C-ATM/BR: A COOPERATIVE ATM CONCEPT PRELIMINARY DEFINITION FOR THE BRAZILIAN ENVIRONMENT

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ABSTRACT
A world wide air traffic growth is expected for the future. Continuous increases of traffic demand faces limited infrastructural resources such as parking positions, airways, or runways. In general, the capacity extension of those resources is limited. New concepts under development in the Air Traffic Management (ATM) field represent a promising possibility to achieve optimal resources usage. This report provides a preliminary definition of some cooperative approaches of future ATM concept for the Brazilian environment, called C-ATM/BR, based on current R&D activities. It represents partial results of an already finished interchange project between the German Berlin Institute of Technology (TU-Berlin) and the Brazilian Aeronautics Institute of Technology (ITA). The approaches were described without considering specific requirements of the main involved stakeholders (e.g. Air Traffic Control - ATC, Airport, and Aircraft Operators) on the ATM processes. Activities and trends of future oriented international research programs like the Single European Sky ATM Research (SESAR) of EUROCONTROL and the Next Generation Air Transportation System (NextGen) of the Federal Aviation Administration (FAA) were examined. Also the Brazilian ATM Operational Conception and the transition program to the Communication, Navigation, and Surveillance / Air Traffic Management (CNS/ATM) system concept for the Brazilian Air Space Control System (SISCEAB) have represented important basis. To guide the description of the cooperative approaches, this preliminary definition considered the main three pillars of: advanced common situational awareness; decision making process support; and control measures implementation. These approaches are intended to help the Brazilian Air Transportation authorities to deal with and improve its Airspace Control.

Keywords: Situational Awareness, Decision Making Process, Cooperative Approaches, Air Traffic Management

1. INTRODUCTION
This report provides a preliminary definition of some cooperative approaches to support the development of a future ATM concept for the Brazilian environment, called C-ATM/BR (Meinerz et al., 2009). Such report represents a deliverable as part of the whole project entitled “Feasibility study on implementation and adaptation of a new cooperative ATM concept into the Brazilian ATM environment”. It comprised an already finished interchange project between TU-Berlin and ITA under the international cooperation program between Brazil and Germany (PROBRAL). This project was supported by the Brazilian Federal Agency for Support and Evaluation of Graduate
Education (CAPES) and the German Academic Exchange Service (DAAD) (Gerhold et al., 2008).

1.1. Objective
The main objective of this document is to describe cooperative approaches of a future ATM concept for the Brazilian environment based on current R&D activities.

1.2. Scope
The preliminary definition of the cooperative approaches are described without considering requirements of the specific involved stakeholders (e.g. ATC, Airport and Aircraft Operators) from the Brazilian environment.

Even though the development of system wide solutions, the quantitative evaluation with real data, and the implantation of system represent crucial issues, but they are beyond the scope of this report. However, the results can be used to support the development of system prototypes.

1.3. Expected Results
As a next step after this preliminary definition the main results expected to be achieved are: (a) Increasing the capacity of utilization; (b) Increasing the punctuality; (c) Identification of optimization potentials; and (d) Setting up the fundaments for applying the Collaborative Decision Making (CDM) concept.

2. RELATED R&D ACTIVITIES IN EUROPE AND USA
This section presents the main short and long term R&D activities accomplished and still under work in Europe and United States of America (USA).

2.1. Short Term R&D Activities
2.1.1. K-ATM
The Project “Kooperatives Air Traffic Management (K-ATM)” was part of a joint German Aviation Research Program III (LUFO III) supported by the German Federal Ministry of Economics and Technology (AT-One, 2007).

The main objective of this project was to develop a cooperative air traffic management concept supporting all involved stakeholders in a cooperative way, to increase the utilization of limited infrastructural resources (e.g. runways).

A further part of this project was the prototyping of a sequence optimization tool able to support different optimization problem (e.g. decrease delay, increase utilization, decrease holding times, and decrease environmental pollution).

2.1.2. Airport CDM
Airport CDM is an operational concept which aims to improve (EUROCONTROL, 2006): (a) The Air Traffic Flow and Capacity Management (ATFCM) at airports, by reducing delays; (b) The predictability of events; and (c) The optimization of resources utilization.

The Airport Operations Program (AOP), under European Air Traffic Management Program (EATMP), is responsible for the development of the Airport CDM Concept under the Airport Operations Team (AOT), and undertakes the promotion and supportability of the pan-European implementation (EUROCONTROL, 2006).
The Airport CDM Project has defined the Airport CDM Concept Elements and their relationships to guide CDM implementation at European airports, facilitating a phased approach to the development of all necessary requirements. This concept is divided into the following elements (EUROCONTROL, 2006): (a) Airport CDM Information Sharing; (b) CDM Turn-round Process – Milestones Approach; (c) Variable Taxi Time Calculation; (d) Collaborative Management of Flight Updates; (e) Collaborative Pre-departure Sequence; (f) CDM in Adverse Conditions; and (g) Advanced CDM.

2.2. **Long Term R&D Activities**

2.2.1. **Single European Sky ATM Research (SESAR)**

The SESAR is the EATMP. According to the primary reference for all future SESAR developments (SESAR, 2007), it aims to develop the new generation air traffic management system capable of ensuring the safety and fluidity of air transport over the next 30 years.

Its key objectives are: (a) To restructure European airspace as a function of air traffic flows; (b) To create additional capacity; and (c) To increase the overall efficiency of the air traffic management system.

It was defined by a representative group of ATM stakeholders with recognized expertise to ensure the decision making level. The SESAR program is organized in three phases: (a) Definition Phase (2005-2008); (b) Development Phase (2008-2013); and (c) Deployment Phase (2014-2020).

2.2.2. **Next Generation Air Transportation System (NextGen)**

The NextGen is the FAA plan to modernize the National Airspace System (NAS) in the 2025 timeframe and beyond (JPDO, 2007).

The Joint Planning and Developing Office (JPDO) is developing a Concept of Operation (ConOps) for the NextGen and its final version will provide an overall and integrated view of NextGen operations.

The three major goals for ATM in NextGen are (JPDO, 2007): (a) To meet diverse operational objectives for all airspace users and to accommodate a broader range of aircraft capabilities and performance characteristics; (b) To meet the needs of flight operators and other stakeholders for access, efficiency, and predictability in executing their operations; and (c) To be: safe, secure, of sufficient capacity, environmentally acceptable, and affordable for both flight operators and service providers.

3. **THE BRAZILIAN AIRSPACE CONTROL SCENARIO**

At the 10th Air Navigation Conference, on September 1991, in Montreal, CNS/ATM concept was approved by ICAO Council. Since then, several States started ATM implementation programs to improve their aviation operations by using CNS/ATM technologies. However, later, it was recognized that a comprehensive concept of an integrated and global ATM system based on clearly established operational requirements was needed. Thereby, the “Global Air Traffic Management Operational Concept” (ICAO, 2005) was created, intending to guide the implementation of CNS/ATM technology by providing a description of how the emerging and future ATM system should operate.
The Brazilian Flight Protection Service (SPV) has adopted a centralized ATC model where civilian and military air activities are under the same control system. According to Siewerdt (2008), this integrated civilian airspace together with military air defense control is considered as creative and efficient by international civil aviation agencies. Though, this compartmentalized model is not favorable to information exchanges and collaborative decision making processes.

According to DECEA (2008), an effective, coordinated, and gradual implementation for the Brazilian CNS/ATM transition is planned mainly by considering the characteristics of the Global ATM Operational Concept components (ICAO, 2005).

The transition aims the modernization of the SISCEAB. The following two documents were generated by the Brazilian Department of Airspace Control (DECEA) and represent the main references in this transition process:

- The Brazilian ATM Operational Conception (DECEA, 2008); and
- The Brazilian ATM Implementation Program (DECEA, 2009).

The transition also aims to assure the evolution from the compartmentalized model to an interoperable global ATM system, as shown in Figure 1.

![Figure 1: The Desired Brazilian Interoperable Global ATM System (DECEA, 2007)](image)

4. COOPERATIVE APPROACHES OF A FUTURE ATM CONCEPT FOR THE BRAZILIAN ENVIRONMENT

This Section presents some cooperative approaches of a future ATM concept for the Brazilian environment. These approaches are mainly based on the following main three pillars:

- The advanced common situational awareness which is essential to fulfill the main preconditions 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
- The implementation of control measures into the ATM system to influence the air traffic by different partners with the same purpose.

Considering the overall ATM control loop, shown in Figure 2, some approaches will cover its all sub-loops-management (i.e. Controller, Control Unit, Disturbance Value,
Adjustment Characteristics, and Measuring Unit). It might result in benefits for the Brazilian ATM environment. Notice, in this figure, the three pillars presented above also identified and highlighted.

![Figure 2: An Overall Control Loop for the ATM Process](image)

This preliminary definition of the cooperative ATM concept is described based on international research results, without considering yet suggestions and requirements from stakeholders.

### 4.1. The Advanced Common Situational Awareness

In the ATM processes it is essential to achieve a common situational awareness to predict future events, making full use of the responsibilities and procedures of all involved stakeholders. Therefore, enabling exchange and sharing accurate information is fundamental for a future cooperative ATM concept. Thereby, when all stakeholders have access to the more up-to-date information, they will have a global overview and hence improve their planning processes.

The scope of the potential information of interest to ATM operations includes, for instance, trajectories (flight plans), surveillance data, aeronautical information, and meteorological information, as well as sensitive civilian and military data.

Aiming to increase the situational awareness, some criteria of data quality and information sharing are presented and discussed in the following sections.

#### 4.1.1. Increasing Data Quality

The ATM community depends extensively on the provision of information to collaborate and make decisions.

The success of a future cooperative ATM Concept depends extensively on the provision of information by all involved stakeholders.

The quality of aeronautical information is a fundamental value to improve ATM processes. The reliability of ATM results depends on the accuracy, availability, and
reliability of input data. To improve the performance of ATM processes, the quality of input data has to be increased by using additional data from other stakeholders or increase the accuracy and availability of currently available data.

The availability of accurate data at the right time and in the right place to all stakeholders who need this information leads to improved predictability and consequently to the resource allocation.

In order to reach a higher data quality, some criteria must be assured: Availability; Accuracy; Reliability; Timeliness; Stability; Predictability; and Integrity.

In some cases, agreements may need to be signed among all stakeholders covering such data quality criteria. According to EUROCONTROL (2006), description of the business processes and policies that will be in effect to create and disseminate the required data also should be included in the agreement.

In order to measure the quality of the exchanging data among all stakeholders, a set of procedures should be put in place to routinely evaluate the data against a set of agreed criteria. The results can be made available to the stakeholders to enable them to make improvements as necessary.

**Standardization and harmonization of data formats**

To reach the global harmonization is essential to manipulate standardized data formats.

A higher operational standard for Aircraft Operators and ANSP is required to ensure the safest global air transportation system. ICAO Planning and Implementation Regional Groups (PIRG) or multilateral agreements coordinate planning and implementation of NextGen transformations to harmonize the application of technology and procedures. This harmonization allows airspace users to perform the maximum benefits of the NextGen transformations (JPDO, 2007).

According to EUROCONTROL (2008a), information standard format of the data is essential to avoid inconsistencies or data recognition problems. As different stakeholders have different formats, filters and converters should be specified and developed in order to interface different systems and avoid data problems.

In Europe, the Aeronautical Information Conceptual Model (AICM) and its analog eXtended Markup Language (XML), and the Aeronautical Information Exchange Model (AIXM) were developed by EUROCONTROL to enable aeronautical data standardization and exchange it among European states. AICM and AIXM organize aeronautical data into six data concept areas: Aerodromes, Airspace, Services, Fixes, Routes, and Procedures. Today, EUROCONTROL uses AICM and AIXM to create products such as the European Aeronautical Information Publication (e-AIP). With the recent adoption of AIXM by the USA, the AICM and the AIXM are on their way toward becoming a global standard for representing aeronautical data. Recently, the FAA's Air Traffic Airspace Laboratory has undertaken an effort to modernize the process used to build, validate, and publish the Temporary Flight Restrictions (TFR). An extension to AIXM, currently named xNOTAM, has been used as a standard for representing a TFR (EUROCONTROL, 2006).
Information Management

Information management provides accredited, quality-assured, and timely information used to support ATM operations. Information management will also monitor and control the quality of the shared information and provide information-sharing mechanisms that support the ATM community (ICAO, 2005).

The term Aeronautical Information Management (AIM) is applied to the globally interoperable provision of aeronautical data (Frangolho and Zerkowitz, 2006). That intends to provide the needed data quality, covering the requirements of present and future ATM system for all flight phases, in a data oriented and holistic approach. Its role is to monitor and check the quality of shared data and to provide mechanisms that support the ATM community in setting up and managing information sharing in a collective effort of all suppliers of data.

The AIM strategy was defined aiming to increase the interoperability among systems. It is based on the networking of various ATM databases, and intends to cover data of the following different management levels: (a) Strategic Planning, (b) Pre-Tactical Planning, (c) Tactical Planning, (d) Operational control, and (e) Post flight activities.

Update rate increases of required data

In some cases the availability of data is represented by the rate of update. To increase the availability of such data it is recommended to check possibilities to increase the update rate. Normally, it depends on technical performance of computing systems (e.g. computing performance).

According to ICAO (2005), an operational analysis represents a necessary part of ATM implementation planning. It culminates in the identification of operational requirements and the establishing criteria for rating alternatives. This leads to the selection of a solution which should be the most effective in fulfilling the ATM objectives, as defined in the operational concept.

In the NextGen project (JPDO, 2007), the update rate of weather information is aligned with the requirement to predict or detect rapidly changing boundary conditions. Infrastructural changes often depend on weather conditions (e.g. realigning sectors regarding a line of thunderstorms). The availability of weather information in the NextGen approach allows a rapid detection of changing weather situations by the decision makers of the strategic and tactical planning level.

Avoidance of data redundancy and integrity problems

Most of communications paths in use today typically provide a secure means of transmitting data. However, it is often not possible for the user to be able to always guarantee this situation. The application of Cyclic Redundancy Checks (CRC) provides a way where each user application may confirm the receipt or extraction of data without a loss of integrity. All data packets shall be individually protected, with a CRC value included as part of the transmission (EUROCONTROL, 2006).

According to ICAO (1944), existing integrity levels of requirements provide a baseline for acceptable data quality. To achieve the necessary levels of integrity, security, and validation, provisions will have to address the following three levels of requirements:
• Level 1 - In this level of requirement, data transfer should be conducted in a manner that ensures the risk of data error is sufficiently low as to enable the safe use of the data for flight operations. This will require, among others, appropriate automated data handling techniques that prevent data from being corrupted;
• Level 2 - Protection shall be employed for data transmission through the mail or using public data networks to prevent inadvertent or deliberate modification; and
• Level 3 - Data need to be validated for correctness, completeness, and to check the validity of information in data fields.

Generation of predictions
A view of the complete ATM network is necessary in order to identify bottlenecks and predicted air traffic based on aeronautical data (e.g. flight plans). Its efficiency depends largely on the quality of the traffic prediction, which is highly influenced by the quality of data. Its inaccuracy is a major source for uncertainty in the overall traffic prediction and this lack of predictability leads to inefficient uses of existing resources. Some further improvements to the flexibility of aircraft and airport operations can be reached by: (a) Ensuring information completeness between en route and airport operations; (b) Improving ground operations predictability; and (c) Improving estimates of take off times for all flights.

Better predicted situations will optimize all ATM operations. Some of interest predictions cover the following aspects: Weather information; Demand prediction; Capacity prediction; Punctuality prediction; Turn-round time prediction; Taxi time prediction; and Four-dimensional trajectories (4DTs).

4.1.2. Information Sharing
Information sharing on a system-wide data basis will allow the ATM community to manage the operational processes in a safer and more efficient manner.

Applications of CDM and information sharing represent two key elements for the future cooperative ATM concept.

Airport CDM defines Information Sharing as a logical and distributed data repository from and to the involved stakeholders (EUROCONTROL, 2008a). It will allow stakeholders to synchronize their activities by sharing experience, monitoring the coordination, communicating and providing feedback, and backup assistance when needed.

To the SESAR ATM Target Concept, information sharing of the required quality and timeliness in a secure environment is an essential enabler to the development of its concept (SESAR, 2007).

At the heart of the NextGen concept there is the information sharing component known as net-centric infrastructure services or net-centricity (JPDO, 2007).

Its features allow NextGen to adapt to growth in operations as well as shifts in demand, making NextGen a scalable system.

Net-centricity also provides the foundation for robust, efficient, secure, and timely transport of information to and from a broad community of users and individual subscribers.
The result is a system that minimizes duplication, achieves integration, and support distributed decision making by ensuring that all decision makers have exactly the same information at the same time.

SWIM is an information sharing concept supporting the Airport CDM requirements by using efficient end-user applications. Access and usage of shared information should follow predefined agreed procedures, as well as the protected of sensitive civilian and military data must be respected.

**Identification of data sources**

Most of the relevant information exists in various systems. Some of them are not available to all involved stakeholders. It is necessary to identify all the existing data delivering systems, to implement them into a future cooperative ATM Concept.

According to EUROCONTROL (2006), information sharing, considered as a data source or data destination, any organization or system may generate and/or use data pertinent to ATM decision making in the context of airport operations. Ground movement surveillance equipment can be cited as an example of data source.

To achieve a Common Situational Awareness (CSA), by facilitating the information exchange among various stakeholders, it will improve the decision making process and the efficiency of operations by using the best available information.

**4.2. The Decision Making Support**

According to EUROCONTROL (2006) and JPDO (2007), the main CDM objective is to increase airspace and control capacity to improve flight operations by increasing the involvement of aircraft operators in the ATM process, as well as maintaining a high level of safety efficiency. This is achieved by developing information management systems and procedures, and implementing functions, which take into account specific priorities of aircraft operators and airport operations, during all flying phases using full data available.

An alternative way to address these issues is to apply the CDM by using collaborative technologies and procedures to get benefits associated with both flight and strategic planning. In this case, the decision making by the stakeholders is facilitated by the sharing of accurate and timely information and by adapted procedures, mechanisms, and tools.

In the future cooperative ATM concept the human will be the most important and finally responsible decision maker. The human workload by using system wide information is limited. Therefore, the decision making process needs to be supported by a comprehensible presentation of data.

**4.2.1. Traffic Situation Visualization**

To observe the current and the expected traffic situation, all decision makers have to be supported by different visualization tools based on the same data. Due to the amount of information it is essential to aggregate some of the values by using suitably visualization items in order to reduce the workload of the users. In this case users and decision makers should have the opportunity to exponentialize all aggregated information in case of they require more detailed level.
The NextGen integrates cooperative and non-cooperative surveillance data and information along with aircraft intent information to create the most accurate view possible of the actual situation. All participants in the system have access to the essential surveillance information needed for the decisions or negotiations concerning their particular activities (JPDO, 2007).

As stated by SESAR (2007), the objective of the surveillance service is to provide a complete picture of the actual traffic situation to ensure a safe separation and efficient traffic flow.

4.2.2. Resources Use Optimization
The air traffic management processes should support an optimized use of limited resources (e.g. airports). The results of these processes should be permanently reflected in a common information sharing platform.

As stated by JPDO (2007), intelligent and improved resource optimization processes enable the efficient management in the enroute, arrival, turn around and departure phases. This offers more abilities to reduce environmental impact on the ground and in the air.

An optimization process, like a runway sequence optimization algorithm, can focus on different target values such as: (a) To maximize utilization of runway capacity; (b) To minimize the overall on-block-delay; (c) To minimize the overall off-block-delay (d) To minimize the holding/transition time of approaches; (e) To minimize the environmental impact; or (f) To minimize fuel consumption. The application of a weighting function allows using a mixture of different target values to generate an optimization result. However, during the optimization process some boundary conditions have to be considered among others: (a) Separation minima; (b) Aircraft performance limits; and (c) Infrastructural constraints.

4.2.3. Advanced Decision Support Tools
The migration from the present system to more advanced ATM systems is based on technologies that should be carefully planned. Assurance is needed at each step on which continued levels of safety will be maintained and improved upon where necessary (ICAO, 2005).

New technologies have been introduced in daily operations to enhance decision support for safety systems. Some examples are advanced ATC tools from Europe like Arrival Manager (AMAN), Departure Manager (DMAN), and Advanced Surface Movement Guidance and Control System (A-SMGCS). In this case, according to EUROCONTROL (2008a), they cooperate with the Airport CDM concept by sharing and optimizing information about arrivals, departures, and ground movement. The integration by using advanced technologies will enhance and extend CSA and increase collaboration between airport stakeholders.

According to SESAR (2007), from the safety performance improvement point of view, the major contribution will come from better planning, increased situational awareness, and automated tools by detecting all aircraft interactions at a far earlier stage than current methods allow. In order to show evidence of these expected safety benefits, the potential risk contributions need to be identified by continuous appropriate screening for
any safety issues during the development and deployment of the ATM Target Concept and by developing appropriate safety assessment methodologies and procedures.

4.3. Control Measures
The results of Decision Making Processes are represented by different control values. These control values are used as a target value. Different control measures can be applied to reach the defined target. In a cooperative ATM concept it is required to identify all currently used control measures, which influence the operational and the ATM processes. Additionally, it is possible to implement new advanced control measures (e.g. new procedures like Continuous Descent Approach - CDA) to support the future cooperative ATM.

As already known, a CDM environment allows all stakeholders of the ATM community to participate in the ATM decision making process achieving an acceptable solution that takes into account the needs of those involved. In this case, the ANSP are responsible for resolving competing demands for an ATM resource and to organize a safe sharing of that resource among the requesters.

Some of the control measures, based on previously agreed procedures, are described as follows: (a) Insertion of ground delays on departure airport; (b) In flight acceleration or deceleration; (c) Prioritization between departures and arrivals; (d) Reallocation of infrastructural resources (e.g. rerouting, runway-change, position-change, ground handling processes); (e) Adaptation of descent profile (e.g. CDA); and (f) Reallocation of personal resources (e.g. loading of baggage).

4.3.1. Continuous Descent Approach (CDA)
The CDA is an advanced operating procedure for arriving aircrafts. Much of positive effects can be recognized by using this procedure by reducing noise pollution and fuel burn. In contrast to a conventional approach with a CDA procedure, the aircraft stays higher for longer and descend continuously from the top to the bottom level by avoiding level segmentations.

According to EUROCONTROL (2008b) the proportion of aircraft achieving CDA will depend on local traffic conditions and local airspace characteristics, although a good success rate may be achieved in high traffic density situations.

The ICAO Working Arrangements are in the process of assessing CDA on a global scale and may also produce CDA guidance. However, the basic CDA techniques described which have been harmonized on a European basis, are not expected to change substantially (EUROCONTROL, 2008b).

5. CONCLUSION
The focus of this report is a preliminary definition of some cooperative approaches for the future ATM concept in the Brazilian environment. These approaches are resulting from an exchange project between researchers of ITA and TU-Berlin supported by CAPES and DAAD.

The description was based on current short and long term R&D activities in Europe and USA, taking into account their bad and mainly good experiences, as well as their past experiences, without considering however suggestions and requirements from the main involved stakeholders.
This research work presented a short view about the Brazilian airspace control scenario status and its intentional transition process. To guide description of the cooperative approaches, this preliminary definition was based on the main three pillars of: the advanced situational awareness; the support of decision making process; and the implementation of control measures.

Although on its initial phase, this work is aligned with the objectives of the Brazilian ATM Operational Conception and the transition program to the CNS/ATM system concept for the SISCEAB. It is trying to help on the development of a National ATM Operational Concept applicable to the Brazilian airspace.

As a next step, it is recommended: to identify new requirements from specific stakeholders of the Brazilian environment; and to adapt its approaches. The authors believe that much future potentials are possible to be aggregated to this environment depending on the insights gained from the evolution of these approaches.

This work is intended only to support the definition of future operating and management processes, procedures, and tools for the Brazilian ATM environment.

6. REFERENCES


