knowledge & development centre
Mainport Schiphol

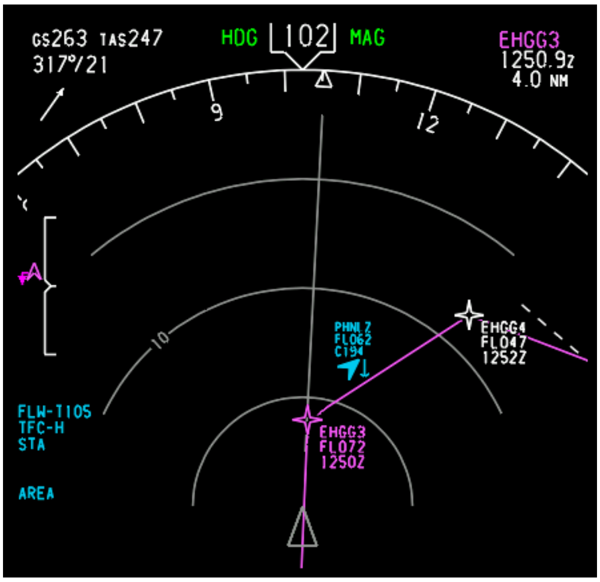
KLM

Amsterdam Airport Schiphol

OPERATIONAL SERVICES AND

ENVIRONMENT DEFINITION

ASAS Interval Management



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Executive Summary

A Continuous Descent Operation (CDO) is an operation, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix. An optimum CDO starts from the top of descent and will achieve the maximum reduction in fuel burn, noise and emissions [1].

Providing benefits to both the environment (low emissions) and the operator (fuel cost), CDO's however have been known to diminish capacity due to the greater spacing needed between the aircraft to account for uncertainty in aircraft performance. To ensure optimal system performance, the controller may need to place constraints on the aircraft (speeds, vectors, routes, altitude profiles), which decreases the efficiency of the CDO. These constraints, although made with the individual aircraft in mind, will inevitably move that aircraft away from its "ideal" descent profile and speed. An Airborne Surveillance Applications System (ASAS) - Interval Management (IM) Operation can help the individual aircraft to make the best trade-off between its own (most efficient) descent profile, and maintaining the system flow at critical junctures (e.g., runway threshold). By shifting the task to precisely space behind a lead aircraft to the cockpit, arrival accuracy may be increased, such that achieved capacity during Continuous Descent Operation remains constant or is improved.

With ASAS IM the controller will instruct the flight crew to achieve and/or maintain an Assigned Spacing Goal relative to a Target Aircraft. The key addition within ASAS IM to current operations is the provision of precise speed guidance within the flight deck to enable the flight crew to actively manage the spacing relative to the Target Aircraft. During IM Operations, the controller retains responsible for separation, while the flight crew is responsible for using the IM Equipment to achieve and/or maintain the Assigned Spacing Goal, that is set by the controller to meet the operational goals.

This document provides the definition of the proposed ASAS-IM Operational Application for Schiphol airport in the form of an Operational Services and Environment Definition (OSED) description. This OSED describes the services, intended functions and associated procedures of the ASAS-IM application and the assumptions about the environment in which the application is specified to operate. The document will form the basis for other future (Safety, Performance, Interoperability) requirements processes, which together provide adequate assurance that all appropriate aspects will perform their intended function in an acceptably safe manner.

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Abbreviations

AAS	Amsterdam Airport Schiphol
AC	Aircraft
AC-AV	Aircraft Avionics
AC-FC	Aircraft Flight Crew
ACC	Area Control
ADS-B ADS-B-RAD ADS-R	Automatic Dependent Surveillance – Broadcast -RAD = Radar -R = Re-broadcast
AGL	Above Ground Level
ALT	Altitude
AMAN	Arrival Manager
AMS	Amsterdam
ANSP	Air Navigation Service Provider
AOC	Airline Operations Control
APP	Approach / Arrival Control
A-RNP	Advanced - Required Navigation Performance
ASAS	Aircraft Surveillance Applications System
ASEP	Airborne Separation
ASPA	Airborne Spacing
ASR	ATM System Requirements
ATC	Air Traffic Control
ATM	Air Traffic Management
ATSA - AIRB	Airborne Traffic Situation Awareness - Airborne
CDM	Collaborative Decision Making
CDO	Continuous Descent Operation
CDTI	Cockpit Display of Traffic Information
CNS	Communication Navigation Surveillance
ConOps	Concept of Operation
CPDLC	Controller Pilot Data Link Communication
CTA	Controlled Time of Arrival
CTA	Control Area
CTR	Control Zone
DCPC	Direct Controller-Pilot Communications
DMAN	Departure Manager
DME	Distance Measurement Equipment
EAT	Expected Approach Time
EFB	Electronic Flight Bag
ETA	Estimated Time of Arrival
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAS	Final Approach Speed
FIM	Flight Deck Interval Management
FIR	Flight Information Region
FMS	Flight Management System

FT	Feet
GIM	Ground Interval Management
GND	Ground
GND-ATC	Ground ATC
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
IAF	Initial Approach Fix
IAP	Instrument Approach Procedure
IAS	Indicated Airspeed
ID	Identification
ILS	Instrument Landing System
IM	Interval Management
KDC	Knowledge and Development Centre
KPA	Key Performance Area
KTS	Knots
LNAV	Lateral Navigation
LVNL	Luchtverkeersleiding Nederland (Dutch ANSP)
M&S	Merging and Spacing
MET	Meteo
MOPS	Minimum Operational Performance Standards
ND	Navigation Display
NEXTGEN	Next Generation Air Transportation System
NG	Next Generation
NM	Nautical Mile
OC	On-condition
OPA	Operational Performance Assessment
OR	Operational Requirement
OSA	Operational Safety Assessment
OSED	Operational Services and Environment Definition
PBN	Performance Based Navigation
PFD	Primary Flight Display
P-RNAV	Precision Area Navigation
R/T	Radio Telephony
RF	Radius to Fix
RFG	Requirements Focus Group
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
RTCA	Radio Technical Commission for Aeronautics
SA	Situational Awareness
SARA	Speed And Route Advisor
SD	Side Display
SESAR	Single European Sky ATM Research
SOFA	Stabilized On Final Approach
SPD	Speed
SPR	Safety and Performance Requirements
SSEP	Airborne Self-Separation

STAR	Standard Instrument Arrival Route
TFM	Traffic Flow Management
TIS-B	Traffic Information Service - Broadcast
TMA	Terminal Manoeuvring Area
TOA	Time of Applicability
ToD	Top Of Descent
TP	Trajectory Predictor
TRACON	Terminal Radar Approach Control
TTG	Time-To-Go
TWR	Tower
UPS	United Parcel Service
UTA	Upper Control Area
VNAV	Vertical Navigation
VSD	Vertical Situation Display
WAM	Wide Area Multi-lateration
WILCO	Will Comply
WTC	Wake Turbulence Categories

Definition of Terms

The following is a list of definitions that is essential for the correct interpretation of this document.

Achieve Stage: The part of the IM Operation, prior to the Achieve-by Point, where the IM Aircraft is driving toward the Assigned Spacing Goal at the Achieve-by Point.

Achieve-by Point: A point on the IM Aircraft's Intended Flight Path, defined as an absolute 2D location, a relative 2D location after initiation, an absolute time, or a relative time after initiation on the IM Aircraft's Intended Flight Path by which the Assigned Spacing Goal is required to be met within the IM Tolerance. The Assigned Spacing Goal is not required to be met prior to the Achieve-by Point.

Aircraft String: An Aircraft String is formed when each aircraft in a sequence is implementing IM Speeds relative to its assigned Target Aircraft, which is the immediately preceding aircraft in the sequence. The concept of an Aircraft String is used in the analysis on IM Speed guidance.

Altitude Constraint: As part of a navigation procedure, a limit or range for the altitude of an aircraft at a given waypoint while climbing or descending.

Assigned Spacing Goal: The time or distance interval between the IM Aircraft and Target Aircraft assigned by the controller as part of the IM Operation. The Assigned Spacing Goal can be a precise interval, a closed interval, no closer than, or no closer than with capture. The Assigned Spacing Goal is determined by the controller issuing the IM Instruction and is developed to achieve the controller's goal of establishing an efficient flow while maintaining separation from all traffic

Coincident Route: Two aircraft are considered to be on Coincident Routes if the Intended Routes coincide no later than the Achieve-by Point and through the Planned Termination Point.

Common Point: A 2D point on the Intended Routes of both the IM and the Target Aircraft that both aircraft have passed or are going to pass based upon their Intended Flight Paths

Controller Intervention Threshold: The bound (either distance- or time-based) where the controller intervenes in the IM Operation because he does not trust that the IM Aircraft is able to conform to the IM Instruction.

Continuous Descent Operation (CDO). An operation, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix /final approach point.

FIM Equipment: The avionics component that provides the IM capabilities defined. The function of the FIM Equipment is to provide IM Speeds to the flight crew to achieve and / or maintain the Assigned Spacing Goal within the IM Tolerance.

IM Aircraft: An aircraft that is equipped with FIM Equipment that is instructed to perform an IM Operation.

IM Clearance: The authority given to the flight crew of the IM Aircraft to conduct the IM Operation. This authority is communicated from the controller to the flight crew and includes the information needed to conduct the IM Operation (e.g., Target Aircraft ID, Assigned Spacing Goal, Achieve-by Point).

IM Clearance Type: The basic action that the IM Aircraft is instructed to perform as a part of the IM Operation. There are three basic IM Clearance Types: Achieve-by then Maintain, Maintain Current Spacing, and Turn.

IM Operation: A combination of IM capabilities and procedures used to initiate and execute an IM Clearance. An aircraft following an IM Clearance is an IM Operation, and comprises a specific instance of an Operational Application.

IM Situation Awareness Information: The information or data presented to the flight crew to assist them in developing awareness of how the IM Operation is proceeding

IM Speed: The speed provided by the FIM Equipment to the flight crew during an IM Operation to achieve the Assigned Spacing Goal

IM Special Points: Points that can be used as part of the IM Clearance, i.e., Achieve-by Point, Planned Termination Point, and Intercept Point.

IM System: The overall system that enables IM Operations. This includes the ground domain's ability to provide the controller with the necessary information to determine whether to issue an IM Clearance and the specifics of that clearance, the provision of surveillance data of surrounding aircraft to IM-capable aircraft and the on-board ADS-B IN capabilities, application processing, and the provision of required information to the flight crew of the IM Aircraft used to perform IM Operations.

IM Tolerance: The bounds on the difference between the Spacing Interval and the Assigned Spacing Goal (i.e., the Spacing Error) at the Achieve-by Point or during the Maintain Stage within which the IM Operation is considered successful. The IM Tolerance is set for the specific IM Operation being performed to ensure that the operational goals are met.

Intended Flight Path: The cleared navigation flight path from which the controller may determine expected behaviour of each aircraft involved in the IM Operation. Intended Flight Paths may include, but are not limited to, routes, routes with altitude and/or speed constraints, published procedures, and 4D trajectories

Intended Flight Path Information: The description of the IM or Target Aircraft's Intended Flight Path, which is made available to the FIM Equipment. This information which is included in the IM Clearance may be communicated directly or inferred for the cleared IM Operation.

Intended Route: The horizontal (2D) projection of the IM or Target Aircraft's Intended Flight Path

Maintain Stage: The part of the IM Operation where the IM Aircraft adjusts its speed to maintain the Assigned Spacing Goal within the IM Tolerance. The Maintain Stage begins after the IM Aircraft has reached the Achieve-by Point, or the IM Operation may be initiated in the Maintain Stage when executing a Maintain Current Spacing Clearance.

Operational Application: An implementation of ASPA-FIM supporting specific IM Operations within a given operational environment and operational objectives. The design of an Operational Application includes the statement of operational goals, a description of the assumed operating environment, and a specific selection of capabilities and variations defined within the OSED

Operational Uncertainty: An uncertainty that causes the Spacing Interval to change during the IM Operation due to differences in Target and IM Aircraft performance or environmental conditions. Examples of Operational Uncertainties include: winds and different aircraft performance during turns and descents.

Performance Level: A fixed level of performance for the IM and Target Aircraft State Data, applied according to the needs of a specific IM Operation and the allocation of the associated IM Tolerance. Two Performance Levels have been identified for use in IM Operations within the FIM SPR [2].

Planned Termination Point: A point on the IM Aircraft's Intended Flight Path where the IM Operation is terminated automatically

Route: The lateral path between two or more points defined as a sequence of waypoints or by latitudes and longitudes. The lateral path may be part of a defined procedure; e.g., jet routes or standard terminal arrival routes

Spacing Interval: The horizontal along-track spacing between the IM and Target Aircraft. The Spacing Interval may be specified in time or distance.

- In the case that the Spacing Interval is specified in time, it is the difference in time between when the IM Aircraft and the Target Aircraft are measured to cross, or are predicted to cross, a reference point. The reference point is a Common Point on Coincident Routes, or an equivalent point on non-Coincident Routes.
- In the case that the Spacing Interval is specified in distance, it is the measured or predicted along-path distance between the IM Aircraft and the Target Aircraft at a point in time. The along-path distance may be measured directly if the IM and Target Aircraft are on a common Route, or it may be measured relative to a common or equivalent point if the IM and Target Aircraft are on non-Coincident Routes.

Spacing Error: The difference between the Spacing Interval and the Assigned Spacing Goal.

Speed Constraint: As part of a navigation procedure, a limit or range for the speed of an aircraft at a given point. Modern Flight Management Systems (FMSs) typically interpret a Speed Constraint as an “at or below” limitation

Speed Restriction: A regulatory limit on the speed of an aircraft in particular airspace. E.g. a maximum indicated airspeed of 250 kts below 10,000 ft.

Target Aircraft: The aircraft against which the IM Aircraft is performing the IM Operation. Note that a Target Aircraft must be ADS-B OUT equipped in this document.

Target Aircraft Identification: A group of letters, figures or a combination thereof that is either identical to, or the coded equivalent of, the Target Aircraft call sign used in air-ground communications, and that is also used to identify the Target Aircraft in ground-ground air traffic services communications.

1 Introduction

1.1 Background

The Aircraft Surveillance Applications System (ASAS) is an umbrella term for a large number of applications using Automatic Dependent Surveillance - Broadcast (ADS-B), see [3]. This data link system transmits information from the aircraft (including identification, position, altitude, speed, course) to the ground and other aircraft. Based on this digital information from (other) aircraft, airborne applications have been developed that support Air Traffic Management (ATM) operations. For applications in [3] the following categories are defined:

- Airborne Traffic Situational Awareness (ATSA)
  - Improving the flight crews' knowledge of surrounding traffic, both in the air and on ground
- Airborne Spacing (ASPA)
  - Establishing and maintaining a given distance or time with another aircraft, as instructed by a (new) Air Traffic Control (ATC) instruction.
- Airborne Separation (ASEP)
  - Delegating the responsibility for the separation of traffic and associated tasks to the flight crew. This delegation of responsibility is limited to traffic by the designated aircraft.
- Airborne Self-Separation (SSEP)
  - The separation of the aircraft relative to all surrounding traffic in accordance with applicable airborne separation standards and air traffic rules.

Several ASAS applications have been developed and examined over the past 10-15 years. For a number of these applications standards have been developed and harmonized in the ADS-B Requirements Focus Group (RFG), a partnership between EUROCAE / Eurocontrol and RTCA / FAA, with input from various parties from the U.S. and Europe (including aircraft manufacturers, avionic manufacturers, air traffic control organizations and research), see [4]. ASAS applications are also an integral part of the new separation methods in the SESAR Concept of Operations (ConOps). It is one of the cornerstones on which the SESAR ATM Target Concept is built, see [5].

In 2008, the KDC ASAS project [6] performed research into applications based on ADS-B that may be of benefit to Schiphol. An important conclusion was that the Airborne Spacing (ASPA) – Flight Deck Interval Management (FIM) application, which is the airborne part of the ASAS – Interval Management (IM) suit, needs to be further developed. ASPA-FIM is an "Airborne Spacing" application, with the important feature that it may overcome the potential capacity reductions, resulting from the introduction of Continuous Descent Operations (CDO) during daytime operations and in particular during peak hours.

Capacity problems associated with Continuous Descent Operations were identified early on and a note of this was made to the KDC Research Agenda:

The government and neighbouring communities have an urgent call for Continuous Descent Operations at Schiphol to be implemented in the coming years. These CDO procedures are based on fixed routes, routes which will be introduced as a result of consultation among various parties at the Alders table. CDOs will yield improvements with regard to fuel use and a number of environmentally aspects such as emissions and noise, when compared to the current so-called step-down approaches. However, the introduction of CDO's also has a downside in that, unless additional measures are taken, CDOs that are based on fixed routes have a negative effect on the landing capacity. Reducing the peak hour capacity will damage the network of KLM/AF and will jeopardize the future of Schiphol. For the Dutch aviation sector, the introduction of CDO with no mitigation procedures or technologies to overcome the shortcomings is unacceptable.

In view of the introduction of CDO's with a high peak hour capacity (> 30 landings per hour per runway) additional steps are required. ASAS-IM (within SESAR also known as ASAS

Sequencing and Merging) is internationally regarded as one of the most appropriate concepts to address this deficiency. With ASAS-IM, aircraft (via ADS-B) exchange flight information and use this information to control an by ATC assigned distance or time interval with a preceding aircraft. This close loop control may provide the accuracy and predictability that is required to maintain peak hour capacity. Initial operational trials have been conducted by United Parcel Services (UPS), in cooperation with the FAA, at Louisville International Airport in the United States and have shown positive results.

The project for which this document is written, is aimed at the further development of ASAS-IM and to demonstrate its feasibility within the specific operating and environmental conditions of Schiphol airport. Research on CDOs with ASAS-IM up till now has only been conducted in Terminal Manoeuvring Areas (TMA), which are much larger than the Schiphol TMA. In principle each local situation must be validated individually, because of the airspace structure, the approach and departure routes and associated procedures and, importantly the supply and composition of air traffic. In order to support a strategic deployment decision, it is very important that testing and evaluations be performed with a fairly high degree of fidelity.

1.2 Document Objective

This document provides the definition of the proposed ASAS-IM application for Schiphol in the form of an Operational Services and Environment Definition (OSED) description. An OSED describes the services, intended functions and associated procedures of the application and the assumptions about the environment in which the application is specified to operate. It contains phase diagrams that give an illustrative (flow chart) description of the steps of the fundamental procedures applied and which are used as part of the analysis process and provides a detailed list of Assumptions and Operational Requirements (OR).

The assumptions in this OSED form an important basis for all future assessments and analyses. All requirements must be considered within the context of the assumptions made, as well as the operations and environments defined. Any deviation from the assumptions noted in this document could impact the corresponding requirements and therefore must be accounted for in supporting analysis or introduction of other assumptions and/or mitigations. The Operational Assumptions are enumerated with the “ASSUMP.#” tag.

The Operational Requirements specify the performance elements of the application associated with the operators and define the necessary procedural steps, tasks and actions that must be performed by these operators for proper execution of the IM Operations. Within the OSED, these Operational Requirements are enumerated with the “OR.#” tag.

This OSED, with its assumptions and Operational Requirements, will form the basis for the Safety Performance Requirements (SPR) and the Interoperability Requirements (INTEROP) processes. The requirements resulting from these processes are necessary to provide adequate assurance that the appropriate aspects of the relevant Communication Navigation Surveillance and Air Traffic Management (CNS/ATM) system, when operating together, will perform their intended function in an acceptably safe manner.

1.3 Document Source

The material in this document has been derived from the “Safety, Performance and Interoperability Requirements document for Airborne Spacing – Flight Deck Interval Management (ASPA-FIM)” developed by the “ADS-B Requirements Focus Group” (RFG) [2]. It has been adapted to the meet the Schiphol environment requirements.

1.4 Document Structure

This first chapter contains the introduction to the subject of airborne spacing in general and ASAS-IM in particular, together with the purpose of this document. The second chapter provides the justification for change. Chapter 3 povides a general description of the ASAS IM concept, together with the selection of IM concept elements for Schiphol. The general ASPA-FIM application is described in more detail in Chapter 4, including variations on the standard application. Chapter 5 provides an example scenario and Chapter 6 the Airspace Characteristics, Supporting Systems and Operational Environment. Chapter 7 describes the ATC arrival planning and procedure, while Chapter 8 addresses the Roles and Responsibilities. The procedural flow is described in Chapter 9 by means of phase diagrams and tables. Chapter 10 concludes with a summary of the assumptions and requirements identified in this document. The last two chapters (11&12) include the references and the document information sheet.

2 Justification for change

2.1 Current situation and justification for change

At Schiphol, CDO has been in operation for almost fifteen years. Schiphol's CDOs have originally been defined with the purpose to avoid noise annoyance in the greater Schiphol airport area. For this reason, the RNAV-Night Instrument Approach Procedures (IAP) have been defined as a lateral path and associated speed and altitude constraints within the Schiphol Terminal Manoeuvring Area (TMA) only with the aim to fly the initial part of these so-called "transitions" at or above FL70 and the final part like a CDO as often as possible, see Figure 2-1 and Figure 2-2. The fixed lateral path is designed with the intention to reduce noise hindrance in urban areas. The majority of inbound aircraft into Schiphol with landing time between 23:00 and 06:30 hour local time fly these IAPs.

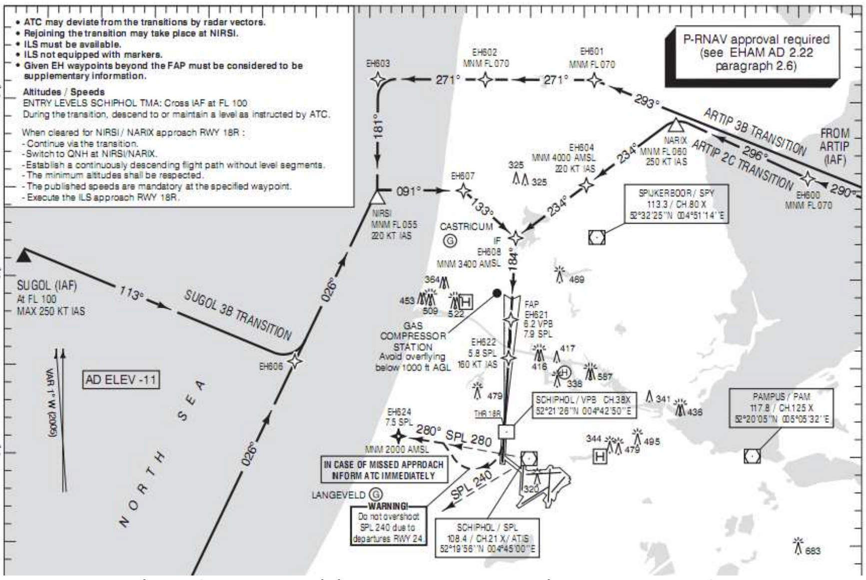

Figure 2-1: RNAV-Night Instrument Approaches to Runway 18R

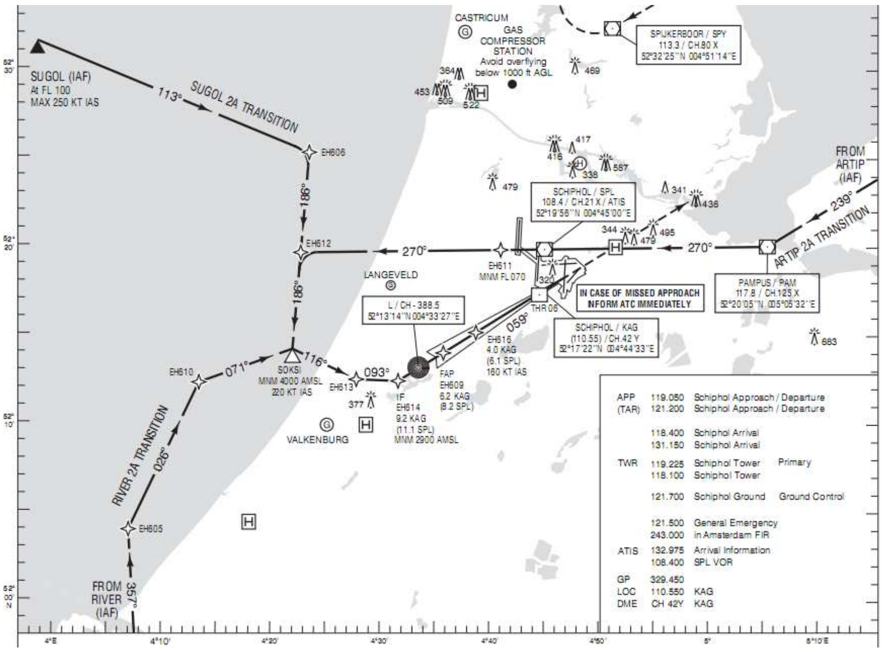

Figure 2-2: RNAV-Night Instrument Approaches to Runway 06

When the traffic situation allows, ATC the Netherlands applies a continuously descending flight paths from higher altitudes as much as possible during night-time hours. However, inbound aircraft into Schiphol with landing time between 06:30 and 23:00 hour local time can not fly these continuous descent procedures. During the daytime regime ATC typically uses radar vectoring, and speed and altitude instructions within the Schiphol TMA to safely and efficiently merge different streams of arriving aircraft and to accurately space aircraft on final approach, or multiple final approaches in case two landing runways are in use. This is illustrated in Figure 2-3, showing the flight paths of inbound traffic between 08:00 and 08:30 local time on July 14, 2010. Vectoring, speed and altitude instructions however prevent continuous descent operations and cause extra fuel burn, emissions and noise hindrance. In comparison Figure 2-4 gives an example of the night-time operation, showing the structure of flight operations along fixed routes during the night.

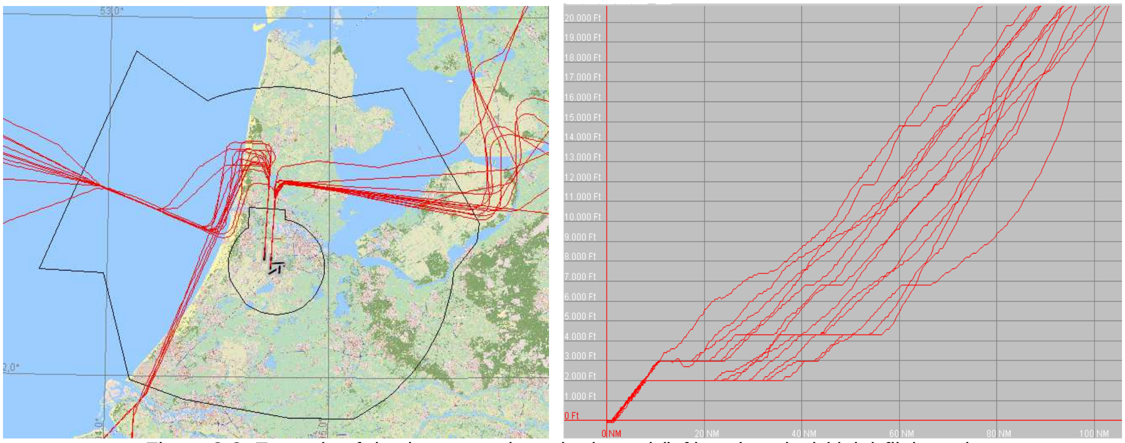

Figure 2-3: Example of daytime operation – horizontal (left) and vertical (right) flight paths

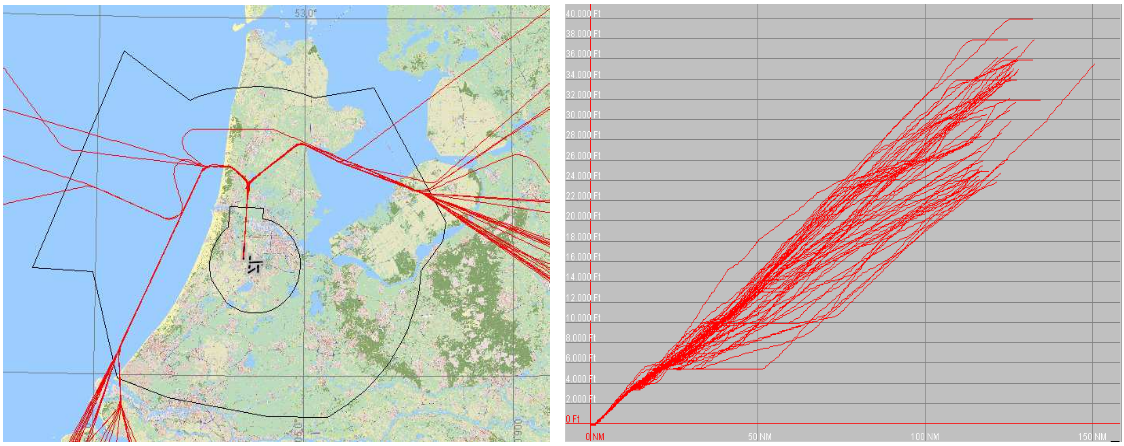

Figure 2-4: Example of night-time operation – horizontal (left) and vertical (right) flight paths

Vectoring is applied to accommodate an operationally required arrival capacity. CDOs and fixed routes in the TMA are currently not feasible during the day because it would mean a capacity reduction. The reduced arrival capacity would be the result of increased spacing margins between aircraft. The need for extra margins has two causes:

- There is a longitudinal spacing issue due to uncertainties in the descent profiles of individual flights. The longitudinal spacing is difficult to predict because of differences in aircraft (deceleration) performance, differences in pilot behaviour and wind conditions.
- Furthermore, the controller has less flexibility to tactically control aircraft on fixed inbound routes and continuously descending flight paths.

The ultimate goal is to realize a much more predictable TMA operation (simpler APP controller tasks) and Continuous Descent Operations along fixed TMA routes (lower aircraft noise hindrance, engine emissions and fuel usage) while retaining or even improving safety and capacity, 24 hours per day and 7 days per week. At Schiphol a number of developments are currently in progress, these developments are seen as stepping stones towards this goal.

Important developments are the planned introduction of the Speed And Route Advisor (SARA) and fixed arrival routes in the Schiphol TMA. The latter will create fixed routes from IAF to FAF for both night-time and daytime operations. The fixed arrival routes in the TMA are however expected to reduce the control flexibility available to APP controllers to manage traffic in their airspace, consequently traffic has to be delivered at the IAF more accurately and SARA will support the ACC controllers to achieve precise delivery of traffic at the IAF. Those two developments will result in more flight operations along fixed routes in the TMA and consequently will concentrate aircraft noise during certain off-peak daytime periods.

However, during periods with larger demand it is anticipated that fixed arrival routes and moreover CDO's will still not be feasible in the Schiphol TMA without additional developments. APP controller intervention will then still be the norm instead of the exception. To realize CDO's along fixed routes during higher demand situations traffic should be actively and precisely merged and spaced down to the runway threshold. Interval Management is regarded, according to current internationally accepted view (SESAR, NEXTGEN), to be the most appropriate to fulfil this operational requirement. This Operational Service and Environment Description (OSED) plans to support both controllers and flight crews by introducing Interval Management to merge and space traffic with a high degree of precision on fixed routes from Initial Approach Fix (IAF) to the runway threshold.

Interval Management (IM) is defined in [2] as the overall system that enables improved means for managing traffic flows and precise inter-aircraft spacing, including the use of ground tools that assist the controller in evaluating the traffic picture and determining appropriate instructions to merge and space aircraft safely and efficiently [7-14]. Interval Management includes both the ground capabilities needed for the controller to issue an IM Clearance and the airborne capabilities needed for the flight crew to follow the IM Clearance. Ground capabilities used for determining IM Clearances issued to aircraft can be simply the provision of the complete traffic picture and the experience of the controller for basic operations or automated tools to assist the controller in more complex traffic patterns or environments. Airborne (i.e. flight deck) capabilities designed to support IM Operations are called Airborne Spacing – Flight Deck Interval Management (ASPA-FIM).

The controller using IM will instruct the flight crew to achieve and/or maintain an Assigned Spacing Goal relative to a Target Aircraft. The key addition within IM operations to current operations is the provision of precise speed guidance within the flight deck to enable the flight crew to actively manage the spacing relative to the Target Aircraft. During IM Operations, the controller retains responsible for separation, while the flight crew is responsible for using the FIM Equipment to achieve and/or maintain the Assigned Spacing Goal that is set by the controller to meet the operational goals. Ground capabilities are foreseen to support controllers in the separation provision, this relates to the controller tasks of monitoring progress (complying with the IM Clearance) and making decisions to intervene or not to intervene. For example, it may be difficult for humans to built confidence that traffic, while performing IM Operations, will always merge with adequate separation.

The envisaged situation in which IM Operations will be introduced is partly similar to the current daytime situation as described above (during peak hours) and is partly based on operations with fixed P-RNAV or A-RNP1 routes from the IAFs to the FAFs (during off-peak hours).

On top of that it is assumed that in this envisaged situation the ACC controllers have a support tool (SARA or a further development of SARA) to precisely control aircraft over the IAFs, supporting time-based continuous descent operations down to the IAF. The primary goal of ASAS IM is to extend the periods in which CDO can be performed along fixed arrival routes in the Schiphol TMA, ultimately to a 24/7 situation.

The main driver to introduce Interval Management (IM) is to retain capacity during CDO, however, compliance with other high level requirements will also be needed. For example:

- The introduction of IM may not have adverse effects on safety, and controller and pilot workload.
- The introduction of IM aims to enable CDO operation during more periods of the day, positively effects on fuel burn, noise and emissions are therefore the underlying requirement.
- The introduction of IM also aims to support and simplify the work of controllers in the TMA, i.e. flying fixed routes in the TMA with controller intervention by exception. The underlying requirement is for predictable and stable traffic flows.
- The introduction of IM will need to support the flexible use of runways at Schiphol (e.g. transitions between inbound and outbound peaks, runway configuration changes due to weather)

2.2 General ATM System requirements

For IM Operations the major ATM System Requirements (ASR) are related a number of Key Performance Areas, such as capacity, predictability, safety and environmental impact (see section 2.1), and are summarized below.

High level capacity requirement
ASR.1 The introduction of IM Operations shall retain daytime capacity while performing Continuous Descent Operations along fixed routes.

High level safety requirements
ASR.2 IM Operations shall not increase the workload of controllers beyond a manageable level.

ASR.3 IM Operations shall not increase the workload of flight crews beyond a manageable level.

ASR.4 The introduction of IM Operations shall not lead to a reduction in safety.

High level predictability requirements
ASR.5 IM Operations shall support the controllers in creating a more predictable and stable traffic flow.

High level environmental requirement
ASR.6 The introduction of IM Operations shall enable increased CDO, which shall decrease the noise and emission impact of flight operations.

High level efficiency requirement
ASR.7 The introduction of IM Operations shall enable increased CDO, which shall increase the fuel efficiency of flight operations.

High level flexibility requirement
ASR.8 The introduction of IM Operations shall retain the flexibility in changing runway configurations.

3 IM Concept

3.1 General IM Concept

IM Operations are designed to assist the controller in managing the spacing between aircraft where the aircraft need to be spaced closely together in an orderly manner. This is accomplished by the assignment of an Assigned Spacing Goal to the IM Aircraft. As IM only uses a limited number of degrees of freedom to achieve the Assigned Spacing Goal, IM does not work in all conditions. For example, IM does not work if there is not enough time prior to the Achieve-by Point to reach the Assigned Spacing Goal by speed adjustment alone. Some combination of controller judgment and ATC automation help determine the conditions where IM can be completed successfully. The controller, with information provided by supporting ground-based automation, determines the appropriate Target Aircraft, the Assigned Spacing Goal, and the location of the Achieve-by Point. The Achieve-by Point is the point where the controller needs a specific spacing interval, e.g. the runway threshold. The controller also includes a Planned Termination Point at which the IM Operation is to be terminated, e.g. the Final Approach Fix (FAF).

The controller instructs the IM Aircraft to manage the spacing interval using speed alone and the IM Aircraft is expected to achieve the assigned spacing objective at the identified Achieve-by Point. Prior to the Achieve-by Point the IM Aircraft is expected to be attempting to achieve the spacing goal at the Achieve-by Point, but may balance the time to achieve the spacing goal with allowing greater flexibility for individual flight trajectories. For example, slower progress towards the spacing goal (or even movement away from the spacing goal) is permitted to allow for an efficient flight trajectory, while still enabling the IM Aircraft to achieve the Assigned Spacing Goal at the Achieve-by Point. The on-board capability is provided by Flight Deck Interval Management (FIM) equipment.

3.2 IM Concept Elements

In general IM Operations has many possible variants and variations. These broad concept elements and the choices that can be made for the anticipated Schiphol operational environment are listed in the table below and discussed thereafter.

Table 3-1: IM concept elements

Concept element	**Options**
Target aircraft	Single target operations Two-target operations
First IM execution moment	Before IAF At IAF Before merge point After merge point
Target aircraft route prior to merge point	Same route as IM Aircraft Direct route (single straight segment) to merge point Segmented route to merge point
IM clearance type	IM Speed manoeuvres • Achieve-by then Maintain • Maintain Current Spacing IM Turn manoeuvres
Assigned spacing goal type	Time-based Distance-based
Assigned spacing goal value	Pair-wise assigned spacing goal One generic assigned spacing goal Generic assigned spacing goal for each wake turbulence category combination Calculated on the ground or in the air
Achieve-by point	IAF Merge Point

	FAF 4 DME to threshold Runway Threshold
Planned termination point	FAF 4 DME to threshold Runway Threshold
Passing the IM instruction to the flight crew	Radio-telephony Datalink (CPDLC)
IM Speed implementation	Flight crew manually inputs the IM Speed IM Speeds autofed to the auto-flight system
IM algorithm	Time history-based algorithm Trajectory-based algorithm
Start of optimized CDO	Top of Descent Initial point on STAR Initial point on Instrument Approach Flight Path (i.e., IAF) Fixed flight level (i.e., FL 070) Point on the Instrument Approach Flight Path (e.g. NIRSI/FL 055, NARIX/FL 060, SOSKI/4000 ft)
CDO altitude profile	Fixed 2-degree descent path At or above constraints at waypoints At constraints at waypoints At or below constraints at waypoints Altitude window constraints at waypoints
CDO speed profile	Speed constraints at waypoints Deceleration constraints precede speed constraints
Longitudinal separation minima	Distance-based – current (5/4/3) Distance-based – current (5/4/2.5) Distance-based – re-categorized Time-based Airborne separation minima
CTA accuracy of delivering aircraft (at the IAF)	30 seconds (99% of the time) – SARA 10 seconds (95% of the time) – SESAR
PBN regime in Schiphol TMA	P-RNAV (i.e., RNAV 1) A-RNP 1 RF legs
Surveillance regime	Radar ADS-B WAM Combination of Radar, ADS-B and/or WAM
Ground IM automation	No support tool Support tool to determine aircraft pair, assigned spacing interval, initiation point, achieve point, etc Support tool to monitor and, if required, to terminate IM Operations Support tool for generating (speed) advisories to achieve & maintain assigned spacing interval for non-IM aircraft

Target Aircraft

The IM Aircraft is able to space of either one or two target aircraft. Two target operation may be beneficial in case of dependent parallel runway operations where the IM aircraft is spacing against an aircraft on the same landing runway, and simultaneously is spacing against an aircraft on a parallel runway. This two target operation is typically foreseen for closely spaced parallel approach operations. For the Schiphol environment it is assumed that operations at the parallel runways will remain independent for the moment. Therefore, for Schiphol the IM aircraft only has to space off one target aircraft, i.e. the preceding aircraft on the same ILS approach.

The IM Aircraft will space off a single Target Aircraft

First IM Execution Moment

The start of the execution phase of the IM Operation is an important design parameter. This is the moment the flight crew has accepted the IM Instruction and actively starts implementing IM Speeds to achieve the Assigned Spacing Goal. For the Schiphol environment a number of possible moments has been identified: at the IAF, well before the IAF, at the aircraft pair's merge point or before the merge point of the aircraft pair.

The advantages of starting at the IAF are:
- A procedure that always starts at a fixed position, clear and predictable for all involved.
- At a natural transfer point (from AMS ACC to SPL APP control).
- At the end of the time-based (SARA, CTA/RTA) operation building the schedule and sequence.
- IM operations are performed in a single sector, i.e. area of responsibility of Schiphol Approach.

The disadvantages of starting at the IAF are:
- Missing opportunities to make early speed changes to make the Assigned Spacing Goal, possibly resulting more aggressive speed behaviour or less precise IM Operation.
- Missing the opportunity to use IM to already space aircraft precisely at the IAF as a further development of SARA, CTA/RTA.
- Aircraft pairs may already fly on the same route prior the IAF (i.e., merge point precedes the IAF), so aircraft are already flying in a sequence but without actively controlling the interval between each other.

The advantages of starting at the merge point are:
- It is the first point where the aircraft pair will actually start flying the sequence in close proximity.
- From this point onwards the aircraft pair is flying the same route; this enables the use of a reactive IM algorithm (e.g. time history based algorithm). Otherwise a trajectory-based algorithm and Target Aircraft Intended Flight Path Information will normally be needed

The disadvantages of starting at the merge point are:
- Missing opportunities to make early speed changes to make the Assigned Spacing Goal, possibly resulting more aggressive speed behaviour beyond the merge point.
- Only the (frequently very limited) distance flown beyond the merge point can be used to make speed adjustments in making the Assigned Spacing Goal. Merge points halfway the TMA or near the FAF will be common and will severely limit the IM Operation.
- In case the merge point is located beyond the IAF, the interval is controlled by ATC for a certain period of time. Errors not corrected or even build up in this time period need to be corrected in the latest stage of the flight. An alternative may be ground automation to support ATC in gradually decreasing and correcting spacing errors.

It has been chosen to start the IM execution at the IAF, until it is shown that the operationally required performance (i.e., retaining current capacity during daytime continuous descent operations) can not be met. In that case an option, for example, is to initiate the IM operation much earlier (e.g. when the Target Aircraft is in ADS-B range).

The IM Aircraft will start the execution phase of the IM Operation at the IAF

Target aircraft route prior to merge point

Another important IM design parameter is the route structure within the Schiphol and in particular the route between the start of the IM manoeuvre (i.e., IAF) and the aircraft pair's merge point. Three options have been identified: the routes of the aircraft pair are always identical, the route between IAF and merge point is a single straight segment (i.e., direct route option) or the route between IAF and merge point is composed of multiple straight and curved segments (i.e., segmented route option). The route structure in the Schiphol TMA is the main factor for this concept element.

The advantages of the identical route options are:
- A relatively simple time-history based IM algorithm would be sufficient.
- Easier to monitor by controllers.

The disadvantages of the identical route option are:
- It doesn't support merging of traffic flows in the Schiphol TMA.
- It only supports limited traffic movements along the foreseen segmented route structure in the Schiphol TMA.

The advantages of the direct route option are:
- A relatively simple time-history based IM algorithm would be sufficient.
- Easier to monitor by controllers.
- Support merging traffic flows in the TMA for a suitable route structure (a single straight leg between IAF and merging point)

The disadvantages of the direct route option are:
- It only supports limited inbound movements along the foreseen segmented route structure in the Schiphol TMA

The advantages of the segmented route option are:
- Supports all inbound flows along the foreseen route structure in the Schiphol TMA

The disadvantages of the segmented route option are:
- A more complex trajectory-based IM algorithm is needed.

The Target Aircraft will fly a segmented route between IAF and the aircraft pair's merge point

IM Clearance type

There are three types of IM Clearances, based on what behaviour the controller desires from the IM Aircraft.

- There are two clearance types (Achieve-by the Maintain and Maintain Current Spacing) where the flight crew follows only IM Speeds; and
- There is one clearance type (IM Turn) that makes use of the IM Turn Point to allow for a one time lateral path change in addition to following the IM Speeds.

The advantages of the IM turn are:
(the opposite are disadvantages of only IM speeds)

- It gives the controller more possibilities and more flexibility to use IM when aircraft are too close and speed control only will not satisfy the merging and spacing operational goals.

The disadvantages of the IM turn are:
(the opposite are advantages of only IM speeds)

- The aircraft decide when to turn back to the fixed route to comply with the IM assigned spacing interval. This turn behaviour is not fully predictable for APP controllers.
- More complex IM instruction in comparison with, for example, a heading and subsequent direct instruction.
- The IM equipment becomes more complex, in particular a more complex algorithm and a more complex IM operational procedure.
- A number of vectoring-like areas are needed in the TMA counteracting the purpose of fixed routes in the Schiphol TMA. Though vectoring (and therefore vectoring areas) is considered as a readily available option for APP controllers to merge aircraft.
- The Schiphol TMA is too small to implement a point merge structure.

It is chosen to aim for IM Operation with only IM speed instructions. The need for vectoring and the possible use of IM turn instructions will have to be determined during an IM Real Time Simulation exercise for the Schiphol TMA.

The IM Operation in the Schiphol TMA will use IM Speed manoeuvres

Assigned spacing goal type

IM Operations may make use of either distance-based or time-based spacing goals.

The advantages of time-based spacing are:
(the opposite are disadvantages of distance-based spacing)

- Runway throughput is a typically time oriented process. An airport establishes a declared runway capacity of a certain amount of landings per hour, therefore on average every so many seconds an aircraft has to land. Factors affecting this interval are wake vortex considerations, runway occupancy times, and a minimum lead time to obtain the landing clearance prior to the actual landing.
- A main factor determining minimum separation is wake vortex. The transport and decay of wake vortices are typical time based processes.
- Another main factor determining spacing between aircraft is the runway occupancy time (ROT) and in low visibility conditions the time needed between vacating the runway and leaving the relevant ILS sensitivity area. Again, time-interval based processes.
- If fixed arrival routes and more or less fixed speed profiles are flown, which is typical for the future Schiphol TMA, then a specific time-interval at the Initial Approach Fix can be maintained down to the runway threshold (only compensated for the differences in Final Approach Speeds). For Continuous Descent Operations, with the possibility to initially retain and subsequently increase runway capacity by means of the Flight Deck Interval Management (FIM) application, it means that larger initial distance separation gradually decreases to the minimum distance separation applied nowadays. Furthermore, it also enables a transition to future time based separation minima with the potential to further increase capacity.
- If a time interval, that is a relative time with respect to a lead aircraft, is controlled then disturbances (deviations from the planned aircraft profiles) of the lead aircraft are taken into account by the trailing aircraft. If an absolute time at the runway threshold would be controlled then larger margins would be required to compensate for different behaviour

of (pairs of) aircraft. Furthermore, for the nominal situation an absolute time at runway threshold would already require a better accuracy to meet the equivalent time interval requirement, caused by the inaccuracies of time control of both aircraft instead of one aircraft.

The disadvantages of time-based spacing are:
(the opposite are advantages of distance-based spacing)

- Currently ATC, including most support tools, is distance oriented though a shift towards time-based operations is foreseen (e.g., SARA and SESAR developments). The reasons that ATC is distance based are that humans are better in working with distance than time and, for high density operations, technology so far has only enabled distance based operations. With current ground based technology (radar) the position of an aircraft can be determined quite accurately but not its future trajectory (inaccurate groundspeed profiles, etc), hampering the predictability of the time of arrival (i.e. time over runway threshold) down to values with an accuracy in the order of a second. And therefore limits time based operations in approach. Air-ground and air-air communication may considerably improve this technology issue in the near to medium future.
- Another issue is the working method of controllers; what is needed to support controllers to safely and efficiently perform their tasks in time based approach operations?

The vision is that a time-based spacing is the way to go for merging and spacing operations during approach, based on an overall ATC system performance point of view.

Time-based IM Operation will be supported in the Schiphol TMA

Assigned Spacing Goal value

IM Operations may use either one generic Assigned Spacing Goal, generic Assigned Spacing Goals for each wake turbulence category combination (i.e.. Heavy-Heavy, Heavy-Medium, Medium-Medium, Medium-Heavy) or specific pair-wise Assigned Spacing Goals. The specific pair-wise Assigned Spacing Goal may be calculated on the ground or onboard the aircraft.

The advantages of a generic spacing goal are:
(the opposite are disadvantages of pair-wise spacing goal)

- It makes the operation simpler because only a limited set of assigned spacing goals (either one or three values) will be used; this is beneficial for both the controllers and flight crew.

The disadvantages of a generic spacing goal are:
(the opposite are advantages of pair-wise spacing goal)

- It limits the overall performance of IM Operations in terms of runway throughput. The generic spacing values will be based on very conservative values of the final approach speed (i.e. a low speed for the IM Aircraft) resulting is high values for the assigned time interval. For an average final approach speed this high time interval will result in distance spacings well above the minimum separation, and will therefore severely limit the attainable throughput.

The calculation of the pair-wise Assigned Spacing Interval may be either ground-based or aircraft-based and will amongst others take into account the minimum radar and wake vortex separation criteria, final approach speed and required IM tolerance.

The advantages of a ground-based calculation are:
(the opposite are disadvantages of an aircraft-based calculation)

- It keeps the onboard IM system simpler, less functionality needed.

- No need to communicate the Target Aircraft Final Approach Speed to the IM Aircraft, at least not for this IM concept element.
- Allows the controller to actively control the operationally desired spacing interval. The controller is responsible for separation and the assigned spacing interval is closely linked with this separation. In his/her role to ensure separation the controller must have the responsibility to determine the applicable assigned spacing interval, based on all relevant factors. Once confidence has been built it perhaps may be worthwhile to consider aircraft-based calculations.

The disadvantages of a ground-based calculation are:
(the opposite are advantages of an aircraft-based calculation)

- It most likely requires a new ground tool to calculate the assigned spacing interval.
- The assigned spacing interval needs to be communicated explicitly. This is not a natural piece of information for controllers to communicate, e.g. 82 or 85 seconds is not really distinctive for controllers.

IM Operation will support pair-wise assigned spacing goals

The calculation of the assigned spacing goal is performed on the ground

Achieve-by Point

In general one has to have a properly accomplished sequence planning at the threshold, satisfying the separation criteria as an essential element, and one has to determine sequencing and spacing criteria of upstream, in-flight conditions as derivatives. Examples of the latter could be CTAs at the IAF and Assigned Spacing Intervals at the FAF. Assuming that the aircraft are properly delivered at IAF, the next steps are to merge traffic flows in the TMA and to realize a given throughput. This can be accomplished by IM Clearances in which the controller's intentions (i.e., what spacing interval needs to be achieved by what point) are made clear to the flight crew. The Achieve-by Point, being an implicit or explicit part of the IM Clearance, is defined as a point on the IM Aircraft's Intended Flight Path, defined by a specific 2D location, or fixed time after IM initiation, by which the Assigned Spacing Goal is required to be met. The Assigned Spacing Goal is not required to be met prior to the Achieve-by Point. In the TMA a number of (typical) locations could be used as Achieve-by Point: the IAF, merge point (if applicable), FAF, 4DME to threshold, and the runway threshold.

Since the IAF is the starting point of IM Operations it can not be used as Achieve-by Point.

The advantages of the merge point are:

- The assigned spacing goal is acquired when the aircraft pair gets and remains in close proximity, therefore making it less likely that the minimum separation will be violated.
- Separation at the merge point is critical for the controllers. It should be noted that the trajectory-based algorithm will (have to) take into account the distance-based minimum longitudinal separation and, if necessary, will (need to) adjust the IM speed to prevent separation violation.

The disadvantages of the merge point are:

- Not all aircraft pairs have a merge point in the TMA, making the IM procedure less consistent and more complex.
- The merge point may be located relatively close to the IAF limiting the spacing accuracy which can be met for a given time accuracy over the IAF.
- There is no real requirement for precise time-based spacing at the merge point; the basic requirement at the merge point is to be at least separated by the minimum separation standards (i.e., three, four or five nautical miles).

- A more aggressive speed behaviour, and consequently thrust behaviour, will be needed to acquire the assigned spacing goal in a relatively short time period.

The advantages of the FAF point are:
(the opposite are disadvantages of the runway threshold)

- Within the FAF the flight crew can fully concentrate their attention on the final approach (e.g. to be stabilized at 1000ft AGL) and subsequent landing, though this is more a Planned Termination Point issue (see below).
- The Target Aircraft Final Approach Speed does not need to be available to the IM Aircraft, the compensation for differences in Final Approach Speed will be performed on the ground and only the resulting Assigned Spacing Goal at the FAF will be communicated to the flight crew.
- The IM algorithm doesn't need to know and control to the IM aircraft's Final Approach Speed, for an Achieve-by Point beyond the FAF this will be required.

The disadvantages of the FAF are:
(the opposite are advantages of the runway threshold)

- Runway throughput is primarily based on time intervals at the runway threshold. In order to assign a spacing goal at the FAF one has to compensate for the time flown between FAF and runway threshold of both IM Aircraft and Target Aircraft.
- This compensation is mainly due to differences in Final Approach Speeds and is anticipated to be less accurate when performed by a ground-based system. Assumptions on the speed profiles of both aircraft are needed, whereas for an aircraft-based compensation at least the intended speed profile of the IM aircraft is accurately known.
- The compensation is continuously calculated onboard the aircraft instead of a single calculation on the ground and therefore it will use the latest available information, for example target aircraft state information received via ADS-B.

The disadvantages of the 4DME to threshold are:
(the opposite are advantages of the runway threshold)

- The disadvantage of the runway threshold (advantages of FAF) are still valid, whereas the advantages of the runway threshold or other advantages are not attained, the above-mentioned compensation has to be calculated partly on the ground and partly in the aircraft. Though all depends on the approach procedure, in case the 4DME point has an associated speed constraint (e.g. 160 kts) the 4DME option is similar to the FAF option in terms of advantages/disadvantages.

There are currently no strong arguments to make a choice between FAF or runway threshold as Achieve-by Point. It is preferred to locate the Achieve-by Point at the runway threshold because this is the point where IM operation (i.e., achieving an accurate spacing interval) is designed for.

IM Operation will use the Runway Threshold as Achieve-by Point

Planned Termination Point

The Planned Termination Point is defined as a point on the IM Aircraft's Intended Flight Path where the IM Operation is terminated automatically. In the Schiphol TMA a number of (typical) locations could be used as Planned Termination Point: the IAF, merge point (if applicable), FAF, 4DME to threshold, or the runway threshold

Since the runway threshold is the foreseen Achieve-by Point the Planned Termination Point can not be located prior to the FAF. Thus, the IAF and merge point have been dropped.

The advantages of the FAF are:
(the opposite are disadvantages of the runway threshold)

- Within the FAF the flight crew can fully concentrate their attention on the final approach (e.g. to be stabilized at 1000ft AGL) and subsequent landing. IM is not a flight crew task during one of the most critical phases of the flight.
- On final approach the speeds and (associated) final configuration changes are fully at the discretion of the flight crew.
- The IM algorithm doesn't need to control to the IM aircraft's Final Approach Speed, for a Planned Termination Point beyond the FAF this will be required.

The advantages of the runway threshold are:

- The Planned Termination Point is co-located with the Achieve-by Point, making the IM Operations straightforward.
- The operationally-required time interval is at the runway threshold and not at a point prior to it. Terminating at the FAF will abandon opportunities to correct spacing errors beyond the FAF (for example until 4DME), whereas spacing errors are still developing on final approach due to operational uncertainties such as deceleration differences. The spacing accuracy at the threshold will therefore be lower.
- It is illogical, from an IM system point of view, to have a Planned Termination Point prior to the Achieve-by Point. The system is supposed to guarantee a certain performance at the Achieve-by Point but its control is limited to a point prior to the Achieve-by Point.
- If the Planned Termination Point is at the FAF then the time between FAF and threshold, of both IM and Target Aircraft, is only modelled. This means that the IM tolerance (at the Achieve-by Point) needs to be translated into an 'IM guidance' tolerance at the FAF.

It is chosen to use the FAF as Planned Termination Point mainly to enable the flight crew to fully focus on the final approach and landing. Required spacing accuracy at the threshold will be achieved only if dissimilar final approach speeds are taken into account.

IM Operation will use the Final Approach Fix as Planned Termination Point

Passing the IM Clearance

ATC may communicate the IM Clearance via either voice communication (i.e., Radio Telephony (R/T)), or datalink communication (Controller Pilot Datalink Communication (CPDLC)).

The advantages of R/T are:
(the opposite are disadvantages of CPDLC)

- Existing communication means can be used, no need to implement another means of communication.

The disadvantages of R/T are:
(the opposite are advantages of CPDLC)

- IM Instruction may be (too) complex.
- Data to be communicated include at least the Target Aircraft Identification, Target Aircraft Intended Flight Path, Target Aircraft Planned Final Approach Speed and Assigned Spacing Interval. The Planned Final Approach Speed of the Target Aircraft is used for correcting differences in Final Approach Speed, this is needed because the Achieve-by point is at the runway threshold.
- The Achieve-by Point and Planned Termination Point may be part of the IM c.q. approach procedure.

It is chosen to perform IM Operation with the use of R/T because CPDLC implementation is at the moment not foreseen by LVNL. The feasibility of R/T will have to be determined during an IM Real Time Simulation exercise for the Schiphol TMA.

R/T will be used to communicate the IM Clearance

IM Speed Implementation

The IM Speeds as generated by the onboard IM algorithm can be implemented by the flight crew in two different ways. The IM Speeds are presented to the flight crew and based on this information the flight crew sets new speed targets for the Autoflight System, alternatively the IM Speed are automatically fed into the Autoflight System. In the latter case the flight crew select the appropriate (IM) flight mode at the beginning of the IM Operation coupling IM to the Autoflight System.

The advantages of manually setting IM Speeds are:
(the opposite are disadvantages of auto-feed)

- Development cost of on-board avionics in support of IM Operation is lower.

The disadvantages of manually setting IM Speeds are:
(the opposite are advantages of auto-feed)

- The flight crew workload will be (somewhat) higher, though it shall not increase beyond a manageable level.
- The IM tolerance that can be met will probably be larger, resulting in a reduced runway throughput [7, 9, 10].

It has been chosen to manually set the IM Speeds, until it is shown that the operationally required performance (i.e., retaining current capacity during daytime continuous descent operations) can not be met.

IM Speeds are presented to the flight crew and based on this presentation the flight crew sets new speed targets

IM algorithm
The IM algorithms to generate IM Speeds consist of two classes, namely time-history based algorithms and trajectory based algorithms.

Constant time delay spacing was developed to overcome the problem of early slowdown of successive aircraft in terminal operations. In this concept, which is also know as time-history spacing, each successive aircraft attempts to fly the speed profile of the aircraft it is following. To do this, the previous time-correlated position data for the leading aircraft are retained by the ownship. Then, if the spacing goal were to maintain a 120 second spacing, then the ownship would attempt to be at a speed and position where its leading aircraft was 120 seconds earlier.

In a trajectory-based control law, the IM speed is a function of the spacing error at a point on the IM Aircraft's intended flight path and the distance to this point. By assuming a 4D trajectory for an aircraft and knowing that aircraft's position, it is possible to determine where that aircraft is on its trajectory. Knowing the position on the trajectory, the aircraft's estimated Time-To-Go (TTG) to a point, in this case the runway threshold, is known. A TTG is calculated for a leading aircraft and for the ownship. Note that the trajectories do not need to be the same. An alternative technique that has been proposed is to have each aircraft compute just its own trajectory and broadcast its calculated time-to-go (TTG) to the trajectory change points. The nominal spacing time and spacing error can then be computed as:

- nominal spacing time = assigned spacing interval + traffic TTG.
- spacing error = ownship TTG — nominal spacing time.

The advantages of time-history based algorithms are:
(the opposite are disadvantages of trajectory-based algorithms)

- Simpler, mainly because there is no need to calculate ETAs at the Achieve-by Point of both IM and Target Aircraft.
- No need for intended trajectory information of both IM and Target Aircraft
- No need for predicted wind information
- Currently available in air transport avionics

The disadvantages of time-history based algorithms are:
(the opposite are advantages of trajectory-based algorithms)
- It puts constraints on the intended route of IM and Target Aircraft. The route normally has to be identical with an allowable exemption that the Target Aircraft intended route to the merge point is a direct to.
- The foreseen route structure in the Schiphol TMA doesn't comply with these constraints on the intended route of IM and Target Aircraft. See also afore-mentioned concept element *Target aircraft route prior to merge point*

IM Speeds will be generated by a trajectory based algorithm

Start of optimized CDO

The Continuous Descent Operations may be initiated at different locations. In the Amsterdam FIR or Schiphol TMA a number of (typical) locations could be used as CDO initiation point: Top of Descent, initial point on the STAR, initial point on the Instrument Approach Procedure (i.e., IAF), a fixed flight level related to the perception of noise (i.e., FL 070), a point on the Instrument Approach Procedure related to the perception of noise (e.g., NIRSI/FL 055, NARIX/FL 060, SOKSI/4000 ft.

- Since the IAF is the starting point of IM Operations a CDO initiation point prior to the IAF is important but not very relevant for IM Operations. It is more related to the control flexibility in the CTA Operations aiming at an absolute time over the IAF.

The advantages of IAF are:
(and the opposite are disadvantages for FL 070 and even more so for NIRSI/NARIX/SOKSI)
- Maximum fuel and CO_2 benefits during approach phase.
- Links up with a CDO initiated prior to the IAF

The disadvantages of IAF are:
(and the opposite are advantages for the FL 070 and even more so for NIRSI/NARIX/SOKSI)
- Minimum control flexibility to correct differences between the Spacing Interval and the Assigned Spacing Goal (i.e., the Spacing Error) during the (initial) approach.

The specific advantage of FL 070 is:
- Minimum CDO initiation requirement based on noise hindrance considerations.

IM Operation will be performed between the IAF and runway threshold, therefore starting the CDO prior to the IAF is not relevant for IM. The IAF is selected to maximise fuel and environmental benefits in the area of IM operations.

IM Operation will be based on Continuous Descent Operation between IAF and runway threshold

CDO Altitude Profile

The CDO procedure will include non-idle vertical flight path segments, from the start of CDO point onwards, to guarantee both a certain level of control flexibility (i.e., a range of flyable IM Speeds) during the IM (and possibly also CTA) part of the CDO procedure and a reliable ETA calculation of the Target Aircraft and subsequent Spacing Error calculation. A number of altitude-constraining options are: fixed 2-deg descent path, altitude constraints ('at or above', 'at', 'at or below' or window) at a number of waypoints in the CDO procedure. Note that the CDO procedure designer should aim for as few as possible (altitude) constraints.

The advantages of a 2-deg descent path and 'at' constraints that effectively result in a 2-deg descent path are:

- Maximum control flexibility to correct differences between the Spacing Interval and the Assigned Spacing Goal (i.e., the Spacing Error) during descent
- Compliance with the vertical path boundaries (on the lower side) as defined in the ICAO CDO Manual [1].
- A predictable altitude profile of the Target Aircraft results in a more reliable ETA calculation and therefore Spacing Error calculation at the Achieve-by Point.

The disadvantages of a 2-deg descent path and 'at' constraints' are:

- The descent path is not based on idle thrust and therefore not optimized for specific aircraft.
- Less fuel and CO_2 benefits in case IM Operations are not needed, for example when traffic demand is low.
- SID design to keep free of CDOs will become more difficult compared to larger descent angles (e.g. 2.5 or 3.0-deg).

The advantages of 'at or above' and altitude window constraints are:

- The descent path may for non-IM Operations be based on idle thrust and therefore optimized for specific aircraft.
- More fuel and CO_2 benefits for non-IM Operations.
- It gives the lower bounds of the CDO needed for IM Operations and at the same time it provides the flexibility, if needed, to further optimize the descent path.
- Altitude window constraints have the additional benefit that the vertical path of all aircraft may be contained for reasons of separating inbound and outbound flows.

The disadvantages of 'at or above' and altitude window constraints are:

- To construct the optimized descent path, prior to Top of Descent, there may be a need to determine whether IM Operations are planned during the descent. With this knowledge the descent path may be optimized for either IM or non-IM Operations.

The advantages of 'at or below' constraints are:

- It provides a means to establish the upper bounds of the CDO and therefore enforces a descent path with an average descent angle of 2-deg or less.

The disadvantages of 'at or below' constraints are:

- The descent path is not based on idle thrust and therefore not optimized for specific aircraft.
- Less fuel and CO_2 benefits in case IM Operations are not needed, for example when traffic demand is low.
- Aircraft are not 'forced' to fly a continuously descending flight path, the probability of level segments is high. Though the average descent angle may be 2-deg or less, the descent path may consist of segments with higher descent angles in combination with level segments.
- Level segments at low altitudes are counteracting the goals of CDO, that is realising fuel, CO_2 and noise benefits.
- SID design to keep free of CDOs will become more difficult in case of 'at or below' constraints resulting in a 2-deg descent angle compared to similar constraints resulting in a larger descent angle (e.g. 2.5 or 3.0-deg).

> The CDO altitude profile will be based on 'at or above' and/or altitude window constraints, resulting in an at least 2-deg descent path (based on the lower bounds) in the Schiphol TMA during IM Operations

CDO speed profile

To calculate a reliable ETA of the Target Aircraft at the Achieve-by Point its intended speed profile needs to be predictable. Two options have been identified to make the speed profile of all aircraft predictable: use of speed constraints at waypoints in the Schiphol TMA and use of speed constraints in combination with deceleration constraints. A deceleration constraint prescribes how to achieve a speed constraint. Note that the CDO procedure designer should aim for as few as possible (speed) constraints.

The advantages of deceleration constraints are:

- The speed profile is highly predictable
- One of the most important operational uncertainties (differences in deceleration between aircraft) that result in accumulation of the Spacing Error is addressed and largely removed.

The disadvantages of deceleration constraints are:

- No state-of-the-art FMS has the capability to include deceleration constraints.

> The CDO speed profile will be based on as few as possible speed constraints at waypoints resulting in a similar speed profile for all aircraft in the Schiphol TMA

Horizontal separation minima

Flight operations in the Schiphol TMA are based on specified minimum separation standards. Currently the horizontal separation minima is based on a generic radar-based value of 3 NM and is increased based on wake turbulence considerations. This means for example that the minimum separation is 4 NM when a Heavy aircraft flies in-trail another Heavy on final approach and 5 NM when a Medium flies in-trail a Heavy. Other options are a minimum generic radar-based separation of 2.5 NM on final, re-categorized wake turbulence minima (still distance-based), time-based separation minima and airborne separation minima.

The advantages of 3/4/5 NM separation minima are:

- In line with current method & tools to provide separation between aircraft

The disadvantages of 3/4/5 NM separation minima are:

- Disconnect between time-based (CTA & IM) operations and distance-based separation provision.
- Runway throughput could be further optimized.

The advantages of 2.5/4/5 NM separation minima are:

- Runway throughput is increased in comparison with current operation.

The disadvantages of 2.5/4/5 NM separation minima are:

- Disconnect between time-based (CTA & IM) operations and distance-based separation provision.
- New separation criteria, and possibly adapted working methods and ATC tools in comparison with current operation.

The advantages of re-categorised separation minima are:

- Runway throughput is increased in comparison with current operation.

The disadvantages of re-categorised separation minima are:
- Disconnect between time-based (CTA & IM) operations and distance-based separation provision.
- New separation criteria and possibly adapted working methods and ATC tools in comparison with current operation.
- Re-categorised separation standards are not (yet) standardised within ICAO

The advantages of time-based separation minima are:
- No disconnect between separation provision and efficient flow management operations, both are time-based.
- Runway throughput is increased in comparison with current operation and could be optimized based on wake turbulence and runway occupancy considerations.

The disadvantages of time-based separation minima are:
- Disconnect between mental processes of controllers (distance oriented) and a time-based separation task, may required support tools for the controller.
- Time-based separation standards are not standardised within ICAO

The advantages of airborne separation minima are:
- Airborne separation minima will be optimized in comparison with separation minima that use ground equipment and procedures.
- Runway throughput is increased in comparison with current operation and could be further optimized in comparison with ground-based separation criteria.

The disadvantages of airborne separation minima are:
- Not standardised within ICAO.
- IM equipment and flight crew need to be qualified for the delegated separation task with respect to the Target Aircraft.
- Separation provision is only delegated to some or many but not all aircraft (which aircraft do use delegated separation and which ones don't)

It has been chosen to maintain the current distance-based separation minima in the Schiphol TMA, until it is shown that the operationally required performance (i.e., retaining current capacity during daytime continuous descent operations) can not be met.

Horizontal separation minima will be the current distance-based criteria (3/4/5 NM) in the Schiphol TMA

CTA accuracy of delivering aircraft at the IAF

An important performance aspect that affects the attainable IM performance at the FAF is the accuracy of delivering the aircraft at the IAF, the starting point of IM operations.
SARA will be designed to deliver aircraft with an accuracy of 30 seconds, 99% (σ=11.6 s). SESAR has set a target CTA/RTA accuracy of 10 seconds, 95% (σ=5.1 s).
A more accurate delivery at the IAF will generally result in a better IM performance at the FAF and a more precise inter-aircraft spacing at the runway threshold.

It has been chosen to assume the SARA-based delivery accuracy, until it is shown that the operationally required performance (i.e., retaining current capacity during daytime continuous descent operations) can not be met.

Time accuracy of delivering aircraft at the IAF will be 30 seconds, 99% of the time.

PBN regime in Schiphol TMA

The current fixed arrival routes in the Schiphol TMA, as in use during the night-time operations at Schiphol, are based on the RNAV 1 (or P-RNAV) navigation specification. The PBN strategy of the Netherlands states that for TMA operations RNAV 1 will be mandated by 2012 and the Advanced RNP 1 (A-RNP 1) navigations specification by 2018. Required lateral navigation accuracy is the same for fault free operations, i.e. within +/- 1 NM of the defined horizontal flight path for 95% of the time. It is anticipated that the Actual Navigation Performance is a more influential factor for the performance of IM operations. One of the main differences is that the Radius-to-Fix legs are included in A-RNP 1. Though the majority of current Flight Management Systems already have RF leg capability.

The benefit of using RF legs in the Schiphol TMA is that the ETA of the Target Aircraft can be calculated more reliably. Turns are another important operational uncertainty (differences in turn radius between aircraft) that result in the Spacing Error accumulation. Introducing RF legs in the TMA addresses and largely removes this operational uncertainty.

It has been chosen to fly turns in the Schiphol TMA without a prescribed radius, i.e. without the use of RF legs. When it is shown that the operationally required performance (i.e., retaining current capacity during daytime continuous descent operations) can not be met the use of RF legs may be considered.

IM Operations are based on fixed RNAV routes in the Schiphol TMA with a navigation specification of at least P-RNAV

RF legs are not used as part of the fixed RNAV routes in the Schiphol TMA

Surveillance regime in Schiphol TMA

Today the surveillance of aircraft is performed by ground-based radar installations. With the advent of ADS-B and Wide Area Multi-lateration (WAM) technologies for aircraft surveillance other options become available. For the Schiphol TMA it is important that the aircraft are under direct control, and the means of surveillance is of secondary importance. Radar, ADS-B, WAM and combinations thereof will suffice. IM operation does not put new requirements on the means of surveillance and therefore radar surveillance is acceptable.

IM Operations are based on an environment with radar surveillance.

Ground Interval Management (GIM) automation

Interval Management includes ground capabilities for the controller to identify the appropriate IM pair, to issue the appropriate IM Clearance, to monitor the progress of IM operations and to support non-IM aircraft in the sequence. It is assumed that the controller has the necessary information at hand when needed. The controller may have access to support tools to satisfy this assumption. The GIM automation is anticipated to include tools to support the controller in initiating the IM Operations (e.g. what are appropriate aircraft pairs, and which spacing interval to apply), monitoring progress (e.g. which aircraft are spacing off each other) and making intervention decision (e.g. building confidence in the merging of traffic flows or detecting misbehaviour). The level of automation will have to be validated during an IM Real Time Simulation exercise for the Schiphol TMA.

GIM automation tools are available to support the controllers in initiating, monitoring and, if necessary, terminating IM operations.

The choices made with respect to the IM concept elements for Schiphol are summarized in the table below.

Table 3-2: Selected IM concept elements

Concept element	**Selected option**
Target aircraft	Single target operations
First IM execution moment	At IAF
Target aircraft route prior to merge point	Segmented route to merge point
IM Clearance type	IM Achieve-by (then Maintain)
Assigned spacing goal type	Time-based
Assigned spacing goal value	Pair-wise assigned spacing goal Calculated on the ground
Achieve-by point	Runway threshold
Planned terminination point	FAF
Passing the IM instruction to the flight crew	Radio-Telephony (R/T)
IM Speed implementation	Flight crew manually inputs IM Speeds
IM algorithm	Trajectory-based algorithm
Start of CDO	At IAF
CDO altitude profile	At or above constraints and/or altitude window constraints at waypoints
CDO speed profile	Speed constraints at waypoints
Horizontal separation minima	Current distance-based criteria (3/4/5 NM)
CTA accuracy of delivering aircraft (at the IAF)	30 seconds (99% of the time) – SARA
PBN regime in Schiphol TMA	P-RNAV (i.e., RNAV 1) No RF legs
Surveillance regime in Schiphol TMA	Radar
Ground IM automation	Tools to support the controllers in initiating, monitoring and, if necessary, terminating IM operations

4 IM description

The following subsections present the activities required for IM operations at Schiphol, based on the operational phases of ASPA-FIM (the airborne part of ASAS-IM). These subsections rely heavily on the ASPA-FIM SPR [2]. Key concepts and terms for IM operations are also defined so that Schiphol specific operational requirements can be prescribed for the issuance of IM Instructions. Human Factors issues that result from these new operations will be identified and addressed in future analysis.

4.1 FIM Operational phases

Interval Management occurs in four phases: Precondition, Initiation, Execution, and Termination.

4.1.1 Precondition Activities

Prior to the Initiation Phase for ASPA-FIM, the controller considers if an IM Operation can be used.

As part of these Precondition Phase activities, the controller:

- identifies the sequence of aircraft;
- determines the IAF scheduled reference crossing time;
- ensures that the aircraft meet the scheduled IAF crossing time;
- identifies the desired spacing at the Achieve point, i.e., Assigned Spacing Goal, between aircraft; and
- ensures that the applicability conditions for IM are met.

The referred sequence of aircraft is determined by the controller (as in today's operations) who also determines the Assigned Spacing Goal to meet operational goals. The proposed IM Aircraft must be capable of performing IM Operations and airborne surveillance of the proposed Target Aircraft must be available to the IM Aircraft. The chosen sequence is such that the aircraft can be expected to complete the IM Operation successfully. The controller will be assisted by ground-based sequencing tools (such as arrival/departure managers – AMAN/DMAN) and other tools (i.e. SARA) to manage the inbound flow to the IAF. Multiple IM Operations can be brought together to have consecutive aircraft performing IM. That is, one aircraft may both be performing IM Operations as well as acting as a Target Aircraft for another IM Aircraft. The controller will consider the implications of coupling multiple IM Aircraft into a string of aircraft performing IM.

OR.1 The controller shall be trained to perform IM Operations.

OR.2 The controller shall determine when to use an IM Operation.

ASSUMP-OSED.1 Intentional misuse or abuse of the FIM Equipment or procedures is outside the scope of this document.

ASSUMP-OSED.2 The controller only issues an IM Instruction that is feasible including appropriate Target Aircraft, the Assigned Spacing Goal, and any included IM Special Points.

ASSUMP-OSED.3 The controller has the necessary information to determine the IM Aircraft, Target Aircraft and Assigned Spacing Goal.

ASSUMP-OSED.4 The airspace is under surveillance (e.g., radar and/or ADS-B-RAD) so that the controller has positive control over all involved aircraft.

The Assigned Spacing Goal instructed by the controller shall be of type 'Precise Value'. This requires the IM Aircraft to achieve the precise value relative to the Target Aircraft (e.g., 120 seconds) at the Achieve-by Point. A precise value is required as the traffic density at Schiphol is high and a stable string of sequenced aircraft is required (e.g. a string of aircraft landing in sequence on the same runway).

OR.3 The controller shall assign a precise Assigned Spacing Goal.

Through verifying that the IM applicability conditions are met the controller assesses that the aircraft involved have:

- appropriate equipment;
- compatible speed profiles (or compatible characteristics with respect to aircraft performance);
- compatible positions (altitudes and relative position); and
- compatible routes.

ASSUMP-OSED.7 The controller has selected an IM Aircraft and Target Aircraft which have the appropriate equipment, compatible speed profiles, compatible positions and compatible routes.

The two elements that in combination define appropriate IM equipage are that the IM Aircraft is able to receive airborne surveillance information and is equipped with the associated FIM Equipment, and that the Target Aircraft is available over airborne surveillance methods. Equipage information for the IM and Target Aircraft can be made available on the ground through means of flight plan data, data tags or other means. The capability of the IM Aircraft to conduct the application, relating to properly functioning equipment and flight crew training in the procedures, is managed through the flight crew's acceptance of the clearance.

The controller ensures that the IM Aircraft and Target Aircraft are following routes that are acceptable for the IM Operation to be used and that the aircraft are positioned appropriately on those routes so that the IM Operation can be successful.

The controllers involved in the IM Operation need to coordinate so that all parties are aware of the IM Operation. It is expected that this coordination will be part of the normal controller-controller coordination that is in place at the time.

ASSUMP-OSED.8 There is appropriate coordination between all controllers involved in the IM Operation to enable the IM Operation to proceed without undo interruption.

The controller will (as part of the IM instruction) specify the runway threshold as the Achieve-by Point. The Achieve-by Point is a point on the IM Aircraft's Intended Flight Path and can be identified as a named waypoint. The Termination Point is selected to be the Final Approach Fix, after which Final Approach Speed will be achieved and maintained. Both points will be an intrinsic part of the cleared navigation procedure.

OR.4, The Achieve-by Point, which is a point on the IM Aircraft's Intended Flight Path, shall be an intrinsic part of the cleared navigation procedure.

OR.5, The Planned Termination Point, which is a point on the IM Aircraft's Intended Flight Path, shall be an intrinsic part of the cleared navigation procedure.

In the IM Operation the IM Aircraft and Target Aircraft are adhering to their cleared navigation procedures, referred to as their Intended Flight Paths, established at the initiation of the procedure. The Intended Flight Paths provide an expectation of the IM Aircraft and the Target Aircraft behaviour to the controller, so that they can manage the overall traffic situation. Similarly, knowledge of the Intended Flight Paths is needed by the FIM Equipment to manage the Spacing Interval, being one component of the traffic situation.

Intended Flight Path Information is identified in the IM Instruction to describe the Intended Flight Paths of the IM Aircraft and Target Aircraft. This information is communicated directly in the IM Instruction. The name of a known route, accessible from an onboard database, is used as the

Intended Flight Path Information from which the FIM Equipment may generate the Intended Flight Path.

OR.6 As part of the IM Instruction, the controller shall identify the Intended Flight Paths of both the IM Aircraft and Target Aircraft.

Up until the final approach fix, aircraft are expected to fly similar speeds along a nominal speed profile and have the flexibility to adjust speeds, within margins around the nominal speed profile, in order to meet the Assigned Spacing Goal. However, near the final approach fix, the flight crew needs to command their Final Approach Speed (FAS) to ensure a stabilized final approach. Because an individual aircraft's FAS is dependent upon the aircraft type, wind conditions, and aircraft weight, among other factors, there is great variability in possible FASs. Differences of 50 kt and above are possible between aircraft, although differences less than 30 kt are more common.

Differences in IM and Target Aircraft FASs have a direct influence on the achievable spacing at the runway threshold if not properly accounted for. The FAS may not be known until very close to the final approach fix or even later. Therefore, the planned FAS is the suggested value to be used in the IM Operation. The expected difference between the planned and actual FAS would be on the order of a few knots and would contribute to a slightly larger variability at the threshold.

To compensate for differences in FAS's a solution would be to have the Target Aircraft flight crew include their planned FAS in a communication with the controller, who could then relay that information to the IM Aircraft.

OR.7 The Target Aircraft will provide planned Final Approach Speed (FAS) to the controller who will include this information in the IM instruction.

If the controller needs to manoeuvre the IM and/or Target Aircraft away from their Intended Flight Paths, the IM Operation should be terminated.

OR.8 When the controller issues a new clearance to the IM and/or Target Aircraft that results in a modification to their Intended Flight Paths, the controller shall terminate the IM Operation.

The IM and/or Target Aircraft may deviate from their Intended Flight Paths for reasons other than tactical controller intervention (e.g., flight crew deviation around weather or flight crew errors). If the IM Operation is in the Execution Phase, the flight crew should terminate the IM Operation and notify the controller if either the IM and/or Target Aircraft have deviated by more than operational limits from their Intended Flight Paths.

OR.9 During the Execution Phase, the flight crew shall terminate the IM Operation and notify the controller if the IM and/or Target Aircraft have deviated by more than operational limits from their Intended Flight Paths.

4.1.2 Initiate

After determining that an IM operation (or set of operations) is appropriate for the management of the traffic scheduling and flow, the controller will issue the appropriate IM instruction to the IM aircraft. This issuance of the IM Instruction begins the initiation Phase of the ASPA-FIM application.

Once all the conditions are met for an IM operation defined in 4.1.1 above, the controller issues the IM Instruction to the IM Aircraft flight crew.

OR.10 The controller shall identify the following information as part of the IM Instruction[1]:

[1] Information in italics may be intrinsic part of the navigation procedure

- Target Aircraft Identification;
- *Assigned Spacing Goal;*
- *IM Manoeuvre;*
- *Achieve-by Point;*
- *Termination Point;*
- *IM Tolerance;*
- Target Aircraft intended Flight Path Information; and
- Target Aircraft Final Approach Speed.

ASSUMP-OSED.7 The IM Aircraft has already received, and is following, a navigation clearance which defines their Intended Flight Path.

ASSUMP-OSED.8 The Target Aircraft Identification used in the IM Instruction matches what the Target Aircraft is broadcasting as its identification.

The controller will communicate the necessary data as a single IM Instruction. However some data may be a reference to values that are part of a navigation procedure (i.e. Assigned Spacing Goal, IM Manoeuvre, Achieve-by Point, Termination Point and/or IM tolerance).

ASSUMP-OSED.9 Direct Controller-Pilot Communications (DCPC), such as voice, data link or other method, is available throughout the IM Operation.

ASSUMP-OSED.10 The controller and flight crew are provided with a new set of voice (and optionally data link) messages to conduct IM.

OR.11 Upon receipt of the IM Instruction, The flight crew shall make the data identified in the IM Instruction available to the FIM Equipment.

OR.12 If one or more of the following conditions are not met, the flight crew shall reject the IM Clearance:

- The Target Aircraft has been positively identified;
- Target Aircraft data quality is sufficient for the IM Operation;
- IM Aircraft data quality is sufficient for the IM Operation;
- The flight crew is trained for IM Operations;
- The FIM Equipment is able to present IM Speed; and
- There is a reasonable likelihood of successfully completing the IM Operation.

OR.13 The flight crew shall be trained how to use the FIM Equipment and to perform the IM Operations.

The flight crew must also verify that the data quality available to the FIM Equipment from both their own aircraft and the Target Aircraft is sufficient for the assigned IM Operation.

Once all of the IM initiation data and surveillance data from the Target Aircraft are available, the flight crew will assess the feasibility of the IM Clearance. This feasibility assessment determines if there is a high likelihood of successfully completing the IM Operation. As the eventual outcome of the IM Operation is dependent upon the behaviour of the IM and Target Aircraft as well as the environmental conditions, the feasibility check will not be able to determine the eventual outcome with certainty. It is therefore an estimate by the flight crew as to whether there is sufficient time and speed margin to correct for any differences between the Spacing Interval, calculated at initiation, and the Assigned Spacing Goal at the Achieve-by Point. The flight crew is expected to use a combination of experience along with data from the FIM Equipment to make this judgment.

If one or more of the above conditions fails to succeed, the flight crew reports the situation to the controller; it is expected that the flight crew states the reason for rejecting the clearance (e.g., due to aircraft speed envelope, target not identified etc.).

4.1.3 Execute

The Execution Phase involves the FIM Equipment calculating and providing IM Speed to the flight crew and the flight crew following that guidance so that the desired spacing is realized. The FIM Equipment also provides other information to assist the flight crew in determining if the IM Operation is progressing in a safe and satisfactory manner towards the desired spacing goals.

Prior to the Achieve-by Point the IM Aircraft is expected to be attempting to achieve the spacing goal at the Achieve-by Point, but may balance the time to achieve the spacing goal with allowing greater flexibility for individual flight trajectories. For example, slower progress towards the spacing goal (or even allowing for movement away from the spacing goal) is permitted to allow for an efficient flight trajectory while still enabling the IM Aircraft to achieve the Assigned Spacing Goal at the Achieve-by Point. It is not expected that the IM Speeds will actively take the IM Aircraft away from the Assigned Spacing Goal but that efficiency may be considered when determining when to change the IM Speed as long as the greater goal of achieving the Assigned Spacing Goal at the Achieve-by Point is met.

Within the Execution Phase the IM Aircraft implements the instructed IM Operation. The IM Aircraft flight crew will:

- implement the IM Speeds provided by the FIM Equipment in a timely manner; and
- monitor the progress of the IM Operation.

The IM Aircraft flight crew is responsible for implementing the controller’s instruction. The flight crew, depending on the IM Operation, achieves and maintains the required spacing by implementing the IM Speed provided by the FIM Equipment.

OR.14 The flight crew shall implement changes from the IM Speed guidance in a timely manner consistent with other cockpit duties, unless safety-of-flight considerations, operational acceptability, or regulatory limitations preclude it.

ASSUMP-OSED.11 The flight crew manually inputs the IM Speed into the speed guidance system, which is active during the IM manoeuvre.

The IM Speed is equivalent to a controller’s speed instruction. The IM Speed replaces Speed Constraints on routes but the IM Aircraft is still responsible for adhering to regulatory speed limits and aircraft performance limits.

ASSUMP-OSED.12 The IM Clearance has the equivalent effect to a controller’s speed instruction and supersedes Speed Constraints on the IM Aircraft’s Intended Flight Path; however, appropriate regulatory Speed Restrictions are still to be respected.

The FIM Equipment needs to predict the Spacing Interval at the runway threshold and speed adjustments cease no later than the point where the aircraft starts decelerating to its Final Approach Speed. Airline policies and Air Traffic Control requirements generally require that a landing aircraft be fully configured and at its FAS by a certain point prior to landing. This point, the Stabilized Approach Point, may vary based on visibility conditions and airline policy. However, it is frequently no later than 1000 feet AGL. For a 3° approach angle, 1000 feet AGL is approximately 3.14 NM from the runway threshold. Satisfying the stabilization criteria by the Stabilized Approach Point is of the utmost criticality for the flight crew to be able to complete a successful landing.

It is assumed that the IM and Target Aircraft will fly the FAS after reaching their Stabilized Approach Point.

OR.15 The flight crew **shall** ensure that the IM Aircraft is stabilized to its Final Approach Speed no later than the appropriate Stabilized Approach Point.

OR.16 The flight crew **shall** terminate the IM Operation prior to decelerating to their Final Approach Speed.

To support the stabilized approach requirements the FIM Equipment should not provide IM Speeds, and effectively terminate, once the IM Aircraft begins its final deceleration. The FIM Equipment may include a notification to the flight crew when it is appropriate to begin their deceleration to their FAS.

The flight crew is required to follow the IM Speed and not modify it based on IM situation awareness or other information. If operational constraints (IM Speeds outside the acceptable range or turbulence) result in the flight crew being unable to follow the IM Speed, they may limit the speed to an operationally acceptable speed. The crew is to return to the IM Speed once it becomes operationally acceptable. In cases where being unable to follow the IM Speeds results in the flight crew no longer being able to conform to the IM Clearance, the crew will notify the controller.

Throughout the Execution of the IM Operation, the flight crew monitors their conformance with the IM Clearance, just like they would with any other ATC Clearance. If the flight crew finds they are unable to continue conforming to the IM Clearance, they notify the controller. Non-conformance could include unacceptable IM Speeds for a prolonged period of time.

OR.17 During the Execution Phase, the following information shall be available for display to the flight crew:

- the IM Speed;
- FIM Equipment status; and
- IM Situation Awareness Information[2].

OR.18 The flight crew shall be notified when the IM Speed guidance changes.

OR.19 If the flight crew is unable to continue conforming to the IM Clearance, they shall notify the controller.

During the Execution Phase the flight crew monitors their conformance with the IM Clearance and if at any time they determine that they are unable to continue conforming to the IM Clearance they will notify the controller. The controller can then either amend the IM Clearance to one that the flight crew can conform with or terminate the IM Operation.

During the IM Execution Phase the flight crew of the IM Aircraft will fly all other aircraft procedures normally as in today's operations.

During the IM Execution Phase, the flight crew:

- maintains a safe flying speed;
- conforms to regulatory speed limits;
- monitors the progress of the IM Operation, and notifies the controller if they will be unable to achieve the Assigned Spacing Goal; and
- monitors the FIM Equipment for annunciated failures.

As in normal operations, the flight crew is responsible for flying safe speeds for the current conditions and airframe configuration.

[2] For the purposes of this OSED, the term "IM Situational Awareness Information" represents the set of information the flight crew needs to be able to assess if the IM operation is progressing safely, as anticipated and towards success.

The FIM Equipment is expected to annunciate to the flight crew when conditions are no longer met in which the IM operation can be performed are detected during the IM Operation. These include at a minimum the quality of IM and Target Aircraft data, validity of IM and Target Aircraft Intended Flight Path Information, and if calculated IM Speeds exceed aircraft speed limits.

OR.20 The flight crew shall terminate the IM Operation if:

- they are unable to continue conforming with the IM Instruction;
- the data quality for the IM Aircraft is no longer sufficient to support the IM Operation;
- the data quality for the Target Aircraft is no longer sufficient to support the IM Operation; or
- if the FIM Equipment is no longer able to provide IM Speed.

During the IM Execution Phase, the controller:

- maintains separation between the IM Aircraft and all other traffic as per normal operations;
- provides instructions and clearances to the Target Aircraft as per normal operations (if applicable);
- monitors all traffic to ensure efficient flow is maintained as per normal operations; and
- terminates or suspends the application if the traffic situation requires.

The controller ensures that the lateral and vertical navigation clearances are consistent with the IM Operation, and if they are not, terminate or suspend the IM Operation.

During the handoff between areas of control or facilities, the receiving controller is made aware of aircraft who are participating in an IM Operation. This could be achieved by controller to controller coordination or via flight crew check-in procedures.

ASSUMP-OSED.13 During aircraft handoffs between controllers, the receiving controller has sufficient information to continue the IM Operation.

The controller remains responsible for separation of traffic at all times. If a conflict is detected the controller applies normal techniques to mitigate the situation; this could require an early termination of the cleared application or if the traffic situation permits, a temporary suspension. In case of an application suspension, the controller, after solving the traffic situation, can re-clear the flight crew of the IM Aircraft to resume the IM Application.

OR.21 As with other instructions or clearances, the controller shall monitor the IM Aircraft to ensure that IM Aircraft is behaving in an acceptable manner and is in conformance with the IM Clearance.

OR.22 The controller shall terminate the IM Operation if it is no longer desirable.

There are no additional tasks/responsibilities related to the Target Aircraft flight crew.

4.1.4 Terminate

When reaching the Planned Termination Point the IM Aircraft terminates the IM Instruction. The FIM Equipment detects reaching the Planned Termination Point and terminates the operation by removing the IM Speed Guidance.

OR.23 The flight crew shall terminate the IM Operation upon reaching the Planned Termination Point.

OR.24 Upon reaching the Planned Termination Point, the FIM Equipment shall terminate the FIM application by removing the IM Speed.

At any time during the IM Operation, due to traffic or other operational reasons, the controller may terminate the IM Operation.

At any time during the IM Operation the flight crew can terminate the IM Operation. In this case, the IM Aircraft flight crew will:

- inform the controller regarding the non-nominal termination of the procedure which should include the reason for termination (e.g., bad weather conditions, aircraft envelope); and
- maintain current or operationally appropriate speed until otherwise instructed.

Once the FIM Application is terminated, the controller returns to non-IM Operations including any additional navigation or speed clearances.

OR.25 If the flight crew initiates the termination of the IM Operation, the flight crew shall notify the controller and maintain an operationally appropriate speed until otherwise instructed.

OR.26 If the controller terminates the IM Operation prior to the Planned Termination Point, the controller shall include a speed instruction in the termination instruction.

OR.27 Once the IM Operation is terminated the controller shall resume conventional control of the IM Aircraft.

Once the IM Operation has been terminated the flight crew no longer follows the IM Speed. In addition, the IM-specific situation awareness information is not necessarily valid and could mislead the flight crew. Therefore, IM-related information should not be displayed to the flight crew after reaching the Planned Termination Point. In addition, for cases where the IM Operation is terminated prior to reaching the Planned Termination Point, the flight crew must have the ability to remove, or suppress, all IM-related displays and information.

OR.28 The flight crew shall only receive IM Speed after successful initiation and up to the Planned Termination Point.

OR.29 The flight crew shall have the ability to remove or suppress all IM-related displays and information.

4.2 Variations on the standard IM Operation

When Able Instruction
There are times when the controller will want to issue the IM Instruction and the IM Aircraft may not be receiving airborne surveillance data from the Target Aircraft because it is not yet within reception range. There are multiple reasons why this may occur. It is expected that there could be benefit to the flight crew and controller to issue the IM Instruction at a consistent point for a given operation. For example, as aircraft enter into the arrival flow into an airport if they knew that any IM Instruction would likely occur 150 – 180 NM from the airport, they could adjust their task load to be prepared. Likewise, the ANSP may want one set of controllers issuing the IM Instruction as the expected sequence is set. For operations that include sequencing aircraft coming along multiple routes, the point where the IM Aircraft is ensured to have airborne surveillance data on their Target Aircraft will vary widely with which routes the two aircraft are following. It is not expected that the controller will know which aircraft has surveillance data on which other aircraft so it would be difficult for them to delay issuing the IM Instruction until they are sure the IM Aircraft could successfully identify the Target Aircraft. The When Able Instruction is defined to support the controller in this case.

If the controller is unsure if the Target Aircraft is within airborne surveillance range of the IM Aircraft, the controller may precede the IM Instruction with “when able.” When the flight crew receives a When Able Instruction they set up the FIM Equipment as normal but if surveillance data is not available for the Target Aircraft, they maintain their current speed and notify the controller that they have not identified the Target Aircraft. Once surveillance data is available for the Target Aircraft and the Target Aircraft has been successfully identified and the other initiation criteria are met (OR.11), the flight crew begins the IM Operation and informs the controller that they have commenced IM Operations.

Due to possible data communication errors and changing environments, it may be possible that the initiation criteria are never met. Both the flight crew and controller need to be aware of this possibility.

OR.30 The controller shall issue a When Able Instruction when they are unsure if the IM Aircraft has airborne surveillance information on the Target Aircraft and they want the IM Aircraft flight crew to begin the IM Operation once the IM Aircraft has airborne surveillance information on the Target Aircraft.

OR.31 Following a When Able Instruction, the flight crew shall inform the controller when they commence IM Operations.

Expected IM Clearance
There may be times when it is operationally beneficial for the controller to inform the IM Aircraft of an impending IM Instruction but to not start the IM Operation until sometime later. Along with the IM Instruction, the controller tells the flight crew when to begin the IM Operation, called the trigger event.

The trigger event could be:

- a specific event such as reaching a specified altitude or waypoint;
- a specific time; or
- a time after the IM Instruction is received.

OR.32 When the controller wants the flight crew to initiate an IM Operation at some later time, the trigger event shall be communicated with the IM Instruction.

The flight crew acknowledges the expect instruction and waits for the trigger event. After the trigger event occurs the flight crew determines if they can accept the IM Clearance (OR.11). At this point the procedures continue normally. Prior to execution, the controller continues to provide speed and navigation clearances as needed.

OR.33 After an expect Instruction, the flight crew shall notify the controller when they are able to begin the IM Clearance.

Amending IM Instruction
As an IM Operation proceeds, the controller's goal may evolve due to changes in the traffic situation. In these cases, the controller may amend the IM Instruction, making changes to the Assigned Spacing Goal, the Achieve-by Point or the Planned Termination Point. In addition, the controller may make changes to the IM Aircraft's or Target Aircraft's Intended Flight Path Information that does not change the overall flow goals. Significant changes, including a new Target Aircraft, will be accomplished by terminating the current IM Operation and initiating a new IM Operation.

OR.34 The controller shall terminate the current IM Operation and issue a new IM Instruction if the Target Aircraft Identification is to be modified**.**

The controller may want to make a minor change to the Assigned Spacing Goal to account for changing wind conditions, changing runway conditions or changes in the traffic flow. Large changes may results in unstable behaviour, especially if several aircraft are performing IM Operations simultaneously. The Achieve-by Point and Planned Termination Point may be moved, especially if the controller needs the Assigned Spacing Goal achieved earlier. The controller can also reroute either the Target Aircraft or IM Aircraft to account for other traffic or changing weather. In all cases, the controller reassesses the applicability conditions that the aircraft are properly positioned and have compatible speeds and routes.

After the modified initiation data is made available to the FIM Equipment the flight crew will assess the feasibility of the new instruction and either accept or reject the modification. If accepted, the flight crew continues with normal IM procedures. If rejected, the controller can terminate the IM Operation or make further modifications.

OR.35 During the Execution Phase, the controller shall be able to amend an existing IM Clearance to change the following data:

- Assigned Spacing Goal(s);
- Achieve-by Point;
- Planned Termination Point;
- IM Tolerance;
- IM Aircraft Intended Flight Path Information;
- Target Aircraft Intended Flight Path Information; and
- Target Aircraft Final Approach Speed.

Prior to accepting a modified IM Clearance, the flight crew will check the feasibility of the new IM Clearance and notify the controller if the new instruction is not feasible.

OR.36 The flight crew shall assess the feasibility of the modified IM Clearance before accepting the new instruction.

Suspend and Resume

At times the controller may want to suspend the current IM Operation and transition to non-IM Operations with the goal of resuming IM at a later time. This may be to handle a short duration event such as needing to manoeuvre the IM Aircraft for separation assurance or due to a temporary loss of the Target Aircraft as a valid target.

The controller instructs the flight crew to suspend the IM Operation, provides a new speed instruction, if necessary, and informs the crew when to expect to resume the IM Operation. While the IM Operation is suspended, the flight crew does not implement IM Speeds. When the controller is ready for the flight crew to resume the IM Operation, an instruction is provided to the flight crew to resume IM. The flight crew reassesses the IM Clearance and continues to execute the IM Operation.

OR.37 The flight crew shall suspend the IM Operation when instructed by the controller.

OR.38 The flight crew shall only resume the IM Operation when instructed by the controller.

OR.39 The flight crew shall reassess feasibility of conforming to the IM Clearance before resuming a suspended IM Operations.

A resume instruction may be combined with a modification to the original IM Instruction.

5 Schiphol IM scenario description

This section describes an example scenario for an ASAS-IM operation of two flights arriving at Schiphol Airport. The runway in use is 18R, both aircraft are performing Continuous Descent Approaches, which are initiated at the IAF. Flight KL642, a Boeing 777-200ER, origin Kennedy International Airport, destination Schiphol Airport (EHAM), enters the Amsterdam FIR at LAMSO flying to the SUGOL IAF (see example chart Figure 5-1). The second aircraft, flight KL1822 a Boeing 737-800 from Berlin Tegel Airport arrives from the east entering the Amsterdam FIR at NORKU towards the ARTIP IAF. Prior to crossing the IAF, the aircraft will be assigned a lead and required spacing, which will be entered into the onboard IM equipment. Both aircraft will continue to fly the CDO and follow the speed instructions from the guidance algorithm. The spacing operations will terminate when the IM aircraft crosses the last Final Approach Fix.

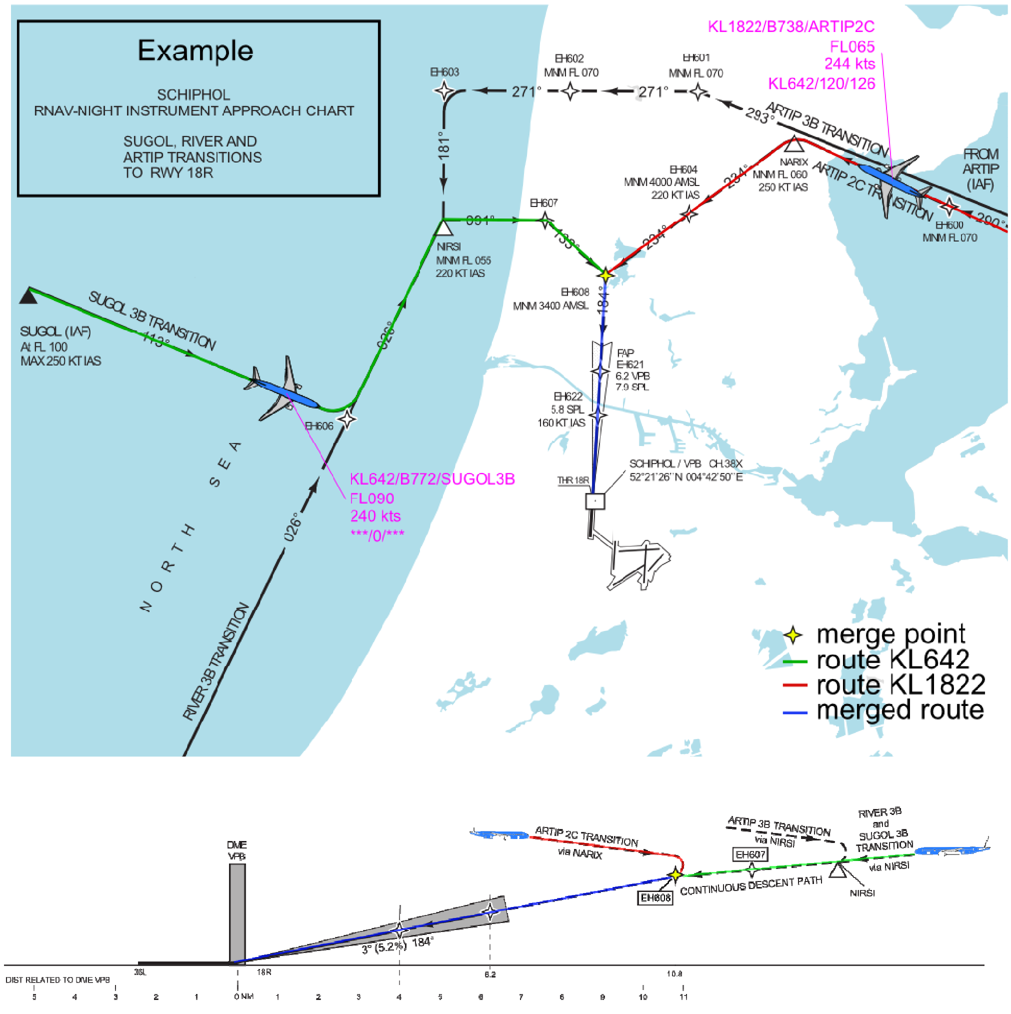

Figure 5-1: The routes flown by the two aircraft (based on Instrument approach chart RWY 06 RNAV June 2009 night transition, ©AIP The Netherlands)

5.1 Initiation

5.1.1 Ground initiation

IM operations start with Schiphol Area Control (ACC) using an arrival manager (AMAN) or other means to build up a properly spaced sequence of aircraft to the designated runway. The sequence and spacing is created using current position & velocity, preferred route, wake vortex separation and predicted runway ETA times. The result is a planned sequence of properly spaced aircraft at the runway threshold. From this planned sequence, aircraft pairs can be determined. Each pair consists of an IM aircraft and a Target aircraft. The Target aircraft may initially be on a different route. In our scenario ACC determines that KL642 is the number one in sequence and therefore Target aircraft to KL1822. As KL642 has no assigned Target aircraft, it will follow the assigned route as indicated by the approach chart.

ATC now needs to assure that both aircraft arrive at their IAF's in time in order to be able to start IM operations. For that ATC uses the Speed And Route Advisor (SARA) tool. This tool helps ACC to deliver the aircraft on their designated Initial Approach Fixes (IAF) at the appointed time with a tolerance of +/-30 sec around the planned schedule time.

In the process of metering the aircraft to their respective IAF, ATC request both aircraft to provide their planned Final Approach Speed (FAS). The speeds are verified against nominal acceptable final approach speed for given aircraft class and type and confirmed with the crew.

Prior to the lead aircraft (KL642) crossing its designated IAF, it is cleared for the normal CDO arrival. The IM aircraft (KL1822) however will receive an IM instruction. For that ATC determines the IM instruction parameters and assesses these to ensure that applicability parameters are met. The IM instruction which will be communicated over radio, includes among other which aircraft to follow, the spacing requirement and the intended route of the Target aircraft:

```
<KL1822> cleared CDO approach runway <18R>, <120> seconds behind
<KL642>. Target is on the <SUGOL-3B> with final approach speed <134
kts>
```

If the applicability parameters are met and both aircraft meet the necessary requirements, IM operations can be initiated by issuing the instruction.

5.1.2 Cockpit initiation

Upon reception of the IM instruction, the flight crew of KL1822 confirms reception and enters the instruction into the onboard equipment. The equipment is subsequently used to determine the likelihood of success for completing the IM operation. The IM application also checks the input to see if the data of both the Target and IM aircraft is of sufficient quantity and quality for IM Operation. When it determines that all execution requirements are met, an initial IM speed is calculated and displayed on the ADS-B Guidance Display (AGD) (see paragraph 6.3.2). The crew now determines if this speed is feasible and stays within any applicable regulatory and/or performance limits. When this assessment is successful the crew notifies ATC that IM operations have been initiated, by means of a WILCO to indicate that they will comply with the instruction.

5.2 Execution

The crew now opens the speed window on the Mode Control Panel (MCP) and dials-in the IM speed. The Auto Throttle System activates and adjusts the throttles to adhere to the commanded speed. Alternatively, the flight crew could decide to adjust speed in the FMS or through another basic mode of the AutoPilot. The commanded speeds will be based-of of a nominal speed profile, which is associated with the arrival procedure and include margins of up to +/- 10 kts to enable adjusting for spacing errors.

During the IM operation both the crew and the IM application will monitor the conformance with the IM instruction. The crew has to ensure that a safe flying speed, which conforms to regulatory speed limits, is maintained. The crew will also make sure that the aircraft is still able to achieve the Assigned Spacing Goal; and check for FIM Equipment or annunciated failures. Any failure of such results in a termination of the IM operation. The flight crew may terminate the IM action at any times if out of conformance or unfeasible IM speeds are observed. If this occurs the IM application is stopped and ATC is notified.

The IM application itself will monitor data quantity and quality of the Target aircraft and whether it is still able to provide an IM speed. It will notify the crew if it can no longer adhere to these requirements.

ATC in the mean time monitors the progression of both flights. When separation and/or spacing issues are identified ATC determines whether to intervene. In some instances tactical adjustments to the lead aircraft may resolve the problem without impacting the IM aircraft. In other instances ATC will suspend the IM instruction so that it can be amended or ATC terminates it altogether. If ATC decides to suspend the IM operation, the flight crew of KL1822 is notified of the suspension and stops the IM application. ATC can then modify the IM instruction, this instruction needs to be re-transmitted and assessed by the flight crew. If the instruction is deemed acceptable active spacing can be resumed.

Both aircraft continue to follow their instructed route and while KL642 follows the FMS guided speed, KL1822 follows the speed provided by the IM application. When KL642 reaches the merge point, the onboard IM equipment of KL1822 indicates that the current spacing at the threshold is 126 seconds, 6 seconds of target. The IM algorithm calculates a new IM speed for KL1822 and displays this on the aircraft's AGD. The crew again assesses this speed and if acceptable enters it in the speed window of the MCP.

Along the descent both aircraft will decelerate and adjust their configuration according to the nominal flap schedule speeds. Pass the FAF, the ILS is intercepted and the aircraft follow the localizer and glide slope up to the runway.

5.3 Termination

The Tower (TWR) controller now clears KL642 to land. After touchdown the B777 decelerates and vacates the runway. Upon reaching the Planned Termination Point (PTP), the IM application will notify the crew of termination and remove the IM speed from the AGD. The crew is now instructed to fly the appropriate FAS in accordance will normal operational procedures. ATC will clear the aircraft for landing and the crew will finalize the 'before landing checklist'. Any existing spacing errors will be closed as a result of the dissimilar final approach speeds. After touchdown, KL1822 decelerates, and vacates the runway.

6 Airspace Characteristics, Supporting Systems and Operational Environment

6.1 Airspace Structure

The following section describes the airspace structure around Schiphol, in order to provide context to the IM operation.

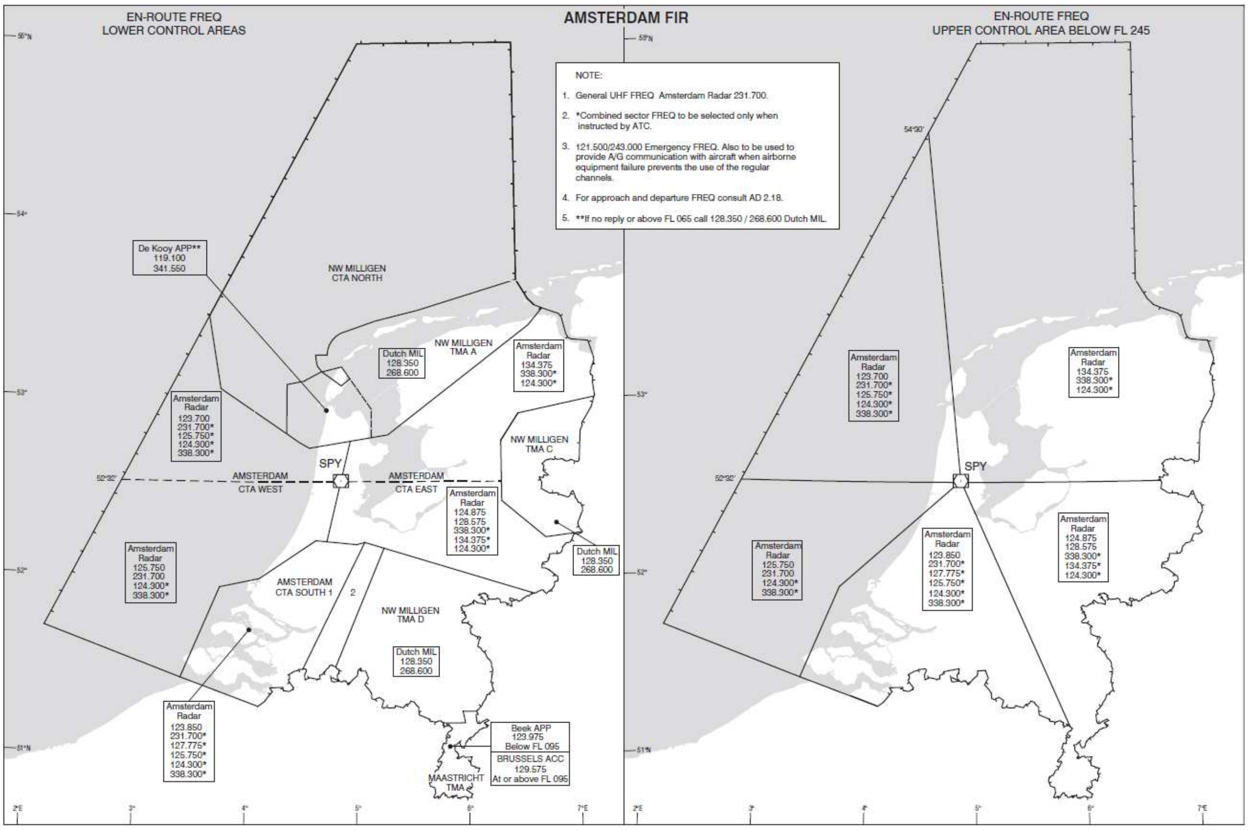

Figure 6-1: Amsterdam Flight Information Region

6.1.1 Amsterdam FIR

Dutch airspace is defined by one Flight Information Region or FIR (Amsterdam FIR). Northwest of the country control is delegated to London ACC. In the Southwest, ATS route L179 is controlled by ACC Brussels. Above FL245, ATC services are provided by the Maastricht UAC (Upper Area Control), which also provides the services in the upper airspace of Belgium, Luxembourg and Northwest Germany.

6.1.2 Arrival Airspace

An example cross section of the airspace, which an arriving aircraft might pass through, is shown in Figure 6-2:

- Airspace above Flight Level 195 (FL195) is designated as Upper Control Area (UTA)
- Airspace above FL245 is controlled by Maastricht Upper Area Control (MUAC);
- Airspace below FL245 and above FL055 is controlled by Amsterdam Radar (ACC);
- Below FL195 and above FL055/FL095[3] is designated as Lower Control Area (CTA)

[3] Depending on the TMA upper level, this varies per TMA.

- Below the CTAs, airspace is divided in Terminal Manoeuvring Areas (TMA). TMAs in the Amsterdam FIR run in general from 1500ft to the lower boundary of the CTA above. TMAs are in general constructed of class A and class E airspace.
- Within the TMAs are the local ATC areas, the Control Zones (CTR). The Schiphol CTR starts from ground level to an altitude of 3000 ft. The airspace is class C.

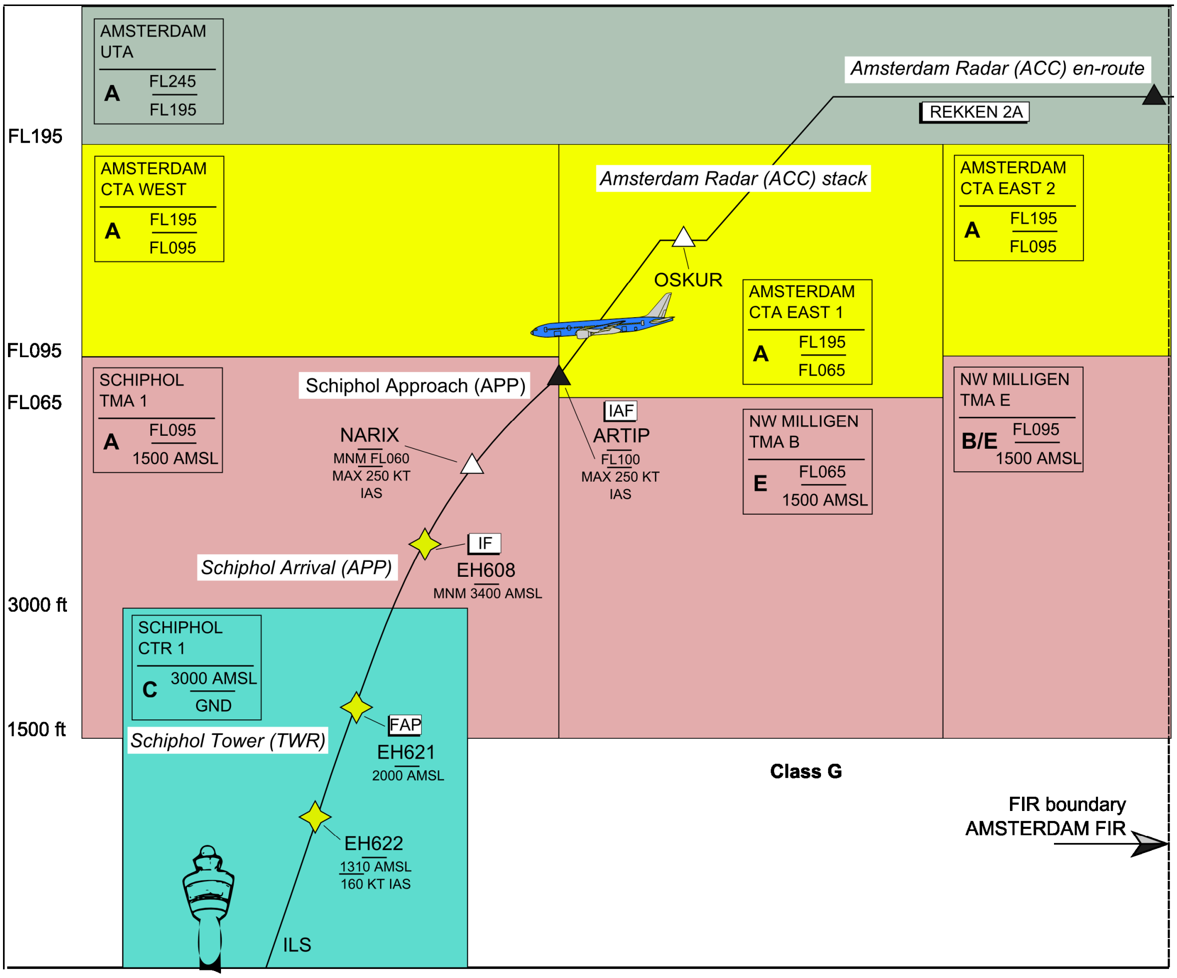

Figure 6-2: Schematic representation of airspace at Schiphol, the route is based on the RWY 18R CDO night arrival via a Rekken 2A ARTIP transition

6.1.3 IM Airspace

IM Operations are defined for and limited to IFR aircraft operating within the Schiphol TMA. In this airspace IM Operations can be implemented regardless of the associated traffic densities and aircraft types. IM Operations can occur in all weather conditions that the aircraft could otherwise operate in.

ASSUMP-OSED.14 IM Operation is defined for the arrival process within the Schiphol TMA only.

ASSUMP-OSED.15 IM Operations can be performed in airspace of any traffic density.

ASSUMP-OSED.16 IM Operations can be conducted under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC).

OR.40 The controller shall only issue the IM Instruction to an aircraft operating under Instrument Flight Rules (IFR).

6.2 Route structure

The routes to be flown are adapted to the IM operation. They consists of fixed P-RNAV routes from IAF to runway threshold. The routes include a nominal speed profile applicable for a specific aircraft performance class and has regulatory speed restrictions. Speed margins of ± 10 kts around the nominal speed profile are included to provide control space for meeting the spacing requirement. Aircraft with different performance characteristics (i.e. turbo-props) will follow a different route. Routes will merge at a point where the speeds are compatible (late merge). The altitude constraints result in a near idle 2° descent and not a full idle descent as this would diminish the control-space of the aircraft to achieve the assigned spacing goal. While allowing for some means of speed control the low thrust setting still reduces noise while the spacing goals can be achieved with speed on throttle control.

6.3 Equipage

ASAS-IM operations put requirements on both airborne and ground surveillance equipment as well as support tools. The goal is to minimize equipage requirements to enable early implementation.

6.3.1 Airborne Surveillance Equipage

There are multiple airborne surveillance methods that might be available to the IM Aircraft such as ADS-B, ADS-R and TIS-B. Any method that provides the necessary information of sufficient quality can be used for IM Operations.

The Target Aircraft for IM must be available to the IM Aircraft via airborne surveillance methods. This only applies to the identified Target Aircraft; therefore, there may be other aircraft in the relevant airspace which are not available to the IM Aircraft via airborne surveillance methods.

ASSUMP-OSED.17 The airborne surveillance level within the deployment environment is mixed.

The IM Aircraft is expected to be equipped with a graphical display of traffic that allows the flight crew to develop traffic situation awareness. This general traffic situation awareness is in addition to the flight crew's requirement to monitor the IM Operation although some shared elements are expected.

ASSUMP-OSED.18 The flight crew has a traffic situation awareness tool, such as ATSA-AIRB, available to them.

6.3.2 FIM Equipment

To perform an IM Operation, the IM Aircraft must have FIM Equipment capable of receiving and processing IM-related airborne surveillance data, processing IM algorithms to calculate availability and IM Speed, and interfaces to receive IM initiation information and display IM Speed and IM Situation Awareness Information.

A possible implementation of these airborne requirements is the use of a surveillance processor, which includes the ASAS-IM guidance algorithm, together with an ADS-B Guidance Display (AGD) and an Electronic Flight Bag (EFB). Initial implementations foresee no integration with the Flight Management System (FMS) or the Autopilot systems. The crew has to manually enter the speed commands (generated by the IM application and presented on the AGD) into the Mode Control Panel (MCP).

Figure 6-3 : Korry's ADS-B Guidance Display located under glareshield

An ADS-B guidance display (Figure 6-3) presents critical data in the pilot's forward field of view. It works in conjunction with an Electronic Flight Bag (EFB), displaying certain EFB information in the pilot's sight line, so the pilot does not have to turn the head momentarily. Information that is presented may include the IM speed, groundspeed difference and range to target[4].

Figure 6-4: Electronic Flight Bag (EFB) with ASPA-FIM information

Information with regard to own aircraft and Target aircraft position together with other essential IM information will be displayed on a EFB (Figure 6-4). As the the display of own-ship position in flight is prohibited on Class 1 or 2 configurations, the EFB for use with ASAS-IM will be of Class 3. A Class 3 EFB is considered "installed equipment" and subject to airworthiness requirements and, they must be under design control. The hardware is subject to a limited number of RTCA DO-160E requirements (for non-essential equipment—typical crash safety and Conducted and Radiated Emissions (EMC) testing). There may be DO-178B requirements for software, but this

[4] http://www.esterline.com/KORRY/Products/Controls/tabid/1314/Default.aspx

depends on the application-type defined in the Advisory Circular. Class 3 EFBs are typically installed under STC or other airworthiness approval.

The ASAS-IM application is characterized as a Type C applications which is subject to airworthiness requirements, such as software certification. Type C applications must run on Class 3 EFB.

The EFB depicted in the Figure 6-4 was used by MITRE CAASD in their Human In The Loop (HITL) studies and included the following information:

- IM aircraft position and route
- Traffic ADS-B information (call sign, position, vector)
- Spacing deviation indicator (green marking in front of IM aircraft)
- A fast/slow bug with the current speed shown
- IM speed
- Target Aircraft ground speed
- Range to Target Aircraft
- Ground speed differential

6.3.3 Ground Surveillance Equipage

The airspace is assumed to be under sufficient surveillance so that the controller has positive control over all involved aircraft. At Schiphol ATC has several means of surveillance available. Figure 6-5 shows a schematic representation of Dutch radar equipment. The two main surveillance systems available are:

- Primary Radar (PR);
- Secondary Surveillance Radar (SSR).

Two long distance radars (LAR) are utilized, located near Leerdam (with a range of max. 200 NM). This system features one primary/SSR main station, with an additional autonomous SSR. Information is then transmitted to the system's users:

- LVNL (Schiphol East)
- Military ATCC (Nieuw Milligen)
- Eurocontrol (Maastricht)

For the benefit of Schiphol Approach (APP), two Terminal Control Area Radars are active:

- Terminal Area Radar (TAR) 4 in the Amsterdam park called Amsterdamse Bos (PR and SSR, range approximately 60 NM)
- An autonomous SSR, TAR 1 at Schiphol functioning as back-up.

The Aerodrome Surface Detection Equipment (ASDE) radar used in Amsterdam Advanced ATC system (AAA) is a self-contained system. The antenna with the transmitters/receivers has been placed on top of the Schiphol tower. As the new 5th Schiphol runway (18R-36L) (Polderbaan) is not in reach of this ASDE, a second ASDE is placed between the 5th runway and the "Zwanenburg" runway (18C-36C) on the new second tower. The ASDE display, which is now using primary radar information, is also planned to show data labels. A transition to SSR-S ASDE is necessary for this, which in turn means that all vehicles need to be equipped with a SSR Mode S transponder.

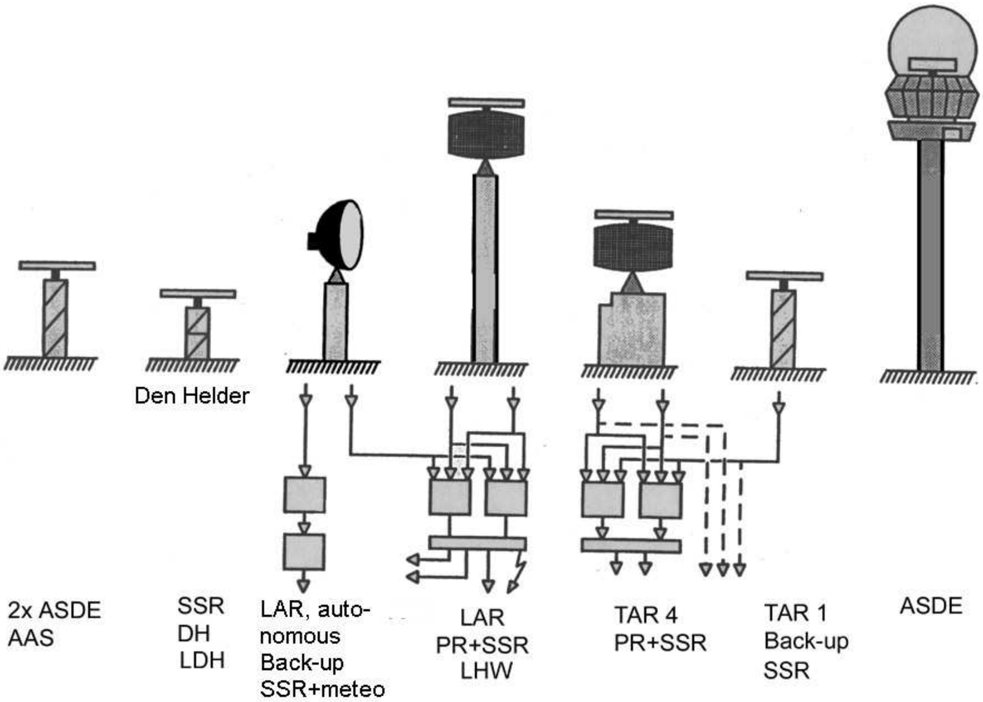

Figure 6-5: Schematic presentation of the Dutch surveillance radars (source [15])

6.3.4 ATC support tools

Support tools may be required to prevent a high rate of unacceptable IM Operations. Through the use of support tools it is assumed that the controller can determine if:

- an aircraft is IM capable;
- a possible Target Aircraft is available via airborne surveillance methods;
- the Target Aircraft's identification on the airborne surveillance method matches the filed flight plan; and
- applicability conditions are met.

The Target Aircraft might not be in the controller's area of responsibility at the time of the IM Instruction. The controller needs to be able to coordinate IM instructions with controllers of adjacent area's. Controllers who receive aircraft participating in an IM Operations as the IM Aircraft, a Target Aircraft or both, need to know the aircraft's status as well as the relevant IM Instruction parameters. It is assumed that the controller has the necessary information at hand when needed.

OR.41 Controllers shall have all necessary information at hand required to initiate an IM instruction, even when the target aircraft is not in the area of responsibility of the controller at the time of the IM Instruction.

During the execution phase the controller will need tools to monitor the operation. The controller needs to be able to compare the current spacing, with the required spacing at the achieve-by point. As the target value may only be achieved at the achieve-by point, discrepancies may occur along the route. A threshold value may be used to alert the controller for large diversions from the target value.

Example:
- Achieve 120 sec at threshold RW18R
- Current spacing 98 sec
- Alert threshold: 30 sec (min 90 sec, max 150 sec)

OR.42 Controllers shall be able to compare the current spacing interval, with the assigned spacing interval. Threshold values shall be used to alert the controller when large discrepancies occur.

Additional tools may be required to monitor the merge. As the merge is the most crucial phase in the operation it may be necessary to accurately predict the horizontal separation at the merge point. Vertical separation can not be guaranteed as all traffic fly CDOs. Research will have to determine if additional tools are required. These tools may come in the form of ghosting or calculation of the predicted separation at the merge point given current state, route and wind conditions.

The controller also needs to the ability to return to normal operations if so required.

OR.43 Controllers shall be able to return to and operate under normal operations.

6.4 Communication Means

Direct Controller-Pilot Communication is required for all IM Operations. Primary means of communication will be voice as data link capabilities such as CPDLC may not be available within the implementation time frame for IM operations. The text does indicate, however, which elements would be suitable for data link communication should it become available.

Table 6-1. Distribution of information over communication channels

Information element	**Communication means**
Lead aircraft call sign	R/T (/ data link)
Name of the approach transition of the lead aircraft	R/T (/ data link)
Final approach speed of the lead aircraft	R/T (/ data link)
Required spacing interval to be achieved by the IM aircraft	R/T (/ data link)
Achieve-by point	Published procedure
Termination point	Published procedure
IM tolerance	Published procedure

For tactical commands voice communication will be used:

- Suspend and resume
- Premature termination
- Tactical intervene

The possible IM Instructions can be grouped into three categories: simple, dynamic instructions; complex, dynamic instructions; and complex, pre-defined instructions.

The simple, dynamic instructions are ones that make use of the basic manoeuvres and provide straight-forward information. Example would include:

- <CALL SIGN> cleared CDO approach runway <ACHIEVE-BY POINT>, <ASSIGNED SPACING GOAL> seconds behind <TARGET AIRCRAFT>. Target is on the <ROUTE NAME> with final approach speed <FAS>; terminate at <PLANNED TERMINATION POINT>; IM tolerance is <TOLERANCE> seconds

In the simple, dynamic instructions all of the required initiation data is explicitly specified in the IM Instruction and the controller is able to specify each of the elements.

The complex, dynamic instructions allow for even more information to be communicated in the IM Instruction. The information will be split over multiple messages. Because there is too much information to reliably communicate by voice, the complex, dynamic IM Instruction will need to be issued via data link.

To enable more complex instructions some of the initiation data could be encoded into a navigation procedure that was designed to support IM Operations. The navigation procedure would be set up to support a particular type of IM Operation and many of the IM initiation parameters would be defined in the procedure. The controller has less flexibility than a full dynamic instruction but can communicate their desires more quickly and with less error. These IM Instructions may be communicated by voice or data link and the procedure defined on a chart or in a database in the FIM Equipment. Examples include:

- <CALL SIGN> cleared CDO approach runway <ACHIEVE-BY POINT>, <ASSIGNED SPACING GOAL> seconds behind <TARGET AIRCRAFT>. Target is on the <ROUTE NAME> with final approach speed <FAS>; [Planned Termination Point and IM tolerance are identified on the procedure and in the IM database if available.]

All IM Special Points will be named waypoints on the Intended Flight Path.

For a full set of pilot/controller phraseology refer to section 9.3.

7 Arrival planning and procedures

To enable IM operations, arriving aircraft need to be sequenced and scheduled to create a feasible and safe arrival stream. The sequence is the ‘natural’ order of arrival (first come first serve), the schedule is the assignment of time slots to the aircraft in the sequence for separation purposes.

The sequence will be determined by an Arrival Manager, which (for each aircraft) will assign a time slot at the IAF. ATC maintains the sequence and the schedule by giving speed or route instructions to the arriving aircraft (vectoring). The Speed and Route Advisory (SARA) tool, which will be implemented in the coming years, will be used to meet the time slot more accurately. The goal is to have the aircraft enter the TMA in the proper sequence, with enough separation, so that the assigned spacing goal can be achieved.

If somehow the time slot can not be realized, the aircraft may need to be taken out of the sequence and be re-scheduled. Improper sequences or large diversions from the assigned IAF crossing time, may result in the IM aircraft not be able to initiate or maintain IM operations. Inability to maintain IM operations results in having to revert back to normal operations.

7.1 Arrival Manager, AMAN

The Arrival Manager (AMAN) at LVNL/Schiphol called the Inbound Planner (IBP) is used to create the sequence and arrival schedule [16]. The core feature of the AMAN is a Trajectory Predictor. This Trajectory Predictor (TP) predicts the 4D trajectory of all arriving aircraft based on assigned route, aircraft type and other information. By predicting the trajectories of all aircraft a sequence of runway Estimated Time of Arrivals (ETA) is calculated, this then is used to determine the aircraft sequence.

IBP operates by defining a default main landing runway per IAF. The traffic to this runway is regulated through the introduction of a landing interval between each aircraft in sequence. The landing interval is either calculated from the minimal Wake Turbulence Categories (WTC) radar separation between two flights or a fixed value. The result is the computation (and display) of landing slots for each inbound flight to the runway and the computation (and display) of its Expected Approach Time (EAT). This result is then manually tuned by the approach planner for optimal runway usage.

The computed EATs are used by ACC controllers as a time reference for the aircraft to pass the IAF and be transferred to APP. Currently a margin of two minutes on this reference time is allowed. For IM operations with CDO’s a higher accuracy is desired. Here the SARA tool comes into view.

7.2 Speed And Route Advisor, SARA

SARA is a tool utilized by ACC (area control) to deliver aircraft with increased precision at the IAFs [16].

In current day operations, the AMAN precision of around 2 minutes at the IAF is accurate enough, as enough control space is available in the TMA for precise delivery. One disadvantage of vectoring aircraft however is noise nuisance because aircraft often need to be vectored over dense populated areas. Therefore there is a strong need to deliver aircraft as accurate as possible at the IAFs as this requires the minimum amount of vectoring in the TMA, increasing efficiency and allowing for flying fixed noise abating (RNAV) routes.

The SARA tool uses an advanced (w.r.t. AMAN TP) trajectory predictor, which calculates the ETA at the IAF based on the current position and route of the aircraft. This current position is initially before the ToD and often extends over the FIR boundary. This extended horizon of the tool means that adjacent ATC centres will be involved.

Further input for the SARA tool is the AMAN sequence with the assigned[5] EATs at the IAFs. SARA compares the AMAN EAT with the own predicted ETA based on current aircraft position and route. If the difference is outside a set bandwidth (+/- 30 seconds at IAF), SARA initiates the process to generate advisories. An iterative process is started where SARA uses the TP to calculate a speed and route combination that will deliver the aircraft to the IAF, such that the difference between the AMAN EAT and the SARA ETA is below the threshold value. Once a solution is found, it is communicated to the controller. The aim of SARA is to deliver aircraft at the IAF within +/- 30 seconds of the scheduled time. Whether this is sufficient for ASAS-IM application has to be determined in the Performance Requirements analysis.

Several concepts are described in the SARA CONOPS [17] which refer to different levels of implementation.

Starting from a given basic concept, three operational concepts have been defined:

- Concept 1 - Speed only
- Concept 2 - Speed and, if required, static route
- Concept 3 - Conflict-free speed and, if required, dynamic route

The goal is to implement a level 2 application at LVNL/Schiphol in 2013 which will include speed and (fixed) route advisories. Level 1 only gives speed advisories while a level 3 implementation is able to give speed and dynamic route advisories.

Even though operational trials have been carried out, the tool is at the moment not operational.

7.3 Arrival procedures

Refer to Figure 6-2 for a schematic representation of the airspace and responsible controllers. The control sequence of an arriving aircraft both in current day operation as well as ASAS-IM operation is described in the following sections.

7.3.1 Initial Arrival

- Involved controller(s): Amsterdam Radar; ACC-en-route, ACC-stack
- Passing through Airspace: Amsterdam UTA Class A, Amsterdam CTA Class A

Table 7-1: Arrival procedure - Current day vs. ASAS-IM

Current day	ASAS-IM
- The expected approach time (EAT) is determined as soon as possible *after or just before the aircraft enters the Amsterdam FIR.* The EAT is computer calculated (AMAN) and based on the predicted time over the touchdown point and the required landing interval. - AMAN determines arrival sequence and calculates the computed EATs which are used by ACC controllers as a time reference for the aircraft to pass the IAF - At or before entering the Amsterdam Control Area (i.e. from UTA to CTA) an arrival clearance will be issued by the Amsterdam ACC-en-route-controller. The clearance contains: ▪ STAR ID, the clearance limit is the IAF; ▪ Main landing runway (usually contained in ATIS and not communicated);	- The expected approach time (EAT) is determined *prior to the aircraft entering the Amsterdam FIR (e.g. prior to ToD).* This means adjecent centers may be involved. The EAT is computer calculated (AMAN) and based on the predicted time over the touchdown point and the required landing interval. - AMAN determines arrival sequence and calculates the computed EATs which are used by ACC controllers as a time reference for the aircraft to pass the IAF - At or before entering the Amsterdam Control Area (i.e. from UTA to CTA) an arrival clearance will be issued by the Amsterdam ACC-en-route-controller. The clearance contains: ▪ STAR ID, the clearance limit is the IAF; ▪ Main landing runway (usually contained in ATIS and not

[5] The scheduled EATs at the IAF become assigned EATs for the SARA tool.

▪ Level instructions (at this point usually a descent instruction); ▪ SSR code. - If traffic permits, profile descents may be executed in order to optimize fuel efficiency. Distance to touchdown will be provided by ATC as soon as possible. - Speed and level restrictions are contained in the published arrival procedures. Additional speed and level instructions: ▪ Cross IAF (ARTIP, RIVER and SUGOL) at or below FL 100 unless otherwise instructed; ▪ Below FL 100 maximum 250 KT IAS unless otherwise instructed; ▪ Cross 15 DME SPL at 220 KT IAS; ▪ ATC will initiate speed reductions below 220 KT IAS; ▪ When established on ILS: maintain 160 KT IAS until 4 NM before threshold; ▪ Speed > 220 KT accurate within 10 KT; speed < 220 KT accurate within 5 KT. - During times of heavy delays, transfer to the ACC-stack-controller takes place after initial descent clearance has been issued and the aircraft is clear of en route traffic. The ACC-stack-controller will issue additional instructions with respect to: ▪ Further descent; ▪ EAT, if delay is affected by holding over the IAF. - Transfer to the approach-controller takes place just prior to the IAF. ACC will instruct the aircraft to descent to FL100, speed 250, contact Schiphol Approach (APP) - While being transferred from ACC to APP, initial contact shall be restricted to: `Schiphol Approach + call sign`	communicated); ▪ Level instructions (at this point usually a descent instruction); ▪ SSR code. - SARA compares the AMAN EAT with the own predicted EAT based on current aircraft position and route. SARA output is used to control aircraft to the IAF - If traffic permits, profile descents may be executed in order to optimize fuel efficiency. Distance to touchdown will be provided by ATC as soon as possible. - Speed and level restrictions are contained in the published arrival procedures. Additional speed and level instructions: ▪ Cross IAF (ARTIP, RIVER and SUGOL) at or below FL 100 unless otherwise instructed; ▪ Below FL 100 maximum 250 KT IAS unless otherwise instructed; ▪ Adhere to nominal speed profile or otherwise instructed by IM equipement; ▪ Speed accurate within 10 KT of the nominal speed profile - During times of heavy delays, transfer to the ACC-stack-controller takes place after initial descent clearance has been issued and the aircraft is clear of en route traffic. - ACC continues to use SARA output to control aircraft to the IAF - ACC will request the aircraft's planned Final Approach Speed. - ACC ensures that all ASAS-IM applicability conditions are met and issue the IM instruction which includes: ▪ Target Aircraft ID ▪ Assigned Spacing Goal; ▪ Achieve-by Point; ▪ Planned Termination Point; ▪ IM Tolerance; ▪ IM Aircraft Intended Flight Path Information; ▪ Target Aircraft Intended Flight Path Information; and ▪ Target Aircraft Final Approach Speed. - The IM instruction acts as the approach clearance, which clears the aircraft to the runway in accordance with the spacing instruction. - Transfer to the approach-controller takes place when the aircraft is clear of the holding area at the IAF. While being transferred from ACC to APP, initial contact shall be restricted to: `Schiphol Approach + call sign`

7.3.2 Initial Approach

- Involved controller(s): Schiphol Approach; APP; Schiphol Arrival; APP
- Passing through Airspace: Schiphol TMA Class A

Current day	ASAS-IM
- Additional approach instructions issued by the Schiphol Approach controller will contain: ▪ Clearance limit and level instructions ▪ Vectors ▪ QNH - Runway in use, transition level, MET information and runway condition is received via ATIS - Transfer to the Schiphol Arrival (APP) controller takes place before the aircraft enters the final approach vector area. - While being transferred from Schiphol Approach (APP) to Schiphol Arrival (APP), initial contact shall be restricted to: `Schiphol Arrival + call sign`	- APP provides QNH - APP monitors the ASAS-IM operations and may suspend or terminate the operation if need be - No additional approach instructions are issued as the aircraft is cleared to the active runway in accordance to the approach procedure - Runway in use, transition level, MET information and runway condition is received via ATIS - Transfer to the Schiphol Arrival (APP) controller takes place before the aircraft enters the final approach vector area. - While being transferred from Schiphol Approach (APP) to Schiphol Arrival (APP), initial contact shall be restricted to: `Schiphol Arrival + call sign`

7.3.3 Intermediate Approach

- Involved controller(s): Schiphol Àrrival; APP
- Passing through Airspace: Schiphol TMA Class A

Current day	ASAS-IM
- The Schiphol Arrival controller will issue instructions for descent and interception on final approach - Traffic sequencing will be established based on traffic demand	- APP monitors the ASAS-IM operations and may suspend or terminate the operation if need be

7.3.4 Final Approach

- Involved controller(s): Schiphol Tower; TWR
- Passing through Airspace: Schiphol CTR Class C

Current day	ASAS-IM
- Transfer to Schiphol Tower (TWR) takes place after the aircraft is established on final approach. - While being transferred from Schiphol Approach/Arrival (APP) to Schiphol Tower (TWR), initial contact shall consist of: `Schiphol Tower + call sign + Runway` - Aircraft cleared to land - After landing the aircraft vacates the runway and contacts Schiphol Ground.	- Transfer to Schiphol Tower (TWR) takes place after the aircraft is established on final approach. - While being transferred from Schiphol Approach/Arrival (APP) to Schiphol Tower (TWR), initial contact shall consist of: `Schiphol Tower + call sign + Runway` - Aircraft cleared to land - After landing the aircraft vacates the runway and contacts Schiphol Ground.

8 Roles and Responsibilities

Two participants are identified that can participate in an IM Operation: the controllers and the flight crew of the IM Aircraft. The controllers remain responsible for ensuring separation of the IM Aircraft from all aircraft, including the Target Aircraft.

Instead of providing numerous speed and vector instructions, the controller uses IM to achieve the same goal by instructing the flight crew to achieve the Assigned Spacing Goal. Once the flight crew enters the IM Information, they follow the IM Speeds provided by the FIM Equipment in exactly the same manner as they follow speed instructions from the controller. The operation is much like operations without IM.

8.1 Roles and Responsibilities of the Controller

The controllers shall be trained to perform IM Operations and have the means to initiate the IM operations, monitor its execution and terminate the IM Operations if need be.

The controller is responsible for:

- ensure proper preconditioning of the arrival flow
- determining if an IM Operation is desirable;
- identifying the IM Aircraft, the Target Aircraft, the Assigned Spacing Goal as well as any other application-specific data needed for the IM Operation;
- verifying that all initiation criteria are met to ensure a reasonable expectation of a successful operation. This may include comparable position, performance and routing of the IM and Target Aircraft as well as equipage levels and other operation-specific criteria;
- communicating the initiation data (IM Operation, Target Aircraft Identification, Assigned Spacing Goal and IM Special Points) to the IM Aircraft;
- ensuring separation between the IM Aircraft and all other aircraft, include the Target Aircraft;
- terminating the IM Operation if the ATM goal is no longer applicable or is not being met; and
- resuming non-IM Operations whenever the IM Operation is terminated.

8.2 Roles and Responsibilities of the IM Aircraft Flight Crew

The crew onboard both aircraft are trained on how to use the FIM Equipment and to perform the IM Operations.

The flight crew is responsible for:

- determining whether to accept or reject the IM Clearance;
- selecting the Target Aircraft and enter the other IM initiation data into the FIM equipment;
- confirming Target Aircraft Identification to the controller using the defined IM procedure;
- determine if IM Aircraft is capable of performing the instructed manoeuvres before initiating an IM Operation;
- informing the controller whether they accept or reject the IM Clearance; (May be combined with target identification if the procedure allows.)
- following the IM Speed and turn guidance;
- monitoring progress towards meeting the IM Clearance; and
- informing the controller when the IM Operation is to be terminated due to equipment failure, when the Assigned Spacing Goal is no longer achievable or other reason.

9 Procedural Flow

The IM Operation is based on the following procedural flow:

Pre-Initiation Phase:

- The controller determines the proper arrival sequence for the runway in use.
- The controller controls the aircraft to the IM initiation point (IAF) within the accuracy requirements for ASAS-IM initiation (+/- 30 sec. of scheduled time).

Initiation Phase:

- The controller determines that the use of an IM Operation would be beneficial and viable.
- The controller determines the IM Aircraft and the Target Aircraft. If the information is available, the controller confirms that the IM and Target Aircraft are suitably equipped and capable. If that information is not available, the controller can proceed with the instruction and when the flight crew assesses the instruction they will determine if they and the Target Aircraft are capable.
- The controller determines the Assigned Spacing Goal, as well as associated parameters. The controller may also need to check any application-specific applicability conditions. The controller may use automation support in this determination.
- The controller communicates to the flight crew the Target Aircraft's identification and the requested IM Manoeuvre with the associated parameters. Information delivery will be by voice communication optionally data link. Target Aircraft Identification request may be in a separate message from the application-specific information.
- The flight crew identifies the Target Aircraft and makes the additional data available to the FIM Equipment. The flight crew accepts or rejects the instruction as appropriate.
- Once the IM Clearance is accepted, the flight crew executes the IM Operation.

Execution Phase:

- The Execution Phase begins when the flight crew accepts the IM Clearance. The FIM Equipment provides an IM Speed to drive to achieve the Assigned Spacing Goal at the Achieve-by Point.
- The flight crew monitors the progression of the operation to ensure that the Assigned Spacing Goal remains feasible and no faults occur with the FIM Equipment, and notifies the controller if it becomes no longer feasible. The flight crew is responsible for conformance to the IM Clearance and determining if an IM Operation is acceptable.
- The controller monitors the procedure execution while providing separation assurance.

Termination Phase:

- If the IM Aircraft reaches the defined Planned Termination Point, the IM Operation is terminated and operations revert to non-IM procedures.
- If the FIM Equipment determines that a valid IM Speed can no longer be calculated the FIM Equipment notifies the flight crew. The flight crew notifies the controller that they are terminating the IM Operation and the controller resumes non-IM procedures. Procedures may be needed until the controller can resume non-IM procedures.
- If the controller determines that termination of the IM Operation is necessary for efficient flow of traffic, or due to separation concerns or the existence of other abnormal conditions, the controller instructs the flight crew to terminate the IM Operation and the controller resumes non-IM procedures.
- If the flight crew ascertains that the operation cannot be continued, or determines the need for resumption of non-IM Operations for other reasons, they terminate the IM Operation and notify the controller.

9.1 Phase Diagram

The following flowchart describes graphically the process to be executed during an IM Operation. The specific actions or decisions are assigned to either the aircraft (AC) or ground (GND) domains. Where applicable, further specificity is achieved for flight crew (AC-FC), avionics (AC-AV) and controller (GND-ATC).

Precondition and Initiation

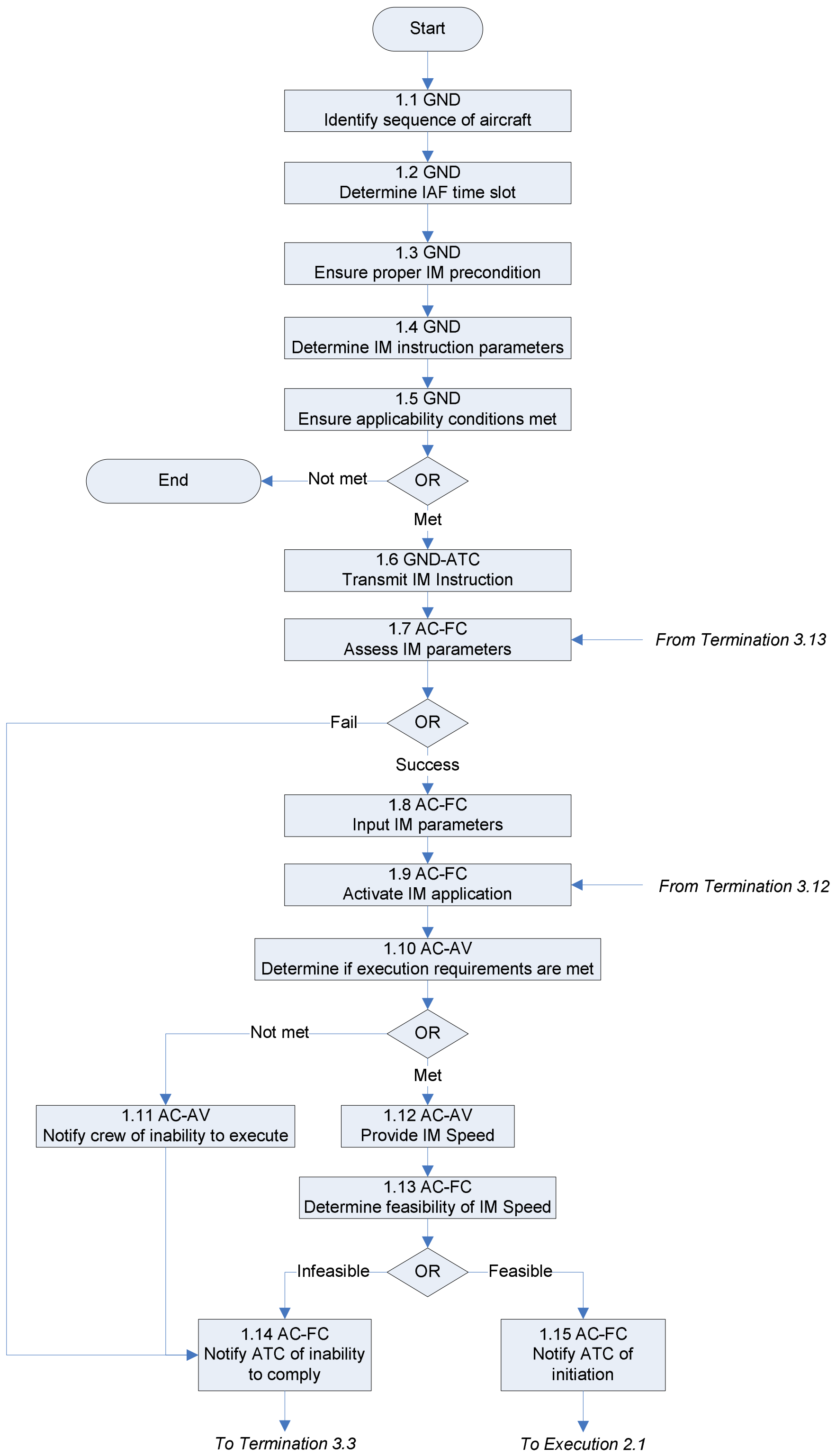

Figure 9-1: ASPA-FIM Precondition and Initiation Phases

Execution

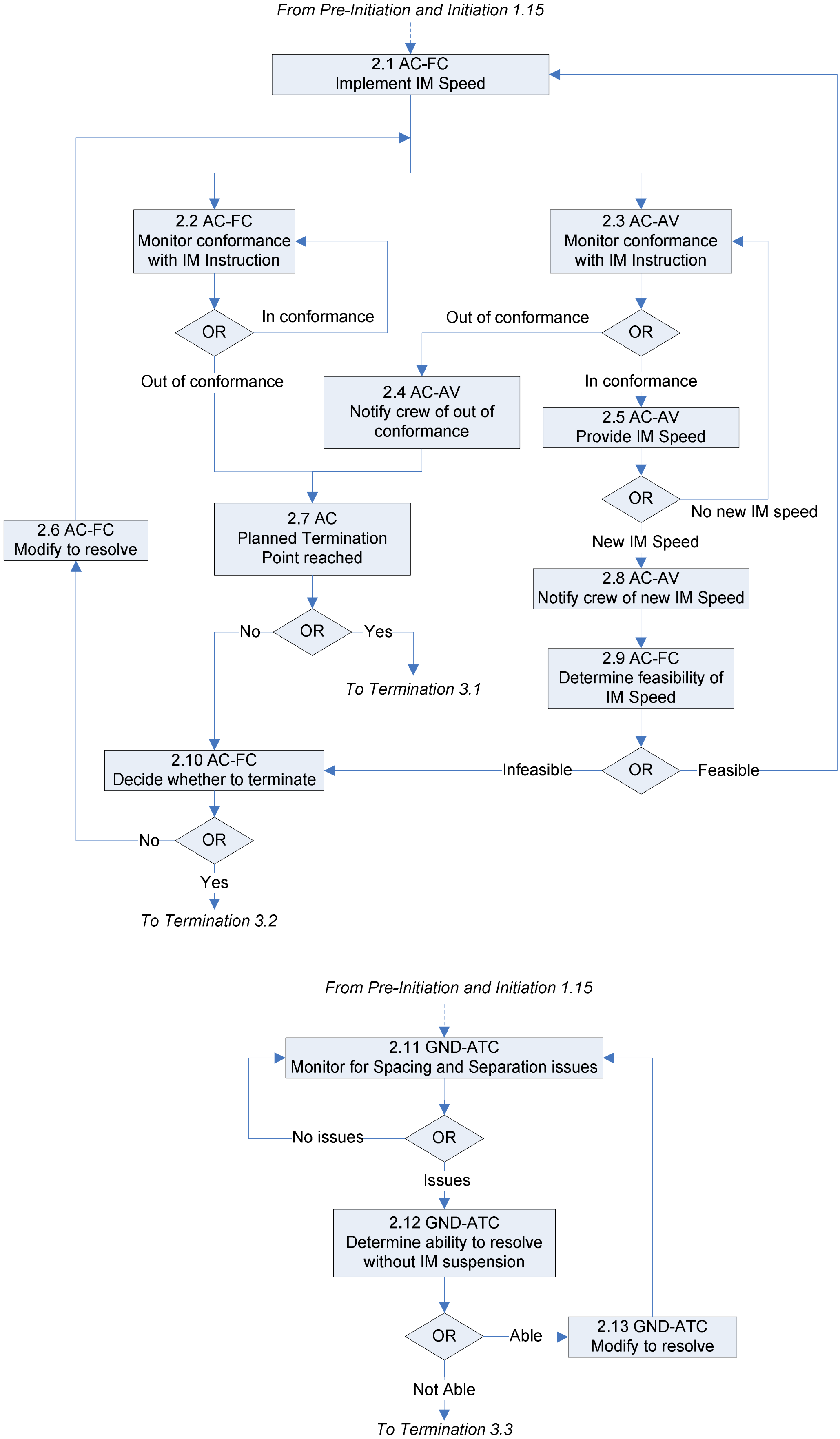

Figure 9-2: ASPA-FIM Execution Phase

Termination

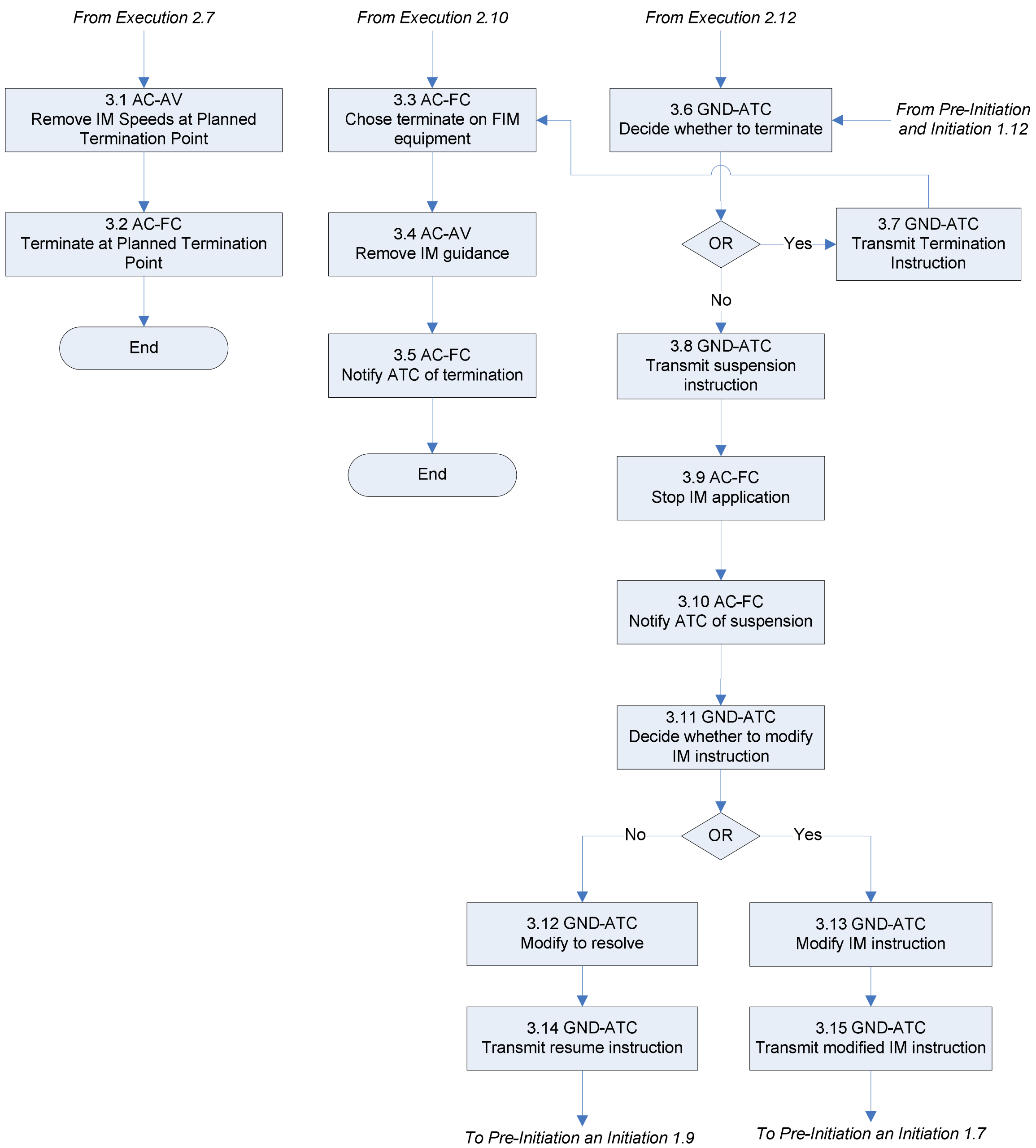

Figure 9-3: ASPA-FIM Termination Phase

9.2 Phase Table

ID	Domain	Description	Information needed	Conditions for transfer to next action	Next
Precondition and initiation					
1.1	GND	Identify sequence of aircraft	- ETA runway threshold - Required runway threshold separation	- AMAN defined Sequence	1.2
1.2	GND	Determine IAF time slot	- ETA runway threshold - AMAN sequence	- IAF reference time slot	1.3
1.3	GND	Ensure IM precondition	- IAF reference time slot - SARA	- IAF crossing within +/- 30 sec of time slot	1.4
1.4	GND	Determine IM instruction parameters	- Target Aircraft Identification; - Assigned Spacing Goal; - IM Manoeuvre; - Achieve-by Point; - Termination Point - IM Tolerance; and - Target Aircraft intended Flight Path Information.	- Complete and correct IM instruction	1.5
1.5	GND	Ensure applicability conditions met	Aircraft involved have: - appropriate equipment; - compatible speed profiles (or compatible characteristics with respect to aircraft performance); - compatible positions (altitudes and relative position); and - compatible routes.	- Applicability conditions met	1.6
				- Applicability conditions not met	End
1.6	GND-ATC	Transmit IM instruction	- IM aircraft Identification - Complete and correct IM instruction	- IM instruction sent	1.7
1.7	AC-FC	Assess IM parameters	- The Target Aircraft has been positively identified; - the flight crew is trained for IM Operations; - the FIM Equipment is able to present IM Speed; and - there is a reasonable likelihood of successfully completing the IM Operation.	- Assessment successful	1.8
				- Assessment not successful	1.14
1.8	AC-FC	Input IM parameters	- IM instruction	- IM parameters entered into FIM equipment	1.9
1.9	AC-FC	Activate IM application			1.10
1.10	AC-AV	Determine if execution requirements are met	- Target Aircraft data quality is sufficient for the IM Operation; - IM Aircraft data quality is sufficient for the IM Operation;	- Execution requirements met	1.12
				- Execution requirements not met	1.11
1.11	AC-AV	Notify crew of inability to execute			1.14
1.12	AC-AV	Provide IM speed			1.13
1.13	AC-FC	Determine feasibility of IM speed	- Respect regulatory speed limits	- IM speed is feasible	1.15

			- Within aircraft performance limits	- IM speed is not feasible	1.14
1.14	AC-FC	Notify ATC of inability to comply	- Reason of inability to comply	- Notification sent	3.3
1.15	AC-FC	Notify ATC of initiation	WILCO include: - Target Aircraft Identification; - Assigned Spacing Goal; - IM Manoeuvre; - Achieve-by Point; - Termination Point - IM Tolerance;	- Notification sent	2.1

ID	Domain	Description	Information needed	Conditions for transfer to next action	Next
Execution (Airborne)					
2.1	AC-FC	Implement IM speed	- IM speed	- IM speed implemented	2.2 2.3
2.2	AC-FC	Monitor conformance with IM instruction	- maintains a safe flying speed; - conforms to regulatory speed limits; - able to achieve the Assigned Spacing Goal; and - No FIM Equipment or annunciated failures.	- In conformance	2.2
				- Out of conformance	2.7
2.3	AC-AV	Monitor conformance with IM instruction	- the data quality for the IM Aircraft is no longer sufficient; - the data quality for the Target Aircraft is no longer sufficient - the FIM Equipment is no longer able to provide the IM Speed	- In conformance	2.5
				- Out of conformance	2.4
2.4	AC-AV	Notify crew of out of conformance	- Reason for out of conformance	- Notification sent	2.7
2.5	AC-AV	Provide IM speed			2.8
2.6	AC-FC	Modify to enable	- Reason for out of conformance	- Modification made	2.2 2.3
2.7	AC	Planned Termination Point reached		- PTP reached	3.1
				- PTP not reached	2.10
2.8	AC-AV	Notify crew of new IM speed	- IM speed	- Notification sent	2.9
2.9	AC-FC	Determine feasibility of IM speed	- Respect regulatory speed limits - Within aircraft performance limits	- IM speed is feasible	2.1
				- IM speed is not feasible	2.10
2.10	AC-FC	Decide whether to terminate	- Reason for out of conformance - Reason for IM speed infeasible to implement	- Modification possible	2.6
				- No modification possible	3.2

ID	Domain	Description	Information needed	Conditions for transfer to next action	Next
Execution (Ground)					
2.11	GND-ATC	Monitor for Spacing and Separation issue	- Surveillance information - Required spacing - Sequence - Predicted runway threshold	- No issues	2.11
				- Issues	2.12

			ETA		
2.12	GND-ATC	Determine ability to resolve without IM suspension	- Reason for having spacing/ separation issues	- Able	2.13
				- Not able	3.3
2.13	GND-ATC	Modify to resolve	- Reason for having spacing/ separation issues	- Resolved issue	2.11

ID	Domain	Description	Information needed	Conditions for transfer to next action	Next
Termination					
3.1	AC-AV	Remove IM Speed at Planned Termination Point	- Location Planned Termination Point	- IM speed removed	3.2
3.2	AC-FC	Terminate at Planned Termination Point	- Location Planned Termination Point	- IM operation terminated	End
3.3	AC-FC	Chose terminate on FIM equipment			3.4
3.4	AC-AV	Remove IM guidance			3.5
3.5	AC-FC	Notify ATC of termination	- Reason for termination	- Notification sent	End
3.6	GND-ATC	Decide whether to terminate	- Reason for possible termination	- Terminate	3.7
				- Do not terminate	3.8
3.7	GND-ATC	Transmit Termination Instruction	- IM aircraft identification	- Termination instruction sent	3.3
3.8	GND-ATC	Transmit suspension instruction	- IM aircraft identification	- Suspension instruction sent	3.9
3.9	AC-FC	Stop IM application	- IM suspend instruction	- IM operation suspended	3.10
3.10	AC-FC	Notify ATC of suspension	- WILCO	- Notification sent	3.11
3.11	GND-ATC	Decide whether to modify IM instruction	- Reason for suspension	- Modify	3.13
				- Do not modify	3.12
3.12	GND-ATC	Modify to resolve	- Reason for having spacing/ separation issues	- Resolved issue	3.14
3.13	GND-ATC	Modify IM instruction	- Modified IM parameters	- Modified IM instruction	3.15
3.14	GND-ATC	Transmit resume instruction	- IM aircraft identification	- Notification sent	1.7
3.15	GND-ATC	Transmit modified IM instruction	- Modified IM instruction	- Notification sent	1.5

9.3 Pilot-controller phraseology

ID	Description	GND-ATC	AC-FC
1.6	Transmit IM instruction	<call sign> cleared CDO approach runway <rwy number>, <interval> seconds behind <target>. Target is on the <transition> with final approach speed <FAS>	
1.14	Notify ATC of inability to comply		Unable spacing due - equipment failure - interval too large/close - no target lock - etc.
1.15	Notify ATC of initiation		Cleared CDO approach, <interval> sec behind <target> on <transition>, with final approach speed <FAS>, <call sign>
3.5	Notify ATC of termination		**Termination due ATC (from 3.7):** breaking off spacing, <call sign> **Termination due AC (from 2.10):** <call sign> breaking off spacing, unable speed profile
3.7	Transmit Termination Instruction	<cal sign> cancel spacing, speed <speed command>	
3.8	Transmit suspension instruction	<call sign> suspend spacing, standby revised clearance	
3.10	Notify ATC of suspension		Suspending spacing, standing by, <call sign>
3.14	Transmit resume instruction	<call sign> resume spacing, <time> seconds in trail behind <target>	
3.15	Transmit modified IM instruction	<call sign> re-cleared spacing, <time> seconds in trail behind <target> on the <transition>, final approach speed is <FAS>	

<call sign>	call sign of the IM aircraft
<target>	call sign of the lead aircraft
<interval>	time-interval in number of seconds
<transition>	name of the CDO transition of the lead aircraft
<FAS>	final approach speed in knots of the lead aircraft
<speed command>	indicated airspeed in knots to be maintained by the IM aircraft

10 Summary of Assumptions and Requirements

10.1 ATM System Requirements

Table 10-1: OSED ATM System Requirements for the relevant KPAs

Reference	System Requirement
ASR.1	The introduction of IM Operations shall retain daytime capacity while performing Continuous Descent Operations along fixed routes.
ASR.2	IM Operations shall not increase the workload of controllers beyond a manageable level.
ASR.3	IM Operations shall not increase the workload of flight crews beyond a manageable level.
ASR.4	The introduction of IM Operations shall not lead to a reduction in safety.
ASR.5	IM Operations shall support the controllers in creating a more predictable and stable traffic flow
ASR.6	The introduction of IM Operations shall enable increased CDO, which shall decrease the noise and emission impact of flight operations.
ASR.7	The introduction of IM Operations shall enable increased CDO, which shall increase the fuel efficiency of flight operations.
ASR.8	The introduction of IM Operations shall retain the flexibility in changing runway configurations.

10.2 Assumptions

Table 10-2: OSED Assumptions

Reference	Assumption
ASSUMP-OSED.1	Intentional misuse or abuse of the FIM Equipment or procedures is outside the scope of this document.
ASSUMP-OSED.2	The controller only issues an IM Instruction that is feasible including appropriate Target Aircraft, the Assigned Spacing Goal, and any included IM Special Points.
ASSUMP-OSED.3	The controller has the necessary information to determine the IM Aircraft, Target Aircraft and Assigned Spacing Goal.
ASSUMP-OSED.4	The airspace is under surveillance (e.g., radar and/or ADS-B-RAD) so that the controller has positive control over all involved aircraft.
ASSUMP-OSED.5	The controller has selected an IM Aircraft and Target Aircraft which have the appropriate equipment, compatible speed profiles, compatible positions and compatible routes.
ASSUMP-OSED.6	There is appropriate coordination between all controllers involved in the IM Operation to enable the IM Operation to proceed without undo interruption.
ASSUMP-OSED.7	The IM Aircraft has already received, and is following, a navigation clearance which defines their Intended Flight Path.
ASSUMP-OSED.8	The Target Aircraft Identification used in the IM Instruction matches what the Target Aircraft is broadcasting as its identification.
ASSUMP-OSED.9	Direct Controller-Pilot Communications (DCPC), such as voice, data link or other method, is available throughout the IM Operation.
ASSUMP-OSED.10	The controller and flight crew are provided with a new set of voice (and optionally data link) messages to conduct IM, but the guidelines for these are out of scope for this document.
ASSUMP-OSED.11	The flight crew manually inputs the IM Speed into the speed guidance system, which is active during the IM manoeuvre.
ASSUMP-OSED.12	The IM Clearance has the equivalent effect to a controller's speed instruction and supersede Speed Constraints on the IM Aircraft's Intended Flight Path; however, appropriate regulatory Speed Restrictions are still to be respected.
ASSUMP-OSED.13	During aircraft handoffs between controllers, the receiving controller has sufficient information to continue the IM Operation.
ASSUMP-OSED.14	IM Operation are defined for the arrival process within the Schiphol TMA only.

ASSUMP-OSED.15	IM Operations can be performed in airspace of any traffic density.
ASSUMP-OSED.16	IM Operations can be conducted under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC).
ASSUMP-OSED.17	The airborne surveillance level within the deployment environment is mixed.
ASSUMP-OSED.18	The flight crew has a traffic situation awareness tool, such as ATSA-AIRB, available to them.

10.3 Operational Requirements

Table 10-3: OSED Operational Requirements

Ref.	Operational Requirement
OR.1	The controller shall be trained to perform IM Operations.
OR.2	The controller shall determine when to use an IM Operation.
OR.3	The controller shall assign a precise Assigned Spacing Goal.
OR.4	The Achieve-by Point, which is a point on the IM Aircraft's Intended Flight Path, shall be an intrinsic part of the cleared navigation procedure.
OR.5	The Planned Termination Point, which is a point on the IM Aircraft's Intended Flight Path, shall either be an intrinsic part of the cleared navigation procedure.
OR.6	As part of the IM Instruction, the controller shall identify the Intended Flight Paths of both the IM Aircraft and Target Aircraft.
OR.7	The Target Aircraft will provide planned Final Approach Speed (FAS) to the controller who will include this information in the IM instruction.
OR.8	When the controller issues a new clearance to the IM and/or Target Aircraft that results in a modification to their Intended Flight Paths, the controller shall terminate the IM Operation.
OR.9	During the Execution Phase, the flight crew shall terminate the IM Operation and notify the controller if the IM and/or Target Aircraft have deviated by more than operational limits from their Intended Flight Paths.
OR.10	The controller shall identify the following information as part of the IM Instruction: - Target Aircraft Identification; - Assigned Spacing Goal; - IM Manoeuvre; - Achieve-by Point; - Termination Point - IM Tolerance; - Target Aircraft intended Flight Path Information; and - Target Aircraft Final Approach Speed.
OR.11	Upon receipt of the IM Instruction, The flight crew shall make the data identified in the IM Instruction available to the FIM Equipment.
OR.12	If one or more of the following conditions are not met, the flight crew shall reject the IM Clearance: - The Target Aircraft has been positively identified; - Target Aircraft data quality is sufficient for the IM Operation; - IM Aircraft data quality is sufficient for the IM Operation; - the flight crew is trained for IM Operations; - the FIM Equipment is able to present IM Speed; and - there is a reasonable likelihood of successfully completing the IM Operation.
OR.13	The flight crew shall be trained how to use the FIM Equipment and to perform the IM Operations.
OR.14	The flight crew shall implement changes from the IM Speed guidance in a timely manner consistent with other cockpit duties, unless safety-of-flight considerations, operational acceptability, or regulatory limitations preclude it.
OR.15	The flight crew shall ensure that the IM Aircraft is stabilized to its Final Approach Speed no later than the appropriate Stabilized Approach Point.
OR.16	The flight crew shall terminate the IM Operation prior to decelerating to their Final Approach Speed.
OR.17	During the Execution Phase, the following information shall be available for display to the flight crew: - the IM Speed; - FIM Equipment status; and - IM Situation Awareness Information.

OR.18	The flight crew shall be notified when the IM Speed guidance changes.
OR.19	If the flight crew is unable to continue conforming to the IM Clearance, they shall notify the controller.
OR.20	The flight crew shall terminate the IM Operation if: - they are unable to continue conforming with the IM Instruction; - the data quality for the IM Aircraft is no longer sufficient to support the IM Operation; - the data quality for the Target Aircraft is no longer sufficient to support the IM Operation; or - if the FIM Equipment is no longer able to provide IM Speed.
OR.21	As with other instructions or clearances, the controller shall monitor the IM Aircraft to ensure that IM Aircraft is behaving in an acceptable manner and is in conformance with the IM Clearance.
OR.22	The controller shall terminate the IM Operation if it is no longer desirable.
OR.23	The flight crew shall terminate the IM Operation upon reaching the Planned Termination Point.
OR.24	Upon reaching the Planned Termination Point, the FIM Equipment shall terminate the FIM application by removing the IM Speed and/or Turn Guidance.
OR.25	If the flight crew initiates the termination of the IM Operation, the flight crew shall notify the controller and maintain an operationally appropriate speed until otherwise instructed.
OR.26	If the controller terminates the IM Operation prior to the Planned Termination Point, the controller shall include a speed instruction in the termination instruction.
OR.27	Once the IM Operation is terminated the controller shall resume conventional control of the IM Aircraft.
OR.28	The flight crew shall only receive IM Speed after successful initiation and up to the Planned Termination Point.
OR.29	The flight crew shall have the ability to remove or suppress all IM-related displays and information.
OR.30	The controller shall issue a When Able Instruction when they are unsure if the IM Aircraft has airborne surveillance information on the Target Aircraft and they want the IM Aircraft flight crew to begin the IM Operation once the IM Aircraft has airborne surveillance information on the Target Aircraft.
OR.31	Following a When Able Instruction, the flight crew shall inform the controller when they commence IM Operations.
OR.32	When the controller wants the flight crew to initiate an IM Operation at some later time, the trigger event shall be communicated with the IM Instruction.
OR.33	After an expect Instruction, the flight crew shall notify the controller when they are able to begin the IM Clearance.
OR.34	The controller shall terminate the current IM Operation and issue a new IM Instruction if the Target Aircraft Identification is to be modified**.**
OR.35	During the Execution Phase, the controller shall be able to amend an existing IM Clearance to change the following data: - Assigned Spacing Goal(s); - Achieve-by Point; - Planned Termination Point; - IM Tolerance; - IM Aircraft Intended Flight Path Information; and - Target Aircraft Intended Flight Path Information.
OR.36	The flight crew shall assess the feasibility of the modified IM Clearance before accepting the new instruction
OR.37	The flight crew shall suspend the IM Operation when instructed by the controller.
OR.38	The flight crew shall only resume the IM Operation when instructed by the controller.
OR.39	The flight crew shall reassess feasibility of conforming to the IM Clearance before resuming a suspended IM Operations.
OR.40	The controller shall only issue the IM Instruction to an aircraft operating under Instrument Flight Rules (IFR).
OR.41	Controllers shall have all necessary information at hand required to initiate an IM instruction, even when the target aircraft is not in the area of responsibility of the controller at the time of the IM Instruction.
OR.42	Controllers shall be able to compare the current spacing interval, with the assigned spacing interval. Threshold values shall be used to alert the controller when large discrepancies occur.
OR.43	Controllers shall to be able to return to and operate under normal operations.

11 References

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Summary
This document provides the definition of the proposed ASAS-IM Operational Application for Schiphol airport in the form of an Operational Services and Environment Definition (OSED) description. This OSED describes the services, intended functions and associated procedures of the ASAS-IM application and the assumptions about the environment in which the application is specified to operate.

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