# USE OF DISTRIBUTED REAL-TIME SIMULATIONS IN ATM VALIDATION: EXAMPLES BASED ON THE ANALYSIS OF CONTROLLER – PILOT INTERACTION

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## Abstract

Based on the development of new Air Traffic Management (ATM) concepts on European- or even worldwide level, requirements to infrastructures for validation of these concepts are changing and might exceed currently available technologies.

To cover all stakeholder domains of the ATM concept under evaluation, the combination of several specialized simulators can provide an appropriate solution. This is becoming especially relevant due to the extended use of data exchange within distributed environments and the increase in automation and computerization within the ATM system. Looking into some detailed concept elements of SESAR and NextGen, new challenges lay ahead for the interplay between pilots and air traffic controllers as the working tasks and role definitions of these ATM actors are up to a significant change.

This paper discusses how the use of distributed simulation setups has already helped validating specific concepts affecting the interaction between controllers and pilots. Coupling of ATC- and flight simulation facilities provided the opportunity for a close look at the dynamic effects of new procedures and technologies on the human actors involved.

Extending its view from this specific example up to a more general look on ATM simulator interoperability, the paper also provides an overview over existing interoperability concepts, upcoming challenges based on the above mentioned new global ATM developments and ongoing attempts for development of an efficient interaction between ATM simulation facilities.

## 1 Introduction

By postulating major changes into the management of air traffic within the coming decade, the framework projects at both sides of the Atlantic, SESAR and NextGen, are targeting at significant changes on a system wide level.

Focusing on trajectory based operations as the foundation of the target concept SESAR has identified several key enablers needed for implementation [6]. Among them of significant importance are

Collaborative planning on all organizational levels as mandatory approach,

System wide information management (SWIM) throughout the ATM network, and

Integrated airport operations facilitating the needs of all involved stakeholders.

The proposed ATM concepts are based on improved ways of organizing and sharing information as well as collaborative decision making between the stakeholders of the Air Traffic System (ATS). Higher integration of information shall facilitate an optimized use of resources, improving the situational awareness for overall system conditions and the implication of decisions made within the operational context.

Accordingly, new technologies and processes have to be developed, tested and validated not only on local isolated levels, especially recognizing the needs of interaction and interconnection between involved actors and organizations.

The collaborative elements of the concepts force up the need of interaction between systems and operational units and respectively the operators themselves. Cross linking between system- and concept elements is increasing as is the overall complexity.

Concept validation in this changed ATM environment is facing new challenges early on in the development process. System wide effects and benefits must be evaluated right at the beginning to gain confidence in the general idea. State of the art analytical methods and fast-time simulation tools try to deliver answers to these questions early on. Later steps eventually have to lead to additional validation trials which will include real-time simulations and field trials, depending on the requirements of the concept being analysed.

Often part-task analysis is sufficient to gain experience and fulfil isolated validation tasks while focusing on specific functionalities and actors. Depending on the concept to be validated, the specific effects of a collaborative environment and dynamic interaction of involved actors can only be obtained by a validation setup covering the operational environments of all relevant actors. With regard to validation experiments based on real-time simulators this often means to use a distributed and coupled simulation infrastructure. In the context of SESAR and NextGen the demand for distributed real-time simulation setups will increase significantly.

## 2 Use of distributed real-time simulation environments from a validation perspective

Verification and validation activities for the later phases of large scale ATM concept development can be broken down in four different stages:

(1) Technical Tests are conducted in order to assess the technical performance of specifically developed equipment, representing the verification subject. Results of technical tests respond to the question “did we build the system right?”

Validation activities itself can be split into three major building blocks. These results respond to the question “did we build the right system?”

(2) Operational Feasibility addressing the definition of the operational use of the equipment in accordance with the system performance assessed during verification. This stage includes

- operational verification (fulfillment of operational requirements)
- system parameter tuning
- system usability aspects

These activities are necessary before further validation of the system with respect to possible improvements and benefits can take place.

(3) Operational Improvements in terms of

- Efficiency
- Capacity
- Safety
- Human Factors (e.g. Situational Awareness, Mental Workload)
- Environmental Issues

Operational Improvements are investigated when both system requirements and user requirements are met by the system as verified and evaluated in the previous stages. In this stage the performance of the specific ATM concept (possibly related with new technology) can be assessed.

(4) Operational Benefits. Only when it has been verified that the system is working properly according to all technical and operational requirements and when it has been validated that there will be operational improvements, it will be possible to translate such improvements into monetary terms.

All areas of verification and validation are closely connected to the choice of the appropriate validation platform. Technical Tests can be performed at first in simulation and – depending on the result – step by step in shadow mode trials during on-site experiments. Operational feasibility then can be exhaustively studied in both real time simulations and on-site. Field tests are especially crucial to check for example transmission time for data link applications in real life.

While the acceptance and feasibility of new operational concepts can be evaluated by a combination of simulation campaigns and field trials, the unique feature of Real Time Simulation (RTS) is given in validation trials dealing with operational improvements. Here the comparison of parameters like efficiency, capacity and human factors requires controlled conditions and a solid baseline. Corresponding results can only be achieved using a real time simulation setup..

Depending on the specific ATM concept to be validated, several practical issues are limiting the possibilities to evaluate operational improvements during live-trials. Considering the fact that full-scale on-site trials require oftentimes very costly investments, these kind of experiments are dedicated to the very late phases of the development lifecycle [1]. This applies especially with regard to ATM concepts designed to affect significantly large parts of the overall air transportation network, like most of the SESAR concepts are.

As mentioned before, on-site trials will not be able to deliver sufficient comparable results for evaluation of operational improvement due to the absence of a real baseline. For obvious reasons safety critical issues are also dedicated for RTS only.

With respect to the cooperative features of the advanced ATM concepts to be developed in SESAR and NextGen, a significant portion of analysis will depend on an validation setup incorporating the interactive elements of human actors and ATM systems. The interaction between air traffic controllers and pilots within specific phases of operation can be used as a dedicated example for the specific requirements and results of distributed real-time simulation setups.

# 3 Using distributed simulations to analyse pilot – controller interactions

In this section we describe the experimental setup and review the results of two specific simulations carried out at the German Aerospcae Center DLR (Deutsches Zentrum für Luft- und Raumfahrt) to validate higher levels of A-SMGCS concepts by using distributed simulation.

## *3.1 Simulator Setup for Coupled Tower- and Cockpit Validation Exercises*

The following experiments have been carried out to validate specific elements of higher level A-SMGCS functionalities. Covering the responsible ATC unit with regard to ground operations, the simulation setup for both experiments included the DLR Apron- and Tower Simulator (ATS).

The ATS consists of a simulation server that generates aircraft movements according to aircraft dynamic models and two separate visual systems that generate and display the synthetic vision (Fig. 1). The control of the entire simulation, the allocation of simulation processes and the daylight and visibility settings is provided by the so called exercise control station. Up to eight pseudo-pilot stations are available to allow direct control of simulated aircrafts and apron vehicles. All relevant data for the visual system like vehicle positions and visibility settings are getting transferred to the Image Generator (IG), a Linux-based IG cluster driven by inhouse-developed software called ALICE.

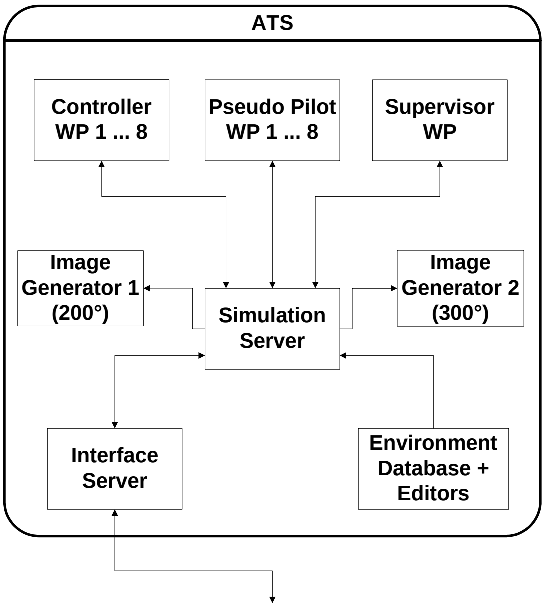

**Figure 1: Basic configuration of the Apron- and Tower Simulator ATS [18]**

Up to four controller working positions can be integrated in each of the simulated tower cabs, equipped with approach radar, airport surface detection equipment (ASDE), flight strips and a lighting panel. Additional consoles permit the installation of airport specific systems and the systems to be tested.

To interact with its environment, the ATS provides an interface server which allows bi-directional transfer of data in real-time, providing not only the necessary data to stimulate the implemented ATM systems but also to interoperate with connected external simulation facilities.

For detailed coverage of the onboard perspective within the experiments, the setup as well included DLRs Generic Experimental Cockpit GECO (Fig. 2). The GECO is a flight simulator based on the Airbus A320 aircraft and DLR's test aircraft ATTAS. Contrary to simulators designed for pilot training which requires the highest degree of realism, the major objective of this Generic Experimental Cockpit is to provide maximum flexibility in order to meet different requirements in the fields of cockpit research regarding new systems including human machine interfaces and new flight procedures. For these purposes GECO offers a suitable platform with all necessary components and a sufficient degree of realism for presentation and realistic tests.

The simulator features a collimated outside view and standard cockpit systems. They include components of the Flight Management System (FMS) like the Flight Control Unit (FCU) and Multipurpose Control and Display Unit (MCDU) as well as Advanced Flight Management functions. In addition GECO provides several input devices for human machine interaction e.g. trackball, touch screen and additional switches and a Head Up Guidance System with Stroke and Raster capability

**Figure 2: GECO cockpit view**

The GECO architecture is based on a central communication module, the so called data pool. The data pool allows a minimized and standardized interface between subsystems. Thereby a heterogeneous distributed system with different hardware, operations systems, and programming languages can be built up. Additionally all relevant simulation data are available via broadcast. If there are special needs of data, an individual connection can be established, for instance an "Outer loop Guidance Vector" or the "Aircraft State Vector".

The simulator is part of the ATM simulation network of DLR. It can be operated stand alone as well as in combination with facilities like DLR Tower simulator ATS and the Air Traffic Simulator ATMOS. Other platforms can be connected via router, ISDN or internet. The communication protocol is attached to the data pool and is based on TCP/IP, offering flexibility for integration of additional systems.

If needed, additional cockpits are available which are based on the same core elements like the GECO but providing lower fidelity regarding the cockpit environment and the visual system.

## *3.2 EMMA2 Validation of Taxi-CPDLC*

Expanding the focus on higher levels of A-SMGCS, the European community funded EMMA2 project concentrated on development and validation of routing and planning functions, facilitated by a Departure Manager (DMAN) and taxi guidance provided via Controller Pilot Data Link Communications (CPDLC). Three test sites have been used within EMMA2, including experiments through real-time simulations and field trials.

### Specific simulation setup

In the Prague real-time simulation trials carried out at the DLR simulation facilities, a complete experimental setting including both Air Traffic Controllers (ATCO) in a tower and pilots in a cockpit environment was used.

The coupling between ATS and GECO simulators has been realized using the DLR proprietary interface, facilitating the data pool for exchange of real-time data. The CPDLC functionalities had to be implemented for three different kinds of operators (Fig. 3) [18]:

Air traffic controllers using the developed and analyzed A-SMGCS CPDLC HMI based on an electronic flight strip system,

Pilots operating the simulated aircraft from the GECO, using the cockpit HMIs to be evaluated within EMMA2,

Pseudo-Pilots serving the ATS by receiving taxi clearances issued not via voice com but as well via CPDLC.

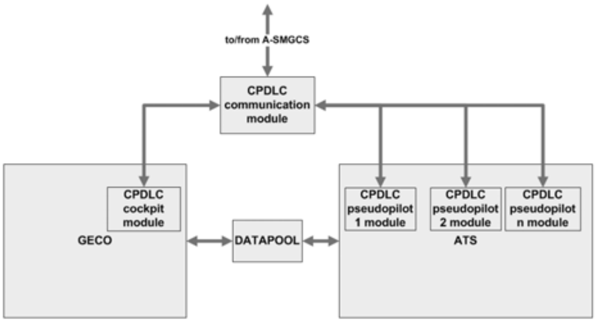

**Figure 3: Coupling of simulators ATS / GECO, and implementation of Taxi CPDLC functionalities for A-SMGCS [18]**

### Simulation trials and results

The trials were executed with three ANS ATCOs, a cockpit crew, and five pseudo-pilots. In total six ATCOs and eight commercial pilots performed 15 test runs resulting in more than 350 movements and more than nine hours of TAXI-CPDLC testing.

ATCOs used Electronic Flight Strips (developed by Park Air Systems) as enabler for TAXI-CPDLC messages (Fig. 4). During the real-time simulations, an additional recording window was presented in the edit bay.

**Figure 4: A-SMGCS Ground Equipment: EFS plus CPDLC functions integrated at the Controller Working Position of ATS**

Pilots used an Electronic Moving Map (EMM) display (Fig. 5) and a modified Eurotelematik Cockpit Display of Traffic Information (CDTI) (Fig. 6), which served for selecting CPDLC messages to be sent and for the textual displaying of received clearances. Fig 5 shows the arrangement in the GECO, with the EMM on the position of the NAV Display and the CDTI on the pedestal.

**Figure 5: On-board Equipment**

```
28-Aug-2008   MESSAGE LOG 13:53 2

WILCO                      13:44:43
REQUEST start-up CLEARAN 13:46:36
START_UP APPROVED          13:41:22
REQUEST pushback CLEARAN 13:50:56
REQUEST taxi CLEARANCE     13:51:47
TAXI TO HOLDINGPOINT A A 10:00:00
WILCO                      13:53:20
```

**Figure 6: Log menu on CDTI**

As described in the “Prague - A-SMGCS Test Report” [3] the controllers worked in the simulation trials with a data link equipage rate of 50% of the participating traffic, which was considered a very likely future traffic scenario. The Ground Executive Controller (GEC) and the Clearance Delivery Dispatcher (CDD) handled START-UP, PUSHBACK, TAXI-in, TAXI-out, and HANDOVER by data link. The Tower Executive Controller (TEC), who was responsible for the runways, used voice exclusively.

The ATCO feedback for handling those clearances by TAXI-CPDLC was predominantly positive [3]. The ATCOs admitted that they were provided with an effective human-machine interface to permit an efficient data link communication with the pilots and that a mix of TAXI-CPDLC and voice communication for different phases of a single flight and a mix of equipped and non-equipped aircraft did not lead to confusion and safety critical communication errors.

Via TAXI-CPDLC they can provide the pilots a more efficient guidance service. They can transmit actual taxi clearance by data link that can be displayed onboard and would facilitate the pilots’ navigation task. Additionally they would save a lot of time spent for routine communication like a handover instruction for instance. Fig. 7 shows the results for R/T channel occupancy for the ground executive controller (GEC) and the clearance delivery dispatcher (CDD) (Fig. 8) in distributed real-time simulations with a data link equipage rate of 50% of the participating traffic. Traffic data are produced by DLR’s fixed based-flight simulator GECO and other aircraft operated by DLR’s pseudo pilots.

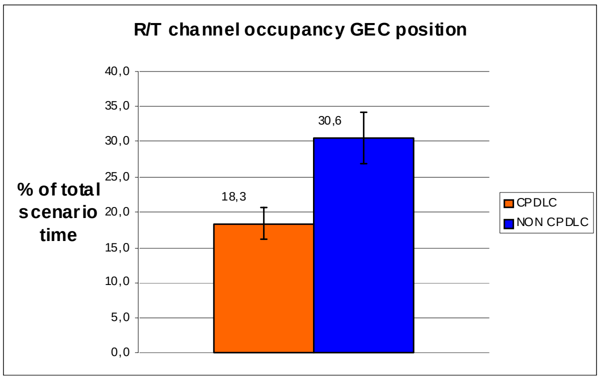

**Figure 7: Comparison of R/T channel occupancy at the ground executive controller (GEC) position for experiments with- and without CPDLC**

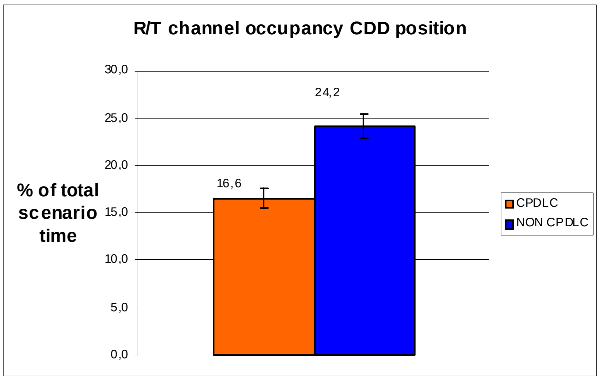

**Figure 8: Comparison of R/T channel occupancy at the clearance delivery dispatcher (CDD) position for experiments with- and without CPDLC**

The pilots' feedback for requesting and receiving clearances by TAXI-CPDLC for start-up, push-back, taxi-in, and taxi out was predominantly positive as well [2]. It must be distinguished clearly between the positively rated graphical information on the EMM display and the rating of the usability of the CDTI, which served for selecting CPDLC messages to be sent and for the textual displaying of received clearances.

The pilots stated that they were provided with a very effective human-machine interface in terms of the EMM display to operate a data link communication with ATC. Nevertheless, modifications to the input device in terms of the CDTI would have the potential to improve handling of the system significantly.

With regard to the testing of data link communication, the EMMA2 trials have been the first simulation campaign worldwide which featured the negotiation of taxi clearances via CPDLC between commercial pilots and certified tower controllers using realistic traffic scenarios.

### *3.3 WFF validation of optimized taxi guidance and routing using taxi guidance lights*

The project WFF – Roll:MOPS has been funded by the German Federal Ministry of Economics. The German acronym translates into taxi guidance, management and optimization system. The developments carried out within Roll:MOPS focused on A-SMGCS functionalities including an optimized routing support for ATCOs, visual guidance information for pilots during taxi through airfield lighting and incursion detection / warning for both ATCOs and pilots [19] [20].

The complete system setup consists of the following functional elements:

- Surface Manager (SMAN), developed by Atrics
- Airfield Ground Lighting Server (AGLS), developed by ADB Airfield Solutions, providing individual light control
- Sensors: Light status based on local sensors
- Moving Map provided by Diehl: CPDLC facilitated through an onboard display

**Specific simulation setup**

The simulation setup in principal resembles the setup chosen for the EMMA2 trials. The setup has been enhanced by adding a second cockpit simulator, using the so called Messecockpit. Additionally, the described concept elements (SMAN, AGLS, Moving Map Display) had to be integrated into the simulation environment and specific parts of the simulation environment had to be prepared to support the integrated systems. This applied especially to the modeling of the airfield lighting for the visual systems of all involved simulators. Fig. 9 gives an overview of the setup that had been implemented for WFF – Roll:MOPS.

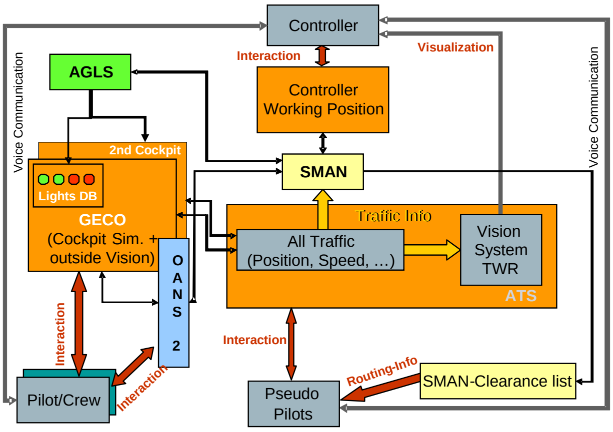

**Figure 9: Coupling of simulators ATS and GECO, using CPDLC switched airfield lighting for A-SMGCS [19]**

As depicted in this diagram not only the pilots operating both implemented cockpit simulators had to taxi their aircraft according to the clearances shown by the taxi guidance lights. The experimental setup required as well to provide sufficient information about the cleared routing to the pseudo pilots controlling the majority of aircrafts at the airport. Cleared taxi routes therefore have been translated into an SMAN clearance list and transmitted to the pseudo pilot in charge of the specific aircraft. For obvious reasons the validation of the visual guidance function and the related human factor aspects had to be based on the pilots operating in the cockpit simulators only.

Fig. 10 shows the cockpit view of the GECO simulator for two different states of taxi guidance lights.

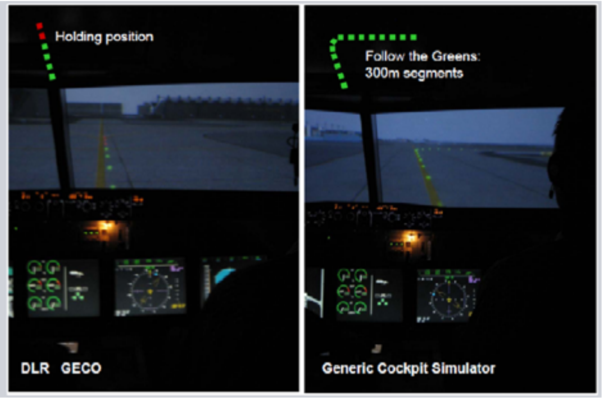

**Figure 10: GECO cockpit view while being guided by individually switched taxi light segments [19][Picture provided by Siemens]**

The simulation database for the WFF – Roll:MOPS trials represented the airfield of the Frankfurt international airport (EDDF).

## Simulation trials and results

The whole real-time simulation campaign lasted 2 weeks and totaled 30+ runs in the distributed simulation environment. Every simulation run included 105 taxiing aircraft within a time frame of about 50 minutes.

Two different locations for apron control have been used during the trials. In addition the visibility conditions varied between 800m and 10km. 14 Pilots and 4 ATCOs participated at the experiments and tested baseline scenarios vs SMAN scenarios.

The participating two cockpit simulators have not only been used to provide an increased flight crew participation per simulation run. The simulation setup included specifically designed events to provoke conflicting situations between these two taxiing aircrafts. The dynamic effects of alerting functions, for both controller and pilots have been analyzed through this setup.

For evaluation of the human operator feedback, the Mental Workload Score (AIM-s) and the NASA Task Load Index (TLX) have been used as subjective indicators via questionnaires. In addition, data recorded within the simulation environment like COM-use, traffic flow, taxi time and punctuality have been analysed as objective indicators.

The results of the WFF – Roll:MOPS real-time simulation campaign are quite complex. The character of the experiments changed especially within the first week of the trials due to early results indicating the need for revised switching of the taxiway lights (activation of green and red illuminated taxiway segments). The distributed simulation environment proved then as a sustainable test bed for detailed tuning of system parameters, including the correct sequencing of switched taxi lights for guidance and alerting functions.

The simulation runs later on revealed that the chosen setup providing the pseudo pilots with taxi clearances via transcripted listings of the visual guidance information released by the ATCOs through their SMAN interface turned out to be a bottleneck. The pseudo pilots were not able to react fast enough to the frequently updated clearance information, especially considering the high amount of traffic to be handled by them simultaneously. As a consequence, full automation of traffic guidance for the aircrafts controlled by the tower simulator itself will have to be realised for similar validation tasks in the future.

Despite the described constraints, the simulation campaign was able to achieve promising results regarding the hypotheses associated with the overall concept validation. While the workload has been rated slightly higher compared to the baseline experiments (which can be associated with several factors of the involved systems and the simulation setup), the positive assumptions for situational awareness, the amount of voice communication, traffic flow, taxi time and departure punctuality have been confirmed [19][20].

### 3.4 Specific findings based on the use of coupled simulation setups

Within the two described examples, a distributed simulation setup helped to validate specific features of the A-SMGCS concept. As the cooperation and interaction between tower controllers and pilots are the essential elements of airport airside operations on the ground, the integration of actors from both operational units are crucial to derive a holistic result.

The dynamic interaction between pilots and controllers gained specific feedback about usability of the CPDLC functionality and its related human-machine interface. While certain technical elements of a new concept could be tested within an interactive but as well isolated environment, the related operational procedures can not – at least not without sacrificing the elementary perspective of one of the actors involved.

As it has been shown within the EMMA2 validation trials, the CPDLC system components as well as the related procedures proved to be beneficial. This result is of especial relevance as the interaction between pilot and controller within the realistic real-time simulation environment allowed consideration of realistic workload and dynamic effects like workload- and task related latencies and delays which may result into increased response time. The environment as well allowed analysis of mixed data link and voice based communication.

In addition, the situational awareness for both specific types of actors could be assessed simultaneously. The same applied to the analysis of CPDLC system interaction on both sides of the data link. These kinds of experiments are only possible within the outlined distributed setup. As described before, on-site trials here will not be able to deliver the required results.

It has to be pointed out that validation of operational improvements so far only is possible within a setup of distributed simulators similar to the one used for the EMMA 2 Prague trials. The validation environment has to include not only ATCOs and pilots operating a flight simulator but as well the pseudo pilots who are responsible for handling the majority of aircrafts in the experiment. This way the complete picture of air traffic operations at an airport can be covered allowing variation of the traffic mix of (CPDLC-) equipped- / non-equipped aircrafts under controlled circumstances. Such a simulation is able to deliver evidence on the benefits provided by the introduction of a new ATM concept.

The second example, the validation setup and experiments of the WFF – Roll:MOPS project, included a lot of comparable elements with regard to the aforementioned EMMA 2 trials. In addition, the analyzed concept was based on a visual element to guide the aircrafts on ground during taxiing. The distributed simulation environment proofed its specific advantages especially regarding the analysis of the dynamic dependencies of controller intention, system interaction and communication of clearances (route switching), illumination of the selected guidance lights and the reception and interpretation of these lights by the pilots while taxiing the aircraft. The dynamic effects of the designed alerting functions have been evaluated and the results could be used to tune the system to facilitate the needs for both kind of actors, controller and pilots, in parallel. This specific task as well only is possible when using a distributed setup that integrates the operational environment of all relevant actors.

## 4 Improvements needed for coupling of distributed simulators

### 4.1 The current situation

The coupling of simulators within distributed setups is not standardized so far – or at least no standard has been established comprehensively in the ATM domain. In the past years, several initiatives and activities are working on improvements in this matter.

In the past, simulators often have been connected via individually designed interfaces. While the effort for point-to-point interconnections is relatively manageable, every new validation project caused repeatedly time consuming efforts to align specifications and requirements and to adapt existing modules to the specific simulator needs.

The complexity of coupling simulators increases with the amount of systems involved and with the number of different actors and organizations participating (Fig. 11). When looking ahead to the validation tasks approaching with the developments of SESAR and NextGen, the complexity to be covered is expected to increase significantly.

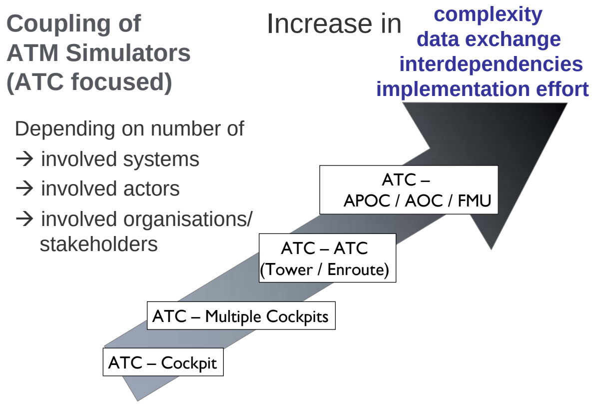

**Figure 11: General effects of covered operational environment on coupling of simulators, ATC focused perspective**

While coupling based on individual interfaces often is straight forward and well established for basic setups like the discussed connection between ATC- and cockpit simulators (point-to-point connection), growing complexity of simulation setups limits the usefulness of this approach. This is especially valid for simulations setups involving facilities at different locations and/or operated by different institutions.

## *4.2 Existing developments facilitating the use of distributed simulations*

There have been several approaches laid out in the past to overcome these limitations and establish a general architecture for coupling of simulators. These activities lead to developments following different approaches for interconnectivity and interoperability.

The early drivers of interoperability between simulators have been military users and system developers. Due to their needs of distributed simulation capabilities, the development of the Distributed Interactive Simulation standard (DIS) has been initialized. Introduced via military activities, DIS later on also has been used for ATM validation trials, e.g. within the SAMS/ATOPS experiments [11][12] which have used a distributed simulation setup integrating the NLR A-SMGCS simulator in Amsterdam, the DERA Boeing 747 flight simulator in Bedford and the DLR ATS in Braunschweig.

Based on DIS experience, a new development has been initialized again by the military domain to establish a standard for modeling and simulation which has been named High Level Architecture (HLA) [13][14]. HLA focused on enabling the interoperability of simulators even with widely different architectures. By specifying the general structure of interfaces to be used by the involved simulators, HLA is not dependent on the specific implementation of each simulation. Yet it demands implementation of a compatible Runtime Infrastructure (RTI) at all participating instances (called federates). Since 2000 HLA has been defined also in the IEEE-Standard 1516.

## *4.3 Recent or ongoing developments to improve simulator interoperability*

Throughout the different projects on national and European levels ANSPs, airports and ATM research organizations have carried out validation experiments coupling real-time simulators if necessary based on their own ideas of efficient interaction. While this pragmatic use offered interesting solutions and most of the time delivered the required results, the different set of partners collaborating in each new validation project constantly required modifications or complete redesign of the interfaces.

Eurocontrol initiated a development which intended to standardize system architecture for validation platforms through the AVENUE project [8]. It upgraded their ESCAPE simulation platform [10] via the ACE (AVENUE-Compliant ESCAPE) project [9], implementing the AVENUE architecture into their simulator and providing specifications for simulation modules to become "ACE compliant". With compliant modules or at least compliant gateways, interoperability between external facilities and the ACE platform can be realized. The approach chosen here is based on the design and provision of an accepted simulation platform.

As the ACE platform has been used successfully since within several projects, this approach on developing a standardized platform for ATM simulation infrastructures is difficult for organizations using commercially available or proprietary developed tools which all have proved their suitability and eligibility for the upcoming validation tasks.

Following a different approach, MITRE in 2003 started the development of a framework supporting the connection of ATM simulators to facilitate a word-wide collaboration capability based on existing standards like HLA. The so called AviationSimNet [7] provides an architecture which consists of a HLA-based distributed environment enriched with additional features supporting the coordination and management of the coupled simulation, an Federate Object Model (FOM) which has been designed specifically with regard to its use in the ATM domain and a capability to support distributed voice communication. AviationSimNet has been adopted especially by the American ATM community but it is open as well for non-American users. Demonstration of the Airborne Precision Spacing (APS) concept [15] and the connection between the Lockheed Martin TSS aviation laboratory and MITRE CAASD's aviation laboratory for TFM & En-Route integration [7][16] can refer as examples for projects that have already used AviationSimNet.

Still ongoing are other projects like GAIA [17] which is carried out by a French consortium to provide a platform for interoperability between Human-In-The-Loop simulators along with their collaborative services. So far a common full-mission scenario was achieved as a first demonstration including voice and data link communications.

### *4.4 Initializing an European Standard for interoperability of ATM Simulators*

Feeling the need of having improved simulation interoperability at hand, several initiatives were recommending activities for standardization in this area. The major advocate for this move has been SESAR, respectively the Joint Undertaking (SJU), whose work package 3 deals with the adaptation and integration of the required validation infrastructure. In addition the EATRADA working group on European Validation Infrastructure (EVI) [17] has recommended the development of applicable high-level communication services and a corresponding architecture, to be covered best by an EUROCAE driven activity.

In 2008, EUROCAE has initiated the working group 81 (WG81), concentrating on the interoperability of ATM simulators. The working group has identified the need to develop specification and guidelines for the ATM simulator interoperability up to the level of detail required for implementation. Its standardization approach shall cover all relevant types of ATM validation infrastructures as there are

- Analytical Performance Models
- Analytical measurement methods and tools
- Automatic- / Fast-Time simulation Tools
- Human-in-the-Loop simulation Platforms (Real-Time simulation), covering all segments of the ATM system
- Experimental platforms to support live trials

The idea of interoperability in this respect is not limited to the runtime coupling of simulators but also includes offline compatibility. Exchange of data describing the operational environment to be simulated shall be made available in standardized ways to also increase efficiency between the subsequent validation phases and transfer from one platform to the next (e.g. evolving the validation process from fast-time to real-time simulation).

The work of the WG81 has been organized in so called streams (see figure 12), focusing on three specific primary topics at the first phase of the development:

- A common definition of operation
- A common communication language
- A common definition of the simulation operational environment

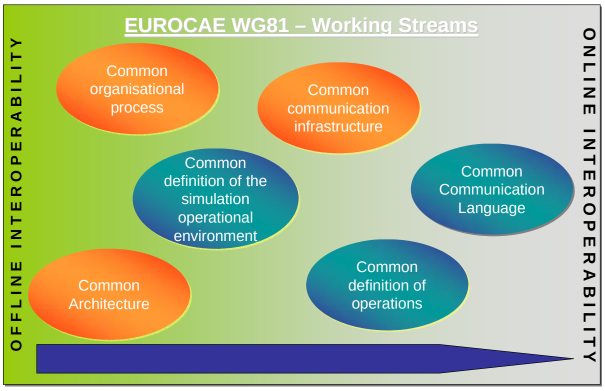

**Figure 12: EUROCAE WG81 organisation in working streams; marked in blue are the primary streams for the first phase of work**

The work of the EUROCAE working group is still in an early stadium. It will be aligned with the activities of the SJU projects (WP3) and it is intended to have close liaison between both activities. As a result, it is intended to deliver a EUROCAE Interoperability specification together with an additional EUROCAE document on process guidance for interoperable simulations.

## 5 Conclusions

As the new ATM concepts under development are based on improved ways of organizing and sharing information as well as collaborative decision making, the need for integrated testing will increase accordingly. The use of distributed real-time simulators complies with these requirements.

Distributed real-time simulation is able to support specifically the validation of concept (elements) featuring dynamic interaction of human operators within an integrated environment.

Due to the fact that coupling of simulators for distributed simulations will be required more often, the efforts will increase with the demand. Additionally the more and more complex system architecture and related interdependencies between the ATM concept elements will affect the design of coupled validation infrastructures in significant ways. The development of additional functionalities to integrate the new concept elements and to facilitate use of the existing simulators most likely will be required.

As a consequence, standardization of online- and offline interoperability between simulators is intended to lead to a more efficient preparation and use of distributed simulation facilities. Several activities have been launched and are working on improvements for ATM simulator interoperability.

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