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SESAR: R&D and Project Portfolios for Airline Business Needs

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'*Even the longest journey must begin where you stand.* *Lao-tzu*

'*In the long run, we're all dead.*' *J. M. Keynes*

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SESAR is Europe's 'Single European Sky Air traffic Research system', targeted at post-2020. The vision is to integrate and implement new technologies to improve air traffic management (ATM) performance. The focus for planning and executing system operations will increasingly be aircraft navigating high-quality 4D trajectories: a 4D trajectory is the aircraft path, three space dimensions plus time, from gate-to-gate, i.e. including the path along the ground at the airport. A 20+ year ATM plan has to use limited information on the success of innovations and the development of large-scale, often safety critical, software, which by its nature can take markedly longer and cost markedly more than early estimates. SESAR must be sufficiently flexible in deployment to maximise financial benefits to individual stakeholders *using their specific financial criteria*. Airline needs are the main ATM system/business drivers. Airlines do not want to commit to developing an 'ultra-modern system' *per se*, but rather to one that makes business-sensible investments in new technologies that are indispensable for achieving improved safety and meeting projected capacity requirements. The approach has been to use simple corporate finance ideas to examine the different viewpoints and business environments of air traffic service suppliers (ANSPs) and individual airlines. The key decision-making point is that ANSPs act as an agent for airlines as a whole. The key financial point is that a typical airline has to work hard to survive and needs quick paybacks on investment. The design of the SESAR R&D and project portfolios can learn lessons from information technology systems design and deployment. 'Real option analysis' of systems can increase business value by improving the sequencing and partitioning of projects, helping to ensure that the system is adaptable to technological innovation and changes in business needs.

KEY WORDS

1. SESAR. 2. ATM. 3. R&D. 4. Airlines.

1. INTRODUCTION.

The quotations below the title are a good summary of the approach in the following pages. ATM R&D, strategies and plans have to start from the present system. The 'long run' is not always the right time framework for decisions. Airlines do not live as long as people do.

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SESAR is Europe's 'Single European Sky Air traffic Research system' (e.g. see Brooker, 2008b). NextGen is its USA counterpart – the 'Next Generation Air Transport System'. SESAR and NextGen are developments targeted at post-2020. The common vision is to integrate and implement new technologies to improve ATM performance. SESAR will be part-funded by the European Union (EU) – several hundred million Euro as of mid-2008 – with mainly in-kind contributions from manufacturers, airlines and air navigation service providers (ANSPs, i.e. providers of air traffic control and related services).

Is SESAR a 'wonderful European initiative' or 'a huge IT systems disaster that could cost Europe an arm and a leg and deliver very little at the end of it' (extracts from Irish and UK parliamentary debates)? What will make it wonderful and prevent any possibility of a disaster? The following attempts to provide part of the answer, by using simple corporate finance ideas to examine the distinctive viewpoints and business environments of ANSPs and individual airlines. The issues are about making financially orientated decisions in the context of a technology and business environment.

A SESAR-era ATM system would ensure flights are on time and navigate fuel-efficient flightpaths. Several practical questions arise:

- How long will it take to create it?
- How much capacity has to be planned for?
- What technical/operational choices are there?
- Mix of COTS ('Commercial Off-the-Shelf') technology and R&D?
- What are wise airline investments?
- Is SESAR solving the right problems?

Safety is the paramount concern – the analysis here is about *safe* ATM futures.

The philosophical underpinning of SESAR is the view that ATM has not fully achieved all the innovations – the best technical and organizational practices – of the Information Revolution that has evolved since the early 1970s (e.g. Perez, 2007). SESAR will combine increased automation with new procedures to achieve safety, economic, capacity, environmental, and security benefits (eg, re safety, see Brooker (2008a). The focus for planning and executing system operations will increasingly be aircraft navigating high-quality 4D trajectories: a 4D trajectory is the aircraft path, three space dimensions plus time, from gate-to-gate, i.e. including the path along the ground at the airport. An important component is 'cooperative surveillance', where aircraft are constantly transmitting their position (from navigational satellites), flight path intent, and other useful aircraft parameters – ADS-B (Automatic Dependent Surveillance-Broadcast). New avionics technologies/ATM centre data-handling platforms will require consequent major changes in the tasks and responsibilities of pilots and controllers.

SESAR essentially aims to exploit *information technology* (IT) beneficially. The design of the SESAR work programme can therefore learn lessons from modern practical approaches to IT system design and deployment, which can offer the best prospect of increasing the expected business value to aviation stakeholders. For example, 'Real Options analysis' of systems – discussed later here – can increase business value by improving the selection and phasing of projects, helping to ensure that the system is adaptable to future patterns of technological innovation and changes in business needs.

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SESAR can be visualised as a portfolio of interlinked IT projects. Typical outputs will be documented sets of standards, system specifications and validated operational concepts to allow improved integration between ATM systems. The benefits from implemented projects can accrue from immediate cash flows, indefinite growing cash flows and real options values. Progress with developing and implementing SESAR will only happen if the major stakeholders agree to invest their money in its core projects. Each SESAR stakeholder must get tangible benefits – or somehow get compensation from gainers (or the taxpayer) for disbenefits. The focus here is on airlines and ANSPs. The airlines provide directly and indirectly the investment capital required. The ANSPs act essentially as agents for the airlines in procuring the necessary ground ATM systems.

In the following, the source data for calculations and rough estimates is reputable official and officially sponsored publications, e.g. Eurocontrol, Federal Aviation Administration (USA) (FAA), National Air Traffic Services (UK) (NATS). UK data is a significant source, mainly because the formal nature of the UK's ATM regulatory arrangements ensures that some information on the system performance goals and the related financial issues is in the public domain.

2. SESAR AND AIRLINES.

Why is the focus here on airlines and SESAR? The reasons are that the core of ATM system design is to meet airline/passenger needs, that airlines make the bulk of the direct costs and contributions to air traffic control (ATC) route charges, and that airline activity generates substantial society/GDP gains. Changes to the design of the ATM system have to meet commercial aviation's needs – and airlines operate in a challenging commercial market. However, there are massive implications for military and business aviation (SDG, 2005). Progress with SESAR will only happen if *all* the main stakeholders agree to invest money in its core projects.

Features of SESAR include (SESAR Consortium, 2007):

- Gate-to-gate system integration
- Change from *reactive* ATM to *anticipatory* ATM
- Network of ground-to-air data links to enable accurate 'trajectory' information exchanges
- System-Wide Information Management & Interoperability
- Exploit satellite navigation/communications technology
- Co-operative:
    - 4D trajectory planning & support tools
    - New roles & task distribution for pilots & controllers
    - Airborne separation assistance
    - Collaborative Decision-making (ATM/Airlines/Airport)

Almost all of the technologies encompassed in SESAR have long histories of successful research, often by programmes covering several countries. Thus, many of the issues are about which R&D should lead to implemented operational systems. SESAR's objectives appear perfectly feasible, but the big questions are about how to achieve this through optimal-chosen technical investment paths. However, note that twenty years ago, the fourth and fifth in the list above would not be there – intranet-type systems are now a backbone for everything, and satellites are.

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The tangible – 'hard cash' – financial benefits to airlines from SESAR potentially arise from:

- *Reduced fuel usage*: aircraft can fly more direct, better flight-profile, more fuel-efficient routes.
- *Reduced Flight Delays*: reduce short-term imbalances between demand and capacity.
- *Reduced ATM costs*: improve productivity of ATM system capacity, e.g. by minimising growth in the required number of controller working positions, and hence reducing ANSP charges for flight.
- *Remove barriers to peak-hour flights*: increased airport traffic is not constrained by airspace capacity.

There are four 'SESAR Performance Objectives' (and many other performance criteria):

- Designed for more capacity: +73% in 2020 (compared to the 2005 situation) … and enabling three times in the longer term.
- Improved safety: three times for 2020 … 10 times in the longer term.
- 10% less environmental impact/flight due to ATM.
- 50% less [direct] ATM cost/flight.

These are very demanding goals.

SESAR is already an enormously complex exercise. The SESAR Consortium produces a large number of substantial documents. It would be unusual for airline decision-makers – the people who actually *authorise* investment spending – to have a detailed technical knowledge of all the concepts potentially incorporated in SESAR. Airlines are concerned with successfully 'packaging' assets and services to make their living, rather than developing technology or software. Thus, airlines buy COTS technology and services – most obviously, aircraft, outsource catering, and use commercial computer reservation systems. To an airline, ATM is part of the business in much the same way that a gas cooker is to a restaurant owner. Does it do a necessary job? Is it good value? The kinds of questions an airline decision-maker asks about ATM spending and SESAR are business-focused:

- What new kit spends are *needed* – and how do we know it will work?
- What are the cash benefits from this spend on new kit?
- What commercial/business environment risks do we need to mitigate?
- Are we dependent on new ground ATC equipment to be in place?
- Are the ANSPs going to charge us a great deal more for the necessary ground investments, training and operational staff?

Questions about potential cash benefits raise a larger set of questions about investment and uncertainty. Airlines will want to make decisions based on good information. Few of SESAR's ideas are very novel: they have already been the subject of research and development, in some cases over many years. For example, the PHARE programme of the early 1990s demonstrated in near-operational trials that aircraft could be flown on fuel-efficient 4D trajectories whilst subject to safety constraints to prevent flight conflicts (e.g. see PHARE (2008)). Further examples are discussed below.

3. AIRLINE INDUSTRY ISSUES.

Airline profitability in recent decades has been subject to major problems. But now there are the effects of an oil price shock,

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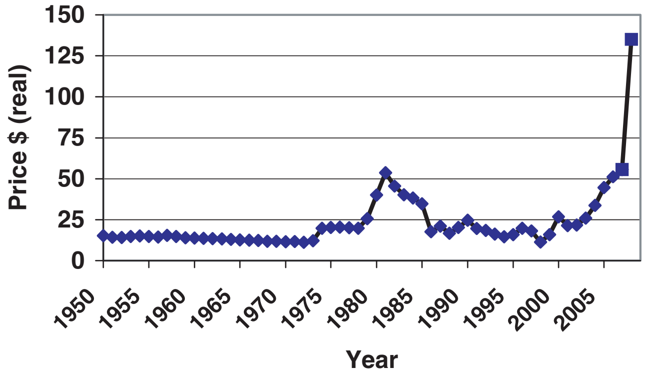

Figure 1. Crude Oil Price History – and Shocks (2007$: EIA, 2008 plus notional $135/barrel for 2008).

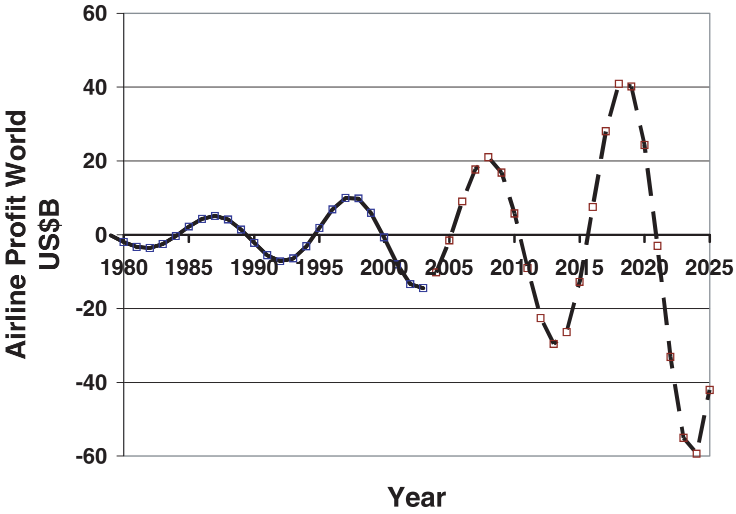

Figure 2. Projected (2004) World Airline Profitability.

with prices progressively rising since about 2001, and the ‘knock on’ effects of the 2007/2008 world financial and economic crisis. Airline financial decision-making is very different from that of ATC suppliers. The product is a commodity. There is a great deal of competition for customers, many of whom are price sensitive. Airlines have huge fixed costs.

The yearly figures in Figure 1 show how bad the 2001–2008 oil price shock has been. People now hope that oil prices have reached their peak, and the price will adjust down to markedly less than $100 a barrel over the longer term – although worldwide GDP falls will tend to bring the price down in the near (?) future. But jet kerosene costs now form a larger part of operating costs. Airline fuel costs will also increase when the EU’s Emissions Trading Scheme (ETS) comes into operation in 2012 (EC, 2008).

Airlines as a whole do not consistently make profits. Figure 2 (derived from Jiang and Hansman, 2006) shows an empirical best-fit to the profitability of the world

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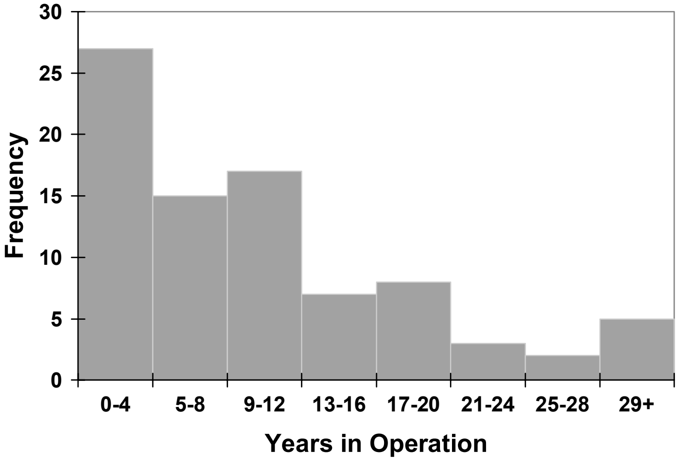

Figure 3. Defunct Post-war UK Airlines (Mid-year 2008 data).

airline industry, using profit data for 1978–2003. The fit is a sinusoidal curve, with an ~11-year cycle, overlaid by exponential growth. The airline profit system is not stable, although it might have been before USA airline deregulation in the late 1970s. In fact, recent data on profitability mean that reality is far less attractive than even this historically based fit would imply. Worldwide financial problems since 2007 have affected the world economy, and there has been a shock of huge increases in fuel prices since 2001. Projected $20Bn profits for 2008 exist only in the airlines' dreams.

An unstable growth path is usually an indicator of problems with system lags. Jiang and Hansman developed a system dynamics model. They included two hypotheses: lag in capacity response and lag in cost adjustment. For example, their model of capacity response indicated that the system stability depends on the delay between aircraft orders and deliveries and the aggressiveness in fleet ordering. They judge that their coupled model with these two factors matched the industry dynamics reasonably well. Jiang and Hansman comment: "*It is clear that future industry growth will be limited at some point, probably by capital investment as the industry becomes less-appealing to investors due to losses in the down cycle, and/or by capacity and traffic demand as the system reaches the limit of the national aerospace system in the up cycle.*" An unstable financial system with periodic exponential oscillations is not an attractive proposition for most investors. Airlines are unusual firms because of the history of state ownership and continued strategic holdings by major investors. For example Turner and Morrell (2003) present data on the concentration of ownership for some major airlines, which is in turn associated with very low volumes of trading of shares on stock markets.

The difficulty of surviving in the airline business is apparent from the fact that Wikipedia has a 'list of defunct airlines'. Figure 3 presents the statistical data on defunct UK airlines' duration in years. This can only be a rough indication of airline lifetimes, given that 'defunct' does not have a precise definition. The evidence is that large proportion of airlines fail in some fashion during their first few years. The median lifetime of defunct UK airlines to mid-2008 (i.e. *before* the late-2008 combination of oil and financial problems for the airlines) was about nine years. Some

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defunct UK airlines operated quite large fleets of aircraft, e.g. Air Europe. Airlines become defunct for a variety of reasons, but common phrases used include short term cash flow problems', 'a major, unforeseen downturn in traffic as a result of recessionary economic conditions', undercapitalisation, unsound financial structure, financially overextended, high-risk strategy. Cash flow problems, i.e. not be able to pay bills for fuel, wages, etc, are always a 'final cause', rather in the same way that heart failure is the final cause of death.

By mid-2008, fewer than 20 UK independent companies currently operate passenger services (from Civil Aviation Authority – CAA – and website searches). They roughly divide into traditional operators, charter firm companies, and low-cost operators. These three groups have very different business models. Successful traditional airlines tend to have valuable strategic operational assets, such as route licences for North Atlantic flights, slots at Heathrow airport or regional niche businesses. The median age of the ~25 currently operating UK passenger airlines, including subsidiary companies, is about 20 years. Just five of these airlines were more than 30 years old. Worldwide, even the largest airlines have difficulty in maintaining financial viability for long periods. The USA probably provides the most dramatic evidence. Its various bankruptcy laws covering airlines provide for liquidation, but more frequently for reorganization (chapter 11 protection). In 2005, four of the top seven carriers in the USA were under bankruptcy protection.

The oil price shock and the ETS, coupled with the 2008 financial/economic crisis and low GDP growth, means that fuel economy is now a strategic high priority and that the likelihood of a high growth scenario for air travel is lower. Low growth and higher costs tend to reduce cash flow benefits from new technology. This implies the need to look very carefully at SESAR's flexibility and the phasing of its project components.

4. CORPORATE FINANCE APPROACH TO ATM/SESAR.

Which R&D & implementation projects should decision-makers chose? Which system functions need replacement, overlaid subsystems or must be entirely new? The approach here is to use some simple corporate finance ideas:

- Examine different viewpoints & business environments of ANSPs & individual airlines.
- Focus on airspace capacity.
- Focus on how choice of R&D & implementation projects makes business sense.

Businesses make choices based on the information available to them about costs and benefits, in the context of general strategies. ANSPs mainly exist to serve airline needs based on large/medium airports: without airlines, the ATM system serving military and business/general aviation would surely be very different. ANSPs provide today's ATC services but they also invest in new ground equipment to meet tomorrow's needs. They are essentially acting as '*ATM agents*' for the airlines in procuring the necessary ground ATM systems. ANSPs need to convince airline customers that capital expenditure plans are *necessary* to meet future traffic growth cost-effectively. Capital investments do not automatically reduce unit costs to customers: the rationale for an investment is that it is a better bargain for the future than other options. The impact on future prices to ATM system users depends on factors such as operational efficiencies and demand growth.

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Table 1. Investment Decisions: Corporate Finance Tools.

NPV	$\Sigma(B_i - D_i - C_i)/(1+r)^i$
Terminal Value	NPV post the planning period – assumes simple growth in net benefits
Real Option Valuation	A 'real option' embodies flexibility in the development of a project – a form of insurance or means to take advantage of a favourable situation 'Real options analysis' is a body of techniques used to value flexibility in the deployment of technical systems, Information Technology (IT) infrastructure (computer reservation systems)

ANSPs are not normal commercial (profit maximising and economically unregulated) companies, i.e. equivalent to individual airlines. ANSPs are not there to make big profits for the state or their owners. This would lead to investment problems (e.g. see Brooker, 2004) – a reason why the UK Government set up NATS as a Public-Private Partnership.

5. CORPORATE FINANCE TOOLS FOR COST BENEFIT ANALYSIS.

Table 1 summarises some appropriate corporate finance tools for cost benefit analysis (CBA) in the widest sense (Brealey et al, 2007).

Modern large-scale businesses use Net Present Value (NPV) calculations to assist in these processes (Internal Rate of Return, IRR, closely related to NPV, is also widely used). NPV focuses on the present and future pluses and minuses of flows of hard cash (in constant price levels) in future years: *money flows*. The general calculation for a NPV is (the individual terms are 'Present Values' – PV_i):

$$NPV = \Sigma(B_i - D_i - C_i)/(1+r)^i = \Sigma PV_i \tag{1}$$

$B_{i,}$ $D_{i,}$ C_i = Benefits, Disbenefits, Costs in year i
r% = Discount rate
Summation over years 0 to n

When a business faces choices, the best investment according to this technique is the one that produces the highest positive NPV. The sum ranges over n + 1 years – from 0 to n: this is to cover the case when there is an immediate investment – year 0. A cost would be an actual expenditure of cash to secure the investment (e.g. on maintaining equipment) while a disbenefit would be an estimated operational cost arising out of the investment (e.g. increased fuel usage).

It would be fanciful to forecast cash flows for an indefinite number of future years. Usually, there is a cash flow NPV planning – 'horizon' – period of several years, supplemented by a 'Terminal Value'. The latter is an approximate value of all PV-ed cash flows after the horizon year. A rough estimate has to suffice because cash flows many years into the future become progressively more uncertain – although ATM NPV calculations often attempt very long-term estimates by extrapolating specific models of traffic and capacity. The terminal value calculation can use various assumptions about growth rate, e.g. using a constant growth rate [Gordon] model (Table 2). The Gordon model equation makes it apparent that the assumed net benefit growth rate (g) post the horizon is a critical parameter.

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Table 2. Example of Airline 'Reality' Cash Flows, NPV, Payback Period.

Year i	0	1	2	3	4	5	NPV £K 5 years	Terminal Value £K
Cash Flow CF_i – £K	–180	50	60	70	80	90		
Present Value PV_i – £K	–180	41·7	41·7	40·5	38·6	36·2	18·6	253·2

Payback Period = 3 years (ie sum of CF_is for years 1 to 3 equals the £180K initial investment)

PV_i definition in equation (1)

Assumed hurdle rate r – 20%; assumed long-term growth g of benefits – 5%

NPV to five years = sum of PV_0 (i.e. –£180K) plus PV_1 to PV_5)

Terminal value (Gordon model) – PV_5 x (1 + g) / (r – g) [*a rough estimate at best*]

NPV *including* terminal value = £271·8K

A firm has two crucial decisions when using NPV: deciding on the hurdle rate r% and the investment horizon n. Corporate finance texts usually recommend that the hurdle rate be set at the Weighted Average Costs of Capital (WACC):

$$WACC = (R_d \times DE + R_e \times EQ)/(DE + EQ)$$

R_d = Company borrowing rate
R_e = Shareholders' expected return on equity
DE = Debt
EQ = Equity

The company borrowing rate R_d – cost of debt – is a function of factors such as the financial condition of the business and the perceived quality of its managers. For example, contractors working for the UK CAA's regulatory assessment of the UK's en route ATC suppler NATS (PwC, 2004) estimated NATS cost of debt as 6·13% in real terms, 1·2% above a risk-free rate on government borrowings.

The estimation of the equity return figure R_e is complex. The value is a function of the risks that investors associate with the company's normal decisions. This most often makes use of the Capital Asset Pricing Model (CAPM):

$$R_e = R_f + \beta \times ERP$$

R_f = Risk-free Rate
β = Equity Beta
ERP = Equity Risk Premium ($R_m - R_f$)

Here R_m is the (expected future) return on shares in the stock market and Beta measures the volatility of the company's shares compared with the market generally. A high Beta – i.e. $\beta > 1$ – is a higher risk stock, a low Beta – i.e. $\beta < 1$ – is a lower risk stock.

Figure 4 is the well-known graph from corporate finance textbooks (e.g. Brealey et al, 2007). It shows the rate of return required on investments versus Beta. Beta measures the volatility in a firm's return on shares associated with general movements in the stock market and the economy. Airlines have effective Betas greater than 1, ANSPs probably no higher than 1. This simply means that airlines require higher rates of return on investments than ANSPs (PwC, 2004; Turner and Morrell, 2003).

Beta essentially reflects the variability in a firm's return on shares associated with general movements in the stock market and the economy. These *systematic* risks

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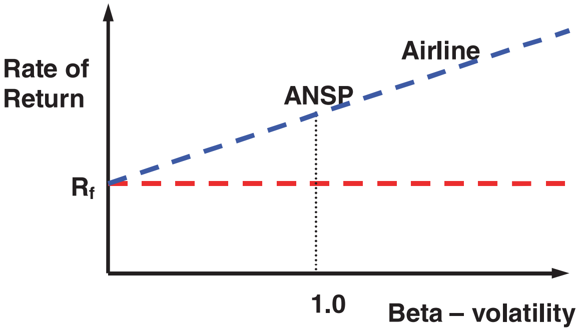

Figure 4. Capital Asset Pricing Model.

would include the consequences of interest rate changes, variations in the rate of inflation, political risk/legislative risk, and the general financial, economic or banking system. The intention is that hurdle rates correspond to the systematic risk of the type of activity under consideration, and would be the same as a firm's general hurdle rate as calculated by the CAPM, if the project is typical of the firm's activities. A project's cost of capital depends on the nature of the project, not the risk of the firm. The WACC is the correct discount rate for projects that have the same risk as the company's existing business. There are also *firm-specific* risks associated with the company's activities, for example *Project Risk* (uncertainty associated with a particular project) and *Sector/Industry Risk* (uncertainty associated with the performance of an industry sector.

Again, using the example of NATS, PwC had to carry out several calculation steps to estimate NATS' Beta – the CAA adopted a figure of 6·75%. NATS's WACC is low in comparison with firms in general, because ATC is a necessary function in an industry that forecasters believe will grow steadily over the long term, and NATS provides a monopoly en route ATC service in the UK.

How does the financial background to the air transport business sketched here affect Beta values, WACCs and NPVs for airline projects? The answer is that it has huge effects – and airlines seldom seem to follow standard assessment practices. Estimated airline Beta values do not conform to finance theory ideas that the cyclical airline industry is traditionally more risky than the market as a whole. It would be expected that β-values should be greater than 1·00, typically in the range 1·2–1·4, but the evidence, using a variety of estimation techniques, is for a value of 1 or less (Turner and Morrell, 2003). One explanation offered is that the shares of the airlines are not traded enough to respond sufficiently to changes in the market, and hence airline returns may not be as sensitive to shocks in the market. Another possibility is that the airline data was analysed when the market was more volatile, because of the increasing dominance of IT and telecommunications stocks.

If the 'true', i.e. in normal well-traded markets, Beta value for airlines were about 1·4, then the WACC would depend on a variety of factors, e.g. debt gearing. For a low gearing, the WACC might be up to 15%, depending on airline managers' views about the Equity Risk Premium. So do airlines use a WACC of 15% in NPV calculations? The answer is very probably no. If they use NPV, then they probably use a higher hurdle value – but they may well not use NPV. Empirical evidence for WACC

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Table 3. Example of Airline Putative 'Best Practice' Cash Flows, NPV, Payback Period.

Year	0	1	2	3	4	5	PBK	NPV £K 5 years	Terminal Value £K
Base case £K	–180	50	60	70	80	90	3		
Base case £K PV	–180	43·5	45·4	46·0	45·7	44·7		45·2	469·8
One year late £K	–180	0	50	60	70	80	4		
One year late £K PV	–180	0	37·8	39·5	40·0	39·8		–22·9	417·6
80% inflow £K	–180	40	48	56	64	72	4		
80% inflow £K PV	–180	34·8	36·3	36·8	36·6	35·8		0·3	375·9

General definitions and caveats as in Table 2.

Assumed hurdle rate r – 15%, assumed long-term growth g of benefits – 5%.

'mark-ups' on the Beta and debt calculated WACC is found in Meier and Tarhan (2007), which shows that the WACC used by financial managers exceeds the computed WACC by 5·3% to 7·5%, depending on the equity premium assumption. This would imply an airline WACC of about 20%. This premium is a way of adjusting decisions for project risks.

Gibson and Morrell (2005) examined the variations in airline financial assessment practices. Many airlines use Payback Period (PBK) rather than NPV. Payback period is the most intuitive of all measures, being the number of periods (months or years) required to recover the initial investment. PBK is a cash-based measure, but ignores the time value of money captured by the discount rate in NPV/IRR. Table 2 illustrates the nature of a typical flow of cash with an ATM investment, which generally have a lifetime of some decades. The firm invests a large sum of money and then a series of smaller cash flows come into the firm. The payback period is three years, the NPV for a 5-year time horizon is £19K, and the indefinite NPV over a large number of years (i.e. if the airline were to include a terminal value) is £272K. Marais and Weigel (2006) note that commercial airline boards typically require a positive return on investment within eighteen months of investing – so in payback terms this would not be a worthwhile investment. On an NPV assessment, it would be a very good investment *if* the airline could be confident of long-term survival, but not exciting if the horizon was five years. But is this an appropriate judgement for this highly cyclical and cash-constrained industry? Airline finance directors are very important people, and one of the lessons they learn is to check all decisions that might lead to the company running out of cash. So terminal values are probably not that interesting to most airlines.

Financial decision-making textbooks and guidance material generally do not recommend adjusting the hurdle rate to take account of project risks. For example, IFAC (2007) recommends "*calculating the probability-weighted expected value of cash flows of an investment. This is done by* (*a*) *developing several scenarios, and* (*b*) *assigning them probabilities of realization* (*including a probability of a project failure if applicable*)." But the future is not wholly objectively assessable: forecasts and quantitative estimates rely on some things being unchanged and others changing in line with existing trends. Good projections of costs, the operating environment and air travel demand several years hence will include large elements of judgement and luck.

To illustrate the problems of the decision-maker, Table 3 shows the cash flow data in Table 2 again, but this time with a 'correct' hurdle rate of 15%. The base case cash

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flow shows a larger NPV for the five-year horizon, simply because the discount rate is lower. The decision-maker carries out two sensitivity analyses, one assuming that all the cash inflows slip by a year, and the second assuming that the cash flows reduce by 20%. These are both reasonable kinds of numbers: often projects take longer to achieve their benefits: often the benefits have been over-estimated, perhaps simply because of reduced market demand for airline flights. The consequence in both cases is that the NPV drops to zero or less: what does the 'medium-term horizon' decision-maker do? Note that the terminal value is very large for all the sensitivity cases – but can the airline be confident about existing beyond the planning horizon?

An important aspect here is the kinds of technological changes envisaged in SESAR involving both ANSPs and airlines carrying out project developments. Airborne and ground-based investments are interdependent and need some degree of synchronization: so actually using the new kit on aircraft relies on successful ANSP hardware, software investments and appropriate controller training. The core problem is that such investments are essentially IT developments. IT projects tend to involve significant technical uncertainties (Tallon et al, 2002). Large IT projects tend to take longer than estimated and cost much more. UK government guidance on 'optimism bias' in IT system development projects note overruns by 10% to 54% and overspends from 10%–200% (Mott MacDonald, 2002).

A concern for airlines about spending money on aircraft fits is that some industry members may equip, but then the ANSP does not provide the requisite ground infrastructure or mandate for all users. Lester and Hansman (2007) give some examples of USA problems:

- *Mode-S:* the FAA tried to mandate Mode-S for all new transponders before building the Mode-S ground stations, but general aviation pressure forced the final rule mandating Mode-S and TCAS for aircraft with 10 or more seats.
- *Microwave Landing System (MLS):* the airlines never had demonstrations of its advanced capabilities: they resisted equipping with airborne MLS receivers – and then GPS largely surpassed MLS technologically.
- *Controller Pilot Data Link Communications (CPDLC):* American Airlines was an early adopter of the CPDLC technology, but – following 9/11 – the FAA did not continue with the deployment of the CPDLC ground infrastructure beyond its Miami Centre trial site, essentially making American Airline's investment worthless.

6. REAL OPTIONS.

How could the concept of 'Real Options' help SESAR decision-making? Real options are a development of NPV techniques (e.g. Brealey et al, 2007). The aim is to fill the gap between finance and strategic thinking, so that management takes decisions to create highest value. Formally, a real option is the right but not the obligation to take an action in the future. There are at least five main types of real options described in the literature, some of great complexity: waiting-to-invest option, growth option, flexibility option, exit option and learning options. Real options take account of managerial decisions on investment with widespread uncertainty, where a degree of flexibility allows managers to make changes to the project. Simple NPV analysis ignores this project flexibility. A real option can capture a project's potential value by taking into account the value of

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being able to change it in response to new information, changing technical situations, market conditions, etc.

The simplest example is that a firm making a decision has the real option to decide to defer a project until better information becomes available about the likely cash flows. For example, if the best current estimate of a project's cash flows is £200K per year, then an NPV will be positive if the investment required is less than the discounted future flows. If this turns out to be a small number, then the firm may well not invest, given the kinds of discussion earlier here about sensitivity analyses. But suppose that in a year's time more information about markets and sales will be available, so that it will be clear if the annual cash flow is either £300K or £100K? After taking account of the different investment timing, it would be a good decision to opt to invest if the higher cash flow is available, and a – very – good decision not to take the investment option in the context of the lower figure.

Option valuation allows the flexibility of making decisions in the future that are *contingent* on the arrival of information. Information is seldom free – investing in an R&D project creates an option in investing in forthcoming development phases. Firms would have to take into account the likely quality of future information and the competitive environment (e.g. deferring decisions to invest could mean that rival firms which commit now would gain cash flows and dominant positions in the markets). Strategic issues that need examination include:

- What are the project goals?
- What are the uncertainties faced by management, and given these uncertainties, the most valuable options.
- Can the costs of (additional) flexibility be justified by the added value when comparing the flexible alternative to the alternative without flexibility?

The literature on real options is huge. Dixit & Pindyck (1994), and Copeland & Tufano (2004) are examples of business analysis approaches. Steffens & Douglas (2007) compares various NPV and real option methods, and has an extensive bibliography. ATM studies using real options are not yet common: MIT and the MITRE Corporation in the USA have sponsored some work, e.g. Steinbach & Giles (2005), and Rivey (2007).

de Neufville et al (2008) discusses real options analysis for complex, large-scale, long-term infrastructure systems that are close to the SESAR issues examined here. The focus is the great uncertainties associated with large-scale systems, a root cause for unsatisfactory generation of value. de Neufville et al distinguishes between real options "on" projects, focused on accelerating or deferring projects (discussed above), and real options "in" engineering systems, focused on optimizing the technical design. The latter is about the designers taking special steps to provide flexibility in the system, recognising the additional costs involved in providing this flexibility. It takes decades to design and develop large technical systems, so there is the possibility of major changes in technology, economic situation, etc. Thus, the need is for concepts and procedures that enable decision-makers to anticipated possible uncertainties, and hence deal with them efficiently as they arise. This implies the need to develop the flexibility to react to events, to take advantage of new opportunities, and to exit from unproductive pathways. de Neufville et al therefore argues that designers of systems need the flexibility to alter development trajectories as needed, hence increasing expected value from investments. If developed wisely, flexible designs

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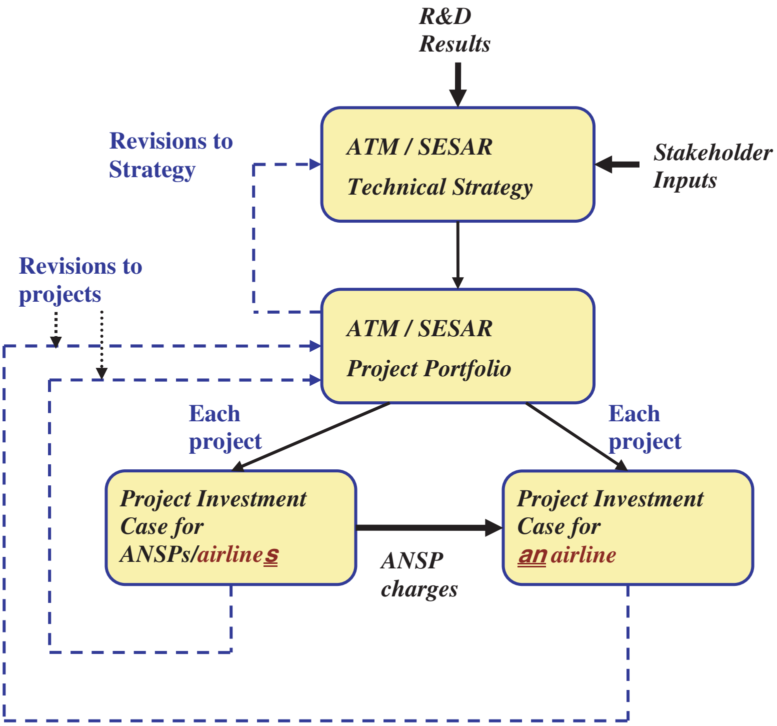

Figure 5. SESAR Strategy and Investment Feedback Loops.

provide more value, because they systematically avoid bad outcomes and exploit opportunities.

7. ATM/SESAR AND PROJECT INVESTMENTS.

The crucial financial logic for ATM and SESAR investment is:

- Need to identify the optimum portfolio – projects sequence that makes financial sense to each of the stakeholders.
- SESAR analyses of costs and benefits generally not estimates of the achievable project cash flows but illustrative calculations.
- ANSPs' aim is a long-term cost-effective ATM system: must take into account NPV, *and* Terminal Value *and* very long-term Real Options.
- But airline's aim is that the business makes cash (and does not go bust), so focus is on commercial NPV with a ~five-year horizon, plus a recognition of Real Options, e.g. reinvestment phasing.

The aim is to generate an 'optimum necessary' project portfolio, a sequence of projects that make financial sense to all stakeholders.

SESAR's central airline business question is to reconcile a long-term ATM vision with a financially-orientated airline stakeholder, which needs to make project investment decisions on a 'pick-and-mix' basis according to projects' cash paybacks. The nature of SESAR will be the result of the combination of a great number of individual project investment decisions to implement R&D products. Figure 5 shows

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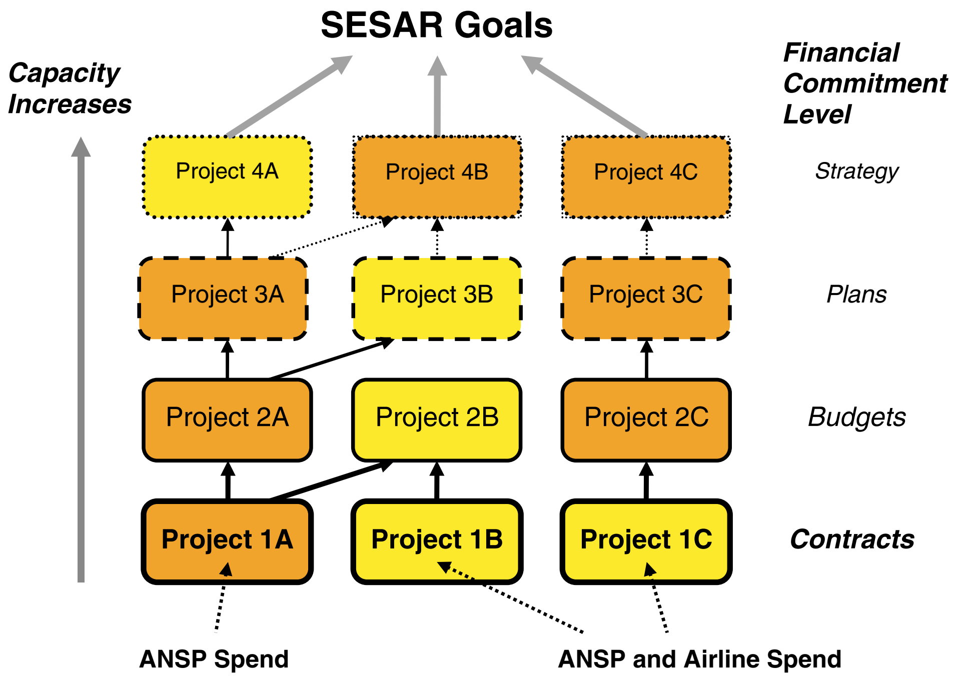

Figure 6. Schematic: Phased Investment Decisions.

the ATM and SESAR decision feedback loops. Airlines will want to have explicit choices and to 'pick and mix' projects whenever feasible if these choices improve projected cash flow benefits. They will want to optimise their project investment portfolio. For example, ANSPs might ask how to carry out SESAR projects better, but individual airlines will ask: "Is this project necessary? Does it need doing now?"

It is not short-sighted of airlines to be careful in signing up to major project investments, given the track record of unstable cash flows. SESAR analyses of costs and benefits use the language of NPVs, but these are generally not estimates of the achieved cash flows from the implementation of specific projects but rather illustrative calculations based on hypothesized characteristics of possible future systems.

Figure 6 illustrates the project-focused financial decision-making for airlines and ANSPs. It shows a highly simplified four-stage process to get to the SESAR endpoint. Each stage, labelled 1 to 4, has several projects, labelled A to C. The labels in the project boxes indicate differing degrees of emphasis, thus the stage 1 boxes are in bold and the stage 4 boxes are in smaller font. This indicates the amount of financial certainty for the projects. The first stage projects are one for which there are actual contracts; the next stage is projects that are in financial budgets for the coming years; then in stage 3 the projects are specified in a plan but not firmly budgeted; and the final stage contains broadly-specified projects which complete the strategic intent. The different colours show where projects are ANSP spend (brown shading) and a combination of ANSP and airline spend (yellow shading). To get to the strategy-level

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and SESAR projects, ANSPs/airlines must implement/financially commit to the previous stages.

The two shadings in the project boxes distinguish between projects carried out almost entirely by ANSPs, e.g. changes to ground systems, software, communications etc, and those that require both ANSPs and airlines to invest, e.g. both in ATC centres and through new kit on board aircraft. The important message from Figure 6 is that the Contracts and Budget level projects are the *building blocks* for SESAR, so the focus later here is on those kinds of pre-SESAR projects. Project linkages matter tremendously. If individual airlines do not decide to put their funding into a project then it and its potential successors disappear. To take a historical example, if airlines had refused to spend money on secondary radar surveillance transponders, none of today's radar and conflict alert systems would exist.

Synchronicity of a project's ground and airborne investment is nice if it happens, but the airlines will ask if it makes business sense. SESAR appears to *assume* a high degree of synchronicity (Marais & Weigel, 2006) for projects' ground and air implementation. But the financial decision-making will focus on NPVs/Terminal Value and Real Options. This will tend to mean that substantial airborne investments will take place later than ground investment spending, i.e. when there is assurance both that ground systems are operational and benefit generation is assured (*unles*s there is external support from other sources, e.g. government). The assurance element of SESAR projects is vital. Airlines will need demonstrations that the project systems are technically feasible and that the estimated benefits are robust against a reasonable range of realistic ground implementation scenarios and business environments. Competent airline managers will want good information on the reliability and uncertainties of project benefit estimates.

8. SESAR AND CBA.

As noted, almost all of the technologies encompassed in SESAR have long histories of successful research, often by programmes covering several countries. These technologies are generally compatible with existing ATM systems, thanks to good technical specifications many years ago (e.g. for Mode S in the case of ADS-B). Is there a major *research* problem? Are there important issues about which research should be *developed* into near-real systems and then *implemented* operationally, e.g. see Arthur D. Little Limited (2000)? The question examined here is how to determine optimal-chosen technical investment paths. 'Optimal' here mainly refers to spending money: aviation's decision makers are primarily concerned with 'dollars and cents' – corporate finance in more formal language.

Airlines will have to pay for most of SESAR, both through ATM user charges and airborne equipment costs. Their enthusiasm for strategic ATM system changes will be in jeopardy if these investments do not translate into a 'good business deal'. Airlines do not want to commit to developing an 'ultra-modern system' *per se*, but rather to one that makes business-sensible investments in new technology, which is *indispensable* for achieving projected capacity requirements.

A notable 'SESAR Deliverable' was the 'ATM Target Concept' (SESAR Consortium, 2007). Its authors make it very clear that it is a vision not a plan, and certainly not a final blueprint of the future system. The Concept paper includes a financial section, which concludes with an outline cost benefit analysis (CBA). The

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Concept CBA is "'what-if' scenarios, with only trend and rough order of magnitude results". Significant points are:

> *"[CBA] has not provided conclusive evidence that the ATM Target Concept will be affordable or economically viable from an Airspace Users perspective. This will require further work."*
> *The best scenario examined assumes that half the cost effectiveness target is achieved (i.e. 25% less ATM cost/flight), because "there is incomplete evidence that the cost effectiveness target is going to be met". In this scenario, the benefits are larger than costs for scheduled airlines (a ratio of 1.7), but negative for business aviation and general aviation.*
> *"[T]he investment in the ATM Target Concept should be seen as long-term and strategic in nature which would justify the need for public funding for implementation."*

SDG (2005) and Brooker (2008b) discuss benefits to society from SESAR, i.e. which could be seen as potentially justifying some degree of public funding. These assessments are complex, but the most important benefit contributions to society arise from passenger time-savings. These gains should generate worthwhile increases in Gross Domestic Product, so governments could be sympathetic to such investments.

In the present context, the most important features of the Concept CBA exercise are the discount rate used and time horizon for NPV calculations. The crucial document is SESAR Consortium (2008b):

> *"A uniform discount rate of 8% is used at the moment for all models letting for later discussion the question of discount rate variability among stakeholder groups or companies or organisations … «One problem at a time»! Discount rate variability is a well-known – and difficult – problem: rigorously, there is a rate per individual and as we are speaking of the future, a rate per future year should be assessed to take into account individual potential conditions of evolution! In our view, there are many more sensitive assumptions to discuss before that one."*

Given the discussions in earlier sections here, this does not seem to be a judicious choice: rational business assessments by airlines generally use a markedly higher figure, 15% or higher. A further problem is the use of a very long time horizon for NPV assessment: the Start and Final Years adopted are 2007 and 2025 respectively, whereas airlines would generally consider a five-year time horizon to be a long one for cash flow examination. These two elements in the SESAR CBAs – low discount rate and very long time horizon – mean that the NPV calculations produce markedly higher positive figures than a typical airline calculation. Note the crucial distinction between the way a commercial airline views NPV assumptions with the way that commercial airlines, i.e. en masse – with ANSPs as their agent, might view financial decisions, particularly in the current non-regulated environment.

The most important aspect of the CBA for SESAR is that it is *not* a cost and benefit analysis. Normally, such an analysis would be *analytic*, in that the nature of the benefits that would flow from a specific investment would be set out and their financial implications estimated and summed. In contrast, the SESAR NPV estimates are *synthetic*, i.e. they are an artificial construct *assuming* future capabilities and performance from general considerations. SESAR Consortium (2008b) makes this clear:

> *"In particular, the analysis made at the moment is a "what if analysis" rather than a cost benefit analysis; the output is nevertheless useful, not for taking a decision, but for challenging the assumptions and linking them to the target concept and further on to the implementation packages … Many assumptions are unrealistic and/or poorly grounded … The economic*

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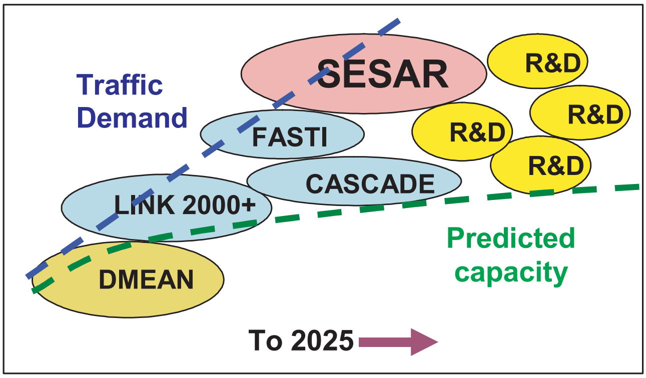

Figure 7. ATM and SESAR Path.

Table 4. Pre-SESAR Projects.

DMEAN	Amalgamates current Eurocontrol initiatives in airspace design, collaborative decision-making, Flexible Use of Airspace, Flow/Capacity Management
LINK 2000+	Provides controllers/pilots with second comms channel: air/ground data link
CASCADE	Implementation of ADS-B: for surveillance purposes (ADS-B-out), and for air traffic situational awareness (ADS-B-in) and airborne separation assistance
FASTI	Deploys initial set of controller support tools, meets short/medium term needs & establishes foundation for further automation
aFDPS	*Advanced Flight Data Processing Systems – using new standard for flight data exchange in Europe*

> *perspective confirms what is heard from other parts of SESAR: it is for the moment unlikely to obtain a consensus about tightly coupling and fully synchronising investments on the ground and airborne.*"

9. PRE-SESAR PROJECTS. Figure 7 is a simplified version of a slide used in a very clear Eurocontrol presentation by Redeborn (2005). Before the ellipse indicating SESAR there are four examples of SESAR 'precursor' activities. Table 4 is a short technical description of what these abbreviations mean. DMEAN is essentially 'best practice' improvements, without significant changes to the existing concept of operation. LINK2000+ is a 'critical step toward wide implementation of data-link technologies and applications'. CASCADE: 'ADS-B is recognised as an essential element in SESAR'. FASTI 'introduces improvements on controller tools, data interchange and integrity'.

These pre-SESAR projects deliver benefits in their own right *and* are strategic components of a SESAR concept for 2025 and beyond. Their value to airlines depends both on what they provide *and* as being components of the ATM system to which they lead. Table 4 also includes aFDPS: there are currently eleven European aFDPS initiatives covering 17 ANSPs, seen as critical to the ATC system and its links to advanced ATC functions (SESAR Consortium, 2008c). aFDPS is just one example of a project that modernises infrastructure to enable the implementation of longer-term SESAR concepts. There are other important projects in this category, for

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example System Wide Information Management (SWIM), which is essentially a net-centric system, providing the infrastructure and services to deliver network-enabled information access to a multitude of ATM system users. SWIM offers substantial system architecture benefits by reducing the number and types of interfaces and legacy sub-systems.

Given that SESAR is to be a 'new ATM paradigm', it is not obvious why DMEAN is 'part of SESAR', although it is discussed in SESAR documents as being in SESAR's first phase. Thus, in SESAR Consortium (2008d), the SESAR Implementation Package 1 has:

> "*the objective to implement short term initiatives and disseminate best practices through a set of Operational Improvement Steps … Unlocking latent and generating additional Network Capacity: the Dynamic Management of European Airspace Network* (*DMEAN*) *programme will generate additional capacity, lead to less delay and improved network and flight efficiency*"

DMEAN includes elements such as capacity planning, improved Flexible Use of Airspace, airspace design improvements, data sharing, ASM/ATFCM (=air traffic flow improvements) processes, traffic forecast, operational air traffic harmonisation, airport integration into the network. The estimate is that DMEAN plus ATFCM produce an airspace capacity increase of 24%–32% (SESAR Consortium, 2008d – Table 2). Rather than being part of a new paradigm, these are essentially 'bread and butter' European tasks to increase the capacity of the current system through best practice. They are not significant changes to the existing concept of ATM operations. Many of them represent continuing work from earlier Eurocontrol programmes rather than new efforts. So, are these short-term improvements benefits from SESAR? – "Much of the benefit was achieved through management action using existing technology" (SESAR Consortium (2008c). This is not an academic point: the SESAR NPV calculations have to be made against a base case – 'Business as Usual' in SESAR jargon – so it is important to determine if that base case is the current operation or 'normal progress' from the past.

Appendix A examines the LINK2000+, CASCADE, FASTI and aFDPS cases. It makes it clear that there are varying amounts of CBA work done on these projects – some with good quality data and methodologies in authoritative national and international sources. But there has to be a warning here that reality can have markedly higher cost timescales than planned for (e.g. Mott MacDonald, 2002).

Table 5 shows how the projects measure up against the financial criteria, *based on these 'official' estimates*. DMEAN has few strategic benefits because it is 'best practice'. CASCADE is the most uncertain in term of estimated benefits for airspace benefits: is ADS-B a better investment than 'multilateration' for surveillance systems replacement? [Multilateration is locating an aircraft's position by computing the time difference signals arriving at multi-receivers – e.g. see Dow (2007). There do not appear to be quantified estimates of the merits of proposed later ADS-B stages at a European level (compare with USA, e.g. Scovel, 2007; Lester and Hansman 2007; Marais and Weigel, 2006). It is hard to find aFDPS benefit figures (SESAR Consortium, 2008c), as the aFDPS decision is strategic transformational IT. To simplify Table 5, the assumed Terminal Value of projects for airlines is taken as zero, i.e. their benefits are through a quick payback and/or the value of real options. Again, ANSPs are spending the 'ATM system' money that the airlines trust them to use wisely, while the airlines are buying new aircraft kit directly.

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Table 5. Pre-SESAR Project Valuations.

	Direct Spend by ANSPs '*In trust*' *for Airlines*			Direct Spend by an Airline	
	NPV	Terminal Value	Real Option	NPV	Real Option
DMEAN	✓	✓		✗	
LINK 2000+	✓	✓	✓	✓	✓
CASCADE	?	?	?	?	?
FASTI	✓	✓	✓	✗	✗
*aFDPS***	✗	✗	?	✗	✗

Existing Eurocontrol/ANSP 'best published' estimates; en route airspace gains: ✓ = estimated, ? = not known, ✗ = unlikely. There can be arguments about valuations, eg see Appendix A.

Sources: DMEAN – SESAR Consortium (2008d), LINK 2000+ – Booker (2007), CASCADE (Dow, 2007), FASTI – Brain (2008), aFDPS – SESAR Consortium (2008c)

In summary:

- DMEAN, LINK 2000+, CASCADE, FASTI, aFDPS have long R&D histories.
- Merits depend on different combinations of NPV, terminal value (dependent on growth), and real option value – data and calculations from authoritative national and international sources, but open to debate.
- CASCADE needs more 'hard CBA' evidence: multilateration appears to be a better investment than surveillance systems replacement by ADS-B. What are the CBA merits of later ADS-B stages?
- aFDPS investment decision is as *the* IT software platform, for implementing value-generating applications and reducing the costs of fragmentation.
- Projects assessment has to be against *good* estimates of software development costs/timescales – in practice often much higher than anticipated in plans.

10. ECONOMIC CONTEXT FOR ATM/SESAR AND AIRPORTS.

What is the economic context for ATM/SESAR? There are several facts and issues to consider, e.g.:

- Airline profitability in recent decades subject to large – and increasing – cyclical oscillations.
- Airline decision-making has to face the chronic oil price shock and the 2008 financial/economic crisis.
- Airline costs to increase with the EU's Aviation ETS from 2012.
- SESAR's goals now appropriate, given present and immediate future economic position and strategic views of the oil price?
- Fuel economy issues and the 2008 financial crisis imply the likelihood of high growth scenario is markedly lower.
- One effect of low growth rates is to reduce investment benefits cash flows – so need to look carefully at SESAR's flexibility, e.g. phasing of its project components.

On simple calculations, the European ETS costs are probably a smaller effect than the oil price – but costs that will still be unwelcome for airlines. A low growth scenario is

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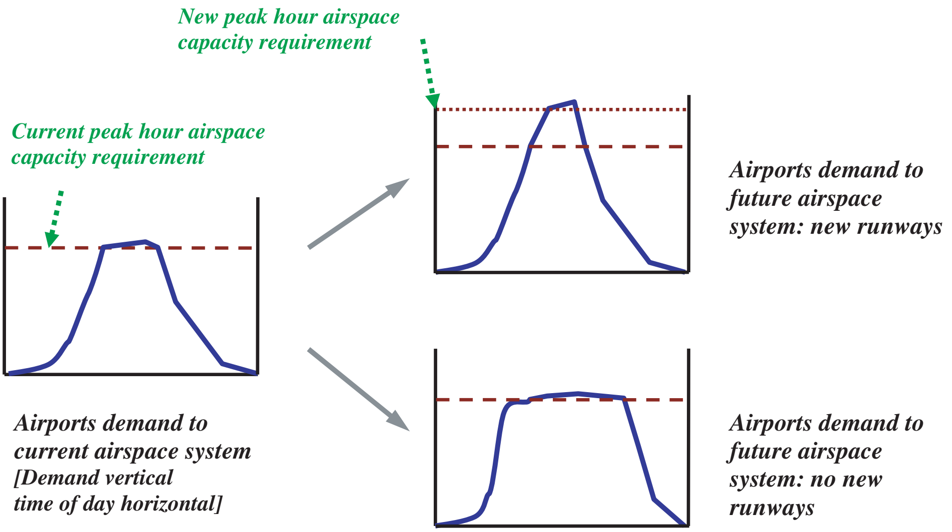

Figure 8. Airport Diurnal demand patterns for congested group of airports.

more likely than before: such a scenario damages the gains shown in cost benefit analyses. So, how could SESAR adapt to this through project flexibility and phasing?

SESAR currently focuses on high growth scenarios and peak hour loading. A Eurocontrol 'Low Growth scenario' (Eurocontrol, 2004) – still 2·5% per annum – makes the airline/ANSP decision-makers look very carefully at project financial benefits and phasing. Under-investment is a bad thing *over the long term*, but financially-constrained airlines will not like actual over-investment.

Is the right goal a challenging 'peak hour loading' scenario, which might well have very low probability of occurrence? Financial decision-makers have to assess the range of strategies in terms of the costs involved for the stakeholders and the gains/losses they would get from over- or under-investment. A Low Growth scenario has major implications for the current implementation projects and SESAR R&D/project portfolios: it suggests deferring projects in the portfolio that deliver capacity above what is projected as needed or do not have big real options values; and it makes the case for matching spending to the available investment budget.

An underlying – and largely implicit – SESAR assumption is large growth in new airports/runways. It is necessary to explain some aspects of Peak Hour Airspace demand estimation. Figure 8 (left hand side) illustrates the summed diurnal demand from a congested – i.e. 'full' at peak hours – a group of nearby airports producing a typical diurnal demand pattern, with a flat top roughly the sum of the hourly runway capacities. Adding one or more new runways produces Figure 8's top right hand side, with a new airspace demand peak corresponding to the sum of the new set of runway capacities. If there are no new runways, then the result is the diagram a the bottom right, in which the extra traffic demand spreads across what were previously shoulder hours, so that the peak hour demand is unchanged. This is very simplified as, in reality, airport slots would get more valuable, and average aircraft sizes and load factors would tend to increase. But the point is that the need for extra peak hour capacity depends on new airports/runways coming into service.

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Eurocontrol's most recent Long Term Traffic Forecast notes (Eurocontrol, 2006):

> "*The forecast is for between 15.5 and 18.9 million IFR flight movements in the Eurocontrol Statistical Reference Area (ESRA) in 2025, between 1.7 and 2.1 times the traffic in 2005 … These traffic totals are typically higher than 2 years ago, lifted by a number of factors including: the continuing prospects for growth in particular after EU enlargement; stronger economic growth forecasts; and slower growth in oil prices, since they now start from a higher level.*"

Note, with the benefit of hindsight, the phrase 'slower growth in oil prices'. In 2004, Eurocontrol had produced its Challenges to Growth Report (Eurocontrol, 2004). This examined four scenarios for air transport growth; one of them, 'D', assumed high oil prices, although this did not quote the price of oil. It concluded:

> "*Scenario D — regionalisation and weak economies (increased tensions between regions with high security costs and high oil prices), resulting in 2.5% growth p.a. and a growth factor of 1.7[i.e. 70%]" [2003-2025].*

The other scenarios had markedly higher growth rates.

A recent CAA paper (CAA, 2008) noted the importance of the oil price in air transport demand. From the paper, noting particularly the comment about the 1970s position:

> "*It appears that there have been three key factors affecting the cost (or convenience) of air travel, either to the passenger or the airline, in recent years. The first has been the rising oil price, which has nearly tripled since the start of 2004 … previous CAA analysis has indicated that the recession and oil crisis of the early 1970s did have a sustained impact on the rate of traffic growth … the CAA's airline statistics show that in 2004, fuel and oil costs represented 16% of all UK airline costs, in 2005 they represented 22%, whilst in 2006 this figure had risen to 25%.*"

CAA (2005) discusses the various elasticities of demand for air travel, which also includes a substantial bibliography on the topic. High oil prices also have a marked impact on a country's inflation and GDP growth, and hence in individuals' personal income. CAA (2005) suggests that demand for air travel is income elastic, i.e. income change causes a *more* than proportionate demand change for leisure air travel.

Eurocontrol (2004) estimated the extent of constrained demand:

> "*With the highest growth scenario airports will severely constrain traffic growth in 2025. Annual demand will have increased to 21 million flights, a growth by a factor 2.5 compared to 2003. However, despite 60% potential capacity increase of the airport network, only twice the volume of 2003 traffic can be accommodated, and 17.6% of demand (i.e. 3.7 million flights per year) cannot take place. This is expected to have a significant impact on airport operations: more than 60 airports will be congested, and the top-20 airports will be saturated at least 8-10 hours per day.*"

Will all the potential new airports/runways materialize?

The Challenges to Growth report headlines "The need to plan for the most challenging scenario". Is this the right goal? What are its merits if the evidence is that this challenging scenario has a low probability of occurrence? To reiterate, from a financial decision-making viewpoint, the need is for assessments of the range of strategies in terms of the costs to stakeholders and the benefits/disbenefits they would get from over- or under-investment.

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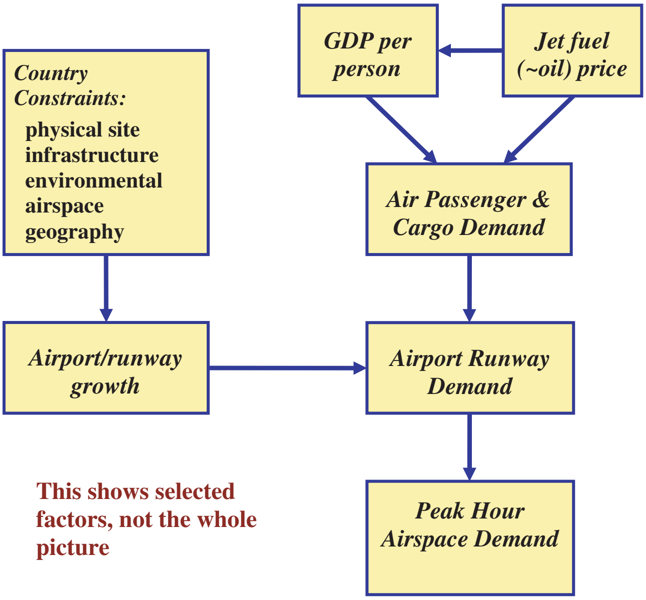

Figure 9. Selected Factors in Predicting Peak Hour Airspace Demand.

11. SESAR PLANNING – LOW GROWTH SCENARIO. Thus, it is vital to examine the context for SESAR planning. Planning for airspace capacity growth has to take place against projections of the future aviation and general business environment. Figure 9 shows some linkages. The point about new airports/runways coming into service has already been made. A reducing oil price is *not* a good economic symptom if it simply reflects slow or negative GDP growth.

It is essential to work through the logical sequence in Figure 9 from an assumption of a Low Growth scenario to the impact on peak hour airspace demand. Without new airport capacity, the discussions on large increases in airspace capacity are academic, because demand will be constrained by airport capacity. To spell out the logic:

- Peak demand is constrained by the airport capacities in use.
- Therefore planning for extra airspace capacity requires good projections on the number of new runways.
- Eurocontrol's 2004 Challenges to Growth study (Eurocontrol, 2004) attempted estimates of constrained demand if major new commercial airports were not developed – will they be?
- Low GDP growth and long-term high oil prices generate a Low Growth scenario.

The simple conclusion is that setting the phasing of new SESAR related projects to deliver airspace capacity gains must take account of fluctuating demand, likely GDP growth, oil prices, and the realities of the phasing of new airport capacity.

What are the quantitative implications of a Low Growth scenario for SESAR requirements? The easiest way to see this is to present some crude sums about the airspace capacity gains from some of the pre-SESAR projects. The increases expected

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from three of the projects examined above are substantial, noting that these all derive from official State and Eurocontrol CBAs, not a reworking of the calculations:

- DMEAN plus air traffic flow measures together produce an airspace capacity increase of 24%–32% (SESAR Consortium, 2008d).
- CPDLC at 100% fit: estimated at 14% improvement (Booker, 2007).
- FASTI generates gains of up to 15% (Brain, 2008).
- In combination, the sector capacity gain would be between 63%–73%, i.e. about the amount required for the Low Growth scenario above.

Thus, taken as a whole, a rough figure across Europe, these pre-SESAR projects deliver the bulk of the capacity needed on a Eurocontrol Low Growth scenario to 2025.

A Low Growth scenario has major implications for the portfolio of SESAR projects. Any projects in the portfolio that deliver capacity above what is projected to be needed or which do not have sizable real options values would be deferred, i.e. moved up the financial priority stages in Figure 6. A Low Growth scenario would change the available investment budget over the coming years, putting constraints on the number of contracted and budgeted projects.

This second impact on the R&D/project portfolio needs some explanation. An analogy is the UK water industry, privatised for several years (Newbury, 2005). In the UK, privatised utilities have to be profitable and self-financing. They are subject to price regulation, which takes the form of 'RPI-X' regulation, where charges to customers cannot increase by more than the 'rate of inflation' (RPI) less an efficiency factor (X) in each year. But the water industry needed a huge capital investment programme to remedy past under-investment and to bring the quality of water/wastewater up to EU standards. Therefore, water prices to customers were increased annually by several per cent *more* than an RPI-X figure.

This is crucial: revenue must finance both operating expenditure and the capital investment programmes, and there are inherent limits on efficiency savings in operating expenditure to maintain the quality of service. Revenue also needs to be able to finance previous capital investment through the return the regulated company earns on its regulatory capital value. A continuing high level of capital investment therefore generally requires the amounts paid by customers to increase if the necessary finance is to be raised. The actual effects on prices to customers depend on the size of the asset base and the growth in demand. For the ANSP/'airlines agents' investments, the airlines have to scrutinise the portfolio of budgeted/planned projects. The regulator wants assurance that budgeted/planned projects would provide better capacity performance, or be a direct enabler of projects with a certainty of providing enhanced performance; and that the evolution of demand in terms of scale and pattern is robust; and that the technologies to be implemented are known and stable. User charges should increase from investment *onl*y if that extra capacity is added cost-effectively.

Thus, high NPV/real options projects, with the new lower growth traffic projections, would go ahead. The remainder would move up to the planning / strategy stages from contracted / budgeted, or be deleted from the present portfolio. Projects dependent on individual airline investment with increased payback periods would be at particular risk. The project portfolio would be the minimum capital investment necessary to deliver the forecast required capacity over the period. If, in future years, a high growth scenario were to develop, then deferred/deleted projects would be reappraised.

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12. CONCLUSIONS.

What has been learnt here about the questions that SESAR plans should try to answer? A five-year ATM plan can work effectively if it is making use of best practice already deployed elsewhere and is extrapolating from good information. A 20–25 year ATM strategy is necessarily much less precise. It must use limited information on the success of innovations, which are dependent on changed functionality, and the development of large-scale, often safety critical, software – whose integration into a legacy infrastructure often takes markedly longer and costs markedly more than early estimates.

Thus, strategic technology plans have to be adaptive. If an expert in aviation had been asked to envisage the 2008 system 20 years ago, would the future have included low-cost business models and buying tickets on the internet? SESAR cannot be a rigid programme – it must be sensibly adaptable to major changes in the business environment. SESAR must be sufficiently flexible in deployment to maximise financial benefits to individual stakeholders *using their specific financial criteria*.

The aim here has been to understand how SESAR can work most effectively for the airlines, whose needs are the main ATM system/business drivers. The approach here uses simple corporate finance ideas to examine the different viewpoints and business environments of ANSPs and individual airlines. The focus has been decisions on projects implementing successive ATM system phases. The key decision-making point is that ANSPs act as an agent for airlines as a whole. The key financial point is that a typical airline has to work hard to survive and needs quick paybacks on investment.

The analysis here identifies the following ATM/SESAR 'best value' issues for airlines:

- European and worldwide GDP effects on traffic and airport growth?
- ATM growth potential using 'existing' technology
- Project choices & sequences
- R&D and project linkages
- Oil price impact?
    - ○ Fuel economy
    - ○ Climate change (taxes and ETS)
- Financial decision making criteria
    - ○ NPV – ANSPs/'airline agents' and an airline cash flows
    - ○ Real options

Examples of the kinds of strategic decisions these would imply for SESAR planning are:

- Must recognise complexities of aviation's financial & operational decision making.
- Must provide hard evidence to airlines about cash flows and option values.
- Must implement mature pre-SESAR programmes with major business benefits & real options for stakeholders – these secure the 'Low Growth' future.
- Must keep SESAR Europe-wide momentum.
- Examine SESAR priorities: create R&D/project portfolio assuring CBA cash flow paybacks & maximising future real options value – build system framework that can meet higher demand by re-phasing.

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APPENDIX A: CRITIQUE OF BENEFITS AND COSTS FOR SOME PRE-SESAR PROJECTS

A1. INTRODUCTION. This Appendix summarises and analyses the pre-SESAR projects LINK2000+, CASCADE, FASTI and aFDPS presented in the main text. The focus is on their costs and benefits to ANSPs and individual airlines.

A2. LINK2000+: CPDLC. The LINK 2000+ programme aims to address the problem of voice communication, which is becoming a limit to the capacity of Europe's airspace sectors. The solution is to provide controllers and pilots with a second communication channel by air/ground data link: CPDLC – Controller Pilot Data Link Communications. Eurocontrol's Link 2000+ website pages provide supporting documentation about CPDLC – see also Roman (2003). Eurocontrol offered financial aid to the first one hundred aircraft installing the required software, and is actively involved in the development of the technology and deployment of ground infrastructure. Commercial activity in this area is very strong.

CPDLC offers safety-related benefits, e.g. preventing controller/pilot misunderstandings and the blocking of voice channels by malfunctioning equipment or garbling, easing the pilot's tasks, and relieving some of the fatigue generated by voice communication. Its main economic benefit is in busy airspace, where voice congestion is a well-known constraint to capacity, voice communication tasks being between 35% and 50% of the controller's overall workload. Most of these voice communications are routine, such as the transfer of flights between sectors, requests to change flight levels, clearances, and SSR (Secondary Surveillance Radar) code changes, so there are gains from replacing some of these routine voice communications with data link.

Eurocontrol simulations indicate for 25% of aircraft CPDLC-equipped, ATC sector productivity would increase by up to 4%, rising to a 14% increase for 100% equipage (Booker, 2007). This most recent CBA of the European CPDLC business case focuses on the increases in peak sector capacity achieved through CPDLC. The base case for assessment assumes that ANSPs would have to deal safely with increasing volumes of traffic by increasing the numbers of sectors whilst maintaining service quality. With CPDLC, controllers would be able to handle more traffic, so this defers the introduction of extra sectors, and thus the additional operating costs. These avoided operating costs are the economic benefits of data link services – the aircraft operators gain by avoiding increased route charges. Based on central estimates of costs and implementation dates, the NPV for CPDLC is a large number – an estimated IRR of 23%.

Is the CPLDC calculation robust? First, it does not take into account the very early benefits to airspace capacity currently expected from DMEAN. At the heart of the estimation process is the assumption that traffic grows consistently, about 3·5% pa for the central case – matching historical trends and allowing for high growth in Eastern Europe. The next assumption is that the traffic at peak periods grows at the same rate. This is a more fragile assumption, given that such growth

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requires a considerable increase in the number of major European runways over the period to 2025. Thus:

> "*In 2006 there were 404 sectors in the data link airspace. By 2016, it is estimated that, without data link, the total will need to rise to 560 to keep pace with the growth in traffic and, by 2025, the total will have risen to 750.*"

Is such a growth in *peak hour traffic* likely in reality? As explained in the main text, general passenger/cargo growth translates into airspace demand at peak hours *if* airport operators bring additional runways into operation – an aspect not discussed in the CBA. The spreading of traffic does have some effects on the need for controllers in these non-peak hours: estimating the size of the effects over the years would be a complex ATC centre dependent exercise: some sectors will simply have an increase in traffic demand while others will have to be 'unbandboxed' (i.e. splitting currently combined sectors).

Thus, if new runways do not come into operation to handle peak hour demand, the need for large increases in sector numbers reduces from the Booker (2007) estimates. This in turn reduces the cash savings achievable from CPDLC implementation. Determining a good estimate for the most probable growth in European runway numbers over 20+ years is a very difficult exercise.

The NPV calculation in Booker (2007) uses the same discount rate as the SESAR work referenced, i.e. 8%. Is this a cautious calculation of future benefits? This is effectively a NPV calculation for an 'ANSPs+Airlines' business system, as it includes the cash flows that will eventually be incurred and received by all the airlines over a long period of time. But this effectively supposes that the airlines are some kind of amalgamated grouping with a WACC, Beta value etc similar to ANSPs', and, as noted in the main text, the individual airlines face their own set of WACCs and time horizons, the latter being much shorter than the 'ANSPs+airlines' combination. This is where real options are important, because it might well be worthwhile for the airlines to delay their CPDLC fits until most ANSPs have operational CPDLC systems in place, rather than 'planned' or 'projected' dates for this to happen.

In addition, the costs of ANSP implementation in the NPV calculations seem largely to use Maastricht data, the only European ATC centre currently using CPDLC: "*Cost information from Maastricht and the ANSPs intending to implement data link by 2008 indicate that the average cost per ACC may be in the region of €10m. Total ground implementation costs are expected to be about €365m*". Booker (2007) notes that costs will vary from centre to centre depending on the nature and age of the current equipment at the centres, and the amount of software development required to integrate new and old systems. Maastricht is in many ways an *avant garde* centre, so older units with a high proportion of legacy equipment and software might have to incur markedly higher development costs. The analysis does not appear to make explicit if it includes all the ANSP costs of CPDLC training. These were high in the USA's terminated CPDLC programme (Jensen, 2003), where the project was over-budget and behind schedule because of inadequate initial resource allocation.

Marais and Weigel (2006) cites CPDLC as an example of a technology where "there is an immediate benefit to an individual equipped user and additional benefits are realized when more aircraft equip". However, in cash flow terms, this is true if an

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equipping airline gets a monetary financial benefit from such equipment. Booker (2007) notes:

> "*The total cost of retrofit is likely to lie in the range €203m to €211m depending on how soon new aircraft will be delivered fully equipped. The total cost of new fit will be of the order of €20m per year, totalling about €255m by 2020 and will reach about €403m by 2025 if the cost of equipage does not fall.*"

As noted, Eurocontrol has already provided subsidies for early equipping airlines. The proposal is that there will be route charge incentives, with reduced route charges for CPDLC equipped aircraft. If this were not to be the case, then the cost saving benefits would accrue to all airlines rather than those that spent money on equipping. Roman (2003) notes a proposed 2% route charge reduction for equipped aircraft. This seems very low: PRC (2007) presents figures on ANSPs showing that 60% of their budget is for staff costs, 48% of these being for controllers. If a 100% fit were to increase controller workload by 29%, and hence increase capacity by 14%, then the 2% figure looks small – there are obviously issues about marginal, average and overhead costs.

CPDLC does appear to be a good investment for the 'ANSPs + airlines' combination, with its low discount rate and long time horizon, although there have to be some concerns about the peak hour traffic estimates (given uncertainties about additional European runways) and possible under-estimation of ANSP implementation costs. A number of individual airlines are already investing in the on-board equipment. If airlines take a real options view of CPDLC, noting their high discount rate and limited time horizon, they could delay their purchases until large areas of Europe have operational CPDLC ground equipment. The five largest ANSPs handle 56% of European traffic (PRC, 2007), so it is very important that they complete CPDLC installation, and that the route charge financial incentives do match the bulk of the ANSPs' savings.

A3. CASCADE: ADS-B. The CASCADE programme co-ordinates the European implementation of ADS-B. The CASCADE pages on the Eurocontrol website provide a great deal of supporting documentation about ADS-B. There are many FAA-sponsored technical and business documents about ADS-B. Interesting recent USA research papers are Marais & Weigel (2006), and Lester & Hansman (2007). Note that the USA ATM needs are different from most of European airspace, e.g. because of the extensive gaps in USA radar coverage.

ADS-B has three components: satellite navigation (usually GPS) on the aircraft, ground-based transceivers, and ADS-B avionics on aircraft. The operation is:

- Aircraft transponders receive GPS signals – used to determine precise locations of aircraft in flight.
- ADS-B converts that position into a unique digital code and combines it with other data from the aircraft's flight-management system (i.e., type of aircraft, speed, flight number, and if it is turning, climbing, or descending).
- This ADS-B signal can be captured:
    - ○ on the ground for surveillance purposes – *ADS-B(Out)*
    - ○ or on board other aircraft for air traffic situational awareness and some variety of airborne separation assistance – *ADS-B(In)*

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ADS-B requires a standard protocol for encoding and decoding the data. The USA proposes two data link protocols, 1090 MHz Extended Squitter (1090-ES) and Universal Access Transceiver (UAT). Europe is implementing 1090-ES, although Sweden and Russia have also been advocating a third protocol, VHF Datalink Mode 4 (VDL-M4). 1090-ES broadcasts additional data, including position, velocity, and intention in the Mode S signal without interrogation from a SSR on the ground or a TCAS system. The 1090 MHz frequency is allocated to SSRs and TCAS, and the ADS-B information does not interfere with the existing uses of the Mode-S transponder. Lester and Hansman (2007) discuss the technical choices made.

ADS-B(Out) requires little modification to current transponders, while for ATC system surveillance via ADS-B, ground stations are needed, essentially replacements for SSR sites, at around a tenth of the costs. [NB: in mid-2007, the FAA awarded an ADS-B contract to build and operate ADS-B ground stations (Scovel, 2007).] ADS-B(In) is a much more expensive investment: aircraft would require CDTI (Cockpit Display of Traffic Information, implying aircraft cockpits and avionics having significant upgrades. ADS-B applications generally require most if not all aircraft to be ADS-B-equipped. For ADS-B(In) applications to deliver large benefits, the nature of the ATC system would probably have to change considerably, particularly in respect of the roles of controllers and pilots.

As regards airline involvement in ADS-B, IATA has specific policy positions on ADS-B (summarised from 2007 conferences presentations):

ADS-B(Out).

- Radar-based ATC using ground radar surveillance to migrate towards ADS-B(Out)
- New surveillance implementations should consider ADS-B(Out)
- Radar installations decommissioned, savings passed on to airspace users in airspace where ADS-B(Out) is declared operational
- Interoperable implementation world-wide
- Early implementation of ADS-B(Out) services prior to devoting extensive resources to ADS-B(In)

ADS-B(In).

- ADS-B(In) a major element of the future surveillance technology mix and of increased task-sharing between pilots and controllers
- Using CDTI, ADS-B(In) facilitates airborne spacing by pilots and possibly, in future, self-separation
- Global consensus must be reached on avionics requirements and satellite receiver specifications and benefits to be derived before ADS-B(In) can be mandated. Consensus international standardisation expected for initial ADS-B(In) applications by 2009.
- Major avionics upgrades of existing fleets require a lead-time of 10+ years

Currently, i.e. late 2008, the FAA proposes only to mandate ADS-B(Out) – by 2020. It is working on the assumption that the safety benefits of receiving traffic, weather, and flight information will encourage aircraft owners to equip voluntarily to receive ADS-B(In).

There are many publications discussing possible ADS-B benefits, e.g. Lester and Hansman (2007) discusses the different kinds of beneficial applications available to the various ATM stakeholders and environments (e.g. in currently non-radar

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airspace). For present purposes, the focus is on commercial aviation in Europe, as a precursor to SESAR. CASCADE provides information on work done on European ADS-B business cases. There are currently four listed on the website. Three of them are interesting, but not very relevant to SESAR-level airspace CBA assessments for states with good wide-area SSR coverage. These studies – Maastricht-Aachen airport, Malta and Trabzon airport – focus on radar technology issues.

The fourth study examines an example with good wide-area SSR coverage: CRISTAL UK: ADS-B in South East England (Dow, 2007). The published version does not include financial information. Its focus is the potential cost savings replacement of SSR sites by ADS-B sites. The payback period estimated is long, around 15 years. Rather than an 'ADS-B only' solution, the technical proposal generally recommends an ADS-B/multilateration passive surveillance system (PSS) combination. The idea is to move to a multi-surveillance source tracked environment enabling the use of all types of surveillance source. The idea would be to run the PSS alongside the existing Mode S and SSR radar assets, combining data from all sources. This would enhance the current mode of operation and enable new technology applications.

Multilateration has been the subject of considerable research in recent years, e.g. see Langhams (2005) and the Eurocontrol-organised Wide Area Multilateration workshop (WAM, 2007), in particular the Hintum presentation. Multilateration uses triangulation principles, which use 'listening post' stations to 'hear' transponder returns – Mode-A/C, Mode-S, ADS-B and military IFF transponders, etc. WAM systems are potentially capable of significantly higher accuracies than an equivalent radar service and at a cost no greater than ADS-B ground networks. Multilateration is backward compatible with existing transponders and forward compatible with ADS-B.

The problem for the ADS-B(Out) CBA case is that multilateration merely requires aircraft to be fitted with the kinds of transponders that they already need for flight in controlled airspace. Thus, the aircraft operator does not need to fit additional ADS-B kit in order for the ATM system to benefit from the replacement of SSR sites. If a multi-surveillance system were to be developed, the early cash benefits would derive from replacement of SSR by WAM rather than by replacing SSR by ADS-B networks, given that the latter would require the bulk (~100%?) of aircraft to be ADS-B(Out)-fitted for the SSR site to be removed. So what would be the incentive for ADS-B(Out) fitment? Note again that individual operators do not gain though incremental ADS-B fits. A slow take-up of ADS-B(Out) presumably implies a longer timetable before widespread ADS-S(In) equipage.

The SESAR studies covering ADS-B do not add much to a CBA understanding. SESAR Consortium (2008c) discusses the CASCADE work, but its NPV analysis covers only ADS-B(Out) replacement of SSR sites *without* any consideration of WAM. SESAR Consortium (2008a) does not mention ADS-B but does discuss ASAS, i.e. airborne self-separation using presumably ADS-B(In), although it makes no estimate of (e.g.) capacity gains for either en route or terminal area airspace.

In summary, from an airline point of view, the ADS-B CBA picture is unclear. There are system benefits from ADS-B(Out) in terms of replacing SSR sites, but not from individual spending decisions, and WAM – requiring no new airline investment onboard – appears to be a major competitor. The airline benefits of ADS-B(Out) are long term and bound up with a SESAR strategic concept using self-separation. ADS-B(In) may be a strategic enabler, i.e. offer real options gains for a new ATM paradigm. But note that the projected ADS-B implementation costs are substantial for both

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military and business aviation stakeholders. Section 10.5 of SESAR Consortium (2008d) provides some details of estimated costs of the various implementation packages.

A4. FASTI. FASTI is the 'First ATC Support Tools Implementation' Programme coordinated through Eurocontrol. The aim of the programme is to assist ANSPs in the implementation of a set of controller assistance 'FASTI' tools to provide a harmonised implementation across Europe. The goal is to develop air traffic capacity increases. FASTI tools provide "interpretative" information about the traffic situation, which reduces the workload associated with planning and maintaining separation tasks, and hence increases the productivity of controllers. The FASTI pages on the Eurocontrol website provide a great deal of supporting documentation. Brain (2007; 2008) are a short overview and executive level summary respectively.

Two examples are the iFACTS work by NATS and the ERATO work by DSNA (see Annexes to Petricel and Costelloe, 2007). For example, NATS iFACTS derives from the FACTS project, undertaken since the mid-1990s (Whysall, 1998). iFACTS includes the majority of the FACTS tactical functionality, subject to the constraints of the existing UK ATC FDPS architecture. The fundamental tools in the iFACTS concept are trajectory prediction flightpath monitoring, providing up-to-date trajectories providing details of future aircraft positions, and conflict prediction tools – medium term conflict detection (MTCD). These rely on a number of display tools, which the controller uses to obtain information or to enter instructions/clearances. MTCD contributes to a significant reduction in controller workload, improves the planning process, and also assists the tactical controller by supporting the routine 'situation monitoring' task.

There are a limited number of investment assessments on FASTI tools. Delarche et al (2007) examined the range of tangible benefits, *inter alia* referring to a previous internal FASTI CBA study by Helios Technology Ltd. The FASTI documents also include a 'FASTI Business Case Report', but this is concerned with methodology for CBA rather than actual estimates. However, two important estimates of the main financial impact of FASTI are (Annex re NATS, Petricel and Costelloe, 2007; Brain, 2008):

> "*The main operational goals of iFACTS are: Overall reduction in controller workload enabling LACC [London Air Traffic Control Centre] to meet the capacity demands from 2008–2012* (*An average capacity increase of 13% across the London FIR*)"
> "*[FASTI] Capacity: Seen as the principal benefit where increased sector capacity and overall ATM network capacity will be achieved through a reduction of controller workload per aircraft. Sector capacity gains of up to 15% are expected.*"

The fact that the capacity gain is about the same amount as the CPDLC case discussed earlier helps to give an indication of the quantitative benefits from FASTI implementation. FASTI tools do not require on-board investment by the airlines: ANSPs incurred the costs by acting for all ATC users. In the latest publicly available version of NATS investment plans, iFACTS was costed at £48M (NERL, 2005 – slide 31). NATS let the contract for iFACTS in early 2007 – with a press release 'NATS pioneers biggest ATC advance since radar'. iFACTS is an IT system development project: as already noted, on past trends, it is likely to overspend from 10%–200% (Mott MacDonald, 2002). Project overspends are much more likely for

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safety critical software that requires very careful step-by-step creation and testing. Thus, in practice, iFACTS will probably cost at the upper limit of the range, say £125M? At mid-2008 exchange rates, £1 ~€1·25, the NATS costs for iFACTS would be about €160M. This is much larger than the typical CPDLC cost quoted by Booker (2007), by around a factor of eight. If NATS were typical, and UK costs scaled to roughly the same extent to CPDLC, then the total European cost for FASTI would be around €3M, about four times the total European CPDLC costs (which include the airborne component). Again, if the investments and phasing of FASTI matched those of CPDLC, this would produce a large negative NPV, of the order of −€1·5M (compare Figure 15 of Booker (2007)).

If FASTI, based on iFACTS and CPDLC data, does not produce a positive NPV, is it a worthwhile project? There are strategic arguments. ATM development usually needs incremental steps rather than dramatic changes, to reduce transition risks. The implementation of FASTI is a necessary evolutionary step to a full set of predictive electronic flight data-based tools. The algorithms, design, controller interfaces and safety case all carry forward to SESAR. FASTI predictive tools offer the potential for near-optimum 4D flight trajectories. FASTI has a high terminal value, because its benefits essentially continue indefinitely into the future; and it has a potentially large real options value, because it is the 'base camp' for further progress towards advanced functionality SESAR concepts.

A5. ADVANCED FLIGHT DATA PROCESSING SYSTEMS – aFDPS. Many European countries currently are developing advanced flight data processing sysems – 'aFDPS'. SESAR Consortium (2008c) lists 11 aFDPS initiatives covering 17 ANSPs. The largest initiative is the 'Interoperability Through European Collaboration – European Flight Data Processing' project (iTEC-eFDP) (iTEC, 2008).

'FDPS' covers a variety of elements. The core task is to receive automatically the flight plan data, process these data, then send them to the other relevant components of the ATC system, and provide controllers with the information at their workstations. iTEC's functions include:

- Flight Data Management and Distribution
- Air/Ground Data Link FDP Applications
- Advanced Trajectory Prediction
- Correlation and SSR Code Management
- Flight Path Monitoring
- MTCD
- Integrated Co-ordination

These indicate how critical aFDPS is both to the functioning of the ATC system and its links to advanced ATC functions.

Coordinated European work on aFDPS issues is being carried out by Eurocae and Eurocontrol, e.g. to develop the 'Flight Object Interoperability Proposed Standard' – FOIPS (FOIPS, 2008). The aim of FOIPS is to provide the basis for a new standard for flight data exchange in Europe. Its scope includes all ATM related flight data pertaining to individual flights of interest to more than one stakeholder system.

The need for aFDPS has an explanation in terms of the history of existing European systems. UK NATS provides a good example. NATS FDPS is called the 'UK National Airspace System', NAS for short. NAS derives from 1960s software, i.e. did not use a currently acceptable modular form. The interoperability of the FDPS system

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is a crucial issue for the Single European Sky: NAS could not satisfy FOIPS – which is why NATS is part of the iTEC consortium. NATS will benefit from iTEC by having common and more resilient FDPS providing a platform for future ANSP interoperable tools. iTEC will be a resilient architecture, e.g. supporting contingency strategy in the event of a catastrophic failure at an ATC centre. The decision to follow the iTEC route is to the airlines long-term benefit – it does not require major on-board investment by the individual airlines.

In 2005, NATS budgeted iTEC at £25M (NERL, 2005). Given the UK evidence of software development costs discussed earlier here, the current estimate would probably be £60-£75M, a large proportion of these costs being NATS-specific software. It will also be necessary to integrate the ITEC FDP into the existing NATS' Infrastructure, which will need at least the same capital investment, probably more.

Performing a CBA for aFDPS is an extremely difficult task. Its value is not in short or medium term cash flow but as a real option for strategic development. SESAR Consortium (2008c) states that 'No CBAs exists in this field', and notes: "The implementation of the advanced FDP systems is intended to reduce the costs of fragmentation, caused by the lack of common systems and the due coordination at the ATS Units interfaces. It has been evaluated that these account for some 23% (€190–325 M) of the entire cost of fragmentation."

Thus, aFDPS is essentially a software platform, which may well not generate value directly, but enables different value-generating applications to be implemented (eg Fichman, 2004). If IT reaches a point where it is seen as a competitive necessity or a cost of doing business, then the investment decision is based on strategy not short-term cash considerations. Thus their main value is in the real options created for building applications, to quote Lucas from Tallon et al (2002): "Nobody likes to invest in IT infrastructure … there's what I like to call transformational IT where you might really be trying to change the whole structure and form of your organization. Again, it is going to be difficult to come up with numbers on these."

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