Simulation of new Display Concepts for Air/Space Traffic Control Systems

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ABSTRACT

A long track record on research on display concepts is available in the domain to assist the Air Traffic Controller in his situation awareness. Most of the concepts were designed to reduce Air Traffic Management (ATM) complexity with respect to traffic density, identification and resolution of conflict situations as well as to enhance the efficiency of the air transport system. The existing concepts mostly do not take into consideration air traffic and space traffic above flight level 600. For the implementation of future display concepts, a validation process is required. We discuss the assets of the DLR Air Traffic Validation Center for life virtual constructive simulations and the methodology of the European Operation Concept Validation Methodology (E-OCVM) of Eurocontrol.

1. INTRODUCTION

With the commercialization of Space Operations under way, the number of Space Vehicle Operation is expected to increase significantly in the upcoming years. Areas of operation will expand from the current established and well known space ports (e.g. Cape Canaveral, Vandenberg AFB, etc) towards new operational sites. A development not only expected to take place in the United States but as well in other countries.

If the expected cost reduction for Space Vehicle Operation can be realized and commercial space operation established beyond support of national research and space programs, the number of launch and reentry activities will increase together with the number of possible launch and landing sites.

While operating a space port at a remote area with low density population might be an adequate approach in the early stages of expanding commercial space vehicle operation, the launch and reentry trajectories of space vehicles nevertheless will most probably have to interact with air traffic operations. As air traffic has increased over the last decades and is expected to continue its growth, this aspect will gain further importance and integrating both kinds of operations should be as seamless and efficient as possible [1].

Although the integration of space flights into the airspace has been extensively managed in the USA during the Space Shuttle program, higher speed and higher rates of decent of space vehicles are not fully considered in Europe yet [2], [3].

Also the operation of space vehicles at spaceports - which could be also passenger airports - has to be considered.

2. THE RATIONALE FOR VALIDATION

When space flight operations in Europe from and to airports will have to be integrated in the airspace system, the flights will be conducted over more populated areas than in the USA. In this context more extensive hazard analysis has to be carried out. Figure 1 shows the possible approach trajectory of a spacecraft to an airport close to the sea in order to avoid flights over highly populated areas. In Figure 2 the hazard area for debris in case of disintegration conducted from Space Shuttle reentry calculations [2], [3]. The pattern was transformed to the European airspace. What clearly can be seen is that in relation to the smaller size of the countries a large area is affected.

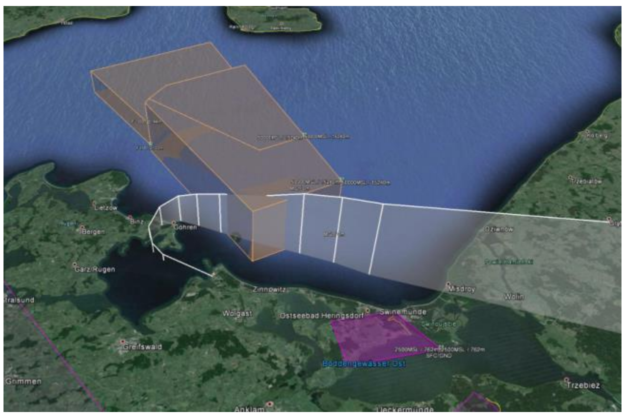

Figure 1: Approach of a spacecraft to an airport close to the sea

Figure 2: Spacecraft disintegration pattern mapped to Europe

Hence a validation chain is needed with the following steps:

- Challenge / problem identification
- Opportunities / Solutions
- Concept definition
- Implementation
- Validation / Verification

3. THE VALIDATION CHAIN

We explain the mentioned validation chain with an example on aircraft integration on airports. This validation concept can similarly applied to for the integration of new types of airspace and airport users like spacecraft.

4. PROBLEM IDENTIFICATION

As an example to explain the validation process, the airport integration is taken.

Solution: An **A**dvanced **S**urface **M**ovement **G**uidance and **C**ontrol **S**ystem (A-SMGCS) was proposed for the guidance of new types of aircraft/spacecraft.

Figure 3 shows the display concept to monitor the different types of aircraft/spacecraft during movement on ground.

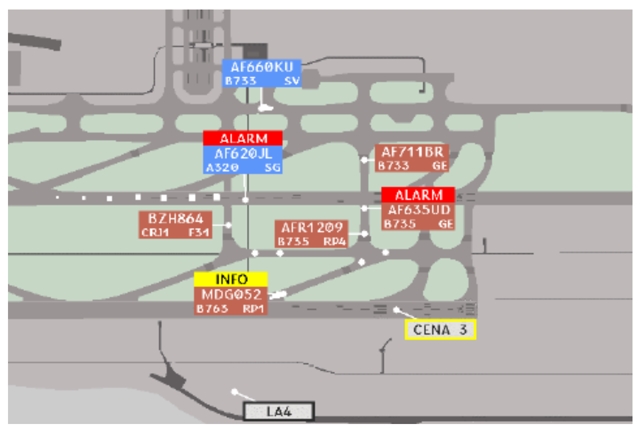

Figure 3: A-SMGCS display for new types of aircraft integration in an airport

This display includes markings for alerts in case a conflict on runway or taxiway may occur.

Figure 4 shows the display for the cockpit of an aircraft or spacecraft.

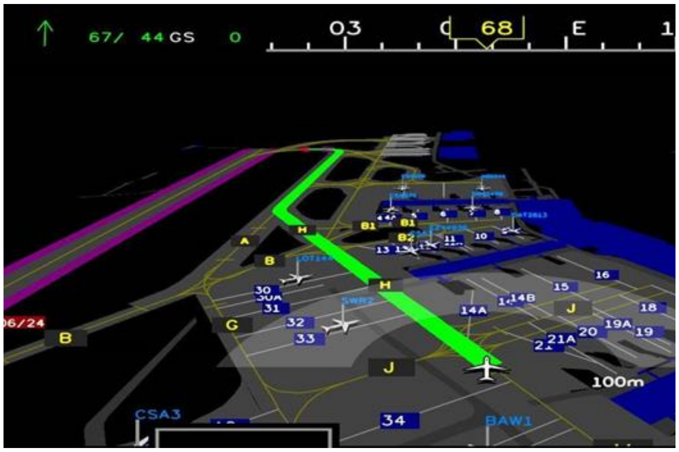

Figure 4: Cockpit /avionic display for a space/air craft which is integrated in a larger airport.

5. CONCEPT DEFINTION

The definition for the concept can be conducted from an ICAO requirement [4]:

"*An Advanced Surface Movement Guidance and Control System (A-SMGCS) is expected to provide adequate capacity and safety in relation to the specific weather conditions, traffic density and aerodrome layout by use of modern technologies and a high level of integration between the various functionality*."

6. IMPLEMENTATION

The concept is implemented in a prototype with different functionalities, see Figure 5

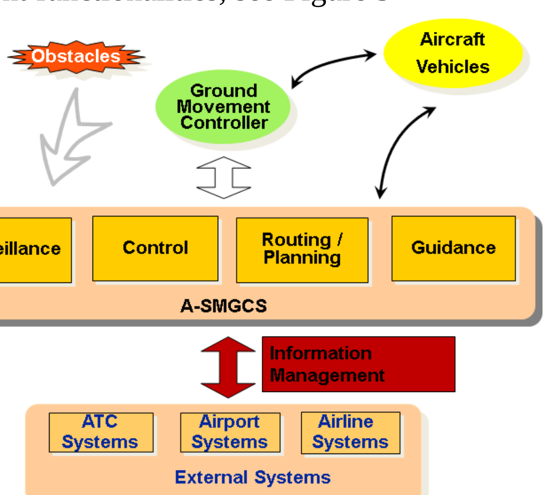

Figure 5: Implementation of a protoype concept for airport integration

7. VALIDATION / VERIFICAITON

This process is an iterative process. After the implementation of a prototype has been planned, it starts with a proof of principles and training, parallel with the equipment development and integration, and the preparation of the test infrastructure. This is followed by operational trials and the evaluation against the concept.

Validation investigates whether the concept is technically feasible. The next step looks to the user requirements and there acceptance of the concept. Finally the benefits on workload, safety and possibly throughput are analyzed.

Validation is carried out in accordance with the European Operational Concept Validation Method (E-OCVM), which describes the development and validation activities as an iterative process within a seven step model [5]. Three steps (V1 to V3) within the seven step model were developed to formalize the process of concept validation for industrialization (Figure 6).

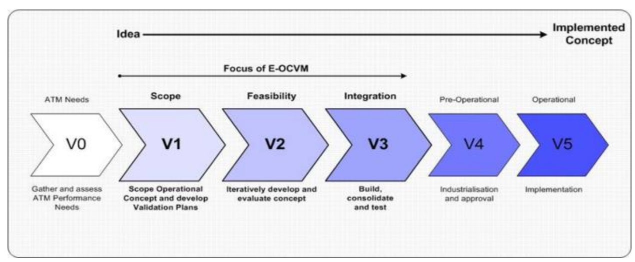

Figure 6: The Lifecycle V-Phases, validation and other ATM systems development activities [5]

Major steps include answers to the questions:

Did we build the right system or did we build the system right?

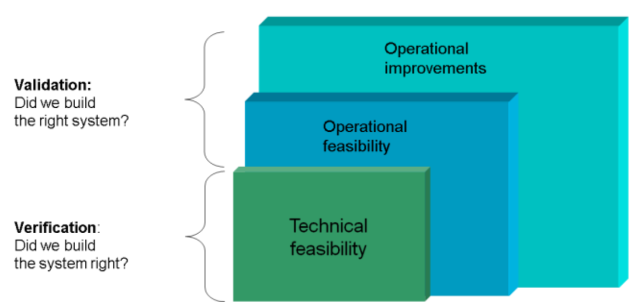

Figure 7: Validation vs. Verification

For the validation and verification trials different conditions have to be considered. Although many tests can be performed by field tests, some essential benefit criteria can only be validated by simulation runs. For example new defined procedures can only be tested in simulation due to safety aspects on one hand (e.g. low visibility operations, 'forced incursions' scenarios, 'forced misunderstandings' scenarios) and because of statistical data analyzing methods on the other hand: Only a simulation environment is providing consistent constraints to ensure an objective measurement of statistical data comparing the today existing technique / procedures (state of the art) with the new developments. Additional to this technical data evaluation, the results become encouraged by developed tailor-made questionnaire conducting thoroughly debriefings as they deliver more important results that simple questionnaire like standard usability scale (SUS) questionnaire. These different evaluation methods can be summarized as follows:

Fast time time simulations: The impact of new procedures of the whole environment can be tested very fast in a simplified simulation, giving answers to the global direction of the benefit. Fast time simulation allows a quick forecast whether the new developments focused to the right challenges.

Real time simulations: Active controllers are operating with new systems / procedures in simulation runs. Here humans-in-the-loop are working in a simulation environment. This can be extended to life virtual constructive simulations, where a simulation is connected with real flying test aircraft.

Shadow mode trials: Passive controllers are observing new systems / procedures on-site without interaction with the real traffic.

Real operational field trials: Active controllers are operating with the new systems / procedures on site, managing the real traffic.

Distributed simulation set-ups an i.e. include air traffic controllers (ATCO), pilots and other stakeholders even at different centers, Figure 8.

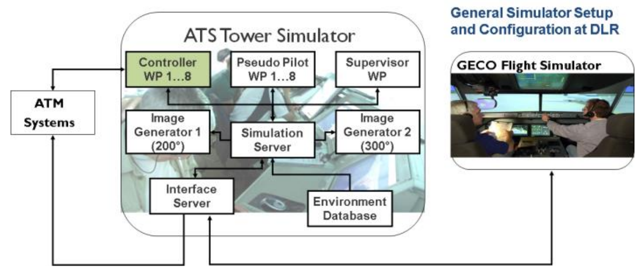

Figure 8: Distributed Simulation

This simulation set-up can investigate at the same time dynamic interaction and dependencies between pilot and controller including time critical effects. This also incorporates interrelationship between operations at flight deck and ATC as well as visual perception and HMI interaction for voice- and data communication, reaction time and situational awareness.

8. NEXT STEPS AND OUTLOOK

For the next steps to include commercial spacecraft in the European airspace, flight dynamic models of these vehicles have to be integrated in the ATM simulation environment. First steps have been done with respect to the Dream Chaser [8] and the Space Liner [9].

Against the background of an increasing complexity in ATM and ATC and the associated growing confidence in interactive displays, a well balanced approach of integrating spacecraft specific information and data is of fundamental significance for future space traffic integration in normal airspace. In a near future step, DLR will examine the data presentation of an approaching simulated spacecraft's debris footprint as a hazard area on an auxiliary controller working position (CWP) display, Figure 9.

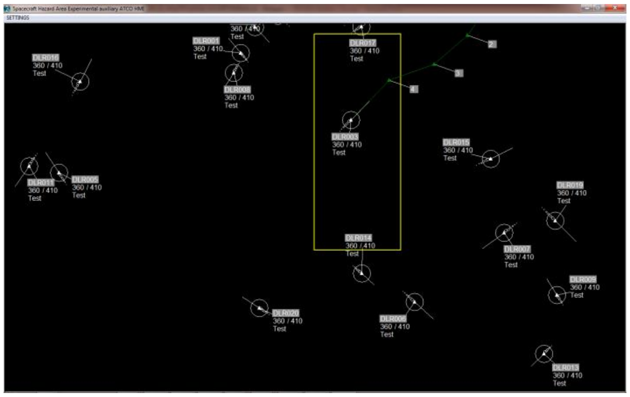

Figure 9: Hazard area auxiliary CWP display

A velocity obstacle based collision avoidance display to be tested as an experimental onboard device is shown in Figure 10 [6].

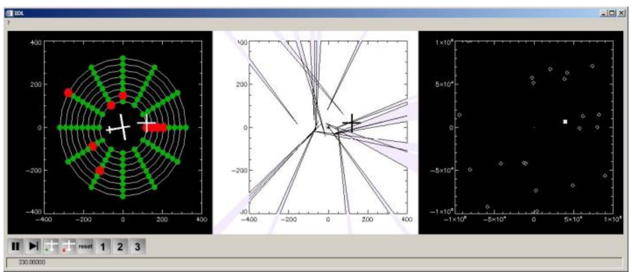

Figure 10: Velocity obstacle based collision avoidance display [6], [7]

These auxiliary displays as part of multiple display arrangements can be tested against their hazard area / collision avoidance display features as part of integrated single display arrangements, taking into consideration the following indicators:

- Instantaneous Self Assessment (ISA) questionnaire.
- Situation Awareness for Shape (SASHA) questionnaire. SHAPE = Solutions for Human Automation Partnerships in European ATM.
- NASA Task Load Index (TLX).
- Eye movement measurements.

9. SUMMARY

The paper presents the methodology for life constructive virtual simulations at the DLR Air Traffic Validation Center including ground and airborne systems. The European Operational Concept Validation Method(E-OCVM) is implemented and is discussed as base for further simulations for spacecraft integration into the European airspace.

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