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Interactive A3 Architecture Overviews

INTUITIVE FUNCTIONALITIES FOR EFFECTIVE COMMUNICATION

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Abstract

The A3 Architecture Overviews introduced earlier provide a powerful communication medium in systems engineering and architecting. Intended originally for reverse architecting, they are now also applied for designing system architectures and for systems of systems. With the current development in user interaction and touch controlled interfaces, a new means of communicating in systems engineering opens: *Interactive A3 Architecture Overviews*. This paper gives an overview of the state of the art of A3 Architecture Overviews before we present an investigation into interactive possibilities and an evaluation of a demonstration using a proof of concept. The results of the demonstration with several experts are listed. The main conclusion is that Interactive A3 Architecture Overviews can convey more information, without impeding usability. We end with a proposal for further development.

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1. Introduction

Systems engineering is a complex discipline. The amount of information that needs to be processed by the systems architect and his/her coworkers is large. In fact, being able to navigate through the information and being able to make far-reaching decisions are key competences of the systems architect. Different support mechanisms exist, of which modelling is an important one. Yet, even with the availability of relevant models, the issue of communicating the

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architecture and its rationale to other stakeholders remains difficult because of the expertise differences of the stakeholders^{1,2}.

The natural tendency of people creating and using models is to search for completeness and accuracy (note the challenge of systems engineering stated by Kalawsky³: “The desire to accurately model/simulate a complex system and its environment in minute detail through to a higher level of abstraction still remains the ultimate challenge.”) Yet, from earlier research, we conclude that such a desire may lead to data-burial and lack of information at the same time. In the field of systems engineering, we have concluded that expert architects do not create their models to a minute detail, but are able to leave out distracting details in order to convey the architecture and its rationale^{2,4}.

The A3 Architecture Overviews (A3AOs) by Daniel Borches^{5,6} are based on this simplification principle, while focusing on communicating the architecture. By limiting the amount of information to (two sides of) a sheet of A3 paper, the architect creating the overview has to reason carefully about what information contributes to the message and what information distracts. As the name implies, the A3AOs are paper based. The goal is to create printouts of the A3AOs that can be used in meetings, daily work and to support architectural reasoning. Considering the present technological developments, in particular display and user-interaction means, we consider it topical to investigate the A3AO approach further to incorporate interactivity. The investigation of the need among system architects for such interactivity and the demonstration of it, is the subject of this paper. In close cooperation with experts from industry, also those familiar with the paper-based A3AO approach, we have created and evaluated ways to add interactivity.

The paper follows the organization of the process. The analysis corresponds with the state of the art, treated in Section 2. The creation and selection of concepts for interactive functionality is described in Section 3. Subsequently, the selected functionalities and the format of the demonstration are detailed in Section 4. Evaluations of each functionality, the hardware and the Interactive A3AO concept as a whole, treated in Section 5, give rise to the conclusions (section 6) and an outlook for future work (Section 7).

2. State of the art

2.1. Systems engineering

While systems engineering has a solid foundation in the defense and space technology, it is becoming increasingly more used in other industries. Nowadays, the development of other products uses findings from the systems engineering discipline. For instance, complex machinery and medical equipment are often developed using these principles. An important trend in the field is model based systems engineering (MBSE), where documentation is not done with report-like documents, but in models. Several standards exist, or are in development, such as ISO/IEC/IEEE42010 superseding IEEE1471⁷. Reichwein and Paredis present⁸ an overview of existing Architecture Frameworks for MBSE. SysML is the predominant formalism for MBSE. Other formalisms exist, such as the ESI/TNO Design Framework^a and the Architecture Modelling Framework^{9,10}. While MBSE aims at creating ever more correct models of the system under design, it can be hard for a developer to find the right information at a particular point in time. Additionally, the development of models often leads to further detailing, with less attention to the big picture or possible emerging behavior.

Another trend that tries to address these issues, is to improve communication in systems engineering^{2,5,11,12}. One of the present authors has presented recommendations for successful complex systems engineering, paying particular attention to communication². These include applying multiple views, simplifying as much as possible (but not more) and using a combination of functional, physical and quantified models. For the implementation of these guidelines, frameworks are used as well, but these are less formally defined. In particular, the A3 Architecture Overviews can be seen as such a framework. Because the A3AOs form the basis of the present research, we will further investigate these in the next subsection.

^a <http://df.esi.nl>

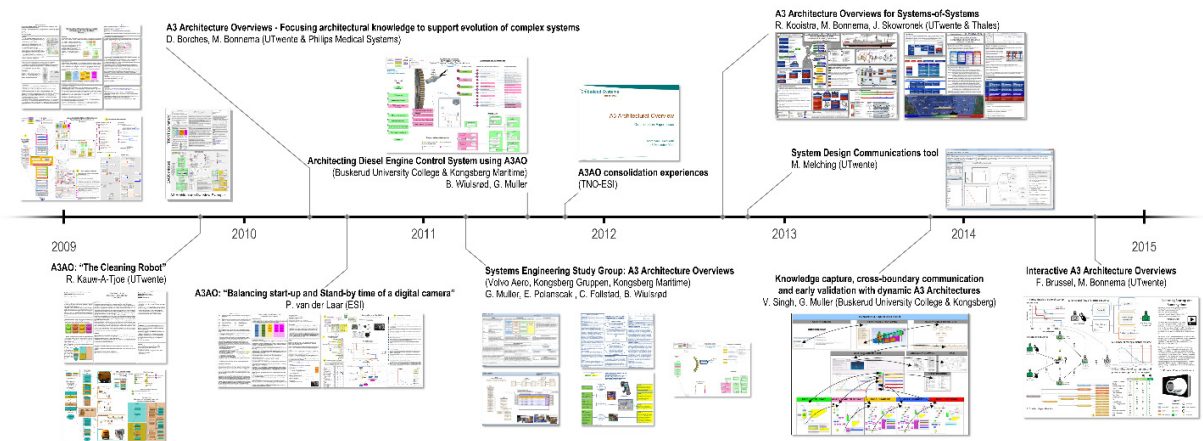


Figure 1: The development timeline of the A3 Architecture Overviews. A zoomable version is available at <http://tiny.cc/ia3ao-t>.

2.2. A3 Architecture Overviews

The timeline of the development of A3 Architecture Overview (as seen in Figure 1, with a zoomable online version at <http://tiny.cc/ia3ao-t>) starts with the proposition by Borches^{5, 6} where he describes both the structure and the contents of the A3AOs, as well as the process to create them. The content offers a shared frame of reference between the diverse stakeholders in the design process. The core of the A3AO exists of a Physical, a Functional and a Quantification view. The original process is aimed at the description of an existing system, through information extraction, abstraction and presentation. The first experiences at Philips Medical Research show that the A3AOs assist in comprehension of the system. Since the initial publications by Borches, further experimentation and development has taken place at TNO¹³, the University of Twente¹⁴ and through Buskerud University College^b at Volvo Aero (now GKN Aerospace Engine Systems), Kongsberg Gruppen and Kongsberg Maritime. An extensive review of the A3 Architecture Overview is performed by Wiulsrød and Müller¹⁵. The involved engineers confirmed that the structured diagrams of the A3AOs enable sharing of system knowledge. The A3AOs provide overview, combined with focus on the details. The paper concludes that A3AOs contribute to communicating the system architecture and enable the user to be a good architect, while applying systems engineering principles.

In “*A3 Architecture Overviews for Systems-of-Systems*”¹⁶ expansion of the A3AO is proposed in the direction of reverse-architecting Systems-of-Systems (SoS). The case used is the Thales Tacticos combat management system. This A3AO describes a SoS on a high abstraction level, yet connecting to the operational context of Tacticos. There are more stakeholders than in the original A3AO approach, leading to more interaction between them. The high abstraction level leads to more generic models or a division of models. Feedback on this approach has been positive. The stakeholders are more aware of their contribution to the entire project and they have a clear operating scope.

Melching¹⁷ describes the “*System Design Communications tool*”. This tool combines the A3AO with the Architecture Model Framework⁹. All types of objects (parts, functions, assemblies, etc.) can be incorporated. Configurations with different parameters can be made, to investigate consequences of changes. The Dynamic A3 Architecture¹⁸ is a hierarchy of A3AOs, from super-system to subsystem. It is based on the paper A3AO approach, and adds hyperlink navigation in a digitized environment. The resulting system is used to support system requirements, design, analysis, verification and validation activities. It is concluded that the dynamic A3AOs promote internal and cross disciplinary communication, facilitate knowledge retention and creates a common understanding of the system. Apart from the hyperlinks, further advantages of digital techniques are not used.

^b See the results of the Systems Engineering Study Group of October 2014 on <http://www.gaudisite.nl/SESG.html#20141016>

Based on the above state of the art, we concluded that recent soft- and hardware developments provide an opportunity to create more interactive A3AOs by using findings from the System Design Communications Tool and the Dynamic A3s. An initial round of interviews with experts confirmed that conclusion. In the next subsections, we will look at the soft- and hardware opportunities. With that in mind, functionality conceptualization for Interactive A3AOs is looked at in section 3.

2.3. Software

Software relevant for displaying interactive and/or zoomable content has been analyzed, see Table 1. The accessibility for the end-user and the comprehensiveness of functionality is shown on scales ranging from -- to ++. The software should provide support for interactive zooming, gesture recognition and for simple if-then constructions or programming capabilities. Purging the options that do not meet this, results in the following candidates:

- *Microsoft Visual Studio* offers support for programming extensive functionalities. However, implementing this option is time-intensive and requires expertise.
- *Intuiface* combines extensive functionalities with an accessible user interface. Its primary use is to create interactive shopping experiences, though it can be adapted to create an Interactive A3AO demonstration.
- *Adobe InDesign* has broad support for animations and other functionalities, but not for interactive zooming. *Openzoom* is an open source project that can be combined with InDesign to add zooming support. However, the project has not been maintained for several years, is not supported by Adobe and does not offer zoomlevel dependent image visibility.

Table 1: Available software for the demonstration, with their evaluation. Multiple pricing correspond with multiple pricing options.

Software	Price	Accessibility	Functionality	Zooming	Gestures	Basic if-then	Programmability
Microsoft Deepzoom	++	+	+	Y	Y	N	N
Microsoft Visual Studio	++ / --	-	++	Y	Y	Y	Y
Prezi	++ / 0 / -	++	+	Y	Y	N	N
Javascript libraries	++	-	0	Y	Y	N	Y
Intuiface	++ / -	+	++	Y	Y	Y	N
Adobe InDesign CS6	--	0	+	N	Y	Y	Y
Openzoom	++	--	0	Y	Y	N	Y
Axure RP	- / --	+	+	N	N	Y	Y
Photosynth	++	+	+	Y	Y	N	N

2.4. Hardware

Potential hardware for the demonstration is presented in Table 2. While some of the options would have been interesting, their unavailability resulted in a smaller list of candidates:

- *The Microsoft Pixelsense table* works optimal as a collaborative working tool. It has good touch sensitivity and processing power.
- *Tablets* are very popular for home use and increasingly so for professional use. For this demonstration Windows tablets provide optimal support for development software. A Microsoft Surface Pro 2 with a screen diagonal of 10.6" is available.
- *The Touchwall* is ideal for interactive presenting, due to the large screen size and vertical orientation.
- *Regular computers* provide a good reference, as these are prevalent in industry.

Table 2: Available hardware for the demonstration, with their evaluation.

Hardware	Price range	Screen size	Industry acceptance	Availability	Use mode
Microsoft PixelSense table	n/a anymore	40"	low	Y	Group collaboration
TouchWall	custom order	80" +	low	Y	Interactive presenting
LCD with touch recognition	\$ 1000 - \$ 5000	40" - 65"	low	N	Interactive presenting
Tablets	\$ 500 - \$ 2000	8" - 13"	medium	Y	Single user
All-in-one tablet PC's	\$ 1000 - \$ 2000	18" - 27"	low	N	Single user
Regular computers	\$ 500 - \$ 2000	15" - 30"	high	Y	Single user

3. Conceptualization

3.1. Concepts of the functionalities

We have developed multiple concepts of functionalities. These are based on the analysis of the work field, the current usage of the A3AOs and the users' needs and demands that followed from the initial interviews. The concepts are described textually in order to let the experts focus on the abstract function, instead of being distracted by a visual representation that would focus too much on the interface. Additionally, this allowed for iterative refinement in-between the different interviewing sessions. In Table 3 all functionalities are listed, with experts' evaluations on the categories advantages, disadvantages, knowledge expansion, adoption likelihood and feasibility.

The ratings have been used to determine the functionalities that should be developed in the demonstration. We have chosen to develop several functionalities, albeit less in-depth, instead of comprehensive development of one functionality. This offers more insight in the overall capabilities of the Interactive A3AO. The selected functionalities are explained in detail in section 4.

3.2. Selection of hardware and software

Realization of the demonstration requires suitable hardware and software, with respect to the previously selected functionalities. These functionalities are aimed at individual use, not at interactive presenting or collaborative working. Therefore, tablets offer the best foundation for the demonstration. This has the added benefit that the demonstration can be held on-site at the selected companies. A laptop is used as a reference, to compare the touch interactions with mouse and keyboard interactions.

The software, both Intuiface and Adobe Indesign combined with Openzoom, does not allow the use of interactive functionalities (such as an if-then action when something is clicked) within zoomable content. This is acceptable for the demonstration, but not for the end product. For this demonstration, Intuiface offers the optimum balance between functionality and accessibility. The zoomable diagrams are made in Microsoft Deepzoom Composer and imported.

4. Demonstration

The goal of the Interactive A3AO demonstration is to determine the added value of the new functionalities, with respect to the A3AOs on paper. The goal is not to validate the preliminary user interface, although feedback will be documented for use in further development. The demonstration is based on realistic content; an existing A3AO has been redesigned to include interactivity. The elements of the demonstration correspond with the chosen functionalities.

Table 3: Proposed functionalities for the demonstration, with their evaluation.

Functionality	Advantages	Disadvantages	Knowledge expansion	Adoption likelihood	Feasibility	Rating
<i>Creating A3 Architecture Overviews</i>						
Draft version – Paper sketching w. simplified digitalization	+	-	++	-	++	3
Draft version – Paper sketching with automatic digitalization	0	--	0	-	-	
Draft version – On the fly creation on interactive table	+	0	++	--	+	2
<i>Reviewing A3 Architecture Overviews</i>						
Making changes on the fly in a meeting, on an etouch wall	+	0	+	+	0	3
Communication (1) – textual contact	+	-	++	0	+	3
Communication (2) – verbal indirect contact	+	0	++	0	0	3
Communication (3) - contact details	+	0	0	+	++	4
Communication (4) – verbal direct contact w. text-to-speech	0	-	0	-	-	
Communication (5) – verbal direct contact w. conclusion	+	0	+	+	+	4
Management of content that is in development / uncertain	+	0	0	++	+	
Extended version control	0	-	+	--	-	
<i>Using A3 Architecture Overviews</i>						
A3AO for system of systems	0	0	0	-	++	
Basic digital accessing of A3AOs	+	0	0	0	++	
Internal links	++	-	++	0	+	4
Zoomable diagrams	++	-	++	+	++	6
Filtering content	+	--	+	--	0	
External links (such as specifications)	+	-	+	+	+	3
Link between textual and graphical side	+	-	+	-	+	1
Audiovisual explanation	++	-	++	+	+	5
Multiple viewports	+	0	+	+	+	4

The selected functionalities have been developed through sketching and deliberation with an expert. A visual overview of all functionalities is given in figure 2. The paper medium of this publication is not optimal for understanding the interactivity, therefore an explanatory video has been made available at <http://tiny.cc/ia3ao-d>. The functionalities are:

- A. *Zoomable diagrams*: these provide an abstract view of the system at the top level. Zooming in on a part of the diagram, the constituent parts appear. Also, zooming enables using miniature images and explanations.
- B. *Internal links (color)*: The system described by the A3AO has several states. When a state is chosen, the corresponding properties in the dependency tree and the quantification view light up using colors.
- C. *Internal links (arrow)*: Arrows signify relations between different parts of the A3AO. The path of the arrow can be hidden, leaving only the start and end points.
- D. *External links*: A symbol (a star) signifies the availability of additional information on the requirements. When clicked, the information is loaded from the external database and shown in a pop-up window.
- E. *Multiple viewports*: All previous functionalities show the A3AO on a single full screen window. This functionality allows the creation of several viewports in which the same A3AO is displayed at different locations and zooming levels.

- F. *Communication for reviewing*: As a preparation for a review session, all participants create comments in a centralized environment. They can see and react to other comments, using the combined communication methods. Multiple symbols and colors indicate categories of comments.
- G. *3D CAD model*: The model, exported from solid modelling software, can be zoomed and rotated.
- H. *Audiovisual explanation*: A novel user of an A3AO clicks on the play icon to receive an audiovisual explanation of the content. The A3AO author creates it by making notes and drawings on the A3AO, which is recorded simultaneously with his speech. This can be used to replace the textual explanation.

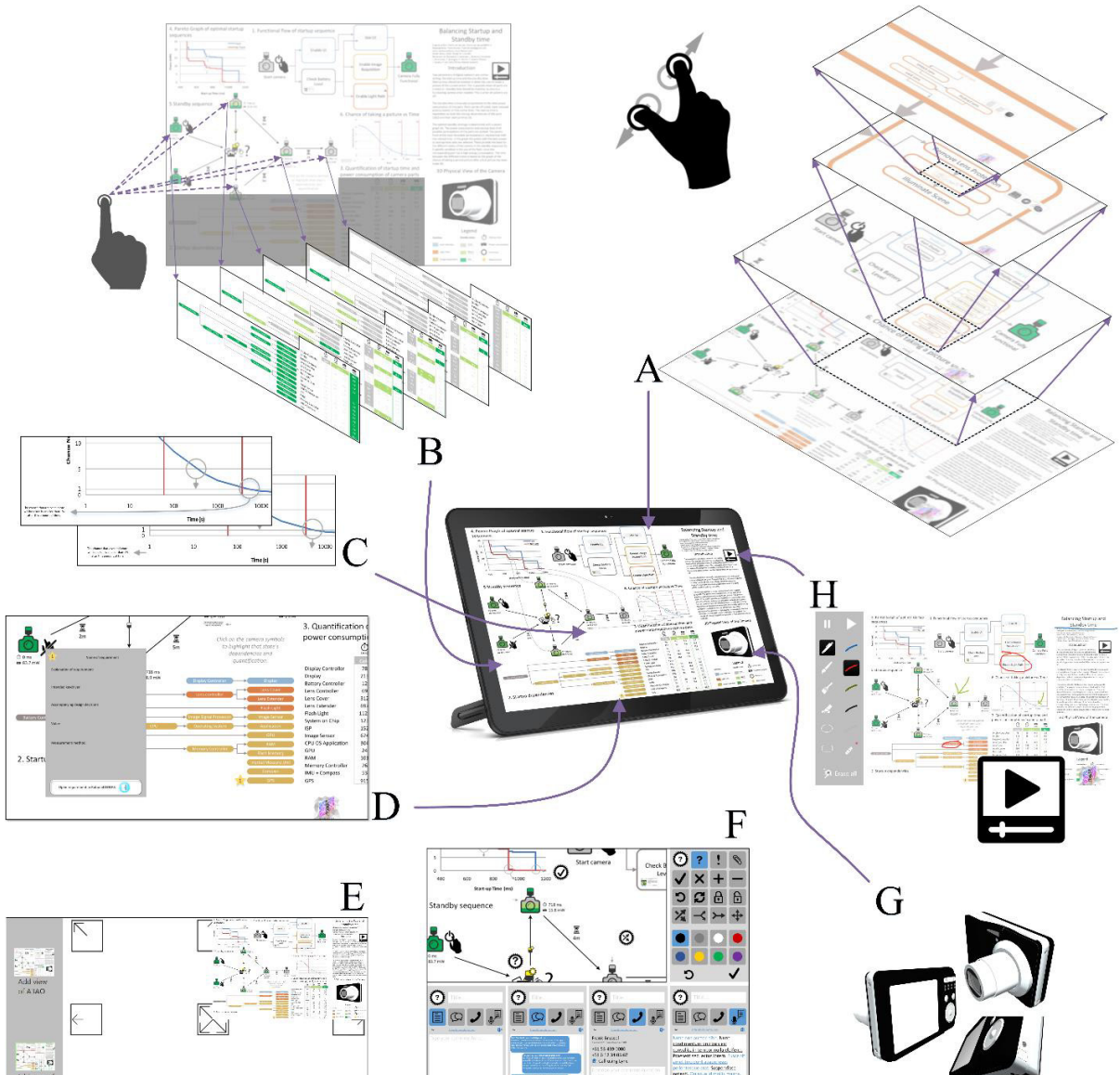


Figure 2: A visual overview of the functionalities in the demonstration. An explanatory video is available at <http://tiny.cc/ia3ao-d>.

5. Results

5.1. Evaluation of each functionality

Four demonstrations, with in total eight experts, have been held: two at the University of Twente, one at a medical equipment manufacturer and one at an organization active in security. All were held in August 2014 and each demonstration took approximately two hours. Each demo started with a short introduction and highlights of the analysis. Subsequently, all functionalities were shown and discussed separately. Questions prepared beforehand structured the discussion. These were both recurring questions and questions specific for that functionality. Concludingly, the possibilities for the Interactive A3AO as a whole were discussed, including the desired future progress. Answers were noted textually. The discussion of the experts led to the following principal results:

- A. *Zoomable diagrams*: This is rated as a powerful primary function, since more information can be contained without impeding usability. It combines abstraction with a level of detail. Points of improvement are marking zoomable areas and the amount of work needed for creation and modification.
- B. *Internal links (color)*: Similarly to the zoomable diagrams, this is seen as a powerful primary function to communicate information in an intuitive way. The information is only shown when needed, thus lowering the threshold for use. Other uses include comparing multiple scenarios or configurations, or to provide insight to required changes. The amount of work needed for creation and modification is an issue.
- C. *Internal links (arrows)*: This functionality assists the definition of relations between parts and views, which is an important aspect of the A3AO. Additional arrows can be placed without cluttering the overview because of the possibility of hiding the line. It is useful, but in itself not a reason for switching to a digital environment.
- D. *External links*: For system requirements, this functionality would be a convenient addition. An augmentation could be to see which A3AOs are influenced by specific requirements. The question rises whether supplementary links should be possible to, for instance, webpages, Matlab simulations, PDF files, etc. Each can be useful, however in total the A3AO could gradually incline to information storage rather than communication.
- E. *Multiple viewports*: The potential need for this functionality is recognized. However, this can only be determined after extended practical experience. The map showing the scope of the current view is a helpful supplement.
- F. *Communication for reviewing*: The current method of reviewing paper A3AOs is rudimentary, and this proposed functionality would offer significant improvements. Additionally, it could be useable for structuring the review meeting itself through determining the order in which comments should be treated.
- G. *3D CAD model*: This is seen as a useful secondary function. It propagates a mental model of the physical properties. Enhancements would be wireframes with components and animations.
- H. *Audiovisual explanation*: All experts see this as a suitable communication method, however they differ on the role. Half of them see it as a replacement of the written text, the other half sees it as an addition. Talking to the tablet while creating the explanation could feel uncomfortable. Augmentations could include separate explanations per part of the A3AO and displaying the duration of an explanation so that an A3AO user can select the explanation based on the available time.

5.2. Evaluation of the hardware

The experts preferred the touch interaction over regular inputs, especially for zooming. Interaction with the mouse is considered acceptable. However, for creation or modification of an A3AO the accuracy and speed of respectively mouse and keyboard is preferred. Being able to zoom mitigated the need for a screen size comparable to the A3 format somewhat. However, the 10.6" screen size of the tablet in the demonstration was found too small. Only few items were readable without zooming. The decreased portability of the current all-in-one tablet PC's with larger screens makes them at present unsuitable for regular use.

5.3. Evaluation of the Interactive A3AO concept as a whole

All experts agreed on the usefulness of the developed concept. The experts of the company where A3AOs are implemented to a greater extent, rate the applicability of the Interactive A3AO concept highest. A general remark is that the concept allows more information to be communicated while keeping a low threshold for use, especially with the zoomable diagrams and the internal links with color. Condensing information to the size of one A3 paper transforms to providing information on levels, maintaining comprehensibility at each level. The experts mention that the A3AO-author should choose functionalities to fit the information that needs to be conveyed.

Approximately half of the experts expect the Interactive A3AO to replace the paper version completely. The other half expect them to coexist, in which it is acceptable that a printout does not offer all information. The paper version is easy to take along and create notes on. Furthermore, incoming messages on a tablet could distract during meetings.

6. Discussion

This research has been performed in cooperation with a group of eight experts. Limited numbers of participants are a recurring problem in systems engineering research^{19, 20}. However, all experts had relevant experiences concerning systems engineering, A3AOs or both. The diversity of their background prevents a biased judgment. The demonstration used realistic data and had a hands-on approach, mitigating differences in interpretation. The experts had minor differences in opinion or considerations, in line with their backgrounds or as result of uncertainty about the future. They indicated when their predictions were uncertain or when more information was needed. Concluding, the results are deemed valid for establishing the prospects for Interactive A3AOs. The experts asserted the applicability and advantages of the Interactive A3AOs. This opens the possibility of further research, in which one company is considering an active role.

The current hardware offers a satisfactory interaction experience. However, a large screen needs to be combined with improved portability. Portable devices with approximately an A3 sized screen would act as a catalyst for adoption of the Interactive A3AO. The industry seems to be working in this direction, using flexible OLED screens^c. Meanwhile, Interactive A3AOs are complemented by their paper counterparts to provide portability.

To create and view Interactive A3AOs, software is required that consolidates interactivity and zooming. It is not likely that current software will develop in that direction, as it is a niche market. Therefore, development of tailored software is recommended. Successive introduction and evaluation of features allows rapid evolution of the tool, achieving practical results. We propose to initiate development with supporting the current paper A3AOs with reviewing functionality in a digital environment. Subsequently, uncomplicated features such as 3D CAD models, video explanations and external links are added. Thereafter, and taking the state of affairs at that time into account, more complicated functionalities will be added, such as zoomable diagrams and internal links using colors. These require tooling support for third party software, e.g. Microsoft Visio, or a connection with an Architecture Model.

Coalescence of Architecture Models and A3AOs seems evident, as the former provides comprehensive information and the latter makes the information understandable and usable. However, at the current moment a fusion would not necessarily fulfill their respective functions equivalently. The focus could drift towards completeness, diminishing the A3AOs capabilities for information selection and abstraction. Therefore, separate (although similar) development is recommended for the near future.

7. Conclusions and Future Work

We conclude that new technologies offer many opportunities to make the A3AO a more useful tool. Regarding the functionalities, primary advantages are diagrams which reveal more information when zoomed and links between

^c Examples can be seen on <http://lgdnewsroom.com/multimedia/images/photos-photos-videos/flexible-display/4135> and <http://www.youtube.com/watch?v=MKG7XRsg9KQ>

different types of content on the A3AO. Secondary advantages are a centralized environment for reviewing, audiovisual explanations and providing links with external information. A core competency of the Interactive A3AO is the ability to convey more information, while keeping a low threshold for use.

At present, no suitable software exists that offers these functionalities, nor is it likely that this will be developed by the current market parties. While the present demonstration has worked, it is based on the abilities and limitations of the software used. Therefore, we recommend to develop a software solution that enables the interactivity of the A3AOs. This includes both the user-side and a means to create the Interactive A3AOs. Conceivable business models are a standalone software package or a service model with consultants aiding information extraction and creation of the Interactive A3AOs. Industry partners are invited to participate in the development.

Additionally, we recommend investigating further connection between the Architecture Modeling Framework and A3AOs in general and Interactive A3AOs in particular. This unfolds a path that might lead to understandable and communicable Information Models that encompass minute details to abstract views, closing the gap to answering the ultimate System Engineering challenge.

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