Avian Alert - a bird migration early warning system

van Gasteren, H.; Shamoun-Baranes, J.; Ginati, A.; Garofalo, G.

Published in:
Proceedings of the 59th International Astronautical Congress (IAC 2008)

IAC-08-B4.4.A2

AVIAN ALERT – A BIRD MIGRATION EARLY WARNING SYSTEM

Hans van Gasteren
Royal Netherlands Air Force, The Netherlands
jr.v.gasteren@mindef.nl
Judy Shamoun-Baranes
University of Amsterdam, The Netherlands
shamoun@uva.nl
Amnon Ginati
European Space Agency/ESTEC, The Netherlands
Amnon.ginati@esa.int
Giovanni Garofalo
European Space Agency/ESTEC, The Netherlands
Giovanni.garofalo@esa.int

ABSTRACT

Every year billions of birds migrate from breeding areas to their wintering ranges, some travelling over 10,000 km. Stakeholders interested in aviation flight safety, spread of disease, conservation, education, urban planning, meteorology, wind turbines and bird migration ecology are interested in information on bird movements. Collecting and disseminating useful information about such mobile animals is no simple task. However, ESA's Integrated Application Promotion (IAP) programme may provide the solution with its system of systems philosophy, integrating space assets (Telecommunication, Navigation, Remote Sensing and Meteorology) in combination with terrestrial systems (radar sensors). FlySafe sustainable services could provide access to various existing radar systems and observation networks, collecting information on bird migration, enhancement of existing technologies, modelling tools, improved access to environmental data and web services.

In the present situation radar measurements of birds are not comparable between countries and are covering only a part of Europe. One of the main motivations for Air Forces to participate in ESA FlySafe is to reduce the number of damaging bird strikes without unbalanced interference with the operations. This can be reached by automatic generation of ad-hoc warnings and timely reliable predictions of increased bird strike hazard for the en-route situation and providing both bird control units and air traffic control with an alerting system of birds crossing the flight path of aircraft during take-off. The aim of FlySafe is to develop such a bird warning system of systems in Europe. Currently four Air Forces (Germany, France, Belgium and The Netherlands), several research and academic institutes as well as industrial partners are participating in this initiative.

This paper deals with the activities that ESA IAP has started in the context of the Bird Migration System of Systems, current achievements and foreseen services.

INTRODUCTION

Every year billions of birds migrate from breeding areas to their wintering ranges, some travelling over 10,000 km. One of the most intriguing examples is the migration of Bar-tailed Godwits on their migration from New Zealand towards Alaska and vice versa. Tagged with a GPS data transmitter a female Bar-tailed Godwit made a 10,000 km nonstop flight to a stopover site in China lasting 7.5 days, without eating and drinking. After a stop-over of one month followed by a second nonstop flight of 7200 km towards the summer breeding grounds in Western Alaska. On her autumn migration an even more intriguing nonstop flight of 11.500 km, lasting more than eight days brought her back to the wintering grounds in New Zealand (http://www.adn.com/wildlife/story/360937.html). On the other hand many short- and medium distance migrants follow the opposite strategy, called hopping. These hops generally takes them 100 – 300 km closer to their breeding or wintering grounds [1]. Birds are incredibly mobile, during all phases of their life. Therefore, they serve as excellent indicators of the quality of our environment. Unfortunately, birds can also cause devastating accidents by colliding with aircraft and just as many other organisms, birds often carry and transmit diseases. Their mobility adds an extra dimension of complexity to avian borne disease epidemiology.

Understanding bird migration is extremely challenging, and today a wealth of techniques are used to track bird movements and understand the relationship between these movements and the environment. These techniques include space based systems for tracking individual birds, ground based military long-range surveillance radars, mobile tracking radars, weather radars, infra-red systems, genetic and chemical markers, bird ringing, avian acoustic monitoring, ceilometers, and traditional visual observations, e.g. www.trektellen.nl or moon watching observations during the night, see also [2].

The European Space Agency (ESA) has the opportunity and capability to contribute greatly to the realization of a large scale, international, Bird Migration System of Systems, especially with ESA's Integrated Application Promotion (IAP) programme, which is a new initiative within the ESA. This initiative aims at stimulating European and international projects that result in sustainable services for different communities and demonstrate the added value of integrated space assets (telecommunication, navigation and earth observation) and terrestrial systems with a System of System approach. Flysafe is one of the proposed projects within ESA's IAP initiative, to demonstrate the usefulness and unique solution that integrated space tools can provide for different user communities. The FlySafe sustainable services will provide access to various existing radar systems and observation networks collecting information on bird migration, enhancement of existing technologies, modelling tools, improved access to environmental data and web services. Within Flysafe ESA, Air Forces, industry and knowledge institutes joined forces to realise a prototype system within 1.5 years. This short time period restricted the user communities to military flight safety only with partners in the Netherlands, Belgium, Germany, and France.

THE FLYSAFE BASIC ACTIVITIES

Introduction bird strike hazard

Bird strikes are a common phenomenon in both civil and military flight safety. The consequences of bird strikes vary from not noticed by the pilot to loss of aircraft. Several papers provide an overview of the loss of aircraft due to bird strikes within the military and civil aviation [3-5]. The costs of damage to aircraft, delay and cancellations of flights, have been estimated to be between US$1.2 and 1.5 billion per year for civil aviation world wide [6]. The impact of bird strikes on military operations can be demonstrated by the data of the Royal Netherlands Air Force (RNLAF). Within the RNLAF the 164 bird strikes over the years 2003 to 2006 resulted in 87 cases of loss of mission time (10 times aborted take-offs, 27 times precautionary landings and 50 times returned to base). Furthermore, 15% of the bird strikes resulted in damage to aircraft. As a consequence, aircraft were grounded for periods varying from 1 hour to 91 days. Unfortunately the RNLAF also lost one F-16 due to a bird strike with feral pigeons in this period.

The nature of the problem is twofold and can best be demonstrated by the speed of fast jets when colliding with birds (figure 1). The frequency distribution shows peaks around take-off speed (150 kts) and during (typical low-level) cruising speed (400-450 kts). This is also confirmed by the location of the bird strikes: on airfield or airport vicinity as local and outside this area as en-route. The impact of high speed collisions during the en-route phase caused twice as much cases with damage compared to local bird strikes at much lower speeds. On the other hand, although only a small proportion of flying time is spent in the local situation, about half of the serious accidents occurred on and in the immediate vicinity of airfields [3, 7]. It is thought likely that the more complicated challenges pilots have to deal with during take-off and landing are responsible for this [8].

Already for many years bird strike prevention is standard practise in aviation (for instance [9]). Different measures are known for local (on-airfield) and en-route situations. Local bird strike prevention is relevant for both civil and military aviation. It is aimed at removing birds from the flight path of aircraft by habitat management of the runway environment; active removing the birds by bird control units with an array of methods (see [9, 10] for an overview), e.g. scaring devices, falconry and spatial planning in the airport vicinity. The en-route bird strike prevention is relevant for military aviation only, with emphasis on low-level cruises. Civil aviation generally operates at higher cruising altitudes where bird collision risk is minor. En-route prevention is aimed at avoiding birds by the aircraft by closing the relevant airspace for fast jet aircraft or

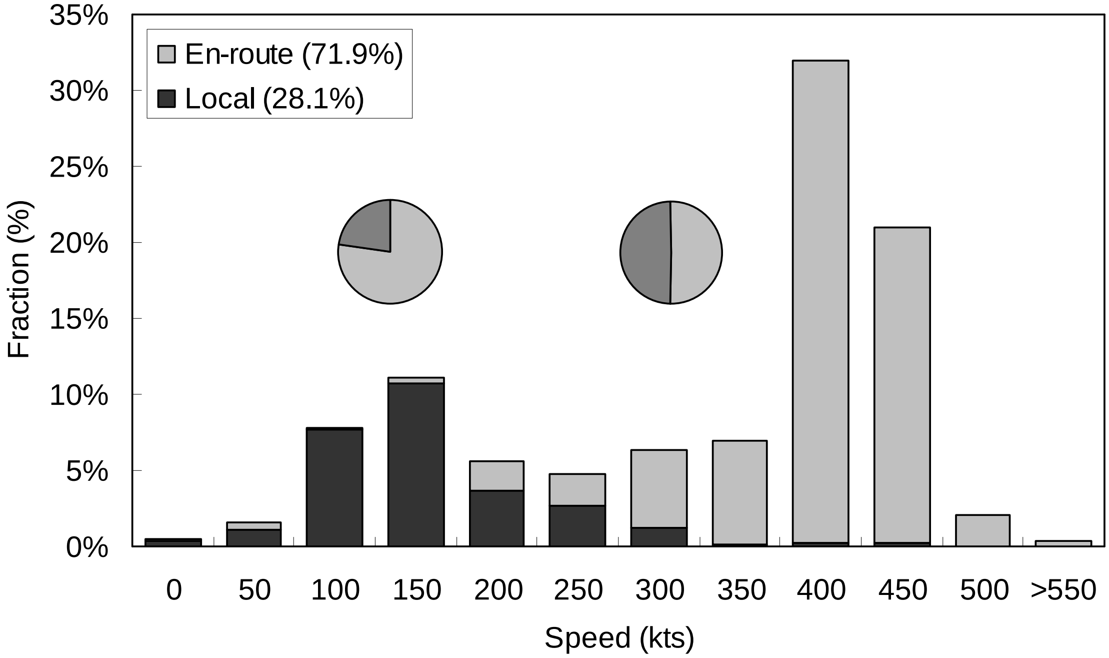

Figure 1: Proportional distribution of bird strikes over speed of military fast jets during local and en-route phases (N=17,732). Proportion of damage during the two different flight phases is indicated by dark grey in the inserted circles. Data is taken from the European Military Bird strike Database [11].

reducing the speed for helicopters. Warnings to the pilots (bird notice to airman, BIRDTAM[1]) are generated by measurements from long-range surveillance radars equipped with dedicated systems to extract birds from radar signals (see below).

Improvements needed

From the users point of view the Flysafe IAP project is aiming at improvements at both the local and the en-route situation. For local bird strike prevention, improvements in active scaring devices are not taken into account within the Flysafe initiative.

Within Flysafe, the main aim on and around airports is to anticipate birds crossing the airport, or more specifically crossing the flight path of aircraft during take-off. The best way to take preventive local actions would be by combining general information of high altitude broad front bird migration with local bird movements provided by small scale radars (figure 2). If these specialized bird radars provide accurate extrapolations of the birds’ flight path, timely action of bird control units and/or air traffic control to hold starts for a short moment could reduce the number of bird strikes.

[1] BIRDTAM (BIRD notice To AirMan) is a specialized message of the standard format NOTAM (the quasi-acronym for a "NOtice To AirMen"). This message is to alert aircraft pilots of any hazards en route or at a specific location. BIRDTAMS contain information of the bird strike risk on a logarithmic 1-8 scale per 1° longitude by 1° latitude square.

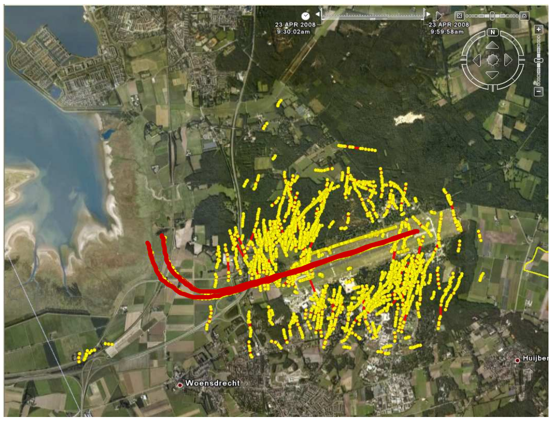

Figure 2: Bird tracks (yellow) around Woensdrecht Air Force base on 23 April 2008, 09:30 -10:00 local time. Two flight paths of PC-7 aircraft (red) crosses several bird tracks during half an hour of data, but at the times of landing no birds cross their path.

Improvement of the en-route bird strike prevention is the main topic of the Flysafe IAP. Since low-level fast jet cruises are crossing borders, the improvements are a set of user requirements drafted by the German Armed Forces, Belgian Air Component, Frence Air Force and Royal Netherlands Air Force. The main improvements needed are:

- Making the existing bird detection system person independent, robust and 24/7 operational (from labour intensive (now) to an automatic system in the future);
- Add more reliable altitude information to the BIRDTAM's;
- Extension of the geographical range of the Air Forces contributing in the Flysafe project;
- Increase temporal and spatial resolution (hours) of the BIRDTAM intensity forecasts;
- Coupling of forecasts and radar measurements into a nowcast, thus ensuring operational information when short term gaps in the detection network occurs (comparable with the analysis product of weather services);
- Harmonization and standardization between the different systems used in the countries;
- Using information from other radar sensors. Weather radar wind profile measurements, for example, are capable of measuring bird migration flight altitudes [12, 13]. Also local bird radars and visual bird migration observations provide useful information;
- Automatic BIRDTAM generation, translating the nowcast into the current warning format.

<u>Flysafe system overview</u>

The long term objective of Flysafe is to develop and support sustainable services for the operation of a bird warning system for aviation in Europe in order to reduce the risk of bird strikes. By implementing a system of systems philosophy, the Flysafe project incorporates and integrates data originating from several sensors to monitor bird movements (figure 3). These include long range military surveillance radars, short range local radar systems, meteorological radars in the OPERA network (Operational Programme for the Exchange of weather RAdar Information), and tracking individual birds from space. This set of data is used iin combination with environmental data from Earth Observation satellites and weather data from meteorological satellites to feed models for nowcast and forecast of bird migration. Information on meteorological conditions is essential when interpreting radar data and modelling bird migration. Therefore ECMWF (European Center for Medium range Weather Forecasting) deterministic model output is also used in the project. Information of landscape and land use is important for stop over ecology, while terrain elevations and large water bodies act as barriers for migrating birds. Therefore CORINE (coordination of information on the environment) landscape and land use data is used in the project, as well as SRTM (Shuttle Radar Topography Mission) digital elevation data. Space telecommunications are used to establish connections among the elements of the system which are temporary or mobile (e.g. transportable radar units operating from remote locations or bird radars located outsite Europe during peace keeping operations). All the Flysafe data types are stored in a database hosted on a project server. The different data types enter the system as flat files, and their content is subsequently processed and inserted into the dedicated database according to a predefined data-model. Data distribution is implemented in three different ways: users can access the data directly and perform queries; original files can be retrieved or information is available via web-based services.

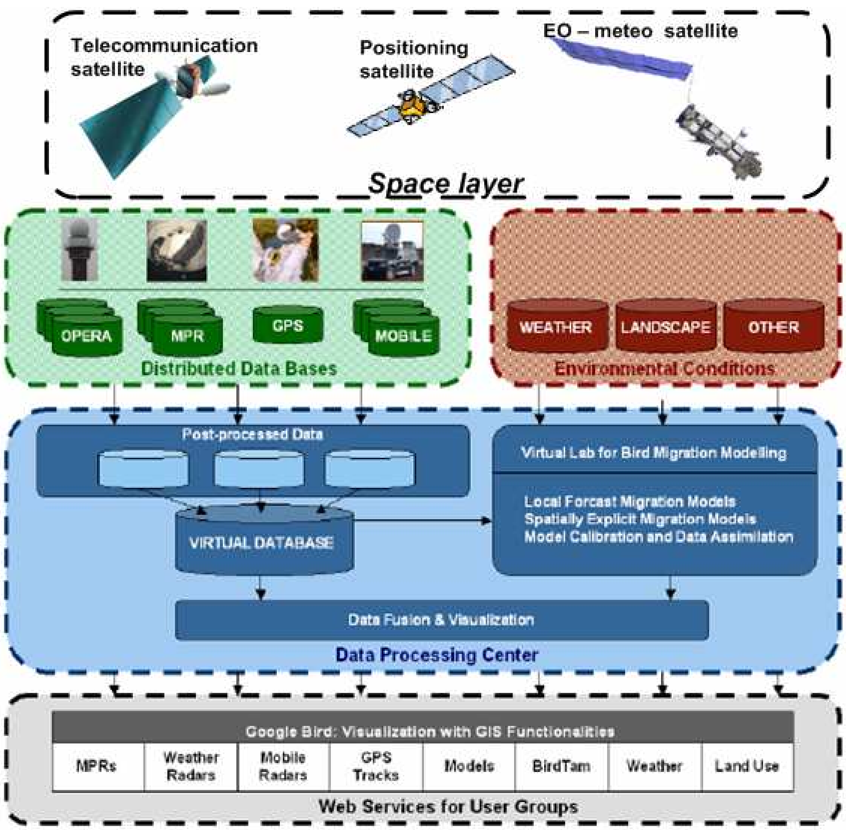

Figure 3: Flysafe system of systems overview. The Flysafe system concept exhibit four main elements: sensors; data collection network; data storage, post-processing and modelling; and data distribution and visualization.

Flysafe service overview

Various user groups and stakeholders require more easily accessible information on bird movements at different scales; some examples are flight safety, avian borne disease, migration ecology, conservation and education. The transfer of knowledge from the ornithological scientific community to user applications is crucial for developing a bird migration early warning system. Sustainable services provided by Flysafe could combine various existing bird migration measurement systems, tracking of individual birds from space and terrestrial assets, improvement and enhancement of existing technologies, modelling tools, improved access to environmental data and diverse web-services.

Within the flight safety community the aim is to build a suite of sustainable services:

- *Nowcast service*. Based on the integration of measurements from different sensors and interpolated in space with the underlying landscape properties the 3D bird migration density (BIRDTAM intensities) in near real time. Initially for the area of northern France, Belgium, The Netherlands and Germany, but with the potential to grow to a pan-European coverage (figure 4).
- *Forecast service*. Bird migration prediction models based on radar measurements, weather and landscape properties provide bird migration densities up to the next 48 hours for mission planning. Bird Migration is not a phenomenon that ends at the border of the radar range. Therefore a second *forecast service* will include local migration observations and local migration predictions into a spatially explicit framework that allows the study of migration flyways over Europe.

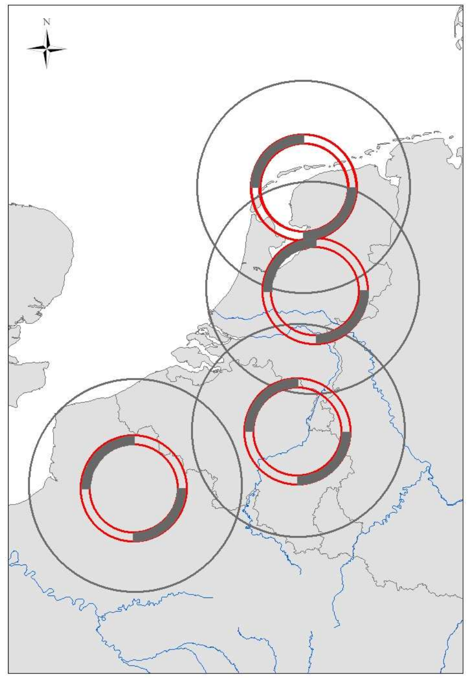

Figure 4: Area of the Flysafe nucleus. The large circles denote the maximum detection range for birds (150 km) of the four military long-range surveillance radars. Standardized measurement windows (50-60 km range, 90-180 and 270-360 degrees azimuth) for quantitative bird densities are indicated by dark grey segments.

- *Airport service*. Providing both bird control units and air traffic control with an alerting system of birds crossing the flight path of starting aircraft. The service is provided as a combination of specialized short range local radars (which detects “large” bird echoes and predicting their track in three dimensions and time) with general information of high altitude broad front bird migration.

- *Airport vicinity service*. Monitoring service for bird movements in the airport vicinity with respect to spatial planning activities and determining (seasonal) hazardous locations.

ACTIVITIES SO FAR

The preliminary activities that ESA IAP has started in July 2007 have already resulted in the following results:

- The user requirements for all four services are formulated and agreed on by all Air Force users.
- Four long-range surveillance radars of three different Air Forces equipped with dedicated bird detection software are used as sensors and store their data automatically into a centralised database.
- Two C-band Doppler weather radars of the Royal Netherlands Meteorological Institute are used as sensors and store their data automatically into a centralised database. The wind profile measurements of these sensors are contaminated with bird signals which are used as bird indicators at 200 m altitude layers between 0 – 4 km altitude.
- Calibration campaigns have been carried out by the Swiss Ornithological Institute with their dedicated bird radar. During three campaigns the calibration was carried out between the bird radar and two C-band Doppler weather radars from the Belgian Meteorological Institute and the Royal Netherlands Meteorological Institute, a dual polarization weather radar from Meteo France as well as two military long-range surveillance radars.
- Both migratory Lesser Black-backed Gulls as well as non migratory Herring Gulls were equipped with GPS-tags to extract 3D data about their daily and seasonal patterns. The data is used as input and calibration for spatially explicit models of bird migration and for adding altitude to models of local movements.
- All the data types are stored in a central database, hosted on a project server by SARA Computing and Networking Services. Users can access the data directly or retrieve information via web-bases services.
- An operational centre for the Air Force users is developed on a tiled panel display.
- Initial development of forecast models by the University of Amsterdam. Both data driven site specific forecast models as well as a concept driven spatially explicit framework for Europe and North-Africa is being built. These models rely on landscape and land use data (from CORINE Project) and weather forecasts (from ECMWF model).
- Testing a small scale dedicated bird radar, developed by TNO, Defence, security and safety for use on airfields or (bombing-) ranges. Such a radar could act as an operational alerting

system for birds crossing the flight path of starting aircraft.

ACKNOWLEDGMENTS

We would like to thank all members of the FlySafe basic activities for their involvement and commitment to the project: members from the German Bundeswehr, the Belgian, French and Royal Netherlands Air Forces, University of Amsterdam (NL), TNO Defence, Security and Safety (NL), SARA Computing and Networking Services (NL), the Institute for Avian Research (Vogelwarte Helgoland) (D), the Swiss and Dutch Ornithological Institutes (SOI and SOVON), Royal Netherlands Meteorological Institute, Meteo France, Belgian Meteorological Institute, IDA TU Braunschweig (G), Thales Raytheon Electronic Systems (F), Thales Alenia Space (F) and The European Space Agency/ESTEC. Arie Dekker from the RNLAF for his fruitful discussions and critical correction of earlier drafts.

REFERENCES

1. Alerstam, T., *Bird migration*. 1990: Cambridge University Press. 419pp.
2. Desholm, M., et al., *Remote techniques for counting and estimating the number of bird–wind turbine collisions at sea: a review.* Ibis, 2006. **148**: p. 76-89.
3. Richardson, W.J. and T. West, *Serious birdstrike accidents to military aircraft: updated list and summary*, in *Proceedings of the 25th International Bird Strike Committee*. 2000, IBSC: Amsterdam, The Netherlands.
4. Thorpe, J., *Fatalities and destroyed civil aircraft due to bird strikes, 1912-2002*, in *Proceedings of the 26th International Bird Strike Committee*. 2003, IBSC: Warsaw, Poland. p. 1-28.
5. Thorpe, J., *Fatalities and destroyed civil aircraft due to bird strikes, 2002-2004*, in *Proceedings of the 27th International Bird Strike Committee*. 2005, IBSC: Athens, Greece. p. 1-9.
6. Allan, J.R., *The costs of birdstrikes and birdstrike prevention*, in *Human Conflicts with Wildlife: Economic Considerations*, L. Clarke, Editor. 2002: Fort Collins: US Department of Agriculture. p. 147-153.
7. Richardson, W.J. and T. West, *Serious birdstrike accidents to U.K. military aircraft, 1923 to 2004*, in *Proceedings of the 27th International Bird Strike Committee*. 2005, IBSC: Warsaw, Poland. p. 1-19.
8. Dolbeer, R.A., *Feathers in the fan.* Airosafety world, 2008(6): p. 22-26.
9. Blokpoel, H., *Bird hazards to Aircraft*. 1976, Ottawa, Canada: Clarke Irwin & Co Ltd. 235p.
10. Transport-Canada, *Sharing the Skies: An Aviation Guide to the Management of Wildlife Hazards*. 2001, Transport Canada Aviation Publishing Division: Ottawa.
11. Dekker, A. and H. van Gasteren, *EURBASE: Military bird strike frequency in Europe*, in *Proceedings of the 27th International Bird Strike Committee*. 2005, IBSC: Athens, Greece. p. 1-10.
12. Holleman, I., H. van Gasteren, and W. Bouten, *Quality Assessment of Weather Radar Wind Profiles during Bird Migration.* Journal of Atmospheric and Oceanic Technology, DOI: 10.1175/2008JTECHA1067.1, 2008.
13. van Gasteren, H., et al., *Extracting bird migration information from C-band Doppler weather radars.* Ibis, doi:10.1111/j.1474-919X.2008.00832.x, 2008.