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OASIS: a big data platform for satellite testing

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Abstract:

Airbus Defence and Space (ADS) has developed a big data platform named OASIS for Open Analytic Services for Satellites. Since 2020, this big data platform is in charge of real-time telemetry ingestion, analytics and visualization for a wide and global ADS Satellite Fleet Supervision. It is used all along the satellite lifetime, from design and test to in-orbit support. The supervised fleet is now composed of 55 satellites and the platform aggregates 300Gb per day.

In particular, OASIS is used in the satellite Assembly Integration and Test (AIT) context, where the final satellites platforms and payloads are assembled and validated on various test benches. The OASIS capabilities to store, index, analyze test data, alert in case of anomaly during tests are vital.

To cover the challenging platform requirements (scalability, high availability, data persistency, security, easy maintenance), OASIS is virtualized on a cloud environment. The architecture offers COTS as well as internal big data analysis applications. Combined with the huge telemetry data available on the platform, they intend to offer Artificial Intelligence (AI) solutions, such as automatic failure detection and predictive maintenance. They represent a huge benefit especially for testing applications, where automatization is the key of future ways of working.

Key words: Satellites, real-time telemetry, Assembly Integration and Test, Artificial Intelligence, Big Data.

Glossary

ADS: Airbus Defence & Space

AI: Artificial Intelligence

AIT: Assembly Integration and Tests

OASIS: Open Analytic Services for Satellites

TM: TeleMetry

TC: TeleCommand

Introduction

Since its entry into service in 2020, the OASIS platform is ingesting, storing, and making available test & operational satellite data for business and engineering exploitation purposes. Today, the OASIS usage is mainly ADS centric. In particular, the platform is a key enabler of satellite testing in the AIT context, from simple data exploration to validation checks automatization and more complex investigation. Decision-making solutions built on Artificial Intelligence capacities are part of the next OASIS challenges. Some AIT use cases involving automatic anomaly detection are currently under development, taking advantage of the data accessibility on the platform and of its computation capabilities.

OASIS platform presentation

The OASIS big data platform creation is part of the global ADS digital transformation plan. By gathering all sort of satellite data, it enables data continuity and breaks data silos within the company. By moving to a data centric way of working, it increases productivity and improves Airbus efficiency. By offering new digital services, it increases customer satisfaction and business outcomes. By creating new analytics products, it enables the company to target larger and more complex systems, such as satellite constellations. For all these reasons, the OASIS adventure has been launched and pushed forward by ADS since 2018 and the platform is in service since June 2020.

OASIS is based on four strong innovation levers: data continuity & persistence, standardized data analytics toolset, optimized data visualization and centralized product

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lifecycle. To achieve these innovation objectives, the OASIS solution is relying on a centralized platform architecture, which supports every operation on satellite data: ingestion, storage, visualization and exploitation. The platform is used all along the satellite lifetime, from design and test to in-orbit support, gathering a large range of different space data. In particular, real-time telemetry from 55 under-development or in-orbit satellites is daily supervised thanks to the OASIS platform, which aggregates 300Gb per day.

The figure 1 illustrates the OASIS platform situation and data exchanges within ADS and with external interfaces.

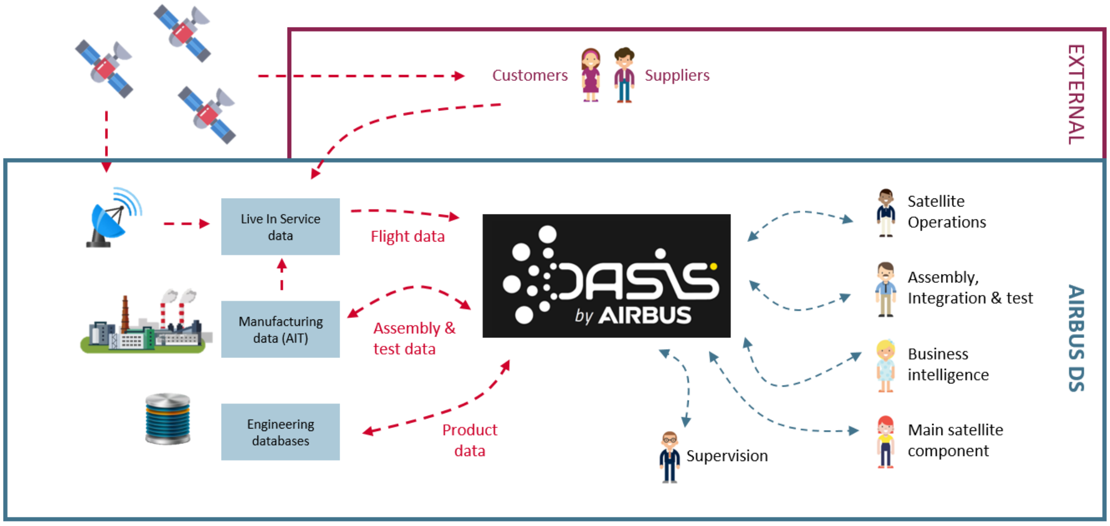

Fig. 1. OASIS platform situation plan.

Within the ADS ecosystem, the OASIS platform is receiving multiple satellite data, mainly satellite telemetries (TM), but also satellite telecommands (TC) and events logs. These various data, either simulated or real ones, come from different data sources all along the satellite lifecycle:

- Product data from engineering databases,
- Test data from ground manufacturing databases and test benches,
- Flight data from live in service data centres. Flight data are either real-time telemetry from in-orbit satellites sensors, or business data from external customers and suppliers.

Different ADS users have access to the platform. Their data usage (from simple visualisation to deeper analysis) is depending on their needs, roles and responsibilities. In-flight satellite operators, Assembly-Integration-Test (AIT) engineers, development engineers, marketing managers… are typical OASIS users. Their access to OASIS is finely managed so that their user experience is maximized and the platform & data security is ensured.

The OASIS platform is supervised daily in order to ensure service continuity to every user.

The data flow between OASIS and its data providers or between OASIS and its data users are not unidirectional. Beyond its data lake role, the platform is indeed also providing data computing and data analytics resources. The resulting added-value is then spread into the entire OASIS community: users as well as data providers can take advantage of this bidirectional communication flow.

Future OASIS improvements will give to the platform a wider dimension, as it will be open to external entities, customers and suppliers. Data governance and right access management are already major OASIS strengths. They will be at the heart of this OASIS next chapter.

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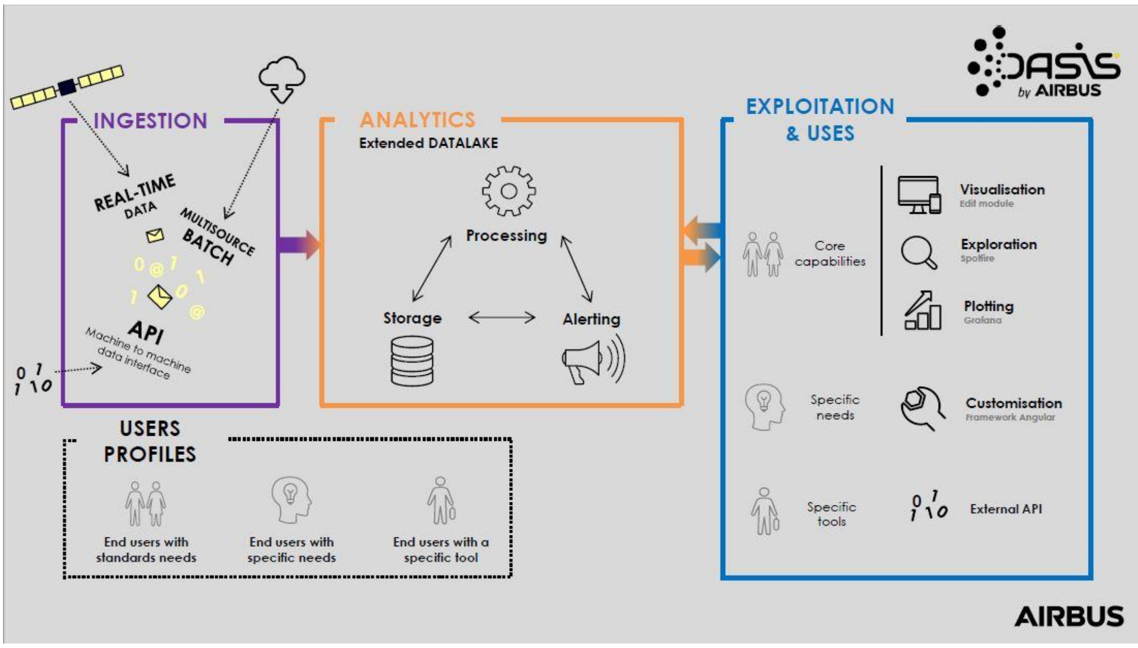

Fig. 2. OASIS three functional pillars.

As shown in figure 2, the OASIS engine is based on three pillars, which are the three main OASIS functionalities:

Ingestion: OASIS is gathering satellite data from different business sources, not only internal (e.g. Airbus ground test data) but also external (e.g. satellite positioning data from the North American Aerospace Defense Command NORAD public source). All ingestions are conducted automatically, in parallel, with multi batch capacities and real-time processing. Application programming Interfaces (APIs) are also used for machine-to-machine communication.

Analytics: once ingested, data are stored on several databases and database instances. The capabilities of this data lake are extended to analytics functionalities, thanks to centralized analytics tools. Once stored, raw data are transformed into gold data, making them ready for consumption. They can be analysed either through basic data analysis algorithms or through elaborated machine learning solutions. Anomalies or specific alerts are then raised to OASIS users when relevant.

Exploitation & uses: OASIS users have the capacity to fully exploit their data through:

- Visualisation and edition: access to the information of interest for the user (in read and/or write mode according to the user's right access) and to digital products via a web based user interface.
- Exploration: Via the Spotfire COTS, data that are not time stamped can be easily manipulated and explored.
- Plotting: Via Grafana, times-series data can be visualised through dedicated dashboards.
- Specific customisation: For specific user needs, the OASIS framework can be customised, so that specific visualisation or analytics requests are satisfied.
- Specific tools: Users can make their own tools compatible with the OASIS platform thanks to dedicated API, taking advantage of the OASIS data management capabilities.

Since its entry into service, the OASIS platform has covered around 20 major use cases. The ones involving AIT will be presented in the following chapter.

AIT use cases

During spacecraft tests and validation phases, OASIS is becoming a true enabler to follow, monitor and validate test sessions.

In its primary role of big data lake, data coming from ground test benches as well as data from the spacecraft itself (being from the service module i.e. platform part, from the communication module i.e. payload part, or from the overall spacecraft) are daily gathered and stored in OASIS platform. AIT engineers

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and architects thus can have access quickly and in one place to numerous data, including TM, TC, events or logs, both from simulations and real tests. It allows then to monitor their tests in real time, but also to perform investigation on dedicated past time periods thanks to archive data stored in the OASIS databases. These monitoring and investigation tasks are enabled using Grafana dashboards, which are thoroughly prepared to display relevant time series data through status or numerical plots.

With its high configurability, the tool offers functionalities, such as transformations to easily compute derived parameters. These transformations are helpful to derive the balancing between battery cells for instance, but also counters to get the exact life duration or total count of equipment activations since beginning of tests.

On top of this, an alerting system allows to get instantly notified by email or text message when an issue occurs. This is particularly very useful in case of loss of the data link between the spacecraft and OASIS, during thermal vacuum test phase (see figure 3).

Fig. 3. Example of OASIS Grafana dashboard for live TM monitoring.

Aside from parameter live monitoring, detailed descriptions of test sessions, named AsRun, are also sent to OASIS by batch multiple times a day. These AsRun files, along with their associated metadata (source, dates, duration, test status to name a few), are collected in structured databases and linked together with related test sessions and satellite.

This relational structure allows to seamlessly explore the 200,000 AsRun today available, as well as other test data, thanks to dedicated Spotfire dashboards, as shown in figure 4.

The wide field of customization possibilities, including multiple visualization types, filters or buttons, enables to quickly navigate among the various data available, and lead to insightful data-driven decisions.

For example, specific dashboards are used to analyze trends of equipment behaviours during the distinct testing phases (ambient, pre-vacuum, hot plateau, etc.) and to compare Airbus test values with respect to tests data coming from manufacturers.

Other dashboards are also being implemented to validate test results, before making them approved and signed off by the different people in charge, namely subsystem architect, AIT leader and even customer.

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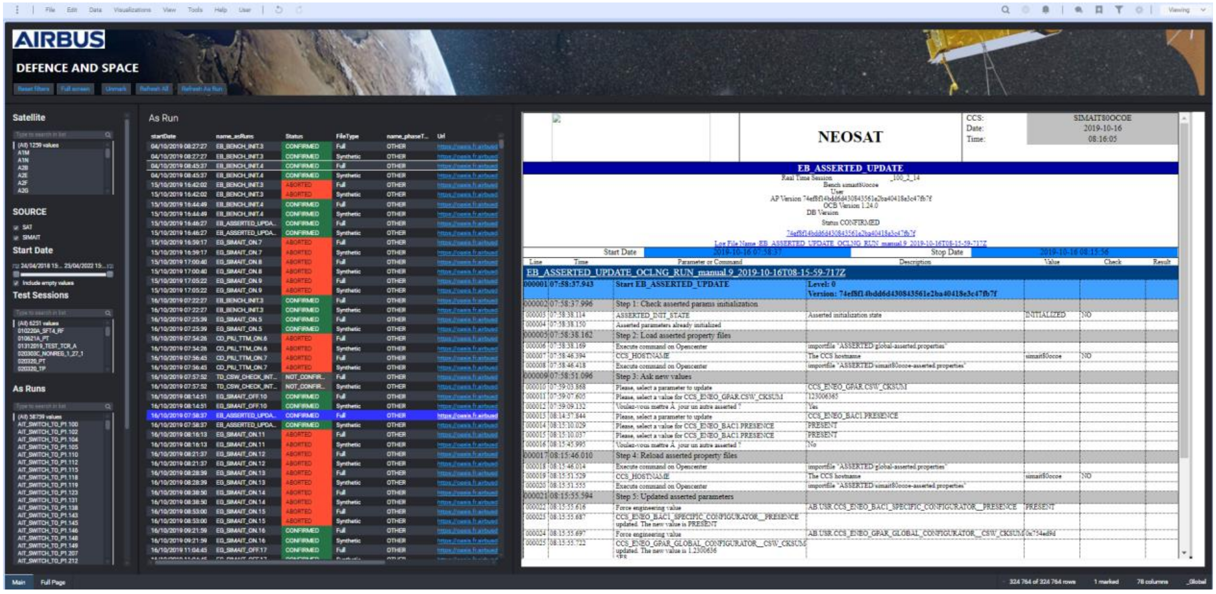

Fig. 4. Example of OASIS Spotfire dashboard for AsRun exploration.

Another important feature more and more used for AIT purposes, is the analytics capability, offered by a development environment made accessible for all the OASIS users. In this perspective, algorithms, from basic analyses to complex and smart solutions, can be developed and deployed so as to leverage the wide amount of data available.

In tests context, processings have been implemented to check that configuration of the spacecraft complies with predefined criteria evaluated within reference periods, either during thermal vacuum or mechanical tests.

Another algorithm has been developed to monitor nominal relay on-off transitions and ensure thermal groups validation. A third one has for objective to verify that all numerical and discrete TM and TC have been successfully tested on all functional chains, so as to demonstrate a proper TM/TC coverage and the end-to-end consistency with spacecraft hardware.

These algorithms can be scheduled to run automatically on a user-defined frequency, but it is also possible to launch them on demand, via a specific widget allowing the user to choose the right satellite, phase, time period, and other input parameters. As displayed in figure 5, this algorithm widget has been specifically designed to offer genericity and flexibility to the users, while keeping simplicity.

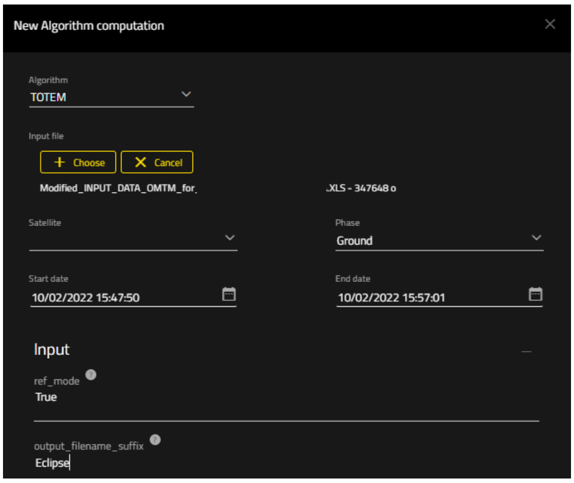

Fig. 5. OASIS Algorithm widget.

Through these various examples, it is shown that exploring and manipulating data is made easily accessible via such digital tools, which is key to ensure good execution and follow-up of spacecraft test phases.

OASIS next challenges: towards decision-making enablers

The OASIS system intends to offer Artificial Intelligence solutions as decision-support enablers. In the ADS ecosystem, possible application fields are numerous:

- In-flight or in-test satellite operators assistance for daily tasks and automated anomaly detection,

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- Automatic reconfiguration proposal in case of failure,
- Failure origin determination assistance for complex and multimodal systems,
- Reconfiguration proposal for complex and multimodal systems,
- Predictive maintenance
- etc.

To address these challenges, the OASIS solution takes advantages of two constituent components of the cloud platform: first, easy access to a large amount of different satellite data and second, easy access to suitable analytics tools.

Today, the supervised in-development, in-test or in-flight satellite fleet is composed of 55 satellites, ingesting continuously their flow of telemetry. Each day, 300 Gb of TM data are thus aggregated by the OASIS platform, and are made available for further analyses. The archived TM of about 20 satellites are also stored since beginning of life. This huge data volume is a strength for the development of AI algorithms, especially for the algorithm training phase.

As seen in previous chapters, OASIS data sources are multiple: real-time or archived, in-flight or on-ground satellite telemetry, manufacturing and test AsRun files, satellite identity cards, etc. All these kinds of data come from Telecommunication satellites, as well as Earth observation, Navigation and Science (ENS) ones. About 800 users can visualise, or even edit, these data, depending naturally on their access permissions. Some key figures on OASIS data are presented in figure 5.

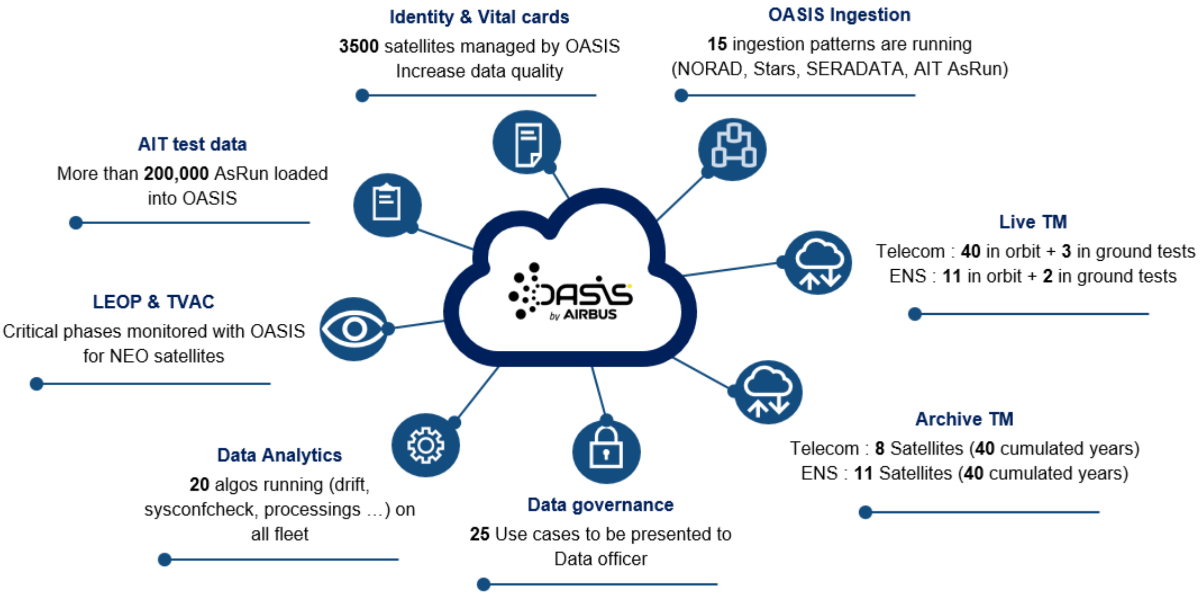

Fig. 5. Key figures on the data aggregated by the OASIS platform.

Despite their diversity, data are ingested, stored and organized the same way (database storage) and using the same technical solutions (InfluxDB for time series data, MongoDB for relational non-time series ones and Hadoop Distributed File System for unstructured and voluminous ones). Doing so, analytics studies can be conducted on every available data, independently of their nature or origin. This enables transversal analyses. An AI algorithm can indeed be developed, trained and validated on a large variety of satellite data, making links between different use cases. Furthermore, one algorithm solution developed in the frame of one particular use case can be easily adapted to another situation, assuming that associated data are available.

The OASIS platform is virtualized on a cloud environment, which offers the following advantages for analytics studies:

- Layer design approach: the OASIS platform architecture is built on a four layers pattern in order to isolate web user interface, data access, data processing and business logic. In that way, main functionalities and in particular analytics functions are independent and can be updated according to specific analytics needs.

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The four layers design approach is presented in figure 6.

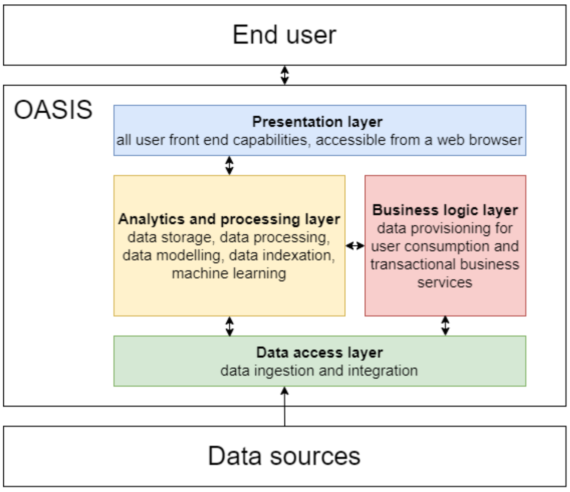

Fig. 6. OASIS high-level functional architecture.

- On-demand resources allocation: the cloud architecture offers the capacity to allocate the right resources amount to each service that is running on the platform, according to its effective needs. The resources allocation is done via Kubernetes resources management.
- Centralized security management: the four layers described above are supported by a set of basic and centralized support functions that ensure data security (through authentication management, data governance process) and data confidentiality.

Huge data amount availability and flexible cloud environment are two key enablers for the development of data-driven solutions on OASIS satellite data. One Airbus AIT use case can illustrate this statement.

For the test campaign of two new Airbus satellites, the OASIS data scientist team is asked to develop a novelty detection solution in order to automatically detect abnormal behaviours in telemetry test data. The ambition is to highlight upstream abnormal events during the test phases thanks to an exploratory methodology. The first version of the study focuses on satellite electrical and power subsystems. This detection intends to assist and complete manual anomaly detection operations, which are time-consuming and, above all, non-thorough.

A non-supervised study based on correlation analysis is performed. The anomaly identification is done without any a-priori on the data (unsupervised study), but using contextual data (i.e. relying on correlation analysis), so that found abnormal behaviours can be explained and, as a future improvement, further reinjected in the algorithm training process.

As in-service data linked to the two targeted satellites is not available on OASIS yet, the algorithm is experimented on substitution data from another similar Airbus satellite with the same avionics, on a few days of recorded telemetry.

After data cleaning, data that are relevant from a functional point of view are selected for the study. The correlation matrix between all TM and all contextual status is then computed. Data are classified (clustered) according to this matrix, and telemetries with similar behaviours are linked together. In that way, the established data groups (clusters) are correlated to known contextual status and can be further analysed. The different clusters are presented in figure 7.

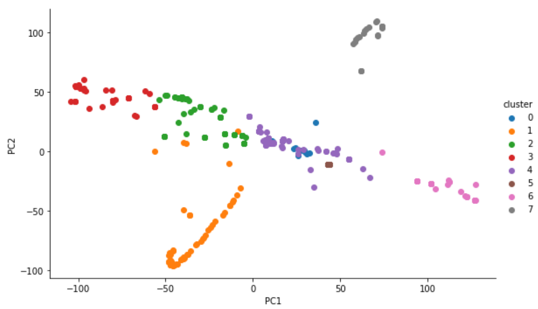

Fig. 7. TM clusters represented according to 2 Principal Components (PC) values.

For each cluster, a “break” detection is then conducted using unsupervised machine learning algorithms. Breaks are dates for which the TM behaviour significantly and abnormally changes. The algorithms give good results in detecting the breaks and in providing context allowing the user to identify their root causes, thanks to the clustering previous operation.

The main advantage of this unsupervised approach is its strong reusability: it can be applied to all TM regardless of the subsystem. An expertise analysis (supervised approach) is nevertheless needed in order to better identify breaks root causes. That is why an hybrid solution taking into account user feedback and strong contextualization is recommended for this AIT use case. This hybrid solution is still under development on the OASIS platform, and will be part of the next platform improvements.

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Conclusion

As digital transformation is becoming widespread in Airbus daily tasks, it is more and more needed to have the right tools to easily manipulate and visualize data, while benefitting from the precious value they can bring. OASIS has been designed to answer this purpose.

Throughout the whole satellite lifecycle, from satellite prospects to end of life, and going through ground tests, launch pad and in-orbit phases, hundreds of gigabytes are daily gathered in this centralized platform for a common objective: towards more and more automation and data-oriented decisions. Given storage, analytics, dashboarding, alerting and other capabilities, a large number of use cases have already proven their values, and in particular in tests and validation context.

One of the main assets of this big data platform is its generic and transverse capability, enabling to create synergies between the diverse business entities. But despite the generic aspect, OASIS also provides a wide range of customization possibilities, to perform automatic data processing and visualization dashboards suitable for each user need. Last but not least, all the infrastructure is relying on a fine-grained data segregation to ensure security requirements about data classification and sensitivity.

Nonetheless, there is still room for improvement, and that is why smart and hybrid approaches are being further studied to enhance AI predictions, while technical optimizations are conducted to improve performance. All this to answer the continuously growing data volume and help bringing data-driven solutions for the challenges of tomorrow.

Platform extension beyond Airbus Space Systems is one of these major challenges, as OASIS is being adapted to integrate Military Aircraft data, but it is also being sold to external customers, in particular as their new payload monitoring tool.