Real Time Engine and Accessory Performance Monitoring Techniques for Fleet of Airline Company Using Selcall

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Abstract— The regularity of air traffic requires significantly increased volumes of information exchanges. This research aims to provide a synthesis of a network system based on satellite constellation to improve exchanging data information related to aircraft. This system allows monitoring engine parameters and associated equipment in real time in order to transmit any failure or anomaly to the maintenance center to anticipate scheduling of reparation. In addition to air navigation information which are needed by air operation to follow every flight and avoid latest and ensure the maximum regularity to aircraft throughout the entire globe. These information have to be transmitted to different ground centers.

Keywords- Data exchange aircraft maintenance, satellite constellation, engines parameters, engine accessories, selcall.

I. INTRODUCTION

The current tendencies are toward satellite systems [1] that provide permanent relays between ground stations and aircraft throughout the entire globe. To deal with the increasing aircraft number, the International Civil Aviation Organization (ICAO) proposes a system of air traffic navigation reliable, capacitive and global based on a concept called Communication Navigation Surveillance (CNS), a system of data link: Aeronautical Telecommunication Network (ATN) [2]. The systems currently used are the Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) [3] that provide position data standard for embedded systems to provide navigation position around the world. The current Air Traffic Management (ATM) procedures [4] are still based on VHF communications and claims for an improvement of ATM concepts. These challenges require the development of satellite communication, navigation and surveillance systems, aiming at providing high reliability and availability system.

Engines are the vital element in aircraft, they provide thrust, and electrical, pneumatic and hydrolic energy therefore monitoring techniques aircraft engine performance in real time in flight and on ground are required. Monitoring of engine parameters is very important because it allows to company to anticipate maintenance by logic and priority programming. This allows avoiding nail aircraft on the ground for long period of time. This process is used by NASA [5-6] to monitor the parameters of the fuse during launch. Effective control of engine accessory is also connected with integration of motor control with aircraft control. This requires new methods for analysis and design of control systems. However, in this paper we will focus on the application of real time methods for aero engine control.

Previous literature have proposed various system and techniques to control engine's parameters. In [7], an automatic system proposed to control an aircraft jet engine's rotation speed, through the fuel injection's control, based on a constant pressure chamber. Concerning flight information, an Automatic Dependant Surveillance Broadcast sysem (ADS-B) [8] was proposed for transmitting aircraft flight data based on satellite constellation. The objective of the work presented in this paper is to develop and investigate algorithms of multivariable engine's parameters control with real-time optimisation of control laws and algorithms. Our sytem is presented in "Fig.1".

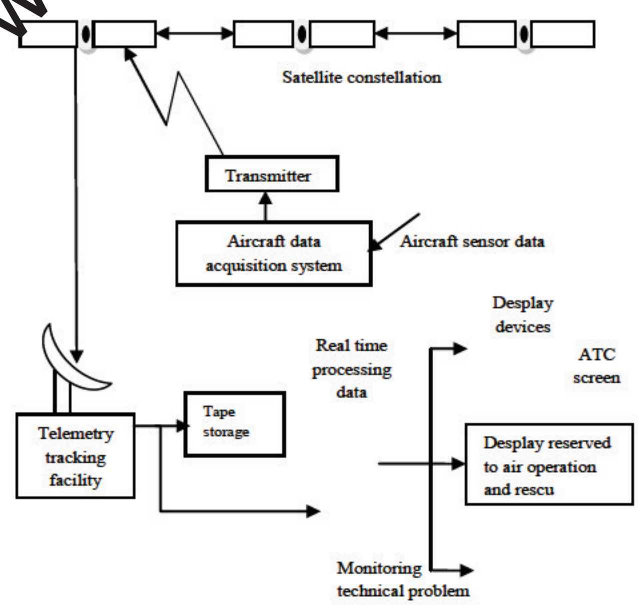

Figure 1. Real time data acquisition system

This paper is organized as follows: Section 2 presents the data model and lists the assumptions and some preliminary notions. Section 3 presents the design of the information system and Section 4 is reserved to discuss the model and the last Section will be the conclusion.

II. Data Model and Preliminary

The engine failure data can be modulated and transmitted by differential phase [9] DPSK (Differential Phase Shift Keying), or by using the ADS-B (Automatic Dependent Surveillance). It should be noted here that this process is available and should be adopted worldwide for the data link ADS-B. According to the ICAO requirements; it must meet the following constraints presented on Table 1:

TABLE 1. Structure of Transmitting Data

Time (μs)	$t \le 0$	$0{,}1 \le t \le 0{,}5$	$t \ge 0{,}6$
p (t)	0	1	0

$$\widetilde{b} = [1,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0,b_1,b_2,.....b_N] \quad (1)$$

The information will be coded and transmitted as:

$$b(t) = \sum_{n=0}^{N} \widetilde{b}(n).p(t - \tfrac{1}{2}nT) \quad (2)$$

Where $\widetilde{b}(n)$ is the N^{th} input, and $T = 1\mu s$ is the period of one pulse.

A. Engine and accessory data

The motors and auxiliary power unit (APU) are also monitored during the flight [5-6]; the sensors continuously record the engine parameters. If a fault occurs, even a fuselage crack expressed by pressure drop, it is immediately sent to the maintenance center. The aircraft real-time situations are displayed directly on a screen. This technique is based on using the selcal of each aircraft. A selcal is a code of four letters assigned to aircraft by the constructor; this code is unique and unchangeable during the life of an aircraft "Fig. 2".

In the past, the classical control systems of engines were implemented mainly by hydro-mechanical elements, which however suffered from some problems for such systems, such as high mass of such systems, inaccuracies due to mechanical looses and low count of regulated parameters. However development of electronic systems and related elements is continuous, which will allow to increase accuracy of regulation of parameters of engines and their count to secure more precise control of engines.

The main global aim of control of turbojet engines [10] is to follow the functioning of the engine and be aware of any problem at the beginning and repair it as soon as one has the possibility of having the aircraft in the hangar. Many thermocouples, vibration sensors are installed on the engine for health monitoring of the thrust vectoring system.

Accessory gear box is important element which must be controlled and it contains the following elements:

- Integrated drive generator (IDG)
- Oil, Fuel and Hydraulic pumps
- Constant speed drive (CSD)

A CSD is used to drive mechanisms, typically electrical generators that require a constant input speed. Each engine has an AC generator. The CSD is the link between the generator and the engine. The generator has to turn at 6,000 RPM. Since the jet engine gearbox speed varies from zero to full power, this creates the need for the CSD.

Each engine is controlled by an engine electronic control (EEC). The EEC uses the thrust lever position and environmental inputs to control the engine's thrust. Primary engine parameters are:

- Exhaust Gas Temperature (EGT) which is a measure of the temperature of the gas exiting the rear of the engine.
- Engine Pressure Ratio (EPR): is a measure of thrust provided by the engine.
- N_1 is the low pressure rotor.

Secondary engine parameters are:

N_2 is the high pressure rotor, fuel flow, oil pressure, oil temperature, oil quantity, and engine vibration.

We will now look at new indications for non-normal conditions, if a previous parameter value goes above or below an operating limit; the flight management computer (FMC) automatically sets it to be transmitted to maintenance center and displayed in real time on screen as shown in "Fig.2".

7T-VJW KPCS	A330	7T-VJV KMBS	A330	7T-VJX KPER	A330
7T-VJG KMBS	B767	7T-VJQ HLDP	B736	7T-VUI EFBL	ATR 72
7T-VUJ EFDM	ATR 72	7T-VJJ DHFP	B738	7T-VJK HKLP	B738
7T-VJP HLBS	B738	7T-VKA BCEL	B738	7T-VKJ EQGH	B738

Figure 2. Display the fleet with the state of aircraft on screen

B. Air operation service data

Fuel weight is important information because, aircraft weight and balance [11] is done by operators and independent handling companies. They use loadsheets which actually consist of two parts: the weightsheet to determine all limiting weights and the trimsheet to determine the trim capabilities of the airplane and the position of the Center of Gravity (CoG). A weightsheet is used to determine the weights as fuel and payload, and is located on the entire left side of the loadsheet, "Fig.3". The next box contains payload information about passengers and freight and its distribution are put in this document.

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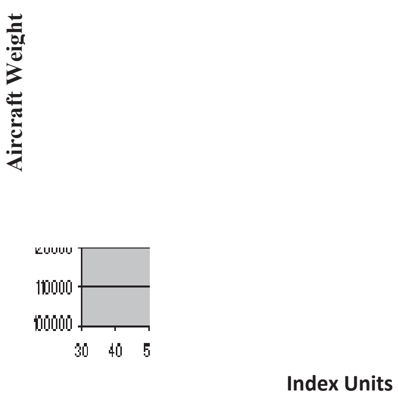

Figure 3. Load and trim sheet software

Making a loadsheet requires having the real weight of fuel at the appropriate time, maximum weights and operating weights are items preprinted on a weightsheet. With these weights and payload weights, the actual weights can be determined. Alternate fuel is not present on a weightsheet as it is already included in the block fuel. When taxiing to from stand to the runway, taxi fuel will be used. The block fuel minus the taxi fuel is the take-off fuel. Fuel used during the trip is called trip fuel. Aircraft are limited by strength and airworthiness requirements, therefore maximum weights are established. The most important are: Maximum Zero Fuel Weight (MZFW), Maximum Take-Off Weight (MTOW) and Maximum Landing Weight (MLW). The MZFW is the maximum weight of the aircraft without fuel. The MTOW is the maximum weight allowed before beginning take-off. A landing demands high loads to the landing gear, so the MLW is applied. Once the pilot or operator is sure the aircraft does not exceed any weight limitations it is necessary to conduct a trim analysis in order to calculate the location of the CoG. The operations must have the real fuel quantity on time by transmitting this information automatically from aircraft to air operation center via satellite. They can fill in the loadsheet as soon as possible and the aircraft can take off on time.

C. Information for search and rescue services(SAR)

Aircraft in emergency must announce the expression PAN or MAYDAY according to the problem faced. Three codes help to evaluate the situation and notify the aid in getting you to the nearest airport. These are the 3 squawk codes which every pilot should commit to memory:
7500 = Aircraft Hijacking
7600 = Lost Communication (radio failure)
7700 = Emergency

Many different types of search and rescue [12] patterns are available to SAR units and in conjunction with the Coordinator Surface Search (CSS) an appropriate pattern to suit the conditions would be put into operation. Most of the following examples are suitable for either air or surface units. The majority of searches take place within defined limits, depending on the target's capability and endurance. Individual search units are usually designated a specific area and the navigator will need to plot these extreme boundaries before instigation of the pattern.The sector search pattern is employed when the position of the target is known with reasonable accuracy and the search is over a small area, as in manoverboard.

D. Management of emergency situations

In case of an emergency, the pilot of an aircraft must transmit emergency messages under any circumstances. An emergency application would typically be a voice communication initiated by the pilot or an emergency data message containing details of the incident. This transfer can be realized by a simple switch to a different programming which gives absolute preference to safety-related applications and does not serve any other applications. The change of the resource management policy can be initiated by the pilot a dedicated control panel. To reduce the time needed to receive capacity assignments for the transmissions, a selcal frame "Fig.2" could always be reserved for emergency communication. These time slots can be allocated permanently.

III. ASSIGNING PRIORITIES TO TASKS AND INFORMATION

The use of communication networks in modern aircraft in real-time applications is rapidly increasing. Although the communication device adds a critical resource to the system, the approach for a real-time application is the main key to handle the complexity of a large system and to improve fault tolerance in safety critical applications. These applications are composed of information, that are communicated by transmitting messages across a communication system. In such application domains, a distributed real-time application is an application that must return coherent results in a short delay, namely a strict timing constraint.

This priority-based [13] total order broadcast service can be used to prioritise different types of aeronautical data, for different purposes. For instance, consider a distributed application that controls the operation of some facilities that include both critical and noncritical information systems. Messages sent to critical systems can be prioritised over messages sent to non-critical systems, by means of a priority-based total order broadcast protocol [14]. The system we consider is composed of a set of processes.

A. Information system logic functions

The information system logic is based on three basic concepts: the priority test such as emergency information has the first priority, and second one is assigned to airliner data"Fig.4".

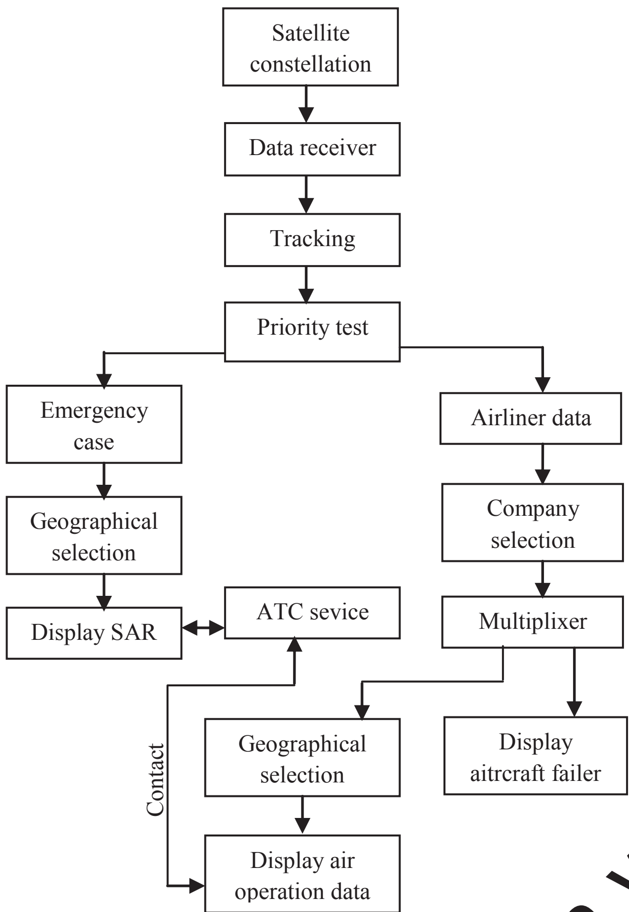

Figure 4. Information system logic functions

Second concept is the geographical selection in order to receive information about aircraft flying in specific area. The third concept is the company selection which is based on selcal, a specific unchangeable code formed by four letters is assigned to each aircraft by the constructor, in order to receive information concerning every aircraft which a given company processes. Although the parameters are strictly defined, the variety of received information makes prediction of exact behavior in real time.

B. *Algorithm for real time communication*

In this section we show an algorithms for real time communication [15] that implement the priority-based total order broadcast service, The priorities of messages are static such that multiple priority levels are used to guarantee the importance of emergency messages. This technique is uesd in the Aeronautical Fixed Telecommunication Network (AFTN) where priority indicators are used depending on the messages category. So messages with priority indicator *SS* have the highest transmission priority. The following algorithm presents the the priority sequencing class of messages.

```
Begin
Initiator
Loop forever
If (new message M arrives) then
Record it and check the priority prefix;
                Procedure TO-broadcast (M, prio):
endif
Parallel: when receive (M):
Record M in incoming, and send it to destination according to prio (M)
If (there are high priority messages)
Send Mi to SAR and do selection position;
else if (there are normal priority messages)
Send Mi to ATC and do selection position;
else if (there are low priority messages)
Send M to maintenance and air operation and do selection fleet;
Sending the message via each communication line to which it is attached
else (ready queue is empty and normal priority messages are pending)
Send REQ M to the repeater;
endif
end Loop
```

C. *Constellation design*

The satellite constellation is designed to provide links to important data. The overall architecture is studied taking into account the requirement to use the standard SSR transponders mode S and it necessitates the use of low earth orbit (LEO Low Elevation Orbit) [16-17] with a height of 1500 km; we use a constellation based on the low polar orbits. We use four low polar orbits, the angle between two successive orbits is 45° and each orbit contains ten satellites. We use also five satellites distributed on the low equatorial orbit ELEO (Equatorial low Earth orbit), and so 45 satellites are used in this constellation. The satellite orbits are defined as in the following table :

TABLE 2. ORBITS LOCALISATION

	Orbit				
	Polar				***Equatorial***
	1	2	3	4	5
Longitude	000°/ 180°	045°E/ 135W°	090°E/ 090°W	135°E/ 045°W	
Latitude					00°
Nomber of Satellites	10	10	10	10	5

The constellation satellite requirements [16] of worldwide coverage with a small, lightweight user handset resulted in a system design using a LEO satellite constellation. The important advantages associated with LEO satellites are lower required transmit power, a lower propagation delay, and polar coverage. The velocity of a LEO satellite relative to the earth is given by (3), where *W* is the earth angular rotation speed, Rg is the GEO satellite orbit radius, and $R_1=R+H$ is the LEO satellite orbit radius.

$$V_1 = \frac{WR_g^{3/2}}{\sqrt{R+H}} \quad (3)$$

The angular rotation of the earth is calculated using the following equation.

$$W = \frac{2\pi}{24} = 0.2618 rad/hour \quad (4)$$

The orbital radius of the satellites is calculated by adding the equatorial radius of the earth, 6378 km, to the satellite altitude. This results in values of Rg = 42178 km and R_1 = 7878 km. The velocity of a LEO satellite relative to earth is calculated as V_1 = 25550 km/h using (4). The satellite constellation parameters result in an orbital period of 116.2 minutes. The satellites weight is approximately 900 kg.

IV. Discussion and Expected Advantages

The good strategy of the aircraft and engine characteristics, aimed by the Europeen organisation JAA (Joint Aviation Authorithies) and the American FAA (Fédéral Aviation Administration), is of the great importance in order to get the system capable of performing certain air tasks with the minimum expenditure energy, This approach consists in developing additional information tecniques in order to develop the business of commercial aviation.

A. Maintenance type used

The type of maintenance used in this model: firstly is conditional preventive maintenance which is subject to a predetermined type of event (information of a sensor, information collected in real time). It is called sometimes predictive maintenance. Second type is corrective maintenance which is maintenance performed after partial failure of an organ.

To be effective, the method of service proposed must in all cases be understood and accepted by airliner managers and have membership of all staff. These methods should be as far as possible standardized between different sectors (air operation and maintenance). With current developments and trends in materials to be more reliable, proportion of accidental failures can be better controlled. Preventive maintenance decrease quantitatively in a systematic way but will improve qualitatively the conditional maintenance. Preventive maintenance, experimental and subjective yesterday, today tends to be more scientific.

B. Expected advantages

The adoption of this system allows the realization of the following objectives:

- Transformation on a global scale
- Optimizing air operations around the world
- The first ever-space-based global aviation surveillance system from a visionary new company
- The control of all aircraft in real time across the entire planet.
- Global aircraft monitoring and management with limited capital investment.
- Billions in fuel savings.
- Operational efficiencies.
- Reduced green house gas (GHG) emissions for the protection of our planet.
- Enhanced air safety.
- Promote global harmonization.
- Avoid nailing aircraft on ground.
- Safety of air transport is more optimized
- Improvement of search and rescue operations

V. Conclusion

It has been shown in previous chapters that the satellite technology used to implement different constellations of data, as these constellations are so important, they are necessary to allow the development of real time analysis and control techniques. This requires careful integration of the aircraft data acquisition and related systems to transmit different information to ground stations.

This research may be considered as generic model for aerospace communication where most aeronautical services are served by the same constellation to improve safety and regularity of aircraft. Thus, we recommend the use of this technique by all airlines to avoid serious damages, explosion engines and nailing aircraft on ground.

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References

[1] G. Galati, G. Perrotta, S. Gentile, R. Dellago, and F. Lanari, "Advanced satellite system for Communication navigation and surveillance," *Presented at workshop on Air traffic management ATM 95*, Capri, Italy, 1995.

[2] Annex 10 to the convention on international civil aviation *Aeronautical telecommunications* Volume IV, *Surveillance and Collision Avoidance systems,* Fourth edition, Ch 4, pp: 4-1.4-23, 2007.

[3] I. Bisio, and M. Marchese, "Analytical Expression and Performance Evaluation of TCP Packet Loss Probability Over Geostationary Satellite", *IEEE COMMUNICATIONS LETTERS,* Vol. 8, NO. 4, pp. 232-234, 2004.

[4] G. Galati, G. Perrotta, S.D. Girolamo, and R. Mura, "Space-Based SSR Constellation for global air traffic control", *IEEE Transactions on Aerospace and Electronic Systems,* Vol. 32, NO. 3, pp. 1088 – 1106, 1996.

[5] J.S. Ronald, W.B. Frank, and H.G. Donald, "Flight determined benefits of integrated flight propulsion control systems," *NASA technical Memorandum 104239*, September 1991.

[6] F.R. James, W.H. John, and D.W. Keith, “Real-time in-flight engine performance and health monitoring techniques for flight research application, *NASA technical Memorandum 4393*, June 1992.

[7] N.T. Alexandru, “Hydro-mechanical jet engine’s speed controller based on the fuel’s injection pressure’s control,” *WSEAS TRANSACTIONS on SYSTEMS Avionics Department, Faculty of Electrical Engineering, University of Craiova.*

[8] S. Rajesh, A.C. Raghavan, and P.O.H. Brook, “Performance Analysis of 1090 MHz Automatic Dependent Surveillance-Broadcast (ADS-B) Using Opnet Modeler,” *0-7803-7367-7/02 IEEE*, pp. 3.E.6-1-3.E.6-11, 2002.

[9] C. Kevin, K. Cheolhwan, and L. Guifang, “All-optical regeneration of differential phase-shift keying signals based on phase-sensitive amplification,” *OPTICS LETTERS* 29, pp. 2357- 2359, 2004.

[10] P. Wygonik, “Influence of basic turbofan engines parameters on multi purpose aircraft maneuvers indexes”, *Journal of polish CIMAC.*

[11] G.W.H. Van, “Analysis of aircraft weight and balance related safety occurrences,” *National Aerospace Laboratory NAL*, 2007.

[12] Annex 12 to the convention on international civil aviation, *Search and rescue*, Eighth edition, Ch 2, pp. 2-1.2-2, 2004.

[13] M. El Richard, P. Richard, and F. Cottet, “Task and message priority assignment in automotive syetems,” *Laboratory of Applied Computer Science, ENSMA.*

[14] E. Miedes, and D.M. “Francesc, Adding priorities to total order broadcast protocols,” *Instituto Tecnologico de Informatic, universidad politecnica de* Valencia, 2007.

[15] O.D. Lyantsev, T.V. Breikin, G.G. Kulikov, and V.Y. Arkov, “Numerical algorithm for optimal multi-variable control of aero engines,” *Department of Automated Control Systems, Ufa State Aviation Technical University*.

[16] R.P. Stephen, A.R. Richard, J.E.F. Carl, and A.T. Micheal, “An operational and performance overview of the IRIDIUM low earth orbit satellite system,” *IEEE Communications Surveys*, pp. 2-10, 1999.

[17] Jun, Z.Y.L., Qian, S., Yong, J. and Yanlang, H. (2011) Topology Control Strategy of LEO Satellite Constellation Based on Optimal Polar Boundary, *978-1-4577-0321-8/11/ IEEE,* pp.4605-4608.