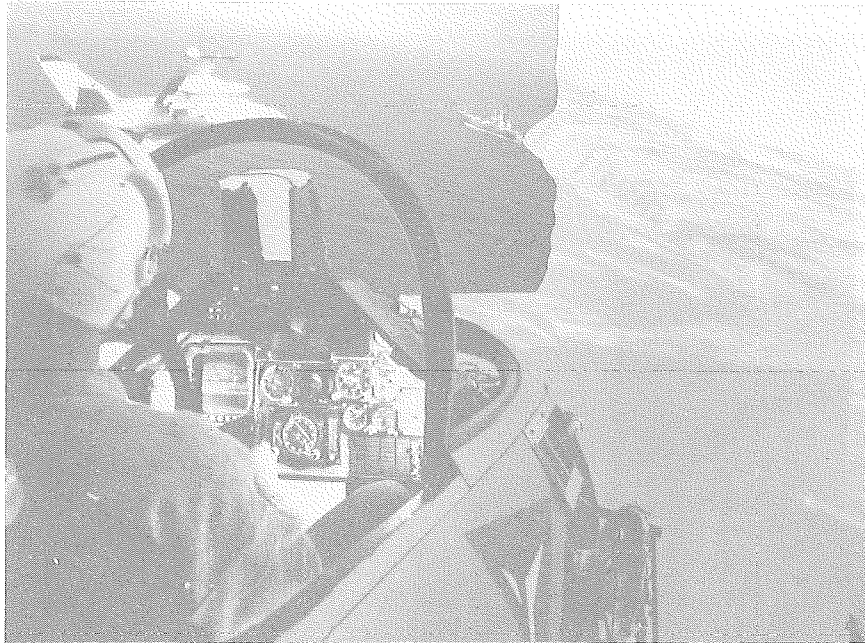


## Training Application of R & D Simulators

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### 1. Introduction

Simulation has achieved its highest engineering expression in the modern aircraft flight simulator.

Ground-based flight simulation increased its importance and its legitimate domain of investigation and application both as a research and development tool and as a training aid.

R & D Simulators are tools supporting the project of aircraft from the beginning of the program to the production phase, evaluating and testing the whole system.

Speaking about defense A/C, the simulation is aimed to the whole weapon system, to its process of design and evaluation leading to definition of H/W and S/W for defense-capable avionic systems and air vehicles.

Intrinsic complexity of modern weapon system, rapid development of supporting technology, high cost of system development and inherently long development lead times, are subjects to increment efforts on flight simulation.

Computer flight simulation is a development tool with unique capacity to develop and to evaluate design information during the all life of the aircraft program. Simulation at the weapon system level has the capacity to create, in repeatable and quantifiable numerical form, the entire environment in which a weapon system must operate, a task which is essentially not "do-able" on a test range with actual H/W.

Training simulators are dedicated not to substitute actual flight time, but to enhance it and make it more efficient. The main simulator training tasks are related to the familiarization of the pilots with flight vehicle system procedures, A/C performances and emergency procedures, mission planning and management, weapons use and mission rehearsal.

Flight simulation training allows to increase and to complete the real flight training avoiding flight restrictions and reductions due to political, economical and safety aspects.

This presentation will give a description about the Alenia flight simulation facilities in Turin as a witness how a R & D flight simulator is able to support training tasks.

Real time, pilot in the loop simulation was extensively used at Alenia since the beginning of the 80's for the AMX program.

The R & D AMX flight simulator supported many aspects of the design and mainly those related to pilot tasks optimizations, in addition to the development of flight controls and handling qualities.

Going through the prototype phase, today the AMX simulation is aimed to study new versions of weapon system and to be a training aid for AMI (Aeronautica Militare Italiana) and FAB (Fuerza Aerea Brasileira).

### 2. Simulation Training Aspects

The concept of using flight simulator for training tasks is relatively older than using it as an engineering tool to support the aircraft development program.

Anyway since from the beginning of the simulation it was identified the effectiveness of a flight simulator on the performance transfer.

The performance of a flight simulator can be represented by:

- quality of the realization
- range of involvement

The first one is characterized by the quality of the simulator in terms of correspondance of the A/C performance (representative mathematical model) and of cue fidelity (visual, vestibular, proprioceptive senses).

The second one is otherwise important because as more the pilot is involved as more the performance transfer exists.

Simulation training vantages:

- safety
- flight and cockpit procedure know-how
- save real flight time, fuel, weapons, maintenance, spares, A/C wear
- Unlimited repetition of manoeuvres with instantaneous reconfiguration of initial conditions
- mission rehearsal
- avoid restrictions on low level flights

Negative aspects of the Simulation training are correlated to a not complete representation of cues:

- human eye resolution
- limited FOV
- low level detailed data base
- no proprioceptive simulation
- not complete motion sensation
- sickness

Therefore expert pilots are minimizing the importance and the value of the simulator to a basic tool for cockpit procedures.



AMX Trainer

### 3. The AMX simulation

The AMX program meets a requirement of Italian Air Force for a Close Air Support/Close Air interdiction/reconnaissance aircraft. Simulation was considered an important development tool since the beginning of the program, and a suitable simulator configuration, as much cost effective as possible, studied. Flight Simulation had to cover the following areas:

- Ground and general handling simulation, fully augmented FCS and with every possible controls degradation.
- Handling simulation with manual flight controls, possibly limited to some significant points in the flight envelope.
- Simulation of flight with failed engine.
- Human engineering assessment (cockpit geometry and layout, Displays & Controls, etc.)
- Operational mission simulation, including phases like air-to-ground attacks, air-to-air self defence combat, formation flight, oriented to the harmonization of the AMX system as a whole.

As a result of all these tasks, the AMX Flight Simulator was built up in a reasonably low cost configuration to satisfy the first set of A/C performances analyses.

At the beginning, AMX Flight Simulator arrangement resulted as follows:

- Fully instrumented cockpit in a dome 30 feet  $\varnothing$ .
- Sky/earth projector (2 axis)

- Visual generating system (model board/graphic computer)
- Slewable projector

Using the described facility, supported by a real time simulation computer and a control and monitoring station, it was possible to perform several simulation activities.

The arrangement of the flight simulator, as said, was such that the test pilots involved in the evaluations were forced to adapt themselves to the situation and to use their imagination in correctly interpreting "rough" informations and cues. However, well experienced company and Air Force test pilots were perfectly able to satisfactorily perform the required activities, giving the engineers enough data to complete the planned activities and project further developments.

On the contrary, trainee pilots should not have gained very much from such a simulator configuration.

To overcome mainly the limits of angular and linear displacement and velocities of the above mentioned visual system, the simulator configuration was subsequently updated to include a simple but effective external world image generated by a general purpose graphic computer.

With this upgraded configuration it was possible to perform some interesting tasks like specific investigation of handling qualities during in-flight refuelling or formation flight, air target tracking with gunsight and particular profiles of air-to-ground attacks like pop-up manoeuvres, high angle bombing or jerking during attack both for handling qualities assessment and human factors evaluation.

The next activities in the AMX development programme requiring flight simulation support were the investigation of handling qualities and definition of the authorized flight envelope in the degraded all mechanical back-up FCS mode following a double hydraulic failure. In this mode the pilot feels the loads induced on the stick by the hinge moments directly.

Therefore, to carry out a more detailed assessment it has been necessary to acquire and integrate in the simulator a digital Control Loading System (CLS).

This CLS was installed in a new cockpit, better representing the production standard aircraft, equipped with aircraft standard displays and controls such as HUD, Navigation Data Entry (NDE) facility and Weapon Control Panel (WCP), mainly for the purpose of evaluating the nav/attack system from an operational point of view.

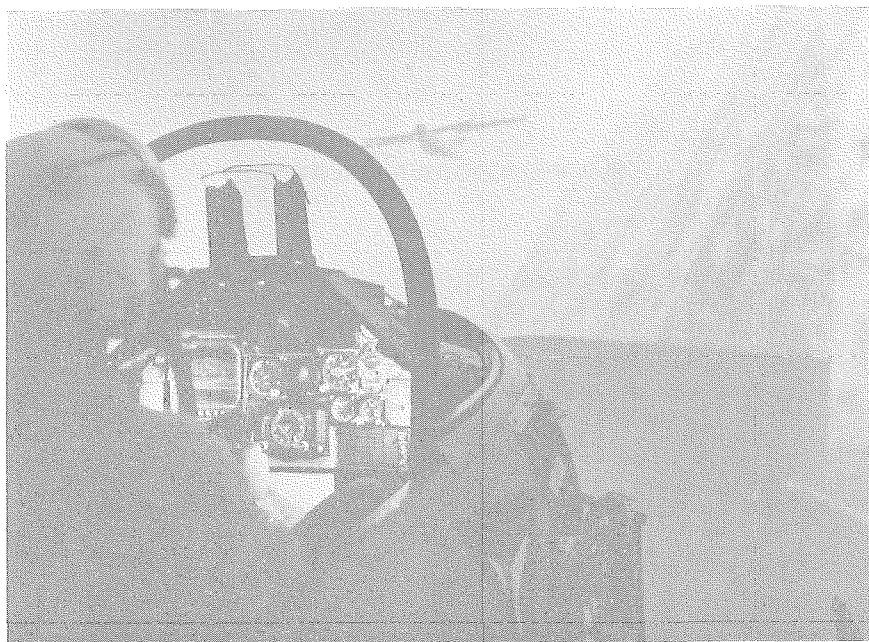
Emulating the aircraft MIL-STD-1553B databus was also necessary, together with simulating the aircraft sensors and some weapons.

At the same time, to evaluate operational concepts of a real mission it was required a better visual system than the basic one in use, in order to overcome limitations of the flat and schematic terrain data base used at that time.

For these reasons the acquisition of a General Electric Compuscene IV CGI system was decided, despite its high cost. A three windows visual configuration was adopted, projecting inside the dome an image covering a FOV about 160 deg. in azimuth by 45 deg. in elevation, that had been considered sufficient for most A/G tasks and adequate enough for supplying the pilot with cues for any possible manoeuvrability and controllability assessment.

The availability of such a system was the great lap in simulation realism, allowing realistic and effective simulations of low altitude nav/attack operations, formation flights, in-flight refuelling and some assessment of air-to-air defensive capabilities.

However, the two most important activities with the new flight simulator configuration were the high angle of attack and spin evaluation and the validation of the nav/attack system.



AMX Simulator

#### 4. The EFA simulation

The EFA (European Fighter Aircraft) is a canard delta, single seat, twin engine aircraft optimized for air-to-air combat with a basic mass empty of 9.75 tonnes, a thrust of 90 kN per engine.

The aircraft is being developed and produced for the Air Forces of UK, Germany, Italy and Spain by Eurofighter Jagd Flugzeug GmbH with its Partner Companies Alenia, British Aerospace, Casa and Messerschmitt-Boelkow-Blohm teamed with Dornier.

Introduction of EFA to the Services will start in the mid '90s and around 800 aircraft are likely to be required by the Air Forces of the Nations concerned.

In the same way, starting from a better potential tools, has been growing up the EFA flight simulator that today has reached an "ad interim" A/A configuration.

The EFA simulation is running to support a lot of activities aimed to the FCS evaluation and pilot assessment using a representative cockpit equipped with commercial H/W replacing the not yet available one.

The architecture of that simulator can be synthesized as follows:

- a fixed-base cockpit is in the center of an inflated dome used as a screen for the projection of the scenario generated by a second G.E. Compuscene IV, more or less similar to the AMX dedicated one, covering a FOV about 190 deg. in az. by 55 deg. in el.
  - A slewable target is projected by a dedicated optic in the whole FOV controlled either by an intelligent programme either by operator console or by the pilot in the other dome.
  - At present the HUD symbologies are projected in the right pilot's FOV and generated by a high speed graphic computer.
- All the H/W in the dome is installed to get the same FOV of the real A/C using wide-angle optics and particular installations.

The EFA Flight Simulation activities to be carried out in the Alenia EFA Simulator include:

- Flight Control System/Handling Assessment



**EUROPEAN FIGHTER AIRCRAFT**



**EFA Simulator**

- Human factors/Cockpit evaluation
- Short/Medium range combat
- A/G attack
- Flight Test Support
- Simulator/rigs integration

with a particular emphasis on the last activity that is on going with same avionics armament and utilities rigs. This integration will be achieved interfacing the Flight Simulator real H/W as well as host computer with rigs H/W via MIL 1553 and STANAG 3910 buses.

#### **5. AMX Training Potential**

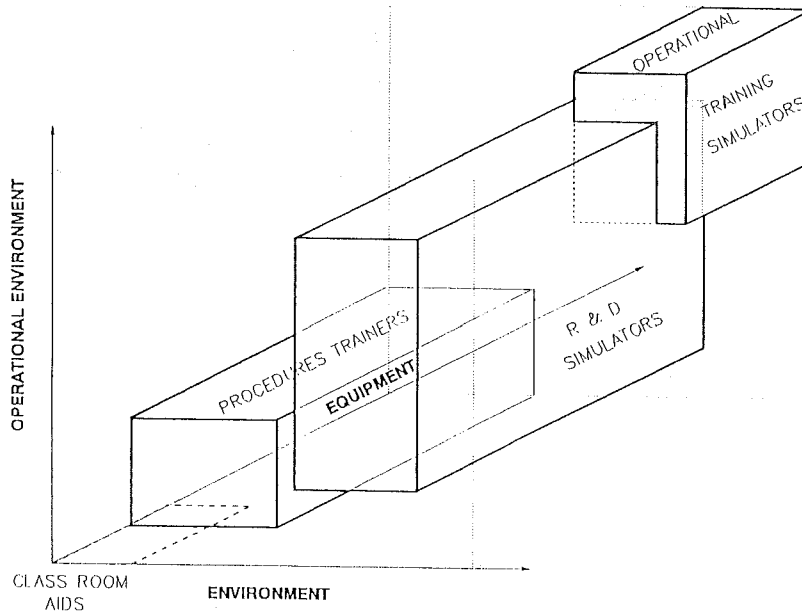
For a training simulator, the constellation of the human factors of the simulation has to be covered. High cost

technology and sophisticated complexity of the equipments is required to challenge the fidelity of simulation, to achieve the complete involvement of the pilot not as abstract performer but as operational protagonist.

The constituents of a flight simulator provide cues that could be synthesized:

**EQUIPMENT CUES** - provide a duplication of the appearance and feel of the operational equipment (the aircraft), i.e., the static and internal dynamic characteristics such as the size, shape, location and color of controls and displays, including controller force and displacement characteristics (real h/w as much as possible).

**ENVIRONMENT CUES** - provide a duplication of the environment and motion through the environment. The most obvious examples are motion from platforms or "g" seats and visual out-of-the-window cues.



### SIMULATOR CUES COMPLEXITY

OPERATIONAL ENVIRONMENT CUES represented by all active and interactive elements (weather conditions, EW, threats, targets, etc.) which generate attention, analysis, adaptation of the pilot, in other words "out of the window" workload.

AMX flight simulator has reached a configuration that matches R & D and Operational Training simulator characteristics allowing both activities.

Coming back to the AMX simulation we can highlight different phases in its life, correlated to specific activities:

#### Project

- sizing of the flight control system
- study of cockpit layout and HOTAS philosophy
- take-off and landing performances
- preliminary failure behaviour

#### Prototype

- flight tests support
- optimization of cockpit layout
- failures simulation
- flight envelope investigation included spin and recovery analysis
- Human engineering assessment
- Harmonization of the AMX as a weapon system

#### Production

- nav/attack system validation
- weapon aiming
- new HUD format and symbology development
- pilots training

#### New developments

- evaluation of new updated versions

Following this process it has been achieved a customer cooperation from the beginning of the program working together to experimental test pilots from the prototype phase in collaboration with company OTC's.

Collaboration that is going to continue also during the production and new development phases to reduce more and more the gap between the user and the project engineers. Following this philosophy a lot of activities have been done and are in progress with the AMX simulator for different

areas, for example a weapon aiming symbols presentation, Flight Director, Autopilot and HUD formats and symbologies definition.

The problem of familiarizing the operational pilots with the new single seater fighter that was near to be delivered to the squadrons was considered by the Air Staffs of the two nations with some concern, since there was not yet a two seater version available and the possible purchase of training simulators continued being shifted in time schedule for the usual defence budgets shrinking.

On the other hand, the AMX Alenia flight simulator had reached the complete configuration described before and was well known to the staffs because of the several simulation sessions performed by their OTC's; so it seemed rather natural to guess some training was also possible with this simulator.

A minimal set of specific improvements was then required to make the simulator suitable for this application. The cockpit was completed also with those items of no use in the engineering simulator (like comm/ident facilities, ECS panels, etc.). To overcome the lack of the motion system, considered important in a training simulator, it was installed a g-seat/g-suite system that provides tactile cues and "rough" feelings of the main motion cues.

Some special software was also developed; it was mainly necessary for the simulation of the utility systems and engine failures and malfunctions that again had been of no interest for the development activities, and for some pre-flight procedures.

Since operational mission training was also envisaged and familiarization with A/A modes was required, being the AIM-9L Missile included in the basic aircraft configuration as its self-defence weapon, a 5 DOF real time simulation model of the missile was developed and validated versus a very accurate non real time, 1 m/sec. increments model with good results.

Italian and Brazilian operational pilots began then to be trained on our simulator under monitor of their own instructor pilots and the technical assistance of Alenia simulation engineers.

Of course many improvements could still be done to increase

the training capacity of the simulator, but the present configuration is considered by the users sufficient to perform:

- normal and emergency procedures
- basic flight manoeuvres
- low level navigation and attack manoeuvres
- formation flight
- familiarization with A/A system characteristics.

The way in which practically this training activity takes place is rather unusual but has some interesting aspects.

The possibility of interaction between operational pilots and development engineers allows on one side the pilots to obtain clarifications about a lot of technical aspects more effectively than through the traditional training channels and on the other side engineers can have a useful feeling on what shall be the real use of the aircraft.

Some events have been recorded and analyzed through the flight simulator, after some particular manoeuvres occurred during real training. An easily analysis has been clarified the situations tailoring proposal of solutions or direct modifications.

The presence of a large population of air forces pilots with different experience and age was moreover the occasion for starting, sidewise, two research activities. One is a data collection about simulation sickness: a first emerging result seems to be that the more a pilot is a "natural pilot" or an experienced one the more he is subject to sickness, due probably to the feeling of cues different from his expectations. The second research, entitled "pilot errors analysis" is aimed to classify the recurring patterns that lead to frequent errors during the simulated missions and to correlate them to pilots' experience and workload of the moment. For this research the simulator sorties are monitored by a psychologist and pilot's actions and voice are recorded for further analysis. Main goal of the analysis is to identify to what extent the design of the pilot interface can be responsible of errors and how to define criteria to minimize this possibility.

#### 6. Recent and future AMX development activities

Since different new updated versions of the aircraft are currently under evaluation in order to expand its operational role, the simulator will continue being used to support development.

In this context, for example, some preliminary evaluations have been performed to assess the requirements on cockpit displays for allowing low level navigation at night.

The Compuscene three channels have been set to a reduced luminosity level to simulate dusk condition, while the fourth channel generated a simulation of infrared image as generated by an aircraft mounted FLIR system. This image is then projected on the dome in front of the cockpit with the same angular coverage as a real FLIR-compatible HUD.

With this configuration it has been possible to "fly" navigation sorties both in dusk and night conditions, evaluating FOV requirements for low altitude navigation in mountainous terrain. These tests are still under way, and they will soon include target tracking at night with a slewable IR sensor.

Development of a new nav/attack system configuration shall also require evaluation of new cockpit layout incorporating state-of-the-art displays and controls. To this extent, it could be possible that a new concept of simulator cockpit is required, to enable performing comprehensive evaluations of multi-functions displays and controls.

A solution currently being proposed is a sort of "active cockpit" using a CRT display to simulate the instrument panel. Using suitable graphic computers to drive simulations of displays and a touch-screen for pilot input, the facility should ease evaluations of different cockpit layouts and relevant presentation of information.

A duplication of HOST computer and CGI has been implemented correlated to a second independent control room to avoid the bottle-neck of two simulators (four in the future) and one computing system.

Nowaday two independent simulations are running to satisfy the needs of AMX and EFA studies and AMX training, reaching as follow-out the possibility to integrate both

simulators in a sort of "short networking" for peculiar tasks like A/A dog fighting simulation.

In the next future the EFA dome will be completed by a dual target projector able to show two independent targets in a complex threat scenario.

#### 7. EFA Future Training Potential

Realistic aircrew training is today's most valuable contribution to tomorrow's successes.

Preparedness for mission accomplishment in EFA is more than having a full inventory of aircraft sensors and weapons. Preparedness includes aircrews skilled in their use.

Experience shows that airborne weapon systems become more effective and at the same time more sophisticated. Demands, peculiar on single crew members increase in respect of the knowledge and the skill to monitor and mentally "stay-ahead" of automated and integrated systems and due to decision based functions to be accomplished in a limited time budget, rather than in respect of traditional flying abilities.

When comes to acquiring skills the traditional "on-the-job" approach still observed in many "front-line" squadrons is inadequate for future utilization.

To gain required skills in order to cope with a deadly and sophisticated environment, a sophisticated, professional, mission oriented, continuous educational and human factors related approach to future aircrew training is necessary.

The approach to a training simulator from a R & D one for EFA will be a natural process beginning from the prototype phase.

Alenia, as the other PC's, will be able to support their Company Test Pilot for the flight tests providing a representative simulator.

The simulator cockpit is the exact replication of a/c cockpit equipped by real h/w ready before the Italian prototype first flight, derived from the "ad interim" R & D cockpit.

The EFA flight simulator will be improved more and more to operational mission simulator integrated in the extended world environment recreated as much as possible similar to the real one.

The major advantage in the simulated operational scenario is reached in the following areas:

- full mission simulation: including operation in every geographical areas;
- effective pilot training: trainees without real operational experience will learn to operate as in the real world, without the complexity (and cost) associated with real multi-force flight exercises;
- continuous pilot proficiency: also in this case pilots capability will be practically assessed only if proficiency verification is carried out in a realistic simulated operational environment;
- development of new A/A tactics: the intrinsic flexibility of simulation shall allow continuous updating and verification of operational tactics.

#### 8. Conclusion

The experiences of Alenia in flight simulation teach that R & D and training purposes can be fulfilled in the same facility during a peculiar phase of the program of the aircraft. The training aid is a consequence and a continuous process of the life of the aircraft translated in a complete and high representative mathematical model without any kind of simplifications that are sometime danger for the real flight. The location of the training aid in the A/C factory reflects the vantage of an harmonized cooperation between the pilots and the design engineers both aimed to optimize and to increase the performances of the aircraft also after the prototype phase.

It is therefore always more important to anticipate the R & D simulation phase to reach the training simulation phase before the A/C availability to the Air Staff.

This is the philosophy which Alenia are going to follow for new programs starting from the EFA one.

List of abbreviations

A/A	Air to Air
A/C	Aircraft
A/G	Air to Ground
CLS	Control Loading System
CGI	Computer Generated Imagery
FCS	Flight Control System
FLIR	Forward Looking Infra Red
FOV	Field of view
HUD	Head Up Display
OTC	Official Test Center
PC	Partener Company
R&D	Research and Development