# **ALUs Toolbox:** GPU-Accelerated Sentinel-1 and ALOS PALSAR Processing Tools

**Martin Jüssi, CGI Estonia**

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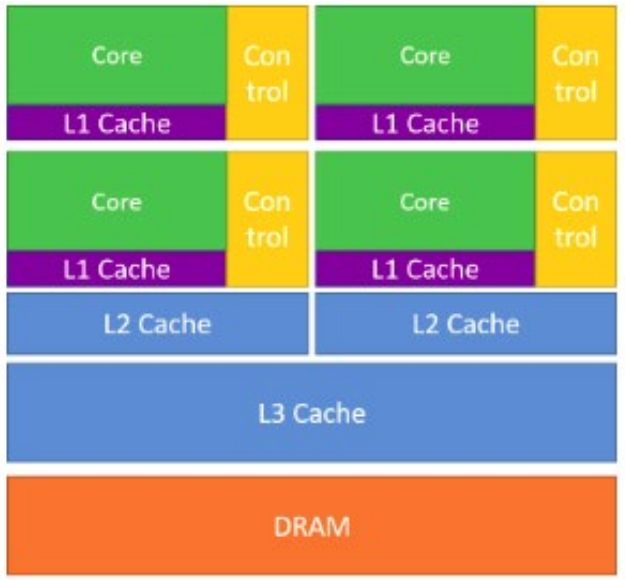
CGI

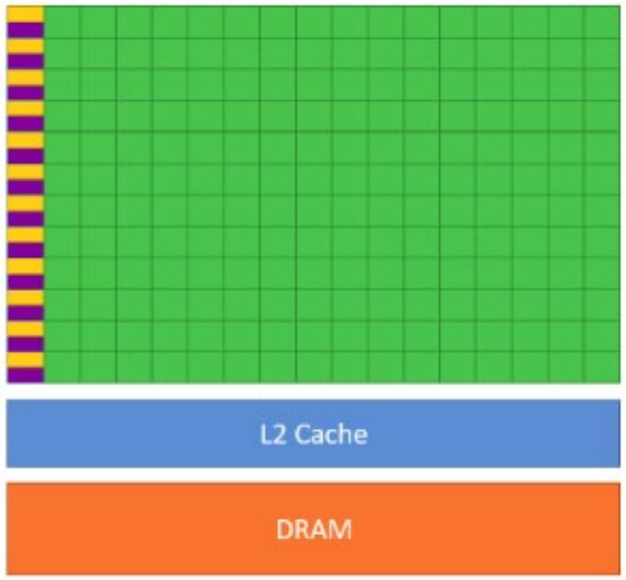
# Outline

- Background
- Software functionality overview
- Processing tools and performance
- Latest developments and opportunities enabled
- Conclusion

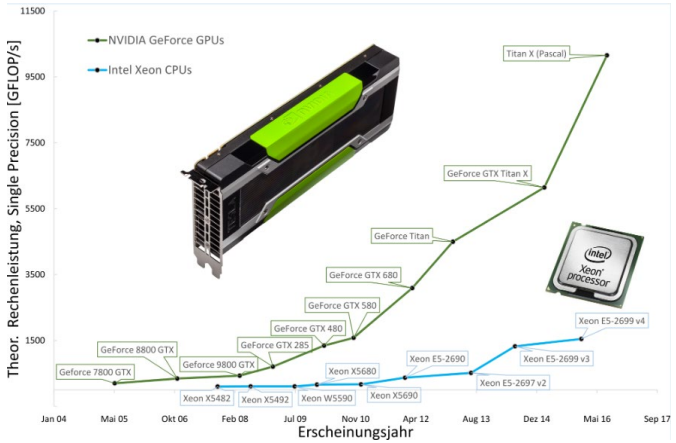
# GPU technology

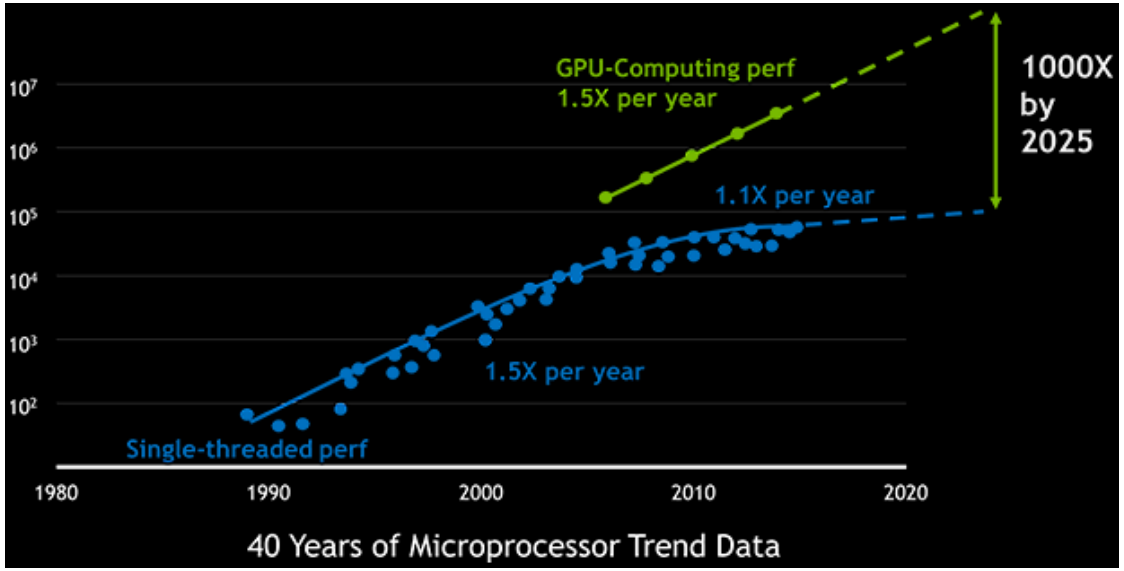
- GPU – Graphical Processing Unit
- Traditional usage:
  - Video rendering
  - Gaming
- Contemporary usage:
  - AI model training
  - Crytocurrency mining
  - Various computational tasks

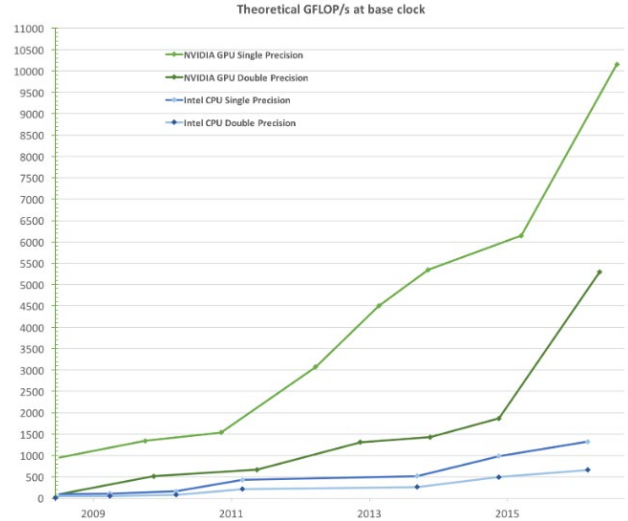


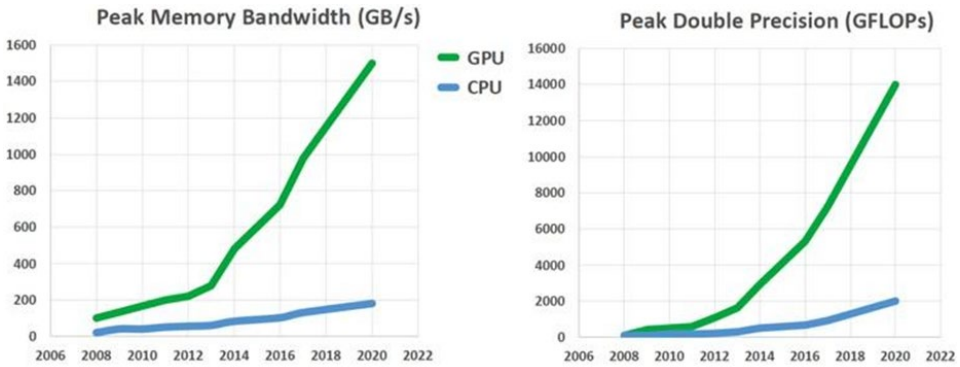



# **GPU technology:** performance trends



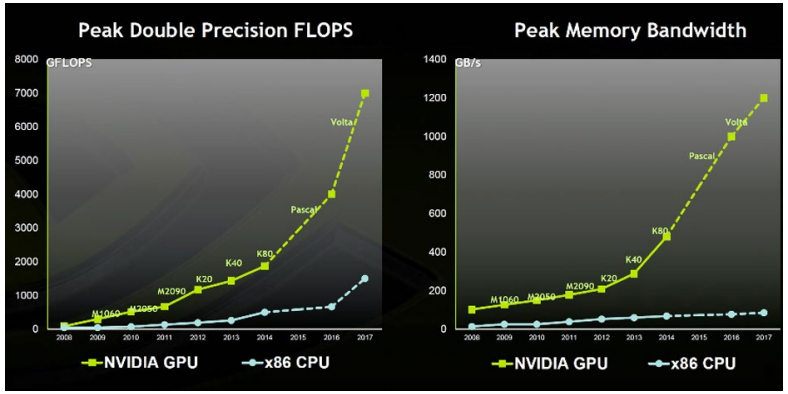



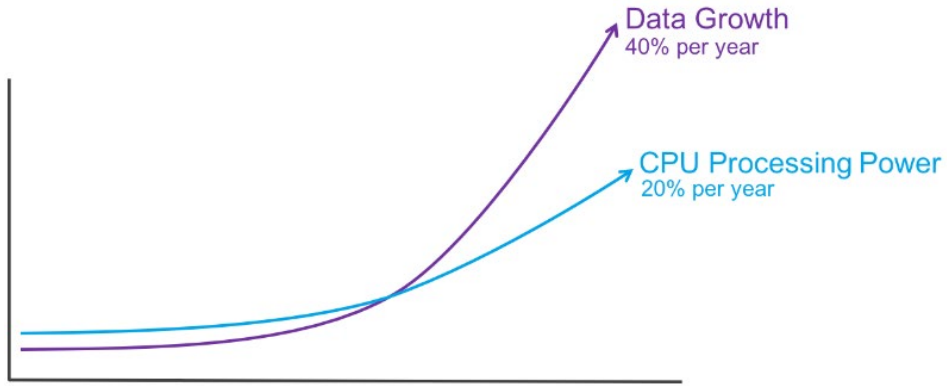



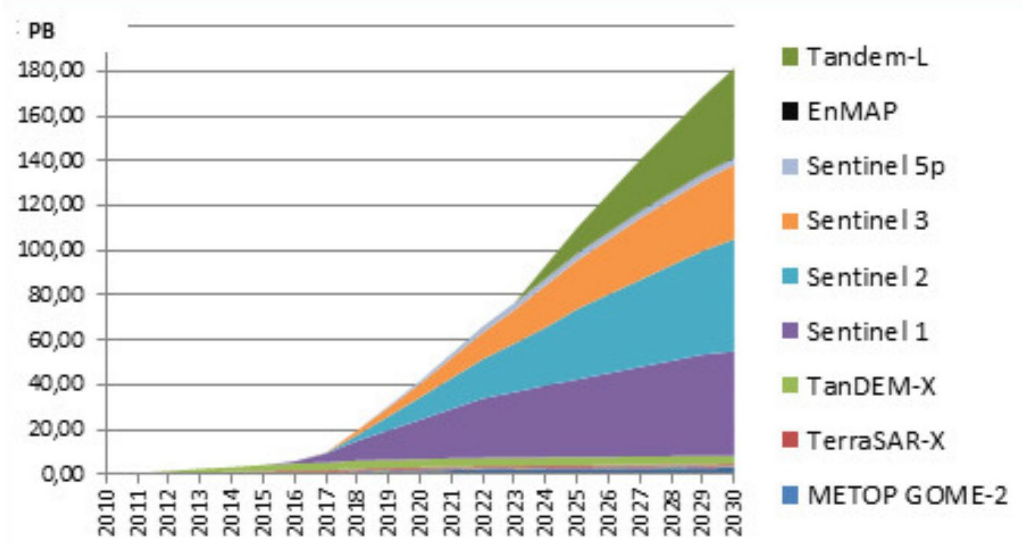


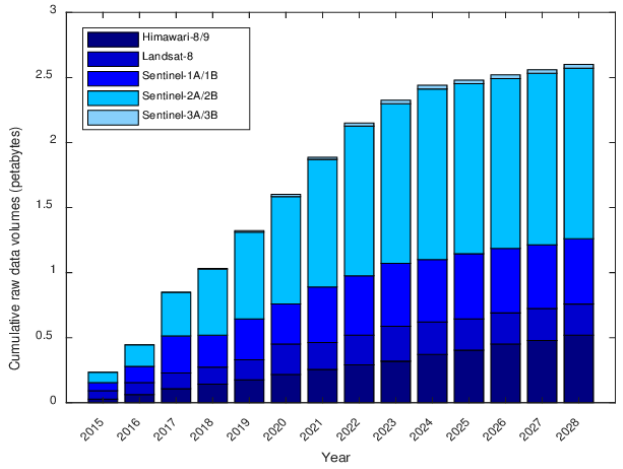


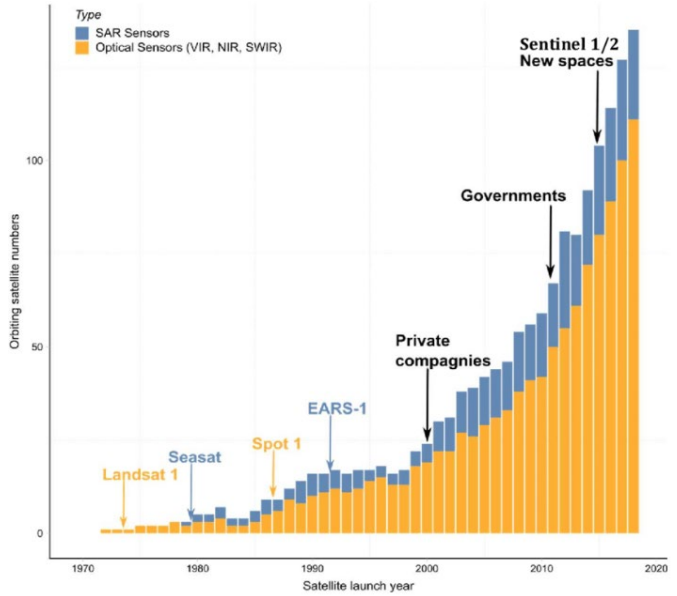


# Meanwhile in Earth Observation...



# ALUs Toolbox introduction

- ALUs Toolbox *(Arithmetic Logic Units)* – an open-source toolset leveraging GPU technology to **accelerate** SAR and optical EO data processing

- https://github.com/cgi-estonia-space/ALUs
  - Open source, free for commercial use

ALUs
GPU-Accelerated
EO processing toolbox by CGI

- Expertise and tools developed and advanced mainly under ESA activities by CGI Estonia:
  - Estonian IIS: Interactive Hosted EO Processing
  - EOEP5 Block 4 Open Call: GPU-accelerated SAR Tools
  - GSTP: GPU-accelerated EO processing tools development
  - TDE: Bulk Processing via Parallel Computing
  - QA4EO – Quality Assurance for Earth Observation 2019-2024

esa

# Expert user input to the toolbox development

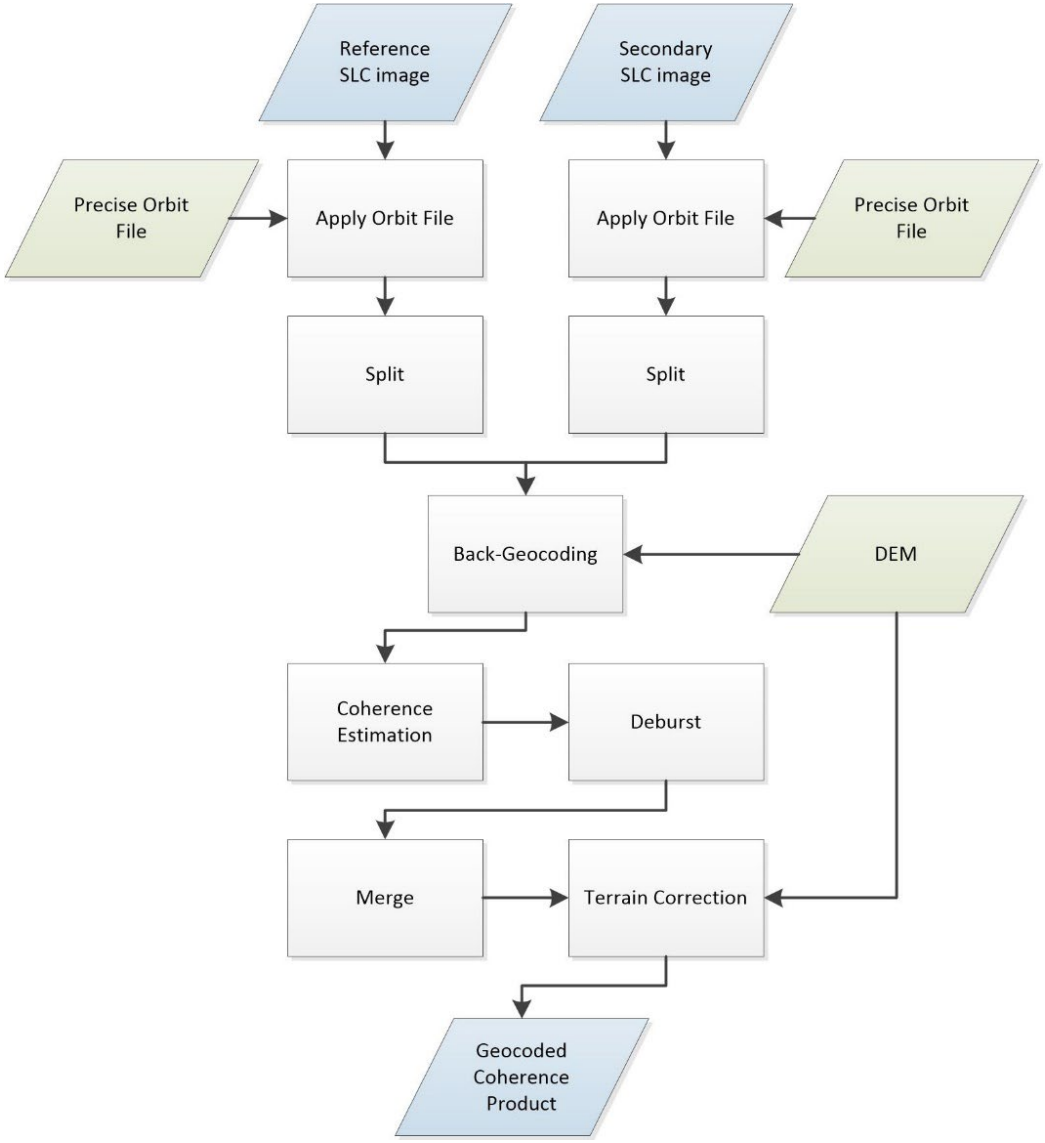
- A number of expert users involved in various activities:
  - DLR-DFD – Geo-Risks and Civil Security department – **Simon Plank**
  - TalTech – Marine Systems Intitute – **Rivo Uiboupin**
  - VTT – team of machine learning engineers in the forestry domain – **Lauri Seitsonen**
  - University of Leicester – AI4EO activity – **Prof. Kevin Tansey**
  - KappaZeta Ltd – an EO SME from Estonia – **Mihkel Veske, Indrek Sünter**
  - EC Joint Research Centre – **Guido Lemoine**
  - ESA-ESRIN – **Cristiano Lopes, Nicolas Longepe, Andreas Vollrath, Jose Manuel Delgado Blasco**

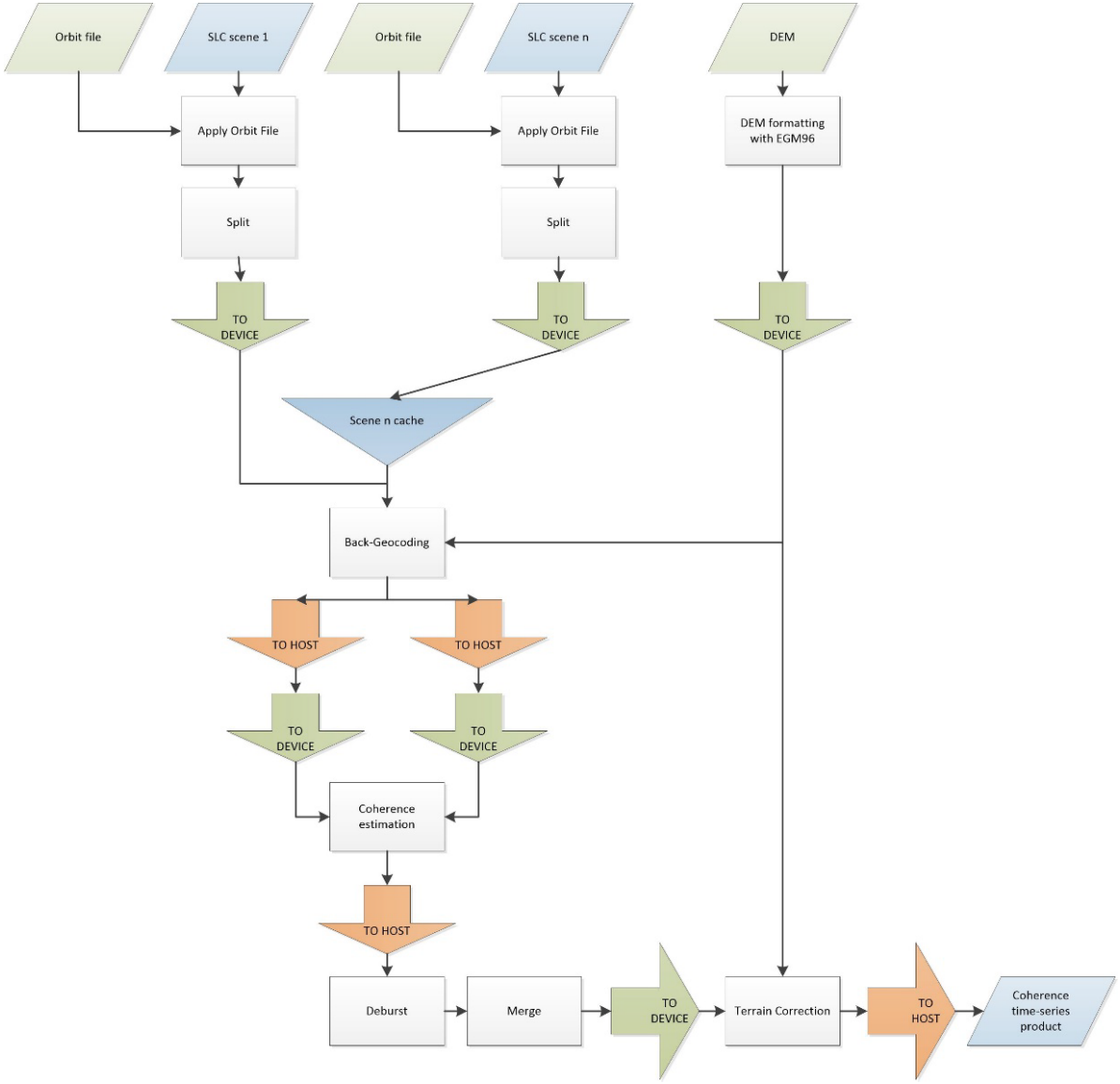
# **Toolbox functionality**: GPU-enabled „routines“

- Based on the most common requests by the expert users shown on the previous slide
- SNAP Toolbox used as the reference implementation

- **Sentinel-1 coherence estimation routine** – generate a Sentinel-1 coherence pair from two SLC scenes.
- **Sentinel-1 calibration routine** – calibrate and geocode a Sentinel-1 SLC or GRD image.
- **Sentinel-1 coherence timeline generation routine** – generate a coherence time-series from Sentinel-1 SLC images.
- **Resampling routine** – resample multiple images in an input selection to one pixel resolution.
- **SAR focussing routines** – ALOS PALSAR, ENVISAR ASAR and ERS SAR focussing tools.

# **Sentinel-1 Coherence Routines:** alus-coh; alus-coht

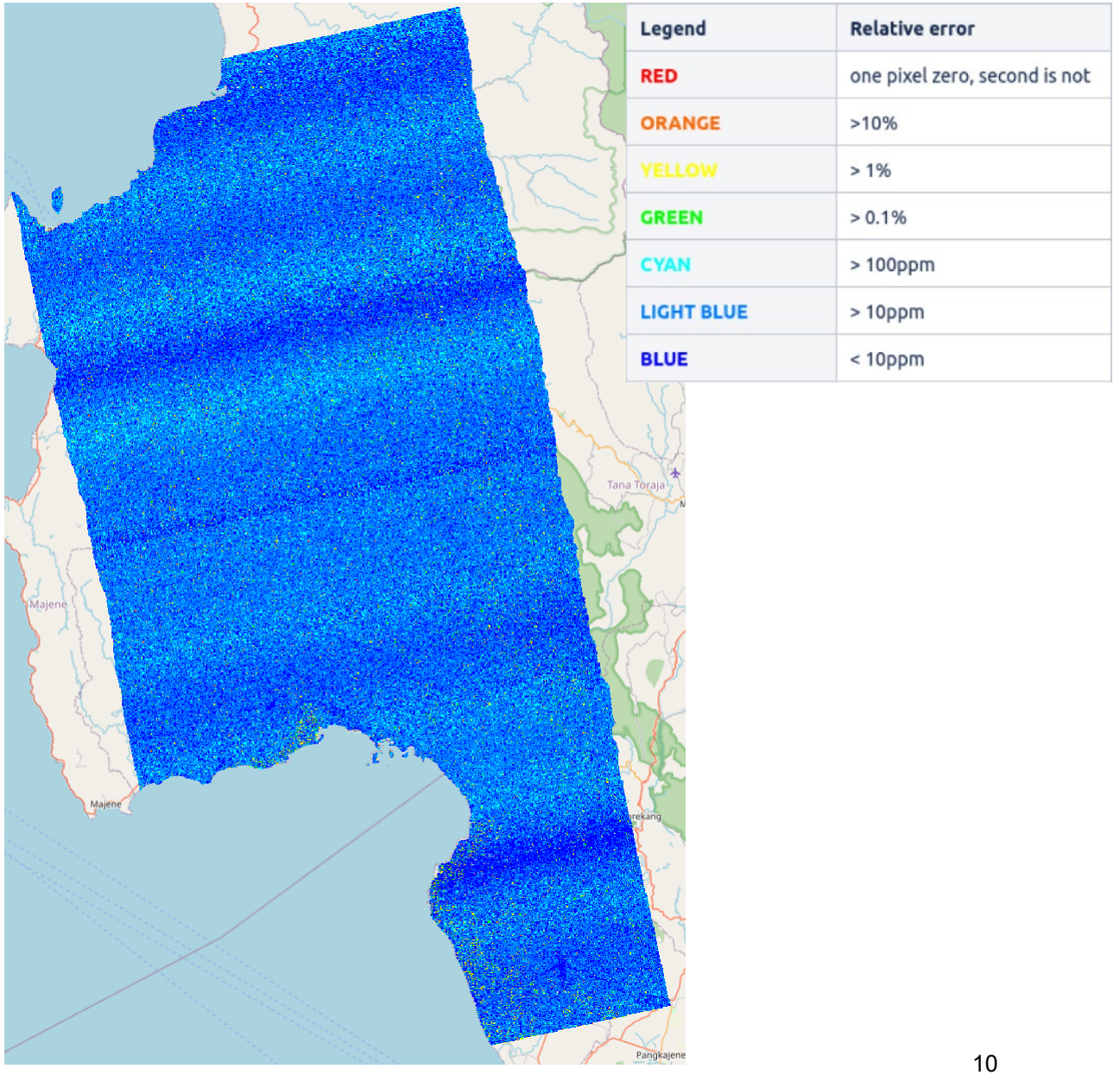


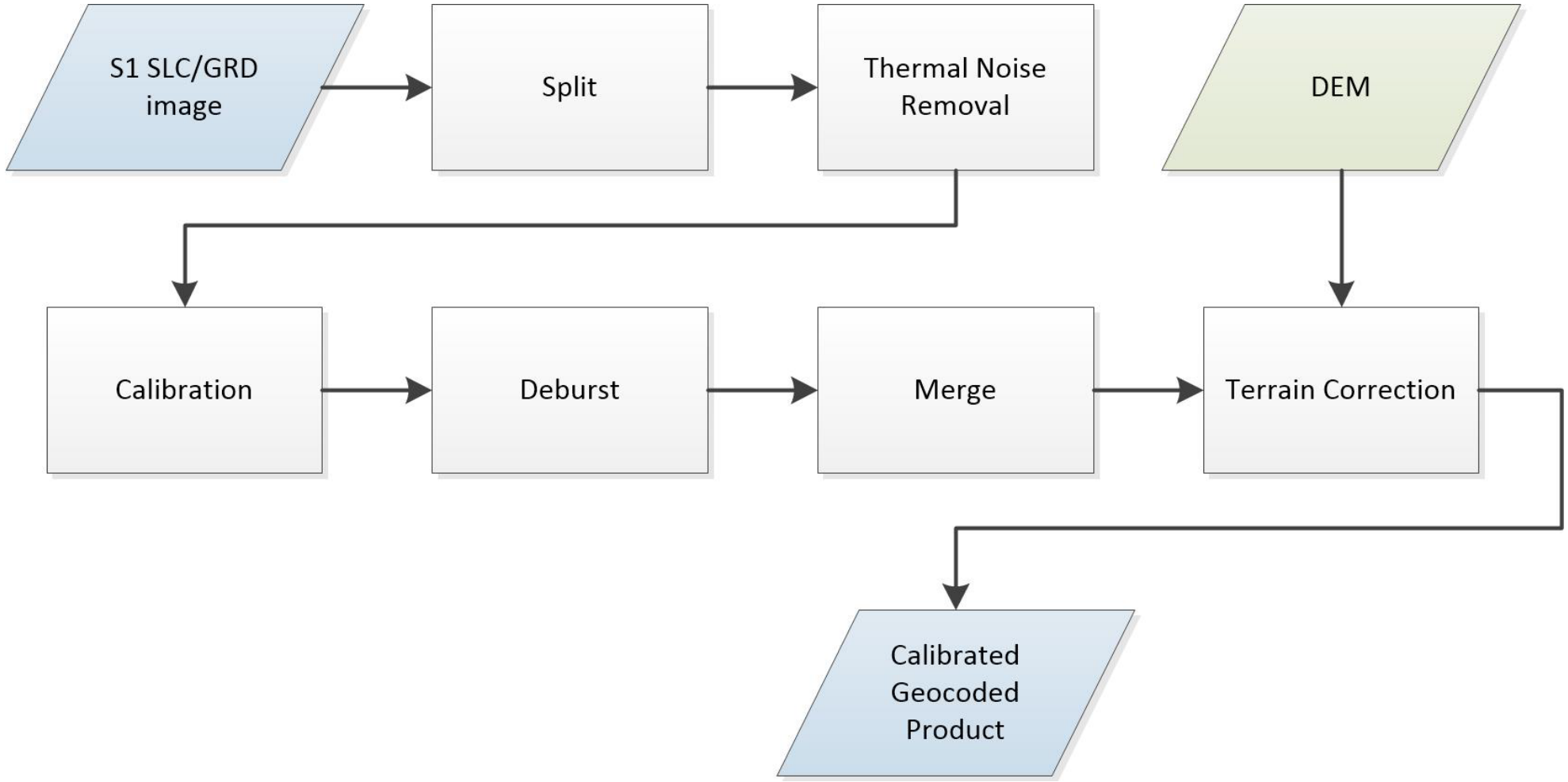
# **Coherence estimation routine:** Accuracy assessment

Pixel value comparison vs SNAP

| Pixel value | Average | Max |
|---|---|---|
| Minimum | 5.67E-07 | 3.14E-06 |
| Maximum | 1.72E-06 | 1.11E-05 |
| Mean | 0.00018 | 0.00108 |
| Average relative (PPM) | 923.36 | 1519.59 |
| Coastal pixels mismatch (PPM) | 45.93 | 448.20 |



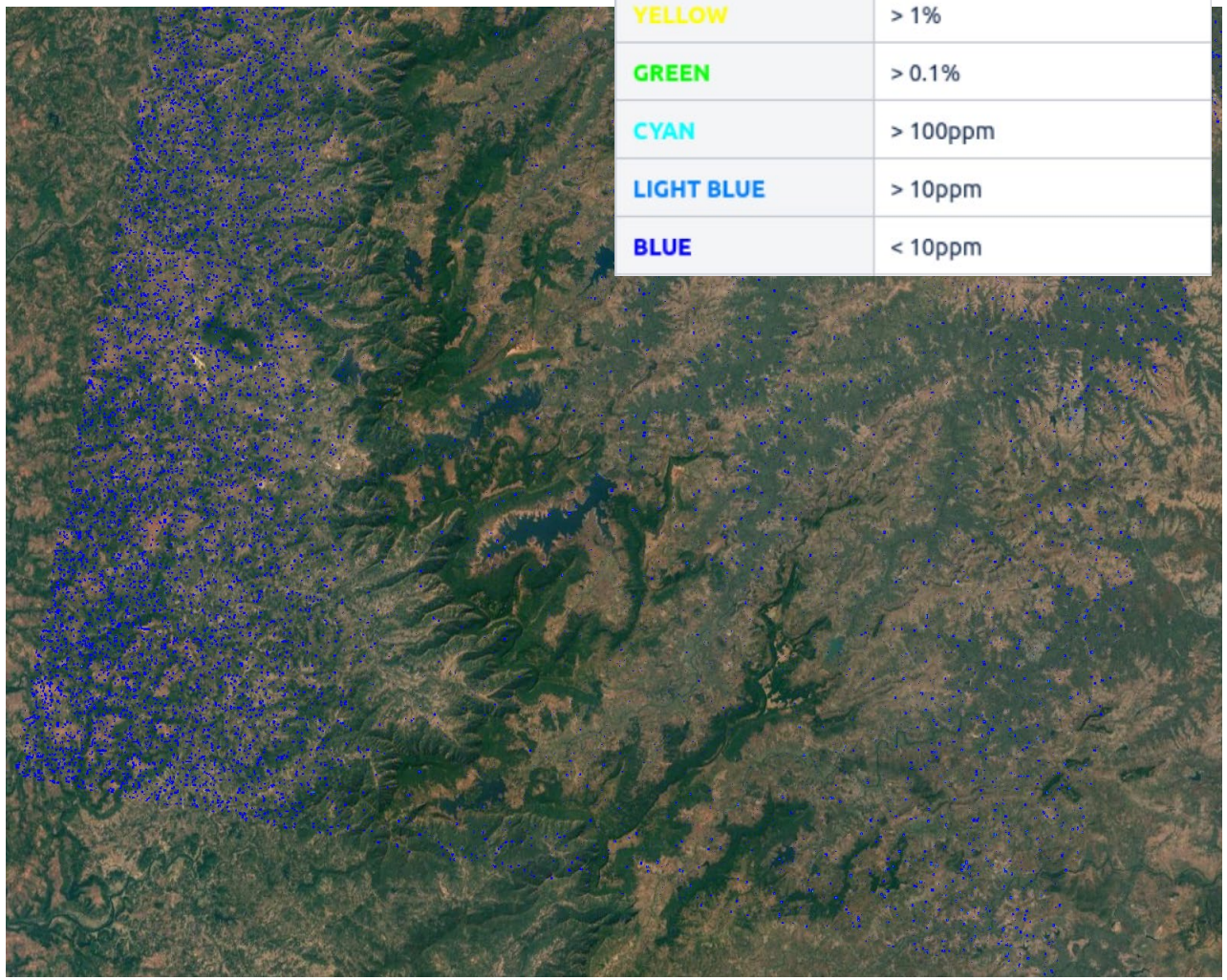
# Sentinel-1 Calibration Routine



# **S1 Calibration Routine:** Accuracy Assessment

Pixel value comparison vs SNAP

| Pixel value | Average | Max |
|---|---|---|
| Minimum | 0 | 0 |
| Maximum | 2.03E-05 | 0.0001 |
| Mean | 9.87E-09 | 2.83E-08 |
| Average relative (PPM) | 8.99 | 28.83 |
| Coastal pixels mismatch (PPM) | 0.23 | 0.74 |



| Legend | Relative error |
|---|---|
| RED | one pixel zero, second is not |
| ORANGE | >10% |
| YELLOW | > 1% |
| GREEN | > 0.1% |
| CYAN | > 100ppm |
| LIGHT BLUE | > 10ppm |
| BLUE | < 10ppm |

# Toolbox general functionality

- GPU-enabled routines (NVIDIA CUDA)
  - Smart use of hardware based on availability
- Inputs supported on multiple levels:
  - Full S1 scene (three subswaths)
  - One S1 subswath
  - One or multiple S1 bursts
  - User-defined input – AoI (SHP or WKT)
- SRTM3 and Copernicus DEM 30 supported

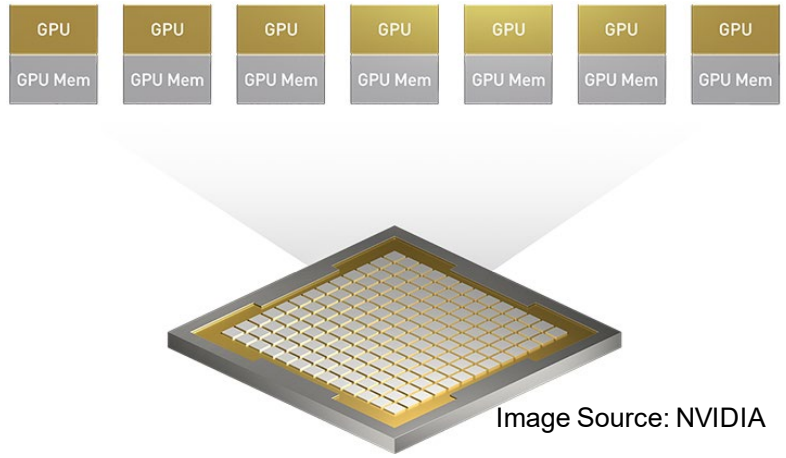
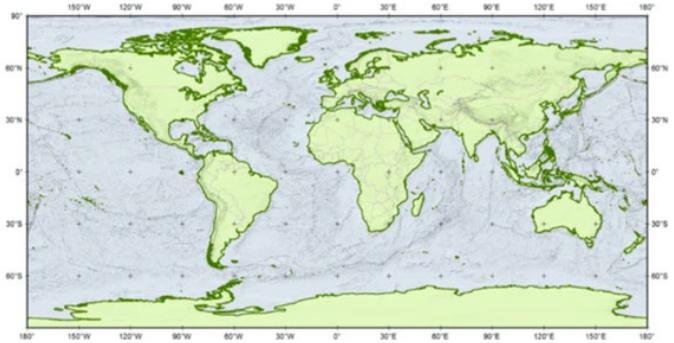
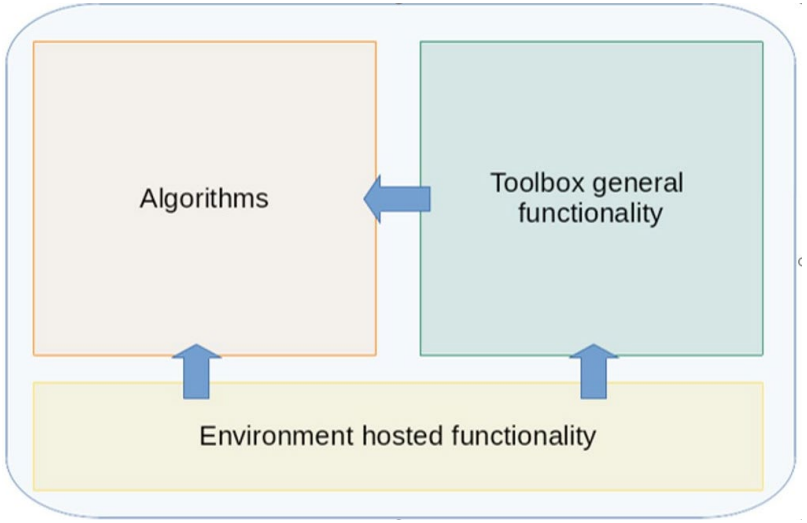


Image Source: NVIDIA



# Software approach

- Emphasis is on pure processing – Command Line Interface. Auxiliary files, analysis etc must be done by external tools
- Can be easily integrated into existing processing environments
  - NVIDIA GPU-s supported (CUDA)
- Official releases built for Ubuntu 20.04 (and its flavors)
  - Docker images available
    - cgialus/alus-focal-jupyter
    - cgialus/alus-devel
    - cgialus/alus-runtime



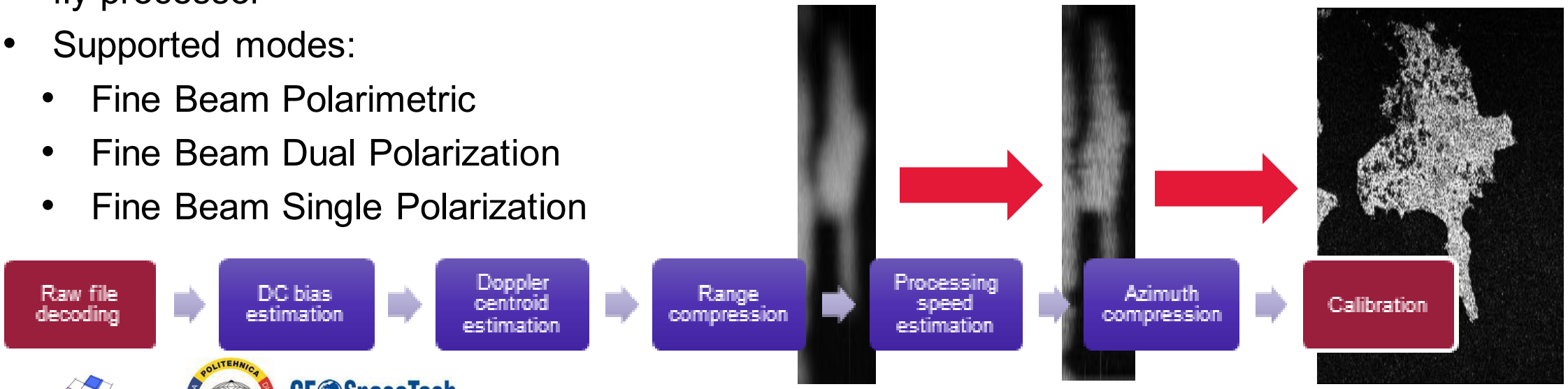

```
alus-coh -r <reference>.SAFE -s <secondary>.SAFE -o <output dir or filename> -p <pol> -a "POLYGON ((…))" -orbit_dir <directory of orbit files POE or RES> --dem <DEM files>
```

# SAR focussing routines (1): BULPP

BULPP

Bulk EO data processing platform by CGI

- ESA TDE activity „BULPP - **Bul**k **P**rocessing via **P**arallel Computing“
- A prototype processor for ALOS PALSAR Zero-Doppler Focussing
  - Consulted and validated by sarmap SA
- Nearly interactive performance achieved – huge potential to develop into a serious on-the-fly processor
- Supported modes:
  - Fine Beam Polarimetric
  - Fine Beam Dual Polarization
  - Fine Beam Single Polarization




sarmap your information gateway

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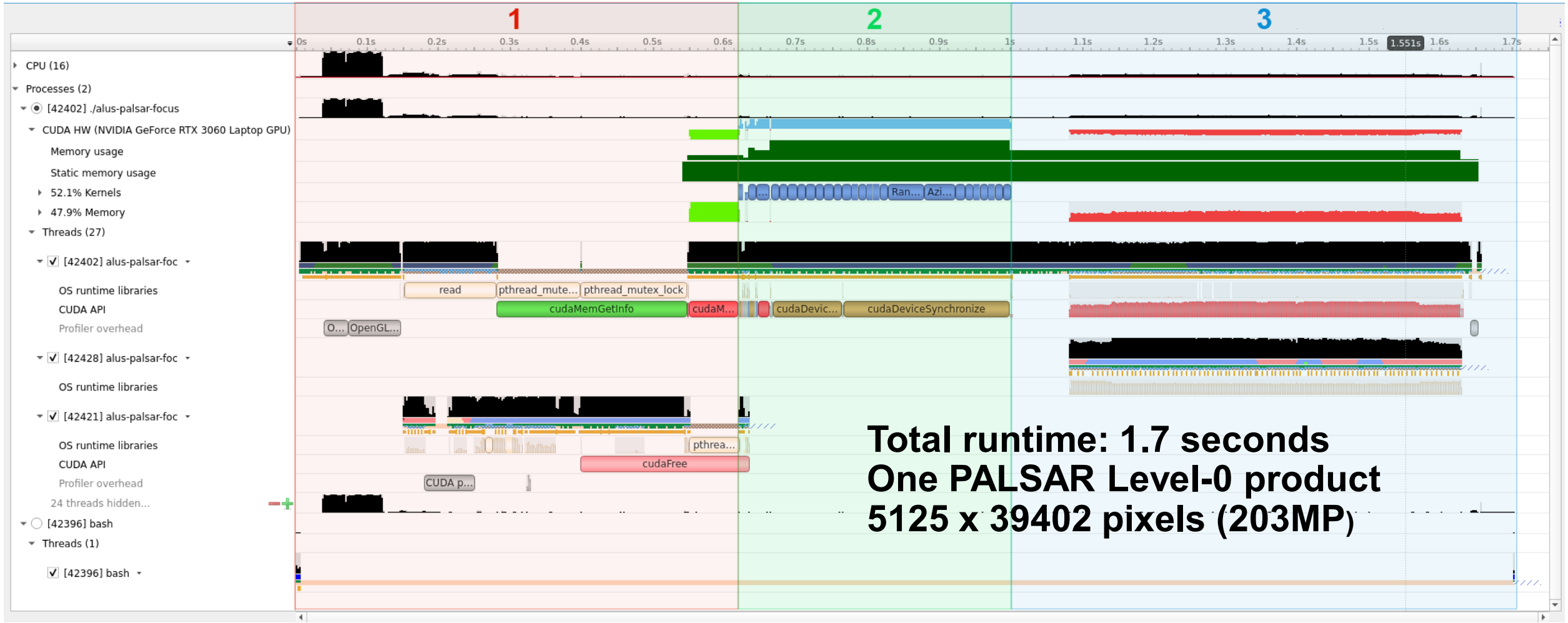
# **SAR focussing:** processing performance

**Initialization, file loading, metadata parsing**

**Calculations on GPU**

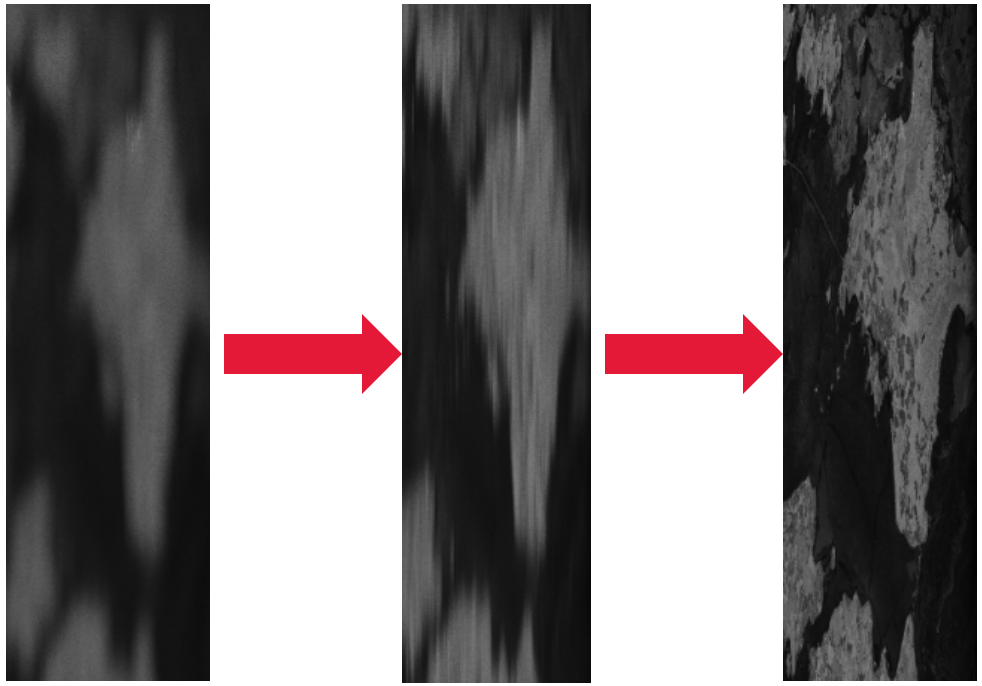
**GPU → CPU → TIFF file writing**




**Total runtime: 1.7 seconds**
**One PALSAR Level-0 product**
**5125 x 39402 pixels (203MP)**

# **SAR focussing routines (2):** ENVISAT ASAR and ERS focussing

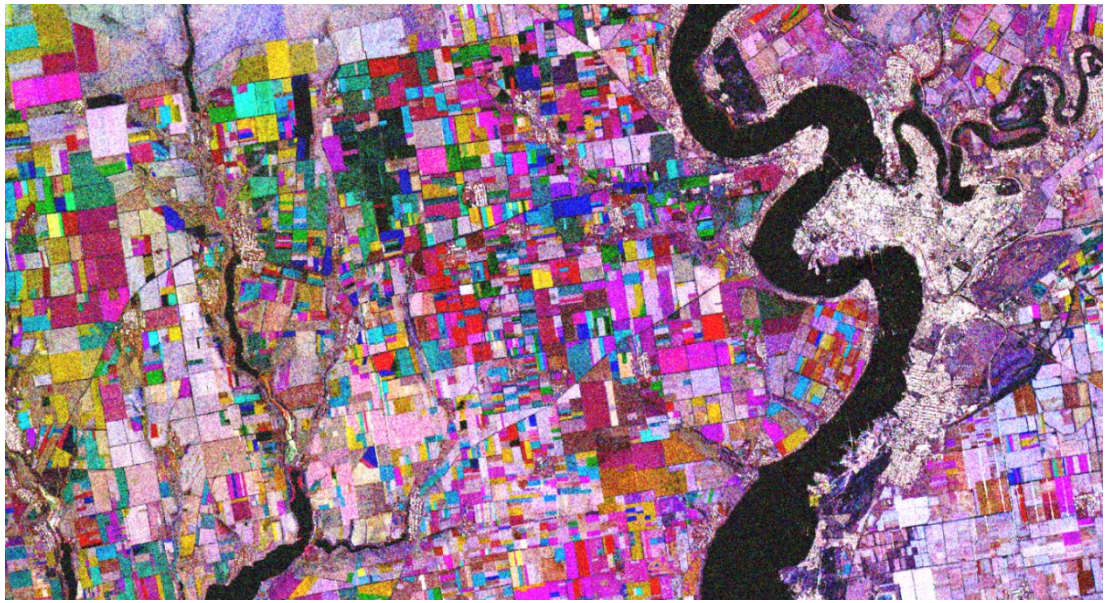
- As part of the ESA „QA4EO – Quality Assurance for Earth Observation“ service led by Telespazio VEGA UK
  - ESRIN are looking into renewing their On-The-Fly processors for heritage data
- This includes ENVISAT ASAR and ERS-1 SAR Level-0 processors (our scope)
- Interactive processors potentially a game-changer for accessing heritage data and performing reprocessing campaigns
  - Sub-second level
  - First results very promising
- Full OTF coverage (ENVISAT+ERS) expected Q1/2024
- **Open-source!**



# Use case: C-SCALE/EO4UA

- Copernicus eoSC AnaLytics Engine (C-SCALE) – a H2020 activity with the aim to federate European EO infrastructure services, such as the Copernicus DIAS and others

- ALUs is the basis for a C-SCALE use case named **SAROnTheFly**
  - Part of the EO4UA initiative
    - Production of ARD over Ukraine
    - Monitor agricultural activity
    - Year-long coherence time-series
  - Deployment in a cloud environment
  - Investigation of data transfer latencies
  - CREODIAS CARD S1 chains as benchmark
  - Coherence: **11 seconds per subswath**



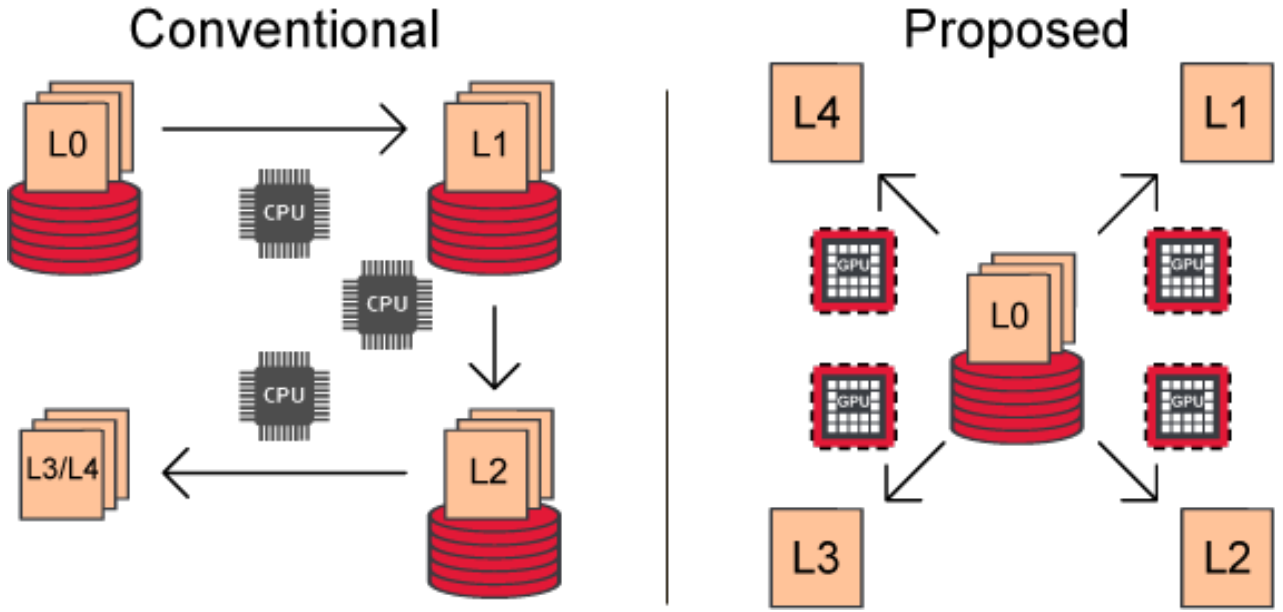
RGB composite of three S1 coherence products produced by ALUs around Mykolaiv, UA
(c) European Commission, Joint Research Centre. Contains modified Copernicus Sentinel information 2022

# **Opportunity enabled:** End-to-end processing from Level-0 -> New approach to data storage and dissemination

Since higher-level products can be generated in (**milli)seconds**, “on-the-fly” processing could be justified directly from raw data instead of storing intermediate products

Due to very fast computations,
smart cache mechanism could generate
and preserve files based on:

- Most requested products
- Acquisitions proximity (time and/or space)



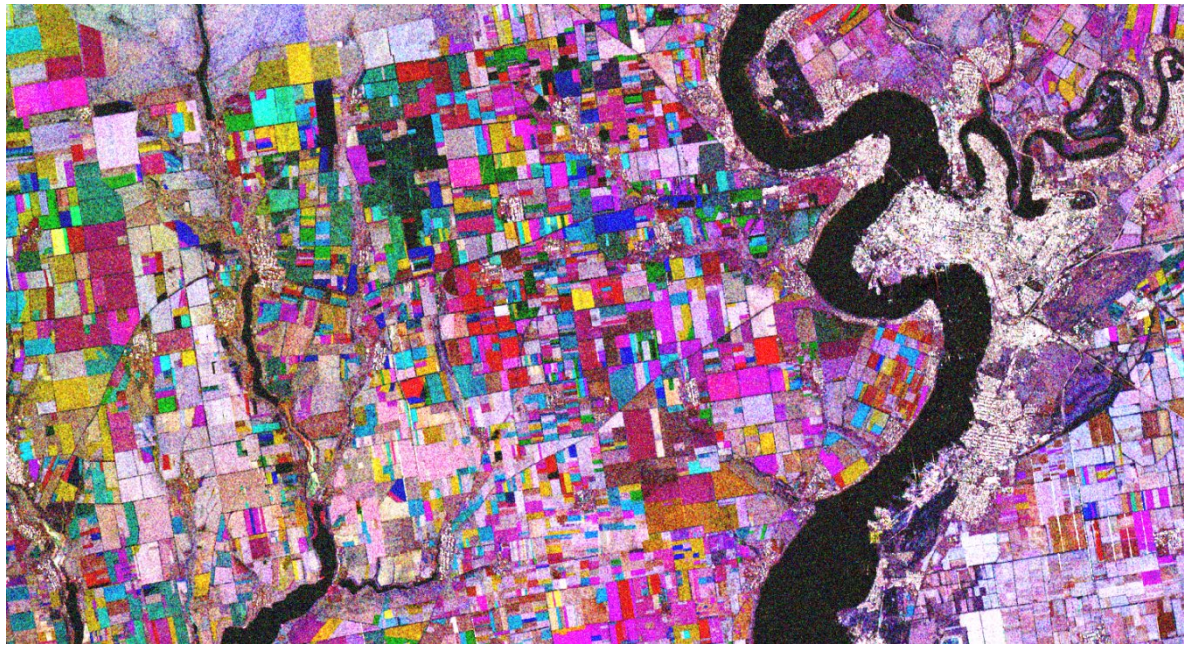

**<u>Benefits:</u>** storage costs reduction, faster time to products, less overhead in processing

**No need for reprocessing campaigns. Products are always created by the latest processor!**

# Thank You!

Martin Jüssi
martin.jussi@cgi.com

https://github.com/cgi-estonia-space/ALUs



RGB composite of three S1 coherence products; Produced by ALUs around Mykolaiv, UA
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ALUs

GPU-Accelerated
EO processing toolbox by CGI