

Implementation of the Swarm FAST Processing Pipeline

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Introduction



The initial NRT processing chain for Swarm PDGS was shelved before launch due to cost and technical issues. However, **recognizing the benefits of a low-latency pipeline** in expanding the use of Swarm data, **a project began in 2021 to evaluate and implement a new FAST processing pipeline**. The approach was gradual and collaborative, involving a feasibility study, a pilot, and community support, culminating in the development of a robust FAST pipeline using Agile and DevOps methods within the **Werum Olib** framework (**CPF**). This pipeline was integrated within the EOP-GE cloud virtual infrastructure. **The success of this project** was attributed to the **incremental approach** and the **teamwork involved**.

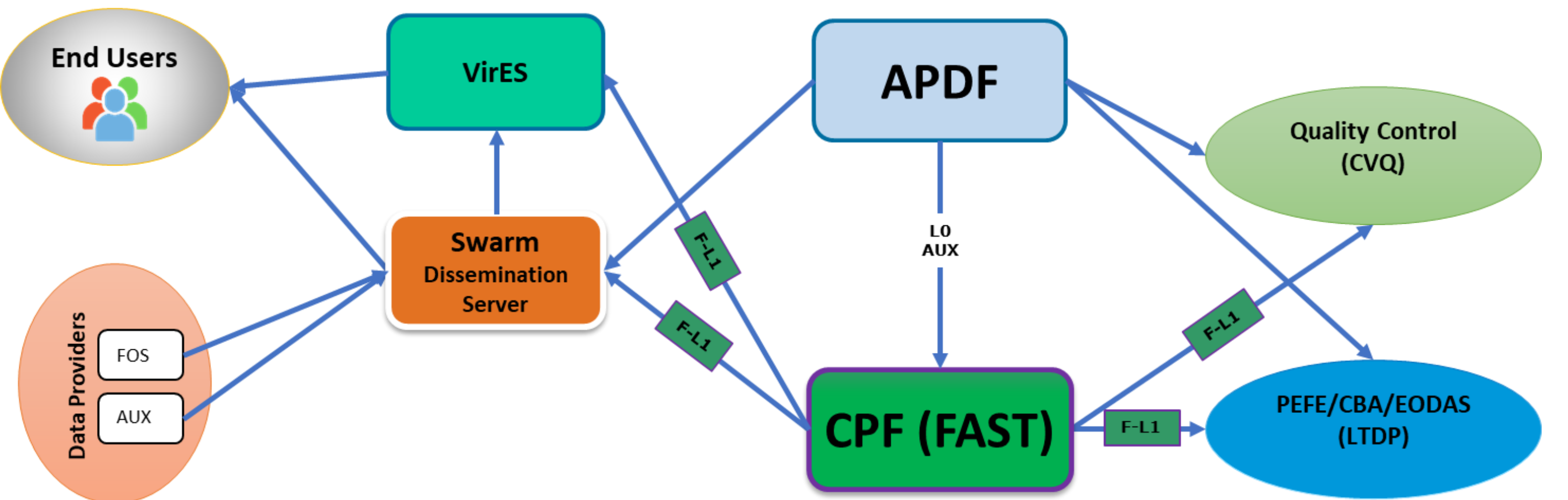
Swarm FAST Drivers for Development and Phased Implementation Approach

- Swarm mission offers **potential for innovative space weather products**.
- Quick data provision** enhances **space event monitoring** and forecasting.
- Implementation progressed through four phases for optimal efficiency.
- New PDGS segment** initiated for immediate Level 1 product distribution.
- Swarm FAST products delivered within 30-45 minutes post-data capture.
- Pre-operational phase** for Swarm's data processing **began April 27, 2023**.
- Data generated for expert validation during pre-operational phase.
- Post-validation, **data access extended to all users from November 3, 2023**.
- Current phase involves **routine operations** based on initial analyses.

PHASE I Analysis	PHASE II -Feasibility	PHASE III Demo	PHASE IV Routine
<ul style="list-style-type: none"> Assess that the IPF are able to process in a data driven approach Confirm availability of alternative Auxiliary Data Generate a 3-days Test Dataset of L1B data Update QC & validation diagnostics for quality assessment Characterise error introduced in regards to nominal processing. Identify L2 product and potential users which would benefit from fast production 	<ul style="list-style-type: none"> Integrate (modified) IPF into a parallel chain Configure retrieval of alternative Auxiliary Data Generate off-line 6 months L1B Dataset (all Spacecraft) as if it had been done on-line, i.e. Evaluation Dataset Provide Evaluation dataset to select users and collect feedback. Perform an overall quality assessment (up to L2 data samples processed offline by related experts). 	<ul style="list-style-type: none"> Robust Fast pipeline implementation and systematic on-line production for all spacecrafts for 3 to 6m. Initially only L1b, after check also L2-CAT2. These would be disseminated to select users, i.e. the Demonstration Datasets. Collect user feedback and consolidate. Confirm data quality and user interest (up to L2 data samples processed offline by DISC experts). 	<ul style="list-style-type: none"> Systematic Fast L1b Data production for all Spacecrafts. Revised dump approach – e.g. predefined dump intervals per spacecraft. Increased number of daily passes Extend to some selected L2 products following same logic and steps (current L2 and future products from Space Weather project)

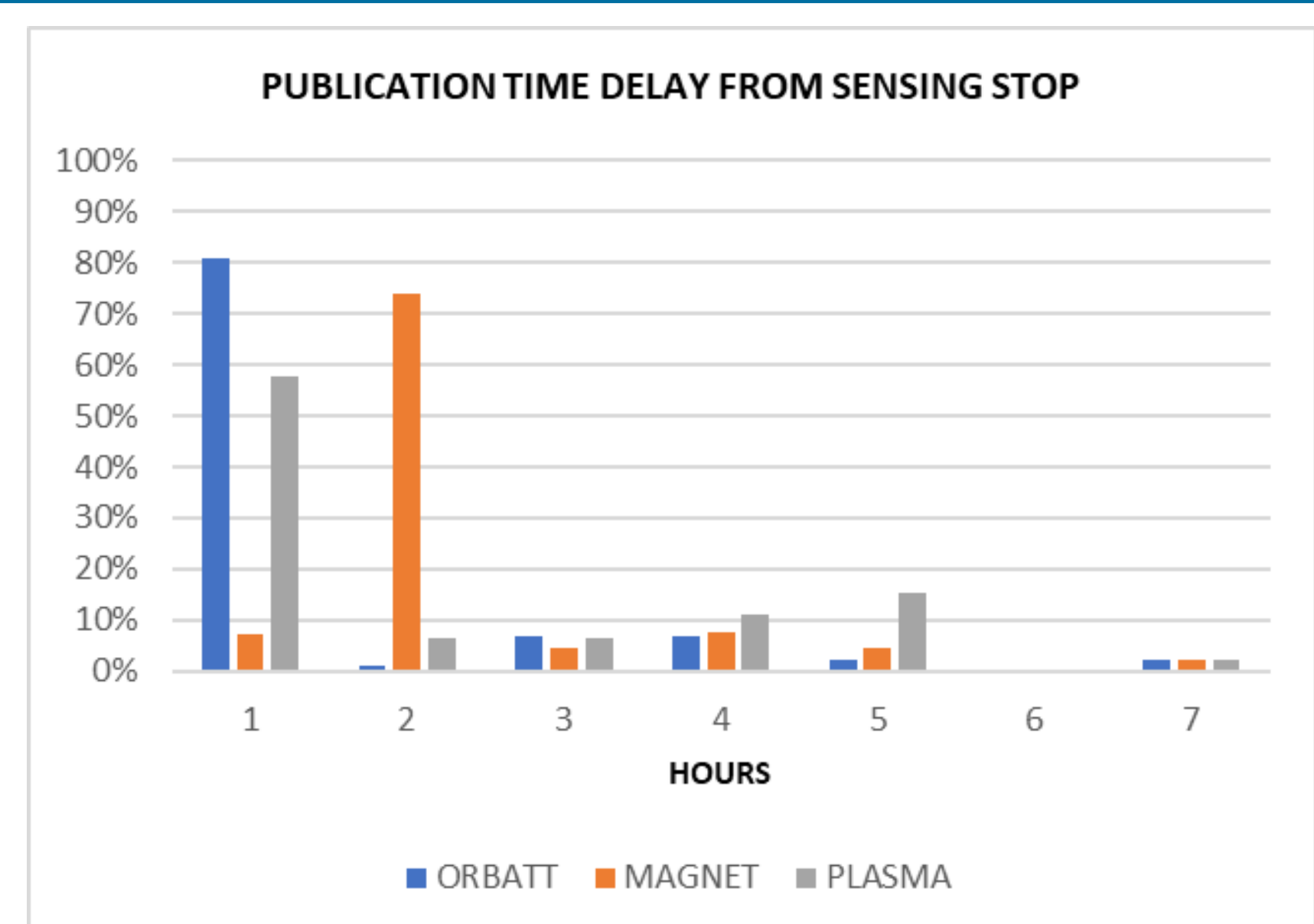
Swarm FAST Chain Integration in the PDGS

- Seamless integration** of the Swarm FAST chain into the existing PDGS framework.
- APDF serves as the primary data input gateway, handling Level 0 and Aux data.
- Efficient procurement of ultra-rapid GPS Auxiliary data through the Swarm Dissemination server.
- Immediate processing of Level 0 into L1** data upon TLM reception from FOS.
- Multi-channel dissemination** of L1 data: publication, interactive engagement, quality control, and archiving.
- Use of the **Swarm Dissemination server** for user **access to FAST L1 data**.
- ViRES** tool enables advanced FAST data interaction for the ESA Swarm mission.
- Quality Control** system ensures data integrity.
- Long-term archiving** of data for future use.
- Efficient satellite data handling and distribution.



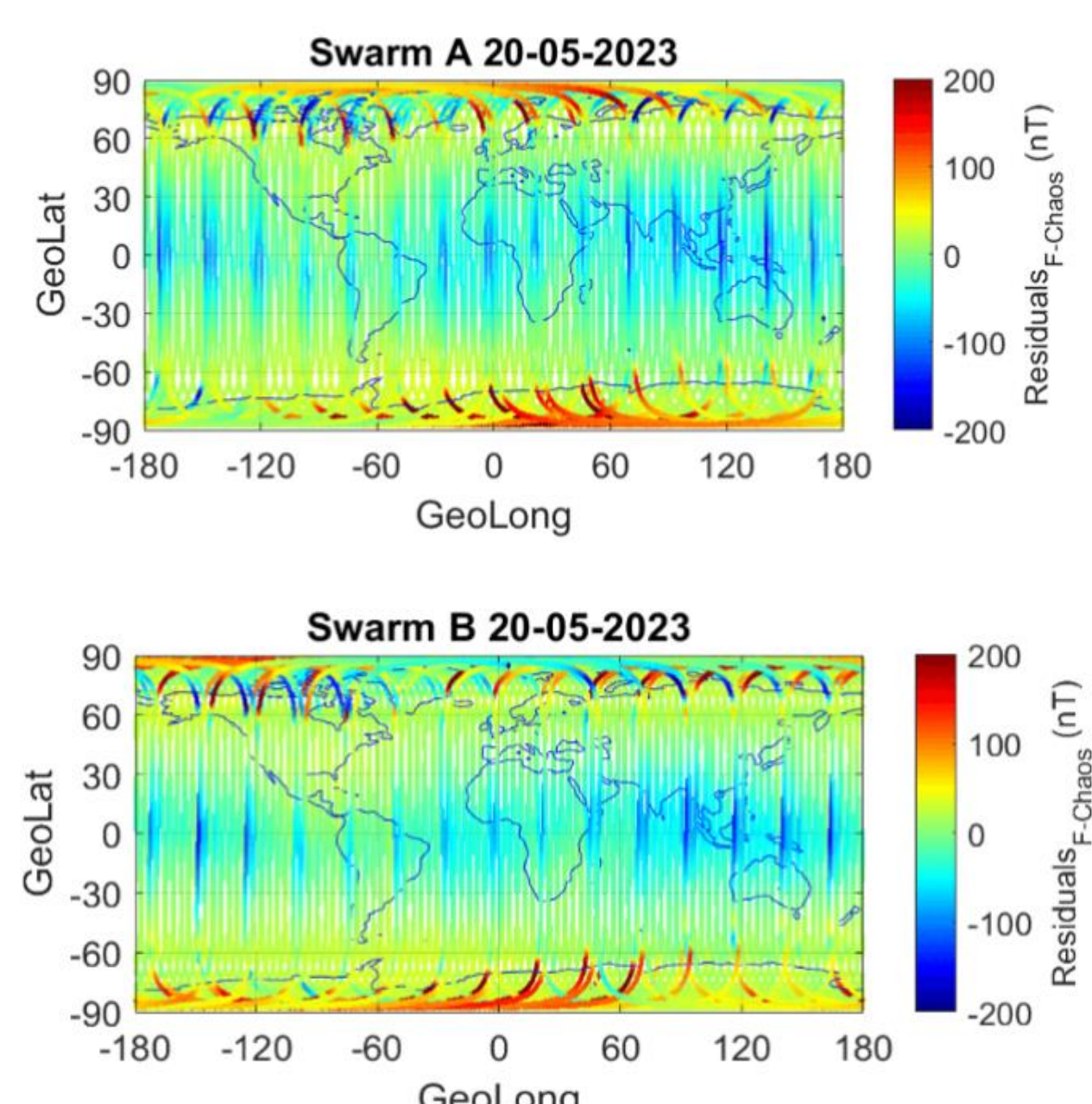
End-to-End Performances

- Swift delivery of Swarm FAST L1 data** is vital, particularly for Space Weather analysis.
- Efforts have been made to **decrease delays** in data use across various sectors.:
- Average Processing Time:** ORBATT 12 min, MAGNET 30 min, PLASMA 3 min.
- Early 2024 saw the **successful implementation of an improved downlink strategy by the FOS**.
- This **strategy enhancement** has **significantly reduced the delay** from data acquisition to publication to users.
- The chart on the right illustrates delay distribution metrics for ORBATT, MAGNET and PLASMA data (Including Downlink time, Transfer from FOS, Processing and Publication).



Real Example of FAST Application

- Intense solar activity recorded on May 20th, 2023, including a moderate **M6.4 flare** at 07:32 UTC and a strong **M8.9 flare** at 12:35 UTC.
- Two **Swarm** spacecraft **captured images of the Earth's magnetic field** strengthening and then diminishing in response to **coronal mass ejections**.
- The **FAST** chain's data acquisition was **nearly simultaneous** with the solar events, offering **rapid insights**.
- This **quick data availability** contrasts with the usual four-day delay in standard Level 1 product availability.



Highlights

- Development and successful deployment of a FAST-Processing Chain**, overcoming initial budget and technical hurdles, to significantly enhance the use of Swarm data for applications such as **space weather**.
- Agile and collaborative project approach**, utilizing the Werum Olib framework (CPF) and EOP-GE cloud infrastructure.
- The commencement of the pre-operational phase on April 27, 2023**, leading to **validated data being made widely available by November 3, 2023**
- Seamless integration of the FAST chain with existing PDGS infrastructure**, utilizing APDF and enabling immediate initiation of Level 1 data generation upon data reception
- Strategic refinements to the downlink strategy early in 2024**, significantly reducing latency and providing a swift transition of data from capture to end-user accessibility, thereby expanding the scope and utility of Swarm data.