MICROFIGHTER AS AN ALTERNATIVE TO FOURTH GENERATION FIGHTER PLANES

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Abstract: *The paper presents an affordable low observable concept for a very light strike-fighter plane, using a mixture of high and low tech. Currently for a small defense budget, trying to comply with leading military standards enables a small number of fourth generation warplanes, typically degraded with respect to essential capabilities such as air defense and deep strike, due to the restrictions in purchase of high performance weaponry. A solution is to eliminate standard compliance and adopt cost effective solutions, based on a mix of proven items and newly emerging technologies, in an attempt to obtain better solutions than degraded fourth generation warplane as available on the market.*

Keywords: *microfighter, super cruise*

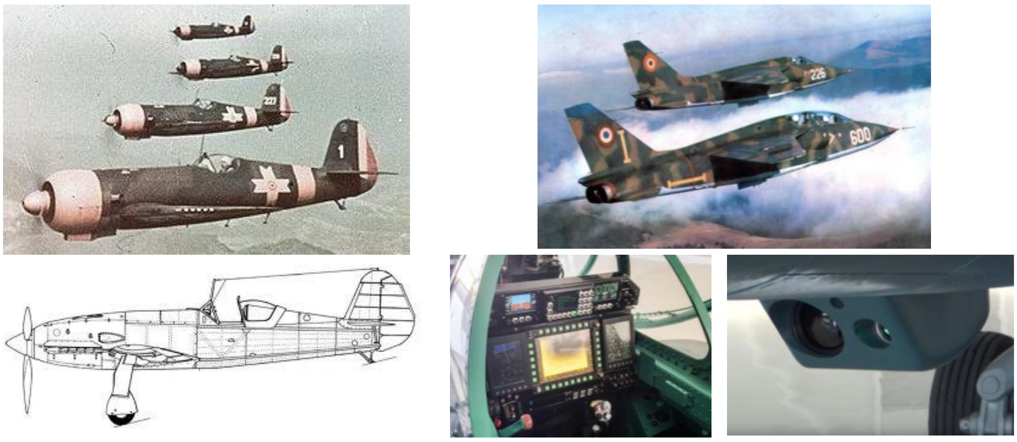
1. NATIONAL HISTORICAL BACKGROUND

Romania was one of the few countries producing fighter planes during the Second World War, namely IAR-80. Although the general performance has been decent around 1941, there has been no significant upgrade during the production/operation. Other warplanes benefited from a significant power/armour/weapons growth during their production life, increasing the effectiveness, so that at the end of the production, around 1944, IAR-80 and its dive bombing variant IAR-81 have become largely obsolete for air defense, while the lack of armour made ground attack a hazardous mission, although the firepower proved to be very good. Around 350 have been produced and were flown until 1952 as trainers. The attempt to install a larger engine failed due to war related procurement constraints, while technically was achievable, **FIG. 1** (a).

During the cold war a joint development/production process took place with Yugoslavia, resulting in IAR-93/J-22, which essentially is a ground strike fighter. For the Romanian version the weapon system was poor, somehow at the level of Mig-17 which IAR-93 was supposed to replace. Unguided only munitions were planned and the reliability of the hydraulic system was low, although this was eventually solved. About 80 airplanes were inducted into service and they have been mothballed in 1998 after a crash and phased out in 2000 under difficult economic-political conditions [1].

The decision to axe such a large number of essentially new airplanes was largely wrong and today such a plane would still be valuable given the new generation of smaller precision guided munitions and the small price of up to date avionics systems. A "scientific" justification has been carefully prepared [4] in order to upgrade Mig-21 to what is known today as Lancer. The author of [4] seems to judge airplane performance with invented numbers as measure of their efficiency, being unaware about the outcome of Falkland and Bekaa Valley aerial battles already a decade before the report issuing date. The effectiveness of Mig-21/32 or Mirage III/Dagger, with rear aspect launching IR missiles was essentially zero against fourth generation fighters armed with all aspect IR missiles. Therefore, a cost effective solution at that time was the simple replacement of the old missiles, keeping the line of sight aiming procedure, as described in [5]. The author of [4] paved the way of upgrading 75 Mig-21 as ground strikers, eliminating IAR-93 from the air force and sending to scrapyard all related human/hardware investments. The ground strike capabilities of IAR-93 and its low level behavior were much beyond those of Mig-21, as proven in a number of exercises [1], not to mention the 2.5 times larger payload. In contrast with IAR-93, the Serbian program Orao 2.0 is a good example of what this warplane would become under a good management **FIG. 2** (b).

The inheritance from IAR-80 and IAR-93/99 programs consists in a number of five manufacturing companies (three state owned, two private) and a number of research establishments covering aerodynamics, propulsion (state owned) plus avionics (private), having the potential to resume the development of an indigenous very small fighter plane. In addition there are a number of RR-Viper 632 engines left from IAR-93 program, which are to be cleared of the afterburner system for the potential micro fighter.



(a) (b)

FIG. 1 IAR-80 standard top, upgraded down (a), IAR-93 top, upgraded Orao 2.0, down (b)

2. GENERAL REQUIREMENTS

The most stringent requirement is to come up with a solution that would preserve the air force existence, its mass, its flight academy and resolve the shortcomings of Mig-21 and F-16 platforms. A partial solution is the adoption of second hand F-16 AM/BM, which as they are equipped are obsolete when compared with up to date Russian warplanes (Su-30, 34, 35, Mig-35), all employing advanced electronically scanned radars and electronic warfare capabilities [12,13,14]. This purchase represents a typical degraded fourth generation package, criticized as cost ineffective in [2], backed by a tiny amount of almost obsolete weapons.

Although a very limited platform, Mig-21 maintenance is mastered at national level, making the airplane supportable in significant numbers, in contrast with F-16, for which there is no national maintenance/upgrade capability, but has much longer lifecycle.

The national air force lost the mass from 350 warplanes (most at very small effectiveness) at the end of the cold war to about 10% of that [3], which is not acceptable.

Considering Mig-21 as the airplane to replace, its main weakness is the combat persistence: range/endurance plus very small payload, specifically in air defense. In realistic conditions it is operated with two under wing tanks and two IR AAM missiles, which by today's standards is not acceptable.

A notional sensor system should be based on: low power/small size mechanical/AESA/hybrid radar, EO turret ventral placed for air to air and air to ground, optical distributed aperture system plus modems to support data exchange with other platforms and weapons in *lock after launch mode*. Such a system would provide an intrinsic reconnaissance capability of moderate performance, since it is not possible to accommodate a large diameter optical system.

A notional weapons package consists in a single outer shape weapon family, covering air to air and air to surface. Two main weapons could be developed: missile and bomb. They use the same foldable rear control fins, actuation, part of navigation system and only exhibit different homers and warheads.

A review of the jet age local wars and war games (Red Flag) shows what was basically learned in WWII. Victories are obtained mostly because of victims' lack of situational awareness. When the technical disparity is very large, in a low density environment (F-14/AIM-54 vs Mig-21/R-13 as in Iran-Iraq war), results are in the favor of technical superiority. If the smaller fighter would have LO and RF awareness capabilities, the BVR engagement would be mostly denied, bringing the fight to close distance, on more equal terms. In a high density environment the technical superiority advantages are largely denied.

A decent radar (in the class of ELTA-2032), as it is part of current inventory is ruled out from the current concept, because of size, weight, cooling requirements, radio frequency noisy operation. Modern radar warning systems and data links could in part compensate for a radar. A radar should provide just enough range to enable full envelope exploitation of the AAMs, since an integrated RWR/modem could provide the tactical picture to reduce radar performance/cost, added constraints. Given the fact that the AAMs on the current platform are in between R-60 and AIM-9X Sidewinder, the tracking range for a fighter like target (F-16, RCS $3m^2$) should not be larger than 20 Km. The notional AAM will rely on a combination of IR homing system and INS/modem for *lock after launch* procedure, in order to maximize the range and probability of kill. For this purpose do contribute the aerodynamic cleanliness of the weapon, as there are no rail jugs, there is a pyramidal optical dome, there are only rear fins.

Given the existing engine (RR-Viper 632) with its high fuel consumption, it only makes sense to have a fast aircraft, ideally a super cruiser. The specific thrust of the engine is just high enough to enable super cruise. Its afterburning device (long tube, variable section nozzle, hydraulics) weights around 120 Kg, produces additionally 400 daN, has an unacceptable impact on the airplane design and therefore cannot be used. The largest inconvenient is the length it adds, which compromises the design. Another candidate engine is the GE J-85, although the maximum thrust is even smaller. However, its nominal thrust is smaller than Viper's, which remains the first option.

Functionality	Mig-21 Lancer	F-16 Block 15	Microfighter
Low observability	fairly good, due to small size	decent	high
Supercruise	no	combat irrelevant	yes
Manoeuvrability	decent	excellent	decent deliberately, to increase combat persistence
Climbing speed	decent	excellent	decent
After burner engine	yes	yes	no
Endurance	low	middle	middle
Capability to fight at supersonic speeds	not practical, over 5000m, severe buffet in transonic	yes, limited time	yes, by definition

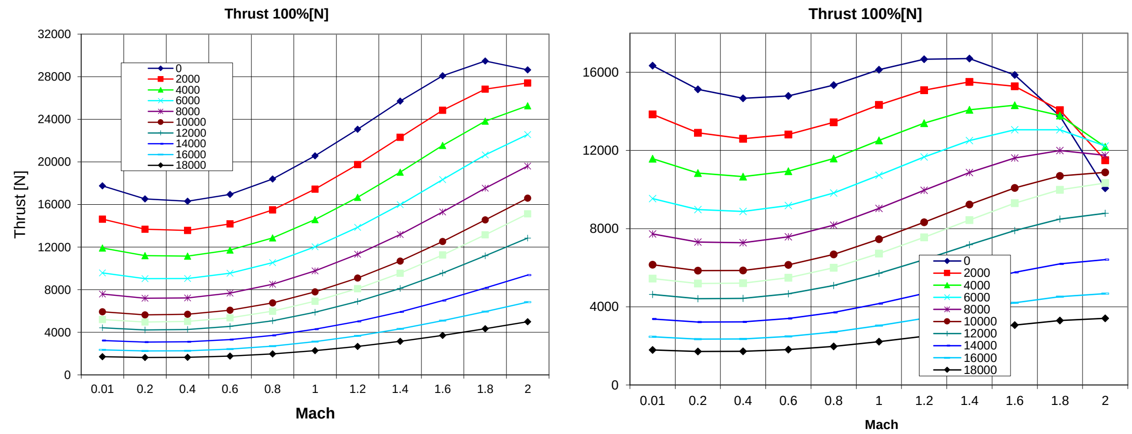
Functionality	Mig-21 Lancer	F-16 Block 15	Microfighter
Pilot interface	decent, HMS	decent	5th generation, HMS tbd, windshield projection
Ejection seat	good	excellent, 0-0 capability	tbd, standard solutions not applicable
G-load system	good	good	tbd, for weight saving and correlated with moderate g load capability

Functionality	Mig-21 Lancer	F-16 Block 15	Microfighter
Radar	fairly good	good	low power PESA, tbd
Ground targeting EO	external, barely used	external, good usage	internal, permanent, lower optical performance, higher integration by design
Distributed EO	no	no	yes
Ground/sea radio sources detection	basic RWR	basic RWR plus external pods, not for Ro	native, by large, integrated RWR arrays and integration with EO and radar
RWR	generic	generic	custom designed
Integration RWR-radar-EO	no	no	yes
Data link	no	no for Ro	desired by definition
Reconaissance pod	yes, barely used	not for Ro	native, by integrated EO system, lacking panoramic view

Functionality	Mig-21 Lancer	F-16 Block 15	Microfighter
Max. Air-Air weapons	4	6	6
BVR weapons	no	4	no
Air-Air payload plus external fuel tanks	2	4	6, no fuel tanks
Cannon	yes	yes	no, by definition
Unguided munition	yes	yes	no
Small caliber guided or unguided rockets	yes	yes	no
Anti-ship missile	use air-ground munition, up to 250 Kg	use air-ground munition for Ro, no specific weapon	small format weapons
Anti radar missile	no	not for Ro	no

FIG. 2 Capabilities/requirements for existing fighters and microfighter

EngineSim from NASA has been used to compute engine charts of Viper and GE J-85. The first engine has been modeled and calibrated (cross area) according to known data to match the nominal thrust and corresponding consumption. The GE J-85 is already modeled in the code and there is no need to calibrate.



(a) (b)

FIG. 3 Thrust characteristics of RR Viper 632 (a) and GE J-85 (b)

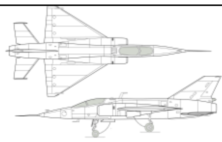
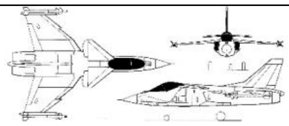
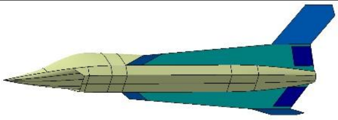
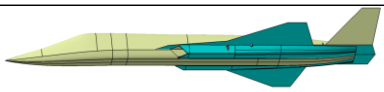
3. MICROFIGHTER ATTEMPTS

In the jet age there was a considerable effort devoted to microfighters and small fighters development as in [9]. Yak-1000 has been converted to the first successful anti shipping missile after an unsuccessful take-off, SNCASO Deltaviex exhibited modest performance due to the small engine, Boeing Quiet Bird was more a ground demonstrator incorporating RF LO features, HA-300 did not achieved the expected performance, P-900 has advanced features for the ‘80s, but remained a concept and is not a microfighter, Piranha was a sound design, Bird of Prey was a technology demonstrator with advanced manufacturability and LO capabilities at low dynamic performance.

Industry risk management made microfighter attempts fail. Two small fighters were anyway successful: Mig-21 plus derivatives and F-5 Tiger.

They lack those features that would enable their further upgrade: supercruise, LO and internal weapon carriage, plus they are old airplanes and have to be simply replaced. Political pressure from super powers disabled some of the national initiatives in the microfighter field.

Table 1. Small and microfighters

No.	***Name***		***Remarks***
1	*Yakovlev Yak-1000 1951*		*Promising concept, poor controllability, redesign needed*
2	*SNCASO Deltaviex 1954*		*Promising concept, innovative controls, poor performance due to lack of proper engine*
3	*Boeing Quiet Bird 1963*		*Promising concept, the earliest LO, both RF and acoustic*
4	*Helwan HA-300 1964*		*Overestimated performance, never proven, lacking supersonic flight aerodynamic features, or credible weapon system*
5	*Northrop P-900 Advanced Fighter Concept, 1982*		*Credible concept, relatively large, very small*
6	*ALR-Aerospace 1979, Piranha*		*Credible concept, limited payload, no LO features, limited supersonic performance*
7	*McDonnell Douglas and Boeing, Bird of Prey, 1996*		*Proof of concept, advanced manufacturing technology and LO, no payload, subsonic*
8	*McDonnell Douglas, X-36, 1997*		*Unmanned, very agile, proven, low speed, no weapon system*
9	*INCAS 2016*		*Radio frequency & supercruise shaped, 8 weapons, ventral semi-recessed*
10	*INCAS 2017*		*Flatter shape for RCS reduction, smaller ref. area, less controls, 6 weapons*

3. AVIONICS & WEAPON SYSTEM

Radar must be hybrid PESA (abandoned in western Europe or US for combat aircraft) or AESA (under development and production), with a mechanical repositioning system for larger aperture. It must be fully integrated with the RWR system and must provide targeting updates for the air-air and air-ground weapons in order to maximize range and probability of kill for missiles.

Low probability of intercept mode is a must for such a system. Antenna reflection is to be minimized versus the identified threats by an adaptive repositioning.

LO management must enable deep penetration with respect to all adversary sensors. Therefore passive detection and optimal navigation/exposure versus adverse sensors must be part of the working procedure.

Two sets of IR instruments are foreseen: one set is dedicated to the accurate detection and attack of aerial and surface targets and one set is dedicated to defense plus targeting assistance in high off boresight weapon delivery modes.

The accurate attack IR suite consists in two IR turrets: on integrated with the windshield with rear and upper field of view, one under the nose with full horizon and down field of view. Affordable IR sensor arrays are available at small price on the market. They can be integrated with normal optics to develop high performance turrets or fixed detectors with high aperture.

Man-machine interface must be very simple due to the small cockpit and for operation simplicity, since there is no double sitter. Two control sticks and two touch screens plus HMS would make for the whole interface. Other control panels are included to be used as mission preparation and technical checks on the ground. Voice command is envisaged, since the technology matured, enabling a simple cockpit layout.

A light ejection seat as a Martin Baker MK-15 derivative is available on the market. A normal fighter seat is beyond the mass budget of such a small aircraft.

3. POSSIBLE MISSIONS

The small platform only allows small weapons delivery. Therefore, accuracy is greatly needed in all possible modes. Since small AA missiles are proven (unique class of R-60), it is the surface/sea attack where larger warheads need to be employed. The most critical would be to antishipping strike, while for the land the assumption is to target military equipment only as vehicles or radars. The size of the platform excludes an internal cannon, which needs special care for the development/integration, in order to minimize interference with engine, structure and sensors. Elimination of the cannon would significantly reduce the amount of flight training and ground crew preparation. Cannon use is also risky in all types of missions and requires hard mechanical loadings at break-away.

A single target acquisition method is foreseen, making use of the data fusion, regardless of the target’s type: aerial, land or sea based. Weapons are to be supported during their flight via guiding modems, when possible. Snap-shot target acquisition/attack is mandatory for all possible targets in visual range, using the HMS/EO turrets, distributed optical system and weapon guidance modems. Fast surface target geolocation is to be used in a second pass or for network distribution.

Reconnaissance and post-strike damage assessment are intrinsic functions of the targeting EO/optical distributed system.

One-ship or multiple-ship surface based radio frequency emitting sources is also a must, under hypothesis of low observability. Therefore SEAD missions are achievable in both kinematic striking or close-range harassing for adversary munition depletion and snap-shot attacks. Weapon shaped external jamming pods may be part of the inventory, enabling better cover/defense.

For long endurance subsonic missions a conformal fuel tank with dorsal mounting is the solution.

Asymmetry with conventional warplanes (small size, LO and super-cruise) must be exploited in air to air, by denying BVR weapons employment.

4. CONCEPT AND APPLICABLE TECHNOLOGIES

A number of configurations have been studied in order to find feasible architectures that would enable accommodation of engine, weapons, pilot, landing gear, offer volume for fuel and still provide LO and super-cruise, [6,7,8,9]. COTS weapons like AIM-9X or AGM-114 are impossible to be accommodated, although currently part of the alliance. They make for a good match, since the length and mass of a single AIM-9X are double to the length and mass of AGM-114. Such a weapon payload as in **FIG. 4** may be integrated in a larger aircraft, having as disadvantage a small payload mass in a large weapon bay. Both weapons in their most modern variants can be used in air to air and air to surface engagements. The no foldable fins makes them impossible to be ventral integrated for LO and therefore a new weapon is required.

The development program is dual: aircraft and weapons package, making use of all existing capabilities at national level.

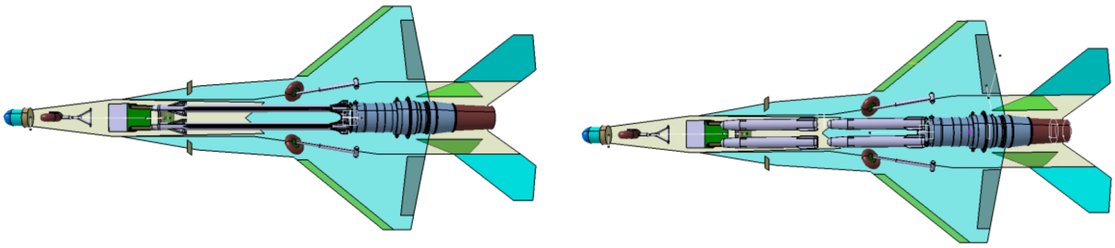


FIG. 4 Configuration relying on existing weapons, unfeasible, 2014

The weapon package consists in a common weapon format as in **FIG. 4**, intended to be used as universal missile (air to air and air to surface) or bomb. Common features are parts of the sensor, optical dome, computer + IMU, fins and their actuators, modem. Motor and warheads are different, while the bomb is expected to be heavier than missile, although with a modest impact in aircraft flight performance. Pyramidal optical nose is used as a mean to reduce aerodynamic drag. An innovative release system eliminates rail/jugs, while rear only foldable fins are provided.

FIG. 5 Universal weapon configuration

Additional COTS weapons may be installed, like 70 and 80mm laser guided projectiles: APKWS, Roketsan Cirit or Electromecanica LRDL.

The airplane in any configuration needs to be a flat platform, with side edge and leading/trailing edge alignment as a set of minimal LO features.

The more or less classical fuselage contains two strakes, providing volume for the landing gear and support for the V-tail. Weapons number has been optimistically considered 8 as in **FIG. 6** and **FIG. 7**, but after some engineering iterations it is now considered at 6, as in **FIG. 8**. This also brings a mass reduction, plus more space for weapon extraction systems as risk management measure.

A droop nose airfoil family is used instead of a complex leading edge flap as a compromise for high AoA and for mass/cost reduction, considering that dog-fighting and strafing are ruled out.

Fixed geometry lateral intakes are chosen instead of dorsal or ventral ones, because of the most promising LO impact as S-duct and as they do not enlarge the side contour, good compromise as functionality as they are under the strakes in a high pressure area at high angle of attack and as good engine protection in foreign object damage.

V-tail is the solution as it offers the smallest wetted area, best promising LO capability, while emphasize is not put on high maneuverability. Also the number of control surfaces and their corresponding actuators is minimized with respect to a standard twin fin tail.

A very long, thin nose, although attractive for a low boom supersonic flight, may bring difficulties with nose sensors integration, as well as with the mechanical loadings. Another way to decrease the acoustic signature is coming from the rear fuselage architecture, which offers an acoustic shielding capability by the use of V-tail and relative engine nozzle positioning. This configuration also provide some IR low observability capabilities, as existing in A-10 aircraft.

Hydraulic control surfaces actuation can be performed with available designs from IAR-93, IAR-95 and IAR-99 programs. Experience with IAR-93 evidenced a large number of technical weaknesses, which have been much better solved in IAR-99. This shows that some parts of the hydraulic system may be replaced from the design with electric systems. The same can be stated about the fuel system, where a safe and simple system is considered from an early stage of development. Due to the available volume in the fuselage, there is no need of wing tanks. Therefore, classic tanks can be accommodated in the fuselage.

Manufacturing relies in large molds, large structural parts, for mass and cost reduction. This is enabled by large milling machines available at national level and the proven way to manufacture molds in high density polyurethane.

FIG. 6 Configuration 2015

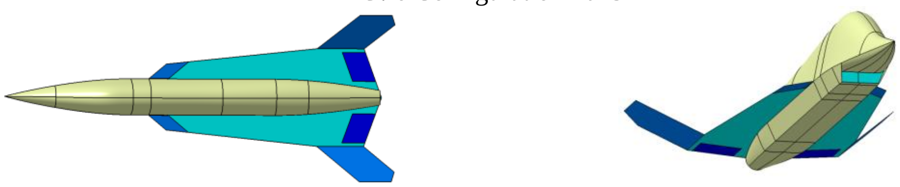


FIG. 7 Configuration 2016

Aircraft shaping is performed in CATIA, using a script organized as a collection of procedures for all main parts. A small set of global variables are used, while most of the defining parameters are introduced at procedure level. Simple splines with analytic definitions for their points and tangent vectors are used for all but wings and tail surfaces, where typical analytic formulations are considered for airfoils.

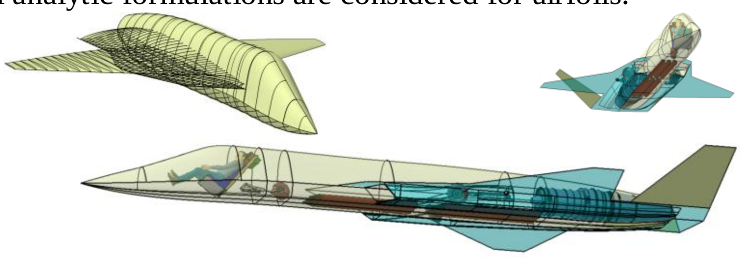
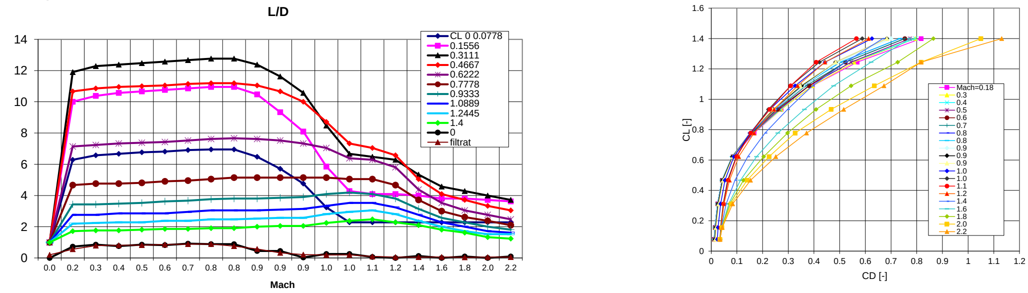


FIG. 8 Configuration 2017

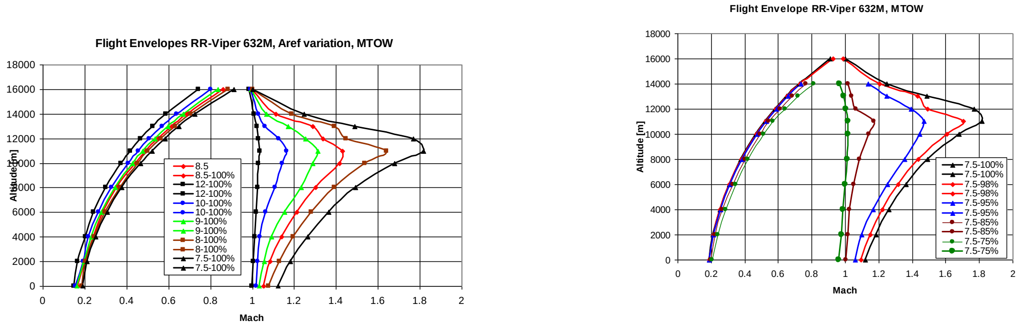
Preliminary performance estimation

The flight envelope is the most desirable chart in an early design stage. Therefore, a routine in VBScript under Excel is used to make this computation. Existing aerodynamic data are considered as for a somehow similar platform, introduced in [6], as trimmed drag polars. The data covers essentially all flight regimes, as they are computed with semi-analytic tools.



(a) (b)

FIG. 9 Notional fighter aerodynamic characteristics [10]



(a) (b)

FIG. 10 Flight envelopes with RR-Viper at 100% rate, various reference areas (a), Flight envelopes with smallest reference area (b)

Reference area, as well as wetted area have a strong impact on the flight envelope, when aiming for super-cruise capability. There is a threshold value for the planform reference area, such that when the design is beyond, supersonic flight is no longer possible, even with significant weight reduction. The supersonic performance sensitivity comes from the fact that the aircraft in [6] is essentially not a super-cruiser. This is going to be further investigated after a complete CAD model is worked and numerical flow analyses are performed.

The required super-cruise engine setting is also important mainly because of thermal constraints. The current engine allows an operating time of 5 minutes at 100%, 30 minutes at 98% and unlimited at 95% of the nominal setting. The best super-cruiser of today can only sustain 30 minutes.

4. CONCLUSIONS AND FUTURE WORK

The study shows that for the given figures super cruise performance is achievable, as the main goal, even at MTOW. LO features are considered as basic, since a computing tool is still under development. However, given the difficulties in training missions of fourth generation fighters with small fighters like Mig-21 or T-38, we are highly optimistic that a simple LO shaping can produce very good results and can make BVR engagements very challenging. Further refinement of LO can completely deny BVR engagements. A comparison with F-5 shows a large difference in the side profile, with greatest impact in LO under normal flight operation (attitude) **FIG. 11**.

A unified target engagement with missile/bomb, plus the lack of cannon with its own skill requirements/aircraft loadings is very attractive for an air force with small allocated resources for training. The national defense system of today has a very small mass of fighter planes. Since the air force shrinking process is ongoing, the forecast is that in few years the military flight academy will be dissolved. Therefore a microfighter solution is possible and can lead to the recovery of capability and beyond, at a cost fraction of the force as it is being foreseen today. Its sustainability would be equivalent to that of a trainer fleet as IAR-99. A microfighter program would help recover the industry at a significant scale, and should be initiated as soon as possible, while the lessons in the development of IAR-93 and IAR-99 are still living through part of the involved engineers and pilots.

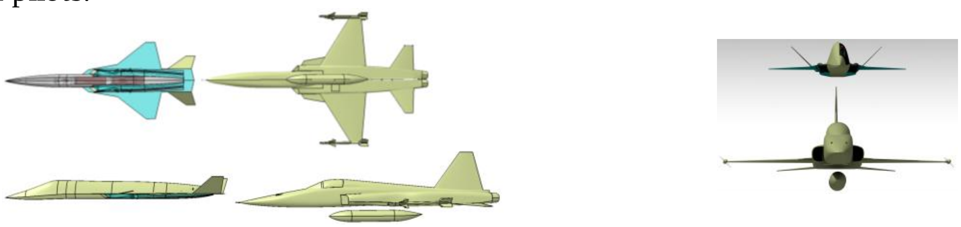


FIG. 11 Comparison with F-5 Tiger

The simple/unified technical and mission requirements, under the mentioned notional weapon system with targeting oriented automation may lead to lean pilot learning/training, lean ground support, lean fighting, lean operation and a new paradigm from the classical “Train as you fight, Fight as you train” straight to “Fight as you play”. Achieving good training for the existing platform ensures success, versus low training on excellent platform [10,11].

Future work is considering the numerical aerodynamic assessment, RCS numerical tool development and endurance/range assessment. Mig-21 R-13 engine without reheat would be a major candidate for a larger design, with greater capabilities.

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