J3.2 EUROPEAN INITIATIVES FOR THE INTEGRATION OF METEOROLOGICAL DATA WITH ATM

Andrew Mirza*, Bob Lunnon, Phil Gill
Met Office, Exeter, United Kingdom

1. INTRODUCTION

World-wide, air passenger traffic is expected to double or triple within the next 20 years [ACARE, 2001; EC, 2000]. With the existing on-board and on-ground systems, this could lead to an increase of aircraft accidents, in the same or a higher proportion. Despite the fact that accidents are rare, this increase is perceived as unacceptable by society and new systems and solutions must be found to maintain the number of accidents at its current low level. An increase in air traffic density also heightens the perceived environmental effects, namely its contribution to global climate change, local air quality and noise pollution [ACARE, 2008]. Adverse weather is seldom the exclusive cause of accidents and delays but nevertheless it is one of the most disruptive factors to aviation activities and the disruption will become more evident as the traffic density increases [FAA, 2007; Weber, 2007].

Weather phenomena can evolve at rapid rates (e.g., micro-bursts), over a wide spatial extent (e.g., upper air ice) as well as transporting hazardous materials across long distances (e.g., volcanic ash). The impact of weather on air traffic management may cause a reduction in traffic flow rate at airports [Markovic, 2008; Weber, 2007] with consequent delays in departures and arrivals; extended holding patterns, diversions and cancellations; the effects of which are inconveniences to passengers; misplaced assets (not just aircraft and crew but also "just-in-time" deliveries of goods); and increased costs through extra consumption of fuel, transit and airport charges, affecting profitability for airline operations; and the environmental impact from noise and pollution. In the main, air traffic planning assumes that fair weather conditions will predominate [FAA, 2007] so the occurrence of adverse weather places an extra demand on air traffic controllers as the effects on traffic flow are realised. The recovery time back toward an orderly traffic flow may take several days. Thus, within the spectrum of aeronautical information, meteorological data or weather information is an important component for the efficient and effective management of air traffic today and in the future [ICAO, 2008; JPDO, 2008; SESAR, 2007, 2008].

In this paper, a brief account is given of the initiatives currently taking place in Europe to mitigate the effects of adverse weather; through forecasting, dissemination and integration into decision making processes; how developments from the FLYSAFE project could be applied to air traffic management; for the provision of data for continuous descent approaches; and for data link developments to integrate weather information into automated decision support tools, which can alert controllers to impacts on traffic flow in the near-term to medium-term timescales.

This paper will also describe the state of development of FLYSAFE's Weather Information Management Systems, used to provide forecasts of the main weather hazards that may affect the safe and efficient conduct of a flight: ice, thunderstorms, wake-vortices and turbulence; as well as, the ground-based weather processor architecture and the data model used to exchange data. These developments are placed into the context of a net-centric information environment that leads the drive toward automation of air traffic management and the role change of air traffic management operators from being "in the decision loop" to "monitoring the decision loop."

2. ICAO GLOBAL AIR NAVIGATION PLAN

The Global Air Navigation Plan issued by ICAO [ICAO, 2007], sets out a series of global plan initiatives (GPI). These are intended to be performance based requirements that meet user expectations for safety, capacity, efficiency and

---

Corresponding author address:
Andrew K. Mirza,
Met Office, Exeter, Devon, UK, EX15 1HA;
email: andrew.mirza@metoffice.gov.uk

predictability. The Global Plan Initiatives (GPI) identified as being relevant to meteorology are:

- GPI-02 Reduced Vertical Separation Minimum
- GPI-06 Air Traffic Flow Management
- GPI-07 Dynamic and Flexible ATS Route Management
- GPI-12 Functional Integration of Ground Systems with Airborne Systems (automated sequence and merging, time of arrival, 4-D trajectories, ground support services – de-icing, runway maintenance, delay management services)
- GPI-14 Runway Operations
- GPI-15 Matching Operating Capacity between Instrument Met Conditions (IMC) and Visual Met Conditions (VMC)
- GPI-16 Decision support systems and alerting systems
- GPI-17 Data Link Applications (uplink & downlink, ADS)
- GPI-19 Meteorological Systems (Global OPMET) to support seamless Global ATM
- GPI-22 Communications infrastructure (atmospheric effects)
- GPI-23 Aeronautical radio spectrum (data link capacity requirements)

The Global Plan draws its content from regional initiatives, which in turn feeds-back into those regional initiatives to achieve harmonisation between them [ICAO, 2008]. Two major regional initiatives that appear to be represented in this plan are the European Union SESAR[1] and the USA NextGen[2] programmes for the refactoring of airspace management. Each of these initiatives aims to address the concept of operations [ICAO, 2005] for a future air navigation system, which includes:

- Airspace organization and management;
- Demand and capacity balancing;
- Aerodrome operations;
- Traffic synchronization;
- Conflict management;
- Airspace user operations;
- ATM service delivery management.

The two major programmes SESAR and NextGen approach their development plan from different perspectives. The US national airspace is homogeneous and is used by freight and passenger aircraft, business jets and general aviation. The infrastructure to service this usage has built-up over a period of time thus there exists range of systems and processes. Ultimately the national airspace is managed by a single authority, the Federal Aviation Administration. By contrast Europe’s airspace is managed by its member states, twenty-seven nation states within the European Union. European airspace management involves up to *49 National Air Traffic Control Centres using 22 different operating systems [EC, 2000]*. European air space follows national borders rather than air traffic flows and is also fragmented between restricted and non-restricted areas according to the responsibilities and liabilities of sovereign states. Air traffic in Europe is utilised mainly by freight and passenger aircraft. (In both cases, no consideration is given here for military requirements for air space.) The redevelopment of air navigation systems within these two domains thus presents different challenges. However, within the development frameworks of SESAR and NextGen a process to enable interoperability and harmonisation should arise if the performance based initiatives set out in the Global Air Navigation Plan and the subsequent environmental and economic benefits are to be achieved.

3. SINGLE EUROPEAN SKY ATM RESEARCH (SESAR)

The SESAR programme is the European Air Traffic Management (ATM) modernisation programme. It will combine technological, economic and regulatory aspects and will use the Single European Sky (SES) legislation to synchronise the plans and actions of the different stakeholders and federate resources for the development and implementation of the required improvements throughout Europe, in both airborne and ground systems [SESAR, 2007].

A fundamental component of SESAR is the concept of System Wide Information Management (SWIM), which aims to deliver aeronautical information to “any user, any time, any where” (the *Martini Principle*). Also, within the SWIM environment clients are not only consumers of data but may also be a producer of data. SWIM

---

[1] SESAR – Single European Sky ATM Research - https://www.atmmasterplan.eu/

[2] NextGen – Next Generation Air Transportation System - http://www.jpdo.gov/

aims to specify an "*information architecture that is open, flexible, modular and secure while being totally transparent to the users and user applications [Eurocontrol, 2007a]*" such that consumers and producers of aeronautical information are aware of each other. In order to progress toward this goal, SESAR will utilise a service-oriented architecture (SOA) to make accessible information relevant to aeronautical activities.

In essence, the service-oriented architecture comprises of a common communication channel to which clients and servers connect [Wiki, 2009]. A middleware function may mediate between the clients and servers. The middleware maybe configured to use the publish-and-subscribe pattern. This pattern allows clients to subscribe for certain information and is notified of or receives updates when these become available. Similarly, producers may publish their content such that clients can retrieve it as they require. Alternatively or in parallel, the middleware may have the capability to provide a request/reply service. In either case some process is required to enable clients to discover what information is available. Thus the middleware maybe composed of a network of information domain servers (IDS) and brokers. The IDS would maintain a catalogue of suppliers or pointers to approved or regulated data centres. So, for example, a client submits its information request to a broker. The broker references the IDS for the location of the required data; submits requests to the suppliers of the data; receives and collates the data; then returns it to the client in a format that meets the client's information request.

Figure 1 illustrates SESAR's logical architecture for its high level European ATM System [SESAR, 2007]. Within this logical architecture there is a supplier of weather (or meteo) information connected to the middleware (common communication) layer.

This middleware layer is likely to include a mechanism that will expose the services made available by the meteo server to all the other clients that are also connected to the layer, which could be facilitated by an information domain server. In addition, the middleware would require a standard interface to enable communication between connected systems, which could also be facilitated by intermediate brokers.

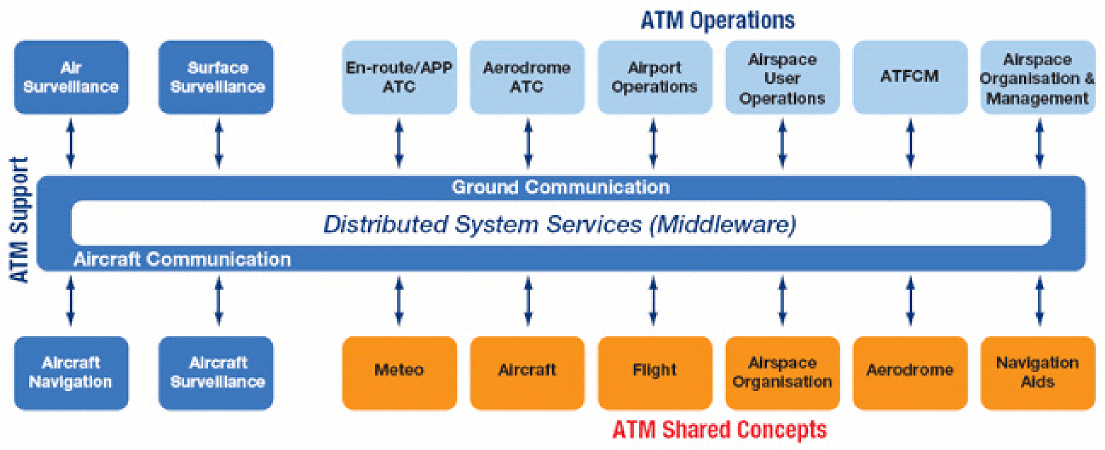


Figure 1 SESAR High-level European ATM System 2020 Logical Architecture [SESAR, 2007]

Within this high-level logical architecture, one use case could be for ATM Airport Operations' requirement for meteorological updates to import into its capacity demand forecast application. Another use case could be for an Aircraft's requirement for meteorological updates to import into its flight management systems to compute its time of arrival based on its current flight trajectory.

4. FLYSAFE

FLYSAFE is a consortium of thirty-six small and medium sized enterprises based within Europe. The project is part funded under the European Commission's 6th Framework for research and development. The project timeframe is four years; having started at February 2005, (EU-FLYSAFE, 2008).

The goal of the FLYSAFE project is to develop a Next Generation Integrated Surveillance System (NG-ISS) for the flight deck that will provide decision support to flight crew. The NG-ISS will consolidate information on the main hazards to the

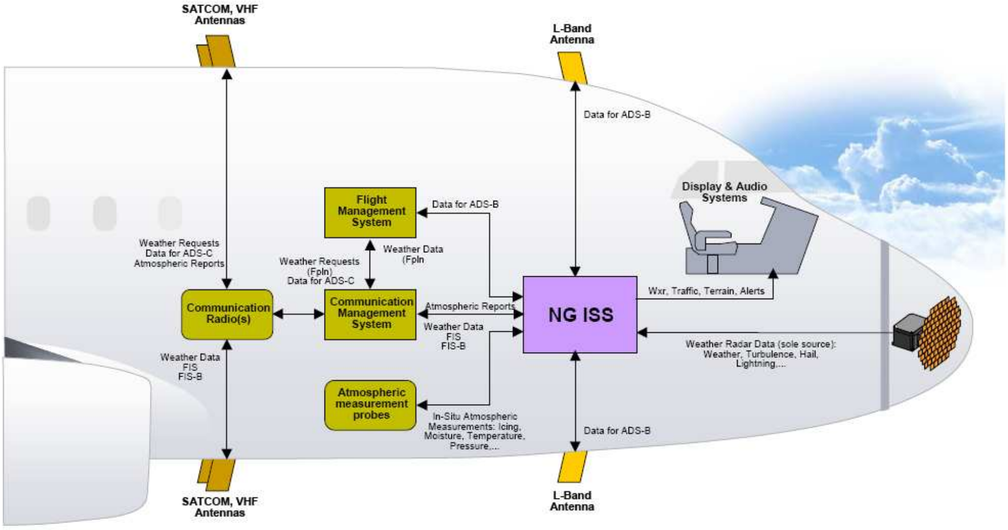


Figure 2 NG-ISS High-level Architecture [FLYSAFE, 2009]

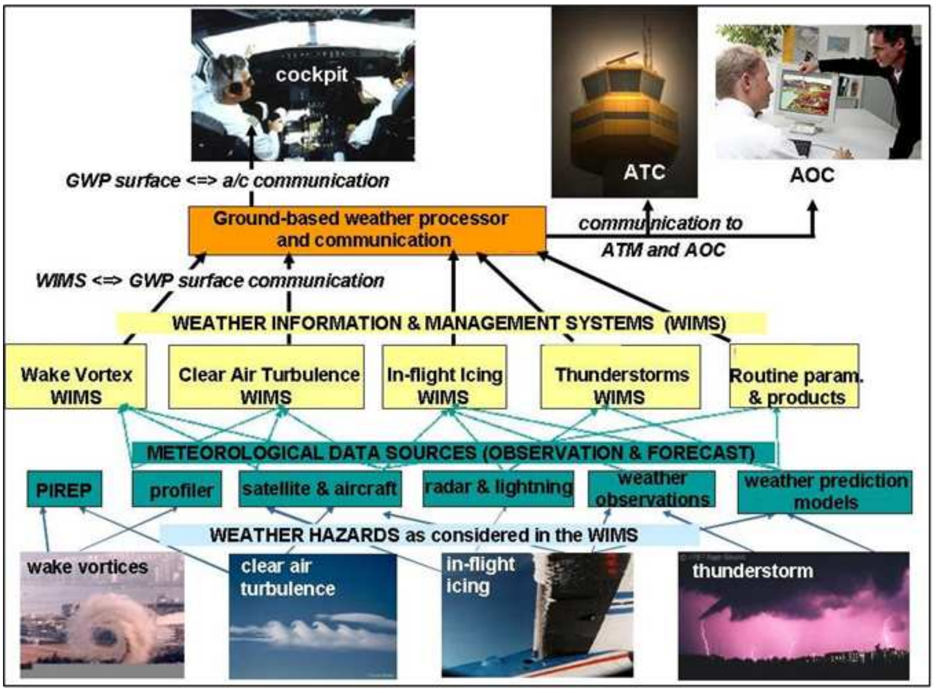


Figure 3 FLYSAFE's ground-based architecture comprising ground weather processors and weather information management systems [Gerz, 2006].

safe conduct of a flight: terrain, traffic and atmospheric conditions. The NG-ISS is complemented by a ground-based service that aims to provide tailored weather information on demand.

The NG-ISS, Figure 2, is the onboard component that comprises systems and functions that provide improved situation awareness, advanced warnings, prioritisation of alerts and an enhanced human-machine interface. Weather detection will use new sensors and data fusion techniques which, when coupled with weather information from the ground component, will present to the flight crew a consolidated picture of the adverse atmospheric conditions that the flight may encounter.

As noted, the NG-ISS is coupled to a ground-based service – the Ground Weather Processor. Figure 3 illustrates the components of the Ground based architecture. Each component is a node within the architecture. Point based observations are reported as measurements by a variety of sensing devices, which includes the aircraft. These are assimilated into numerical models of the atmosphere which generate fields (coverages) that forecast the future state of the atmosphere.

Weather Information Management Systems (WIMS) take as input these forecasts to generate forecasts of atmospheric hazards that effect aviation operations: wake vortices, clear air turbulence, icing and convective activity [Gerz, 2006]. The WIMS operate at specialist centres which maybe the National Meteorological Centre, a commercial operator or maybe an airport operations centre. A network of WIMS would generate forecasts for each of the atmospheric hazards at all spatial and temporal scales; ranging from low resolution, long range global forecasts; regional resolution, medium range forecasts to high resolution, local (TMA) nowcasts. It is anticipated that such spatial and temporal range will cover all phases of flight from planning, departure, en-route and arrival.

5. FLYSAFE – FLIGHT TEST ARCHITECTURE

The purpose of FLYSAFE's flight trials was to evaluate the onboard data fusion between weather radar data and forecast convective activity; and to evaluate the data link capacity between the aircraft and the ground weather processor. In this section the flight test architecture is described from its original high level concept to an instance of its implementation.

Figure 4 [Mirza, 2008a] illustrates the components of FLYSAFE's High Level Architecture as conceived in 2006, which maps closely to those featured in Figure 3. The airborne components are in the upper blue ellipse and the ground components in the lower brown ellipse. Components were included in the ground system to address the requirement for the customisation of the weather information by aircraft type (lower blue boxes); and to provide access to the same weather information to ATC/ATM (orange box). The lower brown rectangle represents a single interface to the ground component. During the course of the intervening two years (2006 – 2008) various constraints have resulted in the development of those components not shaded grey.

This reduced development does not diminish the overall concept or the validation of FLYSAFE's vision. At the ground, the *aircraft-obs* handler is represented today by its current incarnation of the WMO AMDAR program, for which a data-flow and data-link solution exists. FLYSAFE was not in a position to validate the ground component to broadcast weather hazards. The *Pilot* was replaced by a *Flight Test Engineer*. The planned flight trials would involve only one aircraft type therefore customisation of weather information by aircraft type was not developed. For the flight trials there was no direct involvement with *ATC/ATM*, apart from current standard procedures. A component of the *Wake Vortex WIMS* was evaluated for the Winter 2006/07 flight campaign at Frankfurt Airport as part of the DLR project Wirbelschleppe[3] and the EC project CREDOS[4].

---

[3] Wirbelschleppe – Wake Vortex – Weather and Flying http://www.pa.op.dlr.de/wirbelschleppe/

[4] CREDOS - Crosswind - Reduced Separations for Departure Operations http://www.eurocontrol.be/eec/credos/public/subsite_homepage/homepage.html

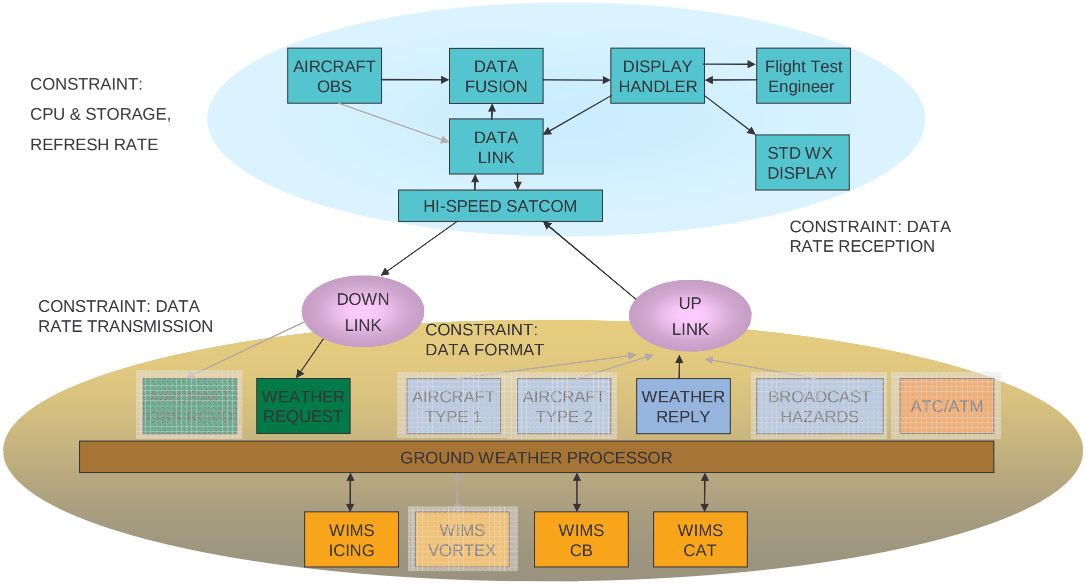


Figure 4 FLYSAFE High Level Architecture [Mirza, 2008a]

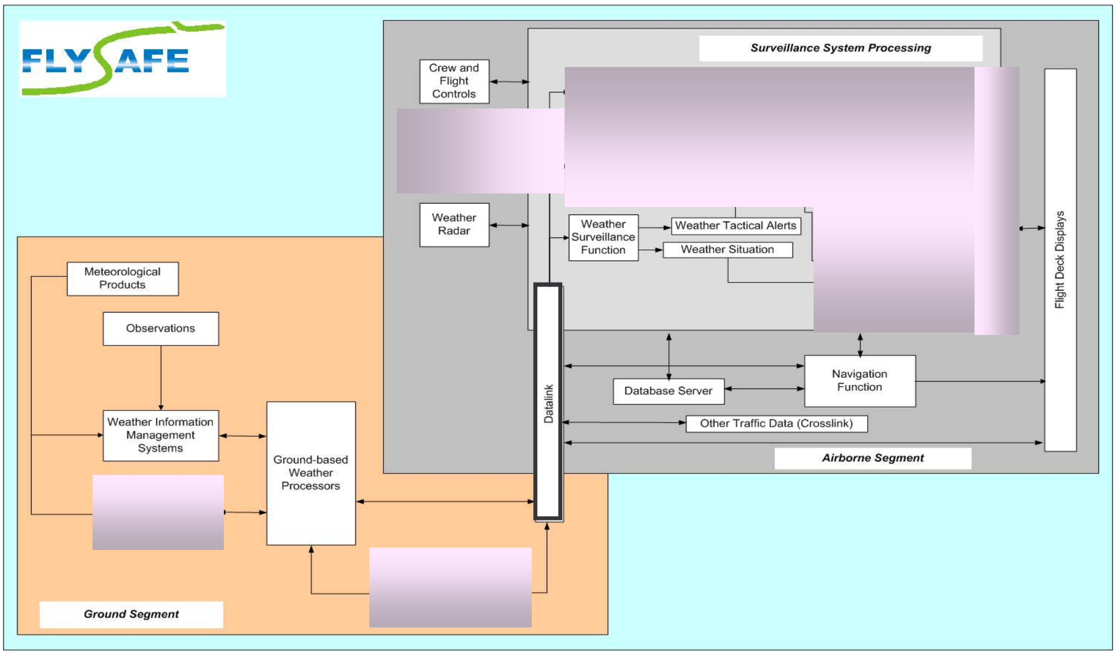


Figure 5 FLYSAFE's Architecture used during Flight Tests [EUROCAE, 2008]

Figure 5 illustrates in more detail the components used during the flight trials. The shaded components were excluded from the flight trials [EUROCAE, 2008].

Within the ground segment, a ground weather processor was installed at Météo France. The weather information management systems were operated from several centres depending on the data's scale and refresh rates. For CAT forecasts – the Met Office provided global scale and Météo

France the regional scale; for ICE forecasts – the Met Office provided the global scale; University of Hanover the regional scale and Meteo France the local scale. For CB Activity – DLR and Météo France provided the regional scale; and Météo France provided the local scale. For the flight trials it was deemed unnecessary to include current routine weather information, volcanic ash or tropical cyclone, as these would be provided through existing channels. Whilst an interface was developed to view the contents of the Ground-based weather and was available for use; however, with respect to access the same weather information there was no participation from ATC.

For the airborne segment only those components required for testing the data fusion and the data link were installed onto the test aircraft: new weather radar and weather fusion components developed by Rockwell-Collins (France); a weather database and display component (Figure 8) developed by GTD (Spain). These drew information from the existing aircraft avionics for flight control and navigation. The output from the weather radar and from the weather data fusion was sent to the Flight Technicians Console.

The data link connection between the ground and airborne components was established using a communication service provider (CSP) for Inmarsat. To enable a seamless connection between the NG-ISS and the GWP, using the HTTPS internet protocol across the satellite data link, SaNTA network components were installed at key points on the end-to-end path. SaNTA implements a new protocol stack, mainly replacing TCP by a proprietary transport protocol suited for the satellite link, which speeds up SATCOM transmission. SaNTA is a development by Skysoft (Portugal). A client-side request/reply manager, also developed by Skysoft, was used to access the Ground Weather Processor (GWP).

For this instance, the GWP is a geo-spatial database (PostGIS) configured to operate using OGC Web Feature Services and was installed at Météo France (Toulouse). A server-side request/reply manager, developed by Meteo France, was used to manage access to the GWP.

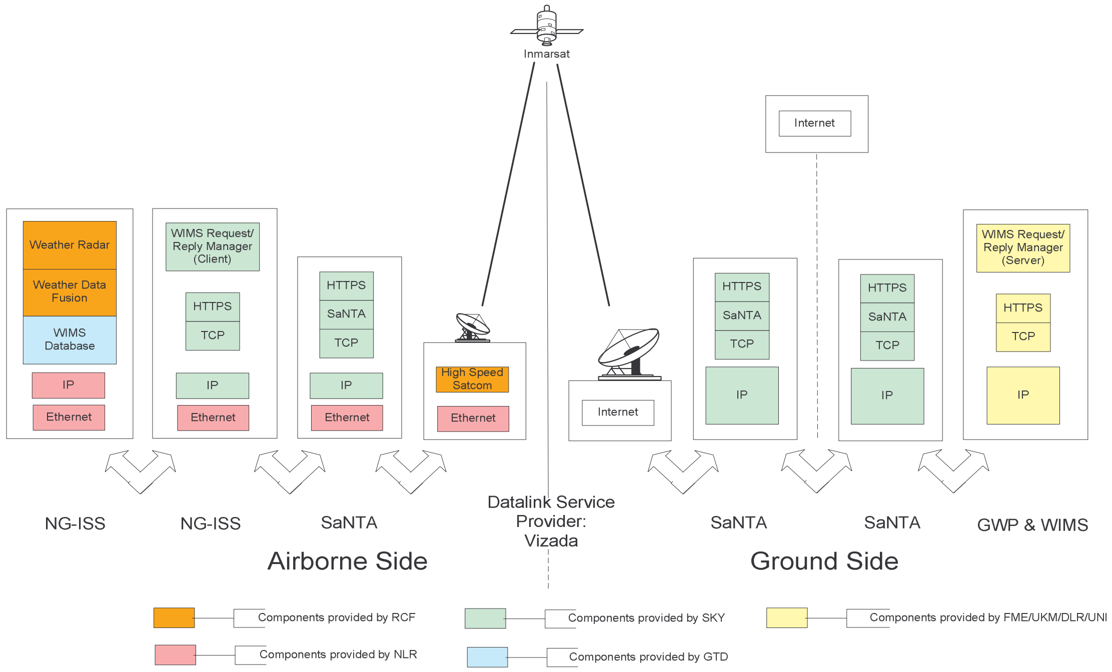
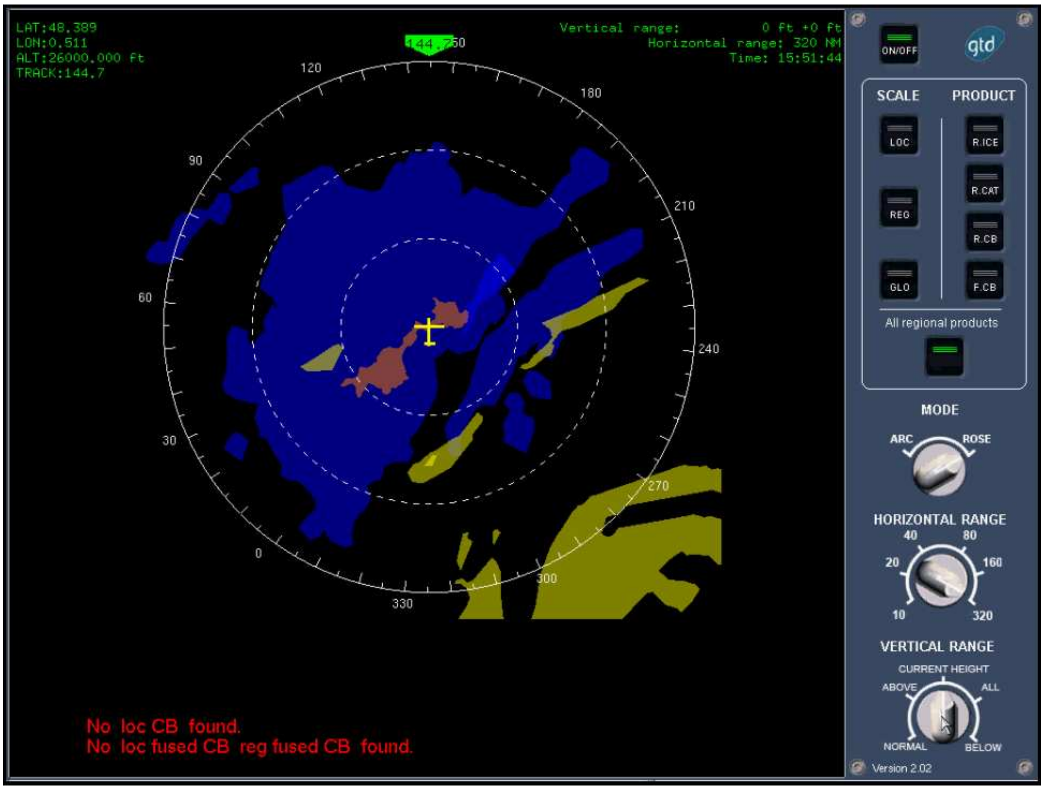


Figure 6 FLYSAFE Data Link Solution for Flight Test [Mirza, 2008a].

Figure 7 NLR's Swearingen Metro II aircraft, a twin turboprop modified for aerospace research. (Image provided by NLR.)



LAT:48.389
LON:0.511
ALT:26000.000 ft
TRACK:144.7

Vertical range: 0 ft +0 ft
Horizontal range: 320 NM
Time: 15:51:44

No loc CB found.
No loc fused CB reg fused CB found.

Figure 8 Weather Situation Awareness Display On-board for WIMS data up-linked from GWP (Image provided by GTD, © FLYSAFE/GTD 2008, used with permission.)

Figure 6 illustrates the key points: between the NG-ISS and the satcom modem; between the CSP and the internet; and between the internet and the GWP [Mirza, 2008a].

The infrastructure described was put in place for a flight trial that took place between 8th August and 12th September, 2008. The airborne components were installed on a Swearingen Metro II aircraft operated by Netherlands Aerospace Research

Centre (NLR) (Figure 7). Teams from NLR, Rockwell-Collins, GTD and SkySoft performed the installation and provided support during this period. The WIMS were operated and supported at their resident locations: DLR – Oberpfaffenhofen, University of Hanover, Météo France – Toulouse and the Met Office - Exeter. Each WIMS provider sent weather objects [Mirza, 2008b], using http web protocols, to the GWP at Météo France.

There were 21 flights accumulating 43 flight hours. The flights took routes across Europe: Spain, France, Netherlands, Germany and the North Sea or locations where thunderstorm activity was forecast.

Figure 8 is a graphical display developed by GTD that shows the forecast weather situation with respect to the current position of the aircraft, and for the current flight level. This display system was used during the flight trials.

The display system shows the spatial extent of forecast convective activity near the aircraft (brown/orange), icing potential (blue) area surrounding the aircraft and probability of clear air turbulence (yellow/green) bearing 290° at 300nm.

6. DIGITAL AIM

The Digital AIM (D-AIM) [LVF, 2007] project is a joint development effort between Eurocontrol and the Swedish Air Navigation Service Provider – LVF. The objective of the D-AIM project is to create a test bed for the shared access to aeronautical information. However, it is not just access that is being developed but also standardised formats and interfaces for the exchange of data obtained from multiple sources. D-AIM is described to be a one-stop shop for aeronautical and meteorological data that is relevant to a client's requirements. The intent is to build a test-bed implementation using a service-oriented architecture (Figure 10).

On November 27th 2008, the D-AIM project conducted a live flight trial using the test-bed architecture [LVF, 2008]. The scope of the trial was limited to a thirty-minute flight in and around the Ostgota terminal area. The airborne components were a Beech B200 aircraft equipped with a NavAero Electronic Flight Bag; the data link service was VDL Mode 4; the ground components were a D-AIM Server, using a Web Feature Service (WFS) for its client interface and an Oracle Database to store messages. The message database contained METARs and SIGMETs, as well NOTAM messages for runway, taxi-way and airspace status (Figure 9).

Placing the role of the D-AIM server within the context of SESAR's high level architecture, it appears that the D-AIM server takes the role of the broker between the data consumer (client) and the data producer (server). In addition, it also acts as an information domain server that catalogues or points to the available aeronautical and meteorological providers. The client submits their request to the D-AIM broker, which either retrieves the latest information from its own data store or from its various suppliers. The D-AIM broker then sorts, filters and packages the data so that the user receives only the information requested and in the required format.

7. MET DATA FUSION DEMONSTRATOR ENVIRONMENT

The MET Data Fusion Demonstrator Environment is a proof-of-concept project under the management of Eurocontrol [Eurocontrol, 2008a, 2008b; ERDAS, 2008], the development phase occurs between November 2008 and February 2009. For the remaining period of 2009 (March – December) the demonstration environment will be used to show that meteorological data for aviation applications could be exchanged using WXXM. The server will be built using OGC Web Service components and versions 1.0.1 of the WXCM, WXXM and WXXS developments [Eurocontrol, 2007b].

The goal of this proof-of-concept is to demonstrate that the current capabilities of national meteorological and hydrological services can be made accessible to the European air transport system. Thus interested stakeholders and members of the SESAR consortium will be able to access the server accordingly. This demonstrator may also afford the opportunity for stakeholders within the European air transport system to benefit from services and products that go beyond the current ICAO Annex 3 requirements.

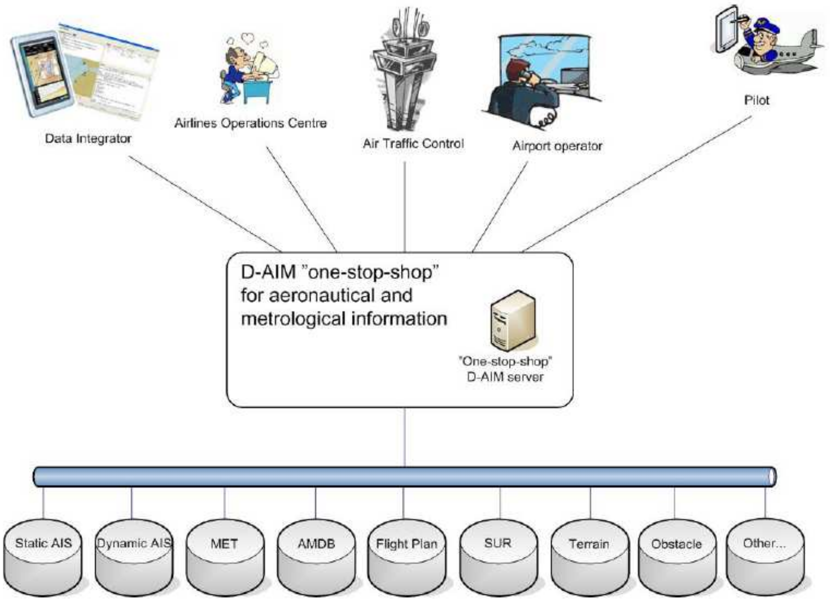


Figure 10 D-AIM “One-stop shop” for Aeronautical Information [LVF, 2007]

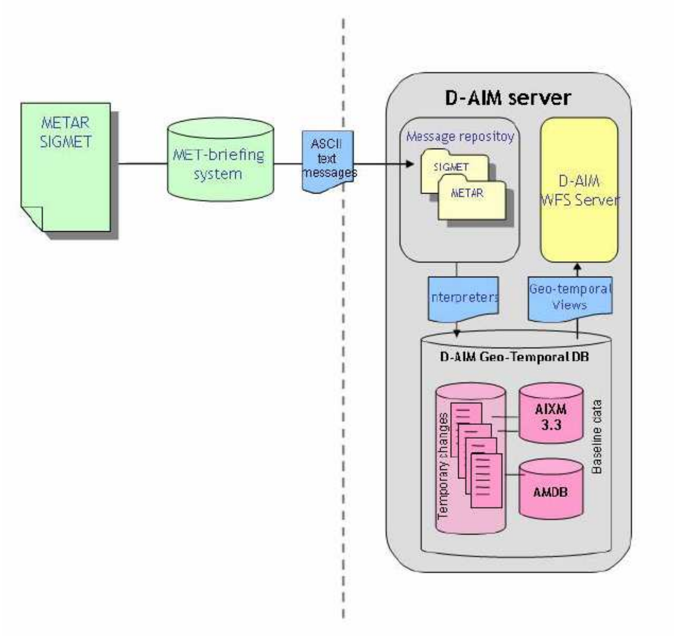


Figure 9 D-AIM Data sources and file format of meteorological information [LVF, 2008]

A key requirement for this development will be access to high quality meteorological data that is currently not used by or is unknown to stakeholders within the ATM community. Within this demonstrator environment the aim is to convert and expose traditional data formats from several sources such as ECMWF, and newer data formats such as GML Weather Objects.

8. MET OFFICE SERVICES

The Met Office[5] is developing its portfolio of services for aviation customers. Some of these are described briefly within the context of air transport management development.

- From Horace and Nimbus to SWIFT

Horace and Nimbus are systems used at the Met Office, its frontline stations and at a number customer sites. These systems are used to visualise all types of meteorological data from around the world, allowing forecasters to easily create text and graphical products for dissemination to customers. The first applications of these systems have been in use operationally in the Met Office since the early 1990s. An internal development programme is now ongoing to update this forecast facility.

Strategic Weather Information Forecasting Tool or SWIFT is the internal name of the new forecaster workstation solution and the name of the project to introduce it. The solution consists of hardware, software, supporting infrastructure and service definitions. The project will replace both the NIMBUS and HORACE systems with a unified system for all forecasting and observing staff. The Met Office is working with its chosen supplier IBL to customise an off-the-shelf product called Visual Weather; which is a database oriented GIS package developed for meteorological applications. Part of the SWIFT development programme is the automated production of significant weather charts.

The goals for the automation of significant weather charts is to improve the general science that will underpin the automation process; and to reduce the time that it takes to produce the charts, this will be done by developing new algorithms to automate production of weather objects for CAT, Jets, Cb and any other meteorological feature that could be beneficial. These weather objects are stored in the Visual Weather's database and can retrieved at the time the significant weather chart is created.

The benefits of this development programme are to reduce forecaster time spent on product generation and to allow more time for quality control; an additional benefit foreseen relates to health and safety of the forecasters by reducing their risk to repetitive strain injuries.

- Continuous Descent Approach

The Met Office is working with the Swedish aviation company Avtech to provide accurate meteorological data for an area around Stockholm's Arlanda [Aviation Week, 2008] airport to assist with continuous descent approaches.

For many approaches into busy airports, stepwise descent profiles are standard practice). For approaches into particularly busy airports such as Heathrow in England, it is very common for aircraft to join "stacks" in which there are alternating phases of level and descending flight. However, it is recognised that continuous descent approaches allow considerable fuel savings with associated reductions in CO2 emissions (Figure 11). In addition the noise footprint is considerably reduced and the chances of encountering a wake vortex from another approaching aircraft are reduced [Gill, 2008].

The meteorological data is from the Met Office's nowcasting tool WAFTAGE - Winds Analysed and Forecast for Tactical Aircraft Guidance over Europe, which can provide short period forecasts of wind and temperature, up to 8 hours ahead. WAFTAGE ingests measurements of wind and temperature, in this case from AMDAR equipped aircraft. In addition to generating forecasts, the work described includes verifying the forecasts against later AMDAR reports. For a full description see [Gill, 2008].

For one week during September 2008 and for one week during November 2008 WAFTAGE forecasts were provided to AVTECH for assimilation into their 4D trajectory management tool. WAFTAGE was scheduled to run approximately 15 minutes before the scheduled hour, assimilating AMDAR observations received during the preceding 45 minutes to update fields retrieved from the latest output from Met Office Mesoscale forecast model.

---

[5] Met Office – http://www.metoffice.gov.uk

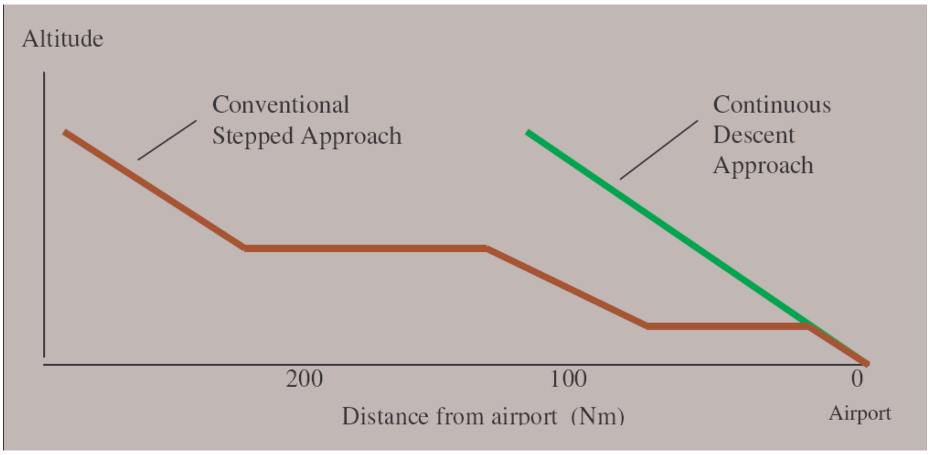


Figure 11 Flight path for stepped and continuous approaches, [Gill, 2008].

The nowcast contained the horizontal vector wind components and atmospheric temperature, for 45 levels from the surface up to around FL100. The data grid points were contained within an inverted conic-shaped toroid centred on the airport with a maximum radius of about 160 NM. The nowcasts were generated hourly with twenty-minute time steps, out to 80 minutes.

The Nowcast data was retrieved by Avtech for use in their 4-D trajectory tool, which computed the optimum continuous descent path such that the aircraft would touch down at its required time of arrival.

Continuous descent approach with a required time arrival affords better management of airport resources ensuring required services: refuelling, baggage handling, and catering and cleaning facilities, are available. In addition the environmental benefits are reduced fuel burn and emission, reduced effects from noise and local air quality.

- De-icing and Open Runway

The Met Office has developed a number of value-added services to assist with decision making processes of airline and airport operators. Two services are described: De-icing and Open Runway.

The Open Runway service is accessible from the Met Office website. The service provides an at-a-glance summary of a 36-hour weather forecast for a chosen airport. The summary information contains:

- Colour-coded hourly summaries of the runway status
- Forecasts of winter hazards: snow, frost, freezing fog and ground ice
- Forecasts of summer hazards: rain, wind and thunderstorms
- Hourly forecast graphs of temperature and wind speeds, with actual conditions plotted from weather reports (METARs) or runway sensors

This information may be used to mitigate any disruptions impacting on ground operations and to ensure the safety of aircraft and passengers in the event of adverse weather.

The De-icing service is also accessible from the Met Office website. This service offers forecasts of aircraft icing conditions at airports. This service is aimed at airline operators to use as a decision aide. The service provides a forecast of holdover times and includes proactive alerts to ground staff to enable the logistic planning to ensure that de-icing resources and crew are available at the time, the location and for the duration required.
These services provide benefits for not only the efficient and effective management of air transportation, e.g., maintaining runway capacity, but also for environmental benefits, e.g., reduced

chemical waste, and reduced fuel burn by aircraft not having to be diverted due to runway or airport closures.

9. DISCUSSION

It is unlikely that any one development will retain its current form in the long term but instead each will evolve alongside the user requirements. However, at a higher level of abstraction it is possible to draw these threads of activity together within the context of a system wide information management domain.

Currently the Met Office provides its value-added services from its own web-site. In addition, weather-object data for the automated production of significant weather charts is held within a dedicated database. FLYSAFE have suggested a weather-object data distribution architecture using data stores at airports for local scale nowcasts and a central (or regional) data store to contain global and regional scale forecasts. These same services and weather-object data could be made more accessible if they were exposed to a service-oriented architecture based around web-services. An information domain server, such as that developed by D-AIM or Eurocontrol could be used to point to these sources. Then it is conceivable that an aeronautical service provider, Avtech, would need only to connect to a data broker, e.g., D-AIM, to retrieve or discover data they require to compute continuous descent flight paths. Alternatively, the flight crew of an aircraft and an ATC operator could retrieve the same data so that they may agree on a projected flight path. Taken to an extreme conceptual level such interactions could take place automatically with little or no human intervention. Such integrated automation may realise the goal of a common situation awareness thus affording more time for users to engage in collaborative decision making and to monitor data quality rather than data production.

10. CONCLUSION

This paper has described a number of initiatives and services that are taking place within Europe. These occur at various scales of granularity from the larger grains of ICAO's Global Plan Initiative and the European SESAR project, to the medium sized grains of FLYSAFE, D-AIM and the Met Data Fusion Demonstration Environment, and to the smaller sized grains represented by the Met Office's developments and services. Finally these threads of development are drawn to a slightly higher level of abstraction to highlight how they could exist within a system-wide information management domain.

11. ACKNOWLEDGEMENTS

FLYSAFE development work is part funded by the European Commission, EU Research 6th Framework, EC contract AIP4-CT-2005-516167.

Contributions to this paper were kindly provided by the following teams:

Met Office:
Bob Lunnon, Philip Gill, Lauren Reid,
Debi Turp

Météo France:
Patrick Josse, Agathe Drouin,
Sébastien Geindre, (Christian Pagé)

DLR:
Thomas Gerz, Arnold Tafferner,
Carline Forster

University of Hanover:
Thomas Hauf, Jakob Tendal, Michael Theusner,
(Sonja Jirsch (DWD))

NLR:
Wilfred Rouwhorst, Con Kranenburg,
Adri Marsman, Marcel Verbeek

Rockwell-Collins (Toulouse):
Frédérique Azum, Olivier Perrier,
(Marianne Ricart)

GTD:
Florent Birling, Joan Roig

Skysoft:
José Freitas, André Rosado

12. REFERENCES

ACARE, 2001: *Vision 2020*, January 2001

ACARE, 2008: *Addendum to the Strategic Research Agenda*, ACARE, November.

Aviation Week, 2008: *2020 ATM Today*, Aviation Week & Space Technology, April 28.

EC, 2000: *Aeronautics for Europe A Position Paper produced by the External Advisory Group for Aeronautics Recommendations to the European Commission*, EUR 19318, April.

ERDAS, 2008: Mondon, E*., Case studies on cataloguing and serving meteorological metadata and data using OGC/ISO standards*, Workshop on the use of GIS/OGC Standards in Meteorology, Presentations, ECMWF, November.

EUROCAE/RTCA, 2008: *Operational Services and Environment Definition (OSED) for Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Services*,

Eurocontrol, 2007a: *D1-1 Basic Principles of Information Management, SWIM Common Services Study by Joint FAA/Eurocontrol Working Group*, Eurocontrol, Brussels, April.

Eurocontrol, 2007b: *WXCM Primer v1.0*, Eurocontrol, July.

Eurocontrol, 2008a: Hodgson, D., *Meteo Information in an ATM SWIM Environment*, Workshop on the use of GIS/OGC Standards in Meteorology, Presentations, ECMWF, November.

Eurocontrol, 2008b: *personal communication with Dennis Hart*, November.

FAA, 2007: *Report of the Weather-ATM Integration Working Group*, October.

FLYSAFE, 2009: *FLYSAFE - http://www.eu-flysafe.org/EU-Flysafe_Public/Project.html*, last accessed 6th January.

Gerz, T., *et al*, 2006: *Improved Weather Information for Cockpit and Tower*, 25th International Congress of the Aeronautical Sciences.

Gill, P., *et al*, 2008: *Wind Nowcasting to Support Continuous Descent Approaches*, 88th Annual Meeting, American Meteorological Society.

ICAO, 2007: *Global Air Navigation Plan, 3rd Edition,* D-9750, ICAO, Montreal.

ICAO, 2005: *Global Air Traffic Management Operational Concept, 1st Edition*, Doc-9854, ICAO, Montreal.

ICAO, 2008: *SWIM/AIM and Global ATM*, ICAO Journal, V 63, No 2, ICAO, Montreal

JPDO, 2008: *Next Generation Air Transport System: Integrated Work Plan: A Functional Outline v1.0*, Joint Planning and Development Office, September..

LVF, 2007: *Deliverable 2 – D-AIM Architecture Description v01*, 2006-37208, LVF

LVF, 2008: *Deliverable 4.2 - D-AIM Airborne and Ground System Implementation Description v02*, 2006-00979, LVF.

Markovic, D, *et al*: *A Statistical Study of the Weather Impact on Punctuality at Frankfurt Airport*, Meteorological Applications, 15: 293–303 (2008)

Mirza, A, 2008a: *FLYSAFE Presentation to RTCA SC-206/EUROCAE WG-76*, NAV Portugal, Lisbon, 10th December.

Mirza, A, *et al*, 2008b: *FLYSAFE - An Approach to Flight Safety - Using GML/XML Objects to Define Hazardous Volumes Space for Aviation*, 88th Annual Meeting, American Meteorological Society

SESAR, 2007: *The ATM Target Concept, Deliverable 3, SESAR Definition Phase*, DLM-0612-001-02-00, SESAR Consortium, September

SESAR, 2008: *The ATM Target Concept, Deliverable 5, SESAR Definition Phase*, DLM-0710-001-02-00, SESAR Consortium, April.

Weber, M, *et al*, 2007: *Air Traffic Management Decision Support during Convective Weather*. V 16, No 2, Lincoln Laboratory Journal

Wiki, 2009: *Service Oriented Architecture*, http://en.wikipedia.org/wiki/Service-oriented_architecture , last accessed 6th January