a Cohort plc company

L-DAP

Lunar Dust Analysis Package

Final Presentation

Agenda

1. Introduction, Study Status overview SEA
2. Reminder of ESA Requirements ; SEA
3. Scientific Aspects ; VU Amsterdam
4. Summary of L-DAP configuration, mass budget SEA
5. AFM/LOM design and expected performance; TUD/Imperial/PhaseFocus
6. RAMAN/LIBS and expected performance; KT/TNO/Leics
7. OM design and expected performance;   SEA
8. Soil Properties ; SEA
9. Sample Handling System design and expected performance; SEA
10. Thermal design and mechanical; SEA
11. Electronics design and operations; SEA
12. Next steps for the study (ie identification of development planning) ; SEA/All

1 Introduction – Team organisation

SEA (UK)
Study Lead
Systems Engineering
(Common Electronics, Sample Handling)

- **Kayser-Threde (D)**
  Lutz Richter
  Raman and Optical Spectroscopy Lead
  (Raman-LIBS Head)
  - **TNO (NL)**
    Maria Sovago
    (Raman-LIBS Spectrometer)
  - **Univ. of Leicester (UK)**
    Ian Hutchinson
    (Consultant - Detectors)
- **Bern University (CH)**
  Nick Thomas
  (Consultant – Optical Microscope)
- **TU Delft (NL)**
  Urs Staufer
  Atomic Force Microscope Lead
  (Atomic Force Microscope)
  - **Imperial College (UK)**
    Tom Pike
    (Consultant)
  - **Nanosurf (CH)**
    Dr. Robert Sum
    (Consultant)
  - **Univ. of Amsterdam (NL)**
    Wim van Westrenen
    (Consultant)
  - **Phasefocus (UK)**
    John Rodenburg
    (Consultant)

Industrial Team

Consultants

1 Documentation/Deliverable Status

- TN 1 (SEA-11-AS-1455-01 iss 4) Requirements Specification and Concept Recommendations
- TN 2 (SEA-11-AS-1455-02 iss 2) Instrument Technology Assessment Report
- TN 3 (SEA-11-AS-1455-06 iss 5) L-DAP System Design Report
- TN 4 (SEA-11-AS-1455-07 iss 3) L-DAP Instrument Design Report
- TN 5 (SEA-11-AS-1455-08 iss 2) L-DAP Science Performance Report
- TN 6 (SEA-12-AS-1455-11 iss 1) L-DAP Development Plan and Breadboard Definitions
- TN 7 (SEA-11-AS-1455-10 iss 3) L-DAP Payload ICD
- ES (SEA-12-AS-1455-15 iss 1) L-DAP Executive Summary - tbs
- CA (SEA-12-AS-1455-16 iss 1) Cost Assessment (draft only) - tbs
- CAD Models
- Various Minutes of meeting/inputs to Ops models

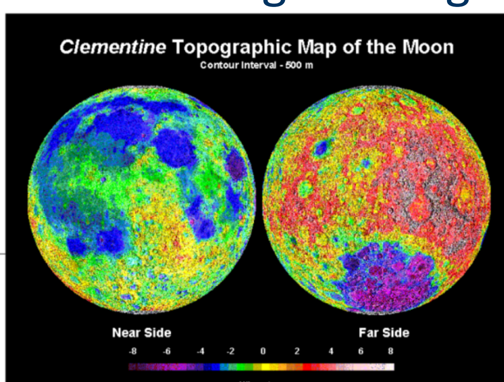
1 - Introduction: Dust Problems...

- *“I think probably the most aggravating, restricting facets of lunar surface explorations is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and it’s restrictive friction-like action to everything it gets on.”*
- *"You have to live with it but you're continually fighting the dust problem both outside and inside the spacecraft.“*

Gene Cernan, Apollo 17 Technical debrief

1 - Introduction: Lunar Dust Analysis Package

- Scientific experiment package for ESA's Lunar Lander mission.
- Intended landing site: South-Pole - Aitken Basin,
  the largest such basin on the Moon and a key location
  to study the geology of the Moon due to its depth.
- Basin provides opportunity to examine deep excavated material, with potential to find/analyse glasses.
- LDAP will analyse the morphology, structure, composition and properties of the lunar dust in the region, with view of establishing:
  - The presence of natural resources in the regolith
  - The geology and early history of the Moon
  - A better understanding of lunar dust to help develop safeguards against it for future human exploration.



2 - ESA Requirements Overview

Requirement	Detail	LDAP
REQ ESA 1	The size and distribution of lunar dust shall be determined for particles of the order of 10 nm to 100 µm.	OM: 2.1 µm to 4 mm AFM: 50 µm scan length at 1 nm x 1nm resolution (x, y only)
REQ ESA 2	The morphology (size, shape and roughness) of lunar dust grains with a diameter of < 10µm shall be determined, with a goal of extending this down to grains in the size range of the order of 10nm to 100nm.	AFM: 50 µm (x, y) and 12 µm (z) scan length at 1 nm x 1nm x 0.1 nm resolution. LOM: 1 µm spatial resolution.
REQ ESA 3	The presence and % abundance of the following minerals shall be measured in surface regolith, where they exist in abundances greater than 0.05 % vol. (TBC): plagioclase, pyroxene (distinguishing between OPX, Augite etc.), olivine, silica, ilmenite, spinel, glasses.	Raman: primary purpose of the experiment. OM: LEDs illuminate the sample at different wavelengths and the reflectivity of the sample can help identify its composition.
REQ ESA 4	The presence and where possible % concentration of the following elements (as a minimum) shall be determined: O, Al, Si, Mg, Ca, Ti, Fe, Mn, and ideally K, Cr and Na.	LIBS: primary purpose of the experiment.

2 - ESA Requirements Overview

Requirement	Detail	LDAP
REQ ESA 5	The abundance and distribution of H_2O and OH shall be determined for concentrations greater than 100 ppm; with a goal of detecting concentrations greater than 10 ppm.	LIBS: primary purpose of the experiment.
REQ ESA 6	The presence and abundance of nanophase Fe shall be determined – feasibility to be evaluated	AFM in dynamic mode: detection of magnetic properties.
REQ ESA 7	The permittivity of lunar soil shall be determined – feasibility to be evaluated	Dielectric probe (TECP).
REQ ESA 8	The magnetic properties of the lunar soil shall be determined –feasibility to be evaluated	AFM in dynamic mode: detection of magnetic properties.
REQ ESA 9	The L-DAP package shall be accommodated on the lander and samples for analysis shall be acquired from the surface and delivered to it by the lander platform.	See TN1.

2 - ESA Requirements Overview

Requirement	Detail	LDAP
REQ ESA 10	Maturity margins shall be applied for mass calculations to take into account the technology maturity of the constituting units. The maturity margin of a unit or equipment shall be calculated as follows: 5% for recurrent equipment 10% for modified equipment 20% for new development	See TN3.
REQ ESA 11	The total mass of the package (including margins) shall be <4 kg (not including any external optical heads for a Raman/LIBS instrument) but including any internal sample handling, sample stage, housing, internal harness and instrumentation.	Non compliant: 7.3 kg. (inc ~20%)
REQ ESA 12	Samples are delivered to the L-DAP package without any processing by the sample acquisition system.	See TN3.

2 - ESA Requirements Overview

Requirement	Detail	LDAP
REQ ESA 13	Data compression and storage shall be assumed to be performed by the lander platform.	See TN3 and TN4.
REQ ESA 14	L-DAP shall provide its own instrument control.	Instrumental Control Electronics (ICE) includes power module, discrete acquisition module and central processor.
REQ ESA 15	The L-DAP shall include redundancy in data and power interfaces to the lander.	See TN3.
REQ ESA 16	Power interface to the lander shall be 28V DC.	See TN3.
REQ ESA 17	L-DAP shall provide its own DC-DC conversion.	See TN4.
REQ ESA 18	L-DAP shall provide its own thermal control.	Thermal control comprising MLI blankets, radiator on top face protected by sunshield and heaters during night.
REQ ESA 19	L-DAP shall be attached to the Lander external surface and shall be exposed to the environment defined in AD1.	See TN3.

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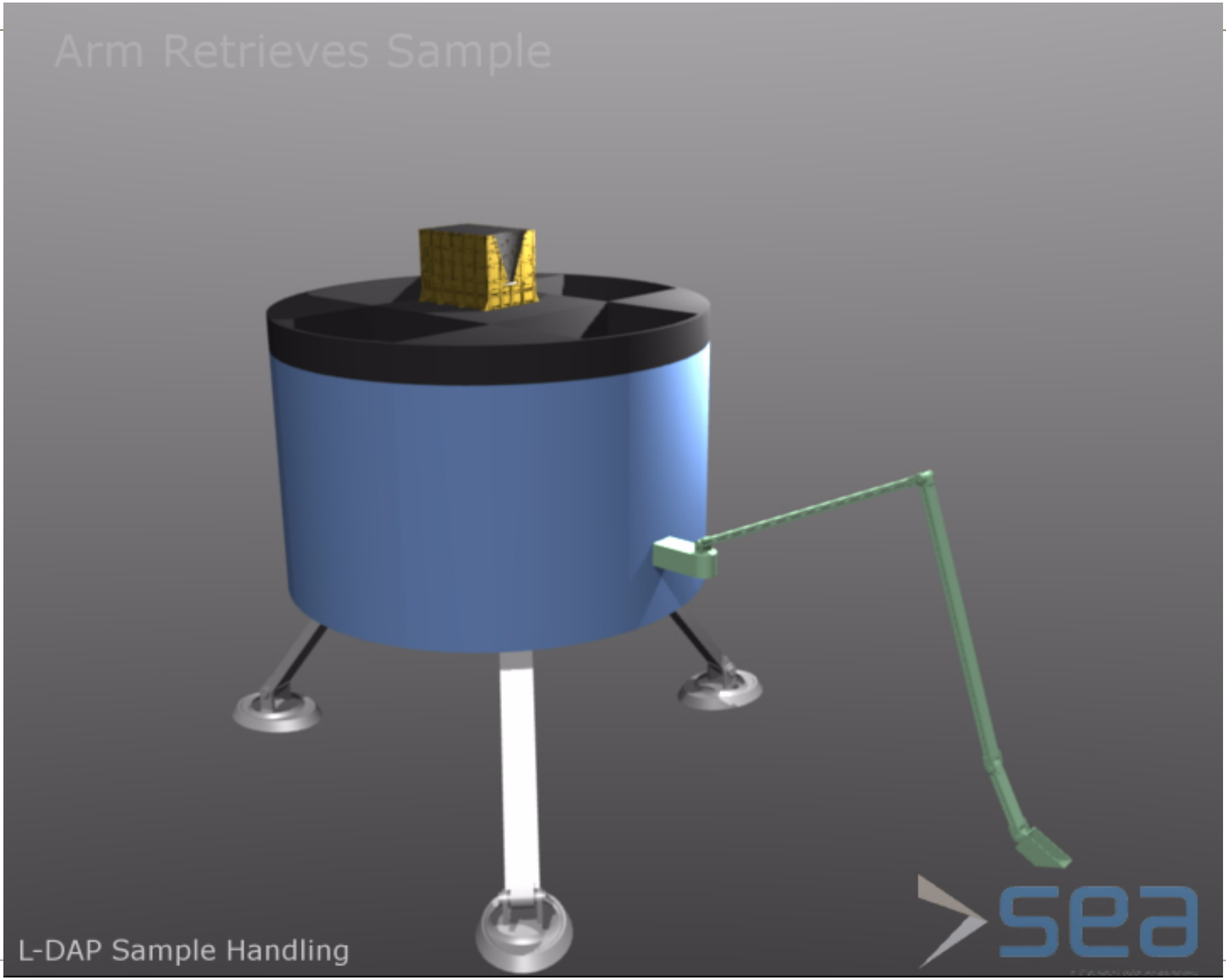
3 – Scientific Aspects

- Wim v.Westrenen

4 : A Brief overview...


Arm Retrieves Sample
L-DAP Sample Handling
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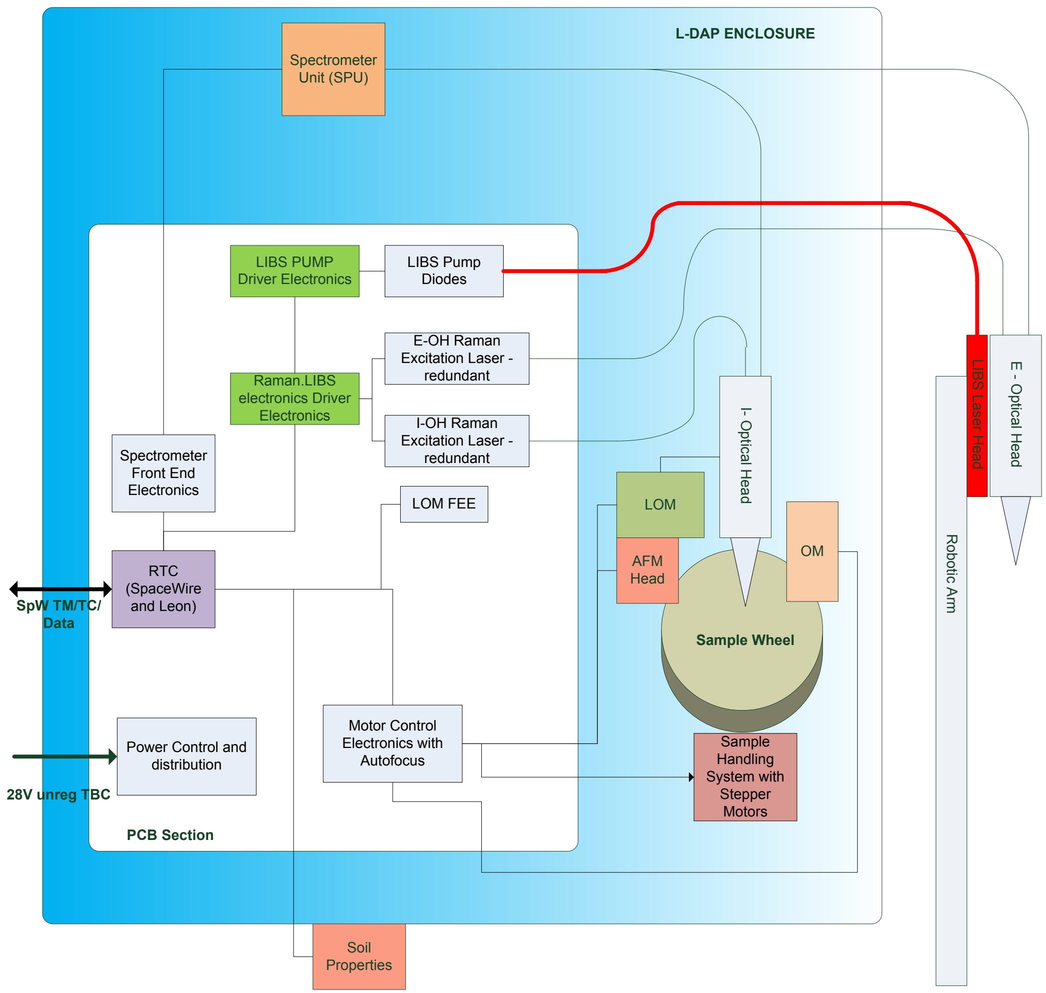
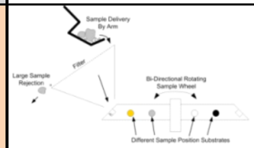
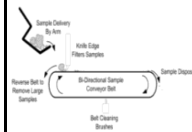
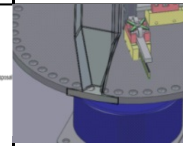
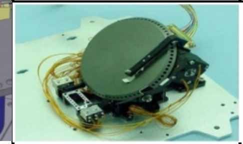
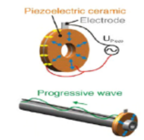
4 - L-DAP System Architecture

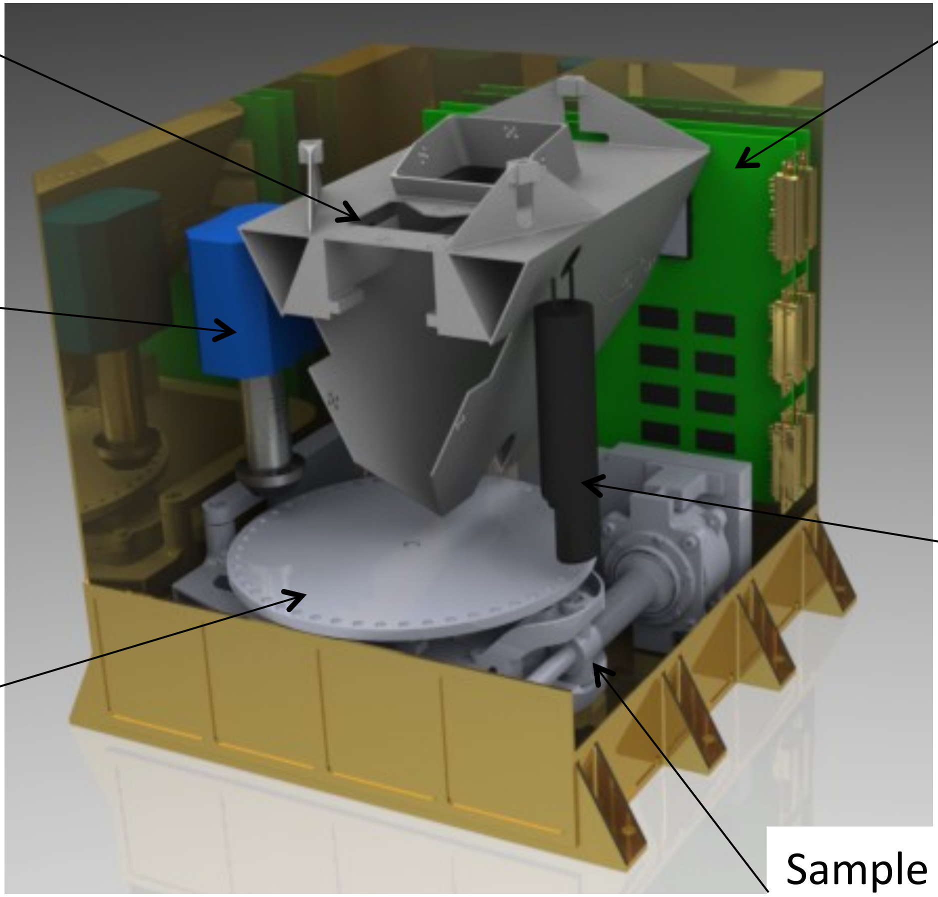
- Single redundancy (multiple Interfaces to S/C)
- 2 or 3 PCBs (isolated) containing FPGAs, power converters, RAMAN/LIBS drivers, Lasers, FEEs
- Optical Bench maintaining coalignment internally.



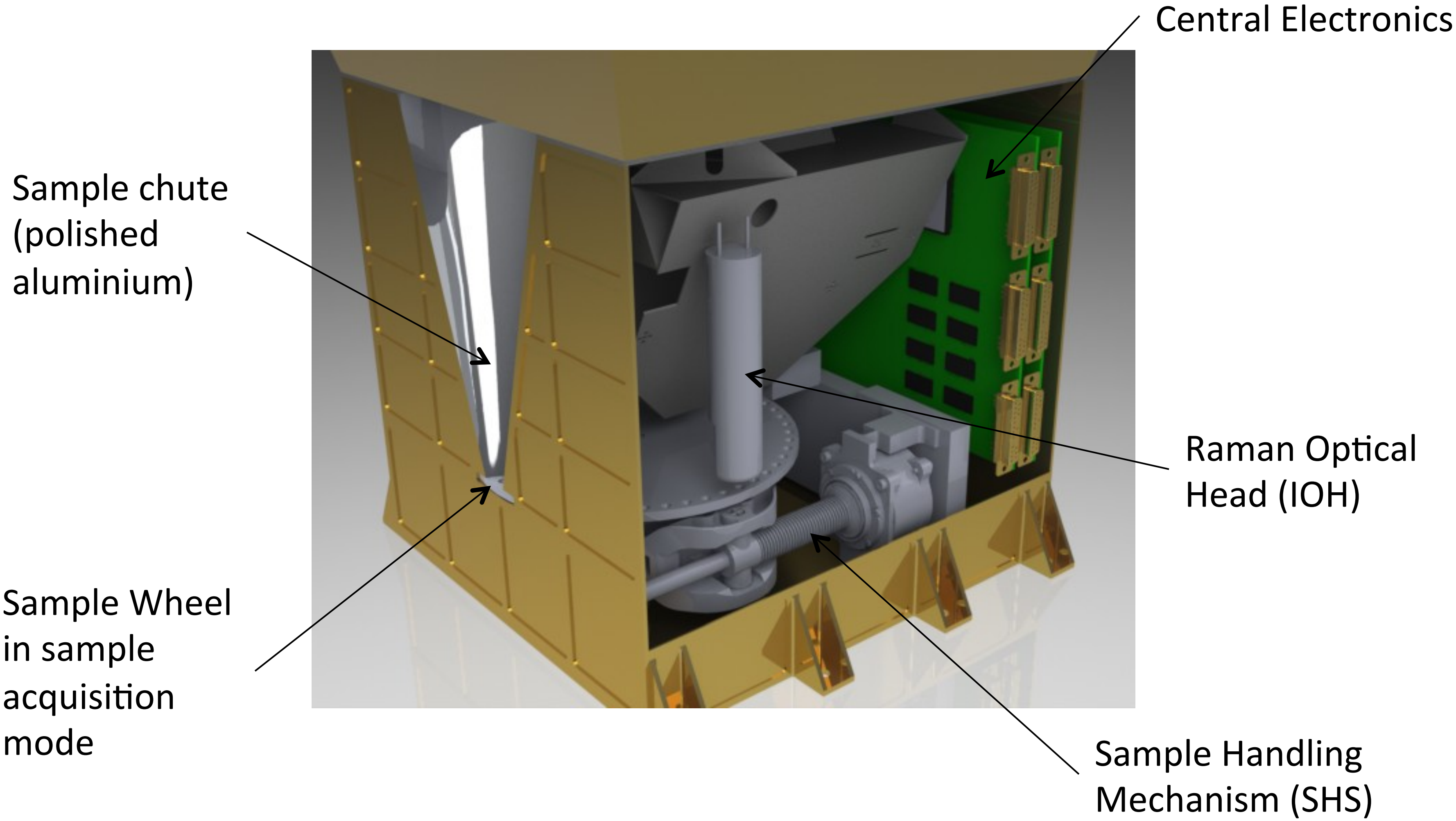
4 - Some Early Configuration Trade-offs

Option Name Image	Weight	1 Horizontal wheel w bevel	2 Conveyor belt	3 Horizontal wheel	4 45 deg Wheel w bevel	5 Piezoelectric vibration
Diagram / heritage		 Derived from MECA	 Cassette winding mechanism	 Similar to ExoMars	 MECA	 None
Sample position correlation	**2**	2 Change focal length of instruments to focus	0 Vertical belt movement (separate actuator) nec.	2 Vertical and rotation movement needed	1 Sample may be disturbed between viewing positions	0 Positioning ability unknown
Contamination	**1**	2 Cross contamination limited	0 Increased chance of cross contamination	2 Cross contamination limited	2 Cross contamination limited	0 Increased chance of cross contamination
Sample number	**2**	1 Limited	2 Unlimited but same substrate	1 Limited	1 Limited	2 Unlimited
Waste	**2**	2 Filter and 45deg tilt	1 Knife and reverse belt	2 Waste dumped outside of package - low risk of blockage	0 Waste dumped inside package	2 Could be dumped externally
Mass	**3**	0 Low but mass nec for adjusting position of instruments	2 Low	1 medium	1 Medium	2 Low
Technology Development	**2**	0 More challenging to engineer for LIBS sample.	1 Belt drive tensioning and brushes nec. Vertical actuation requires detailed design or focussing done by microscopes	3 Mechanisms heritage eg MECA, but also linear actuators such as piezo-legs -	2 LIBS sample may cause problems when excess dust falls off near AFM	0 Access for microscopes difficult. Possible step size unknown.
Weighted Total		**12**	**14**	**21**	**13**	**14**

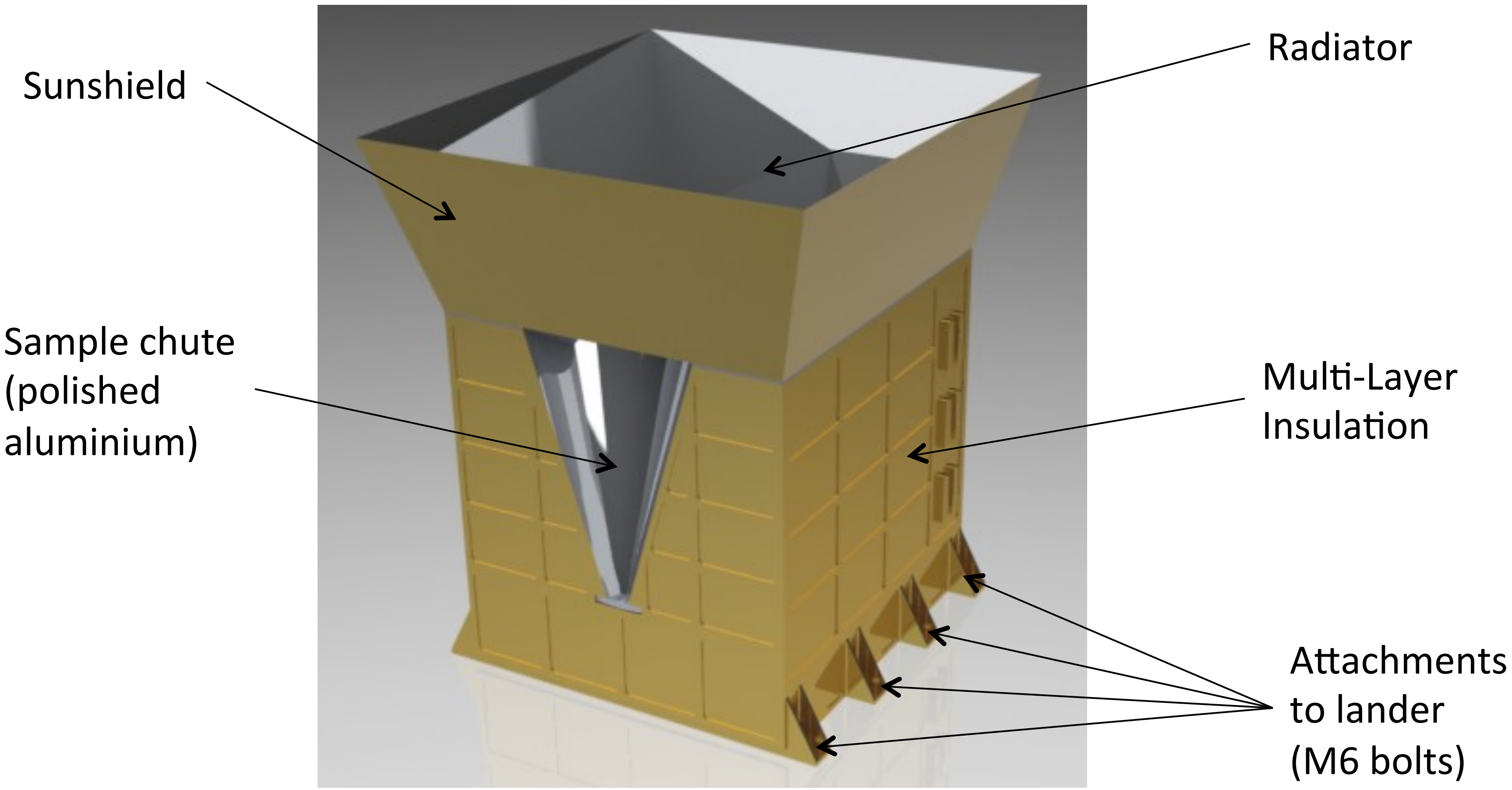
4 - Configuration



4 - Final Configuration



4 - Configuration



4 - Mass Budget

Item	Quantity	Raw mass	Contingency	Mass
Main Housing (1mm)	1	694	20%	832.80
Internal bench structure	1	632	20%	758.40
Sun Shield (5 layer)	1	100	20%	120.00
Main Unit MLI	1	180	20%	216.00
Heaters, thermistors, wire	1	50	20%	60.00
Main PCB	1	600	10%	660.00
PSU	1	900	10%	990.00
Acquisitions/Discrete PCB	1	400	10%	440.00
Internal harness	1	100	20%	120.00
Sample handling steppers	3	195	5%	614.25
Motor housing	2	40	10%	88.00
Rotor body	1	140	10%	154.00
Lateral subframe	1	150	10%	165.00
Various gears, shafts, fixings	1	275	10%	302.50
Sample Wheel	1	46	20%	55.20
Raman LIBs Spectrometer	1	420	20%	504.00
Raman Internal Optical head	1	200	20%	240.00
Raman External Optical head	1	300	20%	360.00
Raman excitation laser	2	80	20%	192.00
LIBS laser with optics	1	90	20%	108.00
Optical harness	1	90	20%	108.00
AFM scanner	1	16	20%	19.20
AFM front end electronics	1	210	10%	231.00
LOM detector	1	25	20%	30.00
LOM AFM bracket	1	21	20%	25.20
Optical Microscope	1	158	10%	173.80
OM detector	1	25	20%	30.00
OM FEE	1	80	20%	96.00
Total				7333.35

4 - Worst case Power Budget

- Indicative power budget for each mode: instruments (OM, AFM, LOM, Raman, LIBS) run for 1 hour each.
- Laser sources will require pre-heating/operation to reach stable temperatures.
- Hibernation mode occurs during lunar night.
- Standby mode is the baseline power requirement during day.

Operational mode	Power (W)
Hibernation	8 W
Standby mode	5 W
During sample wheel motion	From 6.7 W to 10.1 W
During AFM operation	15 W
During LOM operation	8 W
During OM operation	7.7 W (9.2 W peak)
During Raman operation	11.5 W
During LIBS operation	22.5 W

5 AFM/LOM

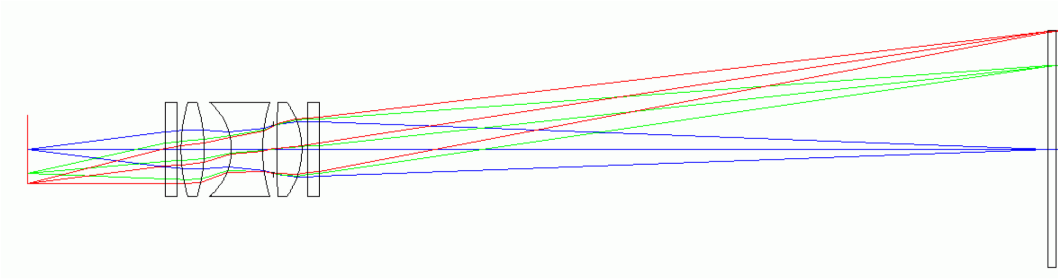
- Urs Staufer /Tom Pike

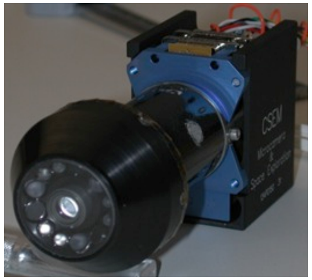
6 Raman / LIBS

- Lutz Richter et al

7 - Optical Microscope: General configuration

- OM provides optical imagery of the sample for scientific purposes and to verify the sample's suitability prior to performing experiments.
- Design derived from Beagle 2 OM and based on Cooke triplet design.

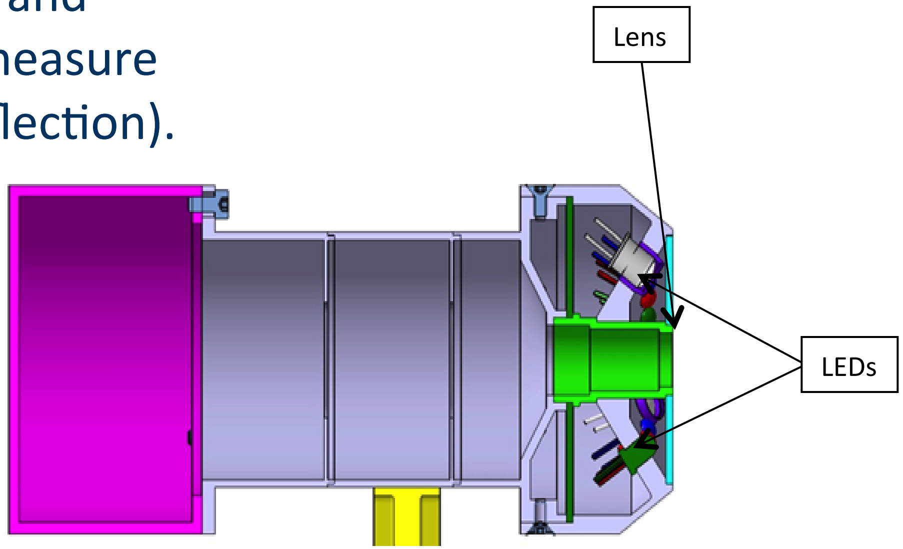




- OM is fixed to secondary structure and casing is to be manufactured out of aluminium.
- Focusing is achieved via translation (z-axis) of wheel (min step: 0.31 μm).
- No significant depth of focus needed (depth of focus = 40 μm).
- Power: 2.7 W; Mass: 293 g.
- Thermal fine control performed by heater(s) during day. No thermal control provided during night phase.

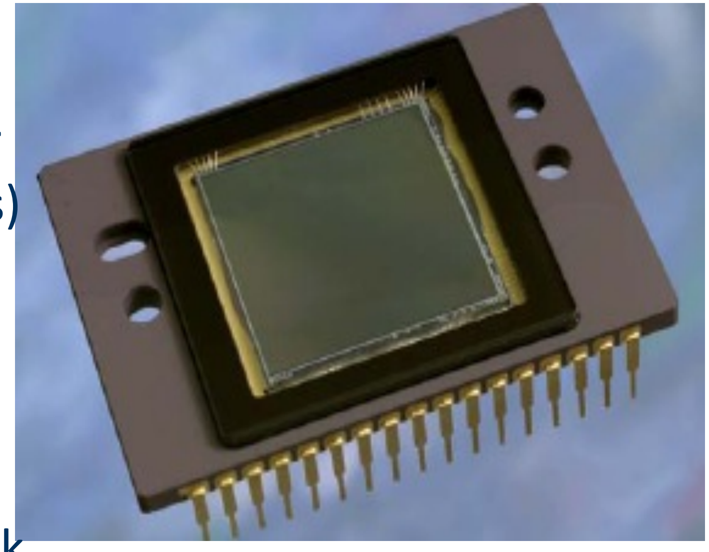
7 - Optical Microscope: Optical Design and Performance

- Working distance: 12 mm
- Magnification of 1:3.5
- Field of view: 4mm x 4mm; pixel size: 2.1 µm.
- Illumination of the sample in 4 colours: Blue (466 nm), Green (523 nm), Red (642 nm), UV (373 nm). This is done by 15 LEDs: 3 each for Blue, Green and Red, 3 for UV (with filters to remove reflected UV light for clean measurement of fluorescence) and 3 for white-light (with polarizers to measure polarization and remove specular reflection).
- LEDs illuminate at an angle of 15°.
- Monochromatic images are taken using the LEDs and false-colour images are reconstructed from the data.



7 - Optical Microscope: Detection and Electronics

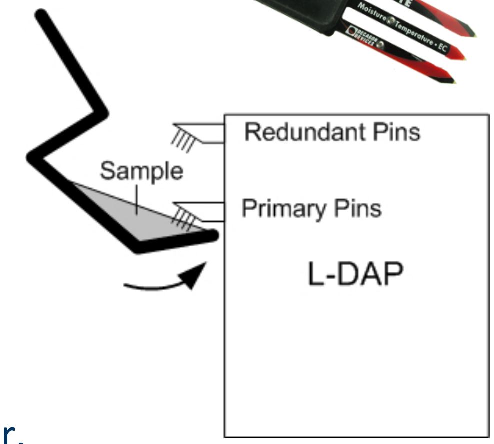
- Images are recorded using a monochromic CCD of 2048x2048 pixels with 7.4 µm pixel pitch (Kodak) (or reuse Raman/LIBS detector to make use of common Readout electronics)
- Anti-blooming function improves quality of image and electronic shuttering enables precise exposure control.
- Microcamera head includes CCD, readout electronics, ADC, noise reduction filters, clock, memory buffer, serial digital interface, RS422 communication protocol (10 Mbits/s).
- No image processing capability is foreseen.



8 - Dielectric & Thermal Properties Measurement

• **CONCEPT**

Probe based on the 5TE Soil Moisture, Temperature and EC Probe, produced by Decagon Devices.



• **OPERATIONS:**

- Electrical conductivity & dielectric permittivity:

  Two pins are buried in the soil and a voltage is applied across the pins. Analogue voltage is converted into digital output via ADC.

- Thermal conductivity (optional):

  A heater raises the temperature of one pin and the effect on the temperature of the other pin is measured by a thermistor.

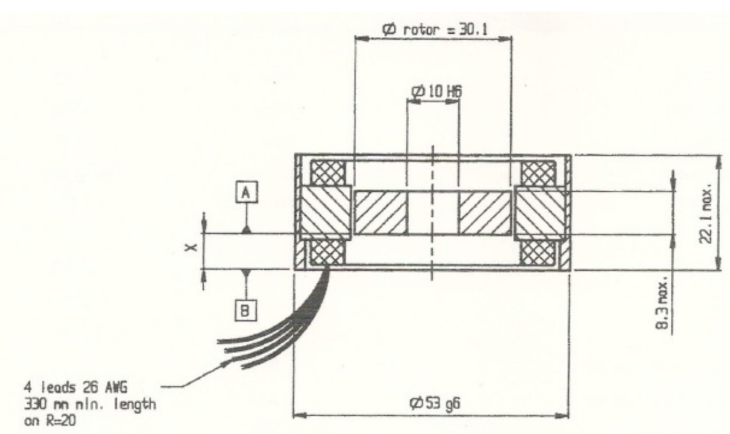
• **CONFIGURATION**

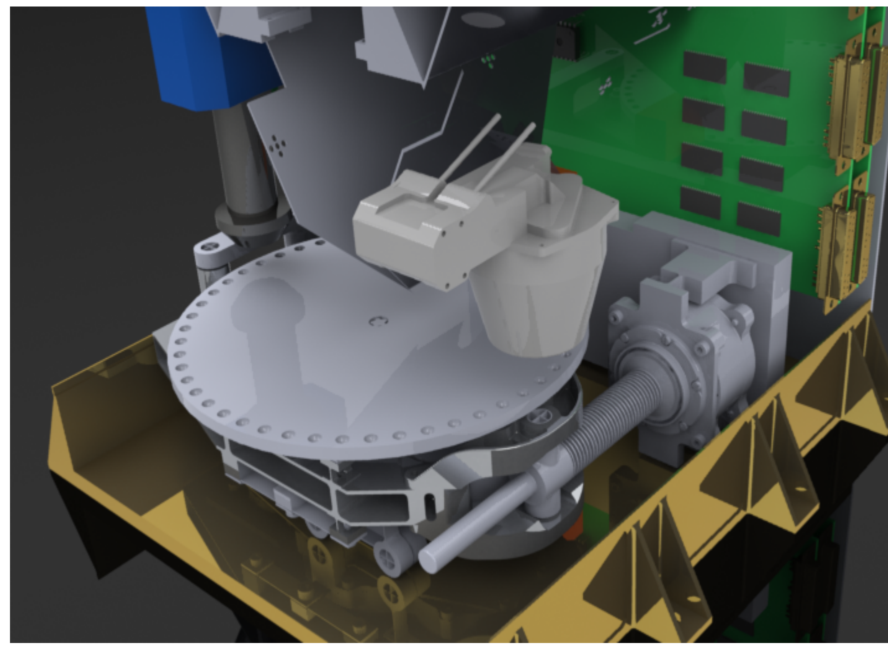
-Experiment station located outside L-DAP package. A redundant experiment station may also be included. Electronics are housed within L-DAP package. Sample analysed within the scoop.

- 4 pins per station, with 2 provided for redundancy.
- Power: 10 mA during operations and 0.3 mA in standby mode at 3.6-15 V DC. The operational phase should last approximately 150 milliseconds.
- Temperature range: -40 C to + 50 C. Probes do not need thermal control, although may become brittle in extreme cold.

9 - Sample Handling Mechanism: Concept

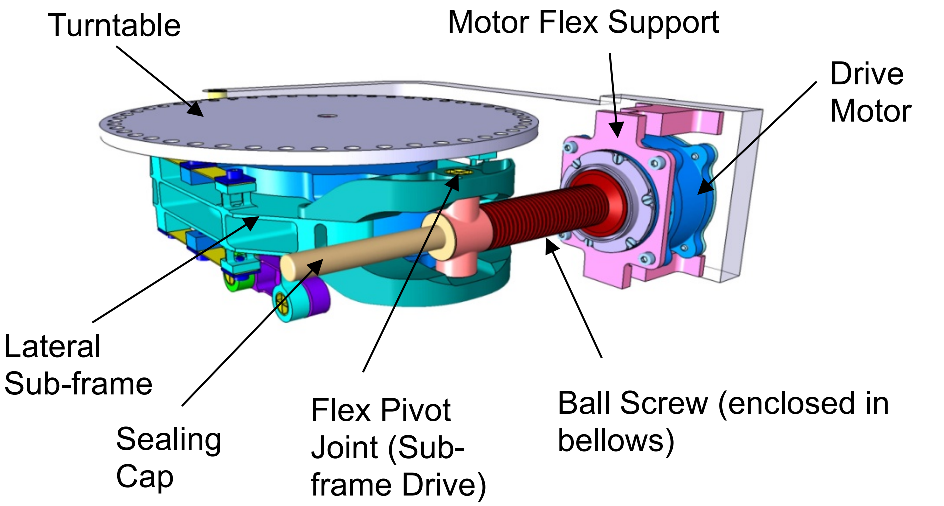
- 3 degrees of freedom, achieved by 3 stepper motors and linear actuators.
- Wheel can rotate 360 degrees via stepper motor with 6:1 gear ratio.
- Parts commonality is an important aspect of design: all 3 stepper motors are identical.
- Design aims to minimise mass, volume, complexity and improve reliability (flex joints, dry lubrication, etc.)
- Stepper motor used is the SAGEM PP 61-01-01-WW

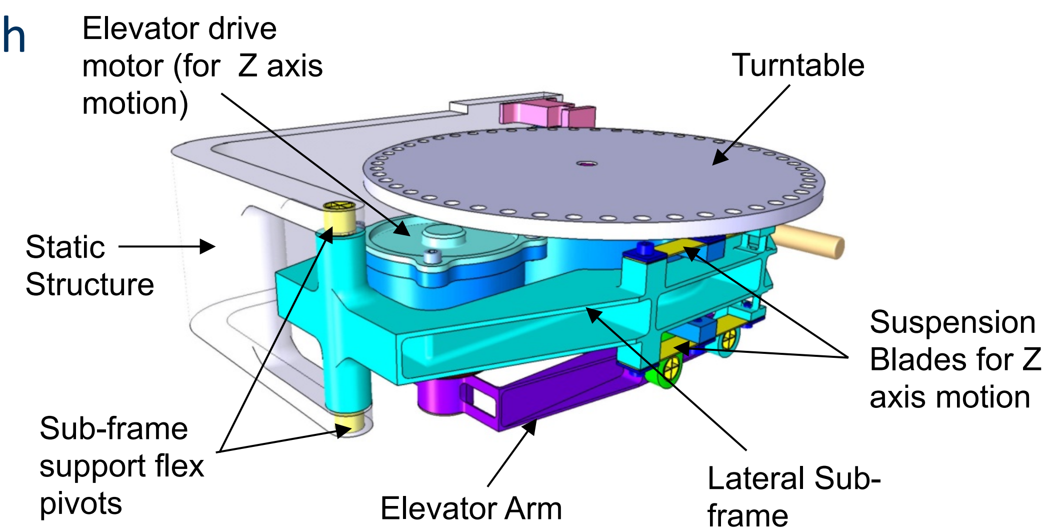




9 - Sample Handling Mechanism: Lateral Drive

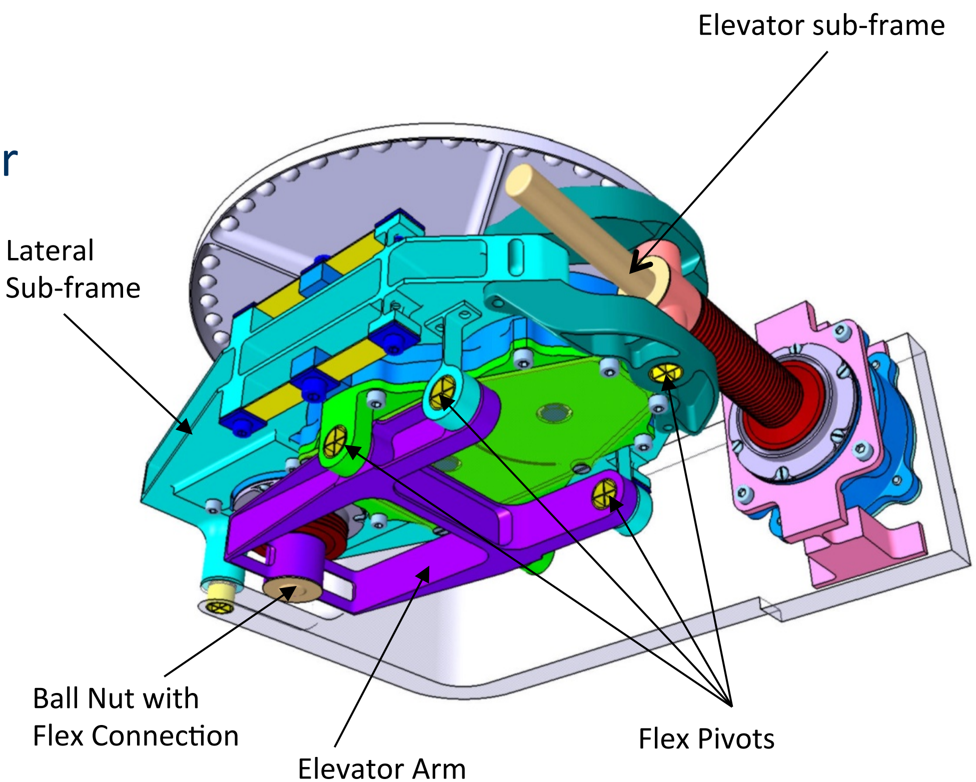
- Movement in x-y plane is achieved by arc-motion of lateral sub-frame under step input from 1.8° stepper motor and recirculating ball screw
- Degrees of freedom are coupled.
- Allows translational movement of sample at experiment station and placement of substrate beneath sample chute for sample acquisition.
- Step size: 4 µm with 1 µm stability.
- Power: 1.7 W.





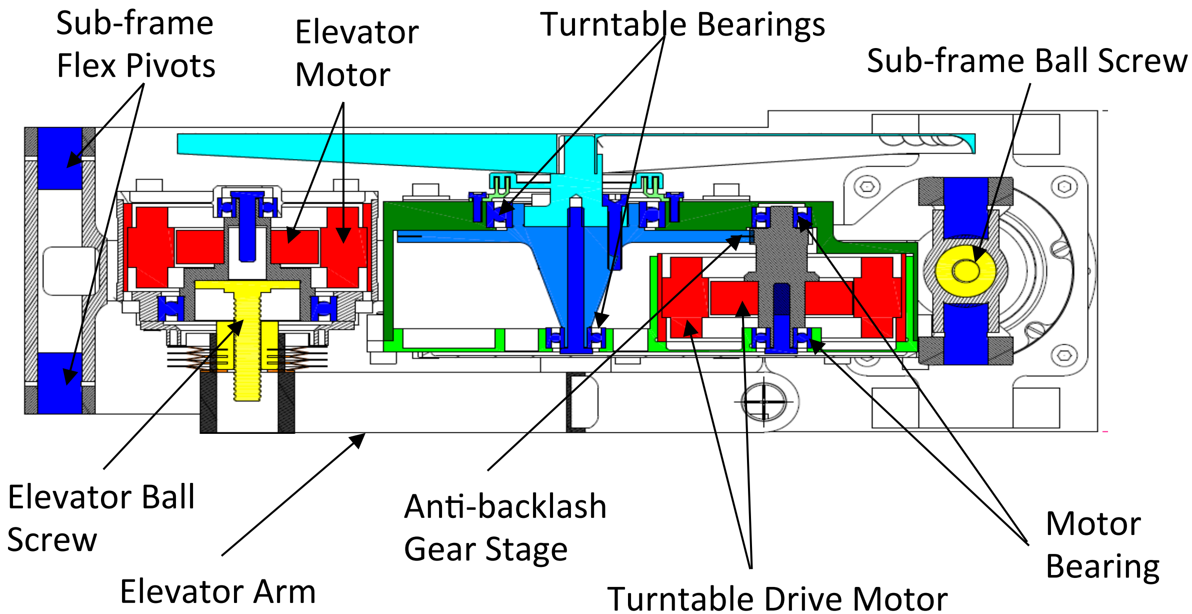
9 - Sample Handling Mechanism: Vertical Drive

- Movement along z-axis is achieved by rotating lever arm about pivot point to raise elevator sub-frame.
- Actuator is a linear screw, activated by stepper motor.
- Elevator sub-system is contained within lateral sub-frame.
- Maximum travel distance: +/- 2 mm.
- Step size: 0.31 µm (microstepping) with stability of 1 µm over entire travel and 0.5 µm in microstepping mode.
- Power: 3.4 W (fine position mode)



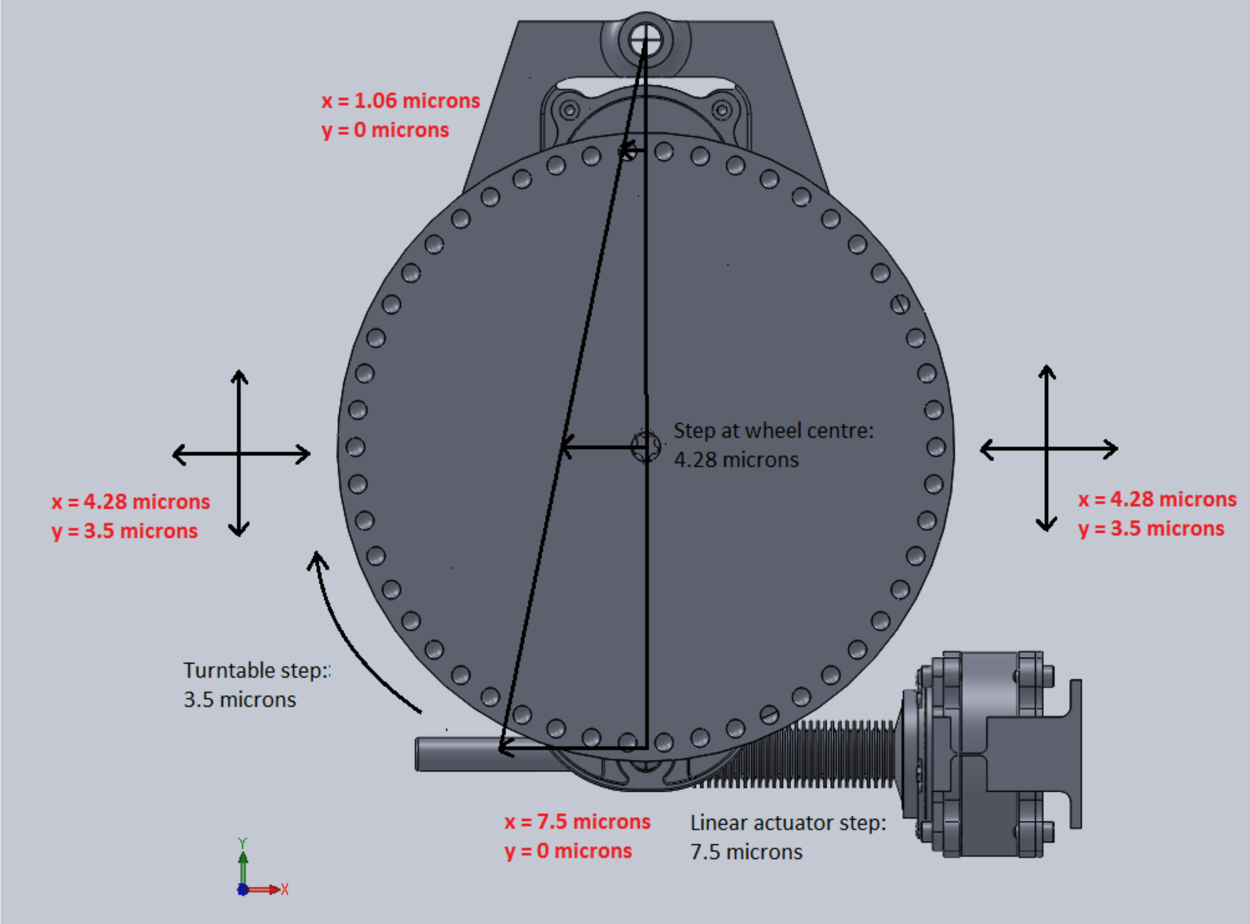
9 - Sample Handling Mechanism: Turntable Drive

- Rotation of the sample wheel is achieved via a stepper motor with a 6:1 reduction gear train and smaller bearings to reduce friction.
- The turntable drive system is contained within the elevator sub-frame.
- Rotation step size: 0.3°.
- Linear step size: 4.1 µm (<10 µm from requirements).
- Power: 1.7 W.

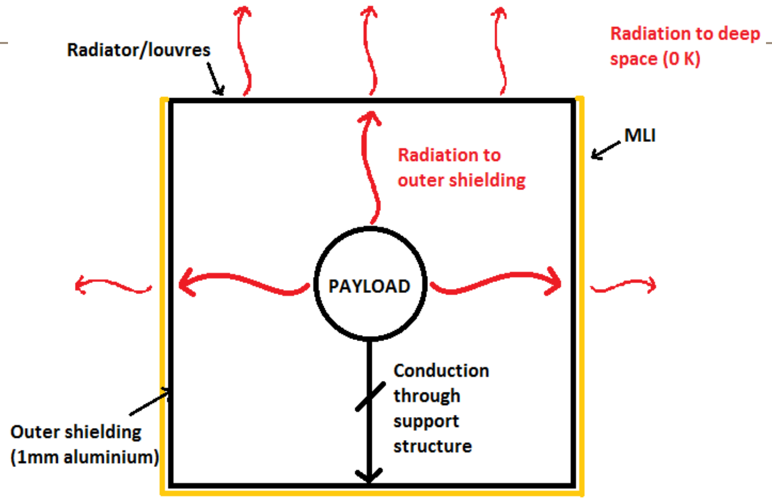


9 - Sample Handling Mechanism: Translational Performance

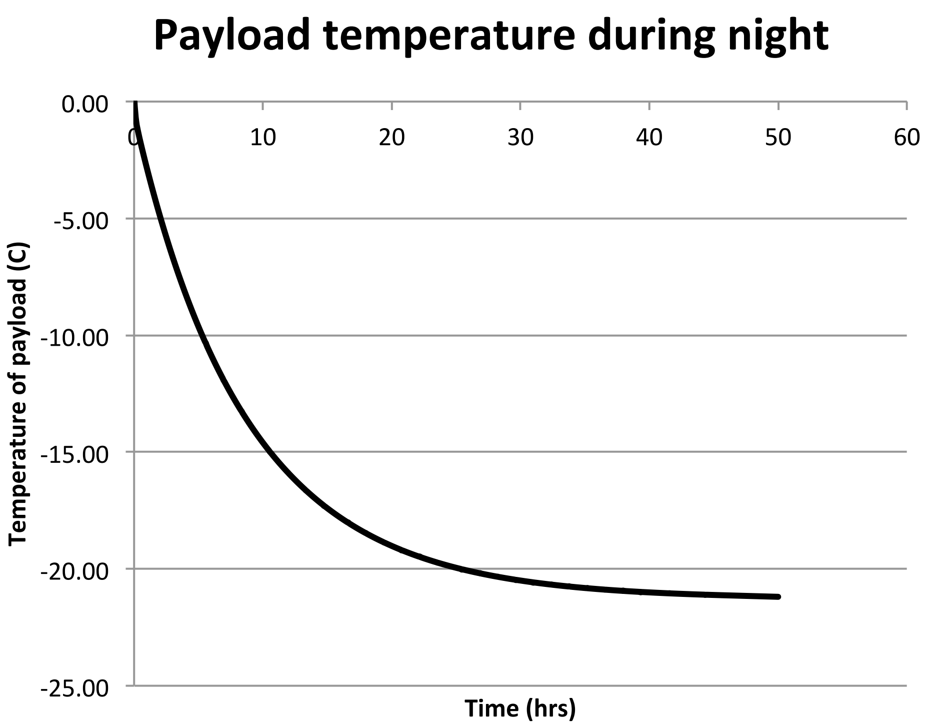
- Movement in the x-y plane is constrained by the design of the lateral sub-frame.
- Effective minimum step size is achieved by using lateral motor and the turntable drive.



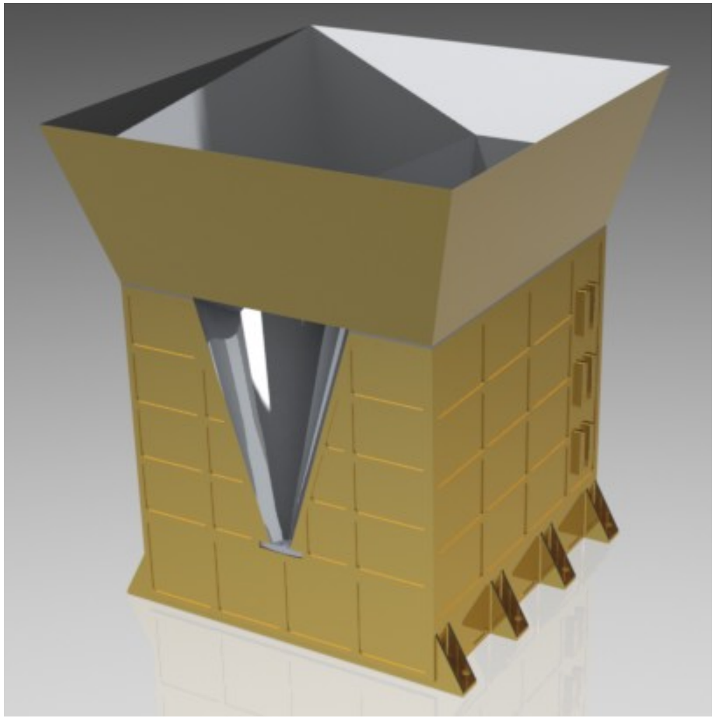
10 Thermal and Mechanical Design



Design features	
Side faces	MLI (20 layers, Mylar) (ε=0.02; α=0.2)
Top face	70% polished aluminium; 30% black paint (ε=0.3)
Sample chutes	Polished aluminium (ε=0.05; α=0.2)
Heaters	8 W; embedded in payload; operational during night
Average day temperature	-3 °C
Min. night temperature	-22 °C
Survival Temperatures	-50 °C to +30 °C
Operational Temperatures	-30 °C to +20 °C



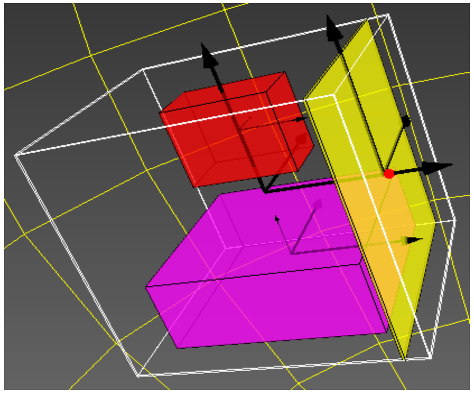
10 - Thermal Design: Sunshield

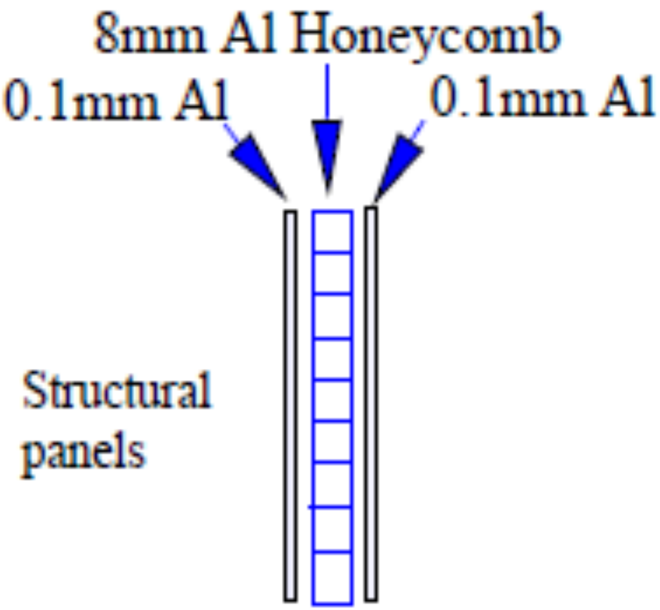


- The sunshield prevents sun illumination of the radiator face if sun angle is <22.5° max.
- Sunshield is slanted at 22.5° away from vertical, and is 120 mm high.
- Uses 5-layer MLI blankets with specular coatings.
- Use of wires/springs to support the blankets considered
- Mass: 100 g approx.
- May be fixed at launch or deployed on lunar surface (requires actuator) – depends on solar illumination during Lunar Transfer

10 - External structure

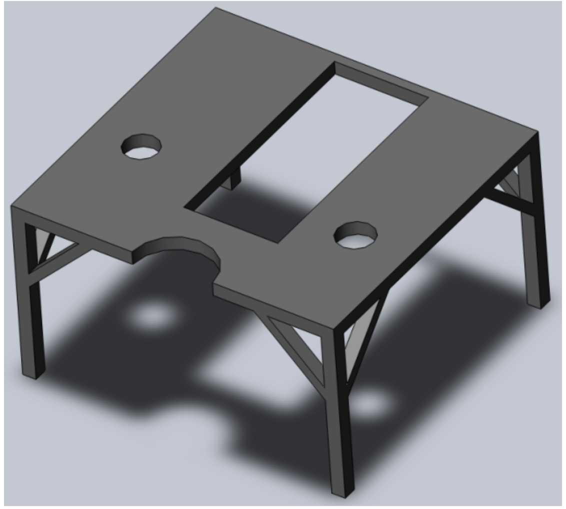
- External structure acts as radiation and micrometeorite shielding.
- Radiation levels suggest worst case total dose 3.5 krad if using 1 mm aluminium shielding.
- Micrometeorite shielding designed assuming 0.2 mm pure Fe particles hitting the structure at 8.5 km/s. Probability: 23%.
- Design trade-off suggests using 8mm aluminium honeycomb panels with 0.1 mm aluminium skins.*
- Composites (e.g. PEEK) were also considered but mass saving is negligible due to the extra material that is required.

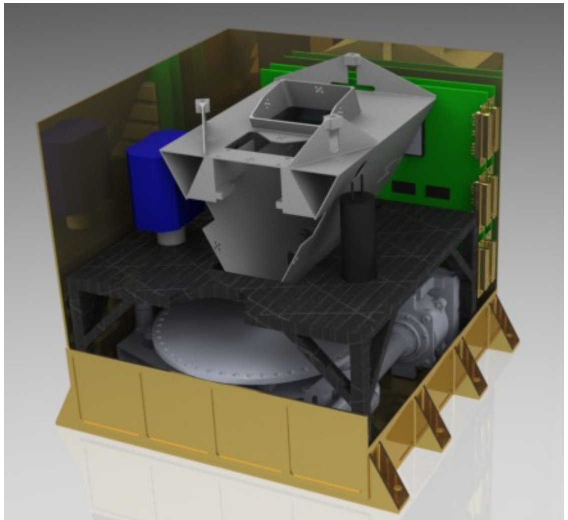




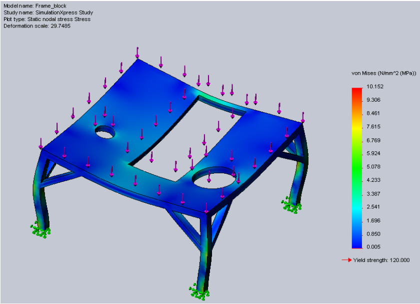
* This provides the same amount of radiation shielding as 1 mm aluminium

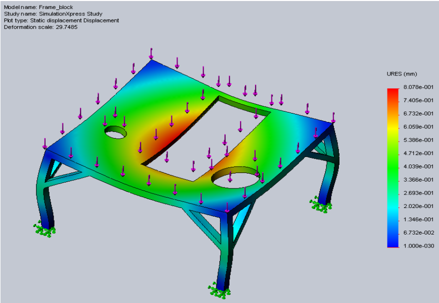
10 - Optical Bench Structure





- Optical bench structure has not been designed but mass and volume have been estimated.
- It will support a mass of 1.457 kg, i.e. 286 N assuming 20g launch loads.
- Material: PEEK (carbon fibre composite)

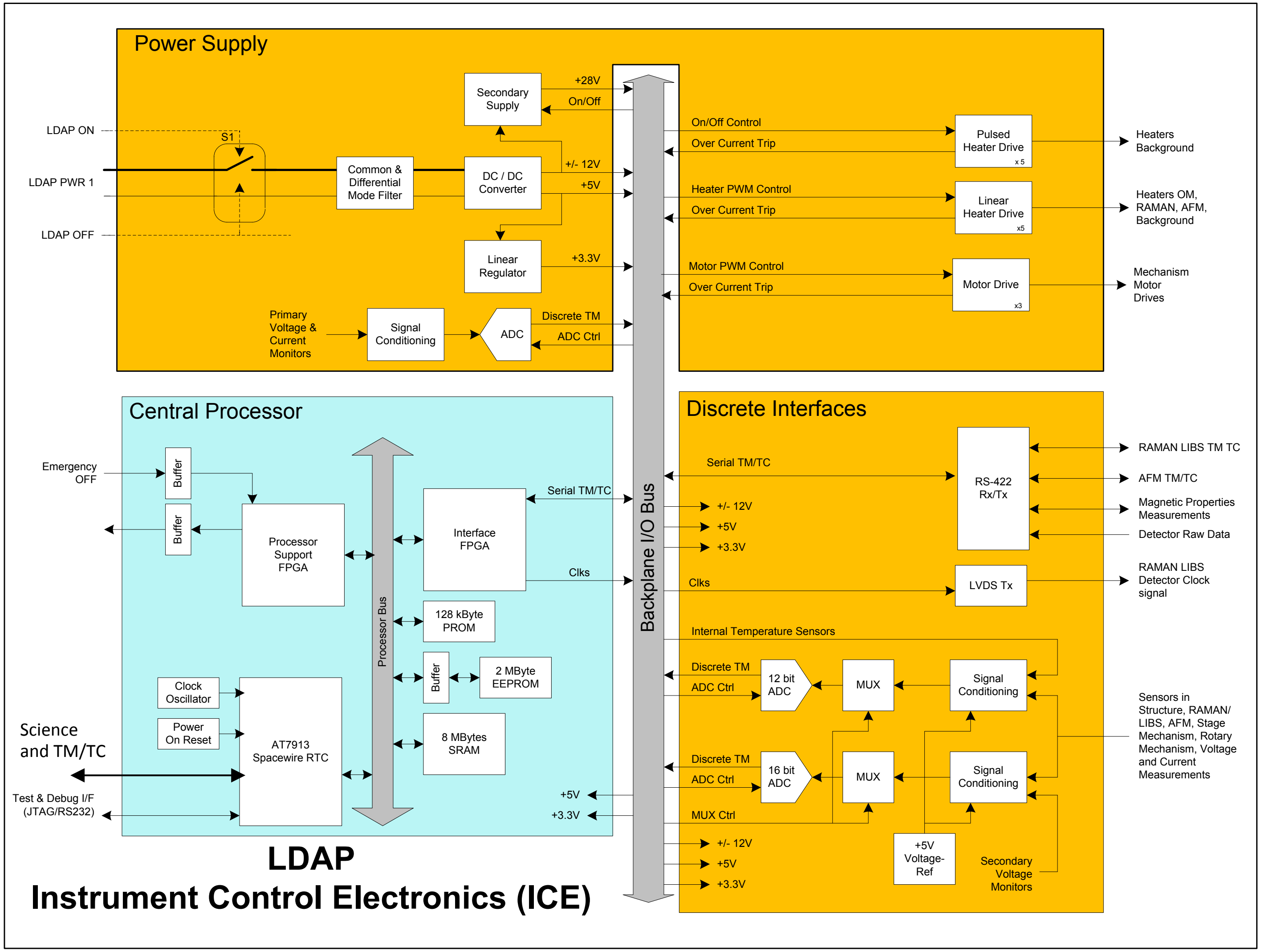




- Max stress: 10.152 Mpa. Factor of Safety: 11.82.
- Max displacement (centre): 0.81 mm.
- Mass estimate: 0.632 kg.
- Volume estimate: 478.6 cm^3.

11 - Electronics: Overview

ICE is responsible for:
- Handling all lander platform interfaces
- Ensuring correct function and health of L-DAP instruments
- Performing support functions, i.e. Data handling, monitoring and control activities, routing science data to lander.



11 - Electronics: Modules

- **Power Module**: power feed from lander power distribution unit. L-Dap may be switched off completely if necessary. Includes DC/DC converter and regulators for Instrument Supplies. The module is also responsible for heater drivers and temperature control of L-DAP.

- **Discrete Interfaces Module**: acquires all the thermistors, analogue values and bi-switch status from instruments and subsystems, as well as internal data from current and voltage monitors. Also incorporates the interfaces as required for serial command and monitoring of each instrument . These use RS422 buffers and have a max data rate of 10 Mbits/s.

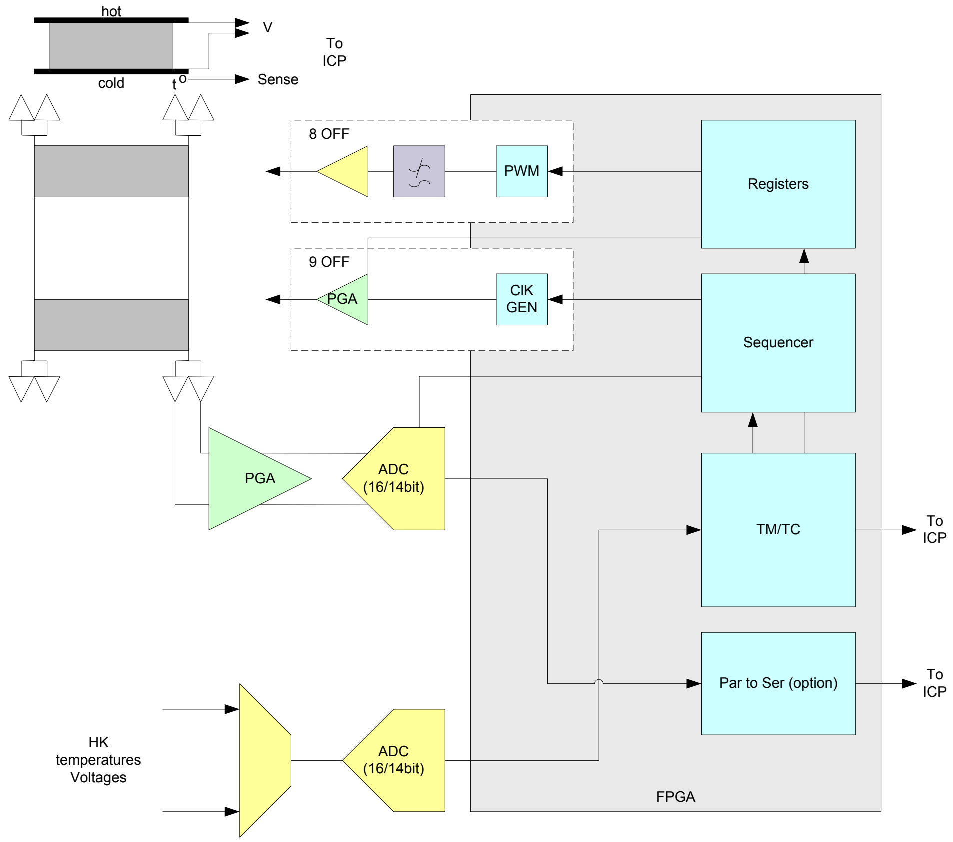
  Recently acquired analogue values are available for immediate access by application software in a memory mapped buffer. Application software is simplified and there are no timing constraints.

  Supplies clock/sync line to ROICs/FEE at detector interfaces.

11 - Electronics Modules; Front End Electronics

- Image from CCD within the spectrometer unit is shifted out through a single port which is acquired and processed by the FEE
- No concerns about FEE being remote (few hundred mm from CCD)
- The FPGA provides programmable PWM with analogue low-pass filter and amplifier to generate demanded bias voltage (x8)
- ~0.1V step resolution (0-30V).
- The drive current is 1A
- ADC up to 16 bit with 800kbps required.
- Clocks (x9) require high voltage (~10V) and high capacitance (up to 12nF).
- High speed op-amp required to buffer the MUX output and provide the high capacitance drive

- **Some harmonisation with other detectors (eg OM and LOM) should be possible (save mass/cost)**



11 - Electronics: Modules

- **Central Processor Module**: manages interfaces between platform and processor and internal communication buses on backplane
  - Atmel AT7913 processor running at 33 MHz, with SpaceWire Link to Lander
  - SRAM (8 Mbytes), EDAC protected.
  - 2 banks of EEPROM for application code images (2 x 2 MBytes), EDAC protected.
  - EEPROM and RAM databuses are 40 bits wide (inc. 8 bits for EDAC protection).
  - 128 kBytes radiation-hardened PROM for boot code.
  - Memory buffer to support transfer of platform interface messages and negate need for DMA on processor bus.
  - 2 FPGAS: one for processor/platform interfaces; one for instrument interfaces (including FEE functions for R/L Spectrometer, OM and LOM)

11 - Electronics: Physical Design

- ICE is made up of 3 main PCBs connected by a backplane board and is housed within the L-DAP package.
- Dimensions: 240 mm (h) x 240 mm (w) x 60 mm (l).
-

Module	Mass (kg)	Comment
Power Module	0.9	Based on Similar PCBs
Central Processor Module	0.6	Based on Similar PCBs
Discrete Interfaces	0.4	Based on Similar PCBs
Total	1.9	

-

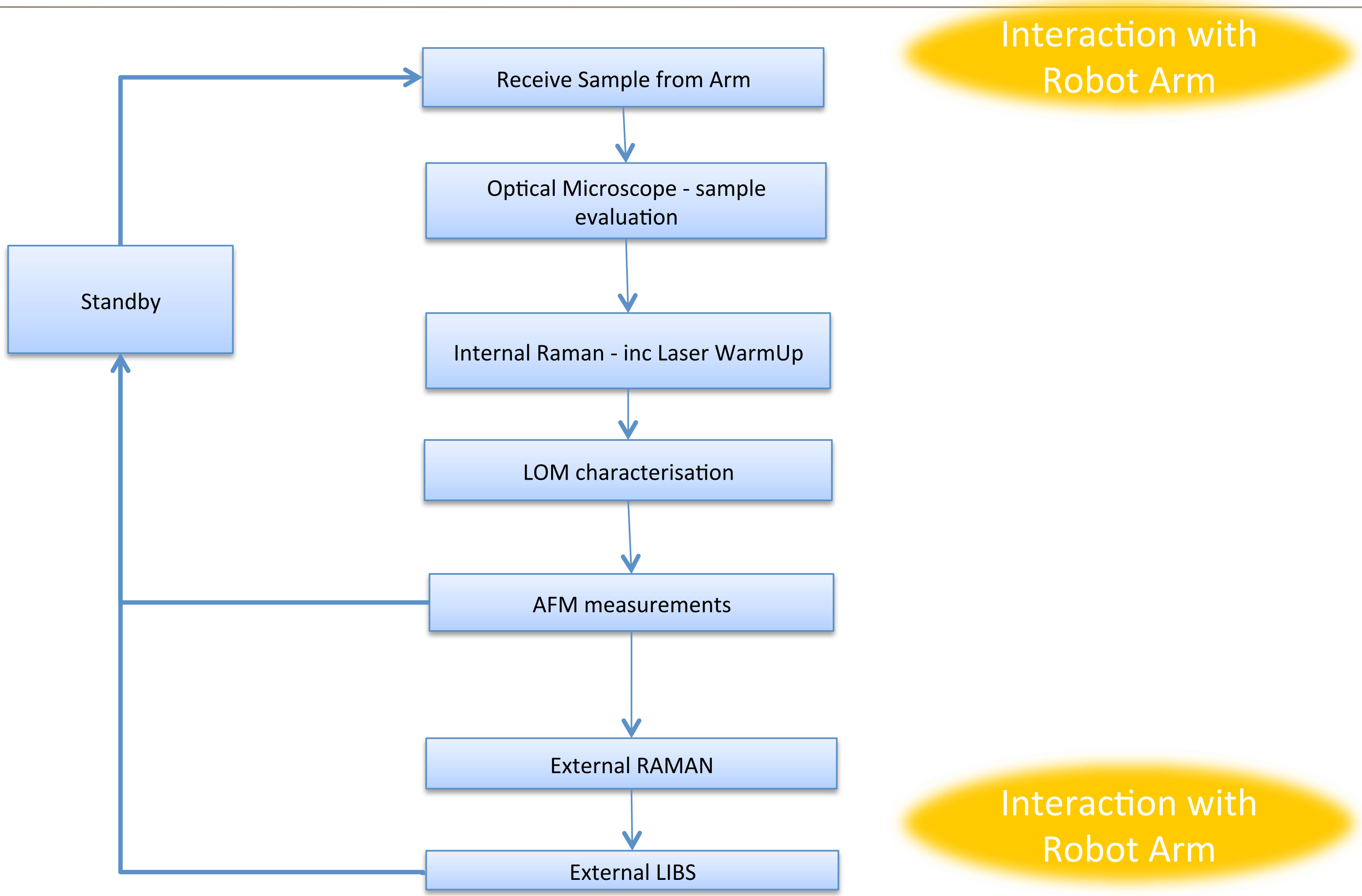
Module	Power (W)	Comment
Power Module	6	Includes all losses for power passed on to instruments
Central Processor Module	7	
Discrete Interfaces	1	
Total	14	

11 - Electronics: Software

- **Boot Software**: runs at start-up or reset. Performs self-tests on ICE processor and hardware before initialising Central Processor and loads and starts applications software. It comprises the following architectural component:
  - Hardware and Software initialisation
  - Application Software loading
  - Boot report
  - Processor Module services

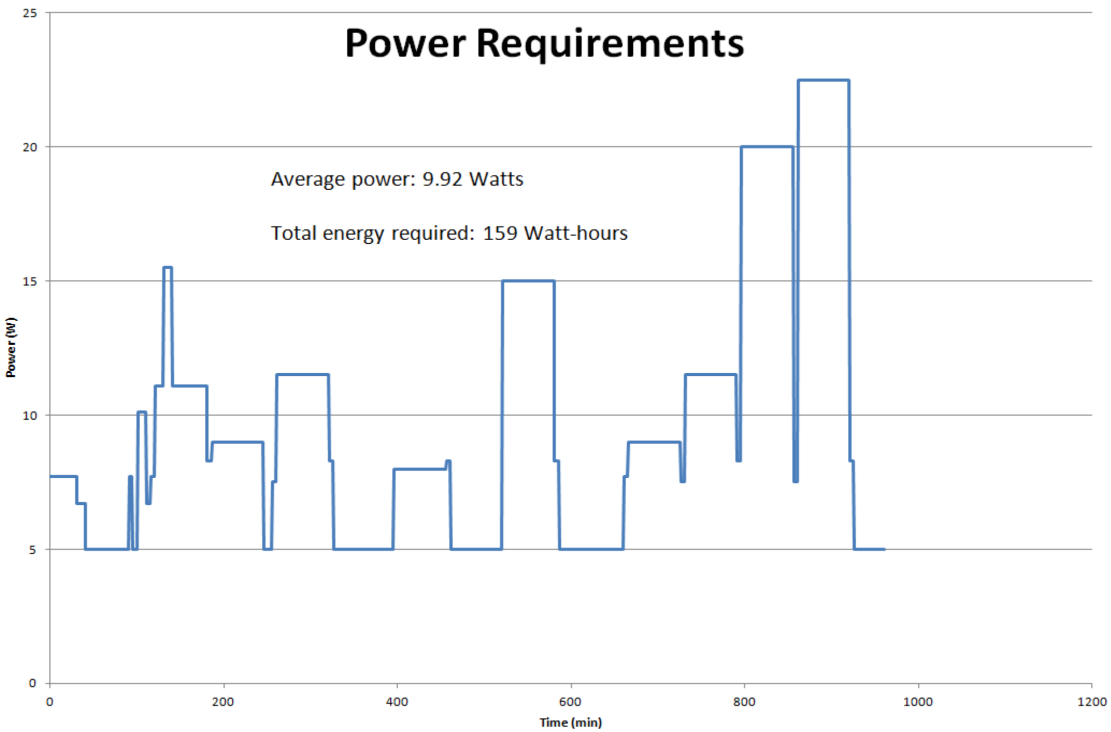
- **Application Software**: located in EEPROM. Manages L-DAP system and performs the following functions: interface configuration, mode management, instrument monitoring, memory scrubbing, error detection and handling, platform command handling, HK TM response packet generation, activity timing, mechanism commanding, mechanism drive timing, thermal control, high level communications protocol handling.

11 - Operations Modes



11 - Operations Modes – Power and Data

Payload mode	Power consumption (W)	Power line	Data rate (kbit/s)
Receive sample	8 W average; 10.1 W peak	Primary Power Line	
Optical Microscope	10.4 W average; 11.1 W peak	Primary Power Line	4 x 48 Mbit (4 colour images)
Internal Raman	9.9 W average; 11.5 W peak	Primary Power Line	7 Mbit/spectra x 5 spectra
LOM	7.9 W average; 8.3 W peak	Primary Power Line	81 x 3 Mbit/image
AFM	13.5 W average; 15 W peak	Primary Power Line	40 Mbit/image
External Raman	9.9 W average; 11.5 W peak	Primary Power Line	7 Mbit/spectra x 5 spectra
External LIBS	15.4 W average; 22.5 W peak	Primary Power Line	7 Mbit/spectra x 5 spectra
Standby	5 W average.	Primary Power Line	1kbit/sec (housekeeping)



12 - Next Steps...Prior Phase B..

- LIBS in vacuum requires further analysis and test such as;
  - Spectroscopy (getting calibration measurements from known target etc)
  - Debris (use of witness plates etc)
  - Target system (formation of pellets instead of powder, angle of collection optics)
  - Advanced LIBS (pre-pulse, colliding plasmas)
- TUD have identified an investigation which is needed to define the details of investigating Magnetic Force Microscopy to measure nano-Phase Fe. This consists of ;
  - Preparing samples
  - Control experiments with TEM/AFM
  - MFM experiments with different tips
  - MFM experiments in vacuum
- Simulink allows mechanisms, electronics and sensors to be modelled accurately and a model of the SHS and interfaces with the Autofocus, AFM drive and Spectrometer/ROIC electronics definition. Model based design has been proven to save money in complex developments by reducing the amount of physical models required. Such modelling will allow better performance assessments and tuning to be made.

12 - Phase B/C/D main activities

- **Development Models for :**
- LIBS Laser
- Internal Optical Head
- External Optical head
- Fibres and Raman Laser (and autofocus)
- Spectrometer Grating
- Selected Optical elements to be combined with the grating
- Detector
- Sample Handling (actuators, gearing, position determination)
- AFM Scanner and Electronics
- LOM (detector, Laser Diode, commercial scanner, structural elements, AFM head)
- Control Electronics (reprogrammable FPGAs, commercial power parts) allows development of FEE

- ## Engineering Model (with some EQM)

- EMs for all elements except Spectrometer (EQM) due to complexity and risk

12 - Phase B/C/D main activities

- Flight Model (PFM)
- All equipment –proto levels
- Flight Spares
- Spare PCBs, and parts to remake Central Electronics/FEE -
- Spectrometer Unit, build and tested
- Testing of Flight Model/Cleanliness...
- Ground Test/Reference Model
- Refurbished from the EM/EQM
- Allows operations and procedures to be developed
- Allows debugging to be performed which might be difficult with simulator
- EGSE/SCOE
- Parallel development of the instruments requires multiple sets of SCOE/EGSE (ie representing key interfaces such as sample handling and central electronics/FEEs
- Development to be started as soon as possible

12 - Schedule for Phase B/C/D

ID		Task Name	Duration	Start	Finish	Prede
1		Kick Off	0 days	Wed 02/01/13	Wed 02/01/13	
2		**Phase B**	**508 days**	**Wed 02/01/13**	**Fri 12/12/14**	
3		System Consolidation Phase	40 days	Wed 02/01/13	Tue 26/02/13	
4		FEE EM Prelimnary Design	250 days	Wed 27/02/13	Tue 11/02/14	3
5		Central Electronics Preliminary D	280 days	Wed 27/02/13	Tue 25/03/14	3
6		Build Electronic BB	70 days	Wed 26/03/14	Tue 01/07/14	5
7		Raman /LIBS Preliminary Design	308 days	Wed 27/02/13	Fri 02/05/14	3
8		AFM Preliminary Design	348 days	Wed 27/02/13	Fri 27/06/14	3
9		OM Preliminary Design	293 days	Wed 27/02/13	Fri 11/04/14	3
10		LOM Preliminary Design	313 days	Wed 27/02/13	Fri 09/05/14	3
11		Sample Handling Preliminary Des	188 days	Wed 27/02/13	Fri 15/11/13	3
12		Sample Handling BB	193 days	Mon 18/11/13	Wed 13/08/14	11
13		FEE Breadboarding	178 days	Wed 12/02/14	Fri 17/10/14	4
14		EGSE/SCOE Design Phase	180 days	Mon 18/11/13	Fri 25/07/14	11
15		Raman/LIBS BB testing with Elec	100 days	Mon 28/07/14	Fri 12/12/14	14,6
16		PDR	0 days	Fri 12/12/14	Fri 12/12/14	4,5,7,
17		**Phase C**	**539 days?**	**Mon 15/12/14**	**Thu 05/01/17**	**2**
18		PDR Closeout	30 days	Mon 15/12/14	Fri 23/01/15	
19		EM MRRs	0 days	Fri 23/01/15	Fri 23/01/15	18
20		EGSE/SCOE development	215 days	Mon 26/01/15	Fri 20/11/15	19
21		SCOE/EGSE delivery	0 days	Fri 20/11/15	Fri 20/11/15	20
22		FEE EM Programme	200 days	Mon 26/01/15	Fri 08/01/16	19
23		Central Electronics EM Program	250 days?	Mon 26/01/15	Fri 11/03/16	19
24		Raman LIBS EM programme	200 days	Mon 26/01/15	Fri 30/10/15	19
25		Raman LIBS testing with FEE/Det	50 days	Mon 11/01/16	Fri 18/03/16	24,22,
26		AFM EM Programme	255 days	Mon 26/01/15	Tue 05/04/16	19
27		OM EM Programme	225 days?	Mon 26/01/15	Mon 14/03/16	19
28		LOM EM Programme	250 days?	Mon 26/01/15	Mon 09/05/16	19
29		Sample Handling EM programme	235 days	Mon 26/01/15	Mon 02/05/16	19
30		System Integration	84 days	Tue 10/05/16	Fri 02/09/16	29,21,
31		System Testing	89 days	Mon 05/09/16	Thu 05/01/17	30
32		CDR	0 days	Thu 05/01/17	Thu 05/01/17	31
33		**Phase D**	**412 days?**	**Fri 06/01/17**	**Mon 06/08/18**	**17**
34		FEE PFM Programme	110 days?	Fri 06/01/17	Thu 08/06/17	
35		Central Electronics PFM Progran	240 days	Fri 06/01/17	Thu 07/12/17	
36		RAMAN LIBS FM Programme	150 days	Fri 06/01/17	Thu 03/08/17	
37		RAMAN LIBS Integration and Tes	140 days	Fri 04/08/17	Thu 15/02/18	34,36
38		AFM FM Programme	240 days	Fri 06/01/17	Thu 07/12/17	
39		OM PFM Programme	240 days	Fri 06/01/17	Thu 07/12/17	
40		LOM PFM Programme	240 days	Fri 06/01/17	Thu 07/12/17	
41		Sample Handling PFM Program	240 days	Fri 06/01/17	Thu 07/12/17	
42		System Integration	40 days	Fri 16/02/18	Thu 12/04/18	41,37,
43		Calibration	80 days	Fri 13/04/18	Thu 02/08/18	42
44		QR	2 days	Fri 03/08/18	Mon 06/08/18	43
45		Delivery to Lander	0 days	Mon 06/08/18	Mon 06/08/18	44