RAPID PROTOTYPING FOR ATM OPERATIONAL CONCEPT DEVELOPMENT

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Abstract

Technical systems tend to undergo changes and thus will sooner or later require adjustments to new requirements or conditions. Currently, major changes in Air Traffic Management (ATM) are on the way, as ATM modernizations programs like SESAR or NextGen are getting momentum. ATM systems are rather complex and pose high demands on safety. Besides safety, other performance parameters like efficiency or environmental and climate impact have to be taken into account. Here, simulations can help to evaluate advantages of new developments or ideas, without jeopardizing the safety of others. New ATM concepts will be introduced on a global level, and early validation with huge traffic scenarios will become more and more important. Similar to the software development domain, tools and ideas of rapid prototyping can be used already in the concept development phase. DLR's Institute of Flight Guidance provides a generic simulation environment suitable as a proof-of-concept simulation for air/ground integrated ATM-concepts and trajectory-based operations. Core of the simulation environment is an air traffic simulation software called TrafficSim, which in detail is capable to simulate realistic aircraft movements and handle high traffic scenarios with more than 30,000 aircraft in real- and fast-time. All aircraft of a scenario can be individually equipped with a subset of modern airborne capabilities: 4D FMS, conflict detection, self separation and interval management functions as well as data link facilities for air-to-air and air-to-ground communication. On the ground side arrival and departure manager, conflict detection and avoidance tools can be integrated and negotiate 4D trajectories with the onboard tools. To customize the simulation environment quickly and easily to project specific requirements, a system architecture with standardized interfaces and central communication module is used. This paper describes the operation area of the basic tools of the simulation environment and how projects can use these tools for rapid prototyping to validate new ATM concepts.

Air traffic simulation; 4D Trajectory; Concept validation; Large traffic scenarios

1. INTRODUCTION

Changes in ATM are on their way. To handle future traffic like forecasted in EUROCONTROL's Long-Term Forecast [1] or FAA's Aerospace Forecast [2], concepts like SESAR (Single European Sky ATM Research) [3], for European airspace, and NextGen (Next Generation Air Transportation System) [4], for America's air transportation system, aspire the harmonizing of airspace systems and use of modern technologies. The scale of concepts is growing from sector based to a global level, e.g. NextGen describes a shift from a ground-based system of air traffic control to a satellite-based system of air traffic management. Both projects, NextGen and SESAR, strive for more precision in guiding and tracking air traffic, and accordingly also predictability. Therefore, trajectory-based operations are investigated.

DLR's Institute of Flight Guidance uses trajectory-based planning for a various number of research projects validating air/ground integrated ATM-concepts and/or tools considering the airborne side aspects (predictability, costs, pilot acceptance), ground side aspects (capacity, controller acceptance) as well as environmental impact (fuel consumption, noise). This comprehensive view of air traffic promises to allow an optimal use of air traffic system resources. To validate such air/ground integrated concepts DLR developed a customizable simulation environment with server client system architecture for rapid prototyping. Basic components of this simulation environment are Datapool and TrafficSim. Datapool is the central communication module and collects and distributes all essential simulation data. TrafficSim generates all aircraft relevant data of the whole traffic scenario. This basic setup (see Figure *2*) can be extended with project specific tools e.g. conflict detection tool (STCA, MTCD), conflict avoidance calculator (airborne side or ground side) and arrival and departure manager (AMAN, DMAN). Within the simulation environment human-in-the-loop simulations can be provided by integrating DLR's ATCO (Air Traffic Controller system) and/or by integrating cockpit simulators (e.g. DLR's Generic Experimental Cockpit Simulator GECO). Furthermore, simulation runs can be extended by integrating real aircraft ATTAS (Advanced Technologies Testing Aircraft) or ATRA (Advanced Technologies Research Aircraft) via HF data link to the simulation environment. To get reliable results from such simulation runs the behavior of the simulated aircraft must be as realistic and accurate as possible. For all trajectory based operations the TrafficSim uses DLR's generic advanced flight management system (AFMS).

The development of an ATM concept follows the model of Rapid Prototyping respectively Rapid Application Development (RAD). This ensures a flexible and periodical development process which has the possibility to integrate upcoming requirements in the next phase. If a concept validation requires new features in TrafficSim or in the project tools, they will be included in the RAD plan also. The RAD process, as described in [5], starts with a planning phase including the definition of project requirements. The second phase consists of choosing a time box in which a spiral process lives with architectural design, construction, prototyping and testing (see Figure 1), to achieve parts coming from the planning phase. First and second phase occur alternately. A key aspect of the RAD process and of main interest is user involvement, as air traffic controller and pilot.

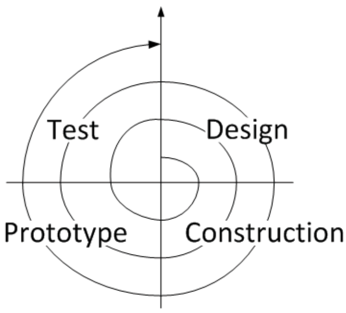

Figure 1 Spiral process

Combining the described simulation architecture with the RAD process yields in the possibility to combine simulation tools easily in order to meet modern concept validation requirements.

In the following the main simulation tools of the simulation environment, Datapool, TrafficSim, Data Link, Conflict Detection and Avoidance are described. After that, the use of the TrafficSim is described in various projects.

2. THE SIMULATION ARCHITECTURE

This chapter describes the simulation architecture and its basic tools seen in Figure *2* in more detail.

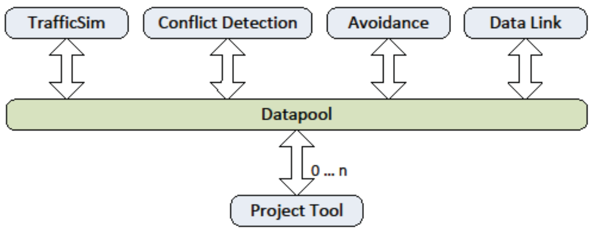

Figure 2 Basic Simulation Architecture

2.1. The Air Traffic Simulator

The air traffic simulator further called TrafficSim is designed to support the development and validation of onboard tools as well as air traffic management tools.

The TrafficSim models a project specific air traffic scenario and supplies project tools with a set of realistic aircraft data.

Traffic Scenario

A traffic scenario can be created based on real traffic data retrieved from various sources e.g. DFS (Deutsche Flugsicherung; German ANSP), DDR (Demand Data Repository) as well as self generated ones (e.g. Direct Routing). Because a navigation database is not part of TrafficSim, the TrafficSim does not limit a scenario to a special geographical region. A traffic scenario can be designed sector wide, country wide, continent wide as well as worldwide. The simulated traffic can simulate arrival and departure traffic flow for an individual airport, country/continent wide traffic including all departures, arrivals and overflights as well as surrounding traffic for an individual aircraft. The scenario script is described in a plain text file specifying each aircraft via callsign, aircraft type, flight plan, timestamp and equipment. The timestamp specifies the aircraft time schedule via departure time, arrival time or overflight time of a specific waypoint in its flight plan.

The TrafficSim is a trajectory based simulation tool. Each individual aircraft is equipped with a 4D-FMS and an autopilot as shown in Figure *3*.

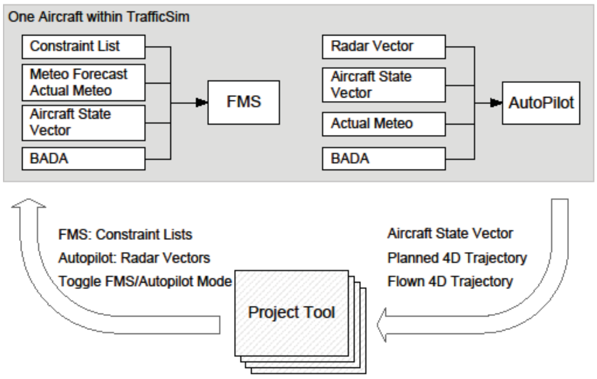

Figure 3 System architecture of Traffic Simulator

Built-in 4D-FMS

By default all aircraft are in FMS mode and are simulated with the built-in 4D-FMS that generates a 4D-trajectory and follows the predicted trajectory automatically and accurately in time.

The TrafficSim uses as built-in 4D-FMS the generic AFMS [6, 7] which was developed at DLR within the project PHARE (Programme for Harmonised ATM Research in EUROCONTROL). Since then the AFMS has been enhanced continuously by DLR by including many improvements and new applications. The AFMS is still under ongoing development to consider new research aspects (e.g. green approaches). The AFMS is validated in flight trials with DLR's research aircraft ATTAS (a VFW614), ATRA (an A320), and in the A330 full flight simulator of Zentrum für Flugsimulation Berlin.

The purpose of this AFMS is to create a highly accurate 4D-trajectory for each aircraft in the scenario [8]. The input data for the generator are a flight plan, performance data, aircraft state vector at starting position and meteorological data. The start point of the predicted trajectory is either on ground defined as take off point on the departure runway or in flight at any position in the simulated airspace. Ground movement is not part of the TrafficSim.

The trajectory generator takes account of altitude constraints, speed constraints, time constraints and profile parameters which may be specified in the flight plan. The initial trajectory is mostly generated without any time constraints apart from the take-off time. Without time constraint the vertical profile is predicted using a nominal speed profile specified for the individual aircraft type. The AFMS ability to meet specified constraints is mostly used to negotiate trajectories with a ground based air traffic control planning tool. The AFMS is capable of generating following approach profiles: Low Drag Low Power (LDLP), Continuous Descent Approach (CDA) and curved approach [9].

Figure 3 shows a scenario with arrival and departure traffic for airport LKPR (Prague, Ruzyne) designed for DLR's ATC Global demonstration in 2008. The main purpose of this traffic scenario was to demonstrate the ability of 4D-FMS and data link equipped aircraft to negotiate onboard predicted 4D-trajectories with an arrival planning system on ground and fly the agreed trajectory within given tolerances fully automatically without further intervention by Air Traffic Control (ATC). The scenario was reused with a separate set of functionalities in SJU project 5.6.1 – "QM1 - Ground and Airborne Capabilities to Implement Sequence" – to validate a CTA (Controlled Time of Arrival) concept.

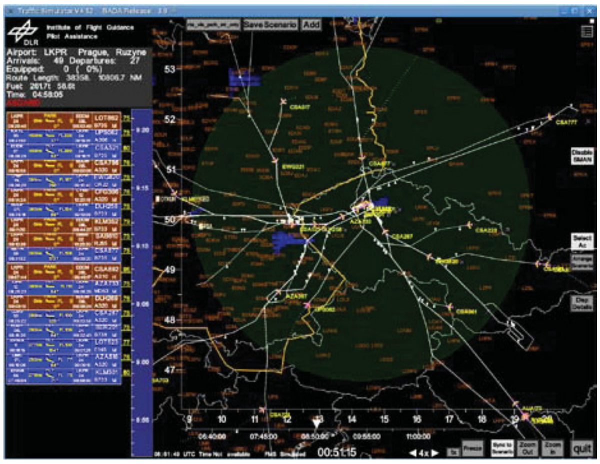

Figure 4 Traffic Scenario with arrival and departure traffic for airport LKPR negotiated with an arrival planning tool

Trajectory Prediction

The lateral route is made up of great circle legs between waypoints and arcs with a fixed radius at the waypoints. The vertical profile consists of a sequence of flight phases: climb, level flight, descent, combined with constant speed or acceleration or deceleration phases. The climb is predicted at high power setting. The descent is planned with idle power setting. Airspeed and altitude profiles are planned and modified such that all altitude, speed and time constraints are fulfilled, whenever possible. In the final phase of the flight, from metering fix to approach gate, the trombone or fan path stretching method is also used to meet time constraints or even altitude constraints.

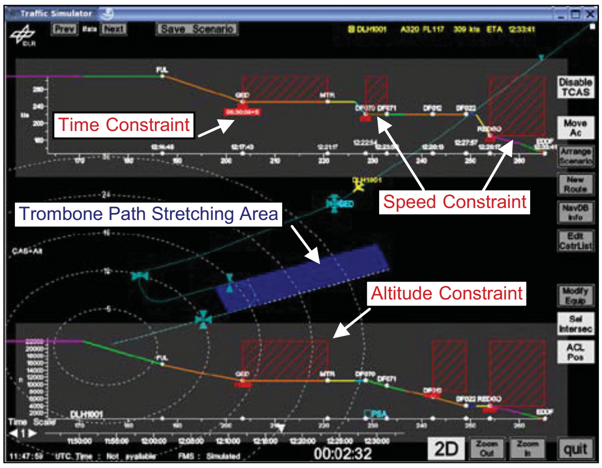

Figure 5 4D-trajectory with lateral, altitude and CAS profile taking account of altitude, speed and time constraints of one individual TrafficSim aircraft flying to airport EDDF

Built-in Autopilot

Each aircraft can be set to autopilot mode at any time to fly a selected altitude, speed, course or an autopilot procedure like intercept ILS, holding or procedure turn. The altitude and airspeed profiles are predicted by integration of the equations of motion. All calculations are done with 50 ms integration steps, also in fast time simulation mode.

Aircraft Performance Data

For calculating a highly accurate trajectory, information about certain performance data of the aircraft is needed. The necessary performance data includes an aerodynamic model, an engine model, characteristic flight procedures such as climb speed, cruise speed, etc. For DLR's test aircraft ATTAS and ATRA these information are retrieved from flight trials, for all other aircraft types this data is obtained from a BADA-file (Base of Aircraft Data) distributed by EUROCONTROL that is especially designed for the use in trajectory prediction algorithms within the domain of ATM. A detailed description of this file can be found in the "User Manual for the Base of Aircraft Data".

Meteorological Data

The condition of the atmosphere is obtained from two meteorological grid files, forecast and actual data, providing wind direction and speed, air temperature and pressure for grid points with free selectable distance and altitude layers. Tools to setup such meteo grid files are available. The TrafficSim is also able to use the original meteorological file format provided by Deutscher Wetterdienst (DWD; the German weather forecast service). The forecasted meteorological data is used for trajectory prediction; the current data are used to calculate the flight profile either in FMS or autopilot mode. Thus, deviations between forecast and actual meteorological data are taken into account. If an atmospheric data base is not available, the TrafficSim automatically uses the International Standard Atmosphere (ISA) for its calculations.

Data Protocols

The TrafficSim has implemented a set of data protocols which can be en- or disabled individually. The kind and frequency of provided data depend on the equipment level of each aircraft. The equipment level specifies the availability of onboard tools and has to be adapted to the project specific requirements for each individual aircraft, see Table 1 for available protocols.

TrafficSim Performance

TrafficSim is able to simulate large-scale traffic scenarios. The TrafficSim performs motion simulation for more than 4,000 aircraft flying interactively at the same time in a large scenario within a cycle time of 250 milliseconds. A simulation run can be done in real time, fast time or slow motion. In any case the equations of motion calculations are done with 50 ms integration steps. The used CPU time for trajectory prediction varies between 8 and 160 milliseconds, depending on profile kind (LDLP, CDA, curved approach) and number of specified constraints (altitude, speed, time). The TrafficSim is a trajectory based simulation tool, so at start time it generates a 4D-trajectory for each individual aircraft. Thus, starting a large scenario may take time depending on the complexity. To speed up the start time of a simulation run the generated scenario can be saved in a binary file for direct reuse without generating initial trajectories; e.g. to start a scenario with 33,000 aircraft will take about 20 minutes for initial trajectory generation, to load the precalculated scenario takes just 1 second.

Example of the European project 4 Dimension Contract – Guidance and Control (4DCo-GC):

Project 4DCo-GC uses a one-day scenario with about 33,000 aircraft in total (including scheduled airline flights, charter flights and cargo flights) and 4,000 aircraft in total simulated simultaneously. This scenario was made up from traffic data retrieved from EUROCONTROL's DDR. The metrics in Table 2 are calculated using this 4DCo-GC scenario and the

Data Protocol	Description	Equipment	Frequency	Keywords
Aircraft State Vector (ASV)	Aircraft State vector describing aircrafts position and motion at current simulation time	-	Parameterized; default: 250 ms	
Radar Data	ATC radar emulation	-	4 seconds	ATCO
Automatic Dependent Surveillance-Broadcast (ADS-B)	Identification and position of aircraft	ADS-B Transponder	Parameterized; default: 2 seconds	ASAS, Free Flight
Trajectory Broadcast	Next 20 minutes trajectory data	ADS-B Transponder	Parameterized; default: 20 seconds	ASAS, Free Flight
ATC Protocol	Air/ground negotiation protocol includes: trajectory downlink, constraint list uplink, accept or reject constraints downlink	Air/ground Data Link	Event based; selectable events are 'Enter TMA' or 'Take-Off' for initial trajectory negotiation	Air/ground cooperative air traffic management
Intruder Radar Data	Position of aircraft detected by an onboard radar	Onboard Radar	4 seconds	UAV, Sense and Avoid
Traffic Alert and Collision Avoidance	TCAS Resolution Advisory (RA) and Clear-Of_Conflict message (CoC)	TCAS	RA: mid-air separation violation detected CoC: requested separation reached; separation distance is parameterized	
Pseudo Pilot Communication	Aircraft control commands to follow controller advisories	-	Event: Pseudo Pilot Input	ATCO
Cockpit Data	All aircraft data which are necessary to drive cockpit displays: ASV, EXO, generated, negotiated and activated trajectories. (Cockpit emulation mode)	-	ASV, EXO, FMS-Guidance data: 50 ms Planning data are event based	HMI

Table 1 Data Protocols

TrafficSim was running on a DELL Precision M6600 2.5 GHz 64 Bit Suse Linux 11.

	Duration
Scenario generation	18 minutes
Loading precalculated scenario	1 second
Motion simulation	40 ms/cycle
Data protocols, minimum set	80 ms
GUI, low level	70 ms/cycle

Table 2 Metrics for 4DCo-GC scenario at a DELL Precision M6600 2.5 GHz 64 Bit Suse Linux 11

2.2. The Conflict Detection

This tool provides information of detected conflicts in the current traffic scenario. A conflict exists if at least two aircraft fall below their minimum separation. Generally, the separation in the en-route airspace is 5 nautical miles radius laterally and 1000 feet vertically. Currently two conflict detection tools are provided. The first predicts intersections between the trajectories of surrounding aircraft and one particular aircraft of interest. The second finds conflicts between all trajectories in a short time even for a large number of trajectories. For example, all conflicts from the 33,000 flight 4DCo-GC traffic sample are identified in less than 5 minutes. This in-house tool is called ConflictChecker and the underlying algorithm is described in [10].

2.3. The Avoidance Tool

The Avoidance Maneuver tool (AVMT) calculates trajectory-based avoidance maneuvers. The objective of this tool is to calculate avoidance maneuvers which are as close as possible to the user preferred trajectory. When a conflict detection message is raised by the conflict detection the AVMT analyses the traffic situation at the conflict area and determines according to the implemented flight rules the avoidance responsible aircraft, called give-way aircraft. Depending on the traffic situation at the conflict area the AVMT selects a suitable avoidance maneuver strategy and calculates constraints to modify the trajectory to regain separation:

- Cross_Behind/Cross_Before:
  - Situation: Conflict area is detected on crossing tracks
  - Maneuver: Insert avoidance points to pass behind or before the right-of-way aircraft.
- Pass_Right/Pass_Left:
  - Situation: Conflict between at least two aircraft catching up on same track.
  - Maneuver: Insert route offset points in order to overtake right-of-way aircraft.
- Pass_Below/Pass_Above:
  - Situation: Conflict in climb or descent flight phase
  - Maneuver: Insert altitude constraints to pass below or above right-of-way aircraft.
- Interval Achievement:
  - Situation: Conflict between at least two aircraft catching up on same track. Use in an area where an overtaking maneuver is not suitable (e.g. TMA), or between aircraft with low performance difference.
  - Maneuver: Adapt speed as necessary to achieve requested separation.

2.4. The Data Link Tool

To have realistic system behavior a data link emulator can be implemented in the simulation environment. Data link is used for air to air communication as well as air to ground communication. The TrafficSim supplies in both cases the data link messages but without considering the physical data link behavior. The data link emulator adds delay times for messages depending on their message type. As shown in *Figure 6* the messages are passed through the data link emulator and will be forwarded after a delay.

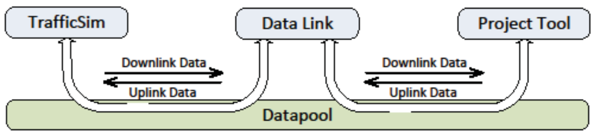

Figure 6 Communication including data link emulator

For example a Controller Pilot Data Link Communication (CPDLC) is tested for project ASEP (Airborne Separation Assistance System Separation) operations for SESAR Joint Undertaking investigations. Figure 7 shows for this case a timing diagram with available timing parameters.

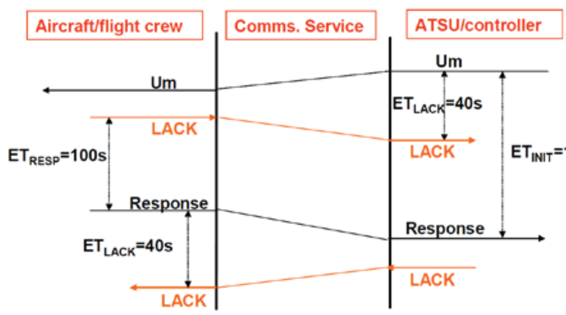

Figure 7 Timers used in a controller-initiated dialogue [11]

Each incoming communication message must be confirmed by the system with sending logical acknowledges (LACK) back to the sender.

2.5. The Datapool

Usually ATM concept validation will end up in a complex simulation environment with many distributed software tools and dedicated interfaces between the modules. Due to the large number of interfaces and communication channels implementation is hard to maintain and supervise. Therefore, DLR developed a software package, called Datapool [12], which allows data exchange between several independent running tools called Datapool clients. The Datapool software consists of the Datapool itself, running as central communication module, and a Datapool library containing all interface functions that are necessary to communicate via the Datapool. Every connected software tool has only one interface to the Datapool server. The Datapool uses two different communication methods: shared memory for local clients and TCP/IP sockets for remote clients. The necessary functionality to connect and interact with the Datapool server is black-boxed by the Datapool interface library. A client may change from a local client to a remote client without modifying its interface and being recompiled. The data transfer is done via sending and receiving messages of any structure and length. The advantages of the Datapool concept are:

- Each tool has only one interface.
- Each tool of the simulation environment uses the same standardized interface.
- Modifications of the communication software don't affect the client software.
- Modifications of the data structure don't affect the communication software

The Datapool software is validated for following operating systems:

- Linux 32 Bit
- Linux 64 Bit
- SUN Solaris
- SGI Irix
- Windows 2000
- Windows XP

2.6. Tool Interaction

Integration of all aforementioned tools provides user friendly simulation environment. This section gives some examples.

2.6.1. TrafficSim and Conflict Detection

The TrafficSim is able to show detected conflicts from the conflict detection tool in its GUI as depicts in *Figure 8*. What is shown up is a conflict between two aircraft. The conflict is marked with a red or orange bold trajectory segment, starting where the separation is below and ends where the separation is reached again for each aircraft. The aircraft liable for avoiding the conflict is marked red (its trajectory is blue because it is selected too), the orange can fly its trajectory as planned. An additional red line connects both starting points. The determined trajectory resolving the conflict is show in white, with its additional trajectory points. In the figure the give-way aircraft crossed the orange below if the conflict resolution is activated. The detour routes are conflict-free for the entire scenario.

In some cases it might be necessary for validation to actively provoke conflicts. Therefore, desired conflicts can be produced by clicking on an intersection, which leads to a simple time shifts of flights.

Figure 8 A conflict situation and advisory to solve the conflict shown in TrafficSim.

3. PROOF OF CONCEPT

The simulation architecture offers variable opportunities to test new functionalities, query user acceptance and/or test an ATM concept. Standard protocols are implemented for interaction between onboard aviation and TrafficSim. Testing ATM concepts and function-alities requires realistic traffic which TrafficSim can emulate. Further, the modeled object based global airspace model [13] provides a basis for concept research by adding conceptual issues on top of this model. With SESAR and NextGen more 4D-trajectory-based operations are aspire to fly more efficient. That changes whole traffic behavior and require flexibility in developing.

For human-in-the-loop simulations, different simulators can be connected to the simulation (Figure 9) to provide required human interaction. If a cockpit simulator is connected then it assumes the control of an aircraft within the simulation. The TrafficSim then has a passive role for this remotely controlled aircraft and visualizes its movements. Flight test preparations are done with a cockpit simulator. Thus, acceptance of the pilots is addressed in advance and a first proof of concept is done.

ASAS functionalities and implementations can be tested in a 'Free Flight' scenario with trajectory-based planned trajectories.

For testing UAV (Unmanned Aerial Vehicle) concepts the TrafficSim can simulate the surrounding traffic. Especially Sense & Avoid scenarios with one or more intruders are possible (see chapter 4 project WASLA HALE Sense & Avoid). For testing avoidance maneuvers different conflicts with fictive intruders are forced at trajectory intersections.

For all kinds of research the simulation provides the ability to record scenarios and play back as often as necessary. Statistical data are produced as required and its evaluation is supported by graphical simulation tools e.g. TrafficSim for evaluating traffic flow and flight profiles.

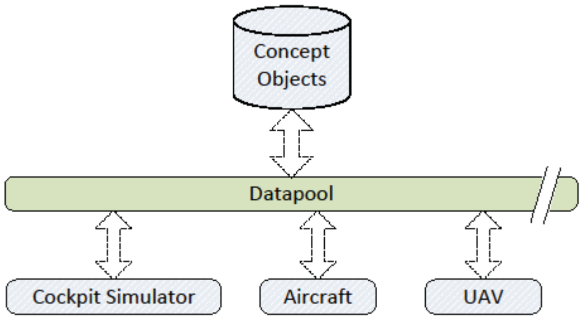

Figure 9 External Simulators

4. PROJECTS BENEFITTING FROM TRAFFICSIM

The TrafficSim is in continuous use since its initial development in 1996. Here are only some of the projects using the TrafficSim, listed in chronological order:

ASSIST (Gate-To-Gate Pilot Assistant System)

The objectives of this project, which began in 2001 and ended in 2004, were the construction and testing of a pilot integrated assistance system to improve the pilot's situation awareness. The ASSIST GUI was integrated in the Full Flight Simulator of "Zentrum für Flug-simulation Berlin" [14]. The TrafficSim simulates surrounding traffic to validate algorithm for conflict detection and airborne separation assurance algorithm.

WASLA HALE Sense & Avoid

This project investigated methods and techniques for the integration of Unmanned Aerial Vehicles (UAV) in civil controlled airspace [15, 16]. The acronym WASLA HALE stands for "weitreichendes, abbildendes, signal-erfassendes, luftgestütztes Aufklärungssystem / high altitude and long endurance". During the project from 2000 to 2007, the TrafficSim simulates HALE's surrounding traffic in various test runs, to validate the developed avoidance algorithm. As experimental aircraft the ATTAS from DLR acted as an UAV with safety pilot. At a ground control station an UAV-pilot guides the ATTAS and speaks to ATC. Two ground stations, one in Braunschweig and the one in Manching, demonstrate a standard handover of an UAV. Generated trajectories from the ground are sent to the ATTAS via HF data link. For testing See/Sense & Avoid methods a TrafficSim scenario is used, in which the UAV must avoid an intruder. After that, flight tests with the UAV flying in a TRA (Temporary Reserved Airspace) and simulated intruder by TrafficSim were conducted. As third step the intruder is a real aircraft, a Dornier 228. The TrafficSim shows surrounding traffic for the real flying ATTAS.

FAGI (Future Air Ground Integration)

This project started in 2007 and was completed in 2010. Major concept element of the FAGI project is a late merging point combined with time based separation to show a possible solution for fuel and noise efficient handling of a heterogeneously equipped traffic scenario in an extended terminal maneuvering area environment [17]. The TrafficSim simulates arrival traffic with mixed equipped aircraft: 4D-FMS-equipped aircraft fly a 4D controlled continuous descent approach considering a time constraint at late merging point. Non-equipped aircraft follow radar vectors, which are given by real air traffic controllers, which were entered in extensive simulation by pseudo pilots. Flight tests with both DLR's ATTAS and ATRA research aircraft using the same FMS as integrated in TrafficSim proved the ability to fly these approaches with high accuracy.

LRM2020 (Airspace Management 2020)

In the project LRM2020 [18, 19] DFS and DLR investigate the feasibility of a sector-less Air Traffic Management concept which focuses on the en-route airspace. In this concept an air traffic controller takes care of a limited number of aircraft from departure to arrival. The concept includes aspects of SESAR and NextGen like trajectory-based and direct routing. The Air Traffic Simulator simulates realistically the whole air traffic, up to 10,000 aircraft, for the day with highest traffic volume in German airspace in 2008 and up to 4100 aircraft in the en-route area (see Figure 10 and Figure 11).

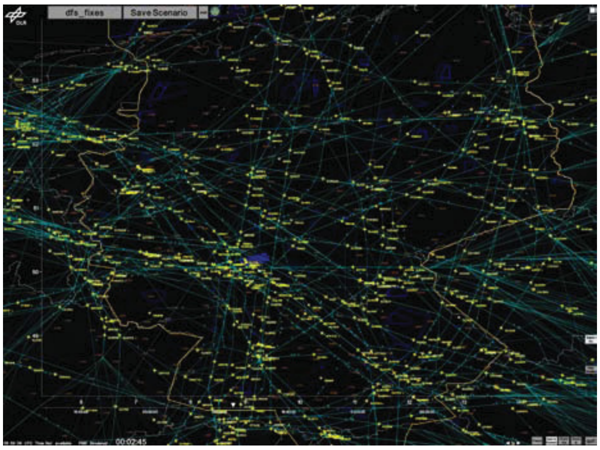

Figure 10 Traffic Scenario with 10,000 aircraft, one day air traffic over Germany

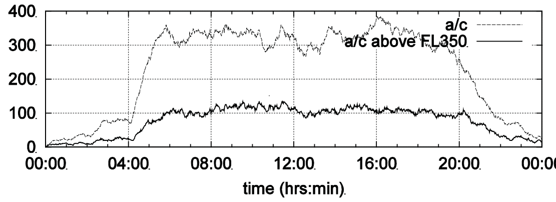

Figure 11 Total number of aircraft and aircraft above FL350 at the day with highest traffic volume in German airspace in 2008

The TrafficSim is connected with an Air Traffic Controller Human Machine Interface (ATCO HMI, by DLR). On the ATCO HMI a controller is integrated in the live simulation. Via data link the ATCO communicates with its airplanes. The pilots are simulated with the auto pilot interface from TrafficSim. The co-operation with DFS, allowed to test the software with real ATCOs. Test runs were conducted in which on the one hand, the processes of conflict detection and resolution were tested and on the other hand, acceptance of the ATCO HMI was investigated. With the ATCO HMI e.g. experimentally automated workflows can be tested. In this environment, scenarios are necessary which contains conflicts which not exist in recorded data. Furthermore, to transmit and negotiate conflict resolutions between ATCO and pilot a Controller Pilot Data Link Communication (CPDLC) is emulated and used.

4DCo-GC

This project started in November 2010 and is described at the project website [20]. It examines the 4D contract concept and is a successor of the IFATS (FP6) project [21]. A contract is negotiated for a 3D flight corridor over a certain period of time. The contract guarantees a conflict-free corridor for each aircraft. Staying within the contract and monitoring contract compliance are tasks of aircraft. Therefore, aircraft generate a trajectory that lies completely in the contract and guide along this trajectory. As soon as contract non-compliance can be forecasted by the aircraft, ground is notified in order to deliver a new flyable contract. The planned architecture of the project tools is shown in Figure 12 and depicts among others the connection to the TrafficSim. The TrafficSim generates in this project the airborne traffic flying according to the 4D contract principle. The trajectories of the scenario will be transferred to other project tools over a backbone interface which includes Datapool interfacing as well as HLA interfacing.

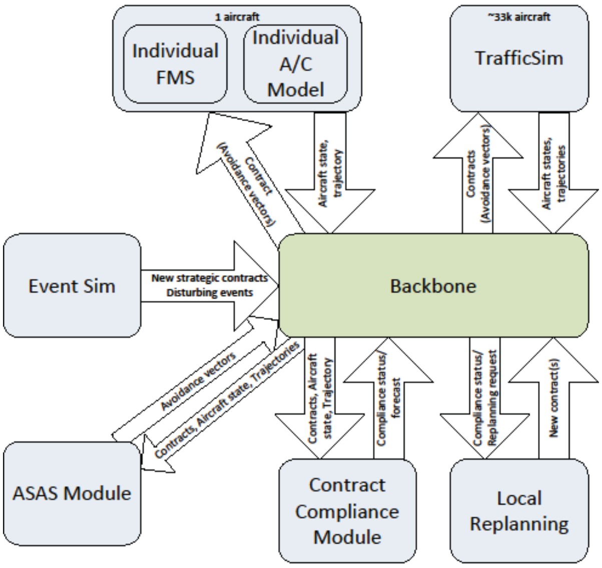

Figure 12 Modules of 4DCo-GC simulation campaign 1 [A. Kuenz, DLR]

For this project it is necessary to equip the TrafficSim with the new feature of 4D contracts. Only then scenarios can be generated in which all aircraft are separated on the basis of 4D contracts. Due to the existing guidance of an aircraft along its trajectory by TrafficSim, the compliance with the contracts can be checked.

5. CONCLUSION AND FUTURE WORK

Within this paper an air traffic management simulation architecture is presented, including several tools for traffic simulation, conflict detection and data link communication which are the core for tests of ATM concept. By using the methodology of Rapid Prototyping implemented with Rapid Application Development the simulation architecture allows easily and quick changes that are necessary due to new or modified requirements and user involvement. Beyond that, external simulators or real aircraft can be connected to the simulation architecture and used in a simulation/test run. As seen in chapter 4, there were several projects which successfully used the tools and described architecture to reach their objectives.

An intended project which focuses on ash clouds will be used the described simulation environment. Planned are two new tools for the simulation environment for integrating ash cloud data from DWD and a tool for generating optimal avoidance trajectories. That way research projects could be done by only expanding project specific tools to the simulation environment and using the existing tools.

[1] EUROCONTROL Long-Term-Forecast 2010-2030. http://www.eurocontrol.int/sites/default/files/content/documents/official-documents/forecasts/long-term-forecast-2010-2030.pdf

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