OBDP 2021

European Workshop on On-Board Data Processing

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14 - 17 June 2021 | Online Event

AN AUTONOMOUS CONTROL SOFTWARE EMBEDDED IN A CUSTOM-DESIGNED ELECTRONIC ARCHITECTURE FOR EXOMARS' RLS INSTRUMENT TO ANALYZE SAMPLES AT MARS SURFACE

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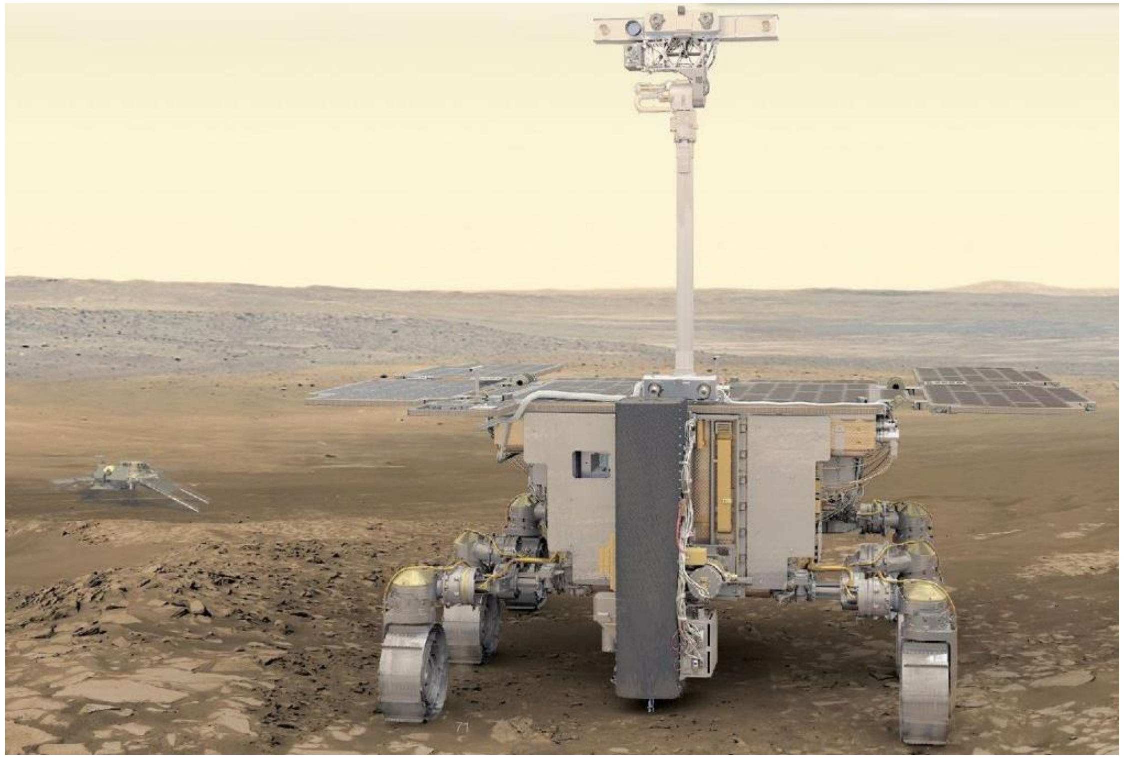
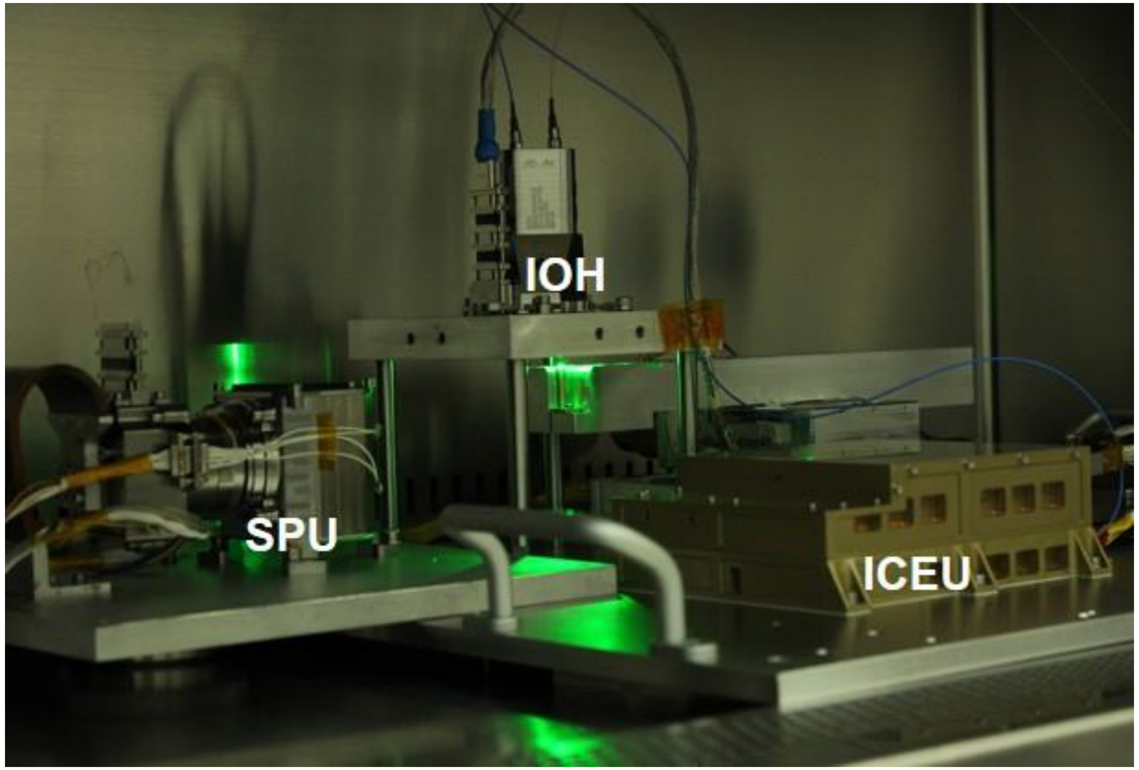
THE RAMAN LASER SPECTROMETER (RLS) ON BOARD EXOMARS 2022

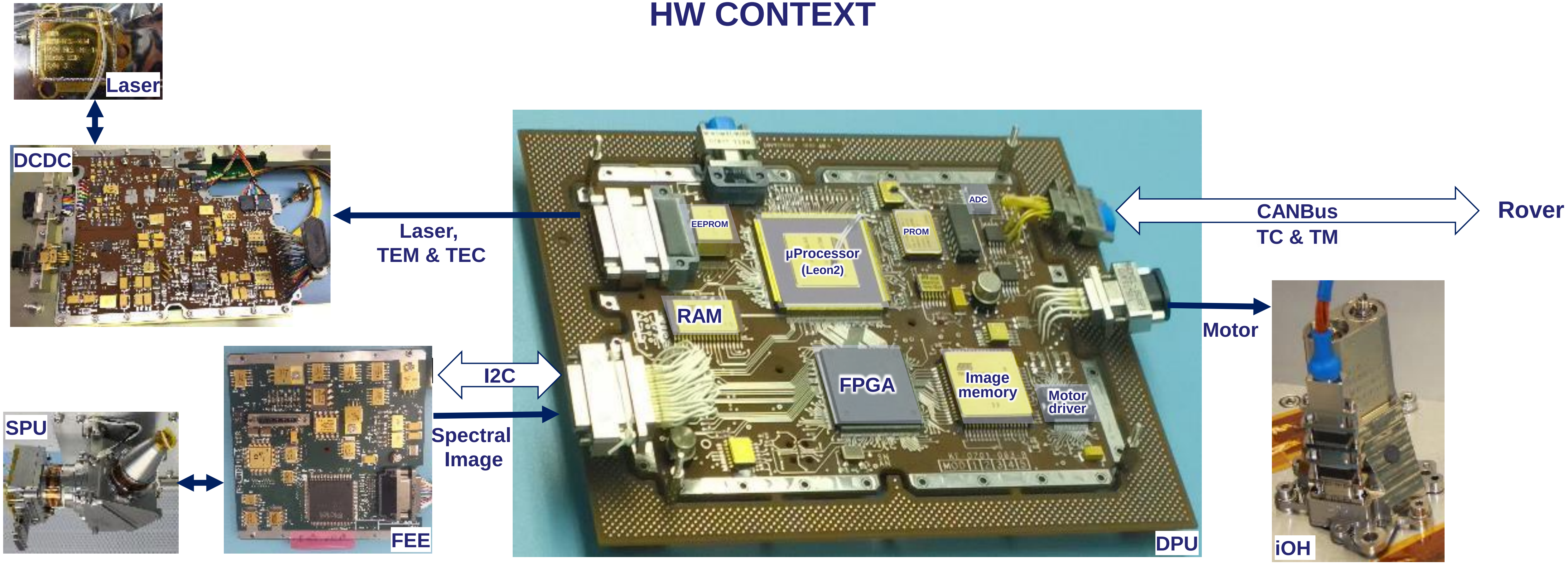
- **ExoMars 2022** mission consists of a Spacecraft Composite that will carry a Surface Platform and a Rover to Mars
- The launch window is foreseen in September 2022 to land on Mars in June 2023
- **RLS** is one of the analytical instruments **on board the Rover**
- The Rover will drill the Mars surface (up to 2m depth) to collect small samples that will be delivered to the analytical laboratory in the heart of the vehicle
- **RLS will perform Raman spectroscopy** on the collected samples
- The Raman analysis is carried out by exciting a sample with a specific laser signal and then doing a spectrometry analysis on the obtained emission from the sample



- RLS is composed of the following main units:
  - The **Spectrometer Unit** (**SPU**), which achieves the spectral dispersion of the signal emitted by the sample, and received on the CCD element
  - The **Internal Optical Head** (**iOH**), which focus the laser excitation signal onto the sample and collects the signal emitted by the sample before sending it to the SPU
  - The **Instrument Control and Excitation Unit** (**ICEU**), which controls the overall instrument operation, processes spectra and provides data and power interface with the Rover through the embedded instrument SW.
    - Includes FEE, DPU & DCDC boards and also the Laser unit



HW CONTEXT



RLS SW runs on the DPU board´s microprocessor

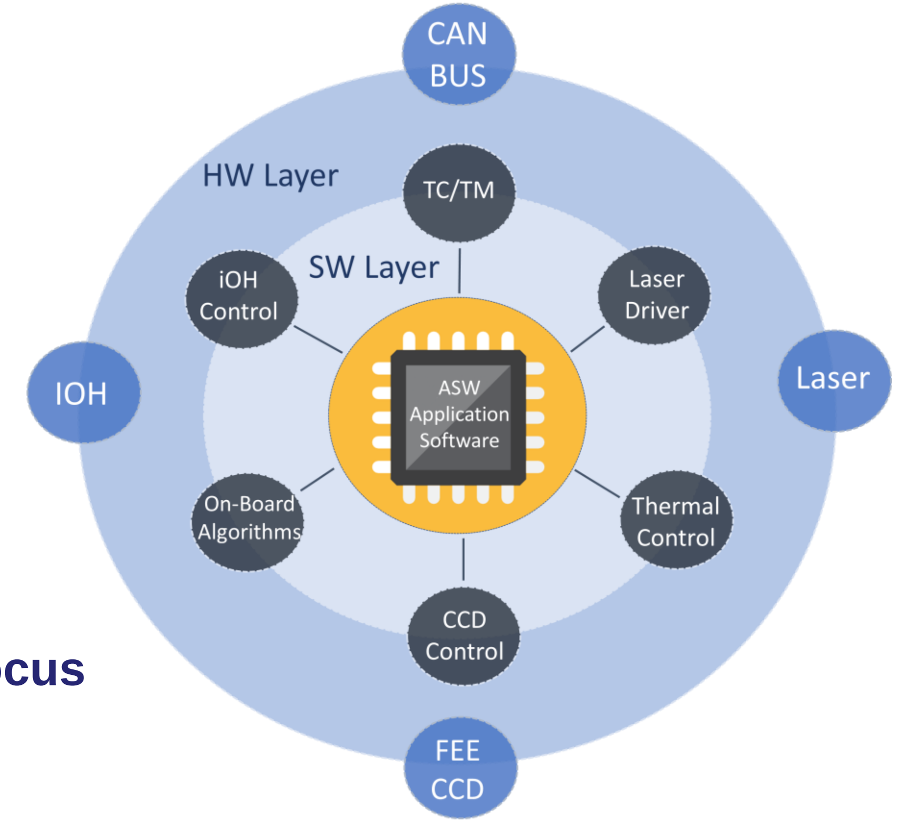
The RLS onboard SW

The RLS SW is composed of :

- The **Application SW**, providing control over the full operation
- The **Boot SW**, performing initialization and App. SW updates

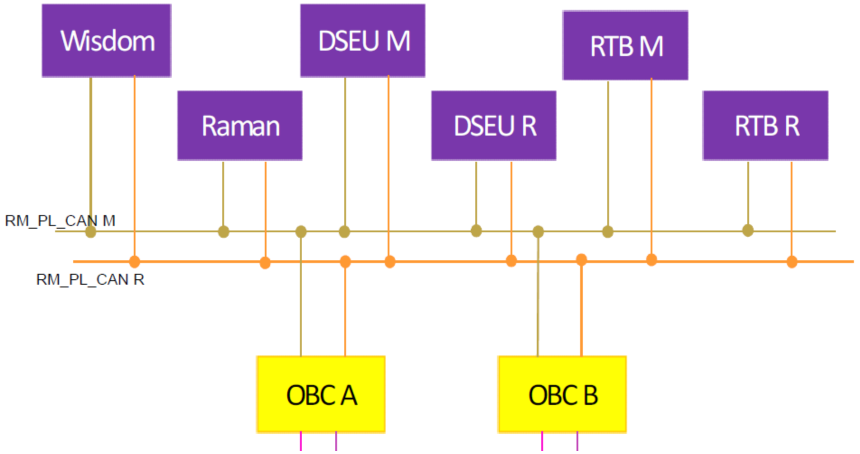
The main functionalities are the following:

- Managing **communications** with the Rover
- Precise **temperature control** of laser and CCD units
- **Laser channel** activation
- Controlling the iOH **focusing** mechanism and performing **autofocus**
- Commanding a CCD image **acquisiton**
- **Post-processing** acquired images to optimize the Raman spectra quality
- **Others**: HK acquisition, events generation, FDIR, management of memory controller, timers, watchdog, interrupts, etc.



Communications with the Rover

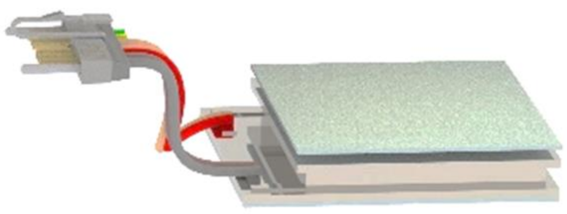
- A redundant 1Mbps **CAN/CANopen** bus is the only data interface with the Rover
- Command reception and Telemetry transmission are performed through CAN/CANOpen. Even long science telemetries (up to around 2Mbytes) are transmitted
- RLS makes use of the CANopen IP Core developed by Sitael embedded in a reprogrammable Flash MicrosemiProAsic FPGA
- The RLS SW handles the IP Core through specific-designed FPGA registers that are mapped in the I/O memory area of the microprocessor
- The RLS SW implements CANopen **synchronous & asynchronou**
  PDOs (Process data objects) and also **SDOs** (Service Data Object)
  block transfers



Thermal Control

The RLS ASW controls:

- The **Laser TEM** (Thermo-Electrical Module), heating and/or cooling until the laser achieves its best working temperature
  - PID-based TEM thermal control, fine control with 0.2 degrees accuracy
- The **CCD TEC** (Thermo-Electrical Cooler), cooling the CCD for performance improvement
  - PID-based TEC thermal control, coarse control reaching -40 degrees



Thermo-Electrical Module

The thermal control is one of the most critical features because a high temperature gradient can damage the laser and CCD permanently.

Thus, the ASW performs a gradual thermal control switch ON/OFF **ensuring safety gradients** for both elements

LASER Driver

The RLS ASW activates/deactivates the selected laser channel:

- Laser channel selection (**2 channels available**)
- Switch ON/OFF the laser
- Monitor laser stabilization
- Minimize power consumption

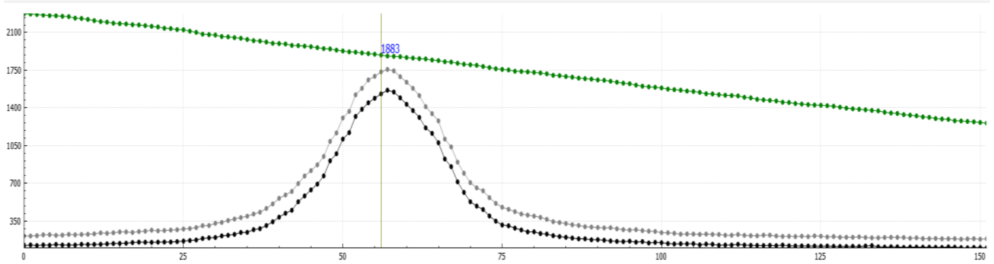
RLS Laser unit

The Laser unit is the instrument excitation source, a diode-pumped solid-state laser emitting at 532nm

IOH Control

The RLS ASW moves the iOH stepper motor by commandig the actuator motor driver. The allowed iOH operations are as follows:

- Move the motor step by step
- Three operation modes available: full step, quarter step and microstepping
- **Go to a specific position** on-demand
- **Perform Autofocus** as a closed-loop algorithm, which moves the focusing optics along a 2 mm travel range until a maximum intensity of the laser reflection is achieved

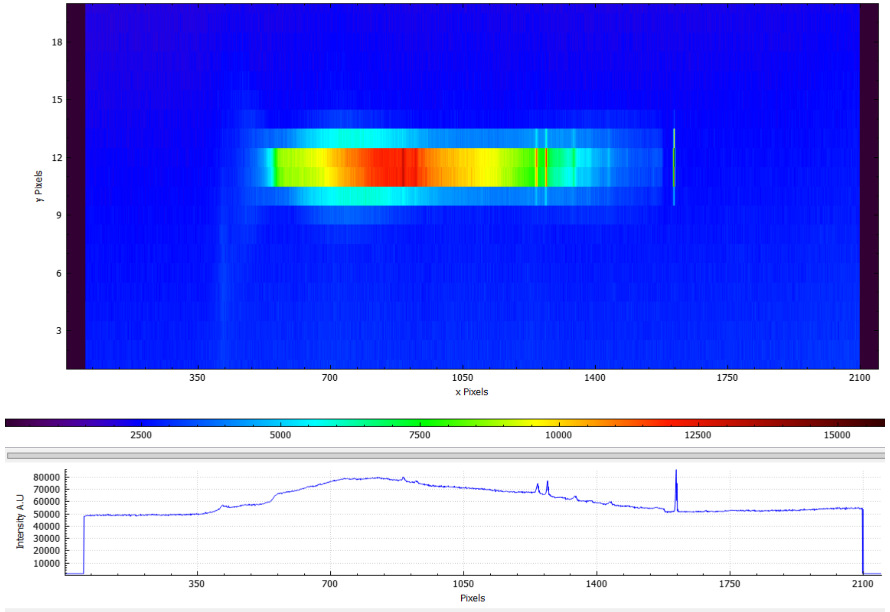


Autofocus graphic representation

FEE & CCD Control

The RLS ASW performs the **image acquisition process**, allowing **low level control** of the CCD for integration and characterization purposes such as:

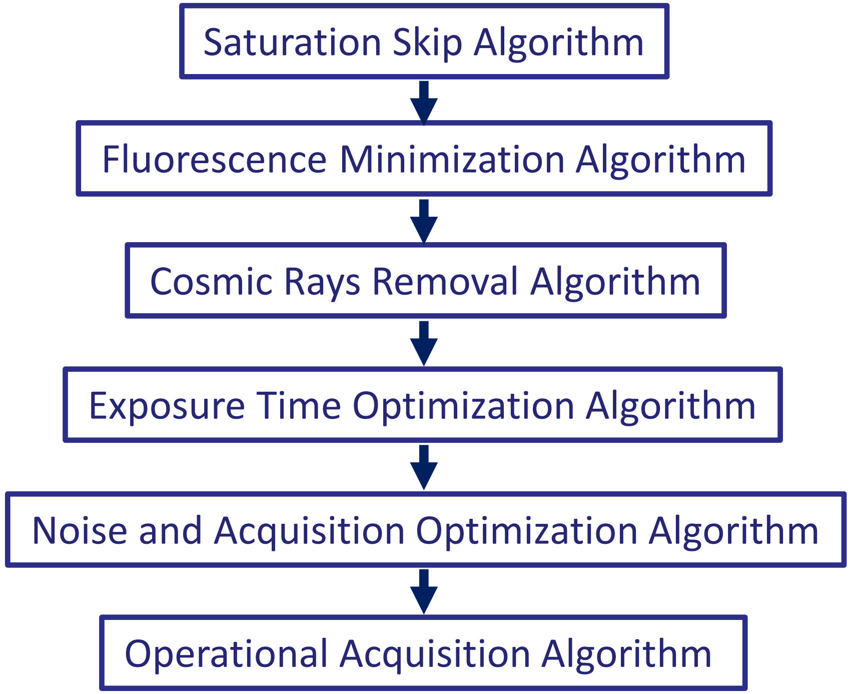
- ROI determination
- CCD noise
- Gain control
- Bias characterization
- Frame size
- Pixel to 14-bit or 16-bit selection
- Other CCD acquisition settings



RLS image and spectrum example

On-board processing algorithms

The RLS SW implements post-processing algorithms to **automate the acquisition of Raman spectral data** and **optimize the scientific performance**, contributing to a prompt identification of those Raman data with possible biological interest



Onboard algorithms execution flow

- **Saturation Skip:** Performs a continuous acquisition, decreasing the acquisition time until CCD pixels are not saturated. Outputs an Acquisition Reference Time
- **Fluorescence Minimization:** Performs a continuous acquisition, with the calculated reference time, until the overall spectrum fluorescence is minimum
- **Cosmic Rays Removal:** Analyses two spectra acquired with the reference time, identifies GCR spikes and cleans them
- **Exposure Time Optimization:** Adjusts the exposure acquisition time to the dynamic range of the imaging CCD in order to maximize the signal
- **Noise and Acq Optimization:** Estimates SNR and calculates the optimum number of image Acquisition to minimize noise and improve Raman signal
- **Operational Acq:** Adapts the Optimum Acquisition Parameters to the available operational resources (time, memory storage, down-link data)

CONCLUSIONS

- A reliable software solution was developed for the RLS instrument
- The RLS SW provides an automated control of all the instrument subsystems as well as capabilities to allow quick analyses of the Raman spectra
- The developed RLS SW was successfully validated on all the RLS models (EIS – Electrical Interface Simulator-, EQM, EQM-2, FM and FS) and is expected to be helpful to reach the ExoMars mission´s goals

THANKS FOR YOUR ATTENTION!

ANY QUESTIONS? PLEASE FEEL FREE TO CONTACT THE EXOMARS RAMAN TEAM AT INTA AT ExoMarsRaman@inta.es

MORE INFORMATION ALSO IN OUR BLOG HTTPS://WWW.INTA.ES/INTA/EN/BLOGS/EXOMARSRAMAN/

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