Airborne Integrated Systems for Safety Improvement,
Flight Hazard Protection and All Weather Operations

FLYSAFE

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Our first presentation to this working group was given when the Met Office was your host in June 2006. Two years have elapsed so we feel it timely to present to you an update on the developments we have undertaken during this time.

Today this presentation will give a reminder of the FLYSAFE project, its goals, scope and objectives. We then consider in a little more detail the developments relating to atmospheric components: the weather information systems, data fusion and communications links. (A second presentation will be given to the Met Sub-group wherein more technical details will be covered.) We will end with a few comments on our experiences from our flight trials. There will be an opportunity to ask questions at the end – I will endeavour to answer these to the best of my knowledge.

FLYSAFE Vision, Scope and Objectives

- FLYSAFE Vision, Scope and Objectives
  - Expectation of an increase in world-wide air-traffic during the next 20 years which may affect flight safety [1]
  - Safety depends on actions of flight crew, which depends on their situation awareness
  - FLYSAFE will design, develop and implement a Next Generation Integrated Surveillance System (NG-ISS) to improve flight crew situation awareness
  - FLYSAFE will improve flight safety by addressing the main causes of accidents: collision with terrain, traffic and adverse weather
  - The NGISS shall be a decisive step towards the ACARE VISION-2020 for flight safety

[1] European Aeronautics: A Vision for 2020, Report by a Group of Personalities, 2001, European Commission, Luxembourg. http://www.acare4europe.org/

A 2001 study by a "group of personalities" [1] envision that by 2020 worldwide air traffic will be at least twice what it was in circa 2000. In their vision they assume that air transportation is safer in the future than it is today; that the impact on the environment from aviation activities will be reduced substantially: noise, air pollution and carbon footprint. As a result of this study the *Advisory Council for Aeronautics Research in Europe* was set-up to encourage and monitor research and development toward this 2020 Vision.

The FLYSAFE project addresses the safety aspect of the 2020-Vision. Safety of flight depends on the actions of the flight crew which, in turn, depends on their situation awareness. The goal of the FLYSAFE project is to develop systems and services to enhance flight crews situation awareness. These developments are an onboard solution called the Next Generation Integrated Surveillance System (NG-ISS) and a ground-based infrastructure for weather information. These developments will address the three main hazards to the safe conduct of a flight – terrain, traffic and adverse weather conditions. FLYSAFE believe that developing these solutions will be a decisive step towards achieving flight safety as envisaged by ACARE's VISION-2020.

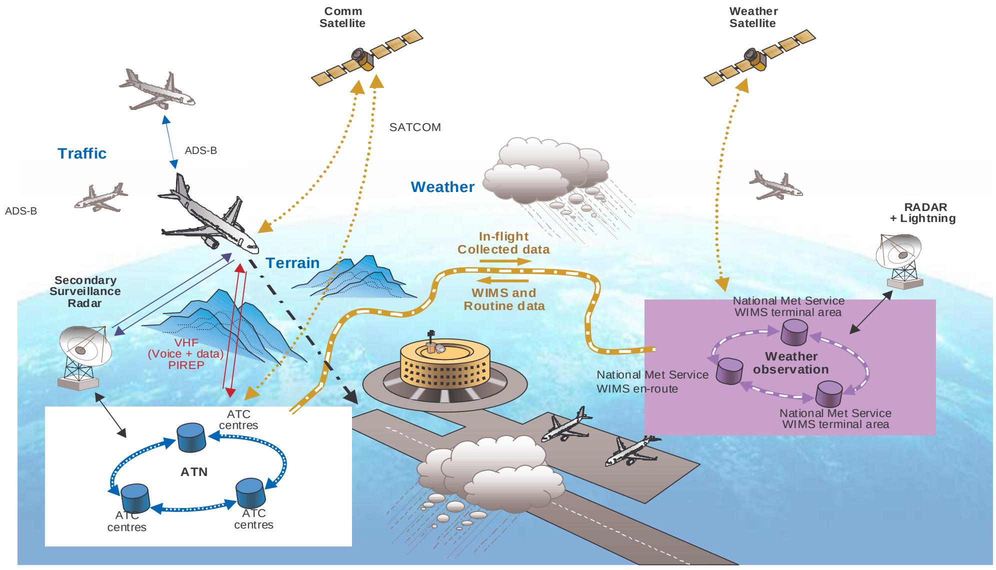
[1] *European Aeronautics: A Vision for 2020*, Report by a Group of Personalities, 2001, European Commission, Luxembourg. http://www.acare4europe.org/

FLYSAFE Vision, Scope and Objectives

- **"Atmospheric hazards" will develop means to increase the awareness onboard the aircraft with regard to all major sources of atmospheric hazards (wake vortex, wind-shear, clear air turbulence, icing, and thunderstorm).**
- **"Traffic hazards" will develop means to increase the crew's traffic situation awareness and provide them with information on potential traffic hazards along the flight path.**
- **"Terrain information management" will develop means to increase the crew's terrain and obstacle situation awareness and provide them with the potential terrain and obstacle hazards along the flight path.**
- **The validation of a prototype NG-ISS system, with both ground and onboard components, will be performed by means of a set of simulator and flight trials, involving a representative group of pilots.**

As noted, FLYSAFE has identified three main hazards which may affect flight safety. The three main hazards identified are atmospheric hazards, traffic hazards and terrain hazards. Each has an effect not only during the course of flight but also at the critical times of landing and take-off. These effects range from delays to departures and arrivals, and the physical threat to the aircraft; in addition there are the economic and environmental impacts due misplaced assets – aircraft and crew in the wrong place due to diversion; extra fuel consumption due to diversion or delays at arrival. FLYSAFE will validate its concept through flight simulations and flight trials (where permitted).

FLYSAFE - Vision, Scope and Objectives



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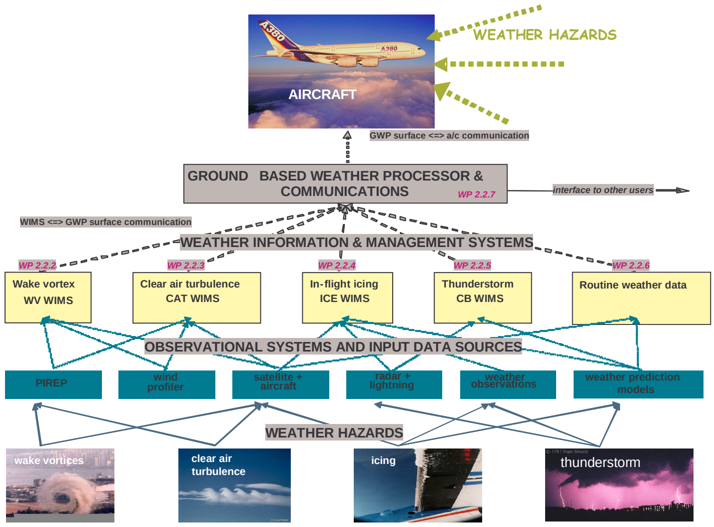
This drawing is an illustration of FLYSAFE’s vision. At the lower right (purple) is the weather service information provider; at the centre of the image is air traffic management; and at the lower left (blue) is the aircraft telecommunications network linking the ground to the air. The upper part of the drawing shows the air traffic exchanging information with the ground and with each other (using ADS). The remainder of this presentation will focus on the weather information services.

Work Package 2: Atmospheric Hazards



FLYSAFE will undertake to develop a solution that provides weather information to the flight crew. Here we envision that each NG-ISS equipped aircraft is coupled to a network of ground weather processors, from which it can retrieve weather information that is relevant to its current flight plan and trajectory. The NG-ISS will fuse weather information with in-situ atmospheric measures, and so make available to the flight crew a single picture of weather related hazards.

The ground weather processors will store data sent to it by specialised weather information management systems (WIMS). Each WIMS provides forecasts of an aviation related weather hazard, namely, wake vortices, clear air turbulence, icing and convective activity. In producing these forecasts the WIMS will ingest the latest numerical forecasts and atmospheric observations. They will provide forecasts at several levels: a local level which will be high resolution nowcasts (~ 1's km with ~120 minute forecasts at 15 minute intervals) and at regional and global scales (~ 10 – 50 km, with ~ 3 – 72 hour forecasts at 60 – 180 minute intervals).

Work Package 2: Atmospheric Hazards

Acknowledgements

Met Office: Bob Lunnon, Andrew Mirza, Debi Turp

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

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

gtd: Florent Birling, Joan Roig

Skysoft Portugal: José Freitas, André Rosado

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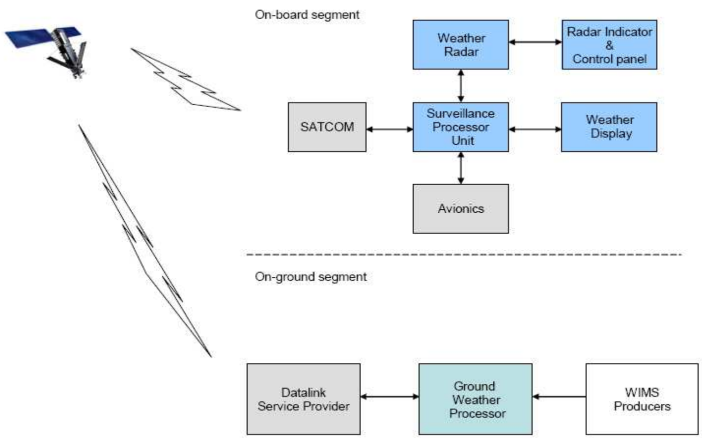
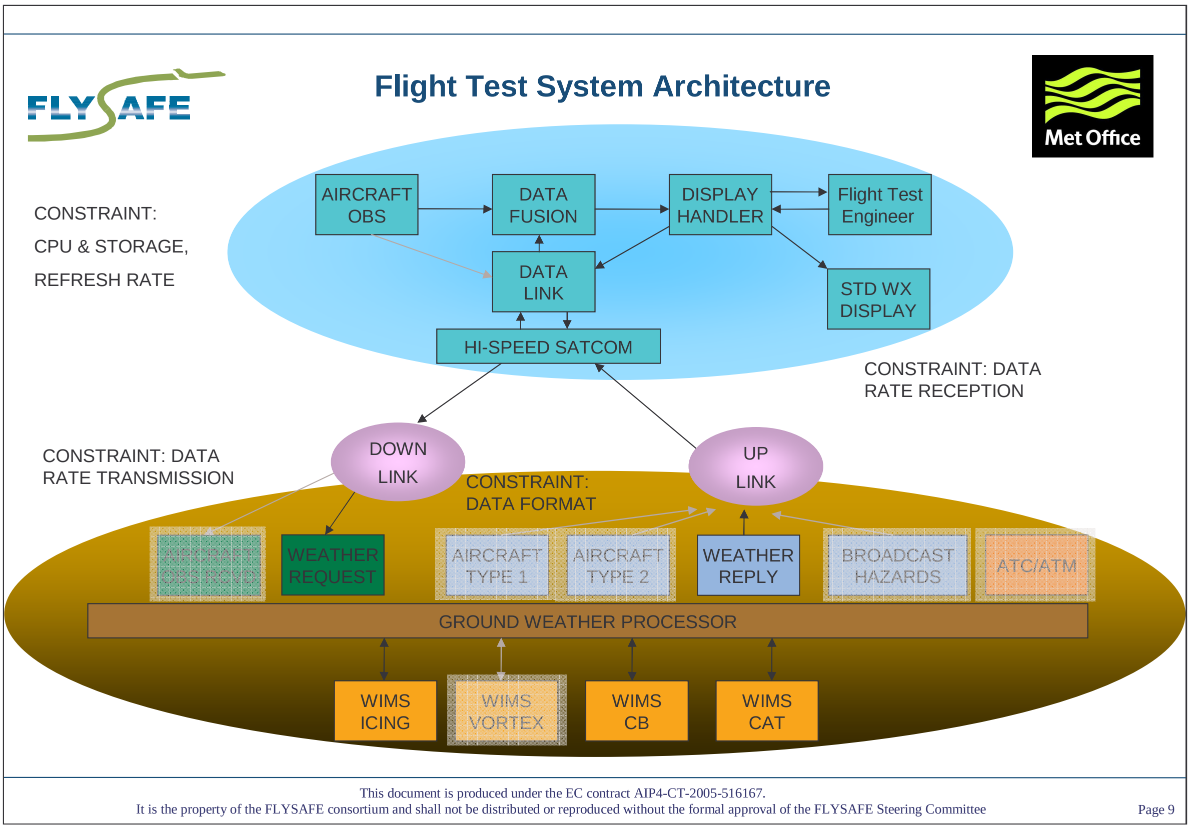
the weather service providers, the UK Met Office, Meteo France, the University of Hanover (in co-operation with the German Weather Service); the German and Netherlands aviation research centres; avionics manufacturers Rockwell Collins (France) and GTD (Spain) and communication specialists Skysoft (Portugal).

Flight Test System Architecture



Simplified view of the data flow between the airborne and ground segments used in FLYSAFE's Flight Trials.

This illustration is a simplified overview of the system architecture used for FLYSAFE's flight tests. The following slides will present a finer grained view of this system architecture.



This diagram illustrates the components as conceived in 2006. The main components are the airborne (in green) and the ground-based in blue, orange and brown. The blue components were included to address the requirement for the customisation of the weather information by aircraft type. The orange box labelled ATC/ATM represents all ground based users that require access to the same weather information. The brown rectangle represents an interface to the ground weather processors.

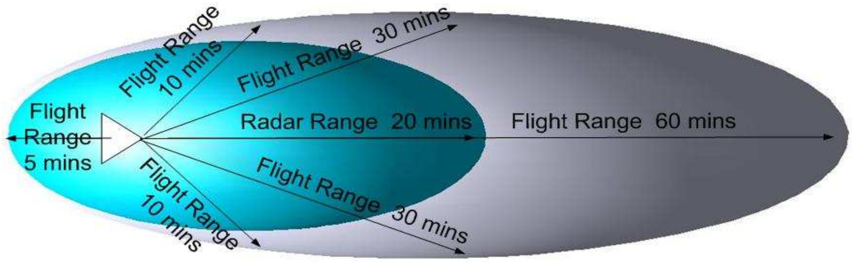
During the course of the intervening two years – only those components not shaded have been developed. This reduced development does not diminish the overall concept nor the validation of FLYSAFE's vision. The air-obs handler is represented today by its current incarnation of the WMO AMDAR program, for which a datalink solution exists. FLYSAFE was not in a position to validate a component to broadcast weather hazards. The planned flight trials would involve only one aircraft type. The Pilot was replaced by a flight technician. The Wake Vortex WIMS was evaluated as part of another European project's flight campaign. Thus without these components, all effort was directed toward development of the remaining components.

FLYSAFE

Communications

Met Office

- **Weather Corridor**
  - **To provide the aviation user with weather information that will correspond to the radar range (at minimum) and with sufficient information to enable decision support for flight times ahead, below, behind and either side.**



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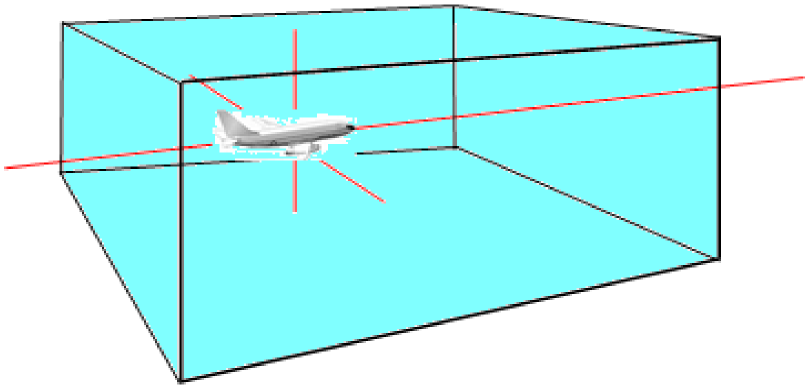
A key concept within FLYSAFE's vision is the weather corridor. This corresponds to the projected flight path of the aircraft up to 60 minutes directly ahead. In addition provision is made for deviations from the projected flight path. The result is a "bubble of weather information" that moves and is updated according to the aircraft's position. To facilitate this a request/reply manager was developed and the "bubble of weather information" was simplified to rectangular box. The flight trials were done with a particular weather corridor and a particular frequency for requests. Both could be changed in order to lower the amount of data.

Communications

- **Weather Corridor**
  - **Weather corridor depends on current aircraft position and is used to select WIMS products that intersect the volume of interest; for the flight trials only the weather radar range was considered with a predefined frequency for requests. Both could be changed in order to lower the amount of data.**



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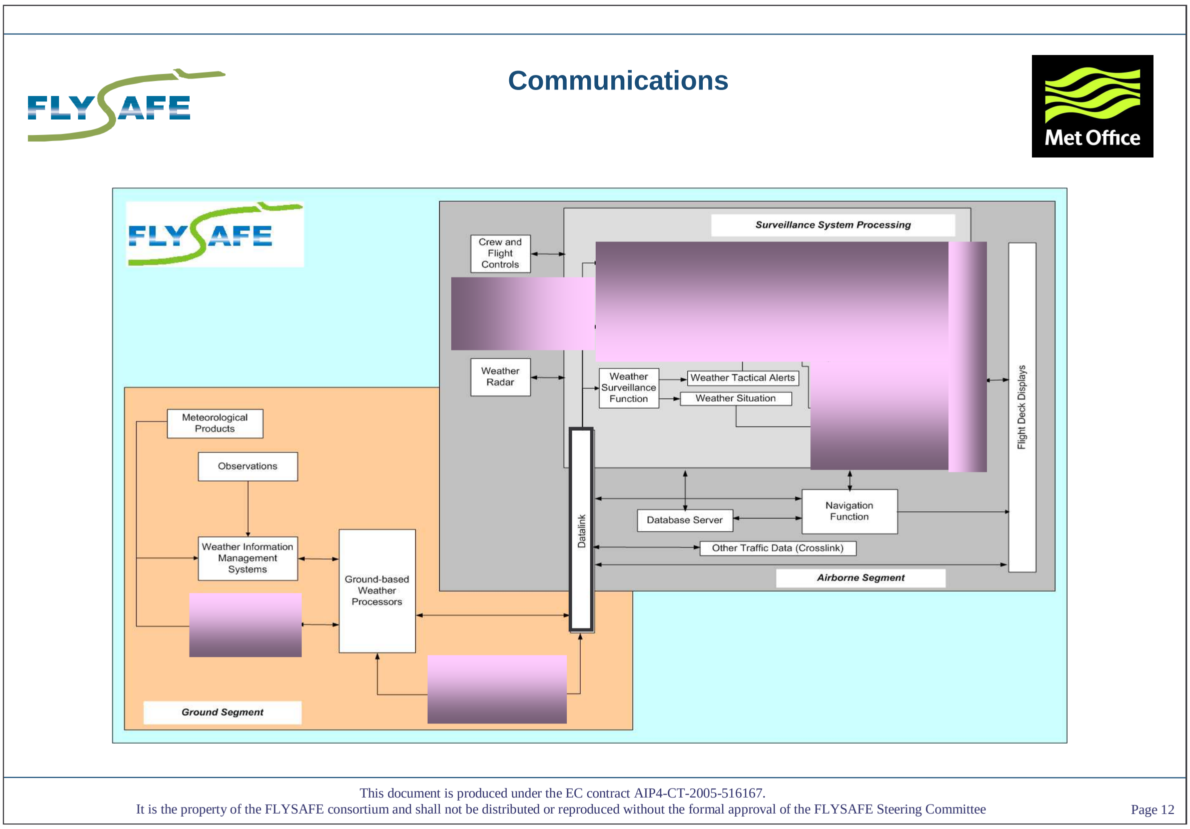
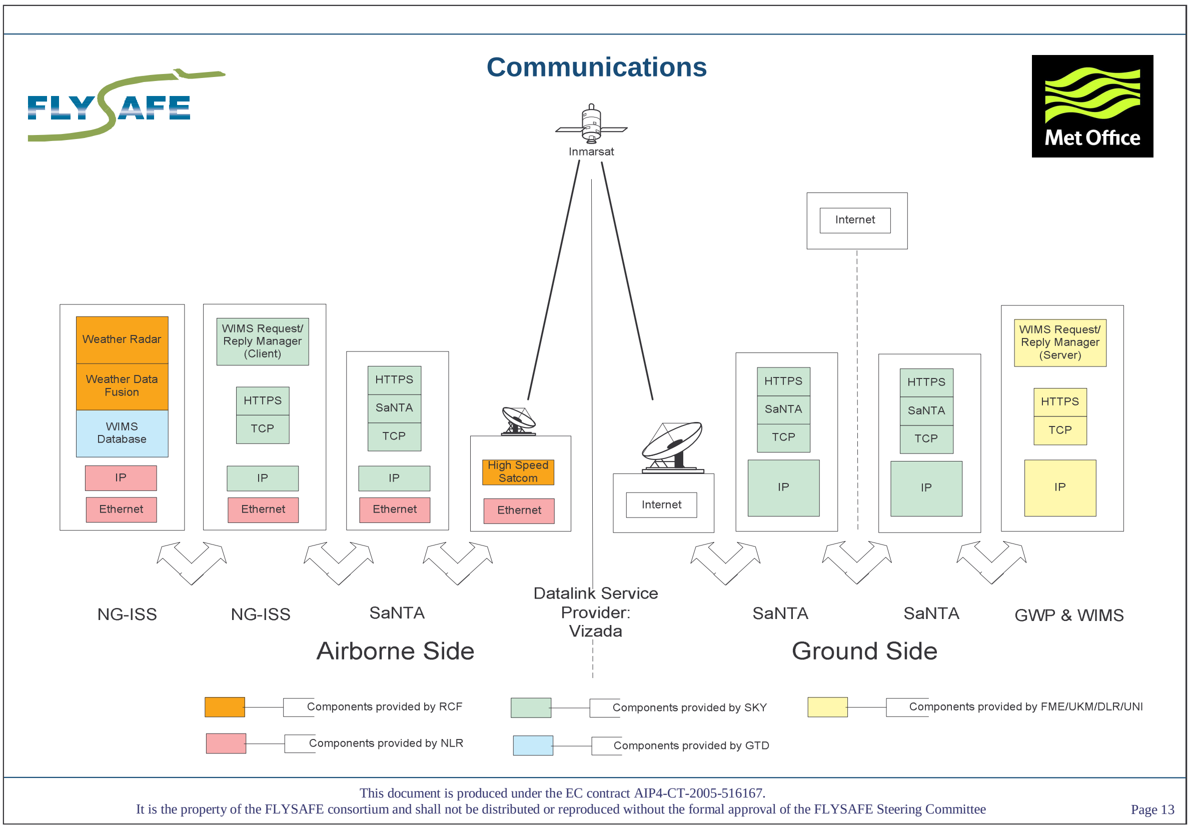


This block diagram illustrates the features used during the flight trials. The shaded components were excluded from the flight trials.

Within the ground segment, a ground weather processor was installed at Meteo France, which was a geospatial database with an OGC Web Feature Service interface.

The weather information management systems were operated from several centres depending on their data's scale and refresh rates. For CAT – the Met Office provided global scale and Meteo France the regional scale; for ICE – the Met Office provided global scale; University of Hanover the regional scale and Meteo France the local scale. For CB Activity – DLR and Meteo France provided regional scale; and Meteo 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 to test the data fusion and the data link were installed onto the test aircraft. A weather radar developed by RCF was installed; a database component and weather fusion components were installed. These drew information of 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.



This diagram illustrates these key points: between the NG-ISS and the satcom modem; between the CSP and the internet; and between the internet and the GWP.

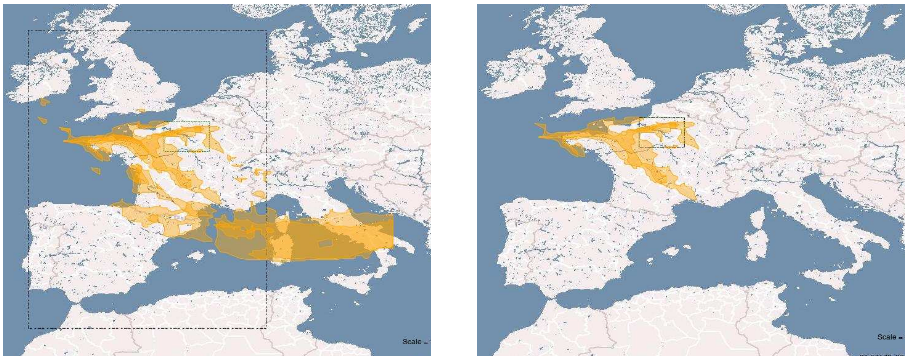
The data link connection between the ground and airborne components was established using a communication service provider (CSP) for Inmarsat. To enable a seamless connection between the NG-ISS and the GWP, using the HTTPS internet protocol across the satellite data link, SaNTA network components were 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.

A client-side request/reply manager is used to access the Ground Weather Processor, which was installed at Meteo France. The GWP is a geo-spatial database (PostGIS) configured to operate using OGC Web Feature Services. A server-side request/reply manager is used to manage access to the GWP.

FLYSAFE

Ground-Based Weather Processor
Spatial & Temporal Selection

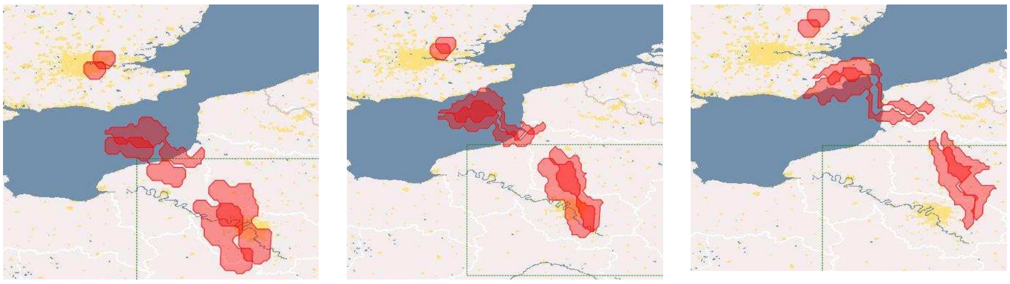
Met Office



Spatial selection of Ice objects: the image on the left shows all the objects retrieved for one flight level within the en-route spatial domain, similarly the image on the right shows for the same flight level the objects retrieved for the TMA spatial domain. Only those objects that intersect the volume of interest are retrieved (Sébastien Geindre).

The data held within the GWP is supplied by Weather Information Management Service Providers (WISPs) operated by FME, UKM, DLR and UNI. The use of a geo-spatial database enables the selection of weather objects based on spatial and temporal domains. As this illustration shows, on the left the bounding box represents the weather corridor of interest; the orange features are the weather objects that represent forecasts for ice. Only those weather objects that intersect the weather corridor are returned to the airborne user. Thus in the illustration on the right, the weather corridor is centred on the Paris TMA, and only those weather objects that form the intersection are returned. Features are not truncated at the boundary of the weather corridor. The weather objects represent the forecast of adverse weather for a region of space and time at a given validity time.

Ground-Based Weather Processor
Spatial & Temporal Selection



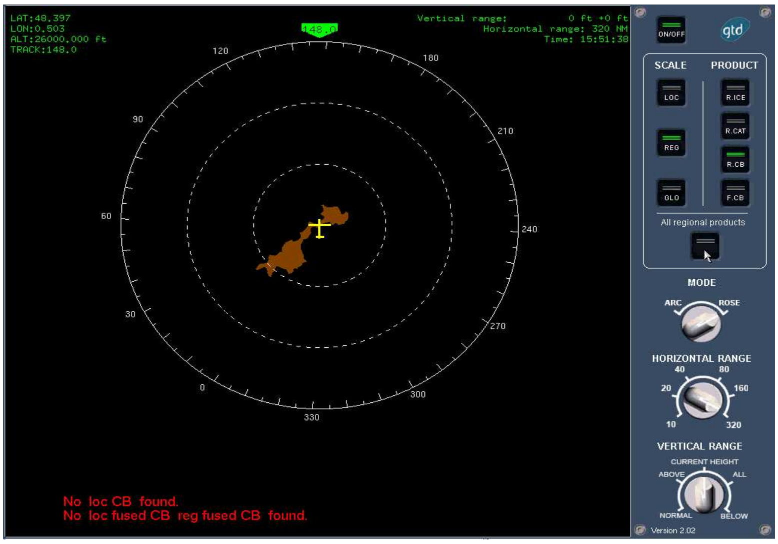
1200-1220 1220-1240 1240-1300

Temporal selection of Cb objects: each image is at an interval of twenty minutes; also showing a forecast position for twenty minutes (Sébastien Geindre).

This is an illustration of temporal selection for forecasts at twenty-minute intervals. These weather objects represent convective activity. Clearly, a combination of spatial and temporal selection is possible, these have been separated purely for this demonstration. The next slide presents a short movie loop of weather objects as received on-board during the flight trials. The display system was developed by GTD to demonstrate how weather objects can be used during a flight.

Weather Situation Awareness Display

On-board WIMS display as up-linked from GWP



For further information about this display contact Florent.Birling@gtd.es

In this video presentation the weather objects are colour coded:

CB-Fused	red
CB	brown/orange
ICE	blue
CAT	yellow/pale green

The viewpoints switch between arc and rose modes. The weather objects are displayed according to the horizontal and vertical range settings.

FLYSAFE Flight Trial (FT5) Objectives

•**Two flight campaigns were undertaken between August and September 2008.**

a) Observational flights by Meteo France: to verify forecast products: Ice, Cb and CAT.

b) Experimental flights by NLR: to test the onboard data fusion between weather radar and forecast Cb; and to test the data link between the aircraft and the ground weather processor.

•**There were 21 flights accumulating 43 flight hours with routes over mainland Europe:**

- Spain, France, Netherlands, Germany and the North Sea

Météo France SAFIRE ATR 42-320 specially modified to scientific use.
(Image from http://www.safire.fr)

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

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 NLR. 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, Meteo France – Toulouse and the Met Office - Exeter. Each WIMS provider sent weather objects, using http web protocols, to a GWP at Meteo France – Toulouse.

Duration of each flight was around 2-3 hours, with flight planning co-ordinated with the team at Meteo France – Toulouse. The flights took routes across Europe: Spain, France, Netherlands, Germany and the North Sea or locations where thunderstorm activity was forecast.

Netherlands: Perpignan to Amsterdam, Amsterdam to Deauville; France: South east of France, Corsica, Toulouse and the Pyrenees, Paris TMA; Spain: Northern Spain; Bastia - Valencia; Saragossa - Ebre Valley, Girona - Madrid; North Sea, Northern Germany.

FLYSAFE

Flight Trial Results

Met Office

- **Initial results for Experimental Flight (b)**
  - Up-linked file size ranges (zip compressed):

Local Cb	**4 - 6 kbyte**		**every 5 min**
Regional Cb	**4 - 20 kbyte**	**(max 150 kbyte)**	**every 15 min**
Regional Ice	**20 - 200 kbyte**	**(max 300 kbyte)**	**every 15 min**

  - Transfer rate (scalable according to size of data to uplink):

1 - 5 kbits/s (small files) **15 - 20 kbits/s (large files)**

Ł **Best case: 29 kbits/s**

  - Costs (Swift 64 - Vizada DSP):

$0.25 - $0.74 per kbyte

Ł **Average: $0.38 per kbyte**

Data from the flight trial is still being analysed, presented here are initial results for the data link. It was found that during the flight trials that the uplinked file sizes varied not only by scale but also by content. All files uplinked were zip compressed before being sent to the data-link. For local Cb the typical range was found to be 4 – 6 kilobytes. Local Weather Forecast will cover a small region with a high spatial and temporal resolution and are refreshed more frequently (in this case every five minutes). For regional scale Cb the typical range was found to be 4 – 20 kilobytes, with the occasional file reaching 150 kilobytes. By far the largest files were for regional ice the file sizes were within the range 20 – 200 kb, with the occasional file reaching 300kb. Regional scale forecasts will cover a larger region but with a lower spatial and temporal resolution and lower refresh rates (in this case every 15 minutes). From the data log, it has been estimated that the data transfer rate for small files ranged between 700 – 5000 bits/s for small files whereas for large files a rate of 29 kbits/s was achieved. Similarly, the cost to uplink the files varied, for small files this ranged from 25 cents to 74 cents per kilobyte; the average cost across all flight trials was 38 cents per kilobyte.

FLYSAFE - Conclusion

Met Office

- **Initial conclusions from Experimental Flight (b)**
  - Difficult to draw a general conclusion since only one aircraft was equipped with FLYSAFE's data-link solution.
    - The available bandwidth depends on the number of other users (contention ratio), e.g., other aircraft and shipping.
    - The limited flight trial experience suggests that the file size containing the WIMS forecast is too large (even with compression) for today's datalink solution, namely Inmarsat Swift-64; and by analogy similar datalink solutions
- Final note
  - One of FLYSAFE's remits is to develop solutions that can be applied not only for *tomorrow* but also for *the day after tomorrow*

It is difficult to draw a general conclusion from the flight trial since only one aircraft was equipped with an NG-ISS type solution and similarly only one ground station exists, which in effect serviced only one aircraft. Clearly, the contention ratio for the data link is a major factor over which users have no control and would have a big impact on the uplink time. The avionics development team felt that the weather object files were too large, even with compression, to be of practical use using today's datalink technology. The ground-based development team acknowledge this weakness and defend their decision for this development: the overhead lies in the use of the XML format. It is acknowledged that XML is not the most efficient method by which to transfer data and formats such as WMO's BUFR and GRIB maybe more suited but these present their own issues with respect to usability. A second presentation in which these aspects and other issues arising will be given to the Met Subgroup. As a final note, one of FLYSAFE's remits is develop solutions that can be applied not only to tomorrow but also for the day after tomorrow.

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