Round Table 2

Simulation and Interactive Visualisation: Building the Space System Digital Twin Collaborative Approach and Virtual Spacecraft throughout Project Phases

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INTRODUCTION

The Round Table was organised with the aim to debate on how to improve the end-to-end development process improving methodologies, tools, and technologies (covering the aspects of Requirements, Design, Manufacturing & Assembly, Integration & Testing).

A first Round Table addressed the **MBSE** application throughout the project lifecycle, preparing the terrain to address the concepts of the **"Design 2 Produce" cross-cutting initiative**, highly connected to the digitalisation.
Building a **"Digital Twin"** of the space system, using adequate models, tools and methodologies could improve space systems development from requirements managing to design and AIT phases.
Sensor technologies, advanced manufacturing, virtual and augmented reality could improve the end-to-end development process, reducing costs and schedule.
Infusion and adaptation of non-space solutions and techniques is considered essential for innovation and competitiveness.
Collaborative approach and interaction among engineers of early and later phases, along with frontloading and required mind-set change will be among the fundamental topics of discussion.

ROUND TABLE OBJECTIVES

The discussion goal was to introduce the themes of the **4th industrial revolution** in the SECESA community, targeting a common understanding of its challenges (confidentiality, exchange of information, standardization & compatibility, …)

Fig. 1: CM 16 – A Motto and a Logo for us to share (courtesy of ESA)

ROUND TABLE FORMAT

The Round Table format consisted in three “open discussion” blocks:

1. The Digital Model: Tools and Processes (focus on later phases)
2. The transition from the Digital Model to the Assembled System
3. Advanced Manufacturing, Assembly, Integration & Testing

Each block was introduced with relevant statements prepared by the the panelists, supporting an open discussion that would involve the round table and the whole audience.

Participants:

Moderator:
Antonio Martelo, DLR, System Engineer and Head of Concurrent Engineering Facility (CEF)

Panelists:
Joachim Fuchs, ESA, Head of System Modelling and Functional Verification section at ESTEC
Christoph Kossira, AUDI, Head of chassis simulation
Jean-Luc Le Gal, CNES, Responsible of the Concurrent Design Facility at the Space Mission Feasibility Study Office
Jan-Christian Meyer, OHB, Project Engineer for Space Systems Studies
Mauro Pasquinelli, TAS, Specialist in Model-based tools and methods
Oliver Romberg, DLR, Head of System Analysis Space Segment Department
Giancarlo Varacalli, ASI, Head of Engineering Office, Technology and Engineering Unit
Francois Verges, AIRBUS, Integration and Test Techno leader.

Fig. 2: Round Table 2 Moderator and Panelists at SECESA 2016 – 5 October 2016, UPM-ETSIAE - Madrid

THE DIGITAL MODEL: METHODOLOGIES AND DESIGN

Round Table 2 opened with stating the need to make sure that info for AIT are included in the Digital Model: the Digital Model needs to look forward to the integration phase.

However, there are a few questions to answer:

1. How early do we need to include this information useful to AIT into the Digital Model?
2. Where would these data come from? From mechanical analysis?

There is a need to define a flow for the required data.
Mission design should involve since the very beginning considerations concerning Integration (cit ADS, Verges) and - with the new manufacturing methodologies, mission design should also start from manufacturing (as it is currently done in Automotive)

Before even defining the content of a Digital Model, there is need to define whether it makes sense to have a Digital Model in the prototype world.
The panel agreed that the need of a Digital Model is surely strong and that an effort should be dedicated to define the content of it.
The discussion acknowledged that a 4th Industrial Revolution is happening in Industry, in particular in the fields of Manufacturing and Robotics.
Simulation and Augmented Reality are promising opportunities, but still far from being ready to use, due to scarce funding available to develop the required technologies.
TAS-F is supporting the R&D on simulation, with an application case, and defends the importance of a Visualisation Tool.

Airbus Aircrafts runs inspections with Virtual Reality, and ADS believes that this sort of applications could be extended to space industry.
Also the ISS experience proves that using VR and Digital Mock-up was beneficial during production and throughout the AIT.

According to the panel, going towards **MBSE is one of the steps required for the implementation of a Digital Model**, and a **definition of its contents and architecture** would be required first.
There is in fact the need to define the usage of the Digital Model to determine its characteristics.
MBSE is needed to improve our production processes (e.g. in AIT, at PDU level, there is a lot of effort between the office table and the assembly line (documentation and assembly procedure) and this could be avoided by adopting models).

MBSE would offer the means to implement a Digital Model, which should enable the transition from design to production, including retro-fit of lessons learned.

Creating a Digital Model, which acts as an archive for all the information related to a system, is the *condicio sine qua non* for improving our practices and extracting more value from data, from project management to requirements management, from design to simulation, from procurement to interactive visualisation (virtual reality and augmented reality) and testing.

A Digital Model would enable **frontloading** (simulate as much as possible, as early as possible) by exploiting the innovative visualisation solutions offered by **virtual and augmented reality (VR/AR).**

ASI mentioned that LSI are making a good step ahead, however SMEs are behind as they do not have budget to take the direction of Industry 4.0. As their contribution is essential in the European industrial ecosystem, dedicated frameworks shall be thought of in order to get them involved in the most adequate way.
One of the main challenges is to understand what is the effort required to integrate the modelling into our space practices.

In serial production modelling is planned and integrated, while for the one-of-a-kind business, the utility of it could make sense only in specific cases, as in critical missions for instance.
The question raised by the panel was: "**How can we import processes and learn from Automotive**?".
It is still unclear what space and automotive can exchange and can learn from each other. Space is more advanced in early phases, while Automotive is in later phases (mass production). This contrast could be the basis to build a collaboration where each party could learn how to improve using the experience and the lessons learned of the other.
Collaboration raises immediately security issues, which should be duly addressed in the definition of a cross-fertilisation framework.

An additional challenge would be the **interoperability of evolving sets of tools**, along with a mind–set change, required even before the tools are ready for use.
The panel recommended to identify and detail use-cases supporting the benchmarking of the MBSE approach, and the assessment of its advantages with respect to standard practices**. A pilot project involving space and non-space stakeholders could offer the opportunity to exchange experiences.**

Definition of use cases requires good skills and expertise and should be done ensuring that they enable cooperation in the most promising areas. Hans-Peter de König mentioned the existence of a joint WG including INCOSE and Nafens (https://www.nafems.org/about/, International Association for the Engineering Modelling, Analysis and Simulation Community): they define relevant use cases on how Systems Engineers and Modelling experts can work together.

DLR proposed a **Working Group**, including experts from space, from Automotive and other domains in order to identify elements that can be shared across domains. Industry shall be involved defining a win-win framework.
TAS-I mentioned that the EU Commission is currently funding a Project where experts from diverse domain (Automotive, Nuclear, Space, …) collaborate on developing technologies of common interest (scanned bar codes for identification of parts, VR…). ESA should coordinate efforts currently on-going in Europe, enhancing harmonisation, cooperation and competitiveness.

THE TRANSITION FROM DIGITAL MODEL TO ASSEMBLED SYSTEM

The second open discussion of the Round Table started acknowledging that several technologies are currently being developed by non-space companies (Google glasses, Virtual and Augmented Reality applications) which could be used to improve AIT. Technology is thus relatively mature; we are not far away from using it (ESA is supporting developments leading to Harness applications with VR). However, a good understanding of which technology we need in space is required, in order to support ad-hoc developments.

Panelists mentioned a few application examples, indicating areas where focus is recommended.

In particular, the use case of a clean room was mentioned: models and visualisation tools could increase the efficiency of assembly and integration procedures, avoiding engineer going back and forth between documentation and test bench. In order to support this application, developments are needed to ensure an adequate link between design models and Virtual/Augmented Reality tools.
TAS-I explained that Virtual Reality tools uses CAD files, which are not a detailed representation of the spacecraft.

In addition, automation of recurring steps in AIT, and re-use of modules are areas where production could become more efficient.

We can think of how to modify our development procedures including these new elements, elaborating new methods, though the very first question we should answer is "how much does it cost to check that the digital model corresponds to the "as built"?"
We need ways to "calibrate" our model and to understand how good we are at building such a model.

A Digital Model would offer the opportunity to perform robustness and sensitivity analysis, not possible when working on the hardware. Once the model will be validated as a reliable representation of the "as built", **hybrid testing approach could be envisaged, possibly embedding simulation in the qualification process.**

This is certainly a long-term view, however the aeronautic industry is already implementing similar procedures, as well as running inspections with VR.

ADVANCED MANUFACTURING, ASSEMBLY, INTEGRATION & TESTING

The Objective of Digitalisation is cost saving through the improvement of the efficiency of our development practices.
Manufacturing is a field undergoing huge innovation, offering opportunities to the production process, both in terms of cost savings and enabling features.
There, the target is the achievement of the maturity of processes, along with the understanding – already at design level – that manufacturing process is no longer necessarily a constraint, but a design parameter.
Last, automation is considered a promising area to improve efficiency and cost of the AIT phases.

PARTICIPANTS' SURVEY

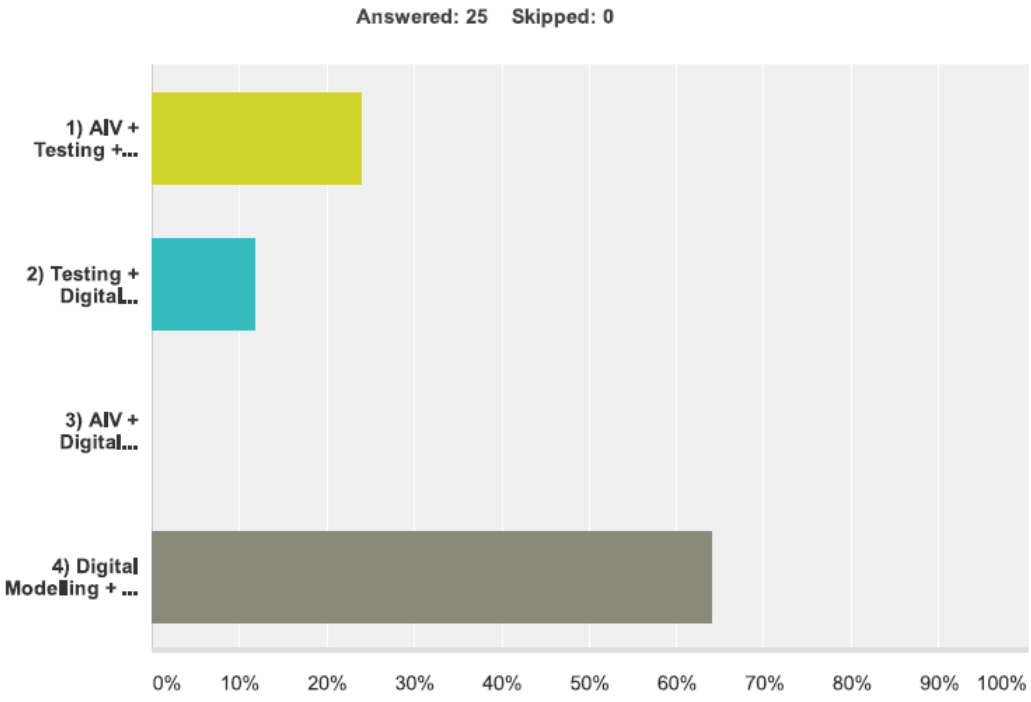
In order to maximise the involvement and contribution of SECESA participants to the discussion, panellists gathered a set of questions which have been answered using smartphones and any device with an internet connection in the time preceding the Round Table.

Results were displayed on a shared screen and discussed during the debate, and are reported here below:

1. **Question 1**

Infusing processes from non-space industry, despite the inherent differences between mass production (which happens in most industries) and prototype development (which is more common in space), would be an opportunity for space practices.
Which areas should we target first with the objective of achieving a fast/successful infusion?

Select the sequence you find more adequate:
1) AIV + Testing + Digital Modelling
2) Testing + Digital Modelling + AIV
3) AIV + Digital Modelling + Testing
4) Digital Modelling + AIV + Testing



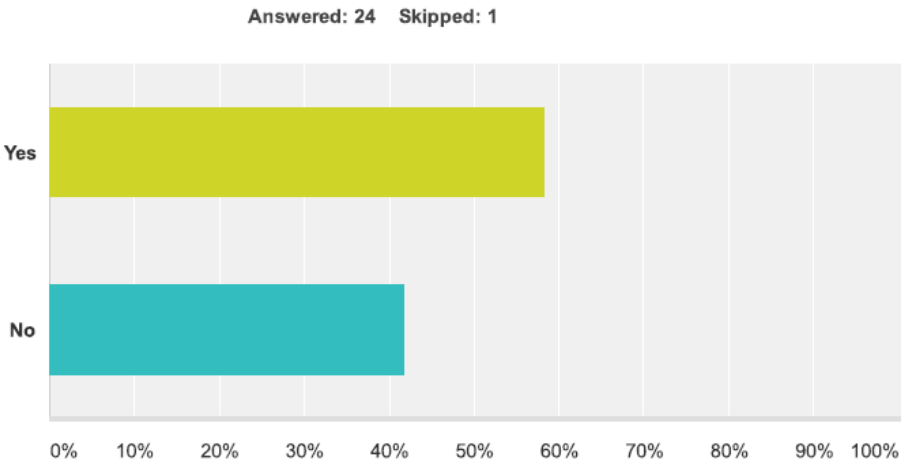
Answer Choices	Responses	
1) AIV + Testing + Digital Modelling	24.00%	6
2) Testing + Digital Modelling + AIV	12.00%	3
3) AIV + Digital Modelling + Testing	0.00%	0
4) Digital Modelling + AIV + Testing	64.00%	16
Total		25

Fig. 3: Question 1 – Participants' Answers

2. Question 2

Assuming that technology would be ready to support testing performed on the virtual spacecraft, would the space community be ready to accept this new approach to count towards qualification?

1) Yes
2) No



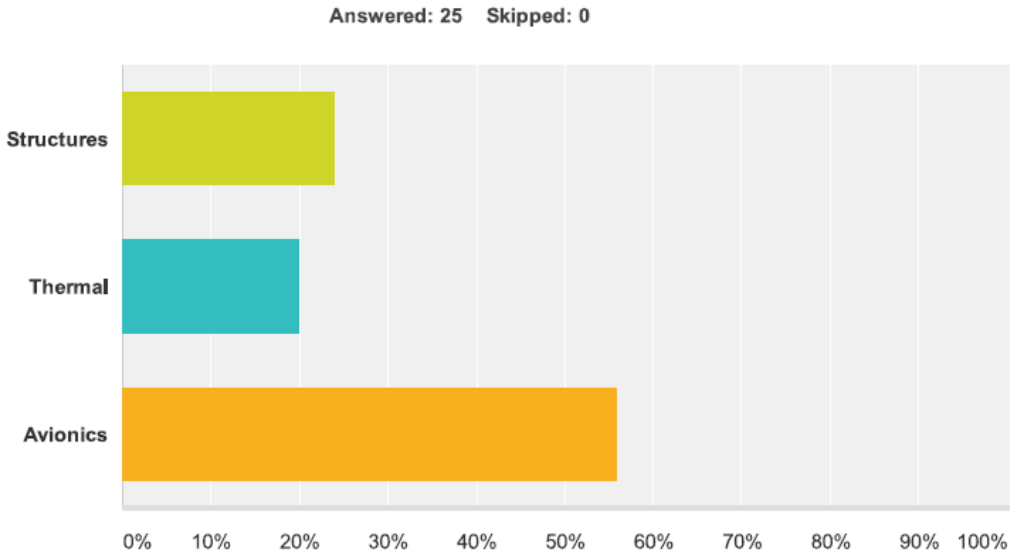
Answer Choices	Responses	
Yes	58.33%	14
No	41.67%	10
Total		24

Fig. 4: Question 2 – Participants' Answers

1. Question 3

On which subsystem(s) could we automatically derive the most relevant satellite tests from the digital model?

1) Structures
2) Thermal
3) Avionics



Answer Choices	Responses	
Structures	24.00%	6
Thermal	20.00%	5
Avionics	56.00%	14
Total		25

Fig. 5: Question 3 – Participants' Answers

CONCLUSION

The Conference has been instrumental to introduce and debate on the concepts of digitalisation and 4th industrial revolution in an international forum, gathering feedback from several stakeholders.

Panelists from National and International Agencies (ESA, NASA), space LSI and automotive industry representatives agreed unanimously on the need to adopt a MBSE approach in projects, debating on the benefits that a Digital Model could bring about.

The outcome of the discussion will feed the decision making process to define the next steps for ESA in supporting European space industry turning into smart factories.