Modeling & Simulation for Experimentation, Test & Evaluation and Training: Alenia Aeronautica Experiences and Perspectives

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ABSTRACT

The use of Modeling & Simulation to support aircraft development is nowadays common practice within any modern aeronautical industry, and a long term key capability of Alenia Aeronautica.

Starting from such crucial role, M&S utilization has progressively expanded to effectively support the aeronautical system's early stages – feasibility and definition, and later stages – in service support and pilots training, becoming an essential element during the entire system's life cycle.

The main tool to implement and sustain such capability is the Synthetic Environment, which relies on the following elements:

- *Flight Simulators with engineering and training potential*

- *Simulators networking at both LAN and WAN (Local and Wide Area Network) levels*

- *Tactical scenarios*

- *Image generation*

- *Virtual reality*

The paper will focus on the latest major experiences of Alenia Aeronautica with the AMX ACOL, Eurofighter, C-27J and Sky-X UAV Programs, from systems concept, through development and experimentation, to pilots training and mission rehearsal.

Moreover, Alenia Aeronautica's approach and perspectives in the field of the simulation of Network Centric Operations will be described: the Network Centric Simulation Environment

1.0 INTRODUCTION

The use of Modeling & Simulation (M&S) in aerospace engineering is nowadays common practice within any modern aeronautical firm and a long term key capability of Alenia Aeronautica.

Along the years, M&S has progressively expanded its role in support of product's life cycle mainly because the concept of "product" itself has changed. The basic utilization of M&S in aerospace is to support the aircraft system's design, development and test phases in a wide area of disciplines and to provide pilots training during the aircraft in-service period. Nowadays, the aircraft product is more and more looked at as an integrated system in a "system of systems"; M&S has therefore been applied to new needs as well, keeping the former fundamental role as a baseline but, at the same time, being directed to a wider range of purposes.

Alenia Aeronautica, a Finmeccanica Company, is the Italian leader firm in the aeronautics field and a key player in the European aerospace business. Products are high performance combat aircrafts, military and commercial transport aircrafts and advanced aerostructures for military and commercial aircrafts.

The Company has strong relationships with major international aerospace players and participates in leading programs including Eurofighter Typhoon, JSF F-35, AMX and Tornado fighter aircraft, C-27J Spartan tactical airlifter, Sky-X and Neuron UAV demonstrators, ATR special mission aircraft, and several commercial aircraft like A380 and B787.

Alenia Aeronautica has a consolidated know-how in the M&S domain. Since it was established some 45 years ago, its Simulation Center designs, develops and operates flight simulators, along with hardware and software tools required for theirs integration. Thanks to its expertise in systems integration, Alenia Aeronautica has matured the capability of designing and operating flight/mission simulators and training systems.

These simulators are mainly used to support the aircraft that Alenia designs and develops autonomously or, more commonly, in the frame of national or international collaborations. In particular, programs such as Eurofighter Typhoon, C-27J Spartan and the UAV demonstrator "Sky-X" are being extensively supported since their early stages by one or more dedicated simulators.

At the same time, the same flight simulators used for aircraft design and development are generally also used as initial training devices for customers' aircrews, before specialized training simulators/devices are finalized and delivered to the customer.

All the wide range of real-time simulation applications and devices developed through the years, strictly integrated with the other design and test assets of the Company at both functional and process levels, are the building blocks of the so called Synthetic Environment.

When applied to the study and design of Network Centric Operations, the Synthetic Environment is named Network Centric Simulation Environment.

2.0 USE OF FLIGHT SIMULATORS IN ALENIA AERONAUTICA

Today, Alenia Aeronautica simulators are mainly used to:

- support the design of the aircraft and its on-board systems, providing a highly realistic environment where the specialists can test various aircraft systems and subsystems configurations;

- support the definition of pilots' normal and emergency procedures;

- familiarize test pilots with flight test procedures, mitigating the risks of "in the air" experimentation on the real aircraft;

- demonstrate the aircraft capabilities and performances to potential customers;

- set up a flexible environment for the research of innovative technologies and methodologies to be applied to new projects.

Furthermore, the engineering flight simulators are heavily used as platforms to assess different solutions in avionics modernization programs (e.g. "mid-life-updates").

After delivery to the customer, the aircraft life cycle enters the operational phase. From now on, Alenia guarantees all the necessary logistic support, so that the aircraft can be operated safely and efficiently.

In this frame, ground and flight personnel training is of paramount importance for a proper and effective operational use of the aeronautical system. Alenia Aeronautica fulfils such customer needs

- making its engineering flight simulators, properly reconfigured, available to meet the requirements of aircrew initial training. This is often crucial when, at the beginning of the operational life of a new aircraft, dedicated training simulation systems are still under development and/or procurement;

- designing, building and operating flight simulators specifically aimed to support training at customer's sites; such simulators can be developed either in partnership with major simulation industries or by Alenia Aeronautica autonomously.

3.0 THE ALENIA AERONAUTICA FLIGHT SIMULATORS

Over the years, Alenia Aeronautica has developed and operated several flight simulators; to name a few, the flight simulators for the G91, G91-Y, G222 and Tornado.

At the present days the Alenia Aeronautica Simulation Center employs five fully operational flight simulators: 2 Eurofighter Typhoon (the development and production configuration simulators), 1 AMX, 1 C-27J Spartan and, last born, the UAV Sky-X Simulator, together with other ancillary simulation devices like the Eurofighter Aircrew Cockpit Procedure ACPT. All of these simulators have been completely designed and developed by Alenia Aeronautica.

Entered into service in mid 80's, the AMX Flight Simulator (figure 1) has been extensively used in the design and development phases of the basic aircraft version and of its variants as well as the initial training of Italian and Brazilian Air Forces pilots.

Figure 1: The AMX Flight Simulator

Recently, this simulator has been partially upgraded to ACOL (Aggiornamento Capacità Operative e Logistiche, i.e. mid-life-update) configuration in order to support the modernization of the aircraft for the Italian Air Force.

The cockpit is equipped with real panels together with some representative panel reproductions. The initially installed real Head Up Display, properly refocused for utilization inside the dome, has been subsequently duplicated with a virtual, projected version in order to gain the flexibility needed to design new symbology during the development activities.

Started in 1998 as an ergonomic mock-up, the C-27J Spartan Flight Simulator (figure 2) has evolved into a functional and complex device. It has been extensively used to support baseline aircraft development and it is being used to support initial training for Hellenic Air Force since 2005, while Italian and Lithuanian Air Forces started in 2006.

The two crew flight station is a high fidelity replica of the real one: the cockpit instruments are real aircraft equipment, including primary flight controls and seats.

Covering a field-of-view of 180° azimuth and 40° elevation, the projection system is a 3 channels SEOS Panorama collimated display, providing both pilot and co-pilot with the correct perspective. The Image Generator includes an Equipe Electronics "Blue Sky" visual system based on SGI "Infinite Reality 2" Onyx2 hardware; such system is going to be replaced with the Alenia Aeronautica proprietary Image Generator "Sapphire" at the end of 2006.

A 5 channels FCS Controls Systems Control Loading System is used to provide both pilot and co-pilot control loads on flight controls (i.e. control wheels, columns, rudder pedals and steering handle) representative of relevant real control forces in powered and reversionary modes.

The C-27J Spartan Flight Simulator available at Alenia Aeronautica, the only one existing for this aircraft at the moment, is being considered a solid reference for the C-27J Training Simulator which Alenia is offering to the Italian Air Force (to be located at the National Training Center of Pisa) as well as, in its variants according to the different requirements, to other customers.
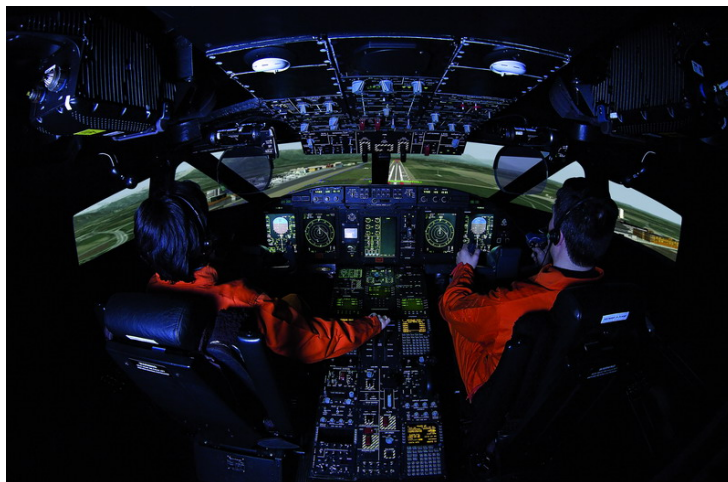

Figure 2: The C-27J Spartan Flight Simulator

The Eurofighter Typhoon Flight Simulator - Production Configuration (figure 3) has been designed as a multipurpose device. In its stand-alone configuration, it is an excellent support to aircraft development engineering activities and, at the same time, a top level training device. In fact since October 2003 it is also used to support training activities of the Italian Eurofighter aircrews.

The cockpit, furnished with a full set of real equipment, provides the pilot with a very highly representative aircraft environment. In particular, the Eurofighter Typhoon glass cockpit based on 3 Multifunction Head Down Displays, Head Up Display control panel, Left & Right Hand Glareshields and Dedicated Warning Panel are integrated and functional as per the production aircraft.

Aimed to provide an enhanced pilot immersion in the virtual world, the cockpit is equipped with a G-seat, developed by Cranfield Aerospace according to Alenia Aeronautica specification. This is an all-electric device capable to realistically reproduce pressures on pilot's body due to vibration, vertical, longitudinal

and lateral accelerations. Coupled with the G-suit, acting as the real equipment with reduced pressure, the G-seat provides the most effective motion cues achievable in a fixed base flight simulator.

The advanced Dome Visual System provides the simulator with full Field Of View coverage by means of high and medium resolution out-of-the-window graphics. The images provided by the set of 5 CRT + 2 LCD projectors are completed by two Target Projectors, resulting in a highly effective visual environment. The external world image is provided by an Equipe Electronics "Blue Sky" Image generator that takes advantage of a 5 pipes, 12 processors SGI Onyx2.

The simulator "flies" over the wide photo-realistic Geographical Database, completely developed in Alenia Aeronautica, covering the entire Italian peninsula.

Figure 3: The Eurofighter Typhoon Flight Simulator (Production Configuration)

An ancillary device is the Eurofighter Aircrew Cockpit Procedure Trainer (ACPT, figure 4). This facility relies on the same simulation models as the other two Eurofighter simulators. The only difference consists in the interface with cockpit equipment that, in this case, is not real aircraft hardware but high fidelity functional replicas.

The ACPT is used to support aircrew training activities in conjunction with the Flight Simulator, particularly this system allows customers' aircrews to get acquainted with the cockpit layout and to practice with the normal and emergency procedures.

More than 1500 training hours have been delivered on Eurofighter ACPT and Flight Simulator until July 2006.

A second ACPT (named "ACPT2") is going to be delivered to Italian Air Force MOB of Grosseto by the end of 2006, while further devices with improved performances (Enhanced-ACPT) are likely to be developed for the same customer in 2007.

Figure 4: The Eurofighter Typhoon Aircrew Cockpit Procedure Trainer

For its UAV flying demonstrator "Sky-X" program, Alenia Aeronautica has developed the Sky-X Simulator (figure 5). The Sky-X is an unmanned aircraft controlled via a Remote Operator Station (ROS), where the operator can act as a pilot using a set of traditional stick, throttle and pedals together with Hands On Throttle And Stick (HOTAS) controls or, alternatively, as a mission manager engaging the autonomous flight functionalities of the system. A couple of cameras installed on the Sky-X aircraft provide the ROS operator with a view of the external world.

The Sky-X simulator is the Alenia Aeronautica prime device for designing, developing and evaluating:

- concepts layouts of displayed formats and controls allocations for the ROS;

- automation philosophies and algorithms implementation;

- Situational Awareness and operator's workload;

- UAV operational modalities.

At the moment this simulator is used to support training activities of the test pilots and as a deployable flight test rehearsal device.

Figure 5: The Sky-X Simulator

The Alenia Aeronautica Flight Simulators are an integral part of the Company's Synthetic Environment (SE), an extended network of applications, models, simulations and equipment, up to and including the real systems themselves – manned and unmanned – in the frame of a common virtual representation of the real world.

In the following paragraph the Alenia Aeronautica SE experience is given.

4.0 THE SYNTHETIC ENVIRONMENT

The Synthetic Environment is an integrated simulation environment, inclusive of human operators, real systems and virtual models, linked together in an interactive, real-time and distributed simulation architecture.

The aims of the SE may be several as:

- enhanced systems operator training (for both single and team operation);
- optimization of armament systems design;
- analysis of tactical scenarios;
- mission rehearsal activities;
- military assets training in virtual polygons (reducing environmental impact)
- project risks assessment

The SE requires a powerful level of simulation of the operational scenario to include the physical environment, all the potential friendly and foe "actors" (ground, naval and aerial assets) with their systems, sensors and weapons and, if necessary, the system/operator itself.

There are a lot of elements that contribute to the SE; the areas which Alenia Aeronautica considers central are the networking of all available flight simulators, a virtual operational environment (tactical scenario) and several support tools added modularly as needed to this SE.

4.1 Simulators networking

The simulators networking in Alenia Aeronautica consists in linking the available simulators in real-time, so that each simulator is aware of the others and can engage in joint operations with various degrees of interoperability. Moreover, such link can be extended to connect this Local Area Network in a Wide Area Network, allowing the distributed simulation to involve other geographically distant simulators.

Most flight simulators were designed for stand-alone operation, principally aimed at design and development of the aircraft. Typical SE applications require on the contrary a substantial level of interoperability: as a consequence, a considerable amount of optimization and integration has been needed.

The preferred methodology and software architecture used for such links is today the High Level Architecture (HLA); this standard provides a common architecture for distributed simulation. Specifically, it defines a simulation Interface Specification and Run Time Infrastructure (RTI) that permits a set of independently-developed simulations, called "Federates", to be brought together into a single coordinate ensemble called a "Federation".

As standards go, the HLA is relatively complex. It contains facilities that allow federates to join and leave a federation; it defines services that federates can use to communicate simulated events to other federates and to receive events that they produce; it provides a timing model with varying levels of guarantees about temporal ordering; it supports object ownership migration.

Within virtually all western nations, in particular the USA and the UK, there has been a substantial effort to integrate and acquire HLA know-how, and to use it as a replacement for earlier DIS (Distributed Interactive Simulation) protocol.

The Alenia Aeronautica networking activity started with local networking among all simulators: the AMX, the C-27J, the 3 Eurofighter, and Sky-X flight simulators.

The process continued with a first experience of remote connection (2000): the real-time link of the C-27J Flight Simulator, located in Torino, with Alenia's Flight Test Control Room, located at Caselle Airport, about 30 km out of town (figure 6). The main purpose of this activity was Control Room personnel training, and in that case a proprietary protocol was used, very similar to DIS.
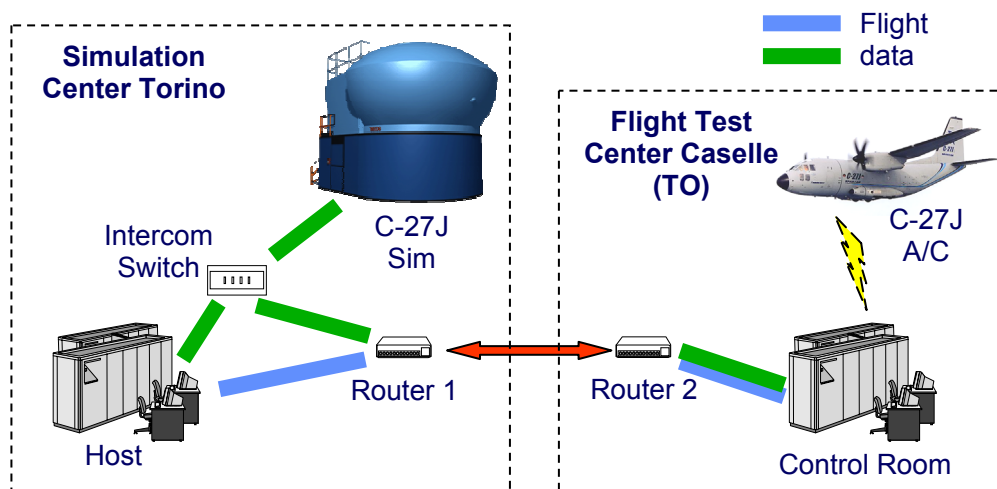

Figure 6: Alenia's Simulation with Flight Test Center connection

Following this experience, adequate partners have been sought, in order to prove the interoperability potential of the SE under development with external participants.

Another experience (2001) was the development of a technology demonstrator in cooperation with CETENA (Center for Technical Naval Studies), located in Geneva: an experimental flight simulator (Alenia Aeronautica) linked by HLA to an aircraft carrier simulator (CETENA): real time decking maneuvers were performed and visualized (figure 7).

Figure 7: Alenia Aeronautica – CETENA HLA network

The next, very important experience was in November 2004 with the NATO RTO SAS-034 "Exercise First WAVE" (Warfighter Alliance in a Virtual Environment).

This exercise 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 employed technologies were HLA and DIS networking, virtual teleconference, low latency WAN.

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).

The roles of the various simulated aircraft included Strike, Offensive and Defensive Counter Air (OCA/DCA), protecting the strike package and the AWACS, Suppression of Enemy Air Defense (SEAD), and Command & Control from the AWACS. Crews collaborated internationally using video teleconferencing and interactive whiteboard technologies to plan, brief, fly and debrief the missions, based on the daily Air Tasking Order. These activities were coordinated via the Exercise Control Center at RAF Lossiemouth.

The main goals of the Exercise First Wave have been:

- evaluate the potential of MTDS (Mission Training via Distributed Simulation) to enhance the operational preparedness 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 "lessons learned" to address future NATO MTDS programs.

The Italian participation (figure 8) in Exercise First WAVE was thanks to:

- Italian Air Force, who took part in Exercise First WAVE with pilots, operational staff and engineers, in close cooperation with Alenia's personnel

- Alenia Aeronautica, who took part in Exercise First WAVE with the Eurofighter Typhoon Flight Simulator and the facilities and equipment of the Simulation Center.

Figure 8: The Italian team who participated to Exercise First Wave

Currently the Alenia Aeronautica Flight Simulators, when necessary, can be linked in shared, dynamic, synthetic battlefield scenario via HLA protocol providing a distributed interactive framework (figure 9), with current applications mainly focused on pilots training and research programs.
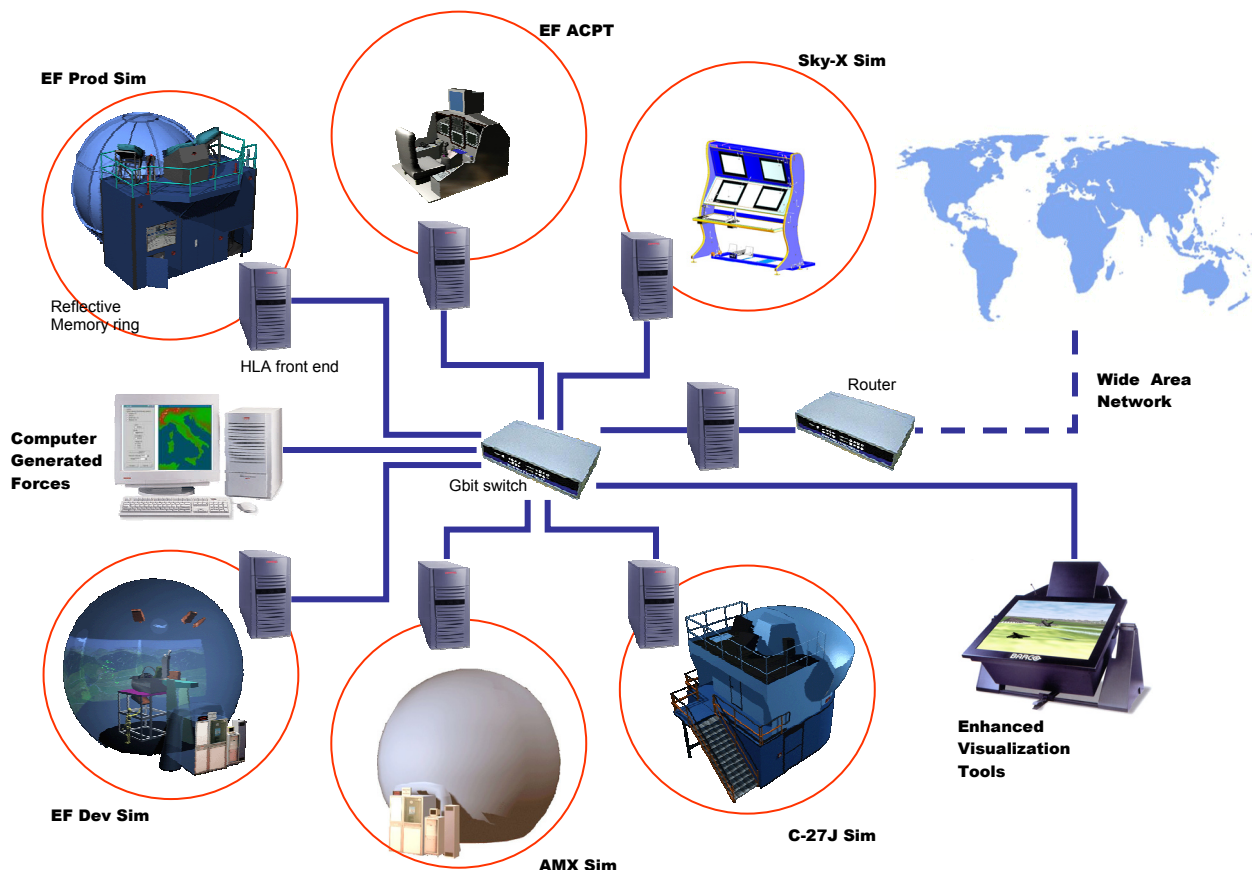
Figure 9: Alenia's Simulators networking architecture

4.2 Tactical scenario

To be successful, the virtual world must surround the user with a realistic operational scenario. The scenario needs therefore to be populated with a number of synthetic actors (CGF – Computer Generated Forces) animated not only by means of a physically appropriated model, but also obeying to a logically and tactically sound doctrine or modeled behavior, in accordance with the assigned role (i.e. friend or foe).

To cope with this requirement, a synthetic tactical scenario generator, called STEP (*Scenario for Test and Evaluation Purposes)*, has been developed within Alenia Aeronautica Simulation Center; STEP is tailored for air to air combat and completely integrated with the Alenia Aeronautica flight simulators.

The essential STEP functionalities are the off-line scenario preparation and the scenario management either in real-time or slowed down / accelerated, as a stand-alone simulation facility or integrated with the full mission simulators. In particular, the user is offered a graphical interface for scenario management, through which it is possible to:

- Initialize a session with a pre-existing tactical situation, selected among those that have been saved in previous runs;

- Insert or eliminate actors, even during execution;

- Modify all actor characteristics (type of aircraft, friend/foe status), even during execution;

- Set up and modify free trajectories (not related to specified waypoints);

- Record and modify free trajectories (not related to specified waypoints).

In order to widen the capabilities of tactical scenarios generation to include multipurpose scenarios and to increase the amount of available actors, some COTS applications are also available. The latest, recently procured is MÄK VR-Forces that will be mainly used as a scenario generator for training purposes.

4.3 Image generation

Of paramount importance for a full immersive experience in a SE is a realistic simulation of the geographical scenario.

Over the years Alenia Aeronautica has matured autonomous skills to elaborate and integrate image generation software and geographical databases needed to run its own simulation facilities.

The proprietary Image Generator (IG, figure 10), called "Sapphire", uses Open SceneGraph OpenGL graphic libraries and can be hosted on PC platforms with Linux operative system.

The IG has been developed for a variety of different applications, ranging from transport to high-performance fast-jet aircraft flight simulation; moreover, it can be tailored to other simulation applications as needed. At the moment, Sapphire is already integrated in most of the Alenia flight simulators, is progressively substituting the remaining COTS still in service and is proposed as a standard for the training simulators that Alenia offers and develops to its customers.

Along with the IG, Alenia develops autonomously also the Geographical Database for its simulators. This currently covers most of Italian territory with areas at different levels of resolution, both geospecific and geotypical, and includes several highly detailed airfields with specific 3D features.

Figure 10: An image generated by "Sapphire"

4.4 Virtual reality

All the set of devices and applications described in the above paragraphs are exploited to support a wide range of activities, both in the engineering and research areas. Among the most interesting areas there is the one of UAVs, and in particular Advanced Human Machine Interface (HMI) and autonomous flight/mission capabilities.

A set of virtual reality applications has been therefore developed to support the most advanced studies and researches, e.g., Scenario Enhanced Visualization System (figure 11), experimental UAVs Control Stations based on virtual reality interfaces (figure 12) and Virtual Mockup (figure 13).
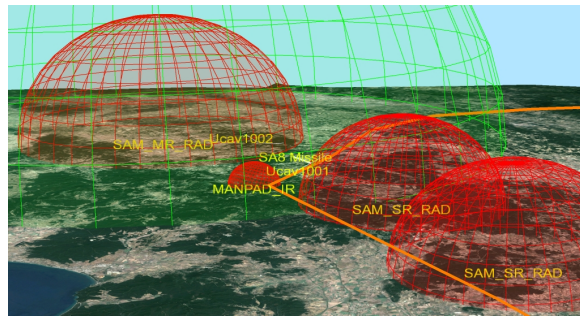
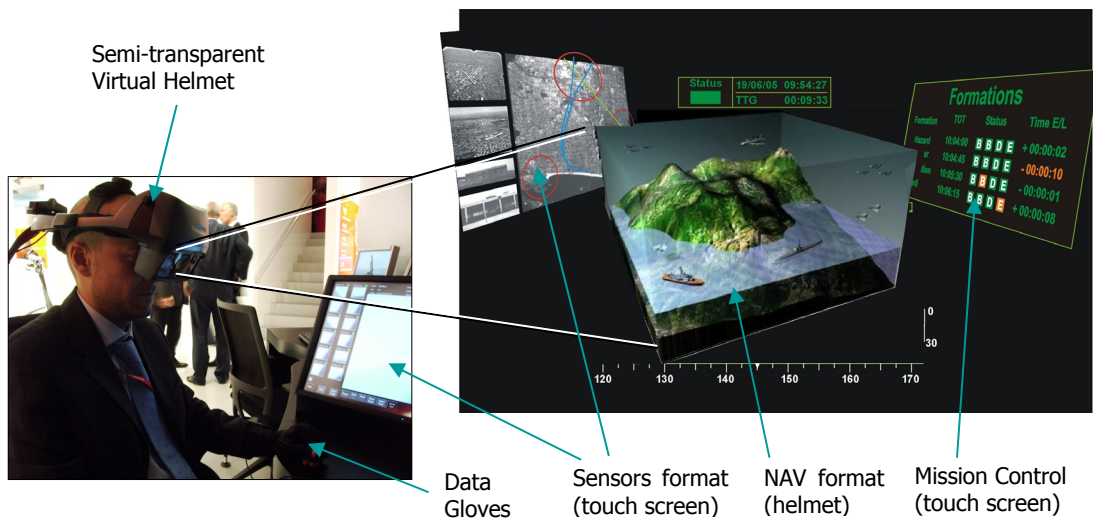**Figure 11: Scenario Enhanced Visualization System**

Figure 12: Experimental UAVs Control Station, presented at Le Bourget 2005

Figure 13: Virtual Mockup, presented at Farnborough 2006

5.0 NETWORK CENTRIC SIMULATION ENVIRONMENT

The availability of scenarios populated with synthetic or human actors, with the contribution of simulators and/or real systems, enables the definition and experimentation of new operational concepts.

The application of the Synthetic Environment to the study of Network Centric Operations constitutes the Network Centric Simulation Environment (NCSE).

Alenia Aeronautica is working in collaboration with the other Finmeccanica Companies in order to share experiences, skills and applications in the frame of the Italian effort in the fields of systems Interoperability and Network Enabled Capabilities (NEC).

Among the major initiatives there are two.

5.1 The SET^2 Community

SET^2 (Simulation for Evaluation, Experimentation, Test & Evaluation and Training) is one of the technological communities within the Finmeccanica MindSh@re Project, that brings together all the Companies on several specific areas in order to implement the "technology governance" of the Group.

SET^2 has conceived a technology platform called SEAMS (Synthetic Environment Advanced Management System) whose concept is now being developed as an enhancer of the possibilities of cooperation in the field of simulation among Finmeccanica Companies and with their customers.

The project aims at taking advantage of the Finmeccanica Companies' available SEs and NCSEs to establish, among other objectives, a simulation network with most of the simulation sites connected.

5.2 The Italian Defense-Industry Integrated Group

The Italian Defense-Industry Integrated Group is a recently started initiative having the goal to strength Interoperability and develop NEC within Italian Defense. The group sees the participation of several industries and Defense institutions within a structured and integrated working group.

M&S is one of the instruments to support the activities of the Integrated Group. Like within the SET^2 Community, but in a different context, one of the objectives of the M&S group is to establish a distributed simulation network among all the suitable simulation centers/assets available to the Italian Defense, complemented by the relevant centers/assets within industry as needed, with the capability to connect at NATO level with other Countries. The skills and experiences of Alenia Aeronautica in the field of SE are going to prove a valuable factor to succeed in this initiative.

As a first step towards the final goal, the HLA network between Alenia Aeronautica and Selex Sistemi Integrati Simulation Centers of Turin and Geneva respectively is going to be set up in the short future.

6.0 CONCLUSIONS

The paper gives an overview if the capabilities and current activities of Alenia Aeronautica in the field of Modeling & Simulation for Experimentation, Test & Evaluation and Training.

Building from a long tradition in flight simulation as an engineering support to aircraft design, the Company has developed significant capabilities as provider of training solutions and operates its Synthetic Environment mastering and integrating all the set of basic components, in most cases Alenia proprietary.

In particular, such experience plays now an important role in the frame of the latest collaboration initiatives with the national Military Customer and within the Finmeccanica Group.

7.0 LIST OF ACRONYMS

ACOL	Aggiornamento Capacità Operative e Logistiche
ACPT	Aircrew Cockpit Procedure Trainer
AWACS	Airborne Warning And Control System
COMAO	COMbined Air Operations
CETENA	Center for Technical Naval Studies
COTS	Commercial Off The Shelf
DCA	Defensive Counter Air
DIS	Distributed Interactive Simulation
CGF	Computer Generated Forces
HLA	High Level Architecture
HMI	Human Machine Interface
HOTAS	Hands On Throttle And Stick
IG	Image Generator
JSF	Joint Strike Fighter
LAN	Local Area Network
LCD	Liquid Crystals Display
M&S	Modeling & Simulation
MOB	Main Operating Base
MTDS	Mission Training via Distributed Simulation
NATO	North Atlantic Treat Organization
NCSE	Network Centric Simulation Environment
NEC	Network Enabled Capabilities
OCA	Offensive Counter Air
ROS	Remote Operator Station
RAF	Royal Air Force
RTI	Run Time Infrastructure
RTO	Research and Technology Organization
SAS	Studies, Analysis and Simulation
SE	Synthetic Environment
SEAD	Suppression of Enemy Air Defense
SEAMS	Synthetic Environment Advanced Management System
SET2	Simulation for Evaluation, Experimentation, Test & Evaluation and Training
STEP	Scenario for Test and Evaluation Purpose
UAV	Uninhabited Air Vehicle
UK	United Kingdom
USA	United States of America
WAN	Wide Area Network
WAVE	Warfighter Alliance in a Virtual Environment

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