Data, Calibration and Processing of Thermal Infrared Data from the LisR ISS Mission

Monday 12th September 2022
Calcon| Logan | Utah

Space Station Instruments

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constellr

Outline

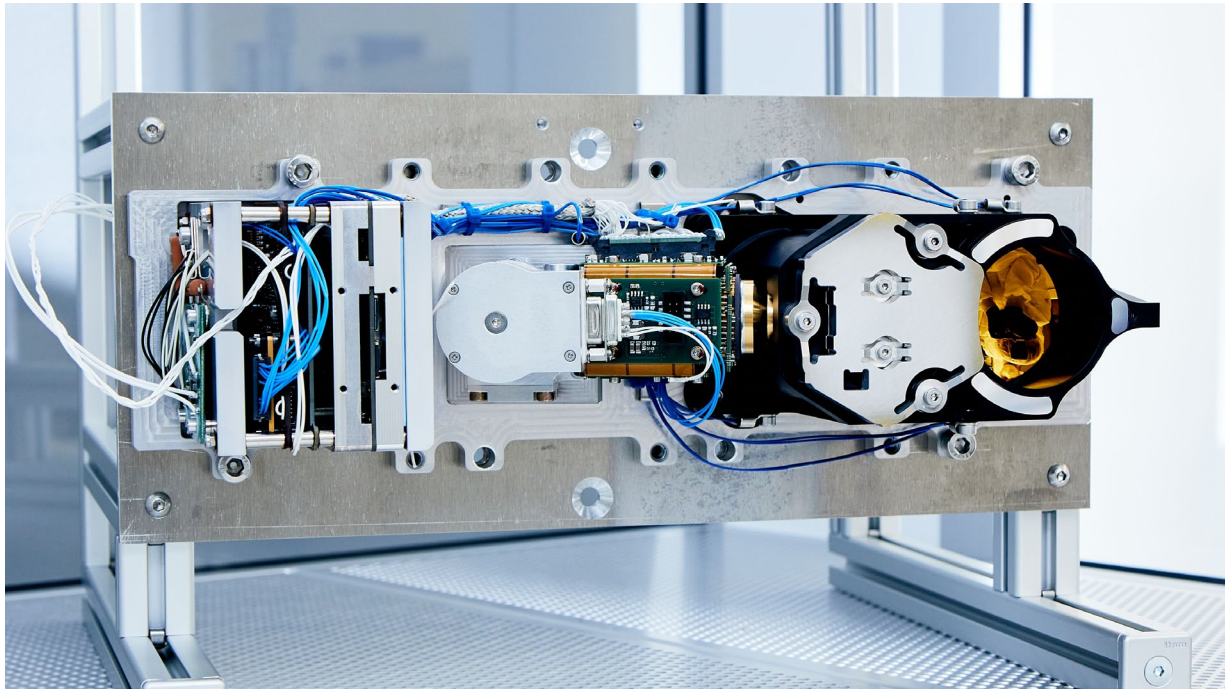
- Company, Mission and Instrument
  - Technical Details, orbit parameters, key parameters
  - Spectral Response Curves

- Ground In Lab Calibration / Characterization
  - Radiometric Characterization (absolute calibration, flat fielding)
  - Focusing of the system

- In orbit adjustment of the flat fielding parameters

- Image processing Steps to L2 LST products

- Outlook and conclusion



Massive environmental, societal, and regulatory drivers

Agricultural transition urgently needed

Climate Change

Up to 46% yield loss in key crops at 2°C increase

Population Growth

Estimate +40% higher water use in agriculture by 2030

Food Security

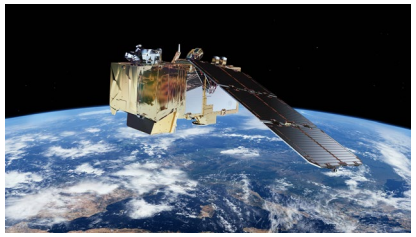
+90% price increase for corn, wheat & rice by 2030

Sources: Global Center of Adaptation, Global Industry Analysts 2021, Infrastructure News 2021, Research and Markets 2019, Geospatial Analytics Market, Green Technology and Sustainability Market, Markets and Markets 2019, Transparency Market Research 2020, Bloomberg (ESG Assets, 2021)
Foto by Markus Spiske from Pexels

We rely on public imagery, and fill the gaps with our own satellites

A robust and cost-effective approach, standing on the shoulders of giants

Free and open data



Sentinel-2

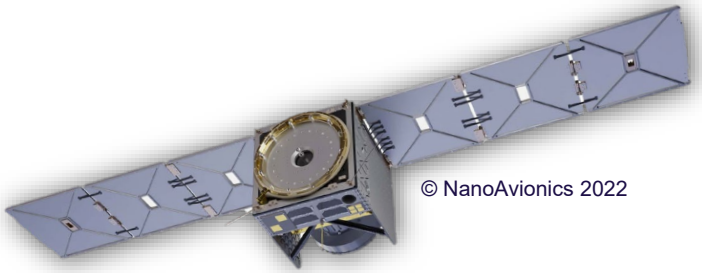
Sentinel-3

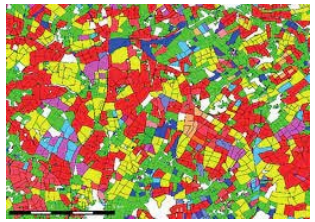
ECOSTRESS

Landsat-8

& many more to come…

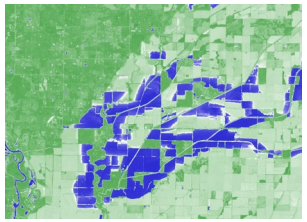
Combined with proprietary layers



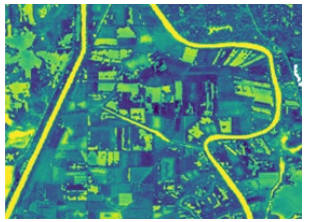


crop classification

vegetation index



flood maps



irrigation map

soil organic carbon

LisR Mission – Long wave Infrared demonStratoR

Mission Objectives

Demonstrate…

- ConstellR´s core **miniaturized technology** for **Land Surface Temperature retrieval**
- the **capability of small COTS components** such as the TIR detector to derive LST
- **free-form** technology for the **optics** on a CubeSat scale

Validate and showcase…

- patented **calibration approach** for LST data and
- the **business case** for commercial LST data

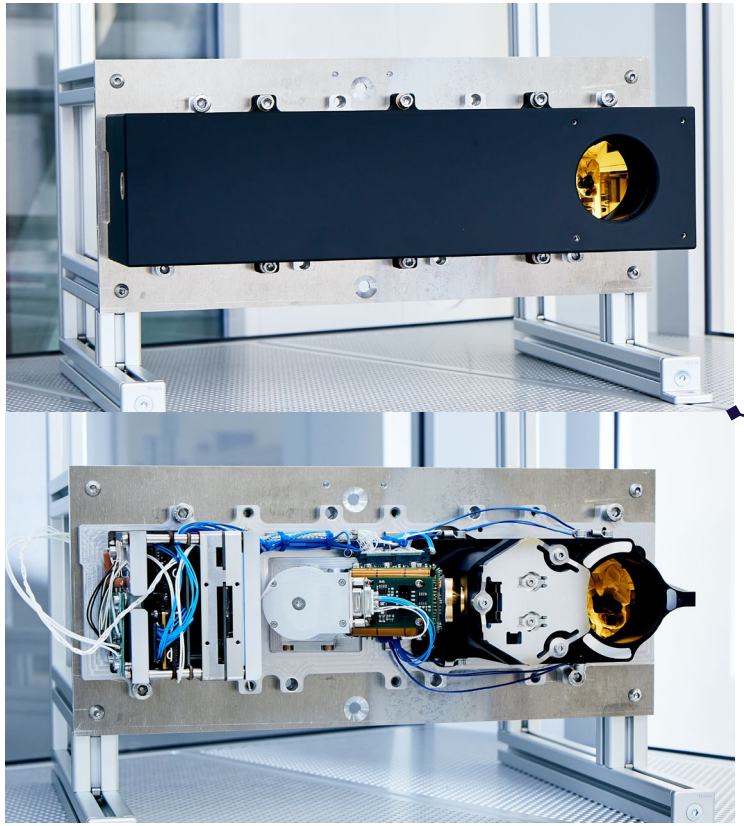
LisR Mission

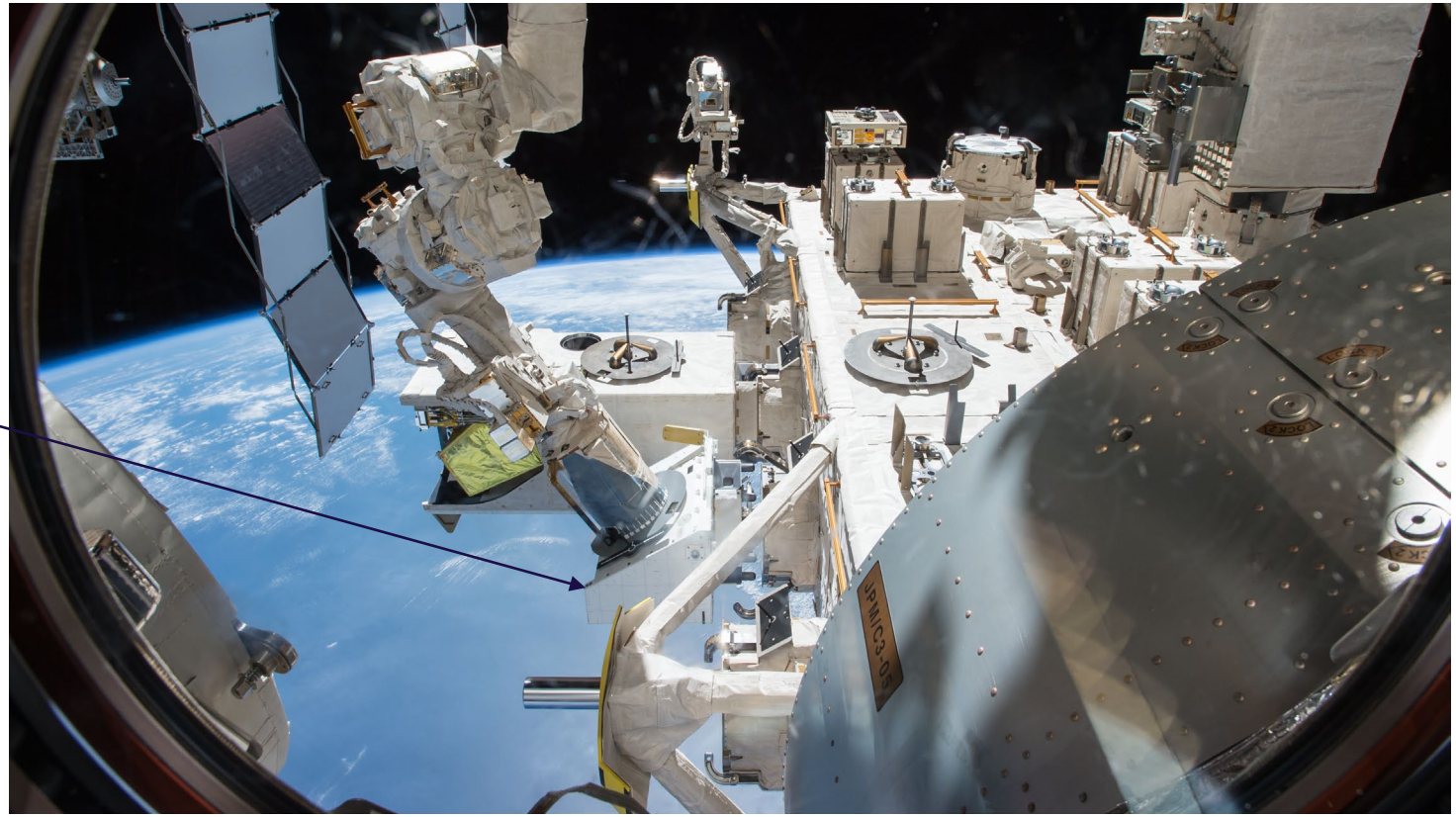
- Mission duration: until June 2022
  - Launch: 19.02.2022
  - Installation outside ISS: 09.03.2022
  - **Initial Activation:** 14.03.2022

In cooperation with Fraunhofer EMI | Fraunhofer IOF | SPACEOPTIX | NASA | Nanoracks

LisR Mission – Long wave Infrared demonStratoR

Launched to the International Space Station on 19th February 2022

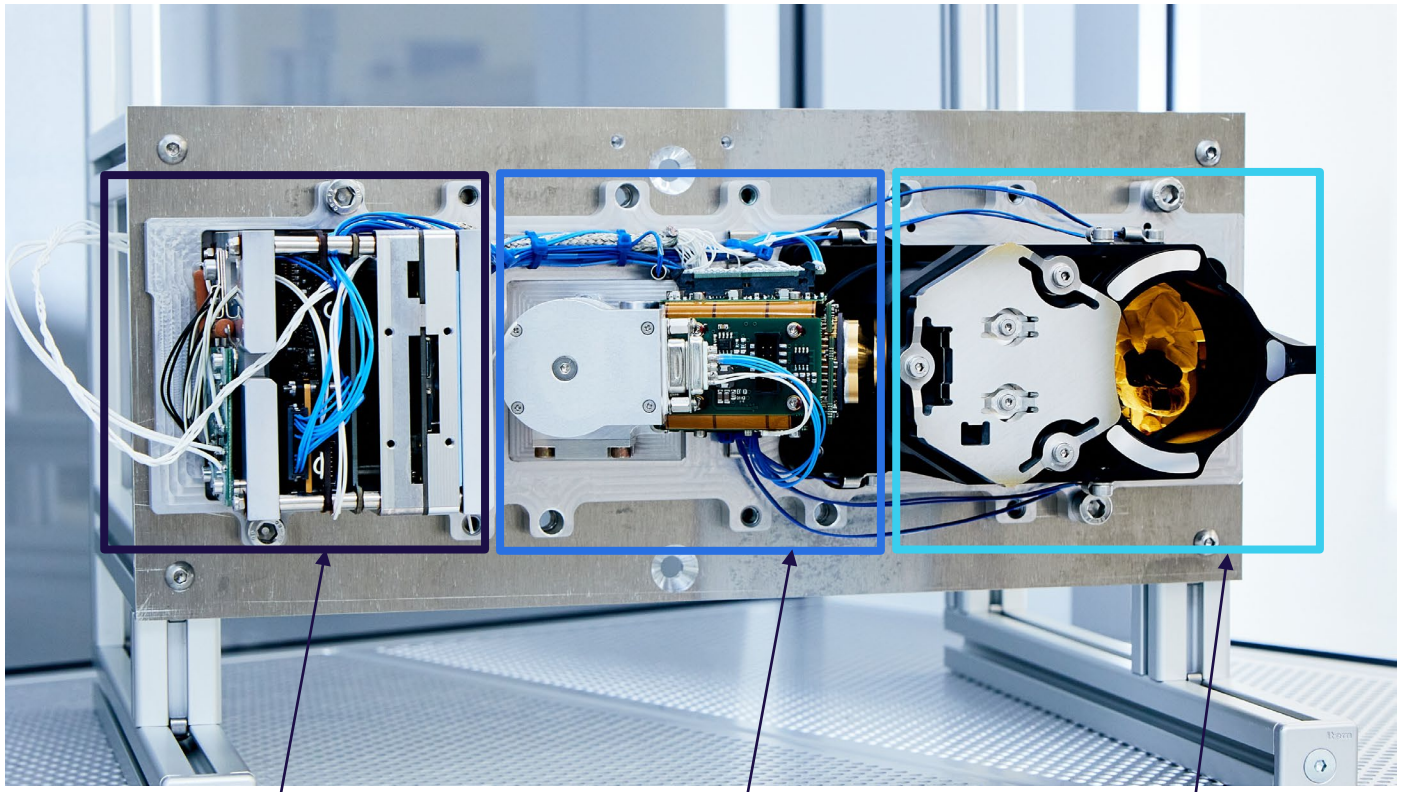




In cooperation with

LisR Payload – Long wave Infrared demonStratoR

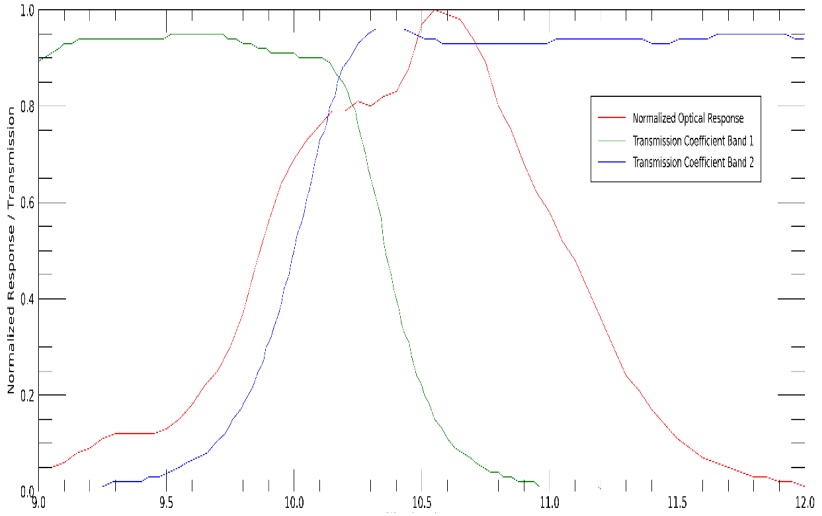
A miniaturized system to monitor Land Surface Temperature

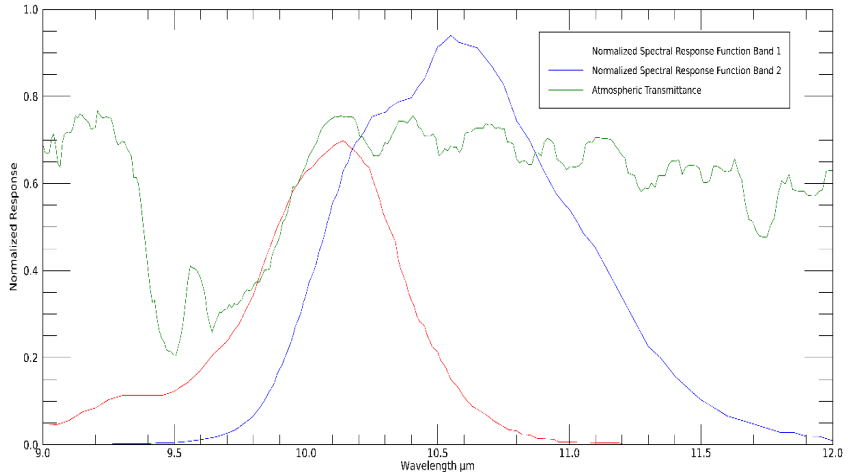


Power Supply and **Data Processing** Unit	Thermal **Infrared** Detector	Metal mirror **Free Form Telescope**

In cooperation with Fraunhofer EMI | Fraunhofer IOF | SPACEOPTIX | NASA | Nanoracks

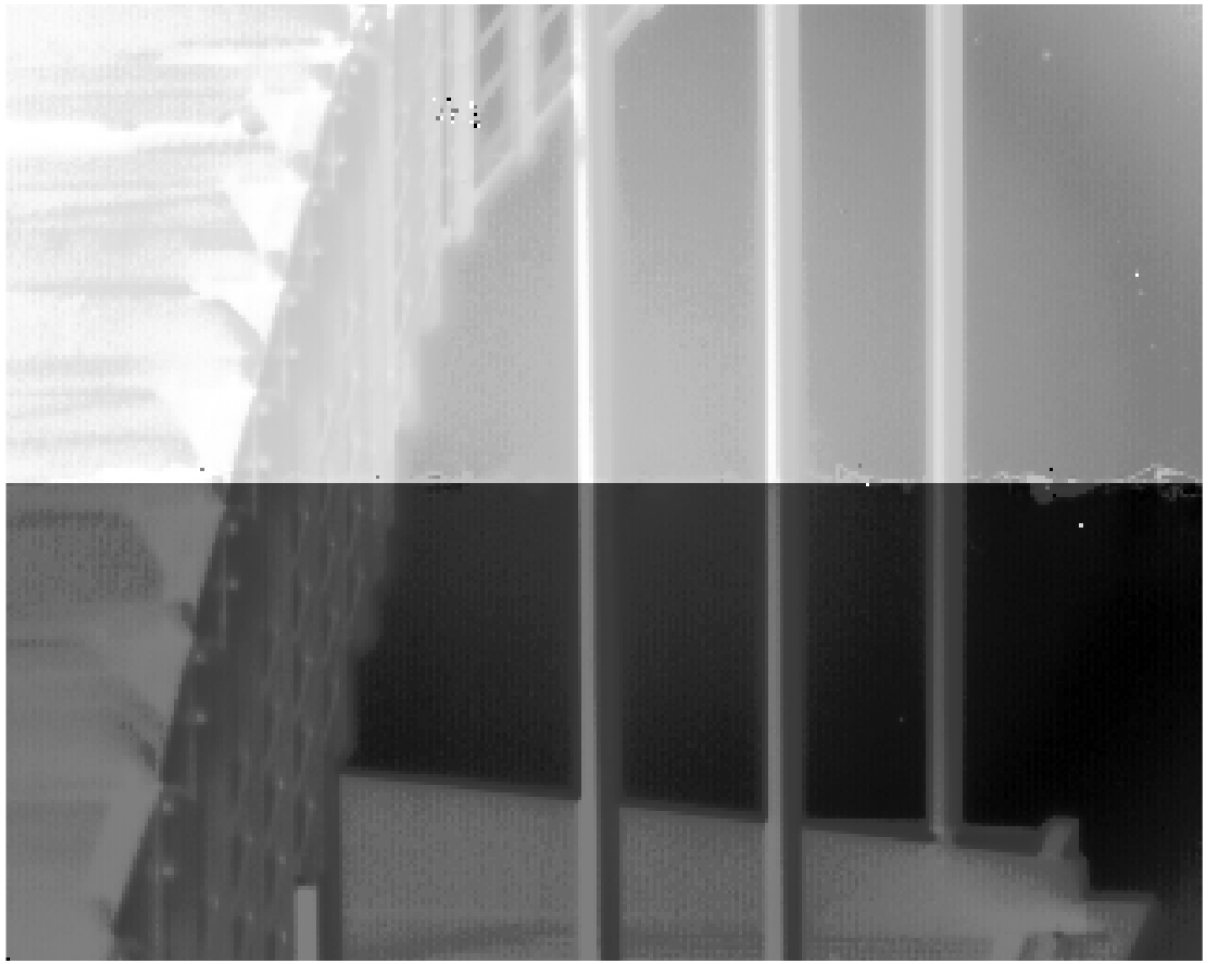
Mission and Instrument Key Parameters





Target Data Product	L2 Land Surface Temperature
Orbit	ISS Orbit, 370 - 460 km altitude, 51.6° inclination, 7.6 – 7.7 km/s
Revisit Time	non-constant, 3-5 days for many areas and times
Coverage	Land and coastal regions between -51° and +51° Latitude
Max. Spectral Response	Band 1: 10.14µm, Band 2: 10.55µm
Full Width Half Maximum (FWHM)	Band 1: 0.41µm, Band 2: 0.9µm
Detector	Cryocooled Quantum Well Infrared Photodetector (QWIP)
Frame Size	320 x 256 pixels, (320 x 128 per band)
Pixel Pitch	30 µm
Optics	Free Form optical assembly
Initial Integration Time	2250 µs
Imaging sequence	6 images / second in operational mode
Focal Length	150 mm
GSD	81.5
Swath width	26.1 km

Spectral Response



- Commercial off the shelf cryocooled QWIPS one band detector array.
- Two overlayd filter elements divide the focal plane horizontally.

- Operations in pushframe configuration levarages the ISS foreward movement to achieve full coverage of the surface in both bands
- Band registration is achieved using image processing methods

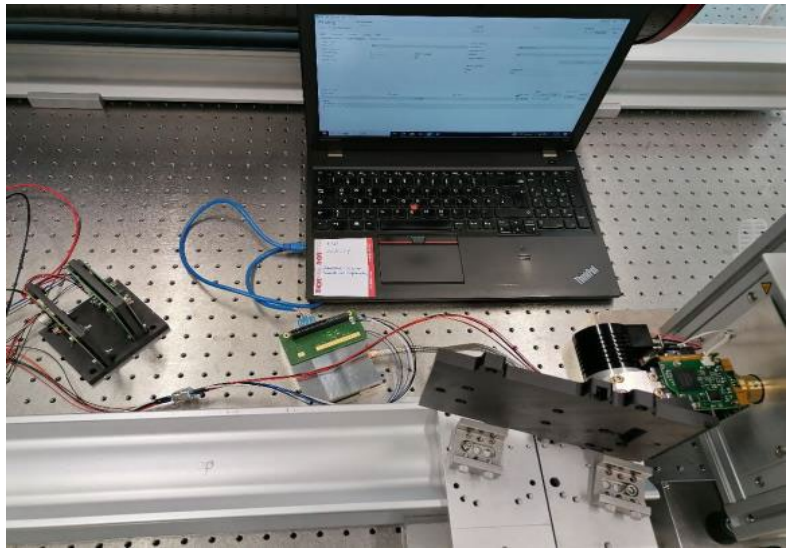
On Ground Camera Calibration

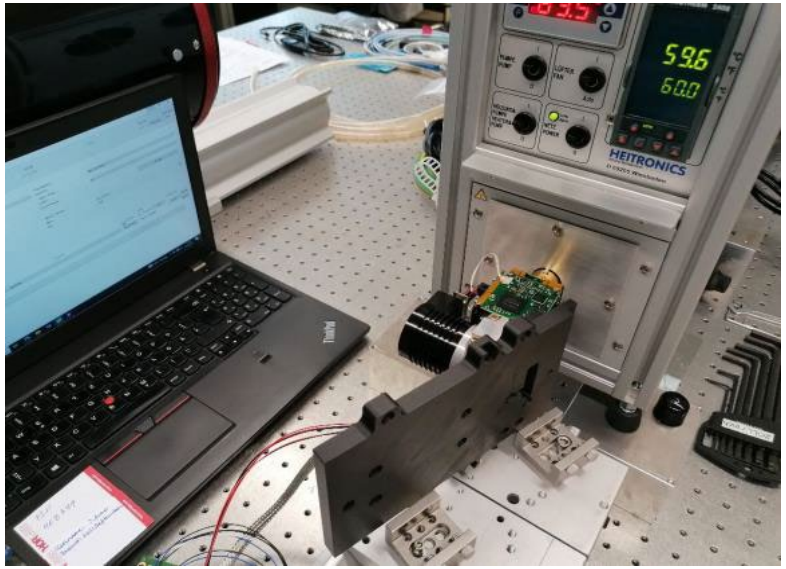
Goals

- Characterize the camera response
    - DN to Radiance (initial absolute calibration)
    - Initial Flatfielding of Frame
- Focus adjustment (distance between focal plane and entrance pupil of the optical assembly)

Equipment

- Black Body Source (Heitronics ME30)
- Chiller (Julabo FL300)
- Collimator (1000 mm focal length)





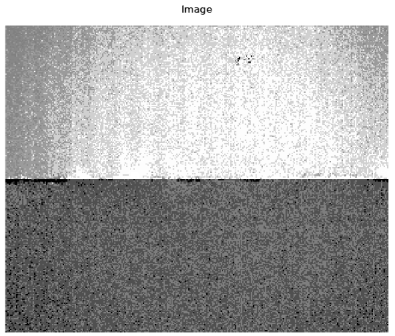
Absolute Calibration

Black Body has been imaged

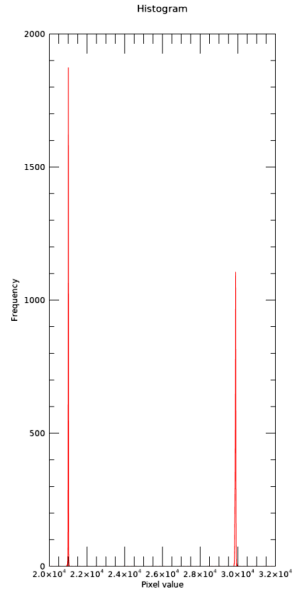
- at 8 different temperatures (-9 to 80°C)
- at 5 different integration times (1250 to 2750µs)

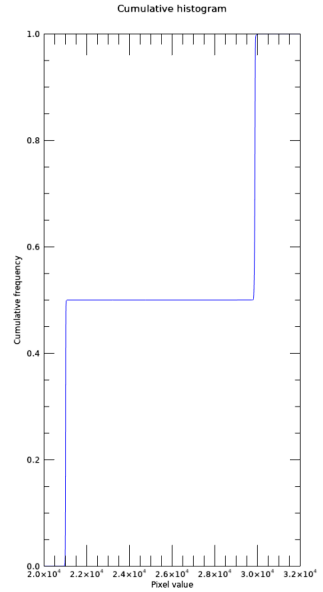
to

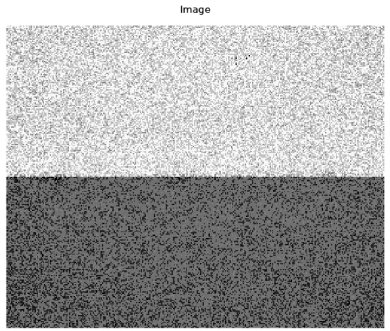
- find the right integration time for an optimum well fill at nominal surface temperatures between -20 and 60°C
- find saturation temperatures



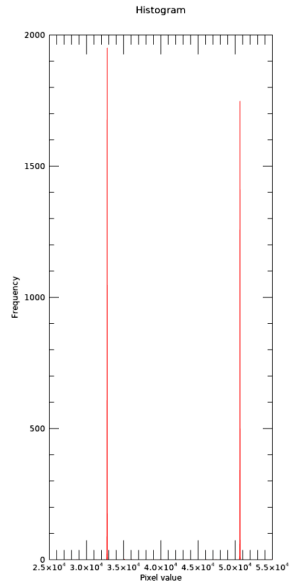
-9°C – 2000µs

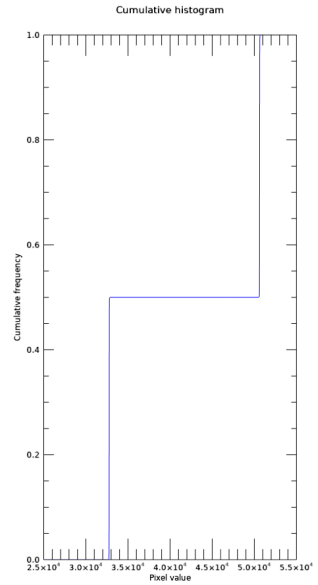






40°C – 2000µs



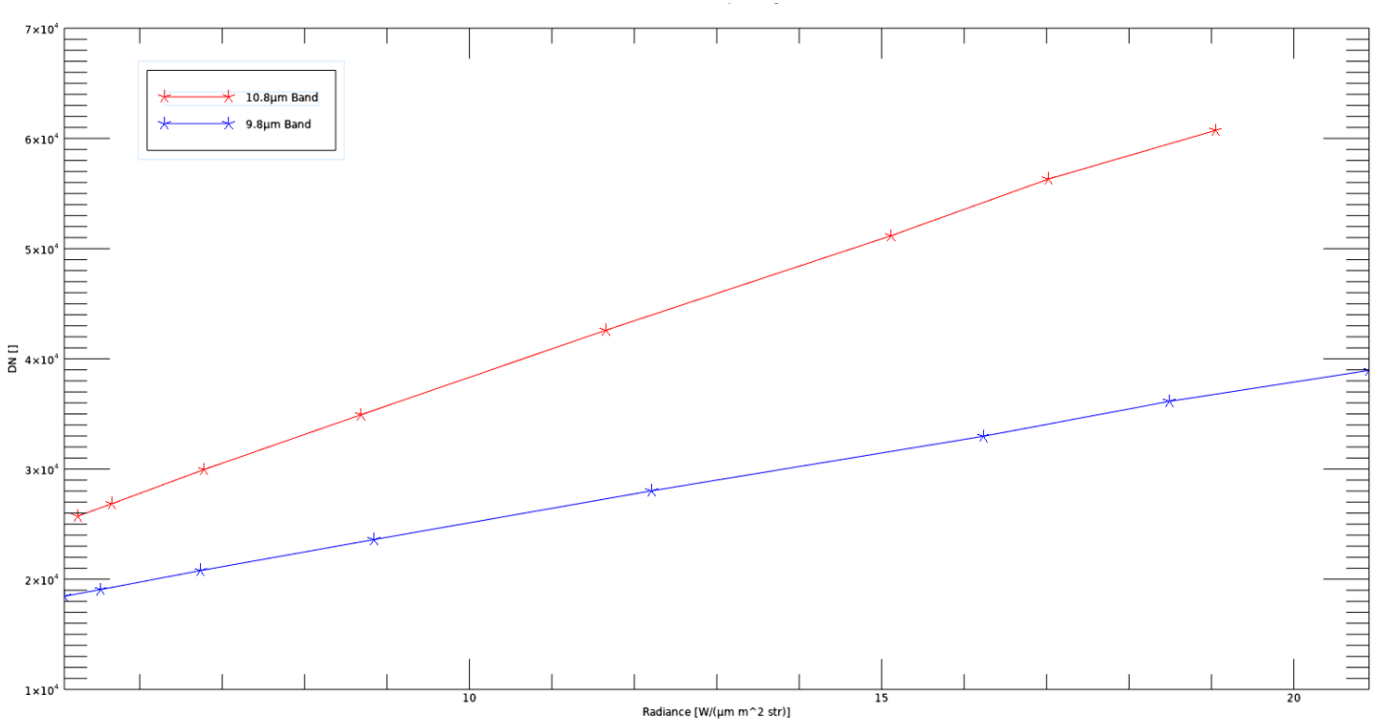


Absolute Calibration

and to find the link between detector DN and Radiance Level.

Brightness temperature of the Black Body is converted to radiance level using Plancks law

Linear fit between the radiance and per band mean detector DN delivers the pre launch initial absolute radiometric calibration parameters (gain and offset)



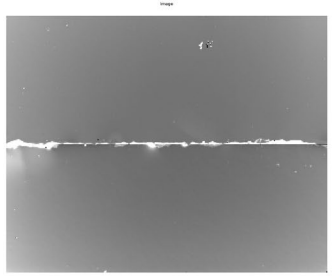
Initial Flatfielding (lab)

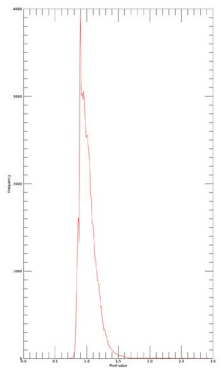
Take images of the blackbody at cold and warm temperatures

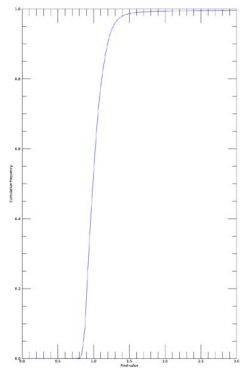
- homogeneous reference over the full focal plane
- well within the linear response of the detectors
- used -9°C and +40°C for the lab flatfielding

$$G^{rc} = \frac{median_{rc}\left(median_{n=1\ldots N}\left(S_n^{rc}(T_{high})\right)\right) - median_{rc}\left(median_{n=1\ldots N}\left(S_n^{rc}(T_{Low})\right)\right)}{median_{n=1\ldots N}\left(S_n^{rc}(T_{High})\right) - median_{n=1\ldots N}\left(S_n^{rc}(T_{Low})\right)}$$

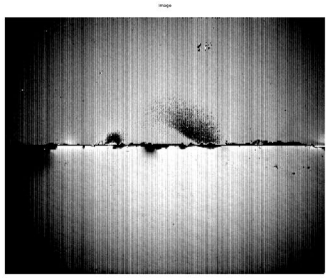
$$O^{rc} = \frac{median_{rc}\left(S_n^{rc}(T_{Low})\right)\cdot\left(S_n^{rc}(T_{high})\right) - median_{rc}\left(S_n^{rc}(T_{High})\right)\cdot\left(S_n^{rc}(T_{Low})\right)}{S_n^{rc}(T_{High}) - S_n^{rc}(T_{low})}$$

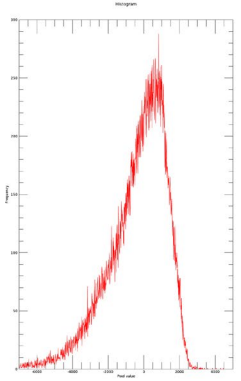


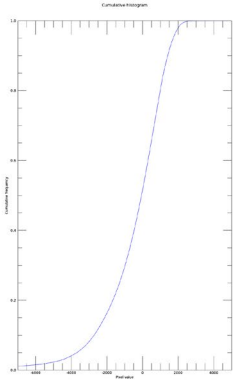




Gain correction map







Offset correction map

In Lab Instrument Focusing

Crucial for sharp images from ISS platform is proper adjustment to infinity.

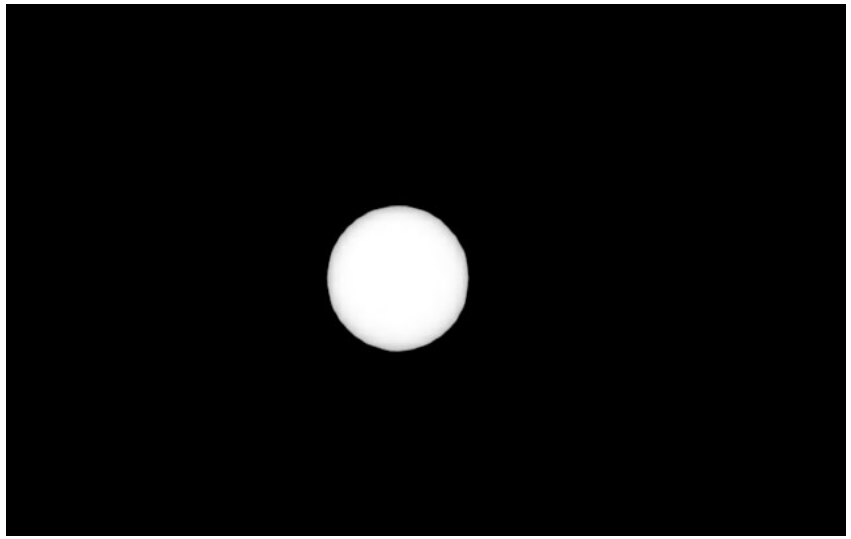
Adjustment of distance between the focal plane array and the entrance pupil of the optics.

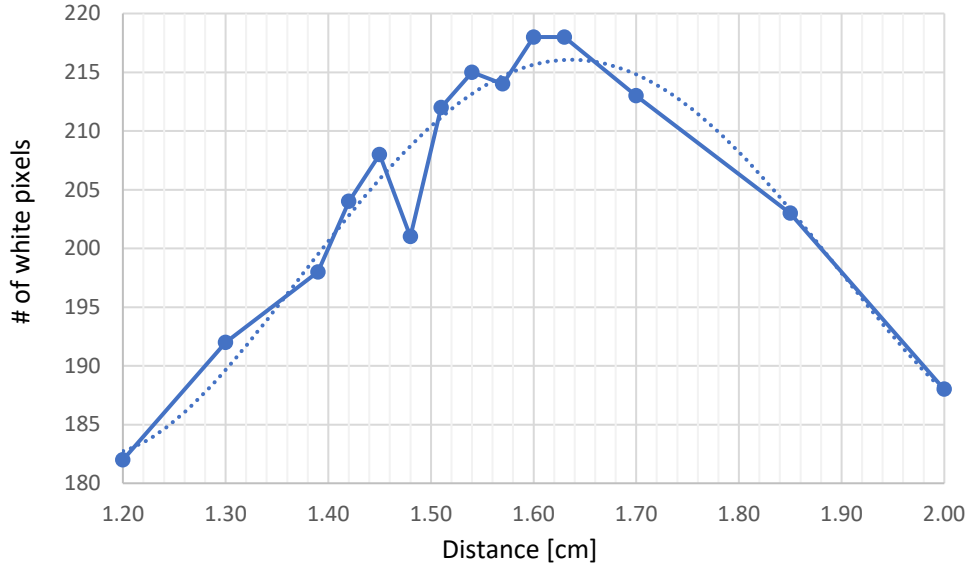
Labs are usually too small to achieve parallel radiation

1000mm telescope (reversed) has been used to achieve parallel rays

thanks a lot to Paul Loregio from Airbus to make the lab work possible and so smooth

In Lab Instrument Focusing



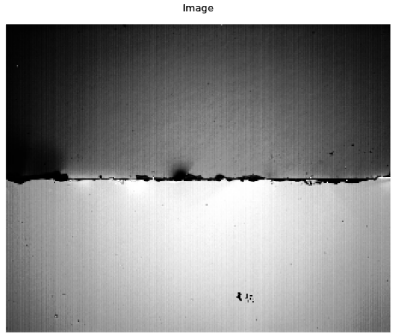


Images of a hot circular blind at different distances between FP and Entrance Pupil are taken
The number of full real white pixels in the image are counted (using a little Image processing tool)
The higher the number becomes the sharper the edge of the circle is imaged

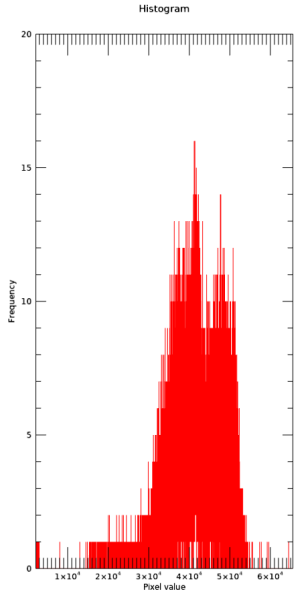
In Orbit Flatfielding

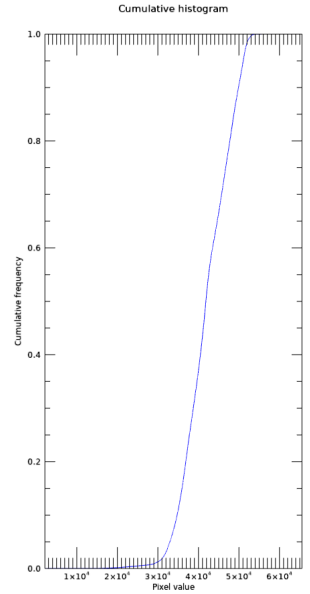
homogeneous images of cold Ocean (+4°C) and desert areas (qpprox. +28°C) replace the lab images.

Several thousands of images are averaged to exclude surface structure from the calculations

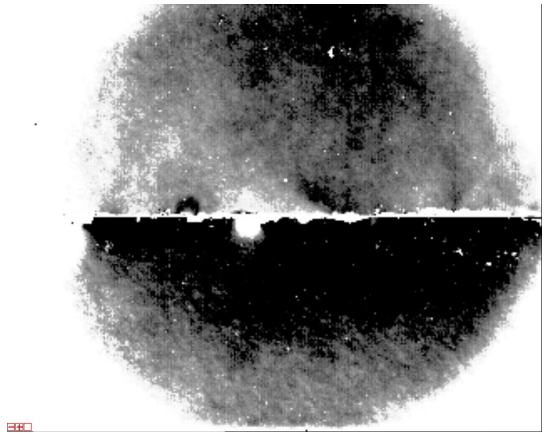


dark image average

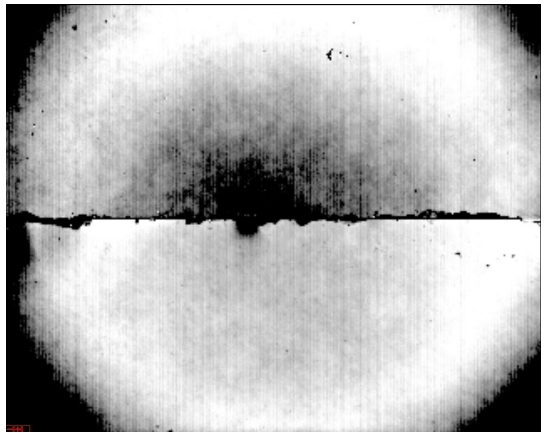


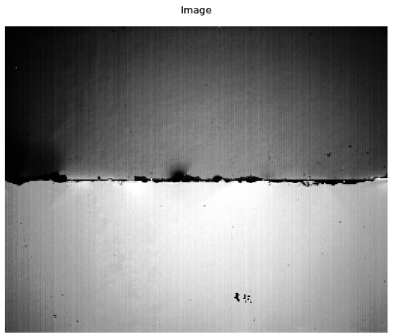


gain

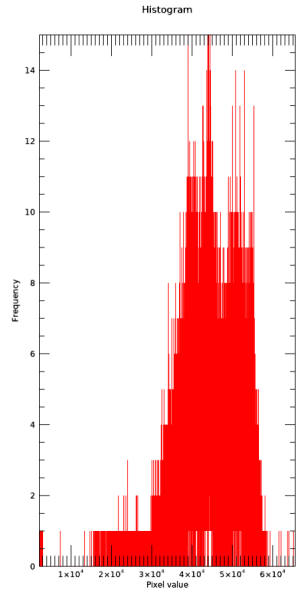


offset





bright image average



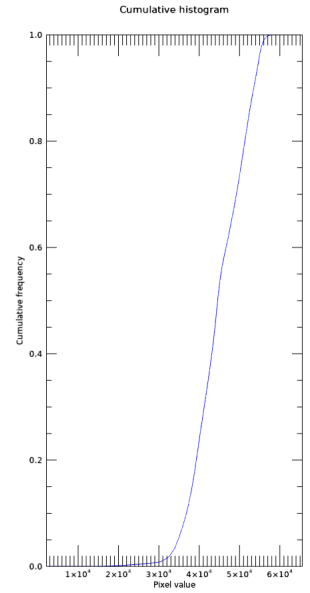
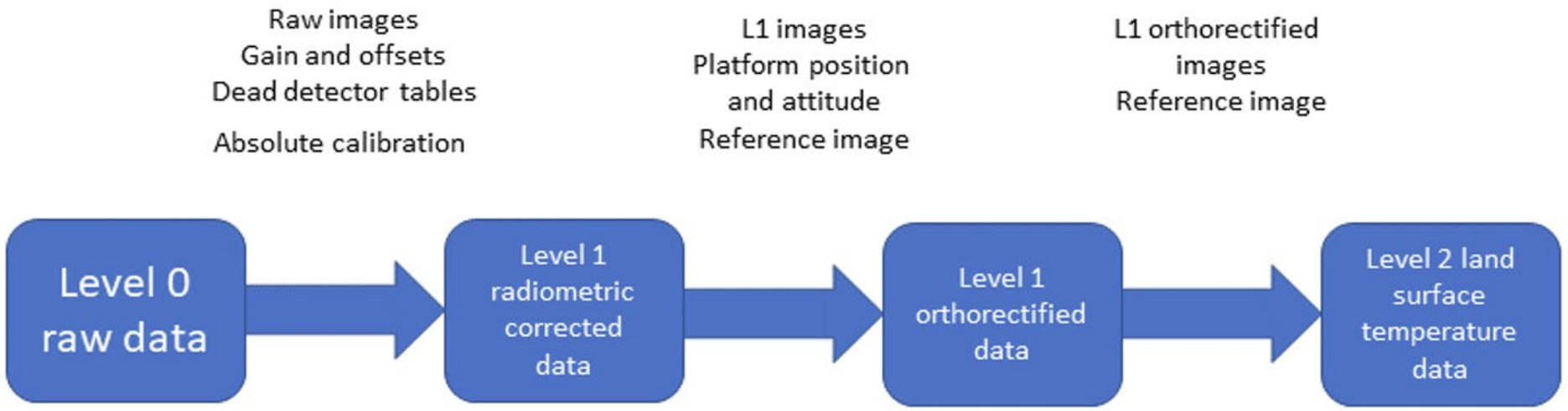


Image Processing Chain I



Archiving: decryption, storage of image and metadata in a database, conversion of coordinates, location of images

```
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                                  Table "raw.lisr_raw_frame"
    Column    |           Type           | Collation | Nullable |       Default
--------------+--------------------------+-----------+----------+---------------------
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 frame_id     | integer                  |           | not null |
 frame_path   | text                     |           | not null |
 frame_md     | jsonb                    |           | not null |
 created_ts   | timestamp with time zone |           | not null | now()
 proc_state   | proc_state               |           | not null | 'waiting'::proc_state
 proc_try     | smallint                 |           | not null | 5
 proc_ts      | timestamp with time zone |           |          |
 proc_id      | text                     |           |          |
 proc_msg     | jsonb                    |           |          |
 footprint    | geometry                 |           |          |
 frame_ts     | timestamp with time zone |           |          |
 sc_pos       | geometry                 |           |          |
 solar_info   | jsonb                    |           |          |
Indexes:
    "lisr_raw_frame_pkey" PRIMARY KEY, btree (record_id, frame_id)
    "lisr_raw_frame_footprint_idx" gist (footprint)
    "lisr_raw_frame_frame_ts_idx" btree (frame_ts)
    "lisr_raw_frame_sc_pos_idx" gist (sc_pos)
Foreign-key constraints:
    "lisr_raw_frame_record_id_fkey" FOREIGN KEY (record_id) REFERENCES lisr_raw_record(record_id)


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                                Table "raw.lisr_raw_telemetry"
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--------------+--------------------------+-----------+----------+---------------------
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 f            | text                     |           | not null |
 t            | bigint                   |           | not null |
 v            | jsonb                    |           |          |
 file_path    | text                     |           | not null |
 file_item_no | integer                  |           |          |
 created_ts   | timestamp with time zone |           | not null | now()
 proc_state   | proc_state               |           | not null | 'waiting'::proc_state
 proc_try     | smallint                 |           | not null | 5
 proc_ts      | timestamp with time zone |           |          |
 proc_id      | text                     |           |          |
 proc_msg     | jsonb                    |           |          |
Indexes:
    "lisr_raw_telemetry_pkey" PRIMARY KEY, btree (g, f, t)
Foreign-key constraints:
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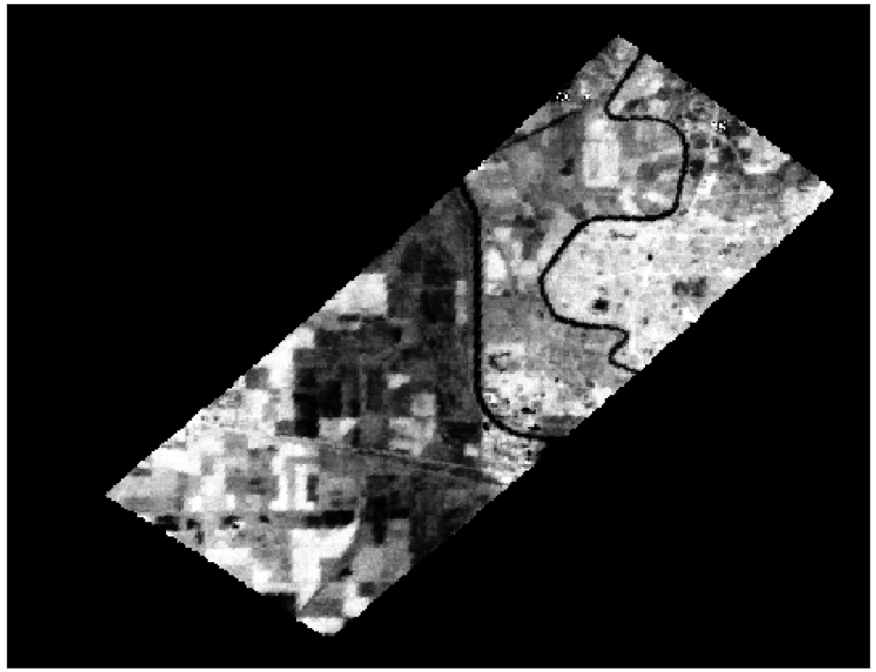
Image Processing Chain II



Dead Detector Correction

Flatfielding

Absolute Calibration

Orthorectification and band registration

To come: Mosaicking to 100 km stripes

Image Processing Chain III

Conversion from Radiance to Land Surface Temperature

- Initially: Cross reference to Ecostress Temperature data
    - Linear fit between Ecostress Temperature and LisR Radiance
- Finally: when the in orbit radiometric calibration is finalized split window approach will be used.
    - To calibrate the split window parameters Ecostress and Landsat LST products will be used.

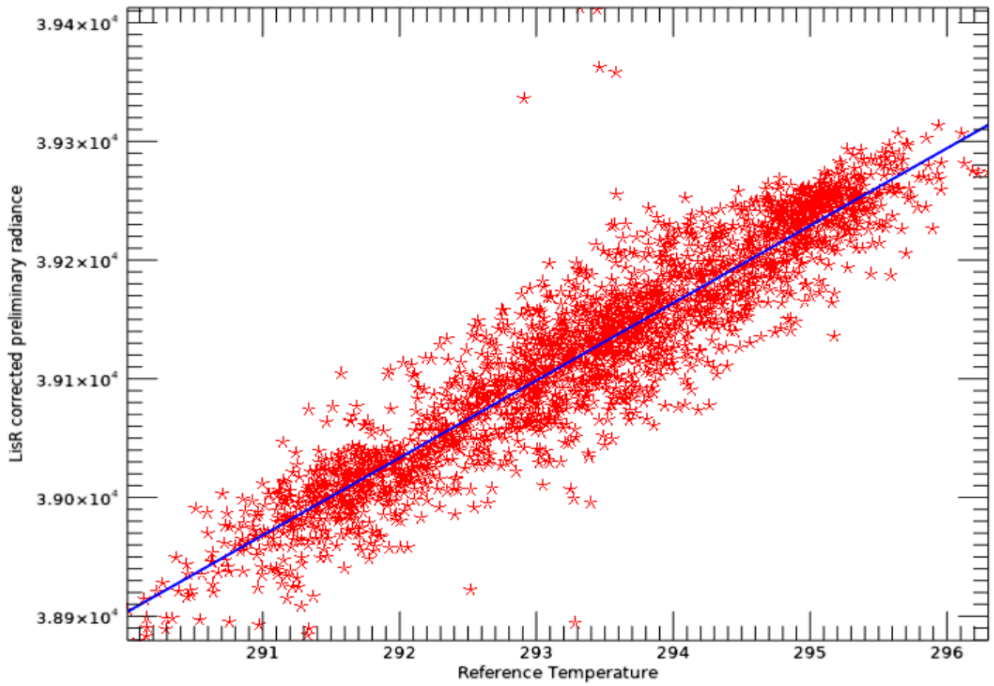
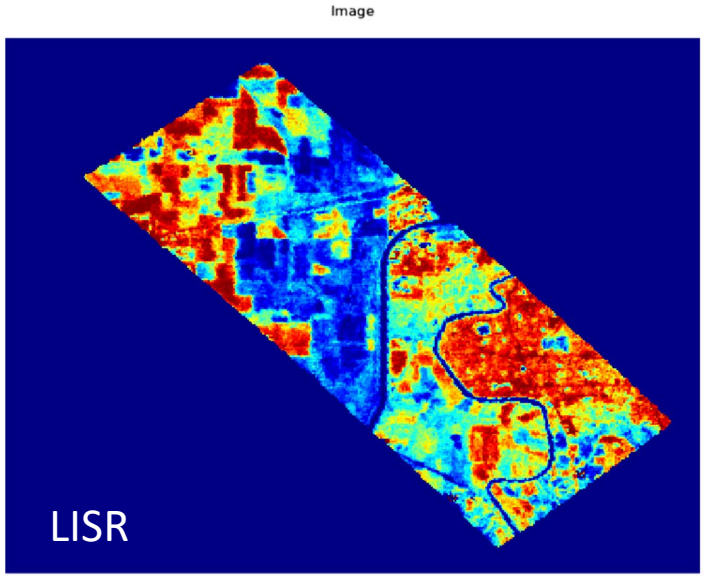
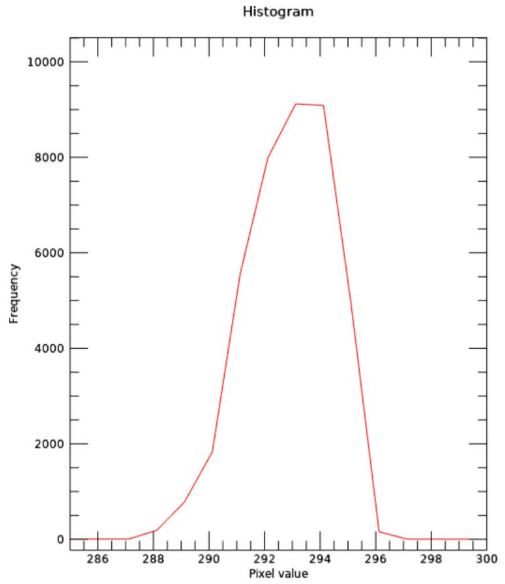
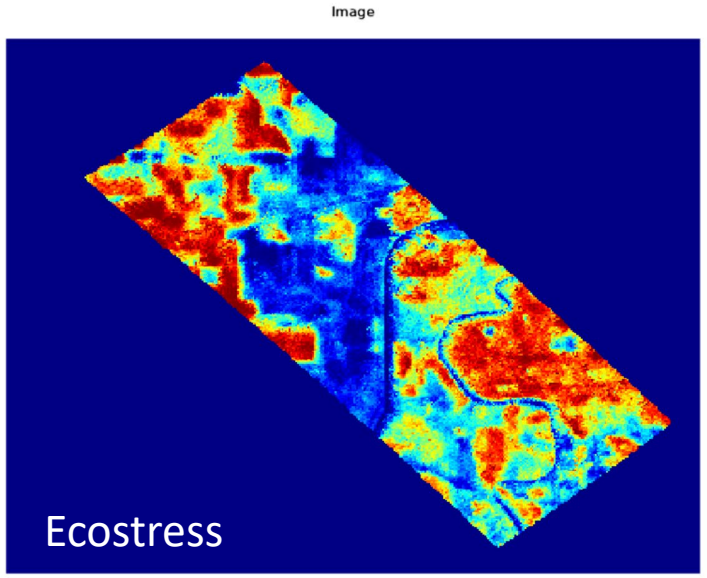


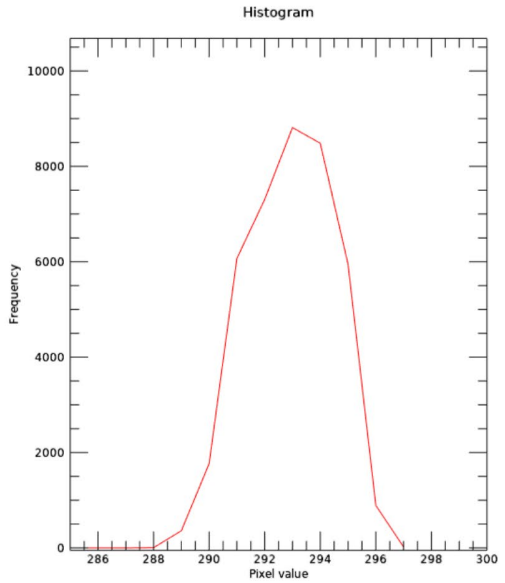
Image Processing Chain IV

- Ecostress seems to be the ideal reference source as it is flying on the same platform than LisR and is mostly available, if not it is replaced by geostationary LST data with coarser resolution,
- Temperatures between LisR and Ecostress match well
- LisR has less striping and banding artefacts
- LisR seems to be sharper than Ecostress images







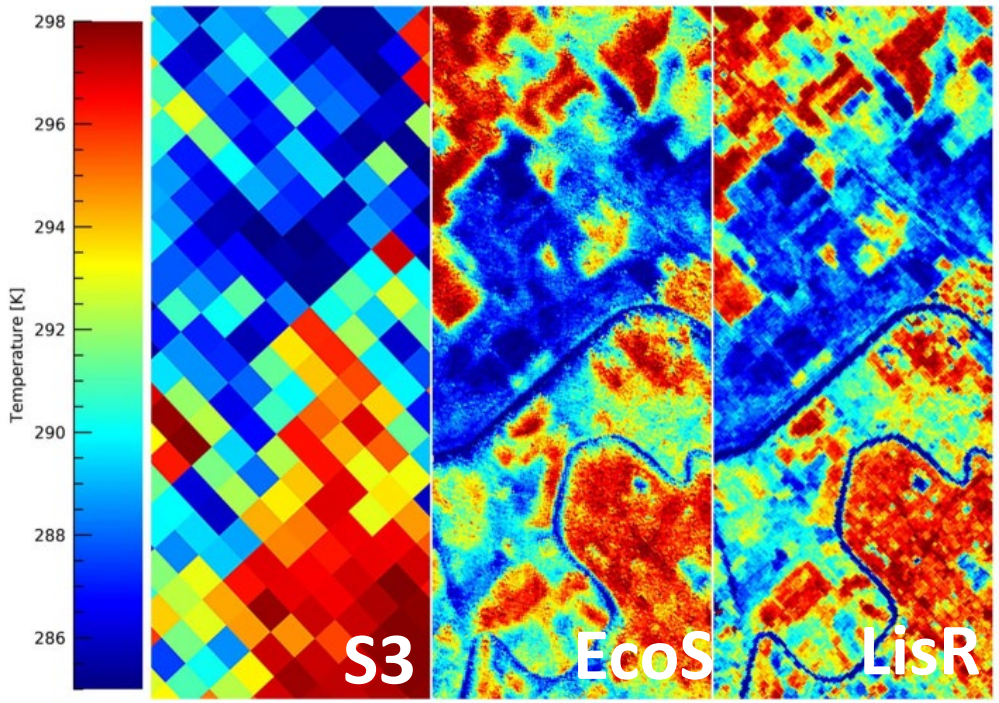


Next Steps

- final absolute calibration (with reference to well calibrated reference systems like Sentinel 3, Seviri)
- adjustment of processing parameters for split window processing
- spatial resolution characterization
- absolute temperature characterization

Company Milestones

- First own VIS/NIR/TIR satellite in orbit by mid 2024
- Constellation of VIS/NIR/TIR satellites by early 2025
- Hyperspectral VIS/NIR/SWIR satellites through purchase of ScanWorld approx. end of 2025



Thank you very much

Questions?

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