VORTEX FLIGHT SAFETY – PROBLEMS AND PROSPECTS INTRODUCTION

Introduction

Introduction of advanced heavy transport aircraft and the continuous growth of air traffic near major airports have put the flight safety problem related to aircraft wake vortices high on the agenda all over the world. The problem of vortex flight safety has been known for many years but the international aviation community heeded the need of resolving it only in the early 1950s.

The United States, Soviet Union and a number of European countries launched systematic research into the problem in the late '60s. About at the same time, ICAO introduced the rules governing the minimum distances between aircraft (safe separations) to ensure safe entrance into the wake vortices generated by a leader aircraft. Then the rules were repeatedly modified to extend the minimum distance, which, in the end, resulted in the world's major airports nearing the breaking point in their throughput capacity.

The scale of the problem necessitated international cooperation to resolve it. Most influential aviation organisations, which shape major air traffic control policies throughout the world (EUROCONTROL, FAA), initiated systematic research into a global revision of vortex flight safety rules and codifying them in line with ICAO's legal standards.

1. Vortex Flight Safety Problem

Wake vortices generated by a flying aircraft may pose danger to any other aircraft entering it. Getting into a vortex wake may result in buffeting (frequency-resonant excitation of an aircraft's components), uncontrolled rate of roll (200/200 deg./s) coupled with an altitude loss (150-200 m), and a loss of control of the aircraft (Fig.1).

The in-flight control loss has been a main reason behind air accidents all over the world over the past decade, according to official FAA data published by the Aviation Week & Space Technology on 26 August 2002 (Fig. 2). The contribution of turbulent wake vortices to the reasons for control loss is more than 30% (Fig. 3). According to the US National Transportation Safety Board (NTSB), over the past 10 years, upwards of 40 aircraft in the United States alone have been seriously damaged or destroyed as a result of entering wake vortices en route or during takeoff or landing.

According to estimates of British experts, in the Heathrow airport there is a precondition for an air accident due to getting into wake vortices per every 150 takeoffs or landings.

With the far less workload on the aircraft in Russia and other CIS member states as compared with the European Union, there have been grave air accidents and fatal accidents recorded, which have been caused by fixed-wing and rotary-wing aircraft-induced wake vortices (Table 1).

Table 1. Grave vortex wake-induced air accidents in Russia and the CIS.

Date	Site	Type of aircraft to get into the wake	Type of aircraft to generate the wake	Outcome	Misc.
24 April 1970	Kapustin Yar (Russia)	Tu-22K	Il-76	Aircraft explosion	Mid-air refuelling
20 March 1979	Charjou (Turkmenistan)	Yak-405	Mi-6	Crash, 56 people dead	
22 April 1986	Akhtubinsk (Russia)	MiG-21	Tu-16	Crash	
16 January 1987	Tashkent (Uzbekistan)	Yak-40	Il-76	Crash, 5 people dead	
22 August 1995	Domna (Russia)	MiG-29	MiG-29	Crash	Takeoff as part of a package

EC international vortex flight safety programme;

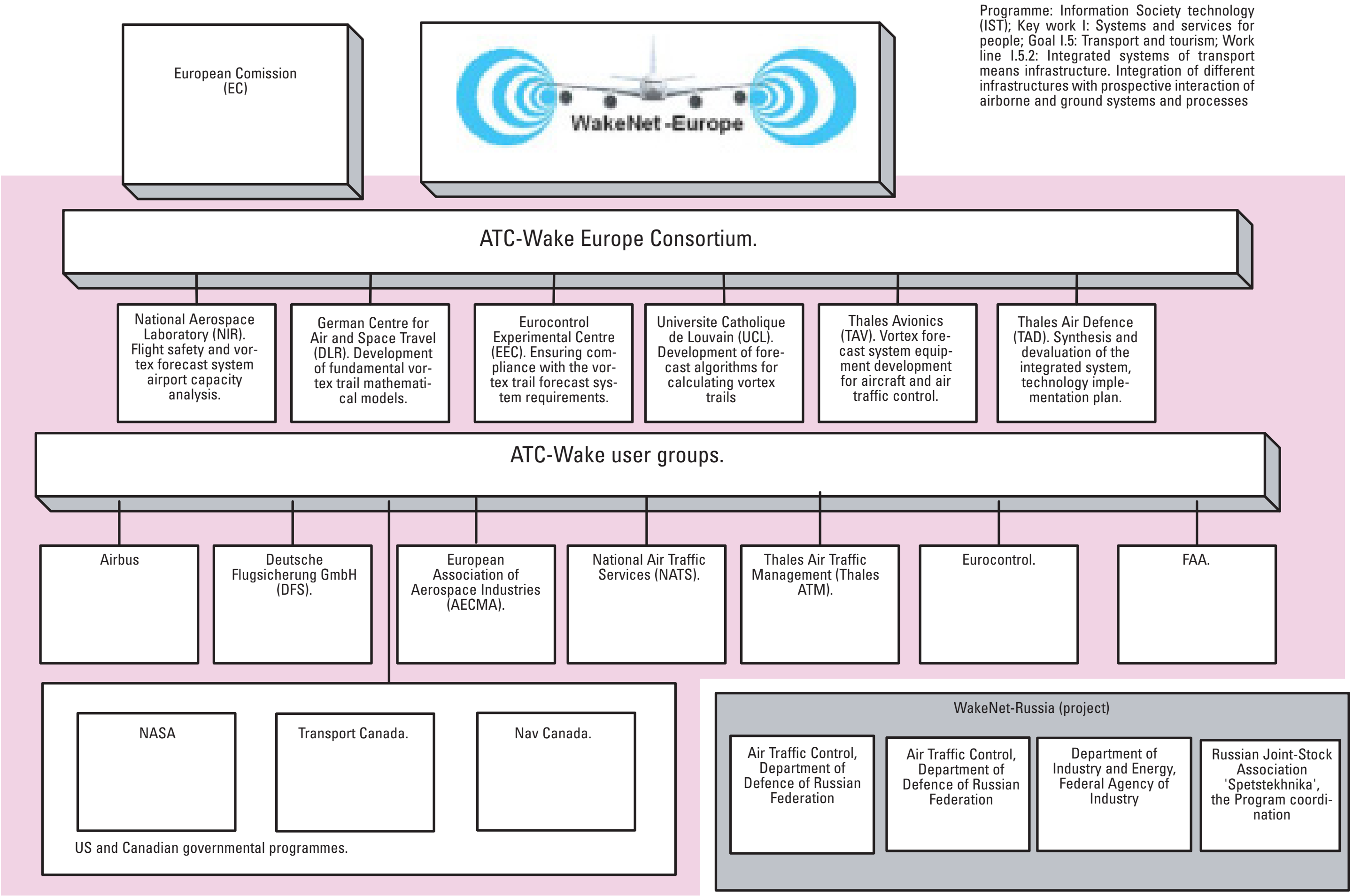

Fig. 5 Structure of the European project on development of the operating integrated vortex trail forecast and monitoring system.

The vortex safety problem is exacerbated by flight crews lacking skills to make up for turbulence resultant from wake vortices and having a vague idea of the vortex position relative to the generating aircraft and of the possible impact of the wake vortices on their aircraft. Still, having found himself within a vortex wake, a pilot has to make the right decision really quickly. It is impossible to learn to behave right within the wake vortices on real missions due to the danger posed by the vortices and their numerous characteristics dependant on factors, as well as due to the lack of dedicated simulators.

2. Flight Rules and Vortex Safety

At present, ICAO rules, setting the minimum separation distances for fixed-wing aircraft flying in the same direction are valid. There are similar civil aviation flight rules NPP GA in Russia. Under the above rules, the minimum safe distance depends on the aircraft types and equal, e.g. 7.5 km for a heavy aircraft following another heavy aircraft and 11 km for a light plane following a heavy one. The permissible time slot is 2-3 min. for landing on or taking off from the same runway or from closely spaced parallel runways.

However even sticking to the rules does not guarantee complete flight safety, which was graphically proven by the crash of a US A300 on 12 September 2001 when 265 people died due to the airliner getting into the vortex wake generated by a Japanese Boeing 747. According to the NTSB (the USA), the A300 was travelling in compliance with the ICAO rules. This underlines the fact that the existing rules are ripe for overhaul, which has repeatedly been undertaken as a result of another crash. Such revisions would arbitrary extend the safe minimum distances. For instance, from 1970 to 1996, FAA altered the aircraft separation distance norms 7 times to achieve vortex flight safety.

Such decisions were taken following a long period of seemingly safe operations with the use of certain separation standards and operating procedures, resulting in air accidents or fatal accidents due to a rare coincidence of operating and weather factors causing aircraft incursions into wake vortices. Nonetheless, the vortex safety separation standards are obligatory during en-route flights, takeoff and landing. According to the WakeNet Europe, departure and landing delays due to the ICAO-compliant safe time slots in European airports are total 19% of all the delays. This is estimated to have grown up to 40% by 2010 and up to 45% by 2015.

According to the NLR laboratory (the Netherlands), such delays cause airport services and air companies to lose EUR 2,486 and EUR 785 per flight respectively. Estimated financial losses to be suffered by air carriers in the

	2002	2003	2004	2005	2006	2007	2008	2009
ATC Wake Project								
Marketing								
Full System Mock-Up								
Test Procedures								
Full Scale Tests								
Evolution of ATM Procedures								
System Final Specification								
Industrialization								

Table 2. Work schedule for developing the operating integrated vortex wake forecasting and monitoring system.

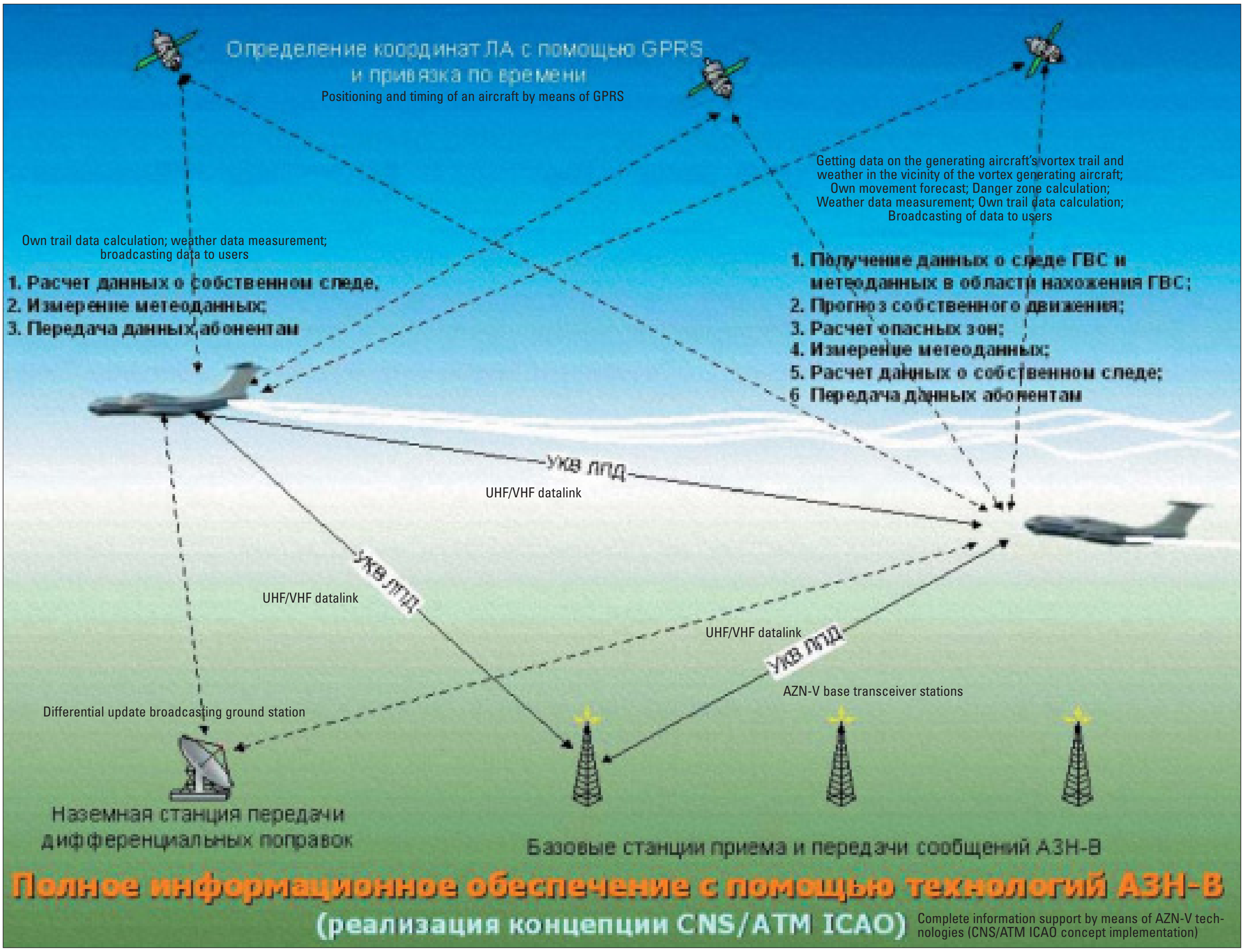

Рис. 6. Интегрированная система вихревой безопасности.

Fig. 6. Integrated vortex safety system.

United States and Europe may have totalled up to $4 billion by 2010.

Aviation experts and scientists from all over the world for years have been seeking a resolution to the problem and developing systems to allow a safe reduction in the minimum distances, thus increasing the airports' traffic capacity and en-route aircraft separation density without hampering the existing flight safety level.

3. EU Programme on Establishing an Operating Integrated Wake Vortex Forecasting and Monitoring System

A solution of the vortex flight safety problem lies in informing flight crews and air traffic controllers of the vortex situation. Vortex wake monitoring may be conducted through observing and measuring the wake vortex parameters or through calculating them. The NASA-developed AVOSS system was the first experimental system of the kind. However, in addition to tackling technical matters, developing such a system calls for a revision of the flight safety regulatory and legal framework. Such complicated interdisciplinary scientific and organisational tasks require the pooling of the efforts of the whole of the international aviation community, including scientists, air companies, airports, flight crews, air navigation services providers, governmental bodies and aircraft developers.

In December 1997, the International Wake Vortex Conference was held in Ottawa. The Conference's objective was to expand the international cooperation in developing wake vortex forecasting systems and discuss approaches to enhance flight safety and efficiency due to vortex wake modeling. Also on the agenda were real-time forecasting and meteorological requirements. Scientists from Russia, Canada, the United States, the UK, France and Germany shared their views of probing into the problem and solutions possible.

The Conference made a decision on the need for financing several national programmes and intensifying the international cooperation in the field. Based on the decision made, organisations, which coordinate R&D and regulatory activities in the field, were established in the United States (WakeNet USA) and Europe (WakeNet Europe). The work done by the WakeNet Europe resulted in a recommendation to have a Europe-wide operating integrated wake vortex forecasting and monitoring system developed. The European parliament agreed to bankroll the major international effort, for which implementation the ATC-Wake Europe commission has been set up. The commission unites 6 European partners, namely (Fig. 5):

- NLR - National Aerospace Laboratory (the Netherlands);
- DLR - German Centre for Air and Space Travel (Germany);
- EEC - EUROCONTROL Experimental Centre (France);
- UCL - Université Catholique de Louvainé (Belgium);
- TAV - Thales Avionics (France);
- TAD - Thales Air Defence (France); and European, Canadian, and US user groups and international organisations.

ATC-Wake is aimed at developing an operating integrated wake vortex forecasting and monitoring system for use as part of the European airport network within the coming 5 to 10 years. The members of the organisation believe it is feasible to complete the technical part of the effort within 5 years and contact ICAO to modify the Standards and Recommended Practices (SARPs) formally in terms of vortex safety roughly within the same timescale (Table 2).

The commission believes that the only thing remaining is the development and implementation of a quite integrated system for the

European airport network. Part of this 'approved' technology is the VFS (Vortex Forecasting System) developed by Russian scientists under the international programme. However, despite Russia's scientific lead is this field, it cannot participate in the ATC-Wake Europe because the programme is funded by the EU, which member Russia is not. As a result, Russia might fall behind in this sphere and have later to fit its air traffic control facilities and airborne avionics suites with foreign-made technologies, which would call for huge spending in hard currency.

4. Status of Russian Vortex Safety R & D Programmes

The main ideas related to the current level of insight in the problem of wake vortex safety were initiatively generalized by the Russian Joint-Stock Association 'Spetstekhnika' with attraction of researchers of the GosNITs TsAGI, the Dorodnitsyn Computer Center RAS, the companies 'Avionika', 'Elektroavtomatika', 'Tupolev', 'Sukhoy', etc. The ideas are based on the approaches to the problem of wake vortex forecasting developed in Russia since the 1970s by Professor S.M. Belotserkovsky and his team at the TsAGI and the Air Force's Zhukovsky Academy beginning from 1970s.

The generalized approaches and separate results have given the basis for the main ideas of the Integrated Vortex Safety System intended to be implemented in Russia. The conception is based on the ICAO recommendation for all world states to build their air traffic control (ATC) using satellite systems of connection, navigation, and surveillance (the CNS/ATM concept) and should be adjusted with the developing European and American systems.

Russia has adopted the 'Concept of Upgrading and Honing the United Air Traffic Control Systems of the Russian Federation' approved by the Russian government in its Resolution #144 dated 22 February 2004. We believe that the vortex flight safety problem should be resolved within the Concept framework, and the proper Russian programme should be elaborated. In so doing, the main task is development of ground and airborne equipment for state air traffic automation, including an integrated wake vortex safety system (Fig. 6).

The CNS/ATM concept is wrapped around the following basics:

C = Communications. Communications with aircraft is to be maintained only via digital means and cover air traffic, messaging (weather reports, NOTAMs), etc;

N = Navigation. Navigation is to be based on the GNSS (Global Navigation Satellite System) and the Russian system GLONASS. The baseline system ensures 20-m accuracy with 95% probability and 2-3-m accuracy in the differential navigation mode;

S = Surveillance. This is the main tool of air traffic controllers to check if the distance between aircraft is right, to manage air traffic and to assist flight crews in handling navigational tasks;

ATM = Air Traffic Management. ATM is aimed at enabling aircraft to stick to their echelons and using preferable routes and altitudes without hampering flight safety.

Once aircraft have been fitted with onboard SATNAV assets and the ADS-B VHF/UHF transceiver, the onboard vortex flight safety system will allow swap relevant data via datalinks based on multisensor data processing.

Under the CNS/ATM concept and its underlying principle 'Everybody sees everybody else', aircraft location and vortex situation data necessary for calculating dangerous vortex areas are to be fed to the cockpits or air traffic controller workplaces via specified data protocols of an open VHF/UHF digital datalink (see Fig. 6). To this aim the Russian Joint-Stock Association 'Spetstekhnika' and the Dorodnitsyn Computer Centre RAS have developed specialized algorithms based on the operating forecasting software VFS. The latter is designed for calculation of wake vortices also with direct participation of researches of the 'Spetstekhnika' and the Computer Centre.

The VFS algorithms have been thoroughly tested by the US independent organisation Northwest Research Associates, Inc. in 2000 based on the data gathered in more than 1,500 flight experiments involving aircraft in different weight classes under ICAO classification - the A300, A310, A320, Boeing 747, Boeing 767, Boeing 737, Boeing 727, DC-9, DC-10, MD-11, MD-80 and L-1011 at dedicated runways of airports in Memphis and Dallas. The software proved to be effective and ready for use as a part of vortex forecasting systems. For example, the VFS algorithms are planned for use in the ATC-Wake Europe.

Thus, Russia has prepared the theoretical and experimental fundamentals of a solution for the vortex flight safety problem. However, given the importance of the problem and the need to resolve it at the governmental level, a national programme (WakeNet Russia), similar to those in major air powers, should be devised to completely resolve the problem.

Conclusion

Thus, the EU and the US are running national wake vortex safety programmes aimed at modifying the ICAO rules and working out new requirements to equipment of aircraft, airport, and ATC systems to provide vortex flight safety since 2007.

There is no national wake vortex safety programme in Russia. Work is being done mostly in a piecemeal manner on one's own hook and is incapable of meeting ICAO's new vortex flight safety requirements to be introduced. The lack of a national programme will result in a hefty monetary damage to be suffered by airlines and aircraft developers.

Meanwhile, the considerable back-log in approaches to the problem of wake vortex safety is accumulated in Russia. For example, the pilot Vortex Vision System (VVS) providing the information on the current wake vortex situation to a pilot is designed. The VVS technology is protected according to the international patent right. The company 'FAPRID' under Russian Department of Justice is performing legal accompaniment of the VVS development. The existing technological backlog in the vortex flight safety field and the current R&D capabilities still allow Russia to quickly integrate into the relevant international programmes under the auspices of ICAO, should there be timely support on the part of the Russian government. АКО