Serious games to advance change in ATM

Customer

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EXECUTIVE SUMMARY

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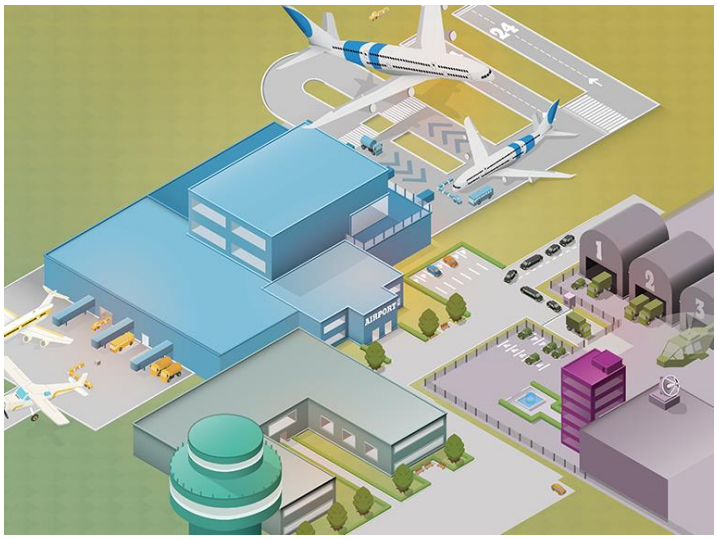

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Problem area

The Air Traffic Management (ATM) system in Europe is at the threshold of a series of change processes to make the system more efficient, cost effective, safer and less complex. Change processes often bring huge challenges, which is especially true for ATM because of the complexity and the number of stakeholders involved. Serious games may be a means for facing these challenges. This paper describes the results of the study of the suitability of using a serious game for facilitating changes in the ATM domain.

Description of work

AeroGame (a SESAR Exploratory Research Project), studied the potential for serious games to support the challenging change processes that ATM faces. Therefore, several topics were

This report is based on a presentation held at the Air Transport and Operations Symposium, Delft, the Netherlands, July 20-23, 2015.

explored to identify which topics would "lend" themselves to be used in a serious game. The selected topic was the transition towards 4D trajectories (4DT). Therefore, a serious game was developed to explore the potential for serious games to support this transition process. The game takes the form of a classic board game that is complemented by a digital scoreboard. Four stakeholder representatives (playing their respective roles) play the game that consists of several rounds in which the stakeholders jointly build an ATM system capable of facilitating 4DT. Pre-test and post-test questionnaires in combination with game observations measured the effectiveness of the serious game. The focus of the measurement instruments was on the expectations, reaction, learning and behaviour of the respondents. The goals were to contribute to the awareness of the player, to create a buy-in and to contribute to the road mapping process of the transition towards 4DT.

Results and conclusions

The findings provide first – not conclusive - empirical support that games can help make people aware of the concept, cost and benefits of 4DT and point out the importance of collaboration in successfully introducing 4DT. In brief, serious games have the potential to effectively facilitate the change in ATM.

Applicability

AeroGame can be used to start discussions amongst and cooperation between stakeholders within the ATM domain. It is suitable for getting stakeholders in a more cooperative mood, but it can also be used to break through deadlocks in negotiations between stakeholders. Its strength lies in the combination of a paper-based and a hybrid game that encourages in-depth communication, negotiation and sense-making processes between stakeholders with diverse views and interests. It therefore allows focusing on the game's goals rather than on scorekeeping. Serious games such as AeroGame can also be useful in comparable complex situations, were various stakeholders need to be involved and be made aware of change processes.

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Serious games to advance change in ATM

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Summary

AeroGame is a serious game developed within the SESAR WP-E programme to study if serious games can contribute to change processes in the ATM domain. In addition to this, it envisages to create a more positive attitude in stakeholders playing the game and to create a buy-in in the change.

European stakeholders representing airlines, air navigation service providers, governments, and airports took part in a game validation session intended to study how playing AeroGame influences their attitudes towards 4D trajectories (4DT). It also gathers important information that can be used to support the change process necessary for a successful transition towards 4D trajectory management.

Observers performed in-game measurements and observed important behavioural markers, such as communications. Furthermore, questionnaires (pre- and post-playing) were used to measure reactions, learning and possible transfer of training. The stakeholders enjoyed playing the game and indicated they thought that they had learned about the topic. A clear indicator for group success in the game was the willingness to cooperate. Although the number of participants to the validation session was not sufficient to always generalize the results, the responses to the questionnaires and the observations provided promising indications that AeroGame is able to raise awareness about the topic and to provide a significant contribution to the change process.


AERO GAME
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Content

Abbreviations

Acronym	Description
4DT	Four Dimensional Trajectory
ANSP	Air Navigation Service Providers
ATM	Air Traffic Management
CDM	Collaborative Decision Making
KPI	Key Performance Indicator
NLR	National Aerospace Laboratory NLR
SWIM	System Wide Information Management

1 Introduction

SESAR aims to modernize the European air traffic system by the introduction of new technologies and procedures [1]. Many complex change processes are attached to this huge task creating not only technical challenges, but also challenges on the human domain. Introducing change in Air Traffic Management is a complex activity requiring active collaboration of many stakeholders. One of the biggest challenges that SESAR faces is therefore how to shape this change process, to gain sufficient support from all stakeholders and to ensure a smooth path towards future ATM.

The complexity is largely the result from the fact that the (European) 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, Air Navigation Service Providers (ANSP), airports, governments, and military. The ATM system is the result of a complex compromise between the varying interests of these stakeholders. These interests differ per stakeholder between safety, cost effectiveness, network capacity, fuel efficiency, etc. Due to the complexity and interdependence of these systems it has become very difficult for stakeholders to fully comprehend the impact of changes on the ATM system. This may seriously hinder the implementation of improvements as stakeholders may need complex and time-consuming processes and simulations to quantify the results of the change. In a worst-case scenario, change processes may even result in deadlocks [2].

Another hurdle in implementing changes is the time lag between upfront SESAR investments by the different stakeholders and the realization of the full benefits. The duration of this lag often varies for different stakeholders and stakeholders can create a *last-mover* advantage by waiting until all others have made their investments.

Games are driven by the concept of play which is an intrinsic human driver for creative problem solving. However, serious games are games that are not primarily developed for entertainment purposes [3], but they can be used as tools for facilitating changes in behaviour (such as learning, buying a product or changing a lifestyle). Also, serious games allow for human interaction, which is important to include when the effects of human behaviour are difficult to model and yet have strong impact on outcomes. A serious game provides players a tool that allows them to experiment in a safe environment and to experience how their behaviours affect their environments (including other players) ([4]; [5]).

Serious games are popular for facilitating behavioural change and their effectiveness has been proved in many studies (e.g. [6]; [7]; [8]) although some studies do not support these findings (e.g. [9]; [10]; [11]). They can be useful for achieving certain carefully selected goals, but not for others [12]. For example, they are effective for training soft skills, such as cooperation and crew resource management, but they may not be effective when the target is the transfer of knowledge. Also, some target groups may be enthusiastic towards serious games while others may have a very negative attitude, which does not improve effectiveness. The goal for the AeroGame project is to pioneer the use of serious games as a tool to support change processes in ATM.

The AeroGame project is jointly executed by The Dutch Aerospace Laboratory (NLR), Thales the Netherlands and the University of Twente. This paper describes the results of an evaluation workshop of AeroGame. It starts with a brief description of the game and its potential, followed by a description of how the evaluation has been approached. Next, the results are described and the paper ends with the conclusion and a discussion.

2 Development of AeroGame

The AeroGame project started with a process to select a useful topic for the game. The selection process focussed on those challenges that were considered urgent, could be translated into an effective serious game and had practical benefits. The latter includes criteria such as sufficient expected exposure possibilities and size of the potential stakeholder group. One of the main activities was the organization of a workshop with representatives of various stakeholders within the ATM domain (e.g. airlines, ANSPs, government). In the workshop, challenges from different perspectives were identified and discussed and a first selection from these challenges was made. This long list included the following challenges:

- System Wide Information Management (SWIM) - How to show the potential to stakeholders (awareness) and how to create a common feeling of urgency to advance introduction.
- Cost/benefit analysis – How to make a solid analysis, but also to reduce the risk of investments and finding effective ways to deal with the often large lags between time of investment and return on investment.
- Collaborative Decision Making (CDM) – Making sure that all ground operations cooperate to guarantee that each aircraft departs at specific departure times (instead of “as soon as possible”).
- Cultural differences – Not only differences between countries and regions, but also between companies involved in the change process.
- Systemic safety – Actions within a specific part in the ATM domain can have consequences on several other parts. A more systemic view, particularly on safety, should be adopted.
- Effective road mapping – How to make a clear roadmap for a change that includes all relevant stakeholders?
- Willingness to change - Plans and ideas within ATM are usually presented in general terms, e.g. “reducing ATM costs with 50%”. Stakeholders are interested how to translate these high level targets into low level targets that fit their organization.
- Politics – How to deal with political interference in local activities?

Based on these challenges a list of possible game topics that could aid in dealing with multiple challenges was created. This shortlist includes the transition towards 4DT, satellite airport development and SWIM/CDM. After careful deliberation, the project team selected the 4DT, because it involves several challenges, such as cost/benefits analysis, effective road mapping, willingness to change and politics. This selection process is described in deliverable 1.1

"Applications report" [13]. The game consists of a framework on which it is relatively easy to implement other topics as well, but as a proof-of-concept, the 4D trajectories edition of AeroGame was used for the assessment.

The goals of AeroGame are defined on two levels, the meta-goals (i.e. with the game) and the game goals (i.e. within the game). The meta-goals are to support change processes in ATM by:

1. Providing valuable input to the definition and roadmap of the change process (share information relevant to the change).
2. Ensuring that players are aware of the necessity of the change, thus facilitating a more positive attitude towards the possible future situation.
3. Letting the players co-create the change (create a buy-in).

Four to eight stakeholder representatives (e.g. low cost airlines, legacy airlines, ANSPs, governments, airports, military) play one of the roles or team up to play one of the four roles that are represented in the game (thus, there are always two roles that are not played). In the game, stakeholders jointly build an ATM system capable of facilitating 4DT in several rounds. In each round the players are confronted with a choice to either invest in technologies or to save resources for later. The goal for each player is to increase the Key Performance Indicators (KPIs) of their choice with a minimum use of resources. Key to the game is cooperation. Without cooperation, none of the players will be able to reach their goals; the better stakeholders work together, the higher the synergetic advantages they create.

At the start of the game, each player choses two KPIs related to 4DT that require the most change for the stakeholder he represents. The KPIs that can be selected are:

- Sustainability
- Network capacity
- Predictability
- Cost effectiveness
- Safety

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.

The game session is led by a *game master*. He is also responsible for keeping scores. In addition, a game *facilitator* is present to promote discussions between players and ask critical questions

about their choices. The facilitator also debriefs the players afterwards to facilitate the transfer of training from the game setting to their daily work. Finally, an *observer* is required to measure in-game performance (i.e. what is the used investment strategy and how does this relate to real life) and to identify cooperative behaviours and other behaviours relevant for creating a roadmap to change.

3 Validation

After a development process of approximately 18 months, with many iterations and test-playing, the game was validated during a full day workshop in January 2015. The validation methodology is described in detail in the Evaluation Methodology deliverable for AeroGame [14]. The results of the validation are fully described in the validation report [15].

3.1 Subjects

A total of 11 stakeholder representatives participated in the game validation. They represented airlines (3), ANSPs (2), Government (1), Airports (2), and other interest groups (3). The members of the other interest group received a stakeholder's role that best suited their knowledge and experience. The team was completed with the addition of one NLR expert.

3.2 Procedure

All stakeholder representatives met at the National Aerospace Laboratory – NLR premises in Amsterdam. They were first briefed on the project and the game. Subsequently, they were asked to fill out a pre-questionnaire to measure their knowledge and opinions on several topics regarding serious games and 4D trajectories. Next, the group was divided into three subgroups. Each group played a tutorial scenario for several rounds to learn the rules and understand how the game works. During this tutorial they did not play the role of the stakeholder that they represented. After lunch the group was divided into three subgroups in which all stakeholders could represent their own organisation. Each group played under guidance of a game master and a facilitator and the behaviours during the game were observed and noted by trained observers. Afterwards the players were debriefed by the facilitator and asked to fill out a post-questionnaire. Finally, the best team received a prize and the winners of each table received an award. Table 1 shows which stakeholders participated in which group.

Table 1: Participating stakeholders

Group 1	Group 2	Group 3
ANSP	Airport	Airport
Government	ANSP	Government
Low fare airline	Legacy airline	ANSP
Airport	Low fare airline	Legacy airline

3.3 Measurements

Evaluation of the game's effectiveness was performed using subjective measures (questionnaires) and more objective measures (observations). The questionnaire was presented to the subjects before (pre-test) and after (post-test) playing AeroGame. See also appendix A for the pre-test questionnaire and appendix B for the post-test questionnaire. The observations were recorded during the game by means of an observation protocol. The observation protocol aimed at guiding observers to focus on the following groups of behaviours:

- game play, e.g. target selection, investments, event cards;
- behaviours indicative of attitudes, e.g. motivations for making game decisions;
- communications, e.g. number of initiated communications and agreements made;
- statements that shed light on how a stakeholder views the game's topics in real life or how a stakeholder would act in a particular situation in real life.

The applied measurements for the targets on a behavioural change level (ensuring awareness of the necessity of the change and creating a buy-in) are based on Kirkpatrick's classification of evaluation techniques for training programs [16]:

- **Reaction**: the reaction of the participants regarding the learning goals and the game itself.
- **Learning**: the learning effect of serious games is the increase of knowledge, skills and/or the change in attitudes.
- **Behaviour**: the transfer of training from the game environment to the working environment.
- **Result**: the final results that occur in real life and are attributable to attending and participating in the serious game.

The **reaction** effect was measured after playing the game using a game engagement questionnaire (questions 2-1 through 2-17 in appendix A). Game engagement is the level of involvement of a player in the game and a precondition for learning. The participants were presented with 17 statements related to game engagement and could respond on a scale from 1 (do not agree) to 10 (agree). The average score is calculated for each participant. Furthermore, each facilitator asked questions about observed behaviours during gameplay in the game debrief. Players' responses were recorded by the observers.

Game-based **learning** results were measured by comparing the differences in attitudes towards 4DT *before* and *after* playing the game. Learning is considered successful when an improvement is found in the construct "attitude towards 4DT". This construct was measured with 7 questions before playing the game (questions 1-18 through 1-24) and the same questions after playing the

game (2-20 through 2-26). The results were compared using a paired samples t-test [17]. Also, after playing the game, participants were asked if they thought that playing improved their understanding of 4DT. These questions were also presented as statements and required the participants to answer on a scale from 1 (do not agree) to 10 (agree). Furthermore, the amount of communications was registered for each round to gain understanding into when the instructor can most likely contribute to learning and to study if communication activities differ between successful and unsuccessful teams.

To measure Kirkpatrick's **behavioural** class, the facilitator asked the players if they expected to change their behaviour in their daily work. The answers were recorded by the observers.

Finally, the "**results**" class was not measured because this would require having the players play the game and gather information on the effects of playing in their real life while filtering out all variables that may have influenced their behaviour. Therefore, this was unfeasible for this evaluation.

Information regarding valuable input from the game for the change process (addressing the meta-goal of the game) was gathered by the observers. They recorded the KPIs that were chosen by each stakeholder and the motivation for selecting these KPIs. The stakeholders were instructed to select the goals that they thought would require the most improvement. Note that these are not necessarily the most important goals, but the goals that require more attention than others. Observers also recorded the general strategy that was used for investing. Furthermore, they recorded the motivation of each stakeholder for using their investment strategy and how much this would resemble the strategy that they would use in real life.

4 Results

4.1 General knowledge and expectations

The attitude towards serious games in general is important. In particular it is important that stakeholders consider the potential of serious games as a tool for attitude changing in a change management process. Letting stakeholders experience a serious game may influence their attitude in a positive way. Before playing AeroGame, the familiarity towards serious games as a tool was neutral (3.5 on a scale of 1 through 5) among stakeholders. Furthermore, participants felt positive (4.1) towards the application of serious games on a scale from 1 through 5 (very negative – very positive; compared to neutral $t(10) = -12$, $p < 0.01$). The motivations for these answers were very diverse. One theme that jumps out is that several participants expect serious games to be an effective means to explain complex situations to various stakeholders.

On a scale from 1 through 5 (very unfamiliar – very familiar), with a value of 3.5, participants indicated that on average they were neither familiar, nor unfamiliar with the SESAR concept of 4D trajectory management. Also on a scale from 1 through 5 (very negative – very positive) participants indicated that their organizations on average have a positive attitude (3.8) towards the introduction of 4DT (compared to neutral, $t(10) = -4.5$, $p < 0.01$). Most motivations for these answers focused on the expectation that 4DT increases capacity. Figure 1 depicts the familiarity with and the organizations' attitudes towards 4DT and serious games. The players' attitudes were measured before and after playing the game and are discussed in the section on learning. Table 2 presents the answers to the open questions regarding expectations towards the game session (before playing the game) and if the game had met these expectations (after playing the game).

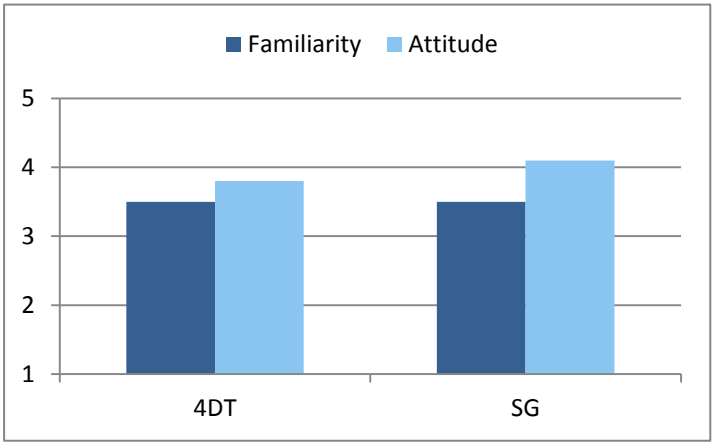

Figure 1: Familiarity with and attitudes towards 4DT and serious games (SG)

Players were asked about their expectations of AeroGame. After the session, it was asked if the expectations had come true (both open questions); the responses are shown in table 2. It is clear from the responses of the players that, in general, AeroGame did meet the expectations of the players. This means that the information that was provided before playing the game was sufficient in terms of raising expectations to the players.

Table 2: Expectation of all test players towards serious games and AeroGame

Pre-game: *"What are your expectations of this game session?"*	**Post-game:** *"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 maintain my 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	Yes. It was important to understand the single contributions to the final game.

Pre-game: *"What are your expectations of this game session?"*	**Post-game:** *"Did AeroGame meet your expectations?"*
management team to take decisions.	
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.

4.2 Reaction

The average score for questions relating to engagement was high: 7.75 (on a scale of 1 through 10), which is significantly higher than the middle value ($t(10) = 18.478$, $p < 0.01$). Figure 2 shows the average scores per question. For 5 questions the scores have been mirrored because these were negative statements.

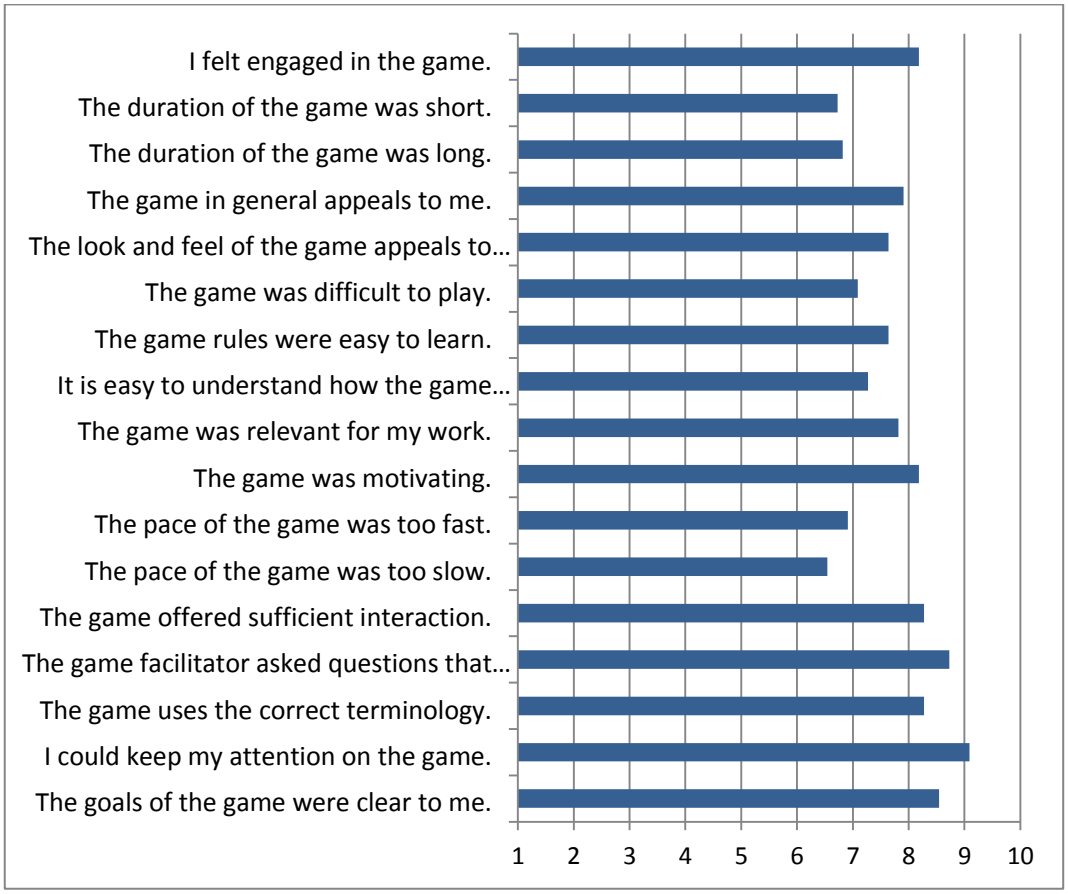

Figure 2: Average scores per engagement question

Looking in 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 (7.1). 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. This indicates that the game has been well designed (in terms of engagement) to support game based learning.

The participants' opinions about the game as recorded by the observers were also perceived positively. The motivations for the positivity were diverse, but included the following remarks:

- The game seems like a good way to get stakeholders at the table and to open up to other stakeholders.
- The game demonstrates that it is possible to get a positive return on investment for all stakeholders involved (i.e. instead of only some stakeholders).
- Good for change management.

4.3 Learning

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. When comparing the pre- and post-results, 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). 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.

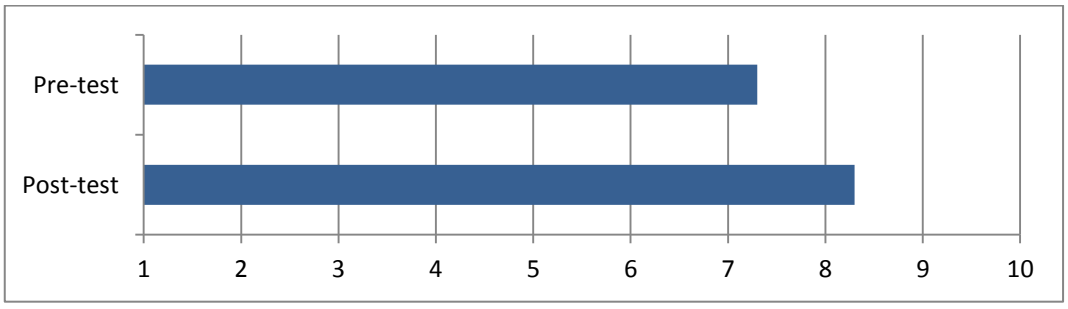

Figure 3: Attitude towards 4DT before and after playing AeroGame

After playing the game, players were asked if their understanding of 4DT has improved after playing the game. With an average of 6.9 - on a scale of 1 (= do not agree) to 10 (= fully agree), it is clear that players agree that they have gotten a better understanding of the issues at stake

regarding the introduction of 4DT ($t(10) = 3.464$, $p < 0.01$). The players were not asked how this better understanding was built up.

Table 3 summarizes the results of the comparison between pre- and post-questions.

Table 3: Pre- and post-questions concerning attitude towards 4DT

Attitude towards	Question	Average pre	Average post
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 from the table, for each of the questions the players are more positive after playing AeroGame. 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 4DT and have a more positive attitude of (the transition to) 4DT.

The second and third questions addressed the perceived need for 4DT for **other** stakeholders. This question provides insight in the view that stakeholders have on the amount of collaboration that is necessary for the introduction of 4DT. When comparing the pre-test and post-test results,

players appear to be more convinced that 4DT is a joint effort (on average 7.9 in the pre-test versus 8.4 in the post-test) with a smaller 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.

Communication between players was lower than average during the second and the eighth rounds and higher than average during the third round.

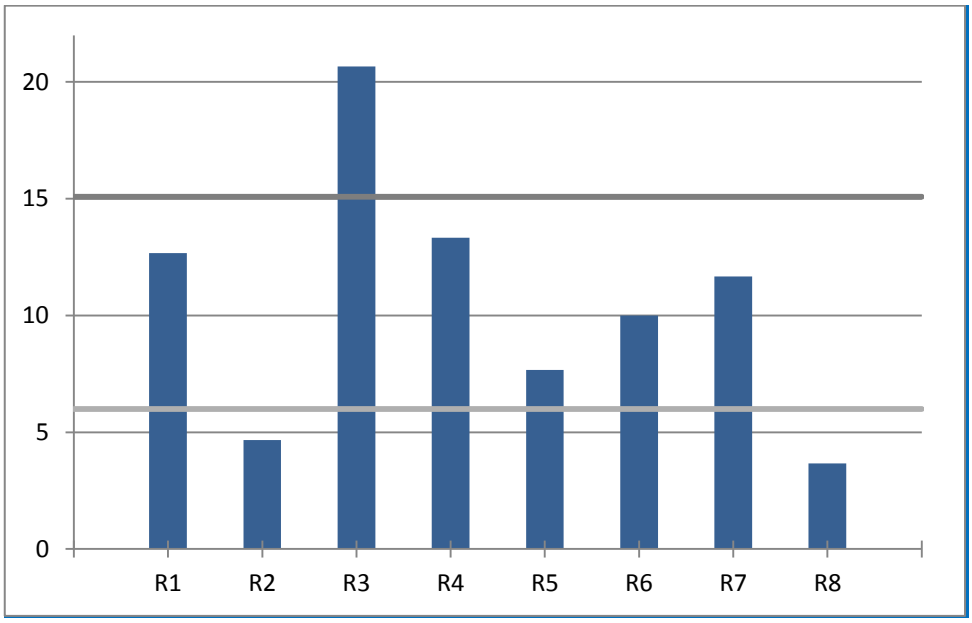

Figure 4: Average number of initiated communications per round.
The horizontal bars display the upper range and the lower range of the average

4.4 Behaviour

The open question regarding what the players have learned and will use in real life resulted in the following summary of answers:

- I need to pay close attention to other stakeholders and cooperate with them to achieve my goals (7);
- I need to disclose information to achieve my goals (1);
- I need to be flexible in my strategy when asking for cooperation from other stakeholders (3);
- The term savings sells better that the term “investments” (1).

4.5 Observations

All airline representatives selected cost effectiveness as their primary goal. Their motivation was, in general, that money is necessary for the airline organizations. One government representative also selected cost effectiveness as his primary goal, because of the public opinion that we need

to cut costs and that aviation should be competitive. The ANSPs preferred to invest in network capacity and in predictability. The targets of the airports and the secondary targets varied a lot even within the groups.

Most players indicated that they consider safety to be the most important objective, but they did not select this target because safety in general is already quite good within the domain and, according to the players, cannot be improved much further. Most targets were chosen because of the economic value for the organization (e.g. cost reduction or productivity increase). Other underlying goals, such as environment and sustainability were rarely mentioned (both only once).

The group that invested the most of their resources did not automatically perform the best of all groups. This group invested the highest percentage of resources, but did not manage to reach the group targets. The group was too competitive in the beginning of the game. The willingness to cooperate was not as obvious as in the other groups and the stakeholders of this group did not spontaneously invest in each other or borrowed each other's resources. They were more focused on their own targets, until the end of the game. By this time, however, they were already too late. They 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.

In one group 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. They said that this was an interesting way to look at investment strategies that they often come across with in real life and gave them a better understanding of what works in a cooperation and what not.

5 Conclusions

AeroGame was primarily developed to study if serious games can facilitate change processes in the ATM domain. In addition to this, it envisages to create a more positive attitude in stakeholders playing the game and to create a buy-in in the change. It 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 important challenges, such as:

- cost-benefit analysis;
- effective road mapping;
- willingness to change;
- politics.

The goals of the game were described in Chapter 2. For each of these goals, conclusions are drawn.

5.1 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. The players indicated that their knowledge about 4DT increased during the game session. However, no objective measurements have been performed to measure exactly what the difference in knowledge levels was before and after playing the game. A suggestion for further research is therefore to objectively measure competency levels (including knowledge and attitude levels) both before and after playing the game and measure what the players have learned during the game.

In contrast to a (regular) workshop, a serious game forces a player to reason about the topic, 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. These elements contribute to the awareness process.

5.2 Contribution to roadmap

The players indicated that their attitude towards 4DT became more positive after playing AeroGame. This attributes to the change process because if the attitude towards the change is

more positive, stakeholders are expected to be more willing to cooperate. If a stakeholder has the feeling that other stakeholders value the introduction of 4DT, they may be more motivated themselves as well. The impression of the attitude towards 4DT of *other* stakeholders did however not increase nor decrease during gameplay. This may be attributed to of the fact that this impression was already very positive beforehand.

It can be concluded that AeroGame provided several indications that serious games can contribute to creating roadmaps. This suggests a careful translation from game to real world. Both observations and reactions from the players indicate that such a translation is possible but more empirical data is necessary to draw definitive conclusions. To get an even better insight into the value of serious games to support change processes in ATM it is recommended to test the game prototype with more players and for other use cases (e.g. SWIM).

The group that invested the highest percentage of the resources was the only group that did not achieve the game's targets. However, since these players did not achieve many targets their total amount of available resources was lower than in the other groups. A much more pronounced indicator for group success is the willingness to cooperate. The group that did not meet the targets did not show as many cooperative behaviours as the other groups.

Future game sessions could focus even more on (the importance of) cooperation. It would be interesting to see how much this will affect the willingness to cooperate after playing the game and to see how far these results can be generalized to the population as a whole. The number of participants in the validation was not sufficient to do this for each stakeholder group (e.g. legacy airlines, ANSPs). However, it did show interesting differences between the investment strategies of individuals which is useful information when building a roadmap involving these particular stakeholders. Future research should go one step further by not only playing the game and measuring its immediate effects, but also building a roadmap and observing to what extent playing the game helps in facilitating the creation of the roadmap.

5.3 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, the results were 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. However, the high engagement plus the fact that all stakeholders volunteered to participate in the validation session may have clouded their responses on their attitudes towards and learning about 4DT. The stakeholders may have been biased to answer that they did learn from playing the game.

During the third round of the game the number of initiated communications were much higher than average. Most teams set some sort of intermediate target for the first two rounds and discussed their investment strategies for the rest of the game in the third round. It is also plausible that, after two rounds, the players realized that they could not achieve their goals without collaboration, which may have contributed as well to the peak in negotiations. In future play sessions this could be the moment at which a facilitator can make a change by focusing more on letting players know how 4DT can impact their organizations. However, further research is necessary to find out if that will create a more distinctive change in attitudes towards 4DT than was measured in this validation session.

5.4 Final thoughts

The findings provide first – not conclusive - empirical support that games can help make people aware of the concept, cost and benefits of 4DT and point out the importance of collaboration in successfully introducing 4DT. Together with the findings of player choices, behaviour and interaction, this information is valuable to contribute to change processes.

Even though there are some pitfalls into concluding how effective the game is regarding to changing attitudes towards 4DT and knowledge about 4DT another associated advantage may have occurred. The players discussed several topics related to 4DT during gameplay. This information may be a very important lubricant for future collaborations.

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 eight players are usually involved in playing a board game. If one wants to reach more stakeholders one either needs to organize more game sessions or turn to computer games (and consequently, miss out on the direct interaction and communication elements of a board game). Since the findings indicate that ‘creating awareness’ is a promising area to deploy serious games, it is interesting to investigate the use of digital games to raise awareness about a certain topic.

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Appendix A Pre-test Questionnaire

Pre-test questionnaire						
1	How familiar are you with the concept of (SESAR) 4D trajectory management?	Very unfamiliar	Unfamiliar	Neutral	Familiar	Very familiar
2	How does your organization perceive the introduction of 4DT?	Very positive	Positive	Neutral	Negative	Very negative
3	Please elaborate.					
4	How familiar are you with serious games?	Very unfamiliar	Unfamiliar	Neutral	Familiar	Very familiar
5	How do you feel about the application of serious games? My general impression of serious games is ...	Very positive	Positive	Neutral	Negative	Very negative
6	Please elaborate.					
7	What are your expectations of this game session (if any)? And if so, please indicate what they are.					
Change in the ATM system (requiring collaboration of multiple stakeholders) is often achieved through a careful but very lengthy process. What is your attitude towards the following means for speeding up this process?						
8	Meetings (i.e. discussing the most important topics with other stakeholders)	Very good	Good	Neutral	Bad	Very bad
9	Workshops (i.e. executing several assignments with other stakeholders)					
10	Serious games (i.e. playing a serious game regarding given topic)					
11	Teambuilding activities (not topic related)					
12	Other means / remarks.					
What is your impression of the attitude towards the introduction of 4DT of the following stakeholders: (You can skip the question for the stakeholder that you represent).						
13	Legacy airline operator	Not important at all	Not important	Neutral	Important	Very important
14	Low-fare airline operator					
15	ANSP					
16	Government					
17	Airport					

The following statements concern the game you have played today. Please indicate to what extend you agree with each statement by crossing the line on a scale of 1 to 10.	
18	I have a good understanding of what comprises the introduction of 4DT.
19	I support time based operations but a full 4DT ATM system is a step too far.
20	I have a positive attitude towards transitioning to 4DT.
21	Introducing 4DT is a cooperative effort (with other stakeholders).
22	Other stakeholders need my organization to successfully introduce 4DT.
23	My organization needs other stakeholders to successfully introduce 4DT.
24	The benefits of introducing 4DT are higher than the costs.
Thank you for filling out the AeroGame pre-test. Good luck and have fun playing the game!	

Appendix B Post-test Questionnaire

Post-test questionnaire	
The following statements concern the game you have played today. Please indicate to what extend you agree with each statement by crossing the line on a scale of 1 to 10.	
1	The goals of the game were clear to me.
2	I could keep my attention on the game.
3	The game uses the correct terminology.
4	The game facilitator asked questions that are relevant for the goals the game tries to achieve.
5	The game offered sufficient interaction.
6	The pace of the game was too slow.
7	The pace of the game was too fast.
8	The game was motivating.
9	The game was relevant for my work.
10	It is easy to understand how the game can be used in my work.
11	The game rules were easy to learn.
12	The game was difficult to play.
13	The look and feel of the game appeals to me.
14	The game in general appeals to me.
15	The duration of the game was long.
16	The duration of the game was short.
17	I felt engaged in the game.
18	Playing the game improved my understanding about the issues at stake regarding the introduction of 4DT.
19	4DT ATM as foreseen by SESAR is clearer to me after playing the game.
20	Introducing 4DT is a cooperative effort.
21	Other stakeholders need my organization to successfully introduce 4DT.
22	My organization needs other stakeholders to successfully introduce 4DT.
23	Benefits of introducing 4DT are higher than the costs.
24	I have a good understanding of what comprises the introduction of 4DT.
25	I support time based operations but a full 4DT ATM system is a step too far.

26	I have a positive attitude towards the transition to 4DT.					
27	Looking back: were you able to play the game from your role as stakeholder? I.e. were you able to show (to the other stakeholders) what your stakeholder's attitude towards 4DT is while playing the game?				Yes	No
28	Please elaborate.					
Change in the ATM system (requiring collaboration of multiple stakeholders) is often achieved through a careful but very lengthy process. After playing the game, what is your attitude towards the following topics for speeding up this process?						
29	Meetings (i.e. discussing the most important topics with other stakeholders)	Very good	Good	Neutral	Bad	Very bad
30	Workshops (i.e. executing several assignments with other stakeholders)					
31	Serious games (i.e. playing a serious game regarding given topic)					
32	Teambuilding activities (not topic related)					
What is your impression after playing the game of the attitudes towards the introduction of 4DT of the following stakeholders (you can skip the question for the stakeholder that you represent):						
33	Legacy airline operator	Not important at all	Not important	Neutral	Important	Very important
34	Low-fare airline operator					
35	ANSP					
36	Government					
37	Airport					
38	Did AeroGame meet your expectations? Please elaborate.					
39	Do you see any application for AeroGame in your field of profession? If so, please indicate where and how.					
40	Which part or aspect of playing the game was most valuable to you, and why?					
41	Would you recommend this game (as a tool to support change in ATM) to others (multiple answers may apply)?	Yes, to colleagues	Yes, to management	Yes, to family	Yes, to others	No
	Please indicate why, or why not.					
42	How can the game be improved?					
43	Do you feel that the game (as a tool to support change in ATM) can be adapted for other				Yes	No

	topics than the introduction of 4DT?		
44	Please indicate, why or why not.		
45	Do you see other applications for serious games in your organisation?	Yes	No
46	If yes, please indicate which applications.		
47	Has your attitude towards serious gaming changed after today's workshop? If so, please elaborate.		
48	Do you have other remarks and/or questions?		
Thank you for filling out this questionnaire!			

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