2nd VH-RODA 2021 Workshop - Summary Report

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1. INTRODUCTION

The Very High-resolution Radar & Optical Data Assessment (VH-RODA) 2021 workshop took place online from 20–23 April 2021.

The 2nd Edition of the Workshop has provided an open forum (new space, commercial and institutional) for the presentation and discussion of status and future 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.

The workshop was very successful with around 400 registrations and a daily audience of 160 participants. The detailed agenda and presentations can be found on the workshop website: https://earth.esa.int/eogateway/events/vh-roda-workshop-2021/agenda.

1.1 Workshop Topics

Due to COVID-19, the workshop has been structured and focused on specific topics related to the continuative comparison and dialogue between the SAR and Optical communities, Institutional and Commercial communities, on the methodologies related the data quality and products validation, instrument calibration and characterization strategies, applications of Artificial Intelligence for Calibration/Validation and data processing, ground-based infrastructures, and calibration networks.

The following list highlights the developed topics:

- Calibration Techniques (requirements, definitions, database, methodologies)
- Calibration Sites and Techniques (cross-Cal/Val, intercalibration, field campaigns, Fiducial Reference Measurements - FRM)
- Analysis Ready Data (ARD), Digital Elevation Model (DEM)
- Calibration of Future Missions (Innovative instrument concepts)
- Quality Control, Best Practice, Product Validation
- Processing and Algorithms (including Artificial Intelligence for Cal/Val).

2. SUMMARY OF SESSIONS

The workshop has been organized in topics divided in four half-days:

Day 1: Tuesday 20 April 2021	Day 2: Wednesday 21 April 2021	Day 3: Thursday 22 April 2021	Day 4: Friday 23 April 2021
13:00-14:00 [CEST] **Introduction** 14:00-18:00 [CEST] **Institutional / Commercial ARD**	14:00-18:30 [CEST] **Fiducial Reference Measurements & Reference Cal/ Val Sites**	14:00-18:30 [CEST] **Quality Harmonisation: Quality Maturity Matrix & Quality Control Best Practice**	14:00-16:50 [CEST] **AI for Cal/Val, AI for QC and Data Processing** 16:50-18:30 [CEST] **Wrap up**

In the following section, all presentations have been summarized, with the recommendations coming from the discussions and translated in highlights and actions.

2.1 Day 1: Tuesday 20 April 2021

2.1.1 Summary of the Introduction Session

The workshop has been opened with a welcome and introductive session, presenting the role of ESA and the main EO programmes (identified by three main lines: **Copernicus**, **Meteorology** and **Science**).

The **2nd VH-RODA** have been successively introduced, showing to the participants the principal objectives of the workshop were firstly, to facilitate dialogue between public and commercial entities on data quality and Cal/Val and, secondly, to identify synergies and gaps across complementary roles and to enable a long-term interoperability. Considering how fast the EO ecosystem is changing and evolving, the imperatives are to understand the quality and uncertainty of the all-new data, and how to perform interoperability.

The agenda with the topics and the structure of the workshop have been presented:

(https://earth.esa.int/eogateway/events/vh-roda-workshop-2021/agenda):

- 1st day on Analysis Ready Data as step towards interoperability;
- 2nd day on reference sites and Fiducial Reference Measurements;
- 3rd day on data quality and maturity matrix for harmonisation step towards certification;
- 4th day new algorithm and Artificial Intelligence for Quality Control.

The role of ESA in the Very High Resolution EO panorama has been presented with the three programmes for the stimulation and support of EO industry activities (1**. ESA InCubed** to support new companies to develop potential future; 2. **ESA Earthnet** and **EDAP** for Third Party Mission data supply and for quality assessment and Cal/Val support; 3. **EU Copernicus**: TPM data for complementing the sentinels in operational Copernicus services).

In this scenario characterized by the increasing of EO data coming from different sources, data quality is essential, and one of the adopted instruments for this assessment and for mission evaluation is the **maturity matrix**.

ESA and NASA (through the **ESA Earthnet** and **NASA Commercial Smallsat Data Acquisition, CSDA programmes**) are actually cooperating for the definition of this common framework for mission quality assessments evolving towards the Cal/Val Maturity Matrix.
The NASA Commercial Smallsat Data Acquisition CSDA (born as pilot activity in November 2017) is focused on the evaluation of data from commercial small-satellites for research and applied science with the goals to complement NASA observations and extent research and applications.

A fundamental role is played by international groups, forum and workshops: **Joint Agency Commercial Imagery Evaluation (JACIE)** is a collaboration between five Federal agencies (**NASA, NGA, NOAA, USDA, USGS**) that are major users and producers of satellite land remote sensing data, with the future objectives to define new references on multi-source/platform products, ARD and interoperability, Machine learning and Artificial intelligence applied to EO data, reference measurements.

2.1.2 Summary of Institutional /Commercial ARD

The first session has been focused on the definition of the Analysis Ready Data and the different point of view have been proposed by agencies and commercial companies.

The first presentation (from **Geoscience Australia**) has been focused on the status of the Analysis-Ready Data for Land (CARD4L). In a coordinated effort by the CEOS Land Surface Imaging Virtual Constellation (LSI-VC) and the CEOS WG on Cal-Val (WGCV) SAR Subgroup, four Product Family Specifications (PFS) have been endorsed, and other five are in development. The PFS are annually reviewed through a cooperative process to assess: the strategy of updates has been presented (ARD website updates, communications, pilots; ref. to http://ceos.org/ard).

Continuing the same argument, the presentation of **JPL** has provided the requirements necessary for the definition of ARD applied to Sea Surface temperatures and ocean disciplines, for coastal applications, atmospheric disciplines and Aquatic Reflectance. Important has been the institution of a team of experts to review the CEOS ARD Framework (Definition, Specifications and processes around CEOS ARD) for completeness and suitability (including looking at changes that make it amenable to non-land domains). Team formed from VC and other Working Group stakeholders in December 2020.

In this context, two presentations on Radar ARD and three on Optical ARD have been illustrated:

1) **ICEYE**: here the concept of ARD (considered too stringent and limited by the risk to lose information and/or to be too easier with errors/bias propagated) is evolved in ARS (Analysis Data Service, where data are derived by defined requirements, with additional processing and specific features).
2) **e-GEOS**: the first and second generation of the Cosmo-SkyMed constellations have been presented, with the improvements in performances and in data for the second generation.
3) **Indigo Agriculture**: ARD has been presented in relation to sensor fusion; considering the number of different and distributed instruments, the heterogeneity of the virtual constellations is the new reality. In this direction fundamental is to provide standardized inputs for sensor fusion: this expands the concept of interoperability to all processing levels.
4) **Planet**: the strategies of the company on data fusion have been presented: advanced radiometric harmonization exploiting calibrated third-party sensors, rigorous cloud detection; fusion of Sentinel-2 and Landsat-8 data, and pixel

traceability information and BDRF variability have been exposed. Important to validate the data, evaluation against ground-based spectrometer data.

5) **MAXAR**: ARD as a stack of images/tiles for faster processing and lower storage cost, but especially, different levels of ARD towards to an application-centric and user-centric approach.

The last presentation (**ESA/USGS/University of Zurich**) has been focused on the status examples of Sentinel-2, Landsat and Sentinel-1 ARD CARD4L compliance.

2.1.3 Summary of Day-1 Discussion

1A6) Discussion

Seed questions presented to trigger the discussion on **Institutional / Commercial ARD**:
 	
• *There is confusion on the actual **meaning of ARD**:*
  o *What is ARD for Commercial Space?*
  o *What is ARD for the Institutional Space?*
• *What is the status of the participation of **commercial Space** in the definition process of the CEOS ARD Specifications?*
• *What is the status of activities related to the definition dedicated specifications for **Very-High Resolution missions**? (e.g., via creation of a dedicated sub-group?)*
• *Is there a need of ARD beyond land?*
• *What can be improved in the **dialogue** between Commercial Space and Institutional Space? And among Commercial Space?*
• *In which areas the Commercial Space still see room for improvement and how the Institutional Space can help filling the gaps and enabling future improvements?*
• *What the Commercial Space would embrace from the Institutional Space and, on the contrary, in which areas they feel confident to provide lessons learned and/or recommendations to the Institutional counterpart.*

The contents of presentations have shown **different perspectives on what ARD is**.

- **On institutional side** there is a most homogeneous vision, there is more consensus, translated in CARD4L;
- **On commercial side** there are more discrepancies on definitions and visions; private sector, moreover, pushes towards an application/services approach.

There is still confusion on the definition of ARD: there is the need to get common understanding on what the meaning is for ARD, still a need of better communicating the effort being made in the frame of CEOS; there is limited uptake from the commercial service; it is important to understand whether it is a question of lack of consensus and how get critical mass to work towards a common approach.

Is there a generic definition of ARD from CEOS?
A CEOS ARD definition has been provided, but it remains generic and a very broad definition, in order to cover a large range of processing levels and possibilities. It could remain a generic term that can be interpreted by the different providers.

ARD can be different from CARD4L and can be defined very generically; but in case the direction would be to go for CARD4L, instead, there would need of family specifications. It was seen that there is different feeling of what is ARD; although institutional want to push everybody toward CARD4L.

Regarding ARD generic concept, it would be disconnected from any specific knowledge about the sensors (orthorectified, atmospheric, angles): this implies to have a generic level of requirements, to go across all type of sensors, technologies and measurements. ARD is really the first step of interoperability: the definition wants to be broad and applicable to e.g. SAR, IR, etc i.e. in general beyond Optical.

Commercial Space Companies work independently on the generation of data, there is no coordination and it is difficult to coordinate with other missions: it has been stated that collaboration among competitors is also possible because companies often collaborate for the same objective.
These kinds of workshops are the occasion to discuss and interact on these topics.

The role of ESA and other institutions could be to facilitate this coordination and to foster the link between CEOS and commercial sector. There is a need for a tuning of ARD specification depending on the application.

In the context of requiring a minimum of standardization, it has been highlighted the need to include quantitative information at pixel level (e.g. metadata), this is also required for a prominent Machine Learning approach.

The way the georeferenced information is packaged should be standardized, CF metadata, EPSG projection codes, WKT, other known vocabularies etc.
Going to VHR, moreover, many other aspects become important e.g. there will not be a very high-resolution DEM at global scale.

Moving to the next steps for ARD other challenges are **interoperability, data fusion** and **integration**. OGC provided a good viewpoint also.

The ARD definitions must be common across institutional and commercial environments.

- A way to have more consensus is to look and review the CARD4L list of specifications and work to consolidate and refine the CEOS definition.

Trying to capture each application needs is difficult (since ARD for user may be different):

- CARD4L is for land and includes many applications → it can be refined for different applications;
- maybe there are few key applications, which can be addressed first.

ARD for Space providers:

- need to have at least co-registered data, data inter-calibrated;

need to remove everything related to sensor and acquisition conditions (similar issue with cloud mask).

2.2 Day 2: April 2021

2.2.1 Summary of Fiducial Reference Measurements & Reference Cal/ Val Sites Session

The second day has been focused on Fiducial Reference Measurements and Cal/Val Sites.

The first presentation (**ESA/Geoscience Australia**) has been focused on the necessity to have suite of independent ground measurements that provide independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission. Two examples have been provided:

1) FRM4VEG (project aiming at applying the FRM concept to in-situ measurements of the several land products ESA distributes) and
2) FRM4SAR (Australian Corner Reflectors Supporting refence measurements and the Australian site also supports independent studies on deformation due to sub-surface resource extraction in the region using InSAR techniques.)

In this context, the ground networks have been introduced (**ESA**):

- **Radiometric Calibration Network (RadCalNet)** is a part of a network including multiple sites designed to provide automated surface and atmosphere in situ data with the purpose of optical imager radiometric calibration in the visible to shortwave infrared spectral range.

There is the necessity to provide validation to metre-scale optical missions, providing also water reflectances, and to integrate and complement the existing network (RadCalNet, AeroNet).

- **HYPERNETS** is H2020 project and will benefit all current and future optical missions, defined by strong requirements for VISNIR and SWIR ranges, for in situ measurements to validate surface reflectance (**RBINS**).

Also, SAR instruments (**JPL**) need external calibration targets in order to calibrate imagery and for long term monitoring of image calibration stability. There are three types of external calibration targets used by SAR: 1) Natural targets, 2) Artificial passive targets, 3) Artificial active targets.

"SARCalNet" is in the early stages of formulation by the **CEOS WGCV SAR subgroup: i**t would be an established network of calibration sites that would facilitate collaboration between sensors by using the same calibration references.

Finally, the new concept that is in the definition phase: **Cal/Val Park (joint ESA-ASI effort):**

- Dedicated to VHR and HR optical missions, both multi-spectral and hyperspectral missions;
- For both TOA radiance and reflectance and BOA reflectance;
- Open to be used by both the "institutional space" and the "commercial/new space";
- Common "playground" to test and run new Cal/Val methodologies, instruments, and initiatives;
- Open to include temporary and long-term instrumentation and initiatives;
- Scalable (as far as possible) to accommodate new needs and new types of EO missions that may come in the next years.

From the commercial point of view:

1) **PLANET**: the Dove Classic, Dove-R, SuperDove and SkySat missions have been presented with their calibration methodologies: the current method is based on gathering a dataset of near simultaneous crossovers with a reference satellite (Sentinel-2A and Sentinel-2B as the reference satellites). A simultaneous crossover is when there was less than two hours difference between a Sentinel-2 image and a SuperDove image for the same point; RadCalNet and Lunar Monitoring.

2) **MAXAR**: reflectance-based vicarious calibration approach developed by the University of Arizona: this method uses in-situ measurements of surface reflectance (of spectrally and spatially homogenous targets) and atmospherics in a radiative transfer model to predict at-sensor radiance for validation and calibration efforts.

3) **ICEYE**: strategy of the radiometric calibration in SAR is the processing needed to associate univocally the received signal with the Backscattering Coefficient. The realization of dedicated in-situ sites with known corner reflectors and/or transponders that are managed by cooperative institutions would give high benefits for Cal-Val activities. The presence of multi-band point targets could support the inter-calibration between satellites of different constellations.

4) **CAPELLA SPACE**: presentation of the two fully operational satellites Capella-2 and Capella-3, Capella-4 in commissioning phase and the validation activities in the EDAP project.

5) **AIRBUS**: general overview of Pléiades Neo and all vicarious calibration strategies have been presented.

The Last Presentation **LabSphere** has been focused on the FLARE station, or node, that consists of mirror array (SPARC Mirrors), radiometric tower, solar panels, and electronic and communications equipment, that is part of a network accessible to customers.
The SPecular Array Radiometric Calibration **(SPARC)** method allows any earth observing sensor to be calibrated to the solar spectral constant just like a solar radiometer. A FLARE target is a constant radiometric reference that tracks the satellite.

2.2.2 Summary of Day-2 Discussion

1B8) Discussion

Seed questions presented to trigger the discussion on: **Fiducial Reference Measurements & Reference Cal/Val Sites.**
 	
• *Is there an interest by Commercial Space to collaborate with Space Agencies into defining internationally community agreed protocols and procedures for satellite data validation?*
• *What would you expect as a **common reference for geolocating** your data?*
• *Need for **common consistent references**?*
• *There are today several different databases of GCPs in construction (GRI, etc.):*
    o *Is there a reason to use different database? (Complementarity?)*
    o *Would it make sense to join our efforts to build a **joint database of GCPs**?*
• *Is there a need for **more or improved reference** Cal/Val Sites and **databases** for **VHR** (<2m) missions?*
    o *Geometry (VHR GCP database)*
    o *RadCalNet is a key component for enabling inter-operability at TOA level, what is still missing and which is the main priority for Commercial Space viewpoint: e.g., geographical coverage, low-radiance reference sites?*
• *What kinds of improvements have been made in terms of availability and use of the data from reference Cal/Val sites since the last VH-RODA meeting? And what is still need?*

- ***Network of Supersites**: should it be just an Agency effort, or a joint effort between Institutional Space and Commercial Space? In which proportions? How?*
  [...Common consistent reference!]
- *Vicarious approaches (e.g., PICS and Moon) are complementing RadCalNet for ensuring accurate radiometric assessment and stability monitoring, though implementation methods often differ, limiting comparability. What is still required in this respect? Are the protocols for vicarious methods unanimously accepted?*

The first point analysed in the discussion has been related to the geometric calibration and validation and the needs to have GCPs DB: there are different DBs for GCPs while a common DB should be, in principle, used.
A **common and open-source high resolution GCP dataset** is a strong key, for instance GRI is now used for Sentinel-2 and Landsat-8 and this reduces the co-registration error across missions.

One important question is related to the **GCPs maintenance** since their characteristics change in time (change in landscape and urban expansion).
Submission of proposal for new site, also using UAV for very accurate DEM and to open this dataset to the community is considered valuable.
There is difference between worldwide database and database for calibration, and it is important distinguish **accuracy** from **uncertainty** for GCP:

- **in order to evaluate geometric distortion within the images a lot of GCPs are needed in a very small image, especially for VHR missions.**

We should develop common VHR database using also the available Lidar data.

Links to CEOS test sites used for calibration and validation activities have been provided:
http://calvalportal.ceos.org/calvalsites
http://calvalportal.ceos.org/point-distributed-targets-db
https://calval.cr.usgs.gov/apps/test_sites_catalog

About Cal/Val Park
The importance of the dialogue with the commercial companies and optical data providers has been highlighted.

First comment was related the MTF targets in the new Cal/Val Park: interesting but probably not necessary because when VHR i.e. < 1 m, many natural targets in the images can be found in nature.

Super-sites are useful for inter-comparing satellite (when there are satellites with different resolutions).
Not only the MTF targets, of course, other type of targets and/or devices can be installed (e.g. for BRDF estimation and for thermal missions).

There is a great need for reference:

- Agencies should lead these kinds of activities and provide the means to inter-compare different sensors and Cal/Val Park is a good answer.

Cal/Val Park should be imaged as a "playground" to test technologies, test measurements.

- Necessity to have goniometric measurements.

Note: actually, thermal missions are more military, not yet emerged as necessity.

Question to commercial companies on the necessity to have the active systems/calibrators: would be great the support of agencies.

2.3 Day 3: April 2021

2.3.1 Summary of Quality Harmonisation: Quality Maturity Matrix & Quality Control Best Practice Session

The third day has been focused on of Quality Harmonisation strategies and instruments, Quality Maturity Matrix and Best Practices.

The first presentation (**NPL/NASA**) has been focused on the tool for the quality control: commercial satellite sector is growing and in particular in the hyperspectral and hybrid sensor domains. The need for a systematic evaluation of the commercial satellite is rising as consequence, in particular the development increasingly comprehensive definition of mission quality through:

- Analysis ready data & interoperability;
- Fiducial reference measurements;
- Traceability;
- Uncertainty evaluation e.g. Sentinel-2 Uncertainty Tool.

The ESA EDAP Project and NASA CSDA Program have been presented, with the emphasis posed on the **maturity matrix**, identified as Common QA Framework**.**

The second presentation (**Telespazio-France/ARESYS/NASA**) has been oriented on the synthesis of Maturity Matrix results for Optical Missions and preliminary analysis on SAR Missions have been presented.

In this context, also the Copernicus Coordinated data Quality Control **(CQC)** has been presented (**Serco Italia**) with the scope of monitoring the quality of Earth Observation (EO) products of the current, and future, Copernicus Contributing Missions (CCMs). CQC activities are carried out within the ESA PRISM contract. The methodology adopted is **the Edge Method (EM)**, an on-orbit approach that, provided the availability of suitable edges in an image, computes a series of functions from which can be derived different sharpness metrics. Additional analyses aimed at investigating the mutual relationships between image geometric properties (e.g., Ground Sampling Distance - GSD, Pixel Size - PS), image radiometry (e.g., dynamic range, image SNR), image sharpness (e.g., different EM-based sharpness metrics) and overall image quality have been suggested.

The fourth presentation (**ESA/USGS**) has been focused **Cooperation and coordination in Cal/Val and harmonisation activities:** Coordination on Cal/Val and data quality activities becomes even more crucial when data from different satellites are used by users worldwide in a complementary and synergetic manner.
Data quality has enormous downstream impacts on the accuracy and reliability of the products;

- Facilitate cross-calibration and interoperability;
- Support synergetic use of data coming from different sensors/satellites.
- Sentinel-2 / Landsat (this has greatly improved the co-registration between the two missions).

In parallel, USGS has evaluated the Copernicus DEM and considering its usage for Landsat data processing. Continuing on the DEM analysis, the DEMIX (DEMs Intercomparison eXercise) has been presented: the project has the scope to perform detailed comparison of participating DEMs at regional and global scale.
It will include also comparison of Sentinel-2 DEM (Copernicus DEM) and Landsat DEM (NASA DEM).

Another presented activity has been the project to provide S2-like surface reflectances with increased frequency through a harmonisation and fusion process combining data from different sensors.

Finally, two future missions have been introduced: **CHIME** (Copernicus Hyperspectral Imaging Mission for the Environment) and **SBG** (NASA's Surface Biology and Geology mission). Activities are on-going and currently aiming at defining a roadmap for cooperation between the two missions.

Airbus presentation has been focused on **Pléiades Neo** imagery quality features: radiometric and geometric requirements have been illustrated, with the commercial products characteristics.

The last presentation (**ESA/HCL**) of the day has been focused on the **ESA ITT Q3 2021,** that responds to the request from ESA EO industry (QA along the complete supply chain), structured with the following tasks:

- Task-1, EO data acquisition & L0/L1 production: an analysis of EO satellite meta data for a set of EO service use cases;
- Task-2, Value adding process – A pre-operational implementation the EARSC Quality Certification scheme;
- Task-3, Product delivery and use - an analysis of various schemes for VA information product certification.

And with the following objectives, to:

- Improve confidence that products and services are supplied in a consistent and supportable manner;
- Improve quality of products and services;
- Provide a reference points for customers to establish their requirements.

2.3.2 Summary of Day-3 Discussion Session

1C7) Discussion

Seed questions presented to trigger the discussion on: **Quality Harmonization - Quality Maturity Matrix & Quality Control Best Practice**

- *How can we work towards **enhancing inter-operability** of current and future VHR sensors? What are the main challenges at the moment and how we can address them in the near future?*
- *Where do you see **major source of discrepancies** in the currently used image processing approaches for VHR sensors: different input files (e.g., DEM, meteo data), cloud/snow/shadow masks, atmospheric corrections methods?*
- ***Inter-comparison exercises** (e.g., ACIX, CMIX, BRIX) provide the means to understand discrepancies between disparate methods and converge in the long run to a harmonized solution. How do you see an inter-comparison exercise focused on VHR missions, which should be the focus?*
- *How have **advanced the discussion between CEOS and the private sector** on the topic of the target sites for radiometric calibration? (status)*
- *How the **quality indicators and quality control** results should be communicated? In the products? In the metadata? Per pixel?*
- *Should we **harmonised/standardised the metadata** information to facilitate interoperability? Is it linked to **ARD** definition?*
- *What do **Traceability & Uncertainty** mean when we refer to Commercial Space missions?*
- *Are we converging towards a **standardized approach for quality control**? Is it possible and is it useful?*
- *For large constellations, can the quality control process still be applied on a "**satellite-by-satellite**" base?*

There is a common feeling about the importance of using quality Maturity Matrixes (MM). Maturity Matrix has been seen as a great tool for discoverability, and it provides the information to understand if a product is acceptable for the intended use ("fit for purpose"). Maturity Matrix should provide information also about the metadata.

The key to this in the long-term goal is the Traceable Uncertainty (at pixel level or point level) related to QA4EO - http://www.qa4eo.org/ .

Quality information of each pixel are deemed necessary for interoperability. Uncertainty at pixel level would be precious but difficult to achieve: although it is the best choice for the user to provide the mean to understand the trust on the specific pixel measurement.

- Pixel quality information needs more effort and an added cost (and probably new-space, that is more service oriented, does not use it).

Uncertainty per-pixel mandatory for medium resolution, crucial for data assimilation, more difficult to get per-pixel in VHR: better to have:

- quality layer per-pixel to provide an initial information on confidence level (uncertainty per-pixel difficult);
- start with good metadata, which are machine readable.

It has been observed that Uncertainty Budget document should be necessary and available for the products.
Since detailed uncertainty information requires a lot of resources (in terms of algorithms and processing, and also in storage), is necessary to provide this information for Basic or High-Level Products?

- Depends: for HR to be discussed; for MR is mandatory; for data assimilation is mandatory. For VHR good metadata and quality flags. And depend by the application.

With these best practices and institutional approaches used to “evaluate” commercial and new-space data (where often calibration methods are not the best and some information are not completed provided or missing), the result is that the data could be judge not-very good even if the offered service is excellent: in fact, they are mostly oriented into providing services.

- How to help/support commercial and new space to go to right direction.

Another important thing is the geometric uncertainty: in the example for an HR optical, going in details in products, even if globally product can be appeared good, distortions have been observed.

Can the quality criteria be adapted to the VHR data (c.a. 30 cm)?

- It is important the “fit to purpose” → depends by the application.
- And in particular for constellations, labour intensive Cal/Val will not perform for VHR, better using statistics, with regular monitoring. Not possible generalize processing only one or two satellites.

There is the need to find a way assess the consistency of data.

Inter-comparison exercises, ACIX and CMIX are recognized very precious (also in a QC context).
This would also be very valuable for metre-scale missions, the main problem is organizational since the missions are mainly commercial.

- Perhaps it is necessary to provide reference data and inter-comparison relevant software for multiple metre-scale missions.

The machine analytics and service providers (many of which are data providers) are working on the quality aspects throughout their data processes and these are getting better all the time and the quality information is available.

The key is the standardized process to be consistent in terms of data availability in the cloud and machine use and in order to provide a quality indicator to the user to decide which sources to use and meet the "fit for purpose" requirement.

In the context of the GHRSST there are standardized, and quality variables and it is trying to build a reference against which it is possible inter-compare the VHR sensors.

It has been also observed that Institutions and Industries move with different paces (most oriented to the market).

As discussed in ARD section, we need to work together: institutional or commercial, they would provide standardization, interoperability, standardization in metadata, quality indicators to facilitate certification process.

A unification of certification with the participation of many world actors is fundamental, the involvement of agencies and international space law is considered important to create certificates for these guarantees and, but not to hinder anyone access, so if we have access to open source, we can guarantee the reliability of the data for.
For an efficient Matrix model, the global participation in this construction will be fundamental.

2.4 Day 4: Friday 23 April 2021

2.4.1 Summary of AI for CAL/VAL, AI for QC and Data Processing

The last day has been focused on the application of Artificial Intelligence for calibration/validation activities, quality control and data processing.
The first presentation (**Kappa Zeta**) has been focused on the results of the application of AI Cloud-Mask processors for Sentinel-2 for Northern European terrestrial summer season conditions.

The second presentation (**Cosine**) was focused on the two HyperScout missions (the second mission not yet launched), and in particular on the synergies between Hyoerscut-1 and Sentinel-2A/B, and Hyperscout-1 and LandSat-8. The second satellite shall be launched in 2022 and will be targeted Polar and Snow monitoring, soil moisture and embark AI for cloud detection.

The third presentation (**Telespazio-UK**) has been focused on AI for quality control. Ease QC activities initially applied to Landsat data: much of the effort of this phase went to the development of a tool to support the labelling of data and definition of training datasets and integrate the activities of the quality control and SW harmonization and development. Similarities between Landsat and Sentinel-2 to be explored.

For the data processing, the fourth presentation (**University College London**) has shown firstly, the development of high-resolution land surface albedo retrieval (10 m / 20 m) using Sentinel-2 MSI, including cloud masking and atmospheric correction methods; and secondly, Super-Resolution Restoration from single and repeat EO images, based on traditional photogrammetric and stochastic approaches, deep-learning based approaches, and novel approaches combining the two.

The fifth presentation (**EarthDaily Analytics**) has introduced applications and results of the Image Correlation for High-Quality Geolocation and Band-to-Band Registration, Accurate Cloud Detection to Support Analytic, Feature Detection for custom applications (i.e. Irrigation Pivot Detection with AI).

2.4.2 Summary of Day-4 Discussion Session

1D6) Discussion
Seed questions presented to trigger the discussion on**: AI for Cal/Val and AI for QC and Data Processing.** • *Does Institutional Space have something to* ***learn from Commercial Space****?* • *How could the Institutional space support the Commercial Space on the use of AI.* • *What should be changed in order to have proper training datasets for AI?* • *Is there a risk of AI as "black box" and how to mitigate this risk?* • *How do you see the use of AI in 10 years?* • *Machine Learning and AI are becoming dominant in an ever-increasing range of EO applications, yet, the main challenge in this domain is the availability of accurate training datasets. How Commercial and Institutional Space sectors can join forces in providing open access to accurate reference training datasets, for e.g., cloud mask, snow mapping, land cover?*

- *With respect to ML/AI methods, which are the main risks of the learning from data paradigm? How biases in radiometry and geometry will affect such approaches when blending data from different EO sensors?*

The first point and proposed question are related to the necessity to have good and reliable training dataset (also in cloud environment): is there Something that Space Agencies can do to facilitate access to training dataset?

There is a difficult and misleading definition of “what is a cloud”. The necessity is surely to have a standard on defining the labelled data, and to provide sample data with this clear labels.

Regarding the cloud definition, in CMIX there is not a definition of clouds and no physical measurements of cloud have been provided: but there was an intercomparisons of cloud masks provided with a reference.
Cloud definition is difficult: it has been within CEOS, but no convergence reached yet; there was a definition being provided within Cal/Val portal, but at the end it depends on the algorithm, some of them are more sensitive to haze. Important point is the objective of retrieval: in terms of algorithms to have good retrievals.

There are independent methods for assessing cloud: MISR (Multi-angle Imaging Spectro-Radiometer) with stereo mode being used in the past to understand where clouds are.
For instance, geometry can be used to generate true cloud. Parallax can be used as well for cloud mask, it is being used also for S2, this can be used to extend truth dataset.

How cloud can be labelled for the benefit of AI developers? it is important because necessary for the usability of the training dataset. It is also important to investigate clouds for SAR (especially in the field of QC).

Working on standard on defining the label data. A clear definition of what label are: cloud, semi-transparent cloud, shadow is needed.

How AI techniques can be applied to multi-sensors, or to specific sensors, or to apply massively these algorithms?
Sometimes there are very good results, but the point is to the training dataset. The transfer learning can be functional, but if you don’t use the right bands, it means that you can generalize to other missions.

What ESA and the agencies can do to improve the Quality transfer information to the Commercial Sector and to the community in general?

Reference data is the central point: It is needed to provide reference data with free & open data policy as ESA do for satellite data.
Labelling and annotations of data are very time consuming:

- large training dataset are the key, made them available and made available the resources with the environment for progressing;
- motivating large number of people as well as providing benchmark is the way Agencies can help the community;
- Promote competition: one competition was done at ESTEC (PROBA-V Super-resolution) in order to involve large community of people working on that, gain credibility.

Please look at the https://ai4eo.eu/ website, this could host a challenge around QC Cal/Val.

Open-Questions raised:

- Is there a way we can use A/MLI to detect understand geometry distortion uncertainties in imagery?

- What is the impact of getting access to high resolution ortho-imagery level country data with control available in the cloud environment integrated with the 1000s of images over the same area on the earth?
- Is there a future AI common geospatial process where the geolocation is statistically defined at very high accuracy and how does this change geometric calibration process of satellite data product inputs?

From Agency perspective, how to help commercial industries into take advantage of good quality of EO data of institutional missions? How to stimulate this transfer learning?
In-situ and other reference data should be more in the focus of data providers and be considered a substantial part of any 'free and open' data policy.

There is a need for a larger input for the spectral radiometry training because the many hyperspectral systems coming in next years.
The inconsistency in spectral bands need to be taken into account: Hyperspectral data are very usable, but not the ones we have been using so far; for instance, Hyperion had a very poor SNR and it is not best suited for match SRF, spectral transfer functions; great idea to use hyper-spectral data, but need to have good sensor SNR.

- Need to create for the future SRF.
- Need to define and support campaign.

In this context the future TRUTHS mission aims to establish an SI-traceable space-based climate and calibration observing system. It would carry a hyperspectral imager to provide benchmark measurements of both incoming solar radiation and outgoing reflected radiation with an unprecedented accuracy.

And considering all hyperspectral missions, it would be important to have simultaneous overpasses.

For AI as black-box two risks are recognized: loose the physical meaning and lose the traceability needed to estimate uncertainty – how to mitigate these risks is a big challenge.

2.4.3 Summary of Wrap-up Session

Ferran Gascon (ESA) – Institutional / Commercial ARD
Summary: There are **two points of view on ARD concept**: • Definition of ARD and interpretation of ARD data (from institutional there are specifications and terminologies coming from CEOS); • **Analysis Ready Services** (ARS) in order to extent the users since ARD are too restrictive and too indicated to a limited number of users. In general, ARD commercial perspective is moving versus higher level Products (Level-4, Level-5). Commercial providers are anyway now supporting the CARD4L initiatives.
Discussion: The ARD definition is still too vague; maybe Maturity Matrix can be a tool to understand the readiness level and the compliancy to ARD requirements. Analytics Ready Data are another concept to be characterized and well defined: there is the necessity to define new categorizes with new thresholds and goals. Moreover, ARDs are providing basic information on what needs to be populated in metadata, which are suitable for analytics: there is the necessity to be supported by expert and commercial partners, with the creation of dedicated working groups.

Philippe Goryl (ESA) – Fiducial Reference Measurements & Reference Cal/Val Sites
Summary: **Fiducial Reference Measurements (FRMs)** are measurements well characterized in terms uncertainties budget, fundamental for validation purposes and very useful for the data intercomparisons and facilitate interoperability. **Reference Networks** are put in place, i.e. **RadCalNet** for radiometry and top of atmosphere calibration (to be extended to cover non nadir measurements); there are a lot of expectations for **HyperNet**, that is the same idea for hyperspectral measurements (for hyperspectral surface reflectance validation); and **SARCalNet** that shall be important for the calibration and SAR missions intercomparison (need to improve and increase corner reflectors at middle latitudes). **MTF** is easy to do thanks to the utilization of natural targets (i.e. stars), but to be well done there is the necessity to maintain artificial targets. There is the big project of the **Cal/Val Park** for multi-mission purposes, to experiment new methodologies, scalable, in order to accommodate new needs, to support new initiatives. FLARE project is very promising for MTF and radiometry. **Geometry**: necessity to have common GCP S2/L8 to facilitate interoperability → Global GCP for VHR is still an open point. **Radiometry**: vision in place, leveraging on methodologies developed, new technologies, HYPERNET/RadCalNet, with long-term of having SI-traceable satellites, linking all approach to a fully traceable system.
Discussion: A lot of attention around MTF. Synthetic images are available on the CEOS Cal/Val portal to test methods. MTF reference Dataset: http://calvalportal.ceos.org/mtf-reference-dataset

There is a lot of interest in obtaining and maintaining key supersites defined with agreed maintenance plans. Is highlighted the need to maintain artificial targets for validation, while for VHR a lot of natural targets are available.

Albrecht von Bargen (DLR) – Quality Harmonisation: Quality Maturity Matrix & Quality Control Best Practice

Summary:

- Different general approaches for QC were presented: ESA-EDAP, NASA and Copernicus CQC.
- Show cases on Preliminary uses of these approaches were shown and capabilities demonstrated for optical and SAR missions.
- With fusion of Sentinel-2 and Landsat-8 products, a demonstration for a harmonized product on higher-level was presented as buy-in for added value.
- Certification process along the production chain was presented for EO products.

Discussion:

There is a strong correlation with the type of mission and applications.

- There are a lot of situations and only the definition of methods and clear criteria can help to be oriented to good data.
- The maturity matrix could be a useful instrument to be used.

Typically, Commercial Space Companies have another pace driven by applications/services, while Institutional and Agencies are oriented with best practices.

One of the key elements is the calculation and provision of **uncertainties**. Moreover, the instruments provider should be part of this process.
How should be the QA, since it also involves cost/effort; need to find the best trade-off.

The big challenge remains the **estimation and provision of uncertainties**; the data providers should ensure availability of the uncertainty:

- A lot of commercial providers are trying to do that, suggest to provide examples on how to do that.

Valentina Boccia (ESA) / Luca Fasano (ASI) – AI for Cal/Val, AI for QC and Data Processing

Summary:

AI techniques are very sectorial and often oriented per areas of interests.
The main challenge in this domain is the availability of accurate training datasets.

In order to apply AI and ML techniques to Optical and SAR data (i.e. for Cloud masking and QC), to a sensor and extent to multi-sensors with same/similar spectral bands, the availability and provision of training dataset (together with computational resources and environments for progressing) is a necessity.

There are two emerged open questions:

1. the first related to the extension of AI optimized for specific region of interest to other regions;
2. the second related to the performances and computational time of these AI techniques.

Another emerged point is related to the AI methodologies implemented on-board and the evolution of this strategy (especially for hyperspectral missions).

Discussion:

Helpful how we can develop tools/framework using AI for detecting artefacts/features, it can be also used for QC: **is difficult to distinguish features from artefacts**.

Super-resolution: AI can be used not only for spatial super-resolution, but also for spectral.

The increasing number of satellites/sensors and constellations, with the commercial space platforms, make available a big number of products can be calibrated with AI.
Tools for QC are probably not adapted for these applications. The nature of AI algorithms poses some problem, e.g. AI methods cannot propagate the uncertainty in the same way of classical methods.

Another theme is the **temporal resolution**: high temporal sampling will allow to capture all range of dynamics.

AI also for capitalize on historical data: use ML algorithm to push forward the reanalysis of historical dataset; such as study of water bodies, forest; atmosphere dynamic.

Train AI with the past in order to have better calibrated algorithms for the future.

The heterogeneity of data borders with Big Data paradigm.

3. CONCLUSIONS

3.1 Highlights

The highlights of the workshop have been captured during the discussions sessions and here harmonized and reported:

- The continuous growth of EO satellites and sensors implies, for the next future, to provide standardized inputs for sensor fusion; this expands inter-operability to all the processing levels, it needs to be ensured through the full chain.
  - This growth suggests also to stimulate the creation a virtual community based on multi-sensors.

- The discussion on the ARD definition is still open: institutional and commercial point of views are complementary, and the need to define a working group where to bring the different actors (together commercial and institutional space) is evident.

- The heterogeneity of EO sensors, with different spectral and spatial characteristics, imposes to sustain and maintain varied calibration sites, since the necessity to improve calibration of these satellites (especially commercial satellites).
  - Coordination within various institutions/agencies is fundamental in order to make this data available and discoverable by the community.
  - Joint effort (commercial and agencies) in order to have a set of sites for improved geometric Cal/Val.

- The availability of larger and distributed GCPs data is becoming fundamental: the accessibility and availability of detailed DB shall be improved in the frame of CEOS and made available on the Cal/Val portal.
  - Interaction with USGS for sharing potential DB for VHR GCPs.
  - In-situ and other reference data should be more in the focus of data providers and be considered a substantial part of any 'free & open' data policy.

- Quality Control of EO data needs coordination: a systematic approach by defining and implementing QA standard requires the effort of all in order to keep up with pace of development.
  - Quality information of each pixel are deemed necessary for interoperability (uncertainty per-pixel mandatory for medium resolution, crucial for data assimilation).
  - Institutional/Commercial providers would provide standardization, interoperability, standardization in metadata, quality indicators to facilitate certification process.
  - Institutions have to work in order to provide common references, in order to permit the sensors intercomparisons at different scales.
  - Uncertainty associated to all measurements and derived quantities is a parameter that should be always included: QA4EO can help on that supporting commercial to improve the provision of this info though standardization.
  - The Maturity Matrix has been recognized as an important instrument for the evaluation of quality: it would be an open-source tool (adopted in processes for QC).
  - With the growth of VHR missions, a VHR inter-comparison exercise involving commercial companies should be considered.

- Artificial Intelligence and Machine Learning methodologies and tools are becoming fundamental instruments in the data processing chains, very promising in terms performances and into supporting the decision making.
  - Large training dataset are the key, made them available and made available the resources with the environment for progressing.
  - Motivating large number of people as well as providing benchmark is the way Agencies can help the community (a way could be promoting competitions);

- Stimulating the interaction between EO and AI communities, too still separated.
- Stimulating initiatives to push forward the re-analysis for past dataset with AI methods;
- Objective for the agencies/institutions: they have to provide reference/ground truth.

3.2 Recommendations

Topic	Recommendations Description
Analysis Ready Data	• Building a virtual community mission based on multi-sensors • Future providing standardized inputs/needs for sensor fusion; ○ this expands inter-operability to all the processing levels, it should be ensured through the full chain • The backbone of the ARD is to have a detailed set of metadata specific for application.
Reference Sites and Fiducial Reference Measurements	• For AI need to provide reference/ground truth. • Need to review the status of Salon test site for MTF; many people use the target, but the site is not maintained. • Coordination within various institutions in order to make Cal/Val data available and discoverable by the community. • Improve GCP data in the frame of CEOS and made available on the Cal/Val portal. • Joint effort (commercial and agencies) in order to have a set of sites for improved geometric Cal/Val.
Data Quality and Maturity Matrix	• To have Maturity Matrix tool open-source (transparent process for QC), • Allow providers to carry out the QA by themselves, • Include the results of the QA in the metadata, • Organize VHR inter-comparison exercise such as ACIX, involving commercial companies. • Idea to have sample materials for Uncertainty → QA4EO can help on that supporting commercial to improve. • Quality information of each pixel are deemed necessary for interoperability (Uncertainty per-pixel mandatory for medium resolution, crucial for data assimilation). • Institutional/Commercial would provide standardization, interoperability, standardization in metadata, quality indicators to facilitate certification process. • Institutions have to work in order to provide common references, in order to permit the sensors intercomparisons at different scales.
Artificial Intelligence for Quality Control	• Large training dataset are the key, made them available and made available the resources with the environment for progressing; • motivating large number of people as well as providing benchmark is the way Agencies can help the community; • Promote competition: one competition was done at ESTEC (PROBA-V Super-resolution) in order to involve large community of people working on that, gain credibility → Stimulating the interaction between EO and AI communities. • In-situ and other reference data should be more in the focus of data providers and be considered a substantial part of any 'free and open' data policy.

	• Working on the development and provision of training dataset. • It would be interesting to push forward the re-analysis for past dataset with AI methods.

3.3 Actions

At the end of panel discussion, the following actions have been collected:

Action ID	Title	Description	Owner
VH-RODA_21_Action_01	Supporting training dataset	Provision of large training dataset and made them available (together with computational resources and environments for progressing) in order to apply AI and ML techniques to different sensors and domains.	ESA
VH-RODA_21_Action_02	Support the transfer learning from institutional to commercial	To provide reference data (i.e. in situ data, calibration data) with free & open data policy as done for satellite data.	ESA
VH-RODA_21_Action_03	Multiple Hyperspectral data	In order to use hyper-spectral data for different applications it is needed to have good sensor SNR. Considering the hyperspectral instruments (i.e. PRISMA from ASI, DESI from DLR on ISS, etc.) the necessity is to have multiple, overlapped and simultaneous acquisitions from different sources and targets. Cooperation between the several Agencies should be sought and interoperability between products generated by different sensors should be encouraged.	ESA/General
VH-RODA_21_Action_04	Promote initiatives on ARD	In order to promote CARD4L initiatives and in general ARD, need to instance workshops and support discussion in the existing framework (JACIE, VH-RODA).	ESA/General
VH-RODA_21_Action_05	ARD: create a link with Commercial Sector	Create Working Group with CEOS and Commercial sector to coordinate this discussion (following the example within LSI-VC). Necessity to integrate inputs form the commercial sector in LSI-VC, WGCV, and WGISS.	ESA
VH-RODA_21_Action_06	Sharing of potential DB for VHR GCPs	Action to get in contact with USGS on sharing available VHR GCPs.	ESA/USGS

VH-RODA_21_Action_07	AI Challenge	Investigate the opportunity of a challenge on AI methods involving and stimulating collaboration between EO and AI communities.	ESA

3.4 Way Forward

Discussion will continue at JACIE 2022: January 11 - 13, 2022 for the 20th annual Joint Agency Commercial Imagery Evaluation (JACIE) Workshop.

3.5 Access to Info and Presentations

For info and presentations can be found on the VH-RODA ESA official web site:

https://earth.esa.int/eogateway/events/vh-roda-workshop-2021

4. ANNEX A

The detailed agenda is reported:

Day-1: Tuesday 20 April 2021			
13:00 – 14:00		**Introduction**	
13:00 – 13:10		Welcome	Toni Tolker-Nielsen (ESA)
13:10 – 13:25		Introduction, Objectives	Philippe Goryl (ESA)
13:25 – 14:00		Update on: • ESA EDAP project • NASA Commercial Smallsat Data Acquisition (CSDA) Program • JACIE coordination	Henri Laur (ESA) Kevin Murphy (NASA) Jon Christopherson (KBR) / Greg Stensaas (USGS)
14:00 – 18:00		**Institutional / Commercial ARD**	**Chair: Ferran Gascon (ESA)/ Steven Hosford (CNES)**
14:00 – 14:30	1A1	CARD4L development and status	Andreia Siqueira (Geoscience Australia)
14:30 - 15:00	1A2	ARD beyond land. CEOS perspective	Edward M. Armstrong (JPL)
15:00 – 15:30	1A3	SAR: ARD from New Space perspective: • ICEYE • e-GEOS	Shay Strong (ICEYE) / Axel Oddone (e-GEOS)
15:30 - 16:00	1A4	Optical Sensor: ARD from New Space perspective: • Indigo Agriculture • Planet • Maxar	Ignacio Zuleta (Indigo Agriculture) Rasmus Houborg (Planet) Fabio Pacifici (Maxar)
16:00 - 16:30	1A5	CARD4L concrete examples: Sentinel-2/LANDSAT and Sentinel-1	Ferran Gascon (ESA) / Steve Labahn (USGS) / David Small (University of Zurich)
16:30 – 16:40		**Coffee Break**	
16:40 – 18:00	**1A6**	**Discussion**	**ALL**
18:00		**End of Day 1**	

Day-2: Wednesday 21 April 2021			
14:00 - 18:30		**Fiducial Reference Measurements & Reference Cal/ Val Sites**	**Chair: Philippe Goryl (ESA) / Joanne Nightingale (NPL)**
14:00 - 14:30	1B1	Fiducial Reference Measurement: concept and example - FRM4VEG and FRM4 SAR	Valentina Boccia (ESA) / Medhavy Thankappan (Geoscience Australia)
14:30 - 14:50	1B2	Reference Calibration Validation Networks: RadCalNet	Marc Bouvet (ESA)
14:50 - 15:10	1B3	Reference Calibration Validation Networks: Hypernet	Kevin Ruddick (RBINS)
15:10 - 15:30	1B4	Reference Calibration Validation Networks: SarCalNet	Bruce Chapman (JPL)
15:30 - 15:50	1B5	Plan for a European Optical Sensor Cal/Val site	Valentina Boccia (ESA)
15:50 - 16:00		**Coffee Break**	
16:00 - 17:00	1B6	Commercial interest and needs in Cal/Val services: • Planet • Maxar • ICEYE • Capella Space • Airbus	Arin Jumpasut (Planet) Fabio Pacifici (Maxar) Andrea Radius (ICEYE) Davide Castelletti (Capella Space) Laurent Coeurdevey (Airbus)
17:00 - 17:15	1B7	FLARE Spatial and Radiometric Capability for CAL-VAL Sites	Chris Durell (Labsphere)
17:15 - 18:30	**1B8**	**Discussion**	**ALL**
18:30		**End of Day 2**	

Day-3: Thursday 22 April 2021			
14:00 - 18:30		**Quality Harmonisation: Quality Maturity Matrix & Quality Control Best Practice**	**Chair: Clement Albinet (ESA) / Albrecht von Bargen (DLR)**
14:00 - 14:40	1C1	A tool for quality control harmonisation: Data Quality Maturity Matrix	Sam Hunt (NPL) / Jaime Nickeson (NASA)
14:40 - 15:20	1C2	ESA and NASA Application of Data Quality Maturity Matrix to SAR and Optical New Space mission assessments	Sebastien Saunier (Telespazio-France) / Davide Giudici (ARESYS) / Will McCarty (NASA)
15:20 - 15:50	1C3	Presenting the Copernicus Coordinated data Quality Control (CQC) Approach for Sharpness Assessment	Luca Cenci (Serco Italia)
15:50 - 16:20	1C4	Cooperation and coordination in Cal/Val and harmonisation activities: Sentinel-2 / Landsat / CHIME / SBG	Valentina Boccia (ESA) / Christopher Crawford (USGS)
16:20 - 16:30		**Coffee Break**	
16:30 - 16:50	1C5	Pléiades Neo: Image quality indicators and products	Laurent Coeurdevey (Airbus)
16:50 - 17:20	1C6	Towards quality certification	Ola Grabak (ESA) / Peter Hollidge (HCL)

17:20 - 18:30	**1C7**	**Discussion**	**ALL**
18:30		**End of Day 3**	

Day-4: Friday 23 April 2021			
14:00 – 16:50		**AI for CAL/VAL, AI for QC and Data Processing**	**Chair: Valentina Boccia (ESA) / Luca Fasano (ASI)**
14:00 – 14:20	1D1	AI for Cal/Val #1: • S2 AI for Cloud masking	Marharyta Domnich (Kappa Zeta)
14:20 – 14:40	1D2	AI for Cal/Val #2: • PhiSat: Cosine	Marco Esposito (Cosine)
14:40 - 15:00	1D3	AI for QC: Landsat and roadmap towards Sentinel-2	Kevin Halsall (Telespazio-UK)
15:00 - 15:20	1D4	AI for data processing #1: • Generation of high-resolution spectral and broadband surface albedo products based on Sentinel-2 MSI measurements, and Super-Resolution Restoration from single and repeat EO images	Jan-Peter Muller (University College London)
15:20 - 15:40	1D5	AI for data processing #2: • Contribution of AI to high-resolution satellite: EarthDaily Analytics	Chris Rampersad (EarthDaily Analytics)
15:40 – 16:40	**1D6**	**Discussion**	**ALL**
16:40 – 16:50		**Coffee Break**	
16:50 – 18:30		**Wrap up**	**ALL**
18:30		**End of Day 4 - End of Workshop**	