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DEVELOPING AND EVALUATING THE FUTURE COOPERATIVE ATM CONCEPT FOR THE BRAZILIAN ENVIRONMENT

Gerhold, T.[(1)], Meinerz, G. V.[(2)], Martins, O. A.[(2)], Hüttig, G.[(1)], Cunha, A. M.[(2)], Dias, L. A. V.[(2)], Silveira, F. F.[(2)], and Schubert, E.[(1)]

[(1)] Berlin Institute of Technology – TU-Berlin
Department of Aeronautics and Astronautics - ILR
Chair of Flight Guidance and Air Transportation
[(2)] Aeronautics Institute of Technology - ITA
Computer Science Division - IEC

ABSTRACT

Today's ATM (Air Traffic Management) systems usually perform well, but are susceptible to disturbances such as weather events, controller inputs, ground and turnaround delays, and runway closings. Therefore the estimated traffic is temporarily reaching capacity limits of infrastructural resources. Furthermore, air traffic is growing so rapidly that airport resources and current ATM systems cannot keep up with the demand. One solution is the expansion of the present infrastructural resources. Another option is applying future cooperative ATM concepts, using collaborative technologies and procedures to enhance process efficiency. This work presents an on-going exchange project between the TU-Berlin (The German Berlin Institute of Technology) and the ITA (The Brazilian Aeronautics Institute of Technology) and information about the main concepts considered in it. This project aims to investigate and propose the main requirements and recommendations for future cooperative ATM concepts, as well as to analyze the effort to implement and adapt such concepts to an existing ATM system.

1. INTRODUCTION

Since the mid nineties, Europe and the United States of America have been working intensely, in several areas to conceive technologies and adjustments of processes to enhance capacity and efficiency, as well as improving safety of their Air Transportation Systems. The perception of this risk came from studies that pointed the inadequacy of the existent systems to support the crescent demand for the use of air space during the next decades.

Having the same problems, aspirations and objectives, and conscious about the fact that air transportation is global and needs coordination and synchronization, those countries began a cooperation process within their respective R&D (Research & Development) programs: SESAR (Single European Sky ATM Research) Program - coordinated in Europe by EUROCONTROL (European Organization for the Safety of Air Navigation); and NextGen (Next Generation Air Transportation System) - coordinated in the United States of America by JPDO (Joint Planned & Development Office) (EUROCONTROL, 2004; JPDO, 2007).

In these programs, concepts of operations were defined for the future, and long term actions were started and are still under execution aiming to the refactoring and the evolution of existing ATM process and systems until to about 2025.

Specification activities, involving industry, institutes, government and private organizations, had resulted in the definition of new concepts and challenges where Information Sharing and CDM (Collaborative Decision Making) are included and represent key research areas. These new concepts and challenges may also represent requirements for a new cooperative ATM for Brazil (EUROCONTROL, 2006).

Two research groups, from the TU-Berlin and ITA, are working together in an exchange program called PROBRAL supported by CAPES (The Brazilian Federal Agency for Support and Evaluation of Graduate Education) and DAAD (The German Academic Exchange

Service) during the years of 2008 and 2009. The main subject of this project is the new cooperative ATM concept, investigating the probable adoption and the feasibility of its implementation to the Brazilian ATM environment.

A comparison of controlled airspace between Brazil and European Union countries (see Figure 1) shows that the size of the Brazilian Airspace is larger than the airspace of European Union. The demands of their big hub airports are comparable. To apply cooperative ATM concepts including different control measures it is supportive to have a large unified airspace available so that control interventions can effectively affect the air traffic.

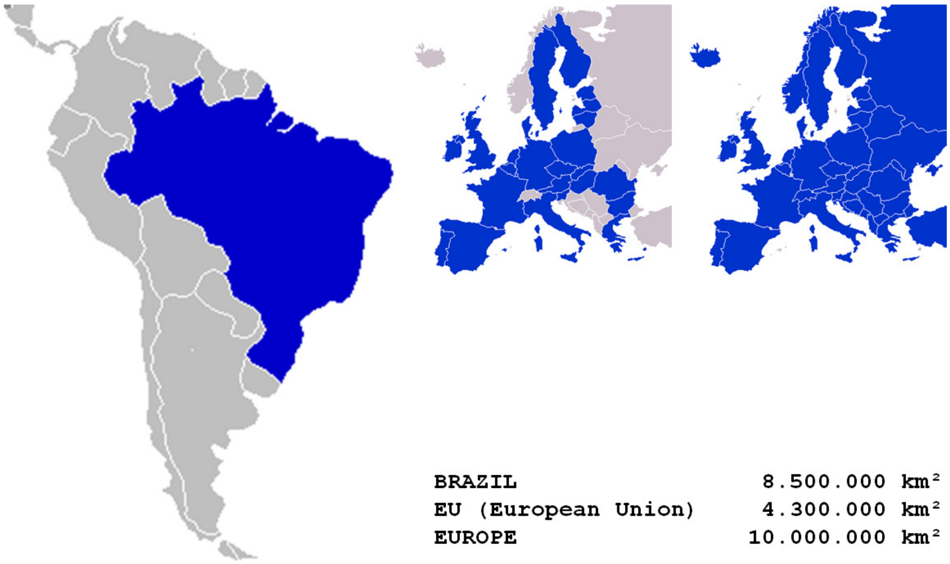

Figure 1: A comparison between Brazilian and European Union Airspace to Scale

The German partners or actors interest in this project is to enhance competence in the area of specification requirements and interface studies for adoption of ATM concepts into another ATM environment, a competence required also in Europe during the implementation phase of such concepts because of the largely different systems operated in Europe by different national ANSP (Air Navigation Service Providers).

This work tackles details about this project. Section 2 presents the main research objectives. Section 3 mentions the research lines of the project. Section 4 describes the activities of the working plan during the first phase, concerning 2008. The main expected benefits are exposed in the Section 5.

2. RESEARCH OBJECTIVES

This study focus on future cooperative ATM concept supported by CDM technologies applying information sharing, decision support, and control measures.

2.1 The Future Cooperative ATM Concept

The future cooperative ATM concept is based on the following main tree pillars:

- An advanced situation awareness essential to fulfill the main precondition for a cooperative decision making process;
- The support of decision making process in a cooperative environment, where different partners are involved in the decision making process; and

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- The implementation of control measures into the ATM system to influence the air traffic by different partners with the same purpose.

The following paragraphs give an overview about these pillars of the future cooperative ATM concept.

The expected benefits of the future cooperative ATM concept are:
- The increase of utilization capacity;
- The increase of punctuality;
- The identification of optimization potentials; and
- The creation of fundaments for using CDM technologies.

2.1.1.1 Advanced Situation Awareness

The future cooperative ATM concept aims to support CDM processes and procedures. One important element of a cooperative concept is to supply all different partners and decision makers with the same information. The situation awareness of all partners in the ATM system is a basic requirement for future cooperative ATM concept. The main partners in the ATM system are: ATC (Air Traffic Control); Flow Management; Airport Operators; Ground Handlers; and Aircraft Operators. All partners are deliverers and users of data at the same time.

One purpose of this project is developing and describing a centralized network solution to collect and distribute information more rapidly from and to all involved partners. It does not necessarily introduce radically new systems or procedures, and its benefits may come from enhancing and improving existing systems and processes. The common situational awareness will be reached by exchanging and sharing timely and accurate information between partners through a common platform.

The situation awareness of all partners depends on availability and accuracy of different data in the ATM system. The availability of data should be increased by information sharing processes including the following items:
- Identification of data sources:
  - Identification of existing data delivering systems, and
  - Generation of data predictions;
- Standardization and harmonization of data formats;
- Data centralization of common database, and interface management (processes synchronization):
- Increases of time horizon of prediction data; and
- Increases of update rate of required data.

To support the future cooperative ATM concept, the accuracy of data which are used to generate the best situation awareness should be increased by following measures:
- Avoidance of data integrity problems:
  - Definition of range values for each data field,
  - Definition of the integrity of check rules, and
  - Verification the database design;

- Avoidance of data redundancy problems:
  - Consolidation of rules and priorities, and
  - Verification of the database design; and
- Extension accuracy of prediction data (e.g. capacity and punctuality predictions).

Figure 2 shows one suboptimal solution for information sharing of flight plan updates of two different data sources. The airport system delivers data to the capacity prediction generator process. The capacity predictions based on this data are used by the runway sequence optimization process. A second data delivering system of the ATC delivers flight plan updates directly to the runway sequence optimization process. In case there is a discrepancy in the content between the two different data sources, the runway sequence optimization process has another view about the traffic situation different from the capacity prediction generator process. The solution of the runway sequence optimization process might therefore be inaccurate.

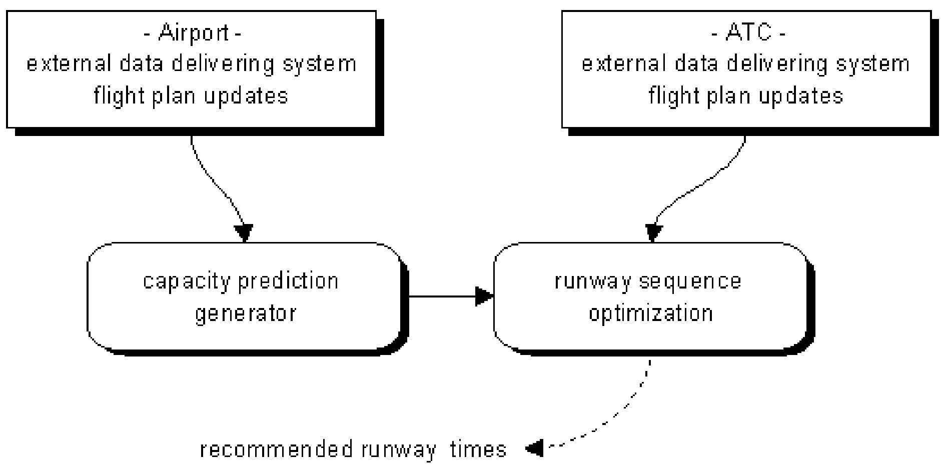

Figure 2: Suboptimal solution from information sharing

Figure 3 shows one better solution for information sharing of flight plan updates. The two systems put the data into separate tables of a centralized database. Data delivering systems have only permissions to insert data into these input tables. An internal data consolidation process will consolidate data, based on previously defined rules and priorities, and will allocate consolidated data into only one output table. Therefore, systems using flight plan updates will have the same view of the traffic situation. The use of special output tables in the centralized database supports the advanced situation awareness for all connected systems and users.

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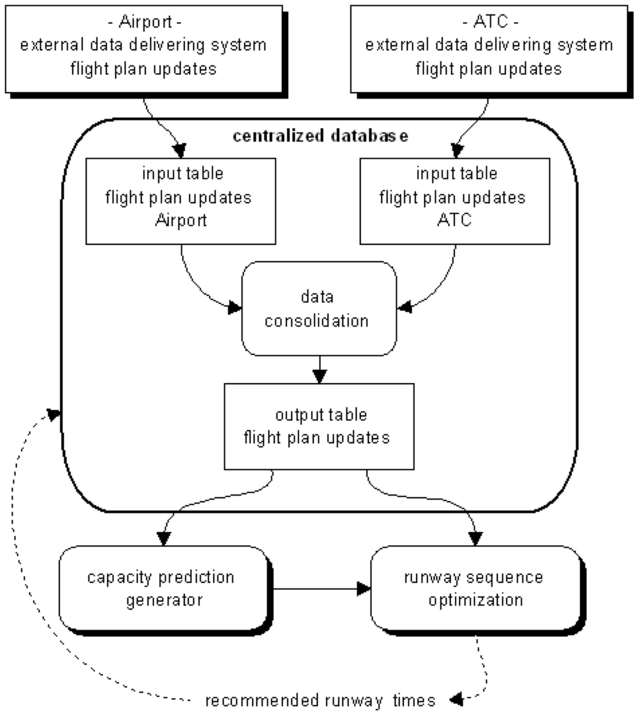

Figure 3: A better solution for the information sharing

2.1.2 Support Decision Making

One further element for the future cooperative ATM concept is the support for decision making processes based at least on the following measures:

- Support an optimal view about current traffic situation including prediction data;
- Usage of common centralized data sources;
- Generation of predictions over extended time horizons;
- Support optimal uses of available local infrastructural resources (e.g. runway sequence optimization); and
- Development and implementation of advanced decision support tools.

In this context, for instance, a runway sequence optimization tool can be implemented for future cooperative ATM environments, providing the calculation of optimal aircraft streaming for a given runway system, considering:

- Weather, capacity, and traffic demand predictions;
- Optimal usage of available infrastructural resources;
- Some constraints like aircrafts performance and separations minima;
- Delays and fuel consumptions; and
- Airline and airport priorities.

Figure 4 shows the current capacity prediction (on the red line) and the predicted demand (on blue columns) over a timeline looking for future situation. Available resources (runways) are limited by a capacity prediction mark. The left diagram shows that the predicted demand can not be accommodated by the available capacity in several time slots. Notice in some time slots of the central diagram the available free capacity not being used. The right diagram shows that the runway sequence optimization process generates an optimal sequence usage of available resources.

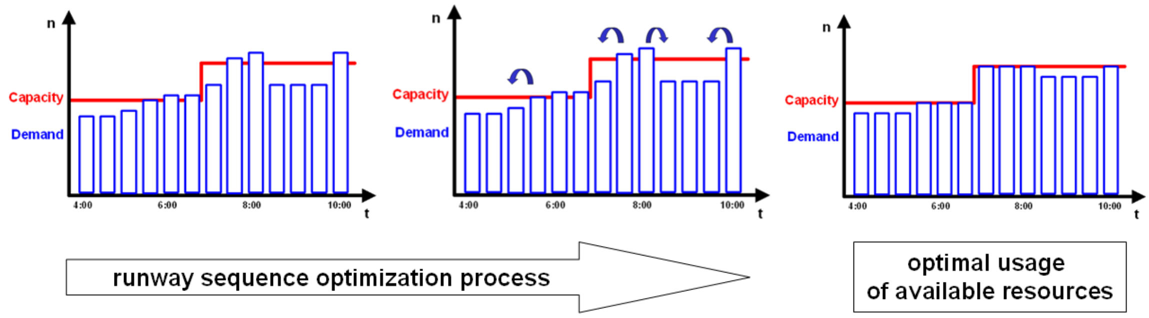

Figure 4: The usage of available resources after sequencing optimization

Figure 5 shows the runway sequence on a timeline. At first the planned runway sequence is given by the scheduled landing time (SLDT) over a long period of time. The data acquisition process generates an updated sequence by using the estimated landing time (ELDT) for each flight having such update. A divergence between planned and estimated sequence appears and a delay (red bar) can be calculated. Based on the estimated demand and the predicted capacity, sequence optimization processes generate a recommended sequence described by the recommended landing time (RLDT) for each flight. The minimization of the overall delay is the main objective of the sequence optimization process. The recommended landing time is a control value for decision making processes which generate measures to control the air traffic operation, in order to reach the recommended sequence. Due to the recording of the actual landing time (ALDT), the performed sequence can be reproduced and used for data analysis processes. Therefore, the delay can be calculated by comparing actual with scheduled landing time.

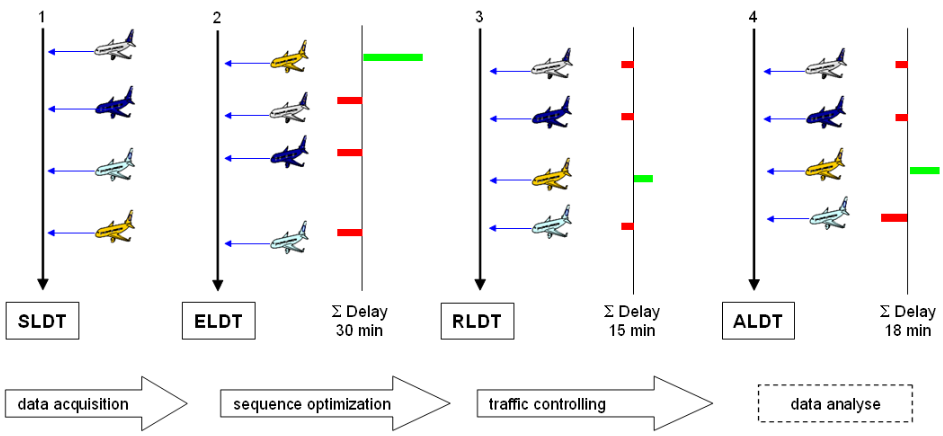

Figure 5: Minimizing overall delay after sequencing optimization

- *Control Measures*

In order to allow the future cooperative ATM concept it is necessary to identify existing control measures and implement some new ones into the ATM system. In this context an investigation to identify possibilities to control the air traffic by different partners is needed.

On flight phases, different partners and measures can affect the runway time for each flight. Considering the flying phases in a gate to gate model view shown in Figure 6, control measures aim to loose or save time to reach the recommended runway time.

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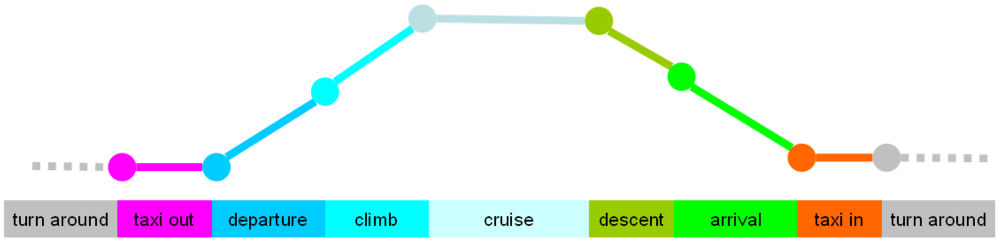

Figure 6: The flight phases in a gate to gate model view

In this case, some possible control measures are: ground delays; sequence changes; in flight accelerations or decelerations; departure and arrival prioritizations; direct routings; descent profile adaptations; and control ground handling processes.

2.2 Implementation Requirements

To accomplish the appropriate administration for ATM system, a vast group of people and organizations, as well as the use of Information Systems have to be considered. Current systems were developed by organizations, considering available technologies and paradigms on each occasion without a dedicated focus on collaboration.

In a management model supported by several systems and in a reasonable amount of partners, the integration is desirable and justifiable by: eliminating possible information redundancies; minimizing data operations importation and exportation; and avoiding the retyping of existing information from other systems.

One of the macro-objectives of this exchange project is the contribution for the alignment of the Brazilian ATM system to the trends and perspectives of the future cooperative ATM concept, concentrating on key research areas related to Information Sharing and Exchange in a distributed network of producers and consumers, making possible the implementation of CDM mechanisms.

Specific objectives of implementation requirements are:

- To obtain and share general knowledge concerning operational concepts of future cooperative ATM, considered by SESAR and NextGen programs;
- To obtain and share general knowledge concerning the Brazilian Air Transportation System, verifying the applicability of future cooperative ATM concept operations;
- To obtain and share knowledge deepened on the specification, project, and implementation of system architecture and technologies models that will promote the sharing and exchanging of information in the distributed environment of the future cooperative ATM; and
- To verify the applicability of the model and technologies that will foster information sharing and exchanging in the distributed environment of the future Brazilian ATM System.

In order to implement a future cooperative ATM concept into an existing ATM system, requirements have to be described. Based on its description, available data, data sources, and processes have to be identified. This requires comprehensive data and process analysis. The description of data requirements aims at:

- Standardization and harmonization;

- Information sharing;
- Data quality improvement (about the current situation); and
- Prediction quality improvement (about the future situation).

3. RESEARCH AREAS

This project involves the research areas of Air Traffic Management and Computer Science.

3.1. Air Traffic Management

The main parts of this research area are: the analysis of current ATM systems; the identification of partners and decision makers; the analysis of processes and procedures; and the development of the future cooperative ATM concept. However, this project is not intended to support any technical implementation.

In the ATM system different partners, operational standards, and constraints are involved in the decision making and traffic flow controlling process. Different interests and requirements are the results of its individual view. This research area will identify special interests and targets of each partner and will describe the resulting requirements for a future cooperative ATM concept.

Furthermore, each partner will have different possibilities to support the future cooperative ATM concept. This research area will identify and describe such possibilities.

Potential supporting for the future cooperative ATM concept are: delivering data; generating control outputs; and following up control inputs.

During its development, different processes and procedures will be analyzed. After a definition phase, requirements for the ATM system will be described. In the next phase it will be necessary to identify the related ATM processes and compare it with requirements. In some cases it will be necessary to define new processes and adapt them to the current ATM system. Therefore, a basic knowledge about the ATM system is needed.

Especially the knowledge about operational procedures and constraints is important to develop the requirements for advanced decision support tools.

Some examples for operational constraints are: the separation minima, which influence runway sequence optimization; the aircraft performance, which influences the prediction of estimated runway arrival time; and the minimum turn around time, which influences the prediction tool of estimated off block time.

In the ATM system process different partners and decision makers are involved. It is fundamental to identify required data for the system and to know about possible data sources, data delivering systems, and dataflow to define and implement the future cooperative ATM concept. In this case, possible required data are the predictions of: weather, demand, capacity, punctuality, and taxi time.

The knowledge about the ATM system will be necessary to describe all data and process requirements and to evaluate adaptation and implementation efforts.

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3.2. Computer Science

Computer Science has much closer relationship with many other areas and disciplines. This project is related to ATM systems focusing on computation and information and their implementation and application to its future cooperative concept. The next two sections explain the importance of applying software engineering, and information technology and management in this project.

3.2.1 Software Engineering

The importance of requirement specification, modeling, design, and evaluate the proposed changes to ATM systems is widely recognized by both, ATM and Software Engineering communities. In this context, among others, some standards, techniques, models, tools and software engineering processes should be applied:

- System Modeling and Documentation – it is necessary to document the existent functionalities of the current ATM system, as well as to specify requirements for the future cooperative ATM concept. For the system modeling, the intention is to use the UML (Unified Modeling Language), as a standard modeling language with a set of graphical notation techniques to create abstract models of current and future ATM systems. The RUP (Rational Unified Process), an iterative software development process framework, gives total support for UML standard diagrams;
- Artificial Intelligence Techniques – the system solution proposal described in a conceptual model can be transformed into a computational model through the application and testing of some Artificial Intelligence techniques; and
- I-CASE-E (Integrated Computer Aided Software Engineering Environment) tools – its use emphasizes design, architecture support, and documentation with UML to demonstrate the software engineering process applied to the future cooperative ATM system.

3.2.2. Information Technology and Information Management

Information sharing is fundamental for the future cooperative ATM concept and represents the basis for the CDM concept implementation. Information Sharing and CDM are enabled by Information Management and the service principle of management of information will be a key to the ATM concept. It represents a supporting process which is essential to all ATM concept partners. Information sharing in a distributed environment of information suppliers and consumers will allow all partners to conduct their businesses in a safe and efficient manner (EUROCONTROL, 2004).

AIM (Aeronautical Information Management) is the term applied to the globally interoperable provision of aeronautical data of required quality, covering the needs of present and future cooperative ATM system and all flight phases in a data oriented holistic approach (FRANGOLLO A.P., ZERKOWITZ, E., 2006; STRICHT, S. V., 2008).

AIM aims to make possible the so-called global interoperable data exchange based on the standardization of data content through data modeling, and the standardization of interfaces to provide well defined means to access data and enable seamless interoperation.

The future cooperative ATM concept aims also to be a kind of wide system. It means that the system intends to have ability to support all information domains (flight data, surveillance, weather, aeronautical information, and airspace infrastructure status) and flight domains (surface, terminal, and oceanic or remote enroute). The main idea is not to construct a new big system, but transform current systems in a kind of “system of systems” by means of application of concepts such as SOA (Service Oriented Architecture) and EAI (Enterprise Application Integration). New systems required will be developed considering these standards.

The future cooperative ATM concept considers AIM as a research and development area looking for standards like Global AIM Data Models which are part of the D-AIM (Digital-Aeronautical Information Management) and is comprised of: AIXM (Aeronautical Information Exchange Model); AMXM (Aerodrome Mapping Exchange Model); WXXM (Weather Exchange Model); ANXM (Airport Operations Information Exchange Model); and TIXM (Terrain Information Exchange Model) (FRANGOLLO A.P., ZERKOWITZ, E., 2006; STRICHT, S. V., 2008).

The D-AIM and SOA represent the basis for implementation of the concept called SWIM (System Wide Information Management) which is the operational concept to provide an open, flexible, modular, manageable, secure information management, and sharing architecture. This concept has been applied in USA and Europe airspace systems operational data together with the agreement and standards from ICAO (International Civil Aviation Organization). Its operational concept includes, but it is not limited to, aeronautical information, flight data, traffic flow management, surveillance, and weather information.

New technologies have been introduced in daily operations to enhance decision support for safety systems. Regarding feasibility and efficiency problems, some optimization methods for scheduling aircraft will be tested in landing and take-off processes, with generic scenarios from Frankfurt and Guarulhos International Airports, considering separation minima constraints.

4. THE MAIN EXCHANGE PROJECT ACTIVITIES

During this exchange project different activities are planed. This section describes the main activities organized in three categories: work packages; exchange travel schedule; and meetings and workshops.

4.1. WORK PACKAGES

On this on-going exchange project some activities are planed and described in different WP (Work Packages).

4.1.1. WP01 Project management

This work package shall perform the project management and controlling, and will generate contacts to different partners and decision makers from the ATM system.

4.1.2. WP02 Data analysis

Within each ATM concept the planning and controlling of air traffic is only possible by using data. It is essential to know all available data in the system. Data quality considering availability and accuracy has a fundamental influence to the quality of planning and controlling results. In WP02 available data have to be identified and characterized. Some results from this work package should be the description of: available data in the current ATM system; data requirements of the future cooperative ATM concept; identified possible data sources; the dataflow for the future cooperative ATM concept; and requirements and recommendations for adaptation and implementation.

4.1.3. WP03 Description of future cooperative ATM concept

In order to define the future cooperative ATM concept, some researches about the state of the art and a review of related projects have to be performed. For example, the following initiatives have to be considered: SESAR (from EUROCONTROL); CDM (from EUROCONTROL); and NexGen (from FAA) (SESAR, 2007; EUROCONTROL 2006; JPDO, 2007).

This project research team will collect and identify requirements from different partners and decision makers. They will perform some creative workshops to generate and define the basic ideas for future cooperative ATM concept. The proposed ideas shall be structured and evaluated by the different partners. Therefore, a future cooperative ATM concept shall be derived. Some results from this work package should be the presentation of main ideas of future cooperative ATM concept.

4.1.4. WP04 Generating requirements for the future cooperative ATM concept

Considering boundary conditions the research team will develop the data requirements for the future cooperative ATM concept. This data design and dataflow will be further described, together with new data sources, if needed. Some results from this work package should be the description of: data requirements for the future cooperative ATM concept; data sources and dataflow for the future cooperative ATM concept; additional processes or adaptation of existing ones; and recommendations to adapt the current system to the future cooperative ATM concept requirements.

4.1.5. WP05 Evaluation of expense for implementation and adaptation

Within this work package, feasibility and expense of changes will be evaluated. The requirements for adaptation and implementation for the future cooperative ATM concept will be described and communicated with the different partners. Some results of this work package should be the evaluation of feasibility and expense of adaptation and implementation.

4.1.6. WP06 Description of databases and interfaces

Within this work package, requirements for adaptation and implementation will be specified. A rough technical description of required interfaces, data delivering and data storage systems have to be created. Some results of this work package should be: rough technical concepts of interfaces, data sources, databases, and data processing systems; and recommendations for adaptation and implementation.

4.1.7.WP07 Evaluation of expanse of technical adaptation and implementation

Within this work package, feasibility and expanse of technical adaptation and implementation will be finally evaluated. Furthermore, requirements of adaptation and implementation will be concretized. Rough technical recommendations of required interfaces, data delivering and data storage systems have to be described. Some results of this work package should be: the evaluation of feasibility and expense of technical adaptation and implementation; and the technical recommendations.

4.2. Exchange Travel Schedule

On the years of 2008 and 2009, some exchanges of researchers are planned. One professor and two doctorate students from the German side, and three professors and two doctorate students from the Brazilian side will be involved. These researchers will travel to each other countries for workshops and meetings with different partners from their foreign ATM systems.

4.3. Meetings and Workshops

To collect all the required information from the different Brazilian ATM system partners and to coordinate a common view about the future cooperative ATM concept, some meetings and workshops are essential to be taken. Two of them already planed are: creative workshops about the future cooperative ATM concept; and meetings with different partner.

5. SOME MAIN EXCHANGE PROJECT BENEFITS

Regarding research objectives, some of the following main benefits are expected from this exchange project.

Both, Brazilian and German institutions will be up-to-date concerning current trends and technologies in the context of the future cooperative ATM concept. The adaptation and validation of this, considering the Brazilian environment and its particularities will be performed. The results can be used by public and private ATM partners in both countries to feed decision making processes concerning adoption needs and possible investments. Some contributions for the future cooperative ATM concept will support the global harmonization process. The collection of knowledge and experiences will enable Brazil and Germany to align different ATM concepts with current trends and perspectives which are currently investigated and evaluated in Europe and USA. Last but not least, the evaluation of results about the future cooperative ATM concept can be applied in the Brazilian environment to solve some of its capacity problems.

6. ACKNOWLEDGMENTS

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