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Abstract

This report provides an overview of the execution and results of the SESAR WP-E AeroGame project.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] NLR	[redacted]	01/05/2015
[redacted] NLR		01/05/2015

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] NLR	[redacted]	06/05/2015

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted]	[redacted]	21/05/2015

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] NLR	[redacted]	07/05/2015

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date

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Executive summary

The AeroGame project investigated how *serious games* can support change in ATM. Compared to real-time simulation, serious games do not provide a 1-to-1 translation of reality; they rather focus on processes and interactions. A serious game, when well designed, can provide an engaging, experimentation and learning environment, which allows players to grasp the essence of complex socio-technical systems. By trying out different strategies and 'seeing' the effects of actions, stakeholders can get a better understanding of how a system works and how it is affected by their actions and those of others.

Based on input from various stakeholders, a serious game framework has been developed to support ATM change processes. AeroGame is a hybrid game, combining a board game with an electronic score board. The use case that was chosen to test the serious game framework is that of the transition from the current Air Traffic System (ATS) to a system in which 4D Trajectories play a key role. At the start of the game, each player (i.e. stakeholder) choses the two KPIs that he would like to see increased. The goal of the game is to use income (received at the start of every round) to invest in technologies and as such to increase KPIs. Key to the game is that cooperation with other stakeholders (i.e. joint investments) leads to synergy. This synergy leads to a quicker increase of the KPIs.

To measure the game's effectiveness, an evaluation methodology has been developed within the project. This methodology has been applied at a final evaluation workshop at which 12 stakeholders participated. Even though the number of players was relatively low, the final evaluation workshop provided strong indications that AeroGame raises awareness about the topic with the players. The introduction, game elements and discussions during and after the game provide information to players about the topic at hand. It was clear from the results that the knowledge about 4DT increased during the game session. In contrast to a (regular) workshop, a serious game forces a player to reason about a topic and weighing the pros and cons, and confronts him with the results of his actions. This increased, among others, the awareness that the introduction of 4DT is a collaborative effort. These elements contribute to the awareness process.

The attitude towards 4DT clearly became more positive after playing AeroGame. This contributes to a change process because if the attitude towards the change is more positive, stakeholders are expected to be more willing to cooperate.

Although AeroGame focussed on one single topic (transition towards 4DT) the game framework can be easily adapted for other subjects as well.

The AeroGame project has demonstrated that Serious Games can play an important role in increasing knowledge about change processes, improve acceptance of new technologies, change attitudes towards these processes (and may lead to behavioural changes), and helps with preparing stakeholders for enabling change in ATM,

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1 Introduction

1.1 Purpose of the document

This document provides a high level description of the AeroGame project and its results.

1.2 Intended readership

All interested in an impression of the approach and results of AeroGame could use this document as a starting point.

1.3 Inputs from other projects

Not applicable.

1.4 Glossary of terms

Not applicable.

1.5 Acronyms and Terminology

Term	Definition
4DT	4 Dimensional Trajectory
ANSP	Air Navigation Service Provider
ASAS	Airborne Separation Assurance System
ATFCM	Air Traffic Flow & Capacity Management
ATM	Air Traffic Management
ATS	Air Traffic System
E-ATMS	European Air Traffic Management System
FAB	Functional Aerospace Block
KPI	Key Performance Indicator
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SWIM	System Wide Information Management
TMA	Terminal Manoeuvring Area

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Term	Definition
UDPP	User Driven Prioritisation Processes

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2 Rationale

The introduction of the SESAR solutions brings several challenges. The European Air Traffic Management (ATM) system has evolved into a highly complex System of Systems in which many stakeholders work together to safely and efficiently transport passengers and cargo. The stakeholders involved in this process include but are not limited to: airlines, ANSPs, airports, governments, military and passengers. Besides safety, which obviously is a common interest of all, the ATM system is the result of a complex compromise between the varying interests of these stakeholders. As systems become more and more complex, it becomes increasingly difficult for stakeholders to fully understand the impact of changes on the system as a whole. Naturally stakeholders tend to focus on a small part of the system in which their interests lie. If many stakeholders have such limited focus then applying changes to improve the system as a whole will become increasingly difficult because stakeholders do not oversee the *system wide* implications of these changes. This may seriously hinder the implementation of improvements as stakeholders may request complex and time-consuming simulations to quantify the results of the change. In a worst-case scenario, change processes may even result in deadlocks because stakeholders are not able to fully comprehend the impact of the changes. Development cycles may seriously increase because of a lack of insight in the full impact of these changes, and the attached hesitation from stakeholders.

(Serious) games are driven by the concept of play. Play is the intrinsic human driver for creative problem solving. Serious games allow for human interaction (human in the loop), which is important to include when the effects of human behaviour are difficult to model and yet have strong impact on outcomes. This is especially the case for multi-stakeholder innovation and change processes such as airspace and airport restructuring.

A serious game provides an engaging and interactive learning environment, which supports grasping the essence of complex (wicked) problems and understanding stakeholder perspectives and interests. An important function of the game is to reduce complexity to such a level of abstraction that players can easily interact with it and discuss it with each other, without losing the link or transfer to reality, while stimulating the players to stay focused and motivated.

The challenge for the project team was to explore the potential of serious games in the ATM domain for supporting the community in the challenging change process that lies ahead.

Some first steps have already been taken to introduce serious games into the air transport domain but using it as a tool to support the change process in the ATM system is a new application in this domain. Focus points for the project team were to generate profound understanding of the complex system using serious games, shorten development cycles and promote cooperation between stakeholders. The results of the project team's effort have been disseminated through an *implementation manual* that can be used by the European CNS/ATM community to be able to stepwise deploy serious gaming in complex change processes [5].

2.1 Challenges addressed

The AeroGame project identified promising applications of serious games in the ATM domain, with the focus on supporting the process of change of the ATM system as foreseen by SESAR. The main challenge of the project was to advance the complex process of change in ATM using serious gaming as a tool. Several sub challenges were distinguished, each contributing to the main goal.

- How to use serious gaming to understand and quantify the impact of changes on the ATM system?
- How can serious gaming be used to accelerate decision making processes in ATM?
- How can serious gaming be used to encourage cooperation between stakeholders?
- How can serious gaming be used to introduce and assess (economic) incentives into the ATM system?

The challenges provided guidance during the execution of the project, but they were never treated as limiting factors.

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3 Approach

The project ran for two years, from May 2013 until May 2015.

3.1 Work packages

The AeroGame project was divided in several work packages:

- WP1: Assessment of potential applications for serious gaming in ATM;
- WP2: Game design and development;
- WP3: Validation of the effectiveness of the game.

Several deliverables were attached to the work packages which are shown in Figure 1.

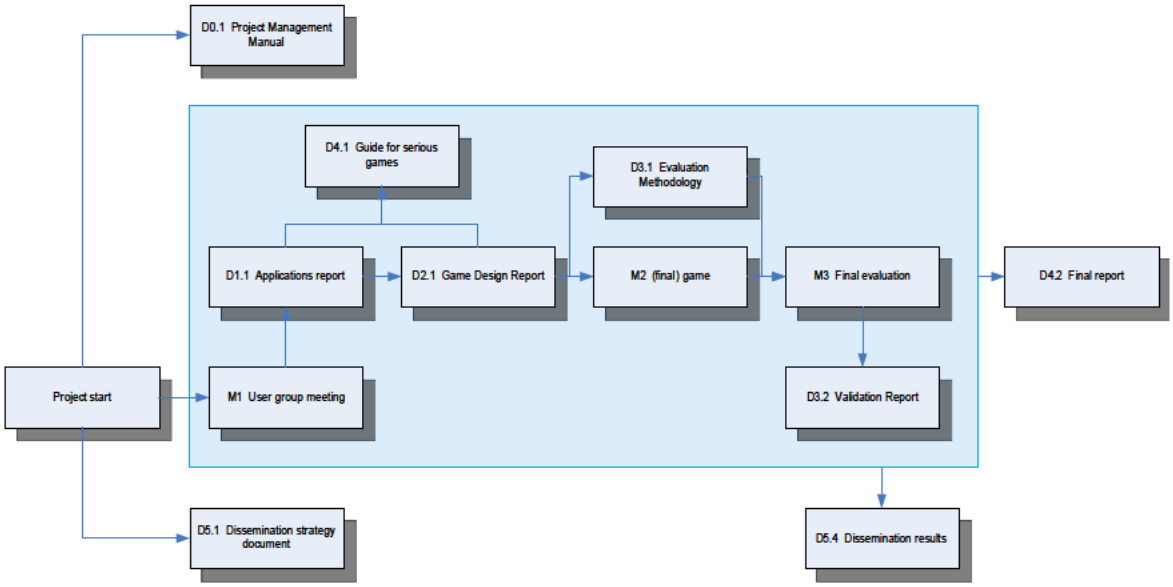

Figure 1: Relations between project deliverables and milestones

3.2 User group

An initial user group was formed even before the start of the project.. As the project is about supporting stakeholders in the change processes, the user group has been considered an important element of the project. During the project, the user group has expanded and eventually consisted of about 18 stakeholder representatives. There were two key moments at which the user group played a large role: during the assessment of potential applications for serious games in ATM and during the evaluation of the game. Throughout the project, the user group was kept in the loop by infrequent updates about the project's progress.

3.3 Workshops

Two workshops have been organized during the project. During the first workshop, the project team assessed potential applications for serious games, together with the user group. The details of the outcome of the workshop can be found in [3].

The second workshop was organized to assess the effectiveness of the game. The evaluation methodology described in [5] was used to test-play the game with the stakeholders of the user group. The results of the second workshop are described in detail in [6].

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3.4 User group survey

With the game development process well underway, a survey was sent to all user group members. It introduced the group's ideas of the game and requested input about specific aspects of the game. The results were used in the fine-tuning process in the last stages of the development process.

3.5 Roles of project partners

The roles of the partners in the project were clear from the beginning. NLR brought vast knowledge of ATM and SESAR and managed the project. T-XChange (Thales and University of Twente) has extensive knowledge about serious games, and was therefore responsible for the game design and development.

These roles were executed as planned.

3.6 Internal meetings and discussions

The project team members had frequent meetings to discuss project progress, to brainstorm and (later in the project) to test-play preliminary versions of the game. For most of these meetings, minutes were made and shared. Action points were defined and discussed via email and at the next meeting. In between the meetings, team members had direct contact with each other via email or telephone when necessary.

Specific action lists were maintained to provide guidance during the complex process of game development.

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4 Methodology

A step-wise approach was used during the project. After defining the scope and goals the first main activity was to select a use case for the assessment. After establishing the use-case, game development started as an iterative process with test-playing, providing feedback and re-designing the game when necessary. Parallel to this activity, the evaluation methodology was defined. Finally, this methodology was used to assess the game in the final workshop. Conclusions were then drawn about the applicability of serious games to advance change processes in ATM.

4.1 Game development methodology

Introducing new innovations requires changes not only in the technical systems itself but also in people behaviours, organisational and institutional structures. There is no single proven recipe for implementing these changes in organisation, let alone across multiple organisations. In the change management literature, however, one can find practical guidance to implement changes in organisations ([7],[8] and [9]). Most noteworthy is the eight-stage process for successful organisational transformation of John Kotter [8]. Based on more than 100 case studies Kotter observed that many change processes fail because organisations do not take a holistic approach required to see the change through. Based on extensive research and consultancy experience he advocates an 8-step process to change, which is supposed to increase the chance of success of change processes. Below we have summarised these steps and position which game type (see previous section) can be of help:

Step 1: Establish a sense of urgency: help others feel a gut-level determination to move and win, now. **Awareness games** can be used to develop awareness for the problem of doing nothing and help create a feeling of a necessity for change

Step 2: Form a guiding coalition: putting together a group with enough power to lead the change. **Co-creation games** can be used for team forming; in particular getting stakeholders to get acquainted with each other's visions and strategic interests.

Step 3: Develop a change vision: clarify how the future will be different from the past. Besides these applications, **Research games** can be used to collect knowledge that can be used for building a change vision, roadmaps and incentive schemes.**Co-creation games** can be used to support stakeholders in co-creating a vision on how to introduce the envisioned SESAR innovations

Step 4: Communicate the vision for buy-in: ensuring that as many people as possible understand and accept the vision. **Persuasive games** can be used to communicate specific characteristics of a particular SESAR innovation or set of innovations (the total package).

Step 5: Enable action: remove barriers and unleash people to do their best work. **Training games** can be used to train people to operate new technological systems.

Step 6: Generate short-term wins: create visible unambiguous success as soon as possible. **Persuasive games** can be used to communicate successes (e.g. the added value of new technologies based on pilot results).

Step 7: Don't Let Up: consolidating gains and producing more change. **Gamification** can be used stimulate people to adopt changes and show the desired behaviour.

Step 8: Make It Stick: anchoring new approaches in the culture for sustained change. **Gamification** can be used stimulate and internalize desired behaviour.

Roughly speaking, these eight steps can be organized into four phases: Envisioning (step 1 and 3), Engaging (step 2 and 4), Enabling (step 5) and Embedding (step 6, 7 and 8).

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Although games are widely used there is little consensus what serious games essentially are. While some view games as an activity, others view games as systems. What most activity-based definitions have in common is that gameplay is seen as an activity in which players pursue a challenging goal by performing actions in a limiting context governed by game rules. Within the AeroGame project, we distinguished game systems from gameplay. When viewed as a system, games can be described in terms of their constituting elements and relationships. Gameplay can then be defined as the observable behaviour of the players interacting with the game system. The design framework for developing our game is based on Schell's [10] building blocks of a game system:

- **Story**: every game contains information that needs to be made accessible to players to be able to play the game.
- **Aesthetics**: how games look, sound, smell, taste and feel. The graphic design of game is an important element in games; it directly influences players' experiences.
- **Technology**: doesn't just refer to video technology but any materials and interactions that make a game possible. Technology is the medium in which the aesthetics take place, the mechanics will occur and through which the story will be told.
- **Mechanics**: procedures and rules of a game. Mechanics describe the goal of a game, how players can try to achieve it, and what happens when they try.

4.2 Evaluation methodology

This section describes how the AeroGame effectiveness was evaluated. As there is little sound literature about measuring the effectiveness of serious games, the work done in AeroGame can be seen as pioneering in this area. The theory of Kirkpatrick [11] for measuring the effectiveness of training media was used as guideline.

4.2.1 Evaluating learning environments

A major advantage of serious games is that they are a much cheaper solution than full blown simulators, while they still allow players to experiment in a motivating and safe learning environment.

Even though the evaluation of the effectiveness of learning environments has received a lot of attention from the scientific community, more specific research into the effectiveness of serious games often lacks a well thought out strategy. If the effectiveness is evaluated, it often stops at a discussion with players or with a questionnaire, which is often very subjective.

The most important hypothesis that is used to base the evaluation of learning environments on is the work of Donald L. Kirkpatrick on evaluating training media [11]. In this work, four levels are introduced on which evaluation can take place. These levels are described in Table 4-1.

Level	Measurement	
1	Reaction	What participants thought and felt about the training medium.
2	Learning	The resulting increases in knowledge and/or skills, and change in attitudes.
3	Behaviour	Transfer of knowledge, skills, and/or attitudes from the training medium to the job.
4	Results	The final results that occurred because of attendance and interaction with the training medium.

Table 4-1 Four levels of learning evaluation

The lower levels (level 1 and 2) are easier to measure and take up less time. The higher levels (level 3 and 4) are (much) more difficult to measure (if they are measurable at all), but a positive outcome more convincingly proves the effects of learning materials and/or the learning environment.

Measure the "Reaction" effect on serious games

The most common evaluation method is to measure the reaction of the participants regarding the learning goals and the game. An effective way to do this is to make use of a so-called "Smile Sheet", which asks players to indicate how much they appreciate various factors related to the game.

Measure the "Learning" effect on serious games

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The learning effect of serious games is the increase of knowledge, skills and/or the change in attitudes. A pre- and post-quiz measuring the knowledge levels, and pre- and post-tests measuring skill levels and/or attitudes create insight in how much was learned during the game.

Measure the "Behaviour" effect on serious games

Measuring the "behaviour" effect signifies measuring the transfer of training from playing the game to the working environment. The player may know and understand why certain results were achieved and others were not achieved in the game, but can he use that understanding in his job?

It is difficult to measure this change in behaviour, because there usually is a time delay between playing the game and executing the task. Therefore, all kinds of factors may influence changes in behaviour, such as tiredness or discussions that the player has had with his employer or a changed environment that forces the player to act differently.

Measure the "Results" effect on serious games

The most difficult outcome to measure is the result. The results are the goals that one wants to achieve and for which purpose the game is deployed. For example, a company wants to increase its profits by 10% within 5 years. One of the means to achieve this is training the employees with a serious game. It is easy enough to calculate if the 10% target is achieved, but it is much harder to deduct how much of this result can be attributed to the game.

To conclude, for AeroGame, the first two levels were most applicable and feasible to measure. The behavioural level requires multiple test groups and requires a significant effort beyond the scope of the project. Finally, the measurement of the “result” according to Kirkpatrick’s theory was considered infeasible and requires isolated research which is impossible to conduct in this domain (ATM). For this reason, a different approach is taken where two different perspectives are evaluated to determine the AeroGame results, as described in the following section.

4.2.2 Evaluating effectiveness

This section describes how the effectiveness of AeroGame was measured. It was approached from two different perspectives:

- **Game engagement (or Kirkpatrick’s Reaction effect),** well-designed games have the ability to motivate and to draw people into the game. Sometimes people find games so engaging that they stop noticing things around them and focus all attention on the game. This psychological state is often referred to as flow [12] Research of Webster, Trevino & Ryan [13] indicates that flow has a positive impact on learning.
- **Game-based learning**, serious games do not focus solely on entertaining people, but on learning. For game-based learning we consider the following two target groups:
    1. The players or stakeholders of the game: The effectiveness of a serious game can be measured by analysing what players (stakeholders) learn from the game.
    2. SESAR and the AeroGame project: Games can also result in gathered information about the players. AeroGame intends to yield information about the motivation of different stakeholders regarding various SESAR topics. This perspective is related to AeroGame’s meta-goals for SESAR.

4.2.2.1 Game engagement

An important pre-condition for learning is that the game facilitates a positive game engagement. The term engagement refers to the level of involvement of a player in the game. Different concepts have been introduced to describe this involvement including immersion, presence, flow, psychological absorption and dissociation. The concept of flow was used as indicator for game engagement. Flow can be defined as a state of complete absorption or engagement in an activity. During flow a person is in a psychological state where nothing else seems to matter.

In order to achieve flow a specific set of conditions must be met. First, one must be involved in an activity with a clear set of goals and progress. This adds direction and structure to the task. Second, the task at hand must have clear and immediate feedback. It is claimed that this will help people to negotiate any changing demands and allow them to adjust their performance to maintain the flow

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state. Third, a good balance between the perceived challenges of the task at hand and people's perceived skills will help to create a flow state.

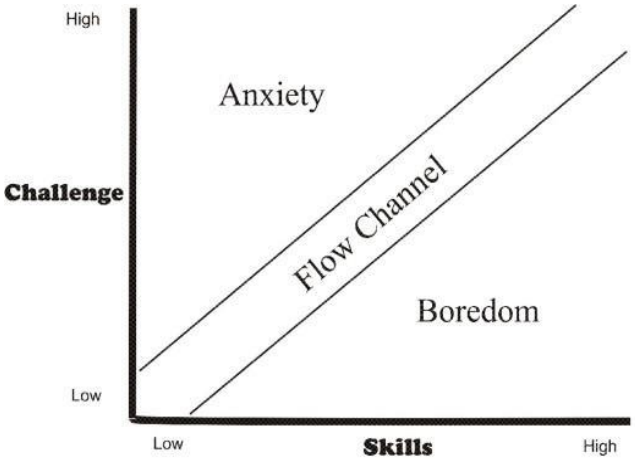

Figure 4-1 Flow [1], page 74.

To measure if a game is effective in achieving engagement, one needs to evaluate the perceived game experience of players. To measure game engagement the 19-item Game Engagement Questionnaire [14] was used.

Table 3-1 Game Engagement Questionnaire items

1	I lose track of time
2	Things seem to happen automatically
3	I feel different
4	I feel scared
5	The game feels real
6	If someone talks to me, I don't hear them
7	I get wound up
8	Time seems to kind of stand still or stop
9	I feel spaced out
10	I don't answer when someone talks to me
11	I can't tell that I'm getting tired
12	Playing seems automatic
13	My thoughts go fast
14	I lose track of where I am
15	I play without thinking about how to play
16	Playing makes me feel calm
17	I play longer than I meant to
18	I really get into the game
19	I feel like I just can't stop playing

4.2.2.2 Game-based learning

The question for this type of evaluation is whether the players of the game have learned something after playing the game. Several learning techniques (e.g. learning by doing, case based learning, experimentation, feedback, role playing, situated learning, etc.) can be used in games to support players in learning. According to Prensky [15] the challenge is to blend these learning techniques with gaming in such a way that they strengthen each other. Not enough emphasis on learning induces the risk of the game being just entertaining; not enough emphasis on gameplay induces the risk of unmotivated students.

The first two levels of learning from Kirkpatrick: *reaction* and *learning* are most practical to measure if players have learned from playing the serious game.

Besides creating awareness among stakeholders, the game can be used as a research tool to investigate how the foreseen SESAR innovations can 'best' be introduced. An important issue is how to ensure the required multi-stakeholder collaboration in deploying and getting the innovations

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accepted. A growing number of studies based on *Game theory* indicate that people are imperfect co-operators and that they tend to cooperate only if others do so. A minority of people show social loafing which is free riding, sometimes at the costs of other people. Research indicates a wide range of psychological factors (e.g. trust, empathy, and equity) influences people's cooperative behaviour [16]. People need to be stimulated to sacrifice self-interest for the collective benefit (e.g. a new information system). This raised the question of how to encourage cooperation between stakeholders with diverse interests?

Serious games can be used as research instruments to find out under which conditions stakeholders are willing to sacrifice their individual interests for the benefit of a group. In this project the following game results or information items apply:

1. Stakeholders' high level understanding of the SESAR innovations.
2. Stakeholders' prioritisation of the Key Performance Indicators (such as economy, safety, environment).
3. Stakeholders' evaluation of the SESAR innovation in terms of value for their business (what is in it for me?).
4. The motivation (argumentation) of each stakeholder to invest or not in particular SESAR technologies.
5. Stakeholders' openness and trust towards each other and their impact on the achievement of individual and collective goals.
6. The level and timing of investments in SESAR technologies of each stakeholder.
7. The occurrence of deadlocks, tactics to deal with these deadlocks, and their effects on the willingness of stakeholders to invest in SESAR technologies.
8. The occurrence of free riders, tactics to deal with the negative effects of social loafing, such as effects on the willingness of stakeholders to invest in SESAR technologies.
9. The external conditions (e.g. government regulation, economic decline) that might stimulate or hamper stakeholders' investments in SESAR technologies.
10. The lessons that can be drawn from game play for the development of the SESAR roadmap.

This information was expected to be of use to support the construction of an acceptable roadmap for the deployment of these technologies. This information was primarily collected using the following data collection methods.

Table 4-2 Data collection methods for evaluating indirect game results

Information item	Data collection method
1, 3, 4 and 5	Asking players to articulate their motivation for choices (during and after game play by a facilitator).
1, 3, 4 and 5	Capturing of player discussions (by an observer)
5, 6, 7, 8 and 9	Logging of player and facilitator actions (by an observer)
10	Debriefing of game play with players (discussion with observer and facilitator after playing the game)

4.2.3 Evaluation plan

The game process consists of the following steps: preparation, instruction, gaming and debriefing. In each of these steps data collection methods were used to evaluate the game design, experience and effects. These are depicted in Figure 4-2.

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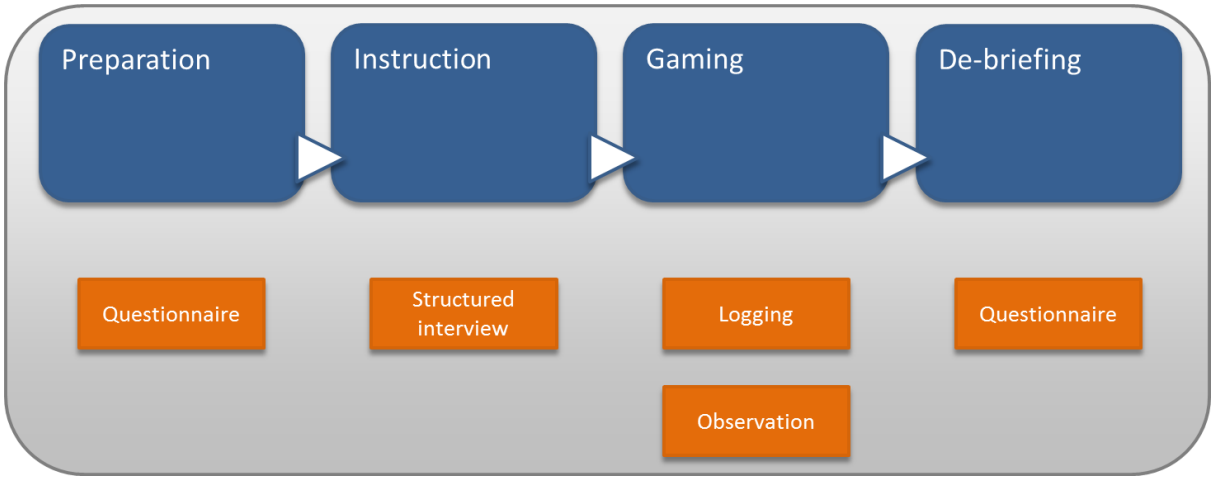

Figure 4-2 Game process and data collection methods

The AeroGame project has made use of a dedicated *observer* to collect the indirect game results related to the SESAR part of the meta-goals of the game. This helped answer the main research question on the value of serious games to support change processes in ATM. Obviously, this method is subjective and depends for a large part on the composition of the group of experts.

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5 Game development process

Before the game development process started, the scope (resulting from WP1) and the meta-goals (relating to the proposal) for the project were defined. Next, using the methodologies described, the game development process started.

5.1 Scope

The scope of AeroGame was narrowed down to the use of serious gaming to support the design of effective deployment roadmaps and incentive schemes. These are critical success factors for the introduction of ATM innovations, according to the experts consulted in the AeroGame brainstorm workshop and user group survey. The meta-goals of AeroGame are a combination of the following:

- Ensure that the players are aware of the necessity of the change and its effects (**awareness goal)**;
- Provide valuable input for a definition and roadmap of the change process (**research goal**).

These goals, combined with entertaining elements, should ensure that AeroGame is a useful tool for supporting change processes in ATM.

Work package 1 resulted in the conclusion that the game concept would be designed in such a way, that it is generic enough to support different use cases. For one use case the AeroGame project developed a ready-to-use game. To demonstrate the generic character of the game concept itself, a second use-case was applied to the framework as well (as a proof of concept, it was not worked out into a full game). The results from the output of the game sessions were defined as important recommendations, aspects to be taken into account, and instructions on how to prevent deadlocks in the process of creating a roadmap for a change process in ATM..

The primary use case that has been selected in work package 1 is the introduction of **4D trajectories** in the ATM system. The secondary use case is that of the introduction of **SWIM**.

5.2 Meta-goals

The intended effects of playing a game are described in two types of goals. The *game-goals* are related to the game itself and describe how the game can be “won”. The *meta-goals* are related to the AeroGame project itself and describe the relation between the outcome of the game and the project. The meta-goals are related both to the players of the game and the SESAR project in general. The meta-goals of AeroGame are listed below.

The meta goals are intended to support change processes in ATM by:

1. Providing valuable input to the definition and roadmap of the change process.
2. Ensuring that the players are aware of the necessity of the change.
3. Letting the players co-create the change (create a buy-in).

The first meta-goal is directed towards achieving goals defined by SESAR. By organizing game sessions with stakeholders around a specific technical solution, valuable input has been identified for the development of a roadmap for SESAR innovation. Important inputs were: stakeholder costs and benefits and the timing of actions. This information can be used to improve existing roadmaps or be used as starting point for developing a roadmap.

The second and third meta-goals are directed towards players of the game. For them, the idea of the game is to provide a safe experimentation environment in which stakeholders can learn more about a particular technical solution, its impact on ATM and under which conditions it will work. This has influenced the attitude of stakeholders towards change.

5.3 Process

The game development process was executed partially in parallel with the game design. Using a rapid prototyping approach, initial ideas were quickly translated into a playable version of the game. Initial versions of the game were tested with the project members. Test playing sessions provided valuable information, which was fed back into the design process. As soon as a more mature version

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of the game was available, the game was test-played with a number of domain experts of NLR to further fine-tune the game.

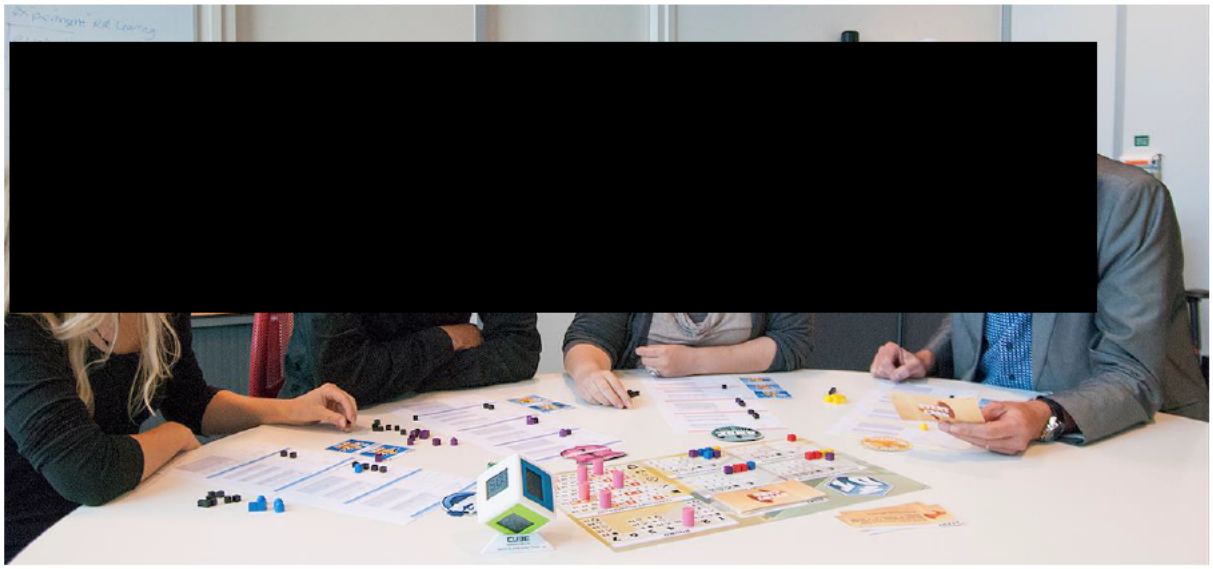

Figure 5-1 Internal test session

During the process, graphics were developed resulting in significant (visible) improvements in each iteration of the game.

5.4 Design Choices

The game concept that formed the foundation of AeroGame was kept as generic as possible. This ensured that the game concept can be used to facilitate multiple types of change processes with different stakeholders or even in different domains. This generic character makes it possible to adapt the game for cases other than the use case chosen for the game and thus makes it more versatile and future proof.

Moving from airspace management to 4DT is a fundamental change to all stakeholders in the ATM system. It entails the systematic sharing of aircraft trajectories between the various participants in the ATM process to ensure that all partners have a common view of a flight and have access to the most up-to-date data available to perform their tasks. It enables the dynamic adjustment of airspace characteristics to meet predicted demand with minimum distortions to the aircraft trajectories.

4DT will only result in the expected benefits when all participants share in the development, investment and simultaneous introduction of the technologies and procedures. Free riders are a risk to the acceptance of solutions. Stakeholders must also allow that more of their operational information becomes available to others outside of their organisation. This potentially results in a business risk to the airlines.

For the 4DT use case, the following subset of SESAR solutions was chosen to play a role in the game:

Moving from Airspace to 4DT Management

This enabler ensures that aircraft trajectories are systematically shared and ensure up-to-date information on the flights. The enabler should lead to a trajectory management framework in which business and mission trajectories are exchanged resulting in the dynamic adjustment of airspace characteristics to meet predicted demand with minimum distortions to the aircraft trajectories. The system interoperability between air and ground for information sharing should be improved/created.

Traffic Synchronisation

The goal of traffic synchronisation is to optimize the traffic sequence of arriving and departing traffic, reduce the need for tactical interventions and to ensure optimal climb/descent profiles. It represents

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investments in arrival and departure management at airports, TMA and en-route. In addition it represents investments in technologies such as ASAS.

Network Collaborative Management & Dynamic Capacity Balancing

This enabler uses trajectory information to improve the planning of the ATM network (flow management) and to improve the insight in traffic flows. The enabler represents investments in Air Traffic Flow & Capacity Management (ATFCM), User Driven Prioritisation Processes (UDPP) and network operations planning.

Conflict Management and Automation

This enabler aims to reduce controller workload with advanced automation tools (while ensuring a central role for the human). It also includes the evolution of ground and airborne safety nets adapted to 4DT management systems. It involves investments in airborne spacing and separation tools and ground based conflict management tools.

The outcome of the game is measured by the values of a set of Key Performance Indicators (KPIs). For the 4DT use case, the following KPIs are used:

- Fuel efficiency;
- Network capacity;
- Predictability;
- Cost efficiency;
- Safety.

All KPIs in AeroGame are measured on the same scale: from 0 to 20. The starting value is 0 for all KPIs. This is of course arbitrary, and does not represent true values of the KPIs. In the game however, the starting point and equal scale makes it easier to compare KPIs and their changes during play. For instance, if an investment leads to an improvement of cost effectiveness by +1, and an improvement of predictability by +2 this means that this investment does more to predictability than to cost effectiveness.

The maximum value of each KPI in the game is not necessarily the value 20 but is based on the expected gains, assuming the 4DT technologies are implemented. The maximum value for each KPI is set between 12 and 20. The scale and the step size is a compromise between simplicity and meaningful representation of the changes brought by the implementation of the 4DT technologies. A short and simple scale is preferable in order to understand the game, have a quicker overview of the game state and help keep the game board size within limits. On the other hand, each player can influence the KPI values. To visualize each change, the scale has to be long enough, since the influence of all four players is added up over time. Also, not all changes have equal effects, so a longer scale makes it easier to represent the step size differences between various effects.

Player roles

The stakeholders translated into player roles within the game are (once again, with the same goal of reducing complexity in mind):

- Air Navigation Service Providers;
- The government;
- Low fare airline operator;
- Legacy airline operator;
- Airports;
- Military.

The rationale for selecting these stakeholders is that they are the stakeholders that play a vital role in the acceptance of 4DT in SESAR. Furthermore, a choice is made to include both a traditional airline operator and a low fare airline operator as their motives and their willingness to invest is likely to be different.

The game is played with four stakeholders. For this reason, a selection is made out of the available player roles based upon the participants and their backgrounds. Each role has a similar personal scoreboard, except for the aesthetics/design of the scoreboard that represents the player role. In

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theory, more than one similar role can be played within a single game (e.g. two ANSPs) if necessary, although this may undermine the awareness goal (you learn less from equals than from others).

In order to represent these stakeholders in a meaningful way, the players are expected to possess knowledge of the domain, the use case and the stakeholders' view. The best results are achieved when the players of the game are actual representatives of the aforementioned stakeholders, preferably on a management level.

5.4.1 Aesthetics: minimalistic styled graphics

The choice concerning aesthetics in AeroGame was led mainly by the choices made for mechanics and story. In order to achieve a balanced experience, the four game building blocks needed to fit each other as best as possible. The use of a low-fidelity simulation model (a model with a low complexity and a rather high abstraction from reality) and the serious nature of the game call for a minimalistic, stylized graphic style. The fidelity of the graphics corresponds with the fidelity of the simulation. One is therefore naturally recognized as appropriate, when the other is considered. The theme of ATM and 4DT was depicted on the board game elements, which helps the players to instantly recognize the subject and the use case. In order to make the learning curve as gradual as possible, most terms in the game are represented by icons as well as text.

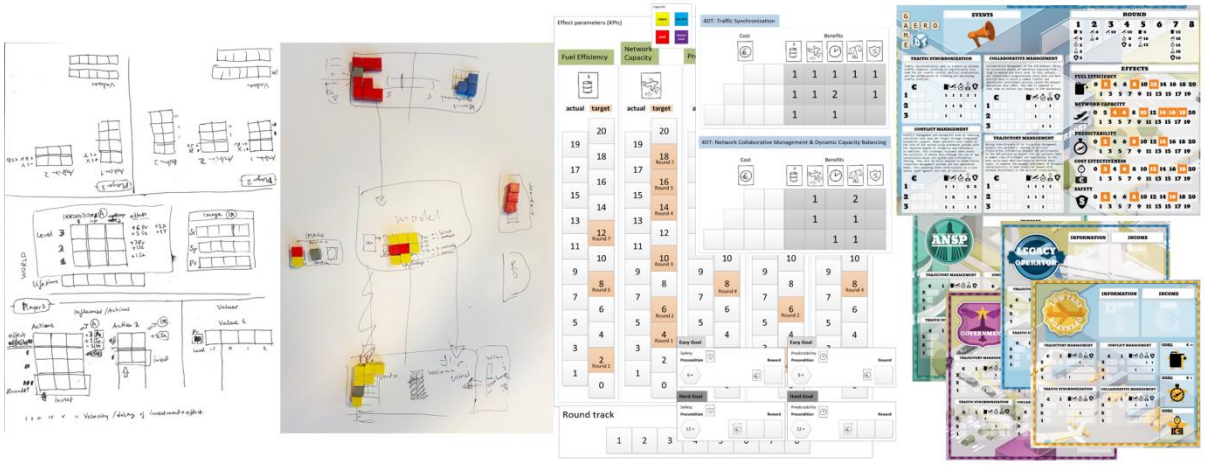

Figure 3-3 AeroGame evolution

Figure 3-3 shows the evolution of the game prototype aesthetics, from the first sketches to the final graphics.

5.4.2 Technology: hybrid game

With respect to technology, a hybrid game was chosen: a (paper-based) board game supported by a computerized effect viewer (i.e. scoreboard).

The board game implementation was chosen over a full digital game for the following reasons. First, the interaction with physical game elements like pawns, dice or coins, adds to the players' feeling of control (agency) and commitment to their actions. Second, a board game provides players with an excellent, hard to beat, overview of complex problem situation and the underlying mechanisms at work. Finally, an advantage of board games is that the game rules, the simulation model, and the content is not programmed, but can be changed by the game master during the game play. Players can add, subtract or change game rules, simulation model and content, even on the fly. This has been done with AeroGame as well, e.g. with the introduction of event cards: these can be skipped during the earlier rounds if the game players do not yet understand the basic rules. This gives AeroGame a level of flexibility that would not be feasible if it were a completely digital game.

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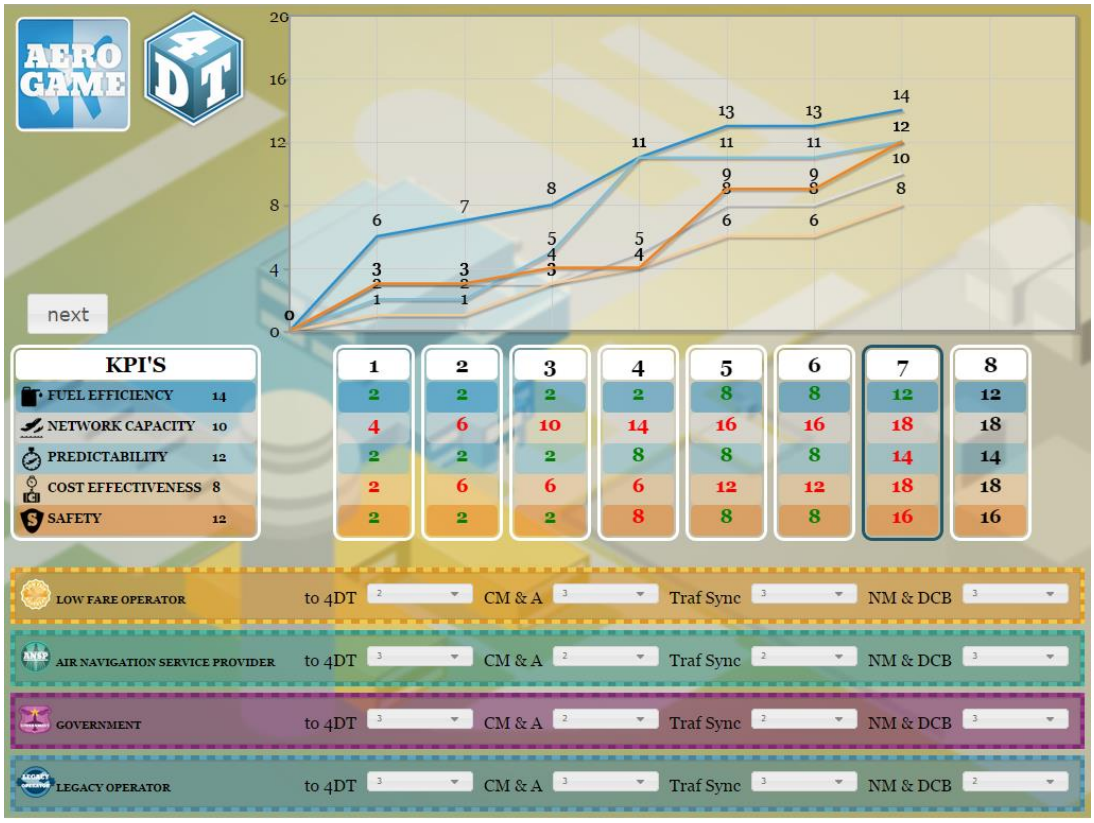

Figure 5-4 Early version of the computerized scoreboard

A computerized effect viewer supplements the board game. This allows speeding up the tedious and error prone activities such as keeping track of the changes during play. The software can also capture the gameplay history, which is useful for debriefing and reporting.

5.4.3 Mechanics: competition and collaboration

AeroGame can be described as a *coopetition*; a combination of a cooperation and a competition game. The coopetition characteristic applies to the game mechanics only. The choice to include them in AeroGame is based on several factors.

Both competition and cooperation mechanics have their value. Both are instantly recognizable and understood by the majority of players. The game tries to be as generic as possible and to be appealing to a broad group of players. A competitive setting motivates most players. This drives them and keeps them playing. The competition mechanic is needed to represent and pursue the individual goals and stakes that resemble those that players have in reality.

A minority of players are more motivated by cooperation and common goals. Inclusion of this mechanic is therefore useful regarding appeal of the game. Additionally, it is fitting when considering the use case, and SESAR-related innovations in general, since a successful implementation of most of them relies on trust and cooperation between the stakeholders. Finally, a cooperative setting helps the group forming process. This is helpful, since a group feeling creates trust and helps the players to adopt an open and sharing state of mind, and this is crucial considering the meta-goals of AeroGame.

The competitive aspect comes from the fact that the players have their own agendas, resources, goals and stakes in the process. The cooperative aspect of AeroGame is expressed through group targets, which need to be reached by the players as a group to win the game, and a degree of cooperation and coordination with other players is a necessary condition for reaching these targets. The multiplayer setting enables discussion, cooperation and creation of shared mental models.

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5.4.4 Summary of main game design choices

For each of the game elements a number of choices have been made. Table 3 shows the mapping of design choices onto the four game elements described earlier.

Table 3 Summary of main design choices

Game element	Main design choices
Story	Use case, and relevant stakeholders modelled and represented in the game. Complemented with player choices (goals and KPI priorities) and real life equivalents of discussed in-game choices (emergent narrative).
Aesthetics	Minimalistic, stylized graphics, recognizable theme, iconic representation of the player roles.
Technology	Board game with tangible game attributes (pawns, cards, dice). Optional computer aided elements (calculation of effects and logging of actions).
Mechanics	Cooperative (group target) and competitive (individual goals, single winner) elements. Multiplayer (4 players), facilitated game. Game simulation model (use case, player roles) complemented by human-in-the-loop model (players tacit and explicit knowledge).

5.5 Overview of the game

The game is played by four players and led by a facilitator. The game has a physical component (game board and cards), and a digital component (the score board). The players interact with each other and the game board while consulting the digital score board. A schematic sketch of the game setting is presented in Figure 5-2.

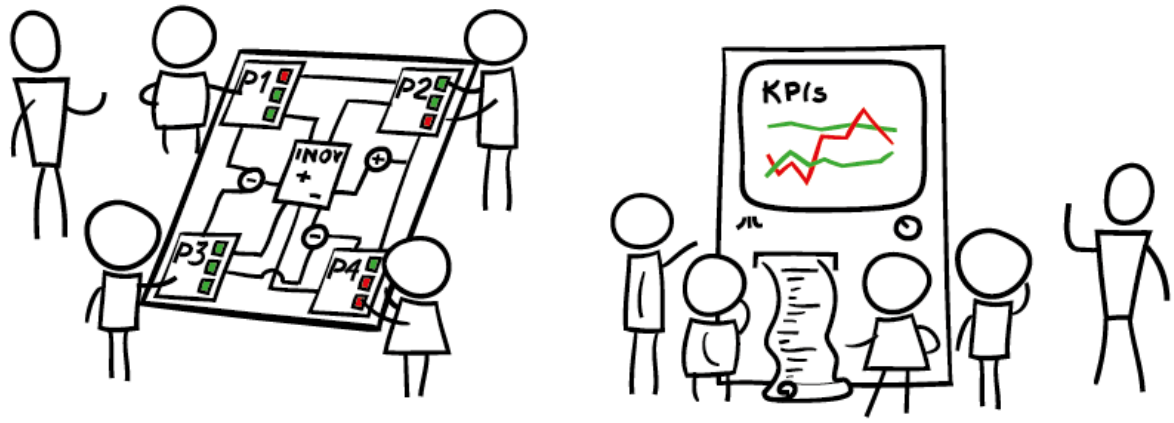

Figure 5-2 AeroGame setting

Players are free to select which goals they want to reach in the game. Each goal is expressed in a minimum target value of one of the KPIs. Each player choses two KPIs that he is most interested to see increased. The goal for each player is to increase the Key Performance Indicators (KPIs) of their choice with a minimum use of resources by investing in the technologies. The player with the most resources left at the end of the game wins. However, when the investments of all stakeholders together are insufficient for a successful implementation of 4DT, everybody loses.

For each technology a number of levels are defined. When a level is reached, a specific set of KPIs, related to that technology increases. Although individual investments in a technology already have a positive effect on the KPIs, this is not sufficient to reach the target levels. Synergy effects come into play when multiple stakeholders invest in the same technology. Therefore frequent discussions and negotiations with the other players are key to playing the game.

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The simulation model, connecting investments to KPIs, does not aim to reach a 1:1 model of reality. The in-game model is a rather simplified model of reality. It is important to simplify in such a way that the players understand and accept the in-game model and recognize its relevance, and are able to communicate their ideas and understanding of the content during game play. This is needed in order to reach meaningful conclusions about the outcome of the game.

To enable a gradual learning curve for the players, all cause and effect relations in the simulation model are modelled using fixed values, i.e. effects of player actions are deterministic. This makes it possible for the players to understand and even predict the effects of their in-game actions. To aid this further, the game is turn-based. Each turn the players repeat a cycle, where they assess the state of the game, discuss and plan their actions, and subsequently execute these actions. This leads to a changed game state, which can be assessed the following turn, and so on. The turn-based character of the game additionally helps the players to comprehend and structure the game and the ensuing discussions.

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6 Validation results

This chapter summarises the key findings of testing the AeroGame prototype with stakeholders in the loop. The game was tested on 30 January 2015 at NLR premises in three parallel working groups consisting of twelve different stakeholders in the roles of low fare airline, legacy airline, ANSP, airport and government. The game was evaluated, using a pre- and post-test questionnaire and observations from an observer.

The data on game engagement, game-based learning and game analytics have been collected using the following three data collection methods:

1. **Pre-questionnaire**: players filled in a questionnaire before playing the game
2. **Post-questionnaire**: players filled in a questionnaire after playing the game
3. **Observation**: observing the game play using a structured observation protocol

The methodology has been described in Chapter 4. The full pre-test and post-test questionnaires can be found in [6]. A more elaborated description of the data collection method can be found in D3.1 (Evaluation methodology report) [5].

6.1 Workshop setup

The workshop was hosted at NLR premises in Amsterdam. The project assembled a user group with representatives from relevant stakeholders, such as airports, ANSPs, low-fare and legacy airliners, and government. The agenda the workshop was as follows:

- Introduction AeroGame project and game prototype
- Pre-test questionnaire
- Playing AeroGame to learn how it works
- Lunch
- Playing AeroGame for real
- Post-test questionnaire
- Evaluation and victory ceremony
- Drinks

The players were first briefed on the project, its goals and were given an overview of the game. They then were asked to fill in the pre-questionnaire. Subsequently the group was divided into three subgroups. Each group then played the game for several rounds to learn the game rules and understand how it works using a test scenario. After lunch the group was divided into three, yet different, subgroups in a way that each table had representatives from different stakeholders. A *game master* and a *facilitator* jointly guided the game. After playing the game, the players were asked to fill in the post-questionnaire. Finally the game was evaluated with the groups (discussion led by the facilitator) and the winners of each game table were awarded a price.

For the evaluation a group of 12 stakeholders was available. These were: 3 airline representatives, 3 ANSP representatives, 2 government representatives, 2 airport representatives and 2 representatives from ATM research institutes.

6.1.1 Attitude/knowledge of 4DT

The pre-game questionnaire was handed out to the players after the general introduction. They had not yet seen the game and had therefore little prior knowledge. To make players aware of the effects of 4DT it is important to determine their baseline attitude towards 4DT. First players were asked how

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familiar they are with the concept of 4DT. The results are depicted in Figure 3.

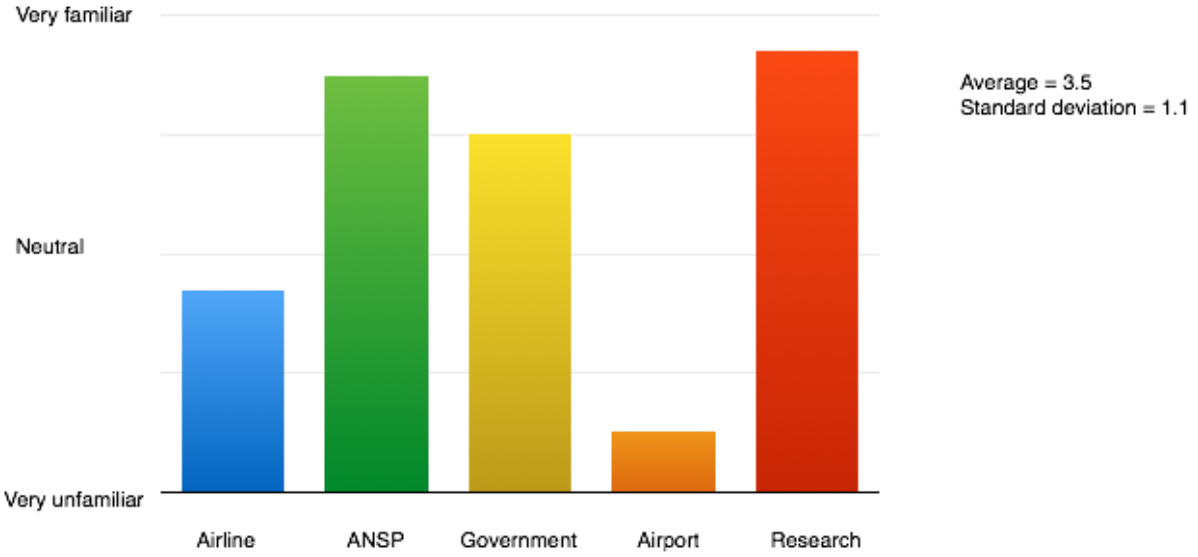


Figure 3: Question 1, "How familiar are you with the concept of 4DT management?"

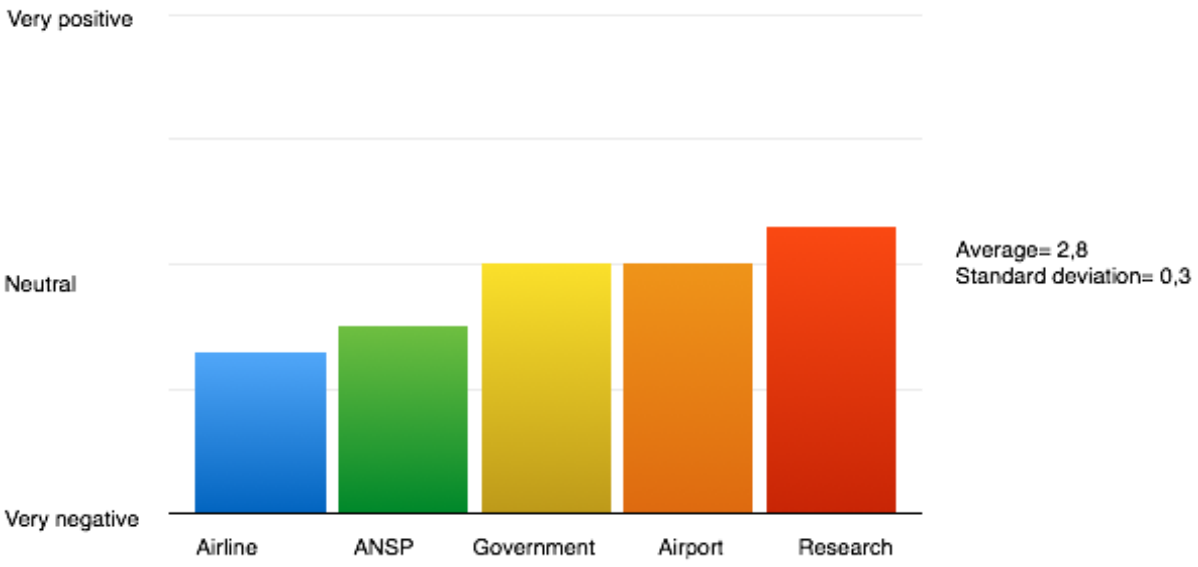
With an average score of 3.5 on a scale of 1 (=very unfamiliar) to 5 (=very familiar) one can say that the players are not familiar and not unfamiliar with 4DT with the airlines and airport scoring relatively low (*t(10)* = 1.047, *p* = .320). The answered differed significantly between stakeholders.

Later, in question 22, players were also asked to respond to the statement: *"I have a good understanding of what comprises the introduction of 4DT*" on a scale of 1 (=do not agree) to 10 (=fully agree), see

Table 4. The result, 6.2 with an standard deviation of 0.3 does not differ statistically significant from the middle (*t(10)* = .747, p = .472). The variation is rather large which is in line with the results of Question 1.

Players were asked how they perceive the introduction of 4DT (question 2). The results show that the players have a moderate to negative attitude towards the introduction of 4DT. The average score is 2.8 on a scale of 1 (=very negative) to 5(=very positive). The results are depicted in Figure 4.

Figure 4: Question 2, "How does your organization perceive the introduction of 4DT?"



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Questions 18-24 were answers to statements about the attitude towards 4DT. The order in the table of the questions has been altered to match the order in the post-questionnaire.

Table 4: Questions 18-24

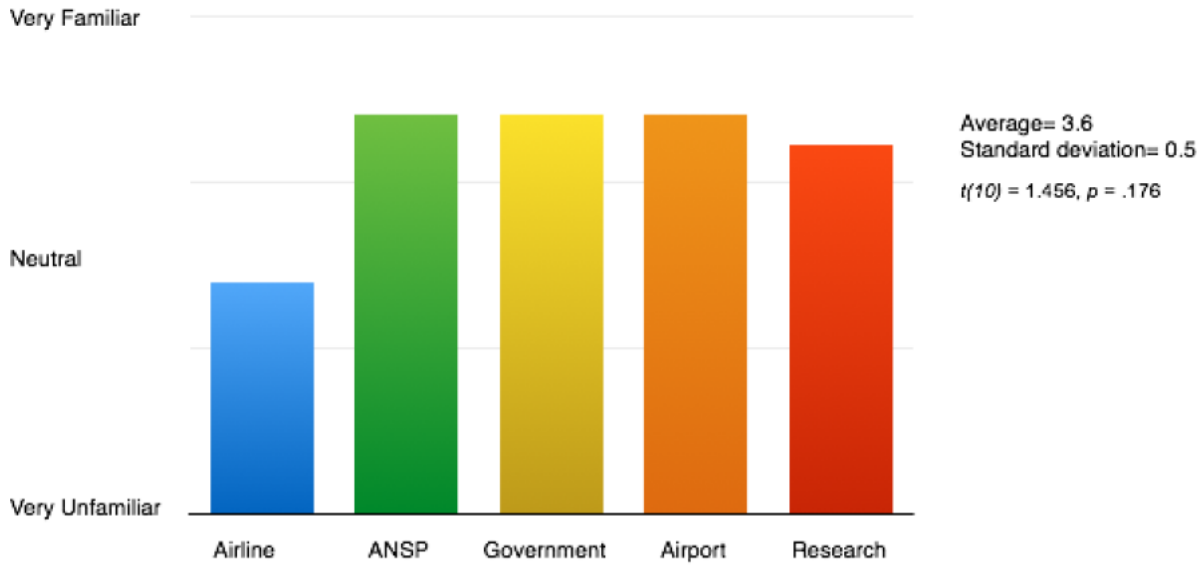
	Question	Avg. answer	Standard dev.
18	Introducing 4DT is a cooperative effort (with other stakeholders).	8.4	1.0
19	Other stakeholders need my organization to successfully introduce 4DT.	7.0	2.8
20	My organization needs other stakeholders to successfully introduce 4DT	7.9	2.0
21	The benefits of introducing 4DT are higher than the costs	6.1	1.6
22	I have a good understanding of what the introduction of 4DT comprises of.	6.2	3.0
23	I support time based operations but a full 4DT ATM system is a step too far	4.3	2.9
24	I have a positive attitude towards the transition to 4D Trajectories.	7.3	2.1

6.1.2 Attitude/knowledge of serious games

Players were asked how familiar they were with serious gaming and how they felt about the application of serious games in general.

Most players seemed to be familiar with the concept of serious gaming. The average score was 3.6 on a scale from 1 (=very unfamiliar) to 5 (=very familiar). The airline representatives seemed to be the least familiar with serious gaming. However, the average did not differ significantly from the middle: neutral ($t(10)$ = 1.456, p = .176). The figure shows the answers of the players to the first question (averaged for each stakeholder).

Figure 5: Question 4, "How familiar are you with serious games?"



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6.2 Results of the post-game questionnaire

The post questionnaire was handed out to the players immediately after the evaluation session.

6.2.1 Engagement

An important pre-condition for learning is that the game facilitates a positive game engagement, also referred to as flow [17]: a state of complete absorption or engagement in an activity. During flow, a person is in a psychological state where nothing else seems to matter.

For measuring the level of engagement of players while playing the game players were asked to respond to 17 statements after playing the game. See the appendix for the exact statements that have been used. Players could respond to the statements on a scale of 10 (1=disagree, 10=agree). These statements tell something about the level of engagement of the different stakeholders. The results are summarized in Table 5.

Table 5: Game engagement

	Question	Average score	Standard deviation
1	The goals of the game were clear to me	8.5	0.9
2	I could keep my attention on the game	9.1	0.8
3	The game uses the correct terminology	8.3	0.8
4	The game facilitator asked questions that are relevant for the goals the game tries to achieve.	8.7	0.8
5	The game offered sufficient interaction	8.3	1.2
6	The pace of the game was too slow (lower is better).	4.4	1.5
7	The pace of the game was too fast (lower is better).	4.0	1.3
8	The game was motivating	8.2	0.9
9	The game was relevant for my work	7.8	0.4
10	It is easy to understand how the game can be used in my work.	7.3	0.6
11	The game rules were easy to learn	7.6	1.3
12	The game was difficult to play (lower is better).	3.9	2.2
13	The look and feel of the game appeals to me	7.6	0.9
14	The game in general appeals to me	7.9	0.5
15	The duration of the game was long (lower is better).	4.1	2.3
16	The duration of the game was short (lower is better).	4.2	1.4

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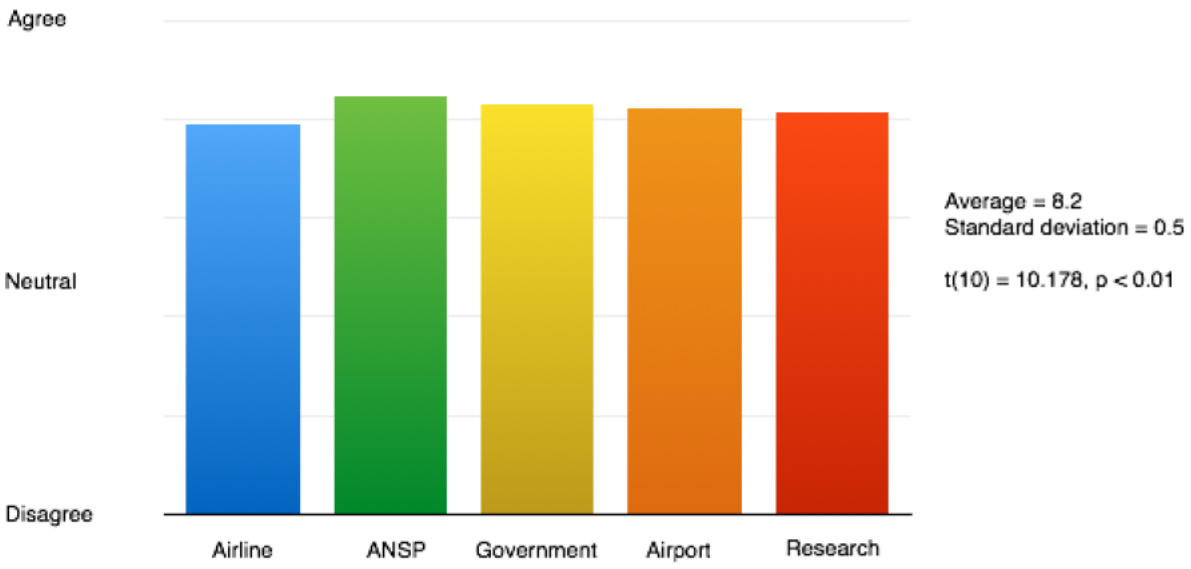
Question 17 directly asked the players to score game engagement.

Figure 6: Question 17, "I felt engaged in the game"



6.2.2 Attitude towards 4DT

Next, the players responded to 9 statements about their attitude towards AeroGame and serious games *after* playing the game. Some of these questions were also asked in the pre-test. The (averaged) answers are depicted in the following table:

Table 6: Questions 18-26, (change of) attitude towards 4DT

	Question	Avg. answer	Standard dev.
18	Playing the game improved my understanding about the issues at stake when introducing 4DT	7.0	1.2
19	4DT ATM as foreseen by SESAR is more clear to me after playing the game	6.7	1.7
20	Introducing 4DT is a cooperative effort (with other stakeholders).	8.7	1.1
21	Other stakeholders need my organization to successfully introduce 4DT.	8.0	1.7
22	My organization needs other stakeholders to successfully introduce 4DT	8.4	1.7
23	The benefits of introducing 4DT are higher than the costs	7.3	1.3
24	I have a good understanding of what the introduction of 4DT comprises of.	7.1	1.2
25	I support time based operations but a full 4DT ATM system is a	5.1	2.9

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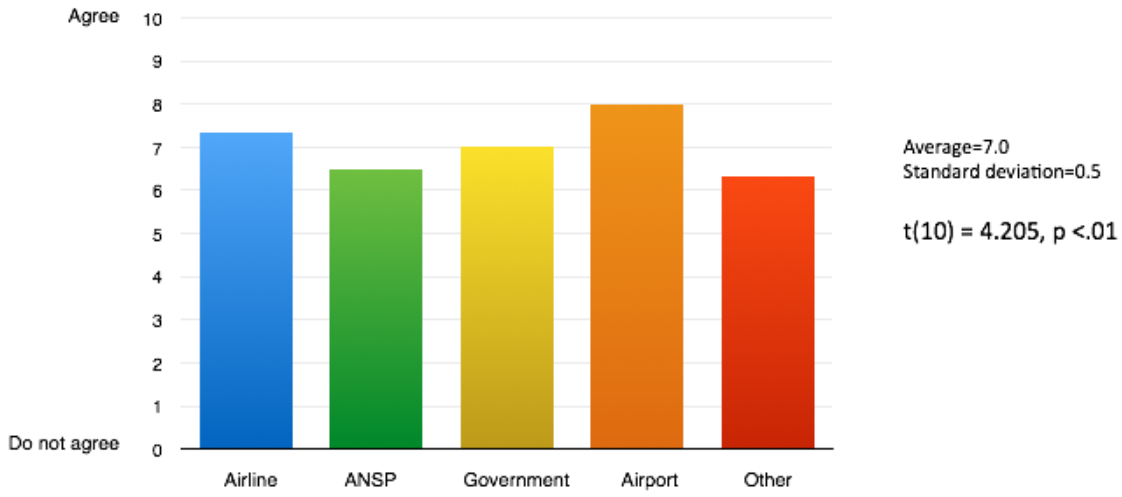
	step too far		
26	I have a positive attitude towards the transition to 4D Trajectories.	8.3	0.9

6.2.3 Knowledge about 4DT

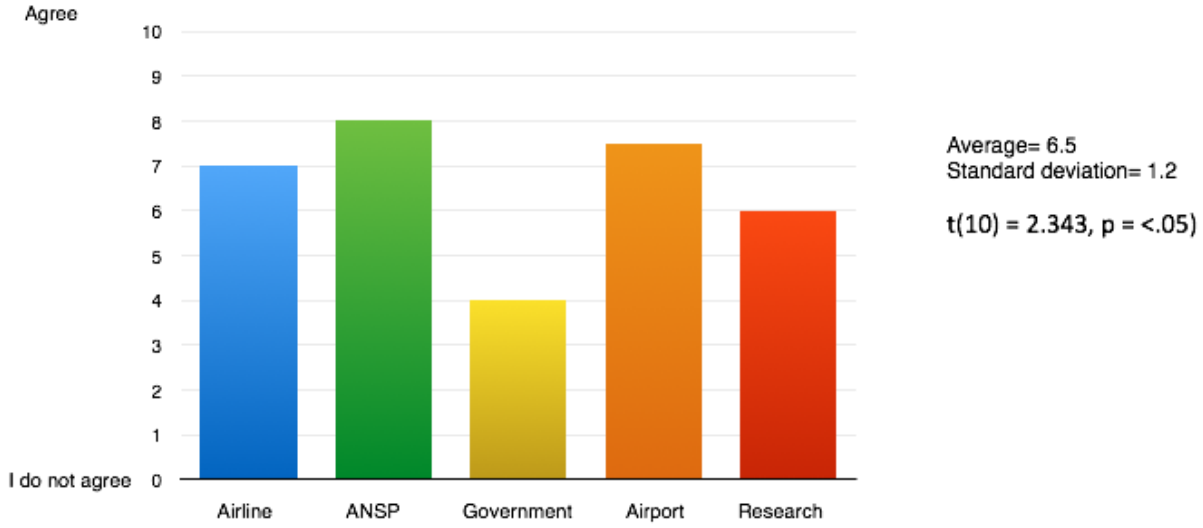
Zooming in on the results of question 18: "Playing the game improved my understanding about the issues at stake regarding the introduction of 4DT" results in the following figure:

Figure 7: Question 18, "Playing the game improved my understanding of the issues at stake regarding the introduction of 4DT"



Detailing question 19 shows that the standard deviation is rather high (1.7). However, the average deviates positively from the middle (*t(10) = 2.343, p <.05).*

Figure 8: Question 19, "4DT ATM as foreseen by SESAR is clearer to me after playing the game"



Questions 38 through 40 were open questions about the attitude of stakeholders towards AeroGame, and results can be found in Appendix A.

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6.2.4 Perception of the game

Question 43 was about the broader applicability of the game within ATM. All stakeholders (100%) see this applicability. Within their own organization, 63% see application for serious games. There were also some open questions that provided further evidence to support this answer. The answers on these questions gave a good impression of the players on the game, and can be found in Table 13 and Table 14 of Appendix A.

Question 41 asked about whether stakeholders would recommend the game to others. The responses are given in Table 7.

Table 7: Question 41, "I would recommend AeroGame to…"

To colleagues	To management	To family	To others	No
70%	90%	10%	20%	0%

6.3 Results of the observations

6.3.1 Target selection

The selection of the primary and secondary targets provides insight into which targets require the most improvement in the eyes of the represented stakeholder. Most players were leaning towards selecting safety as primary or secondary targets, but this target was not selected often because it is considered to already be at a sufficient level within the domain. Also, the players indicated that they do not think that it can be improved much further.

Table 8 displays the targets that were chosen by each player.

Table 8: Stakeholder objectives; green shows primary objectives, orange shows secondary goals.

Stakeholder	ID	Sustainability	Network capacity	Predictability	Cost effectiveness	Safety
Airline	Low fare-1					
	Low fare-2					
	Legacy-1					
	Legacy-2 (research)					
ANSP	ANSP-1					
	ANSP-2					
	ANSP-3					
Government	Government-1 (research)					
	Government-2					
	Government-3					
Airport	Airport-1					
	Airport-2					

6.3.2 Investment strategies

Of the three groups that played the game, two achieved the group targets and one did not. This was not due to a lack of willingness to invest resources since the latter group invested the highest

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percentage of their resources. However, when comparing notes of the observers of the three groups it becomes clear that this group was much more competitive in the beginning of the game than the other groups. Also, the willingness to cooperate was not as evident as in the other groups. Furthermore, the stakeholders of this group did not spontaneously invest in each other or lend each other's resources. They were more focused on their own targets until halfway through the game. By this time, however, they were too late to fully make up for the uncooperative decisions they had made at the beginning of the game and could not reach the targets set by the game. The other two groups were much more oriented towards cooperation. They did find creative ways of cooperation, such as lending each other money or even guaranteeing success by offering a compensation of resources in case of failure.

During the debriefing, two players indicated that they tried to use an investment strategy that they would normally not use. They took on a different role to see how this would affect the other stakeholders. Also, they wanted to explore how alternative investment strategies would work out for them that they often came across with in real life. They indicated that this gave them a better understanding of what works in a cooperation and what not.

Resources were initially managed in a very open fashion. Players showed their current resource pool, income and profits. Some players became more secretive over time. They tried to hide their resources and tried not to draw attention to themselves when things were going well. They would try to influence the group based on the resources available to each player. Some players actively helped others who were doing badly and took action against others doing well. In one case a player even put his resources in his trouser pockets and acted as if he did not have any. This of course also represents real-life as most companies are not too transparent about their financial state.

6.3.3 Game engagement

The observers were asked to pay attention to high level occurrences during the game, such as comments, topics of the discussions and investment strategies. However, it is also possible to focus observations on the much deeper level of behavioural markers. These are indications that are relevant for successful behaviour. For example, behavioural markers for communications are (amongst others) making eye contact, display an active listening posture and paraphrasing. Game engagement can be measured by focussing on behavioural markers that are important for game engagement. However, these behavioural markers are, by our knowledge, not yet defined. Questionnaires are much more common for measuring game engagement and were therefore the sole pre-defined measurement instruments for game engagement.

Even though there are no scientific grounds (yet) for observing game engagement, the facilitators, game masters and some observers were asked to give an indication of the engagement after playing the game. The engagement was considered quite high: all players seemed to actively participate in the game and appeared to be engaged.

6.3.4 Lessons learned

In the debriefing sessions, players were asked about lessons learned during the workshop. The most striking answers are depicted in Table 9.

Table 9: Lessons learned

Role	Lessons learned
Airport	System is the winner
	In real life you just indicate that there is no money for investment, now will ask something
	Cooperation: save money and reach target
	Interesting to see that low cost airline invests in network capacity
Low fare operator	Could not reach my goals without talking to other stakeholders
	You need to do one step back, before you can do two steps forward
	In savings every one is listening, sells better than investments, a bit of grey areas in the 4 investment categories
ANSP	Discussion on primary goals within group helps reaching your own goals
	Establish common interest at the beginning of the game

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	It is necessary to all invest in technology, otherwise it does not work
	Understand roles and impact on strategy. Hiding money has been practiced by all partners, exercise in strategy and risk assessment
Legacy airline	Game can make people softer: more open to listen to others
	Investment decisions of others have an impact
Government	More attention to goals of others, look from the perspective of others, find common strategy, agree upfront on quick wins, change/ be flexible on strategy: follow, push, anticipate

6.4 Interpretation of the results

Using the results of the pre-game questionnaire, the post-game questionnaire and the reports of the observers of each table, conclusions can be drawn about the impact that AeroGame had on the players. In this chapter, for each of the evaluation goals, conclusions are drawn based on the available data.

6.4.1 Engagement

On the whole, players evaluated the game engagement relatively high (average of 8.2). Looking at more detail to the individual questions shows that the goals of the game were very clear to players (8.5), players were very well able to keep their attention on the game (9.1), the game was motivating (8.2) and the game was not too difficult to play (3.9). Finally, the relevance of the game to the work of the players was scored with a 7.8. When asked directly, players scored their engagement with an 8.2. Also, the players seemed to be engaged in the game during playing according to the facilitators, game masters and some observers. This indicates that the game has been well designed (in terms of engagement) to support game based learning.

6.4.2 Game based learning

In this section the findings regarding the player's learning process are summarized.

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6.4.2.1 Learning about 4DT

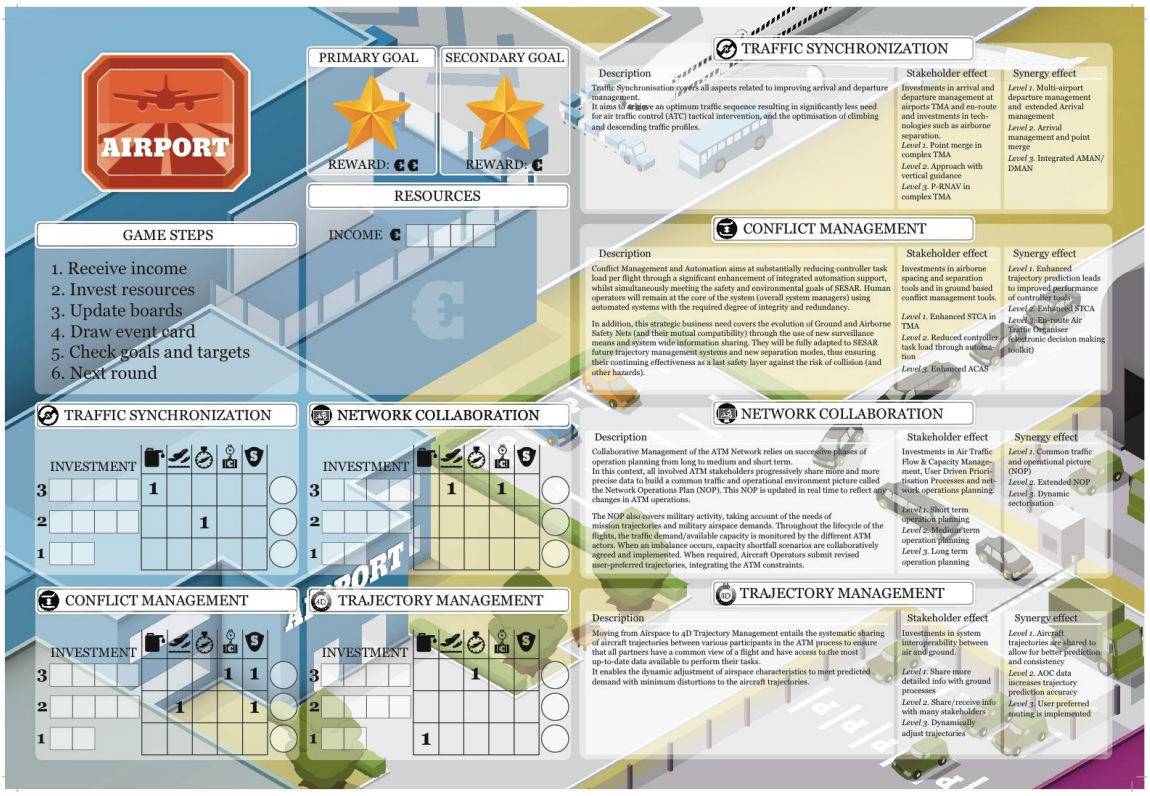

Figure 9: Game board for airport stakeholder

During the game development process, it was decided that each player/stakeholder would receive a similar player scoring board (See Figure 9), which describes the technologies, their different levels and the effect on the KPIs. As the SESAR concepts are still in development, not all details about 4DT are decided on. However, all information about technologies that is used in the game is based on the latest versions of the SESAR concept description. In addition, the interaction model that connects the investments in technologies to changes of the KPIs is based on several business cases defined by SESAR (see e.g. the appendix of [18]).

As the game is a simplification of reality, it does not cover *all* aspects of 4DT, however, taking the above into account, it can be concluded that all information about 4DT provided in the game is based on the most recent concept descriptions of SESAR.

Summarizing, it can be concluded that the knowledge of 4DT increases positively when playing AeroGame. For more in-depth knowledge on 4DT, other means (workshops, courses, literature) are still needed.

6.4.2.2 Learning about serious games

The attitude towards serious games in general is important for stakeholders to consider serious games as a tool in a change management process. Letting stakeholders experience a serious game may change this attitude in a positive way. Before playing AeroGame, the attitude towards serious games as a tool was neutral among stakeholders (pre-question 5), players were also asked about their expectations of AeroGame (open question). After the session, it was asked if the expectations had come true. It is clear from the responses of the players that, in general, AeroGame did meet their expectations. This means that the information that was provided beforehand was sufficient in terms of raising expectations to the players.

A question about the attitude towards various means of speeding up change was asked both before and after playing the game [6]. The positive attitude towards serious games increased after playing the game, while the attitude towards other means stayed equal.

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One of the final questions in the post-game questionnaire was about the change in attitude towards serious games after playing AeroGame (Appendix A, Table 14). From the responses it is clear that this attitude was either already positive, or has become more positive after playing the game.

6.4.2.3 Learning about collaboration

Players were asked what they have learned from the game. The results are shown in Table 9. In general players indicated that they have learned that they are dependent on each other and need to cooperate if they want to realize their goals. Openly discussing goals with others helps to understand the motives of other stakeholders and also helps to realize their own goals.

6.4.3 Game results

Besides creating awareness among stakeholders, the meta-goal of the game is to use it as a tool to determine how innovations and change processes in ATM can be 'best' introduced. These findings can then be translated for the definition of roadmaps for the introduction of new technologies, This section describes the results of the questions and observations related to this goal.

6.4.3.1 Objectives and priorities

The selection of targets was largely influenced by the economic value for the organization (e.g. cost reduction or productivity increase). Other underlying targets, such as environment and sustainability were rarely selected (both only once).

The observers noted that all airline representatives selected cost effectiveness as their primary targets. Their motivation was, in general, that money is necessary to maintain a healthy airline organization. A government representative also, surprisingly, selected cost effectiveness as primary goal because of the public opinion that costs should be cut and that aviation should be competitive. The ANSPs preferred to invest in network capacity and in predictability. Other targets varied a lot between stakeholders and within the groups.

6.4.4 Game strategies

Based on the investment schemes of the game and the results of the observations, game strategies of the players could be devised. Initially, on all tables the group discussions about where to invest and where not to invest in was led by only one of the stakeholders. This strategy evolved in a more individual investment plan over time and turned in a true group decision to the end. This is in line with the expected effects of the individual goals and common targets.

In the early rounds, players invested their resources in those solutions that were most beneficial to their goals. After a couple of rounds however, the players created new investment schemes. They started to invest in the solutions of other stakeholders, borrowed money from each other, and introduced conditional investments. All these investment strategies have their equivalents in real-life. These observations show that serious games have the potential to break the ice between stakeholders and to create thrust.

The outcome of the observations shows the potential of the game. A lot of information can be extracted from player behaviour. To draw definitive conclusions, more data is necessary (i.e. more games played) and it may be necessary that an observer targets a specific research question.

6.4.5 Changes in attitude

To determine if playing the game has changed the attitude towards 4DT, players were asked to answer several questions twice; once before and once after playing AeroGame. In Table 10 the results are summarized, showing both pre- and post-game answers.

Table 10: Pre and post questions concerning attitude towards 4DT

Attitude towards	Question	Average answer pre	Average answer post

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Collaboration	Introducing 4DT is a cooperative effort (with other stakeholders).	8.4	8.7
	Other stakeholders need my organization to successfully introduce 4DT.	7.0	8.0
	My organization needs other stakeholders to successfully introduce 4DT	7.9	8.4
4DT	The benefits of introducing 4DT are higher than the costs	6.1	7.3
	I have a good understanding of what the introduction of 4DT comprises of.	6.2	7.1
	I support time based operations but a full 4DT ATM system is a step too far	4.3	5.1
	I have a positive attitude towards the transition to 4D Trajectories.	7.3	8.3

As can be seen, for each of the questions the players are more positive after playing AeroGame. For example the attitude towards 4DT increased from 7.3 to 8.3. The feeling that the introduction of 4DT is a cooperative effort was already high, but has even increased more after playing the game. The idea that the benefits are higher than the costs increased from 6.1 to 7.3. While not all answers are statistically significant, this does suggest an important result: playing AeroGame seems to have a positive influence on the attitude towards 4DT. Players seem to be more aware of the importance of collaboration with other stakeholders for successfully introducing 4DTand have a more positive attitude of (the transition to) 4DT.

One of the questions addressed the perceived need for **other** stakeholders for 4DT. This question therefore provides insight in the view that stakeholders have on the needs of other stakeholders. When comparing the pre-test and post-test results, players appear to have a more positive attitude of stakeholders towards their needs to successfully introduce 4DT (on average 7.9 in the pre-test versus 8.4 in the post-test) with less standard deviation (2.0 in the pre-test versus 1.2 in the post-test). Especially the airport stakeholders have adjusted their opinion after playing the game.

When comparing the pre- and post-results for the last question of this series, a more positive attitude of stakeholders towards 4DT (on average 7.3 in the pre-test versus 8.3 in the post-test) is seen in the post-test with less variance (the standard deviation was 2.1 in the pre-test versus 0.9 in the post-test). Again, the airport stakeholders in particular have adjusted their opinion after playing the game. Because of the small amount of players, the result is not statistically significant ($t(10) = 1.402$, $p = .191$), but still can be considered a strong indicator.

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7 Findings and Conclusions

In January 2015, the final version of the game was evaluated. During the evaluations sessions, several stakeholders test-played the game. They were extensively observed, debriefed and questioned using the pre- and post-game questionnaires. The evaluation session has resulted in a number of conclusions that could be drawn. An extensive description of the evaluation sessions and its results can be found in [6]. Here the main conclusions are described.

AeroGame was primarily developed to study if and how serious games can facilitate change processes in the ATM domain. It envisaged to create a more positive attitude in stakeholders playing the game and to create a buy-in in the change. AeroGame stimulates players to cooperate and allows observers to measure investment strategies and to identify factors that may be important when implementing a change process with the stakeholders playing the game.

The introduction of 4D trajectories was selected as a first assessment of the usability of serious games for change processes in ATM, because this involves several interesting challenges, such as:

- cost-benefit analysis;
- effective roadmapping;
- willingness to change;
- politics.

The goals of the project are described in Section 5.2. For each of these goals, conclusions are drawn separately.

7.1 Contribution to roadmap

One of the main questions in the project is how the results can be used as input for designing incentive schemes and deployment roadmaps. The topic of *willingness to change* is explicitly part of this process. AeroGame provides some important building blocks that contribute to this process:

- It informs players about the technology that is introduced thereby reducing the lack of knowledge for stakeholders;
- It is able to positively change the attitude of players to the new technologies;
- It provides a better insight into the incentives of the players by analysing their chosen goals and their investment strategy during the game;
- It informs the players about the stakeholders at the table and what their motives are for investing and adapting new technologies.

As stated in the AeroGame Applications report [3] creating a complete roadmap is an on-going process in which the readiness of the stakeholders to cooperate is important. For the purpose of getting the stakeholders ready to cooperate, a serious game can play an important role.

The AeroGame serious game does not provide a game to construct the roadmap for 4DT itself: this would require a very specific, detailed game. Such a game will be harder to play and is less suitable to be re-used for other change processes other than 4DT. Instead, a serious game such as AeroGame can be most beneficial in the first phase of such a process: it helps bringing stakeholders together and brings along a more intense teambuilding experience than alternatives, while still staying close to the topic.

To address 4DT in more detail with a serious game, while at the same time keeping the game “playable”, the game could focus on the implementation of *parts* of the concept, instead of the whole concept. In this way, the incentives of each stakeholder in this part can be identified.

Serious games can also help to identify both bottlenecks and issues that are not yet identified by previous processes. This would require a different game than AeroGame by making use of specific co-creation techniques.

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The game in its present form can best be deployed *before* the actual road mapping process. The game then contributes to a good understanding between stakeholders, creates awareness and "breaks the ice".

7.2 Awareness

Even though the number of players was relatively low, the workshop provided strong indications that AeroGame raises awareness about the topic with the players. The introduction, game elements and discussions during and after the game provide information to players about the topic at hand. It was clear from the results that the knowledge about 4DT increased during the game session. In contrast to a (regular) workshop a serious game forces a player to reason about the topic and weigh the pros and cons, and confronts him with the results of his actions. This increased, among others, the awareness that the introduction of 4DT is a collaborative effort.

7.3 Buy-in

The stakeholders responded that AeroGame was very engaging. This indicates that players enjoyed playing the game and that they thought that they had learned something. Although the attitude towards 4DT seemed to increase during gameplay, because of the relative limited amount of games played the results are not statistically significant. However, combined with the results from the observations and open questions in the questionnaire, there are strong indications that AeroGame is able to positively change the attitude towards the topic, which is very important in creating a buy-in.

7.4 Conclusions

The AeroGame project provides first – not conclusive – empirical support that serious games are able to contribute to an ATM change process by contributing to the road mapping process, raising awareness and creating a buy-in. AeroGame raises awareness about a specific topic by the players and contributes to a climate in which players are more susceptible for other stakeholders' opinions. In addition, support was found that serious games help to create a more collaborative climate among stakeholders in the introduction of new technologies. Together with the observation of player choices, behaviour and interaction, this provides interesting new information that can be used to contribute to ATM change processes.

Although AeroGame focussed on one single topic (transition towards 4DT) the game framework can be easily adapted for other subjects as well.

The strength of the combination of paper-based and hybrid games is that they encourage in-depth communication and sense-making processes between stakeholders with diverse views and interests. An important limitation of these types of games is, however, their scalability. At most 8 players are usually involved in playing a board game. To increase awareness with the players one could either organize more game sessions or turn to computer games (and consequently, miss out on the direct interaction and communication elements of a board game). For the sole purpose of creating awareness, it is interesting to investigate the use of digital games to reach a broader audience.

For academia, this project is relevant because it is to our knowledge one of the first studies which investigates the use of serious gaming to support technology-induced change processes in a complex system-of-systems across organisational, institutional and national borders. This research contributes to our understanding of serious gaming for change in two ways. First, it shows how serious games can be used to support change processes. Second, it provides insights how stakeholders can be made aware of the characteristics, costs and benefits of introducing technological innovations using a serious game.

To directly contribute to a change process, future games could go one step further by not only playing the game and measuring its immediate effects, but also jointly building a roadmap for change and observing to what extent playing the game helps in facilitating the creation of such roadmap. This does however require a very specific, detailed game.

The AeroGame project has demonstrated that serious games can play an important role in increasing knowledge about change processes, improve acceptance of new technologies, change attitude

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towards these processes (and may lead to behavioural changes), and helps with preparing stakeholders for enabling change in ATM,

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Appendix A Results of post-questionnaire open questions

Questions 38 through 40 were open questions about the attitude of stakeholders towards AeroGame. For question 38, also the corresponding question 7 in the pre-game questionnaire is shown, to that responses from individual stakeholders can be compared.

Table 11: Expectation of players towards serious games and AeroGame

Pre-game question 7: What are your expectations of this game session?	Post-game question 38: Did AeroGame meet your expectations?
A better understanding of a serious ATM game with its possible benefits for future ATM.	Yes. The briefing for the game was very good (and the free trial game) since there are quite a few common areas between the KPIs.
1. Reduce the tension between different stakeholders 2. Better understanding of ATM needs and in particular, different stakeholder needs.	A general overview on 4DT is essential before starting the game.
To bring people together and to solve problems.	Yes. To have more information on the whole, seen from different point-of-views.
1. See if the game does what it sets out to do 2. See if it could be deployed in a suitable way at our company to help us spread awareness about our product and brand 3. Provide input as an ANSP/Government type stakeholder	+ Excellent demonstrator of risk assessment versus strategy setting - 4DT as a topic does not penetrate sufficiently well in the game design
Hope the game will bring clarity about interactions between players and that the outcomes are helpful to SJU.	Yes. If it becomes accepted it can be very useful to stakeholders.
None, just interested in the process and to what result (any) this will lead.	I had no expectations and found it surprisingly fun and interesting to play. It was activating and I could xxx attention.
Improve my attitude to solve problems regarding my role in the airport.	Yes.
To learn how serious gaming may be introduced in that apt environment in order to help the management team to take decisions.	Yes. It was important to understand the single contr butions to the final game.
Positive, fun, interactive.	Yes. It is a good game, easy to learn, but difficult to play well. Good mix of interactions, optimization, choices, random...
Evaluate if the game developed shows clearly the different expectations, fears, motivation of various stakeholders.	Yes, it allowed to experiment and gain insight.

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Table 12: Questions 39-40.

Do you see any application for AeroGame in your field of profession?	Which part or aspect of playing the game was most valuable to you?
Aerogame has great potential to get all the stakeholders involved in the future development of ATM.	Merging my representative input on behalf of low cost with the other stakeholders in aviation.
Yes, when cooperation between different stakeholders is required.	Decisions that involved team building.
As a pilot, no. But at a higher level in the company, yes.	Working together. Convincing others.
AeroGame team is invited to come to us to demonstrate the finished product.	1. -Interactive dynamic with other actors, amplified by sourcing relevant actors, familiar with their roles. In the real world there are already entrenched industrial relation stereotypes between parties, the question is whether this should be reflected in any way in the game. 2. Duality of objectives (official policy vs private interest) becomes tang ble in the gameplay.
A-CDM airports. Introduction of new procedures to controllers.	Cooperation among players.
We could use it within our department, as part of our own strategy building for the next years.	1. Interaction with the other players. Their goals and attitude and now it is re-found in game. 2. The overall risk-reward assessment.
In the what-if scenario evaluation for middle-term master planning.	The graphic interface
Yes, why not present our futuristic view of ATM systems through such serious games.	Choose where to invest your income (limited).
In particular if you can make the game higher. Precisely what we did here. Play and learn about others perspectives.	The discussion/negotiation. That could be a good 'training' in itself, for discussing with the other parties in reality, understanding their perspective. The simplification of the reality helped to understand what the main principles and interests are.

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Table 13: Answers to (open) questions 44 and 46 on the perception of the game

Use AeroGame for other topics than 4DT.	Other applications for serious games in your organization?
Has a variety of possible applications. Team building, operation management, interpersonal skills etc.	Role playing possible as past of promotion checks for pilots, ground staff, management, etc.
Any subject that involved different stakeholders having their own "pre-agenda".	As above
Any place where parties meet with different goals.	
Absolutely, a good example would be the introduction of RPAS in common civil airspace. Stakeholders are society-NGO, private businesses, operators, other manned vehicle AU, ANSP, regulator, military. Game requires a thorough understanding of the subject matter.	See above. In a broader scope, I have made several proposals in the past to use gaming for change management internally and brand awareness building externally. As an ANSP we are avid users of RTS which falls into the definition.
During the trial it was not clear anymore that 4DT was the topic. **This was an indication that the topic can easily be changed.**	A-CDM
	Airport development
To get agreements on short-term strategy.	
CDM	A-CDM, 4DT, ...
Of course, totally generic.	
The structure of the game is very generic. Basically the game is about negotiation and setting priorities. That is relevant for more than just 4DT.	Any change that requires switching from a certain fixed skill or pattern to a new way of operation. There are probably specialists who can determine what part of such a change can be supported by serious game.

Finally, question 47 addressed the change in attitude towards serous gaming after the AeroGame workshop. The results are depicted in the following table:

Table 14: answers to question 47

Has your attitude towards serious games changed after today's workshop?
My first experience, all positive.
Positive before, positive after, nice experience
As it was before, I believe in it.
remained positive
Was good, stays good.
No, positive already (as a game)
Yes, totally.
No
No, was aware of the benefits.
Still interested and more convinced of the results it could bring.
I think not that much, but that is mainly because I was already aware and also positive about the applicability of serious games.

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