4G SPACE & DEFENCE TECHNOLOGIES

HUSAT

210-14

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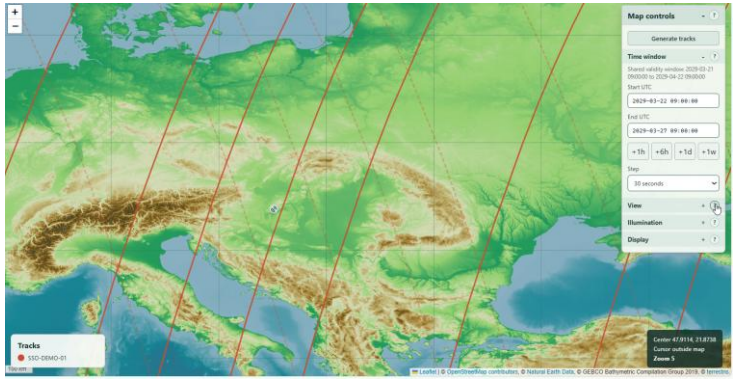
Orbital parameters

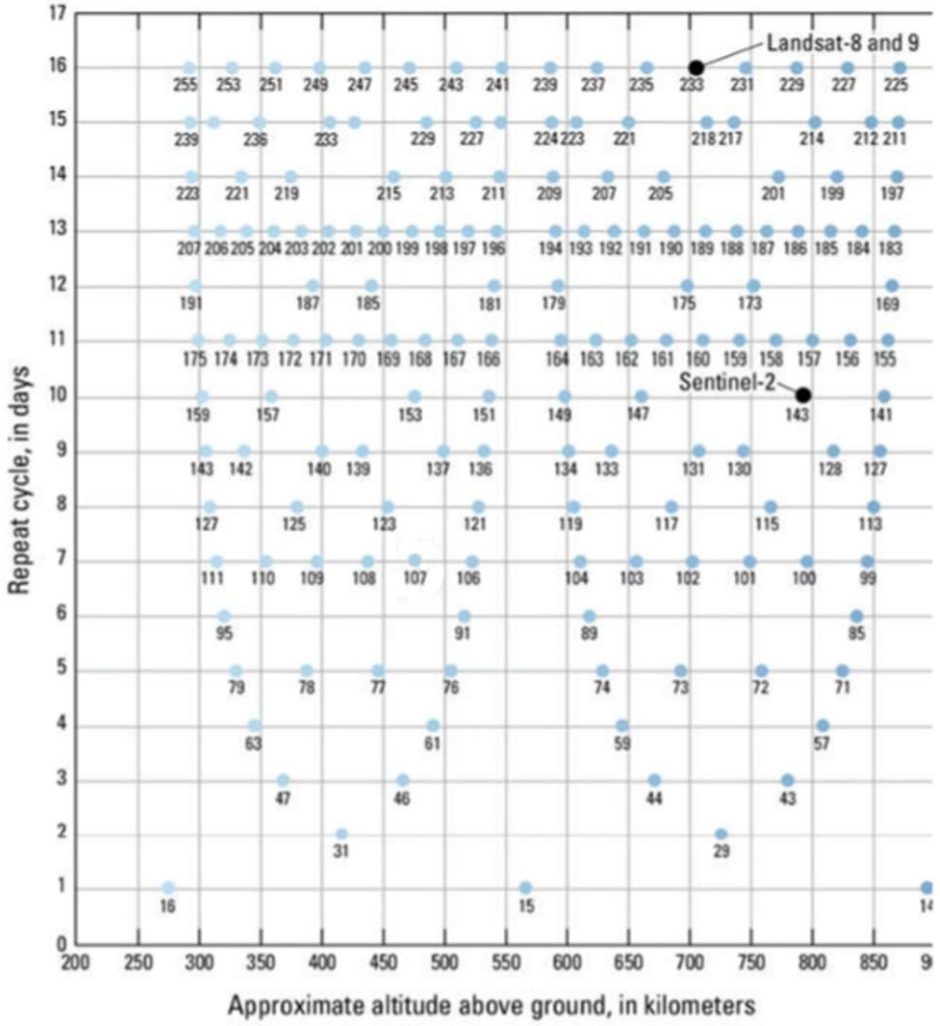
210-14-480-98-D12301505

No. of orbits – repeat cycle – altitude – inclination – ECT

+ maximum off-nadir = coverage

- resolution
- relative speed to ground
  - TDI ➔ SNR, MTF
- off-nadir angle needed for revisit time





01

HUSAT

What is PDGS

Geodata | Tasks

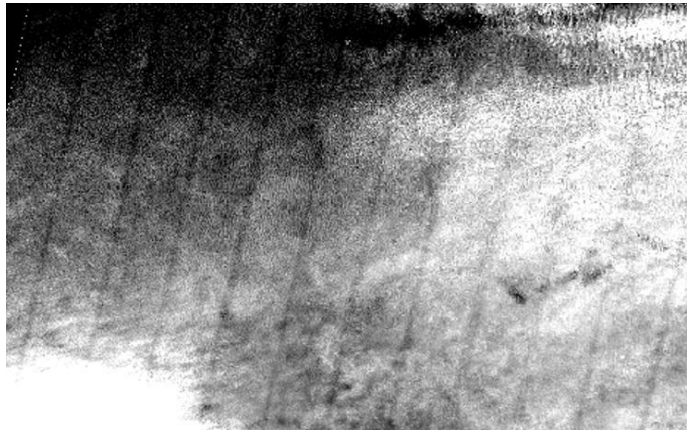
SW development
- Image processing pipeline
- Ordering dashboard
- Request Management System

Mission analysis from data point of view
- Frequency
- Quality

Payload operations
- Nominal operating modes
- Emergency operating modes

Data processing & image quality
- SNR, MTF, CE90

Level 3 & 4?
- user needs & AI processing

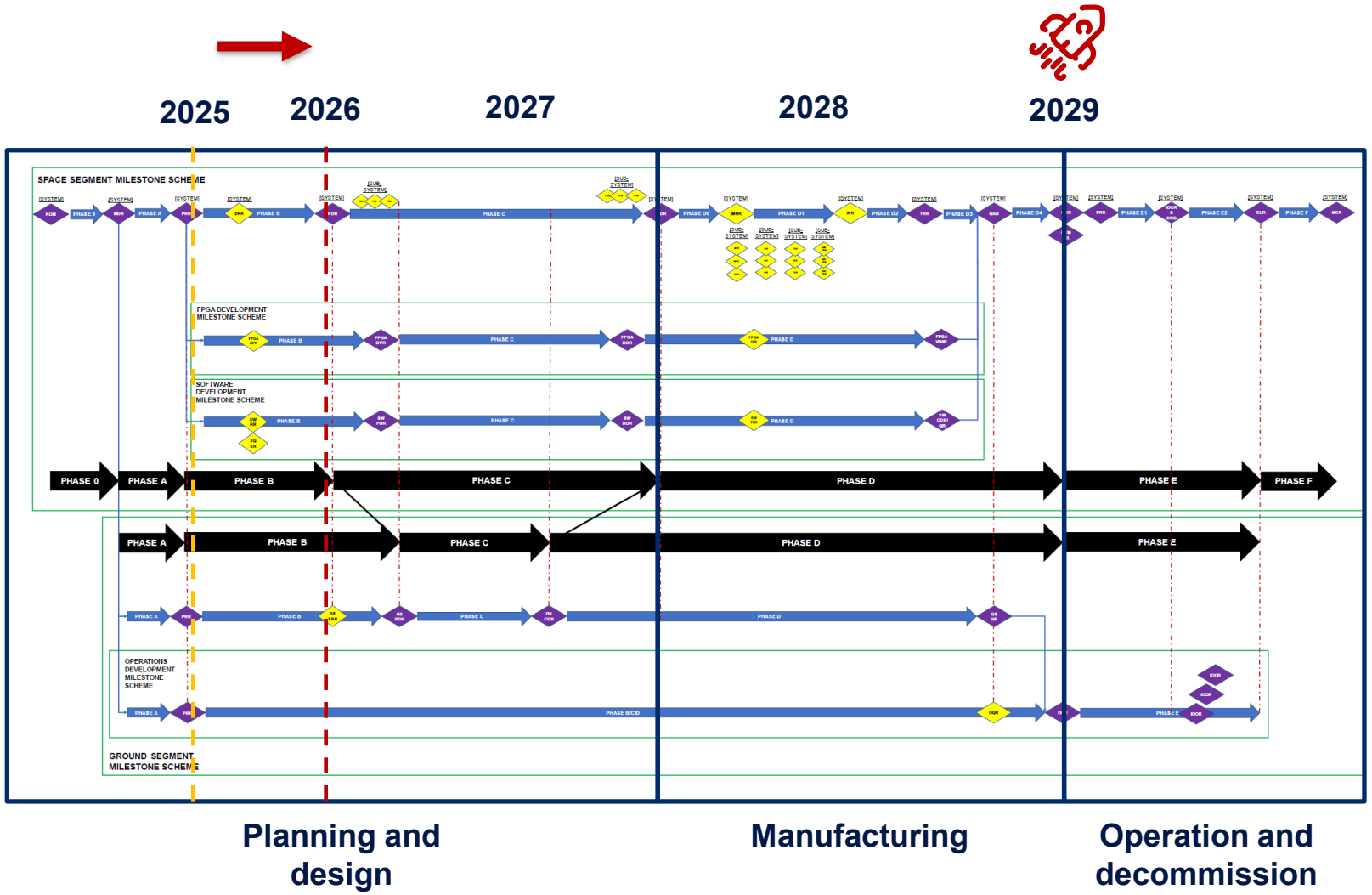


02

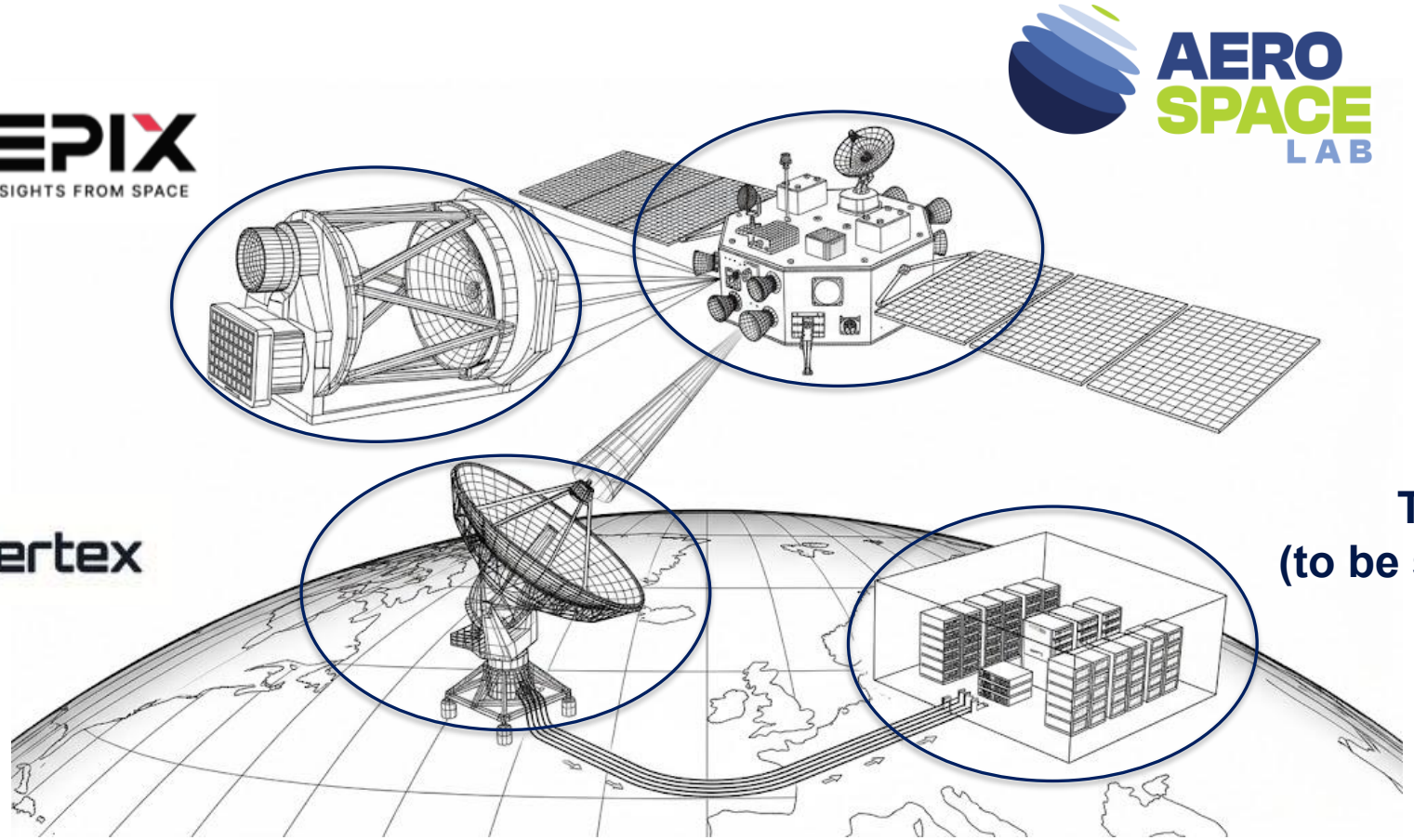
HUSAT

Where is HUSAT now?

The ideal project



Vendor selection - HUSAT



TBS
(to be selected)

Payload selection - EOP

Things to consider:

- general Signal-to-Noise ratio
  - which is affected by applicable TDI stages
    - which is affected by platform stability
      - which is affected by camera mounting methods
        - which is affected by thermal budget
          - which is affected by….
- end-to-end MTF values (which is affected by…)
- number of bands:
  - CB,B,G,R,RE,NIR
- spectral purity (no overlapping bands!)
- SWATH
  - 2xdetector = 12km
- resolution:
  - 0,5 m PAN, 1m MS
    - witch a chance of pixel shifting
- Native CE90 vs. processed CE90

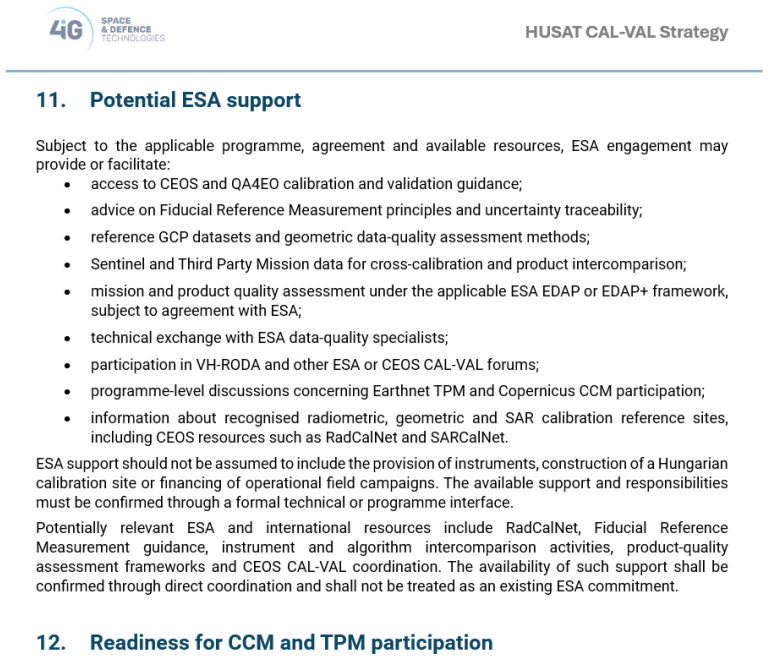
03

HUSAT

Image quality

Cal/Val

- goals ➔ to become an ESA CCM or TPM
- access to CEOS and QA4EO calibration and validation guidance;
- advice on Fiducial Reference Measurement principles and uncertainty traceability;
- reference GCP datasets and geometric data-quality assessment methods;
- Sentinel and Third Party Mission data for cross-calibration and product intercomparison;
- mission and product quality assessment under the applicable ESA EDAP or EDAP+ framework, subject to agreement with ESA;
- technical exchange with ESA data-quality specialists;
- participation in VH-RODA and other ESA or CEOS CAL-VAL forums;
- programme-level discussions concerning Earthnet TPM and Copernicus CCM participation;
- information about recognised radiometric, geometric and SAR calibration reference sites, including CEOS resources such as RadCalNet and SARCalNet.



HUSAT CAL-VAL Strategy

11. Potential ESA support

Subject to the applicable programme, agreement and available resources, ESA engagement may provide or facilitate:

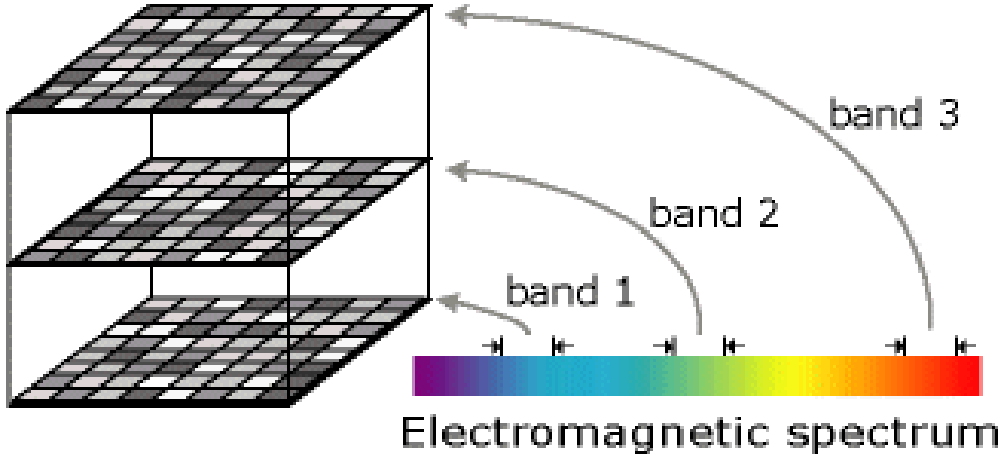
- access to CEOS and QA4EO calibration and validation guidance;
- advice on Fiducial Reference Measurement principles and uncertainty traceability;
- reference GCP datasets and geometric data-quality assessment methods;
- Sentinel and Third Party Mission data for cross-calibration and product intercomparison;
- mission and product quality assessment under the applicable ESA EDAP or EDAP+ framework, subject to agreement with ESA;
- technical exchange with ESA data-quality specialists;
- participation in VH-RODA and other ESA or CEOS CAL-VAL forums;
- programme-level discussions concerning Earthnet TPM and Copernicus CCM participation;
- information about recognised radiometric, geometric and SAR calibration reference sites, including CEOS resources such as RadCalNet and SARCalNet.

ESA support should not be assumed to include the provision of instruments, construction of a Hungarian calibration site or financing of operational field campaigns. The available support and responsibilities must be confirmed through a formal technical or programme interface.

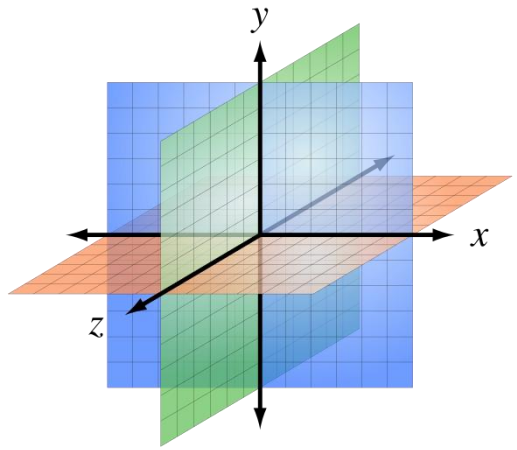
Potentially relevant ESA and international resources include RadCalNet, Fiducial Reference Measurement guidance, instrument and algorithm intercomparison activities, product-quality assessment frameworks and CEOS CAL-VAL coordination. The availability of such support shall be confirmed through direct coordination and shall not be treated as an existing ESA commitment.

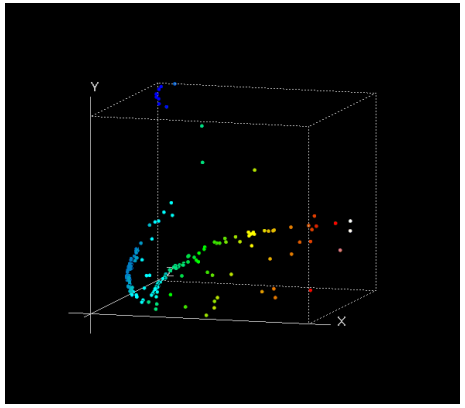
12. Readiness for CCM and TPM participation

What is image data?



Yes, but…





What is image quality?

Image quality:

- No unified definition ← depends on use case
  - Closest: „The level of accuracy with which different imaging systems **capture**, process, store, compress, transmit and display the **signals** that form an image" – Burningham et al. 2002

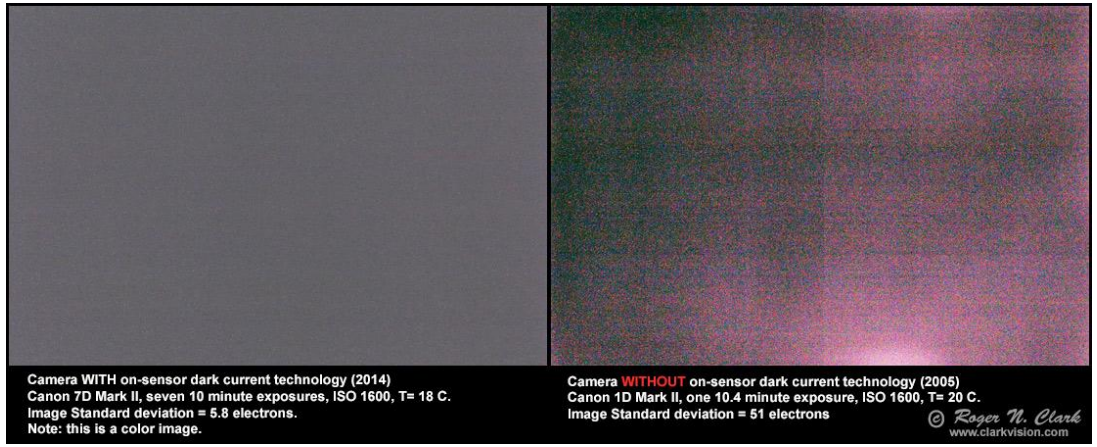
Factors affecting image quality:

- **Pixel purity:** How well the raw pixel represents the assumed associated area on the surface. ← this mainly depends on SNR and MTF
- Atmospheric Interference: Scattering and absorption by clouds, haze, and dust degrade clarity, requiring Atmospheric Correction.
- Geometric Distortions: Caused by Earth's curvature, rotation, and sensor tilt, requiring geometric calibration to match real-world map coordinates.
- Cartographic representation: The methodology to present the data to subjectively transfer it to the user. Visulaization without data transformation. In case of images this is basically displaying conrast and brightness.

Burningham, Norman; Pizlo, Zygmunt; Allebach, Jan P. (2002). "Image Quality Metrics". In Hornak, Joseph P. (ed.). *Encyclopedia of imaging science and technology*. New York: Wiley. doi:10.1002/0471443395.img038. ISBN 978-0-471-33276-3.

Potential image problems to avoid – High Signal to Noise Ratio (SNR)

- zaj (noise) =σ_{bg}(háttér szórás) = dark current value (d)
- de-noise = jel (pixelérték – háttér átlag)
- jel/zaj = SNR (Signal to Noise Ratio)



$$\mathrm{SNR} = \frac{\bar{I}_{x,y}^{(\mathrm{obj})} - \bar{I}_{x,y}^{(\mathrm{bg})}}{\sigma_{\mathrm{bg}}}$$

REQ!
Signal to Noise Ratio (SNR): PAN: 60, Coastal blue: 30, Blue: 35, Green: 50, Red: 50, RedEdge: 50, NIR: 50

PERFORMANCE SPECIFICATIONS - FSI AND BSI

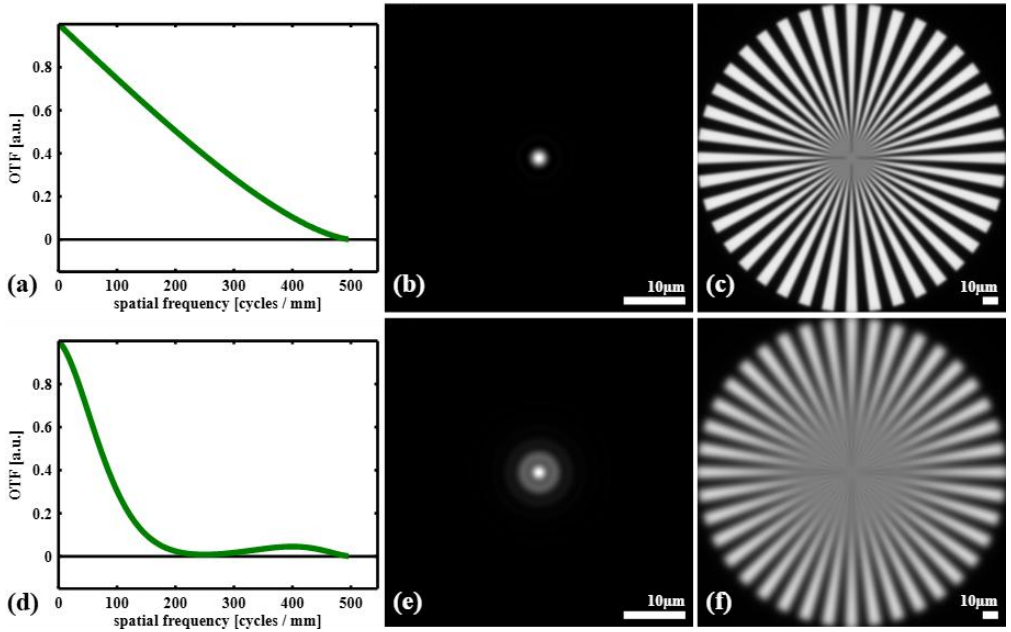
Specification	FSI	BSI
Pixel Size (µm²)	P: 7 X 7; B: 28 X 28	
Max. Line Rate (kHz)	P: 40; B: 10	
CTE per Transfer	≥ 0.99993	
Full Well Capacity (ke-)	P: ≥ 70; B: ≥ 280	
Antiblooming	≥ 70X	
Noise RMS (e-)	P: ≤ 34; B: ≤ 110	
On-chip ADC Resolution (bits)	12	
Dynamic range (dB)	≥ 65	
Outputs per Sensor	8 Primary and 8 Redundant	
PRNU (Global), all stages at 50% of Sat (peak-to-peak)	≤ 7.5%	
Output Nonlinearity (% of Sat)	≤ 2%	
Responsivity @ centre wavelength of each band (DN/nJ/cm²)	P: ≥ 6500 B1: ≥ 1800 B2: ≥ 3000 B3: ≥ 5700 B4: ≥ 5000	P: ≥ 7500 B1: ≥ 6000 B2: ≥ 6500 B3: ≥ 7400 B4: ≥ 5300
Fixed Pattern Noise (% Sat, peak-to-peak)	≤ 5%	
Avg Dark Current Density @25°C (nA/cm)	≤ 8	≤ 12
Power Dissipation (W)	≤ 6	

Potential image problems to avoid – High Signal to Noise Ratio (SNR)

vs.

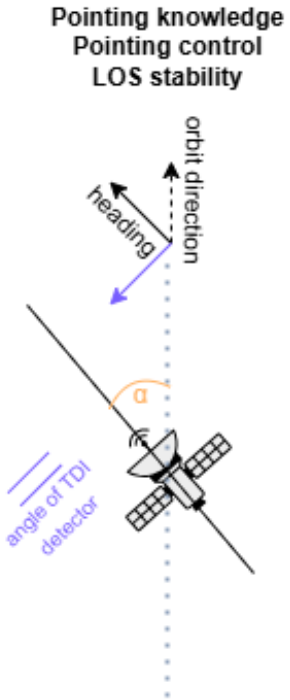
Potential image problems to avoid – Low MTF

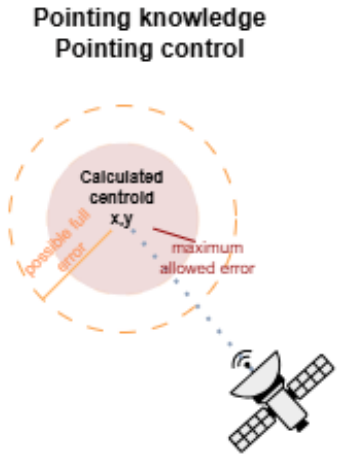
- MTF: Ability to transform an imaging systems contrast from an object to an image.
  - ~ how well pixel information travels through the system.
- If MTF is too high (exceeding Nyquist frequency): aliasing and pixelation occurs
- If MTF is too low (below a subjective threshold): image will be blurry, neighbouring pixel information shifts



Potential image problems to avoid – Image deformation

- Pointing direction may vary while not being logged in AOCS
- Problem 1: We do not know what we are looking at (geopositioning error)
- Problem 2: Pixel and image boundaries may not follow on-the-ground assumed footprints.





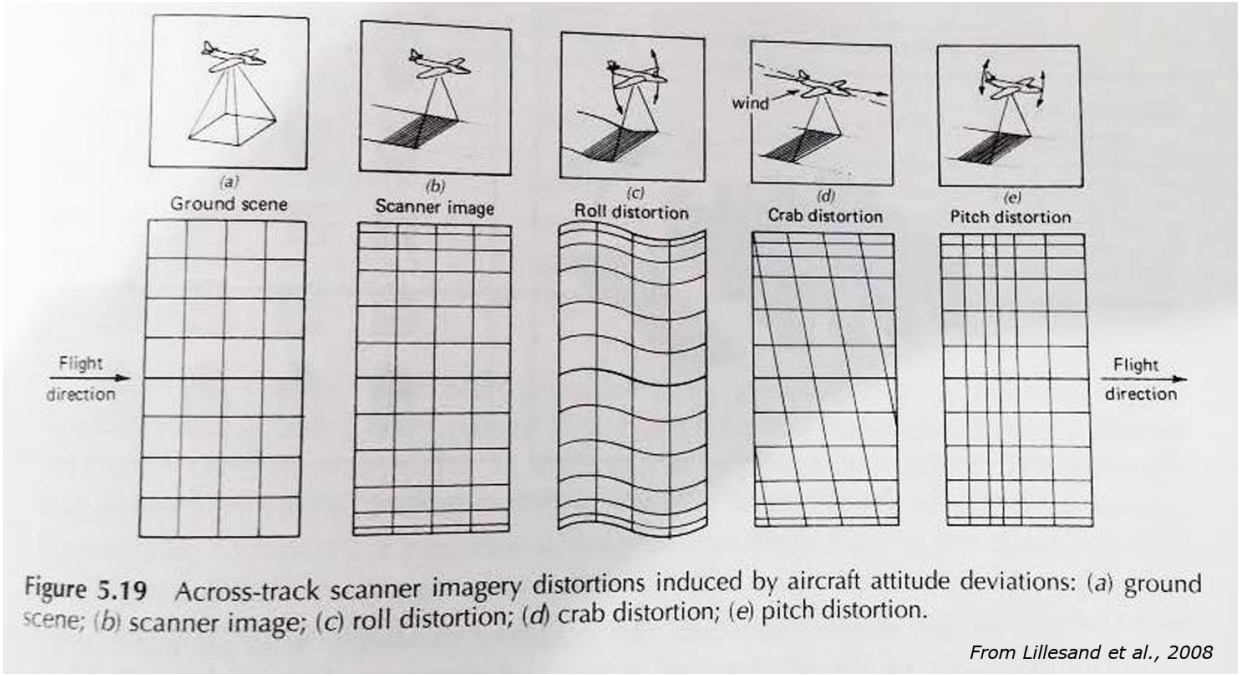
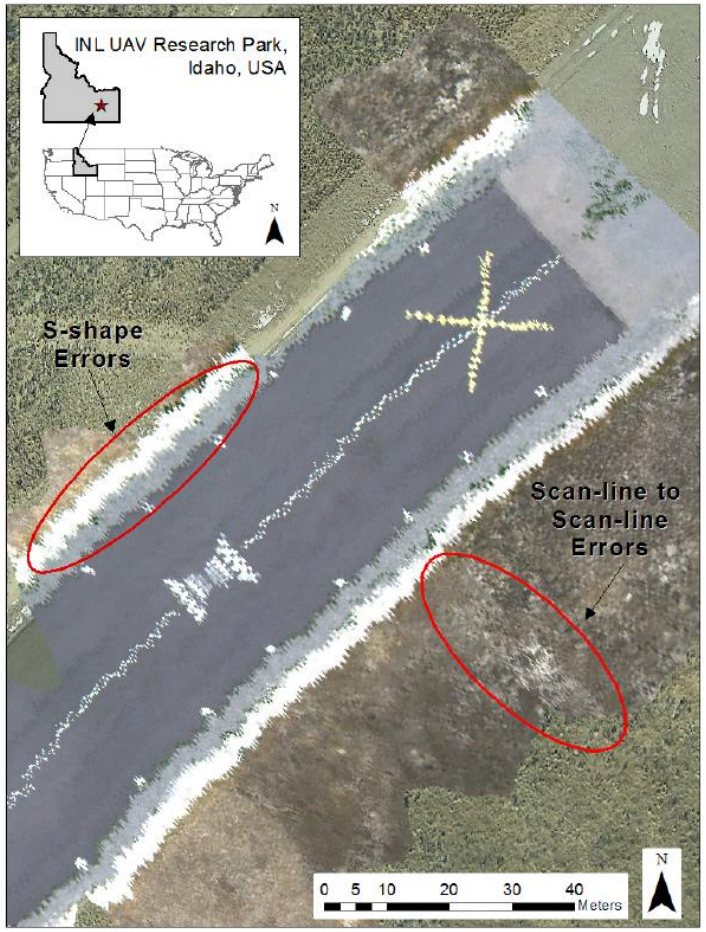


Figure 5.19 Across-track scanner imagery distortions induced by aircraft attitude deviations: (*a*) ground scene; (*b*) scanner image; (*c*) roll distortion; (*d*) crab distortion; (*e*) pitch distortion.

From Lillesand et al., 2008

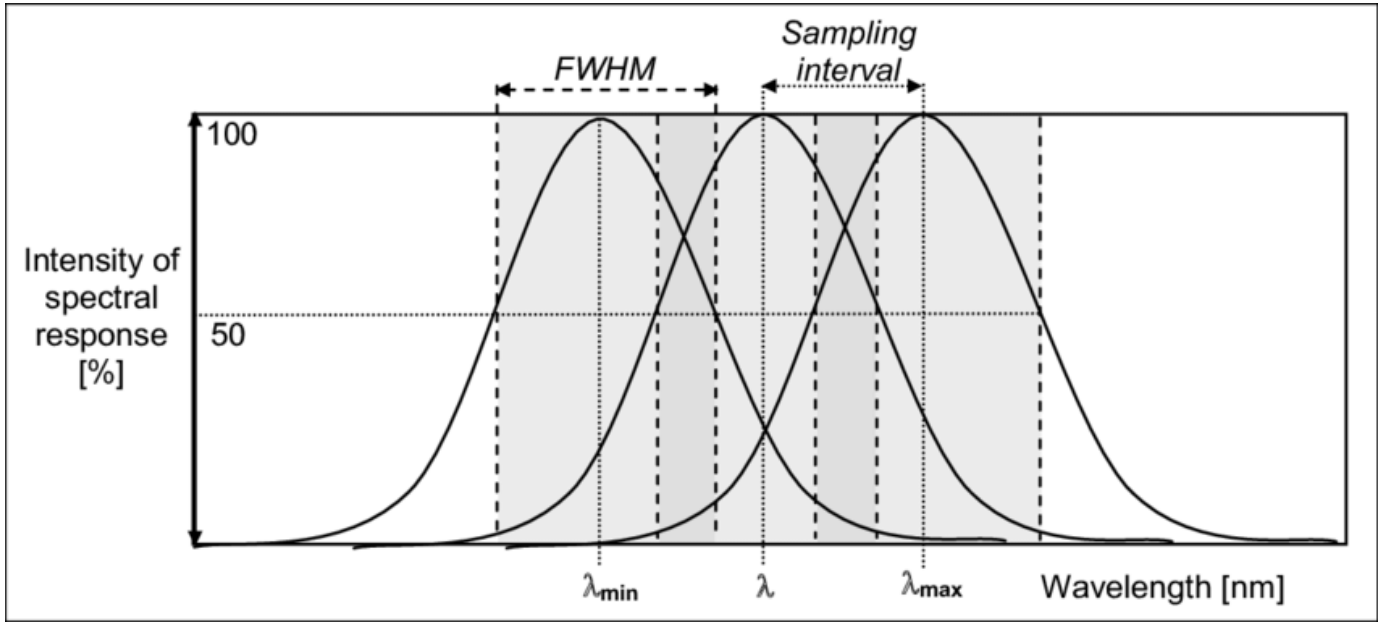
Potential image problems to avoid – Image deformation

vs.



Potential image problems – Spectral purity

- Not really addressed, but TPX is up to industry standards.
- Spectral overlapping: Different bands have overlapping sensitivity in some spectral ranges.
  - Depends on: Full Width at Half Maximum ← sensitivity peak and overall spectral range



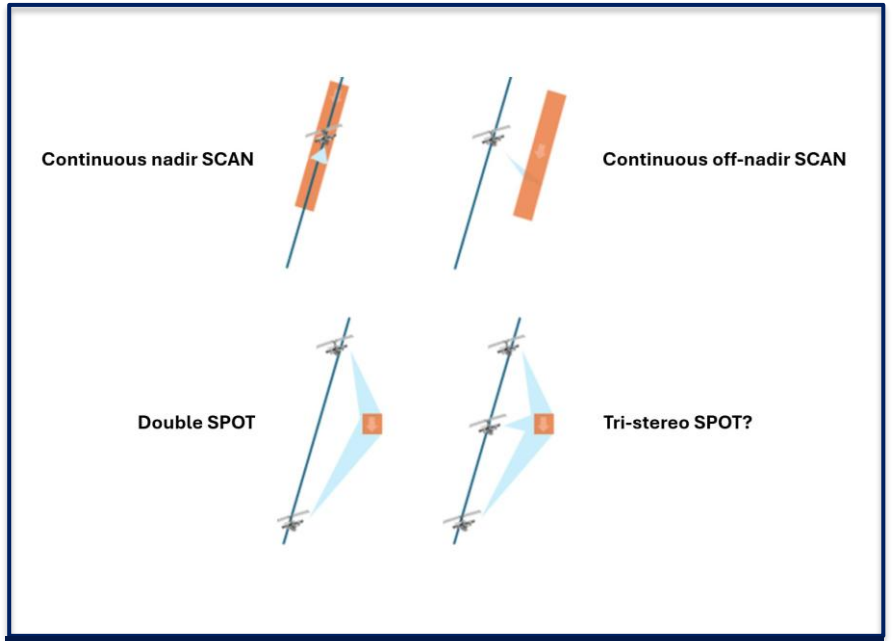
04

HUSAT

Payload operations

What is payload operations?

- „Payload operations concept”
- Payload operation tasks in engineering phase:
  - Creating the data flow architecture.
  - Creating nominal operational scenarios. Open questions are for example:
    - Can bands be switched off separately? ← Defining acquisition products
    - What is the data storage architecture?
    - What are the metadata?
  - Creating emergency & anomaly scenarios
    - Overheating, emergency cooling.
    - Data loss handling.
    - Anomaly detection and response

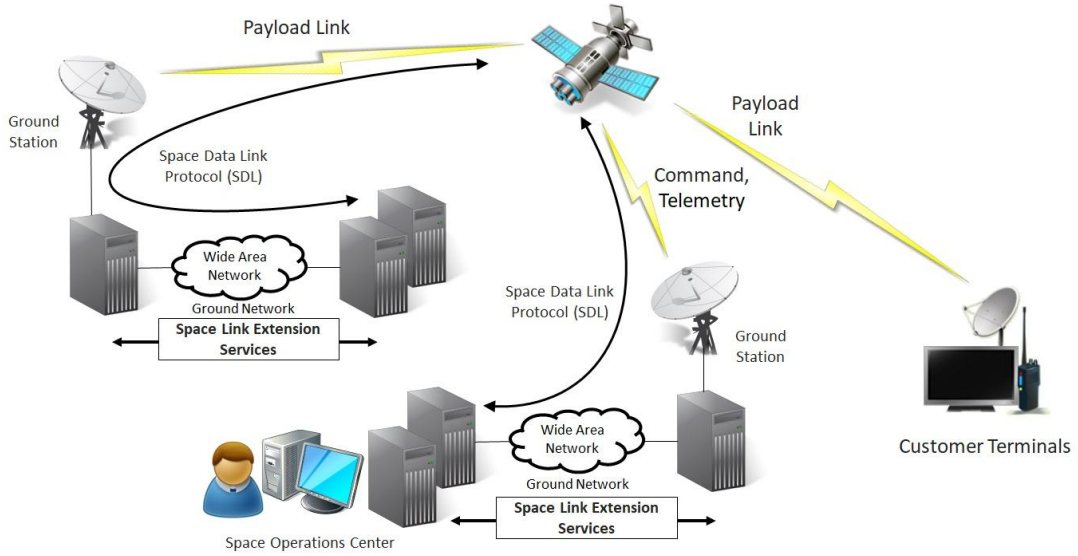


Examples for nominal operational scenarios

Project document: Payload operations concept document - HULEO-DC-AB1-AD-016

What is payload operations?

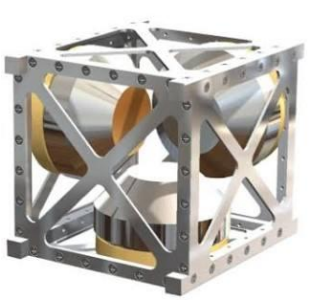
- Payload activities in operating phase
  - Commanding
  - Monitoring
  - Calibration
    - Dark noise detection for each aquisition (subject to temperature)
    - Dark noise calibration (needed to be done in some intervals)



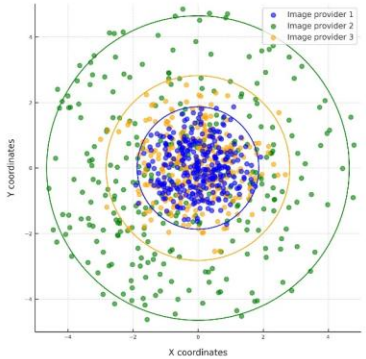
Project document: Payload operations concept document - HULEO-DC-AB1-AD-016

AOCS

- Agility is the speed in which the satelitte turns including slew and stabilization.



- CE90 a statistical measure of horizontal positional accuracy that defines a circular radius centered on a true ground point, within which 90% of all measured or mapped points in a dataset are guaranteed to fall.



Project document: Payload operations concept document - HULEO-DC-AB1-AD-016

05

The Sphere

After 2040… ?

The Sphere

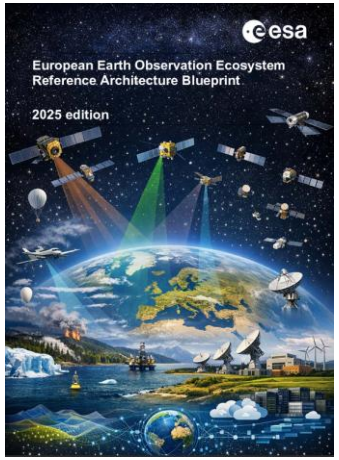
Project scope: Assess the relationship of ESA to business satellite image providers from 2040.

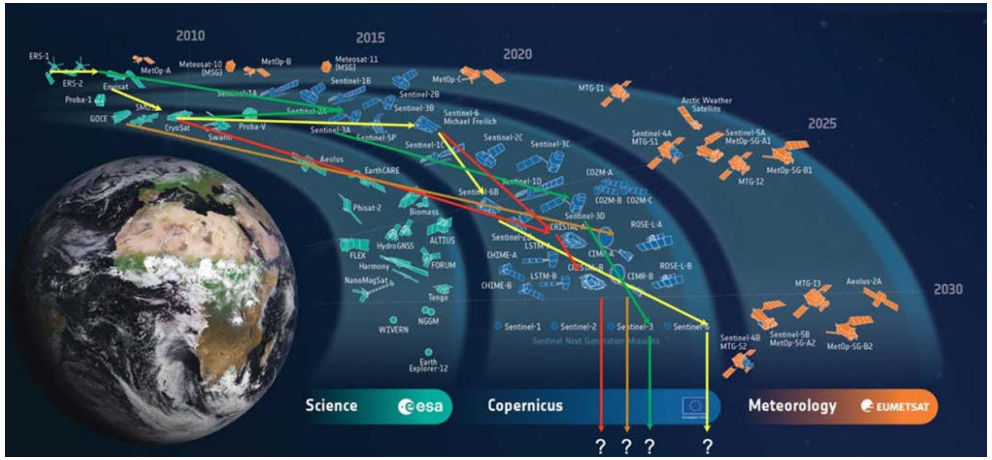
S&D scope: Set quality criteria for business providers regarding accuracy and resolution, considering different use cases.

Client: ESA

Name of tender: ESA AO/1-12611/24/NL/RA The European Earth Observation Ecosystem Evolution from 2040+

Earth Observation Architectural Challenges 2040–2060 Workshop





The Sphere – Observatory groups

- Inland water quality and optical properties
- Ocean and sea state, temperature, colour & coastal biogeochemistry
- Cryosphere, ice & sea ice dynamics

- Fire disturbance and thermal anomalies
- VHR imaging & object detection
- Flood identification & monitoring

- Soil moisture & surface state
- Vegetation, agriculture & forestry

- Earth radiation budget, ozone layer and local irradiance
- Greenhouse gas monitoring and carbon cycle
- Atmospheric composition & aerosols
- Meteorology & cloud analysis, upper-air wind speed and fluid dynamics
- Surface level meteorology, wind speed and fluid dynamics
- Thermal monitoring & sounding

- Land cover mapping & cartography
- Solid earth geodynamics & interferometry
- Mineral detection & identification

The Sphere – Main statements

1. Resiliency is key.
2. Good quality is a must have.
3. The role of AI is still unsure.
4. Earth Observation is no longer an experts field but implemented everywhere.
5. Information is more important than data.
6. European sovereignty needed over short term profits.
7. Cyberattacks are the main threat, cybersecurity is the new essential knowledge.
8. Defence & security will be the main use cases.
9. Agile constellations and agile/AI targeting is needed.
10. Level 1 will be more important than level 2 (in case of EO large scale monitoring).
11. Dynamic missions needed (2-3 years from concept to launch).
12. Ocean & climate change are the main drivers.
13. Images are needed in minutes ➔ ISL!
14. Cost of launching will drop (<1k USD per kg).
15. Continuity for EO data is required.
16. Temporal resolution needs to be increased.
17. Space debris will be a problem.

A realistic future scenario is: „European EO systems are no longer considered decision-grade infrastructure. While scientifically robust, they are not trusted for time-critical or legally binding applications. Users increasingly rely on external, vertically integrated providers that can deliver traceable, near-real-time and uncertainty-quantified information."

4iG SPACE & DEFENCE TECHNOLOGIES

Thank you

Questions & discussion

#WEDOIT