Aerosol-UA satellite mission for polarimetric study of aerosols in the atmosphere: state-of-art and prospects

Yaroslav Yatskiv, Oleksandr Degtyarev, Ivan Syniavskyi, Gennadii Milinevskyi, Mikhail Sosonkin, Vassyl Danylevsky, Yevgen Oberemok, Andrii Bovchaliuk, Janna Dlugach, Ihor Fesianov, Yury Ivanov

Main Astronomical Observatory, NAS of Ukraine
Yangel Yuzhnoye State Design Office of State Space Agency of Ukraine
Taras Shevchenko National University of Kyiv, Ukraine

genmilinevsky@gmail.com

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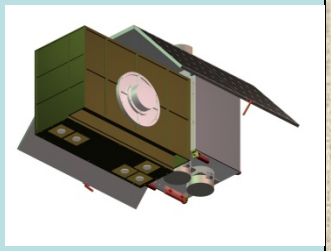
I. Ukrainian satellite project Aerosol-UA: polarimetric study of atmospheric aerosol

Three segments of the mission:

In orbit: YuzhSat platform

and

ScanPol+MSIP combined instrument



Data processing:

Mission products

AOD, SSA, etc.

Cal/Val: AERONET

EARLINET

Idea for Aerosol-UA mission come from Glory experiment and APS instrument

Features of Aerosol-UA instruments concept

1. The concept is based on combination of the multispectral Scanning Polarimeter (ScanPol) and the MultiSpectral Imaging Polarimeter (MSIP)

2. **ScanPol** and **MSIP** polarimeters are designed to provide high precision measurements:

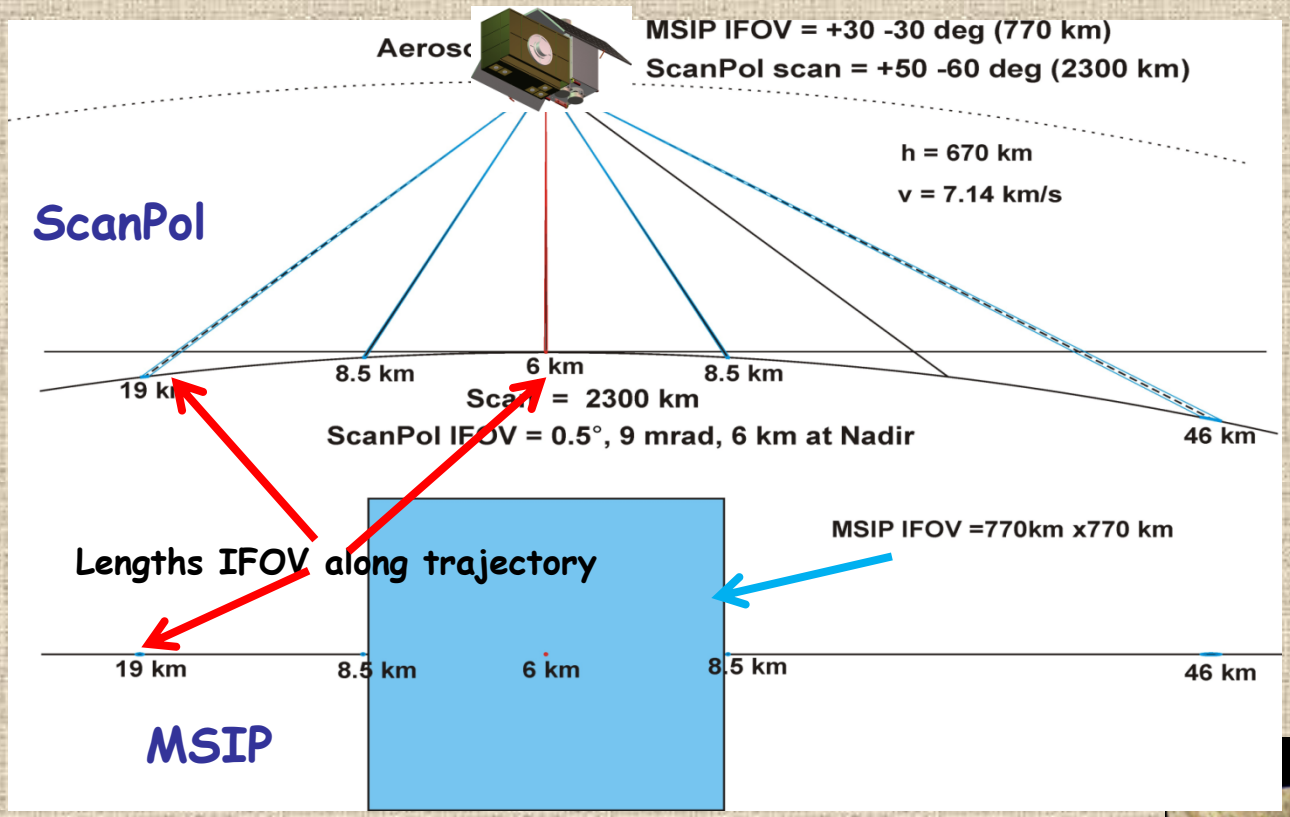
ScanPol measuring three Stokes parameters I, Q and U, from about 150 viewing along-track directions.

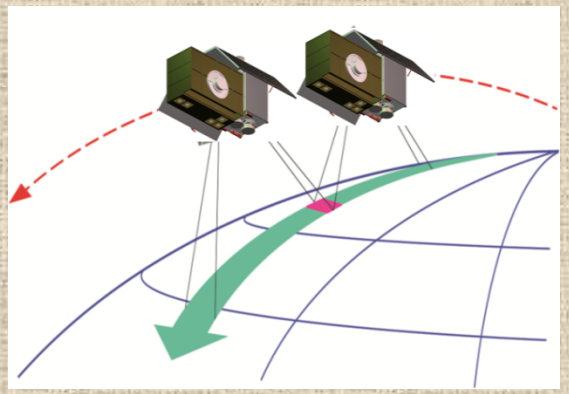
MSIP provides the aerosol parameters with wide FoV, aerosol/clouds separation, and ScanPol data correction.

3. These two Aerosol-UA instruments, combined together, allow multi-angular measurements of the polarized radiance

4. Besides onboard calibration, ScanPol allows cross-calibration since FoV of the two instruments overlapping

Measurements geometry ScanPol and MSIP





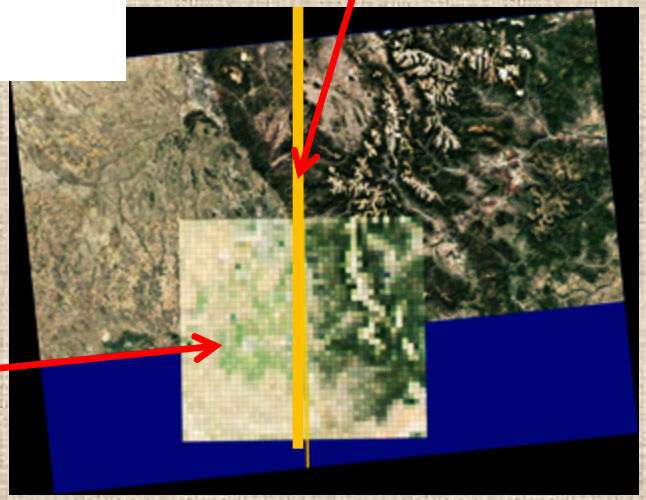
ScanPol track

ScanPol: period of scan 1.5 sec

(40 revolutions per minute)

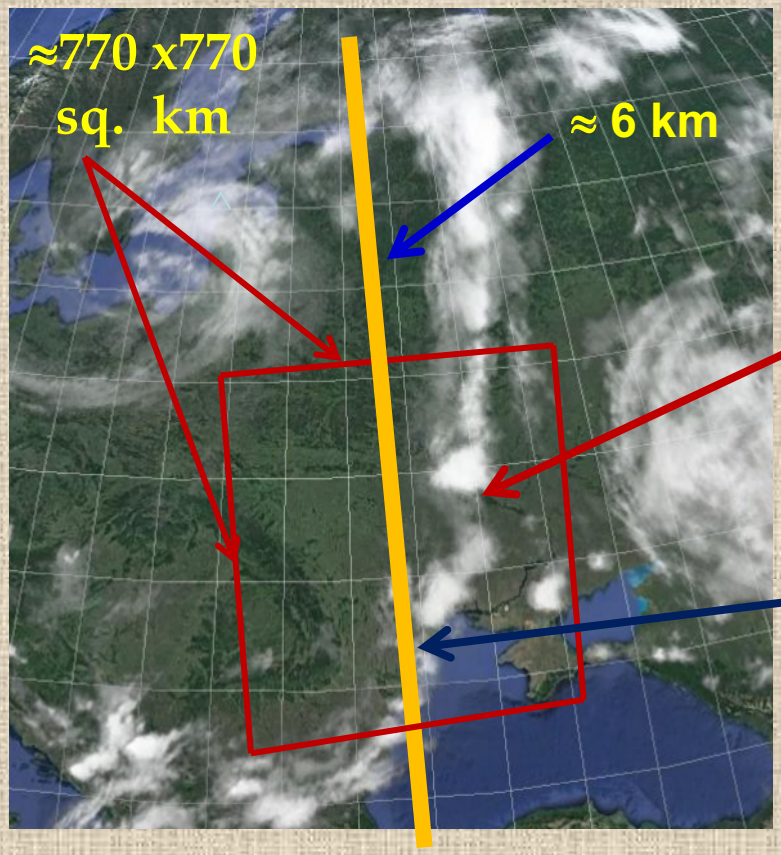
Combined field-of-view MSIP and ScanPol

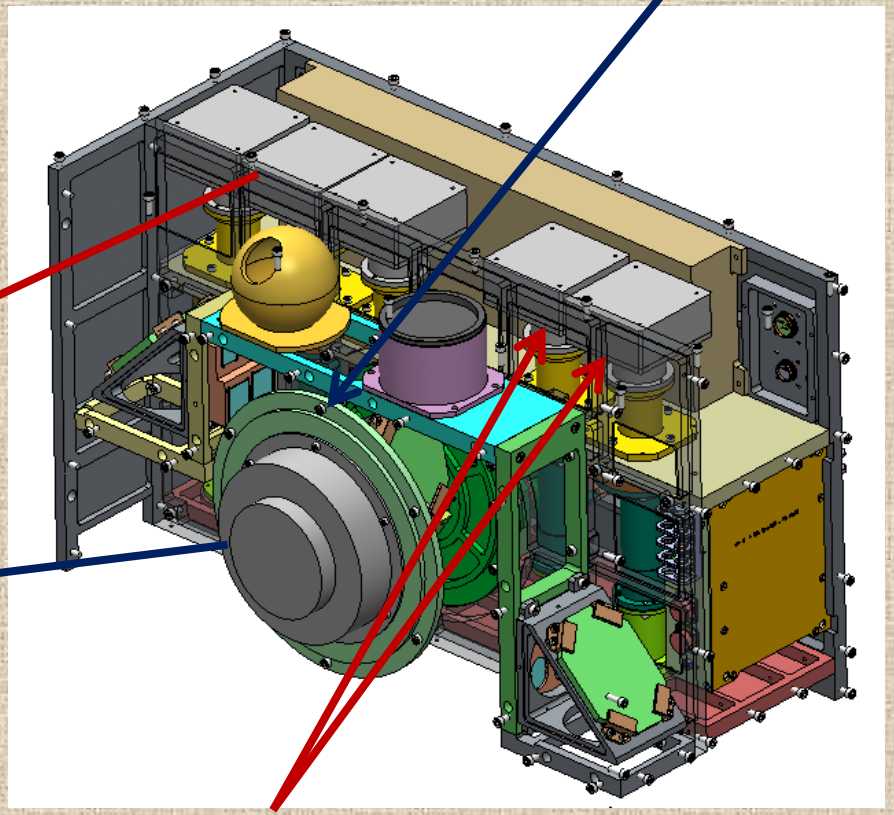
MSIP



Aerosol-UA: final design of two combined instruments and field-of-view overlapping

Scanning Polarimeter: ScanPol

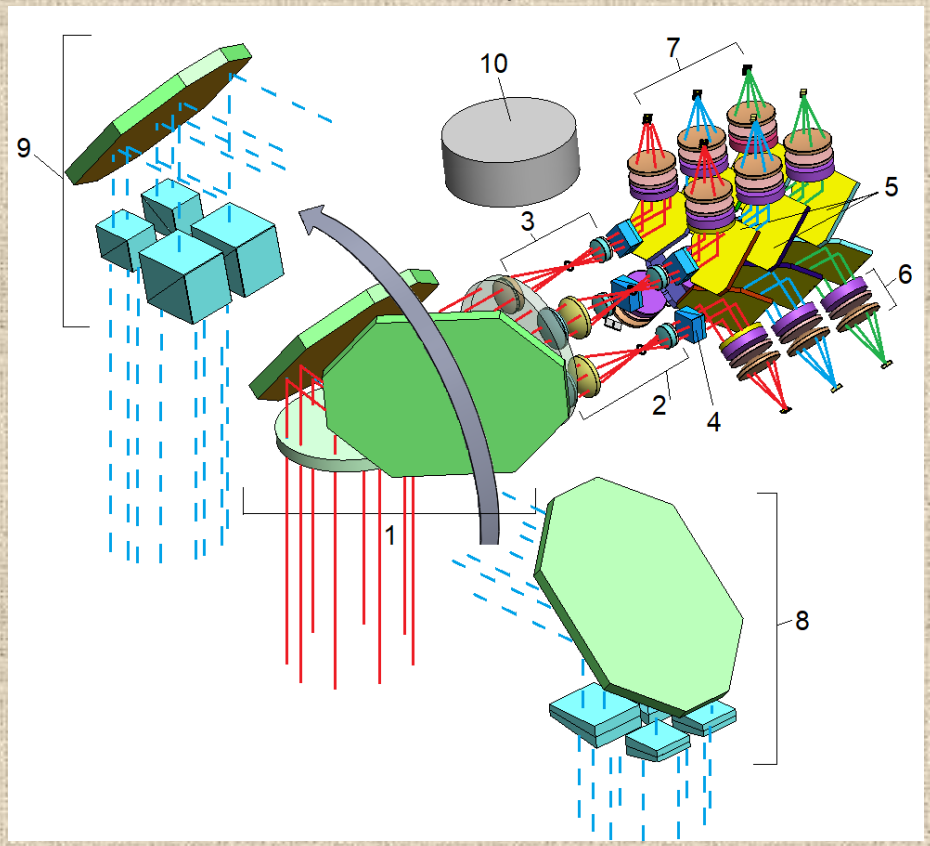




MSIP channels
Multi-Spectral Imager-Polarimeter

II. ScanPol polarimeter optical design

Spectral band: 370-1610 nm,
six spectral channels:



370 nm – tropospheric aerosol and top of clouds

410 nm – aerosol over ocean and surface

555 □□ – aerosol over ocean and surface, ocean color

865 nm – aerosol over ocean and surface

1378 nm – separate cirrus clouds, stratosphere aerosol, separation of troposphere and stratosphere aerosol in case of volcanic eruption

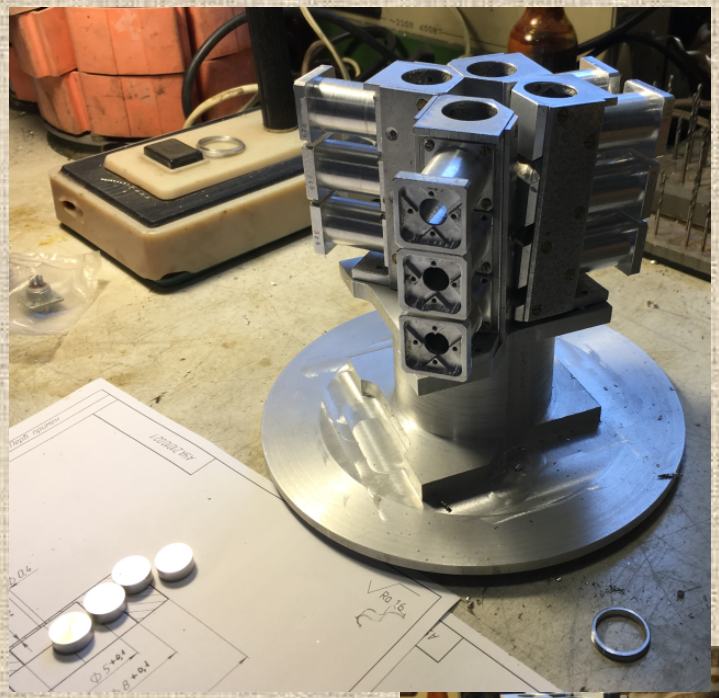
1610 nm – separation surface signal from aerosol over Earth' surface

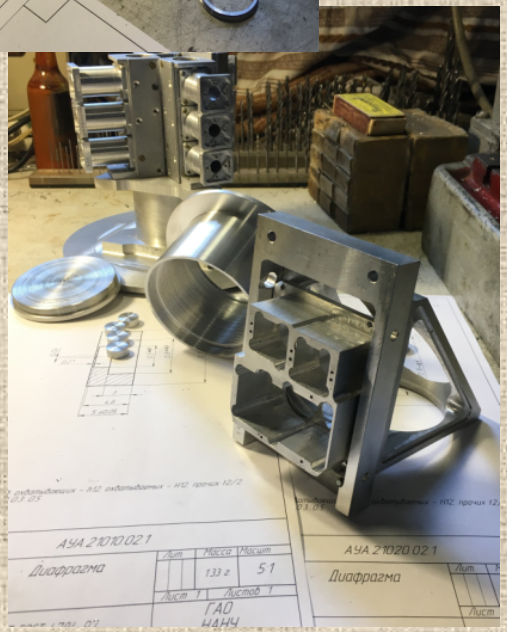
Filter FWHM: 20 - 40 nm

Observable Stokes parameters: I, Q, U (0,90,45,135°)
Photometric accuracy: 4%
Polarimetric accuracy: 0.15%
On-board calibration: all three Stokes parameters

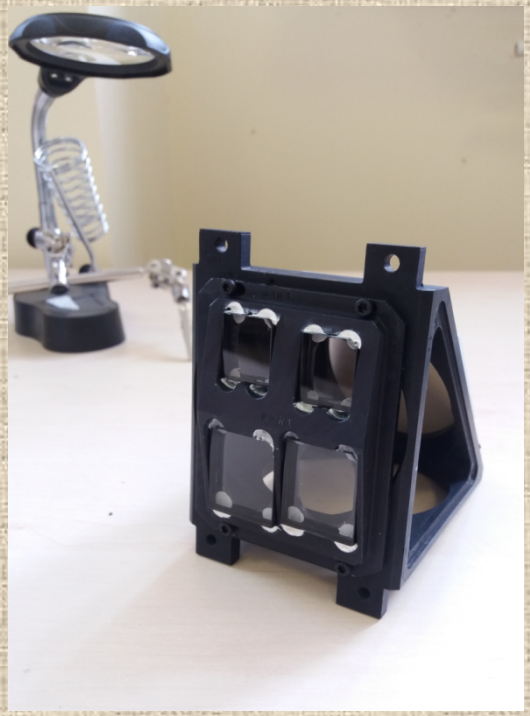
ScanPol is similar to APS Glory

ScanPol polarimeter hardware construction

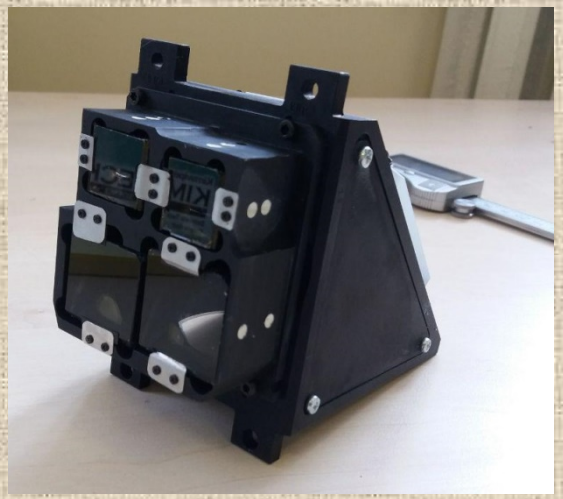




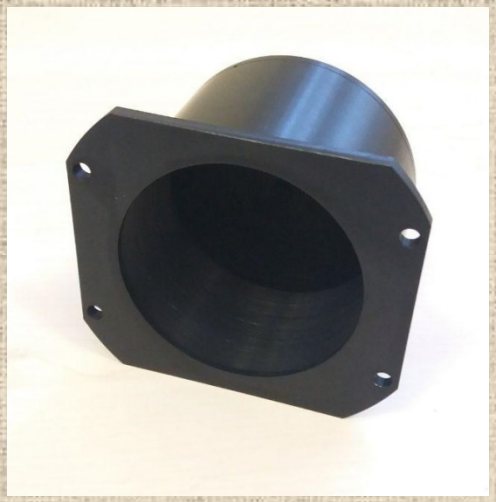
ScanPol on board calibration units



Calibration unit on depolarized light



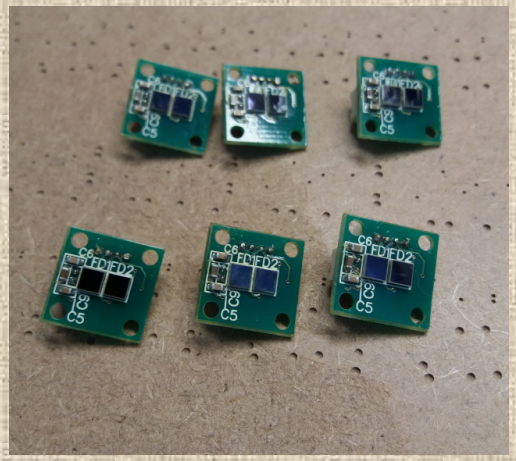
Calibration unit on polarized light



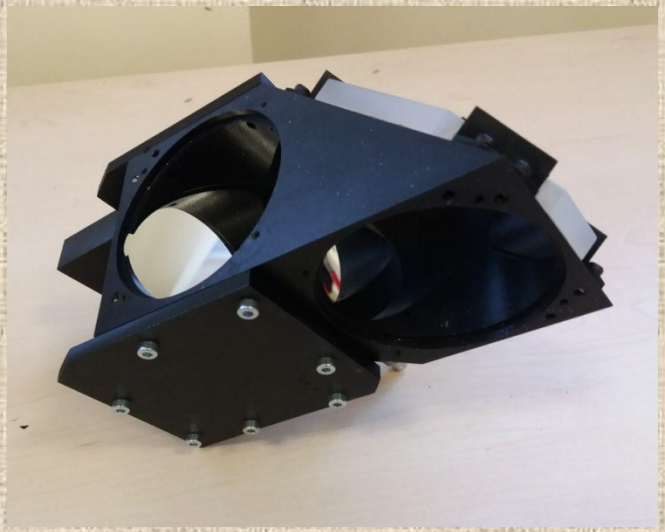
Black body

ScanPol optical-mechanical unit hardware

Optical channels of ScanPol



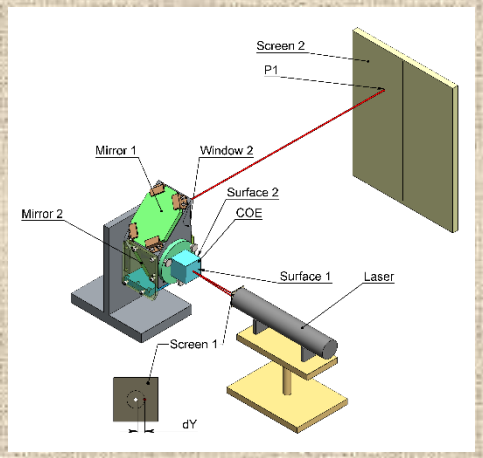
Sensors for ScanPol VIS channels

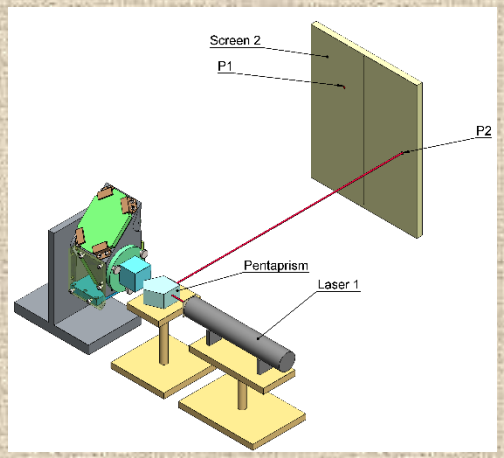


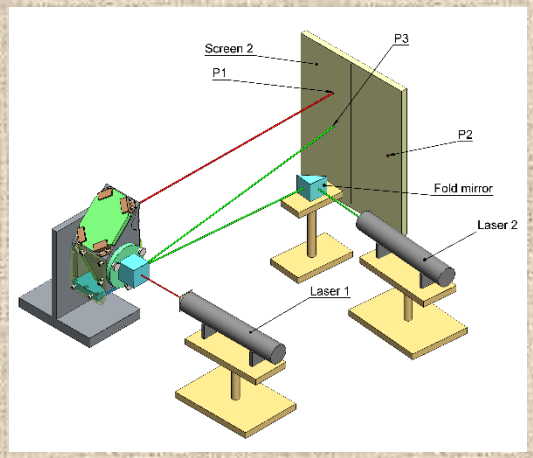
ScanPol mirrors scanning system

ScanPol mirror scanning system adjustment

Test the mirror assembly, alignment technique provides accuracy 10'



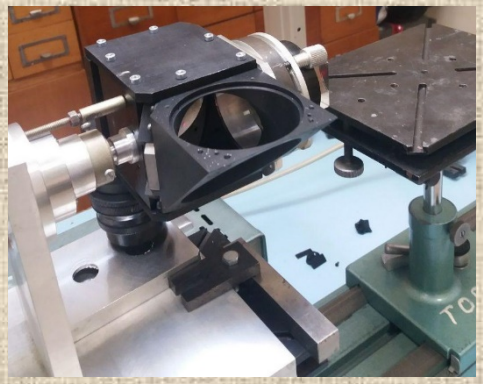




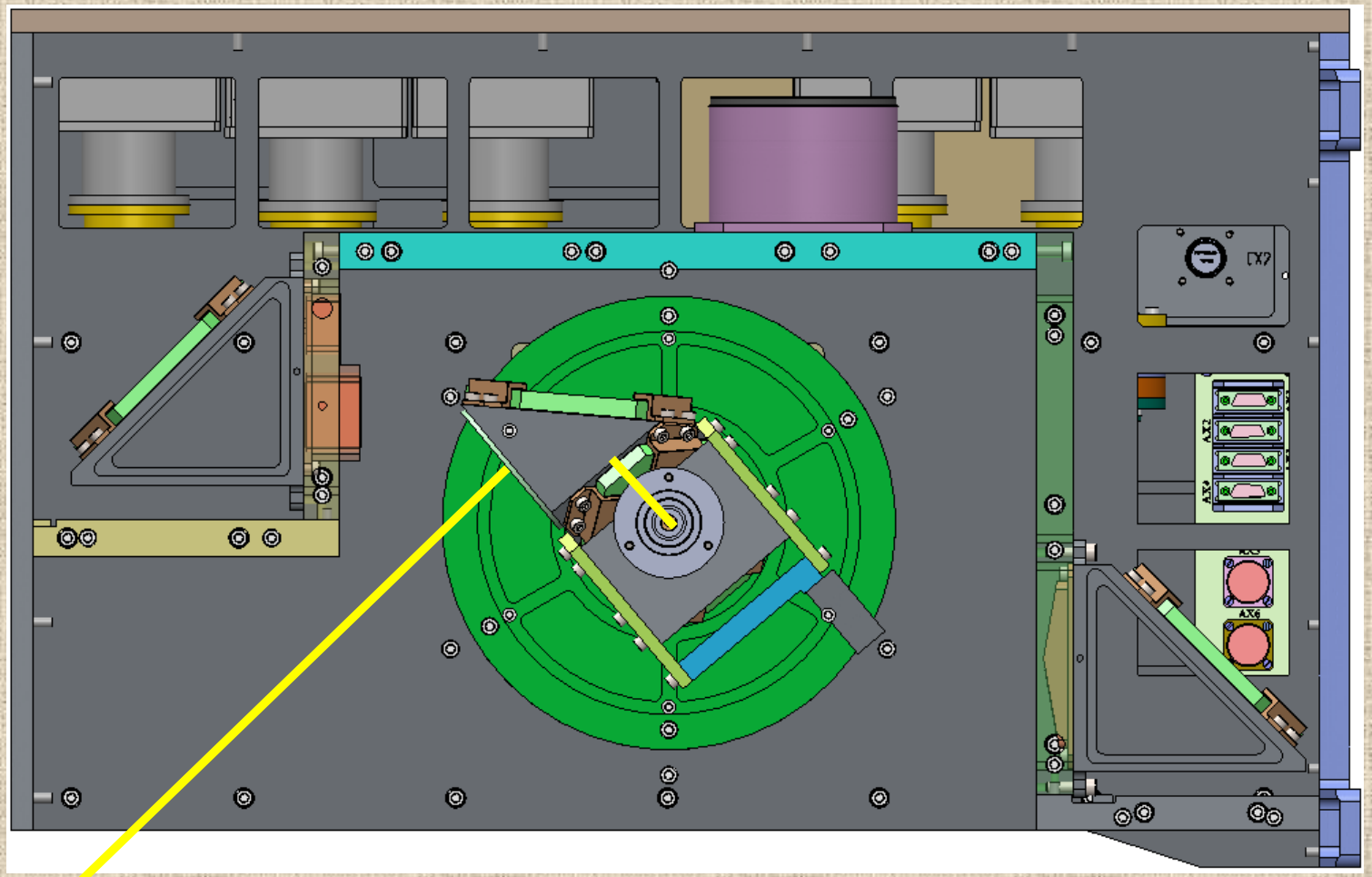
Step 1

Step 2

Step 3

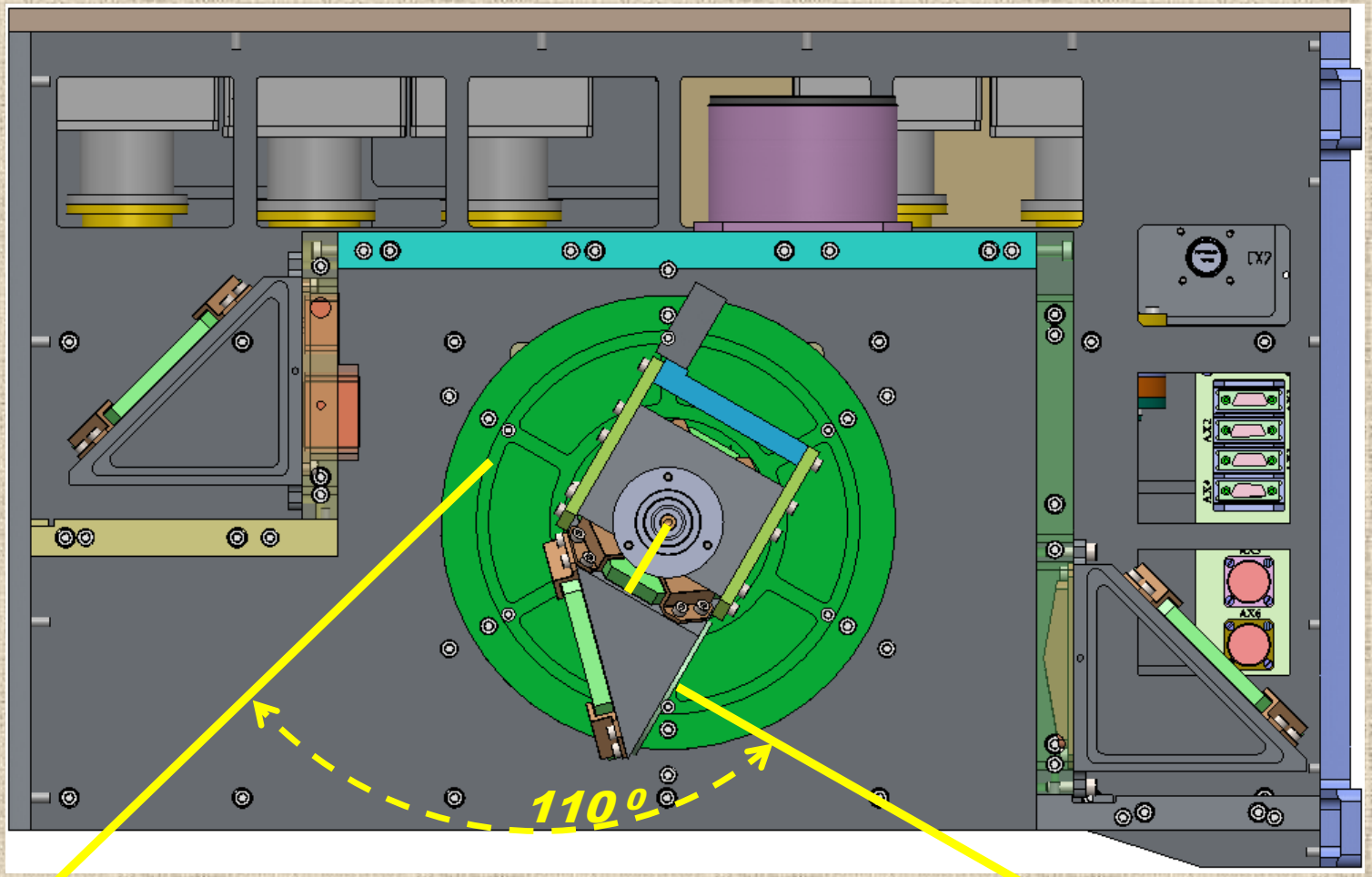


ScanPol onboard calibration at each scan



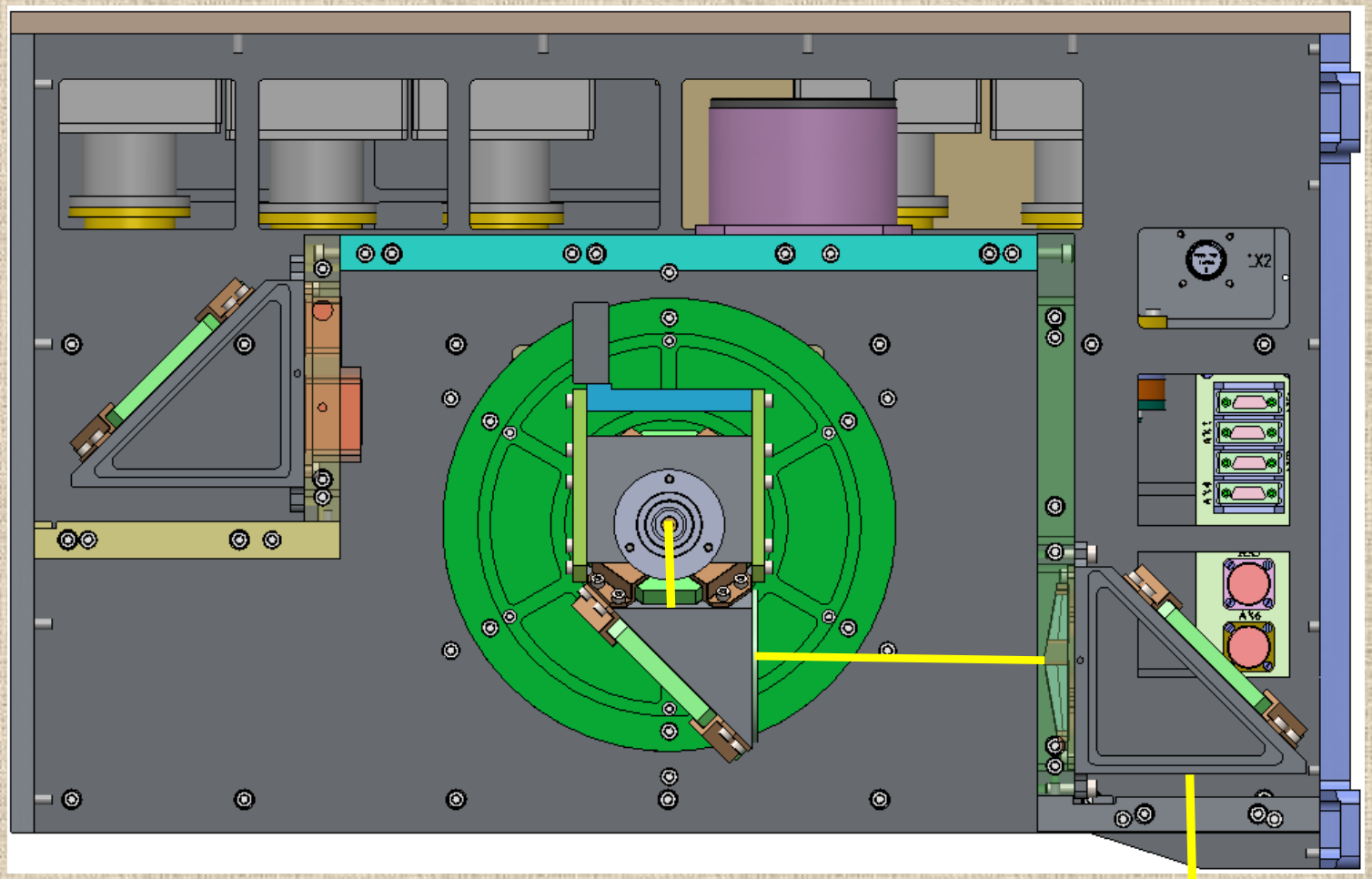
Scan atmosphere and Earth surface

ScanPol onboard calibration



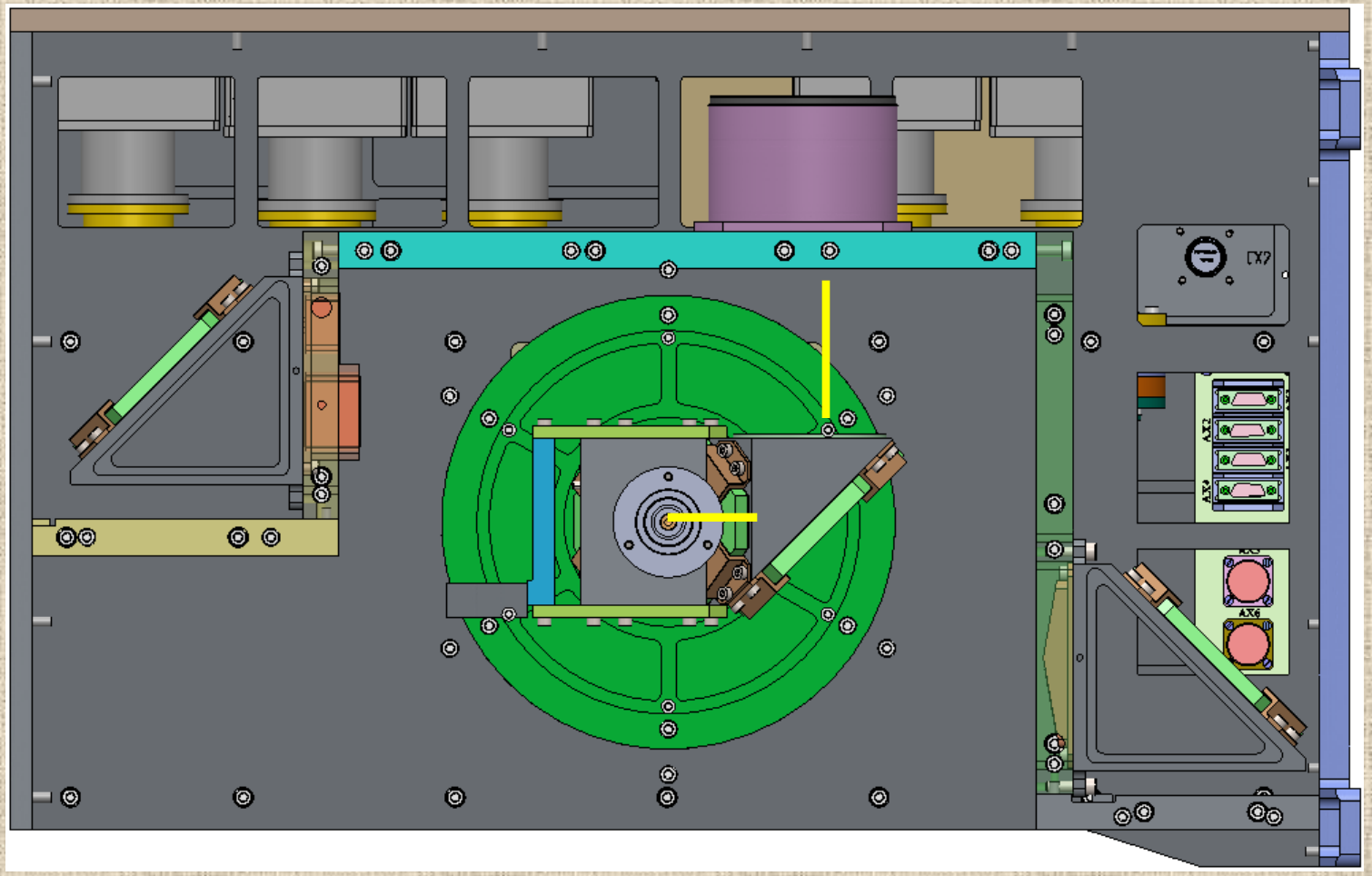
Scan atmosphere and Earth surface

ScanPol onboard calibration



Scan depolarized light: quartz wedges

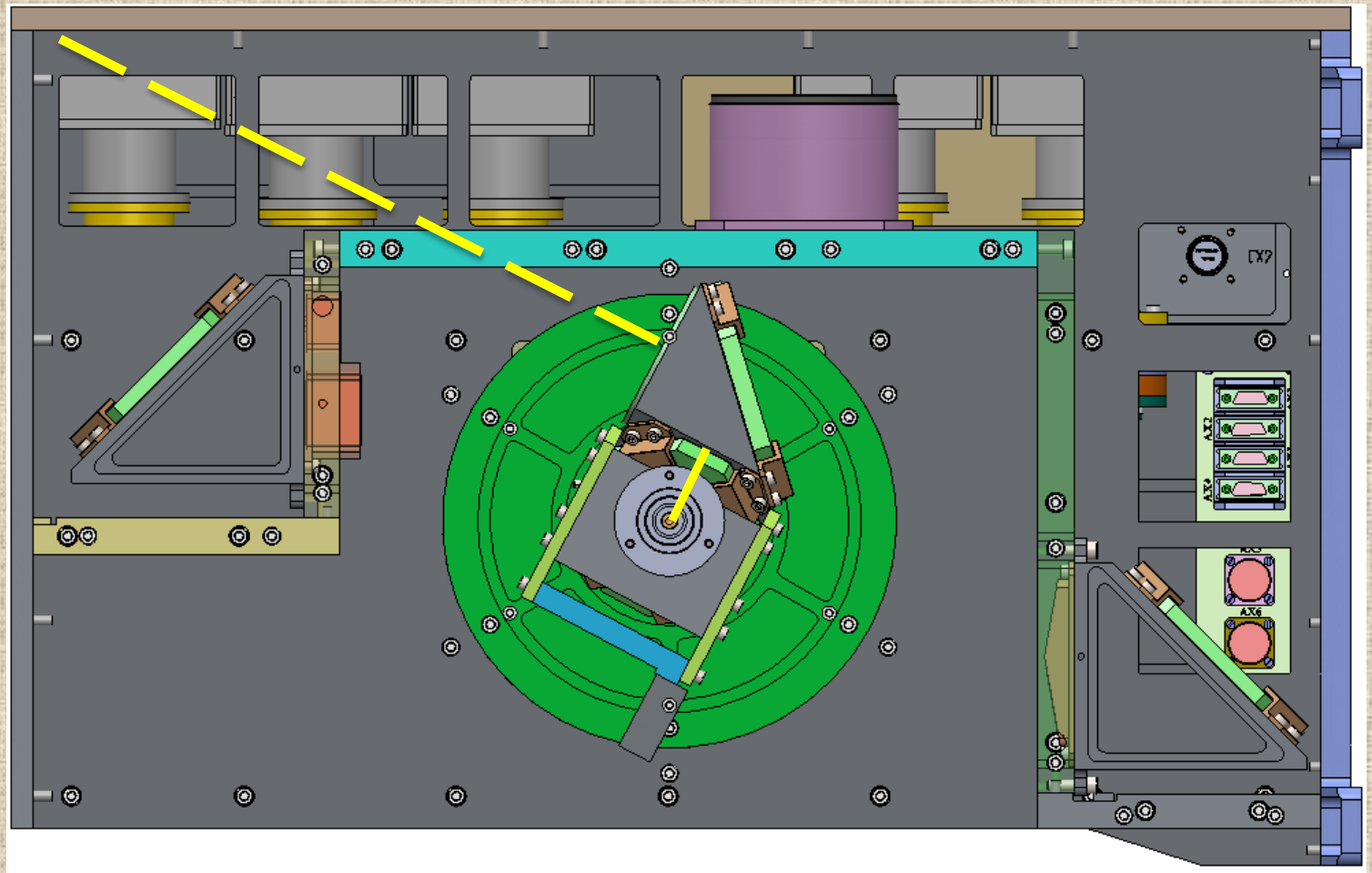
ScanPol onboard calibration



Scanning dark unit

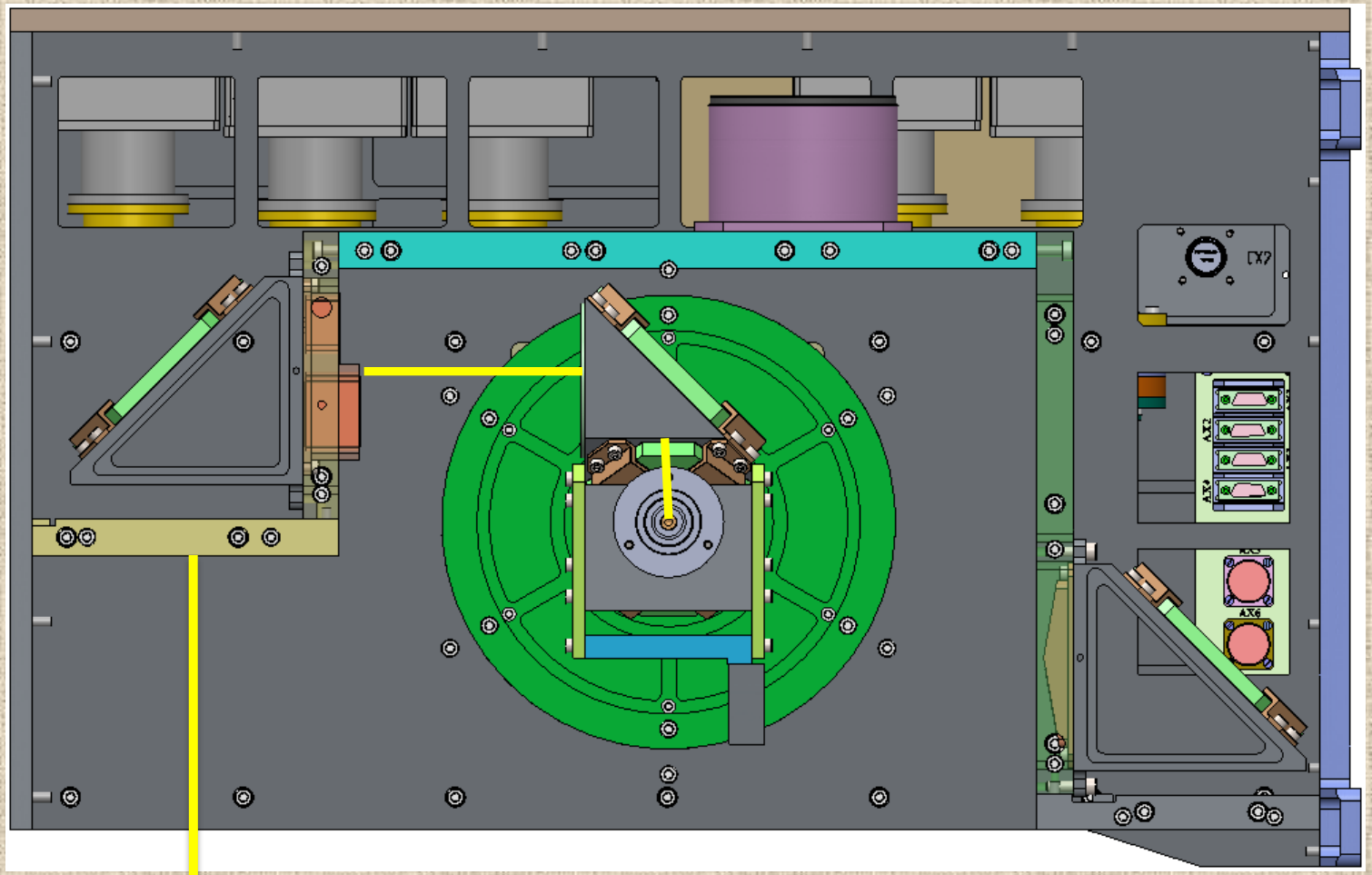
Дніпро 2019

ScanPol onboard calibration



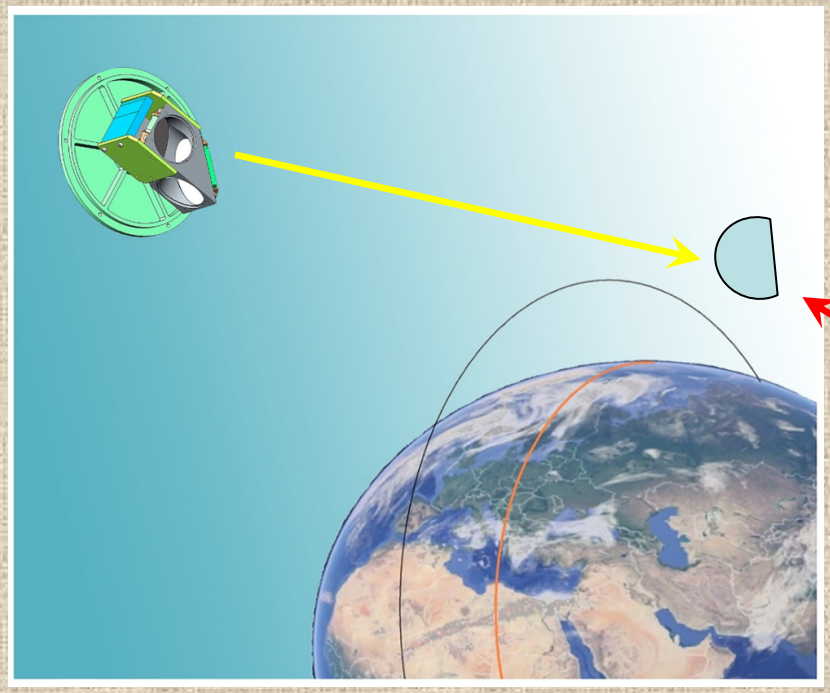
Scan Sun light unit

ScanPol onboard calibration



Scan polarized light: Glan prism

ScanPol/MSIP intercalibration by Moon



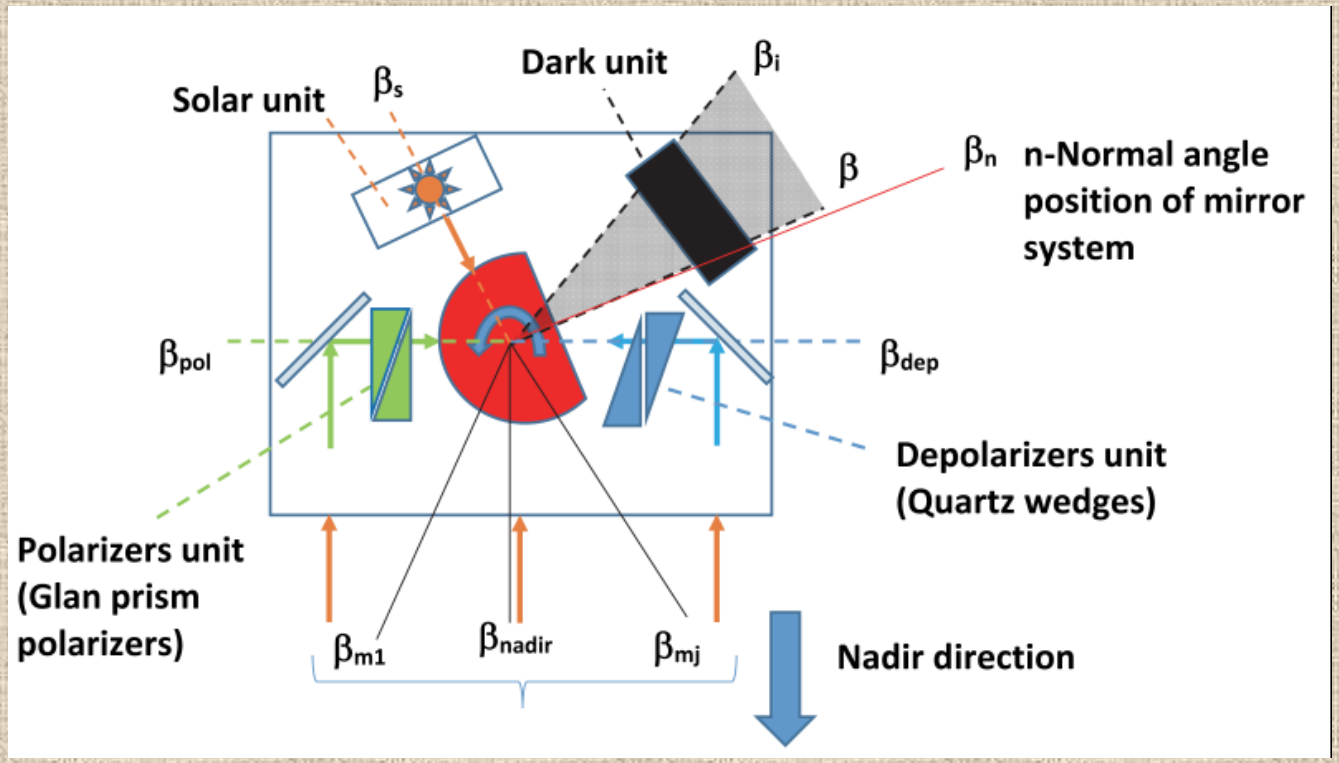
MSIP FoV

ScanPol FoV

Moon

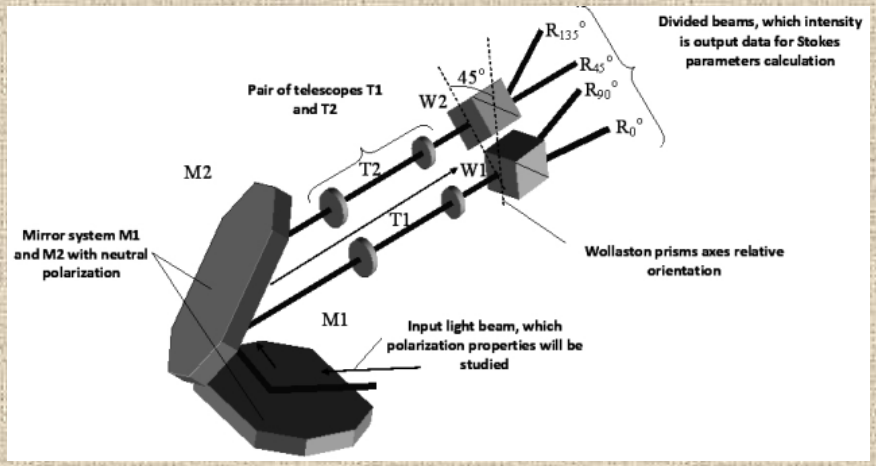
ScanPol polarimeter calibration model, 2019

Milinevsky et al. Calibration model of polarimeters on board the Aerosol-UA space mission. JQSTR Special Issue, 2019



The scan mirrors and calibration units layout of the ScanPol instrument: red segment - scan mirrors; blue element - quarts wedges of the depolarization unit; green element - the Glan prism polarizer unit, black element is the dark unit; solar calibration unit seen at β_s angle. Scanning directions along-track between scan angle β_{m1} = +50° and β_{m2} = –60° from nadir (β_{nadir}).

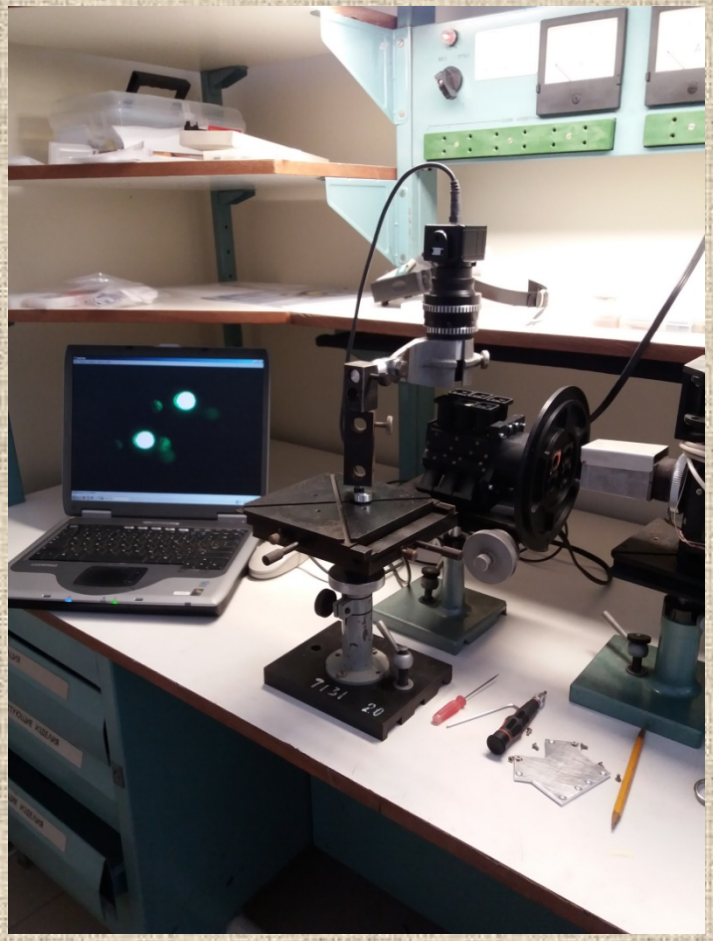
ScanPol polarimeter sensors laboratory tuning



Equivalent polarization scheme of the ScanPol polarimeter.

ScanPol standard error is 0.0008, correspondent to relative error 0.08%

(Milinevsky et al., JQSRT 2019)

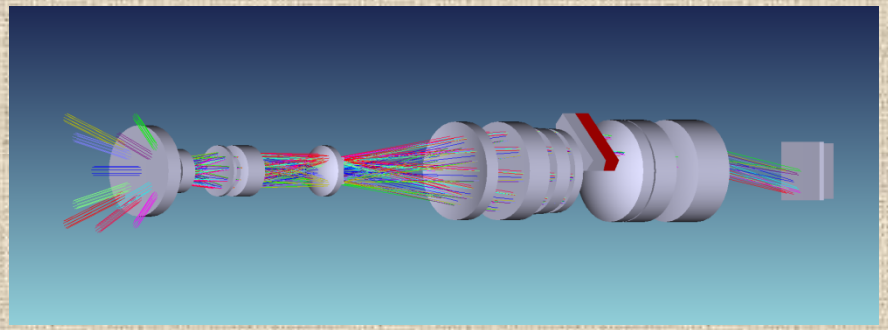


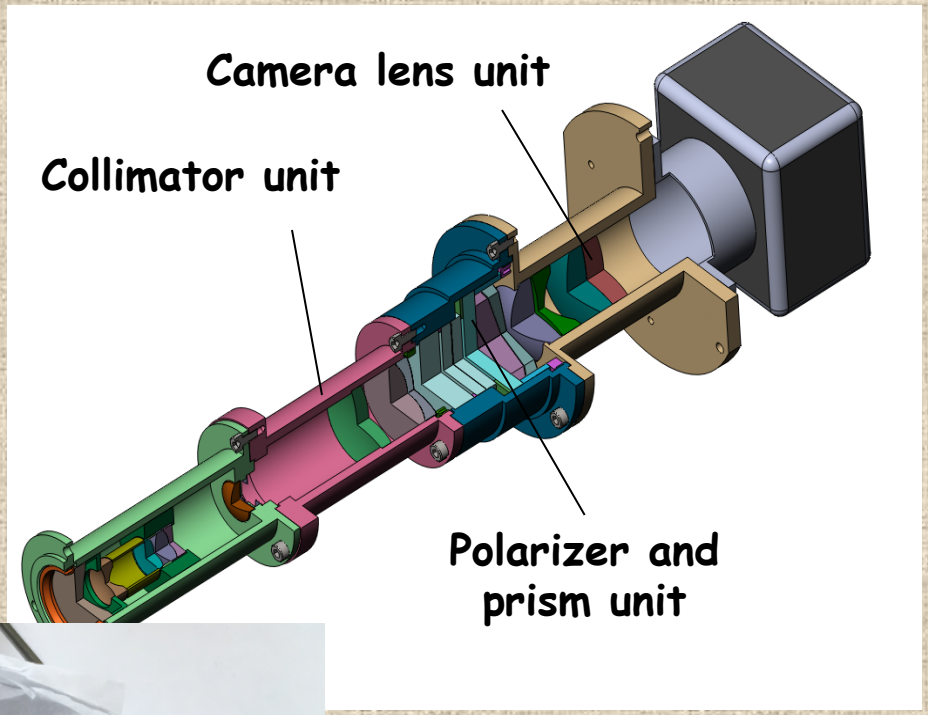
Laboratory tuning of the ScanPol sensors. Glare is visible - will be removed by reflective diaphragms.

III. Multi-Spectral Imaging Polarimeter (MSIP)

- MSIP: aerosol/clouds parameters measurements and aerosol - clouds separation in the field-of-view
- Three polarimetric channels: 410, 555, 865 nm with 0°, 45°, 90°, 135° directions each
- Two intensity channels: (1) 410, 443, 470, 490; (2) 555, 670, 865, 910 nm
- Wide FOV: 60°x60°, 770x770 km, resolution 6 km
- Images rate from 1.5 ÷ 6.0 frames per second
- Intercalibration of the MSIP using ScanPol scans, ~ 1% accuracy (Milinevsky et al., JQSRT 2019)

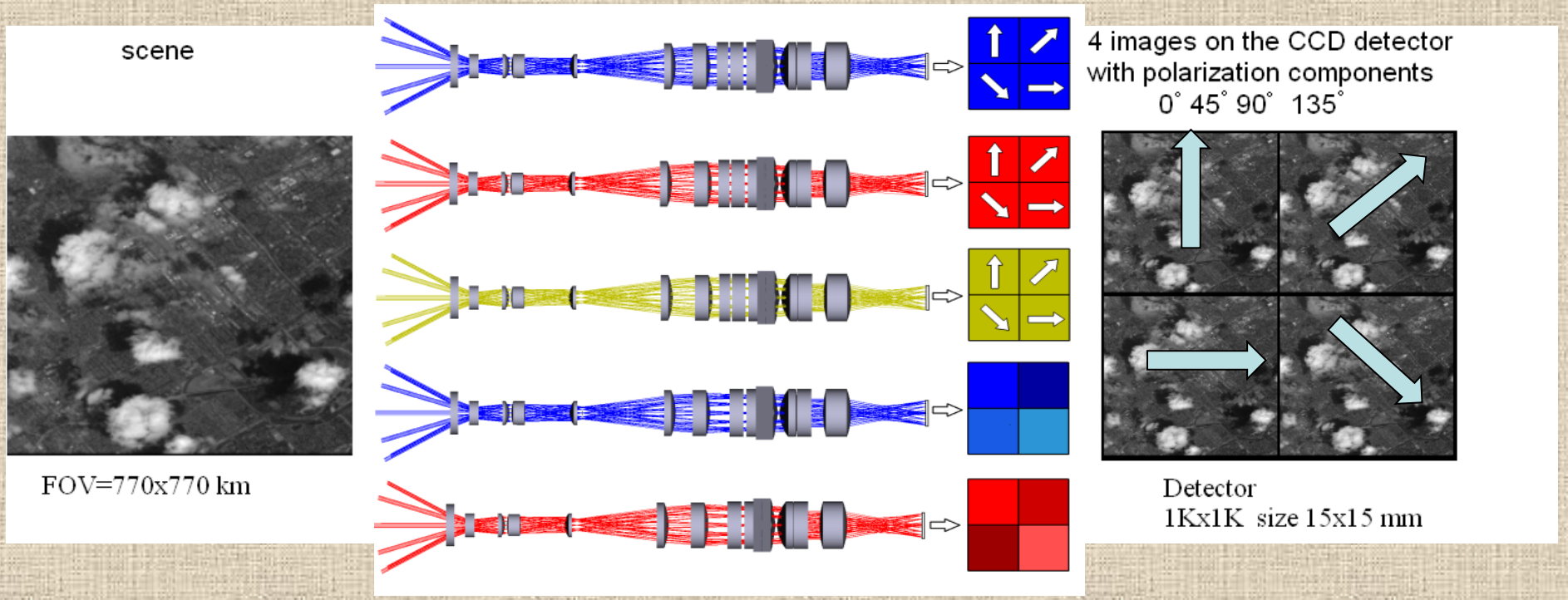
MSIP optical channel

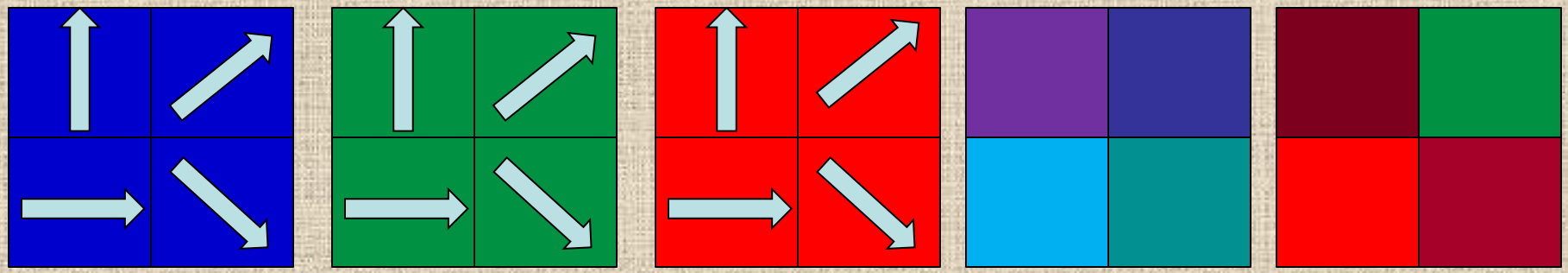




Prism for image separation

MultiSpectral Imaging Polarimeter MSIP





Polarization 0°, 45°, 90°, 135°

410 nm 555 nm 865 nm

Overall 20 Spectral/Polar channels

Intensity

410+443+ 555+670+

+470+490 nm +865+936 nm

MSIP test images in four intensity channels

490 nm

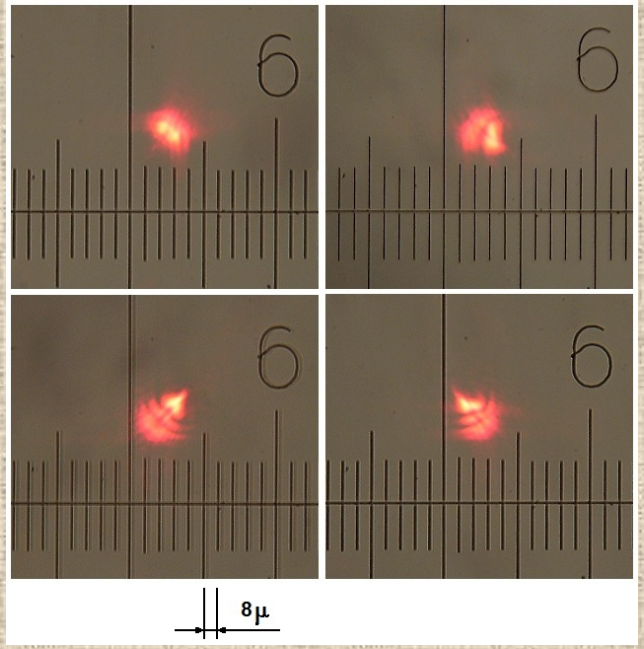
470 nm

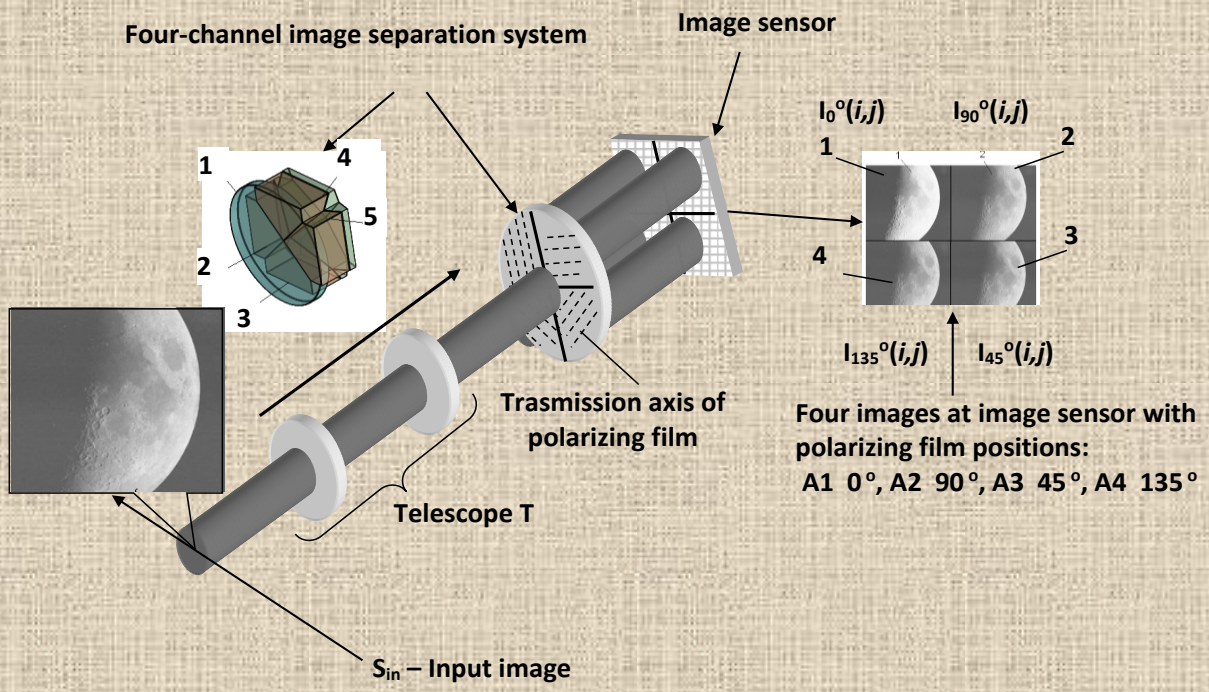
443 nm

410 nm

Spectral full width at half maximum (FWHM): 20 nm

MultiSpectral Imaging Polarimeter test measurements



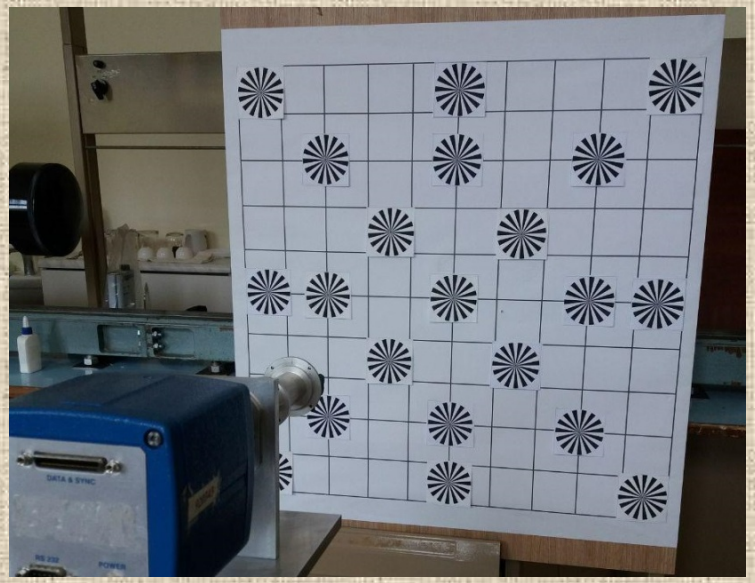


Four images size in MSIP from the dot source, size of spot = 30 μ

Elements of the one spectral polarization unit of the MSIP polarimeter for calibration model

(Milinevsky et al., JQSRT 2019)

MSIP image quality test



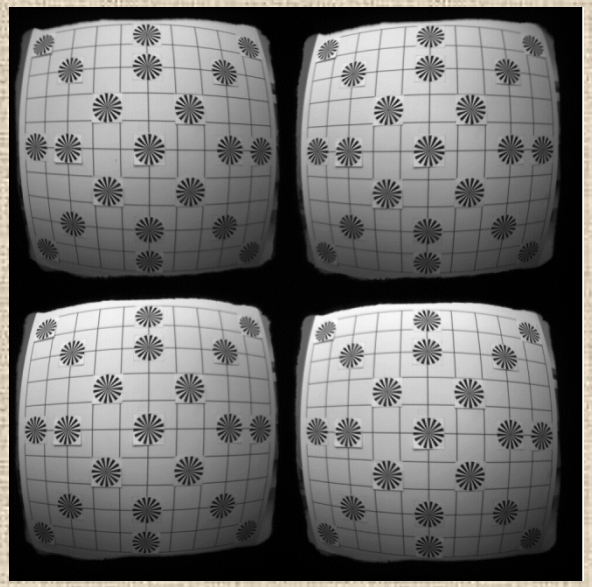
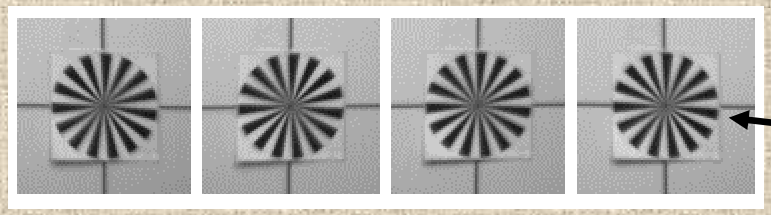
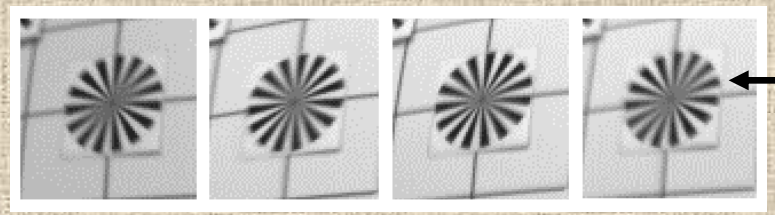


Image quality test on distortion using CCD-camera

MSIP channel without polarizer

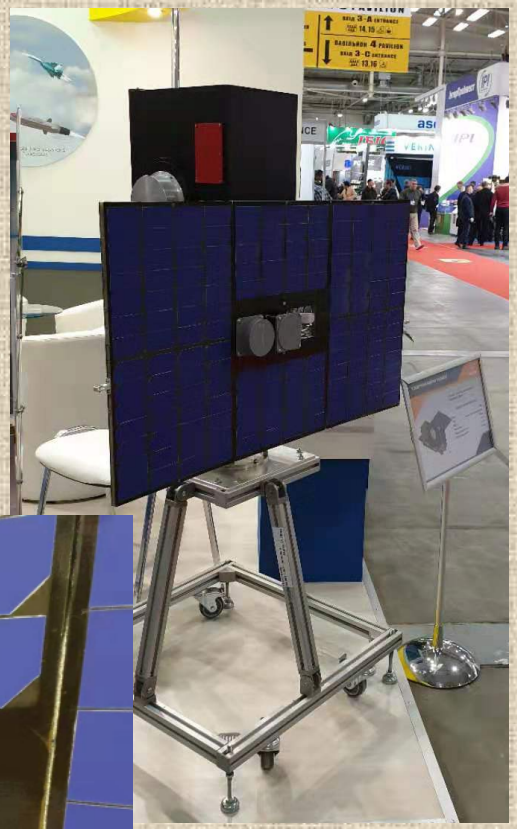


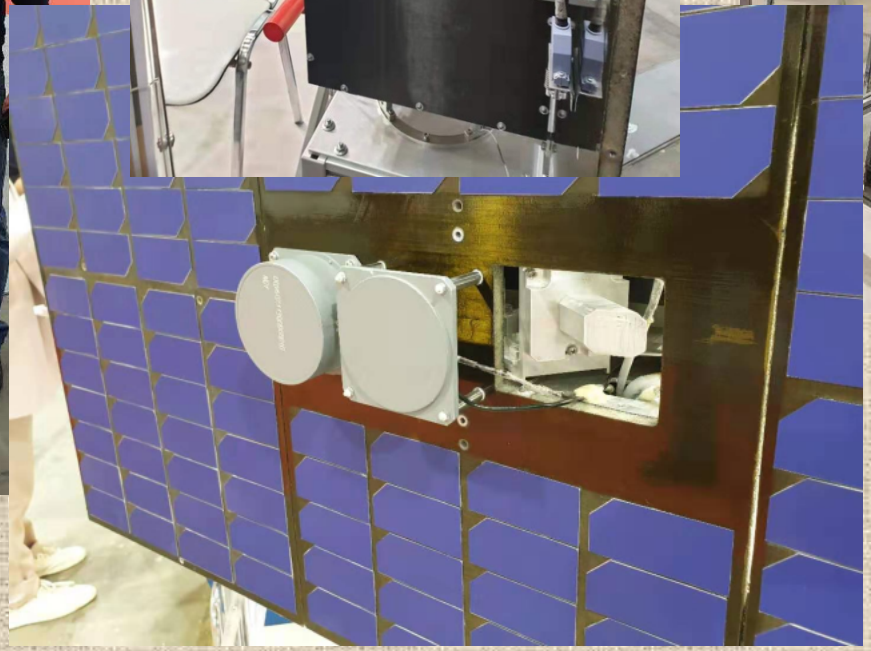
Equivalent spatial resolution at the center FOV - 1,5 km



Equivalent spatial resolution at the edge FOV - 2-3 km

Aerosol-UA instrument (model) adjusted to YuzhSat satellite platform





ScanPol and MSIP polarimeters for space missions Aerosol-UA

Small satellite platform YuzhSat designed by Design Bureau "Yuzhnoe"

Characteristics of satellite platform and orbit

Orbit

Type: sun-synchronous

Inclination: ~98°

Altitude: ~705 km

YuzhSat platform:

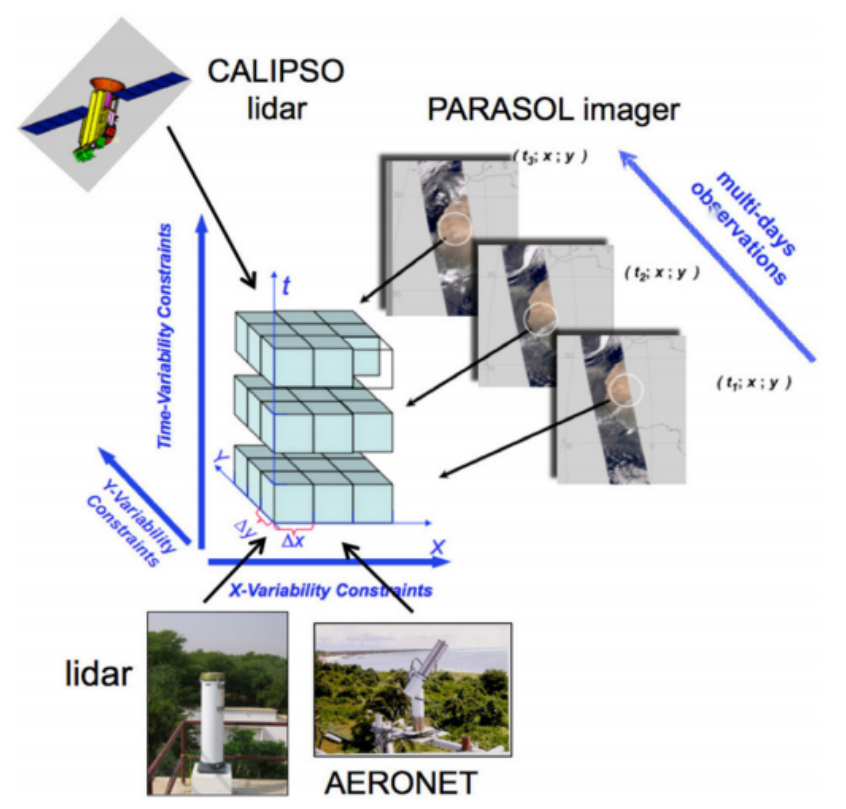
Pointing accuracy: ~0.1°

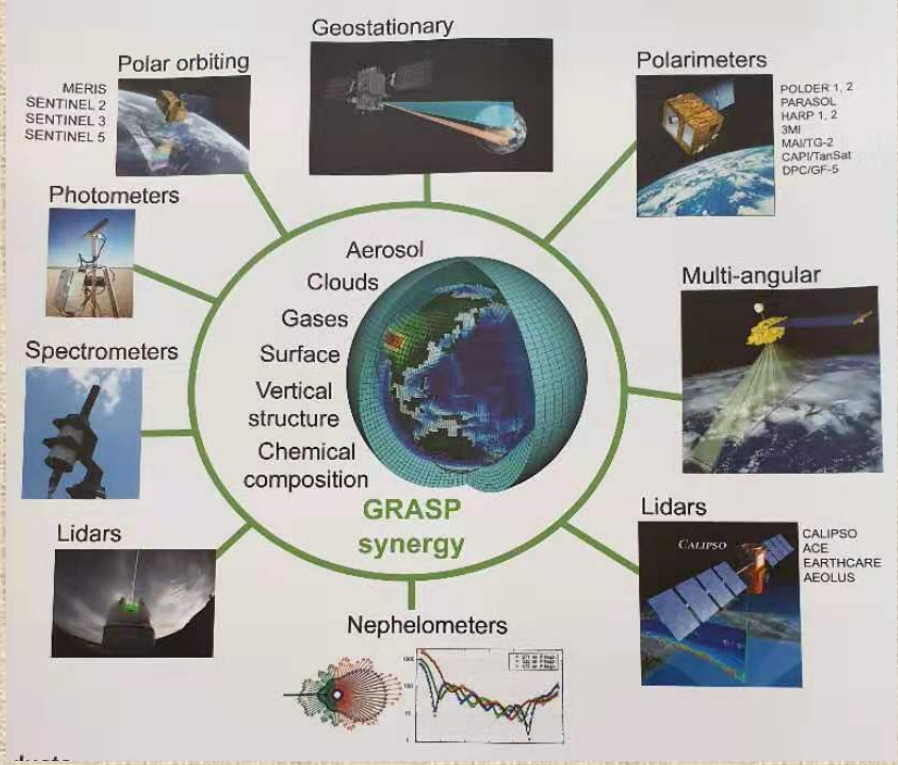
Total mass of scientific payload estimated: ~22 kg

Power for payload: ≤ 25 W

Design life: >3 years

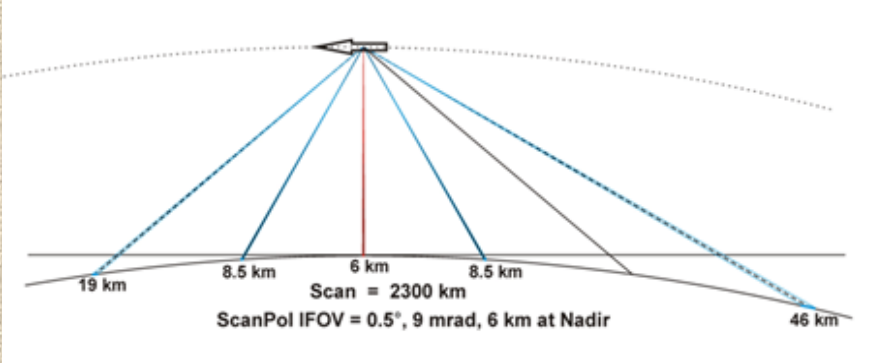
IV. Applying the approach for data processing from different devices (GRASP)

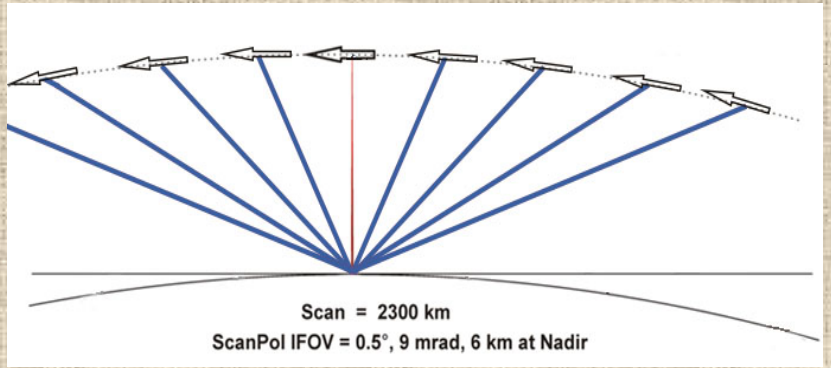




The diagram illustrates the principle of combining and processing data received from different devices using multi-pixel approximation (Dubovik et al., 2011, 2014, 2019).

Transition from satellite time data sequence to grouping data for GRASP processing

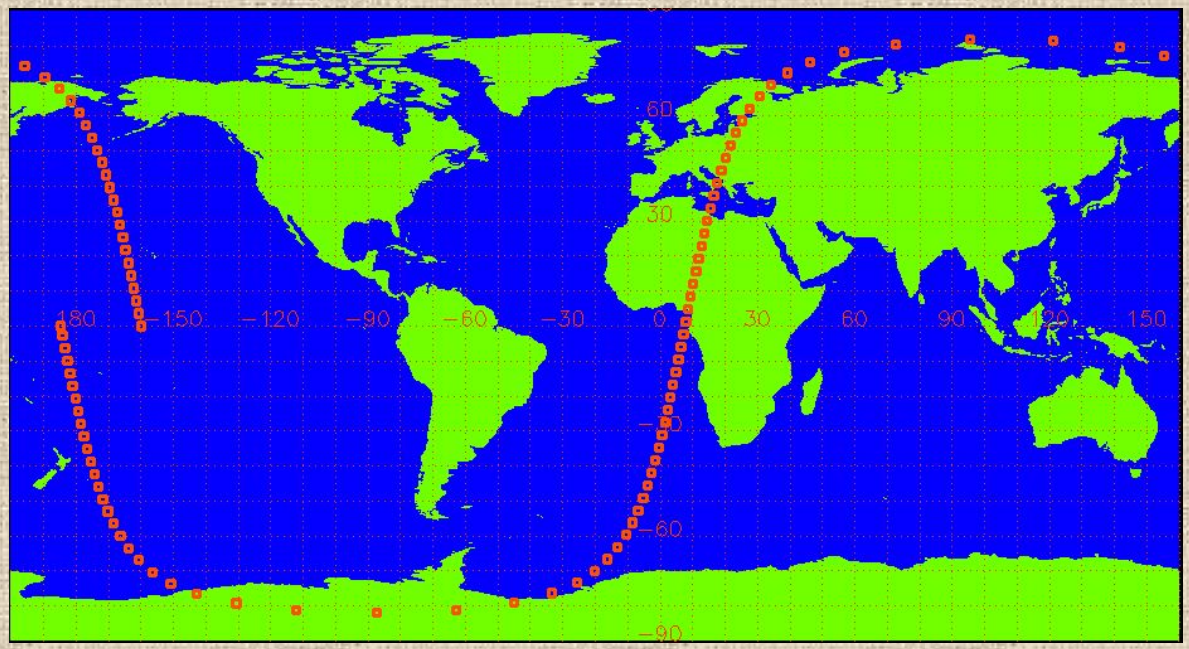


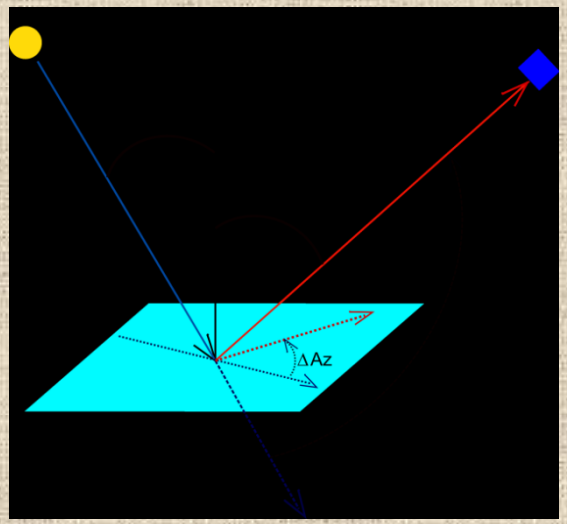


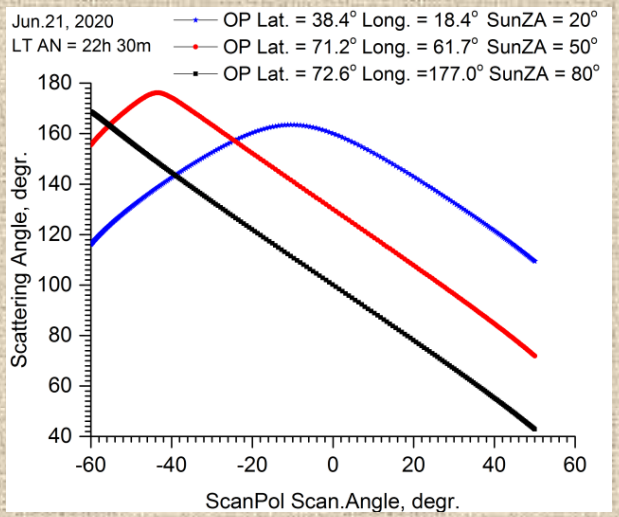
Grouping data at the beginning of processing (left), and at the enter to GRASP (right)

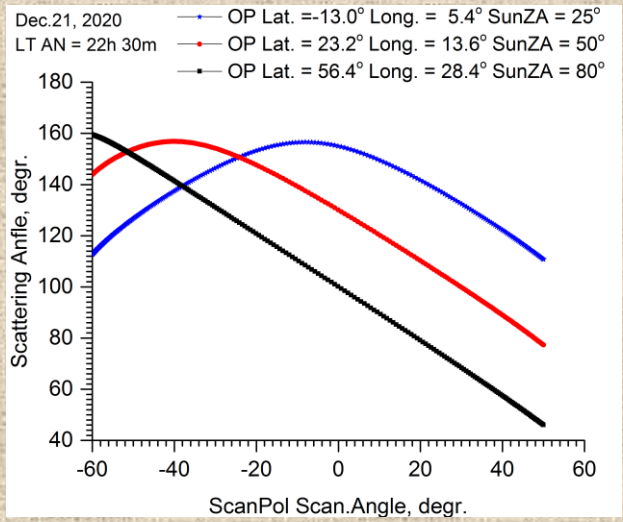
Having received the calibrated values of the Stokes parameters, pixel coordinates, solar angle values and other telemetry data, we group all these and other relative data to observed scene areas

Calculation geometry: orbit, scattering angles for 2020 depended on latitude

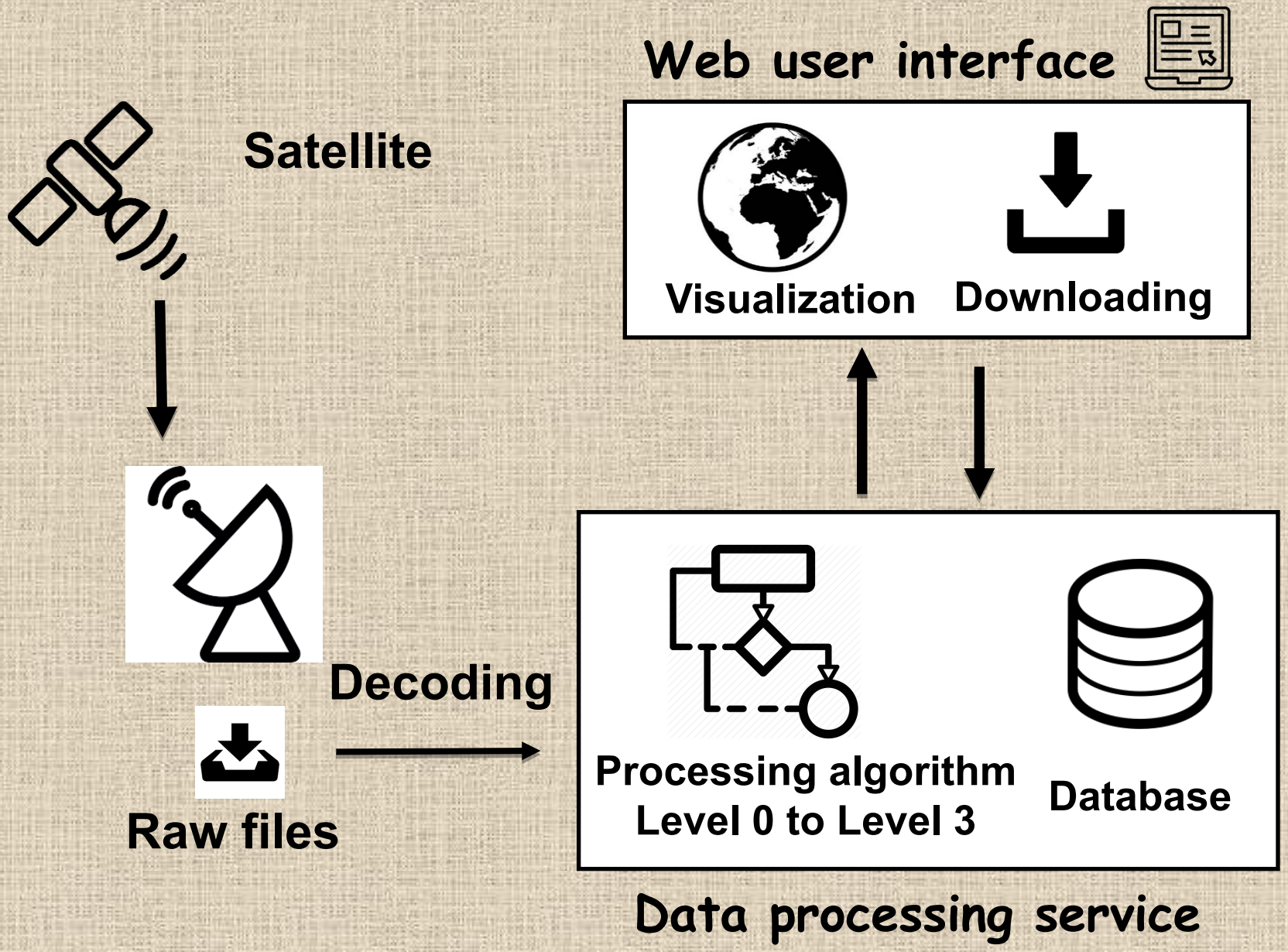




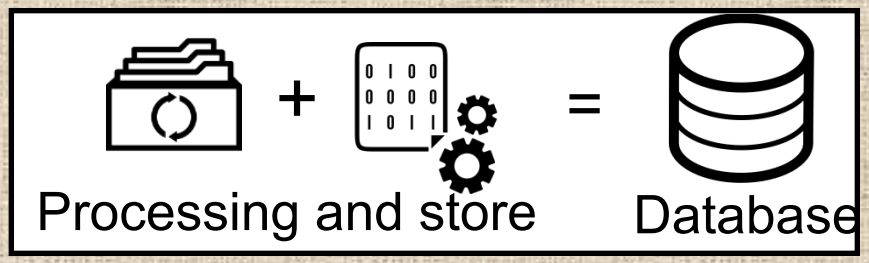




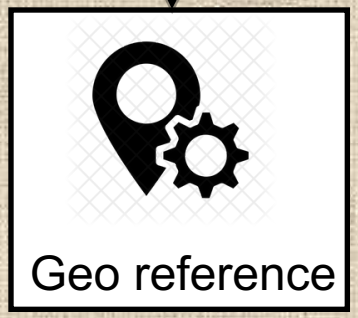
Aerosol-UA data transfer between key data processing elements

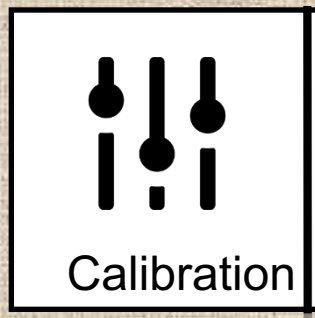


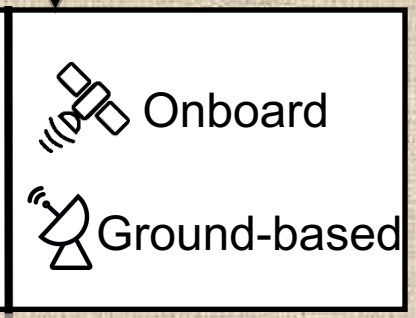
Data processing service: Level 0 to Level 2

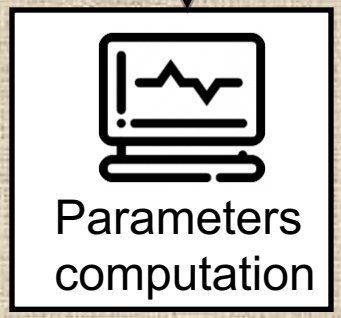


Level 0. Raw files

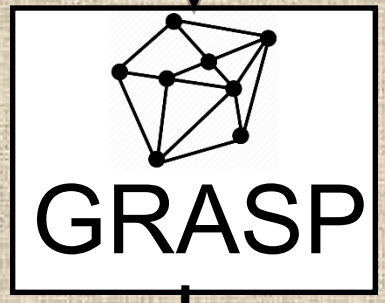


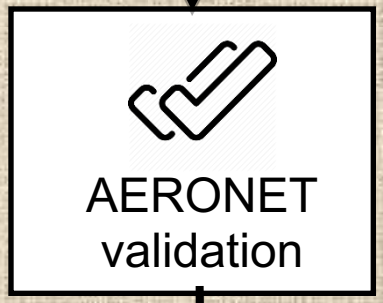






Level 1B. Prepared for GRASP



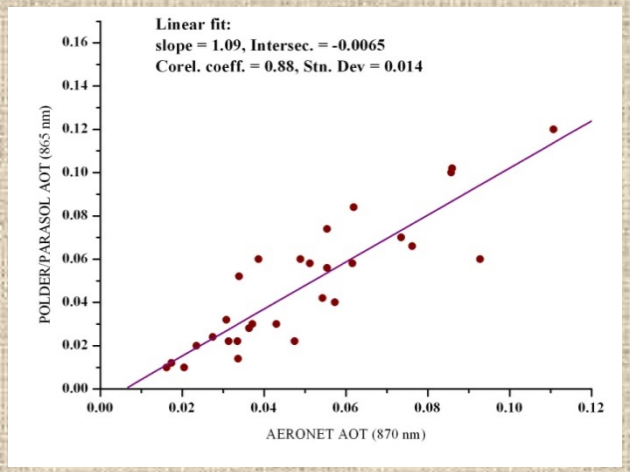


Level 2. Measured values

V. Ground-based support of Aerosol-UA: cal/val by AERONET, EARLINET networks

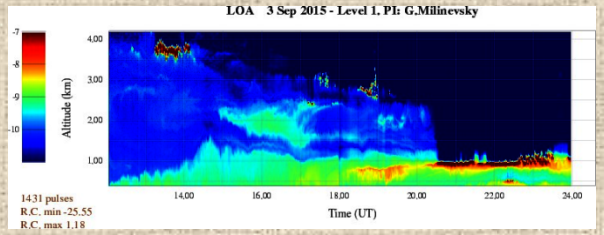
by direct simultaneous measurements

- Permanent AERONET sites
- mobile AERONET/Microtops II



POLDER/AERONET data comparison

Lidar EARLNET data



Conclusions and Timeline

Several aerosol polarimetric missions planned for 2020-2022 in USA, China, Europe.

The Ukrainian Aerosol-UA mission concept at YuzhSat platform will provide a synergy of precision scanner-polarimeter and imaging polarimeter.

1. ScanPol MSIP laboratory calibration – end 2019
2. Producing combined test instrument – mid 2020
3. Data processing algorithm – mid 2020
4. Airborne test observations – fall 2020
5. Producing in flight instrument – mid 2021
6. In flight combined instrument test – end 2021
7. Aerosol-UA launch – planned 2022

Thanks to

Chief designer Aerosol-UA instruments *Ivan Synyavsky*

Oral 14:40 Nov 5. APOLO 2019

Volcanic aerosol in the stratosphere, 1378 nm

Zhanna Dlugach

Poster 22. APOLO 2019

Instruments Mueller matrix description *Sergey Savenkov*