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Enterprise architecture approach at European Space Agency (ESA)

Robert Suzić, robert.suzic@esa.int
Niklas Lindman, niklas.lindman@esa.int

ESA – ESTEC, TEC-SWM, Noordwijk, The Netherlands

6th of February 2012

Outline

- About European Space Agency (ESA)
- Complex (system of) systems challenges at ESA
- R&D Activities: ESA Architecture Framework (ESA-AF)
- Case study: Space Situation Awareness
- Conclusions and Outlook

PURPOSE OF European Space Agency (ESA)

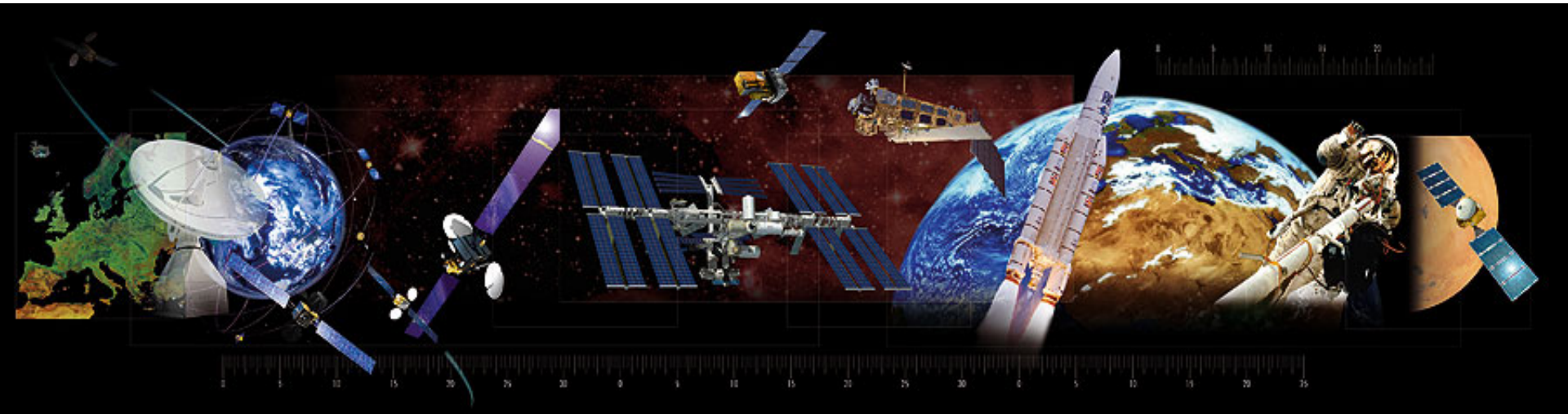
"To provide for and promote, for exclusively peaceful purposes, cooperation among European states in **space research** and **technology** and their **space applications.**"

Article 2 of ESA Convention

ACTIVITIES

ESA is one of the few space agencies in the world to combine responsibility in nearly all areas of space activity.

- **Space science**
- **Human spaceflight**
- **Exploration**
- **Earth observation**
- **Launchers**
- **Navigation**
- **Telecommunications**
- **Technology**
- **Operations**

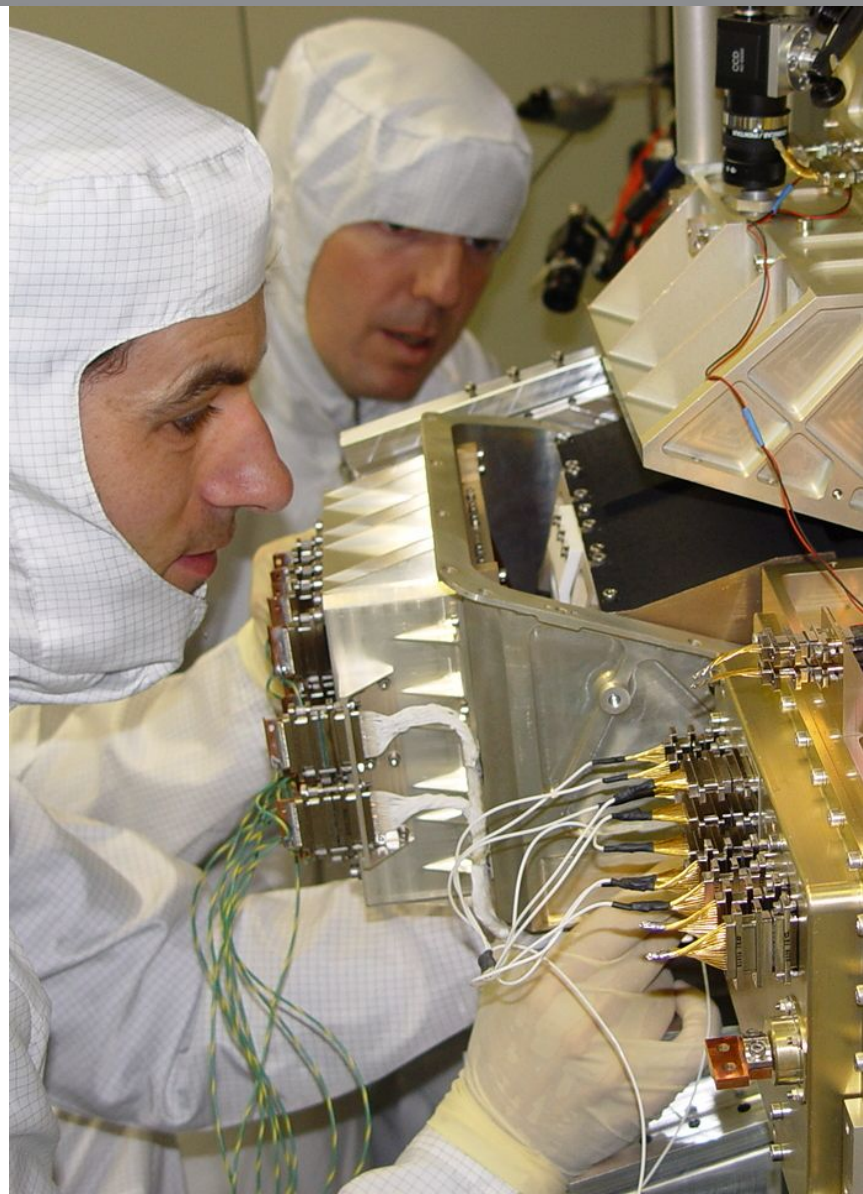


ESA'S INDUSTRIAL POLICY

About 90% of ESA's budget is spent on contracts with European industry.

ESA's industrial policy:

- ensures that Member States get a fair return on their investment;
- improves competitiveness of European industry;
- maintains and develops space technology;
- exploits the advantages of free competitive bidding, except where incompatible with objectives of the industrial policy.




esa
Complex (system of) systems challenges at ESA
European Space Agency

Todays Challenges

- **Increased complexity -** ESA is getting increasingly challenged by the call for developments of systems that should **no longer be considered space systems only**
  - Opportunities of **sharing assets** require systems capable of providing services comprising of capabilities delivered by a combination of independently developed and operated systems,
  - European characteristics of wide **diversity of regulations, different socio-technical attitudes, plethora of technical interfaces, economical directives,** introduce new strategic, operational and system-technical challenges;
  - especially, when aiming to implement **joint and combined European capabilities in order to optimize benefits from available and planned heterogeneous assets**. Such assets shall support provision of a number of services by combining different types of systems such as space and ground as well as civil and dual-use.

Todays Challenges

- **Financially very demanding (affordable only through joint financing and execution) -** Space systems can be financially very demanding and the most types of programmes like GMES or SSA can be delivered only **through joint efforts**, by integrating **available** and **planned functionalities** and **reusing existing assets** as configurations of **loosely coupled systems**.

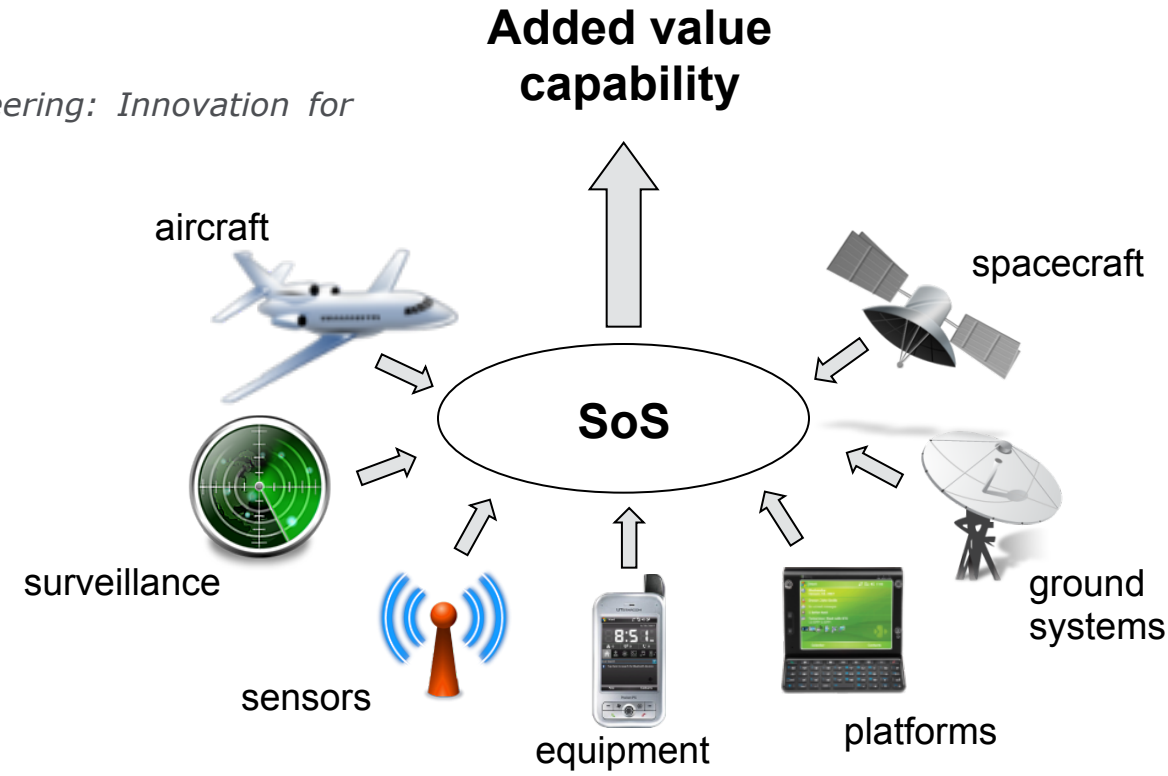
Examples at ESA

- Global Monitoring for Environment and Security (GMES)
- Galileo/COSPAS-SARSAT
- Space Situational Awareness (SSA)
- Human Exploration

System of Systems

"Large scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal"

Jamshidi, M., Systems of Systems Engineering: Innovation for the 21th Century, Wiley, 2009



General System Engineering Issues

- **System Engineering Issues:**
  - **System design/architecture is typically captured in office tools**
  - **Traceability issues**
  - **Difficult to ensure completeness and consistency**
  - **Heavy review processes**

➢ **There is a need to improve the management and system engineering methods to cope with the increasing size and complexity while maintaining quality.**

➢ **Model Based System Engineering**

Particular challenges with complex system (of systems)

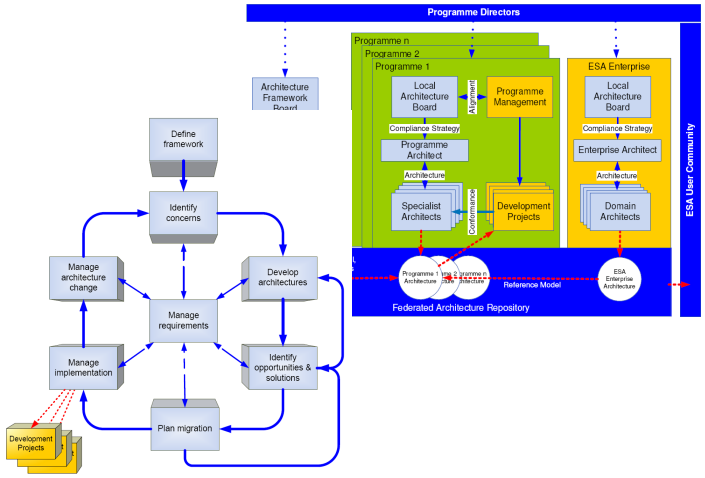
- **SoS Governance i.e. ownership, control, IPR, operating entities, agreements, funding, decision making processes,**
- **Policy conformance e.g. security and data policies,**
- **Communication between stakeholders,**
- **Ensuring traceability, consistency and completeness,**
- **Interoperability i.e. both technical as well as programmatic,**
- **(Architecture) trade-off analysis,**
- **Gap analysis,**
- **Operability,**
- **Performances and integrity (Reliability, Availability, Timeliness etc.),**
- **Standards conformance and Technology readiness (e.g. TRL)**

R&D Activities: ESA Architecture Framework (ESA-AF)

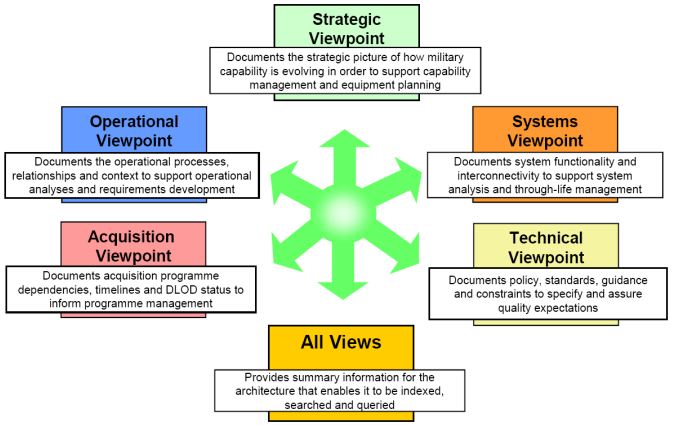
ESA Architecture Framework (ESA-AF) Overview

- To support the System-of-Systems architecting, TEC-SWM has developed an architecture framework (ESA-AF) for ESA programs:
  - Service to projects/programmes within ESA
  - Tool solution to be used by ESA and suppliers
- The solution is mainly based on existing standards (UPDM/MODAF v.1.1) and COTS (MagicDraw, Eclipse BIRT) with some ESA specific extensions, like e.g.,:
  - Financial views – e.g., costs, financial contributions, projects
  - Agreements views – e.g., agreements, projects, deliverables
  - Risk views – e.g. riskType, subjectOfRisk, riskOwner
  - Data policy and security views
  - Availability, Reliability and Maintainability - extends the UPDM resource constraint
- The ESA-AF provides a model based approach to the system-of-system architecting.

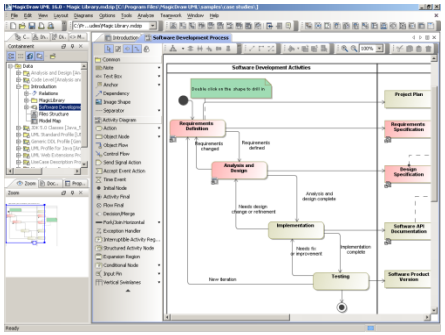
ESA-AF Elements



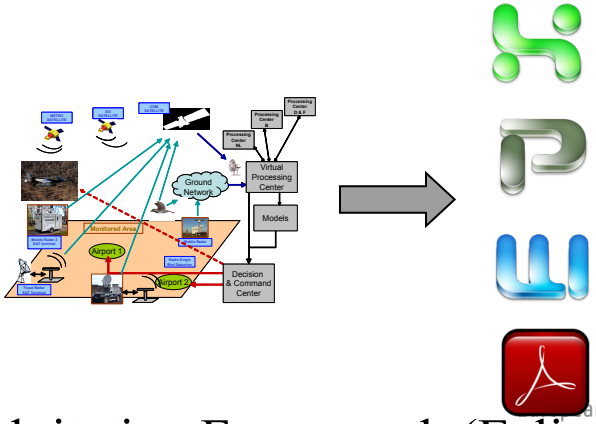
Process and Governance (TOGAF alike)



Glossary and Meta-model (UPDM/MODAF and ESA-AF specific)

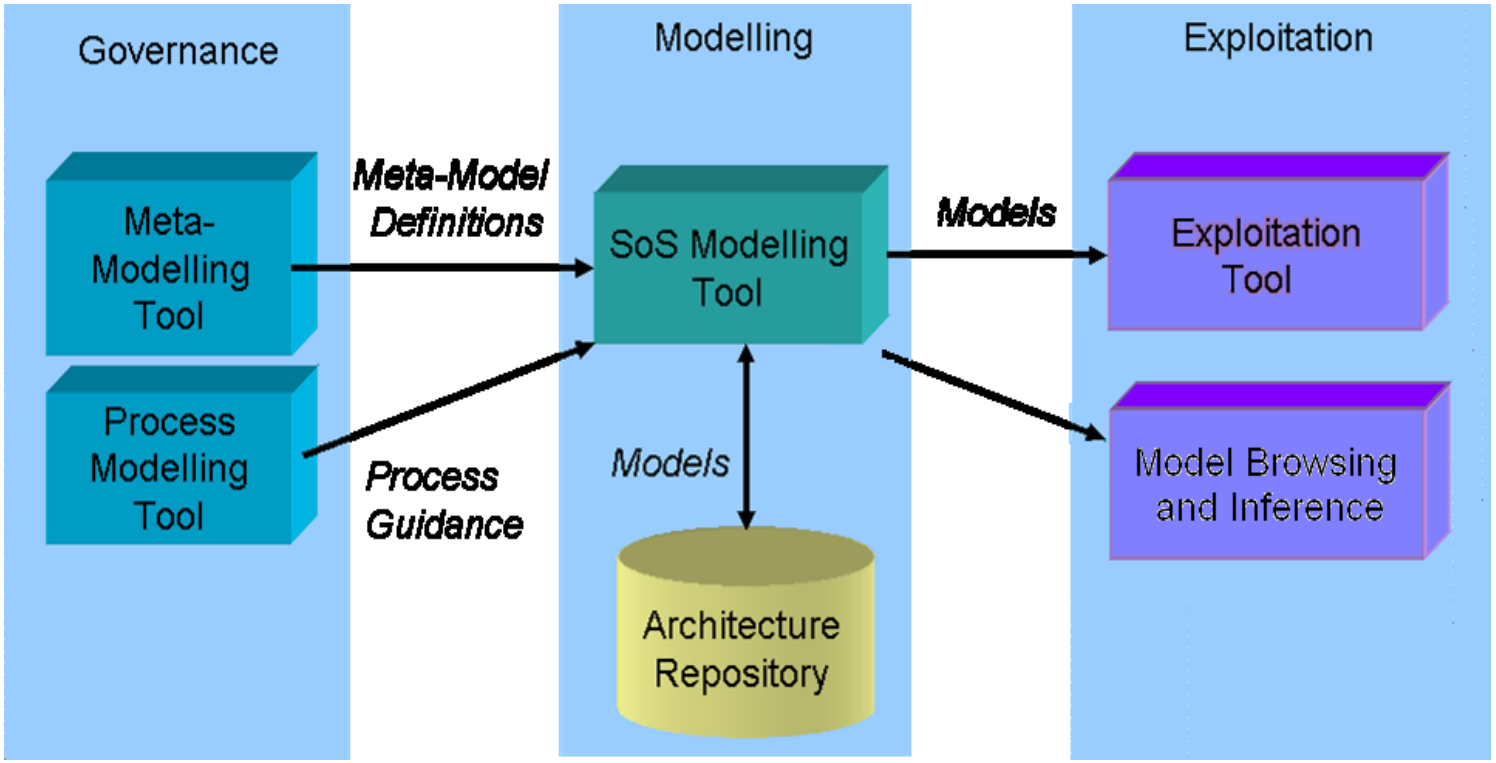


Modelling Tool (MagicDraw ESA-plugin)



Exploitation Framework (Eclipse BIRT)

ESA-AF Architecture: high level

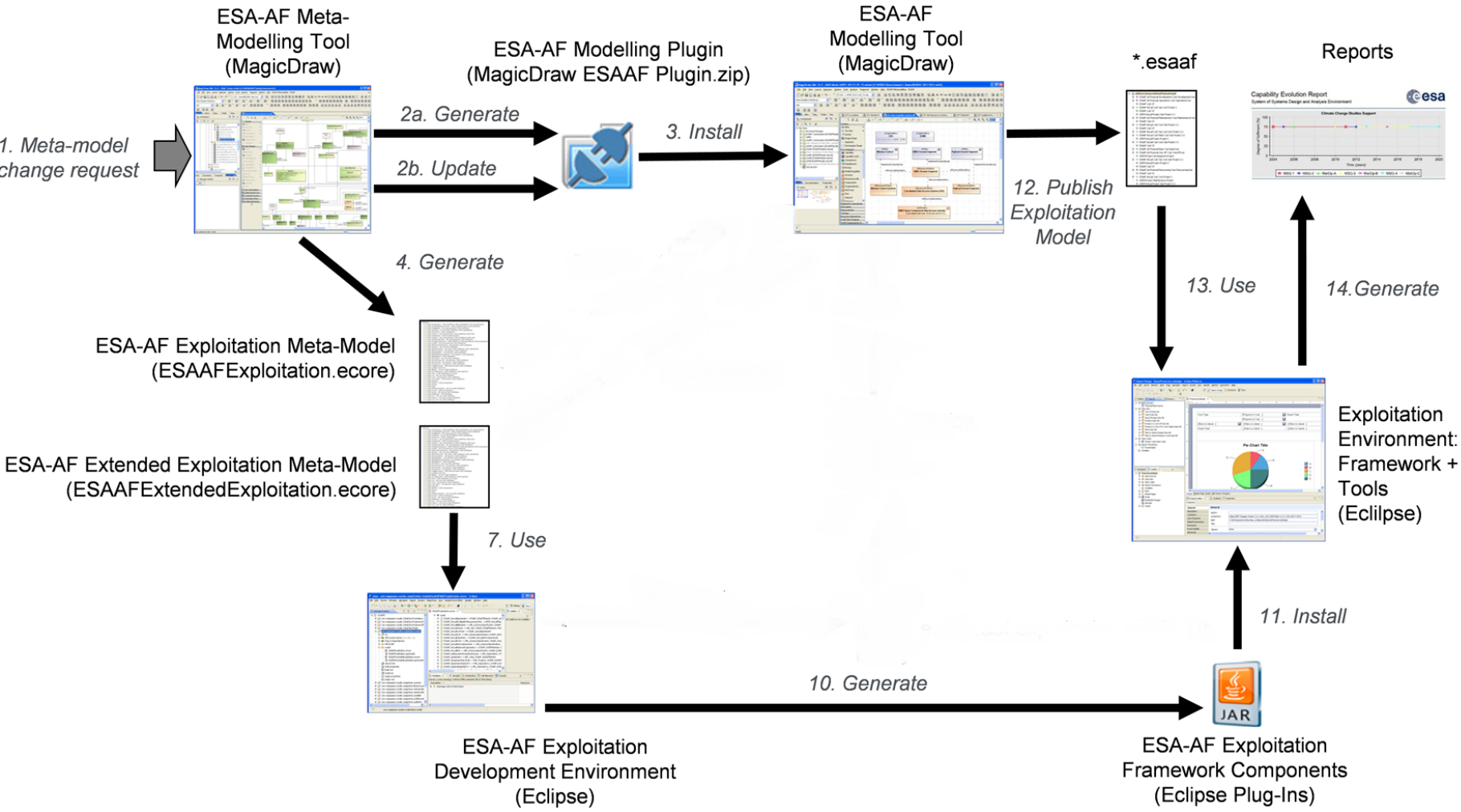


Meta-Modeller and Process Modeller

Enterprise Architect and Modeller

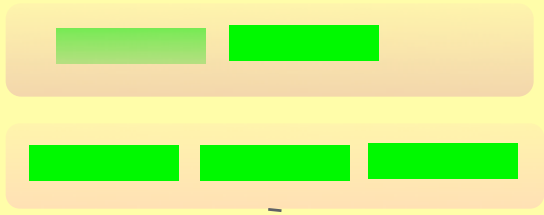
Systems Manager, Programme Manager and Customer

ESA-AF Architecture: solution level

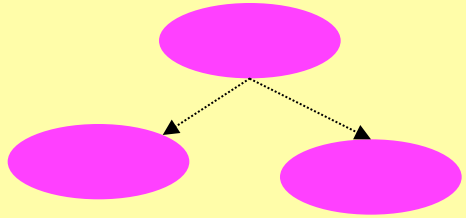


Meta-model scope

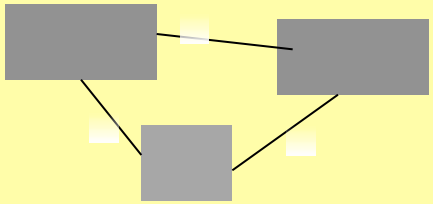
Enterprise Goals



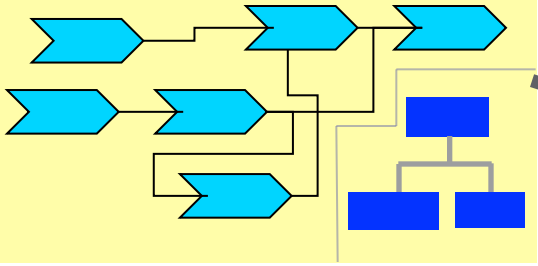
Service architecture



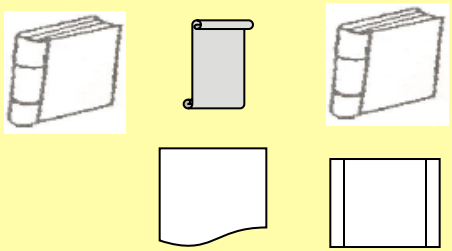
Programm



Operational architecture



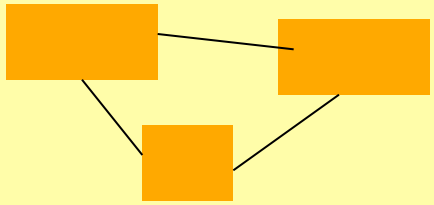
Policy



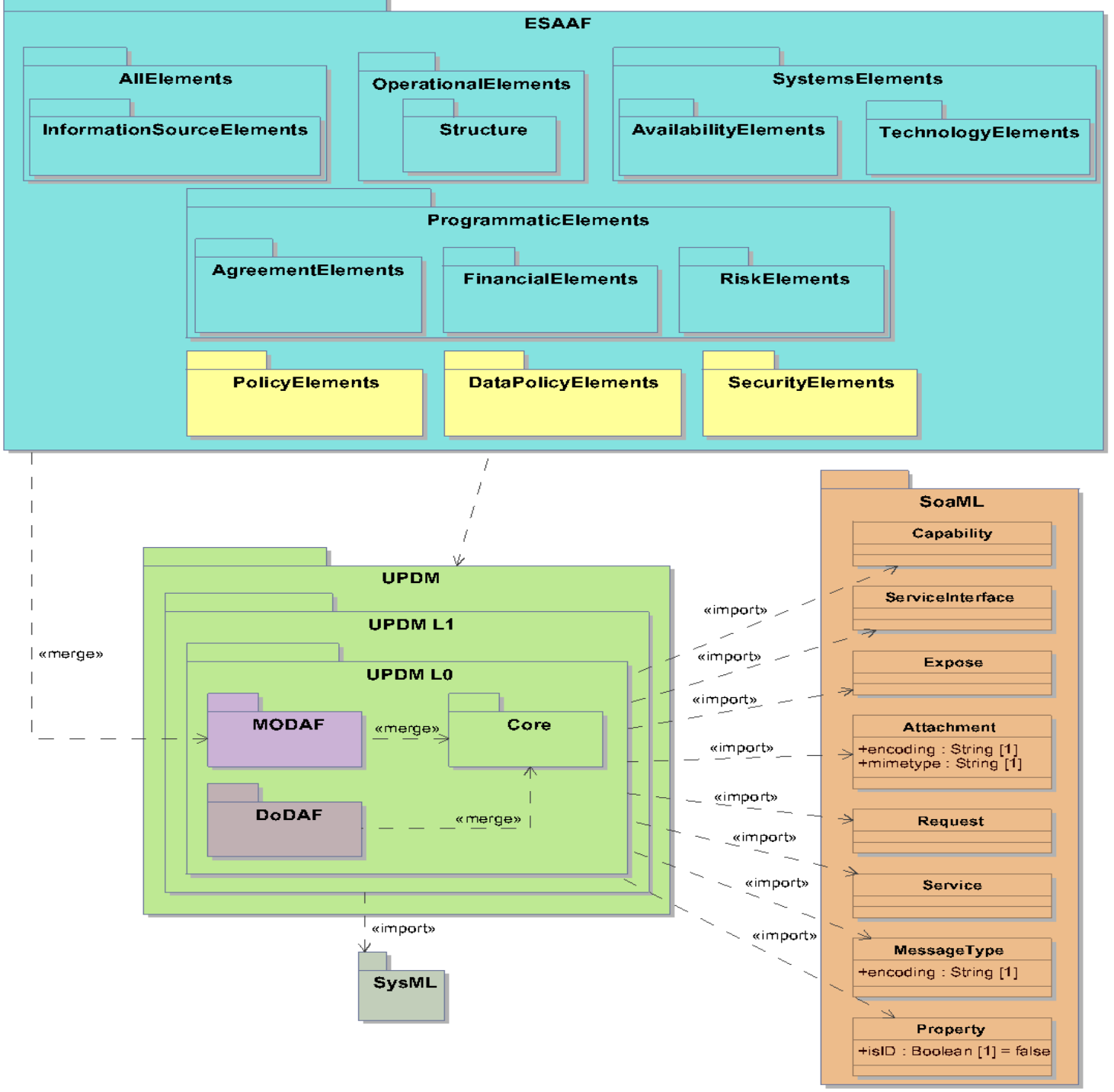
Standards and Technologies

Service Area	Service	Applicable Elements	Standard / Policy
ISTAR Governance	Operations	All fielded capability	SOPs
	Acceptance	All fielded capability	ISTAR Acceptance Procedure
MOD Strategy	Systems Engineering	SPECS 2 & interfaces	MOD Systems Engineering Management Plan (SEMP)
US Interoperability	Communications / Networking	SPECS 2 external US communications network interfaces	US Guidance Notes
Sustainment & Logistics	Ability to sustain capability	SPECS 2 & DLoD support	MOD Sustainment guidelines

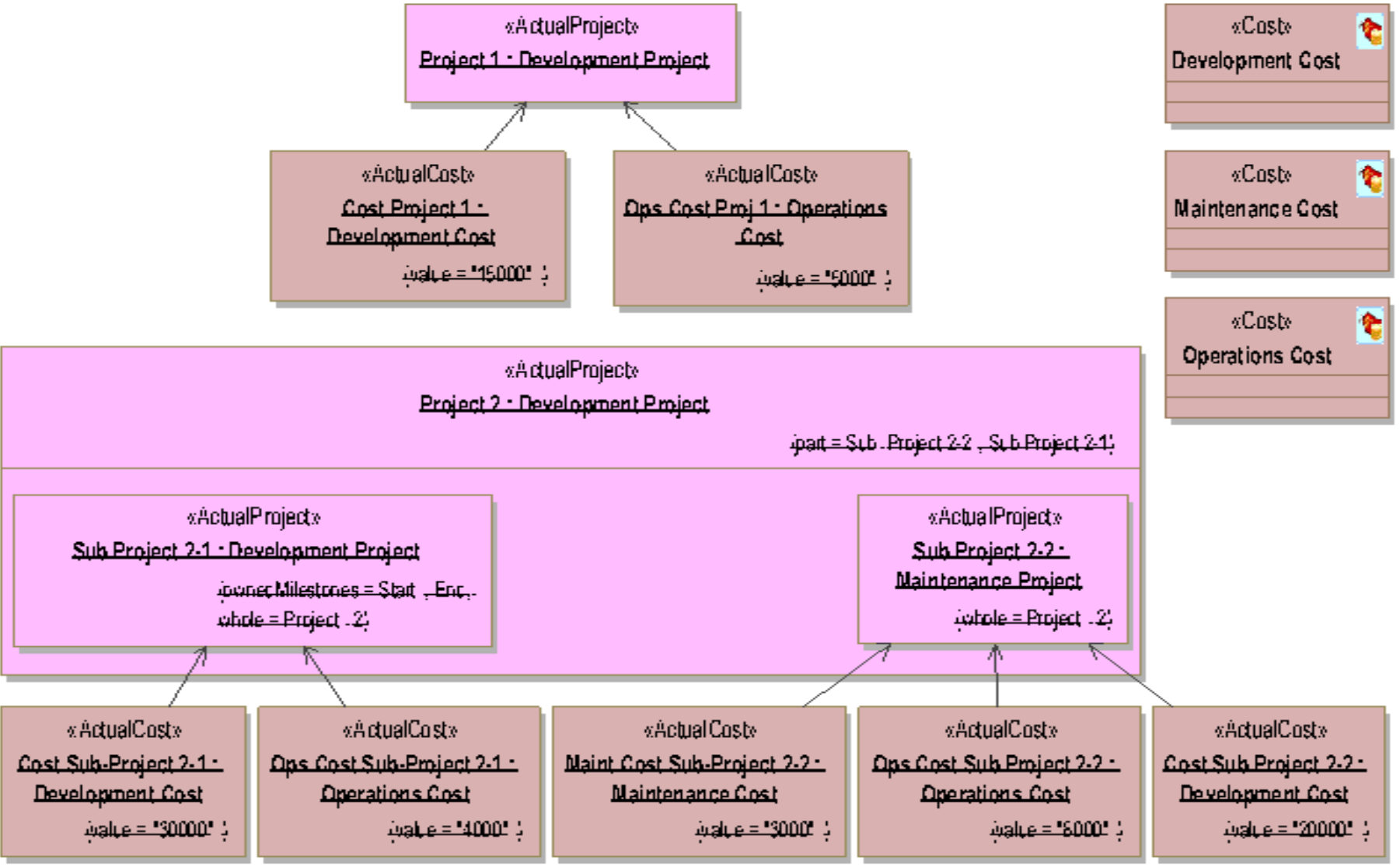
System architecture



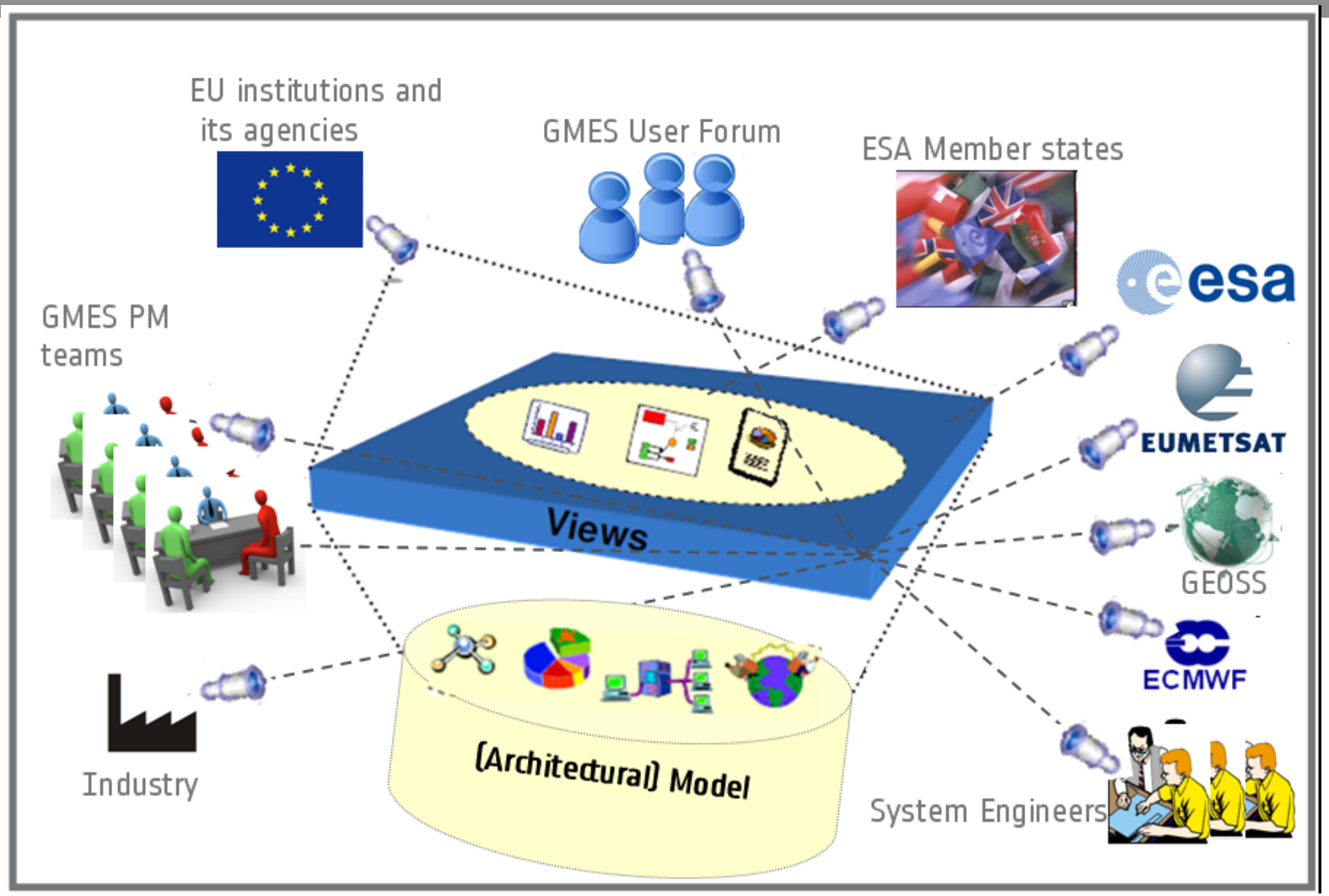
Security


ESAAF
AllElements
InformationSourceElements
OperationalElements
Structure
SystemsElements
AvailabilityElements
TechnologyElements
ProgrammaticElements
AgreementElements
FinancialElements
RiskElements
PolicyElements
DataPolicyElements
SecurityElements
«merge»
UPDM
UPDM L1
UPDM L0
MODAF
«merge»
Core
DoDAF
«merge»
«import»
SysML
«import»
«import»
«import»
«import»
«import»
«import»
«import»
«import»
SoaML
Capability
ServiceInterface
Expose
Attachment
+encoding : String [1]
+mimetype : String [1]
Request
Service
MessageType
+encoding : String [1]
Property
+isID : Boolean [1] = false

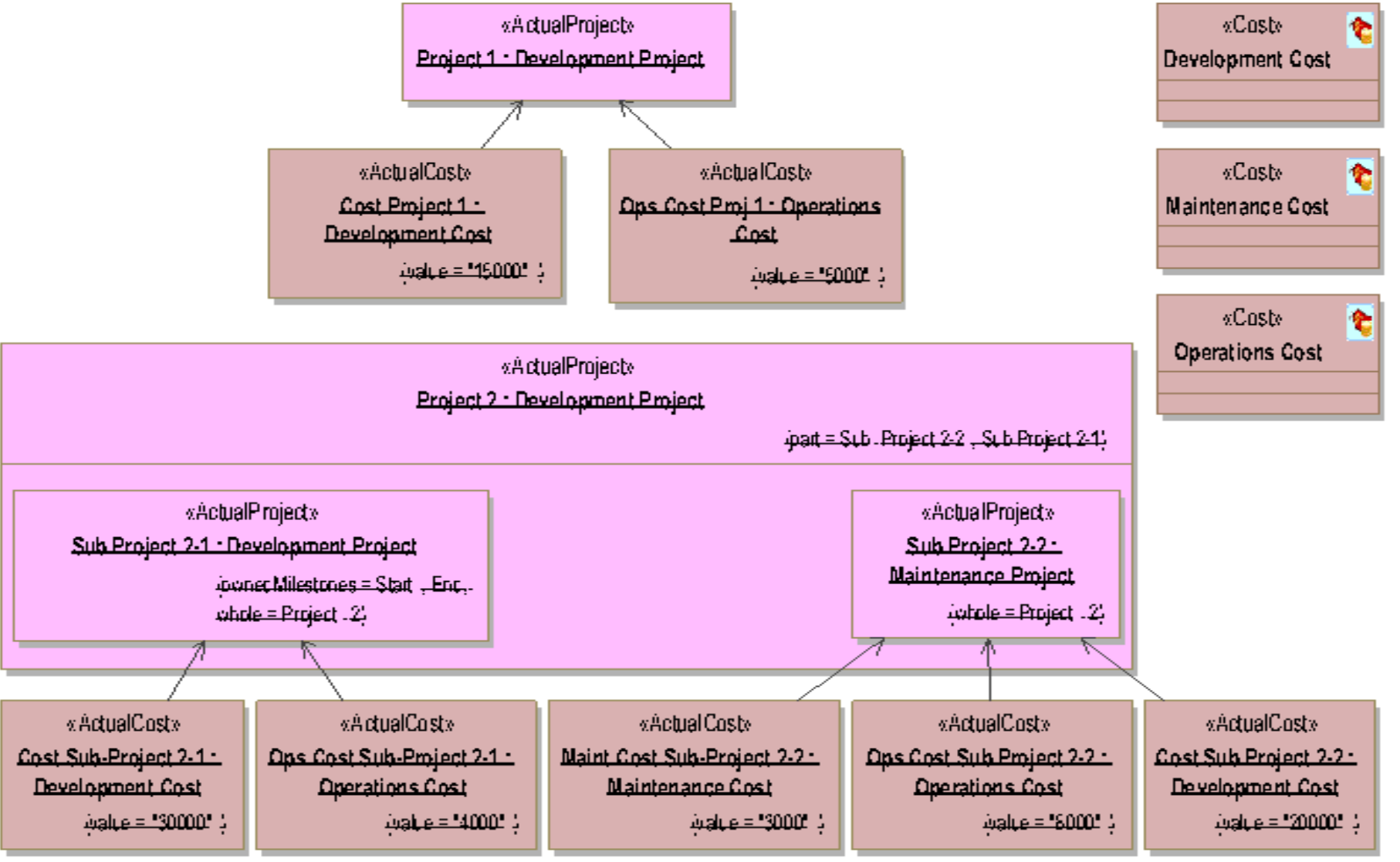
ESA-AF Cost Modeling: Example



ESA-AF Exploitation Framework



ESA-AF Model might not be perfect choice for decision maker



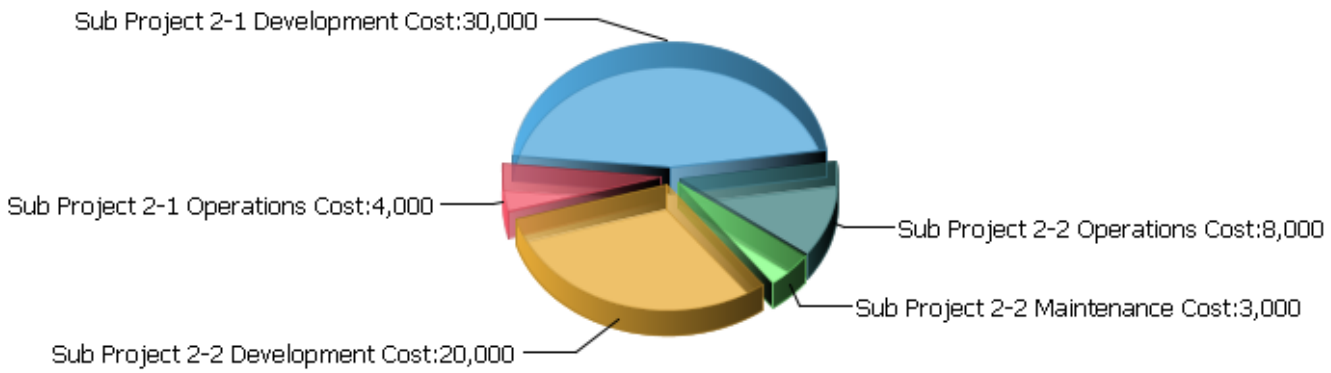
ESA-AF Exploitation Framework Reporting

Cost Overview:

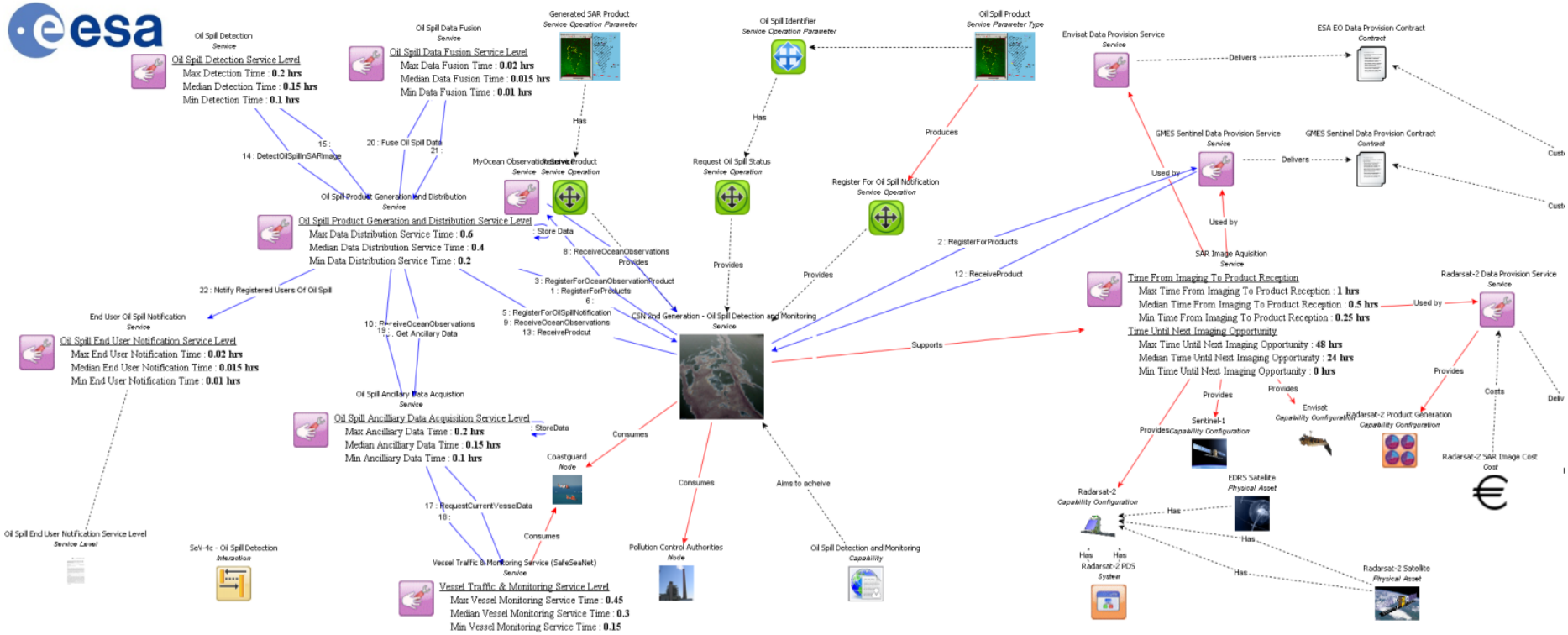
- The total project cost should be no grater than 50 000 (otherwise colored red)
- A total operational cost above 10 000 is questionable (colored orange)

Cost Type	Project 2		Grand Total
	Sub Project 2-1	Sub Project 2-2	
Development Cost	30000	20000	50000
Maintenance Cost		3000	3000
Operations Cost	4000	8000	12000
Grand Total	34000	31000	65000

Project 2 Cost Distribution



ESA-AF Exploitation Framework Diagramming

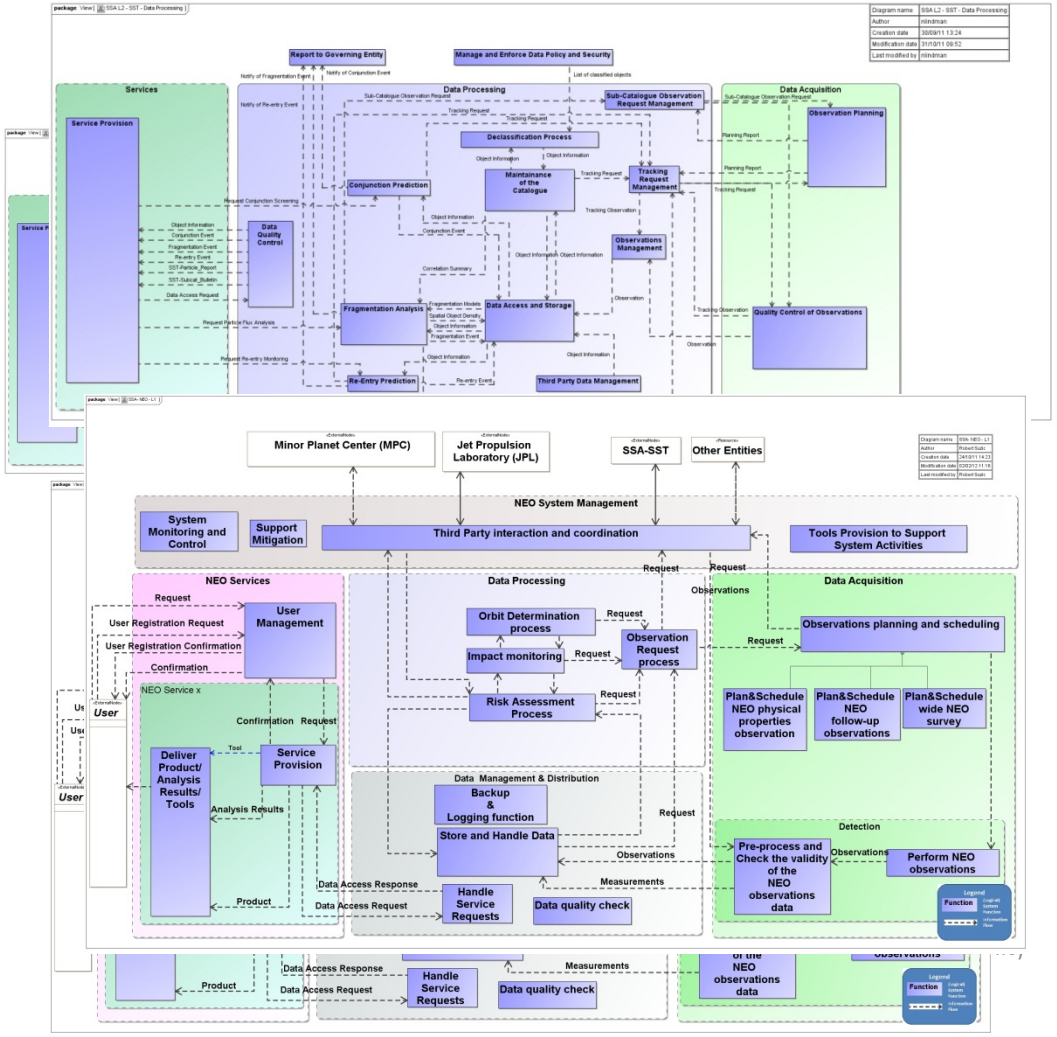



esa
SPACE SITUATIONAL AWARENESS
(SSA)
European Space Agency
Image: Dan Durda/FIAAA

SSA Related Work

Functional system requirements verification and refinement

- **Logical level analysis for defining:**
  - **System and service functionalities**
  - **Flows between (material and information)**
  - **Hierarchy between functionalities**
  - **Information models on different granularity levels for each segment**



SSA Related Work: lessons learned

- **Use as clear and clean as possible view descriptions**
- **Hide meta-modeling complexity and do not over-explain the framework (stakeholders want robust solutions to the problems and are typically not interested in framework details)**
- **Use as few as possible different types of (meta-modeling) artifacts**
- **Readability can be a challenge: Not easy to put complex views in documents**
- **Document inconsistencies in the models and raise them on recurrent basis (i.e., there are no stupid questions)**
- **Successes factor: verification and requirements' refinement was performed in a close cooperation with subject matter experts (in an iterative manner)**

SSA Related Work: next step

- **ESA-AF made applicable to SSA design activity with industry required to deliver a system design for its all three segments according to the ESA-AF method and tools.**

Conclusion and Outlook

European Space Agency

Conclusion and Outlook

- **ESA-AF is a mean to address EA and SoS engineering challenges and complexity within ESA programs**
- **ESA-AF:**
  - **Based on industry and open standards to foster adoption**
  - **Flexible, model-driven approach facilitating future framework development,**
  - **Exploitation framework, enabling enhanced decision support by bridging the perspectives of technical and non-technical decision makers in space programs**
- **ESA-AF delivers a solid base for enterprise architecting and SoS engineering for ESA programs/projects by establishing a common architecture definition language and processes tailored to ESA's needs as well as associated exploitation best-practices**
- **Main challenge for the future is to introduce and apply the EA methods consistently within and across ESA programs.**

Would you like to know more?

Robert Suzić, robert.suzic@esa.int

Niklas Lindman, niklas.lindman@esa.int

European Space Agency

Back-up slides

ESA FACTS AND FIGURES

- Over 40 years of experience
- 18 Member States, 19 in 2011
- Five establishments in Europe, about 2200 staff
- 4 billion Euro budget (2011)
- Over 70 satellites designed, tested and operated in flight
- 17 scientific satellites in operation
- Six types of launcher developed
- Celebrated the 200th launch of Ariane in February 2011

19 MEMBER STATES AND GROWING

ESA has 19 Member States: 17 states of the EU (AT, BE, CZ, DE, DK, ES, FI, FR, IT, GR, IE, LU, NL, PT, RO, SE, UK) plus Norway and Switzerland.

Eight other EU states have Cooperation Agreements with ESA: Estonia, Slovenia, Poland, Hungary, Cyprus, Latvia, Lithuania and the Slovak Republic. Bulgaria and Malta are negotiating Cooperation Agreements.

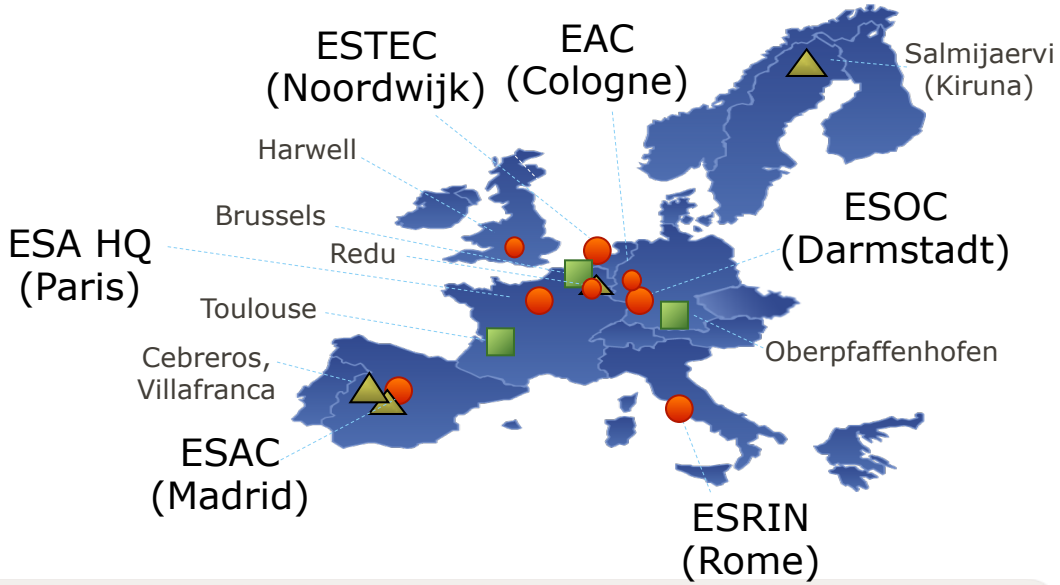
Canada takes part in some programmes under a Cooperation Agreement.

ESA'S LOCATIONS

ESA sites/facilities

Offices

ESA ground stations



COOPERATION WITH THE EU

- The Lisbon Treaty of 2009 reinforces the case for space in Europe and strengthens the role of ESA as an R&D space agency. Article 189 of the Treaty gives the EU a mandate to elaborate a European space policy and take related measures, and provides that the EU should establish appropriate relations with ESA.
- ESA/EU Framework Agreement currently in force
- Seven Space Council meetings and related resolutions and orientations provide directions and guidelines
- Programmes: Galileo, GMES, SSA