

Consultation Paper and Concept Note

The Future of CEOS-ARD

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Taking CEOS Analysis Ready Data to the Next Level

The Future of CEOS-ARD – Consultation Paper and Concept Note

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1: Introduction

CEOS Analysis Ready Data (CEOS-ARD) caused a significant and positive paradigm shift in the Earth observation community, further democratizing Earth observation by making data more transparent and easy to use, while also setting a foundation for improved interoperability.

CEOS-ARD mandates a minimum level of pre-processing, metadata, and documentation that allow users to acquire and use data with a minimum of additional user effort. CEOS-ARD has set a critical benchmark for non-CEOS data providers and has encouraged a more thoughtful approach to data provision – ensuring non-experts can benefit alongside the scientific community.

The Earth observation sector has significantly matured since CEOS-ARD was first conceptualised, with major technological trends – particularly in AI/ML and cloud-native approaches – shaping the expectations of users. Furthermore, as dataset offerings continue to grow, demands for increased interoperability are necessitating renewed focus on the bounds of what can be called ‘analysis-ready’.

We recognise the need for CEOS-ARD to evolve and introduce new requirements and considerations to ensure CEOS-ARD remains consistent and relevant to the evolving user needs base and their expectations. In short, this paper seeks to answer: *What opportunities exist to improve CEOS-ARD, and how can we make CEOS-ARD more effective and impactful?*

2: Approach

The CEOS-ARD Oversight Group is tasked with maintaining a high-level strategy for CEOS-ARD development, which is to be updated every two years. Throughout 2025 we have undertaken a comprehensive community engagement campaign to connect with satellite data producers and users – particularly those outside of CEOS – to help us understand exactly how CEOS-ARD needs to evolve. This campaign included presence at key events such as ESA’s Living Planet Symposium (LPS), the International Geoscience and Remote Sensing Symposium (IGARSS), and the International Astronautical Congress (IAC); and a survey to gather feedback to “*Help Shape the Future of CEOS-ARD*”.

The CEOS-ARD Oversight Groups’ findings are presented in this paper for consideration at the 2025 CEOS Plenary to:

1. *Articulate a clear vision of what the future of CEOS-ARD should look like, as defined by the community.*
2. *Demonstrate the benefits and necessity of this vision by incorporating perspectives from data providers, end users, data procurers, and other stakeholders.*
3. *Seek CEOS Principal approval to develop the CEOS-ARD Strategy 2026 (for endorsement at CEOS Plenary 2026), which will define the actions, resources, and commitments required to deliver this next level of ambition.*

The CEOS-ARD Strategy 2026 will be developed throughout 2026 by the CEOS-ARD Oversight Group in collaboration with various CEOS entities and in consultation with external stakeholders. An initial outline would be presented at SIT-41, with a near complete draft then prepared for discussion at SIT Technical Workshop 2026, ahead of presentation for endorsement at CEOS Plenary 2026.

3: Community Consultation

2025 has been a pivotal year for community and commercial sector engagement in CEOS-ARD. Strong presences at ESA's Living Planet Symposium and IGARSS, as well as further connections with the commercial sector at LSI-VC meetings have gone a long way to increasing the reach of CEOS-ARD.

We will continue working to invite the commercial sector, non-traditional users, and global data providers into the shared, open, and trustworthy ecosystem of CEOS-ARD. The commercial sector is keen to engage and learn from CEOS agencies and we have active engagements with EarthDaily, OroraTech, Planet, SatVu, Constellr, Aistech Space, Marble Imaging AG, SatSure, Catalyst, Synspective, Esri, Hyspace, SkyServe, Pixxel, SatSure, Synspective, and more.

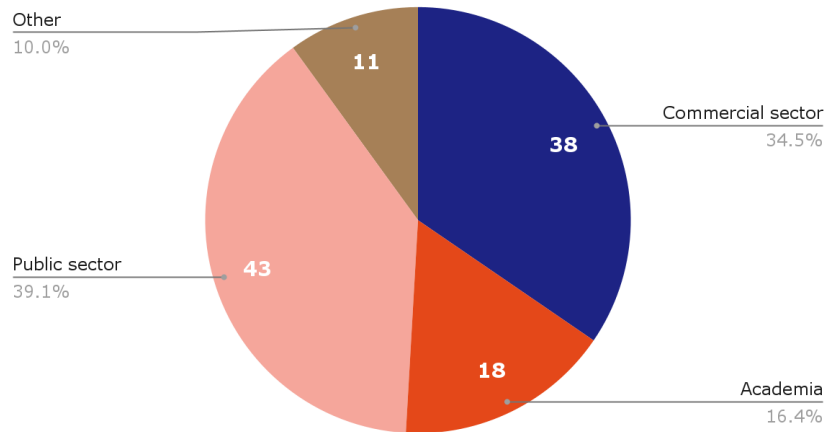
To understand the evolving user base and technological landscape, a survey was undertaken in 2025 to gather feedback on a number of questions. Participants were asked:

- Core questions and tailored questions for data producers, users, distributors;
- Thoughts on characteristics needed to make an EO dataset 'Analysis Ready';
- What they value most in the CEOS-ARD Framework and what should be prioritised for future development;
- Whether they see a need for formal EO ARD standards or whether a 'community standard' approach like CEOS-ARD is sufficient;
- What makes an EO dataset 'AI/ML ready';
- To identify any barriers to use of the CEOS-ARD Framework / products;
- Specific datasets they would like to see assessed and endorsed as CEOS-ARD;
- Thoughts on opportunities to accelerate the uptake and impact of CEOS-ARD;
- About their CEOS-ARD self-assessment plans.

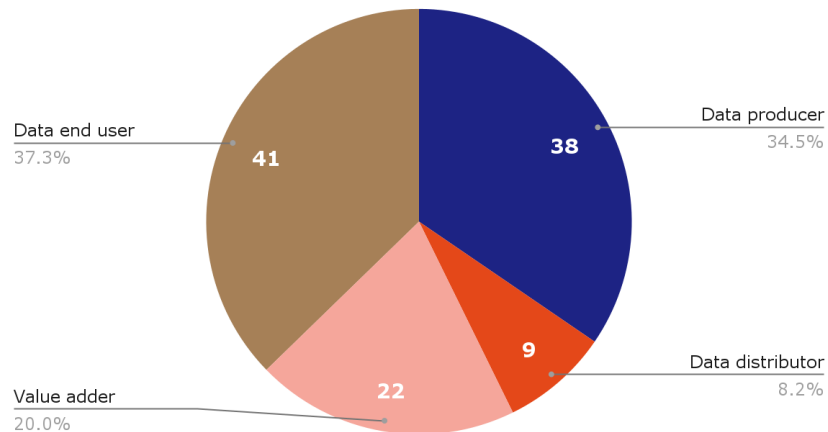
The survey was distributed widely across all sectors of the Earth observation community and to date over **110 responses** have been received. These responses have been critical inputs for this consultation paper and concept note to inform the development of the future CEOS-ARD Strategy. A summary of the feedback gathered through the survey is provided in Appendix B. In addition to inputs and survey responses from CEOS agencies, LSI-VC members, the CEOS-ARD Oversight Group, WGISS, and WGCV, the survey received responses from the following companies and organisations (sometimes multiple responses from different people):

Commercial	Other
Airbus Defence and Space GmbH AISTECH SPACE, S.L. Arlula Pty Ltd Auspatious CATALYST (PCI Geomatics) Common Space Constellr EarthDaily ENVEO IT GmbH EOIntelligence Esri First Street GeoInsight GRASP Earth Marble Imaging AG Pixalytics Ltd Pixxel Planet Labs Riscognition GmbH Sarmap SA SatSure India Analytics Pvt Ltd SatVu Sparkgeo SpectralEO Telespazio UK USACE-AGC World from Space	Aberystwyth University Anna University Conicet Curtin University Kasetsart University KTH Royal Institute of Technology Landgate Natural Resources Canada OGC STFC Trier University UK Met Office UK Ordnance Survey Univ. Colorado, Boulder University of Maryland University of Tartu University of the Free State University of Venda

Sector



Role



The survey will remain open for the duration of 2026 to capture any changes in perspective from 2025 to 2026. Engagement will be continued at upcoming events such as VH-RODA in December 2025 and JACIE in early 2026, where a dedicated CEOS-ARD session is being considered.

4: Topics that a Future CEOS-ARD Strategy Should Consider

These categories aim to address the main feedback from the community survey as well as inputs from discussions at consultation events and with other CEOS entities and specialists.

List of high-level categories:

- Consistent and Enhanced Metadata Specifications
- Data and Metadata Quality
- Ongoing Quality Assurance and Integrity Monitoring
- Fitness for Purpose
- Increased Support to Scientific Applications and Environmental Adaptation and Resilience
- Solidifying the Business Case and Increasing Commercial Relevance
- Tools to Aid Compliance Assessments and Peer Reviews
- Supporting Opportunities and Reducing Risks Related to AI / ML
- Measurand Consistency and Algorithm / Application Resilience
- Alignment with the Software Ecosystem
- Analysis Ready Data Standards
- Thematic and Higher-level ARD Products
- Training and Outreach
- Capturing Use and Impact

1: Consistent and Enhanced Metadata Specifications

Issues:

- Unlike the Combined SAR PFS which has a counterpart metadata specification that dictates a common format for metadata, there is no counterpart for the optical PFS specifications, leading to highly variable metadata for optical products making use and CEOS-ARD assessment more difficult.
- CEOS-ARD metadata specifications are not fully aligned with leading metadata specifications like STAC.
- Metadata requirements for CEOS-ARD have evolved over the years, however, these updates have not been made consistently across all of the Product Family Specifications (PFS) leading to inconsistency and potential for confusion.

Risks:

- Inconsistency in CEOS-ARD product metadata formats makes uptake and assessment more difficult and leads to confusion.
- Complex and variable metadata formats undermine the 'analysis-readiness' of datasets.
- CEOS-ARD metadata requirements may be superseded by OGC or ISO implementations.

Opportunities:

- Bring all metadata requirements up to date and align requirements across all PFS.
- Update PFS metadata requirements to address feedback regarding the need for more information on uncertainty, data provenance, and spectral response functions to be provided.
- Ease uptake of CEOS-ARD by aligning metadata specs with STAC to the maximum degree possible.
- Engage with OGC as a community-based, international standards entity.

CEOS Dependencies:

- Must convene a team of subject matter experts to propose a consistent metadata specification to the CEOS-ARD Oversight Group for formal adoption across all of the optical PFSs. This will primarily require input from LSI-VC and OCR-VC as custodians of the existing optical specifications.

2: Data and Metadata Quality

Issues:

- CEOS-ARD peer reviews have shown that while datasets might satisfy all of the reporting requirements regarding pre-processing, inclusion of specific metadata, documentation, etc., there are no quantitative bounds placed on the 'quality' of these characteristics.
- Poor quality of the measurand (i.e., its accuracy / uncertainty); accuracy of the supplied ancillary information (e.g., flags / masks); or low quality supporting documentation and external references all affect the 'analysis-readiness' of a dataset.

Risks:

- A dataset that has some sort of quality ‘deficiency’ will not meet the original intent of analysis-ready data, that is, to make data easier to use. If a user has to work around data quality issues, this is not making their life easier. Low ‘quality’ CEOS-ARD risks the reputation of the CEOS-ARD brand and undermines the goal of lowering barriers to effective utilisation of EO.

Opportunities:

- ‘High quality’ (definition to be subject to further discussion) CEOS-ARD will build trust and protect the reputation of the satellite Earth observation community in the eyes of stakeholders.
- For data providers, compliance with the evolved CEOS-ARD will demonstrate and imply a high level of ‘quality’.

CEOS Dependencies:

- WGCV; cal/val networks such as RadCalNet, SARCalNet, Hypernets, TIRCalNet; WGCV Maturity Matrix; Quality Factor of the CEOS Interoperability Handbook v2.0.
- WGISS: for discussions regarding the trade-off between quality information and file size (e.g., pixel-level quality information may increase file size too much unless links to external information are used).
- Joint ESA-NASA Quality Assessment Framework. Engagement of the ESA Earthnet Data Assessment Pilot (EDAP) and NASA Commercial Satellite Data Acquisition (CSDA) teams.

3: Ongoing Quality Assurance and Integrity Monitoring

Issues:

- CEOS-ARD assessments only require a single data sample with submission of the completed self-assessment package. There are no provisions in the framework for periodic/continuous monitoring of dataset compliance; ongoing monitoring of data quality; or loss of CEOS-ARD compliance due to degradation of data / metadata quality.
- Data provenance / chain of custody is not a part of the CEOS-ARD Framework.

Risks:

- With no ongoing monitoring of data or metadata, trust is reliant on satellite data providers ensuring their data continues to conform to the relevant CEOS-ARD standard.
- Identifying non-compliant data as CEOS-ARD undermines the framework and trust of the community.
- Datasets are often mirrored in multiple locations and hosted by a number of parties. Without having data provenance / chain of custody a central part of the CEOS-ARD Framework it is difficult to ensure the integrity of a dataset’s CEOS-ARD compliance.

Opportunities:

- Establishing mechanisms to assess data quality and integrity is essential for assuring users of the enduring quality of CEOS-ARD datasets and, in the event that quality degrades over time, to quantify trends in performance.
- A requirement to actively monitor and calibrate datasets, including verifying stated instrument performance and spectral response functions would be seen as a benefit of CEOS-ARD. By

achieving compliance with an evolved CEOS-ARD specification, suppliers could demonstrate their commitment to quality, providing a point of differentiation and competitive advantage for their products. Guidance should state the appropriate frequency of continuous calibration to align with particular targets.

- Clarify the propagation of uncertainties/errors in environmental descriptors derived from CEOS-ARD, i.e., how do reflectance errors propagate into retrieval algorithms and impact downstream products.
- Coordinate validation activities with publicly available missions to ensure comparability and reliability.

CEOS Dependencies:

- WGCV; cal/val networks such as RadCalNet, SARCalNet, Hypernets, TIRCalNet; WGCV Maturity Matrix; Quality Factor of the CEOS Interoperability Handbook v2.0; WGCV Product Validation Platform.
- CEOS Missions, Instruments, and Measurements (MIM) database as a central and authoritative record of missions and instruments.
- WGISS support on data provenance / chain of custody solutions.

4: Fitness for Purpose

Issues:

- CEOS-ARD might not provide enough information to guide non-expert users on the suitability of products for specific purposes.

Risk:

- CEOS-ARD aims to support non-experts and new users of EO. However, the current CEOS-ARD assessment levels of “Threshold” and “Goal” provide limited guidance on which datasets are suitable for specific tasks.
- Without some way of classifying the suitability of datasets for specific purposes, non-expert users might be misled by the capabilities of a particular CEOS-ARD dataset.

Opportunities:

- Adding more specificity regarding the assessment levels or introducing fitness for purpose metrics as a specific metadata requirement could help categorise datasets and better support users.
- Aid data providers in understanding the requirements of specific use cases and enable them to set goals for improvement.
- Provide clarity to data providers on how they can develop datasets towards higher levels of fitness for purpose / support specific applications.
- Improve transparency, inform user choices, drive improvements (through incentive to reach higher levels of fitness for purpose)
- Provide a means to distinguish high-stability, science-grade observations from observations that are, e.g., only suitable for visual analysis, while still encouraging data providers to uphold the

other principles of CEOS-ARD around metadata completeness, pre-processing, and documentation.

CEOS Dependencies:

- Application requirements and understanding the physical meaning of measurements will require expertise from various application-focused groups across CEOS, such as the agriculture (GEOGLAM) subgroup of LSI-VC, the forests and biomass subgroup of LSI-VC, the Biodiversity Study Team, WGDisasters, WGCapD, COAST-VC, OCR-VC.
- WGCV and teams such as the Land Product Validation (LPV) subgroup.
- Quality Factor of the CEOS Interoperability Handbook v2.0.

5: Increased Support to Scientific Applications and Environmental Adaptation and Resilience

Issues:

- CEOS-ARD doesn't include requirements for dataset stability (that is, the change in bias over time – quoted per decade).

Risks:

- Without explicit requirements for stability and bias correction CEOS-ARD may be excluding a significant base of scientific and other users that rely upon such metrics.
- Stability should only be a “Goal” level requirement / covered by fitness for purpose metrics to ensure that new (i.e., those without decadal-scale datasets) or less advanced data providers are not disadvantaged or prevented from CEOS-ARD compliance.

Opportunities:

- CEOS-ARD mandating documentation of long-term accuracy and stability would facilitate, for example, the generation of bias-corrected long-term records for moderate resolution optical and SAR data for use in adaptation and resilience (note: many frameworks use 1990 as a baseline year).
- Support the Global Goal on Adaptation.

CEOS Dependencies:

- WGCV.
- 2026 CEOS Chair and 2026-27 SIT Chair priorities on adaptation and resilience.

6: Solidifying the Business Case and Increasing Commercial Relevance

Issues:

- “Unclear benefits or added value” was identified by 20% of the data providers that responded to our survey question regarding barriers to uptake of CEOS-ARD.
- The commercial business case for investment in CEOS-ARD needs to be made clearer and stated more explicitly.
- Product Family Specifications must be adapted for very-high-resolution data, accommodate constellations and mosaic/composite products, and consider other realities of commercial sector platforms (e.g., availability of ATBDs and other proprietary information).

- Open, high-resolution DEMs need to be available to support the provision of CEOS-ARD products like radiometrically terrain corrected SAR.
- Some CEOS-ARD requirements require disclosure of proprietary information such as sensor calibration details and Algorithm Theoretical Basis Documents (ATBDs), and this is often not possible/desirable for commercial providers. Likewise, sharing of auxiliary data sources obtained commercially can be troublesome.

Risks:

- Without a clear business case and technical updates to accommodate the realities of the commercial sector, uptake will be impacted and we will not realise the potential of a rich and diverse ecosystem of CEOS-ARD across both the public and private sectors.

Opportunities:

- For commercial satellite vendors, CEOS-ARD endorsement represents more than a technical validation, it is a market differentiator that enhances customer trust, accelerates adoption, and strengthens alignment with international best practices. Achieving CEOS-ARD endorsement signals to governments, research institutions, and private-sector customers that commercial vendor products meet the highest standards for usability, interoperability, and reliability. This endorsement could lead to new partnerships, markets, and revenue streams while reducing barriers to user adoption.
- If CEOS-ARD could be positioned as a baseline for agency/country commercial data procurement, CEOS has the opportunity to avoid duplication of effort in data assessment and incentivise CEOS-ARD assessments and participation by the commercial sector. CEOS-ARD can help agencies across the public sector de-risk commercial data procurement by providing a consistent benchmark for quality and interoperability. For commercial providers, future CEOS-ARD offers a clearer path to market by aligning with recognised, credible standards.
- Further commercial uptake of CEOS-ARD will raise sector practices and ambitions around data quality, cal/val, etc.
- Increased alignment of CEOS-ARD requirements and those of the intelligence community (a major purchaser of commercial EO data) could drive uptake of CEOS-ARD and ultimately increase the number of CEOS-ARD datasets available for societal benefit.
- In response to the survey, commercial providers suggested there might be potential to increase interoperability by being more prescriptive in certain areas without undermining the core principles of CEOS-ARD.
- Engage the commercial sector in the process to define Product Family Specifications. Co-development will bring in new perspectives and make the specifications more robust and relevant.

CEOS Dependencies:

- Connections to the Joint ESA-NASA Quality Assessment Framework.
- Engagement of the ESA Earthnet Data Assessment Pilot (EDAP) and NASA Commercial Satellite Data Acquisition (CSDA) teams.
- Copernicus Contributing Missions and the Mission Performance Clusters.

- CEOS Agency support to engage the JACIE and VH-RODA communities.
- Commercial sector participation in CEOS Working Group and Virtual Constellation meetings.

7: Tools to Aid Compliance Assessments and Peer Reviews

Issues:

- Self-assessments and peer reviews are manual and time consuming for data providers and the WGCV peer review team.
- Self-assessments are built on a very basic manual completion of a Word/PDF form.
- When data providers encounter issues with a particular PFS requirement their only means of resolution is a time intensive scheduled discussion with CEOS-ARD experts, and the appropriate point of contact is not always clear.
- In survey responses, fifty percent of data providers highlighted “automated validation tools” as a means to increase uptake of CEOS-ARD.

Risks:

- The current model of self-assessments and peer reviews does not scale in line with the ambition of the CEOS-ARD initiative to capture a significant portion of Earth observation data providers.
- A high volume of submissions could overwhelm the WGCV peer review team, leading to delays in assessments and discouraging data providers from participating.
- Data providers might deem the process too time intensive to invest.

Opportunities:

- Streamline and introduce a degree of automation for self-assessments and peer reviews.
- Elimination of manual checks of metadata compliance.
- Make the assessment process more self-sufficient, easier to scale, and increase uptake by data providers.
- Provide automated tools, web forms, and more information on requirements (e.g., examples, documentation).

CEOS Dependencies:

- CEOS-ARD GitHub.
- WGCV peer review team support.
- WGISS / agency software developers.

8: Supporting Opportunities and Reducing Risks Related to AI / ML

Issues:

- AI/ML Earth observation models risk being compromised by poor quality input data.
- CEOS-ARD must evolve to meet emerging AI/ML needs to maintain relevance.

Risks:

- Risk to the reputation of the EO sector if AI/ML models are producing inaccurate results due to their use of poor quality input data.

- Stakeholders are uninformed on the importance of high-quality, science-grade EO missions and instruments in the AI/ML era and overly rely on models to correct / compensate for deficiencies.

Opportunities:

- Position CEOS-ARD as a trusted foundational reference for AI/ML applications.
- CEOS-ARD datasets recognised as the 'gold-standard' training data for Geospatial Foundation Models (GFM) and other AI/ML applications (owing to their quality and inclusion of robust provenance and traceability metadata, among other things).
- Ensure there is a broad collection of trusted data available for training AI/ML models and to demonstrate how data should be prepared to ensure robust AI/ML applications.
- Increase trust in AI/ML applications built on CEOS-ARD through inclusion of sufficient traceability and provenance information.
- Demonstrate the importance and relevance of CEOS Agencies in upholding quality and accuracy of EO data.

CEOS Dependencies:

- WGISS / Technology Exploration Interest Group (TEIG).

9: Measurand Consistency and Algorithm / Application Resilience

Issues:

- CEOS-ARD tolerates different approaches for deriving the measurand, meaning that while two different datasets might both be classified as, e.g., Surface Reflectance CEOS-ARD, this doesn't mean they are inherently consistent / comparable. Furthermore, this impacts the ability to harmonise multi-sensor products, limiting utility for applications requiring time-series data from several sources.

Risks:

- Inconsistency in similar products from different providers limits multi-source applications of CEOS-ARD.

Opportunities:

- For like-products, having CEOS-ARD compliant datasets be sufficiently interchangeable will improve redundancy in source data and confidence in data supply availability, promoting operational uptake.
- Measurand consistency will promote applications that are more resilient to changes in input data supply.
- Planned major archive collection upgrades provide an opportunity for changes to be made in support of improved alignment and harmonisation of families of products.

CEOS Dependencies:

- Surface Reflectance Consistency project under WGCV.
- WGISS Interoperability Handbook v2.0.
- ESA's "interoperability by design" effort.

10: Alignment with the Software Ecosystem

Issues:

- Survey participants identified lack of tooling support and standardised metadata as primary barriers.
- The CEOS-ARD SAR XML metadata specification is commonly provided for CEOS-ARD SAR products, but it is not widely supported by software implementations.

Risks:

- Uptake of CEOS-ARD will be limited if CEOS-ARD metadata and data are not readily interpreted by widely used software tools.
- Extending the SAR XML specification to optical PFSs may prove ineffective and create lock-in, potentially reducing the overall utility of CEOS-ARD products.
- Providing data in niche file formats creates barriers to adoption. Likewise, distributing data in archive formats (e.g., ZIP) or in non-cloud-optimized formats limits accessibility and performance.
- When common software (e.g., GDAL, QGIS, ArcGIS) and libraries (e.g., *xarray* in Python) lack support for CEOS-ARD products, users are unlikely to perceive the data as truly 'analysis-ready'.

Opportunities:

- There is an opportunity to map CEOS-ARD requirements to widely adopted metadata standards such as the SpatioTemporal Asset Catalog (STAC) and/or ISO 19115. The SAR XML metadata specification could continue to exist for specialized use cases or for information not yet supported in other standards. For example, while STAC cannot currently capture all elements required for compliance with the Combined SAR PFS, it can reference CEOS-ARD XML files as supplementary resources. This unlocks compatibility with a broad software ecosystem for many use cases, but gives flexibility for other use cases to make use of the complete CEOS-ARD XML metadata.
- Encourage space agencies to consider publishing data in cloud-optimized formats that align with best practices from the Cloud-Native Geospatial (CNG) community and are natively supported by widely used GIS software and programming libraries (many of which rely on GDAL).

CEOS Dependencies:

- The existence of metadata mappings to the CEOS-ARD requirements in a machine-readable way. This could be achieved using/providing XPath mappings and XSD schemas for XML-encoded metadata, and/or JSON Path/Pointer mappings and JSON Schema for JSON-encoded metadata.

11: Analysis Ready Data Standards

Issue:

- 37.5% of survey respondents said that formal standards for ARD are a necessity.
- The concept of ARD is rapidly evolving to account for technological developments and is not suited for a formal standard at this point in time .

Risks:

- Without a clear strategy for CEOS-ARD to become a stable, standardisable framework, the field is left open for others to define and occupy this space.
- However, too short a timeline will lead to a rushed standard that is not fit for purpose and increases confusion in the community.

Opportunities:

- Begin work towards an open, flexible, community standard built upon CEOS-ARD as a basis, which is crucial to allowing agile development on an unrestricted timeline which can be reintroduced to the standardisation process after it has been iteratively improved, implemented, and has seen adoption by real-world user communities and data providers.
- A clear roadmap for the evolution of CEOS-ARD from a community standard to a formal standard will reassure the community that investing in the development of CEOS-ARD is a worthy investment.
- Achieve broad community involvement in CEOS-ARD such that it becomes the *de facto* community standard for satellite-based Earth observation analysis-ready data.

CEOS Dependencies:

- CEOS-ARD Oversight Group engagement with OGC/ISO
- CEOS agency commitment and engagement with national standards bodies to ensure sufficient representation of CEOS-ARD positions in formal standards voting procedures.

12: Thematic and Higher-level CEOS-ARD Products

Issues:

- Users and frameworks such as the Essential Agriculture Variables (EAVs) and Essential Biodiversity Variables (EBVs) are looking for CEOS-ARD to include Product Family Specifications for higher-level products, beyond the Level 2 specifications (e.g., surface reflectance) currently targeted by CEOS-ARD.

Risks:

- CEOS-ARD is not addressing the needs of end-user communities, limiting uptake and impact.
- Going too far down the value chain.

Opportunities:

- Extending the CEOS-ARD Framework to accommodate higher-level products would provide scope to increase support to other CEOS priorities like agriculture and biodiversity.
- Build relationships with communities using CEOS-ARD products – application-focused groups like GEO-LDN, GEO BON, and GEOGLAM, etc. They provide a mechanism to engage with users of CEOS-ARD for user needs elicitation and product refinement.
- Facilitate discussion between CEOS agencies on delivering and harmonising higher-level products.
- Formalise a robust typology / product level characterisation, which will support discussions on standardisation.
- Specification for atmospheric products (e.g., ozone, NO₂, SO₂, methane, etc.)

CEOS Dependencies:

- CEOS Agriculture, Forestry and Other Land Use (AFOLU) Roadmap Team (including Ramsar Convention connections through ESA and JAXA).
- LSI-GEOGLAM Subgroup (Essential Agriculture Variables).
- Biodiversity Study Team (connections to GEO BON, UN SEEA, Global Biodiversity Framework, GEO-LDN, etc.).
- CEOS Agency operational platforms like the European Commission's Copernicus Land Service.

13: Training and Outreach

Issues:

- "Lack of awareness" and "need for training" were highlighted by survey respondents as key reasons for not engaging with CEOS-ARD to date.

Risks:

- By not providing the necessary support we risk limiting the uptake of CEOS-ARD.

Opportunities:

- The top opportunity to increase adoption of CEOS-ARD identified by both users and data providers was training and outreach.
- Provide support on the use of CEOS-ARD compliant products, including guidance on how to access and download data.
- Engage new regions with multilingual documentation and metadata.
- Support data providers with the development of compliant metadata, pre-processing approaches, and completing self-assessments.
- Leverage existing CEOS agency efforts (e.g., pilot activities) and incorporate CEOS-ARD as a way to connect with and train users.

CEOS Dependencies:

- WGCapD support for training events, online courses, connections to end users, etc.
- Application-focused groups across CEOS, such as the agriculture (GEOGLAM) subgroup of LSI-VC, the forests and biomass subgroup of LSI-VC, the Biodiversity Study Team, WGDisasters and its Pilot activities, COAST-VC, etc.
- CEOS Agencies to facilitate workshops / integrate CEOS-ARD into existing training and outreach events.

14: Capturing Use and Impact

Issue:

- To date, examples of the impact of CEOS-ARD have not been well captured or compiled.

Risk:

- Without additional examples like those from the Global Mangrove Watch (see slide 3 [here](#)) and Digital Earth Africa ([source](#)) we are not capturing and communicating the true value of CEOS-ARD.

Opportunities:

- Compile a concrete set of examples to present to CEOS Principals and others that demonstrate how being CEOS-ARD compliant adds substantial value to end users and data providers.
- Grow the ceos.org/ard/impact case study website.
- Present a strong body of evidence for continued investment in CEOS-ARD.
- Strengthen the business case for the commercial sector.

CEOS Dependencies:

- CEOS SEO support on comms and CEOS website maintenance
- Application examples from application-focused groups across CEOS, such as the agriculture (GEOGLAM) subgroup of LSI-VC, the forests and biomass subgroup of LSI-VC, the Biodiversity Study Team, WGDIsasters and its Pilot activities, WGCapD, COAST-VC, etc.

5: Conclusion

This consultation paper captures the voices of the Earth observation community across governments, research institutions, commercial satellite vendors, and the private sector and highlights both the opportunities and the risks ahead. The findings presented here provide a foundation for the development of the CEOS-ARD Strategy 2026, which will define the vision, resources, and actions required to take CEOS-ARD to the next level.

By addressing gaps in metadata, quality, monitoring, standards, and commercial engagement, while strengthening links to science, resilience, and AI/ML, CEOS-ARD can continue to set the benchmark for analysis-ready data worldwide. With CEOS Agency commitment and broad community collaboration, the future CEOS-ARD will not only maintain its relevance but also expand its role as a trusted, global reference for high-quality, interoperable Earth observation data.

Appendix A: Author Team and Contributors

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With substantial inputs from the CEOS-ARD Oversight Group, the Land Surface Imaging Virtual Constellation (LSI-VC), and the Working Group on Calibration and Validation (WGCV).

Appendix B: High Level Summary of Survey Responses and Main Themes

To understand the evolving user base and technological landscape, a survey was undertaken in 2025 to gather feedback on a number of questions. Participants were asked:

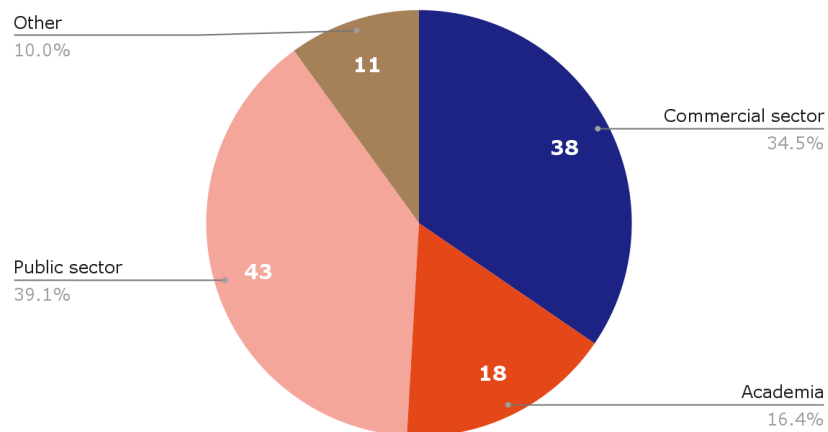
- Core questions and tailored questions for data producers, users, distributors;
- Thoughts on characteristics needed to make an EO dataset 'Analysis Ready';
- What they value most in the CEOS-ARD Framework and what should be prioritised for future development;
- Whether they see a need for formal EO ARD standards or whether a 'community standard' approach like CEOS-ARD is sufficient;
- What makes an EO dataset 'AI/ML ready';
- To identify any barriers to use of the CEOS-ARD Framework / products;
- Specific datasets they would like to see assessed and endorsed as CEOS-ARD;
- Thoughts on opportunities to accelerate the uptake and impact of CEOS-ARD;
- About their CEOS-ARD self-assessment plans.

The survey was distributed widely across all sectors of the Earth observation community and to date over **110 responses** have been received. These responses have been critical inputs for this consultation paper and concept note to inform the development of the future CEOS-ARD Strategy. In addition to

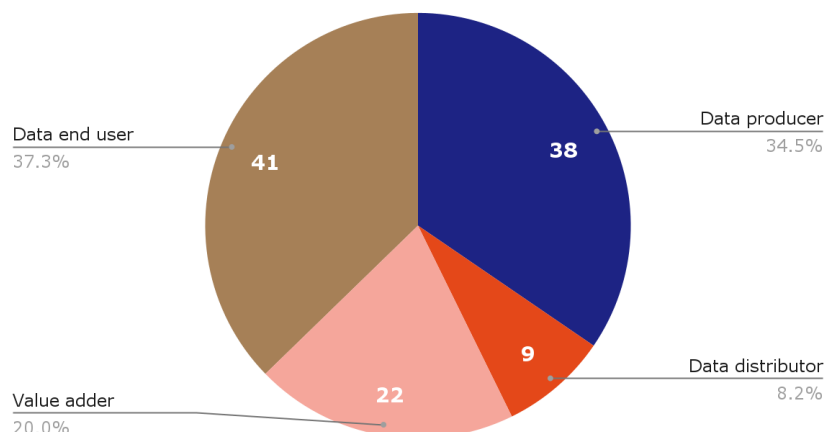
inputs and survey responses from CEOS agencies, LSI-VC members, the CEOS-ARD Oversight Group, WGISS, and WGCV, the survey received responses from the following companies and organisations (sometimes multiple responses from different people).

Commercial	Other
Airbus Defence and Space GmbH AISTECH SPACE, S.L. Arlula Pty Ltd Auspatious CATALYST (PCI Geomatics) Common Space Constellr EarthDaily ENVEO IT GmbH EOIntelligence Esri First Street GeoInsight GRASP Earth Marble Imaging AG Pixalytics Ltd Pixxel Planet Labs Riscognition GmbH Sarmap SA SatSure India Analytics Pvt Ltd SatVu Sparkgeo SpectralEO Telespazio UK USACE-AGC World from Space	Aberystwyth University Anna University Conicet Curtin University Kasetsart University KTH Royal Institute of Technology Landgate Natural Resources Canada OGC STFC Trier University UK Met Office UK Ordnance Survey Univ. Colorado, Boulder University of Maryland University of Tartu University of the Free State University of Venda

Sector



Role



The main messages from the survey responses are summarised below.

Top 10 Characteristics for Analysis Ready Data (multiple choice)

Rank	Characteristics sorted by ranking
1	Consistent metadata specifications
2	Machine-readability
3	Interoperability through time (relative geolocation)
4	Findable, Accessible, Interoperable, Reusable (FAIR) compliance
5	Consistency (data has temporal and spatial consistency)
6	Consistent terminology
7	Accessibility
8	Interoperability with other datasets
9	Geometric correction using DEM (ortho-rectified)
10	Fitness for purpose indicators (that the product fulfills the requirements of a specific application, e.g., land cover mapping, precision agriculture, etc.)

Respondents were also asked to provide additional characteristics and comments in a free text field. Feedback has been integrated into concept note.

- Notably, quality characteristics were mentioned six times.



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Metadata Enhancements

Consistent metadata specifications were rated as highly important to analysis-readiness. Feedback also emphasized the need to include provenance metadata in products to enable re-analysis, re-calibration, re-validation, or verification. A common set of metadata, supported by clear and well-understood tags along with process guidance (as done by the SAR PFS team) was seen as an essential part of a future evolution of CEOS-ARD.

AI/ML Readiness

Respondents suggested that rich, consistent, and interpretable metadata is essential for AI/ML readiness. This includes standardised flagging of data issues and anomalies, and new flags (or labels) for traceability, and provenance. Clear versioning and lineage information is critical for reproducibility and explainability in AI-driven workflows. It was suggested that the CEOS-ARD specifications should focus on machine readability and metadata completeness to maximise the utility for AI/ML. The top 10 multiple choice answers were as follows:

Rank	Characteristics Sorted by Ranking
1	Machine-readable formats
2	Rich, consistent, useful and interpretable metadata
3	Easy access via APIs or cloud providers
4	Rigorous definition of data values/content (no ambiguities)
5	High-quality data and continuous QA/QC
6	Large-scale accessibility
7	Temporal consistency
8	Supply of training datasets that are consistently and accurately labelled
9	Automated pre-processing
10	Standardised acquisition parameters

Machine Readability

Machine readability and adherence to FAIR principles were highly rated as enablers of analysis-readiness by respondents. Integration and representation of CEOS-ARD in STAC is needed to avoid reliance on custom extensions. Survey respondents noted the need to be able to meet minimum CEOS-ARD thresholds through STAC and the CEOS-ARD extension. STAC and cloud-native formats were deemed critical for analysis-readiness because being able to easily access data at scale is just as important as other considerations. Machine-readable formats was the top ranked requirement for increasing the AI/ML readiness of CEOS-ARD in the multiple choice question.

Accessibility

Accessibility was identified by the community as a key aspect of analysis-readiness. GDAL-readable and cloud native formats, direct data access via URL with simple authorisation, and avoiding dependency on a specific cloud provider were highlighted. Long-term data preservation and resilience; human readability; easy visualisation of data on a portal or browser; and public domain data and derivatives were also noted. Cloud-native approaches were deemed critical for analysis-readiness. Respondents considered that CEOS-ARD might want to implement/reference specific requirements for data storage, accessibility, and cataloging. Easy access via APIs or cloud providers was the third highest rated characteristic for increasing AI/ML readiness in the multiple choice question.

Data Quality

Respondents highlighted the need for standardised data quality information, including uncertainty and traceability requirements for measurements. The importance of continuous calibration and validation was also emphasised. It was suggested that official guidance on the level of accuracy (geometric and spectral) required to achieve CEOS-ARD compliance would increase industry buy-in and consumer confidence in CEOS-ARD.

Respondents also requested more guidance on necessary geometric/spectral accuracy. Current sub-pixel geometric accuracy requirements were noted as not suitable for very high-resolution satellites, impacting the commercial sector and also some CEOS data providers that supply high resolution EO data. CEOS agencies have also encountered these troubles and found this requirement to be very difficult to meet for historical archives, e.g. Landsat, MERIS, when trying to build ARD-compliant reprocessed historical data records. However, respondents did point out that concessions would be needed to promote near-real-time products.

It was noted that quantitative measures on quality for radiometry and cloud masks would help enforce the value of CEOS-ARD for applications and provide a way to differentiate data products' fitness for purpose.

Respondents suggested that there should also be a deeper inclusion of cal/val of CEOS-ARD datasets to ensure consistency – perhaps a common data quality platform, allowing assessment of data against a common set of references using a standardised cal/val approach. A dashboard application showcasing the performances would be a great goal for future development. The WGCV Product Validation Platform is a step in this direction.

Fitness for purpose indicators (i.e., that the product fulfills the requirements of a specific application, e.g., landcover mapping, precision agriculture, etc.) were also requested. This could also be addressed by tools that enable users to determine for themselves whether a dataset is fit for purpose.

High-quality data and continuous quality assurance/quality control (QA/QC) were rated very highly (fifth) on the list of items that would enhance the AI/ML readiness of CEOS-ARD (multiple choice question).

Ongoing Monitoring and Verification

Respondents emphasised the need for continuous verification to ensure that data sets comply with the CEOS-ARD specifications. This could be achieved through regular monitoring and quality assurance (QA) processes. It was suggested that data providers could give evidence of a systematic QA/QC process, and CEOS verify/certify the adherence of this process to community standards and guidelines. Additionally, respondents highlighted the importance of further integrating networks such as RadCalNet and Hypernets to assess compliance with the CEOS-ARD specifications.

Data Processing and Corrections

Respondents highlighted several key data processing steps and corrections, including the refinement of Digital Elevation Model (DEM) data, Bidirectional Reflectance Distribution Function (BRDF) correction, terrain illumination correction, and the use of cloud masks and probability thresholds. They also suggested implementing some standardised processing methods, common grids, and providing clear definitions for processing levels to enhance interoperability.

Interoperability

Interoperability with other datasets and maintaining consistency over time and across locations were highly valued by respondents. Respondents suggested that implementing standard processing steps, or using the same DEM and/or atmospheric correction code could enhance data compatibility and analysis-readiness. Using uniform frameworks for gridding and sampling, organising raster data consistently, and employing standard terminology and notations were identified as key factors in achieving these goals.

Respondents also suggested that interoperability could be improved by mandating, across different data types, interoperable gridding/sampling frames for easy alignment (without need of regridding) and consistency in time intervals. Additionally, interoperability with *in situ* data was a priority for some respondents.

Respondents noted some existing requirements and definitions are open to interpretation and require clarification. Consistent terminology and definitions are necessary. For example, many sections of the PFS use the term "machine-readable" without explaining what it means. Ensuring semantic consistency across datasets, including variable names, units, and value ranges, can reduce pre-processing needs and improve the portability of AI/ML models. Well-managed, widely accessible, controlled vocabularies are essential.

To improve interoperability, it is necessary to include more information about data quality and requirements for uncertainty and traceability in CEOS-ARD (see 'Data Quality' section above).

Versioning and Change Tracking

Robust versioning and change tracking is needed to enable transparent, traceable compliance and updates to processing chains. The PFS will need regular updating, but frequent changes make compliance difficult without a robust versioning framework.

Thematic Products

Respondents suggested starting to apply CEOS-ARD criteria to higher-level products. They called for more predefined thematic indicator products and more diversity of data and sensor types. It was suggested that accessibility could be improved for non-experts with thematic, pre-processed products. Closer alignment of specifications with the application needs of users was encouraged to drive adoption.

Respondents also called for a specification for atmospheric products (e.g., ozone, NO₂, SO₂, methane, etc.).

Tools, Documentation, Training

The top barrier identified by both users and data providers was 'lack of awareness'. 'Limited support' represented another substantial response regarding barriers to CEOS-ARD uptake. The top opportunity identified by both users and data providers was training and outreach.

Requests for tools, documentation and training were well represented in the free text responses, with respondents calling for user guides and open-source code examples; documentation and training material; ARD tools and software; and multilingual support. Expanded reference implementations and

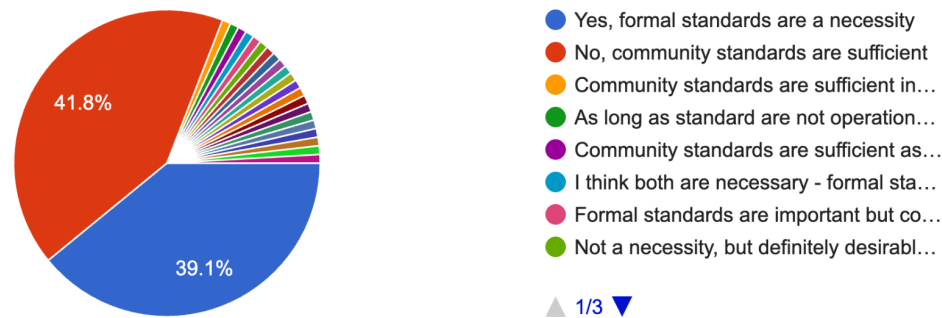
open tools for first-time adopters were also requested. Defining CEOS-ARD tools and workflows to achieve the specifications and streamline the self-assessment process were suggested.

ARD Standards

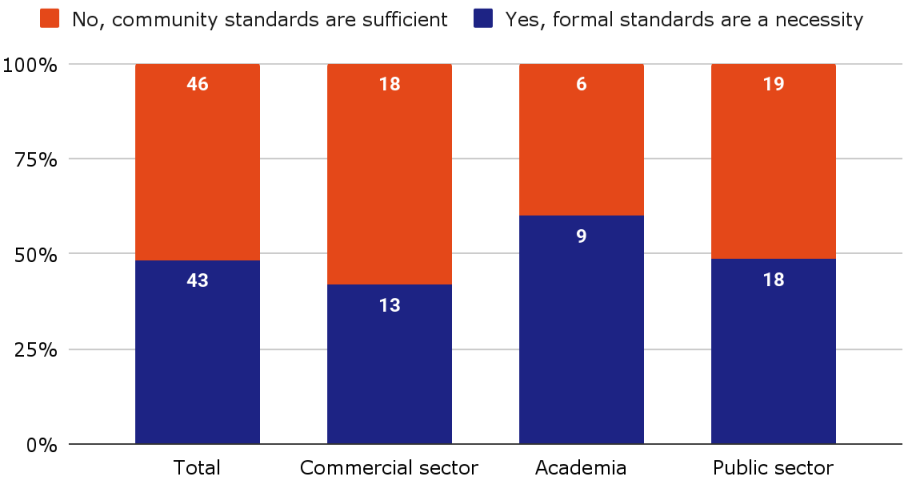
In a simple yes/no question, respondents were divided on the topic of formal versus community standards. However, free text submissions strongly favoured free-and-open community standards over closed, standards body approaches, which can make publishing updates more difficult and inflexible. It was recognised that a community standard will need more formalised processes and review to satisfy governmental bodies.

For your purposes, do you see a need for formal EO ARD standards (e.g., through bodies like OGC, ISO, IEEE) or is a 'community standard' approach like CEOS-ARD sufficient?

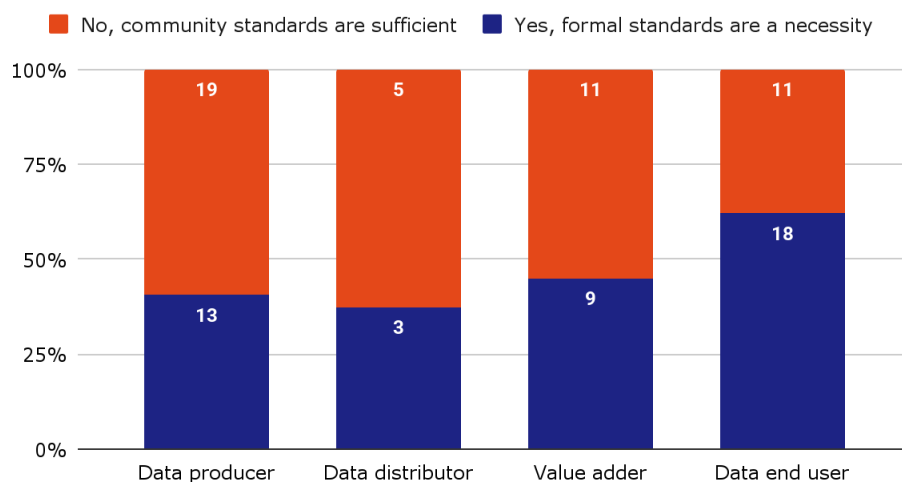
110 responses



Standards opinions by sector

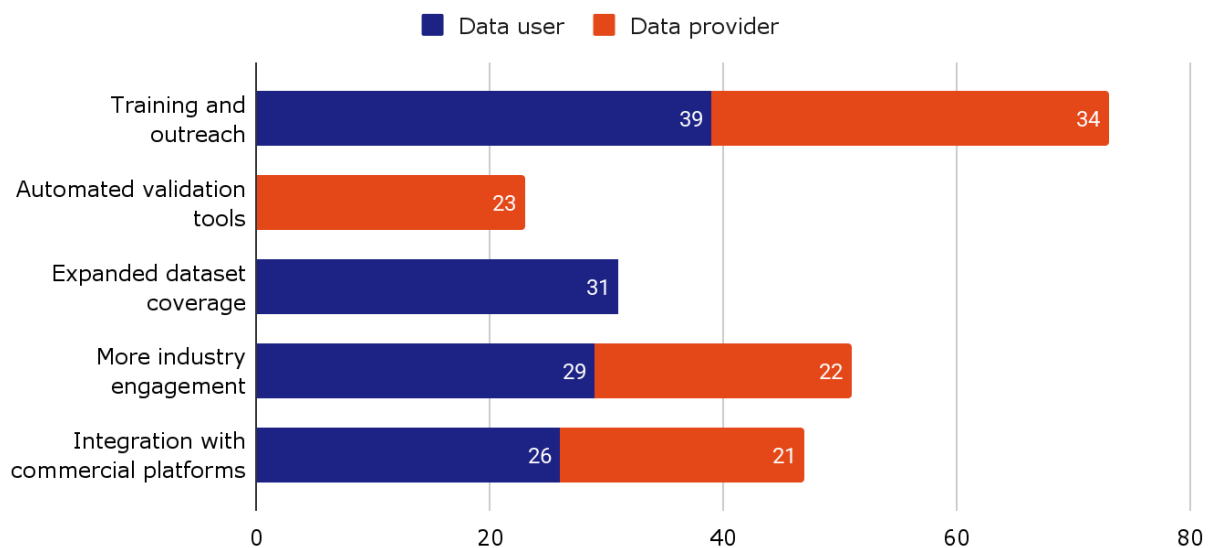


Standards opinions by role

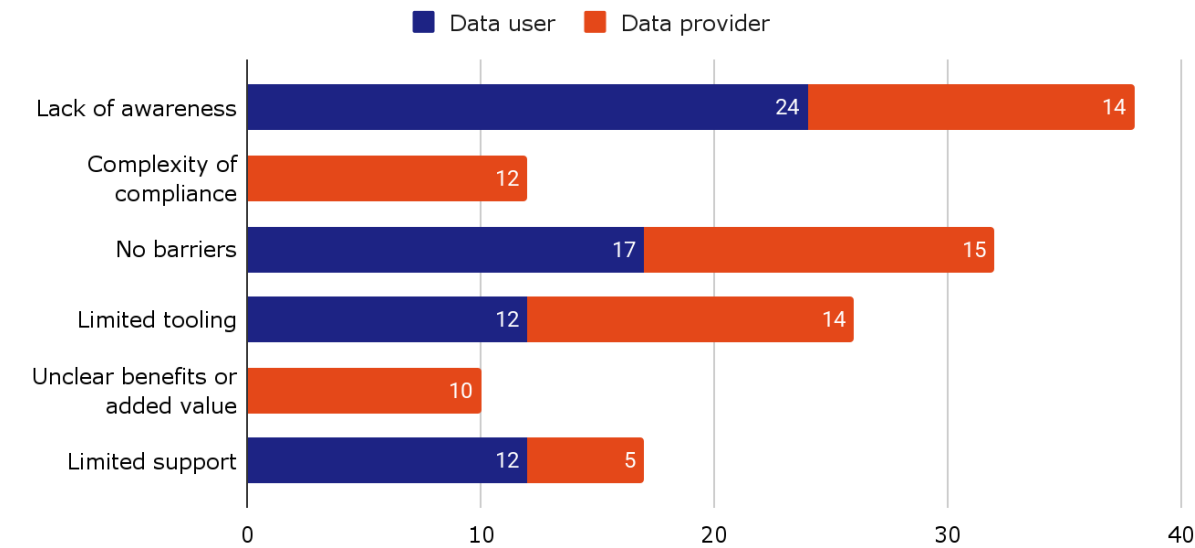


Opportunities and Barriers

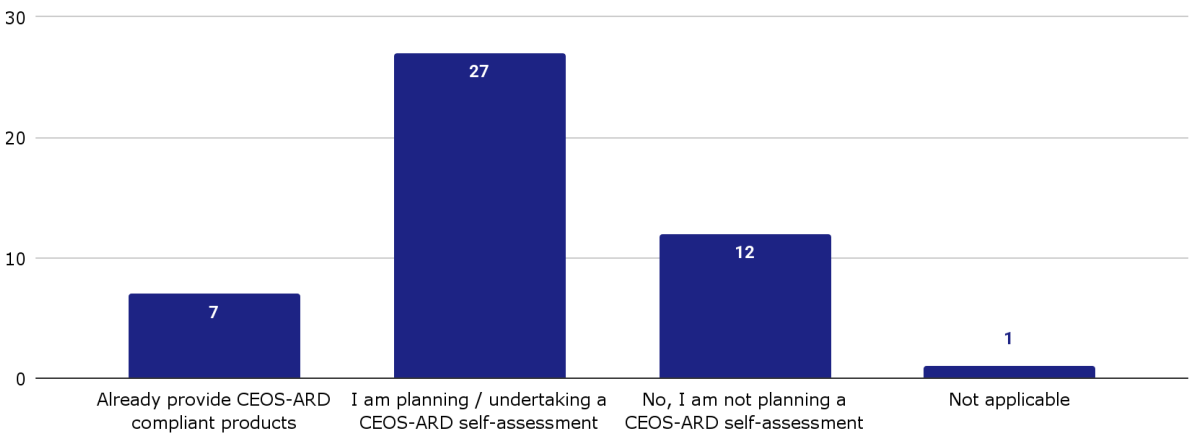
Opportunities



Barriers



Data provider/distributor current engagement



Are there specific datasets you would like to see assessed and endorsed as CEOS-ARD?



- Commercial data sources
- SAR datasets with consistent radiometric calibration performed, using the same DEMs
- Copernicus data
- MODIS and all ESA Sentinel products
- Thematic products for vegetation biomass SAR
- Planetscope
- PACE
- All EO data that are licensed by National Govts and are either public or commercial
- The data from the EO workshops such as Landsat, Sentinels, PACE, VIIRS etc.
- Reanalysis model data such as ERA-5
- NovaSAR-1
- High resolution datasets
- Sentinel-1,2,3
- Global elevation models like AW3D, COP30 or COP90
- Low level (e.g. surface reflectance) products that involve multi-sensor integration
- NISAR
- Sentinel-5P L2 data (e.g. NO2, O3, SO2, Cloud etc.)