電子航法研究所/仏国DSNA共同講演会
ENRI/DSNA Workshop

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これからの航空交通管理
Future Air Traffic Management

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November 30, 2005

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電子航法研究所/仏国DSNA共同講演会

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これからの航空交通管理
Future Air Traffic Management

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November 30, 2005
Benoît RULLEAU

Airspace Modeling and Performance Assessment

direction générale de l'Aviation civile
direction des services de la Navigation aérienne
direction de la Technique et de l'Innovation

Airspace Modeling and Performance Assessment

- Part I – Need for Performance Assessment

1. Benchmarking European Operations
2. Assessing new concepts
3. Validating airspace and route design

- Part II – Metrics, Modeling and Simulation Tools

4. Performance metrics
5. European airspace modeling tools
6. The OPAS simulator family

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ATFCM and CFMU

- ATFCM: Air Traffic Flow and Capacity Management

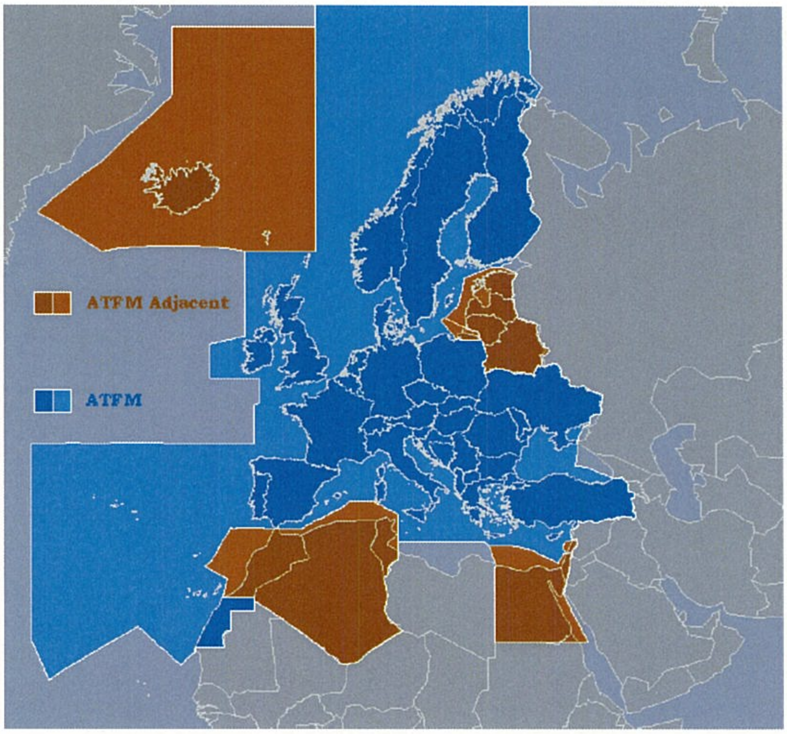
  "an ATM service established to ensure that ATC capacity is utilized to the maximum extent possible, and that the traffic volume is compatible with the capacities declared by the appropriate ATS authority"

  ➢ Balancing Capacity and Demand

- CFMU: Central Flow Management Unit
  - A Eurocontrol Service
  - In charge of ATFCM over Europe

ATFCM and CFMU

- ATFCM Phases
  - Strategic: 6 months to 7 days prior day of operation
    - Route definition, routing scheme
    - Preparation of special events: Olympic Games, Le Bourget airshow, …
  - Pre-Tactical: 6 days prior day of operation
    - Control sectors opening schemes
  - Tactical: day of operation
    - Slot allocation, rerouting
- Slot allocation process
  - ATS Authorities declare their capacity
  - CFMU computes the demand, compares it to capacity
  - If demand > capacity, some planes are given departure slots (delays)



Benchmarking & the PRC

- PRC: Performance Review Commission
  - Independent advisory body to Eurocontrol
  - Reviews performance under defined Key Performance Areas (KPA)
  - Defines relevant indicators (KPI), proposes performance targets, measures progress over time
  - Compares Air Navigation Service Providers (ANSP), fosters best practices and makes recommendations
- PRU: Performance Review Unit
  - Produces indicators for the PRC
  - Does all the handwork for the PRC

Benchmarking & the PRC

- The KPAs:
  - Safety
  - Capacity & Delays
  - Flight efficiency
  - ATM Cost-Effectiveness (ACE)
- Capacity & Delays
  - In Europe, departure delays are given by CFMU when ATC capacity overload are foreseen
  - Delays are attributed to most penalizing capacity bottleneck
  - PRC evaluates capacity improvements through delay assessment

Benchmarking & the PRC

- Flight effectiveness
  - Flown miles (compared to direct routes)
  - ➢ Fuel consumption
  - ➢ Journey time
- ATM Cost-Effectiveness
  - Cost-effectiveness benchmarking of European ACCs and ANSPs
  - based on overall costs compared to provided service
  - Valuable for policy-makers, airspace users, ANSPs
  - Based on information delivered by ANSPs
  - But difficult to evaluate the complexity of the ATC/ATM tasks

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European ATM Programs

- European Commission programs
  - Mediterranean Free-Flight (MFF)
  - European Single Sky
  - Gate-to-Gate (G2G)
  - C-ATM
  - Sesare
- Programs architecture
  - Each program contains different ATC/ATM concepts
  - Sesare is a new larger program, resumes C-ATM
  - Consortiums regrouping industrial and ANSP partners

ATM Concepts

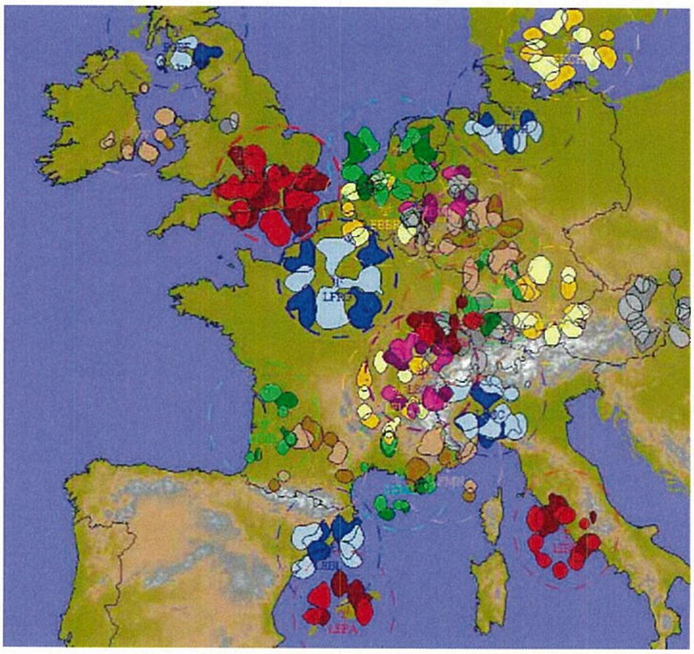
- ATM Concepts under development:
  - ASAS-enabled: Spacing, Crossing, CoSpace , Free Flight
  - Functional Airspace Block (FAB)
  - Arrival Manager (AMAN), Departure Manager (DMAN)
  - Collaborative Decision Making (CDM)
  - Dynamic Management of the European Airspace Network (DMEAN)
  - Multi-Sector Planning
  - Erasmus
  - Network Operating Plan (NOP)
  - …

Assessing New Concepts

- What we want to know
  - Feasibility
  - Safety
  - Capacity
  - Controller's Workload
  - Flight efficiency
- What is the aim
  - Answer questions
  - Produce quantified evidence
  - Show system changes
- Easier with control concepts than with organizational concepts

Example: FAB

- FAB aims
  - Airspace not limited to country's boundaries
  - Harmonized ATM practices and charging
  - Cross-boundary cooperation
- Our study
  - What is a "functional" airspace block?
  - ➢ Airspace belonging to major airports



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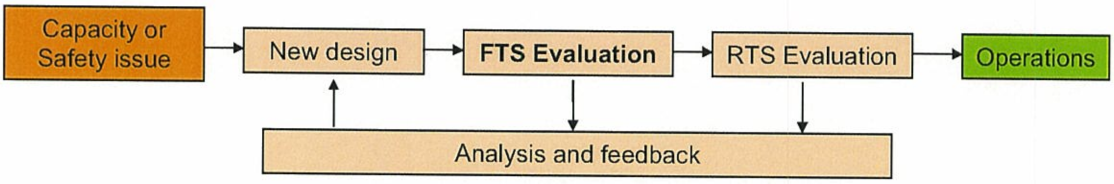
Airspace and route design

- Airspace and Route design is in perpetual motion
  - Routes, waypoints, sectors, military areas, SIDs & STARs, … are subject to change
  - 50 airspace redesign projects ongoing in France
- ATC operators
  - Know where capacity and safety issues occur
  - Imagine new design
  - Need to evaluate the design
    - Feasibility
    - Capacity
    - Flight efficiency
    - Safety

Airspace and route design



- New design
  - ATC operators
  - Use dedicated airspace editing tool, or just paper & pencil
- Fast-time simulation
  - TAAM, RAMS, … or OPAS
- Real-time simulation
  - Validate the design
  - Controller training

Need for fast-time simulation

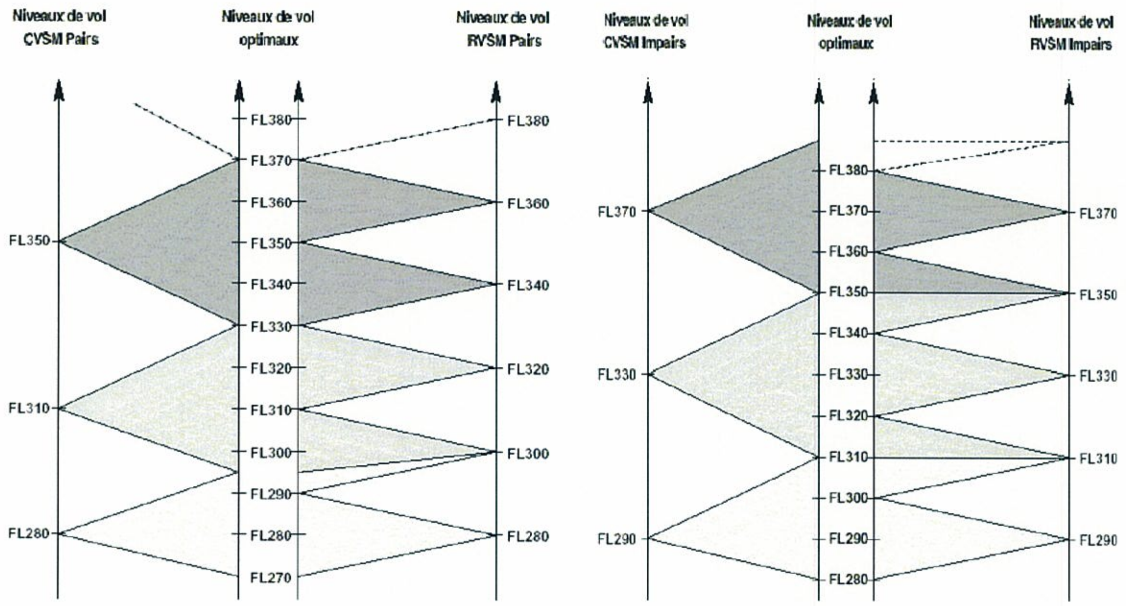
	RTS	FTS
Set-up time	12 months	4 months
Staff needed	++++	+
Realism	+++	++
Size of traffic sample	+	++++
Control perspective	+++	+
Performance perspective	+	+++

- Main FTS advantages
  - Quick
  - Cheap
  - Test many scenarios on many days of traffic
  - Performance point of view
- Need of performance validation
  - Feasibility (aircraft performance)
  - Capacity
  - Environmental impact (noise)

Example: RVSM

- Reduced Vertical Separation Minima (RVSM)
  - A major European-wide airspace redesign (24th January 2002)
  - More flight levels available
  - Change of all one-way routes
- … needs FTS assessment
  - Model new routes
  - Dispatch flight plans on newly available flight levels
  - Run simulations at ACC level, and more
  - ➢ Future airspace performance

Example: RVSM



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Performance metrics

- A wide range of metrics
  - From economic to operational indicators
  - Productivity, ATM, Flight efficiency, Safety
- ATM metrics are correlated
  - Real capacity:
    - Theoretical capacity of ATM structure
    - Controller workload limit
  - Controller workload:
    - Volume of traffic
    - Complexity of traffic
    - Control working methods
    - Technology, tools

ATM metrics

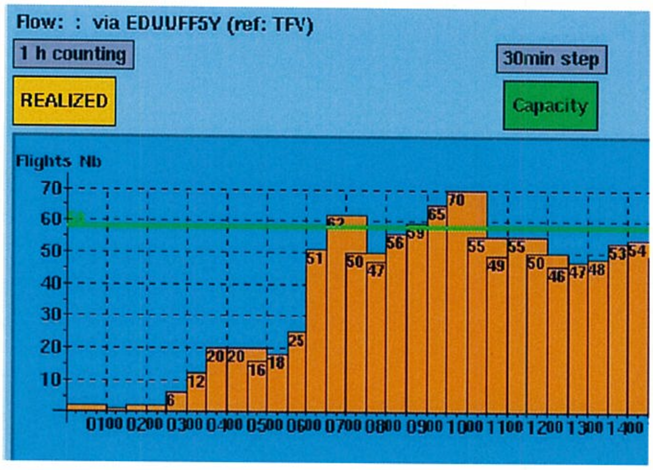
- Measuring
  - Number of flights
  - Number of separation losses
  - Number of conflicts (with uncertain trajectory prediction)
  - Flight efficiency: flight time, fuel consumption
- Trying to grasp
  - Workload (en-route workload model)
  - Capacity
- Recurrent problem: data
  - Flight profiles, airspace boundaries are often unrealistic
  - ➢ Number of controlled flight hours at Paris ACC: not so easy!

Complexity metrics

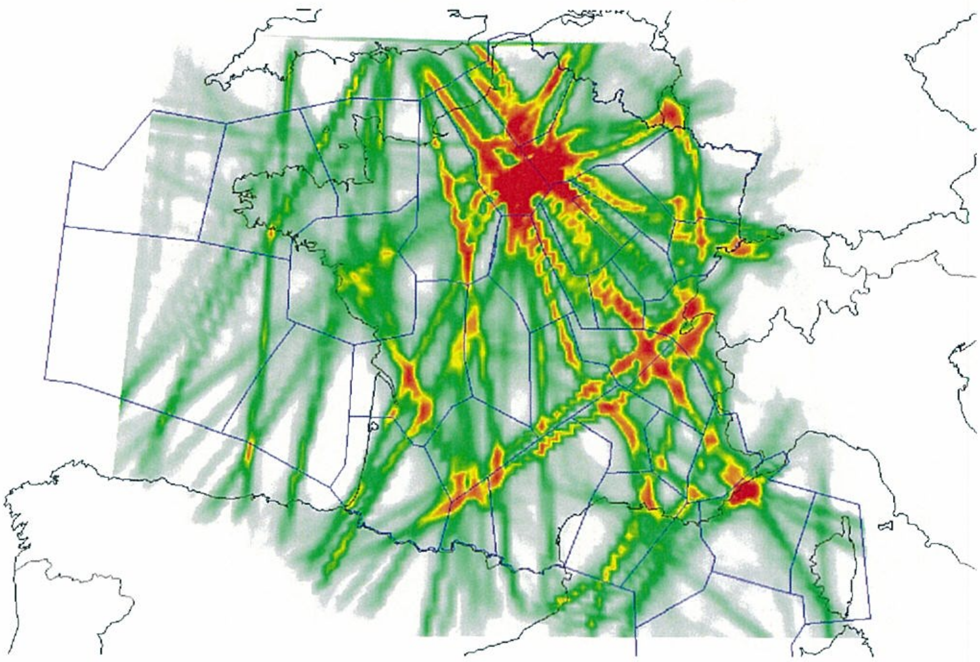
- Complexity
  - Studied for 20 years, but…
  - … no agreed definition of the concept
  - … many different indicators
  - ➢ An open field
- Some indicators
  - Density: raw, adjusted, …
  - Interactions: vertical, horizontal, overtaking (traffic mix)
  - Proximate pairs
  - Convergence, divergence

Setting up new metrics

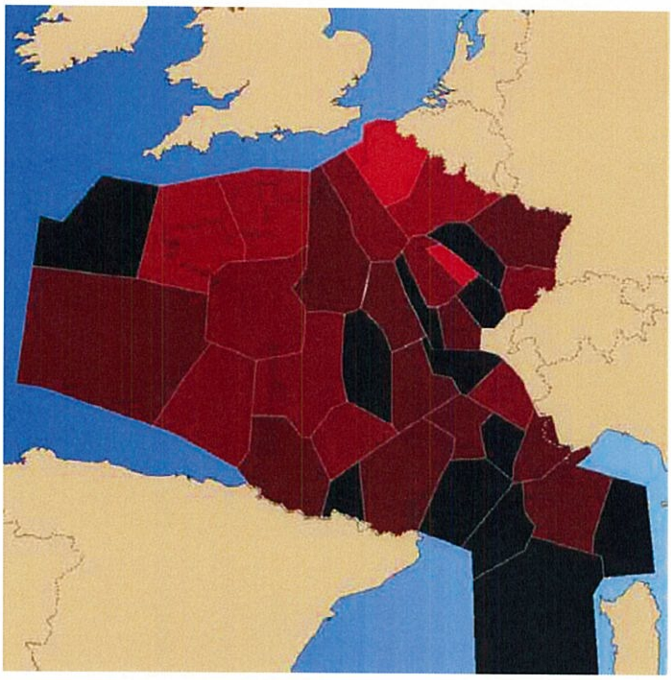
- Now: sector capacity metric = flights per hour
  - Easy to measure and regulate
  - Real sector capacity depend on traffic structure
  - ➢ Operators take safety margins
  - ➢ Capacity loss
- Idea: complexity-based metric
  - Grasp the workload
  - Dependant on traffic configuration
  - ➢ Full capacity



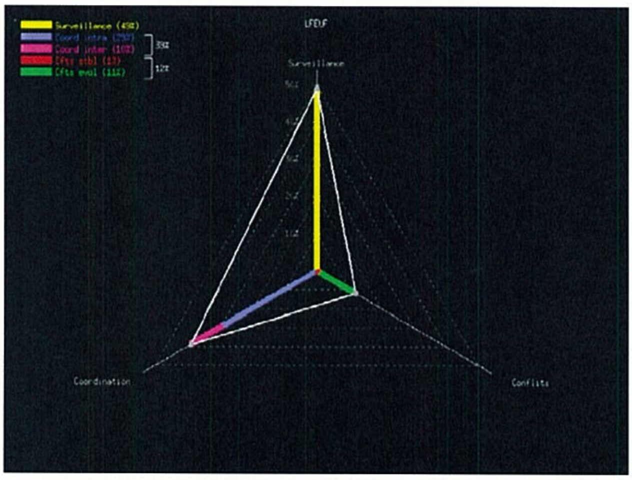
Presenting results: density

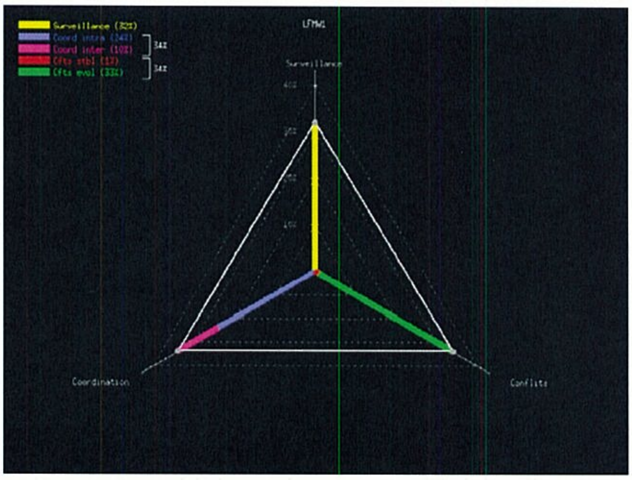


Presenting results: conflicts



Presenting results: workload





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European airspace analyzing tools

- Hand-made
  - Paper & pencil ☺
- Model based tools
  - ATFCM tools (Flow and capacity analysis)
    - COSAAC-SHAMAN, SAAM, DARTS, ICO, DPL…
  - Environment tools
    - INM-ENHACE, AEM 3, …
  - Airspace and traffic (FTS)
    - TAAM, RAMS, SIMMOD, OPAS, …
- Real-time simulators (RTS)
  - EDEP, ESCAPE, ELECTRA, MASS-DARWIN, IVY

European airspace modeling tools

- COSAAC-SHAMAN
  - Developed through DSNA & Eurocontrol cooperation
  - Traffic flow analysis
- ICO (Innovative Configuration Optimization)
  - Eurocontrol's sector configuration optimization tool
  - Adapts ACC capacity to best suit demand
- DPL (Dependences: Protections & Limitations)
  - Network effect analysis tool by DSNA
  - Aims at optimized regulation of traffic

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The OPAS Simulator Family

- FTS tools developed by DSNA
  - OPAS-En-route: en-route simulations
  - OPAS-TMA: designed for approach areas
  - OPAS-Coupled: en-route/approach interface

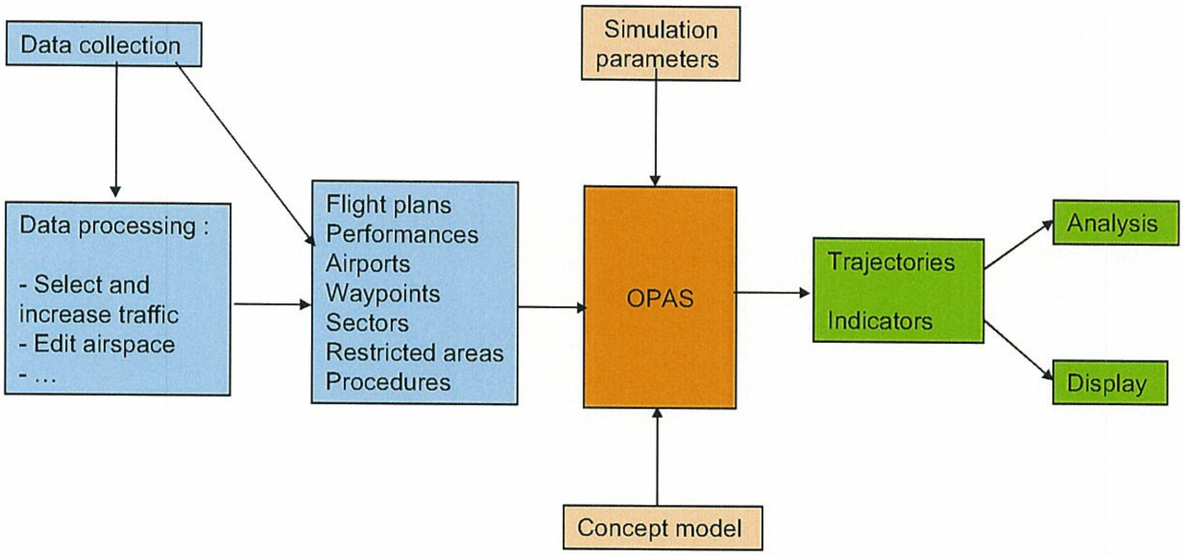
- OCaml language
  - Developed by INRIA, France
  - Linux and Windows (XP, 2000)

The OPAS Simulator Family

- Lightweight, modular, tools
  - easy to maintain
  - can adapt to different concepts

- The OPAS family capabilities
  - Test new concepts and new algorithms
  - Use different navigation logics, dynamic choice of trajectory
  - Provide figures to evaluate performance
  - If needed, indicators can be computed during simulation (no need for post-processing)

Simulation Process



OPAS-En-route

- En-route FTS, developed & used since 1998
- Input
  - Flight plans (France, Europe)
  - Performance model (Eurocontrol BADA v3.6 Total Energy Model)
  - Sectors, beacons, airports, restricted areas, …
  - Weighting factors (for workload computation)
- Output
  - Trajectories, and any indicator based on geometry :
    - time and distance flown
    - sector charge, …
  - Conflicts (type, location, aircraft involved, …) and Workload
  - Fuel consumptions

OPAS-TMA

- Developed since 2001, validated in 2004
- Input
  - Flight plans; Performance model; Beacons, runways, stacks, sectors, ...
  - Procedures (adapted from SIDs and STARs with help from controllers)
    - Available: Paris (de Gaulle & Orly), Lyon
    - Ongoing: Toulouse, Nice
    - Planned: Marseille, Dublin
  - Volumes linked to environmental constraints
- Output
  - Trajectories, applied maneuvers, and any indicator based on geometry :
    - time and distance flown
    - Use of stacks, delayed departures ...
  - Density maps, trajectories envelopes

OPAS-Coupled

- Developed since 2003 for Gate-to-Gate program
- Allows FTS in en-route and approach mixed environment
- Main challenge: connect two simulators with different logics
  - In OPAS-En-route, aircraft are simulated simultaneously
  - In OPAS-TMA, aircraft are simulated one after another

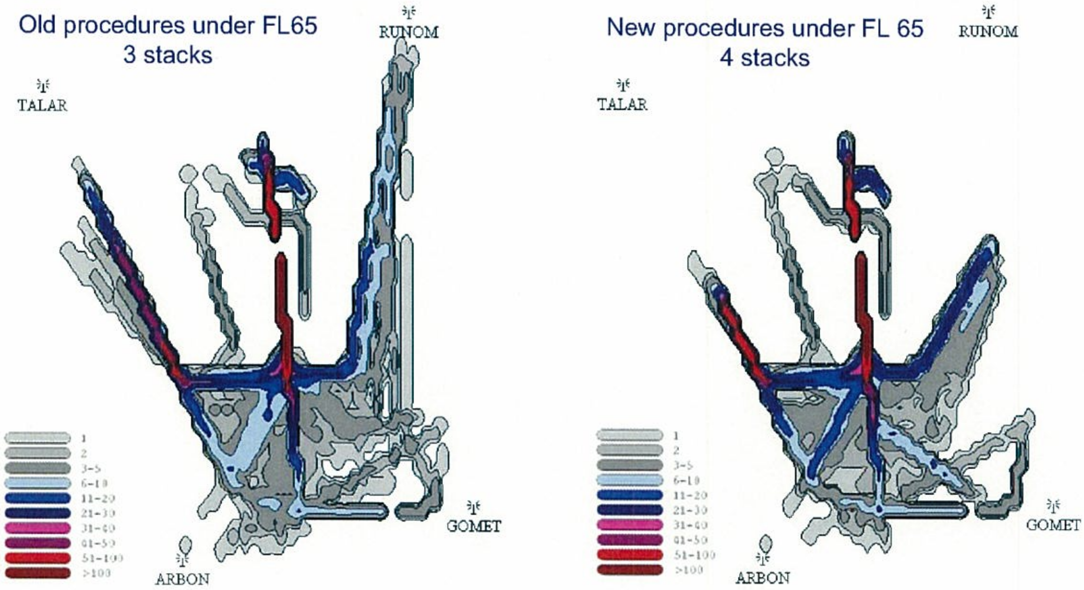
Past studies with OPAS

- OPAS-En-route
  - RVSM on 5 French ACCs
  - Comparison between radar tracks/free-route/flight plan route
  - ASAS-Crossing procedures (MFF)
  - Dynamic restricted areas avoidance (Free-Route for MFF)
- OPAS-TMA
  - Lyon: CLARINES project
  - Orly: South departures
  - Toulouse: important changes in airspace structure
- OPAS-Coupled
  - ASAS-Spacing concept in Paris TMA (Gate2Gate)

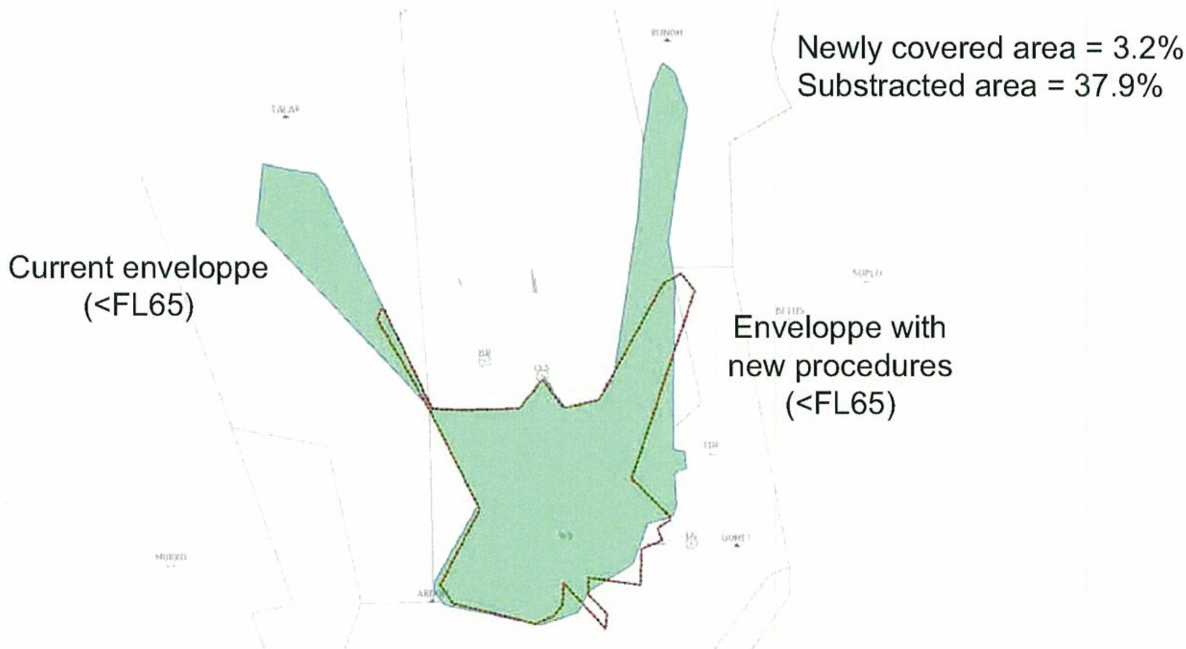
Study-case: CLARINES at Lyon

- Context
  - Creation of a 4th stack in the South-East
  - Several procedure modifications
  - Main issue: does the new arrival trajectories envelope below FL65 add less or more than 10% of newly overflown areas?
- Simulations with OPAS-TMA
  - 3 airports: Lyon, Bron, Grenoble
  - 2 scenarios: current (reference) and modified procedures
  - 3 months of traffic (~29200 flights)
  - Output: trajectories, density maps, statistics on the use of stacks, flight times/distances

Study-case: CLARINES at Lyon



Study-case: CLARINES at Lyon



Demonstration of OPAS

- Lyon airport simulation
  - The new CLARINES procedures at Lyon

- Full scale Paris area simulation
  - Westward configuration

日本におけるATM研究
ATM Research in Japan

独立行政法人　電子航法研究所
管制システム部　空域研究グループ
上席研究官　山本哲士
Tetsushi Yamamoto

1

ATM Strategic vision

To foster implementation of a seamless, global air traffic management system that will enable aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints and without compromising agreed levels of safety.

（ICAO GLOBAL AIR NAVIGATION PLAN FOR CNS/ATM SYSTEMSから抜粋）

2

問題･課題解決へのステップ
（Step to Solution ）

1. 問題･課題の認識（問題･課題の特定/定義付）
   What is issues?
2. 実情の認識（問題･課題の有無を把握）
   Actual Status of such issues
3. ﾎﾞﾄﾙﾈｯｸの究明（問題･課題とその要因の因果を究明）
   Analysis for Bottleneck
4. ﾎﾞﾄﾙﾈｯｸの認定（問題･課題とその要因の因果を認定）
   Identification of Bottleneck
5. ﾎﾞﾄﾙﾈｯｸの排除（問題･課題とその要因の因果を分断）
   Resolution against Bottleneck
6. 実情の確認（ﾎﾞﾄﾙﾈｯｸの排除効果を確認）
   Evaluation of Bottleneck

3

現状における問題･課題
Issues of present status

1. 遅延(Delay)
   遅延とは？
2. 飛行Profile (Flight Profile)
   運航者が希望する飛行Profile（経路･高度…）とは？
   User preferred flight profile(Route, altitude…)
3. 現行CNS/ATMの限界･制約(Constraints of current CNS/ATM)
   ① CNSの覆域、性能等に基づく異なる管制方式
   Deferent ATC Procedures depending on CNS coverage and performance
   ② 管制負荷の軽減･管制業務効率の向上
   Reduction of ATC work loads and improvement of efficiencies
4. 安全性の確保(Attainment of safety)
   目標安全度の設定(Target Level of Safety)

4

ボトルネックの究明(Bottleneck)

1. 遅延(Delay)
   実情調査・要因の解析(Survey of current status, Analysis of factors related)
2. 飛行Profile(Flight Profile)
   ① 固定経路とFlexible/Random経路の比較調査(Comparison of Fixed route and Flexible/Random route)
   ② 現行「航空路」概念から新たな概念の構築(Development of new concept from Current En-Route concept)
3. 現行CNSの限界(Limitation of current CNS)
   ① 通信負荷の軽減策検討(音声通信とDL通信の比較)
   Reduction of communication load(Comparison of Voice communication and data link communication)
   ② 管制業務効率向上策検討(支援機能の効果を推定)
   Enhancement of ATC efficiency (Effect of supporting tool)
4. 安全性の確保(Attainment of Safety)
   ① 目標値の設定(Set of Target Level)
   ② サブシステム性能等の安全性要件の検討(Safety requirement like as performance of subsystem)
   ③ 評価手法の構築(Development of evaluation methodology)

5

容量(Capacity)

- 容量(Capacity)
  - 器物(供給)の中に受け入れられる(需要の)分量(Amount of supply which can accept of demand)
- 供給(Supply)
  - 各サブシシステムによる供給(Supply by sub systems)
    - 管制処理容量(ATC Capacity)
    - 滑走路処理容量(Runway Capacity)
  - システム全体による供給(Supply with total system)
    - システム容量(System Capacity)
    - 空域容量(Airspace Capacity)
- 需要(Demand)
  - 航空機の運航(Flight Operation)

6

効率(Efficiency)

- 効率とは(What is efficiency?)
  - 目標とした効果に対する達成率(Attainment level to target effect)
  - 供給(容量)に対する需要(運航)の達成率(Attainment level of the demand for supply(capacity)

  各指標の目標値と実行値の差(The difference of target level and actual level)

- 容量との関係(Relation to the capacity)
  - 特定の効率(Specific efficiency) ⇔ 容量(Capacity)
- 費用対効果(Cost effectiveness)

7

容量の素(Factors for Capacity)

ある空港･空域における需要に対するサーﾋﾞｽ供給量(Service supply to the demand of some airport or some airspace)

空港容量(*Airport*) = *f*(*ATM*ｼｽﾃﾑ能力・空港のﾃﾞｻﾞｲﾝ...)
空域容量(*Airspace*) = *f*(*ATM*ｼｽﾃﾑ能力・空域のﾎﾟﾃﾝｼｬﾙ...)

空港のﾃﾞｻﾞｲﾝ = *f*(*Airside*、*Landside*の広さ、･形･*Layout*...)
空域のﾎﾟﾃﾝｼｬﾙ = *f*(広さ･形･地理上の位置...)
*ATM*ｼｽﾃﾑ能力 = *f*(*ATC*能力･航空機の能力･情報管理処理能力..)

*ATC*能力 = *f*(作業負荷･管制方式･管制機器...)
航空機の能力 = *f*(作業負荷･飛行方式･搭載機器･機体性能...)
情報管理処理能力 = *f*(精度･種類･伝達速度･伝達範囲...)
作業負荷 = *f*(人の作業負荷･機器の作業負荷...)

8

負荷(Load)

- 負荷とは(What is load?)
  - 所要のプロセス実施に要する労力・作業量等(Work load for the process)
- 難しさ(Difficulty)
  - プロセスの複雑さ・実施速度(Complexity and Speed of process)
- 忙しさ(Business)
  - プロセスの実施頻度・実施速度(Frequency and Speed of process execution)

9

従来型ATC対空通信の実情(Current status of conventional ATC communication)

通信速度·質が通信需要に対して限界に近づいている(communication speed and demand is nearly closing to limit)

- 通信のための作業負荷が生じる(Work load of communication)
- 1対1の通信(One by one communication)
  - 混雑時には、通信の順番待ちが生ずる(Sequential processing and have to wait until the channel is available)
- 音声通信(Voice communication)
  - 「言葉」以外の情報が通信できない(No communication other than language)
  - 通信内容の誤解や通信相手を取違える場合がある(Risk of Misunderstanding of the contents, misconnection to the different pilots)
- 「言葉」依存の通信(Depending on the Language)
  - 一定の通信時間を要する(Need certain time to transfer)
- ATC-Pilot直接通信(DCPC)の覆域に制約がある(Coverage Limit)

10

まとめ(Conclusions)
（ATC対空通信の改善案）

1. 通信時間の短縮(Reduction of communication time)
   ① 意図を正確且つ簡潔に伝える（正しい用語等の使用）(Simple and Correct)
   ② 受信：何でもかんでも復唱せず、キーワードで確認(Key word repetition)
   ③ 送信：一度に多数の指示等が含まれないよう努める(Simple Contents)

2. 負荷の軽減(Reduction of workload)
   ① 到着機の密集度緩和(Reduction of density of arrival aircraft)
   ② 通信の自動化(Automation of communication ・・・ Data Link)
      - 通信移管(Transfer of communication)
      - 交通情報(Traffic Information)
      - 気象情報(Weather Information)

11

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direction générale de l'Aviation civile

direction des services de la Navigation aérienne

direction de la Technique et de l'Innovation
sous-direction Etudes et Recherche appliquée

Présented by
Jean-Marc Loscos

Global Plan for Future ATM and Air-Ground Cooperation

ENRI-DSNA WORKSHOP on
Future Air Traffic Management

Tokyo, November 30, 2005

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RÉPUBLIQUE FRANÇAISE

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Global Plan for Future ATM and Air-Ground Cooperation

- ICAO global plan for future ATM
- European perspective for the evolution of the ATM system
- Air-ground cooperation & Airborne Separation Assistance System (ASAS)
- ASAS concept & ASAS applications
- Concluding remarks

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ICAO global plan for ATM

- Why ?
  - A Common Vision and the Path to the Future
- How (ANConf/10, 1991) and What (ANConf/11, 2003)
- Definition: the ICAO global plan
  - is a high level description of the set of ATM processes and services necessary to accommodate traffic in a given area and in a given time frame;
  - mainly describes performance and interactions;
  - focuses on the delivery and use of information.

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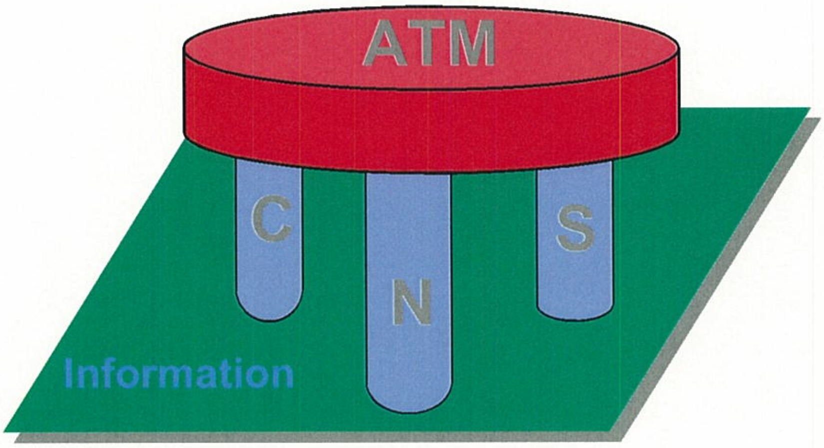
Concept CNS/ATM or ATM/CNS



Air Traffic Management relies upon Communication, Navigation and Surveillance and information systems

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ATM System evolution in Europe

Why do we change?

- Need for Change
  - Capacity (Europe-USA)
  - Flight efficiency
  - Too high ATS cost
  - New technologies
  - Airport congestion

- Obstacles to change
  - Safety
  - Present aircraft, equipment, systems
  - Diversity of Actors
  - ATS cost
  - Users (airlines, GA) Cost

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Global Plan for Future ATM and Air-Ground Cooperation 5

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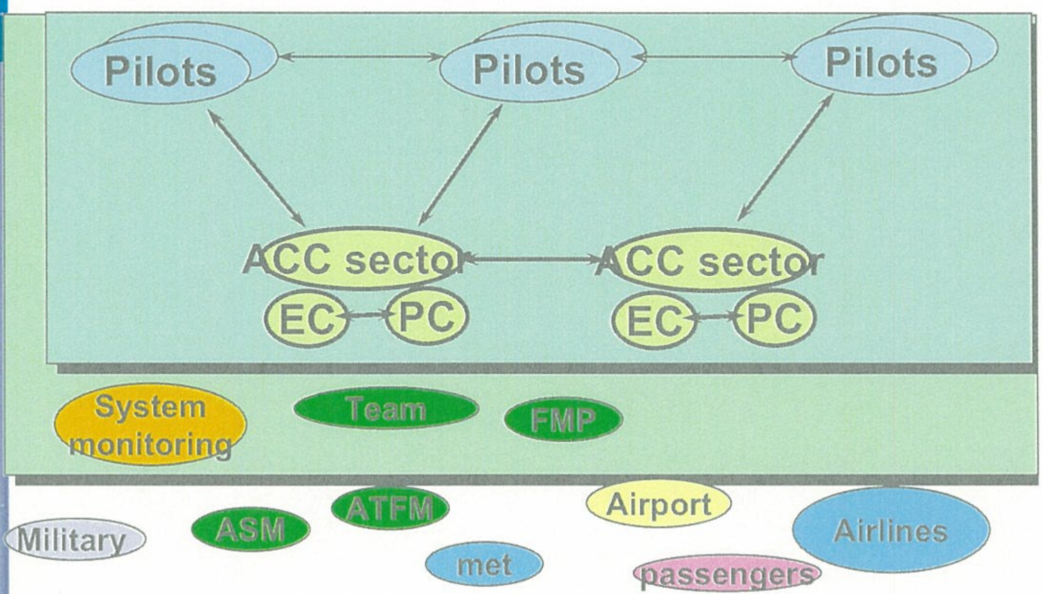
ATM actors



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Global Plan for Future ATM and Air-Ground Cooperation 6

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Present safety filters in the ATM system

• Air Space Management	1 year
• Air Traffic Flow management	
– strategic	1 day
– Pre-tactical	
– Tactical – ***(take off time)***	2 hours
• Planning	
– traffic organisation	30 minutes
– sequencing	
• Separation provision	10 minutes
• Ground safety net STCA	2 minutes
• Airborne Safety-net ACAS . . .	30 seconds

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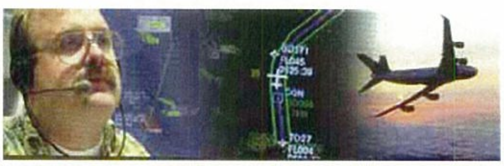
Air-ground cooperation role in future ATM

- 1) the airspace user is at the heart of the ATM system.
  ➔ air-ground cooperation must increase and improve.

- 2) Operations in the future ATM system must be thought in terms of traffic synchronization and conflict management.
  ➔ ASAS can support these two areas.



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The ASAS concept (date of birth 1994)

  - In-trail-climb procedure in the Pacific Ocean using TCAS ☹
  - Several years of TCAS operations triggered new operational requirements from the flight deck ☺
- The ASAS concept was "invented" at CENA in 1994 to cope with possible drift from ACAS use for non collision avoidance purposes.
  - Look at the acronyms
- ACAS= Airborne Collision Avoidance System
- ASAS= Airborne Separation Assistance System

Is it possible to use airborne surveillance for separation ?

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Main principle

Air Traffic Services
can be enhanced through
a greater involvement of the flight crews
and the aircraft systems (the flight deck)
in co-operation with controllers
and the ATM systems

2001: Publication of the Principles of Operation for the use of ASAS (PO-ASAS)
2002: First set of AS/GS applications of ADS-B (Package I)
2003: draft ICAO ASAS Circular available at ANConf/11

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ASAS definition

- Airborne Separation Assistance System: *An aircraft system that enables the flight crew to maintain separation of their aircraft from one or more aircraft and provides flight information concerning surrounding traffic.*

- The installation of ASAS onboard an aircraft will impact existing systems (e.g. FMS) or equipment (e.g. displays) and may also require new equipment depending on the required airborne architecture.

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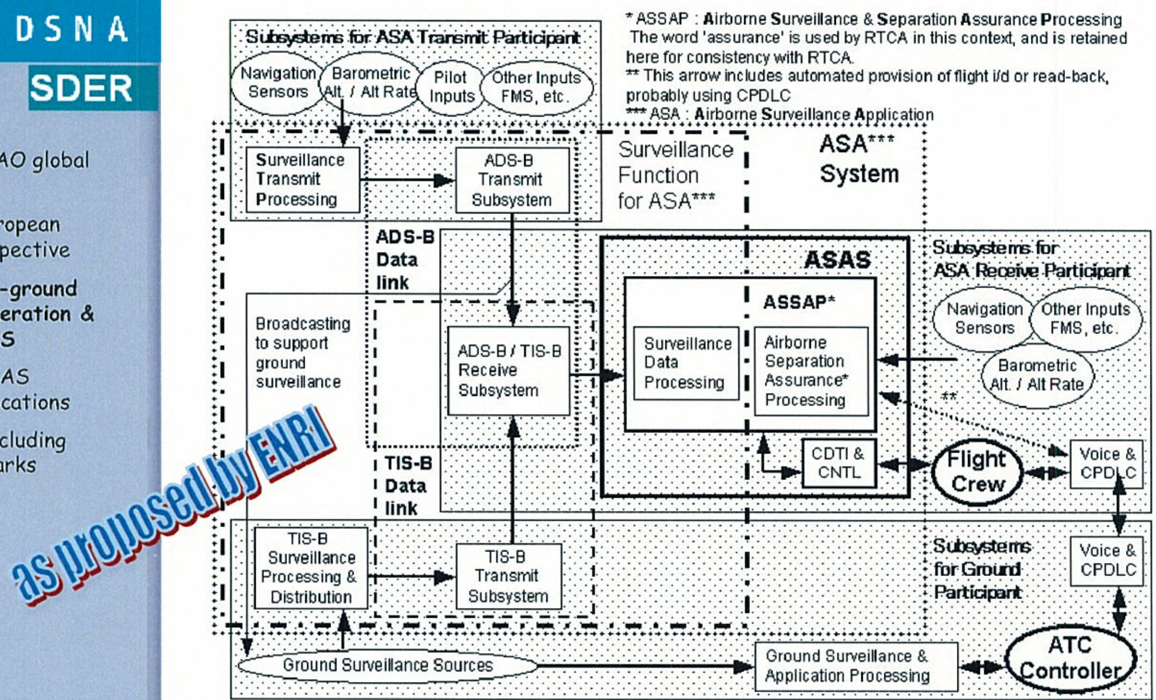
ASAS in the ATM Architecture



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ASAS applications

- Definition: *A set of operational procedures for controllers and flight crews that makes use of the capabilities of airborne separation assistance systems to meet a clearly defined operational goal.*
- ASAS Application Categories:

  Airborne Traffic Situational Awareness applications =ATSAW

  Airborne Spacing applications = SPACING

  ===TRANSFER OF RESPONSIBILITY FOR SEPARATION===

  Airborne Separation applications = SEPARATION

  Airborne Self-separation applications = AUTONOMOUS

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Procedures vs. ASAS application category and airspace

<table>
<tr><td>En-Route</td><td rowspan="3">Enhancement of current operations (surface, airborne and visual separation procedures)</td><td rowspan="2">Sequencing procedures</td><td>Crossing and passing procedures</td><td>Autonomous aircraft operations in Free Flight Airspace</td></tr>
<tr><td>TMA</td><td>-</td><td>-</td></tr>
<tr><td>Surface</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Airborne Traffic Situational Awareness</td><td>Airborne Spacing</td><td>Airborne Separation</td><td>Airborne Self-Separation</td></tr>
</table>

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ATSAW: Airborne Traffic Situational Awareness

Enhancement of the current traffic situational awareness of the flight crew during flight and on the airport surface

Example of a VFR flying near Paris:

This kind of traffic display would be of precious help for visual acquisition in general aviation.

(actual radar data used in simulated navigation display (ND))

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ATSAW: Airborne Traffic Situational Awareness

It can easily be seen that the TCAS display is not suitable for clear, unambiguous awareness of the air traffic situation: geometric symbol without a heading or identification, limited range.

With ADS-B information, the image can be enriched with appropriate information such as the heading and identification for ranges that can go up to 100 NM. Thanks to this additional information, the flight crew disposes of a traffic situational awareness, even in dense traffic areas such as Paris TMA.

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Airborne spacing

The flight crew is able to maintain a time or distance from designated aircraft.

The controller can use new spacing instructions to expedite and maintain an orderly and safe flow of traffic.

The controller is responsible for providing separation in accordance with the applicable ATC separation minima.

DSNA is developing "enhanced sequencing & merging" in Paris for arrivals:

- *Operational concept*
- *Operational validation through real time simulations*
- *Operational benefits & limitations through fast time simulations.*

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Airborne spacing: merging example

- **The controller requests the ASAS equipped aircraft (by radio or data-link) to identify a given aircraft.**

"AFRXXXX, Identify target AFR3141"

- To sequence two aircraft on flows merging at one point (e.g. INKAK in sector AR), the controller can give a "Merge" instruction: s/he specifies the INKAK point in his/her instruction, and the required separation.

"AFRXXXX, behind target, merge INKAK 90s behind"

- **Spacing (> Separation) is maintained on board by adapting the aircraft's speed (flight crew or FMS mode).**

Airborne spacing: merging example

Spacing is accomplished. The controller can cancel the new instruction at any time and take over the usual control.

The controller monitors the situation on his/her radar screen, which may be adapted for the needs of ASAS (display of linked aircraft for example). The ASAS procedure is continued during sector transfers (ACC/North-CDG), but it can be interrupted upon request by the TMA controller.

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Airborne separation

· ICAO global plan
· European perspective
· air-ground cooperation: ASAS
· ASAS applications
·Concluding remarks

- Principle of Operation:
  - The flight crew is able to provide separation from designated aircraft in accordance with the applicable airborne separation minima
  - The controller can delegate separation relative to designated aircraft to the flight crew through a new clearance
  - The controller is responsible for providing separation in accordance with the applicable ATC separation minima from other aircraft
- Expected benefits:
  - Capacity and flexibility: transfer of tasks to the flight crews, potentially reduced separation minima
- Aircraft systems:
  - Automation tools may be needed to assist the flight crew in performing separation tasks
  - Criticality: The performance of the systems will be very high so as to maintain airborne separation minima

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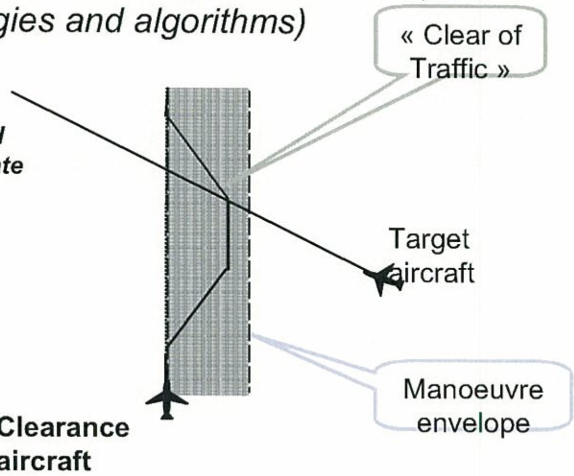
Airborne separation: lateral crossing example "pass behind"

Extrapolation of visual clearance for IFR aircraft in radar airspace evaluated in a European project: *ASSTAR (advanced safe separation technologies and algorithms)*

AFRXXXX is ASAS-equipped and is cleared by the ATCO to separate from GMI759 at 8 NM minimum

After the crossing, ATC would authorize AFRXXXX to resume climbing to FL280



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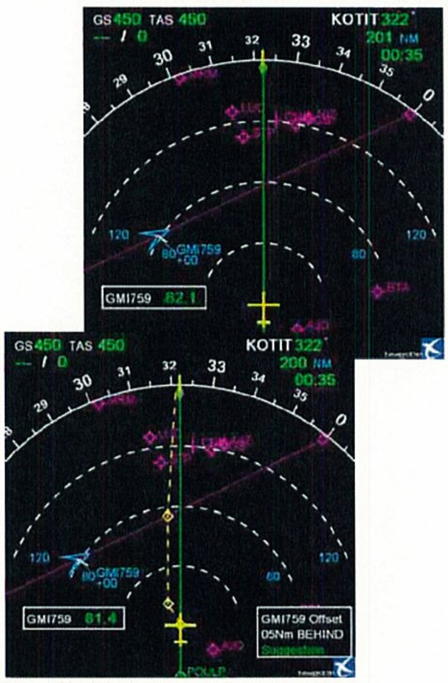
Airborne separation: lateral crossing example

– **Using appropriate airborne equipment, the flight crew must select the designated aircraft that is less than 100NM away.**

"AFRXXXX, cleared to pass behind target GMI759"

– **In order to perform the lateral crossing behind the designated aircraft, ASAS proposes solutions to the flight crew (in yellow)**



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Airborne separation: lateral crossing example "pass behind"

· ICAO global plan

· European perspective

· air-ground cooperation: ASAS

· **ASAS applications**

·Concluding remarks

– **The solution is accepted and the new route is activated (in green)**

– **The flight crew reaches the point of minimum proximity and can therefore advise "Clear of Traffic".**

"Marseille ACC, from AFR XXXX, clear of traffic and resuming navigation"

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Concluding remarks

· ICAO global plan

· European perspective

· air-ground cooperation: ASAS

· ASAS applications

·Concluding remarks

– **Careful attention is necessary when selecting the category for an ASAS application: Categories are associated with different principles.**

– **Rigorous safety analysis and validation will be required before implementing an ASAS application**

– **Methodologies and guidelines for these analyses will need to be agreed at the international level.**

- ASAS application has the potential of increasing capacity without affecting safety.
- Human factors issues are numerous, including acceptability by both sides of the new sharing of responsibilities.

Air-ground cooperation objectives supported by ASAS

National security

Safety

environment

Flexibility
freedom

Capacity
punctuality

Efficiency

Concluding remarks

- The Review of existing ASAS applications highlights the efforts, resources in the R&D organizations.

R&D DOES DELIVER!

- Starting from a concept paper in 1995, the R&D community produced major documents (PO-ASAS in 2001, ASAS Circular in 2003).
- Significant validation work is under way, a path towards implementation is proposed by the ATM stakeholders.
- Experts from EUROCONTROL, the FAA, EUROCAE, RTCA, Australia and Japan are working within the scope of the Requirement Focus Group (RFG) to harmonise ADS-B Package I applications for global interoperability.

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Thank you for you attention

- http:/www.icao.int/
- http://www.icao.org/icao/en/anb/meetings/anconf11/documentation/

- http://www.cena.fr/english/index.html
- http://www.cena.fr/english/pages/4publ/div_sas.html

Any questions ?

30 Nov 05 **Global Plan for Future ATM and Air-Ground Cooperation** 27

電子航法研究所/仏国DSNA共同講演会
ENRI/DSNA Workshop

順序間隔付けツールの開発
Development of Sequencing and Spacing Tool

平成17年11月30日

November 30, 2005

電子航法研究所 管制システム部

Electronic Navigation Research Institute

Traffic Management Systems Division

福田 豊

Yutaka Fukuda

発表内容 Contents

- 到着機の順序・間隔付け支援システム
  COSMOS (Computer Oriented Spacing and Metering Optimization System)
- 開発の背景 Background
- 概要 Outline
- 機能 Function
- 評価 Evaluation
- 今後の課題 Future Works
- まとめ Summary

背景 Background

- 航空機の離発着が輻輳するターミナル空域の効率的運用と航空機の安全確保

  Safety and efficiency are required.

- 欧米では到着機に対する順序・間隔付け情報等を管制官に提供するシステムを開発

  Arrival Management Tools (Sequencing and Spacing Tools) are developed in Europe and USA.

概要 Outline

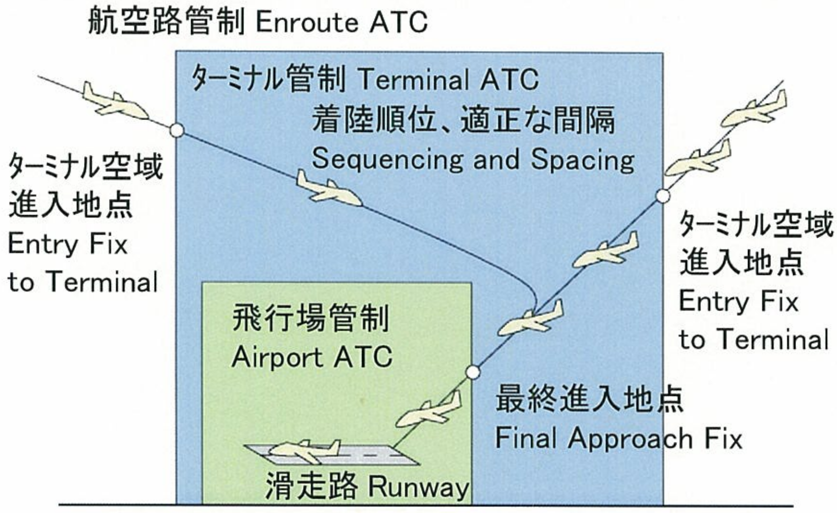
- 着陸順序の決定や最終進入地点通過時刻の予測等の状況分析に必要なデータを示す。

  COSMOS shows landing sequence and estimated time on final approach fix.

- 電子航法研究所が研究開発（平成５年度から平成９年度）

  ENRI developed and evaluated COSMOS from FY1993 to FY1997.

順序・間隔付け業務　Terminal ATC



管制官の作業　Controller's Task

状況認識（航跡の監視）
Situation Awareness (Monitor)

↓

予測（将来の状況を予測し、管制間隔が確保できない等の問題の検出）
Prediction (Detect Future Problem)

↓

意思決定（問題の解決方法）
Decision Making (Resolve the Problem)

管制支援システム D/S Tool

入力：到着機の飛行計画情報と航跡情報

Input : Flight Plan and Radar Track

処理：管制方式基準や管制官の専門知識

Processing : ATC Rules and Expertise

出力：順序・間隔付け支援情報を管制卓に表示

Output : Assisting Information on Radar Display

最終進入地点の順序、予測到着時刻、計画到着時刻

Sequence and Estimated Time on Final Approach Fix

計画到着時刻を実現するための遅延経路

Route to Final Approach Fix

表示方法　Display

- 最終進入地点の予測通過時刻や予測着陸時刻を時間軸表示

  Estimated Time on Time Line

- 想定経路と推奨遅延経路を視覚的に表示

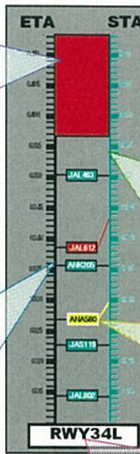
  Estimated and Delayed Route on Terminal View

タイムライン表示 Time Line

空域表示 Terminal View

タイムライン表示 Time Line

使用禁止時間帯:
No Runway Operation Time :
滑走路が出発専用または閉鎖状態にある場合等の表示
Runway Time for Departure or Closed



計画到着時刻:
STA (Scheduled Time of Arrival) :
適正な間隔が確保された基点通過時刻
Time with Adequate Separation

予測到着時刻：
ETA (Estimated Time of Arrival) :
当該機の位置から予測した基点通過予測時刻
Time on Final Approach Fix or Runway by Shortest Route

タイムラインターゲット:
Time Line Target :
航空機の便名
Call Sign of Aircraft

基点：滑走路、最終進入地点
Base of Timeline : Runway or FAF

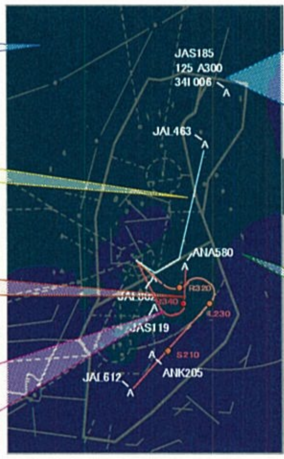
空域表示 Terminal View

空域マップ
Airspace Map

ETA想定経路
ETA Route

STA遅延経路
STA Delayed Route

軌道変更点
Trajectory Change Point
R230 針路 Heading 230 deg
A040 高度 Altitude 4,000 ft
S210 速度 Speed 210 kt



航空機の詳細情報
便名
高度 型式
滑走路 順序
Full Data Block
Call Sign
Altitude Type
Runway Sequence

航空機の簡易情報
Simple Data Block

リスト表示 Arrival List

SPENS

0430	JAL379	B767	120
0428	ANA456	B767	100
0425	JAS287	A300	140
0420	ANK085	YS11	080
0419	JAL391	B747	120
0415	JA8845	B767	100

ターミナル空域入域地点の通過機:
Arrivals at Terminal Entry Fix:
通過予定時刻, 便名, 型式 ,高度
Estimated Time, Call Sign, Type, Altitude

待機旋回：待機旋回地点, 待機高度, 進入予定時刻
Holding : Fix Name, Altitude, Expected Approach Time

RWY34L

09	ANK085	0425	130	370	180	AMI	130	0419
08	JAS287	0420	140	350	060	WESTN	100	0415
07	ANA456	0419	094	210	080			
06	JAL379	0415	085	200	075			
05	JAL456	0470	078	210	047			
04	ANK785	0405	062	200	035			
03	ANA548	0401	050	200	010			
02	JAS568	0358	040	180	345			
01	JAL364	0355	030	175	340			

間隔の警告
Warning of Separation

現在の高度、速度、針路
Current Altitude, Speed, Heading

計算手順 Prediction Process

レーダ追尾前 Before Radar Tracking

ﾀｰﾐﾅﾙ空域進入地点の予測通過時刻＋最終進入地点への飛行時間
ETA = Estimated Time of Entry Fix + Estimated Flight Time to Final Approach Fix

↓

最終進入地点の予測通過時刻の早い順に到着順序を想定
Sequence on First Come First Served at Final Approach Fix

↓

レーダ追尾後 After Radar Tracking

航空機の位置の更新毎に最終進入地点の予測通過時刻を再計算
Recalculation of ETA on Every Surveillance Cycle

↓

遅延経路を現在位置から再計算
Recalculation of Delayed Route from Current Position

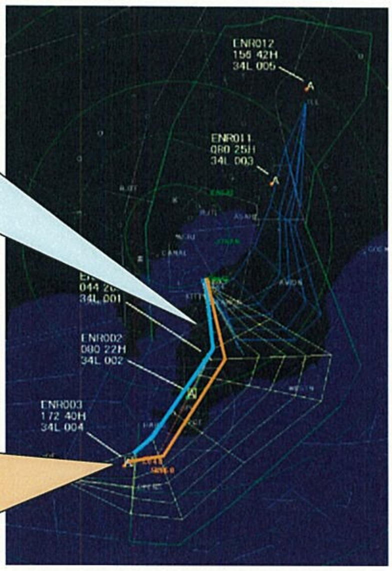
経路の算出　Route Generation

現在位置から最終進入地点に最短で飛行する想定経路を算出

The shortest route for ETA is assumed.

予め設定した通常飛行の経路帯の中で遅延経路を算出

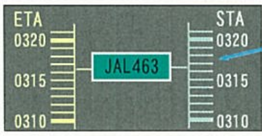
Delayed route for STA is searched in pre defined route generation area.



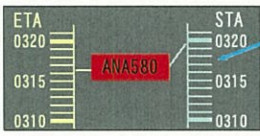
表示と操作　Display and Operation

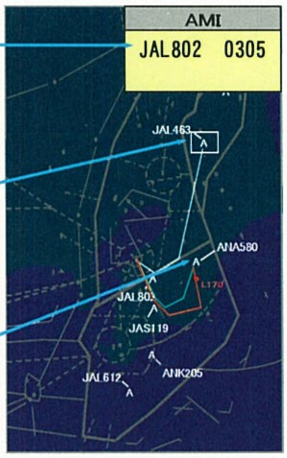
未追尾状態
Before radar tracking

追尾状態で間隔が確保できる場合
After radar tracking with good separation



先行機との間隔が不足するため遅延が必要
Without separation, so delay is required

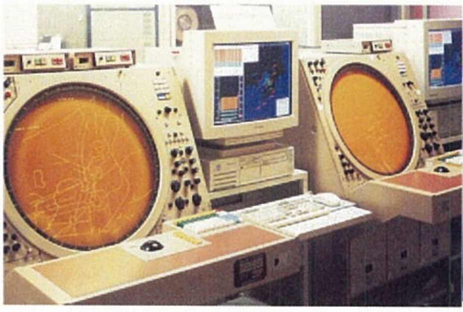




順序はマウス操作で変更可能
Sequence can be changed with simple operation.

評価 Evaluation

- 管制官の参加によるシミュレーション実験
  Real Time Simulation of Air Traffic Controllers



第1回実験システム
1st Experimental System

第2回以降の実験システム
2nd Experimental System

管制官の意見 Comments at Simulation

- 予測と順序が適切であれば、初期針路の判断、航空機への順序の通知等の参考となる。
  If prediction time and sequence are good, it is useful for initial heading and sequence notification to pilot.
- レーダ画面への統合表示が望ましい。
  Integration with radar display is required.
- 将来のターミナル空域の交通量の予測により、航空交通管制部や空港管制塔との調整業務の参考となる。
  Future traffic volume prediction is useful on the coordination with Air Traffic Control Center and Airport Tower.

運用までの経緯 History for Operation

- 電子航法研究所での研究（平成5年度-平成9年度）
  Study on ENRI (FY1993-FY1997)
  - 実験室モデルの設計開発シミュレーション実験による評価
    Design, Development and Real Time Simulation Evaluation
- システム開発評価・危機管理センターでの改良と評価（平成11年度-）
  Improvement and Field Evaluation on SDECC (Systems Development, Evaluation and Contingency Management Center) (FY1999-)
- 中部国際空港の新型レーダ管制卓（ARTS-F）の機能として運用（平成16年度）
  Operation as a function of New Radar Display (ARTS-F) at Central Japan International Airport (FY2004-)

関連する利用方法 Other Usage

- 到着順位、滑走路、遅延状況の情報による航空会社等との共通の状況認識の基盤、空域の性能モニタ
  Base for common situation awareness with airlines and performance monitor on information of sequence, runway usage and delay
- 航空交通流管理の指標
  Index for Air Traffic Flow Management

今後の課題 Future Works

- 予測精度の向上
  Improvement of Prediction Accuracy
- 管制官が認識しやすい遅延経路の生成
  Improvement of Route Generation
- 空港面管理システム、航空路の支援システム、航空交通流管理システムとの連携による統合システムの構築
  Integration with Airport Tool, Enroute Tool and Air Traffic Flow Management System

まとめ Summary

- 到着機の順序・間隔付け支援システムの概要、機能、評価について紹介した。
  Outline, Function and Evaluation of COSMOS
- 支援システムの開発では、予測精度の向上、管制官の専門知識のシステムへの組込み、管制官へ提供する情報の内容と表示方法が重要な課題であった。
  Important points of development COSMOS were prediction accuracy, integration with ATC rule and Graphical User Interface.