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The impact of fragmentation in European ATM/CNS

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EUROCONTROL

BACKGROUND

This Report has been commissioned by the Performance Review Commission (PRC).

The PRC was established in 1998 by the Commission of EUROCONTROL, in accordance with the ECAC Institutional Strategy (1997).

One objective in this Strategy is "*to introduce strong, transparent and independent performance review and target setting to facilitate more effective management of the European ATM system, encourage mutual accountability for system performance and provide a better basis for investment analyses and, with reference to existing practice, provide guidelines to States on economic regulation to assist them in carrying out their responsibilities.*"

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The impact of fragmentation in European ATM/CNS

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SUMMARY

This report documents the results of a study that has evaluated the impact of fragmentation in en-route European Air Traffic Management and Communications, Navigation and Surveillance (ATM/CNS).

Keywords

Fragmentation	En-route	Scale effects	Piecemeal procurement
ATM systems	ANSP	Duplication	Support costs
CNS infrastructure	Area Control Centres	Maintenance	Transition costs

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Executive Summary

Introduction

1 The adverse impact of fragmentation in the European Air Traffic Management and Communications, Navigation and Surveillance (ATM/CNS).system has long been a concern of the Performance Review Commission (PRC). The recent Single European Sky legislation is intended to have a major impact on fragmentation; in particular it will foster airspace rationalisation and restructuring, consolidation of facilities, and harmonisation of systems and procedures. The opportunities provided by this legislation, combined with commercial and other pressures to manage costs, have prompted several ANSPs to take actions to reduce the adverse impact of fragmentation.

2 In order to have a more informed debate on this complex issue, the PRC commissioned the Solar Alliance (now Helios Economics and Policy Services) to undertake a study of the impact of fragmentation in European ATM/CNS. This document is the report of that study.

3 In conducting the study, we drew extensively on the experience of EUROCONTROL Agency staff. As well as bilateral discussions with a number of ANSPs and user representatives, three Stakeholder Consultation meetings were held, in January, July and November, at which representatives of a wide variety of interests were shown the emerging conclusions of the work, and given the opportunity to share their views with the consultants, the PRC and the PRU. Our final conclusions have benefited greatly from the feedback obtained from stakeholders in this way.

Objectives and scope of the study

4 The main objective of the study was to establish the order of magnitude of the impact of fragmentation, and in which areas the impact was most important. This was an essential first step to distinguish the areas in which most benefit can be gained from measures to reduce fragmentation from those in which only minor benefits can be expected. We then reviewed the range of measures that have been (or are currently being) taken to reduce fragmentation, and considered whether there are significant gaps. Experience from two other industries (rail and electricity) was also reviewed, to see if there were any useful lessons for ATM/CNS.

5 The focus of the study was limited to en-route ATM/CNS, and in particular to fragmentation issues around ACCs, ATM systems and interfaces, duplication of CNS infrastructure, and duplication of associated support costs. Terminal ANS, ancillary services such as aeronautical MET and AIS were outside the scope of the study, as were costs of on-board equipment. In addition, fragmentation between civil and military provision was also excluded. All these issues are likely to have an impact on fragmentation, but to restrict the study to an achievable scope, they have not been addressed so far.

6 The costs of moving from a fragmented system to a defragmented one may be substantial and in some cases prohibitive. The transition costs will depend critically on both the timing of the defragmentation measure – measures taken at the end of the lifetime of assets will generally be less costly – and on the geographical location of the measure. Transition costs were not addressed in this study. They would probably be best addressed in the context of determining priorities for

individual programmes. The policy implications for defragmentation measures would differ depending on whether the measures involved simply coordination of operations, on the one hand, or included consolidation of capital assets (such as ATM systems and buildings), on the other. Equally, policy implications will differ depending on whether the major consolidation or coordination is required at a national, regional or pan-European level.

7 The Terms of Reference of the study emphasised the costs of fragmentation, but require us also to examine the impact in other key areas of performance: safety, quality of service, and capacity. In general these can be assessed as the other side of the coin from costs. We would argue that fragmentation does not reduce safety, but increases the costs of maintaining or enhancing the required levels of safety. Similarly, fragmentation does not necessarily reduce capacity, but increases the cost of providing and enhancing capacity.

A definition of fragmentation

8 For the purpose of the study "fragmentation" was defined as referring to the division of air navigation service provision into smaller decision-making or operational units than would result from considerations of optimum scale. In Europe, this has mainly arisen from the organisation of ANS at the state level. However, fragmentation also arises through smaller than optimal operational units within national ANSPs. These units may have become sub-optimal, for example, as changes in the technology of service provision have raised the optimum size of a centre upwards.

Costs of the European ATM/CNS system

9 The first step in assessing the costs of fragmentation in the European ATM system was to understand what the costs of that system were and how they arose. Only then can one start to assess the impact of fragmentation on each area of cost. Two major resources are required to run an ATM/CNS system: the capital assets, and the staff, with associated non-staff operating costs. The study sought to estimate the order of magnitude both of the total costs of the existing system in each of these categories, and how those total costs arose in terms of the areas of focus of the study: ACCs and ATM systems; CNS, and associated support.

10 The task of assessing the total costs of the system and how they were divided up in this way was a surprisingly difficult one. ACE data, CRCO data and ANSPs' Annual Reports gave an incomplete picture, particularly concerning how costs and asset values were split between ACCs and ATM systems, CNS and support. We estimated costs based on physical infrastructure and industry estimates of unit capital replacement and operating costs, with validation against Annual Reports. Given the lack of consistent and complete data, this approach was not precise, but provided a way to make a first estimate of the orders of magnitude.

11 Table 1 highlights key figures characterising the European ATM/CNS physical infrastructure:

		Number
COM	VHF ground stations	1123
	Ground-ground voice links	2246
	ACC links (inter-State)	160
	ACC links (intra-State)	386
NAV	DME	601
	NDB	349
	VOR	617
SUR	En-route primary plus Mode S	63
	En-route Primary plus MSSR	5
	Approach primary plus MSSR	92
	Approach primary only	43
	MSSR only	140
ATM	ACCs	69
	Sectors[1]	792

Table 1: Key European ATM/CNS physical infrastructure (2003 data)

12 In addition to this physical infrastructure, a large number of diverse ATM systems exist, although it is difficult to assess precisely how many since it is questionable how much systems must diverge before being regarded as “different”.

13 We assessed capital replacement costs for ATM systems and ACC buildings from recent examples of new centres by deriving a statistical relationship including a fixed cost and a cost per sector, as shown in Figure 1 below.

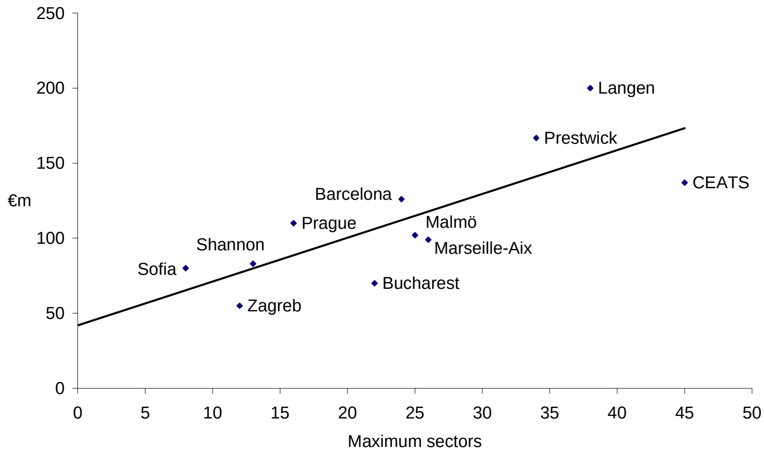

Figure 1: Capital costs of typical new ACC developments

[1] Maximum number of physical sectors available for the ACCs. The number of sectors actually used in 2003 was 606.

14 Using these techniques, we assessed the capital replacement costs for the en-route European ATM/CNS system as some €10 billion in 2003, as shown in the first column of Table 2 below; annual operating costs amounted to some €3500m. Total annual costs (around €4340m) were obtained by annualising the capital costs over eleven years (a typical ratio for ANSPs between asset acquisition costs and the sum of depreciation and finance costs).

	Capital replacement costs	Annual operating costs	Total annual costs	
COM	€560m	€60m	€110m	2.5%
NAV	€230m	€10m	€30m	0.7%
SUR	€3,000m	€210m	€500m	11.5%
ACCs & ATM systems	€4,900m	€2,100m	€2,500m	57.6%
Associated support	€1,000m	€1,100m	€1,200m	27.7%
Total	**€9,690m**	**€3,480m**	**€4,340m**	**100%**

Table 2: Costs for European en-route ATM/CNS (2003 data)

15 It is evident that the costs of NAV and, to a lesser extent, COM, are rather small compared with other aspects of the system. The costs of fragmentation in these areas are therefore likely to be small compared with those in SUR and ATM operations. As a consequence, efforts in trying to identify the adverse impact of fragmentation were concentrated on the latter areas.

Main results on the costs of fragmentation

16 The major areas where fragmentation was expected to have an adverse impact are summarised in Table 3, along with the associated order of magnitudes of costs:

	Cause of fragmentation	Annualised costs	% of cost of fragmentation
Common issues	Piecemeal procurement (mainly ATM systems)	€30m - €70m	**14%**
	Sub-optimal scale in maintenance and in-service development (mainly CNS)	€10m - €15m	
	Fragmented planning	€60m - €120m	
ACCs	Economies of scale in ACCs (operating costs)	€370m - €460m	**53%**
	Economies of scale in ACCs (capital cost)	€105m - €140m	
	Constrained sector design (flight efficiency benefits)	€50m - €100m	
ATM systems	Lack of common systems (operating costs)	€150m - €215m	**23%**
	Lack of common systems (capital costs)	€30m - €90m	
	Increased coordination at interfaces	€10m - €20m	
CNS infrastructure	Optimum location of en-route navaids	€3m - €7m	**4%**
	Overprovision of secondary radar	€15m - €60m	
Associated support	Economies of scale in training, administrative costs and R&D	€40m - €100m	**6%**
	Total costs of fragmentation	€880m - €1400m	**100%**

Table 3: Summary of fragmentation costs

17 The overall order of magnitude of the costs of fragmentation in the European en-route ATM/CNS system was estimated at some €880m - €1,400m. Although there is inevitably some uncertainty around such estimates, this is undoubtedly a significant amount; it represents around 20-30% of the annual en-route costs (see Table 2). This finding supports the suggestion that fragmentation is an important contributing factor to the performance gap between Europe and the US.

18 The main components of the cost of fragmentation are (1) many ACCs are below the optimum economic size, (2) duplication of bespoke ATM systems (including piecemeal procurement and sub-optimal scale in maintenance and in-service development), and (3) duplication of associated support (training, administration, and R&D).

19 A number of other issues were identified as important but were not associated with a quantified impact. These comprised:

- fragmented planning: the main impact of fragmented planning is manifest through the emergence and persistence of a sub-optimal fragmented European ATM/CNS system. The costs of this sub-optimality have been measured in the areas where they fall: ACCs and ATM systems, and CNS infrastructure. However, a modest impact has been included in Table 3 above, related to duplicated planning activities (see paragraph 25);
- unsynchronised or inconsistent adoption of technological change; again, the impact of this is manifest in the observed sub-optimal European ATM/CNS system;
- lack of ATM systems interoperability, which has an impact that has been captured either under piecemeal procurement of ATM systems, under fragmented maintenance and development, or as part of the economies associated with ACC size;
- increased costs of providing contingency capability when systems are incompatible; this was judged to be too uncertain to be able to quantify in this study;
- inconsistent principles regarding the provision and use of en-route primary radar for civil purposes; it was arguable whether this was a cost of fragmentation in the same sense as the others and it was omitted from the overall total.

20 The rationale and assumptions behind the estimates in each area shown in Table 3 are outlined below.

Common issues

21 Common issues were those that related to a number of service domains. They comprised piecemeal procurement, sub-optimal scale in maintenance and development, and fragmented planning.

22 The costs of piecemeal procurement of ATM/CNS systems could be reduced by procurement specifications common across ANSPs and the reduced need for adaptation of systems to bespoke designs, as systems become interoperable. The scope for reduction is likely to be less for CNS infrastructure than ATM systems, since to a large extent the CNS infrastructure already has common requirements across ANSPs. The accumulated cost of piecemeal procurement in existing ATM

systems was assessed at some 7-15% of the total capital replacement cost, while the reduction in replacement costs for CNS infrastructure was assumed to be half that for ATM systems. A recent CANSO initiative has focused on this area as a promising one for cost savings.

23 We recognised that fragmented maintenance and development operations might be of sub-optimal scale. A highly fragmented system, where there are many different types of equipment at several locations, requires more maintenance and development staff than a single location utilising a limited number of equipment types. We assumed that the largest five ANSPs (Aena, DSNA, DFS, ENAV and NATS) already had some degree of centralised maintenance of CNS infrastructure, while the remaining 31 ANSPs could potentially reduce their CNS maintenance costs by 5-7%.

24 Similar costs of fragmentation related to ATM system maintenance at ACCs are dealt with under “ACCs” in paragraphs 26-30 below.

25 The costs of working towards diminishing the adverse impact of fragmented planning and investment appraisal were counted as a cost of fragmentation. The objective of the EUROCONTROL EATM programme is to define and manage pan-European programmes for ATM and therefore it could be argued that a proportion of the cost of the EATM programme is a cost of fragmentation. This is not to suggest that the work is superfluous, just that in a fragmented system, greater coordination effort is needed, both at the European level and by ANSPs. The EUROCONTROL EATM budget[2] for 2003 was €123m and we assumed that at least 50% of these costs could be saved, either at the European level or in ANSPs, if fragmentation in planning were removed.

ACCs

26 Fragmentation costs arising from sub-optimal ACC size could arise both through the economies of scale in the centres themselves, and through lost flight-efficiency as airspace and route design is organised in a fragmented way.

27 The typical size of a European ACC is much smaller than those in the US, as shown in Figure 2. In the current European ATM system, there are 69 ACCs, of which 47 operate with 10 sectors or fewer at maximum configuration. In Europe, the average centre operates 9 sectors at maximum configuration; the average US centre 37 sectors. Furthermore, the FAA is currently examining the possibility of consolidation among its existing 21 centres.

[2] EUROCONTROL Annual Report 2003.

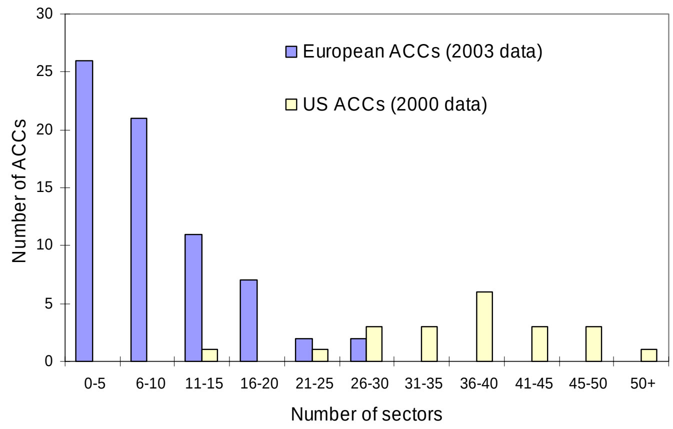

Figure 2: Centre sizes in Europe and the US

28 There is substantial evidence for economies of scale in ACCs, both in capital and operating costs. These arise in two ways: (1) through the low utilisation that will inevitably occur at times of low demand in very small ACCs; and (2) through economies of scale from sharing the fixed costs of an ACC over more activity. In the study, a typical cost structure was postulated, and validated against, among other things, data from the ACE US-Europe comparison, and the data on the cost of new centre construction shown in Figure 1. As shown in Figure 3 some costs are directly proportional to the number of sectors while other costs are to some degree fixed and therefore show efficiency gains as the number of sectors increases.

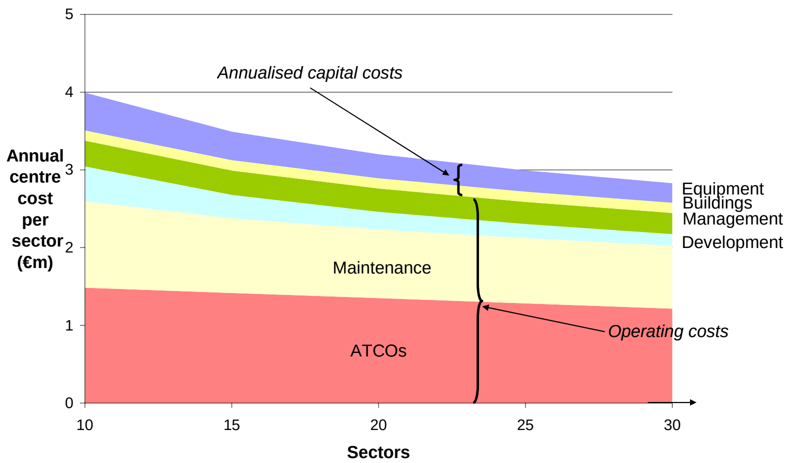

Figure 3: Variation of cost per sector with centre size

29 Obviously there will be limits to the feasible size of an ACC. Recent consolidation exercises in the UK and Germany have produced or will produce ACCs that can accommodate 50-60 sectors, making them comparable with the scale of the larger US ACCs. There is a general view that consolidation to scales greater than this may not necessarily lead to further economies of scale – difficulties in coordination and in providing contingency backup may start to outweigh fixed cost savings.

30 Consequently, in order to estimate the cost savings associated with economies of scale in ACCs in a defragmented system, the costs of current ACCs, estimated according to our assumptions concerning which were fixed and which variable, were compared to the costs estimated for a system in which ACCs operate with around 25 sectors at maximum configuration. This figure is well short of the maximum scale currently operating in Europe. However, such larger scales may only be practically feasible in the densest regions; 25 sectors is a conservative assumption for a non-fragmented system. It was estimated that fragmentation into ACCs of suboptimal scale was responsible for excess operating costs of 25% and excess capital costs of 34%, with major savings in maintenance and in-service development costs.

31 However, as discussed below in paragraphs 37-38, much of the in-service development cost, as well as some of the capital replacement costs, could also be reduced without consolidation of centres, through convergence to common ATM systems. To count these costs again as costs of fragmentation of ACCs would be double counting, so this element was removed from the costs allocated to fragmentation of ACCs.

32 Fragmentation of ACCs also has an impact through constrained sector design. Sector design is currently constrained by national and, to a lesser extent, ACC boundaries. A defragmented system would allow improved sector design by removing the constraints of national boundaries. This would allow improved routing through the defragmented airspace and hence greater flight efficiency. PRR8[3] estimated that 4.2% of route distance constituted inefficiency caused by suboptimal route design, with a cost of around €1,000m a year. However, much of the inefficiency could be caused by restrictions on the use of airspace by civil users through segregation of airspace for military use, rather than through fragmentation of civil airspace management. It was assumed that 5-10% of this route inefficiency results from constrained sector design. This is an area in which further analysis would be valuable in providing a more robust estimate.

33 It is important to note that these savings, while associated with ACC fragmentation, do not necessarily require ACCs to be consolidated to achieve them. They could be achieved, for example, by collaborative route and sector design, as should be achieved in a Functional Airspace Block (FAB).

34 Efforts to mitigate the adverse impact of fragmentation of ACCs are not lacking, although at present they are confined to projects within single ANSPs. Consolidation projects implemented since the base year for our data (2003), or currently planned, will have an appreciable impact on this cost of fragmentation; recent or currently planned national consolidation projects in Germany, Norway, Sweden and the UK might eliminate around €100m of the cost of fragmentation of ACCs, according to our models.

ATM systems

35 An important cost of fragmentation could arise from each centre having different software from others. If a number of ACCs use common ATM systems (identical or very similar systems), further economies can be made on the software element of those systems. Clearly, the lack of such common systems becomes less of a problem as the number of centres is reduced, and therefore cannot be treated in isolation from the costs arising from fragmentation of centres.

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[3] Performance Review Report 8, Performance Review Commission, April 2005.

36 The cost arising from this fragmentation was estimated as €5m-€15m capital costs per centre, and €2.2m-€3.2m a year operating costs per centre.

37 This cost could be applied either to the existing number of centres, or to the number of centres in a defragmented system, as shown in Figure 4.

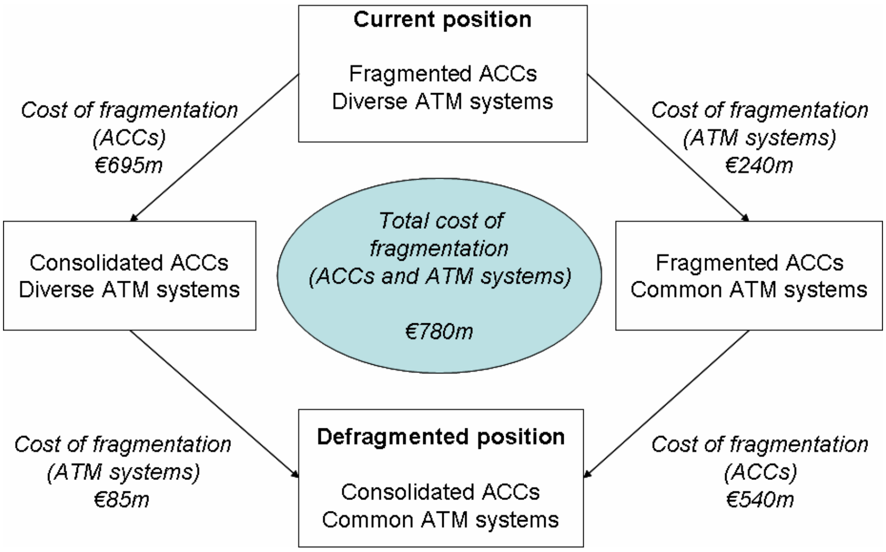


Figure 4: Fragmentation costs of ACCs and ATM systems

38 The total cost of fragmentation in ACCs and ATM systems taken together is €780m a year (for clarity, the midpoint of the ranges is shown). This results from reduction of the costs of purchasing and developing the systems, and from the reduction of the number of centres. The top left of the diagram shows the costs of fragmentation obtained by considering ACC consolidation without convergent ATM systems (€695m). This is the figure obtained from the argument in paragraph 30. The costs of retaining diverse ATM systems in this smaller number of ACCs is relatively small (€85m). However, we considered it clearer to apply the costs of fragmentation in ATM systems to the existing number of ACCs, as in the top right of the figure; a move towards common systems is likely to happen on shorter timescales and with lower transition costs than consolidation of centres. This assigns higher cost to fragmentation of ATM systems (€240m) and a correspondingly lower amount (€540m) to fragmentation of ACCs.

39 This is an area of fragmentation where costs could rise substantially if no action is taken, because of new requirements for certification of ATM systems. Although a number of initiatives to reduce fragmentation in this area are being undertaken, there is a feeling amongst stakeholders that more needs to be done.

40 An additional benefit of common systems would be improved coordination at interfaces between centres. The PRU US-Europe study[4] identified inter-centre coordination as possible reason for lower ATCO productivity in Europe. There is higher workload for hand-over in European centres than US centres. In a non-fragmented system, with increased interoperability, the inter-centre coordination time required was assumed to be half that required at present.

[4] A comparison of performance in selected US and Europe en-route centres, Report commissioned by the EUROCONTROL Performance Review Commission, May 2003.

CNS infrastructure

41 Costs of fragmentation associated with fragmented maintenance and procurement of CNS infrastructure were subsumed in the corresponding "common issues", discussed above in paragraph 22-23.

42 Costs of fragmentation associated with potential excess provision of CNS infrastructure were assessed separately for C, N and S.

43 Given the proportionately low costs of COM systems, we assumed that the cost of fragmentation in terms of overprovision were correspondingly small. However, given that much COM equipment resides at ACCs, a major element of COM costs was included in ACC costs.

44 We assessed the coverage of navaids using an analysis of where the spacing between pairs of navaids is less than might be expected from basic coverage consideration alone. This suggested a surplus of navaids that might lie between 8% and 25% of total current provision.

45 A similar analysis for secondary radars suggested that between 5% and 22% might be surplus, through excess coverage at national boundaries.

Associated support

46 Finally, we identified potential economies of scale in a number of support functions, particularly training, R&D, and HQ administration. It was difficult to obtain any cost information at all that was useful in this context. An illustrative order-of-magnitude estimate of the savings that might be achievable was some 4%-10% of total support operating costs (excluding ACC costs and CNS infrastructure costs).

Measures to mitigate fragmentation costs

47 In the second part of the study, we reviewed existing collaborative initiatives, in the light of the major areas of costs of fragmentation identified. For each major fragmentation issue, we explored the following questions:

- what collaborative activity would be expected in this area?
- would it be at a regional level (bordering countries); multi-national (collaborating countries without necessarily having common borders), or pan-European?
- is current collaborative activity meeting this perceived need?

48 We obtained feedback from stakeholders at a workshop in which they had an opportunity to present their views on the importance, adequacy and effectiveness of measures currently being undertaken.

49 We noted that the scarcity of information that would help assess the impact of fragmentation might be a major cause of the lack of focus of collaborative initiatives on fragmentation issues.

Common issues

50 Pan-European and indeed global collaborative activity was identified in the area of piecemeal procurement, with activity by CANSO. There was also extensive multi-national activity, with groups of ANSPs collaborating largely for historical reasons.

There was a lack of initiatives at a regional level, perhaps surprisingly as there are additional advantages to be obtained if neighbours collaborate. The activity recently initiated under the SESAR programme (previously known as SESAME) should also bring benefits in the future in this area.

51 There was little evidence of collaborative activity in mitigating fragmented maintenance and development, although moves towards common procurement would bring benefits in this area as a by-product.

ACCs

52 We expected that ACC consolidation would take place at regional level. While some major consolidations are happening at a national level, little evidence was seen at this stage of major plans for cross-border consolidation; current plans for CEATS envisage continuation of eight ACCs below the consolidated upper airspace. Current FAB plans, which could in principle form the core of plans for consolidation, have not usually had ACC consolidation as a major focus.

53 Current **national** consolidation initiatives will have an appreciable impact on the cost of fragmentation of ACCs, although there is still plenty of scope for both national and cross-border initiatives to reduce fragmentation.

54 We also identified that lack of commonly available data on the costs and characteristics of ACCs inhibited the initiation of plans for consolidation, and that there was no requirement for projects seeking European funding to consider cross-border alternatives to national projects.

ATM systems

55 There was extensive collaborative activity in this area at the pan-European level, through a framework for developing interoperability standards by Eurocontrol and the EC and industry wide standards being developed by standards bodies. Some stakeholders did think there were gaps in this area, but it is expected that these will be filled adequately by the development of Implementing Rules and Community Specification under the SES legislation.

56 At the same time, there are a number of multinational initiatives in the development of new ATM systems. Again, there was a view that joint specification development work was lacking. In the longer term, SESAR should also be expected to make a significant contribution.

CNS infrastructure

57 While extensive pan-European and multinational activity exists in this area, it is not focused primarily on reducing the costs of fragmentation, but on planning future infrastructure. A lack of regional activity in addressing the excess coverage issue was noted.

58 We also noted that some regional initiatives were likely to take place under the general umbrella of FAB activity – groups of ANSPs were taking the opportunity of cooperation in airspace to consider cooperation in CNS provision as well.

Associated support

59 There were coordination activities at a pan-European level that addressed coordination of R&D, but none seemed focused particularly on mitigating the cost of fragmentation in R&D.

60 Some multinational and regional activity is taking place in training; again, groups of ANSPs cooperating in the context of a FAB are taking the opportunity to look for economies in joint training.

61 Little or no activity was found in addressing the impact of fragmented administrative arrangements. FAB initiatives that included no organisational consolidation plans were expected to have little impact in this area; however, where organisational consolidation was considered a realistic possibility, there was thought to be scope for reductions in administrative and HQ costs.

Lessons from other industries

62 We reviewed how cooperation had worked in other industries to reduce the adverse impact of fragmentation. Two industries were selected: rail transport and electricity supply. Both industries had significant fragmentation issues, although they were not on the same scale relative to overall activity as in ATM/CNS. There were important differences between these industries and ATM. Measures to reduce the costs of fragmentation were often focused on ensuring effective functioning of markets, which is not applicable in the current European ATM/CNS system. Nevertheless, there were some general lessons that could be learnt from the relative successes of different types of measures:

- there is a tendency for bilateral or regional blocs to emerge, which can exacerbate fragmentation problems at the wider level;
- there has been a tendency for industry vested interests to resist changes aimed at reducing fragmentation; mandatory and prescriptive measures have had more success than purely voluntary ones.

Conclusions

63 The study was necessarily broad-brush and order-of-magnitude in its approach. It was perhaps surprising that the basic data that would enable the assessment of the contribution of various areas to the costs of the systems were so difficult to obtain. Nevertheless, the major conclusions of the study are robust and can be summarised as follows:

- fragmentation of European en-route ATM/CNS carries a high cost – around €900m - €1,400m annually, perhaps 20-30% of annual costs;
- the main causes of this cost of fragmentation were the fragmentation of ACCs, and of ATM systems; other important costs of fragmentation resulted from fragmented planning, piecemeal procurement, and duplication of support activities.

64 While the main area of fragmentation costs arises from the fragmentation of ACCs, this is also the area in which transition costs are likely to be highest. In both this area and the related one of ATM systems the transition costs depend critically on the timing of moves, particularly in relation to system and facility life-cycles. A move towards common systems is likely to happen on shorter timescales and with lower transition costs than consolidation of centres.

65 Many collaborative initiatives are currently taking place across Europe at all levels, regional, multinational and pan-European. Often, these initiatives are well-placed to mitigate the costs of fragmentation. Pan-European initiatives on interoperability, and regional initiatives to form FABs have an important contribution to make.

However, there is sometimes a lack of focus in the collaborative activities on the areas where a real difference could be made.

66 One of the reasons for this might be that information on ANSPs' activities is not widely or consistently available at the level of detail that would allow consistent and systematic assessment of the priority areas of fragmentation to address, whether in terms of the fragmentation issues to focus on, or of the geographical areas to examine.

67 Initiatives at a pan-European level to set standards and make plans tend to be more widespread than those at a regional level to implement major changes with a big impact. Few ANSPs have financial incentives to collaborate; even when ANSPs are subject to economic regulation, conventional national regulation can inhibit collaborative activity that reduces system costs. Furthermore, major collaborative initiatives to reduce the costs of fragmentation might threaten vested interests, and therefore face opposition.

68 Finally, we must emphasise that while the costs of fragmentation in European ATM/CNS in 2003, as studied in 2005, are of great importance, a number of important potential areas remain to be addressed: fragmentation of terminal ANS, ancillary services such as MET and AIS; the impact of fragmentation on on-board costs; fragmentation of civil and military service provision; and fragmentation of regulation.

Contents

Executive Summary

Introduction i
Objectives and scope of the study i
A definition of fragmentation ii
Costs of the European ATM/CNS system ii
Main results on the costs of fragmentation iv
Measures to mitigate fragmentation costs x
Lessons from other industries xii
Conclusions xii

1 Introduction 1
1.1 Background 1
1.2 The scope of the study 2
1.3 What is fragmentation? 2
1.4 Document structure 3

2 Outline of existing ATM/CNS infrastructure 5
2.1 Introduction 5
2.2 ATM/CNS systems 6
2.3 Area Control Centres (ACCs) 7
2.4 Communication, Navigation and Surveillance (CNS) 8
2.5 Conclusion 9

3 Costs of the European ATM/CNS System 11
3.1 Introduction 11
3.2 Cost definitions 12
3.3 Sources of information 14
3.4 Our approach to estimating the costs of the existing system 14
3.5 Communications 15
3.6 Navigation 15
3.7 Surveillance 16
3.8 ACCs and ATM systems 18
3.9 Associated support 20
3.10 Estimates of the costs of the European en-route ATM/CNS system 21

4 Fragmentation issues 25
4.1 Introduction 25
4.2 Common issues 25
4.3 ACCs 28

4.4 ATM systems 30
4.5 En-route CNS infrastructure 34
4.6 Associated support 35
4.7 Safety performance 37
4.8 Summary of fragmentation issues 40

5 Costs of Fragmentation 41
5.1 Introduction 41
5.2 Common issues 41
5.3 En-route CNS infrastructure 42
5.4 ACCs and ATM systems 45
5.5 Associated support 54
5.6 Summary of the costs of fragmentation 54

6 ATM coordination activities and their coverage 59
6.1 Introduction 59
6.2 Framework for coordination activities 59
6.3 Common issues 63
6.4 Coordination activities for ACCs 65
6.5 Coordination activities for ATM systems 66
6.6 Coordination activities for CNS infrastructure 67
6.7 Coordination activities in associated support 68
6.8 Coordination gap analysis 69

7 Coordination activities in other industries 73
7.1 Railways 73
7.2 Electricity 75

8 Conclusions and recommendations 79

A ATM and CNS systems and operations 85
A.1 Introduction 85
A.2 ACC 85
A.3 Communications 88
A.4 Navigation 88
A.5 Surveillance 89

B Supporting information for current system cost estimates 91
B.1 Air-ground-air communications 91
B.2 Ground-ground communications 93
B.3 ACCs 95

C Costs of fragmentation detailed estimates and assumptions 99
C.1 Navigation 99
C.2 Surveillance coverage analysis 101
C.3 Primary radars 105

D List of projects investigated in Phase 2 107
D.1 Regional activities 107
D.2 Multi-national activities 108
D.3 Pan-European activities 109
D.4 Other activities 111

E Glossary 113

List of figures

Executive Summary

Figure 1: Capital costs of typical new ACC developments iii
Figure 2: Centre sizes in Europe and the US vii
Figure 3: Variation of cost per sector with centre size vii
Figure 4: Fragmentation costs of ACCs and ATM systems ix

Main Report

Figure 2.1: Components of ATM 5
Figure 2.2: ATM/CNS systems 6
Figure 3.1: Geographical scope of the study (membership in 2004) 12
Figure 3.2: Breakdown of total European ANS costs in 2003 13
Figure 3.3: Capital costs of typical new ACC developments 18
Figure 3.4: Variation of US centre costs with size 19
Figure 3.5: Capital replacement costs for European en-route ATM/CNS, 2003 22
Figure 3.6: Annual operating cost estimates for European en-route ATM/CNS 22
Figure 3.7: Total annual cost estimates for European en-route ATM/CNS 23
Figure 4.1: Centre sizes in Europe and the US 29
Figure 4.2: System suppliers in European ATM 31
Figure 4.3: Flight-hours served by systems from different suppliers 31
Figure 4.4: Barrier model 38
Figure 5.1: Variation of annual costs with centre size 48
Figure 5.2: Variation of cost per sector with centre size 49
Figure 5.3: Allocation of fragmentation costs between centres and ATM systems 52
Figure 5.4: Costs of fragmentation 56
Figure 6.1: The key elements and processes in European ATM 61
Figure 6.2: Gaps in European Coordination 71

Annexes

Figure A.1: An example operations room configuration 85
Figure A.2: An example of a control suite configuration 86
Figure A.3: An example ACC operations unit structure 87
Figure C.1: DME & VOR/DME Coverage at FL100 99
Figure C.2: DME & VOR/DME Coverage at FL50 100
Figure C.3: Radar coverage at FL50 (RASCAL) 102
Figure C.4: Radar coverage at FL30 (RASCAL) 103

List of tables

Executive Summary

Table 1: Key European ATM/CNS physical infrastructure (2003 data) ... iii
Table 2: Costs for European en-route ATM/CNS (2003 data) ... iv
Table 3: Summary of fragmentation costs ... iv

Main Report

Table 3.1: Summary of communications costs ... 15
Table 3.2: Navaids costs ... 16
Table 3.3: Capital replacement costs of radar ... 17
Table 3.4: Annual operating costs of radar ... 17
Table 3.5: ACCs and ATM systems costs ... 20
Table 3.6: Associated support costs ... 20
Table 4.1: Summary of fragmentation issues ... 40
Table 5.1: Costs of fragmentation for inconsistency in en-route navaid planning ... 43
Table 5.2: Costs of over-provision of radar ... 44
Table 5.3: Summary of cost parameters used ... 48
Table 5.4: Costs of fragmentation in ACCs ... 50
Table 5.5: Annual costs of fragmentation ... 55
Table 6.1: Gaps in European coordination ... 70

Annexes

Table B.1: Numbers of VHF ground stations (ACC and APP) per State ... 92
Table B.2: VHF air-ground-air station costs ... 93
Table B.3: Ground-ground communications networks costs ... 95
Table B.4: Maximum number of physical sectors for ACCs ... 96
Table B.5: Recent ACC investments ... 97
Table C.1: DME inter-distance analysis ... 101
Table C.2: VOR inter-distance analysis ... 101
Table C.3: Inter-distance analysis for all secondary radars ... 104
Table C.4: Inter-distance analysis for en-route secondary radars ... 104
Table C.5: En-route primary radar in Europe ... 105

1 Introduction

1.1 Background

1.1.1 The adverse impact of fragmentation in the European Air Traffic Management and Communications, Navigation and Surveillance system (has long been a concern of the EUROCONTROL Performance Review Commission (PRC). The PRC and the Performance Review Unit (PRU), which supports it, have commented that fragmentation appears to be a major factor in reducing ATM performance and underlies much of the observed performance gap between European and US ATM performance[1]. The issue was addressed in the PRC's Performance Review Report PRR5, An Assessment of Air Traffic Management in Europe during 2001, which looked at fragmentation, assessed its possible impacts and the measures that were at the time being considered to reduce it.

1.1.2 The recent passage of the Single European Sky legislation is intended to have a major impact on fragmentation. Among other things, its provisions aim to:

- reduce airspace fragmentation by introducing common principles for sector and route design, and through the introduction of a single upper airspace FIR;
- allow some reduction of support costs at ANSP level through harmonised requirements for certification and training;
- allow some consolidation or reduced costs of fragmentation at ACC level through the facilitation of the introduction of Functional Airspace Blocks (FABs);
- facilitate harmonisation of systems through moves towards interoperability.

1.1.3 Furthermore, there is a strong will among many ANSPs to take action to reduce the adverse impact of fragmentation. CANSO took as a major theme for its 2004 Annual Conference the need for cooperative behaviour – an important element in this was cooperation among ANSPs. As a result of this, a CANSO Working Group was convened to examine the potential gains from cooperation, and reported back to the CANSO Annual Conference in 2005.

1.1.4 In the light of these developments and the importance of the topic, the PRC is committed to investigate further the extent and costs of fragmentation. To support this, the PRU commissioned the Solar Alliance to undertake a study of the impact of fragmentation in European ATM/CNS, to focus on the following areas:

- fragmentation of en-route ATS units;
- fragmentation of ATM systems and interfaces;
- fragmentation and duplication of CNS infrastructure; and
- associated support costs.

1.1.5 The work has taken place in three phases:

- **Phase 1**: to examine and quantitatively assess order-of-magnitudes related to the costs of European ATM/CNS fragmentation and duplication;

[1] A comparison of performance in selected US and Europe en-route centres, Report commissioned by the EUROCONTROL Performance Review Commission, May 2003.

- **Phase 2**: to identify and assess needs for coordination activities for an effective European ATM network system; and
- **Phase 3**: to examine and assess the role of EUROCONTROL as agent to reduce European ATM/CNS fragmentation and minimise its impact.

1.1.6 This document is the Final Report for the study. It reports on the work done for Phases 1 and 2 described above. The work done for Phase 3 did not reach any firm conclusions and has therefore not been written up in this report. The remainder of this section describes the scope of this report and sets its context within the project.

1.2 The scope of the study

1.2.1 The scope of the study was specified as covering ATM/CNS. We agreed that within ATM/CNS the study would focus on the four areas described in paragraph 1.1.4. Furthermore, it would confine itself to en-route ATM/CNS services, as far as it was feasible to keep them separate from other services. Terminal services are inherently more fragmented and would add an extra layer of complication to the examination. For practical purposes, we have assumed that the en-route system comprises Area Control Centres (ACCs) and Approach Control Units (APPs) and the CNS systems that serve them. While it is true that many APPs are not strictly or wholly en-route, we do not consider that the difference is material in the context of the overall size of the problem. When considering fragmentation of operating units, we have confined our attention to ACCs. When considering the CNS systems, we have excluded parts of that system that exist exclusively to serve airports.

1.2.2 Ancillary air navigation services other than ATM/CNS (aeronautical meteorological services (MET), aeronautical information services (AIS) and search and rescue (SAR)) are also outside the scope of this assessment of the impact of fragmentation, as are the costs of regulation, on-board equipment, and civil-military fragmentation.

1.3 What is fragmentation?

1.3.1 “Fragmentation” was not formally defined in PRR5, and we are not aware of any widely accepted definition. It refers to the division of air navigation service provision into smaller decision-making or operational units than would result from considerations of optimum scale. In Europe, this has mainly arisen from the organisation of ANS at the state level. However, fragmentation is also discussed in PRR5 in relation to smaller than optimal operational units within national ANSPs. These units may have become sub-optimal as changes in the technology of service provision have raised the optimum size of a centre.

1.3.2 In discussion with the PRU, we have agreed that the study should examine fragmentation by assessing the impact of having a system that has developed within the constraints both of national boundaries, and of historical decisions that may have become sub-optimal with technological or demand changes.

1.3.3 We assess the impact therefore by comparing the current system with a system that is not subject to those constraints. It could be argued that such an approach is “theoretical” and effort would be better focused on seeking areas for immediate improvement. We, with the PRU, would counter-argue that examining the overall impact as we will in this study is an essential first step, in that it:

- establishes the overall order of magnitude of the impact;

- identifies the areas in which most benefit can be gained from measures to reduce fragmentation; and

- identifies areas in which only minor benefits can be expected.

1.3.4 It therefore gives us information needed to establish the priority of different measures aimed at alleviating fragmentation, and the overall priority of fragmentation measures against more general performance-enhancing measures.

1.3.5 Because the work is aimed at establishing these overall impacts, we have not in this study examined the costs of moving from a fragmented system to a defragmented one. This will be best addressed in the context of individual programmes of related measures.

1.3.6 The Terms of Reference of the study emphasise the costs of fragmentation, but require us also to examine the impact in other key areas of performance: safety, quality of service, and capacity. In general these can be assessed as the other side of the coin from costs. We would argue that fragmentation does not reduce safety, but increases the costs of maintaining or enhancing the required levels of safety. Similarly, fragmentation does not necessarily reduce capacity, but increases the cost of providing and enhancing capacity. Where fragmentation results in capacity provision that is less than optimum, there are costs to users. Similarly, where fragmentation introduces difficulty in providing a system resilient against extraordinary events, through lack of contingency provision, there are costs to users.

1.3.7 The study will examine the impact of fragmentation in these other key performance areas in the context of the way that it alters the trade-offs that are inevitable between different areas of performance.

1.3.8 Fragmentation could also, in principle, cause direct costs to users (for example if they have to install and maintain more complicated avionics to deal with fragmented CNS systems). We will address such issues in our assessment of the costs but will not include these costs (whether capital or operating costs) in our assessment of the magnitude of the costs of the current fragmented system.

1.3.9 A final area of fragmentation to address concerns fragmentation between civil and military provision. Besides fragmentation between different ANSPs and countries, some countries have separate military ANS provision; others are integrated. Since there are a number of countries that have moved to closer civil-military integration recently (for example Germany, Sweden and Switzerland) there would seem to be a prima facie case for a cost of fragmentation between civil and military provision. This area of fragmentation would have to be addressed in another study.

1.3.10 A final point concerning the scope of the study is the degree to which failure to attain best practice can be considered a cost of fragmentation. We have agreed with the PRU that the costs of inefficiency should be kept separate from the costs of fragmentation, and that in this study and in Phase 1 in particular we should only address the costs that were specifically associated with the fragmentation itself, rather than the costs associated with one service provider being less efficient than another, or than some ideal model.

1.4 Document structure

1.4.1 The remainder of the document is structured as follows. Sections 2-5 describe the results of Phase 1 of the study:

- **Outline of existing ATM/CNS infrastructure (Section 2)** gives a brief description of the ATM and CNS systems and infrastructure and their components, to provide context for the rest of the study;
- **Costs of the European ATM/CNS system (Section 3)** describes how we have assessed the capital and operating costs of the current European ATM/CNS system;
- **Fragmentation issues (Section 4)** describes the main areas of ATM and CNS for which fragmentation may have an adverse impact on cost-effectiveness, safety, capacity or quality of service;
- **Costs of fragmentation (Section 5)** describes how we have estimated the impact of fragmentation for each area of ATM and CNS.

1.4.2 Sections 6 and 7 summarise the results of Phase 2:

- **ATM coordination activities and their coverage (Section 6)** summarises the coverage of the coordination activities we have identified, and reviews how well matched the activities are to the major fragmentation issues identified in Phase 1.
- **Section 7** reviews the experience of European coordination in railways and electricity sectors.

1.4.3 Conclusions and recommendations are presented in Section 8.

1.4.4 There are also several annexes. The Annexes are as follows:

- Annex A gives an introduction to the main system components and operations discussed in the report.
- Annex B gives supporting information for our estimates of the costs of the current system.
- Annex C describes the detailed analyses of the costs of fragmentation.
- Annex D lists the projects reviewed in exploring the framework for coordination activities.
- Annex E is a glossary for the report.

2 Outline of existing ATM/CNS infrastructure

2.1 Introduction

2.1.1 In this section we provide a brief introduction to the concepts of ATM and CNS and give a general description of the existing European ATM/CNS infrastructure and systems, covering the communications, navigation and surveillance equipment and the ATM systems within the Area Control Centres (ACCs). Further explanation is given in Annex A.

2.1.2 Figure 2.1 shows the standard ICAO definitions for ANS[2] and its component services. The areas of interest for this study are highlighted.

2.1.3 ANS is comprised of air traffic management (ATM), communications, navigation and surveillance (CNS) and other services such as aeronautical information services (AIS), MET and search and rescue (SAR). ATM encompasses air traffic services (ATS), air traffic flow management (ATFM) and airspace organisation and management (ASM).

2.1.4 Air traffic services comprise en-route, terminal and aerodrome air traffic control (ATC), Flight Information Services and alerting services, as shown in Figure 2.1.

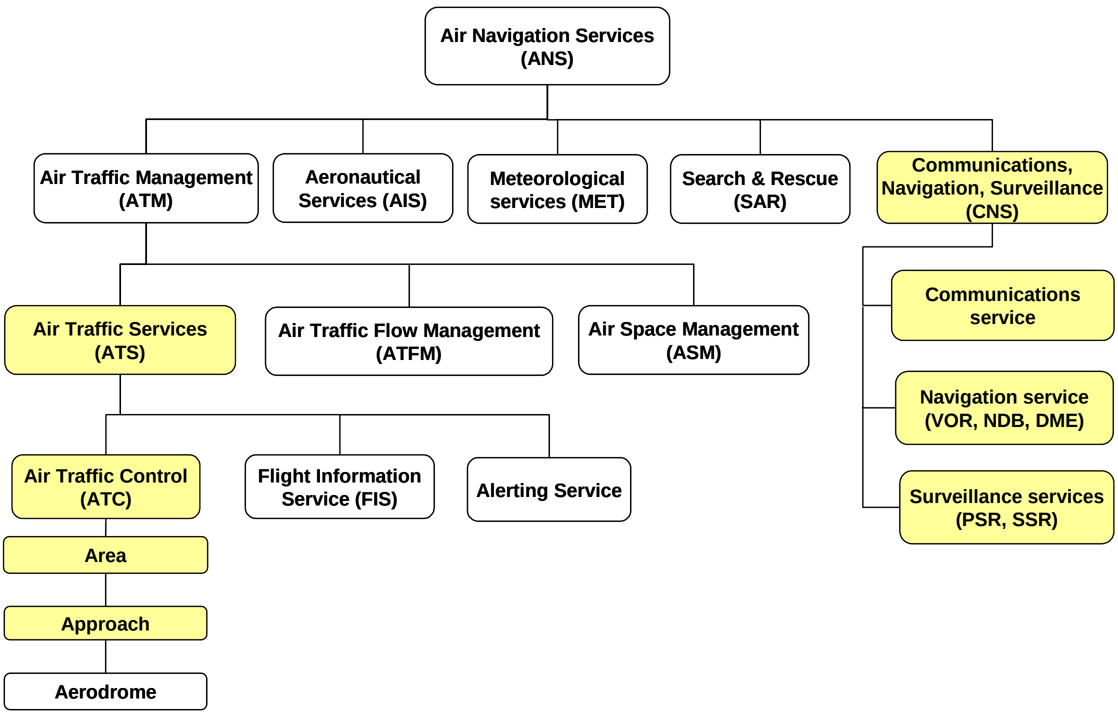


Figure 2.1: Components of ATM

[2] ICAO Doc 9082/6, ICAO's Policies on Charges For Airports and Air Navigation Services, Sixth Edition, 2001.

2.1.5 Air Traffic Control (ATC) is a service provided for the purpose of:

- preventing collisions between aircraft;
- preventing collisions on manoeuvring areas between aircraft and obstructions on the ground;
- expediting and maintaining the orderly flow of air traffic.

2.1.6 En-route air traffic control is carried out in Area Control Centres (ACCs), of which there may be one or more in any State. Each ACC is responsible for a defined volume of airspace, which is split into blocks called sectors. Each sector is controlled by one or more Air Traffic Controllers (ATCOs). Approach units (APPs) control parts of en-route airspace and terminal areas. Tower units control traffic in the immediate vicinity of airports.

2.2 ATM/CNS systems

2.2.1 The generic system diagram shown in Figure 2.2 is a simplified representation of the key elements of current en-route ATC systems. It defines the core systems and interfaces which are the subject of this study. In practice, the detailed configuration varies from one service provider to another. The diagram excludes technologies that are not yet widely implemented.

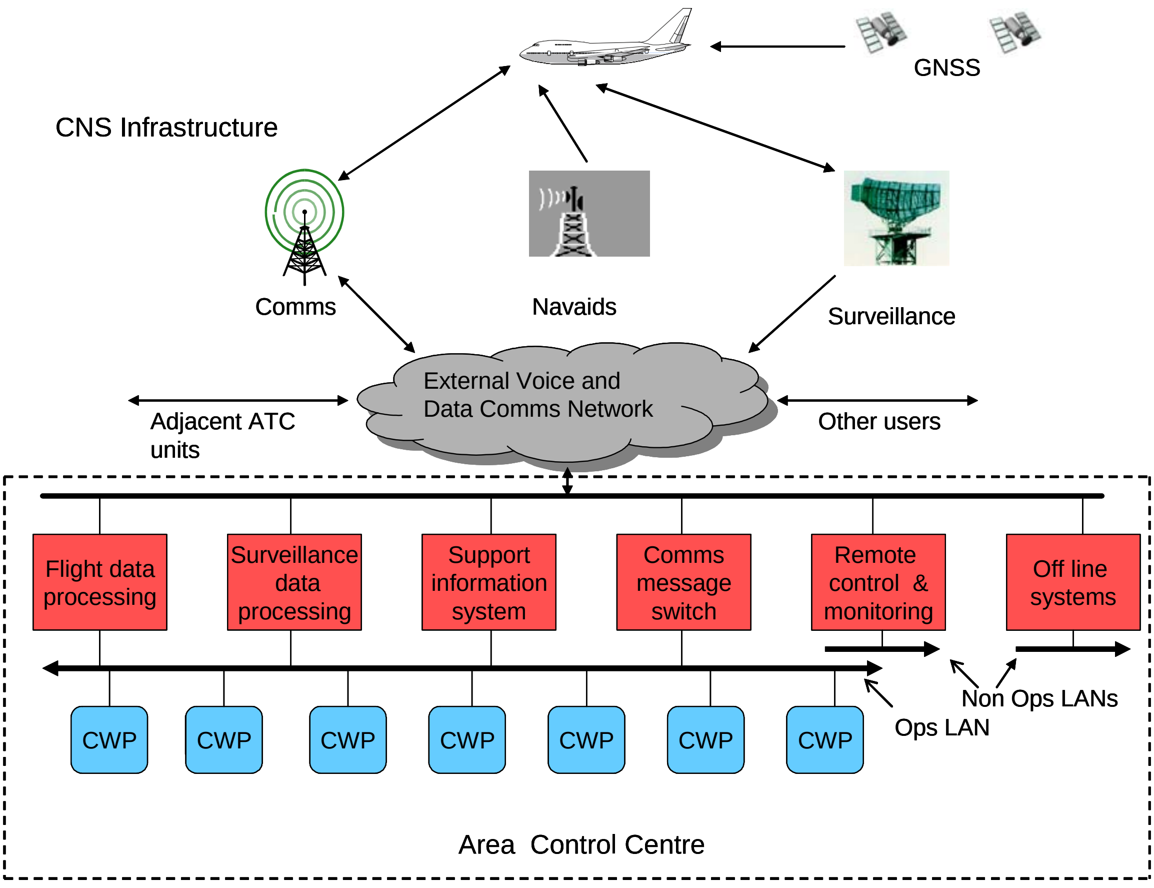


Figure 2.2: ATM/CNS systems

ATM systems

2.2.2 Area Control Centres interface directly with the voice and data communications networks to provide all the inputs and outputs (voice and data) to the Centre. The systems architecture is typically based on a number of servers with discrete functions as illustrated on Figure 2.2. In practice, many different configurations exist, with fully integrated server functions being a common architecture in more modern systems. The generic server functions are as follows:

- Flight Data Processing (FDP). FDP manages the distribution and update of aircraft intent data (flight plans).
- Surveillance Data Processing (SDP). SDP manages the distribution and correlation of surveillance data (normally radar data).
- Support Information System Processing (SIS). SIS provides management of other types of operational information such as meteorological information, maps and reference data.
- Communications Message Switch (CMS). CMS routes controller messages to the appropriate air/ground/air transmitter receiver station, ATC unit or airport.
- Remote Control and Monitoring Facilities (RCM). RCM distributes and displays status information on all systems to the system control authorities.
- Off Line Systems (OLS). These systems include training facilities for controllers and maintenance staff, development systems for the generation of new software and test equipment.

2.2.3 The information from these servers is disseminated to the controller working position (CWP) via high-availability, error-free local-area networks (LANs). Off-line systems and the remote control and monitoring facilities are generally connected to non-operational LANs to avoid any risk of interference with ATC operational information.

2.2.4 The controller working position (CWP) is a generic title for the equipment providing the services to each controller position. This typically includes a large data display for surveillance and flight data and a smaller display for support information. It also contains a control panel for the display and usually a discrete input device to control communications.

2.2.5 The provision of ATM systems at ACCs is demanding as the facilities have to meet particularly stringent requirements in terms of availability, functionality, response times, ease of maintenance and development potential. These parameters must be consistent with the overall safety objectives which demand extensive testing prior to operational use. All these objectives must be achieved at reasonable cost which can be difficult, given the diversity of systems used in Europe.

2.3 Area Control Centres (ACCs)

2.3.1 ACCs generally provide ATC services to aircraft in the upper airspace, usually within national boundaries. Depending on the geographical division of airspace, there may be more than one ACC serving a particular nation state. Multiple centres also provide for contingency support in the event of systems failures. The size of each centre tends to vary, usually in relation to their area of responsibility.

They are served by long-range radars and technologically advanced communications and may be located considerable distances from airports.

2.3.2 ACCs have two main technical functions: the operational unit, which provides the requisite air navigation services, and a unit responsible for the maintenance and development of the centre systems, including monitoring and control. Other functions may also be located physically within the ACC (for example certain administrative functions). We have chosen to focus on the operations unit, as within an ACC, this is where fragmentation issues are most likely to have an impact. Fragmentation issues related to maintenance and development are addressed at a systems level (that is, ATM systems and CNS) and those related to administration are addressed within associated support costs.

2.3.3 Military units are often co-located with civil ATC and share the ATM systems. Military issues will have an impact on the defragmented system. However, this is out of the scope of this study and we shall not address it further.

2.3.4 The core element of any ACC is the operations room from where air traffic control officers (ATCOs) provide radar services. These are large halls within which there are banks of workstations equipped with radar consoles, air/ground communications and associated information displays. In addition, many ACCs have dedicated training suites within the operations room whilst others have separate training facilities.

2.4 Communication, Navigation and Surveillance (CNS)

2.4.1 The infrastructure required to provide information to support ATS has three main components: Communications, Navigation and Surveillance, commonly called the CNS infrastructure.

2.4.2 Surveillance is a means of acquiring the aircraft's position so that an ATCO can maintain separation between aircraft. Navigation requires positioning and guidance and is the means by which an aircraft is guided from one known point to another known point. Communications allows information to be transmitted (as voice or data) from the aircraft to ATC and vice versa.

2.4.3 The CNS infrastructure has been developed over many years and has in many respects been optimised to meet developing operational requirements. The ground CNS infrastructure is constrained in terms of location to meet coverage requirements. Generally, these systems have been planned and implemented on a national basis and there may be some duplication of services at national boundaries.

2.4.4 CNS infrastructure and systems are characterised by relatively long life expectancy (typically 15-20 years) and it is important to ensure that the system maintenance skills can be made available for the full operational service life. There is usually not much need for in-service development.

2.4.5 The adoption of more modern satellite-based technologies will provide some opportunity to rationalise services. However, the introduction of these technologies has been slow due to a lack of international agreement on strategy and standards. Furthermore, implementation is complicated by the need to plan and fund the provision of equipment across the aircraft fleet.

2.4.6 A further major component of the CNS infrastructure is the ground voice and data networks which link the communication and surveillance remote stations with the end users. These networks often carry additional information to support operations as a whole, for example, status and administrative information. These networks rely on services provided directly by ANSPs and third party service providers.

2.4.7 CNS systems are, by nature, distributed facilities. Technology now permits a high degree of centralised management and maintenance of such systems with consequent reductions in costs and improved service delivery. This approach is not universally adopted and results in increased capital and operating costs.

2.5 Conclusion

2.5.1 This section has provided an overview of the physical infrastructure and equipment which comprise the capital assets that an ANSP needs to have in order to operate. The costs of this infrastructure and its operating costs are discussed in the next section.

3 Costs of the European ATM/CNS System

3.1 Introduction

3.1.1 The first step in assessing the costs of fragmentation in the European ATM system is to understand what the costs are and how they arise. We assessed the costs of fragmentation in terms of the following questions:

- Does the existing, fragmented system require more capital assets than an ideal, defragmented one?
- Does it have higher operating costs than a defragmented one?

3.1.2 There is a clear mapping between these questions and the conventional "cost base" used in the EUROCONTROL Route Charges System. The first question maps into the capital-related elements of the cost base, depreciation and finance costs; and the second into the operating components (labour costs and non-staff operating costs).

3.1.3 We also divide the elements of the system up into those that might be affected in different ways by fragmentation. The division we have used follows the Terms of Reference of the study, but separates out the C, N and S elements. In examining the overall costs of the system, it does not make sense to separate ACCs from ATM systems and interfaces, and therefore we have looked at the costs of ACCs and the ATM systems collectively.

3.1.4 We therefore look at the capital requirements and operating costs of each of the following areas:

- Communications (C) ;
- Navigation (N) ;
- Surveillance (S) ;
- ACCs and ATM systems; and
- associated support costs.

3.1.5 We need also to have a common definition of the European system. We include all member states of EUROCONTROL at 1 September 2004 and those non-member states of EUROCONTROL that are reporting data to the PRU from ACE 2003[3]. This comprises 37 member states. However, in practice only the systems of 35 States need be considered, as the ANS assets and costs of Luxembourg and Monaco are negligible. These 35 states comprise the 27 States of the Single European Sky (the EU member states plus Norway and Switzerland), plus a number of other states in South-East Europe.

3.1.6 Air navigation services in these 35 states are provided by 36 Air Navigation Service Providers (ANSPs); one for each of the states, plus Maastricht Upper Area Control Centre (MUAC), operated by EUROCONTROL. EUROCONTROL is also an ANSP, both as the operator of MUAC and as the provider of certain central services such as flow management through the Central Flow Management Unit

[3] ATM Cost-effectiveness (ACE) 2003 Benchmarking Report, April 2005, Performance Review Unit; see also similar reports from previous years: ATM Cost-Effectiveness (ACE) 2002 Benchmarking Report, May 2004, and ATM Cost-Effectiveness (ACE) 2001 Benchmarking Report, September 2003.

(CFMU), billing and collection through the Central Route Charges Office (CRCO) and international coordination and harmonisation through the European Air Traffic Management programme (EATM).

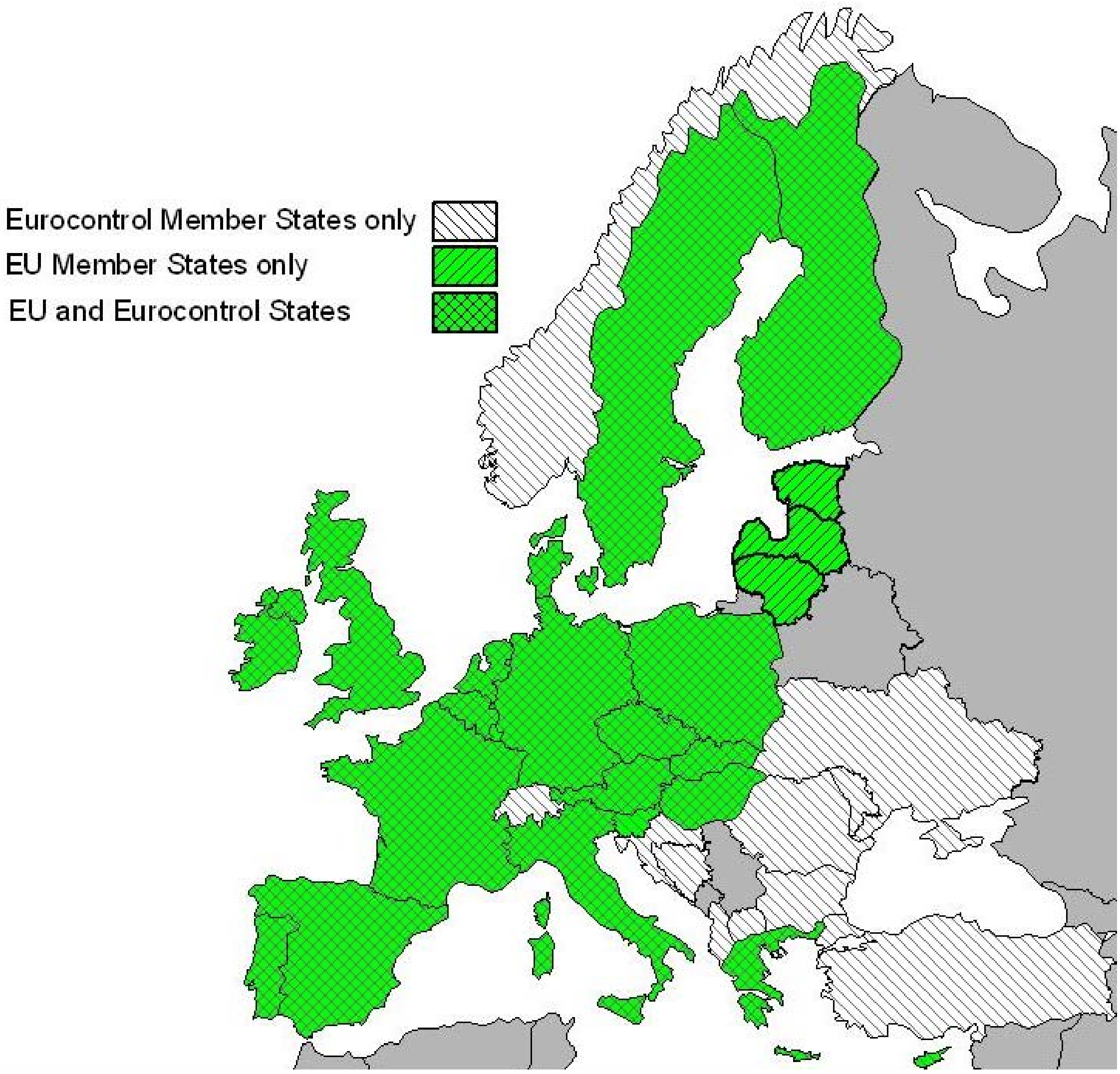
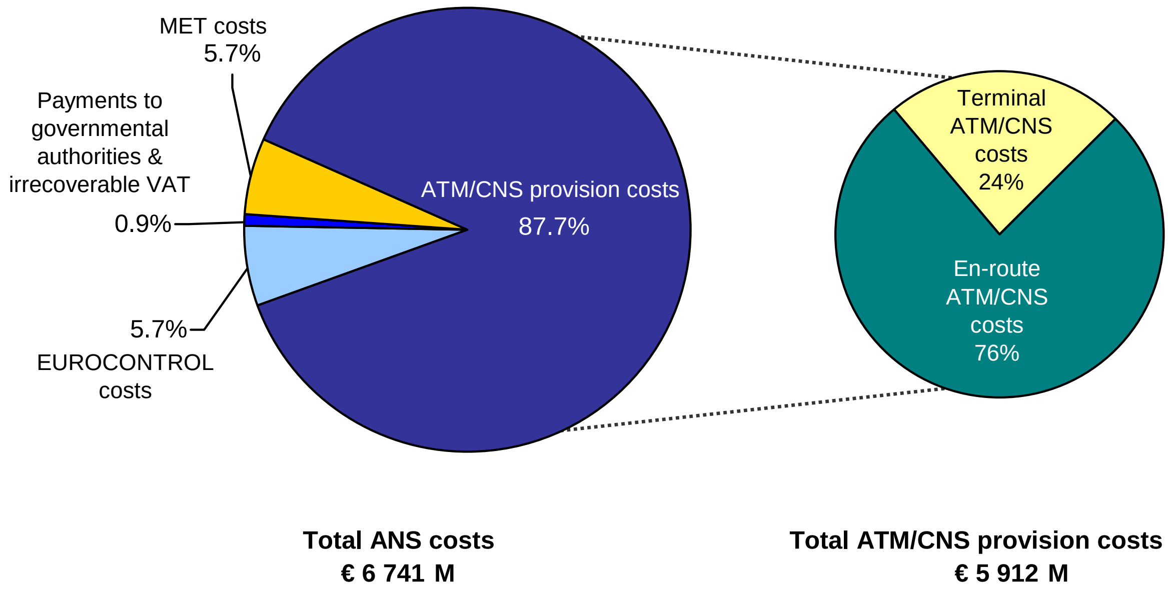


Figure 3.1: Geographical scope of the study (membership in 2004)

3.2 Cost definitions

3.2.1 Our definitions of costs follow the PRU's ATM Cost-Effectiveness (ACE) analysis. We have confined our attention to the costs they (and the CRCO) define as Air Traffic Management and Communication, Navigation and Surveillance costs (ATM/CNS). This excludes a number of cost elements such as aeronautical meteorological services (MET); aeronautical information services (AIS); and the costs of regulation. While there are undoubtedly costs associated with fragmentation in these areas, they will be difficult to address, and more benefit will be obtained from focusing on ATM/CNS. Nevertheless, we note that a recent project to reduce fragmentation has been implemented in the area of AIS (the European AIS database project or EAD).

3.2.2 The annual costs published in the ACE report for 2003 are shown in Figure 3.2. The costs described in that report as ATM/CNS costs in practice include also the costs of AIS and Search and Rescue (SAR). However, the costs in these areas are unlikely to be material in the context of the ATM/CNS system as a whole.



Gate-to-gate ANS costs (€ M)	2003	% total
ATM/CNS provision costs (including AIS, SAR & MUAC)	5 912	87.7%
MET costs	387	5.7%
EUROCONTROL costs	384	5.7%
Payment to governmental authorities and irrecoverable VAT	58	0.9%
Gate-to-gate ANS costs	6 741	100.0%

Figure 3.2: Breakdown of total European ANS costs in 2003[4]

3.2.3 We look at two major resources required to run an ATM/CNS system: the capital assets, and the operating costs.

3.2.4 We have measured the capital assets both by physical measures, where appropriate, and by financial measures. The financial measure we would ideally use is the replacement cost of the assets required to operate the system. The replacement cost is an appropriate baseline for the assessment of the cost of fragmentation since it reflects the existing asset base, but does not include any penalty for technological obsolescence. In practice, it is quite difficult to assess, especially in a system served by a multitude of organisations, since it is not a standard part of financial reporting. A more readily accessible measure is the Gross Book Value of the assets required (sometimes referred to as the cost or historic cost of the assets). This differs from the replacement cost because of the impact of inflation in raising costs, and of technological progress that improves asset productivity. However, even this measure is not universally available, and cannot generally be split into the assets used in the different parts of the system (C, N, S, ACCs).

[4] Diagram reproduced from ACE2003 (see footnote 3 on page 11).

3.2.5 Our approach to estimating the value of assets used has therefore been two-pronged. We have estimated the physical quantity of assets required in each category, using published or EUROCONTROL Agency data, and used industry estimates for the unit capital cost in each area. Where this is applicable, it gives a good estimate of the replacement cost.

3.2.6 We have also developed methods to validate this approach against other available data: Gross Book Values from published accounts; Net Book Values and depreciation figures from accounts and ACE data. Such data could, in principle, also be used when an approach based on physical quantity of assets is not applicable (for example in support).

3.2.7 The operating costs comprise the resources required to operate the system and to maintain it to an adequate standard, and include all the labour costs (sometimes referred to as “staff costs”) and the costs of the necessary materials and services.

3.3 Sources of information

3.3.1 The sources of information we have used in assessing existing costs are as follows:

- the PRU has collected extensive operating cost, depreciation and finance cost information in the course of its ACE benchmarking exercise;
- many ANSPs publish an Annual Report and Accounts, which provides data on various elements of costs as well as on asset values;
- the EUROCONTROL Agency has information about many areas of physical infrastructure and their costs;
- there is a variety of information available from trade publications or on the web concerning particular projects or transactions;

In addition, we have sought validation by ANSPs on particular cost items.

3.4 Our approach to estimating the costs of the existing system

3.4.1 Our approach to estimating the costs is as follows. For each of the areas of activity discussed in paragraph 1.1.5, we have undertaken a bottom-up approach to estimating costs:

- estimate the existing quantity of physical infrastructure;
- apply industry estimates of unit capital replacement costs and operating costs to that physical infrastructure.

3.4.2 In each case, we have used the best information we can find from published sources and from Agency sources, supplemented by the judgments of our team. These estimates have been validated, where possible, with ANSPs[5], and the conclusions in this Final Report have taken into account the feedback we have received from ANSPs.

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[5] Feedback was solicited at three Stakeholder Consultation meetings, in January, July and November 2005, to which ANSPs and other interested parties were invited. There has been contact between the team and representatives of a number of ANSPs throughout the study. In addition, all ANSPs in the scope of the study were approached with a written request to validate the assumptions used. Responses were received from nine of them, including a number of the larger ones.

3.4.3 We also need to estimate associated support costs, such as finance, administration and training. These are costs not directly linked to specific ATM/CNS infrastructure and systems, and are described in more detail in Section 3.9.

3.5 Communications

3.5.1 The communications infrastructure (as illustrated in Figure 2.2) includes both air-ground-air communications (the VHF ground stations) and ground-ground communications (the voice and data networks). The costs of voice communications switches at ACCs are assumed to be included in ACC costs. The capital costs and annual operating costs of the communications infrastructure are estimated as shown below. Further details of the calculation are given in Annex B.

	Total capital replacement cost	Total annual operating cost
Air-ground-air	€ 450m - € 670m	€ 20m
Ground-ground	-	€ 40m
Total	**€ 450m - € 670m**	**€ 60m**

Table 3.1: Summary of communications costs

3.6 Navigation

3.6.1 We have included DMEs, NDBs and VORs in the cost of navigation infrastructure. Navaids such as ILS, MLS, glide paths and localisers, which are used for landing and are located at airports, have not been included in the costs.

3.6.2 The numbers of DMEs, NDBs and VORs were derived from EUROCONTROL navaid data[6], which includes only en-route or en-route/approach navaids[7].

3.6.3 The costs of navaids are based on costs from the EUROCONTROL RNAV Business Case[8], which gives capital costs, annual running costs and flight check costs for navaids. We have assumed that the annual operating costs comprise annual running costs and flight check costs.

3.6.4 The capital and operating costs for navaids are summarised in Table 3.2.

[6] Provided by EUROCONTROL Agency, 2005.

[7] We have assumed that the cost of a precision DME (DME-P) is similar to that of a DME and therefore the numbers of DMEs and DME-Ps have been aggregated.

[8] RNAV Business Case, EUROCONTROL, August 2002.

Navaids	Number	Capital replacement cost per unit	Annual operating cost per unit	Total capital replacement cost	Total annual operating cost
DME	601	€ 100,000	€ 2,500	€ 60m	€ 1.5m
NDB	349	€ 35,000	€ 2,500	€ 12m	€ 0.9m
VOR	617	€ 250,000	€ 11,500	€ 154m	€ 7.1m
Total				**€ 227m**	**€ 9.5m**

Table 3.2: Navaids costs

3.6.5 The total estimated capital replacement cost of navaid infrastructure in Europe is around €230m and the annual operating costs around €10m per year.

3.7 Surveillance

3.7.1 Our estimates of the costs of current surveillance infrastructure are based on the numbers of primary and secondary (including Mode S) radars in Europe today. The numbers of radars have been sourced from EUROCONTROL data[9] and figures provided by ANSPs. The data gives 203 primary radars (both co-located and non co-located) and 300 secondary radars (both co-located and non co-located). We have included airport radars as these provide coverage in terminal areas.

3.7.2 Although the EUROCONTROL data does not differentiate between MSSR radars and Mode S, we have estimated that approximately 63 Mode S radars are planned in Europe by 2004, according to the States' implementation plans, based on their AICs[10]. We assume that all primary en-route radars are co-located with secondary radars (Mode S or MSSR)[11]. We have assumed four different configurations of radar: primary en-route radar co-located with secondary radar (MSSR or Mode S), primary approach radar co-located with secondary radar (MSSR), primary approach radar only and MSSR radar only.

3.7.3 Capital and operating costs for approach primary radars are assumed to be less than those for en-route radars.

3.7.4 Capital costs for radars include both the capital cost of the radar installation itself, and the capital cost of the necessary land, buildings, and services (such as utilities). The cost of land, buildings and services for enroute radars will vary, depending on whether it is a stand-alone MSSR station or is co-located with a primary radar.

[9] Radar data provided by the EUROCONTROL Agency, 2005.

[10] Module 4, The Mode S programme, Mode S Volume 2, Helios Information Services Ltd and Pennyford Consultants Ltd, 2003.

[11] According to EUROCONTROL surveillance data provided to us, there are six primary en-route radars that are non co-located. However, for the purposes of calculating order of magnitude costs, we have assumed that all primary en-route radars are co-located with secondary radars.

Capital replacement cost

3.7.5 Our estimates of the possible range of costs are summarised in the table below. The estimated capital replacement cost of radars includes radar equipment, buildings, access roads and standby electricity supplies, and is estimated, for the system as a whole, to amount to around €1,890m - €4,120m.

	Number of radars	Capital replacement cost per primary radar	per secondary radar	buildings and services	Total capital replacement costs
En-route primary plus Mode S	63	€6.0m - €10.4m	€2.5m - €3.5m	€2.0m - €10m	€662m - €1508m
En-route primary plus MSSR	5	€6.0m - €10.4m	€2.5m - € 4.5m	€2.0m - €10m	€53m - €125m
Approach primary plus MSSR	92	€2.0m - €3.0m	€2.5m - €4.5m	€1.5m - €3.0m	€552m - €963m
Approach primary only	43	€2.0m - €3.0m	–	€1.0m - €1.5m	€129m - €194m
MSSR only	140	–	€2.5m - € 4.5m	€1.0m - €5.0m	€490m - €1326m
Total					**€1,885m - €4,116m**

Table 3.3: Capital replacement costs of radar

Operating costs

3.7.6 We have assumed that the annual operating costs of radars (both primary and secondary) are between 6% and 14% of the purchase costs. This range is consistent with the feedback we have received from ANSPs. The costs are summarised in Table 3.4.

3.7.7 The annual operating costs of radars, which comprise maintenance costs, are estimated as in the range €86m - €345m per year.

Radar	Annual operating cost per radar	Number of radars	Total annual operating costs
En-route primary plus Mode S	€0.5m - €2.0m	63	€32m - €123m
En-route primary plus MSSR	€0.5m - €2.1m	5	€3m - €10m
Approach primary plus MSSR	€0.3m - €1.0m	92	€25m - €96m
Approach primary only	€0.1m - €0.4m	43	€5m - €18m
MSSR only	€0.2m - €0.6m	140	€21m - €88m
Total			**€86m - €345m**

Table 3.4: Annual operating costs of radar

3.8 ACCs and ATM systems

3.8.1 We estimated the costs of ACCs by examining the actual costs of recent ACC investments, sourced from press releases and ATC industry literature (including the costs both of the ATM systems and of the building infrastructure). We also validated the information, where possible, with ANSPs. Information on recent or planned investments provided by ANSPs[12] was also reviewed.

3.8.2 We assumed that the average replacement cost is €39m plus €2.9m per sector, figures compatible with these examples of ACC investments[13]. This is illustrated in Figure 3.3.

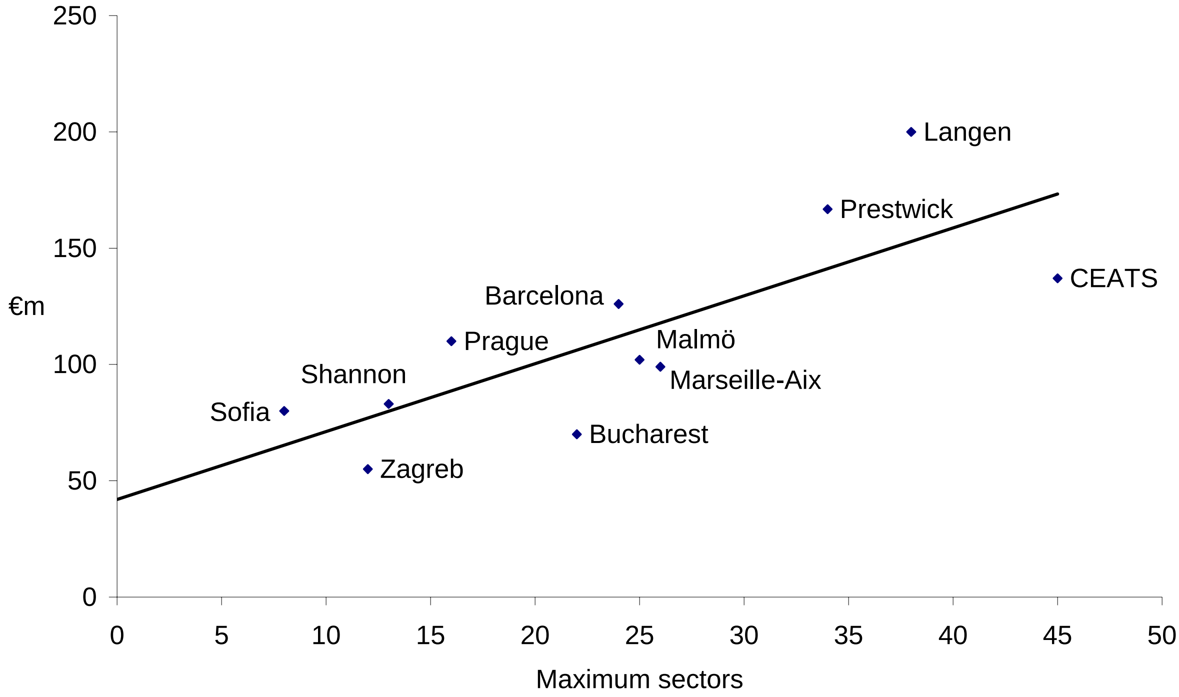


Figure 3.3: Capital costs of typical new ACC developments

3.8.3 We then used these estimates of fixed and variable capital costs and the physical maximum number of sectors at ACCs[14], obtained from the EUROCONTROL Agency or, where provided, by an ANSP[15], to estimate the total capital costs of the

[12] NATS has provided investment figures for its new ACC in Prestwick, which is due to be operational in 2008/9. Source document: NERL SIP 2005, issue 1.

[13] NERC (Swanwick) has substantially higher capital costs that the others in our sample. The high costs of NERC may be related to historical conditions that are not relevant to current replacement costs. NERC has been omitted from consideration in arriving at our conclusions. Barcelona and Marseille-Aix have also been omitted – for both centres the costs do not include new software, and for Barcelona, the buildings costs may include buildings not strictly associated with area control.

[14] This is the maximum number of sectors for which space and physical equipment is available. We have included both area and approach sectors in the maximum physical number of sectors.

[15] ANS Czech Republic, LGS, Oro Navigacija, MATS, Skyguide and NATS.

European ACCs. This gives a total replacement cost ACCs of around €4,900m. Further details supporting this estimate are given in Annex B.

3.8.4 It should be noted that this is an estimate of the replacement costs of replacing existing centres as they are now, with technology and features typical of the centres in the above sample. A number of factors will mean that what would actually be chosen to replace existing centres would in practice be more costly. For example, new centres would be built with the capacity to handle further traffic growth, new technologies to enhance ATCO productivity, and new features to improve safety. The certification of ATM systems to meet SES regulations will also increase replacement costs. These changes will tend to increase the costs of fragmentation.

3.8.5 Data on operating costs for ACCs, and the extent to which they are fixed or dependent on size, are difficult to find. Some material on operating costs of ARTCCs in the USA has been provided to the PRU by the FAA showing the relationship between centre operating costs (excluding HQ costs, but including CNS costs relating to the area controlled by the centre) and the size of the centre, as measured by the number of sectors. This is shown in Figure 3.4. The linear relationship is clear, although the figures are not strictly comparable to those we are looking for because of the inclusion of CNS costs.

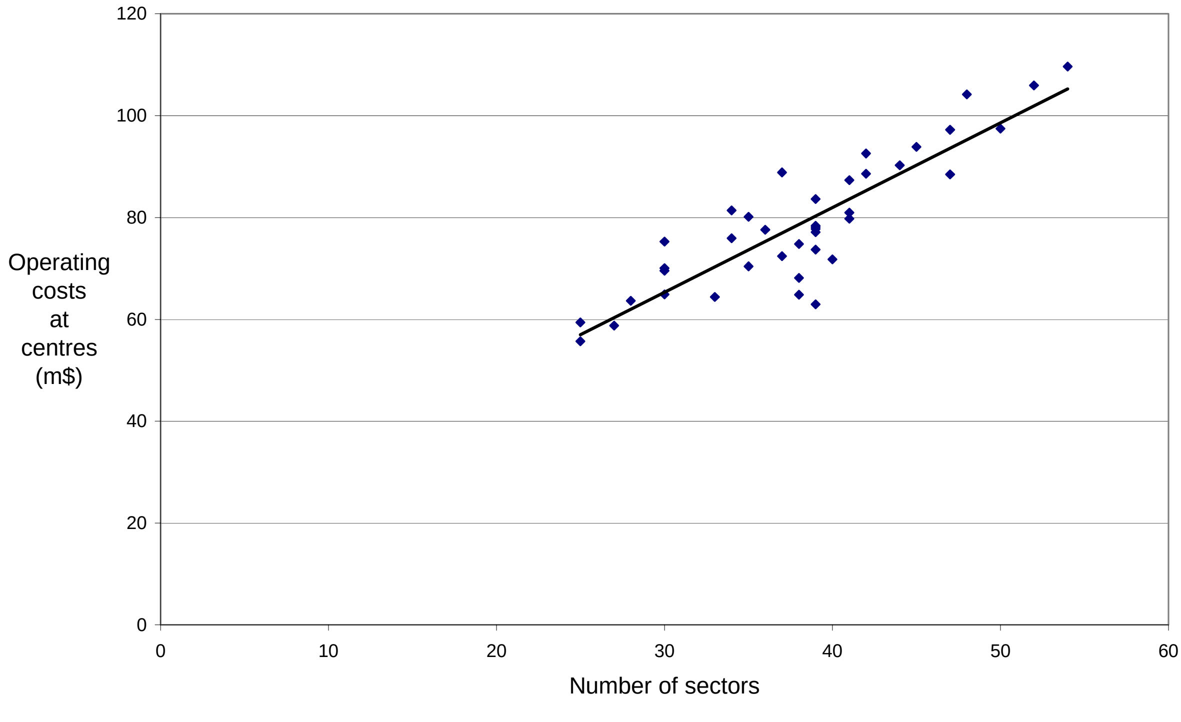


Figure 3.4: Variation of US centre costs with size

3.8.6 Operating costs for ACCs have been estimated using a model of ACC costs, developed for this study and described in detail in Section 5.4. The model has a form similar to the one that can be inferred from the US data shown above. The parameters of the model are based on data from the US-Europe en-route centres study[1], the recent experience of new build shown in Figure 3.3 above, and on our own experience. Application of the model to the current centres in Europe gives a total operating cost of around €2,100m per year.

	Total capital replacement costs	Total annual operating costs
ACCs and ATM systems	€ 4,900m	€ 2,100m

Table 3.5: ACCs and ATM systems costs

3.9 Associated support

3.9.1 The final area of costs is 'associated support costs', which we have defined as the assets and support costs required which are not directly linked to the previous four areas: communications, navigation, surveillance and ACCs. Therefore the associated support cost excludes the operating costs associated with maintaining the CNS network, operating ACCs and the associated systems and infrastructure. We have assumed furthermore that development costs for ATM/CNS systems are included in the previous costs estimates, so are also excluded from 'associated support'.

3.9.2 The remaining areas of operating costs to be considered are summarised in the following table. Some of these areas are explicitly excluded from consideration in this study, notably airspace planning and regulatory support. However, at this stage of the analysis we have not excluded their costs, as they are likely to be rather small in the overall scale of things.

Associated support cost area	Comments
'Strategic planning' of the whole system	Airspace design, strategic investment planning concerning system architecture, the location of centres and items of CNS infrastructure
Ab initio training of controllers	On-the-job training in pursuit of new validations is included with ACC costs
Basic training for maintenance staff	
Research and development	
Central administration costs	Includes finance, human resources, legal and corporate costs, safety and quality management, regulatory support, non-operational IT and general training

Table 3.6: Associated support costs

Capital replacement cost

3.9.3 To estimate the capital assets required for 'associated support', we attempted to calculate the difference between the total GBV of assets and our previous estimate of ATM/CNS capital replacement costs, as follows:

(a) We made an estimate of the total capital assets required to operate the whole system (en-route and terminal) using published GBV figures from Annual Reports. Where GBV figures are not available, we made estimates of them using NBV figures from ACE and estimates of the average age of assets.

(b) We then made an estimate of the proportion of this asset base that is used for en-route services, again using figures from ACE.

(c) We subtracted our previous estimate of ATM/CNS capital replacement costs from (b) to obtain a residual figure.

3.9.4 In principle, the above method should yield an estimate of assets used to provide 'associated support'. However, using data available publicly and from PRU sources, we were not able to obtain a reliable estimate. The ATM/CNS costs assessed above were greater than the estimate of total GBV assessed as described in the previous paragraph.

3.9.5 This result could have occurred for any of three reasons:

- the "bottom-up" process could be an over-estimate;
- the GBV/NBV ratios for the 13 ANSPs examined were not typical of the system as a whole; or
- the ANSPs in their information disclosure classed some assets as "terminal" that we have included in our estimate.

3.9.6 It seems likely that all three factors will have contributed to the discrepancy.

3.9.7 We were therefore unable to use this approach to estimate the replacement capital costs of assets in this "associated support" category, which includes non-operational IT, vehicles, office furniture and HQ buildings. We expect, however that such assets constitute a relatively low proportion of the total. In the absence of further information, we have tentatively estimated their replacement cost at €1,000m.

Operating costs

3.9.8 We estimated the associated support operating costs as around €1,100m, the difference between our estimate of ATM/CNS and the total en-route operating cost from ACE 2003[3] (€3,422m). We used the en-route figure from ACE 2003 as the focus of this study is en-route ATS units, and we did not make estimates of the operating costs of other operating units.

3.10 Estimates of the costs of the European en-route ATM/CNS system

3.10.1 Using the methods described above, we estimated both the capital replacement costs of the system, and its operating costs. We divided our estimates into the five areas discussed above: C, N, S, ACCs and ATM systems, and associated support.

Capital replacement costs

3.10.2 The capital replacement costs for the en-route European ATM/CNS system, estimated using the methods given above, are as shown in Figure 3.5 below. Costs are for 2003, since this is the latest complete set of data available to us.

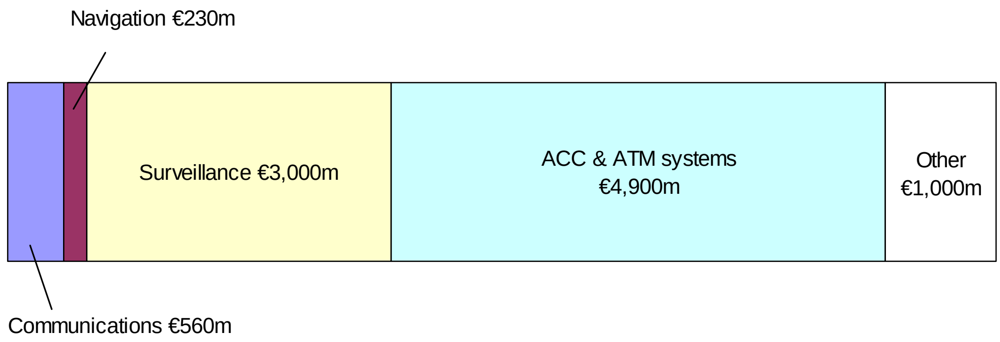


Figure 3.5: Capital replacement costs for European en-route ATM/CNS, 2003

3.10.3 The orders of magnitude of capital replacement costs seem consistent with a scale of capital expenditure of around €1b a year and depreciation costs of €721m a year from ACE[16].

Operating costs

3.10.4 The operating costs for the en-route European ATM/CNS system, estimated using the methods given above, are as shown in Figure 3.6 below. Again costs are in 2003 prices, for 2003.. The cost for "associated support" is inferred from the ACE 2003 en-route ATM/CNS operating costs, less the estimates for the individual areas.

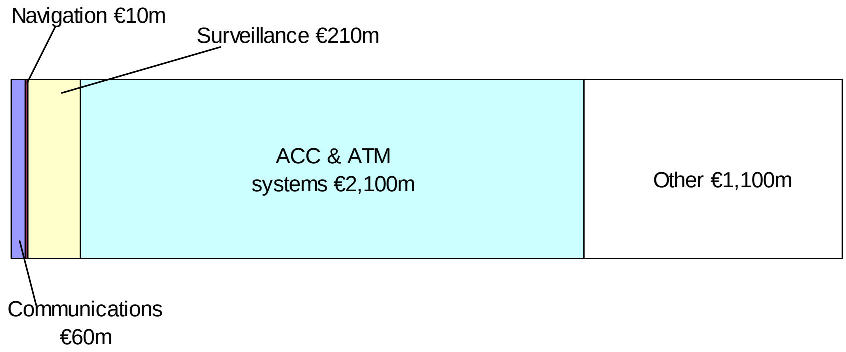
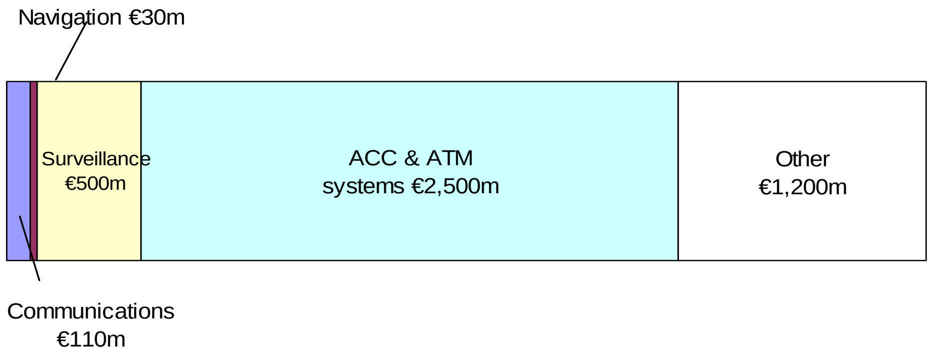


Figure 3.6: Annual operating cost estimates for European en-route ATM/CNS

[16] This figure, from ACE 2003 (footnote 3), relates only to a subset of our definition of "Europe" – Poland and Bosnia-Herzegovina are excluded. This should not make a material difference.

Comments on the cost estimates

3.10.5 Our overall estimate of the costs of the system (around €4350m) was obtained by annualising the capital costs over eleven years (a typical ratio for ANSPs between asset acquisition costs and the sum of depreciation and finance costs). The distribution of the overall costs among those areas is shown in Figure 3.7.



	Capital replacement costs	Annual operating costs	Total annual costs	
COM	€560m	€60m	€110m	2.5%
NAV	€230m	€10m	€30m	0.7%
SUR	€3,000m	€210m	€500m	11.5%
ACCs & ATM systems	€4,900m	€2,100m	€2,500m	57.6%
Other	€1,000m	€1,100	€1,200m	27.7%
Total	**€9,690m**	**€3,480m**	**€4,340m**	**100%**

Figure 3.7: Total annual cost estimates for European en-route ATM/CNS

3.10.6 It is evident that the costs of navigation and, to a lesser extent, communications, are rather small compared with other aspects of the system. Our conclusion is therefore that the costs of fragmentation in these areas are likely to be small compared with those in surveillance and ATM operations. We have therefore concentrated our efforts on the latter areas.

3.10.7 Both capital and operating costs are dominated by the costs of ACCs and ATM systems. We have not been able to find any hard evidence that will enable to estimate the split between the various elements of this cost, although the centre model, described in Section 5.4, uses insights from various sources to estimate the impact of fragmentation in each area.

4 Fragmentation issues

4.1 Introduction

4.1.1 In this section we examine the fragmentation issues that might have an adverse impact on costs or another key performance area. The section addresses fragmentation issues in the following order:

- issues common to a number of domains;
- ACCs;
- ATM systems;
- CNS;
- associated support costs; and,
- safety performance.

4.1.2 We did not consider the impact of fragmentation on airborne infrastructure as it was outside the scope of this study.

4.2 Common issues

4.2.1 The common issues examined were as follows:

- piecemeal procurement;
- sub-optimal scale in maintenance and in-service development;
- fragmented planning;
- unsynchronised or inconsistent technological change.

Piecemeal procurement

4.2.2 Although some specific initiatives for common procurement are under way, the procurement of systems for ATM/CNS is usually based on a specification of operational and support requirements pertaining to an individual ANSP. In the absence of common approaches, system suppliers incur and pass on higher development costs. Given the high costs associated with the development of ATM/CNS systems, there is a correspondingly high potential for cost reduction. This cost reduction could be realised by procurement specifications common across ANSPs. The overall consequence of the current piecemeal approach is to increase the capital costs of the initial procurement because each system is seen as unique and requires bespoke design.

4.2.3 Under the Single European Sky, the intention is to establish interoperable systems through common industry specifications and to incorporate only the essential minimum of local adaptation (in any case, the requirement for local adaptation should be challenged). There is a tendency for existing custom and practice to be carried across to the next generation of systems partly because of the conservative nature of the industry. The capital cost benefits of common procurement can be summarised as follows:

- reduction in effort in the preparation of procurement specifications;
- reduced bidding costs for the supplier industry;

- reduced capital costs for system due to reduced development requirements;
- shorter implementation timescales;
- reduced timescale drift;
- reduced resource requirements for system integration and test; and
- reduced resource requirements for the preparation of safety documentation.

4.2.4 The use of common procurement specifications may carry with it the danger of a reduced number of suppliers in the market, with an adverse impact on prices. This could come about because competitions would be less frequent. However, it could equally be argued that as specifications become more standard, barriers to entry are reduced. The procurement process must be carefully designed to ensure the eligibility of a full range of suppliers.

Sub-optimal scale in maintenance and in-service development

4.2.5 ANSPs assume varying responsibilities for the maintenance and in-service development of the ATM/CNS systems. The cost of providing the resources to carry out these tasks is related to the number of different types of system in service. It is therefore appropriate to examine these tasks in more detail.

4.2.6 Maintenance of systems falls into three main categories:

1. Monitoring, control and restoration of services.
2. Repair of hardware.
3. Update of operating parameters.

4.2.7 Restoration of services involves the monitoring and control of operational systems to ensure that, in the event of a failure, the necessary corrective action is taken. The first line of action is usually to ensure that the standby facilities are brought in to service and that those responsible for remedial action are notified.

4.2.8 Repair of hardware is carried out in stages. Usually repair can be implemented in the short term by replacing individual modules. These modules are then normally sent to the original supplier for repair.

4.2.9 Update of operating parameters includes the routine update of parametric data in software, which is required to reflect new operational situations. This does not usually require software design skills.

4.2.10 On the other hand, development of systems involves the addition of new functions. This is a design task which requires different skills from maintenance. Most development is carried out in system software and is very costly. The majority of ANSPs rely on the system supplier to carry out system development although some of the larger ANSPs (such as NATS and DSNA) have in-house resources.

4.2.11 The resource requirements to carry out maintenance and development work are significantly affected by the degree of fragmentation. A highly fragmented system, where there are many different types of equipment at several locations, requires more maintenance and development staff than a single location utilising a limited number of equipment types.

4.2.12 Furthermore, fragmentation has the potential to reduce the utilisation of maintenance staff. In order to achieve the necessary repair response times, expert staff must be on hand to carry out remedial work. In situations where there is a limited amount of equipment, these staff can be underemployed.

Fragmented planning

4.2.13 In most of our discussion of the impact of fragmentation, we are concerned with how fragmentation causes the costs of the existing system to be higher than it would otherwise be. However, fragmentation can also inhibit or delay investments that would result in improvements to efficiency and quality of service, or even cause sub-optimal investments to be undertaken.

4.2.14 Planning and investment appraisal is the responsibility of individual ANSPs, who, in principle, should plan investments on the basis of sound economic appraisals of investment options[17]. However, in today's fragmented system, there will be a tendency for each ANSP to make decisions based on the costs and benefits associated with local service provision, rather than taking into account the full impact on the European network. Benefits that accrue to neighbouring ANSPs, or users of their services, may not be considered. Furthermore, each ANSP may act without full knowledge of the investment plans of its neighbours. Investments appraised solely on a single ANSP's objectives and criteria may therefore result in the perpetuation or worsening of the impacts of fragmentation – for example in duplication of CNS resources, or the continuation of non-interoperable systems.

4.2.15 Actions to alleviate such problems can be taken through bilateral or multilateral initiatives. Bilateral initiatives have the advantage that in general it is easier to obtain both parties' commitment – however, it only diminishes rather than eliminates the problem, as planning is still fragmented between the two parties in the bilateral arrangement and the rest of the system.

4.2.16 Multilateral initiatives are often conceived at the EUROCONTROL level. The Agency may undertake initiatives to reduce inefficiencies and improve the coordination of investments by standardisation and coordination. However, such initiatives have their own costs. The process of consensus building can be time-consuming and costly in human resources. The consensus that is arrived at may not be the system optimum, because of the different weights placed on the views of different ANSPs or States' representatives. The process of building consensus can delay the introduction of beneficial improvements. And finally, there is no certainty that the solution recommended by the Agency is actually adopted by individual ANSPs or states.

4.2.17 In assessing the costs of fragmentation, it is not appropriate to assign a separate cost to the impact of fragmented planning. This would be double counting. The costs of fragmented planning appear in the individual areas, as the costs of a sub-optimal, fragmented system. In a fragmented environment, planning activities are carried out both by ANSPs themselves and EUROCONTROL, resulting in duplication. In a defragmented environment we would expect ANSPs to carry out these activities. Therefore, some of the costs of working towards diminishing the adverse impact of fragmented planning and investment appraisal (including, for example, a proportion of the EUROCONTROL Agency costs) should be counted as a cost of fragmentation.

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[17] If investments are not carried out by each ANSP according to sound economic appraisals, that is a cost of inefficiency, rather than of fragmentation.

Unsynchronised or inconsistent technological change

4.2.18 The introduction of new technology is increasingly reliant on many sub-systems working together to achieve the required functions. Usually this involves satellite, airborne, communications and ACC components working together in a fully compatible way. This is recognised in the interoperability requirements of the Single European Sky[18]. The effect of fragmentation is to make this a very difficult objective to achieve as each sub-system type incurs separate development costs. Furthermore, synchronising updates is very difficult or impossible to achieve as each service provider is working to their own development timescales.

4.2.19 Again, the impact of this is manifest in the observed sub-optimality of the European ATM/CNS system, and to ascribe a specific cost to this issue would be double counting.

4.2.20 The impact of this issue will be that certain tyoes of fragmentation will take a long time to remove even if the appropriate measures are taken – of the order of one investment cycle.

4.3 ACCs

Economies of scale in ACCs

4.3.1 There is substantial evidence for economies of scale in ACC operation. This arises in two ways:

- through the low utilisation that will inevitably occur at times of low demand in very small centres; and
- through economies of scale from sharing the fixed costs of a centre over more activity.

The latter will have an impact on capital costs as well as operating costs.

4.3.2 In the current ATM system, 47 of the current 69 ACCs operate with 10 sectors or fewer. On average the productivity of their ATCOs is around 25% lower than the bigger ACCs[19]. There is an evident lack of flexibility in operating such small ACCs; in simple terms, an ACC cannot operate with less than one sector, and the opportunities for reducing the use of ATCOs at slack periods is more restricted in such small units.

4.3.3 The typical size of a European ACC is much smaller than those in the US, as shown in Figure 4.1. In Europe, the average centre operates 9 sectors at maximum configuration; the average US centre 37 sectors. Furthermore, the FAA is currently examining the possibility of consolidation among its existing centres.

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[18] Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation).

[19] See all the ACE Benchmarking Reports (reference in footnote 3 on page 11) and the Solar Alliance report for the UK CAA (reference in footnote 30).

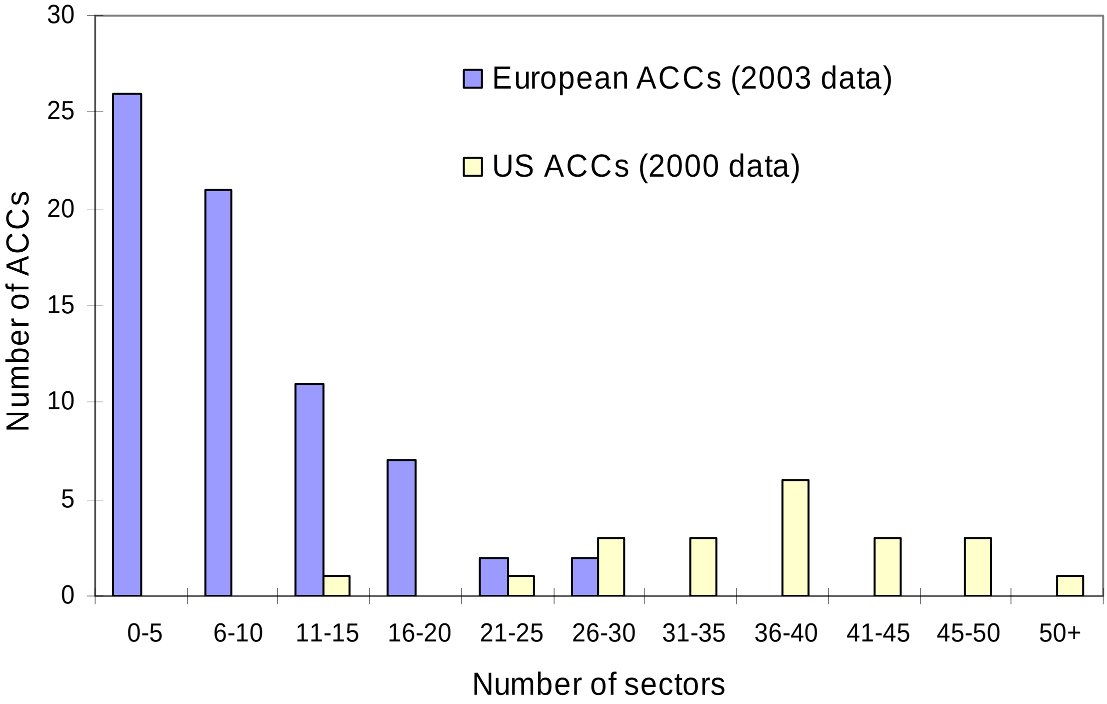

Figure 4.1: Centre sizes in Europe and the US

4.3.4 The references shown also indicate that the productivity of ATCOs rises with increasing scale. Whether this is an economy of scale of the centre or of the density of the traffic at the centre is not fully resolved. However, there are certain fixed elements of the cost of a centre, and this suggests that fixed costs would be saved if centres were larger. Some evidence for the capital elements of those fixed costs is apparent in the costs for new centres shown in Figure 3.3.

4.3.5 There will be limits to the feasible size of a centre. Recent consolidation exercises in the UK and Germany have or will produce centres that can accommodate 50-60 centres. This is comparable with the scale of the larger US area control centres. There is a general view that consolidation to scales greater than this may not necessarily lead to further economies of scale – difficulties in coordination and in providing contingency backup may start to outweigh fixed cost savings. We take this into consideration in our quantitative analysis in Section 5.

Constrained sector design

4.3.6 Sector design is often constrained by national boundaries, which would be removed in a defragmented system. This could have an impact on operational efficiency by allowing a reduction in the number of sectors and for more efficient flight profiles.

4.3.7 A particular case of this is where approach sectors have arriving traffic bound for airports located near national boundaries. Aircraft in the descent phase, crossing over national boundaries, may fly non-optimal flight profiles during the cross-over and the coordination between the sectors may be increased, because of specific procedures for national boundary traffic. Recent collaborations have been targeted at this problem, for example in Estonian airspace in the approaches to Helsinki.

4.3.8 Even in the example of Maastricht UAC, where the centre covers the airspace of more than one member state, the sectors are still constrained by national boundaries.

4.3.9 One example of where ANSPs have worked around this problem is that in French airspace, where control of the airspace around Geneva airport is delegated to Skyguide, the Swiss ANSP.

4.3.10 A more standardised approach to airspace design would allow progress towards the creation of more generic sectors. Currently, ANSPs ensure that controllers have specific local knowledge through a process of endorsement or validation, which allows them to work on specific sectors. In a defragmented system, generic sectors would reduce the requirement for this local specialisation. There would be a consequent reduction of training costs including the need for training cover. It would also increase flexibility (in combination with the Single European Sky requirement for a common ATCO licence) by reducing the need for specific training from ATCOs moving between ACCs or ANSPs.

4.3.11 A standardisation of sectors may result in more ATCOs being available to resource those sectors and consequently introduce more flexibility in rostering. A reduction in staff and fewer staff shortages could result.

4.4 ATM systems

Lack of common systems

4.4.1 Use of different software by different centres is a significant cost of fragmentation. It results not only in greater implementation costs, but also in increased development costs, as upgrades must be dealt with separately at individual centres.

4.4.2 At present, very few centres have common systems, even those operated by the same ANSP. it is difficult to assess precisely how many separate systems exist since it is questionable how much systems must diverge before being regarded as “different”.

4.4.3 76% of the flight-hours in the European system are served by systems from five major suppliers, and another 4% from minor suppliers. The remaining 20% of flight-hours are served by bespoke systems. This is illustrated in Figure 4.2 and Figure 4.3[20].

[20] The pie chart is for those ANSPs reporting to ACE 2003. It therefore excludes Poland and Bosnia-Herzegovina.

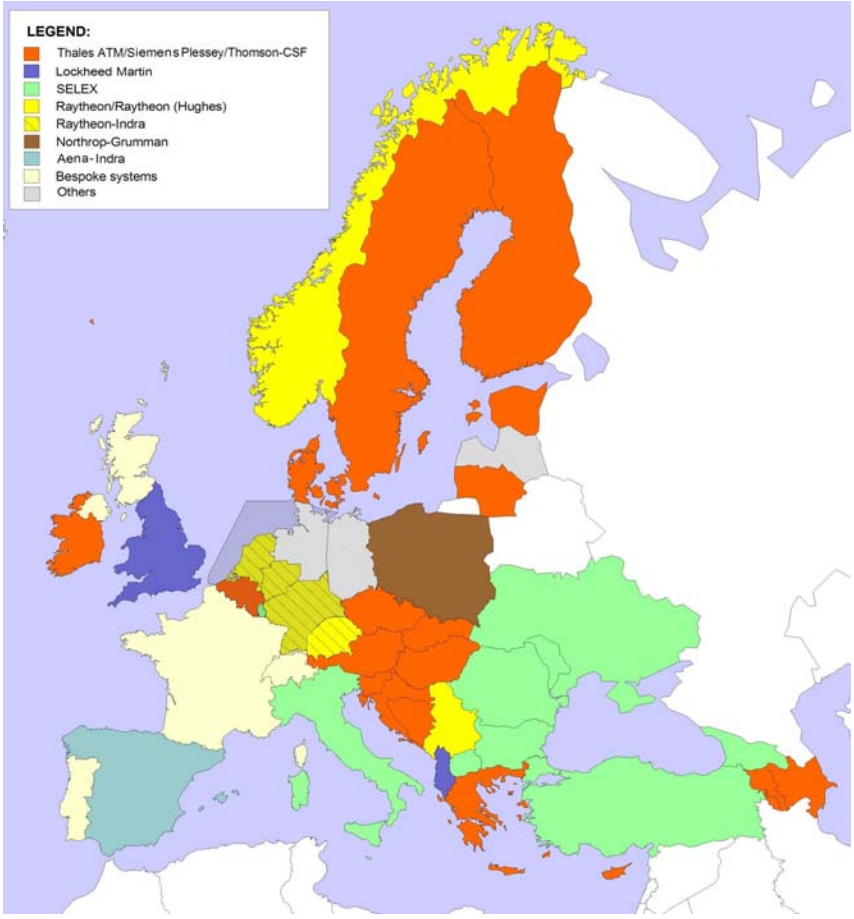

Figure 4.2: System suppliers in European ATM

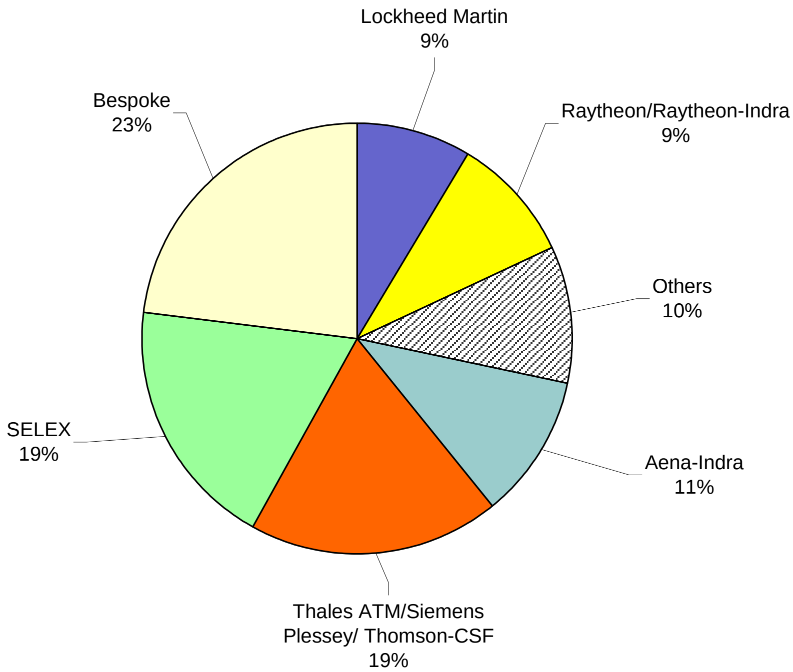

Figure 4.3: Flight-hours served by systems from different suppliers

4.4.4 The costs of fragmentation arising through lack of common systems will be much reduced if ACCs are consolidated and their numbers reduced. For this reason, it is somewhat arbitrary whether the cost of fragmentation is classified as a cost arising from lack of common systems or from fragmentation of ACCs. For this reason, when we quantify the impact of this fragmentation issue in Section 5, we deal with it under Section 5.4, which relates to ACCs.

4.4.5 In the absence of common systems, a further fragmentation issues is the lack of interoperability between the separate systems, which is discussed below.

Lack of systems interoperability

4.4.6 Interoperability is a key issue which the SES seeks to improve. The term is difficult to define but the objective is best satisfied by common functionality of systems and common interface definitions. Common functionality is a prerequisite to the introduction of common interfaces. In a fragmented system, the transfer of information between centres is more limited because the functionality is usually different. Special interface gateways are usually required to achieve a degree of interoperability. This approach incurs costs and has limited potential for system development as the desired level of integration increases to meet requirements of future, more advanced, ATC.

Lack of contingency capability

4.4.7 The availability of ACCs is a major issue. The loss of a centre could result from industrial disputes, technical failure, services failure, and fire or security issues. Failure of an ACC has not only has safety implications but involves severe disruption to services and results in costs to airlines, airports, ANSP and passengers alike.

4.4.8 The loss of an ACC service can range from short-term systems failures to catastrophic destruction of facilities, which could result in long-term outages. Short-term system failures can be minimised by adequate systems redundancy and ACCs are generally provided with high-integrity systems including building services. Catastrophic failures are much more difficult to overcome and this has resulted in ICAO and EUROCONTROL publishing recommendations for adequate contingency plans.

4.4.9 ANSPs are increasingly looking at contingency plans which involve neighbouring centre(s) taking on responsibility for the airspace of the failed centre. However, the feasibility of this sort of transfer of responsibilities can be limited in a fragmented environment where the systems may be different and are unlikely to have the same human machine interfaces. Therefore, a fragmented environment tends to work against the provision of practical and effective contingency arrangements.

4.4.10 On the other hand, it could also be argued that resilience in the face of possible loss of a centre could be enhanced by fragmentation of centres, in that there are more possibilities for contingency arrangements. However, such arrangements will be most effective when other obstacles that result from fragmentation (such as lack of interoperability and lack of coordinated training) are removed.

4.4.11 The reality is that centre sizes are likely to increase due to potential efficiency gains and the deployment of larger centres makes the requirement for adequate contingency planning more critical. Fortunately, the use of common systems and HMI make the provision of adequate contingency arrangements for the longer term outages easier to achieve.

Increased coordination at interfaces

4.4.12 Coordination across national boundaries can be more onerous than that within a national ANSP. This is due primarily to interoperability issues and variances in local procedures. A rough order of magnitude would indicate that twice the amount of time is spent on voice coordination between centres, because of lack of interoperable systems and procedures. Increasingly interoperable systems can reduce the amount of coordination between centres.

Other ATM systems fragmentation issues

4.4.13 In addition to the above causes of fragmentation, we have identified the following issues:

- **Economies of scale**. A consequence of increasing centre size to achieve the economies of scale would also tend to minimise the maintenance and development costs at centres, with fewer types of systems to support.
- **Piecemeal procurement**. Many ANSPs have a policy of establishing their own procurement specifications and their own operational support facilities. This means that the risks and costs are higher and the track record of the implementation of new centres points to a norm of delays and cost overruns.
- **Standards**. Very few standards apply to ATM systems. As a result of the Single European Sky legislation, standardisation authorities are currently working on interoperability standards for flight data processing systems and ATM system architecture. The development of modern interoperability standards for FDP is an enabler for many of the new functions to improve flow and provide dynamic management of flights. The work on ATM systems architecture is aimed at providing systems which can accept updates to functionality without major internal system redesign. Without this type of standard, the introduction of common systems is likely to be delayed.
- **System lifecycle**. ATM systems and interfaces are characterised by a requirement for quick maintenance response times when a system fails and the need to develop the systems to incorporate new functionality. The implications of these basic requirements are:
  - The need to provide a maintenance team scoped to meet the response time requirements and with the necessary expertise.
  - The need to have access to a software development team with a detailed knowledge of the software design of the operational systems.
  - Each of these teams has to be provided with the appropriate test and development hardware. In practice, the level of resources and whether the resources are provided in house or from the system supplier is a complex subject. However, the effect of fragmentation is to increase the cost of providing the relevant expertise. Furthermore, the maintenance and development costs provide a further argument for reducing the number of centres as the resource requirements are not proportional to the size of the centre.

4.5 En-route CNS infrastructure

Coverage and frequency requirements for VHF radio

4.5.1 A defragmented system could have better airspace design and route structure; some rationalisation of communications infrastructure would therefore be possible. Aircraft flying over national boundaries and from one sector to another will change VHF channels in order to utilise voice communications in the adjacent sector. In a defragmented system, the absence of national boundaries could result in fewer sector changes and this could have an impact on the number of frequencies required and thus the number of VHF ground stations required and the complexity of message switches. This would reduce capital and maintenance costs

4.5.2 Frequencies for VHF voice communications are currently allocated on a national basis. This is unlikely to give a frequency allocation optimal for the whole European system. A fragmented environment tends to prevent an efficient analysis of frequency allocations against demand and has the potential to incur frequency allocation overheads to meet individual national requirements.

Optimum location of navaids

4.5.3 Centralised and coordinated infrastructure planning, as opposed to planning on a national basis, may result in more effective geometry in the location of navaids. Aircraft flying over national boundaries will seamlessly use navaids located in other States, and therefore interface issues are not relevant in the navigation infrastructure.

Surveillance

4.5.4 Radar stations have interfaces between the aircraft, the ground communications network and the end user air traffic management systems at centres and airports. The standards relating to the airborne interfaces (SSR and Mode S) are well defined by ICAO for global interoperability. The interfaces to the ground systems are defined by the EUROCONTROL Asterix format, although there are a number of legacy systems still in use. These legacy interfaces may, in theory, preclude radar data sharing between countries but these issues can be resolved at low cost. The technical interface issues related to radar data sharing are therefore not considered to be a significant cost of fragmentation.

Overprovision of secondary radar

4.5.5 Overlapping cover at national boundaries is a complex subject because it requires knowledge of the terrain topography in the boundary area and a detailed understanding of the operational requirement for radar cover in the regions concerned. Nevertheless, unnecessary overlaps could well exist and contribute to increased costs. Note that the EUROCONTROL standard[21] encourages the use of radar data sharing.

4.5.6 Primary radar in en-route airspace is also used by some countries, for example, where there is a need to identify non-transponding aircraft and to provide an ATC service to military aircraft.

[21] EUROCONTROL standard document for radar surveillance in en-route airspace and major terminal areas, March 1997.

4.5.7 The consistency of the application of the EUROCONTROL standard is relevant to a study of fragmentation. Possible over-provision can occur for two main reasons:

- provision at national boundaries does not take into account cover available from adjacent States;
- primary radar is provided in en-route airspace.

Inconsistent use of primary radar

4.5.8 The requirement for primary radar in the context of civil en-route ATC has been the subject of much debate in the context of civil-military cooperation national policies on requirements. The consequence is that there are wide variations in its application across Europe.

4.5.9 Provision of primary radar surveillance in en-route airspace could be justified through a military need, although in this case it is not strictly a cost of civil ANS provision and costs might therefore be charged to the military. In some States, it is argued that primary radar surveillance is required as a safety net for civil en-route control; however, this is not consistent with the current EUROCONTROL standard.

4.5.10 A final aspect is that as primary radar detects all aircraft without relying on any aircraft response, growing emphasis on security considerations may give some impetus to its continued use in an en-route environment. In this study we are unable to definitively answer whether the inconsistent use of primary radar represents a cost of fragmentation. If future European harmonisation requires en-route primary radar, the costs would increase from the present level; and the challenge for ANSPs would be to jointly plan coverage and avoid future fragmentation.

4.6 Associated support

4.6.1 As discussed in Section 3.9, associated support comprises a variety of activities, not all of which are within the scope of this study. In many of these areas, there would seem to be scope for reduction of costs by the reduction of fragmentation. In particular, less fragmentation might allow for a reduction in central coordination activity, in particular the harmonisation aspects of European Programmes such as EATCHIP; noting that much of current coordination effort is focused on such areas as capacity and safety.

Economies of scale in training

4.6.2 Training is at present largely undertaken at the level of individual ANSPs – there is essentially one training institution per ANSP (although a number of ANSPs' training institutions undertake work for external parties)[22]. This is unlikely to result in the optimum scale or geographical distribution of training institutions throughout Europe. Some consideration is currently being given to unify training across the ANSPs in Norway and Sweden.

4.6.3 Validation training for ATCOs has been included as a centre-level cost. Nevertheless there may be economies in this area to be obtained by a defragmented approach to procedures, systems and sector design.

[22] The EUROCONTROL Institute of Air Navigation Services (IANS) undertakes a variety of continuing professional training for ATCOs and other staff, as well as the *ab initio* training for MUAC ATCOs.

Economies of scale in administration costs

4.6.4 The issues in strategic planning are most likely to arise with duplication of effort in small, adjacent ANSPs. While important on a scale of the individual ANSPs, the costs of fragmentation in this area are likely to be small in the overall European context. Note that this is a discussion of the possible economies of scale in the planning function, not one of the consequences of fragmented planning, where the consequences could be much greater.

4.6.5 Finance would seem to be another function where there might be economies of scale. The requirements for management information to run the business would be similar across all ANSPs (especially given the requirements of the Single European Sky concerning financial reporting and the common charging regime) and there would be a case for common systems reducing the need for customised support, installation and training. However, a complication arises when individual member States' tax or accounting laws require extensive disclosure in different formats from those required for management of the business – in these cases, extensive national customisation would still be required. The adoption of common accounting standards should ease this problem but is unlikely to eliminate it. There is, therefore a cost of fragmentation in this area, but not all of it could readily be eliminated. Nevertheless, there would seem to be scope for reduction of fragmentation, particularly in small and medium-sized ANSPs.

4.6.6 There may also be some costs because of duplication of revenue collection systems, for example, where States retain their own route charges offices, which may to some extent duplicate the work of the CRCO.

4.6.7 Similar considerations apply to safety management and to regulatory support; there are very likely to be economies of scale, but different national regulatory requirements might make the diseconomies of small scale difficult to eliminate.

4.6.8 Economies of scale in human resources, legal and general corporate costs are likely to be less and the relevant costs smaller.

Economies of scale in R&D

4.6.9 The extent to which R&D is 'fragmented' depends on a number of factors, including the following:

- the degree of coordination of R&D at the European level. There would appear to be good coordination throughout Europe through EUROCONTROL and European Union funded Framework projects;
- how far into the future the R&D is. It is easier for organisations to collaborate on longer term R&D, as there are fewer constraints relating to legacy systems, operations and commercial factors;
- the alignment of R&D to ANSP business plans, particularly in the medium term;
- the accessibility of R&D results, through published papers;
- the efforts of ANSPs to monitor and become engaged in international R&D as a means of sharing R&D costs; and
- ex-ante and ex-post evaluation of R&D and how this informs the future decision making process.

4.6.10 The above list is not exhaustive and addressing the cost effectiveness of R&D would be a study in its own right. Many of the above factors will be addressed by the SESAR[23] project, which should bring earlier decision making, improved stakeholder involvement, greater coordination and measurable outputs.

4.7 Safety performance

4.7.1 As discussed in paragraph 1.3.6, the impact of fragmentation on safety is likely to be manifest as an increase in costs required to maintain safety levels. In this section we examine the impact of fragmentation on safety.

Introduction

4.7.2 ATM safety performance may be measured by the number of serious accidents or incidents with a direct ATM contribution, for a given level of activity. The Safety Regulation Commission (SRC) has proposed a target level of safety, to be reached by 2015, is 1.55 x 10^{-8} aircraft accidents, with direct ATM contribution, per flight hour. As there are currently around 10 million flight hours a year in Europe, reaching this target would mean, on average, an 'ATM direct contribution' accident every 6 years. The target derives from the SRC's strategic objective for ECAC to ensure that the number of ATM related accidents per year do not increase, and where possible decrease.

4.7.3 The Safety Regulation Commission has also produced a system of performance indicators, although full reporting of these is frustrated by a lack of data from States[24] Nevertheless, the SRC has been able to report statistics on accidents with a direct ATM contribution.

4.7.4 In this study, it is important to try to determine to which extent the current level of European fragmentation impacts on achieved levels of safety. This is difficult given the rarity of serious accidents or incidents, since there is little data to rely on as statistical evidence. Incident statistics would be more useful in this study; however, such data is harder to obtain and any data that are reported often do not give much insight into the underlying reasons for an serious accidents or incident, such as controller loss of situational awareness or mis-communication.

4.7.5 The first part of this assessment considers the main ATM accident prevention measures. It asks whether their performances can in any way be related to fragmentation.

Accident causal factors

4.7.6 Variants of the safety barrier model have become widely accepted as a metaphor for understanding the nature of and preventing accidents. A full description of a current version is contained in the EUROCONTROL Safety Assessment Methodology (SAF.ET1.ST03.1000-MAN-01-01-03-I).

4.7.7 In the barrier model, the ATM system can be considered as sets of 'barriers' that operate to prevent, resolve and recover from incidents. A simplified view of the ATM barrier model is illustrated in Figure 4.4.

[23] Previously known as SESAME

[24] SRC Annual Safety Report 2004, SRC DOC 35, Sept 2004

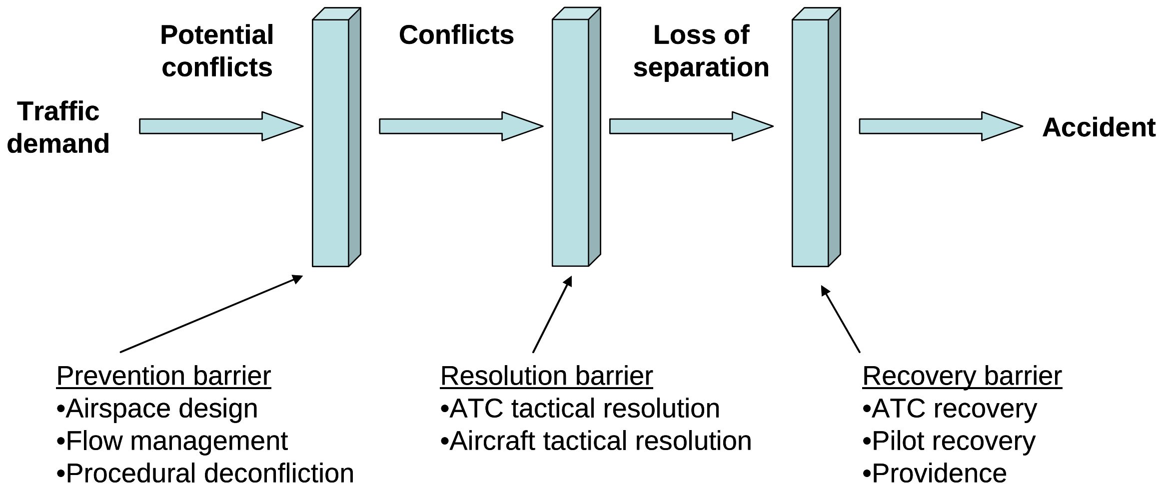

Figure 4.4: Barrier model

4.7.8 The contribution of the individual barriers in maintaining safety depends on the ATM environment under consideration. The number of barriers breached indicates the degree of loss of control. Thus, ground-based ATC can be considered to have lost control if a loss of separation can only be resolved by a pilot or providence. As more barriers are breached, the likelihood of an accident increases accordingly.

4.7.9 The effectiveness of the 'barriers' is influenced by the rate of occurrence of failure conditions. A barrier's effectiveness is not static – it can be significantly eroded, for example because of ATM system failure, or human error (ATCO or pilot). Taking each barrier layer in turn, some of the following fragmentation issues might be expected to arise:

- Prevention Barrier. This addresses how to prevent, at the strategic level, conflicts between aircraft, obstacles and terrain. It includes the design of airspace, flow management and operating procedures. Fragmentation is likely to impact:
  - Where the design of airspace (especially where departures/arrival phase of flight is concerned) is interrupted by sector boundaries created purely for the delineation of flight information regions based on sovereignty. In these cases procedures are developed to ensure downstream ATC units have up to date information on the flight, such as assigned level and routing, through controller voice or system coordination. This introduces the possibility of errors in coordination leading to serious accidents or incidents. Additionally larger separation standards than those prescribed in ICAO documents are often applied for aircraft crossing these boundaries, which may increase controller/pilot workload.
  - Flow control, where controllers working in downstream sectors may become overloaded if flow control procedures are inefficient or do not exist. Even where there are flow tools in use or planned to be used these require real-time flight data to accurately predict demand and advise on delay absorption times. Hence where tactical flow control is an issue across boundaries (say 50 minutes before arrival), complexity is introduced in spite of automated tools and coordination procedures. This complexity may increase the probability of controller overload.

- Resolution Barrier. When the prevention barriers fail, conflicts occur, which must be resolved to avoid a loss of separation. Resolution will most likely be by controllers detecting the conflict and resolving it by instructions to the affected aircraft. Fragmentation is likely to affect:

  - Resolution where the best tactical action is either not possible or requires inter-centre coordination. Inter-centre coordination may involve issues of communication, data sharing to produce a shared traffic picture, language, common procedures and phraseology. Tactical choices for resolving conflicts may therefore be limited or require an increased workload.

  - Automated tools to assist with tactical resolution such as Medium Term Conflict Detection (MTCD). Such tools need to share data between centres where conflict points are located close to sector boundaries. Data sharing is likely to be more difficult in a fragmented system.

- Recovery Barrier. If the conflict is not detected by a controller as part of their normal monitoring, then it should be noticed by a supervisor, picked up by a safety net, detected by an STCA alarm, or alerted by TCAS. These should trigger appropriate action by controllers and pilots as appropriate, and hence prevent the 'system breach' from becoming an accident. Providence, i.e. the closeness and orientation of the aircraft flight paths, plus the degree of manoeuvring in progress, is particularly relevant in this layer. Fragmentation is not likely to have a significant impact on this barrier. However in a de-fragmented system there is an increased possibility that supervisor/controller ratios and structures would be more uniformly implemented to best practice standards; thus improving the likelihood that a conflict not detected by the controller is better managed and does not lead to an accident.

Evidence of fragmentation affecting safety performance

4.7.10 For each barrier layer above, reducing fragmentation is likely to improve safety, yet there is not much empirical evidence about how large any problem is in the first place. There are distinct factors to consider in each of the layers. The following list suggests example ways that potential effects of fragmentation might be reduced:

- Fragmentation at the prevention layer through harmonisation of airspace design and operating procedures.

- At the resolution layer, through reduced coordination effort (for example through fewer ACCs, and improvements in interoperability through seamless information flows between ACCs).

- At the recovery layer, through common procedures, harmonised tools and training.

4.7.11 This study initially considered whether any of above issues were identified in the findings of the Überlingen mid-air collision. We questioned whether the findings could be portrayed within different layers of the barrier model, and whether there were any lessons for fragmentation. It became clear, however, that a greater sample size was needed. There were many different opinions about whether any particular Überlingen finding was a fragmentation issue or a failure that might have anyway happened in a 'de-fragmented' system. Given the scope of the study and the paucity of data, our findings are inconclusive.

4.7.12 Although our assessment of the impact of fragmentation on safety is inconclusive, many commentators perceive that there is some impact, likely to be manifest as increased cost rather than lower levels of safety. For example, additional handover procedures incur some cost and may also reduce capacity, so both increasing cost and reducing cost-effectiveness.

4.8 Summary of fragmentation issues

4.8.1 The following table summarises the key fragmentation issues identified in Section 4.

Common issues
Piecemeal procurement (ATM and CNS)
Sub-optimal scale in maintenance and in-service development
Fragmented planning
Unsynchronised or inconsistent technological change
ACCs
Economies of scale in ACCs
Constrained sector design
ATM systems
Lack of common systems
Lack of systems interoperability
Lack of contingency capability
Increased coordination at interfaces
CNS infrastructure
Coverage and frequency requirements for VHF radio
Optimum location of navaids
Overprovision of secondary radar
Inconsistent use of primary radar
Associated support
Economies of scale in training
Economies of scale in administrative costs
Economies of scale in R&D
Safety performance

Table 4.1: Summary of fragmentation issues

5 Costs of Fragmentation

5.1 Introduction

5.1.1 The costs of the current system, estimated in Section 3, and the likely causes of fragmentation discussed in Section 4, lead us to identify key areas where we consider fragmentation to be significant. In this section we estimate the costs of fragmentation for those key areas.

5.2 Common issues

Piecemeal procurement

5.2.1 Given the high costs associated with the development of ATM/CNS systems, there is a correspondingly high potential for cost reduction. This cost reduction could be realised by procurement specifications common across ANSPs and the reduced need for adaptation of systems to bespoke designs, as systems become interoperable. We consider the scope for reduction to be less for CNS infrastructure than ATM systems, since to a large extent the CNS infrastructure has common requirements across ANSPs.

5.2.2 We estimated that the capital replacement costs of systems could be reduced by up to 5% through common procurement specifications and by a further 10% through reduced adaptation costs for ATM systems. However, some existing systems are already based on standard systems, so some of these cost reductions will already have been achieved in a fairly small minority of systems. We have therefore assumed that the cost of piecemeal procurement in the existing system is 7-15% of the total capital replacement cost. The reduction in replacement costs for CNS infrastructure is assumed to be half that for ATM systems. The replacement costs for ATM systems are estimated to be around €3,400m[25] and that for CNS infrastructure €3,800m (see Section 3). The cost of fragmentation through piecemeal procurement is estimated to be around €240m - €510m in replacement costs of ATM systems and €130m - €280m in replacement costs of CNS infrastructure.

Sub-optimal scale in maintenance and in-service development

5.2.3 A highly fragmented system, where there are many different types of equipment at several locations, requires more maintenance and development staff than a single location utilising a limited number of equipment types and has the potential to reduce the utilisation of maintenance resources. We have addressed this as follows:

- Centralised management and maintenance of CNS systems results in lower costs and improved service delivery. In estimating the costs of fragmentation, we assume that the largest five ANSPs (Aena, DSNA, DFS, ENAV and NATS) will already have some degree of centralised maintenance of CNS infrastructure. We have assumed that the remaining ANSPs could potentially reduce their CNS maintenance costs by 5-7%. Given an estimated annual cost of CNS maintenance of €245m, the cost of fragmentation in CNS maintenance is estimated to be €10m-€15m per year.

[25] We have assumed that 70% of ACC capital costs are ATM systems costs.

- The 'centre model' referred to later in this section accounts for the costs of fragmentation related to ATM system maintenance (at ACCs).

Fragmented planning

5.2.4 To avoid double counting, we have not assigned a separate cost to the impact of fragmented planning. The costs of fragmented planning appear in the individual ATM/CNS areas as the costs of a sub-optimal, fragmented system. However, there is duplication in planning activities, which take place both at ANSP level and in EUROCONTROL and the costs of this duplication should be taken account of.

5.2.5 The costs of working towards diminishing the adverse impact of fragmented planning and investment appraisal were counted as a cost of fragmentation. The objective of the EUROCONTROL EATM programme is to define and manage pan-European programmes for ATM and therefore it could be argued that a proportion of the cost of the EATM programme is a cost of fragmentation. This is not to suggest that the work is superfluous, greater coordination effort is needed, both at the European level and by ANSPs. The EUROCONTROL EATM budget[26] for 2003 was €123m and we assumed that at least 50% of these costs could be saved, either at the European level or in ANSPs, if fragmentation in planning were removed.

Unsynchronised or inconsistent implementation of technology

5.2.6 The unsynchronised or inconsistent implementation of technology is likely to have been a major reason for existing fragmentation. If it persists, it will continue to generate costs of fragmentation in the future. However, the costs of this effect are manifest in the other measures of cost that we have examined and we have not therefore produced a separate estimate of the impact of this effect – to do so would be double counting.

5.3 En-route CNS infrastructure

Coverage and frequency requirements for VHF radio

5.3.1 Given the proportionately low costs of communications systems we have not estimated the cost of fragmentation, which are likely to be correspondingly small. We note, however, that much communications equipment resides at ACCs and a major element of communications costs has been included in ACC costs. Furthermore, there are costs associated with fragmented procurement and maintenance of communications that are subsumed in the overall CNS figures discussed previously.

Optimum location of navaids

5.3.2 Our assessment of navaids has been by an analysis of navaid overprovision by estimating the actual and required coverage. Coverage is a complex issue which involves consideration of local operational requirements, terrain topography, logistical issues and costs. Navaid coverage is currently implemented on a national basis. ANSPs use analysis tools (for example, Demeter) to determine the level of coverage required and the location of navaids. The coverage and location of navaids will depend on the navigation requirements for aircraft in a particular

[26] EUROCONTROL Annual Report 2003.

airspace and for a particular operation. For example, the greater the number of DMEs, the higher the accuracy of the navigation solution for the aircraft, and therefore DMEs will be concentrated in areas where higher navigation accuracy is required or where there is dense traffic.

5.3.3 A complete analysis of navaid coverage was judged to be outside the scope of this study and we therefore carried out an 'inter-distance' analysis. This reviewed the locations of navaids and examines areas where the spacing between pairs of navaids is less than might be expected from basic coverage consideration alone. This approach will illustrate order-of-magnitude costs of overlapping cover. It must be emphasised that the results can only be validated if a full analysis using the second approach is carried out.

5.3.4 The details of the 'inter-distance' analysis are given in Annex C.

5.3.5 If we assume that for each threshold distance, 50% of the number of navaids (DMEs and VORs) that are located in different countries are due to inconsistency in planning, then our analysis shows that with thresholds of 50 nautical miles (NM), 75 NM and 100 NM, the number of DMEs involved is around 50 to 150. A similar number is found for VORs.

5.3.6 The costs of fragmentation based on this assumption are shown in Table 5.1. These costs, though important in themselves, are negligible when placed in the context of the costs of fragmentation for other areas. In addition, we note that there are costs associated with fragmented procurement and maintenance of navigation infrastructure that are subsumed in the overall CNS figures discussed previously.

	DME	VOR	Total
'Excess' numbers, due to inconsistency in planning	49 - 152	55 - 162	
Capital replacement costs	€5m - €15m	€14m - €41m	€19m - €56m
Annual operating costs	€0.1m - €0.4m	€0.6m - €1.9m	€0.8m - €2.2m

Table 5.1: Costs of fragmentation for inconsistency in en-route navaid planning

Over-provision of secondary radar

5.3.7 For the purposes of this fragmentation study, it was assumed that ANSPs (for economic reasons) are unlikely to over-provide radar facilities when the coverage is wholly within their national boundary. However, there may be circumstances where international sharing of radar services, which could diminish the requirements, is not taken into account when planning at the national level. Given the high cost of surveillance facilities, ideally we should identify whether over-provision exists at national boundaries and establish order-of-magnitude costs.

5.3.8 Our analysis was similar to the navaid analysis, in that we chose an 'inter-distance' analysis of the locations of radar stations. This examined areas where the spacing between radar stations is less than might be expected from basic coverage consideration alone.

5.3.9 The details of the 'inter-distance' analysis are given in Annex C.

5.3.10 The inter-distance analysis for all radars gives an estimate of about 16 to 65[27] radar stations which may be in the category of providing excess coverage at national boundaries. This amounts to a surplus of 5% - 22% and the lower value appears to validate our simple coverage analysis.

5.3.11 As a check on these numbers, we also carried out a simple analysis of radar coverage at FL50. This used line-of-sight (LOS) calculations, without taking account of topographical or national boundary constraints. It allows us to estimate the number of secondary radars required to give dual coverage over Europe. We assume an antenna height of 30m, which gives a LOS range of 100 NM at FL50. The coverage area of the European land mass is taken to be 12,631,621 km^2. The required number of secondary radars for dual coverage, using this simplified analysis, is estimated to be 289. Since there are currently 300 secondary radars in Europe, this would indicate a surplus of 4%.

5.3.12 The inter-distance analysis for en-route radars gives an estimate of about 7 to 37[27] radar stations which may be in the category of providing excess coverage at national boundaries. This amounts to a surplus of 4% - 19% of en-route secondary radars.

5.3.13 The costs[28] related to the over-provision of secondary radar are shown in Table 5.2. In calculating building and services costs, we assume that 30% of the secondary radars are co-located with a primary approach radar and 70% are not co-located. Capital costs comprise the cost of the radar equipment and building and services costs.

	All radars	En-route radars
Surplus caused by inconsistency in planning	16 - 65	7 - 37
Capital replacement costs	€90m - €380m	€40m - €220m
Annual operating costs	€6m - €25m	€3m - €14m

Table 5.2: Costs of over-provision of radar

Inconsistent use of primary radar

5.3.14 We examined the extent to which the cost of en-route primary radar is met by civil airspace users. Annex C lists the number of en-route primary radars in each State and whether the costs of primary radar are recovered from the military.

5.3.15 The inconsistent use of en-route primary radar across Europe reflects the different approaches taken by States, with respect to its impact on safety and security. If this were resolved as a fragmentation issue, it could be that en-route primary radar is seen as a requirement creating additional costs. On the other hand, if it is no longer seen as a requirement, its costs are likely to decrease. If we assume that 50% of primary en-route radar is paid for by the military and the remainder by civil

[27] The lower figure in the range corresponds to an inter-distance threshold of 50nm and the higher figure corresponds to an inter-distance threshold of 100nm.

[28] For the purposes of calculating over-provision costs, we take the mean value from the range of values given for capital and operating costs for MSSR radars in Section 3. These values are €3.5m per MSSR radar, €1.0m for buildings and services per co-located MSSR and €3.0m for buildings and services for a non co-located MSSR. Annual operating costs are €0.4m per MSSR.

users, the estimated cost to civil users is €240m - €525m in capital costs and €14m - €51m per year in operating costs.

5.4 ACCs and ATM systems

5.4.1 The main fragmentation issues for ACCs are economies of scale in ACC capital and operating costs and the constraints on sector design caused by national boundaries. Because the issue of lack of common ATM systems is closely linked with that of number of ACCs, and the allocation of the cost of fragmentation between these categories is to a degree arbitrary, we have also discussed the costs associated with the lack of common systems in this section.

Economies of scale

5.4.2 A move to fewer ACCs could reduce costs or bring about other improvements, raising a number of questions:

- Are some very small ACCs too small to achieve a reasonable level of efficiency?
- Are there more general economies of scale in ACC operation, either:
  - in ATCO productivity; or
  - in other areas.
- Will the introduction of Functional Airspace Blocks (FABs), as required by the Single European Sky legislation[29], bring about efficiency gains?
- Will improved sector design bring greater efficiency?

5.4.3 To address these questions we have taken two approaches:

- an examination of the statistical evidence for scale economies;
- an ACC model, based on assumptions of fixed and variable costs.

Statistical evidence for economies of scale in ACC operations

5.4.4 Recent work undertaken by the Solar Alliance for the UK CAA has examined the production function for an ACC through statistical analysis of ACE 2001 and ACE 2002 data on individual ACCs[30]. In this analysis it was found that there were economies of scale in ATCO productivity: the larger the ACC, in terms of traffic handled, the more traffic was handled by each ATCO; all other things being equal. This tendency was independent of measures of traffic complexity, such as density, intensity of vertical movement and seasonal variability.

5.4.5 The economies of scale appeared through two separate causes:

- there appeared to be a minimum number of ATCOs required even at the smallest levels of traffic; and

[29] Regulation (EC) No 551/2004 of the European Parliament and of the Council of 10 March 2004 on the organisation and use of the airspace in the Single European Sky (the airspace Regulation).

[30] Cost benchmarking NATS relative to selected ANSPs, November 2004, available at http://www.caa.co.uk/erg/ergdocs/sp5_anspbenchmarking.pdf

- there appeared to be increasing returns to scale; each additional ATCO-hour appeared to be associated with the ability to handle more traffic.

5.4.6 We can use this statistical evidence to make some order-of-magnitude estimates of the impact of economies of scale on ATCO productivity.

5.4.7 The minimum number of ATCOs required at the lowest traffic levels was apparent through the regression line linking flight-hours with ATCO-hours crossing the vertical axis. In other words, all other things being equal, an ACC would require a certain minimum level of ATCO resources even if the traffic levels were vanishingly small. In practical terms, this minimum level of resources amounted to 14,500 ATCO-hours, or around 10 ATCOs at typical levels of working hours.

5.4.8 A number of ACCs are fairly close to this minimum scale: Tallinn, Riga, Vilnius, Rovaniemi (Finland), Chisinau, Skopje, Tirana and Malta[31]. The cost of preserving these very small units could be regarded as a cost of fragmentation, and the statistical analysis suggests that merging these with neighbouring ACCs could save, in principle, 14,500 ATCO-hours per ACC. However, the saving that would result would (while large in the context of those ACCs) be very small in the context of the system as a whole - perhaps €1.5m -€2m a year).

5.4.9 The increasing returns to scale were apparent through a quadratic term in the equation linking flight-hours to ATCO-hours. This resulted in substantially higher ATCO productivity in the larger ACCs than in the smaller. The average ATCO productivity in ACCs handling less than the average traffic was around 20% lower than that for ACCs as a whole. This lower than average productivity could be considered a consequence of fragmentation. Raising the productivity of the 35% of ATCOs who work in these smaller ACCs to the average level would reduce the overall ATCO requirement by 7%. Costs might not be reduced commensurately, since these smaller ACCs are not necessarily those with the highest-paid ATCOs (although they do include ACCs in Spain, Switzerland and the UK). This suggests an order-of-magnitude cost of fragmentation in ACCs of €50m through loss of economies of scale in ATCO costs alone.

5.4.10 Economies of scale should be even more apparent in the non-ATCO element of ACC costs. Unfortunately, there is no comprehensive source of data on costs at the ACC level other than the employment costs of ATCOs, and the line of investigation based on statistical evidence cannot therefore be pursued further.

A model of economies of scale in ACCs

5.4.11 We have developed a model of the capital and operating costs of an ACC. The model is based on empirical evidence where available, but also on a degree of professional judgement. We have used the model to investigate the extent of possible economies of scale in such elements as system maintenance, system development, buildings, and management and administrative overheads.

5.4.12 Our approach was to develop the model to illustrate the economies of scale arising from providing and operating an increasing number of sectors from a single centre. The model considers both capital replacement costs and operating costs and takes into account the following elements based on common systems and support:

[31] Some other very small ACCs in Norway and Sweden are already the subject of closure programmes through consolidation with others in the same country. Costs associated with their retention are not, therefore, a cost of fragmentation.

- building and services costs;
- equipment costs;
- ATCO employment costs;
- maintenance costs;
- in-service software development costs;
- management and administration costs;

5.4.13 The main assumptions of the model are as follows.

5.4.14 Costs are divided into those that are directly proportional to the number of sectors those that are to some degree fixed and therefore show efficiency gains as the number of sectors increases.

5.4.15 Both the capital replacement costs and the operating costs of buildings and services are assumed to be directly proportional to the number of sectors. In the case of capital costs this is proportional to the physical maximum number of sectors that can be accommodated; for operating costs it is the maximum number actually operated. This is probably a conservative view in that some second-order efficiency gains are possible. For example, reduced staff numbers in larger centres are likely to result in reduced accommodation requirements.

5.4.16 Equipment capital replacement costs are split into two elements. Peripheral equipment (essentially, controller workstations) is assumed to be required in direct proportion to the number of sectors operated. On the other hand, the cost of core equipment such as radar and flight data processing servers is assumed to be largely independent of the number of sectors. Core equipment costs include both hardware costs and initial software development costs.

5.4.17 ATCO employment costs are considered to be basically proportional to the number of sectors, with a very small fixed element. However, the model makes allowance for some increase in controller productivity at bigger centres, as inferred from the statistical work described above. However, it is unreasonable to assume that these costs are transferable from one centre to another across countries where average income levels vary by orders of magnitude, and there are also substantial differences in tax and social security liability.

5.4.18 The model assumes that equipment maintenance costs can be considered in the same way as for equipment replacement costs. The cost of maintenance of core equipment is considered to be independent of the number of sectors while the cost of maintaining peripheral hardware is considered directly proportional to the number of sectors. Also included in maintenance costs is an allowance for the materials and services consumed by the centre, also assumed to be proportional to the number of sectors.

5.4.19 The development of software during the in-service life of the system is assumed to be independent of the number of sectors. This is one of the areas where commonality of systems brings tangible benefits.

5.4.20 The model assumes that management and administrative overheads are sector dependent. However, that dependence is not assumed to be strictly linear – the incremental cost falls for larger centres.

5.4.21 In the absence of published data on ACC cost components, we have estimated a split of costs based on our professional judgment. The distribution of capital replacement costs and operating costs between the different cost elements will differ amongst ANSPs.

5.4.22 The cost parameters used are summarised in Table 5.3. The numbers are consistent with the estimates of capital replacement costs in Section 3.

Area of cost	Capital replacement costs		Annual operating costs	
	Fixed	**Variable per sector**	**Fixed**	**Variable per sector**
Buildings and services		€1.45m		
Equipment	€39m	€1.45m		
ATCO employment	Sector-dependent but varies between countries			
Maintenance			€4.5m	€0.66m
In-service software development			€4.5m	
Management and administration				€0.30m[32]

Table 5.3: Summary of cost parameters used

5.4.23 The variation of overall annual costs for an ACC with ATCO employment costs typical of those used in the US-Europe study[33] are illustrated in Figure 5.1. The variation of costs per sector with centre size is shown in Figure 5.2.

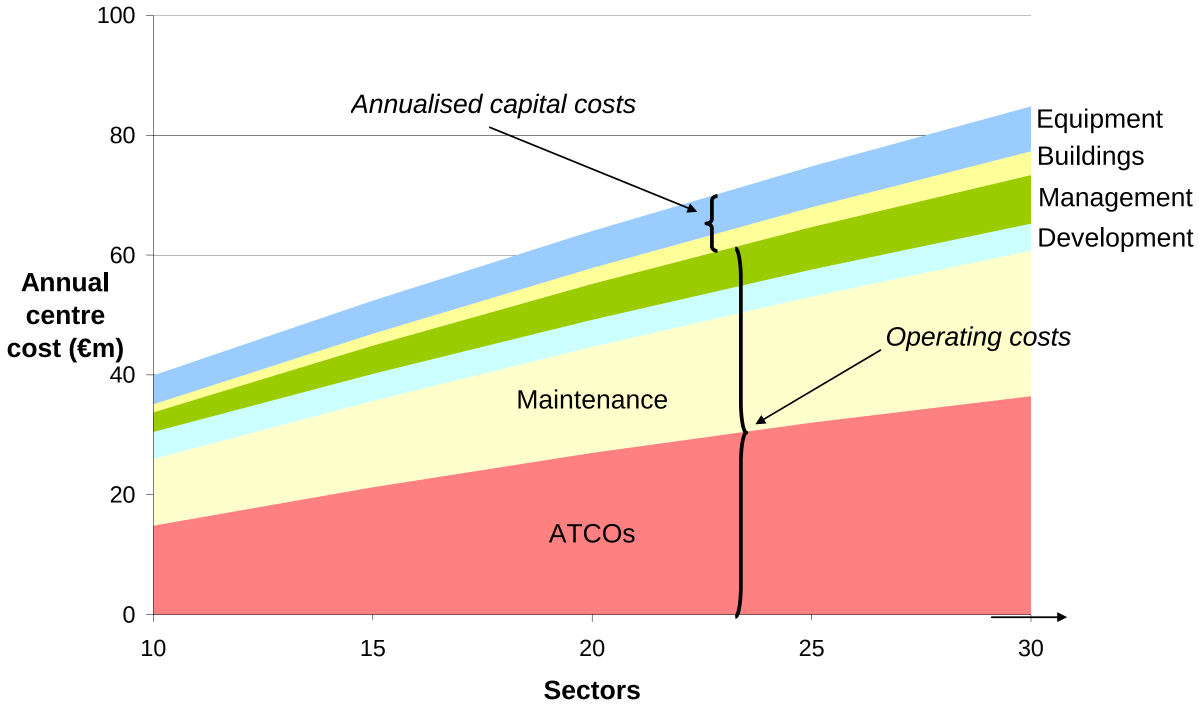

Figure 5.1: Variation of annual costs with centre size

[32] An average value for medium-sized centres. The incremental cost is assumed be €0.27m between 20 and 30 sectors, €0.33m between 10 and 20 sectors, and €0.37m between zero and 10 sectors.

[33] See reference in footnote 1 page 1.

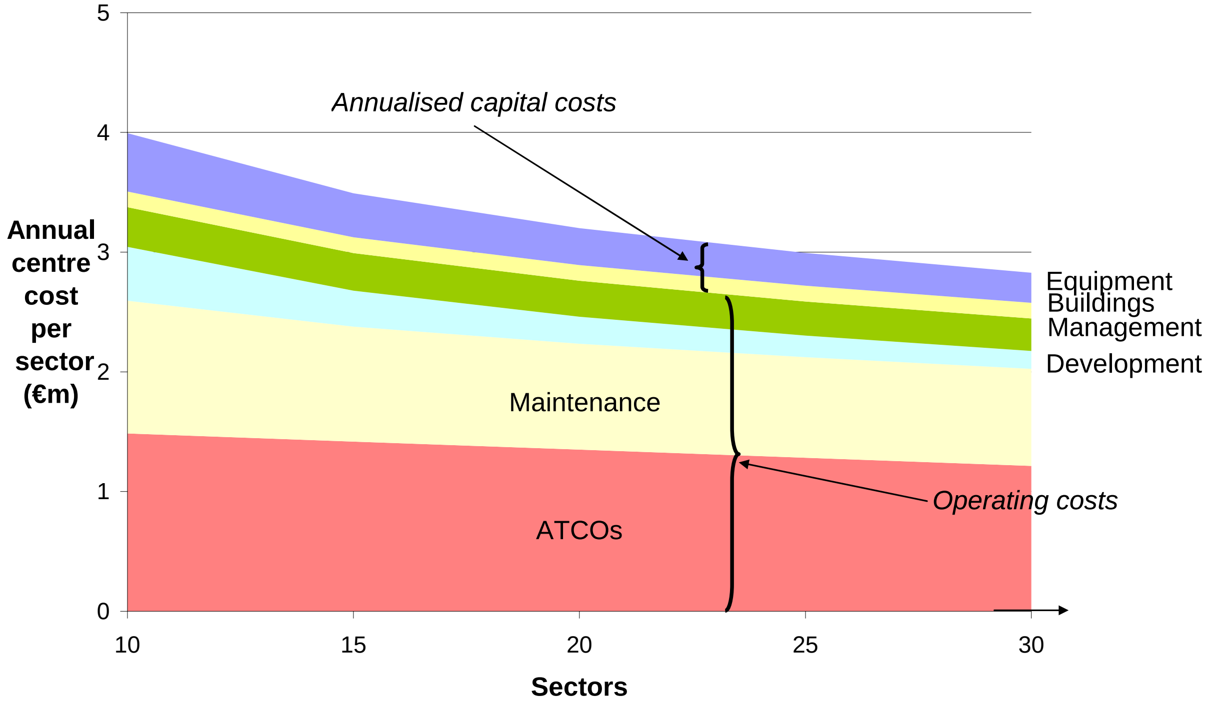

Figure 5.2: Variation of cost per sector with centre size

5.4.24 This analysis suggests that, because of the fixed element of costs, economies of scale might continue to apply on all scales – that is, unit costs per sector would fall indefinitely with the size of the centre. However, the problems, such as coordination and remoteness from the "front line" with running large entities are likely at some stage to outweigh these economies of scale. Opinion among ANSPs is that centres larger than the largest operating or currently planned in Europe may be of the maximum economically efficient scale. We note that the Swanwick centre, when London Terminal Control is moved there, as is planned in 2007, will be able to accommodate over 60 sectors. The currently planned German consolidation will reach figures of 45-50 sectors. These are sizes that are comparable with the larger US centres. There appears to be a general consensus that beyond this level, difficulties in coordination and in providing contingency may outweigh further economies from increased size.

5.4.25 Costs of piecemeal procurement have not been included in the model, and were discussed in Section 5.2.

5.4.26 In order to estimate the cost savings associated with economies of scale in ACCs in a defragmented system, we compared the costs of current ACCs as estimated using the model with the costs of a system where ACCs were operating with, on average, 25-26 sectors. This figure is well short of the maximum scale currently operating in Europe. However, such a large scale may only be practically feasible in the densest regions, and we have conservatively adopted this smaller number as a likely average for a non-fragmented system. To isolate the impact of economies of ACC scale, we assumed that the total number of sectors is the same at 606.

5.4.27 The results are shown in Table 5.4, and show that fragmentation into ACCs of suboptimal scale was responsible for excess operating costs of around 25% and excess capital costs of around 34%. Operating costs have been broken down to show the savings in different areas of operating costs; major savings are obtainable in maintenance and in-service development costs. This analysis does not include the possibility that fewer sectors will be required in the defragmented system; this is evaluated in the next section concerning the impact of constrained sector design.

	Current system	Defragmented system	% savings
Capital costs	€ 4,900m	€ 3,200m	**34%**
Operating costs	€ 2,100m	€ 1,600m	**24%**
of which:			
ATCO employment	€ 870m	€ 780m	**10%**
Maintenance	€ 700m	€ 510m	**27%**
In-service development	€ 300m	€ 110m	**64%**
Management and administration	€ 200m	€ 180m	**10%**

Table 5.4: Costs of fragmentation in ACCs

5.4.28 If a higher average centre size could be achieved, the savings could be commensurately greater. With an average size of 30 sectors, the savings might be around 37% in capital costs and around 28% in operating costs.

5.4.29 This analysis would indicate a range of €1,600m - €1,800m in capital costs, and €500m - €600m in operating costs as the possible range of costs of fragmentation in the area of ACC size. This is derived from the 25-sector and 30-sector centre models, with some widening of the range to allow for uncertainty of the parameters. However, as discussed below in paragraphs 5.4.32-5.4.38, much of the in-service development cost, as well as some of the capital replacement costs, could also be reduced without consolidation of centres, through convergence to common ATM systems. To count these costs again as costs of fragmentation of ACCs would be double counting, so this element was removed from the costs allocated to fragmentation of ACCs.

5.4.30 It should be noted that the link between ACC size and cost is a **theoretical and statistical** effect. It should not be taken as implying that all small ACCs are less efficient or more costly than all larger ACCs. ACCs will differ in many respects, most obviously in the varying wage rates they have to pay their staff. The relationship should rather be interpreted as that **all other things being equal**, we would expect a smaller ACC to show higher costs, because of the inevitable element of fixed cost.

5.4.31 It should be noted also that a degree of consolidation has already been achieved since the base date for our calculations, and more is planned for the near future. These planned consolidations are all within national ANSPs (in Germany, Norway, Sweden and the UK). If we include these plans in our model, we can assess how much of the projected cost of fragmentation is already planned to be eliminated by these measures. We find that these planned consolidations will eliminate around €100m in capital and operating costs taken together, or around 14% of the estimated costs of fragmentation of ACCs.

Lack of common systems

5.4.32 As discussed in paragraphs 4.4.1 to 4.4.4, an important cost of fragmentation could arise from each centre having different software from others. If a number of ACCs use identical or very similar systems, further economies can be made on the software element of those systems. This is one of the aims of the SESAR programme. Clearly, the lack of such common systems becomes less of a problem as the number of centres is reduced, and therefore cannot be treated in isolation from the costs arising from fragmentation of centres.

5.4.33 The costs of fragmentation associated with the lack of common systems arise both in the capital costs of centres and in their operating costs.

5.4.34 We have estimated the potential saving in capital costs as €5m-€15m per centre.

5.4.35 The operating costs savings are also substantial. We estimate that a large proportion of the in-service development costs (upgrades, etc) can be saved, amounting to perhaps 50-70% of the total, which in our centre model amounts to a fixed cost per centre of €2.2m-€3.2m a year.

5.4.36 This cost of fragmentation could be applied either to the existing number of centres, or to the number of centres in a defragmented system. This interaction of this cost of fragmentation with that of fragmentation of centres is illustrated in Figure 5.3.

5.4.37 The total costs of fragmentation in ACCs and ATM systems are the difference in costs between the current system and a theoretical ideal in which there is a reduced number of centres, with common systems. This difference is around €780m a year (for clarity, the midpoint of the ranges is shown[34]). The top left of the diagram shows the costs of fragmentation obtained by considering ACC consolidation without convergent ATM systems (€695m). This is the figure obtained from the argument in paragraph 5.4.29. The costs of retaining diverse ATM systems in this smaller number of ACCs are relatively small (€85m). However, we considered it clearer to apply the costs of fragmentation in ATM systems to the existing number of ACCs, as in the top right of the figure; a move towards common systems is likely to happen on shorter timescales and with lower transition costs than consolidation of centres. This assigns a higher cost to fragmentation of ATM systems (€240m) and a correspondingly lower amount (€540m) to fragmentation of ACCs.

[34] The extremities and mid-points of ranges cannot be manipulated arithmetically when adding together different areas of cost, since in some cases a high value of one cost is associated with a low value of another.

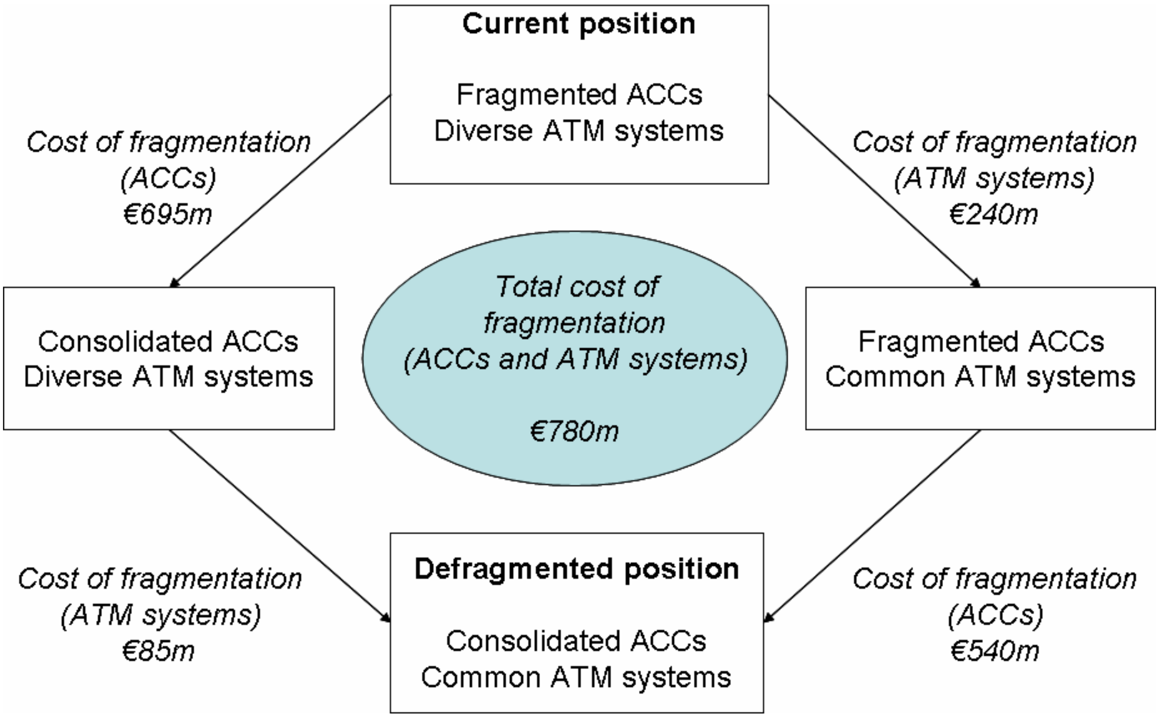

Figure 5.3: Allocation of fragmentation costs between centres and ATM systems

5.4.38 This is an area of fragmentation where costs could rise substantially if no action is taken, because of new requirements for certification of ATM systems.

Constrained sector design

5.4.39 Sector design is currently constrained by national boundaries. A defragmented system would allow improved sector design by removing the constraints of national boundaries. This would allow for more efficient flight profiles, because of more optimal routing through the sector.

5.4.40 PRR8[35] identified airspace design and its strategic utilisation as the main source of en-route horizontal flight inefficiencies. It estimated that there was 6.2% en-route horizontal inefficiency, of which 4.2% was direct route inefficiency and 2% was TMA/en-route interface inefficiency. The total cost of direct route inefficiencies cited by PRR8 is €1,000m per year. This could be caused by restrictions on the use of airspace by civil users caused by segregation of airspace for military use, location of crossing points away from sector boundaries (constrained sector design) and the need for one-way routes for safety and capacity reasons (route design). We have assumed, following feedback from experts at stakeholder consultation, that 5 -10% of direct route inefficiency results from constrained sector design. Based on this assumption, the cost of fragmentation due to constrained sector design is estimated to be €50m - €100m per year. This is an area in which further analysis would be valuable in providing a more robust estimate.

5.4.41 The costs of constrained sector design have been addressed above. The costs of inconsistent sector design principles will be accounted for in the ACC model.

[35] Performance Review Report 8, Performance Review Commission, April 2005.

Comments received from stakeholders suggested that specific instances of both issues (for example, reduced training through generic sectorisation and climb and descent phases through constrained sector design) were not considered to be significant issues. We therefore have not pursued these items further.

Lack of systems interoperability

5.4.42 An increasingly interoperable ATM system would allow lower procurement costs through common specifications and lower adaptation costs because of a reduced requirement to adapt commercial off-the-shelf systems. These costs of fragmentation have been included in our estimate relating to piecemeal procurement in Section 5.2. Internal economies within ANSPs can be made possible by increased interoperability of systems and by pooling workforce resources with other ANSPs. This leads to economies in engineering support through shared resources, lower specialisation and increased outsourcing opportunities. The costs of fragmentation associated with the lack of these have already been included in the centre model.

Increased coordination at interfaces

5.4.43 The PRU US-Europe study[1] identified inter-centre coordination as possible reason for lower ATCO productivity in Europe. There is higher workload for hand-over in Europe centres than US centres. The US experience of hand-over workload is the same for inter-centre as intra-sector. Interoperability may play some part in this. The benefits of increased interoperability were assumed to halve inter-centre coordination time required.

5.4.44 From a previous study[36], we assumed that the average time taken to control 100 aircraft is 116 minutes, of which about 10 minutes are spent on coordination tasks. We estimate that around 9% of controller time is spent on coordination. We estimated that at least 30% of this coordination would involve centre to centre coordination, and taking into account ANSPs' views, we assumed that around 3% - 5% of total controller workload was dedicated to inter-centre coordination. We assumed that improved interoperability would halve the inter-centre coordination time required.

5.4.45 We applied this reduction to the number of ACC ATCO hours on duty for 2003[37] to give a saving of around 160,000 – 308,000 hours due to reduced time on inter-centre coordination. We used the ACE figure for "staff costs for ATCOs in OPS" for 2003[37] (€1,552m) to derive an employment cost for ACC ATCOs on operational duty (€850m), which gave a cost per ACC ATCO hour of €69. The resultant cost savings through improved inter-centre coordination were therefore €10m - €20m per year.

Lack of contingency capability

5.4.46 It is very difficult to assess the costs resulting from the long term failure of a major ACC. Passengers, airlines, ANSPs and indeed national economies are all impacted by the loss of aviation services. The actual costs are directly affected by the frequency and duration of the failure.

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[36] Roadmap for the implementation of data link services in European Air Traffic Management (ATM) -Application Assessment, October 2002, Helios Technology for the European Commission.

[37] Data sourced from ACE 2003 (see footnote 3 on page 11).

5.4.47 The frequency of failures of this type is likely to be extremely low and there are no adequate statistics available. However, there are a relatively large number of centres and certain risks, particularly those related to security, are considered to be increasing. Furthermore, public perception is that adequate contingency planning should be in place.

5.4.48 The time taken to rectify catastrophic failure is very difficult to assess. However, fire or other major damage is likely to require a degree of rebuilding followed by replacement and integration of new hardware. Cabling is very vulnerable to damage under this type of failure. It is therefore reasonable to assume that periods of six months or more would be required to reinstate facilities following partial damage to a centre. The time taken to replace a centre following a total loss can be related to the implementation time of a new centre: years rather than months.

5.4.49 Air France indicated that their daily loss resulting in failure of the Paris Centre would be of the order of €10m per day. The proportion of Air France flights at Paris is cited by Aéroports de Paris[38] as 53.4%. If we assume the same loss would be incurred by other airlines using the same facilities, this would amount to some €3,600m over a six month period. These figures make no allowance for costs incurred by passengers or indeed to national economies.

5.5 Associated support

5.5.1 As discussed in Section 4, the main specific areas of associated support where fragmentation is likely to have an adverse impact of fragmentation are training and administrative support, particularly finance. However, this is an area where there is very little information and we have not been able to quantify the cost of fragmentation with any reliability. However, it seems evident that there is scope for savings from removing fragmentation in a number of areas of HQ and administrative operating costs. For completeness, we have included a highly speculative range of 4-10% of the total costs associated with these functions; broadly, €40m-€100m a year.

5.5.2 This is an area that would repay further investigation, perhaps through benchmarking at a more detailed level than is possible with current ACE data.

5.6 Summary of the costs of fragmentation

5.6.1 Table 5.5 summarises the estimates we have made of the impact of fragmentation on the cost of the system. The figures in the table are annualised costs, including both capital-related costs and operating costs. Annual capital-related costs (depreciation and finance costs) have been estimated by dividing the capital replacement costs by 11 years. This is a rough estimate of the ratio of capital replacement costs to finance and depreciation costs, as inferred from our own estimates and from ACE data. We have not included any estimate of contingency planning, as it is difficult to ascribe the proportion of costs of a major failure to fragmentation.

[38] Répartition du traffic à Paris par companies aériennes, Aéroports de Paris, Edition 2004 (http://query.adp.fr/chiffresde2004/index.html).

	Cause of fragmentation	Annualised costs	% of cost of fragmentation
Common issues	Piecemeal procurement (mainly ATM systems)	€30m - €70m	**14%**
	Sub-optimal scale in maintenance and in-service development (mainly CNS)	€10m - €15m	
	Fragmented planning	€60m - €120m	
	Unsynchronised technological change	Counted elsewhere	
ACCs	Economies of scale in ACCs operating costs	€370m - €460m	**53%**
	Economies of scale in ACCs capital costs	€105m - €140m	
	Constrained sector design (flight efficiency benefits)	€50m - €100m	
ATM systems	Lack of common systems (operating costs)	€150m - €215m	**23%**
	Lack of common systems (capital costs)	€30m - €90m	
	Increased coordination at interfaces	€10m - €20m	
CNS infrastructure	Requirements for VHF radio	Not significant	**4%**
	Optimum location of en-route navaids	€3m - €7m	
	Overprovision of secondary radar	€15m - €60m	
	Inconsistent use of primary radar	Not included	
Associated support	Economies of scale in training, administrative costs and R&D	€40m - €100m	**6%**
	Total costs of fragmentation	€880m - €1400m	**100%**

Table 5.5: Annual costs of fragmentation

5.6.2 The costs of fragmentation are estimated to be around €880m - €1400m a year or 20%-30% of the relevant system costs. The relative costs are shown in Figure 5.4. The major areas of costs of fragmentation are:

- lost economies of scale in ACCs (around 12% of the overall system costs);
- fragmented ATM systems (around 6%)
- associated support (around 2%);
- constrained sector design leading to flight-inefficiency (2%); and
- piecemeal procurement of ATM systems and CNS (around 1%).

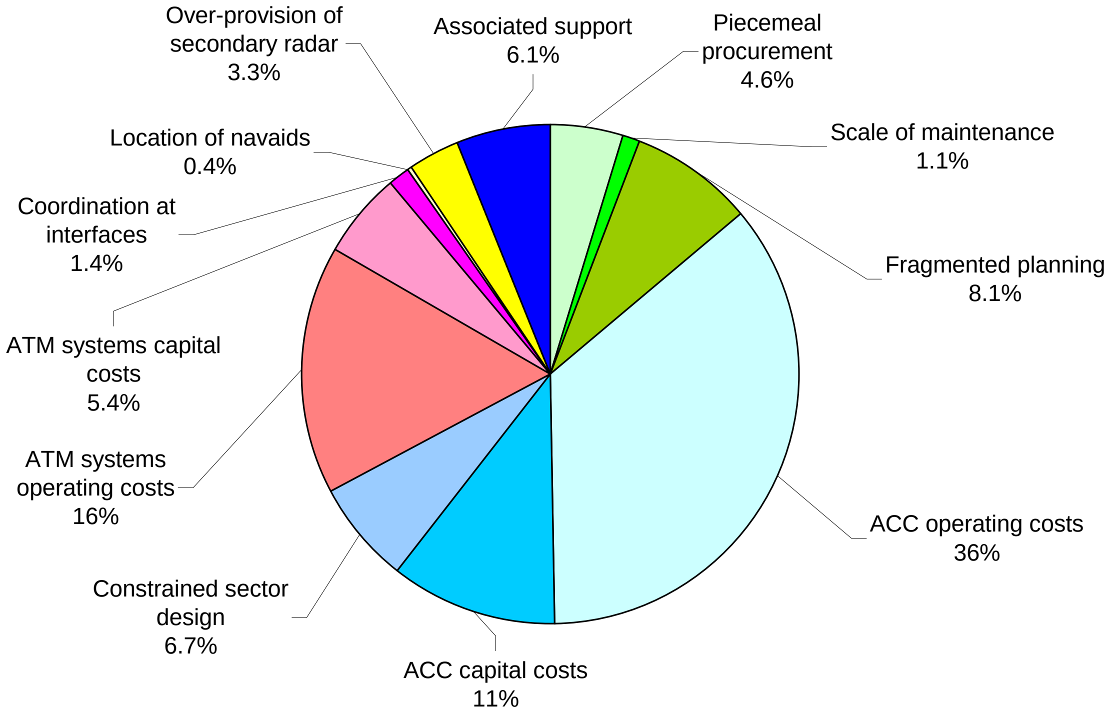

Figure 5.4: Costs of fragmentation

5.6.3 The identification of such a large cost arising from fragmentation does not, of course, mean that measures can readily be taken to remove such costs from the system. The transition from the existing system to an idealised, defragmented system might have prohibitive costs – indeed, achievement of such a system might be completely infeasible. However, the figures we have produced provide an indication that fragmentation, in general, is an area worth addressing, and that within fragmentation, of the many areas worth addressing, the most important are those listed in the previous paragraph.

5.6.4 The areas of fragmentation that we have addressed in this study are by no means all the areas where fragmentation might have a major impact. Fragmentation could have a serious adverse impact through fragmentation of airspace planning, civil-military coordination, and in requirements for on-board equipment, as well as in areas outside ATM/CNS as defined in this study.

5.6.5 In some of the areas considered, defragmentation may carry with it large transition costs such as new buildings and staff relocation costs. In practice, it is likely that actions to reduce fragmentation without physical consolidation are likely to be more economically feasible.

5.6.6 The inconsistent use of primary radar is also a big area of cost but may not constitute a cost to the ATM/CNS system as we have defined it. Were it to be considered a cost of fragmentation, we estimate its fragmentation cost as € 35m - €100m.

5.6.7 In addition, we note that the increased complexity and requirements for certification of ATM systems are likely significantly to increase the cost of fragmentation in future.

5.6.8 However, there are many actions that have been taken recently, and that are proposed, that are aimed at reducing the adverse impact of fragmentation.

5.6.9 These coordination activities, particularly those aiming to reduce the impact of fragmentation in these areas mentioned above, are addressed in subsequent sections of the report.

6 ATM/CNS coordination activities and their coverage

6.1 Introduction

6.1.1 In the preceding sections we have identified the causes of fragmentation and estimated its costs. In this section we consider what actions are in place that will tend to reduce fragmentation through coordination and where there may be gaps.

6.1.2 Our approach has been as follows:

- developing a framework to identify and assess 'local' and pan-European coordination activities required to minimise the impact of fragmentation of the European ATM/CNS system;
- identifying and assessing gaps given current coordination activities;
- investigating coordination activities in certain other European network infrastructure industries (railways and electricity) and the potential lessons for ATM;
- identifying any shortcomings and issues to be further investigated.

6.1.3 Our framework is derived from an *a priori* view of what coordination activities we would expect to see to reduce fragmentation. The work has focused on those fragmentation issues identified in Phase 1 that have the highest costs of fragmentation: ACCs, ATM systems, surveillance, piecemeal procurement and fragmented maintenance and development. We have also included associated support, as although we have not been able to assess the fragmentation cost for this area, we understand from qualitative assessments that it may be important.

6.1.4 We have not explicitly assessed coordination activities in areas that are out of scope of the study. These include airspace, ATFM, safety, aeronautical information services, MET, airports and civil-military issues. However, at the request of the PRU, we have included some information on a number of coordination activities within these areas.

6.1.5 Coordination activities in other European network industries are addressed in Section 7.

6.2 Framework for coordination activities

6.2.1 The framework examined attributes for each activity, such as its objectives, its geographical scope, the type of coordination the activity encompasses, its intended benefits, its costs, complement and substitute activities, timescales and states or organisations involved in the activity.

6.2.2 The geographical scope of the activity could be:

Regional – activities that involve a grouping of two or more states that are neighbours or geographically linked.

Multi-national – where the activity involves a number of states which are not necessarily geographically contiguous.

Pan-European - where the activity is intended to extend to all EUROCONTROL or ECAC member states. We included in this category activities that are planned on a pan-European basis.

6.2.3 The type of coordination that the activity encompasses could be any of the following types of activities that reduce the impact of fragmentation:

- joint planning;
- joint development;
- joint procurement;
- interoperable systems;
- common maintenance and training;
- joint operations;
- equipage mandates;
- industry-wide standards.

6.2.4 For each important fragmentation issue, we assessed the volume of coordination activity that was taking place, and compared the nature of the coordination activity – its geographical scope and the type of activity – with our *a priori* expectations.

Coordination activities

6.2.5 The coordination activities we assessed were gathered from a variety of sources, including ICAO, CANSO, ITU, European Commission, Single European Sky, ECAC, EUROCAE, ANSPs, industry and aviation publications. We have also looked at EUROCONTROL activities across its four main business lines.

6.2.6 We have included both current coordination activities and coordination activities that have recently been completed or that were particularly successful.

6.2.7 Some activities (for example, recent projects to cooperate in the formation of Functional Airspace Blocks in a number of regional groupings) address a number of different fragmentation issues in a unified way.

6.2.8 The list of coordination activities is given in Annex D.

***A priori* analysis**

6.2.9 Figure 6.1 links the causes of fragmentation to potential coordination activities that may be expected to mitigate fragmentation. Our *a priori* expectation of coordination activities arises from a vision of improved, defragmented ATM in Europe and is also illustrated in Figure 6.1. This is our own view and acts as a baseline for carrying out the gap analysis.

6.2.10 We validated our *a priori* analysis and subsequent gap analysis through a series of break-out sessions with stakeholders during a Stakeholder Workshop. Stakeholders were consulted on each area of fragmentation and discussions focused on what needed to be done to reduce fragmentation, the factors for success and the barriers to success. Stakeholders were also invited to provide their comments on the coordination activities they expected to see in each area of fragmentation, whether these would be effective in reducing fragmentation and whether there was a lack of coordination in each area via a questionnaire that was distributed during the Workshop.

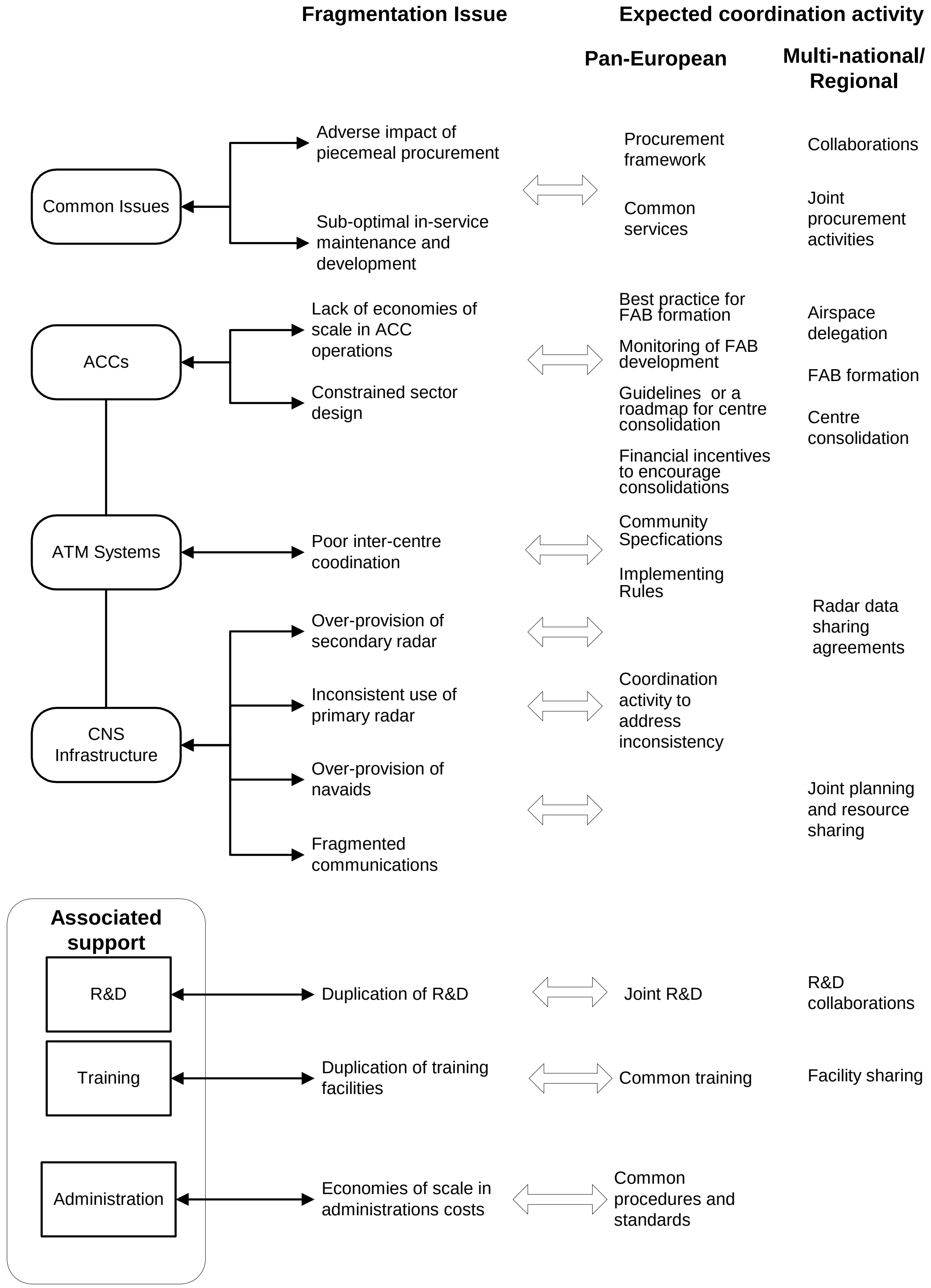

Figure 6.1: The key elements and processes in European ATM

Expected coordination activities

6.2.11 At pan-European level, we would expect to see activities that provide overall direction to the evolution of European ATM and foster reduced fragmentation, including:

- Implementing Rules, Community Specifications, guidelines and equipage mandates to promote interoperable systems and concepts. This would include, for example, guidelines for the formation of FABs.
- Legislative guidelines, roadmap, financial incentives and other initiatives to encourage and facilitate centre consolidation.
- A framework for common procurement through Europe-wide standards for ATM systems and CNS. We would not expect a single European procurement of systems and CNS infrastructure, as this would remove competition. We would therefore expect joint procurements of CNS and ATM systems by multi-national or regional groupings of ANSPs.
- Coordination to address the inconsistent use of primary radar.
- Activities to provide common services. This would include establishment of common databases, pan-European planning tools and monitoring activities.
- Pan-European coordination and collaboration in R&D, complemented by regional or multi-national R&D collaborations.
- Establishment of common training and common procedures and standards for administration.

6.2.12 At regional and multi-national level, we would expect to see activities aimed at breaking down local barriers and taking opportunities to achieve economies of scale. Typical expected activities include the following:

- In ACC collaboration, we would expect regional and local activity, where neighbouring ANSPs have collaborated or ANSPs have consolidated operations within their State. In order to complement this bottom-up approach, we would expect some guidance or monitoring of ACC consolidations through FABs at pan-European level.
- A key area for increased coordination is to provide a common approach to ATM/CNS procurement and maintenance activities at regional and multi-national levels.
- For CNS we would expect to see joint planning activities to optimise the use of resources such as limited spectrum. Activities to address fragmentation in surveillance should be expected at regional level, through bi-lateral and multi-lateral radar sharing initiatives.
- We would expect to see common training activities at European level and regional level, where training facilities are shared amongst a small grouping of States.

6.2.13 The development of interoperable systems should be expected at all levels, although we would expect that multi-national and regional developments would occur much earlier than a pan-European development, because it is much easier to develop systems in collaboration with a smaller number of States, without the requirement for a European strategy and consensus. The timeframe for pan-European developments would be a much longer one.

6.2.14 The following sections review, for each of the key areas of fragmentation, the existing coordination activities against these *a priori* expectations, and identify the gaps, which are summarised in Section 6.8.

6.3 Common issues

6.3.1 For the common fragmentation issues we focus on joint procurement and 'maintenance and development'.

Coordination of procurement

6.3.2 Multi-national activities are focused on the joint development of interoperable systems. These are joint developments for specifications and joint procurements of ATM and FDP systems, such as the iTEC-eFDP and COFLIGHT projects (joint procurements of FDP systems), the SACTA development and the COOPANS project (joint procurements of ATM systems).

6.3.3 Joint developments for specifications and joint procurements of ATM systems tend to occur at multi-national level because of historic developments in the evolution of ATM systems.

6.3.4 There is a lack of a regional approach to ATM systems joint development and procurement. Although economies of scale are gained in multi-national procurements, these benefits can be enhanced by cross-border coordination gains and potential economies of scale in maintenance and development in regional procurements of interoperable systems. Nevertheless, it is important to ensure that common interfaces exist at regional level, in order to maintain regional interoperability, in spite of systems differences.

6.3.5 Most activity in ATM systems procurement occurs at multi-national level through ANSPs grouping together to procure systems jointly. For individual ATM systems, local or regional requirements are likely to require some element of systems customisation. Hence, we think that pan-European joint procurement is unlikely for such systems. However, we would expect to see European wide standards being developed for ATM systems procurement. There is a lack of coordination activity at European level to address piecemeal procurement.

6.3.6 The Single European Sky Implementation Programme (SESAR) is one of the activities addressing this need. SESAR aims, among other things, to coordinate common standards development and facilitate procurement of interoperable systems at a European level. It is currently about to enter its definition phase. The precise role of SESAR in joint procurement is not yet defined. Its objectives in this area are to ensure a more efficient and cost-effective procurement of ATM systems in Europe for ANSPs. The European Commission has a responsibility to drive forward the activities in interoperability, under the Single European Sky.

6.3.7 There is concern however, that with European-wide common standards for joint procurements, there could be a move towards a single supplier for systems. Coordination activities to address piecemeal procurement need to ensure that there is no danger of an abuse of monopoly power in systems supply.

6.3.8 The CANSO Joint Procurement Work Group is a global activity, set up in 2002, with the aim of reducing costs through sharing project and specification information and through the joint procurement of equipment. The group is now aiming to target procurements of more complex systems. It is also looking at joint aviation liability insurance.

6.3.9 Many stakeholders agreed that we would expect to see coordination activities to address the lack of common standards and joint procurements at pan-European level and that these would be effective in reducing fragmentation. It was agreed that there was a lack of activity in this area.

6.3.10 Many of the activities to address piecemeal procurement in CNS are happening predominantly at multi-national level. Although pan-European procurements for ATM systems are thought unlikely, there may be some elements of infrastructure, such as CNS or AIS, which could be the subject of pan-European procurement similar to Galileo.

6.3.11 Joint procurements in CNS are mostly in the surveillance area – the high costs of radar encourage moves towards a collaborative approach in joint radar procurement, where substantial gains can be made. Successful examples of joint procurement at multi-national level are the Pre-Operational European Mode S Programme (POEMS), which was the joint development and procurement of Mode S radars by three States: France, Germany and the UK and the joint procurement of Mode S radar by Skyguide, DFS and LVNL.

6.3.12 We have found no joint procurement of communications and navigation infrastructure. Stakeholders agreed that we would expect to see coordination activities in this area and that they would be effective in reducing fragmentation. Third party suppliers, such as ARINC and SITA are positioning themselves to provide data link communications to ANSPs. This will lead to competing multi-national networks and potentially a different procurement strategy for ANSPs related to the purchase of services rather than equipment.

6.3.13 Joint procurement of new air-ground voice communications and navigation infrastructure may lead to lower procurement costs, but the nature of the services provided means that there is little scope for reducing the infrastructure deployed.

6.3.14 Stakeholders felt that common procurements would be encouraged by agreement of a common concept for ATM and through formation of strategic partnerships among suppliers and providers. It is noted that the airline industry routinely use a common procurement approach to drive down costs. It is believed that the SES will act to remove barriers and push ANSPs towards common procurement.

Coordination of maintenance and in-service development

6.3.15 Fragmented maintenance and development tends to be addressed as a second-order effect of other coordination activities. For example, ACC cooperation addresses fragmentation in maintenance and development, by default. Joint procurements of ATM systems and surveillance infrastructure also reduce fragmentation in maintenance and development and this is particularly visible at multi-national level. There is little focused activity on maintenance and development at any level and no activity at pan-European level. A majority of stakeholders agreed with this and expected coordination activities to exist and be effective in reducing fragmentation. Maintenance may be more difficult to centralise because there is always a need for local staff.

6.3.16 Common systems are a pre-requisite for common maintenance and development, and moves towards this, through common procurements of systems, are being initiated. Progress in common procurements is required before coordination in maintenance and development can take place. As systems become more reliable and more standardised, there is greater potential for centralising maintenance. However, it has been recognised that centralisation may decrease the quality of service in the event of a system failure.

6.4 Coordination activities for ACCs

6.4.1 Most of the activity in joint operations in ACCs is taking place at regional level, rather than at multi-national or pan-European level. Examples of this are:

- Maastricht Upper Area Control Centre (MUAC), which has successfully provided air traffic control services in the upper airspace of Belgium, Netherlands, Luxembourg and North-West Germany; and
- the Central European Air Traffic Services Programme (CEATS), which is a regional grouping of eight[39] States to provide a single air traffic control service for the upper airspace over these States.

6.4.2 The NATS/IAA FAB initiative is another recent activity to assess the feasibility of a FAB between the UK and Ireland[40]. This work not only assessed the potential for gains in productivity from ACC cooperation and redesign of the joint airspace, but also at a number of other fragmentation issues, including fragmented planning of CNS infrastructure, and fragmented support.

6.4.3 This focus on regional activity is to be expected, as growth in this area, with activities such as the formation of FABs and delegation of airspace, is taking place bottom-up and tends to be focused around regional groupings. We would not expect formation of FABs or delegations of airspace to be carried out at multi-national level.

6.4.4 Coordination activities for ACCs concentrate on coordination of and increased cooperation in ACC operations. ACC operations may lead, eventually, to the consolidation of centres, with the ensuing benefits – economies of scale in ACC operations and improved sector design, resulting from the irrelevance of national boundaries. Consolidation of centres is not the only way of coordinating operations – dynamically controlling cross-border airspace from different control centres and cross-border delegation of services can also achieve benefits.

6.4.5 We would expect activities in centre consolidation at regional and pan-European level. We have found some examples of centre consolidations within States, for example, NATS' Two Centre Strategy to consolidate its four en-route centres into two en-route centres and the German consolidation from six centres to four. However, we have found that there is a lack of supranational regional initiatives towards centre consolidation. Collaborative initiatives at this level (such as CEATS) have tended to focus on issues other than consolidation; indeed the CEATS proposal at the time of writing introduces an additional centre.

6.4.6 At pan-European level, we would expect initiatives to facilitate and promote centre consolidation. These might comprise guidelines on the economics of centre consolidation, data on system replacement or upgrade cycles, benchmark costs and characteristics of ACCs, and guidance on the best ways of dealing with social

[39] Austria, Bosnia and Herzegovina, Croatia, the Czech Republic, Hungary, the northern part of Italy (Padua), the Slovak Republic and Slovenia.

[40] *Study into the issues and options associated with establishing a functional airspace block in UK and Irish airspace,* commissioned by NATS and the IAA from the Solar Alliance, June 2005.

issues. The EU Directive on the common ATCO licence promotes ATCO flexibility and mobility, which removes a possible obstacle to cross-border centre consolidation.

6.4.7 At pan-European level, we would also expect incentives to ANSPs to encourage consolidation and overcome national barriers to consolidation. These are currently lacking. Indeed, financing appears to be readily available for projects that reinforce fragmentation, such as upgrades for national centres of sub-optimal size, planned without consideration of the possibility of collaboration with neighbours. The financing of projects for major centre upgrades should take due consideration of their impact on centre fragmentation and the likely adverse effects on future consolidation plans.

6.4.8 Currently, at pan-European level, the airspace regulation of the Single European Sky mandates the formation of FABs. There is no guidance for setting up of FABs or for monitoring their effectiveness and performance. A mandate on Support for Establishment of FABs, developed by EUROCONTROL, partially addresses the lack of guiding principles, but is not prescriptive. While FABs might provide a mechanism for consolidation to be considered, they do not in themselves require the consolidation of centres.

6.4.9 The Industry Consultation Body (ICB), set up by the European Commission, is particularly interested in this area, and part of its work is to advise the EC on the effectiveness of FABs and their implementation, particularly in the case of the bottom-up definition of FABs.

6.4.10 There is a role for the monitoring and compliance of FAB implementation from the top-down, to ensure that bottom-up activities are supported and guided and are effective in their performance. There are pertinent lessons for ATM, from other industries (see Section 7), on the dangers of incompatibility that may arise from regional coordination efforts, and monitoring and compliance initiatives could ensure that this does not arise.

6.4.11 In the future, there may be moves towards legislation, requiring the establishment of FABs, in order to accelerate progress in this area.

6.4.12 At regional level, as well as joint operations (CEATS, MUAC) there is also delegation of service provision (Skyguide). Not all regional initiatives concerning ACC coordination are planned to result in a net decrease in the numbers of ACCs. For example, the CEATS initiative is planned to merge the upper airspace responsibilities of eight ANSPs, but it is not clear whether there will be a reduction in the number of centres in the regions.

6.4.13 A majority of stakeholders expected to see coordination activities to address a lack of support for FAB development through guiding principles, monitoring and compliance and legislation. A small majority agreed that there is a lack of activity to address fragmentation in ACCs, although a much larger proportion agreed that these activities would be effective.

6.5 Coordination activities for ATM systems

6.5.1 Most ATM systems interoperability activity occurs at pan-European level, with some activity at multi-national level. There is no activity at regional level.

6.5.2 At pan-European level, there is a focus on interoperable systems, equipage mandates and industry wide standards. The activities behind this are Implementing Rules and Community Specifications. Examples of these are the

Implementing Rule on Coordination and Transfer, the Implementing Rule on Flight Data Processing (FDP), and a corresponding Community Specification on the interoperability of FDP.

6.5.3 At pan-European level, this is exactly what we would expect to see - industry wide standards followed by equipage mandates for ATM systems, through a process of Implementing Rules and Community Specifications. In fact, EUROCAE is developing European wide standards for the interoperability of FDP systems and ATM systems.

6.5.4 Implementing Rules and Community Specifications are effective in promoting ATM systems interoperability. Industry-wide standards are required and are crucial in addressing ATM systems interoperability at a European level. We understand that priorities in this work will be set by the European Commission. Many stakeholders agreed that we would expect to see pan-European coordination activities to address a lack of industry-wide standards for interoperability and joint development of specifications and that these would be effective at reducing fragmentation.

6.5.5 EUROCONTROL is developing work such as the Overall ATM/CNS Target Architecture (OATA) and operational concepts work to address some of these gaps.

6.5.6 Stakeholders acknowledged that a framework for producing interoperability standards already exists through EUROCONTROL and the EC and it is not clear whether there is a need for further work. However some stakeholders did think there was a lack of activity in this area. Stakeholders also felt that joint specification development work was lacking. Barriers to success include overcoming differences in the timing of system upgrades, different requirements of each stage and the need to interface with legacy systems.

6.6 Coordination activities for CNS infrastructure

6.6.1 Currently, there is no coordination activity to address the inconsistent use of primary radar in en-route airspace in Europe. EUROCONTROL has already developed a standards document for radar coverage requirements in Europe[41], but this is not consistently applied by ANSPs.

6.6.2 There is a lack of coordination to address the issue of over-provision of secondary radar. Although some activity appears to be at pan-European and multi-national levels, through initiatives such as ASTERIX, ARTAS and RADNET, we have found very little evidence of coordination at regional level. Bi-lateral initiatives such as radar data sharing between neighbouring states are known to exist, although it is unclear how widespread these activities are. It is likely that regional coordination will be addressed under the overall cooperative umbrella that is used to implement a FAB.

6.6.3 A majority of stakeholders agreed that we would expect to see coordination activities to address the inconsistent use of primary radar, the over-provision of navaids and fragmented communications, and that these activities would be effective in reducing fragmentation. They agreed that there was a lack of such

[41] EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas, SUR.ET1.STO1.1000-STD-01-01, March 1997.

activities. However, it was recognised that the potential for reducing the numbers of CNS facilities may not be great.

6.6.4 Some stakeholders suggested that the separation of CNS provision from ATM service provision might reduce fragmentation. However, barriers to success were thought to be national regulations, liability issues and transition costs.

6.6.5 Fragmented planning is addressed through coordination activities in CNS. Examples we have looked at are EUROCONTROL programmes such as 8.33kHz, B-RNAV and P-RNAV.

6.6.6 At multi-national level, there is a focus on planning, development and industry wide standards. Some EUROCONTROL activities include CASCADE, ANDRA/ECG, Link 2000+ and examples of ANSP initiatives include Mode S and joint FDP procurements.

6.7 Coordination activities in associated support

6.7.1 We identified no examples of coordination at multi-national level to address fragmentation in associated support (training, R&D and central administration).

6.7.2 Coordination of European R&D is well-supported by TEN-T and Framework Programme funding, through programmes such as ARDEP. However, until very recently, no clear coordination mechanism existed for coordinated R&D in ATM. The ACARE initiative was established by the European Commission to address the need for a co-ordinated approach to R&D covering all aspects of aviation. ACARE recently launched the 2nd version of the Strategic Research Agenda which will act as a guide for the SESAR project and future FP funding decisions. The implementation of SESAR will address the issue of fragmented R&D at European level, with a common vision of ATM R&D for the whole of Europe.

6.7.3 Examples of common training programmes are the planned Nordic ATCO training academy at regional level and the EUROCONTROL Institute of Air Navigation Services at pan-European level. A good example of coordination in regional training is the CEATS Research, Development and Simulation Centre (CRDS). Improvement to regional capability in simulation training and collaborative research are both objectives of CRDS. There is a lack of regional collaboration in training and research and development.

6.7.4 There is a view that language could be a barrier to common training and that harmonisation could reduce fragmentation.

6.7.5 The existence of common procedures at pan-European level is a pre-requisite for common training and staffing activity. Joint operations in ACCs and new automation tools will drive forward progress in common procedures. There is little progress towards common procedures in order to exploit common training and staffing activities.

6.7.6 The Single European Sky regulation on service provision imposes a number of requirements on ANSPs in relation to their financial systems and reporting[42]. Despite the commonality of requirements across ANSPs, there is currently very little pan-European coordination activity in financial systems and reporting.

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[42] Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the Single European Sky (the service provision Regulation), Articles 12, 14, 15 and 16.

6.7.7 Many stakeholders agreed that we would expect to see activities to address a lack of collaboration and coordination in R&D at regional and multi-national levels and a lack of common procedures and standards to achieve economies of scale in administration costs. There was no obvious consensus on whether there was a lack of these activities, but most agreed that they would be effective.

6.8 Coordination gap analysis

6.8.1 The main gaps in European ATM/CNS coordination are summarised in Table 6.1 and illustrated in Figure 6.2.

Area of coordination	Fragmentation issues	Gap in coordination
Common issues	Adverse impact of piecemeal procurement	A lack of common standards and joint procurements at pan-European level A lack of joint procurements for communications and navigation at all levels
	Sub-optimal maintenance and in-service development	A lack of progress in common systems procurement to drive forward common maintenance and development, in particular, at pan-European level
En-route ATS units	Lack of economies of scale for en-route ATS units	A lack of guiding principles on FABs at pan-European level A lack of monitoring and compliance of regional FABs, to ensure that development is effective A lack of prescriptive legislation at pan-European level on implementation of FABs to accelerate progress A lack of centre consolidation at regional (supra-national) level A lack of guiding principles or a roadmap at pan-European level on consolidations A lack of incentives at pan-European level to encourage consolidations
	Constrained sector design	
ATM systems and interfaces	Poor inter-centre coordination	A lack of industry wide standards for interoperability at pan-European level A lack of joint development of specifications
CNS infrastructure	Over-provision of secondary radar	A lack of coordination to address over-provision of secondary radar at regional level A lack of activity at pan-European level to address the inconsistent use of primary radar A lack of joint activities to reduce fragmentation in communications and navigation infrastructure at regional level
	Inconsistent use of primary radar	
	Over-provision of navaids	
	Fragmented communications infrastructure	
Associated support	Duplication of R&D	A lack of collaboration and coordination in R&D at regional and multi-national levels A lack of progress in common procedures to drive forward common training and staffing at all levels
	Duplication of training facilities	
	Lack of economies of scale in administration costs	

Table 6.1: Gaps in European coordination

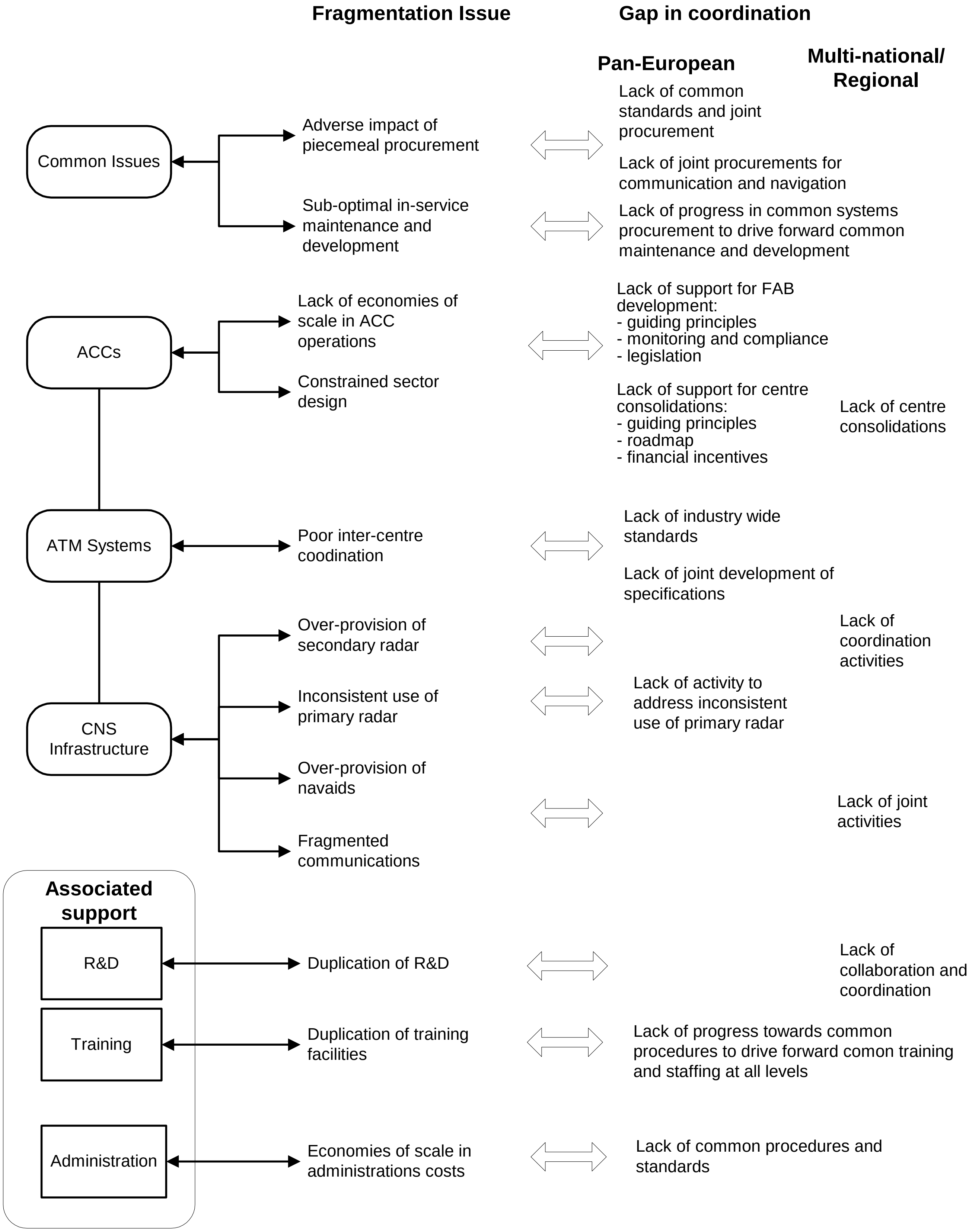

Figure 6.2: Gaps in European Coordination

7 Coordination activities in other industries

7.1 Railways

Sector background

7.1.1 Railways have historically developed as independent national networks, primarily designed to serve domestic traffic. International services are very much an "afterthought". We estimate that within Europe only 10% of travel is cross-border and probably less than 1% crosses more than one border.

7.1.2 As a result, the problems caused by fragmentation of railway networks have not been the highest priority issues in railway policy.

7.1.3 International railway services tended to be added on to national services, with technical standards based on the lowest common denominator. Changes of locomotive and crew were often required at borders. Timetables and capacity allocation had to fit in to domestic requirements. Charging and revenue allocation was typically ad hoc.

7.1.4 In recent years, there have been examples of international links built according to bilateral or multilateral arrangements (Thalys, Eurostar). Typically, these will be to specific standards agreed for the specific service. They can eliminate many of the delays and other aspects of poor quality of service and inefficiency in traditional international services. However, they effectively result in further fragmentation as the international system itself may be incompatible with the surrounding network.

The impact of fragmentation

7.1.5 The impact of fragmentation in railways may arise in a number of ways. Different technical standards may limit interoperability:

- different track gauges may require complex and expensive fitting of special infrastructure on the trains;
- different loading gauges require restriction of trains to the more restrictive standard;
- incompatible electrification systems require the use of less economical diesel locomotives, changes in locomotive, or expensive multi-system locomotives;
- incompatible coupling systems require the introduction of extra "match" vehicles which require the carrying of dead weight and wasted space;
- multiple signalling systems require special equipment and space for it, as well as extra training for crews (including operating in different languages).

7.1.6 These fragmentation issues may also have an impact on safety.

7.1.7 Imposition of international standards is not a practical proposition because of massive sunk costs in the existing infrastructure (of the order of hundreds of billions of euros).

7.1.8 The piecemeal development of railways according to different national standards has also led to a fragmented supply industry, exacerbated by nationally biased purchasing policies. This has also raised costs.

7.1.9 Capacity planning is again carried out at the national level and any new international services tend to involve a bespoke solution.

7.1.10 Capacity allocation is seen to be an area where domestic traffic is given priority, and free access by international operators has been discouraged. Where steps have been taken to allow more competitive access to capacity, it has tended to highlight congestion, as measures to increase capacity cannot readily or speedily be implemented.

7.1.11 Capacity pricing tends again to discriminate against international traffic and particularly transit.

7.1.12 Different systems of operational control, by contrast, lead to relatively few problems with international traffic.

Approaches to improve coordination

7.1.13 A wide variety of initiatives have been conceived to improve international coordination in European railways. They can broadly be categorised as:

- supply market initiatives;
- pan-European initiatives (usually top-down in nature);
- multilateral initiatives;
- regional initiatives; and
- bilateral initiatives.

7.1.14 Supply market initiatives have resulted from a steady process of consolidation in the supply industry, which has been a major driver for standardisation and harmonisation in Europe. They have resulted largely in the upward harmonisation of standards. However, lead times for implementation can be long, and there is a tendency for multiple "blocs" to emerge, converging on different standards.

7.1.15 There have been many pan-European, top-down initiatives, usually at the European Union level, including both legislation mandating structures and standards, and programmes (such as TEN-T) focusing funding on international transport.

7.1.16 In general, such initiatives have not been effective in reducing the impact of fragmentation. Their precise implementation has been difficult to agree and tends to result in convergence on a lowest common denominator, and even then with opt-outs permitted.

7.1.17 Multilateral initiatives, usually initiated by groups of infrastructure managers or train operators, have met with some success in areas such as coordinated relationships between train operators and infrastructure managers, and common procurement.

7.1.18 Regional and bilateral initiatives have included some effective transnational mergers of rail freight operations, and the construction of a number of cross-border links. Such initiatives can be successful, but tend (like supply initiatives) to result in incompatible "blocs".

Lessons for ATM

7.1.19 The tendency for permissive central, top-down initiatives to have relatively little impact may yield some lessons for ATM. The tendency of supplier-led or regional and bilateral initiatives to result in blocs of incompatible systems is a danger to be noted. The fragmentation that might thereby be "frozen in" would be relatively more damaging in the case of ATM than in the railways, where even international traffic tends to be more geographically localised.

7.2 Electricity

Sector structure

7.2.1 While electricity supply, like air transport, is a network industry, there are important differences arising from differences in structure that need to be borne in mind in any comparison between the sectors. In particular:

- There is no physical movement of the product, and indeed it is not possible physically to identify particular generators of electricity with particular customers (although notional identification is usual for charging purposes).
- Electricity is a homogeneous product, so the final customer has no interest in the deemed source of the electricity.

7.2.2 The key activities of the electricity supply chain can be thought of as:

- generation, the activities concerned with production of electricity;
- transmission, the activities concerned with the bulk transport of electricity on high-voltage transmission networks;
- distribution, the activities concerned with the local transport of electricity from transmission networks to final customers, usually on lower-voltage distribution networks; and
- retail, the activities concerned with bulk purchase of generation, transmission and distribution services and their repackaging and resale to final customers, including the customer-related activities of meter reading, billing, cash collection and complaint handling.

7.2.3 The relative costs of the activities depends on local circumstances, particularly the costs of fuel and customer characteristics, but typical relativities are: generation some 65% of total costs, transmission 5-10%, distribution 20-25% and retail 5%.

7.2.4 Generation and retail activities can be subject to competition with prices determined by market mechanisms, whereas transmission and distribution activities are natural monopolies, with prices determined by regulation. Wholesale competition occurs as retailers purchase bulk electricity from competing generators. Retail competition occurs as final customers purchase electricity from competing retailers. Both wholesale and retail competition rely on "open access" to the monopoly transmission and distribution networks that deliver electricity under regulated charges.

7.2.5 In recent years, in the European Union and elsewhere in the world, there has been a strong thrust to unbundling of these four main activities to ensure non-discriminatory access to the monopoly networks, and hence to facilitate competition in potentially competitive activities. Current EU law still permits common ownership but requires, at a minimum, legal separation and full management independence of (monopoly) transmission system operators from (potentially competitive) generation and retail.

The impact of fragmentation

7.2.6 Fragmentation in the electricity industry is not so much an issue of multiple entities either in the competitive markets (where multiple entities could be seen as a sign of healthy competition) or in the monopoly network operators (where operations are geographically self-contained), but of multiple markets operating under different rules, and sometimes with capacity constraints on the links between them. While issues such as failure to achieve economies of scale (particularly in distribution) might also be seen as costs of fragmentation, they have not been the focus of extensive coordination activity in the sector.

7.2.7 The adverse impacts of fragmentation can therefore be categorised as follows:

- sub-optimal location of generation plant, caused either by physical constraints in the transmission networks, or by non-economic pricing or discriminatory access restrictions to the networks;
- sub-optimal planning of transmission networks (perhaps on a national basis), not taking into account existing and planned transmission capacity on networks owned or operated by other entities;
- incompatible market rules – this might lead to barriers to market entry and hence to higher prices;
- divergent system operation rules – this might again restrict competition;
- piecemeal pricing of access to transmission networks, determined on a bilateral, border-crossing basis – this can impose an artificially high cost on generators separated by more than one network from their customers;
- the implementation of agreed economically beneficial infrastructure expansion plans is not always enforced.

Approaches to improve coordination

7.2.8 The most successful initiatives in the sector have been multilateral or pan-European in nature. Indeed, certain types of bilateral coordination could be seen as part of the problem rather than a solution (for example on transmission charges). Some regional initiatives have been successful (for example the Nordic "pool" – a single market covering four nations).

7.2.9 The bulk of the coordination initiatives have come from the European Commission. An initial directive in 1996 was aimed at facilitating competition and full market access. However, its success was seen as limited because:

- many of its provisions were implemented only at member states' discretion;
- it allowed the option of "negotiated" access arrangements as an alternative to a transparent, non-discriminatory pricing structure;
- it did not mandate independent regulation and monitoring of compliance.

7.2.10 As a result, a second, more prescriptive package was embodied in the directive of July 2003 (2003/54/EC). This directive mandates many of the measures that were left to discretion in the 1996 directive, in particular regulation, transparent and non-discriminatory network pricing, transparent rules for the balancing market, and free competition in the retail market.

7.2.11 This second package has had more success. For example, 24 out of 25 states now have a single compatible market model. However, there is still some resistance to change – by October 2004, 18 member states had still not notified the Commission of the steps they had taken to implement the 2003 Directive. This is thought to arise at least in part from the rather close relationship in some states between system operators and the Government.

7.2.12 In parallel, measures on a wider European stage have been introduced by the Union for the Coordination of Transmission of Electricity (UCTE), a trade association of transmission operators covering 22 states in Continental Europe (that is, excluding the separate – though linked – networks in the UK, Ireland and Scandinavia, and including operators from some non-member states). UCTE's coordination activities in the area of system operation rules have shown a similar pattern to those of the European Commission on access and pricing. An initially permissive approach based on guidelines has been recently replaced by more compulsion and contractual commitments.

7.2.13 In many instances of coordination activities in which there might be "foot-dragging" by individual entities, it has been found that publicising the successes of coordination has been effective in encouraging compliance. Also, it has been found that where there has been an apparent failure of coordination with consequent costs for consumers (such as national power failures), the opportunity can be taken to press for more rapid compliance.

Lessons for ATM

7.2.14 While the fragmentation issues faced by the electricity industry are different in nature to those faced by ATM, some lessons can nevertheless be learnt. In particular, it can be noted that:

- a prescriptive approach is more likely to reduce the cost of fragmentation than a permissive one;
- independent bilateral actions can be part of the problem;
- vertical integration of natural monopoly activities with potentially competitive ones can impede progress to efficient markets and hence lower costs;
- publicising progress, and energising action by highlighting consumer dissatisfaction with system failures, can be effective ways to promote beneficial change.

8 Conclusions and recommendations

8.1 The report has presented the results of a study of the impact of fragmentation in European Air Traffic Management and Communications, Navigation and Surveillance (ATM/CNS). The study focused on the following areas:

- fragmentation of en-route ATS units;
- fragmentation of ATM systems and interfaces;
- fragmentation and duplication of CNS infrastructure; and
- associated support costs.

8.2 Fragmentation is defined as *"the impact of having a system that has developed within the constraints both of national boundaries, and of historical decisions that may have become sub-optimal with technological or demand changes"*.

8.3 The study has considered fragmentation costs associated with ground infrastructure only. Consideration of the cost impact on avionics was outside the scope of the study.

8.4 We identified the major potential areas where fragmentation would have an adverse impact, and, as far as possible from the information available to us, evaluated the order of magnitude of this impact. These order-of-magnitude estimates were a significant proportion of the overall cost of the system.

8.5 Throughout the progress of the work, we sought information and views from stakeholders, especially ANSPs, both individually and at a series of workshops. Stakeholders' input was invaluable in helping us reach our conclusions.

8.6 The most significant fragmentation arises from lack of economies of scale in ACC operations associated with the large number of small ACCs operational in Europe. The study has estimated that this costs the industry around €475m - €600m a year, although this was being reduced by current and planned national consolidation projects. There are a number of current activities in Europe that aim to reduce this type of fragmentation including regional airspace delegation and consolidation projects However, consolidation projects appear currently to exist only at national level. There appears to be no pan-European guidance or incentives for ANSPs to consider cross-border consolidation – indeed central financing can be provided to initiatives that work against defragmentation, like the upgrade of uneconomically small national centres. We were struck by the lack of information available in this critical area of cost, and we would recommend enhanced requirements for information disclosure and intensified benchmarking in the area of ACC economics, to facilitate the identification of beneficial defragmentation projects. We would also recommend that any ACC renewal or upgrade projects seeking European funding be required to consider, and be assessed against alternatives involving cross-border cooperation and consolidation.

8.7 ACC fragmentation is also associated with constrained sector design. Sector design is often constrained by national boundaries, which would be removed in a defragmented system. This could have an impact on operational efficiency by allowing a possible reduction in the number of sectors and allow for more efficient flight profiles, because of more optimal routing through the sector. The study has estimated that this is costing between €50m and €100m a year. Some regional airspace delegation projects help alleviate this cost but it is expected that the formation of FABs will be the major enabler. It is therefore recommended that activities be launched to monitor the compliance of regional FABs to ensure that development is effective.

8.8 A related area that gave rise to substantial costs was fragmentation of ATM systems, which might give rise to costs of €190m - €325m a year, through increased purchase and development costs, and through increased costs of coordination at the interfaces between different systems. Current interoperability initiatives, including Implementation Rules, and in particular, the SESAR programme, might be expected to have a beneficial impact in this area.

8.9 Another important cause of fragmentation is the adverse impact of piecemeal procurement. Although some specific initiatives for common procurement are under way, the procurement of systems for ATM/CNS is usually based on a specification of operational and support requirements pertaining within an individual ANSP. In the absence of common approaches, system suppliers incur and pass on higher development costs. Given the high costs associated with the development of ATM/CNS systems, there is a correspondingly high potential for cost reduction. This cost reduction could be realised by procurement specifications common across ANSPs. The overall consequence of the current piecemeal approach is to increase the capital costs of the initial procurement because each system is seen as unique and requires bespoke design. The study has estimated that this is costing €30m - €70m a year.

8.10 There are some current initiatives involving groupings of ANSPs to provide a common procurement approach for ATM systems and there is some pan-European activity coordinated by EUROCONTROL for infrastructure projects. SES legislation will provide further impetus via the specification of Implementing Rules and Common Specifications. This is expected to improve interoperability between systems and therefore to reduce the costs of custom design. It is also expected that cost-effectiveness considerations will drive ANSPs towards common specifications and procurement.

8.11 In the longer term, it is expected that the SESAR project will provide a basis for common procurement of solutions favoured by the majority of stakeholders. In the shorter term, it is recommended that:

- appropriate Implementing Rules and Common Specifications are developed by EUROCONTROL to provide rapid technical convergence of systems and equipage.
- consideration is given to establishing joint procurements for communications and navigation infrastructure.

8.12 A further important area of fragmentation is associated support; we identified ab initio training, administration, and R&D as areas where there might be lost economies of scale. It was very difficult to obtain information in this area that would help us estimate the costs; they might amount to between €40m and €100m. Little activity is currently being undertaken to promote collaboration in these areas, with the exception of R&D.

8.13 The study also identified a number of other causes of fragmentation cost:

- sub-optimal maintenance and in-service development;
- fragmented planning; and
- over-provision of navaids and secondary radar.

Together these contribute up to about €100m - €200m a year in fragmentation costs.

8.14 A number of gaps in coordination were identified and it is recommended that coordination activities are initiated in the follow areas:

- to encourage common maintenance and development;
- to improve inter-centre coordination by the establishment of industry wide standards for interoperability at pan-European level and the joint development of specifications;
- to address the inconsistent use of primary radar;
- to provide collaboration and coordination in R&D at regional and multi-national levels;
- to define common procedures to drive forward common training and staffing at all levels.

8.15 The study has provided order-of-magnitude estimates of the cost of fragmentation only, and furthermore only in specific areas. It will be instructive in future:

- to review the costs of fragmentation in the areas not investigated in this study (such as terminal ANS; ancillary services such as MET and AIS; on-board costs; fragmentation between civil and military service provision; and fragmentation of regulation)
- to investigate in more depth the major areas of fragmentation identified in this study, and refine the cost estimates;
- to identify the geographical scope for actions to mitigate fragmentation;
- and to propose legal or financial mechanisms to promote movement to a more economically efficient system.

Annexes

A ATM and CNS systems and operations

A.1 Introduction

A.1.1 This annex gives further information on the concepts of ATM and CNS

A.1.2 The ICAO ATM Operational Concept document[1] defines Air Traffic Management (ATM) as "the dynamic, integrated management of air traffic and airspace - safely, economically, and efficiently - through the provision of facilities and seamless services in collaboration with all parties." EUROCONTROL[2] states that the objective of ATM is to “enable aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints, without compromising agreed levels of safety. It comprises ground elements and airborne elements which, when functionally integrated, form a total ATM system.”

A.2 ACC

Operations room

A.2.1 The core element of any ACC is the operations room from where air traffic control officers (ATCOs) provide radar services. These are large halls within which there are banks of workstations equipped with radar consoles, air/ground communications and associated information displays. Although there is no prescribed layout for operations rooms, a typical layout could be as shown in Figure A.1. In addition, many ACCs have dedicated training suites within the operations room whilst others have separate training facilities.

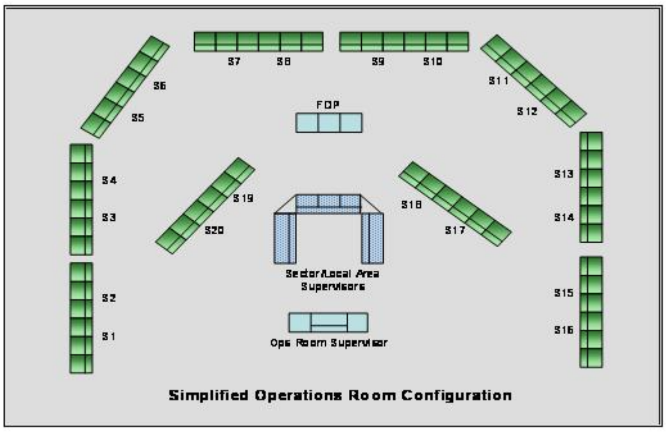

Figure A.1: An example operations room configuration

A.2.2 The area of coverage is divided into volumes of airspace known as sectors and the workstations are arranged such that each sector is served by one or more designated control suites. Sectors are usually identified by a number which is often displayed on the respective control suites. Other overt means of identifying local area sector groupings include colour coding.

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1 ICAO ATM Operational Concept Document, Appendix, AN-Conf/11-WP/4.

2 http://www.eurocontrol.int/corporate/public/standard_page/cb_airtraffic_controller.html.

A.2.3 A team of ATCOs and, in many ANSPs, assistants is allocated to each sector, which, depending on its size, may be served by a grouping of control teams and suites. Although different terminology is used to identify the controllers with their task, the most generally employed is Planner and Executive. As the title suggests, the Planner controller monitors aircraft approaching from adjacent sectors and airports. Using landline communications and flight plan information this controller organizes approaching aircraft to facilitate the most efficient traffic flow through the sector. The Executive controller actually controls the aircraft, maintains radar surveillance and issues pilots with instructions to ensure a safe and expeditious traffic flow. The Sector assistant provides and disseminates air traffic data and liaises on behalf on the controllers with airfields, other sectors and adjacent centres. An illustrative example of a typical control suite is shown in Figure A.2.

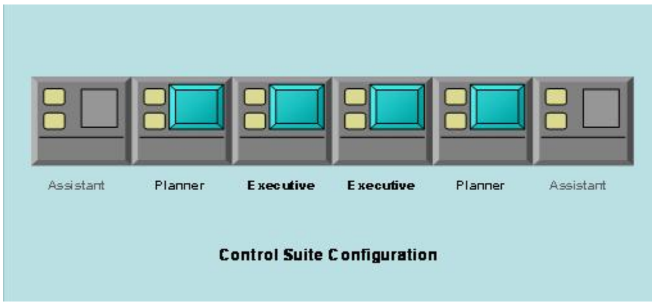

Figure A.2: An example of a control suite configuration

A.2.4 Each controller requires authorisation to manage particular sectors. Such an authorisation ("validation" or sometimes "endorsement") requires specific training. This form of licensing is used because each area of airspace differs in its characteristics. It derives from ICAO requirements on the need for ANSPs to establish that controllers have sufficient 'knowledge' to operate under a licences rating.

A.2.5 Validations are awarded after an in-house training programme. This usually comprises a period of local simulator training followed by supervised 'live' sessions at an operational control position. Increasingly, ACCs are establishing teams staffed by qualified on-the-job training instructors who train ATCOs to the required standard for validation.

Operations structure

A.2.6 The structure shown in Figure A.3 is a representation of an operational unit structure within an ACC. This is a simplified example of how an ACC could be arranged to ensure a 24-hour ATM operation - it is by no means typical as the operational unit structure will differ depending on the size and complexity of the ACC.

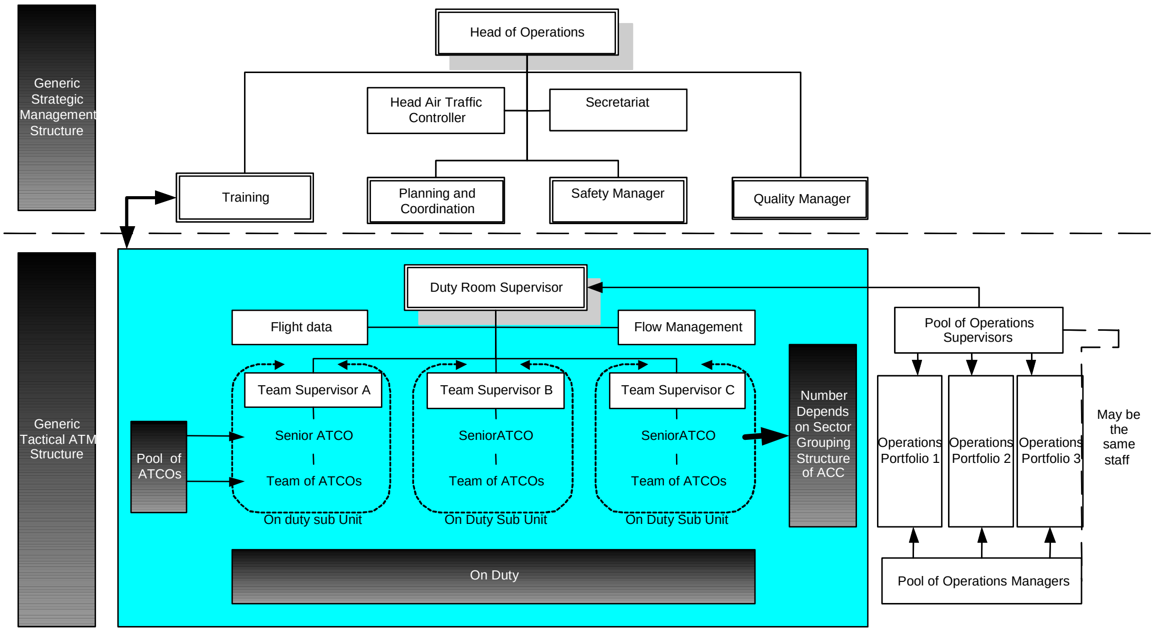

Figure A.3: An example ACC operations unit structure

A.2.7 Typically, an operations room supervisor is in charge of the tactical management of the operations room. This position is responsible for the overall smooth running of the operations.

A.2.8 A particularly large ACC can be divided into various workgroups, where each workgroup is based on a regional grouping. For example, an ACC with 500 controllers could have up to seven workgroups (with around 70 controllers in each) with each one being run on an individual basis to ensure 24-hour coverage of the sectors in the workgroup.

A.2.9 There could be further division within the workgroups in the form of teams. Each team could contain 10-12 controllers that are generally on shift together and will, as a team, hold enough airspace endorsements (or validations) to manage a cluster of, say, up to 6 sector volumes per shift. In such a scenario, each workgroup requires around 6-7 teams to account for the 24-hour nature of ATC and its variable traffic flows, days off, leave and training requirements.

A.2.10 Typically, a Deputy or Team Supervisor supervises the workgroups. Their role is to assist the operations room supervisor in fulfilling their responsibilities especially in relation to contingency management (such as system failures) and In-Flight Emergency Response activities.

A.2.11 The Team Supervisor position also manages sector configuration to allow for the ebbs and flows of air traffic. As air traffic increases in a particular region (for example because of a morning burst of scheduled flights arriving at a busy airport), a decision may be made to 'split' a previously combined group of sectors into smaller sectors, continuing to staff those sectors from within the team. This mitigates excessive controller workload. It is the team supervisor who often bears the responsibility of operating this mitigation.

A.2.12 Each team will also often have a senior air traffic controller. This position may hold responsibilities for the periodic validation of controller's licences through on-the-job monitoring and/or written exams. The position may also share responsibility along with other senior controllers for input into procedural development for the workgroup.

A.2.13 The training component of the tactical ATC environment is a significant one. At any one time a workgroup may be training a number of ab initio trainees on the job and may also be re-validating controllers who have been away on extended leave or projects. This task is usually given to the more senior controllers.

A.2.14 The procedural development, training needs, roster management and safety accountabilities may be seen as portfolios with each one affecting the other. An ACC may employ separate personnel to manage these components of the tactical environment or may share the responsibilities amongst the pool of duty room supervisors.

A.3 Communications

A.3.1 Controller-pilot communications (the air-ground-air service) use VHF radio links. This service, which is currently mainly voice communication, provides the basic method to implement the control function. A network of VHF radio stations provides full geographic coverage. Essentially, each sector of airspace is allocated a single frequency which gives the sector controller uninterrupted access to aircraft under his control. In busy areas, this has led to a shortage of VHF frequency allocations which has resulted in the need to reduce the bandwidth allocated to individual radio channels[3].

A.3.2 The voice and data communications network carries many different types of voice and data information including:

- air-ground-air communication (voice and data) between ATC units and the radio stations;
- ground-ground communication (voice) between ATC units and other interested parties;
- ground-ground communication (data) between ATC units and other interested parties (for example Aeronautical Information Services, Flight Data Exchange);
- surveillance data transmitted to ATC units; and
- information on the status of the CNS infrastructure, required for control and monitoring.

These networks may be implemented by individual sub systems or by a more integrated approach. They have demanding availability and integrity requirements.

A.4 Navigation

A.4.1 Navigation is based on systems which provide radio navigational information to aircraft. This information enables the aircraft to establish its current position. Ground systems currently in use include VHF Omni-directional Range (VOR), Distance Measuring Equipment (DME) and Non-Directional Beacons (NDB). Satellite navigation based on the Global Navigational Satellite System (GNSS) is developing relatively quickly which will result in the potential to reduce the ground station infrastructure, notably VORs.

[3] Channel bandwidth has recently been reduced from 25kHz to 8.33kHz in Europe for FL 195 and above; this may be extended down to FL 100.

A.5 Surveillance

A.5.1 Surveillance systems provide controllers with information on the position and identity of aircraft. The main surveillance tool is radar. Europe's Air Navigation Service Providers (ANSPs) operate a network of radar stations to provide adequate surveillance coverage. Radar stations may have primary radar, secondary radar or both. Primary radar provides only range and azimuth information but has the advantage that it does not rely on any equipment on board the aircraft for its operation. Secondary surveillance radar (SSR) is the main radar surveillance tool for civil en-route ATC. Secondary radar uses information from equipment on board the aircraft and provides aircraft identity, range bearing and height information. The next generation of SSR (Mode S) is currently being implemented. Mode S overcomes a number of limitations with conventional SSR. In particular, it has the ability to uniquely identify a larger number of aircraft and to provide higher resolution of altitude information. Surveillance based on the transmission of satellite derived (GNSS) aircraft position is also under development. The aircraft positions are transmitted to the ground by means of a data link inherent in the Mode S system or by a VHF data link.

A.5.2 Currently, the main surveillance infrastructure in Europe is based on radar services which are normally provided in accordance with the EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas[4]. This standard requires duplicated secondary surveillance radar coverage in en-route airspace and duplicated secondary surveillance radar plus single primary surveillance cover in major terminal areas.

[4] Reference SUR.ET1.STO1.1000-STD-01-01, March 1997

B Supporting information for current system cost estimates

B.1 Air-ground-air communications

B.1.1 We have calculated the number of VHF ground stations used for voice communications in Europe, by using the ICAO COM 2 table[5], which contains data on the frequency assignments for Europe.

B.1.2 We have filtered out frequencies used for ACC and APP services. Each frequency has a corresponding location attributed to it, given in latitude and longitude. We have assumed that each instance of a unique latitude and longitude indicates a different ground station. One ground station can have a number of different frequency assignments for ACC and APP services. For every ground station that provides an ACC service, we have assumed that a back-up antenna will exist. We have assumed no back-up antenna for ground stations that do not provide ACC services. A number of ANSPs[6] have provided information on VHF ground stations for ACC/APP services and we have used these figures in our analysis, accordingly.

B.1.3 Table B.1: shows the number of VHF ground stations for ACC and APP services per State, derived by the method described above. Note that some ground stations for ACC services will also provide APP services. Ground stations given under APP services, provide only APP services.

B.1.4 The total number of VHF ground stations in Europe is 377 (for ACC services) and 1123 (for both ACC and APP services). We include both ACC and APP services in our cost estimate, and have therefore based our estimate on 1123 ground stations.

[5] The ICAO COM 2 table data was provided by the EUROCONTROL Agency.

[6] ANS CR, DSNA, Oro Navigacija, Skyguide, DFS and NATS.

	Ground stations for ACC services	Ground stations for APP services
Albania	4	1
Austria	4	7
Belgium	4	7
Bosnia & Herzegovina	2	4
Bulgaria	8	15
Croatia	2	9
Cyprus	2	3
Czech Republic	3	3
Denmark	14	12
Estonia	4	5
Finland	14	31
France	43	89
FYROM	4	1
Germany	57	69
Greece	8	34
Hungary	4	6
Ireland	6	4
Italy	8	37
Latvia	4	2
Lithuania	4	4
Luxemburg	0	1
Malta	2	0
Moldova	2	3
Netherlands	4	7
Norway	10	41
Poland	14	21
Portugal	8	11
Romania	12	18
Slovak Republic	2	8
Slovenia	6	3
Spain	4	25
Sweden	20	62
Switzerland	10	6
Turkey	14	70
UK	30	106
Ukraine	40	21
Totals	**377**	**746**

Table B.1: Numbers of VHF ground stations (ACC and APP) per State

Capital replacement cost

B.1.5 One estimate for the capital replacement cost of a VHF ground station is cited in the ICAO ALLPIRG/4-WP/28 Appendix - Cost Tables for CNS/ATM Planning and Evaluation Tools[7]. This estimate is $190,000 in 2000 prices and includes purchase and installation only. However, probably at least as much again is required for buildings and services (including the tower). This would make the total cost per ground station (including buildings and services) around €400,000. However, in our own experience, a realistic figure for the total project capital cost would be €600,000.

B.1.6 The total capital replacement cost for VHF ground stations in Europe is estimated to be in the range €450m - €670m.

Annual operating cost

B.1.7 The maintenance costs of a VHF station are given in the ICAO ALLPIRG/4-WP/28 Appendix - Cost Tables for CNS/ATM Planning and Evaluation Tools[7] as $17,000 per year.

B.1.8 The annual operating cost, comprising maintenance costs, is around €20.0m a year.

Summary of capital replacement and annual operating costs

	Cost per ground station (including buildings and services)	Number	Total
Capital cost	€400,000 - €600,000	1123	**€ 450m - € 670m**
Annual operating cost	€ 17,800	1123	**€ 20.0m**

Table B.2: VHF air-ground-air station costs

B.2 Ground-ground communications

B.2.1 The costs of communications networks are based on the annual costs of leasing lines and local ends. Message switches and other communications infrastructure have **not** been included in the cost estimates. Communications links costs for non-operational functions such as IT, support information such as MET etc have not been estimated.

B.2.2 Leased line costs are based on BT prices[8], which vary according to transmission rate and kilometre distance of the leased line. Communications costs also include an annual cost of local ends.

B.2.3 The ground-ground networks comprise:

- radar networks;
- ground-ground voice and data networks;

[7] ICAO ALLPIRG/4-WP/28 Appendix - Cost Tables for CNS/ATM Planning and Evaluation Tools, 6-8 February 2001. This equates to €17,800 per year, using 2000 exchange rates (European Central Bank http://www.ecb.int/stats/eurofxref/eurofxref-hist.xml).

[8] BT prices from BT 'Private Circuits Price Information' January 2004.

- ACC links (inter-state);
- ACC links (intra-state).

The costs of these have been estimated as described below.

B.2.4 **Radar network costs**. We have assumed that every radar has two communications links (one link for redundancy) to one ACC. Each leased line is assumed to have an average distance of 100km and a transmission rate of 128kbps. The cost of leasing the main link and local ends is €9,700 per year. Our discussion of surveillance identifies 503 radars. Assuming that there are two such lines for each radar, the total cost is €9.7m per year.

B.2.5 **Ground-ground voice network costs**. We have assumed that each VHF radio station has two communications links (one link for redundancy) to one ACC. Each leased line is assumed to have an average distance of 100km and a transmission rate of 128kbps. The annual cost of leasing the main link and local ends is €9,700. We have assumed that 2246 such links are used for the ground-ground voice network, which gives a total cost of €21.7m per year.

B.2.6 **ACC links (Inter-State)**. In estimating the costs of inter-State ACC links, we have assumed two communications links (one link for redundancy) between neighbouring States - around 160 links in total in Europe. The leased line is assumed to have a transmission rate of 128kbps and an average distance of 400km, based on an average of city-pair distances. The cost of leasing the main link and local ends is €18,000 per year. The cost of 160 such links is €2.9m per year.

B.2.7 **ACC links (Intra-State)**. The costs of intra-State links have been based on a ring topology (ie two links between each State's ACCs and APPs[9]). According to the PRU's ATM Cost-effectiveness (ACE) benchmarking work[10], there are 216 relevant operating units in the area covered[11]. However, we estimate that 49 APPs are co-located with ACCs and therefore do not require a specific link. Assuming an additional 26 units for Greece, Ukraine, Poland and Bosnia-Herzegovina, not included in ACE 2002, we have used a figure of 193 units for Europe as a whole. The leased line is assumed to have a transmission rate of 128kbps and an average distance of 250km. The cost of leasing the main link and local ends is €13,800 per year. The cost of 386 such links is €5.3m per year.

B.2.8 The total cost of ground-ground communications networks is estimated at €39.6m per year.

[9] APP units are included as they cover terminal manoeuvring areas (TMAs), which are within the scope of this study. TWR units serve airports and are therefore excluded.

[10] From ACE2002 (see footnote 3 on page 11).

[11] Allowing three locations for the multi-centre ACC in Romania

Networks	Annual cost of main link and local ends	Number of links	Annual cost
Radar	€ 9,700	1006	€ 9.7m
Ground-ground voice	€ 9,700	2246	€ 21.7m
ACC links (inter-State)	€18,000	160	€ 2.9m
ACC links (intra-State)	€13,800	386	€ 5.3m
Total			**€ 39.6m**

Table B.3: Ground-ground communications networks costs

B.3 ACCs

B.3.1 Clearly, the cost of the ACC and associated systems is driven by variables related to the potential amount of controller activity and the equipment required to support it. A measure of this is the maximum number of sectors for which space and physical equipment are available (the "physical maximum number of sectors"). This information was supplied by the EUROCONTROL Agency[12] and by a number of ANSPs and is summarised in Table B4. This will in many cases be greater than the number of sectors currently operated.

B.3.2 Costs of recent or planned ACC investments which have been identified include those for Langen (Germany), NERC at Swanwick (UK), Prestwick (UK)[13], NUAC at Malmö (Sweden), CEATS, Shannon (Ireland), IATCC (Prague), Sofia (Bulgaria), Bucharest (Romania) and Zagreb (Croatia). These are shown in Table B.5:, together with the maximum number of physical sectors in the centre, as defined above.

B.3.3 For our purposes, the appropriate cost to use to estimate the capital replacement cost is the full implementation cost, including buildings, infrastructure and development costs. However, there may be difference between the scope of the cost estimates in the table; some ANSPs may have counted some development costs as current expenditure.

[12] Data from the EUROCONTROL Agency, March 2005.

[13] Information provided by NATS, 2005. Source: NERL SIP 2005, issue 1.

State	ACC	Maximum physical sectors		State	ACC	Maximum physical sectors
Albania	Tirana	4		Moldova	Chisinau	3
Austria	Vienna	15		Norway	Bodo	4
Belgium	Brussels	9			Oslo	7
Bulgaria	Sofia	8			Stavanger	5
	Varna	4			Trondheim	1
Croatia	Zagreb	12		Poland	Warsaw	11
Cyprus	Nicosia	4		Portugal	Lisboa	11
Czech Republic	Prague	16		Romania	Bucharest	22
Denmark	Copenhagen	18		Slovak R	Bratislava	5
Estonia	Tallinn	4		Slovenia	Ljubljana	5
Finland	Tampere	5		Spain	Canarias	10
	Rovaniemi	2			Barcelona	24
France	Bordeaux	24			Madrid	24
	Reims	14			Palma	8
	Paris	22			Sevilla	8
	Marseille	26		Sweden	Malmo	12
	Brest	18			Stockholm	7
FYROM	Skopje	5			Sundsvall	4
Germany	Berlin	18		Switzerland	Geneva	10
	Frankfurt +Dusseldorf	38			Zurich	9
	Munich	18		The Netherlands	Amsterdam	10
	Rhein	16		Turkey	Ankara	8
	Bremen	12			Istanbul	6
Greece	Athens + Makedonia	15		UK	Manchester	8
Hungary	Budapest	13			Scottish	18
Ireland	Dublin	6			London AC	40
	Shannon	13			London TC	26
Italy	Brindisi	10		Ukraine	Kyiv	11
	Milano	16			Dnipropetrovs’k	3
	Padova	12			Simferopol	6
	Roma	26			Kharkiv	6
Latvia	Riga	4			L’viv	4
Lithuania	Vilnius	3			Odesa	5
Malta	Malta	3				
Maastricht	MUAC	18		**Total**		**792**

Table B.4: Maximum number of physical sectors for ACCs

NB. The centres and the estimates of maximum physical number of sectors relate to 2003 data, for comparability with the latest available ACE data.

ACC	Costs of ACC buildings and systems	Maximum number of physical sectors[3]
Langen	€ 200m[1]	38
NERC	€ 1050m[2]	82[2]
Prestwick	€ 170m[3]	34
NUAC	€ 102m	25
CEATS	€ 137m[4]	45[4]
Shannon	€ 83m[5]	13
IATCC (Prague)	€ 110m[6]	16
Sofia	€ 80m[7]	8
Bucharest	€ 70m[8]	22
Zagreb	€ 55m[9]	12

Table B.5: Recent ACC investments

Notes:

1 Performance Review Report 5, July 2002, Performance Review Commission.

2 Figures provided by NATS. Due account was taken of the fact that NERC was designed not just for London ACC that moved in in 2002, but also for London Terminal Control, which is due to move in in 2007, with some military sectors..

3 Data for the physical maximum number of sectors was available for Langen, Shannon, IATCC (Prague), Sofia, Bucharest and Zagreb.

4 Source: CEATS Business Plan, 2004.

5 Figures provided by the IAA.

6 Source: ANS Czech Republic Annual Report 2003. Figures reported in the Annual Report show a 1.2 billion CZK investment in buildings and 2 billion CZK investment in equipment. Exchange rates are sourced from European Central Bank (http://www.ecb.int/stats/eurofxref/eurofxref-hist.xml).

7 Source: see footnote 12.

8 Source: EUROCONTROL Agency, December 2004. Investments relating to ACC buildings, ATM systems and CNS infrastructure at Bucharest ACC total €100m. We have made the assumption that 70% of the investment is for ACC buildings and ATM systems. This figure requires further refinement and validation.

9 Source: www.ebrd.com/new/pressrel/2002/02sep05x.htm - Press release Sep 2002 – "Croatian Air Traffic Control lands EBRD support".

C Costs of fragmentation detailed estimates and assumptions

C.1 Navigation

Coverage maps

C.1.1 The figures below show a European overview of DME and VOR/DME coverage at FL100 and FL50 respectively. The coverage colours relate to:

- black or white or terrain visible: less than two DME facilities available
- red: two DME facilities available (one pair, within RNAV geometrical constraints (30-150deg from aircraft)); accuracy achievable, no redundancy;
- yellow: three DME facilities available (two pairs within RNAV geometrical constraints); accuracy achievable, limited redundancy;
- blue: more than three DME facilities available (min three pairs within RNAV geometrical constraints); accuracy achievable, full redundancy.

C.1.2 The coverage maps show the complexity of analysing navaid coverage. Although at FL100, large areas of Europe seem to have coverage from more than three DME facilities, at lower altitudes this is not the case. In fact, the coverage at FL50 shows that there are areas of Europe with coverage from less than two DME facilities. It is difficult to assess over-provision with coverage maps alone and without knowledge of traffic routes, and therefore we have used the approach described below.

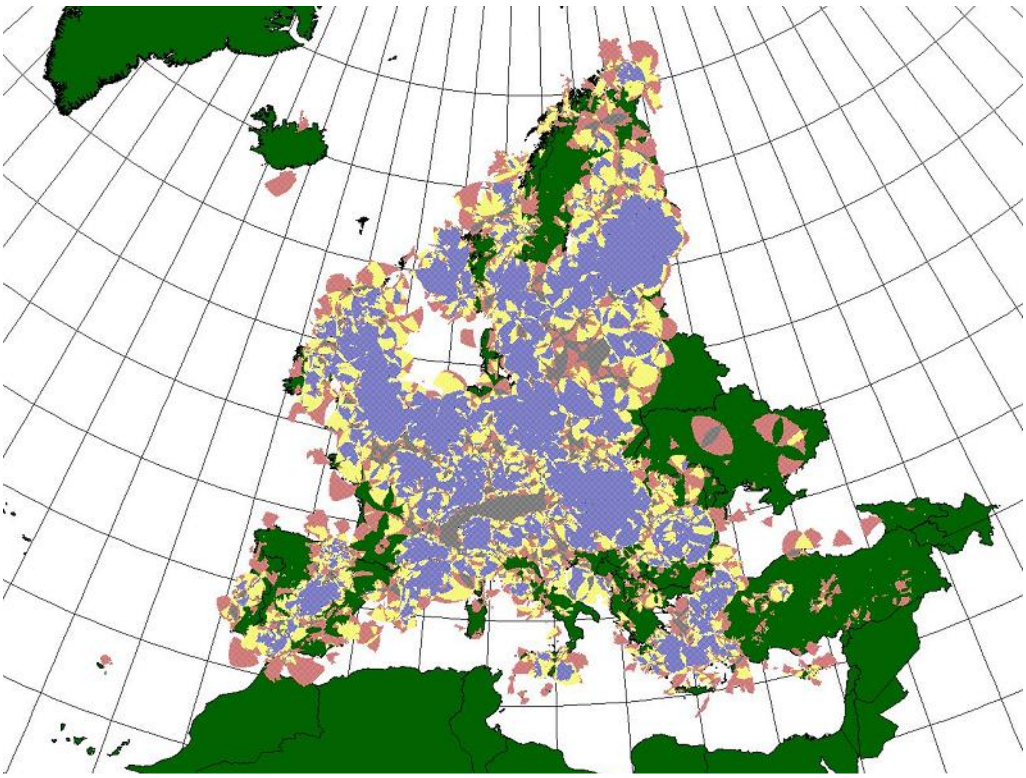

Figure C.1: DME & VOR/DME Coverage at FL100

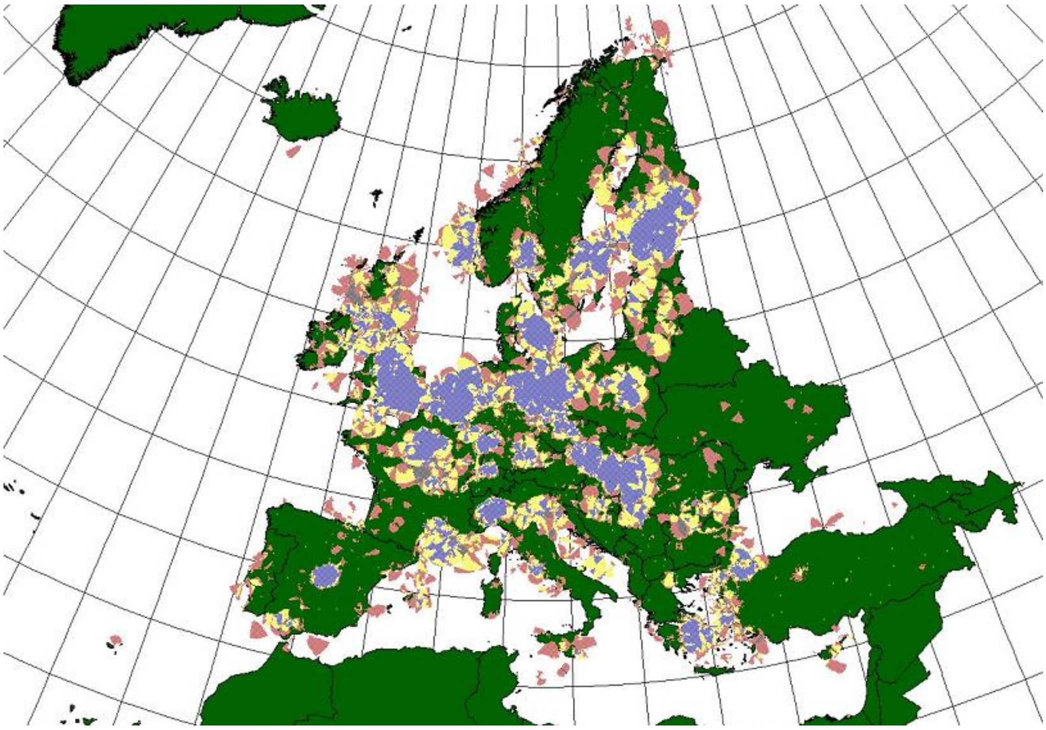

Figure C.2: DME & VOR/DME Coverage at FL50

Inter-distance analysis

C.1.3 Our approach is to carry out an inter-distance analysis which looks at actual locations of navaids and examines areas where the spacing between navaids is less than might be expected from basic coverage considerations alone. The objective is to focus on those navaids which are in different States, which may indicate potential inconsistency in planning due to fragmentation. This gives some indication of the maximum cost savings possible (and therefore the upper bound on the costs of fragmentation).

C.1.4 Navaid location data from the EUROCONTROL Agency was used for the inter-distance analysis. We have analysed inter-distances for the DME and VOR network separately. We have not carried out a similar analysis for NDBs, as the overall costs of this equipment are insignificant[60], when placed in the context of the total costs of navaid infrastructure.

C.1.5 We filtered out all duplicated location data for DMEs and calculated the great circle distances between the remaining DMEs. We filtered out all those DME pairs which were above 100nm apart and separated the remainder into distance bins. DME pairs in different countries were identified. A similar approach was used for VORs.

C.1.6 The results of the inter-distance analysis are shown in the following tables:

[60] Approximately 10% of total capital costs for navaids relate to NDBs.

Category	Number of pairs where DMEs are in different countries	Number of DMEs involved in pairs where DMEs are in different countries
<100nm	562	304
<75nm	253	200
<50nm	78	97
<40nm	38	51
<30nm	16	24
<20nm	7	10
<10nm	1	2
<1nm	1	2

Table C.1: DME inter-distance analysis

Category	Number of pairs where VORs are in different countries	Number of VORs involved in pairs where VORs are in different countries
<100nm	756	324
<75nm	340	220
<50nm	102	109
<40nm	54	66
<30nm	23	33
<20nm	8	12
<10nm	3	6
<1nm	2	4

Table C.2: VOR inter-distance analysis

C.2 Surveillance coverage analysis

C.2.1 The analysis of radar coverage is a complex issue which involves consideration of local operational requirements (often for more than one user), terrain topography, environmental issues, radar performance, logistical issues and costs. A superficial analysis of overlapping cover will often show an apparently high level of overlap but this could be caused by one or more of the factors listed above, as well as over-provision.

C.2.2 We have considered three possible approaches to the analysis of radar coverage as follows (in ascending order of complexity):

- A simple coverage analysis based on number of radar stations required across the European land mass to provide line of sight coverage at FL50.
- A inter-distance analysis which looks at actual locations of established radar stations and examines areas where the spacing between radar stations is less than might be expected from basic coverage consideration alone.
- A complete analysis of radar coverage which takes into account operational requirement, terrain topography, environmental issues, radar performance, logistical issues and costs.

C.2.3 We have carried out work using both the first two approaches to illustrate order-of-magnitude costs of overlapping cover. It must be emphasised that the results can only be validated if a full analysis as described under the third approach is carried out. Unfortunately the amount of specialist work involved in this is such that it is outside the scope of this study.

Coverage maps

C.2.4 The EUROCONTROL Radar Sharing Calculation (RASCAL) tool can show radar coverage at differing flight levels. Figure C.3 and Figure C.4 show European overviews of SSR radar coverage at FL50 and FL30 respectively. Single coverage is given by the blue colour, double coverage by the brown colour, triple coverage by the pink colour and more than triple coverage is given by the green colour. Note that Ukraine, while within the scope of this study, is not included in this data set.

C.2.5 The coverage maps show the complexity of analysing radar coverage. Although at FL50, a large area of Europe seems to have more than double coverage, there is less over-provision at lower altitudes. In fact, the coverage at FL30 shows that there are areas of Europe with no SSR coverage and larger areas with just single coverage. It is therefore difficult to assess over-provision with coverage maps alone and we have used the approach described below, which has been validated with surveillance experts at EUROCONTROL.

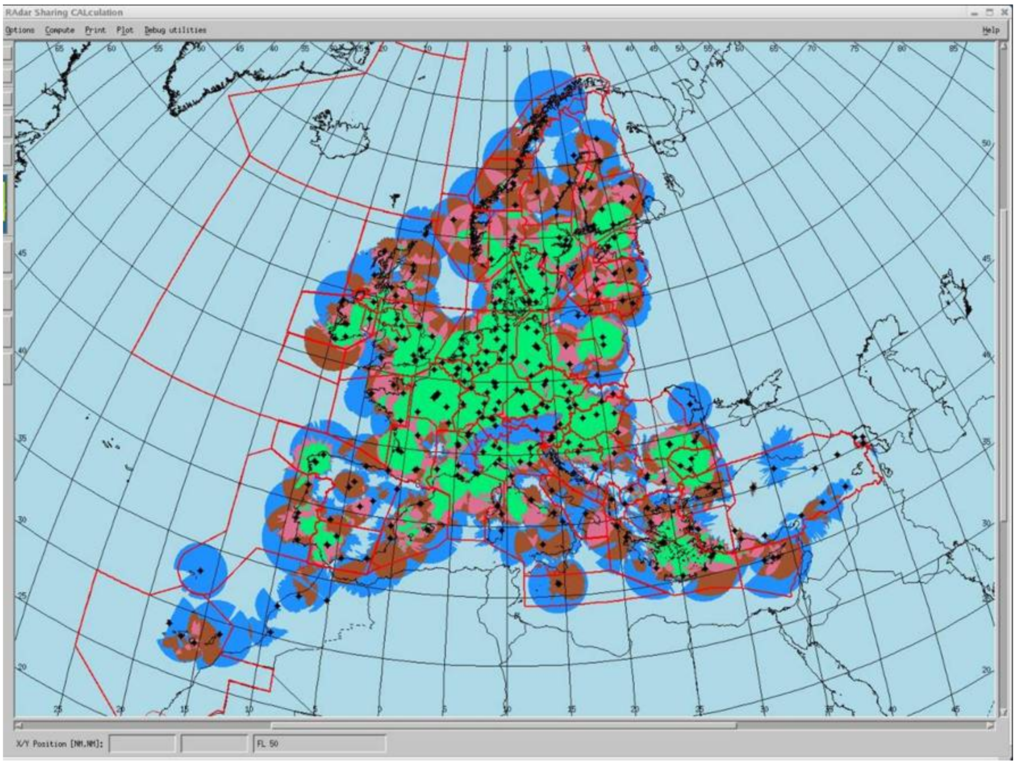

Figure C.3: Radar coverage at FL50 (RASCAL)[61]

[61] Data from the EUROCONTROL Agency, 2005.

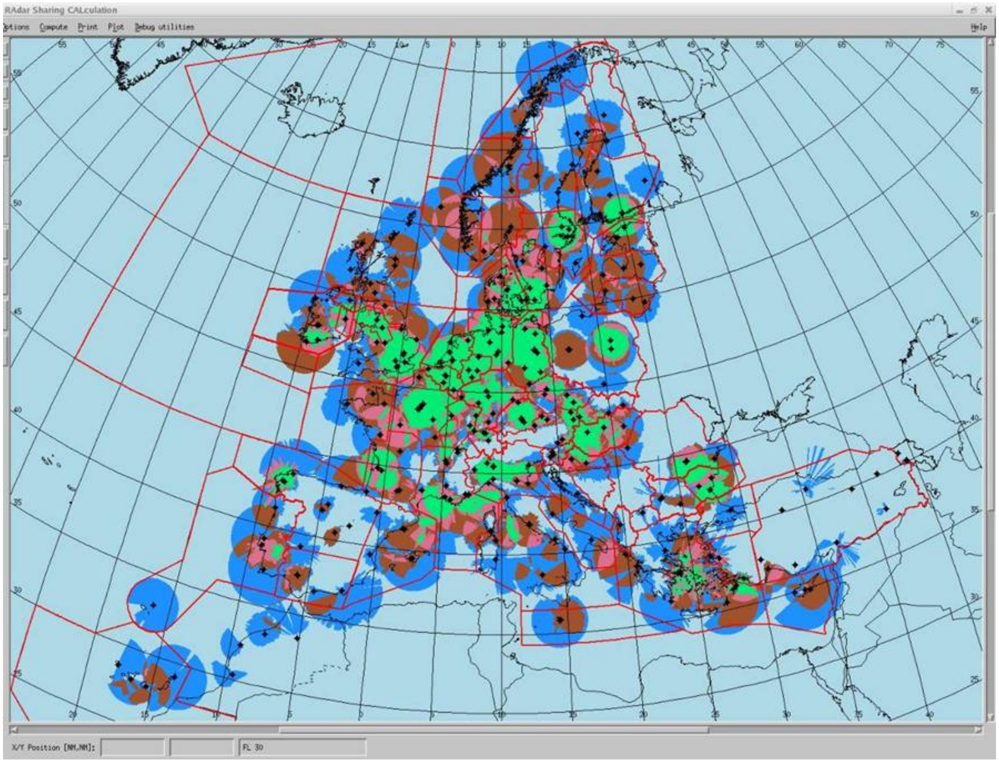

Figure C.4: Radar coverage at FL30 (RASCAL)[61]

C.2.6 We have carried out an inter-distance analysis which also examines radar services' overlap across national boundaries (in ideal circumstances) to see whether there is any scope for rationalisation of services and hence cost savings. It must be stressed that this approach is aimed at indicating possible saving only and would require further detailed analysis, discussion and validation with the relevant ANSPs.

C.2.7 We used radar location data from the EUROCONTROL Agency for the inter-distance analysis. We filtered out all duplicated location data for radars and calculated the great circle distances between the remaining radars. We filtered out all those radar pairs which were above 100nm apart and classified the remainder according to the distance between them. Radar pairs in different countries were identified and the numbers of radars involved in these pairs were assessed.

C.2.8 We carried out the analysis for all radars (en-route and approach) and then separately for en-route radars only[62]. The results are shown in Table C.3: for all radars and in Table C.4 for en-route radars only.

[62] Comments received from surveillance experts have questioned the inclusion of approach radars in the inter-distance analysis. Since approach radars are at airports for operational requirements and their location is constrained by the airport site, the over-provision of approach radar is more difficult to assess. Nevertheless we think that there is still scope for defragmentation and have therefore included approach radars in the first analysis.

Distance between pair of radars	Number of pairs where radars are in different countries	Number of radars involved in pairs in different countries
< 50nm	23	32
< 75nm	77	77
< 100nm	190	129

Table C.3: Inter-distance analysis for all secondary radars

Distance bin	Number of pairs where radars are in different countries	Number of radars involved in pairs in different countries
< 50nm	7	13
< 75nm	25	36
< 100nm	66	74

Table C.4: Inter-distance analysis for en-route secondary radars

C.2.9 We focused on radar pairs which were less than 100nm apart, as we judged that radars with a LOS coverage range of 100nm would be expected to be placed further apart. We assumed that 50% of these radars may be as a result of over-provision due to the existence of national boundaries.

C.3 Primary radars

	En-route primary radars	Costs recovered from military?
Austria	4	
Belgium	2	
Bulgaria	2	
Croatia	1	
Cyprus	1	
Czech Republic	0	
Denmark	1	
Finland	0	
France	0	
Fyrom	0	
Germany	6	✓
Greece	1	
Hungary	2	
Ireland	3	
Italy	9	
Latvia	1	No
Lithuania	2	✓[63]
Malta	1	No
Moldova	3	
Netherlands	1	
Norway	0	
Poland	2	
Portugal	0	
Romania	0	
Slovak Republic	0	
Slovenia	1	
Spain	0	
Sweden	1	✓
Switzerland	0	
Turkey	0	
Ukraine	13	
United Kingdom	11	✓[64]
Total	**68**	

Table C.5: En-route primary radar in Europe

[63] The Lithuanian Air Force pays for radar data. Source: Oro Navigacija, 2005.

[64] The £45.3m that was recovered from the military in 2004/5 as indicated in NATS Holdings Ltd Annual Report includes a payment for shared use of these radars. Source: NATS, 2005.

D List of projects investigated in Phase 2

D.1 Regional activities

D.1.1 Regional activities in CNS are:

Baltic ATSO Telecommunication Network (BAN) – to develop and implement a common Aeronautical Telecommunication Network for the Baltic States;

CNS/ATM Technical Development Plan for Baltic States – a joint plan between the ANSPs of Latvia, Lithuania and Estonia to harmonise and integrate air navigation systems and set up a coordinated approach towards implementation of new ATM systems and technologies;

AEFMP Plan – a plan between Spain, France and Portugal (extended to Morocco and Algeria) to harmonise and integrate their air navigation systems;

Common flight calibration and benchmarking of Air Navigation Systems in Switzerland, Germany and Austria – Skyguide, DFS and Austrocontrol have teamed up with Flight Calibration Services GmbH (FCS) for flight calibration services in order to reduce the costs of flight calibration**.**

D.1.2 Regional activities in ACC operations are:

Central European Air Traffic Services (CEATS) Programme – the CEATS programme will create a single, unified air traffic control system for the upper airspace over eight nations – Austria, Bosnia and Herzegovina, Croatia, the Czech Republic, Hungary, the northern part of Italy (Padua), the Slovak Republic and Slovenia;

Nordic Upper Area Control Centre (NUAC) Project - a joint Nordic project whose aim is to establish an organisation that runs an Upper Area Control Centre to provide Air Traffic Services over Denmark, Finland, Norway and Sweden above FL 285;

Maastricht Upper Airspace Control Centre (MUAC) - operated by EUROCONTROL on behalf of Belgium, the Netherlands, Luxembourg and Germany, Maastricht UAC provides air traffic control (ATC) services to civil aircraft in the upper airspace of Belgium, the Netherlands, Luxembourg and the North-West of Germany;

Functional Airspace Block Alps (ALPS) Project – a Skyguide initiative to achieve better organised airspace in the transalpine sector, through bi-lateral initiatives with its neighbours;

Confederatio Helvetica, Italia, España and France (CHIEF) Development Project – a collaboration between Switzerland, Italy, Spain and France on optimisation of sectors at borders;

ATM Cooperation in Southeast Europe (ACE) Initiative – the Civil Aviation Authorities of Bulgaria, Moldova, Romania and Turkey have signed agreement to cooperate *inter alia* on the creation of a functional airspace block;

Potential Functional Airspace Block of UK and Ireland (NATS/IAA FAB Project) – NATS and the IAA have commissioned a study to look at the issues surrounding the establishment of a functional airspace block between the UK and Ireland;

Common planning of the New Geneva TMA – the new Geneva TMA was developed in close collaboration with the French Air Navigation authorities and the users, in order to ensure a co-ordinated definition of the Lyon, Chambéry and Geneva TMAs;

Reciprocal delegation of ATS in Swiss neighbouring countries – delegation of air traffic services between Switzerland and Germany, Austria, Italy and France.

D.1.3 Regional activities in associated support are:

Nordic ATCO Training Academy – a project to look into the feasibility of providing a common Swedish/Norwegian/Danish ATCO Training Academy to handle demand for initial Air Traffic Controller training from the participating countries;

CEATS Research, Development and Simulation Centre (CRDS) – the CRDS will contribute to the overall CEATS project by co-ordinating all possible ATM R&D capabilities in the region;

D.1.4 We have included **NATS' Two Centre Strategy**, which is a local activity within the regional matrix.

D.2 Multi-national activities

D.2.1 Multi-national activities in CNS are:

Link 2000+ Programme[65] - this programme is addressing the problem of limited voice communication capacity in Europe by providing controllers and pilots with a second communication channel through air/ground datalink;

Co-operative ATS through Surveillance and Communication Applications Deployed in ECAC (CASCADE) Programme – a follow-on from Link 2000+, this programme is a coordinated implementation of air/air and air/ground data links for co-operative air traffic services;

Advanced Node for Data Relay in the Aeronautical Telecommunication Network/EATMP – Communications Gateway (ANDRA/ECG) - two competing but interoperable gateways are being developed, both based on the data format of the new Air Traffic Service Message Handling System (ATSMHS). Germany, along with STNA was commissioned to develop one of the two ECG systems. A validation process being developed by EUROCONTROL and Aena will guarantee the interoperability between the two gateways;

Pre-Operational European Mode S Project (POEMS)[65] – a partnership between EUROCONTROL and UK NATS, French DNA and the German DFS to develop in parallel two designs of Mode S ground station. This approach

[65] We have categorised both the Link 2000+ programme and POEMS as multi-national activities as only a subset of European States are involved in the programmes and we have judged that they are not pan-European.

allowed a common evaluation and validation of the two developments to take place;

Mode S Enhanced Surveillance: 3 States Project – France, Germany and the UK have harmonised plans and regulatory approaches for enhanced surveillance implementation;

Joint procurement of Mode S radar by Skyguide, DFS and LVNL – to undertake a joint procurement of Mode S radar where 95% of the specifications were common and 5% were specific to each ANSP;

Radar Data Network (RADNET) - a surveillance application network running on the underlying communication infrastructure (RAPNET) and extends over Belgium, the Netherlands, Luxembourg, Germany and Maastricht UAC, to allow the sharing of radar data. RADNET is composed of RMCDEs (RADNET Nodes), which allow surveillance data to be distributed to other States.

D.2.2 Multi-national activities in ACC operations are:

Temporary employment of IAA ATCOs in DFS - the Irish Aviation Authority (IAA) agreed to the temporary employment of some of its controllers in DFS, Germany to alleviate staff shortages.

D.2.3 Multi-national activities in ATM systems are:

Cooperative Air Navigation Services – former EUROCAT User Group (COOPANS) Project – Naviair and the ANSPs of Finland, Ireland, Sweden, Switzerland and Hungary already using or intending to use the air traffic management system, EUROCAT are developing future functions of the system with Thales ATM to reduce procurement, development and maintenance costs;

Sistema Automatizado de Control Transito Aereo (SACTA) Development Project – NATS, Aena and DFS are collaborating on the joint development of an ATM system, which will provide the platform for the adoption of a new generation of FDP system in the frame of iTEC-eFDP;

Interoperability Through European Collaboration – European Flight Data Processing project (iTEC-eFDP) – a collaboration between Aena, DFS and NATS (and Indra) to jointly develop the next generation of European FDP interoperable systems;

Common Development of a new generation of Flight Data Processing System (COFLIGHT) – a collaboration between DNA, ENAV and Skyguide for the common definition, development and procurement of a new generation of flight data processing system based to a large extent on the e-FDP requirements designed previously by a EUROCONTROL programme;

CANSO Joint Procurement Work Group – a CANSO initiative to achieve cost reductions to the provision of Air Traffic Management through the sharing of project & specification information and the joint procurement of equipment.

D.3 Pan-European activities

D.3.1 Pan-European activities in CNS are:

World Radiocommunication Conferences (WRC) - frequency management for aviation is coordinated and safe-guarded at a European level by EUROCONTROL at the annual World Radiocommunication Conferences;

8.33 kHz Work Programme - to alleviate the shortage of VHF radio frequencies in the congested upper airspace of the ICAO European Region, the introduction of 8.33 kHz channel spacing (reduced from 25kHz) was implemented;

On-line Data Interchange and Community Specifications on On-line interchange (OLDI and Community Specification on OLDI) - OLDI is an existing EUROCONTROL standard. This activity concerns the development of a Community Specification based on the existing OLDI standard to ensure that Air Traffic Control Units will be interoperable for co-ordination and transfer purposes;

Basic Area Navigation (B-RNAV) - Basic Area Navigation (B-RNAV) is the forerunner of the RNAV programme. It was introduced to enable capacity gains to be achieved through modifications to the en-route structure;

Precision RNAV procedures and requirements for ECAC Terminal Airspace (P-RNAV) - P-RNAV is an important element in the achievement of more consistency in RNAV procedure design and execution for the safe operation of RNAV in ECAC Terminal Airspace;

Roadmap for Rationalisation of the Ground Navigation Infrastructure - actions described in the Navigation Strategy for ECAC will allow for the development of transition/rationalisation/withdrawal plans for the existing navigation aids, ensuring the transition to the GNSS in the long term, as recommended by ICAO;

World Geodetic System 1984 (WGS 84) - WGS 84 is an earth fixed global reference frame, including an earth model. Its implementation was coordinated by EUROCONTROL as part of EATCHIP;

All Purpose Structured EUROCONTROL Radar Information Exchange (ASTERIX) Programme - ASTERIX is a EUROCONTROL Standard for Surveillance data and it develops common standards, specifications and guidelines for the interchange of surveillance-related data;

ATM Surveillance Tracker and Server (ARTAS) - ARTAS, the ATM Surveillance Tracker and Server System, has been developed by EUROCONTROL, Member States and industry in a collaborative effort to ensure that throughout the ECAC area all ATC centres will have access to a high-quality air traffic picture;

Surveillance Analysis Support System for Centre Tool Development (SASS-C Tool Development) – coordinated by EUROCONTROL, this project aims to provide standardised methods and tools to assess surveillance performance to ECAC states;

D.3.2 Pan-European activities in ACC operations are:

Mandate on Support for Establishment of Functional Airspace Blocks (FABs) - the European Commission has issued a mandate to the EUROCONTROL to request assistance in the facilitation of the establishment of FABs, to identify “key issues” associated with FABs as a means of establishing best practices for their establishment.

D.3.3 Pan-European activities in ATM systems are:

Single European Sky Implementation Programme (SESAME) - a dedicated and large-scale implementation programme involving the airspace users, operators and supply industry, bringing together the regulatory framework, the funding sources, and the implementation forces across Europe. It aims to coordinate air and ground infrastructure development and synchronise implementation;

Implementation Rule on Co-ordination and Transfer (IR on COTR) – an implementing rule will be developed aimed at addressing the interoperability for the exchange of system information between ATS units in the process of 'notification, coordination and transfer of flights';

Development of Implementing Rule for interoperability on communication services to support Flight Message Transfer Protocol (FMTP) - the European Commission has issued a mandate to EUROCONTROL for the development of this rule;

Community Specifications on interoperability of Flight Data Processing (CS on interoperability of FDP) - Community Specifications on the interoperability of FDP, currently in the definition phase, concern the definition of a standard flight data model that should previously define the Flight Object Model (FOM);

Implementing Rule on Flight Data Processing (IR on FDP) - purpose of this implementing rule is to mandate the minimum requirements for FDP systems: interconnectivity, common data exchange format, performance and core functions.

D.3.4 Pan-European activities in associated support (training, R&D and central administration) are:

EUROCONTROL Institute of Air Navigation Services (IANS) – a training facility that provides training to Air Traffic Management personnel from the 41 European Civil Aviation Conference (ECAC) States;

Advisory Council for Aeronautics Research in Europe (ACARE) - creation of a Strategic Research Agenda that would enrol all those with a stake in the future of aeronautics to collaborate in exploring and advancing technologies. Common mechanisms will be created for research and technological development;

Analysis of Research & Development in European Programmes (ARDEP) – a programme which supports the coordination of European ATM R&D activities by collecting and disseminating information about R&D projects, and analysing results and trends.

D.4 Other activities

D.4.1 Coordination activities not within scope of this study are:

- European Aeronautical Information Services Database (EAD);
- Programme for AIS Automation & Harmonisation of European Aeronautical Data (AIS AHEAD Programme);
- Advanced Surface Movement Guidance and Control System Project (A-SMGCS Project);
- European Reduced Vertical Separation Minimum Programme (EUR RVSM);

- EUROCONTROL's Initial Proposal on European Commission's Mandate for Airspace Design;
- Development of draft Implementing Rules on the Flexible Use of Airspace;
- Mandate on Airspace Classification in the Lower Airspace;
- Establishment of a single European Upper Flight Information Region;
- Development of Implementing Rules for Air Traffic Flow Management;
- Development of a draft Implementing Rule for interoperability on the initial flight plan;
- Collaboration of Skyguide and Austro Control in the flight preparation field.

E Glossary

ACC	Area Control Centre
ACARE	Advisory Council for Aerospace Research in Europe
ACE	ATM Cost-Effectiveness
ADS-B	Automatic Dependent Surveillance Broadcast
Aena	Aeropuertos Españoles y Navigación Aérea (the Spanish ANSP)
AFTN	Aeronautical Fixed Telecommunications Network
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
APP	Approach Control operating unit
ARDEP	Analysis of Research and Development in European Programmes (EUROCONTROL initiative)
ARTAS	ATM Surveillance Tracker And Server system (EUROCONTROL programme)
ASM	Airspace Management
ASTERIX	All-purpose Structured EUROCONTROL Radar
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Service
BT	British Telecom
CANSO	Civil Air Navigation Services Organisation
CASCADE	Co-operative ATS through Surveillance and Communication Applications Deployed in ECAC (EUROCONTROL programme)
CEATS	Central European Air Traffic Services
CEF	Capacity Enhancement Function of the EUROCONTROL Agency
CFMU	Central Flow Management Unit
CMS	Communications Message Switch
CNS	Communications, Navigation, Surveillance

CRCO	Central Route Charges Office
CRDS	CEATS Research, Development and Simulation Centre
CWP	Controller Working Position
DFS	Deutsche Flugsicherung GmbH (the German ANSP)
DME	Distance Measuring Equipment
DME-P	Precision Distance Measuring Equipment
DSNA	Direction des Services de Navigation Aérienne (the French ANSP)
EAD	European AIS Database
EATM	European Air Traffic Management
EBRD	European Bank for Reconstruction and Development
ECAC	European Civil Aviation Conference
ENAV	Societá Nazionale per l'Assitenza al Volo (the Italian ANSP)
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
FAB	Functional Airspace Block
FDP	Flight Data Processing
FIR	Flight Information Region
FL	Flight Level
FUA	Flexible Use of Airspace (between civil and military use)
GBV	Gross Book Value
GNSS	Global Navigation Satellite System
HQ	Headquarters
HR	Human Resources
IATCC	Integrated Air Traffic Control Centre (Prague)
ICAO	International Civil Aviation Organisation
ICB	Industry Consultation Body
ILS	Instrument Landing System
IP	Internet Protocol
ITU	International Telecommunications Union
IT	Information Technology
LAN	Local Area Network
LOS	Line of Sight

MET	Aviation meteorological service
MLS	Microwave Landing System
MSSR	Monopulse Secondary Surveillance Radar
MUAC	Maastricht Upper Air Control centre
NATS	National Air Traffic Services (the UK ANSP)
NBV	Net Book Value
NDB	Non-Directional Beacon
NERC	National En-Route Centre (Swanwick, UK)
nm	nautical miles
NUAC	Nordic Upper Airspace Centre (Malmö, Sweden)
OATA	Overall ATM/CNS Target Architecture
OLDI	On-Line Data Interchange
OLS	Off-Line Systems
POEMS	Pre-Operational European Mode S Programme
PRR	Performance Review Report
PRC	Performance Review Commission
PRU	Performance Review Unit
RASCAL	EUROCONTROL Radar Sharing Calculation Tool
RCM	Remote Control and Monitoring
R & D	Research and Development
RADNET	Joint Radar Development Network in Benelux and Germany
RNAV	Area Navigation
RNP	Radio Navigation Plan
ROMATSA	Romanian Air Traffic Services Administration
SAR	Search and Rescue
SDP	Surveillance Data Processing
SES	Single European Sky
SESAR	European Commission SES project to modernise ATM in Europe
SIS	Support Information System Processing
SITA	Société Internationale de Télécommunications Aéronautiques
SSR	Secondary Surveillance Radar
TEN-T	Trans-European Networks (Transport) – EC programme for assistance

TMA	Terminal Manoeuvring (control) Area
UCTE	Union for the Coordination of the Transmission of Electricity
VHF	Very High Frequency
VOR	Very High Frequency Omni-directional Range

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