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iFly

Safety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management

Specific Targeted Research Projects (STREP)

Thematic Priority 1.3.1.4.g Aeronautics and Space

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Identification of Potential Directions for Further refinement of the A3 ConOps

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Abstract

iFly defines an innovative Operational Concept based on aircraft operation in autonomous mode. It considers the capability of separation self-management among aircraft under very high en-route traffic demands. Due to the innovative and challenging nature of this development, iFly project addresses E-OVCM Phase V1 (scope) only.

In this report, an outlook is given of potential directions for further improvement and refinement of this innovative Operational Concept, e.g. during E-OCVM phase V2 (feasibility).

The process used to identify potential directions for further improvement and refinement starts with an expert based identification of potential risks requiring further attention.

Key inputs to experts are the following iFly reports:

- D1.3: advanced concept design,
- D2.4: critical human factors based analysis of this advanced concept,
- D6.4: cost-benefit analysis of the advanced concept,
- D7.1b: hazard identification for the advanced concept.

Based on these inputs, experts working groups have been created to identify the potential risks on the advanced concept of operation, as well as potential directions for further improvement and refinement.

The outlook concludes with a systematic analysis of the differences and similarities among the numerous potential identified directions for improvement. This leads to a synthesis regarding the main potential directions for further improvement and refinement.

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1 Introduction

Some researchers believe that airborne self-separation can safely accommodate traffic levels much greater than current en-route traffic. Other researchers believe that airborne self-separation cannot work safely for high density airspace. Both types agree that for airspace having sufficiently low traffic densities, airborne self-separation may be safe.

From a research perspective this requires a study which evaluates up to which traffic levels airborne self-separation is safe. This is exactly the key aim of the iFly project. For en-route traffic, iFly has the objective to develop an advanced airborne self-separation design together with a vision how the well-equipped aircraft can be integrated within SESAR concept thinking. The goal is to accommodate a three to six times increase in current en-route traffic levels. This incorporates analysis of safety, complexity and pilot/controller responsibilities and assessment of ground and airborne system requirements and which make part of an overall validation plan. The proposed iFly research combines expertise in air transport human factors, safety and economics with analytical and Monte Carlo simulation methodologies providing for "implementation" decision-making, standardisation and regulatory frameworks.

iFly performs two operational concept design cycles and an assessment cycle comprising human factors, safety, efficiency, capacity and economic analyses. During the first design cycle, state of the art Research, Technology and Development (RTD) aeronautics results will be used to define a "baseline" operational concept. For the assessment cycle and second design cycle, innovative methods for the design of safety critical systems will be used to refine the operational concept with the goal of managing a three to six times increase in current air traffic levels. These innovative methods find their roots in robotics, financial mathematics and telecommunications.

iFly has developed a challenging concept referred to as Autonomous Aircraft Advanced (A^3) Concept of Operations (ConOps [iFly D1.3]). This A^3 ConOps is defined on the basis of aircraft operations flying in autonomous mode without air traffic controller support. Due to the innovative and challenging nature of this development, iFly addresses E-OVCM Phase V1 (scope) only. This report provides an outlook to potential directions for further improvement and refinement of this Operational Concept, e.g. during E-OCVM phase V2 (feasibility).

This report is an input to the final report. It is organised as follows:

Section 2 – work package objectives

Section 3 – Identification of potential risks
This section covers steps 1, 2 and 3, leading to the identification of potential risks.

Section 4 – Potential direction for refinement
This section covers step 4 leading to the identification of potential directions for refinement.

Sections 5 and 6 – Analysis
This section covers step 5, and identifies relevant correspondences between risks and potential directions for refinement.

Section 7 - Conclusions

2 Objectives of this report

The aim of this report is to analyse potential risks regarding key performance areas (KPA's): safety, cost/benefit and capacity. The chosen approach starts with an expert based identification of potential risks requiring further attention, e.g. during E-OCVM phase V2.

Key inputs to experts are the following iFly reports:

- D1.3: advanced concept design,
- D2.4: critical human factors based analysis of this advanced concept,
- D6.4: cost-benefit analysis of the advanced concept,
- D7.1b: hazard identification for the advanced concept.

On these inputs basis, experts working groups have been created in order to identify potential risks of this advanced operation concept as well as potential directions for further improvement and refinement.

The activities have been organized using the following systematic steps:

Step 1: Identification of technical areas.
This step identifies the most relevant technical areas in relation to KPA's: safety, cost-benefit and capacity.

Step 2: Evaluation and filtering of results.
This step identifies and filters the information provided by previous studies and the work done in previous work packages.

Step 3: Identifications of potential risks.
This step identifies potential risks with aircraft using the A^3 ConOps rules.

Step 4: Identification of potential directions for refinement.
This step aims to identify potential directions for refinement of the ConOps of the previously identified risks.

Step 5: Study of redundancy and correspondence.
This step is aimed to avoid redundancies or contradictions within the identified potential directions for refinement.

Step 6: Results.
In this step the main potential improvement activities are identified.

3 Identification of potential risks

iFly develops a new concept for aircraft flying in autonomous mode without air traffic controller support. This mode is not currently operative due to technical limitations. The proposed ConOps aims to facilitate the extension of airspace capacity without increasing the operational costs of aircrafts in flight or deteriorating the en-route safety level.

The main areas studied (considering the SESAR frame) are the following:

- Safety: the safety level must be kept at least at current operation safety level values
- Capacity: the capacity in the air space must increase the current level by at least three times.
- Costs/Benefit analysis: the time horizon to implement the A3 ConOps is 2025; this implies high investments in a limited time. The defined condition is that the following Benefit/Cost rate must exceed 1.

The methodology used to identify the potential risks is a top-down process.

- The process starts with the identification of Key Constraints Areas (KCA) stated above: safety, capacity and cost/benefit analysis.
- The next step addresses the identification of the Constraint Focus Area (CFA)
- The last step is the identification of potential risks.

3.1 Potential risks in the safety area

Safety is a critical KPA of any advanced ATM operation. Following the top-down approach, two Constraint Focus Areas (CFAs) were identified:

- Human Factors (HF).
- Technical Problems.

Human factors could be considered as a KCA due to its relevance in the operation of A^3 ConOps and the results obtained in iFly. However in the analysis process, Human Factors (HF) is considered as a subset area of safety and capacity KCAs.

Two typical Technical Problem risks are addressed: HW risks and SW risks. Both types of problems are studied and analysed in order to identify the potential risks.

Table 1 summarizes the main potential risks identified in the safety area and associated codes.

KEY CONSTRAINT AREA (KCA)	
1	SAFETY
CONTRAINT FOCUS AREAS (CFA)	
1.1	HUMAN FACTORS
	POTENTIAL RISKS IDENTIFICATION
1.1.1	Pilots may not continue monitoring potential conflicts in a critic phase
1.1.2	Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear.
1.1.3	It is not a viable manoeuvre and the actors involved are unaware
CONTRAINT FOCUS AREAS (CFA)	
1.2	TECHNICAL PROBLEMS
	POTENTIAL RISKS IDENTIFICATION
1.2.1	Wrong surveillance data can raise false alarms.
1.2.2	What if AC without any transponder or not working?
1.2.3	Malfunctions in communications equipment
1.2.4	Non-nominal encounter condition STCD&R

Table 1 Safety: Potential risks

3.1.1 Pilots may not continue monitoring potential conflicts in a critical phase. (code: 1.1.1)

The pilot requires updated and clear information about the current aircraft situation and the potential conflicts. In some situations it is possible that the pilot is unaware of the whole situation (mainly due to high workload and/or the poor information provided by the HMI). Potential conflicts may not be detected on time for a safe operation.

3.1.2 Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear. (code: 1.1.2)

The information provided by the conflict detection system must be so intrusive and clear that it supports the pilot unambiguously in his decision making process, even in high workload conditions. Poor or inefficient information would result in no decision or wrong decision made by the pilot, with a potential repercussion on the safety of the flight.

3.1.3 It is not a viable manoeuvre and the actors involved are not aware (code: 1.1.3)

The Aircraft attitude is not viable or it is not conflict free while nobody is aware and the crew have not all the required information. This situation could lead to conflicts and misunderstandings between the actors involved because they are not working with the same information.

3.1.4 Wrong surveillance data can cause false alarms (code: 1.2.1)

The information provided by the systems must be robust and reliable. If data are wrong, the pilot can be induced to make a wrong decision, activating the corresponding operational procedures.

3.1.5 What if an aircraft (AC) has no transponder or it is not working? (code: 1.2.2)

If the aircraft without the transponder working cannot transmit information of identification and situation, it is an aircraft without full capabilities. Other aircraft do not have appropriate information of their environment situation, due to the lack of information of non-transponder-equipped aircrafts. The on-board alert systems in the surrounding airspace will have incomplete information that could induce making a wrong decision.

3.1.6 Malfunction in the communication equipment (code: 1.2.3)

The aircraft is not sending the intention and current positional data due to communication equipment malfunction but nobody is aware of this problem. Other aircraft are working with wrong information. This situation can cause incidents in different phases of flight, mainly in the transition phase from SSA to MA and vice versa.

3.1.7 Non-nominal encounter condition STCD&R (code: 1.2.4)

The A^3 operational concept will be used with the current operative systems. These systems performance is defined in a non-A^3operational scenario. The use of these systems and STCD&R will imply that these systems must adapt their performance to the A^3 requirements. If these systems are not well adapted, problems in conflicts resolution may arise leading to non-optimal manoeuvres.

3.2 Potential risks in the capacity area

One of the main objectives of iFly is increasing three times the number of aircraft flying in the airspace using the technological and innovative procedure defined in the A^3 ConOps.

To facilitate the analysis in this area, three Constraints Focus Areas were identified:

- Availability in airspace.
- Procedures.
- Human factors.

Table 2 presents the main potential risks identified in Capacity area and the associated code.

KEY CONSTRAINT AREA	
2	CAPACITY
CONTRAINT FOCUS AREAS (CFA)	
2.1	AVAILABILITY IN AIR SPACE
	POTENTIAL RISKS IDENTIFICATION
2.1.1	Mixed aircraft flying in the same non segregated airspace
2.1.2	Problems of capacity in controlled areas. (TMA).
CONTRAINT FOCUS AREAS (CFA)	
2.2	PROCEDURES
	POTENTIAL RISKS (PI) IDENTIFICATION
2.2.1	Trajectory deconfliction
2.2.2	Constraints due to weather conditions
2.2.3	Constraints due to unexpected restricted areas
2.2.4	Unexpected growth of air traffic in any given time

2.2.5	Unexpected conditions due to flight incidents
CONTRAINT FOCUS AREAS (CFA)	
2.3	HUMAN FACTORS
	POTENTIAL RISKS IDENTIFICATION
2.3.1	Increasing the air-crew workload in self-separation
2.3.2	No clear definition of the roles of each actor
2.3.3	inexperienced air crew in flight

Table 2 Capacity: Potential risks

3.2.1 Mixed aircraft flying in the same non segregated airspace (code: 2.1.1)

Aircraft flying with different functionalities and performance in the same airspace indicates that this airspace cannot be fully A^3 compliant the capacity of the air space could decrease if the operation is adapted to aircraft with fewer capabilities.

3.2.2 Problems of capacity in controlled areas. (TMA) (code: 2.1.2)

The problems in neighbour areas are usual in the controlled airspace. This problem in the A^3 is presented when the TMA is saturated or capacity problems arise; in this case, the entry point area will have regulation problems (priorities) and airspace control degradation.

3.2.3 Trajectory deconfliction (code: 2.2.1)

During the pre-flight phase, the trajectories planned by the aircrew are deconflicted. The defined Business Trajectory (BT) will be planned with the information provided by different sources. The BT will be updated taking into account the optimization in time and performance, avoiding future conflicts. If the information is not reliable and correct, this can imply increasing flight time and reducing airspace capacity.

3.2.4 Constraints due to weather conditions (code: 2.2.2)

Meteorological conditions can decrease the capacity of airspace; the trajectories must be planned as deconfliction trajectories, so the RBT must be updated to avoid unfavourable meteorological conditions.

3.2.5 Constraints due to unexpected restricted areas (code: 2.2.3)

This potential risk is similar to the previous one. Nevertheless, unexpected restricted areas may appear; the RBT must be updated to avoid these areas.
In both cases, the capacity could be affected since it is required to keep safety levels with a reduction of the availability in the air space.

3.2.6 Unexpected growth of air traffic at any given time (code: 2.2.4)

Seldom could it be possible an unexpected growth of air traffic due to random circumstances. Therefore, it is possible an increase of conflicts by congested air space and new constraints in the air space capacity that may arise.

3.2.7 Unexpected conditions due to flight incidents (code: 2.2.5)

Seldom unexpected conditions could be possible and change the operational scenario or flights conditions of the aircraft, (alarms, problems with the on board systems).

3.2.8 Increase the air-crew workload in self-separation (code: 2.3.1)

The workload of the pilot will be increased, because the separation is self-managed by the pilots. The aircrew must identify, assess and make the correct decision in a limited timeframe. Due to safety issues, in some circumstances, the distance between aircraft could be extended due to the restriction in the air space capacity.

3.2.9 No clear definition of the roles of each actor (code: 2.3.2)

The role and the responsibility of each actor must be clearly defined; ambiguities in the roles with duplicated functionalities could lead to contradictory orders and false information about the safety situation. This can lead to constraints in the air space and reduce the capacity of the air space.

3.2.10 Inexperienced air crew in flight (code: 2.3.3)

The lack of experience using on-board systems can cause delays in air navigation route; this will leads to an increase in the separation between aircraft, reducing the capacity of airspace.

3.3 Potential risks in Cost/Benefit area

In the Key Constraint Area of Cost/Benefit analysis, three Constraints Focus Areas have been identified:

- Investments
- Operational costs
- Indirect Costs maintenance

Table 3 presents the main potential risks identified in the cost/benefit area and associated code.

KEY CONSTRAINT AREA	
3	ECONOMIC
CONTRAINT OF FOCUS AREAS (CFA)	
3.1	INVESTMENTS
	IDENTIFIED POTENTIAL RISKS
3.1.1	Increased investment
CONTRAINT OF FOCUS AREAS (CFA)	
3.2	OPERATIONAL COSTS
	IDENTIFIED POTENTIAL RISKS
3.2.1	Increase of the Operating Cost (due to transition to new operational procedures)
3.2.2	Increase of the costs by Flights delayed, (due a non-optimal use of the new systems)
CONTRAINT FOCUS AREAS (CFA)	
3.3	COSTS-MAINTENANCE
	POTENTIAL RISKS IDENTIFICATION
3.3.1	equipment maintenance cost (avionics)

Table 3 Cost/Benefit: Potential risks

3.3.1 Increased investment (code: 3.1.1)

Information is a key element needed to perform navigation based in A^3. To obtain robust and reliable information, it is necessary to provide a communication systems infrastructure providing real time data to update and improve the Reference business trajectory. The costs of this infrastructure could delay the implementation of the A^3 concept.

3.3.2 Increase of the operating cost (due to the transition to new operational procedures) (code: 3.2.1)

A^3 concept is based on flight self-management by keeping safety levels. This will lead to an operating procedures improvement. It is needed to define new operational procedures. It should be remarked that these procedures could eventually increase the operating costs.

This restriction applies mainly during the implementation period. Once the changes are implemented, new modifications should maintain a reduced cost profile.

3.3.3 Increase of the operating cost (due to flight delays arising from the non-optimal use of the new systems) (code: 3.2.2)

New avionics and functionalities may lead to additional operating cost, due to non-optimal use of the new systems and/or poor equipment performance. Delays due to these issues will increase fuel consumption and operating costs, especially during the A^3 ConOps implementation period.

3.3.4 Cost – in equipment maintenance (avionics equipment) (code: 3.3.1)

There will be a cost increase due to the introduction of new equipment to perform A^3 based flights that will also increase aircraft maintenance cost.

4 Directions for dealing with potential risks

This section presents potential directions for refinement dealing with potential risks already identified in the previous Section.

4.1 Safety directions

SAFETY			
Code	Potential risks identification	Code	Potential direction
1.1.1	Pilots may not continue monitoring potential conflicts in a critical phase.	1.1.1.1	Priorities rules. The existing procedure in TMA entry points must be performed with clear priority rules.
		1.1.1.2	Clearly defined HMI. Definition of a resolving system HMI to help monitoring the conflicts status.
1.1.2	Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear	1.1.2.1	Alternative information sources.
		1.1.2.2	Adding an additional screen representing information on cockpit, to improve HMI functionalities.
		1.1.2.3	Specific information regarding conflicts, in a dedicated screen, with specific warnings about state (not just "position-triggered alarms").
1.1.3	The manoeuvre is not a viable and the actors involved are unaware	1.1.3.1	Periodic checking
		1.1.3.2	Redundant architectures
1.2.1	Wrong surveillance data can raise false alarms.	1.2.1.1	Using voice channel
		1.2.1.2	Defining a protocol to ensure the quality of data.
		1.2.1.3	Redundant architecture
		1.2.1.4	Alternative information sources (data link, radar) Alternative sensors on-board?
1.2.2	What if an aircraft (AC) has no transponder or it is not working?	1.2.2.1	Using Voice Channel
		1.2.2.2	A standard procedure should be included as a requirement, helping to define an emergency protocol. Additional sensors on board?
1.2.3	Communications equipment malfunctions	1.2.3.1	Redundant architecture
		1.2.3.2	Improving communications protocols
		1.2.3.3	Periodic checking/cyclic test protocol
1.2.4	Non-nominal encounter condition STCD&R	1.2.4.1	Improving performance
		1.2.4.2	**Clearly defined HMI.** Improving STCD&R system, in order to alert Aircrew to reduce as far as reasonable, Aircrew reaction time.
		1.2.4.3	**Clearly defined HMI.** Improving HMI to ensure timely alerts from STCD&R can draw instant Flight Crew attention.
		1.2.4.4	Training
		1.2.4.5	Improving performance
		1.2.4.6	Improving the way STCD&R and ACAS System are working together. Sharing critical alerts.

Table 4 Safety: potential directions for refinement

4.1.1 Potential direction for refinement when the Pilots may not continue monitoring potential conflicts in a critical phase – code: 1.1.1

When the air-crew workload is increased, the monitoring of the surveillance system decreases. This implies that problems can arise due to poor systems monitoring by the aircrew

4.1.1.1 Priorities rules – code: 1.1.1.1

Priority rules will help to organize air traffic in a self-managed airspace helping the transition to controlled air space. These rules should be established according to traffic and flight conditions (constraints areas, weather conditions).

4.1.1.2 Clearly defined HMI – code: 1.1.1.2

The information provided by the HMI must be clear and easy to understand. An appropriate amount of data should be available.

4.1.2 Potential direction for refinement when pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear – code: 1.1.2

The pilot may not initiate an evasive manoeuvre if the air crew is not reported of a potential conflict due to poor information provided by the HMI.

4.1.2.1 Alternative information sources – code: 1.1.2.1

The capability of the surveillance system for a correct detection of critical scenarios must be reinforced. There is some equipment identified as part of the Surveillance System integrated in systems related to Navigation, Communication, etc. In these systems there is equipment that can provide extra information about current situation. With the intent data of the aircraft; this information can be used to strengthen surveillance information, improving the capacity of surveillance to detect critical scenarios.

4.1.2.2 Add additional display/representation of information on cockpit – code: 1.1.2.2

All the information must be displayed in a clear and precise way. Therefore, additional representation is needed to show information on the display to inform about the potential conflicts. The information can be displayed with new symbols and new functionalities defined in the surveillance screen.

4.1.2.3 Specific information regarding traffic conflicts, in other screen – code: 1.1.2.3

When the information provided by a system is very critical it can be useful to dedicate one screen to display critical system information. This information will not be mixed with other systems information in other screens since clear information about the current state and the potential conflicts must be given.

4.1.3 Potential direction for refinement in case of a non-viable manoeuvre and the actors involved are not aware - code: 1.1.3

A non-viable or non-conflict-free trajectory is selected, the air crew is not aware of the potential risks and they are flying the RBT selected.

4.1.3.1 Periodic checking - code: 1.1.3.1

It is necessary to perform a periodic check of flight information and the business trajectory in order to ensure that the air crew is aware of the current situation of the aircraft in flight. So the air crew must be in the loop, while checking displayed information must be considered as a periodic activity.

4.1.3.2 Redundant architecture – code: 1.1.3.2

The problem arises when the surveillance equipment fails: backup equipment is needed to identify malfunction. The redundant HW architecture is usual in the avionics equipment; the implementation of algorithms to verify the results and data mainly in conflict detection and conflict resolution will be useful to solve these potential risks.

4.1.4 Potential direction for refinement when the false surveillance can cause false alarms - code: 1.2.1

The information provided by the surveillance systems must be reliable. When the information provided is not reliable this may raise false alarms.

4.1.4.1 Using the radio voice channel to provide the position data – code: 1.2.1.1

The voice channel will be used to verify the transmitted information or to clarify a potential conflict. The voice channel will be used as a last resource to verify the information provided by the surveillance systems.

4.1.4.2 Defining a protocol to check the quality of data- code: 1.2.1.2

The use of a sole source of information can raise false alarm, because it is using subjective information. It is necessary to define a protocol to check the information using other sources, verifying in this way the quality of information.

4.1.4.3 Redundant Architecture - code: 1.2.1.3

All the systems have errors introduced in the equipment operation; some of them are amended during the operation. However there are other errors that cannot be amended by the system. The use of parallel equipment in a redundant architecture will facilitate the identification of errors and the accuracy of data.

4.1.4.4 Alternative Sources - code: 1.2.1.4

The use of additional navigation systems can be considered as alternative sources; these systems have the capability to provide similar information to surveillance equipment. The information provided by these systems can be used to verify the quality of the information. Therefore, information checking will do more reliable the navigation process as well as the conflict detection.

4.1.5 Potential direction for refinement in the "3.1.5 What if an aircraft (AC) has no transponder or it is not working?" case – code: 1.2.2

The transponder is needed for an unequivocal identification of aircraft. An aircraft without transponder or a transponder not working properly is a problem for the operation and the surveillance activities

4.1.5.1 Use "identification" procedure by means of radio checks – code: 1.2.2.1

When a transponder on board is not available, or the transponder is out of service it is necessary to define a procedure to identify the aircraft. So, identification could be performed by using the voice channel or complementary equipment reporting identification to other aircraft or operation centres.

4.1.5.2 Define an emergency protocol - code: 1.2.2.2

In case of an emergency, a protocol must be defined that would facilitate the operation helping the usual operation between aircraft, avoiding conflicts.

4.1.6 Potential direction for refinement in case of malfunction in communications equipment – code: 1.2.3

Data communications equipment has a main role in the development of aircraft flying in autonomous mode; A^3 ConOps is based on the information available in the network and shared by the actors involved in this process.

Problems arise when data are not available and the actors involved are not aware of current conditions

4.1.6.1 Redundant Architecture – code: 1.2.3.1

The hardware architecture must be safe (fault tolerant). The redundant architecture in systems and equipment will support the availability' of reliable information. Automatic switching between main equipment and back up equipment is required. The switching will be selected by the best quality signal available.

4.1.6.2 Improve the Communications protocols – code: 1.2.3.2

The protocols of communication must be fault tolerant. The protocols should provide availability to recover the information. These protocols will provide a transparent way to the end-user, pilots and air-crew.

4.1.6.3 Periodic checking - code: 1.2.3.3

It is necessary to define an operational protocol for the identification of activities and tasks, to facilitate the periodic check-up of equipment.

4.1.7 Potential direction for refinement in case of non-nominal encounter condition STCD&R – code: 1.2.4

The systems must adapt their performance to the A3 requirements. If these systems are not well adapted, problems in conflicts resolution may arise leading to non-optimal manoeuvres.

4.1.7.1 Improve Performances- code: 1.2.4.1

The STCD&R must be improved by defining a threshold to facilitate conflict detection. The operative conditions will be adapted to provide reliable information about the potential conflicts. The resolution will only be applied when the new functionalities are on-going and the new threshold defined in operation.

4.1.7.2 Clearly defined HMI – code: 1.2.4.2

HMI of STCD&R system must be improved in order to alert periodically the Air Crew. When a conflict is detected, an alert will be displayed on the screen system providing information to the pilot. In the A^3 environment the workload of the pilot is increased due to the performed tasks, so the pilot can relegate some detection alert due to other high priority activities. It will be useful to have a periodic reminder to the pilot of these potential conflicts, to avoid alerts stale outs.

4.1.7.3 Clearly defined HMI – code: 1.2.4.3

The HMI will ensure periodic alerts from the STCD&R systems. The HMI will provide the information about conflict detection. The information will be displayed and clearly identified in the screen, using functionalities such as blinking and flashing. The HMI will ensure a clear understanding of the detected conflict, displaying information about the resolution of the conflict.

4.1.7.4 Training - code: 1.2.4.4

The pilot flying in autonomous-mode must be fully operative. The amount of activities performed needs a better coordination and training of the air crew. Pilot Training should be carefully established to respect and emphasize the critical safety importance of the reaction time.

The air crew is involved in the decision making process, without ground segment support. Training will improve the operations of the aircrew assuring a safe operation.

4.1.7.5 Improve the coordination between STCD/R - ACAS- code: 1.2.4.5

Improved systems in conflict detection and resolution will lead to a better knowledge of a potential short-term conflict. The increase of the pilot workload can produce conflicts due to a non-optimal detection on time. Enhancements to STCD&R - ACAS could improve situational awareness of Flight Crew.

Two main points are:

- Coordination in alert function. This will help to a correct identification of potential conflicts on time.
- Improving the HMI, mainly in awareness situation with new functionalities to help the aircrew in the decision making process.

The scheme of the system is sketched in Figure 1.

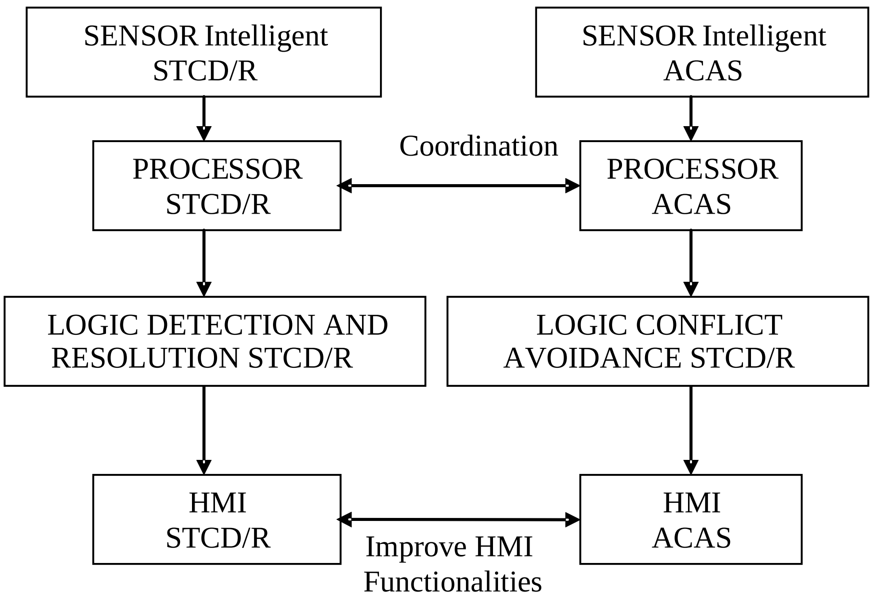

Figure 1 Coordinated STCD/R-ACAS Layout

4.1.7.6 Improving the way STCD&R and ACAS interoperation- code: 1.2.4.6

Interoperation can be a step forward unlike the full integration of the systems, sharing the information and results provided. This is depicted in Figure 2.

This way, the awareness and the compatibility in the alerts provided by different equipment will increase.

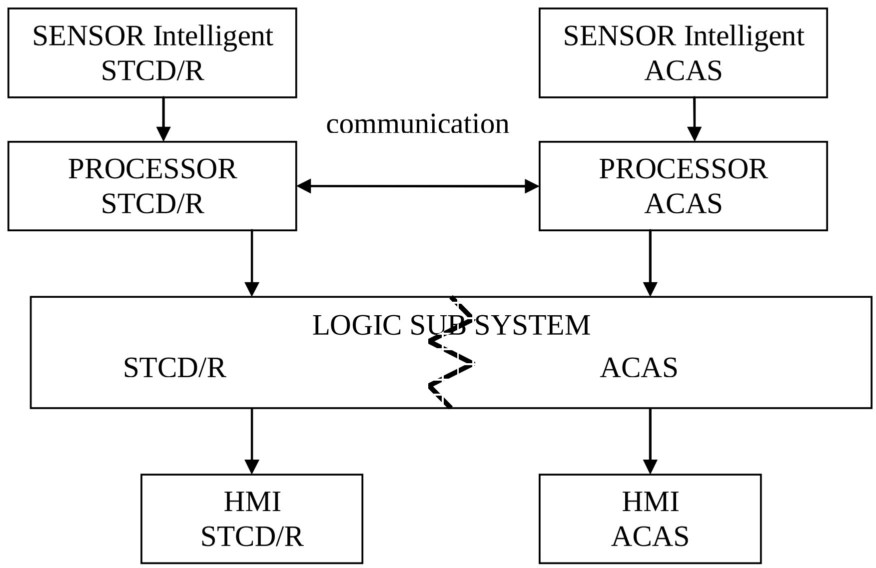

Figure 2 STCD/R -ACAS interoperation layout

4.2 Capacity directions

CAPACITY			
Code	Potential risks identification	Code	Potential direction
2.1.1	Mixed aircraft flying in the same non segregated airspace	2.1.1.1	Identification of the role of each actor.
2.1.2	Problems of capacity in controlled areas. (TMA).	2.1.2.1	Improving the information of RBT.
2.2.1	Trajectory deconfliction	2.2.1.1	All the aircrafts must use similar equipment
2.2.2	Constraints due to weather conditions	2.2.2.1	Better planning of RBT
2.2.3	Constraints due to unexpected restricted areas	2.2.3.1	Better planning of RBT
2.2.4	Unexpected growth of air traffic at any given time	2.2.4.1	SWIM.
2.2.5	Unexpected conditions due to a flight incident	2.2.5.1	Priority Rules
		2.2.5.2	Identification of the role of each actor
2.3.1	Increasing air-crew workload in self-separation	2.3.1.1	**Clearly defined HMI.** Improving and a clear description of functionalities of HMI
2.3.2	No clear definition of the roles of each actor	2.3.2.1	Identification of the role of each actor. The role must be clearly defined and with complementary functionalities in the actors involved and clearly defined.
2.3.3	Inexperienced air crew in flight	2.3.3.1	Training.

Table 5 Capacity: potential directions for refinement

4.2.1 With Mixed aircraft flying in the same non segregated airspace - code: 2.1.1

Aircraft with different performance in the on-board equipment, mainly in surveillance and navigation systems are considered.

4.2.1.1 Identification of the role of each actor – code: 2.1.1.1

The definition of the role of each actor must be improved In the Self-managed aircraft in the airspace the role of the actors involved in the process must be clearly defined and identified. This will help the operation in a non-segregated airspace, given the roles and the priorities in critical manoeuvres according to the capabilities of the aircraft.

4.2.2 Controlled areas capacity constraints. TMA – code: 2.1.2

The problems in controlled areas have an influence in Self-Separation Area (SSA). The entry points can be conflict areas when the enclosed areas have traffic constraints.

4.2.2.1 Improving the Information of RBT – code: 2.1.2.1

The information about constraints in neighbouring areas will be transmitted through the SWIM. The aircraft can modify its own RBT to fit CTA to the capacity in the enclosed controlled areas. The aircraft priority could be modified or other flight parameters could be adapted to help improving the capacity the near areas.

4.2.3 Trajectory deconfliction – code: 2.2.1

The definition and the execution of conflict free trajectories are needed in order to facilitate a safe operation without decreasing the capacity of the airspace.

4.2.3.1 All the aircrafts must use similar equipment – code: 2.2.1.1

All the Systems used in the process must have similar capabilities and performance to reach equal results. The results provided by the on-board equipment must provide similar information.

4.2.4 Constraints due to weather conditions – code: 2.2.2

The weather has a large influence in the different flight phases. In the pre-flight phase, the weather information will help to determine the optimum aircraft trajectory while during the flight phase the weather information will help to optimize the trajectory, avoiding stormy areas.

4.2.4.1 Best planning of RBT – code: 2.2.2.1

Weather information will facilitate defining an optimum RBT, helping long term prediction.

4.2.5 Constraints due to unexpected restricted areas – code: 2.2.3

Restricted areas will be **stated** as aeronautical information. This information must be facilitated to help in the definition of the RBT.

4.2.5.1 Best planning of RBT – code: 2.2.3.1

An unexpected restriction area can be identified during the flight. The information about these restricted areas will be sent helping the aircrew in the RBT planning and improving RBT performance.

4.2.6 Unexpected growing of air traffic of any given time - code: 2.2.4

The air traffic may be increased due to unexpected situations or traffic conditions not taken into account.

4.2.6.1 SWIM - code: 2.2.4.1

SWIM is the backbone of this system. The aeronautical information will be transmitted via SWIM. The change in the number of aircraft in the airspace must be reported to the users to get a real picture of the air space situation.

4.2.7 Unexpected conditions of flight incident – code: 2.2.5

Events in the flight can affect the Business Trajectory modifying the flight conditions. These events must be controlled to ensure flight safety and minimize its influence in the Business Trajectory.

4.2.7.1 Priorities rules- code: 2.2.5.1

The correct application of flight priorities must help the flight operation. These clearly identified priorities will help to solve potential conflicts without the implication of external actors to A^3 ConOps. (Ground support teams).

4.2.7.2 Identification the role of each actor- code: 2.2.5.2

The role defined for the aircraft in the A^3 operation must be according to the flight operations, the capacity of the aircraft, and the executed trajectory. A clear definition of these issues will help to detect potential conflicts, avoiding potential risks.

4.2.8 Increase the air-crew activities in self-separation – code: 2.3.1

The workload of the aircrew will be increased due to activities to be done in the surveillance operation with other self-managed aircraft.

4.2.8.1 Clearly defined HMI – code: 2.3.1.1

It is necessary to provide a clear description of the HMI functionalities. The HMI is the cornerstone to facilitate the aircrew a clear picture of the situation; this will help to a fast understanding of the situation helping in the decision making process.

4.2.9 Identification the role of each actor - code: 2.3.2

In the last sixty years there has been a clear definition of the roles of the actors involved in the air management process. These roles and the responsibility assigned to each one are a main part of the operation. The A^3 concept is an innovative and challenge concept in which the roles of the different actors are redefined trying to maximize the performance of the new environment, adapting the capabilities of this environment to the technical capacities of the systems involved.

4.2.9.1 The role must be clearly defined. code: 2.3.2.1

The roles of each actor will be clearly identified. The enablers provide the services required for a coordinated management of the systems.

The main problem emerge in the border with management areas, where the ground segment – Air Traffic Control Centre - will have a similar role to the aircrew in other phases of the Flight (en-route) in the A^3 operation in the decision making. The transition between controlled near areas and the roles of each actor must be clearly identified, improving the operability and decreasing hazard in the transition operation.

4.2.10 Inexperienced air crew in flight – code: 2.3.3

The aircrew is flying with new systems and new procedures in a self-managed air space. The flight mode is similar to the controlled air space but the new conditions increase the workload of air crew, with new functionalities and new procedures.

4.2.10.1 Training code: 2.3.3.1

The aircrew must be trained in the new operational activities; the air crew flying in the SSA must be experts in the activities performed and the systems used.

4.3 Cost / Benefit directions

ECONOMICS			
Code	Potential risks identification	Code	Potential direction
3.1.1	Increased investment	3.1.1.1	New Functionalities
		3.1.1.2	Ground equipment, (SWIM), Could it be possible to use existing networks, with similar functionalities? (SITA)
3.2.1	Increase of the Operational Cost (due to transition to new operational procedures)	3.2.1.1	The new operational procedures must be optimized.
3.2.2	Increase of the operating cost caused by Flights delayed (due a non-optimal use of the new systems).	3.2.2.1	Training.
3.3.1	Indirect cost – in equipment maintenance (avionics)	3.3.1.1	New functionalities.

Table 6 Cost/Benefit: potential directions for refinement

4.3.1 Increased investment – code: 3.1.1

In order to facilitate the operations in the SSA it is required to carry equipment and systems that support the operation of autonomous aircraft. Current systems are used in defined ground coordination scenarios, providing service control. It is necessary to improve some infrastructures, systems and equipment to facilitate A^3 operations (SWIM, support surveillance, etc.).

4.3.1.1 New functionalities- code: 3.1.1.1

The current on board equipment must improve the functionalities supporting the new operations defined in the A^3 ConOps. The answer time of avionics must be improved, providing a faster answer and helping in the decision making process of the aircrew and resolution of problems.

4.3.1.2 SWIM – code: 3.1.1.2

SWIM will provide the whole ground information needed by the autonomous aircraft for their operation, facilitating the communications and the transmissions of Business Trajectories needed for the normal operation of aircraft.

4.3.1.3 Cost Benefit Analysis Assessment

A Cost-Benefit analysis assessment to identify the investment (per stakeholder) is required. This can cover with the expected benefits.

4.3.2 Increase of the operating cost (due to transition to new procedures) – code: 3.2.1

The operational cost is linked with the adaptability of the autonomous aircraft to the operational environment, capacity problems. Operation in mixed aircraft environment and non-optimal decision can increase the operational cost decreasing the effectiveness of flight with self-management in separation between aircraft.

4.3.2.1 Definition of new procedures- code: 3.2.1.1

The adaptation to the SSA will be a continued process with strong problems of adaptability that must be solved without decreasing the safety operation levels. This factor can break the costs and safety balance, increasing the operational cost to keep safety levels. This may be a temporary factor, which will be solved with the gradual implementation of the A^3 concept and the definition of new operational procedures.

4.3.3 Increase of the costs by Flights delayed – code: 3.2.2

Improvement in avionics (equipment and functionalities) may not be linked with direct improvements in the Business Trajectory of the aircraft, because there could be a non-optimal use of the system or a poor performance of the systems. Delays by these issues will increase fuel consumption and costs.

4.3.3.1 Training – code: 3.2.2.1

The use of new equipment with operability modifications will imply a change in performance and the flight aircraft operability. In some cases, only a good knowledge of the system and their performance can solve the emerging problems. Previous training and good instruction will help to the air crew to execute an optimum trajectory without introduce delays at the flight.

4.3.4 Indirect cost – in equipment maintenance – code: 3.3.1

There will be an increase on avionics costs due to the equipment improvements with new capabilities to perform the A^3 flight. This will be part of the aircraft costs in equipment.

The analysis of results in investment and Cost/Benefit analysis will supply information about the feasibility of the concept.

4.3.4.1 New functionalities- code: 3.3.1.1

New equipment carried in aircraft flying in autonomous mode will provide new functionalities helping the usual operation. It is expected that an increase in the operability will result on improving the functionalities in surveillance and navigation. These new functionalities will increase safety helping to perform a more effective and cheaper Business trajectory that would help to balance the maintenance cost.

5 Potential risks influence: cross-section analysis

In the previous sections, potential risks and potential directions for refinement have been identified from three perspectives, i.e. safety, capacity and cost/benefit.

As these potential risks and potential directions for refinement may overlap or conflict, this section studies their "redundancy and relations". For example, Potential risk 1.1.2 (Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear) is closely related to potential risk 2.3.1 (increasing the air-crew workload in self-separation), since the aircrew will not perceive potential conflicts because the work load is increased".

A cross-section analysis between potential risks is performed and shown in the following tables. This step is aimed to avoid redundancies or contradictions within the identified potential directions for refinement.

Annex III provides the whole information in a summary table, including cross references between potential risks.

5.1 Safety versus other issues

Table 7 shows a cross-section study between potential risks of Human Factors in safety versus other potential issues.

				SAFETY - 1		
				HUMAN FACTORS – 1.1		
		Code		1.1.1	1.1.2	1.1.3
			Potential risk	Pilots may not continue monitoring potential conflicts in a critical phase.	Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear	It is not a viable manoeuvre and the actors involved are not aware
SAFETY -1	HUMAN FACTORS 1.1	1.1.1	Pilots may not continue monitoring potential conflicts in a critical phase.			
SAFETY -1	HUMAN FACTORS 1.1	1.1.2	Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear			
SAFETY -1	HUMAN FACTORS 1.1	1.1.3	It is not a viable manoeuvre and the actors involved are not aware	The pilot can decide a nonviable manoeuvre, because they are not monitoring in a critic phase and they are not aware		
SAFETY -1	TECHN I CAL PROBLEMS 1.2	1.2.1	False surveillance data can raise false alarms.	When the pilot cannot continuously monitor, data it can raise false alarms.		Wrong surveillance data can promote a non-viable manoeuvre.
SAFETY -1	TECHN I CAL PROBLEMS 1.2	1.2.2	What if an aircraft (AC) has no transponder or it is not working?			
SAFETY -1	TECHN I CAL PROBLEMS 1.2	1.2.3	Malfunctions in the communications equipment		When communications are not working well, information can be wrong. The pilot can make wrong decisions.	With communication malfunction a wrong decision about a non-viable manoeuvre can be made.
SAFETY -1	TECHN I CAL PROBLEMS 1.2	1.2.4	Non-nominal encounter condition STCD&R	With a non-continuous monitoring, non-nominal condition can lead to non-optimal solutions.	The aircrew could not be reported of a potential conflict, because the information is non-nominal.	The non-nominal condition can promote a non-viable manoeuvre.
CAPACI TY - 2	PROCEDURES 2.2	2.2.1	Trajectory deconfliction			Looking a trajectory deconfliction, a non-viable manoeuvre can be decided.
CAPACI TY - 2	PROCEDURES 2.2	2.2.2	Constraints due to weather conditions	The aircrew cannot detect the weather constraints.		By weather constraints detected or not detected a non-viable manoeuvre can be decided.

				SAFETY - 1		
				HUMAN FACTORS – 1.1		
		Code		1.1.1	1.1.2	1.1.3
			Potential risk	Pilots may not continue monitoring potential conflicts in a critical phase.	Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear	It is not a viable manoeuvre and the actors involved are not aware
		2.2.3	Constraints due to unexpected restricted areas	The new conditions of RBT cannot be detected because the Aircrew are not continuously checking.		The restricted areas can promote a non-viable manoeuvre.
		2.2.4	Unexpected growing of air traffic of any given time	The pilot may not detect the growing of traffic because the aircrew are not continuously monitoring the system the screen.		The emergence of new traffic can promote a non-viable manoeuvre.
		2.2.5	Unexpected conditions due to flight incidents			
	HUMAN FACTORS 2.3	2.3.1	Increase the air-crew workload in self-separation	A growing workload can lead to a bad monitoring of the on-board system.	The aircrew will not be aware of potential conflicts because the work load is increased.	When increasing the workload, the possibility of a wrong decision about a viable manoeuvre increases.
		2.3.2	No clear definition of the roles of each actor			
		2.3.3	inexperienced air crew in flight	Lack of experience will imply bad monitoring of the on board equipment.	Lack of experience may imply that the aircrew could not observe potential conflicts.	Lack of experience of the air crew, may promote a wrong decision about a viable manoeuvre
ECONOMIC - 3	OPERAT I ONAL COST – 3.2	3.2.1	Increase of the Operational Cost	The operational cost will increase. With inadequate monitoring the decisions cannot be optimal.	The operational cost will increase. With inadequate monitoring the decisions will not be optimal.	
		3.2.2	Increase of the Flights delayed costs, (due a non-optimal use of the operative improvements)	Inadequate monitoring will increase the delay time	Inadequate monitoring will increase the delay time	

Table 7 Safety (I): human factors versus other potential issues

Table 8 presents a cross-section study of the influence of technical problems in safety and other issues, excluding human factors, in safety.

				SAFETY - 1			
				TECHNICAL PROBLEMS – 1.2			
		Code		1.2.1	1.2.2	1.2.3	1.2.4
			Potential risk	False surveillance data can raise false alarms.	What if an aircraft (AC) has no transponder or it is not working?	Malfunctions in the communications equipment	Non-nominal encounter condition STCD&R
SAFETY -1	TECHNICAL PROBLEMS-1.2	1.2.1	False surveillance data can raise false alarms.				
		1.2.2	What if an aircraft (AC) has no transponder or it is not working?				
		1.2.3	Malfunctions in the communications equipment	Malfunctions in communications can provide wrong information and therefore raise false alarms.			
		1.2.4	Non-nominal encounter condition STCD&R	The non-nominal encounter condition will provide wrong surveillance data.			
CAPACITY-2	HUMAN FACTORS-2.3	2.3.1	Increase of the air-crew workload in self-separation			When the communication equipment is not working, could increase the workload with new tasks, to facilitate the operation.	The workload will grow because the data received are not in nominal condition.
		2.3.2	No clear definition of the roles of each actor				
		2.3.3	inexperienced air crew in flight				Due to the lack of experience of the aircrew, the air data could not be correctly interpreted with non-nominal condition
ECONOMIC-3	OPERATIONAL COST-3.2	3.2.1	Increase of the Operational Cost				Flying in a non-nominal condition, will increase operational costs
		3.2.2	Increase of the costs by Flights				

			delayed, (due a non-optimal use of the operative improvements)				

Table 8 Safety (II): Technical Problems versus other potential issues.

5.2 Capacity versus other issues

Table 9 provides preliminary results about capacity. The table shows the cross-section study considering only the potential issues in capacity.

				CAPACITY - 2	
				AVAILABILITY IN AIR SPACE – 2.1	
		Code		2.1.1	2.1.2
			Potential risk	With Mixed aircraft flying in the same airspace no segregated	Problems of capacity in the controlled areas. TMA.
CAPACITY -2	AVAILABILITY IN AIR SPACE – 2.1	2.1.1	Mixed aircraft flying in the same non segregated airspace		
		2.1.2	Problems of capacity in the controlled areas. TMA.	The air space capacity is reduced with mixed aircraft.	
	PROCEDURES – 2.2	2.2.1	Trajectory deconfliction		
		2.2.2	Constraints due to weather conditions		
		2.2.3	Constraints due to unexpected restricted areas	The growing of the numbers of mixed aircrafts can increase the number of restricted areas.	
		2.2.4	Unexpected growth of air traffic at a given time		
		2.2.5	Unexpected conditions due to flight incidents		
	HUMAN FACTORS 2.3	2.3.1	Increase of the air-crew workload in self-separation	The aircrew workload will grow with mixed aircraft flying in the same airspace and different capacities.	Capacity problems in the TMA involve problems in near areas, increasing the workload of aircrews, because increases the tasks done in separation activities.
		2.3.2	No clear definition of the roles of each actor	The roles in airspace with mixed aircraft must be clearly defined	
		2.3.3	inexperienced air crew in flight		The inexperience of the air crew can imply capacity problems in the en-route operation but with special impact in the TMA areas.
ECONOMIC	OPERATIONAL COST 3.2	3.2.1	Increase the Operational Cost	Mixed aircraft in the airspace will increase the operational cost. The operation must be coordinated due to the two types of aircraft flying with different operational modes	The problems of capacity will increase the operational cost.
		3.2.2	Increase of Flights delayed costs, (due a non-optimal use of the new systems and operations)	The flights delayed will increase the flight cost because there would exist two operative modes, with different procedures.	The problems of capacity in the TMA will increase the cost of operation, with potential delays in flight.

Table 9 Capacity (I): availability in air space of versus other potential issues

Table 10 analyses the influence of the constraint focus areas of procedures versus human factors in capacity.

				CAPACITY -2				
				PROCEDURES 2.2				
		Code		2.2.1	2.2.2	2.2.3	2.2.4	2.2.5
			Potential risk	Trajectory deconfliction	Constraints due to weather conditions	Constraints due to unexpected restricted areas	Unexpected growth of air traffic of any given time	Unexpected conditions due to flight incidents
CAPACITY -2	HUMAN FACTORS – 2.3	2.3.1	Increase of the air-crew workload in self-separation				Unexpected events will increase the workload of the crew	increase of the workload by unexpected conditions
		2.3.2	No clear definition of the roles of each actor					
		2.3.3	inexperienced air crew in flight					The inexperience of the aircrew with unexpected conditions can provoke no clear situations, delaying the operations time.

Table 10 Capacity (II): Procedures versus Human factors

5.3 Cost/Benefit versus other issues

Table 11 describes the influence of technical problems in capacity and the economic constraints.

				CAPACITY -2		
				HUMAN FACTORS 2.3		
		Code		2.3.1	2.3.2	2.3.3
			Potential risk	Increase of the air-crew workload in self-separation	No clear definition of the roles of each actor	inexperienced air crew in flight
CAPACITY - 2	HUMAN FACTORS 2.3	2.3.1	Increase the air-crew workload in self-separation			
		2.3.2	No clear definition of the roles of each actor	The roles of each actor should be clearly identified to avoid overlapping activities, and increased workload.		
		2.3.3	inexperienced air crew in flight	the inexperience will increase the aircrew workload	The inexperience of aircrew may provoke a non-clear identification of the roles of each actor involved in conflicts process.	
ECONOMIC -3	OPERATIONAL COST 3.2	3.2.1	Increase of Operational Cost (due to the transition to new operational procedures)		Badly defined roles will increase the operational costs	The inexperience of the aircrew will increase the operational costs
		3.2.2	Increase of delayed Flights costs, (due a non-optimal use of the operative improvements)		The delays will grow, when the roles are not well defined (e.g. overlapping responsibilities)	The inexperience of the aircrew will increase the delays

Table 11 Cost / Benefit (I): Human factors versus capacity and economics

Table 12 presents the influence only related to economic factors.

				ECONOMIC - 3	
				OPERATIONAL COST – 3.2	
				3.2.1	3.2.2
			Potential risk	Increase the Operational Cost	Increase the costs by Flights delayed, (due a non-optimal use of the operative improvements)
ECONOMIC - 3	OPERATIONAL COST – 3.2	3.2.1	Increase of Operational Cost		
		3.2.2	Increase of delayed Flights costs , (due a non-optimal use of the operative improvements)	When the delay grows, operational costs increases	

Table 12 Cost / Benefit (II): Operational costs

6 Potential risks and improvements relationships

6.1 Potential risks links

Relationships identified in the previous sections summarised in Annex III are also presented in Figure 3. Here potential risks are presented as linked bubbles (coded with potential risks), showing their influence among them.

In the next figure, blue bubbles represent safety potential risks, green bubbles correspond to capacity potential risks and, finally, yellow bubbles correspond to cost/benefit potential risks. Each bubble has a number inside representing the potential risk code in Table 1, Table 2 and Table 3.

The figure shows a strong influence between the capacity potential risks and the safety potential risks (blue and green bubbles, respectively). This determines the operational behaviour of A^3 ConOps.

Tables 4 (paragraph 3.1), 5 (paragraph 3.2) and 6 (paragraph 3.3) provide information with the activities that can mitigate the potential constraints detected in the analysis done in the current document. Some of the potential improvements identified are useful only for one potential risk. However, specific potential improvements can help to moderate several potential risks. These potential improvements can be identified as key potential improvement activities because their influence to moderate several potential risks is higher, helping to facilitate the implementation of A^3 ConOps.

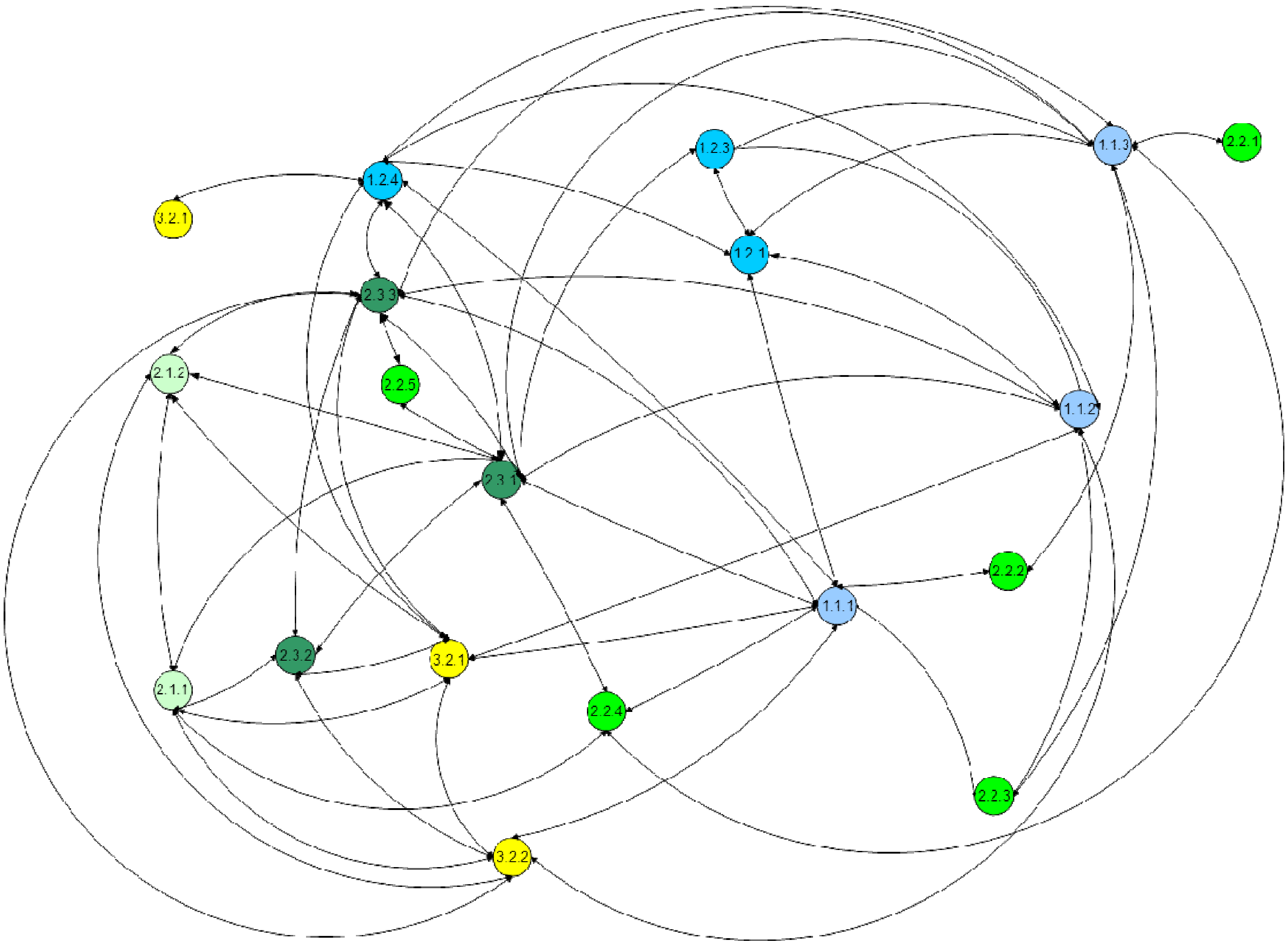

Figure 3 Potential risks link diagram

6.2 Potential improvement links

The identification of "key potential improvement" was performed by analysing these tables and considering the influence between potential risks, described in Table 7 to Table 12. The results are shown in a graphical mode in Figure 4.

- Big circles represent potential risks.
- Dashed arrows show the links between potential risks identified in Table 7 to Table 12.

Potential risks: Each potential risk has at least one potential improvement action represented by smaller circles. The number of the small circles is the potential improvement code (see Table 4, Table 5 and Table 6). The arrows between coloured circles and white circles represent the type of potential improvement action, so the potential improvement actions 2.2.5.2, 2.1.1.1 and 2.3.2.1 (Roles) are related to the improvement of the roles of the actors involved, in the potential risks 2.2.5 (Unexpected conditions due to flight incidents), 2.1.1 (With Mixed aircraft flying in the same non segregated airspace) and 2.3.2 (No clear definition of the roles of each actor). The potential improvement actions 1.2.2.1 and 1.2.1.1(voice channel) are in relation with the use of voice channel in the potential risks 1.2.2 (False surveillance data can cause false alarms) and 1.2.1 (What if an AC without any transponder or not working?).

Link between potential risks: The potential risk 1.1.3 (It is not a viable manoeuvre and the actors involved are not aware) is related with potential risk 1.2.1(False surveillance data can cause false alarms) and 1.2.3 (Malfunctions in the communications equipment) (see Table 7). Similarly with 2.3.2 (No clear definition of the roles of each actor) and 2.1.1 (Mixed aircraft flying in the same non segregated airspace) (see Table 9).

Potential improvement actions such as “Voice channel” and “SWIM“ use moderate the constraint, but its potential risks are not related between them. In other cases, as "Clearly defined HMI" the potential improvement activity is moderating several potential risks (1.1.1- Pilots may not continue monitoring for potential conflicts in a critic phase. 1.2.4- The non-nominal encounter condition will produce false surveillance data., and 2.3.1- Increase of the air-crew workload in self-separation) related between them in agreement with the analysis of Table 7 (Comparative Human factors of safety versus other potential risks). Therefore in these cases the potential improvement activity helps to moderate the potential risks related between them, doing an "influence ring" to get the more optimal potential improvement.

These types of potential improvement actions are considered “key potential improvement activities” and can be considered as key elements to facilitate the A^3 ConOps operation by their activity and facilitate the influence between potential risks.

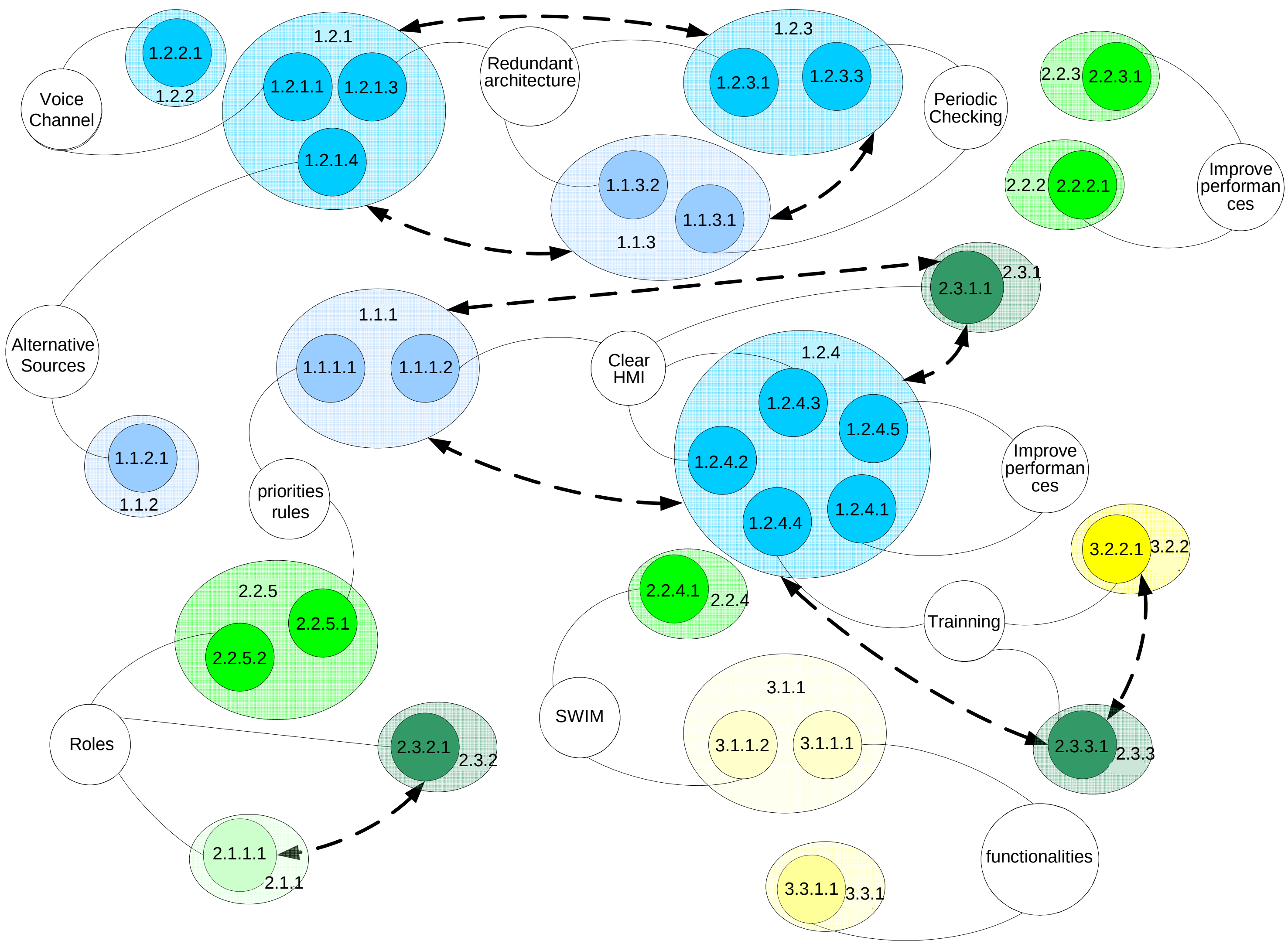

Figure 4 Potential risks: main potential improvement links

7 Conclusions

From a research perspective, a study is required assessing traffic levels for a safe airborne self-separation. This is exactly the key aim of iFly project. For en-route traffic, iFly has the goal to develop an advanced airborne self-separation design integrated within SESAR concept framework. The goal is to accommodate a three to six times increase in current en-route traffic levels. The project incorporates an analysis of safety, complexity and pilot/controller responsibilities and an assessment of ground and airborne system requirements and which make part of an overall validation plan. iFly research combines expertise in air transport human factors, safety and economics providing hints for "implementation" decision-making, standardisation and regulatory framework.

iFly has developed a challenging concept referred to as Autonomous Aircraft Advanced (A^3) Concept of Operations (ConOps [iFly D1.3]). A^3 ConOps is defined on the basis of aircraft flying operations in autonomous mode without air traffic controller support. Due to the innovative and challenging nature of this development, iFly addresses E-OVCM Phase V1 (scope) only. This report provides an outlook to potential directions for further improvement and refinement of this Operational Concept during E-OCVM phase V2 (feasibility).

iFly defines an innovative Operational Concept based on aircraft operation in autonomous mode. It considers the separation capability self-management among aircraft under very high en-route traffic requirements. Since iFly develops an innovative concept with a practical application for the aircraft usual operation, the development of this concept is supported with the studies performed in previous project work packages.

As a new concept, some challenges are not completely solved. Moreover, there are some constraints that must be identified and defined in order to facilitate the implementation of the proposed ConOps. In order to illustrate the strength of a concept it is required to identify weak points. Bearing in mind this key idea, the activities of this Work Package have been developed. The identification of A^3 ConOps potential risks has been promoted from a critical point of view. Only the main constraints identified in this process were considered as potential risks. Subsequently, an analysis was performed on these restrictions. A description of these restrictions was also provided.

The next step was the identification of potential refinements in order to deal with these potential risks. This activity was done after a critical analysis by an air traffic management expert team, considering only operation in airspace A^3 ConOps.

A limited number of main risks and directions for refinement have been identified considering KPA's safety, capacity and cost/benefit analysis. This matches with the expectations that the A^3 ConOps is a solid concept that defines a future airspace operation without air traffic controller support.

SAFETY			
Code	Potential risks identification	Code	Potential direction
1.1.1	Pilots may not continue monitoring potential conflicts in a critical phase.	1.1.1.1	Priorities rules. The existing procedure in TMA entry points must be performed with clear priority rules.
		1.1.1.2	Clearly defined HMI. Definition of a resolving

SAFETY			
Code	Potential risks identification	Code	Potential direction
			system HMI to help monitoring the conflicts status.
1.1.2	Pilots will not initiate an evasive manoeuvre when the conflict alert is not sufficiently intrusive and clear	1.1.2.1	Alternative information sources.
		1.1.2.2	Adding an additional screen representing information on cockpit, to improve HMI functionalities.
		1.1.2.3	Specific information regarding conflicts, in a dedicated screen, with specific warnings about state (not just "position-triggered alarms").
1.1.3	The manoeuvre is not a viable and the actors involved are unaware	1.1.3.1	Periodic checking
		1.1.3.2	Redundant architectures
1.2.1	Wrong surveillance data can raise false alarms.	1.2.1.1	Using voice channel
		1.2.1.2	Defining a protocol to ensure the quality of data.
		1.2.1.3	Redundant architecture
		1.2.1.4	Alternative information sources (data link, radar) Alternative sensors on-board?
1.2.2	3.1.5 What if an aircraft (AC) has no transponder or it is not working?	1.2.2.1	Using Voice Channel
		1.2.2.2	A standard procedure should be included as a requirement, helping to define an emergency protocol. Additional sensors on board?
1.2.3	Communications equipment malfunctions	1.2.3.1	Redundant architecture
		1.2.3.2	Improving communications protocols
		1.2.3.3	Periodic checking/cyclic test protocol
1.2.4	Non-nominal encounter condition STCD&R	1.2.4.1	Improving performance
		1.2.4.2	**Clearly defined HMI.** Improving STCD&R system, in order to alert Aircrew to reduce as far as reasonable, Aircrew reaction time.
		1.2.4.3	**Clearly defined HMI.** Improving HMI to ensure timely alerts from STCD&R can draw instant Flight Crew attention.
		1.2.4.4	Training
		1.2.4.5	Improving performance
		1.2.4.6	Improving the way STCD&R and ACAS System are working together. Sharing critical alerts.

CAPACITY			
Code	Potential risks identification	Code	Potential direction
2.1.1	Mixed aircraft flying in the same non segregated airspace	2.1.1.1	Identification of the role of each actor.
2.1.2	Problems of capacity in controlled areas. (TMA).	2.1.2.1	Improving the information of RBT.
2.2.1	Trajectory deconfliction	2.2.1.1	All the aircraft must use similar equipment
2.2.2	Constraints due to weather conditions	2.2.2.1	Better planning of RBT
2.2.3	Constraints due to unexpected restricted areas	2.2.3.1	Better planning of RBT
2.2.4	Unexpected growth of air traffic at any given time	2.2.4.1	SWIM.
2.2.5	Unexpected conditions due to a flight incident	2.2.5.1	Priority Rules
		2.2.5.2	Identification of the role of each actor
2.3.1	Increasing air-crew workload in self-	2.3.1.1	**Clearly defined HMI.** Improving and a clear

	separation		description of functionalities of HMI
2.3.2	No clear definition of the roles of each actor	2.3.2.1	Identification of the role of each actor. The role must be clearly defined and with complementary functionalities in the actors involved and clearly defined.
2.3.3	Inexperienced air crew in flight	2.3.3.1	Training.

ECONOMICS			
Code	Potential risks identification	Code	Potential direction
3.1.1	Increased investment	3.1.1.1	New Functionalities
		3.1.1.2	Ground equipment, (SWIM), Could it be possible to use existing networks, with similar functionalities? (SITA)
3.2.1	Increase of the Operational Cost (due to transition to new operational procedures)	3.2.1.1	The new operational procedures must be optimized.
3.2.2	Increase of the operating cost caused by Flights delayed (due a non-optimal use of the new systems).	3.2.2.1	Training.
3.3.1	Indirect cost – in equipment maintenance (avionics)	3.3.1.1	New functionalities.

The analysis performed shows the key potential improvements that could help A3 operation:

Improvement	**Rational**
A clearly defined HMI.	A proper definition of an operative man-machine interface is required.
A redundant architecture.	A safe architecture of on-board equipment operation must be available.
Intensive Aircrew Training	The air crew must be operative to solve potential conflicts
Clear roles definition.	A clear identification of the roles of actors involved in the usual operation should be identified.

The implementation of the whole potential improvement activities will help to facilitate the operation of A3 ConOps, but the Key potential improvement activities will have a large influence to moderate the potential risks due to the correspondence between potential risks.

I Acronyms List

Acronym	Definition
A^3	Autonomous Aircraft Advanced
AC	Aircraft
ACAS	Airborne Collision Avoidance System
BT	Business Trajectory
CFA	Constraint Focus Area
ConOps	Concept of Operations
CTA	Controlled Time of Arrival
GPS	Global Position System
HF	Human Factors
HMI	Human Machine Interface
HW	Hardware
ICI	Identification Constraint Indicator
KCA	Key Constraint Area
KCI	Key Constraint Indicator
RBT	Reference Business Trajectory
SSA	Self-Separation Area
STCD&R	Short Term CD&R
SW	Software
SWIM	System Wide Information Management System
TMA	Terminal Area
WP	Work Package

II References

1. iFly D1.3 report, Autonomous Aircraft Advanced (A^3) ConOps
2. iFly D2.4 report. Potential human factors improvements for A^3 ConOps.
3. iFly D6.4 report. Cost benefit analys[i]s results presentation.
4. iFly D7.1b report. Hazard Identification and Initial Hazard Analysis of A3 ConOps based operation.

III Analysis Summary

INFLUENCE TABLES	1.1.1 Pilots may not continue monitoring for potential conflicts in a critic phase.	1.1.2 Pilots may decide to initiate a evasive manoeuvre, only if they observe a potential conflict	1.1.3 It is not a viable manoeuvre and the actors involved are not aware	1.2.1 Wrong surveillance data can cause false alarms.	1.2.2 What if an AC without any transponder or not working?	1.2.3 Malfunctions in the communications equipment	1.2.4 Non-nominal encounter condition STCD&R	2.1.1 With Mixed aircraft flying in the non segregated same airspace	2.1.2 Problems of capacity in the controlled areas. TMA.	2.2.1 Trajectory deconfliction	2.2.2 Constraints due to weather conditions	2.2.3 Constraints due to unexpected restricted areas	2.2.4 Unexpected growing of air traffic of any given time	2.2.5 Unexpected conditions due to flight incidents	2.3.1 Increase the air-crew workload in self separation	2.3.2 No clear definition of the roles of each actor	2.3.3 inexperienced air crew in flight	3.1.1 increased investment	3.2.1 Increase the Operational Cost	3.2.2 Increase the costs by Flights delayed, (due a non optimal use of the operative improvements)	3.3.1 Indirect cost – in equipment maintenance (avionics equipment)
SAFETY																					
1.1.1 Pilots may not continue monitoring for potential conflicts in a critical phase.	O																				
1.1.2 Pilots may decide to initiate a evasive manoeuvre, only if they observe a potential conflict		O																			
1.1.3 It is not a viable manoeuvre and the actors involved are not aware	The pilot can decide a non viable manoeuvre, because they are not monitoring in a critic phase and they are not aware		O																		
1.2.1 Wrong surveillance data can cause false alarms.	When the pilot cannot monitor continuously the data can cause false alarms.		The false surveillance data can promote a non viable manoeuvre.	O																	
1.2.2 What if an AC without any transponder or not working?					O																
1.2.3 Malfunctions in the communications equipment		when communication are not working properly the information can be wrong so the pilot can take the wrong decisions.	With mal function in communication a wrong decision about a non-viable manoeuvre can be taken.	Malfunctions in communications can provide wrong information and therefore raise false alarms.		O															
1.2.4 Non-nominal encounter condition STCD&R	With a monitoring not continue, the non-nominal condition can give non-optimal solutions.	The aircrew could not be perceived of a potential conflict, because the information is non-nominal.	The non-nominal condition can promote a non viable manoeuvre.	The non-nominal encounter condition will produce wrong surveillance data.			O														
2.1.1 Mixed aircraft flying in the same airspace no segregated								O													
2.1.2 Problems of capacity in the controlled areas. TMA.								The air space capacity is reduced with mixed aircraft.	O												
2.2.1 Trajectory deconfliction			Looking a trajectory deconfliction, a non-viable manoeuvre can be decided.							O											
2.2.2 Constraints due to weather conditions	The aircrew cannot detect weather constraints.		By weather constraints detected or not detected a non-viable manoeuvre can be decided.								O										
2.2.3 Constraints due to unexpected restricted areas	The new conditions of the RBT cannot be detected because the aircrew are not continuously checking.		The restricted areas can promote a non viable manoeuvre.					The growing of the numbers of mixed aircrafts can increase the number of restricted areas.				O									
2.2.4 Unexpected growth of air traffic of any given time	The pilot may not detect the traffic growth because they aircrew are not monitoring continually the system the screen.		The emergence of new traffic can promote non viable manoeuvre.										O								
2.2.5 Unexpected conditions due to flight incidents														O							
2.3.1 Increase of the air-crew workload in self separation	When the workload is growing the monitoring of the on-board system could be bad	The aircrew will not perceive the potential conflicts because the work load is increased.	When the workload incresases, it increases the possibility of a wrong decision about a viable manoeuvre.			When the communication equipment is not working, it could increase the workload with new tasks, to facilitate the operation.	The workload will grow because the received data are not in nominal condition.	The aircrew workload will grow with mixed aircraft flying in the same airspace and different capacities.	Capacity problems in the TMA involve problems in near areas, increasing the workload of aircrews. Increase of the tasks done in separation activities.				Unexpected events will increase the workload of the crew	increase of the workload by unexpected conditions	O						
2.3.2 No clear definition of the roles of each actor								The roles in a airspace with mixed aircraft must be clearly defined							The roles of each actor should be clearly identified to avoid overlapping activities and increased workload.	O					
2.3.3 inexperienced air crew in flight	The inexperience will imply badly monitoring of the on board equipment.	inexperience may imply that the aircrew could not observe potential conflicts.	inexperience of the air crew, may promote a wrong decision about a viable manoeuvre				Due to the inexperienced of the aircrew, the air data could be wrongly interpreted with non-nominal condition		The inexperience of the air crew can imply capacity problems in the en-route operation but with special impact in the TMA areas.					The inexperience of the aircrew with unexpected conditions can provoke no clear situations, delaying operations time.	the inexperience will increase the aircrew workload	The inexperience of aircrew may provoke a non clear identification of the roles of each actor involved in conflicts process.	O				
3.1.1 increase of investment																		O			
3.2.1 Increase of Operational Cost (due to the transition to new operational procedures)	The operational cost will increase, because with a bad monitoring the decisions cannot be optimal.	The operational cost will increase, because with a bad monitoring the decisions will not be optimal.					To be flying in non-nominal condition will increase the operational costs	With mixed aircraft in the airspace will increase the operational cost. The operation must be coordinated due to the two types of aircraft flying with different operational modes	The problems of capacity will increase the operational cost.							Badly defined roles will increase the operational costs	The inexperience of the aircrew will increase the operational costs		O		
3.2.2 Increase of costs by Flights delayed, (due a non optimal use of the new systemes and operation)	A bad monitorization will increase the delay time	A bad monitoring will increase the delay time						The flights delayed will increase the flight cost because there would exist two operative modes, with different procedures.	The problems of capacity in the TMA will increase the cost of operation, with potential delays in flight.							The delays will grow, when the roles are not well defined (e.g. overlapping responsabilities)	The inexperience of the aircrew will increase the delays		When the delay grows, increase the operational costs	O	
3.3.1 Indirect cost – in equipment maintenance (avionics)																					O

Annex Table: Summary: potential risks links