The European GNSS Evolution Programme

An optional programme of the European Space Agency

Lisbon, 10 July 2012

Programme Objectives

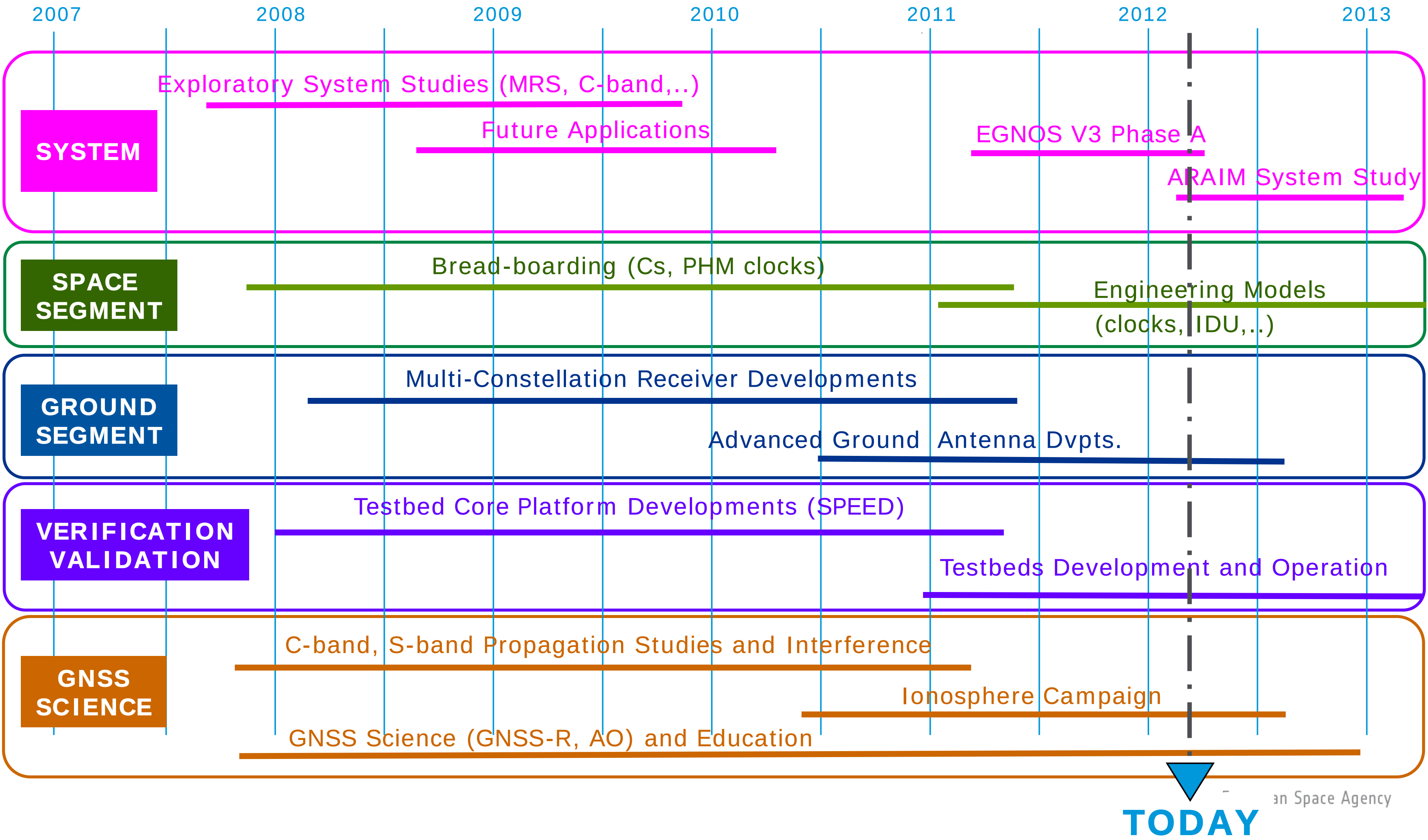
The European GNSS Evolution Programme (EGEP) is an optional programme of the Agency. It has presently a financial envelope ~100 M€ funded by 18 ESA Member States since 2007.

Programme objectives:

- Enable technical readiness for upgrades and evolution of EGNOS and Galileo caused by mission evolution, operability improvements and/or technology obsolescence
- Maintain technical European know how, competences and infrastructures at par internationally
- Sustain competitiveness and innovation capabilities

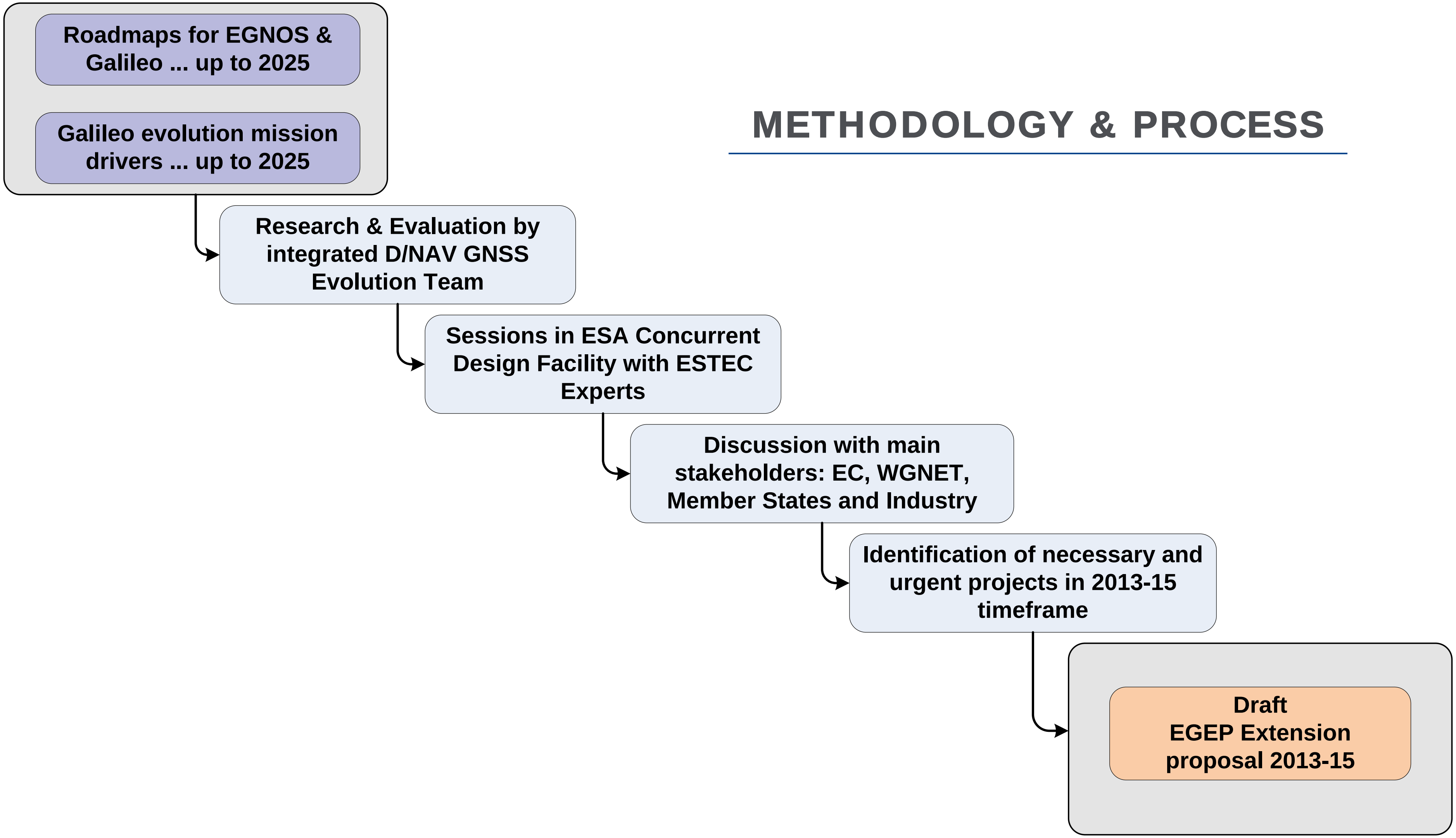
The activities focus on infrastructure technology R&D and system development covering Phase A/B

Activities of the 1st phase 2007 - 2011
A few examples

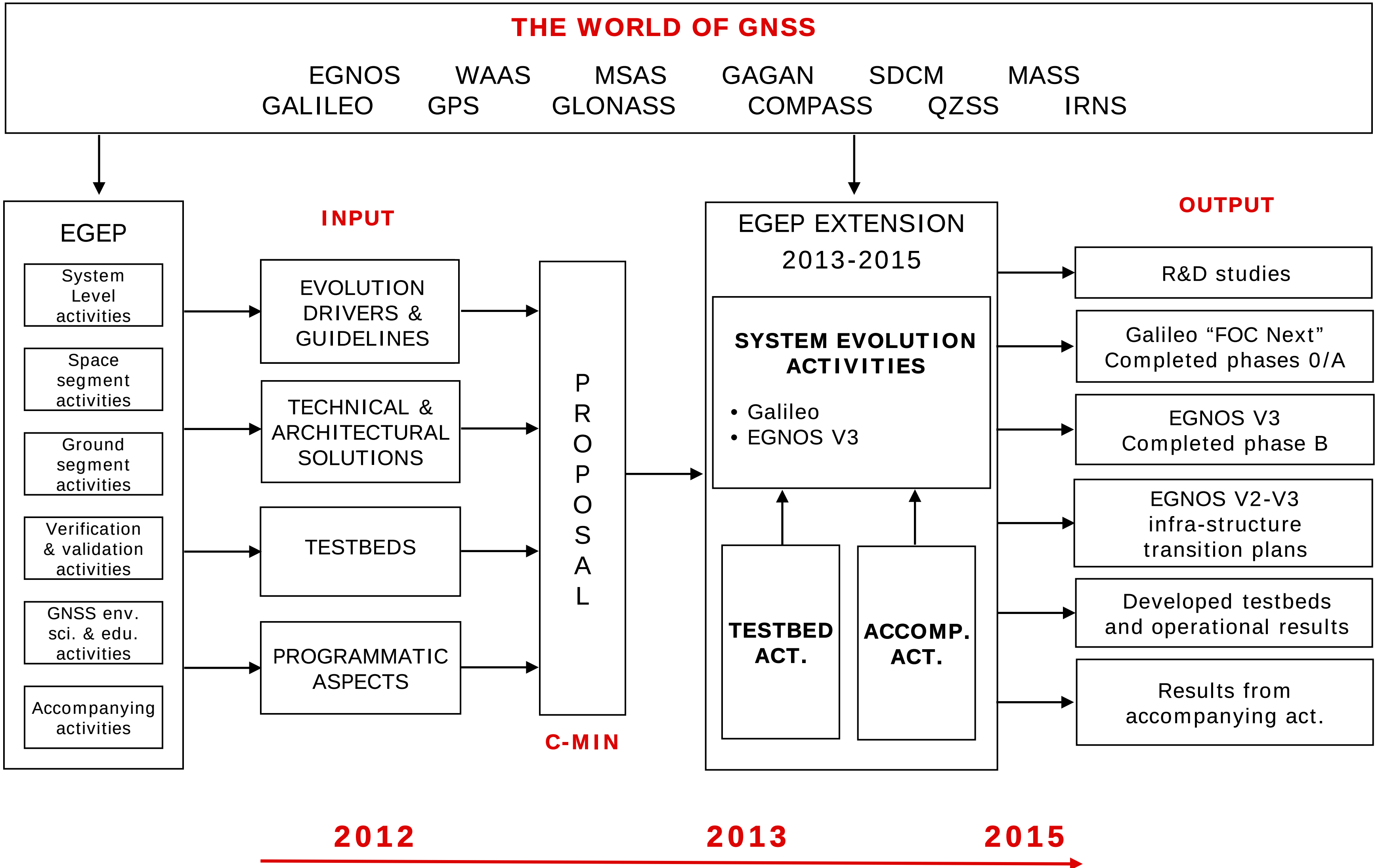


EGEP Extension Proposal 2013-2015

METHODOLOGY & PROCESS



EGEP Extension – Input & Output



Why Evolution of EGNOS?

Why Evolution of EGNOS ?

1. **Continuity after 2020**

   Codeless tracking of GPS L2P(Y) is no more guaranteed by the US after 2020

   However, second frequency is needed for the ionospheric impact

2. **Evolutions induced by other SBAS: WAAS**

   FAA prepares WAAS dual frequency L1/L5 services by 2018

3. **Competitiveness and European Context**

   Robustness to loss of one constellation and/or frequency (add Galileo)

   Service extension: ECAC airspace, Africa, Middle-East, the Arctic

   Additional new services: ADS-B, maritime, railway, etc.

   Improved performance

4. **Cost benefit improvement**

   Optimisation of architecture

   Automation of operations

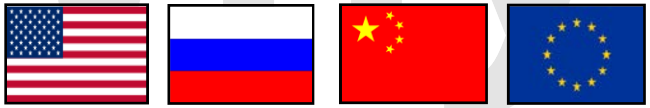
   Streamlining of AIV and deployment processes

Why Evolution of Galileo ?

Why Galileo Evolution?

1. **Resolve the current system shortcomings and needs for evolution**

   Aligned and according to programme objectives



2. **Competitiveness**

   Galileo is the last of four worldwide GNSS

3. **Opportunities offered by evolving technologies**

4. **Cost benefit improvement**

   Optimize exploitation efficiency w/r to cost and operability

   Safety-of-Life (SoL) removal

   Launch cost

   Number of ground stations

   Synergies with EGNOS

Identifying Galileo System Evolution Drivers

- Shortcomings and residual risks of the current system were carefully analyzed
- Expressed in the form of 10+1 Galileo System Evolution Drivers
    - **10 Galileo System Evolution Drivers**
    - Allocated to three groups: Space Segment, Ground Segment and Frequencies, Signals and Services
    - **One horizontal driver** affecting most of all other 10 drivers: **Cost Benefit Improvement**
- Afterwards solutions were identified which satisfy the Galileo System Evolution Drivers
- Families of scenarios were then defined for evolution opportunities
- Launch strategies were included

Overview
Galileo System Evolution Drivers

Horizontal

1. *** Cost Efficiency / Cost benefit of Galileo System

Space Segment

2. *** Increase platform & launcher flexibility
3. ** Guarantee the availability of diversified and independent European GNSS technologies
4. * Optimize Satellite Constellation with Alternative Orbits

Ground System

5. *** Increase Ground Segment (GS) Robustness

Frequencies, Signals and Services

6. *** Increase Robustness and/or Compatibility of Galileo Public Regulated Service (PRS)
7. ** Mitigate Vulnerability of Galileo (and GNSS) Signals to Interference
8. ** Increase Competitive Service Performance in Comparison to other GNSS
9. ** Increase Operational Capabilities of PRS
10. * Increase Utilization of Galileo with Respect to Integrity Applications
11. ** Improve Protection of Ground-to-Space Links for all Phases of Operations

*** High Priority ** Medium Priority * Low Priority

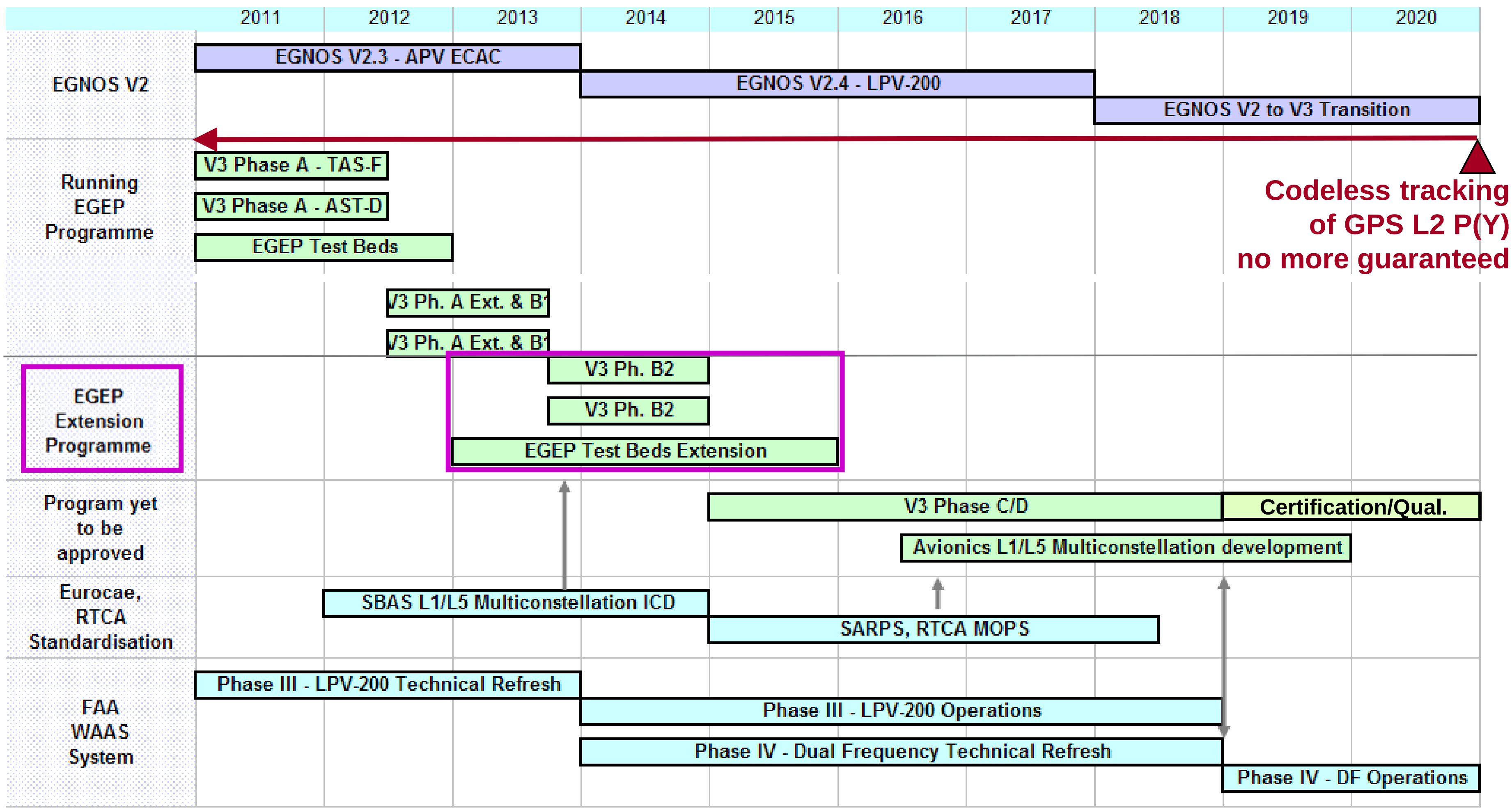
Possible Solutions for the System Evolution Drivers

Examples

- **Further PRS robustness**
- **Inter-Satellite Links payload** to improve sizing of GDDN, TTC, ULS and GSS and to increase performance. On-board clock technology can be simplified.
- **SBAS L1 / L5** transparent or generative payload
- **Additional power**
- **Flex-power, smart power management**
- **C-band payload**
- **Satellite Failure Detection Unit** (FDU) for increased reliability of signals
- **Self Equalising Payload** (SEP) for increased reliability and accuracy of signals
- **Additional acquisition signal** (E1D) to improve TTFF.
- **Advanced CMCU ensemble** for improved reliability
- ...

Why Starting with EGNOS and Galileo Evolution Now ?

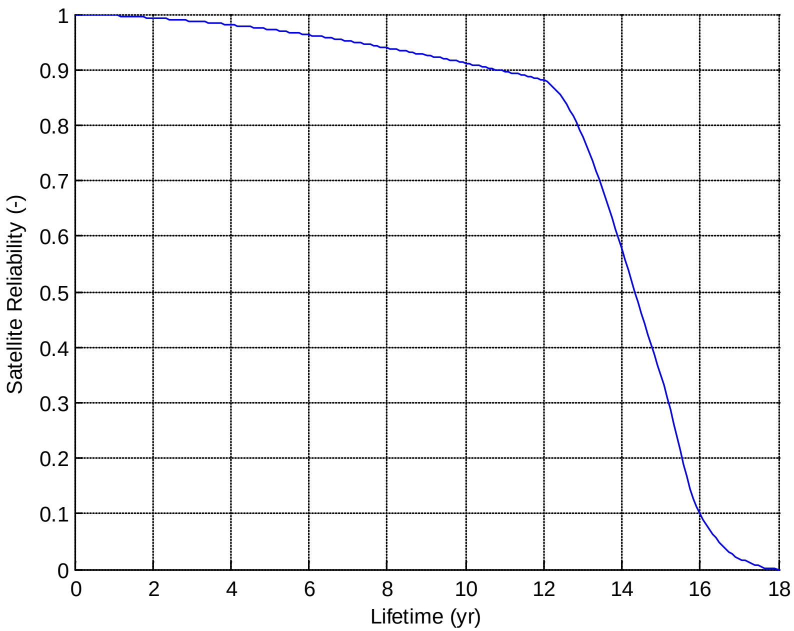
EGNOS Evolution
Why Did We Start 2011 and Must Continue?



First Replacement of IOV/FOC Satellites

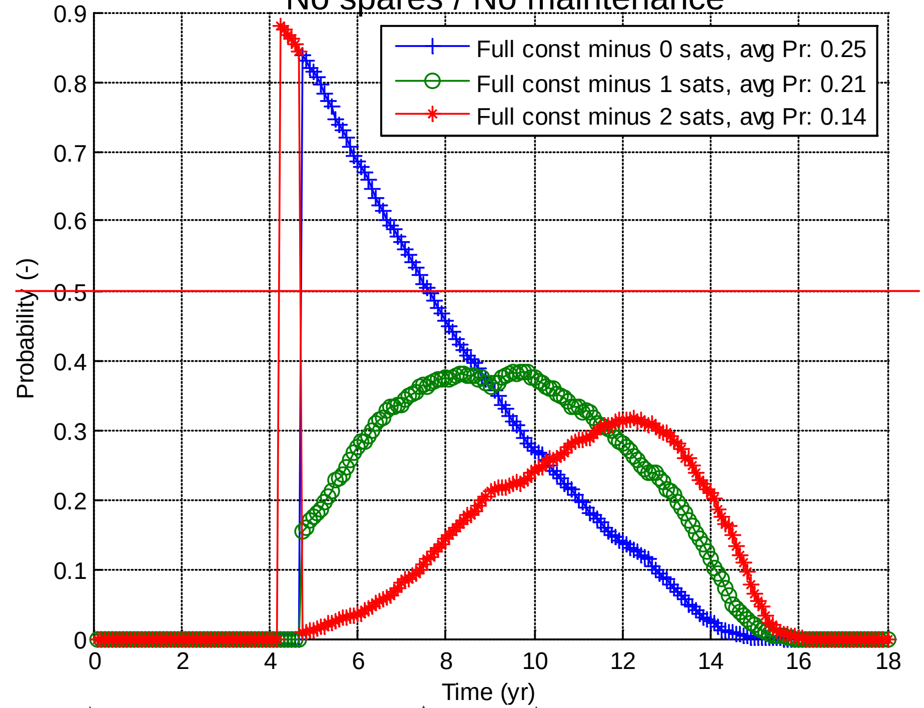
Updated analysis IOV/FOC satellites data
Based on CDR data (0.88 @ 12 yrs)
Original launch schedule FOC

Satellite Reliability 0.88 at 12 yrs



2011 2017 **2021**

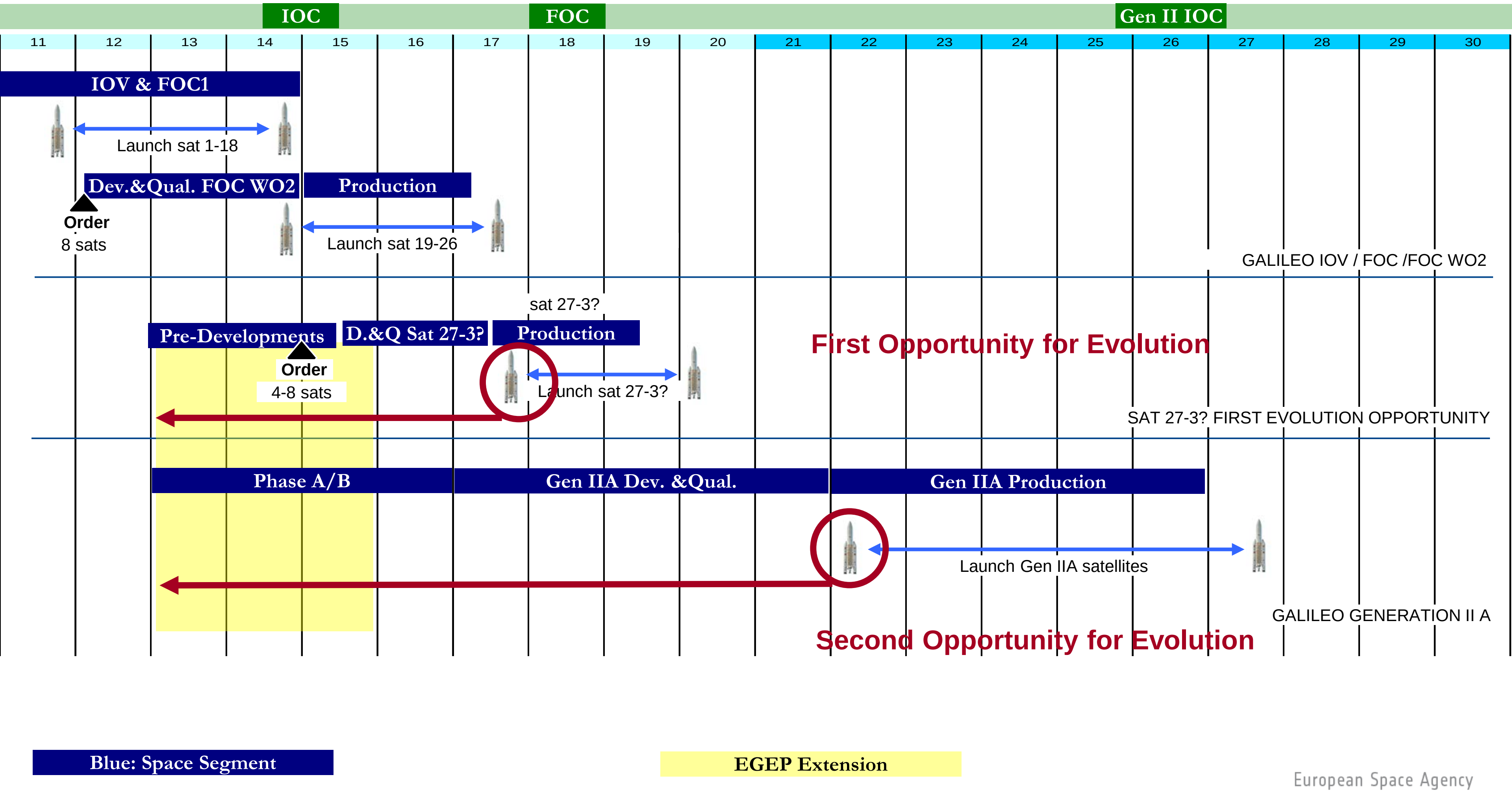
Constellation 24 satellites
No spares / No maintenance



2011 **2018** 2021

Note: IOV Numbers at QAR are in between

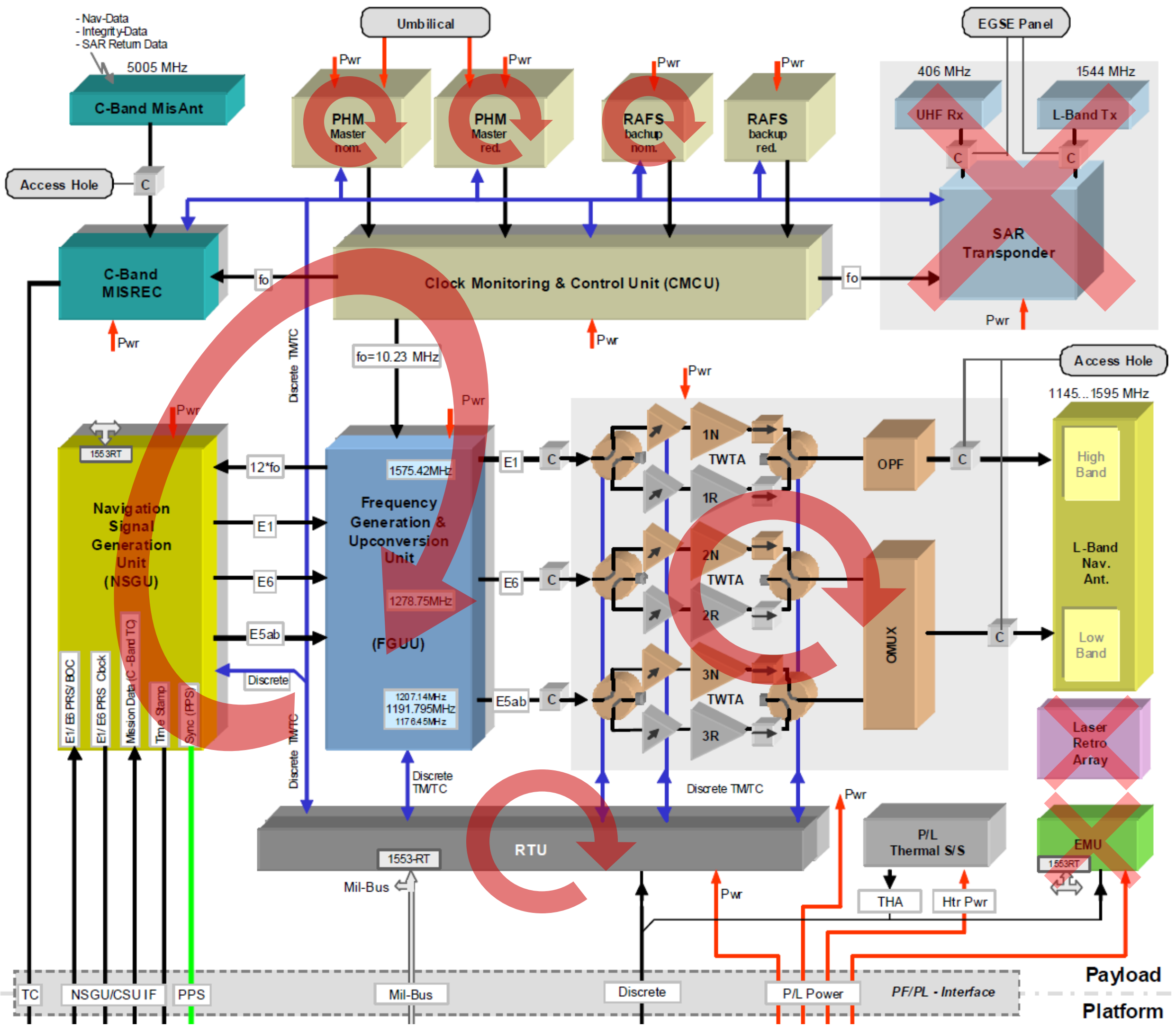
Opportunities for Galileo Evolution
Why Starting Now?



The Present Galileo Satellite Platform and Payload

What is still possible with the FOC payload ?

Possible Mass / Power Savings



Ideal Savings

Item	Average Power (W)	Components Mass + Margin (kg)
EMU	5.4	3.4
Min. PHM 1	25.0	9.5
Min. PHM 2		9.5
LRA		3.3
Total	**30.4**	**25.7**
Sat. margin	86.1	24.5
Total	**116.5**	**50.2**
SART	60.9	6.2
SARANT		7.9
Total	**177.4**	**64.2**

Realistic Savings

Conclusions Present Galileo FOC Platform

- Realistic investigations show that there is only **very limited power and mass available – around 65W and 20kg**
  - ➢ Only small changes in payload within the margins above or not impacting available power and mass are feasible
    - Flexpower, antenna, no SAR, modified NSGU, Self-equalization unit, etc.
  - ➢ As a consequence fully satisfying the Galileo Evolution System Drivers is not possible
- A larger platform can only satisfy the Galileo Evolution System Drivers - for example, **1500kg/3kW payload power** (> SmallGEO platform)
- **BUT:**

  Launch cost will double!
  - ➢ Would require single satellite launch w/ SOYUZ

Keeping Launch Costs Within Present Cost Envelope

The Way Out

The Way Out: Electrical Propulsion

- Using a larger platform and keeping still the launch costs within the present budget
  - **Use of Electrical Propulsion (EP)**
    - Proven technique
    - Used for ARTEMIS, SMART-1, GOCE, ASTRA
    - Planned for LISA, Small GEO, Alphabus, BEPI
    - US intends to use it also for GPS-III (recent information)
- Moreover, using EP for a whole Galileo generation may result in avoiding spending of the order of **1 B€ in launch costs** (when using a large platform & versus one single satellite launch w/o EP)
  - Savings when launching 3-4 satellites w/ SOYUZ & EP
- EP can be adapted to all launchers: SOYUZ, ARIANE5, VEGA
- **The Penalty:**
  - No direct injection in MEO orbit possible
  - Transfer time of the order of 1 year (but parking in an intermediate orbit may be considered)
  - New replenishment scenarios have to be developed

Families of System Scenarios

Fam.1: **Obsolescence SS + GS**

Maintain system as it is at FOC, replenish the same satellites and manage GS obsolescence.

Fam.2: **Current class PF + supporting GS**

Relatively 'small' changes to current FOC satellite class (750kg)

- 2A: Dual launch with Soyuz using direct injection into MEO
- 2B: Triple/Quad. launch with Soyuz into LEO, using EPS to reach MEO

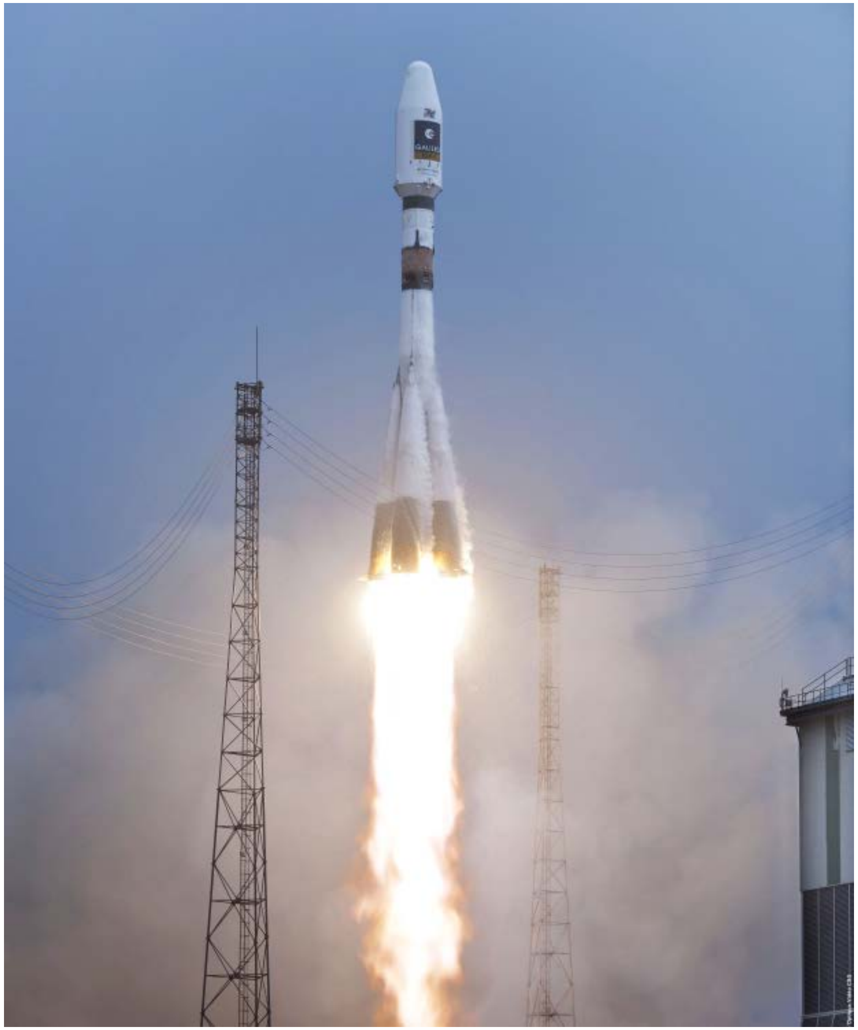
Fam.3: **Larger class PF + supporting GS**

Larger class satellite (1500kg dry) which has flexibility for additional payloads.

- 3A: Single launch with Soyuz with direct injection into MEO
- 3B: Dual launch with Soyuz into LEO, using EPS to reach MEO

Satellite class	Family	Launcher		
		Vega	Soyuz	Ariane 5
Current (750kg)	2A		2 sat	4 sat
	2B	1 or 2 sat	3 or 4 sat	6, 7 or 8 sat
Larger (1500kg)	3A		1 sat	2 sat
	3B	1 sat	2 sat	4 sat

- Green: **Save Launch Cost**
- Orange: **Cost Neutral**
- Red: **Increase Launch Cost**



Activities EGEP 2013-2015

- EGNOS V3
- Galileo evolution
- Testbed maintenance & evolution
- Complementary activities & developments

EGEP Extension Activities Overview

EGNOS Phase B2 tender to be released beginning of 2013.

Two parallel contracts foreseen of 1-1.5 years.

Galileo requires work on two parallel streams:

1. **Satellite 25-30:**
    a. For satellite 25-30 two options can be envisaged:
        – Adapt current FOC like platform to accommodate payload enhancements and new capabilities.
        – Develop large class platform with EPS.
    b. Parallel phase B contracts will be needed for:
        – Space Segment (for both options).
        – Ground Segment (delayed w/r to SS).
        – System (delayed w/r to SS).
    c. Decision date for satellite 25-30 procurement mid/end 2014.
2. **Satellite 31-...:**
    a. Large class platform favourite solution.
    b. Parallel Phase A/B studies.

Testbed Maintenance & Evolution

1. **HISTB Extension**
   a. *To secure EGNOS V3 Phase C/D by experimenting innovative points raised during phases A & B.*
2. **HISTB New integrity concepts testbed**
   a. *Support EGNOS V3 Phase B2 for specific experimentations in order to secure innovative concepts.*
3. **MLU testbed extension**
   a. Disaster Management Centres will be connected in full real time mode.
   b. Emergency service user receiver power optimisation at acquisition / tracking level.
4. **Arctic testbed extension (tbd)**
   a. New Services (notably maritime)
   b. Field trial on North Pole via broadcast on MEO/HEO
5. **ARAIM testbed (tbd)**
   a. To validate key ARAIM assumptions with long term data collection in real environment and analysis.
   b. To develop prototype ground infrastructure to compute and disseminate ARAIM ISM message. This will include deploying a network of multi-constellation receivers world wide.
6. **Review of testbeds postponed during current EGEP Phase**

Important note: testbeds will require use/lease of GEO satellite

Complementary Activities

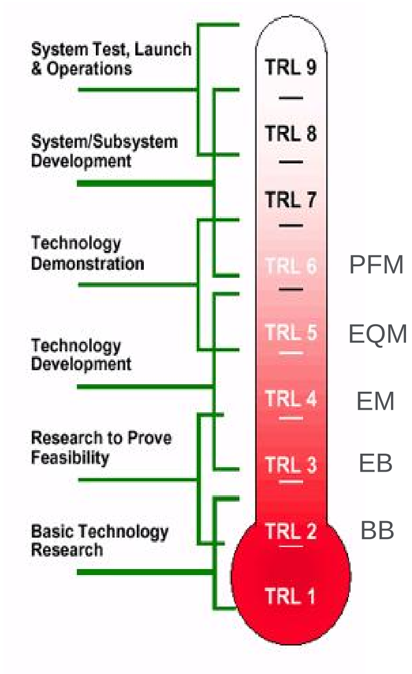
Four lines identified:

1. **Actions or studies undertaken directly by the Agency**
    a. Gather input from the main stakeholders.
    b. ESA participation in working groups of standardization.
    c. ESA participation in international level forums.

2. **Support studies**
    a. Aim at confirming the feasibility/non-feasibility of a mission objective.

3. **Development and implementation of technical facilities**
    a. Support system and segment activities.

4. **Technology developments**
    a. See next slides.



Technology development - Large class platform

1. **Preliminary design phase (~9 months to PDR):**
    a. 2 parallel contracts
2. **Development phase (~27 months to CDR):**
    a. Structural Thermal Model (STM): ~15 months
        - Structure
        - Thermal
        - Mechanisms
        - Launcher Interface
    b. Representative Engineering Model (EM): ~15 months
        - On board software development
        - Interface PF/PL design (including additional payloads)
        - P/F Subsystem design (maximise COTS from existing telecom satellites e.g. SmallGEO, Eurostar, etc.)
        - Additional payloads plug-in during the development phase
    c. Testing: ~12 months after STM/EM
    d. Detailed design: ~27 months
3. Total design and development phase: ~3 years.
4. Acceptable risk if procurement is started before CDR to launch in 36 months @ standard practice.

Technology development - Payloads

Main payload to be developed:

a. ISL transponder and antenna, using on ground breadboard

Other payload development activities may include (depending on the consolidation of Galileo Evolution requirements):

a. Additional signal aiding acquisition (E1D)
b. Additional signal power E1B/C (+2dB)
c. Miniature PHM
d. Caesium Clock
e. Advanced CMCU (ensemble) Failure Detection Unit (FDU)
f. Self Equalising Payload (SEP)
g. L-Band / C-Band spot beam antenna
h. L-Band / C-Band active BFN antenna
i. Flexible amplifiers (TWTA/SSPA)
j. Secure TT&C transponders

Activities shall lead to EQM models TRL 5/6.

Technology development -
Other ground & user segment projects

Main ground segment developments:

a. GSS and RIMS next generation including advanced interference and multipath rejection, using Beam Forming Network antennas, interference real time monitoring and more flexibility.

Other ground / user developments may include (depending on the consolidation of Galileo Evolution requirements):

a. GST Ensemble

b. Test User Receiver - Next Generation
   - Higher resistance to interference/multipath (e.g. improved antenna + improved RFFE + improved DSP)
   - Lower acquisition and tracking thresholds (e.g. improved antenna + improved DSP)

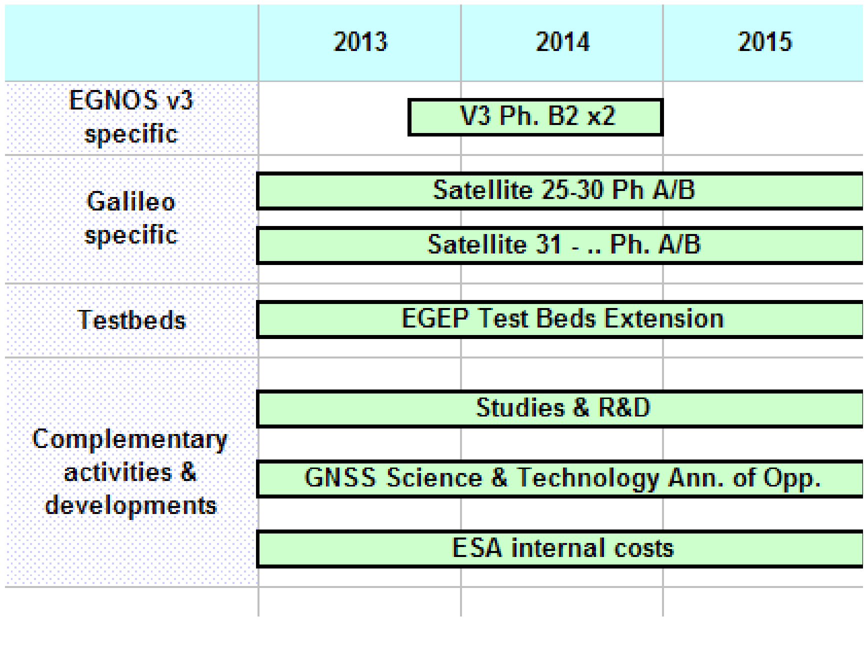
c. GNSS Performance Monitoring
   - GPS, Glonass, Galileo, Compass
   - WAAS, EGNOS, MSAS, SDCM, GAGAN

d. Ionosphere monitoring to support EGNOS for Africa

e. Prototyping of SBAS L1/L5 flexible user receiver (S/W receiver)

f. SBAS L1/L5 Payload simulation upgrade and integration with SPEED

Summary



1. **Four lines of activity for EGEP extension have been defined.**
2. **Budget is under discussion with ESA Member States and will be finalised at ESA Ministerial Conference end 2012.**

Concluding Remarks

- Based on system evolution drivers discussed, families of scenarios are identified
- Potential evolution opportunities are:
  - A first batch of 4-8 (tbd) evolution satellites targeting a launch window of 2017-2019, based on either:
    - Limited re-optimisation of current FOC payload, or
    - A larger class platform (~1500kg) with electrical propulsion
  - From satellite 3X and beyond with a launch window starting 2021, a larger class platform (~1500kg) using electrical propulsion
    - Satisfying all Galileo System Evolution Drivers w/ max flexibility
    - Staying within the current launch cost
- **In order to meet the presented target dates for both scenarios, it is mandatory to start with preparations in EGEP extension 2013-2015**
- **Evolution mission requirements and priorities have to be stabilized and consolidated within 2012**

Concluding Remarks

- Whereas the first phase of EGEP was mainly techno-driven, the intention with the extension phase 2013-15 is to develop the evolution of the systems EGNOS and Galileo.
- EGNOS testbeds are for the purpose of supporting EGNOS V3 Phase B.
- Selected studies in R&D in the line of Complementary Activities & Developments will be carried out only for the purpose of supporting the evolution of EGNOS and Galileo.