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COMPETITIVE AND SUSTAINABLE
GROWTH PROGRAMME

SOURDINE II

D3-2
Enhanced Functions for Pilot and ATCo Tools

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AENA	Aeropuertos Españoles y Navegación Aérea	*ESP*
AIRBUS F	*AIRBUS FRANCE SAS*	*F*
EUROCONTROL	*European Organisation for the safety of Air Navigation*	*INT*
ISDEFE	*Ingenieria de Sistemas para la Defensa de España S.A.*	*ESP*
INECO	*Ingenieria y Economia del Transporte*	*ESP*
SICTA	*Sistemi Innovativi per il Controllo del Traffico Aereo*	*IT*

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1. INTRODUCTION

1.1. Purpose

The aim of this document is to point out the new functions which are required by the users in order to perform the SII procedures.
In order to have a clear idea about the functionalities which will be at the base of the enhancement of nowadays tools, we need to know:

1. The constraints which Pilots and ATCo are subjected to when applying the current CDAs.
2. The constraints which could be encountered in applying the new Sourdine II proposed procedures.
3. And most of all the possible solutions (functions) proposed or available.

The study follows a bottom-up approach which is best applied where some of the lower functions may be well understood and documented. However, the process of integrating these modules onto a higher subset presents difficulties as the interaction between the individual subsystems is not fully known.

Thus the document will not offer the RTS work package 6 with the full systems but modules which will indicate the basic functions, may they be already part of developed tools or in the process of being constructed.

1.2. Background

ATC and Pilots
Pilots are observed to have an aircraft-centric view and are primarily concerned with traffic which will impact their current or planned trajectories. Conversely the Controllers have a more system Route centred "big picture" view and are concerned with how the trajectories and overall flows will interact. [MIT]

In an ACDA [ANAP] procedure the following Technologies are integrated:

- Approach with continuous lateral and vertical guidance (LNAV,VNAV). In principle a constant 3' glidepath can be flown
- The procedure is carried out as an approach, controlled via an FMS
- 4-D RNAV: a prediction of the aircraft track in position and time, is made before the aircraft initiates an ACDA procedure. The prediction is based on the aircraft's flaps schedule /speed/thrust/vertical profile and the available information on the wind profile (implementation forecasted for after 2015).
- ATC new monitoring and planning tools.
- Pilot tools.

The Sourdine II proposed procedures are based on the CDA concept and envision the use of modern or future infrastructures and technology, making these ACDAs (please refer to the Glossary below).

1.3. Document Structure

The following document can be divided into three general parts:

Part 1: Constraints and general prospected solutions resulting in the performance of the SII NAPs (constraints based on current CDAs). Which includes section 1 to 2.

Part 2: Current ATCo environment based on NLR RTS platform (section 3 and 4).

Part 3: ATCo and Pilot tool requirements. Section 6 and 5.

The three parts deliver problem, analysis and solution to the SII procedures' implementation.

1.4. Mandating and recommendation phrases

This document contains "shall" and "should" with following meanings:

The use of the word "shall" indicates a mandated criterion; i.e. compliance with the particular procedure or specification is mandatory and no alternative may be applied;
The use of the word "should" (and phrases such as "It is recommended that …", etc...) indicate that though the procedure or criterion is regarded as the preferred option, alternative procedures, specifications or criteria may be applied, provided that the manufacture, installer or tester can provide information or data to adequately support and justify the alternative;
The use of the word "will" describes expected system behaviour when the system complies with the references and/or this document's requirements.

1.5. Glossary

Term	Description
AAA	The Amsterdam Advanced ATC system - The ATC system used by ATC The Netherlands (LVNL).
ACDA	An Advanced CDA (ACDA) is a CDA that is enhanced with future infrastructure, ATC tools and crew tools in order to meet demands of capacity and safety. During an ACDA, the requirements for ATC speed control may be relaxed, or even removed, and additional constraints may be added; for example to execute a part of the approach with thrust idle or to follow a certain fixed vertical flight path.
ACDA	Advanced Continuous Descent Approach (MAX 2nm segment of level flight)
ACOD	Area Conflict Detection
Actor	An organisation or agency, formal or informal, or an individual involved in validation activity or any of its tasks
Air traffic	All aircraft in flight or operating within the manoeuvring area of an aerodrome
Air traffic management	The equipment, manpower, and processes required to enable aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints, without compromising existing safety levels
Analytical	Validation technique in which the behaviour of a real-word element being

Technique	validated is expressed in a mathematical model that defines the relationships between the input and output variables, enabling the performance of the real-world element to be assessed mathematically for a characteristic quality
ASP	Arrival Sequence Planner
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
CDA	Continuous Descent Approach. A noise abatement technique for arriving aircraft in which the pilot, when given descent clearance below the Transition Altitude by ATC, will descend at the rate he judges will be best suited to the achievement of continuous descent. Whilst meeting the ATC speed control requirements, the objective being to join the glide-path at the appropriate height for the distance without recourse to level flight. [ANMAC]
CDA	Continuous Descent Approach
CDA initiation point	The 3D point in which the aircraft engages the CDA procedure. In a fixed glidepath CDA the point is fixed in space.
EC	European Community
EUROCONTROL	European Organisation for the Safety of Air Navigation
Exercise runs	The set of individual time periods over which measurements are made in a validation exercise
FAA	Federal Aviation Administration
FCU	Flight Control Unit
FIR	Flight Information Region
FPA	Flight Path Angle
GENOVA	Generic Overall Validation for ATM
GNSS	Global Navigation Satellite System
GP	Glidepath
GPS	Global Positioning System
GST	General Statement
HUD	Head Up Display
Hypothesis	In the context of a validation exercise, a proposition regarding the success of an operational concept in addressing a problem about operational concepts that is stated in statistical terms, based on the low-level validation objectives and constrained by the metrics that are available
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IMC	Instrument Meteorological Conditions
Indicator	A metric that is indirectly related to the objective of interest (e.g., workload

	is an indicator of capacity)
MAEVA	A Master ATM European Validation Plan
MAS	Measurement and Analysis Specification
Metric	A system parameter measured in a validation exercise to provide the data used to derive conclusions
NAAP	Noise Abatement Approach Procedure
NADP	Noise Abatement Departure Procedure
NAP	Noise Abatement Procedure
NPA	Non-Precision Approach
OPERATIONAL	Set of concepts which cover all 8 Invariant Processes and is described answering to the questions who, what, how, when, and where
PMP	Project Management Plan
P-RNAV	Precision Area Navigation
RNAV	Area Navigation
RoD	Rate of Descent
RTS	Real Time Simulation
RWY	Runway
SID	Standard Instrument Departure
SOIA	Simultaneous Offset Instrument Approach
Sourdine	Study of Optimisation procedURes for Decreasing the Impact of NoisE
SPD	Speed
TERPS	United States Standard for Terminal Instrument Procedures
TID	Touch Input Device
TMA	Terminal Manoeuvring Area
TTA	Tactical Training Area
UPS	United Parcel Service (airline)
UR	User Requirement
Validation	The process through which a desired level of confidence in the ability of an operational concept to operate in a real-life environment may be demonstrated to the user, against the actual needs captured as a pre-defined level of functionality, operability and performance
Validation exercise	The set of one or several tests performed to determine whether an ATM configuration meets the validation requirements specified for it, which may range from a formal meeting of experts to the performance of empirical trials in validation environments and platforms.
Validation Scenario	Representation of an operational situation in which an ATM operational concept is validated within one or several validation exercises, to enable the measurement and characterisation of the operational concept's performance. Descriptions of validation scenarios should cover location,

	timeframe, events and ATM environment
Validation Technique	Method used to achieve the validation objectives of a specific validation exercise
VDEV	Vertical Deviation
VGH	Validation Guidance Handbook. A consolidated set of guidance materials to be produced by the MAEVA project
VSD	Vertical Situation Display
VMP	Validation Master Plan

1.6. Reference Documents

LIST OF REFERENCE DOCUMENTS	
Short Reference	**Author / Organisation, Title, Edition, Date and Reference**
[ANAP]	"*Advanced Noise Abatement Procedures for Approach and Departure*", by Louis j.j. Erkelens, NLR Amsterdam , The Netherlands (2002)
[ATCinNA]	"*The influence of ATC in approach noise abatement*" By A.D. Kershaw, D.P. Rhodes & N.A. Smith – USA/Europe ATM R&D Seminar, Naples, ITALY (13-16th June 2000).
[BoeingATM]	"*Development of continuous descent approach concepts for noise abatement*" Anthony Warren & Kwok-on Tong, Boeing Air Traffic Management, 2001, USA.
[D3v83]	D 3.1-1: Establishment of noise abatement solutions.
[D5v1.6]	Final Report Sourdine I
[DADI-2]	"*Datalinking of Aircraft Derived Information 2*" Project Reference: IST-1999-11246, DG-Unit: B5/Transport&Tourism
[LOUIS]	*"CDA Flight Demonstration Test at Louisville International Airport" by J.P.Clarke et Al, MIT. Report No.ICAT-2003-1, March 2003.*
[MFK]	M.F. Koeslag: "*Advanced Continuous Descent Approaches -An algorithm design for the Flight Management System-*". Master degree thesis, Delft University of Technology, Delft. March 1999.
[MIT]	"*The effect of Shared Information on Pilot/Controller and Controller/Controller Interactions*" by R.J.Hansman and H.J.Davison, 3rd USA/Europe ATM R&D Seminar, Naples,13-16 June 2000.
[MIT7]	*'The Future of Air Traffic Control, Human Operators and Automation'* by Wickens, Christopher D., Mavor, A.S., Parasuraman, R., and McGee, J.P., ed., , National Academy Press, Washington, DC 1998.
[FI]	*"Downlinked advisory tests prove successful"* AIR TRANSPORT – article by FLIGHT INTERNATIONAL 6-12 January, 2004
[PO-ASAS]	"*Principles of Operation for the Use of Airborne Separation Assurance Systems*" by FAA/EUROCONTROL COOPERATIVE R&D PO-ASAS-V7.1.doc Released Issue 19/06/2001

[Sourdine I]	*"Requirements for tools", PL97-3043, D4Version 2.5, Sourdine I European Project.*
[NASA]	*"Staying Ahead of the Automation: A Vertical Situation Display Can Help"* by T. Prevot & E. Palmer, San Jose State University/NASA Ames Research Center, Moffett Field, CA - 2000-01-5614 Copyright © 2000 Society of Automotive Engineers, Inc.
[VSD Boeing]	"*New Flight Deck Features: Technology Demonstrator*" by Mike Carriker Chief Pilot, NAPD Engineering Flight Test Boeing Commercial Airplane

1.7. Required Inputs

Sourdine I

During SI the optimisation of the departure procedures conducted for the A340 highlighted the problems which the pilot would encounter in order to follow the new procedures profile without the aid of newer avionics.
This previous study was key in pinpointing the needs for new functionalities tailored for the new procedures, from a pilot point of view.

Sourdine II

Experts` judgement and advise from Brainstorms 1, 2 and 3.

Work packages
Inside Sourdine II the deliverables D3.1-1 and D5.1 have been thoroughly used: the first deliverable as it defines the basic procedures proposed in the project; the second deliverable as it points out which procedures are the most promising.

Past general work on the subject
Mostly based on work and analysis conducted on the subject of human factors (please refer to reference).

1.8. Expected Outputs

Enhanced functionalities for Pilot and ATC tools to be implemented and simulated in the Real Time Simulation Sessions (WP6).

2. PROCEDURES DESCRIPTION AND CONSTRAINTS

2.1. Objectives

This section will go through the problems and constraints linked to using procedures based on the CDA idea.
Hereafter we will find the SII basic CDA procedure idea as well as three examples of operational procedures currently used today:

1. The SII basic design (CDA-Variable path, CDA-Speed)
2. Heathrow Airport, London, Continuous Descent Approach (UK)
3. Schiphol Airport updated CDA procedures (Netherlands)
4. Louisville, CDA test (U.S.A).

The objective is to collect from all these examples a clear idea of what, in term of added functionalities, the ATC and Pilots would need, in order to fly, control and manage the new procedures.
The way the different users in different countries cope with these problems is a way for filtering out what is really necessary and what is not, as well as what is common.

2.2. General characteristics of Sourdine II CDAs

During the first third of the project the Sourdine II consortium has, together with the expert panel, forwarded a choice of new NAPs which will be tested in Fast and Real Time Simulation.

Following are certain general characteristics of the procedures which were chosen by the Consortium, based on the results from D5.1 deliverable and the Preliminary NAAP and NADP choice document (data valid for Airbus aircraft).

In general the best performing procedures are, in order, of two types:

1. **Speed ACDA**

   With the 'Speed ACDA' the flight path and thrust profile (power settings idle) are fixed. If the forces acting on the aircraft have a component along the flight path opposite to the flight direction (drag force higher than the combined thrust and weight components), the aircraft will decelerate. A way to influence the speed profile without using thrust or a change in vertical flight path is by changing the configuration.

   DISADVANTAGE

   Predictability of procedure is lost: every aircraft type will have a specific speed profile resulting from the prescribed vertical profile with thrust idle. As the speed profiles are different, the exact location in time will vary depending on the aircraft type.

2. **Variable Path ACDA**

   With the 'Flight path ACDA' the geometry of the vertical flight path is used as control variable. The aircraft's Flight Management Computer (FMC) calculates a vertical profile and a top-of-descent based on thrust-idle power settings and the aircraft-specific speed profile. During this ACDA, the aircraft performs a thrust-idle flight until a point before ILS-localiser interception. The distance from this point to ILS-localiser is used as a buffer in case it is required to reduce the speed further to landing speed.

DISADVANTAGE

Predictability of procedure is lost: every aircraft type will have to fly a specific vertical profile in order to follow the prescribed speed profile with thrust idle. As the vertical profiles are different, the exact location in time will vary depending on the aircraft type.

Both for A340 and A320 aircraft Increased Glideslope CDAs (Speed CDAs) have performed better (noise wise) than Variable path CDAs or standard Approach Procedures.

CONSTRAINTS

In general the controller only has the information on the Pilots radar measured states (refresh rate) and what can be inferred from the flight plan and voice communications. As a consequence the Controller must allow a significant separation buffer to allow for uncertainty in Pilot intent. In cases when the Pilot's intent is well known (e.g. final approach) it is sometimes possible to reduce the separation criteria[MIT].

2.2.1. ACDA procedure general

When the procedure begins no un-programmed change in velocity or vectoring is admitted, if not for safety reasons, since it would spoil the noise abatement procedure.

Operational Change

ATC cannot intervene after initial approach point has been passed by aircraft this means intervention needs to be before approach waypoint.

Monitoring constraints

The two main constraints that spring up from the two designs are hence:

1. CASE - Exact Location in Space (3D) and Time;
2. CASE - Exact Location in Space (2D since vertical FP prescribed) and Time.

Horizontal variability will be decreased by the use of BRNAV or even better PRNAV certified equipment.

Possible solution

NEED TO HAVE THIS DATA AVAILABLE from source, and in advance with possible real time update.

Planning constraints

ATC cannot intervene after initial approach point has been passed by aircraft this means intervention needs to begin before.

Such operations as Sequencing or Permission to Approach need to be sent in advance.

2.3. Current CDA procedure Heathrow airport [ATCinNA]

The CDA procedure used in Heathrow requires an aircraft to descend from 6000ft altitude to interception of the ILS glideslope without recourse to level flight. At Heathrow, CDA is achieved through joint participation of controllers and flight crews. Controllers give range estimates from touchdown, from which flight crews select appropriate rates of descent (RoD) in order to maintain descending flight until joining the glideslope.

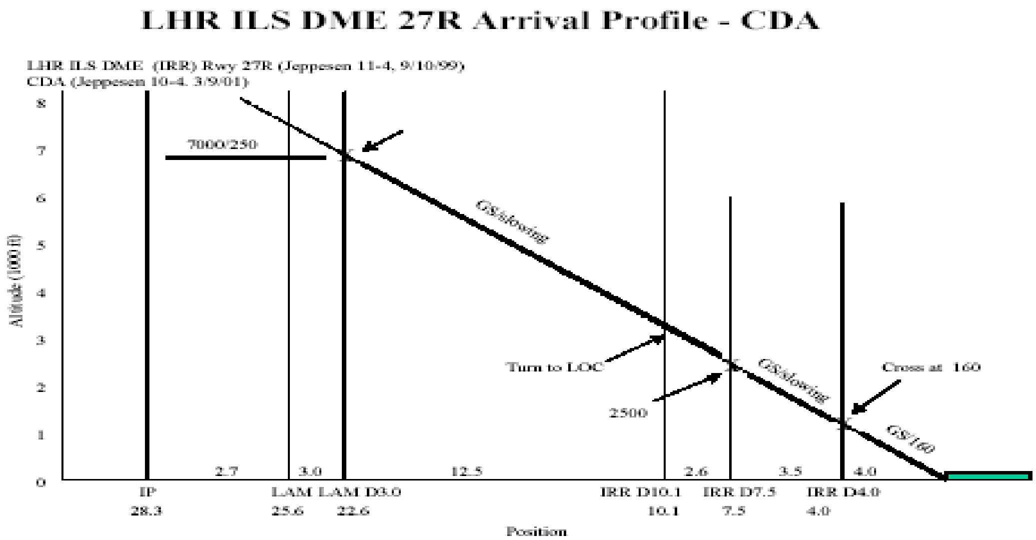

Fig. 1.CDA vertical flight patch at Heathrow Airport

The main findings from the research conducted on the Heathrow airspace, illustrate that when descent clearance from MSL is given 'early', the likelihood of achieving CDA Is decreased resulting in flying at lower altitudes than necessary with longer level segments. The results indicate a significant improvement in the CDA achievement, through improved ATC descent Clearances and exact distance from touchdown estimations.

2.3.1. Constraints

1. Erroneous estimation of distance from touchdown and descent clearance
2. Sequencing flexibility
3. Pilots do not respond uniformly to ATC instructions.
4. Some Aircraft systems apply bank angles to initiate turns more quickly than others, turning at different rates hence resulting in different turn radii (turn radius depends on height, bank angle, speed and wind).
5. DME Distance estimated on intercepting airport fix (Navaid radial distance only)

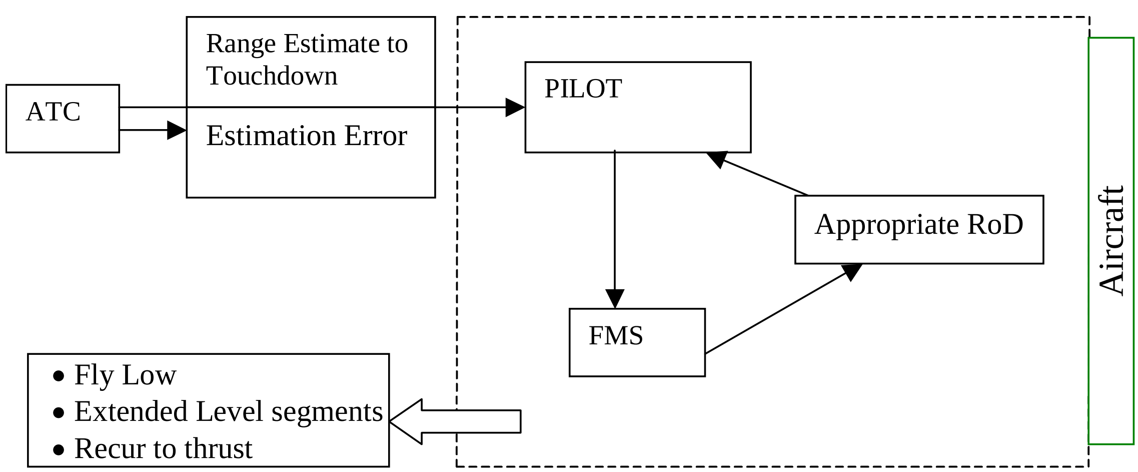

Fig. 2.Simplified schematic diagram of constraint in CDAs for Heathrow Airport.

The input "Distance to Runway" means this data is provided by the ATC and the hypothesis is radar vectoring. Airbus does not believe it's the good way to proceed: this data is an internal computation since the FMS knows the lateral trajectory.

The problem can be overrun by using the aircraft onboard instruments such as FMS which, is capable of giving range estimates to runway through DME and GPS support, once clearance for CDA is given by ATC .

2.4. CDA IAF Procedure Schiphol

The CDA implemented on runway 06 and 18R, as shown in Fig. 3 are of the Speed CDA type which has previously being described in Section. 2.2-1 and are considered as a RNAV Approach.

General Remarks [EHAM AD 2-2-9.5]

During daytime.

The use of RNAV approaches is at ATC discretion
The RNAV approaches from SOKSI for RWY06 and NIRSI for RWY 18R, provide lateral guidance to intercept the ILS for the relevant runway. Altitude and speed are instructed by ATC.

During night time

On the other hand the transitions provide lateral guidance only, ATC will issue clearance for further descent below FL70 and the instructions to reduce speed below 250 KT IAS.
The descent from transition level from 4000ft AMSL or above begins at SOKSI for RWY 06 and at NIRSI for RWY18R. At ATC initiative a transition for RWY 18R via NARIX from FL060 or above may be available. The descent after SOKSI/NIRSI/NARIX is a low noise continuous descent. For various positions along the route, minimum altitudes and fixed speeds are given on the instrument approach charts. A published speed should be reached at or before the position where the speed value applies.

The example of ATC instruction "Cleared for SOKSI approach RWY 06" implies clearance to fly published route on ILS approach to the relevant runway.
The vertical profile over and after SOKSI/NIRSI/NARIX (see below) is at pilot's discretion provided he complies with the minimum altitudes.

The expression "at pilot's discretion" means the pilot is free to optimise the vertical and/or speed profile.
When cleared for the CDA the pilot starts his descent from FL40. The procedure requests the pilot to make an optimum descent path with engines set to idle or nearly idle, until the ILS is intercepted at approx. 2500ft.

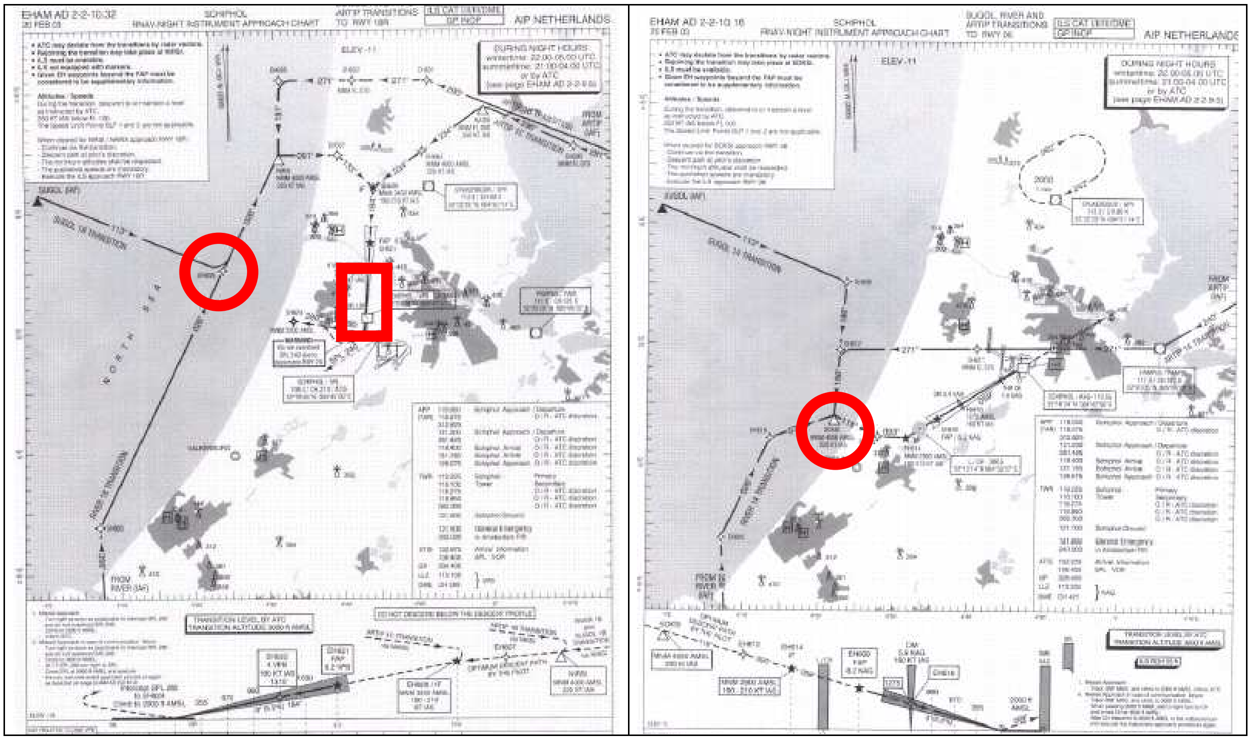

Fig. 3. New CDA procedures in Schiphol. New runway 18R; new flow converging waypoints.

Differently from the previous temporary CDA [Jeppesen chart 30-5-97], the following procedure is defined as continuous only from 4000ft for noise relief; flows converge in one waypoint (App RWY 06 right chart) while two are selected for new RWY 18R; minimum AMSL is prescribed on CDAs starting waypoint (SOKSI/NIRSI/NARIX).

IMPROVEMENTS

The sequencing constraint due to monitoring and sequencing before the three CDA starting waypoints has been brought down to one constraint : all a/c start the CDA procedure from one point (red circle above).

1. Constraints present in old AIP CDA chart that can be partly transposed to the new AIP CDA chart (above).
   - Operationally a considerable vertical track spread was observed [ANAPFAD] during this procedure, before the GP was intercepted. This is due mainly to the fact that no unique approach path is defined until the aircraft arrives on the ILS localiser/glidepath.
   - Although the distances to go from the CDA starting waypoints to RWY06 are all known, the elapsed time to fly each of these approaches can differ appreciably due to the effect of wind.
   - The resulting uncertainties in approach time prediction require the separation distances between approaching aircraft to be increased substantially (from 1.8 to 4 min).
   - Transition onto ILS GP proceeds are not very smooth, some aircraft are very high and consequently have to intercept the glideslope from above, which is an undesired situation since it increases crew workload. Other aircraft are too low and have to fly a horizontal segment in order to intercept the ILS glideslope. In this case

thrust is frequently used closer to ground, which spoils the noise benefit of the procedure.

2. Possible Solutions

- **Pilots**

Need an FMS which can calculate the CDA profile and make a prediction of the CDA duration (Estimated Time to Threshold).

Alert on appropriate moment for Flap/slat selection.

Adjust flap selection speeds during approach, to compensate for deviations from the nominal speed profile.

Wind data profile along approach track in advance.

Accurate Lateral and horizontal Navigation (LNAV and VNAV).

- **ATC**

MONITORING

Better monitoring of separation above all for merging traffic.

Aircraft Flight data on approach flight path in advance (4D).

Medium Term Conflict Detection (MTCD) which compares the flight paths of the aircraft in advance to discover before CDA waypoint start if there is any conflict.

Accurate Expected Time of Arrival (ETA).

PLANNING

Approach flight plan in advance (4D and ETA) from source (aircraft) and in advance in order to sequence aircraft to landing or to fixed waypoint for CDA clearance.

A sequencer which may use aircraft's FMS data in advance as input and as output hand the full sequence.

MTCD and Sequencer would be working together with the same input, nowadays studies couple this with the Trajectory Predictor (FMS on ground with aircraft parameters, etc) please refer to sect.5.

2.5. CDA Louisville

The procedure tested in Louisville with the use of UPS B767s is based on a Flight Path CDA with two segments: the initial segment is a nominally constant flight path angle (FPA) segment, while the second is the 3`ILS glideslope. The two segmented approach was chosen so to provide pilots and controllers with more predictable aircraft performance.

The initial segment Flight Path Angles considered were 2`, 2.5`, 3`, while the top of descent initially chosen at 7000ft was later increased to 12,000ft as it was determined that the procedure could be initiated at a higher altitude with no performance penalty.
The interception with the ILS Glideslope was fixed at 3500ft MSL and the aircraft was kept at thrust idle till then.

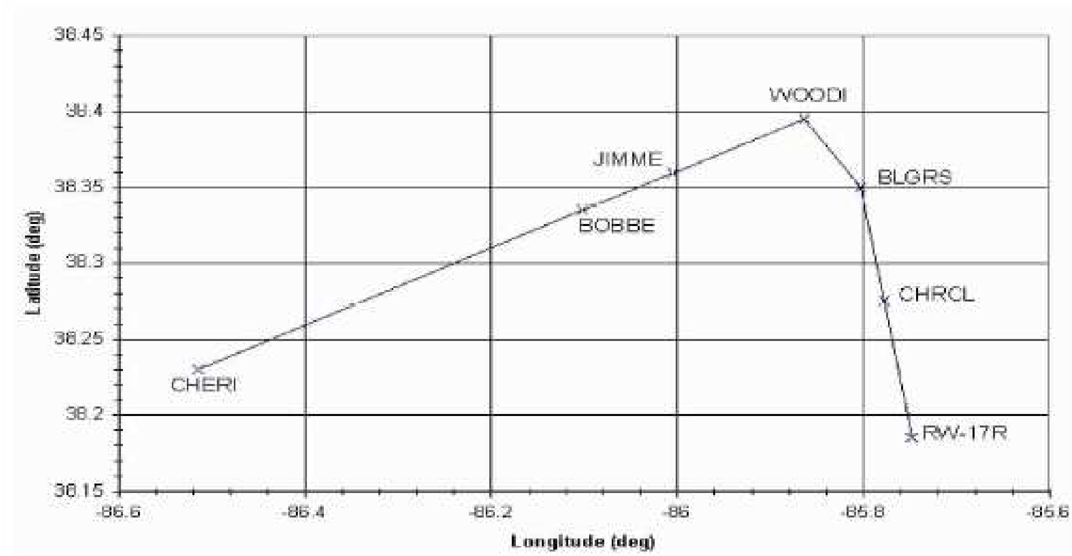

Fig. 4.CDA procedure horizontal flight path and waypoints

CDA procedure Horizontal Flight Path

The ground track in Fig. 4 was enabled using the lateral navigation (LNAV) function in the FMS, and defined using the position (latitude and longitude or database selection) of each waypoint.

After the first web of testing, the speed and altitude constraints at JIMME and BOBBE were removed because the UPS pilots felt that these constraints were unnecessarily restrictive.

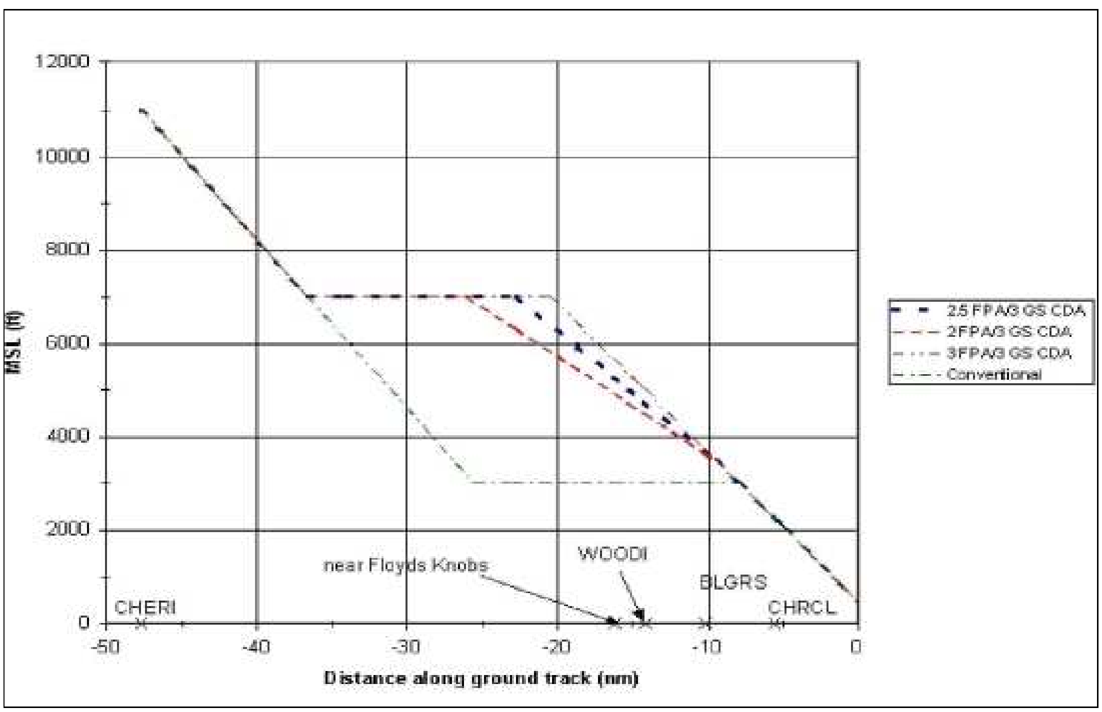

Fig. 5.CDA procedure vertical flight path

The vertical profile (above) was enabled using the vertical navigation (VNAV) function in the

FMS, and defined using speed and altitude constraints at each waypoint. the VNAV-enabled procedure was developed because
UPS preferred it, because it provided better delivery accuracy and ILS glide slope capture consistency. Both Systems were enabled at 12,000ft.

Speed profile
A step-down speed profile was decided by the research team, as opposed to a continuous deceleration profile, to make it easier to control the separation between aircraft, and to reduce crew workload through the use of the flight management computer to manage the speed stepdowns.

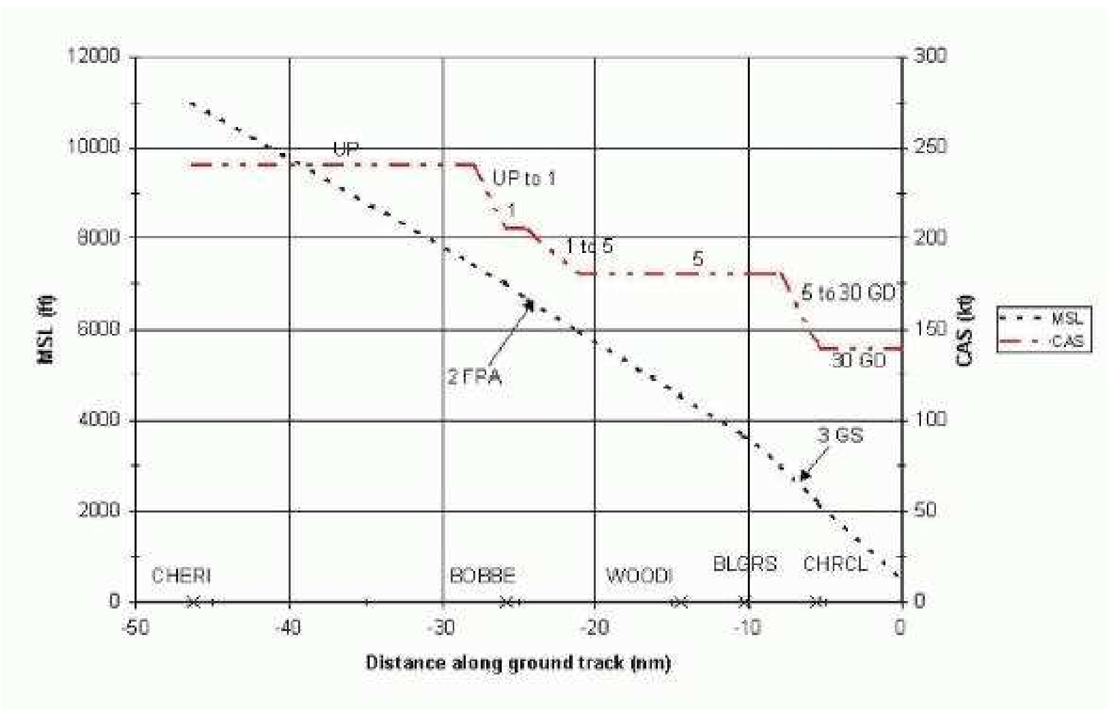

Fig. 6.CDA speed profile

Robustness to Winds
The robustness of the procedure was evaluated using values for the wind speed and direction from the Boeing proprietary Global Weather database. The wind speed (mean and standard deviation) and direction near KSDF from near ground to 10,000 ft were obtained for the months of October through March.

Results
Benefits to regions between 14-18 miles of the airport were detected with a decrease in dBMax of around 3 to 6 dB, compared with the standard approach.

Constraints

Pilots

The procedure must be flown with an advanced FMS and with both LNAV and VNAV systems engaged in order to obtain the procedure's noise benefits. Thus the pilot must follow the commands given by the on-board FMS strictly (unless safety reasons surge).
CDA procedure is clearly marked and loaded in FMS database and cannot be changed.
Flaps deployment should be accurately timed. Today, this is probably best achieved by specification of flaps in the CDA procedure. In the future, flap advisories or energy

management may be directly supported by the VNAV system and appropriate cockpit displays [LOUIS]. Wind profile data accuracy is needed.

ATC

Once given the pilot clearance for the approach (called NOISE1[LOUIS]) procedure, no interference or vectoring is permitted.

No other constraint was noted at this stage as the air traffic was not mixed in order for the test to roll on without any problem.

The objective of the Louisville test was to show the noise benefit of the CDA procedure through design, simulation and Flight Testing.

3. ATCO TOOLS

3.1. Introduction

This section will present an ATCo tool environment choosing as an example the NLR RTS platform (NARSIM). This overview is necessary to build a comparison base for the better understanding of the ATCo tool requirements, which will follow (sect.6).
The description will be addressing specifically the tools used currently in the TMA and it is important to point out that only a small number of these tools are specifically used for the CDA flight procedures.

3.2. Overview of the ATC RTS Platform

The following list is an overview of the main tools of NARSIM (NLR's Air Traffic Control Research Simulator) required for SII:

- Short Term Conflict Alert (STCA)
- Flight Position Monitor (FPM)
- Monitoring Aid (MONA)
- Trajectory Predictor (TP)
- Arrival Manager (AMAN)
- Continues Descent Approaches Tool (CDA)[1]
- Converging Runway Display Aid (CRDA)[2]

Additionally:

- Data-link.
- HMI: Amsterdam Advanced ATC system.

3.3. Conflict alert

Short-Term Conflict Alert (STCA)

The Short-Term Conflict Alert (STCA) tool supports the executive air traffic controller by detecting near-term separation infringements between aircraft from data supplied by the radar data processing system. STCA can therefore be considered as a safety net tool for short-term periods, a few minutes ahead. STCA's main goal is to assist the air traffic controller in maintaining the required horizontal and vertical separation criteria.

STCA starts its conflict search for all aircraft under control of ACC and within Sourdine II also APP sectors as soon as a flight is within a certain geographical area, and will be re-executed every track update. It observes pairs of aircraft (where flights under control of ACC will be compared with all other flights), checking for conflicts in the vertical direction first. If a possible conflict is detected, the horizontal STCA detection is started.

[1] Currently implemented for only one runway (06)

[2] Currently implemented for only one runway combination (18R-27)

3.4. Monitoring

Flight Position Monitor (FPM – AAA tool)

The Flight Position Monitor (FPM) supports the air traffic controller by monitoring flight progress, detecting possible deviations from the planned route.
The purpose of the FPM is two-fold. Firstly it is designed to reduce the workload of air traffic controllers by removing the burden of continuously having to check each flight for compliance with its planned route. Secondly the introduction of automated tools like ACOD requires that the flight plan data is up-to-date and representative of the actual situation to function properly.

The FPM has two main functions, the simplest of which is to monitor flight progress: the route of a flight usually contains several waypoints and it is the task of the FPM to keep track of the next waypoint of each flight. Having established the next waypoint, the second function of the FPM is to monitor each flight and warn the air traffic controller whenever an aircraft deviates from its planned route. Also if the aircraft is within its cleared route but is not headed for its next waypoint a warning is generated. Having generated a warning, the FPM checks if the aircraft is actually headed for its next waypoint

EFL monitoring (AAA tool)

The Executive Flight Level (EFL) monitoring tool is currently not operational in the AAA system, although it is implemented. This tool can be used by APP controllers and detects possible deviations between the cleared (executive) flight level by the controller and the actual flight level flown by the aircraft.

Monitoring Aid (MONA – EATCHIP tool)

MONA compares the current flight data with the system trajectory. If the flight deviates by more than a given parameter from the system trajectory then MONA either informs the controller (information message displayed on line 0 in aircraft labels) or triggers recalculation of the system trajectory based on the current position and performance of the flight.
The recalculation will be based on the nominal position and observed performance of the flight. The nominal position is obtained by horizontally projecting the current position of the flight onto its system trajectory path. In determining the observed performance of a flight, the performance must be averaged over a sufficiently long period of time in order to achieve stability in the system.

Continues Descent Approach (CDA) tool

The CDA is a continuous descent from a certain flight-level to the ILS interception along established CDA routes.
It is possible for the pilot to select the descent from a flight level so that a quiet approach (approach with noise reduction according to the standard approaches) is possible until ILS intercept.
When a CDA tool projects the positions of the aircraft on the extended runway centreline, the values of the longitudinal separation are much better visible. The use of this tool makes easier for the controller, to see if the separation at the fixing point of the three CDA routes will be enough.
This tool has shown that a relatively simple change in the plan view display enables the insight in the way the CDAs are executed. With this increased insight the longitudinal separations during the approach can be decreased and therefore the capacity can be increased.

Ghosting (L)

One area in which automation has successfully improved Controller performance is in integrating the tasks of two inter-dependant local Controllers.

The Converging Runway Display Aid, for example, electronically integrates the aircraft from the two runways on each Controller's runway display through *ghosting* or 'ghost planes' from the other runway to ease the aircraft converging process.

Using this aid, the Controller does not need to acquire the position of the other Controllers' aircraft and mentally integrates the position information with his or her own aircraft. This electronic aid has been successfully integrated into several airports including Boston, Newark, and St. Louis that all use converging runways. [MIT7]

Ghosting is already used by the CDA Tool to indicate on the RWY centreline the aircrafts in sequence, proposal is to use this functionality also when merging a/c flows in approach (please see waypoint EH606 on fig.3 sec.2.4) such that sequencing could be done earlier and monitoring could be easier in advance..

Converging Runway Display Aid (CRDA)

At airports with converging landing runways the landing capacity falls dramatically under deteriorating weather conditions (IMC). Especially when flight paths of aircraft landing on different runways intersect, it is impossible to independently use both runways under IMC conditions. Because single runway operations are mandatory under these conditions, the capacity drops dramatically.

The Converging Runway Display Aid (CRDA) enables the air traffic controllers to stagger approaching traffic on two runways, ensuring sustained separation up to and after the intersection point.

The CRDA mechanism is very simple. One of the converging runways is designated the master runway, the other is the slave. The air-traffic controller lining up traffic for the master runway will create a sequence with a certain, constant spacing. This traffic is projected onto the approach path of the slave runway, where they appear as ghost plots. The controller lining up traffic on the slave runway will essentially consider these ghosts as real traffic and vector his traffic into the gaps between them. At all times, he must maintain a minimum separation between every aircraft under his control and the ghost plot that precedes it.

The final gain in using CRDA is that instead of using a single runway with a separation of, for example 3 NM, two runways can be used with a separation per runway of, for example 4 NM with a stagger distance of 2 NM.

The LVNL has also investigated a variant of the CRDA mechanism, whereby the plots are not only projected onto the slave runway, but also moved backwards 2.5 NM. In this case, the ATCo vectors his aircraft not between the ghosts, but exactly on top of them. Because the ghosts are moved, the separation of 2.5 NM at the intersection is still guaranteed. This mode of operation is called the *tie mode*. The advantage is the possibility of precise vectoring, because any deviation from the required aircraft position shows up much more clearly.

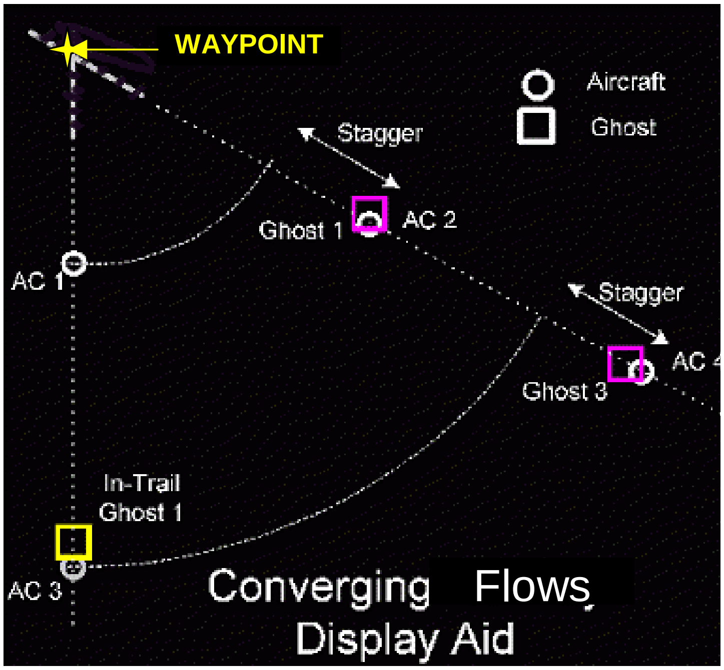

Fig. 7.Converging RWY Display aid using ghosting (NAVCANADA) for merging traffic to a runway (waypoint).

The above tool is widely used by the Canadian Air Traffic Control in airport with converging runways and has being under testing on the NARSIM (NLR RTS) platform.

3.5. Sequencing

Arrival Manager (AMAN)

The Arrival Manager (AMAN) fulfils the task of sequencing and guiding aircraft to the ground as safely, efficiently and expeditiously as possible.

The primary task of the Arrival Manager is to decide which aircraft should go to which runway, and at what time. A secondary task of an arrival manager can be to monitor an aircraft position during the approach and arrival phase. Also, the computing of the time interval between aircrafts and of the time each aircraft passes the metering fix is sometimes considered part of the arrival management process.

Apart from sequencing the aircraft at the metering fix and assigning them to a runway, a human air-traffic controller has to be able to monitor and understand the process. In the end the controller is the one responsible for guiding all aircraft to the ground safely - with or without an arrival manager.

Finally the Arrival Manager needs to interface with the rest of the ATC NARSIM environment, for example, the system plan database, the airspace structure server and the trajectory predictor.

Trajectory Predictor (TP)

The Trajectory Predictor (TP) computes and stores the expected 4D-trajectory, based on an aircraft's flight-plan, flight progress, current position and weather data. As different ATM tools require different kinds of results (e.g. a full 4D-trajectory, only top-of-climb positions, or only specific ETO's), the TP accommodates all such requirements. Trajectory prediction data is required to support the development and evaluation of ATM tools in NARSIM. For several ATM tools trajectory prediction is required to compute relevant data (e.g. ACOD and AMAN).

At regular intervals, at least once every minute, after each flight-plan update and when explicitly requested, the TP computes the trajectories of all aircraft (soon to be) within the FIR. The TP uses aircraft specific data, weather data and airspace structure data (positions and types of waypoints, FIR identification, TMA boundary).

Whenever the TP is triggered for a certain aircraft, it uses the relevant and available flight-plan and track data (departure, destination, waypoints, planned flight-levels at these waypoints, current positions, heading, etc.) to calculate the horizontal and vertical flight profile.

Trajectory Synthesis

The trajectory synthesis is a TP functionality which creates a trajectory by implementing constraints from the scheduler (e.g. RWY, TTA at RWY, TTA at IAF). The TP will be able to take into account preferences from the aircraft and airline involved when it synthesises a trajectory.

Conclusion

The use of such systems as an AMAN/DMAN (see sect.5) is advisable in order to control and sequence traffic.

The Trajectory Prediction or TP , an AMAN module, can calculate an accurate Expected Time of Arrival, especially when the flight is capable of Downlinking Aircraft Parameters (DAP). It is also possible for the TP to use the ETA received via DAP.

3.6. Human Machine Interface

Amsterdam Advanced ATC system (AAA) HMI, with two trackballs and two TIDs.

4. FUTURE CONCEPTS AND SUPPORT SYSTEMS

4.1. Data-link support to other systems

In this section we do not want to go into describing the different systems or hardware which make a Datalink possible, rather its support as an information transmitter to other functionalities and systems.

Collision Avoidance

Recommendations on Downlinking airborne collision avoidance system (ACAS) Resolution Advisories (RA) directly to air traffic controllers is under investigation by Eurocontrol and is currently under exploratory trials.

The case is that pilots often do not have time to tell controllers that they are reacting to an ACAS RA, even though procedures suggest they should. The difference, in this case would be that information on the Pilot reaction would be downlinked to the controllers.
The controllers would then see increased their air traffic situational awareness and would help them take decisions, particularly, about third party aircraft that might be affected [FI].

Automatic Dependant Surveillance Broadcast (ADS-B)

Automatic Dependent Surveillance - Broadcast (ADS-B) is a new development in aviation surveillance in which aircraft periodically broadcast details of their position, altitude, velocity and other flight data via a digital data link. The ADS-B concept can enable Airborne Separation Assistance Systems (ASAS) and supplement air-to-ground and airport surveillance.
One of the potential advantages of Automatic Dependant Surveillance (ADS) will be a reduction in sampling delay and the possible incorporation of feed forward states indicating aircraft intention such as heading, turn rate or even the programmed trajectory within the aircraft's Flight Management System.
Speed of response and the periodic content of Pilot voice transmissions.
The importance of shared affective information should be considered in future Datalink environments.

Automatic Dependant Surveillance Contract

An ATC Ground System establishes an ADS-Contract with an aircraft to obtain data relative to its position. The aircraft replies automatically and periodically with report contents and rate depending on the request.
An ADS-Contract is an agreement between an ATC ground System and an aircraft. The contract is defined by the ground ATC system that specifies what information an aircraft reports and when it reports it.
There are three types of contract possibly established between the ground ATC system and an ADS-C equipped aircraft:

Periodic: The aircraft transmits its position reports at a regular rate.

Event: The aircraft transmits its position reports (for example an altitude or speed change) independently of any periodic contract in effect.

On demand: The aircraft transmits a single position report when requested by the ground ATC system.

An aircraft may also report in emergency mode. This mode is initiated by the aircraft and does not require a contract.

Traffic Information Service – Broadcast (TIS-B)

Traffic Information Service-Broadcast (TIS-B) provides the pilot situational awareness and decision support tools based on the same surveillance data used by the controller. Uplinking plot level fused data to the cockpit gives the pilot both ADS-B and Non-ADS-B aircraft in a single situational display. This approach provides data usable for Cockpit Display of Traffic Information (CTDI) and Conflict Detection and Resolution in a partial ADS-B equipage environment.

Meteorological Data

Data on wind values encountered by aircrafts and updated storm fronts could be collected and shared by airborne, ground and ATM/ATC systems (sec.7).

Downlink Aircraft Parameters (DAP)

Several aircraft parameters give information to both the ATCo and the ATC system about the intentions of the pilot. Using Data link there is no need anymore to ask the pilot for the actual, speed, heading of the aircraft, etc..,, since this information is directly down-linked from the FMS to the ground. With the 'future improvement functionality' parameters (the 'selected' values) there is a much better possibility to check whether the pilot actually adheres to the issued clearance or not.

In general, there are two different methods of obtaining Mode-S data from an aircraft, Static Enhanced Surveillance and Dynamic Enhanced Surveillance.

With static ES, there is an automatic data-exchange between the Mode-S ground system and the Mode-S equipped aircraft within its coverage. In this situation the radar data processing system is not participating in extracting the data from the aircraft, and is just a passive recipient of the ES data. In the Dynamic ES environment, the radar data processing system is actively involved in extracting airborne data.

4.2. Airborne Separation Assurance System [PO-ASAS]

An aircraft system that enables the flight crew to maintain separation of their aircraft from one or more aircraft, and provides the flight crew with information regarding surrounding traffic and, in some cases, decision support tools that aid in providing separation from that traffic. This allows the flight crew to participate with controllers in providing separation from proximate traffic, and ultimately, to provide the primary, and possibly sole means for separation. The introduction of airborne separation is expected to result in improvements in the safety, efficiency and capacity of the ATM system.

Taking into account various considerations (conceptual, operational procedures, human factors, aircraft systems, enabling technologies, users' perspectives and implementation), four ASAS application categories have been defined:

- **ASAS application**: A set of operational procedures for controllers and flight crews that makes use of the capabilities of Airborne Separation Assurance Systems to meet a clearly defined operational goal [PO-ASAS].
- **Airborne Traffic Situational Awareness applications**: These applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation, both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their flight. No changed in separation tasks or responsibility are required for these applications.
- **Airborne Spacing applications**: These applications require the flight crews to achieve and maintain a given spacing with designated aircraft, as specified in a new ATC instruction.

Although the flight crews are given new tasks, separation provision is still the controller's responsibility and applicable separation minima are unchanged.

- **Airborne Separation applications**: In these applications, the controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew, who ensures that the applicable airborne separation minima are met. The separation responsibility delegated to the flight crew is limited to designated aircraft, specified by a new clearance, and is limited in time, space, and scope. Except in these specific circumstances, separation provision is still the controller's responsibility. Implementation of these applications will require the definition of airborne separation standards.
- **Airborne Self-separation applications**: These applications require flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation standards and rules of flight.

The previous ASAS applications are grouped in four packages for their development, validation and implementation.

4.2.1. Package I (Expected implementation date 2007 to 2012):

Ground surveillance/ airborne surveillance applications ASAS GS/AS comprising

- Airborne traffic situation awareness applications
- Airborne spacing applications

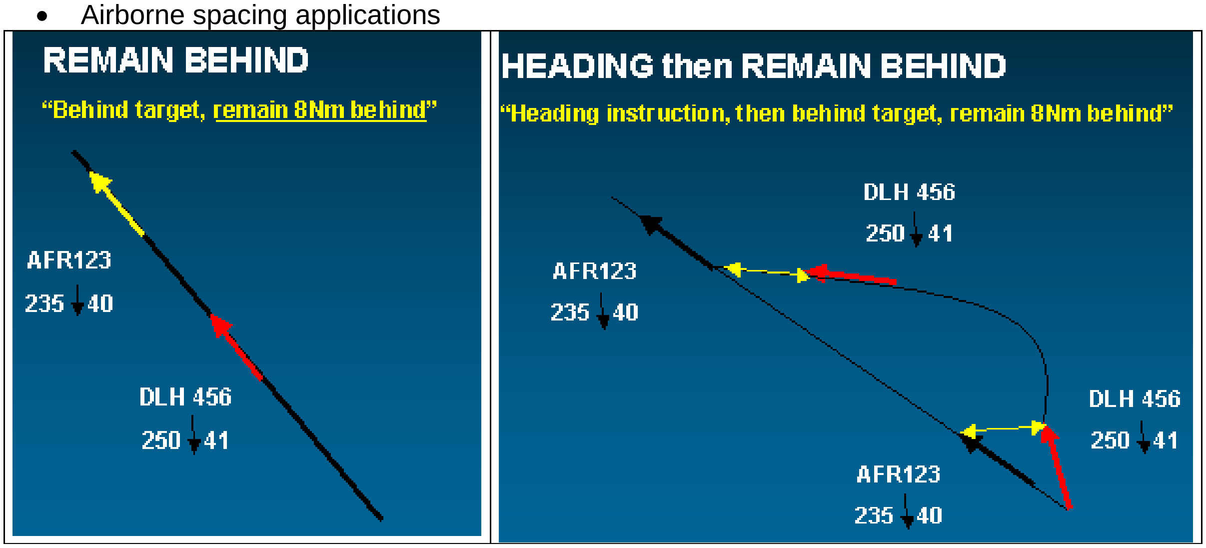

Fig. 8.Example of ASAS package I flow management (in commas the orders by the ATCo)

4.3. DATALINK SYSTEM SUPPORT Summary table

DAP download aircraft parameters

- State, speed, intention, weight, ETA (Expected Time of Arrival), planned final approach phase speed
- Expected Arrival Time at approach fix
- Wind speed and meteorological data (Uplink of forecast winds, temperature and pressure)
- FMS 4D calculated trajectory and/or CDA profile

ADS-B automatic dependant surveillance

- 3D values (as Radar)
- CAP (Controller Access parameter)
- IAS, Mach number, Indicated Magnetic Heading, Selected Altitude, Vertical Rate, Wind vector
- ISAS (System Access parameter) for improvement in tracking and safety nets

Tbn: pilot not affected by aircraft sent information.

ASAS Airborne Separation Assurance System

UPLINK/DOWNLINK

- Meteorological Data and wind profiles.

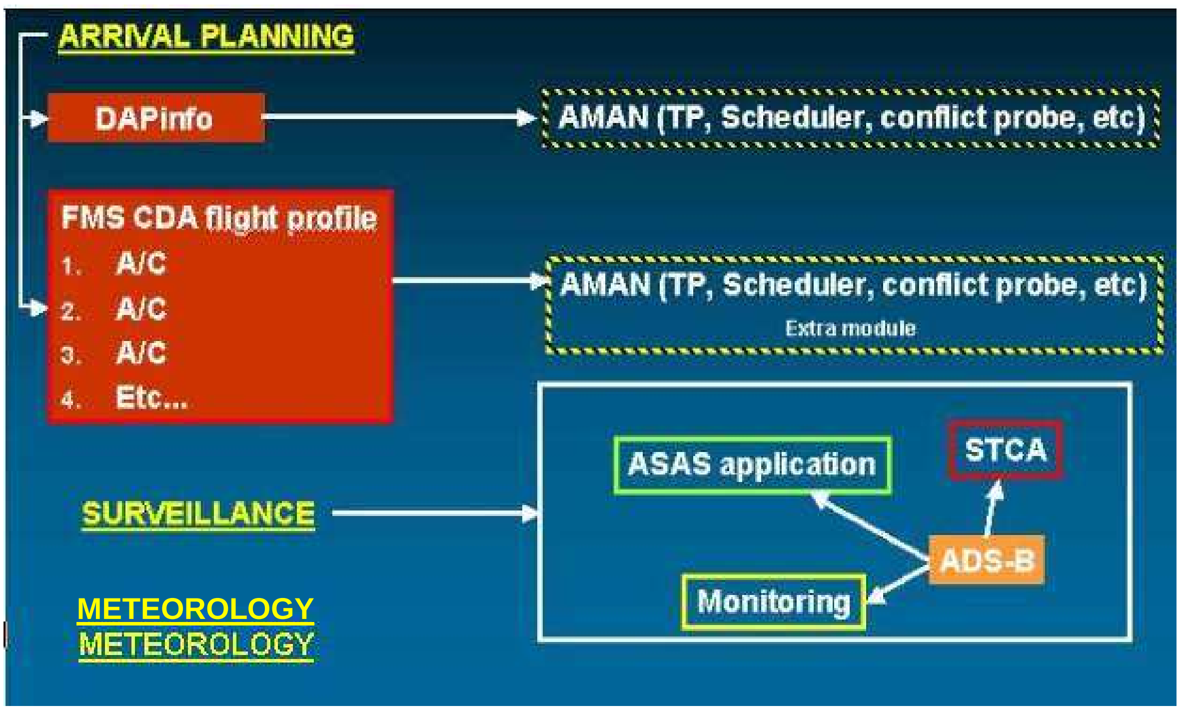

Fig. 9.Central support role for Datalink in future applications

5. PILOT TOOLS REQUIREMENTS

5.1. Departures Pilot assistance tools [Sourdine]

The different propositions made hereafter are high level specifications that in any case prevail of feasibility.
The development of such pilot assistance tools by manufacturers would rely on automatism simulations.

5.1.1. For take-off

During take-off, the crew already receive a lot of information in particular from the air traffic controllers.

Thus, to ensure safety, any new procedure must not add any workload and that is why adapted pilot assistance tools are needed.

For the take-off procedure with a progressive thrust increase after the cut back, two types of help are identified so far:

- A pilot assistance in terms of checking target speed, pitch attitude and rate of climb will be useful to perform each segment; indeed, having clear targets will help the pilot fly the best compromise between climbing (higher pitch and rate of climb but lower acceleration) and accelerating (lower pitch and rate of climb but higher acceleration) in terms of noise; the display of the next segment targets is also important as it helps the crew to check that the aircraft is well prepared for a proper transition from the present segment to the next one.
- The FMS should display the real time parameters (such as time to, etc..), associated with the targets to achieve, in order to perform the profile that optimises the noise, and should provide solutions to correct deviations. Thus, if a parameter were to be outside a window centred on the target, the pilot would take action to correct the deviation and would normally use the propositions made by the FMS. This function requires a database that optimises the aircraft profile for a full range of initial conditions (Take Of Weight, temperature, airport altitude, humidity, etc..).

A second step in the development of this kind of pilot assistance tools, is to integrate the procedure and the optimisation rules into the FMS so that the autopilot can fly it and reduce even more the pilot workload.

In case of cut back, a backup function restoring Max Climb thrust or Max Continuous thrust, and accelerating to the clean configuration minimum speed (if the speed is lower and the configuration not clean). Allowing the flap retraction in order to achieve the best rate of climb, is mandatory for safety reasons. As above it could be included into the FMS.

In the lateral plane, it is necessary, at low power, to limit the bank angle so that the minimum climb gradient can still be achieved. It will also be necessary that the crew be able to monitor the progress in case a certain SID needs to be accurately tracked on climb-out, especially in case of turning departures.

In particular for the Sourdine II take off procedures II and III (refer to D3.1-2_update _report_v2.3.doc), it was also identified that in the future aircraft manufacturers will have to automate the OEI thrust setting, in order to keep the same level of workload.

5.1.2. For approach

During approach, a pilot has different targets, the main one being to reach stabilisation before the minimum stabilisation height. We can imagine many intermediate targets, but first let us see what is a target for a pilot.

In approach, a target point is a point generally identified by:

- . a distance from a radio-navigation device and,
- . a height where a speed and a configuration must be reached.

To optimise the flaps extension sequence, new targets should be defined. For example, if the pilot must reach a given speed and configuration at a given distance (and/or height), a good pilot assistance tool should display the time remaining before the point is reached, the target speed and configuration and the estimated time to reach this double target. Thus the pilot can anticipate and avoid a high energy approach situation. The need for a "Go around advisory" becomes more urgent when operating CDA procedures: the tool/function would be useful for compacting the flaps extension sequence in actual procedures as well as for CDA.

For a flap extension sequence, a further level of automation could consist in integrating the profile of the flap extension schedule with the associated speed, pitch, and flight path angle parameters on the primary flight display.

The system would provide both a visual indication showing at what speed during the deceleration the next flap setting should be selected and a sound signal indicating that the target speed has been reached.

Current FMS provide an energy circle on Navigation Display, that allow the crew to know if they are able to land on an airport from their position. Moreover, if the lateral path is completely defined and shared with the ATC, the FMS vertical descent profile indicates clearly to the crew the Top of Descent. A published CDA, containing the relevant FPA and SPD constraints, will then be completely defined in FMS.

The pilot is always able to monitor the FMS vertical guidance through the VDEV parameter or the Vertical Profile display, VSD [NASA/VSD Boeing].

Conceptual change

The input "Distance to Runway" (ref. Sec 2.3.1) means this data is provided by the ATC and the hypothesis is radar vectoring. We believe, this data should be an internal computation since the FMS knows the lateral trajectory.

Today, some procedures have FPA coded in the NDB and the FMS is able to fly them. Current FMS lateral and vertical guidance (so called LNAV and VNAV) are capable of flying a CDA in other words, without any CDA in FMS NDB, the crew should be able to fly a CDA with a good accuracy using FPA mode on FCU.

General remarks:

- Current FMS (Boeing and Airbus) are very complex and have already great capabilities. Up to now, these capabilities are not used since all lateral and vertical computations and predictions for approach are ignored in order to fly by radar vectoring.
- The main issue to fly NAAP, is to have the aircraft flying a lateral and vertical flight plan shared in advance with the ATC. Tools improvement are needed (on board and on ground) to allow controller to be confident enough in giving delegation to the aircraft (sharing of Flight Plan, trajectory etc...).

- As far as navigation is concerned, NAAPs are mostly composed of intermediate approach segment with a defined FPA. Such published procedures could be encoded into the Navigation Data Base and flown by the onboard systems. If speed targets have to be reached along this path, some constraints can be entered by the crew.
- About providing energy feedback or guidance and indication on where to put flaps or airbrakes is a complementary item. Pilots during the brainstorm sessions say it is part of their airmanship to know when to apply the configuration. On the other hand advise on flap/slat deployment is seen as interesting.

Being the objective to determine, which are the absolutely necessary tools, in term of navigation and pilot tools there seems to be not much to do. Other than, aircraft Datalink systems may need to be adapted to provide much more data to the ground.

No special requirements for tools are hence envisaged more than using better and effectively. the current ones.

No additional tools are estimated to be required to support the departure procedures proposed by SII.

6. ATC TOOL REQUIREMENTS

6.1. Departures:

No additional tools are estimated to be required to support the departure procedures proposed by SII.
There is no conceptual change in the way the controller has to manage conventional or SII departures. In addition, aircraft are moving from a convergence area to a zone of greater volume, which eases the task of the controller.

Conventional departure managers are deemed to be sufficient to cope with mixes of traffic including low climbing performance aircraft.

Departures and arrivals should be strategically de-conflicted.

6.2. Arrivals

Arrival tasks involve high workload, especially in busy TMAs, as aircraft are converging to a small volume of airspace and due to the special characteristics of the approach manoeuvre that becomes more critical as the aircraft is closer to the airport.

The two main responsibilities of the TMA controllers are the separation and sequencing of traffic. Additional tasks are monitoring the aircraft to guarantee they respect assigned tracks and altitudes.

Two major modifications in the concept of operations for arrivals cause the need of advanced ATCo tools.

1) No controller action over the aircraft is permitted once this has been cleared for CDA, unless for safety reasons. Therefore metering and sequencing actions have to be performed beforehand.
2) Aircraft trajectory parameters have to be calculated on board the aircraft, as noise abatement procedures are aircraft type dependent. However, these trajectories have to comply with the required ATC constraints

The needs derived from the previous modifications are the following:

1) Greater predictability in the TMA, especially in the zone where controller actions are not allowed
2) Better exchange of information between air and ground to agree a trajectory: integration of FMS and ATC ground functions

As ATCo are not allowed to intervene through tactical instructions in the last part of the CDA approach procedure, the provision of separation during the fixed part of the sequence should be given beforehand. A strategically planned landing sequence should be elaborated including target times over waypoints in the part of the sequence that do allow for tactical intervention.

The controller cannot calculate the mentioned target times without assistance of automation tools. They cannot resolve traffic conflicts that will occur in the fixed part of the sequence by actions and decisions taken in advance unless they are provided with conflict detection/resolution tools.

6.3. Proposed characteristics of DST

The Decision Support Tools to sustain the CDA operations should be provided with the following characteristics:

- They will be trajectory prediction based. The current trajectory synthesis algorithms should be improved on the one hand to increase the accuracy and on the other hand to make the predicted trajectory closer to that obtained on board the aircraft (FMS) to ease the air ground interchange of data. The last part of the trajectory, from the CDA initiation point onwards should be computed on board the aircraft and downlinked to the ground to take into account the particularities of the CDA for that specific aircraft.

- They will include the usual arrival manager capabilities i.e. runway allocation, arrival sequence elaboration, arrival scheduling and provision of conflict-free advisories to comply with the schedules.

- They should be based on flexible route planning (RNAV), adaptable to changing constraints

- They will be focused on strategic planning based on the existing constraints. As tactical intervention is not allowed once the CDA is initiated, the main additional constraint will be the respect of the last segment of approach as calculated on board. Aircraft separation minima and arrival flow rate will be also considered as constraints.

- They should incorporate a conflict probe functionality capable to detect conflicts 15/20' ahead based on trajectory prediction and provided with "what if" capabilities (tending towards the automatic resolution of conflicts). This functionality would support the strategic solution of conflicts. Medium term horizons allow for more time to develop a clearance that satisfies both pilot and controller needs.

  Conflict probe parameters should be particularised for the special characteristics of the TMA and the approach procedures regarding time horizon, separation criteria, type of conflicts (for example including wake vortex conflicts), etc.
  Traditional conflict probe tools are not adapted to TMA environments since descending aircraft generate large uncertainty areas causing high rate of false conflicts making the tool inoperative.
  The degree of accuracy of conflict detection will progressively improve as more accurate data on aircraft intention becomes available via data link

- They should include conformance monitoring facilities of cleared trajectories

- They should allow a correct arrival traffic flow visualisation, for example combining the plan view that shows the spatial characteristics of each flight with a tabular view that includes a timeline showing the scheduled arrival flow. Colours, labels and any other visualisation technique can be used to ease the controller task. Both views should be interlinked. That is, a flight will be highlighted in one view when recalled in the other one.

6.4. Proposed basic mode of functioning of DST

From the set of inputs listed below, the aircraft trajectories are computed and the arrival sequence and schedule are created:

- Flight trajectory/aircraft state (radar track/ airspeed, heading, altitude/position)
- Flight intent (flight plan and downlink of last CDA segment calculated on board)
- Atmospheric predictions (winds, temperature, pressure, etc)
- Controller inputs (preferences, acceptance rates at certain points, required separations, RWY assignment strategies, etc)
- Optimisation criteria (minimum overall delay, efficient apportion of the delay, etc)

The basic outputs that the tool offers to the controller are the following:

- Arrival sequence: The order of the aircraft is calculated. When necessary, merging advisories are generated.
- Arrival route: For the sequencing and scheduling purposes the tool can open or close alternate routes: approach variants, direct-to segments, etc.
- Arrival schedule: Target times at each relevant waypoint of the trajectory are assigned. Tactical metering advisories are generated and presented to the controller. These advisories include the delay to absorb and the means to absorb the delay, which should be the following in order of preference:
    - Speed adjustment when the delay is lower than a specific value
    - Path stretching/route diversion
    - Holding

      When aircraft are entered into holding patterns to absorb a certain amount of delay, there is a high degree of uncertainty on the time estimates in the first part of the route after leaving the holding. When given clearance to exit the holdings, the paths followed by the aircraft present great dispersion as well as the speed at which the manoeuvre is flied.

      Achieving a target time over a specific waypoint after the holding can be very complicated, which could interfere with the strategic planning of the landing sequence and the fulfilment of the target times.

In general RNAV-flown turns are more difficult to predict, affecting the creation of the landing sequence.

6.5. New ATCo roles in CDA supported by DSTs

The role of the controller is completely changed form tactical to strategic on the one hand; from autonomous to relying in the performance of a set of automation tools; from active participation to supervision, execution and monitoring of tools solutions.

The change to a more passive role has in addition the disadvantage of losing control skills and decreasing of alert levels by ATCos.

Back up to traditional methods in case of necessity is not envisioned, as controller cannot manage the new situation without assistance.

Despite the previous considerations, in the concept the controller keeps being responsible for separation, which is not fully accepted.

7. METEOROLOGICAL DATA

Especially for the evaluation of trajectory prediction functionality and FMS CDA profile calculation, short term forecast of improved quality, based on the additional processing of recent weather observations (measurements : wind gradient along approach and landing phase) from the aircraft is necessary.

The use of wind data from Approach level to ground could greatly improve predictability.

Preceding aircraft on CDA could send to airborne and ground systems the wind velocity values encountered for every relative flight level. Thus enabling the creation of a wind profile along its descent.

On board FMS and on the ground seamless systems would use the above wind profiles via Datalink to adjust CDA flight profiles' calculations., ETA and flight predictability in general.
Aircrafts would hence become probes for the collection of weather data.

Wind Profile

One of the biggest constraints for the exact calculation of the approach procedure by the aircraft is the wind gradient. No data is available for all the different steps from approach fix to ILS GS intersection.

Often reports are not available, particularly for late night or early morning operations or during the early part of a controllers shift, hence the principal difficulty is the inconsistency in coverage and age of the information.

Wind changes in direction and speed with altitude [ATNinNP]. As aircraft descend, the effect of wind on the ground track (drift) varies. For aircraft which descend at different rates the overall effect of drift will be different. When wind shear exists an aircraft may experience a rapid change to its ground track or speed as it descends through the wind shear level.

Solution

The wind speed data already processed on board could be broadcasted to following surrounding aircraft, which are on the process of applying an ACDA or CDA procedure. Thus, depending on the frequency of landings we may obtain wind speed and direction information constantly and for every height.

The added value to this type of communication is that the same data could be relayed on the ground to the controllers, in fact controllers have a limited weather presentation on their displays. As a consequence they rely on Pilot reports of convective weather, turbulence, WINDS icing and deviation requests to build a mental representation of the spatial extent of weather within the sector [MIT].

8. PRELIMINARY SCHEMATIC FUNCTION PROPOSAL

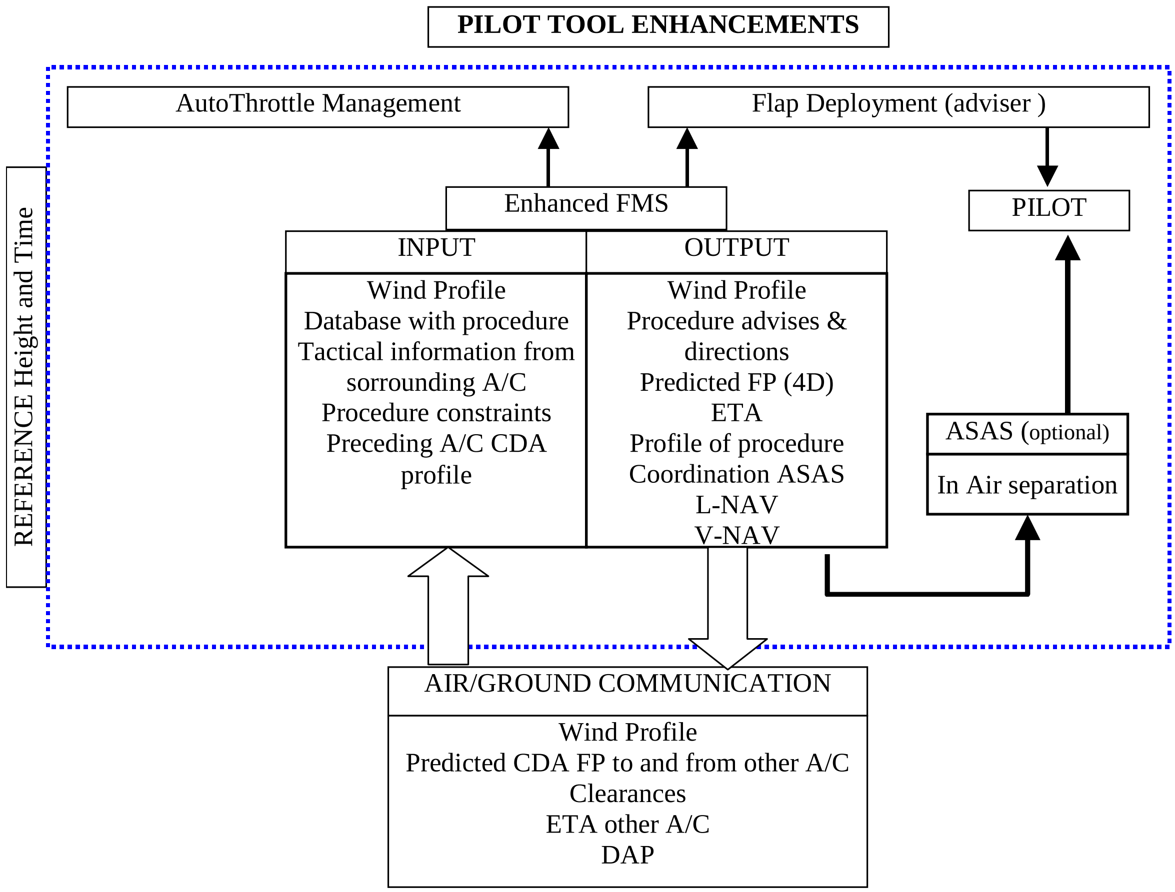

Fig. 10. Schematic view of functions for enhanced Pilot tools

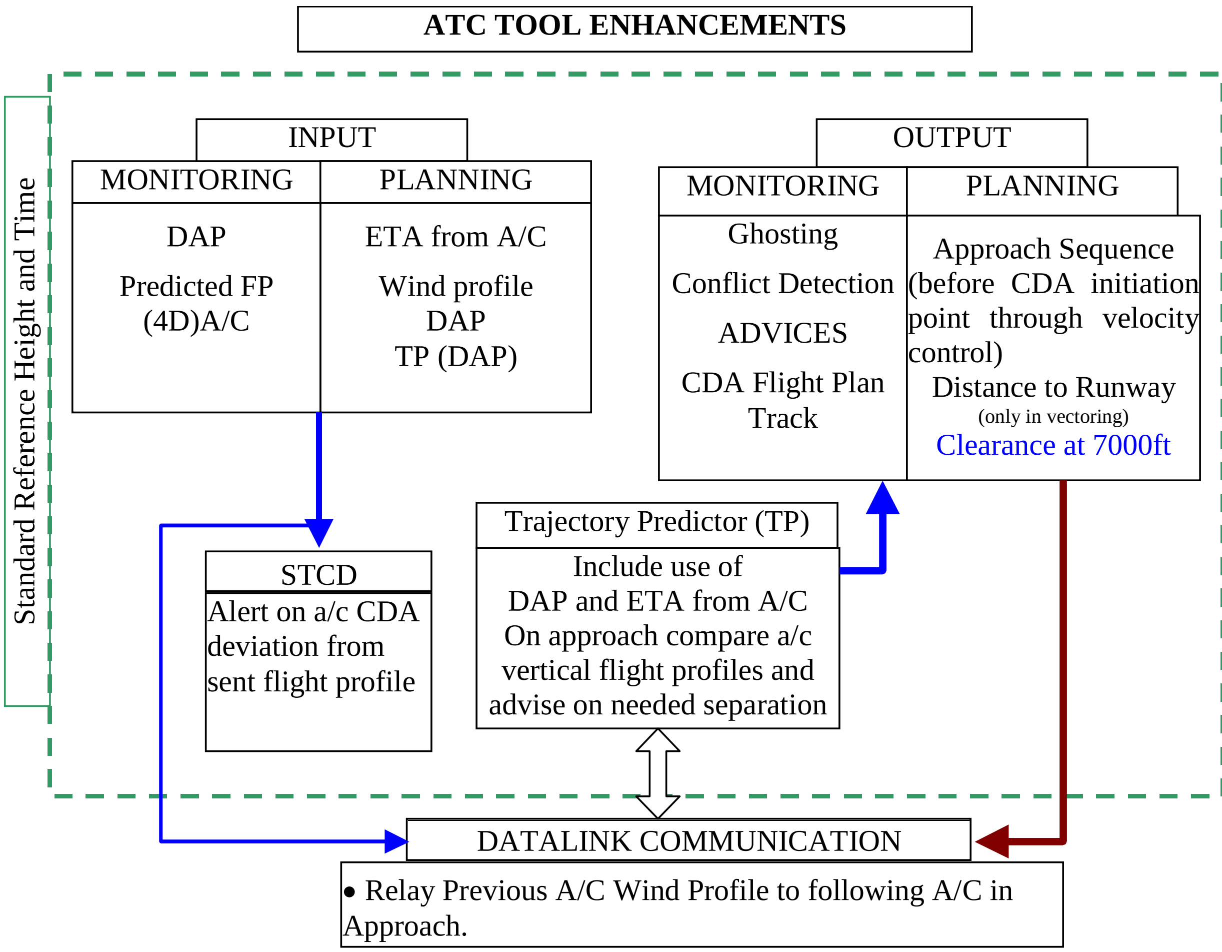

Fig. 11. Schematic view of functions for enhanced ATCo tools

The above schemes only show the added functionalities needed to solve many constraints linked with the use of CDA's. As such it does not include those functionalities which have already been developed and are used in current operations.

9. CONCLUSION

The users stress the fact that tools which can make Common Decision Making and advanced planning available, are at the top of the requirements' list.

The need for A/C parameters to be continuously sent down to ground through a Datalink, plus its use inside new or enhanced monitoring tools is basic for the good noise results which will be obtained by the procedures.

The above would thus be achieved through the adoption, in service, of co-operative systems and processes that will optimise task distribution between air and ground actors, improve decision making through sharing of common data across the system, optimise system capacity through dynamic flow management and 4-D trajectories and contribute to a better situational awareness of air and ground actors.

This deliverable therefore addresses both the airborne and ground segments of a collaborative ATM system, encompassing CNS/ATM concepts and capabilities such as ASAS procedures, 4D FMS capabilities and trajectory planning, air-ground data-link, interoperability, System Wide Information Management, Advanced tools to support Separation Management, Flight Data processing and Flow Management.

The minimum requirements encompass not only the tools which are required but also the operational practises which should be changed.

The minimum requirements needed for the CDA procedure as proposed by the Users are: <u>ATCo</u>

- Possibility of having the a/c parameters downloaded directly to the ground, enhancing the accuracy and reliability of the data.
- Monitoring tools which use directly such data including ghosting (desirable).
- Planning system which takes into account this new data and uses it and makes scheduling in advance possible.(AMAN essential).
- Safety nets

<u>Pilot</u>

- NO interruption in procedure after CDA initiation point (unless for safety reasons)
- 4D Flight management system and Datalink system which can support the flow of information demanded by the procedure.
- CDA inserted into the NDB (Navigation Database).
- Surrounding Traffic awareness (visual display, supported by TIS).
- Optimised deployment of flaps/slats (desirable but not essential).

The ASAS package I should be available by the timeframe of the SII procedures, but it is a desirable system, not essential.

Between the two domains ground and airborne tools, the second is where the Sourdine II procedures' characteristics have more influence, both on departures (thrust management system, airport noise specific procedure loaded into the FMS, etc.) and on arrivals (new procedure specific advisory display, pilot cues, etc.).

But no requirement can be stated to belong specifically to one procedure only. This is to say that if specific developments are needed for tool enhancement for the Sourdine II procedures, these in a large scale will be confined to the airborne side, since the ground side tools are not Sourdine II specific, but aid the controller in his task (monitoring and early merging because of RNAV procedures) and enhance the whole ATC system.

The enhancements here contained are the product of a preliminary study engulfing both users (ATCo, Pilots) and the Sourdine II CDA based procedures (SII). A further assessment on the user acceptance during human in-the-loop trials will evaluate to which degree (prerequisite, nice to have, etc.) these tools and functions are needed specifically for the Sourdine II procedures.

Appendix I.

Systems required or desired as addressed by Experts in Brainstorm I–II and III.

Requirements from Brainstorms I-II and III concerning Enhanced Pilot Tools.

From the three brainstorms the following requirements where proposed as important for the achievement of the ACDA's and the Departure NAPS:

1. Advanced Performance FMS 4D (energy management, automatic flap sequence deployment adviser and auto throttle depending on NAP and performance curve,….)
2. Air/Ground Datalink. communication : communicating vertical and horizontal flight path with real time corrections, Top of Descent, ETA and STA (estimated and supposed time of arrival), weather and wind velocity, etc
3. P-RNAV capacity (RNP 1) for TMA.
4. Would be interesting to test HUD display, which can indicate status of Approach, advise on configuration, landing steps, separation, high energy or low energy status, etc,.. (not essential).
5. ASAS (Airborne Separation Assistance system) which can secure the separation between a/c, thus taking away workload from ATC could be an option, if system mature (package I foreseen for 2007-2012 [PO-ASAS].
6. ADS-B/C for tactical awareness, accuracy and frequency of data.
7. AMAN manager with all its sub modules (TP, Scheduler, ASP, etc..).
8. CDA monitoring tool with the use of ghosting (as used in CANADA LAHSX)
9. Pilots opinion is not to have more tools rather to use the ones they already have

More information on the last brainstorm is gathered in "SII_WP10_Jun2003_EP3_results_v022".