OPTIMI Lot 1

Work Package 2 Report - Implementation Feasibility Analysis of the OPTIMI Flight Tracking Service (Deliverable L1-D6)

OPTIMI/CEDAR1/Lot1/WA2-1 Issue 1.3

Executive Summary

This is the Executive Summary of the Work Package 2 report of the Oceanic Position Tracking Improvement and Monitoring Initiative (OPTIMI), Lot 1.

The objective of the OPTIMI Project is to conduct a study that will analyse and demonstrate the feasibility of implementing oceanic flight tracking services and the down linking of safety data in the Atlantic areas of the NAT, EUR and AFI ICAO regions at a reasonable cost and within a limited timeframe (2011). The key issues for the OPTIMI study are;

- That the solution should be based on existing ADS-C technology and initial CPDLC,
- That Flight Data Recorder and Cockpit Voice Recorder equipment should be considered,
- That the study must include as wide a range of stakeholders as possible, including all of those who will be impacted by the introduction of any new service,
- The implementation and in-service cost of any new service must be fully understood,
- The regulatory aspects of any new service must be fully understood,
- The safety impact of any new service must be fully understood and mitigations identified where necessary.

OPTIMI consists of 5 lots;

- Lot 1 – Analysis of the Current Situation (WP1) and Implementation Feasibility Analysis for a Flight Tracking Service (WP2),
- Lots 2, 3 and 4 – Demonstrations,
- Lot 5 – Elaboration of an Initial Business case.

The key findings of Lot 1, Work Package 1 (Analysis of the Baseline) were;

- FANS1/A equipage by Airlines is not high and there is no significant stimulus to equip,
- FANS1/A service provision in the Atlantic is incomplete,
- Aircraft do not always log on using FANS1/A, this is either to save message costs or due to failed log on attempts – the reasons are not known with certainty,
- There is approaching 100% ACARS equipage for AOC purposes. Whilst it is not certified for ATC purposes, it is readily used by AOCs for messaging,
- There is a known issue with absent flight plans since the overall 'system' and the method of ATC control is dependent on them,
- There are apparent regional practices in co-ordination between OACCs and in SAR alerting procedures that deviate from ICAO SARPs,
- There is current technology that can readily down link FDR content but this is limited to the Iridium satellite network, whilst most aircraft use the Inmarsat system,
- There may be personal issues surrounding any new use of data for flight monitoring, due to existing local privacy arrangements at airlines and due to European data protection legislation.

In conducting OPTIMI Lot 1 WP2 (Implementation Feasibility Analysis of a Flight Tracking Service), the CEDAR consortium has built on the output of OPTIMI WP1 which described the current operational, technical, procedural and regulatory environment relevant to oceanic flight tracking. The consortium developed a wide range of possible methods of providing a new service and conducted a wide ranging analysis of those potential solutions in order to identify the most appropriate method. Key technical requirements were considered along with the need to demonstrate the chosen solution in 2010 and implement it in 2011.

The consortium identified the following **Core Short Term Solution** as being the optimum method of providing a flight tracking service in the Atlantic parts of the NAT, EUR and AFI ICAO regions;

- FANS1/A based ADS-C Event/Deviation alerts.

The consortium also identified the following **Ancillary Short Term Solution**, which provides additional beneficial functionality and is provided with FANS1/A, but would not enable the provision of an effective enhanced flight tracking service in itself;

- FANS1/A based ADS-C Periodic Position Reports,
- FANS1/A based ADS-C Demand Contracts.

The consortium identified a set of solutions that could also provide an enhanced oceanic flight tracking service but which could not be implemented in the short term. The **Medium Term Solution** consists of;

- Central position data repository for FANS1/A and AOC messages,
- Flight Data Recorder Down Linking System.

The consortium also identified a number of potential solutions that could be implemented in the short term which were considered worthy of further study, but which were either not deemed to be within the scope of the OPTIMI project, or were deemed to not be sufficiently mature to allow inclusion in the solution without further study. These are included as **Recommendations for Further Study (Short Term)**;

- AOC Position and Aircraft Status Reports,
- Improved Adherence to ATC Procedures by OACCs,
- FANS1/A Mandate and Incentives,
- Automatically Generated Emergency FANS1/A Based ADS-C Reports,
- FDR/CVR Real-Time Transmission via Inmarsat,
- ADS-C Without Log-on.

Analysis of the economic aspects of the OPTIMI Short Term Solution found that the total attributable cost of implementation to ANSPs is approximately 250,000 EURO, with only Santa Maria FIR requiring significant investment. The cost of implementation to airlines is not inconsiderable, the cost for equipping new aircraft with FANS1/A is between approximately 100,000 EURO and 150,000 EURO per aircraft, while for aircraft requiring retro-fit of FANS1/A (plus other associated equipment) the cost is between approximately 83,000 EURO and 863,200 EURO per aircraft, however not all of this cost is attributable to OPTIMI. The most directly attributable cost is that associated with the use of SATcom for OPTIMI services; analysis showed that this cost is approximately 18.5 EURO per transatlantic flight.

With regard to the OPTIMI Short Term Solution described in this document, the regulatory procedures and underlying standards are well established. However, there is a need to harmonise operational practises concerning the use of the relevant FANS1/A functions between Atlantic Oceanic FIRs and globally. The ICAO Global Operational Data Link Document (GOLD) initiative is a potential mechanism for such harmonisation.

The diagram below illustrates the solutions on a timeline;

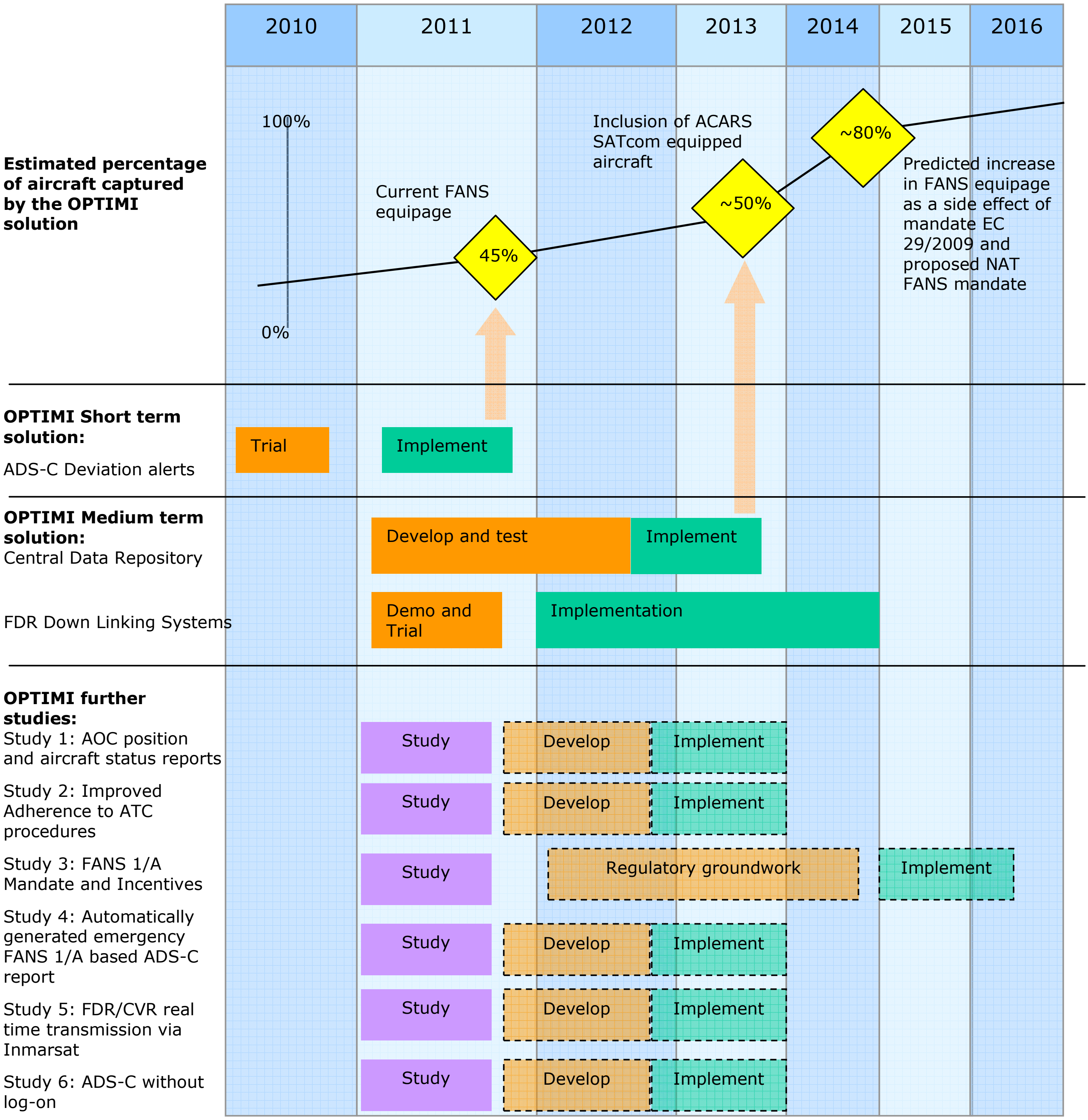

Figure 1 – The OPTIMI Roadmap

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1 Introduction

This document is the output of OPTIMI Work Package 2 (Deliverable L1-D6), the Implementation Feasibility Analysis of the OPTIMI flight tracking service. The input to this task was the output of WP1, which described the current technical, operational, procedural and regulatory environment relevant to oceanic flight tracking in the Atlantic areas of the NAT, EUR and AFI ICAO regions. Input was also derived from the recent ICAO High Level Safety Conference (Montreal 2010) and from the initial findings of the AF447 accident investigation (Interim report No.2, ref f-cp090601ae2). All inputs to WP2 are described in section 1 of this document.

The requirements for the OPTIMI flight tracking service are described in section 1.4 and an operational and technical analysis of the FANS1/A systems is included in section 2. The short and medium term solution and recommendations for further study are then detailed in sections 3, 4 and 5. Economic analysis is included in section 6.

Information on potentially useful solutions that were not deemed worthy of inclusion in either of the solutions, nor of further study, are mentioned for completeness in APPENDIX A.

The output of OPTIMI Lot 1 was discussed at a workshop held in Lisbon on the 17th June 2010. This workshop was attended by members of the CEDAR consortium, the SESAR Joint Undertaking (SJU) ICAO and representatives from the wider aviation industry, including system manufacturers and other ANSPs. Conclusions from this workshop are included in APPENDIX C.

1.1 Work Package 1 Conclusions – Current Situation

1.1.1 FANS1/A & ADS-C

FANS1/A service availability is already widespread in the Atlantic, which is conducive to the provision of a suitably scoped Atlantic-wide flight tracking service. SITA provides FANS1/A coverage throughout the Atlantic region and most OACCs provide a FANS1/A ADS-C service, with the current exception of Lisbon (under deployment), Sal, Casablanca and Rochambeau (under planning). Airline FANS1/A equipage is at best 40%-50% in the northern Atlantic region.

1.1.2 ACARS

ACARS AOC services are available throughout the NAT and EUR/SAM corridor and are generally more widely available in the other areas than ADS-C and CPDLC services. Uptake is on an operator by operator basis and is believed to be the majority, but less than 100%. However the certification issues associated with using ACARS for critical ATC purposes would prevent major developments in that area in the OPTIMI timeframe.

1.1.3 ATN

The deployment of ATN is in the initial stages, it is generally only available in non oceanic areas in the core EUR region. ATN provides CDPLC but not ADS-C functionality.

EC regulation EC29-2009 mandates the carriage of Link2000+ compliant ATN/VDL2 datalink CPDLC equipment from the 1st of January 2011 for new aircraft (aircraft with an individual certificate of airworthiness issued on or after that date) and from 5th of February 2015 for retro-fit (aircraft with an individual certificate of airworthiness issued before the 1st of January 2011).

Approximately 6% of European continental traffic is also long haul (mainly oceanic) and approximately 40% of oceanic traffic uses FANS1/A, therefore approximately 3% of European continental traffic is equipped with FANS1/A. Long haul oceanic traffic equipped with FANS1/A is exempt from the ATN mandate, as it would otherwise be required to carry two different systems, which would not be economically justified. However not all European ANSPs intend to accommodate FANS1/A services in continental airspace.

The deployment of ATN is supported by the FAA's NexGen programme and it is included within the NexGen roadmap, in the guise of FANS B, as an enabling technology within the mid term (2015).

1.1.4 FDR

Carriage of Flight Data Recorder (FDR) equipment is a mandatory requirement, it is therefore 100%. There are potentially useful FDR down-linking technologies in operation, using Iridium satellite communications, by some smaller operators and business aviation.

1.1.5 Data Costs

To the airborne user, the in-service usage cost of ADS-C and other SATcom messages is proportional to the number of messages sent. Cost for ANSPs tends to be on a fixed bandwidth and data quantity basis.

1.1.6 Ongoing Initiatives

Several initiatives are on going, or planned within a short time of implementation, to harmonize standards and to foster the transition from voice services to data link services at a global level, either on the ground to ground segment or the air-ground segment. This is strongly supported by the airlines and should encourage the airline adoption of FANS1/A. The increased use of FANS1/A by aircraft and OACCs will deliver better quality information for the SAR services.

Significant enhancements could be delivered in a short time frame using new ATM conformance monitoring and/or an increased frequency of FANS1/A based position reports;

- There are plans in the NAT region to increase the frequency of, or introduce, ADS-C periodic reporting and/or ADS-C conformance contracts to support new ground ATM tools and to increase the level of ATC services offered (separation reductions, increased capacity, and optimized flight profiles),
- On several ground ATM systems ADS-C Lateral Deviation Event and Altitude Range Change Event contracts will be introduced in 2010 or shortly after that. Such contracts will notify controller of deviations from the cleared aircraft routes and levels,
- The availability of new ATM tools making use of ADS-C Lateral Deviation Event and Altitude Range Change Event contracts or the increased frequency of FANS1/A position reporting (e.g. from 60 minutes to 15/18 minutes) could have a significant beneficial impact on SAR operations,
- There is the potential for AOC/SAR investigation using information available in the AOCs via ACARS,
- There are some initial discussions on mandatory FANS1/A equipage in the North Atlantic region, for a 2015 time frame.

1.2 Other Known Issues for WP2 to Consider

1.2.1 ATC Operational Practises

A recent ICAO High Level Safety Conference identified issues surrounding coordination between Atlantico and Dakar FIRs as contributing to the excessive delay in alerting the SAR services to the disappearance of AF447. This was attributed to 'regional practises' diverging from ICAO Standards and Recommended Practises (SARPS) and specifically related to the handover from Atlantico FIR to Dakar FIR and the consequent failure of Dakar OACC to notice the missing aircraft or alert the relevant SAR agency of its disappearance.

1.2.2 Missing Flight Plans

It is recognised that flight plans are sometimes not distributed to all relevant ATSUs, they are therefore sometimes absent in ground ATM systems and it is not uncommon for aircraft to transit Oceanic regions with no flight plan. This is sometimes due to incorrect filing by the airline, or incorrect processing and onward transmission by an ACC.

1.2.3 FANS1/A Log-on

FANS1/A aircraft sometimes fail to log on to an OACC. This may be due to;

- the expense to the airline of datalink messages (although the actual cost for logging on is only that of a single AFN log-on message),
- because a FANS1/A service is not provided by the OACC,
- or because there is some technical difficulty.

Log-on failure, due to technical difficulties, is experienced by less that 1% of flights that attempt to log on. The most common reason for log-on failure is a discrepancy between the flight callsign and the aircraft registration contained in the log on message (the AFN log-on message) and those contained in the flight plan held on the ground. It should be noted that in most systems a flight plan is required against which to correlate the FANS1/A log-on request from the aircraft.

1.2.4 AF447 Accident Investigation Interim Findings

Recent interim findings from the AF447 accident investigation reveal the following 4 facts;

- It took 5 days to find the first floating wreckage,
- The last position report made by the crew was at 01:35 GMT and the last automated report was at 02:10, but the first alerts to start a search and rescue effort were raised between 08:00 and 08:30,
- The crew made three attempts to contact the Dakar OACC using FANS1/A but had not succeeded by the time the aircraft was lost,
- Neither the flight data nor cockpit voice recorder has yet been found.

1.3 Summary of Key Issues

- FANS1/A equipage by Airlines is not high and there is no significant stimulus to equip,
- FANS1/A service provision in the Atlantic is incomplete,
- Aircraft do not always log on using FANS1/A, this is either to save message cost or due to failed log on attempts – the reasons are not known with certainty,
- There is approaching 100% ACARS equipage for AOC purposes. Whilst it is not certified for ATC purposes, it is readily used by AOCs for messaging,
- There is a known issue with absent flight plans since the overall 'system' and the method of ATC control is dependent on them,
- There are apparent regional practices in co-ordination between OACCs and in SAR alerting procedures that deviate from ICAO SARPs,
- There is current technology that can readily down link FDR content but this is limited to the Iridium satellite network, whilst most aircraft use the Inmarsat system,
- There may be personal issues surrounding any new use of data for flight monitoring, due to existing local privacy arrangements at airlines and due to European data protection legislation.

1.4 The OPTIMI Requirement

Based on the key issues listed above and on the Technical Specification of the OPTIMI Call for Tender, the following criteria for an effective Oceanic flight tracking service have been identified;

- The solution shall provide a flight tracking service in procedural airspace,
- The flight tracking service shall provide improved knowledge of aircraft position compared to current operations,
- The flight tracking service shall alert the relevant OACC should an aircraft deviate from its expected trajectory,
- The flight tracking service should minimise associated controller and aircrew workload,
- The flight tracking service should not require aircrew action during an unusual event or emergency scenario,
- The flight tracking service shall allow the identification of a possible emergency scenario in the relevant OACC within (say) 5 minutes of its occurrence,
- The flight tracking service shall make use of Satellite communications (SATcom) as the primary means of communication due to its oceanic location,
- The flight tracking service shall be available to as many aircraft as possible,
- The flight tracking service shall be available in as wide a geographic area as possible within the NAT, EUR and AFI oceanic airspace,
- The flight tracking service should, if possible, have a low regulatory impact,
- It must be possible to conduct a cost benefit analysis of the flight tracking service,
- It must be possible to trial any solution in 2010,
- It must be possible to implement any solution in 2011.

2 FANS1/A Technical & Operational Analysis

2.1 Airborne infrastructure

2.1.1 ACARS

The **Aircraft Communications Addressing and Reporting System (ACARS)** is a digital datalink system for transmission of short, relatively simple messages between aircraft and ground stations via radio or satellite. The protocol, which was designed by ARINC to replace their VHF voice service and deployed in 1978, uses a character based text format similar to that of the AFTN and uses centralised servers, operated by ARINC and SITA, to route messages to their destination. Eventually it is expected that ACARS will be superseded by the Aeronautical Telecommunications Network (ATN) protocol for Air Traffic Control communications and by the Internet Protocol for airline communications. ATN is a bit based TCP/IP protocol that uses a locally switched IP network to deliver data. There is approaching 100% ACARS equipage for AOC purposes. It should be emphasised that although used for ATC communications, the ACARS infrastructure was primarily designed for AOC – this is both an advantage (access to a rich repertoire of airline-specific messages) and a disadvantage (e.g. lack of reliable message assurance and robust prioritization). In the context of an oceanic flight monitoring service to alert in the event of an emergency, this may not be an issue. However, it should be further investigated to understand what level of service could be expected from ACARS service.

2.1.2 SATCOM

Since the area of interest to OPTIMI is the ocean, the optimum means of communications is SATcom, whether for voice or data. The basic ACARS communications system described above does not in itself demand SATcom – the level of SATcom equipage is therefore much lower than that of ACARS. SATcom Voice is in its infancy with some countries having published procedures while others have not; the development of global guidance material is being tackled by ICAO.

Two satellite constellations provide a SATCom service to aviation; the Inmarsat and the Iridium constellation. The vast majority of aircraft that are equipped with a SATcom system are equipped with Inmarsat compatible equipment (approximately 2500 aircraft use SITA services over Inmarsat, while approximately 100 aircraft use these services over Iridium). This is due to the fact that although the cost of equipping with Iridium compatible equipment is lower, Iridium is not yet certified for ATS services.

2.1.3 INMARSAT

Currently operating two generations of geostationary satellites (known, respectively, as "I3" and "I4" satellites), Inmarsat is a commercial corporation serving many markets, one of which is aviation. Both ARINC and SITA offer services via Inmarsat Ground Earth Stations (GESs) which make this communications channel transparently available to ACARS traffic. A large number of commercial aircraft are fitted with Inmarsat antennae, approximately 6300. Not all of these aircraft have a datalink capability, many are business/government aircraft primarily using the satellite connection for its voice capabilities.

2.1.4 IRIDIUM

A constellation of 66 Low Earth Orbit (LEO) satellites, the communications system commonly referred to as "Iridium" (operated by Iridium Satellite LLC) has the potential to provide satellite communications on a worldwide basis, including the Polar Regions. Already used for AOC communications, Iridium is currently in the latter stages of approval for the provision of ATC communications, such as FMC waypoint Reporting and FANS1/A. While certain performance issues remain unresolved it seems clear that this service will be of great value to aviation, partly because retrofitting for Iridium avionics/antennae appears to be more economical than with their Inmarsat counterparts.

2.1.5 HF

HF voice radio equipage is mandatory for all aircraft flying in oceanic airspace. Although it is the default communication method its performance is often degraded by atmospheric interference and it can be time consuming to use, this can lead to long communication latency times. The use of HF voice as a potential method of providing an improved flight tracking service is not considered within the scope of the OPTIMI project.

Some aircraft are equipped with HF datalink radios, although the equipage level is not considered sufficiently high to justify its use as part of a solution for OPTIMI. HF datalink is generally not as fast or reliable as SATcom although there are some advantages for polar flights, see section 2.3.8.

2.1.6 GNSS

Although the navigational accuracy of GNSS may not be required within OPTIMI, such equipment is specified as a prerequisite for FANS1/A equipage.

2.1.7 Other

Although the consortium is aware of a number of other satellite systems (such as COSPAS/SARSAT) that may be of relevance in any discussion of, *inter alia*, the alerting of rescue assets, these were not pursued within the study as they do not have an obvious linkage to the applications listed below.

2.1.8 Airborne Architecture

2.1.8.1 FANS1/A

The following diagram illustrates the high level on-board system architecture for FANS1/A;

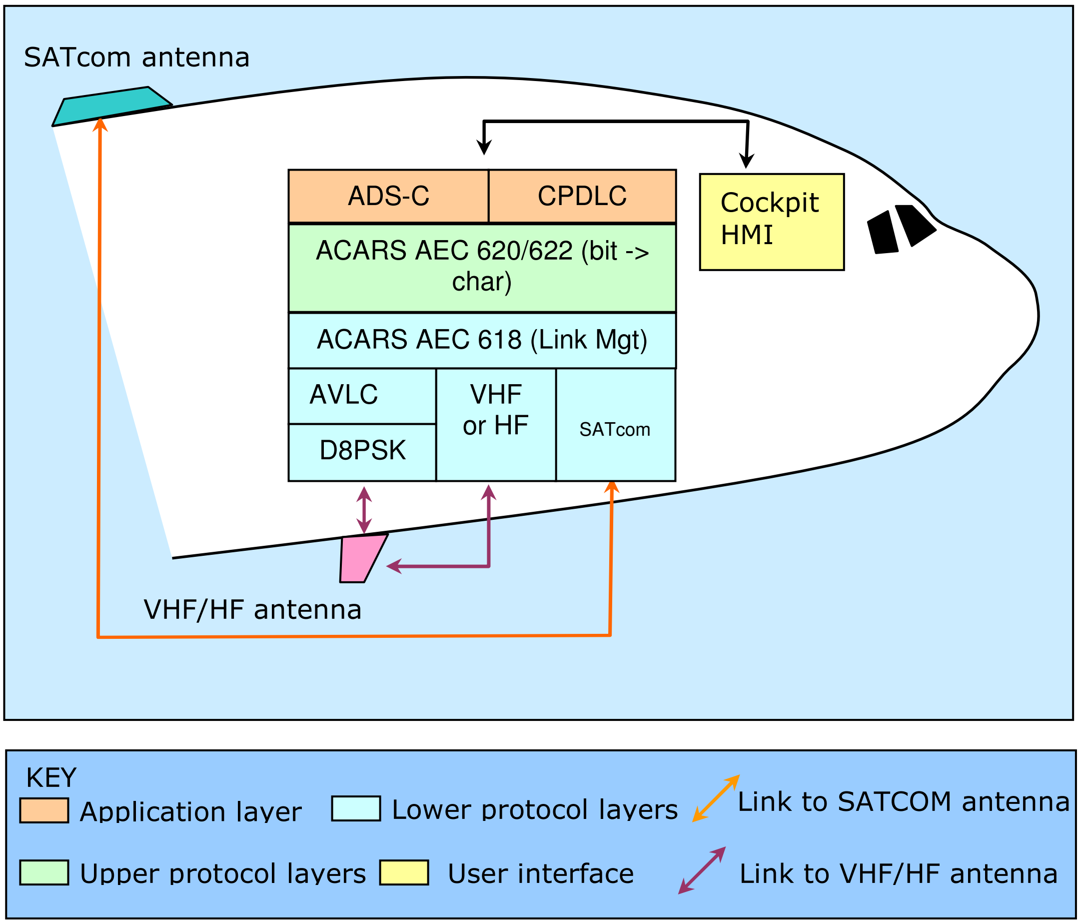

Figure 2 – High level on-board system architecture for FANS1/A

2.1.8.2 ATN

The following diagram illustrates the high level on-board system architecture for ATN;

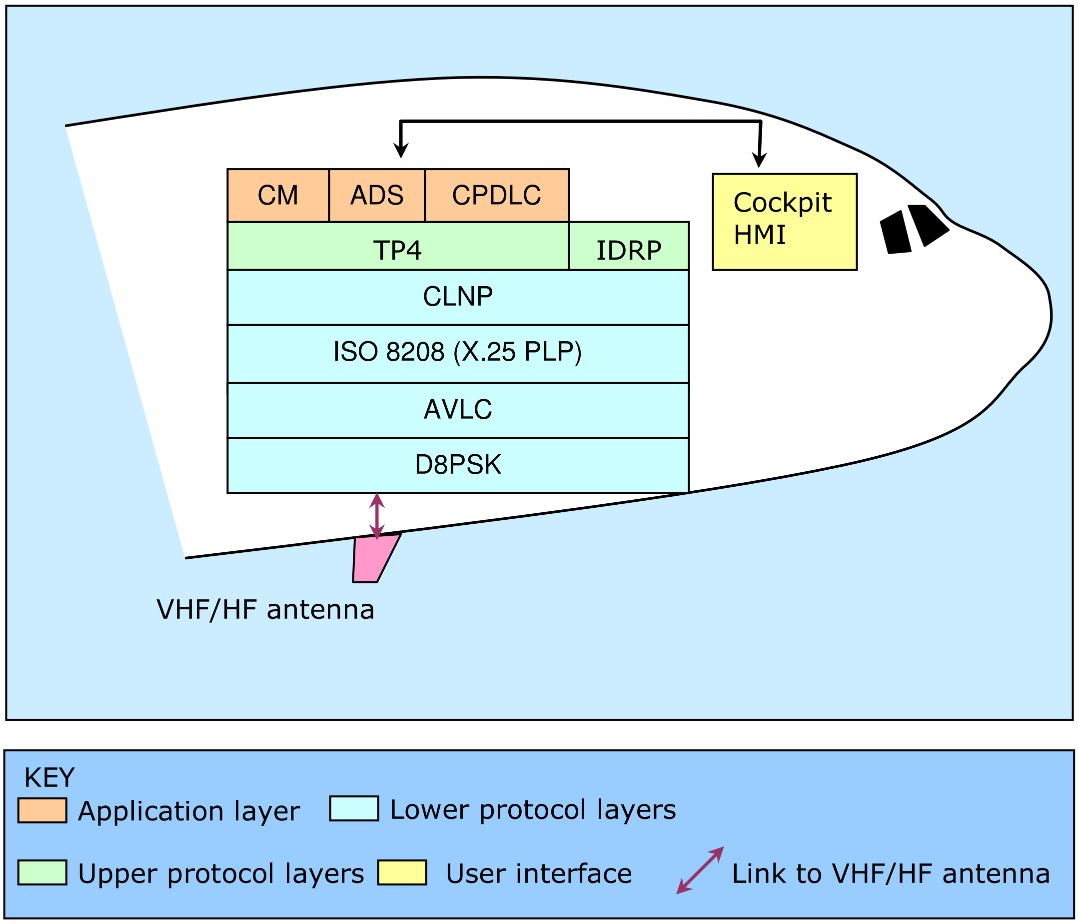

Figure 3 – High level on-board system architecture for ATN

2.2 Ground Infrastructure

An infrastructure based on the generation, transmission, receipt and processing of messages requires automation. The centres supporting FANS1/A will, by definition, have such automated systems. In the northern part of the Atlantic these FANS1/A systems are closely integrated into the flight data processing systems, this aspect of other systems is unknown. It should be noted that use of a centralized system for ADS-C does not call for a high level of automation in centres availing themselves of such a service.

Centralized ADS-C (CADS) Systems are currently being operated by both SITA (for Edmonton, Canada) and ARINC (for Bodo, Norway). The functioning of these systems hinges on the fact that these companies are the carriers of messages between aircraft and the ground, they can monitor for indications of FANS1/A capabilities (typically a logon) and, when such are seen, set up ADS-C contracts with the flight in question.

2.3 Applications

Two of the potential applications with relevance to the goals of OPTIMI (FANS1/A and use of AOC messaging) are based on ACARS. Others (e.g. Iridium based systems) use a different communications infrastructure. The focus of study has been on automated reporting but not to the exclusion of consideration of crew initiated emergency reports. Voice, whether via satcom or radio, is not considered due to the elaborate setup required and unsuitability to immediate reporting.

2.3.1 FANS1/A

FANS1/A and equivalent systems, as described in EuroCAE ED-100/100A and other standards documents, are currently carried by approximately 40% to 50% of the fleet operating the Atlantic air routes. This percentage fluctuates between winter and summer with older, non-FANS1/A, aircraft being added to the route network during busy periods, but is trending upwards in the longer term. The European mandate for datalink equipage is leading to an increase in the rate of retrofitting with FANS1/A because this grants an automatic exemption from the European mandate 29/2009. It is also worth noting that mandating FANS1/A in the NAT region is currently being discussed within the NAT Systems Planning Group (NAT/SPG). Although the issue is still in doubt (it hinges on the users' preference) such a mandate would obviously have a very positive effect on efficacy of any OPTIMI solution based on FANS1/A.

Support for FANS1/A is almost universal in the North Atlantic, Bodo centre is the only one that only supports ADS-C (through a centralized service), FANS1/A support in the South Atlantic is also close to universal. In any case it is clear that providing FANS1/A support is the goal of all ANS Providers controlling Atlantic oceanic airspace – with the longer term objective being the transition to ICAO SARPS-compliant systems. In oceanic airspace such systems would of course need to provide both ADS-C for surveillance and CPDLC for other communications.

Much FANS1/A functionality can be provided by centralized ADS-C systems <u>outside</u> airspace where FANS1/A is natively supported. It should however be noted that since such systems do not have flight plans with which to correlate the FANS1/A data they will be unable to detect divergence from conformance, especially in the lateral plane. They might still be used to report rapid changes to flight level – and perhaps also departure from a previously occupied level (without any knowledge of whether this was cleared or un-cleared, however). The routing of ADS-C information would be by geographic coordinates (i.e. a map of the respective areas of responsibility would have to be used by each such system). In the context of an oceanic flight monitoring and alerting service, this could be acceptable as long as false alerts were not too numerous. In the event of such an alert, the controlling authority could be alerted to investigate further, by evaluating the legitimacy of the deviation manoeuvre and by attempting to contact the aircraft if any doubt exists.

Although a crew logon is a prerequisite for CPDLC services there is no technical obstacle to setting up ADS-C contracts with any aircraft known to be suitably equipped. Flight plan correlation would be achieved by querying the aircraft for its aircraft identity (ACID) and noting its registration. Further confirmation could be obtained by querying the aircraft for its "intent".

Another current impediment to the use of FANS1/A, as mentioned earlier, is the possible lack of a flight plan. Although such cases should not occur, the fact remains that procedures exist to allow flights to proceed to their destination even when some of the ATS Units along their flight path do not hold a copy of their flight plan. This is accomplished by exchanging sufficient information to ensure the safe progress of the flight. This information may however NOT be sufficient to support a FANS1/A logon; under such circumstances the logon is rejected with an appropriate error code. Although it is in fact possible to define procedures that would obviate any danger of misidentification of aircraft under such circumstances, the fact remains that the standards documents specifically require correlation of the aircraft-transmitted data with a centre-stored flight plan.

This issue can be tackled in three ways:

(a) Improve the basic mechanism controlling FPL dissemination,

(b) Put in place a procedure where IFPS in Europe is queried for an FPL (using an RQP),

(c) Employ sufficiently robust AIDC protocols to ensure a CPL is held by all centres.

It should be noted that option (b) would only be applicable if the flight either originated within the IFP zone or its destination lies within the zone – and if the airline DID send the flight plan to the appropriate AFTN addresses serving IFPS. This option has however served one ANSP very well.

As noted elsewhere the centralized systems used for ADS-C dissemination (CADS systems) do not hold flight plans – this is however offset by the fact that they only collect ADS-C information from flights, they do not exchange CPDLC messages – where misidentification would be potentially hazardous.

The following diagram illustrates the approximate use of FANS1/A throughout the world;

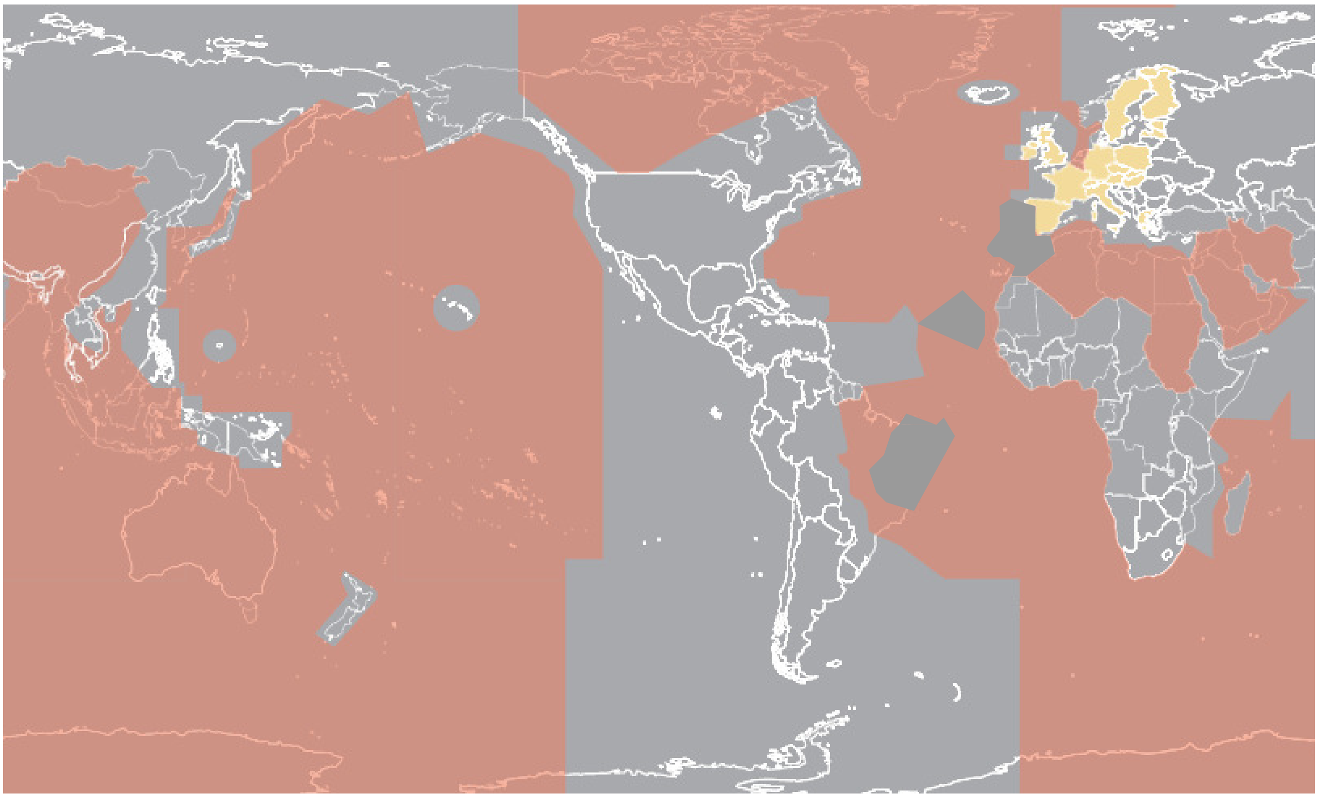

Figure 4 – Global FANS1/A use (in red) (2007).

2.3.2 ADS-C

Automatic Dependent Surveillance - Contract is one of the two component service of FANS1/A, the other being CPDLC. It allows ground systems to set up "contracts" with the aircraft to transmit position updates and other data associated with the aircraft's progress at fixed intervals or upon the occurrence of defined "events". These events can be the passing of a waypoint or specific changes to the aircraft's profile (3D path). With the exception of the waypoint event these event contracts will only "fire" once and then require re-initialization. The important aspect of event contracts for OPTIMI is that they do not require crew initiation, once the condition of the contract is satisfied a position report will be automatically transmitted.

Unlike CPDLC, ADS-C is a connection between the aircraft's system's and the ground, there should be little need for crew involvement (and thus training) to enable this application's use to meet OPTIMI's objectives.

2.3.3 ADS-C Event Reports

FANS1/A supports the reporting of four types of events; Waypoint Change, Vertical Rate, Altitude Range and Lateral Deviation. The first of these, the Waypoint Change Event, is in fact radically different from the others, it replaces the Position Reports used in the voice environment and although these do indeed contribute towards monitoring flights, the Waypoint Change Event report will not be discussed further.

The other three event types are intended to support conformance monitoring, i.e. the adherence of aircraft to their cleared profiles. Since the immediate effect of a catastrophic event is likely to involve a divergence from clearance, it would seem that properly constructed contracts of these types might contribute towards achieving the goals of OPTIMI.

Conformance monitoring event contracts are currently being implemented in all the NAT centres that natively support ADS-C (Bodo, using CADS, will not be able to use them). Published information indicates that the capability also exists in Canarias, Dakar and Atlantico.

It should be noted that once these conformance monitoring events have "fired" (i.e. sent a single report in response to the previously set threshold having been exceeded) they will not repeat their message until re-initialized by the ground system. Since the ACARS network does not guarantee the safe delivery of messages there exists the possibility of the single event report getting lost – this would obviously cause a failure to re-initialize since the ground system would be unaware of the need to do so.

Also worth mentioning is the possibility of a catastrophic event being too rapid to allow the transmission of a report – the only workaround to that problem would be a steady stream of reports until the catastrophe occurs, see below.

2.3.4 ADS-C Periodic Reports

Periodic ADS-C contracts of 15 min are already being used in Canarias (according to AIPs, 15 min are also being used in Dakar Oceanic UIR and of 20 min in Atlantico UIR). In the NAT, many centres currently use 30 minute periodic contracts for MET reporting – with decreased separation it is expected that a reduced interval of 18 minutes will be instituted.

One advantage of periodic reports for flight following is that detection of abnormal situation through cessation of reports is more reliable than depending on event reporting. This advantage is however offset by the fact that absence of a report will not pinpoint the location of the aircraft at the time of a catastrophe – it may have been anywhere along the path flown since the last received report. Reducing this uncertainty by means of very short intervals can be very expensive.

An ancillary benefit of periodic reporting is its beneficial effect on conformance monitoring though event reporting is a more direct way of achieving the same effect.

2.3.5 ADS-C Demand Reports

This facility is typically used to query an aircraft for its position when an expected report (typically position report) has failed to arrive. In the circumstance being considered by OPTIMI the aircraft would be unlikely to respond to the demand contract – this function is therefore of limited applicability.

2.3.6 ADS-C Emergency Reports

A variant of periodic reporting; initiated by crew action (through interaction with the aircraft's computer systems, this is not available at the press of a button) and continued at whatever rate periodic reporting had been set to previously. Each report carries an emergency tag until reset.

2.3.7 CPDLC

CPDLC provides a feature-rich communications environment which can be of crucial importance in exchanging important information when the crew of an aircraft in distress have the capacity to do so – but in the circumstances being considered by OPTIMI this facility would appear to be of limited usefulness. The functionality relevant to emergencies is described listed below, again it should be pointed out that crew initiation is required.

2.3.7.1 CPDLC Emergency Reports

In discussing CPDLC Emergency messages it should first be noted that sending such a message will also activate ADS emergency mode, sending such a message would therefore seem to be the best option for a crew with a CPDLC connection (assuming that the opportunity exists). Receipt of an emergency message by a ground system should cause the words "MAYDAY MAYDAY MAYDAY" (an urgency message containing "PAN PAN PAN" also exists) to be displayed to the recipient. In addition to this text, in some aircraft types, the message contains an abbreviated position report (current position, time, and level) and may, at the option of the crew, also indicate the offset being flown, the crew's intention to divert, an altitude to which the aircraft is descending and the amount of fuel and number of persons on board.

Finally it should be repeated that CPDLC emergency messages require crew initiation through interaction with the aircraft's computer systems, this function is not available at the press of a button.

2.3.8 Maintaining FANS1/A contact with flights in polar regions

Polar flights in the north number approximately 5 to 10 a day, although this number is expected to increase.

Since most air/ground communication via satellite utilizes geostationary satellites it follows that coverage cannot extend to the Earth's poles. The size of the coverage "holes" is not precisely defined; some message exchanges may succeed at latitudes as high as 87° while others fail at much lower latitudes. One ATSU, Reykjavik (BIRD), has defined a northern boundary to its FANS1/A Service Area at 82°N to avoid the occurrence of partial CPDLC dialogues which are considered very undesirable.

Two technological alternatives to geostationary satellites currently exist. One, High Frequency Data Link (HFDL), is in reasonably widespread use but has performance characteristics which may rule out its use for ATC communications, at least as far as CPDLC is concerned. ADS reports are not as time-critical and may usefully be transmitted via this means as an alternative to using HF voice.

The other alternative to geostationary satellites is use of Low Earth Orbit (LEO) satellite systems. One airline (Cargolux - CLX) is currently trialling use of one such system (Iridium) for FANS1/A in the NAT region, another airline (Continental – COA) is using the same technology for FMC Waypoint Reporting (FMC-WPR). Performance data gathered to date seems to indicate that this medium will satisfy performance requirements but far more data is required.

3 Short Term Oceanic Flight Tracking Service

Short term refers to trials in 2010 and implementation in 2011, Medium term refers to trials in 2011 and implementation after 2012.

The short term solution is described below in two parts;

- The Core Short Term solution provides the core functionality associated with the fundamental elements of the flight tracking service,
- The Ancillary Short Term solution is the functionality that is also provided with the Core Short Term solution. While this functionality would not be suitable as an enhanced flight tracking service in itself, it does provide some improved knowledge of aircraft position and status.

This section of the document provides a description of each part of the core and ancillary short terms solution.

3.1 FANS1/A based ADS-C Event (deviation alert)

The events available in FANS1/A based ADS-C are;

- lateral deviation,
- altitude range,
- altitude change rate.

Event alerts are a very effective way of alerting an air traffic controller to the fact that an aircraft has deviated from its intended course, its intended altitude, or has exceeded a predetermined safe altitude change rate. In each case the controller receives a messaging describing the event that has occurred and a position report from the aircraft concerned.

The magnitude of the deviation from the flight plan, or increase in vertical change rate, can be set at the initiation of the ADS-Contract. The following parameters are given as initial values;

- lateral deviation - 5 nautical miles
- altitude range - 300 feet.
- altitude rate change – minus 5000 feet per minute.

In the case of cleared climbs/descents it is possible for an altitude range deviation alert to serve as a 'Leaving FLXXX' report. In this case an automated ground response to such a report would set up a new altitude range deviation event ending just before the new cleared flight level (serves as a 'Reaching FLXXX' report). The automated response to the 'Reaching FLXXX' deviation alert would establish a new altitude range deviation alert at the new cleared flight level.

These values and the optimum combination of deviation alerts to be used should be examined in subsequent lots of the OPTIMI project. Controller workload issues should also be considered.

3.1.1 Advantages

This solution is potentially very economical from an in-service and airline perspective, as no reports are generated in normal conditions, and there is little impact on controller and aircrew workload. Furthermore, no changes are required to current airborne equipage, since event based contracts are set up in the ground system rather than the airborne system. Event alerts could also be provided by a centralized ADS-C service in non-FANS1/A airspace (though current centralized systems do not support such contracts). However there is potentially an initial development cost to ANSPs.

3.1.2 Disadvantages

A catastrophe occurring to an aircraft may be too rapid for an event report to be generated (while periodic reporting is not so affected, although it is much more expensive). There is a risk that the single event report, which initiates only once, may be lost en route. However, this risk is thought to be low for such a service. A centralized service could be established for monitoring outside FANS1/A service areas. Such a centralized service would not be in possession of sufficient ATC information to distinguish between manoeuvres that are cleared and those that are not, so the deviation alert criteria would have to be carefully trialled to ensure false alerts to ATC are minimised. In the event of an alert, the centralised service would need to pass the information to the controlling authority to react and assess the deviation.

3.1.3 Summary and Conclusion

ADS-C event based contracts are already used in Canarias and according to the respective AIPs ADS-C event based reports are also supported in Dakar Oceanic and Atlantico UIRs. In the NAT they are being implemented for conformance monitoring purposes. Although mentioned for completeness, the likelihood of messages being lost by the ACARS infrastructure once received from the aircraft is very low. The issue of a centralized service not having access to clearance details might limit the choice of events to monitor to the vertical rate change - this would require some tuning to define a descent rate sufficiently high to raise an alarm. Some false alarms would be inevitable; this would have to be accounted for in the overall system's design. Generally this is an economical and effective solution that compliments other FANS1/A solutions well.

3.2 Ancillary Solution - FANS1/A based ADS-C Periodic position reports

Periodic reporting will not provide sufficient knowledge of aircraft position in itself to fulfil the OPTIMI requirement unless a very short period is used (around 1 minute), in which case it is expensive and has a high bandwidth requirement.

Figure 5 – A **comparison of the financial cost and possible aircraft location for different position reporting periods.**

shows the relationship between the financial cost and possible aircraft location (the possible search area in square kilometres) for different position reporting periods;

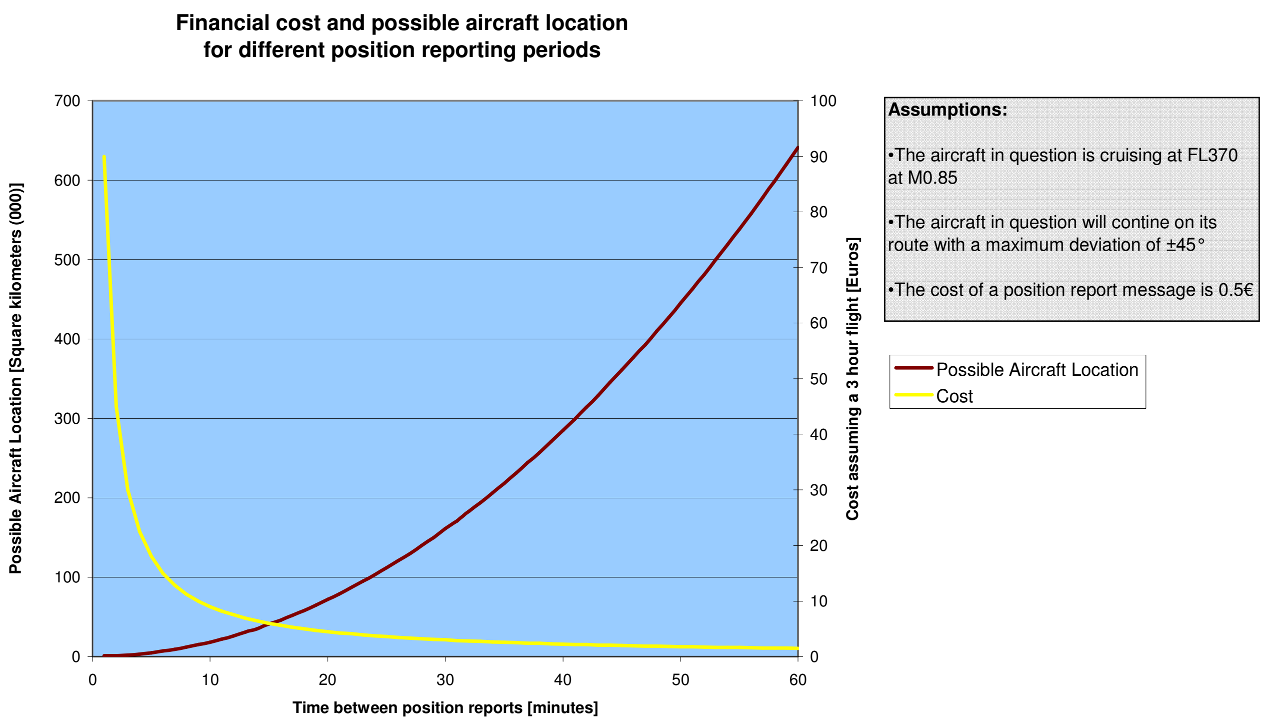

Figure 5 – A comparison of the financial cost and possible aircraft location for different position reporting periods.

The relationship between position reporting period and possible aircraft location is shown further in Figure 6, which shows the possible initial search area in square kilometres for 60, 40 and 18 minute position reporting periods. As the figure shows, a change from 60 to 18 minute reporting reduces the possible aircraft location area by >90%.

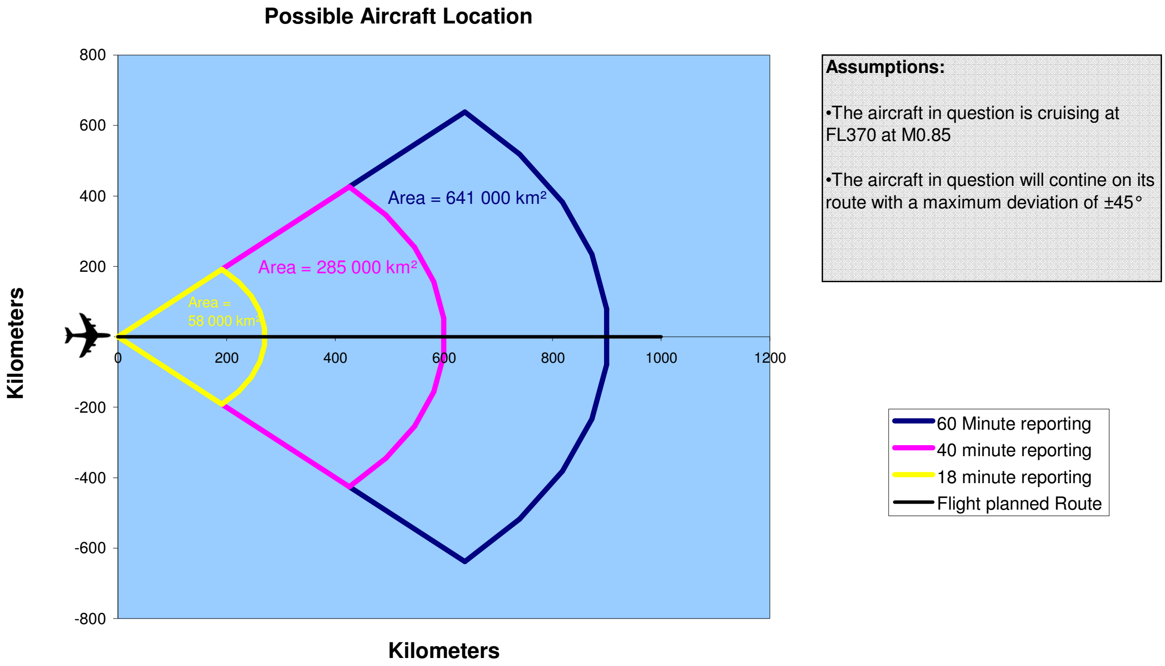

Figure 6 – Possible aircraft Location in 2-D for 60 minute, 40 minute and 18 minute reporting intervals

Periodic position reporting is an ancillary benefit to the core FANS1/A solutions and does provide some improvement in aircraft tracking if for example, 15 or 18 minutes period is used.

3.2.1 Advantages

Detection of an abnormal situation through cessation of reports is more reliable than depending on event reporting. This solution would also contribute to safety in that conformance monitoring is enhanced. Can be provided by centralized ADS-C in non-FANS1/A airspace. A report rate increase from the current 40 to 60 minutes (dictated by the spacing of waypoints) to 15 or 18 minutes will reduce any potential search area by a factor of 4.

3.2.2 Disadvantages

Although technically feasible, very short intervals (on the order of a minute) would be expensive since an inverse relationship exists between the length of the interval and cost. The signal (cessation of reports) may be ambiguous – loss of communications is more likely than loss of aircraft. Centralized service would need to be established for monitoring outside FANS1/A service areas (though it should be noted that the fact this CAN be done is an advantage in itself).

3.2.3 Summary

Periodic contracts are already used by most ATS systems in the Atlantic. Most NAT centres currently use a 30 minute interval for MET reports, planned reductions in separation will dictate a shorter interval of 18 minutes. Periodic ADS-C contracts of 15 min are used in Canarias and, according to AIPs, 15 min are also being used in Dakar Oceanic UIR and 20 min in Atlantico UIR.

3.3 Ancillary Solution - FANS1/A based ADS-C Demand contracts

The use of ADS-C demand contracts alone to provide a flight tracking service is ineffective. Demand contracts are essentially a request sent by the air traffic controller to the aircraft requesting it to send a position report. If used routinely to provide improved knowledge of aircraft position associated workload would be prohibitively high. This method cannot therefore provide any information in the case of a catastrophic event occurring to an aircraft.

3.3.1 Advantages

This method is very economical as no reports are generated unless a contract is issued by ATC. Can be used for conformance monitoring and can be automatically generated when normal reports are overdue. Can determine aircraft current position and/or possible connection failure.

3.3.2 Disadvantages

In the context of a catastrophe this is a contradiction in terms - the demand would by definition be issued too late. Cannot be implemented in centralized systems except perhaps as an automated facility in response to non-receipt of a message reporting a position indicated as the "next" position in a previous waypoint report.

3.3.3 Summary

This potential solution cannot be considered as part of the core solution as it would normally only be used after the failure to receive an expected message - in the circumstance relevant to OPTIMI it would be very unlikely that the aircraft could respond to the demand contract. However ADS-C demand contracts are an ancillary solution to the core and could be used in times of doubt to establish aircraft position.

4 Medium Term Oceanic Flight Tracking Service

Short term refers to trials in 2010 and implementation in 2011, Medium term refers to trials in 2011 and implementation after 2012.

The medium term solution consists of two parts;

- A central repository of FANS1/A and AOC messages,
- Flight Data Recorder down linking system.

This section of the document provides a description of each part of the medium term solution. There then follows a description and technical and operational analysis of the systems that provide the solutions.

4.1 Central repository for FANS1/A and AOC messages

This option would collect position and status data already available through various means (ADS-C, AOC) and centralize this data to make it available to various stakeholders (ANSPs, SAR, Airlines). Under procedural rules to be defined, SAR actions could be started in due time. The implementation of this complex solution is not compatible with the OPTIMI timescales, however it is recommended that it be studied further.

4.1.1 Advantages

The routing of all position data through one central repository could lead to reduced cost (due to cessation of duplicate reporting) and enhanced data availability (through translation of airline-specific formats to a single format). . Since this option relies on already existing data, it does not require any additional avionics or data link systems. This solution is potentially cost effective and simple from a certification perspective, and it compliments other the FANS1/A solutions.

4.1.2 Disadvantages

Position data supports the surveillance function in oceanic ATS systems and is very time-critical in nature. Also, the source of the data may be significant in determining its applicability for separation of aircraft. Centres may need to be able to control reporting characteristics, such as report rates. Due to the variety of message formats used this solution may be complex to implement.

4.1.3 Technical and Operational Analysis – Central repository for FANS1/A and AOC messages

The WP1 report from Lot 1 of the OPTIMI study clearly evidenced a number of Air/Ground applications that are currently exchanging data between aircraft flying trans-Atlantic routes, and ground-based users or stakeholders.

The OPTIMI study's first objective is to identify improvements to oceanic tracking, it therefore makes sense to focus on the position reporting element of this data exchange. WP1 has shown that current ATC and AOC applications already report positions data:

- In the ATC domain, the FANS1/A services, including the ADS-C application, are provided, or will soon be provided, in the EUR/SAM corridor and in all of the NAT region,
- In the AOC domain, many airlines are exchanging position data using, for example through the WPR (Way Point Reporting) application, and services such as CFRS that make it possible for WPRs to also be available for ATC purpose.

Furthermore, another objective of the OPTIMI study is to investigate how the coordination between various stakeholders (airlines-ANSP, Airlines-SAR, ANSP-SAR) can be improved and hence the distribution of position data. Considering the short term framework within which the OPTIMI study is undertaken, it seems logical to assess how available position data currently exchanged on Air/Ground data links can be better distributed between stakeholders in order to enhance oceanic tracking.

4.1.3.1 Description of Service

The *Position Data Repository* would collect position and status data already available through various means (ADS-C, AOC), and make this data available to stakeholders with a need for such data (ANSPs, SAR, Airlines). Each of these stakeholders would make use of these data according to their specific needs and associated missions.

The position data repository could be seen as building, in the specific area of oceanic flight tracking, on principles similar to that introduced by SESAR as System Wide Information Management (SWIM) in the ATM Target Concept document (D3 Deliverable of the SESAR Definition Phase). SWIM is defined in SESAR D3 as "*A net-centric operation where the ATM network is considered as a series of nodes, including the Aircraft, providing or consuming information*". SESAR Work Package 14 is dedicated to investigating the technical architecture required to support SWIM within the SESAR Master Plan.

The similarities between the *Position Data Repository* and the SWIM concept, reside in the existence of geographically distributed producers and consumers of information, each of them needs to have transparent access to consistent information, with specific Quality of Service (QOS) requirements, which may however differ according to the intended usage. In oceanic tracking, considering applications such as ADS-C and CFRS, the aircraft is the main producers of the position information, at least when flying in open oceanic areas (closer to coasts, position data may also be produced by radar trackers and/or ADS-B stations). Consumers of information must be able to request and obtain position data through the use of standard interfaces. Consumer of information may be:

- **ANSPs:** they need position information to ensure separation. ANSPs have stringent requirements on the quality of position information, notably on availability, integrity, end-to-end delay, authentication, in order to satisfy regulatory and/or safety requirements,

- **Airlines:** position data serves airline operational purposes. Airlines rely on the provided position information for the monitoring of flight progress. It must be noted that the requirements for such a service are far less onerous that those associated with services used by ATC for separation supposes,

- **SARs:** the Search and Rescue organizations currently do not receive position data directly from the producers of such data. Under adequate procedural rules to be defined, an easier access to position data could be provided to SAR organizations.

The following diagram illustrates a possible high level system architecture for a *__Position Data Repository__*;

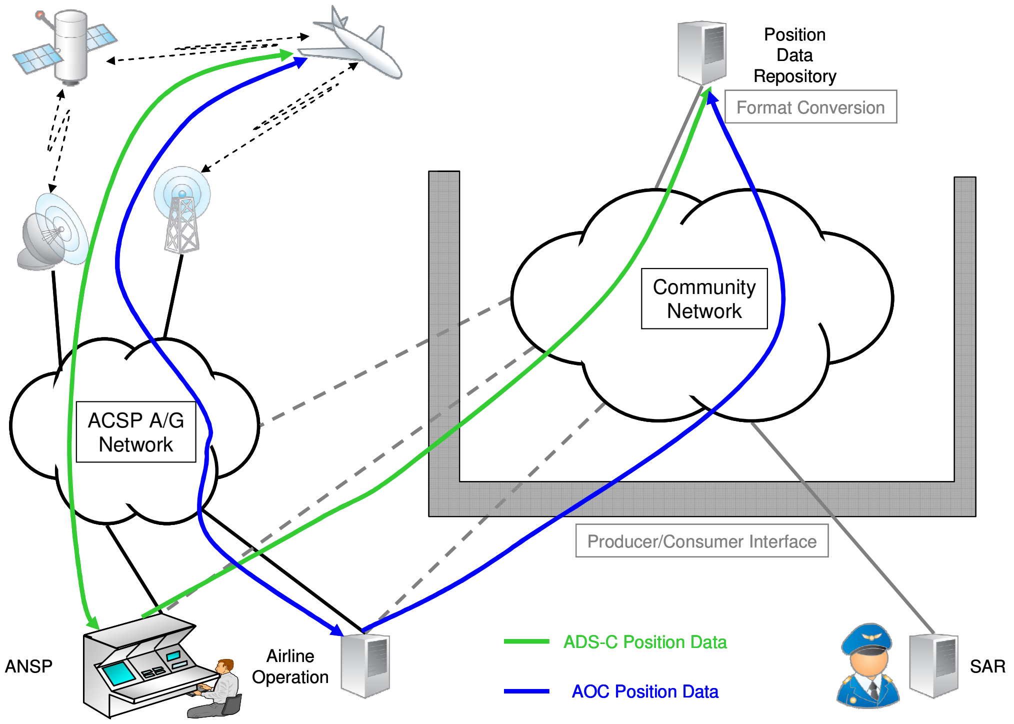

Figure 7 – High level system architecture for a central data repository.

4.1.3.2 Benefits

A central repository of position data would:

- ensure that the latest position information, regardless of the original sender and recipient, is available to all stakeholders in opportune time,
- make use, in the short term, of existing avionics and air/ground technologies, e.g. currently issued WPR and ADS-C reports,
- provide different sources and channels for the dissemination of position data, thereby increasing the resilience to a fault in any specific application,
- allow SARs to conduct an earlier assessment of special situations, and possibly to shorten the decision process leading to SAR actions.

4.1.3.3 Issues

Position reports currently generated through the ADS-C application, the WPR application or other means, have different formats and standards. Formats not only define the way in which the data is coded, but in some cases different semantics as well. The central repository would need to address the heterogeneity of formats and solve any semantic gap between the position data issued through different means. This requires a thorough assessment and the development of interfaces as intended within the SESAR SWIM concept.

Not all applications and stakeholders need the same level of accuracy of position data. The various protocols and applications used over the Air/Ground link reflect the different needs. The central repository will need to offer ways by which stakeholders can retrieve position data with quality appropriate to its intended usage.

Position data may be subject to security and/or confidentiality requirements that constrain their dissemination. The central repository would need to implement such restrictions, and be accountable for their observance.

Different architectures may be designed to implement a central repository of position data. In any case, ground communication means would be required that provide access to the locations of each stakeholders. While there exists regional or inter-regional initiatives that address ground-ground communication infrastructures in support to ATM (for example, the PENS project in Europe), the availability of such an infrastructure for all stakeholders of the North and South Atlantic regions may represent a difficult issue.

4.1.3.4 Scoping

The development of a central repository that addresses all issues listed under section 4.1.3.3 is a long term endeavour, which requires the development of appropriate standards, and well-driven mandated collaboration between stakeholders.

In the short term however, prototyping or demonstrations of concepts can be envisaged, the objective of which would be to display on a central system all position information, regardless of the application in use, relative to a single transatlantic flight.

4.1.3.5 Certification Issue

The current legal frameworks regarding regulatory or certification matters must be used, as it would be unrealistic to expect or require new legislative measures for this solution.

Regarding the SWIM concept, the SESAR definition phase noted that *"a clear regulation should be developed to define the boundaries of SWIM in ATM with clear rules to access and use. Roles, Responsibilities and Rules should be defined per stakeholder. Responsibilities and boundaries of ATM should be clearly specified based on policies that relate to the functional criticality of the different concept elements".*

These principles would apply to a central repository of position data. The highest criticality would be required for data used by ANSPs for separation purpose. The European regulatory framework regarding safety assessment and certification processes would certainly be made applicable in that case.

However, airline operation and SAR actions would not require the same criticality level as ANSP operations. A detailed analysis of the adopted architecture would be needed to identify which elements are common to all stakeholders, and therefore subject to the more stringent ANSP requirements, and which ones would demonstrably serve stakeholders benefiting from a lower level of criticality.

4.2 Flight Data Recorder Down Linking Systems

There are systems that use bespoke avionics and SATcom over Iridium that support the down linking of Flight Data Recorder contents.

FlyHT, a CEDAR consortium sub-contractor, markets an Iridium based system known as AFIRS 220. This system supports;

- Position reporting with intervals from a few seconds to any longer period,
- Automatic triggering of messages on level changes, vertical rate changes, speed changes, or anything else outside of predefined limits,
- Automatic triggering of streaming FDR data based on pre-defined criteria on the aircraft,
- Pilot initiation of data and position streaming mode,
- Ground initiation of data and position streaming mode,
- Transmission of aircraft status at any configurable time period,
- A reliable regular 2-way telephone quality SATcom voice service.
- Future systems will also support CPDLC and Link 2000+.

AFIRS 220 is currently operational on 25 aircraft types and in use daily by several operators making trans-Atlantic and trans-Pacific crossings. AFIRS 220 supports delivery to any IP address securely within 12 – 15 seconds. This can include ATC centres and/or SAR organizations.

The implementation of this complex solution is not compatible with the OPTIMI short term timescales.

4.2.1 Advantages

This solution offers great flexibility and is unique in its ability to use a wide range of events to trigger alerts/position reports automatically. Down linking FDR data during specific periods is also potentially of great value. This system does not require ACARS or FANS1/A equipage; rather it monitors Arinc 429 and 717 data buses and transmits selected data in accordance with rules embedded in the on board software.

4.2.2 Disadvantages

Such a system cannot replace FANS1/A and its use for air traffic control purposes. It may, therefore, not be attractive to airlines to equip with this solution, although it is already demonstrated to be technically feasible for both types of system to co-exist on the same aircraft. This solution may therefore be attractive to types for which no FANS1/A avionics exist.

In the FLYHT AFIRS 220 system the event/status reporting capabilities form a small part of a turnkey solution. Whilst FLYHT believe their existing customer airlines recover the relatively low cost of installation within one year of operation, and therefore such a solution would be attractive in the short term to airlines, the pace of change and the time it will take to achieve a credible mass of equipped aircraft limits this option to the mid term rather than the short term.

There may be issued surrounding the FDR down linking functionality and data protection. ED112 states that FDRS/CVR messages are strictly confidential and shall not be transmitted from aircraft during flight.

Such systems use the internet as the communication network. The safety and security aspects of this would require attention.

4.2.3 Technical and Operational Analysis – Flight Data Recorder Down Linking System (AFIRS 220 / 228)

One objective of the OPTIMI program is to identify and evaluate the readiness and cost of technologies for improved aircraft tracking and emergency communications. Much discussion has focused on ACARS, FANS1/A, and SATCOM over Inmarsat, and operating scenarios have been discussed using those technologies as the basis for evaluation. The purpose of this section is to describe an alternate approach that utilizes a global SATcom network and IP delivery mechanisms across the most ubiquitous communication system ever invented-the internet. This capability can co-exist with traditional navigation and communications solutions or can act as a stand alone for aircraft that are not equipped with ACARS, SATCOM, or FANS1/A. This section will examine this approach in relation to the specific areas of interest to the OPTIMI project.

Systems exists today using certified avionics, that can, upon command, cause a continuous stream of 4-D GPS position reports and FDR data to be sent to any number of IP addresses via satellite over Iridium and the internet. Operators, OEMs, SAR organizations, and ATC personnel can all receive the data within 15-20 seconds. The streaming can be initiated by (a) the crew with a single button press, (b) the avionics automatically through situation recognition logic, or (c) by ground personnel. 2-way voice and texting over Iridium is also integrated into one package and communications channel.

Figure 8 – System Architecture for an Iridium based FDR down linking system.

This capability helps ground personnel support abnormal in-flight situations by providing real time awareness of developing situations in the air along with all the supporting data from the aircraft. It can also support after-the-fact investigation of accidents and incidents. Position data can be refined to 1 second resolution and FDR data resolution is as fine as ¼ second where applicable. Current in-service data streaming has included up to 240 FDR parameters streamed continuously.

Figure 9 – Ground Notification in the FLYHT FlyhtstreamTM system.

The position/FDR data streaming mode can be triggered automatically by the avionics when;

- the aircraft state meets pre-defined criteria. This is enabled by monitoring a discrete parameter value or several parameter values on the FDR bus (ARINC 717), the trigger algorithms can be customised to the aircraft type and operator,
- by the cockpit crew via a single button press,
- or by the operations staff on the ground.

The transit latency (aircraft to end user) is 15 seconds, but the high resolution data record received starts 30-90 seconds before the event in question being transmitted over SATcom to the ground. The data can then be rapidly reconstructed on the ground where it can be graphically presented in various forms for different subject matter experts. As an example of the range of data parameters that can be down linked, a full list of data parameters for a single aircraft type is included in APPENDIX B.

When the system is in normal operation, a wide range of AOC and Maintenance messages are provided, including automated OOOI messages, engine take off and cruise reports, aircraft exceedances reports as well as free text messaging to and from the aircraft. Two way voice over iridium is also supported over the same communications path.

Future systems will also feature ATS messaging and CPDLC functionality (including compatibility with Eurocontrol Link 2000+).

Figure 10 – Data Reconstruction and Presentation in the FLYHT Flyhtstream TM system.

4.2.3.1 Geographical Scope Analysis

The use of the Iridium satellite network means that there are no geographical restrictions on retrieving the data from any aircraft. Iridium has global coverage with no gaps. Messages and data sent to the ground are delivered securely using the Internet meaning that, once again, there are no geographical restrictions.

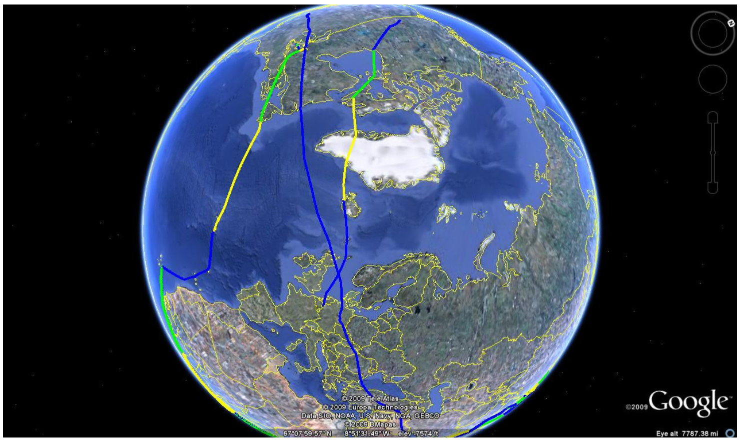

Figure 11 – Geographical Data Presentation in the FLYHT Flyhtstream TM system.

4.2.3.2 Data Volume

Current FDRs commonly record at rates of 64, 128 or 256 words per second, where each word consists of 12 bits. The data volumes associated with different recording rates are shown below (based on the SAGEM Solid State FDR system, not including checksum/overhead bits);

Words/second	Bits/second	kb/second	Recording capacity (hours)	Memory size (kb)
64	768	0.768	100	276,480
128	1536	1.536	50	276,480
256	3072	3.072	25	276,480

Table 1 – Data volume for various different recording rates.

The 88 legally required FDR parameters can be recorded at any of these recording rates, this data therefore gives an indication of the bandwidth required to down link FDR data. For example to down link 256 words per second the required bandwidth is 3.072 kb/s, it is therefore quite feasible to down link the 88 legally required FDR parameters. This assumes continuous data transmission, burst data transmission requirements differ and depend on the number and type of parameters to be downlink and on the length of time period for which down is linked.

4.2.3.3 Economical Analysis

The full infrastructure to support this mode of communications exists today globally. There is zero cost and no time delay required to create the infrastructure to provide 100% global coverage using the Iridium system. The satellite constellation is deployed and operational, and the other ground-based component is the internet. The only infrastructure requirement is a computer capable of accessing the internet. The data retrieved can be delivered to any IP address, over secure, encrypted channels with 12-15 seconds from the generation of the message on the aircraft. This data can, within seconds, be redirected to ATC centres, SAR organizations or a centralized source once the IP addresses are known (these would normally be determined in advance). The aircraft contact information (including phone number) can be made known to controllers through a central processing centre hosted by a secure redundant web server. Customers pay from a few USD to no more than 10USD per flight hour for a whole range of data services delivered over Iridium and the internet. Position reporting constitutes a small subset of these charges. The costs for position and data streaming in an emergency are under 3USD per minute, and these costs only occur on an individual aircraft basis and only when a streaming mode has been triggered.

4.2.3.4 Social Analysis

There are some concerns regarding the security of and access to data retrieved from an aircraft flight data recorder. All data collected by such systems is stored in a secure web server with strict access controls. The data is only stored for as long as is deemed necessary and the data may not be disclosed to other parties without the consent of the organization concerned. These regulations are broadly in line with national data protection acts. FOQA and FDM data can be isolated and delivered to specified users.

4.2.3.5 Regulatory Analysis

The afirs system is operational today and in use daily by operators making transatlantic and trans-pacific crossings. The on-board systems are certified by EASA, FAA, Transport Canada, and CAAC (China) on over 25 aircraft types/models. Some of the aircraft types covered include the Airbus A320 family, Boeing 737 (classic and next gen), Boeing 757, Boeing 767, and DC-10. The satellite network, Iridium, used by thousands of aircraft for voice communication and flight tracking, in the final stages of certification for safety services; ATC data certification is expected in Q3 of 2010, with voice certification in 2011.

4.2.3.6 Conclusion

A significant issue regarding the loss of an aircraft in oceanic airspace is the difficulty this can cause in retrieving the Flight Data Recorder and the Cockpit Voice Recorder from the aircraft. This can subsequently lead to difficulties in conducting an effective accident investigation.

The FLYHT AFIRS 220 system is a valid option for consideration within the OPTIMI project as being universally available to civil and military operators within reasonable timeframes. The relevant flight data can then be easily accessed, using an appropriately controlled access procedure to enable accident investigation, though the ACARS messages described earlier would no doubt duplicate some of the FDR data.

This process can be set up to only transmit in abnormal situations, thereby reducing data volume and cost. Streaming is normally limited to specific aircraft during periods warranted by aircraft status. A full FDR and 4-D GPS data stream over Iridium would cost approximately $3 per minute - the equivalent cost via INMARSAT should be investigated.

Such systems are operational with over 25 operators worldwide, all of whom are realizing significant savings to their operations while improving their operational control and awareness by knowing aircraft location and status at all times. The system requires no additional ground infrastructure to be developed or set up by the operator. The operating costs are also very economical with the amount of data transmitted controllable by the operator. The data is stored in a secure location and can be delivered to any computer in the world securely and within seconds. Supplemental Type Certificates (STC) exist for over 25 aircraft types/models and by different governing bodies thus certifying the system for worldwide use.

Data protection issues will need to be considered.

5 Oceanic Flight Tracking Solutions for further study

5.1 Study 1 – AOC Position and Aircraft Status Reports

There are two topics in the area of AOC use of ACARS that are worthy of assessment in the context of OPTIMI, they are the use of AOC position reports and AOC reports of aircraft status.

5.1.1 AOC Position Reports

It is not uncommon for airlines to track the progress of their flights using position reports sent via ACARS to the relevant AOC. This practice could potentially be used to contribute towards a flight tracking service if the position report messages were forwarded from the relevant AOCs to OACCs, SAR coordination centres etc.

5.1.1.1 Advantages

The provision of an oceanic flight tracking service using AOC position reports could be quite effective. Reports can be sent every 10 minutes, for example, and are already provided to AOC in many cases, so the necessary infrastructure in place. This could be a useful alternative to ADS-C where it is not available.

5.1.1.2 Disadvantages

The wide scale implementation of a system that forwards messages sent to AOC to OACC would be a complex task due to wide range of message formats used, potential legal issues, data protection etc. May require complex processing of diverse airline-specific formats. Dissemination might be problematic, AOC messages currently have a lower priority than ATC messages.

5.1.1.3 Summary

This solution could never be universal since it is wholly dependent on the arrangements each airline may - or may not - have set up for a tracking service. Were it to be pursued one option would be for the automated systems at the AOCs to retransmit the data (perhaps in a standard format) to the ATS units concerned - possibly a centralized service could be used for determining which units need the information (dependent on the position reported). An alternative would be to centralize the entire process, capturing the AOC information and reformatting it, but that might not find favour with the airlines whose data are being handled. It is recommended that this potential solution be studied further in combination with the central repository of data described in 4.1.

5.1.2 AOC reports of aircraft status

Reports of aircraft status are already being provided to AOCs in many cases. As an example, AF447 provided a series of messages which could possibly have prompted SAR action had a relevant agency monitored or known of their existence.

5.1.2.1 Advantages

Since this option relies on already existing data, it does not require any additional avionics or data link systems.

5.1.2.2 Disadvantages

Format and content may vary from operator to operator and a centralized service for decoding and forwarding messages would need to be established. Access to data problematic since many messages may contain sensitive information. Sheer volume of data may be excessive. In the case of AF447 most of the last messages were maintenance ones not sent to AOC but to maintenance applications. The process for anomaly detection would require definitions.

5.1.2.3 Summary

This solution is more difficult to implement than AOC position messages, one of the issues would be how to define, from monitoring data, a situation critical enough to merit raising an alarm. If this option were to be pursued it would almost certainly be best left to each airline to determine when to raise the alarm, i.e. messages arriving at the AOC automated systems might trigger the transmission of an alert to the ATS unit responsible for the flight, possibly through a centralized data dissemination service capable of deriving the appropriate destination from the position reported. Recommend for further work.

5.2 Study 2 – Improved Adherence to ATC Procedures by OACCs

It is recommended that a review be completed of common ATC practises in order to establish how they differ from ICAO SARPS on a regional basis.

The lack of adherence to ICAO SARPS by OACCs, specifically relating to co-ordination and position reporting, can cause significant difficulties in the successful monitoring of oceanic air traffic. ICAO Doc 4444 PANS-ATM (chapter 10) specifies the correct procedures for co-ordination between ATC units. The reporting period required within a FIR is defined in the relevant Aeronautical Information Publication (AIP) and the local procedures for ensuring compliance with the defined reporting period is included in the local Manual of Air Traffic Services (MATS). Lack of conformance to either the reporting period or co-ordination procedure can cause significant problems in the identification of, and timely response to, unexpected or catastrophic events. However this topic is in the ICAO domain, and as such it is beyond the remit of OPTIMI.

5.2.1 Advantages

Could be implemented in relatively short time. Avoids the need for wide scale equipage.

5.2.2 Disadvantages

Would still leave between 40 and 60 minutes before an aircraft would be detected as missing.

5.2.3 Summary

This topic is within the domain of ICAO, however efforts should be made to ensure conformance to ICAO SARPS.

5.3 Study 3 – FANS1/A Mandate and Incentives

The topics of a possible FANS1/A mandate for the Atlantic regions of the NAT, EUR and AFI ICAO regions should be studied in combination with the possibility of providing financial incentives to airlines for FANS1/A equipage.

5.3.1 FANS1/A Mandate for Ground and Air

A regulation mandating the carriage and use of FANS1/A equipment would ensure the availability of the core solution, however such issues are beyond the influence of the OPTIMI project.

5.3.1.1 Advantages

Would ensure high equipage and likely to happen in medium term.

5.3.1.2 Disadvantages

Costly to airlines and slow to implement.

5.3.1.3 Summary

There are significant advantages to mandating the use of FANS1/A, however it should be noted that equipage in itself does not guarantee the provision of an effective flight tracking service, as demonstrated by the loss of AF447, log-on and effective use must also be ensured.

5.3.2 Financial incentive for FANS1/A equipage

Incentivisation of the carriage and use of FANS1/A equipment would ensure the availability of the core solution, however such issues are beyond the influence of the OPTIMI project.

5.3.2.1 Advantages

Would achieve high levels of equipage more quickly than a mandate, ensuring the availability of the core solution. The incentive approach was demonstrated to be very successful in the LINK2000+ Programme as a means of achieving early equipment of aircraft with ATN/VDL2: the initial forecast was to achieve 100 aircraft equipped; at the end there are more than 400 aircraft. The EC is already providing incentives for ATN equipage by virtue of the mandate for CPDLC/ATN/VDLm2.

5.3.2.2 Disadvantages

Costly to implement. Potentially limited to airlines registered in the EU.

5.3.2.3 Summary

There are significant advantages to encouraging the use of FANS1/A, however it should be noted that equipage in itself does not guarantee the provision of an effective flight tracking service, as demonstrated by the loss of AF447, log-on and effective use must also be ensured.

5.4 Study 4 – Automatically generated emergency FANS1/A based ADS-C reports

The use of automatically generated emergency FANS1/A based ADS-C reports is effective but requires a change to aircraft avionics. It is therefore a very long term solution with equipage low initially.

5.4.1 Advantages

Would report events (with location) even in cases of crew incapacitation. Can be provided by centralized ADS-C service in non-FANS1/A airspace.

5.4.2 Disadvantages

Currently only implemented for Gulfstream aircraft.

5.4.3 Summary

This functionality is currently only fitted to a small number of business jet aircraft. There is however nothing to prevent this functionality being added to other avionics - it could even be argued that no change to the FANS1/A specification would be needed - only the automation of those tasks that currently require crew input (i.e. the initiation of emergency mode under specific circumstances). In the longer term a full study of the potential should be conducted by the SC-214 committed currently working on the next generation of data link systems. This topic is worthy of future study.

5.5 Study 5 – FDR/CVR real-time transmission via Inmarsat

The transmission of FDR data in real time via SATcom has been demonstrated and is in service using the Iridium based system, see section 4.2. However that vast majority of aircraft that are equipped with SATcom equipment are equipped with Inmarsat compatible equipment rather than Iridium compatible equipment. While it is possible that this equipage scenario may change when Iridium is certified for ATC use, the use of Inmarsat to down link FDR data would capture a much larger portion of the transatlantic fleet for some considerable time to come.

In the frame of OPTIMI, Airbus do not plan any feasibility study about FDRS/CVR down links, indeed this kind of datalink transmission cannot be performed through existing installation.

5.5.1 Advantages

In the event of an aircraft loss this is very effective way of ensuring the availability of the data required for accident investigation if the FDR and CVR units cannot be recovered from aircraft wreckage. If pre-specified events are used to trigger down linking this is also a very cost effective solution

5.5.2 Disadvantages

While theoretically possible, the down linking of FDR and CVR data via Inmarsat SATcom has not been demonstrated. In order to implement such a solution a development and test programme would have to be undertaken, as well as the modification of line aircraft.

5.5.3 Summary

The down linking of FDR and CVR data via Inmarsat SATcom is theoretically possible and could provide significant benefits, however the technical feasibility of this and the implications in term of the implementation programme, need to be fully assessed.

5.6 Study 6 – ADS-C without log on

During the "normal" establishment of FANS1/A connectivity (ADS and CPDLC) – i.e. when a crew transitions from non-FANS1/A airspace to a FANS1/A area (thus not addressing centre/centre transitions) the sequence is initiated by the flight crew selecting the ATSU identifier (usually the FIR designator) and initiating the logon. This causes the avionics to transmit a message, the so-called 'AFN_Logon' message, which contains details of the flight identifier (ACID in ICAO terminology), registration and location of the flight, thus allowing correlation with a flight plan held by the receiving centre. The centre responds by transmitting a "connect request" message, once the aircraft accepts this by transmitting a "connection confirmed" message, CPDLC connectivity exists.

In addition to the "connect request" message the centre will also send a message instructing the aircraft to start transmitting ADS reports. In the NAT the instruction is usually a request for waypoint reports and, optionally, periodic reports, while in the South Atlantic it is for periodic and event reports.

This request for ADS reports is in no way dependent on the preceding AFN_Logon, that message is just a convenient indicator that the aircraft is approaching the area and has functioning FANS1/A avionics (and is an absolute prerequisite for CPDLC because of the need for crew training). If a centre has received coordination from an adjacent centre and knows that the aircraft in question has ADS-C (either because of a flight plan indication, via coordination or prior history) then ADS contracts can be established before the logon or indeed without any logon.

Where ADS reporting is established in this fashion there is an obvious need to establish correlation between the aircraft (as represented by its registration, used to route the ADS request message) and the relevant flight plan to make up for the lack of the information normally received in an AFN_Logon message. This is done by setting up an ADS demand contract requesting a single message including the ACID and present position, these variables coupled with the registration fully duplicate the correlation information contained in an AFN_Logon message.

Once the aircraft has been correlated with a flight plan the next event is the establishment of a "normal" ADS contract, i.e. one involving waypoint reports and periodic reports.

It should be noted that since the first message in this ADS-specific procedure is ground initiated, there is a slight complication stemming from the fact that messages use two different formats depending on the type of aircraft. The workaround is to read the type designator from the flight plan and determine the format to be used accordingly.

It is also worth noting that correlation failure modes will be slightly different from those experienced using an AFN_Logon – instead of starting with the ACID and failing to correlate the registration, the revised procedure will start with the registration (because that will determine to which aircraft the ADS request is addressed) and possibly fail to correlate with the ACID. With appropriate system design the difference is transparent.

Finally, it should be pointed out that ADS will need to be “armed” (active) for this approach to work, although this is the default state. This of course applies equally to the normal logon procedure but there it can be taken for granted that the equipment is armed prior to initiating the procedure. The possibility that ADS may not have been armed will somewhat lower the likelihood of this approach working but was not found to be a major issue during the period when one ATSU (offering only ADS at the time) used this approach.

5.6.1 Advantages

Ensures the availability of the core solution for all suitably equipped aircraft.

5.6.2 Disadvantages

Removes airline/pilot discretion and increases their cost. Necessitates software upgrade in ground systems (but NOT in aircraft). May not be a viable option for centralized systems outside FANS1/A service areas.

5.6.3 Summary

Aircraft capable of using ADS-C occasionally fail to log-on to OACCs successfully. This can be due to technical problems or because the aircrew choose to no log-on. Initiating ADS-C from the ground side can overcome these issues in many circumstances and ensures the availability of event/deviation alerts. Potentially a very effective solution but not yet researched thoroughly.

6 Economic Analysis

6.1 Technology required for the implementation and operation of OPTIMI.

An infrastructure based on the generation, transmission, receipt and processing of messages requires automation. The centres supporting FANS1/A will, by definition, have such automated systems. In the northern part of the Atlantic and in Canarias these FANS1/A systems are closely integrated into the flight data processing systems; this aspect of other systems is unknown. It should be noted that use of a centralized system for ADS-C does not call for a high level of automation in centres availing themselves of such a service.

Centralized ADS-C (CADS) Systems are currently being operated by both SITA (for Edmonton, Canada) and ARINC (for Bodo, Norway). The functional basis of these systems is fact that, as these companies are the carriers of messages between aircraft and the ground, they can monitor for indications of FANS1/A capabilities (typically a logon) and, when such are seen, set up ADS-C contracts with the flight in question.

6.1.1 Ground systems required for the operation of OPTIMI

To analyse ground systems needed, three cases can be identified:

1. Adding ADS-C capabilities to an existing ground system,
2. Adding the capability to initiate ADS-C contract without a prior AFN logon from a ground system already supporting ADS-C,
3. Developing a "centralized service" for monitoring outside FANS1/A service area.

Neither a centralized service nor the capability to initiate ADS-C contract without logon are being considered for the short-term phase

Assessing the costs associated with ground system equipment is complex as there are many factors that influence the cost. The estimates in this document are based on previous upgrades to ground system completed by Adacel.

The cost of adding the capability to initiate ADS-C without a prior AFN logon from a ground system, to a system already supporting ADS-C, could be in the order of 200 k€.

The cost of adding ADS-C capabilities to an existing ground system, including the AFN application, could be in the order of 1000 k€.

It should be emphasized that many factors will affect the cost of a particular implementation, for example;

a) Architecture of the ground system. In extreme cases it could even be necessary to replace the ground system completely,

b) Development processes in place or required by the ANSP. Those could account for more than 90% of the costs,

c) ATS functions to be supported by the ADS-C application. ADS-C can be used to provide other ATS functions such as improved surveillance in addition to the flight tracking service. The software assurance level associated with these other functions could differ from the level associated with the flight tracking services, thus imposing more stringent processes,

d) Sequencing of the changes. Introducing the necessary modifications as part of another scheduled update introduces significant economies of scale.

A precise estimate can only be done individually by each ANSP.

6.1.1.1 Santa Maria FIR

Currently communication and surveillance within the Santa Maria FIR are based on a mixed mode environment using approved communication and surveillance systems, including voice over HF, VHF and SatCom and CPDLC for communications, and ADS-C position reports and radar for surveillance.

Regarding the FANS1/A functionality required for the OPTIMI short term solution, CPDLC is currently available to exchange ATS messages with FANS1/A equipped aircraft, using voice as back-up. The SATL Oceanic Flight Data Processor System in Santa Maria is also capable of processing ADS-C position information for surveillance purposes.

Santa Maria FIR has the basic functionality required for the operation of OPTIMI; however NAV Portugal has yet to implement ADS-C periodic reports for surveillance and lateral and vertical event reports for conformance monitoring.

6.1.1.2 Shanwick FIR

The ATC systems currently used by NATS for operations in the Shanwick FIR have the required functionality to support the OPTIMI short term solution. The FANS1/A datalink processor, called the NavCanada Gateway, already automatically sets up an ADS Event/Deviation alerts contract when an aircraft initiates an AFN logon with the NavCanada Gateway.

NATS would be required to make some system changes to support the medium term solution; forwarding ACARS messages, not originally destined for NATS, from central servers. These would be software developments, the cost and timeframe of these changes would be dependent on the message format defined.

6.1.1.3 Canaries FIR

All of equipment needed to operate the OPTIMI short term solution is fully implemented in the Canarias FIR and ADS-C event based contracts are already used in.

The SACCAN V2 system, the ADS-C/CPDLC system in operation in the Canaries ATC Centre, provides full FANS1/A compatible ADS-C/CPDLC features to the operational automated ATS system (SACTA) in operation in this facility.

6.1.1.4 Reykjavik

Because of the complex interaction between surveillance-based and procedural separation used in Reykjavik's airspace, the system architecture is correspondingly complex. At the core of the ATM functionality are two systems, the Flight Data Processing System (FDPS) and the Radar Data Processing System (RDPS). These two systems present a common situation display interface to the user through the so-called Integrated Situation Display System (ISDS), the FDPS also manages its own "electronic strip" display.

6.1.2 On board system needed to operate OPTIMI

The core short term solution identified as the optimum means of meeting the objectives of OPTIMI is based on the use of FANS1/A, which has two component services: ADS-C and CPDLC.

Airborne equipment requirements for operating ADS-C and CPDLC include the following;

- VHF and SATcom transceivers to connect with the ACARS network,
- A communications unit with data link capability to link messages between VHF/ SATcom and avionics,
- An IT data link communications application for ADS-C and CPDLC. This application should be available to the pilot, therefore the integration of the application on the Flight Management System is required.

Since avionics equipment is specific to each aircraft, data will have to be collected accordingly and it is noteworthy that currently there is no global and comprehensive source for this data. The costs of on-board implementation are related to the provision of specific avionic systems.

FANS1/A equipage by Airlines is not high and there is no significant stimulus to equip, although there are some initial discussions on mandatory FANS1/A equipage in the North Atlantic region, for a 2015 time frame.

6.1.3 SATcom Service

SITA supports AOC Operations throughout the world by providing the AIRCOM communication service. This service is ensured between the aircraft onboard radio and the interface with the airline's operation centre. It uses both a VHF ground radio network which counts more than 1200 radios, supporting ACARS transmission throughout the world, and VDLm2 transmission in specific regions such as Europe. The exchange of AOC messages between ground and air is based on the ACARS messaging protocol, which was specifically designed for AOC applications.

The AIRCOM service exists in two major brands;

- The satellite AIRCOM service, which makes use of the Inmarsat and Iridium constellations. It is primarily used over oceanic areas, or other areas with limited ground VHF coverage (desert areas).
- The VHF AIRCOM service, which makes use of the VHF ground radio stations

6.2 Scenario/s and timeframe of the study

The timeframe of the economic study will start in 2010 and will finish in 2029, Lot 5 will take this period into account.

Under the requirements of the SJU all technology included in this study (Core and Ancillary Short term solution) is available in the short term. Short term refers to trials in 2010 and implementation in 2011, e.g. the short time term timeframe is defined as 1-2 years.

Regarding the costs analysed in this document: Ground equipment cost and on-board equipment cost will be fully incurred in the period of one year (Implementation Cost).

Cost of the trials will be taken into account in Lot 5.

ANSPs and Airlines companies will incur Operational Costs, such as the cost of SATCom service, from 2011 to 2029 (Operational period).

The geographical scope chosen for the economical analysis is the NAT, EUR and AFI region.

6.3 Economic Assumptions

In order to carry out a clear and efficient cost assessment, the following assumptions were made;

- Inflation will not be taken into account (The Lot 5 CBA model will use a Real Discount Rate),
- Cost figures are in present value terms (based on 2010 prices),
- The economical units used are Euros (€). Data originally provided in dollars was converted to euros using the following rate: 1USD=0.83 Euros.

6.4 Technical assumptions

The following technical assumptions were made;

- The majority of the airborne equipage information came from Air Europa and Air France resources,
- Although OPTIMI is a global system developed to insure that aircraft can safely operate on a worldwide basis, this project does not take into account Americans ANSPs.

6.5 Impact of Ground Equipment on economic assessment

6.5.1 Santa Maria FIR

Equipment	Cost (€)	Timeframe
ADS-C vertical & longitudinal contracts Ground Equipment (Santa Maria FIR)	250 k€	2011 (one year for full implementation)

Table 2 – Cost of equipment in Santa Maria

6.5.2 Shanwick FIR

Equipment	Cost (€)	Timeframe
FANS1/A compliant system to instigate and receive ADS-C Event/Deviation alerts	No Cost, current system provides this capability	Already fully implemented

Table 3 – Cost of equipment in Shanwick

6.5.3 Canaries FIR

Equipment	Cost (€)	Timeframe
FANS1/A system able to manage all FANS1/A defined contracts (event, periodic, demand and emergency contracts)	No cost, current system provides these capabilities	Already fully implemented

Table 4 – Cost of equipment in Canaries

6.5.4 Reykjavik FIR

Equipment	Cost (€)	Timeframe
The cost of implementing an event-driven conformance monitoring setup	It will be non-zero but since ISAVIA have committed to doing this for operational reasons there will be no cost for OPTIMI	It is assumed that the system is going to be fully implemented in 2010.

Table 5 – Cost of equipment in Reykjavik

6.6 Impact of On Board Equipment on economic assessment

Regarding the chosen solution in the short term timeframe; on-board equipment has no impact on the economic assessment.

The short terms solutions are specific ADS-C contracts, and are thus accepted by FANS1/A equipped aircraft.

Other solutions, such as automatically generated emergency FANS1/A based ADS-C reports, will have an impact on the economic assessment for FANS1/A equipped aircraft. This impact is fully dependent on the cost of the SB and the time of implementation for the software upgrade.

The current Air France fleet is composed of short, medium and long haul aircraft. The long haul fleet is fully equipped with FANS1/A.

The current Air Europa fleet is composed of a Short & Medium haul fleet (B737-800's and Embraer 195) and a long haul fleet (B767-300 and A330-200).

The short & medium haul fleet is intended to fly mainly in continental areas. It is partially equipped with data link ATN systems and there are plans to equip the whole fleet in the coming years in order to comply with the data link mandate in Europe. This fleet is not suitable for use on long haul flights in oceanic areas, mainly due to the performance limitations (i.e. range vs. payload) of these aircraft. Consequently they are not fitted with the required equipments for ETOPS (Extended Twin Engine Operations). Additionally they are not equipped with FANS1/A as they do not operate in oceanic areas. In summary, Air Europa's short & medium haul fleet is out of the environment considered for OPTIMI.

The long haul fleet is fully appropriate to the use of FANS1/A. In the case of Air Europa, this fleet is composed of 6 Airbus 330-200 and 2 B767-300 aircraft.

The 2 B767-300s are not equipped with data link systems. For this aircraft type the cost of a retrofit to install FANS1/A systems is estimated to be 622.5 k€ (per aircraft). Taking into account a planned retirement date of 2013 for these aircraft; the retrofit option is discarded due to its very high cost.

The 6 Airbus 330-200s are all equipped with FANS1/A (including SATcom).

Consequently, in the case of Air Europa and Air France, there is no need to install any additional equipment and therefore no cost associated with avionics.

For Air Europa and Air France, the only costs for the short term solutions are those associated with the use of the Communications Service Provider network for the extra message traffic generated, which is considered to be a small part of the total cost of communications within a flight.

6.6.1 Retrofit Costs

With regard to airlines that would like to use the flight tracking service but do not operate FANS1/A equipped aircraft, the cost is dependent on the initial level of equipage of the aircraft in terms of navigation & communication systems.

The relevant aircraft operated by the airlines examined closely in this study (Air France and Air Europa) are already equipped. Therefore, for the chosen short term solutions, there is no retrofit cost due to on-board equipment.

A study in the NAT region showed that retrofit costs for FANS1/A are dependent on the equipment purchased and the days the aircraft is required to be out of service during installation of the new equipage. It is estimated that 42% of Shanwick traffic (approximately 694 aircraft) is equipable but not equipped yet, and therefore this analysis is focused on them. Aircraft expected to have ATN CPDLC are excluded, as well as non-equipable aircraft.

The following table shows the retrofit costs estimate in the NAT region for FANS1/A equipable aircraft;

System	Average Purchase Cost (€)	Average OOS (days)
FANS1/A	29.05 K€ to 33.2 K€	0 - 1
Inmarsat	62.25 K€ to 249 K€	14
Iridium	29.05 K€	7
GPS	290.5 K€	15
FMC/CMU Upgrade	53.95 K€ to 290.5 K€	3 – 21

Table 6 – Retrofit costs estimation in the NAT region for FANS1/A equipable aircraft

Taking into account the number of equipable aircraft, the type of aircraft, and that the costs depend on the required level of equipage, the implementation costs for FANS1/A on equipable aircraft is between 19.92 M€ (if only software is needed) and 3.735 B€ (if software and SATcom, GPS and FMC are required). However the actual cost is between these two figures and is not known, it depends heavily on the level of GPS and SATcom equipage of the aircraft.

6.6.2 Forward fit

For new aircraft bought, there is a cost to the airline for activation of the FANS1/A system which is between approximately 100 K€ and 150 K€.

6.6.3 Evolution of aircraft equipped

The current fleet of Air Europa is composed for a short & medium haul fleet and long haul fleet;

- The short & medium haul fleet is intended to fly mainly in continental areas and as such is out of the scope of OPTIMI.
- The long haul fleet is completely equipped with FANS1/A (including SatCom).

In the case of Air France, all of the long range aircraft are already equipped with Inmarsat SatCom & FANS1/A (A+) systems.

It is impossible to predict with confidence how many aircrafts will be bought by the companies in the future. Consequently the total cost of new Inmarsat SATCom & FANS1/A (A+) systems for new aircraft is also difficult to predict.

6.6.4 Total On-board equipment cost

Equipment	Cost (€)	Timeframe
Cost of the activations of FANS1/A systems	Between 100 K€ and 150 K€ per aircraft	Incurred at the time of purchase

Table 7 – Total on-board equipment cost

All of Air Europa's and Air France's long haul fleet are already equipped with FANS1/A, there is therefore no cost to equip these aircraft. However, for other airlines, the forward fit cost to activate the FANS1/A system is around 100 K€. to 150 K€.

6.7 Impact of SATcom Services on the economic assessment

Since the area of interest to OPTIMI is the ocean, the optimum means of communications is SATCom, whether for voice or data.

6.7.1 Cost of the service to Airlines

6.7.1.1 Overview

The cost assumptions developed in this section make use of average costs. They include exclusively the communication costs, and do not include SATcom (Inmarsat or Iridium) equipage cost for an aircraft, nor do they include maintenance cost for the SATcom devices. Actual communication costs, as addressed in the following section, will depend on the specific contractual arrangements between the airlines and the contracted CSP. Under these assumptions, the costs are made directly dependent on the volume of exchanged messages. The OPTIMI trial Lots are therefore required to identify the volume of exchanged messages, in order to derive the direct communication costs.

6.7.1.2 Volume estimates

In order to analyse the financial impact of the use of the OPTIMI service, the data transmission pattern for oceanic flights must first be estimated. The OPTIMI service will be based on ADS-C technology and more specifically;

- ADS-C event reports,
- ADS-C periodic reports,
- ADS-C demand reports.

In order to evaluate the data transmission volume of the OPTIMI service, a number of assumptions must be made;

- An estimate must be made of the additional traffic generated by the use of the ADS-C application. It is assumed that each aircraft makes a single daily return flight between Europe and US.
- The size of an ADS-C message is assumed to be 1 Kb (which is the average of 1 block with 125 characters in the ACARS network).
- Assume that on average we will have;
    - ADS-C event reports (1 per 15 minutes),
    - ADS-C periodic reports (1 per 15 minutes),
    - ADS-C demand reports (1 per hour).
- Assume an 8 hours flight with 6 hours over the Atlantic Ocean.

6.7.1.3 Financial impact

In order to evaluate the data transmission costs of the OPTIMI service, a number of financial assumptions must be made;

- Analysis showed that the cost of incremental traffic (in addition to the overall traffic of AOC/ATC messages) on radio link (VHF) is around 0.16 € per kilobit and 0.29 € on satellite link. (Note that these figures are given as an order of magnitude but may vary significantly from one airline to another depending on the size of the fleet, the number and geographical distribution of flown routes, the volume of messages exchanged, etc.).
- Assume that 25% of data traffic is routed via radio link and 75% is routed via satellite link.

If we combine these financial assumptions with the volume estimates we can calculate the average communication costs of the OPTIMI service. This leads to the following estimates for communication charges related to the use of the OPTIMI service.

- Total traffic would be 12 messages per hour, 72Kb per flight.
    - 54Kb on Sat x 0.29€ = 15.6€
    - 18Kb on VHF x 0.66€ = 2.9€
- Total ADS-C cost 18.5€ for 1 flight (order of magnitude).
- Within the assumptions above, an ADS-C message sent every 15 min costs 18.5€ per flight (or per 30 min 9.25€).

6.7.1.4 Contractual aspects

Although the financial impact is directly linked to the volume of traffic, it must be noted that contractual arrangements between the CSPs and the airlines relating to the SATcom based data link services are specific to the airlines.

6.7.2 Cost of the service for ANSPs

Cost of the SATcom service to ANSPs will widely depend on the specific arrangement between each ANSP with the CSPs.

6.7.2.1 Santa Maria FIR

The additional operational costs in Santa Maria associated with future daily operations (e.g. additional ADS-C contract messages) are not relevant for inclusion in this analysis.

6.7.2.2 Shanwick FIR

If the volume of messages sent and received did not change dramatically, the day to day provision of the short term OPTIMI solution would incur no additional communications costs to NATS beyond the Communications Service Provider costs identified in WP1.

6.7.2.3 Canaries FIR

If the volume of messages sent and received did not change dramatically, the day to day provision of the short term OPTIMI solution would incur no additional communications costs to AENA beyond current communication costs.

6.7.2.4 Reykjavik FIR

A 30 minute interval ADS-C periodic reporting is currently used for MET reporting but a reduction to an interval on the order of 15 minutes is anticipated for operational reasons (the NAT is currently planning 18 minutes for a longitudinal separation reduction - 15 might seem reasonable when reduced lateral separation is implemented) - only if an interval shorter than that were required would there be a cost attributable to OPTIMI (but incurred by the operators) not by the ANSP.

7 Conclusions

7.1 Solution Identification

The CEDAR consortium considered a wide range of solutions that could be used to provide an oceanic flight tracking service. Each solution was examined thoroughly using the wide range of expertise available within the consortium to determine if the OPTIMI requirements, as defined in 1.4, were met. This analysis enabled the identification of a short term and a medium term solution to the OPTIMI requirement for an oceanic flight tracking service.

Solutions have been classified as one of the following;

- Core Short Term Solution,
- Ancillary Short Term Solution,
- Medium Term Solution,
- Recommendation for Further Study.

(Short term refers to trials in 2010 and implementation between 2011 and 2013, Medium term refers to trials or development from 2011 and implementation after 2013).

Each category is summarised below.

7.2 Core Short Term Solution

The following solutions provide the core functionality of the flight tracking service;

Solution	Advantages	Disadvantages	Rationale
FANS1/A based ADS-C Event (deviation alert)	Very economical, no reports generated while operations normal. Combines well with conformance monitoring (to detect pilot error) in centres using ADS for ATC purposes. Can be provided by centralized ADS service in non-FANS1/A airspace (though current centralized systems do not support such contracts).	The catastrophe may be too rapid for an event report to be generated (cf. the discussion of the advantages of periodic reporting - which is not so affected). The single event report (these events only "fire" once) may be lost en route. Centralized service would need to be established for monitoring outside FANS1/A service areas. Such a centralized service would not be in possession of sufficient ATC information to distinguish between cleared and uncleared manoeuvres; this would detract from its value (and possibly limit the scope of events monitored).	Economical, effective, compliments ADS-C without log-on and mandate solutions well.

Table 8 - Core Short Term Solution

7.3 Ancillary Short Term Solution

The following functionality is delivered with the application that provides the core solution described above. These add some benefits in terms of oceanic flight tracking but would not provide an effective enhanced flight tracking service in themselves;

Solution	Advantages	Disadvantages	Rationale
FANS1/A based ADS-C Periodic Position Reports	Detection of abnormal situations through cessation of reports is more reliable than depending on event reporting. Will also contribute to safety in that conformance monitoring is enhanced. Can be provided by centralized ADS in non-FANS1/A airspace. The reporting rate increase from the current 40 to 60 minutes (dictated by the spacing of waypoints) to 15/18 minutes will shrink any potential search area by a factor of 4.	Although technically feasible, very short intervals (on the order of a minute) would be expensive since obviously an inverse relationship exists between the length of the interval and cost. The signal (cessation of reports) may be ambiguous - loss of communications is more likely than catastrophe. Centralized service would need to be established for monitoring outside FANS1/A service areas (though it should be noted that the fact this CAN be done is an advantage in itself).	Periodic reporting will not provide sufficient knowledge of aircraft position in itself unless a very short period is used (around 1 minute), in which case it is expensive and has a high bandwidth requirement. However it is an ancillary benefit to the core FANS1/A solutions and does provide some improvement in aircraft tracking if 15/18 minutes period is used.
FANS1/A based ADS-C Demand Contracts	Very economical, no reports generated unless contract issued. Can be used for conformance monitoring and can be automatically generated when normal reports are overdue and help determine aircraft current position and/or possible connection failure.	In the context of a catastrophe this is a contradiction in terms - the demand would by definition be issued too late. Cannot be implemented in centralized systems except perhaps as an automated facility in response to non-receipt of a message reporting a position indicated as the "next" position in a previous waypoint report.	Not effective as the core solution as by definition it could not be used as an ATC alerting mechanism, it also requires controller workload, however this solution provides some benefits in times of uncertainty.

Table 9 - Ancillary Short Term Solution

7.3.1 Economic Analysis

This section summarises the costs of the ground and on-board equipment required to implement and operate OPTIMI and operational SATcom costs. The scope of this assessment is the Atlantic region of the NAT, EUR and AFI ICAO regions. Given that different systems are employed in different ANSPs (and regions), costs have been assessed by taking into account the deployment level of each ANSP's system.

The following table shows the implementation costs for the ground equipment required by the OPTIMI short term solution for each ANSP studied;

FIR	Equipment	Cost (€)	Timeframe
Santa Maria FIR	ADS-C vertical & longitudinal contracts Ground Equipment (Santa Maria FIR)	250 k€	2011 (one year for full implementation)
Shanwick FIR	FANS1/A compliant system to instigate and receive ADS-C Event/Deviation alerts	No cost	Already fully implemented
Canarias FIR	FANS1/A system able to manage all FANS1/A defined contracts (event, periodic, demand and emergency contracts)	No cost	Already fully implemented
Reykjavik FIR	The cost of implementing an event-driven conformance monitoring setup	No cost for OPTIMI	The system is going to be fully implemented in 2010.

Table 10 – Implementation costs of the OPTIMI ground equipment

As can be seen in Table 10, most of the ANSPs are already equipped with the technology required to operate OPTIMI, only Santa Maria incurs direct costs. With regard to Reykjavik; the required ground systems will soon be implemented for (other) operational reasons, there is therefore no cost directly attributable to OPTIMI.

Regarding on-board systems; there is no directly attributable equipment cost to airlines for aircraft that are equipped with FANS1/A.

With regard to new aircraft airlines will incur in forward fit cost associated with FANS1/A. This cost is associated with the activation of the FANS1/A system and is between 100 K€ and 150 K€.

Equipment	Cost (€)	Timeframe
Cost of the activations of FANS1/A systems	Between 100 K€ and 150 K€	Incurred at the time of purchase[1]

Table 11 –Activation of the FANS1/A system

For aircraft already in service that are not equipped with FANS1/A, the equipage cost is likely to be beyond that considered cost effective. This cost depends heavily on the equipage level of other systems, such as SATcom and GPS, so the range of cost estimates is wide. The total cost of equipping the entire NAT fleet with FANS1/A is thought to be between 19.92 M€ and 3.735 B€.

With regard to SATcom costs, actual communication costs will depend on the specific contractual arrangements between the airlines and the contracted CSP(s) and between the ANSPs and the contracted CSP(s). Under these assumptions, the costs depend directly on the volume of messages exchanged. Taking into account the financial assumptions used, the average communication costs of the OPTIMI service are;

SATcom Cost	Cost (€)	Timeframe
Cost of SATcom communications for Airlines	18.5 € per flight	ADS-C message sent every 15 min
Cost of SATcom communications for ANSPs	Fix/Flat Rate	Depends upon individual arrangements between ANSPs and CSPs

Table 12 – Average communication costs of the OPTIMI service

Both ANSPs and airlines foresee that if the volume of messages sent and received did not change dramatically, the day to day provision of the short term OPTIMI solution would incur no additional communications costs to them.

7.3.2 Regulatory Analysis

With regard to the OPTIMI Short Term Solution described in this document, the regulatory procedures and underlying standards are well established. However, there is a need to harmonise operational practises concerning the use of the relevant FANS1/A functions between Atlantic Oceanic FIRs and globally. The ICAO Global Operational Data Link Document (GOLD) initiative is a potential mechanism for such harmonisation.

[1] This does not take into account any finance schemes used to purchase aircraft nor any method of attributing or amortising aircraft acquisition costs.

7.4 Medium Term Solution

The following medium term solutions could provide significant advantages in terms of oceanic flight tracking however implementation in the short term is not possible due to the complexity of the implementation programme.

Solution	Advantages	Disadvantages	Rationale
Central repository for FANS1/A and AOC messages	The routing of all position data through one central repository could lead to reduced cost (due to cessation of duplicate reporting) and enhanced data availability (through translation of airline-specific formats to a single format).	Position data supports the surveillance function in oceanic ATS systems and is very time-critical in nature. Also, the source of the data may be significant in determining its applicability for separation of aircraft. OACCs may need to be able to control reporting characteristics, such as report rates.	Cost effective and relatively simple from a certification perspective, compliments other FANS1/A solutions but complex to implement.
Flight Data Recorder Down Linking System	This solution offers great flexibility and uses a wide range of events to trigger alerts/position reports automatically. Down linking FDR data during specific periods is also potentially of great value.	Such a system cannot replace FANS1/A for ATC purposes - it may in fact be unrealistic (economically if not technically) to expect that both types of system could co-exist on the same aircraft. May therefore be limited to types for which no FANS1/A avionics exist. Event/status reporting capabilities form a small part of a turnkey solution - this may adversely affect the cost of implementation.	Potentially an effective solution but equipage very low.

Table 13 - Medium Term Solution

7.5 Recommendations for Further Study

The following potential solutions are recommended for further study;

Study	Solution	Advantages	Disadvantages	Rationale
Study 1	AOC Position Reports	Effective, reports can be sent every 10 minutes for example. Already provided to AOC in many cases, infrastructure in place. Useful alternative to ADS where it is not available.	Wide scale implementation of a system that forwards messages sent to AOC on to OACC would be a complex task due to the wide range of message formats used, potential legal issues, data protection etc. May require complex processing of diverse airline-specific formats. Dissemination might be problematic.	Effective as reports can be sent every 10 minutes for example. Already provided to AOC in many cases so the infrastructure in place. Useful alternative to FANS1/A based ADS-C where it is not available but complex to implement due to wide variety of message formats in use.
	AOC reports of aircraft status	Already being provided to AOC in many cases. Since this option relies on already existing data, it does not require any additional avionics or data link systems.	Format and content may vary from operator to operator. Centralized service for decoding and forwarding messages would need to be established. Access to data problematic since many messages may contain sensitive information. Sheer volume of data may be excessive. In the case of AF447 most of the last messages were maintenance ones not sent to AOC but to maintenance applications. Need to define process for anomaly detection.	Cost effective, AF447 demonstrated that this would be effective if the appropriate monitoring were in place, complex to implement due to wide variety of message format in use.
Study 2	Improved adherence to ATC procedures by OACC.	Could be implemented in relatively short time. Avoids need for wide scale equipage.	Needs policing. Very political. Would still leave up to one hour before an aircraft would be detected as missing.	This issue is in the ICAO domain and beyond the scope of OPTIMI, it could however deliver significant benefit.

Study	Solution	Advantages	Disadvantages	Rationale
Study 3	FANS1/A Mandate for Ground and Air	Will ensure high equipage. Likely to happen in medium term.	Costly to airlines. Slow to implement. Should make observations on the likely negative consequence of the ATN mandate on FANS1/A equipage.	Compliments Deviation Alert and ground initiated ADS-C solutions, beyond the scope of OPTIMI but likely to happen anyway.
	Financial incentive for FANS1/A equipage	Could be achieved quicker than a mandate. Would achieve high equipage for oceanic monitoring.	It is unclear who would provide the incentive.	Compliments Deviation Alert Message, Mandate and ground initiated ADS-C solution well. Beyond the scope of OPTIMI.
Study 4	Automatically generated emergency FANS1/A based ADS-C reports	Effective and cost effective, not reliant on crew action.	Only available on one aircraft type, costly and time consuming to implement more widely.	An effective solution but requires a change in aircraft avionics, therefore it is a long term solution with equipage low initially. A solution worthy of further study.
Study 5	FDR/CVR real-time transmission via Inmarsat	Potentially very valuable, ensures availability of FDR and VCR data for investigation, relatively high equipage for SATcom system.	Expensive, especially considering the rarity of the events being monitored. Not an ACARS function. Centralized service might need to be established.	FDR data transmission effective and efficient (if triggered by a pre-determined event) but equipage very low. CVR data transmission not yet demonstrated.
Study 6	ADS-C without log-on	Ensures the availability of the core solution for all suitably equipped aircraft.	Removes airline/pilot discretion and potentially increases their cost. Necessitates software upgrade in ground systems (but NOT in aircraft). May not be a viable option for centralized systems outside FANS1/A service areas. Aircraft type and registration must be known and ADS-C system must be armed.	Aircraft capable of using ADS-C occasionally fail to log-on to OACCs successfully. Initiating ADS-C from the ground side can overcome these issues in many circumstances and ensures the availability of event/deviation alerts. Potentially a very effective solution but not yet researched thoroughly.

Table 14 - Recommendations for Further Study

7.6 Solutions Deemed Not Suitable

The following potential solutions were deemed not suitable for the reasons described below. Further details can be found in APPENDIX A.

Solution	Rationale
Pilot-initiated emergency FANS1/A based ADS-C reports	Ineffective as it is dependent on aircrew action in an emergency scenario and it is non-automated, even though it could be useful in some circumstances.
Pilot-initiated emergency FANS1/A based CPDLC reports	Ineffective, dependent on aircrew action in emergency scenario and it is non-automated.
FMC WPR Pos reports	Equivalent to Voice/HF in terms of tracking.
SATCom Voice	Equipage unlikely to be high, ineffective in emergency situations, it is non automated & takes long time.

Table 15 - Solutions Deemed Not Suitable

APPENDIX A Solutions Deemed Not Suitable

A.1 Pilot-initiated emergency ADS-C reports

Type: Pilot-initiated emergency ADS-C reports.
Rationale
Ineffective as it is dependent on aircrew action in an emergency scenario and is non-automated (even though it could be useful in some circumstances).
Advantages
Very economical, no reports generated while operations are normal. Can be provided by centralized ADS-C service in non-FANS1/A airspace. Requires less crew action than establishing voice communications.
Disadvantages
Dependent on crew action. Any single report may be lost en route (but subsequent reports likely to arrive provided aircraft remains capable of transmitting). Centralized service would need to be established for monitoring outside FANS1/A service areas.
Comment
On most of aircraft HMI the pilot has to press a minimum of 4 keys to trigger the emergency mode. Although due to disadvantages it cannot be considered as a solution in itself, it will supplement any other FANS1/A based solution.
Conclusion
Not suitable as a solution as dependent on aircrew action.

A.2 Pilot initiated emergency CPDLC reports

Type:
Rationale
Ineffective, dependent on aircrew action in emergency scenario and is non-automated.
Advantages
Very economical, no reports generated while operations are normal. Can include information describing emergency if time permits.
Disadvantages
Dependent on crew action. Report may be lost en route. Cannot be provided by centralized ADS-C service in non-FANS1/A airspace since CPDLC is strictly a controller/pilot connection.
Comment
All the issues surrounding ADS-C emergency reporting also apply here - there is in fact a linkage between the two applications where the CPDLC emergency message switches ADS-C into emergency mode. Other issues may exist and need study.
Conclusion
Not suitable as a solution due to dependency on aircrew action.

A.3 FMC WPR Pos Reports

Type: FMC WPR Pos Reports
Rationale
Equivalent to Voice/HF in terms of tracking.
Advantages
Automated.
Disadvantages
Do not improve accuracy of known aircraft position over voice/HF.
Comment
Does nor provide any improvement in flight tracking over voice/HF reports.
Conclusion
Offers little benefit in terms of aircraft tracking.

A.4 SATCom Voice

Type: SATCom Voice
Rationale
Equipage unlikely to be high, ineffective in emergency situations (non automated & takes long time).
Advantages
Has the potential to provide a direct controller/pilot communications (DC/PC) link which may contribute to early understanding of (and intervention in) emergency. Global guidance material being discussed by ICAO TF.
Disadvantages
Call setup requires crew intervention. Routine use of SATcom Voice involves calls to radio facilities, not controllers, thus not DCPC. Most commercial passenger aircraft equipped with SATcom Voice also have FANS1/A (not true for business jets).
Comment
SATcom voice is already used in the NAT during periods of poor HF propagation. It has proven to be a useful alternative to HF for those aircraft equipped - but obviously suffers from some of the same disadvantages when considered in the context of OPTIMI - the greatest one being the effort and time needed to set up the connection.
Conclusion
Not suitable as a solution as it offers little benefit over HF voice.

APPENDIX B FDR Down Link Parameters for Airbus A320

Parameter	Type	Hz		Parameter	Type	Hz
altitude_coarse	int	0.5		engine_1_n1_epr_command	int	0.5
altitude_fine	int	1		gps_latitude	real	0.2
heading_true	real	1		gps_longitude	real	0.2
normal_acceleration	real	4		gps_ground_speed	real	0.2
longitudinal_acceleration	real	2		gps_height	real	0.2
lateral_acceleration	real	2		gps_track	real	0.2
pitch_attitude	real	2		gpws_terrain_fault	disc	0.5
roll_attitude	real	1		antiskid_sel_on	disc	0.5
flap_position	real	0.5		alternate_braking	disc	0.5
slaps_position	real	0.5		squat_switch_nose	disc	0.5
captain_pitch_command_pos	real	2		squat_switch_right	disc	0.5
captain_roll_command_pos	real	2		squat_switch_left	disc	0.5
rudder_pedal_position	real	1		marker_beacon_passage	disc	1
FO_pitch_command_pos	real	2		vhf_keying	disc	1
FO_roll_command_pos	real	2		hf_keying	disc	1
aileron_position_right	real	2		system_page_origin	disc	0.5
aileron_position_left	real	2		alt_std_baro_sel_captain_1	disc	0.5
elevator_position_right	real	1		alt_std_baro_sel_captain_2	disc	0.5
elevator_position_left	real	1		alt_baro_set_capt_coarse	disc	0.5
rudder_position	real	1		ground_spoiler_armed	disc	0.5
rudder_trim_position	real	0.5		left_spoiler_1_out	disc	0.5
stabilizer_position	real	1		right_spoiler_1_out	disc	0.5
radio_altitude	real	0.5		thrust_lpr_mode	disc	1
angle_of_attack_left	real	0.5		alpha_floor_active	disc	1
angle_of_attach_right	real	0.5		ats_thrust_n1_mode	disc	1
total_air_temperature	real	0.5		ats_engaged	disc	0.5

Parameter	Type	Hz		Parameter	Type	Hz
selected_heading	real	0.5		ats_active	disc	0.5
selected_track	real	0.5		ats_speed_mode_active	disc	0.5
selected_speed_mach_auto	real	0.5		retard_mode_active	disc	0.5
engine_1_n1	real	1		ap_2_engaged	disc	1
engine_1_n2	real	1		ap_1_engaged	disc	1
engine_1_egt	real	1		fd_2_engaged	disc	1
engine_1_fuel_flow	int	0.5		fd_1_engaged	disc	1
engine_1_thrust_power_lever	real	0.5		spoiler_5_l_r_valid	disc	1
engine_1_n1_vibration	real	1		eng_2_hpv_not_full_close	disc	1
engine_1_n2_vibrataion	real	1		eng_1_hpv_not_full_close	disc	1
engine_1_n1_epr_command	int	0.5		wing_anti_ice_valve_r	disc	0.5
engine_1_n1	real	1		eng_2_anti_ice_pb_on	disc	0.5
engine_1_n2	real	1		wing_anti_ice_valve_l	disc	0.5
engine_1_egt	real	1		eng_1_anti_ice_pb_on	disc	0.5
engine_1_fuel_flow	int	0.5		eng_2_anti_ice_valve	disc	0.5
engine_1_thrust_power_lever	real	0.5		wing_anti_ice_pb_off	disc	0.5
engine_1_n1_vibration	real	1		eng_1_anti_ice_valve	disc	0.5
engine_1_n2_vibrataion	real	1		apu_bleed_valve	disc	0.5
hp_fuel_valve_engine_2	disc	1		pred_ws_off	disc	1
hp_fuel_valve_engine_1	disc	1		gps_captain_primary	disc	1
fuel_fire_valve_engine_2	disc	1		gps_FO_pirmary_lost	disc	1
fuel_fire_valuve_engine_1	disc	1		heading_discrete	disc	1
dc_ess_bus_on	disc	0.5		normal_brake_fault	disc	1
cabin_pressure_warning	disc	0.5		antiskid_fault	disc	1
engine_2_fire	disc	0.5		lo_armed	disc	1
engine_1_fire	disc	0.5		medium_armed	disc	1
avionic_smoke_warn	disc	1		maximum_armed	disc	1

Parameter	Type	Hz		Parameter	Type	Hz
cargo_smoke_warn	disc	1		heading_track_sel	disc	1
lavatory_smoke_warn	disc	1		egpws_terrain_on_nd	disc	1
engine_2_oil_low_pressure	disc	1		FO_egpws_inst	disc	1
engine_1_oil_low_pressure	disc	1		captain_egpws_inst	disc	1
tcas_ta2	disc	0.5		pred_ws_warn_terrain	disc	1
tcas_ta1	disc	0.5		pred_ws_alert_terrain	disc	1
engine_2_reverser_unlock	disc	1		FO_wxr_valid	disc	1
engine_1_reverser_unlock	disc	1		FO_egpws_valid	disc	1
engine_2_reverser_full_deploy	disc	1		captain_wxr_valid	disc	1
engine_1_reverser_full_deploy	disc	1		captain_egpws_valid	disc	1
gear_up_locked	disc	0.25		speed_brake_cmd	disc	1
gear_down_locked	disc	0.25		gpws_warn	disc	1
pitch_discrete	disc	1		normal_flight_law	disc	0.25
roll_discrete	disc	1		FO_side_stick_inop	disc	1
mach_selected	disc	0.5		captain_side_stick_inop	disc	1
auto_speed_control	disc	0.5		flight_alt_1_law	disc	0.25
approach_control	disc	0.5		flight_alt_2_law	disc	0.25
dmc_3_xfr_captain	disc	0.25		flight_direct_law	disc	0.25
cmc_3_xfr_FO	disc	0.25		x_feed_valve_eng_1_2	disc	0.25
pfd_nd_xfr_captain	disc	0.25		sdac_2_valid	disc	0.25
pfd_nd_xfr_FO	disc	0.25		sdac_1_valid	disc	0.25
pfd_captain_anomaly	disc	0.25		ecam_du_2_anomaly	disc	0.25
pfd_FO_anomaly	disc	0.25		ecam_du_1_anomaly	disc	0.25

Parameter	Type	Hz		Parameter	Type	Hz
nd_fo_anomaly	disc	0.25		ac_1_bus_on	disc	0.2 5
dmc_2_invalid	disc	0.25		ac_2_bus_on	disc	0.2 5
dmc_1_invalid	disc	0.25		dc_2_bus_on	disc	0.2 5
ecam_nd_xfr_captain	disc	0.25		dc_1_bus_on	disc	0.2 5
ecam_nd_xfr_FO	disc	0.25		sec_1_fault	disc	0.2 5
flaps_fault	disc	0.25		sec_2_fault	disc	0.2 5
slats_fault	disc	0.25		elac_1_pitch_fault	disc	0.2 5
engine_2_fadec_fault	disc	0.25		elac_1_roll_fault	disc	0.2 5
engine_1_fadec_fault	disc	0.25		elac_2_pitch_fault	disc	0.2 5
radar_egpws_mode_captain_1	disc	0.5		elac_2_roll_fault	disc	0.2 5
radar_egpws_mode_captain_2	disc	0.5		elac_2_fault	disc	0.2 5
radar_egpws_mode_captain_3	disc	0.5		elac_1_fault	disc	0.2 5
elac_3_fault	disc	0.25				
ac_ess_bus_on	disc	0.25				
left_right_elevator_fault	disc	1				
ap_off_warn	disc	1				
side_stick_not_in_to	disc	1				
red_warn	disc	1				
master_warn	disc	1				
apu_fire	disc	1				
vmo_mmo_over_speed	disc	1				

Parameter	Type	Hz		Parameter	Type	Hz
stall	disc	1				
engine_2_ice_detected	disc	1				
engine_1_ice_detected	disc	1				
right_side_stick_fault	disc	1				
left_side_stick_fault	disc	1				
tcas_sensitivity_1	disc	0.25				
tcas_sensitivity_2	disc	0.25				
tcas_sensitivity_3	disc	0.25				
alt_std_baro_sel_FO_1	disc	0.25				
alt_std_baro_sel_FO_2	disc	0.25				
alt_capture_mode	disc	1				
alt_track_mode	disc	1				
gs_track_mode	disc	1				
gs_capture_mode	disc	1				
open_climb_mode	disc	1				
expedite_climb_mode	disc	1				
immediate_climb_mode	disc	1				
open_descent_mode	disc	1				
expedite_descent_mode	disc	1				
immediate_descent_mode	disc	1				
hyd_low_press_blue	disc	0.5				
hyd_low_press_green	disc	0.5				
hyd_low_press_yellow	disc	0.5				

APPENDIX C Conclusions from OPTIMI workshop, Lisbon 17/06/10

Comment & Questions made during OPTIMI Workshop;

10:30 Inmarsat: Question about how the ADS-C logon workaround has been implemented by ISAVIA.

10:30 ARINC: Mention that HFDL could be used as well, not only SATCOM.

ARINC: HF Data link – ARINC see over 1000 aircraft using HFDL daily, so the medium term solution of centralised repository could use this data.

ARINC: There is mention in some of the options that ACARS can suffer communications failure. This is the same infrastructure for both FANS1/A and ACARS, so it is contradictory.

NATS: FDR Downlinking could be incorporated into the medium term central repository via airline Operations centre data source.

~10:44 ICAO: Clarification - the purpose of the FANS1/A mandate in the NAT is not to allow separation reduction. FANS1/A will allow reductions in separation but this improvement could be implemented without the mandate. The mandate was already been decided.

Inmarsat: AFIRS 228 will complete in Q4 2010 and will be capable of using Inmarsat as well as Iridium. (In reply to an Inmarsat question) Bandwidth on Inmarsat is not an issue.

Other Flyht clarifications:

- RTCA 222 Is working on the issues found on interference / intermodulation between dual equipage antennas (SATCOM / IRIDIUM).
- The inclusion of CVR downlink is not on the roadmap at this time.

ENAV: Note that the equipment costs shown on AFIRS (IRIDIUM) are far lower than the ones presented in the WP2.2 (FANS1/A on SATCOM).

ARINC: All applications are available over ACARS already, except for FDR content, so what benefit does the FLYHT downlinking of FDR data give? The business case for AFIRS will be compromised by the introduction of a FANS1/A mandate.

At this time views on the reasons for the FANS1/A mandate have been exchanged between ICAO and the FAA.

NATS: good for niche aircraft who cannot fit FANS1/A or ACARS and who would be exempt from any mandate. Would also be good for business jets.

Joaquim: Questions to FLYHT with regard to storage and ownership of downlinked data. FLYHT state airlines retain ownership of their data. FLYHT have already supported incident investigations.

ADACEL: Noted A380 is FANSA+ which allows the termination of individual ADS connections and such functionality should be extended to B777.

FAA: Question on why the ATM systems presented will not use the ICAO24 bit code. Answer: Its used for ADS-B & multilateration.

--------------- Lunch break ------------------

AE: Description on the crew FANS1/A certification.

Suggestion: The data link communications charging model to be applied in Europe with ATN could also be applied to oceanic areas – the CSPs charge the ANSPs who pass the cost on via route charges.

FAA: Wonders how many of the world's approx 200 FIRS provide FANS1/A services.

- AFR key points: The introduction of a AOC repository would require the standardisation of a currently un-standardised domain (the ACARS AOC).

- Initiative launched internally (at AFR) to reduce communications datalink costs. When an ADS-WPR message is issued to the ANSP a copy is sent to the AFR AOC avoiding the requirement to send an AOC WPR message only.
- Adacel asked AFR about the report rate used on the data-link communications for Tailored Arrivals: Answer: The manoeuvre starts with 5” reports till 1” at the end.
- There is an investigation underway regarding the possibility of changing the FMS to allow the termination of some contracts.

FAA: Lot 1 has not looked at procedural aspects associated with FANS1/A usage (e.g. what to do at the loss off communications or failure of logon). Lots 2, 3, and 4, should spend time doing this. Our core solution does not stop another AF447.

NATS: pointed out that this is the purpose of ADS-C periodic reports.

FAA: Also interested in survivability of SATcom link in various attitude, e.g. falling aircraft. (BEA investigation is examining this. The SJU/José took the opportunity to discuss the SAT OPTIMI.

ICAO: Data gathered from Lots 2, 3 and 4 will be very useful in order to demonstrate the performance of ADS-C event contracts, since they are often asked this. Also, a comparison of performance between FANS-1 and FANS-A would be useful, since it is believed there are differences.

SITA presentation.

AFR: Remark; In general the satellite FANS1/A communications traffic is more expensive than the VDL FANS1/A, and as some messages are very “heavy”, and not all of them urgent, the company is using on some aircrafts (B777) geographic filters to delay the send of the heavy messages (not time critical) until more the most economical communications channel is available.

The possibility of the ACARS message type filtering by geography is not known by most.

TRIAL LOTS

ICAO: requested access to the trial outcomes namely if it could address different FANS1/A avionics types (A+, A1, A).

SJU: Declared their willingness to share the outcomes. The SJU usually raises no obstacles in sharing safety and regulatory outcomes.

SJU: Showed desire to include operational procedures impact factors in the trials.

17:10 FLOOR OPEN FOR DEBATE

SJU: (On answer a question from ARINC regarding the OPTIMI schedule) on the results (deliverables) dates:

Lot 1: July, Lots 2/3/4 – Sep/Oct, Lot 5: End of year.

The opportunity to setup a similar workshop will be pursued.

The OSCO should have two or three more meetings. The next should be scheduled soon (by webex).

SJU: Referred to the probable launch by September of an new ITT – OPTIMI II.

ARINC: Suggested SJU participation on the datalink users forum.

ENAV: Concerned about initial CBA. The document quotes NAVCanada estimate of $20m-$3.5bn. This compares with a complete AFIRS equipage of $200m. We need to investigate this further. Also, we should consider more the option of obtaining airline ops provided position reports directly to a SAR facility.

ADACEL: Should airlines be mandated to collect this data?

SJU: This would elevate the service to an ATS safety service, which would impose onerous requirements on airlines.

ENAV: Raised the possibility of the European - North African interface (Mediterranean) area facing a similar situation as in the oceanic areas.

SJU: Pointed out that the regulatory challenges are far bigger than the operational & technological ones. As example the EASA regulation process requires 2/3 years.

SJU: It's clear that some a/c will not be able to be retrofitted (age …).

SJU: Interoperability – it was been expressed by several countries operating in remote areas (e.g. central Asia) the desire to apply similar recommendations as the OPTIMI ones.

Portugal Military: Need to ensure the Demonstrations conduct comparable procedures for SAR, else little comparison can be drawn.

SJU: The procedural aspect is very important, the SJU is not a regulatory body but is capable of bridging the gap between airlines, regulators ….

APPENDIX D Acronyms

Acronym	Definition
ABI	Advance Boundary Information
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
ACID	Aircraft Identity
ACL	ATC Clearance
ACM	ATC Communications Management
ACP	Access Communications Processor
ACSP	Air Communications Service Provider
ACT	OLDI
ADS	Automatic Dependent Surveillance
ADS WPR	Automatic Dependent Surveillance -
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
AEA	Air Europa
AESA	Agencia Estatal de Seguridad Aérea
AFI	Africa Indian Ocean
AFN	ATS Facilities Notification
AFTN	Aeronautical Fixed Telecommunications Network
AIC	Aeronautical Information Circular
AIDC	Air Traffic Services Interfacility Data Communications
AIMS	Airplane Information Management System
AIP	Aeronautical Information Publication
AIRE	Atlantic Interoperability Initiative to Reduce Emissions
AMC	ATC Microphone Check
AMHS	Aeronautical Message Handling Service

Acronym	Definition
AMSS	Aeronautical Mobile Satellite System
ANSP	Air Navigation Service Provider
AOC	Airline Operations Centre
AOS	Airport Operations Services
APU	Auxiliary Power Unit
APW	Area Proximity Warning
ARCC	Aeronautical Rescue Co-ordination Centre
ARINC	Aeronautical Radio Incorporated (USA)
ARTAS	ATM Surveillance Tracker And Server
ARTCC	Air Route Traffic Control Center
ASD	Air Situation Display
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATO	Actual Time Over
ATS	Air Traffic Service
ATSS	ATO/TFC/Safety Nets System
ATSU	Air Traffic Service Unit
CAA	Civil Aviation Authority
CADS	Controller Auxiliary Display System
CADS	Centralized ADS
CAPSIN	Civil Aviation Packet Switching Integrated Network
CBA	Cost Benefit Analysis
CC-ICD	Common Coordination Interface Control Document
CDA	Current Data Authority
CFMU	Central Flow Management Unit

Acronym	Definition
CFRA	Central FANS1/A Reporting Agency
CFRS	Centralized FMC Waypoint Reporting system
CIDIN	Common ICAO Data Interchange Network
CLAM	Clearance Level Adherence Monitoring
CM	Context Management
CMS/CFDS	Control and Monitoring System/ Centralized Fault Display System
CMU	Central Maintenance Unit
CNS	Communication, Navigation and Surveillance
COM	Communication
CPDLC	Controller Pilot Data Link Communications
CPIOM/NSS	Core Processing Input/Output Modules/ Network Systems Server
CRC	Cyclic Redundancy Check
CSP	Communication Service Providers
CVR	Cockpit Voice Recorder
DAR	Direct Access Recorder
D-ATIS	Datalink- Automatic Terminal Information Services
DCDU	Datalink Control Display Unit
DCL	Departure Clearance
DCPC	Direct Controller/Pilot Communications
DFDAU	Digital Flight Data Acquisition Unit
DFDR	Digital Flight Data Recorder
DLASD	Data-Link Application System Document
DLGM	Data-link Guidance Material
DLIC	Datalink Communications Initiation Capacity
DLM	Data-Link Manager
DLS	Data Link Services

Acronym	Definition
DLT	Data Link Terminal
DMU	Data Management Unit
DSP	Datalink Service Provider
EASA	European Aviation Safety Agency
EC	European Commission
EEA	European Economic Area
EID	Electronic Information Distribution
ELT	Emergency Locator Transmitters
ETFMS	Enhanced Tactical Flow Management System
ETOPS	Extended Twin Engine Operations
EU	European Union
EUR	European-Mediterranean region
FAA	Federal Aviation Authority
FANS1/A	Future Air Navigation Systems
FDM	Flight Data Monitoring
FDP	Flight Data Processing
FDPS	Flight Data Processing System
FDR	Flight Data Recorder
FDR	Flight Data Recorder
FDS	Flight Data Section
FIR	Flight Information Region
FMC WPR	Flight Management Computer Waypoint Reporting
FMS	Flight Management System
FOM	FANS1/A Operational Manual
FOQA	Flight Operations Quality Assurance
FOQR	Flight Operational Quality Assurance
FPL	Flight Plan

Acronym	Definition
FS	Flight Server
FSA	First System Activation
GES	Ground Earth Station
GOLD	Global Operational Data Link Document
GPS	Global Positioning Service
HF	High Frequency
HFDL	High Frequency DataLink
HMI	Human Machine Interface
HQ	Headquarters
ICAO	International Civil Aviation Organisation
IFP	Initial Flight Plan
IFPS	Integrated Initial Flight Plan Processing System
IGA	International General Aviation
IMG	Implementation Management Group
IP	Internet Protocol
IR	Implementing Rule
ISDS	Integrated Situation Display System
IT	Information Technology
JAA	Joint Aviation Authorities
JCAB	Japan Civil Aviation Bureau
LAM	Logical Acceptance Message
LAN	Local Area Network
MATIP	Mapping of Airline Traffic over IP
MCDU	MultiPurpose Control Display Unit
MET	Meteorological
MIS	Management Information System
MNPS	Minimum Navigation Performance Specifications

Acronym	Definition
MRCC	Maritime Rescue Co-ordination Centre
MSAW	Minimum Safe Altitude Warning
MTSAT	Multifunctional Transport Satellites
NAT	North Atlantic
NATSPG	NAT Special Planning Group
NCGW	NavCanada GateWay
NDA	Next Data Authority
NIM	Navigation Integrity Monitoring
NSA	National Supervisory Authorities
OACC	Oceanic Area Control Centre
OCA	Oceanic Control Area
OCC	Oceanic Control Centre
OCD	Oceanic Clearance Deliver
OCL	Oceanic Clearance
ODS	Operational Display System
OFDPS	Oceanic Flight Data Processor Systems
OLDI	On-Line Data Interchange
OOOI	Out Off On In
OOS	Out Of service
OPTIMI	Oceanic Position Tracking Improvement and Monitoring Initiative
ORCA	Oceanic Clearance Route Authorisation
PCMCIA	PC Memory Card International Association
POS	Position report
QAR	Quick Access Recorder
QOS	Quality of Service
RAM	Route Adherence Monitoring
RAP	Recording and Playback

Acronym	Definition
RCC	Rescue Centre
RDCU	Radar Data Compressor Unit
RDPS	Radar Data processing System
RDPS	Radar Data Processing System
REV	Revision Message
RGS	Radio Ground Station
RMCDE	Radar Message Conversion & Distribution System
RQP	Request Flight Plan
RTCA	RTCA Inc (USA) formerly Radio Technical Commission for Aeronautics
RTF	Radiotelephony
RVSM	Reduced Vertical Separation Minimum
SAATS	Shanwick Automated Air Traffic System
SAM	South American
SAR	Search and Rescue
SARPS	Standards and Recommended Practices
SAT ATM/WG	SAT ATM Working Group
SAT FIT	SAT FANS1/A Interoperability Team
SATcom	Satellite Communications
SATL	Sistema Atlántico
SDD	Situation Data Display
SDP	Surveillance Data Processing
SELCAL	Selective Calling
SIGMET	SIGnificant METeorological report/information
SP	Strip Printer
SPV	Supervision Terminal
SRR	Search and Rescue Region
SSR	Secondary Surveillance Radar

Acronym	Definition
STC	Supplemental Type Certificate
STCA	Short Term Conflict Alert
TACT	Tactical Flow Management Working Position
TDT	Traffic Display Terminal
TFC	Track Flight Plan Correlation
TGL	Temporary Guidance Leaflet
TMA	Terminal Manoeuvring/control Area
UAC	Upper Area Control Centre
UIR	Upper Information Region
ULB	Underwater Locator Beacon
UTC	Universal Coordinated Time
VDL	VHF Datalink
VDLM2	VHF Datalink Mode 2
VDR	VHF Data Radio
VHF	Very High Frequency
WACAF	Western and Central African
WPR	Waypoint Position Reporting

APPENDIX E References

Organisation	Project, Version, Section,..
Bureau d'Enquêtes et d'Analyses	Interim Report No2 f-cp090601ae2
SJU /CEDAR consortium	DoW of OPTIMI Project
SJU / CEDAR consortium	OPTIMI. Lot 1. WP1.2.
SJU / CEDAR consortium	OPTIMI. Lot 2. WP2.1 Report (V0.9)
Eurocontrol	Standard inputs for Eurocontrol Cost Benefit Analysis. 2007 Edition (V3.0)
CEDAR Contributions	Contributions by partners (sent by emails)
ICAO	ICAO Regions figure
NavCanada	Data Link Users Forum

APPENDIX F FDR Downlink Issues

F.1 Mandatory Parameters

The identification of the 'mandatory 88 parameters' is a complex issue, the label 'mandatory 88 parameters' itself is perhaps somewhat misleading as the mandatory parameters are dependant on several factors (such as aircraft type, date of manufacture, country of registration, country of operation, modification status of the aircraft and so on). Furthermore, the list of parameters for a particular aircraft could only be provided with the agreement of the aircraft owner and the aircraft operator. This information is not available within the CEDAR consortium as the consortium does not contain an organisation that owns or operates an aircraft equipped with the afirs system. Reference to the afirs system is essential to the remaining analysis presented below. The key reason for identifying the mandatory parameters is to determine a data volume that represents the mandatory parameters, for use in datalink analysis. As some of the mandatory parameters are encoded values and others are discrete, the data volume can be represented as:

- 88 parameters, divided into;
    - 65 – 12 bit words, recorded every second,
    - 23 discrete values – 1 bit values recorded every second.

This gives a total of 803 bits of recorded data every second. For calculation purposes we should round this to 800 bits, or 100 bytes. This is a very good estimation of the data volumes (at a bit level) required to encode the 88 parameters (this includes any housekeeping bits, headers, footers etc.).

F.2 Downlinking Mandatory Parameters

F.2.1 Downlinking mandatory parameters at a rate of 3,072Kb/second

To stream the data described in question 1 above in real-time would require a transfer rate of 100 Bytes per second or 0.8 Kbps (Kilobits per second). If the volume of data required for the 88 parameters were greater than estimated by a factor of 2 and the necessary data volume were actually 200 Bytes per second, the necessary throughput would be 1.6 Kbps (Kilobits per second).

One hour of flight would result in a file of size 360 KB (KiloBytes), or 720 KB (KiloBytes) if the volume of data required for the 88 parameters were greater than estimated by a factor of 2.

The actual question of 3,072 Kb/second (~384 KB per second) is answered in 2.2 below.

F.2.2 Downlinking rate and duration for mandatory parameters

The following table is based on a one hour FDR file, recorded at 100 Bytes per second and at 200 Bytes per second. For FDR files larger than 1 hour in length, these values can simply be multiplied by the desired number of hours. i.e. for a 8 hour flight, the time to transfer a 720 KB / hour FDR recording at 50 KB per second would be: 720 KB * 8 hours / 50 KB per second = 115.2 seconds.

Transfer rate	360 KB file	720 KB file
3 KB per second	120 seconds	240 seconds
50 KB per second	7.2 seconds	14.4 seconds
1 MB per second	0.36 seconds	0.72 seconds
50 MB per second	0.0072 seconds	0.0144 seconds
100 MB per second	0.0036 seconds	0.0072 seconds

Table 16 – Downlink duration.

Note that this table is for a 1 hour sample flight. Multiply the provided download times by required number of hours to determine times for flights longer (or shorter) than one hour.

F.2.3 Downlink optimisation

The list of parameters for the A320, as described in Appendix B, is an example of this process. For example in a typical A320 FDR recording the Vertical Acceleration value is recorded at 8Hz and streamed from the aircraft at 4Hz.

This process of selecting the important parameters and their recording frequency is key Intellectual Property belonging to Flyht and it is therefore not possible to share additional samples. The concept is well understood and can easily be used to determine new download times for given download speeds.

It is not of value to describe, at an individual parameter level, the various possible recording rates. For example, if 88 parameters are considered, each with 4 different recording frequencies, an unmanageable number of FDR file combinations result.

A better approach is to identify that by increasing / decreasing the number of parameters and their recording frequency, the volume of the FDR data that needs to be streamed is impacted. For example, if it were determined that the per second volume was 455 Bytes per second, Table 16 above can be used to determine the download times at the rates already calculated.

F.3 Event Triggered Downlinking

F.3.1 Triggering Parameters

The parameters described in Appendix B for the A320 are a good sample of the necessary data needed for most accident investigations. 10 – 30 parameters in not sufficient according to the BEA working group or the accident investigation boards that Flyht has consulted with.

The list of parameters given by Flyht for the A320 can be regarded as the minimum set of data.

F.3.2 Triggering Values

The thresholds for airframe or engine parameters are sufficiently unique that each airframe and engine combination would need to be addressed individually. This issue cannot therefore be addressed within the scope of OPTIMI WP2.

F.4 Reducing the Parameter Set

To stream a set of FDR data that can effectively represent the state of the aircraft during an event/accident the list or parameters and recording frequencies described in Appendix B can be regarded as a minimum set. Anything less than this set of parameters will not provide a meaningful representation of the state of the aircraft.

F.5 SatCOM capability

The afirs system uses one of the protocols of Iridium. Another protocol, called Iridium Open Port, is also available. Iridium Open Port provides broadband level download speeds, however further information is not available within the membership.