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A Look at Current Status of Turkish MMU/TF-X Program

by İbrahim SÜNNETÇİ

The TF-X (Turkish Fighter-Experimental) a proposed single-seat, twin-engine all-weather multi-role fighter being developed by Prime Contractor TUSAŞ/ Turkish Aerospace with technological assistance from BAE Systems. Turkish Aerospace refers to this program as the Turkish Fighter (TF) and exclude the "X" at the end of its title with an emphasis that it is no longer an Experimental aircraft.

Unveiled for the first time via a full-sized mock-up (which was constructed by Turkish Aerospace-KALAY Joint Venture Company in Germany within 35 months, cost the company almost Euro2 Million [US$2.25 Million]) during the Paris Air Show(PAS) on June 17, 2019 and later in September 2019 at the Teknofest Istanbul, Turkey's next generation National Combat Aircraft (abbreviated as MMU in Turkish), also known as TF-X, will replace the F-4E 2020 Phantom IIs and F-16C/D Fighting Falcon combat aircraft currently in the service of the Turkish Air Force (TurAF)during the first quarter of the 2030s.

Featuring Low Observability and Supercruise capabilities and to be equipped with domestically developed systems and sensors, the MMU/TF-X will be a 5th Generation indigenous air superiority fighter with secondary ground attack capability. The TurAF currently operates some 30 F-4E 2020s (which were planned to be replaced by F-35As and to be phased out of TurAF service in 2020 but now expected to remain in the service until 2025) and 238 F-16C/D aircraft and Turkey is likely to procure some 150 to 200 TF-Xs in the long term to replace F-4E 2020s and F-16s. Since the F-16C/D combat aircraft, that forms the backbone of TurAF's airpower, will be deactivated from the service starting from 2030 (Block 30 and Block 40 versions) and the deliveries of F-35As (procurement of up to 110 aircraft were planned) to TurAF has been halted by the US Government in 2019 the MMU/TF-X Program has became more important for the Turkey. In December 2019 the US Secretary of Defense has been authorized to fly up to 6 Turkish F-35As (tail numbers AT-01 to AT-06) to a storage location in the US and to induct these 6 aircraft into a long-term storage condition.

According to Turkish Fighter General Characteristics data that was released by Turkish Aerospace during Paris Air Show 2019, the aircraft would measure 21 meters in length, have a 14-meter wingspan, will be 6m in height, with a wing area of around 60sqm and a maximum takeoff weight (MTOW) of over 60,000lb (27,215kg+). To be powered by a pair of 27.000lb class indigenous turbofan engines (prototypes will be powered by a pair of F100-GE-129E engines, each generating 29.500lb of thrust) the TF-X is intended to have a maximum speed of Mach 1.8, a service

ceiling of 55.000ft and a combat radius of 600 nautical miles carrying four beyond-visual-range (BVR) and two within-visual-range (WVR) air-to-air missiles and internal fuel. The TF-X will be capable of pulling negative 3Gs to positive 9Gs. In the light of this data in every aspect of size – height, weight, wingspan, weight – the TF-X is bigger than the existing 5th Generation fighters including F-22 Raptor, F-35 Lightning II, J-20A/B Mighty Dragon and KF-X. Nevertheless, the overall design of the TF-X mock-up bears similar features to the F-22 Raptor (such as twin-engine, fixed diverter inlets, Air Pressure Relief Doors on the back of fuselage, super cruise, Thrust Vector Control [TVC, either 2D or 3D, a round exhaust which is needed for 3D thrust vectoring reflects more radar energy back to the radar receiver than a rectangular (2D) one that the F-22 Raptor has], internal weapons bays and canted vertical tail design) and F-35 Lightning II JSF (internal weapons bays, Electro-Optical Targeting System [EOTS] and a Integrated Cockpit Display System) stealth fighters, but with a narrower and longer fuselage and wider wingspan.

Even if it will be an all-weather, multirole fighter the MMU/TF-X's primary role would be air-superiority. Like the F-22 Raptor air superiority fighters the MMU/TF-X has both cheek and ventral internal weapons bays. The ventral internal weapon bay can hold up to four launchers for

medium/long-range (BVR) air-to-air missiles and air-to-ground munitions and missiles weighing between 250lb to 2.000lb. Each cheek weapons bay, on the left and right of the fuselage, can hold two launchers for short-range (WVR) air-to-air missiles.

The MMU/TF-X will also have new generation features including Low Observability, High Maneuverability (to be better than F-16C), Internal Weapon Bays, External Weapon Carriage (for NATO and Indigenous weapons), Increased Situational Awareness, Interoperability with AEW&C aircraft, UCAVs and AARs, Super cruise, Advanced Avionics for Sensor Fusion (5th Generation avionics suit) and Independent Operation Capability (no need for other A/C). The aircraft will be equipped with an indigenously developed gallium-nitride (GaN) Active Electronically Scanned Array (AESA) Radar, Integrated Processing Computer (Mission Computer), Infrared Search and Track (IRST) System (in front of the cockpit), Integrated EW Suit, as well as a Integrated Electro-Optical Targeting System (which is abbreviated as BEOS in Turkish and will have a similar function as the Electro-Optical Targeting System [EOTS] on the F-35), Helmet Mounted Sight System (HMDS, there is no HUD at the cockpit) and an Integrated Cockpit Display System (panoramic cockpit display) like that on the F-35 Lightning II aircraft. Aselsan has been contracted to develop indigenous AESA Radar, BEOS, IRST System and EW Suit. Negotiations regarding the Integrated Cockpit Display System (panoramic cockpit display) and HMDS are currently on-going. TUBITAK, on the other hand, has been contracted for the development of the Integrated Processing Unit (IPU, a mission computer and abbreviated as BÜİT in Turkish). Within the scope of the MMU/TF-X Program, Aselsan also is developing Integrated RF System (abbreviated as BÜRFİS in Turkish) for the MMU/TF-X. The BÜRFİS Project aims to increase the Technology Readiness Level (TRL) by developing critical technology elements with national means such as:

- Low Visibility Radar and Electronic Warfare Integrated Antenna Designs suitable for 5th Generation aircraft structure
- Radar and EW Integrated Receiver/ Transmitter Structures
- AESA-based Combat Aircraft Radar Algorithms with simultaneous function capability
- Broadband high-performance RF Components.

Within the course of the MMU/TF-X Program, new capabilities and equipment will be added to the aircraft under a "Block Development Approach", and in each

Block, the level of local content ratio will be increased. The first TF-X prototype will be in Block-0 configuration and is expected to be rolled-out in 2023 (on March 18, 2023 is planned), when Turkey will celebrate its 100th anniversary of the founding of the Republic. Following the ground tests that are scheduled to start some time in 2023 and to last around 2 years, the maiden flight will be performed with the first prototype aircraft. The Block-0 configuration will not feature either stealth capability or some of the main internal avionics and equipment (such as AESA radar) and various sub-systems onboard the aircraft will be procured from abroad such as turbofan engines, integrated cockpit display system (panoramic cockpit display) and landing gears. The Block 0 aircraft is expected to be in 4th++ Generation configuration. The Block-I prototypes, that expected to feature 4.5th Generation Fighter performance and sensor fusion capability, will be in air superiority configuration and the first aircraft that expected to enter TurAF service in 2029 will be in Block-I configuration. The TurAF will achieve/declare IOC with Block-I TF-X. A Turkish Aerospace official who spoke to us during PAS 2019 had underlined that the TurAF had originally planned for the first entry into service to occur in 2029 but since they have accelerated their efforts the date of entry into service was brought forward one year.

However, in November 2019 Turkish Aerospace President & CEO Temel KOTIL announced that TF-X delivery to the TurAF would be commenced in 2029. According to Program schedule Turkish Aerospace will start MMU/TF-X Block-II (in full 5th Generation fighter configuration) deliveries in 2031 and following their entrance into TurAF service, FOC will be declared by the end of 2031. The MMU/TF-X Block-IIs, multi-role model, will have the capability to perform a full air-to-air and air-to-ground combat mission and to feature increased local content share thanks to their indigenously developed turbofan engines, sub-systems and avionics. If it can be implemented and realized as planned the TF-X Program would elevate Turkey into the "elite" of the handful of nations such as the USA, Russia and China who have afforded the development and production of a 5th Generation Fighter.

MMU/TF-X Program Schedule

The Preliminary Design (Phase-I Stage-I) contract was signed between Turkish Aerospace and the Presidency of Defense Industries (SSB) on August 5, 2016 and on January 28, 2017 BAE Systems and Turkish Aerospace signed a US$156 Million to collaborate under the Preliminary Design (Phase-I Stage-I) Phase of the MMU/TF-X Program. The Turkish Aerospace-BAE Systems Collaboration Agreement became effective on August 25, 2017.

The Project Implementation Schedule (To) was started on September 17, 2018 following the selection of TR Motor Power Systems (started operations in April 2018) as Prime Contractor and Supplier for the turbofan engines that will power the MMU/TF-X production aircraft. In October 2018 Turkish Aerospace selected General Electric (GE)'s F110-GE-129 (probably the F110-GE-129E version due to twin-engine configuration) to power the MMU/TF-X prototypes and initial batches of series production aircraft. On November 8, 2018 the SSB signed a Framework Agreement with TR Motor Power Systems for the development of a next generation turbofan engine that will power the MMU/TF-X.

The MMU/TF-X Program is planned to be carried out under three Phases as the Preliminary Design (Phase-I Stage-I, September 2018 - September 2022), Detailed Design & Qualification (Phase-I Stage-II, September 2022 – September 2028), Acquisition of Initial Operation Capability and Full Operation Capability (IOC/FOC, Phase-II, September 2028 – December 2031) and Serial Production (Phase-III, 2032-2035+). Turkish Aerospace was designated as the Prime Contractor for the MMU/TF-X Development Program's Engineering Development & Preliminary Design Phase in line with the Defense Industry Executive Committee (DIEC, the highest decision-making body on defense procurement in Turkey) Decree dated April 2015. Under the Engineering Development & Preliminary Design Phase, the Preliminary Design Review (PDR) document is expected to be completed in late 2021. During the Preliminary Design Phase beyond the design and development of the TF-X aircraft, engineering capabilities, technology development activities (for key sensors like radar, electronic warfare, etc.), test

infrastructure establishment and certification processes will be performed and extensive capabilities for a new generation jet fighter design, development and production will be gained by the Turkish Defense & Aerospace Industry.

As of July 2020, the Engineering Development & Preliminary Design Phase (Phase-I Stage-I) is continuing. Developing a stealth fighter is an expensive enterprise. The Preliminary Design Phase, scheduled to last four years, is expected to cost around US$1.3 Billion (according to Turkish Aerospace President & CEO Temel KOTIL around US$300-400 Millions of this figure would be allocated for infrastructural investment and around US$1 Billion for the engineers). This will be followed by a nine-year Detailed Design & Qualification Phase (which also covers Critical Design Review [CDR] and Prototype Production and the Qualification Phase) and IOC/FOC, which are estimated to cost around US$7.3 Billion. A total of 12 TF-X jets will be manufactured to achieve the declaration of IOC and further 20 jets for FOC. According to Turkish Aerospace engineers taking part in MMU/TF-X design activities, under the Detailed Design & Qualification (Phase-I Stage-II, September 2022 – September 2028) Phase, a total of seven Turkish Fighter prototypes (six for flight tests and one for ground tests) in three different configurations namely; Block-0, Block-I and Block-II, will be manufactured for test, evaluation and qualification purposes. However, during the PAS 2019 it was reported that there would be five MMU/TF-X prototypes.

Another US$14 Billion is earmarked for the Serial Production of the MMU/TF-X fighter jets. The production of the first TF-X prototype was expected to start in 2020 but due to delays that stem from both internal (unfavorable impacts of the novel type coronavirus [COVID-19] pandemic on the Turkish Defense & Aerospace Sector, lack-of sufficient number of experienced engineers/staff [mainly a result of brain drain, hundreds of experienced staff have left the country during recent years] in local companies that take part in TF-X Program, and national motivation difficulty experienced in local companies and their personnel) and external reasons (impacts of COVID-19 and heavy embargoes implied by so-called friendly and allied countries have caused several months of delays in procurement and deliveries of some subsystems, Governments of some European countries even did not allow their local companies to obtain RFP documents issued by Turkish Aerospace for the procurement of subsystems to be installed on prototype aircraft within the scope of TF-X Program) it is believed that this schedule could not be kept and can be postponed to 2021.

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During his address at unveiling ceremony held on June 17, 2019 at PAS 2019 Turkish Aerospace President & CEO Temel KOTIL had underlined that TF-X would be able to carry long-range, air-to-air METEOR missile of the European manufacturer MBDA and disclosed that the aircraft would be rolled-out in 2023, first flight would take place in 2025 and the next generation fighter to enter service with the TurAF in 2028. In July 2019 President for Defense Industries (SSB) Ismail DEMIR disclosed that they have been working to brought forward the date of TF-X's first flight from 2026 to 2025 and said, "The MMU/TF-X may have A, B and C versions." In July 2019 Turkish Aerospace Deputy General Manager Responsible for the MMU/TF-X Program Prof. Dr. Mustafa CAVCAR (also Chief Engineer of the Program) said, "Studies on different solutions of the TF-X aircraft are continuing. Meanwhile, some wind tunnel tests were carried out. Very good results obtained from the initial tests." On November 5, 2019 SSB DEMIR announced that the 48-month Preliminary Design Process was withdrawn to 36 months in the MMU/TF-X Program schedule and disclosed that there were 2-3 countries seriously interested in the MMU/TF-X Program. At hiss address performed on November 16, 2019 SSB DEMIR named Azerbaijan, Pakistan, Qatar, Indonesia and Malaysia as countries seriously interested in the MMU/TF-X Program. The TF-X unveiling ceremony held at PAS 2019 was attended by Royal Malaysian Air Force (RMAF) Commander General Tan Sri Dato' Sri Affendi bin BUANG. Turkey has been looking for international joint development partners to collaborate with Turkish Aerospace and various Turkish sub-contractors on the MMU/TF-X Program, and Malaysia is one of the potential candidates for this role. According to local sources, such as Malaysia Flying Herald, Malaysia feels the need to join TF-X Program because it sees two nearby neighbors namely Indonesia and Singapore will have next generation aircraft, namely IF-X and F-35. The initial step to join TF-X Program was marked by a MoU signed between Turkish Aerospace and DefTech in 2018. The MoU is said to be a basis for Malaysia to get TF-X in next 10 years. Malaysia is reported to plan replace RMAF's F-18Ds and Su-30MKMs, which will be retired in 2035 and 2042 respectively, with the MMU/TF-X fighters. Spoke to Anatolian News Agency (AA) on January 10, 2020 Turkish Aerospace President & CEO KOTIL stated that Turkey has invited Malaysia to join a mutual production of the MMU/TF-X and Turkey's indigenous jet trainer and light attack aircraft, the HURJET. "We made them a proposal and they showed great interest," KOTIL said. He added that Malaysian Prime Minister Mahathir MOHAMMED had previously visited the Turkish Aerospace Ankara facilities, adding they also held bilateral meetings during President Recep Tayyip ERDOGAN's visit to Malaysia in December 2019. Turkey wants the MMU/TF-X Program to be a multi-partnered program, like the one enjoyed by the F-35 JSF Program.

At his address during Turkey 2023 Summit held on November 30, 2019 KOTIL said that TF-X delivery to the TurAF will be commenced in 2029 and Turkish Aerospace would be able to deliver 2 aircraft per month with a combined production capacity of 24 aircraft per year. Speaking at 'Turkish Defense Industry - MMU/TF-X Dialogues Conference held at Cukurova University on December 13, 2019 Head

of SSB Aircraft Department Abdurrahman Seref CAN disclosed that currently on-going Preliminary Design Phase would be completed in 2022, first MMU/TF-X prototype would be rolled out in 2023 and first flight would be carried out in late 2026 or early 2027. He also disclosed that as of December 2019 a total of around 400 Turkish Aerospace engineers from different disciplines are currently taking part MMU/TF-X design activities and BAE Systems supports design of the MMU/TF-X with some 90 engineers based in Ankara. Speaking at the same Conference Turkish Aerospace Deputy General Manager Responsible for the MMU/TF-X Program Prof. Dr. Mustafa CAVCAR underlined that the TF-X will have super cruise capability and to feature internal weapon bays. According to CAVCAR, during 2018 successful wind tunnel tests were carried out, in 2020 further wind tunnel tests will be performed. "The TF-X will undergo over 20.000 hours wind tunnel tests," CAVCAR said. According to data from the American Institute of Aeronautics and Astronautics (AIAA), approximately 35,000 to 45,000 hours would be required to develop a typical modern transonic/low supersonic military aircraft (the F-35 required 63,000 hours for three variants) (AIAA 2009). At his address CAVCAR also shared a slide showing MMU/TF-X technical characteristics. According to this slide, which contains some different data on the official specifications of the TF-X that released by Turkish Aerospace first in December 2017 and then during PAS 2019, the aircraft would measure 19 meters (60ft) in length, have a 14-meter (46ft) wingspan, with a wing area of 70sqm (750sqft) and a maximum takeoff weight (MTOW) of over 60,000lb (27,215kg+). To be powered by a pair of 29.000lb class indigenous turbofan engines (prototypes will be powered by a pair of F100-GE-129E engines, each generating 29.500lb of thrust) the TF-X will have a combat radius of 500 nautical miles carrying four beyond-visual-range (BVR), two within-visual-range (WVR) air-to-air missiles and internal fuel. According to official specifications, which had released by Turkish Aerospace in December 2017 the TF-X would have a MTOW of 60,000lb (27,215kg+), a length of 19m and a wingspan of 12m, an operational radius of over 1.100km, a flight ceiling of over 16.700m (55.000ft) and a maximum speed of Mach 2.

Temel KOTİL - Turkish Aerospace President & CEO

According to Turkish Aerospace President & CEO KOTIL, during next 10-year period a total of 10,000 Turkish and foreign (including those from BAE Systems) engineers from different disciplines, with supersonic fighter design and manufacture experience (know-how), will work under the MMU/TF-X Program. Under the contract BAE System will provide 400 personnel/year engineering support for a period of 4 years to Turkish Aerospace under the Engineering Development & Preliminary Design Phase (Phase-I Stage-I) of the MMU/TF-X Program.

The computer generated footage of Lightning Test Facility

New Capabilities & Infrastructures for the MMU/ TF-X

To support the MMU/TF-X Program Turkish Aerospace is also establishing new infrastructures in its Ankara facilities such as Near Field Radar Cross Section Test Facility (contract was signed between Turkish Aerospace and TUBITAK BILGEM on December 26, 2019, test facility is planned to be completed in 2021) and Lightning Test Facility (Yıldırım Test Tesisi, contract awarded on February 6, 2020 and the facility is scheduled to be ready for use during the first half of 2022) that to be fully established under Phase-I Stage-I and Full Anechoic Chamber Test Facility and Far Field RCS Test Facility (Uzak Alan RKA Test Tesisi) that to be partially established under Phase-I Stage-I. Moreover, on May 2, 2019, during IDEF '19 Fair held in Istanbul, Turkey, Turkish Aerospace signed an agreement with Aiolos Engineering Corporation, based in Canada, for the construction of a "Subsonic Wind-tunnel" at the Turkish Aerospace facilities in Ankara to support the MMU/TF-X and other future programs. Turkish Aerospace aims to build one of the World's three ''Subsonic Wind-Tunnels", and to activate it in 2022. Turkish Aerospace also previously signed a contract on 19 July 2018 with the company Aircraft Research Association (ARA), an independent research and development organization providing a range of specialist services to the worldwide aerospace industry, of the UK regarding the risk reduction phase of the wind tunnel tests for the TF-X aircraft. The highest level of quality wind tunnel data is required to verify an aerodynamic design. Since Turkey presently lacks a sufficient infrastructure in high-speed wind tunnel testing, BAE Systems capabilities in this field have been planned to be utilized during TF-X's wind tunnel test phase especially at supersonic speeds. The BAE Systems Wind Tunnel facility is home to two tunnels, known respectively as the low speed and high-speed tunnels. In the latter, tests can be carried out at speeds up to Mach 3.8, which makes it perfect for transonic work. Meanwhile, on June 7, 2020 TR Airworthiness Services Inc., a subsidiary of Turkish Aerospace, commenced its operations with the aim of getting certified by local and international civil aviation authorities and becoming an authorized audit organization in the field of airworthiness and certification. TR Airworthiness Services Inc. will provide consultancy services in airworthiness and certification processes in both civil and military aviation. The company will also take part in military certification of the Turkish Fighter Jet (MMU/TF-X), which is Turkey's largest aviation project and will provide technical support to Turkish Aerospace in military certification activities for HURJET, Multirole Heavy Combat Helicopter (ATAK Mk-II) and HURKUS-B New Generation Trainer Aircraft.

Turkish Aerospace also signed an agreement with Havelsan to carry out software development and embedded training among others to speed up development of the TF-X National Combat Aircraft Program. Announced by SSB DEMIR on May 2, 2020, the agreement covers; Embedded Training, Flight Training and Maintenance Simulators and Engineering Support (Virtual Test Environment, Project-Level Software Development, and Cybersecurity). SSB DEMIR said, "With this cooperation, Turkish Aerospace and Havelsan will carry out many works such as software development, simulation, training and maintenance simulators. When the TF-X project is completed, our country will be among the countries with the infrastructure and technology that can produce a 5th Generation combat aircraft after the USA, Russia and China. " Within the scope of TF-X Program Turkish Aerospace is constructing a new MMU/ TF-X facility (a total of 3.000 engineers will be employed at this facility) at the Ankara Aerospace Industrial Zone as well as new Composite Building (spreading on 95.000 sqm area of which 63.000 sgm is indoor and consists of 9 blocks), both of which are scheduled to be completed in 2021. On April 22, 2020 Turkish Aerospace President & CEO Temel KOTIL disclosed that the works at the new Composite Building (where the composite parts of the MMU/TF-X to be manufactured) continue despite COVID-19. KOTIL stated that the construction activities were planned to be complete in July 2020 and that the installation of the machinery/equipment would start by September 2020. Underlining that autoclave machines and robots are about to be delivered, KOTIL stressed that production would start at the beginning of 2021 at Turkish Aerospace' new Composite Building. In his comments to Anatolian News Agency on January 3, 2020 KOTIL stated that Turkish Aerospace has hired 2,500 engineers during last 3 years and procured two 10,000-core "supercomputers" (the first one was purchased in March 2018). These supercomputers have sufficient calculating power to shoulder the detailed design of the TF-X and its subsystems.

First Piece of TF-X is Revealed: Air Inlets

Having spoken with C4 Defence on December 30, 2019 Turkish Aerospace President & CEO Temel KOTIL stated that Turkish Aerospace and TUBITAK BILGEM have started to work on the reflection of radar waves from the TF-X aircraft. KOTIL said, "We have started cutting the air inlets, we made the first air inlets. We began to work on their electromagnetic reflection with TUBITAK BILGEM. The first air intake is now at TUBITAK. We want to see whether the inlet is swallowing or reflecting the RF waves. We have started to analyze this and are physically hands-on in the process now. So, it's not just on paper anymore."

Supplying the engines with the necessary quantity of air for generating thrust takes place by specially designed air inlets. The task of the air inlet is to supply the engine with a uniform, stable, low-loss flow. The air inlets come in a variety of shapes and sizes with the specifics usually dictated by the speed of the aircraft. One of the critical designs affecting the performance of the aircraft engine at subsonic, supersonic speeds and high angle of attack is the air inlet design of the aircraft. The geometric shape of the air inlet also closely concerns its reflection from the radar.

The MMU/TF-X will be fitted with a pair of Fixed-Shape Supersonic Inlets with stationary diverters (fixed diverter inlets). When the airframe design of the TF-X mock-up is examined closely, one of the first details that draws attention is that the air inlets are fixed as in the F-22 and there is a 3-4 inch gap between the fuselage and the air inlets, which aims to isolate boundary layer airflow. Just like the F-22, there are also Air Pressure Relief Doors on the back of the TF-X fuselage. The 5th Generation aircraft, such as the F-35 JSF, J-20 and FC-31, are usually fitted with Diverterless Supersonic Inlets (DSI). DSI type supersonic air inlets have better stealth ability than fixed diverter air inlets and are more efficient, but they have a performance limit that will not allow the aircraft equipped with them to exceed Mach 1.8 - Mach 2.1. The F-35 JSF is a multi-role combat aircraft, which is designed primarily for air-to-ground combat, so it doesn't need either to fly at high speeds or to have supercruise capability. Because of that, the F-35's maximum speed is Mach 1.6. The F-22 and TF-X, on the other hand, are air superiority fighters (MMU/TF-X's primary role would be air-superiority), which means they should be capable of flying at high speeds. It is believed that with the 29,000lb class indigenous turbofan engines the TF-X might exceed the speed limit of DSI type air inlets. So using DSI type air inlets on the aircraft would not be a good idea for the MMU/TF-X. Moreover, as in the case with the F-22, which could achieve Mach 1.5+ speeds without the use of afterburners (supercruise capability), the TF-X will also have supercruise capability.

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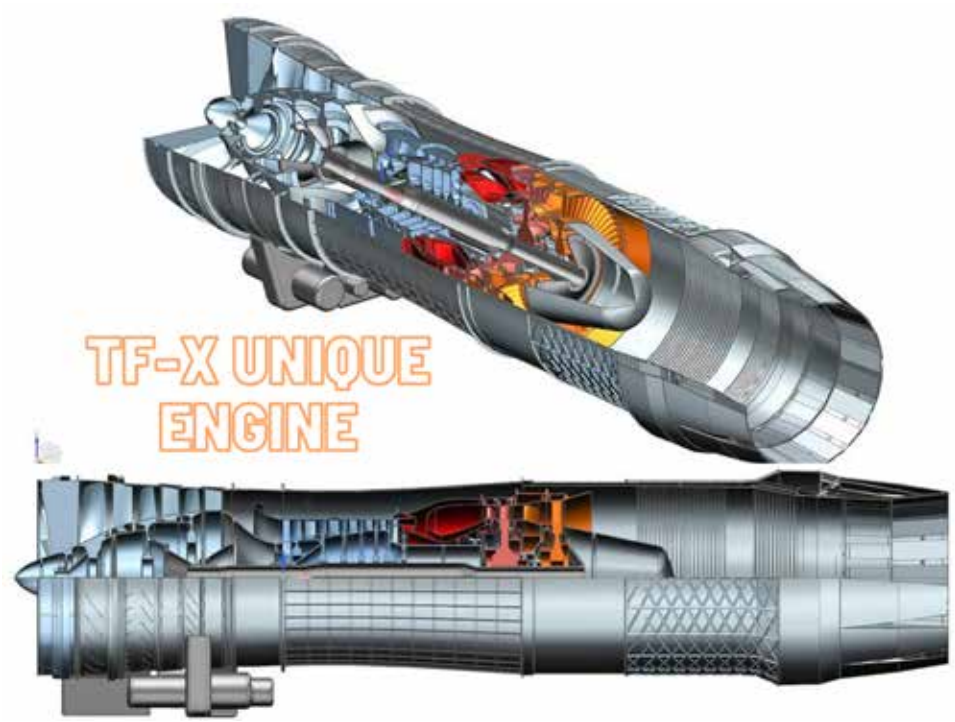
TF-X and Indigenous Turbofan Engine

General Electric's F110 Turbofan Family has been selected as a stopgap solution until Turkey has built its indigenous turbofan engine for the MMU/TF-X. On June 23, 2019 Turkish Aerospace President & CEO Temel KOTIL disclosed that they have ordered 5 turbofan engines from General Electric (GE) and they are currently in the delivery state. "We will use F-16 engines (probably F110-GE-129E version due to twin engine configuration) in the first prototypes of the TF-X for the first flights. The development of indigenous turbofan engine is continuing" KOTİL added. We estimate four of the engines will be installed on two of the Turkish Fighter prototypes and the fifth engine will be used as a spare. Starting from the third prototype, the MMU/TF-X aircraft is planned to be powered by a pair of indigenously developed turbofan engines to be developed by TR Motor Power Systems, a national engine consortium (formed by BMC Power [55%], Turkish Aerospace [35%] and the SSB [10%]).

On 8 November 2018 the SSB signed a Framework Agreement with TR Motor Power Systems for the development of a next generation turbofan engine that will power the MMU/TF-X, or Turkish Fighter, aircraft. Speaking at the signing ceremony President of Defense Industries (SSB) Ismail DEMIR said the final goal is that the engine would not face limitations from foreign countries in terms of use and exports, and for Turkey to control all technological features and Intellectual Property (IP) rights. The SSB's President DEMIR also noted that development of the indigenous turbofan engine would be a long process, nearly 10 years, and the agreement that was signed with TR Motor will serve as a framework in this process. On the occasion of the signing ceremony on November 8th, a computer-generated image (CGI) of TR Motor's Turkish Indigenous Turbofan Engine was also shared with the media. Our initial analyses suggest that the current design has several similarities in terms of internal configuration with the F110 Turbofan Family.



Osman DUR - General Manager of TR Motor Power Systems - Prof. İsmail DEMİR- SSB President

In this context for example, like the F110-GE-129 and -132 engines the Turkish Indigenous Turbofan Engine also features a Variable Inlet Guide Vane and as in the case with the F110-GE-132 engine it features "blisks" (bladed-disks) in the three-stage modular fan section in lieu of traditional blades to improve performance and maintainability. The engine also incorporates one High Power turbine (HPT) and a Low Power Turbine (LPT). According to our sources the Turkish Indigenous Turbofan Engine to be supplied by TR Motor Power Systems will have similar dimensions and weight with F110 Turbofan Family.

A CGI of turbofan engine to be developed by TAEC for the TF-X

After cancelling the first tender (for which the RFP was issued on January 17, 2014 and covered the direct procurement of 7-sets of turbofan engines to be used on TF-X prototypes) in mid-2017, during the second half of 2017 the SSB had issued a new tender for the development of a totally new national engine, the IP rights of which would belong to Turkey (SSB), with a foreign engine supplier/ Technical Support Provider. The winner of the tender would cooperate with TR Motor Power Systems for the development and manufacture of 27,000lb class indigenous turbofan engine. The SSB received proposals from TEI (without GE) and TAEC (Kale Group and Rolls-Royce JV company) in December 2017, while EuroJet decided not to participate in the tender. On May 8, 2017 Kale Group announced that they would set up a joint venture company (TAEC, 51% Kale Group and 49% Rolls-Royce) with UK-based Rolls-Royce to develop civilian and fighter aircraft engines, including Turkey's planned TF-X fighter jet. According to Kale Group if they are selected, they will develop the first production engine by 2023 and start serial production of the engine by 2030 following the completion of all certification processes. According to Chris CHOLERTON, the then President of Rolls-Royce Defense Aerospace (currently serves as President – Civil Aerospace of the Company), they plan to develop an engine from scratch for the planned TF-X fighter jet and Turkey will hold the intellectual property (IP) rights of this new engine. During the second half of 2018 Rolls-Royce was selected as the Engine Technical Support Provider and negotiations were launched with the company. However, in early March 2019 it was reported that Rolls-Royce has backed out of the project due to a dispute on the IP issue. Rolls-Royce has made clear that they are unwilling to share Intellectual Property (IP) with BMC Power. In November 2019 the SSB's President DEMIR disclosed that they have restarted negotiations with Rolls-Royce, and they were about to make a deal with the company. In his statement to Bloomberg News Agency on December 13, 2019 regarding the Turkish Indigenous Turbofan Engine for the MMU/TF-X fighter jets, DEMIR said; "We may find middle ground with Rolls-Royce for an engine... We shall solve the issue if we sit down at the table." Answering questions from Turkey's leading defense magazines, including Defence Turkey Magazine, during a live interview broadcast via a domestic video conferencing system on May 7, 2020 DEMIR said, "Our main target for the TF-X Project is to utilize Turkey's capabilities to the maximum extent possible. We remain in contact with all partners, and especially the major defense companies and TUBITAK (The Scientific and Technological Research Council of Turkey). The utilization of foreign subsystems, even only in the transition process, would obstruct us in the future. We will not rely on any foreign systems in the future, as no matter how binding the agreement, there can be blockages. We have had our fingers burnt before in similar situations. Making every system indigenous is a costly process in the global system. In the first phase, we will use an off-the-shelf engine, but the final engine will be indigenous... We have started working on the TF-X engine, but the F110 engine will be used in the first phase. We consider a twin-engine design. Currently, there is no problem with the supply of F110 engines, which is an engine that

we know very well. 5-6 engines have already been supplied. It is an engine that TEI has extensive experience in maintaining and repairing, so we feel it would be safer to start with this engine. Work on an indigenous engine is currently underway, but we are also in contact with numerous countries about the jet engine."

During the online panel organized by the SETA Foundation on May 28, 2020, the SSB's DEMIR made critical statements on the TF-X Program. Answering questions about the TF-X Program and the Turkish Air Force's new generation fighter aircraft requirement that arose after the US Government halted the delivery of F-35As to the TurAF, DEMIR said: "In particular, I can say that off-the-shelf procurement of a new fighter is not on our agenda at the moment. All our efforts are concentrated on the 5th Generation TF-X. We have determined to realize this Program under a 'Block Development Approach' (the performance and capacity of the TF-X fighter aircraft will be improved with each block). That is, instead of providing all the desired performance parameters that were defined in the Operational Requirement List of the aircraft in one stroke; we will determine an approach where certain parameters are provided, put on top of each other and the final performance target is achieved within phases. In this sense, our first prototypes may not be in 5th Generation configuration and would have 4.5/4++ Generation fighter performance, but in time as we progress the 5th Generation configuration is eventually achieved."

According to Osman DUR, General Manager of TR Motor Power Systems, work to develop the indigenous turbofan engine continues at full speed, in cooperation with related institutions and as of January 2020 some 80 engineers are working on the TF-X fighter jet's domestic engine project, in cooperation with the Turkish Air Force Command. "We will run the first-ever start test of our engine in 2026 or in 2027. Then the ground tests will start. Our National Combat Aircraft (TF-X) will perform its first flight with our indigenous engine in 2029," DUR added. Speaking to Anatolian News Agency (AA) on January 10, 2020 TR Motor Power Systems General Manager DUR said the firm had been negotiating with international engineering and design firms, along with Original Equipment Manufacturers (OEM), given that design and production represented two separate operations. "There is no point in designing technologies that we cannot put into production. Therefore, we continue our best efforts to develop local suppliers for the domestic aircraft industry," DUR said.

According to the information obtained from the TR Motor Power Systems official, with whom we had the opportunity to meet at the company stand during Teknofest Istanbul 2019 September 17-22, 2019, the Conceptual Design Phase for the MMU/TF-X Engine was ongoing, and the engine development/design work was being carried out in parallel (rubber to rubber) and in coordination with the aircraft development. As of September 2019, more than 50 engineers including Turkish engineers working in foreign engine companies abroad were working on the project. As of September 2019, the delivery of the first set of indigenous turbofan engines to the TurAF for testing on the TF-X is planned to take place in 2028 ■