ARD is needed to support all of the Open Data Cube pilot projects. To date, we have interactions with 33 countries and are actively working on several pilot projects that use ARD.

Countries have expressed a strong desire to minimize pre-processing burden and to help them obtain the “best” ARD for their application needs.

Radar data is becoming a popular request, as many regions have issues with clouds and would like increased temporal sampling for change detection.

The primary issue was SAR data is that developing countries do not have experience pre-processing SAR data or using it for application products.

CEOS Agencies can add significant “value” by routinely producing and offering ARD to users, or as a minimum, providing tools for developing ARD and ingesting this data into Data Cubes.
## S1 CEOS ARD Summary

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>CEOS ARD</th>
<th>Google</th>
<th>Zhou (CSIRO)</th>
<th>Lewis (GA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orbit Updates</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>GRD Border Noise</td>
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<td>x</td>
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<tr>
<td>3</td>
<td>Thermal Noise</td>
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<td>x</td>
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<tr>
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<td>Radiometric Calibration</td>
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<td>x</td>
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<tr>
<td>5</td>
<td>Radiometric Terrain Correction</td>
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<td>x</td>
</tr>
<tr>
<td>6</td>
<td>Speckle Filter</td>
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<td>no</td>
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<td>no</td>
</tr>
<tr>
<td>7</td>
<td>Orthorectification</td>
<td>x</td>
<td>x</td>
<td>x</td>
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</tr>
</tbody>
</table>

**Unprocessed** - VH Intensity
Location: Sogamoso, Colombia

**Steps 1 to 6**
Gamma-0, Intensity

**Step 7 - Orthorectification**
Gamma-0, Intensity, UTM-WRS84
We have developed Python algorithms to prepare **Sentinel-1** ARD products (VV and VH gamma-nought intensity) from GRD data.

These algorithms are based on the Sentinel-1 SNAP Toolbox.

With about 20-22m ground resolution at slant range (10m pixel spacing used for GRD products), we are moving toward a final product with 30m pixel spacing to match Landsat and enhance interoperability.

The choice of 30m spatial resolution is flexible and DOES NOT impact the primary requirements for ARD production. The user can always use a different projection and spatial resolution for their end product.
WASARD (Water Across Synthetic Aperture Radar Data) is a new machine learning algorithm for water detection using radar datasets. The algorithm is trained using Landsat data and the Australian WOFS water detection algorithm, which has >97% accuracy. WASARD has shown >96% correlation with WOFS results using Sentinel-1 data over Vietnam. WASARD produces a simple linear water classifier algorithm with the format: 

$\text{(Coefficient-1)} \times (\text{VV-band}) + \text{(Coefficient-2)} \times (\text{VH-Band}) + \text{Bias}$

Sample water detection results for Lake Buon Tua Sarh in Vietnam. The correlation between WOFS and WASARD was >96%. 

Sentinel-1 WASARD

Landsat WOFS
Examples in Vietnam

These Sentinel-1 and Landsat acquisitions are on the same day. The presence of clouds reduces water visibility with Landsat, but using Sentinel-1 and WASARD can achieve a full view of the water extent.
The majority of S1 data products are GRD format, which tends to appeal to the majority of global users, but complex slant range (SLC) data is powerful.

A recent presentation by Zheng-Shu Zhou (CSIRO) at IGARSS showed the benefit of (2-dimensional) dual-pol decomposition (alpha angle (a), anisotropy (A), entropy (H)), which can be generated from the larger (5GB) Sentinel-1 SLC product.

With 5 “bands” of information (vs. 2 bands for GRD) and cloud-free images in a time series, it is possible to produce excellent land classification in high-cloud regions.

Clustering algorithm results demonstrate the value of dual-pol decomposition and the value of time series cloud-free images to improve land classification discrimination.
We would like to develop a Python algorithm to prepare Sentinel-1 ARD products derived from the SLC product.

It is assumed this product would include intensity (VV and VH) and the (2-dimensional) dual-pol decomposition parameters ($\alpha$, $A$, $H$).

This SLC-based ARD product needs to be documented along with the GRD ARD product as part of the CEOS ARD initiative.

We need help!

(1) What is the minimum amount of data that should be produced from the SLC product that will impact the largest number of users?

(2) How are the decomposition parameters best included in this ARD product?

(3) Are there other data parameters (not including metadata) that are needed in the ARD product?
(1) **Orbit Updates** - Updates satellite ephemeris for improved geolocation
(2) **Remove GRD Border Noise** - Removes processed artifacts at scene edges where non-zero noise values exist.
(3) **Remove Thermal Noise** – Removes thermal noise using thresholds. Not a significant correction, but commonly used by most users.
(4) **Radiometric Calibration** - Converts raw data to backscatter intensity (beta-0 output)
(5) **Radiometric Terrain Correction** - Radiometric normalization (terrain flattening) using DEM data (gamma-0 output)
(6) **Speckle Filter** – Removes noise but distorts the original pixel information. This may be applied as an “optional ARD” product for select users.
(7) **Geometric Terrain Correction** - Orthorectification using DEM topography data (gamma-0 output in preferred grid projection)

* Unit conversion from linear intensity (DN) to decibels (dB) was not considered. Many applications apply algorithms to DN values and only convert to dB units numerically or use dB units for visual image products.
* Assumes Interferometric Wide Swath (IW) mode and GRD data format