Project no.: FP6-2005-AERO-1 (Call 3A)-AST5-CT-2006-030911

SOFIA

SAFE AUTOMATIC FLIGHT BACK AND LANDING OF AIRCRAFT

Instrument: STREP (Specific Targeted Research Project)

Thematic Priority: AERO-2005-1.3.1.3d Aircraft Security

SOFIA Final Publishable Activity Report

Due date of deliverable: 15/02/2010 **Actual submission date:** 15/02/2010

Start date of project: 01/09/2006 **Duration:** 40 months

Organisation name of lead for this deliverable: <Organisation Name>

Revision: 1.0

Approval status		
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17/03/2010	18/03/2010	30/03/2010

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Document Change Log				
Revision	Edition Date	Author	Modified Sections / Pages	Comments
1.0	30-03-2010	Juan Alberto Herrería/ Jorge Bueno	All	First version of the Final Publishable Activity Report

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1. Publishable Executive Summary

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1.1. Abstract of the SOFIA Project

1.1.1. SOFIA Concept and Objectives

SOFIA 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 were started in the framework of the SAFEE SP3 project. SOFIA project is proposed as the continuation of the SAFEE works on the Flight Reconfiguration Function (FRF), the system that automatically returns the aircraft to ground.
SOFIA aim is to design architectures for integrating the FRF system into several typologies of avionics for civil transport aircraft; development of one of this architectures; validate (following E-OCVM) the FRF concept and the means to integrate it in the current ATM; assess the safety of the FRF at aircraft and operational (ATC) levels (applying ESARR).

The SOFIA product is the FRF system that takes the control of the aircraft and manages 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 mean that the FRF creates and executes a new flight plan towards a secure airport and lands the aircraft at it. The flight plan can be either generated on ground (ATC) or in a military airplane and transmitted to the aircraft or even created autonomously by the FRF system itself. The execution of the new flight plan is autonomously performed by FRF without any command and control from ground and also allows to perform aircraft rely procedures with a military aircraft.

Additionally, SOFIA investigates the integration of such solution into current and future airspace.

Finally, SOFIA validates FRF by using several validation platforms comprising an ATC simulator and the ATENA flight cabin simulator linked, the Airlab™ test bed and the DA-42 flight simulator on ground, and by performing flight trials with two real aircraft (I-23 manager and DA-42 Twin Star).

SOFIA is mainly a technological project, with a strong technical component, but it also considers the operational aspects are relevant enough. For this reason, SOFIA dedicates an important effort in assessing the operational issues related with the integration of the FRF system into the airspace.

The SOFIA consortium is a well balanced and skilled set of 9 organizations comprising Avionics and Aircraft Manufacturers, Air Navigation Service Providers, Research Centres and Consultancy Companies. The project is coordinated by ISDEFE and participated by DFS, Galileo Avionica, Alenia SIA, Skysoft, THALES Avionics, Instytut Lotnictwa, RDE and Diamond Aircraft Industries

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1.1.2. SOFIA Steps to achieve the Objectives

The final aim of the SOFIA project has been to validate the Flight Reconfiguration Function system and to assess of its integration into the airspace. SOFIA is mainly a technological project, but also dedicated an important effort in assessing the operational and regulatory issues related with the integration of the FRF system into the airspace. The operational assessment approach was not only a theoretical study but also practical since the validation exercises considered the interaction of FRF with the airspace.

Taking the fact of the clear symbiosis between the FRF system and the Unmanned Aerial Systems (UAS), SOFIA considered the UAS development and progresses as a constant reference in the project. This reference was not only present in the operational aspects, but also in the technological ones that enables the integration of the UAS into the airspace. For a few years, works are focused on the operation of UAS in non-segregated airspace, and in particular on the “sense and avoid” concept, that will enable to detect any other aircraft, and therefore to define and fly the appropriate trajectory permitting the collision avoidance.

SOFIA follows a stepwise approach in its development, formed by four main interrelated steps, facilitating a clear continuation of the activities. SOFIA is split in four main steps:

- Assessment on the issues related with the operation of the FRF.
- Design of the FRF system: functions, databases, components, interfaces…
- Development of the FRF system for enabling the validation exercises.
- Validation of the FRF system and its integration into the airspace.

1.1.2.1. STEP 1: Assessment of the Operational Issues

The main goal of this step was to define the future FRF environment, and thus prospected 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 studied 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 task also assessed the avionics architectures where the FRF system will have to be integrated. This activity has been quite interesting for the project because the determined environment for the FRF deployment has been the reference for the whole project in two key aspects: FRF functions and validation exercises.

Once the FRF environment was defined, the challenge of integrating the aircraft equipped with the FRF system into the airspace was affordable. In the current situation, aircraft are controlled by pilots who interact with air traffic controllers (ATCO). The ATCO can command the pilot to execute manoeuvres (increase speed, change flight level, direct to a new waypoint…) that the pilot is in charge of executing. But when due to threats on-board the FRF takes in control of the aircraft, the data link remains as the only possibility to communicate the controller with the FRF, by sending flight plans that the FRF will execute. But even this possibility can be disrupted. Then, the ATCO faces an aircraft flying its own flight plan, without any possibility of being commanded from the ground systems. In both events, new procedures are needed to guide the ATCO behaviour. Such new procedures have been proposed by the SOFIA project. SOFIA also introduced the need of a Ground Security Decision Station (GSDS) to manage these security events.

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A special focus was given to the regulatory and certification issues to which FRF integration gave rise. At this point, the reference to the UAS progress revealed crucial, and thus it was used as a main source to propose the appropriate regulatory and certification framework for the FRF and the new procedures designed for its implementation. With respect to other projects dealing with future ATM environment and tackling the problem of integrating autonomously flying aircraft, the distinctive feature of SOFIA was to take account of the security – related circumstances under which the autonomous flights occur.

1.1.2.2. STEP 2: Design of the FRF System

Its main goal was to specify both the FRF system and its integration into the different avionics architectures that can be expected for the future, considering the three operational solutions envisioned for the FRF:

- Flight Plan with Negotiation (FRF_N): the FRF executes a flight plan generated on ground and transmitted to the FRF via data link. FRF analyses the feasibility of the flight plan according to the aircraft conditions and performances. In case of agreement, the flight plan is executed. Otherwise, next operational solution is on.
- Flight Plan without Negotiation (FRF_WN): after negotiation is finished without agreement or communication disruption, FRF executes the flight plan elaborated by itself, without any control from ground.
- Military aircraft relay: this is an intermediate step between the two previous operational solutions. FRF receives a flight plan from a military aircraft and operates as in the FRF_N solution.

As most of the FRF implied automation modes are expected to be already present in future aircraft, SOFIA more specifically addressed 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 HMI devices, and to perform specific in depth safety analyses to define an architecture that fits all of the needs and constraints.

SOFIA in particular studied the autonomous flight re-planning function with the associated monitoring function, and the interfaces to make available onboard surveillance systems which provide the means to detect various threats (equipment failure, terrain, traffic or weather hazard) and to autonomously make decisions about flight plan update. It is remarkable the iterative process that was run between the design activity and the regulatory, certification and safety assessments. As part of FRF design, SOFIA included thus a study focused on data bases with the aim of identifying FRF-related requirements and specifying, with respect to the databases foreseen for future aircraft, the modifications and new data fields that are required to fit FRF needs and the set of databases that enables the calculations to be performed by FRF

Also worthy to note is the innovation brought about by SOFIA on the ground side regarding the ATM procedures and tools, for which the impact of FRF related procedures and functions were assessed. During the FRF design, a safety assessment was carried out. The main goal of this activity has been to propose design requirements derived from the safety analysis of the preliminary design at FRF and aircraft level and from the safety issues related to the FRF integration into the airspace. Both safety assessments comprise the performance of a Functional Hazard Assessment (FHA) and a Preliminary System Safety Assessment (PSSA). EUROCONTROL EATMP SAM and SAE ARP 4761 are applied.

1.1.2.3. STEP 3: Development of the FRF System

Its main goal was to develop the FRF functions for their validation and set up the simulation environments which allowed FRF functional validation to be performed according to the objectives and requirements set out in the SOFIA validation plan. The task included the adaptation of already available platform components and the development of appropriate new mock-ups components in order to get functional test beds ready for carrying out the FRF validation. Only the solutions FRF with Negotiation (FRF_N) and the FRF without Negotiation (FRF_WN) were carried out.

Five validation platforms were used in the SOFIA project:

- ATENA, flight simulator developed by GALILEO Avionica.
- AIRLAB™ flight simulator developed by THALES Avionics.
- DFS ATC simulator.
- IoA´s I-23 Manager aircraft.
- Diamond Aircraft Industry Twin Star DA42 aircraft and simulator.

1.1.2.4. STEP 4: Validation of the FRF System and its integration into the Airspace

Its main goal was 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 followed a validation plan elaborated according to the European Operational Concept Validation Methodology (E-OCVM).

The validation of FRF was only made on the solutions FRF with Negotiation (FRF_N) and the FRF without Negotiation (FRF_WN). To carry out the validation, five experiments were proposed for SOFIA 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 was carried out during the development phase. The ATENA simulator was linked to the DFS ATC simulator. This experiment was focused at refining the FRF functions, particularly the assessment of the FRF functions and its integration into the airspace through the validation by ATCOs of the ATC procedures designed for aircraft under FRF. The options Flight re-planning with negotiation and Flight re-planning without negotiation modes were assessed.
- A flight trial was executed during the development phase to refine the development process by using an aircraft provided by the IoA. This trial was focused on the assessment of the Flight re-planning without negotiation mode.
- A validation exercise was run in the THA AIRLAB™ simulator to assess the feasibility of the FRF solution for the commercial and business aircraft worlds.
- A flight trial by using an aircraft provided by DAI. This trial was focused on the assessment of the Flight re-planning with negotiation mode thanks to the linkage to the DFS ATC facility. This flight trials was preceded by simulation runs in the DA-42 flight simulator.
- The SOFIA validation cycle is presented in the Figure 1. 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.

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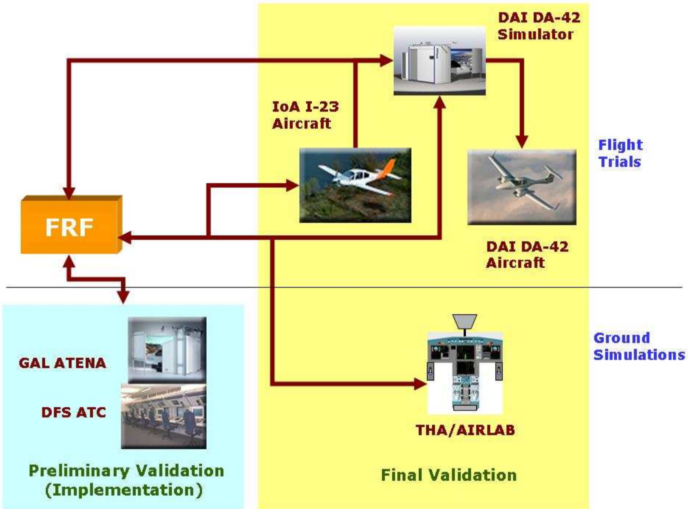

Figure 1: SOFIA Validation Cycle

1.1.2.5. Conclusion and Recommendations

SOFIA has defined different procedures for managing aircraft in security emergency being controlled by the Flight Reconfiguration Function (FRF). Safety and operability of these procedures were validated and approved by ATCOs. S a conclusion from this assessment, it was detected the need of a ground authority and/or system (like a Ground Security Decision System) at European level to take the legal responsibility of the decisions, to generate and track the flight plan for the FRF aircraft, and to coordinate with national authorities, ANSP and airports.

SOFIA moves aviation security a step forward, and apart of the technological development the project has collaborated to this movement through the assessment of regulatory and certification frameworks for such security systems not only by the research itself but also through discussions with ICAO, EASA, EUROCONTROL, SESAR and several National CAAs.

SOFIA opens the door towards the exploration of new application areas for a Flight Reconfiguration Function functionality in fields like: Safety, small - general aviation aircraft, highly automated systems, UAS or single crew operations. Thanks to the extensive (and intense) validation strategy carried out in SOFIA, FRF functions are now available for aircraft operations in the future SESAR environment specially for 4D trajectory management and trajectory generation.

SOFIA has satisfactorily validated the FRF functions that open new possibilities for the automatic and autonomous creation and execution of trajectories. The next step to be afforded is the upgrade of the FRF to manage the collaborative negotiation of the FRF trajectory with other aircraft, in collaboration with the ground ATC. The upgrade and validation of the FRF to operate in ADS-B and ACAS scenarios is the next step forward. This would enable a higher integration of the FRF aircraft into the future airspace as defined by SESAR. Additional improvements of the FRF can be foreseen by integrating it with the new on-board surveillance systems currently under development.

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2. SOFIA Project Objectives

The main objective of SOFIA project is to develop and validate the Flight Reconfiguration System (FRF), to safely and automatically return to ground civil transport aircrafts under hostile actions conditions.

The FRF system provides the aircraft with the capacity to automatically return to ground when an on-board hostile action supposes such hazards that the activation of FRF is the only solution to avoid any major damage, not only to the aircraft and its passage but also to the population and infrastructures on ground. Additionally to the automatic return of the aircraft to ground, FRF also acts autonomously: it does not react to any input from the cockpit commands, thus disabling the control of the aircraft by hostile individuals that have replaced the pilots. FRF has the capability to generate and execute a flight plan until a selected airport and land the aircraft at it. Additionally, FRF enables the interaction with the ground by accepting and executing flight plans generated by the ground authority in command. This later functionality depends on the availability and security of the communications between ground and the aircraft. SOFIA shall:

- design architectures for integrating the FRF system into several typologies of avionics for civil transport aircraft,
- develop one of these architectures,
- conduct the validation of the FRF concept (following the E-OCVM) and the means to integrate it in the current ATM by using ground simulators (both ATC and cabin simulator) and real aircraft,
- conduct the safety assessment of FRF at aircraft and operational (ATC) levels (applying ESARR),
- investigate the integration of FRF into different airspace environments: current ATM, ASAS/ADS-B, automation of ground functions, airspace with/without radar coverage, CDM, 4D trajectory negotiation (coordination with ERRIDS and SESAR programme is foreseen).

SOFIA is mainly a technological project, with a strong technical component, but it also considers the operational aspects related with the integration of the FRF system into the airspace. To develop the FRF function, SOFIA mixes the UAV world and commercial aviation world, considering development and progresses as a constant reference in the project.

SOFIA project objectives are split into several categories (overall, operational, technical and validation) and addressed here after.

2.1. Overall Objectives

The overall objective of the SOFIA Project is to develop and validate the FRF system to safely and autonomously return to the ground the civil transport aircraft under a hostile action situation. In order to accomplish this goal, the SOFIA project shall demonstrate that:

- FRF can be designed and developed in a reliable and affordable manner.
- An FRF equipped aircraft is safe during its normal operation.
- When FRF is in command of an aircraft, this can be safely and securely returned to ground at a designated airport.

The reliability, affordability and safety of the FRF systems will be assessed thanks to the works performed in the SOFIA project. Therefore, reliability and affordability will be demonstrated through the development of several versions of the FRF capable to be validated in different avionics environments. The need of

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creating different FRF version is due to the characteristics of the several validation platforms to be used in the project for the validation FRF. The validation exercises themselves will prove the reliability and affordability of the FRF system. Finally, the safety is assessed through a complete safety assessment performed in a dedicated WP.

2.2. Operational Objectives

The main operational objectives of the SOFIA Project are listed below:

- Analyse the global impact of FRF in the current scenario
  - Current ATM system.
  - Areas with no radar coverage
  - Existing rules and procedures for the ATC
- Analyse the compatibility of FRF with the future scenarios
  - ASAS applications
  - Automation of ground and air functions
- Proposals to integrate FRF in the current and future (ADS-B, CDM, Trajectory Negotiation) airspace
- Coordination with ERRIDS program and related projects (PEGASE, SAFEE…)
- Analyse how certifiable the FRF system is in the current certification framework
- Analyse the linkage between the FRF and the UAVs world, and use of the UAVs developments.
- Analysis in the responsibility on the aircraft under FRF: national authority, controller, airliner…

2.3. Technical Objectives

The main technical objectives of the SOFIA Project are listed below:

- Design of FRF for its integration into different avionics architectures: Integrated, Modular, Future, including a generic architecture for UAV.
- Determination of the modifications needed in the ground ATC systems due to FRF
- Assessment of the FRF safety at aircraft and integration on airspace levels
- Design and development of the FRF functions:
  - Automatic Flight re-planning function
  - Guidance functions and automatic mode transition for the execution of the flight plan
  - Flight plan monitoring function
  - Air-ground communication management
- Design and development of the FRF data base

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2.4. Validation Objectives

The main validation objectives of the SOFIA Project are listed below:

- Provide data to populate the VDR
- Validation of the impact of the FRF system on ground:
  - Assessment of the reliability of the airspace control and management in a FRF scenario
  - Assessment on the reaction of the ATCO when FRF is on
- Validation of the FRF system
  - Creation of the flight plan by FRF on air
  - Cross checking by FRF of the flight plan received from ground
  - Execution of the flight plan and landing of the aircraft by FRF

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3. SOFIA Achievements

The SOFIA goals are achieved by the realisation of a set of tasks grouped in different work packages (WP):

- WP1 FRF Environment
- WP2 FRF Design
- WP3 FRF Development
- WP4 FRF Validation

The achievements in each WP are shown hereafter together with a crosscheck of the initial objectives stated in the SOFIA Technical Annex forming part of the contract with the European Commission and the final results of the research done in the project.

3.1.1. WP1 FRF Environment

3.1.1.1. FRF Solutions

In an emergency situation (e.g. a security crisis on-board as it is the case in SOFIA) the highest priority is to land the aircraft as quickly as possible. Therefore the flight to the selected aerodrome shall be as short as possible. The aircraft shall normally fly directly to the aerodrome. This part of the FRF flight will be the same for all the three FRF solutions introduced in the following paragraphs.

3.1.1.1.1. Solution 1: Autonomous Flight Re-planning

For the FRF, it is very easy to create a new flight plan to a special emergency aerodrome, because all necessary information is available on board. The information about the crisis on board, the status of the aircraft and databases about the airspace are part of the safety and security systems. Information about the conditions at the selected aerodrome could be available, e.g. via ATIS. En-route weather information could also be received via data link or on board weather radar. As all information is available a route to the airport can be calculated quickly. FRF can down link the route to the GSDS, so ATC can keep the surrounding controlled traffic away. GSDS can also inform the selected airport and security authorities. In case of data link problems the FRF aircraft flies to the aerodrome without information to/from GSDS. ATC monitors the flight and using predicting techniques (ATC tools) ATC can anticipate the possible aerodrome selected by the FRF system. Thus ATC can also inform the corresponding aerodrome and the authorities. This procedure is similar to today's procedure for an aircraft with r/t failure. Therefore this solution is easy to work, clearly structured and preparation time is relatively short. This is the preferred solution for the controllers according to the outcomes from the workshop hold with them at the DFS.

3.1.1.1.2. Solution 2: Flight Re-planning with Negotiation

Due to the negotiation between the FRF system and the GSDS, the preparation phase in solution 2 is more time consuming. For the negotiation, data must be exchanged via data link. Depending on the technical equipment this data exchange may take longer. Additionally, during the negotiation phase two decisions must be taken. At first GSDS has to decide about the destination aerodrome (and the alternative); and secondly, the FRF system has to decide about the FPLN proposed by GSDS. Both decisions need extra time to compute. If the negotiation fails, the FRF uses the flight plan calculated by itself, reverting to Solution 1.

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This information will be down linked to the GSDS through a secure data link. Regarding the premises made above, the aircraft will consume more time for the preparation phase than in Solution 1. Due to the decisions foreseen in the procedures, the structure of this solution is more complex. For the controllers this procedure is not as easy to work as Solution 1.

3.1.1.1.3. Solution 3: Mil. A/C Relay

Regarding the amount of time required and the complexity of the procedures, Solution 3 is the least preferred solution. Intercepting the FRF aircraft requires time. A specially equipped military aircraft must be informed and flown to intercept it. Then the military aircraft has to connect to the FRF aircraft and receive the status information. Based on this information the GSDS must calculate a new route to the emergency aerodrome. This information is to be transmitted via the military aircraft to the FRF flight. Then the FRF aircraft can start the flight plan. If the connection between the military aircraft and the FRF flight or the connection between the military aircraft and GSDS fails, the FRF system creates a flight plan and follows it to the emergency aerodrome. The interception of the FRF aircraft as well as the transmission of the data to GSDS via the military aircraft and back to the FRF aircraft are both time consuming. Due to the integration of a third party (military aircraft) in the negotiation process the complexity of this solution is higher than in the other solutions.

3.1.1.1.4. Discussion on the solutions

Initially a combination between the three solutions was envisaged. The proposed stepwise approach started with solution 2, then solution 3 and, as a last back up, solution 1. This approach is very time consuming, very complex and not easy to work for all participating parties, particularly the Air Traffic Controllers (ATCO). Therefore in SOFIA a clear structured solution is preferred. This preferred solution could either be solution 1, solution 2, or solution 3. In solution 2 and solution 3 elements of solution 1 are integrated as back up procedures if failures occur during the normal procedure. So a combination of solution 2 and 1 or solution 3 and 1 is foreseen, not as a stepwise approach but as one solution. However the preferred solution according to the ATCO inputs is solution 1.

3.1.1.2. Certification and Regulation

SOFIA project has analyzed the impact of the Flight Reconfiguration Function (FRF) in the certification and regulatory frameworks. SOFIA has kept several meetings with ICAO, EASA and EUROCONTROL.

The major demand regarding certification activities was detected on the air segment. Although the philosophy underlying the design of the FRF system shall pursue compliance with current regulatory framework, since the FRF system is a particularly innovative one, the existence of conflicts or gaps in current regulations is inevitable, and some changes in those regulations will be required in order to make possible the certification of the FRF system. Most conflicts detected in the current certification framework analyzed stem from being the pilot out of the loop when the aircraft is under command of the FRF system. In particular, the main associated issues are the fact that there is no pilot to 1) take over control of the aircraft when a critical system fails, and 2) to monitor malfunctions or emergencies on-board so that the pilot can react to them. Requirements have been derived and became a valuable input for the design of the FRF system from all the analyzed codes for the air segment.

On the ATC segment the certification issues are not so problematic, as ATC does not influence directly the FRF flight, only the configuration of already existing certified ATC systems has to be changed. Also the interface to the GSDS is based on existing technology.

On the ground segment the GSDS is the only relevant system that has to be certified. The responsibilities for the certification of the GSDS or the certification process are not defined. As the GSDS has the ability to influence the FRF flight directly it has to be regarded as a combination of air and ground segments. For regulatory issues, at least one of the proposed ATCO procedures has to be confirmed by ICAO. All developed procedures have to be integrated into the ATM. Therefore the ANSPs procedures and documentations, including training, have to be updated with the FRF ones.

With regard to the regulatory issues of the air segment, as in the case of the certification issues, the main conflict with regulations stem from being the pilot out of the loop when the aircraft is under command of the FRF, since current regulatory framework assume, explicit or implicitly, that a pilot is on board to follow the prescribed procedures. Another important issue leading to conflicts with regulations is the loss of communications with ground when the aircraft is under command of the FRF system, since in this situation GSDS is not informed on the aircraft status and evolution of the crisis on-board, and no vital information can be up-linked to the aircraft when necessary. In addition, other aspects considered in the analysis of regulatory issues are Training, Aircraft Maintenance and Security. Regarding training new programmes dealing with ‘security avionic systems’ should be developed. Analogously, procedures for handling these special systems should be developed for Aircraft Maintenance Organizations, based on requirements to be included in the regulatory framework.

3.1.1.3. FRF Environment Crosscheck of Objectives and Results

Objective	Level of Accomplishment	Explanation
Establishment of the timeframe when the FRF will be in use	High	Based on the technology assessment performed in order to determine the FRF environment, some of the technologies needed to integrate seamlessly FRF equipped aircraft into the airspace as well as for operate the FRF in a reliable and safe manner are not currently available although many of them are in are in a research status. Therefore the timeframe when the FRF will be in use is 2025 and beyond.
Definition of procedures for the FRF both air and ground	High	The FRF operational aspects are based on the different solutions described. Solution 1. Autonomous Flight re-planning Solution 2. Flight re-planning with negotiation Solution 3. Military A/C relay For each of these solutions, procedures for the ground segment (ATC) have been described. A preliminary definition of the Ground Security Decision Station (GSDS) has been also introduced to consider security and responsibility aspects with regard to the operation a pilotless aircraft in a security scenario.
Assessment of Regulatory Issues	High	The regulatory aspects and conflicts with existing regulations related to the operation of an aircraft equipped with the FRF have been identified through a thorough revision of International (e.g. ICAO, FAA), European (e.g. EC, EASA) and national (e.g. Spain, Germany) regulations. Moreover regulatory issues have been discussed with relevant regulatory and certification bodies such as ICAO or EASA.

Objective	Level of Accomplishment	Explanation
Assessment of Certification Issues	High	The certification aspects and conflicts with existing certification standards related to the operation of an aircraft equipped with the FRF have been identified through a thorough revision of International (e.g. ICAO, FAA), European (e.g. EC, EASA) and national (e.g. Spain, Germany) certification standards and regulations. Moreover regulatory issues have been discussed with relevant regulatory and certification bodies such as ICAO or EASA.

Table 3-1. WP1 Evolution of Objectives

3.1.2. WP2 FRF Design

3.1.2.1. FRF Functions

In order to enable the implementation of the FRF the airplane avionics must be fly-by-wire. The design of the FRF has resulted in a set of eight (8) functions. The functions perform the actions assigned to the FRF to command and control the flight, and communicate with GSDS during the FRF flight of the airplane in emergency.

The FRF functions are described hereafter:

The Decision Centre Function (DCF) shall manage the different FRF capabilities. It shall act like an event controller. It performs the FRF initialization (including built in test), modes management and systems interface management (including update of databases). The modes management deals with the four FRF modes: START, IDLE, ARMED and ACTIVE, described hereafter:

- START: power up of the system.
- IDLE: mode during the normal of operation of the airplane in absence of security emergencies or threats.
- ARMED: the FRF primary functionality is to calculate a new flight plan that flies the aircraft to a safe landing.
- ACTIVE: the FRF executes the flight plan calculated when in ARMED mode and prepares the aircraft for landing.

The Health Monitoring System Interface (HMS) gathers data from systems critical to the operation of the FRF, and performs corrective actions in case of failure in order to ensure continuity of the FRF service. If a failure is critical enough not to be recoverable, the FRF will notify it to ground (GSDS). This will give the GSDS the opportunity to consider the best course of action for the given situation.

The Route Planning and Static Flight Monitoring (RPL) generates a suitable flight plan to a secure landing airfield. It takes into account the external airfield selection criteria and authorizations and the information coming from the FRF databases regarding commercial routes and airports, terrain, restricted area and military airports, static and dynamic Prohibited Security Areas and weather.

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The Guidance and Leg Management (GLM) monitors the flight of the aircraft along the route continuously evaluating the displacements from the desired path and providing inputs to the autopilot for guidance. It also performs all the operations of leg change and connection.

The Route Re-planning (RRP) performs any type of amendment to the flying plan during its execution due to external constraints (e.g., traffic, weather…). Procedures similar to the (RPL) shall be applicable.

The Dynamic Flight Monitoring (DFM) consists of different sub-functions that shall be activated during the FRF flight of the airplane:

- A/C Performance Monitoring, in order to provide all the necessary information (fuel consumption, timing information etc.) to FRF to perform a check along the selected path,
- Resolving conflicts with static obstacles, e.g. terrain and PSAs,
- Resolving conflicts with air traffic, performing automatically the TCAS procedures,
- Resolving conflicts with bad weather conditions

The External Communication (COM) produces the information to be exchanged between FRF and the GSDS: FRF Mode, FMS acceptance/rejection of the GSDS flight plan, selected airfield to land, selected flight path, Modified Flight Path and Health Data.

The Display Management (DSM) provides the interface between FRF and Display Function. As a general philosophy, in order to respond to the terrorist attack on board, a solution that prevents hijackers to know the real state of the aircraft (engines, trajectory etc) is preferred, only displaying the FRF mode.

3.1.2.2. FRF Safety Assessment

Safety is a requirement "society" poses on the air transport. Although air travel is one of the safest forms of transportation, an increase in the number of accidents will not be accepted, not even in a context of growing traffic or emerging threats, such as for instance related to security. Hence the challenge to industry and regulatory agencies is to make an already safe system even safer.

The FRF provides a solution to a situation with a potentially catastrophic ending caused by the presence of a security threat. When a hijacking (or similar threat) occurs on-board an aircraft, the probability of losing the aircraft increases considerably, therefore any action taken to mitigate this possible end result will significantly improve safety. From this point of view, it might not be necessary to design a system to the same level of safety as it is required for current on-board aircraft systems, however the inadvertent activation of the FRF shall be strongly prevented.

The issue of making sure that the FRF is only activated when it should become then crucial. It can be demonstrated that the inadvertent activation of the FRF can be dealt with a moderate increase of workload by flight crews and will never have catastrophic consequences. Nevertheless, having a lot of spurious FRFs will not be acceptable by pilots or airlines and will not be sustainable by the ATS. Therefore requirements are necessary to keep this number small enough.

Since the expected number of FRF like scenarios is still to be better assessed, conservative estimates have been performed when imposing safety requirements on the FRF functionalities. Clear show stoppers have not been identified although equipment redundancy and additional design effort might be necessary to reach some of the targets.

While the FRF is in operation there are two main modes that have been assessed throughout this work. The following two paragraphs discuss the feasibility of the functionalities proposed in the different modes from a safety point of view.

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In the ARMED mode, a number of failures in this functional area could endanger the success of the FRF mission, not only during the calculation of the first FLPN but also in the hypothetical case that the FRF has to recalculate the flight plan and choose a new destination due to unanticipated events (e.g. conflict with traffic, change of threat, weather, etc).

In the ACTIVE mode, safety requirements necessary to guarantee a safe landing without pilot-in-the-loop are also quite rigorous. This includes not only those functions associated to actions performed to configure the airplane for landing but also functions intended to resolve conflicts found on the way to the chosen destination (like traffic or weather).

The following paragraphs discuss the feasibility of the different scenarios from a safety point of view.

3.1.2.2.1. Scenario 2: Solution 1 with datalink where the FRF autonomously chooses a 4D route.

A large proportion of the safety requirements derived seem feasible for this scenario. Clear show stoppers (safety requirements that definitely cannot be identified) have not been identified. Nevertheless, a number of safety requirements may be very difficult or costly to achieve:

- Information regarding the state of the airport, its runways, its navigation equipment and suitability of weather conditions for landing are of critical importance for the ‘blind’ landings to be performed by the FRF. This poses challenging requirements on availability and quality of the information provided to the FRF at the holding as well as the information provided by ATIS when the FRF is approaching a certain airport and runway. In case of late information that the selected approach and landing can for whatever reason not be performed safely, the FRF has to re-plan a runway, airport, approach and possibly even a holding. This process has neither been defined nor assessed in the present work.
- A general issue is the selection of a set of suitable airports where FRF should land. These airports on the one hand, should be quiet, such that procedures necessary for clearing approaches, runways and their neighbourhoods are feasible. On the other hand, the navigation equipment of these airports needs to be of very high quality and availability as safe landing of an FRF critically depends on it. Such equipment may be relatively costly for such airports.
- Another general issue is that when overflying cities, nuclear reactors or generally areas where one would not want to have security challenged flights such as FRF is considered as a severe situation (severity class 2) in itself, this poses challenging requirements to onboard and ground databases regarding the corresponding information.

3.1.2.2.2. Scenario 3: Solution 2 where the destination airport is negotiated with ATC

The general situation is that the safety requirements for scenario 3 are equally or less difficult to achieve than for scenario 2. This is intuitively clear, as the selected airport and route have been assessed and confirmed by ATC in the negotiation process between FRF and ATC. Nevertheless, the difficult safety requirements for scenario 2 are generally still a challenge.

3.1.2.2.3. Scenario 1: Solution 1 without datalink, where the FRF autonomously chooses a 4D route

Scenario 1 generally seems very difficult to achieve in a manner satisfying safety objectives and requirements. A crucial point on top of the aforementioned requirements, which here are even more difficult to achieve, is that the FRF blindly chooses a destiny airport and approach and is then completely dependent on ATIS for information to confirm that the actual state of the runway, navigation equipments, weather, etcetera allow a safe landing. It seems very difficult to have ATIS contain all necessary

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information of sufficient quality in a sufficiently timely manner, also because the FRF does not inform about the airport and route it has selected. For the latter reason, the FRF also implies a considerable challenge to ATC.

The work is not complete, even after the safety assessment has been defined and turned over to the system developers responsible for leading the implementation of the FRF. The implementation activities should be continuously monitored to ensure that action is being accomplished, any roadblocks to implementation are removed and the plan accommodates any newly identified gaps.

This safety enhancement process is best accomplished in a step-wise fashion to move to the next level of maturity. Once the initial action plan has been completed, the process should be repeated in order to identify the next safety enhancement actions to implement.

3.1.2.3. FRF Databases

In order to enable the FRF to perform the calculations related to the flight reconfiguration in an autonomous way, a set of three (3) databases (DB) were considered:

<u>DB1: Static and Dynamic Data Base</u>

The static part stores:

1. The Terrain and Obstacles Database.
2. The predetermined Prohibited Security Areas.
3. The Military Airports and military installation and their characteristics for emergencies.
4. The Restricted Areas prohibited during normal flight condition and made available during the threat conditions.

The dynamic part contains:

1. Flight Plan and Airport selected from FRF
2. Prohibited Security Areas changed during flight.
3. Weather data

<u>DB2: Aircraft Performance Database</u>

It includes the aircraft performances that are needed to perform the guidance function. It allows FRF to reproduce the FMS function able to compute an optimal flight plan taking into consideration the aircraft status, internal and external constraints (fuel consumption and remaining fuel, wind, maximum speed at flight level, airport destination, etc…)

<u>DB3: Navigation Data Base</u>

It is requested to support the FRF. It contains navigation data and is constituted by two elements: Avionic Jeppessen database plus Airliner specific flight plans, geographic fixes, preloaded before flights plus any other design specific modification to implement the FRF functions.

For the development of this databases, it was fount that parts of the databases could be derived from Commercial Off The Shelf (COTS) avionic products. In these cases, the performances of such databases were crosschecked with the needs for the FRF. In case of eventual gaps, proper “ad hoc” solutions were designed to suit these databases in accordance to the FRF applicable requirements.

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In addition to the above distinction, it is very important to remark that one of the main characteristics of the FRF DB was the absolute coherence between the air segment data (on board data) and the ground segment data (ATC / TARMS data).

Based on this, SOFIA therefore identified the requirements and the different ways in which the three above DB's were needed to be employed, in the different aspects of the project. In particular, it was distinguished between:

- ATA general requirements, or the requirements that will be available for the next future aviation (Airbus, Boeing, etc.).
- Simulation requirements for demonstration, or the requirements that were applicable for all the simulation phases in laboratory test environment that were performed during the SOFIA project.
- Simulation requirements for demonstration, or the requirements that will be applicable for all the final flight test phases that were performed during the SOFIA project.

3.1.2.4. FRF Design Crosscheck of Objectives and Results

Objective	Level of Accomplishment	Explanation
Establishment of FRF requirements and specifications	High	A total of eight functions have been specified and designed to fulfil the overall SOFIA objectives, i.e. to allow the safe flight back and landing of an aircraft in the event of a security threat on board the aircraft when the authorised pilot has been neutralised. These functions are: • Decision Centre Function • Health Monitoring System Interface • Route Planning and Static Flight Monitoring • Guidance and Leg Management • Route Re-planning • Dynamic Flight Monitoring • External Communication • Display Management
Establishment of databases requirements and specifications	High	Three databases needed by the FRF to properly carry out its tasks have been specified and designed. These three databases are: • Static and Dynamic Database • Aircraft Performance Database • Navigation Database

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Objective	Level of Accomplishment	Explanation
Establishment of safety requirements for the FRF for the purpose of FRF certification and for the integration of aircraft equipped with the FRF into the airspace	High	A complete safety assessment has been performed on the FRF for the three solutions defined in WP1 FRF Environment. The safety assessment has been performed at three levels: • FRF Level: to assess whether the FRF functions are safe enough and what safety requirements need to be imposed on the design • Aircraft Level: to assess the impact of the FRF on the aircraft systems that interact with it and to derive safety requirements that need to be imposed on the design of the FRF and surrounding aircraft systems • Airspace Level: to assess the safety of the operation of an aircraft equipped with the FRF in an airspace where other aircraft are operating. The operational procedures defined in WP1 FRF environment were, for this purpose, assessed and safety requirements that served for the improvement of the operational procedures were given.

Table 3-2. WP2 Evolution of Objectives

3.1.3. WP3 FRF Development

In the context of the SOFIA project six platforms have been used in the validation exercises to validate the FRF. The platforms range from simulators to real aircraft:

<u>Simulators</u>

- ATC Simulator from DFS
- ATENA Simulator from GALILEO Avionica
- Airlab™ Simulator from THALES Avionics
- DAI DA42 flight simulator.

<u>Aircraft</u>

- I-23 Manager Aircraft from Institute of Aviation
- DA42 Twin Star Aircraft from Diamond Aircraft Industries

In order to validate the SOFIA concept in general and the FRF functionalities in particular, the FRF software (including databases) was customized for each one of the above mentioned platforms considering their specificities and the validation needs based on the validation objectives of the exercises undertaken in each platform. This specific software for every platform was based on a generic software in which the main functionalities of the FRF were implemented.

The generic version of the FRF covers the following FRF functionalities:

- FRF Decision Centre
- Route Planning and Static Flight Monitoring
- Guidance and Leg Management
- Route Replanning

Based on this generic version different modules were implemented for each platform:

- ATC Simulator from DFS: no specific needs were implemented as they were not needed
- ATENA Simulator module: it covered the data exchange specificities of the ATENA Simulator to enable the validation of the FRF in this simulator
- Airlab™ Simulator module: In the context of the Airlab™, the complete SOFIA flight reconfiguration function is shared among:
  - The FRF module for:
    - Flight reconfiguration tasking & scheduling,
    - Destination airport and procedure selection,
    - Flight monitoring and re-planning trigger,
    - Elaboration of the constraints parameters to be considered for reconfiguration,
  - The ISS system for:
    - Elaboration of a flight plan section safe against detected threats such as terrain, PSA and moving weather hazards via the ROUTING (Replanning On Unexpected Threat Integration of NaviGation and Surveillance),
    - Performing a final flight plan check of the elaborated route to ensure that ROUTINGS constraints and FMS path computations are consistent and that activated route remains safe after fine computation with current aircraft true capabilities elaborated by FMS predictions.
  - The FMS system for:
    - Fusion of selected procedure and ROUTINGS elaborated section of flight plan
    - Computation of aircraft performances and range,
    - Activation of FRF flight plan and guidance along both lateral and vertical paths
    - Communication with ATC (for downlink only in THA scope for SOFIA)
  - The Navigation database server for:
    - Collection of official navigation data provided to the FRF to select the best airport and procedure according to the current aircraft situation and surrounding threats.
- I-23 Manager aircraft module: This module covered the I-23 specificities and also the needs for the validation exercise. In this case the AP receive the navigation and flight data from the measurement systems via CAN Bus and passes it to the FRF Function via COM Classes. With the same rate the FRF Function delivers via COM Classes certain parameters to AP for automatic flight realization. Additionally pilot may receive through graphical interface information about automatic flight realization and commands concerning the flap and gear control.
- DAI-42 aircraft and simulator module: In this module FRF functionality was considered under specific operational conditions without D/L available to ATC (autonomous flight plan execution) and with D/L available to ATC (informing ATC, accepting flight plans from ATC, rejecting flight plans from ATC). Aircraft data (position, altitude, speed etc.) is read from the Garmin G1000 into FRF. On command FRF generates a flight plan (negotiating this flight plan in some cases with ATC) and then autonomously executes the flight plan on the DA42. After computing the trajectory the aircraft is controlled by stimulating the input of the cross deviation indicator (CDI) of the autopilot via two analogue voltages for horizontal and vertical deviations.

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The different FRF version were not only developed but also integrated in the respective platforms to validate the SOFIA concept.

3.1.3.1. FRF Development Crosscheck of Objectives and Results

Objective	Level of Accomplishment	Explanation
Specification of the validation platforms to enable FRF functional validation described in the validation plan	High	All the validation platforms used in SOFIA were specified in D3.1. The needs and requirements imposed by the validation objectives and aims and the FRF design are translated into requirements that specify the modifications to be performed into the validation platforms to, first, integrate the FRF on them, and second, run the validation exercises. Just one of the validation platforms used is not specified in this report: the DAI DA-42 flight simulator. The decision of using such platform was taken very late in the project. As far as the DA-42 simulator is quite similar to the DA-42 aircraft, no new requirements were identified to integrate the FRF on it.
Adaptation of already available flight simulator components: ATENA flight simulator ATC simulator Airlab test bed DA-42 flight simulator	High	The works to adapt the flight simulators were performed in the WP3.2 and addressed in the D3.2. The simulation platforms were prepared for the integration of the FRF functions. The data exchange modules among the simulation platforms components and the FRF functions. Data was gathered to populate the FRF data bases according to the scenarios designed for the validation exercises. The excellence of the works done are demonstrated in the success of the validation exercises run in these platforms.
Adaptation of already available aircraft: I-23 Manager DA-42 Twin Star	High	The works to adapt the two aircraft used in SOFIA were performed in WP3.2 and are addressed in D3.2. IoA aircraft needed more hardware modifications than DAI one, specially to enable the FRF controlling the aircraft. The excellence of the works done are demonstrated in the success of the validation exercises run in these platforms.

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Objective	Level of Accomplishment	Explanation
Development of the SW for the different FRF functions according to the specifications issued from WP2 and WP3.1	High	The FRF functions were developed in the WP3.3. Some of these functions were customized to the validation platform characteristics, and this resulted in an intense and large amount of work due to the fact that up to five validation platforms were used in the project. The FRF functions development work lasted for almost one year in the project, largely exceeding the initially foreseen duration for this tasks. Malfunctions and bugs were identified during the test performed in the validation platforms along the integration phase. All the malfunctions and bugs were identified, traced and successfully solved.
Development of the adaptations needed to complete existing data bases for the FRF functions performance	High	The FRF databases were developed in the WP3.4 and are addressed in the D3.4. Many of these databases were customized to the validation exercise scenarios, and this resulted in an intense and large amount of work due to the fact up to 20 validation scenarios were used in the project, being some of them variations of root scenarios in one validation exercise (e.g. in THA one).
Integration of the SW of the FRF functions in the simulation platforms for the validation phase	High	The FRF functions SW developed for every validation platform was integrated and tested in each of them. This task was performed in the WP3.5 and is addressed in the D3.5. The works were done in parallel and deep collaboration with WP3.2, WP3.3 and WP3.4. Many test were performed, specially in the Airlab simulator (nearly 140.000 flight hours of simulation), 17 flights in the IoA aircraft and several flights in the DA-42 aircraft. It was this last platform the only reporting FRF behaviour problems not solved during the integration phase. The problems were related with instability of the FRF track when the flight was started with a range of headings far from the initial heading to be taken to initiate the FRF flight. This combinations were avoided during the validation exercises in order to guarantee the safety of the flight exercises.

Table 3-3. WP3 Evolution of Objectives

3.1.3.2. WP4 FRF Validation

Initially SOFIA proposed a sequence and relation of validation exercises as the one presented in the Figure 3-1. It graphically introduces the sequence to be followed in the validation exercises (trials) proposed in SOFIA. The first version of the FRF would be validated, first in the ATENA ground simulator and DFS ATC simulator and then in the IoA aircraft performing a flight trial. With the results from these two validation exercises, the FRF would be improved accordingly and converted into version 2, which would be validated in the THA Cabin Simulator with inputs from a simulated EAS. Finally FRF version 2 would be validated in the flight trials to be run using the DAI aircraft.

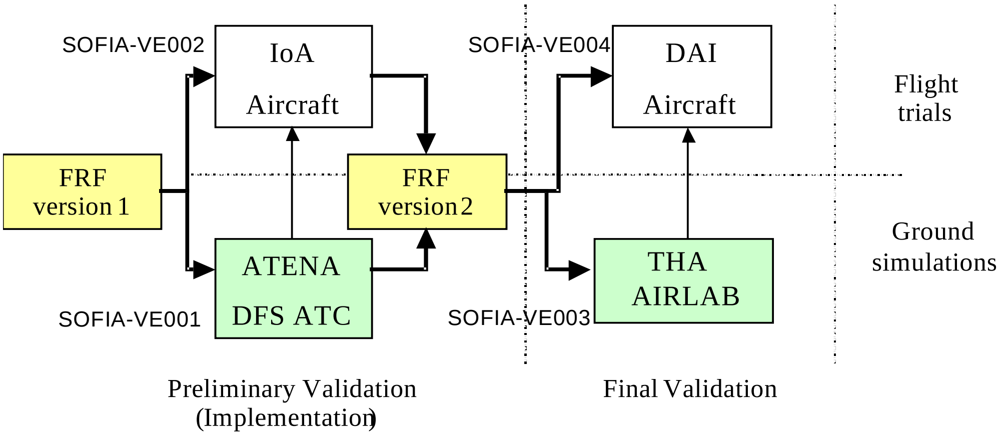

Figure 3-1. Validation Exercises Sequence in the Technical Annex

As result of the difficulties found in the stabilisation of the FRF SW to be run in the IoA aircraft, and the long time consumed to fix and solve the problems, the IoA validation exercise could not serve as the trials to freeze the free of failures SW version to be installed and validated in the DAI aircraft. As the time run towards the start of the planned DAI validation exercise without a mature FRF version, it was decided to check FRF into the DA-42 simulator to, first try to fix the potential problems that could appear when installing the FRF in the DA-42, second check the safety of the DA-42 flight, and third support the IoA trials that were by that time being performed looking for the problems fixing. SOFIA team was very committed with the resolution of the appearing problems and all of them were fixed and solved before the time was totally consumed. This enable to finish the IoA flight trials, and perform the DAI flight trials with the minimum safety levels required. The Figure 3-2 presents the actual validation exercises flow adopted in the project.

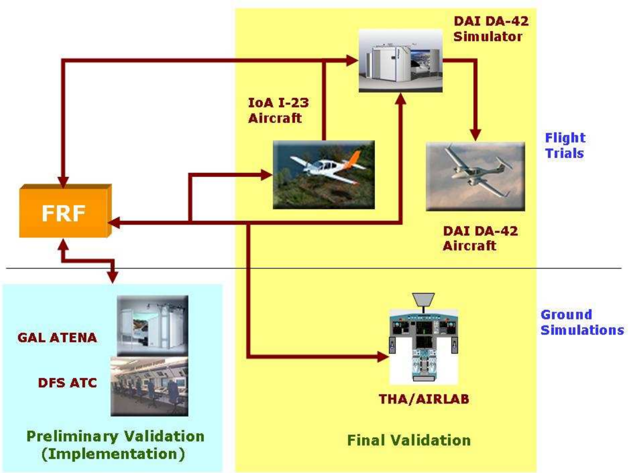

Figure 3-2. Validation Exercises Sequence performed in the Project

As can be seen in the Figure 3-2 the IoA validation exercises were no longer a preliminary exercise but a final one as tested a mature version of the FRF, the same as tested in the DAI validation exercise.

Following the validation cycle adopted by SOFIA, the first validation exercises were run in November 2008. This validation experiment was performed by DFS and GALILEO Avionica (GAL). The validation platform used for the experiment was composed by the ATC simulator from DFS and the ATENA flight simulator from GAL. Both simulators were connected through a high wide band telephonic line, used to interchange the flight data between both simulators. Solution 1, Flight Plan without Negotiation, and Solution 2, Flight Replanning with Negotiation, were tested, involving ATCOs in the ATC simulator and a pilot in the ATENA simulator.

Several objectives for the validation exercise were defined, both with regards to the technical performances of the FRF, and the operation of the procedures and connivance with the FRF by the ATCOs:

- Test the FRF capacity to negotiate a flight plan.
- Test the FRF capacity to crosscheck a flight plan received from ground and accept it.
- Test the FRF capacity to execute the accepted flight plan.
- Evaluate the performance of the ATCO when operating in both solutions.
- Assess the impact of each solution in the work load of the ATCO.
- Evaluate which solution is preferred by the ATCO and which provides better performances.

The environment considered comprises the North of Italy, running a flight departing from Sion airport and having the landing scheduled at Milan airport. The flight to be operated by the FRF is inserted in a real flight plan occurred in the area a few days ago, and proposed to the ATCOs as another aircraft more to be managed. The flight is operated by the pilot in normal conditions until, in the middle of the flight; the FRF is activated and takes the control of the airplane. Communication is then established between the GSDS (represented by the ATCOs in the exercises) and the FRF, using a data link simulated in the telephonic communication. Once the FRF takes possession of the control and command of the airplane, the pilot remains out of the loop for the rest of the experiment. Depending on the solution tested, the communication between the ATCOs and the FRF includes or not the flight plan negotiation. The destination airport chosen to land the aircraft meanwhile the FRF is active is Turin.

Finally, three previous operational scenarios are considered in the experiment, resulting in three different exercises carried out by the ATCOs:

Scenario 1, i.e., flight plan without negotiation and without data link. The flight plan adopted by the FRF is not downloaded to ground as the data link is out of service. This implies the ATCO is not aware of the flight plan the FRF is to execute.

Scenario 2, i.e., flight plan without negotiation and with data link in service. This implies the ATCO is aware of the FRF intentions as the flight plan is downloaded through the data link.

Scenario 3, i.e., flight plan with negotiation. The ATCO has now the capacity to define the flight plan to be executed by the FRF.

The outcomes from these three exercises demonstrate the technical feasibility of the FRF, being able to manage the solutions (with and without negotiation) without failures. Even more interesting than these conclusions was the assessment of how the human part of the exercises performed. With regards to this, the following conclusions can be stated for each of the scenarios tested:

- Scenario 1, i.e., flight plan without negotiation and without data link. The main concern and problem found by the ATCOS is they are not aware of the FRF intents. Therefore they are every

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time reacting to the FRF executions but not medium term prevention is possible. The main risk is the time needed by the ATCO to clear the surrounding airspace and to advise the potential airports were the airplane could land. The FRF provides the ATCO with a time to react between the alert is launched and the FRF starts to execute its flight plan. This time has to be augmented in this scenario to enable good and safe ATCO performance (the length of stay in the holding pattern should be 15 minutes minimum). The negative point is the time increase could jeopardise the FRF performance (more fuel consumption). The affected sector has to be closed completely. With regards to the workload, initially, it increases in the affected sector and once this is clear of traffic, the workload increases in the surrounding sectors. Due to the uncertainty introduced in the ATCOs tasks, this scenario jeopardises the safety of the air traffic system.

- Scenario 2, i.e., flight plan without negotiation and with data link in service. The concern and difficulty in the previous scenario disappear in this second scenario. The ATCOs are aware of the flight plan to be executed and the airport to land at by the FRF. Due to the fact that the flight plan and the landing airport are known, the traffic flow can be handled almost normal. Only the flights to the landing airport must be diverted to other airports. The affected sector does not have to be closed completely. ATCOs considered the safety is kept in the current values.
- Scenario 3, i.e., flight plan with negotiation. The ATCOs generate the flight plan to be executed and the airport to land at by the FRF. This supposes an increase in the ATCO work load not well accepted by them. Due to the fact that the flight plan and the landing airport are known, the traffic flow can be handled almost normal. The only impact is the flights to the landing airport must be diverted to other airports. The affected sector does not have to be closed completely. ATCO workload increases due the necessity of creating and editing the flight plan for negotiation. ATCOs considered the safety is kept in the current values.

After performing the validation exercises, debriefing sessions were run with the ATCOs participating in every exercise. Debates were opened and questionnaires were distributed to gather the information needed to evaluate every scenario, the ATCOs preferences, concerns, problems, and in general, all the information that could enable a ranking of the scenarios and solutions tested. After the assessment of the information, it can be concluded that the most preferred scenario for the ATCOS to operate is Scenario 2, followed by Scenario 3 and Scenario 1 in the last position, being this last the unique considered as jeopardising the safety of the air traffic system.

The second validation exercises were performed in another simulator platform by THA on its Airlab™ Simulator. Such simulator controlled SAFEE EAS function activated by a basic simulation of the SAFEE TARMS, in order to activate SOFIA FRF implementation shared between existing systems (FMS, ISS, CDS, …) and SOFIA dedicated ones (FRF and associated databases systems).

This selection has been an added value for SOFIA project to guarantee the continuation of research in FP6 projects. Additionally, SOFIA has joined the EAS and FRF functions. That means the complete security function proposed by SAFEE to protect the aircraft against intended collision into ground is available to design the validation exercises.

The THA validation exercise was mainly focused at the reproduction of FRF_WN scenario: In case the communication between ATCO and the FRF is interrupted, the FRF starts to operate autonomously. In this scenario, new procedures are to be introduced by the ATCO, and different parameters were assessed: creation and execution of the flight plan by FRF and selection of the destination airport by FRF.

This simulation was conducted with two main streams :

- “Off-Line” Stream: The off-line stream was performed to assess ROUTINGS library reliability and integrity, generating safe flight plans. Simulated trajectories were created automatically under constraints by a dedicated tool able to configure ROUTINGS input constraints such as a geographic area and local airports. For each couple of airports available in the local area, this automatic process generated a flight plan, which was accepted only when overall distance was within a selected range (to remove "too-short" and "too-long" trajectories)

- "Routine" and "Emergency" Streams: This run of evaluations comprised 17 simulation executions. For each execution, aircraft flight parameters were recorded, including position, altitude, FRF computed flight plan and FMS computed trajectory. A results analysis was performed off line of all scenarios correctly executed. Elements checked for correctness at run-time, by the operator in charge of the evaluation scenario, are listed hereafter:
    - The simulation initialization to ensure the trivial preliminary required to run the simulation
    - The flight mode display (in FMA on PFD), as this information is the description to the crew of the current operating mode of the aircraft. This parameters were used in SOFIA context to assess that the system in charge of the guidance is the correct on executing the correct sub-mode.
    - The execution of the trajectory. In particular, to note the time frames where the aircraft position may be enhanced (versus expected trajectory) and thus ease further off-line analysis.
    - The selected destination computed by the FRF, considering the expected scenario and the currently displayed candidate airports locations.
    - The automatic execution of actions generally handled by the crew (selection of the clearance altitude, activation of the auto-pilot, extensions of flaps and gears, …) required to fully match SOFIA context conditions.

The simulators configuration selected for the SOFIA validation trials facilitated a large scope of validation exercises to perform all the tasks foreseen, with two clear added values with respect to the flight trials: it permits more flexible environments and exercises with no risk to the airspace and enables to check two important tasks like cross-checking of the flight plan and application of the new ATM procedures.

About 140.000 flight hours were simulated to test ROUTINGS operational performances. Correct ROUTINGS behaviour was assessed by a safety check of the generated route via a certified TAWS functions compliant with FAA and EASA standards (TSO/eTSO c151b), based on the product code delivered by THALES to ACSS T2CAS and T3CAS products lines available for major carriers as Airbus single aisle, long range and wide body families.

The conclusion of this simulation stream was that no ROUTINGS malfunction was noted.

For the second stream, all scenarios designed for SOFIA implementation successfully ended in a stabilized final approach on a candidate airport with no proximity event versus terrain, obstacles, PSA nor weather threats. Thus, the proposed design for the FRF implementation gave very good operational results.

Additionally, no significant discrepancy in the FRF behaviour was measured among the various scenarios. So, the operational expected result of the function was not impacted either by the selected cruise altitude and speed, or type of terrain under the current flight plan, or density of the different types of forbidden areas.

Complementarily, experimental flight tests with real aircraft were carried out within SOFIA. One preliminary requirement was that the FRF software functionality on-board should not jeopardise the A/C airworthiness requirements. Two flight trials in different locations and with different aircraft were undertaken. One flight was performed by IoA in Poland and the other was carried out by RDE and DAI in Germany. The rationale for duplicating the flight trials was to demonstrate the feasibility of FRF by implementing the designs created in WP2 in two different aircraft with two different avionics architectures.

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The flight trial undertaken by IoA with the I-23 Manager aircraft was focused on the assessment of the FRF when flying in the FRF_WN mode. Therefore, the FRF generated flight plans and executed them. Approach to the runway will be also autonomously performed by the FRF on-board.

The flight trial performed by RDE and DAI was focused on the assessment of the FRF when flying in the FRF_N mode. For the purpose the DAI-42 aircraft was used. The flight plans were created on ground and transmitted to the aircraft. The aircraft executed the flight plan received from ground and approached to the airport selected by the ATC in a automatic manner.

Due to the intent of achieving similar FRF performances in both aircraft, they were used as backup each one of the other to mitigate the risk one of them failing and the validation exercises allocated to it could not be performed.

In the IoA flight trials, the aircraft was flown automatically but with a pilot will be onboard for safety reasons, i.e. in case a failure occurs (e.g., malfunction of the FRF) the pilot would resume the control of the aircraft and the FRF functions would be automatically disconnected. In the DAI flight trials, the aircraft was under the full control of the pilot. The FRF acted as a guidance system which was able to send steering signals to the autopilot. The autopilot was also under the full control of the pilot. All normal disconnecting functions were still active. The pilot had also control of the AP-functions that had to be selected manually (e.g. HDG-, NAV- or APR-Mode). Again for safety reasons, in case of a FRF malfunction of the FRF, the pilot was able to deactivate the autopilot via the normal deactivating mechanism like the 'A/P disconnect'- button or the trim switch. These functions were certification items which should be kept on for the flight trials for safety reasons.

During the IoA flight trials there appeared some problems:

- Application problems, such as stability problems, registry problems or problems with access to some control variables. All these problems were fixed and the flight tests could be performed normally.
- Algorithm problems, such as the impossibility of generating a flight plan in certain places or impossibility to start the FRF flight from a position different than the one related to the first waypoint. Again all these problems were solved.

Trials completed by IoA showed that the FRF software worked properly in the fundamental points. The flight plan was calculated correctly and the dynamic trajectory management (WP switching) and the calculation of control parameters for AP was correct.

It was found that other FRF functions such as the calculation of the fuel consumption, time of the flight, changing of the altitude, require more tests on flight simulators or flight trials.

One lesson learned from this exercise was that the testing of software during flights test is very demanding and expensive.

As shown in Figure 3-1, within the original SOFIA planning this DAI and RDE flight exercise should demonstrate the capabilities of FRF in its final SOFIA development stage after running successfully through all the previous validation exercises including additional software improvement cycles. It was foreseen to demonstrate the FRF_N mode in flight. Because of time slips in the other validation exercises and the instability of the FRF software package DAI and RDE decided for safety reasons to change the objectives of the flight exercise to the followings:

- Demonstrate only FRF_WN mode
- Evaluate FRF behaviour inside a simulator prior to flight
- Only execute those scenarios in flight which were validated successfully in the simulator before.

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For safety reasons additional (not foreseen) simulation runs were added to evaluate the behaviour of the FRF and to find stable areas of the software where FRF can guide the validation aircraft without any risk for crew and aircraft. Depending on the results of the simulation runs it was in the responsibility of DAI and RDE to decide on a permission to flight. Finally the simulation run were performed correctly and the flight trials took place.

The different flight trials performed with the DAI-42 aircraft showed that trajectories were calculated correct and could be flown in the way FRF proposed it.

First of all trials performed with the DAI-42 aircraft were made to prove that the simulated input of deviation signals lead to the correct reaction of the A/P. The flight showed that the qualitative reaction of the A/P was correct. There were quantitative differences between right and left turns noticeable. In left turns the turn rate was less than for standard turns. That led to a higher turn radius which had to be corrected manually. Only little corrections had to be done.

The guidance functionality of FRF in combination with the built-in autopilot showed a fully sufficient precision (horizontal and vertical) for reaching the selected airport.

One important result is that a safe final approach would require additional technical effort to improve position measurement (x, y, and z) as well as functionalities like auto land incl. auto flare which are far away from the functionality of today's autopilots.

During the flight trials all air traffic around the flight test area and especially in the control zone of Bremen Airport that is only a few miles away from the flight test area was monitored by DFS Deutsche Flugsicherung GmbH. Regular air traffic was controlled by the responsible air traffic controllers of the "DFS centre north" located at Bremen Airport. The SOFIA flight which was as well visible in the control centre was additionally monitored by an externally installed air traffic control display.

3.1.3.3. FRF Validation Crosscheck of Objectives and Results

Objective	Level of Accomplishment	Explanation
To assess the reliability of the procedures defined for the operation of the FRF	High	The procedures designed in WP1 for the operation of the FRF in the different solutions were validated during the validation exercise performed by DFS and Gal. A set of air traffic controllers from the DFS participated in the simulation runs to evaluate the procedures proposed.
To assess the reaction of the ATCO workload based on the different FRF operational modes.	High	Additionally to the questionnaires with regards to the applicability and workability of the procedures, the ATCOs stress and strain were evaluated following the NASA-TLX model. After every simulation run the ATCOs were debriefed and asked to fulfil questionnaires.
To assess the creation of the flight plan by the FRF on air (FPLN_WN)	High	The SW of the FRF functions was installed in both aircraft (I-23, DA-42) and the three flight simulators (ATENA, Airlab, DA-42). In all of them, FRF satisfactorily generated the flight plan and executed it. The FRF was also installed and run into the ATC simulator. It also performed satisfactorily.

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Objective	Level of Accomplishment	Explanation
To assess how the FRF behaves when it receives a flight plan from ground (FLPN_N)	High	The DFS-GAL and DAI validation exercises considered the possibility of FRF receiving a flight plan from ground. In these exercises, the FRF received a flight plan from an external source, processed it, and when feasible accepted it for execution. When its acceptance was not feasible, the negotiation process started uo to a flight plan was agreed.
To assess the execution of the flight plan by the FRF	High	According to the stored traces of the flights performed by the FRF in the different validation platforms used in SOFIA (ATENA, Airlab, I-23 aircraft and DA-42 aircraft and simulator) the execution of the flight plan can be considered as acceptable. No significant deviations were noticed in any of the validation trials run.
To assess the execution of the landing and taxiing (if feasible) of the aircraft by FRF	Null	None of both aircraft were landed and taxied automatically by the FRF. Safety was the major constraint to enable these performance from the FRF onboard the aircraft. The SOFIA team, following the proposal of the aircraft owners, decided not to test the automatic landing and taxiing of the aircraft in the project. It must bear in mind both aircraft are not prepare to perform such advance manoeuvres even with the FRF installed. The validation exercises run in the Airlab ended at the IAF after the FRF command and control up to this point. The validation exercise run in the ATENA simulator landed the aircraft but did not taxi it.

Table 3-4. WP4 Evolution of Objectives

3.2. Main Conclusions Reached

SOFIA, through its research, has reached the following main conclusions:

- SOFIA has defined different procedures for managing aircraft in security emergency being controlled by the Flight Reconfiguration Function (FRF).
- Safety and operability of these procedures were validated and approved by ATCOs.
- SOFIA started the assessment of regulatory and certification frameworks for such security systems not only by the research itself but also through discussions with ICAO, EASA, EUROCONTROL, SESAR and several National CAAs
- It is needed a ground authority and/or system (like a Ground Security Decision System) at European level to:
  - Take legal responsibility of decisions
  - Generate and track the flight plan for the FRF aircraft
  - Coordinate with national authorities, ANSP and airports

- SOFIA moves aviation security a step forward
- SOFIA opens the door towards the exploration of new application areas for a Flight Reconfiguration Function functionality in fields like:
  - Safety
  - Small general aviation aircraft
  - Highly automated systems
  - UAS
  - Single crew operations
- SOFIA validated FRF functions are now available for aircraft operations in the future SESAR environment specially for 4D trajectory management and trajectory generation.

3.3. Recommendations for Further Research

The FRF system is proposed as countermeasure to terrorist, hostile actions that aims to use the aircraft as a means to affect assets 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, 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 start to operate, in order to guarantee the security introduced by them. Additionally to the technological development, SOFIA considers that it is needed to promote further research in:

- Integration of the FRF with ACAS to enable the automatic response from FRF to ACAS alerts. Creation and execution of diversion trajectories or simply the execution of the trajectories proposed by the ACAS and ulterior resume of the previous flight plan.
- Collaborative negotiation of the FRF trajectory with other aircraft, in collaboration with the ground ATC. The integration of FRF with the ADS-B is therefore needed. This would enable a higher integration of the FRF aircraft into the future airspace as defined by SESAR.
- Integration of the FRF with advance surveillance systems, like those being proposed by the FLYSAFE and ALICIA projects.
- Explore the application of FRF into other scenarios like safety ones, crew reduction, UAS, very small and personal aviation.
- Need of a ground authority and system (GSDS) at European level to:
  - o Take legal responsibility of decisions (flight plan, destination airport…)

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- Generate and track the flight plan for the FRF aircraft
- Coordinate with national authorities, ANSP and airports

- Testing of the software during flights test is very demanding and expensive. It is recommended to test the SW in ground simulators and tools well in advance.

Moreover SOFIA poses the following open questions that need of further research to be answered:

- Who is responsible for the management and upgrading of the FRF database, including the PSA and airports?
- Who is responsible for uploading and upgrading the FRF database into the airplanes?
- Who is responsible for the designation of the airports capable of dealing with the foreseen threats?, and furthermore,
- Who is responsible for designating to what airport an FRF aircraft is to be deviated?
- Who is responsible for the aircraft when it is flown by the FRF system: the airliner, the FRF manufacturer, the nation of the airliner, the nation of the airspace, the nation of the destination airport, EUROCONTROL, the EC, the EDA?
- What is the responsibility of the ATC system, and particularly of the ATCOs, when dealing with an FRF airplane?
- Who is responsible on ground for generating the new flight plan for the FRF aircraft?

4. Dissemination and use

4.1. Exploitable Knowledge and its use

This section presents, summarized in the Table 3-1, the exploitable results, defined as knowledge having a potential for industrial or commercial application in research activities or for developing, creating or marketing a product or process or for creating or providing a service.

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Safety of aircraft systems in a security scenario	Contribution to aeronautical standards	Aviation	2011	N/A	ISD
Operation of more autonomous and automatic aircraft	Contribution to concepts for single pilot and Unmanned Aircraft Systems operations	Aviation	2011	N/A	ISD
Validation of aircraft systems	Contribution to the improvement of the European Operational Concept Validation Methodology	Aviation	2011	N/A	ISD
New SW Suite for Simulation & Scenario for FRF event	Simulator Products, & Security and Safety Training Services	Aerospace Industry, & Air Traffic Management	After program adaptation from research to commercial product and services	Materials patent may be issued after adaptation agreement. Planning may be from 2011.	Aerospace Part (GAL) & ATM Part (DFS)

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
New SW Suite for Flight Validation of FRF equipment	Simulator Products, & UAV/UAS System	Aerospace Industry, & Air Traffic Management	After program adaptation from research to commercial products and services	Not yet ready for patent request	Aerospace Part (GAL) & ATM Part (DFS)
New SW Suite for Prohibited Security Area	Flight Navigation Equipment ATM Security Equipment Equipment for Safety, Security, Simulation	Aerospace Industry, Air Traffic Management Human Factor Application	After program adaptation from research to commercial product and services	Prototype ready for patent request	GAL
Prohibited Security Area (PSA)	New Aerospace Standard, Ground and Airborne, and related to: EASA Eurocontrol ICAO	Aerospace Industry, Air Traffic Management Human Factor Application	Prototype procedures are available from research program	Not applicable	As per consortium partners
New SW knowledge on • PSA • FRF Simulation • FRF Flight validation • FRF Scenario	Flight Navigation Equipment ATM Security Equipment Equipment for Safety, Security, Simulation	Aerospace Industry, Air Traffic Management Human Factor Application	New EC Research Program as per SESAR, SOFIA 2nd & Aeronautic Safety & Security Research	Not applicable	GAL

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Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Autonomous flight management mode	Contribution to concepts for emergency safe return in civil transport	Avionics	2015	N/A	THAV
Autonomous flight management mode	Contribution to automatic replanning concepts for unmanned air vehicles	Aeronautics	2015	N/A	THAV
Assisted flight management mode	Contribution to concepts for reduction of pilots workload through decision aids	Aeronautics	2013	N/A	THAV
Assisted flight management mode	Contribution to concepts for obstacle avoidance and tactical replanning in military transport	Aeronautics	2013	N/A	THAV
Enhanced technico-operational simulation environment	Simulation services	Aeronautics	2013	N/A	THAV

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Autonomous Flight / Unmanned Flight	Portable Flight Management Support System / Interfaces to Onboard Avionics	Avionics	2013	N/A	RDE
Autonomous Flight / Unmanned Flight	Emergency Safe Return System	Avionics	2015	N/A	RDE & DAI
Autonomous Flight / Unmanned Flight	Optionally Piloted Aircraft (either manned or unmanned)	Aeronautics	2015	N/A	RDE & DAI
Autonomous Flight / Unmanned Flight	Unmanned Aerial Systems Insertion into non-segregated Airspace	Aeronautics	2013	N/A	RDE
Autonomous Flight / Unmanned Flight	Automation of aircraft operations	Avionics	2013	N/A	RDE
Autonomous Flight / Unmanned Flight	Safe Operations of Unmanned Aerial Systems	Aeronautics	2012	N/A	RDE

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Techniques of in-flight trials aimed at investigations of unmanned flights	In-flight trials (organisation, execution) for research projects aimed at the problem of including the unmanned flights into the controlled airspace. Experimental aircraft I-23 prepared and equipped for in-flight tests in research for testing a novel sophisticated avionic solutions.	Novel Avionics Design Novel solutions for Air Traffic Control Crew reduction Small and personal aircraft Highly automated aircraft	2011 (in new research project)	N/A	IoA (owner)
Know-how within the area covering general problems of flight safety, applicable to General Aviation Flight Safety Problems	The on-board computer designed and prepared for realising sophisticated experiments within the area of flight safety (including the automatic control of unmanned flights)	Novel Avionics Design Novel solutions for Air Traffic Control Crew reduction Small and personal aircraft	2011 (in new research project)	N/A	IoA (owner)

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Contribute to the development of regulation to integrate unmanned aircrafts in controlled airspace	CONOPS and requirements	Unmanned aircraft market (UAV)	2015	N/A	Skysoft
Integration of unmanned aircrafts with the ATC system	CONOPS and enabling technologies	Unmanned aircraft (UAV) and ATC market	2015	N/A	Skysoft
Avionics solutions to safely guide an aircraft to a specified location, especially with regards to unmanned aircrafts	CONOPS and enabling technologies	Unmanned aircraft (UAV) and avionics market	2013	N/A	Skysoft
Consolidate and extend SKY know-how in ATM Safety and Security processes	Technology and standards through R&D activities	ATM market	2010	N/A	Skysoft and European partners

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Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
Management of terrain and obstacle elevation models	Unmanned aircrafts Ground proximity warnings systems Terrain visualisation	Avionics GPWS equipments Simulation	2010	N/A	SIA
Autonomous Flight	Automation of aircraft operations Backup navigation Unmanned aircrafts	Avionics	2013	N/A	SIA
Extend SIA knowledge in integration with ATC system	Unmanned aircrafts ATM Equipments	Avionics ATC market and management	2015	N/A	SIA
Techniques for safe flights	Safe flights for manned or unmanned aircrafts	Avionics	2013	N/A	SIA

Table 4-1. Exploitable knowledge and its use

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4.2. Dissemination of Knowledge

SOFIA has disseminated the knowledge created through the project by means of different activities. These activities are split into:

- Dissemination activities organised by SOFIA (Table 4-2)
- Meetings with relevant organisations (Table 4-3)
- Dissemination of SOFIA in technological Forums and Seminars through papers and presentations
  - o Papers presented to technological forums and seminars (Table 4-4)
  - o Presentations made in technological forums and seminars (Table 4-5)
- Collaboration with related projects (Table 4-6)
- SOFIA project web site: www.sofia.isdefe.es

Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
15th December 2006	SOFIA Website	All Internet Users	Worldwide	N/A	ISD
26th May 2009	SOFIA Workshop with Pilots in Madrid	Airline Pilots	Europe	20	All
19th November 2009	SOFIA Dissemination Forum in Barcelona	Aeronautical Sector	Europe	40	All

Table 4-2. Dissemination Activities Organised by SOFIA

Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
9th-10th January 2007	SOFIA presentation at meeting with SESAR organised by DG-TREN in Brussels	Aeronautical Sector	Europe	100	ISD
12th July 2007	SOFIA presentation at EUROCONTROL DCMAC, ATM Concepts, Surveillance and ERRIDS in Brussels	Aeronautical Sector	Europe	10	ISD, DFS and GAL
13th Septembe r 2007	SOFIA Presentation at ICAO NAT ATMG/30 in Paris	Aeronautical Sector	Worldwide	100	ISD and DFS
14th November 2007	SOFIA Presentation at Second Coordination Meeting with SESAR organised by DG TREN in Brussels	Aeronautical Sector	Europe	100	ISD
7th December 2007	SOFIA Presentation at Coordination Meeting with NASA (Aeronautics Systems Analysis Branch, Langley RC) in Madrid	Aeronautical Sector	Europe and US	20	ISD
10th-14th March 2008	Presentation at ARINC 424 Committee in Montreal	Aeronautical Sector	Worldwide	100	THA
28th April 2008	SOFIA presentation at EASA in Cologne	Aeronautical Sector	Europe	10	ISD, GAL and DFS

Table 4-3. Meetings with Relevant Organisations

Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
7th-8th November 2006	Components and Technologies for Defence and Security (DGA) in Paris. France	Defence and Security Sector	France	N/A	ISD
2nd-5th July 2007	ATM2007 Sixth USA/Europe Air Traffic Management Research and Development Seminar in Barcelona, Spain	Aeronautical Sector	Europe/USA	N/A	ISD
10th-12th September 2007	Paper and Presentation at 5th Conference of Avionics in Rzeszow, Poland	Academic	Europe	100	IoA
December 2007	Paper of SOFIA project published in the DFS Research and Development publication “TE im FoKus”	Aeronautical Sector	Germany	Several thousands	DFS
10th-14th March 2008	Paper and Presentation accepted to be published at DATE 08 Conference in Munich, Germany	Aeronautical Sector	Worldwide	N/A	ISD
29th June – 2nd July 2009	Paper and Presentation in the ATM2009 Eighth USA/Europe Air Traffic Management Research and Development Seminar in Napa, California, USA	Aeronautical sector	Europe/USA	N/A	ISD
15th-18th September 2008	Paper and presentation published at ICAS 2008 Conference in Anchorage, Alaska, USA	Aeronautical Sector	Worlwide	N/A	ISD
21st-22nd October 2009	SOFIA Presentation at the Eurocontrol 6th Safety and Human Factors R&D Seminar, Sevilla, Spain	Aeronautical Sector	Worldwide	80	ISD
October 2009	Article on DFS validation Results in the DFS publication “TE im FoKus”	Aeronautical Sector	Germany	Several thousands	DFS

Table 4-4. Papers presented to Technological Forums and Seminars

Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
11th-13th September 2006	Poster at ASAS TN2 in Glasgow	Aeronautical Sector	Europe	100	ISD
13th September 2006	SOFIA presentation at meeting of the Polish CAA with SESAR	Aeronautical Sector	Poland	10	IoA
14th-16th November 2007	SOFIA Presentation at International Congress on Innovation in Unmanned Air Vehicle Systems in Madrid	Aeronautical Sector	Europe	200	ISD
11th-13th March 2008	SOFIA present at ISDEFE stand in Amsterdam ATC GLOBAL 2008 Fair	Aeronautical Sector	Worldwide	N/A	ISD
23rd-24th October 2008	SOFIA Presentation at the Colloquium on "Trajectory based operations enabling UAS integration into the Airspace" in Palma de Mallorca	Aeronautical Sector	Europe/USA	100	ISD
10th-12th March 2009	Presentation at the 2nd INOUI Stakeholder Workshop "R&D Activities Towards the Integration of UAS at Aerodromes in Gran Canaria	Aeronautical Sector	Europe/USA	50	ISD
June 2009	SOFIA presentation at DFS Research and Development Colloquium	Aeronautical Sector	Germany	Several thousands	DFS
7th-8th July 2009	SOFIA presentation at the General Aviation and European Air Transport System Forum in Warsaw	Aeronautical Sector	Europe	100	ISD
29 Sept-01 October 2009	SOFIA presentation at Carl Cranz Gesellschaft Seminar	Aeronautical Sector	Germany	100	DFS
	SOFIA presentation at UAV DACH	Aeronautical Sector	Europe	300	DFS

Table 4-5. Presentations made in Technological Forums and Seminars

Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
13th March 2007	SOFIA Presentation at coordination meeting with PEGASE project	Aeronautical Sector	Europe	20	ISD
21st June 2007	SOFIA Presentation at SAFEE User Club	Aeronautical Sector	Europe	90	ISD
25th September 2007	SOFIA Form to SESAR	Aeronautical Sector	Europe	50	ISD
18th March 2008	Presentation at the second coordination meeting with PEGASE project	Aeronautical Sector	Europe	20	ISD
1st-2nd October 2008	Attendance to to CAATS II second Workshop	Aeronautical Sector	Europe	70	ISD
20th March 2009	SOFIA Presentation to the AGAPE Security Group	Aeronautical and Security Sectors	Europe	50	ISD

Table 4-6. SOFIA Collaboration with related projects

5. Acknowledgments

The SOFIA consortium wants to thank the European Commission for having given the opportunity to carry out such research with their contribution to the funding.

Special thanks to the European Commission Project Officers, Mr. Jean-Luc Marchand and Mrs Stephanie Stolz-Douchet. Without their ever correct guidance the SOFIA project would have not been developed in so adequate way.

The SOFIA project would like to thank all those that externally to the project has supported, contributed and shown interest in the SOFIA project achievements. Special acknowledgement is to be given to EASA, ICAO and EUROCONTROL for their cooperation, to the pilots and representatives of the industry and research centres that participated in the SOFIA workshop and dissemination forum and to the PEGASE project coordinator, Mr. Bruno Patin, for the good relationship between both projects.

Finally, SOFIA project coordinator would like to sincerely thank the staff of the SOFIA partners that have participated in the project along its life. Most of them have get to the end of the project but some left on the road after an important contribution. To all of them thanks a lot for making SOFIA a successful project and a nice and kind environment to work on.

Annex A. Extract of Glossary of Terms

4D	Four Dimensions
ACARE	Advisory Council for Aeronautics Research in Europe
ADS-B	Automatic Dependent Surveillance Broadcast
ANSP	Air Navigation Service Provider
ASAS	Airborne Separation Assistance System
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATENA	Advanced Test ENvironment for Avionics
ATM	Air Traffic Management
CAATS	Cooperative Approach to ATS
CARE	Co-Operative Actions of R&D in EUROCONTROL
CDM	Collaborative Decision Making
DAI	Diamond Aircraft Industries GmbH
DB	Data Base
DFS	DFS Deutsche Flugsicherung GmbH
E-OCVM	European Operational Concept Validation Methodology
EAS	Emergency Avoidance System
EC	European Commission
ECAC	European Civil Aviation Conference
ERRIDS	European Regional Renegade Dissemination System
ESARR	EUROCONTROL Safety Regulatory Requirement
EU	European Union
EUROCAE	European Organization for Civil Aviation Electronics
EUROCONTROL	European Organisation for the Safety of Air Navigation
FCS	Flight Control System
FHA	Functional Hazard Analysis
FLYSAFE	Airborne Integrated Systems for Safety Improvement, Flight Hazard Protection and All Weather Operations
FMEA	Failure Modes and Effects Analysis technique
FMS	Flight Management System
FP	Framework Programme
FPL	Flight Plan
FRF	Flight Reconfiguration Function
FRF_N	Flight Reconfiguration Function With Negotiation
FRF_WN	Flight Reconfiguration Function Without Negotiation
FTA	Fault Tree Analysis
GAL	GALILEO Avionica
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organisation
IFR	Instrumental Flight Rules
INTENT	the Transition towards Global Air and Ground Collaboration in Traffic Separation Assurance

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IoA	Instytut Lotnictwa (Institute of Aviation)
ISD	Ingeniería de Sistemas para la Defensa de España
MAEVA	Master ATM European Validation Plan
OC	Operational Concept
OCVM	Operational Concept Validation Methodology
OTDS	On-board Threat Detection System
PSA	Prohibited for Security Areas
PSSA	Preliminary System Safety Assessment
RDE	Rheinmetall Defence Electronics GmbH
RTS	Real Time Simulation
SAFEE	Security of Aircraft in the Future European Environment
SAM	Safety Assessment Methodology
SIA	Alenia SIA SpA
SKY	Skysoft Portugal, Software e Tecnologias de Informação S.A
SME	Small and Medium size Enterprise
SO	Safety Objectives
SOFIA	Safe Automatic Flight Back and Landing of Aircraft
SP3	Sub Project 3
SR	Safety Requirements
SRA	Strategic Research Agenda
TARMS	Threat Assessment, Resolution and Management System
TAWS	Terrain Awareness Warning System
THA	THALES Avionics SA
TN	Thematic Network
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicles
VDR	Validation Data Repository
VFR	Visual Flight Rules

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Annex B. List of Partners

Partic. Role	Partic. No.	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	1	Ingeniería de Sistemas para la Defensa de España S.A.	ISD	Spain	T1	T40
CR	2	DFS Deutsche Flugsicherung GmbH	DFS	Germany	T1	T40
CR	3	GALILEO Avionica una societa' FINMECCANICA	GAL	Italy	T1	T40
CR	4	Skysoft Portugal, Software e Tecnologias de Informação S.A	SKY	Portugal	T3	T40
CR	5	Alenia SIA SpA	SIA	Italy	T4	T40
CR	6	THALES Avionics SA	THA	France	T1	T40
CR	7	Instytut Lotnictwa (Institute of Aviation)	IoA	Poland	T8	T40
CR	8	Rheinmetall Defence Electronics GmbH	RDE	Germany	T14	T40
CR	9	Diamond Aircraft Industries GmbH	DAI	Austria	T14	T40

Table B-1. SOFIA List of Partners

This project has been carried out under a contract awarded by the European Commission

Annex C. Workpackage Breakdown Structure

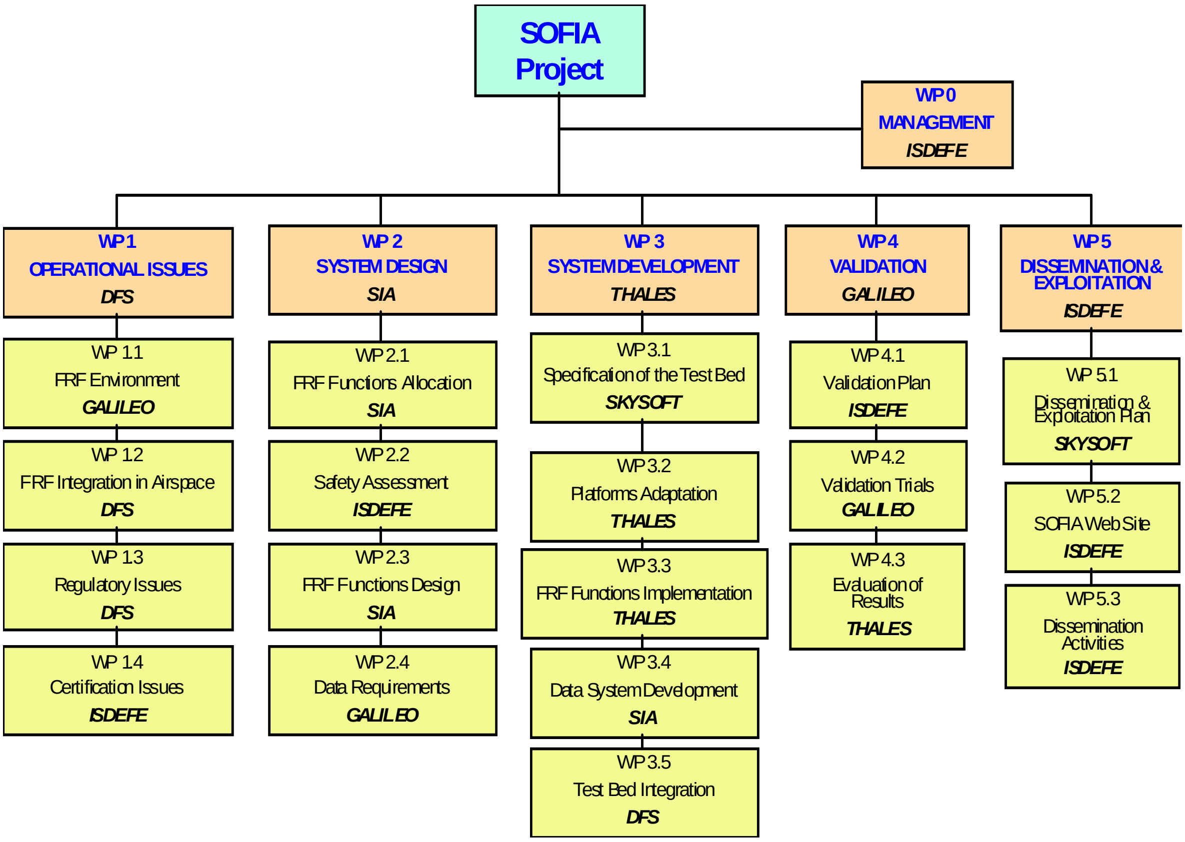

Figure C-1. SOFIA Workpackage Breakdown Structure