A Stepwise Approach to Evolve the European Galileo Ground Segment towards Continuous Integration and Continuous Deployment

Steven Bouchired, Alexandre Ballereau, Artemio Castillo, Sonia Toribio, Miguel Manteiga (ESA)
Antonio Pineda (EUSPA)
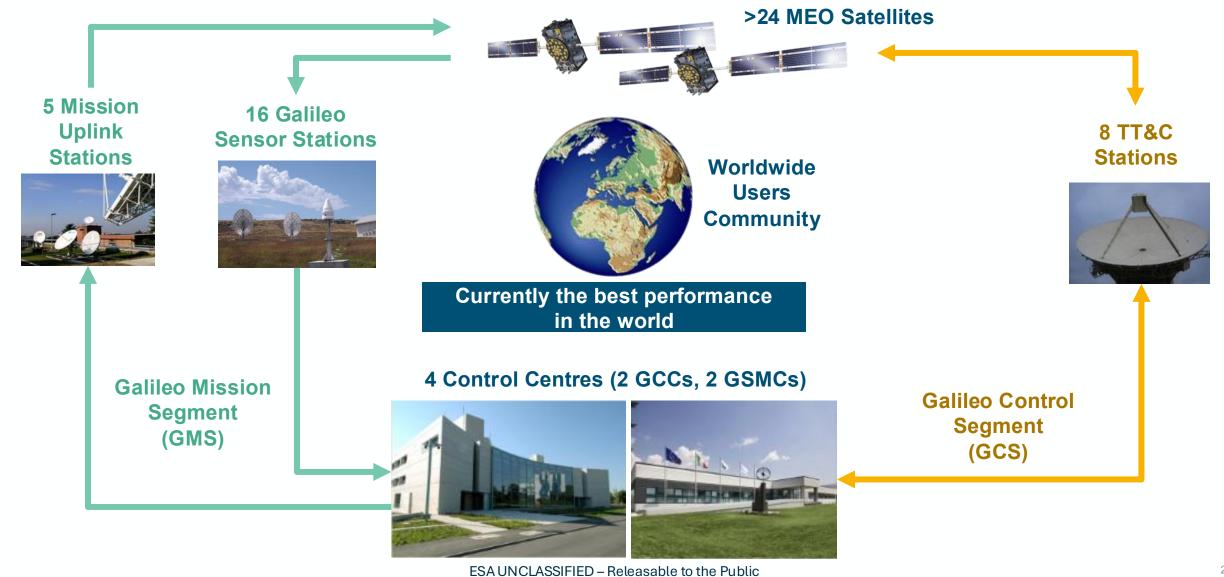Xavier Maufroid (European Commission)

23/01/2025

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Galileo: How does a Navigation System work?

>24 MEO Satellites

5 Mission Uplink Stations

16 Galileo Sensor Stations

Worldwide Users Community

8 TT&C Stations

Currently the best performance in the world

4 Control Centres (2 GCCs, 2 GSMCs)

Galileo Mission Segment (GMS)

Galileo Control Segment (GCS)

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Galileo History: An Incremental "FFP" Development

2003 — 2009 — 2015 — 2021 — 2027

IOV Phase | EOC Phase | G1 FOC Phase

PDR

2004-05
Security added

2006
End of Public
Private Partnership

2009-10
Safety-of-Life
Service descoped

CDR

QR

Initial
Ground Segment

2011
IOV Satellites
1st Launch

2014
Wrong orbit

Incremental
System Qualification

QR

2016
IOC
Initial Services

2016
Security Monitoring,
Public Regulated Service
Change request

Maintenance is evolving the system in parallel

2020-21
COVID

2022
24 operational
satellites

Open Service
FOC

Public Regulated Service
IOC and then FOC

2027
First G2 satellites
launch

Hand-over of maintenance to EUSPA

Start of G2
Phase B

2023
Crypto
Change request

G2 PDR

Anything new?

Long incremental Vee-Cycles.
Unplanned events inevitably occur.
Complexity keeps increasing.
Cost of evolutions increases with the technical debt.

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We Met a Few Enthusiastic and Inspiring Agilists

SKAO … one observatory two telescopes three continents

- Usage of the **Scaled Agile Framework** (SAFe)
  - Started small in 2018 with 30 people.
  - Ramped up to 25 Agile teams in 3 Release trains (including non-software).
- Very interesting reflexion on **Agile contracts**.

Firm fixed price — Target price — Cost plus — Time and materials

- NEC contracts: Spirit of mutual trust and collaboration. Light and easy to manage relational contracts.
- Long terms relations more important than short wins

- **Techniques:**
  - Behaviour and Test-Driven Development. What matters is a working product.
  - Introduce techniques at the right moment to the right people.

SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of June 2022)   African Partner Countries

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- **THEMIS:** Re-Usable Rocket First Stage Demonstrator by ESA STS Directorate
- Usage of the **Scaled Agile Framework** (SAFe)
- Collaborative spirit generates high level of commitment from all teams.
- Approach of "Good Enough" Minimum Valuable Product (MVP).

2021 → 2026

Standard Project Management — Scope / Quality / Time / Cost — ESTIMATED

Agile Management → Feasible with suitable customer relationships — FIXED — Cost / Time / Quality / Scope

- **MAIASPACE** start-up building on this project.
- See interesting first RETEX here:

JÉRÔME VILA Directeur Général Adjoint MAIASPACE

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Return of Experience on Transitioning to Agile
Gen. Ellen Pawlikowski, US Air Force 14/07/2017   2/2

What are the barriers to success in Agile transition in Governmental Organizations.

Barriers are 90% cultural (14:40)

Those who test must know the code (31:10)

"I hate to say this, but maybe it is time for time-and-material contracts" (30:00)

Young people only know Agile → Problem of recruitment if we don't change (29:30)

Separation between software development and its maintenance is non-sense (23:45)

We are in love with our Vee-cycle development process (15:00)

These barriers are critical, but none of them is unsurmountable. (34:06)

On the dark side of the "zero-risk" culture (22:30)

Vee-cycle reviews are against the basic principles of Agile… (15:22)

We must change the way we think about systems engineering and requirements (16:55)

Detailed requirements flow down is not the right way → slice transversally instead of vertically (17:15)

"We are bad at putting businesspeople with developers together" and at empowering – **too many layers** (17:58)
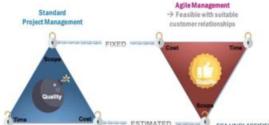
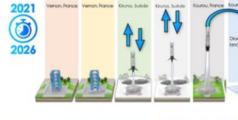"We hold on to stuff too long" – "**Sometimes it is better to throw the old stuff away**" (21:40)

Link to youtube

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- We met **enthusiastic Scaled Agile Framework (SAFe) practitioners** on both customer and supplier sides sharing their learned lessons,
- In **similar contexts** (e.g., international organisation),
- … but also, warnings that **evolving the ways of working in a large and complex organisation is a long and difficult journey.**

Releasable to the Public   4

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SKAO Global HQ, Jodrell Bank, UK

SKA-Mid Site, Karoo, South Africa

SKA-Low Site, Murchison, Western Australia

SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of June 2022)
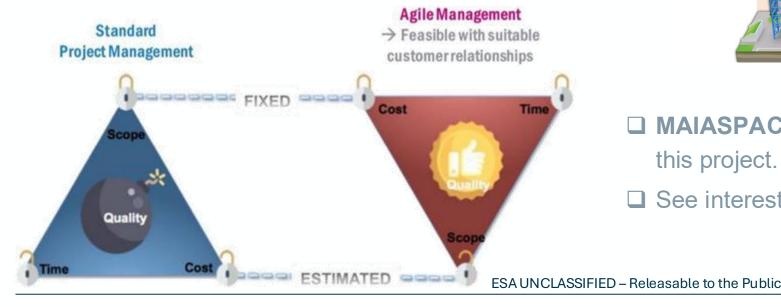
African Partner Countries
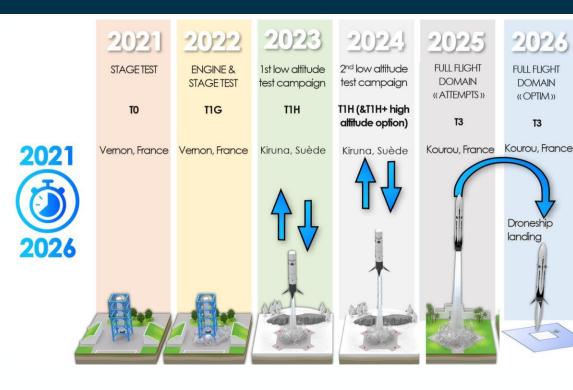
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2021	2022	2023	2024	2025	2026
STAGE TEST	ENGINE & STAGE TEST	1st low altitude test campaign	2nd low altitude test campaign	FULL FLIGHT DOMAIN «ATTEMPTS»	FULL FLIGHT DOMAIN «OPTIM»
T0	T1G	T1H	T1H (&T1H+ high altitude option)	T3	T3
Vernon, France	Vernon, France	Kiruna, Suède	Kiruna, Suède	Kourou, France	Kourou, France

Standard Project Management

Agile Management
→ Feasible with suitable customer relationships

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Key 2ⁿᵈ Generation Galileo Architecture Principles

☐ **Towards Message Bus and Micro-Services:**

CURRENT SW Architecture

Sender V01 [T0]

Consumer V04 [T0]

Network (Unicast/Multicast)

Sender V02 [T1]

Consumer V05 [T1]

Network (Unicast/Multicast)

Elements

ICD's
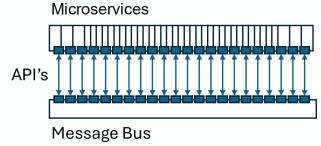
Synchronous upgrade necessary.
Harder to evolve.
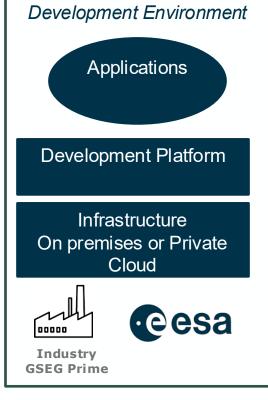
TARGET G2 SW Architecture

Publisher V01 → V02 → V03

Subscriber V04 → V05

T0 - V01 → $[X, Y]_{Version\,n}$
T1 - V02 → $[X,Y]_{Version\,n}$
→ $[X,Y,Z]_{Version\,n+1}$

T0 - ←V04 $[X, Y]_{Version\,n}$

T2 - ←V05 $[X,Y,Z]_{Version\,n+1}$

T3 - V03 → $[X,Y,Z]_{Version\,n+1}$

Messaging System

Microservices

API's

Message Bus
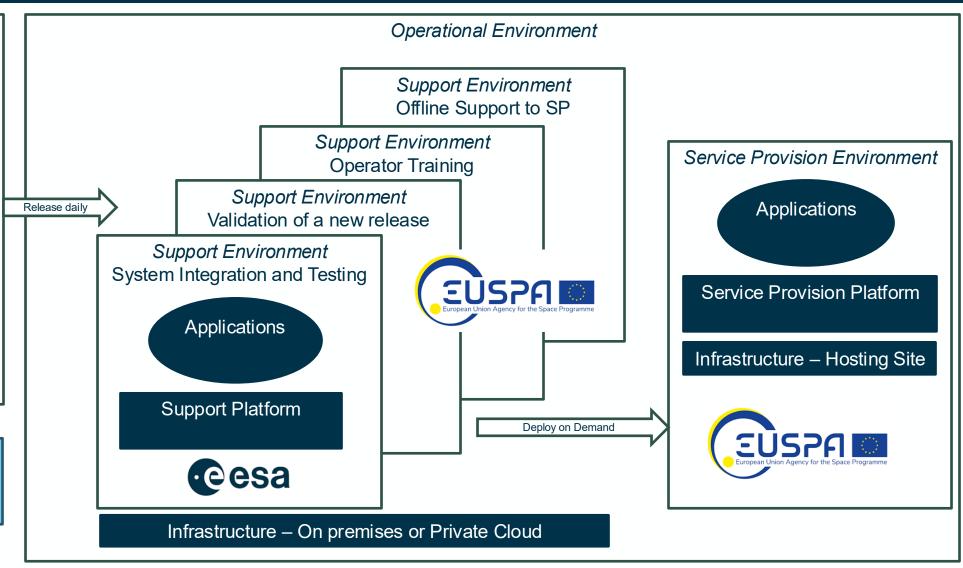
Asynchronous upgrade possible.
Allows blue / green continuous deployment.

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Key 2ⁿᵈ Generation Galileo Architecture Principles

Galileo Long (but Steady) Road Towards Agility

2026-2029:
First fully agile contract
Short duration "Cost+" (TBC),
Limited scope,
Continuous Integration /
Continuous Deployment
(CI/CD) pipeline

2028-…
**Extension of agility
to other functions**

2018-2023:
**Three parallel
G2 ground segment
phase B**
Last 9 months spent on
experimenting SAFe
developing an incubator.

2023-2027:
**Three ground segment
contracts (>500M€) with
SAFe … but in Firm- Fixed-
Price (FFP) contracts.**

*High level
requirements*

Service Provision Environment Gradual Evolution: Intermediate Status at SB 2026-2027

Galileo Mission Segment (GMS)

Galileo Control Segment (GCS)

Message Generation, Timing provision

Orbit and Clocks Determination Algorithms, Support functions

Mission monitoring

Shared TTC Between Service Provision and IOV Environments

Service Provision Environment

- BM-Elts
- BM (*)
- Virt-Elts
- PaaS
- ISC infrastructure
- GSS SW
- BM
- BBM Ampli Antenna
- ULS SW
- BM
- BBM Ampli Antenna
- Virt-Elts
- Platform (PF)
- Virt. TTC SW
- PF
- BBM Ampli Antenna
- Local Network

Local Network

Wide Area Network (inter sites)

2nd Generation In-Orbit Validation Environment

Local Networks

Local Network

- GMS IaaS
- Virt-Elts
- PaaS
- PaaS-Elts
- BM
- ULS SW
- BBM Ampli Antenna
- GCS IaaS
- Virt-Elts
- GCS PaaS
- PaaS-Elts

Development with SAFe of a Galileo 2nd Generation IOV Environment operated in parallel of services provision to gradually evolve towards the new cloud-native architecture (limited CI/CD).

☐ **Cloud Native / Micro-services**   (*) BM = Bare-Metal

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Service Provision Environment Gradual Evolution:
Increment in SB 2028-2029

Galileo Mission Segment (GMS)

Galileo Control Segment (GCS)

Timing provision

Orbit and Clocks Determination Algorithms,

Message Generation, Mission monitoring, Support functions

Service Provision Environment

- BM-Elts / BM (*)
- Virt-Elts / PaaS-Elts / PaaS / ISC infrastructure
- GSS SW / BM
- ULS SW / BM
- BBM Ampli Antenna
- BBM Ampli Antenna

- Virt-Elts / PaaS-Elts / GCS PaaS / GCS IaaS
- Virt. TTC SW / PF
- BBM Ampli Antenna

Local Network

Wide Area Network (inter sites)

Local Network

2nd Generation In-Orbit Validation Environment

Local Network

- IaaS^3 / PaaS^3 / Appli Fcts
- IaaS^3 / PaaS$_3$ / GSS SW
- IaaS^3 / PaaS$_3$ / ULS SW

BBM Ampli Antenna

BBM, Ampli Antennas (standard, adaptive)

The service provision environment is upgraded at a higher pace until reaching a full CI/CD capability. New complex features can be validated in operation before migration to the service provision environment.

☐ **Cloud Native / Micro-services**   (*) BM = Bare-Metal

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Main Take-Aways

- The **main challenges** of the evolution of Galileo towards agility:

  HUMAN FACTORS
  - Convince all stakeholders top level managers, that the wins in adopting Agility are worth the perceived additional risk taken. ➜ Top management sponsorship is mandatory to transform.
  - Change the deeply anchored Vee-Cycle culture (ECSS standards heritage).
  - Build trust with suppliers and other stake-holders.
  - Embark operators and security accreditation authorities in the process (DevSecOps, Continuous Accreditation).
  - A continuous and significant follow-up involvement is required.
  - We are transforming an existing operational system with a service continuity constraint, which has not been designed for Continuous Integration / Continuous Deployment (CI/CD).

- **It is worth the effort!**
  - Once you try it, there is no going back (collaborative spirit, transparency, embedded continuous improvement …).

| **50%** Faster time-to-market | **35%** Increase in productivity | **50%** Defect reduction | **30%** Happier, more engaged employees |

THANKS FOR YOUR ATTENTION
Contact us for more information

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