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JANUS – A NEW APPROACH TO AIR COMBAT PILOT TRAINING

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Abstract

Advanced jet training still relies on old concepts and solutions that are no longer efficient when considering the current and forthcoming changes in air combat. The cost of those old solutions to develop and maintain combat pilot skills are important, adding even more constraints to the training limitations. The requirement of having a trainer aircraft able to perform also light combat aircraft operational mission is adding unnecessary complexity and cost without any real operational advantages to air combat mission training.

Thanks to emerging technologies, the JANUS project will study the feasibility of a brand-new concept of agile manoeuvrable training aircraft and an integrated training system, able to provide a live, virtual and constructive environment. The JANUS concept is based on a lightweight, low-cost, high energy aircraft associated to a ground based Integrated Training System providing simulated and emulated signals, simulated and real opponents, combined with real-time feedback on pilot's physiological characteristics: traditionally embedded sensors are replaced with emulated signals, simulated opponents are proposed to the pilot, enabling out of sight engagement. JANUS is also providing new cost effective and more realistic solutions for "Red air aircraft" missions, organised in so-called "Aggressor Squadrons".

Keywords: air combat; advanced training; red air; training concept; innovation;

1. INTRODUCTION – TODAYS AIR COMBAT TRAINING SYSTEMS

The European Advanced Training "landscape" is fragmented. Many of the European Combat Jet Training platform (CJTP) units are aging and need to be replaced. Many European countries are using

non-European services such as US ones to fulfil their training needs. The arrival of the next generation of combat aircraft is accelerating this process. In parallel, information technologies will enable new solutions that can enhance the depth, range and the organisation of training, as well as reduce costs.

Also in the context of the EDIDP-ACC-CJTP-2019 topic, EU based jet pilot training is defined as a key condition to ensure high-level combat-operational readiness within Member States, using the latest and cost-effective training systems.

For decades, advanced jet training has been constrained by a reliance on old concepts, both in terms of platforms and training systems: training concepts didn't follow the pace of air combat platforms and functions' development. Some progresses have been made since 2000s, but still do not reach the required level of efficiency: Integrated Training Systems (ITS) and simulated complex aircraft interfaces have been developed, but more progress is needed in virtual weapon systems' data transfer and integration in global training systems.

There are also strong needs for "Red-air" aircraft in high numbers. The Air Forces rely exclusively on legacy, outdated and expensive combat aircraft or trainers in so-called "Aggressor Squadrons".

Currently, none of the systems in use worldwide achieves the twin goals of operational readiness and cost effectiveness. There is therefore an urgent need to improve overall combat aircraft training system concepts relying on European expertise and capabilities.

1.1. Advanced jet training has reached a dead end

Recent operations have shown that it is necessary to qualify and maintain an important reserve of pilots to support protracted conflict. As workload and operational demands have become heavier and more complex, pilots have to maintain their operational skills flying powerful training aircraft with appropriate training systems. However, the cost of deploying front line combat aircraft is now so high that these will be prioritized for operations or high-level exercises. Additionally, combat aircraft are often heavily committed to operations and cannot be diverted to routine Advanced Training missions.

Equally, it is likely that a change in the air dominance paradigm will see the emergence of more capable adversaries challenging NATO air dominance. This implies a heavier operational preparation to reduce losses. Moreover, current trainers, although less costly to operate, are unable to download the training programs needed to maintain pilot efficiency, from air combat aircrafts to advanced trainers (downloading), especially the simulation of realistic combat scenarios reflecting flight domain, combat mission complexity and combat environment.

1.2. The air combat evolution raises the necessity to consider the increase of training complexity

The multi-targeting capabilities (air-to-air, air-to-surface) of modern combat aircraft raise the necessity of operating against larger numbers of opponents in the "Aggressor Squadrons". Equally, the use of simulators is insufficient to train experienced pilots under combat conditions. This is due to the use of mostly out-dated trainers lacking the dynamic performance or retired combat aircraft lacking up-to-date (real or emulated) weapons systems. Therefore, the efficiency/cost ratio is not optimal. Even the latest generation of trainer aircraft has insufficient performance to cover the whole training spectrum, because of light combat aircraft design requirements. Moreover, their ITS are proprietary systems, and are difficult to integrate into a Distributed Mission Operation Centre (DMOC).

1.3. Necessity to increase the efficiency of training and reduce costs

The need to reform advanced jet training also covers the "red air" missions (manned targets for exercise and training). Red air missions need dedicated, more realistic and less costly platforms. However, this makes sense only if the performance of these platforms is comparable to a front-line combat aircraft,

particularly in terms of high specific excess power and high levels of agility. Failure to address this issue would lead to unrealistic training scenarios and a negative training experience.

None of the advanced training platforms currently in service or in development fulfil these fundamental requirements combined with low acquisition and life cycle costs. The aim of the JANUS project is to reduce by 30 % the exploitation cost below the standard supersonic training aircraft. The JANUS aircraft, studied in this project, will benefit from the latest aerodynamic software, is lighter (due to using composite materials and minimizing on board avionic systems), and hence, the cost of fuel consumption is reduced.

1.4. The world of advanced trainers is caught between two unsatisfactory solutions

The trainer is either a conventional subsonic jet aircraft, less costly but not able to achieve the required levels of performance; or is developed as a small state-of-the-art supersonic combat aircraft with appropriate weapon system, but which is too costly to procure and operate. Most of these aircraft are designed to fulfil Light Combat Aircraft (LCA) missions, that may be of questionable value against a better-armed adversary. Light Combat Aircraft are now challenged by Unmanned Combat Aerial Vehicle (UCAV) which up to now are rarely used in operations. Added value is for training aircraft therefore very poor and leads to a cost increase and potential decrease in performance.

1.5. JANUS management and Partners

To perform the JANUS feasibility study, a consortium was founded consisting of European specialists of defence and aeronautics systems: SCALIAN (coordinator), Air Liquide (Al-aT), VENTURA and BOWEN in France, STRAERO/INCAS National Institute for Aerospace Research in Romania, VZLU Major Centre for Aeronautical Research in Czech Republic, ILOT Institute of Aviation, (MUT) Military University of Technology and (WUT) Warsaw University of Technology in Poland, ALR in Switzerland, LOGIC in Italy.

The study will start by setting up high level requirements and with participation of European air forces in a validation phase through a user seminar. Two work packages dedicated to the aircraft platform and the ITS will be based on these requirements. They will study the feasibility of the components, and will compare on the-shelf technologies and new developments as solutions for each part (engines for example). The JANUS consortium will provide a market study for the system, acquisition and operating costs study and a follow-up program description.

2. OBJECTIVE OF THE JANUS PROPOSAL

JANUS will study the feasibility of a low-cost operationally effective solution for air combat pilot training, combining a very agile air platform, fully dedicated to training, and a flexible, interoperable, integrated training system (ITS) using simulations to provide a complete LVC solution. The JANUS study will explore innovations applicable to the learning and maintaining of skills, develop a first pilot physiological survey and propose a follow-up program aimed at developing a fully European air combat training service by 2028 or beyond.

2.1. Janus Concept Description

JANUS aims to radically improve combat aircraft training with a dedicated platform designed specifically to meet advanced training and “aggressor squadron” requirements and with an advanced ITS system able to supplement the flight operations with a fully simulated combat environment delivered by a ground-based system and programmable pilot interfaces. The JANUS concept is based on:

- An innovative Air Vehicle concept design and related technological demands:
  - The JANUS air platform is fully dedicated to advanced training and "Red air missions", without considering any Light Combat Aircraft (LCA) requirements.
  - The project aims at a radically low-cost basic platform design, with no payload, no on-board weapon systems hardware components but a high energy performance level requirement.
  - In order to achieve the goal of producing a very light air vehicle but capable of high g-loads at supersonic speed, 50% of the airframe will be made of composite materials leading to lower weight, higher thrust-to-weight ratio (T/W) and lower wing loading.
  - Existing engines and derivatives, as well as advanced propulsion technologies will be considered.
  - As far as possible and consistent with weight and cost reduction, European 'off-the-shelf' equipment (such as landing gear) will be used.

- An innovative concept of an agile open Integrated Training System (ITS)
  - The JANUS ITS will be a fully configurable platform able to integrate all training phases from basic up to Lead In Fighter Training (LIFT), ensuring the interfaces between all learning tools and platforms.
  - ITS will embrace the preparation, rehearsal, air training, debriefing and Learning Management Systems using a mix of emulation, simulation and Virtual Reality-Augmented Reality (VR-AR) and Artificial Intelligence (AI) technologies deployed on the air vehicle as well as in the control centre.
  - The JANUS ITS will avoid on-board weapon systems by simulated avionics including electronic warfare, cybersecurity and weather radar system, animated from the ground with data transferred via data link and combined with on-board simulation.
  - The JANUS ITS will include advanced and innovative functions (such as transmission of fictive radar locks), using a global environment simulation.
  - The JANUS ITS will deliver a modern Live Virtual Constructive (LVC) environment, mixing real flights (Live), manned simulated flights (Virtual), and software simulated flights (Constructive). The integration in a DMOC, dedicated to high level advanced training and exercises, will be studied.
  - JANUS will study new advanced features for pilot monitoring and aiding both instructors and pilots (such as AI assistance to improve situation awareness, and physiological monitoring).
  - The JANUS ITS will also integrate measures needed to ensure a high level of security of transferred information and computer-generated data as well as integral cyber protection.

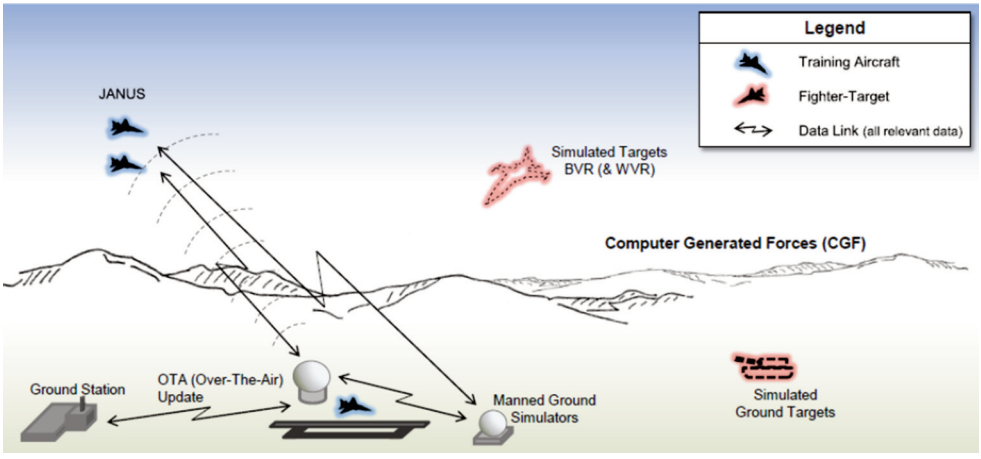


Figure 2. JANUS concept in „Air Combat and Ground Attack" mission

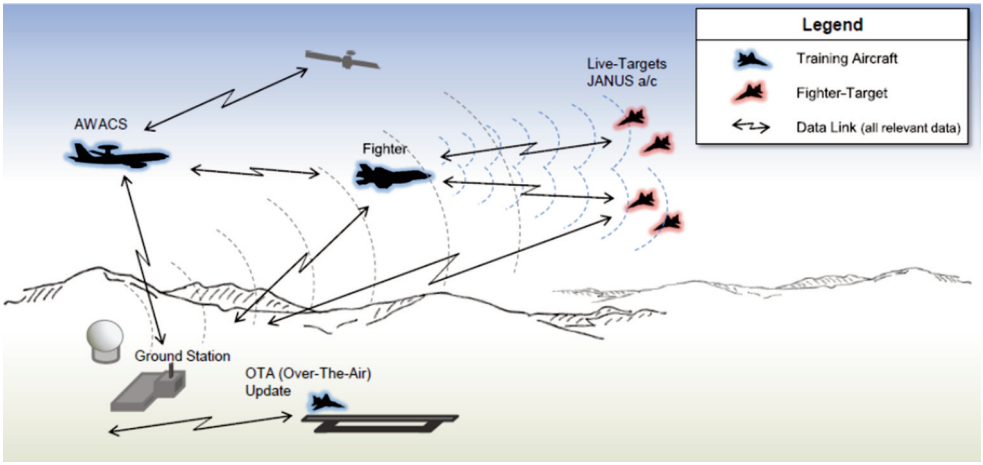


Figure 1. JANUS concept in „Red Air" mission

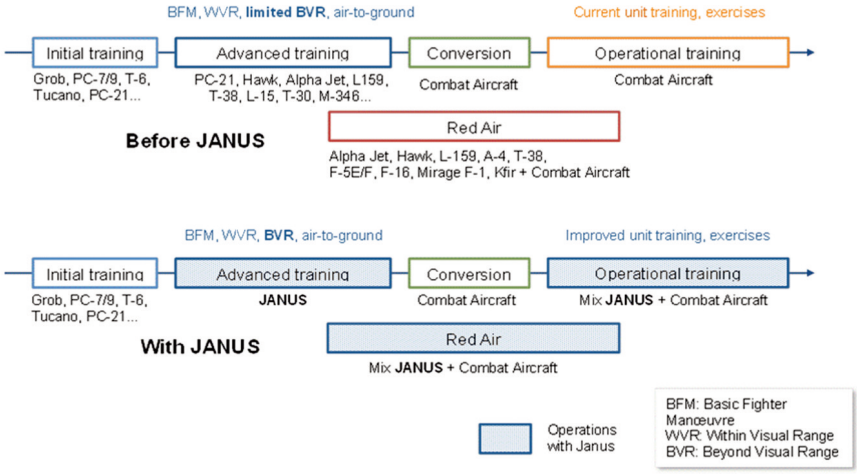


Figure 3. Extended training range with JANUS

2.2. Janus Methodology

The JANUS design concept would revolutionize the future initial and advanced air combat training by dramatically reducing its cost and enhancing its performances. The JANUS consortium will provide a systemic answer for the medium and long term training, with some applicable solutions to be fielded more rapidly. Given the demanding nature of the overall concept, the Janus project team will perform a feasibility study to demonstrate its viability. The following topics will be addressed:

- Definition of the operational needs and detailed requirements
- Feasibility of the air vehicle: starting from the baseline concept, a range of solutions around suitable propulsions in the range from 42 kN to 50 kN (reheat). will be presented
- Design of the ITS architecture: ground installation, data link choice and on-board avionics dedicated to weapon system simulation and training environment, required interfaces
- Conclusion of the overall concept: cost analysis, requirement review in Seminars with operational users (European Air Forces), review with European and national technology and strategy authorities

The JANUS 7 nations consortium consists of experienced specialists from 14 leading national Research Establishments, Universities as well as specialised Industries. The composition of the consortium guarantees for high standard in preliminary and detail air vehicle design, in ITS and in network IT design. The consortiums airpower advisors and former military efficiently contribute with Operational know how, training and air system design. The consortium is not influenced by any product-bias and acts in complete independence.

2.3. Janus Proposal Added Value

The JANUS concept is providing a solution that can accelerate the pilot initial training and allows to perform already an important part of the advanced fighter training. It increases the training efficiency and reduces costs. Enhanced cost-effectiveness will be achieved through innovation in the platform design and using an extended ITS (realistic simulation of all existing aircraft interfaces and weapon systems, as well as complex electromagnetic and cyber environment). The system will be designed to reduce Life Cycle Costs, using the latest predictive maintenance technologies and optimizing maintenance, repair and operations (MRO) organisations.

The JANUS architecture will be designed to be adaptable to existing situations and address future air combat systems evolutions. All training environment definitions and tools will be available to partner nations. JANUS system is a global solution developed to provide a European cooperative service able to encompass all existing and forthcoming training materials (e-learning, simulators, etc.), from basic up to LIFT. It proposes a solution for "red air aircraft" that can be connected to a modern DMOC. The JANUS system will be capable of providing demanding electronic and cyber warfare operational environments to enhance the realism of scenarios.

It integrates cutting-edge innovations. The JANUS architecture will be designed to integrate future innovations enhancing system capabilities and to reduce operating costs. 'Big data" solutions, (for example predictive maintenance, artificial intelligence for "red aircraft' behaviour, virtual and augmented reality interfaces, pilot physiological, cognitive and emotional monitoring) will be studied.

2.4. Why a New Supersonic, Light, Advanced Trainer and "Red Air" Aircraft?

The volume inside the SEP envelope (Figure 4) shows the available Specific Excess Power SEP potential depending of Mach number and Altitude: SEP is directly representative for climb rate and acceleration or a combination of both. The surface of the volume represents steady-state conditions i.e. at 1 g (no turns).

- Supersonic trainer and fighter present high energy potentials (SEP) required in air combat manoeuvres
- A subsonic trainer cannot match those qualities and does not fulfil advanced trainer requirements

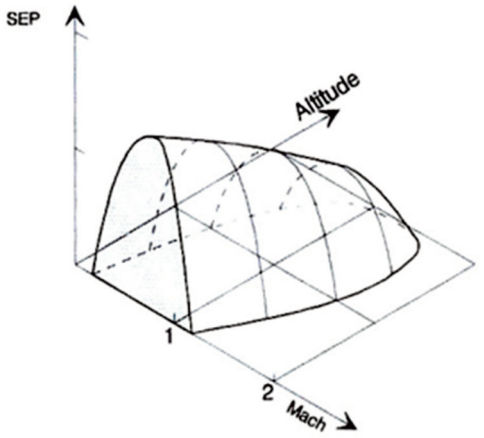
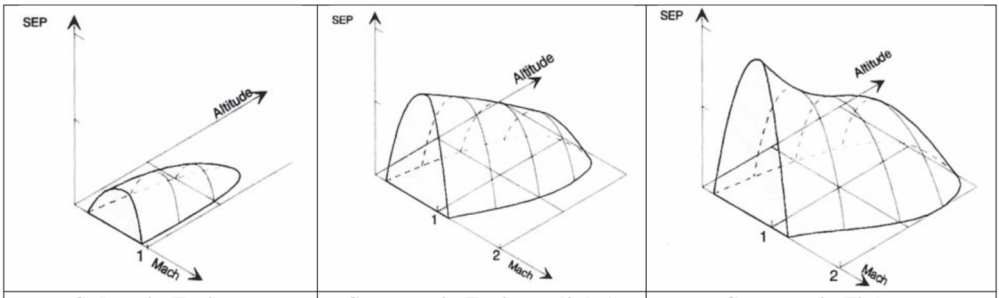


Figure 4. Specific Excess Power versus altitude and Mach number



Subsonic Trainer (engine without reheat subsonic configuration)	**Supersonic Trainer „light“** (engine with reheat, supersonic configuration)	**Supersonic Fighter** (engine with reheat, supersonic configuration, F-16 type)

Figure 5. Specific Excess Power versus altitude and Mach number for traditional subsonic trainer, supersonic "light" trainer and supersonic fighter

But also regarding T/R (sustained and instantaneous turn-rates), the superiority of a supersonic A/T design is evident: especially in the transonic region from Mach 0.85 to 1.2, superior performance is required for a maximum of "downloading" from extremely expensive high performance combat aircraft flight hours to the supersonic A/T. The same performance and low-cost requirements are needed in the "red-air" missions. In this context, the upper-end of Advanced Training missions can already be performed on the Advanced Trainer, and must not be executed on the high performance fighters.

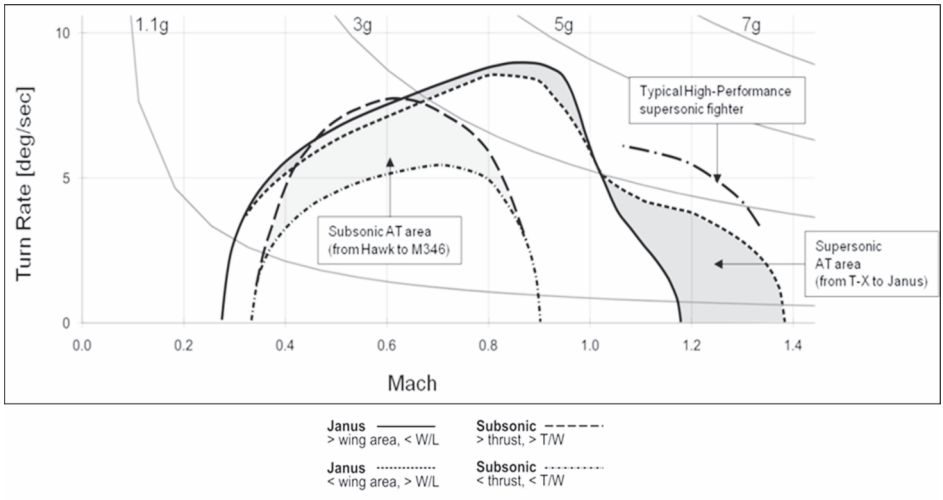


Figure 6. Sustained Turn Rates versus Mach number of supersonic and subsonic Advanced Trainer (at 30 kft, 50% internal fuel)

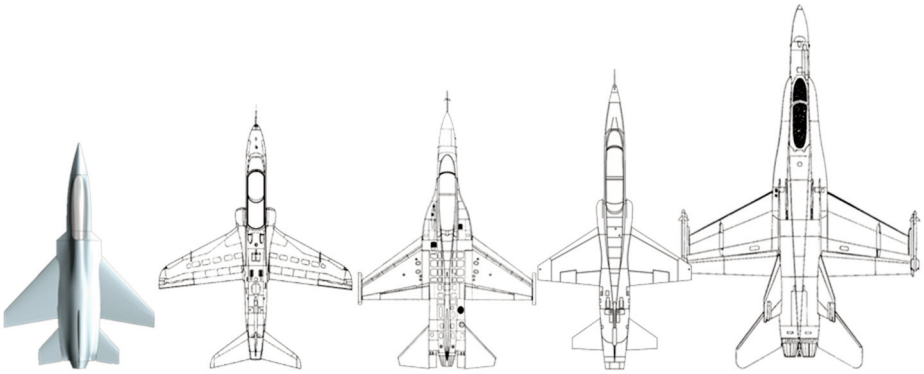
A major difficulty for the Air Forces in their training syllabus lies in the fact that in peace time supersonic flight is restricted to dedicated areas or over the sea. However, a real BVR fight can often start in the supersonic and continue into the high subsonic regime (Mach 0.85 to 1) after a few minutes. Therefore the Janus superior performance in the transonic region (Mach 0.85 to 1.2) will bring the following advantages (as clearly seen in Figure 6):

- In the rare opportunities to train in the lower supersonic regime, Janus can provide similar performance like combat aircraft.

- In the usual advanced training in the high subsonic regime, Janus offers excellent realistic performance in a region where the conventional AT performance collapses beyond Mach 0.8 and does not provide realistic training results.

Supersonic designs (Janus, T-7, T-50) with reheat engines present performance close to high performance fighter aircraft, which is operationally important. Subsonic designs with high turn rates at low subsonic Mach numbers present operationally less important capabilities. The Janus future conceptual selection procedure emphasis will address higher supersonic capabilities at the expense of less subsonic turn rates (lower wing-loading W/L). Or, vice versa, higher subsonic turn rates at the expense of supersonic capabilities. High thrust to weight ratio (T/W), also due to an advanced engine for instance, will enhance mainly SEP incl. supersonic performance.

The Feasibility Study shall be executed in close cooperation between User (Requirements) and Study Team (Solutions). The early Conceptual design with basic layout and data (T/W and W/L) is key for operational utility and must be addressed with the User right at the beginning. The users are therefore offered early participation in the requirements development.



AT Janus	BAE Hawk Mk 65	T-50 Golden Eagle	T-38A Talon	F/A-18C/D
Length 11 m	12.4 m	13.1 m	14.1 m	17.1 m
Area 18 m²	16.7 m²	23.7 m²	15.8 m²	38 m²
empty weight 3.1 t			empty weight 3.27 t	
Small Size and Low Weight Means Low Cost!				

Figure 7. Comparison of size between JANUS Baseline Design, Hawk, T-50, T-38 and F/A-18 C

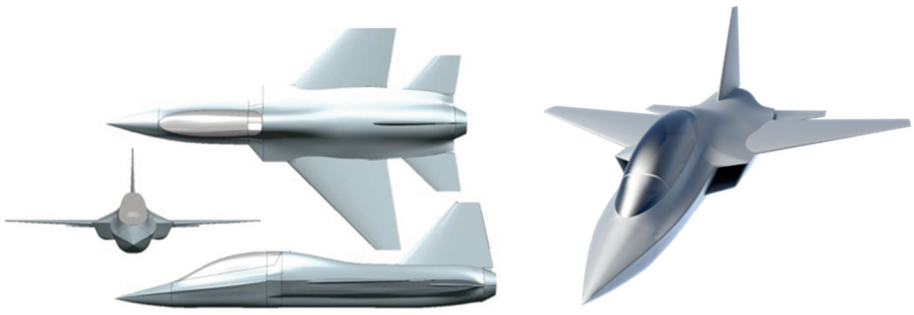


Figure 8. JANUS three side view and perspective drawing

3. CONCLUSION

The JANUS concept is providing optimized air combat training capabilities: this means a solution, which is considering the full envelope/all options of air combat engagements in order to increase the training efficiency. First, by being able to train earlier a complete combat scenario on a representative air platform, which helps to accelerate the advanced training phase and to identify and download situations showing what can be done by current fighters to JANUS (or the other way around). This acceleration is providing a real gain in training efficiency. As JANUS system can also be used as a realistic opposing ("red") aircraft, it helps also to increase the efficiency of advanced training and exercises by providing very realistic targets. It allows to reinforce the skills of pilots in those phases, thus increasing the efficiency of the operational training.

The core of the JANUS project is a study of a solution that aims to reduce training costs through an affordable operational air vehicle and an agile ITS. This goal will be reached by a design methodology that will concentrate the innovation and the developments to the critical issues for the concept (aerodynamics, propulsion, simulated weapon system, ITS architecture, etc.): the remaining topics will be adapted from existing solution, optimizing the development.

By developing a low weight/high performance aircraft and simulations to replace part of the training to be performed on fighter aircraft, the JANUS system is drastically reducing the fuel consumption and thus its impact on air forces budgets. In addition, JANUS specifications will integrate also new MRO concepts (such as predictive maintenance based on big data analysis coming from sensors) in order to reduce the MRO costs both for the air platform and ITS. In addition, technologies like simulators, virtual aircraft, simulated optronic or EW environment are aimed at reducing the global training life cycle costs, leaving more front-line aircraft for operations. Finally, the small engine size of JANUS (compared to a real fighter) and the use of simulation to build complex scenario with a limited number of flying aircraft is limiting the noise level generated by the training, particularly during night and reduce fossil energy consumption. These characteristics helps to increase the training hours and training areas compared to equivalent situation based on fighter only.

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List of abbreviations

A/C	Aircraft
ACMI	Air Combat Manoeuvring Instrumentation
AFB	Air Force Bases
AI	Artificial Intelligence
AT	Advanced Trainer
AoA	Angle of Attack
APP	Aircraft Performance Programme
BFM	Basic Fighter Manoeuvre
BVR	Beyond Visual Range
CAD	Computer Assisted Design
CATS	Contracted Airborne Training Services
CDP	Capability Development Plan
CFD	Computational Fluid Dynamics
CJTP	Combat Jet Training Platform
COTS	Commercial Off The Shelf
DMO	Distributed Mission Operations
DMOC	Distributed Mission Operation Centre
DMT	Distributed Mission Training
EAB	End-users Advisory Board
EC	European Commission
ECM	Electronic Countermeasure
ECP EC	Collaboration Platform
EDTIB	European Defence Technological and Industrial Base
EM	Electromagnetic
FAC	Forward Air Controllers
FCAS	Future Combat Air System
FCS	Flight Control System
FOC	Full Operating Capabilities
FSD	Full-Scale Development
GSI	Ground Surveillance Intercept
GUI	Graphical User Interface
HLR	High Level Requirements
HMI	Human Machine Interface
IOC	Initial Operating Capabilities
ITS	Integrated Training Systems
LCA	Light Combat Aircraft
LIFT	Lead In Fighter Training
LMS	Learning Management System
LVC	Live Virtual Constructive
MDR	Mission Definition Review
MRO	Maintenance, Repair and Operations
MST	Management Support Team
OBOGS	On-Board Oxygen Generating System
PC	Project Coordinator
PE	Physiological Events
PSC	Project Steering Committee
SEP	Specific Excess Power
SMB	Security Management Board
TRMPMM	Technical Review and Project Management Meetings
UCAV	Unmanned Combat Aerial Vehicle
USAF	United States Air Force
UxV	Unmanned Vehicle
VMC	Visual Meteorological Conditions
VR-AR	Virtual Reality-Augmented Reality
WVR	Within Visual Range