Complex Systems Engineering

Modelling & Simulation

Fausto Bruni
Alenia Aeronautica

NATO RTO Lecture Series SCI-176: "Mission Systems Engineering"
November 2006

Summary

- Mission systems operational scenario
- M&S – SE concepts
- Application cases
- Technologies

Mission Systems scenario

- Transformation of the military instrument:
  - Fast evolution of operational needs
  - Quick solutions are required
  - Increasing integration between different systems and enhanced complexity of operational criteria and Network Enabled Capabilities (NEC)

- Need for the Industry to
  - react and adapt through development of processes enabling the analysis of the requirements evolutions with a suitable level of flexibility, efficiency and effectiveness and solutions fast identification
  - properly plan technology evolution/integration in support to the development of more cost-effective system solutions

Mission Systems scenario

Customers are defining their requirements in terms of capabilities, which are high level statements which requires significant discussions and decompositions to be fully explored.

NATO has defined its requirements for improvements in the capabilities in the Prague Capabilities Commitment (PCC) which lists more than 400 areas collated in the following 8 fields;

- Chemical, biological, radiological and nuclear (CBRN) defence
- Intelligence
- Surveillance and target acquisition
- Air-to-ground surveillance
- Command, control and communication
- Combat effectiveness (incl. PGM & SEAD)
- Strategic airlift and sealift
- Air-to-air refuelling

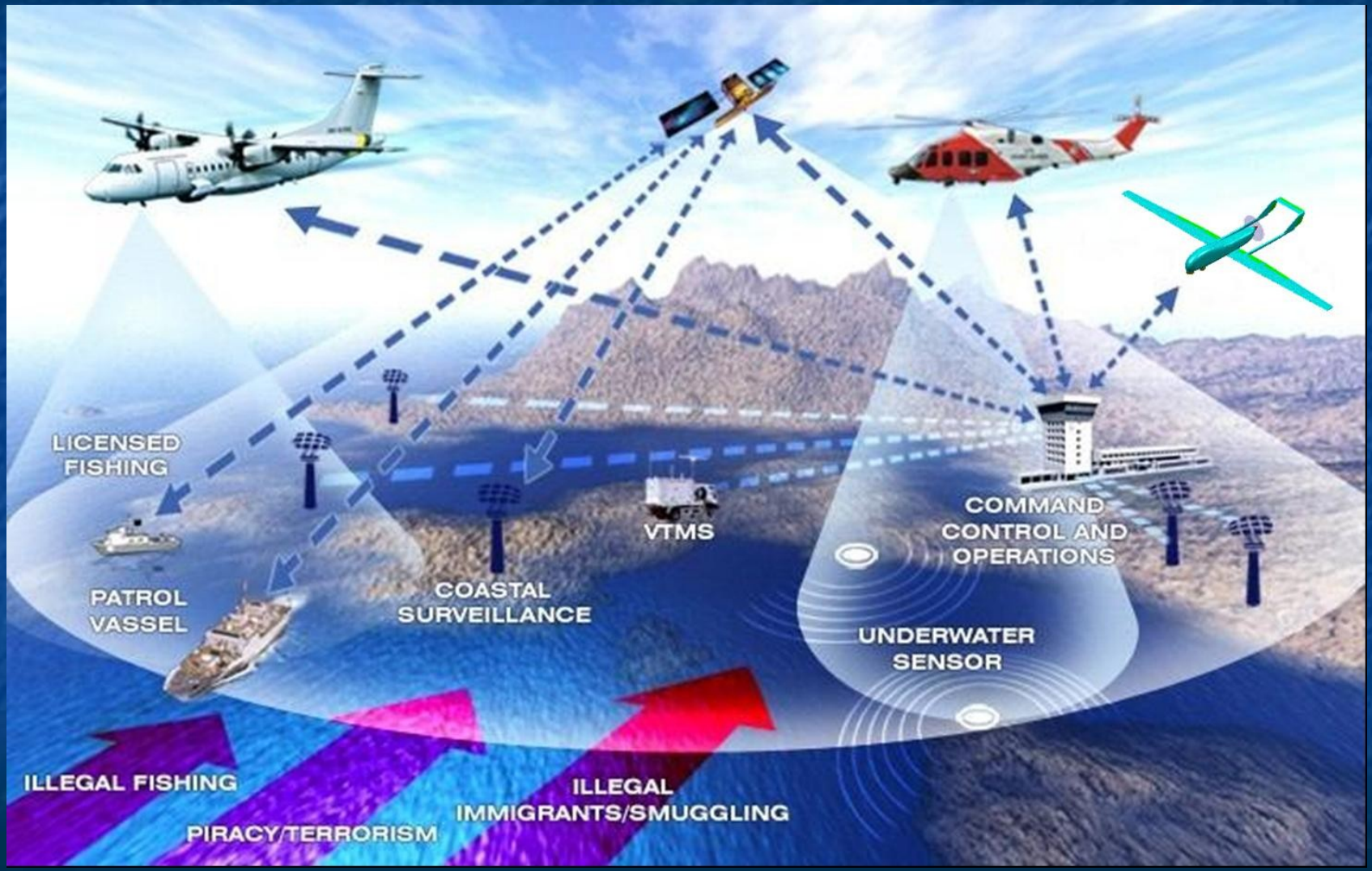
Mission Systems scenario

Other requirements derive from the exploitation of concepts/operations such as:

- Network-Enabled Capability (NEC)
- Effect Based Approach to Operations (EBAO)
- Joint operations for multi-services collaboration
- Multi-national collaboration
- Dual application for military and civil use of assets
  - crisis management
  - disaster relief operations
  - Enhanced civil-military co-operation

This new approach has introduced the concept of Systems of Systems (SoS) and developing tool for their analysis and development

Scenario


LICENSED FISHING
PATROL VASSEL
COASTAL SURVEILLANCE
VTMS
COMMAND CONTROL AND OPERATIONS
UNDERWATER SENSOR
ILLEGAL FISHING
PIRACY/TERRORISM
ILLEGAL IMMIGRANTS/SMUGGLING

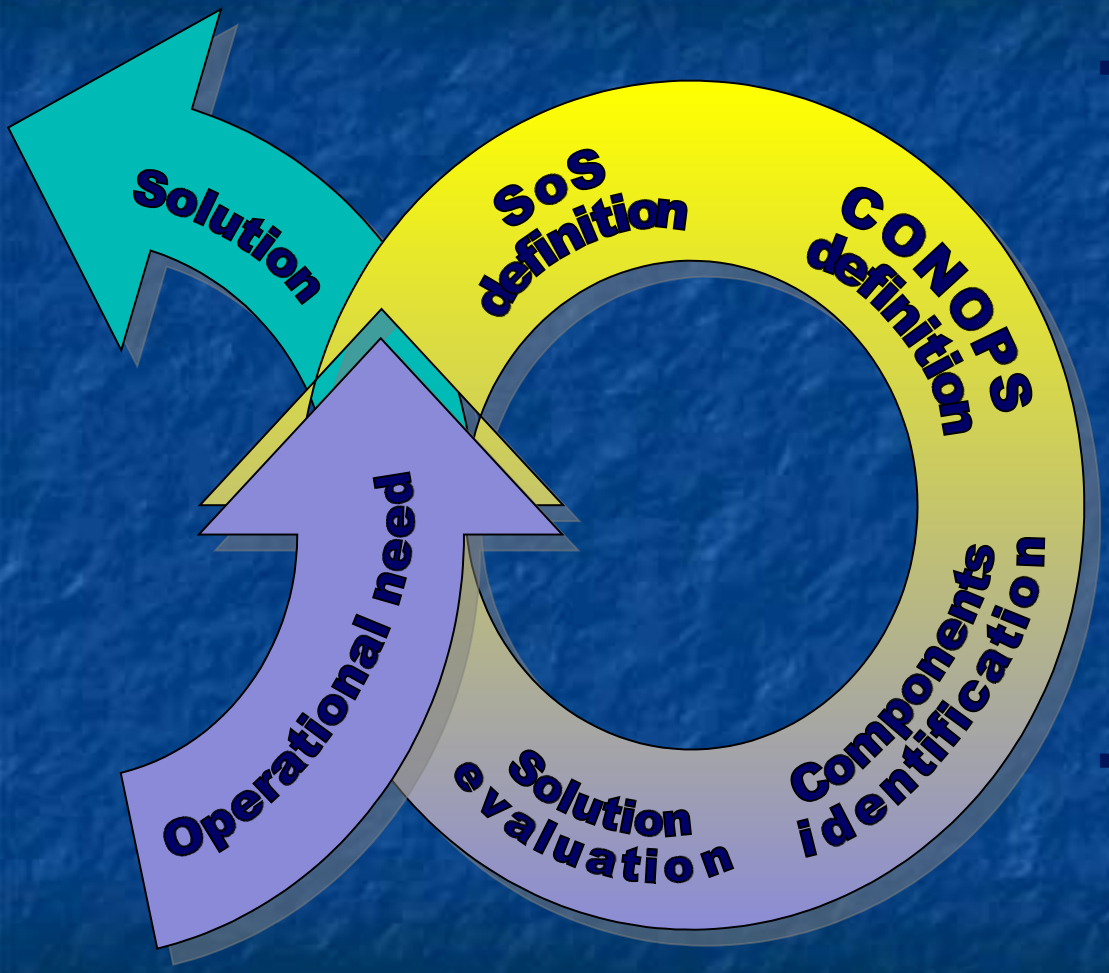
Scenario

Scenario

The TMPA is required to perform the following missions:

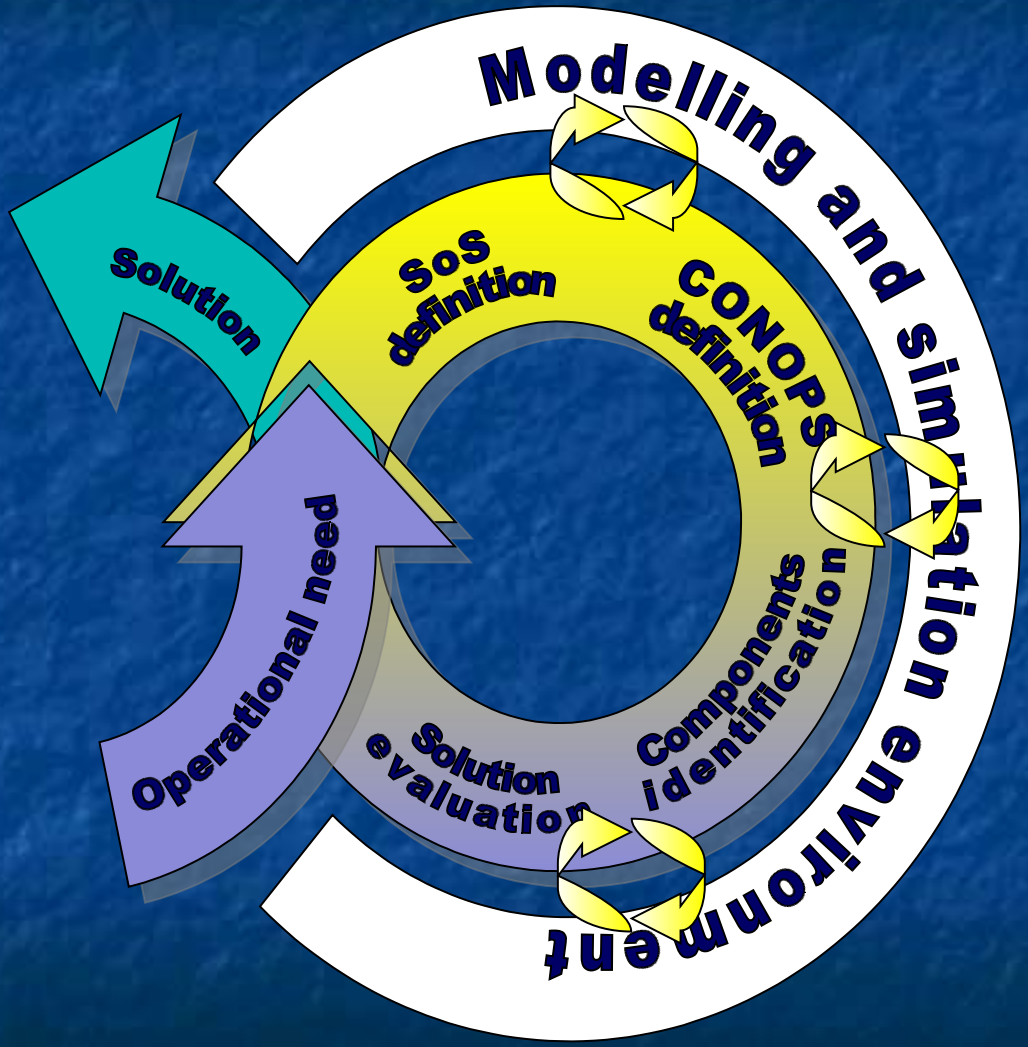
- Surface Surveillance and Reconnaissance (primary)
  - explore both visually and with sensors a defined area of sea to autonomously detect, locate, classify and identify surface targets
  - transmit information to other units or ground stations via on-board equipments
- Anti Submarine Warfare (primary)
  - explore both visually and with sensors a defined area of sea to autonomously detect, locate, classify, identify and attack submarines both on-surface or underwater
  - attack is done with both torpedoes and depth charges
  - transmit information to other units or ground stations via on-board equipments
- Search and Rescue / Coastal Surveillance (secondary)
  - explore both visually and with sensors a defined area of sea to autonomously detect and locate vessels in difficulty, wrecks and survivors/victims
  - transmit the position of items of interest and other useful information to other units or ground stations via on-board equipments
  - launch survival kits

M&S – SE concepts

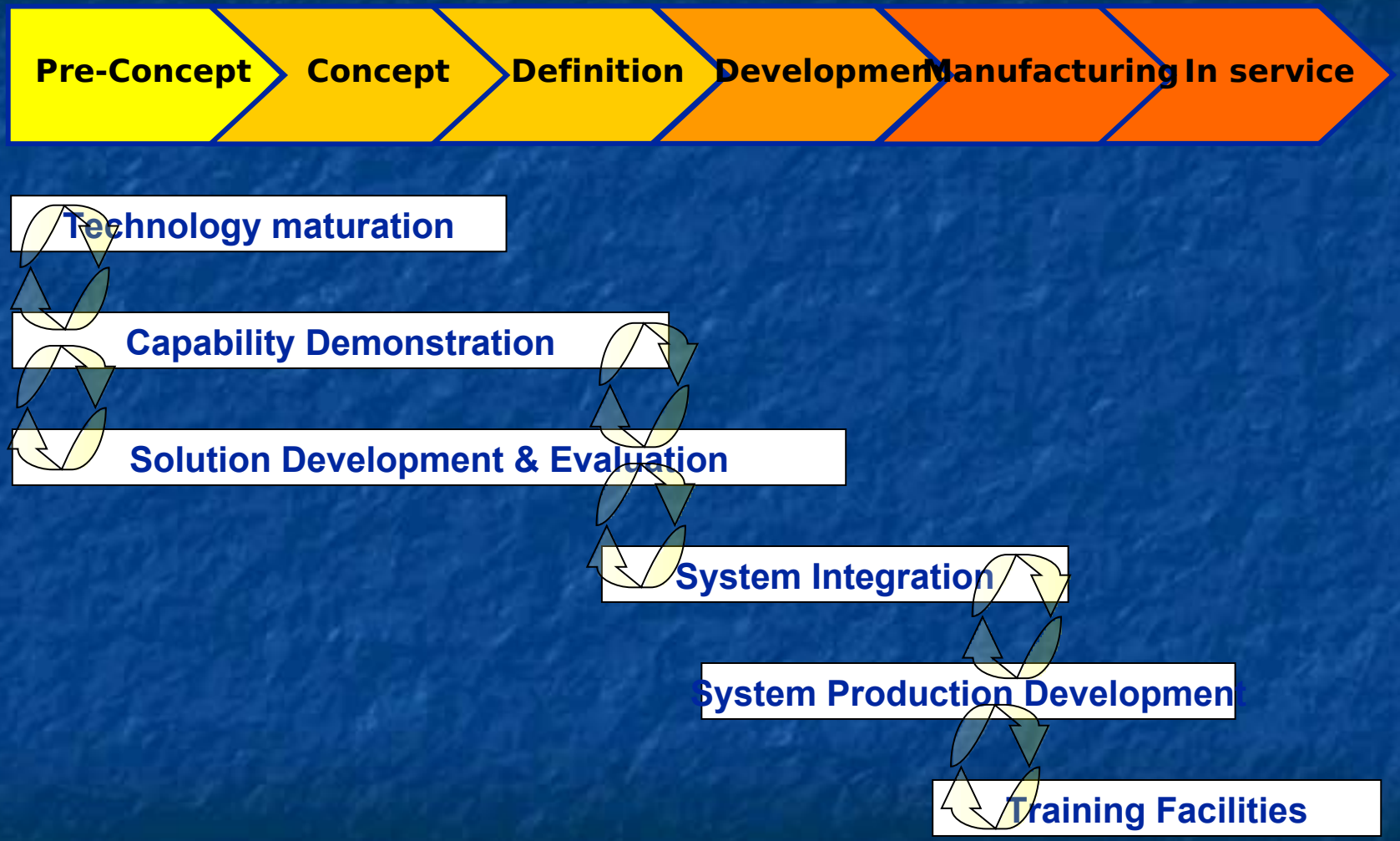


- Main characteristics of the process should be the capability of:
  - apply standard System Engineering approach
  - analyze all aspects of interest and represent them with suitable level of detail
  - support selection of most promising solutions
  - provide results in short time
- The tools to be used should be characterized by high levels of:
  - flexibility
  - modularity
  - fidelity

M&S – SE concepts



M&S – SE concepts



M&S – SE concepts

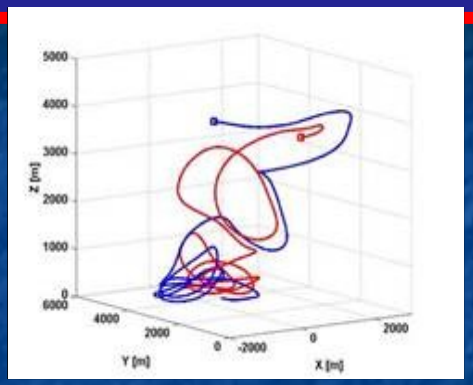
OPERATIONAL ANALYSIS is a systematic approach to help a decision maker choose a course of action by:

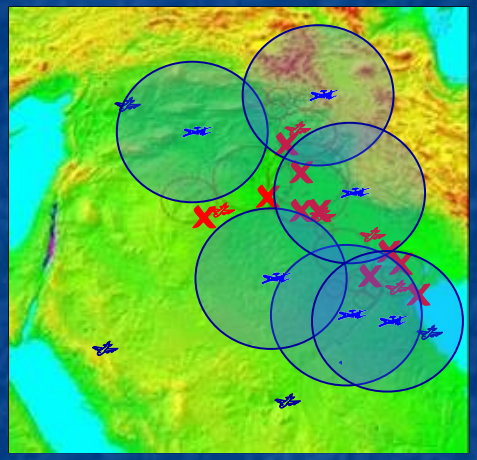
- investigating his full problem
- searching out objectives and alternatives comparing them in the light of their consequences
- using an appropriate framework to bring expert judgment and intuition to bear on the problem

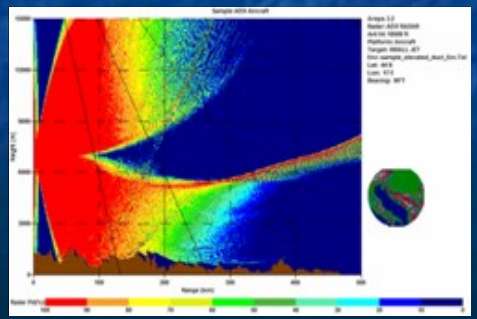
This suggests to consider a cycle consisting of:

- definition of objectives
- exploration and evaluation of alternatives in terms of their costs and effectiveness

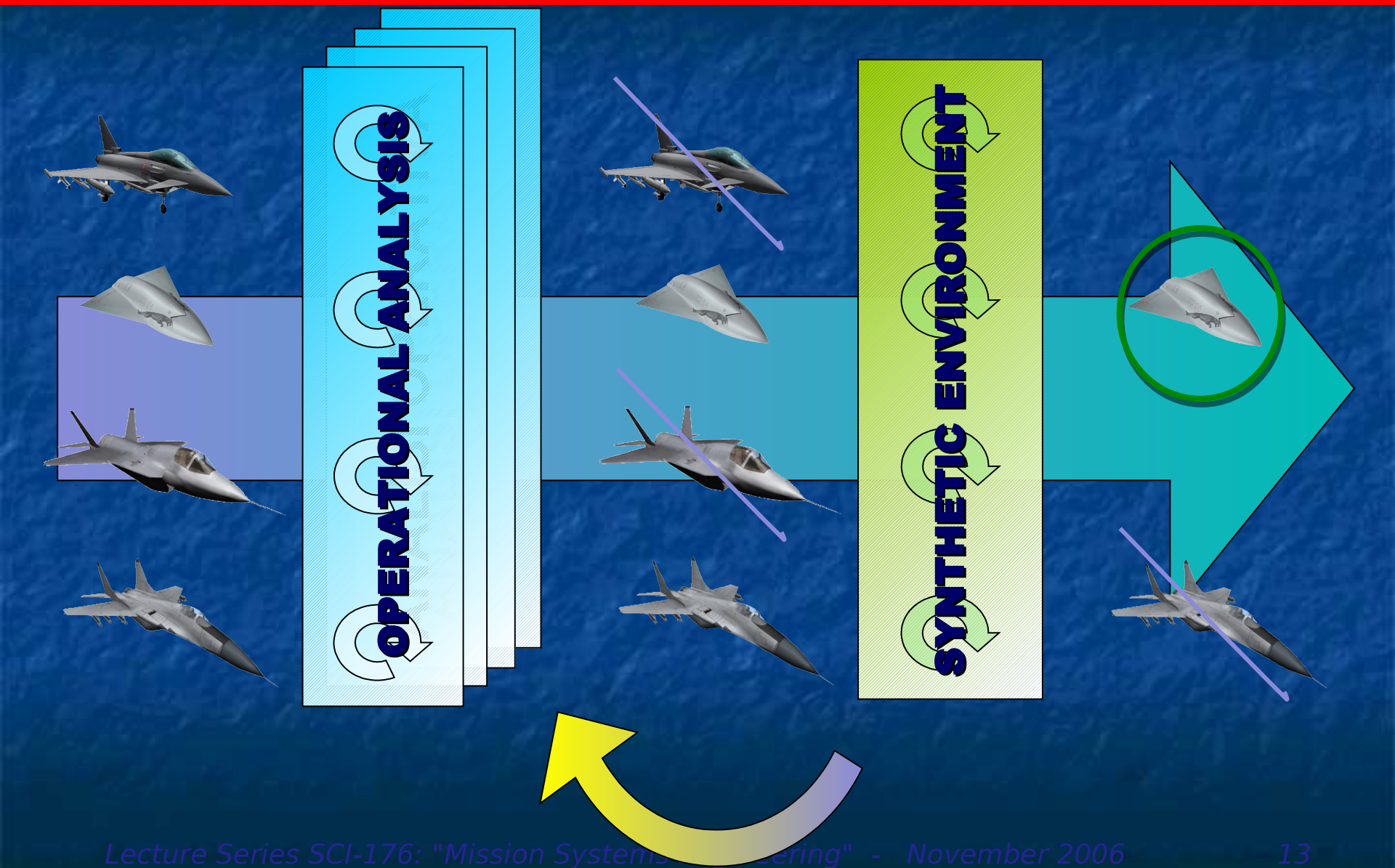
The cycle may be repeated in the light of new information required while redefining the objectives and identification and evaluation of alternatives, till the total spectrum is completely understood.







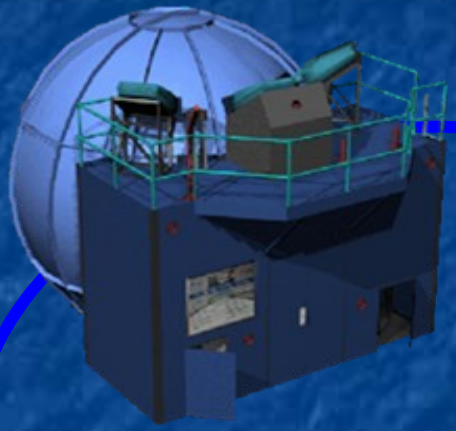
M&S – SE concepts



M&S – SE concepts

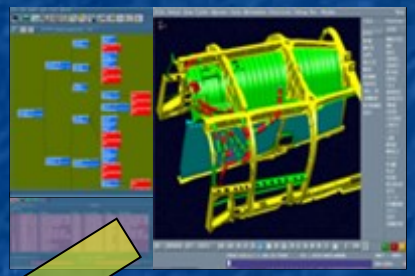
Real-time WAN (HLA)

Flight Simulators

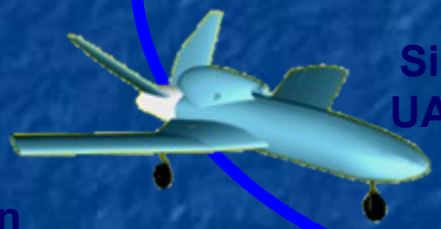


Real systems

Company's Product Database



Simulated UAV/UCAV



Computer Based Training

Visualisation Systems

Computer Generated Forces

Application cases

Alenia Aeronautica is involved since years in Unmanned Air Vehicles (UAVs) with research projects on the main UAV flight related themes.

In 2003 a technological demonstrator development started to have a flying platform to fully integrate and experiment all UAV technologies under maturation: the Sky-X

The main characteristics are:

- High performance vehicle with the flexibility to quickly incorporate new technical solutions and modularity to allow testing of new aerodynamic, structural and avionic solutions.

First flight: 29 may 2005

Application cases

Sky-X made use of a dedicated flight simulator since very early stages of the project

Main characteristics:

- ✓ Real-time, man-in-the-loop
- ✓ Aero-mechanical model derived from wind gallery and CFS
- ✓ Identical control laws as in the Flight Computer
- ✓ Same HW e SW as in the real Remote Operator Station (ROS)
- ✓ On-board camera simulated by a proprietary image generator

Application cases

A dedicated rig, with the entire avionic suite, has been developed to test the Sky-X flying systems with a specific stimulation and acquisition system which can interface with external systems.

The Sky-X simulator can be linked to the rig to perform verification sessions also with hardware and man in the loop

The ROS can also be connected to verify a complete system test and simulate flights

Application cases

- Alenia Aeronautica has recently announced the Molynx project which is an unmanned surveillance air vehicle (USAV) with high altitude (45000 ft), long range (2000 nm) and long endurance (25-30 up to 36 h) capabilities
- The platform makes use of diesel engines to minimize fuel consumption

Application cases

- Molynx can load different sensors (e.g. SAR, EO, IR, hyperspectral) with satellite data-link.

- Alenia Aeronautica Synthetic Environment is being used to define both Molynx operational use, technologies and technical characteristics:
  - automatic mission re-planni
  - optimized surveillance path
  - civil traffic compatibility
  - autonomous flight
  - sensors performances
  - communications capabilities
  - control station HMI

Application cases

In November 2004, NATO RTO MSG SAS-034 Exercise First WAVE (Warfighter Alliance in a Virtual Environment) was the first ever true multinational exercise of real time distributed simulation, involving 7 participant NATO Nations with several Flight Simulators: Canada, France, Germany, Italy, The Netherlands, UK and USA.

The Scenario was conceived to allow the crews to plan the mission, perform briefing and debriefing and conduct true-to-life COMAO (CoMbined Air Operations).

Main goals:

- evaluate the potential of MTDS (Mission Training via Distributed Simulation) to enhance the operational readiness of aircrews for NATO COMAOs, including training, simulation technologies and management
- improve the knowledge of the potential of MTDS within NATO military communities
- gather experience and derive learning to drive future NATO MTDS programmes

Application cases

Mission Planning

Mission Briefing

Monitoring & Control

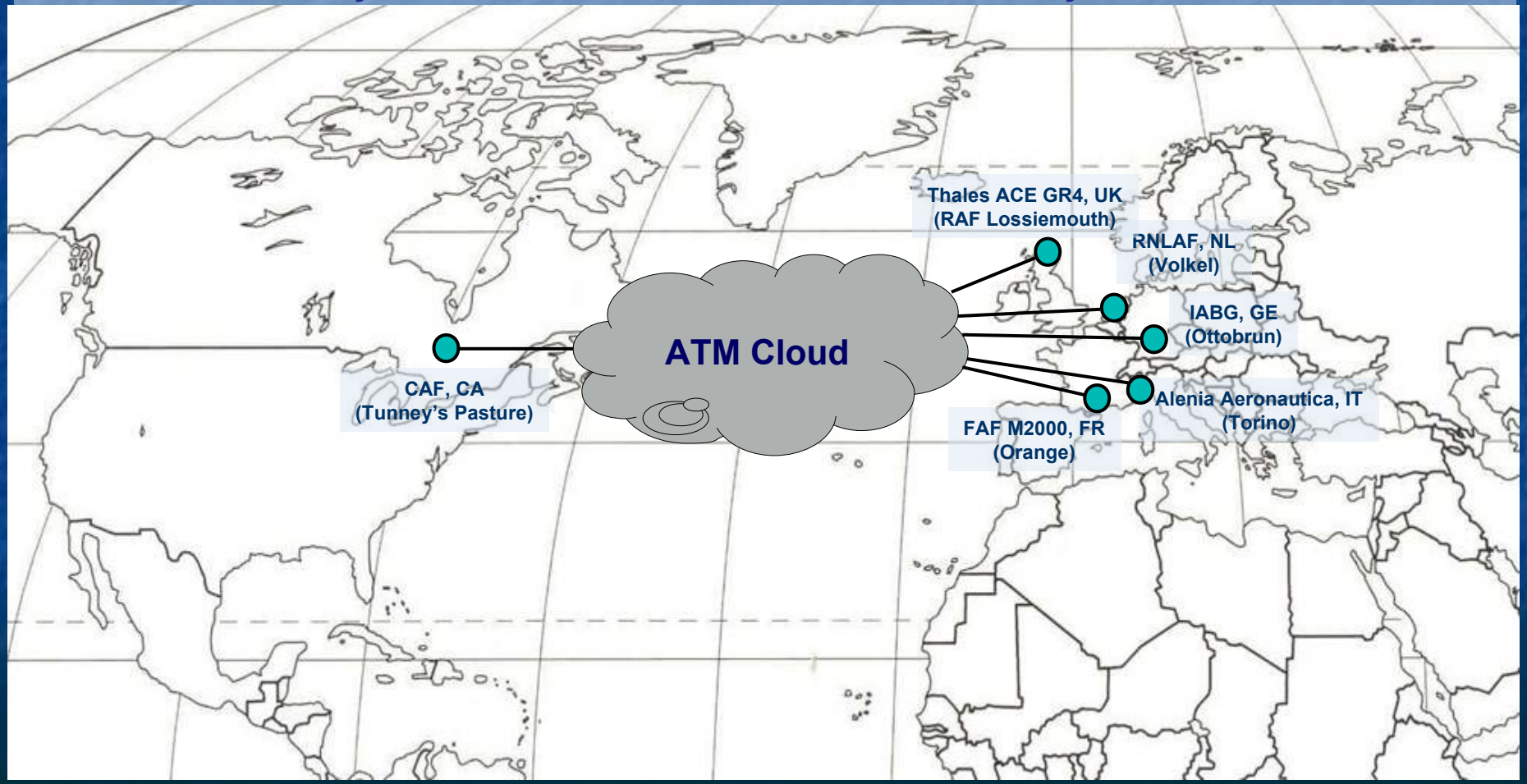
Mission Debriefing

Mission Execution

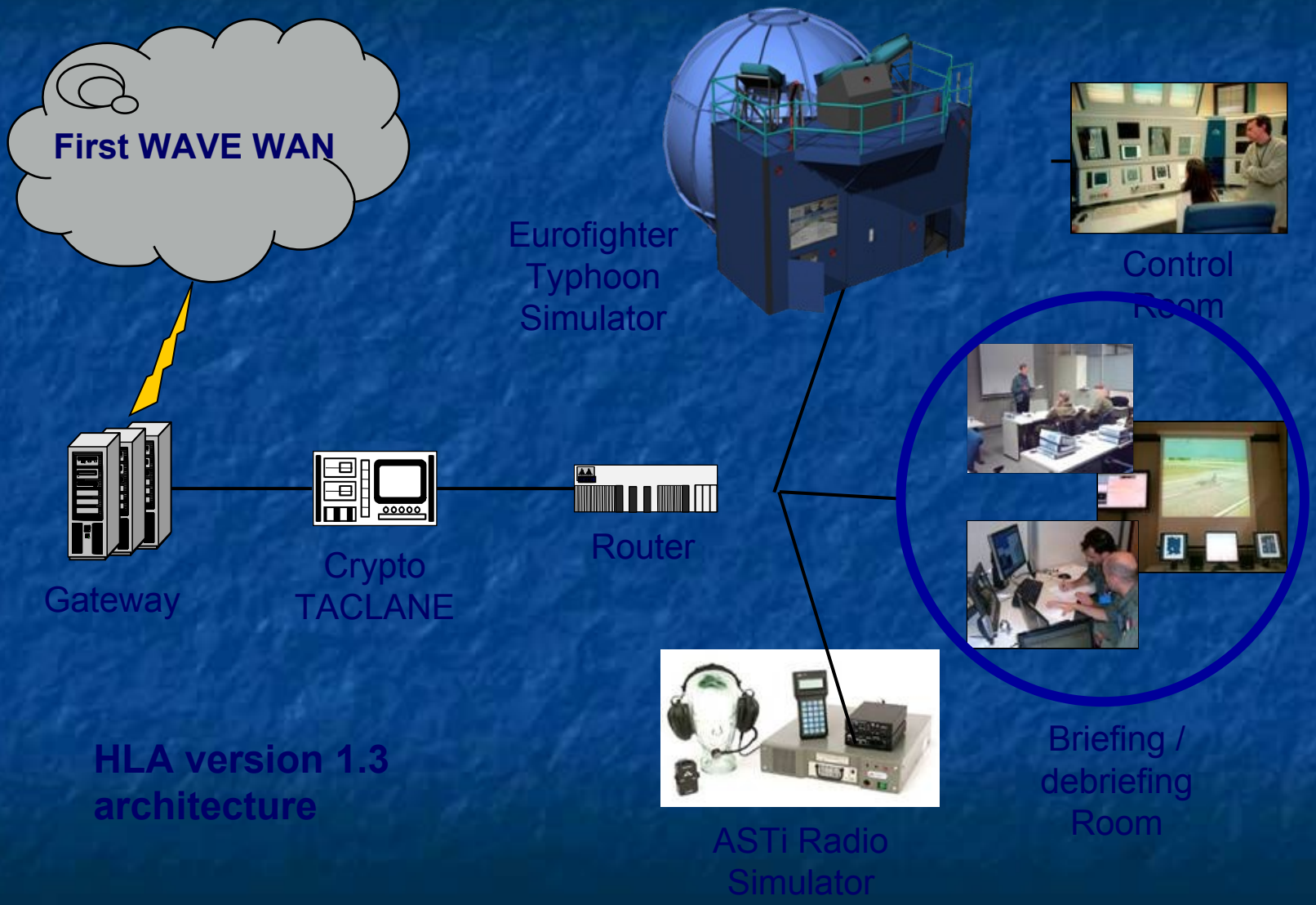
Application cases

To prove the achievement of the goals a distributed simulation environment has been created.

Main connection points were: Thales ACE GR4 in UK (controlling the WAN), Alenia Aeronautica in Italy, FAF M2000 in France, IABG in Germany, RNLAF in Netherlands,



Application cases



HLA version 1.3 architecture

Application cases

Security aspects became a relevant issue and security process that enabled the successful execution of First WAVE was evolutionary.

No two national procedures were identical.

There was no clear concept of what security arrangements were required and issues had to be revisited and revised several times based on new or updated information. Extensive discussions occurred about the documentation required to certify and accredit the First WAVE network.
Also NATO procedures were not appropriate or flexible enough for a short-term R&D project.
The solution came with the signature of a formal agreement (MoU) and the creation of a dedicated Project Security Instruction (PSI) with security instructions, release of information directives, access to facilities and security education/awareness.

Application cases

Other lessons learned are:

- lack of emissions/IFF interactions
- low updates from certain sites and visual database correlation discrepancies
- ever changing incoming entity IDs
- central reference document repository and information management is essential
- reduce number of software components
- videoconferencing system needs improvement with voice quality and scalability; use of headsets ought to be made mandatory
- use of smartboards was prevented; let pilots get acquainted with it
- clear directives on configuration of common hardware are essential
- inadequate testing schedule, an incremental testing schedule would have been good
- implement a clear risk management policy

Technologies

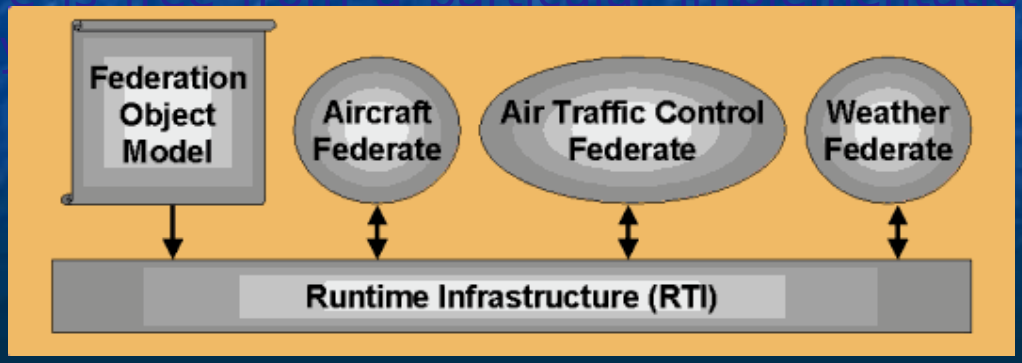
High Level Architecture (HLA)

- HLA is an IEEE standard (IEEE 1516) which is in the final phases to standardization phases by NATO as STANAG-4603
- The project took off in the early '90 when the US DoD realised the need to improve the lack of flexibility and abstraction required for a wide reuse of simulation components provided by DIS (Distributed Interactive Simulation) used, at that time, for multiple-user simulations
- Its adoption enables the users to have several benefits:
  - a single interface specification to support a wide range of applications
  - a range of tools needed by those applications
  - the ability to specify a common testing method and to operate distributed simulations securely
- The architecture is designed to be compatible with future implementations of the HLA: one of the advantages of specifying an architecture (as opposed to an implementation or a protocol) is precisely that all future advances in software technology, telecommunication, and simulation concepts can be easily incorporated within an existing framework

Technologies

HLA (cont'd)

- In HLA terminology, the "macroscopic" simulation is called a "federation". The standard does not preclude the possibility of simultaneous execution of multiple non-related federations, sharing the same resources.
- Each federate is characterised by its single attachment point to the RTI (Run-Time Infrastructure), a software layer which isolates all concurrent actors from each other, and takes care of all the exchange of information among them (the main difference between DIS and HLA is in fact the presence of the RTI whose behaviour is also defined only by its interface with the federates). In this way the architecture is free from a particular implementation, and can be replaced by



Technologies

Federation Development and Execution Process (FEDEP)

- To facilitate the introduction of HLA and to improve the effectiveness of its use, the Defence Modelling and Simulation Office (DMSO) devised FEDEP as an adaptable process by which federations can be successfully created, tested, run, and maintained.

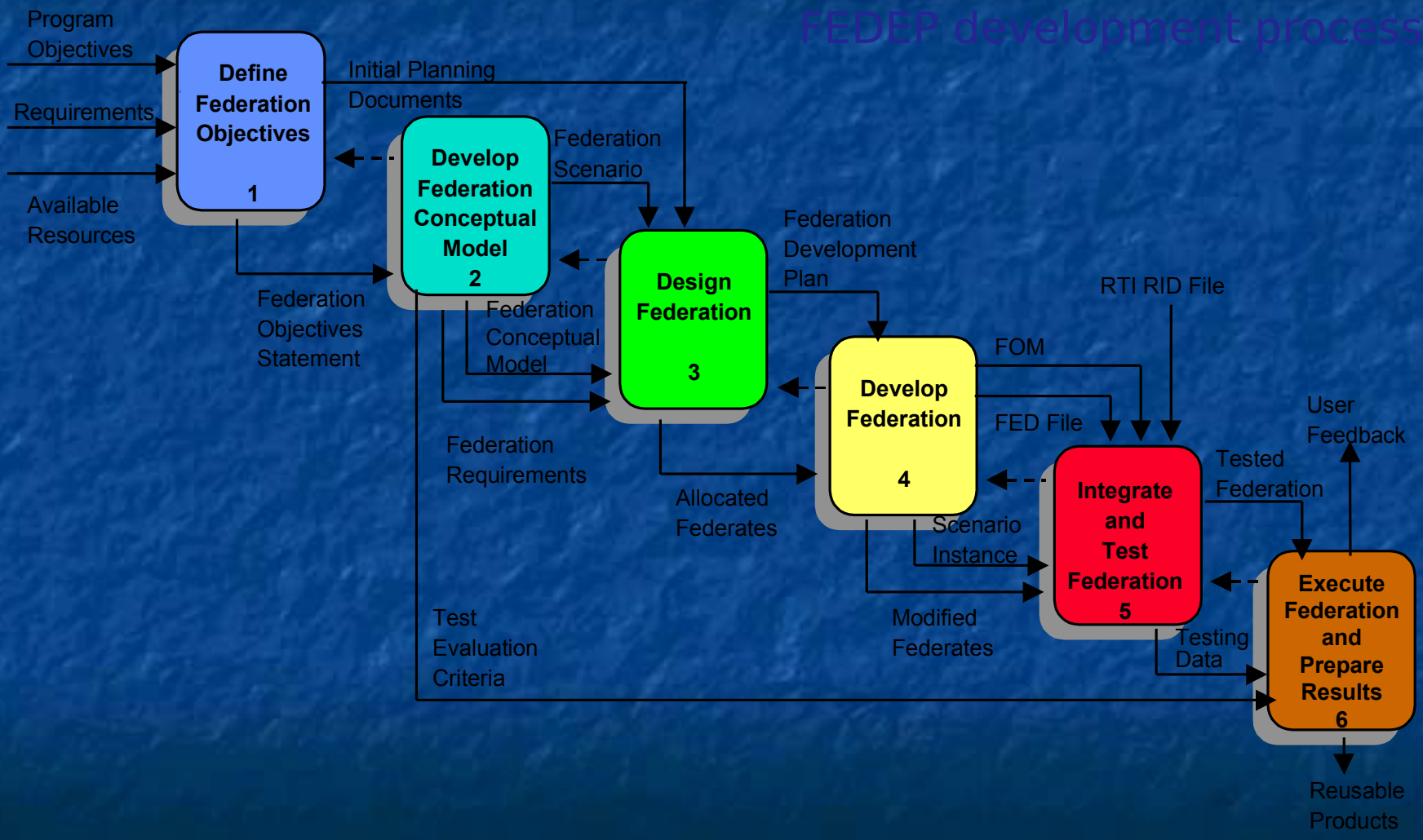
- Its application is intended to be the paradigm for end-to-end development of any HLA project: because of this general nature in scope, six main steps are identified, and defined in the following slide.

Technologies

FEDEP (cont'd)

- In the first step, the federation objectives and requirements are defined, and available resources are assessed. A statement is issued, and the development of the conceptual model can begin. Each step takes advantage of feedback from subsequent phases, given that a recursive dynamic can be of great help.
- After the conceptual model has taken shape, the design of the federation and its functionality, the integration of a scenario, and more federation requirements can be included in the federation design, which will evolve into the federation development proper. By creating a federation instance, and application of the FOM (Federation Object Model), the entire federation can be integrated and tested. After successful completion of this phase, the federation is ready to be run, analysed, and delivered to the user who will give feedback and optionally restart the FEDEP process.

Technologies



THANK YOU for your attention

Questions?

contact:
Fausto Bruni
Alenia Aeronautica
fbruni@aeronautica.alenia.it