Considerations regarding aircraft maintenance system approach in Romanian air force

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Abstract: *The Romanian Air Force increased the interoperability with the NATO partners, including the acquisition and operation of the F-16 aircraft from the Norwegian and Portuguese Air Forces, F-16s that are distributed within different Romanian airbases. In this respect, the Romanian Air Force must undertake necessary steps in the direction of gradually grow of the operational capabilities, starting from a first phase by making operational one squadron of F-16 A/B MLU (Mid Life Update) aircraft in 2017. The squadron operationalization includes the logistics services starting from the Air Force Headquarters and implemented at the ground level of the airbases assigned to receive the specific aircraft. An updated, with new efficient solutions for maintenance management system, was envisaged and destined to the safety operation and maintenance activity of the new family of aircraft.*

KEYWORDS: *MAINTENANCE MANAGEMENT SYSTEM; MAINTENANCE IMPROVEMENT CONCEPTS; CONFIGURATION MANAGEMENT.*

1. Introduction

The aim of this paper is to present some researched aspects regarding challenges for the maintenance system that had to be set up in supporting the new aircraft purchased within Romanian Air Force airbases.

Transition from a standard long time established maintenance system dedicated to the MIG-21 aircraft toward a different manufacturer and aircraft model is doable but far from an easy task. The previous maintenance activity went through a transformation phase when the MIG-21 aircraft suffered an upgrading process, regarding the avionics and weaponry, in the mid-90th. That was a proper training stage for the maintenance engineers to learn transition for specific systems. When the new complex 4th generation aircraft arrived from the mentioned NATO countries, a lot of similarities were identified and so the transition was more accurate and safety.

Definitely this transition has involved also new requirements and usage of different/modern concepts and requirements of maintenance and maintenance management, that made also the subject of our research and briefly and partially are presented also in this paper.

2. General requirements for operation maintaining

From the beginning was considered a new implementation for the maintenance system, that must correspond to the new type of aircraft in correlation with the type of missions which these aircraft must fulfill and considering the maintenance levels intended to be adopted. Therefore, was made a primary list with aspects to be addressed:

- Maintenance management (concepts, configuration, Technical Orders TOs) [1];
- Maintenance organizational structure;
- Infrastructure;
- Staff training;
- Technical documentation/Technical Order Distribution Office (TODO) [2];
- Tools and checking devices, measuring and control devices, maintenance equipment;
- Ground Support Equipment –GSE;
- Special vehicles (fuel trucks, fire trucks, sweepers, snow removal machine, etc.);
- Pilots survival equipment;
- Personnel protective equipment;
- Joint Mission Planning System – JMPS [3];
- Flight simulator;
- Maintenance simulator;
- Spectrometric Oil Analysis Program – SOAP;
- Precision Measurement Equipment Laboratory-PMEL;
- Tactical Air Navigation-TACAN [4];
- Multifunctional Information Distrubution System – MIDS [5];
- Aircraft spare parts and ground support equipment;
- Consumables for aircraft maintenance;
- Alternate Mission Equipment –AME (pylons, launchers, bomb racks, fuel tanks;
- Weapons (missiles, bombs) and pods (Electronic Countermeasures-ECM, Targeting Pod-TGP);
- Generate the supply chain;
- Quality assurance system;
- Tools control system;
- Flight and ground safety programs(e.g. Foreign Object Damage –FOD program);
- Standard Operating Procedures- SOPs for emergency situations: usage/hydrazine H-70 leaks, landing with loaded weapons, hot brakes, aircraft crash;
- Crash recovery kit;
- Structure of a deployable detachment (6 aircraft for 6 months –deployment kit).
- Access to some USA and NATO digital platforms:
  - Field Information Network – FIN [6];
    Processing, Evaluating and Reporting of FORce Management data Software –PERFORMS/Lockheed Martin Aero FALCON 2020 [7];
  - Foreign Military Sales Electronic Technical Order System – FETODS/Air Force Security Assistance Center-AFSAC [8];
  - International Digital Technical Order Delivery-IDTOD/Technical Coordination Group – TCG [9];
  - Engine Maintenance And Tracking System –EMATS For F-100 –PW-220E engine/Pratt & Whitney [10];
  - FedLOG Catalogue/Defence Logistics Agency –DLA [11];
  - NATO Logistics Stock Exchange-NLSE/NATO Support Agency-NSPA [12];
  - NATO Master Catalogue of References for Logistics – NMCRL [13].

3. Maintenance concepts and requirements

3.1. Maintenance concepts

For the new acquisition 4th generation aircraft maintenance, the study starts from the specialized literature to identify the guiding lines in the operational maintenance approach. From the study there were selected three main concepts/levels [14]:

- „O" **Organizational level**- inspections and works which are performed at the squadrons (in flight line or parking platform/apron);
- „I" **Intermediate level**- inspections and works/minor repairs which are performed at the hangar/workshops;
- „D" **Depot level** - major repairs, modifications, upgrades or overhauls which are performed at the facilities of Original Equipment Manufacturer- OEM or at the economic operators/commercial companies which accomplish Maintenance Repair and Overhaul – MRO.

3.2. Maintenance requirements

In the TO 1F-16AM-6 (Scheduled inspection and maintenance requirements) are well established the types of maintenance works that must be provided:

- scheduled inspections:

- sortie generation inspections (combined preflight/postflight inspection, end-of-runway inspection, thruflight inspection, launch and recovery inspection, basic post flight inspection, walkaround before first flight of day inspection);
- aircraft phased inspection will be accomplished upon accrual of a specified number of aircraft flying hours;
- engine phased inspection will be accomplished upon accrual of a specified number of engine flight hours.

➢ special inspections:

- Special inspections after a specific occurrence, consisting in: event inspections (airspeed limit exceeded, excessive G load, hard landing, whenever aircraft is struck by lightning, whenever unusual noises or vibration is experienced, whenever an engine stall occurs in supersonic flight, after modification of aircraft which results in as unknown change to basic weight and balance, whenever a brake fire has occurred, whenever engine is removed due to foreign object damage, prior to installation of external fuel tank (center line or wing tank), whenever an engine flameout occurs, etc.
  - recurring inspections that will be accomplished upon the accrual of a specified number of flying hours, engine flight hours, equipment hours of operation, a lapse of calendar time.
- Aircraft Structural Integrity Program (ASIP) inspection originate from data received from individual aircraft trucking (IAT) program. The IAT program predicts potential crack growth in critical structural areas of the aircraft. The inspection time for each aircraft vary according to individual history of flight intensity.
- Depot level inspections are major repairs, modifications, upgrades and overhauls.
- Replacement schedule of equipment that is to be replaced upon the accrual of a specified number of flying hours, equipment hours of operation, a lapse of calendar time or after the occurrence of a specified or unusual condition; the hourly and calendar requirements, when due, will be added to and accomplished at the nearest phased inspection.
- base level repairs:
  - line replacement unit (LRU)-fixing defects by replacement of modular components at the flight line („O" level of maintenance);
  - shop replacement unit (SRU)-repairs accomplished at the hangar/backshops („I" level maintenance).

In addition to works established in the TO 1F-16 AM-6, there are additional works provided in performed technical bulletins. These are Time Compliance Technical Orders (TCTOs)-directives issued to provide changes, modifications or inspections of equipment or installation of new equipment. All TCTOs material is provided in the form of kits.

Starting from the analysis of all mentioned documents, within the Romanian Air Force airbases were introduced the „O" and „I" maintenance levels, for performing the following works:

At the flight line crew chiefs and loaders execute „O" level maintenance: sortie generation inspections, part of the special inspections and some base level repairs/fixing minor defects by replacing the components (line replacement unit – LRU);

At the hangar/aircraft maintenance sections, technicians and engineers perform "O" and "I" level maintenance like: replacement of engines, phased inspections, fixing major defects by components repairs (shop replacement repair – SRU), all TCTOs and the LRU which are not performed at the flight line.

Depot "D" level repairs/overhauls are not provided for this kind of aircraft. Repairs of high complexity that may occur in the future (major repairs, modifications/upgrades) will be executed by an economic operator (probably a civil company). Never the less this activity is necessary to be implemented in the air bases and in the Air Force headquarters as the Aircraft Structural Integrity Program (ASIP), for evaluating the aircraft structure condition and to provide information regarding the inspections/modifications planning for specific components in the aircraft structure, followed with data generation for the risk analyzes and the life cycle costs of the components.

AT the engine, level "O", "I" and 'D" maintenance works are implemented to be performed. Level "D" works/overhauls on each of the 5 modules are performed only accordingly to the numbers of cycles operated in the 4 modules (low pressure compressor, core engine, low pressure turbine and augmenter duct and nozzle). Usually is considered 4000 cycles each (approximately 1500 operating hours) and, according to the number of hours of engine operation (ground and flight) for one module (the gearbox), resulting in the 3000engine operating time (EOT).

The possibilities in executing level "D" works on the F100-PW-220E engine modules that are equipped the aircraft in the acquisition made for Romania, were analyzed. So far, if necessary, efficient maintenance contracts can be concluded in the shortest possible time, with the designated economic operator/civil company.

In order to avoid the suction of foreign objects within the engine, followed by very high engines repair costs, for the airbases was designed and implemented a rigorous FOD program.

A great attention was allocated to tracking the resource/potential of the aircraft components (including those of the pyrotechnic cartridges in the ejection seat) and the engine. Many of the components (Time Change Items–TCI) having different resource/potential until the execution of certain special inspections or until they are replaced for overhauls or until the total resource/potential expires. It is to be mentioned the cases where components with identical functionality, mounted in the same place on the aircraft, have different Part Numbers and different resource/potential. Therefore, the purchasing planning must be flexible in design to be adapted to the real conditions. One example may be the Pyrotechnic cartridges (the Cartridges actuated Devices – CAD and the Propellant Actuated Devices – PAD) that requires any way long time to be purchase (the lead time is long)and therefore is to be considered that must be ordered with 3-4 years in advance.

4. Configuration and material management

4.1. Aircraft configuration management

The management of the aircraft configuration is very important, and therefore is necessary to follow the components and type of software installed on each aircraft. The resource/potential is to be monitored up to the scheduled /special inspections, including the defects found and changes made /or to be made on the aircraft. The engine components resource/potential is tracked using EMATS, a system provided by the Pratt & Whitney company, the manufacturer of the F100 family engines.

The maneuverable of F16 is a plus for the air-to-air combat and air-to-surface attack, but the relatively low-cost, high-performance weapon system implies a permanent maintenance activity for all mechanical organs and avionics. The works on aircraft are made by the authorized or qualified personnel (using TOs/work cards, the corresponding tools/devices and personal protective equipment), initiated by the opening Work Orders, and controlled by production inspectors. All the records are stored in the aircraft book (LOGBOK) and adjacent specifics documents, as well as digitally, inserted in the forms defined within the aircraft maintenance information system. Discrepancy reports are practically instantly used to send components for repair.

In the research, the possibility of using technical documentation (Technical Orders/ Workcards) in digital format at the airbases level, is being analyzed for both works: the ones performed at the flight line and for those performed at the hangar. For the level "I", engine maintenance, the Interactive Electronic Technical Manual (IETM) is directly used.

4.2. Materials management

Being procured by the air forces of 25 other nations than US, the F-16 becomes in 2024 the world's most common fixed-wing aircraft in military service, with 2,145 operational aircraft. That is an advantage for the common maintenance and procurement programs, reducing the diversity of the necessary spare parts, but on

the other hand the maintenance activity is specialized on distributed centers that implies an entire logistics for queuing the maintenance activities and creates also long waiting times for some specific parts. The management of materials (repairable and consumables) for aircraft maintenance, requires a great attention, by identifying as precisely as possible the necessary for materials, and purchasing them in a timely manner, storing them in appropriate conditions and distributing them just in time for the required interventions. The purchase of materials is done through Foreign Military Sales (FMS) or by direct commercial sales, knowing that the purchase /repair cycle of materials/repairable is quite large. For the effectiveness of materials management, a specific information system is used for materials management. To make even more effective the logistics/maintenance processes, some of the Lean Management principles are considered to be applied, some of them being already used successfully by the Portuguese partners. The bases of the Lean Management generally imply the elimination of waste (materials, time, money, etc.) and promote within processes the use of those operations/activities that are value adding. In essence, it means to achieve more with the existing resources or with less [15]. The implementation of these principles led to a significant reduction in the execution time of some works (especially phased inspections) and in the same time to an important decrease of the costs.

Due to the fact that the entire process is a complex one with many variables and implications from different kind of players, in figure 1, is intended to represent the overlap of the activities and the consistency of the decision line, by representing the main stakeholders who are involved at different levels and with different participation within the maintenance management logistics support for the Romanian new purchased aircraft.

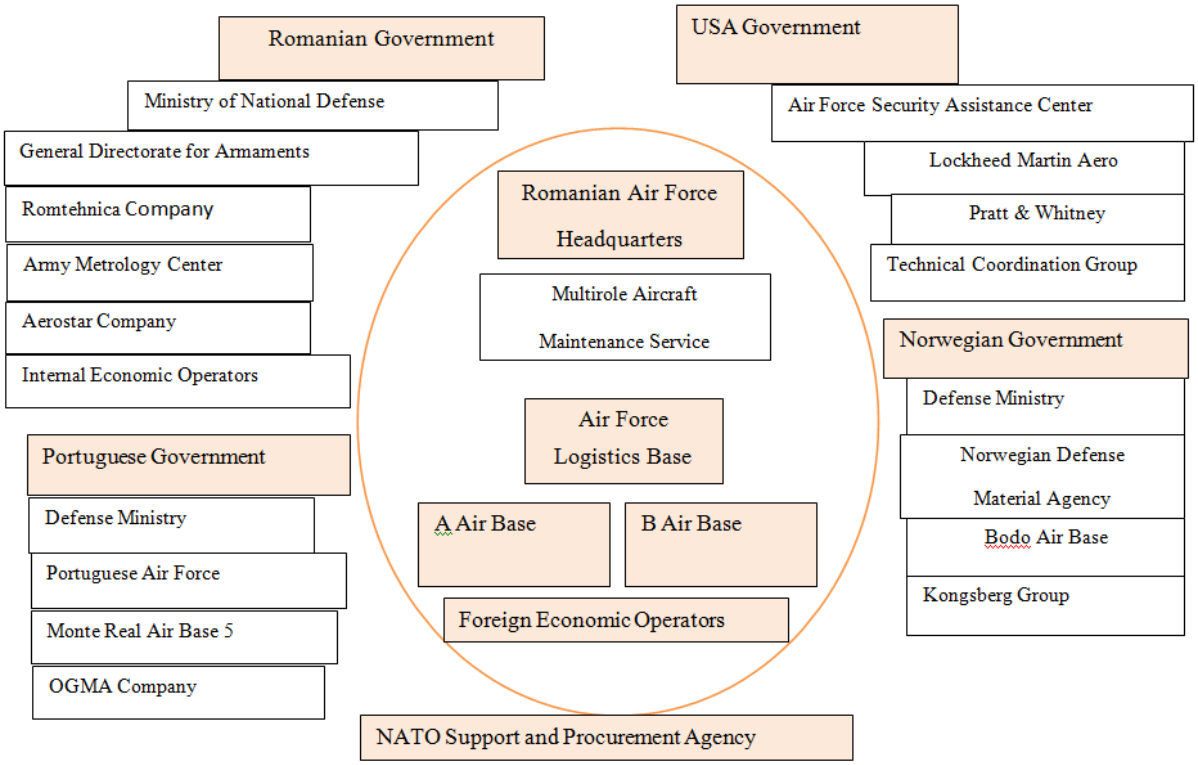

Figure 1: *Stakeholders*

5.Conclusions

The systemic approach of the maintenance processes transition for a single major type of aircraft to another single major type of aircraft is based on standard maintenance regulations and procedures. The implementation of a new maintenance system in the Romanian Air Force, imperative required for operating the new entered 4th generation aircraft that endowed the Romanian airbases, represented a challenge for all those involved in the process. Especially for the personnel at the beginning of their carrier that face with a lot of new and inexperienced elements, starting with the change of mindset in the way of understanding and applying the new maintenance logistics concepts and procedures, already successfully used in the Air Forces of the NATO member states that operate the same aircraft.

Beside the regular way of creating an implementation transition must be consider the Russian-Ukrainian conflict at the northern direct border of Romania, where Romania as a NATO and EU member and follower share some responsibilities.

A huge change in the responsibility and approach on larger distributed maintenance process starts with the receiving by the Ukraine of the first American made F16 fighter jets, that marks a crucial milestone in boosting the capabilities of Ukraine's air force, actually largely rely on old Soviet-era jets, but also the events will come and the interaction with the NATO and EU countries.

In spite of the fact that the number of existing and expected F-16s is unknown, the fact is that the Ukraine does not (yet) have enough trained pilots to fly the new generation of aircrafts and also no maintenance capability.

Some dedicated activities will be performed by and in Denmark, the Netherlands and the US, the provider countries but is assumed that similar role must be taken also by Romania as the most closed and prepared country for the pilots training, maintenance activities and maintenance training and transfer possibilities, but not parking them in the Romanian air force bases, especially that more F-16s are expected and hoped in the months ahead.

Theoretically around 65 F-16s have been pledged by NATO countries since US President Joe Biden first authorized willing European allies to send them to Ukraine in August 2023. But the new evolution of the pre-election program in the United States may add some changes on that. Still is to consider that F-16 was introduced in 1978 and many Western militaries are in the process of retiring the ageing fighters, replacing them with the US-made F-35, introduced in 2015. A particular exception is the UK that does not have any F-16s in its air force, but it is supplying long-

range Storm Shadow missiles which can be fitted to the jets, though it is supplying long-range Storm Shadow missiles which can be fitted to the F16 jets andwill work alongside with other western-supplied surface-to-air missile systems such as Patriot and NASAMS.

In May 2024, 10 Ukrainian soldiers had completed training for the F-16 aircraft maintenance in the Netherlands. The training included assembling and testing an emergency rescue package, servicing all the important parts for a fighter pilot, including oxygen systems, helmets, and parachutes on board.

As one of the most advanced single engine multirole fighter aircraft, the F16 is still in high demand, in spite of the price of about 19 million, being produced by General Dynamics and Lockheed Martin, with Turbofan GE F110 engine. Each aircraft needs a detailed maintenance at 300 flight hours or after 16 month depends on what came first. The regular inspections, repairing and replacements require about 16-18h of work for each hour of flight, that is the equivalent of about 60 man-hours per flight hour. That may lead to a maximum capacity of 75 operations before a detailed maintenance process, in total needing about 18.000 man-hours.

Important findings from first research in 2016, leads to the extension of the aircraft structural maintenance that reveals that non-destructive inspections may reveal earlier loose or sheared fasteners on the bulkheads that may lead to cracks in unexpected areas as the one of high stress. That kind of inspection leads to 75% of bulkhead replacement, a better situation then the one when cracks appear.

In conclusion, the pilots basically trust their lives to the military personnel who maintain the aircraft, the knowledge and skills of people that ensure that the aircraft is in working order and safe. Within the terms of the new international security environment, is emphasized the importance of implementing the "Multirole Air Force Aircraft" procurement program (aircraft, logistics support, equipment, training and infrastructure) at the established deadlines. The training programs must include both pilots and engineering teams. The major Ukraine F-16 maintenance will take place in Poland.

This major program for the endowment of the Romanian Air Force represents a special financial effort and a huge step in equipping the Romanian army with air combat capabilities at NATO standards. The 4th generation aircraft is a "sensitive prima donna" compared with former soviet era aircraft, including the landing gear. The high engineered new aircraft need much more maintenance.

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