Met Office

The development of GML weather objects for use in decision aid technologies, with particular application to aviation activities.

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Andrew K. Mirza

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Amendments

2016-11-10	Updated image credits. Corrections to compass directions in section 13.

Abstract

Geospatial enabled systems are becoming more widespread in their application, from simple portrayal of geographic and demographic data to route planning and tracking of assets. The facility to visually inspect spatially varying data from different sources is an invaluable aide to establishment of relationships between the data sources. The revelation of such relationships helps inform decision makers and planners for the allocation of budgets, resources, propositions for new business enterprises, technologies or applications.

In this paper, an account of the FLYSAFE project is given with particular emphasis on the development of GML Weather Objects to aid flight crew decision making with respect to the safe conduct of a flight. This paper also describes briefly the ground-based web service architecture and the data model used to exchange weather information with an airborne system in support of flight trials.

Flight trials were undertaken to demonstrate how weather objects could be integrated into flight deck avionics and how the same weather objects could be accessible to ground-users.

These developments are placed into the context of a net-centric information environment as envisioned by the regional projects SESAR and NEXTGEN, with a discussion for how GML Weather Objects could be integrated into Air Traffic Management systems to aid decision making processes.

1. INTRODUCTION

In this paper, an account of the FLYSAFE project is given with particular emphasis on the development of the GML Weather Objects for use in geospatial systems. This paper also describes the ground based web service architecture and data exchange model used during FLYSAFE's flight trials.

The flight trials were undertaken to demonstrate how weather objects could be integrated into flight deck avionics and how the same weather objects are accessible to ground-based users. The details of the flight trials are described briefly and are covered in more detail in Verbeek et al (2009).

The main developments from FLYSAFE are placed into the context of a net-centric information environment as envisioned by the regional projects SESAR and NextGen. The paper gives an outline account of how weather objects are used for conflict detection with an aircraft; and concludes with a suggestion for how the same weather objects could be integrated into Air Traffic Management systems to aid decision making processes.

This paper also highlights issues and subjects for further discussion that will affect the drive toward automation within air traffic management and the role change of ATC operators from being "in the decision loop" to "monitoring the decision loop."

2. GEOSPATIAL ANALYSIS

Geospatial enabled systems are becoming more widespread in their applications, for example, route-based navigation (sat-nav) for road and sea transport; exploration of the environment for natural resources or for leisure activities; monitoring patterns of wildlife migration; mobile telephony tracking and asset tracking.

It is the revelation of relationships between the data sources that helps inform decision makers, investigators and planners; whether this is within an operational environment, where minute by minute decisions may affect safety of human life or within a long-term context where environmental impacts must be considered. Once relationships are known and their impacts are understood then decision makers and planners can allocate budgets and resources to meet the anticipated needs.

However, geospatial analysis is not a new technique; the classic example of such analysis is John Snow's investigations into the cholera outbreak, London, 1854. Snow's later analysis of this outbreak includes a street map on which he records the number of outbreaks; their spatial distribution and the positions of the water supply pumps. From the graphical analysis Snow was able to show that a likely source of the infection was a particular water pump situated in Broad Street. His evidence convinced the local authorities to implement measures to prevent further spread of the disease (Snow, 1854).

Advancements in computing technology and communications now make it possible for geospatial analysis to be available within an operational environment. For example, to assess the hazard of the accidental release of chemicals and its subsequent atmospheric dispersion toward a nearby population centre. The data for the hazardous chemicals, the current and forecast atmospheric state, the population and terrain when combined and displayed using a geospatial system provides the emergency services with invaluable information; permitting the safe deployment of resources, containment measures and treatments for the affected areas and population.

3. AVIATION ACTIVITIES

During the next twenty years, air passenger traffic is expected to double or triple levels recorded at year 2000 (ACARE, 2001; JPDO, 2008). As a consequence air traffic density will increase to meet this rising demand, especially along favoured optimal routes. This increase in air traffic density could lead to an increase in aircraft accidents if managed by the existing on-board and ground-based systems. (An air accident in this context is deemed to be any manoeuvre or encounter that would endanger the safe and efficient conduct of a flight from gate-to-gate.)

Air accidents are rare events but any increase in such incidents would be perceived as unacceptable by society. Thus new systems and solutions should aim to maintain the number of accidents at its current low level, at the same or smaller proportion of current air traffic movements (c2000). In the domain of accident investigations, adverse weather is seldom the exclusive cause but in the domain of daily operations it is a disruptive factor (FAA, 2007, CFMU, 2009).

4. WEATHER PHENOMENA

Weather phenomena that effect aviation operations can evolve at rapid rates; occur over a wide spatial extent, vary by intensity or severity; and persist for extended periods. The effects of such phenomena are numerous and may occur in isolation or as a combination creating a hazardous environment. The effects of such events may be short causing only minor delays or create a domino effect along the supply chain. For example, strong wind shear due to micro-bursts could endanger an aircraft whilst landing; atmospheric turbulence could cause personal injuries to flight crew and passengers; an approaching thunderstorm may cause air traffic to be re-routed or increase flight crew work load as they undertake more precise manoeuvres to navigate through the phenomena; persistence of low visibility conditions or the occurrence of snow may effect aviation commercial operations causing delays and diversions which result in passenger inconveniences; misplaced assets; increased costs; and extra demands on air traffic controllers as the effects on traffic flow are realised.

5. FLYSAFE’S VISION, SCOPE AND OBJECTIVES.

FLYSAFE comprised a consortium of thirty-six small and medium sized enterprises based within Europe. The consortium partners were drawn from industry, academia and government services. The project was part funded by the European Commission under the 6th Framework for research and development. The project time frame was about four years; having started in February 2005 and concluding in June 2009.

The project’s vision was to address the safety aspect of the “2020 Vision” for aviation as reported by the Advisory Council for Aeronautics Research in Europe (ACARE, 2001). In particular, safety of flight depends on actions of the flight crew which, in turn, depends on their situation awareness.

The goal of the FLYSAFE project was to develop systems and services to enhance the flight crew situation awareness through the development of an on-board innovative solution called the Next Generation Integrated Surveillance System (NG-ISS), which would be supported by a network of Ground Weather Processors (GWP) and Weather Information Management Systems (WIMS). These developments would address the three main hazards to the safe conduct of a flight – terrain, traffic and adverse weather conditions. FLYSAFE's consortium believed that developing an integrated solution would be a decisive step toward achieving flight safety as envisaged by ACARE's Vision 2020 (EU-FLYSAFE, 2009).

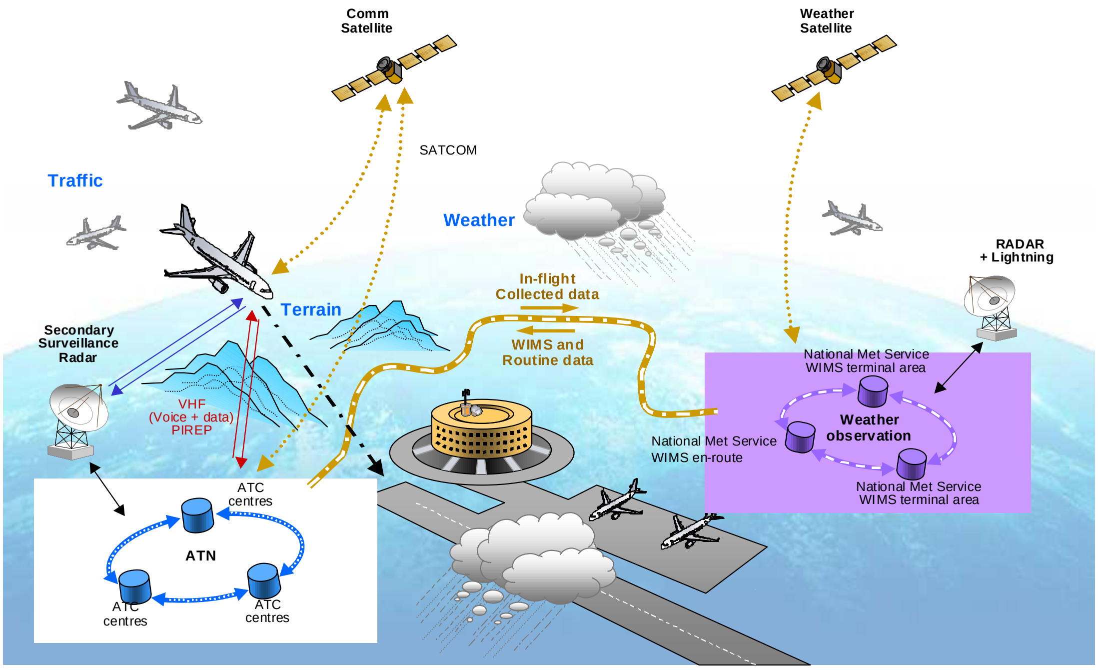

Figure 1: FLYSAFE's vision for an integrated framework of operation that conveys information on hazards to aviation users.
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To achieve this goal the FLYSAFE project was partitioned into four domains of activity, which defined the scope. The first three domains each address one of the main hazards: traffic, terrain and atmospheric hazards. The fourth domain was for the outcomes of the first three domains to be made into an integrated solution and to demonstrate a cohesive framework of operation.

Figure 1 illustrates the context for the FLYSAFE Project. Any airborne user equipped with an NG-ISS would "sense and detect" its environment with respect to nearby air traffic, terrain and atmospheric conditions. Additional information would be available from ground based services or exchanged with other airborne users; either being "pulled" or "pushed."

The information exchanged maybe positions of other airborne users not suitably equipped; instructions from air traffic control or airline operation centres; updated forecasts of weather information.

All sources of information are consolidated and assessed by the NG-ISS. Where a threat to the safe conduct of the flight is detected then this is brought to the attention of the flight crew.

6. GROUND WEATHER PROCESSORS.

FLYSAFE's domain for atmospheric hazards envisages a ground based network of weather processors. Each GWP node on the network would furnish on-demand weather information relating to icing, clear air turbulence, thunderstorms and atmospheric state parameters for in-situ computation of wake-vortex effects. In addition to these data and to maintain backwards compatibility, each GWP node would make available current products and formats as defined by ICAO Annex 3 (ICAO, 2007), e.g., METAR and TAF, and would include tropical cyclone reports and volcanic ash alerts. The latter, as with wake vortex, is not a meteorological phenomenon but an effect driven by meteorological conditions, and thus presents a hazard to air navigation.

7. WEATHER INFORMATION MANAGEMENT SYSTEMS.

Weather Information Service Providers would receive in-situ observations sent to the GWP for input into numerical weather prediction (NWP) systems; this would be in addition to other sources of data from national and international meteorological observing networks. Output from the NWP system would be post-processed by Weather Information Management Systems which are optimised for aviation forecasts. It is the output from the WIMS that is sent to the GWP. This concept of operation is illustrated in figure 2. Further details about the WIMS can be found in Gerz et al (2006) and Tafferner et al (2009).

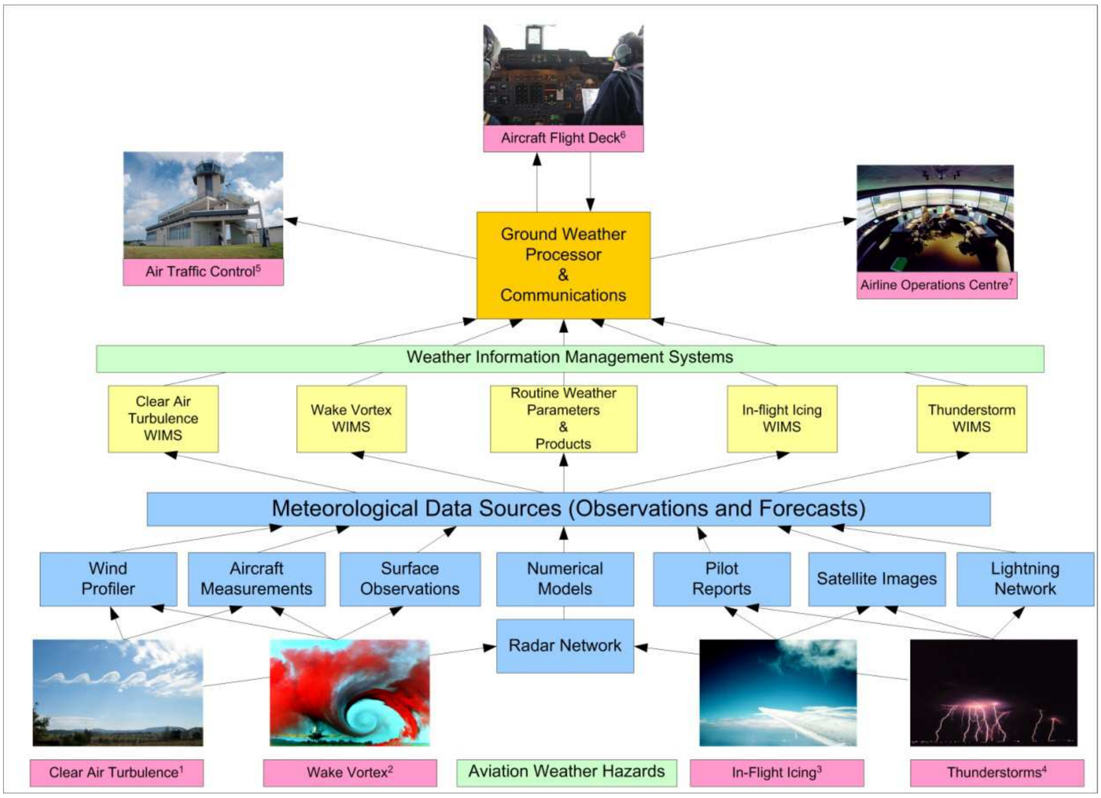

Figure 2: Dataflow FLYSAFE's ground-based architecture comprising ground weather processors and weather information management systems.

(Imagecredits: Clear Air Turbulence, courtesy of GRAHAMUK, 2006; Wake Vortex, Air Traffic Control, Airline Operations Centre courtesy of NASA; In-Flight Icing ©UCAR; Thunderstorms courtesy of NOAA; Aircraft Flight Deck ©Philip Gill, 2006, used with kind permission.)

8. WEATHER INFORMATION EXCHANGE.

To facilitate the exchange of weather information between the NG-ISS (airborne system) and the GWP (ground based system) a data exchange protocol was developed, which is referred to as the Meteorological Data Model (MEMO). This data model was developed for the specific instance of message exchange between prototype systems developed within the FLYSAFE project. The methodology used for MEMO's development is similar to that used for weather exchange conceptual model that emerged at a later date (Eurocontrol, 2007a).

Data exchange protocols already exist within the aviation industry, e.g., ACARS, and meteorological service providers, i.e., WMO's BUFR and GRIB (WMO, 2002). The aviation standard, ACARS, is character oriented and is designed for short text messages whereas the WMO formats are for binary data exchange that require look-up tables at the sender and receiver stations. It was found that neither protocol was suitable for use within FLYSAFE's concept of development; equally the trend within the aviation industry is to employ the use of eXtensible Mark-up Languages (XML).

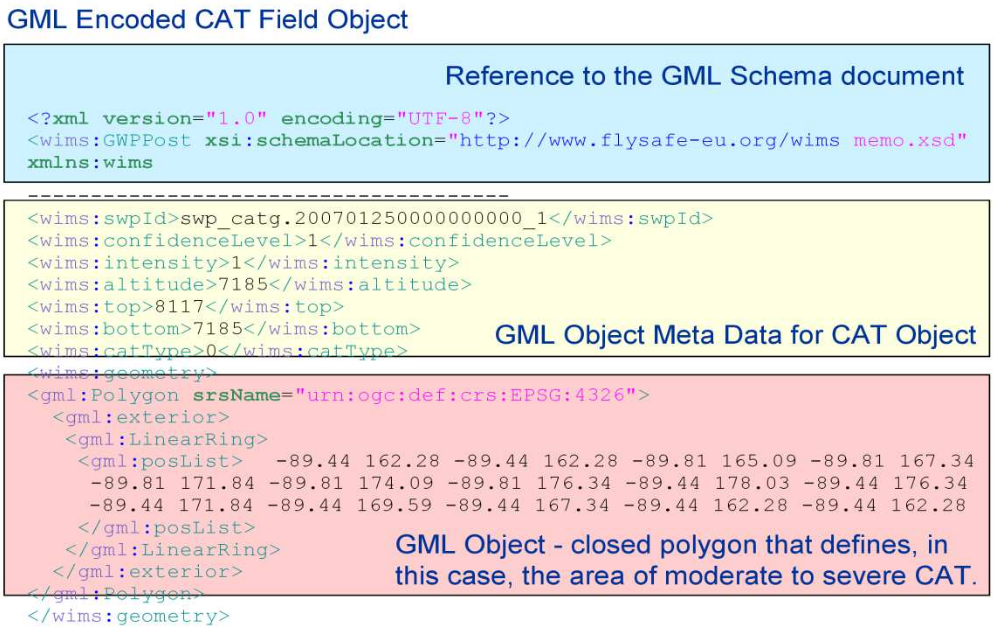

Figure 3: Weather Object expressed using Geospatial Markup Language (Mirza et al, 2008) © Crown Copyright, 2009, Image reproduced under Open Government Licence for Public Sector Information version 3 (http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/)

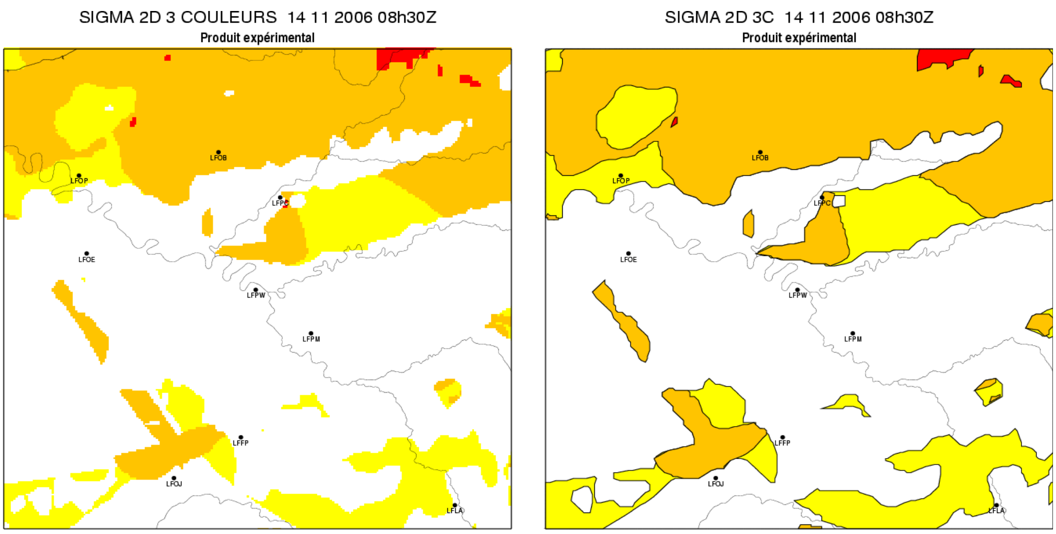

Figure 4: Gridded field for Icing potential (left) converted to corresponding Weather Objects (right), (Mirza et al, 2008).
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Figure 3 shows an example of a weather object expressed using the Geospatial Mark-up Language. The weather object is composed of sections for references to schemas, metadata relating to forecast of the weather object and a series of polygons with corresponding attributes.

Figure 4 shows an output from a meteorological model for potential icing. The image on the left is the original gridded field whereas the image on the right is composed of the corresponding weather objects. The colour coding is for light (yellow) moderate (orange) and severe (red) regions of potential icing.

9. GML WEATHER OBJECTS.

The chosen medium for the exchange of weather information within FLYSAFE is defined around the Geospatial Markup Language (GML), a specialised version of XML (OGC, 2008).

A conceptual weather object is a feature which defines a volume or region of space that presents a hazard to an airborne user. The volume or region is contained within a closed outer boundary, and which may also contain a closed inner boundary. Attributes assigned to the weather object describe its physical, spatial and temporal properties with respect to the hazard, along with its occurrence, duration, intensity or severity and metadata about the issuing meteorological authority. The methodology for the routine production of weather objects is described more fully in Mirza et al (2008).

10. FLYSAFE’S FLIGHT TRIALS.

Flight trials took place between 8th August and 12th September, 2008. A full description of this campaign is given by Verbeek et al (2009). This section provides an outline of the campaign.

The NG-ISS airborne components were installed on a Swearingen Metro II aircraft operated by NLR. Teams from NLR, Rockwell-Collins, GTD and SkySoft performed the installation and provided support during this period. The components were weather radar, for in-situ observations; satellite communications data link that enabled the use of TCP/IP protocols; a database system to store weather objects; a data fusion module to fuse in-situ and forecast data for convective activity; a geospatial display system to show the position of the aircraft relative to identified weather hazards.

The WIMS were operated and supported at their resident locations: DLR, Oberpfaffenhofen; University of Hanover; Meteo France, Toulouse and the Met Office, Exeter. The GWP was installed at Meteo France, Toulouse. Each WIMS provider sent weather objects, using http web protocols, for input to the GWP.

Duration of each flight was around 2-3 hours, with flight planning coordinated with the team at Meteo France, Toulouse. The flights took routes across Europe: Spain, France; the Netherlands, Germany and the North Sea or locations where thunderstorm activity was forecast. During the flights, requests were sent at regular time intervals, for a defined volume of space surrounding the current position of the aircraft (the flight corridor) for a given time horizon.

The GWP returned only those weather objects that intersected the volume of spaced defined for the time horizon (figure 5).

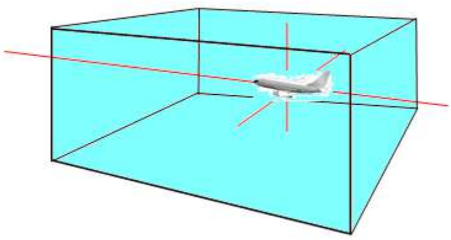

Figure 5: Illustration of the aircraft's flight corridor used to select Weather Objects from the GWP.) © Crown Copyright, 2008, Image reproduced under Open Government Licence for Public Sector Information version 3 (http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/)

11. INDUSTRY DEVELOPMENTS IN THE WIDER CONTEXT.

FLYSAFE's developments can be considered as a bottom-up approach to address the safety and efficiency requirements for a denser air traffic environment. There are two regional developments to reform air traffic management, which can be considered as the top-down approaches. Both are geared towards realising latent capacity that is believed to exist when more efficient methods are used to manage air traffic flow, whilst maintaining safe operations.

The European initiative is SESAR – the Single European Sky ATM Research (SESAR, 2007); the initiative in the United States is NextGen – the Next Generation Air Transport System (JPDO, 2008). Both programmes aim to combine technology, resources and regulation in such a way as to increase the efficiency and effectiveness of the respective air transport systems – not just at the regional level also at the international level.

The aims of the two programmes are similar but each has a solution that differs slightly in emphasis. In SESAR, the emphasis is on the concept of System Wide Information Management (SWIM) whereas in NextGen it is the concept of the 4-D Weather Cube. In both programmes automated 4-D trajectory management is considered key to realising the latent capacity.

The aim of SWIM is to specify an “information architecture that is open, flexible, modular and secure while being totally transparent to the users and user applications (Eurocontrol, 2007b)” 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. Collectively this architecture is referred to as net-centric.

The aim of the 4-D Weather Cube is to be a source of weather information stored within a virtual database accessible across the network via a single portal. A subset of the data held in the 4-DWx3 would be designated as the single authoritative source; it is this data that would be used for decisions to manage air traffic movements within the continental USA (NNEW, 2008).

Clearly for these two architectures to interact there must be agreement with respect to interoperability and data exchange formats. Figure 6 illustrates Eurocontrol’s vision for the harmonisation and interoperability in which aeronautical and meteorological data will be exchanged within the net-centric future of the aeronautical domain. This vision would be realised through agreed standards and recommended practices, in particular with a family of data models which can be expressed using GML; WXXM is the proposed standard for the exchange of meteorological data (Eurocontrol, 2007a).

The use of this family of data exchange schemas would afford the possibility to integrate spatially and temporally all data relevant to an individual flight - the so-called 4-D

Trajectory would take account of restrictions to airspace, availability of airport services; runway configurations, present and forecast weather situations.

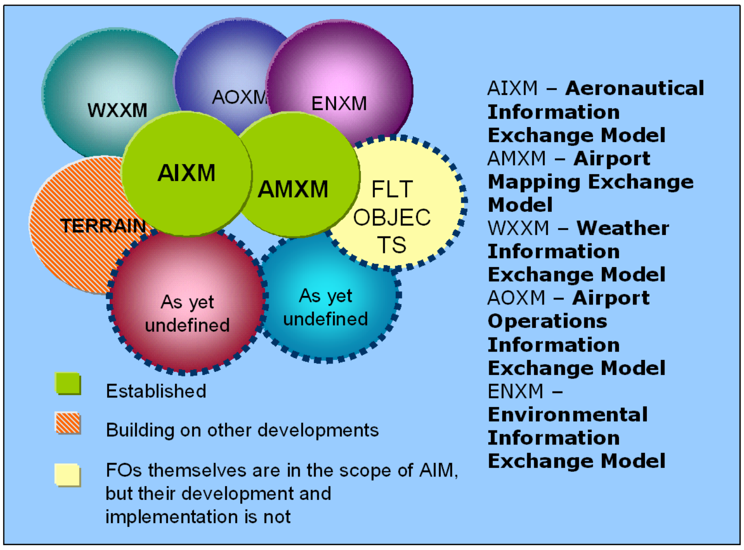

Figure 6: Eurocontrol's proposed family of interoperable models for data exchange within the aviation domain (Eurocontrol, 2006).

12. DISCUSSION: USING WEATHER OBJECTS IN FLIGHT MANAGEMENT DECISION MAKING

The following concepts of operation are based upon developments completed within the FLYSAFE project.

A major characteristic of weather information is that it is "fuzzy" due to the uncertainties relating to its dimensions: spatial and intensity distribution; temporal onset and duration; and probability of occurrence. Weather objects are irregular polygons that represent a meteorological hazard to aviation therefore must encapsulate these dimensional properties as metadata.

To a first order, simple weather objects are generated according to applied thresholds for intensity, the polygon represents the forecast spatial distribution; forecast onset and duration are expressed in terms of the validity period; probability of occurrence is represented by a simple confidence index based upon the availability of data sources used in the forecasting process; these are included as attributes to the object.

A team led jointly by GTD Sistemas de Información in Spain and GMV-Skysoft in Portugal (EU-FLYSAFE, 2008) developed a methodology to integrate weather objects returned by the Ground Weather Processor (GWP) within a strategic conflict detection algorithm. The algorithm takes into account the irregular shape and fuzzy properties of a weather object.

In developing the conflict detection algorithm the GTD-Skysoft team classify weather objects as either static or dynamic. This is to account for the observed properties of meteorological phenomena, and which simplifies the detection algorithm. A static weather object is one in which the rate of change of the phenomena is expected to be much less than the rate of change of the position of the aircraft or the range of the onboard weather radar. Examples of such phenomena are potential icing, a region of clear air turbulence and volcanic ash. A dynamic weather object is one in which the rate of change of the phenomena occurs rapidly or is of the same order of magnitude as the rate of change of the aircraft's position. Examples of such phenomena are wake vortices, thunderstorm cells and tropical cyclones.

The conflict detection algorithm (CDA) uses an approach that is similar to that used by the Ground Weather Processor. The GWP uses the geometric intersection in time and space of the weather object with the aircraft's defined weather corridor (fig 5). Similarly the CDA uses the intersection of the future position of the aircraft with a weather object. The aircraft is represented using a regular polygon. A conflict is detected when the aircraft object intersects with a weather object, which represents the hazardous area.

The CDA creates a time-series of aircraft objects, where each aircraft object has associated attributes for time and position, and attributes to represent a safety zone around the aircraft. When a collision is detected the position and time to intercept can be computed. The CDA then passes parameters to other sub-systems that would compute a safe trajectory around the weather object and the flight crew alerted using a display system which shows the aircraft in relation to the detected threat and its resolution.

Figure 7 illustrates the approach used by the CDA. The weather objects represent areas of potential icing (as in figure 4) which are considered to be static with respect to the aircraft's speed. The grid represents all the possible positions of the aircraft within the domain. The coloured squares represent the future and possible positions of the aircraft. The lines represent the trajectory of the aircraft.

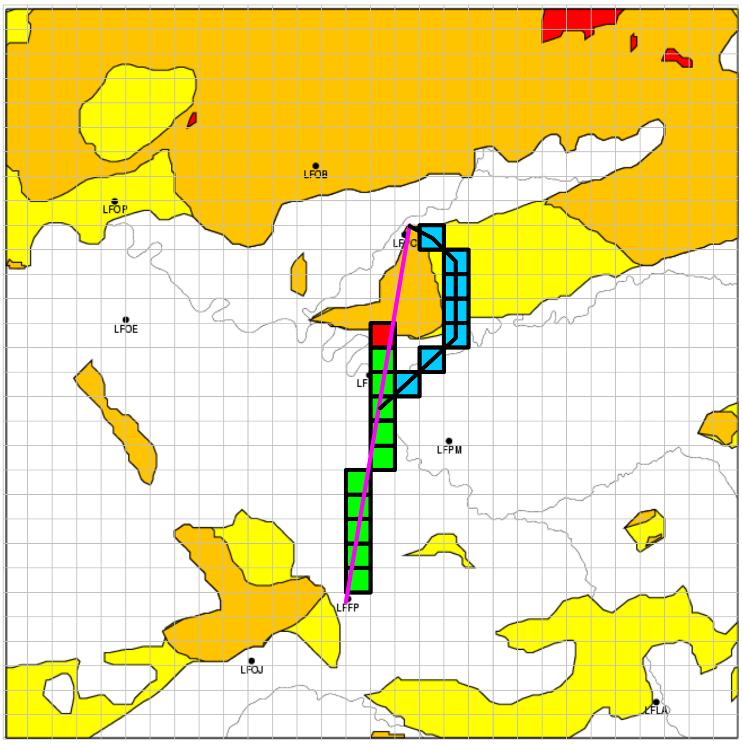

Figure 7: Conflict detection using static weather objects and aircraft objects.
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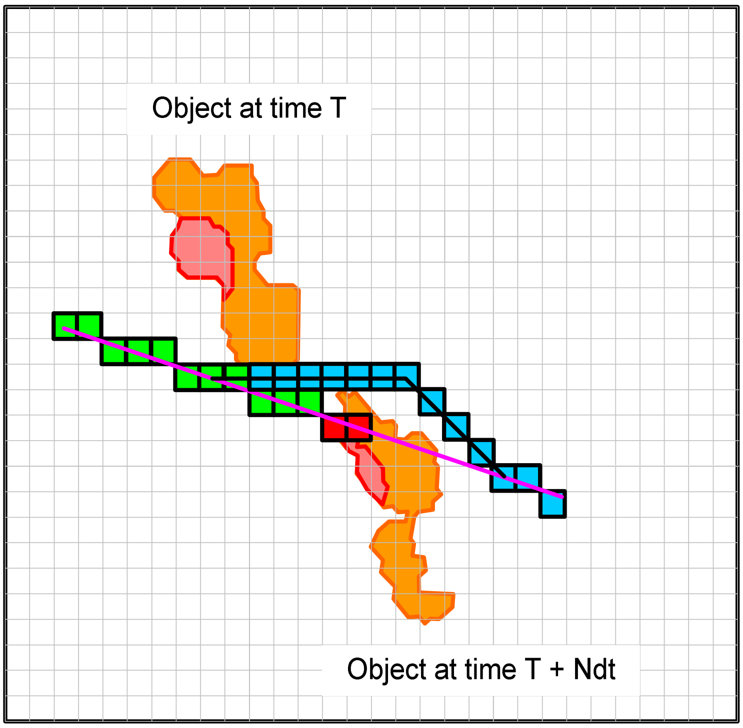

Figure 8: Conflict detection using dynamic weather objects and aircraft objects.
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In this illustration the planned 4-D trajectory at the time of departure is shown (pink line). The green squares indicate the position of the aircraft along the 4-D trajectory until it reaches a weather related hazard (red square). A new trajectory is computed (the black line) and the proposed position of the aircraft with respect to the weather hazard is shown (blue squares). With this computation the flight crew can be alerted in good time to negotiate with ground services on the proposed re-route; thereby the weather hazard is avoided and the safe conduct of the flight continues to its destination.

For static weather objects this is a trivial problem; however, for dynamic weather objects this is a non-trivial problem. The position of the dynamic weather object needs to be interpolated between its last known position and its forecast position.

The time interval for interpolation of the weather object needs to be comparable to the time interval used to forecast the position of the aircraft object; and the rate of change of the shape of the dynamic weather object. This introduces another layer of uncertainty when assessing the result of the conflict detection. (This could be mitigated by extending the safe zone around the aircraft object based upon the confidence index or probability value associated with the weather object.). For the CDA a simple interpolation scheme was employed to enable demonstration of the concept.

Figure 8 illustrates the approach taken by the CDA. For clarity the map background has been suppressed. The weather object represents a thunderstorm (Cb) – the top anvil (red) and the column (orange). The position of the Cb weather object is forecast at times T (shown) and T2 (not shown). At each time step, dt, the position, shape and intensity of the Cb weather object are interpolated and the position of the aircraft (green squares) is computed along its planned 4-D trajectory (pink line). For clarity, the position of the weather object is shown only at its start and at some intermediate time. The CDA detects a collision with the Cb weather object after N x dt steps, from which the time to intercept can be computed. This information is passed to a sub-system which computes a new trajectory (black line and blue squares) to avoid the collision with the Cb weather object; as before, the flight crew are alerted using a display system which shows the aircraft in relation to the detected threat and its resolution.

13. DISCUSSION: USING WEATHER OBJECTS IN TRAFFIC MANAGEMENT DECISION MAKING.

At busy airports, such as Heathrow, Paris Charles de Gaul and Frankfurt, during adverse weather conditions the cognitive load on human operators would be very high; as they are required to hold a mental model of the positions of surrounding air traffic and mobile weather phenomenon, which cause disruptions to the orderly flow of air traffic. The increased complexity of traffic management in these circumstances increases the risk of an air accident arising. The reduction of the operator's cognitive load may be addressed by implementation of reduced traffic flow rates along defined trajectories; and the extensive use of delayed arrivals, holding patterns and delayed departures, until the adverse weather systems have cleared. However, if the projected increase in passenger air traffic is realised then such a strategy maybe insufficient due to increased complexity of traffic management.

During FLYSAFE's flight trials, the GML Weather Objects which were contained in the GWP were also available to ground-based users at the same time.

The GML format of the Weather Objects is amenable to serialisation using the standards for the Internet. (The bandwidth constraint is less obvious between ground-to-ground systems than in ground-to-air systems.) In addition, the form of the Weather Objects as polygons also make them amenable for integration into trajectory based software solutions.

If a trajectory is expressed as a sequence of straight line segments then it is possible to compute the intersection of the trajectory with the boundary of a polygon. The detection of an intersection with a hazardous volume of space would enable computation of an avoidance trajectory with a minimum distance from the weather polygon.

The recomputed trajectory should also take account of the time and spatial evolution of the polygon boundary (horizontal and vertical). (Prete and Mitchell, 2004, describe an avoidance trajectory algorithm that incorporates constraints due to weather radar returns).

Figure 10 illustrates a conceptual decision–aid system for an ATC operator, with snapshots of its display taken at ten minute intervals. In reality such a display would be refreshed continuously. The following discusses the concept of operation in more detail.

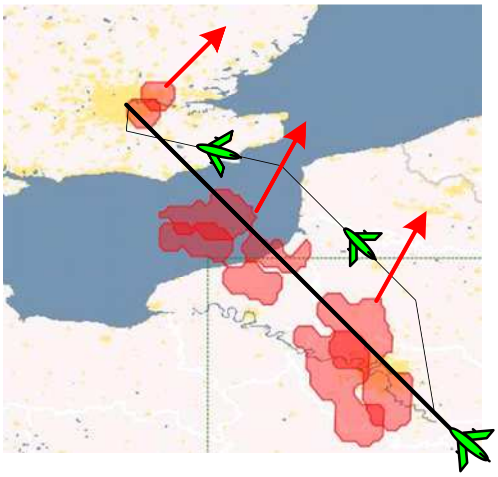

Figure 10: Preferred approach trajectory (thick line) intersects a series of atmospheric hazards, e.g., thunderstorms, moving NE, at time T+00 and T+20 minutes. An avoidance trajectory (thin line) is recomputed with a minimum distance from hazard.

Figure 10, shows a preferred flight trajectory (thick line) from Paris to London. The display also shows forecast hazardous areas, as weather objects, in this case a line of thunderstorms, at two time intervals, T+00 and T+20. The red arrows show the line of thunderstorms is moving in a north-easterly direction. The air traffic shown is assumed to be separated by one-minute intervals.

The preferred trajectory is shown to intersect the line of thunderstorms at T+20. The ATC operator could divert the air traffic to a new trajectory to the west or the east of the line of thunderstorms. However, the option for the west could put air traffic in conflict with the current position of the thunderstorm. For this instant in time, the decision-aid system, using the additional metadata for each object, recommends a more optimal re-routing of the traffic to a trajectory running parallel and to the east of the preferred trajectory.

Figure 11, is the same display as discussed for figure 10 but now it is ten minutes later. The display shows the preferred flight trajectory (thick line) from Paris to London. The display also shows the forecast position of the line of thunderstorms, at two time intervals, T+00 and T+20. However, thunderstorms are a dynamic feature; their spatial extent and intensity reflect their growth and decay. At this snapshot in time, they are shown to be decaying in spatial extent but still moving in a north easterly direction. The preferred trajectory still intersects the hazard. For this instant in time, the decision-aid system, using the additional metadata for each object, recommends a more optimal re-routing of the traffic to a trajectory running parallel but at this instance to the west of the preferred trajectory.

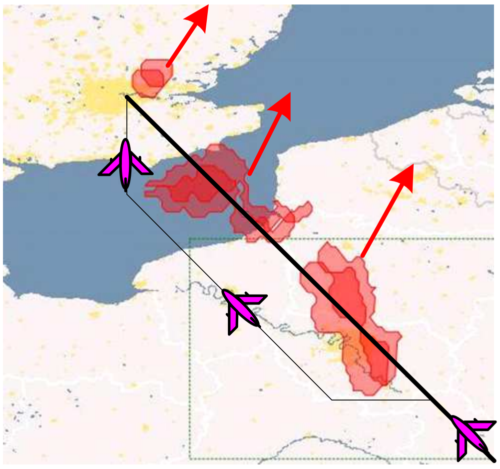

Figure 11: Ten minutes later, preferred approach trajectory (thick line) intersects a series of atmospheric hazards, e.g. the same line of thunderstorms, moving NE, at time T+00 and T+20 minutes. An avoidance trajectory (thin line) is recomputed with a minimum distance from hazard.

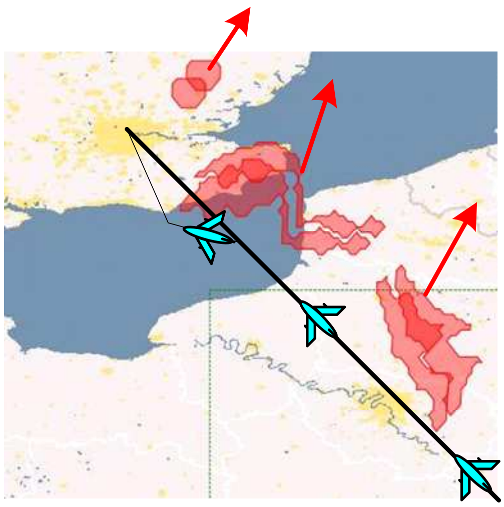

Figure 12: Ten minutes later, preferred approach trajectory (thick line) now intersects an isolated atmospheric hazard, e.g., the tail-end of the line of thunderstorms, moving NE, at time T+00 and T+20 minutes. An avoidance trajectory (thin line) is recomputed with a minimum distance from hazard.

Figure 12, is the same display as discussed for figures 10 and 11 but now it is ten minutes later. The display shows the preferred flight trajectory and the forecast position of the line of thunderstorms. At this snapshot in time, the thunderstorms are shown to be continuing to decay in spatial extent but still moving in a north easterly direction. The preferred trajectory still intersects the hazard but only as air traffic approach London. For this instant in time, the decision-aid system recommends a more optimal re-routing of the traffic – in this case continuing along the preferred trajectory then indicating an avoidance route around the tail-end of the isolated hazard.

This concept of operation has used only one preferred trajectory for the whole time sequence, with air traffic maintained at one minute separation and moving in one direction, to explore how a decision-aid system can incorporate dynamic hazards and recommend solutions. A real situation is far more complex due to the number of trajectories that would have to be considered; with air traffic arriving and departing; and other restrictions to air space usage, which could occur due to adverse weather conditions, special events or military operations.

If the concept of operation described in this paper is applied to all trajectories within a TMA then effects on time-of-arrival, sequencing and merging of traffic, and separation standards can be assessed automatically, especially during adverse weather conditions or when such conditions are forecast.

Automated decision aid systems would change the role of the ATC operator from direct management of flight trajectories toward monitoring the flight trajectories to maintain a safe and efficient flow of air traffic.

14. DISCUSSION: AUTOMATION

The goal of SESAR and NEXTGEN is to automate processes as far as possible. This is because the expected increase in air traffic movements will become too complex for any human operator to manage unaided. Thus ATC operators will move from being “in the loop” of active traffic management to “monitoring the loop” of automated traffic management.

This raises important requirements for any automated system, especially with respect to confidence in the system performance. Confidence in automated management of traffic with respect to safe separation, terrain and obstacles maybe realised more easily than confidence in systems that ingest weather information. This is because uncertainty inherent within weather forecasts grows with forecast lead time.

Within a time constrained, safety conscious environment there is no room for uncertainty. It is easier to deal with situations “now” or in the “near future” than with situations forecast with long lead times. In the aviation environment, lead times are in the order minutes and hours compared to the meteorological environment where the lead time is hours and days, except during severe weather events.

FLYSAFE addresses these two dimensions within the architecture of its Ground Weather Processor. The GWP has two sub-components, a Central Weather Processor (CWP) and a Local Weather Processor (LWP). The role of the CWP is to maintain weather information for long lead times, low resolution and update rates at the order three hours; at the regional and global scales. The role of the LWP is to maintain, local scale, high resolution, short-range forecasts, with update rates at the order of fifteen minutes. The ‘local scale’ is anticipated to be the terminal manoeuvring area. Because all users will have the access to the CWP and LWP a common weather picture between the ground and air can be maintained, which affords collaborative decision making. However, the usability of the system will depend upon agreed standards for data exchange, harmonisation of data sources and interoperability between systems.

15. CONCLUSIONS.

This paper has described the FLYSAFE project and the reasons for its proposed developments. FLYSAFE’s concept of operations was realised in the form of actual flight trials using prototype versions of the NG-ISS, the GWP and WIMS as an integrated infrastructure to make accessible weather information for flight management.

The integrated nature of the project demonstrated used an agreed standard for data exchange of not only the weather information between the suppliers and servers but also for the request and replies between the clients and servers.

Weather information was provided in the form of GML Weather Objects. This form is consistent with developments being undertaken in the wider context, in particular with respect to the family of data exchange models for aeronautical information.

Through the application of a concept of operations the GML weather objects developed for FLYSAFE is shown to have additional uses as a decision aid for flight management and air traffic management. In particular, integration of geospatial information represented as preferred trajectories, flight objects and weather objects.

Further work in this area is required to assess the feasibility of traffic flow management using weather objects. In the first instance the use of a fast simulation of traffic flow, based upon real traffic patterns could be used (Himmelsbach et al, 2009).

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Met Office
FitzRoy Road, Exeter
Devon EX1 3PB
United Kingdom

Tel (UK): 0870 900 0100 (Int) : +44 1392 885680
Fax (UK): 0870 900 5050 (Int) :+44 1392 885681
enquiries@metoffice.gov.uk
www.metoffice.gov.uk