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<td><strong>Originator (Corporate Author) Name/Location:</strong></td>
<td>EUROCONTROL Experimental Centre B.P.15 F - 91222 Brétigny-sur-Orge CEDEX FRANCE Telephone : +33 (0) 1 69 88 75 00</td>
</tr>
<tr>
<td><strong>Sponsor:</strong></td>
<td>DED-1</td>
<td><strong>Sponsor (Contract Authority) Name/Location:</strong></td>
<td>EUROCONTROL Agency Bernard Miaillier Rue de la Fusée, 96 B -1130 BRUXELLES Telephone : +32 2 729 9011</td>
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<tr>
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<td>A. Joyce J. Watkins S. Jonkhart</td>
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<td><strong>Abstract:</strong></td>
<td>This interim report presents the results of a review of concepts for technical systems and operational procedures to improve airport capacity. A preliminary, qualitative assessment of the estimated impact of these concepts, technologies, and procedures on airport capacity is also presented.</td>
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TOSCA-II

Testing Operational Scenarios for Concepts in ATM (Phase II)

(Airport Capacity Enhancement)

WP7: Airport Capacity Enhancement
Interim Report
Reference: TOSCA/EEC/WPR/7/01
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<th>Name</th>
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<th>Country Code</th>
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<tr>
<td>Henk BERGHUIS VAN WOORTMAN</td>
<td>NLR</td>
<td>(NLR)</td>
</tr>
<tr>
<td>Henk BLOM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mariken EVERDIJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>John BENNETT</td>
<td>DRA</td>
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</tr>
<tr>
<td>Philippe KERLIRZIN</td>
<td>SOFREAVIA</td>
<td>(SOF)</td>
</tr>
<tr>
<td>Peter CRICK</td>
<td>Eurocontrol Experimental Centre</td>
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<tr>
<td>Keith HADLAND</td>
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<td></td>
</tr>
<tr>
<td>Bernard MIAILLIER</td>
<td>EUROCONTROL HQ</td>
<td>(EUR)</td>
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<tr>
<td>Philippe ENAUD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lars LÖNNBERG</td>
<td>DG VII</td>
<td>(EU)</td>
</tr>
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</table>

**Written by:**

Tony JOYCE  
John WATKINS  
Saskia JONKHART

**Reviewed by:**

EEC, NLR

**Approved by:**

Henk Berghuis Van Woortman, Project Leader.  
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Executive Summary

One of the objectives of the EATMS is to ensure that the Air Traffic Management (ATM) system will make the best use of airport infrastructures (gates, aprons, taxiways, and runways). The EATMS incorporates measures to maximise the use of available airport capacities within the gate-to-gate philosophy, including measures to combat the constraints caused at times of poor visibility. Even so, by 2015 a number of European airports in the high traffic density areas will routinely be operating at their maximum capacity levels for prolonged periods of the day, and will be unable to increase their throughput because of airside, infrastructure, or environmental reasons. In order to plan the ATM system as a whole, it is necessary to estimate the capacities of both the enroute and terminal area elements.

This TOSCA work package investigates the perceived beneficial effects of existing EATMS concepts for technological systems and operational procedures affecting airport and terminal area operations and, using fast time simulation, to compare these with predicted future demand composition on airport and terminal manoeuvring area (TMA) capacity.

This interim report reviews concepts for technical systems and operational procedures to improve airport capacity and makes a qualitative assessment of their estimated impact on air traffic management system capacity.

This initial assessment led to the selection of ten concepts, procedures, and technologies for in-depth evaluation during Phase II of this work package. These include, in order of expected benefit:

- Wake Vortex Tracking
- A-SMGCS
- Reduced Separation on Parallel Runways
- Reduced Separation
- FMS
- Integrated Arrival and Departure Manager
- Arrival Manager
- Departure Manager
- Optimisation of Arrival and Departure Routes
- Segregated Airspace

Phase II of the TOSCA WP7 will investigate the perceived beneficial effects of these selected concepts, procedures, and technologies on airport and terminal area airspace capacity. Improvements in TMA and/or airport capacity will be estimated using the SIMMOD and TAAM simulation models on a hypothetical “Europort” (a simulated airport platform based upon Airport Amsterdam Schiphol). Results of this analysis should be delivered before the summer of 1998.
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1 Introduction

1.1 Background

It is the current perception that within the ECAC (European Civil Aviation Conference) area much of the congestion in the future air traffic system will occur at airports. Therefore, it is important to establish whether (and when) airport capacity reserves will be exceeded by demand. Such knowledge is also valuable in the estimation of whether capacities of the enroute and terminal area systems will be balanced against each other in the future. The European Air Traffic Management System Operational Concept Document (EATMS OCD), dated 01 March 1997, states that, since there will be no significant increase in the number of airports and runways in the ECAC area over the EATMS time frame, efficient use of the available airport capacity will progressively become a major concern (particularly in the busier ECAC traffic areas). This mismatch between demand and available capacity will present a major challenge for the users and airport operating authorities.

1.2 Purpose of this Study

1.2.1 Description

One of the objectives of the EATMS is to ensure that the Air Traffic Management (ATM) system will make the best use of airport infrastructures (gates, aprons, taxiways, and runways). The EATMS incorporates measures to maximise the use of available airport capacities within the gate-to-gate philosophy, including measures to combat the constraints caused at times of poor visibility. Even so, by 2015 a number of European airports in the high traffic density areas will routinely be operating at their maximum capacity levels for prolonged periods of the day, and will be unable to increase their throughput because of airside, infrastructure, or environmental reasons. In order to plan the ATM system as a whole, it is necessary to estimate the capacities of both the enroute and terminal area elements.

1.2.2 Study Objectives

The objective of this TOSCA work package is to investigate the perceived beneficial effects of existing EATMS concepts for technological systems and operational procedures affecting airport and terminal area operations and, using fast time simulation, to compare these with predicted future demand composition on airport and terminal manoeuvring area (TMA) capacity.

1.2.3 Deliverables

The study comprises two phases:

- Phase One - In phase one, a review of EATMS concepts for technical systems and operational procedures to improve airport capacity is used to make a qualitative assessment of their estimated impact on air traffic management system capacity. This interim report details the phase one review and describes the experimental design to be used in phase two of the study.

- Phase Two - In Phase two, the simulation of technologies and associated procedures on a hypothetical airport platform will lead to quantitative estimates of capacity gains. A study report will be issued setting out the results from these simulations.
2 The EATMS Concept

2.1 Procedures and Technologies

In order to determine the relative improvements in airport capacity that could be anticipated with the implementation of EATMS concepts, it is necessary to convert today’s knowledge of these technical systems and operational procedures into estimated parameters that may be used in an airport/TMA model.

Section four of this report comprises a survey of procedures, concepts, and technologies available or under development that may lead to increases in efficiency in airport and terminal airspace operation. Some procedures, concepts and technologies in (or approaching) a mature state are included in this report to give a balanced view, as they will form an integral part of airport operations over the period for study. Indeed, it has become an established policy within the ECAC region that those “mature” procedures and techniques that can be implemented without undue delay are adopted wherever appropriate.

The technologies surveyed in this interim report include applications relating to both airborne and ground-based resources. Information is drawn from EATMS, FAA, APATSI, EU, National, and other TMA Research projects.

2.2 Balancing Airport and TMA Improvements

Experience has indicated that, within the TMA and Airport environment, the application of individual improvements to technical equipment, changes to procedures, and automation of support to air traffic controllers will often yield only marginal capacity increases. At high-density airports and their associated TMAs, the overall capacity can be limited by airport infrastructure or airspace design. Technical equipment, procedures, or control capacity can in turn limit these two factors. There is no general rule controlling which element will be the governing limitation: this is dependent on the specific situation and circumstances at the particular airport or TMA in question. It is evident that for any given airport and TMA, airport capacity, airspace capacity, and control capacity (together with their influencing factors) are extremely interdependent.

2.3 EATMS Stages

The path of the EATMS is envisaged in sequential stages with implementation completed by the end of each period. The most recent estimate (EATMS Operational Concept Document Ed.1.0 1 March 1997) of the time scale that will apply is described below. The description remains at a high level for the time being.

The following table summarises each of the four stages:
### Table 1

<table>
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<th>Stage</th>
<th>Years</th>
<th>Plan</th>
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<tr>
<td>1</td>
<td>2000 – 2005</td>
<td>• Improve the structure and use of airport and airspace resources.</td>
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<tr>
<td></td>
<td></td>
<td>• Enhance ATM working practices (individual and team).</td>
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<tr>
<td></td>
<td></td>
<td>• Computerise support for tactical ATC functions.</td>
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<tr>
<td></td>
<td></td>
<td>• Introduce new open-data processing systems.</td>
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<td>2</td>
<td>2002 – 2006</td>
<td>• Introduce free routings, starting in the upper airspace.</td>
</tr>
<tr>
<td>3</td>
<td>2005 – 2012</td>
<td>• Enhance planning functions.</td>
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<tr>
<td></td>
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<td>• Increase user involvement in real time decision making.</td>
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<td></td>
<td>• Optimise runways and CNS/ATM infrastructure.</td>
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<tr>
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<td>• Enhance airport capacity in low visibility conditions.</td>
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<tr>
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<td>• Integrate air and ground.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Integrate gate-to-gate.</td>
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<td>4</td>
<td>2010 – 2015</td>
<td>• Redistribute responsibilities between controllers and pilots.</td>
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<tr>
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<td>• Maximise freedom of movement to the greatest extent possible and</td>
</tr>
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<td>exploit new opportunities.</td>
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#### 2.4 Traffic Growth

Although there is a variation in traffic densities across the ECAC area, the underlying requirement for the EATMS stems from the need to handle overall forecast traffic increases in excess of 100% by 2015 safely and cost effectively while providing airspace users with the ability to operate on time and with greater flight efficiency.
3 Definition of Capacity

3.1 Overview

Capacity is a complex subject affected by a variety of issues; however, in terms of the EATMS, the OCD describes capacity as encapsulating the freedom to operate aircraft on time. Flight efficiency is described as encompassing the freedom to operate aircraft effectively in terms of optimum flight profiles.

The overall capacity of the current ATM system is determined by three inter-related factors:

- Airspace - The number of aircraft that the airspace can physically accommodate,
- ATM - The number of aircraft which the ground ATM system is capable of handling safely, and
- Airports - The number of aircraft that can take off and land during the hours of operation.

The physical capacity of the airspace is a function of how much airspace is available, the amount of traffic that wishes to use it, and the rules and separation minima applied. ATM capacity is dictated by the workload limits of the roles and tasks of the people who provide the ATM services, in particular, in present concepts, the tactical controller. All three of these factors have to be balanced if delays are to be avoided.

While the EATMS incorporates a gate to gate strategy, it does not include the need for, or provision of, new runways and airports. The relevant airport capacity issue, therefore, is for the EATMS to exploit the available airport runways, taxiways, and stands to the fullest extent. This, in turn, includes consideration of how to narrow the gap between normal and low visibility operations.

3.2 Factors Affecting Airport and TMA Capacity

Airport capacity is affected by a wide variety of factors. Many of these factors are not directly linked to the air traffic management system. Factors affecting how and when an airport is operated (and thus its capacity) include:

- Airfield Configuration,
- Airspace Design,
- ATC Operational Rules,
- ATC Facilities,
- Aircraft, Pilot and Controller Performance,
- Traffic Mix (aircraft types),
- Traffic Distribution (arrival and departure flows),
- Predominant Weather Conditions, and
- Environmental Constraints.
3.3 Runway Capacity

Runway capacity is the maximum number of aircraft operations that can be processed during a specific time interval and under specific conditions. The measurement is conventionally air transport movements per hour, distinguishing between IFR and VFR operations. It is capacity under IFR conditions that is significant to European airports where IFR conditions predominate. There are a number of definitions of runway capacity and there remains within Europe substantial differences in how runway capacity is declared.
4 Concepts, Procedures and Technologies

The ATM system capacity within a TMA is determined by a combination of factors. Among these are airspace constraints, airspace design, mix of traffic, technical systems, infrastructure, operational procedures and rules, separation criteria, weather, controller workload, and level of automation. One or more of these may affect capacity. The overall capacity of the TMA may be governed by the capacity of the airport, the airspace, or the ATM system.

A possible path to the introduction of new concepts, procedures, and technologies over the EATMS time frame is set out in the EATMS OCD V 1.0. It is a high level view of the possible stepped operational changes needed to reach the targets envisaged by EATMS. Suggested progress over the period to 2015 is set out with potential changes grouped into seven interrelating axes. The OCD diagram illustrating this is reproduced below:

![Figure 1](image-url)

Not all of these stepped changes are underpinned by the analysis completed to date (March 1997), and there will be need for further research to investigate their feasibility and benefits. Nevertheless, the diagram serves to illustrate the type of changes that will be needed over time to reach the EATMS target concept.

This review, examining those aspects affecting TMA and airport operations, is arranged in the following subsections using the seven axes found in the diagram to provide compatibility with EATMS documentation.
4.1 Airspace and Airport Infrastructure

4.1.1 Airspace Infrastructure

4.1.1.1 Optimisation of Arrival and Departure Routes

The Strategic Deconfliction of Arrival and Departure Routes is an established principle of terminal airspace design. Airspace planners establish and publish standard arrival (STARs) and departure (SIDs) routes and associated procedures within TMA airspace which are adequately separated from one another. Controllers clear aircraft to operate on these routes on a routine basis. Where the capacity of TMA airspace is a constraint at a particular airport, deconfliction and resectorisation can often adjust the routeing and procedure so that the TMA is no longer the constraint. The deconfliction of terminal airspace enables the operation of a number of adjacent runways or airports more safely and efficiently, supporting, where possible, additional runways to meet demand.

Environmental constraints may require that SIDs are co-located with noise preferred routes (NPRs), to the detriment of capacity due to the difficulty in deconfliction. The introduction of SIDs and STARs defined by PRNAV can overcome this to some extent as aircraft are more precisely positioned on their routes.

The introduction of the Terminal Area All Round Arrival & Departure concept together with associated automation and support tools allows the development of procedures where aircraft arrive and depart on any heading. In the case of departing aircraft, the ability to input waypoints into the system, or pre-plan and store a PRNAV departure route, facilitates the design of SIDs as there is no need to provide ground-based navigational aids (also saving the associated costs). Further, earlier and more precise turns onto track by departing aircraft may enable an increase in runway capacity by reducing the time required before release of the runway following a departing aircraft.

4.1.1.2 Airspace Design and Traffic Segregation Based on Performance

Future airspace design and use will tend to be determined by aircraft performance, avionics and equipment fit. Portions of terminal airspace may be reserved for the exclusive use of aircraft able to receive an improved service using new ATC procedures allied to specific minimum equipment fit. The development of new ATM procedures requires airlines to adhere to certain minimum standards of avionics and communications equipment, called here the MNP fit.

The aim of the ATM authorities is to increase ATM capacity using these new procedures. However, in order for the procedures to give maximum benefit to the airspace users, it may be necessary to segregate the traffic into MNP/Non-MNP airspace. There it will be possible to employ different separation standards and to use new control procedures (such as time control).

4.1.1.3 Separate Access Landing System (SALS)

SALS is a mature procedure where a discrete approach path is provided for commuter aircraft to make their approach to a subsidiary runway. Steep approach paths and displaced thresholds allow commuter aircraft to use shorter subsidiary runways. The procedure is in use in the USA and has been tested in Europe.
4.1.1.4 Contribution to Capacity

Each of these modifications to airspace management holds promise for increasing capacity; however, more research is needed to determine the level of capacity gain that can be achieved. These concepts hold particular promise for reducing departure aircraft delays.

4.1.2 Ground Movements

4.1.2.1 General

A number of procedures and techniques that may contribute to increased airport capacity are already in a mature state and in some cases in use at specific locations. Although these often do not fall into the category of future concepts and indeed might not be considered EATMS concepts for this study; it is nevertheless necessary to consider them as a part of the package of enhancements that will combine to provide the capacity needed for future airport operations. Modification of airfield surface operations, such as taxi-patterns, entry/exit points, and holding points can increase departure and arrival capacities and impact on flight efficiency and environmental factors.

4.1.2.2 Airfield Layout

One area where capacity gains can be made is by improving the efficiency of airfield surface operations thereby increasing landing and departure rates. This can bring consequential benefits to the flow management system by removing at least some elements of the delays caused by airfield constraints. Example areas of improvement include:

- Departure queue pads enabling improved flexibility for the ordering of departures,
- Aircraft staging areas to improve gate allocation while reducing taxipath congestion, and
- Parallel uni-directional taxipaths to provide fluid aircraft flow.

4.1.2.3 Runway Exits

Implementation of improved runway exits improves system capacity by reducing runway occupancy time. Examples of programs include the Provision of Appropriate Rapid Exit Taxiways (RETS) and Rapid Access Taxiways (RATS).

4.1.2.4 Contribution to Capacity

The airfield design is a fundamental factor in any technology program to increase capacity. As arrival separations are reduced the ability of pilots to clear the runway in a consistent minimum time, becomes increasingly significant. Potential flight efficiency along with environmental and capacity gains from the introduction of arrival/departure management tools and ASMGCS are significantly affected by airfield design.

4.2 ATFM (Air Traffic Flow Management)

4.2.1 General

Current European ATFM falls into three distinct but integrated layers: strategic, pre-tactical and tactical, which range in time from six months to immediately before a flight.

The main objectives of this planning process are to balance capacity with demand to prevent any overloading of the ATM system. These objectives aim to identify and resolve capacity
shortfalls by managing and optimising traffic flows at the earliest possible stage (thereby causing the minimum of user disruption).

At present ATFM stops once the flight is airborne. Any additional flow issues are resolved tactically by ATC. This latter requirement to regulate traffic flows in real-time has led to the introduction of Arrival Flow Management tools such as MAESTRO and COMPAS (which provide traffic metering and sequencing information) and the proposed development of the Aircraft Situation Display (ASD) to aid short-term ATFM and tactical flow streaming. The use and development of these tools is limited to only a few ECAC areas at present.

A shift towards the use of more random routings to improve flexibility may reduce ATFM planning horizons and place a greater emphasis on the need for some form of shorter-term tactical ATFM to manage capacity. Options in this area include the use of an Area Manager concept involving shorter-term, multi-sector flow planning just prior to a flight (60 to 10 minutes before departure) coupled to the principles of dynamically changing sectors and supported by Departure and Arrival Manager tools.

4.2.2 Tactical Flow Manager
The Tactical Flow Manager (TFM) assists the controller with traffic flow management. It is anticipated for use in the time horizon between Strategic Flow Management, where a global traffic flow will be influenced, and a short term ATC planning function, where the individual aircraft is already under control. With the Tactical Flow Manager, the operations of a single aircraft will already be influenced to avoid both sector overloads and traffic (airspace) conflicts. This will be achieved with flight plan updates resulting in ground-holding delays in combination with small airborne delays and/or alternative flight paths (giving consideration to user preferences).

4.2.3 Advanced Traffic Management System
The FAA Advanced Traffic Management System (ATMS) is designed to allow air traffic managers to identify in advance when en route or terminal conditions such as weather may require traffic flow intervention to expedite and balance the flow of traffic. The aim is to research automation tools that will minimise the effects of system overload on user preferences.

4.2.4 Contribution to Capacity
When combined with the potential from arrival/departure/ASMGCS tools for delivery of flights with reduced variation from planned times, development of ATFM techniques will contribute to the optimisation of flow (and thus capacity). Such optimisation is expected to provide both flight efficiency and environmental gains.

4.3 Traffic Management Procedures
4.3.1 Distributed Air and Ground Responsibilities
Airborne Collision Avoidance System (ACAS) has already brought a degree of situational awareness to the cockpit. This trend is likely to continue with the introduction of ASAS (Airborne Separation Assurance Systems) and improved cockpit HMI (Human Machine Interface). As in ACAS, ASAS incorporates a surveillance element that may be used to effect separation assurance based on airborne equipment.

Flight crews will increasingly become aware of the surrounding airborne traffic situation. This has led to the notion of autonomy of flight, where flight deck awareness could be put to active and practical use.
With this increase in awareness comes the possibility to distribute air and ground responsibilities that involve the sharing of responsibility for separation assurance with aircraft suitably equipped to ensure their own separation from other aircraft (thereby reducing controller workload).

The Traffic Alert and Collision Avoidance System (TCAS) is under further development to assist in implementing an independent airborne collision avoidance capability. TCAS technology is aimed at increasing situational awareness and contributing to increased capacity in situations such as simultaneous approaches to parallel runways and pilot-maintained in-trail spacing via an improved cockpit display.

The NASA Airborne Information for Lateral Spacing (AILS) project uses airborne technology-assisted approaches to reduce lateral spacing requirements during Instrument Meteorological Conditions (IMC). The aim of this system is to provide crew with information on nearby traffic comparable to that available in Visual Meteorological Conditions (VMC).

### 4.3.2 Contribution to Capacity

While autonomous separation has the potential to help reduce ATC workload and enhance flight efficiency, the feasibility and potential benefits of autonomous operations in busy traffic areas which are already well served by CNS/ATM infrastructures have still to be demonstrated. There are a number of key issues still to be resolved concerning the ability of aircraft employing autonomous separation to successfully negotiate safe trajectories in multi-conflict situations. Also the separation minima to be adopted may be in excess of that which could be achieved using ground-based systems. The impact of autonomous separation on capacity is, therefore, still largely unknown.

### 4.4 Systems

#### 4.4.1 Enhanced Arrival Sequencing and Metering

Enhanced sequencing and metering of arrivals provides for direct ATM arrival/departure management and FMS negotiations for terminal area trajectories. It also recognises individual aircraft performance capabilities and operator preferences for arrival timing and fuel management. Further developments could also address other control functions such as separation monitoring, conflict identification, generating conflict-free aircraft groups, and wake vortex warnings.

##### 4.4.1.1 General

Computer based tools are being developed to optimise the arrival flow from the enroute system into an approach sequence, minimising unnecessary gaps between arrival traffic (thereby maximising runway utilisation).

Tools such as COMPAS, MAESTRO, and CTAS are under development to assist the approach controller in the more accurate management of the arrival and departure streams, increasing peak arrival capacity. This becomes essential as more wake vortex categories are implemented and when wake vortex tracking allows a dynamic optimisation of the arrival separations used.

##### 4.4.1.2 Arrival Managers

The Arrival Manager (AM) is a ground-based planning tool with the purpose of assisting the controller in guiding both equipped (4-D FMS with data link) and non-equipped (without any data link capability) aircraft, ensuring the safe, efficient, and economic flow of inbound traffic.
into a terminal area. The AM is part of an integrated ATM concept making use of functions related to onboard (EFMS) and ground-based tools.

The Arrival Manager’s area of responsibility covers a distance of about 100 to 150 nautical miles around the considered airport and is called an extended TMA. For all inbound flights within this area, it generates optimised scheduling and sequencing constraints, taking into account airport configuration aspects. In the case of an equipped aircraft, these constraints can be transmitted and further processed by the onboard EFMS. Otherwise, for non-equipped aircraft, the constraints will be transformed into advisories that the controller shall enable to guide the aircraft on calculated trajectories in time.

### 4.4.1.2.1 Arrival Managers Currently in Operation or Under Development

A number of systems are currently in operation or under development including:

- The Dutch ASA system at Schiphol since 1981.
- The German COMPAS (Computer Orientated Metering Planning and Advisory System) system at Frankfurt since October 1989.
- The French MAESTRO/MOZART (CENA) (Means to Aid Expedition and Sequencing of Traffic with Research of Optimisation) since 1989. Sequences TMA arrival flows into one landing stream.
- The EUROCONTROL Zone of Convergence (ZOC).
- The NASA Centre/TRACON Automation System (CTAS) with four subsystems: Traffic Management Advisor (TMA); Descent Advisor (DA); The FAST (Final Approach Spacing Tool) element of this system which assigns and constantly updates landing runway, sequence numbers, speed and turn advisories; and the Expedite Departure Path (EDP).
- 4D-Planner (DFS/DLR).
- ADAS (Aircraft Departure / Arrival Sequencing system).
- ARAMIS, to enhance the accuracy of the sequence of arriving aircraft.
- ARCOS (Arrival Co-ordination System).
- ASMAP (Approach Sequencing, Metering and Advisory Processing).
- CRDA (Converging Runway Display Aid) developed by the Mitre Corporation.
- OSYRIS (Ortogon System for Real-time Inbound Sequencing) based on ZOC.
- PATAM (PHARE Advanced Tool Arrival Manager).
- TCSGD (Terminal Control Systems Development Group), developed by the UK Defence Research Agency (DRA) Malvern, with three experimental computer based tools: LOC (Landing Order Calculator), SCA (Speed Control Advisor), PATCAS (Predictive Approach Control Tactical Advisory System).
- SARP (Signal Automatic Radar Data Processing). An ETA calculator.

All the tools currently in operation, and the majority of those under development, are self-contained ‘stand-alone’ tools, (i.e. used as add-on elements to the current ATM-systems). In this case no air/ground co-operation or negotiation is performed. All these tools are strictly ground-based, and are used to assist controllers in the current ATC environment with the current aircraft equipment. All sub functions required, (e.g. trajectory prediction, conflict probing and problem solving) are incorporated in the tools themselves.

### 4.4.1.2.2 Contribution to Capacity

Arrival Sequencing tools contribute to capacity by smoothing out controller workload, and avoiding overload conditions. Final approach spacing tools assist the controller in spacing aircraft more accurately and may provide capacity gains as aircraft are delivered to final approach more efficiently.
4.4.1.3 Departure Managers

The Departure Manager (DM) is a ground-based planning tool intended to provide optimised departure schedules and advisories to departure controllers, meeting constraints from flow control while ensuring the efficient and safe flow of outbound traffic from airports into enroute control sectors. The DM should also provide climb profiles that are negotiated with the aircraft that should allow economic, uninterrupted climb-out and the safe integration of the flight into over-flying enroute traffic.

4.4.1.3.1 Departure Managers Currently in Operation or Under Development

In general, the development of planning tools dealing with the management of the departure traffic is relatively immature when compared to development in arrival management. The first step towards providing such a tool was made by DEPCOS (Departure Co-ordination System). DEPCOS is an automatic tool dealing with the co-ordination of outbound traffic. It has been in operation at Frankfurt since May 1991 and has also been installed in the new Munich II airport. Departure scheduling functions have also been included in the MAESTRO/MOZART system at Orly (since May 1994).

Additional systems in operation or currently under development include:

- EDP (Expedite Departure Path) by the FAA provides optimum climb profiles and routings for departing traffic in sequence with arrival streams, and
- PATDM (PHARE Advanced Tools Departure Manager).

4.4.1.3.2 Contribution to Capacity

Assistance in establishing and achieving an optimum order for departures, taking into account flow restrictions, TMA routing and aircraft type, should ultimately increase airport and TMA capacity by optimising departures flow.

4.4.1.4 Integrated Terminal Area Automation Tools

Integrated terminal area automation provides the ability to anticipate and adapt to changes in runway configuration or availability. Flexibility resulting from terminal area automation allows rapid adaptation to weather conditions that normally would deny use of portions of terminal area airspace.

Automated systems serving airports situated in close proximity may be combined and integrated to enable reduced co-ordination. This philosophy can be developed to accommodate increasing traffic levels and can be enhanced so that integration is achieved even across national boundaries.

4.4.1.4.1 Integrated Tools Currently in Operation or Under Development

The development of integrated tools for terminal area arrival and departure management is relatively immature. Examples of current activities include:

- The European Commission and Eurocontrol are co-operating to develop a combined approach to CADS (Combined Arrival and Departure Sequencing).
- In the US, the FAA TATCA (Terminal ATC Automation) program aims to develop automation aids to assist air traffic controllers and the Traffic Management Unit (TMU) co-ordinators in enhancing the terminal area air traffic management process and to facilitate the early implementation of these aids at busy airports. Longer-term activities include the integration of traffic flow management tools with other air traffic control systems and cockpit automation capabilities. The AATMS (Advanced Air Traffic Management System) element
is designed to allow air traffic managers to identify in advance when en route or terminal weather or other factors require intervention to expedite and balance the flow of traffic. The program researching automation tools is aimed at minimising the effects of NAS overload on user preferences.

4.4.1.4.2 Contribution to Capacity
The benefits to capacity have not been measured; however, the reduction in controller workload combined with the capability to provide a sustained optimised traffic flow will inevitably provide some capacity benefits.

4.4.2 Surface Movement Guidance and Control Systems (SMGCS)

4.4.2.1 Simple Visual SMGCS
Under visual SMGCS, the orderly flow of aircraft movements on the ground depends solely on the use of painted guide lines (e.g., taxiway centre line, taxi hold position, taxiway intersection, a/c stand, apron safety markings) and signs (mandatory instructions and/or information). Navigation of aircraft and vehicles on the airport surface depends on visual sighting rather than automated systems or ASDE.

4.4.2.2 Complex Visual SMGCS
Complex Visual SMGCS is a more advanced and complex guidance system employing today's technology where switched taxiway centrelines and stop-bars are used to aid surface traffic movement. Such systems are in wide use at today's medium to high-density airport operations.

4.4.2.3 Advanced SMGCS
A-SMGCS incorporates a guidance and control leader system. These systems provide for the routing, guidance, surveillance and control of aircraft and other airport vehicles in order to maintain their movement rate under all local weather conditions. The main functions of an A-SMGCS include:

- Surveillance, i.e. detecting the relevant ground traffic and obstacles on the airport’s movement area, compiling a picture of the current traffic situation and to make this information available to controllers in a useable format.
- Planning, i.e. computer-supported planning of surface traffic and assignment of ground routes to individual aircraft and vehicles (taking into account the current traffic situation and external planning data from Air Traffic services in order to optimise the traffic flow and to display recommendations for the traffic management to controllers).
- Control, i.e. assessing the traffic situation and detecting traffic conflicts such as runway incursions and taxi conflicts, as well as plan deviation conflicts.
- Guidance, i.e. making available the facilities, information and advice necessary to provide continuous, unambiguous and reliable information to pilots and vehicle drivers.

Function systems that characterise A-SMGCS include:

- Advanced lighting systems (including segmented taxi guidance from runway to parking position, taxi route planning, conflict prediction, and stop-bars).
• Advanced features such as RADAR and infrared systems to provide runway incursion warnings, improved controller displays and assistance tools, TV monitoring, automatic guidance, and docking.

• Surface Movement Radar technology that includes the use of colour displays and identification labelling to support automated taxi clearance, guidance and position monitoring.

• Full automation with aircraft positional information being derived from on-board systems via ADS-B and data-link.

• A situational display for the flight deck and vehicles that can be updated by satellite positioning systems incorporating the transponder identification.

• Enhanced Vision Systems and D-GNSS guidance and control systems.

• Ground Situation Management concept where the ground (and cockpit) display of the airport surface and traffic enables the automation of surface traffic management.

• A ground conflict probe.

4.4.2.3.1 Development

A number of systems are currently under development, including:

• AIRPORT-G ECARDA, addressing specific aspects of A-SMGCS with a view to enhancing ground movement and maintaining safety. Validation sites: LFPO & EHAM.

• ATHOS -ECARDA project looking at technological developments to assist the tower control function. Validation sites include EDDF, LFPG, EHAM, LIML, and EGLL.

• ATIDS (Airport Surface Target Identification System), an FAA project to develop aids such as airport surface surveillance, communications and automation techniques to provide all-weather runway incursion alerts and prevention capability.

• DAVINCI (Departure and Arrival Integrated Management System for Cooperative Improvement of Airport Traffic Flow), an ECARDA Program to define and demonstrate the feasibility of integrating and/or co-ordinating the components of existing and future airport traffic management systems.

• DEFAMM ECARDA project to implement a demonstrator system for A-SMGCS to analyse the results of systems implemented at four sites within Europe: Orly, Milan, Braunschweig, and Bonn.

• MANTEA (Management of Surface Traffic in European Airports) ECARDA project to develop decision support tools dedicated to the improvement of surface management in airports.

• SMA (Surface Movement Advisor) (FAA) The SMA will interface with and improve other NAS management systems and co-ordinate surface activities with air traffic control, the airlines, and airport operators through sharing of operationally-crucial surface movement information.

4.4.2.3.2 Contribution to Capacity

New and still developing technologies, including automation capabilities, are expected to help increase capacities at airports (particularly in low visibility conditions). ICAO Standards and Recommended Practices are being developed but will take some time to mature. In the
interim, ICAO is developing draft Operational Requirements and Guidance Material to aid the regional planning and implementation of modular Advanced-SMGCS.

The main capacity gains are likely to be in adverse weather conditions that today reduce the traffic flow drastically. Gains may also be expected in fair weather conditions by making best use of the available capacity. Additional benefits may be achieved by providing:

- ASMGCS interfacing and integration among airlines, airports and the elements of advanced ATM systems, and
- Better flight efficiency and reduced environmental damage by minimising ground operations with engines running; thus reducing fuel consumption, pollution, and noise.

4.4.3 Wake Vortex

4.4.3.1 Wake Vortex Tracking and Approach Control

With available technologies, it is not possible to track the wake vortices from aircraft. Consequently, each aircraft is placed in one of four or five classes according to their weight. The separation that the controller allows on the approach depends on these classes and is sufficient to allow safe operation in the worst case conditions. If real time tracking were available, it would be possible to separate the aircraft not by a fixed amount, but by the minimum that would allow avoidance of wake vortices. As this would result in a general reduction in separation between aircraft on approach, runway capacity could be increased.

4.4.3.2 Reduction of Wake Vortex Separation

There are two potential approaches to a possible reduction of wake vortex separation:

- Collect more accurate data on the vortex characteristics of each aircraft type, perhaps using actual take off weight and landing weight to derive a more complex set of separation minima.
- Predict, detect and/or monitor continuously the vortices as they are shed in the current atmospheric and wind conditions, setting the separation minima appropriately.

Each approach requires computer assistance for the controller. Automation is necessary to allow wake vortex separation standards to be configured to the actual rather than perceived threat, thereby improving flow rates.

4.4.3.2.1 Development

To track wake vortices a multi-step process to provide information to the approach controller is required so that aircraft may be separated in the most efficient way. Current development work is centred in the following areas:

- Development of laser or microwave radar sensors to detect and track wake vortices,
- Development of prediction algorithms that use tracking data and wind measurements,
- Trials at airports to gather data on wake vortices under typical conditions through the year and for a wide range of aircraft, and
• Development of approach sequencing tools and displays to enable controllers to use wake vortex data.

In the US, the FAA AVOSS (Advanced Vortex Spacing System) concept is under development to allow the application of dynamic separation standards between aircraft pairs using a prediction algorithm and real-time vortex wake detection sensors. The concept is based on development and implementation of a prototype Aircraft Vortex Spacing System (AVOSS). AVOSS uses current and short-term predictions of the atmospheric state in approach and departure corridors to provide to ATC facilities, dynamic weather-dependent separation criteria with adequate stability and lead time for use in establishing arrival scheduling. The AVOSS concept is planned to achieve this through a combination of wake vortex transport and decay predictions, weather state knowledge, defined aircraft operational procedures and corridors, and wake vortex safety sensors. Work is currently underway to address the critical disciplines and knowledge needs so as to implement and demonstrate a prototype AVOSS in the 1999/2000 time frame.

NASA is also conducting work under the TAP (Terminal Area Productivity) project to investigate new technologies for wake vortex evaluation and prediction including vortex motion and decay prediction, vortex encounter modelling, wake vortex hazard characterisation, and in-situ flow sensing.

4.4.3.2.2 Contribution to Capacity

The possibility of the existence of wake vortices extends the required approach and departure separations beyond the minima needed for adequate radar separation, runway usage, and missed approaches. Any action that reduces the operational impact of vortices will contribute to increased capacity at many airports – especially those with segregated arrival and departure streams. Even with the introduction of prediction and detection technology, factors such as prevailing weather and traffic mix will influence the potential gains at each particular airport.

4.5 Communications

4.5.1 Aeronautical Data-link

For start-up, taxi, climb-out, en-route and arrival phases of flights, information will be increasingly passed via ground/ground, gate-link or air/ground data links, rather than RT. This is made possible via ATN-compatible data-links that are under development for direct exchanges between aircraft and ground systems, automated negotiations with ATC for terminal area trajectories, and airport tower information. Ground communications, both for flight data and radar data, will be developed during the period and will gradually become ATN compliant.

As data-links become more available, impacts include:

• Sending ATC clearances via data-link will be extended.

• Replacing telephone communications by data link facilities except for non-standard messages, and telephone exchange facilities developed to provide direct and immediate selective access to specified recipients.

• Negotiating an arrival slot assignment based on ETA and descent performance calculated on-board individual arriving aircraft. The ground system can negotiate to minimise total system delay and to assign approach slots.
• Supplement RT for the communication of clearances and routing data that are not subject to time-critical transmission and which do not require instantaneous assimilation and action.

• Provide a potential source and update for situation displays that are used in ground vehicles and on the flight deck. Such data linking facilities and update can be provided for ATC ground stations.

• Assist in monitoring flight progress in the climb out, en-route and arrival phases.

• Pass information such as ATIS and aircraft/airline/airport services requests and notification of needs.

• Assist with routine or frequent ATC transactions between the pilot and controller.

• Download to ground systems on-board systems such as FMS actual flight data.

4.5.2 Development

Development of these communication concepts is governed via regulatory bodies. The principal ICAO bodies are ICAO ATN Panel and ICAO ADSP for development of Operational Requirements for AIDC (ATS Inter-facility Data Communications). ICAO operational requirements for inter-facility communication are available and the first implementations for validation are taking place. ICAO ATN Standards and Recommended Practices will be available from 1998 to support inter-facility data communications.

The initial implementation of the ATN will become available from 1998 onwards, progressing towards a coherent single network to support all data transfers (and in the future, possibly voice). Initially this will encompass existing networks by means of internet working protocols. The applications of AFTN, OLDI/SYSCO, CIDIN, and ADEXP will be supported in the early part of the timeframe.

4.5.3 Contribution to Capacity

Direct gains in capacity are difficult to judge; however, indirect gains may be inferred from anticipated benefits. Those protocols that assist in monitoring and conflict detection functions will provide better service to the user through more efficient communications. Data-link communications will also improve air/ground communications and contribute to system safety and capacity by improving pilot accessibility to information, relieving congested voice frequencies, and reducing the workload of pilots, specialists, and controllers.

4.6 Navigation

4.6.1 Flight Management Systems

4.6.1.1 Flight Management Systems

3D FMS are already in use and 4D systems may be available within the EATMS time frame. In conjunction with automated Meteorological, navigational and altimetry information inputs via data link from the ground, future flight management systems should be capable of selecting and monitoring optimised flight trajectories with great accuracy and applying any necessary corrections. These systems may also be capable of negotiating trajectories and clearances with the ground system, and effecting changes during all phases of the flight, including airfield surface operations.

Cockpit display facilities, which could include HUD (Head Up Display) and HDD (Head Down Display), may also be enhanced to improve situational awareness in the cockpit. This
could include the use of specific functions tied to particular operations such as taxi clearances, position monitoring (both on the ground and in the air), moving maps, weather display, and trajectory information. It may also be possible to use displayed SSR, ADS-B, or ground supplied surveillance information to monitor other aircraft for reduced separation minima during the approach and landing phases.

4.6.1.2 Advanced Airborne Navigation Equipment
Currently, research and development is taking place on improved Flight Management Systems (FMS), using advanced navigation systems (such as RNAV). These systems provide high navigational accuracy in four dimensions (lateral, longitudinal, vertical, and time). The systems rely upon data-link communication with ground systems for the exchange of data on meteorology, cleared flight path, requested (optimum) flight path, and information about other aircraft. In principal the navigation system assumes a three dimensional area (“bubble”) which travels as close as possible along its optimum flight path with accurate time constraints of when to reach certain (way) points. The navigation system keeps the aircraft within this three-dimensional area.

Development of this equipment requires the existence of highly accurate navigation input, data-link (suitable for time critical applications) and a sophisticated ATM ground system. Successful implementation depends not only on the airborne navigation system, but also on the existence of an appropriate ATM/CNS infrastructure.

Currently, the ATM concept, and the ATM function of 4-D navigation with sophisticated FMS, is still under development. Technical developments evolve much faster than the definition of the operational use. Operators will only equip their aircraft when the economic and/or operational benefit is clear.

It is expected that 4-D FMS will be technologically demonstrated by the year 2005. However, as the concept of 4-D navigation is closely related to ATM itself, the extensive operational use of 4-D FMS will depend on their defined function as part of the future ATM system (which is still under development).

4.6.1.3 Provision of Separate Airspace for 4-D Equipped Aircraft
It has been suggested that separate lanes of airspace be allocated to aircraft that have 4-D FMS equipment. It is essential to evaluate the impact this will have on the rest of the ATM system and to determine the costs and benefits of providing separate air lanes for these equipped aircraft, thereby assessing its feasibility.

4.6.1.4 Satellite Navigation
GNSS (Global Navigation Satellite System) is already in use in some areas and is expected to form the cornerstone of future navigation operations. Its use is also linked to the expansion of RNAV operations. RNAV equipment fits are expected to become standard in most aircraft in the future. When used in conjunction with other airfield systems, the accuracy they provide may also be used as the basis for automated surface movement and docking at airfields. Future developments include their use in developing ground-independent landing systems.

ICAO endorses GNSS as the future global navigation system, for sole means navigation. As such, their reference system, referenced as GNSS2, can be used to meet navigational requirements. The US Global Positioning System (GPS), developed for military purposes using the WGS84 co-ordinate system, is available. Russian Federation Global Orbiting Navigation Satellite System (GLONASS) will become available but is however not yet fully developed.
Systems are under development to increase the availability and integrity of GNSS (e.g. WAAS in US and EGNOS in Europe). Use of GPS is permitted by some European States, but another approved means of navigation must be serviceable and continuously displayed to the crew (i.e., GPS is currently used as a supplemental means of navigation).

In 2005, it is expected that GNSS will be available to be used for supplemental navigation (GNSS1). However this will not give the benefits in the core area of Europe, which would result from sole means use (GNSS2).

Whether GNSS for sole means en-route use will be available in 2005 depends on the pace of development of ICAO Standards and Recommended Practices, aircraft requirements, the FOC (Full Operational Capabilities) of EGNOS, and of the GNSS itself which should meet all civil aviation requirements. It is the intention that EGNOS FOC will provide the technical capability for sole means to ‘near CAT 1’ approaches in the year 2002.

4.6.1.5 Contribution to Capacity
On-board satellite navigation systems are central to future reductions in separation minima (and the subsequent increases in airspace capacity), including the use of curved approach paths, and reduced separation parallel and intersecting runway operations. As a result, improvements to navigation systems should subsequently result in increased airport capacity.

4.6.2 Landing Systems

4.6.2.1 Curved approaches (Using FMS/MLS/ILS/GPS)
It may be possible to increase arrival capacity by using curved approaches to optimise the sequencing of arrival aircraft.

The original perception of the benefits of a curved approach was that a slow aircraft could be inserted into the approach sequence relatively close to the runway preventing delay to following faster aircraft. In practice, it is normal today for all aircraft to maintain approximately the same speed until final approach. The capacity gain from this feature of a curved approach is therefore not as significant as originally believed.

There are, however, a range of circumstances where a PRNAV/MLS/GPS curved approach could affect a capacity gain:

- Intersecting ILS paths,
- Terrain avoidance,
- Weather at non ILS/MLS equipped airfields,
- Very closely spaced runways,
- Noise sensitive areas.

4.6.2.2 Satellite Systems
The availability of D-GNSS has opened up an alternative for landing systems under Category I and, possibly, Category II conditions. Work is needed to evaluate the performance of such systems and to obtain certification. The prime objective is to provide GNSS with the necessary degree of accuracy, availability, and integrity for all phases of flight (including approach and landing guidance).

GPS will make precision approach procedures available to more airports by significantly reducing frequency congestion problems associated with ILS. Improving the capacity of the airspace surrounding airports, it will reduce the interdependency of proximate airports. Augmented GNSS Improved Approaches may provide a precision approach capability to all
runways with flexibility to permit operations into and out of closely spaced runways and adjacent airports.

4.6.2.3 Enhanced Vision Systems (EVS)

The use of Enhanced Vision Systems (EVS) for the pilot may also play a role in facilitating low visibility approaches to airports. These systems could be based on thermal imaging or millimetric imaging technologies. The performance of these systems needs to be evaluated in real aircraft and the means of integrating them with the other avionics systems should be demonstrated to evaluate the technologies that are available to give approach and landing guidance in Category IIIB conditions.

4.6.2.4 Contribution to Capacity

The capacity benefits from curved/segmented approaches will apply mainly in special circumstances. These will include situations where ILS paths intersect, separate access and landing systems (SALS) and obstructed straight in approaches including those caused by noise or environmental aspects.

In the later part of the EATMS period, integration of Enhanced Vision Approach and Landing technology with ASMGCS EVS may bring significant gains during poor weather operations by allowing full airport operation.

4.7 Surveillance

4.7.1 TMA Surveillance

A principle of the EATMS is to develop a co-ordinated plan, for the whole of the area covered by the EATMS, addressing the siting and operational procedures for the surveillance systems in each area. The goal is a unified system, taking into account interaction with adjacent areas while giving optimum performance, rather than a set of independent systems.

Several factors affect the development of the future TMA surveillance infrastructure:

- The number of aircraft under surveillance coverage will increase significantly.
- Multi-RADAR tracking and data fusion systems should result in greater sharing of data.
- There will be a greater variety of surveillance systems in use. For example, Mode S stations will be operating in areas adjacent to conventional mono-pulse SSR systems. Passive surveillance systems, such as ADS, will be available for sole use or as a supplement to the radar systems.

During the period of transition to future systems, it will be necessary to ensure continuation of surveillance performance and services in one area as the systems in the adjacent areas are changed.

4.7.2 Aircraft Separation

4.7.2.1 Separation Standards

Historically, separation standards in ATM have always evolved to reflect the capabilities offered by improvements in navigation and surveillance systems. The availability of air-ground data communications and GNSS position information for navigation and surveillance, together with other relayed information about aircraft dynamics and status, means that it will
be possible to determine an aircraft’s position and movement in relation to other traffic with a far greater accuracy. This, in turn, offers possibilities for reducing separation minima.

There are various choices on how reduced separation minima could be applied, and what division of responsibility for separation should be shared between the air and ground elements. The options that take advantage of more accurate positional information are intrinsically linked to the division of responsibilities and concepts adopted. Examples of these choices include:

- Tactical separation using on-board systems and aids such as ADS-B and, or, ASAS.
- Application of reduced wake vortex minima, or the adjustment of wake vortex categories, predicated on real-time information derived dynamically from aircraft via data link.
- One-way directional routes or flight levels, which could be linked to traffic flows and densities.

### 4.7.2.2 Reduced Separation

Separation standards (lateral and longitudinal) may be reduced for appropriately equipped aircraft to reflect the greater accuracy of the systems in use. However, a number of factors (buffers) are built into separation standards both on the ground and in the air.

In the air they are:

- Wake vortex requirements,
- Reduced visibility factors,
- Equipment performance,
- Human intervention,
- Fixed track requirements, and
- Environmental factors.

On the ground they are:

- Wake vortex requirements,
- Reduced visibility factors,
- Equipment performance,
- Human intervention,
- Taxiway configuration, and
- Runway configuration including the position and design of turnoffs.

### 4.7.2.3 Contribution to Capacity

Development of Surveillance accuracy presents possibilities for reducing separation minima. There are, in turn, various choices on how reduced separation minima could be applied, and what division of responsibility for separation should be shared between the air and ground elements.

The options available to apply separation to take advantage of more accurate positional information are intrinsically linked to those taken on the divisions of responsibilities and concepts adopted.
4.7.3 Simultaneous Use of Parallel Runways - Precision Runway Monitor

4.7.3.1 General
In recent years, there has been significant activity to establish methods of achieving capacity gains from the simultaneous use of parallel and intersecting runway operations both in Europe and, particularly, in the USA.

4.7.3.2 PRM (Precision Runway Monitor)
The Precision Runway Monitor (PRM) consists of an improved mono-pulse antenna system that provides high azimuth and range accuracy and higher data rates than the current airfield surveillance RADAR. The PRM system also allows controllers to monitor the parallel approaches of aircraft on high-resolution colour displays and generates controller alerts when an aircraft appears to wander off course.

There are two versions of the PRM system. One system, (E scan), updates an aircraft’s position every 0.5 seconds using an electronic scanning antenna. The other system uses two rotating antennas mounted back to back and provides an update interval of 2.4 seconds.

4.7.3.3 Contribution to Capacity
The FAA claims that the PRM system can increase IFR capacity by 40-100 percent, depending upon the operating baseline. The procedure reflects, however, the present layout of many large US airports, where increased operation can be achieved either with existing runways or by expansion within airport boundaries.

A number of Europe’s busiest airports could potentially benefit in terms of improving runway capacity subject to other constraints. The gains from this tool would be difficult to realise without its integration with other measures to address airspace constraints and limitations on the ground. The PRM may be an essential tool where any future runways are built at Europe’s relatively small and environmentally constrained airports.

4.7.4 Airport Surveillance

4.7.4.1 General
One of the factors limiting airport capacity is the lack of accurate surface traffic surveillance data. Airport surveillance is a fundamental tool to assist the airport controllers in the awareness of the surface traffic, including aircraft and vehicles, for them to give movement guidance.

Present day systems make use of data from Airport Surface Movement RADAR (ASMR). There are now several emerging technologies that may be applied to this task to improve the accuracy and integrity of the surveillance data.

4.7.4.2 ADS-Broadcast
Position reporting systems, often referred to as ADS-B (ADS-Broadcast) systems, apply an appropriate mobile data-link to broadcast the position of the aircraft (or any other vehicle). This position information can then be transmitted to any receiving station within coverage range - there is no dedicated link between aircraft and ATC and no ADS-contract.

One option is to develop an ADS system utilising a network of omni-directional aerials spread around the airport to give the required coverage. The system would provide accurate state information (such as position and speed), derived from D-GNSS, obtained from the vehicle or aircraft on-board systems. This could be based upon ADS-Mode S using an extended squitter.
Presently two position reporting broadcast systems are under development:

- The Mode S extended squitter, where the standard Mode S is extended with position information. In GPS squitter technology, Mode S transponders relay two additional messages: 1) GPS position and altitude in the air or position, heading and speed on the ground. 2) Aircraft identity.

- The VHF data-link, suitable for position reporting, using Self-organising Time Division Multiple Access (STDMA).

Another option is to develop multi-lateration for Mode S. This system also uses a network of omni-directional aerials but with multiple receivers. The time of reply of the extended squitter at each aerial is measured. This information is then used to determine the aircraft’s position. The receivers may be synchronised using the GNSS time reference. The standard Mode S squitter can also be used but this is not transmitted when aircraft are on the ground.

The EATMS approach is to define candidate systems and develop a prototype of the system. The performance and integrity of surveillance link to the aircraft or vehicle is then evaluated, to prove that the system can provide sufficient coverage. Finally, the on-board systems are validated to show that they can provide positional data of sufficient accuracy (for the ADS type system).

### 4.7.4.3 Development

Details of the planning for airport surveillance development and regulation have been addressed by various panels, including:

- ICAO ADS Panel: development of operational requirements for “ADS-B”,
- ICAO AMCP: for development of CSMA/VDL and STDMA/VDL SARPs,
- RTCA SC 186: technical requirements for “ADS-B” in US, and

### 4.7.4.4 Contribution to Capacity

Production of a verified airport surveillance system suitable for integration with existing systems should help allow the safe, orderly and efficient airport traffic flow under all weather and visibility conditions and in all airport layout complexities. These surveillance systems form an important part of an improved Airport Ground Movement Control & Management system and could be expected to increase substantially the capacity of airports under IFR weather conditions.
5 Modelling Considerations

From the aspects affecting TMA and airport operations, described in section 4, ten topics have been selected for further examination. The criteria used for the selection are:

- Whether the concept, procedure, or technology may enhance capacity of an airport or TMA.
- Whether the application of the concept, procedure, or technology under Low Visibility Conditions may enable an airport to maintain capacity.

The concepts, procedures, and technologies used for modelling considerations may be identified by applying the two criteria above to determine whether they lead to:

- Improvements in airport and TMA capacities, or
- A stabilising effect, so that even under Low Visibility Conditions, the same capacity is maintained.

Based on these criteria, the following topics have been selected for further examination:

- Segregated Airspace,
- Arrival Manager,
- Departure Manager,
- Integrated Terminal Area Arrival and Departure Manager,
- A-SMGCS,
- Flight Management Systems,
- Wake Vortex Tracking,
- Optimisation of Arrival & Departure Routes,
- Reduced Separation, and
- Reduced Separation on Parallel Runways.

Most of the topics listed above are candidates that may be expected to enhance airport and TMA capacities. A-SMGCS alone is a concept that might assist in achieving normal capacity levels under Low Visibility Conditions.

The concepts, procedures, or technologies listed above are all candidates for simulation during phase two of this study. To estimate the capacity gain that can be achieved by each of these, they have been modelled using a capacity calculating spreadsheet.¹

The concept of the spreadsheet and the calculated capacity gains are described in section 5.1. Based on these calculated capacity gains, the ten selected concepts, procedures or technologies are arranged in an order of decreasing expected capacity gain. This will then be used to order the simulation topics for phase two. The experimental design of those simulations is outlined in Section 5.3.

5.1 Initial Estimation of Capacity Gain

To calculate the expected capacity gain of the selected concepts, procedures and technologies, a spreadsheet was used. This spreadsheet is capable of calculating the runway capacity for four different modes: arrivals only, departures only, mixed mode if arrivals have a priority in

¹ We would like to thank the owner of the spreadsheet (P. Frankena, NLR) for his permission to use it for the TOSCA II, WP7 purposes.
the use of the runway over departures and mixed mode if at least one departure is to be released after each arrival.

5.1.1 Description of the Data

The spreadsheet takes the following input parameters into account:

- For arrivals, the error in the estimation of the time at which the interception point of the ILS will be reached (position error),
- The probability of violating the minimum separation rule for arrival spacing,
- The length of the approach path,
- Distribution of the aircraft mix over four different categories of aircraft, expressed in percentages,
- The approach speed for each of the categories of the aircraft mix,
- The runway occupancy time for each of the categories of the aircraft mix,
- The minimum distance from the arrival threshold at which an arrival must be for a departure to be released,
- Separation standards for departure-departure separation, and
- Separation standards for arrival-arrival separation.

To estimate the expected capacity gains, a basecase was created for comparison with the situations in which the proposed concepts, procedures, or technologies are applied. For the basecase situation, Amsterdam Airport Schiphol (AAS) in 1996 under good and bad weather conditions was used.

It should be noted here that the figures found in Annex A are rough estimates of the input parameters. They are only meant to calculate the theoretical runway capacity. This section does not pretend to give exact figures of the capacity or of the capacity gains, although the reference situation is validated with official figures from AAS.

5.1.2 Selected Concepts, Procedures or Technologies

5.1.2.1 Segregated Airspace

In the situation where different types of airspace are used for aircraft with different types of navigational equipment within the TMA, two different flows of aircraft will result. Those aircraft with the equipment fit suitable to exploit the improved service should intercept final approach with far greater accuracy. These aircraft are roughly modelled by applying a 15-second position error for the interception of Final (see the data definitions in Annex A).

5.1.2.2 Arrival Manager, Departure Manager, and Integrated Terminal Area Arrival and Departure Manager

Arrival, Departure, and Integrated Arrival and Departure Managers will be aimed at achieving a more optimal landing and departing sequence. One possible method to achieve this is to replace the FIFO (first in, first out) queue management concept with procedures that group aircraft of the same Wake Vortex Category. This process results in a decrease of the mean separation and therefore leads to a capacity enhancement. To model this effect, the input parameters of the runway capacity calculating spreadsheet were not altered. Rather, the concept of the spreadsheet itself was changed slightly by assigning a greater possibility for aircraft of the same wake vortex category following each other than is found in the original spreadsheet.
5.1.2.3 A-SMGCS

A-SMGCS is aimed at smoothing the traffic flow on the ground irrespective of weather conditions. An A-SMGCS should provide the same ground traffic guidance under Low Visibility Conditions as under good conditions. In order to express the effect on airport capacity resulting from the use of A-SMGCS a runway occupancy time of 60 seconds is used under all weather conditions.

5.1.2.4 FMS

Aircraft equipped with 4D-FMS are expected to fly more accurately on the time schedule and are to have a smaller position error in the estimation of time at the interception point on Final. That is why the choice is made to roughly model FMS (or 4-D FMS) by applying a position error of 1 sec. for the interception of Final (see the data definitions in Annex A).

5.1.2.5 Wake Vortex Tracking

With the various initiatives for Wake Vortex Prediction and Tracking, it is possible that a general reduction in separation between aircraft in the arrival and departure streams might be achieved. If this reduction in achieved, segregated mode operations (where arrivals are dedicated to one runway and departures to another) would see a substantial increase in capacity. In order to estimate this effect, the standard wake vortex separation minima is replaced in the spreadsheet by a minimum separation value of 2.5 nm between all aircraft groups (see the data definitions in Annex A).

5.1.2.6 Optimisation of Arrival & Departure Routes

The use of PRNAV by arriving and departing aircraft together with associated automation and support tools will permit the development of procedures whereby aircraft use any desired track. In practice, environmental constraints may require that SIDs are co-located with noise preferred routes (NPRs), to the detriment of potential capacity due to the difficulty in deconfliction. The introduction of SIDs and STARS defined by PRNAV can overcome this to some extent, depending upon the airport and noise sensitive geography, as aircraft are more precisely positioned on their routes.

To examine the possible impacts, it is assumed that the optimisation of departure routes will enable 50 percent of the aircraft to benefit from procedures such that the separation applied between departures is based on wake vortex separation only (no longer wake vortex figures coupled with speed differences). For arrival aircraft, while PRNAV may reduce overall route distance on approach, it would not deliver an increase in capacity as aircraft would still join the final approach track at five to seven miles from the runway threshold.

5.1.2.7 Reduced Separation

It is assumed that the minimum separation within the TMA can be reduced to 2.5 nm, corresponding to improved RADAR surveillance. As a result, the possible capacity gains are modelled in the spreadsheet with the use of 2.5 nm separation between aircraft in the same category where traditional wake-turbulence category differences are used for the separation between different aircraft categories (see the data definitions in Annex A).

5.1.2.8 Reduced Separation on Parallel Runways

When a Precision Runway Monitor or similar system is used, it may be possible to use two closely spaced parallel runways (which are currently treated as dependent runways) as independent runways. Current practice adds an extra diagonal separation of 2NM to arriving aircraft on different parallel runways when the runways are separated by more than 760m and...
less than 1035m. For runways separated by less than 760m, the extra diagonal separation criteria results in a minimum separation for arriving aircraft on the same runway of 3.9NM.

To model the reduced separation on parallel runways, no diagonal separation is required. Instead, a minimum separation for arriving aircraft on the same runway of 2.5NM is applied. This situation is also modelled by the Reduced Separation case.

For departures, parallel runways are currently treated independently in situations where the runways are separated by more than 760m. Reduction of the separation on such runways is modelled in the same way as Reduced Separation. For runways separated by less than 760m, separations are determined by wake vortex and aircraft category. Aircraft on different runways are treated as if they were on the same runway. Because of the small distance between the runways, and with respect to the Wake Vortex separation, the capacity of the two runways does not significantly differ from the capacity of a single runway. This situation is not modelled in the runway capacity calculating spreadsheet.

5.1.3 Results

The data found in Annex A were used to calculate the gain in capacity for four modes of operation: arrivals only, departures only, mixed mode with arrivals having priority over departures in the use of the runway and mixed mode with at least one departure released after each arrival. The following approximations of the capacity enhancement, expressed in percentages, were found:

<table>
<thead>
<tr>
<th>Concept, Procedure, or Technology</th>
<th>Arrivals Only</th>
<th>Departures Only</th>
<th>Mixed Mode</th>
<th>Mixed Mode At Least One Departure is Interleaved with Arrivals</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segregated Airspace</td>
<td>-3</td>
<td>0</td>
<td>-3</td>
<td>-4</td>
<td>-6</td>
</tr>
<tr>
<td>Arrival Manager</td>
<td>6</td>
<td>0</td>
<td>-8</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Departure Manager</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Integrated Arrival and Departure Manager</td>
<td>6</td>
<td>3</td>
<td>-8</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>A-SMGCS</td>
<td>0</td>
<td>0</td>
<td>54</td>
<td>14</td>
<td>54</td>
</tr>
<tr>
<td>FMS</td>
<td>9</td>
<td>0</td>
<td>11</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Wake Vortex Tracking</td>
<td>28</td>
<td>22</td>
<td>8</td>
<td>2</td>
<td>58</td>
</tr>
<tr>
<td>Optimisation of Arrival and Departure Routes</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Reduced separation</td>
<td>12.5</td>
<td>11</td>
<td>13</td>
<td>0</td>
<td>36.5</td>
</tr>
<tr>
<td>Reduced separation on parallel runways</td>
<td>28.5</td>
<td>11</td>
<td>10</td>
<td>0</td>
<td>49.5</td>
</tr>
</tbody>
</table>

Table 2 Expected Capacity Enhancements Expressed As Percentages

2 Total is the summation of the expected capacity enhancement, expressed in percentages, of the arrivals only mode, the departures only mode, and the best of the mixed modes.

3 The spreadsheet estimates an even higher number of movements per hour for A-SMGCS under bad weather conditions than under good weather conditions. This is the result of the far greater arrival-arrival separation presently used under Low Visibility Conditions. This increased separation between two successive arrivals allows multiple departures to be interleaved. Note that these assumptions do not take into account ILS protection criteria.
The last column of Table 2, Total, is meant to give an indication of the degree of expected capacity enhancement, irrespective of the runway usage mode. Using the runway capacity calculating spreadsheet all concepts, procedures and technologies showed a possible increase in capacity, except for the concept of segregated airspace (which resulted in a possible decrease of the capacity).

Based on these indications, the selected concepts, procedures and technologies can be arranged in order of decreasing expected capacity enhancement:

- Wake Vortex Tracking
- A-SMGCS
- Reduced separation on parallel runways
- Reduced separation
- FMS
- Integrated Arrival and Departure Manager
- Arrival manager
- Departure manager
- Optimisation of Arrival and Departure Routes
- Segregated airspace
6 Phase II Experimental Design

6.1 Introduction

During Phase I of TOSCA WP7, presented in this interim report, a variety of proposals for new technical systems and operational procedures to enhance airport and TMA capacity were evaluated to determine expected benefits. This process led to the selection of 10 concepts, procedures, or technologies to be further evaluated with computer-based modelling techniques:

- Wake Vortex Tracking
- A-SMGCS
- Reduced Separation on Parallel Runways
- Reduced Separation
- FMS
- Integrated Arrival and Departure Manager
- Arrival Manager
- Departure Manager
- Optimisation of Arrival and Departure Routes
- Segregated Airspace

6.2 Phase II Objectives

The TOSCA WP7 investigates the perceived beneficial effects of concepts, procedures, and technologies on airport and terminal area airspace capacity. For those expected to yield improvements in TMA and/or airport capacity, the impact on capacity will be measured.

6.3 Simulation Specifications

6.3.1 Software

Each of the 10 concepts, procedures, and technologies determined during the Phase I analysis will be examined during Phase II to determine their impact on airport and TMA capacity. The simulation modelling systems SIMMOD\(^4\) and TAAM\(^5\) will be used for the capacity evaluation.

6.3.2 Study Airport

To thoroughly evaluate the 10 concepts, procedures and technologies for their impact on airport and TMA capacity, the simulations will use a generic “Europort”. Europort is based upon Amsterdam Airport Schiphol with modifications to make this platform suitable for analysis of runway operations for the following configurations:

- Parallel dependent segregated mode,
- Parallel dependent mixed mode,
- Parallel independent segregated mode,
- Parallel independent mixed mode,
- Crossing segregated mode,
- Crossing mixed mode, and
- Single runway.

\(^4\) SIMMOD is the US FAA’s Airport and Airspace Simulation Model.
\(^5\) TAAM is the Preston Group’s Total Airport and Airspace Model.
6.3.3 Traffic
The traffic used in the simulation plays an integral part in determining airport and TMA capacity. There are two critical parts that define the traffic sample: Fleet mix and hourly demand.

The fleet mix, which represents the percentage of aircraft types using the airport and TMA infrastructure, changes markedly depending upon the airport location and market share. For example, smaller regional airports may have a proportionately higher number of smaller jets (such as B737 and A320s as well as smaller aircraft), while major European airports have higher percentages of large and heavy jets (such as B767, B747, A330, and A340). To reflect this, Eurocontrol’s STATFOR office in Brussels will prepare three fleet mix distributions to represent Major Hub, Minor Hub, and Regional Airport activities.

Four traffic demand levels will be simulated for each traffic fleet mix for each of the airport runway configurations. These traffic levels will correspond to typical reference case traffic levels for the airport configuration (a level resulting in virtually no delays for the airport configuration), followed by three increasing samples corresponding to traffic growth through the year 2015.

6.3.4 Capacity Determination
The Europort platform will be simulated under normal visibility and low visibility conditions using standard ATC procedures to define the two basecases. Similarly, the addition of each of the concepts, procedures, and technologies will be simulated on the Europort platform under the two visibility conditions. The simulations will produce average aircraft travel and delay statistics that will be used for calculating airport capacity figures.

To provide a flexible means for capacity definition, two capacity analyses will be done. The first analysis will generate curves that plot the average delay time per aircraft verses the hourly demand. When this average delay exceeds 10 minutes per aircraft, airport capacity is reached. In a similar manner, curves will be generated that plot the number of aircraft exceeding 15 minutes of delay in the simulation verses the hourly demand. When this value exceeds 3% of the traffic, capacity of the airport capacity is reached.

6.3.5 Simulation Scenarios
A simulation scenario is defined by a combination of Airport Platform, Operating Procedures, Runway Configuration, and Traffic. The table below summarises each of these simulation parameters:

<table>
<thead>
<tr>
<th>Simulation Parameter</th>
<th>Description</th>
<th>Number Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Platform</td>
<td>Europort</td>
<td>1</td>
</tr>
<tr>
<td>Operating Procedures</td>
<td>Normal and Low Visibility Conditions for the basecase and then each of the 10 concepts, procedures and technologies identified in this report.</td>
<td>12</td>
</tr>
<tr>
<td>Runway Configuration</td>
<td>Operating configuration of the runways and their direction. For this simulation, a total of seven runway configurations are examined (described in Section 5.2.3.2)</td>
<td>7</td>
</tr>
<tr>
<td>Traffic</td>
<td>Four traffic levels are simulated for each configuration corresponding to basecase traffic and three increasing levels.</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total Number of Scenarios to Simulate (Combined from Above)</strong></td>
<td></td>
<td><strong>336</strong></td>
</tr>
</tbody>
</table>
6.3.6 Simulation Teams

This large number of scenarios will, in fact, be split across two simulation teams. The work will be split evenly between the EUROCONTROL Experimental Centre (EEC) and the Nationaal Lucht-en Ruimtevaartlaboratorium (NLR). The EEC team will use SIMMOD while the NLR will use TAAM. Both the EEC and NLR will simulate all of the operating procedures and traffic. To ensure validation of the two modelling approaches, both teams will simulate all of the basecase runway configurations. The remaining runway configurations will be split between both teams.

6.4 Project Plan

The project is divided into five principal tasks:

- WP 7.4: Integrate individual concepts, procedures and technologies into the simulation platform,
- WP 7.5: Construct the traffic samples,
- WP 7.6: Run the simulations,
- WP 7.7: Analyse results and estimate capacity, and
- WP 7.8: Prepare and distribute report.

The following gantt chart summarises the planning for these tasks:
### 7 GLOSSARY

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAS</td>
<td>Amsterdam Airport Schiphol</td>
</tr>
<tr>
<td>ACAS</td>
<td>Airborne Collision Avoidance System</td>
</tr>
<tr>
<td>ADAS</td>
<td>Aircraft Departure / Arrival Sequencing System</td>
</tr>
<tr>
<td>ADEXP</td>
<td>ATS Data Exchange Protocol</td>
</tr>
<tr>
<td>ADS</td>
<td>Automatic Dependent Surveillance</td>
</tr>
<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance-Broadcast</td>
</tr>
<tr>
<td>AFTN</td>
<td>Aeronautical Fixed Telecommunication Network</td>
</tr>
<tr>
<td>AIDC</td>
<td>ATS Inter-facility Data Communications</td>
</tr>
<tr>
<td>AILS</td>
<td>Airborne Information for Lateral Spacing</td>
</tr>
<tr>
<td>AM</td>
<td>Arrival Manager</td>
</tr>
<tr>
<td>AMCP</td>
<td>Aeronautical Mobile Communications Panel</td>
</tr>
<tr>
<td>APATSI</td>
<td>Airport/Air Traffic System Interface</td>
</tr>
<tr>
<td>ARAMIS</td>
<td>???</td>
</tr>
<tr>
<td>ARCOS</td>
<td>Arrival Co-ordination System</td>
</tr>
<tr>
<td>ASAS</td>
<td>Aircraft Separation Assurance Systems</td>
</tr>
<tr>
<td>ASDE</td>
<td>Aerodrome Surveillance Display Element</td>
</tr>
<tr>
<td>ASD</td>
<td>Aircraft Situation Display</td>
</tr>
<tr>
<td>ASM</td>
<td>Airspace Management</td>
</tr>
<tr>
<td>ASMGCS</td>
<td>Advanced Surface Movement Guidance Control System</td>
</tr>
<tr>
<td>ASMR</td>
<td>Airport Surface Movement RADAR</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATFM</td>
<td>Air Traffic Flow Management</td>
</tr>
<tr>
<td>ATIDS</td>
<td>Airport Surface Target Identification System</td>
</tr>
<tr>
<td>ATIS</td>
<td>Automatic Terminal Information Service</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATMS</td>
<td>Air Traffic Management System</td>
</tr>
<tr>
<td>ATN</td>
<td>Aeronautical Telecommunication Network</td>
</tr>
<tr>
<td>AVOSS</td>
<td>Advanced Vortex Spacing System</td>
</tr>
<tr>
<td>CADS</td>
<td>Combined Arrival Departure Sequencing</td>
</tr>
<tr>
<td>CENA</td>
<td>Centre d'Etudes Navigation Aerienne</td>
</tr>
<tr>
<td>CIDIN</td>
<td>Common ICAO Data Interchange Network</td>
</tr>
<tr>
<td>CNS</td>
<td>Communication, Navigation and Surveillance</td>
</tr>
<tr>
<td>COMPAS</td>
<td>Computer Orientated Metering, Planning and Advisory System</td>
</tr>
<tr>
<td>CRDA</td>
<td>Converging Runway Display Aid</td>
</tr>
<tr>
<td>CTAS</td>
<td>Centre/TRACON Automation System</td>
</tr>
</tbody>
</table>
CSMA ...............................Carrier sense Multiple Access
DA .......................................Descent Advisor
DEPCOS ...............................Departure Co-ordination System
DFS ......................................Deutsche Flugsicherung
D-GNSS ...............................Differential Global Navigation Satellite System
DLR ......................................German Airspace Research Establishment
DM ........................................Departure Manager
DRA .....................................Defence Research Agency
EATCHIP .............................European Air Traffic Control Harmonisation and Integration Programme
EATMS ................................European Air Traffic Management System
ECAC ...................................European Civil Aviation Conference
ECARDA ................................European Coherent Approach for Research and Technological Development for Air Traffic Management
EFMS ..................................Experimental Flight Management System (Project of PHARE)
EGNOS .........................European Geostationary Navigation Overlay Service
ETA ......................................Estimated Time of Arrival
EU ........................................European Union
FAA ......................................US Federal Aviation Administration
FAST .....................................Final Approach Spacing Tool
FIFO .....................................First In, First Out
FMS ......................................Flight Management System
FOC .......................................Full Operational Capabilities
GLONASS ...........................Global Orbiting Navigation Satellite System
GNSS ....................................Global Navigation Satellite System
GPS .......................................Global Positioning System
HDD ......................................Head Down Display
HMI .......................................Human Machine Interface
HUD ......................................Head Up Display
ICAO ....................................International Civil Aviation Organisation
IFR .......................................Instrument Flight Rules
ILS .......................................Instrument Landing System
IMC .......................................Instrument Meteorological Conditions
LOC .......................................Landing Order Calculator
MAESTRO ...........................Means to Aid Expedition and Sequencing of Traffic with Research Optimisation
MANTEA .............................Management of Surface Traffic in European Airports
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLS</td>
<td>Microwave Landing System</td>
</tr>
<tr>
<td>MNP</td>
<td>Minimum Navigational Performance</td>
</tr>
<tr>
<td>MOZART</td>
<td>Means to Aid Expedition and Sequencing of Traffic with Research of Optimisation</td>
</tr>
<tr>
<td>NAS</td>
<td>National Airspace System</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NPR</td>
<td>Noise Preferred Routes</td>
</tr>
<tr>
<td>OCD</td>
<td>Operational Concept Document</td>
</tr>
<tr>
<td>OLDI</td>
<td>On-Line Data Interchange</td>
</tr>
<tr>
<td>OSYRIS</td>
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<td>Traffic Management Unit</td>
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<tr>
<td>VDL</td>
<td>VHF Data Link</td>
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</table>
VFR............................Visual Flight Rules
VMC ..........................Visual Meteorological Conditions
WAAS............................Wide Area Augmentation Service
WGS-84.........................World Geodetic Reference System 1984
ZOC ..........................Zone of Convergence
ANNEX A
In Table 4 below, the input parameters described in Section 5 of this report and used in the spreadsheet are reported with shading.

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<td>Aircraft mix&lt;sup&gt;6&lt;/sup&gt;</td>
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<td>A=20% B=49% C=28% D= 3%</td>
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<td>A=20% B=49% C=28% D= 3%</td>
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<sup>6</sup> Four different categories are used to represent the aircraft mix: A = Heavy aircraft, B = fast Medium aircraft, C = slow Medium aircraft, D = Light aircraft.
## Reference situation under good weather conditions

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<th>Runway occupancy time (s)</th>
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<th>Arrival manager</th>
<th>Departure manager</th>
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<th>FMS</th>
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<th>Optimised arrival and departure routes</th>
<th>Reduced separation on parallel runways</th>
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These separation values were applied for 50% of the departures in the Wake Vortex Tracking scenario. The remaining 50% of the departures used the standard separation values (found in the reference situation under good weather conditions).
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Table 4 Input parameters, used in the runway capacity calculating spreadsheet.