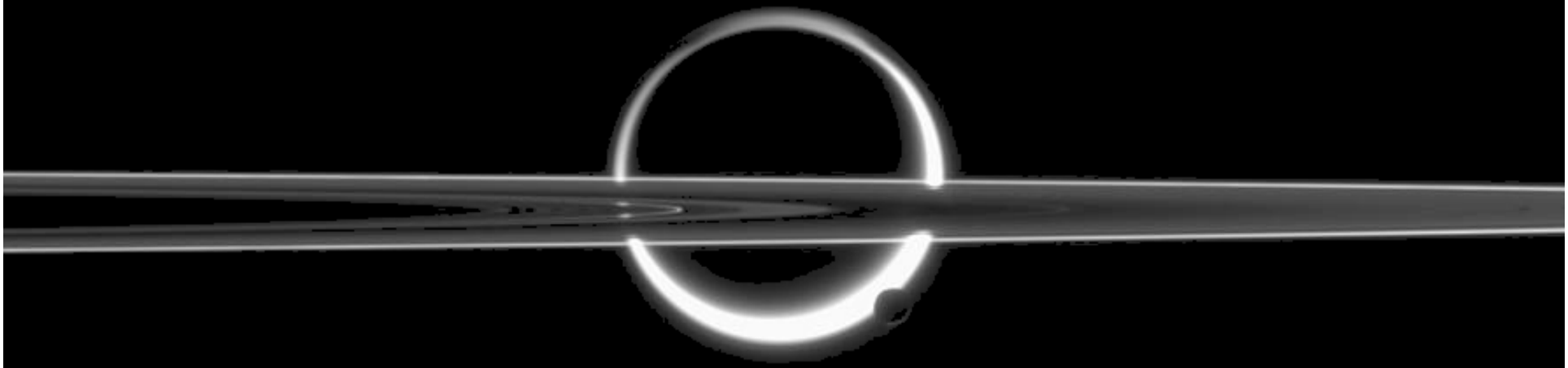
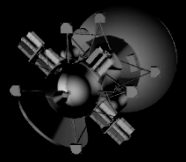
Titan Orbiter Instrument Overview





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Presentation at OPFM Instrument Workshop
3 June 2008
Jet Propulsion Laboratory,
California Institute of Technology Pasadena CA

Titan Orbiter Payload Topics

- Purpose of example payload
- Performance measurement requirements
- Example instruments
- Instrument locations and fields-of-view
- Preliminary resources for the payload
- Interface requirements
- Descriptions of example instruments

Purpose of Example Payload

- The example payload is designed to demonstrate that the mission is feasible
  - Measurement and science requirements are achievable
  - Resources are adequate
  - Risk is low
- The example instruments meet the resource constraints and the measurement requirements
- The AO will only specify the measurement requirements, not a particular instrument, design, or technology.

Preliminary Measurement Requirements (1)

- Near-IR imaging and spectroscopy
  - Global surface imaging to 50-m resolution with SNR ≥100; two bands (1.8 and 5.0 μm centers)
  - 0.9 – 5.8 μm spectral images with resolving power 1,000 with 200-m resolution and SNR ≥100
- Thermal IR spectroscopy
  - Atmospheric temperatures to 1 K via thermal radiance measurements
  - Composition, including isotopes, detectability down to 10^{-11}
  - 30 – 1500 wavenumbers (6 – 300 μm), spectral resolution of 0.1 to15 wavenumbers (scan time 1 to 120s), spatial resolution of <5 mrad IFOV
- Sub-millimeter atmospheric sounding
  - 400-480 GHz and 1080-1280 GHz with resolution 300 kHz
  - Measure atmospheric abundances of selected molecules to 0.01 ppb
  - Measure pressure to 10% with resolution less than the scale height
  - Measure wind velocities with vertical resolution of 10km and deep atmospheric temperatures to 0.1 K via radiance measurements of emission lines at high spectral resolution with an integration time of time ≤120s

Preliminary Measurement Requirements (2)

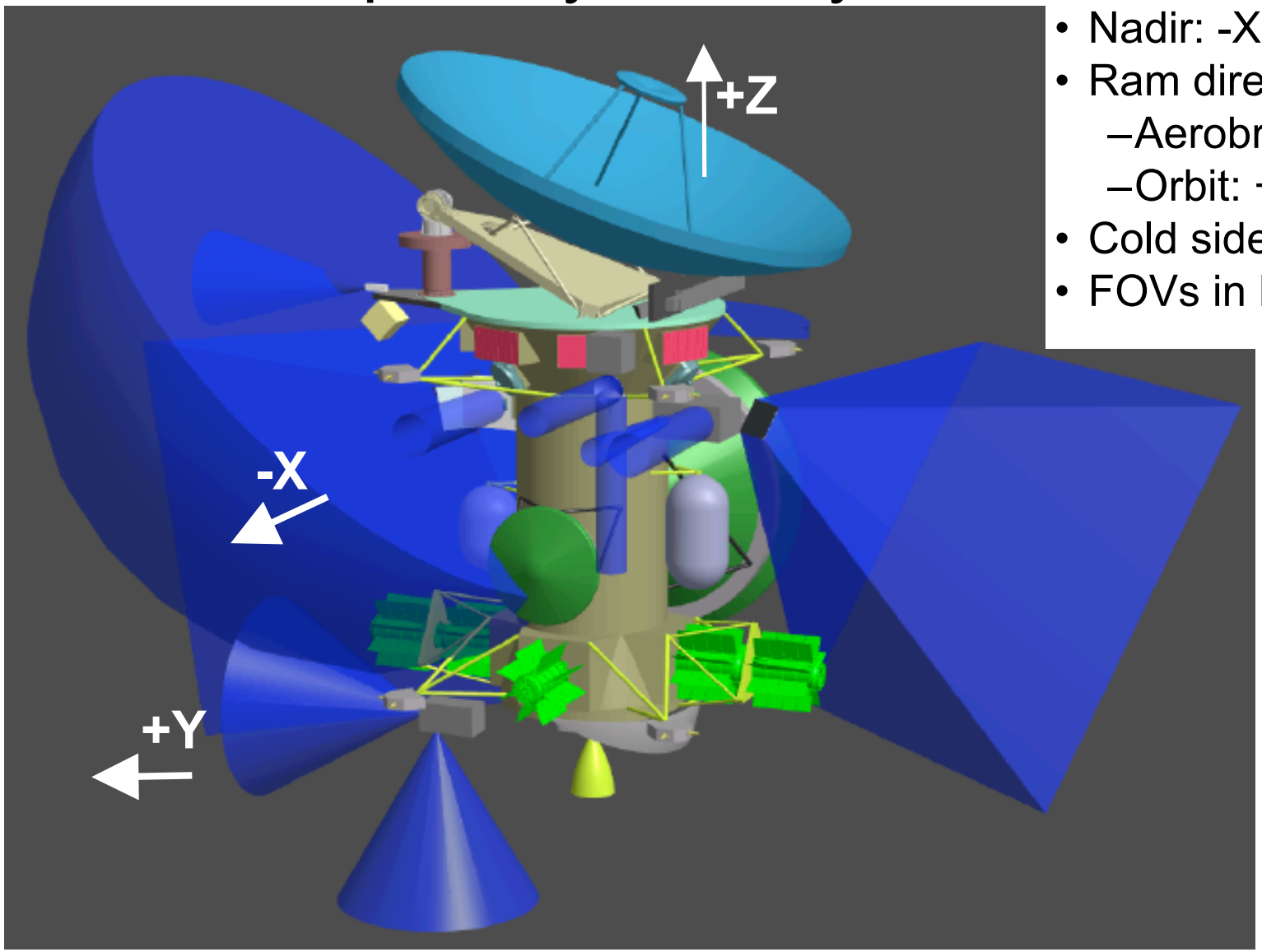
- Altimetry and sub-surface sounding
  - Altimeter: 10-m height accuracy with 1-km by 10-km surface footprint
  - Sounder: 100-m height accuracy to 1-km depth
- Ion and neutral mass spectroscopy
  - Identify and measure atmospheric species 1 AMU to 10,000 AMU with a resolving power of 10,000 at 1% of peak.
  - Dynamic range of 10^8
- Magnetics and plasma
  - Measure energy and distribution of electrons from 10eV to 2MeV; energy resolution of 10% and angle to 20 degrees
  - Measure plasma ion distribution function and composition over 2π sr; up to ~10 keV/charge
  - Measure distribution of energetic particles up to 5 MeV with energy resolution of 10 keV/nucleon
  - Measure magnetic field vector to 0.5 nano Tesla
- Gravity science
  - Obtain Doppler accurate to 50 microns/s with 60-s integration periods
  - Measure rotation parameters to 0.1 degree/year

Example Payload

Example names and acronyms are for the purpose of this study. (Also referred to as the “Planning Payload”)

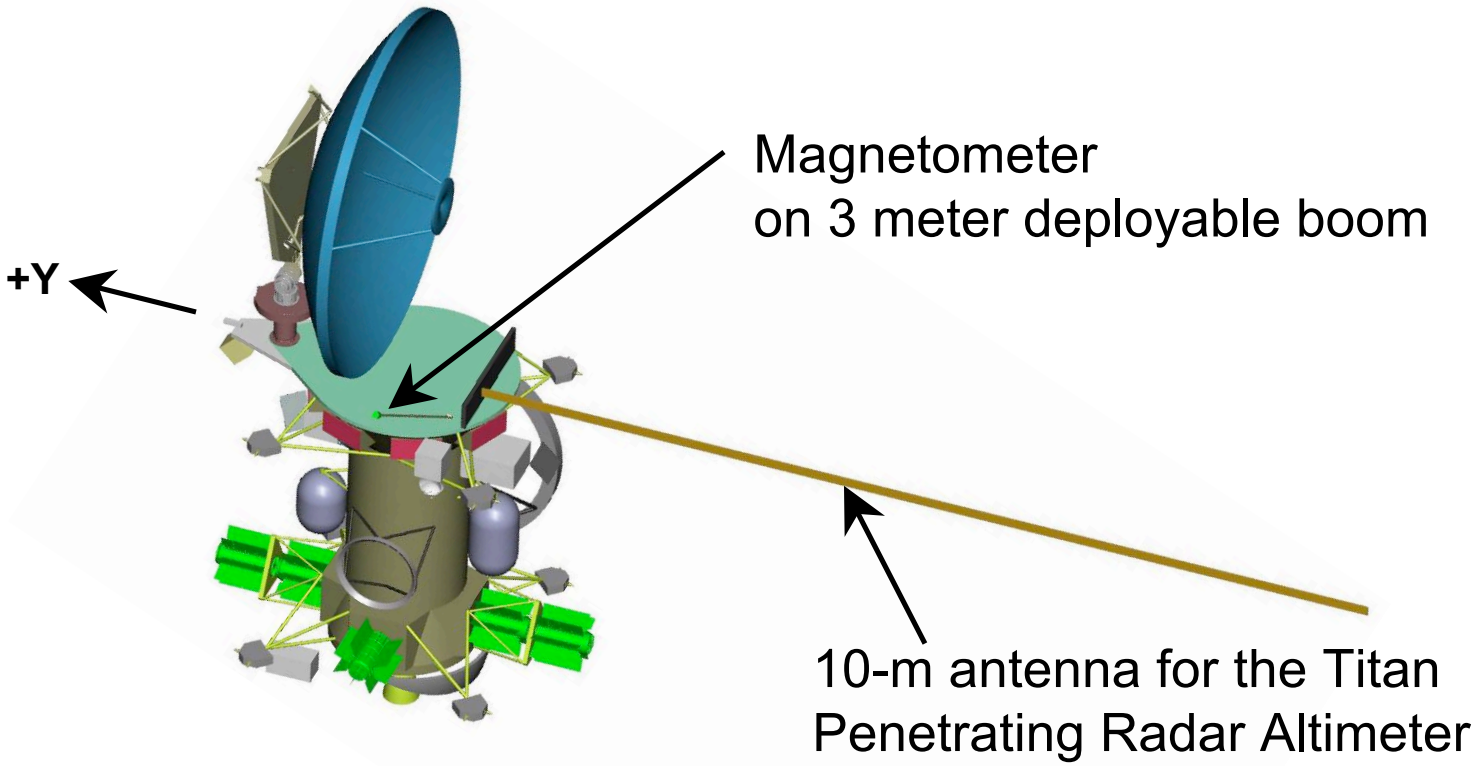
- HiRIS: High-Resolution Imager and Spectrometer (near IR)
- TIRS: Thermal IR Spectrometer
- SMS: Sub-Millimeter spectral Sounder
- TIPRA: Titan Penetrating Radar and Altimeter
- PMS: Polymer Mass Spectrometer
- MAPP: Magnetometer And Plasma Package
  - Magnetometer
  - Plasma sensor (<30 keV)
  - Energetic particle spectrometer (30 keV)
  - Langmuir probe
- RSA: Radio Science + Accelerometer

Example Payload Layout: Overview



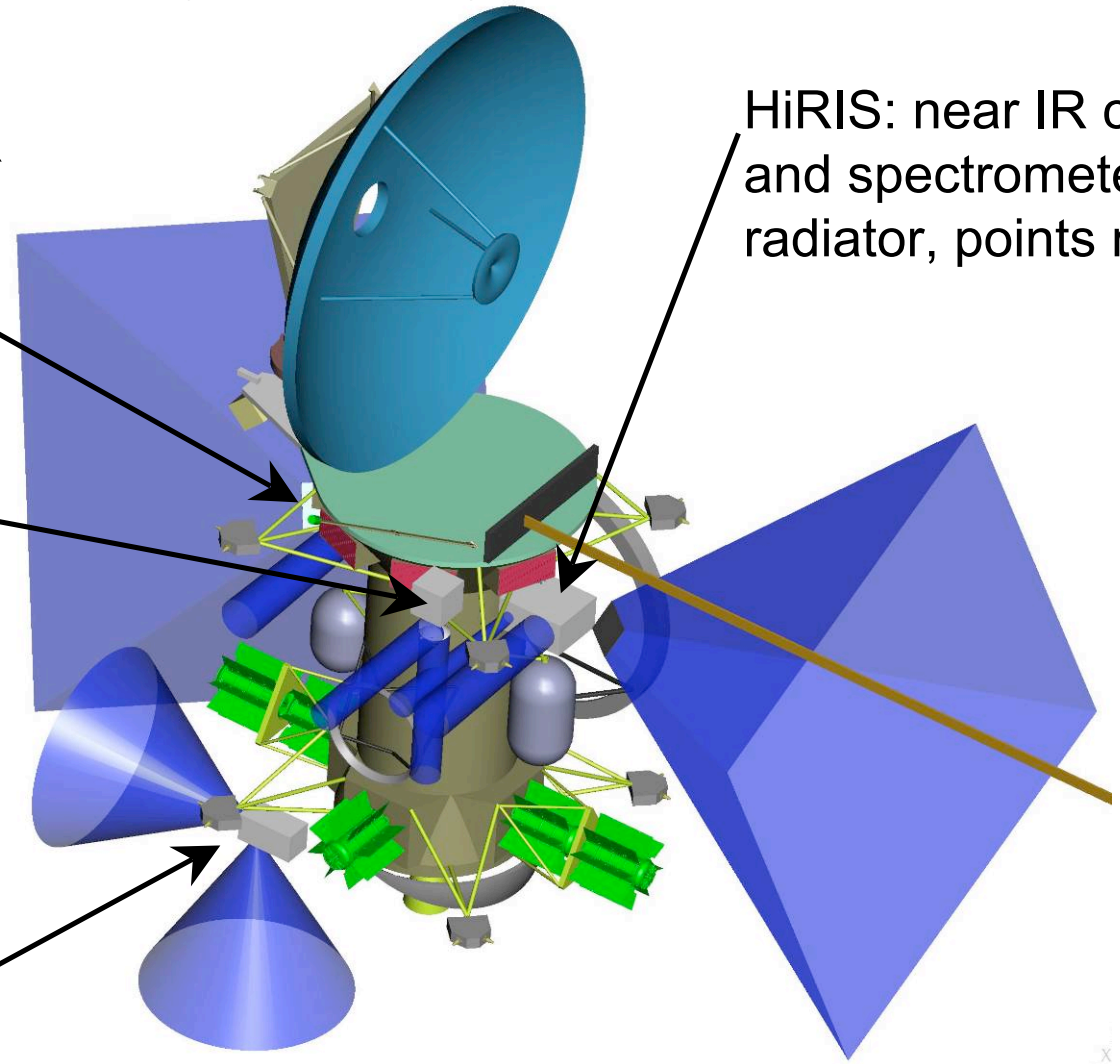
- Nadir: -X
- Ram direction
  - Aerobraking: -Z
  - Orbit: +Y
- Cold side: -Z
- FOVs in blue

Example Payload Layout: Deploy Items



Deployed with HGA rotated 180 deg

Example Payload Layout: Nadir View



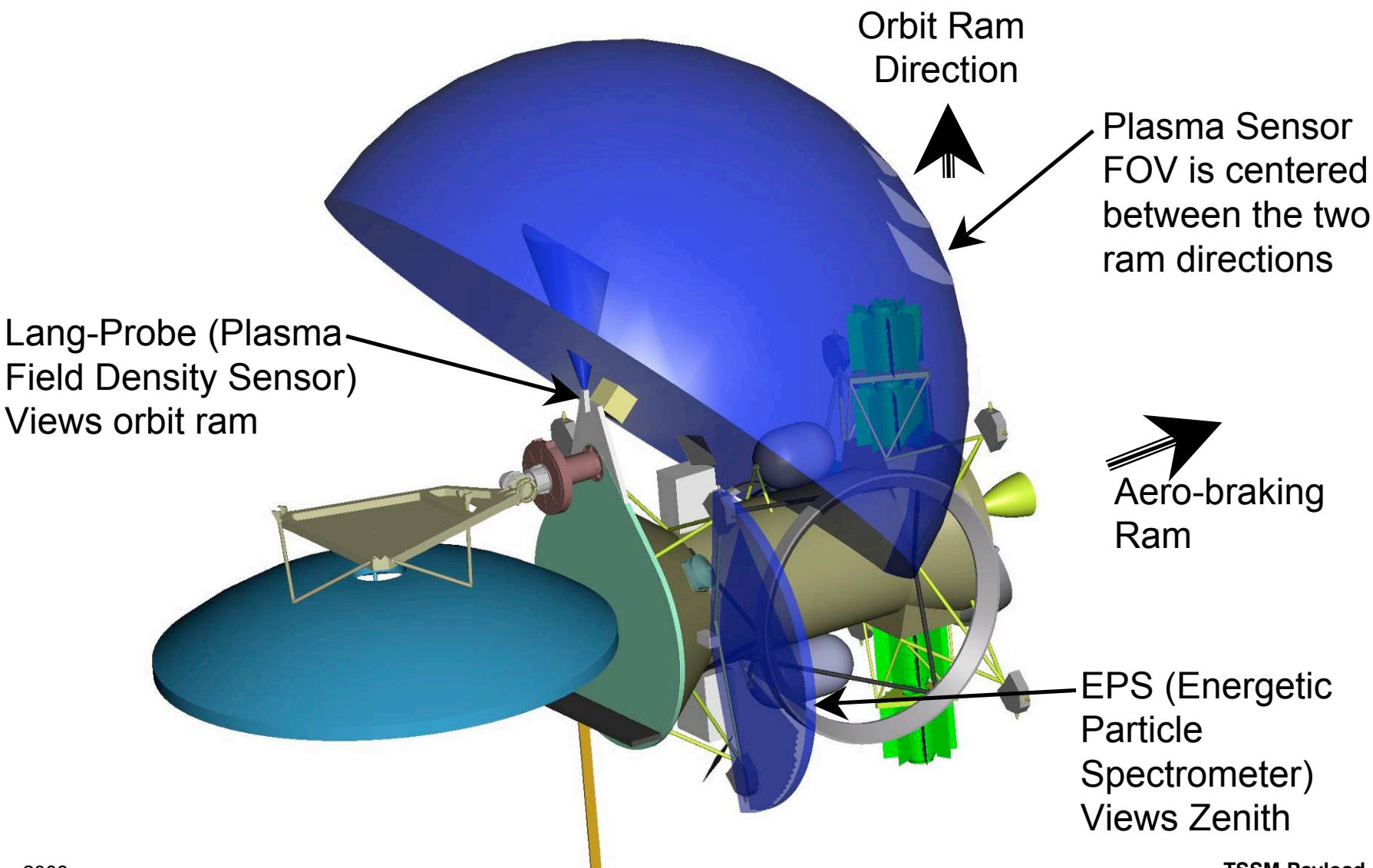
TIRS: Thermal IR Spectrometer

HiRIS: near IR camera and spectrometer, with radiator, points nadir

SMS: Submillimeter Spectral Sounder, views nadir and ram for aero-breaking

PMS (Polymer Mass Spectrometer) views Ram for Orbit and Aero-breaking

Example Payload Layout: Plasma



Resource Summary for the Example Payload

- Total mass is within the payload allocation of 100 kg
- For the study, 50% reserve is added to payload mass and power CBEs
- Data rates and power are used to build example observing scenarios for power and data management.

	Name	Mass (kg) CBE	Power (W) CBE	Downlink Data Rate kb/s
HiRIS	High-Resolution Imager and Spectrometer (near IR)	28.4	28	75
TIPRA	Titan Penetrating Radar and Altimeter	9.0	25	15
PMS	Polymer Mass Spectrometer	23.0	47	5
SMS	Sub-Millimeter spectral Sounder	10.0	40	7
TIRS	Thermal IR Spectrometer	15.0	15	5
MAPP	Magnetometer	2.0	2.5	4
	Energetic particle spectrometer	1.5	2.5	5
	Langmuir probe	1.5	1	0.1
	Plasma	5.0	9	0.1
RSA	Radio Science + Accelerometer	0.0	0	
Total		95.4		

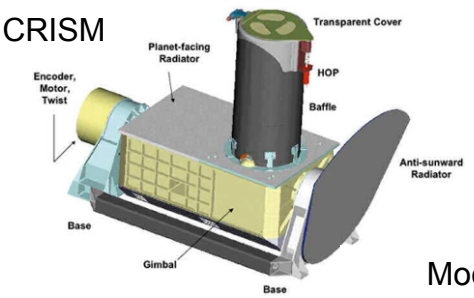
Preliminary Guidelines for Instrument Interfaces

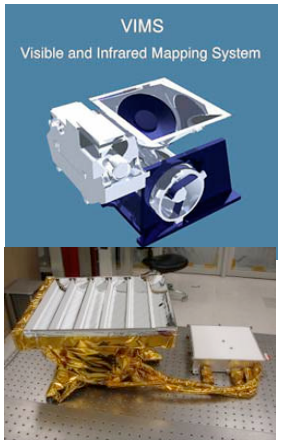
- Power: 28V DC +/-7V
- Data: 1553, RS-422, or LVDS
- Data compression, command handling, and packaging performed by instrument
- Instrument data stored by spacecraft until downlink
- Contamination and instrument protection under evaluation for ring crossing and aero-braking.
- Mechanical mounting surface provided
- Electronics boxes are thermally coupled to spacecraft bus

Example Instrument Descriptions

Example: Hi-res Imager / Spectrometer (HiRIS)

MRO CRISM

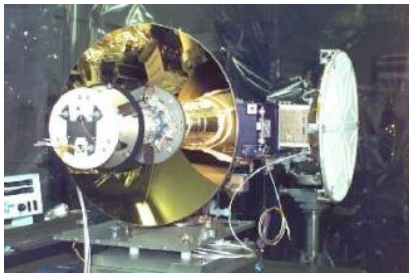




Moon Mineralogy Mapper

- Science goals
  - Determine contents of lakes
  - Characterize volcanism and tectonics
  - Identify and map surface organics
  - Characterize clouds possibly associated with rain
  - Determine abundances of atmospheric constituents
- Mounting: boresights nadir facing with 20° clear FOV; radiator facing +Z direction with ≥60° clear FOV
- Example operating plan
  - On alternating Titan days observe in one wavelength with 40% duty cycle; produces 25% surface coverage each Titan day and full coverage in one color in 4-5 months
  - On selected orbits, observe the atmosphere along with TIRS and SMS
- Heritage examples: CRISM, ARTEMIS, TBair, COMPASSair, VIMS

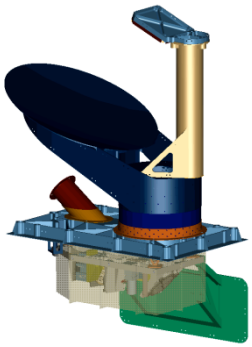
Example: Thermal-IR Spectrometer (TIRS)



Cassini CIRS

- Science goals
  - Determine atmospheric composition (gas, aerosols, condensates) and thermal structure in troposphere and middle atmosphere (30-550 km) over time
  - Detect new atmospheric species (define degree of chemical complexity)
    - Derive thermal winds from temperature maps
    - Surface temperatures, possibly some composition
- Example operating plan
  - Operate w/ 100% duty cycle during 16-day campaigns in circular orbit
  - Limb observations during aero-sampling, also during circular orbit (see Annex 1)
  - Can trade spectral and spatial resolution, default design is no pointable mirror in front of the telescope -- however, we are considering it in our design trade-offs.
- Mounting: boresight limb facing with 20° clear FOV in direction parallel to orbit, aligned with SMS in limb mode; do this for most of the low orbits; occasionally have a 16-day segment with the s/c altitude altered to look at nadir; radiator facing +Z direction with ≥60° clear FOV.
- Heritage example: CIRS

Example: Sub-mm Sounder (SMS)

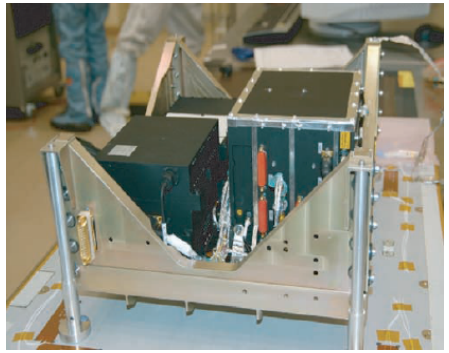


Rosetta MIRO

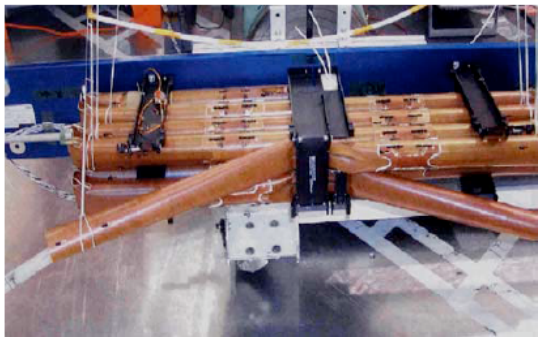
- Science goals
  - Determine atmospheric composition, temperature, and dynamics at 100 – 1200 km altitude
  - Determine quantities of minor atmospheric species
- Example operating plan
  - SMS to be boresighted with MIRaS and HiRIS
  - On alternating Titan days observe with 25% duty cycle; usually using limb view with slow scan (amplitude of scan TBD) but occasionally (~10% of SMS observing time) with nadir view
  - On selected orbits, observe the atmosphere along with HiRIS and MIRaS
  - Observe blank sky and distant Saturn system targets on occasion for calibration
- Mounting: boresight facing limb in direction perpendicular to the orbit plane and away from the Sun with 20° clear FOV
- Heritage examples: MIRO, ODIN, SWAS and MLS

Example: Titan Penetrating Radar Altimeter (TIPRA)

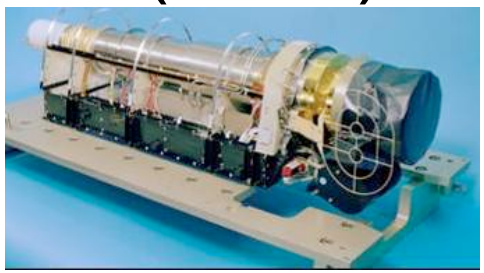
- Science goals
  - Map global topography
  - Subsurface geological probing to determine depths of lakes, ices, dunes.
- Example operating plan
  - On alternating Titan days, map 40% of the track each orbit.
  - Altimeter and sounder modes allocated to capture best sub-surface features and to manage data rate
- Data
  - Telemetry rate: 300 kb/s sounder mode, 30 kb/s altimeter only. Raw data rate is up to 30 Mb/s and is processed within the instrument to the telemetry rate.
  - Interface: RS-422/1553
  - Volume: up to 2 Gb/day
- Mounting
  - 10-m dipole antenna deployed at end of aero-braking phase of the mission
- Heritage examples: SHARAD, MARSIS



SHARAD Electronics and Deploying antenna (JGR-Planets, Phillips 2007)



Example: Polymer Mass Spectrometer (PMS)



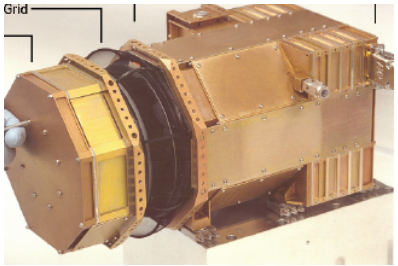
Rosetta ROSINA

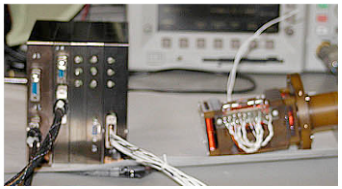
- Science goals
  - How are the polymers made in the atmosphere? What's the energy source?
  - Determine the interaction of Titan's upper atmosphere with Saturn's magnetosphere and the evolution of Titan's atmosphere, loss of materials, source of free energy and heat
  - Determine the chemical pathways of tholin formation
  - Determine exchange of energy and escape of major volatile species, including H2, methane and N2, by comprehensive longitudinal sampling
  - Perform a global survey of the species in the upper atmosphere at multiple solar-beta angles
- Example operating plan
  - During aero-braking/aero-sampling phase, collect data at altitudes from 600 km to 2,500 with full range of masses and full mass-resolution
  - During orbit phase, collect high-resolution data for masses less than 500 AMU for 16 days every 6 months.
- Mounting
  - Boresight is faces ram for both aero-braking and orbit phases
    - Can articulate the instrument for the two ram directions or have two orthogonal input sources
  - 10-degree field of view
- Heritage examples: ROSINI, Cassini INMS

Example: Magnetometer and Plasma Package (MAPP)

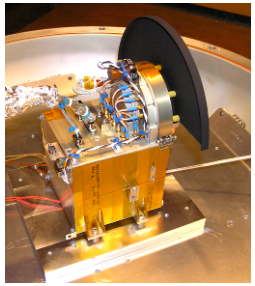
- Science goals
  - Is ammonia present and what is the loss rate of the major gases? Does Titan have an internal magnetic field?
  - Determine source of energy input to Titan's atmosphere from magnetosphere and solar wind.
  - Need more
- Performance/measurement requirement
  - Detection of energetic particles from solar wind and magnetosphere
  - Measure magnetospheric electrons
  - Measure ion velocity distribution in the ionosphere
  - Measure escape flux of superthermal neutrals
  - Determine energetic particles over range xx-xx keV
- Example operating plan
  - All plasma instruments on for 16 consecutive days every 6 months
  - Most plasma instruments on for much of the rest of the science phases.
- Mounting
  - Plasma sensor: 2π FOV; orient to cover both ram directions
  - Langmuir probe: clear FOV in ram direction
  - Energetic particle spectrometer: FOV is 10deg x 150 deg, toward zenith
  - Magnetometer: one sensor at end of 3-m boon, the other a mid boom.
- Heritage examples: PEPE, Cassini, MESSENGER, JEDI, PEPSSI

Deep Space 1 PEPE





MESSENGER MAG



New Horizons Energetic Particles

Example: Radio Science with Accelerometer (RSA)

- Science goals
  - Determine if Titan has a metal core
  - Determine Titan's gravity field, and its time-variation, to degree and order 6
  - Measure the pressure and temperature of the upper atmosphere
- USO, accelerometers (part of IMU), and Ka/Ka transponder are components of the spacecraft bus
- Example operating plan
  - Doppler data acquired during every telemetry contact
  - Capture atmospheric occultation data every orbit for 16 days (10 occultations per day, 5 ingress and 5 egress) every 2 months

Summary

- The example payload demonstrates that the science measurements can be accomplished within the mission constraints.

- The instrument Announcement of Opportunity will ask for proposals based on the measurement requirements, not based on the example instrument designs or technologies.