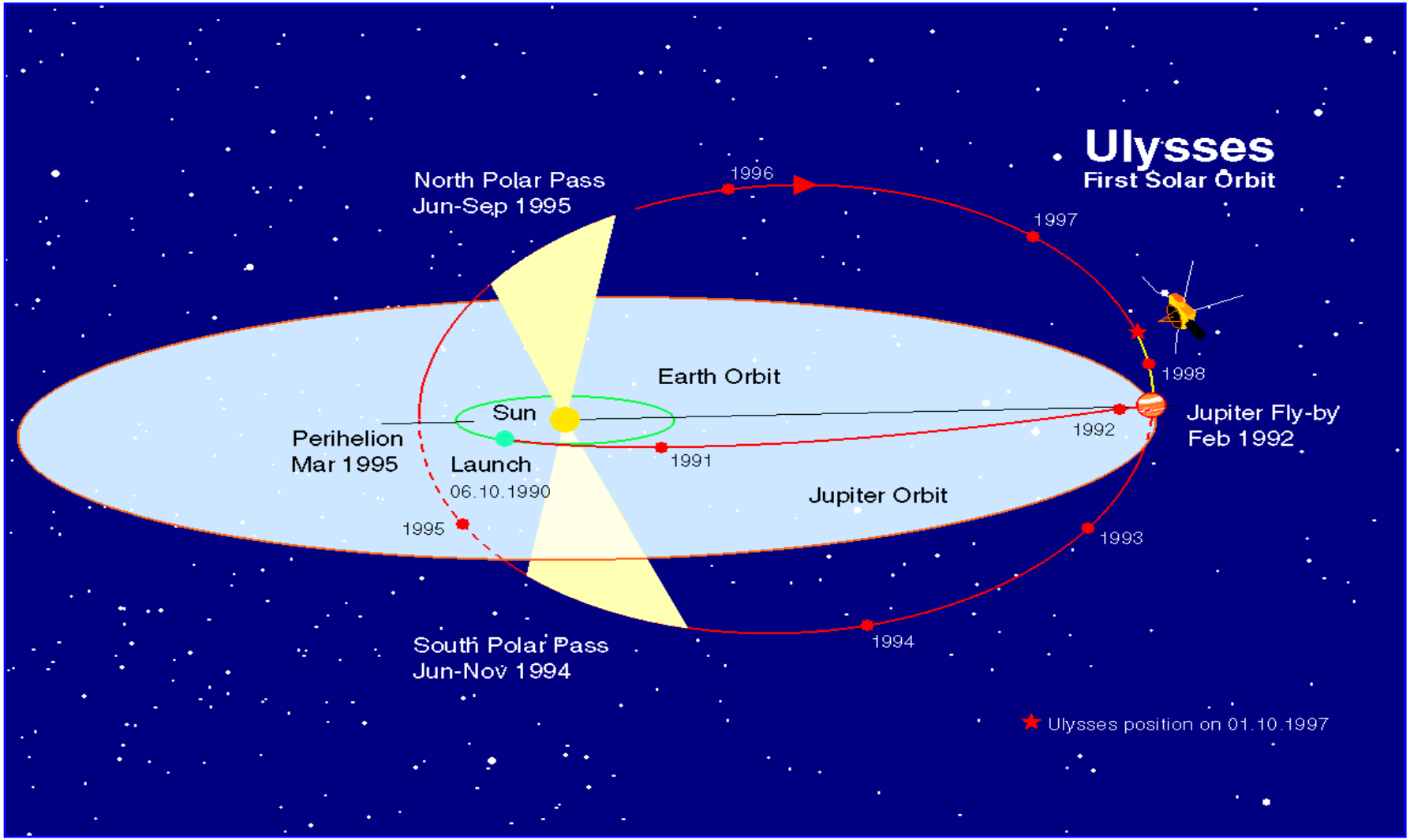
Launch

- Launch
  - 6th October 1990
  - On-board space shuttle *Discovery* to low Earth orbit
  - 2 solid rocket motor upper stages inserted *Ulysses* into outbound trajectory for Jupiter
    - Inertial Upper Stage (IUS)
    - Payload Assist Module (PAM-S)
    - Earth departure velocity 15.3kms^{-1} (only superseded by *New Horizons*, 16kms^{-1}, in Jan 2006)

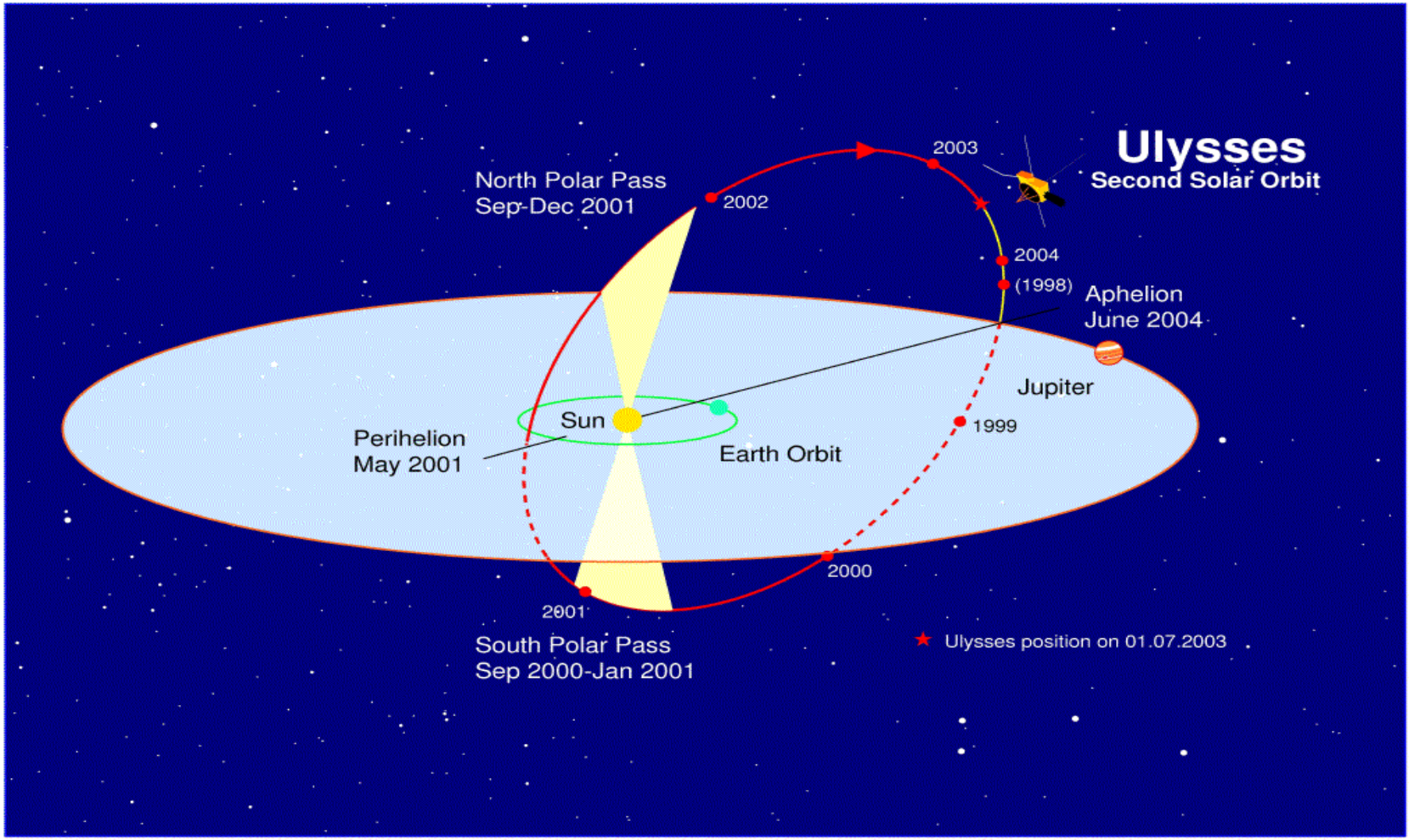
Jupiter Gravity Assist

- Gravity assist at Jupiter
  - Orbital plane rotated from in-ecliptic to over the Sun's poles
  - Ecliptic relative inclination changed from 2.3 to 85.1º
  - Perihelion distance raised from 1.0 to 1.4 AU
    - Ulysses was never closer to the Sun than on launch day!
- Jupiter closest approach
  - 8th February 1992 06:00:34 UTC
  - Jovicentric distance – 408,894 km (6.3 Rj)
- Data from fly-by improved knowledge of Jupiter's position

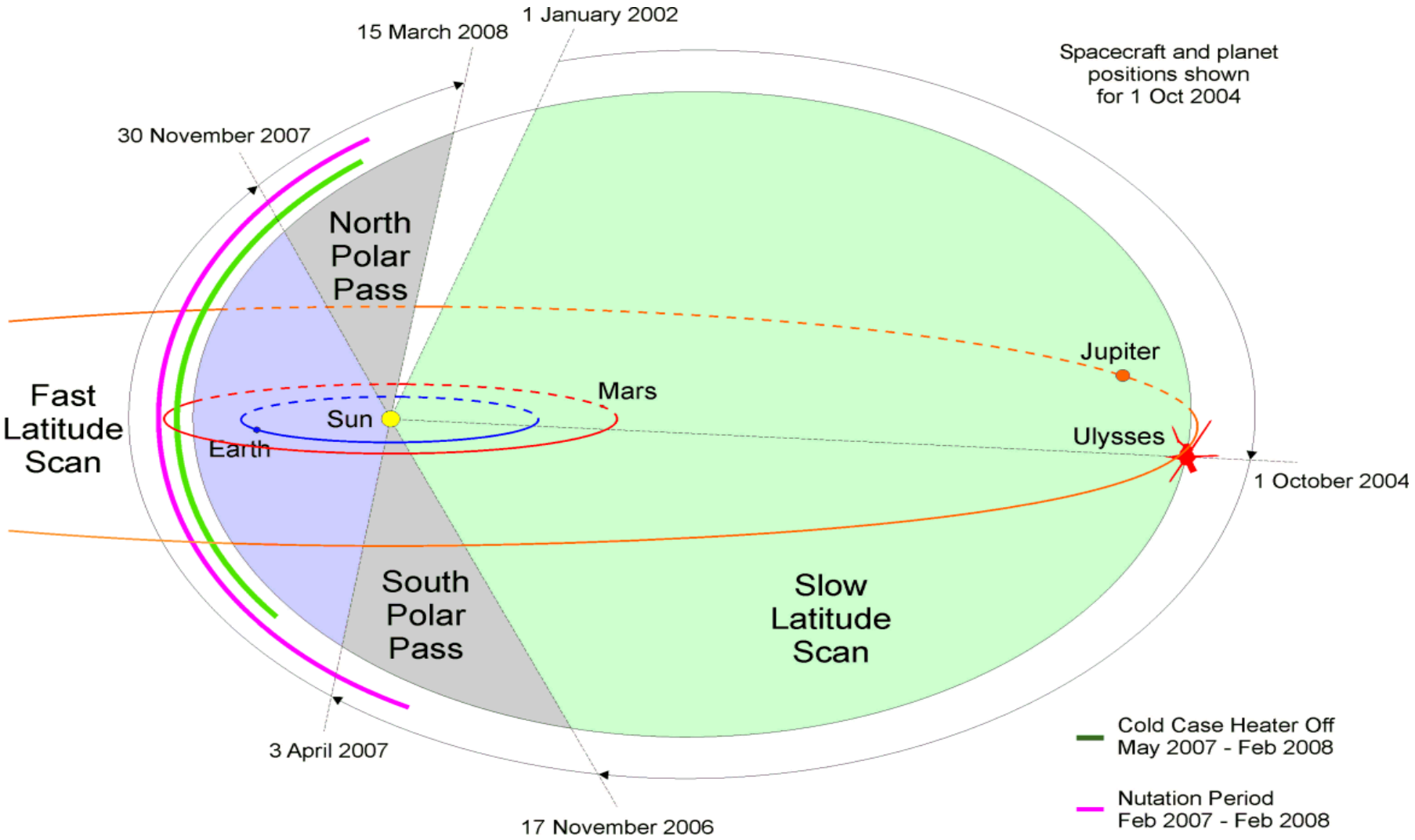
1st Solar Orbit



2nd Solar Orbit



3rd Solar Orbit



Orbit Characteristics 1

- Polar Heliocentric Orbit
  - From http://ssd.jpl.nasa.gov/?horizons
  - Earth Mean Equator 1950 reference frame (B1950, EME50)
  - Heliocentric data for 20-May-2007 00:00:00 UT
    - Semi-major axis: 508742655 km (3.39 AU)
    - Eccentricity: 0.590
    - Inclination: 100.333º
    - Argument of perihelion: 350.306º
    - Longitude of ascending node: 337.469º
    - True anomaly: 300.696º
    - Mean anomaly: 345.820º
    - Period: 2,292 days (6.275 years)
    - Perihelion radius: 208,387,806 km (1.389 AU)
    - Aphelion radius: 809,535,548 km (5.397 AU)
    - Heliocentric range: 254,683,277 km (1.698 AU)

Orbit Characteristics 2

- Distance to Earth (20-May-2007 00:00 UTC)
  - 284,948,700 km (1.905 AU)
  - one-way light time 15m50s
- Earth closest approach
  - 26th August 2007
  - approx 62,200 km (0.42 AU)
- Mars closest approach
  - 20th July 2007
  - approx 133,700 km (0.89 AU)

The Ulysses Mission – Over the Sun's Poles

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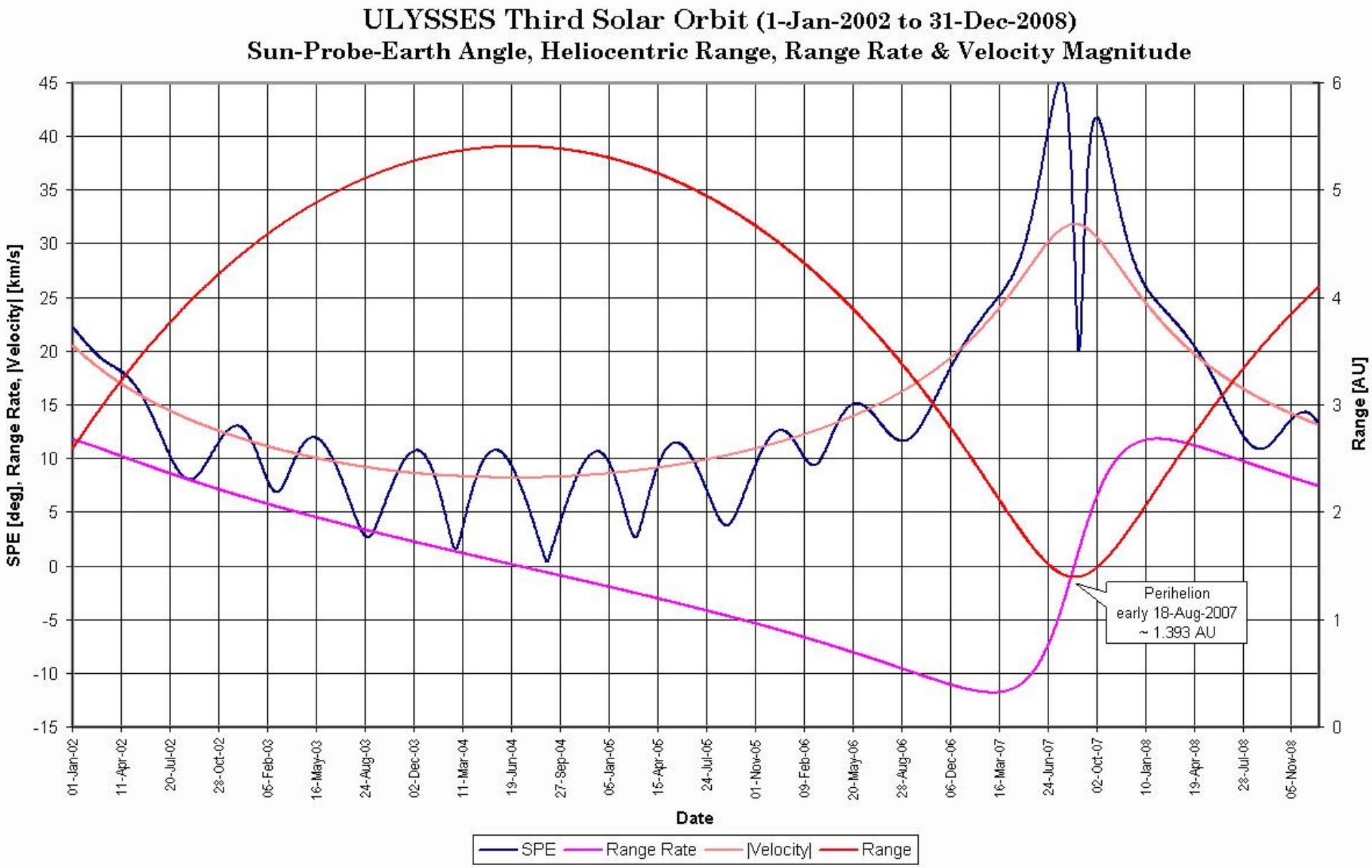
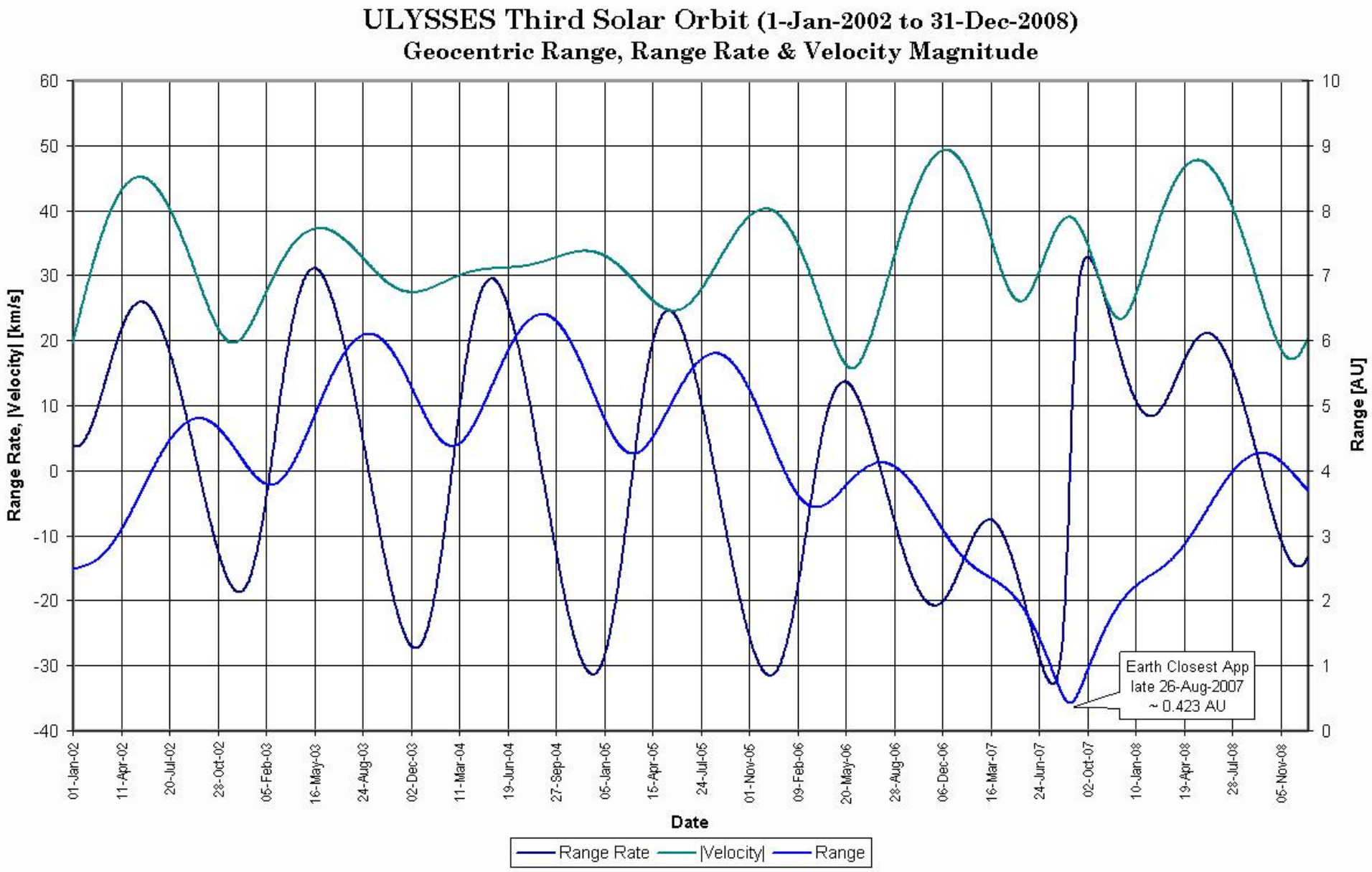



ULYSSES Third Solar Orbit (1-Jan-2002 to 31-Dec-2008)
Geocentric Range, Range Rate & Velocity Magnitude
Range Rate, |Velocity| [km/s]
Range [AU]
Date
Range Rate
|Velocity|
Range
Earth Closest App
late 26-Aug-2007
~ 0.423 AU

Ground Stations 1

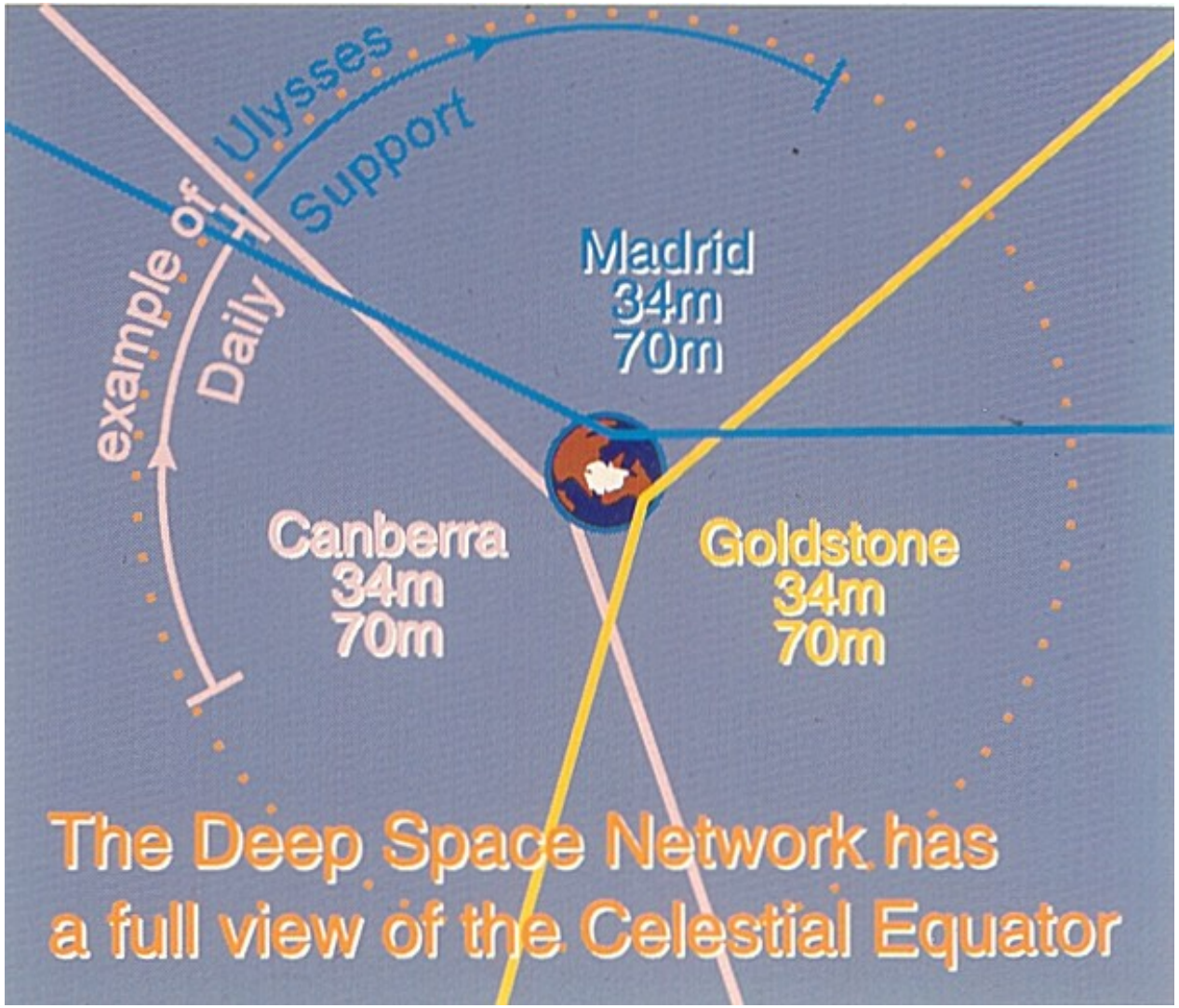
- NASA Deep Space Network for routine support (26m, 34m & 70m antennas)
  - Goldstone (near Barstow, CA), USA
  - Madrid, Spain
  - Canberra, Australia*
- Ground stations for non-routine support
  - ESA Kourou, French Guiana (15m)*
  - ESA New Norcia, Australia (35m)*
  - DLR (German space agency) Welheim, Germany (30m)
  - Univ of Chile, Santiago station (9m, uplink only)
  - Parkes, Australia (as seen in movie "*The Dish*") (64m)

* in use this weekend

Ground Stations 2

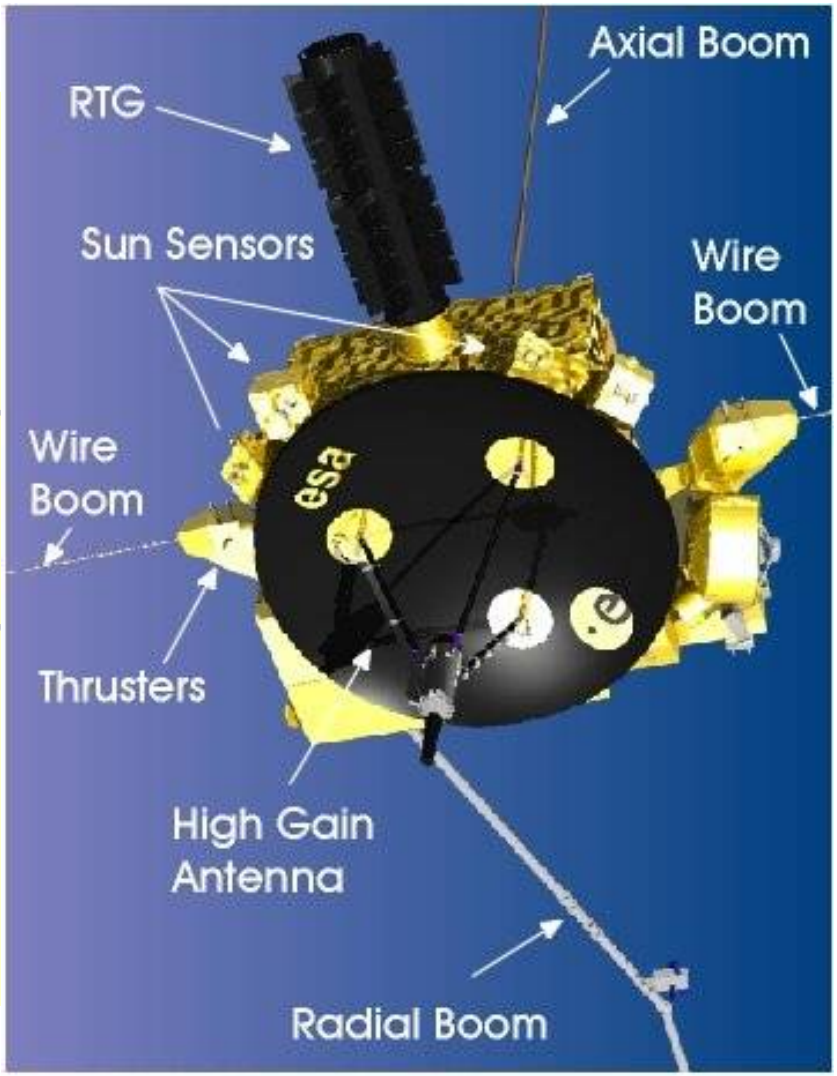
Goldstone 70m antenna – DSS14

Ground Stations 3

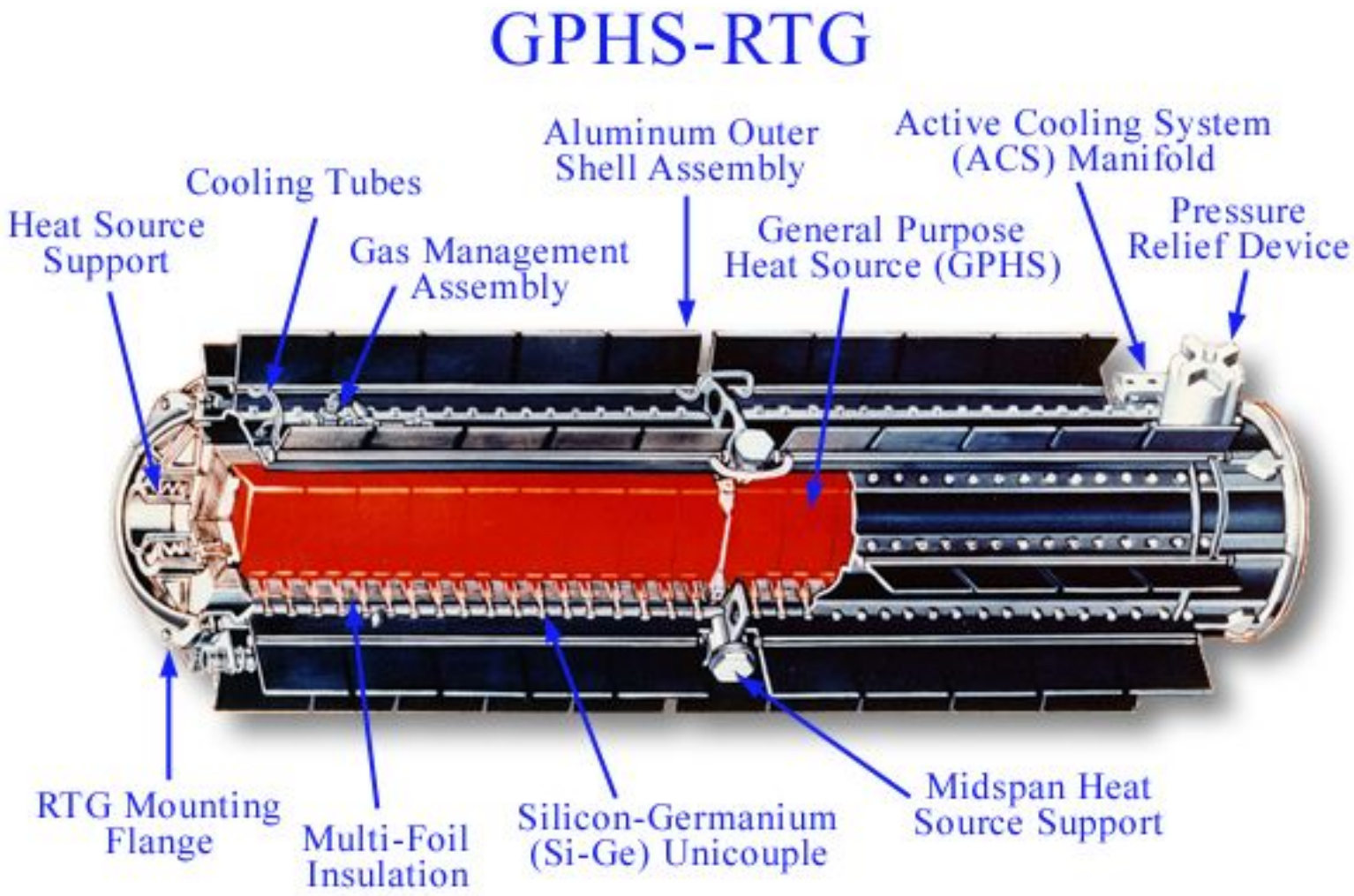


Spacecraft 1

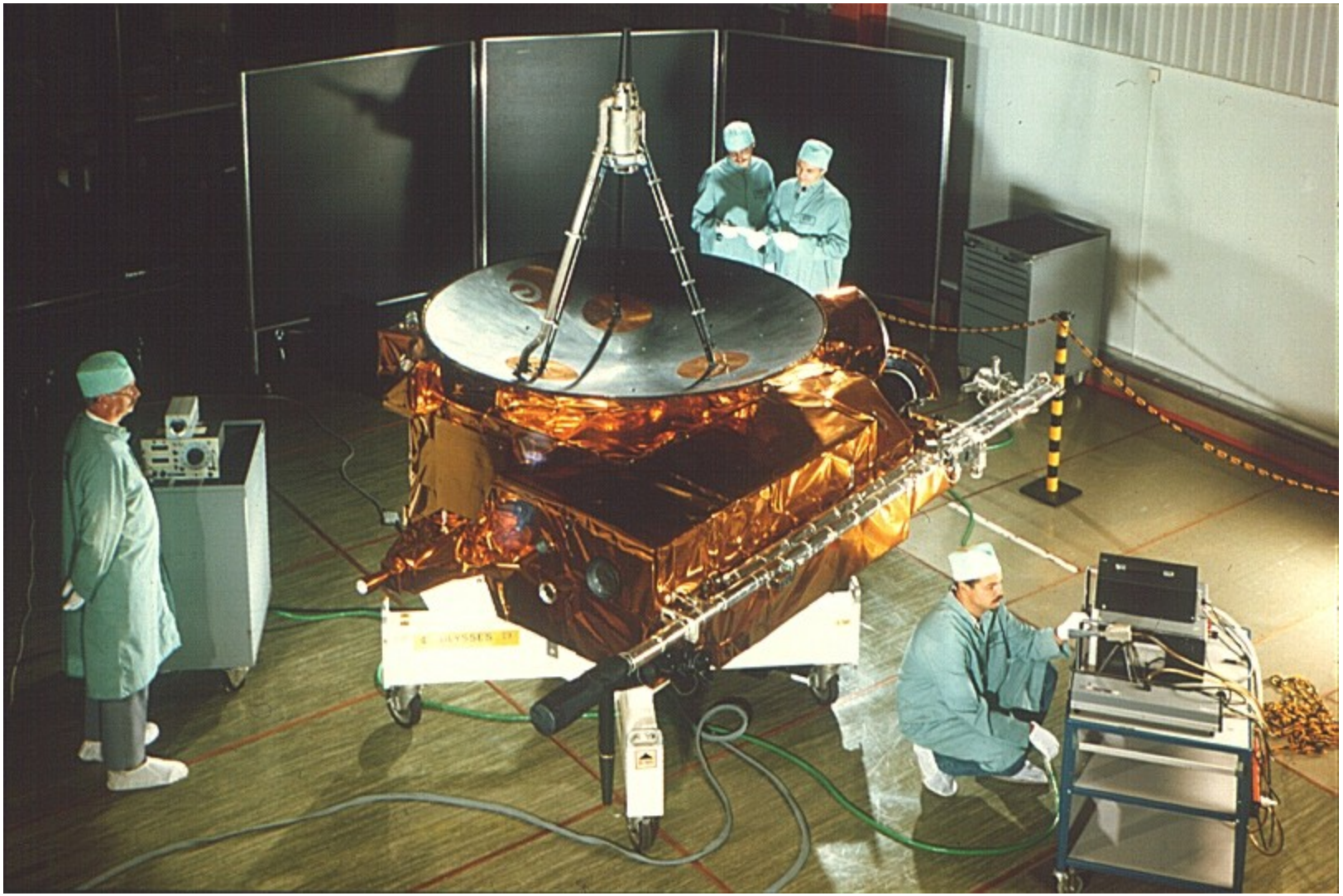
- Dimensions
  - Length 3.2 m (booms stowed)
  - Width 3.3 m
  - Height 2.1 m
- Mass
  - Total at launch 366.7 kg
  - Scientific payload 55.1 kg
  - Payload cover ejected 0.1 kg
  - Fuel (hydrazine N_2H_4) for attitude control
    - Beginning of mission 33.5 kg
    - May 2007 ~6.7 kg
- Power
  - Radioisotope Thermoelectric Generator (RTG)
    - Beginning of mission 283 W
    - May 2007 ~195 W



Spacecraft 2

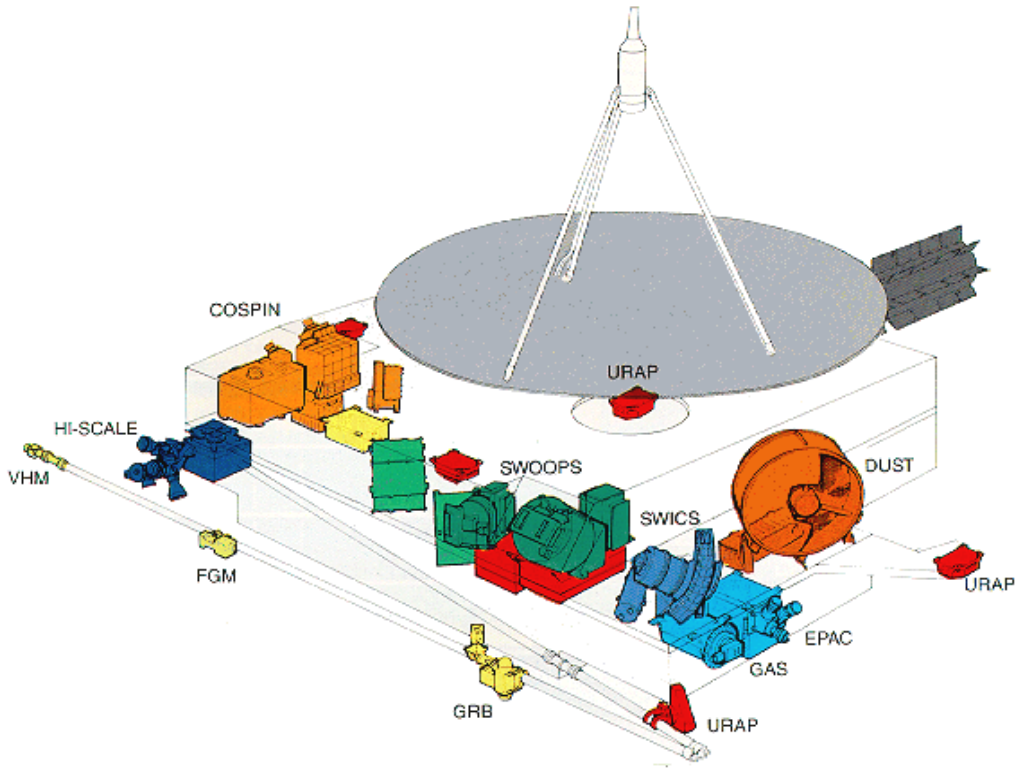


Spacecraft 3

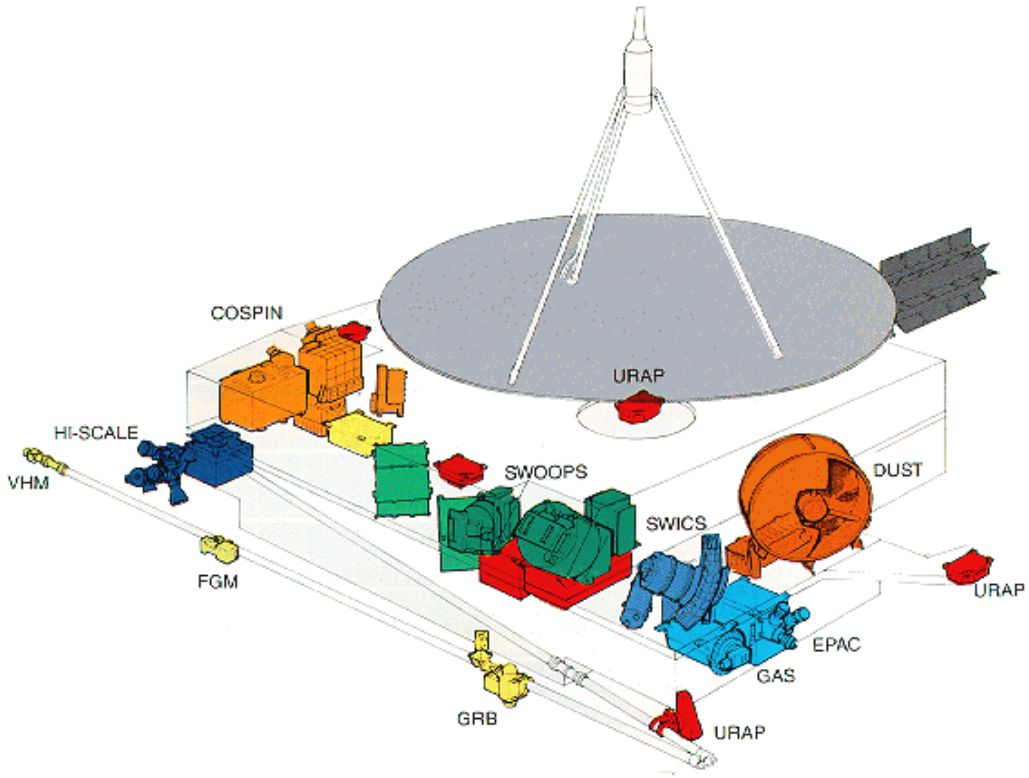


Science Payload 1

Acronym	Instrument
COSPIN	Cosmic rays and solar particles
DUST	Cosmic dust
EPAC/GAS	Energetic particles and interstellar neutral gas
GRB	Solar X-rays and cosmic gamma-ray bursts
HI-SCALE	Low-energy ions and electrons
SWICS	Solar wind ion composition
SWOOPS	Solar wind plasma
VHM/FGM	Magnetic field
URAP	Radio and plasma waves



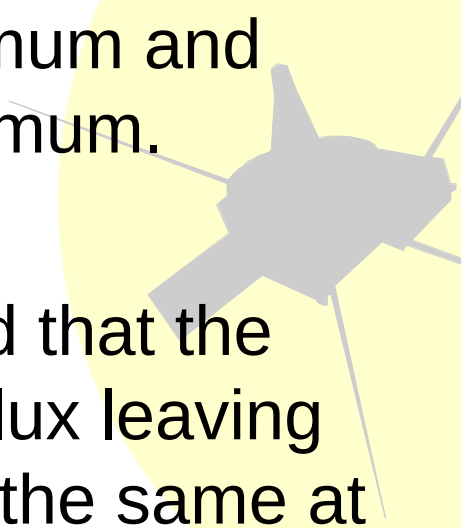
Science Payload 2



Acronym	Mass (kg)	Power (W)	Data Rate (bps)
COSPIN	14.8	14.8	160
DUST	3.8	2.2	8
EPAC/GAS	4.3	4.0	16
GRB	2.0	2.6	40
HI-SCALE	5.8	4.0	160
SWICS	5.5	4.0	88
SWOOPS	6.7	5.5	160
VHM/FGM	4.8	5.1	80
URAP	7.4	10.0	232
Total	***55.1***	***52.2***	***944***

Science - Major Achievements

- First detailed measurements of the solar wind from the Sun's polar regions at solar minimum and solar maximum.
- Discovered that the magnetic flux leaving the Sun is the same at all latitudes.
- Discovery of energetic particle "reservoirs" surrounding the Sun.
- Discovery of interstellar dust in the Solar System.
- First direct measurements of interstellar helium atoms in the solar system.



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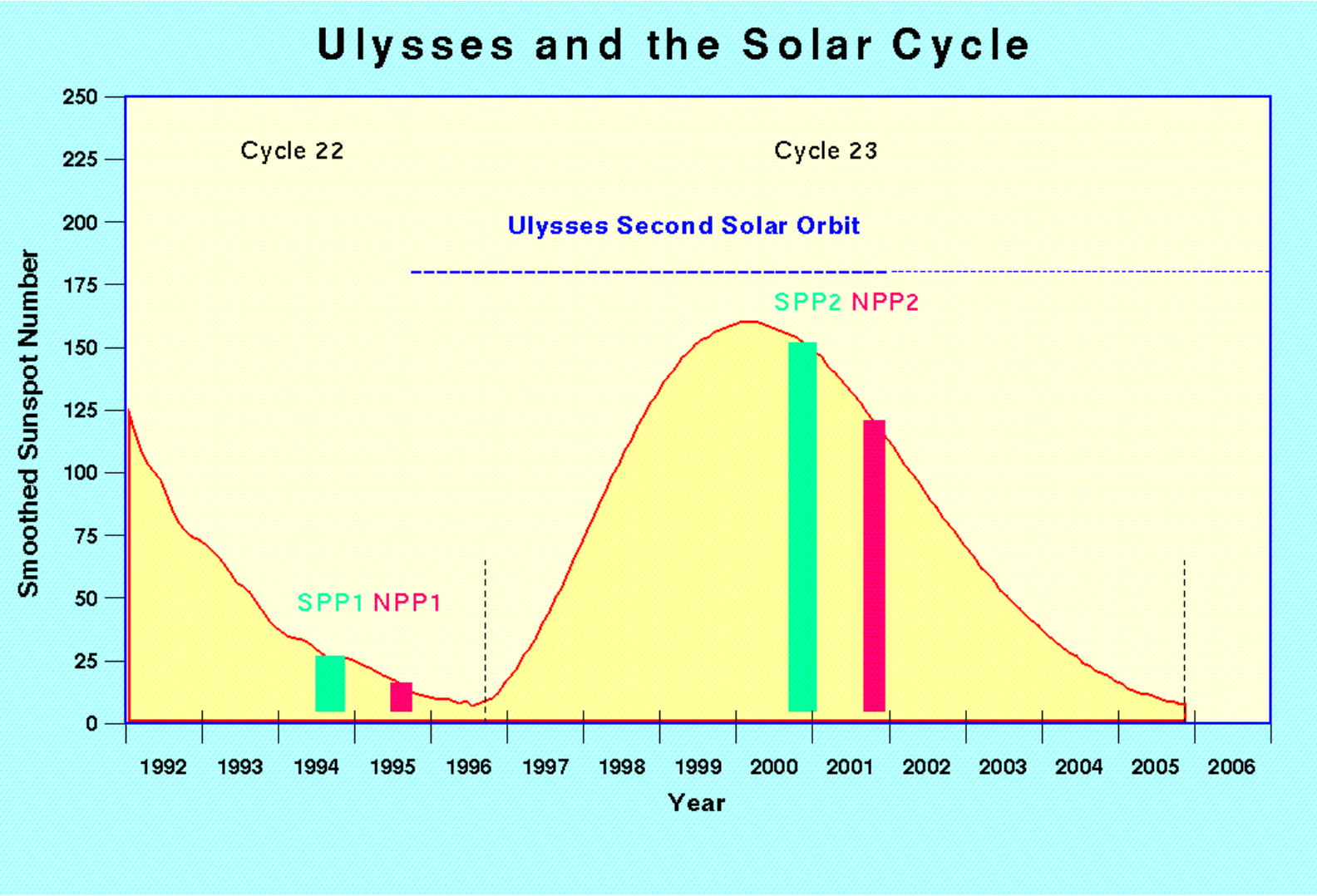
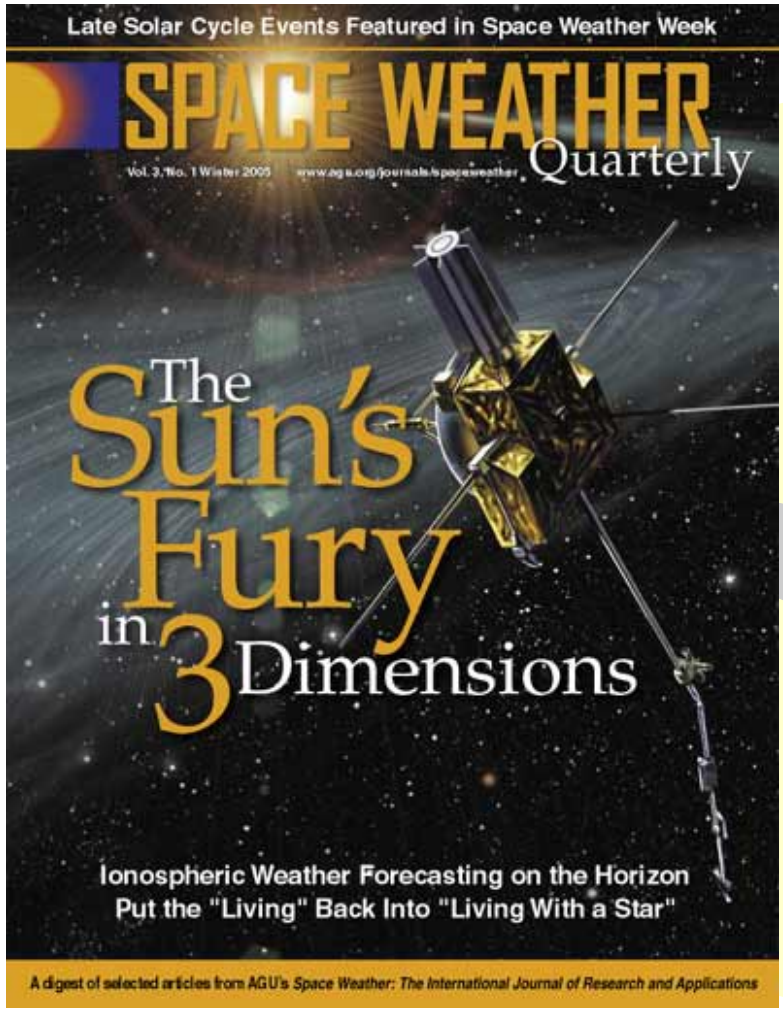
Science – Ulysses & the Solar Cycle



Science - Space Weather Data

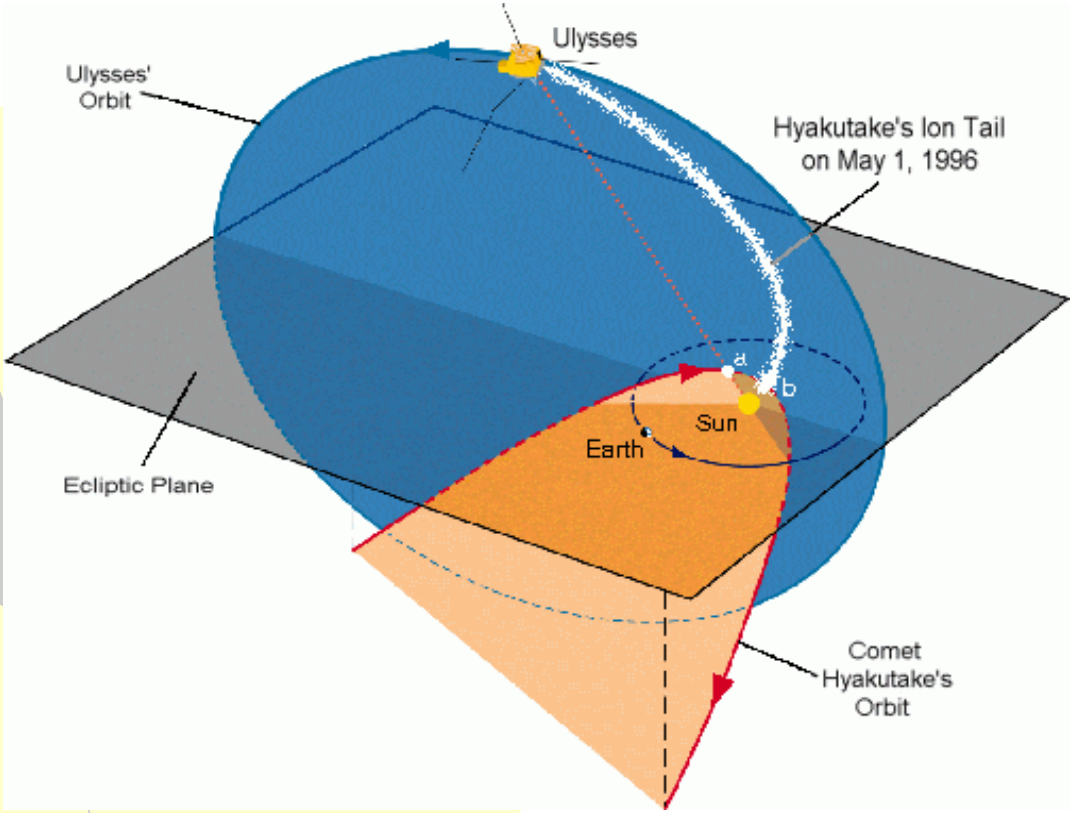


- 2D data insufficient for practical space weather forecasting models
  - SOHO (@L1 since Apr 1996)
  - ACE (@L1 since Dec 1997)
  - STEREO ("ahead" & "behind" Earth, since Apr 2006)
  - SDO (geosync, launch Apr 2008)
  - numerous Earth orbiters
- Ulysses adds 3D data coverage
  - solar-polar since Feb 1992
  - Sun range from 1.3 to 5.4 AU

http://www.agu.org/journals/sw/swa/free/newarticle/print.php?id=2005SW000195

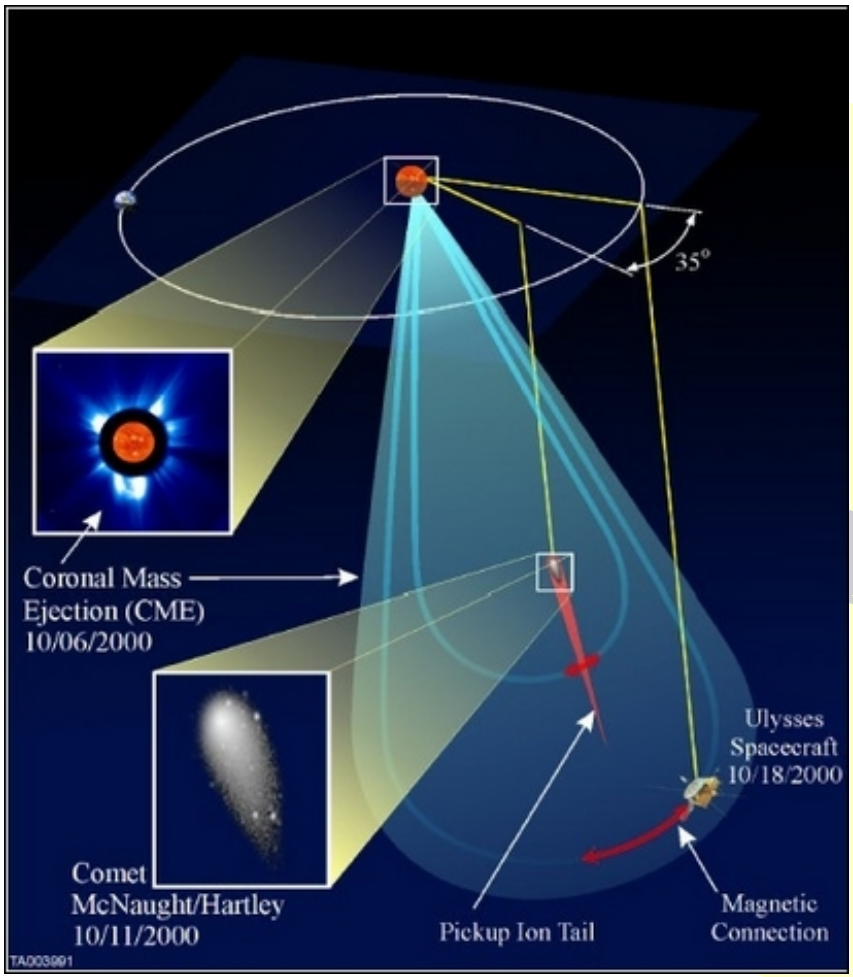
Science – Comet Tail Encounter

In 1998, three Ulysses science teams discovered evidence that Ulysses had passed through the tail of comet Hyakutake in 1996! Tail length calculated to be 3.8 AU - longest comet tail ever recorded.



http://www.sp.ph.ic.ac.uk/Ulysses/comet/

Science – Another Comet Tail!



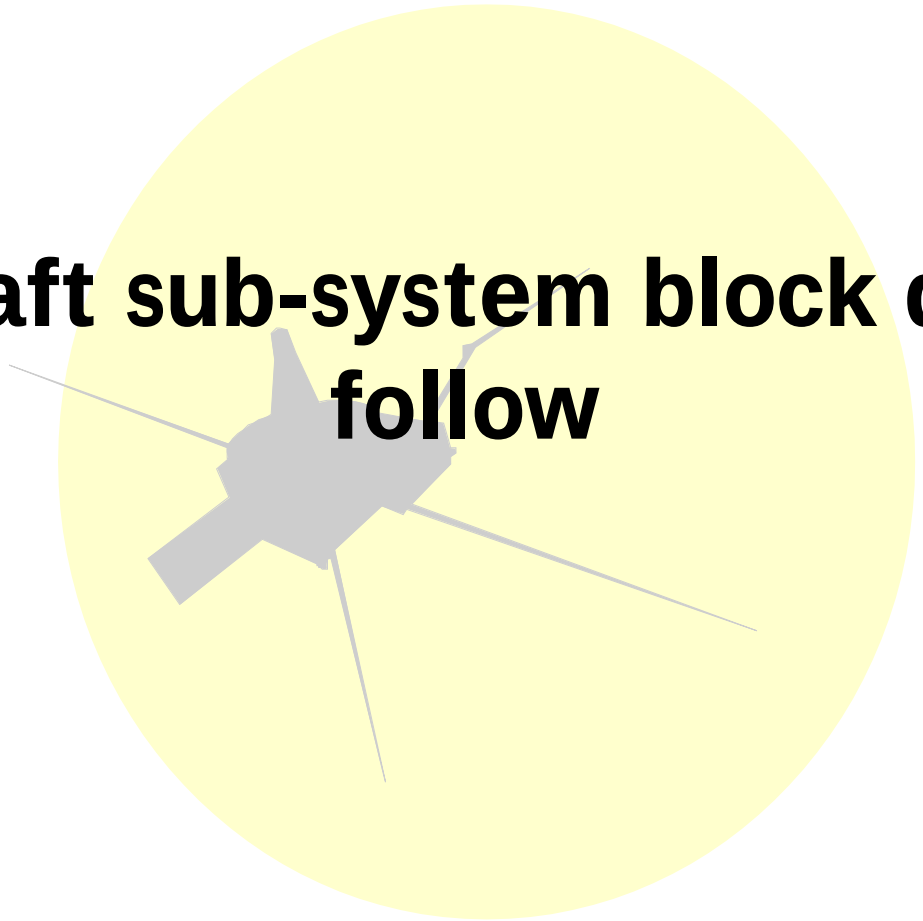
In Oct 2000, a Coronal Mass Ejection (CME) moving away from the Sun enveloped both the comet and the spacecraft, carrying the cometary material to Ulysses.

http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=34612

Ulysses Mission Web Sites

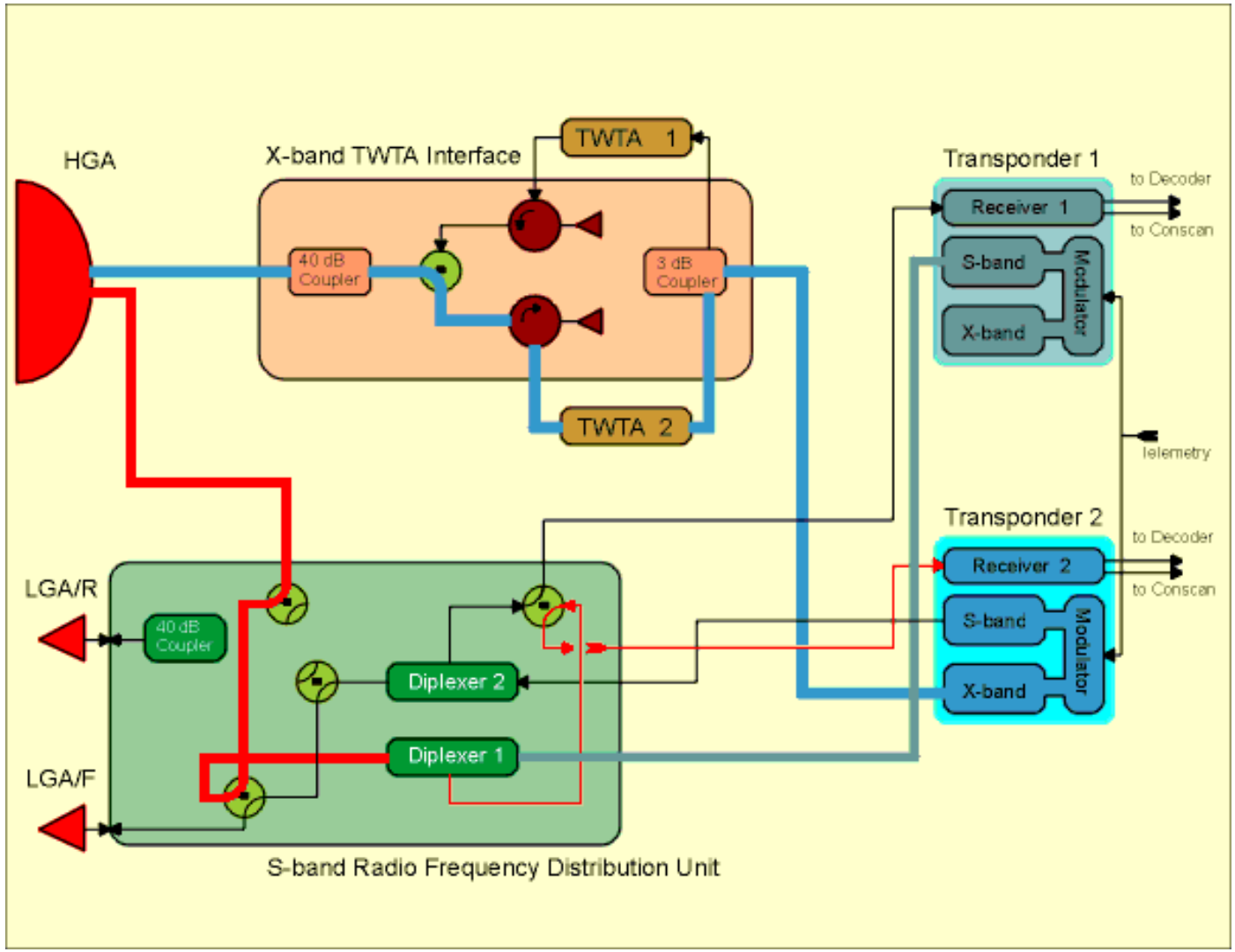
- Ulysses section of ESA Science:
  http://sci.esa.int/ulysses/
- ESA Ulysses science and data archive:
  http://helio.estec.esa.int/ulysses/
- JPL Ulysses science:
  http://ulysses.jpl.nasa.gov/
- Ulysses mission operations:
  http://ulysses-ops.jpl.esa.int/

This presentation is available at:
http://ulysses-ops.jpl.esa.int/presentations/

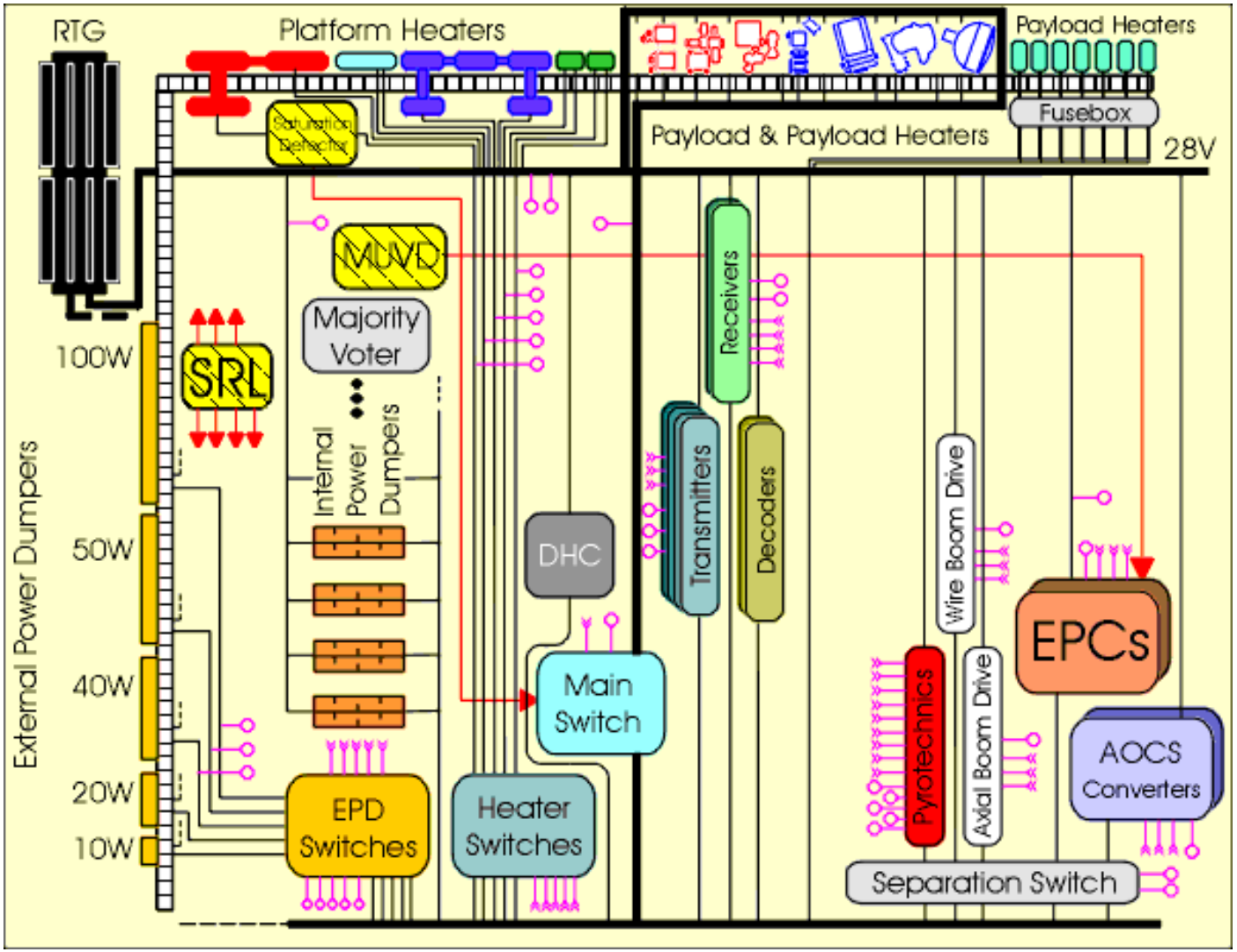


Spacecraft sub-system block diagrams follow

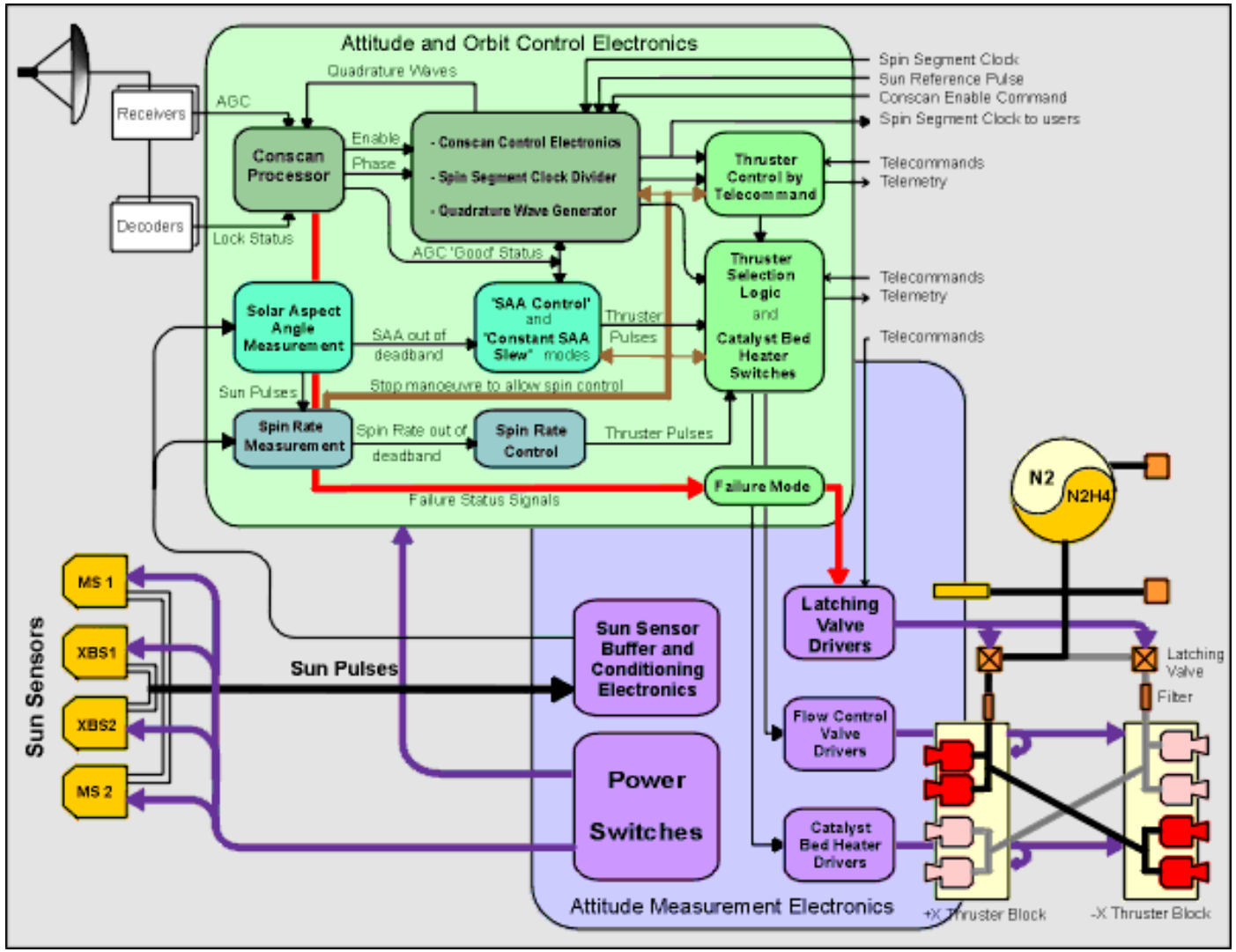
Spacecraft - Telecoms



Spacecraft - Power



Spacecraft - Attitude & Orbit Control



Spacecraft – Data Handling