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About Feasibility of a 5th Generation Light Fighter Aircraft

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Abstract: The paper aimed to illustrate an idea about the feasibility of a peculiar aircraft, i.e., a 5th generation light fighter. At first, a short description of previous "generations" of jet fighter is given, introducing the interest that has always been originated by the concept of "light fighter" for every of the first four fighter generations. The derivation of the first idea of a new 5th generation light fighter is then described. Then to further investigate the feasibility of idea, a conceptual design study has been driven up by utilizing peculiar tools, both for quantitative and qualitative (i.e., the aircraft layout definition) evaluations. With the further support of preliminary study of subsystems, the result shows the feasibility of the concept.

Key words: Light fighter, 5th generation fighter, fighter conceptual design, fighter layout.

1. Introduction

Fighters conceptual design is a very challenging research theme, and many papers and books deal with such a topic [1-5]. It is particularly interesting to consider dimensional boundaries for future fighter aircraft in relation to the technological generation.

It is well known that fighter aircraft (only considering jet engine fighters) evolution is very well described by several technological generations occurred along the time since the WWII; In Table 1, the five fighter generations are synthetically defined.

In Figs. 1-4, the first four technological generations are simply characterized by statistical plot showing engine thrust (T) and empty weight (We) related to maximum take-off weight (W). The same is made in Fig. 5 for the 5th generation; please note that even if not shown in the figures for first four generations, a lot of data are available, but this is not true for the 5th generation that comprises very few aircraft, with data known only for a part of them.

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It can be noticed that for first four generations, we have always aircraft with size significantly reduced; we are speaking, for example, about aircraft represented in Fig. 6, that are interesting as, even with performances and capabilities reduced in comparison with other fighters of the same generation, but generally still appreciable, the reduced size means reduced costs. So the light fighters can have a good efficacy to cost ratio and they can be the only solution for operators with limited financial resources. The paper is organized as follows: Section 2 describes a pre-design of a 5th generation fighter; Section 3 presents the conceptual design of this fighter; and Section 4 gives conclusions.

2. A 5th Generation Light Fighter Pre-design

In order to give answers to the question proposed in Fig. 5, i.e., "is it possible a 5th generation light fighter and how large its size could be?", please consider Fig. 7; the plot, line 1, presents again the relation We = K1 W, already seen in Fig. 5 and the line 2 represents W (equation: W = W).

"Weight" is proportional to W; by the way, that it is not true for elements with weight not related to total weight W, for example the pilot and the elements

Table 1 Jet fighter generations.

Generation	Period	Technical characteristics	Reference aircraft
1^	1943-1950	-Subsonic -Straight wing -Turbojet engines	Messerschmidt Me 262 Lockheed P80 DeHaviland vampire
2^	1950-1960	-Transonic—low supersonic -Wing swept back -Turbojet with or without A.B.	North America F 86 Dassault Mystère MIG 15/17/19 SAABJ29 Tunnan
3^	1955-1980	-Mach 2 and more -Supersonic shape -Turbojet with A.B.	Lockheed F104 SAAB J35 Draken McDonnell F 4 Phantom II Dassault Mirage III/F1
4^	1975-2010	-Mach 2 and more -Supersonic shape/moderate W/S -Low by pass ratio turbojet with A.B. -Relaxed stability/advanced FCS	Boeing F 15 Eagle Lockheed Martin F 16 Eurofighter Typhoon SAAB J39 Gripen
5^	2000-	-Like 4^ generation -Stealth/internal weapons bays -Advanced avionics	Lockheed Martin F 22 Lockheed Martin F 35 Sukhoi PAK 50

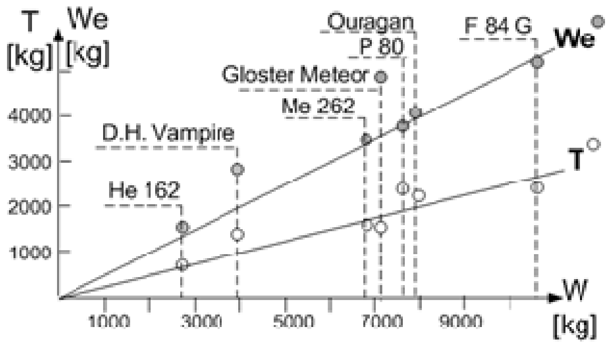

Fig. 1 First fighters generation.

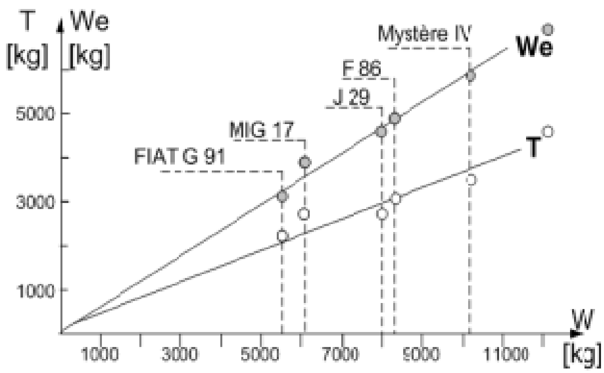

Fig. 2 Second fighters generation.

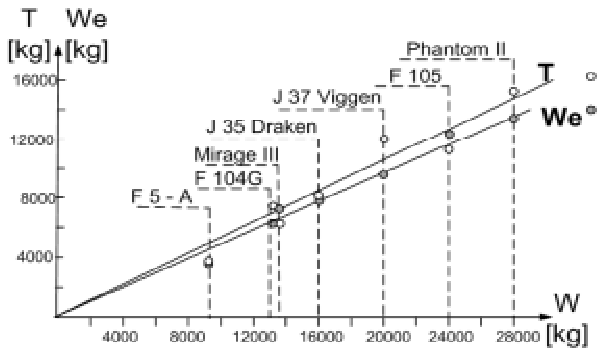

Fig. 3 Third fighters generation.

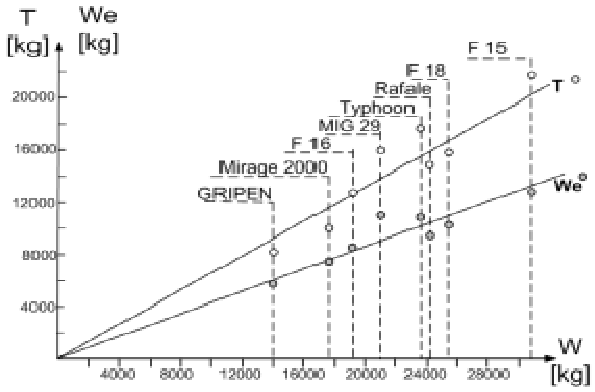

Fig. 4 Fourth fighters generation.

connected to the pilot (furnishing and life support systems), the mission avionics (almost in part), and partially on board gun. So we can defined a WFIX, that, by considering one pilot and related elements, avionics and a gun (Mauser 27 mm can be a reasonable choice), can be assumed 1,500 kg; the line 3 in Fig. 7, represents We + WFIX. So the "gap line 2-line 3" represents the sum of fuel and pay load weights. By considering W_{fuel} for F 22, Pak 50 and F 35 and reporting them starting from line 3, the line 4 (representing the sum We + WFIX

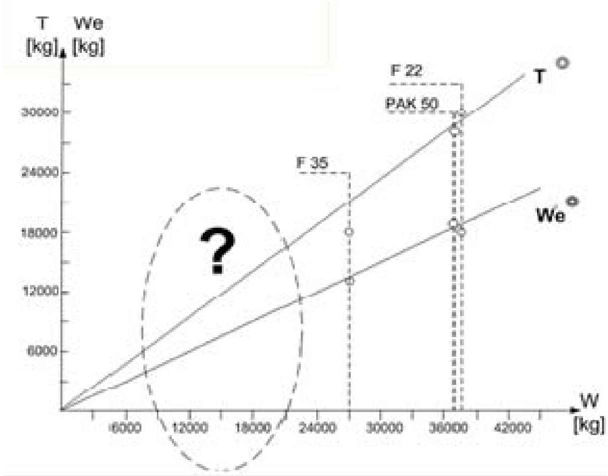

Fig. 5 Fifth fighters generation.

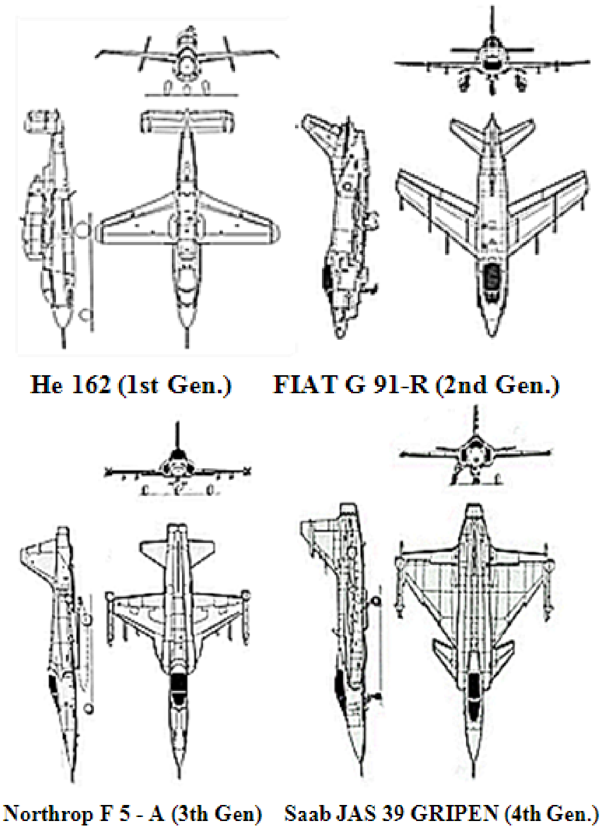

Fig. 6 Light fighter (of 1th to 4th generation).

+ W_{fuel}) is obtained, (by considering W_{fuel} = K2 W).

Reminding that the "gap line 2-line 3" represents the possible weight of pay load and fuel, it is clear that this weight is function of W. So in Fig. 7, it is clear that W_{pl} + W_{fuel} decreases when W decreases and if it becomes the minimum acceptable a plane with such weight represents a minimum size for the kind of plane.

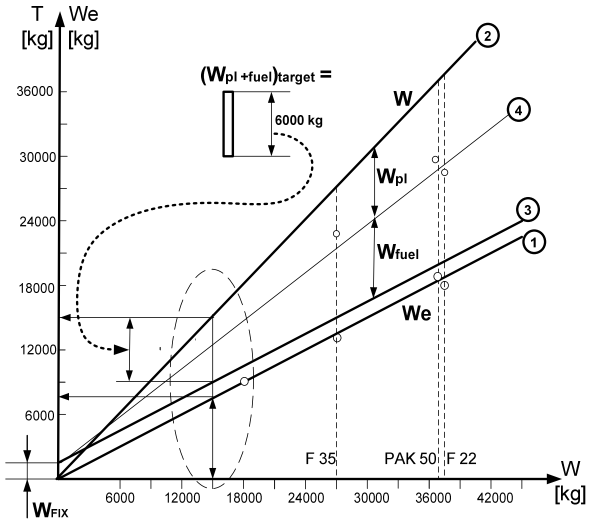

Fig. 7 5th generation light fighter size definition.

By the way, if a minimum value for W_{pl} + W_{fuel} is mandatory, it is possible to indentify the corresponding value of W. In Fig. 7, it is shown how W_{pl} + W_{fuel} = 6,000 kg is related to about W = 15,000 kg, so we will have We = 7,500 kg. It is to be noticed that, with the values considered, we will have:

W = We + WFIX + W_{fuel} + W_{pl}.

By substituting numerical values we will obtain:

W= 7,500 kg + 1,500 kg + 6,000 kg = 15,000 kg

It is to be noticed how the decision of assuming W_{pl} + W_{fuel} = 6,000 kg has been conceived; the first step of the process is the choice of W_{pl} = 1,500 kg, with the assumption that this is only payload carried in internal weapon bays. Such a choice has been based on consideration of two possible internal pay load configurations, illustrated in Fig. 8. Two typical missions are considered: a "ground attack" and an "air to air". As to the first one, a three guided bomb GBU 16 paveway II, plus two air to air self-defense missiles AIM 9X sidewinder weapons suite and as to the second one three air to air missiles AIM 120 AAMRAM plus two air to air self-defense missiles AIM 9X sidewinder weapons suites are considered.

As shown in Fig. 8, since the dimension of GBU 16 paveway II and AIM 120 AAMRAM, both weapons suites can be considered sizing the volumes of internal weapons bays. From weight point of view, the ground

Weapons data

Name	Size ($L \times \varphi_{max}$) (m)	Weight (kg)	Range (km)
AIM-9X Sidewinder	2.85 × 0.63	86	30
AIM-120 AAMRAAM	3.66 × 52.58	151	75
GBU-16 Paveway II	3.7 × 0.36	447	-

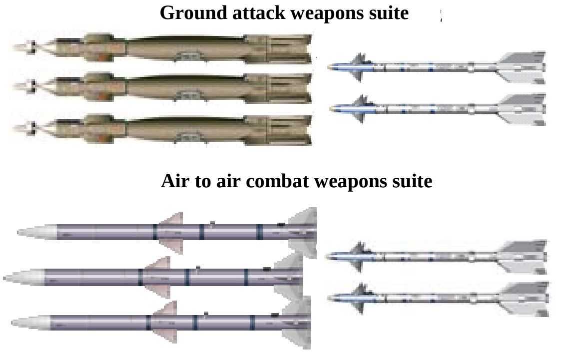

Fig. 8 Weapon's suites.

attack weapons suite will determine a weight of 1,513 kg, well corresponding to the previous assumption of W_{pl} = 1,500 kg that has led to the first definition of the aircraft, as shown in Fig. 7. It is important to observe that the aircraft will consequently be sized in "ground attack" configuration with W_{pl} = 1,513 kg (only internal and with the exception of gun ammunitions, accounted in WFIX), whereas in air to air mission the same clean configuration will present a take-off weight 900 kg lower due to different weight of the considered internal weapons suites, with advantage in combat agility. Assuming, as power plant, two EJ 200 (the same of Eurofighter "Typhoon"), with a total thrust of about 18,000 kg, this brings to a considerable thrust to weight ratio. Looking at Fig. 5, this kind of thrust to weight ratio is more than adequate for the 5th generation standard (in particular better than the one of F 35). For both missions, an internal fuel weight of 4,500 kg (as suggested in Fig. 7) seems, at first, adequate also considering the just hypothesized propulsion system; in particular please note that 4,500 kg of internal fuel is similar to the value of Eurofighter Typhoon, for which any pay load is necessarily dropped. Anyway the take-off weight of 15,000 kg could be exceeded considering dropped payload and/or external fuel tanks, in the case that "heavy/long range ground attack missions" are requested.

The aforesaid data seem to define a concept of a 5th generation fighter with appealing characteristics, even if with a size equal 2/3 of the Lockheed F 35 one.

In order to verify the feasibility of such a plane concept, a conceptual design process has been driven up about.

3. 5th Generation Light Fighter Conceptual Design

As to validate the hypothesis of a 5th generation light fighter, a typical procedure of conceptual design has been applied. Such a procedure based on a methodology set up and tested in Ref. [3], consists in two main parts; the first is the application: a computerized tool for requirements synthesis [4]. Then, on the basis of consequent results, in good accordance with "pre-design" hypothesis, a configuration study, aimed to aircraft architectural layout definition, has been performed. A very first definition of structural layout and of main on board subsystems has been added; the sub-systems possible installation, considering structural layout, has been verified. Having obtained positive results which were in these cases, a preliminary dynamic flying model has been set up and it has confirmed acceptability of performances and flight qualities even if at very preliminary level.

3.1 Requirement Synthesis

The tool utilized for the quantitative definition of future aircraft main characteristics, widely described in Ref. [4], as well as classical, popular calculation tools (see for Refs. [5] and [6]), is founded on an organized series of performances, empirical aerodynamic, weight estimation, statistical relationships. In comparison with other methodologies, also previously proposed in Ref. [7], the simplicity of use (the tool is based on a spreadsheet on MS Excel) and adaptability to kind of aircraft have been pursued; moreover, on the contrary of other conceptual design methodologies that do not take into consideration the aircraft layout topics, such a tool estimates values like fuselage length, the wing longitudinal position, the wing platform with mean aerodynamic chord and aerodynamic pressure center (subsonic and, if it the case, supersonic) location and the longitudinal abscissa of aircraft center of gravity. This last value is evacuated on the basis of weights estimated for the various elements of the aircraft and of values of abscissas of relative CoG of various elements, either estimated by the program or supplied as inputs by the operator. The program correlates the positions of aerodynamic pressure center and of center of gravity, also indicating the position of the main landing gear (giving the opportunity of evaluating the height and suitability of sitting angle) and also offering basic indications for the structural layout. In the case of supersonic aircraft, the wing-Mach cone interaction is considered. These features of the program are exemplified in Fig. 9.

As to the more usual aspect of the conceptual design methodologies, i.e., the definition, on the basis of the requirements, of the numerical values of the main characteristics that define the aircraft concept, the inputs numerical values and the values of the parameters hypothesized in the present case study are respectively summarized in Tables 2 and 3. On the basis of aforesaid values, collections of data that globally define the aimed concept have been obtained. Among these data the most significant are reported in Table 4. The graphical representation, usually defined "matching chart", is a further output of the tool; for the specific application of 5th generation light fighter, it is reported in Fig. 10. It shows how the "design point" is defined by the values W/S = 400 kg/m^2 and T/W = 1.2; such a point satisfy, at minimum value of T/W (i.e., at minimum W if engines have been already chosen), all performances requirements, graphically expressed, at the basis of the project. The take-off weight W = 15,022 kg obtained from the tool practically is the same of W = 15,000 kg defined in pre-design phase. The values obtained from the Matching Chart bring to a wing surface S = 37.5 m^2 (Table 4) and confirm the propulsion system based on two EJ 200.

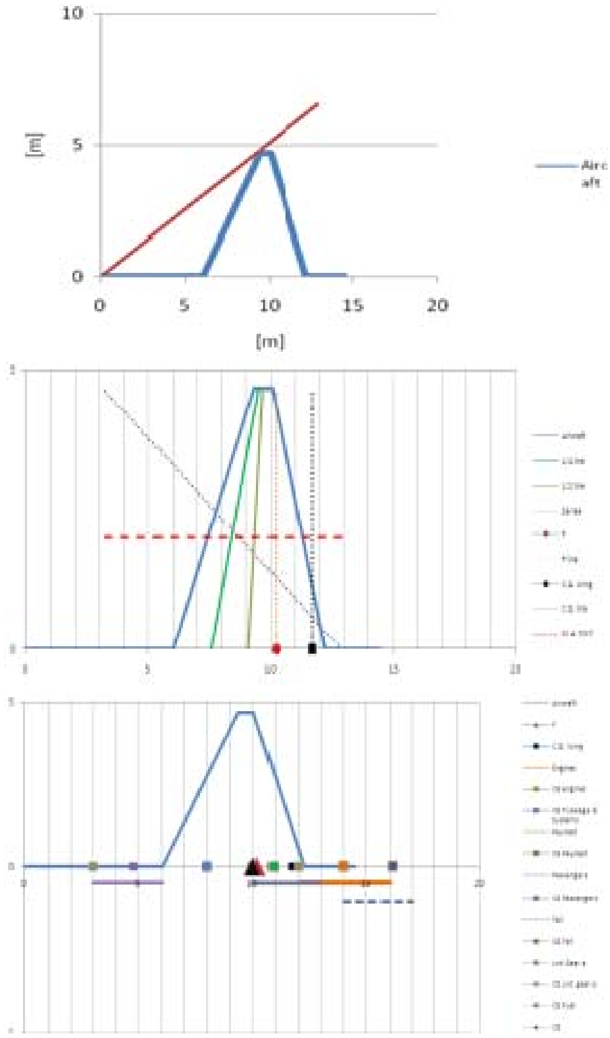

Fig. 9 Layout indications.

Table 2 Inputs of conceptual design program.

Input value		Input value
Pay load	1,500 kg	LTO 700 m
N° of crew	1	Lland 700 m
Range	2,000 km	Airfield altitude sea level
Cruise speed	1,100 km/h	N° of Engines 2
Cruise altitude	7,500 m	Engine thrust dry 60,000 kN
S.S. cruise speed	Mach 1.4	SFCdry0.8 kg/kg/h
S.S. cruise altitude	7,200 m	Engine Thrust AB 90,000kN
Comb. turn radius	5,000 m	SFCAB 1.8 kg/kg/h
Mach max	2.2	Engine weight 989 kg
		WFIX 1,500 kg

Table 3 Hypothesized values (parameters).

Parameters values	Parameters values
$C_{L\max}$1.5	% Composite wing 0.85
$C_{L\max TO}$1.7	% Composite fuselage 0.85
$C_{L\max LAND}$2.3	K_i Weight coefficient for several elements
Aspect ratio 2.7	
Taper ratio0.11	

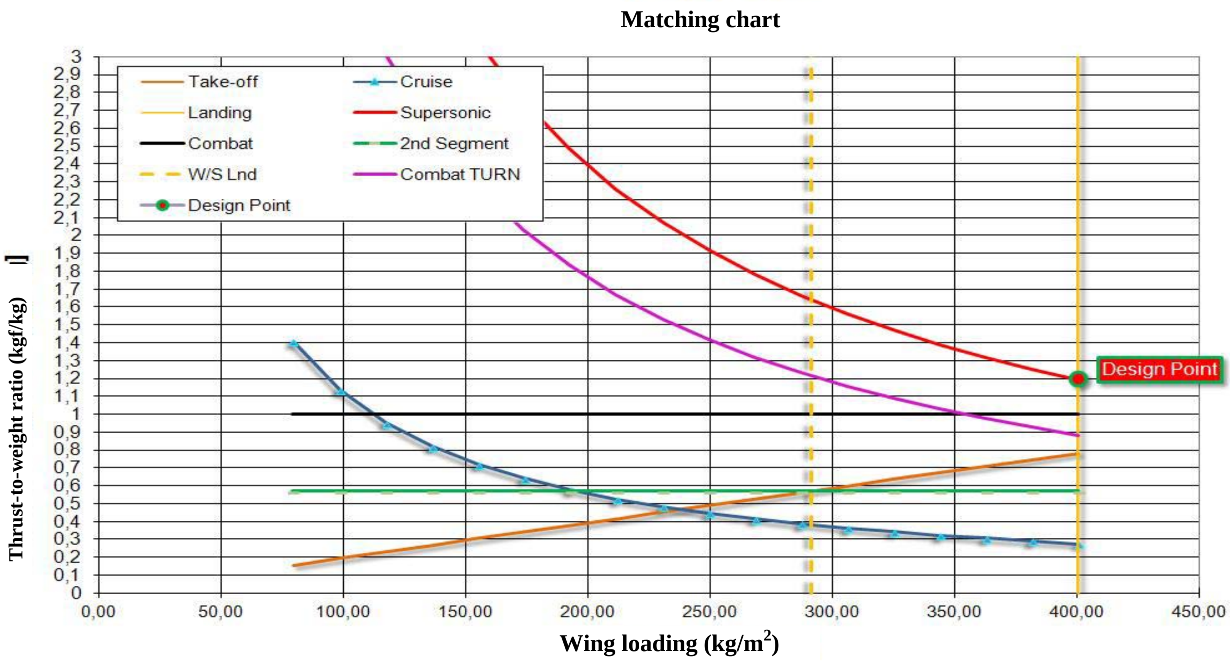

Fig. 10 "Matching chart" plot.

Table 4 Outputs of conceptual design program.

Output value		Output value	
SW	37.5 m^2	Weight wing	1,014 kg
Sweep angle	23°	Weight fuselage	1,375 kg
Wing span	10.1 m	Weight tail	304 kg
Root chord	6.7 m	Weight land gear	330 kg
Tip chord	0.74 m	Weight airframe	3,023 kg
Fuselage length	14.5 m	Weight engines	1,978 kg
Nose-TopRootChord	6 m	Weight FCS	465 kg
X CoG	10.11m	Weighthydraulic	75 kg
X MLNDG	12m	Weight electric	525 kg
		Weight ECS	240 kg
Weight empty	7,461 kg	Weight fuel-system	255 kg
WFIX	1,500 kg	Weight eng. system	225 kg
Weight FUEL	4,547 kg	Weight avionics	675 kg
Wpay load	1,513 kg	Weight systems	2,460 kg
W(MTOGW)	15,022kg	Weight empty	7,461 kg

First of all, the results of conceptual design program perfectly agree with the hypotheses elaborated in pre-design phase, and so balanced to lead towards a further activity of the studied aircraft layout definition.

3.2 Aircraft Layout Definition

The next activity of 5th generation light fighter layout definition has been helped by the specific conceptual design methodology utilized that, as seen, has already given much information about aircraft architecture. Moreover, it has been the occasion of setting up and testing a new procedure of "fighter layout definition", in phase of elaboration by the Authors. Fig. 11 shows how this procedure is aimed to operate either immediately after the calculation tool of conceptual design, or even contemporarily to it, exchanging data step by step. In this way, the results of conceptual design are a mix of numerical values and architectural characteristics, i.e., a graphical visualization, even if simplified, of the aircraft. It is also relevant that the layout definition activity tends to operate as feed-back of the numerical definition activity. The possibility of obtaining practically at the same time and in a coordinate way numerical and graphical results increases the value added by the conceptual design methodology, improving the definition level and the precision of elaborated concepts.

Fig. 12 shows as the basis of the procedure of layout definition for aircraft concept can be a simple sheet of paper on which the definition of the two views, top and side is set up.

As shown in Fig. 13, the layout definition can be carried on manually drawing, or by conducting the same operations, in sequence as the procedure says, but

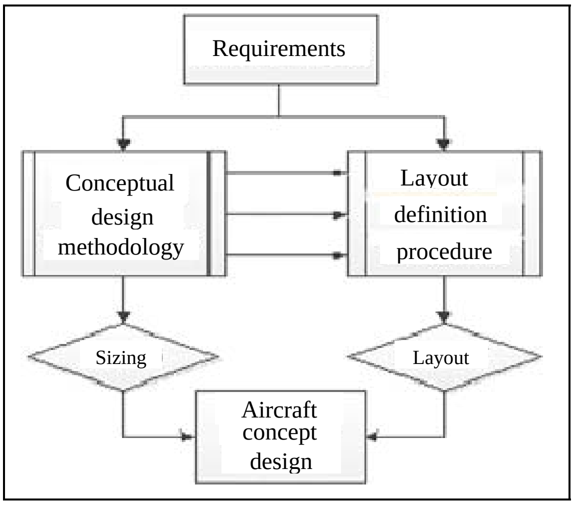

Fig. 11 Layout definition in conceptual design.

performed on CAD-3D. As already said, the procedure must be applied precisely, in order to obtain standardization and enough repetitive results and also because the defined sequence of operations appears to be the most useful.

Fig. 14 shows results obtained for 5th generation light fighter, by applying the layout definition Procedure in close link with conceptual design tool application; in fact some iterations of the tool have been suggested by some evidence appeared during architectural layout definition. In Fig. 14, the logical steps that bring to the layout definition are listed; for any of them the solution chosen, in the studied case is indicated, so allowing recreating the logical path that has brought to define the 5th generation light fighter layout. Such a layout has appeared so satisfactory to be adopted becoming essential part of the 5th generation light fighter concept.

A direct consequence is the possibility of defining the classical "three view drawing" representation (Fig. 15) that integrates numerical values and architectural concepts. Moreover, by utilizing the aircraft graphic definition in CAD-3D context, we obtained the aircraft 3D model, with possibility of defining, on such a base, a preliminary structures layout (Fig. 16). It is to be noticed that such activity has been well addressed by several choices provided by the layout definition procedure (Fig. 14).

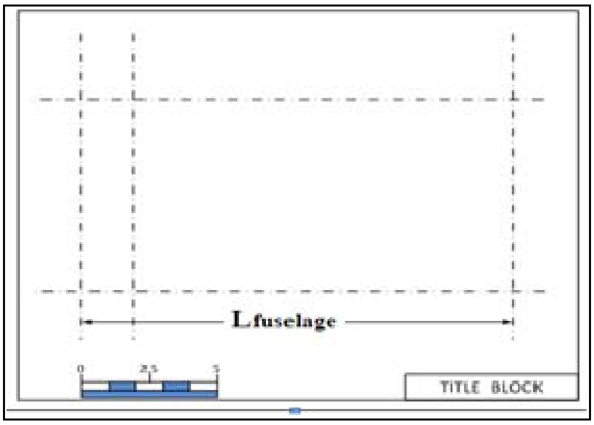

Fig. 12 Base of layout definition procedure.

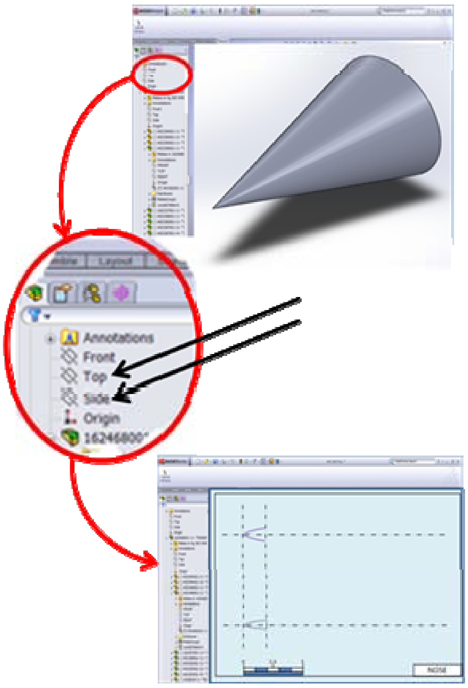

Fig. 13 Layout definition and CAD-3D.

Please note that the availability of such aircraft 3D-CAD model with preliminary structural layout offers possibility of studying subsystems and equipment integration in the airframe and so obtaining a useful digital mock up, even if at conceptual level [8].

3.3 Further Definitions Activities

The good results of conceptual design bring to consider also a preliminary definition of the sub-systems of the plane. Sub-systems preliminary definition is very useful for a better conceptual design of a plane if it is driven up in synergic way, exactly as

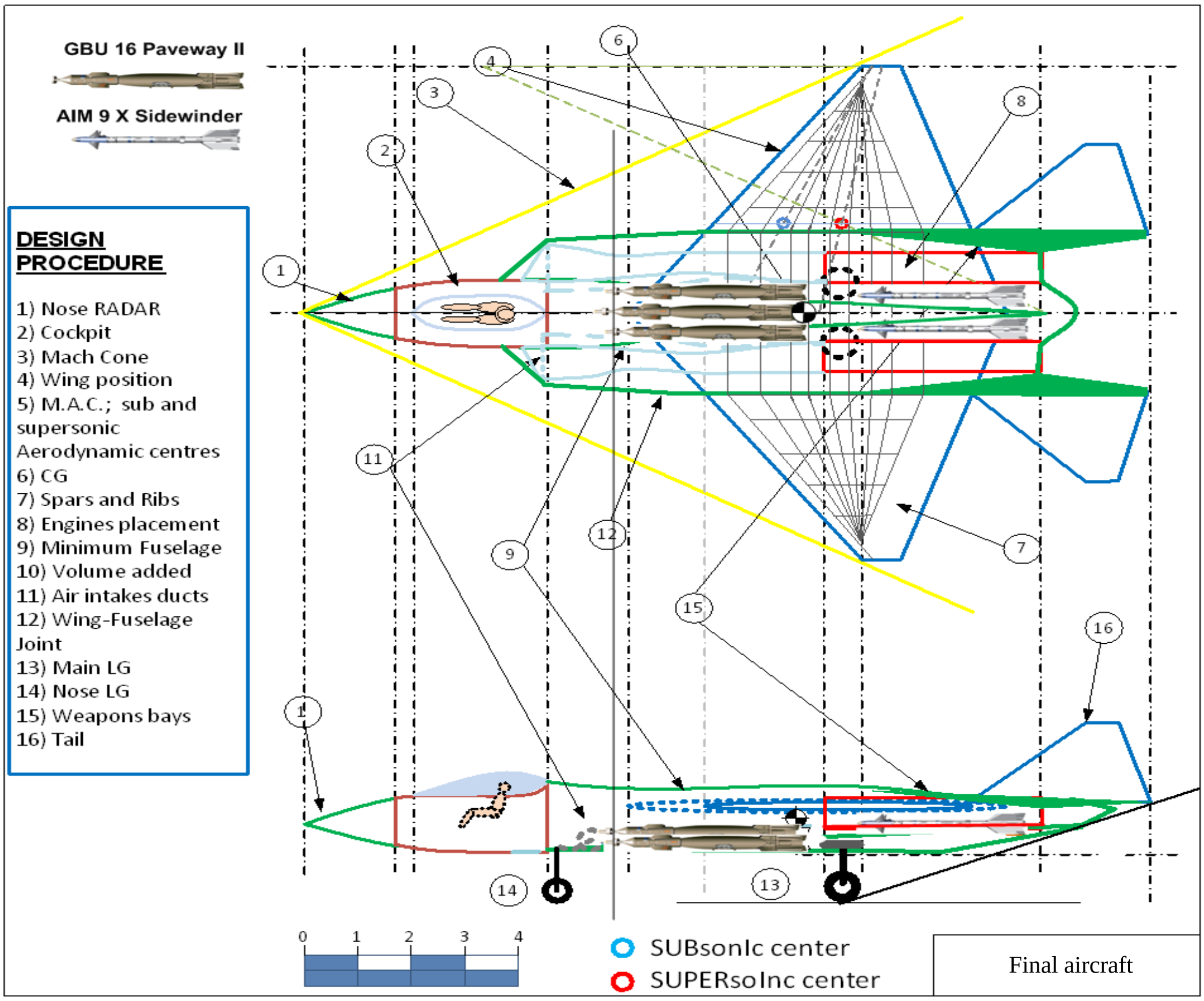

Fig. 14 Fighter layout definition procedure.

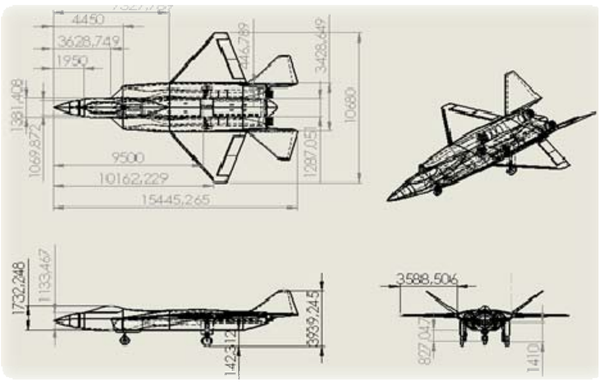

Fig. 15 5th generation light fighter concept.

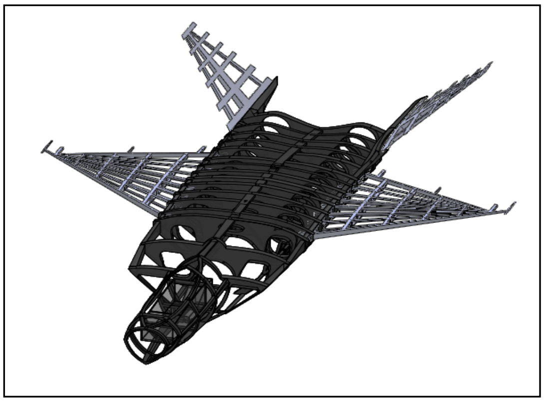

Fig. 16 Structures layout.

we discussed about conceptual design and architectural definition [9]. Obviously, it is not possible to describe here the solutions elaborated for all the on board systems, even if a preliminary sizing has been performed for all of them [10] by utilizing a specific tool developed in Ref. [11]. Result of these activities was that the several on board systems have been demonstrated feasible maintaining each weight estimated by the conceptual design tool (Table 4). As peculiar aspects of the on board systems configuration elaborated, particularly interesting are:

- The definition of an advanced avionic system. Globally, it appears characterized by the values shown in Table 5. With such values, the possibility of installing avionics into the airframe has been verified (Fig. 17);
- An "All Electric" configuration that has led to the adoption of "bleedless ECS (environmental control system)" and of electric actuators for flight control system and landing gear (hydraulic system has been maintained only for wheels brakes, as confirmed by its reduced weight as shown in Table 4). The scheme of electric generation system (that allows the starting of engines and APU (accelerated processing unit) too) is reported in Fig. 18. It reveals a certain similarity with the one of F 35 (in particular the adoption of generation voltage of 270 VDC and of three 90 kW "switched reluctance machine-SRM" as starter/generators), but with the advantage of the greater flexibility offered by twin engines configuration.

As further activity aimed to confirm the feasibility of considered concept, we remind the realization of a dynamic model of the Aircraft to play in X-plane context; it is well known that X-plane is FAA (Federal Aviation Administration) approved as flight simulator, so the model and the positive results obtained from its tests will represent a good, even if preliminary, verification of aircraft flight qualities and performances [12]. To offer example of application to the 5th generation light fighter study in Fig. 19, a sequence of a take-off and the sequence of landing gear retraction are shown.

4. Conclusions

The elaborated concept, also for the fact that the study has been extended to a preliminary definition of on board systems and to the development of a dynamic model for flight simulation seems to be complete enough and impressive. From the results obtained, the feasibility of the 5th generation light fighter seems to be confirmed. Even if the activity has been carried on

Table 5 Global values for avionics.

Weight (kg)	Volumes (liters)	Power required (kW)
994	1,470	19.49

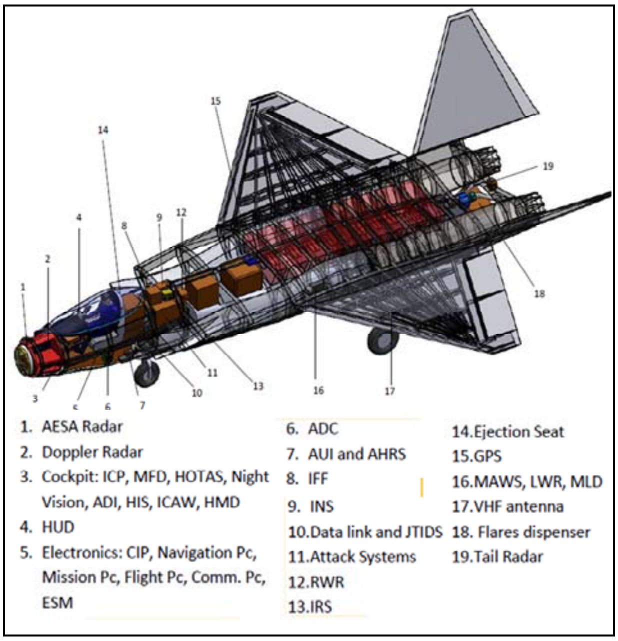

Fig. 17 Avionic installation.

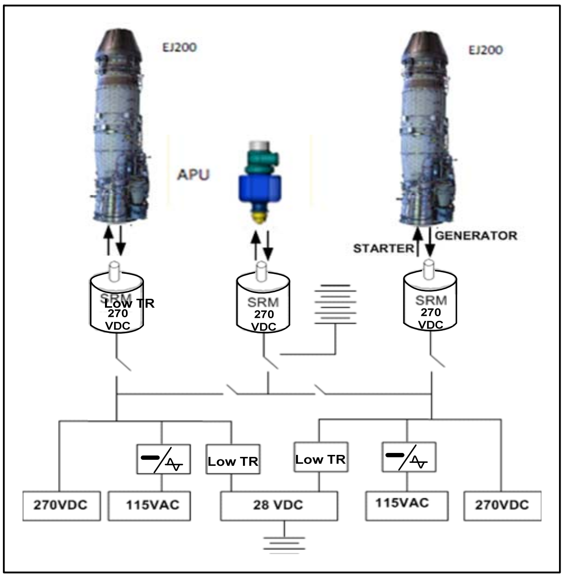

Fig. 18 Electric generation system.

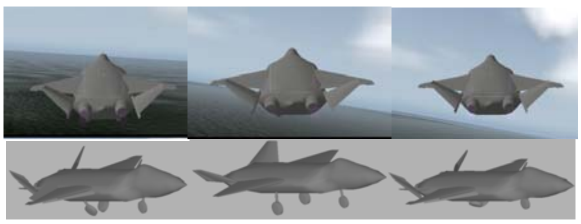

Fig. 19 X_plane dynamic model of the concept.

in academic context, and with relevant educational follow up, we think that the first confirmation to the hypothesis expressed in “pre-design” ambitious about 5th generation light fighter is realistic. This hypothesis consequently seems worth of further future deeper analysis, even in industrial context, taking into account the possible advantages, in particular in a reduced financial resources situation.

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