European Technology Harmonisation on Ground Systems Software

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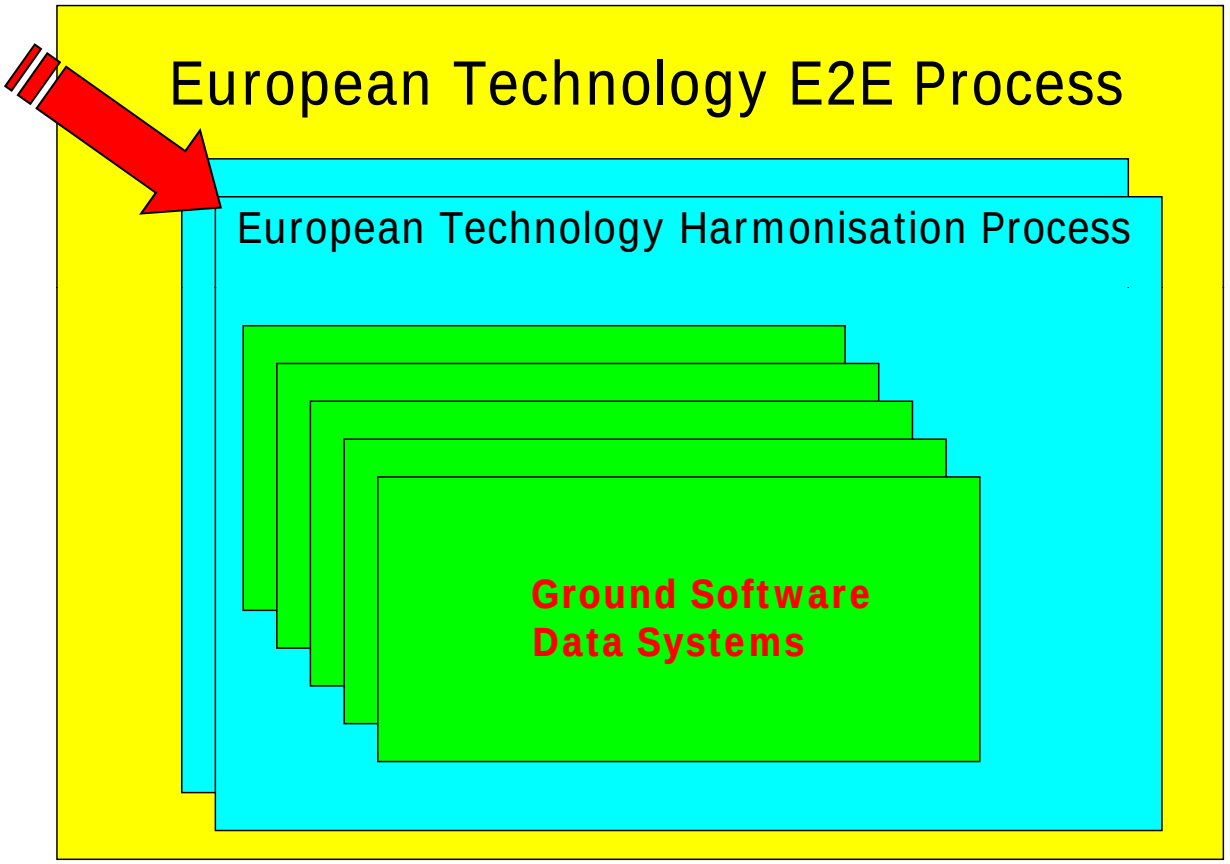
Outline

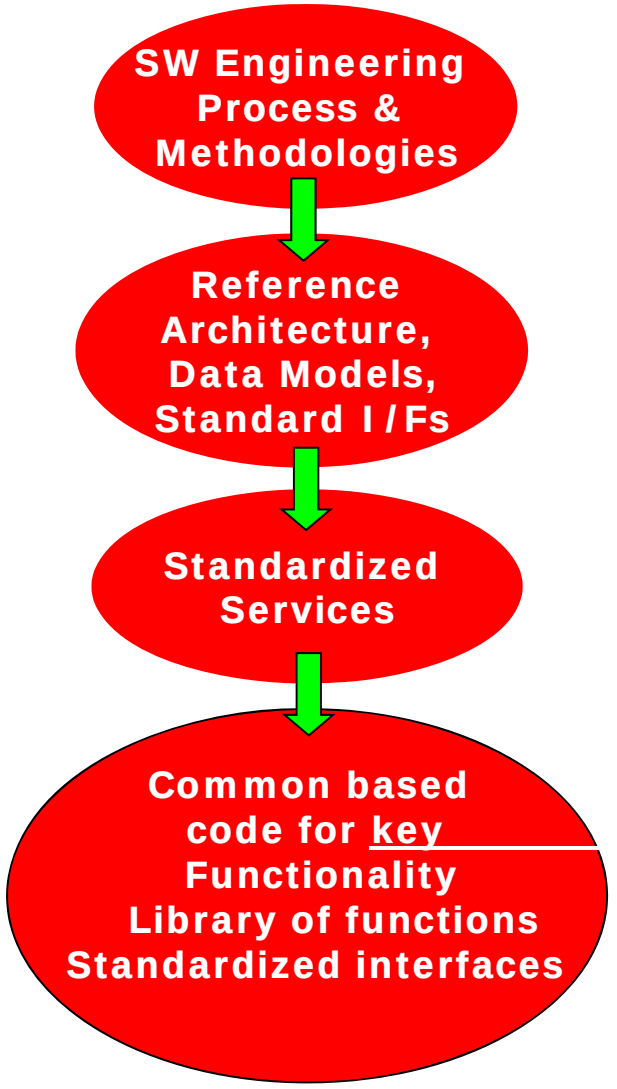
1. European Technology End To End Process
2. European Harmonisation Process
3. Harmonisation on Ground SW Systems
4. Interfaces Harmonisation
5. A Monitoring & Control Common Core
6. Lessons learned
7. Conclusions

Overview

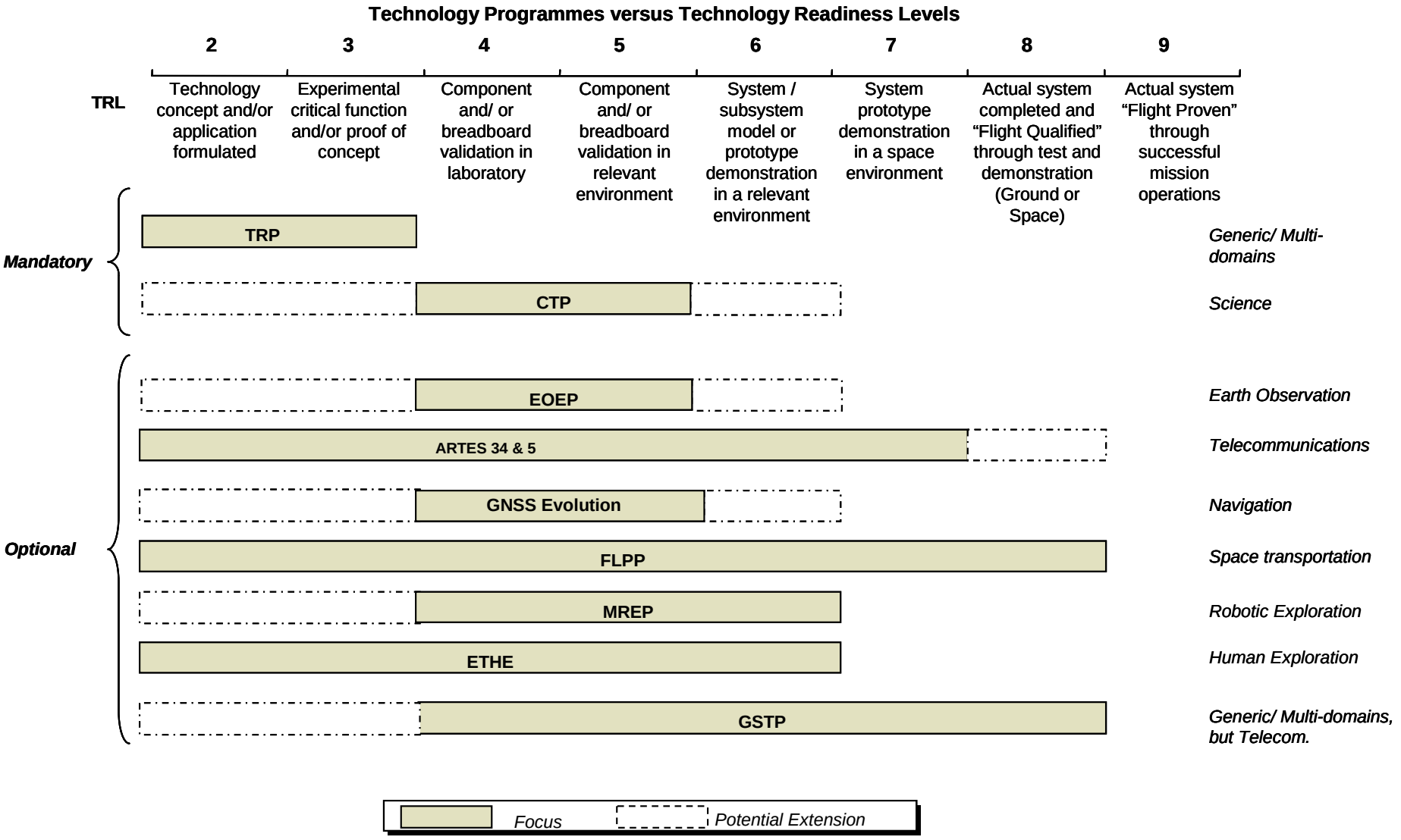


! 18 National Space entities (25 in the future), 3 Primes, 50-80 SW SMEs and ESA !

Ground SW Harmonisation



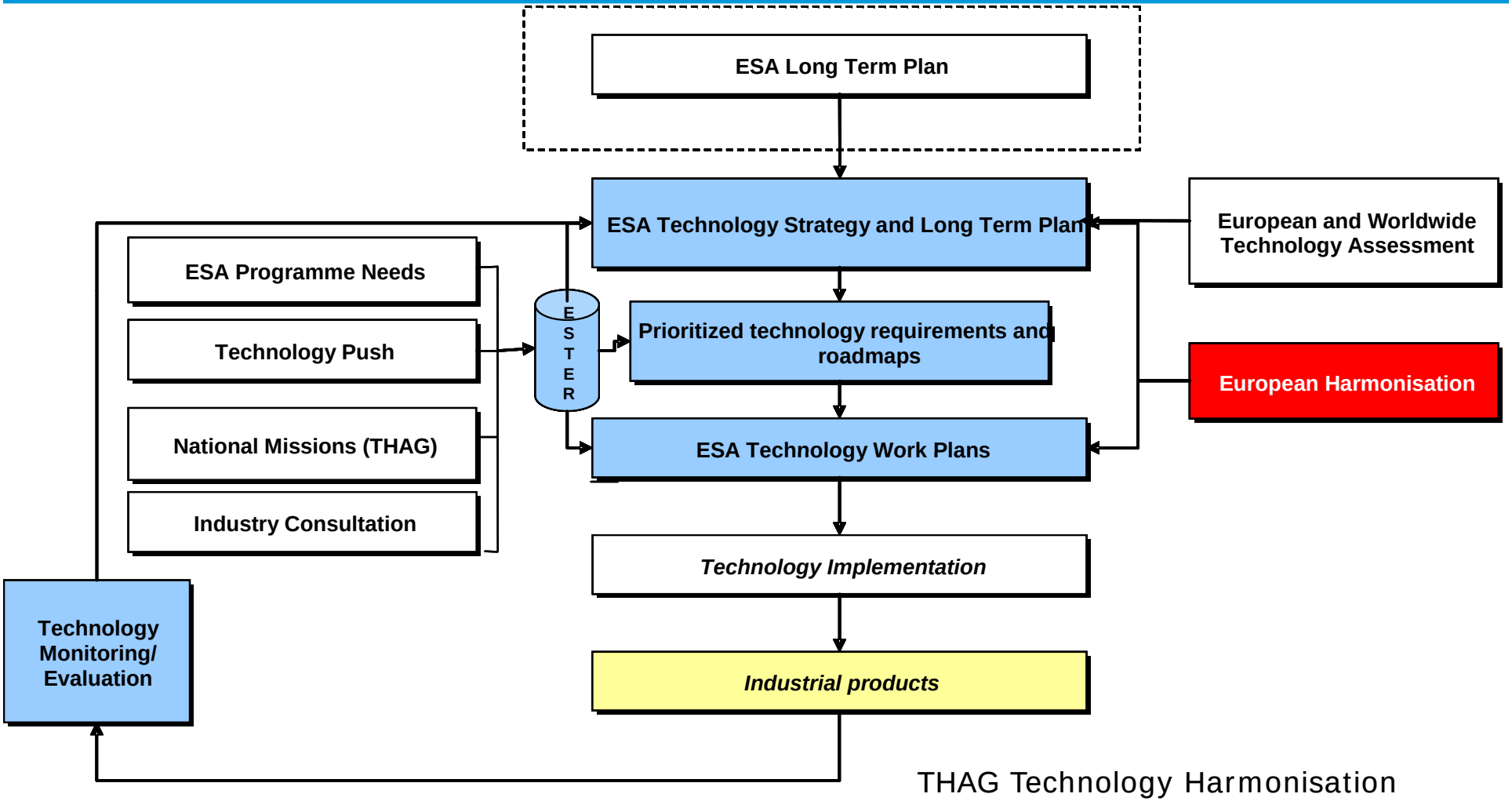
Overview on ESA Technology R&D programmes



The E2E Process

- The main objective of the E2E technology process is to undertake well planned coordinated developments in answer to user requirements
  - missions needs,
  - industry competitiveness,
  - non-dependence in order to have technology ready at the maturity level required at each stage by the users.
- The process is guided by the following main principles:
  - Integrating the different technology Programmes within a common set of processes and objectives
  - Securing the funding at the right time and in the right programme
  - Rendering the ESA technology process fully transparent, well coordinated and efficient
  - Leveraging on and reinforcing the technology harmonisation process
  - Setting a real product policy
  - Developing a systematic monitoring and evaluation process of the technologies developed
  - Exploiting synergies with non-space sectors, favouring the spin-in of non-space technologies.

The E2E Process



THAG Technology Harmonisation Advisory Group
ESTER European Space Technology Requirements

The E2E Process

The E2E process is structured according to 9 Service Domains (SD)

- Every SD is divided in Technology Domains (TD)

1. Earth Observation (EO)
2. Science (SCI)
3. Human Spaceflight and Exploration (HSE)
4. Space Transportation (ST)
5. Telecommunications (TEL)
6. Navigation (NAV)
7. Generic Technologies and Techniques (GEN) covering multi-use technologies and technology innovation.
   a. TD1
   b. …
   c. TD9 Ground Segment Data Systems and Operations
   d. ….
   e. TD26
8. Security (SEC)
9. Robotic Exploration (REX)

ESA Mandate for Technology

Ministerial Resolution:

" The Ministerial Council Meeting, in Edinburgh, on November 2001, invited the ESA Director General and the Member States, together with the other players in the space sector, to:

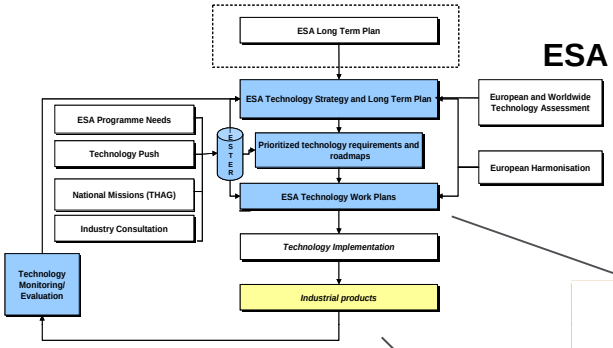
⇨Pursue the programmatic coordination and harmonisation of technology programmes in Europe and prepare the European Space Technology Master Plan (ESTMP)

⇨Define roadmaps and harmonised implementation schemes for the development of critical technologies, involving industrial funding as appropriate"

Extract from the European Space Policy:

⇨*" The ESA led- process of harmonising technology development programmes provides transparency on research across Europe and paves the way for improved coordination."*

European Harmonisation Process



ESA E2E Technology process

Technology Monitoring

ESA Technology Plans

National Agencies Technology Plans

European Union Plans

Harmonised Roadmaps

ESA National Agencies Industry

ESTER

Data Consoli-dation

European Space Technology Master Plan (ESTMP)

R&D Activities

European Space Technology Harmonisation process

Harmonisation

Technology Observatory

Selection of technologies to harmonise (for the year) - Harmo. WORKPLAN-

Technical Dossier

Mapping Meeting (open)

Proposed Road-map

Road-map Meeting (ESA, Member States, EC)

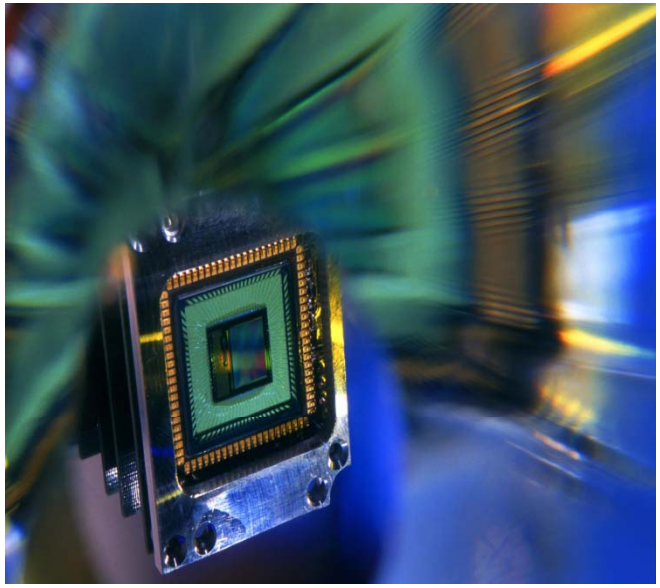
Conclusions &Proceedings

Follow-up and Status Report

Per Technology

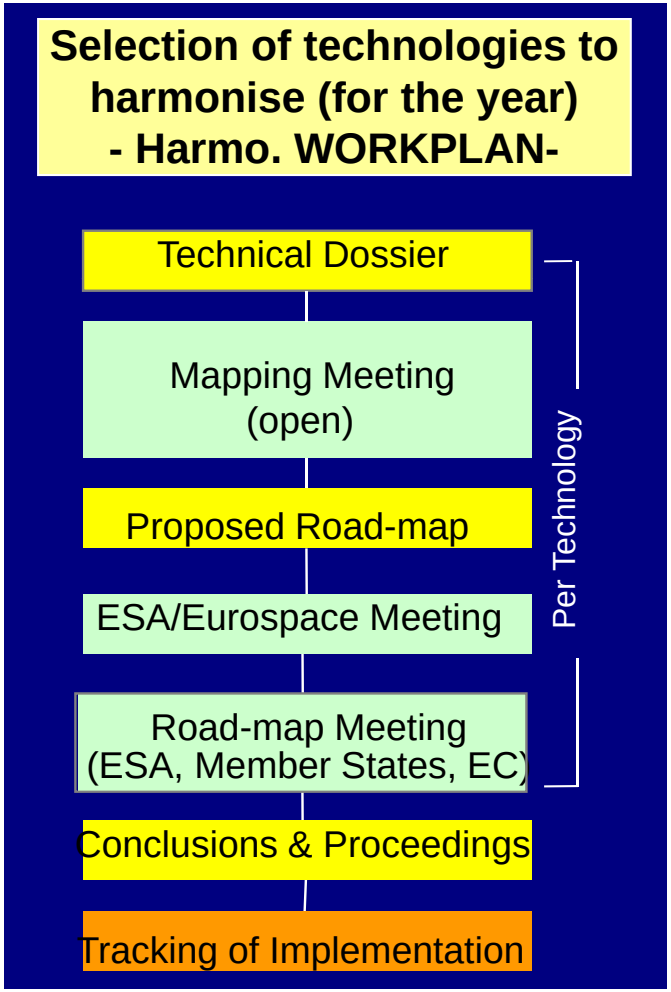
European Space Technology Harmonisation Main Objectives

- "Fill strategic gaps" and "Minimize unnecessary duplications"
- Consolidate European Strategic capabilities
- Achieve a coordinated and committed European Space Technology Policy and Planning
- Ensure continuity and coherence between Technology and Industrial Policies



How Technology Harmonisation works

- Participants are ESA Member State Delegations (Technology Harmonisation Advisory Group, reporting to Industrial Policy Committee IPC), European Industries and Eurospace and ESA directorates (European Comission, European Defense Agency and future new Members are also invited)
- Space Technologies are addressed one at a time (typically 8 per year – 2 semesters)
- The Harmonisation is based on 2 meetings:
  - Technology Mapping
  - Technology Roadmap
- Agreed Conclusions are endorsed by IPC
- Complete Proceedings are issued after meetings
- Technologies are revisited every 3 to 5 years



Harmonised Technologies 2000-2008

- ✓Automation and Robotics
- ✓Cryogenics and Focal Plane Cooling
- ✓SAR
- ✓On Board Radio Navigation Receivers
- ✓Thermal SW tools & Space Environment SW I/F
- ✓Aerothermodynamics tools
- ✓Energy Storage (Batteries)
- ✓Microelectronics
- ✓Chemical propulsion (Components, Micropropulsion)
- ✓Electrical Motors
- ✓**Ground Systems SW**
- ✓On Board Computer and Data Systems
- ✓On Board Payload data processing systems
- ✓On Board Software
- ✓TTC transponders and Payload Data Transmitters
- ✓Pyrotechnics Devices
- ✓Thermal Heat pipes and 2 phase fluid loops
- ✓Power Management and Distribution
- ✓Inflatable and deployable structures
- ✓Solar Arrays Drive Mechanisms
- ✓Deployable Booms
- ✓Upper stage propulsion
- ✓Microwave Power Breakdown Modelling and Characterisation
- ✓Antenna Reflectors
- ✓Hold-down and Separation Systems
- ✓Critical Microwave RF Payload Technologies
- ✓Electric Propulsion Technologies
- ✓Electric Propulsion Pointing Mechanism
- ✓Solar generators and Solar Cells
- ✓AOCS Sensors and Actuators
- ✓High Pressure Tanks and Vessels
- ✓Components for Electric Propulsion
- ✓Composite Materials
- ✓Space Radiation Environment Models and In-orbit Monitors
- ✓Radiation Test Facilities and Engineering Tools
- ✓Array Antennas
- ✓Lidar Critical Solid State Technologies
- ✓Frequency & Time Generation
- ✓Fuel Cells
- ✓Technologies for Optical Remote Passive Instruments
- ✓Technologies for Passive mm and sub-mm Wave Instruments
- ✓System Design and Verification
- ✓Technologies for Formation Flying Metrology
- ✓Optical communication for space

Output of Technology Harmonisation

Per Technology addressed:

- Mapping of the situation inside and outside Europe, including identification of critical issues. Technical Dossiers provide complete overview (see next slide)
- Technology Roadmaps agreed at European Level with ESA, National Delegations and Industry
- Recommendations agreed with ESA, National Delegations and Industry
- Industrial Policy Committee (IPC) endorses all through Conclusions document (1 per Semester)

Technical Dossiers

Contents of the Technical Dossier

1. Introduction

2. Executive Summary

3. Technology Status Overview

3.1. **Technology Overview**: This section introduces the reader to the technology from a broad point of view, the use of Figures and diagrams is recommended

3.2. **Areas Covered by this Technology Dossier**: This section sets the boundaries of the systems and subsystems addressed in this document. Reference to the Technology Tree shall be reported here

3.3. **Rationale for a Harmonisation of the Technology**: This section should address the reason that lead to the selection of this technology for the Harmonisation process (based on Workplan) and describe the advantages of having an overall European Technology Roadmap and how to achieve it.

3.4. **Technology State of the Art**: This section enters deeper into the technical aspects providing:

- Technical characteristics of the technology addressed
- Industry, Research Institutions and other Organisations involved in the Technology (tabular)

3.5. **Competitiveness and Benchmarking**: This section contains a comparison of the current European industrial situation with a key player (the benchmark) outside Europe

3.6. **Technology Trend**: The section describes the current and expected mid and long-term technology evolution. It gives an overview of on-going activities, within Europe and outside

4. Missions needs and Market perspectives

4.1. **Application to missions**: This section specifies which mission will benefit from the development of the technology

4.2. **Market perspectives**: If applicable, defines the application of the technology to the Space commercial market

4.3. **European Strategic Interest**: This section outlines the strategic relevance of the selected technology having reference to

- Technology availability
- Maintaining expertise within Europe
- Enabling technologies for future missions and/or products
- Technology non-dependence

4.4. **Technology Requirements**: This section identifies the requirements that shall be satisfied in order to meet Missions Needs and Market competitiveness. A table matching requirements to needs shall be reported. Technology requirements shall refer explicitly to those documented in Dossier 0.

5. Roadmap

5.1. **Summary of the Mapping Meeting**

5.2. **Development Approach**: This section describes the development activities that would satisfy the Technology Requirement

5.3. **Schedule**: In the form of a bar chart for each activity

5.4. **Costs**: Table listing activities, budget, technology programme to which the activity belongs or for which it should be proposed and TRL levels.

5.5. **Roadmap Implementation Status**: To be filled when information is available, and also for revisit cases.

6. Conclusions summarises considerations made during the process

6.1. **Conclusions**: Conclusions on the Agreed Roadmap

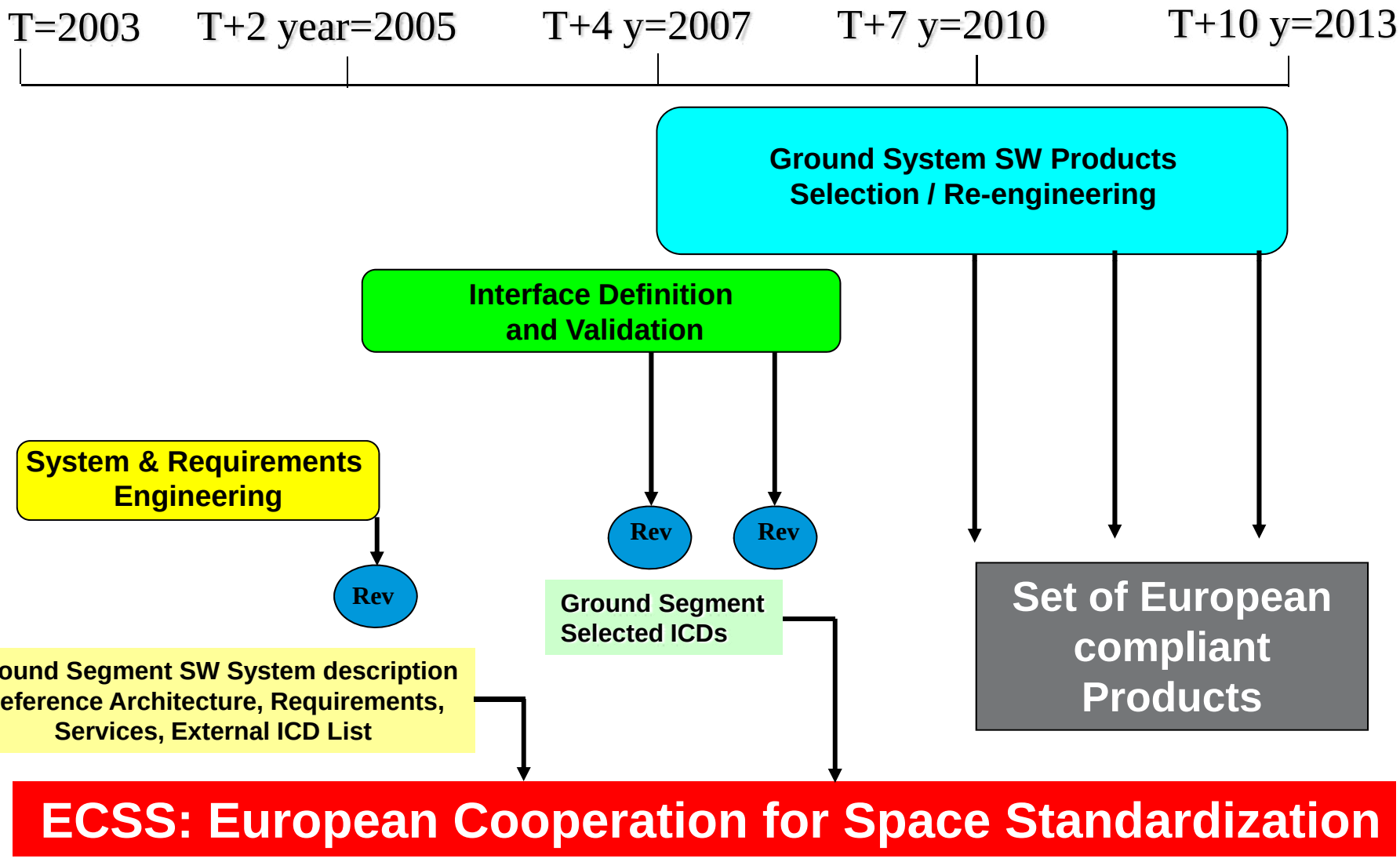
6.2. **Actions**: Actions stemming from the Roadmap meeting with THAG

Annex
Market Estimate

Ground SW Systems
Conclusions after Roadmap Meeting

1. Conclusion No 1
    a. Harmonisation of the European technologies is supported through standardisation of functions and interfaces
2. Conclusion No 2
    a. It was agreed to broaden the scope of this harmonisation (initially MCS and Electrical Ground Support Equipment –EGSE-) to include the other Ground System Components(e.g. Flight Dynamics, Simulators, Data Archiving, Mission Planning, etc.)
3. Conclusion No 3
    a. The 3 Phase approach is agreed (Medium Term Strategy) with:
        – Phase 1 (System Level)
            – To define, with the user community, a common system reference architecture and common high level requirements
        – Phase 2
            – Define standard interfaces between modules
        – Phase 3
            – Product re-engineering.
4. Conclusion No 4
    a. Establish a "Ground Systems SW Steering Board"

Agreed Roadmap ; Schedule

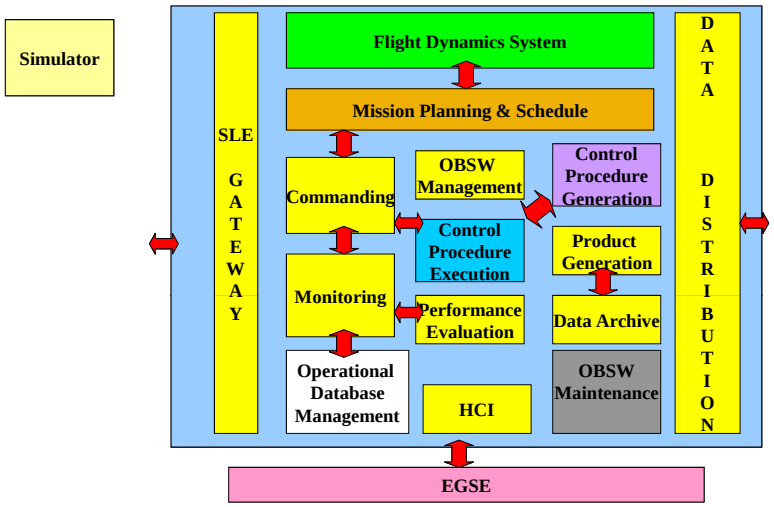


European GS SW Tech Harm
The final goal

Reference Architecture, Data Models, Standard I/Fs

esa

SCENARIO 1



NA X Product C

ESA Product A

NA Y Product D

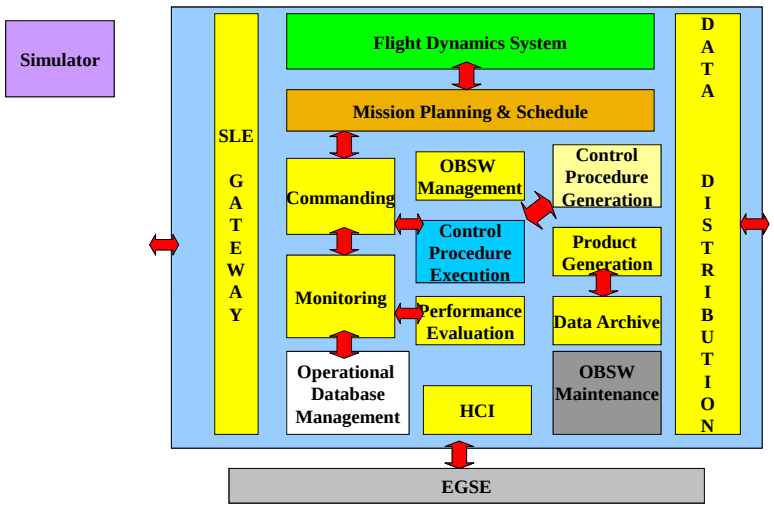
ESA Product B

Industry 1 Product E

Industry 2 Product F

Industry 3 Product G

SCENARIO 2



NA X Product C

ESA Product A

NA Y Product D

ESA Product B

Industry 1 Product E

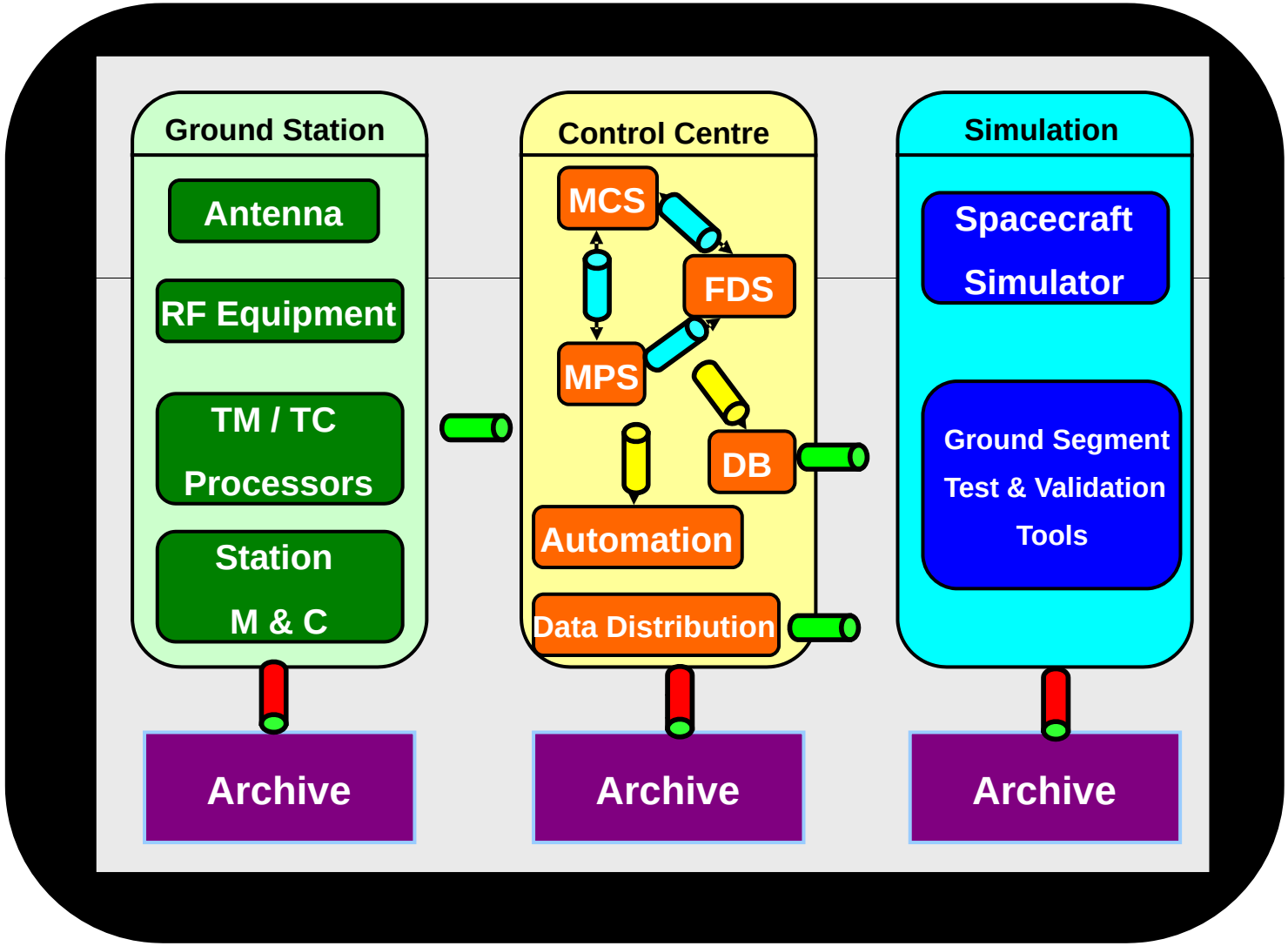
Industry 2 Product F

Industry 3 Product G

CCSDS, ECSS, OMG Standard

Ground Segment I/Fs under Harmonisation

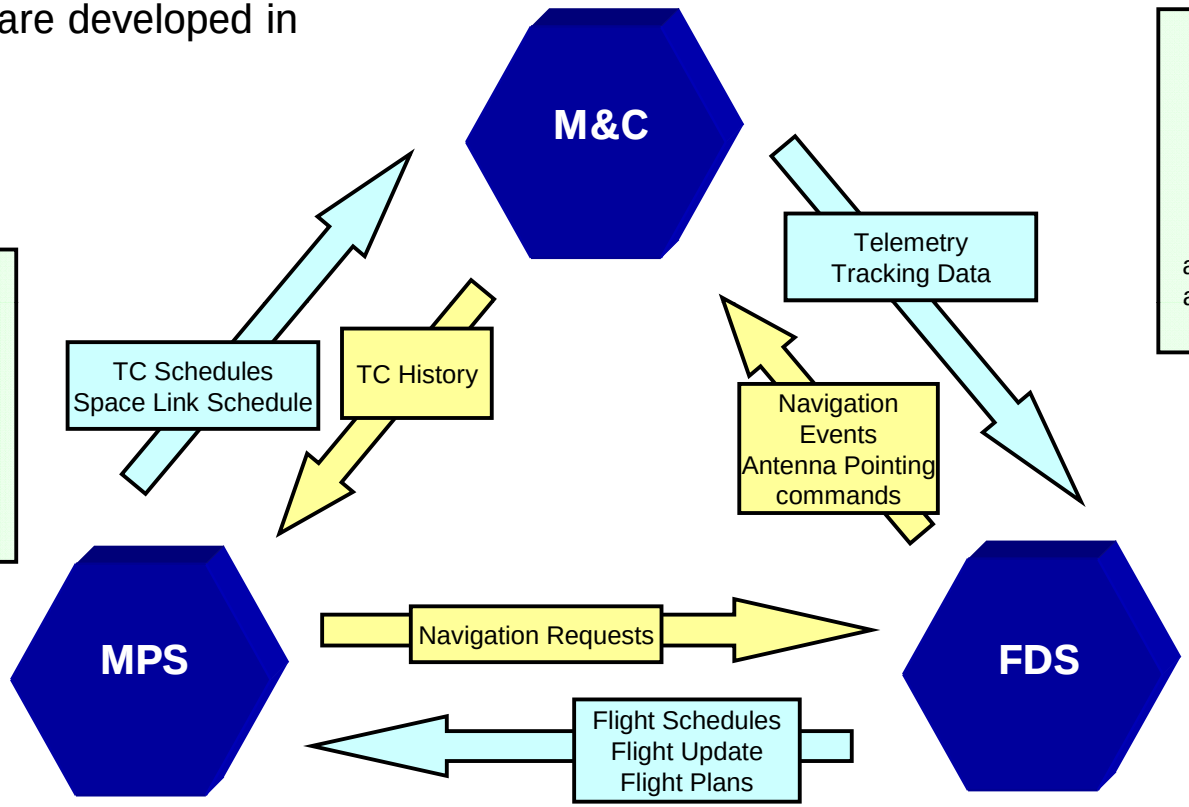
Reference Architecture, Data Models, Standard I/Fs



Interface Requirements (MPS-M&C-FDS)

Reference Architecture, Data Models, Standard I/Fs

The three Ground Control interface requirements are developed in coordination



MPS-M&C
Allows MPS to send operational schedules for execution on the M&C or elsewhere. M&C provides feedback to MPS on the success or failure of scheduled activities.

FDS-M&C-
allows flight dynamics to monitor and exert control over the spacecraft flight. Additionally it allows M&C to use and distribute FDS data.

FDS-MPS - FDS receives navigation change requests from MPS and then calculates maneuvering schedule needed to perform them. This schedules are then supplied to MPS.

Prototype for I/F Validation:
- DLR Terrasar-X MPS
- CNES SMOS FDS CLEO
- ESA M&C SCOS-2000

Ground Segment I/Fs under Harmonisation

Reference Architecture, Data Models, Standard I/Fs

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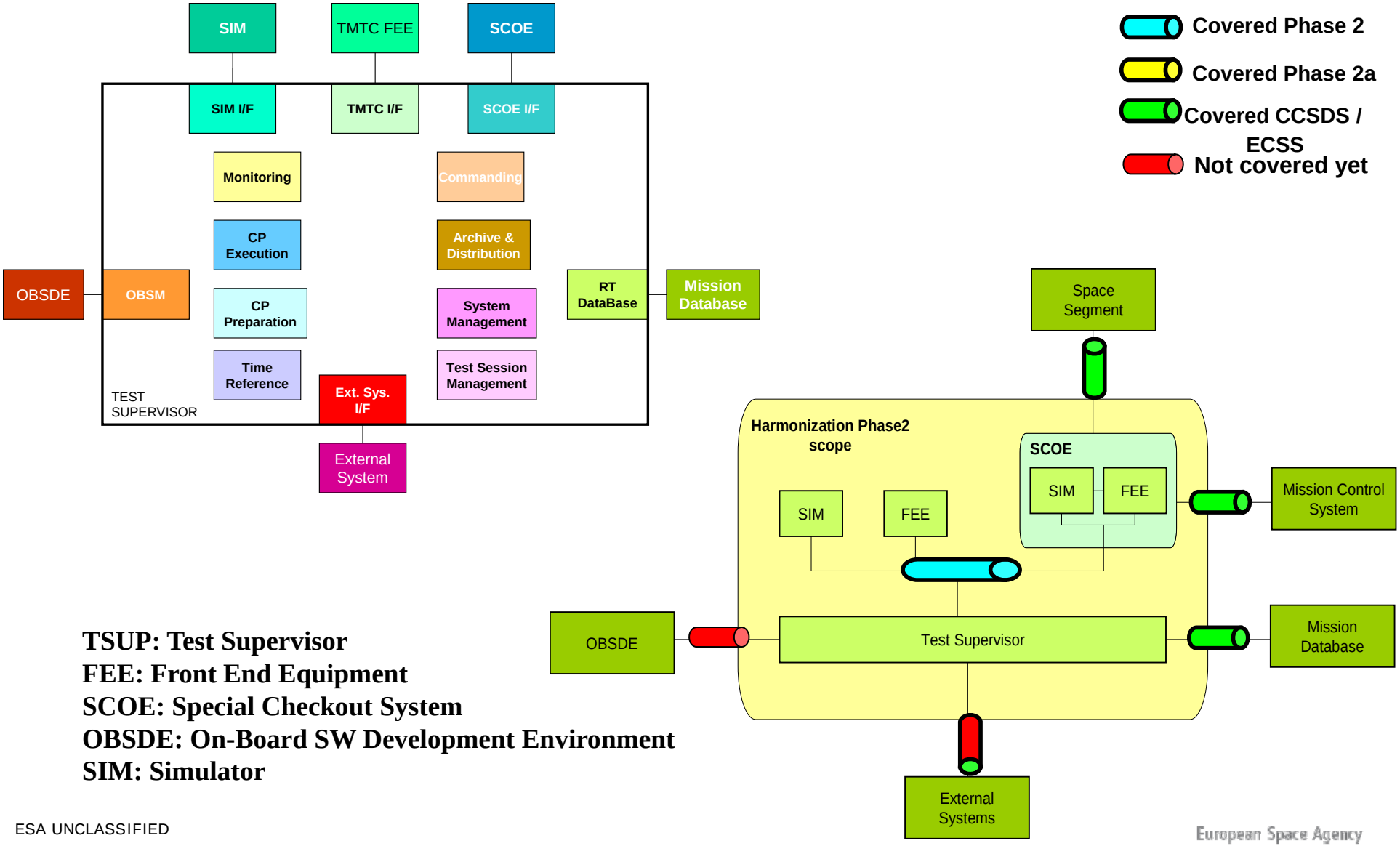
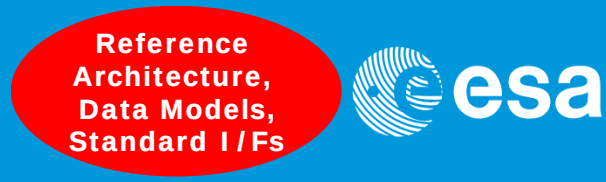


TSUP: Test Supervisor
FEE: Front End Equipment
SCOE: Special Checkout System
OBSDE: On-Board SW Development Environment
SIM: Simulator

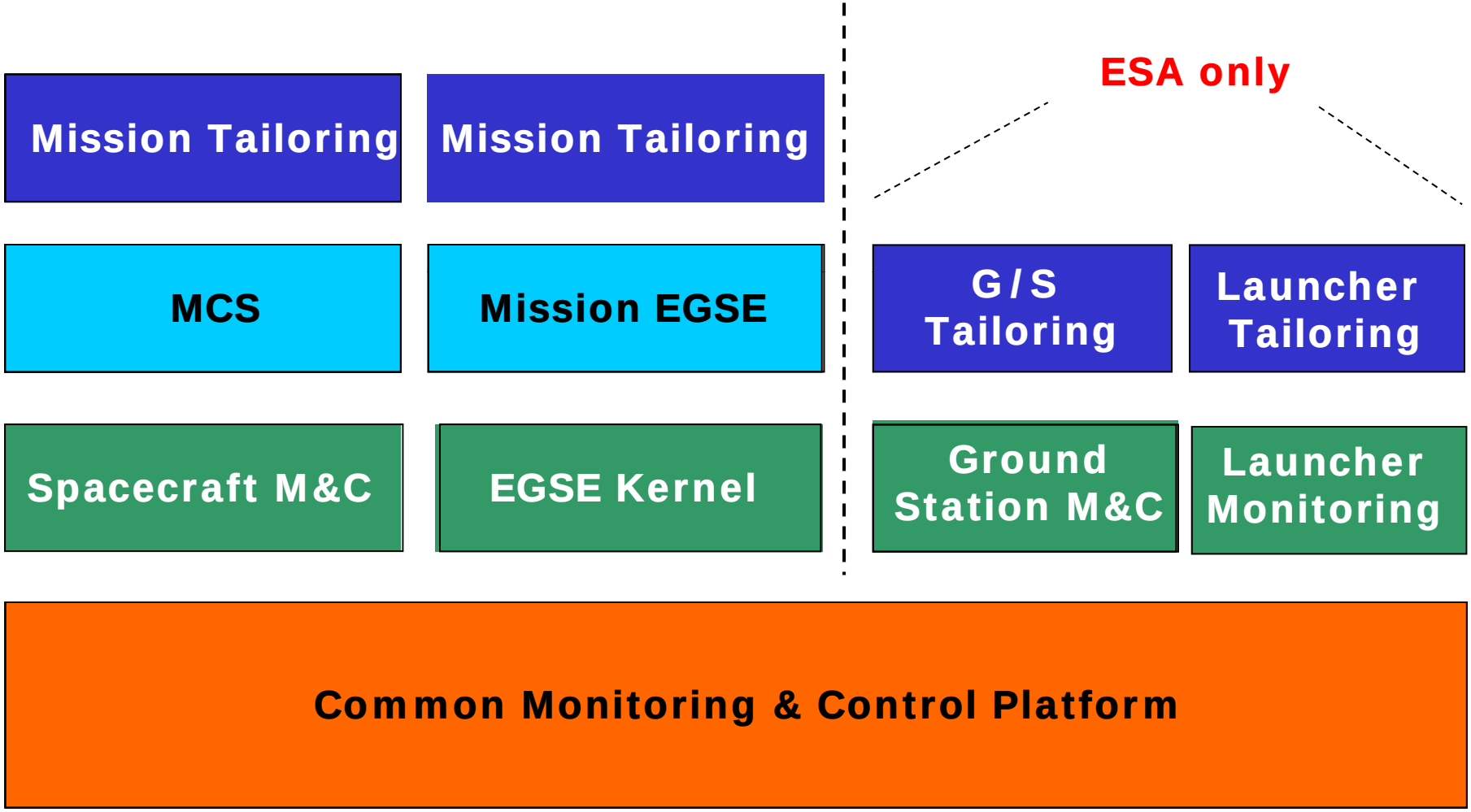
Harmonisation Status



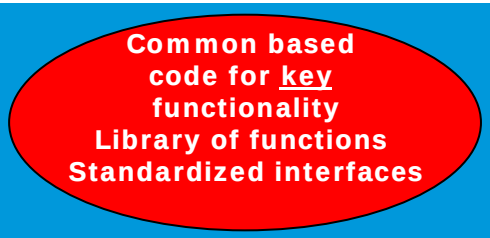
1. Mission Control Centre
    a. Reference Architecture issued
    b. High level requirements issued
    c. M&C – FDS – MPS ICDs issued
    d. ICDs validated
    e. All outputs delivered to ECSS for its further standardization
2. SIM – EGSE ICD issued
    a. ICD validated
3. Reference Architecture being updated with feedback from previous phases
    a. Considering
        – New CCSDS SM&C work
        – Common M&C Platform

Way Forward (1/4)

Common based code for key Functionality
Library of functions
Standardized interfaces



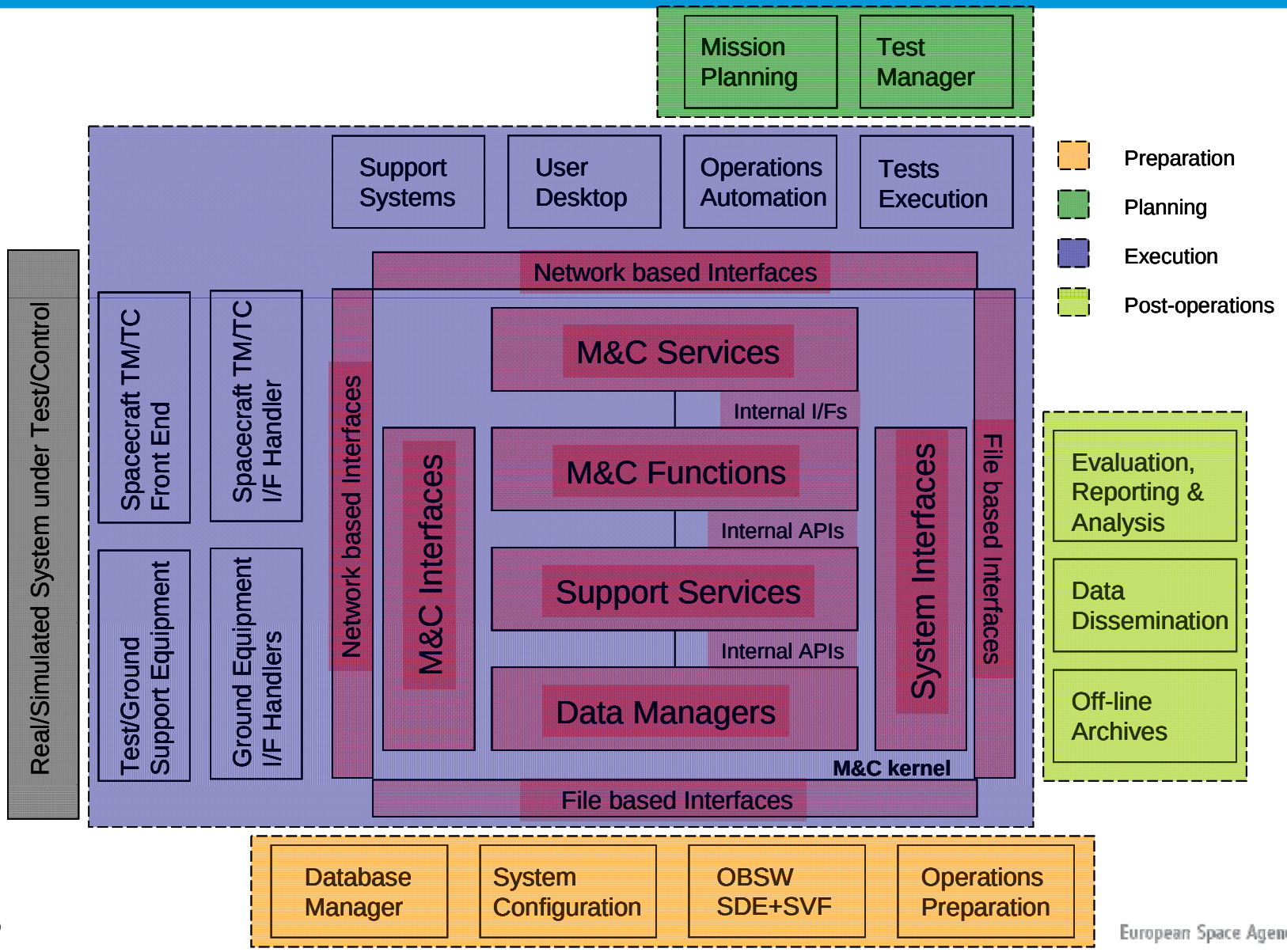
Way Forward (2/4)



- Establish a European Common Ground System Core with common functions and data models for BOTH Checkout AND Operations in order to:
  a. Facilitate synergies between Institutional and Commercial (i.e Telecommunications and EO) projects
  b. Ensure consistency between AIT (Assembly Integration and Test) and Operations (e.g. for data validation)
  c. Ensure consistency between instrument, platform and S/C AIT (e.g. with several contractors)
  d. Ensure consistency between design, verification and AIT (virtual spacecraft design)
  e. Reduce development and maintenance costs

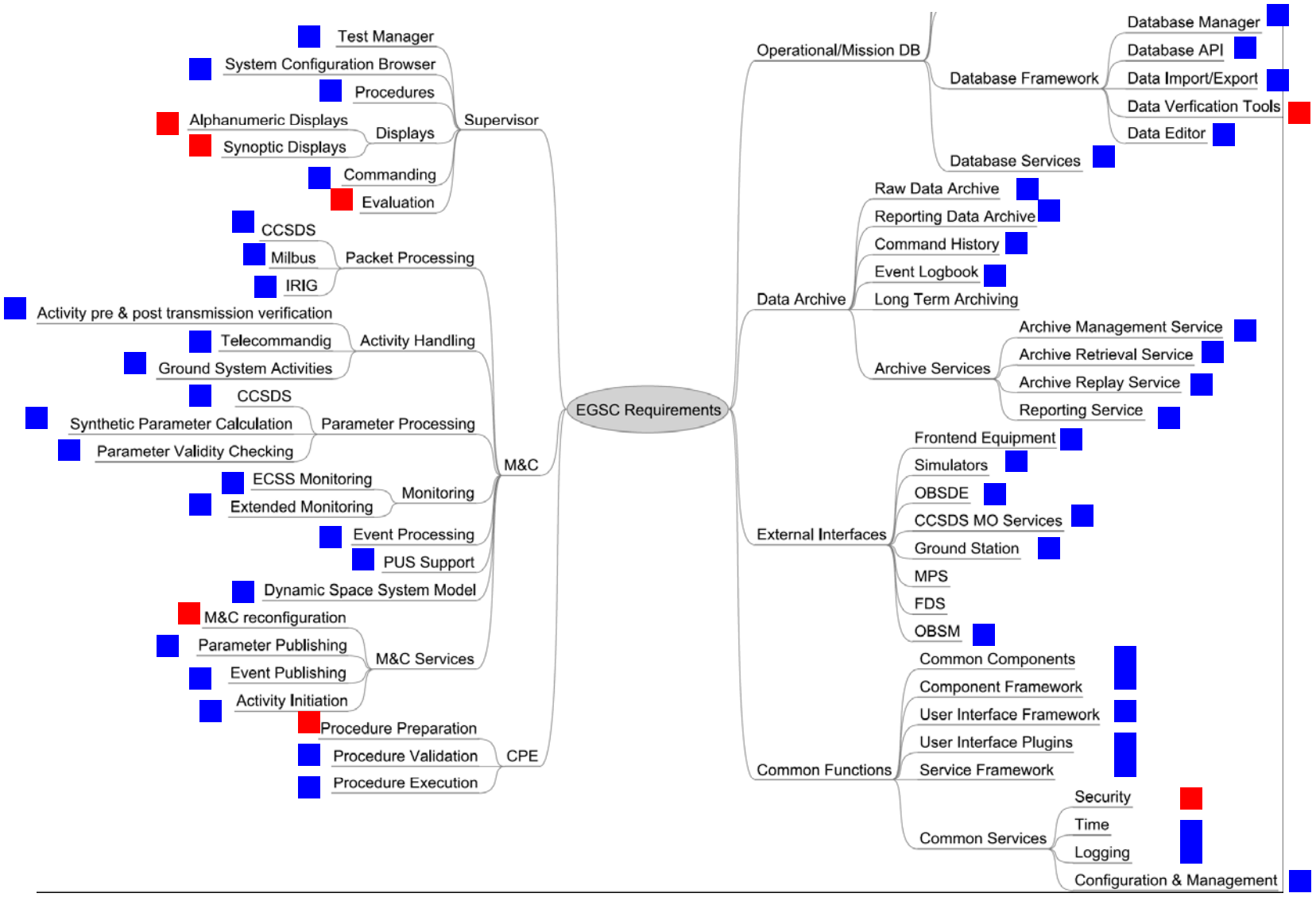
Way Forward (3/4)

Common based code for key Functionality
Library of functions
Standardized interfaces



Way Forward (4/4)

Common based code for key Functionality Library of functions Standardized interfaces



Lessons Learned (1/2)

Reference Architecture, Data Models, Standard I/Fs

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1. KISS
2. Volume of work too large and resources are minimal
3. Terminology, uses scenarios, data collection, processes, reference architecture is the way to go
4. Selection of an architecture tool is a must
5. You can not build a reference architecture without looking at real architectures of stakeholders legacy systems and their owned future evolution
    a. Confidentiality is an issue
6. Involvement of Mission Operations is a must
7. Involvement of System Developer and COTS vendors is a must
8. Joint Operations experience is a must
9. Discovery of Commonalities across systems shall be a goal
    a. Ref Architecture is at most derived from these commonalities

Lessons Learned (2/2)

Reference Architecture, Data Models, Standard I/Fs

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1. One Industrial Architecture Integrator managed only by one entity
2. WG co-ordinating reviews as focal points within their organizations
3. Iterative process (as SCRUMS / SPRINTS in AGILE methodology for SW development)
    a. Start with one view at functional level (not at the deepest architectural level)
    b. Agree
    c. Produce additional views
    d. Start with next level and continue iterating
4. 5 years elapsed time to produce Reference Architecture for
    a. Process is too slow (e.g. several members involved, scarce resources, long delays to start industrial contracts, etc.)
    b. 6 meetings per year (2-3 M€ total cost of this Phase)
    c. MOC (as a whole, and concentrating then on MPS/FDS/M&C)
    d. EGSE – Simulator – Test Supervisor
5. Cultural differences between Primes, Government Agencies and SMEs

HARMONIZATION / HARMONISATION Conclusions

1. Challenges to overcome:
   a. Different interests from National Agencies, EUROSPACE, Industries representing some delegations and ESA
      – Achieving consensus is a tedious process
      – Steering a Board with 20 members ????
   b. Seamless Transition from legacy systems to new System
   c. Capability of the stakeholder to adapt its owned roadmap to the Harmonisation Technology Dossier
   d. Continuous evolution of technology and standards
   e. Lack of funds
   f. Co-ordination / Liaison with other bodies
      – CCSDS Architecture Framework, ECSS, OMG
   g. Co-ordination with other R&D activities within stakeholders
   h. Schedule too optimistic

Every group of stakeholders shall find its own way to harmonize / harmonise Ground SW Systems