SAFE AUTOMATIC FLIGHT BACK AND LANDING OF AIRCRAFT
FLIGHT RECONFIGURATION FUNCTION (FRF)

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Abstract
SOFIA (Safe Automatic Flight Back and Landing of Aircraft) project is a response to the challenge of developing concepts and techniques enabling the safe and automatic return to ground in the event of hostile actions. Activities in this sense have been started in the framework of the SAFEE SP3 (Secure Aircraft in the Future European Environment Sub-Project 3) project. SOFIA project is proposed as the continuation of the SAFEE works on FRF (Flight Reconfiguration Function), the system to automatically return the aircraft to ground. SOFIA will design architectures for integrating the FRF system into several typologies of avionics for civil transport aircraft; development of one of this architectures; validation, following E-OCVM (European Operational Concept Validation Methodology) of the FRF concept and the means to integrate it in the current ATM (Air Traffic Management); safety assessment of FRF at aircraft and operational (ATC-Air Traffic Control) levels.

The SOFIA product is the FRF system that will take the control of the aircraft and will manage to safely return it to ground under a security emergency (e.g. hijacking), disabling the control and command of the aircraft from the cockpit. This means to create and execute a new flight plan towards a secure airport and landing the aircraft at it. The flight plan can be generated in ground (ATC), or in a military airplane and transmitted to the aircraft, or created autonomously at the FRF.

1. Background
Europe is already researching in this area, taking benefit from the 6th Framework Programme sponsored by the European Commission (EC) [1]. Within such initiative several projects, participated by key European companies in the sector, are currently investigating in the FRF arena, e.g., the SAFEE and the SOFIA projects. These projects are the response to the EC concerns regarding the aviation security. Such concerns are derived from the results achieved by the Advisory Council for Aeronautics Research in Europe (ACARE) group. These results conforms the VISION 2020 and are presented in the ACARE Strategic Research Agenda (SRA2) [2]. The SOFIA outcomes rely in the SAFEE project results.

Meanwhile the SAFEE project provides the aircraft with the capacity to detect the on-board hostile action and perform a diversion to take the aircraft up to a secure area, the SOFIA project controls the aircraft autonomously and lands it on a secure destination [3].

The FRF developed in the SOFIA project is the response from several leading European companies to the demand from the society of improving the security of the aircraft operation. And the improvement is gotten in an autonomous way, as requested in the ACARE SRA2 [2]. The SOFIA project also analyses the integration into the airspace of such airplane flown by the FRF system and the requirements imposed to the ATC system, and assessing the regulatory and certification implications of this new development.

Figure 1: SOFIA Scope

The SOFIA project consortium is composed of the following partners: Isdefe (coordinator), Deutsche Flugsicherung, GALILEO Avionica, Skysoft, Alenia SIA, THALES Avionics, Instytut Lotnictwa, Rheinmetall Defence Electronics and Diamond Aircraft Industries.

2. SOFIA Development
As stated above, the overall objective of the SOFIA project [3] is the design, development and validation of the Flight Reconfiguration Function system and the assessment of its integration into the airspace. SOFIA is mainly a technological project, with a strong technical component, but it also considers the operational aspects are relevant enough.
SOFIA follows a stepwise approach in its development. It is formed by four main interrelated steps. Thus, the results achieved in one of the steps are inputs for the next ones, enabling a clear continuation of the activities. These steps and their current status and outcomes are described hereafter.

2.1 Step 1: Assessment of the operational issues

The main goal of this step is to define the future FRF environment, and thus prospects forthcoming avionics architectures considering in particular what can be expected for the features relevant to FRF, which are around Flight Control and Management and air-ground communication. Furthermore, the task studies the ATM environment that can be expected for the timeframe for the FRF implementation (initially 2025), in order to define, together with the modalities of the FRF, the integration into that environment and the procedures required for the management of FRF-controlled aircraft flying autonomously in the airspace.

The environment for the FRF operation has been defined in accordance with the development currently taking place in the framework of the Single European Sky initiative. Hence, Airborne Surveillance Assistance System (ASAS) and its applications based on air to ground and air to air data links enabling the negotiation of trajectories 4D are the backbone of the ATM system of the future. Three possible solutions have been defined for the operation of the FRF system:

- Flight Replanning Without Negotiation: The flight plan is autonomously generated by FRF and automatically flown by it.
- Flight Replanning With Negotiation: The flight plan is negotiated between the FRF and the ground services and automatically flown by the FRF.
- Military Aircraft Relay: The flight plan in generated by a military aircraft.

For these three solutions of operations, they have been designed operation procedures, modes of transition, controllers tasks and, finally, it has been identified the need of a ground centre to manage such crisis, a so called, Ground Security Decision System (GSDS). The procedures considers the operation in degraded modes, e.g. data link out of service. The preference for one of these three solutions will be a consequence of further assessment to be carried out in the next steps, mainly considering the results from the safety assessment and from the validation exercises.

A special focus is given on the regulatory and certification issues to which FRF integration gives rise. The applicable regulations for the air and ground segments have been selected and assessed. For this assessment, SOFIA considers the security-related circumstances under which the autonomous flights occur. A large set of norms and standards published by International Civil Aviation Organisation (ICAO), European Aviation Safety Agency (EASA), Federal Aviation Administration (FAA), European Commission (EC) and Joint Aviation Authorities (JAA) have been analysed:

- For the Air Segment, ICAO Annexes 2 and 6 (Parts I & II), JAA JAR-OPS –1, FAA CFR-14 (Parts 91, 121 and 135), EC Regulation 1702/2003 – Part 21, EASA CS-25, EASA CS-AWO, EASA CS-ETSO.
- For the Ground Segment, Eurocontrol Safety Regulatory Requirements 5 (ESARR), EC directorates for the Single European Sky, and national regulations based on ICAO Annexes and Manuals.

The points assessed are compliance with laws, regulations, rules and procedures, pilot in command responsibility and procedures, collision avoidance, communications with ground, training, aircraft maintenance, security, certification of the system and impact on related avionics equipment.

As outcome from the assessment, it is determined that the FRF system will have a major impact on the air segment regulatory and certification frameworks than in the ground ones. The most conflicts arise due to the fact the pilot is not on the loop when the FRF is in control of the aircraft, and hence, tasks only supposed to the pilot can not be afforded.

2.2 Step 2: Design of the FRF System

Its main goal is to specify the FRF system and its integration into different avionics architectures that can be expected for the future.

As most of the FRF-implied automation modes are expected to be already present in future aircraft, SOFIA more specifically addresses the solutions allowing this automation and the associated mode transitions to be performed autonomously with no possibility for a malevolent onboard to intervene. This has lead SOFIA to focus especially on FRF interfaces to existing systems, and to perform specific in depth safety analyses to define an architecture that fits all of the needs and constraints. SOFIA in particular has studied the autonomous flight replanning function with the associated monitoring function, and the interfaces to available onboard surveillance systems which provides the means to detect various threats (equipment failure, terrain, traffic or weather hazard) and to autonomously make decisions about flight plan update.

The design process has been run in parallel to the regulatory, certification and safety assessments, with direct feedback among all of them. With this process SOFIA aims to create the most realistic design of the FRF systems not only for functional aspects but also safely operable and as much certifiable as possible. The functions that have been designed in this activity are:
• FRF Decision Centre Function (DCF), that manages the FRF initialization, the FRF modes and the system interfaces
• Health Monitoring System Interface (HMS), that gather data from systems critical to the operation of the FRF, and perform corrective actions in case of failure
• Route Planning and Static Flight Monitoring (RPL), that generates a suitable flight path to a secure landing airfield
• Guidance Management and Leg Management (GLM), that evaluates the correct compliance of the flight plan
• Route Re-planning (RRP), that varies the flight plan when needed
• Dynamic Flight Monitoring (DFM), that monitors the performance of the aircraft and monitors conflicts with terrain or obstacles, aircraft and weather
• External Communication (COM), that generates the data to be sent to ground
• Display Management (DSM)

Complementary to these functions, a set of data bases to support the FRF functions is also being designed:
• A general database addressing terrain, obstacles, airports, PSA, flight plan calculated by the FRF, airport selected as destination, traffic data from ADS-B and weather data.
• An aircraft performance parameters database.
• A navigation database with routes, waypoints, procedures, airports, etc, directly taken from commercial products, e.g., Jeppessen and completed with airline specific data.

The development of both functions and data bases follows will comply with the adequate levels of the DO-160D standard. Such levels are being determined with the safety assessment being performed following the SAE ARP 4761.

2.3 Step 3: Development of the FRF System

Its main goal is to develop the FRF functions for their validation and set up the simulation environments that allow FRF functional validation to be performed according to the objectives and requirements set out in the SOFIA validation plan. The task includes the adaptation of already available flight simulator components and the development of appropriate new mock-ups components in order to get functional test beds ready for the FRF validation. Six validation platforms are used in the SOFIA project:
• ATENA, flight simulator developed by GALILEO Avionica.
• Cabin simulator developed by THALES Avionics.
• UAV simulation platform developed by THALES Avionics.
• DFS ATC simulator.
• IoA’s I-23 Manager aircraft.
• Diamond Aircraft Industry Twin Star DA42 aircraft.
This step started in October 2007 and runs until January 2009.

2.4 Step 4: Validation of the FRF System and its integration into the Airspace

Its main goal is to perform the validation experiments envisaged for the SOFIA project to assess, first whether the design of the FRF system is capable of supporting the functionality required and second, the operation of FRF system integrated in the ATC procedures as proposed by SOFIA. The validation exercises follow a validation plan elaborated according to the European Operational Concept Validation Methodology (E-OCVM).

The validation of FRF will be only made on the solutions FRF With Negotiation (FRF_N) and the FRF Without Negotiation (FRF_WN). To carry out the validation, five experiments are proposed according to a stepwise strategy to feed back the development phase with validation results from a first set of validation exercises, to refine the design and development of the FRF:
• A preliminary validation of the FRF functions will be carried out during the development phase. The ATENA simulator is linked to the DFS ATC simulator. This experiment is focused at refining the FRF functions, particularly the assessment of the FRF functions and its integration into the airspace. The option Flight Re-planning With Negotiation will be assessed.
• A flight trial is executed during the development phase to refine the development process by using an aircraft provided by the IoA. This trial is focused at the assessment of the Flight Re-planning Without Negotiation mode.
• A validation exercise is run in the THA UAV simulation platform to assess the feasibility of the FRF solution for the UAV world. The SOFIA validation cycle is presented in the Figure 2. Such figure shows the linkages among the validation exercises, how they are used to refine the FRF versions.
developed in the project, and what validation platforms are used in each exercise.

Figure 2: SOFIA Validation Cycle

The validation objectives are those related to the demonstration of the FRF concept reliability in realistic environments: Issues relative to the appropriateness and feasibility of the FRF operational modes, evaluation of the impact on the ground segment (ATCO work load, flight plan creation on ground), cross checking and execution of the flight plan and landing of the aircraft by FRF that are to be assessed in SOFIA.

This step will start in November 2008 and runs until July 2009. By November 2008, the preliminary validation will start with the DFS-GAL validation trial, followed by the IoA one. The outcomes from these two validation trials will be used to improved the design of the FRF system and create a version 2 to be tested in the second set of validation exercises. This second set will start in May 2009 with the THA exercises followed by the DFS-DAI one. Initial results are expected by the early 2009 and the final results are expected at the end of the project, September 2009.

3. SUMMARY AND CONCLUSIONS

The FRF system is proposed as countermeasure to terrorist, hostile actions that aims to use the aircraft as a mean to affect asserts on ground. The affection can be implemented in different ways: crashing the aircraft, using it to propagate biological or chemical agents, or to multiply the effects of the explosion of a mass destruction weapon on-board the aircraft. As a response to this challenge, SOFIA project [3] develops the FRF system that enables the safe, automatic and autonomous return to ground of an airplane in the event of hostile actions. To carry out this action, the FRF disables the control and command of the aircraft from the cockpit, creates and executes a new flight plan towards a secure airport and lands the aircraft at it. Regarding the generation of the flight plan to be executed by the FRF, several options are considered in the SOFIA project: The flight plan can be generated in ground (ATC) or in a military airplane and transmitted to the aircraft, or created autonomously at the own FRF system. Additionally, the SOFIA project investigates the integration of such solution into different airspace environments: current ATM, ASAS/ADS-B, automation of ground functions, airspace with/without radar coverage, Collaborative Decision Making (CDM), 4D trajectory negotiation. Finally, SOFIA project also analyses the impact of the regulatory and certification frameworks into the FRF system and vice-versa, first, to constrain the FRF design to such frameworks and second, to propose new procedures and standards to facilitate the technological development.

The FRF system developed in the SOFIA project proposes a solution to one of the biggest challenges of the future aviation: to make the aircraft more secure by themselves. But it also introduces some interesting questions that will have to be solved before these systems starts to operate, in order to guarantee the security introduced by them:

- Who is responsible of the management and upgrading of the FRF data base?
- Who is responsible of uploading and upgrading the FRF data base into the airplanes?
- Who is responsible of the designation of the airports capable of dealing with the foreseen threats? And furthermore,
- Who is responsible of designating to what airport an FRF aircraft is to be deviated?
- Who is responsible of the aircraft when it is flown by the FRF system?
- What is the responsibility of the Air Traffic Control system, and particularly of the Air Traffic Controller, when dealing with an FRF airplane?
- Who is responsible on ground of generating the new flight plan for the FRF aircraft?

4. REFERENCES