OGC Earth Observation Applications Pilot

Summary Engineering Report

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OGC Public Engineering Report

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Table of Contents

Chapter 1. Subject

This Engineering Report (ER) summarizes the main achievements of the OGC Innovation Program initiative Earth Observation Applications Pilot, conducted between December 2019 and July 2020.

Chapter 2. Executive Summary

This Engineering Report (ER) summarizes the main achievements of the OGC Innovation Program initiative OGC Earth Observation Applications Pilot, conducted between December 2019 and July 2020. The pilot explored an Earth Observation Application software architecture that was developed in OGC Testbeds 13-15. The architecture allows the deployment and execution of externally developed applications on Earth Observation (EO) data and processing platforms. The architecture is essentially based on three major components:

- Execution Management Service (EMS): This component provides a RESTful interface (defined using OpenAPI) to register applications and build workflows from registered applications. The EMS selects the appropriate ADES platform to execute the processes based on the runtime input parameters (close to the data).
- Application Deployment and Execution Service (ADES): This component allows deployment, discovery, and execution of applications or processing of quoting requests.
- Applications are delivered in the form of Docker images along with corresponding metadata called an Application Package (AP). The application package provides all information for deployment and execution of an application.

The pilot demonstrated that the interoperability arrangements developed and documented in OGC Innovation Program initiatives Testbed 13, 14 and 15 provide a solid starting point for maturity tests within operational platforms. Additional arrangements and more detailed definitions have been developed during the pilot that now allow deployment and execution of an application on various platforms with minimal adaptions.

The pilot produced very valuable results. It confirmed the general approach to use Docker for application packaging and HTTP Web APIs or Web Services for application handling and execution. It defined application patterns based on data inputs/outputs, confirmed the role of the Common Workflow Language (CWL) for application description, execution, and workflow building; and recommends the usage of the SpatioTemporal Asset Catalog (STAC) as a data manifest for application inputs and outputs.

2.1. Objectives

The Earth Observations Applications Pilot explored and evaluated the maturity of the Earth Observation Applications architecture. The architecture has been developed in various OGC Innovation Program initiatives over the last three years. This pilot now explored everything in operational environments.

2.2. Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Contacts

Name	Organization	Role
Ingo Simonis	OGC	Editor

2.3. Foreword

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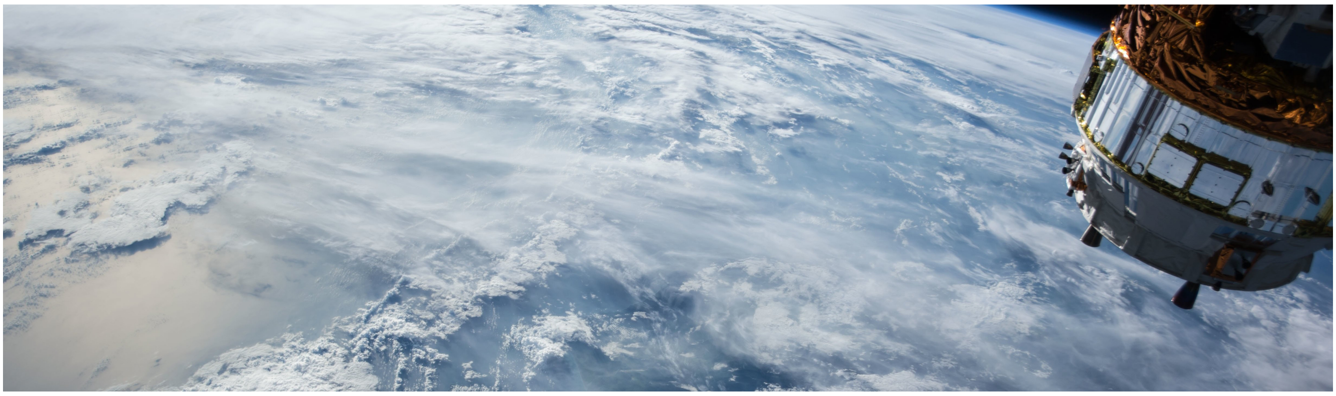
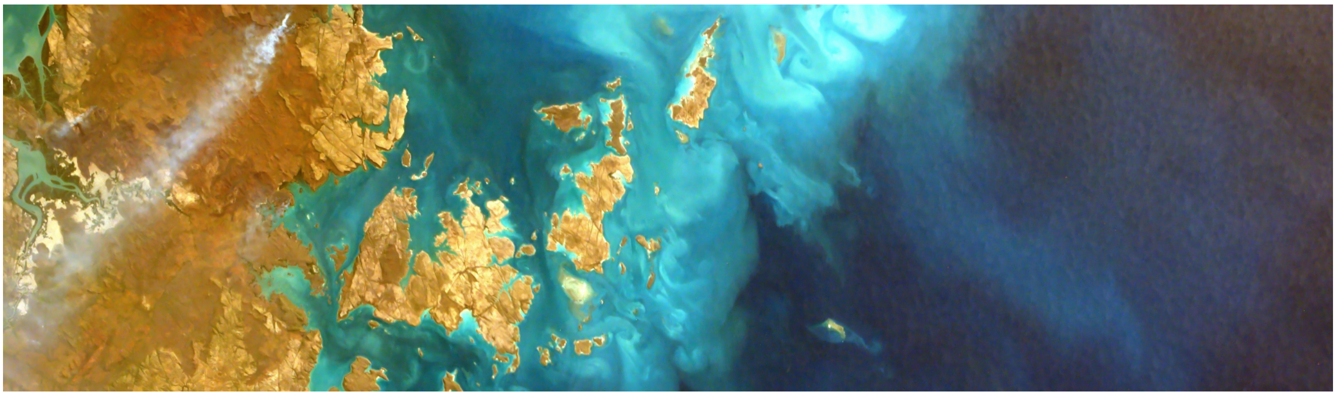
Chapter 3. Introduction

This Engineering Report (ER) summarizes the main achievements of the OGC Innovation Program initiative Earth Observation Applications Pilot, conducted between December 2019 and July 2020. The Call for Participation was published in December 2019. The actual execution phase lasted from January to July 2020.



The growing volume and wide availability of Earth Observation data together with affordable cloud computing resources creates an opportunity for the wide adoption and use of Earth Observation (EO) data in all fields of our society. At the same time, petabyte-sized distributed data storages, long lists of complex data products, and continuously evolving processing chains, tools, and models pose major challenges for software architects. Since it is clear that the classic linear, one-directional model of "data provider", download, "data consumer", "analysis and representation" had served its time in the context of EO data processing, software architects encapsulate application logic into executable units that can be deployed and executed on platforms. Platforms provide all pieces required by application developers "as a service", i.e. Data-as-a-Service, Storage-as-a-Service, Computing-as-a-Service, Infrastructure-as-a-Service etc. Thus, platforms allow the application developers to concentrate on their core business. Platforms reduce the time to market, reduce investment costs, and open access to wide ranges of potential customers.



The Earth Observation Applications architecture is fully aligned with this paradigm shift from “bring the data to the user” (i.e. user downloads data locally) to “bring the user to the data” (i.e. move user exploitation to hosted environments with collocated computing and storage). The pilot explored several operational platforms that provide infrastructure, data, computing and software as a service. These platforms allow scientific and value-adding activities and generate targeted outputs for end-users.

3.1. Background

OGC activities in Testbed-13, Testbed-14, and Testbed-15 initiated the development of an architecture to allow the ad-hoc deployment and execution of applications close to the physical location of the source data with the goal to minimize data transfer between data repositories and application processes (see References). The various Testbeds produced several draft specifications, which addressed both application description and discovery, APIs for deployment, execution, and result access, billing and quotation models, as well as specifications for service chaining and workflow building.

In summary, the architecture fulfils the following requirements:

- Decouple application developers from platform operators from application consumers
- Allow application developers to make their applications available on any number of platforms with minimal modifications
- Allow application developers to focus on application development by minimizing platform specifics and particularities
- Enable platforms to support any type of EO application that works on platform or external data
- Allow chaining of applications to build complex workflows

The following figure provides a high-level view on the resulting setup. Application developers on the left side develop their application and make it available in the form of a Docker container image. The developers register their application in the platform and thus make it available to all users of that platform. At the same time, application developers can discover other applications and integrate these into workflows, where the output of one application serve as input into the next application.

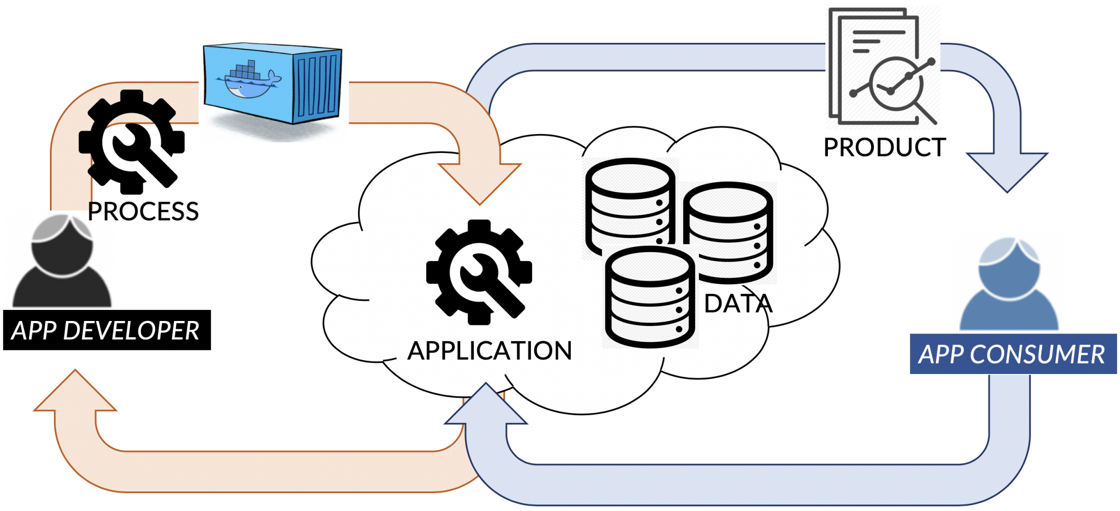


Figure 1. Application developers and application consumers interacting with the cloud platform

Platform providers offer APIs that allow both, application developers as well as application consumers to interact with the platform. All interaction, including application registration, deployment, and execution requests, are supported by a Web Processing Service (WPS) interface or an interface conforming to the OGC API - Processes candidate standard. To differentiate the various interactions, two logical services have been defined: The Execution Management Service (EMS), and the Application Development and Execution Service (ADES).

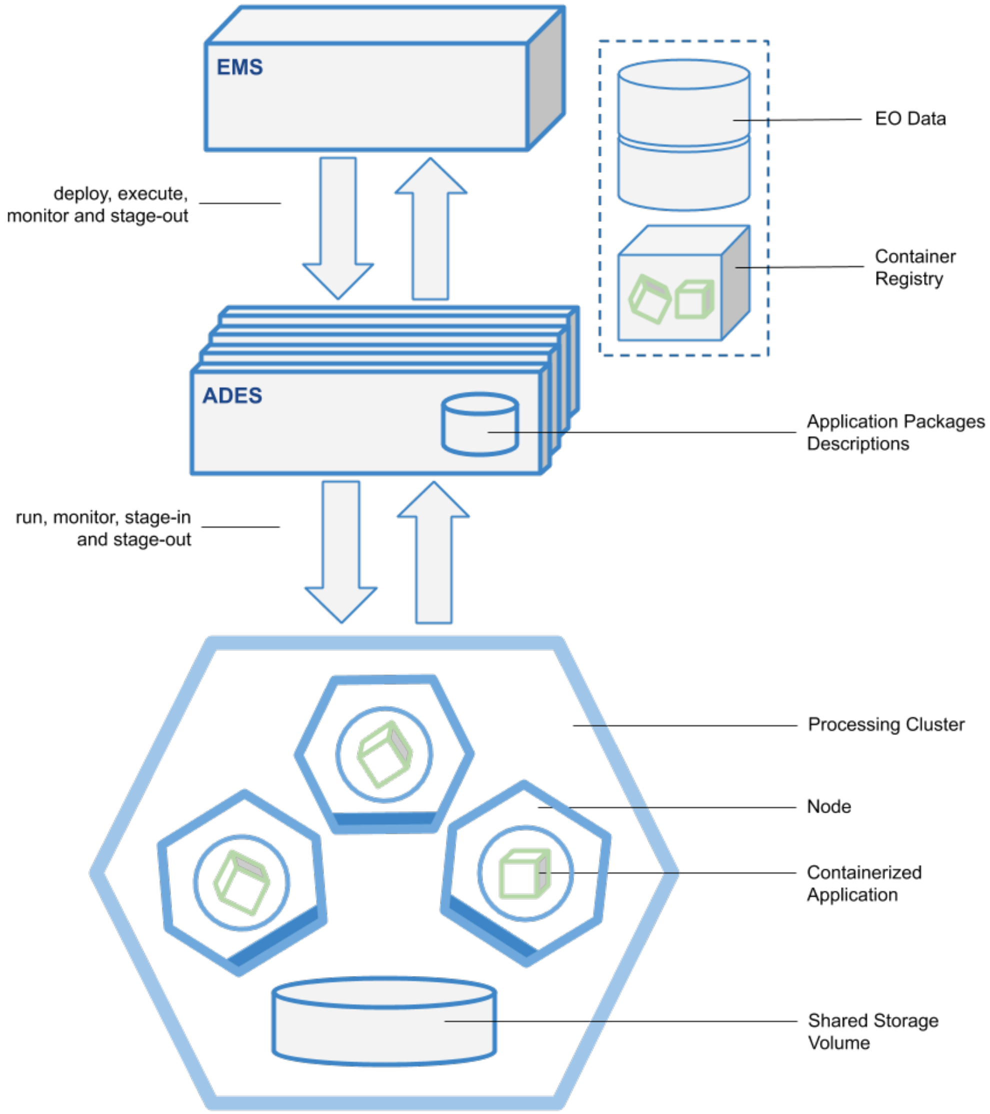


Figure 2. Platform High-level Architecture (source: Terradue)

Together, both APIs provide all functionality necessary to handle the different types of interactions between application developers and the platform (mostly registration and update of applications) and application consumers and the platform (mostly application discovery and execution).

The Terradue report provides a good introduction into ADES and EMS, as do the reports by CRIM and Spacebel.

3.2. Results and Videos

All results have been captured in detailed Engineering Reports. Each participant delivered a report that documents all detail about the various applications and platforms, describes interoperability challenges, and recommended solutions.

In addition to the Engineering Reports, all participants produced promotional videos that are available on the OGC Youtube channel:

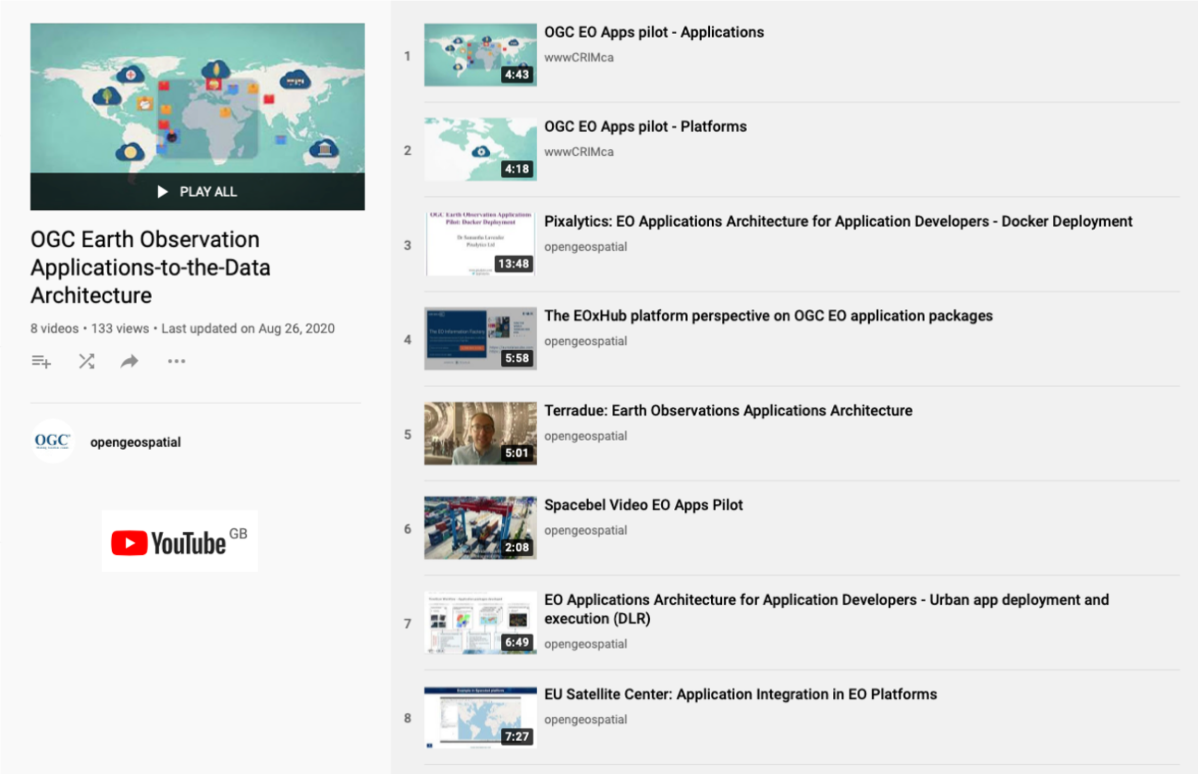


Figure 3. OGC Youtube Channel: https://www.youtube.com/playlist?list=PLQsQNjNIDU84GcHzFzUCFGOpAZukuRcTm

Chapter 4. Participants

The following table lists all organizations that participated in the pilot.

Table 1. List of participants and corresponding Engineering Reports

Organization	Role	Engineering Report
Computer Research Institute of Montreal (CRIM), Canada	Applications + Platform	http://docs.opengeospatial.org/per/20-045.html
European Union Satellite Centre, Spain	Applications	http://docs.opengeospatial.org/per/20-038.html
EOX Consortium: EOX, Austria; DLR, Germany, University of Western Timisoara, Romania; Terrasigna, Romania; Sinergise, Slovenia	Applications + Platform	http://docs.opengeospatial.org/per/20-043.html
Pixalytics Ltd, UK	Applications	http://docs.opengeospatial.org/per/20-037.html
Spacebel s.a., Belgium	Platform	http://docs.opengeospatial.org/per/20-034.html
Terradue Srl	Applications + Platform	http://docs.opengeospatial.org/per/20-042.html
European Space Agency	Sponsor + Applications	-
Natural Resources Canada	Sponsor + Platforms	-
Telespazio VEGA UK Ltd	Sponsor (on behalf of the European Space Agency (ESA))	-
RHEA	Sponsor (on behalf of the European Space Agency (ESA))	-

Chapter 5. Results

The pilot explored the EO Applications Architecture in high detail. The following paragraphs discuss the main findings, as reported throughout the detailed reports as listed in participants listing. Additional insights are provided by ESA/Rhea. Details about the various applications and platforms are provided in the individual reports. Overall, there was strong agreement that the high-level approach with *Application Package*, *Execution Management Service*, and *Application Deployment and Execution Service* is a solid approach to realize an efficient Earth Observation Applications Architecture. Combined with standardized Web APIs and container solutions, the Earth Observation Applications Architecture allows for rapid, cost efficient deployment of the key components and high levels of interoperability across platforms and applications. The stringent usage of open standards reduces adaptation costs for application developers, because only minimal changes need to be applied to applications for deployment on various platforms.

More precisely, the following advantages of the standards-based EO Applications Architecture compared to either in-house or non-standards based approaches have been named repeatedly:

- **Flexibility**: It has been demonstrated that the same application can be deployed in different platforms without major changes. Only some minor changes in the application descriptors had to be applied. The different platforms offered various application deployment schemas: Spacebel offered a web-based user-friendly (GUI) that allowed participants to deploy, run, and monitor their own app autonomously. CRIM provided a command line interface (CLI) to their platform where a more expert user can deploy and interact with the platform. Both EOX and Terradue handled the deployment and execution of applications without offering user interaction interfaces. All three approaches are valid and resulted in different levels of user experiences.
- **Robustness**: The pilot explored two types of interface designs. Some implementations of the OGC Web Processing Service (WPS) followed the Service Oriented Architecture (SOA) design, whereas others implemented the emerging OGC API-Process specifications. It has been demonstrated that the underlying principle does not cause any substantial modifications to the overall design. Thus, the transition path from SOA-based WPS to OGC API based implementations is a rather natural process. It has most consequences on implementation efficiency and cost, which are substantially reduced with OGC API-based approaches.
- **Scalability**: By deploying on a platform, it is possible to make use of the cloud-based advantages offered by the platform: Easy up-scaling and simultaneous execution of multiple processes.
- **Cost-efficiency**: Applications are deployed and executed on a per-use basis, thus do not cause hardware costs when not in use.
- **Ready-to-use-services**: Moving to a cloud-platform allows developers to focus on the actual EO application while benefiting from the additional offerings from the platform. These include, but are not limited to:
    - Authentication
    - Accounting
    - User management
    - Processing models

- **Application Performance**: Processes are deployed and executed physically close to the data: Applications had been executed successfully with data available directly on the platforms and data selection in interactive modes.
- **Focus**: EO application developers can focus exclusively on the application itself: Moving the application to the platform allows the EO Applications developers to focus on the implementation and integration of the processing algorithm, rather than devoting time and effort in putting in place an infrastructure and all its building blocks.

Experiences show that the deployment and execution of applications on remote platforms was not a smooth experience from the start of the pilot, but improved substantially once additional interoperability arrangements had been set. Still, the successful execution of an application sometimes failed due to missing input data (data not offered by platform) or simply stumbled over non-supported URL characters. All these experiences show the necessary level of detail in future standards to guarantee interoperability between application developers and platform providers. Selected results, usually shared across most participants, are documented as follows.

5.1. Open Standards

The pilot was executed during the transition phase from the Service Oriented Architecture period towards the modern Web APIs. The pilot has demonstrated that the transition is in fact very smooth. Though it is essential to use a limited set of open standards to achieve interoperability, the choice of JSON encodings vs. XML payloads and consistent usage of REST principles vs. SOA-remote procedure calls has effects on implementation costs, but less on achievable interoperability.

On a more detailed level, the pilot has proven that the path towards a harmonized set of Web API building blocks rather than a service-oriented concept with disjunct functionality bundled in a concrete service is very promising. It needs to be implemented carefully with keeping both interface design as well as resources representation and serialization in mind. It needs to be avoided that a variety of resource models will have negative effects on the level of interoperability and thus perceived performance from both application developers' and application consumers' perspectives.

It has been demonstrated that open standards are required for all steps of the process. This is in particular true for the platform-internal processes of data provisioning and result handling and their respective discovery. For application developers, these steps have the highest risk for interoperability issues and thus unsuccessful application execution. Platforms shall provide open standards based discovery and data access mechanisms independently of their internal data storage and management system. Only then application developers can deploy their apps on multiple platforms without adapting these crucial parts of their applications from one platform to the next.

5.2. Application Patterns

General agreement was achieved on the definitions of data processing design patterns.

The data driven application fan-in patterns refers to the execution of a data processing function that aggregates several input products. The platform application accesses a list of input products, retrieves and proceeds with the stage-in of the products making them available to the application execution block.

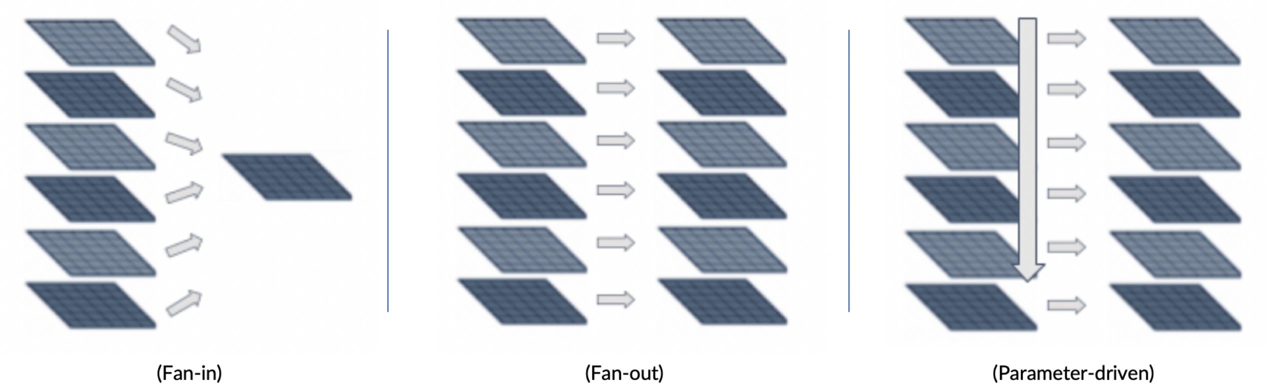


Figure 4. Application data-driven design patterns (source:Terradue)

The data driven application fan-out patterns refers to the execution of a data processing function that processes concurrently several products generating independent output for each input. The platform application loops from a list of input products, retrieves and proceeds with the stage-in of the individual products making them available to the application execution block. The platform can apply different strategies to parallelize the execution of each individual product.

Parameter-driven data flows permit cyclic, systematic retrieval of selected groups of input products between selected the parameter intervals (e.g. start and end dates). In this scenario, the parameter interval acts as a step function, determining how the next batch of products is to be selected.

5.3. Application Package and CWL

The Application Package (AP) contains all information necessary for application platforms to deploy and execute the application correctly. These include information about the application process itself, input and output requirements, dependencies, or hardware requirements. There was common agreement on the items that the AP needs to include, but some discussion about its serialization format. Overall, there was a clear tendency towards the adoption of the Common Workflow Language (CWL) for that purpose. Only Spacebel emphasized the need for complementary approaches. Further work shall identify the essential CWL elements and clarify the use of the CWL specifications Command Line Tool and Workflow Description. See Terradue's report for a mapping of CWL elements to the WPS data model and CWL element usage in general. EOX on the other hand reported a necessary use of heuristics for properly translating CWL types to the corresponding WPS types and vice versa. There was common agreement to add hardware parameters to the Application Package.

Further on, supporting a well-established declarative format like CWL to define application workflows gives platform providers the possibility to leverage a wide ecosystem of existing tools. These can be used by the platforms themselves as well as offered to application developers (e.g. to compose workflows visually) or to application consumers (e.g. to monitor workflow execution).

5.4. ADES and EMS Deployment

CRIM successfully deployed the same core ADES-EMS implementation in three different sites, PBC, EODMS and CRIM and reported only minor adaptation requirements (mostly to deal with different security environments and settings). The use of an application profile to register external WPS proves to be a rather simple, but useful tool to build a federated cloud.

5.5. High-level Architecture

The separation of roles between EMS and ADES is seen as beneficial, the former being closer to thematic platforms with cross-cutting concerns, the latter located near mission data, or more specifically to the ground segment.

5.6. Data Discovery

Testbed-14 introduced the OpenSearch API for selecting the EO data inputs submitted to the process. Experiences have shown that, despite some inconsistencies among OpenSearch implementations, OpenSearch provides the most promising approach to handle data discovery aspects across platforms. This is particularly important as different platforms use different identifiers for the same product and make the data available in different formats (zipped, unzipped, folder, tar-ball, SAFE etc.).

5.7. SpatioTemporal Asset Catalog (STAC)

The data flow management plays a prominent role in this architecture. Most applications do not bring their own data, but require data being made available by the platform. In addition, applications produce a variety of output data as result. Thus, it is essential to describe both the inputs and outputs of an application in full detail. In the pilot, it turned out that data flow management by using local catalogues encoded in compliance with the SpatioTemporal Asset Catalog (STAC) specification as a data manifest for application inputs and outputs is a very promising approach. STAC, a profile of OGC API-Features and thus based on open standards, blends in very well with the set OGC API building blocks and design patterns.

For a detailed discussion of STAC and its integration with CWL see Terradue's report. Spacebel argued that STAC would introduce additional, unnecessary conventions that that could be avoided by using OGC data access services such as OGC Coverage (WCS) and Feature (WFS) Services or their OGC API counterparts.

5.8. Container Format

There is common agreement that Docker is the state-of-the-art container format to be used in the EO Applications Architecture. Its maturity, widespread use, and the numerous resources and examples make Docker the recommended solution. Experiences differ in terms of optimal Docker image handling, which led Spacebel to run experiments with server-side production of Docker images; mostly triggered by security concerns (see Spacebel report).

5.9. Quotation and Billing

CRIM noted that producing accurate quotations for workflows will be a very difficult challenge, while quoting for applications in simple federations is probably feasible.

5.10. Workflows

Experiments with CWL workflows have been successfully conducted.

5.11. Graphical User Interfaces

As has been shown that the availability of GUIs, ideally paired with directly accessible log files, is an essential ease-of-use cornerstone for application developers.

5.12. Kubernetes Cluster Support

Although Earth Observation platforms are typically installed in a Cloud infrastructure, the implementations in previous OGC Testbeds had limited the execution on a single node machine. This considerably restricts the system scalability and computing possibilities. Kubernetes has become the de facto standard for deploying containerized applications in private and public cloud environments. This pilot experimented with Kubernetes clusters and explored the options to execute atomic tasks in parallel. Experiences have been very promising so far. The automated scalability of the cluster nodes allows to extend the infrastructure by provisioning additional machines when multiple processes are requested or when single requests can be split into parallel tasks. This approach allows to execute a very high number of concurrent jobs and exploits advantages of cloud platforms.

Chapter 6. Future Work

The following general recommendations for future work items have been made. Please consult the individual reports for further details.

6.1. APIs

OGC API-Processes

Align the architecture with the emerging OGC API-Processes, which will complement the WPS standard in the near future.

Standardize ADES and EMS

Conformance classes for ADES API shall be standardized.

6.2. Application Package Description and Workflow Building

CWL and Application Packages

Define subsets of CWL that shall be supported by all platforms to ensure consistent experiences for application developers. Produce an *OGC Best Practice* document to document the use of Common Workflow Language for application packages. The proposed Best Practice document should cater for the various application design patterns discussed in this pilot and provide guidelines for automated generation of CWL (e.g. from Jupyter Notebooks).

In addition to CWL, other approaches shall be reviewed again, such as a simple command line syntax to describe the base command and corresponding arguments for Docker container execution.

The usage of different CWL versions may lead to issues in the future and should be addressed.

Workflows

More tests are required to better support application workflows running in multiple platforms. In order to build a federated cloud, these tests have to run regularly, in a structured and systemic fashion.

6.3. Application Handling

Logs, Status, Progress, and Error Reports

Currently, platforms provide individual settings for reporting progress, management of logs, and handling of errors. These should be further harmonized.

6.4. Data

Data discovery and access is among the biggest challenges for application developers. All platforms use slightly different approaches. A consistent usage of data access services that are offered by all platforms might facilitate this problem.

OpenSearch and Data Discovery

OpenSearch has been reported as both being very powerful for data discovery, but still not fully consistent across the various platforms. Here, further tests and derived standards shall clarify both OpenSearch usage and provisioning of results.

Metadata

Extend the set of provided metadata to allow platforms to describe their hard- and software capabilities. Explore how metadata can be generated more automatically rather than being based on application developer inputs.

From the application perspective, it shall be investigated how the application package can register the supported input/output formats and file access mechanisms (e.g. direct access S3, http(s), GDAL virtual file systems, etc.), so that platforms can choose the optimal match between platform and application and potentially skip staging in data or outright reject the package if no compatible format is available.

Use of Data Access Services and Datacubes

The use of services for data access, such as the OGC Web Coverage Service, have not been investigated as most platforms provide their data for processing as files staged into the application environment. Thus, it is still open whether application packages should make use of web services for data access or rely on the data provided by each platform.

Semantics, Correlations, and Constraints

Further explore strong semantics and the usage of standard compliant taxonomies for attribute names and values. Explore parameter correlations and constraints can be handled.

STAC

Produce an *OGC Best Practice* document that discusses data flow management using STAC local catalogues as the input and output manifests between the ADES and the hosted application and between ADES and EMS.

6.5. Docker

Explore Docker build pipeline

Explore modified Docker build pipelines to solve concerns with respect to Docker image access control, security enforcement, and version control. Docker images could be built on the ADES side rather than by the application developer.

Docker Repositories

In most cases, Docker images have been stored in public repositories. The usage of private repositories shall be standardized.

6.6. General Guidelines and Performance

Tutorials

Tutorials should be developed as lots of development follows examples, in support of standards and specifications.

Parallelization

Further work is required to explore the parallelization and other application performance drivers. These include RAM optimization and GPU processing.

Appendix A: References

The following documents are referenced in this document.

- OGC Testbed initiatives that developed parts of the Earth Observation Applications Architecture
  - OGC Testbed-13: EP Application Package Engineering Report (17-023)
  - OGC Testbed-13: Application Deployment and Execution Service Engineering Report (17-024)
  - OGC Testbed-13: Cloud Engineering Report (17-035)
  - OGC Testbed-14: Application Package Engineering Report (18-049r1)
  - OGC Testbed-14: ADES & EMS Results and Best Practices Engineering Report (18-050r1)
  - OGC Testbed-15: Catalogue and Discovery Engineering Report (19-020r1)
- Relevant OGC Standards, Extensions, and Profiles
  - OGC 06-121r9, OGC® Web Services Common Standard
  - OGC 14-065r2, OGC Web Processing Service 2.0.2 Interface Standard Corrigendum 2, 2018
  - OGC 13-026r8, OGC OpenSearch Extension for Earth Observation 1.0, 2016
  - OGC 10-032r8, OGC OpenSearch Geo and Time Extensions 1.0.0, 2014
  - OGC 10-157r4, OGC Earth Observation Metadata profile of Observations & Measurements 1.1, 2014
  - OGC 14-055r2, OGC OWS Context GeoJSON Encoding Standard, 1.0, 2017
  - OGC 17-069r3, OGC API - Features - Part 1: Core, 1.0, 2019
- External specifications
  - Commonwl.org: Common Workflow Language Specifications, v1.0.2
  - Commonwl.org: Common Workflow Language Specifications, v1.1
  - STAC: SpatioTemporal Asset Catalogs v1.0.0

Appendix B: Terms and definitions

B.1. Technical terms

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard OGC 06-121r9 shall apply. In addition, the following terms and definitions apply.

- **Container**

  A standardized unit of software (Docker).

- **OpenAPI Document**

  A document (or set of documents) that defines or describes an API. An OpenAPI definition uses and conforms to the OpenAPI Specification [OpenAPI]

- **OpenSearch**

  Draft specification for web search syndication, originating from Amazon's A9 project and given a corresponding interface binding by the OASIS Search Web Services working group.

- **Service interface**

  Shared boundary between an automated system or human being and another automated system or human being

- **Workflow**

  Automation of a process, in whole or part, during which electronic documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules (source ISO 12651-2:2014)

B.2. Abbreviated terms

- ADES Application Deployment and Execution Service
- AOI Area Of Interest
- AP Application Package
- BPEL Business Process Execution Language
- CFP Call For Participation
- CWL Common Workflow Language
- DWG Domain Working Group
- EMS Execution Management Service
- EO Earth Observation
- EP Exploitation Platform
- ER Engineering Report
- ESA European Space Agency

- GUI Graphical User Interface
- JSON JavaScript Object Notation
- MEP Mission Exploitation Platform
- OWC OWS Context
- REST REpresentational State Transfer
- TEP Thematic Exploitation Platform
- TIE Technology Integration Experiments
- TOI Time Of Interest
- UI User Interface
- URI Uniform Resource Identifier
- URL Uniform Resource Locator
- VM Virtual Machine
- WKT Well-Known Text
- WCS Web Coverage Service
- WFS Web Feature Service
- WPS Web Processing Service
- WPST Web Processing Service Transactional

Appendix C: Revision History

Table 2. Revision History

Date	Editor	Release	Primary clauses modified	Descriptions
August 10, 2020	I. Simonis	1.0	all	initial release
September 14, 2020	I. Simonis	1.1	all	editorial changes