

CEOS Analysis Ready Data: Involving the Private Sector

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Discussion Paper Prepared by the CEOS Strategic Implementation Team

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1 Executive Summary

This paper provides an initial evaluation of the views from the private sector on how the CEOS community needs to engage with the broader community to successfully advance the CEOS Analysis Ready Data (CARD) initiative to the next level. Further, the paper offers an overview of the next steps that the CEOS community should consider to ensure all three main stakeholder groups (EO data providers; Big Data hosts and aggregators and data users) are actively involved in the CARD initiative.

Methods of evaluation included consultation with a small group from the private sector through an initial teleconference, follow-up emails and informal face-to-face discussions. All comments received during the first engagement call can be seen in Appendix I.

Outcomes from this initial engagement show that the private sector recognises the CARD work as an important initiative and is open for future collaboration with the CEOS community.

The next steps proposed in this paper include:

- Share Information on CEOS Analysis Ready Data to build engagement support
- Understand the Industry Perspective
- Engage Industry in Specifications
- Move CEOS specifications into the broader community

1.1 Recommendations for CEOS

1. Establishing mechanisms for constructive and appropriate engagement with the private sector;
2. Avoid *unnecessary* barriers to participation (from industry) in the CARD discussion and processes;
3. Provide appropriate documentation on the various aspects of the CARD initiative;
4. Identify a CEOS ARD framework process for assessing private data products for compliance with Specifications;
5. Move CEOS concepts into the broader standards realm to include the private sector.

2 Remit and Purpose

CEOS Analysis Ready Data (CARD) is a priority of the SIT Chair Team for 2020-2021. This paper has been prepared in response to Task 2.4 of the [CEOS Analysis Ready Data Strategy](#). The CEOS ARD Strategy identifies that CEOS should:

Ensure effective engagement of the three key stakeholder groups: EO data providers (both public and private); Big Data hosts and aggregators who stage increasing amounts of CEOS Agency free and open data; and data users.

And specifically, Task 2.4 of the Strategy calls on CEOS to:

Prepare a paper on the Interplay of Industry and CEOS ARD.

This paper presents recommendations regarding how CEOS can and should engage with the private sector in the area of Analysis Ready Data.

3 Background

3.1 CEOS Development of Analysis Ready Data

From 2015 CEOS has been developing the concept of ‘CEOS Analysis Ready Data’, seeking to be specific about what CEOS Agencies mean by this term, and clear in the benefits to CEOS Agencies of pursuing Analysis Ready Data.

The CEOS [Land Surface Imaging Virtual Constellation \(LSI-VC\)](#) served as the forum for developing the first CEOS Analysis Ready Data definition – specifically for land but with wider relevance. *CEOS Analysis Ready Data for Land (CARD4L) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis, with a minimum of additional user effort, and interoperability both through time and with other datasets.* CARD4L underpins a large amount of the future data architectures work being progressed within CEOS. The CARD4L definition and framework were endorsed by the CEOS Plenary in 2016.

The overall CARD4L framework has three elements; a) the definition, b) the Product Family Specifications (PFS) and c) the Product Alignment Assessment (PAA). The definition identifies that the major benefit of ARD lies in enabling a broad community of non-remote sensing experts to better use CEOS data; and in increasing the interoperability of products through space and time as a foundation for ‘Big Data’ analyses, future data architectures and the application of AI (artificial intelligence and machine learning) methods.

The CARD4L definition identifies that in order to be ready for general use as scientific observations, CARD4L products should be geophysical measurements of Earth’s surface; the location and time of the observation must be known, and corrections will need to have been made to produce a useful measurement. The nature and importance of those corrections will differ between instruments and measurements.

An important step in the CARD specification approach is that it is not prescriptive with regard to the data processing approach. This recognises that there are generally multiple approaches and that these will evolve through time. However, the data provider must document and disclose their methods.

Furthermore, CEOS developed the concept of ‘Product Families’, the second element of the CARD framework – primary geophysical measurements that can be derived from CEOS satellite instruments.

With input from a growing number of expert groups (each with open participation), several Product Family Specifications have been, and are in the process of being, agreed. These specifications detail the corrections that are essential and/or desirable.

The CEOS Working Group on Calibration and Validation (WGCV) has worked with the LSI-VC to establish formal procedures for the assessment of products against the PFS. This process is part of the third element of the framework which allows data providers to ‘self-assess’ how well they meet the specifications and for an independent assessment and peer review to be done. The peer-review is currently being exercised by WGCV.

As of early 2020, the status of the Product Family Specifications is as follows:

Product Family Specification (Measurement Type)	Status*	Currently Available or Closely Anticipated Sources of Global Products Meeting the PFS
Surface Reflectance (dimensionless)	Complete	Landsat optical instruments with processing anticipated through USGS 'Collection 2'. Sentinel-2 MSI instruments.
Surface Temperature (degrees)	Complete	Landsat thermal instruments.
Normalised Radar Backscatter (NRB)	Complete	ALOS PALSAR instruments, in particular as global mosaics provided by JAXA. Sentinel-1 instruments.
Polarimetric Radar (PR)	Complete	Radar expert teams have proposed these products and are working to finalise the specifications during 2020.
Geocoded Single Look Complex (GSLC)	Under Development	Radar expert teams have proposed these products and are working to finalise the specifications during 2020.
Interferometric Radar (InSAR)	Under Development	Radar expert teams have proposed these products and are working to finalise the specifications during 2020.
Ground and Canopy Height (metres)	Under Development	Space LiDAR missions are producing new information with the potential to transform global assessments of landscapes, vegetation structure, biomass, and biodiversity. A specialised team including researchers and managers from the GEDI and ICESat-2 missions has formed as is working to identify and specify the product families that can be produced by space LiDAR. Ground and Canopy height is the first product family that the team is investigating.
Aquatic Reflectance (AR)	Under Development	Landsat optical instruments.

*Product Family Specifications are reviewed annually to ensure that they remain current with the latest science and technology and in response to stakeholder feedback.

Importantly, CEOS ARD products are not exclusive. CEOS Agencies will continue to provide other products such as the ones from the Group of High-Resolution Sea Surface Temperature ([GHRSSST](#)) which takes into account data specifications and interoperability aspects considering broad standards and conventions. The GHRSSST products provide an example of how the use of broad standards and conventions can allow products to be interoperable with other datasets from other communities on top of enabling multiple data producers to create consistent analysis-ready products. These products may involve less, or more, processing than CEOS ARD products and are likely to be in demand by remote sensing experts and specialist users of particular data streams. To those users, these products are also 'analysis ready'. At the same time, there is a broad and growing pool of non-traditional users and operational applications that will drive demand for CEOS ARD-specified data.

3.2 Matters Not Covered in the Product Family Specifications

In order to focus effort on the core concepts of CEOS Analysis Ready Data, specifically **taking a repeatable measurement of a geophysical property**, the scope of the specifications was intentionally limited. The areas below are therefore *not* covered in CEOS Analysis Ready Data specifications.

Data Policy

Free and open data policies are a fundamental enabler of CEOS' mission and are of the greatest importance for the global EO community. However, the policy of the data provider is not inherently relevant to the readiness of the data for use.

Data Accessibility

The ability to access data is increasingly critical to the global EO community. Automated machine-level access to globally available, high quality, analysis ready data streams that are consistent through time will be key. However, the question of access to the data can be tackled separately to the question of the suitability of the data for use, once accessed.

Data Supply Assurance

As the use of EO data becomes more operational and commercial, data users need to understand the supply chain for the data, and to what extent they can rely on the data source being available into the future.

Data Format

Data formats are the container for the data. Efficient, familiar and consistent data formats are important to users and to the effective use of EO products. Data formats are evolving rapidly through the informatics community to enable, for example, efficient compression and high performance in cloud environments, and we can expect that evolution to continue. Technologies such as GEOTIFF supported by Spatio-temporal asset stacks (STAC) are emerging as current front runners. The CARD4L Framework does not specify data formats but is expected to evolve to *recommend or provide guidance on* formats that the community deem to be most effective.

Data Interoperability

It is important for CEOS to develop agreed and understood language around the concept of interoperability, including to avoid confusion around the purpose and scope of CEOS ARD. This work is progressing under CEOS' analysis ready data strategy, led by the working group for information systems and services (WGISS).

Standards

CEOS ARD Specifications are standardisation of products but are not formal Standards. The 'if' and 'how' of whether the Specifications should be more formalised as Standards is a topic of consideration under the CEOS ARD Strategy (below). Standards may emerge as a key factor in CEOS engagement with the private sector.

Although the matters above are not included in the CEOS specifications, given their importance both within CEOS and to industry and other stakeholders, CEOS may choose to address them within the broader *CEOS Strategy for ARD*. For example, additional advice elements could be included alongside the specifications, and indeed the Radar specifications are already including such advice. Advice might relate for example to preferred data formats, or to the use of Spatio Temporal Asset Catalogue (STAC), to open data licences, or to the provisioning of data as 'on-demand' v. 'pre-processed'.

3.3 CEOS ARD Strategy

Recognising the applicability and importance of Analysis Ready Data beyond the LSI-VC, the CEOS SIT Chair Team brought forward CEOS ARD (CARD) as one of three priorities to be progressed during the 2020-2021 Chair period.



Noting the need for broad consensus on the evolution of this work, on the prioritisation of future products as the basis for new ARD standards in different thematic areas (including oceans, atmosphere, etc.), and on the extensive engagement of data suppliers, of Big Data hosts and aggregators, and of data users for maximum impact and benefit, CEOS has agreed on the need for a top-down, coordinated ARD strategy.

The Analysis Ready Data Strategy for CEOS is based around four pillars:

1. CEOS ARD User Needs & Specifications
2. Assured Production and Access
3. Pilots and Feedback
4. Communication & Promotion

This Strategy aims to escalate, elevate and encourage the accomplishment of ongoing and resourced pieces of CEOS work through coordination under a collective banner.

The CEOS Analysis Ready Data Strategy is available online [here](#).

4 Private Sector Interest, Activities, and Roles

Private sector interest in Analysis Ready Data, and in CEOS work on CARD4L, has been growing since at least 2018, with private sector engagement in various workshops and conferences.

Strong interest from industry is indicated by their proactive approach to organising two events in North America focussed entirely on the idea of analysis ready data, viz:

- **Mid-2018:** Planet, supported by USGS, convened a workshop in Menlo Park, California.
- **July 2019 (ARD-19):** Planet and other companies convened a second workshop, again supported by USGS.

Private sector interest comes from multiple directions, including companies that operate high resolution satellites, companies that host data, and software vendors. The open data / informatics community, which is a general collaboration involving industry, government, non-government and academia, is also directly relevant to CEOS ARD because it is developing the current and next generation data formats and computational environments.

4.1 Satellite Operators

Commercial satellite operators are seeking to produce calibrated time-series of data that enable high spatial and temporal resolution monitoring of various areas of interest. Government satellite

programs provide the ‘gold standard’ and a scientific reference point. Products that are consistent with CARD products produced by CEOS Agencies will be regarded as trustworthy and will be more readily accepted by users familiar with those longer-standing programs. If CEOS ARD specifications are available to commercial operators they could independently produce data that meet or exceed those specifications.

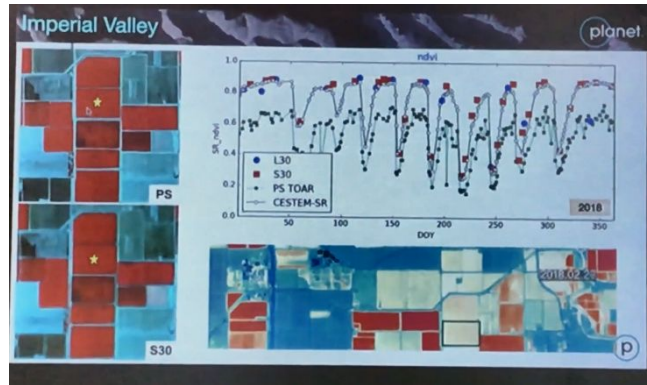


Figure 1. A photograph of a presentation during ARD19, July 2019, showing how Planet are able to correct their data to match surface reflectance from Landsat and Sentinel-2, giving daily high resolution updates. ESA and USGS are providing trusted and accepted government data sources. Consistency with these increases trust in the commercial products.

4.2 Data Hosts

Data hosts, including cloud providers, benefit from hosting Landsat, Sentinel and other collections of EO data that are in demand by a broad segment of users. The more ready-to use the data, the better the return on investment for the data host. The interests of data hosts include knowing that the datasets are from an authoritative and sustained source such as the actual data producer, and also that the data are co-located with complimentary data types so that users can look to the host to provide access to multiple sources of interoperable data.

4.3 Software Providers

Providers of remote sensing software also have an interest in CEOS ARD. Systems or services that can correct a variety of Level-0 data streams to CEOS ARD specifications could enable new data sources to be applied more quickly, and historic archives (e.g., SPOT archive data over Southern Africa) to be unlocked as part of the international time-series of Earth observations. Some industry players appear to be specialising in this area.

4.4 Value-add Sector

The value-add sector is a growing industry and includes companies, organisations and individuals that develop applications based on EO imagery. This portion of the sector should greatly benefit from CEOS ARD and will have specific interests in datasets that are authoritative, continued and interoperable over time so that they can produce their value-added products efficiently and consistently.

Evidence of increased uptake by the value-add sector would point to the value of CEOS ARD, for example a preference for data processed to surface reflectance. Preferential uptake is already indicated by a rapid increase in the Archive Exploitation Ratio for Sentinel-2 L2A data, from 1:5 in 2017, to 1:10 in 2018, attributed to the ramp-up of L2A production over the year¹.

¹ 2018 Copernicus Sentinel Data Access Annual Report

5 The Importance of CEOS ARD as Industry Involvement Grows

The relationship between CEOS and the private sector in CARD is evolving. Various combinations of government and private capabilities are available, forming a complex ‘menu of possibilities’. In the table below each column represents a set of choices that are known to be progressing. The table is not exhaustive - other combinations are possible.

Scenario Processing Steps	A PALSAR Mosaics	B USGS Landsat	C GA	D DEAfrica	E PCI	F Planet	G UN	H Data Users
Observations are taken by:								
CEOS satellite	X	X	X	X	X			
Commercial satellite					X	X	X	
Processing algorithm is:								
CEOS Agency	X	X						
CEOS Agency other than sat. op.			X					
Open toolkit				X				
Commercial in confidence					X	X	X	
Processing is executed by:								
CEOS Agency	X	X	X					
Commercial company				X	X	X	X	
Third party, e.g. data users								X
Processing is funded by:								
CEOS Agency	X	X	X	X	X			
Commercial company				X		X		
Third party, e.g., UN							X	
Products are hosted by:								
CEOS Agency	X	X	X		X			
Commercial cloud for CEOS		X						
Commercial cloud				X				
Commercial operator						X	X	
Products are distributed as:								
Commercial services						X		
Free and open data	X	X	X	X				
Government data, not open					X		?	
Products are validated against:								
CEOS Agency data and systems	X	X	X	X	X	X		
Independent commercial						X	?	
Product specifications:								
CARD4L compliance intended	X	X	X	X				
Unknown					X	X	X	

Table 1. The scenarios from A – G represent differing involvement of the commercial sector. As the commercial sector provides more and more capabilities, the scenarios become more complex. A= PALSAR Mosiacs; B= USGS' production of Landsat Collections; C=Geoscience Australia production of surface reflectance products from Landsat and Sentinel-2; D=Digital Earth Africa 'fostering' CARD4L pipelines; E= indicative of the business model of PCI Geomatica; F= indicative of the business model of Planet; G = indicative of a hypothetical large data-buy by a group such as the UN, from a company like Planet.

As more 'production pathways' evolve, the value of a unifying CARD specification as an end point will also grow. CEOS has a unique opportunity to progress this to the wider community. Signs from industry are that they are supportive of the CEOS ARD approach, but feel disconnected from it and not empowered to engage.

6 Engagement with Industry on CARD4L

CEOS has sought to communicate its work on CARD4L through multiple outlets:

- Publishing materials on ceos.org/ard;
- Running sessions and presenting at multiple conferences (for example, Pecora 18, IGARSS, Big Data from Space conference), and publishing in conference proceedings;
- Participating in industry-led conferences including ARD18 and ARD19;
- Inviting industry participation in workshops and panels.

These efforts have been successful, however there is more to do.

6.1 Objectives and Outcomes in Engaging with the Private Sector

CEOS should have clear outcomes in mind when engaging more widely on CARD, including that:

- 1. Industry and CEOS efforts on Analysis Ready Data are coordinated**
- 2. Private sector companies produce products according to CEOS Analysis Ready Data Specifications**
- 3. Specifications are improved through the involvement of industry expertise and viewpoints**
- 4. Industry involvement increases the evidence base for the value of CEOS Analysis Ready Data**
- 5. Educational aspects to the industry involvement is coordinated and clear so there is a better understanding on how to communicate about CEOS ARD**

6.2 Benefits

There are several reasons why CEOS should engage with the private sector on CARD:

CEOS (and CEOS Agencies) must evolve with the private sector continuously evaluating its value proposition as commercial players become more active in providing high quality and operational EO services. Operational EO capabilities are evolving to be shared effort of government and private sector capabilities and assets. Government policy, rapid innovation in the private sector,

technological disruption in computing, storage, networks and space capabilities, and a growing non-government user base for EO products and services are all driving this change. CEOS ARD is an idea area for engagement between CEOS and the private sector.

Private sector players are key stakeholders in the development of CEOS ARD. Analysis Ready Data is a ‘non-procurement’ space in which CEOS can readily engage with private sector stakeholders with probity. Involving industry in the development of CEOS Analysis Ready Data will:

- increase the relevance, acceptance and quality of CEOS ARD Specifications, and avoid a situation where industry and government have different approaches to the same need. CEOS will benefit if industry adopt CARD specifications – industry products that meet or exceed CARD Specifications would be a ‘good news’ story for CEOS.
- benefit CEOS’ reputation as a forward-looking organisation; CEOS’ reputation and visibility will be enhanced through an inclusive approach on CEOS Analysis Ready Data.
- deliver better user experiences by encouraging an industry in which products are more interoperable with government capabilities;
- make clear the value proposition of CEOS Agencies’ imaging programs, doing the ‘heavy lifting’ to provide the data and information infrastructure that innovators can leverage, delivering more value to society;
- avoid duplication of effort as the private sector move in the same direction as CEOS ARD, and ensure that the private sector remains supportive of CEOS’ ARD work;
- ensure that industry benefits from, and does not feel disadvantaged by, the development of CEOS ARD;
- give CEOS greater access to experiences and insight that indicate the value of CEOS ARD. CEOS ARD Specifications and standards will benefit from the expertise and fresh perspectives of private sector experts who are already working at the leading edge. Industry players are already at the leading edge of imaging, interoperability and hosting of data. CEOS’ work will benefit from access to this expertise.

6.3 Challenges and Opportunities

- Despite CEOS’ efforts at outreach, private sector players remain disconnected from CEOS efforts. Proactive steps are needed to avoid divergence of effort by government and non-government interest on Analysis Ready Data. Outreach to the EARSC² in 2019 received a positive response, but there is not a sense of urgency from Europe. North American companies are pursuing ARD with urgency, but appear to be ambivalent about CEOS’ role, or unclear about it.
- As a priority, the concerns and wishes of industry players need to be better understood by CEOS. We must recognise that despite our efforts so far we have not successfully engaged with industry as a whole. This is not to deny the strong positive relationship that some CEOS agencies are building with some private sector players around the production, storage and distribution of analysis ready data.
- Initial feedback from industry suggests that there is strong interest in CEOS ARD, but limited resources to be involved. Matters of interest to the industry include:
 - Having access to government reference data and agreed protocols for validation, so that potential users of industry products are assured of the quality or comparability with government sources

² European Association of Remote Sensing Companies

- Being involved, with a ‘light touch’, in discussions around the development of specifications. For example, through telecons and email discussions that are not resource intensive, nevertheless containing a defined structure (e.g. follow-up material and results presented)
 - Processes that are clear, understood, and easy to use; for instance guidance on metadata, benchmarks that can be used as a reference and procedures, for instance the steps in self-assessment.
 - Understanding the forward trajectory of CEOS ARD, so that the private sector can identify its niche and value add, can avoid duplicating work that agencies are likely to do, and can understand their market opportunities.
 - Having access to methods and workflows (even if these are not open-source) so that the private sector can use them to analyse where they need to adjust their own processes to meet CARD specifications.
 - Focusing emphasis on the standards as they are and on peer reviewed methods and published work.
 - Having the CEOS community to set a clear CARD standards and lay down the rules for a competition (objective tests on quality and samples of ideal products to aspire to) so that the private sector can provide the best possible service to clients which ultimately will open market opportunities and stimulate competition and productivity.
- The Open Geospatial Consortium (OGC) is investigating Analysis Ready Data, at the request of an undisclosed patron. It is less than ideal for a standards organisation *to be exploring a standard ahead of the industry*, rather than to support, converge, and formalise approaches that industry itself has found to be relevant and effective.
 - Commercially produced data products will need to be assessed against the CARD Specifications. A new process will be needed to confirm CARD compliance – one that avoids conflicts of interest, retains probity and is manageable.

7 The way forward

Principles to guide the approach

A level playing field. A key principle for engagement with the private sector is that the engagement is impartial and open, providing equal opportunity for any industry player to engage - a ‘level playing field’.

Advancing CEOS’ mission. CEOS’ mission will involve increasing interaction with the private sector. Establishing mechanisms for constructive and appropriate engagement with the private sector *outside of procurements* is in CEOS’ greater interests. CARD is one such area.

CEOS has responsibility as a leader. CEOS (along with CEOS agencies) has a unique leadership role as the dominant provider of Earth observations globally, and as the peak expertise in the science and technology of Earth observation data. CEOS ARD is one example of this leadership.

Including all stakeholder groups. CEOS Analysis Ready Data strategies will not succeed in the long term unless all key stakeholders are engaged. Industry is a key stakeholder, and is moving quickly. The success of CEOS ARD Strategy rests on finding mechanisms to include industry in the process. CEOS should commit to finding those approaches.

- CEOS should avoid *unnecessary* barriers to participation (from industry) in the CARD discussion and processes; CEOS ARD has broad implications for the entire EO community and they should not be *unnecessarily* excluded. As a start point, documentation should be made freely available.
- CEOS ARD *processes* (such as assessing data products for compliance with Specifications) involve the time and effort of CEOS Agencies. Those processes are available at the discretion of CEOS Agencies to support the shared work of CEOS. However, there is no reason that a third party could not, for example, self-assess against the CEOS ARD framework.
- One approach is to rapidly seek to move CEOS concepts into the broader standards realm.

Recommended next steps

Share Information on CEOS Analysis Ready Data to build engagement support

1. Ensure that CEOS ARD Specifications and concepts continue to be publicly available and are promoted via the website and other means.
2. Add supplementary informative materials to the CEOS ARD website such as videos explaining the CARD framework and its elements as well as links to past presentations (papers, videos) in conferences and workshops.
3. Add a dedicated area on the CEOS ARD website for “Latest News on “CARD” where LSI-VC can update the community on achievements, PFS endorsements, participation in workshops, conferences, meetings etc

Understand the Industry Perspective

4. Continue to pursue a ‘light touch’ engagement approach with the private sector through teleconferences and emails – e.g. follow up call from the initial meeting will be scheduled to March 2020
5. Reach out to industry leaders to seek advice and ideas on the tactical approach:
 - Convene a workshop with industry in Europe in September 2020, publicised through the EARSC, to share the CEOS approach broadly with European industry players, gauge levels of interest, identify industry-based leaders and expertise, and identify expectations and concerns.
 - Proactively include the private sector in the Sep 2020 CEOS ARD workshop design and program development, so opportunities and expectations can be better understood and managed on both sides.

Engage Industry in Specifications

6. Invite nominations, through industry forums and workshops, of experts from private sector companies to participate in expert working groups on CEOS Product Family Specifications.

Move CEOS specifications into the broader community

7. Engage with standards processes as a priority, to provide profile to CEOS ARD, to support its independent formalisation and to ensure that there is universal access to specifications within the EO community.

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Appendix 1.

De-identified comments from discussions with industry, February 2020.

The reasons why the commercial sector has not been involved earlier are:

- CARD community has been building this concept within CEOS and getting the buy in within CEOS, and that has taken a couple of years,
- CEOS is an organisation of government agencies and to talk with private sector is not in its nature,
- CARD community has been trying to outreach the ARD concept through groups like Pecora, Living Planet, IGARSS and others by engaging and talking with people, but there is a lot to do in that spectrum.

The views and input from the private sector on how the CEOS CARD community should approach the broader community and the commercial sector are crucial for the success of CARD initiative.

NASA datasets are really important for the commercial sector. NASA operates systems that acquire daily global coverage measurements and that data should be the golden standards which uncertainties and errors can be assessed in the ARD products.

NASA is an active participant within the CEOS community. NASA products are an inspiration for what CARD community is currently envisaging for Landsat/sentinels products. Up until now, most of the CARD efforts have been on moderate resolution optical (e.g. Landsat and Sentinels) - previously agencies did not generate a physical measure of the surface for those like to what already happens with NASA datasets.

The specifications seem to have a focus on radiometry and surface reflectance. Pixel and alignment and accuracy are very important for end-users to be able to do multi-temporal analytics.

The specifications talk about pixel accuracy and deals with the alignment issue by looking at a certain level of accuracy in the pixels (Reference Item 4.1, Geometric Correction Threshold requirement in both the SR and ST PFS documents).

Calibration and validation sites are available in different locations, latitudes, terrains and surface types, therefore it would be useful for the commercial sector to get access to this data to validate products.

Further information on free and open calibration/validation data is found in <http://calvalportal.ceos.org/calvalsites>.

CARD self-assessment process is done by the data provider (not by customers) and peer-reviewed by another group (that is the CEOS model). However there isn't a formal process yet for the private sector.

It is very important to have a say on experimental designs and how industry can measure and validate their products against it. That would give industry a benchmark to market their algorithms and products.

Product Family Specifications do not look into algorithms, and do not prescribe algorithms or methods to be used. It may be an advantage for private industry to comply with CARD4L specification when it comes down to tender applications.

The work the CEOS community has been doing in CARD4L is very important, however it is very central to have validation samples - The Sentinel Hub for instance may produce CARD products, but there aren't any CARD samples to be comparing Sentinel Hub products to.

In parallel with validation samples it is important to have a clear definition of the process on how to get from raw data to validation samples. And with software processes the only deterministic description is source code, which should be open-source so that others can analyse and compare the steps done in the process.

It is imperative that the CARD products are useful to end-users.

CARD community is planning to make available the self-assessed products from agencies e.g. USGS has provided data samples during the peer-review process – samples will be publicly available on the CEOS ARD webpage.

CARD4L specifications are algorithm and processing systems agnostic - It is really about the measurements and meeting what is defined in the specifications - The Product Family Specifications are about what should be done not how it should be done.

Issues to refer to any benchmarks/examples for the Target compliance since the Target level hasn't been reached by agencies yet.

Industry is aware about the discussions on CEOS ARD but they also are seeking clarity of government road-maps. If the commercial sector is aware of the trajectory then they can understand their market opportunities.

Emphasis should be on the standards as they are and on peer reviewed methods and published work. This does not however mean that the secret sauce needs to be entirely public.

To have the CEOS community setting clear standards (CARD) and lay down the rules for competition (objective tests on quality and samples of ideal products to aspire to) so that the private sector can provide the best possible service to clients which ultimately will open market opportunities and stimulate competition and productivity.

The expectation is that the European industry will get actively involved in the CEOS ARD workshop including EARSC:

- Documentation should be provided before the workshop so everyone can be on the same page and provide concrete comments – It is very important that industry attend the workshop prepared and comes out with a tangible way forward, not just ideas.
- Reference datasets are very important – customers want to know if it works. So, it will be important to have topics covering reference datasets and validation on the workshop agenda.
- Design of the experiments (e.g. design tests to validate products against the specifications) is important and should be considered as a topic in the agenda – e.g. how to make data compatible to one another, how to do spectral or geometric resampling etc. Interoperability (Landsat-Sentinel) should be part of the agenda.
- The first step towards data interoperability is CARD, but it is not the whole picture. The CARD community has not been that far yet, and it may take a while for the community to

get there.