New Space Cal/Val and Usability Assessment

Chairs:

Clement Albinet - *ESA*
Alfreda A. Hall – *NASA GSFC*
Leonardo De Laurentiis - *ESA*

Panel:

- Henri Laur - *ESA*
- Kevin Murphy - *NASA HQ*
- Sebastien Saunier - *Telespazio Fr*
- Batuhan Osmanoglu - *NASA GSFC*

Living Planet Symposium 2022 - 24th May 2022

Introduction

- In recent years, the increasing range of applications of Earth observation data products and availability of low-cost satellites have resulted in a rapidly increasing number of commercial satellite systems.
- These ‘NewSpace’ players are now playing an important role in the EO international strategy as these services may provide complementary capabilities to those of space agencies.
- Adoption of these data products for many applications requires that they meet an assured level of quality that is fit for the given purpose.
- For the most efficient exploitation of EO data, therefore, assessment of data quality, calibration and validation are indispensable tasks, forming the basis for reliable scientific conclusions.

Panel

- Henri Laur - ESA

  Head of the EO Mission Management & Product Quality Division

- Kevin Murphy - NASA HQ

  Science Mission Directorate - Chief Science Data Officer

- Sebastien Saunier - Telespazio Fr

  Optical instrument Cal/Val Expert

- Batuhan Osmanoglu - NASA GSFC

  SAR instrument Cal/Val Expert

Agenda

A. Introduction to ESA TPM programme and activities

B. Introduction to NASA CSDA programme and activities

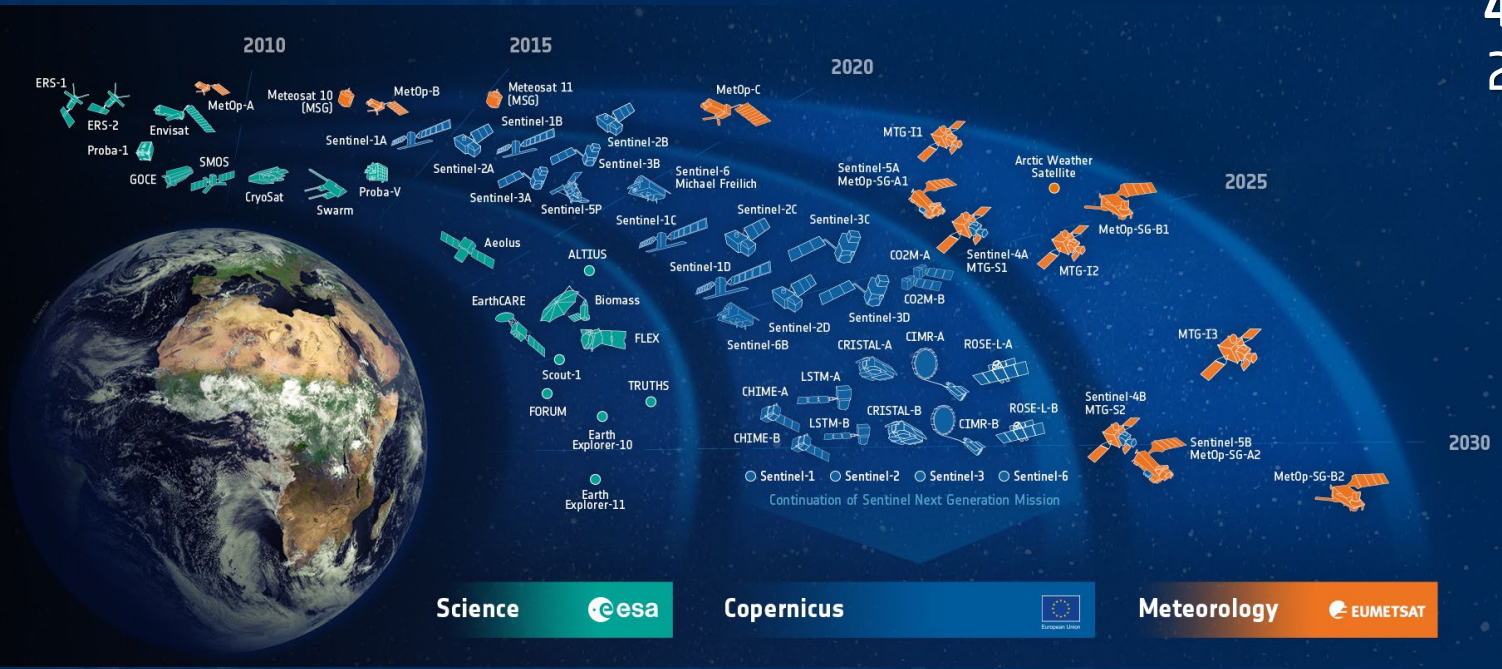
C. Cal/Val Maturity Matrix and Proposal for data usability

D. Discussions

A. Introduction to ESA TPM programme and activities

A. ESA-Developed Earth Observation Satellites

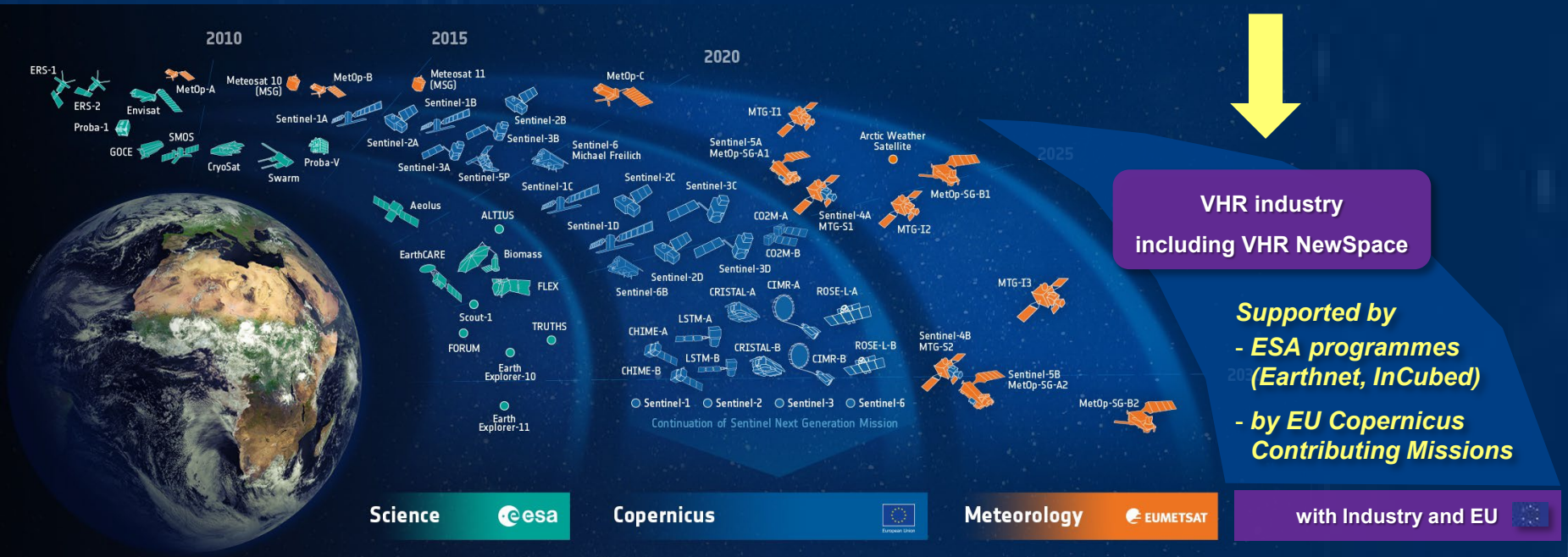
12 in heritage
15 in operation
41 in development
22 in preparation
(90 in total)



A. Growing relation with VHR EO industry

ESA as customer for VHR EO for:

- ✓ science/R&D needs and seed funding with ***ESA Earthnet*** & ***InCubed*** programmes
- ✓ operational public needs with ***EU Copernicus Contributing Missions*** programme



VHR industry including VHR NewSpace

Supported by
- ESA programmes (Earthnet, InCubed)
- by EU Copernicus Contributing Missions

Science | Copernicus | Meteorology | with Industry and EU

A. Growing relation with VHR EO industry

TPM = Third Party Missions

VHR industry
including VHR NewSpace

Supported by
- ESA programmes (Earthnet, InCubed)
- by EU Copernicus Contributing Missions

with Industry and EU

***ESA InCubed** (New Space):*

→ Support for development of potential future TPM

ESA Earthnet:

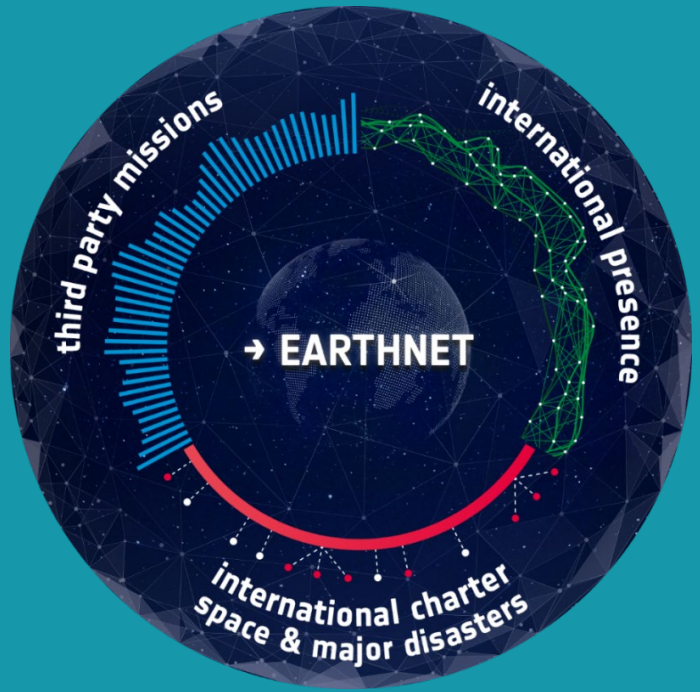
→ TPM data supply for science & research purposes

→ TPM data quality assessment & Cal/Val support

EU Copernicus:

→ TPM data supply for operational services (Copernicus Contributing Missions)

A. Earthnet → ESA programme since 1975

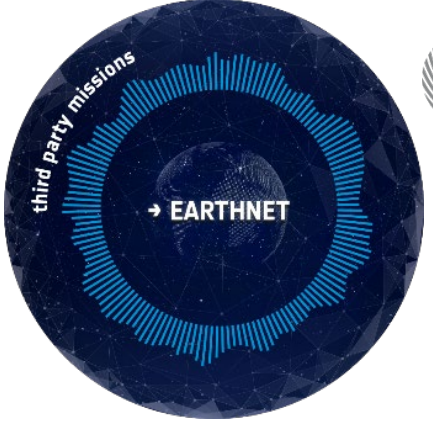


International cooperation to share resources & foster their interoperability

- Support access to data from national and international **Third Party Missions** (TPM) for scientific, research and pre-operational applications
- Data quality assessment and data harmonization activities (**Earthnet Data Assessment Pilot - EDAP**)
- Support the **International Charter** operations

- Ensure coordination in international organisations and committees (e.g. **CEOS**, GEO) and promotes **collaborative initiatives** (e.g. Tiger, Dragon) for the use of EO data

A. TPM integration within Earthnet programme



Possible integration steps:

1- Before integration as formal ESA TPM:

→ ***Data evaluation***:

✓***Earthnet Data Assessment Pilot*** (EDAP) on data and documentation quality,

✓***Preliminary user feedbacks*** on data usability (selected users and/or dedicated ESA application projects).

2- Integration as formal ESA TPM:

→ ***Candidate TPM report*** approval by ESA Member States

3- The above process paves the way towards the utilization of the data for **operational** services in Copernicus context (***EU Copernicus Contributing Mission***)

A. What is EDAP?

Earthnet Data Assessment Pilot

- ✓ The main objective of EDAP activity is to perform **early data quality assessment of existing or future missions**, with specific focus on **New Space** and **multi-mission activities**
- ✓ It is achieved through provision of **clusters of expertise in various domains** *(Very High, High and Medium Resolution optical sensor, Low Resolution optical sensor, SAR sensor, Atmospheric Missions)*
- ✓ Specific focus is also be put on **capacity building** in the relevant data provider with the set up and evolution of documentations, tools and procedures to allow to efficiently perform data quality assessments in the domains of expertise defined within this activity

A. A flexible service approach

- ✓ The cluster of expertise provides **technical reports** on data quality from various missions.
- ✓ Some missions and studies were already identified at the start of the project; some other missions and studies were identified in the course of the project.
- ✓ It could be a recurrent process if for example a constellation sends new type of payloads.

A. Limitations that are present today

- Quality information is often communicated to users in an ill-defined or incomplete manner.
- Both the CSDA and EDAP are coordinating on a generic satellite mission quality assessment framework, developed within EDAP, that is designed to provide a thorough review of the most important aspects of mission quality.
- The assessment results are conveyed at a top level to the user as a quality assessment matrix diagram.
- The framework itself is based on the principles of CEOS QA4EO (Quality Assurance for Earth Observation) and builds on the experience of several European projects that worked towards practical implementation.

A. ESA-NASA common framework for quality assessments

ESA Earthnet ⟷ **NASA Commercial Smallsat Data Acquisition (CSDA) Program**

EDAP *Cal/Val Maturity Matrix* Summary

Data Provider Documentation Review			Validation Summary
Product Information	**Metrology**	**Product Generation**	
Product Details	Sensor Calibration & Characterisation Pre-Flight	Calibration Algorithm	Measurement Validation Method
Availability & Accessibility	Sensor Calibration & Characterisation Post-Launch	Geometric Processing	Measurement Validation Results Compliance
Product Format, Flags & Metadata	Metrological Traceability Documentation	Retrieval Algorithm	Geometric Validation Method
User Documentation	Uncertainty Characterisation	Mission-Specific Processing	Geometric Validation Results Compliance
	Ancillary Data		

Key
Not Assessed
Not Assessable
Basic
Good
Excellent
Ideal
Not Public

Validation Cal/Val Maturity Matrix for the optical domain

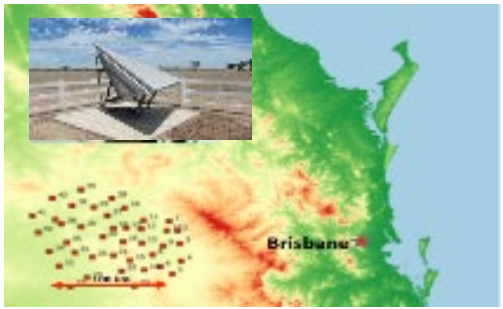
<Entity> Detailed Validation			
Radiometric		**Geometric**	
Absolute Calibration Method	Absolute Calibration Results Compliance	Sensor Spatial Response Method	Sensor Spatial Response Results Compliance
Signal to Noise Method	Signal to Noise Results Compliance	Absolute Positional Accuracy Method	Absolute Positional Accuracy Results Compliance
Temporal Stability Method	Temporal Stability Results Compliance	Band-to-Band Registration Method	Band-to-Band Registration Results Compliance
		Temporal Stability Method	Temporal Stability Results Compliance

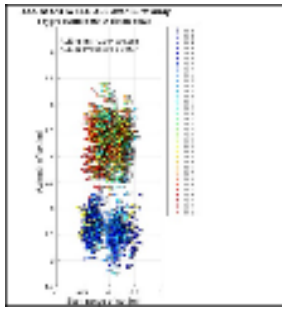
A. Proposed approach: Joint ESA and NASA guidelines for data quality assessment

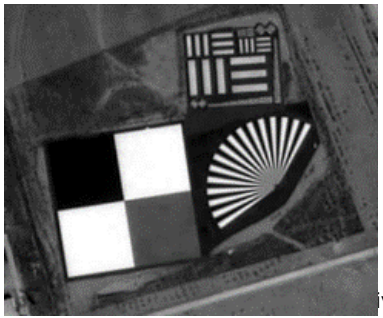
- The framework has the potential for more general use within both institutional and commercial Earth observation.
- There is potential for international collaboration among space agencies, to synergise quality assessment approaches and results, to work toward the development of a common standard and an understanding of new commercial data sources.
- This is what ESA and NASA aim to achieve by working toward a coordinated approach and by defining jointly a common set of guidelines for assessing optical and SAR sensors data quality parameters.

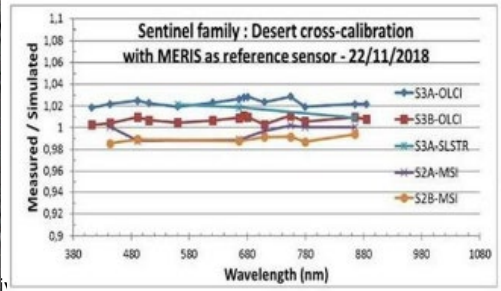
A. EDAP Evolution

- ✓ Earthnet Data Assessment Pilot toward Earthnet Data Assessment Project
- ✓ Kick-off in June-July 2022
- ✓ Evolution toward VHR and NewSpace
- ✓ Expertise, reference, open science









EDAP

→ *https://earth.esa.int/eogateway/activities/edap*

ESA Third Party Missions (TPM)

→ *https://earth.esa.int*

➔ VH-RODA 2022 workshop announcement

Very High-resolution Radar & Optical Data Assessment workshop

https://earth.esa.int/eogateway/events/vh-roda

7 - 10 November 2022 | ESA-ESRIN, Frascati, Italy

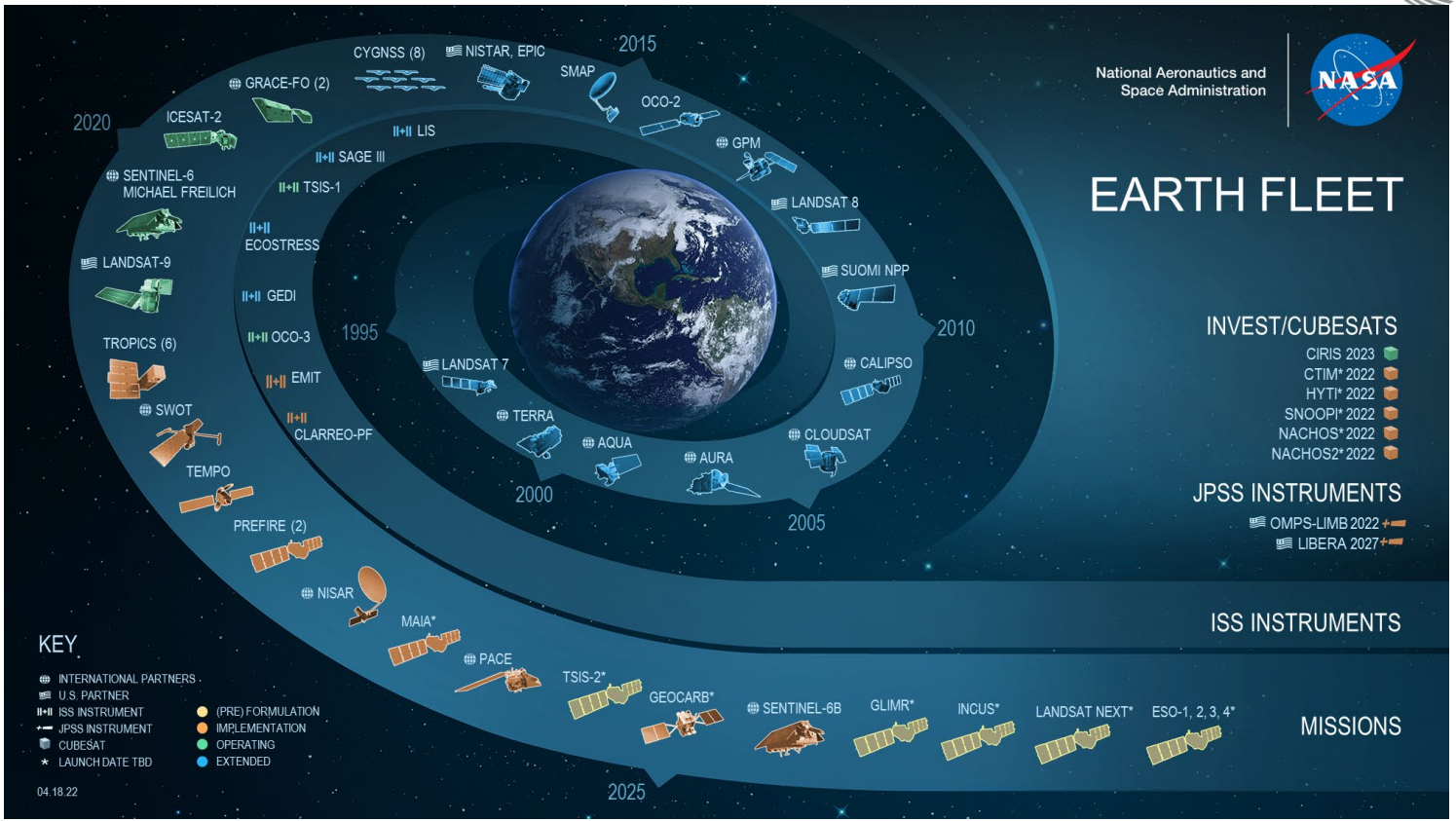
3rd edition: Open forum (new space, commercial and institutional) on status and developments related to the **calibration and validation** of space borne **very high-resolution SAR and optical sensors** and data products, focusing the attention on the commercial entities in Cal/Val activities, synergies between optical and SAR communities, presentation of standards and best practices for data quality.

Workshop topics (for VHR data):

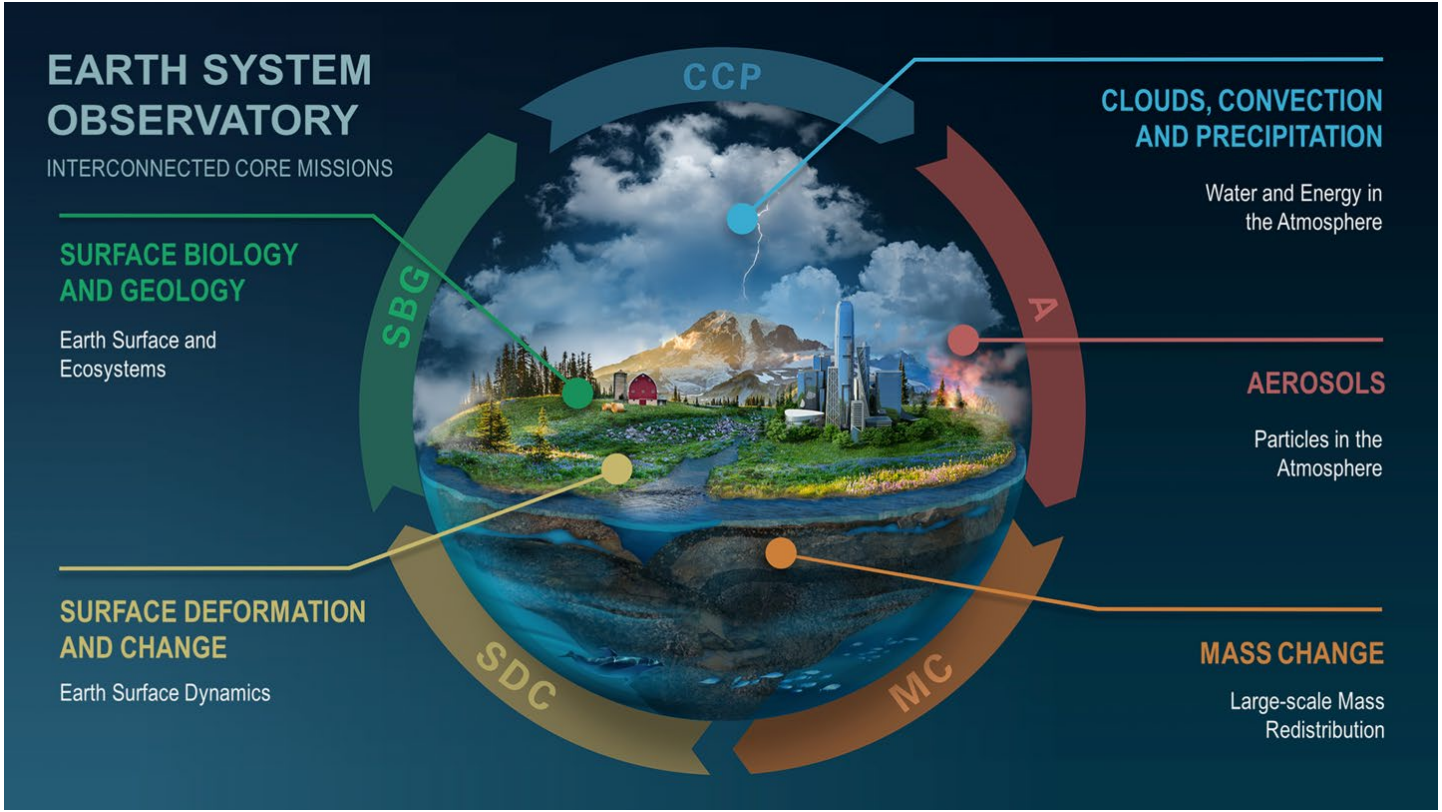
- Calibration Techniques (requirements, definitions, database, methodologies)
- Calibration Sites (cross-cal/val, intercalibration, field campaigns)
- Fiducial Reference Measurements
- Analysis Ready Data, Digital Elevation Models
- Quality Control, Best Practice, Product Validation
- Processing and Algorithms (incl. Artificial Intelligence for Cal/Val)
- Cal/Val and Data quality for Constellations and Big Data
- Calibration of Future Missions (Innovative instrument concepts)

B. Introduction to NASA Commercial Smallsat Data Acquisition (CSDA) Programme and activities

B. NASA's Fleet of Missions

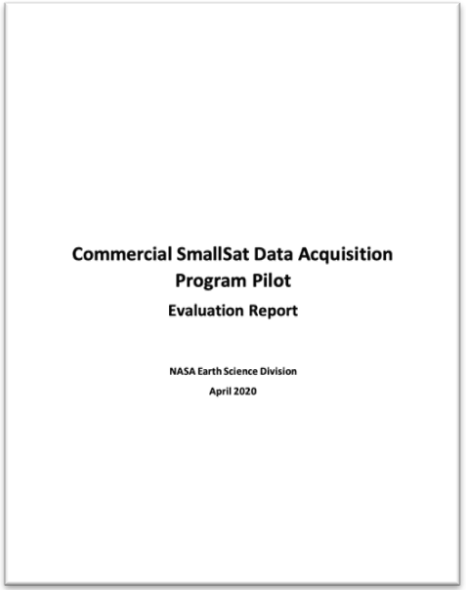


B. Earth System Observatory



B. What is NASA CSDA?

- Pilot initiated in November 2017 to evaluate data from operating commercial small-satellite constellations for research and applied science activities
  - Augment and/or complement NASA observations
  - Cost effective means to advance/extend research and applications
- Blanket Purchase Agreements (BPAs) were awarded in September 2018 to Maxar (DigitalGlobe) Inc., Planet Labs Inc., and Spire Global.
- Pilot successfully ended early 2020 → sustained program - CSDA Program
  - On-ramp #2: BPAs awarded to Airbus US for Synthetic Aperture Radar (SAR) and BlackSky for optical imagery
  - On-ramp #3: Sole source synopsis posted for Capella Space, ICEYE US, Inc, GeoOptics, Inc, and GHGSat, Inc.
- The data evaluation is performed by a team of investigators selected from the research and applications communities to assess their utility in achieving the scientific objectives of ESD.



B. Program Objectives

- Establish a continuous and repeatable process to onramp new commercial data vendors.
- Enable sustained use of purchased data for broader use and dissemination by NASA scientific community.
- Ensure long-term data preservation, access and distribution of purchased data and long-term access for scientific reproducibility.
- Coordinate with other US Government agencies and international partners on the evaluation and scientific use of commercial data.

B. Evaluation Criteria

The goal of each project's evaluation is to address:

1. Accessibility of vendor supplied imagery and data
   The ease and efficiency with which data can be searched, discovered, and downloaded from vendor systems.
2. Accuracy and completeness of metadata
   The accuracy and completeness of metadata that accompanies the data provided by the vendor.
3. Quality of User Support Services
   The availability, responsiveness, and technical expertise required to answer PI inquiries.
4. Usefulness of data for advancing Earth system science research and applications
   The ability of vendor-provided data to support Earth system science research and applications activities.
5. Quality of vendor supplied imagery and/or data
   Data attributes such as geolocation accuracy, radiometric calibration, and platform intercalibration. Data quality criteria will target the ESA-NASA Evaluation Guidelines drafted for data.

B. ESA-NASA SAR Evaluation Guidelines

This assessment is designed for instrument performance and not for data utility. It consists of the following:

Documentation Review

- Product Information (Metadata...)
- Metrology (Sensor Calibration...)
- Product Generation (Algorithms...)

Measurement Validation

- Absolute Radiometric accuracy validation
- Radiometric Stability validation
- Sensitivity validation
- Polarimetric accuracy
- Interferometric quality validation

Geometric Validation

- Impulse Response Function validation
- Geocoding accuracy validation
- Channel to channel coregistration validation (for multi-polarization data)

Earth Observation Mission Quality
Assessment Framework - SAR Guidelines

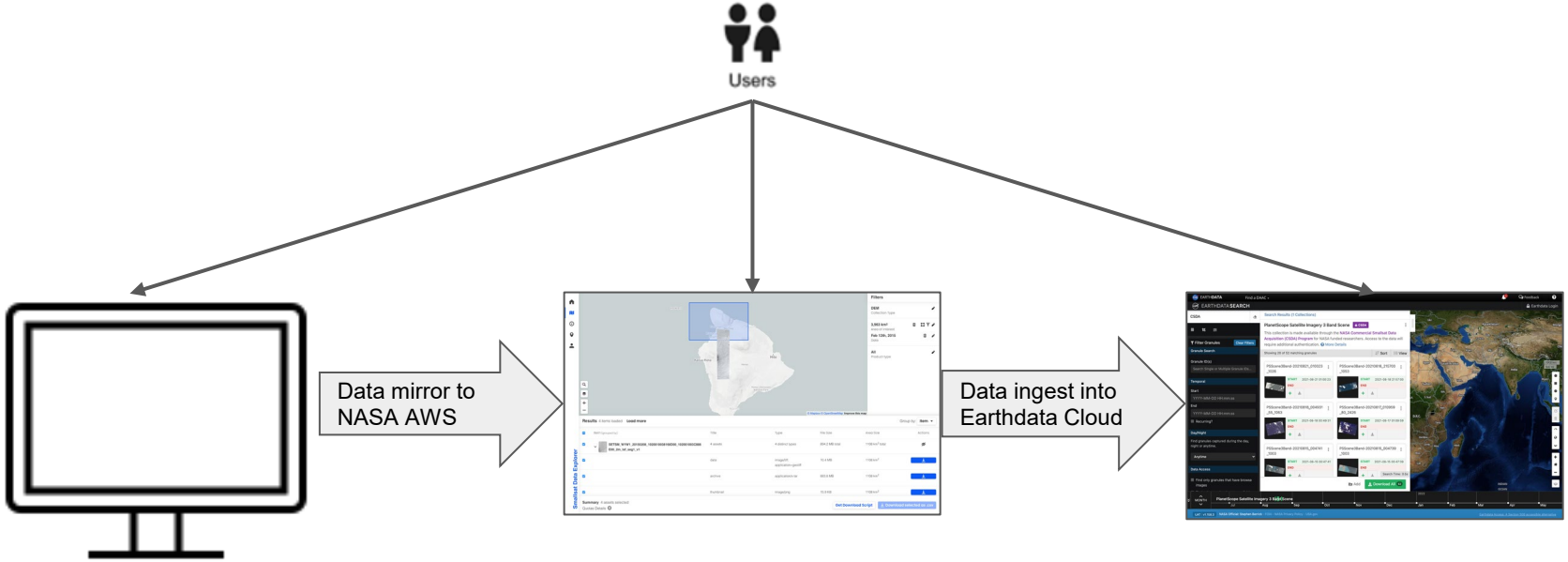
Author: Samuel Hunt, NPL EDAP Project Technical Expert

Approval: Alfreda Hall, NASA, CSDA

Accepted: Clément Albinet, ESA, EDAP Project Technical Officer

EDA RREF 00X Issue: 0.1 8 March 2021

B. How Users Get Data?

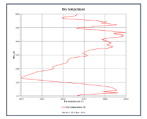
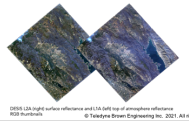


1. Vendor Interfaces and API's.

2. CSDA Smallsat Data Explorer with EarthDEM thumbnail displayed

3. CSDA acquired data discoverable in the EOSDIS Earthdata Search Client – ***Coming Soon***

B. Data Holdings

Vendor	Constellations/ Products	Availability Dates	Orbit Characteristics	Spatial Resolution	Spectral Characteristics	Sample
Planet	PlanetScope, RapidEye	12/31/2005 - Present	Sun Synchronous	3 - 6.5 meters	RGB, NIR (440-860 nm), Panchromatic	
	SkySat	3/10/2015 – 12/12/2019		< 1 meter	RGB, NIR (450-900 nm), Panchromatic	
Spire Global, Inc	GNSS Radio Occultation, GNSS Grazing Angle Reflectometry, Satellite Precise Orbit Determination (POD) and Satellite Attitude, Total Electron Content, Ionospheric Profiles, Scintillation, Magnetometer, Raw IF	9/24/2018 - 4/18/2019 (partial) 11/1/2019 - Present (all)	GNSS-R and GNSS-RO receivers satellites: 37° and Sun Synchronous			
Maxar Technologies	Worldview 1-4, GeoEye-1, QuickBird, IKONOS	10/24/1999 - Present	Sun Synchronous	0.31 - 4.0 meters	Multispectral and Panchromatic (400 - 2245 nm)	
Teledyne Brown Engineering, Inc.	DESIS L1B, L1C, and L2A	11/21/2018 - Present	Non Sun Synchronous 52° N to 55° S (ISS)	30 meters	235 channels, 2.5nm from 402 to 1000 nm	
Polar Geospatial Center EarthDEM product	individual strips and mosaic Digital Elevation Model	2009 - Present		2 meters		

Commercial Smallsat Data Acquisition (CSDA) Program

https://earthdata.nasa.gov/csdap

C. Cal/Val Maturity Matrix and Proposal for data usability

C. Data Usability – Why? What is it?

- For a wide community of EO-data users → Most of them are **not specialists**
- **Needs of users:**
  - Support on how to use EO-data
  - **Proof** that data are **fit for** their application **purposes**

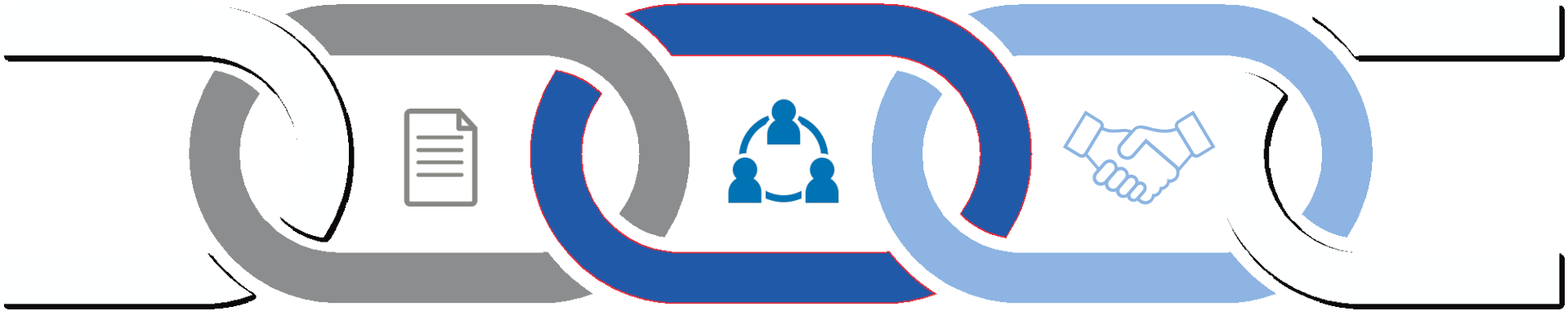
- → **Users** can be **confident** that they can derive **useful information**, **for** their application **purposes**, from data!

C. Data Usability – Why? What is it?

- How to address a mission's data usability or fitness for purpose?
- Data usability (aka FitnessForPurpose):
    - **Usefulness of data with respect to a given purpose/ to a given application (set of applications)**

- Final objective→ **Data Quality report addressing Cal/Val maturity and Data Usability**

C. Approach towards ESA-NASA Data Usability Joint Guidelines



Phase 1

ESA Draft

Phase 2

ESA-NASA Joint Draft

Phase 3

ESA-NASA Joint Guidelines

C. Data Usability – Inspiration – WMO OSCAR

- **OSCAR** (Observing Systems Capability Analysis and Review Tool)

Variable	Relevance for measuring this variable	Operational limitations	Explanation
Fraction of vegetated land	1 - primary	Cloud sensitive.. Daylight only.	VIS, NIR and SWIR channels
Land cover	1 - primary	Cloud sensitive.. Daylight only.	VIS, NIR and SWIR channels
Fire fractional cover	2 - very high	Daylight only.. Cloud sensitive.	VIS channels with high resolution for boundary detection
Leaf Area Index (LAI)	2 - very high	Cloud sensitive.. Daylight only.. Infrequent coverage.	VIS, NIR and SWIR channels
Cloud optical depth	3 - high	Low-density cloud only.. Infrequent coverage.. Daylight only.	VIS, NIR and SWIR channels
Aerosol volcanic ash	4 - fair	Cloud sensitive.. Daylight only.	VIS, NIR and SWIR channels with changing solar incidence angles as daylight progresses
Photosynthetically Active Radiation (PAR)	5 - marginal	Cloud sensitive.	VIS channels, range undersampled

- Developed by **WMO** in support of Earth Observation applications, studies and global coordination
- List of measurements that can typically be retrieved (Tentative Evaluation of Measurements, based on expert systems and/or mission objectives)

C. Data Usability – Inspiration – NIIRS

- **NIIRS Framework** (National Imagery Interpretability Rating Scale)

NIIRS	Resolution	EO	IR
0		Un-interpretable Image	Un-interpretable Image
1	> 9.0 m	Distinguish between roads, runways	Detect cleared areas
2	4.5 to 9.0 m	Detect parking garage	Distinguish vegetation
3	2.5 to 4.5 m	Detect parking space	Detect tank tracks
4	1.2 to 2.5 m	Recognize vehicle types	Detect thermally active vehicles
5	0.8 to 1.2 m	Recognize vehicle configurations	Detect front of vehicle
6	0.4 to 0.8 m	ID vehicle classes	Detect engines
7	0.2 to 0.4 m	ID vehicle tires	Detect people
8	0.1 to 0.2 m	ID driver	Detect turrets
9	< 0.1 m	ID vehicle plates	Detect guns

- Originated in the Intelligence Community, mainly focused on military equipment
- Standardized measure of image interpretability and usefulness (MTF and other metrics are not always sufficient to describe interpretability/usability)

C. Data Usability – Related – GPART

- **From USGS/NASA**

(Greg Snyder, JACIE 2022)

Geophysical Parameter Assignment and Rating Tool (GPART)

GPART is a tool to automatically assign geophysical parameters (GPs) and GP Ratings to sensors based on specific sensor characteristics

- **GPART 1.0 (fall 2021)**
- Sensor assigned a Rating for each Geophysical Parameter based solely on:
  - Spectral bands (placement, bandwidth)
  - SAR (radar frequency)
- GPART 1.0 bins sensors into coarse relative categories

GP Rating Categories	
Very High	Provides a **very accurate measurement of the GP**. Spectral bands or radar frequency chosen specifically to retrieve the GP as one of its primary purposes.
High	Provides a **high-quality measurement of the GP**. Sensor attributes allow for a high-quality measurement but is not specifically designed for that purpose.
Medium	Provides a **reliable measurement of the GP**. Users have reasonable confidence in the information accuracy without major limitations.
Low	Provides a **crude estimate of the GP**. Often requiring additional information or assumptions.
No Match	Provides **no value in measuring the GP** at all.

USGS

- GPART 2.0 (longer-term effort)
- Rating criteria will expand to incorporate more factors
  - Measurement accuracy
  - SNR
  - Radiometric resolution
  - Spectral response
  - Data quality
  - Other factors
- Rating categories will expand and become more nuanced

C. Application-Oriented Data Usability (ESA)

esa approach

LAND	WATER	SNOW & ICE	ATMOSPHERE	GEODESY	WEATHER	NATURAL RISKS	MOVING TARGETS	SECURITY & DEFENCE
Soil Moisture Retrieval	Oil Slicks	Snow Depth	Air Quality	Subsidence, Deformation	Temperature	Landslide	Water Masses Tracking	Refugee Camps or Military Bases Detection/ Monitoring
Vegetation (Health) and Agriculture (Crop yield, sowing,..)	Ocean Currents	Snowpack	Wind Speed/Fields	Earth Fields Mapping	Barometry	Fires Mapping	Vessel Detection	National Boundaries Monitoring
Land Cover/Use	Ocean Color (Algal Blooms,..)	Glaciers/Ice Monitoring (Melting, Crevasses, Depth,..)	CO2 and greenhouse gases	DEM Mapping	Hurricanes Monitoring	Floods Mapping	Moving Targets Tracking	RFI Monitoring
Change Detection	Bathymetry				Blowing Snow Detection	Damages Mapping		Target Detection
Biomass Estimation					Clouds Monitoring			Target Classification

Keys/Grades

- Primary
- Very High
- High
- Fair
- Marginal
- NOT ASSESSED
- Data Provider
- Spatial Resolution and Constellation capabilities

C. Application-Oriented Data Usability (ESA)

LAND	WATER	SNOW & ICE	ATMOSPHERE	GEODESY	WEATHER	NATURAL RISKS	MOVING TARGETS	SECURITY & DEFENCE
Soil Moisture Retrieval	Oil Slicks	Snow Depth	Air Quality	Subsidence, Deformation	Temperature	Landslide	Water Masses Tracking	Refugee Camps or Military Bases Detection/ Monitoring
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Keys/Grades

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- Very High
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- Marginal
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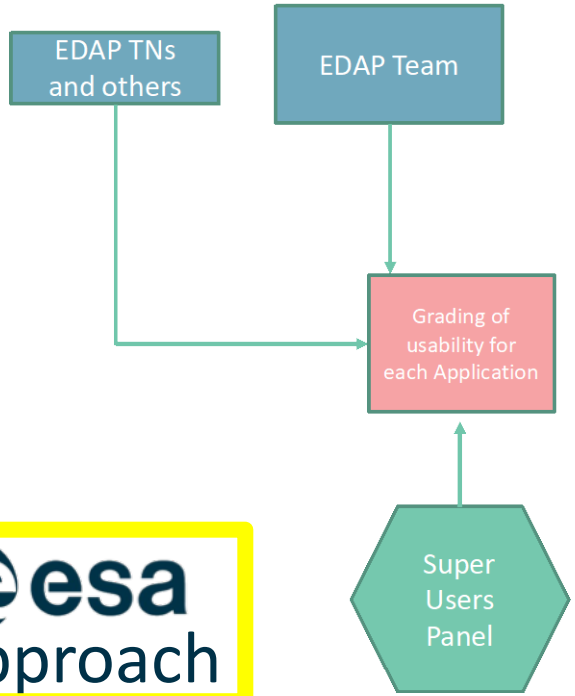
esa approach

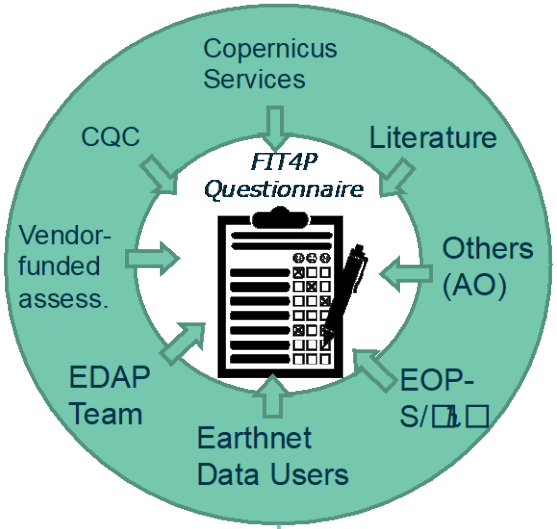
C. Application-Oriented Data Usability (ESA)

Quantitative approach (based on technical facts and documents)



esa approach

Qualitative approach (based on information and feedbacks from users)



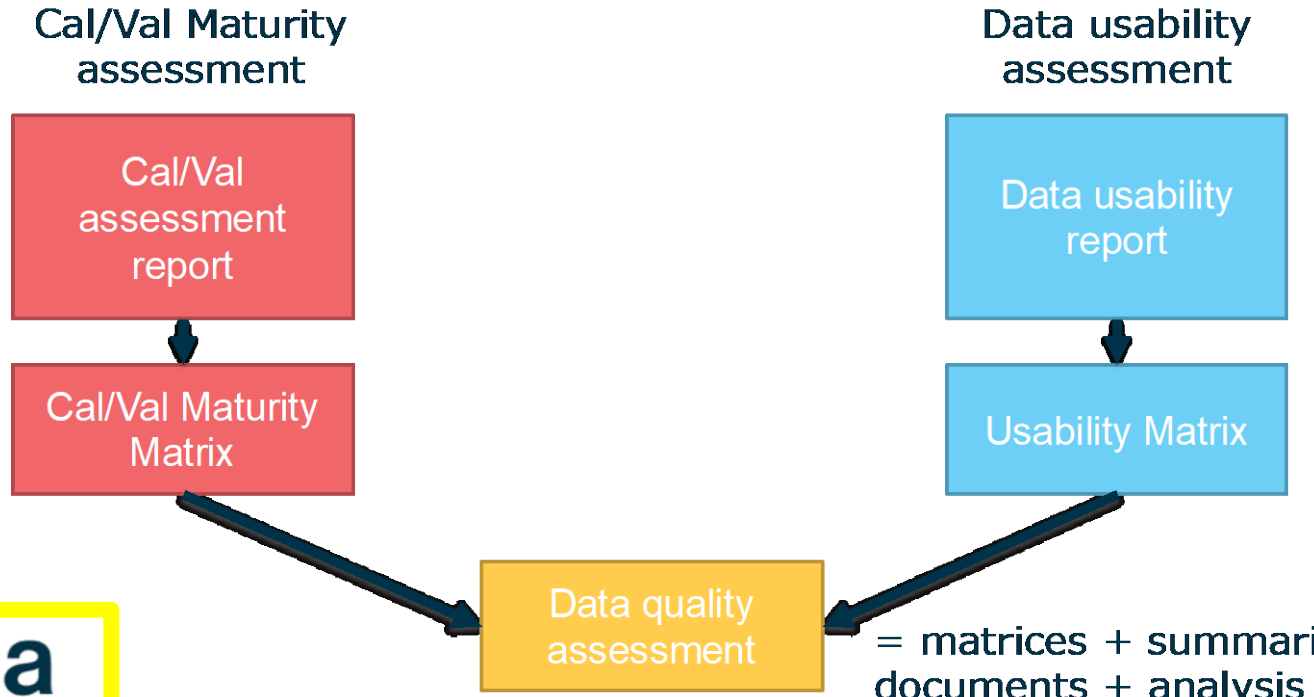
Questionnaires compilation and GRADES EVALUATION

C. Data Usability – Guidelines

The guidelines on usability will provide:

- The questionnaire
- The template of Technical Note (including the template of the matrix)
- The guidelines explaining how to compile the questionnaires and generate the final usability matrix

C. Toward an overview on Data Quality



esa approach

C. Next Steps

esa approach

Short-Term [first ESA draft]

Advance on the definition/ consolidation of the APPLICATION-ORIENTED DATA USABILITY schema/workflow with data experts

Potential update of existing Technical Notes (e.g. Planet SkySat or other) to include an additional chapter on data usability

Early 2023

First draft of ESA-NASA joint usability guidelines

Mid-2023

1st Technical Notes on Mission Data Usability

D. Discussions

D. Discussions - Cal/Val assessment

- Is the proposed approach clear for the data users(=you)?
- What is missing? Would you want more or less details?
- How to support future uses? (new applications, AI data analysis, etc.)

D. Discussions - Usability assessment

- Is the proposed approach clear for the data users(=you)?
- What is missing? Would you want more or less details?
- How to support future uses? (new applications, AI data analysis, etc.)
- Is the usability based on applications or science communities?
- Should the usability be based on monitoring or model inversion?
- How related are the Cal/Val and Maturity Assessment?
- How much should the guidelines be tailored to the different types of missions?
- Who should be involved in the definition of requirements (needed for grading) for each application/domain? Users? Experts only? Both?

D. Discussions - For data providers/vendors

- What are the requirements to join an evaluation at ESA or NASA?
- How to help you to better identify/advertise the potential of your data?
- How to help you to better identify/advertise the expectations and needs of the data users?

D. Discussions - Other

- Are the Cal/Val+usability assessments only focusing on missions that are intended to be potentially included as TPM? Or are they also focusing on all types of missions, regardless of interest to add them as TPM or not?

- Henri and Kevin: How binding are the results of the evaluations in terms of future acquisitions of ESA and NASA?

- Sebastien: How much should the guidelines be tailored to the different types of missions?

- Batu: Who should conduct the evaluations at ESA and/or NASA?