Analysis of modern military jet trainer aircraft

Ilie NICOLIN*,[1], Bogdan Adrian NICOLIN[1]

*Corresponding author
[1]INCAS – National Institute for Aerospace Research "Elie Carafoli",
B-dul Iuliu Maniu 220, Bucharest 061126, Romania,
nicolin.ilie@incas.ro*, nicolin.adrian@incas.ro

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Abstract: *New technical solutions and the application of modern technologies have led to combat aircraft configurations with a significant improvement in reliability, flight performance and operational performance through the creation of new features that enhance the ability to integrate sensors and process information. On one side, this pace of development has created operational advantages, but on the other side it has made the use of modern multifunctional combat aircraft increasingly expensive. In this context, the need for the use of modern military jet trainer aircraft has become more and more acute, the cost being reduced by about 10 times per hour of instruction in comparison to a jet fighter. The aim of this paper is to analyze the technological performances of the newest and most advanced jet trainers in the world and the development perspectives in the field, to determine the directions of development and the design of a new Romanian jet trainer to be used for school, training and light combat and to be competitive for the time period 2030-2040.*

Key Words: *analysis, military, jet, aircraft, trainer, modern.*

1. FOREWORD [1, 2, 3, 4, 5, 6]

A jet trainer is a jet aircraft used for training purposes both for basic and advanced flights. Jet trainers are either custom designs or modifications of existing aircraft. With the introduction of military jet-powered aircraft towards the end of the World War II it has become absolutely necessary to prepare pilots for flying this type of aircraft.

As the training has developed, different air forces have begun to use jet trainers for different phases of training. Pilots who were picked to fly fighter or strike aircraft then went on to fly more advanced training aircraft. As the jet trainer has also developed it was used for weapon training as well, which led to some trainers being modified as light strike aircraft.

The two seating configurations for trainer aircraft are pilot and instructor in tandem, usually with the pilot in front and the instructor behind. The tandem configuration has the advantage of being closer to the normal working environment that a fast jet pilot is likely to encounter.

Given the expense of military pilot training, air forces typically conduct training in phases to eliminate unsuitable candidates. The cost to those air forces that do not follow a graduated training regimen is not just monetary but it is also quantified in human lives.

There are two main areas for instruction, flight training and operational training. In flight training a candidate seeks to develop his flying skills. In operational training the candidate learns to use his or her flying skills through simulated combat, attack and fighter techniques.

Modern advanced trainers feature programmable multi-function displays which can be programmed to simulate different electronic systems and scenarios. Most advanced trainers do not have radar systems of their own, but onboard systems can be programmed to simulate radar contacts. With datalinks and GPS, virtual radar systems can be created with similarly equipped aircraft relaying to each other their positions in real time and onboard computers creating a radar display based on this information [7]. The aim of programmable displays is to speed pilot training by replicating as far as possible the systems a pilot will find in an operational aircraft.

As the capabilities of front-line aircraft have increased, this has been reflected in increasingly sophisticated advanced trainers. As the costs of developing new aircraft have risen in real terms, it has become more likely that fewer aircraft will be designed specifically for the training role. The advanced trainer was often seen as a stepping stone by most nations in developing a fast jet design and manufacturing capability. With increasing costs, even major air forces will have difficulty reaching the economies of scale to justify development of new advanced trainers. Nations will be required to continue to push the modernisation of existing aircraft (some such as the Hawk dating from the 1970s) or co-operate in the development and procurement of advanced training aircraft. Furthermore, they must better utilise available funding by developing aircraft with an enhanced combat capability by producing operational single-seat variants, and better utilise aircraft on inventory incorporating operational systems either within the aircraft or as external pods [8].

The trend of programmable electronic systems and datalinks is likely to continue with the possibility that ground-based radar systems and processing systems will allow advanced training aircraft to function as if they truly had onboard radar systems, with the cockpit closely replicating the look and feel of an air force's more capable aircraft for maximum familiarity [9]. Programmable engine management and fly-by-wire flight control systems will allow an aircraft to mimic the flight characteristics of frontline aircraft [10] with actual performance being restricted to a pilot's level of ability, with more power and greater agility becoming available as a pilot's skill improves. In the next table there is a list of current jet trainers [1, 2].

Table 1. List of current jet trainers in the world

Aircraft Name	Country of origin	1st flight	No. built	Status
Aermacchi MB-339	Italy	1976	230	Active in production
Aero L-39 Albatros	Czechoslovakia	1968	+2,800	Operational
Aero L-59 Super Albatros	Czechoslovakia	1986	+60	Operational
AIDC AT-3	Taiwan	1980	63	Operational
Alenia Aermacchi M-346 Master	Italy	2004	+67	Operational
BAe Hawk	United Kingdom	1974	+1,000	Operational
CASA C-101	Spain	1977	166	Operational
KB SAT SR-10	Russia	2015	1	under development
Dassault/Dornier Alpha Jet	France/Germany	1973	480	Operational
Douglas TA-4F/J Skyhawk	United States	1954	2,960	Operational

Aircraft Name	Country of origin	1st flight	No. built	Status
FMA IA 63 Pampa	Argentina	1984	27	Operational
HAL HJT-36 Sitara	India	2003	+4	Limited series production
Hongdu JL-8/Karakorum-8	China/Pakistan	1990	+500	Operational
Hongdu L-15	China	1990	+3	Flight testing, limited series production
IAR 99	Romania	1985	+20	Operational
KAI T-50 Golden Eagle	South Korea	2002	82	Operational
Kawasaki T-4	Japan	1998	+208	Operational
McDonnell Douglas T-45 Goshawk	United States	1988	221	Operational
North American T-2 Buckeye	United States	1959	1,146	Operational
Northrop T-38 Talon	United States	1958	529	Operational
Boeing-Saab T-X	United States/Sweden	2016	2	under development
Saab 105	Sweden	1963	192	Operational
Soko G-4 Super Galeb	Yugoslavia	1978	85	Operational
SIAI-Marchetti S.211	Italy	1981	60	Operational
Yakovlev Yak-130	Russia	1996	100	Operational

2. ALENIA AERMACCHI M-346 MASTER [1,11,12]

The Alenia Aermacchi M-346 Master is a military twin-engine transonic trainer aircraft. Originally co-developed with Yakovlev as the Yak/AEM-130, the partnership was dissolved in 2000 and Alenia Aermacchi proceeded to separately develop the M-346 Master, while Yakolev continued to work on the Yakovlev Yak-130.

The first flight of the M-346 was performed in 2004. The type is currently operated by the air forces of Italy, Israel, Singapore, and Poland. Since 2016 the manufacturer became Leonardo-Finmeccanica as Alenia Aermacchi merged into the new Finmeccanica, finally rebranded as Leonardo in 2017.

The Aermacchi M-346 is the most advanced trainer aircraft available on the market today and the only one specifically designed to prepare pilots for high performance new generation aircraft.

Since 2013, the M-346 is in service with the Air Forces of Italy, Republic of Singapore and Israel, and more recently it was adopted by the Polish Air Force that signed a contract for 8 aircraft in 2014 and 4 more in 2018.

Every aspect of the M-346 design is technically innovative.

Coupled with the unparalleled experience of the Leonardo Aircraft Division in training systems, this translates into a leading edge aircraft with exuberant performance and state-of-the-art equipment.

Fig. 1 – Alenia Aermacchi M-346 Master

The wide flight envelope, high thrust/weight ratio and extreme maneuverability allow the M-346 to offer handling similar to those of next generation combat aircraft, including the Eurofighter Typhoon and the F-35. This maximises the training effectiveness and reduces the need to fly sorties on the far more expensive two-seat variants of frontline types.

Its Embedded Tactical Training Simulation (ETTS) allows the M-346 to emulate sensors, countermeasures and weapons, as well as allowing pilots to interact in real time with a virtual tactical scenario, further enhancing flexibility and cost reduction.

Thanks to its Helmet Mounted Display, voice command, in-flight refueling probe and hard-points for up to 3,000 kilos of external loads, the M-346 can carry out a complete tactical training syllabus.

The M-346 is the keystone of an Integrated Training System that includes a complete Ground Based Training System (GBTS), comprising academics, simulators, mission support system and computer-based training management system. In order to maximise aircraft availability and mission generation, the Aircraft Division has developed and offers a dedicated Integrated Logistic Support (ILS) package.

The M-346 is the basis of the T-100 Integrated Training System (ITS), the solution offered by Leonardo DRS in the T-X competition for the U.S. Air Force's advanced pilot training system program.

General characteristics

- Crew: two, student and instructor
- Length: 11.49 m
- Wingspan: 9.72 m
- Height: 4.76 m
- Wing area: 23.52 m²
- Empty weight: 4,610 kg
- Loaded weight: 6,700 kg
- Max. takeoff weight: 9,500 kg
- Powerplant: 2 × Honeywell F124-GA-200 , 28 kN each

Performance

- Never exceed speed: Mach 1.2 (1,470 km/h)
- Maximum speed: 1,059 km/h
- Stall speed: 176 km/h
- Range: 1,981 km

- Ferry range: 2,722 km; with 3 external drop tanks
- Endurance: 2.75 hours (4 hours with external drop tanks)
- Service ceiling: 13,716 m
- Rate of climb: 6,705 m/min
- Wing loading: 285 kg/m²
- Thrust/weight: 0.84

Armament

Hardpoints: Provisions for a total of 9 pylon stations (2× wingtip, 1× under-fuselage plus 6× underwing), capable of mounting up to 3,000 kilograms of external payload and up to 3× 630 litres external drop tanks (only pylon stations 4, 5, 6 are wet-plumbed).

Variants

M-346 - Designation for the basic type

T-346A - Italian military designation from 2012 for the M-346

M-346LCA - Armed variant offered to Poland as a replacement for aging Su-22[13]

M-346FT - Multirole variant capable of switching between training and combat operations. New features include a new tactical datalink system and different armament capability, but do not include physical changes to the hardware [14]

M-346FA - Multirole variant capable of air-to-air and air-to-surface combat with a 2 tonne payload spread over 7 hardpoints, advanced Grifo-346 radar, countermeasures and stealth features including engine intake grids and radar-absorbing coatings on the canopy and wing leading edge. It is being marketed as a light attack aircraft also suitable for aggressor training purposes. The aircraft was revealed on June 18, 2017 in a static display at that year's Paris Air Show. The aircraft is being marketed for export to South American and East Asian countries, and is claimed to be able to carry out operational missions at far lower costs than those of front-line fighters [15,16,17].

T-100 - Designation used for the United States Air Force's T-X program.[18]

3. KAI T-50 GOLDEN EAGLE [1, 19, 20]

The KAI T-50 Golden Eagle is a family of South Korean supersonic advanced trainers and light combat aircraft, developed by Korea Aerospace Industries (KAI) with Lockheed Martin. The T-50 is South Korea's first indigenous supersonic aircraft and one of the world's few supersonic trainers [21]. Development began in the late 1990s, and its maiden flight occurred in 2002. The aircraft entered active service with the Republic of Korea Air Force (ROKAF) in 2005. The T-50 has been further developed into aerobatic and combat variants, namely T-50B, TA-50, and FA-50. The F-50 single-seat multirole fighter variant was considered. The T-50B serves with the South Korean air force's aerobatics team. The TA-50 light attack variant has been ordered by Indonesia. The Philippines ordered 12 units of the FA-50 variant. The T-50A is being marketed as a candidate for the United States Air Force's next-generation T-X trainer program [22]. Thailand ordered 12 units of the T-50 advanced trainer variant [23,24]. The program has expanded beyond a trainer concept to include the TA-50 light attack aircraft and the FA-50 light combat aircraft, similar to the multirole KF-16. The TA-50 variant is a more heavily armed version of the T-50 trainer, intended for lead-in fighter training and light attack roles. It is equipped with the Elta EL/M-2032 fire control radar. The TA-50 is designed to operate as a full-fledged combat platform for precision-guided weapons, air-to-air missiles and air-to-ground missiles. The TA-50 can mount additional utility pods for reconnaissance, targeting assistance, and electronic warfare.

Reconnaissance and electronic warfare variants are also being developed, designated as RA-50 and EA-50. The FA-50 is the most advanced version of the T-50, possessing more internal fuel capacity, enhanced avionics, a longer radome and a tactical datalink. It is equipped with a modified Israeli EL/M-2032 pulse-Doppler radar with Korean-specific modifications by LIG Nex1. The engine could be either Eurojet EJ200 or General Electric F414, upgraded to 20,000 lb or 22,000 lb thrust, roughly 12–25% higher than the F404's thrust and are offered to prospective customers for the T-50. The radar of the FA-50 has a range two-thirds greater than the TA-50's radar. The EL/M-2032 was initially chosen over Lockheed Martin's preferred AN/APG-67(V)4 and SELEX Vixen 500E active electronically scanned array (AESA) radars. Other AESA radars such as Raytheon Advanced Combat Radar and Northrop Grumman's Scalable Agile Beam Radar are options for future production and may be shared with the radar chosen for USAF and ROKAF F-16 fighters. Samsung Thales is also independently developing a domestic multi-mode AESA radar for the FA-50. In December 2008, South Korea awarded a contract to KAI to convert four T-50s to FA-50 standard by 2012. In 2012, the ROKAF ordered 20 FA-50 fighters to be delivered by the end of 2014. The maiden flight of the FA-50 took place in 2011. 60 FA-50 aircraft are to be produced for the ROKAF from 2013 to 2016. KAI received a 1.1 trillion won ($1 billion) order for FA-50 fighter aircraft in May 2013.

In December 2015, KAI announced and revealed the new KAI-LM T-50 T-X upgrade intended to compete in the U.S. T-X program that will start testing in 2016. This variant features a dorsal hump for extra internal fuel and an aerial refuelling receptacle, large area display (LAD), and embedded ground training systems.

Fig. 2 – KAI T-50 Golden Eagle

In October ADEX 2017, KAI unveiled the T-50A as a new variant based on the FA-50 multirole combat aircraft. Including fifth generation cockpit, an aerial refuelling receptacle, cockpit multifunction display, dorsal hump for extra internal fuel, and an embedded training suite at the ADEX 2017.

General characteristics

Crew: 2
Length: 13.14 m
Wingspan: 9.45 m
Height: 4.94 m
Wing area: 23.69 m²

Empty weight: 6,470 kg
Max. takeoff weight: 12,300 kg
Powerplant: 1 × General Electric F404 (built under license by Samsung Techwin) afterburning turbofan
Dry thrust: 53.07 kN
Thrust with afterburner: 78.7 kN
Performance
Maximum speed: Mach 1.5 (1,640 km/h, at 9,144 m)
Range: 1,851 km
Service ceiling: 14,630 m
Rate of climb: 198 m/s
Thrust/weight: 0.96
Max g limit: -3 g/+8 g
Armament
Guns: 1× 20 mm General Dynamics A-50 3-barrel rotary cannon
Hardpoints: Total of 7 with 4 underwing 2 wingtip and one under fuselage; holding up to 3,740 kg of payload
Rockets: Hydra 70, LOGIR
Missiles:
Air-to-air: AIM-9 Sidewinder, AIM-120 AMRAAM (planned for FA-50)
Air-to-ground: AGM-65 Maverick, KEPD 350K-2 (planned for FA-50)
Bombs: Mk 82, Mk 83
CBU-97/105 Sensor Fuzed Weapon
Spice-equipped bombs
Joint Direct Attack Munition (JDAM) bombs
Wind Corrected Munitions Dispenser (WCMD)
Avionics
AN/APG-67 (T-50)
EL/M-2032 (TA-50 and FA-50)
Lockheed Martin Advanced Avionics
Variants
T-50: Advanced trainer version.
T-50I: Version of the T-50 for Indonesian Air Force.
T-50TH: Version of the T-50 for Royal Thai Air Force.
T-50A: Candidate for the US Air Force T-X program, based on the FA-50.
T-50B: Aerobatic specialized T-50 version for Korea Air Force's aerobatic display team, the Black Eagles.
TA-50: Lead-in fighter trainer and light attack version.
FA-50: Light attack version, originally named A-50. A prototype from a converted T-50 first flew in 2011.
FA-50PH: Version of the FA-50 for the Philippine Air Force.
T-50IQ: Version of the FA-50 for Iraqi Air Force.

4. BOEING-SAAB T-X [1, 25, 26, 27, 28, 29, 30, 31, 32]

Boeing-Saab T-X is an all-new advanced pilot training system designed specifically for the U.S. Air Force training mission. It includes trainer aircraft, ground-based training and support – designed together from the ground up. The U.S. Air Force Advanced Pilot

Training System competition, commonly known as T-X, is designed to replace the T-38 trainer in use today. It will help train fighter and bomber pilots for generations to come.

The Boeing-Saab T-X aircraft has one engine, twin tails, stadium seating and an advanced cockpit with embedded training. It's the cornerstone of the complete advanced pilot training system, which also includes state-of-the-art ground-based training and a maintenance friendly design for long-term supportability. The clean-sheet approach allows use of the latest technology, tools and manufacturing techniques – creating a more affordable and flexible option than older, existing aircraft. The system is also designed to evolve as technology, missions and training needs change.

Fig. 3 – Boeing-Saab T-X aircraft

Boeing-Saab T-X is designed to look, feel and perform like fighter aircraft. The twin-tail design offers improved stability and is visually similar to current and future fighters, to enhance training. Twin tails provide excellent control, inherent speed break functionality, and safer air refueling.

Stadium seating allows for ideal instructor positioning and visibility for flight instruction, from teaching basic traffic pattern operations to advanced visual air combat training. And, JPATS 1-7 compliant seating allows a wider range of individuals to train and instruct.

The Boeing-Saab T-X design focuses on accessibility, fewer and more common fasteners, and readiness of critical items like engine and seats. It is also designed around common U.S. Air Force ground equipment and uses established suppliers to reduce supply chain complexity.

A modern fighter-like cockpit, flexible avionics and a reconfigurable large area display allow students and instructors a maximum range of training options.

Boeing-Saab T-X offers fly-by-wire flight controls, ample thrust, and excellent handling at all speeds, configurations and high angle-of-attack.

Boeing-Saab T-X is a complete advanced pilot training solution providing real-as-it-gets simulation, interactive classroom lessons, computer-based training modules, adaptive training that adjusts to students' needs, and a complete suite of instructor tools – for optimum results on the ground and in the 'classroom in the sky'.

- Boeing signed a joint development agreement with Saab in December 2013, to compete for T-X with an all-new, purpose-built design.
- Boeing revealed its first production aircraft, the cornerstone of the complete Boeing-Saab T-X advanced pilot training system, in St. Louis Sept. 13, 2016.
- T-X is a top priority for the U.S. Air Force. The initial acquisition is expected to include 350 aircraft and the associated ground-based training and support [32].

5. CLONCLUSIONS [1]

The new Romanian jet trainer will be designed to have the following main items.
Tricycle landing gear, crew: 2 pilots (student and instructor), in tandem.
Weight: empty: 5800-6000 kg, maximum take-off mass: 10000 kg
Loading on the wing, max: 890 kg/m²
Main expected performance: speed (sea level) = 1300 km/h, speed at 9000m = 1500 km/h
- Rate of climb: 30 m/s
- Ceiling max: 15000 m
- Flight duration: 4 h, with external drop tanks
- Ferry range: 4000 Km, with external drop tanks.

Avionics and embedded systems will have a modular architecture based on the MIL-STD-1553B (dual redundant digital databus), which has the capability for additional systems and stored/calculated management data can be displayed on any of the cabin MFDs.

The radar will be modern, NATO-compatible, operational day and night in any weather conditions.

Flight Control System (FCS) will be digital and multi-redundant Fly-by-Wire (FBWS)

Integrated Navigation System (INS) will be an inertial navigation system with a laser gyroscope with a built-in GPS receiver and will include omni-directional tactical aerial navigation.

The communication system will have a pair of transmitters/receivers and a Traffic Collision Avoidance System (TCAS).

The cabin will be "Glass cockpit", full digital cabin, open architecture computers and on-board simulation systems.

The Arms Management System's presentation/display and control functions use any of the MFDs in both pilot cabs. HOTAS (Hands-on throttle and stick) controls are used to select weapons, and weapon delivery is controlled by the central processor, the required data being presented to the pilots via HUD or the helmet-mounted display (HMD), and MFD

The aircraft will be equipped with a cannon and air-to-air missiles, guided missiles, bombs and a self-defense system.

The aircraft will have 7-9 pilons for additional fuel tanks and armament: guided missiles, bombs and a self-defense system.

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ABBREVIATIONS

AJT: Advanced Jet Trainers
FA: Fighter Attack
FADEC: Full Authority Digital Engine Control
FBW: Fly By Wire
HMD: Helmet Mounted Display
JPATS: Joint Primary Aircraft Training System
LA: Light Attack
LCA: Light Combat Aircraft
LIFT: Lead in Fighter Trainer