L-DEPP Executive Summary

L-DEPP

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1 INTRODUCTION

1.1 PROJECT DESCRIPTION

1.2 PURPOSE AND SCOPE

This document is the Executive Summary of the Lunar Dust, Plasma, Wawes and fields package for Lunar Exploration (L-DEPP) study of a consortium lead by Finnish Meteorological Institute. The subcontractors for FMI in this study were: 1) Swedish Institute for Space Physics - Kiruna (IRF-K), University of Bern and Arquimea.

In addition to Prime role, FMI was responsible of Instrument package system design and Lagnmuir Probe (LP) design. IRF-K was responsible on Ion/Electron Spectrometer (IES) design. Arquimea was responsible on design of the Dust Sensor (DS). University of Bern studied the Lunar dust properties.

This summarizes the proposed design for the L-DEPP payload. It is based on the evaluation and develoment work documented in the other technical documents provided in the context of this project. For technical and performace details see especially [RD3].

1.3 ABBREVIATIONS

Acronym	Meaning
TM/TC	Telemetry/Telecommand
TBD	To Be Defined
TBA	To Be Added
TBC	To Be Confirmed
SMA	Shape Memory Alloy
L-DEPP	Lunar Dust Environment and Plasma Package
IRR	Instrument Requirements Review
RQ	Requirement
AD	Applicable Document
RD	Reference Document
IES	Ion / Electron Spectrometer
LP	Langmuir Probe
EMC	Electro Magnetic Compatibility
EGSE	Electrical Ground Support Equipment
MGSE	Mechanical Ground Support Equipment
I/F	Interface

Acronym	Meaning
FPGA	Field Programmable Gate Array
ADC	Analog to Digital Converter
CCEM	Ceramic Channel Electron Multiplier
SPEDE	Spacecraft Potential, Electron and Dust Experiment / ESA SMART-1 instrument
N/A	Not Applicable
DPU	Data Processing Unit
PROM	Programmable Read Only Memory
EEPROM	Electrical Erasable Read Only Memory
I/O	Input / Output
PDCU	Power Distribution and Conditioning Unit
IP	Intellectual Property
DAC	Digital to Analog Converter

1.4 REFERENCES

1.4.1 Applicable Documents

Reference	Document
[AD1]	LLB1-LES-ESA(HSF)-0001 Lunar Environment Specification
[AD2]	LLB1-SUM-ESA(HSF)-0001 Lunar Lander Mission Summary and Interfaces
[AD3]	Experiment Interface Definition Document: Part A (EID-A), vs. 23/05/2012.
[AD4]	

1.4.2 Reference Documents

Reference	Document
[RD1]	LL-ESA-ORD-413 Lunar Exploration Objectives and Requirements Definition
[RD2]	LDEP-FMI-TN-001 L-DEPP Requirements Specification and Concept Recommendation
[RD3]	LDEP-FMI-TN-007 L-DEPP Payload Interface Document
[RD4]	
[RD5]	

2 L-DEPP SCIENCE

2.1 PROPERTIES OF THE LUNAR DUSTY PLASMA ENVIRONMENT: SUMMARY

The properties of the dust above the lunar surface depends on the properties of the Sun, the solar wind, and the properties of the Moon itself. Figure 1 gives a schematic illustration of the physical parameters, which affect to the charging of dust particles. Moreover, Figure 1 shows the physical parameters affecting the electric field, which can lift and accelerate dust particles.

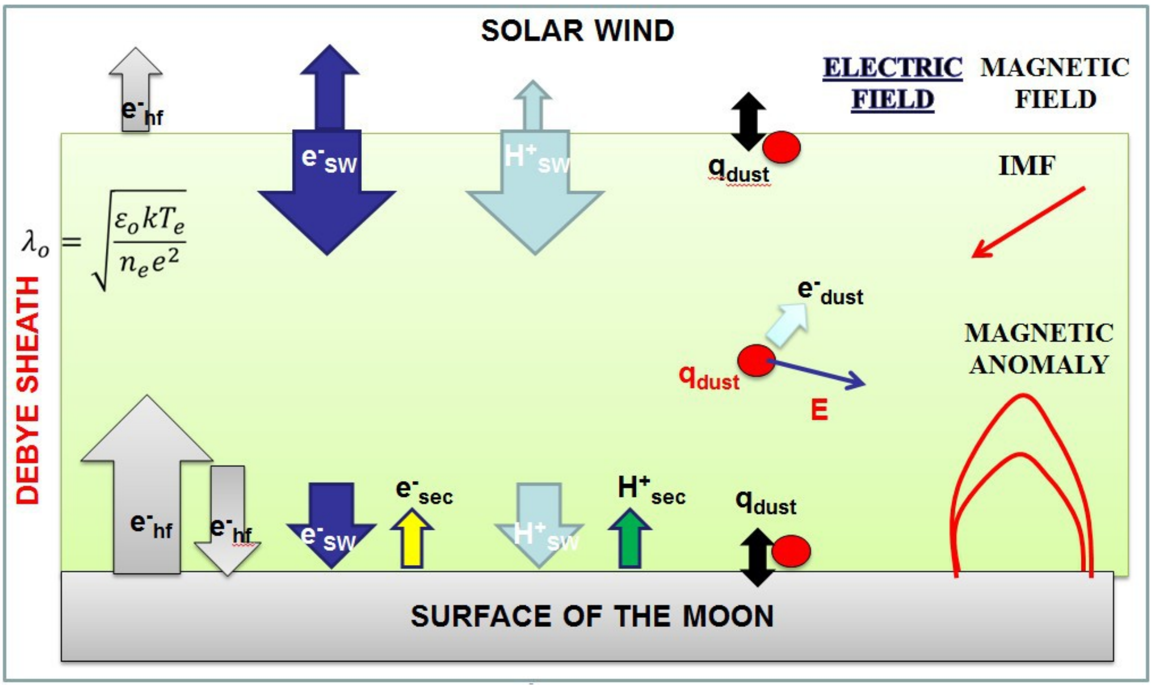

Figure 1: Summary of the identified critical physical parameters for the lunar dust environment based on the L-DEPP study.

2.1.1 Protons and electrons

i) Solar wind protons and electrons

Solar wind electrons and ions affect to the Lunar surface potential, charging of the dust and, consequently, to the acceleration of the dust particles. The properties of the solar wind plasma at Moon have spatial and temporal variations due to many resons: The Moon is orbiting around the Earth, the Moon is part of its orbit period in the magnetosheath, in the magnetotail and in the plasma sheet, the solar wind has also long-term and short-term variations, and due to the varying illuminating conditions.

ii) Photoelectrons

Photoelectrons are emitted when a photon is absorbed on the Lunar surface making the lunar surface positively charged. The properties of photoelectrons have also noticeable spatial and temporal variations because: The illumination conditions change from location to location on the surface and have temporal variations while the Moon is orbiting around the Earth, the shape of the energy distribution function (as well as the photoelectron current) depends strongly on the surface material, and because the photoemission depends on the energy spectra of the sun light.

iii) Secondary ions and electrons

The impacting charged particles to the surface can result in emission of charged particles from the surface. The secondary electron yield depends on the energy of electrons and on the properties of the surface.

vi) Dust electrons

A dust particle can be a net sink or a net source of electrons. If an initially neutral dust particle becomes negatively charged, it has been a net sink for electrons. A dust particle is instead a net source of electrons if it is positively charged.

2.1.1 Electric field and electric potential

One critical unknown physical parameter is the shape of the electric potential function near the Lunar surface. The details of electric potential depends on the relative importnat of two electron populations: *Lunar electrons* (photoelectrons, secondary electrons and dust electrons) and the *solar wind electrons*. The former(latter) source alone would make a monotonically decreasing(increasing) potential with increasing altitude. In the cases when both sources are important the electric potentail is non-monotonic and there can be a local minimum between the surface and the solar wind. This electric field associated with the charged particles abowe the surface can therefore change its direction. The second important electric field source is the *cohesive force* which connect a dust particle on the lunar surface.

2.1.2 Charged dust particles

A dust particle attached on the lunar surface or a lifted charge particle is electrically charged. The charging level of the particle depends on the solar illumination, and the ambient electron and ion plasma. The charge of a dust particle at a given point can be negatively charged or positively charged depending on the electron and ion velocity distributions and on the UV light conditions. As already emphasized, the properties of electrons and ions near the Moon have temporal and spatial variations and, consequently, also the charging of a dust particle varies in time and in space. Two important factors, which are currently not well determined, which affects the dust charging are the shape and the electric properties of the dust particles. These uncertainties limits our possibility to analyse and to model the lifting and the acceleration of the lunar dust particles accurately.

2.1.4. Magnetic field

Lunar surface has two kind of magnetic fields: the magnetic field associated with (1) the Lunar magnetic anomalies, and (2) with the interplanetary magnetic field, IMF, and its currents. The role of the magnetic field for the lunar potential sheath is not well established but it is foreseen that the magnetic field, especially near strong magnetic anomalies, affects to the properties of the plasma and the electric field because the magnetic field affects to the motion of the charged particles. Especially, electrons can move more easily along the magnetic field line than perpendicular to it, which can affect to the electric potential and how easily electrons can flow to various places in 3D space.

2.2 SCIENTIFIC REQUIREMENTS

In the L-DEPP science requirement study the starting point was ESA's science requirements which are shown in Table 1, the column on the left. During the L-DEPP project, those requirements were critically evaluated and their rationaly estimated. This scientific evaluation resulted in L-DEPP science requirements. Table 1, the column on the right, summarises the obtained L-DEPP science requirements. As can be seen in Table 1, the L-DEPP project proposed to focus on relatively strongly charged and relatively slowly moving particle and to measure relatively smaller electric potential range that seen in the ESA's science requirements. Another important feature that the L-DEPP project does not propose to have a radio instrument onboard but rather suggests to put resources (mass, power, telemetry etc.) to the proposed L-DEPP instruments (see Section 4).

Original ESA requirements	**Derived L-DEPP requirements**
RQ1 Measure the charges on levitating lunar dust particles > 0.1 fC	Charge: > 1 fC
RQ2 Measure velocities for levitating lunar dust particles in the velocity range 1 – 5000 m/s	Velocity range: < 100 m/s
RQ3 Determine the sizes and charges of grains as a function of height and time	- Size range (radius) 0.1 to 6 μm - Time resolution: ≤ 1 min
RQ4 Determine the trajectory of levitated dust particles to < 1°	Angular resolution: ≤ 30°
RQ5 Measure the temperature of the local plasma	- LP: [0.1, 3] eV - IES: SW plasma
RQ6 Measure the density of the local plasma	- LP: [0.1, 100] cm-3 - IES: SW plasma
RQ7 Measure electric surface potential in the range from 10V to – 10 kV with respect to the interplanetary plasma potential and associated electric fields	- Electric potential: [-200, +50] V - Vertical electric field: [-50, +50] V/m
RQ8 Monitor the radio spectrum in the range 10 kHz - 100 MHz with 100 MHz instantaneous bandwidth	No requirements *(no radio instrument)*

Table 1: Original instrument requirements (left colums) vs. derived instrument requirements (right column)

3 L-DEPP SYSTEM

3.1 L-DEPP SYSTEM DESIGN

The proposed L-DEPP payload consists of three separate mechanical units:

1. the Power Distribution and Conditioning Unit (PDCU), the central Data Processing Unit (DPU) with integrated Langmuir Probe front-end electronics, the mechanically attached Ion / Electron Spectrometer (IES) with its own front-end electronics and the mechanically attached deployment system for the Langmuir Probe boom 1,
2. the deployment system for the Langmuir Probe boom 2,
3. the Dust Sensor with front-end electronics and deployable sensor net cage.

Unit 1 should be mounted close to the edge of the upper panel with a free field of view for the IES and a clear deployment direction for the LP boom outward from the Lander.

Unit 2 should be mounted close to the edge of the lower panel such that both deployed LP-booms are vertically above one another. The distance between both LP sensors should be as large as feasible to increase the precision of the electric field measurement. The deployment volume should be sufficiently far away from the deployed Lander legs to avoid mechanical problems during deployment and electrical interference with the LP-measurement due to grounded Landing gear structure elements.

Unit 3 should be mounted at the lower edge of a side panel with an unobstructed deployment and measurement volume.

All electrical interfaces to the Lander system are routed through the unit 1. The DS is connected to unit 1 by a power and a bi-directional serial data link. The sensor at the tip of each LP-boom is connected to the LP-front-end electronics inside the DPU via a Triax-cable each. The heater and thermal cable cutter at each LP-boom deployment device are connected to separate +5V supplies of the PDCU via shielded double-wire cables.

The DPU is based on a Field Programmable Gate Array (FPGA) with 32-bit processor IP-core, memory and interface control system and the sequencer and DAC for the LP detector. All data interfaces are implemented as differential serial lines. Housekeeping monitoring of voltages, currents and temperatures are implemented as ADC-IP-core into the central FPGA. This design allows the minimization of the DPU's power consumption and concentrates needed radiation protection measures to one component which is available as radiation hardened version.

Figure 1 shows a block diagram of the proposed L-DEPP instrument package and the electrical connections between the units and towards the Lander system. Figure 2 shows the proposed accommodation of the three L-DEPP units.

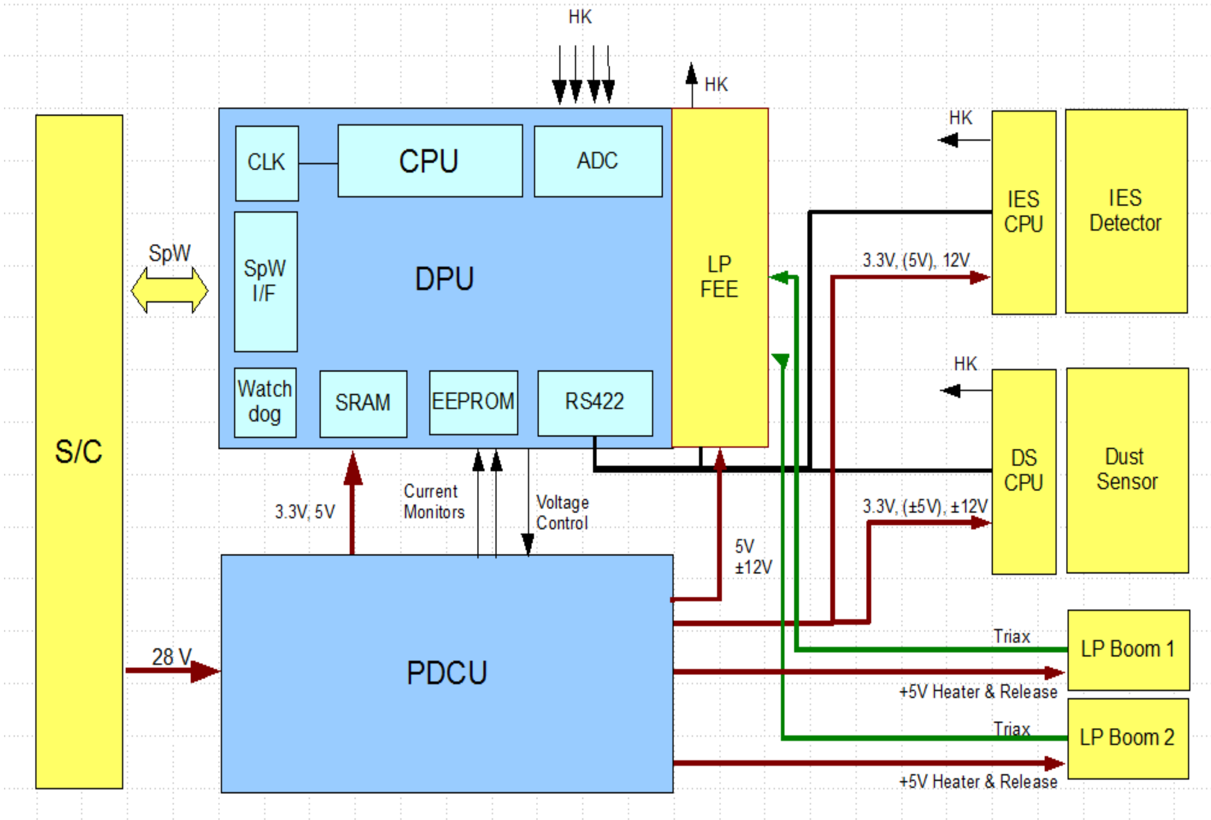

Figure 2: L-DEPP block diagram

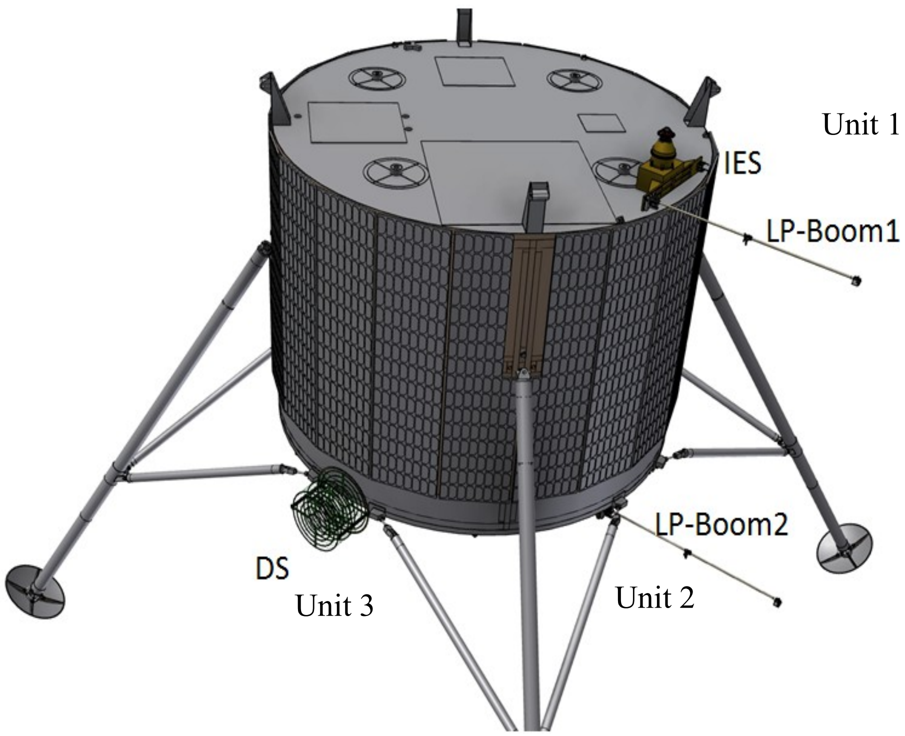

Figure 3: Proposed accommodation of the 3 L-DEPP units

4 L-DEPP SENSOR PACKAGE

4.1 ION / ELECTRON SPECTROMETER

The IES unit is mounted on top of the DPU box and contains the front-end electronics of the spectrometer. While not measureing the spectrometer entrance is protected by a motor controlled lid. To ensure the functioning of the lid mechanism the upper part of the spectrometer structure has to be heated by non-operational heaters as long as the IES itself is not powered. Figure 4 shows the structure of the IES with closed and opened lid:

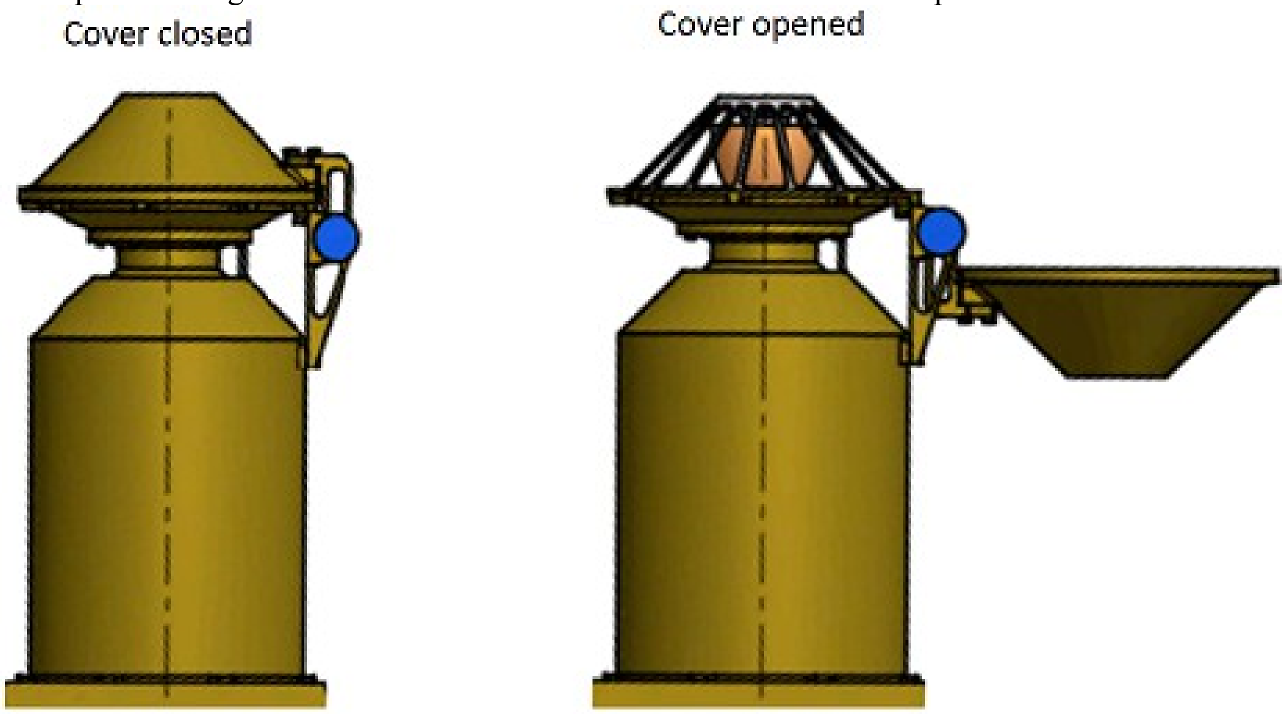

Figure 4: IES with cover mechanism

Depending on the polarity of the acceleration high voltage and the start-signal plate the analyzer works as either ion or electron analyzer. Via an optimized entrance geometry and electrostatic sweeping up to 5 kV the Ceramic channel electromultipliers (CCEMs) detector has a full 2 π field of view coverage across the energy and mass range. A reflectron is used to increase the mass resolution. Details are shown in figure 5 . The detector achieves an angular resolution of 22.5° azimuth x 11° elevation and an energy resolution of dE/E = 0.1 .
The detailed operation of the IES and data preprocessing including signal filtering are handled by an own processor implemented in the control FPGA of the front-end electronics. The front end electronics provides 16 separate counters for the azimuth bins and separate timing controls for low and high mass resolution operation.

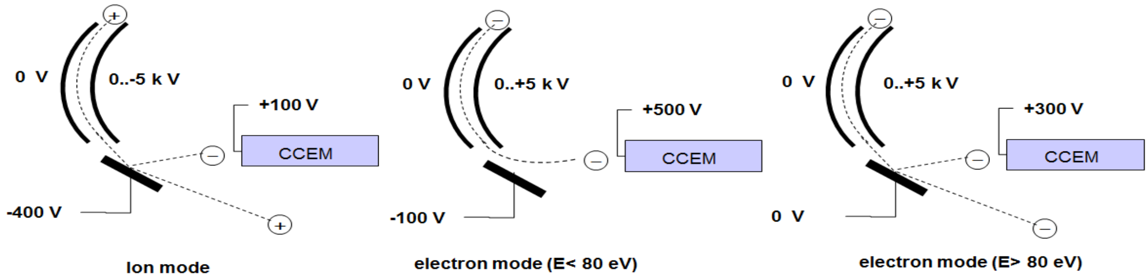

Figure 5: IES functional principle

4.2 LANGMUIR PROBE FRONT END ELECTRONICS

The Langmuir probe works in two different modes.
Langmuir mode: The sequencer generates via its DAC function a bias voltage reference ramp between 0V and +4.5V which is amplified and level-shifted to a range of -12V to +12V. In a voltage booster stage the resulting voltage is translated to -400V to +400V. The booster stage is disabled if the high-voltage protection connector is inserted. The resulting current from the sensor causes a voltage drop across a series resistor, which is amplified, level-shifted to a range between 0.75V and 2.25V and monitored by the ADC-function of the FPGA. Only one sensor is activated at a time to prevent modification of the near field by the high voltage of the other probe.
Electric Field mode: The bias generator is disconnected from the sensor lines by reed relais which instead connect the sensor lines to a high-impedance differential amplifier which monitors the potential difference between the two sensors. The result is monitored by the ADC. If sampled with 40 kHz, plasma waves up to 20kHz can be measured. Averaging over a few samples the electric field between the two sensors is measured directly. For a calibrated result the relative geometry of both sensors has to be known as precisely as possible.

4.3 LANGMUIR PROBE BOOM 1 AND 2

The spheric detector is mounted at the tip of a 1.1 m long 2-segment folded carbon fiber tube boom filled with foam as enforcement. The deployment is controlled by a spring located inside the mounting plate, see fig. 6 for boom 1 at unit 1. The folded boom is locked by a wire to the mounting plate. A wire cutter releases the boom which locks into its final configuration after reaching the final configuration. To ensure the deployment also under cold vacuum conditions, the hinges have to be heated for a few minutes before the wirecutter releases the springs. The hollow metallic detector sphere of 7 cm diameter is covered with a few micrometer thick Titan Nitrid layer which is very resistant against pollution and minimizes photoelectric effects. The 154 cm^2 conductive area is connected from the inside of the sphere to the central wire of a Triax-cable, which is rooted through the inside of the boom tube and should be rooted further to the Triax-connector at the DPU box. No intermediate connectors are foreseen to prevent signal losses and capacitve coupling of the high-impedance signal to the structure. The inner cable shield is used as guard, actively kept at the same potential as the signal wire, but without connection to the sensor area or the measurement circuitry.

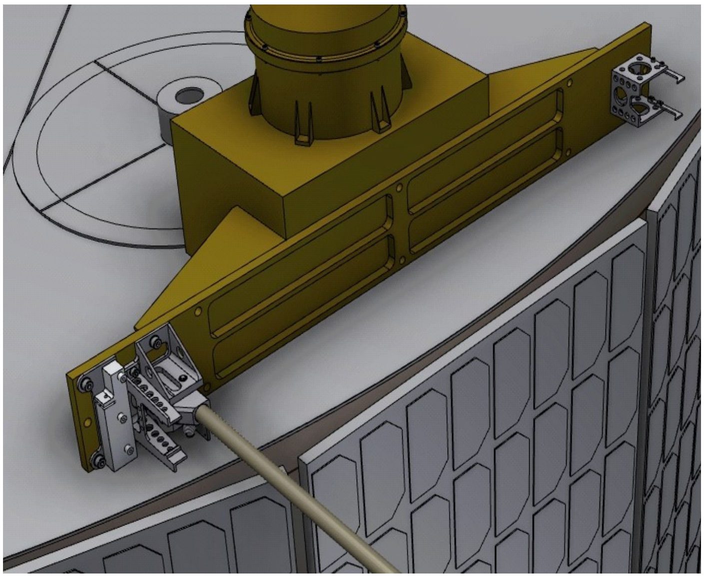

Figure 6: LP-boom 1 in deployed position, integrated with DPU and IES unit

4.4 DUST SENSOR

A deployable cylindrical metal wire grid, shown in fig. 7 is used to detect the trajectory, velocity and charge/mass ratio of passing charged dust particles with low sensitivity to radiation and with the capability to operate in a wide range of environmental conditions. From its flat stowed position the grid can be opened by a very simple spring loaded system.

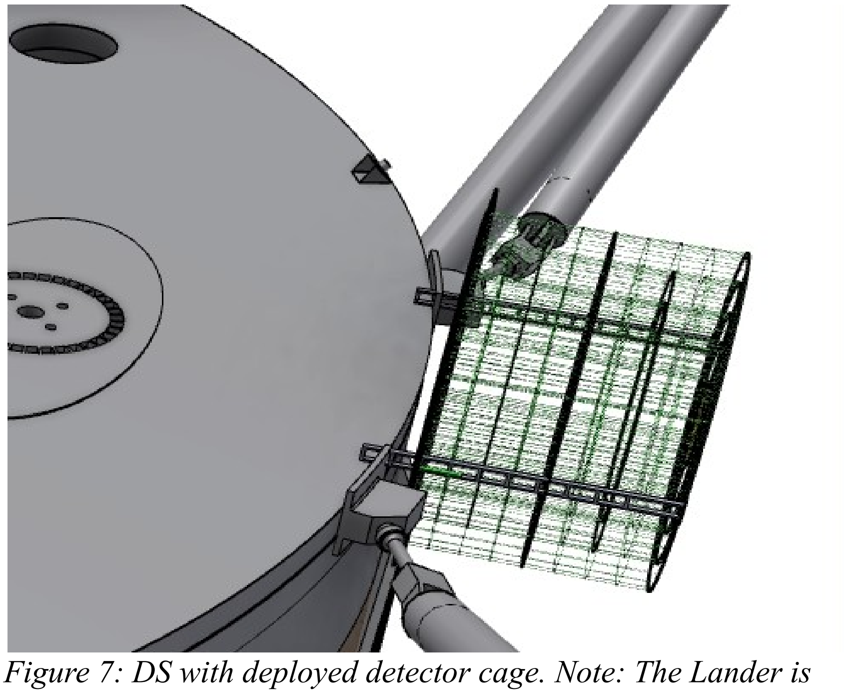

Figure 7: DS with deployed detector cage. Note: The Lander is shown bottom up!

4.4.1 Measurement principle

Induced charge sensor.

If a charged particle is moving near a conductive wire it induces an electric signal that can be measured and registered. Crossing through the grid it will induce a charge on each wire of the grid with the amplitude depending on the distance between the particle and the grid. Dedicated ASICs placed at the bottom of the grid amplify the signals and measure the location of the particle's passing. With several grids placed at known distances it is possible to estimate the following parameters:

- **Trajectory.** Figure 8 shows a schematic representation of a particle crossing two grids separated by a distance d. The wires in the close vicinity of the particle trajectory will a generate stronger signal than the others. In this way the trajectory of the particle can be calculated.
- **Velocity:** Registering the time where the particle crosses both grids and knowing the distance between grids it one can calculate the velocity of the particle.
- **Charge:** From the induced charge in each individual wire measured as the amplitude of the induced signal the charge of the dust particle can be estimated.
- **Mass:** Once the charge, direction and velocity of the incoming particle are known, its mass can can be determined by the deflection angle caused by an additional electric field between the innder grids.

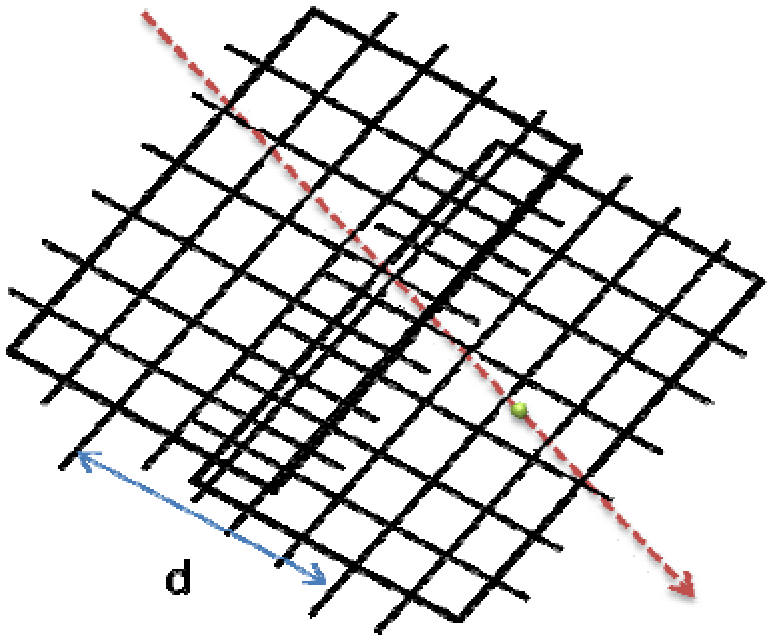

Figure 8: Induced charge technique principle of measurement

4.4.2 Mounting

When mounted to Lunar Lander's lower panel and the grid protruding outwards from the lander body, the instrument is capable of measuring particles moving in ballistic trajectories, upwards and downwards, and also be capable of detecting particles moving horizontally. The field of view is approximately 360º, permitting measuring particles which cross the cage upwards, downwards or laterally, see fig. 9

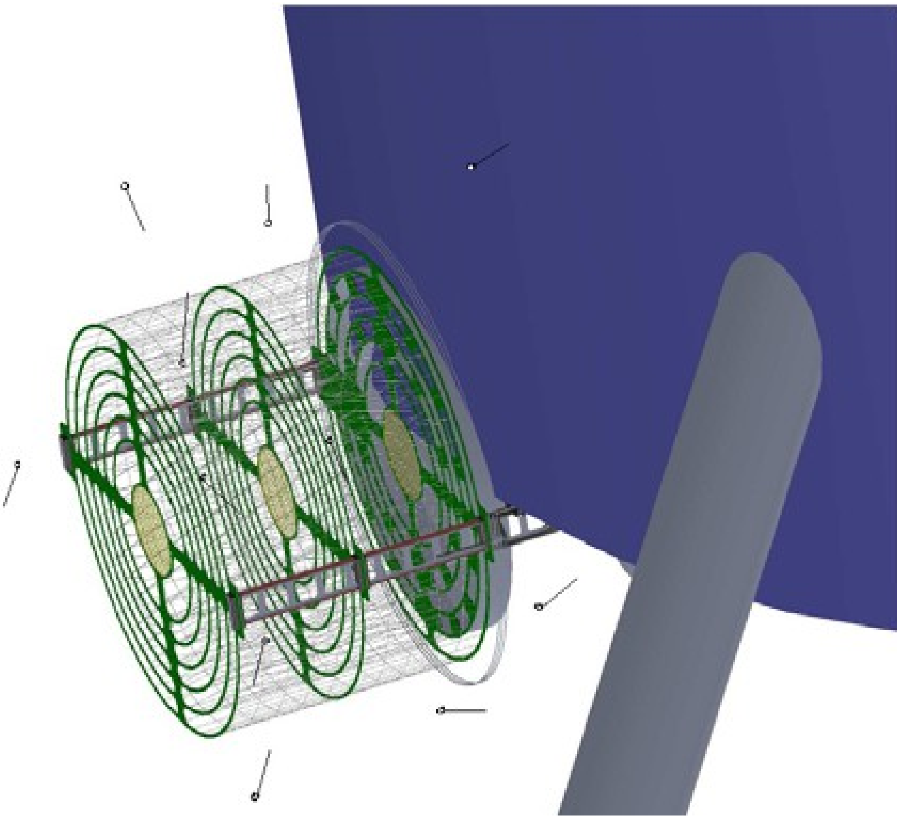

Figure 9: Cylinder cage proposed is able to measure particles arriving from several directions

The sensor is created using 7 concentrically cylinders as shown in Figure 11:
External cylinder (1): Faraday cage that protects the inner sensing elements from external spurious electromagnetic fields. This grid will be used as measuring reference for all induced charge measurements.
Second and third cylinders. They are formed by sensitive wires used for measure induced charge as a charged particle crosses them. These two cylinders outline the basic measuring cell. Trajectory, velocity, mass and charge of the particle are estimated from measurements obtained from second and third cylinder and measurement in fourth and fifth cylinders.
Fourth and fifth cylinders. They are formed by sensitive wires used for measure induced charge as a charged particle crosses them. These two cylinders outline the basic measuring cell. Trajectory, velocity, mass and charge of the particle are estimated from measurements obtained from second and third cylinder and measurement in fourth and fifth cylinders.
Sixth cylinder. Faraday gace connected to the external grid used for protect the second and third cylinder from external spurious electromagnetic fields.
Inner cylinder (7). Using the horizontal plates of this inner cylinder an electric field is

generated and used for particle trajectory deflection.

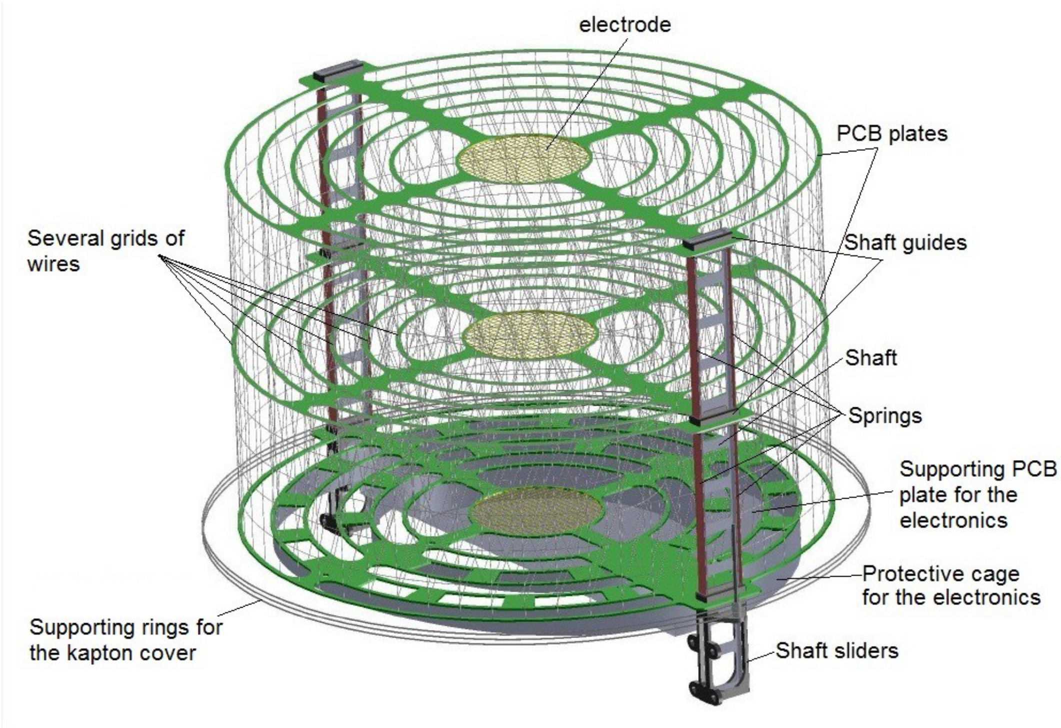

Figure 10: General overview of the cylinder cage of the sensor

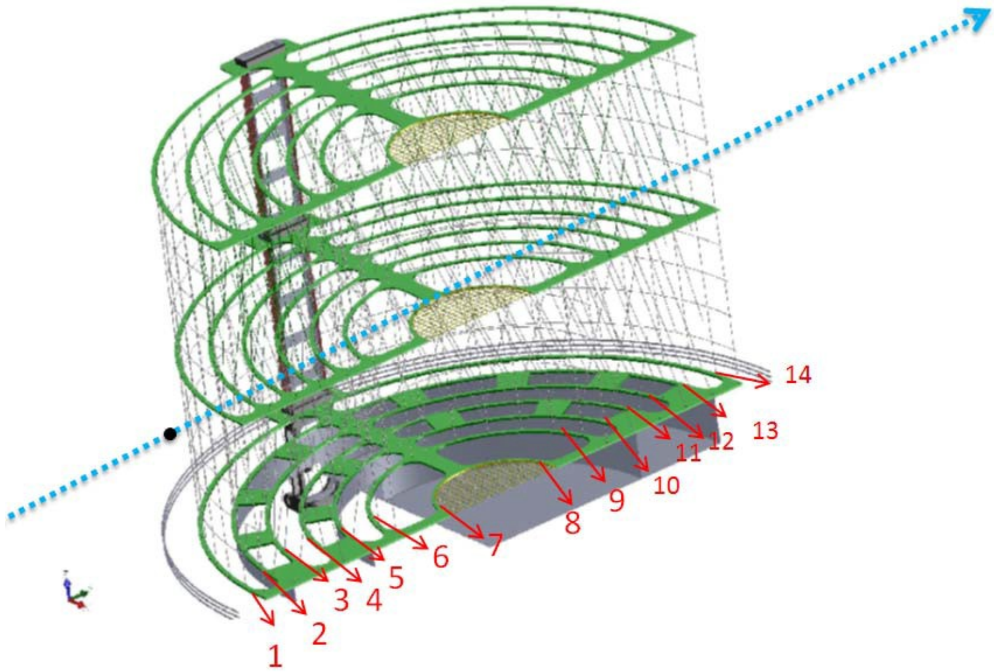

Figure 11: Crossection of the cylinder cage

4.4.3 Deployment Mechanism

The deployment system is based on the action of eight springs in two sections operating between the Teflon sliders in the sides of the PCB plates (refer to Figure 12 and Figure 13). Springs are made of thin curved metal shafts. The force applied by this kind of springs depends on the degree of curvature given to the plates in the axial direction. The springs will separate them simultaneously and will drag the support shafts, because they are fixed to the front shell.

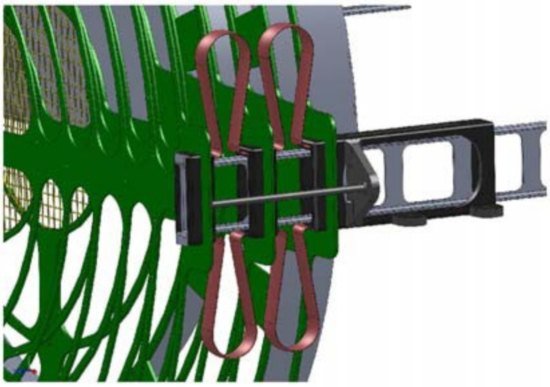

Figure 12: Springs compressed before deployment

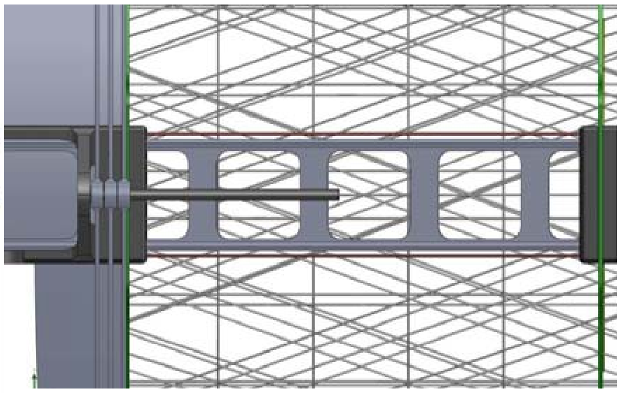

Figure 13: Springs deployed

Once the actuator is releases, the springs continue to push the sturcture open until they are completely extended. After full extension they will resist undeployment of the cage and become structural elements that are fixing the position of the PCB plates, hence increasing the stiffness of the system.

The release mechanism is Shape Memory Alloy (SMA) based pin-puller actuator, which releases the strusses and the spring mechanism.

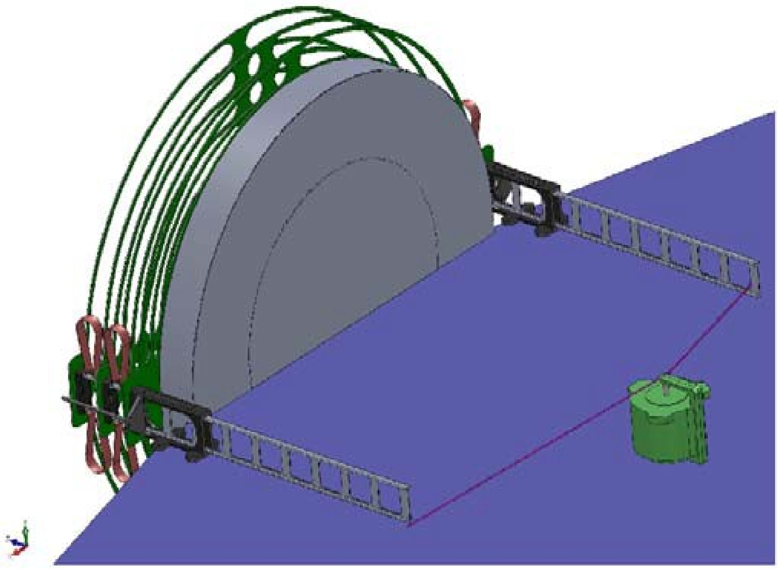

Figure 14: Deployment of the cylinder cage

5 INSTRUMENT BUDGETS

5.1 ENVELOPE

	Dimension (mm)	Remarks
Height	282	
Width	215	This is IES part of mechanics. LP boom and IES are in same mechanics, together overall width is 605mm
Depth	142	This is IES part of mechanics. LP boom and IES are in same mechanics, together overall depth is 224mm

Table 2: Dimensions of Unit 1 (including PCDU, DPU, IES and LP-boom 1)

	Dimension (mm)	Remarks
Height	282	
Width	215	This is IES part of mechanics. LP boom and IES are in same mechanics, together overall width is 605mm
Depth	142	This is IES part of mechanics. LP boom and IES are in same mechanics, together overall depth is 224mm

Table 3: Dimensions of: LP-boom 1 mounting and deployment structure:

	stowed (mm)	opened (mm)	Remarks
Height	90	90	
Width	605	605	
Depth	142	1268	

Table 4: Dimensions of Unit 2 (including LP-boom 2)

	Folded (mm)	Unfolded (mm)
Height	229,60	50.60
Width	358.98	358.98
Depth	358.98	358.98

Table 5: Dimensions of Unit 3 (Dust Sensor):

5.2 MASS BUDGET

Unit		**Mass [kg] (20% margin)**
Unit-1 without LP-boom 1		**2.42 (2.91)**
	DPU	0.32
	Power system	0.40
	IES	1.20
.	LP-electronics	0.10
	DPU-structure	0.40
Unit -1.1		**0.20 (0.24)**
	LP-boom	0.20
Unit -2		**0.20 (0.24)**
	LP-boom	0.20
Unit 3 DS		**0.490 (0.588)**
	Induced charge	0.282
	Electronics	0.071
	Mechanism Release	0.050
	Protective cover	0.070
	Screws	0.017
L-DEPP total		**3.31 (3.98)**

Table 6: L-DEPP instrument mass budget

5.3 POWER REQUIREMENTS

PCDU: Input +20 .. +34V DC, average power_ 9V including 20% margin

Unit	Mode	Power (W)	Remarks
DS	Sleep mode	0	
	Release	16.0	Few seconds
	Idle	0.4	
	Check	0.5	
	Heating	TBD	
	Induced Charge measurement	11.0	TBC
	Trajectory deflection measurement	12.0	TBC
	Data Transfer	3.0	TBC
IES	Stand-by	0	
	Nominal	7.1	
	Burst/wave	N/A	
	Deployment	5.8	
	Heater	8.0	TBC
LP	Stand-by	0.10	
	Nominal	0.22	
	Burst/wave	TBD	
	Custom	TBD	
	Deployment	4.0	
DPU	Stand-by	0.1	
	DPU Nominal	0.6	
	Interface Nominal	TBD	Depends on used standard
	Interface Transfer	1.0	TBC
	Other Electronics Nominal	TBD	

Table 7: L-DEPP instrument power requirements

5.4

5.5 DATA VOLUME AND RATES

Housekeeping:
IES: Nominal: 8kb/s for IES-I, 1kb/s for IES-I; bust mode TBD
LP:

Stand-by: 1 / s, housekeeping only
Langmuir mode: <1kbit/s
E-field 1 (raw data): <10kbit/s
E-field 3 (power spectrum): <0.5kbit/s

DS:

Chek-out: 100 bytes once per activation
Observation: 10 kByte once per measurement. Data rate TBD

6 SCIENTIFIC PERFORMANCE

One of the main clonclusion of the analysis of the properties of the plasmas and field near the lunar surface is that the parameter ranges of many (even critical) physical parameters relevant to lunar dusty-plasma environment are not well known. In many cases there are not even estimates of the typical parameter value and when estimates existing, the values are based on highly simplified models and assumptions.
Altought these uncertainties it is antisipated that the science requirements most relevat to caracterice the relevan for caraterisiing of the lunar dusty-plasma anvironment can be fulfilled by an instrument package which contains four instruemnst: [1] The Dust Sensor (DS), [2] the Ion/Electron Spectrometer (IES) and [3] the Langmuir probe (LP). The physical parameters which can be characterised by these tree instruments are illustrated in Fig. 15: The LP instrument will focus to characterice the fields (electrci field), the IES instrument focus on the charged elementary particles and the DS instrument focus on the properties of the dust.

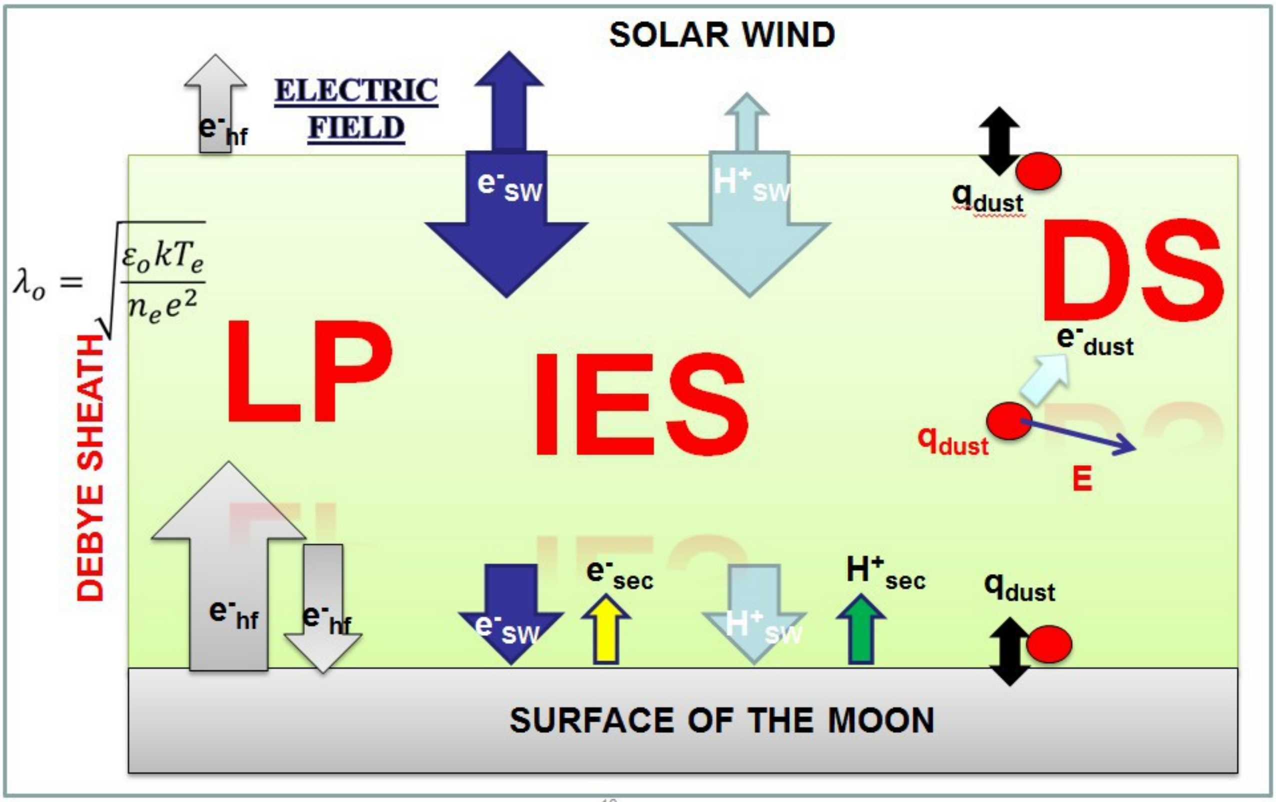

Figure 15: Summary of the proposed instruments for the Lunal Lander based on the L-DEPP study.

6.1.1 Dust Sensor (DS)

The proposed dust sensor will measure the velocity vector and charge of the dust particles. The mass of the dust particle is proposed to be derived indirectly combined the obtained measurements and models of the lunar plasma environment. To fully characterize the

Lunar dust, the proposed instrument concept is a deployable cylindrical cage through which particles can pass (see Section 4 for details).

6.1.2 Ion/Electron Spectrometer (IES)

The proposed IES instrument will contain two sensors: [1] An electron spectrometer, which will measure the energy spectra of “hot” electrons (IES: Sensor-E), and [2] an ion mass spectrometer, which will measure the energy spectra and mass/charge ratio of ions (IES: Sensor-I). The IES instrument is proposed to be moundet on the top of the Lunar Lander (see Section 4).

6.1.3 Langmuir probe (LP)

The suggested LP instrument will measure the density and temperature of electrons, the electric field and the properties of the cold plasma. Using two sensor booms mounted above one another at one of the Lander's legs and at the top of the Lander body, the instrument allows determination of low energy plasma properties close to the Lander, spacecraft potential estimates for the Lander structure, and electric fields and their variations between the two booms.

Table 8 summarises the L-DEPP science requirements RQ1-LDEPP - RQ8-LDEPP and the instrument performance of the suggested L-DEPP instrument package. As can be seen in Table 8, the suggested instruments are compliant with the L-DEPP science requirements. Moreover, at several cases the instrument performance exceed noticeably the science requirements (RQ2-LDEPP, RQ4-LDEPP, RQ7-LDEPP). Note that L-DEPP instruments can not measure directly the radius of a dust particle and that has to be derived indirectly from L-DEPP measurements with modelling.

L-DEPP science requirements	Instrument performance	Compliance
RQ1-LDEPP Charge: > 1 fC	Charges: > 1 fC	YES
RQ2-LDEPP Velocity range: < 100 m/s	Velocity range: [1, 1000] m/s	YES
RQ 3-LDEPP - Size range (radius) 0.1 to 6 μm - Time resolution: ≤ 1 min	0.01 C/kg (For a range of particles velocities: 33– 105 m/s) - Time resolution: 4 MHz	N/A YES
RQ4-LDEPP Angular resolution: ≤ 30°	Angular resolution: 1°	YES
RQ5-LDEPP - LP: [0.1, 3] eV - IES: SW plasma	- LP: *at least* [0.1, 3] eV - IES: SW plasma	YES YES
RQ6-LDEPP - LP: [0.1, 100] cm-3 - IES: SW plasma	- LP: *at least* [0.1, 100] cm-3 - IES: SW plasma	YES YES
RQ7-LDEPP - Electric potential: [-200 ,+50] V - Vertical electric field: [-50 , +50] V/m	- Electric potential: [-400 , +400] V - Vertical electric field: [-200 , +200] V/m	YES YES

Table 8: L-DEPP science requirements v.s. Instrument performance: Summary