

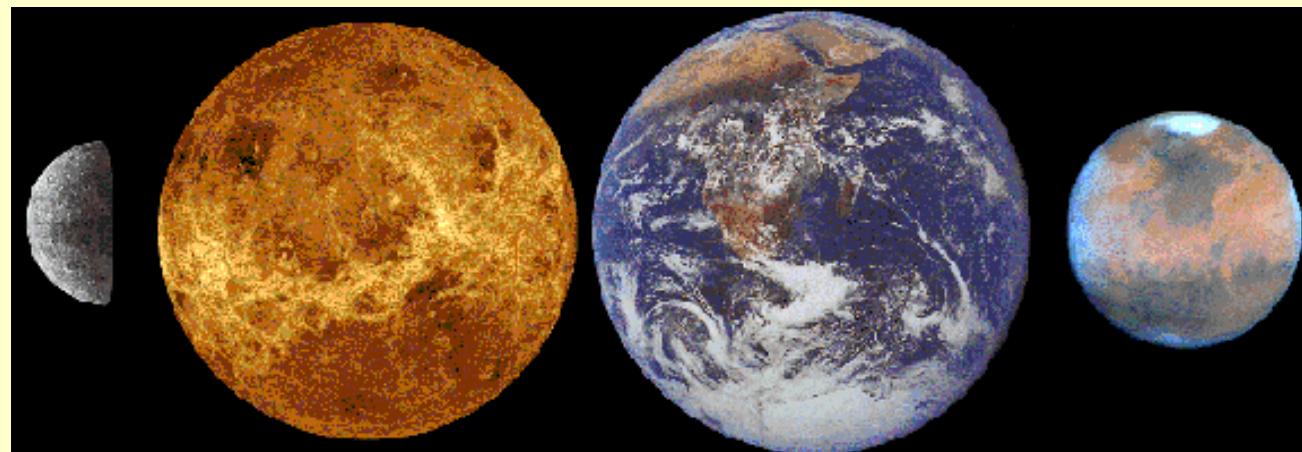
Highly Integrated Payload Suites and Related Data Link Requirements

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Planetary Exploration Studies



Overview

1. Background

- **Technology Reference Missions (TRM's)**

Motivation

Missions (TRM's)

- **BepiColombo and Solar Orbiter**

Payload Suites

2. Application

- **Highly Integrated Payload Suites**

=> Requirements for Data/Command Links

3. Conclusion

Technology Reference Missions (TRM)

- Strategic focus on critical technology developments for potential future science missions
- Study technologically demanding, science driven missions that are not part of the science program
- Identifying **critical technologies** to enable future missions
- Establishing a **roadmap** for technology developments
- Enable **low resource** exploration missions
- Enable new “**low-cost**” science missions at increased frequency

Technology Reference Missions



Current TRMs:

- Solar Polar Orbiter
- *Deimos Sample Return*
- *Venus Entry Probe*
- *Jovian Explorer*
- *Interstellar Heliopause Probe*
- Atomic Interferometer
- X-ray Interferometer
- Gamma Ray Imager



International SpaceWire Seminar 2003
ESTEC, 4-5. November, P. Falkner, SCI-A

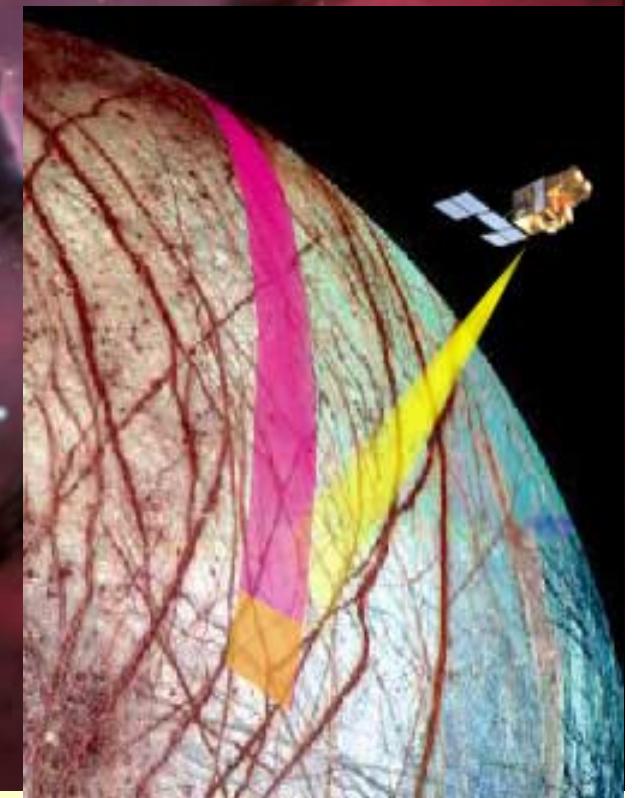


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Technology Reference Missions

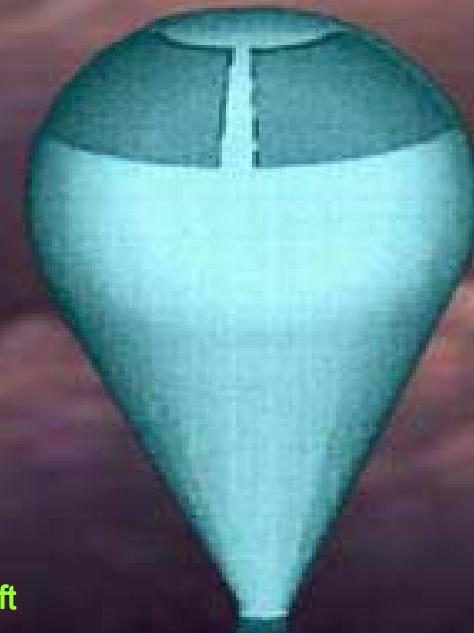
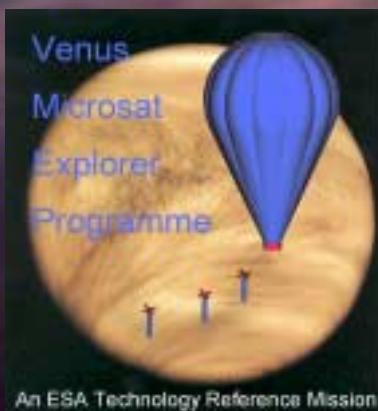
- ***Use of MicroSats (200 kg class)***
- ***Smaller launcher, lower cost - typical Soyuz-Fregat class***
- ***More frequent (phased approaches)***
- ***Based on Highly Integrated Payload Suites***
- ***Use of Centralised Processing and Power Supply Systems***
- ***Require resource reduction (Payload and S/C-subsystems)***



Venus Entry Probe - TRM

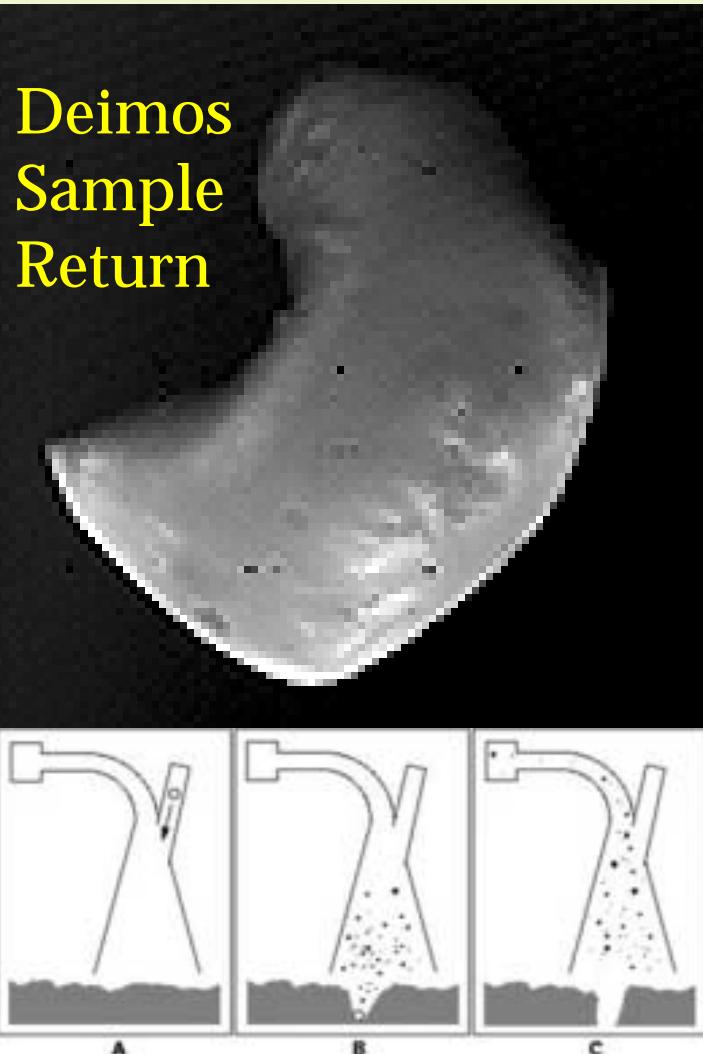
Detailed study of Venus lower atmosphere (physics, chemistry and exobiology)

- Origin and evolution of Venus atmosphere
→ Comparative planetology
- Composition of lower atmosphere
→ Atmospheric chemistry
→ Greenhouse effect
→ Tracking active volcanism
- Atmospheric dynamics
→ Super-rotation
→ Hadley cell circulation?
- Aerosol analysis/Exobiology
→ Analysis of large cloud particles



- Low resource spacecraft
- Highly integrated remote sensing payloads
- Atmospheric entry of a micro-aerobot
- Micro-aerobot suitable for Venus atmosphere
- Miniaturized payload for in-situ atmospheric measurements
- Atmospheric micropores

Deimos Sample Return - TRM



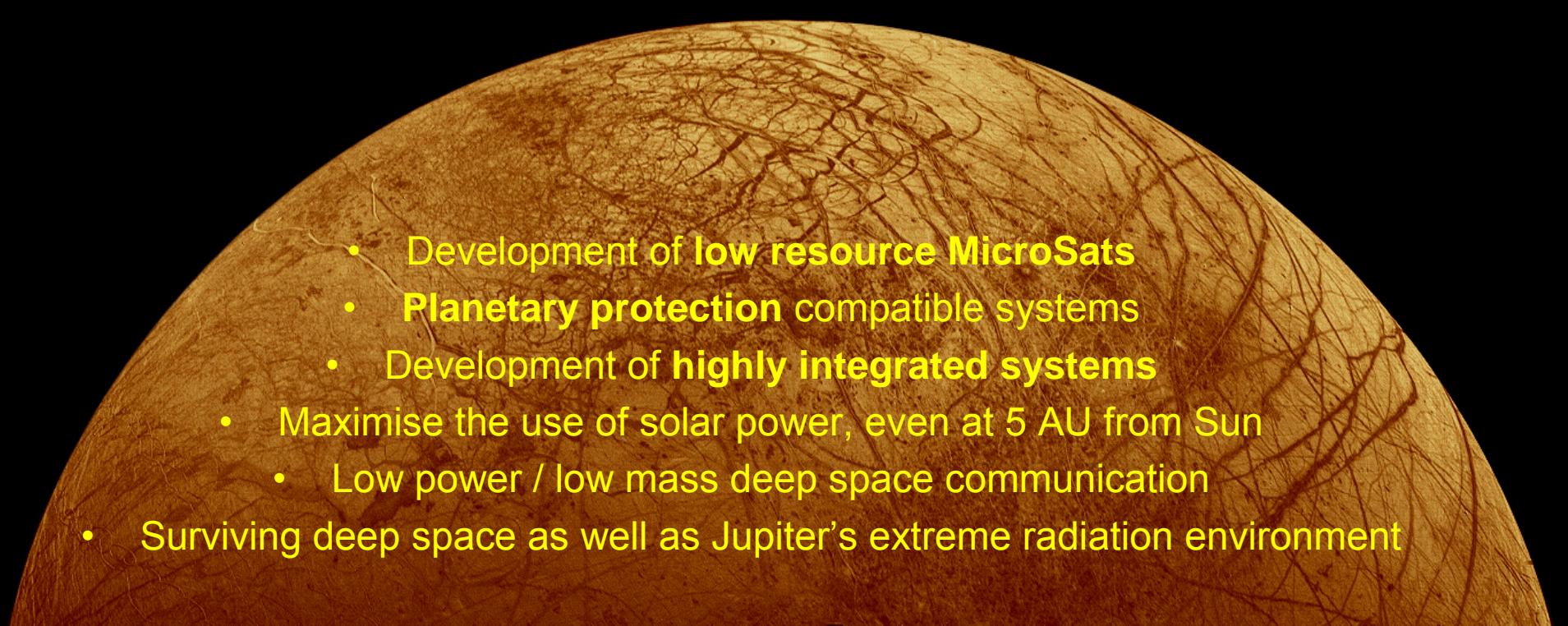
**Projectile Impact coupled with Cone Shaped Collector
(as designed for MUSES-C)**

- Obtain material from a D-class asteroid
- Sample will contain 10% of Mars material
- Mission Heritage can be used for future Small Body Sample Return Missions
- Direct Earth Re-Entry
- Main P/L:
Sampling Device & Supporting Instruments
(cameras, imaging spectrometer, lidar, laser altimeter)
- Sample Mechanism, Rendezvous Technology, re-entry

The Jupiter Microsat Explorer - TRM

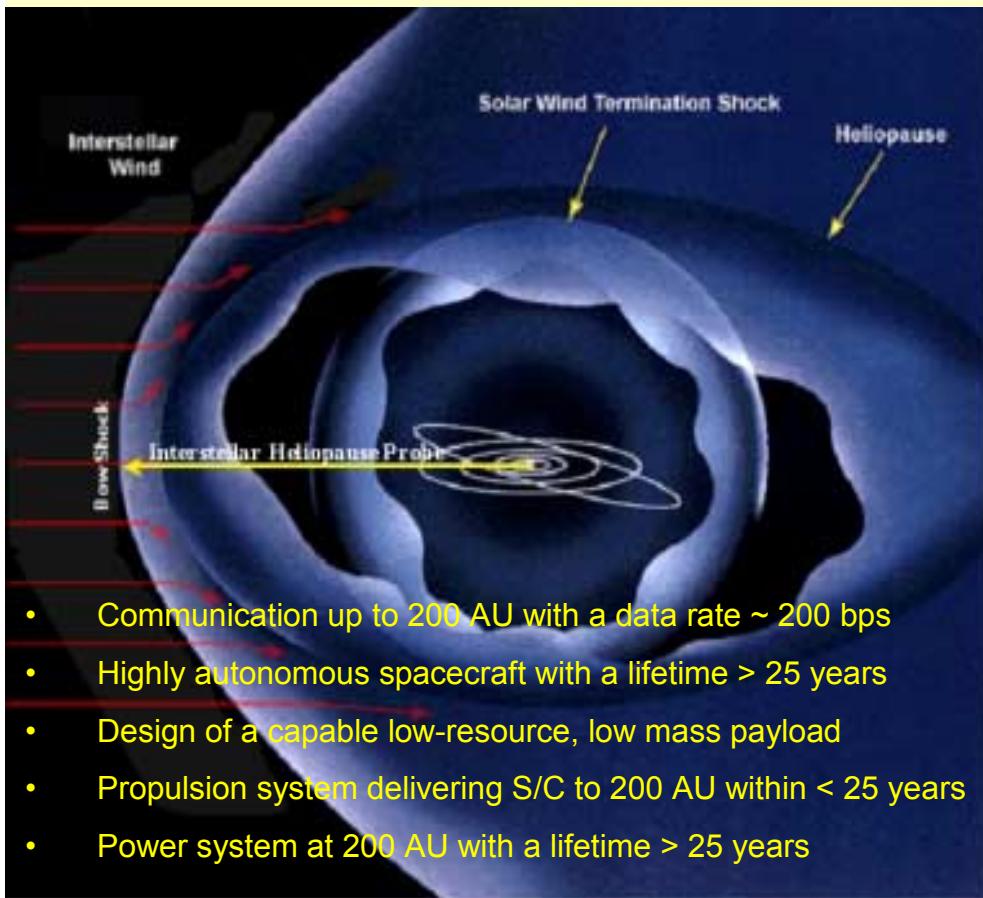
Study the Jovian environment (e.g. radiation, magnetic field)
& Investigate Jovian Moons, especially Europa:

- study the **global topography**
- study the **composition of the (sub)surface**
- mapping of the **ice thickness**
- is a **subsurface ocean** present ?

- 
- Development of **low resource MicroSats**
 - **Planetary protection** compatible systems
 - Development of **highly integrated systems**
 - Maximise the use of solar power, even at 5 AU from Sun
 - Low power / low mass deep space communication
 - Surviving deep space as well as Jupiter's extreme radiation environment

Interstellar Heliopause Probe - TRM

Explore and Investigate the Interface between the Local Interstellar Medium and the Heliosphere



Scientific questions to be answered:

- What is the nature of the interstellar medium?
- How does the interstellar medium affect the solar system?
- How does the solar system impact the interstellar medium?
- What are the clues to the solar system origin in the outer solar system?

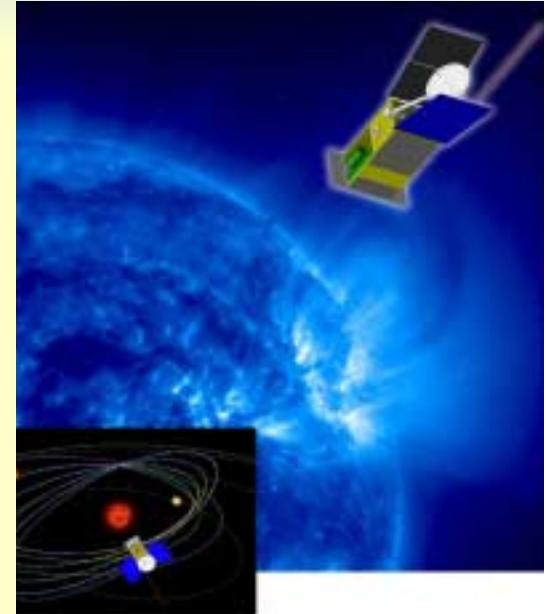
Requirements:

- Reach 200 AU in 25 years in direction of Heliopause nose
- Soyuz-Fregat SF-2B launch vehicle
- enabling Technologies for outer Planets (Saturn, Uranus, Neptune, Pluto)

Solar Orbiter (SOLO)

Solar Orbiter will, *for the first time*:

- Explore the uncharted innermost regions of our solar system
- Study the Sun from close-up (45 solar radii)
- Fly by the Sun tuned to its rotation and examine the solar surface and the space above from a co-rotating vantage point
- Provide images of the Sun's polar regions from heliographic latitudes in excess of 30°



Solar Orbiter Challenges:

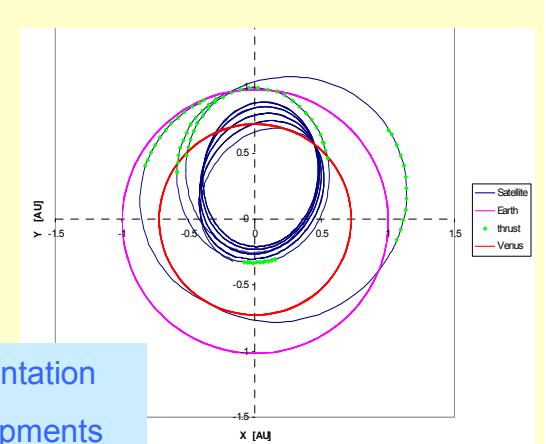
Heat load: up to 34 kW m^{-2} (**25 solar constants**), variable

Radiation environment affects:

- Detectors
- Electronics
- Optical coatings and filters

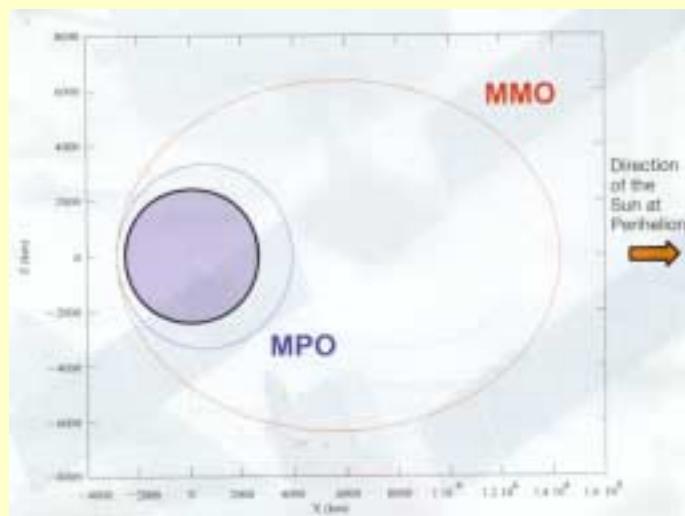
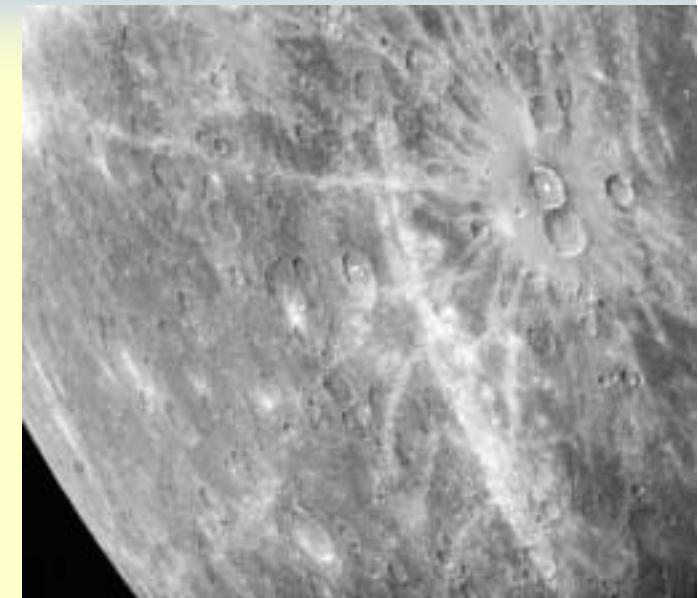
Limited spacecraft resources: mass, power, telemetry

- ⇒ Develop smart and low-resource instrumentation
- ⇒ Target and initiate new technology developments
- ⇒ Study critical payload and spacecraft issues



BepiColombo

1. Origin and evolution of a planet close to the parent star
2. Mercury as a planet
form, interior, structure, geology, composition, craters
3. Mercury's **vestigial atmosphere** (exosphere):
composition and dynamics
4. Mercury's **magnetized envelope** (magnetosphere):
structure and dynamics
5. **Origin of Mercury's magnetic field**
6. Test of **Einstein's theory of general relativity**
(Detection of potentially **Earth-threatening asteroids**)

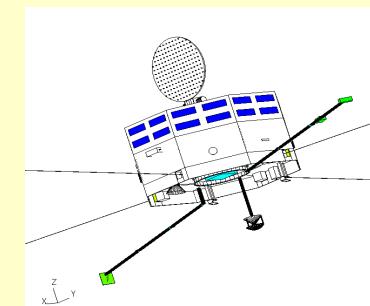


Three Scientific Elements

Mercury Planetary Orbiter (MPO)

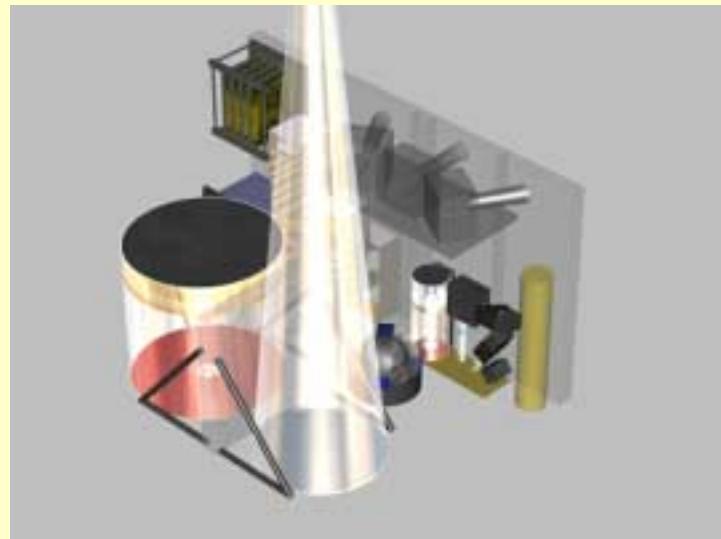
Mercury Magnetospheric Orbiter (MMO, ISAS provided)

Mercury Surface Element (MSE)

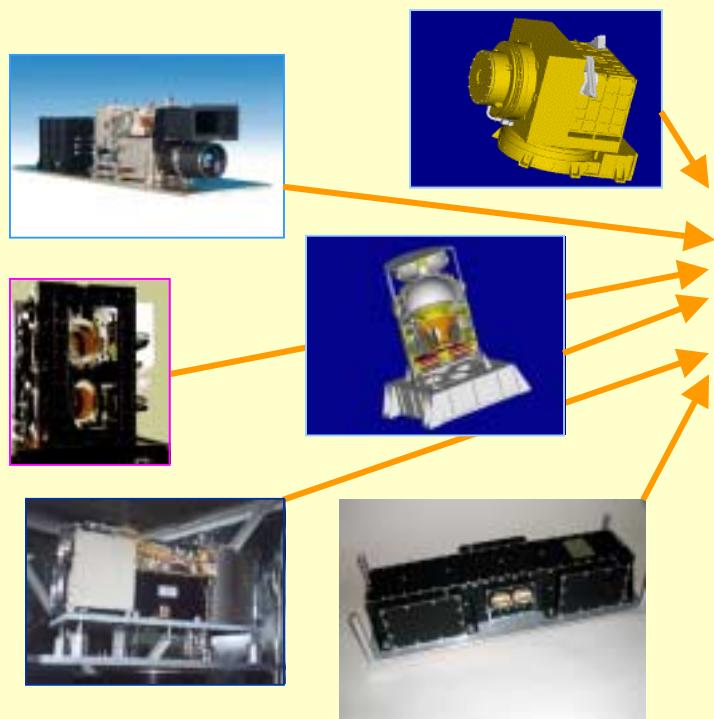


Highly Integrated Payload Suites

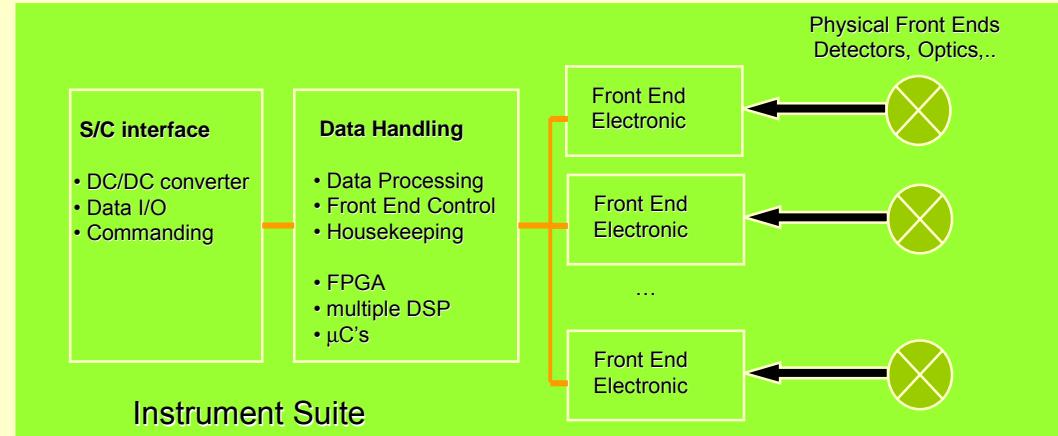
=> data link/ command link
top level requirements



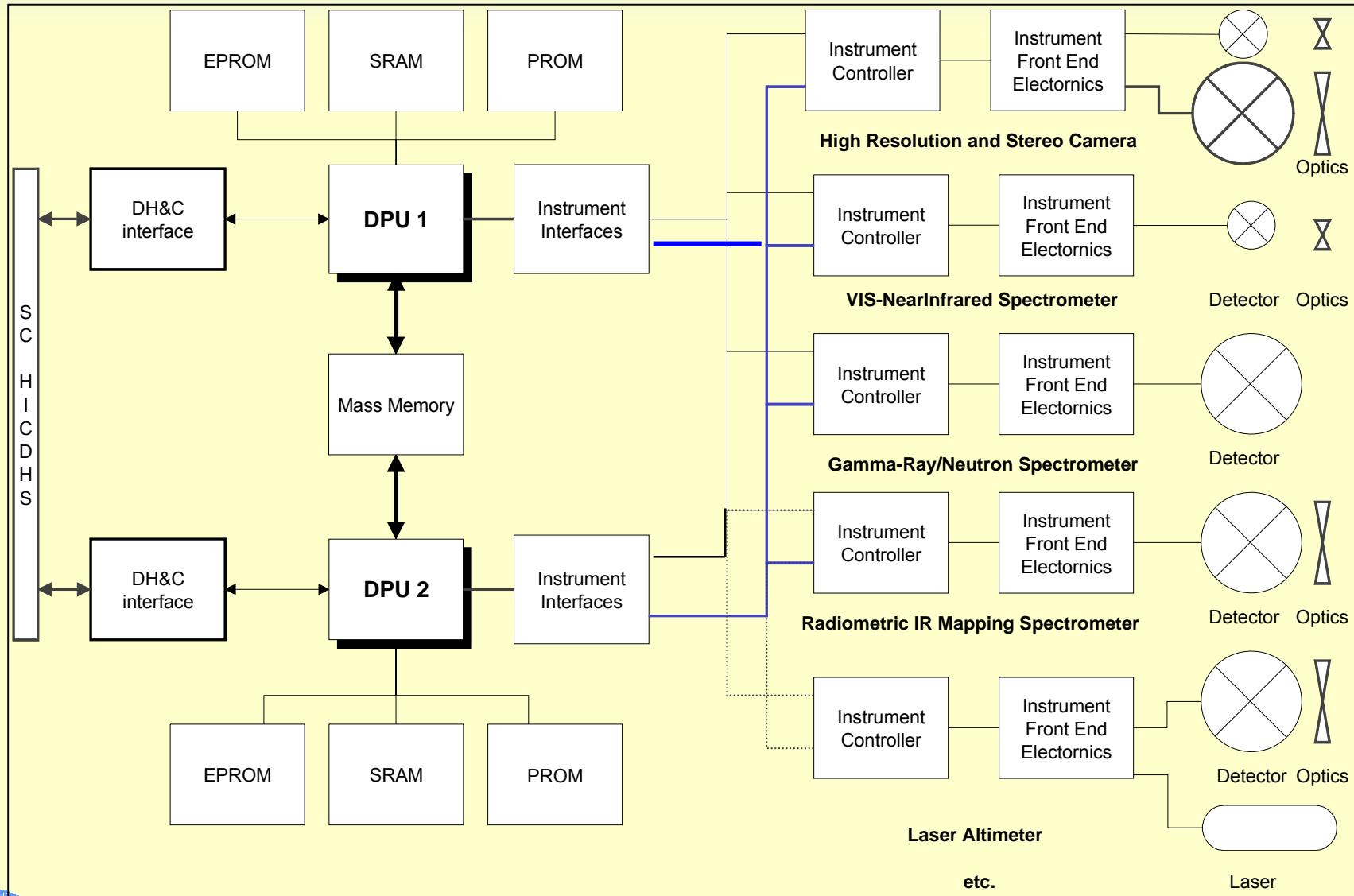
Highly Integrated Payload Suite (HIPS)



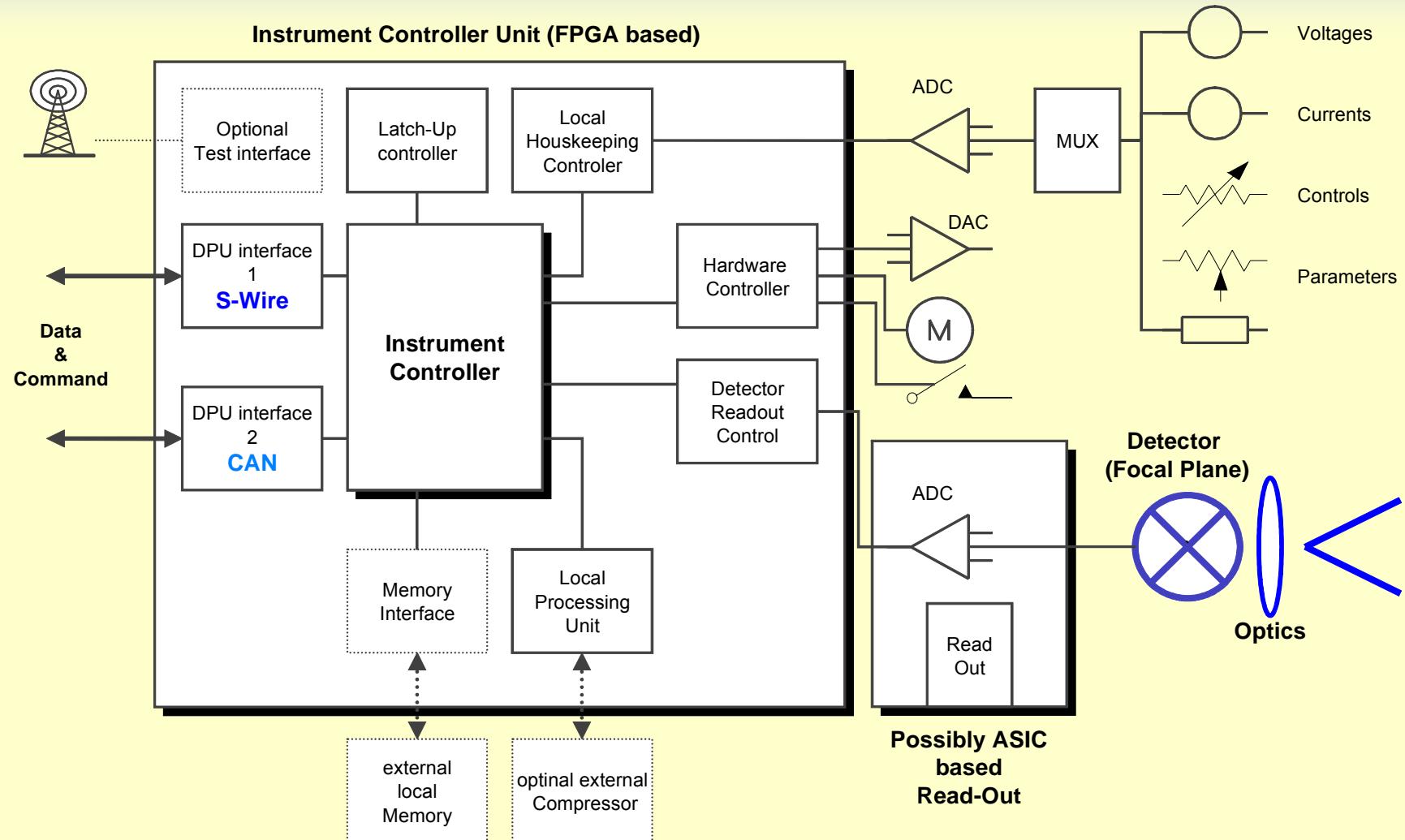
Collection of Instruments



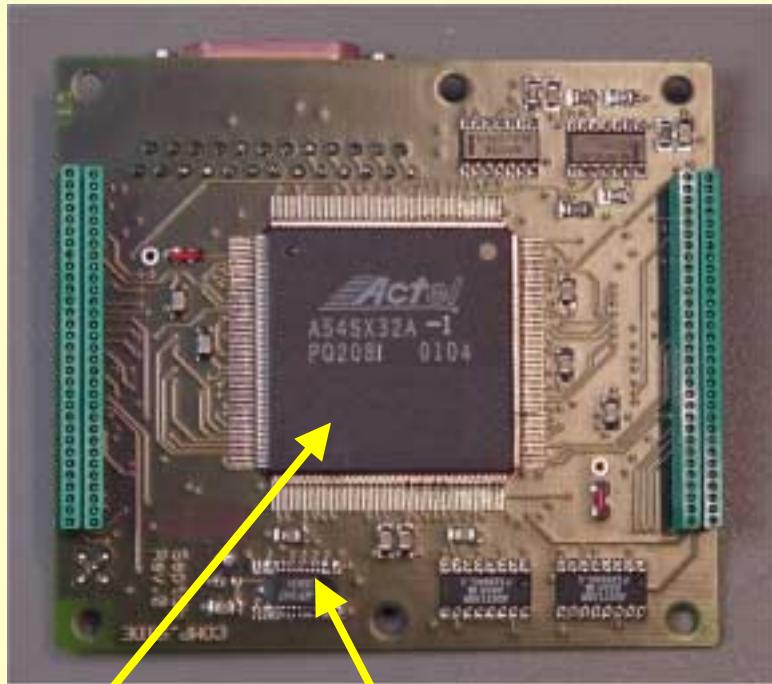
Principle Block Diagram



Instrument Controller



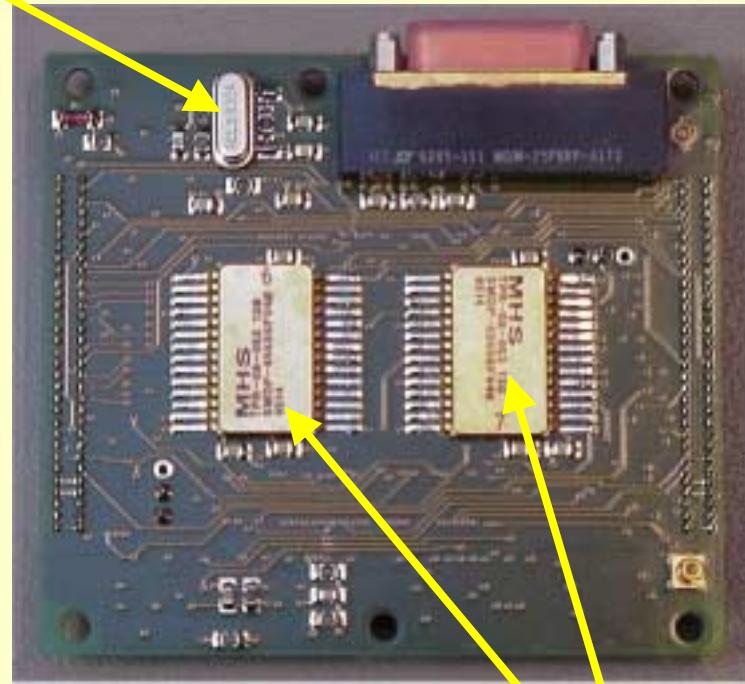
Instrument Controller - Example



FPGA

DAC

Crystal

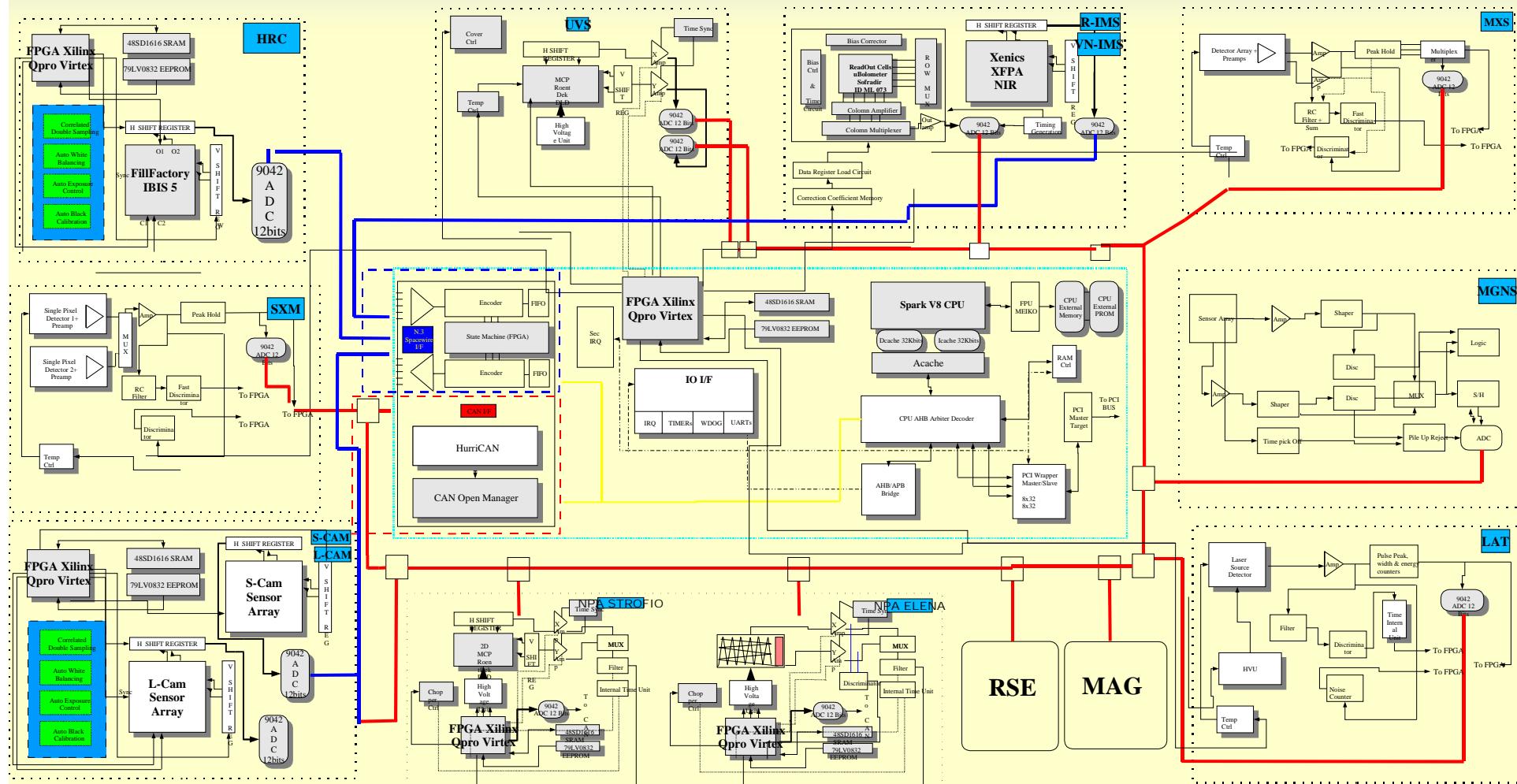


SRAM

Stereo SEPT Instrument Controller, P.Falkner 2001

Instrument controller
FPGA based
Stereo / Solar Electron and Proton Telescope

Complete Block Diagram



Courtesy of Cosine B.V.

Used for analysis and optimization of the integrated instrument suite

Highly Integrated Payload Suites / TM- rates

Mission	P/L Mass Range (kg)	Data Rate
Solar Orbiter	< 150	75 kps (750 kbps max)
BepiColombo - MPO	40 - 50	~ 60 kbps
Deimos Sample Return (TRM)	10 - 20	10 kbps
Venus Entry Probe - Relay Sat (TRM)	20	~ 50 kbps
Venus Entry Probe - Orbiter (TRM)	10 - 20	50 kbps
Jupiter Explorer (TRM)	20	~ 50 kbps
Interstellar Heliopause Probe (TRM)	20 - 40	200 bps
Aerobot	5	1 kbps
MicroProbes	0.01 - 1	100 bps

BC/MPO – HIPS present model P/L

			(kg)	(W)	(Mbps)	(kbps)	(kbps)
Nr.	Instruments		Mass	Power	Peak Rate	Data Rate uncompr.	Data Rate compr.
1	High Resolution Colour Camera	HRC	1.10	1	34.0	85.5	6.0
2	Stereo Camera	S-CAM	0.55	1	2.5	37.9	2.7
3	Limb Camera	L-CAM	0.34	1	0.6	4.2	0.3
4	Visible Near Infrared Mapping Spectrometer	VN-IMS	0.80	7	1.7	21.6	7.2
5	Radiometric Infrared Mapping Spectrometer	R-IMS	2.20	3	1.9	33.5	6.7
6	Ultraviolet and Visible Spectrometer (UVS)	UVS	1.65	2	0.20	1.7	1.1
7	Mercury X-ray Spectrometer / Solar x-ray Monitors	MXS/SXM	2.10	5	0.04	13.2	6.6
8	Mercury γ-ray Spectrometer	MGNS	3.00	3	1.6	1.6	1.6
9	Laser Altimeter	LAT	5.53	(20)	NA	0.14	0.1
12	Neutral Particle Analyzer	NPA	1.80	3	0.014	3.2	1.0
10	Radio Science Experiment	RSE	6.70	10.6	<<<	0.1	0.1
11	Magentometer	MAG	4.15	2	0.004	0.1	0.1
13	Platform		3.00	0			
14	Dual Central Processing Unit	2CPU	3.00	20			
15	Central Payload Power Supply	CPPS	0.70	11.7			
16	Harness			1.68			
	Subtotal		38.3	70.3		202.7	33.5
	Contingency		7.7	14.1			

Highly Integrated Payload Suites

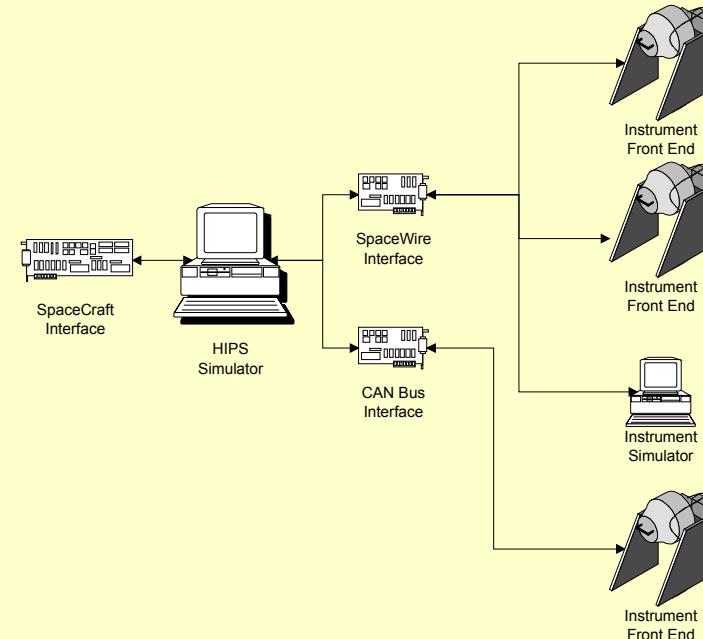
- FPGA's and ASICS (e.g.) contain instrument controller + data link/commanding interfaces
- Strong interest to reduce part count -> keep PCB small, manufacturing and testing simple.
- Space Wire as high data rate link > 1 Mbps (standard requires ~ 5000 gates = % range)
- CAN bus as low data rate link < 1Mbps (6.5% of Actel RTAX-1000)
- Low resource need allows implementation of both controllers into single FPGA including Transceiver, Interface and the Instrument Controller
- Driver is the data link
(command link low data rates, except instrument FE configuration)



Courtesy of Cosine B.V.

Highly Integrated Payload Suites - Implementation

- Next Step = Implementation into Bread Board
study data flows & potential conflicts
- Use of simulators and instrument Bread Boards
- Main CPU's possibly implemented in rad-hard FPGA's
(e.g. ACTEL RTAX 1000/2000)



Conclusion

- HIPS require **medium and high speed** links (CAN & S-Wire)
- **VHDL based implementation** of transceiver and controller into FPGA and ASIC's
- For small distances: use of FPGA I/O levels
(e.g. LVDS support by Actel -> reduces need for additional drivers)
- Precise time stamping required (ms range)
- PC based equipment needed for test/development phase already available
- All doable – no showstopper => start to implement into Bread Board
- Potential need for support by specialists -> motivation of this talk

References

- [1] Julian Harris (Swiss Space Technology), Study of the use of FPGA technologies in a highly integrated payload suite, Ref SST-HC-TN-001, October 2003
- [2] C. Erd et.al., BepiColombo Payload Definition Document (PDD) 3.1.1, 30 June 2003,
ref: SCI-A2002/007/Dc/CE,Cr_BC_TN15
- [3] P. Falkner, Science Future Programme Technologies, Workshop on Spacecraft Data Systems, 5.-7.
May 2003 @ ESTEC
- [4] M. Collon, J. Montella, S. Kraft (cosine Research B.V.), Highly Integrated Payload Suites (HIPS)
Concept Study, 5th IAA conference on low cost Space Missions

- END -