A reliable and lightweight dust sensor for Mars missions based on spectral and angular resolutions of local IR scattering.

METEO ExoMars20 Dust Sensor characteristics and performances

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Saariselka, Finland
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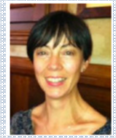
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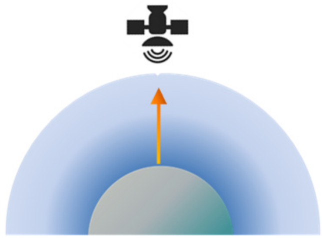
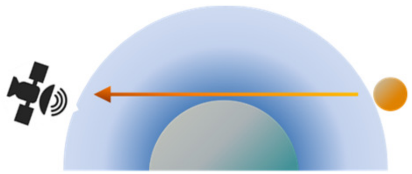
Measuring dust in Mars



Nadir measurements



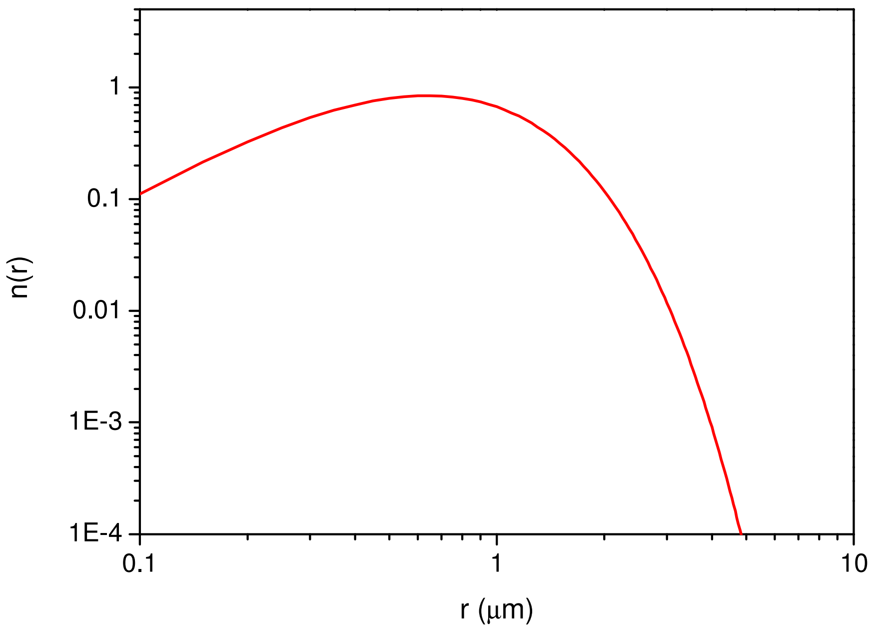
Solar occultation measurements)profiles)

Sky brightness measurements

These techniques have always an “integrated” character

These measurements can not explore the surface

Measuring dust in Mars



$$n(r) = c\, r^{\alpha}\, exp\left\{-\frac{\alpha}{\gamma}\left(\frac{r}{r_m}\right)^{\gamma}\right\}$$

(Deirmenjian 1969))

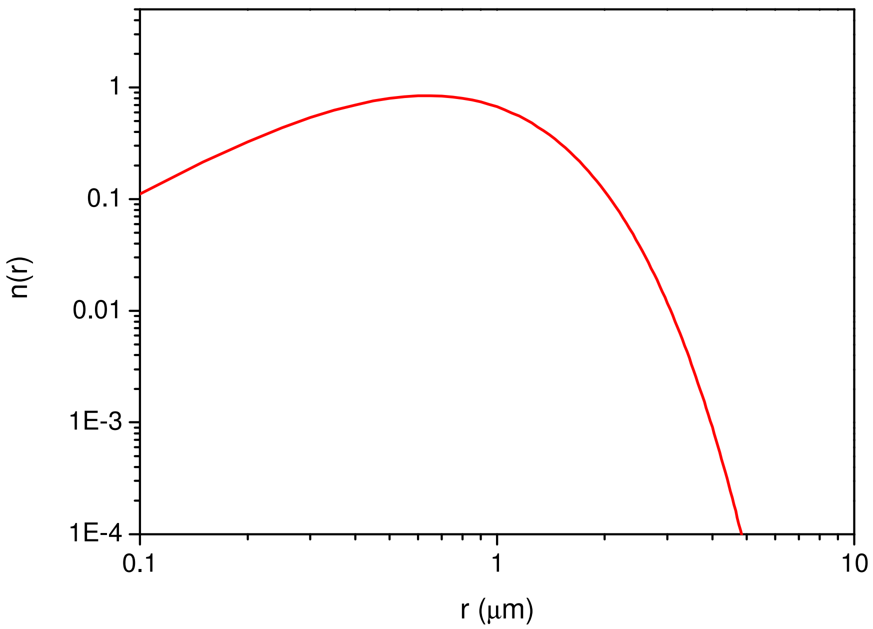
$$n(r) = c\, r^{\frac{1-3\,\nu_{eff}}{\nu_{eff}}}\; e^{-\frac{r}{r_{eff}\,\nu_{eff}}}$$

(Hansen and Travis 1974)

Mathematical expression for n(r) is imposed in the retrieval model

r_{eff} and ν_{eff} are the parameters to be retrieved

Measuring dust in Mars



r_{eff} = 1.6 ± 0.15 µm
ν_{eff} = 0.35 ± 0.15 µm

Pathfinder Imager: sky brightness measurements at VIS filters
(Tomasko et al. 1999)

Phobos: solar occultation λ= 1.9 and 3.7 µm
(Korablev et al. 1993)

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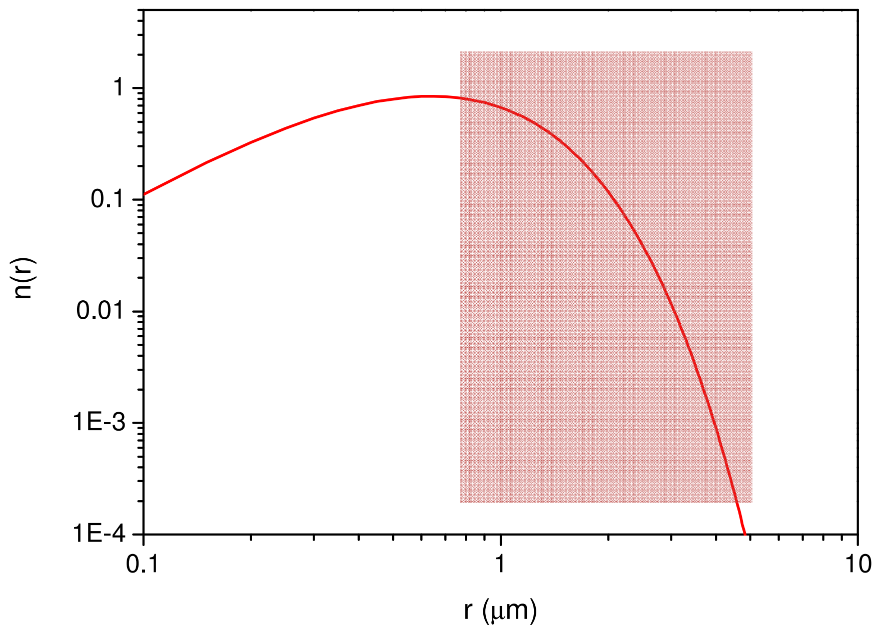

Particles in the micron-size range are expected

IR scattering is efficient for micron-size particles

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Scattering by a sphere: the Mie theory

Incident unpolarized plane wave

$$\begin{pmatrix} I_s \\ Q_s \\ U_s \\ V_s \end{pmatrix} = \frac{1}{k^2 r^2} \begin{pmatrix} S_{11} & S_{12} & 0 & 0 \\ S_{12} & S_{11} & 0 & 0 \\ 0 & 0 & S_{33} & S_{34} \\ 0 & 0 & -S_{34} & S_{33} \end{pmatrix} \begin{pmatrix} I_i \\ Q_i \\ U_i \\ V_i \end{pmatrix}$$

$$S_{11} = \frac{1}{2}\left(|S_2|^2 + |S_1|^2 \right)$$

$$\begin{pmatrix} E_{||s} \\ E_{\perp s} \end{pmatrix} = \frac{e^{ik(r-z)}}{-ikr} \begin{pmatrix} S_2 & 0 \\ 0 & S_1 \end{pmatrix} \begin{pmatrix} E_{||i} \\ E_{\perp i} \end{pmatrix}$$

$$S_1 = \sum_n \frac{2n+1}{n(n+1)} (a_n \pi_n + b_n \tau_n)$$

$$S_2 = \sum_n \frac{2n+1}{n(n+1)} (a_n \tau_n + b_n \pi_n)$$

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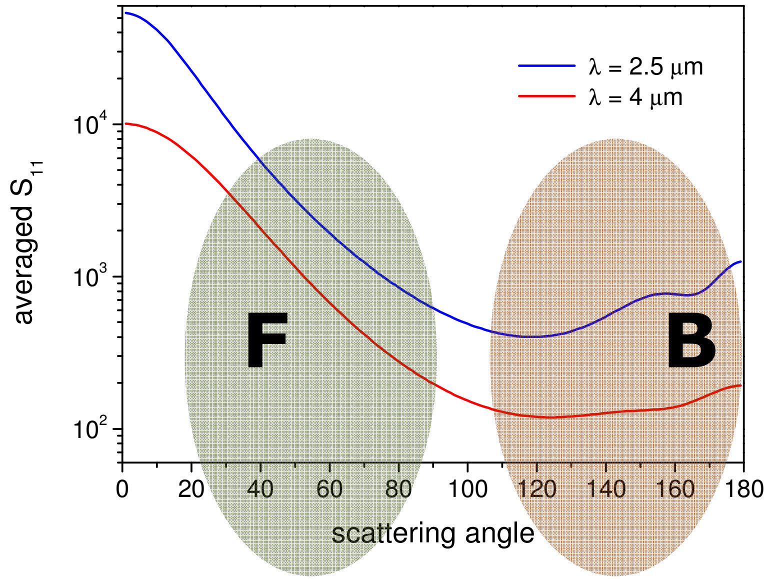
Averaging over the size distribution

$$S_{11}\,(\theta,\lambda) = \int_{rmin}^{rmax} S_{11}\,(\theta,\lambda,r)n(r)dr$$



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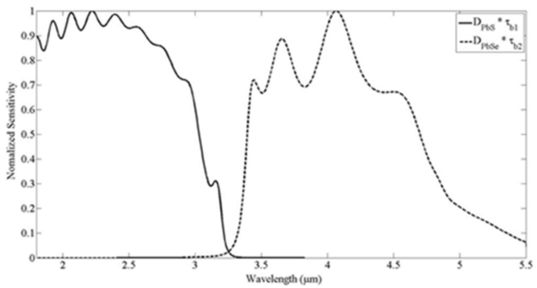
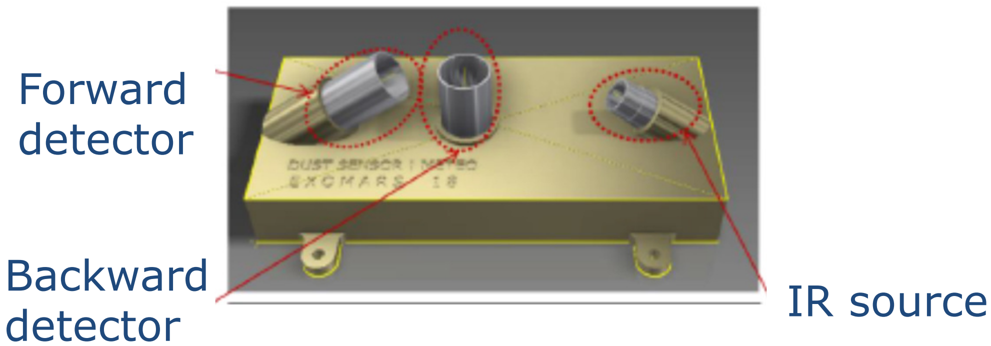
How many wavelengths?



How many spatial directions?



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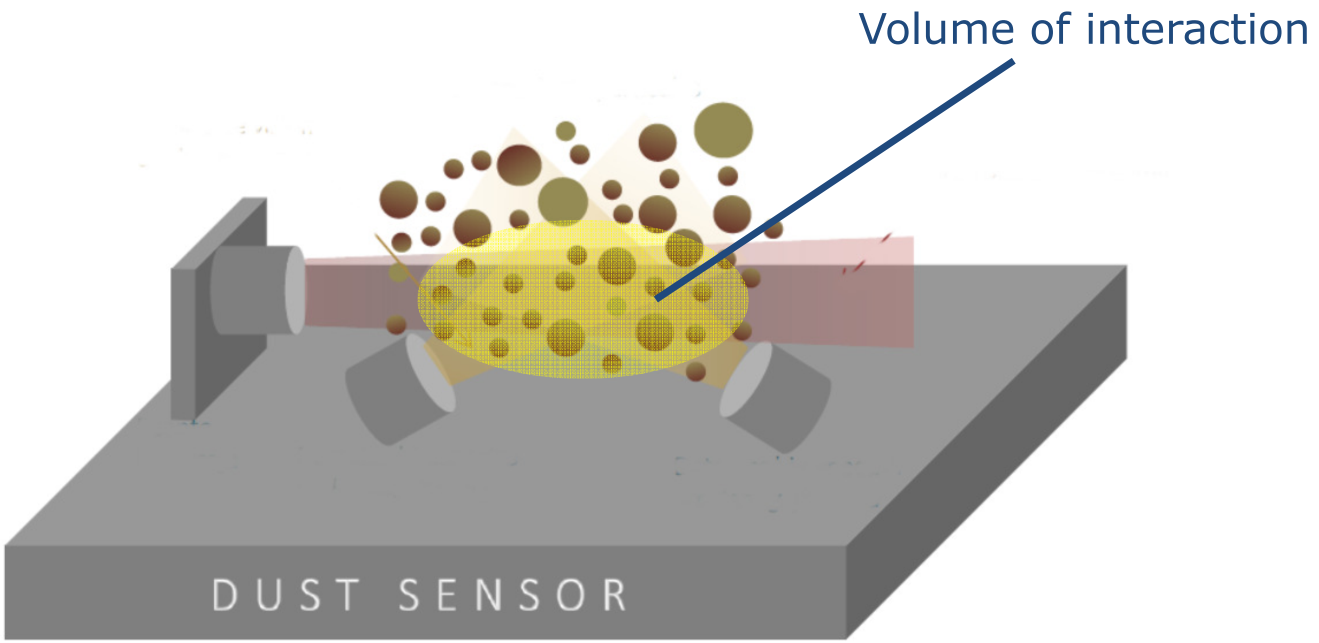
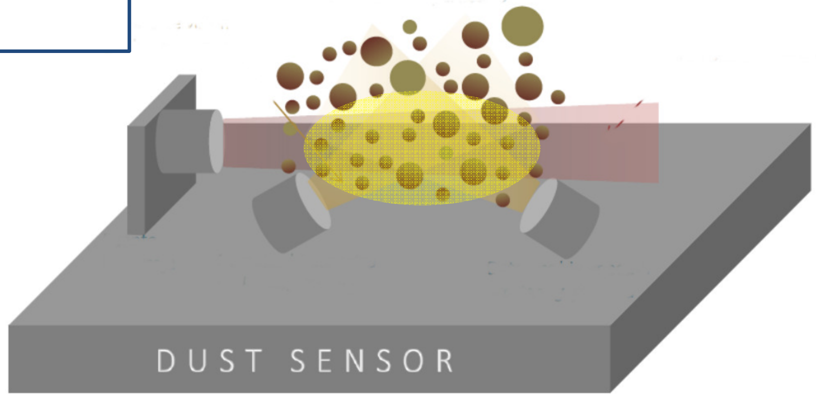


Simulating the DS

Simulate the emission of IR modulated source

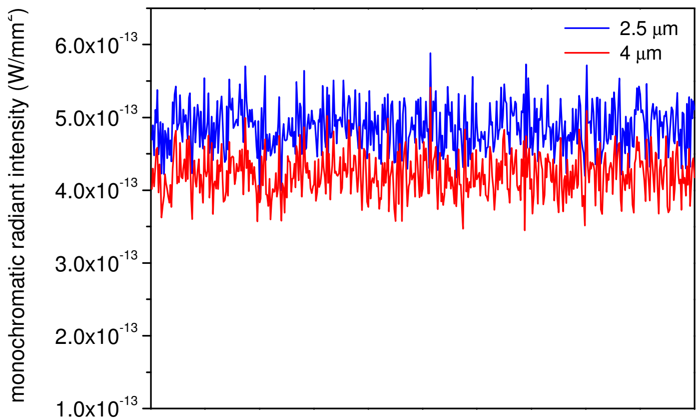
Calculate the histogram and locates each particle randomly into the volume of interaction



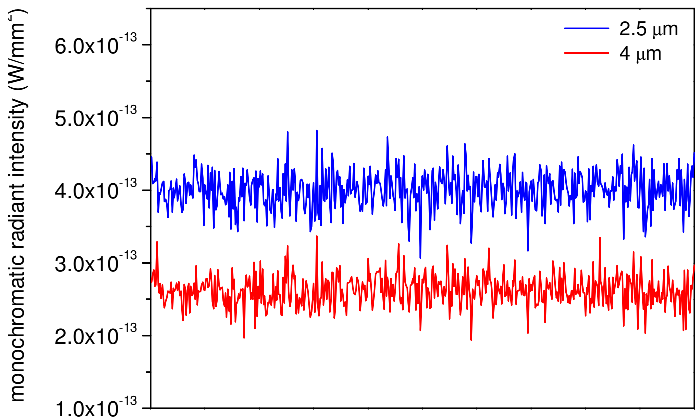
No need of absolute radiometric calibration

Elliptical concentrator integrated in the package (aprox 80x in each band)

Calculate the S_{11} element for each particle and the energy impinging in each detector according to the particle location

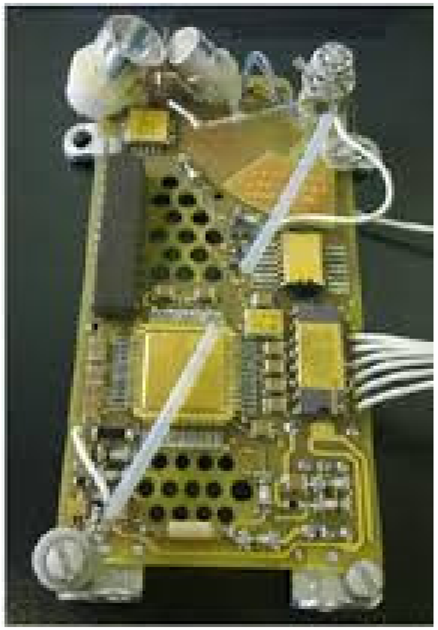

monochromatic radiant intensity (W/mm²)
6.0x10⁻¹³
5.0x10⁻¹³
4.0x10⁻¹³
3.0x10⁻¹³
2.0x10⁻¹³
1.0x10⁻¹³
2.5 µm
4 µm

F

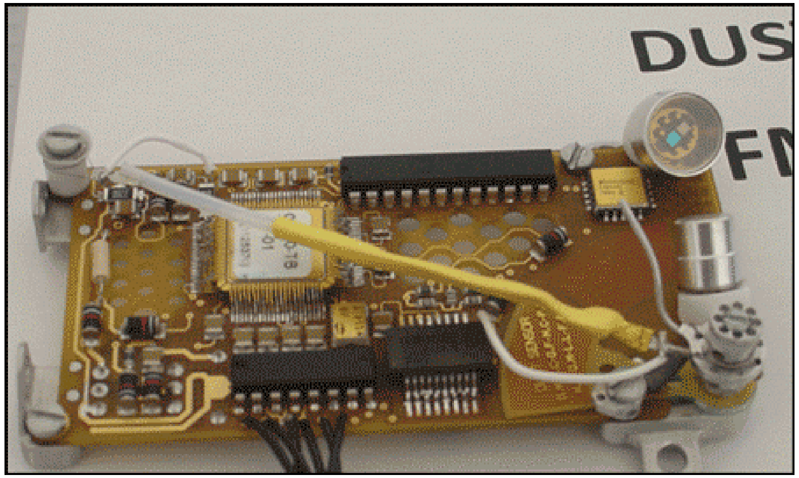

monochromatic radiant intensity (W/mm²)
6.0x10⁻¹³
5.0x10⁻¹³
4.0x10⁻¹³
3.0x10⁻¹³
2.0x10⁻¹³
1.0x10⁻¹³
2.5 µm
4 µm

B

Dust Sensor v1 - MetNet Precursor Mission



Bi-spectral (B1: 1-3 μm & B1: 3-5 μm)
Backscattering direction
Not protective case
<50 gr.
Engineering by Spanish Industry: ARQUIMEA
Ability to retrieve global dust concentration

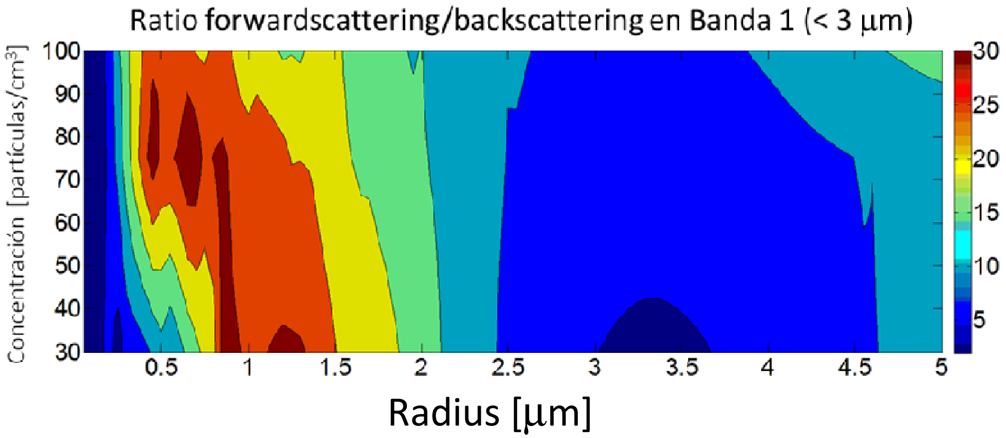


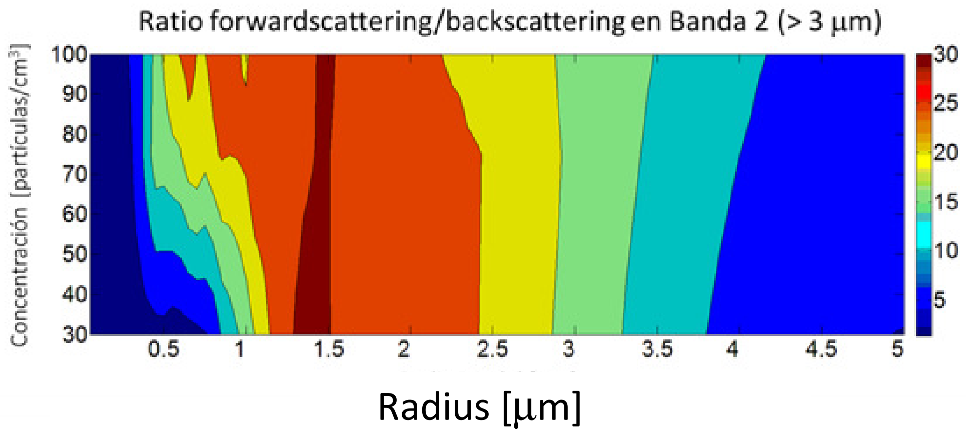
DS METEO-Operation Fundamentals & upgrades

- **Objective:** to obtain representative parameters of existing particle size distribution models (r_{eff})
- **Challenge:** to isolate size and concentration parameters

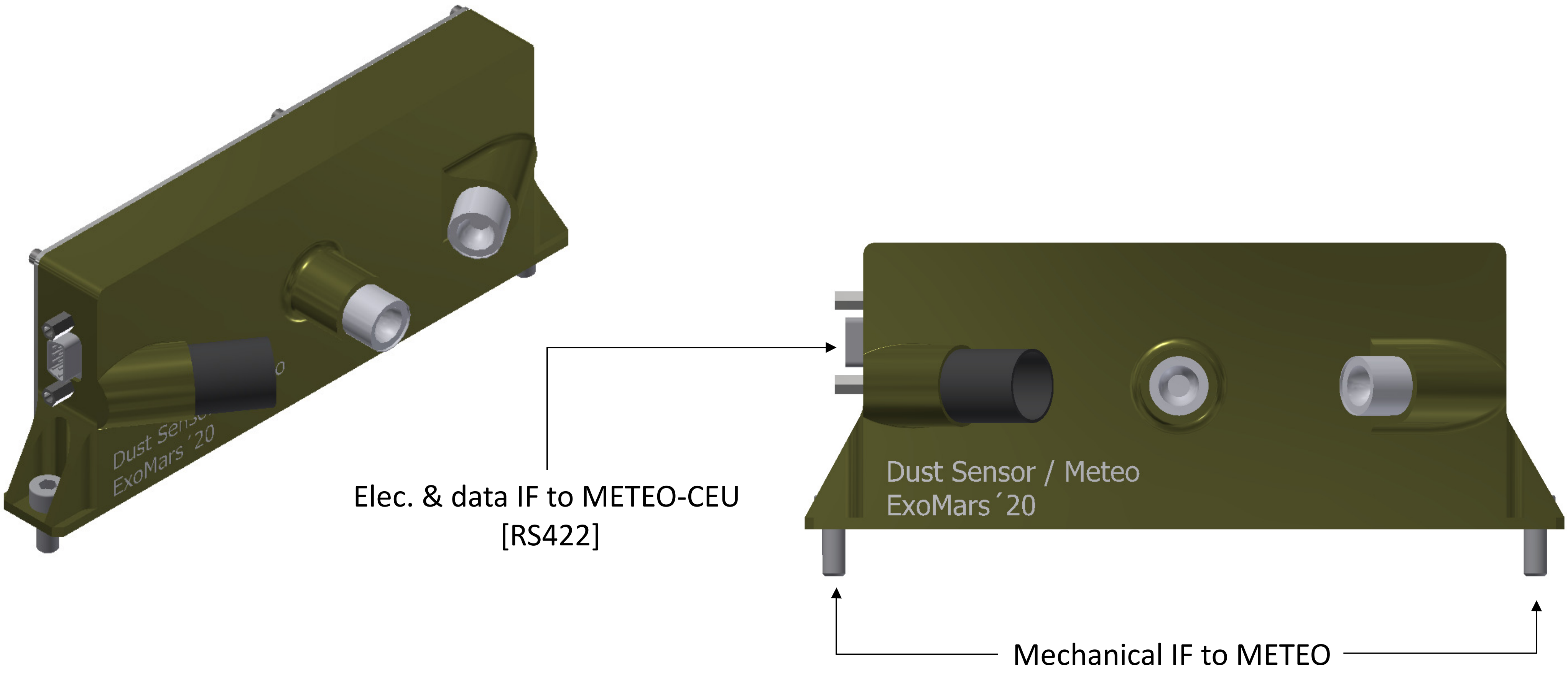
  Inverse problem: Many "small" particles will scatter equivalent signal levels than few big

- **DS contribution:** Dust Distribution Retrieval Based on power balance between both: bands & angular signal (4 channels)
- Not quantitative calibration with dust, neither radiometric is required
- Based on pulsed IR source: digital lock-in amplifier for SNR improving

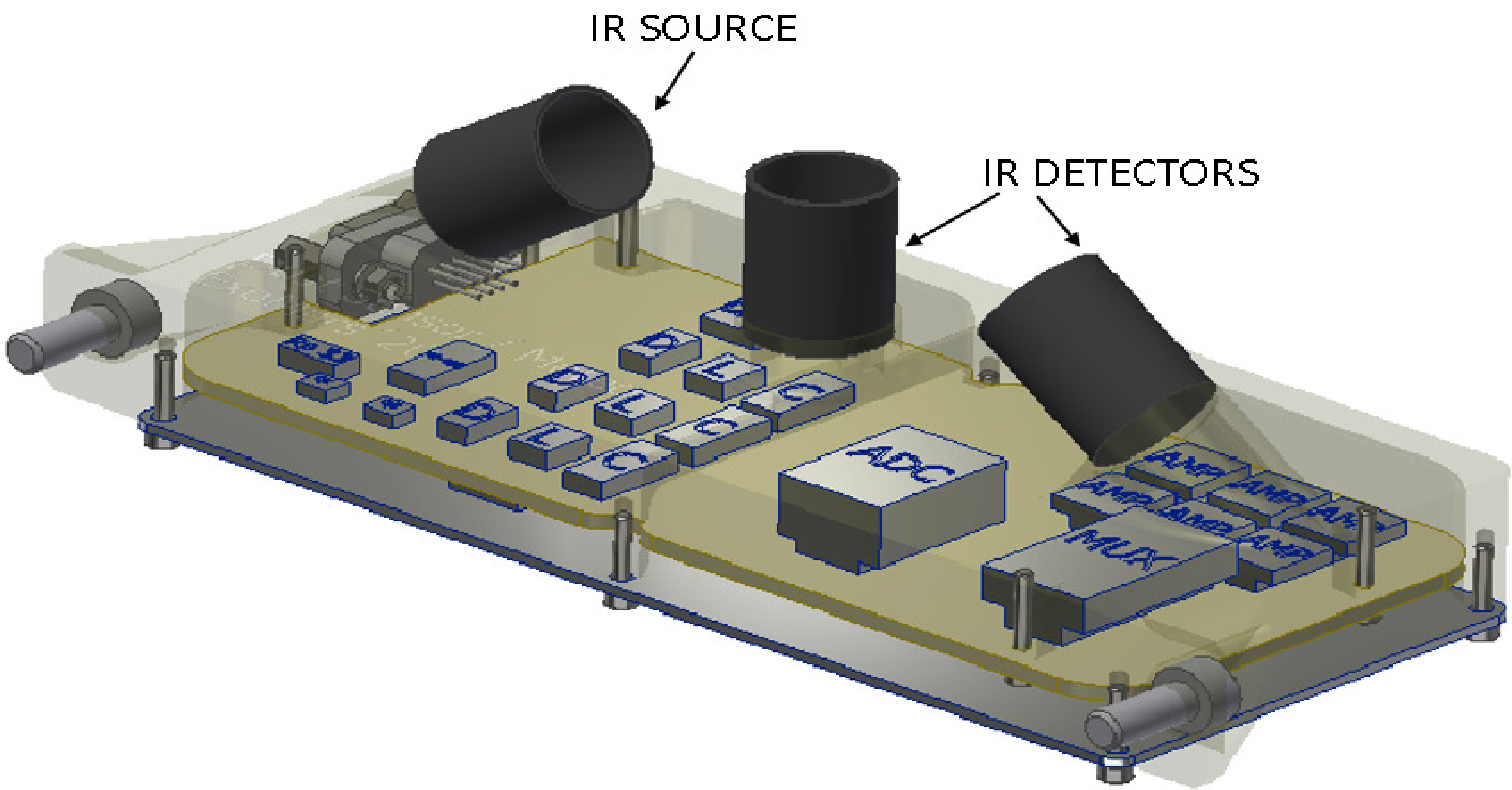




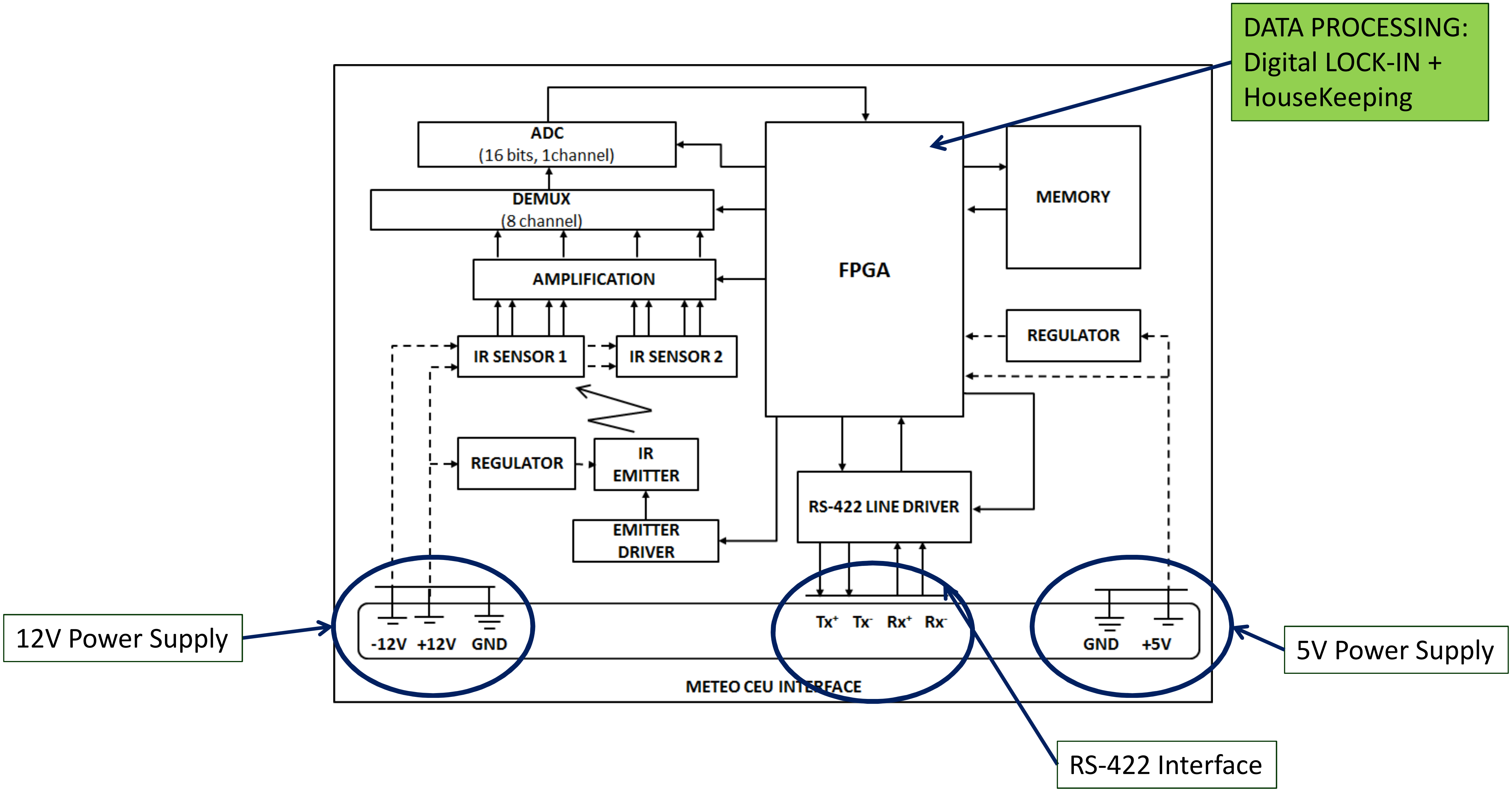
Final Envelope Design of DS in METEO - EXOMARS



Dust Sensor Instrument: General Architecture

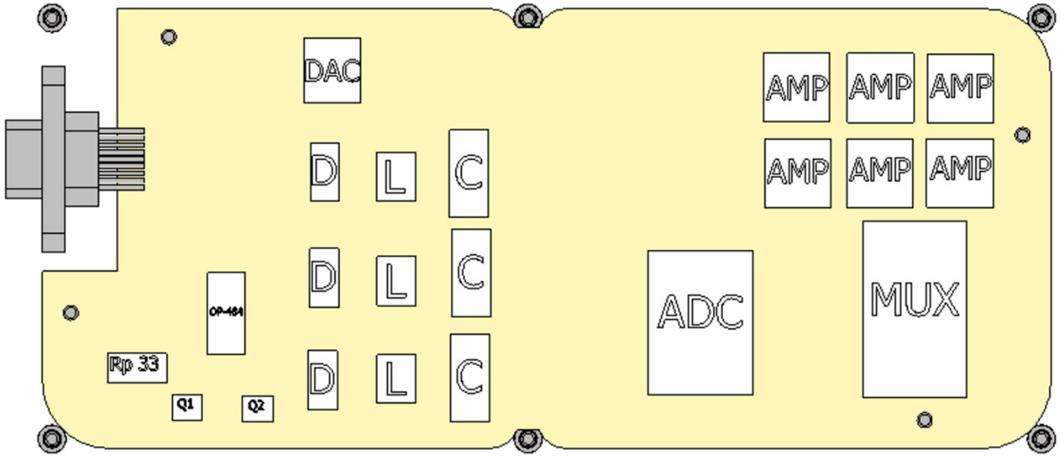


Dust Sensor Electronics: Architecture

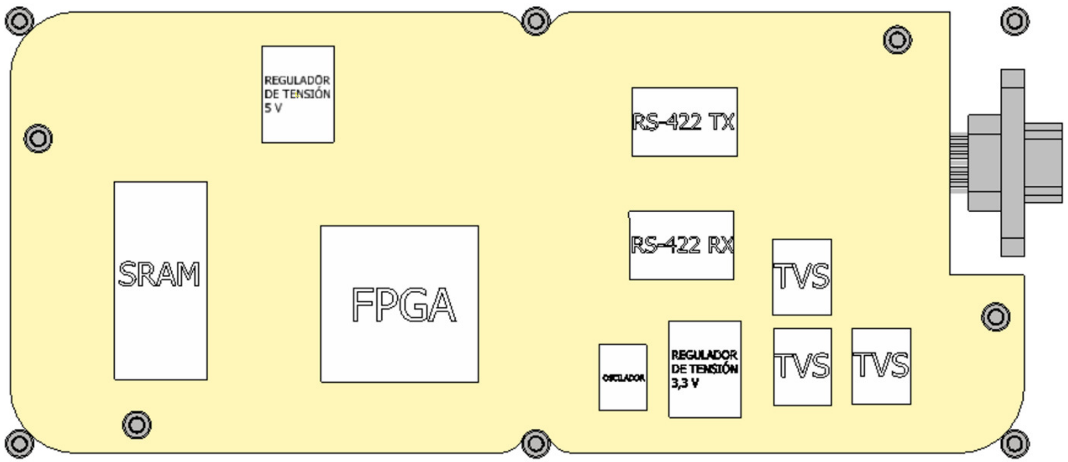


Dust Sensor Electronics: PCB placement

FRONT VIEW

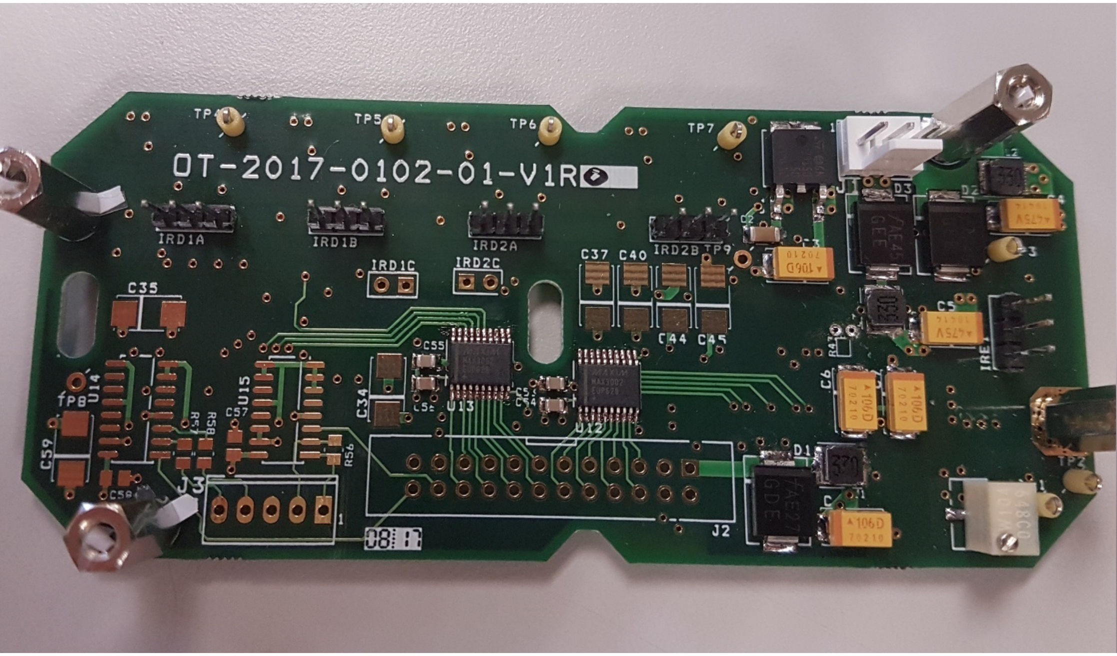


BACK VIEW

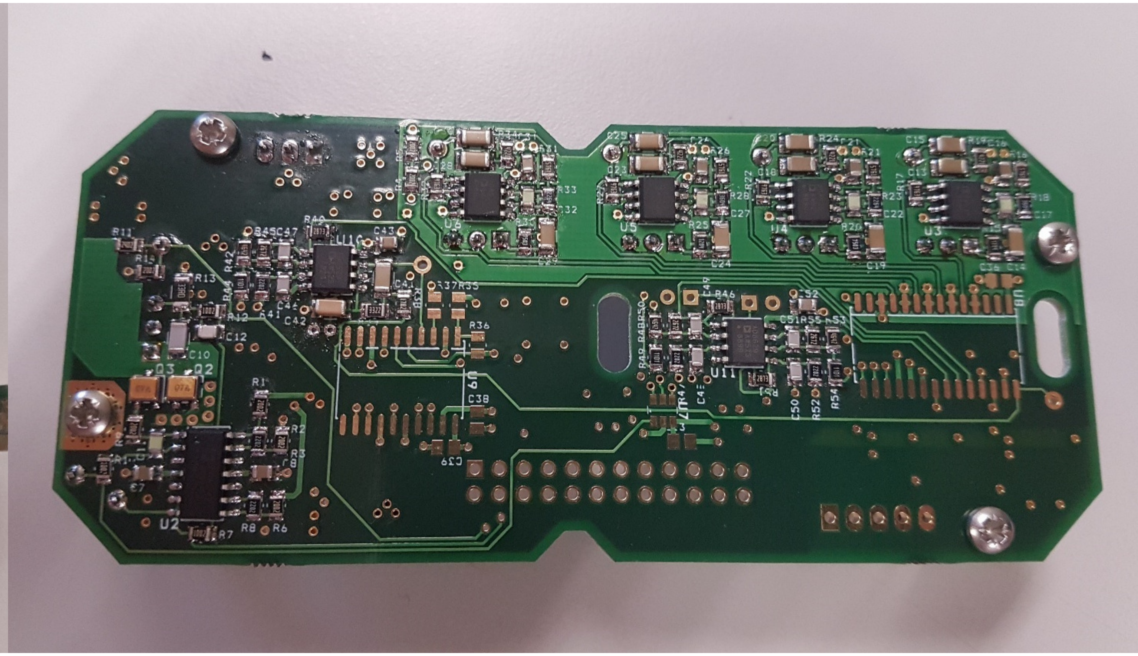


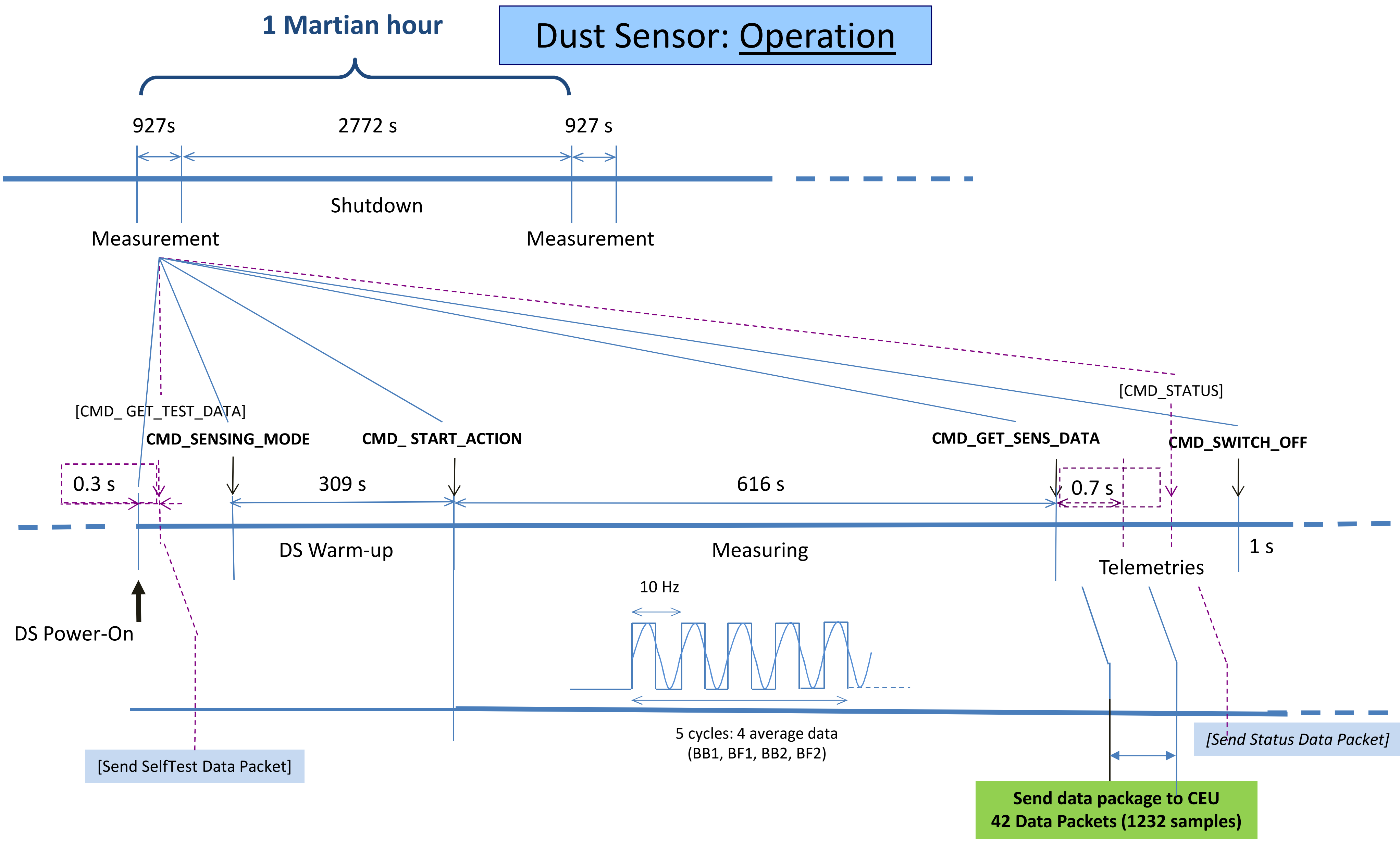
Dust Sensor Electronics: EBB

Front View



Back View



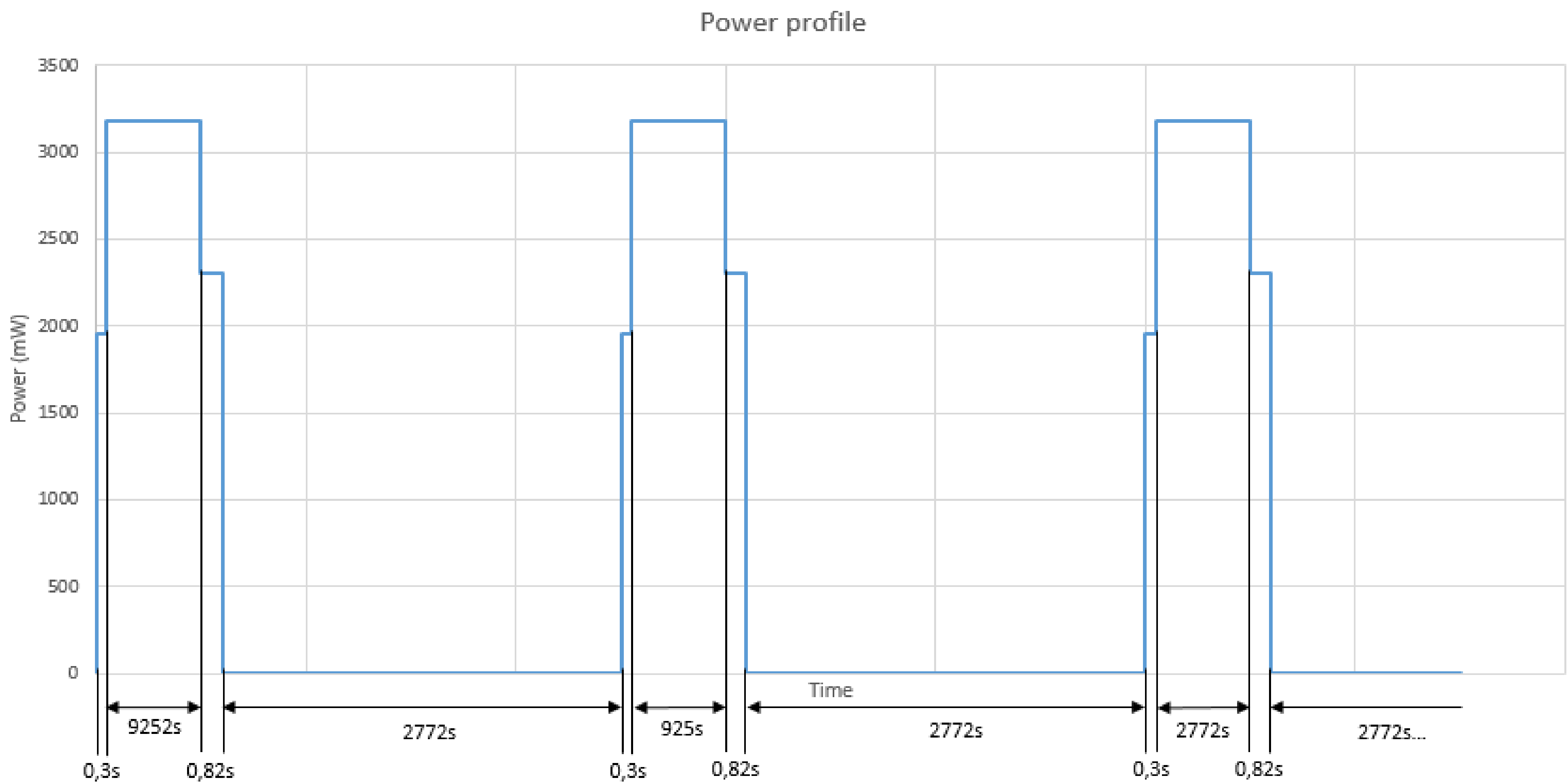

1 Martian hour
Dust Sensor: Operation
927s
2772 s
927 s
Shutdown
Measurement
Measurement
[CMD_STATUS]
[CMD_ GET_TEST_DATA]
CMD_SENSING_MODE
CMD_ START_ACTION
CMD_GET_SENS_DATA
CMD_SWITCH_OFF
0.3 s
309 s
616 s
0.7 s
DS Warm-up
Measuring
1 s
Telemetries
10 Hz
DS Power-On
5 cycles: 4 average data
(BB1, BF1, BB2, BF2)
[Send SelfTest Data Packet]
[Send Status Data Packet]
Send data package to CEU
42 Data Packets (1232 samples)

Dust Sensor Accommodation: Features

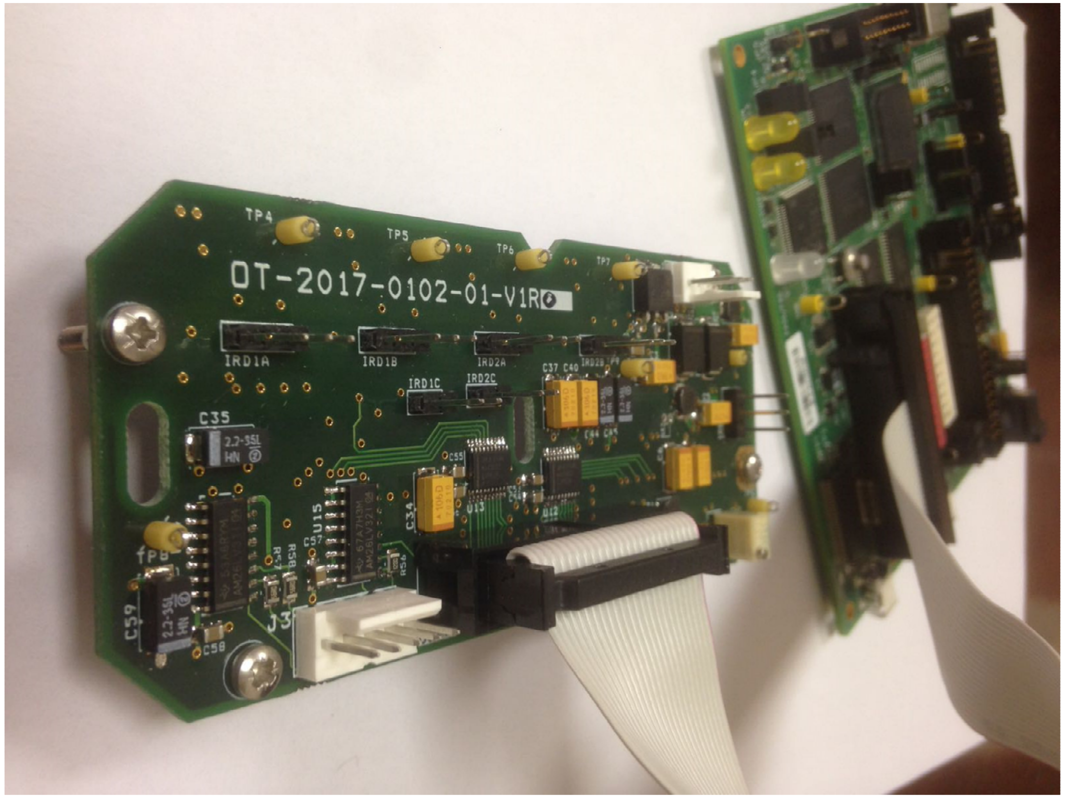
MASS BUDGET		
Total mass (g)	**Total mass + margin(g)**	**Margin (g)**
100,647	**120,7764**	**20,1294**

POWER BUDGET	Idle	Sensing	TM
5V line			
DS Total power (mW)	1369,38	1809,29	1665,99
DS Total contingency (20%) (mW)	273,876	361,858	333,198
DS Total power with contingency (mW)	1643,256	2171,148	1999,188
+/-12V line			
DS Total power (mW)	510	1090	510
DS Total contingency (20%) (mW)	102	218	102
DS Total power with contingency (mW)	612	1308	612
Total			
DS Total power (mW)	1879,38	2899,29	1825,99
DS Total contingency (20%) (mW)	375,876	579,858	365,198
DS Total power with contingency (mW)	**2255,256**	**3479,148**	**2191,188**

Dust Sensor Accommodation: Power Profile



EBB – Electronics Functional Test



Thanks for your attention

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