TOTAL AIRPORT MANAGEMENT AS THE ENABLER FOR SESAR COLLABORATIVE AIRPORT PLANNING

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Abstract

The Single European Sky ATM Research (SESAR) initiative aims to design and validate a future operational concept which enables all categories of airspace users to conduct their operations with minimum restrictions and maximum flexibility while meeting or exceeding a number of key performance targets.

The SESAR initiative must also take into account the global nature of air transport and therefore be compatible, notably from a technology perspective, with similar initiatives such as NEXTGEN in the United States.

The SESAR operational concept [8] is a trajectory based system (business trajectory) with the trajectory being sourced by the airspace user and executed in so far as possible according to the user requirements. At each stage of the planning and execution phases of a flight, the trajectory information will be shared between relevant actors via a System Wide Information Management (SWIM) network. The Network Operational Plan (NOP) will ensure a flexible and continuous balancing of capacity and demand through dynamic airspace management in order to adapt available resources to the required demand.

At the heart of the airport elements of the SESAR concept is an evolution toward a more collaborative, performance based process of airport planning. In particular, SESAR calls for the identification and definition of those processes necessary for ensuring common planning, common situational awareness and a common performance framework for airport operations planning. In parallel the necessary decision support tools and procedures in support of these processes are required to be developed.

The future SESAR Collaborative Airport Planning (CAP) approach will build on the Airport Collaborative Decision Making (A-CDM) [4] framework which is currently being implemented at a number of major European airports. A-CDM enables collaborative work between all airport partners through the sharing of relevant information notably relating to aircraft turnaround milestones. The sharing of airborne flight progress information and departure planning information between the network and CDM equipped airports ensures a more accurate planning of network and airport resources due to timely and more accurate information. During implementation trails it has been found that an environment which ensures the availability of accurate data at the right time in the right place to airport partners who needs this information leads to improved predictability and thereby to improved resource allocation.

Nevertheless, despite the improved data sharing, there still remains today the reality that operational decisions within an airport are implemented in such a way that the "solution" is limited to maximizing the immediate interests of those making the decision. The aim of Total Airport Management (TAM) is to create an environment where operational decisions taken by any principal airport actor may be made in the full knowledge of the operational constraints and/or priorities of other actors who may be impacted by the decision. The management of degraded situations will be improved, coupled with a faster recovery to normal operations. The decision making process in this environment will be centered around an agreed performance framework as prescribed by SESAR.

1. Total Airport Management (TAM)

As a first step in the development of the future Total Airport Management concept, the German Aerospace Center (DLR) and the EUROCONTROL Experimental Center (EEC) have developed, as a joint initiative, the "Total Airport Management – Operational Concept Document" (TAM-OCD) [1], which is fully in line with the SESAR Operational Concept and will be further addressed within SESAR WP6.

TAM considers the airport holistically as one single node of the overall Air Transport Network (ATN, see Fig. 1). In order to ensure an overall Quality of Service (QoS) of an airport to the customers and to the air transport network, TAM concentrates on the initial medium and short term planning phases, using the most accurate information available, followed by monitoring, problem diagnosis and, when required, reactive (re-)planning of airport operational resources and/or procedures.

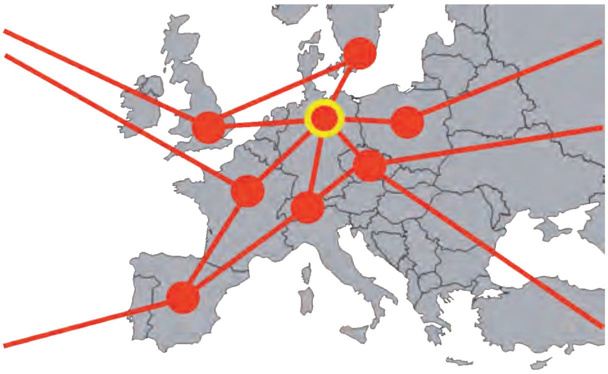

Fig. 1: A schematic view of the ATN in Europe

In summary, the TAM objectives are:

- More dynamic and responsive ways to incorporate priorities of customers – the airspace users.
- Fair and transparent means of handling competing interests at one airport.
- Performance-based airport operations in order to enable a performance-based Air Traffic Management (ATM) system.
- Improved predictability of the behavior of the system “airport” within the ATN.
- Harmonization of different airports’ performances by measuring with a common set of performance indicators.
- Offer solutions to handle degraded situations in the most appropriate way to ensure that the QoS is fulfilled as far as possible.

The central principle of TAM is to create an environment enabling airport partners to develop and maintain a joint plan, the Airport Operations Plan (AOP), thus working towards dynamically agreed goals in order to most optimally utilize the airport’s resources and additionally to get the full CDM benefits (for example efficiency, punctuality, reduced cost and robust schedules).

1.1 Scope of TAM

The execution phase of decisions is not part of TAM, although the interconnection between the phases is very important as each other potentially can induce changes to the other. Due to time and competency enforcements, decisions at the execution phase are and will be made in the existing Operation Centers, but the outcome of these decisions have to be taken into account in TAM. The extension of TAM is limited to one single airport but with influence on other airports, and the whole ATM.

The SESAR Operational Concept states clearly that airport operations during the medium/short term planning phase will be built upon the framework of Collaborative Decision Making (CDM) but with further enhancements in terms of more intensive data sharing (SWIM) and performance based airport management (Total Airport Management) through the direct participation of key airport stakeholders. Therefore TAM focuses in the temporal scope on the medium/short term planning (Fig. 2). Long term planning is not part of TAM, but the analysis from data recording in an Airport Operation Centre (APOC) might be a valuable basis to decide on long term adjustments and modifications.

The spatial scope of TAM is the entire airport, monitoring and guiding airside and landside operations while taking into account additional information available through System Wide Information Management (for example from departure airports). C-ATM [5] details this approach even further.

1.2 Methodological Approach

The foundation of TAM is to operate the Airport

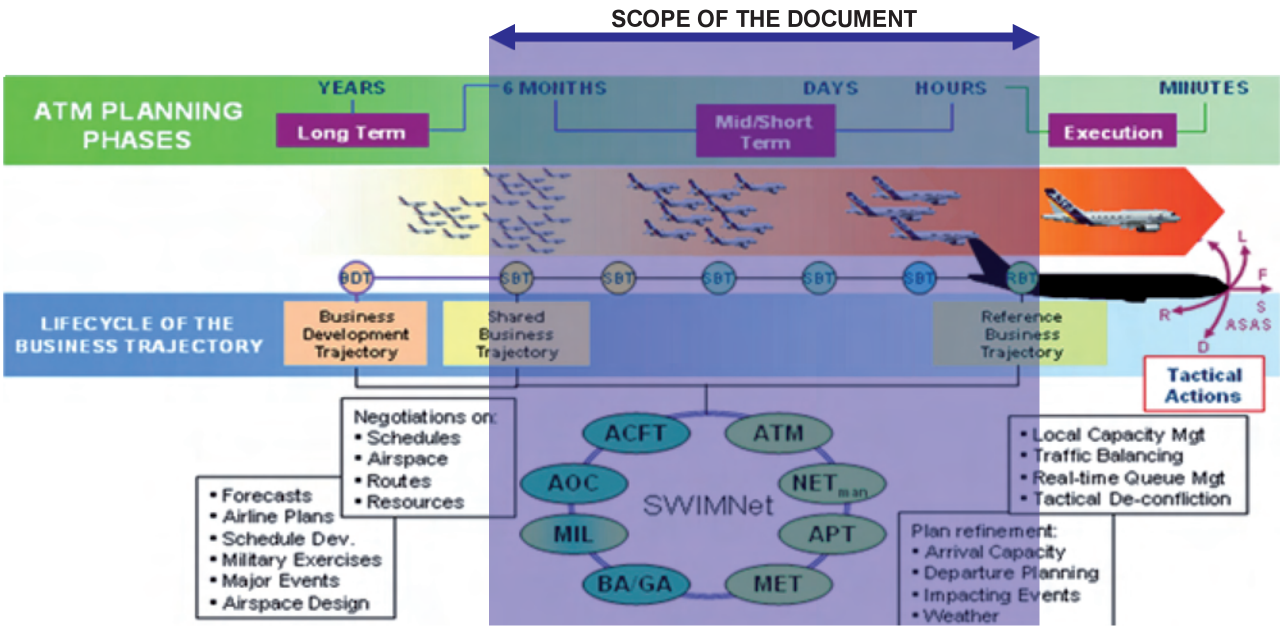

Fig. 2: Scope of the document as part of Collaborative Layered Planning

based on identified management cycles using Command, Control, Communication, Computer and Intelligence (C^4I) Principles, ensuring all partners (airport stakeholders) are working efficiently towards agreed common goals [3]. The identified management cycles (here called levels) are:

- Performance level: The stakeholders agree on a Quality of Service level (QoS level), a commonly agreed set of performance parameters that shall be ensured towards the customer and the network.
- Flow level: Based upon the QoS level (the performance parameter setting) the demand is adjusted by the stakeholders to cope with the predicted resource capacity.
- Event level: The flight events are then adjusted according to the demand by the Operation Centers.

This top-down, layered, hierarchical guidance and leadership within the Airport leads to Performance Based Airport Operations enabling Performance Based ATM. The objective is to have a **pro-active** instead of a re-active management leading to predictable and reliable schedules.

1.3 Human Centered Design

In the TAM concept the main focus can be located in the design of the common decision making processes of actors from different airport stakeholders. Based on the stakeholder interests potential conflicts and diverging goals should be identified and concepts for conflict solution should be found.

The definition of the human role in TAM and the resultant interaction of actors is a theme for the collaborative decision making process. The creation of TAM will permit the generation of a global information picture (for this airport) derived from a number of local information sources (from each stakeholder). Aspects are the integration of local information into a global picture or the kind of negotiation between human actors of different organizations with respect to their different goals and intents. The expected benefits of co-operative working and decision processes in TAM are:

- possibility of verbal communication and discussion,
- representation of information by means of common used displays,
- common computer aided simulations,
- transmission of planning orders, action proposals or action instructions,
- better negotiation and solution of conflicts and communication of interests.

2. Extension of the TAM-OCD

To further develop and to validate the TAM concept, DLR is carrying out an internal project called FAMOUS (Future Airport Management Operation Utility System) addressing the implementation, test and validation of a complete prototypical APOC in the DLR Airport Simulator facilities in Braunschweig, Germany. For this objective the TAM-OCD had to be extended by the FAMOUS-OK (Operational Concept) [2], which includes further operational details. It is planned to incorporate these extensions into the TAM-OCD, which will be further developed by DLR and EEC during the year 2009.

2.1 Scope of the FAMOUS project

While the spatial scope of FAMOUS still comprises of the whole airport, covering air- and landside activities, the temporal scope focuses on the pre-tactical phase (the next 24 hours up to the next seven days with the main

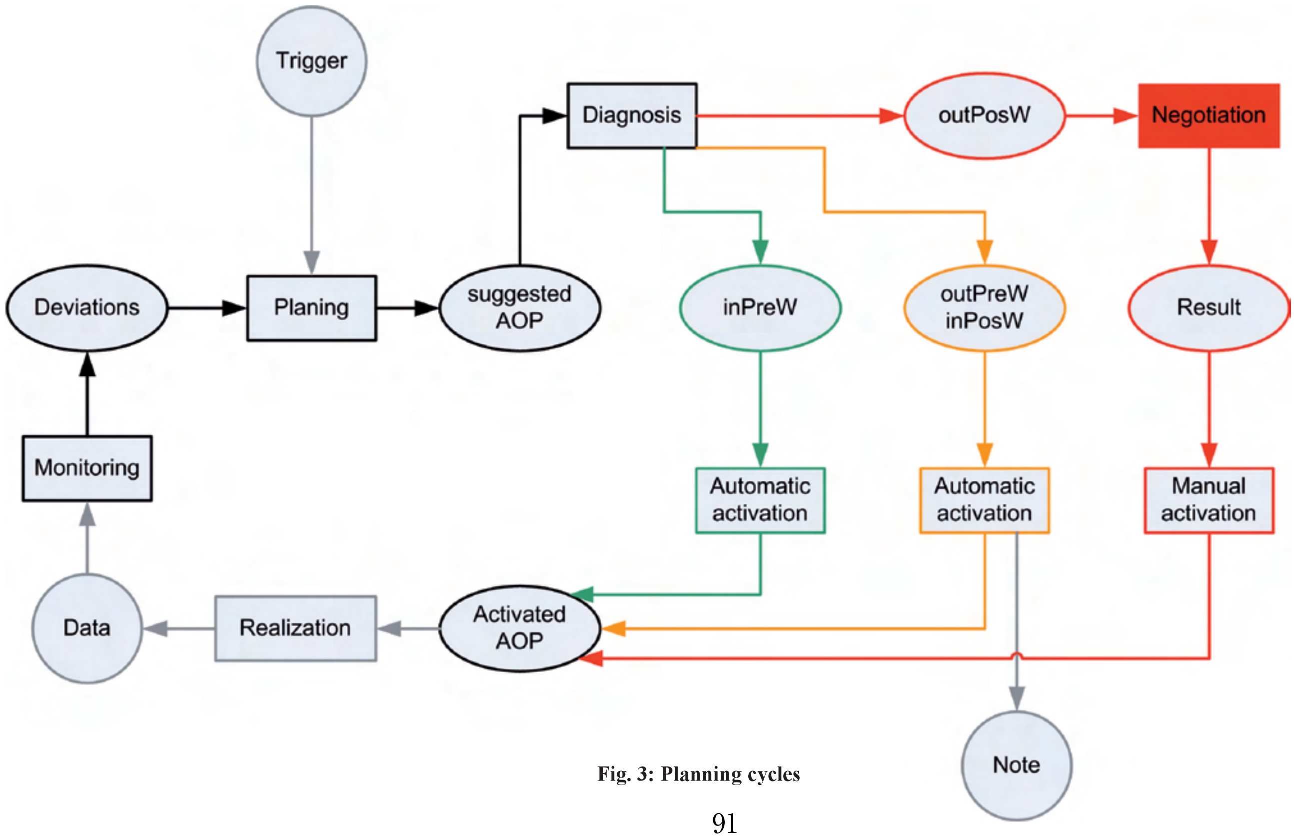

Fig. 3: Planning cycles

focus on the day of operations within the next 24h). The strongest argument for this is the reliability and precision of the currently existing weather forecasts and the availability of estimated times concerning a flight.

2.2 The Planning Cycles

The FAMOUS-OK envisions three different planning cycles (Fig. 3), depending upon the adherence to the preferences of the stakeholders, from fully automated up to collaborative decision making (always possible). The automated overall planning of the Airport Operations Plan is achieved by the Total Operations Planer (TOP) planning and support tool. Fairness and mitigation of conflicting interests is ensured through an evaluation system.

As it is not feasible for any stakeholder agent to keep a detailed track of any process and its variation for the next 24h, certain assumptions are established. An agent defines certain levels (allowed variation, for example of any process or duration). The preference window (PreW) borders around the estimated time of the event itself and indicates the variation for this process still acceptable by the agent. Bordering around the preference window is defined the possibility window (PosW) which indicates the possible variation for a given process. In direct comparison the PosW defines the possible and from the possible the agent defines what he prefers with the PreW.

If the event is planned to be within the defined preference windows (inPreW) an automatic activation of the AOP is done by TOP. Are some or all of the preference windows violated (outPreW), but the overall planning still adheres to the possibility windows (inPosW), an automatic activation, together with a notification to the agents in the APOC takes place. Is a predefined amount of the possibility windows violated, a collaborative decision making process has to take place. In this case the AOP is negotiated between the agents and then activated manually.

2.3 Human Centered Approach

Despite a high level of automation the system design still follows a human centered approach. Representatives (agents) from Aircraft Operators, the Airport Authority, the Air Navigation Service Provider (ANSP), the Air Traffic Flow and Capacity Management (ATFCM, CFMU successor) and Ground Handling Agents are integrated in the APOC. Their duty is to maintain the AOP, which is a joint and collaborative airport partner plan of TAM, an enroute-to-enroute conversion of the Network Operational Plan (NOP see [5]), enriched by airport specific data. An independent moderator assists in the negotiation process and ensures that the overall performance of the airport is in line with commonly agreed objectives (Quality of Service Levels).

Each agent in the APOC has its own TOP-Client for separate and joined what-if probing (to explore "**what** happens **if** I do this…" scenarios). The TOP-Clients are connected to the corresponding Operation Centers for fast communication and decision making process. All clients have a common view upon the data and the relevant data together with the outstanding tasks (the topics that have to be negotiation within the APOC) is displayed on a big video screen, termed powerwall, for ensuring a common situational awareness among all agents.

FAMOUS focuses on a centralized APOC. Depending on the size of the airport, decentralized APOCs may be feasible as well.

2.4 Collaborative Decision Making (CDM)

Heart of the FAMOUS-OK is the description of the collaborative decision making process. As stated in "Airport CDM Implementation – The Manual" [4]:

"Airport-CDM allows an Airport CDM Partner to make the right decision in collaboration with other Airport CDM partners, knowing their preferences and constrains and the actual and predicted situation."

To enable the agents of the Airport CDM Partners to make the right decision in collaboration with the other agents in the APOC, use cases of typical discussion and negotiation situations were developed in the FAMOUS-OK. These use cases are well defined workflows for decision making processes to ensure that on the one hand collaboration between the partners is possible and will be enhanced in an APOC and that on the other hand no CDM process has a dead end. Especially when there are two or more decision makers involved in a CDM process it can be difficult to obtain a solution due to the diverging goals the different stakeholder may have.

To encourage the decision makers towards a higher degree of collaboration concerning the overall performance of an airport, an evaluation system for decisions is applied. Each partner who accepts a disadvantage and implements this in order to enhance the overall performance of the airport, approaching the fulfilment of the QoS level, obtains a bonus that can be used to take an advantage in an upcoming decision. This evaluation system ensures fairness and transparency in the collaborative decision making process.

For evaluation purposes the FAMOUS-OK first focuses on a selected number of different use cases, three of them having more than one decision maker. The most important use case is "Set Quality of Service Level", where the agents in the APOC decide about the QoS level that will be the basis for further planning and adherence checks of airport operations.

3. Technical Realisation – Implementation

Within the FAMOUS project several aspects led to the categorisation of the required systems, support tools and participating actors into four categories (Fig.4):

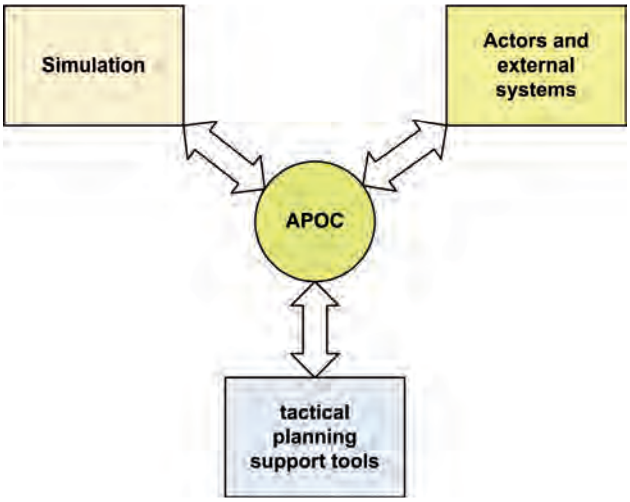

Fig. 4: Support Tool Categories

„APOC", „simulation", „tactical planning support tools" and „actors and external systems".

While APOC support tools will be centralized within the APOC, other support tools in general are not. These are distributed among the participating stakeholders in their back-office environment.

Data from tactical planning support tools (for example arrival or departure management systems A/DMAN) poses an important input into the APOC. It is a tactical planning constraint for APOC pre-tactical planning and is used for the required performance analysis.

Among the differences between "external systems" and "tactical planning support systems" are the planning horizons of the tools (with the tactical tools only looking ahead in time up to about one hour) and the availability of these tools within the FAMOUS project. Strong interaction between the agents and these systems is expected when solving the challenges of AOP creation.

The APOC agents are not directly interacting with the tactical planning support tools; while on the other hand, an addition to an agent's APOC working position surely will feature a direct interface to his employer's external back-office system, embedded into the TOP client system.

Generally it is assumed that all airport systems interface over the central airport database, following the airport SWIM principles. While the integration of the tactical planning support tools is an important aspect of the FAMOUS project, external systems are not further focussed.

The split of systems into the „simulation" category came naturally as the group of these systems represent the drivers to emulate reality for the APOC as well as the tactical tools. The realisation of the simulation will be described in chapter 4 in more detail.

A first stand-alone negotiation demonstrator offering a subset of APOC services has been developed in close cooperation between the EEC and DLR [6]. This demonstrator enables APOC agents to negotiate the airport's AOP performance levels (define the Airport QoSL) and allows first scenario war-gaming exercises. Among the main objectives of the demonstrator tool is to offer a way of obtaining an increased awareness of how various stakeholder actions will affect the airport's performance.

3.1 APOC

Key target of the APOC is the creation and maintenance of the performance driven AOP by the agents in consideration of the QoS level contracts with the overall Air Traffic Network. Further, the APOC agents are responsible to initiate necessary steps to ensure the stakeholder's compliance with the AOP objectives.

APOC tools have to support the agents and offer solutions for them to fulfil these tasks. These tools have to offer services for planning (TOP in conjunction with TOP clients), as well as monitoring and analysis of compliance of operations to the AOP targets. Conformance monitoring and analysis services are obtained by the Total Airport Performance Assessment System (TAPAS) tool that is supported by the TOP clients' functionality of scenario gaming (what-if probing and analysis). The simplified technical system architecture is depicted in Fig. .

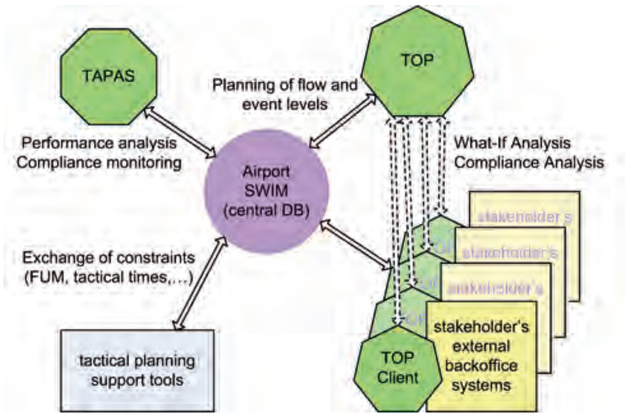

Fig. 5: Simplified system architecture

To ensure a consistent situational awareness of the current and the predicted airport's performance inside the APOC, available data is evaluated and visualised by these central APOC tools. This data is supplemented by access to restricted internal data and made available to the stakeholder's agent through the stakeholder's TOP client external system interface.

Information important to all APOC agents will be displayed in a consistent manner on the APOC powerwall.

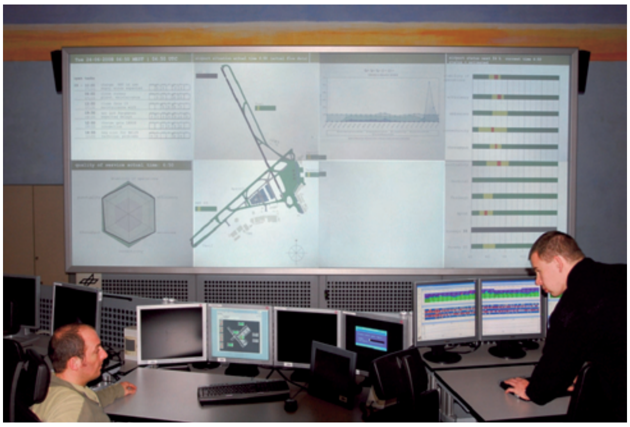

Fig. 6: Design Study of Powerwall HMI

The moderator is responsible for ensuring that the relevant information is presented (see Fig. for a design study of a powerwall HMI).

Although the tactical planning and support tools are important within the TAM context, these are not further focussed. Industrial systems such as AMAN or DMAN are well established and documentation about these is spread widely. On the other hand, the concept of an APOC and its support tools is rather new.

3.2 TOP

Primary target of TOP is to offer planning and negotiation support services for the three levels of planning mentioned earlier in the first chapter.

The performance targets negotiated between the APOC agents and the Air Traffic Network will be used by TOP as soft optimisation targets and by TAPAS as a boundary for compliance monitoring.

Based on flight plans, resource capacity predictions and existing constraints, TOP will create an optimized traffic flow plan. These flow targets are fed back into the tactical systems to steer these into the direction necessary to cope with the medium term targets specified in the AOP.

Taking further into account information about the flight's connectivity, predicted turnaround duration, dependencies to other flights, slot allocation and other constraints, TOP creates a sophisticated event level plan for each individual flight.

If all preference windows are met (inPreW), this plan will be established as the new AOP and transmitted into the Air Traffic Network. If any compliance fails, negotiation about finding a suitable solution acceptable to all stakeholders is established within the APOC, as defined in chapter 2.2.

3.3 TOP-Clients

The TOP client systems are operated by the APOC agents. Not only offer these clients the possibility of obtaining a more detailed view on the current and predicted situation of the airport, these are as well used to participate in negotiation procedures initiated for AOP creation.

Further, the client systems allow each individual agent to create personal scenarios and probe these with what-if analyses. The results, after TOP calculated the potential outcome of the given scenario, can be used to propose modifications to the AOP more suitable to the proposing agent, possibly initiating new APOC negotiation tasks.

If TAPAS predicts compliance violations, the TOP client systems can be used for detailed analysis of the reasons and to probe for possible modifications that have to be established to comply with the performance levels specified by the AOP.

Since stakeholders do not necessarily share all of their private business data with the SWIM database, access to this data will be integrated into each agent's individual TOP client variant. This is believed to be necessary to enable the agent to solve the complex scenario and what-if analyses and to prevent competing stakeholders (in the case of multiple airlines participating in the APOC) of obtaining too much insight into the business of competitors.

3.4 TAPAS

TAPAS monitors the performance of the airport by analysing and aggregating data available in the airport SWIM database. The Key Performance Indicators (SESAR KPIs) and airport specific metrics are derived and stored in the database for further utilisation by APOC components.

Based on the committed performance contracts in the AOP with the Air Traffic Network, TAPAS monitors compliance to the defined preference and possibility control windows and alerts the APOC agents of any violations (see Fig. 7 for a QoSL compliance prediction by TAPAS shown in a TOP client; green indicates compliance, yellow and red indicate violations over the day of operations time horizon). Depending on the severity of the alert, further actions may have to be taken by the APOC agents.

4. Simulation Environment

Looking at the airport operations as a whole requires also simulating the airport as a whole, including airborne and ground traffic, turnaround processes, even passenger and baggage movements as well as interfacing with tactical (XMANs) and pretactical planning tools like TOP. Such a simulation is currently being built up mainly

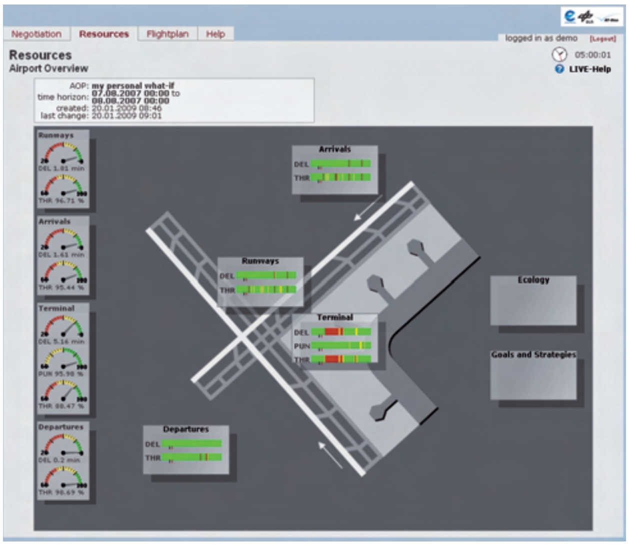

Fig.7: TOP Client Airport Overview sample page

from existing components at DLR. This simulation environment can also be used in the validation of SESAR concepts.

4.1 Requirements

The main requirements for the total airport simulation are:

- Flexibility and Scalability,
- Consistency of data,
- Easy to maintain,
- Real-time and (to some degree) fast-time capability,
- Central simulation control (system time, start-stop-pause),
- Central logging and debugging capability.

The TAM simulation environment is based on a modular concept which clusters several simulation components and allows adaptation to specific experimental needs (for example switching between automatic and Human-in-the-loop simulations). The central component of the simulation is the simulation datapool, which provides data connections between all modules as well as central control, logging and debug mechanisms. This datapool is an in-house development of DLR. It provides data transport by a subscriber mechanism, meaning that simulation modules do not need to query the datapool for new information but get updated data automatically. In the proposed setup all simulation modules communicate exclusively via this datapool, point to point connections are not allowed. The connection to the central airport SWIM database, which is used by the airport operations planning processes in various projects, is done via a single interface point. The only data sent and received via this interface are data that are also available in the real world.

Tactical tools are not really considered part of the simulation, but must be integrated closely with the simulation environment, depending on the mode of operation. In normal operations tactical tools would require a human operator and interface with the real world (for example to an aircraft by voice communication). This mode of operation can also be done in simulations, for example with radar or tower simulators with real controllers and pseudo pilots. For total airport management research it is envisioned that the tactical level will run automatically, so fully automatic simulations can be used. This requires however that the tactical tools can directly control the aircraft in the simulations.

The general layout of the overall simulation is shown in Fig. 8. All simulation modules as well as the central simulation control are connected directly to the datapool. Tactical tools are connected to the central airport SWIM database, which is also the database used by the airport operations planning processes. The tactical tools have an additional optional connection to the simulation datapool, which handles the direct control of aircraft when human operators are not involved at the tactical level.

For the current TAM projects the following simulation models will be included in the setup:

- The ATFCM (Air Transport Capacity and Flow Management) module will not really simulate the ATFCM, but provide an interface such that the behaviour of the ATFCM as experienced by the airport operators can be mimicked. This module will initialise the Network Operations Plan for the day of operation, respond to slot requests, etc.
- Airborne traffic: Two simulations are available for airborne traffic, NARSIM (National Airspace and Radar Simulator, NLR) for piloted simulations and TRAFSIM (Traffic Simulator, DLR) for fully automatic traffic. For TAM mainly TRAFSIM will be used, which simulates any number of 4D-capable aircraft.
- Taxiing Traffic: Again two simulations are available, ATS (Advanced Tower Simulator, UFA) for piloted simulations and ASGARD (Autonomous Simulation of Ground Movements, ARrival and Departure, DLR) for autonomous traffic. For TAM mainly ASGARD will be used, which provides automatic taxi route planning and simulates the taxi movements accordingly.
- Turnaround simulation: The turnaround process is modelled using an event-based framework with an underlying resource model.
- Passenger simulation: Here the DLR development TOMICS (Traffic Oriented Microscopic Simulator) will be adapted to the simulation framework. TOMICS provides a microscopic passenger simulation including features such as modelling security checks, queues and check-in.

In order to deal with the problem of data consistency it is planned to develop a common database for the configuration data of all simulation modules. This database along with the required converters to the module

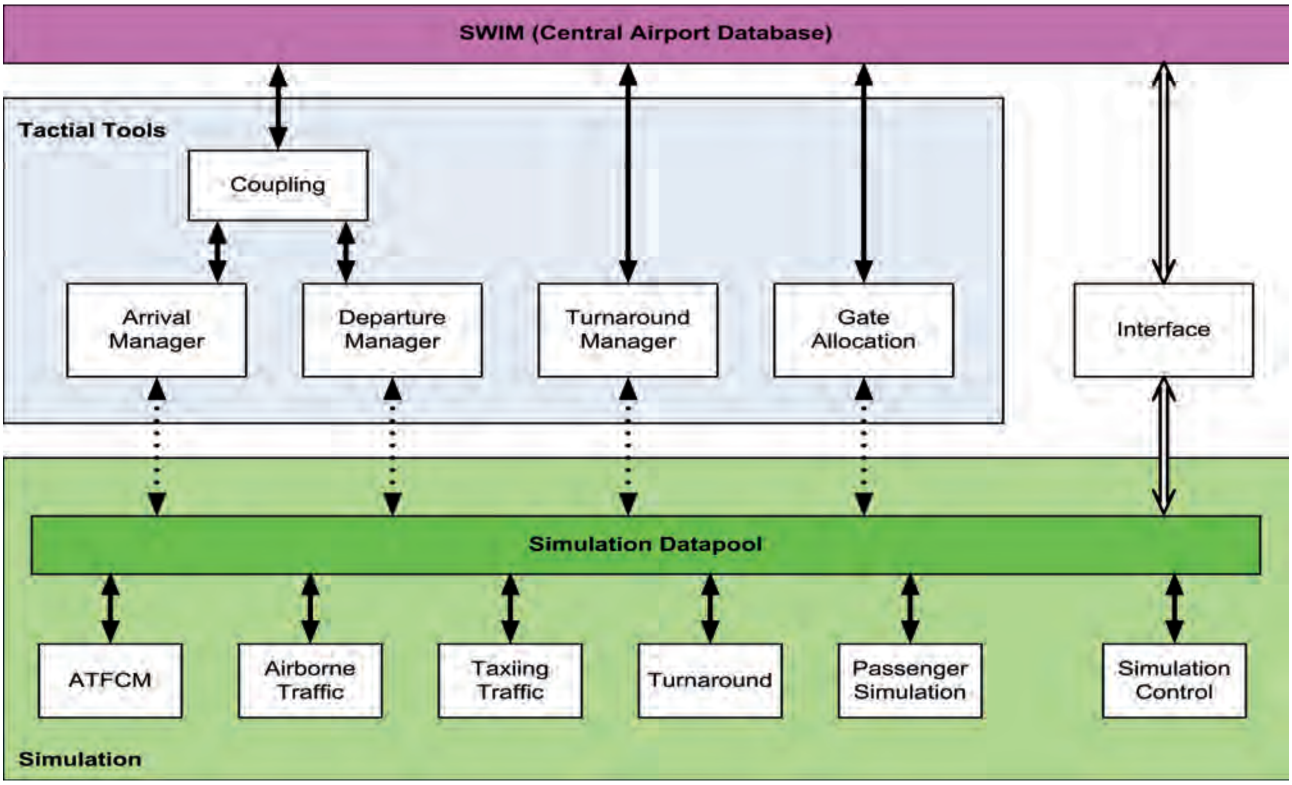

Fig. 8: General layout of Total Airport Simulation

specific formats will however be developed in a later phase.

5. Summary and Conclusions

To cope with the demand of consistently growing air traffic, new concepts have been developed and are further enhanced. These have to be subjected by validation within the near future. Steps towards the implementation, simulation and validation will be taken by SESAR.

A first step is taken by EEC and DLR with the performance display and negotiation demonstrator tool that is to be employed in EPISODE-3 trials in April 2009.

Further steps are taken by the FAMOUS project that will evaluate the advantages of TAM implementation by installation of a full scale APOC within a simulation environment. This article gave a brief description of the work objectives that will be continuously explored until the end of 2010.

With the beginning of 2009 the German industry has under the funding of the Ministry of Economics and Technology under the leadership of SIEMENS initiated the first TAM industrialization project TAMS (Total Airport Management Suite) where DLR will play a major role in further conceptual development and long term research aspects as well as the integration of airside processes into the landside aspects of a TAM.

Open issues left by FAMOUS consist of the relatively small number of use cases addressed and to be validated within the project. These use cases are crucial to demonstrate the advantages of a TAM APOC. The selected use cases reflect those APOC actions that are considered the most important and most often occurring ones suitable for evaluation purposes.

In following projects that extend work on this important aspect of TAM, evaluation of a greater number of use cases should be considered, most preferably those use cases stated and identified in the SESAR DOD [7].

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