

ECCOE Workshop - JACIE ARD/Interoperability Breakout Sessions

Monday 1/10/2022 (9:00am EST)

Monday, January 10th
(1) ECCOE Workshop: ARD/Interop Chair: Cody Anderson, USGS
A Vision for the Future: Matt Hanson, Element84
Analysis Ready Data (ARD) 2021 Conference Wrap-up & Carry Forward: Ignacio Zuleta, Indigo
Committee on Earth Observation Satellites (CEOS) Analysis Ready Data: Steve Labahn, USGS
Sentinel-2 Surface Reflectance Products: Valentina Boccia, European Space Agency (ESA)
Focusing on Data Quality: Cody Anderson, USGS
<i>Group Discussion & Actions</i>

Timing: Preparation and Introduction - 10 minutes; Each presentation 15 minutes with a question and transition period for each presenter of ~ 5 minutes (75 minutes plus 10 minutes – 85 minutes); Workshop group Q and A and Discussion period - 25 minutes.

Matt – Why ARD/Interoperability is important from a use case perspective; focus on land use cases

Ignacio – Wrap up of ARD workshops and key items required – actions from the workshop; mainly related to Land optical use cases

Steve – CEOS bigger picture couple and cover CEOS definitions, focus on Land ARD, showing Landsat ARD, Push for a larger steering function for Land ARD/Interoperability

Valentina – Focus on ARD and plans for ESA

Cody – What is needed to ensure quality in interoperability

Questions – Session chair should have some key questions to support discussion as needed. Developed key Facilitator questions for the presentations and discussion

Thursday 1/13/2022 (1:00pm EST)

(8) ECCOE Workshop: ARD/Interoperability Chair: Greg Stensaas, USGS
Emerging IEEE P4001 Hyperspectral Standard: Chris Durrell, LabSphere
Implementing the Maturity Matrix: Valentina Boccia, ESA
Breakout Sessions
Breakout Reports
<i>Summary of Actions</i>

1. **Total Session time: 150 minutes**
 - a. **Two presentations - 35 minutes total** – 15 minutes for each briefings (Chris Durrell and Valentina Boccia), and 5 minutes for questions.
2. **Breakout Session - 115 minutes total**
 - a. 5 minutes - rules of engagement
 - i. The breakout group session leaders (in bold) will have defined key topics and points with a couple of key questions and points provided to them for consolidation by their facilitators prior to the workshop.
 - ii. Each breakout group session will designate 1-2 note takers.
 - iii. Each breakout group session will focus on questions listed on the breakout kickoff slides.
 - iv. Facilitators will help drive and support the breakout session.
 - v. The breakout group will allow 5-10 minutes at the end of their breakout session time window to prepare a summary out brief to be given by the breakout lead to the workshop audience.
 - b. 15 minutes - 3 Group leads (listed below in Breakout Groups) – 5 minutes each to detail group breakouts.

Defining the key questions (keep the list manageable – 5 - 7 questions) and get feedback on actions and priorities during breakout to allow out brief of the top actions required.
 - c. 50 minutes; Breakout groups to address each area
 - d. 30 minutes – 10 minute out brief for each group
 - e. 15 minutes – Questions, Discussion, Actions

The three (3) breakout group leads will work from experience, past information from ARD21 ideas and summaries, and advice from breakout facilitators and workshop breakout participant advice to: 1) facilitate questions/actions for the ARD/Interoperability session and 2) provide a way forward for future workshops and working groups.

Breakout Groups

The Breakout leads will define initial questions and get inputs via email prior to workshop from facilitators, i.e., white papers, publications, efforts, and actions to continue this year and in the future.

i. **Calibration, data quality, and accuracy and traceable uncertainty.**

Lead/Facilitators: **Cody Anderson** / Valentina Boccia, Arin Jumpasut (Planet), Nigel Fox (NPL), Jon Christopherson (KBR), Brandon Russell (Labsphere), Bob Ryan (I2R)

Breakout Session 1 Strawman Questions:

- What are the most important/impactful data quality factors of a dataset to communicate to users?
- When looking at combining datasets, what factors need to be defined/reported to address differences between datasets?
- Is a standard per-pixel traceability/uncertainty process possible? Are there shortcuts?
- How do users use per-pixel traceability/uncertainty?
- Can a standard documentation method for per-pixel traceability/uncertainty be defined?

Rough Notes/questions:

(Need more work to establish the cal/val JACIE studies, test sites and process, and uncertainty process; we should be able to get JACIE members to participate in this. RSRs, common process, and how does it get used across the data quality arena? How do these processes change or become enhanced or automated in machine environment? Why are the most important commonly used definition for sensor/data measurands not consistent?

ii. **Implementation for Geospatial Workflows – machine learning, metadata, software, and tools.**

Lead/Facilitators: Speaker: **Ignacio Zuleta (Indigo)** / Pete Doucette (USGS), Fabio Pacifici (Maxar), Jim Vrabel (KBR), Wolfgang Luck (Pink Matter), Chris Rampersad (EarthDaily Analytics), Matthias Mohr (UNIVERSITY OF MÜNSTER / Radiant Earth), Radiant Earth), Rob Woodcock (CSIRO), Ajit Sampath (KBR)

Rough Notes/questions: This area is very important as it become the interface for the user and establishes common tools and processes that allow a measure of confidence or uncertainty in the answer provided. How will the workflow in a machine environment allow automated products? What happens when there a multiple version of the same product with varying answers and uncertainty. How does the machine list available options for user? Is there a verification/validation/certification function? It is obvious that the data and metadata drive the future, how is this done consistently for remote sensors?

iii. **Governance and Leadership of ARD/Interoperability - Definition, Distinction, and Standards.**

Lead/Facilitators: **Matt Hanson (Element84)** / Ferran Gascon (ESA), Steven Labahn (USGS), Greg Stensaas (USGS), Chris Durell (Labsphere), Frank Avila (NGA), Medhavy Thankappan (Geoscience Australia), Michele Kuester (Maxar), Mary Pagnutti (I2R), George Percivall (IEEE)

Rough Notes/questions:

Follow on to the cal/val, how do we make sure that there is a process to incorporate the information from i and ii.

(Funding to have someone leading, is it a consortium? Is it a (Government and Industry) project manager? How does this fit within CEOS and industry realms? How do you bring in Govt, Industry, academia, and Societies/ Consortiums / Bodies into alignment? Who is overall leader, with influence across community? standards bodies have things happening in interoperability, how do they fit into the process? You can't have standards bodies going one way and other ad hoc definitions being made, if so, how do they meet?) Steering groups/ad hoc groups required!

Previous ARD Workshop Groups and Information

1. Calibration, Data Quality, and Accuracy and Uncertainty

- a. What do we believe is the relationship between useability, interoperability, and quality? How do we mix instruments of different levels of calibration uncertainty? What is the relationship between traceable measurements and vicarious calibration?

- Summary from ARD21: GROUP 5 SUMMARY LIST

- Forum that continues this Cal/Val discussion is very important - a steering group or another regular forum and a place to get the materials. Is that ASPRS, or another standards body? Center of Excellence?
- Maturity matrix/EDAP concept is good one that can be applied to situations and determine “fit for purpose”
- Traceable uncertainty has to be a common thread throughout systems.
- Resiliency and usability really must be approached from a System of Systems concept that ensures interoperability
- Self-assessment?

2. Governance and Leadership of ARD/Interoperability - Definition, Distinction, and Standards.

- a. Common definitions and standards Summary from ARD21: GROUP 4 SUMMARY LIST
- b. As well as some of the points from ARD21: GROUP 5 SUMMARY LIST
- c. Action from ARD21: Create steering group and ad hoc groups; ARD, VHRODA, others.
- d. Define Interoperability and ARD overall at high level so everyone is speaking consistent and properly on interoperability overall.
- e. Interoperability involves input from all measures from the sensor through output of products and information to the user. There are many pieces across this scenario. The definition of these components is critical to solving the miscommunication across “interoperability” big picture.
- f. The key is related to having traceable measures and documentation of such at all levels so the machine can use and provide interface and processing to address the user’s questions and products and provide a measure of accuracy and uncertainty to the science information, products, and answers to the user’s need and questions.
- g. ARD is a results of this process, allowing the (ARD) information and products, to be used by the machine to address the user’s question. The information and products are documented accordingly in the ARD to be used in the interoperability process.

Room 4: Standards Formation Process

Agile standards formation, or **product-managing the virtual ARD product** across the industry. Who are we building common practices for? What is our **ARD product manifesto**? One standard to rule them all or a series of interlocking standards? Bottoms up or top-down? What has worked in the past in other industries? How do standards interact with velocity of development?

- Summary:

- Value in having ARD tile data cubes that include data from many sources. Standards are needed to enable
- ESA Desire for concrete plan for standardization... a single standard?
- How do we get user voice involved in the standardization process, on equal footing with the providers and agencies? Via CEOS and OGC
- Landsat and Sentinel-2 as pathfinders
- Velocity impedance match. Uncharted universe of users.
- Community develops it and then gets formalized so can be used in procurement, ability to reference in compliance and other standards. OGC has process for supporting this. Community working on a practice may not include all stakeholders, current and emerging. So, a formal and sustained standards development / maintenance processes can often more explicitly include that diversity and adaptation.
- Where is "water's edge" in delivering data/information? USGS is making L2 available, ESA has Copernicus services.
- ARD = Taxonomy of common workflows, can have users at different stages.
- Additional notes:
- Advocates are needed, OGC and ISO are prime candidates. Looking at bottoms-up: CEOS is the org with strong inertia with industry engagement. What is the other way to go?
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- Good enough now versus perfect later is a tradeoff. There are also users that are out there that leaders may not know of. While there is an excellent community of professionals, the ultimate end user community may need additional outreach to engage with the standards development community. Example of farmer: wanted two-hour imagery to watch worker productivity.
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- Stratification of users: figure out the "water's edge". Provide exploitable datasets, with no defined endpoint for services. There is a range of users from beginner to expert, from individual to national. Goal is to enable industry to have access to data for purposes across the whole spectrum, with a focus on good observational data. It would be good to define that best fit for most uses.
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- Perhaps raw data is useful to experts with skill, while pre-defined products to fit major users be defined. Then let industry choose where they fit. "Stream" service of ingredients versus final products.
- OGC looking to involve more people into the process.

3. Implementation for Geospatial Workflows – machine learning, metadata, software, and tools.

Room 1 and 2 Combined: Canonical processing levels and new data abstractions including non-sequential calibration of remote sensing data and edge processing

- What are the canonical **processing levels** for different observation modalities? What needs to happen in 2022 so that processing levels are a useful tool for assimilating data from different sources that "*just works*". Is calibration a sequence of corrections (levels) applied in series to data?
- To **raster or not to raster** - new data abstractions that are not equally spaced and enable efficient last-mile aggregation, assimilation, delivery, and resampling of heterogeneous data. This includes point clouds and generally non-raster workflows including **non-sequential calibration of remote sensing data and edge processing**.
- Summary:
 - Current state: Level definitions are not satisfactory - each level too much variability in product definition (1, 2). Scheme needs to be refined. (optical) Has been traditionally: 1st getting geometry right, then everything after --- is this what we still need? (chicken and egg??)
 - Often divide by optical vs. SAR vs hyperspectral: Maybe what we really need to focus on: **Active vs. Passive**
 - Consider
 - *Matrix* of processing options: geometric and radiometric
 - Axes: radiometry and geometry
 - Providing steps + associated uncertainties at every step,
 - Distinguishing fusion vs. model vs. inference ready
 - order of operations matter

Room 3: Standard core metadata

Standard **core metadata**, or what is the minimum metadata needed for effective sensor fusion, interoperability, and harmonization? How to address incorporating this **core metadata in STAC metadata** to document for provenance, traceability, data integrity, and quality. What can we learn from other industries with similar products in the imaging industry? What about privacy, governance, and licensing?

- Summary:
 - Optical
 - Processing levels with definition
 - Geometric accuracy
 - How is it measured
 - Uses a reference dataset. Via link to STAC item(s)
 - RPCs (for lower processing levels)
 - Measurement accuracy
 - DN, reflectance, radiometric

- Inter-band registration
- Spectral band profiles
- Atmospheric correction
 - What inputs were used (aerosols, water vapor, climate model)
 - Model details
- Topographic correction details
 - What DEM (link to a STAC Item)
 - Accuracy
- BRDF
 - Gap-filling ?
- SAR
- Processing level
 - SLC
 - Geocoded
 - GRD
- Geometric accuracy
- Image formation
- Measurement accuracy
 - Radiometric Accuracy
- Topographic correction
 - DEM user
- ...

Room 6: Open-source development for ARD

What is missing? What are canonical workflows we can use to test maturity and feature completeness? What are emerging workflows? Are they reaching the intended users? What are focused open-source efforts we could fund?

- Summary
 - -Dedicated funding
 - - Geospatial support with Dask <https://dask.org/>
 - -Multidimensional file support; integrating the GDAL multidimensional API with rasterio
 - -Would like improved functionality for map algebra w/ multiple rasters of various projections/resolutions

- -GDAL/Rasterio, Xarray, Rioxarray ...
- -Marc to reach out to Rasterio dev to see if interested in contributing
- -Improved processing of raster and vector data simultaneously within the ecosystem
- -Increase collaboration on items like ARD & STAC in rasterio

Notes from ARD 21:

Breakout Room Topics Room 1 and 2 were combined in workshop

- **Room 1:** What are the canonical **processing levels** for different observation modalities? What needs to happen in 2022 so that processing levels are a useful tool for assimilating data from different sources that "*just works*". Is calibration a sequence of corrections (levels) applied in series to data?
 - **Room 2:** To **raster or not to raster** - new data abstractions that are not equally spaced and enable efficient last-mile aggregation, assimilation, delivery, and resampling of heterogeneous data. This includes point clouds and generally non-raster workflows including **non-sequential calibration of remote sensing data and edge processing**.
 - **Room 3:** Standard **core metadata**, or what is the minimum metadata needed for effective sensor fusion, interoperability, and harmonization? How to address incorporating this **core metadata in STAC metadata** to document for provenance, traceability, data integrity, and quality. What can we learn from other industries with similar products in the imaging industry? What about privacy, governance and licensing?
 - **Room 4:** Agile standards formation, or **product-managing the virtual ARD product** across the industry. Who are we building common practices for? What is our **ARD product manifesto**? One standard to rule them all or a series of interlocking standards? Bottoms up or top-down? What has worked in the past in other industries? How do standards interact with velocity of development?
 - **Room 5: Calibration, quality, and accuracy.** What do we believe is the relationship between useability, interoperability, and quality? How do we mix instruments of different levels of calibration uncertainty? What is the relationship between traceable measurements and vicarious calibrations?
 - **Room 6: Open source development for ARD** - What is missing? What are canonical workflows we can use to test maturity and feature completeness? What are emerging workflows? Are they reaching the intended users? What are focused open-source efforts we could fund?
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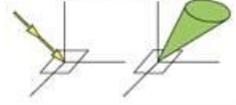
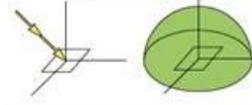
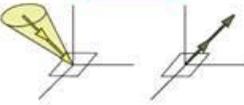
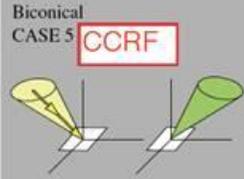
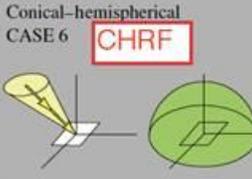
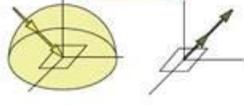
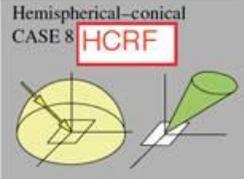
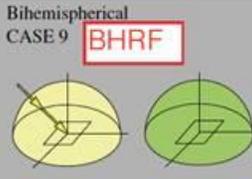
ARD21 Topics

Room ½ Combined: Canonical processing levels and new data abstractions including non-sequential calibration of remote sensing data and edge processing

- What are the canonical **processing levels** for different observation modalities? What needs to happen in 2022 so that processing levels are a useful tool for assimilating data from different sources that "*just works*". Is calibration a sequence of corrections (levels) applied in series to data?
- To **raster or not to raster** - new data abstractions that are not equally spaced and enable efficient last-mile aggregation, assimilation, delivery, and resampling of heterogeneous data. This includes point clouds and generally non-raster workflows including **non-sequential calibration of remote sensing data and edge processing**.
 - **Processing levels**
 - OPTICAL
 - Level 2 definition ambiguities: we need to come to a consensus
 - 2a = Surface reflectance - corrections? 2a
 - Illumination, BRDF corrections? US vs. ESA
 - Propose → "2b" = illumination and BRDF corrected?
 -

- Differences in 1T vs. 1C
- What is *surface reflectance*? Need geometry information
- Metadata needs:
 - What has been to do the data (can work backwards)
 - What information is needed to apply further corrections downstream
- Original vs interpolated measurements

Table 2
Relation of incoming and reflected radiance terminology used to describe reflectance quantities

Incoming/Reflected	Directional	Conical	Hemispherical
<i>Directional</i>	Bidirectional CASE 1 BRF 	Directional-conical CASE 2 DCRF 	Directional-hemispherical CASE 3 DHRF 
<i>Conical</i>	Conical-directional CASE 4 CCRF 	Biconical CASE 5 CCRF 	Conical-hemispherical CASE 6 CHRF 
<i>Hemispherical</i>	Hemispherical-directional CASE 7 HDRF 	Hemispherical-conical CASE 8 HCRF 	Bihemispherical CASE 9 BHRF 

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- Geolocation issues:
 - Sequence of orthorectification vs radiative calibration
- RADAR
 - Interchangeably working in slant range vs. ground range
 - Often bring other data sources (DEMs) to
 - Within SAR community - levels are generally well understood
 - Calibrated, GRD \sim BRDF corrected optical
 - Need to understand
- HYPERSPECTRAL
 - Maybe what we really need to focus on: **Active vs. Passive**
 - In active system: we need additional information on transmitted illumination

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	• radiometry	
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- Ideal:
-

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Room 5: Calibration, quality, and accuracy.

- What do we believe is the relationship between useability, interoperability, and quality? How do we mix instruments of different levels of calibration uncertainty? What is the relationship between traceable measurements and vicarious calibration?
 - **Notes:**
 - ChrisD: Thinks we need to be moving forward to formal standards. Provide some sort of known standard body - IEEE, OGC, etc. - and get people meeting on regular basis, some structure, etc.

- GregS - Agreed, needed - somehow get the people together
- CharlesM - Should ASPRS PDAD be involved? GregS - yes, but only as a player
- GregS - What are the channels? NIST, OGC, IEEE, NPL, APSRS, CEOS, ESA EDAP, JACIE, VH-RODA, Industry and Govt calibrators, ...,
- JonC - Needs to be some recognized body
- ChrisD - a known body helps bring people out to participate from their individual "silos".. Need to have one group that is responsible to assemble standards, bring people to help build them, etc. Has to be a consensus process
- JonC - is this one standard or multiple? Some discussion - general agreement that it is multiple standards to cover the scope of the entire process
- GregS - We (ARD) can maybe help set up an "enabling" team to help energize the standards body/ies.
 - Need some kind of steering group to corral all people involved, get all voices together
- GS: Fit for Purpose is the key for the user
- Brandon Russel - The Maturity Matrix is so useful because it helps people determine if data is "fit for purpose"
- GregS - one thing we, in this Calibration room, need to strive for is "traceable uncertainty" BarbaraG - suggested we all get the maturity matrix up and displayed so that we can mark it up refer to it, and reliably discuss it.
- CharlesM - Need something to help users understand what can be done with these data, and/or what else is needed with it
- ChrisD - Does someone (provider) need to certify himself? Like with CARD4L - how does one get certified? - One can self-assess, but some other body should have ot audit and certify
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Product Details	Product Generation	Ancillary Information	Uncertainty Characterisation	Validation
Product Information	Sensor Calibration & Characterisation Pre-Flight	Product Flags	Uncertainty Characterisation Method	Reference Data Representativeness
Availability & Accessibility	Sensor Calibration & Characterisation Post-Launch	Ancillary Data	Uncertainty Sources Included	Reference Data Quality
Product Format	Retrieval Algorithm Method		Uncertainty Values Provided	Validation Method
User Documentation	Retrieval Algorithm Tuning		Geolocation Uncertainty	Validation Results
Metrological Traceability Documentation	Internal Processes			

Key
Not Assessed
Not Assessable
Basic
Intermediate
Good
Excellent

EDAP Product Quality Evaluation Matrix – example

-
- <https://earth.esa.int/eogateway/activities/edap/edap-best-practice-guidelines>

- I agree simple functions and certification (verification process)
-
- ChrisD - Goal - outline some basic, simple tests to self-certify. A multi-layered approach to the auditing. Something that can be done quickly, cheaply, etc. The next level of assessment (in the CalVal world) would involve a laboratory
- GregS - We've had standards for accuracy forever for geometric/geodetic, but for radiometric we don't have much in the way of standards for data.
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- JonC - We need to have standards that people will want to use. Standards must be written to be useful/wanted by the next step down the chain.
- ChrisD - We need "Systems of Systems" to ensure resilience
- Recommendation from this Breakout - Some sort of Steering Group should be set up to bring the groups together, begin the process and shepherd it through.
 - Thought: May be one over-arching Steering Group and then subgroups for subsets of the standards.
- BrianH - Probably could be a role for ASPRS PDAD to develop a rating system or something for providers to use to rate their processes. One group we may want to approach is the Cloud people- they might be very much in favor of this.
- ChrisD - Someone has asked - what do the data collectors (clouds) do to "screen" the data that is coming in?
- GROUP 5 SUMMARY LIST (Chris Durell):
- Forum that continues this Cal/Val discussion is very important - a steering group or another regular forum and a place to get the materials. Is that ASPRS, or another standards body? Center of Excellence?
- Maturity matrix/EDAP concept is good one that can be applied to situations and determine "fit for purpose"
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Room 6: Open source development for ARD

- What is missing? What are canonical workflows we can use to test maturity and feature completeness? What are emerging workflows? Are they reaching the intended users? What are focused open-source efforts we could fund?
 - -Dedicated funding

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- -Multidimensional file support; integrating the GDAL multidimensional API with rasterio
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- -GDAL/Rasterio, Xarray, Rioxarray ...
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- -Improved processing of raster and vector data simultaneously within the ecosystem
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Room 1: Combined: Canonical processing levels and new data abstractions

Room 2: Non-sequential calibration of remote sensing data and edge processing

Room 3: Standard core metadata

Room 4: Standards Formation Process

Room 5: Calibration, quality, and accuracy

Room 6: Open-source development for ARD