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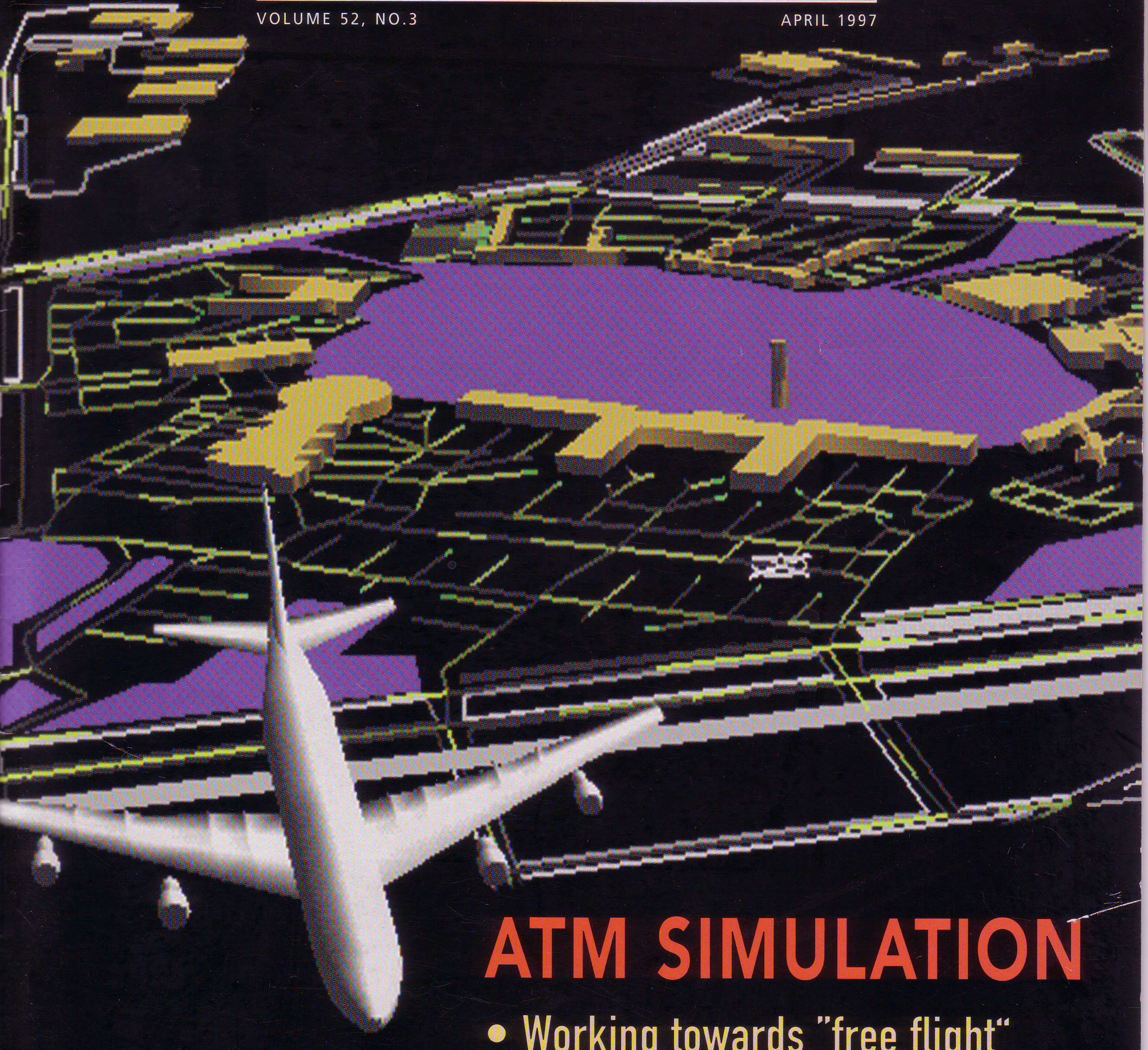

ATM SIMULATION

- Working towards "free flight"
- CNS/ATM: costs vs. benefits

Spanish study of costs and benefits shows profitable results at country-wide level

A recent cost-benefit analysis completed by Spain reveals that the value of the benefits provided by the new CNS/ATM systems outweigh the costs of their implementation in a number of different scenarios. In all cases studied, the beneficiaries included the ATS provider, aircraft operator and airline passenger.

DAVID DIEZ
AEROPUERTOS ESPAÑOLES Y NAVEGACIÓN AÉREA

MIGUEL NARDIZ
ARTHUR ANDERSEN (SPAIN)

THE GLOBAL communications, navigation, surveillance and air traffic management (CNS/ATM) systems concept now being implemented worldwide was adopted by ICAO contracting States in 1991. Aside from the evident technological advantages offered by the new systems, support for the concept came from a broad economic study which indicated that, on a global basis, the benefits greatly exceeded the costs of implementing the new technologies.

Although this study showed that implementation of the future air navigation system concept was cost-effective on a global basis, more information was needed concerning its implications at the regional and national levels. For that reason, States were urged to undertake their own cost-effectiveness and/or cost-benefit analyses to determine how they would be affected by the implementation of the new systems.

In Spain, the Aeropuertos Españoles y Navegación Aérea (Aena) initiated a cost-benefit analysis with the objective of evaluating the economic feasibility of implementing the new technologies nationally and analysing the different implementation alternatives for the purpose of determining which was the best option. The study focused on the airspaces depicted in *Figure 1.*

The analysis, performed over a 10-month period by a team of personnel from Aena's Directorate of Systems and Facilities and from the consulting firm Arthur Andersen, was completed in June 1996. The overall results revealed that the value of the benefits outweigh the costs in several different scenarios.

Analysis methodology

The cost-benefit analysis was performed by comparing the so-called "project case" (implementation of the CNS/ATM systems concept) with the "base case" (retention of the existing ground-based technology in the long term). The analysts determined the net benefit, or rather the net present value (NPV), of the new systems, presented in detail in an ICAO publication, Economics of Satellite-Based Air Navigation Services (ICAO Circular 257).

The ICAO guidance material focuses primarily on methods for determining the costs of operating the existing and new systems and on the impact of these two systems on the cost of operating aircraft. Implementation of new CNS/ATM systems is complex and consists of a package of investments. Measures of the viability of the new investment package (i.e. the project case) are based on a comparison with the costs of maintaining the existing systems in the absence of a transition to the new technologies (i.e. the base case). In other words, the benefits from implementing the CNS/ATM systems will include the cost savings from withdrawal of the ground-based facilities of the existing systems. The benefits will also include the reduction in aircraft operating costs brought about by increased airspace capacity and/or more direct flight paths made possible by the new systems. Reduced flight times for passengers are another benefit which can be expressed in monetary terms.

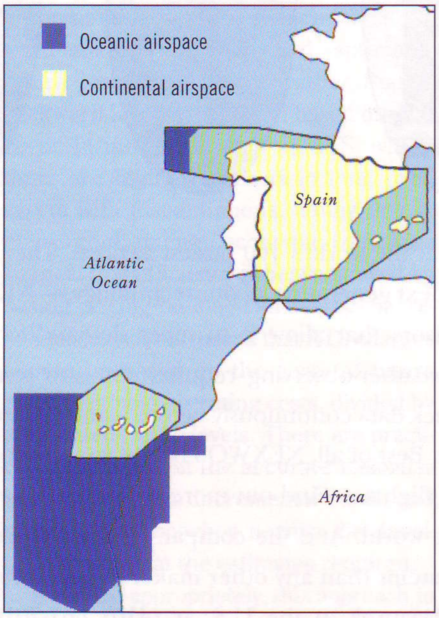

Figure 1. The cost-benefit analysis for Spain focused on peninsular FIRs and the Canarias FIR.

The NPV or life-cycle approach is a rigorous method for developing a measure of the expected economic performance of an investment project, and focuses on the annual cash flows of costs and benefits related to the project. As noted in the ICAO circular, these costs and benefits in cash-flow terms will not be distributed evenly over time. Typically, there will be large expenditures in the early years of a new project, followed by many years of benefits as well as of operating and maintenance costs.

Figure 2 shows the general methodology applied in the cost-benefit analysis undertaken for Spain. This methodology is based on the NPV approach.

The base case includes the investments and costs for maintenance, operation, training, etc., which would be incurred over the next 20 years if the new systems were not implemented and the conventional technology continued to be used. The project case includes investments and costs related to implementation of the CNS/ATM systems over a 20-year period. The project case costs correspond to both advanced systems and to current-technology systems, such as SSR, which might also be present in the project case. The project case also accounts for benefits to arise from efficiencies such as more direct flight paths and a reduction in delays.

Substantial annual expenditures which are common to both the project case and the base case during the entire analysis period, including many of the costs of maintaining, expanding and operating Spain's ATC system (known as SACTA), were excluded from the cost calculation.

Implementation scenarios

Since the CNS/ATM systems concept offers different alternatives based on the type of equipment used to perform the various functions, 12 scenarios were considered for the project case. The differences between these scenarios are limited to the equipment in use for air-ground communications and for surveillance.

The two air-to-ground communications alternatives which differentiate the scenarios are very high frequency (VHF) data link (or VDL), used for voice and data, and aeronautical mobile satellite service (AMSS) voice and data. In surveillance, the alternatives are monopulse secondary surveillance radar (MSSR), Mode S radar and automatic dependent surveillance (ADS), based either on VDL or AMSS. The navigation system, common to all scenarios, is based on satellite systems augmented by the European geostationary navigation overlay service (EGNOS), which is a wide area augmentation system (WAAS) allowing for Category I approaches. The local area augmentation system (LAAS) and the microwave landing system (MLS) are the alternatives for Category II and III approaches. The ATM system, also common to the 12 scenarios considered, is based on the current ATC system and is augmented mainly by automated and expert ATC systems which will support controller-pilot data link communications (CPDLC) and perform part of the current controller's routine work. This reduction in workload will allow the controller to manage a higher number of aircraft and therefore increase ATC capacity. The most important element of on-board air traffic management is the area navigation (RNAV) equipment which will support closer and more direct routes. In all project case scenarios, it is assumed that equipment such as VOR, DME, NDB and ILS are progressively withdrawn from service, and that primary radar is replaced by ADS in most cases, with the number of secondary radars kept to a minimum. Voice communications are replaced progressively by data communications.

The scenario generating the most impressive results, later known as Scenario 1, assumes the implementation of the following technologies: in continental airspace, communications would be provided using VDL (redundant configuration), navigation would be based on WAAS-EGNOS plus LAAS or MLS, and surveillance using MSSR (single coverage) plus ADS (VDL). ATM would be based on the SACTA ATC system plus expert systems and automation. In oceanic airspace, communications would be carried out using AMSS (redundant configuration) and surveillance would be based on ADS/AMSS (redundant configuration). Both the navigation and ATM systems would be as described for continental airspace (except for LAAS/MLS).

The implementation of these technologies by the ATS service providers needs to be accompanied by the installation of corresponding compatible avionics on board the aircraft fleet. In Scenario 1, it is assumed, for example, that 100 per cent of the commercial and instrument flight rules (IFR) general aviation fleets will become equipped with EGNOS/WAAS navigation, VDL and time division multiple access (TDMA) communications, and ADS surveillance; satellite communications equipment (AMSS) will be installed in 50 per cent of the international commercial and IFR general aviation fleets; and so on.

Efficiency benefits

The improvements in navigation, communications and surveillance, and air traffic management expected from implementation of the new systems will generate benefits in the form of improved flight efficiencies and a reduction in delays. For aircraft operators, these improvements will generate savings in fuel and other aircraft operating costs. For the passengers, they will result in reduced travel time.

The efficiency benefits represented by the project case (i.e. the 12 different scenarios) have been calculated for a maximum number of aircraft equal to the maximum number that the base case could accommodate.

Although it is evident that the project cases could manage more aircraft than the base case, the possible benefits deriving from these additional aircraft have not been quantified. This is because the validity and significance of these benefits is questionable. In the base case, once the maximum number of aircraft that the ATS system is able to accommodate has been reached, the growing passenger demand could continue to be satisfied by simply replacing existing aircraft with aircraft of greater capacity. The benefits for operators coming from such replacements — which are not quantified in the base case — would be counterbalanced by the benefits derived from the deployment of additional aircraft possible under different scenarios of the project case, at least for the 20-year period considered in the analysis.

It has been assumed that all scenarios eventually produce the same amount of benefits in terms of improved flight efficiencies and decreased delays. Obviously, some scenarios have slight advantages over others from an operational standpoint (e.g. better coverage at low altitudes or in mountainous areas, better redundancy levels, lower data-link transit delays, etc.), or even from an institutional standpoint, which should be taken into consideration in deciding between scenarios with a similar cost-benefit ratio.

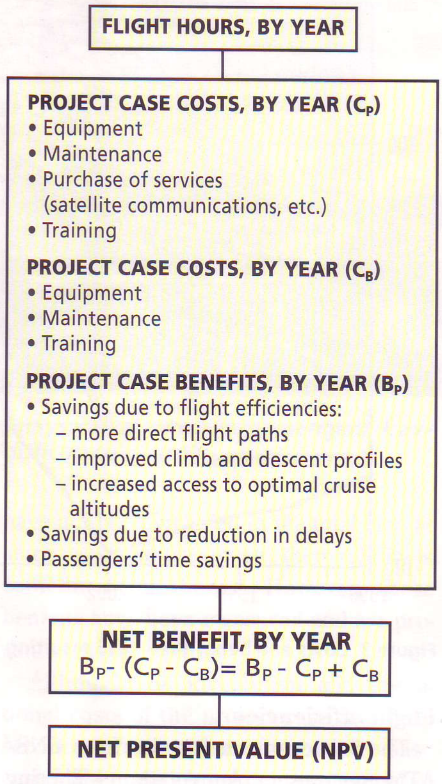

Figure 2. Methodology for the calculation of the net present value.

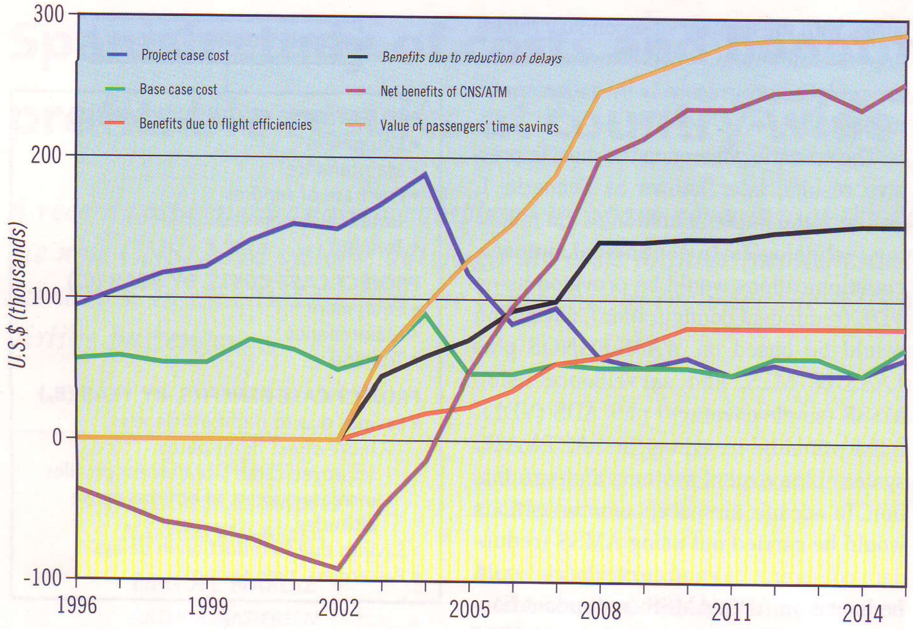

Figure 3. Costs and benefits to 2015 resulting from systems implementation under Scenario 1.

Flight efficiencies

The improvements to arise from CNS/ATM systems implementation will bring about increased efficiency in the form of direct routes, shorter and more efficient approach and take-off procedures, improved climb and descent profiles, and a greater availability and utilization of optimal flight levels. These efficiencies will generate economies in fuel and crew costs.

For the purpose of quantifying all these cost savings, which will mainly benefit aircraft operators, the percentage of aircraft equipped at any given time with the required avionics had to be estimated. Also estimated were the dates on which both the new CNS/ATM systems and the airspace structures and associated procedures needed to achieve the above-mentioned efficiencies are expected to come into operation.

The improvements in efficiency are based mainly on:

- precision RNAV navigation, using EGNOS (WAAS), which will permit implementation of a concept called "reduced lateral route spacing" and, consequently, a much more efficient direct route structure characterized by the extensive use of closely spaced pairs of parallel airways oriented in opposite directions rather than bidirectional airways. The elimination of bidirectional airways will allow optimum climb and descent profiles, which will not be staggered since aircraft will not be limited by traffic in the opposite direction.
- the reduction in the controller's workload per aircraft as a result of the progressive implementation of new automated functions which will, in turn, make extensive use of the air-ground data link and CPDLC messages. This reduced workload will make it possible for the controller to increasingly authorize more direct trajectories, especially in the terminal control area during approach and take-off.
- improved surveillance, based on ADS and its integration with radar, making it possible to apply increasingly smaller separation minima since greater levels of precision, availability, integrity and continuity of service will be ensured.

Another assumption is the dates when the stated efficiencies can be expected to take effect. These milestones are dependent on when the CNS/ATM systems themselves will begin to operate in the airspace concerned, and the date of this development, in turn, is a reflection of the selected scenario. There are several scenarios, but the element that sets them apart and has the most effect on the development of flight efficiencies is the data-link system, which may take the form of AMSS or VDL. In the case of AMSS-based scenarios, flight efficiencies would begin to take effect in 2003 and be fully achieved by 2006. For VDL scenarios, it is assumed that flight efficiencies would also be achieved in 2003, but not fully achieved until 2010.

Efficiencies are expected to first appear in 2003 in both AMSS and VDL scenarios despite the fact that avionics compatible with the AMSS will begin to be implemented much earlier than VDL avionics. The reason for this is that improvements in efficiency will not be significant until EGNOS (WAAS) is available. The AMSS scenarios assume that maximum improvements in efficiency are achieved more quickly than in the VDL scenarios because AMSS data link will be implemented in all aircraft before VDL can be fully in place.

The quantification of savings in time and fuel, derived from the flight efficiencies provided by the project cases over the base case, has been a difficult and complex task. The analysis shows that once the new CNS/ATM systems have been fully implemented, the savings that result from improved climb and descent profiles and the greater availability of optimal flight levels in the Canarias Flight Information Region (FIR) would amount to 1.5 per cent of the total fuel that would be consumed by all aircraft in the base case. For the peninsular FIRs as a whole, the savings would be 1.3 per cent.

The savings generated by direct routes and shorter trajectories in terminal control areas in the Canarias FIR would be 2.7 per cent of the total flight hours that would be flown in the base case by all aircraft. For the peninsular FIRs as a whole, it would be 3.4 per cent. Obviously, a reduction in flight hours means fuel and crew cost savings.

Reduction in delays

When traffic volumes approach the theoretical traffic handling capacity of the airspace, the resultant congestion may cause delays in flights and disruptions to timetables. Unless capacity is increased, growth in demand would cause congestion and delays to escalate rapidly, with serious consequences for aircraft operating costs and passenger transit time. Furthermore, unacceptable delays will constrain demand, since passengers will opt for other, more efficient, means of transport. Reduced separation standards and improved airspace management made possible by the implementation of the CNS/ATM systems will increase capacity and hence eliminate most of the congestion costs that might otherwise be incurred.

In order to estimate the benefits to result from a reduction in delays, it has been necessary to forecast the extent of the delays that would be expected year-by-

CNS/ATM improvements that reduce flight delays will also reduce passengers' travelling time, but the value of this benefit is difficult to quantify. Boeing photo

year in the event that the CNS/ATM systems are not implemented.

The benefits that have been taken into account are only those related to flights which depart or arrive at Spanish airports. These benefits have been calculated separately for domestic flights, which are constrained by the capacity limitations of the Spanish ATS system, and for international flights, as they are constrained mainly by the capacity limitations of the European ATS system.

For the purpose of estimating the benefits from a reduction in delays, it has been assumed that the increase in theoretical capacity over the base case — as a consequence of CNS/ATM systems implementation — will grow to 50 per cent between 2002 and 2015. Were CNS/ATM systems not implemented, it is estimated that increasing delays would prevent further domestic traffic growth (in terms of the number of flights) from 2008, with international traffic reaching a plateau in 2003. The average hourly cost of a delay was assumed to be between U.S. $1,223 and $1,408, depending on aircraft type.

Time savings for passengers

CNS/ATM improvements that allow more direct flight trajectories and reduce airspace congestion and flight delays will also reduce passengers' travelling time. If passengers value such time savings, they of course represent an additional benefit.

Time savings will depend on aircraft size (the average number of seats for each type of aircraft), average load factors, and the value of passenger time.

The value of passenger time is, in practice, extremely difficult to quantify and depends on passenger perceptions and trip purpose (e.g. leisure or business). Since its validity is sometimes questioned and ultimately depends on the passenger's willingness to pay for it, this benefit has not been included in the calculation of a project case net benefit; nevertheless, it has been calculated for information purposes, taking into account the flight hours saved, and assuming an approximate cost of $25 per hour (a value obtained from a cost-benefit analysis of high-speed train services in Spain).

Scenario	ATS Service Provider	Aircraft Operators	Total NPV	Time Savings for Passengers
Scenario 1	82 165	306 723	388 888	822 681
Scenario 2	131 196	202 034	333 230	865 323
Scenario 3	109 500	183 735	293 235	865 323
Scenario 4	32 197	294 563	326 760	865 323
Scenario 5	39 013	289 184	328 197	865 323
Scenario 6	144 904	212 746	357 650	865 323
Scenario 7	105 333	281 589	386 921	829 544
Scenario 8	143 806	182 646	326 452	865 323
Scenario 9	128 886	178 458	307 344	865 323
Scenario 10	69 777	279 097	348 874	865 323
Scenario 11	68 951	274 724	343 675	865 323
Scenario 12	149 364	202 761	352 125	865 323

Figure 4. The net present value in thousands of dollars for 12 scenarios. A positive outcome is indicated for each scenario.

Results of the analysis

The results show that all of the alternatives are profitable at a country-wide level, both from the perspective of the ATS service provider and the aircraft operator. The analysis also showed, of course, that all alternatives are beneficial to the passenger.

Figure 3 illustrates the annual flow of costs and benefits over the 20-year period for Scenario 1. The overall net present value for Scenario 1, including the impacts on the ATS service provider and the aircraft operators, is estimated to be $389 million (all financial figures in U.S. currency). This was better than the equivalent results for the other scenarios. For Scenario 1, the NPV for the ATS provider is $82 million, and for the aircraft operators, $307 million. The value of the passenger time savings is estimated to be $823 million for this scenario — an impressive, although perhaps debatable additional benefit.

Figure 4 presents a summary of the results for all the scenarios. The benefits from a reduction in passenger travel time have not been included in the total benefit since, as stated previously, their validity is sometimes questioned. However, these benefits have been measured and are presented independently.

Although the investment and operational costs of the project case are in all scenarios greater than those of the base case, the benefits from an improvement in flight efficiencies and a decrease in flight delays produce overall positive results.

Since there are no great differences in the profitability of the different scenarios, sensitivity analysis takes on special significance. This is so because a small difference in the value of certain variables, such as the cost per kilobit of satellite communications, could affect the profit-based ranking of the scenarios. For example, if this cost were $0.40 instead of $0.50, Scenario 5 — where double surveillance coverage is provided by ADS/VDL and ADS/AMSS, and where satellite communications offer redundancy and service in areas not covered by the VDL — would be as profitable as Scenario 1.

It has not been the goal of this cost-benefit analysis to reach a final conclusion about what is the best possible alternative for Spain, since that decision must also take institutional and political issues into consideration. This analysis and its results are offered as guidance in finding the best possible alternative. It could also help other analysts to perform more detailed calculations, and help generally in planning the implementation of the CNS/ATM systems in Spain. □

David Diez is the Analysis Technical Director for the Aeropuertos Españoles y Navegación Aérea (Aena). Miguel Nárdiz is the Analysis Execution Director for Arthur Andersen, a consultancy specializing in financial matters.