# BOOK OF ABSTRACTS

## Design is a Team Sport

25th International Conference on Engineering Design
11 - 14 August 2025

THE UNIVERSITY OF TEXAS AT DALLAS

ICED25 Dallas, TX

**Dallas, TX, USA**

# ICED 25

## 25th International Conference on Engineering Design

Dallas, Texas, 11 - 14 August 2025

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# 25th International Conference on Engineering Design

Dallas, Texas, 11 - 14 August 2025

## “Design is a Team Sport”

Design as a Team Sport will be the general theme for ICED25. Design is recognized as fundamentally collaborative, requiring collaborations between engineers and stakeholders, between different disciplines, between different cultures, between different skills, and between human and artificial agents. Our goal is to bring together the practitioners of design to share their experiences and best practices, especially including collaboration and teamwork. We are excited to learn about the research that is being done in supporting this collaboration, be that inquiry based research, problem based research, or invention based research. The conference itself is essentially a team: it is a group of people with a defined objective to learn and share knowledge for a defined period of time. Join the ICED25 team by preparing your contributions now.

The conference will be organized around plenary, podium and discussion sessions. Academic and industrial experts will deliver high-level keynotes. The General Meeting of the Design Society, the Special Interest Group Day and Young Members’ event will offer great opportunities to share and discuss ideas. Finally, social events will give an opportunity to appreciate the local hospitality and culture of Dallas.

We look forward to welcoming you at ICED25!

25th International Conference on Engineering Design
Dallas, Texas, 11 - 14 August 2025

# PREFACE

# President's Welcome

ICED – the International Conference on Engineering Design, flagship event of the Design Society – returns to the United States after 16 years, this time hosted at UT Dallas. This is the 25th edition of the conference that was first held in Rome in 1981, building on the foundations laid by Workshop Design Konstruktion (WDK). Since its first edition, ICED has been hosted in 16 countries across Europe, North America, Asia and Oceania, and we look forward to visiting new regions all over the world.

With this brief welcome, I'm delighted to greet all delegates, as well as returning and new members of the Design Society, as we come together once again to celebrate the spirit of ICED.

This special edition of ICED coincides with the 25th anniversary of the Design Society. It offers a rich programme of activities and opportunities to share research achievements, reflect on the evolution of our field, strengthen our community, and build new professional and personal connections.

It is also a moment to reaffirm our commitment to fostering global collaboration for sustainable innovation and development towards a more just society. This commitment stands in contrast to rising political tensions, increasing fragmentation, and growing attempts to limit research autonomy and the freedom to study, visit, and collaborate across borders.

We proudly echo the ICED25 motto, "Design is a team sport", conceived four years ago and now more relevant than ever. Let us reaffirm our shared mission to drive a global effort towards a future rooted in diversity, equity, and inclusion.

# Programme Committee's Welcome

Dear Reader,
Welcome to ICED25, the 25th International Conference on Engineering Design, hosted this year in Dallas, Texas. Centred on the theme "Design is a team sport," the conference highlights the collaborative nature of engineering design research and practice.
The scientific programme presents 341 peer-reviewed papers spanning a broad and evolving spectrum of topics. Contributions explore key challenges and advances in areas such as design for sustainability and for societal challenges, AI in design, design for health and wellbeing, new design methods and processes, human behaviour in design, design creativity, design innovation, design for advanced manufacturing, systems design and design education.
Complementing these sessions are a diverse range of engaging workshops, four keynote presentations, and dedicated events for early-career researchers—all designed to foster interdisciplinary dialogue and collaboration across experience levels and research domains.
We extend our sincere thanks to all authors, reviewers, and session chairs for their dedication and insight. Your work strengthens the ICED community and drives forward the knowledge that shapes design practice and research.
We hope ICED25 offers not only intellectual stimulation, but lasting collaboration in the spirit of our theme.
Sincerely,
The ICED25 Programme Committee

# Conference Chair's Welcome

Greetings Y'All to ICED 2025 here in Texas.

We are excited to host the Design Society's biannual conference at the University of Texas at Dallas, with a team-up with the Lyle School of Engineering from Southern Methodist University. We have a busy week scheduled, be use hope that everyone can take some time to enjoy all that the Dallas metro area and Texas have to offer. We have spread the workshops across the week to give everyone a chance to sample different topics and themes. We have some fantastic keynote speakers sharing their views and thoughts on design both current and future. There are over 400 registered participants at the conference, from 30 different countries. The Publications Committee and the Organizing Committee has worked diligently for the past three years to try to make this a memorable and meaningful conference. Take a chance to thank our members if you see them this week. Your patience through this has been greatly appreciated and we sincerely hope that you can take with you new ideas, new networks, new contacts, and new memories. Enjoy our hospitality and the air conditioning!

Joshua SUMMERS, University of Texas at Dallas, USA


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SMU
Lyle School
of Engineering


UTDesign|R

# General Information

## Sunday
11-Aug-25

- SIG Workshops 14:00-17:00
- BM-Meeting 14:30-16:00
- BM-Meeting 16:30-18:00

## Monday
10-Aug-25

- Registration 10:00-11:00
- Lunch 11:45-13:00
- SIG Workshops Part 1 up to 6 in parallel 11:00-12:30
- SIG Workshops Part 1 up to 6 in parallel 13:00-14:30
- Opening 14:45-15:30
- Keynote 1 15:30-16:15
- Keynote 2 16:15-17:00
- Transfer 17:15-18:00
- Reception/Birthday Party SMU 18:00-19:30

## Tuesday
12-Aug-25

- Transfer 8:00-8:30
- Registration 8:30-9:00
- Slot 1 9:00-10:00
- Slot 1 10:30-11:30
- Lunch 11:45-13:00
- Marketplace 12:00-13:00
- Workshops 12:00-13:00
- Keynote 3 13:15-14:00
- Keynote 4 14:00-14:45
- Slot 3 15:00-16:00
- Transfer 16:00-16:15
- Young Members Event 16:15-18:30
- Transfer 18:30-19:00

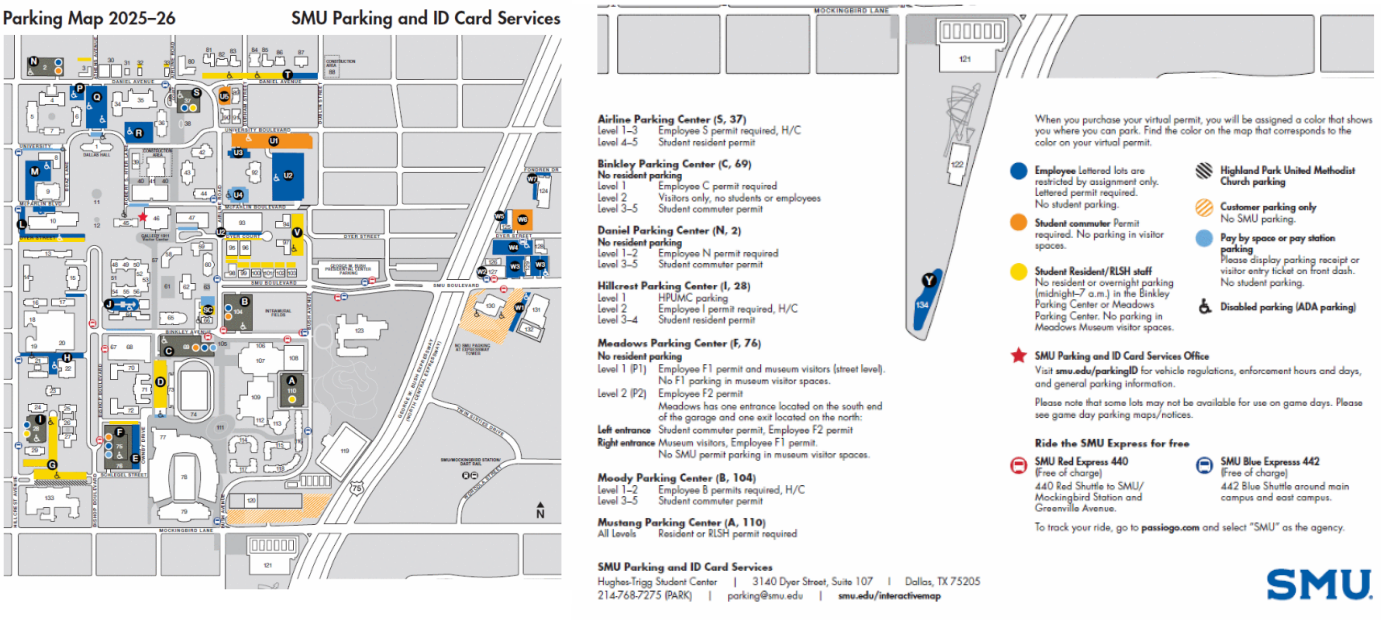
## Wednesday
13-Aug-25

- Transfer 8:00-8:30
- Registration 8:30-9:00
- Slot 4 9:00-10:00
- Slot 5 10:30-11:30
- Lunch 11:45-13:00
- Workshops 12:00-13:30
- Slot 6 13:45-14:45
- Slot 7 15:15-16:15
- DS General Assembly 16:30-17:30
- DS AB & BM Meeting 17:30-18:15
- Transfer 18:15-19:00
- Conference Dinner Southfork ranch 19:00-22:00

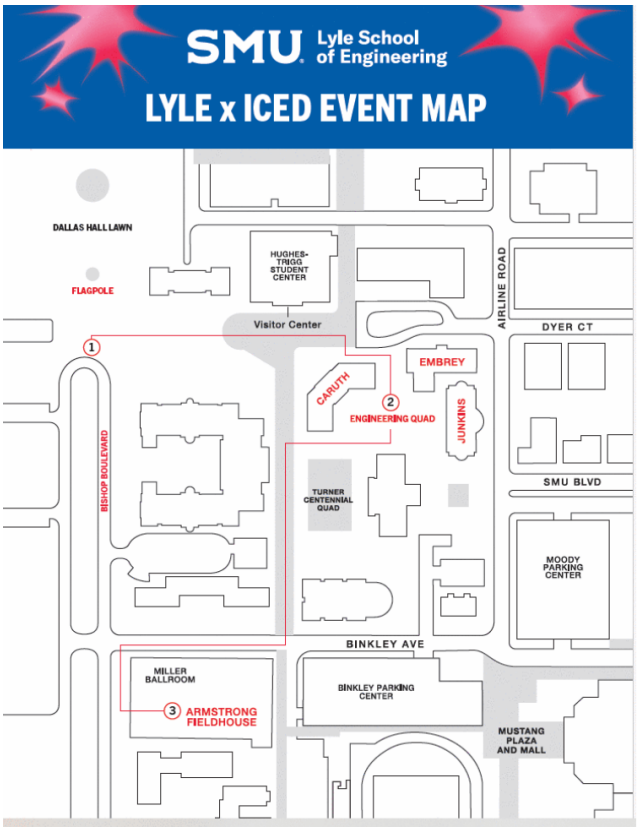
## Thursday
14-Aug-25

- Transfer 8:00-8:30
- Registration 8:30-9:00
- Slot 8 9:00-10:00
- Slot 9 10:30-11:30
- Lunch 11:45-13:00
- Workshops 12:00-13:30
- Slot 10 13:45-14:45
- Slot 11 15:15-16:15
- Closing 16:30-17:15
- Farewell UTD campus 17:15-18:45
- Transfer 18:45-19:15

# SMU Campus Parking Map




# SMU LYLE X ICED EVENT MAP



# UTDallas Venue Map



## Floor 1


## Floor 2


## Floor 3


## Floor 4

## Opening Ceremony

Chair: Joshua Summers, University of Texas at Dallas, United States of America

Location: ATEC 1.101

**Date: Monday, Aug/11/2025 2:45pm-3:30pm**

## Reception/ Birthday Party SMU

Location: SMU Field House

**Date: Monday, Aug/11/2025 6:00pm-7:30pm**

## Young Members Event

Chair: Kristin Paetzold, TU Dresden, Germany

Location: ECSW Bird Nest (Second Floor)

**Date: Tuesday, Aug/12/2025 4:30pm-6:45pm**

## General Assembly

Chair: Gaetano Cascini, Politecnico di Milano, Italy

Location: ECSW 1.315

**Date: Wednesday, Aug/13/2025 4:30pm-5:45pm**

## Conference Dinner

Location: South Fork Ranch

**Date: Wednesday, Aug/13/2025 7:00pm-10:00pm**

## Closing Ceremony

Chair: Joshua Summers, University of Texas at Dallas, United States of America

Location: ECSW 1.315

**Date: Thursday, Aug/14/2025 4:30pm-5:15pm**

## Farewell

Location: APC 1.100

**Date: Thursday, Aug/14/2025 5:15pm-7:00pm**

25th International Conference on Engineering Design

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## Sunday, 10/August/2025

# Workshops

# Workshop Place and Time

| | Sunday | Monday | Tuesday | Wednesday | Thursday |
|---|---|---|---|---|---|
| Room | 2025.08.10<br>13:00-16:00 | 2025.08.11<br>11:00-14:30 | 2025.08.12<br>12:00-13:00 | 2025.08.13<br>12:00-13:30 | 2025.08.14<br>12:00-13:30 |
| ECSW 1.364 | W1 | W6 | | W16 | |
| ECSW 1.365 | W2 | W7 | W11 | W17 | |
| ECSW 2.325 | W3 | | W12 | W18 | W21 |
| ECSW 3.210 | W4 | W8 | W13 | | W22 |
| ECSW 3.250 | W5 | W9 | W14 | W19 | W23 |
| ECSW 4.315 | | W10 | W15 | W20 | |

# Sunday, 10/Aug/2025 Workshops

**Date: Sunday, 10/Aug/2025**

| | | | | |
|---|---|---|---|---|
| 1:00pm - 4:00pm | **W 1: Transforming Product-Service Systems: AI-Driven, Resilient and Human-Centric Solutions (SIG: Product Service System)**<br>Location: ECSW 1.355<br>Chair: **Yong Se Kim**, Tongji University, China, People's Republic of | **W 3: Sketch Ideation Opportunities and Workflows with AI (SIG: Design Sketching)**<br>Location: ECSW 2.325 | **W 4: Workshop: Can Prototypes be Creative? (SIG: Design Creativity)**<br>Location: ECSW 3.210<br>Chair: **Srinivasan Venkataraman**, Indian Institute of Technology Delhi, India | **W 5: Expanding Horizons: Academic Career Pathways for PhDs Beyond Research-Intensive Institutions**<br>Location: ECSW 3.250<br>Chair: **Rahul Sharan Renu**, Austin College, United States of America |

# W 1: Transforming Product-Service Systems: AI-Driven, Resilient and Human-Centric Solutions

***Session Chair: Yong Se Kim, Tongji University, China, People's Republic of***

**Time: Sunday, 10/Aug/2025: 1:00pm - 4:00pm Location: ECSW 1.355**

This workshop aims to explore the latest advancements in PSS technologies and methodologies, highlighting how human-centered approach and AI/data driven approach can support the creation of more adaptive, intelligent, and user-friendly systems. By integrating resilience-oriented design principles, these systems can better withstand, recover from, and adapt to unexpected challenges while maintaining core functionalities. By focusing on the integration of AI with human-centered design principles, we seek to push the boundaries of what is possible in product-service offerings, ensuring that they meet both the functional needs of users and the ever-changing demands of modern industries.

# W 3: Sketch Ideation Opportunities and Workflows with AI (SIG: Design Sketching)

***Organizer: Amos SCULLY (aasfaa@rit.edu)***

**Time: Sunday, 10/Aug/2025: 1:00pm - 4:00pm Location: ECSW 2.325**

The rapid advancement of Generative Artificial Intelligence has ushered in an unprecedented paradigm shift in design, presenting new opportunities while simultaneously redefining traditional workflows. The acceleration of development within the field necessitates a reconsideration of foundational skills and methodologies. While industrial design has expanded to encompass problem-solving in services and systems, product design remains central to the discipline, with sketch visualization serving as a fundamental tool for conceptual exploration. However, proficiency in sketch-based ideation is a skill that often requires years to cultivate, posing a significant challenge for many designers. This difficulty can become a substantial barrier to participation in conceptual development, limiting opportunities for engagement in form exploration. Within the authors' program, students frequently withdraw from ideation, encountering frustration in the exploratory process and experiencing reluctance to share their ideas due to perceived inadequacies in their sketching abilities. Given the immediacy and accessibility of AI-generated visualizations, what are the broader implications for traditional sketching? How will strategies for product design conceptualization evolve in response to these advancements? Are we witnessing a fundamental redefinition of this core skillset, wherein AI-driven prompting becomes an integral component of the visualization process? This workshop examines the intersection of traditional sketching and AI-assisted ideation, with a particular focus on Vizcom. It explores the essential skills, emergent workflows, and collaborative methodologies that can facilitate the integration of AI into aesthetic character development, thereby redefining the role of sketching in contemporary design practice.

# W 4: Can Prototypes be Creative?

***Session Chair: Srinivasan Venkataraman, Indian Institute of Technology Delhi, India***

**Time: Sunday, 10/Aug/2025: 1:00pm - 4:00pm Location: ECSW 3.210**

Audience: Industry, Students, Faculty
Research in design creativity has primarily investigated creativity in ideas/concepts and products. Prototypes are sandwiched between ideas/concepts and final products. Creativity in prototypes has not been explored.
Understand views that contribute to creativity, novelty and value;
Understand assessment of novelty, value and creativity;
Help build creative prototypes;
Help assess prototypes
Organizer: Srinivasan VENKATARAMAN (srinivenk@iitd.ac.in)

# W 5: Expanding Horizons: Academic Career Pathways for PhDs Beyond Research-Intensive Institutions

***Session Chair: Rahul Sharan Renu, Austin College, United States of America***

**Time: Sunday, 10/Aug/2025: 1:00pm - 4:00pm Location: ECSW 3.250**

Audience: Students, Industry
Many PhD candidates are unaware of what it takes to be tenure-track/tenured faculty at a teaching-focused institution. This workshop will help shed light on this career pathway.
In this workshop, participants will gain hands-on experience exploring jobs available at teaching-focused institutions. A select few jobs will be used as case studies and participants will develop application packets for them. Participants will develop these applications only after fully understanding expectations for tenure at a teaching-focused institution.
Organizer: Rahul RENU (rrenu@austincollege.edu)

25th International Conference on Engineering Design

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## Monday, 11/August/2025

# Welcome Keynotes Reception

## Date: Monday, 11/Aug/2025

| | | | | | | |
|---|---|---|---|---|---|---|
| 10:00am - 11:00am | **WR 01: Welcome & Registration** | | | | | |
| 11:00am - 2:30pm | **W 10: How can we define success of a shared mental model in collaborative engineering design teams. (SIG: Collaborative Design)**<br>Location: ECSW 4.325<br>Chair: **Ian Marcus Edgecomb**, University of Strathclyde, United Kingdom | **W 2: Artificial Intelligence X Design (SIG: AI X Design)**<br>Location: ECSW 2.325<br>Chair: **Filippo Chiarello**, Università di Pisa, Italy | **W 6: Mind the Bias: Understanding, Identifying and Mitigating Cognitive Biases in Design**<br>Location: ECSW 1.355<br>Chair: **Chris McTeague**, Technical University of Munich, Germany | **W 7: Design Theory for Transitions (SIG: Design Theory)**<br>Location: ECSW 1.365<br>Chair: **Pascal Le Masson**, MINES ParisTech-PSL, France<br>Chair: **Chris McTeague**, Technical University of Munich, Germany | **W 8: PhD and Graduate Forum**<br>Location: ECSW 3.210<br>Chair: **Massimo Panarotto**, Politecnico di Milano, Italy | **W 9: How is your research area affected by robustness aspects? (SIG: Robust Design)**<br>Location: ECSW 3.250<br>Chair: **Stefan Goetz**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany |
| 11:30am - 1:00pm | **LB 01: Lunch Break** | | | | | |
| 2:45pm - 3:30pm | **OC: Opening Ceremony**<br>Chair: **Joshua Summers**, University of Texas at Dallas, United States of America | | | | | |
| 3:30pm - 4:15pm | **Keynote 1: Forging future Pathways for the engineering Design Field - Tamara Carleton - Stanford University**<br>Chair: **Ola Isaksson**, Chalmers University of Technology, Sweden | | | | | |
| 4:15pm - 5:00pm | **Keynote 2: From Insult to Impact - Tim Pilson - Southwest Airlines**<br>Chair: **Ola Isaksson**, Chalmers University of Technology, Sweden | | | | | |
| 6:00pm - 7:30pm | **REC: Reception** | | | | | |

Keynote

# Forging Future Pathways for the Engineering Design Field

**Location: EABUC123**

Wednesday, August 13, 2025 13:30-14:15


## *Tamara CARLETON*



**Abstract:**

Where is the field of engineering design headed? How will engineering design stay relevant and connected in a rapidly changing, even chaotic, world? Drawing on her extensive background across academia and consulting, plus books on radical innovation and strategic foresight, Tamara Carleton will offer practical insights that explore ways for this community to forge future pathways for the engineering design field.


**Biography:**

Tamara Carleton, PhD, is an award-winning professor, industry advisor, and author of radical innovation and strategic foresight. She holds the UNESCO Chair in Anticipatory Leadership and is also a Distinguished Global Professor of Radical Innovation at Tecnológico de Monterrey in Mexico. Tamara also holds several other academic positions around the world, including in Sweden, Switzerland, Finland, and Japan. She has been recognized as one of the Top 50 Women Leaders in Education (in 2023 and 2024) by Women We Admire. Tamara is also the founder and CEO of the Innovation Leadership Group, which helps leaders and teams to build innovation capacity and map bold futures. She has written several seminal books in innovation, including the award-winning Building Moonshots: 50+ Ways to Turn Radical Ideas into Reality and the Playbook for Strategic Foresight and Innovation. She holds a doctorate in mechanical engineering from Stanford University.research, or invention based research. The conference itself is essentially a team: it is a group of people with a defined objective to learn and share knowledge for a defined period of time. Join the ICED25 team by preparing your contributions now.

# From Insult to Impact

**Location: EABUC123**

Monday, August 11, 2025 14:15-15:00

*Tim PILSON*

**Abstract:**

Your design is perfect...until someone uses it. At Southwest Airlines, we've spent over 50 years innovating the airline business. For the last 10 years, we've dedicated teams specifically to innovation, by building a human-centered design practice and recruiting a set of innovators capable of enabling these powerful solutions. We'll bring you on that journey, share some of our stories, and look to the future of the design process.

**Biography:**

Tim Pilson is the leader of the Technology Innovation Team for Southwest Airlines. He has served numerous technical roles in his 24 years at Southwest, with the last 8 years specifically focused on the Innovation practice. His team delivers rapidly prototyped solutions which enable the ability to test the corporate strategic vision in a tangible way. These solutions utilize the combination of data and functional products to test and learn the impact prior to rolling out enterprise scaled products. Tim has worked in areas such as infrastructure, service management and enterprise programs.

# W10: How can we define success of a shared mental model in collaborative engineering design teams. (SIG: Collaborative Design)

***Session Chair: Ian Marcus Edgecomb, University of Strathclyde, United Kingdom***

**Time: Monday, 11/Aug/2025: 11:00am - 2:30pm Location: ECSW 4.325**

Audience: Faculty, Students, Industry
Currently, there is a lack of understanding as to how the factors that affect collaboration impact the development of shared mental models. There lacks consensus on the best approaches to measure, and confidently state that a shared mental model has been achieved within engineering design teams. The community lacks a systematic way to determine this. This workshop will ask, what is the success criteria for a team to achieve a shared mental model? The workshop will be split into two sections, the first will approach the challenge from a systems engineering perspective and will ask delegates to map the factors of collaboration to a systems diagram. We will build upon current research principles to achieve this. The second will focus on the human factors in the system and will ask delegates to share their experience to create case studies of collaboration that lead to successful and unsuccessful shared

# W 2: Artificial Intelligence X Design (SIG: AI X Design)

***Session Chair: Filippo Chiarello, Università di Pisa, Italy***

**Time: Monday, 11/Aug/2025: 11:00am - 2:30pm Location: ECSW 2.325**

Audience: Industry, Faculty, Students
Assess the current state (AS-IS) and define the future direction (TO-BE) of AI in/for Engineering Design (AIXD) within the community. The Special Interest Group (SIG) aims to identify key challenges, gaps, and opportunities in AI applications for ED by engaging in a structured analysis process leading up to ICED 2025 and beyond.
The AIXD SIG will first define key research questions (Feb-May 2025) and conduct AS-IS analysis through desk research (June-July 2025) to map the current state of AI in Engineering Design. At ICED 2025 (Aug 2025), a workshop with the ED community will discuss the TO-BE state and identify future research directions. The findings will then be synthesized into an AIXD manifesto to guide the field, finalized before DESIGN 2026.
Organizer: Filippo CHIARELLO (filippo.chiarello@unipi.it)

# W 6: Mind the Bias: Understanding, Identifying and Mitigating Cognitive Biases in Design

***Session Chair: Chris McTeague, Technical University of Munich, Germany***

**Time: Monday, 11/Aug/2025: 11:00am - 2:30pm Location: ECSW 1.355**

Audience: Industry, Faculty, Students
We will develop a shared understanding of what cognitive biases are and consider their potential effects on the design process (both positive and negative), explore methods and approaches for identifying cognitive biases in design education and practice, and explore approaches and technological interventions for counteracting undesirable biases to enhance design outcomes. Participants will be first invited to reflect on how cognitive biases manifest in various stages of engineering design. The goal is to determine their relevance and impact on design decision-making and problem-solving. These individual reflections will then be shared and expanded upon through small-group discussions, where participants will compare perspectives, challenge assumptions and work towards a common understanding. Building on these insights, participants will then collaboratively explore methods and approaches for identifying cognitive biases during the engineering design process. The goal is to start defining a shared standpoint for bias identification and assessment, which could potentially also lay the groundwork for self-assessment metrics that designers might use in their practice. In the final activity, participants will examine the role that technology can play to address cognitive biases in engineering design. This includes both established tools (e.g., computational design tools) as well as emerging ones (e.g., Artificial Intelligence). Through this exploration, participants will consider how such technologies

# W 7: Design Theory for Transitions (SIG: Design Theory)

***Session Chair: Pascal Le Masson, MINES ParisTech-PSL, France***
***Session Chair 2: Chris McTeague, Technical University of Munich, Germany***

**Time: Monday, 11/Aug/2025: 11:00am - 2:30pm Location: ECSW 1.365**

Audience: Faculty, Industry, Students
Design theory deepens the scientific foundations of design and engineering; it bridges the gap with other design professions (such as industrial design) and helps in addressing critical, contemporary innovation issues; providing scientific models of generativity, design theory also contributes to address generativity issues in many disciplines (biology, agronomics, chemical engineering, philosophy, management,...). The symposium will provide some illustrations of these results, in four contrasted streams of research, with a specific focus on Design Theory for Transitions.
Organizer: Pascal LE MASSON (pascal.le_masson@minesparis.psl.eu)

# W 8: PhD and Graduate Forum

***Session Chair: Massimo Panarotto, Politecnico di Milano, Italy***

**Time: Monday, 11/Aug/2025: 11:00am - 2:30pm Location: ECSW 3.210**

Audience: Students
Organizing a peer-review feedback seminar among graduate students and PhD students with junior and senior experts. In its current form the PhD Forum has been running successfully at alternating DESIGN and ICED conferences since 2012. This event routinely attracts between 20-40 PhD students, as well as bringing together early career an
We believe that this joint effort will be the opportunity to increase the research quality at different levels (e.g., publications, writing applications, pedagogy).d senior academics in the field.
Organizer: Massimo PANAROTTO (massimo.panarotto@polimi.it)

# W 9: How is your research area affected by robustness aspects? (SIG: Robust Design)

***Session Chair: Stefan Goetz, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

**Time: Monday, 11/Aug/2025: 11:00am - 2:30pm Location: ECSW 3.250**

Audience: Students, Faculty
Short introduction to robustness principles and its potential fields of application
Discussion on the different fields of application considering robustness
Discussion of the differences in implementation, e.g. considering the different inputs, outputs, objectives and constraints
Presentation of the discussion results and identification of similarities and blind spots
Organizer: Stefan GOETZ (goetz@mfk.fau.de)

25th International Conference on Engineering Design

Dallas, Texas, 11 - 14 August 2025

## Tuesday, 12/August/2025

# Programs & Abstracts

## Date: Tuesday, 12/Aug/2025

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8:30am - 9:00am | **WR 02: Welcome & Registration** | | | | | | | |
| 9:00am - 10:00am | **P 01-1: Design in Healthcare and Medical Applications**<br>Location: ECSS 2.412<br>Chair: **Abigail Clarke-Sather**, University of Minnesota Duluth, United States of America | **P 01-2: Applications of AI in Design**<br>Location: ECSS 2.410<br>Chair: **Kosa Goucher-Lambert**, University of California, Berkeley, United States of America | **P 01-3: Food and Design**<br>Location: ECSS 2.312<br>Chair: **Anja Maier**, University of Strathclyde, United Kingdom | **P 01-4: Design Information Data Management**<br>Location: ECSS 2.311<br>Chair: **Bernhard P. Bettig**, West Virginia University Institute of Technology, United States of America | **P 01-5: AI in Design Creativitiy 1**<br>Location: ECSS 2.306<br>Chair: **John Gero**, UNC Charlotte, United States of America | **P 01-6: Complexity in Design 1**<br>Location: ECSS 2.305<br>Chair: **Dieter Krause**, Hamburg University of Technology, Germany | **P 01-7: Resiiliance and Innovation**<br>Location: ECSS 2.203<br>Chair: **Niccolo Becattini**, Politecnico di Milano, Italy | **P 01-8: Human Robots Data**<br>Location: ECSS 2.201<br>Chair: **Arlindo Silva**, Singapore University of Technology and Design, Singapore |
| 10:00am - 10:30am | **CB 02-1: Coffee Break** | | | | | | | |
| 10:30am - 11:30am | **P 02-1: Sustainable Design 1**<br>Location: ECSS 2.412<br>Chair: **Tim McAloone**, Technical University of Denmark, Denmark | **P 02-2: Knowledge and Requirements Management**<br>Location: ECSS 2.410<br>Chair: **Ian Whitfield**, University of Strathclyde, United Kingdom | **P 02-3: Lightweight Design 1**<br>Location: ECSS 2.203<br>Chair: **Sandro Wartzack**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany | **P 02-4: LLMs and CAX**<br>Location: ECSS 2.311<br>Chair: **Ji Han**, University of Exeter, United Kingdom | **P 02-5: AI in Design Creativitiy 2**<br>Location: ECSS 2.306<br>Chair: **Tanja Katharina Schmitt-Fumian**, SRH Mobile University, TUM - Technical University of Munich, Germany | **P 02-6: Data-Driven Design**<br>Location: ECSS 2.305<br>Chair: **Benoit Eynard**, Université de Technologie de Compiègne, France | **P 02-7: Challenges in Design Research 1**<br>Location: ECSS 2.203<br>Chair: **Massimo Panarotto**, Politecnico di Milano, Italy | **P 02-8: Design Management 1**<br>Location: ECSS 2.201<br>Chair: **Katharina Ritzer**, Technische Universität Hamburg (TUHH), Germany |
| 11:30am - 1:15pm | **LB 02: Lunch Break** | | | | | | | |
| 12:00pm - 1:00pm | **MP: Marketplace**<br>Chair: **Noe Vargas Hernandez**, UTRGV, United States of America | **W 11: Evaluating AI Generated Solutions to Ill-structured Design Problems**<br>Location: ECSW 1.365<br>Chair: **Ryan Bruggeman**, Northeastern University, United States of America | **W 12: Rethinking Collaboration: How AI is Changing Work and Team Dynamics in Design Organizations**<br>Location: ECSW 2.325<br>Chair: **Yakira Imaris Mirabito**, MIT, United States of America | **W 13: Teaching Design Best Practices**<br>Location: ECSW 3.210<br>Chair: **David Ullman**, oregon state university, United States of America | **W 14: Workshop** | **W 15: Editorial Board Meeting for Design Science Journal (by invite)**<br>Location: ECSW 4.325 | | |
| 1:15pm - 2:00pm | **Keynote 3: Lessons from Design Collaboration - Wally C. Rhines** | | | | | | | |
| 2:00pm - 2:45pm | **Keynote 4: Ethics by Design: Incorporating Ethical Considerations into the Design Process - Philip Brey- University of Twente** | | | | | | | |
| 2:45pm - 3:15pm | **CB 02-2: Coffee Break** | | | | | | | |
| 3:15pm - 4:15pm | **P 03-1: Designing for a Circular Economy 1**<br>Location: ECSS 2.412<br>Chair: **Peter Törlind**, Luleå University of Technology, Sweden | **P 03-2: LLMs for Knowledge and Requirements Management**<br>Location: ECSS 2.410<br>Chair: **Zhenghui Sha**, The University of Texas at Austin, United States of America | **P 03-3: Lightweight Design 2**<br>Location: ECSS 2.312<br>Chair: **Marcel Bartz**, TU Dortmund University, Germany | **P 03-4: Optimal and Robust Design**<br>Location: ECSS 2.311<br>Chair: **Paul Christoph Gembarski**, Leibniz Universität Hannover, Germany | **P 03-5: Additive Manufacturing & Materials**<br>Location: ECSS 2.306<br>Chair: **Roland Lachmayer**, Leibniz Universität Hannover, Germany | **P 03-6: Prototpying 1**<br>Location: ECSS 2.305<br>Chair: **Stefan Zorn**, University of Rostock, Germany | **P 03-7: New Methods**<br>Location: ECSS 2.203<br>Chair: **Christian Köhler**, htw saar - Saarland University of Applied Sciences, Germany | **P 03-8: Design Justice and Ethics**<br>Location: ECSS 2.201<br>Chair: **Christine Toh**, University of Nebraska at Omaha, United States of America |
| 4:30pm - 6:45pm | **YME: Young Members Event**<br>Chair: **Kristin Paetzold**, TU Dresden, Germany | | | | | | | |

# Lessons From Design Collaboration

**Location: EABUC123**

Wednesday, August 13, 2025 13:30-14:15


## *Walden (Wally) RHINES*



**Abstract:**

Starting with design lessons that were learned through the development of the first successful single-chip digital signal processor, the TI TMS 320, Dr. Rhines traces what was done wrong and how the limitations were overcome. He then applies these lessons, and others, to the recently completed Cornami MX2 Secure AI Inferencing Processor and the reasons for its successful performance and power. This experience leads to a roadmap for how future high performance computing processors will emerge despite the slowing evolution of manufacturing technology.


**Biography:**

WALDEN C. (Wally) RHINES is Chairman of the Board of Qorvo, a semiconductor company focused on RF communications. He is also a member of the Board of Silvaco, an EDA company and three private companies: Cornami, a semiconductor company focused on fully homomorphic encryption for generative AI; Caspia, a semiconductor cybersecurity company; and Pallidus, a semiconductor company producing silicon carbide. He was previously CEO of Mentor Graphics for 25 years and Chairman of the Board for 17 years. During his tenure at Mentor, revenue nearly quadrupled and market value of the company increased 10X. Prior to joining Mentor Graphics, Dr. Rhines was Executive Vice President, Semiconductor Group, responsible for TI's worldwide semiconductor business. Dr. Rhines has served on the boards of Cirrus Logic, QORVO, TriQuint Semiconductor, Global Logic, PTK Corp., Silvaco, Pallidus and as Chairman of the Electronic Design Automation Consortium (five two-year terms). He is a Lifetime Fellow of the IEEE. Dr. Rhines holds a Bachelor of Science degree in engineering from the University of Michigan, a Master of Science and PhD in materials science and engineering from Stanford University, an MBA from Southern Methodist University and Honorary Doctor of Technology degrees from the University of Florida and Nottingham Trent University. In 2021, the Global Semiconductor Alliance honored Dr. Rhines, with its prestigious Dr. Morris Chang Exemplary Leadership Award.

Keynote

# Ethics by Design: Incorporating Ethical Considerations into the Design Process

**Location: EABUC123**

Monday, August 11, 2025 14:15-15:00


## *Philip (Phil) BREY*



**Abstract:**

Ethics by Design is a new approach that emphasizes the intentional integration of ethical considerations into design and development processes. Its aim is to support the creation of products that reflect and respect the moral values and expectations of society and relevant stakeholders. This talk will introduce and contextualize the Ethics by Design framework. While it was originally developed in the context of AI systems and other digital technologies, the presentation will demonstrate its broader relevance across diverse domains of engineering design. It will also explore its value for designers, companies, and society at large. By embedding ethics early in the design process, the approach enables organizations to build trust, meet regulatory expectations, and foster socially responsible innovation.


**Biography:**

Philip Brey is professor of philosophy and ethics of technology at the Department of Philosophy, University of Twente, the Netherlands. In his research, he investigates social, political and ethical issues in emerging technologies. His focus is on artificial intelligence, extended reality and other digital technologies, and he has also studied biomedical and environmental technologies. Ethics of engineering design is a recurring theme in his work.  He has co-developed the Ethics by Design approach for AI that is being used by the European Union in ethical review of research proposals in AI, big data and robotics. He is former president of the International Society for Ethics and Information Technology (INSEIT) and of the Society for Philosophy and Technology (SPT), and winner of the 2022 Weizenbaum Award for excellence in the field of digital ethics.

# P 01-1: Design in Healthcare and Medical Applications

## Session Chair: Abigail Clarke-Sather, University of Minnesota Duluth, United States of America

## Location: ECSS 2.412

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Design of boundary objects to improve communication in pediatric care

***Neda Barbazi[1], Ji Youn Shin[1], Gurumurthy Hiremath[1], Amr El-Bokl[2], Carlye Anne Lauff[1]***
***1 The University of Minnesota, Twin Cities, USA; 2 The University of Texas at Austin, USA***

Designing healthcare interventions for children with complex health needs often overlooks the perspectives of key stakeholders, including children. Collaborative design is essential for creating solutions that integrate diverse viewpoints and bridge communication gaps. However, prior studies lack tools to align stakeholder perspectives in pediatric care. This study introduces Octo, an educational toy, as a boundary object to enhance communication among children aged 4 to 10 with congenital heart disease (CHD), their parents, and healthcare providers. Octo evolves from a prototype to a functional educational tool, fostering engagement through play while promoting health literacy and stakeholder collaboration. This research through design (RtD) demonstrates the effectiveness of boundary objects in advancing inclusive, child-led interventions and collaborative healthcare design.

### Supporting parent-child bonding and attachment practices in the NICU: Designing and evaluating a non-intrusive health monitoring solution

***Harika Yarlagadda[1], Jomara Sandbulte[1], Sonya Wang[2], Abigail Clarke-Sather[1]***
***1 University of Minnesota Duluth, USA; 2 University of Minnesota Medical School, USA***

This research addresses the critical need for designing alternative healthcare monitoring systems that support health benefiting parent-child interactions during hospital stays, especially in neonatal intensive care units (NICUs). We developed a HIPAA-compliant, remote healthcare monitoring system designed to facilitate positive interactions between parents and their infants such as skin-to-skin contact. To evaluate the proposed system, we conducted a proof-of-concept experiment using video and sensor data collection to assess the system's feasibility and usability with adult participants. Additionally, we examined participants' subjective experiences through post-interaction surveys and interviews. Overall, the system was perceived as helpful in supporting caregiver-patient interactions. Future improvements can address concerns about continuous monitoring and data management.

# P 01-1: Design in Healthcare and Medical Applications

## Location: ECSS 2.412

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Clinical diagnosis is complex, But why? Identifying factors contributing to diagnostic complexity of infectious diseases in emergency medicine

***Swagatam Dey[1], Shrirang Joshi[2], Prakash Ranjan Mishra[2], Pramod Khadilkar[1]***
***1 Indian Institute of Technology Delhi; 2 All India Institute of Medical Sciences New Delhi***

A major cause of diagnostic errors is the underlying complexity caused by patient presentations and the context in which diagnosis is being undertaken. This is especially true for settings like emergency medicine and disease spectrums like infectious diseases. To design artefacts that counter such errors, it is essential to map the factors contributing to diagnostic complexity. However, existing complexity assessment methods in healthcare are limited in scope. Addressing this gap, our work operationalises a complexity estimation tool to identify factors contributing to the diagnostic complexity of 10 infectious disease cases in an emergency medicine setting. Our objective findings are further validated by a strong correlation with the difficulty perceived by attending doctors. The work provides a basis for the design of targeted interventions aiming to mitigate complexity in diagnosis.

### Reconciling data-enabled design and clinical trials: conceptual phases for eHealth development

***Hosana Cristina Morales Ornelas[1,3], Maaike Kleinsmann[1], Gerd Kortuem[1], Arend W. van Deutekom[2]***
***1 Delft University of Technology; 2 Erasmus Medical Center - Sophia Children's Hospital;***
***3 Tecnológico de Monterrey***

eHealth systems, such as digital care applications or remote monitoring devices, can improve health outcomes using user-centered design principles to create medical devices that adapt to users' needs and contexts. Data-enabled design (DED) builds on these principles by leveraging user-generated data to iteratively refine systems based on real-world use, enabling adaptive and context-sensitive solutions. However, its exploratory and iterative nature conflicts with the rigid protocols required in clinical trials to evaluate safety and effectiveness. This study revises DED in alignment with clinical trial requirements, identifying four key challenges and proposing a four-phase Clinical Data-Enabled Design (C-DED) framework. This framework reconciles exploratory design with trial methodological demands, supporting the development of safe, effective, and user-centered eHealth medical devices.

# P 01-2: Applications of AI in Design

## Session Chair: Kosa Goucher-Lambert, University of California, Berkeley, United States of America

## Location: ECSS 2.410

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Mapping AI applications in design: Support and activities across the product development process

***Ingo Jonuschies, Lisa Siewert, Elias Michaelsen, Kilian Gericke***
***University of Rostock, Germany***

The study investigates the integration of artificial intelligence (AI) into the product development process (PDP). It addresses two key research questions: which AI technologies exists to support designers across different phases of the PDP and which specific design activities these technologies enhance. Employing a systematic literature review, the research identifies AI technologies utilised in the design process and categorises them across the various phases of PDP. The findings emphasise a predominant focus on early-stage phases and the support of single activities within the PDP. Notable challenges include the lack of comprehensive end-to-end integration and limited compatibility in later phases. The study underscores the potential of AI while drawing attention to existing gaps in its adoption and the necessity for further research into cross-phase integration.

### Artificial intelligence in engineering design: an industry perspective

***Ian Marcus Edgecomb, Ross Brisco, Kieran Gunn, Alexander "Freddie" Holliman***
***University of Strathclyde, Scotland***

This research is a first of its kind, building an understanding of the opinions of industry professionals on the imminent AI revolution. Semi-structured interviews with eight experienced engineers from a range of industries were conducted. Transcripts of interviews were coded revealing engineering practitioner's understanding of, experience with, and vision for the use of AI technologies. The significance of the outcomes reveals the challenges industry face in realising an AI-driven design future and the actionable support that researchers and educators can provide to achieve this future.

## Location: ECSS 2.410

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### From theory to practice: derivation of the application domain card for supporting AI system development

***Benedikt Müller, Daniel Roth, Matthias Kreimeyer***
***University of Stuttgart, Germany***

The contribution introduces the Application Domain Card (ADC) as a structured, problem-oriented method for documenting the status quo and challenges within application domains, addressing a gap in existing AI development methodologies. Derived through a literature review, the ADC emphasizes flexibility, modularity, and accessibility, thereby enabling domain experts to identify AI use cases independently while fostering collaboration with AI experts. The practical applicability of the ADC was confirmed by a support evaluation involving technical drawing assessments in the context of design theory exercises. Future research will focus on refining the ADC to meet specific demands of industrial product development. This includes developing a software-supported application with automated tools for information collection and creating a library of practical examples for the method's modules.

### AI-led design innovation: Understanding design-centric AI methods and assistance types

***Boyeun Lee[1], Jongmo Kim[2]***
***1 University of Exeter, UK; 2 King's College London, UK***

With recent advancements in data-driven methods, there has been a growing interest in implementing AI in design. Despite this, a comprehensive understanding of the critical AI methods in design and how they support design practices remains lacking. To deepen our understanding, we conduct a comprehensive literature review and propose a novel, design-centric AI typology, associated with six AI assistance types for product service development. Our typology differs from traditional ones by shifting the focus from an algorithmic perspective to how models support design practice. Key findings highlight how these six design-centric AI methods support design practices in different ways, each with its own application challenges. Establishing a shared design-centric AI typology and assistance framework will enhance the understanding of how AI works differently and supports practitioners.

## Session Chair: Anja Maier, University of Strathclyde, United Kingdom

## Location: ECSS 2.312

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Sustainable legume-based foods: From collaborative diagnosis to co-creative concepts

***Renaud Voisin, Lucia Espinosa-Brisset, Anne Saint-Eve, Caroline Pénicaud***
***Université Paris-Saclay, INRAE, AgroParisTech, UMRSayFood, 91120 Palaiseau, France***

Legumes offer valuable agricultural and nutritional properties to face the urgent need for food system changes. To eco-design legume-based products, the value chains need to consider the constraints of their stakeholders, from farmers to consumers. This article describes an eco-innovation approach combining collaborative value mapping with KCP® workshops to design sustainable legume-based foods. This eco-innovation approach led to the emergence of expected concepts linked to the properties of products and more disruptive concepts related to dynamics in the value chain. Existing knowledge and knowledge gaps were identified. The results highlight the value of articulating value mapping and KCP® workshops. The approach proved to foster innovative, systemic solutions that consider both stakeholders' needs and sustainability.

### Advancing technology readiness level of sustainable food preservation technology through experimental design - increasing food shelf life by dissolving CO2

***Henrik H. Øvrebø, Sara Esmaeilian, Jørgen Lerfall, Martin Steinert, Anna Olsen***
***Norwegian University of Science and Technology (NTNU), Norway***

Designing sustainable technologies is challenging, as established technology is often more cost-effective than new, sustainable options. This study shows how a design-driven approach can advance Soluble Gas Stabilization (SGS) beyond low Technology Readiness Levels. SGS is a $CO_2$-based method extending muscle food shelf life. A $CO_2$ flow chamber prototype, developed from previous simulations and research, identified key parameters and adjustments for improved performance. Initial tests revealed issues such as heat build-up and meeting flow targets but also offered insights for better configurations. This paper illustrates how iterative, hypothesis-driven experimentation links theory and practice by integrating virtual simulations with hands-on prototyping. This workflow supports emerging sustainable technologies progressing from proof-of-concept to industrial-scale demonstration.

## Location: ECSS 2.312

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Food printing design approach for fabricating overhang structures with starch and protein inks

***Md Ibrahim Khalil[1], Yashwanth Kumar Kondabathula[1], Ranadip Pal[2], Farnaz Maleky[3], Paul F Egan[1]***
***1 Department of Mechanical Engineering,Texas Tech University, USA;***
***2 Department of Electrical & Computer Engineering, Texas Tech University, USA;***
***3 Department of Food Science and Technology, Ohio State University, USA***

3D food printing is transforming the food industry by enabling the production of customized, on-demand foods with intricate designs. However, achieving high shape fidelity remains a challenge for optimized food ink formulations. This study investigates 3D-printed foods with overhang designs using extrusion-based 3D printing. Mashed potato and pea protein were selected as base ingredients with varied water content to assess their differences in moisture content (70–87%), pH (5.66–7.06), firmness (0.52–8.12 N), and adhesiveness (0.29–2.73 N·s). Shape fidelity was evaluated by printing geometries with overhang angles of 0° and 60°. Results showed the best printability at a 1:4 ratio (81% moisture) for mashed potato and 1:3.5 ratio (78% moisture) for pea protein. These insights provide guidelines for engineering high-fidelity food inks, that advances additive manufacturing in food design.

### Print fidelity assessment for 3D food printed designs using manual and automated approaches

***A K M Ahasun Habib1, Md Ibrahim Khalil1, Farnaz Maleky2, Ranadip Pal3, Paul F Egan1***
***1 Department of Mechanical Engineering,Texas Tech University, USA;***
***2 Department of Food Science and Technology, Ohio State University, USA;***
***3 Department of Electrical & Computer Engineering, Texas Tech University, USA***

The ability to modify designs, personalize nutrition, and improve food sustainability makes 3D food printing (3DFP) an exciting emerging technology. Food materials' complex chemistry and mechanics make it difficult to consistently print designs of different shapes. This research uses two methods to assess printed food fidelity: Manual and automated image analysis with custom-developed algorithm. Fidelity based on printed area was measured for three overhang designs (0°, 30°, and 60°) and three food ink mixtures. The manual method provided a baseline for analysis by comparing printed images with CAD images. Both methods showed consistent results with only ±3% differences in analyzing printed design areas. While the computational method offers advantages for efficiency and bias reduction, making it well-suited for fidelity assessment to assess designs.

# P 01-4: Design Information Data Management

## Session Chair: Bernhard P. Bettig, West Virginia University Institute of Technology, United States of America

## Location: ECSS 2.311

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Mastering the list of requirements: A demand or a wish?

***Shakuntala Acharya, Kavyashree Venkatesh, Mahima Prasanna, Dhwani Doshi***
***Indian Institute of Technology Guwahati***

The process of gathering needs and generating requirements for design for individuals with special needs can be particularly challenging, and the intended solutions are increasingly evolving into Cyber-Physical-Social Systems (CPSS) further complicating the task. Co-design is the preferred approach but when the primary users are children, the challenges are compounded since they are unable to partner in the design process making the task of eliciting needs further difficult. This paper presents an empirical attempt to collate a master list of requirements for design for children with special needs to aid the design process.The study revealed several lacunae in comprehensibility of Requirements and Criteria, and mapping of the two, prompting further investigation into the hindrances to developing a robust and comprehensive resource for designers by designers.

### Graph-based social impact diffusion optimization across a theoretical socio-technical system

***Samuel Archibald McKinnon, Christopher Andrew Mattson***
***Brigham Young University***

The engineering design community has increased their focus on sustainable development, which has resulted in design methodologies and optimization techniques for the design of socio-technical systems involving engineered products. An essential part of design for sustainable development is understanding the social impacts that technology has on people. Social impact diffusion can model how these impacts propagate through society. This paper combines social impact diffusion models, graph-based socio-technical representations, and computational optimization techniques to present a social impact diffusion objective function for optimizing social impact in socio-technical systems. The results of the paper indicate that using social impact diffusion objective functions can improve upon random or best guess designs for socio-technical systems.

## Location: ECSS 2.311

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### A new approach to ontological harmonisation in design

***Neil Alasdair William Harrison[1], Robert Ian Whitfield[1], Antony Powell[2], Alexander Frederick Holliman[1]***
***1 University of Strathclyde; 2 Yorkmetrics Ltd***

How well a team can design something depends on how well their collective understanding comes together. In the design of modern complex systems this involves multiple conceptualisations of the system undergoing design. These perspectives become instantiated in a large volume of design description that is deep, wide and diverse. This must carry shared meaning reliably, which is impossible to assure if the ontology in which every statement is nested is left implicit and unmanaged. This paper outlines a technical approach to assure ontological harmony without necessarily or only employing formal semantically rigorous knowledge representations. It empowers an incremental investment in description coverage and ontological coherence, better supporting the spectrum of thinking styles and description needs that design teams encounter when taking on complex systems development today.

### The twelve ways to convey engineering information visually

***Bernhard P. Bettig[1], Winnie H. Fu[1], David A. Lamb[2]***
***1 West Virginia University Institute of Technology; 2 U.S. Army DEVCOM-GVSC***

A systematic process was used to develop a complete taxonomy of visual representation mechanisms applicable to the display of any kind of engineering information. The resulting twelve categories are broadly divided into eight related to graphical elements treated individually and four related to the arrangement of two or more graphical elements treated in conjunction with each other. The taxonomy is oriented to inform the further development of user interface software frameworks supporting the automated display of interactive engineering information in any form.

## Session Chair: John Gero, UNC Charlotte, United States of America

## Location: ECSS 2.306

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Analysing designer-GenAI interactions: Characterizing designers' behaviours during inspiration and ideation

***Charlie Ranscombe[1], Linus Tan[1], James Gopsill[2]***
***1 Swinburne University of Technology, Australia; 2 University of Bristol, Great Britain***

Text-to-Image Generative AI (GenAI) platforms offer designers new opportunities for inspiration-seeking and concept generation, marking a significant shift from traditional visualisation approaches like sketching. This study investigates how designers work with text-to-image GenAI during inspiration-seeking and ideation, aiming to characterise designers' behaviours through designer-GenAI interaction data. Analysis of 503 prompts by four designers engaging in a GenAI supported design task identifies two distinct behaviours: exploratory, characterised by short, diverse prompts with low similarity; and narrowing, characterised by longer, high-similarity prompts used with detail focused variation functions. The findings highlight the value of GenAI interaction data to reveal patterns in designers' behaviours, offering insights into how these tools support designers and inform best practices.

### Design exhibitions as spaces for controlled experiments

***Susanne Dreyer, Chris McTeague, Shuyun Liu, Katja Thoring***
***Technical University of Munich, Germany***

Design research faces growing challenges from multifaceted developments, which traditional methods and lab settings often struggle to address. New approaches are needed to bridge the gap between controlled lab settings, field studies, and these complexities. Exhibition spaces offer opportunities for dynamic, real-world studies beyond lab-based research's limitations. This study explores a hybrid 'exhibition-experiment' format by examining a design exhibition on biophilic workspace design. Participants visited different design exhibits (experimental conditions) within the experiment while a suite of passive measurement devices measured their emotional and physiological responses. The findings highlight the strengths and limitations of 'exhibition-experiments', provide insights into the usage of technology-driven tools, and discuss them as a hybrid approach between lab and field studies.

## Location: ECSS 2.306

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### ★ Semantic and network analysis of design protocols to reveal design framing phenomena

***Nick Kelly[1], John S. Gero[2]***
***1 Queensland University of Technology, USA; 2 University of North Carolina at Charlotte, USA***

This paper introduces a novel approach to analysing design protocols using a combination of methods. It describes an approach using a synthesis of concept extraction (using an LLM), semantic analysis (using word vectors and conceptual clustering), and network analysis (following graph construction). It suggests that the resulting measures are useful for studying design framing and for aiding qualitative analysis. It demonstrates this technique with data from a study of 17 designers addressing two design problems. The method enables the comparison of designers working on the same problem as well as the study of individual designers' use of concepts over time during a think-aloud study.

### Design exhibitions as spaces for controlled experiments

***Gregory Litster[1], Emily Moore[1,2]***
***1 Department of Mechanical and Industrial Engineering, University of Toronto;***
***2 Institute for Studies in Transdisciplinary Engineering Education and Practice, University of Toronto***

Problem framing is a foundational aspect of the engineering design process, shaping how designers perceive challenges and potential solutions. Qualitiative methods, such as protocol analysis, have provided valuable insights about problem framing but are labor-intensive and time consuming. This study explores the use of a NLP technique BERTopic, to analyze framing in design conversations. BERTopic retains contextual nuances, offering a tool for uncovering the diversity and uniqueness of concepts explored by design teams while also making the analysis process more efficient. The results provide one representation of eight design group's processes, highlighting the different and changing topic representations that emerge throughout a design session. The findings highlight the potential of NLP tools for enhancing our understanding of framing in design cognition and team dynamics.

# P 01-6: Complexity in Design 1

## Session Chair: Dieter Krause, Hamburg University of Technology, Germany

## Location: ECSS 2.305

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### ★ The impact of complexity on new product development in the Engineer-to-Order context: A case study from the aerospace industry

***Jonathan Gerhardus Visagie[1], Robert Ian Whitfield[2], Dorothy Evans[2]***
***1 Heroux-Devtek; 2 University of Strathclyde, Scottland***

This paper examines the impact of complexity on New Product Development (NPD) within the context of an Engineer-to-Order (ETO) organisation. A descriptive literature review identified three categories of complexity: organisational, process and product complexity. The influence on NPD performance due to the dimensions contained in these categories are investigated in terms of the Law of Requisite Variety. A case study of NPD at Héroux-Devtek Inc., a landing gear supplier, evaluates these dimensions in practice. The findings reveal that increased organisational complexity often improves NPD performance, while increased process complexity reduces NPD performance. Product complexity evolves from being 'complex' initially to 'complicated' or 'simple' at delivery. Insights into managing these complexities contribute to understanding their role in achieving project success in the ETO context.

### A data-driven framework for engineering design research: Combining virtual and physical testing

***Oliver Liewerenz, Andre Becker, Jonas Hemmerich, Christoph Wittig, Patric Grauberger, Sven Matthiesen***
***IPEK - Karlsruhe Institute of Technology (KIT), Germany***

This paper presents a hybrid framework that integrates physical and virtual testing to enhance cross-sectional studies in the field of engineering design. The framework addresses the critical challenge that valid inferences in realistic cross-sectional studies are often hampered by the manufacturing constraints of physical prototypes and the limitations of virtual prototypes. Using the example of a snap-fit system, the framework shows how predictive modelling and parametric design enable efficient iterations for building design knowledge. By combining the empirical accuracy of physical testing with the scalability of virtual simulations, the framework reduces iteration times, improves resource efficiency and adapts to different study conditions.

## Location: ECSS 2.305

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Managing complexity in smart product systems - The case of smart nature-based systems

***Charlotte Lucinda Markey, Saeema Ahmed-Kristensen***
***University of Exeter, UK***

Climate change and rapid urbanisation constitute wicked problems to which the design community must respond. This paper focuses on hybrid smart Nature Based Solutions (NBS) which combine digital, engineered and natural components. Based on case studies and interviews, this paper presents a model to enable manufacturing organisations to navigate the complexities of designing and commercialising such complex systems, focusing on the inter-organisational partnerships required and mitigation techniques to address complexities throughout the project lifecycle. This work challenges existing concepts of hybrid, complex systems to account for NBS and their unique complexities. We argue that smart Nature Based System is a more apt way to conceptualise these solutions which incorporate digital twin, A.I and weather data to deliver urban resilience and sustainability.

### Bridging theory and practice in software design management: Insights from practitioners

***Julie Johnson, Ada Hurst, Frank Safayeni***
***University of Waterloo, Canada***

Research into the foundational theories and management of software design remains limited. A 2010 workshop was convened to explore professional software development practices. The workshop sought to foster collaboration between the software engineering and design communities by examining foundational aspects of software design. Building on that workshop's objectives, this paper investigates contemporary professional software design practice and its management within organizational contexts. It is informed by findings from three interviews with experienced software design managers. This work addresses an important gap by examining software design management through the lens of design rather than solely from a project management perspective. Additionally, it contributes to the development of a general theory of software design by integrating diverse theoretical frameworks.

## Session Chair: Niccolo Becattini, Politecnico di Milano, Italy

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Assessing the engineering design costs to meet environmental regulations: the case of packaging

***Marion Deshoulières, Hélène Cogez, Pascal Le Masson, Benoît Weil***
***Mines PSL University, France***

This novel contributions reveal how environmental regulations drive engineering design costs, focusing on the emblematic case of packaging. Using a regulatory database and simulation-based modeling, we evaluate functional expansion as a key driver of cost escalation, identifying its volume effect (rising costs from added environmental functions) and scope effect (increased interdependencies among ecosystem actors). The findings offer a simulated cost envelope to support engineering design teams in their forecasts, but also underscore the hurdles of sustainably managing these regulatory-driven costs in the packaging product system, by benchmarking cost trajectories against sustainability metrics, such as carbon pricing.

### Requirements to balance risk and multi-user experience: The case of pharmaceutical packaging design

***Alessandra Bianco, Philip Farrugia, Maresca Attard Pizzuto***
***University of Malta, Malta***

This paper presents two studies with packaging design engineers and quality and risk professionals in the pharmaceutical packaging industry, addressing the critical need for design support. The studies contribute to the development of a framework aimed at balancing risk management and multi-user experience in the context of product support. A review of prior work highlights the gap in tailored support for designers in this field. Using structured interviews and thematic analysis, seven key requirements were identified to guide the framework's creation. A user persona was also developed, capturing the core responsibilities, challenges, and motivations of quality and risk professionals. These findings provide actionable insights to aid designers address complex regulatory and user-centric challenges, paving the way for innovation and improved outcomes in pharmaceutical packaging design.

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### An approach for continuous monitoring of product properties between strategic foresight and the product engineering process

***Carsten Thümmel, Sebastian Ebi, Michael Schlegel, Andreas Siebe, Tobias Düser, Albert Albers***
***Karlsruhe Institute of Technology***

Rapid pace of change and increasing complexity in today's world demand innovative approaches to product development. Foresight methods enable the anticipation of future scenarios and the derivation of product properties. However, current approaches lack mechanisms to continuously align product development with evolving environment and customer requirements, often resulting in late changes and high costs. Early detection of deviations is needed. This paper presents an approach for continuous monitoring, bridging strategic foresight and the product engineering process (PEP). By analyzing prior work and literature, a process model was developed to identify tipping points where product adaptations are necessary using indications and indicators. Initial evaluation through a case study using coffee machines showed the approach's usability but improvement potential was also identified.

### Innovating products in the humanitarian sector: how to ensure adequate response in a challenging ecosystem

***Niccolo Becattini[1], Bart Bossink[2], Marco Cantamessa[3], Walid Ibrahim[4], Paul McManus[5], Marianna Nigra[4], Milinda Pathiraja[6]***
***1 Politecnico di Milano; 2 Vrije Universiteit Amsterdam; 3 Politecnico di Torino;***
***4 World Food Programme - UNHRD; 5 Boston University Questrom; 6 EPFL - University of Moratuwa***

The humanitarian sector requires innovation to enhance emergency response efficiency and effectiveness. This paper examines the sector's unique challenges, including complex emergencies, specialized products, diverse actors, and barriers to innovation. To address these, UNHRD has revamped its approach, blending accelerator initiatives with design-driven activities via its Innovation Lab. A task force of academics and experts is developing a tailored workflow integrating product design and business process management to improve decision-making. Efforts like market scouting, innovation contests, and in-house R&D aim to overcome current limitations, fostering collaboration among stakeholders. This approach offers a more adaptive and inclusive innovation ecosystem.

## Session Chair: Arlindo Silva, Singapore University of Technology and Design, Singapore

## Location: ECSS 2.201

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Codesign and AI: AI-assisted clustering of perception patterns of seniors on ageing and technology in Singapore

***William Siew[1], Arlindo Silva[1], Boyeun Lee[3], Karen Wee[4], Jeremy Mok[4], Joseph Lua[4], Bina Rai[2]***
***1 Singapore University of Technology and Design, Singapore; 2 National University of Singapore, Singapore; 3 University of Exeter, England, UK; 4 Lions Befrienders Service Association, Singapore***

AI-assisted methodologies captured lived experiences and enhanced innovation practices, supporting practitioners, policymakers, and researchers in designing ageing technology. This study examined AI-assisted methods, leveraging open conversations with 30 seniors to address the complexities of ageing and technology in Singapore. Using prompt engineering, we analysed coded data with role-based, context-providing, and information-seeking prompts, generating Python code for clustering analysis. The focus was on seniors' perceptions of technology and health concerns, revealing 25 indicators across six health dimensions. Of these, 12 social-emotional determinants influenced perceptions through emotional support and social interaction on technology adoption. Our analysis produced a four-cluster typology, providing a systematic framework to categorise perception patterns and address seniors' diverse needs.

### Toward a conceptual framework for AI and robotics in aging in place: Insights from constructivist grounded theory

***Sheng-Hung Lee[1,3], Devin Liddell[6], Maria Yang[1,3], Joseph F. Coughlin[4], Olivier L. de Weck[2,5]***
***1 Massachusetts Institute of Technology Department of Mechanical Engineering, USA;***
***2 Massachusetts Institute of Technology Department of Aeronautics and Astronautics, USA;***
***3 MIT Ideation Laboratory, USA; 4 MIT AgeLab, USA; 5 MIT Engineering Systems Laboratory, USA; 6 Teague***

This descriptive study examines participant reactions to a new framework categorizing aging-in-place (AIP) services with AI and robotics through a think-aloud method. Using grounded theory, we examined older adults' perceptions of AI's role in promoting independence. The framework consists of four AI archetypes that address the cognitive and functional needs of the elderly with physical or digital interventions: Advisor AI, Burler Robot AI, Valet Robot AI, and Conductor AI. The authors conducted virtual interviews with four Boston-based retirees (mean age 70), revealing expectations and concerns regarding health monitoring, routine assistance, and social well-being. The findings emphasize inclusivity, adaptability, and practical relevance for aging populations and underscore the importance of trust, lifestyle integration, and adaptability in fostering meaningful AIP applications.

## Location: ECSS 2.201

Time: Tuesday, 12/Aug/2025: 9:00am - 10:00am

### Data-driven simulation method for strategic decision-making in circular economy business design

***Yudai Tsurusaki[1], Yongsil Hwangbo[2], Shinichiro Matsushima[2], Koji Kimita[1]***
***1 The University of Tokyo, Japan; 2 SS Market Co., Ltd.***

The circular economy (CE) seeks to replace traditional linear models by focusing on resource reuse and circulation. However, developing effective CE business strategies is difficult due to complex user behaviors and product flows. Existing scenario analysis tools often rely on survey-based conjoint methods, raising concerns about discrepancies with real purchasing patterns.
This study introduces a data-driven simulation approach that employs a consumer preference model and product circulation processes based on actual operational data. Applied to a second-hand PC rental business, our method more accurately reproduces market behavior and reveals that targeting certain customer segments can enhance profitability and resource utilization. These findings underscore the approach's value as a practical tool for pre-evaluating strategies in CE businesses.

### The normative body and “stupid AI”: Challenging compulsory able-bodiedness in human-AI interaction

***Jinxiu Rebecca Han, Anne Balsamo***
***The University of Texas at Dallas***

This research examines, during the human-AI interaction process, how generative AI's depiction of human bodies reflects and perpetuates able-bodied norms, positioning disabled or grotesque bodies as "errors." Through a feminist and disability studies lens and employing archival research and visual analysis, this research challenges traditional notions of bodily normativity, advocating for inclusivity in AI-generated imagery. It underscores how labeling nonconformity as an error perpetuates able-bodied standards while erasing the visibility and autonomy of disabled bodies. By critiquing generative AI's role in reinforcing societal norms, this study calls for reimagining human-AI interactions with a shift in perception and advocates for an approach that neither devalues nor excludes disabled bodies.

# P 02-1: Sustainable Design 1

## Session Chair: Tim McAloone, Technical University of Denmark, Denmark

## Location: ECSS 2.412

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Data-driven Systems Engineering in the interdisciplinary system generation engineering - A Case study in mechatronic system development

***Steffen Wagenmann[1], Artur Krause[2], Felicia Weidinger[1], Nikola Bursac[2], Albert Albers[3]***
***1 TRUMPF Machine Tools SE+Co.KG; 2ISEM - Technical University of Hamburg-Harburg, Germany;***
***3 IPEK - Karlsruhe Institute of Technology, Germany***

This work develops a method to integrate operational data into system models following MBSE principles. Empirical analysis reveals significant obstacles to data-driven development, including heterogeneous and non-transparent data structures, poor metadata documentation, insufficient data quality, lack of references, and limited data-driven mindset. A method based on the RFLP chain links operating data structures to logical-level elements. Data analyses are aligned with specific requirements or functional/physical elements, enabling systematic data-driven modeling. This method improves efficiency, fosters system knowledge development, and connects technical systems with operational data.

### Methodological support in sustainable engineering through data-driven design of mechatronic systems

***Artur Krause[1], Alexander Teicht[2], Steffen Wagenmann[3], Albert Albers[3], Nikola Bursac[1]***
***1 Hamburg University of Technology (TUHH), Germany; 2 Heilbronn University of Applied Science, Germany;***
***3 Karlsruhe Institute of Technology (KIT), Germany***

Current legislative frameworks reflect a societal consensus to prioritize sustainability, incentivizing industries to integrate environmental goals into strategic objectives. Embedding sustainability into product development requires appropriate methods and tools. Technological advancements enable the utilization and analysis of operational machine data to support the development of new generations of sustainable systems and the conduction of Life-Cycle-Assessments. This research presents a method to support data-driven product development to reduce the environmental impact of new product generations of complex mechatronic systems during operation, addressing key factors such as the technical system, organizational infrastructure, and regulations. The application of the method resulted in multiple proposed design changes able to enhance machine sustainability and operational efficiency.

## Location: ECSS 2.412

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Bridging the gap: Streamlining Life Cycle Assessment for practical application in product development

***Rafael da Rosa Selhorst, Arlindo Silva***
***SUTD Singapore University of Technology and Design, Singapore***

This study addresses the challenges of applying traditional Life Cycle Assessment (LCA) during early-stage product development by proposing a Streamlined Life Cycle Assessment (SLCA) approach. Traditional LCA, while robust, is often inaccessible due to its complexity, time requirements, and cost, making it impractical for many industries. The developed SLCA approach offers a simplified alternative by leveraging tools like artificial intelligence, 3D modeling, and secondary databases. The SLCA methodology was validated through a case study on an electronic device, demonstrating a 69.77% reduction in input requirements, a 91% decrease in time spent, and an average accuracy of 90.05% compared to traditional LCA. These results highlight the potential of SLCA to enable designers to identify environmental hotspots early in the design process, fostering sustainable product development.

### Integrating Life Cycle Assessment in Product Service System Design: Use case for robots in waste management

***Abhishek Gupta[1,2], Anne Magdalene Syré[1,2], Rasool Okhovat[1], Dietmar Göhlich[1]***
***1 Technische Universität Berlin; 2 Contributed Equally***

This paper examines the integration of Life Cycle Assessment (LCA) in the development method of autonomous product-infrastructure service systems, demonstrating the application on the use case for waste management. Integrating LCA in the earlier phases of development methodology, sustainability analyses identify key environmental hotspots and improvement strategies. Scenario evaluations revealed the potential for energy-efficient operations with reduced emissions through smart infrastructure integration and optimized system designs. Findings underscore the importance of early-stage sustainability assessments and highlight pathways for achieving eco-design goals in urban robotics. This research work provides substantial insights for scalable, sustainable solutions with autonomous product-infrastructure service systems.

# P 02-2: Knowledge and Requirements Management

## Session Chair: Ian Whitfield, University of Strathclyde, United Kingdom

## Location: ECSS 2.410

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Towards precision in bolted joint design: A preliminary machine learning-based parameter prediction

***Ines Boujnah, Nehal Afifi, Andreas Wettstein, Sven Matthiesen***
***Karlsruhe Institute of Technology (KIT), Germany***

Bolted joints are critical for maintaining structural integrity and reliability. Accurate prediction of parameters is essential for optimal performance. Traditional methods often fail to capture the non-linear behavior or require significant computational resources, limiting accuracy and efficiency. This study addresses these limitations by combining empirical data with a feed-forward neural network. Leveraging experimental data and systematic preprocessing, the model effectively captures nonlinear relationships, including rescaling output variables to address scale discrepancies, achieving 95% predictive accuracy. While limited dataset size restricts generalizability, the findings demonstrate the potential of neural networks as a reliable, efficient alternative for bolted joint design. Future work aims to expand datasets and explore hybrid modeling techniques to enhance applicability.

### Leveraging knowledge graphs in virtual product development for enhanced collaboration

***Carolin Lehmacher[1,2], Lisa Engstler[2], Nico Suchomel[2], Johannes Staeves[2], Kristin Paetzold-Byhain[1]***
***1 Technical University Dresden, Germany; 2 BMW Group***

This paper introduces a method for developing a knowledge graph aimed to enhance collaboration and information management in virtual product development. The proposed methodology integrates data from diverse sources, including CAD models and geometry, requirements and user-related data to construct a knowledge graph that enhances the retrieval and organization of information. Use-cases, such as information retrieval, tracking changes, and user-issue management, are explored to illustrate the potential of the knowledge graph. The paper details the steps of building the knowledge graph, from defining the ontology to implementing the graph using a structured data format. The structured method presented demonstrates significant potential to enhance collaboration and support the virtual development process, potentially leading to reduced development times and costs.

# P 02-2: Knowledge and Requirements Management

## Location: ECSS 2.410

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### ★ Scenario to specification: Promises and pitfalls of AI in developing user-centered engineering specifications with interdisciplinary teams

***Ulugbek Vahobjon Ugli Ismatullaev, KwanMyung Kim***
***Ulsan National Institute of Science and Technology (UNIST), South Korea***

This study evaluates a framework for translating user scenarios into engineering specifications with AI integration. We conducted workshops with AI-assisted and non-AI teams to assess AI's impact on usability, efficiency, and collaboration. We collected data through surveys, interviews, and observations. Results indicate the framework is moderately to highly usable. While AI improved efficiency, it did not enhance output comprehensiveness or collaboration. Information overload and limited contextual understanding hindered AI integration. The study highlights AI's potential as a technical consultant and interdisciplinary bridge, emphasizing the need for domain-specific training and enhanced interactivity capabilities to optimize human-AI collaboration. These findings underscore AI's role in engineering design, contributing to scalable methods for developing user-centered specifications.

### Uncovering the limits of visual-language models in engineering knowledge representation

***Marco Consoloni[1,2], Vito Giordano[1,2], Federico Andrea Galatolo[1], Mario Giovanni Cosimo Antonio Cimino[1], Gualtiero Fantoni[1,2]***
***1 University of Pisa; 2 Business Engineering for Data Science (B4DS) research group***

Visual-Language (VL) models offer potential for advancing Engineering Design (ED) by integrating text and visuals from technical documents. We review VL applications across ED phases, highlighting three key challenges: (i) understanding how functional and structural information is complementarily expressed by text and images, (ii) creating large-scale multimodal design datasets and (iii) improving VL models' ability to represent ED knowledge. A dataset of 1.5 million text-image pairs and an evaluation dataset for cross-modal information retrieval were developed using patents. By Fine-tuning and testing the CLIP base model on these datasets, we identified significant limitations in VL models' capacity to capture fine-grained technical details required for precision-driven ED tasks. Based on these findings, we propose future research directions to advance VL models for ED applications.

# P 02-3: Lightweight Design 1

## Session Chair: Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Methodology for transferring topology optimization results into a production- and lightweight-oriented differential design

***Philipp Busch, Michael Lorenz, Philipp Schleicher, Thomas Bauernhansl***
***Fraunhofer-Institute for Manufacturing Engineering and Automation, Germany***

Deriving parametric CAD geometries from topology optimization results is a time-consuming step in the development of lightweight components, as the topology developed for the given building space corresponds to a non-parametric integral model. A labor-intensive constructive geometry repatriation is necessary and the choice of usable manufacturing processes is limited due to the integral design. Depending on the quantity, the components are often cast or additively manufactured. These restrictions prevent the economic use of topology optimization. Against this background, a methodology was developed with which topology-optimized structures can be converted into a production- and lightweight-oriented differential design for any quantities. The applicability and added value of the methodology are validated by successfully applying it to a mechanical engineering component.

### Streamlining design cycles with a flexible geometry reconstruction method

***Johannes Mayer, Sandro Wartzack***
***Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

Topology optimization is a powerful tool for the development of light and strong structures. Due to the preliminary nature of the resulting design proposals, a geometry reconstruction process is required. This primarily serves the purpose to create a functional design. In doing so, parameterization of the geometry and the option to modify are demanded in product development as well as automation. A specific medial axis based reconstruction method not only facilitates the automation, but also the intervention with several possibilities for modification of an optimized design proposal. In this paper, we examine at an examplary use case, how this practice could reduce design iteration cycles, although intermediate new design requirements emerge. We discuss the advantages and limitations of this approach.

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Lightweight design optimization of an electrified Cross Skate

***Sandro Wartzack, Stefan Goetz, Stephan Freitag***
***Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

Lightweight design plays a crucial role in enhancing efficiency and sustainability. The strategic use of advanced materials, such as fiber-reinforced plastics, can help achieving lightweight designs. However, the anisotropic material properties of composite materials also lead to new challenges in the design and manufacturing process. Additionally, due to the layered structure of composite parts, the number of design points is increased drastically. Moreover, the complex manufacturing process, including curing, makes composite parts prone to variations. Therefore, this research paper presents an innovative lightweight design approach that aims to overcome the described difficulties by linking the individual simulation steps, providing a continuous simulation strategy and taking variations into account. Finally, the presented simulation strategy is applied to an electrified cross skate.

### A framework for the continuous simulation of the manufacturing and assembly process of composites considering fibre angle variations

***Stephan Freitag, Stefan Goetz, Sandro Wartzack***
***Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

Carbon fiber-reinforced plastics (CFRP) have a great lightweight potential due to their high strength-to-weight ratio. However, new challenges arise due to complex production processes and the large number of design parameters that are subject to variations. This study advances simulation methodologies to address these challenges by modeling the entire CFRP production process while accounting for fiber angle variations at each step. The approach enables prediction of assembly stresses and deformations by utilizing surrogate models, and supports further approaches, such as tolerance optimization and process refinement. Two case studies demonstrate the effectiveness of the method and illustrate its potential to support the optimization of the production process.

## Session Chair: Ji Han, University of Exeter, United Kingdom

## Location: ECSS 2.311

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Enhancing numerical simulation analysis with the use of explainable artificial intelligence and large language models: a case study on vehicle side crash optimization

***Janis Mathieu[1,2], Stefan Kronwitter[3], Johannes Pfahler[1], Michael Di Roberto[1], Michael Vielhaber[2]***
***1 Porsche Engineering Group GmbH; 2 Saarland University, Germany; 3 Dr. Ing. h.c. F. Porsche AG***

Substantial engineering efforts are dedicated to reducing injury risks in crash scenarios during the development of new vehicles. This is achieved by performing crash simulations to optimize the nonlinear behavior of systems. However, the complexity makes their behavior difficult and time-consuming for engineers to understand. To reduce the analysis time, this study introduces a modular framework combining Explainable Artificial Intelligence and Large Language Models (LLM). Shapley Additive Explanation values allow for simulation-wise feature importance attribution and generate a data-driven understanding. An LLM assists by making result data interactively accessible and supports technical report generation. Validated through a real-world vehicle side crash optimization use case, the framework demonstrates enhanced and accessible insights into system behavior within virtual engineering.

### ChAx: A RAG-based chatbot for CAx education

***Sarah Steininger[1,2], Saltuk Kezer[1], Jona Rief[1], Emily Spicker[1], Sebastian Preis[1], Johannes Fottner[1]***
***1 Technical University of Munich, Germany; 2 BMW Group, Munich, Germany***

ChAx is a chatbot designed to support in technical drawing lectures by leveraging Retrieval-Augmented Generation. Addressing challenges such as the complexity of rules and dependencies in technical drawing, the system accesses the specific lecture materials to provide students with accurate and context-aware answers. The architecture combines modular components, including a RAG pipeline and a frontend with an interactive PDF viewer, ensuring transparency and user-friendliness. Optimization strategies like semantic chunking, fine-tuning, and cost-effective configurations enable efficient performance within constrained server environments. Evaluation metrics, including factual correctness and answer relevancy, were evaluated by using the LLM-as-a-judge method. The results underline ChAx's potential to enhance educational outcomes by enabling students utilize materials more effectively.

## Location: ECSS 2.311

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Exploring the use of LLMs to evaluate design creativity

***Jiazhen Zhang, Ji Han, Saeema Ahmed-Kristensen***
***University of Exeter, UK***

Creativity is a fundamental aspect of design that can bring us novel and useful products. However, measuring creativity in design can always be challenging as there is a lack of standardized quantification methods and the inherent limitations of mathematical modelling. Previous approaches often rely on human experts to assess design creativity. Still, humans can be subjective and biased in their evaluation procedures. Recent advancements in AI have inspired us to integrate LLMs as evaluators in engineering design. In this study, we utilize LLMs to assess the novelty and usefulness of design ideas. We developed an evaluation procedure and tested it using design samples. Experimental results demonstrate that the proposed method enhances creativity evaluation capabilities across various LLMs and improves the alignment between LLM and human expert assessments.

### ★ From text to design: a framework to leverage LLM agents for automated CAD generation

***Aurel Schüpbach[1], Raul San Miguel[1], Julian Ferchow[1], Mirko Meboldt[2]***
***1 Inspire AG; 2 ETH Zürich***

Design generation using traditional Computer-Aided Design (CAD) tools remains a labor-intensive and manual task. This paper introduces a framework for automating CAD geometry generation using Large Language Models (LLMs) with function calling and agent workflows. The framework enables both expert and novice designers to use textual prompts to automatically generate CAD code. We evaluate it with five LLMs and four agent workflows. The agent workflow incorporating automated visual feedback outperforms the others, especially with multimodal LLMs like ChatGPT-4o. A case study shows its use in topology optimization and additive manufacturing with minimal human input. Remaining challenges include limitations in spatial reasoning, prompt dependency, and workflow adaptability. Future work should focus on improving design-for-manufacturing capabilities, visual tools, and evaluation benchmarking.

# P 02-5: AI in Design Creativitiy 2

## Session Chair: Tanja Katharina Schmitt-Fumian, SRH Mobile University, TUM - Technical University of Munich, Germany

## Location: ECSS 2.306

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### AI as an element to overcome creative fixation in design teams

***Vanessa Sattele, Juan Carlos Ortiz***
***CIDI - Universidad Nacional Autónoma de México, Mexico***

The aim of this research is to analyze the potential of Generative Artificial Intelligence (GenAI) to support the design process and overcome creative fixation in teams during the initial problem framing, ideation and concept exploration stage. Fixation is a common problem in design, and can be exacerbated during collaborative work due to diverse issues such as team dynamics or perceived hierarchy. Current research is exploring whether AI can help teams overcome this problem or on the contrary, might actually contribute to it. Through a creative ideation workshop with design students, we investigate how AI influences team dynamics as well as the creative results. We propose a conceptual model to work with AI in a team setting.

### ★ Artificial creativity in design: A theory-based framework for implementation

***Qihao Zhu[1], Jianxi Luo[2]***
***1 Singapore University of Technology and Design, Singapore; 2 City University of Hong Kong, Hong Kong***

This paper presents a novel framework for Artificial Creativity (AC) in design, emphasizing the co-development of problem and solution spaces. Grounded in cognitive psychology and design theories, the framework leverages advancements in artificial intelligence (AI), particularly generative AI models, to augment human creativity in design. The study identifies four key design spaces—Solution-Knowledge, Solution-Concept, Problem-Knowledge, and Problem-Concept—and defines operators that automate reasonings within and across these spaces. By enabling simultaneous divergence and convergence of problem and solution spaces, it fosters creativity while balancing novelty and effectiveness. This work bridges AI capabilities with cognitive processes of design creativity, laying a foundation for advancing artificial creativity and human-AI collaboration in design.

## Location: ECSS 2.306

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Ai vs. human: Exploring the potential of generative AI as a feedback tool to support ideation in design education

***Tanja Katharina Schmitt-Fumian, Selina Tauscher, Katja Thoring***
***Technical University of Munich, Germany***

This paper investigates the role of generative Artificial Intelligence (AI) in academic settings, focusing on its effectiveness in providing feedback during the brainstorming phase of the design process. A controlled study with 25 students (n=25) compared feedback from Generative AI (GPT-4) to that from six human educators. Findings reveal that AI-generated feedback enhances student motivation during ideation and facilitates iterative idea refinement. Generative AI's ability to deliver rapid, scalable feedback proves advantageous in resource-constrained contexts, supporting more effective design processes. This research highlights the potential for AI-driven feedback mechanisms to transform human-AI collaboration in design education, addressing key challenges in personalized and scalable feedback delivery.

### Multimodal generative AI for conceptual design: Enabling text-based and sketch-based human-AI conversations

***Gaelle Baudoux, Chenjun Guo, Kosa Goucher-Lambert***
***University of California, Berkeley, USA***

Recent advances in AI offer promising opportunities for creative design, particularly through the generation of inspirational images. While prior research has explored the general benefits and limitations of text-to-image tools, there is significant potential in overcoming these constraints by investigating agile, multimodal prompting to facilitate more project-appropriate human-AI interaction. We present the development of a system designed to support both text-based and sketch-based image generation, serving as a research artefact for studying creativity support through multimodal Generative AI. The system enables dynamic dialogue interaction and visualization of the respective contributions. This paper focuses on the development of this AI system as a research artefact to enable future research through design, exploring how multimodal prompting can influence the design process.

## Session Chair: Benoit Eynard, Université de Technologie de Compiègne, France

## Location: ECSS 2.305

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Towards proactive design for sustainability in Industry 4.0/5.0

***Bertrand Marconnet[1,2], Raoudha Gaha[2], Benoît Eynard[2]***
***1 LabECAM, Université de Lyon, ECAM LaSalle, France;***
***2 Laboratoire Roberval, Université de Technologie de Compiègne, France***

The paper proposes an approach called proactive design for sustainability (DfS) in the context of Industry 5.0, for human-centred innovation and environmental sustainability, combined with the technological focus of Industry 4.0. Computer Aided Design (CAD) must integrate sustainability considerations into product development, with the use of Artificial Intelligence (AI), Digital Twins (DTw) and the Internet of Things (IoT) to dynamically monitor and optimise environmental impacts during the design process, with the integration of Key Sustainability Indicators (KSI) into the CAD interface to enable informed decision-making, aligning design parameters with resource availability and environmental constraints. A case study of an autonomous mobile robot (AMR) will show how operational data from the product lifecycle, combined with AI predictions, can reduce energy consumption and emissions.

### A scalable framework for demand-oriented model-based systems engineering application: The MBSE Cube

***Umut Volkan Kizgin, Thomas Vietor***
***Technische Universität Braunschweig***

The complexity of modern products poses significant challenges for the industry. Existing model-based systems engineering (MBSE) methodologies often lack the scalability and mechanisms for assessing maturity required to meet diverse organizational needs. Implementing MBSE all at once is impractical due to the complexity of changes required and resistance to change among employees. The MBSE Cube was developed as a scalable, demand-oriented framework to support organizations transitioning from no systems engineering processes or document-based approaches to model-based practices. This artifact-based approach guides the systematic creation of development artifacts, forming the foundation for MBSE implementation. By integrating abstraction levels, system views, and maturity levels, the Cube helps organizations assess their state and develop tailored MBSE adoption strategies.

## Location: ECSS 2.305

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Generating preinventive structures: AI-driven creativity in product repurposing

***Elisa Kwon[1], Kosa Goucher-Lambert[2]***
***1 University of Toronto, Canada; 2 University of California, Berkeley, USA***

This study presents an AI-driven method for generating preinventive structures - initial precursors to creative design concepts - using the Geneplore model as a theoretical framework. Multimodal AI is leveraged to derive preinventive structures from combinations of components of an existing product. This method is evaluated by comparing AI-generated structures of a product to those reverse identified from real repurposing solutions for the same product (IKEA hacks). The appearance of AI-generated preinventive structures in the repurposed designs suggests that this method can inspire and lead to viable design concepts. Implications extend to sustainable design, creative ideation, and the theory-driven development of design methods that support design in constrained solution spaces. Future work can refine these approaches and investigate broader applications in diverse design contexts.

### Enabling data-driven design by deriving consumer appliance use from household energy data

***Nathan Morris, Sindre Eikvag, James Gopsill, Maria Valero, Ben Hicks***
***University of Bristol***

Achieving Net Zero requires designers to have a better understanding of the product use with studies showing user behaviour, cultural norms, seasonality and product interactions concomitantly dictate energy consumption. Data on product use can support data-driven design processes that have been shown to improve the efficiency of existing products. The paper reports a method that generates data for data-driven design processes from non-intrusive load monitoring (NILM) of household energy consumption data. The method produced appliance classification accuracies of 0.9984 while reducing sample size, sampling frequency and machine learning model complexity showing potential for it to be deployed at scale across communities.

## Session Chair: Massimo Panarotto, Politecnico di Milano, Italy

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Principles of positive sum design

***Ian Gonsher[1], Will Rutter[2], Arthi Krishnaswami[3], Ruth Schmidt[2]***
***1 Brown University, USA; 2 Illinois Institute of Technology, USA; 3 Carnegie Mellon University, USA***

The notion of "zero-sum" games describes situations characterized by scarcity and competition. Reframing these situations to yield more positive sum scenarios benefits from design strategies that can identify new sources of value, oriented toward out-comes that reward collective benefit over maximizing one's individual strategy to win at others' expense. This emergent practice, called Positive Sum Design, identifies and critiques the conditions that contribute to zero-sum bias in the interest of creatively reframing challenges and redesigning scenarios to encourage more cooperative strategies and pluralistic values. Positive Sum Design can be thus characterized as both a cultural critique and a set of creative practices applied toward that critique to help practitioners identify opportunities for transcending presumed constraints and transmuting zero sum games into non-zero-sum ones.

### ★ Exploring generative design in context of mass personalization

***Petar Kosec[1,2], Iris Huic[1], Tomislav Martinec[1], Stanko Škec[1]***
***1 University of Zagreb, Croatia; 2 Neo Dens Ltd.***

This study examines generative design (GD) within mass personalization (MP) workflows, using custom dental implant abutments as a case study. Selected for their complex functional requirements, a parametric model developed in Rhino3D and Grasshopper, augmented with Wallacei for optimization, was compared to conventional industrial CAD approaches. GD automates design iterations and handles multi-objective optimizations, with performance improvements achieved by segmenting the parametric model. However, GD requires precise parameterization, posing challenges for less experienced designers. While GD enhances iteration efficiency and explores complex design spaces, its computational demands and limited adaptability to extensive geometric variations reduce overall efficiency.

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Prepare for the unexpected: Design with a non-linear payoff function

***Massimo Panarotto[1], Claudia Eckert[2], Gaetano Cascini[1]***
***1 Politecnico Di Milano, Italy; 2 The Open University, UK***

Products are often optimized for "most likely" conditions, but unexpected variations can render designs ineffective. Using examples from engineering systems, this paper explores the benefits of leveraging non-linear "payoff functions," where small changes in conditions lead to disproportionate outcomes. By analyzing the direction and curvature of these functions near observed boundaries, designers could gain an understanding of behavior beyond expected ranges. Non-linear modeling can aid in assessing design margins, especially in long-lived systems. Integrating this approach into design processes can be helpful and effective in considering the "preparedness" of a system in the face of unexpected events of different natures.

### Mindfulness and the unseen: Understanding the impact of dark patterns in mindfulness applications

***Ezgi Özkürkçü, Demet Doğanay***
***Middle East Technical University***

The rise of mindfulness apps has integrated these tools into daily life, but concerns arise about preserving traditional practices and the ethical use of manipulative dark patterns that undermine user autonomy. This study examines the impact of dark patterns on user perceptions, engagement, and trust in mindfulness apps using expert reviews, surveys, journaling, and interviews. Three apps—Calm, Headspace, and Insight Timer—were analyzed for dark patterns, with participants documenting their experiences and perceptions. The findings underscore the need for ethical design practices to enhance trust and informed decision-making while highlighting the influence of dark patterns on user behavior and experience.

# P 02-8: Design Management 1

## Session Chair: Katharina Ritzer, Technische Universität Hamburg (TUHH), Germany

## Location: ECSS 2.201

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Undisciplined design: risks, challenges, limitations and strategies for navigating through chaos

***Yueh-jung Lee, Anupama Gowda***
***The University of Texas at Dallas, USA***

Undisciplined Design (UD) is an emerging approach suited for experiment-driven innovation and creative processes, allowing fluid disciplinary engagement in engineering design. However, its openness and adaptability also introduce challenges, particularly when integration, evaluation, and risk mitigation mechanisms are absent. This paper examines the Google Glass project through the lens of boundary objects, identifying two key dangers in UD: overconfidence in technological inevitability and unintended consequences. The analysis highlights the need for structured checkpoints to manage epistemic uncertainty while preserving UD's exploratory potential. To address these challenges, we propose incorporating participatory design methods to facilitate cross-disciplinary negotiation and present a decision-making checklist to guide UD projects in product design and innovation.

### Effects of new ways of working in product development - a systematic evaluation in an engineering simulator

***Katharina Ritzer, Rahil Mithani, Nikola Bursac***
***ISEM, Hamburg University of Technology (TUHH), Germany***

This study explores the impact of new work practices on product development in an Engineering Simulator by comparing traditional practices with new ways of working in a compressed product development process. By introducing flexibility, digital tools, and autonomy, the study highlights improvements in individual productivity and innovation. For example, teams employing new work practices developed their first prototypes 30% faster than control groups. However, challenges in communication and team dynamics emerge, underscoring the need for structured support systems. The findings further suggest that while these modern practices foster creativity and efficiency, successful implementation at the organizational level requires balancing autonomy with clear guidelines and effective management. This study provides actionable insights for adapting new work methods to engineering environments.

## Location: ECSS 2.201

Time: Tuesday, 12/Aug/2025: 10:30am - 11:30am

### Exploring differences in design context construction within social innovation collaborative initiatives

***Tinglei Cao***
***Tongji University***

Design has shifted from product manufacturing to tackling systems' complexities in social innovation, focusing on participatory and human-centered design. Despite tools developed to enhance participation, differing perspectives complicate co-creation, necessitating better ways for interdependent thinking and communication. Designers must be embedded within the same social and cultural contexts as others, engaging in long-term participation. Establishing a design context that transcends temporary action but with a joint vision and tasks achievement is crucial. This study identifies varying levels of designers' involvement and the differences of design context construction. Three modes are illustrated: (1) patching-based, (2) intertwining-based, and (3) expanding-based design context construction. This study advances design theory, encouraging designers to engage in multi-level collaboration.

### Mapping project alignment: A case study of using concept maps to analyze shared understanding in a multi-disciplinary long-term creative practice project

***Pavan Kumar, Anupama Gowda, Heidi Rae Cooley, Joshua Summers***
***University of Texas- Dallas***

This paper explores the role of concept maps in investigating and highlighting project alignment through shared understanding within a multidisciplinary, long-term, creative, practice-based project called "Fish Project." By combining surveys and concept maps, the case study investigates team dynamics, skill diversity, and evolving project comprehension. The project aims to integrate augmented reality and geo-locative technologies to cultivate care, community, and collaborative design through a digital fish ecosystem. Analysing concept map: metadata, topology, and vocabulary, the research highlights gaps in team alignment and provides areas for cohesive project visioning and execution. The findings underscore the importance of iterative communication tools to bridge interdisciplinary boundaries and strengthen team coherence.

# P 03-1: Designing for a Circular Economy 1

## Session Chair: Peter Törlind, Luleå University of Technology, Sweden

## Location: ECSS 2.412

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Exploring the sensory impact in second-hand clothing shopping through visceral, behavioural, and reflective design

***Marie Das[1], Ingrid Moons[2], Els Du Bois[1], Dirk Van Rooy[1]***
***1 Faculty of Design Sciences, University of Antwerp, Belgium;***
***2 Faculty of Business and Economy, University of Antwerp, Belgium***

This study examines how second-hand clothing (SHC) store design influences consumer perceptions and purchase behaviour. Based on findings from two studies (study 1: survey, n=268; study 2: experimental, n=90), design strategies were developed informed by Norman's Emotional Design model. Results show that fresh and floral scents enhance hygiene perception and purchase intention, while attractive visual presentation improves purchase intention, willingness to pay, and quality and hygiene perceptions. While visceral design addresses some consumer concerns, strategies at all three levels are needed to fully improve the SHC shopping experience as they address consumer concerns, build trust, and encourage sustainable purchasing behaviour.

### Behaviour change design for reducing plastic usage by perceived similarity nudge

***Quentin Ehkirch[1], Ferdi Raharja[1], Udari Samaranayake[2], Ken-ichi Sawai[1], Akane Matsumae[1]***
***1 Kyushu University, Japan; 2 Edith Cowan University, Australia***

This study explores the influence of perceived similarity on pro-environmental behavior, focusing on plastic reduction. Participants' daily plastic use and reduction were tracked over 30 days via online chat software, with controlled nudges from an agent. Each group included two examinees and one agent. Behavioral data were analyzed to evaluate predictability from various perspectives and its relationship with behavioral change. Results showed significant differences in predictability based on perceived similarity, particularly during the first 10 days. Furthermore, nudges, consumption levels, and behavioral changes significantly affected predictability within the first 20 days. These findings contribute to understanding how perceived similarity can enhance nudging strategies to promote sustainable behavior and reduce plastic consumption.

## Location: ECSS 2.412

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### ★ How to deal with products in circular economy: An approach to model specific design knowledge illustrated at the example of a circular factory for angle grinders

***Jonas Hemmerich, Annika Kirn, Gregor Walter, Christoph Wittig, Patric Grauberger, Sven Matthiesen***
***Karlsruhe Institute of Technology (KIT), Germany***

The reprocessing of used products within a circular factory relies on instance-individual design decisions. This requires specific design knowledge (SDK) on relations between embodiment and functional behavior. However, existing approaches do not model SDK in a way that supports product reuse to fulfill the functional requirements of new product generations. This paper presents a hypothesis-based modeling approach on building and structuring qualitative SDK. Drawing on elements of existing product models, the approach yields three outcomes - a function-related structure, design hypotheses, and the assignment of testing strategies. A case study of an angle grinder demonstrates how the approach addresses the requirements of a circular factory by facilitating targeted SDK buildup, ensuring comprehensive documentation, and preparing the quantification of knowledge.

### Exploring sustainable consumer behavior: The Circular Behavior Integration Framework (CBIF)

***Janaina Mascarenhas[1], Dryelle Rodrigues Freitas[1], Sania da Costa Fernandes[2]***
***1 University of São Paulo; 2 Federal University of São Carlos***

This study investigates the elements influencing consumer behavior in the proper disposal of e-waste to advance management practices and circularity. Anchored in Sustainable Behavior Theory and the SHIFT framework, it analyzes secondary data from 51 Brazilian e-waste management companies through document analysis. Findings reveal diverse strategies addressing behavioral barriers and gaps in consumer engagement, informing the Circular Behavior Integration Framework (CBIF). The CBIF provides actionable insights for aligning consumer behavior with reverse logistics systems, advancing material circularity. This study contributes to theory by integrating behavioral dimensions with circular economy principles and offers practical guidance for policymakers and practitioners.

# P 03-2: LLMs for Knowledge and Requirements Management

## Session Chair: Zhenghui Sha, The University of Texas at Austin, United States of America

## Location: ECSS 2.410

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Exploring LLM-based agents for need analysis of knowledge management practice

***Yixuan Su[1,2], Reza Mirafzal[1,2], Julie Stal-Le Cardinal[2]***
***1 Sibylone, France; 2 Centrale-Supélec, France***

Need analysis is essential for organisations to design efficient knowledge management (KM) practices, especially in contexts where knowledge is a critical asset and evolving fast. The research explores the application of large language model (LLM)-based agents in automating need analysis for KM practices. A two-layered model using Retrieval-Augmented Generation (RAG) architecture was developed and tested on datasets, including interviews with managers and consultants. The system automates NLP analysis, identifies stakeholder needs, and generates insights comparable to manual methods. Results demonstrate high efficiency and accuracy, with the model aligning with expert conclusions and offering actionable recommendations. This study highlights the potential of LLM-based systems to enhance KM processes, addressing challenges faced by non-technical professionals and optimising workflows.

### Probabilistic methods for evaluating human and LLMs during design problem-solving

***Ryan Bruggeman, Estefania Ciliotta Chehade, Tucker Marion, Paolo Ciuccarelli***
***Northeastern University, USA***

We present a probabilistic method for assessing design reasoning in design problem settings using soundness and completeness as metrics. Building on how inference mechanisms are employed during latent need elicitation from product reviews, we compare human-led and Large Language Models (LLMs) via protocols, workshops, and surveys. We demonstrate that human reasoning patterns tend to leverage user opinions, achieving deeper coverage of need potential, whereas LLMs often produce narrower, categorically constrained needs. These findings highlight the importance of balancing inference mechanisms to ensure both coherent reasoning steps and comprehensive exploration of the design space. By formally framing reasoning during design problem-solving, we offer a foundation for developing design enabled AI and deepens our understanding of how complex reasoning unfolds in practice.

# P 03-2: LLMs for Knowledge and Requirements Management

## Location: ECSS 2.410

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Enhancing knowledge transfer through LLM-based applications: A preliminary study

***Alexander Patrick Schlegel, Alexander Koch***
***University of the Bundeswehr Munich, Germany***

Need analysis is essential for organisations to design efficient knowledge management (KM) practices, Large Language Models offer a novel approach with low barriers to entry to potentially improve knowledge transfer in product development. After identifying knowledge barriers from literature that are potentially addressable through LLM-based applications, we analyze two GDPR-compliant LLM applications - ChatGPT Enterprise and Langdock - examining their key features: assistants and chatbots for both, and prompt libraries and LLM-based file search for Langdock.Then, we evaluate each feature's potential to mitigate each barrier. Our findings show that assistants and chatbots provide wide-ranging support across many barriers, whereas prompt libraries and file search deliver targeted solutions for a narrower set of specific challenges. Given the numerous influencing factors and the rapidly evolving field of LLMs, the study concludes with a research agenda to validate the theoretical findings.

### Prompt engineering study: Comparing pre-service engineers to large language models in requirements generation

***Shanae Edwards, Kenny Nonso-Anyakwo, Joshua Summers, Oredola Adebayo***
***University of Texas at Dallas***

The objective of this research is to compare the requirements generated by human participants and large language models (LLMs). Requirements are statements that capture the needs and desires from stakeholders and organize them into design parameters. These statements are expressed in natural language which may lead to incompleteness and ambiguity. Due to the recent advancements in the natural language model such as ChatGPT and Gemini as a tool for requirement generation, this study investigates the quantity, variety and completeness of requirements generated by 66 pre-service engineers and 4 LLMs. This is because in some design projects, stakeholder access may be limited. The results show that pre-service engineers outperformed LLMs in variety, quantity and completeness. Future work could involve developing and comparing true human personas to LLMs.

## Session Chair: Marcel Bartz, TU Dortmund University, Germany

## Location: ECSS 2.312

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Design of a lightweight skateboard truck: a framework for optimizing sports equipment under real conditions

***Felix Pfister[1], Marcel Bartz[2], Sandro Wartzack[1]***
***1 Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany; 2 Technical University Dortmund***

Skateboards used in competitive events such as the Olympic Games are sophisticated products that have remained largely unchanged for over four decades. This presents an opportunity for improvement in the form of reduced weight and moment of inertia, while maintaining comparable stiffness to the most popular skateboard truck currently in use. To achieve this, topology optimization was employed with consideration of real-world loads, which are inherent to street skating. To ensure a reliable and predictable handling, a re-engineering of the benchmark truck was used. To assess the impact of weight reduction on the overall system, all skateboard components were modelled and assembled to compare the center of mass and moment of inertia with the benchmark. Following the virtual validation, the skateboard truck was printed via SLS with a weight reduction of 19 % compared to the benchmark.

### A procedure model to manage requirements for topology optimization and additive manufacturing

***Johannes Soika1, Felix Endress[1], Jakob Schenk[2], Markus Zimmermann[1]***
***1 Technical University of Munich, Germany; 2 AUDI AG, Ingolstadt, Germany***

Topology optimization combined with additive manufacturing enables the creation of complex, high-performance products. However, industrial applications often involve numerous and complex requirements, making it challenging to align the design and manufacturing process to meet all demands. A particular challenge is to determine which requirements should be included in the optimization problem statement. This paper presents a procedure model to integrate requirements and feasibility constraints into the design and manufacturing process. It includes two major steps: organizing requirements and constraints in the process and identifying the problem statement. The procedure is applied to the requirements of an engine bracket of AUDI AG, demonstrating its ability to handle numerous requirements and to specify the problem statement.

## Location: ECSS 2.312

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### ★ Design tool for topology and particle damping optimization of additively manufactured parts

***Marcus Oel, Arne Roeder, Ina Meyer, Roland Lachmayer***
***Institute of Product Development (IPeG), Leibniz University Hannover,***
***An der Universität 1, 30823 Garbsen, Germany***

Thanks to its design freedom, additive manufacturing (AM) offers the possibility of directly integrating functions and effects into parts. One of these effects is particle damping, which can significantly increase the damping of parts due to the friction of loose particles in closed cavities. However, the design of these cavities is challenging due to a large number of influencing factors. This article presents a tool that optimizes the component topology and creates particle damping cavities. Using the bidirectional evolutionary structure optimization method, an optimization of mass, stiffness and damping is achieved. The verification of the tool shows that, in addition to reducing the part mass, the integration of the particle dampers is successfully implemented in compliance with the design principles from the literature. Furthermore, restrictions of the AM process were implemented.

### Approach for investigation of CFRP tribological stressed interfaces through levels of abstraction

***Floyd Daniel Bischop, Pascal Inselmann, Dieter Krause***
***Hamburg University of Technology***

Carbon Fiber Reinforced Plastics (CFRP) offer high lightweight potential, particularly for dynamic machine components due to their strength-to-weight ratio and low thermal expansion. However, integrating CFRP into stressed interfaces, such as tool spindles, poses challenges like anisotropic properties and tribological complexity. This study presents a multi-level approach to investigate and transfer tribological parameters in CFRP systems. Using the hierarchical product component test pyramid, it bridges product, structure and meterial levels, e.g. through simplified block-on-plate, as well as block-on-tube tests. Through abstracted and application-oriented test setups, key influencing factors can be identified and analyzed. The hierarchical test pyramid allows for stepwise knowledge transfer between abstraction levels, reducing testing effort without sacrificing relevant information.

# P 03-4: Optimal and Robust Design

## Session Chair: Paul Christoph Gembarski, Leibniz Universität Hannover, Germany

## Location: ECSS 2.311

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Finding optimal solution principles in conceptual design

***Philipp Rosenthal, Artur Liebert, Oliver Niggemann***
***Helmut Schmidt University, Germany***

Automating the structuring of Solution Principles within conceptual design is crucial for efficiently covering Function Structures while reducing time-intensive manual processes. Solution Principles are central in bridging functional requirements and technical implementations, yet traditional methods depend heavily on human expertise. To address this, a novel approach leveraging a search algorithm is proposed to automatically identify an optimal set of Solution Principles for a given Function Structure. The approach formalizes the problem and provides rules for the selection and application of Solution Principles. Key components include a function for applying Solution Principles to functions and a heuristic that minimizes principle selection, guiding the search toward optimal solutions. An evaluation shows the potential of this method to reduce time and effort in early product design.

### A hypothesis-based method for building specific design knowledge for robust design

***Jiahang Li, Johanna Luening, Patric Grauberger, Sven Matthiesen***
***IPEK - Karlsruhe Institute of Technology (KIT), Germany***

Robust Design (RD) is crucial in product development to ensure that products maintain reliable performance under varying conditions. Design knowledge is fundamental to RD. However, current methods lack a systematic approach to support design engineers in building design knowledge for RD. This paper addresses this gap by introducing a hypothesis-based method for systematically building design knowledge for RD. RD hypotheses are specifically developed for this purpose and are tested through a five-step method. The application of this method is demonstrated in a case study involving a hand-operated coining machine. The results show that the proposed method supports building specific design knowledge through two RD hypotheses. By employing this method, design engineers are systematically supported in making design decisions, leading to more robust product concepts.

## Location: ECSS 2.311

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Modeling constraint-based manufacturing networks: Theory, application and best practices

***Kevin Herrmann, Felix Pusch, Christian Becker, Paul Christoph Gembarski, Roland Lachmayer***
***Leibniz University Hanover***

This paper demonstrates how the Portfolio of Capability Constraint Network (PCCN) facilitates modeling and analyzing complex manufacturing networks by framing them as constraint satisfaction problems (CSPs). These models face high complexity due to numerous n-ary constraints and large solution spaces, posing challenges for standard solution algorithms. Existing CSP remodeling approaches were reviewed but found unsuitable for the specific needs of PCCNs. As a result, tailored design guidelines and heuristics were developed to reduce problem complexity effectively. The applicability of these guidelines was validated using a use case involving the production of a multi-material shaft with tailored forming technology. Results showed significant efficiency gains in solution searches, emphasizing the practical value of the proposed methods in simplifying and optimizing PCCN-based models.

### Research topic evolution: A comparative analysis of human and machine approaches

***Siyi Xiao, Daniel A. McAdams***
***Texas A&M University, USA***

Exploring patterns in large text corpus is essential for effective knowledge discovery in research domains. However, machine-driven methods often introduce noise and rely heavily on parameter thresholds. Human expertise is therefore essential for ensuring reliable outcomes. This study conducts a comparative analysis of a classification task performed by both human and computer algorithms. During the task, human experts are asked to categorize a list of abstracts based on their semantic contents, where computer algorithms perform computations, including network analysis and document embeddings, to group the abstracts. The findings show a significant level of disagreement between human and computer-generated clusters, indicating the need for further investigation into the factors influencing community categorization and incorporating more advanced techniques to improve the results.

# P 03-5: Additive Manufacturing & Materials

## Session Chair: Roland Lachmayer, Leibniz Universität Hannover, Germany

## Location: ECSS 2.306

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Approach for a shape decomposition process to reduce material waste of structural sheet metal components

***Lukas Kömm, Kristin Paetzold-Byhain***
***TU Dresden, Germany***

Automating the structuring of Solution Principles within conceptual design is crucial for efficiently covering Function Structures while reducing time-intensive manual processes. Solution Principles are central in bridging functional requirements and technical implementations, yet traditional methods depend heavily on human expertise. To address this, a novel approach leveraging a search algorithm is proposed to automatically identify an optimal set of Solution Principles for a given Function Structure. The approach formalizes the problem and provides rules for the selection and application of Solution Principles. Key components include a function for applying Solution Principles to functions and a heuristic that minimizes principle selection, guiding the search toward optimal solutions. An evaluation shows the potential of this method to reduce time and effort in early product design.

### Beyond human perception: designing nonhuman material affordances for ecological reintegration

***Javier de Urquijo Isoard[1], Samantha Grover[2], Olivier Cotsaftis[1]***
***1 RMIT University School of Design, Australia; 2 RMIT University School of Science, Australia***

Biodegradability is often framed as an intrinsic material property. By integrating industrial design and soil science, this research examines how material design can actively support ecological reintegration. Through a case study of Polylactic Acid (PLA)—marketed as sustainable yet resistant to breakdown in everyday soil—we challenge how biodegradability claims misalign with real-world decomposition. To address this, we designed and tested 3D printing filaments, using compost respiration analysis to show that microbial engagement depends on material composition and environmental factors. We then introduce decayability as a novel affordance that supports microbial activity. By extending affordance theory beyond human perception, this study establishes a framework for designing materials that mediate interactions between human fabrication needs and nonhuman decomposition processes.

## Location: ECSS 2.306

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Material selection methods: Brittleness filter are often too strict

***Michelle Hedvard, Ingo Jonuschies, Maja Eichler, Philipp Weißgraeber***
***University of Rostock, Germany***

To specify the solution principles of a design, a material selection should be performed already in the concept phase. Based on the design constraints, inappropriate materials are removed using an attribute filter. Brittle materials are often removed using fracture toughness attribute limits, but this does not take into account the strength specific stress level and incorrectly excludes entire classes of materials. We propose a novel filtering method to account for brittle failure in material selection. Based on linear elastic fracture mechanics, we establish a relationship that correctly describes the transition between brittle and ductile materials. Representing the proposed filter on an Ashby plot, we evaluate its effect on the further material selection process. Additionally, we show how different defect sizes in the materials can be incorporated into the filtering process.

### Methodology for design and additive manufacturing of radiotherapy bolus using 3D scanning: a low-cost alternative

***Marcelo S. Brito Arrieta, María J. Calvopina Orellana, Fausto A. Maldonado G., Jorge L. Amaya-Rivas, Gabriel A. Murillo Zambrano, Carlos Saldarriaga, Jorge Hurel, Carlos G. Helguero***
***FIMCP- ESPOL Polytechnic University, Escuela Superior Politécnica del Litoral, Ecuador***

FIMCP- ESPOL Polytechnic University, Escuela Superior Politécnica del Litoral, Ecuador
Radiotherapy involves applying radiation doses to tumor cells and healthy tissue. To protect healthy tissue, an accessory called a bolus is used. Traditional boluses face issues such as limited adaptability and inconsistencies in radiodensity. This study proposes a low-cost process that uses 3D scans and additive manufacturing (AM) to design and produce custom boluses.
The method uses a 3D scanner as an alternative to standard medical image acquisition, processes the images with CAD and mesh optimization, and then manufactures the pieces through additive manufacturing using polylactic acid (PLA) as the printing material.
By optimizing the fill percentage, radiodensity was controlled, resulting in boluses that achieved a 65% cost reduction in material and an 81% savings in imaging compared to the traditional method.

## Session Chair: Stefan Zorn, University of Rostock, Germany

## Location: ECSS 2.305

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### A knowledge framework of environment reconstruction methods for mixed reality prototype applications

***Aman Kukreja[1], Mattia Trombini[2], Chris Cox1, Chris Snider[1]***
***1 University of Bristol, UK; 2 Polytechnic University of Turin, Italy***

Mixed reality prototypes are used for applications like design, analysis, and training. They combine high-fidelity overlays on low-fidelity tangible prototypes, giving users physical interactions in virtual environments. Suitable virtual environments are crucial in taking full advantage of these prototypes. However, there is a lack of guidance in the literature on choosing environment reconstruction methods for various applications. The rapid advancements in this area necessitate the characterisation of the reconstruction methods. This paper thus presents a novel knowledge framework for mapping the reconstruction methods with the requirements of MR prototype applications. The aim of the proposed framework is to help designers and engineers make informed decisions. The effectiveness of the framework has been illustrated using five reconstruction methods and testing via four case studies.

### Analysing influences on design space exploration: Insights from testing a new study design

***Keisuke Yamashita[1], Stefan Zorn[1], Michael Schabacker[2], Björn Kokoschko[2], Kilian Gericke[1]***
***1 University of Rostock, Germany; 2 Otto von Guericke University Magdeburg, Germany***

This paper examines the effects of prototyping on design space exploration (DSE). Based on a literature review, a study design is proposed that attempts to integrate a longitudinal view from downstream development steps in the point-in-time investigation of design fixation. This study design is tested in a pilot study, the results are presented and discussed. The observation of participants' design fixation (DF) in downstream activities shows that the need to create prototypes limited DSE behaviour, and suggestions for further adaptation of the study design are made. Challenges related to group dynamics, bias and logistical issues highlighted the need for a more refined study design. The findings highlight the role of prototyping in limiting DSE behaviour and suggest improving metrics, refining interventions and using structured moderation to improve future DF and DSE research.

## Location: ECSS 2.305

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### Evaluation of virtual prototypes: Literature and empirical findings

***Shivam Jaiswal, Srinivasan V.***
***Indian Institute of Technology Delhi, India***

The objective of this research is to identify and synthesize metrics to assess virtual prototypes in product design. The metrics are identified from literature and practitioners (novice/experienced designers and design faculty members), and evaluation categories are constituted. The identified metrics and constituted evaluation categories from: (a) literature and practitioners, and (b) across various practitioner groups, are compared. 144 and 29 distinct metrics are identified from literature and practitioners, resulting in 15 and 9 evaluations categories, respectively. The metrics from the practitioners is a subset of the metrics from the literature. The differences between: (a) literature and practitioners, and (b) across various practitioner groups, suggest the need for support to help practitioners choose relevant metrics for their prototyping context from an encompassing list.

### Findings from a field study of prototyping of digital engineering technologies in operational settings

***Trifeena Marie James, Anna-Maria McGowan***
***NASA Langley Research Center***

The authors investigated the prototyping and iteration of three prototype workflows in an operational engineering organization. Data were collected from an ethnographic field study that included observations, interviews, and participatory design workshops. The data were triangulated and synthesized thematically, yielding the following key findings: (1) The value of having an ethnographic field study in improving engineering teams' prototyping (2) Prototyping digital engineering capabilities in realistic operational settings offers enhanced opportunities for buy-in and technology infusion (3) Experienced professionals identified and refined new use cases through prototyped workflows. The findings and the context-rich details from the field study have been instrumental in furthering digital engineering applied research and in defining follow-on efforts to advance engineering practice.

# P 03-8: Design Justice and Ethics

## Session Chair: Christine Toh, University of Nebraska at Omaha, United States of America

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### How well can we reflect? Examining the quality and content of novice designers' reflections on social identity

***Evan Brown, Rohan Prabhu***
***Lafayette College, USA***

Humans, with their various social identities, form an important part of engineering design. Therefore, designers must reflect on the implications of social identity when designing products. However, little research has examined the quality and content of student designers' reflections on the importance of social identity in design, and we aim to explore this research gap. The results of our study revealed higher frequencies of responses related to personal experiences and design/action among designers with minoritized social identities. Designers with minoritized identities also provided higher-quality reflections than those in the majority group. These results suggest that designers with different social identities may vary in their ability to critically reflect on the impact of social identity in design and call for the need for new reflective design tools and educational approaches.

### What makes a Top-Tier internship: Ranking internships in industrial design

***Carly Hagins[1], Betsy Barnhart[2]***
***1 University of Kentucky, USA; 2 The University of Kansas, USA***

Students, educators, and professionals find value in industrial design students participating in internships, however, there is currently no approach for evaluating the quality of internships students are participating in. This research addresses the need for a standardized metric to evaluate industrial design internships. During a two-year longitudinal study conducted at three comprehensive universities, data were collected on internship experiences. Using this data, the authors developed a weighted ranking approach, providing a valuable tool to evaluate internships' quality and relevance. This ranking fills a critical gap, offering unique insights for students, academic programs, and internship providers to assess and enhance internship quality, currently unaddressed by existing tools.

## Location: ECSS 2.203

Time: Tuesday, 12/Aug/2025: 3:15pm - 4:15pm

### A framework for analyzing goal alignment and social relevance of research papers to identify impact of women in design research communities

***Bethany Parkinson[1], Gul e Fatima Kiani[2], Mary I. Frecker[1], Christine A. Toh[2]***
***1 The Pennsylvania State University, USA; 2 University of Nebraska at Omaha, USA***

The underrepresentation of women and gender minorities in certain STEM fields remains a persistent issue despite decades of research and outreach. This framework introduces a novel perspective by investigating how gender differences may influence the nature of research itself. We propose a coding protocol for systematically analyzing stated goal alignment through the lenses of social relevance, goal type (communal or agentic), and goal function (advancing or fortifying). The protocol was iteratively developed through a coding analysis of research papers from a major design engineering conference and journal (N = 297). The protocol is demonstrated through coding two papers. Use of this protocol will help researchers demonstrate how published research portrays social relevance and communal focus and thus improve understanding of the participation of women in STEM.

### Co-creating a justice-centered product design specifications tool

***Madhurima Das[1], Tomás Estrada[2], Sara Atwood2, Maria C. Yang[3], Cynthia Breazeal[3], Catherine D'Ignazio[3], Anastasia K. Ostrowski[4]***
***1 The University of Melbourne; 2 Elizabethtown College; 3 Massachusetts Institute of Technology; 4 Purdue University***

As society and the field of engineering evolves, it is necessary for engineering tools to evolve as well. Through a co-design approach, this work explores the re-design of Pugh's Product Design Specifications tool for engineering design courses to increase scaffolding of the tool for student learning and incorporate societal implications drawing upon design justice. This re-design was conducted in collaboration with Elizabethtown College faculty members, instructors and students. This paper details the iterative co-design process, showcasing the evolution of the tool that culminated in the latest iteration of the re-designed PDS tool. We conclude with a reflection on this co-design process and recommendations for evolving other engineering design tools to incorporate social justice concepts.

# W 11: Evaluating AI Generated Solutions to Ill-structured Design Problems

***Session Chair: Ryan Bruggeman, Northeastern University, United States of America***

**Time: Tuesday, 12/Aug/2025: 12:00pm - 1:00pm Location: ECSW 1.365**

Audience: Faculty, Industry, Students
In the workshop we will begin with a 10 minute presentation, introducing participants to ongoing research in the area of generative AI evaluation and open questions. We will then spend 10 minutes presenting the activity to the participants — the details of which are the following: in groups of 5 the participants will evaluate latent user needs that have been generated based on user reviews for the redesign of a product line. Similar to a Turing test, the participants will not know which has been generated by an AI model and which by a human. Alongside the latent user need statement, the participants will also receive an analysis of user behavior from the user reviews, i.e. "80% of users discussed comfort, 40% discussed running, etc.". The complexity of the latent need domain is that such needs are not readily verifiable, i.e. they need to be utilised in the redesign of the product and further

# W 12: Rethinking Collaboration: How AI is Changing Work and Team Dynamics in Design Organizations

***Session Chair: Yakira Imaris Mirabito, MIT, United States of America***

**Time: Tuesday, 12/Aug/2025: 12:00pm - 1:00pm Location: ECSW 2.325**

# W 13: Teaching Design Best Practices

***Session Chair: David Ullman, oregon state university, United States of America***

**Time: Tuesday, 12/Aug/2025: 12:00pm - 1:00pm Location: ECSW 3.210**

# W 15: Editorial Board Meeting for Design Science Journal (by invite)

**Time: Tuesday, 12/Aug/2025: 12:00pm - 1:00pm Location: ECSW 4.325**

25th International Conference on Engineering Design

Dallas, Texas, 11 - 14 August 2025

## Tuesday, 12/August/2025

# Marketplace

## Chair: Noe Vargas Hernandez, UTRGV, United States of America

## Location: ECSW Atrium (ground floor)

Time: Tuesday, 12/Aug/2025: 12:00am - 1:00pm

***Muthaiah, Ponaravind; Zagorski, Scott; Kress, Austin; Bartholomew, Meredith; Helber, Nick; Andreatta, Dale; Heydinger, Gary***
***Organisation(s): S-E-A Vehicle Dynamics Division***

Topics: Design for E–mobility, Evaluation methods, Product innovation engineering, Platform design, modularization, product family design, Systems Engineering, Complex Systems Design, Engineering of Robotics and Mechatronic Systems

***Barbazi, Neda (1); Shin, Ji Youn (1); Hiremath, Gurumurthy (1); El-Bokl, Amr (2); Lauff, Carlye Anne (1)***
***1: The University of Minnesota, Twin Cities; 2: The University of Texas at Austin***

Topics: Design for patient-centred care, Design driven innovations in healthcare, User-centred design in healthcare, Product development models and strategies, Design tools and -techniques for service design, Teamwork in design, Collaborative and participatory design, Design communication, Representation of design information, Creative design processes

***Günther, Florian Joseph; Schlegel, Alexander Patrick; Koch, Alexander***
***Universität der Bundeswehr München***

Topics: Requirement management, user orientation, user integration, Product development models and strategies, Agile design and manufacturing practices, Additive Manufacturing, 3D/4D Printing, Teamwork in design, Collaborative and participatory design, Design communication, Representation of design information, Decision Making

***Eynard, Benoît (1); Guérineau, Julia (2)***
***1: Université de technologie de Compiègne, France;***
***2: École de technologie supérieure, Montréal, Canada***

Topics: Data collection and knowledge management for big data, Design information and knowledge, Engineering ontologies, Organisational understanding of product development

## Location: ECSW Atrium (ground floor)

Time: Tuesday, 12/Aug/2025: 12:00am - 1:00pm

***Ko, Jaechang (1); Lee, Donghyuk (2)***
***1: Texas A&M University; 2: Seoul National University***
Topics: Machine learning, Semantic data processing, Modelling and simulation methods, Industry 4.0, Decision Making

***IQ Design***
***University of Texas- Dallas***
Topics: Design for mental health and wellbeing, Artificial Intelligence and Awareness, Researching of designs and design methods, Awareness of societal consequences, Designers' thinking and skills, Design for emotion and experience, Creative design processes

***Uhari-Pakkalin, Maria Pauliina***
***Aalto University***
Topics: Design of organizational processes, Design of workspaces to manage product development, Product development models and strategies, Design process modelling and management, Innovation strategies and innovation management, Training in design (academic and industrial), Collaborative and participatory design, Creative design processes, Supporting design creativity

***Pradas Gomez, Alejandro***
***Chalmers University of Technology***
Topics: AI and the data driven economy, Artificial Intelligence and Awareness, Design tactics and methods, Design for Interfaces, Human-Machine Interfaces, Systems Engineering, Complex Systems Design, Design for Autonomous Agents

## Location: ECSW Atrium (ground floor)

Time: Tuesday, 12/Aug/2025: 12:00am - 1:00pm

***Renter, William J.; Egan, Paul F.***
***Texas Tech University***
Topics: Additive Manufacturing, 3D/4D Printing

***Johnson, Julie; Hurst, Ada***
***University of Waterloo***
Topics: Design theories and approaches, Teamwork in design, Representation of design information

***Flus, Meagan; Olechowski, Alison***
***University of Toronto***
Topics: Collaborative and participatory design, Assessing creativity

***Tull, Jeremy; Pour, Bahar N.; Campbell, Jenn***
***University of Arkansas***
Topics: Teamwork in design, Collaborative and participatory design, Decision Making

***Taylor, Megan Claire; Campbell, Jenn Michel***
***University of Arkansas***
Topics: Awareness of societal consequences, Designers' thinking and skills, Decision Making

## Location: ECSW Atrium (ground floor)

Time: Tuesday, 12/Aug/2025: 12:00am - 1:00pm

***Habib, A K M Ahasun; Egan, Paul F***
***Department of Mechanical Engineering, Texas Tech University, USA***

Topics: Design of medical devices, Design driven innovations in healthcare, User-centred design in healthcare, Product innovation engineering, Additive Manufacturing, 3D/4D Printing

***Alrizqi, Mohammed***
***Cornell University***

Topics: Evaluation methods, Modelling and simulation methods, Researching of designs and design methods, Design process modelling and management, System of Systems Design, Product architectures, structural complexity, Design for Interfaces, Human-Machine Interfaces, Design theories and approaches, Theory-driven design, Systems Engineering, Complex Systems Design, Designers' thinking and skills, Decision Making

***Sha, Zhenghui; Clay, John***
***The University of Texas at Austin***

Topics: Design theories and approaches, Education experiences, plans, and visions, Designers' thinking and skills

***McKay, Alison (1); Batres Prieto (2), Rafael; Trowsdale (1), Dan;***
***Huerta Cardoso, Omar (1); Chau, Hau Hing (1); Espinoza García, Juan Carlos (2)***
***1: University of Leeds, UK; 2: Tecnológico de Monterrey, Mexico***

Topics: Design for the environment, Design for cleaner production, Environmental and sustainability assessment

## Location: ECSW Atrium (ground floor)

Time: Tuesday, 12/Aug/2025: 12:00am - 1:00pm

***McKay, Alison (1); Ahmed-Kristensen, Saeema (2); Maier, Anja (3)***
***1: University of Leeds; 2: University of Exeter; 3: University of Strathclyde***
Topics: Design for patient-centred care, Design driven innovations in healthcare, User-centred design in healthcare

***Wettergreen, Matthew***
***Rice University***
Topics: Design tactics and methods, Researching of designs and design methods, Product development models and strategies, Design theories and approaches, Teaching examples and experiments

***Schauer, Anastasia***
***The University of Texas at Austin***
Topics: Representation of design information

25th International Conference on Engineering Design

Dallas, Texas, 11 - 14 August 2025

## Wednesday, 13/August/2025

# Programs & Abstracts

## Date: Wednesday, 13/Aug/2025

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8:30am - 9:00am | **WR 03: Welcome & Registration** | | | | | | | |
| 9:00am - 10:00am | **P 04-1: Designing for a Circular Economy 2**<br>Location: ECSS 2.412<br>Chair: **Gordon Krauss**, Harvey Mudd College, United States of America | **P 04-2: HBiD Eye Tracking Studies**<br>Location: ECSS 2.410<br>Chair: **Ingo Jonuschies**, University of Rostock, Germany | **P 04-3: Decision Making and Information Management**<br>Location: ECSS 2.312<br>Chair: **Alexander Koch**, University of the Bundeswehr Munich, Germany | **P 04-4: Systems Engineering 1**<br>Location: ECSS 2.311<br>Chair: **Benoit Eynard**, Université de Technologie de Compiègne, France | **P 04-5: Additive Manufacturing Research 1**<br>Location: ECSS 2.306<br>Chair: **Arlindo Silva**, Singapore University of Technology and Design, Singapore | **P 04-6: Prototyping and Prototypes**<br>Location: ECSS 2.305<br>Chair: **Roland Lachmayer**, Leibniz Universität Hannover, Germany | **P 04-7: Design Management and Processes**<br>Location: ECSS 2.203<br>Chair: **Dietmar Göhlich**, Technische Universität Berlin, Germany | **P 04-8: Design Modelling & Communication**<br>Location: ECSS 2.201<br>Chair: **Amaresh Chakrabarti**, Indian Institute of Science, India |
| 10:00am - 10:30am | **CB 03-1: Coffee Break** | | | | | | | |
| 10:30am - 11:30am | **P 05-1: Resiliance and Sustainability in Design**<br>Location: ECSS 2.412<br>Chair: **Gaetano Cascini**, Politecnico di Milano, Italy | **P 05-2: Design Studies**<br>Location: ECSS 2.410<br>Chair: **Ramana Pidaparti**, University of Georgia, United States of America | **P 05-3: Design Theory and Methodology 1**<br>Location: ECSS 2.312<br>Chair: **Pascal Le Masson**, MINES ParisTech-PSL, France | **P 05-4: Requirements and Data Mangement 1**<br>Location: ECSS 2.311<br>Chair: **Alexander R. Murphy**, Florida Polytechnic University, United States of America | **P 05-5: Additive Manufacturing Research 2**<br>Location: ECSS 2.306<br>Chair: **Paul Egan**, Texas Tech University, United States of America | **P 05-6: Data Driven Design and Automation**<br>Location: ECSS 2.305<br>Chair: **Stanko Škec**, University of Zagreb, Croatia | **P 05-7: Virtual Reality and Design Representations**<br>Chair: **Stefan Zorn**, University of Rostock, Germany | **P 05-8: Collaborative Design 1**<br>Location: ECSS 2.201<br>Chair: **Oredola Adebayo**, The University of Texas at Dallas, United States of America |
| 11:30am - 1:45pm | **LB 03: Lunch Break**<br>Location: ECSS 2.203 | | | | | | | |
| 12:00pm - 1:30pm | **W 16: Designing for Care: Exploring Behavioral and Ethical Strategies for Pharmaceutical Return Systems**<br>Location: ECSW 1.355 | **W 17: Defining and Exploring A New Research Field in Design: Extreme Design**<br>Location: ECSW 1.365<br>Chair: **Tucker Marion**, Northeastern University, United States of America | **W 18: Agile design for hardware**<br>Location: ECSW 2.325<br>Chair: **David Ullman**, oregon state university, United States of America | **W 19: Mind the Gap: Accelerated approaches to perspective sketching: A guiding hand.**<br>Location: ECSW 3.250<br>Chair: **Paul Richard Kennea**, the Nottingham Trent University, United Kingdom | **W 20: Collaboration and Constraints: A role-playing game of Systems Design (SIG: Collaborative Design)**<br>Location: ECSW 4.325<br>Chair: **Klemens Hohnbaum**, Technical University of Munich, Germany | | | |
| 1:45pm - 2:45pm | **P 06-1: Challenges in Design Research 2**<br>Location: ECSS 2.412<br>Chair: **Saeema Ahmed-Kristensen**, University of Exeter, United Kingdom | **P 06-2: Challenges in Embodiment Design 1**<br>Location: ECSS 2.410<br>Chair: **Pavan P Kumar**, University of Texas at Dallas, United States of America | **P 06-3: Creative Problem Solving**<br>Location: ECSS 2.312<br>Chair: **Noe Vargas Hernandez**, UTRGV, United States of America | **P 06-4: Emotion in Design**<br>Location: ECSS 2.311<br>Chair: **Chris McTeague**, Technical University of Munich, Germany | **P 06-5: DfAM and Design Optimisation**<br>Location: ECSS 2.306<br>Chair: **Rahul Sharan Renu**, Austin College, United States of America | **P 06-6: Design Education 1**<br>Location: ECSS 2.305<br>Chair: **Frederike Kossack**, Ruhr-Universität Bochum, Germany | **P 06-7: Biomedical Engineering 1**<br>Location: ECSS 2.203<br>Chair: **Paul Egan**, Texas Tech University, United States of America | **P 06-8: Computer Aided Design**<br>Location: ECSS 2.201<br>Chair: **Kristin Paetzold**, TU Dresden, Germany |
| 2:45pm - 3:15pm | **CB 03-2: Coffee Break** | | | | | | | |
| 3:15pm - 4:15pm | **P 07-1: Design Theory and Methodology 2**<br>Location: ECSS 2.412<br>Chair: **Yoram Reich**, Tel Aviv University, Israel | **P 07-2: Challenges in Embodiment Design 2**<br>Location: ECSS 2.410<br>Chair: **David S. Nobes**, University of Alberta, Canada | **P 07-3: Sustainable Design and Circular Economy 1**<br>Location: ECSS 2.312<br>Chair: **Apoorv Naresh Bhatt**, Technical University of Clausthal, Germany | **P 07-4: Value Driven Design**<br>Location: ECSS 2.311<br>Chair: **Fatima-Zahra Abou Eddahab-Burke**, Delft University of Technology, Netherlands, The | **P 07-5: Design Creativity 1**<br>Location: ECSS 2.306<br>Chair: **Akane Matsumae**, Kyushu University, Japan | **P 07-6: User Studies 1**<br>Location: ECSS 2.305<br>Chair: **Yuan YIN**, Imperial College London, United Kingdom | **P 07-7: Sustainable Design 2**<br>Location: ECSS 2.203<br>Chair: **Ola Isaksson**, Chalmers University of Technology, Sweden | **P 07-8: Data Driven Design 1**<br>Location: ECSS 2.201<br>Chair: **Mario Storga**, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia |
| 4:30pm - 5:45pm | **GA: General Assembly**<br>Chair: **Gaetano Cascini**, Politecnico di Milano, Italy | | | | | | | |
| 7:00pm - 10:00pm | **GD: Gala Dinner** | | | | | | | |

# W 16: Designing for Care: Exploring Behavioral and Ethical Strategies for Pharmaceutical Return Systems

### *Session Chair: Yoon Jung CHOI*

**Time: Wednesday, 13/Aug/2025: 12:00pm - 1:30pm Location: ECSW 1.355**

The growing environmental and public health risks posed by improperly disposed pharmaceutical products present an urgent but often overlooked challenge for sustainable systems design. Despite the existence of pharmaceutical take-back programs in many countries, public participation remains low due to limited awareness, convenience barriers, and lack of caring motivation. This workshop is motivated by the need to explore how engineering and product-service system designers can better support caring behaviors through ethically grounded, behaviorally informed design strategies. While behavior change is widely acknowledged as a key component of sustainable design, few frameworks explicitly address the role of care ethics and relational responsibility in shaping sustainable user practices. By integrating the COM-B model (a robust framework for behavior change), Tronto's Five Phases of Care (from political and feminist care theory), and Design for Sustainable Behavior (DfSB), this workshop introduces a multidimensional approach to designing for behavior change—one that considers capability, opportunity, motivation, and the ethics of care as intertwined elements of responsible design. The activity will engage participants in understanding why people do or do not return expired medicine, and guide them through ideating design strategies that cultivate care—for the environment, for others, and for future systems. This aligns with ICED's commitment to exploring the social, systemic, and ethical implications of engineering design and contributes to the growing conversation around designing for sustainability, responsibility, and human well-being.
Organizer: Yoon Jung CHOI (yjchoi@vt.edu)

# W 17: Defining and Exploring A New Research Field in Design: Extreme Design

### *Session Chair: Tucker MARION and Maria YANG*

**Time: Wednesday, 13/Aug/2025: 12:00pm - 1:30pm Location: ECSW 1.365**

Audience: Industry, Faculty, Students
Extreme Design (XD)—which focuses on addressing issues that lie multiple standard deviations beyond the mean. XD emphasizes the development of innovative, interdisciplinary approaches that can generate exceptional solutions for highly complex, urgent issues. By pushing the boundaries of conventional design, XD seeks to create methodologies and tools capable of tackling the extremes in physical environments, user needs, and societal constraints.
Organizers: Tucker MARION (t.marion@northeastern.edu) and Maria YANG

# W 18: Agile design for hardware

***Session Chair: David Ullman, Oregon State university, United States of America***

**Time: Wednesday, 13/Aug/2025: 12:00pm - 1:30pm Location: ECSW 2.325**

Audience: Industry, Students, Faculty
Agile is a widely used design process for software. It is more challenging for hardware. Here we explore why and what to do about building software/hardware design process compatibility. This workshop is based on consulting and training provided to industry. We will cover the keys to employing agile for hardware design.
Organizer: Dave ULLMAN (ullman@davidullman.com)

# W 19: Mind the Gap: Accelerated approaches to perspective sketching: A guiding hand

***Session Chair: Paul Richard Kennea, the Nottingham Trent University, United Kingdom***

**Time: Wednesday, 13/Aug/2025: 12:00pm - 1:30pm Location: ECSW 3.250**

Audience: Students, Industry, Faculty
The declining proficiency in design sketching prior to university in the UK has been a growing concern for well over a decade. Meanwhile, both domestic and international students in ever increasing numbers arrive with very diverse backgrounds, skill levels, and educational needs. The challenge is to ensure engagement for all, while accelerating cognitive, spatial, and vocational skillsets. For us, the primary goal is for students to reach a level of competency within their first year of study that fosters confidence, strengthens engagement through demonstrable gains, and provides a framework for further improvement that aligns with industry expectations.
Organizer: Paul KENNEA (paul.kennea@ntu.ac.uk)

# W 20: Collaboration and Constraints: A role-playing game of Systems Design (SIG: Collaborative Design)

***Session Chair: Klemens Hohnbaum, Technical University of Munich, Germany***

**Time: Wednesday, 13/Aug/2025: 12:00pm - 1:30pm Location: ECSW 4.325**

Audience: Faculty, Students, Industry

The workshop allows participants to experience the communication challenges inherent in Systems Design. Even a simple design problem may seem unsolvable if the necessary information is distributed among a team and not fully available to each member. Therefore, the interactive role-playing game lets participants take the role of collaborative engineers within a sociotechnical system working towards a common goal: designing a (significantly simplified) lightweight vehicle. To achieve this, participants will work in small teams under realistic constraints, including limited communication via text-based platforms such as chat or mail, to simulate the restricted communication habits often found in corporate settings. Teams will face time pressures, conflicting goals, and incomplete information, reflecting the complexity of real-world engineering collaboration. The controlled environment enables participants to explore and evaluate communication strategies, focusing on how requirement formulation and structured interaction influence team dynamics and outcomes: in the point-based mode, target values are specified. In contrast, the interval-based mode provides design freedom to reconcile conflicts of goals. The session concludes with team and plenary discussions to compare results, identify lessons learned, and reflect on the experienced collaboration.

Organizer: Klemens HOHNBAUM (klemens.hohnbaum@tum.de)

# P 04-1: Designing for a Circular Economy 2

## Session Chair: Gordon Krauss, Harvey Mudd College, United States of America

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Sustainable design approaches for thermoplastics in additive manufacturing

***Andrew Evans, William Renter, Paul F Egan***
***Texas Tech University, USA***

Additive manufacturing is enabling on-demand fabrication of desirable polymer designs. Due to the technology's widespread use, there is a need to ensure sustainable design approaches are practiced. Here, thermoplastics for fused deposition modeling is reviewed for life-cycle stages, mechanical properties, and design strategies. Life-cycle stages assessed include formulation, processing, applications, and end-of-life as well as recycling processes. Mechanical properties are considered for recyclable thermoplastics, with fillers to enhance functionality. Finally, design methods are considered to create mechanically efficient designs, such as metamaterials, that reduce material usage and processing time. The review highlights the great potential for creating sustainable designs with additively manufactured polymers, and their mechanical capabilities for broad applications.

### Consumer electronic redesign for automated disassembly using general-purpose robots

***Mahmoud Akkawi[1], Filippo Talami[2], Maximiliano Romero[3], Valerio Modugno[4], Pingfei Jiang[5], Claudio Gaz[1]***
***1 Department of Mechanical Engineering, Kingston University London, UK;***
***2 Fraunhofer Portugal AICOS, HCD Team, Porto, Portugal; 3 Department of Design, Politecnico di Milano, Italy;***
***4 Department of Computer Science, UCL, UK;***
***5 Department of Innovation, Technology and Entrepreneurship, University of Exeter, UK***

The rapid increase in Waste Electrical and Electronic Equipment (WEEE) presents significant environmental challenges, requiring the development of efficient and effective disassembly and recycling strategies. Although extensive theoretical research has explored product redesign to facilitate automated disassembly, practical validations of such approaches remain limited. This study examines the technical feasibility of applying design-for-disassembly principles to enable automated dismantling processes using general-purpose robotic systems. Using a consumer electronic remote control as a case study, this paper demonstrates how targeted product redesign can improve compatibility with robotic systems during disassembly. The findings provide valuable insights into sustainable product design and end-of-life management, with implications for supporting a circular economy.

# P 04-1: Designing for a Circular Economy 2

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Design for circularity: Applications and implications for a factory in space

***Farouk Abdulhamid, Brendan P. Sullivan, Sergio Terzi***
***Politecnico Di Milano; Italy***

Increased interest in space exploration demands a shift in the design and manufacturing of space systems. Traditionally, space structures are limited by constraints associated with launch systems that affect cost, volume, and mass. The concept of Factory in Space (FIS) proposes the fabrication of systems in space to circumvent the launch constraints. FIS offers a transition to a circular economy in space by minimizing resource consumption and creating a self-sustaining factory ecosystem. This paper evaluates the role of circular design in FIS. Circular design in FIS leads to a reduction in design complexity and modular designs that could enhance space exploration. Material selection, modular design, design for robustness, and lifecycle thinking are highlighted as factors that influence design for circularity in FIS. Finally, the challenges associated with circularity in FIS are presented

### Robust design as a team sport — Mastering upcoming challenges in modern product development

***Stefan Goetz[1], Felician Campean[2], Tobias Eifler[3], Stephan Husung[4], Martin Roth[5], Benjamin Schleich[6], Rikard Söderberg[5], Kristina Wärmefjord[5]***
***1 Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany; 2 University of Bradford, United Kingdom; 3 Technical University Denmark, Denmark; 4 Technische Universität Ilmenau, Germany; 5 Chalmers University of Technology, Sweden; 6 Technische Universität Darmstadt, Germany***

Robust Design is essential for developing high-quality products by minimizing their sensitivity to variation and uncertainties from diverse sources. Despite the wide range of approaches from industry and research, it faces challenges due to their siloed usage. Motivated to gain a better understanding of these challenges and to derive implications for how to overcome them, this paper discusses different viewpoints on Robust Design, taking into account different life cycle phases, domains, and system levels. This highlights the challenges of enhanced product complexity and shifting focuses, for instance, when it comes to cyber-physical systems or sustainable design, and the need for collaboration. Accordingly, the vision of a collaborative approach to Robust Design in a team is presented, in which the actors' strengths are combined to further increase efficiency and significance.

# P 04-2: HBiD Eye Tracking Studies

## Session Chair: Ingo Jonuschies, University of Rostock, Germany

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Looking around: Comparing saccades and fixations among designers with and without ADHD

***Rachel Kimball[1], Rohan Prabhu[2]***
***1 Neuroscience Program, Lafayette College, USA;***
***2 Department of Mechanical Engineering, Lafayette College, USA***

Engineering design tasks are cognitively complex and there is a growing interest in understanding the neurocognitive processes involved in design. Consequently, researchers are increasingly using bio-physical markers such as eye tracking to study design neurocognition. However, these studies are largely correlational, and little is understood about the construct validity of eye-tracking metrics such as fixation durations and saccade frequency. Moreover, these studies rarely account for non-design factors such as neurodivergence (e.g., ADHD) on eye-tracking metrics during design. We aim to examine this research gap through a causal-comparative study with designers with and without ADHD, performing divergent and convergent design tasks. Our findings call for a deeper investigation into the construct validity of eye-tracking metrics while considering a broad range of external factors.

### ★ Can I catch up later? Design of personalized intervention for online learning using eye-tracking-based video reconstruction and replay

***Chunzhi Li, Ting Liao***
***Stevens Institute of Technology***

While online learning allows learners to access materials flexibly and at their own pace, many struggle to self-regulate without supervision. Real-time interventions like pop-out quizzes, screen flashes, and text warnings aim to improve attention focus but risk distracting learners and segmenting the learning process. Despite eye-tracking technology being widely used for real-time intervention design, its potential for delayed and personalized interventions remains underexplored. To address this gap, we proposed and tested an eye-tracking-based video reconstruction and replay (EVRR) method, offering targeted review at the end of online classes without disrupting the learning process. EVRR shows significant positive effects on improving learning outcomes compared to self-paced reviews, especially for learners who are unfamiliar with the concepts.

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### ★ Bridging the gap in engineering creativity evaluations: Exploring novice eye-gaze behavior across design modalities

***Duk Hee Ka[1], Sanaz Motamedi[1], Faez Ahmed[2], Farnaz Tehranchi[1], Scarlett Miller[1]***
***1 The Pennsylvania State University; 2 Massachusetts Institute of Technology***

The Consensual Assessment Technique (CAT) is one of the most effective and commonly used design evaluation methods. However, it fails to capture implicit cognitive processes and has mainly been studied in a homogenous design modality. To bridge this gap, the present study investigates the impact of design ideas represented in different modalities (i.e., text-only, sketch-only, text + sketch) on design evaluations for creativity, novelty, and usefulness, and examine human gaze patterns during the evaluation process. Our findings showed that novice raters exhibit higher interrater reliability and greater convergence in visual attention when rating ideas containing sketches compared to text-only design modality, highlighting the value of visual elements in design evaluations.

### Dynamic eye-tracking on large screens: A 3D printed adjustable guide rail platform

***Shivam Acharya, Lingyun He, Farnaz Tehranchi***
***Pennsylvania State University***

This paper provides a design solution to the existing problem of using eye trackers for large screens. Traditional eye trackers are limited to commercial and smaller-sized screens. However, as larger screens become increasingly popular and essential for various tasks, their impact needs further investigation in user performance and behavioral studies. This work introduces a design approach for adjustable guide rail system to make moving an eye tracker along with the user's head position possible. The testing results showcase robust, accurate and functions under varying real-world conditions, making it ideal for Human-Computer Interaction and User Experience Research. The Guide Rail design employed by this system is easy to manufacture and incorporates 3D printed parts making it easily reproducible and open for customization.

# P 04-3: Decision Making and Information Management

## Session Chair: Alexander Koch, University of the Bundeswehr Munich, Germany

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Towards improving the information management of aircraft cabin retrofits by processing quantity-on-hand documents

***Fabian Niklas Laukotka, Markus Christian Berschik, Dieter Krause***
***Hamburg University of Technology (TUHH), Germany***

Retrofitting aircraft cabins is characterized by a large number of documents created and required, most of which are currently processed manually. Engineers need to identify which documents include the information that is required for a specific task. This paper proposes an approach that builds upon a digital knowledge base and moves towards automatically processing the quantity-on-hand documents to reduce the work required to identify the required documents without the labour-intensive creation of the knowledge base in beforehand. After describing the scenario this work faces, comparable approaches and promising techniques are discussed. A process-chain that builds upon these fundamentals is presented, including a selection of feasible techniques and algorithms. Finally, the steps towards an implementation as part of the transformation towards a data-driven value chain are presented.

### Exploring decision-making in manufacturing process selection: an interview study

***Christoph Wittig, Jonas Hemmerich, Sven Matthiesen***
***IPEK - Karlsruhe Institute of Technology (KIT), Germany***

The manufacturing process selection (MPS) greatly influences possible design decisions regarding the product's embodiment. However, a gap remains in understanding how design engineers make these selections and what data and resources inform them. Through semi-structured interviews with engineers across various mechanical engineering industries insights into current decision-making processes are gained. The findings reveal that MPS is mostly guided by personal and collective experience, with influencing factors such as functionality and product quantities. The use of support tools remains limited. A systematic integration of data-driven tools and structured knowledge management is mostly absent. It's concluded that reliance on experiential knowledge risks overlooking alternative processes and integrating systematic tools with existing experience-based practices could enhance MPS.

# P 04-3: Decision Making and Information Management

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Effective System-of-Systems simulation in a VUCA world: lessons learned for design decision-makers

***Carl Nils Konrad Toller Melén, Marco Bertoni, Christian Johansson Askling***
***Blekinge Institute of Technology, Sweden***

Today, Manufacturing companies are adopting a servitization strategy and Product-Service System model to enhance value and remain competitive. Often, this transition also means to embrace a System-of-Systems (SoS) perspective. Concurrently, companies face challenges with volatile, uncertain, complex, and ambiguous (VUCA) environments. One way to tackle VUCA is to utilize simulation modeling. However, developing SoS simulations can be complex and cumbersome. This paper extracts lessons learned from six case studies to identify effective and ineffective practices in developing simulation models. The analysis has led to nine design principles for more effective simulation modeling. Furthermore, the paper explores simulation techniques for modeling SoS and discusses effective VUCA management. Finally, the paper proposes four future research directions to advance SoS simulation research.

### Designing a compatibility evaluation framework for integration of 3PL warehouse clients in warehouse systems: An action design research study in a danish 3PL company

***Frederik Holm Nielsen, Anton Seistrup Hermann, Niels Henrik Mortensen***
***Technical University of Denmark (DTU), Denmark***

This study explores the design of a compatibility evaluation framework for integrating 3PL warehouse clients into semi-automated warehouse setups. Using Action Design Research (ADR), an artifact was developed that combines data-driven decision-making (DDD) and multi-criteria decision analysis. The framework, implemented in Microsoft Power BI, enables the evaluation of client compatibility based on configurable criteria and relevant metrics. It was co-created with stakeholders and tested using data from 33 warehouse clients, demonstrating its practical value in identifying operational fit while facilitating data-driven discussions. The study highlights the potential of structured decision frameworks in environments with limited data, offering generalizable insights for 3PL warehouses and similar contexts.

# P 04-4: Systems Engineering 1

## Session Chair: Benoit Eynard, Université de Technologie de Compiègne, France

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Framework for circular AI-driven model-based systems engineering

***Damun Mollahassani[1], Martin Becker[1], Thomas Eickhoff[1], Jessica Pickel[2], Stefan Goetz[2], Sandro Wartzack[2], Jens C. Göbel[1]***

***1 RPTU Kaiserlautern, Germany; 2 Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

The development of interdisciplinary Smart Products involves complex architectures and processes, which results in new challenges like managing heterogeneous and unstructured data causing inefficiencies. Model-Based Systems Engineering (MBSE) addresses these issues through precise system modeling but encounters obstacles like a lack of model reuse and complexity. This paper introduces a novel framework integrating Artificial Intelligence into MBSE to enhance sustainability and circularity by automating model generation and reusing existing system models. Using ontology-based knowledge management and large language models, model creation, interoperability, and decision-making can be enhanced and automated and visualized in real-time. The framework's capabilities and benefits are demonstrated through the instantiation of a wireless charger system example.

### Modeling variability in product line engineering (PLE) for systems engineering (SE)

***José Lameh[1,2], Alexandra Dubray[2], Marija Jankovic[1]***

***1 Université Paris Saclay - CentraleSupélec, Laboratoire Genie Industriel, Gif-sur-Yvette, France;***

***2 Renault Group - Ampère, Technocentre, 1 Av. du Golf 78288 Guyancourt, France***

Product Line Engineering (PLE) and Systems Engineering (SE) are critical for developing complex systems, yet current methodologies inadequately address the integration of variability across multiple layers of system design. This study introduces an integrated variability modeling framework based on FODA and aligned with ARCADIA's MBSE method, addressing operational, functional, and constructional viewpoints. Validation using Renault's Advanced Driver-Assistance Systems (ADAS) showcased reduced design time and enhanced configuration adaptability. Key challenges, such as aligning feature models and managing dependencies, were addressed through a modular, layered strategy. The proposed approach ensures flexibility, scalability, and system integrity, offering a robust framework for diverse domains.

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### A community-driven database for the dynamic representation of approaches, processes, methods, and tools for multidisciplinary product development

***Muhammad Bilal[1,2], Benoît Eynard[3], Julia Guérineau[1]***
***1École de technologie supérieure, Canada; 2 National University of Sciences and Technology, Pakistan; 3 Université de technologie de Compiègne, France***

The advent of multidisciplinary product development may require a corresponding evolution or adaptation of product development practices within companies. To support this, researchers have developed various groupings of concepts and techniques, such as "toolboxes" or "maps", which can be assimilated to static databases. Consequently, this article presents a first step towards a community-driven database for the dynamic representation of links between approaches, processes, methods and tools in research documents. Following a comparative analysis of different representations, a preliminary design of a dynamic database is presented using Unified Modeling Language models to define its architecture. A use case diagram paired with screenshots of the dynamic database presents the core functionalities, which include real-time data filtering, visualisation, navigation and modification.

### Design of a framework for categorizing and describing use cases for data-driven model-based systems engineering

***Denis Tissen, Benjamin Tiggemann, Ruslan Bernijazov, Roman Dumitrescu***
***University of Paderborn, Germany***

The integration of Model-Based Systems Engineering (MBSE) and data analytics (DA) has introduced a novel approach, Data-Driven Model-Based Systems Engineering (DDMBSE), which combines structured system modelling with data-driven insights. DDMBSE offers the potential for improvements in model optimisation, economic efficiency and the implementation of dynamic system updates based on real-time data. However, the diverse applications of DDMBSE lack a structured overview of its use cases. This paper addresses this gap by proposing a comprehensive framework for the categorisation and description of DDMBSE use cases. It provides users with a structure to navigate within DDMBSE landscape, consolidate knowledge, and identify underexplored areas for future research. This contribution establishes a foundation for advancing the implementation of DDMBSE across industries and fostering its adoption.

# P 04-5: Additive Manufacturing Research 1

## Session Chair: Arlindo Silva, Singapore University of Technology and Design, Singapore

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Current challenges in the development of products for additive manufacturing - an interview study

***Florian Joseph Günther[1], Gregory-Jamie Tüzün[2], Matthias Kreimeyer[2], Alexander Koch[1]***
***1 University of the Bundeswehr Munich, Germany; 2 University of Stuttgart, Germany***

The industrial application of additive manufacturing (AM) necessitates close collaboration between design and manufacturing. However, significant challenges persist throughout the product development process. To explore these challenges, we conducted interviews with 11 engineers from different companies utilizing AM technologies. These interviews revealed recurring themes, such as a lack of AM-specific mindset and uninformed decision-making, which pose challenges across different phases of product development. The identified challenges, along with proposed solutions and practices, were mapped to specific product development phases, providing a scope for development frameworks for AM. Our study indicates that while some challenges are phase-specific, others impact the entire product development process. Operational solutions for different development phases are still missing.

### ★ Design of internal structures to enhance the thermal performance of additively manufactured heat exchangers

***Ina Meyer[1], Robin Kahlfeld[2], Cameron Owen Messmann[1], Marcus Oel[1], Timo Stauss[1], Stephan Kabelac[2], Roland Lachmayer[1]***
***1 Leibniz University Hannover, Institute of Product Development;***
***2 Leibniz University Hannover, Institute of Thermodynamics***

Bio-inspired designs offer innovative solutions for optimizing heat exchangers, though their complexity often exceeds the capabilities of traditional manufacturing methods. Additive manufacturing (AM) enables intricate geometries with enhanced surface areas for improved heat transfer. This study presents a modular algorithm to integrate internal structures into heat exchanger designs, balancing thermal performance and manufacturability. A case study demonstrates the design, simulation, and production of internal structures, identifying the "Diamond Radial" structure as the optimal choice due to its high R-factor and potential to improve efficiency. Future work includes exploring multi-material components and designs for hydrogen storage and fuel cell applications, paving the way for more efficient, application-specific systems.

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### I cast the drains down in africa: AM-augmented casting as an enabler for the african manufacturing industry

***Mariam Sulleiman[1], Ramin Ahmed[2], Michael Kay[2], Guhaprasanna Manogharan[3], Christopher McComb[1]***
***1 Carnegie Mellon University; 2 North Carolina State University; 3 The Pennsylvania State University***

Africa's manufacturing sector is pivotal for economic growth and technological advancement. However, challenges such as inadequate infrastructure, supply chain disruptions, geopolitical tensions, and high costs hinder its development. These issues impede domestic production and reduce global competitiveness. Addressing them is essential for economic resilience. While beneficial, traditional strategies often overlook fundamental production constraints, especially in manufacturing sectors reliant on repair, maintenance, specialized components, and tooling. Manufacturing methods like casting face limitations in flexibility, cost, precision, and lead times.This research proposes using additive manufacturing (AM)-assisted casting to address these challenges. We identify agriculture and automotive as sectors with high potential to implement AM-assisted casting.

### Exploring the role of aesthetic interaction in controlling music playback and user experience

***Chajoong Kim, Jayoung Yoon***
***Ulsan National Institute of Science and Technology, South Korea***

We explore the role of aesthetic interaction in controlling music playback control and its influence on user experience. Three music playback control designs of different aesthetic interactions were developed and prototyped. An experiment was conducted to measure how their experiences varied regarding aesthetic interaction. Participant responses were then gathered through PrEmo that measured the influence on emotions and user experience, Results indicate how each aesthetic interaction evoked particular emotions and experiences. The aesthetic interaction of music playback control was shown to influence the participants' appraisal of their music-listening experiences significantly. Findings contribute to a better understanding of how aesthetic interaction in the music listening experience implicates the user's affective response.

# P 04-6: Prototyping and Prototypes

## Session Chair: Roland Lachmayer, Leibniz Universität Hannover, Germany

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Methodology for consideration of different load cases in the design of a sensor-integrating, gentelligent Antenna

***Alessio Galfione[1], Sören Meyer zu Westerhausen[2], Timo Stauß[2], Max Leo Wawer[2], Salvatore Amaduri[3], Giovanni Totaro[3], Marco Esposito[1], Roland Lachmayer[2], Marco Gherlone[1]***
***1 Politecnico di Torino, Italy; 2 Leibniz University Hannover, Germany;***
***3 CIRA Italian Aerospace Research Centre, Italia***

The industrial application of additive manufacturing (AM) necessitates close collaboration between design and manufacturing. However, significant challenges persist throughout the product development process. To explore these challenges, we conducted interviews with 11 engineers from different companies utilizing AM technologies. These interviews revealed recurring themes, such as a lack of AM-specific mindset and uninformed decision-making, which pose challenges across different phases of product development. The identified challenges, along with proposed solutions and practices, were mapped to specific product development phases, providing a scope for development frameworks for AM. Our study indicates that while some challenges are phase-specific, others impact the entire product development process. Operational solutions for different development phases are still missing.

### Affordance-based design strategies to support well-being: A case study of university transportation

***Olivia M. Wilburn[1], Milo Oswald[1], Robin Rucker II[2], Christopher S. Mabey[2], Grace Burleson[1]***
***1 University of Colorado Boulder; 2 Clemson University***

People rely on daily interactions with artifacts, greatly influencing their physical, mental, and social well-being. Despite this, current design practices often overlook well-being as a core consideration. Affordance theory, which explains how an artifact's features enable specific user actions and experiences, offers a promising lens for addressing this gap. This study focuses on assessing affordance mechanisms as a potential tool to support design practices to design for positive well-being outcomes. Using transportation modes as a case study, we interviewed college students to explore how specific mechanisms can contribute to positive or negative well-being outcomes. Findings resulted in 233 examples, which showed trends in mechanisms, modes, and well-being outcomes. Ultimately, this work presents an initial framework for embedding well-being considerations into design.

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Comparing physical and virtual reality product models for design education

***KayDee Pratt[1], Almudena Palacios-Ibáñez[2], Kristin Bartlett[1]***
***1 University of Kentucky; 2 Universitat Jaume I***

Virtual reality (VR) based product evaluation is a growing area of research, but has not yet been studied in the context of design education. In this study, participants evaluated four pairs of product design student models in physical and VR form using a custom VR application. The models included a variety of product types and a variety of prototyping materials. Participants rated the physical and VR models using a rubric adapted from a study of design student prototyping. Significant differences were found in VR versus physical ratings of some model evaluation categories, but only for certain products. The majority of participants preferred the physical model evaluation over the VR evaluation. Our findings suggest that VR product evaluation may be suitable for use in design education contexts, especially when budget or time for physical prototyping is limited.

### Interactive machine learning framework enabling affordable and accurate prototyping for supporting decision-making

***Qiyu Li, Daniel McAdams***
***Texas A&M University***

This study proposes an ML-based interactive framework for early-stage design, addressing the challenge where physical prototypes are accurate but costly, and virtual prototypes are affordable but less reliable. The NN-based human-in-the-loop framework integrates pre-training and fine-tuning techniques to reduce reliance on extensive physical prototyping while maintaining model accuracy. Using projectile motion as an example, the framework demonstrates its ability to guide design by iteratively updating models based on limited experimental data and human expertise. The results highlight the framework's effectiveness in achieving performance comparable to models trained on larger datasets, offering a cost-effective solution for creating accurate design models.

# P 04-7: Design Management and Processes

## Session Chair: Dietmar Göhlich, Technische Universität Berlin, Germany

## Location: ECSS 2.203

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Validating a process model for future-robust product portfolios - two cases

***Michael Schlegel, Christoph Kempf, Carsten Thümmel, Tobias Düser, Albert Albers***
***Karlsruhe Institute of Technology (KIT), Germany***

In this paper, two case studies are presented to validate a process model for the future robust advancement of product portfolios. In the first case study, the process model is implemented for a supplier in the automotive industry and evaluated by two company experts. In the second case study, the process model is implemented in a medical equipment company for 6 months. The evaluation shows that the investigated model can be applied and supports the process. The success evaluation is only assessed as expected added value, as the added value can only be observed when realizing the product portfolio. The evaluation in two case studies confirms the applicability and support potential of the model in corporate practice. At the same time, the need for improvement and multi-year implementation in the companies is identified.

### Agile performance measurement - An impact model to describe improvements in design processes

***Johannes Müller, Nicolas Laurin Mehwald, Sophie von Klitzing, Tobias Düser, Albert Albers***
***Karlsruhe Institute of Technology (KIT), Germany***

Companies in the development of cyber-physical systems are responding to the ever faster changing requirements of their own products by implementing agile methods. Until now, however, there has been a lack of ways to determine the true effects of agile transformation on their own processes to operate them in a targeted manner. This paper presents an impact model that defines factors that can be used to describe process changes and outlines the interdependencies between the individual factors and describes the influence of known agile methods. This allows the benefits of agile methods to be presented transparently and objectively.

## Location: ECSS 2.203

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Agile design process for additive manufacturing, an exploratory study

***Alessandro Pisanu[1], Kari Kleine[1], Anita Friis Sommer[2]***
***1 University of Southern Denmark, Denmark;***
***2 Novo Nordisk Foundation CO2 Research Center (CORC), Denmark***

This study explores the use of agile methods to support Additive Manufacturing (AM) in transitioning from R&D to production. Using a consumer goods company division as a case study, the research examines how agile methods facilitate flexibility, collaboration, and innovation despite challenges such as the materiality of products methods inconsistencies. Findings reveal how tailored agile practices designed for Additive Manufacturing enhance technology readiness and identify areas for improvement, including stakeholder engagement and role alignment. Recommendations are proposed to refine an Agile Design Process Model for Additive Manufacturing and improve technology maturation.

### Impact, benefits and challenges of agile development – an explorative study on physical products

***Lisa Siewert[1], Kilian Gericke[1], Nadja Siller[2], Jolissa Rusin[1], Dietmar Göhlich[2]***
***1 University of Rostock, Germany; 2 Technical University of Berlin, Germany***

Companies operate in dynamic global markets and face constant internal and external changes requiring adaptability. Agile methods have emerged as a key approach to enhancing resilience. For manufacturing companies, the question arises whether agile practices, originally developed for software, can be applied to physical product development. To investigate this topic, a cooperate study was conducted that includes 26 semi-structured interviews with representatives from various industry sectors. The findings indicate that agile methods are successfully applied to physical product development, especially in research and development. Benefits include improved communication and team dynamics. However, challenges such as resistance to change and misunderstandings about agility persist, which can often be mitigated through effective expectation management and tailored communication strategies.

# P 04-8: Design Modelling & Communication

## Session Chair: Amaresh Chakrabarti, Indian Institute of Science, India

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### The use of configurators to support warehouse service design: A case study of a logistics service provider

***Erika Marie Strøm[1], Lars Hvam[1], Anders Haug[2]***
***1 Technical University of Denmark, Denmark; 2 University of Southern Denmark, Denmark***

E-commerce's rapid growth has increased demand for logistics services, pressuring logistics service providers (LSPs) to offer more competitive solutions in a fragmented industry. This drives a shift from customized to standardized services, which also impacts business processes. While configuration systems are widely adopted in manufacturing companies to support the sales process of products, their application in LSPs remains unexplored. A case study explored their feasibility in warehouse services and found that these services could be modeled and incorporated in a sales configurator, saving time on customer communication, reducing errors during the sales process, and enhancing collaboration on warehouse service design. Thus, the study points to a new application area for configurators, which neither the industry nor academia has given much focus.

### A study on representation of services using the SAPPhIRE model of causality

***Kausik Bhattacharya, Amaresh Chakrabarti***
***Indian Institute of Science Bangalore, India***

With increasing servitization, manufacturers are transitioning from solely selling products to integrated products and services. While the SAPPhIRE model of causality effectively represents technical systems and aids in product design activities like analysis, synthesis, and assessing design novelty, few studies have explored its extension to services. Previous research extended SAPPhIRE constructs to capture causality in Service Systems. This research compares SAPPhIRE models for services with Object Process Methodology (OPM), a benchmark for systems modeling. Results show that SAPPhIRE not only captures details represented by OPM but also provides additional useful information for service representation. The causal description of products and services using SAPPhIRE helps understand and improve existing service systems, trace root causes of issues, and foster creative ideation for new designs.

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 9:00am - 10:00am

### Narrative experience design: Integrating narrative-driven approaches into service design

***Yasuyuki Hayama***
***Kyushu University***

The intersection of design and narrative plays a crucial role in shaping meaningful experiences. While narrative experience has been explored in product design, its role in service design remains underdeveloped. This study introduces a narrative-driven service design approach, integrating narrative to enhance user experiences. Using a Research through Design methodology, ten digital service prototypes were developed, embedding "stories of moments of joy" as a design foundation. Findings suggest that starting with narratives fosters deeper emotional engagement and enhances service interactions. Participant feedback highlights how this approach provides an alternative to traditional problem-solving models, emphasizing narrative-driven innovation in service design. By positioning narrative as a central design element, this study contributes to advancing service design methodologies.

### Development and evaluation of the documentation templates to support the design thinking process

***Apoorv Naresh Bhatt, Amaresh Chakrabarti***
***Indian Institute of Science***

This paper aims to assist learners in effectively documenting, transforming, and managing natural language-based information during the Design thinking (DT) process. Further, it seeks to aid evaluators in ensuring traceability and capturing design rationale when assessing the process and outcomes of DT. To achieve this, it presents templates that facilitate documentation and assessment. The effectiveness of these templates was evaluated through an empirical study involving 20 undergraduate students in a design thinking workshop. Analysis of documented templates, questionnaires, and interviews reveals the positive effects of templates on documentation and assessment activities and justifies using proposed documentation templates. The templates can be used as a support tool for process-based documentation as well as assessment activities during the early stages of the DT process.

# P 05-1: Resiliance and Sustainability in Design

## Session Chair: Gaetano Cascini, Politecnico di Milano, Italy

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Enhancing the process sustainability of metal additive manufacturing: a proposal of design framework applied to filament fusion fabrication with metal injection molding

***Ons Mrabet, Raoudha Gaha, Julie Marteau, Benoît Eynard***
***Université de Technologie de Compiègne, France***

The environmental impacts generated by manufacturing processes have become a concern, as underlined by regulation controls. Studies tend to focus on optimization of the processes through process parameter refinement to try to reduce energy consumption and raw material consumption. However, a thorough assessment of the building of a component linked to its use should be performed to help decision making. The focus of this paper is to define a methodology that helps the choice of the process parameters since the first design steps, by assessing this choice on the mechanical properties and thus the global environmental impact of the manufactured component. To do so, a case study is applied to a given additive manufacturing technology combining metal injection molding and fused filament fabrication. This combination is part of the additive manufacturing processes involving material extrusion.

### Balancing safety and sustainability: Quality assurance in re-sterilization of Single-Use Medical Devices

***Kaat Dhondt, Els Du Bois, Regan Watts***
***University of Antwerp, Belgium***

The healthcare sector is a large contributor to climate change, due to their size, resource use and extensive use of single-use devices (SUDs). Despite the European Medical Device Regulation (MDR) permitting the resetting of SUDs, healthcare professionals are hesitant and seek evidence-based guidelines. This demonstration study investigates how design engineering can contribute to the feasibility of resetting SUDs that are theoretically suitable for reuse, contributing to the broader discussion on medical device sustainability. The research focuses on the quality evalualtion of reset SUDs through a detailed protocol ensuring that reused devices meet safety and performance standards. Results reveal a discrepancy between the theoretical feasibility of resetting SUD and its actual practicability. This finding highlights the necessity for more practically oriented protocols.

# P 05-1: Resiliance and Sustainability in Design

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Resilience-by-Design: Standard-based definition of Resilience and identification of action fields for the systems design of mobility system

***Isaac Mpidi Bita1, Aschot Hovemann1, Roman Dumitrescu2***
***1 Fraunhofer Research Institute for Mechatronic Systems Design IEM, Germany;***
***2 Paderborn University (HNI), Germany***

The increasing complexity and connectivity of the mobility system and modern automotive systems, particularly connected autonomous vehicles, demand a paradigm shift toward resilience-by-design to address disruptions in dynamic environments. Unlike established safety and cybersecurity engineering in automotive, resilience engineering has yet to be systematically integrated into development processes. This paper defines resilience using a standard-based definition method, emphasizing disruption tolerance, adaptability, and recoverability. We identify action fields to advance the topic and propose a resilience-by-design framework extending safety and cybersecurity perspectives. Resilience-by-design offers strategies and methods to design robust, adaptive systems, ensuring reliability and availability of automotive systems, functions, and components in operation.

### Harnessing digital vs physical design for sustainable behavior strategies: A review

***Nicole Goridkov, Kosa Goucher-Lambert***
***UC Berkeley***

Digital products and applications are rapidly evolving, offering immense potential to drive social change and encourage sustainable behaviors. This raises a critical question: how can we effectively design these products to support and inspire sustainable practices? This paper presents a literature review of design for sustainable behavior (DfSB) strategies across various digital and physical product-service systems in engineering design and human-computer interaction. The review examines DfSB intervention trends over the last decade, highlighting the increasing diversity of technological interventions, and categorizes the design methods employed in these technologies. These categories identify opportunities where future DfSB interventions can be applied and illustrate how the unique affordances of digital vs physical technologies can be effectively used to support sustainable practices.

## Session Chair: Ramana Pidaparti, University of Georgia, United States of America

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Bio-inspired vision intelligence in the middle school curriculum: A capstone design project

***Ramana Pidaparti[1], Suren Jayasuriya[2]***
***1 University of Georgia, USA; 2 Arizona State University, USA***

In the undergraduate design education curriculum, there is a growing recognition of the transformative potential of including bio-inspired design thinking concepts. This paper describes a capstone design project for senior engineering students at UGA that involved integrating bio-inspired AI and vision in K-12 lesson modules. Through the capstone design project, one student team developed a product that integrated bio-inspired vision in a lesson module for K6-8 incorporating state Standards of Learn-ing.. The results of student work in terms of final design/product and project experiences are presented and discussed. Implications for engaging K-12 teachers/students through bio-inspired AI and vision design concepts, and inspiring them to pursue STEM careers are discussed.
Keywords: Captsone Design, Bio-inspired Intelligence, Middle School, Innovative Designs

### Map to safety: Longitudinal examination of psychological safety in engineering capstone students

***Aoran Peng[1], Winnie Fang[1], Jessica Menold[1], Roxanne Moore[2], Scarlett Miller[1]***
***1 Pennsylvania State University; 2 Georgia Institute of Technology***

Teams have been favored due to the diverse knowledge access. However, diversity can also have negative effects, and team outputs can be influenced by many factors, such as psychological safety. While the effects of psychological safety have been studied, its development has received less attention. Prior research in this area has focused either on specific populations or cross-sectional effects. To add to this area, this study examined the longitudinal development of psychological safety in engineering capstone students: how it evolves, and whether this can be influenced by team-related experiences. This study showed that although psychological safety did change meaningfully with time, neither time nor experience alone could capture the change. The results could shed light on the evolution of psychological safety, as well as what factors could potentially influence its development.

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Pre-registering a case study: Requirements and narrative alignment in teams

***Shanae Lekeisha Edwards[1], Joshua Summers[1], Lisa Retzlaff Deering[2], Scott Ferguson[2]***
***1 The University of Texas at Dallas; 2 North Carolina State University***

This paper serves as a template for, and argument to, the engineering design research community to pre-register research studies. Pre-registering allows for a research plan to be validated and results published, no matter the findings. To support pre-registering, we propose a case study to study how individual perspectives and decision-making processes interact as design teams collaborate and reach consensus. We explore how narrative misalignments within a design team—disagreements on the best path forward—are shaped by individual perspectives. Driving requirements, requirements that reflect a designer's prime motivations, are used to shed light on individual priorities. A data collection and analysis plan are introduced to explain how the team will examine how consensus was achieved, which divergent personal interests persist, and how future decision-scenarios might be influenced.

### ★ Understanding ChatGPT's impact on student-team ideation outcomes for new product development

***Benjamin Justin Bunn, Bryan F. Howell, Geoff Wright***
***Brigham Young University***

Previous studies found ChatGPT-assisted ideation produced lower fluency, flexibility, and originality with shorter ideation sessions. This research hypothesized that a longer 24-minute session would improve ideation outcomes for the ChatGPT-assisted approach and enhance team engagement. Undergraduate students participated in two design workshops: one using a ChatGPT-assisted approach (n=22), the other using only analogue methods (n=17). Results showed that while the analogue group slightly outperformed the ChatGPT group in flexibility and originality, the fluency difference was larger, with the analogue group producing over twice the number of ideas. Evidence suggests team-based ideation behavior has more impact on ideation outcomes. Future research will explore a hybrid individual-to-team approach that combines individual contributions with team collaboration.

# P 05-3: Design Theory and Methodology 1

## Session Chair: Pascal Le Masson, MINES ParisTech-PSL, France

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### The pioneering role of Stanford DesignX and legacy of Larry Leifer on the field of engineering design

***Tamara Carleton[1], William R. Cockayne[1], John Feland[2]***
***1 Blekinge Institute of Technology, Sweden; 2 CableLabs***

This retrospective paper explores the profound impact of DesignX at the Stanford Center for Design Research (CDR) on engineering design research and education. Through a historical lens, the authors examine the evolution of the DesignX laboratory and its role in fostering interdisciplinary collaboration, innovative research, and team-based research by highlighting key milestones and influential projects over time. The authors also discuss the pioneering role of Stanford Professor Larry Leifer, whose leadership of CDR for much of its history shaped the practices and methodologies of engineering design from the 1980s up through the 2020s. This paper underscores the significance of Leifer's contributions to the academic community and the enduring legacy of DesignX in advancing the field of engineering design research and education.

### ★ AI at the fuzzy front end - creative iteration in design

***Jonathan Burgess, Asha Ward, Christian McLening, Jordan Cutler***
***Arts University Bournemouth, UK***

Artificial intelligence is a transforming design practice. This research explores human-AI interaction in relation to human centred design principles in early stage design projects. Using a qualitative workshop methodology, this empirical study took a multidisciplinary team of participants from a yacht manufacturer through a series of divergent, discover phase activities that were augmented by AI tools. The results demonstrated how the advanced capabilities of AI to rapidly analyse vast quantities of data could be purposefully implemented to enhance engagement. the role off facilitator as an intermediary between the AI and participants allowed the interface between human and AI to be moderated and provided insights into effective effective use of AI during the fuzzy front end.

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Employing network analysis to identify research topic evolution

***Siyi Xiao, Daniel A. McAdams***
***Texas A&M University, USA***

This study proposed a framework to visualize research trends and create methods to forecast future directions in the design research methodology field from 2018 to 2022. A case study is conducted using a dataset of abstracts from conference proceedings included in the American Society of Mechanical Engineers (ASME) International Design Theory and Methodology Conference track from 2018 to 2022. The proposed method involves extracting keywords from research articles, transforming them into vectors, determining the similarity between keyword pairs to form a keyword network, and constructing a Sankey diagram to show the topic evolution pathways. The resulting Sankey diagrams provide insight into relationships between research topics.

### Paradigmatic design thinking: How generative design changes the role of human designers

***John Clay, Zhenghui Sha***
***The University of Texas at Austin***

Engineering design has recently undergone a paradigm shift led by generative artificial intelligence (AI). The Generative Design (GD) paradigm utilizes generative AI tools (e.g., large language models) to define the objective space and computationally exploit the design space. This is a drastic shift from the roles of human designers in the Traditional Design (TD) paradigm which consists of manual design-objective space co-evolution, and has created a research gap for Generative Design Thinking (GDT): how a designer thinks and cognitively approaches the design process during GD. To fill this gap, we propose the Paradigmatic Design Thinking Model which uniquely defines design thinking as situated within three factors (Design Cognition, Design Tools, and Design Methodology) and use it to explain design thinking in two paradigms: Traditional Design Thinking and Generative Design Thinking.

# P 05-4: Requirements and Data Mangement 1

## Session Chair: Alexander R. Murphy, Florida Polytechnic University, United States of America

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Digital engineering transformation for sustainability: An approach to systematically integrate sustainability data in engineering processes

***Fabian Wyrwich[1], Ulf Könemann[1], Denis Tissen[2], Tinus Bohnenkamp[1], Aschot Hovemann[1], Roman Dumitrescu[2]***
***1 Fraunhofer Institute for Mechatronic Systems Design (IEM), Germany;***
***2 Paderborn University (HNI), Germany***

Digital engineering transformation in industrial companies requires addressing diverse needs and their impact on every impacted engineering aspect. This paper analyses Changes initiated by transformation drivers and presents a systematic approach to integrate sustainability into engineering processes and artifacts. As a currently important topic the integration of sustainability data in engineering is used as an example of application. Based on identified use cases, sustainability parameters are derived and linked to engineering data objects to pinpoint their placement within the early product development. The results demonstrate how data-driven approaches enable effective sustainability integration and provide a foundation for future digital engineering transformations due to diverse divers.

### ReqGPT: a fine-tuned large language model for generating requirements documents

***Kata Amanda Schiller, Meno-Said Haddad, Arthur Seibel***
***Leuphana University Lüneburg, Germany***

Effective product development relies on creating a requirements document that defines the product's technical specifications, yet traditional methods are labor-intensive and depend heavily on expert input. Large language models (LLMs) offer the potential for automation but struggle with limitations in prompt engineering and contextual sensitivity. To overcome these challenges, we developed ReqGPT, a domain-specific LLM fine-tuned on Mistral-7B-Instruct-v0.2 using 107 curated requirements lists. ReqGPT employs a standardized prompt to generate high-quality documents and demonstrated superior performance over GPT-4 and Mistral in multiple criteria based on ISO 29148. Our results underscore ReqGPT's efficiency, accuracy, cost-effectiveness, and alignment with industry standards, making it an ideal choice for localized use and safeguarding data privacy in technical product development.

# P 05-4: Requirements and Data Mangement 1

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### ★ A maturity based data management integration in engineering research projects

***Max Leo Wawer[1], Laura Mueller[2], Jaouhar Ben Khaled[1], Timo Stauss[1], Johanna Wurst[1], Iryna Mozgova[2], Roland Lachmayer[1]***
***1 Institute of Product Development, Leibniz University Hannover;***
***2 Data Management in Mechanical Engineering, Paderborn University***

With the increasing amount of data in collaborative engineering research, the need for effective data management is growing. This paper uses a maturity-based process model to examine the execution of research data management (RDM) in engineering projects. A process model visualizes a research-supported implementation of RDM and helps researchers evaluate their data management strategies through maturity level assessment. For this approach, activities are assigned to different maturity levels based on a maturity level characteristic providing a differentiated view of the implementation of RDM. An example from an ongoing project shows the application and support of the developed maturity-based process model. The work emphasizes the importance of standardized and quality-assured data management for the success of research projects and their contribution to the scientific community.

### Test-oriented Resilient Requirements Engineering (ToRRE): extending model-based effect chain analysis to verification objectives

***Iris Graessler, Marcel Ebel***
***University Paderborn (HNI), Germany***

Verification and Validation (V&V) are essential processes in engineering Cyber-Physical Systems. However, the role of V&V engineers is often not given sufficient attention. Based on a systematic literature analysis and practical observations, a four-step method for Test-oriented Resilient Requirements Engineering (ToRRE) is developed. The steps are planning V&V, executing V&V activities, documenting V&V activities and analyzing results of V&V activities. Applying ToRRE ensures continuous information flow and traceability. Engineers are enabled to analyze requirements using engineering artifacts connected through Model-Based Systems Engineering. Adopting methods for Model-Based Effect Chain analysis to evaluated test cases and test scenarios, conclusions on requirements engineering and change management are enabled. The method is evaluated in an EU research project.

# P 05-5: Additive Manufacturing Research 2

## Session Chair: Paul Egan, Texas Tech University, United States of America

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### A dual DfAM worksheet to assess design opportunities and restrictions in additive manufacturing

***Gregory-Jamie Tüzün, Matthias Kreimeyer***
***University of Stuttgart, Germany***

Additive Manufacturing (AM) design projects often fail when feasibility and practicality are unclear during product development. To address this, we developed a dual design for additive manufacturing (dual DfAM) worksheet to support users with novice to intermediate DfAM competence. The worksheet incorporates restrictive and opportunistic criteria and calculates a feasibility and practicality index for quick evaluations. Verified through a workshop with 73 engineering students, all participants found the worksheet helpful, and 71 expressed willingness to reuse it in future design projects. Furthermore, we found indications that repeated use of the worksheet could enhance dual DfAM competence, as designs became more feasible and practical. These results highlight the worksheet's potential as a structured tool for improving dual DfAM assessment and decision-making in product development.

### Design and mechanics of 3D printed synthetic organ tubules for biomedical applications

***Michael Tomori, Paul F Egan***
***Texas Tech University, USA***

There is a need for design of synthetic organs due to the high demand of organ replacements for patients and low availability of alternatives. Recent advancements in additive manufacturing are enabling the creation of biomimetic organs with biocompatible materials suitable for use in the body. Here, we consider a design, build, test approach for creating synthetic blood vessel tubules by comparing fused deposition modelling and stereolithography printing processes. Tubules were printed with vessel diameters from 10 mm to 20 mm and wall thicknesses of 1 mm to 2.5 mm. Mechanical testing results demonstrated high elongation of tubules prior to breaking. Results highlight the possibility for designers to create flexible biomimetic structures to aid biomedical applications, which opens the doors for new types of patient treatments in organ repair and transplantation.

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### A motion-based taxonomy for lattice structures in additive manufacturing: geometry-driven classification for dynamic deformation

***Alan Air[1,2], Andrew Wodehouse[1]***
***1 University of Strathclyde, Scotland; 2 National Manufacturing Institute Scotland (NMIS), Scotland***

This paper presents a motion-based taxonomy for classifying lattice structures in additive manufacturing (AM) based on their geometric suitability for linear, oscillating, reciprocating, and rotary motions. While existing classification frameworks primarily focus on static load-bearing performance, this study develops a geometry-driven taxonomy, classifying 51 lattice variations based on how tessellation patterns and wall thickness influence motion-driven deformation. The taxonomy provides a framework independent of materials, aiding the selection of lattices for compliant structures, and energy-absorbing applications, by isolating geometric tessellations to assess their role in dynamic deformation and motion suitability. This approach links lattice geometry to motion-driven behaviour, offering a predictive framework for AM design while emphasising its role in motion applications.

### ★ Design of a reconfigurable crawler based on waterbomb origami

***Lingchen Kong, Yaoyao Zhao***
***McGill University, Canada***

Inspired by nature, where organisms adapt their shapes to navigate complex challenges, engineering systems can benefit from reconfigurable designs that move beyond rigid, conventional strategies. Reconfiguration offers a promising solution for systems to adapt dynamically to changing operational requirements. Origami, known for its ability to transform from simple 2D sheets into intricate 3D structures, provides a powerful framework for designing adaptable and reconfigurable systems. In this study, a waterbomb origami-based (WOB) crawler is proposed featuring reverse movement without changing actuation. The unfolding and folding process of the WOB enables motion due to the friction between the vertex and the ground, whereas the reverse movement is achieved by leveraging the local bistability of one WOB crease.

# P 05-6: Data Driven Design and Automation

## Session Chair: Stanko Škec, University of Zagreb, Croatia

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Enhancing product design with digital twins: framework and application in an industry case study

***Timo Stauss[1], Philipp Wolniak[2], Mathias Tergeist[2], Johanna Wurst[1], Roland Lachmayer[1]***
***1 Leibniz University Hannover, Germany; 2 Baker Hughes INTEQ GmbH***

Products need to be developed faster and more efficiently, which is why companies are seeking to leverage the benefits of digitalization. A current trend is the digital twin (DT), which offers many advantages but also involves high development efforts. Research has addressed the use of the DT along the product life cycle (PLC) to compensate for the development effort, but these approaches are often imprecise and not directly applicable in industry. This paper therefore describes how the individual components of the DT can be utilized along the PLC beyond the manufacturing and use phase with a focus on product design. The resulting framework is then illustrated using a case study of a product service system. This article aims to facilitate the use of the DT in industry to improve product design across product generations.

### A team of three: The role of generative AI in the development of design automation systems for complex products

***Alejandro Pradas Gomez[1], Maximilian Kretzschmar[2], Kristin Paetzold-Byhain[2], Ola Isaksson[1]***
***1 Chalmers University of Technology, Sweden; 2 Technische Universität Dresden, Germany***

Given the rise of Generative AI and Large Language Models (LLMs), there is a high interest in their use also in engineering design domain. Current research approaches lack to leverage LLM's new orchestration capabilities and use the LLMs in ways that expose their inherent weaknesses. We present a conceptual model to visualize the contribution of LLMs to design tasks and distribute ownership in the design activities: the triangle of design responsibility.
A literature review on the design engineering field presents its current uses in this community. The understanding of the model is validated with industry via survey. We identify future research directions in the field of complex product design.We hope that this model helps design automation developers, researchers and industry practitioners to position and assign responsibility effectively in their design automation implementation.

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Expanding data usage in systems: An empirical study of combined model-based and data-driven development in Complex Intelligent Systems (CoIS)

***Appu Balachandran[1], Eswaran Subrahmanian[2]***
***1 Linköping University, Sweden; 2 Carnegie Mellon University, USA***

AI is becoming an important part of complex products and systems (CoPS), transforming them into complex intelligent systems (CoIS), on which our society depends. Traditionally, system development relied on model-based approaches, and the emerging data-driven approaches offer new possibilities. This paper explores the intertwining of model-based and data-driven approaches in emerging CoIS through a comparative case study of their role in cloud-based automotive systems, which are part of the transportation system. The findings show that data-driven approaches not only complement model-based approaches but also play a pivotal role in the evolution of CoIS.

### Systems engineering of AI-based systems from Perspective of design teams

***Oliver Bleisinger[1], Mareike Keil[2], Martin Eigner[3]***
***1 University of Kaiserslautern-Landau, Germany;***
***2 University of Mannheim, Germany; 3EIGNER engineering consult***

Given the rise of Generative AI and Large Language Models (LLMs), there is a high interest in their use also in engineering design domain. Current research approaches lack to leverage LLM's new orchestration capabilities and use the LLMs in ways that expose their inherent weaknesses. We present a conceptual model to visualize the contribution of LLMs to design tasks and distribute ownership in the design activities: the triangle of design responsibility.
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# P 05-7: Virtual Reality and Design Representations

## Session Chair: Stefan Zorn, University of Rostock, Germany

## Location: ECSS 2.203

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Brain-derived neural networks distinguish design representations in different media

***Samuele Colombo[1,3], Nayeon Kim[2], John Gero[3]***
***1 University of Strathclyde, Scotland; 2 Catholic University of Korea, South Korea;***
***3 University of North Carolina, Charlotte, USA***

Products need to be developed faster and more efficiently, which is why companies are seeking to leverage the benefits of digitalization. A current trend is the digital twin (DT), which offers many advantages but also involves high development efforts. Research has addressed the use of the DT along the product life cycle (PLC) to compensate for the development effort, but these approaches are often imprecise and not directly applicable in industry. This paper therefore describes how the individual components of the DT can be utilized along the PLC beyond the manufacturing and use phase with a focus on product design. The resulting framework is then illustrated using a case study of a product service system. This article aims to facilitate the use of the DT in industry to improve product design across product generations.

### Understanding VR-mediated empathy in design: Measurement approaches, inconsistencies and implications

***Xinhui Hu[1,2], Hernan Casakin[3], Georgi V. Georgiev[1]***
***1Center for Ubiquitous Computing, University of Oulu, Finland;***
***2School of Information Sciences, University of Illinois at Urbana Champaign, Champaign, Illinois, United States;***
***3Ariel University, Israel***

Virtual Reality (VR) has garnered significant attention as a potential 'empathy machine' for its ability to simulate firsthand experiences of others' perspectives. However, recent research reveals conflicting evidence regarding VR's effectiveness in fostering empathy, with outcomes ranging from strong positive effects to complete ineffectiveness. By analyzing both subjective experiences and objective measures, this study aims to elucidate the relationship between VR design and human empathy, addressing three prevalent perspectives on the field's inconsistencies: flawed mechanisms, ineffective design, and mismatched methodology. The findings contribute to the theoretical understanding of empathic VR and provide practical implications for designing effective VR-based empathy interventions in engineering contexts.

# P 05-7: Virtual Reality and Design Representations

## Location: ECSS 2.203

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### CAD in Virtual Reality: Integration of solid modeling in stand\-alone VR application

***Alexander Prinz, Kil-Young Lee, Abhishek Gupta, Sangyoung Park, Dietmar Göhlich***
***Technische Universität Berlin***

The advent of virtual reality (VR) enables immersive visualization, evaluation, and interaction with 3D models. Efforts have been made to integrate parametric solid modeling into VR, but efficient 3D solid model processing and intuitive user interface (UI) design remain challenging. This work proposes an architecture, which, unlike existing approaches, integrates the geometric modeling kernel Open CASCADE directly into the game engine Unreal Engine allowing standalone operation on a VR device without external hardware or software. Our prototype supports creating and editing primitives, and applying topological algorithms. STEP format 3D models can be imported, edited, and exported for compatibility with standard computer-aided design (CAD) applications. A foundation for CAD in VR is established, focusing on a customizable UI design to enhance interaction in future developments.

### Leveraging AR/VR technologies to teach Industry 5.0 principles to students and practitioners through learning factories

***Mohammad Hossein Dehbozorgi, Monica Rossi, Brendan Patrick Sullivan***
***Politecnico di Milano, Italy***

The transition to Industry 5.0 (I5.0) marks a shift toward human-centric, sustainable, and resilient manufacturing, leveraging technologies like collaborative robots (cobots) and AR/VR to enhance inclusivity, empowerment, and safety. This study investigates how Learning Factories (LFs) can effectively convey I5.0 principles to students and professionals. A simulated production line using AR/VR allowed participants to interact with virtual cobots, assessing key pillars of safety, inclusivity, and empowerment. A survey was used to assess the impact of this immersive environment on participants' perceptions and unconscious reactions. The findings demonstrate LFs' potential to prepare a workforce that integrates human creativity with technological innovation.

# P 05-8: Collaborative Design 1

## Session Chair: Oredola Adebayo, The University of Texas at Dallas, United States of America

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### AI-Driven feedback for improving teamwork and learning in collaborative engineering design

***Sabah Farshad, Clement Fortin***
***Skolkovo Institute of Science and Technology, Russia***

Engineering design is inherently a collaborative process that requires active engagement and effective communication. Project-based Learning (PBL) is increasingly recognized for fostering these essential skills. However, instructors face challenges in objectively monitoring interactions and providing process-oriented feedback, particularly in large-scale settings where free-riders and disengaged participants affect team dynamics. This study introduces a generative AI approach to deliver real-time, scalable, and empathetic feedback that enhances team collaboration. Findings highlight the potential of AI-driven systems to improve student engagement and learning outcomes, though limitations remain in providing context-specific advice. A secure framework for AI integration in collaborative learning environments is also proposed.

### Teamwork in design - A case study on how digital visual planning software addresses barriers to efficient project communication

***Malin Hane Hagström, Ola Isaksson, Dag Bergsjö, Henrik Wahrén, Erik Panzar***
***Chalmers University of Technology, Sweden***

Developing new factories is effectively a design task. In this paper a case study on barriers to efficient project communication is presented. Preceding research has shown that production systems design projects can be more efficiently executed and that as many as 95% of all problems in collaborations are due to a lack of communication. The study was designed to grasp project communication barriers from three projects and developed a visual planning tool. The findings show that digital planning software supports mainly in the categories of Egocentrism and Mistrust, Equivocality and Ambiguity and less in Interaction Capability, Asynchronisity and Noise and Information-sharing Behaviour. Recommendations for future research is to connect the project communication support to quantitative project performance aswell as the acceptance of technology in production systems design.

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 10:30am - 11:30am

### Misunderstand me correctly - Comprehensibility in interdisciplinary collaboration

***Thomas Alexander Voelk1, Lars Gesmann1, Stefan Götze3, Kevin Feichtinger2, Stefan Eric Schwarz1, Tobias Düser1, Ralf Reussner2, Albert Albers1***
***1IPEK - Karlsruhe Institute of Technology (KIT), Germany; 2KASTEL – Karlsruhe Institute of Technology (KIT), Germany; 3KHYS - Karlsruhe Institute of Technology (KIT), Germany***

Interdisciplinary work environments, such as in the engineering of Cyber-Physical Systems (CPS), face significant communication challenges due to the need for collaboration among different engineering domains. This study examines communication comprehensibility within a CPS research project involving 30 researchers from multiple universities. We conducted two surveys to assess the status quo of communication comprehensibility. While most research descriptions are generally understandable, significant barriers exist due to technical terminology and differing epistemic foundations. The study presents a systematic approach to assess communication comprehensibility in interdisciplinary projects and highlights the need for support in enhancing communication. Further data from multiple projects is needed to develop effective communication models for interdisciplinary teams.

### Integrative and integrated product and production system development: A taxonomy for managing dependencies and processes

***Jan-Philipp Disselkamp[1], Tobias Seidenberg[1], Svenja Westphal[1], Jonas Lick[1], Lukas Ptock[2], Fabian Wyrwich[1], Aschot Hovemann[1], Roman Dumitrescu[3]***
***1 Fraunhofer Research Institute for Mechatronic Systems Design IEM, Germany;***
***2 Schmitz Cargobull AG; 3University of Paderborn, (HNI), Germany***

The increasing complexity of modern product and production system development, driven by dynamic market demands, supply chain disruptions and economic pressures, poses significant challenges for companies. Existing methodologies often fall short due to their domain-specific focus, inconsistent terminology and lack of integration. To address these challenges, this paper presents a taxonomy for integrative product and production system development. The taxonomy systematically structures key elements, dependencies and processes to improve collaboration, decision-making and communication within organisations. Developed iteratively the taxonomy identifies ten core artefacts. It enables organisations to better plan improvements, synchronise development processes, and select appropriate methods and tools.

# P 06-1: Challenges in Design Research 2

## Session Chair: Saeema Ahmed-Kristensen, University of Exeter, United Kingdom

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Scenario-based planning of design method validation studies and the associated effort

***Olga Sankowski[1], Lukas Paehler[2], Christoph Wittig2, Selin Uereten[1], Matthias Eisenmann[2], Sven Matthiesen[2], Dieter Krause[1]***
***1 TUHH - Hamburg University of Technology, Germany; 2 KIT - Karlsruhe Institute of Technology, Germany***

Design method validation is fundamental to ensure that design methods achieve their objectives in the intended situations and are accepted in practice. Although various method validation approaches have been developed, there is still a lack of practical guidance for planning validation studies based on project characteristics. To address this, an intensity map of the validation effort is presented as the core of a scenario-based planning approach. It categorizes projects according to the novelty of the method and the state of research on the problem or the research area, enabling the required validation studies, their sequence and validation criteria to be identified. Thereby, researchers can plan validation studies and estimate the required effort situation-based, allowing for a better alignment with their individual project characteristics before starting studies.

### Circular product design: A literature-based identification of challenges from the perspective of product designers

***Jan Jagnow, Bernd Stoehr, Ruslan Bernijazov, Christian Koldewey, Roman Dumitrescu***
***University Paderborn (HNI), Germany***

The importance of the circular economy as an alternative to today's prevailing linear economy is recognised in both industry and research. Product designers are having a major influence on this transition by adapting the characteristics of physical products in the early phases of the product development process. However, most products follow a linear approach and are far from being circular. This paper aims to identify the challenges that product designers face when designing circular products. Building on a developed understanding of related terms in circular product design, an exploratory literature review is conducted. The results help to gain an overview and understanding of the challenges that need to be addressed. Therefore, further research directions are derived to support the transition from linear to circular products in the long term.

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### A dual perspective on validation during early development projects - insights from literature and industry

***Stefan Eric Schwarz, Saskia Weiß, Manuel Wei Spekker, Albert Albers***
***IPEK - Karlsruhe Institute of Technology (KIT), Germany***

Many developments, such as the Amazon Fire Phone and Microsoft Zune, fail in the market, often due to addressing non-existent needs or providing no added value. Therefore, it is necessary to validate these needs and benefits in the early phases of development projects. One way to do this is by using a product profile that models needs and benefits and makes them accessible for validation. According to the literature, there are nine challenges and four fields of action for developing a design support in validating these product profiles. These fields of action range from stakeholder integration, method selection, and prototyping to the interpretation of results. This publication evaluates and describes the challenges and fields of action derived through expert interviews and literature research. A total of 28 publications were analyzed, and eight expert interviews were conducted.

### ★ Leveraging generative AI tools for design method support: insights, challenges, and best practices

***Olga Sankowski, Pascal Inselmann, Dieter Krause***
***TUHH - Hamburg University of Technology, Germany***

Publicly available generative AI tools, such as ChatGPT, Midjourney, and DALL-E 3, have the potential to transform product development by accelerating tasks and improving design ideation.Through case studies of scenario management and persona storyboarding, this research explores the strengths and limitations of generative AI (GenAI) tools. The results highlight GenAI's ability to accelerate routine tasks, improve ideation, and support iterative design, but also reveal limitations in contextual understanding and output quality. Key findings show that effective GenAI integration depends on precise prompt design, iterative interaction and critical validation. Despite their potential, GenAI tools cannot replace human expertise for nuanced design tasks. The study provides actionable insights and best practices for leveraging GenAI tools, paving the way for enhanced human-AI collaboration.

# P 06-2: Challenges in Embodiment Design 1

## Session Chair: Pavan P Kumar, University of Texas at Dallas, United States of America

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### On the potential of the Quality Information Framework (QIF) standard driving the interoperability in variation simulation

***Martin Roth[1], Stefan Goetz[2], Marx Raghu Raja Dharmaraj[1], Kristina Wärmefjord[1], Rikard Söderberg[1]***
***1 Chalmers University of Technology, Sweden; 2 Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

Design method validation is fundamental to ensure that design methods achieve their objectives in the intended situations and are accepted in practice. Although various method validation approaches have been developed, there is still a lack of practical guidance for planning validation studies based on project characteristics. To address this, an intensity map of the validation effort is presented as the core of a scenario-based planning approach. It categorizes projects according to the novelty of the method and the state of research on the problem or the research area, enabling the required validation studies, their sequence and validation criteria to be identified. Thereby, researchers can plan validation studies and estimate the required effort situation-based, allowing for a better alignment with their individual project characteristics before starting studies.

### Investigating the Design-Roughness-Performance relationship using additive manufacturing design artefacts

***Didunoluwa Obilanade[1], Pia Åkerfeldt[1], Fredrik Svahn[2], Peter Törlind[1], Jörgen Kajberg[1]***
***1 Luleå University of Technology, Sweden; 2 GKN Aerospace Engine Systems***

Laser Powder Bed Fusion (LPBF) enables complex metal components for the space industry. However, as-built surface roughness affects material properties and is closely linked to design geometry. As computer-aided design tools struggle to model roughness accurately, this study explores Additive Manufacturing Design Artefacts (AMDAs) to investigate design-related roughness and its impact on fatigue performance. A space industry case study using AMDAs to replicate a 4 mm unsupported roof radius of a rocket engine component found fatigue performance reductions of 88% in horizontal builds and 65% in vertical builds compared to machined surfaces. Microstructural analysis confirmed the influence of roughness and grain structure on fatigue behaviour. Findings highlight how AMDAs provide design-specific insights and support engineers in investigating uncertainties.

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Designing an embodiment - a design methodology perspective

***Tobias Eifler, Mogens Myrup Andreasen***
***Technical University of Denmark***

Gradually transforming abstract, conceptual ideas into physical assemblies is seen as one of the key competences of design engineers. Despite the general recognition of the Embodiment Design task as essential phase of every development process, a general methodical support seems either not available or, at least, not influential. Instead, Embodiment Design is often considered an expert task. In this context, our paper offers a discussion of embodiment design from a design methodology perspective. Drawing from a review of relevant literature, we explain why embodiment might be better understood as the representation of the physical artifact rather than a design phase, provide properties and characteristics of good embodiment solution, and give initial guidance for the transition from the creative exploration of concepts to the actual search for satisfactory, or even optimal, embodiments.

### Efficient product portfolio optimization with SAT-based association rule mining using Apriori algorithm

***Thorsten Schmidt, Steffen Marbach, Frank Mantwill***
***Helmut Schmidt University, University of the Federal Armed Forces Hamburg***

Managing high-variant product portfolios effectively is a crucial competitive advantage in offering mass customized products on saturated markets. Association Rule Mining (ARM) is a field of data mining determining frequent itemsets from historic transactions and deriving patterns of conclusion. This paper introduces a new approach to transfer ARM to feature-based configuration e.g. in the German automotive industry. Combined, existing apriori product knowledge is used in constraints to effectively lowering runtime by reducing the number of candidate-sets through introduction of a Boolean satisfiability check. For an efficient implementation, three different Apriori algorithms are tested and benchmarked on a generic dataset for different parameters. Results show a significant improvement in using SAT-based pre-screening while efficiency of the implementation depends on the given example.

# P 06-3: Creative Problem Solving

## Session Chair: Noe Vargas Hernandez, UTRGV, United States of America

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Defining technical creativity: Iterative development of a shared understanding

***Albert Albers, Annika Bastian, Tobias Düser, Thomas Alexander Voelk, Maximilian Kuebler***
***Karlsruhe Institute of Technology (KIT), Germany***

Creativity is a requirement for excellence in product engineering. Despite its important role, the concept of creativity in engineering is challenging to articulate and define, both for practitioners and researchers. What makes technical creativity unique? Existing definitions often fall short of capturing the essence of creativity in technical contexts. The process of defining technical creativity is performed iteratively. In product engineering, creativity is not an abstract concept but a practical necessity, requiring motivation, imagination, expertise and experience. Therefore, two workshops with product engineers were held and the results were used to refine the definition. A shared understanding of technical creativity, that can be applied in daily engineering practice is created, enhancing both research and practical outcomes in product engineering.

### A mixed-method approach in ergonomic analysis utilising personalised data dashboards

***Isabelle Ormerod[1], Natalie Shortt[2], Mike Fraser[1], Chris Snider[1]***
***1 University of Bristol, UK; 2 Kinneir Dufort, UK***

How we gather individual data to inform product design is changing. In ergonomics, methodologies are rooted in qualitative approaches, providing a holistic approach but can lack objectivity and precision. In this work, we explore novel quantitative techniques, involving machine vision and muscle sensing, to create personalized data dashboards that enrich qualitative practices in a mixed-method design. We conducted a pilot study (n=10), evaluating participants' motion in a simple ergonomic task, followed by interviews discussing the dashboards. A thematic analysis showed that all participants agreed the dashboards affirmed their experience. Furthermore, the order of data presentation influenced their language, affecting subjectivity and specificity. This study highlights participants' roles as stakeholders, underscoring the need for their engagement to achieve meaningful design outcomes.

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Making space for designers at hackathons: Uncovering developer-designer tensions in hackathon teams

***Meagan Flus[1], Ada Hurst[2]***
***1 University of Toronto, Canada; 2 University of Waterloo, Canada***

Hackathons have recently garnered significant research interest. Hackathon teams frequently include developer, business, and designer roles, yet the designer role and experience of design in hackathon teams are poorly understood. In this paper, we present findings from ten interviews with designer hackathon participants. A thematic analysis reveals that the responsibilities of designers at hackathons roughly align with more typical design contexts, although the format of hackathon events forces designers to adapt approaches to design. Hackathon participants value teams with diverse skills, including design skills, yet designers face resistance from peers in developer roles when seeking to use established design methods for validating needs and generating solutions. This tension can make designers feel unwelcome at hackathons, harming efforts to attract a more diverse participant pool.

### An exploration into identifying assumption-making: Pilot study and early insights

***Kudrat Kashyap, Vishal Singh***
***Indian Institute of Science, India***

Assumption-making is a critical cognitive process in design, where incomplete information is ever-present. Understanding how assumptions are formed, maintained, and adapted can offer key insights into decision-making. While theoretical explorations of assumptions exist, empirical research remains limited. This pilot study investigates how varying temporal constraints influence assumption-making while solving ill-structured problems. The challenge lies in isolating the temporal and cognitive factors at play. The early insights reveal that task ambiguity, contextual framing, and time constraints play significant roles in shaping responses, highlighting the dual nature of assumption-making as both adaptable and resistant to change. The insights highlight the importance of strategic task design that balances ambiguity and structure to deepen our understanding of assumption-making.

## Session Chair: Chris McTeague, Technical University of Munich, Germany

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Emotional interactivity of products: A literature review

***Ayushi Pandey, Gaurav Vinod Vaidya***
***IIT Jodhpur, India***

Incorporation of emotional interactivity into the design framework can help strengthen the connection between user perception and designers intent with product as its medium. The method involved in this qualitative literature review is analysis of journal articles, conference papers and other literary sources. With the help of thematic analysis parallel assessment of journals was done to figure out the main highlights of the themes patterns and theories that stood out. The paper's main objective is to analyze, role of emotional interactivity in user experience and product design. The study examines and collectivizes the current knowledge of emotional interactivity and its applications in various domains, including sensorial design elements, storytelling and marketing, user personalization, and AI-driven product adaptation and emotional recognition.

### Emotional responses to the design of multisensory interior spaces

***Chris McTeague, Susanne Dreyer, Shuyun Liu, Aycan Kizilkaya, Katja Thoring***
***Technical University of Munich***

The properties of the external environment such as colour, light, sound and scent, have been shown to influence the emotional responses of the people in those spaces. However, these findings are typically drawn from studies using stimuli designed by researchers. It remains unclear whether workspace designers can intentionally elicit specific emotional responses in the occupants of those spaces. To address this, we evaluate two workspaces designed by students to ‘activate’ and ‘relax’ their occupants. The spaces were used as stimuli in a controlled experiment conducted during a design exhibition. Self-report measures of emotions showed that the activating room energised its occupants and the relaxing room both calmed and reduced the tension perceived by its occupants. Future analyses will determine whether physiological and behavioural measures are consistent with these findings.

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Understanding barriers in the design process for elderly's positive emotion regulation

***Yong Jun Park[1], Chajoong Kim[2], Jungkyoon Yoon[3]***
***1 UNIST - Ulsan National Institute of Science and Technology;***
***2 School of Design and Human Engineering, UNIST, Ulsan, Korea, Republic of;***
***3 College of Human Ecology, Cornell university, Ithaca, New York, United States***

As the global elderly population grows, emotional challenges unique to this demographic are often neglected in design under the assumption that older adults can regulate their emotions independently. This study highlights the importance of fostering positive emotions in the elderly through leisure activities. It examines (1) how design practitioners conceptualize emotion regulation in older adults, (2) the challenges they face in creating supportive designs, and (3) enablers identified by elderly individuals. Twelve design practitioners generated 64 interactive design concepts to enhance elderly leisure experiences, followed by interviews with five elderly participants to explore their emotional needs and preferences. The findings underscore designers' challenges and highlight opportunities for user-centered approaches to promote emotional well-being in aging populations.

### Design opportunities for daily emotion regulation to enhance young adults' emotional well-being

***Jinhee Cha, Chajoong Kim***
***UNIST, Ulsan, Korea, Republic of***

This study examines daily emotion regulation strategies of young adults aged 20-30 and proposes design opportunities for enhancing emotional well-being. Research with 29 participants revealed a preference for behavioral strategies (73.4%) over cognitive strategies (26.6%), particularly “Seek pleasure or relaxation” strategies. Significant differences were observed between positive and negative emotional contexts. Four main categories of emotion regulation strategies were identified: Disengagement, Seek pleasure or relaxation, Reallocate resources, and Engagement. Design opportunities were proposed based on these findings. This study enhances understanding of young adults' emotion regulation and offers design strategies for product development. Future research should validate these strategies and explore personalized approaches, considering long-term impacts and ethics.

# P 06-5: DfAM and Design Optimisation

## Session Chair: Rahul Sharan Renu, Austin College, United States of America

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Engineering-based DFA approach for automation-compatible design of hydrogen electrolyzer stacks

***Idris Yorgun[1], Sebastian Müller[2], Lennart Lamers[1], Bernd Kuhlenkötter[3], Kai Lemmerz[1], Aaron Westermann[3]***
***1 RIF Institute for Research and Transfer e.V., Germany; 2 FFT Produktionssysteme GmbH & Co. KG, Germany; 3 Ruhr-University Bochum, Germany***

The transition to renewable energy and the urgent need to reduce greenhouse gas emissions highlight green hydrogen's role in decarbonizing various sectors. To address the increasing demand, the research initiative H2Giga FertiRob focuses on automating the production of hydrogen electrolyzers, emphasizing PEM stack assembly. Existing stack designs are often incompatible with automation and hinder scalable production. This paper introduces an adapted Design for Automation approach for PEM stacks. Through the evaluation of a reference stack, key design limitations are identified, leading to the development of an optimized stack with reduced part diversity, improved handling, and enhanced automation compatibility. The methodology provides a systematic framework to advance the automated production of PEM stacks, supporting the scalability of green hydrogen in the global energy transition.

### Computational analysis of overhang surface roughness effects on self-supporting channels

***Alexander Seidler, Stefan Holtzhausen, Kristin Paetzold-Byhain***
***Technical University Dresden, Germany***

Additive manufacturing (AM) enables the creation of complex internal geometries, including cooling channels. Yet, the impact of AM-induced surface roughness on their fluid dynamics remains underexplored. The goal of this study is to provide insight into the effects of surface roughness on the fluid dynamics of AM channels. A parametric surface roughness model and computational fluid dynamics (CFD) simulations were employed to examine three representative AM channel cross-sections: diamond, droplet, and circular. The findings indicate that diamond profiles result in higher pressure losses and turbulence intensity compared to the other cross-sections. In contrast, droplet profiles exhibit lower pressure losses and turbulence intensity compared to diamond profiles, while circular channels remain optimal in non-overhang areas.

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### ★ Optimising AI-driven solutions without trade-offs: Predicting and preventing potential failures in sustainable innovation

***Mas'udah Mas'udah[1], Pavel Livotov[1], Niklas Hartmann[1], Björn R. Kokoschko[2], Wanyu Xu[3], Saptadi Nugroho[1,4], Saurav Bhowmick[1], Büşra Meral[1]***
***1 Offenburg University of Applied Sciences; 2 Otto-von-Guericke-University Magdeburg; 3 Texas A&M University; 4 Albert Ludwig University of Freiburg***

The application of Generative Artificial Intelligence (AI) in early-stage design processes has emerged as a promising method for generating innovative solution concepts. However, AI-driven concepts may introduce secondary problems when implemented practically. This study proposes a systematic framework integrating Generative AI (GPT-4o), patent analysis using Retrieval-Augmented Generation (RAG), and Failure Mode and Effects Analysis (FMEA) to predict, evaluate, and mitigate potential risks. Applied to a case study on nickel recovery through froth flotation, the framework significantly enhanced the feasibility, usefulness, and sustainability of solution concepts. The research highlights the scientific contribution and practical benefits of combining Generative AI with structured risk-analysis methods for sustainable innovation.

### Extracting FMEA information from publicly available datasets using large language models

***Rahul Sharan Renu***
***Austin College***

The objective of this research is to explore the use of publicly available recall data from the National Highway Transportation Safety Administration to extract Failure Modes and Effects Analysis data. This large data set was analysed using a Large Language Model chatbot. To assess the usefulness of priming the chatbot with this data, the chatbot was also asked to generate data without priming it with the recall data. This was performed on two specific products. It was found that primed-chatbot results were more specific and used technical terminology appropriate to the product being analysed. The proposed approach can be used by designers in the forward design process during new product development. The proposed approach provides designers with insight into potential failures, the associated consequences, their severity, and root causes as well.

## Session Chair: Frederike Kossack, Ruhr-Universität Bochum, Germany

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Focused competencies in higher education for engineering product development and its different activities

***Fabian Dillenhöfer[1], Frederike Kossack[2], Alina Sersch[3], Bernd Künne[1], Beate Bender[2], Peter Gust[3]***
***1 TU Dortmund University, Germany; 2 Ruhr-University Bochum, Germany; 3 University of Wuppertal, Germany***

This paper analyses the amount of design-oriented content in higher education, as well as the extend of activities from product development such as clarification of problem or task, shaping the modules and usage requirements and assurance of fulfilment of requirements. The mechanical engineering study degree program of three universities is analysed by categorizing courses to design-oriented, design-related, basic science and additional expense. These particular courses are then further investigated by assigning the learning hours to certain product development activities regarding the VDI 2221 guideline. The results show that between 14 % and 26 % (bachelor) and from 27 % to 33 % (master) of courses are design-oriented. Most of the time is spent on achieving competencies in shaping modules, e.g. design parts. The other eight activities are treated less than 10 % of the total workload.

### ★ Assessing competencies in engineering design education with an automatically evaluable digital exam format

***Frederike Kossack, Eike Uttich, Beate Bender***
***Ruhr-University Bochum, Germany***

The possibility of automatic evaluation in online exams offers the advantage of automatic evaluation compared to paper-based exams with manual assessment. Nevertheless, teachers and students have major concerns about digital exams e.g. students are afraid of getting worse grades due to reduced inputs and determined evaluation steps. To analyze these concerns for Engineering Design Education this paper investigates to what extent can be found differences in the results between digital and paper-based examination formats when assessing the same learning outcomes with the same tasks about dimensioning machine elements. The paper contains the transformation of existing paper-based exam tasks into digital automatic evaluable tasks and the data from students participating in a digital exam are compared with data from students with a paper-based exam.

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### First experiences from using CADdrive with digital LEGO for product design and systems engineering education

***Georg Hackenberg, Christian Zehetner***
***University of Applied Sciences Upper Austria***

Due to rising product and system complexities, design and engineering have become a team effort that requires well planned and synchronized activities to achieve a high degree of process efficiency and effectiveness. Inspiring high school children to pursue a carreer in this field and preparing undergraduate as well as graduate students for what they will face in practice remains a challenge for societies and institutions worldwide. To overcome this situation, in this paper we present our experience from conducting two courses for Master students and one workshop for high school children based on an online collaboration platform and the digital LEGO framework. We provide insights into the organization of the different formats, the various backgrounds and profiles of their participants, the work results produced by the individual teams, as well as the participants' learning experience.

### A game-theoretic research platform for team-based design decisions under competition

***Xiang Li[1], Siyu Chen[1], Alparslan Emrah Bayrak[2], Zhenghui Sha[1]***
***1 The University of Texas at Austin; 2 Lehigh University***

Design decision-making under competition is a critical challenge in real-world engineering design. These challenges are compounded by bounded rationality, where cognitive limitations and imperfect information influence decision-making strategies. To address these issues, we develop a game-theoretic research platform to investigate team-based design under competition. This platform abstracts and simulates real-world competitive design scenarios through controlled experiments. It features a user-friendly interface to collect behavioral data, which supports the analysis of team and individual strategies. Additionally, we validated the platform through a pilot study, demonstrating its ability to capture realistic design features and generate meaningful insights into competitive design behaviors.

# P 06-7: Biomedical Engineering 1

## Session Chair: Paul Egan, Texas Tech University, United States of America

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Personalization for the clinic: A review of spinal fusion cage design

***Bishal Karki, Ryan Reilly, Andres Mena, A K M Ahasun Habib, James Yang, Paul F Egan***
***Texas Tech University, USA***

There is great potential for engineering design approaches in medicine to personalize treatments according to unique patient physiology and needs. However, it is challenging to optimize solutions such as medical implants given the complex biomechanical interactions between the body and implant. Here, we review personalization for clinical needs, biomechanical modelling, and computational design for interbody spinal cage implants. By reviewing relevant literature, research suggests specific clinical needs are addressable by redesigning cages with multi-objective optimization or artificial intelligence methods integrated with finite element modelling of the spine. Such an approach is generalizable to further biomechanical design cases, where personalized design provides promise to deliver higher quality solutions for the clinic.

### Bridging design, engineering, and medicine: lessons from the WeBreath development process

***Ceren Usta[1], İdil Aktaş[1], Bahar Şener[1], Ayhan Ozan Yılmaz[2]***
***1 Middle East Technical University,Turkey; 2 Biyomod Ltd., Turkey***

This paper discusses the development of WeBreath, a wearable system designed to monitor respiratory health for individuals with chronic respiratory diseases and sleep disorders. The project brought together experts in engineering, industrial design, and medicine, requiring an iterative process to address user needs, medical requirements, technical feasibility, and commercial constraints. Beyond describing the product, the paper examines how multidisciplinary collaboration shaped its development, highlighting challenges such as regulatory requirements, user adoption, and market readiness. It explores design challenges from a user experience perspective, balancing functionality with comfort, wearability, and usability. The paper provides insights into structuring teamwork in medtech projects, showing how user-centred design principles guided decision-making and shaped the outcome.

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Identifying the needs of low-income angioplasty patients and caregivers to inform the design of a support platform

***Saurabh Rahul Sardar[1], Santosh Jagtap[2], Prashant Goswami[3], Jayant Karve[4]***
***1 Indian Institute of Technology Guwahati; 2 CIKS, Indian Institute of Technology Guwahati;***
***3 Blekinge Institute of Technology, Sweden; 4 RCupe Lifesciences Pvt Ltd, Bangalore, India***

This research investigates the needs and preferences of low-income angioplasty patients and their caregivers in India during post-angioplasty recovery. Through in-depth interviews and contextual inquiries, the study uncovers critical informational, physical, and emotional needs. Patients often lack access to reliable health information, leading to misconceptions about care and medication adherence. Pain management and emotional support are significant concerns for both patients and caregivers. The study proposes the integration of digital health solutions to address these challenges, providing a platform for reliable information, communication, and support. This research emphasizes the need for context-sensitive interventions to improve patient outcomes and enhance the quality of life for vulnerable populations in developing countries.

### Adapting the engineering design process to develop a business model for service-oriented living labs: a case study of PISCES

***Anubhab Majumder[1,2], Titing Reza Fahrisa[1,3], Spyridoula Gerassimidou[1,4], Gatot Yudoko[1,5], Susan Jobling[1,4], Eleni Iacovidou[1,4], Vishal Singh[1,2], Amaresh Chakrabarti[1,2]***
***1 The PISCES Partnership; 2 Indian Institute of Science; 3 Sepuluh Nopember Institute of Technology;***
***4 Brunel University London; 5 Bandung Institute of Technology***

This paper focuses on the development of a viable business model for the PISCES Living Lab, which seeks to address plastic pollution in Indonesia. The overarching aim is to transition it from a project-based initiative to a self-sustaining service enterprise. The paper introduces a new modified engineering design process as a workshop template to guide an interdisciplinary team in creating a business model for a service-oriented living lab. A four-day workshop was conducted in Banyuwangi, Indonesia, involving a diverse group of stakeholders from the project, and the final outcome was the creation of a Business Model Canvas outlining the core components of the PISCES Living Lab's business model. The findings demonstrate the effectiveness of integrating the engineering design process with business model innovation, offering a structured yet flexible approach to developing self-sustaining Living Labs.

## Session Chair: Kristin Paetzold, TU Dresden, Germany

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### ★ Augmented design automation: leveraging parametric designs using large language models

***Fabian Schöfer, Arthur Seibel***
***Leuphana University Lüneburg, Germany***

Traditional design automation enables parameterized customization but struggles with adapting to abstract or context-based user requirements. Recent advances in integrating large language models with script-driven CAD kernels provide a novel framework for context-sensitive, natural-language-driven design processes. Here, we present augmented design automation, enhancing parametric workflows with a semantic layer to interpret and execute functional, constructional, and effective user requests. Using CadQuery, experiments on a sandal model demonstrate the system's capability to generate diverse and meaningful design variations from abstract prompts. This approach overcomes traditional limitations, enabling flexible and user-centric product development. Future research should focus on addressing complex assemblies and exploring generative design capabilities to expand the potential of this approach.

### Generative AI-powered parametric modeling and BIM for architectural design and visualization

***Jaechang Ko, John Ajibefun, Wei Yan***
***Texas A&M University, USA***

Parametric modeling and generative design hold promise for architecture, yet their reliance on scripting and predefined constraints has often discouraged early-stage exploration. This paper proposes a conversational AI framework to address these challenges, integrating ChatGPT into two workflows: user-driven (Revit+Dynamo) and AI-driven (Grasshopper). By transforming natural-language prompts into Python scripts or Grasshopper definitions, designers can iterate on geometry, materials, and forms without extensive coding. AI-based visualization tools such as Veras provide near-instant feedback, accelerating the loop from concept to refinement. Rather than evaluating a single software tool, this exploration highlights collaboration between architect and AI, demonstrating how large language models can augment design intent, expand the parameter space, and adapt to contextual needs.

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 1:45pm - 2:45pm

### Challenges and opportunities in the integration of generative AI with computer-aided design

***Elias Berger[1,2], Maximilian Peter Dammann[1], Jan Mehlstäubl[2], Bernhard Saske[1], Felix Braun[2], Kristin Paetzold-Byhain[1]***
***1 Technical University Dresden, Germany; 2 MAN Truck & Bus SE***

Computer-aided design (CAD) has become essential for hardware product development in our industrial age. However, increasing complexity, shorter lead times, and cost pressures present new challenges. While generative AI has gained significant attention and transformed various business functions, its application in engineering design with CAD remains underdeveloped. Our research aims to explore why generative AI has not yet reached its potential in CAD, despite its prominence in other fields, by identifying key challenges through case studies and a literature review. These challenges include small datasets, difficulty representing mixed data types, proprietary file formats, and lack of advanced CAD modeling commands. We propose future developments such as high-quality datasets, a vendor-neutral format, novel neural network architectures, and expanded generative methods.

### Bridging disciplines: An analysis of collaboration and communication in technical drawings based on Geometrical Product Specifications (GPS)

***Alina Sersch, Muhamed Hamadamin, Peter Gust***
***University of Wuppertal***

In the product development process, the way in which different departments collaborate and communicate affects the challenges faced by employees, their level of motivation, and the time and cost of development. This paper examines the collaboration and communication in technical drawings based on the Geometrical Product Specifications (GPS). The idea of different types of technical drawing documents (ISO/TS 21619:2018) is explained. Based on a survey, a comparison with the industrial application is made. The current status of communication in the departments is analyzed and challenges, potentials and possible measures are considered. The results show that the document types and their possibilities are rather unknown (43 %). Another insight was that there is a significant difference between standardization and the (working) reality, in which collaboration plays a major role.

# P 07-1: Design Theory and Methodology 2

## Session Chair: Yoram Reich, Tel Aviv University, Israel

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### What is the value of design theory?

***Yoram Reich[1], Emilia Lavi[1], Kuti Shoham[2]***
***1 Tel Aviv University, Israel; 2 Afeka College of Engineering, Israel***

This paper explores the multifaceted concept of design theories value, challenging traditional views of science and philosophy and proposing a novel framework for evaluation. Through critical analysis, considering design theories like C-K theory, PSI, GDT, and CDP, and insight from the history of science, we establish the need for a new value model of design theories that includes design-related and other general properties such as generativity, robustness, and impact on practice. We adapt a recently developed system value model (SVM) to consider the diverse perspectives of design theory stakeholders. Our framework is tested on the PSI theory, demonstrating its applicability. This paper redefines how we perceive and measure the value of design theories, offering insights that could influence future research and practice in design science.

### Development of a communication model for the efficient exchange of information between user and designer

***Kristin Paetzold, Lino Stoiber***
***TU Dresden, Germany***

Designer and user have different perspectives on a product. This can lead to differences in their evaluation and classification in usage situations. Not least, products are evaluated from different backgrounds of experience. Communication between user and designer therefore appears to be crucial to support this mutual process of understanding. Prototyping is a widely used and recognised tool in development. The use of these as non-verbal instruments in communication, however, poses specific challenges for the designer, since ambiguities in interpretation are also possible here. The aim of this paper is therefore to develop a model that describes the communication between developer and user via prototypes to identify factors influencing the communication-process. Based on this communication model, initial implications for the design of prototypes will be derived

## Location: ECSS 2.412

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Training for transforming: design theory-based training for managing the unknown

***Antoine Bordas[1], Agathe Gilain[2], Pascal Le Masson[1], Maxime Thomas[1,3], Chipten Valibhay[1], Benoit Weil[1]***
***1 Mines Paris, PSL University, Centre de Gestion Scientifique (CGS), i3 UMR CNRS;***
***2 IRT SystemX, Centre d'intégration Nano-INNOV; 3 EPF Engineering School***

Current transitions, such as digital and ecological ones, bring new challenges for organizations, characterized as unknowns. Addressing them requires new management paradigms for which design-based methods show promise. Yet their organizational implementation remains limited, what this paper investigates. Based on a two-year collaboration with a French healthcare company, the study involved developing, delivering and evaluating a four-day training program. Based on interviews and evaluations from 65 participants, results indicate high satisfaction, significant habit disruption and intent to adopt design-based tools. Due to the development of a common language in the organization and the emphasis on learnings' co-creation, this training had a transformative power. Thus, highlighting its practical value and opening pathways for exploring its long-term impact on organizational practices.

### Using design principles as a lens to interpret user needs: A case study using a new 3D Tic-Tac-Toe game

***Joe Thomas, Rajath S, B Sankar, Muzammil Bagewadi, Vishal Singh***
***Department of Design and Manufacturing, Indian Institute of Science***

This study investigates user engagement and its relationship with the visual aspects of design using a newly designed 3D Tic-Tac-Toe. The research examines user experience factors like cognitive engagement, fun, stress relief, etc., and to analyze their correlation with the design principles found in literature, such as Contrast, Framing, and Balance. 15 teams, comprising 2 players each, from design academic backgrounds, were provided with the game board to play. Researchers observed interactions and challenges, while subsequent surveys captured experience, aesthetics, emotional response, and design principles. The findings reveal the strong and weak correlations amongst the factors and the principles, highlights further prototype refinement. The insights integrate cognitive and emotional dimensions with core principles of design to create engaging and visually satisfying products.

# P 07-2: Challenges in Embodiment Design 2

## Session Chair: David S. Nobes, University of Alberta, Canada

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Enhancing computer-aided design with deep learning frameworks: A literature review

***Sarah Steininger[1,2], Jasmin Zhao[1], Johannes Fottner[1]***
***1 Technical University of Munich, Germany; 2 BMW Group, Munich, Germany***

Generative artificial intelligence (GenAI) has the potential to further revolutionize Computer-Aided Design (CAD) by recognizing patterns, making predictions, and generating automated design suggestions. This paper presents a systematic literature review that examines the current state of research on the use of GenAI in CAD-based product development. With a focus on 3D modelling, it provides an overview of current approaches, most used datasets and commonly used AI models. Four application areas where GenAI can enhance CAD were derived: Design generation, Design reconstruction, Design retrieval, and Design modification. In total, 47 papers were selected, analysed and categorised.

### A systematic approach to deriving links between product models in engineering design research

***Lukas Paehler, Jiahang Li, Sven Matthiesen***
***Karlsruhe Institute of Technology (KIT), Germany***

It is necessary to pass on design knowledge through links between product models to efficiently utilise the design knowledge built up throughout a design process. Yet, researchers lack support for deriving new links between product models. Based on the findings from analysing publications that present links, a systematic approach to deriving links between product models in engineering design research is developed and subsequently demonstrated in an illustrative case linking two product models. The approach enables researchers to derive new links between different product models in a systematic and traceable way. This offers the potential to increase the density of known links within the body of product models. Further, this facilitates the integration of previously unlinked product models into design processes and their efficient combination through the passing on of design knowledge.

# P 07-2: Challenges in Embodiment Design 2

## Location: ECSS 2.410

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Automating the assessment of CAD drawings and solid models

***David S. Nobes***
***University of Alberta, Canada***

The power, speed and sophistication of software for computer-aided design (CAD) drafting has revolutionized the design process and the productivity of experienced users. Assessment and mark-up of student drawings in a university class is still time-consuming and requires teaching assistants to be well-versed and proficient. This bottleneck can slow the learning of students if they are not provided with timely and proficient feedback. Software can be developed that uses the quantitative information stored in electronic files for direct comparison with a solution. This however requires an appropriate learning/teaching approach that is complementary with the assessment approach. A learning approach with complementary assessment is outlined along with the developed software for the assessment of large numbers of student submissions in a university level engineering course on drafting.

### Designing for machine longevity - A literature survey

***Scott Edward Rice[1], Christopher Andrew Mattson[1], Benjamin C. Sannar[1], Michael L. Anderson[2]***
***1 Brigham Young University; 2 United States Air Force Academy***

Complex machines are expensive to develop and build, which causes many to be maintained in service for longer than designed, as they still effectively perform valuable tasks. Long-lasting service lives of centuries versus decades are a valuable characteristic for certain machines in several industries, whether for continual service, extended storage, or remote deployment, such as in defense, agriculture and space exploration. Although various archival publications focus on longevity, we seek to identify product architecture decisions which impact a machine's longevity and can then be extrapolated out for timescales greater than 100 years. We refer to this as hyper-longevity. This paper seeks to find patterns in the literature that can identify causes linked to longevity effects, their frequency in the literature, and the types of impacts they have in facilitating longevity.

# P 07-3: Sustainable Design and Circular Economy 1

## Session Chair: Apoorv Naresh Bhatt, Technical University of Clausthal, Germany

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Design-for-decarbonization: A framework for decarbonizing cyber-physical production systems at the design stage

***Nick Schreiner[1,4], Adam Cowen[1,2,4], Thomas Volling[2], Roman Dumitrescu[1,3]***
***1 Fraunhofer Institute for Mechatronic Systems Design (IEM), Germany; 2 Technical University of Berlin, (POM), Germany; 3 University of Paderborn, (HNI), Germany; 4 Joint first co-author***

Cyber-physical production systems (CPPS) are responsible for a significant portion of manufacturers' carbon emissions. Since 80% of product-related environmental impacts are determined at the design stage, there is a need for CPPS manufacturers to focus on decarbonization at the design stage. To date, there is a lack of design-for-decarbonization guidance for CPPS. This paper proposes a procedural framework for the effective selection of decarbonization measures for the design of CPPS. A Decarbonization Wheel is developed to establish a product-specific decarbonization strategy. This tool is linked to a catalogue of decarbonization measures. A measure prioritization logic provides a structure for systematizing selected measures. The framework is validated in the case of an intelligent industrial control valve.

### A product transformation approach to exploit existing production assets applied to the automotive supplier industry

***Lucien Zapfe, Klemens Hohnbaum, Markus Mörtl, Markus Zimmermann***
***Laboratory for Product Development and Lighweight Design, TUM School of Engineering and Design, Technical University of Munich***

The automotive industry faces many simultaneous challenges like transitioning from combustion engines to electric vehicles. Suppliers must adapt to changing markets and develop new solutions. Existing transformation approaches focus on strategic goals and comprehensive implementation. However, there is no focus on the transition of the product portfolio.
This paper presents a design-thinking-based approach to rapidly generate innovative product ideas. First, company assets, product portfolios, and market environments are analysed to define the ideation focus. Next, these are recombined by interdisciplinary teams to generate ideas, which are then evaluated.
In a workshop with 15 experts from an exhaust pipe manufacturer, over 400 ideas were generated and refined into 15 actionable concepts in five hours. This approach supports rapid, cost-effective innovation and strategic transformation.

# P 07-3: Sustainable Design and Circular Economy 1

## Location: ECSS 2.312

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Investigating support strategies for users in repair activity of household appliances

***Apoorv Naresh Bhatt[1], David Inkerman[1], Kilian Gericke[2]***
***1 Technical University of Clausthal; 2 University of Rostock***

Repair plays a critical role in promoting circular economy principles and fostering resource efficiency. However, the current environment often discourages repair activities. While new policies, such as the Green Deal and EU directives, aim to disseminate and implement repair strategies, there remains a significant need to support users throughout the repair process. This study aims to explore the existing body of knowledge that supports users at various stages of the repair activity, focusing specifically on household appliances. Through a systematic literature review, 12 articles were identified, analyzed, and categorized into five themes. Furthermore, seven key attributes were identified, against which the selected papers were classified. The analysis highlights the need for effective and efficient support, particularly for non-tech-savvy users, during self-repair activities.

### Model-driven scope 3 upstream (procurement) CO2 emission calculation for the design space exploration of maritime vessels

***Mubeen Ur Rehman, Alessandro Bertoni***
***Blekinge Institute of Technology***

The marine industry is increasingly adopting platform and modular design strategies while facing growing sustainability regulations and emission constraints. This paper proposes an approach that integrates scope 3 upstream CO2 emissions (i.e., procurement) into a Decision Support Environment (DSE) for design space exploration of alternative modular ship design concepts. The DSE, deployed in the conceptual design stage, enables simultaneous testing of various cruise ship configurations regarding CO2 emissions using a bottom-up approach with parametric CO2 models. It leverages data-driven models from existing databases or AI-generated data exemplified in a case study on the hotel system of a cruise ship illustrates how parametric design variables influence CO2 emissions, demonstrating a preliminary result of a prescriptive study in collaboration with a major international ship manufacturer

# P 07-4: Value Driven Design

## Session Chair: Fatima-Zahra Abou Eddahab-Burke, Delft University of Technology, Netherlands, The

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Identifying break points in early product family design using an integrated VDD approach

***Jack Martin Boggs, Trevor T Robinson, Frank Kirkland, Mark Price***
***Queen's University Belfast, Northern Ireland***

This paper presents an Integrated VDD Approach, formulated to address the lack of, and limitations associated with, work concerning the application of VDD to product families. The focus of the results obtained from the application of the Integrated VDD Approach, and the subsequent discussion, will be on the identification of break points to aid objective decision making early in the design process. Results include the identification of the most valuable common wingspan across three conventionally powered aircraft and the identification of the additional system mass which would render an aggressive electrification strategy to facilitate earlier electrification of an initially conventionally powered aircraft futile in comparison to a nominal electrification strategy.

### Consideration of values in design methodologies for value-driven design

***Antoine Persehais1,2, Thierry Gidel1, Pierre-Emmanuel Fayemi2***
***1Université de Technologie de Compiègne, France; 2Ikos Lab***

This study examines the integration of values into design methodologies, essential for guiding value-driven design processes. Values, spanning ethical, economic, and functional dimensions, influence decision-making and project outcomes. Through Principal Component Analysis (PCA), five clusters of design methodologies were identified, each addressing distinct aspects of value integration. Interviews with designers highlighted challenges in defining, formalizing, and adapting values due to their inherent subjectivity and volatility. This study, by adopting a values-centered perspective, enriches our understanding of design methodologies and paves the way for more informed methodological choices across various contexts.

## Location: ECSS 2.311

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Teaching value-based participatory design of complex socio-technical systems

***Fatima-Zahra Abou Eddahab-Burke, Pieter van Langen, Geertje Slingerland, Frances Brazier***
***Delft University of Technology, Netherlands***

The advent of complex socio-technical systems in modern society calls for teaching value-based participatory design in engineering curricula. Yet, no scientific literature supports teachers in this effort. This paper introduces a teaching approach called "value-based participatory design of complex socio-technical systems" and reports on its implementation. It emphasizes the importance of actively involving stakeholders and tapping into their values from the very start of the design process. Following this approach, students learn to (1) design with stakeholders, (2) identify key values and conflicts to create a value-based mission statement, (3) navigate uncertainties, (4) adopt an iterative design process, and (5) recognize that only stakeholders can define what works best. Results of an academic course based on this approach confirm its value and importance for engineering curricula.

### Using agent-based modelling to explore the impact of social events, labour dynamics, and human factors on food production: apple harvesting as a case study

***Yufeng Nie, Alex Sparks, Ben Hicks, Aydin Nassehi, Maria Valero***
***University of Bristol***

Food production systems are shaped by external factors, such as social events and economic shifts, which influence and are influenced by labour dynamics—e.g., workforce availability—and human factors—e.g., worker skills. Using a systems approach, this paper explores how labour shortages impacting worker teams—such as in terms of mixture of availability, skills, and human behaviours—affect production and quality. UK apple harvesting is chosen as a case study due to its reliance on skilled seasonal migrant workers. Findings highlight the need for strategies such as upskilling local workers, enhancing training programmes, and adopting new technologies to mitigate labour shortages and enable high-performance collaborative worker groups.

## Session Chair: Akane Matsumae, Kyushu University, Japan

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### ★ Linguistic effects in background music on creativity using Vocaloid

***Akane Matsumae, Kohei Wakabayashi, Ken-ichi Sawai***
***Kyushu University, Japan***

This study examines the effects of linguistic elements in Vocaloid BGM on creativity, fluency and originality, aiming to design sound environments that enhance creative performance. Experiments were conducted under three BGM conditions: voiced-meaningful (VF), voiced-meaningless (VL), and non-voiced (NV). VF utilized the original Vocaloid song with lyrics, NV excluded lyrics entirely, while VL replaced lyrics with the syllable "la." Results revealed that VF BGM could disrupt concentration and reduce creativity, while VL and NV conditions enhanced relaxation and improved originality. These effects became more pronounced as tasks progressed. A positive correlation was identified between mind-wandering tendencies and creativity, particularly with VF BGM. The findings highlight the importance of tailoring sound environments to cognitive modes and personal characteristics.

### An attempt to estimate the creative state during co-creation by using a Hidden Markov Model

***Keisuke Shoji, Ken-ichi Sawai, Yuki Motomura, Akane Matsumae***
***Kyushu University, Japan***

Resonance, where individual creative moments resonate with each other, has been qualitatively recognized as an important phenomenon during co-creation. In a previous study, the authors conducted a concept generation pair work experiment using biosignal indicators and quantitatively grasped the difference between creative states that are simply creative and those that are resonant. This study explores whether it is possible to estimate these creative states using biosignal indicators with the Hidden Markov Model. The parameters for the Hidden Markov Model were based on multimodal biosignal indicators and subjective self-reflection reports regarding the creative states during co-creation. The results suggested that creative states can be estimated during co-creation using a Hidden Markov Model, and resonance can be understood as a shared form of self-resonance driven by concept generation.

## Location: ECSS 2.306

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Forward tools to enhance creative performance based on neurobiological foundations and implications: Bridging divergent and convergent thinking

***Björn R. Kokoschko1,2, Michael K. Schabacker1, Martin T. Wiesner2***
***1Otto-von-Guericke-Universität Magdeburg; 2Hochschule Anhalt***

One focus of creativity research is the question of how creative potential can be effectively unleashed in relation to certain cognitive styles such as convergent and divergent thinking. Neurobiological findings show that different brain structures need to be activated in order to specifically stimulate these cognitive styles. By integrating tools that help understand and optimize the neurochemistry of creativity into the design process, we enable a comprehensive application of creativity and improve the ability to develop innovative solutions. In this contribution, we therefore examine which neurobiological structures undaerlay creativity and how they can be activated in a natural way. We present practical tools for fostering creativity from litertaur, make the scientific mechanisms underlying creativity accessible to designers and propose an approach for implementing the tools.

### Can large language models support machine learning implementation in product development? A comparative analysis and perspectives

***Sebastian Sonntag, Janosch Luttmer, Arun Nagarajah***
***Universität Duisburg-Essen***

Recent advancements in machine learning (ML) offer substantial potential for enhancing product development. However, adoption in companies remains limited due to challenges in framing domain-specific problems as ML tasks and selecting suitable ML algorithms, requiring expertise often lacking. This study investigates the use of large language models (LLMs) as recommender systems for facilitating ML implementation. Using a dataset derived from peer-reviewed publications, the LLMs were evaluated for their ability to recommend ML algorithms for product development-related problems. The results indicate moderate success, with GPT-4o achieving the highest accuracy by recommending suitable ML algorithms in 61% of cases. Key limitations include inaccurate recommendations and challenges in identifying multiple sub-problems. Future research will explore prompt engineering to improve performance.

## Session Chair: Yuan YIN, Imperial College London, United Kingdom

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Modeling data flows in a complex stakeholder network - a case study on autonomous public transportation

***Christopher Langner, Yevgeni Paliyenko, Daniel Roth, Matthias Kreimeyer***
***University of Stuttgart, Germany***

Advances in information and communication technology (ICT) foster smart systems. Seamless data flows between stakeholders are crucial for their functioning. Designing communication systems to manage data exchange in distributed multi-stakeholder networks is challenged by the complexity of diverse stakeholders with varying interests and data needs. This requires a comprehensive understanding of data flows and communication dynamics. This paper investigates methods for modeling and analyzing data-related links between stakeholders in complex systems. After defining requirements and reviewing available methods, an approach combining dependency and structure modeling (DSM) and systems modeling language (SysML) is identified as most suitable. This is applied to a case study of autonomous buses in public transport, demonstrating its applicability and providing a foundation for further work.

### Designing user-oriented wearables: integration of a thermoelectric module into a motorcycle protective jacket regarding aspects of functionality, perceived safety, and usability

***Johanna Riedel1, Martin Luccarelli1, Aline Klippel2***
***1Reutlingen University, Germany; 2Mahle GmbH, Germany***

Among state-of-the-art research, thermoelectric modules using the Peltier effect are used for general personalized climatization. However, none of the personalized climatization approaches found in literature reviewed the usability for the wearer, let alone in the context of motorcycle driving. This work was aimed at integrating Peltier technology into a motorcycling protective item in such a way that it is functional, perceived as safe, and usable for motorcyclists. Multiple integration options observing the requirements for motorcyclist's safety equipment were generated. The functionality and usability of the integration approaches, as well as their impacts on perceived safety of the driver were evaluated. This work could serve as a base for future studies addressing user-oriented methodologies for the validation of technical products in the context of motorcycle protective clothing.

## Location: ECSS 2.305

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Can AI estimate product impressions? Comparison of consumers', designers', and AI model's ratings of car wheels

***Takahiro Yamaguchi1, Hisao Ichikawa2, Hiroyuki Sakai1***
***1Toyota Central R&D Labs., Inc., Japan; 2Toyota Motor Corporation, Japan***

Estimating consumer impressions of a product's appearance is essential. However, this is not easy because of the variety in consumers' tastes and differences in how consumers and designers experience design. Multimodal foundation models trained on datasets from the internet could be applicable for the estimation; however, it remains unclear if the models' tastes are similar to those of consumers or experts like designers. Therefore, we conducted surveys in which consumers and designers rated the appearance of car wheels. In addition, a foundation model estimated the visual impression of the wheels. The model's ratings were more similar to those provided by designers than consumers. Therefore, the models could have tastes similar to those of experts because the datasets could contain advertisements and reviews written by experts or product owners who have opinions on product appearance.

### Abilities of design professors to distinguish design assignments generated by students and AI

***Yuan Yin, Boheng Wang, Haoyu Zuo, Ruocong Liu, Shafina Iqbal Vohra, Saul Haydon-Rowe, Peter R N Childs***
***Imperial College London, UK***

This study aims to detect the ability of professors to distinguish design assignments generated by students with and without using AI. Ten students were recruited to undertake a conceptual design task twice, one with and one without the help of AI. 105 higher-education associate, assistant and full professors from industrial and product design programmes were recruited to assess the generated designs using a 7-point Likert Scale with nine indexes. The results indicate that assessors have moderate ability to distinguish between design assignments of students using AI and those where students did not use AI. Three cues to suggest the risk of the design assignment is made with AI instead of students who did not use AI were identified. By considering the three cues, lecturers distinguish design assignments generated by students with or without AI.

## Session Chair: Ola Isaksson, Chalmers University of Technology, Sweden

## Location: ECSS 2.203

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Roadmap to enable sustainable and circular designs in collaborative automotive ecosystems

***Ola Isaksson[1], Sophie Isaksson Hallstedt[1,2], Matilda Sandgren Watz[2], Adam Mallalieu[1], Håkan Björklund[3]***
***1 Chalmers University of Technology, Sweden; 2 Blekinge Institute of Technology, Sweden;***
***3 Volvo Group Trucks Technology, Sweden***

A roadmap for advancing sustainable and circular designs within the automotive industry is proposed. The emphasis is on the critical role of collaborative ecosystems following the increased transparency and traceability underway in regulations. Emerging Digital Product Passports are central means in Europe's Green Deal and expects to drive transformation of practices in the automotive ecosystem. The study, conducted by researchers in collaboration with a global truck manufacturer, identifies key areas for action, including data quality, stakeholder value, and communication strategies, to facilitate the circular and sustainable transformation. The vision and actions proposed were refined in workshops with automotive suppliers and service providers. By addressing these challenges, the automotive industry can leverage from data accessibility and accelerate its shift towards sustainability.

### ★ Designing a method-testbed for planning upgradeable mechatronic systems - an interview study

***Maximilian Kuebler, Julian Lucas Gruetzner, Tobias Düser, Albert Albers***
***Karlsruhe Institute of Technology (KIT), Germany***

In response to the environmental challenges posed by climate change and shortened product lifecycles, businesses must prioritize the design of sustainable and adaptable products. Upgradeable products present a viable solution to incorporate environmental impacts by maintaining technological relevance and addressing evolving user and customer needs, thus minimizing resource waste. To develop an effective design support for this, it is essential to create a specified method-testbed. This work employed a guideline-based expert study, applying qualitative content analysis to eight interviews. The analysis identified 38 factors crucial for supporting the development of sustainable, upgradeable mechatronic systems. These factors were consolidated into distinct objectives, resulting in 13 requirements that represent the method-testbed for a design support aimed at strategic upgrade planning.

## Location: ECSS 2.203

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Information management for the digital product passport: A 150% approach

***Malte Trienens[1], Valentin Orlowski[1], Luca Schröder[1], Aschot Hovemann[1], Roman Dumitrescu[1,2]***
***1 Fraunhofer IEM; 2 Heinz Nixdorf Institute, Paderborn University***

Sustainability is no longer just a trend for companies, but is now seen as a mandatory measure for the environmentally friendly and responsible use of existing resources. The Digital Product Passport (DPP) is a transformative tool that aims to increase transparency and promote sustainability throughout the product lifecycle. This paper presents the 150% Information List, a comprehensive framework to help companies identify mandatory and optional data for the DPP. Using a systematic literature review, grey literature analysis and interviews with industry stakeholders, the study compiles 148 data points grouped by product relevance, availability and life cycle phase. The findings highlight the flexibility of the list to adapt to different industries and underline its potential to optimise resource use, meet regulatory requirements and drive innovation in product development.

### A graph-theoretic approach for assessing the alignment of circular economy principles with integrated product development and supply chain design

***Sobhan Mostafayi Darmian, Fabio Sgarbossa, Torgeir Welo***
***Department of Mechanical and Industrial Engineering, NTNU, Trondheim, Norway***

This study explores a graph-theoretic approach to assess the alignment of R-imperatives with the integrated product development and supply chain design decisions in the transition toward a circular economy. By modeling interdependencies as a multi-layer graph, our framework quantifies alignment levels, identifies gaps, and provides strategic insights for improving circularity. The methodology employs a hierarchical matrix representation and scenario-based analysis to assess integration performance under different conditions. Numerical results from a case study in the lighting systems industry illustrate the approach's practical applicability. Findings highlight that repair and remanufacturing exhibit the highest alignment potential, while repurposing shows limited viability. This research offers a structured assessment tool for companies to enhance circularity in supply chain management.

# P 07-8: Data Driven Design 1

## Session Chair: Mario Storga, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Data-driven design: predicting functional attributes in early-stage automotive engineering

***Maximilian Rahn, Dietmar Göhlich, Tu-Anh Fay, Kien van Ho***
***Technische Universität Berlin, Germany***

This paper investigates the effectiveness of machine learning models in predicting customer-relevant functional attributes of vehicles based on selected design variables, using a limited automobile market dataset. By comparing machine learning algorithms such as Support Vector Regression, k-Nearest Neighbour Regression, and Lasso Regression, the study evaluates the models' predictive accuracy and their potential application in automotive design. The findings highlight both the opportunities and limitations of these methods, emphasising their capacity to support data-driven decision-making despite constraints posed by dataset size, as encountered in real-world, early-stage automotive platform strategies.

### ★ Revealing axiomatic design relations in patent documents with Natural Language Processing (NLP)

***Marco Losanno[1,2], Vito Giordano[1,2], Marco Consoloni[1,2], Filippo Chiarello[1,2], Gualtiero Fantoni[1,2]***
***1 University of Pisa; 2 Business Engineering for Data Science Lab (B4DS) research group***

Natural Language Processing (NLP) has been widely applied in design, particularly for analyzing technical documents like patents and scientific papers to extract engineering design knowledge. This work aims to enhance this process by integrating the Axiomatic Design methodology with NLP techniques applied to patent texts. The objectives are to (1) extract Functional requirements (FRs) and Design parameters (DPs), and (2) identify how FRs and DPs are related in text (Axiomatic relations). The second objective is particularly challenging due to limited focus on understanding semantic relations in literature, and previous studies often extract Axiomatic relations in an unstructured way. The approach achieves 60% precision for the first objective and 30-50% for the second. Moreover, a case study shows the practical application of this methodology to assist the work of designers.

# P 07-8: Data Driven Design 1

## Session Chair: Mario Storga, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

## Location: ECSS 2.201

Time: Wednesday, 13/Aug/2025: 3:15pm - 4:15pm

### Driving circularity—An approach to identify potentials for circular design of automotive electronics

***Henning Peitzmeier[1,2], Claas Tebruegge[1], Ghada Bouattour[2], Arthur Seibel[2]***
***1 HELLA GmbH & Co. KGaA, Germany; 2 Leuphana University Lüneburg, Germany***

The amount of electronic waste worldwide is increasing every year and the often incorrect handling of it has a major impact on the ecosystem. As electronics are also gaining more share in the automotive sector, the industry has to find a suitable way of dealing with them at the vehicle's end-of-life stage. For this reason, this work introduces an approach consisting of the Physical Component Mapping (PCM) for the interface representation of automotive electronics, alongside the Eco-Sensitivity Framework (ESF) as guidance for circular automotive electronics design. A case study shows how the approach accompanies the product development process and supports identifying suitable strategies that are potentially possible or can be made available through design changes. This helps car makers and suppliers of vehicle electronics to accelerate their transition to a circular economy.

### Application of scenario technique analysis for anticipating future impacts of service robots

***Alexander Grahle, Abhishek Gupta, Pelin Kelesoglu, Dietmar Göhlich***
***Technische Universität Berlin***

This paper explores the employment implications of integrating service robots in waste management. Using the scenario technique method, 14 critical influencing factors were identified and analyzed to develop a Best-Case, Worst-Case, and Trend scenario. A SWOT analysis was used to identify implications and develop measures. The findings indicate that service robots can enhance working conditions and enable service expansion but pose risks like job displacement without proper education and re-skilling. The study underscores the need for regulatory frameworks, workforce adaptation, and education to ensure socially sustainable robotic integration.

25th International Conference on Engineering Design

Dallas, Texas, 11 - 14 August 2025

## Thursday, 14/August/2025

# Programs & Abstracts

## Date: Thursday, 14/Aug/2025

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8:30am - 9:00am | **WR 04: Welcome & Registration** | | | | | | | |
| 9:00am - 10:00am | **P 08-1: Biomedical Engineering 2**<br>Location: ECSS 2.412<br>Chair: **Yaoyao Fiona Zhao**, McGill University, Canada | **P 08-2: Complexity in Design 2**<br>Location: ECSS 2.410<br>Chair: **Apurva R Patel**, Florida Polytechnic University, United States of America | **P 08-3: Sustainable Design and Circular Economy 2**<br>Location: ECSS 2.312<br>Chair: **Tetiana Shevchenko**, CentraleSupélec, France | **P 08-4: Design Team Performance**<br>Location: ECSS 2.311<br>Chair: **Julie Linsey**, Georgia Institute of Technology, United States of America | **P 08-5: User Experience and Cultural Influences**<br>Location: ECSS 2.306<br>Chair: **Hao Wu**, Sichuan Normal University, China, People's Republic of | **P 08-6: User Studies 2**<br>Location: ECSS 2.305<br>Chair: **Yong-Gyun Ghim**, University of Cincinnati, United States of America | **P 08-7: Sustainable Design 3**<br>Location: ECSS 2.203<br>Chair: **Ralf Stetter**, University of Applied Sciences Ravensburg-Weingarten, Germany | **P 08-8: Requirements and Data Mangement 2**<br>Location: ECSS 2.201<br>Chair: **Antoine Bordas**, Mines Paris, France |
| 10:00am - 10:30am | **CB 04-1: Coffee Break** | | | | | | | |
| 10:30am - 11:30am | **P 09-1: Design Creativity 2**<br>Location: ECSS 2.412<br>Chair: **Charlie Ranscombe**, Swinburne University of Technology, Australia | **P 09-2: User Studies and Design Cognition**<br>Location: ECSS 2.410<br>Chair: **Stanko Škec**, University of Zagreb, Croatia | **P 09-3: Sustainable Design and Education**<br>Location: ECSS 2.312<br>Chair: **Massimo Panarotto**, Politecnico di Milano, Italy | **P 09-4: Design Creativity and Team Performance**<br>Location: ECSS 2.311<br>Chair: **Joshua Summers**, University of Texas at Dallas, United States of America | **P 09-5: Prototpying 2**<br>Location: ECSS 2.306<br>Chair: **Chris Snider**, University of Bristol, United Kingdom | **P 09-6: GenAI in Design**<br>Location: ECSS 2.305<br>Chair: **Filippo Chiarello**, Università di Pisa, Italy | **P 09-7: Complexity and Innovation**<br>Location: ECSS 2.203<br>Chair: **Tucker Marion**, Northeastern University, United States of America | **P 09-8: Data Driven Design 2**<br>Location: ECSS 2.201<br>Chair: **Noe Vargas Hernandez**, UTRGV, United States of America |
| 11:30am - 1:45pm | **LB 04: Lunch Break** | | | | | | | |
| 12:00pm - 1:30pm | **WS 21: Design Creativity SIG meeting (SIG: Design Creativity)**<br>Location: ECSW 2.325<br>Chair: **Akane Matsumae**, Kyushu University, Japan | | **WS 22: Design Justice and Ethics: Evaluating Where We Are and Our Visions for Next Steps (SIG: Design Justice and Ethics)**<br>Location: ECSW 3.210<br>Chair: **Anastasia K. Kouvaras Ostrowski**, Purdue University, United States of America | | **WS 23: ASME Journal of Mechanical Author and Paper Development Workshop: Supporting Emerging Scholars in Mechanical Design**<br>Location: ECSW 3.250<br>Chair: **Tucker Marion**, Northeastern University, United States of America | | **WS 24: Mentoring, opportunities through the Design Society**<br>Location: ECSW 4.325<br>Chair: **Ian Whitfield**, University of Strathclyde, United Kingdom | |
| 1:45pm - 2:45pm | **P 10-1: Design Management 2**<br>Location: ECSS 2.412<br>Chair: **Nikola Bursac**, Hamburg University of Technology (TUHH), Germany | **P 10-2: Collaborative Design 2**<br>Location: ECSS 2.410<br>Chair: **Ross Brisco**, University of Strathclyde, United Kingdom | **P 10-3: Design for a Circular Economy**<br>Location: ECSS 2.312<br>Chair: **Albert Albers**, Karlsruhe Institute of Technology (KIT), Germany | **P 10-4: Desing Teams and Human Factors**<br>Location: ECSS 2.311<br>Chair: **Tomislav Martinec**, University of Zagreb, FSB, Croatia | **P 10-5: Prototyping and Testing**<br>Location: ECSS 2.306<br>Chair: **Srinivasan Venkataraman**, Indian Institute of Technology Delhi, India | **P 10-6: Systems Engineering 2**<br>Location: ECSS 2.305<br>Chair: **Markus Zimmermann**, Technische Universität München, Germany | **P 10-7: Design Theory and Methodology 3**<br>Location: ECSS 2.203<br>Chair: **Ariella Knight**, NASA, United States of America | |
| 2:45pm - 3:15pm | **CB 04-2: Coffee Break** | | | | | | | |
| 3:15pm - 4:15pm | **P 11-1: Patents and Standards**<br>Location: ECSS 2.412<br>Chair: **Eswaran Subrahmanian**, Carnegie Mellon University, United States of America | **P 11-2: Digitalisation and Digital Twins**<br>Location: ECSS 2.410<br>Chair: **Rainer Stark**, Technische Universität Berlin, Germany | **P 11-3: Sustainable Design and Circular Economy 3**<br>Location: ECSS 2.312<br>Chair: **Yong Se Kim**, Tongji University, China, People's Republic of | **P 11-4: Creativity and Collaboration**<br>Location: ECSS 2.311<br>Chair: **Vishal Singh**, Indian Institute of Science, India | **P 11-5: Design Education 2**<br>Location: ECSS 2.306<br>Chair: **Gordon Krauss**, Harvey Mudd College, United States of America | **P 11-6: Complexity and Data**<br>Location: ECSS 2.305<br>Chair: **Matthias Kreimeyer**, Universität Stuttgart, Germany | **P 11-7: Design Knowledge and Computation**<br>Location: ECSS 2.203<br>Chair: **Zhenghui Sha**, The University of Texas at Austin, United States of America | |
| 4:30pm - 5:15pm | **CC: Closing Ceremony**<br>Chair: **Joshua Summers**, University of Texas at Dallas, United States of America | | | | | | | |
| 5:15pm - 7:00pm | **FW: Farewell** | | | | | | | |

# W 21: Design Creativity SIG meeting (SIG: Design Creativity)

***Session Chair: Akane Matsumae, Kyushu University, Japan***

**Time: Thursday, 14/Aug/2025: 12:00pm - 1:30pm Location: ECSW 2.325**

Audience: Faculty, Students, Industry
This Special Interest Group on Design Creativity will hold a meeting at ICED 2025 to foster networking and communication among those with a passion and interest in all things related to design creativity. Through this meeting we intend to promote the Design Creativity SIG by reconnecting with older members and enrolling new members. We would also like identify new activities for the SIG to keep the members engaged with this SIG throughout the year.
Organizer: Akane MATSUMAE (matsumae@design.kyushu-u.ac.jp)

# W 22: Design Justice and Ethics: Evaluating Where We Are and Our Visions for Next Steps (SIG: Design Justice and Ethics)

***Session Chair: Anastasia K. Kouvaras Ostrowski, Purdue University, United States of America***

**Time: Thursday, 14/Aug/2025: 12:00pm - 1:30pm Location: ECSW 3.210**

Audience: Industry, Faculty, Students
In this workshop, we will complete the following activities: (1) Overview of justice-, equity- and ethics-based work in design fields, including engineering design; (2) Introduce the new DJE SIG to the community and provide a summary of previous community discussions held in the past year; (3) Interactive discussions to gain an understanding of how workshop participants conceptualize justice and ethics in design and what they mean for them in their work; (4) Map out research gaps in the field to support visioning for future work in justice and design, and how ethics can support them; (5) Analyze the intersection between justice-, equity-, and ethics-based work in engineering design (to inform how to approach visioning for the DJE SIG); and (6) Translate this visioning to concrete initiatives and/or activities that the new DJE SIG can lead/organize. These discussions will also contribute to ongoing research in the engineering design space on justice in design.
Organizer: Anastasia KOUVARAS OSTROWSKI (akostrow@purdue.edu)

# W 23: ASME Journal of Mechanical Author and Paper Development Workshop: Supporting Emerging Scholars in Mechanical Design

***Session Chair: Tucker Marion, Northeastern University, United States of America***

**Time: Thursday, 14/Aug/2025: 12:00pm - 1:30pm Location: ECSW 3.250**

Audience: Students, Faculty
This workshop aims to support PhD students and early-career faculty in developing high-quality research papers for submission to the ASME Journal of Mechanical Design (JMD).
Overview of JMD submission standards, presentations on emerging research topics.
Paper Development and Review: Structured feedback sessions with experienced mentors to help participants improve their manuscripts.
Publication Strategies: Insights on navigating the submission and peer-review process for JMD.
Breakout sessions with mentors for detailed feedback on manuscripts.
JMD-focused discussions, including suggestions on paper structure, methods, etc
Organizers: Tucker MARION (t.marion@northeastern.edu)

# W 24: Mentoring, opportunities through the Design Society

***Session Chair: Ian Whitfield, University of Strathclyde, United Kingdom***

**Time: Thursday, 14/Aug/2025: 12:00pm - 1:30pm Location: ECSW 4.325**

need content

# P 08-1: Biomedical Engineering 2

## Session Chair: Yaoyao Fiona Zhao, McGill University, Canada

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### A machine learning algorithm to predict changes in upper airway during mouth opening to support design of video laryngoscope blade

***Harshit Mourya[1], Jay Dhariwal[1], Kaushik Mukherjee[1], Nishkarsh Gupta[2]***
***1 Indian Institute of Technology Delhi, India; 2 All India Institute of Medical Sciences Delhi, India***

Anatomical variations in the upper airway significantly impact the effectiveness of video laryngoscope blades. Existing literature on upper airway dynamics and blade design lacks a comprehensive framework to address these variations. The proposed model uses the extent of mouth opening with three demographic features and three anatomical features in the closed-mouth state to predict the anatomical features in the open-mouth state, which can support the design of a laryngoscope blade. Pearson's correlation was studied to understand the correlation between the features, and the ordinary least square method was used to develop a model. For all three outputs, a separate model was developed, which gave R-squares of 0.98,0.74 and 0.94. The findings highlight the potential of data-driven approaches to optimize laryngoscope blade designs.

### Meta-level design parameters for bio-inspired impact resistance: a case study in helmet design

***Pavan Tejaswi Velivela, Nikita Letov, Yaoyao Fiona Zhao***
***McGill University***

Bioinspiration offers an innovative approach to product design. A key challenge is selecting suitable biological features for complex engineering problems. The phenomenon of convergent evolution, where distantly related organisms independently develop similar functions, adds to this complexity. This study introduces novel meta-level design parameters to systematically select biological features with differing geometries yet similar functions. These parameters were derived through physical testing and numerical analysis of woodpecker-beak-inspired and Balanus-inspired structures, focusing on their impact resistance capabilities. These structures demonstrate potential for practical applications, such as in bicycle helmet liners.

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Design of a personalised electrode sleeve for differentiation of finger muscle activity in sEMG biofeedback therapy

***Christian Sure, Sascha Selkmann, Frederike Kossack, Marc Neumann, Beate Bender***
***Ruhr-Universität Bochum***

sEMG biofeedback therapy can be used to treat arm paresis after a stroke by using surface mounted EMG electrodes to measure muscle activity in the forearm and provide visual feedback to the patient. Since current sEMG biofeedback systems rely on manual placement of a few large electrodes, they cannot be used to discriminate between individual extrinsic finger muscle activities, which is necessary for training everyday hand movements. In this paper, we present our concept for the development of a device that enables the resolution of individual finger activities. We have developed a method that uses and reduces information from large-scale sEMG scans of a person's forearm to identify suitable locations for the strategic placement of a minimal number of electrodes in a personalised forearm sleeve, which is the key component of an effective biofeedback device for everyday hand movements.

### Advancing prosthesis design: Ontology driven multi-disciplinary framework for evolving amputee needs

***Nicholas Patiniott, Jonathan C. Borg, Philip Farrugia, Owen Casha, Alfred Gatt, Adrian Mercieca***
***University of Malta***

To address the evolving life-cycle needs of both the amputee and prosthesis, input from key stakeholder (amputees and family members, prosthetist, physiotherapist, and prosthesis technician) is essential. Collaborative decision-making is necessary for timely involvement in the design, redesign, and maintenance of prostheses. Our framework, adProLiSS, supports this process by integrating stakeholder knowledge and real-time data obtained from smart prosthetic devices. Through an Ontology-Driven Prosthesis-Service System Framework incorporating an Ontology-Driven Consequence Mapping Model, key decision makers can visualise the consequences of their choices, enhancing communication, alignment, and adaptability. This holistic, data-driven approach prioritises patient-centred care, advocating for a paradigm shift in healthcare design practices.

# P 08-2: Complexity in Design 2

## Session Chair: Apurva R Patel, Florida Polytechnic University, United States of America

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Comparative analysis of conformal prediction: Split, full, and adaptive approaches for statistical and neural network models

***Yuwei Zong, Yanwen Xu***
***The University of Texas at Dallas, USA***

Conformal prediction (CP) provides uncertainty quantification with valid marginal coverage for predictive models. The main methods are divided into Bayesian and statistical inference methods, with split, full, and adaptive conformal prediction being the basic statistical inference methods. Despite numerous variations, a clear comparison is lacking. This paper compares these three basic methods on low-dimensional and high-dimensional datasets to highlight their advantages and disadvantages. The experiment shows that split conformal prediction offers stable coverage but faces issues with data partitioning. Full conformal prediction fails to achieve expected coverage but can reduce the prediction interval. Adaptive conformal prediction struggles with quantile distribution deviation in complex models. The paper also suggests directions for future research.

### Towards an indicator for assessing the potential for geometric standardization in the development of variant lightweight products

***Finn H. Christiansen, Johann Schellhorn, Dieter Krause***
***Hamburg University of Technology***

Product development is a dynamic, multidisciplinary field shaped by evolving customer demands and the need for individualized products, increasing product variety. Key factors include economic performance, customer satisfaction, and sustainability. Lightweight design drives innovation by enhancing weight-specific performance, optimizing resources, and reducing CO☒ emissions, especially in transportation. However, conflicts arise as lightweight design focuses on individual variants, neglecting broader product family implications, while Design for Variety strategies often exclude lightweight design. This study examines the interplay between product variety and lightweight design, proposing a measurement framework to support the development of variant products and their components within product families in the context of lightweight design.

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### An examination of system clustering behaviour: Influence of product identification

***Alexander R Murphy, Apurva R Patel***
***Florida Polytechnic University***

Engineering systems are represented in a variety of physical, graphical, and virtual ways, supporting decision making about the systems and their operation. As part of a larger research endeavor exploring influences of representation modality, the presented work examines how product identification impacts subsystem clustering behavior. This is achieved through a study using pictorial and functional representations of common household products. Participants were tasked with grouping elements into non-overlapping clusters. Results suggest that correctly identifying a product does not affect clustering behavior regardless of representation modality. This implies that other aspects of the representations are impacting partition convergence. These factors, along with connections to prior work are explored as discussion points and areas of future research.

### Exploring the role of layer variations in ANN crowd behaviour and prediction accuracy

***Oredola Adebayo, Joshua Summers***
***University of Texas at Dallas***

This paper explores the influence of layer variations within Artificial Neural Network (ANN) crowds on their collective behavior and prediction accuracy. While prior research has demonstrated the effectiveness of ANN crowds, understanding how architectural variations impact performance is limited. A coding scheme is used to categorize architectures into distinct behavioral profiles (Normality, Centrality, Width). These profiles provide insights into how individual architecture contributes to the overall behavior and performance of the crowd. The research uses two prediction models. Analysis of behavior distributions across layers reveals minimal fluctuations in both models, suggesting consistent behavior across varying layer configurations. Future work will explore the relationship between layer variations and error metrics to understand their impact on performance.

# P 08-3: Sustainable Design and Circular Economy 2

## Session Chair: Tetiana Shevchenko, CentraleSupélec, France

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### "Build Back Better" for war-torn Ukraine: Dual strategies for integrating circularity in post-disaster recovery

***Tetiana Shevchenko[1], Bernard Yannou[1], Michael Saidani[1,2]***
***1 CentraleSupélec, France; 2 Luxembourg Institute of Science and Technology, Luxembourg***

The circular economy has long been regarded as a fundamental strategy for achieving sustainable development. Most recently, it has also been acknowledged as an effective approach to crisis response. This study contributes to this nascent literature by introducing a dual hierarchy of 6Rs strategies as an inspiring framework for circular post-disaster recovery and reconstruction, supporting the "Build Back Better" principle through circular initiatives. The key distinction between the proposed hierarchy and the traditional 6Rs framework lies in the two-vector operationalization of each strategy, addressing both past and future considerations. Also, this article examines the case of war-torn Ukraine as one of the most severe man-made disasters. The study explores Ukraine's potential for circular recovery within the framework of European Union policies in the construction sector.

### Enhancing end-of-life sustainability through modularity and interface design in product development

***Pascal Inselmann, Torben Deutschmann, Dieter Krause***
***Hamburg University of Technology***

This study highlights the importance of interface design in sustainable product development within a circular economy. By focusing on the end-of-life (EOL) phase, the research emphasizes modular product architectures' role in improving component separability, reusability, and recyclability. An extended Module Interface Graph (MIG) was developed to assess interface variance, detachability, and material pairings, enabling the identification of critical interfaces that significantly influence EOL outcomes. The approach was successfully applied to a portal milling machine, demonstrating its ability to highlight key areas for design improvements, such as transitioning from non-detachable to standardized, detachable interfaces. This method showcases the potential for early interface considerations to enhance both environmental sustainability and product lifecycle management.

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Teaching sustainability in higher engineering education: A structured approach to sustainable product development

***Daniele Jung, Niklas Quernheim, Abdul Nafey Zafar, Benjamin Schleich***
***Technical University of Darmstadt***

The Sustainable Product Development (SPD) module bridges sustainability concepts into higher education, equipping Master's students with theoretical knowledge, practical skills, and critical thinking to address sustainability challenges. Combining lectures with hands-on exercises and a flipped classroom, it engages students with tools like Life Cycle Assessment (LCA) and Material Flow Analysis (MFA) to apply sustainability principles in real-world scenarios. Topics such as circular economy, sustainable business models, and ecolabels provide a comprehensive understanding of sustainability across the product lifecycle. The course progresses from foundational principles to advanced applications, linking theory and practice. This prepares students to assess environmental impacts, develop sustainable solutions, and balance competing requirements, meeting industry and societal needs.

# P 08-4: Design Team Performance

## Session Chair: Julie Linsey, Georgia Institute of Technology, United States of America

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Effective management support for design: Towards a model of managerial competence

***Bernd Stoehr, Christian Koldewey, Ruslan Bernijazov, Roman Dumitrescu***
***University Paderborn, Germany***

Well-designed products are crucial to a company's business success. Management support is a critical success factor in ensuring that design-related aspects are given appropriate attention during product development. Despite the importance of management, the literature doesn't provide a clear picture of what characterizes a competent manager in product design. This gap impedes competence development and explains why organizations struggle to leverage the benefits of well-designed products. This research aims to address this gap by synthesizing important findings from the literature into a model of managerial competence. The model provides initial insight into the individual competencies managers need to meet their responsibility for good product design in organizations.

### Exploring the link between students' MBTI personality types and design team performance

***Immanuel Hendra, Lucienne Theresia Maria Blessing, Arlindo Silva, Ricky Ang***
***Singapore University of Technology and Design, Singapore***

This study investigates the relationship between MBTI personality type diversity and team performance in the first-year "Introduction to Design" course at SUTD. Analysis reveals a statistically significant yet weak correlation between greater MBTI diversity and higher final project grades. Additionally, teams with more introverted (I) and intuitive (N) members tended to perform better, consistent with research linking introverts to deep reflection and structured decision-making, and intuitives to creative problem-solving and future-oriented thinking. Result also shows that teams with INTJ and ISTP members performed better, while those with ISFP members showed lower performance. While these findings suggest personality composition influences team performances, measured in terms of grades, further research is needed to establish causation and underlying mechanisms.

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Towards a new understanding: Building a shared mental model for design teams

***Ian Marcus Edgecomb, Ross Brisco, Andrew Wodehouse***
***University of Strathclyde, Scotland***

Understanding how Shared Mental Models (SMMs) develop within design teams has sparked interest in the design community of decades. But to date, there is still a lack of understanding of the factors that influence the development of these structures. This review examines the literature related to SMMs and the factors that impact collaborative efforts. Aiming to bring these two research fields together, this review proposes a new framework to help researchers better understand how SMMs develop and provide a foundation for new research and empirical evidence to establish the factors that influence the development of SMMs

### Impact of team size on requirement quantity

***Kenny Nonso-Anyakwo, Joshua Summers***
***University of Texas at Dallas***

This paper presents and experimental study that compares the performance of teams of one, three, and six in terms of generation of requirements from given design prompts. Team size has not been fully explored in the literature in comparative experimental studies for requirements generation. The study was conducted with 116 teams of one, 86 teams of three, and 92 teams of six composed of pre-service engineers in an introductory engineering course. Two prompts were used for the in-class activity. Results indicate that the size of the team did not have significant influence on the number of requirements generated. However, this suggests that there is a difference in efficiency of generating requirements. Analyzing the variety, novelty, and completeness of the requirements generated is reserved for future work. This work helps to lay the foundation for justifying team size.

# P 08-5: User Experience and Cultural Influences

## Session Chair: Hao Wu,
## Sichuan Normal University, China, People's Republic of

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Challenging dating and gender stereotypes in Indian digital advertising: A semiotic analysis

***Akanksha .[1], Pratul Kalita[2]***
***1 Indian Institute of Technology Guwahati, India; 2 Indian Institute of Technology Guwahati, India***

Advertisements play a key role in shaping perceptions of gender identity, which are influenced by biological traits and cultural beliefs. In India, practices like arranged marriages have historically defined gender roles, but younger generations are increasingly challenging these norms, especially through dating apps. This study examines how dating app advertisements address gender dynamics and societal challenges in India. By applying Barthes' Semiotic theory, we analyzed a popular Bumble ad. The findings reveal how the ad promotes female agency, subverts gender norms, and portrays men as emotionally expressive. By blending modern technology with family values, the ad presents dating as empowering and respectful, challenging rigid societal norms. The study promotes inclusivity and shows how ads reshape gender narratives, and offers insights for creating socially responsible campaigns.

### User-informed LLM learning: Identifying effective design features for sustainable behavior through AI perception

***Sara Laura Wilson, Maria C. Yang***
***Massachusetts Institute of Technology, USA***

This study presents a methodology for leveraging an LLM to generate user-centered recommendations in design for sustainable behavior. A survey of 50 users captured reasonings for evaluating thermostats' eco-friendliness and sustainable design features. Through in-context learning, GPT-4o learned to take user perspectives for similar evaluations. The model classified 196 thermostats by eco-friendliness and design intervention types—persuasive, decisive, or both. Analysis of user sentiment and ratings of these thermostats' reviews showed persuasive designs, which offer users behavioral control, received higher satisfaction. GPT-4o extracted features from these classifications to generate design recommendations. This method is a scalable approach for identifying user preferences and informing sustainable design decisions.

# P 08-5: User Experience and Cultural Influences

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Research on the Sanxingdui cultural and creative product design based on an AIGC design framework

***Hao Wu, Mingyi Zhong, Shan Chen, Yuhan Zhang, Xiaoya Zhou***
***Sichuan Normal University***

This study applies Artificial Intelligence-Generated Content (AIGC) to design cultural products inspired by Sanxingdui, an ancient Chinese civilization famed for mystical bronze artifacts. Addressing the challenge of merging tradition with modernity, an AIGC framework automates cultural element extraction, generates design concepts, and optimizes aesthetics using generative models. Comparative analysis via Quality Function Deployment (QFD) shows AIGC products achieve higher user satisfaction in aesthetics, symbolism, and engagement. The research highlights the significance of AI in enhancing creativity, efficiency, and cultural preservation, despite algorithmic limitations. It provides actionable strategies for integrating AI into cultural industries, bridging heritage and technology to drive sustainable innovation.

### Museum mobile APP design based on user experience

***Yuhan Zhang, Hao Wu, Mingyi Zhong, Xiaoya Zhou***
***Sichuan Normal University***

This paper presents the Chinese Cizhou Kiln culture via a User Experience (UX) based mobile APP. By applying Garrett's UX methodology, this research proposes a ' Culture-UX Integration Framework '. Section 1 introduces the digital background for heritage designs. Section 2 describes the Cizhou Kiln development challenges. Section 3 provides the examples of the existed crafts APP designs. Section 4 ilustrates the Hi-Fi prototype. Section 6 contains the evaluation and validation parts of this work, and this paper ends by Section 7, the conclusion. This paper contributes a novel of the knowledge that design paradigm balancing heritage preservation and functionality, validated via testing. The authors' framework offers replicable methods for digital heritage design， By merging aesthetics, function, and culture, it advances preservation.

## Session Chair: Yong-Gyun Ghim, University of Cincinnati, United States of America

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Unlocking product ecosystem insights: Analyzing customer sentiment and interoperability through video reviews

***Kangcheng Lin, Harrison Kim***
***University of Illinois at Urbana-Champaign, USA***

This paper introduces a novel methodology for analyzing customer preferences within product ecosystems by leveraging video reviews from social media platforms. The approach includes three stages: collecting and preprocessing video reviews, extracting product features using Latent Dirichlet Allocation (LDA), and analyzing sentiment with the VADER package. By utilizing video reviews, this study captures a more detailed and structured understanding of customer experiences compared to traditional textual reviews, offering actionable guidance for product interoperability and user sentiment analysis. The research highlights the importance of understanding the relationships between products and their accessories, providing specific design insights for creating cohesive product ecosystems that resonate with users on both functional and emotional levels.

### Exploring dynamic movement representations in context using generative AI: Effects of media types on the evaluation of service robot morphology

***Yong-Gyun Ghim***
***University of Cincinnati***

With the increase of service robots, understanding how people perceive their human-likeness and capabilities in use contexts is crucial. Advancements in generative AI offer the potential to create realistic, dynamic video representations of robots in motion. This study introduces an AI-assisted workflow for creating video representations of robots for evaluation studies. As a comparative study, it explores the effect of AI-generated videos on people's perceptions of robot designs in three service contexts. Nine video clips depicting robots in motion were created and presented in an online survey. Videos increased human-likeness perceptions for supermarket robots but had the same effect on restaurant and delivery robots as images. Perceptions of capabilities showed negligible differences between media types. No significant differences in the effectiveness of communication were found.

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### ★ Towards automated video-based human behavior analysis: Leveraging AI capabilities for spatial behavior detection

***Shuyun Liu, Chris McTeague, Susanne Dreyer, Katja Thoring***
***Technical University of Munich***

To investigate human behavior in spatial environments, researchers commonly implement video-based behavioral analysis, which is time-consuming and tedious. With improvements in algorithmic performance and expansions in behavior datasets, vision-based AI demonstrates great potential to support human behavior analysis and understanding in design research automatically. To bridge this gap, we proposed a framework for utilizing vision-based AI models for spatial behavior analysis tasks in design research and utilize it in applications. This work offers new insights for design researchers, pointing toward strategies for refining AI-enhanced human behavior analysis and integrating emerging AI technologies into the study of human behavior in design settings.

### Challenges experienced by disabled people when traveling on and interacting with an autonomous bus

***Julian Faig, Gregory-Jamie Tüzün, Daniel Roth, Matthias Kreimeyer***
***University of Stuttgart***

Traveling on and interacting with an autonomous bus confronts disabled passengers with a handful of different and unknown challenges in terms of accessibility. To address this, a user journey was developed that includes the challenges for disabled passengers when traveling and interacting with an autonomous bus. The user journey provides a chronological list of occurring challenges for passengers with a disability. With the help of three qualitative studies in which four bus operators, ten bus drivers and 25 disabled passengers participated, the challenges of the user journey could be identified and some important requirements for possible solutions could be determined. By identifying the challenges, solutions can now be developed so that disabled passengers can travel on an autonomous bus and therefore the accessibility of autonomous buses can be increased.

## Session Chair: Ralf Stetter, University of Applied Sciences Ravensburg-Weingarten, Germany

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Identifying measures to improve sustainability using the double diamond: A case study of industrial digital printers

***Klemens Hohnbaum[1], Philipp Schröder[1], Andreas Fill[1,2], Markus Mörtl[1], Markus Zimmermann[1]***
***1 Technical University of Munich, Germany; 2 Forschungsstelle für Energiewirtschaft (FfE), Germany***

Various methods, such as LCA, LCC, or circularity indicators, are used to integrate sustainability into product development. However, these approaches often require extensive expertise in both processes and sustainability, which is not always available in combination. This paper introduces a framework based on the double diamond model, structured into (1) a preliminary assessment, (2) a collaborative workshop, and (3) a prioritization process. It aims to help engineers identify sustainability improvements without requiring prior expertise. A case study on an industrial digital printing system identified five opportunities for enhancing sustainability. Three measures were validated using LCA and the RPR metric. The study resulted in seven principles for sustainable printer design, with a lightweight door design, reduced number of rivets, and logistical improvements as key outcomes.

### Function-oriented system design for resilience and sustainability

***Udo Pulm[1], Ralf Stetter[2]***
***1 University of Applied Sciences Hamburg, Germany;***
***2 University of Applied Sciences Ravensburg-Weingarten, Germany***

The main objective of this paper is the investigation of possibilities to enhance the resilience and sustainability of technical systems by means of function-oriented system design. Design for Resilience aims at creating technical systems capable of withstanding and adapting to internal and external changes. Design for Sustainability has the objective to create solutions that meet present needs without compromising future generations, for instance by means of avoiding environmental destruction, improving resource efficiency, and achieving a long-term ecological balance. Function-oriented design is the most abstract form of solution generation. This paper presents arguments to verify the hypothesis that function-oriented system design is a prerequisite for both Design for Resilience and Design for Sustainability, discusses connections between both aspects, and proposes a common process.

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### Exploring design trade-offs among sustainability, performance, and manufacturability when considering integration of new technologies

***Julian Martinsson Bonde[1], Ola Isaksson[1], Timos Kipouros[2], Michael Kokkolaras[3], Petter Andersson[4]***
***1 Chalmers Tekniska Högskola; 2 University of Cambridge; 3 McGill University; 4 GKN Aerospace***

To meet the upcoming sustainability challenges, aerospace manufacturers need to develop products that both address complex sustainability factors and ensure profitable realization. Furthermore, the sustainability perspective needs to be lifted from focusing on carbon emissions, and broadened to include a system-level socio-ecological view. Manufacturers are thus challenged to balance sustainability, manufacturability, and performance, but lack the methods and tools to make well-informed decisions. We propose a method for conducting multi-domain trade-off studies in the early design phase. A functional architecture modelling approach is utilized to model performance and manufacturing aspects. Together with a relative sustainability fingerprint conducted on design alternatives, design spaces can be explored with respect to performance, manufacturability, and sustainability.

### Design framework for circular and sustainable packaging solutions

***Rizwan Khan Pathan, Marco Aurisicchio***
***Imperial College London***

Packaging waste contributes significantly to resource depletion and pollution. Despite the crucial role of packaging in product preservation, its environmental impact has become a major issue. Addressing the circularity and sustainability (C&S) of packaging by design offers a route to mitigate these impacts and reduce waste. However, integrating C&S into the current packaging design process presents significant challenges, such as conflicts between C&S and functional requirements and inadequate tools to provide packaging-specific practical solutions. To address these challenges, this study proposes a novel packaging design framework developed through literature review, brainstorming sessions, and field visits. By incorporating iterative design strategies and leveraging past design knowledge, the framework empowers designers to create packaging solutions that meet C&S requirements.

# P 08-8: Requirements and Data Mangement 2

## Session Chair: Antoine Bordas, Mines Paris, France

## Location: ECSS 2.201

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### ★ AI-based management and generation of non-functional requirements in vehicle development and integration

***Mahmoud Bazzal[1,2], Adriana Lungu[2], Benjamin Kruse[2], Ruslan Bernijazov[1], Roman Dumitrescu[1]***
***1 Paderborn University, Paderborn, Germany; 2 AUDI AG, Ingolstadt, Germany***

Developing products with diverse features presents challenges, especially when involving multidisciplinary teams and managing extensive Compliance Requirements (CRs). Ineffective handling of CRs can lead to inconsistencies in subsystem designs or failures. This study introduces an application of Quality Function Deployment to integrate CRs systematically in design lifecycle. The proposed approach utilizes a multi-layered matrix to translate CRs to specific design parameters, cascading requirements to subsystems and engineering directives. A case study on Sunswift Racing, UNSW solar car team, demonstrates the method's efficacy in embedding compliance in iterative design, enhancing cross-disciplinary collaboration, ensuring adherence to CRs. Findings present a robust traceability model linking CRs to design parameters, offering a replicable solution for multidisciplinary design challenges.

### An innovative Quality Function Deployment approach to manage design requirements in a team design

***Andy Danis, Manan Rathi, Vaishnavi Nanda Kumar, Direshkrishna Roshandeivendra, Shourya Nitin Saklecha, Ilina Sharma, Christopher Winkle, Naveen Thayyil, Shiva Abdoli***
***University of New South Wales, Wales***

The main objective of this paper is the investigation of possibilities to enhance the resilience and sustainability of technical systems by means of function-oriented system design. Design for Resilience aims at creating technical systems capable of withstanding and adapting to internal and external changes. Design for Sustainability has the objective to create solutions that meet present needs without compromising future generations, for instance by means of avoiding environmental destruction, improving resource efficiency, and achieving a long-term ecological balance. Function-oriented design is the most abstract form of solution generation. This paper presents arguments to verify the hypothesis that function-oriented system design is a prerequisite for both Design for Resilience and Design for Sustainability, discusses connections between both aspects, and proposes a common process.

# P 08-8: Requirements and Data Mangement 2

## Location: ECSS 2.201

Time: Thursday, 14/Aug/2025: 9:00am - 10:00am

### The unique feature of designing with digital twin uncovered by design theory

***Flora Mercat, Pascal Le Masson, Benoit Weil***
***Mines PSL***

Digital Twins are widely recognized as a transformative technological trend, yet their potential to foster innovation, particularly their generative capabilities, remains underexplored. This paper investigates how they can transcend traditional optimization roles to serve as tools for advancing knowledge and generativity in the design of their physical counterparts. Leveraging C-K theory, a framework is presented for modeling design processes with Digital Twins, characterizing design scenarios and identifying two distinct forms of generativity. An illustration of these results shows how designers can leverage Digital Twin reflexive capacity to challenge and reconfigure underlying knowledge of their physical counterparts. The transformative value of this reflexivity, combined with remodeling capabilities, is highlights the exploration of new design pathway for Digital Twins themselves.

### Navigating viewpoints in MBSE: Challenges, potential and pathways for stakeholder participation in industry

***Felix Förster[1], Christian Koldewey[2], Ruslan Bernijazov[2], Roman Dumitrescu[2], Nikola Bursac[1]***
***1 ISEM – Institute for Smart Engineering and Machine Elements, Hamburg University of Technology (TUHH);***
***2 Advanced Systems Engineering, Heinz Nixdorf Institute, Paderborn University***

Model-based Systems Engineering (MBSE) supports managing complex engineering projects. A pivotal element of MBSE is the concept of views which provide tailored representations of a system model to address stakeholder concerns. Despite standards describing the use and generation of views, the adoption and practical implementation of MBSE views and viewpoints in industrial practice remain insufficiently explored. Interviews with German practitioners reveal a disconnect between theory and practice: views and viewpoints and the involvement in MBSE are often limited to technical experts, excluding non-technical stakeholders. High complexity, abstract representations, and tool-related barriers impede broader engagement. The findings suggest stakeholder-specific, accessible visualizations integrated into easy-to-use tools to improve understanding, collaboration, and decision-making.

## Session Chair: Charlie Ranscombe, Swinburne University of Technology, Australia

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Visual communication in engineering design: Impact of line-work in explanative sketching

***Shiho Nakamura, Dingmohen Li, Julie Linsey***
***Georgia Institute of Technology***

As conceptual design sketches are a common tool used to communicate between team members, it is important to understand the relationship between sketch characteristics and engineers' perceptions. This study evaluates 4 line styles common in many sketch techniques: the Single Line, Feathered Line, Heavily Feathered Line, and Variable Line. 40 mechanical engineers ranked preferences of complex engineering products in these line styles and provided adjectives to describe their choices. Results show that engineers preferred the Single Line, which had the common adjectives of clear and professional. The findings suggest that engineers should generally be learning and using a single, uniform and clean line style.

### A generic framework for the collaborative and creative generation of lightweight and sustainable products

***Kristian König[1], Simon Zeidler[2], Florian Kößler[2], Jürgen Fleischer[2], Michael Vielhaber[1]***
***1 Saarland University, Germany; 2 Karlsruhe Institute of Technology, Germany***

The growing demand for responsible resource use presents a significant challenge in today's time-, cost-, and quality-driven product development. Therefore, this paper explores integrating creativity techniques into early development phases to achieve innovative, lightweight, and sustainable designs. Using a case study on extending the useful life of a bicycle trailer, a generic framework is introduced, aligning lightweighting and sustainability objectives in the idea generation process. Lessons learned highlight the critical role of the moderator, the importance of an iterative process, and the need for guidelines on method selection. The findings provide actionable recommendations for fostering sustainable innovation in lightweight design and form a basis for further research on adapting creativity techniques to sustainability goals.

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Improving the quality of data in the world café method: the crucial role of the table hosts

***Annika Klatt[1], Eveline van Zeeland[1], Jörg Henseler[1,2]***
***1 University of Twente, Netherlands; 2 Universidade Nova de Lisboa, Portugal***

The World Café method is an explorative research method that includes elements of participatory and qualitative research and is suitable for design science. The iterative approach and usage of the wisdom of the crowd enable researchers to collect data in small and large groups in a cost- and time-efficient way. However, researchers lack guidance on how to scientifically conduct the method from a process perspective and what they can do to improve the quality of the data collected. Regarding that last perspective, the table hosts play a crucial role. To solve this, we designed a Three-Phase Blueprint of the World Café method, which includes a three-step instruction procedure for preparing the table hosts. This instruction is an artifact that we tested and evaluated for its effectiveness.

### Training as an affordable and powerful lever to stimulate the evolution dynamics of a newly designed technology platform at the frontier between academia and industry

***Agathe Gilain[1,2], Patrice Aknin[1], Claudiu Balan[1], Pascal Le Masson[2], Milad Leyli Abadi[1], Benoit Weil[2]***
***1 IRT SystemX; 2 Mines Paris - PSL***

Technology platforms spanning several scientific and technological fields hold great promise, both as future innovative tools for industry and as future experimental tools for academia. However, some of their characteristics are also still unknown and need to be designed. A classical approach to initiate their evolution dynamics is to seek funding for a subsequent design project. Using a single case study, we show that a much less costly approach is possible: adding training to the platform can play a central role in increasing the intensity of its use, with both scientific and industrial impacts. Yet, this approach requires that the training knowledge enables the exchange of 'independent knowledge' between platform designers and users: this demanding condition requires further research to characterise this promising training model which we propose to call "double impact training".

## Session Chair: Stanko Škec, University of Zagreb, Croatia

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Exploring the relationship between stakeholder identification and divergent thinking on design teams

***Jenn Campbell, Yakhoub Ndiaye, Jeremy Tull***
***University of Arkansas***

In this paper, we explore the relationship between divergent thinking and stakeholder identification on 15 student engineering design teams. We examine the relationship between fluency, originality, flexibility, and elaboration on the Alternate Uses Task (AUT), a common measure of divergent thinking, and in stakeholder identification. We find fluency and originality to be positively and statistically significantly correlated between the AUT and stakeholder identification task. Flexibility was positively correlated and elaboration was negatively correlated; both lacked statistical significance. Our results suggest that divergent thinking and stakeholder identification may be correlated, and leveraging exercises to improve divergent thinking may also help improve stakeholder identification. Future work can continue to explore this relationship with larger sample sizes and additional tasks.

### Investigating relationships between performance and workload in CAD tasks

***Fanika Lukačević[1,2], Niccolò Becattini[2], Stanko Škec[1]***
***1 University of Zagreb, Croatia; 2 Politecnico di Milano, Italy***

CAD tasks require engineering designers to manage cognitive, perceptual, and motor demands while solving complex design problems. Understanding the relationship between workload (WL) and CAD performance is essential for improving design outcomes and processes. However, this relationship, particularly under varying task complexities, remains insufficiently explored. This study investigates WL-performance relationships in two CAD modelling tasks of differing complexity. WL was measured with NASA TLX, including its individual components. CAD performance was evaluated and described through outcomes and processes using multiple metrics. The results revealed significant monotonic relationships between WL and performance, with stronger correlations in the high-complexity task.

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Bridging the gap: The role of designer's awareness in co-design with people with lived experience

***Hilde Van Dyck[1], Lore Brosens[2,3], Melis Örnekoğlu Selçuk[2,3], Francesca Ostuzzi[2,3], Kristof Vaes[1]***
***1 University of Antwerp, Faculty of Design Sciences, Department of Product Development;***
***2 Ghent University, Department of Industrial Systems Engineering and Product Design, Kortrijk, Belgium;***
***3 Design.Nexus, Ghent University, Kortrijk, Belgium***

This paper, positioned within two universities' contexts on design education, explores the critical role of awareness in co-design with individuals who have lived experiences. The study introduces a SkillsLab designed to prepare students for managing awkward moments during co-design sessions. A SkillsLab is an intensive learning activity combining hands-on practice, theoretical insights, and practical exercises to bridge the gap between theoretical knowledge on a topic and the real-life application of this knowledge in a project-based setting. The learning activity aims to enhance students' confidence and skills in navigating awkward moments in co-design. The findings suggest that such educational interventions can significantly improve students' preparedness for real-world co-design challenges, fostering a more inclusive and empathetic approach to design.

### Silent streets and smart signals: Insights for the design of future electric autonomou vehicle interface

***Teresa Monti, Graziana Blandino, Francesca Montagna***
***Politecnico di Torino, Italy***

The increasing number of accidents involving electric vehicles (EVs) and pedestrians underscores the need of enhancing pedestrian safety. Autonomous vehicles (AVs), which have been introduced to mitigate traffic injuries caused by human error, still miss pedestrian trust due to the absence of a human driver. To improve pedestrian perceptions, EVs and AVs must integrate communication interfaces. This study administers two questionnaires to assess pedestrians' emotional responses when crossing in front of EVs and AVs, and their preferences of modes of interaction. Vehicles' ability to communicate their intentions through visual signals results crucial for pedestrians. Finally, findings regarding signals effectiveness when interacting with EVs and AVs allow for guidelines to emerge for the design of EAVs interfaces, offering valuable insights for the development of such vehicles.

# P 09-3: Sustainable Design and Education

## Session Chair: Massimo Panarotto, Politecnico di Milano, Italy

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Second life product strategies leading to LCA ambiguity: challenges for sustainable design

***Niccolo Becattini, Massimo Panarotto, Gaetano Cascini***
***Politecnico di Milano***

Current quantitative methods for estimating product-related environmental emissions face limitations in supporting sustainable design, particularly in second-life product strategies. This paper highlights challenges in accurately assessing emissions and environmental impacts under existing regulations, which often fail to reward designs enabling circularity. Through examples of current practices, it underscores methodological ambiguities and regulatory gaps, proposing a research agenda for improved tools and frameworks. These advancements aim to better support the design, production, and certification of sustainable, second-life-ready solutions, fostering more effective environmental impact reduction. Additionally, the paper emphasizes the need for regulatory adaptation to incentivize circular design practices, ensuring a fair evaluation of products conceived for second-life applications

### Regenerative responsibility: A strategy for design education

***Luis Miguel Gutierrez Contreras***
***Instituto Tecnologico y de Estudios Superiores de Monterrey, Mexico***

Regenerative Responsibility (RR) emerges as a transformative framework for design education, addressing the urgent need for sustainability and ethical practices in the field. By integrating principles of ethics, regeneration, and pedagogy, RR redefines the role of designers as agents of systemic change. It incorporates methodologies such as project-based learning, systems thinking, and ethical reflection to align design practices with social, environmental, and economic considerations. Regeneration thinking empowers future designers to adopt innovative and responsible approaches, positioning design education as a catalyst for addressing global challenges and fostering regenerative practices across disciplines.

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Exploring the product carbon footprint through gamification: A learning tool for children

***Jan Oliver Osterod, Umar Ali, Benjamin Schleich***
***Technical University of Darmstadt***

Sustainability is one of the most important topics of our time and will continue to stay relevant, as mitigating the effects of global warming will stay a challenge for decades to come. Therefore it is of high importance to teach children the concepts of sustainability and how their actions can affect the climate. We design an experiment for an open day at our university consisting out of a physical and digital demonstrator that aims to teach the consequences of material choice in a product to children aged six and above. To achieve this, a simple carbon footprint calculation for a rocket is conceptualized. The users can manipulate several interacting parameters, creating a complex challenge. The complex topic of sustainability is augmented with gamification elements to provide a level of motivation and interaction and achieve a better accessibility.

### Redesigning reusable surgical gowns: usability and innovation for sustained adoption

***Charlotte Harding[1], Regan Watts[1], Gunter De Win[2], Ingrid Moons[1], Els Du Bois[1]***
***1 University of Antwerp, Belgium; 2 University Hospital of Antwerp, Belgium***

To support the transition towards a circular economy in hospitals, this qualitative study aimed at understanding how the adoption of reusable surgical gown can be facilitated. It investigates design features that enhance usability and promote sustained (re)use. A wearing test identified difficulties in wearing reusable gowns. Data collection included observations of 34 surgeries and a survey completed by 73 respondents. Thematic analysis revealed opportunities to improve usability, such as optimising packaging to speed up donning, a wider neck opening to reduce discomfort, and incorporating 'tearable' closures to simplify doffing. Innovation strategies relevant to the users involve thermal regulation, monitoring gown performance, and including reusable gowns in custom procedure tray packaging. These findings are discussed in relation to design adjustments and value-chain partners.

# P 09-4: Design Creativity and Team Performance

## Session Chair: Joshua Summers, University of Texas at Dallas, United States of America

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Facing the future: Trends in development environments that enable engineers to thrive

***Katharina Ritzer[1], Fabian Dernbach[2], Christoph Kempf[2], Albert Albers[2], Nikola Bursac[1]***
***1 ISEM, Hamburg University of Technology (TUHH); 2 IPEK, Karlsruhe Institute of Technology (KIT)***

The evolving landscape of engineering is shaped by trends such as digitalization, sustainability, and globalization. While these trends impact product development, their direct effects on engineers remain underexplored. This study investigates how current trends shape engineering work environments and identifies key factors that enable engineers to thrive. Using a mixed-method approach, we conducted qualitative interviews and a quantitative survey with 122 engineers across industries. Our findings reveal that trends influence collaboration, autonomy, stakeholder involvement, and digital tool integration. The results emphasize the need for human-centered approaches, such as New Work, to balance flexibility and structure. The insights contribute to designing adaptive engineering environments that foster resilience, well-being, and innovation.

### Managing design heritage - Grandfather rights as a precursor for creative preservation

***Nicolette Lakemond, Gunnar Holmberg***
***Linköping University, Sweden***

This paper explores how creative preservation, affected by a regulatory framework, unfolds in the design of complex systems. Based on a case study of the Boeing 737 aircraft, it focuses on the role of grandfather rights, as part of the regulatory framework of aircraft design, as a precursor for creative preservation. The paper analyzes three design decisions related tot the evolving Boeing 737 aircraft models over a period of six decades and highlight the changing logic of creative preservation in relation to technology maturity, increasing complexity of design decisions, and expanded stakeholder involvement. Overall, the paper demonstrates that the management of design heritage is a 'living system' and that foundational practices may slowly become ineffective.

# P 09-4: Design Creativity and Team Performance

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### ★ Case study: Is there a space for TRIZ in the era of ChatGPT?

***Vanja Čok[1], Luka Samsa[1], Miha Brojan[1], Jože Tavčar[2], Nikola Vukašinović[1]***
***1 University of Ljubljana, Facutly of Mechanical Engineering; 2 Lund University, Faculty of Engineering***

This study investigates the integration of Large Language Models with the TRIZ to improve problem solving and innovation in industrial product development. By combining the structured problem-solving framework of TRIZ with LLMs to process large amounts of data and generate ideas, this hybrid approach seeks to overcome the limitations of traditional TRIZ and optimize solution generation. In a case study conducted in an industrial setting, the effectiveness of this integration was investigated by comparing team-generated solutions with those derived using LLMs and TRIZ-enhanced LLMs. The results show that while LLMs accelerate idea generation and provide practical solutions, the additional structure of TRIZ can provide unique insights, however depending on the application context.

### Establishing a practical coding scheme to computationally measure concept maps

***Pavan Kumar, Joshua Summers***
***University of Texas at Dallas***

This paper presents a systematic method and coding scheme to convert concept maps into bi-partite graphs that can be computationally evaluated for topological complexity measurements. The coding scheme is focused on splitting concepts with multiple elements embedded and linking these objectively. The guidance for this is established and the method presented with examples. The motivation for this work is to establish a means to objectively compare concept maps generated by individuals at the beginning and the end of an intervention to measure the impact of the intervention. The reliability of the coding scheme is presented in separate work.

## Session Chair: Chris Snider, University of Bristol, United Kingdom

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Understanding prototype testing: How student designers structure sessions and ask questions with stakeholders

***Pa Chang Vang[1,2], Carlye Anne Lauff[1,3]***
***1 College of Design, University of Minnesota, Twin Cities, USA; 2 Human Factors & Ergonomics Program, USA; 3 School of Product Design, USA***

While prototype testing with stakeholders is key for valuable feedback in iterative design, there is limited research on how novice designers, who lack the relevant experience, solicit meaningful feedback. This paper analyzes 30 prototype testing sessions from five student design teams to understand how novices structure their testing time by identifying and reporting the instances of testing interactions and types of questions within different contexts. Initial findings show that novices effectively set up testing, engage in active listening, and ask more close-ended follow-up questions. However, they rarely conclude sessions, seek stakeholder questions, and use fewer leading questions in later testing sessions. This preliminary understanding highlights opportunities to strengthen novices' skills in prototype testing and how testing approaches affect stakeholder feedback quality.

### A compass to navigate the multiple dimensions of prototyping

***Régis Lomba, Benoit Herman, Benoit Raucent***
***Université Catholique de Louvain, Belgium***

The emergence of new technologies, such as additive manufacturing, and places to promote access to these equipment's, such as fablabs and makers space, has supported the development of new methodologies based on prototyping. From problem definition to customer validation, prototypes can support the different phases of the innovation process. The biggest challenge being to design the right prototype to address the objective of each phase. Here, we propose to transpose and develop a model from human-computer interaction (Houde & Hill, 1997) (Yang, 2005) to the field of design sciences. The model intends to separate design issues into the “role”, the “look and feel” and the “implementation” axes. Next, we illustrate its potential through the characterization of different prototypes fabricated within the product development process of a tool design to unbend electric pylons.

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Automatic generation of product architectures with application to prototyping in mechatronics

***PJohann Maria Maximilian Amm, Markus Zimmermann***
***Technische Universität München, Germany***

Generating electronic solutions to be integrated into mechatronic prototypes can be challenging for nonexperts. Available electronic modules already implement certain functionalities. Selecting the suitable modules and connecting them in the right way can be tricky. This paper presents a method that (1) maps project requirements onto sets of electronic modules and microcontrollers from a database, (2) optimizes module selection and combinations using search algorithms based on graph theory, (3) maintains electrical feasibility, (4) and generates a bill of materials. The result is a blueprint that describes how to connect the selected modules to enable the desired functionalities.

### Evaluation of self-directed usage of parallel and iterative prototyping strategies by first-year engineering students

***Kristoffer Sjolund[1], Brock Brito[1], Alexander Murphy[2], Julie Linsey[1]***
***1 Georgia Institute of Technology; 2 Florida Polytechnic University***

Prototyping is an important component of the engineering design process and has become a frequently studied topic in engineering education. The iterative strategy of creating prototypes, where a single design is refined with repeated improvements, is widely taught and considered to be the default approach to prototyping. However, research has shown that a parallel approach to prototyping, where multiple concepts are tested simultaneously, has potential benefits when exploring a complex design space. Recent studies on parallel prototyping in first-year engineering classrooms have shown that students required to use a parallel strategy produced higher performing final designs than students who used an iterative strategy. This work places the parallel and iterative prototyping strategies in a typical classroom setting where first-year engineering students have control over their strategy.

## Session Chair: Filippo Chiarello, Università di Pisa, Italy

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Towards fostering human ownership in GenAI-assisted design

***Ye Wang, Jiwon Jun***
***Autodesk Research***

GenAI has significant potential to transform the design process, driving efficiency and innovation from ideation to testing. However, its integration into professional design workflows faces a gap: designers often lack control over outcomes due to inconsistent results, limited transparency, and unpredictability. This paper introduces a framework to foster human ownership in GenAI-assisted design. Developed through a mixed-methods approach—including a survey of 21 designers and a workshop with 12 experts from product design and architecture—the framework identifies strategies to enhance ownership. It organizes these strategies into source, interaction, and outcome, and maps them across four design phases: define, ideate, deliver, and test. This framework offers actionable insights for responsibly integrating GenAI tools in design practices.

### Artificial Intelligence (AI) in the design process—a review and analysis on generative AI perspectives

***Mohammad Mohiuddin Choudhury, Boris Eisenbart, Blair Kuys***
***Swinburne University of Technology, Australia***

The predominant adoption of artificial intelligence (AI) in the design process is constantly evolving with the continuous upgradation of generative AI tools. Current studies emphasised generative AI's role in individual disciplines, with limited understanding of its use across diverse design disciplines like product, fashion, and UX design. Therefore, the importance of this review is to explore the latest trends in utilisation, commonalities, and differences of generative AI tools and tasks, and AI types across design disciplines. With the assistance of Google Scholar, relevant papers were identified based on alignment with the review's scope. The study highlights the transformative role of tools like ChatGPT and DALL-E in enhancing creativity, ideation, and decision-making. The outcomes of the review offer insights for future systematic reviews and practical guidance for designers.

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Scaling generative design for production through the use of standard parts

***Jonathan Raines, David Barton, Ben Hicks***
***University of Bristol, UK***

GD tools can produce high-performing components with complex geometries that are challenging to conceive via traditional methods. While potentially disruptive, GD tools have yet to achieve widespread use in industry. One reason is that current GD tools are limited to manufacturing methods capable of producing intricate geometries that GD often creates such as 3D-printing. To overcome this barrier, this paper quantifies the benefit of altering generatively designed parts to use standardized elements like wire stock and sheet metal via processes such as CNC bending and water jet cutting. Using a parametric cost model, we show that parts incorporating standard components can halve the unit price for production volumes of only 4 parts. FEA reveals that replacing up to 60% of part volume has minimal impact on performance. Our findings highlight a gap and opportunity in existing GD research.

### Leveraging GenAI for technology foresight

***Kai Ellermann, Tobias Seidenberg, Laban Asmar, Jonas Knepler, Roman Dumitrescu***
***Fraunhofer IEM***

Facing increasingly dynamic market environments and global challenges such as climate change and resource scarcity, companies are under constant pressure to innovate and remain competitive. As technology is a key enabler, companies need to understand the drivers of technological change. Technology Foresight systematically identifies and analyzes emerging technologies to support engineering design decisions. However, the growing volume of data is outpacing manual processing capabilities. This research explores the integration of Generative AI to enhance Technology Foresight by automating technology analysis and information synthesis. This paper presents a comprehensive problem analysis, reviews existing solutions, and proposes a framework that demonstrates the potential of Large Language Models combined with a Retrieval Augmented Generation architecture to transform Technology Foresight.

# P 09-7: Complexity and Innovation

## Session Chair: Tucker Marion, Northeastern University, United States of America

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Formulating a decision parameter for implementation of product innovation ideas

***Sushil Chandra***
***BML Munjal University, India***

For a multi- product manufacturing organization, product innovation is a constant process. A question which every such organization must answer for every innovative idea is whether that idea is to be incorporated in the existing product as a continuous process or it should be implemented as a new product? This paper studies the impact of architectural and design factors on this decision and formulates a decision parameter to facilitate this decision. This has been done by studying various innovation ideas implemented at two motorcycle manufacturers, collected by studying their spare parts catalogues across models and the implementation decision in case of each idea. The study reveals a clear relationship between the factors and the decisions, and the formulated parameter can clearly demarcate the ideas between the two implementation choices.

### Advancing in-process innovation metrics: A framework for navigating uncertainty

***Tucker Marion[1], Fixson Sebastian[2]***
***1 Northeastern University, USA; 2 Babson College, USA***

Most innovation performance measurement approaches focus on ex-post outcome data, leaving decision-makers without timely guidance during the early phases of new product development (NPD). This gap is particularly critical in high-risk, high-regulation industries such as Urban Air Mobility (UAM), where long development cycles, regulatory hurdles, and uncertain user adoption demand real-time, in-process innovation metrics. In this paper, we propose a Desirability-Feasibility-Viability (DFV) framework that links key innovation phases (Discovery, Development, and Commercialization) to leading indicators that track innovation progress before market entry. Using UAM as an illustrative case study, we demonstrate how our framework enables stakeholders to navigate uncertainty, optimize resource allocation, and make data-driven innovation decisions.

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Component classification for modularization of passenger vehicles for enabling lifetime extension within a circular economy

***Jörn Hasenkrug, Steven Peters***
***Technical University of Darmstadt, Germany***

Extending the lifetime of products is one objective of a Circular Economy. The lifetime of a vehicle is limited not only by wear, but also by declining customer satisfaction. Customer satisfaction is related to the different types of quality. Components aim for different types of quality. That is why modularization is seen as a possible enabler to facilitate both durability and adaptability in the vehicle structure. Additionally, extending their lifetime integrates passenger vehicles into a Circular Economy. This paper aims to define classes of components to support the development of a modular structure for passenger vehicles that is suitable for a Circular Economy. It provides four classes based on the relevance of components to customer satisfaction and their expected lifetime. This enables the targeted development of R-strategies for components.

### Functional decomposition of technical products based on large language models and Monte Carlo tree search

***Meno-Said Haddad, Arthur Seibel***
***Leuphana University Lüneburg***

Functional decomposition (FD) is essential for simplifying complex systems in engineering design but remains a resource-intensive task reliant on expert knowledge. Despite advances in artificial intelligence, the automation of FD remains underexplored. This study introduces the use of GPT-4o, enhanced with a proposed Monte Carlo tree search for functional decomposition (MCTS-FD) algorithm, to automate FD. The approach is evaluated qualitatively by comparing outputs with those of graduate engineering students and quantitatively by assessing metrics such as structural integrity and semantic accuracy. The results show that GPT-4o, enhanced by MCTS-FD, outperforms smaller models in error rates and graph connectivity, highlighting the potential of large language models to automate FD with human-like accuracy.

## Session Chair: Noe Vargas Hernandez, UTRGV, United States of America

## Location: ECSS 2.201

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Opportunities and challenges of AI in design: A practical study from the manufacturing industry

***Ji Han, Pingfei Jiang, Saeema Ahmed-Kristensen***
***University of Exeter, UK***

Artificial Intelligence (AI) techniques are increasingly explored to support design activities within the manufacturing context mainly driven by the development of AI technologies. However, few studies were conducted in practice from industrial perspectives. This research aims to understand the opportunities and challenges of AI in design in the real world. A workshop involving twenty-five participants from more than ten manufacturing firms is organised to collect relevant information. The opportunities and challenges identified are categorised by adopting a readily available data-driven design framework. Seven research directions are proposed accordingly to address the industry challenges and opportunities. This research serves as a guide for ensuring future AI in design research and applications are grounded in practice to bridge the gap between academic research and industry practice.

### Data-driven decision support in the design and controlling of Systems Engineering Transformation: A maturity model

***Iris Graessler, Benedikt Grewe, Luc Felgen***
***University Paderborn (HNI), Germany***

Challenges of increasing system complexity and the need for interdisciplinary collaboration are prompting companies to reorganize towards Systems Engineering (SE). As part of the implementation of large-scale transformation programs, transformation progress is of great interest to management and employees involved. Existing maturity models lack measurable variables and reliable forecast. For this reason, a maturity model for evaluating SE Transformation is developed, that builds on quantitative metrics and enables an overarching view on transformation considering cultural aspects. Literature-based criteria for evaluating SE Transformation lay the foundation for measures and referenced metrics and indicators. Due to its data-centricity, the model presented enables a more comprehensive, fact-based decision-making basis for the design and steering of SE Transformation programs.

## Location: ECSS 2.201

Time: Thursday, 14/Aug/2025: 10:30am - 11:30am

### Exploring the role of human data in data-driven design

***Karl Johnson, Saeema Ahmed-Kristensen***
***University of Exeter***

Human data has significant value in Data-Driven Design, offering opportunities for user-centered product and service development. This paper explores how human data, categorized into behavioral, physiological, feedback, and emotional types, contributes to problem framing, iterative refinement, customization, and emotional design. Real-world case studies from academic literature and industry demonstrate how human data enables adaptive, personalized, and emotionally engaging solutions. Ethical challenges, including privacy, bias, and transparency, are explored, highlighting the importance of responsible data practices. The analysis underscores human data's value in combining technical precision with empathetic design, fostering innovation and enhancing user experiences while promoting ethical use through principles of privacy, consent, and inclusivity.

### Reducing uncertainties in data & information - an ontological approach to support satellite development projects

***Emir Gadzo, Alexander Koch***
***Universität der Bundeswehr München***

The evolving needs of customers and stakeholders necessitate the collaboration of diverse system elements within a cyber-physical, socio-technical network. Such Sociotechnical systems, are characterized by numerous complex interdependencies as well as by endogenous and exogenous influences. A key issue that developers must address is the mitigation of data and information uncertainties. This paper introduces an ontological approach to facilitate the identification and mitigation of uncertainties in data and information within a model-based methodology for satellite development projects.The work outlines the results of preliminary studies forming the foundation for this ontological concept. The proposed approach comprises an overarching General Ontology, complemented by a Uncertainty and Structure Ontology, creating a framework for uncertainty management in satellite development.

# P 10-1: Design Management 2

## Session Chair: Nikola Bursac, Hamburg University of Technology (TUHH), Germany

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### A systematic literature review on emerging technology risks in Industry 4.0/5.0: Identification, clustering and developing mitigation strategies

***Dominik Fuchs1, Blair Kuys1, Boris Eisenbart1, Kilian Gericke2***
***1Swinburne University of Technology, Australia; 2University of Rostock, Germany***

This systematic literature review comprehensively assesses the risks associated with implementing Industry 4.0/5.0 technologies. It clusters these risks into six groups (strategic, financial, operational, technological, environmental, and sociocultural). Using a PRISMA-guided approach, the analysis of 83 peer-reviewed papers identified 36 unique risks out of a total of 811. The findings reveal critical challenges, including in cybersecurity threats, financial burdens, technological obsolescence, and workforce adaptation. These results provide a structured risk categorization that can assist enterprises, in effectively mitigating risks and aligning their strategies with Industry 4.0/5.0 transitions. This framework closes knowledge gaps and offers actionable insights for a robust and sustainable implementation.

### ★ Smart services in manufacturing - approaches for the organizational design of technical service organizations for smart service delivery

***Laura Wagner[1], Dr. Ing. Philipp Humbeck[2], Tom Koerner[2], Maximilian Rolle[2], Steffen Wagenmann[2]***
***1 TRUMPF Lasersystems for Semiconductor Manufacturing SE; 2 TRUMPF Werkzeugmaschinen SE + Co.KG***

The complexity and dynamism of global markets is driving the manufacturing industry to evolve from product-based business models to solution providers by integrating smart services. This shift poses challenges, particularly for the organizational design of technical service organizations that deliver these services. Despite the growing importance of servitization, research on the organizational impact of smart services remains limited. Combining a systematic literature review and case study approach with expert interviews, this study examines how smart services affect organizational design of technical service organizations, in the following dimensions: structure, people, processes, and reward systems. The findings offer initial design approaches for manufacturers transitioning to smart service delivery and advance theoretical and practical insights in this field.

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Analyzing organizational capability using the TASKS framework

***Jiami Yang, Hongyi Cao, Xiaoying Wang, Yong Zeng***
***Concordia University***

Organizational capability is key to achieving strategic goals and adaptability. This study applies the TASKS framework to evaluate taskload, affect, skills, knowledge, and stress using a questionnaire developed through the Environment-Based Design (EBD) methodology. A structured perception-centered evaluation was conducted to assess employees' perceptions of organizational alignment, with middle managers' responses serving as a reference. Findings emphasize the need for better communication, leadership engagement, and goal clarity to enhance transformation readiness. The TASKS framework's perception-centered evaluation assesses organizational capability and identifies role-based misalignments. Future research will expand the framework's application to validate its effectiveness and refine strategies for enhancing organizational capability.

### Early engagement in co-designing Mixed Reality assembly instructions in manufacturing industry

***Andreea Strineholm[1], Jens Von Axelson[2], Bengt Köping Olsson[1], Nils Erlands[1]***
***1 Mälardalen University; 2 Mälardalen Industrial Technology Center***

This paper presents a case study within a small manufacturing company, engaging in the early phases of co-designing Mixed Reality assembly instructions. Using generative tools through two co-design workshops, we engaged the participants in reflecting, visualising and defining their processes, needs, challenges and future ways of working in relation to new technological applications. We gained insights into the participants' current practices and identified areas where new technologies could improve these practices. We co-designed a lock assembly instruction paper prototype to use as support for future MR development, focused on their apprenticeship training. We also uncovered other areas of technological implementation, setting the framework for co-designing a customised production system.

# P 10-2: Collaborative Design 2

## Session Chair: Ross Brisco, University of Strathclyde, United Kingdom

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### A comparative analysis of synchronous and asynchronous computer-supported collaborative design

***Harris Maxwell, Ross Brisco***
***University of Strathclyde, Scotland***

This research aimed to explore the challenges designers face when using asynchronous collaboration methods across different time zones. A literature review revealed a knowledge gap in comparing synchronous and asynchronous collaboration methods and in comparing design students and professional practice. To fill this gap, a study was conducted with a group of engineering design students and practitioners asking them to conduct two design exercises, one synchronously and one asynchronously. The results highlighted unique challenges faced and that experience of design process had little effect on performance when using unfamiliar design tasks. The study contributes new insights and firsthand recommendations for design teams, educators and software developers.

### Supporting structured reflection in engineering design by chatbots: Potentials and concept for a reflection chatbot

***Theresa Ammersdörfer, David Inkermann***
***Technische Universität Clausthal (IMW), Germany***

Structured reflection can initiate learning, increase team performance and support engineering teams in adapting their engineering design activities or methods. Engineering teams with limited reflection experience use reflection often not effectively. Therefore, additional support in the implementation of reflection, guiding and structuring reflection and in providing goal-related reflection guiding questions is needed. To improve the quality of reflection and enable engineering teams to reflect, a chatbot-supported reflection concept to assist engineers is proposed in this contribution. For this purpose, the potential and challenges of existing chatbot approaches are analyzed and classified. Based on the reflection process and tools from preliminary work, use cases and an initial architectural reflection chatbot concept are developed and presented in this paper.

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### A framework of AI collaboration in engineering design (AICED)

***Chijioke C. Obieke[1], John Bridgeman[2], Ji Han[3]***
***1 Queen's University Belfast, United Kingdom; 2 University of Liverpool, United Kingdom;***
***3 University of Exeter, United Kingdom***

While performing design tasks, engineers rely heavily on their knowledge. However, the expanding knowledge space makes it impractical to perform the design tasks without external inputs. This study explores how AI can bridge the knowledge space expansion gap in design. The study introduces the AICED framework implemented as a web tool Pro-Explora, leveraging advanced multi-agent LLM technology to accelerate early-stage design tasks. Pro-Explora generates professional problem definitions, PDS documents, and unique solution concept images within five minutes, maintaining creative flow. Its effectiveness was validated in a real-life project, with outputs deemed highly relevant by experienced designers. The study highlights the AICED framework's industry implications, addressing required knowledge. This pioneering study opens new avenues for specific LLM applications in engineering design.

### Crafting the 'dream' design brief : Smells like team spirit

***Shakuntala Acharya[1], Mamata N. Rao[2]***
***1 Indian Institute of Technology Guwahati, INDIA; 2 National Institute of Design Bengaluru, INDIA***

Crafting the design brief is often the first task of the design process and an arduous one. Design brief serves as the guiding beacon for the designer or design team to understand needs and envision intent, position stakeholders, qualify requirements, identify key criteria, outline objectives, and clarify if the 'task' is in line with the ask. Literature reports on the process of 'briefing' and 'reframing', and further articulates the structural components of a brief. Vision, Need statement, Criteria; and Goals characterise the final state of a brief, yet designers struggle with the process. This paper investigates the quality and structuring of design briefs developed by novice designers, individually versus in multi-disciplinary design teams, to assess the implication of teaming up and finds a significant improvement. After all, design is a team sport!

# P 10-3: Design for a Circular Economy

## Session Chair: Albert Albers, Karlsruhe Institute of Technology (KIT), Germany

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Supporting medical phantom design through a comprehensive design catalogue for phantom materials

***Marie Wegner, Nadine MacMillan, Dieter Krause***
***Hamburg University of Technology (TUHH), Germany***

Medical phantoms are models used for imaging and therapy, enabling research, quality assurance, and training without human test subjects. Their development relies on selecting tissue-mimicking materials, however the lack of a holistic overview to guide this process poses challenges. This work presents a comprehensive design catalogue for phantom materials, offering a structured overview of materials and their imaging properties for computed tomography (CT), magnetic resonance imaging, and ultrasound, including parameters such as CT numbers, relaxation times, and acoustic properties. It is implemented as a digital tool with filtering options, enhancing usability and decision-making. Despite limitations from incomplete data in the literature, the catalogue establishes a groundwork for a standardized, expandable resource to support future phantom design.

### Towards design for cross-generational remanufacturing: Guidelines to enable a forward-looking circularity

***Leonard Tusch, Stian Nußbaumer, Michael Jäckle, Tobias Düser, Albert Albers***
***Karlsruhe Institute of Technology (KIT), Germany***

To enable a circular economy, remanufacturing is considered a key strategy due to the high level of value retention. However, for short-cycled products, the accelerated obsolescence of conventionally remanufactured products on the secondary market poses challenges to leverage the potential. Cross-Generational Remanufacturing (CG-Reman) has been developed as a new concept in response, which aims to restore used products into the latest generation for sale on the primary market. For its practical success, it is critical to support product engineers in designing products suitably. Hence, in this paper we further explore the overall CG-Reman process with a lifecycle description, derive requirements for the product's design and conduct a systematic literature review of 209 sources targeting selection, clustering and matching of Design-for-X (DfX) guidelines with the needs for CG-Reman.

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### An integrative perspective on digital technologies and circular economy: A systematic literature review

***Michel Scholtysik[2], Anja Rasor[1], Lisa Petzke[1], Christian Koldewey[1], Roman Dumitrescu[1,2]***
***1 Universität Paderborn - Heinz Nixdorf Insitut; 2 Fraunhofer Institute for Mechatronic Design***

Digital transformation has reshaped the manufacturing sector, driving innovation and new business models. Simultaneously, sustainability pressures and stricter regulations push companies to adopt circular economy (CE) principles, focusing on reducing, reusing, and recycling materials. This transition requires adapting business models, product design, and management while integrating processes such as reverse logistics. Digital technologies play a crucial role by enabling data generation, processing, and analysis, optimizing production, and reducing resource use. However, many companies face knowledge gaps regarding how to implement these technologies effectively for CE. This study addresses these challenges through a systematic literature review, offering a framework that links digital technologies to CE principles, focusing on slowing, narrowing, and closing material loops.

### Reusing used components in new product generations - a systematic literature review on challenges and future research

***Johannes Meyer, David Inkermann***
***Technische Universität Clausthal***

This paper presents a systematic literature review to figure out challenges of integration of used components into new product generations. Reuse of components is an essential strategy of circularity and is becoming highly relevant as resources are limited and sustainability requirements have to be meet across industries. The reuse process was examined from a constructive perspective. It was found that the reuse process is not uniformly defined and that there is a divergent understanding of it. This divergent understanding continues through the Reuse process steps and the added value of using Reuse. Various technical challenges of reuse were identified. These challenges were translated into requirements that are intended to enable reuse for used components. An initial concept for solving the design problem of integrating used components is proposed with the help of these requirements.

# P 10-4: Desing Teams and Human Factors

## Session Chair: Tomislav Martinec, University of Zagreb, FSB, Croatia

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### PhylOrg: Towards an efficient organizational design method by adapting phylogenetic analysis

***Olivier Bertrand[1,3], Mickaël Gardoni[2], Mike Burrows[4], Julie Stal-Le Cardinal[1,3]***
***1 Université Paris Saclay, France; 2 École de technologie supérieure (ÉTS), Canada;***
***3 CentraleSupélec, France; 4 Agendashift***

Organizational design implementations frequently fail, with existing dominant frameworks and tools, such as the ever-present maturity assessments, falling short in addressing the complex, nonlinear nature of socio-technical systems (STS). This paper introduces PhylOrg, a methodology leveraging phylogenetic analysis to guide organizational design by mapping evolutionary pathways of socio-technical traits (STTs). By identifying coherent and efficient sequences of change, PhylOrg minimizes resistance and aligns initiatives with organizational contexts. Grounded in theories of complex adaptive systems (CAS) and evolutionary processes, PhylOrg proposes to offer prescriptive, context-sensitive guidance to Organizational design leaders. A pilot study demonstrates PhylOrg's potential, highlighting foundational evolutionary traits as prerequisites for more advanced capabilities.

### Co-intelligence in design: The importance of trust in artificial intelligence

***Chiara Lelli[1,2], Filippo Chiarello[1,2], Vito Giordano[1,2]***
***1 Università di Pisa, Italy; 2 Business Engineering for Data Science Lab, Italy***

As Generative Artificial Intelligence (GenAI) gets integrated in design processes, building trust in these systems is critical for effective human-AI collaboration. This study introduces a framework aimed at translating the abstract concept of trust into practical strategies for design teams, focusing on four trust factors: transparency, accountability, similarity, and performance. We tested the framework's impact on trust-building and trust learning using a mixed-methods approach, incorporating design tasks and structured workshops involving university students.The results highlight the framework's ability to enhance participants' understanding of trust in AI. Insights from this study contribute to advancing educational approaches for embedding trust in AI-driven design, revealing that design activities alone are not enough to impact trust learning.

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### ★ Uncovering collaboration dynamics in design projects using network analysis and log data

***Lovro Sever[1], Tomislav Martinec[1], Matthew Mueller[2], Stanko Škec[1]***
***1 University of Zagreb, Croatia; 2 TBA***

This study explores the integration of network analysis and CAD/PDM log data to analyze collaboration and activity patterns in a multi-year engineering project. Using logs from a collaborative CAD platform with PDM features, the research examines team interactions and network evolution over time. Key findings reveal that early project stages featured smaller, denser networks, while later stages saw larger, less interconnected structures. Subteam formations were dynamic, with variations in size and number. Individual-level analysis showed that user influence, measured through eigenvector centrality, did not always align with activity volume. This work highlights the potential of CAD/PDM data for understanding collaboration dynamics and lays the groundwork for further studies on team interactions in design processes.

### Generative design as a means of effective communication in multidisciplinary teams: a systematic review

***Melissa Mireles Esparza, Ma. del Rosario Martínez Blanco, Luis Octavio Solís Sánchez***
***Autonomous University of Zacatecas***

This systematic review examines how generative design enhances communication and collaboration in multidisciplinary engineering teams. Using the PRISMA framework and CASP evaluation program, we analyzed 1,105 sources to assess its role in improving workflows, facilitating collaboration, and reducing communication gaps through CAD, algorithmic modeling, and AI-driven platforms. The findings show that generative design supports teamwork, optimizes design processes, and strengthens interdisciplinary collaboration. While widely used in architecture, aerospace, and automotive industries, its adoption in product design remains limited, presenting opportunities for further research and innovation. These insights contribute to a better understanding of how generative design can bridge communication barriers in engineering projects.

# P 10-5: Prototyping and Testing

## Session Chair: Srinivasan Venkataraman, Indian Institute of Technology Delhi, India

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### A configurable dynamometer to evaluate vehicle and battery performance of micromobility devices

***Ponaravind Muthaiah, Scott Zagorski, Austin Kress, Meredith Bartholomew, Nick Helber, Dale Andreatta, Gary Heydinger***
***S-E-A, USA***

The usage of micromobility devices is growing to promote sustainable transportation, prompting manufacturers and regulators to enable its safe integration into urban environments. This has created the need for a tool to evaluate such devices. This paper presents the development of a versatile dynamometer design for verification and validation of micromobility devices by emulating real-world conditions while capturing vehicle and battery performance in real-time. A custom Graphical User Interface (GUI) is used to control and configure the system, as well as enabling the user to analyze and save incoming data. Six devices were chosen from distinct categories to collect data and demonstrate the capabilities and modularity of the dynamometer. The results reflect the ability of the dynamometer to be used for standardized testing of various micromobility devices.

### Design of a wireless sensor network for load and deformation reconstruction for technical inheritance of gentelligent structural components

***Sören Meyer zu Westerhausen, Samuel Haußmann, Timo Stauß, Max Leo Wawer, Johanna Wurst, Roland Lachmayer***
***Leibniz University Hannover, Germany***

Sensor-integrating, "gentelligent" components allow to "inherit" operational loads-data for design optimisations from one generation to the next. For area-wide acquisition and reliable transmission of this data, wireless sensor networks (WSN) are often used, but small sensor nodes for reconstructing deformations and loads, so-called shape sensing, are rarely considered as well as a methodical development of such sensor nodes. This paper presents the development of a small sensor node in accordance to the VDI 2206 for shape sensing with a prototype with strain gauges, HX711 A/D converters and an Arduino Nano 33 IoT microprocessor. An infrastructured WSN is built and tested on an aluminium part at a test rig. The shape sensing is carried out with three sensor nodes and the deformed shape is displayed on a server-website to demonstrate the functionality of the methodically developed WSN.

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### ★ Incorporating contextual factors in back-end design stages: Development and pilot testing of the Contextual Product Testing Protocol

***Carlota Serrano, Grace Burleson***
***Paul M. Rady Department of Mechanical Engineering, University of Colorado Boulder***

Designing products for diverse stakeholders and environments requires understanding contextual factors, as neglecting them often leads to design failures. However, guidance on integrating context during back-end design phases is limited. To address this gap, we developed the Contextual Product Testing (CPT) protocol, which involves testing prototypes in stakeholders' contexts of use, gathering data through observations and interviews, and analyzing insights based on contextual factor categories. To evaluate the protocol, we conducted a case study using an interactive toy chest prototype that encourages children to clean up after playtime. Results from ten families revealed contextual barriers, enablers, and actionable recommendations. Our findings suggest the protocol offers a structured approach for incorporating context into back-end design, improving products for real-world use.

# P 10-6: Systems Engineering 2

## Session Chair: Markus Zimmermann, Technische Universität München, Germany

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### AI-augmented systems engineering: Conceptual application of retrieval-augmented generation for Model-Based Systems Engineering Graph

***Fabian Hanke[1], Isaac Mpidi Bita1, Oliver von Heißen[1], Weller Julian[1], Hovemann Aschot[1], Dumitrescu Roman[2]***
***1 Fraunhofer-Institut für Entwurfstechnik Mechatronik IEM, Germany; 2 Paderborn University (HNI), Germany***

This paper presents the MBSE-Graph-RAG framework to address key challenges in Model-Based Systems Engineering (MBSE). Traditional MBSE tools suffer from usability barriers, limited accessibility, and integration challenges. By combining knowledge graphs with Retrieval-Augmented Generation (RAG), the proposed framework enables AI-Augmented engineering through natural language interactions and automated system architecture generation. A systematic literature review establishes a solid research foundation, identifying gaps in AI-assisted MBSE. Key contributions include a structured MBSE-Graph interface, improved usability via Large Language Models (LLMs), and automated graph construction aligned with SysML. A proof-of-concept demonstrates the potential of this approach to enhance MBSE by reducing complexity, improving data accessibility, and supporting engineering collaboration.

### A machine learning approach towards automated classification of modal analysis results

***Timo Köring[1], Detlef Gerhard[1], Matthias Neges[1], Fares Seddik[2], Lukas Kömm[3], Kristin Paetzold-Byhain[3]***
***1 Ruhr University Bochum, Germany; 2 Synera GmbH, Germany; 3 TUD Dresden University of Technology, Germany***

Engineering of lightweight and robust structures is significant in mechanical engineering. Nevertheless, weight optimization of such structures leads to undesirable vibrations. Modal analysis is a common technique used in industry to investigate vibration behaviour. The classification of the mode shapes resulting from the analysis is conducted through human visual inspection, which can be time-consuming and susceptible to error. This paper presents an exploratory study investigating the potential of ML methods to classify three-dimensional vibration modes of truck frame structures. The aim is to evaluate the potential of such an approach to automate the modal analysis process to streamline the development process. As a result, the developed ML model can classify the vibration modes with high performance and additionally demonstrates flexibility regarding changes in geometry topology.

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### A quantitative analysis of rational decisions under uncertainty in engineering systems design

***Kaan Mutlu[1], Nikoo Javadpour[1], Zhenghui Sha[2], Alparslan Emrah Bayrak[1]***
***1 Lehigh University, USA; 2 University of Texas at Austin, USA***

Rational decision-making is crucial in the later stages of engineering system design to allocate resources efficiently and minimize costs. However, human rationality is bounded by cognitive biases and limitations. Understanding how humans deviate from rationality is critical for guiding designers toward better design outcomes. In this paper, we quantify designer rationality in competitive scenarios based on utility theory. Using an experiment inspired by crowd-sourced contests, we show that designers employ varied search strategies. Some participants approximate a Bayesian agent that aimed to maximize its expected utility. Those with higher rationality reduce uncertainty more effectively. Furthermore, rationality correlates with both the proximity to optimal design and design iteration costs, with winning participants exhibiting greater rationality than losing participants.

### Advancing systems engineering with artificial intelligence: A review on the future potential, challenges and pathways

***Victor Vilhelm Poulsen[1], Matthias Guertler[1], Boris Eisenbart[2], Nathalie Sick[1]***
***1 University of Technology Sydney; 2 Swinburne University of Technology***

Artificial Intelligence (AI) provides a unique opportunity to enhance and augment Model-Based / Systems Engineering (SE and MBSE). Through a systematic literature review, this paper explores current and potential uses of AI in SE across the V-model and analyses barriers of AI adoption in SE/MBSE. The results show that despite a significant potential of AI to enhance SE, several barriers exist, such as unavailability of data, trust and explainability issues, and technical limitations of AI systems. Based on the findings, this paper suggests future research directions, focussing on increasing the availability of high-quality datasets, integrating explainable AI techniques into SE, investigating Human-AI team dynamics, exploring MBSE roles for facilitating AI and how to address technical limitations of current AI models.

# P 10-7: Design Theory and Methodology 3

## Session Chair: Ariella Knight, NASA, United States of America

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Beyond 3D Tic-Tac-Toe: From O to ball and X to boX

***Rajath S, Joe Thomas, Muzammil Bagewadi, Vishal Singh***
***Department of Design and Manufacturing, Indian Institute of Science***

This study explores user engagement and strategic interaction with a newly designed tangible game board- a 3x3x3 cube frame with 27 voids and 27 game pieces. 15 teams, each with 2 players, were provided with only the game set to develop their own game rules and strategies, encouraging participants to engage in the spatial and experiential aspects that the game board offers. Researchers observed how players approached the 3D structure and developed gameplay tactics without predefined rules, fostering creativity and exploration. Importantly, the study captured feedback on the structure's versatility, with many participants developing new game rules, which implies its potential as a game platform. The experiments revealed that one of the emergences resulting from the affordances of the game platform is a game strategy for 3D Tic-Tac-Toe, amongst the many other possible games identified.

### Decoding the grammar of design theory for large language models: the case of axiomatic design

***Vito Giordano[1,2], Marco Consoloni[1,2], Marco Losanno[1,2], Filippo Chiarello[1,2], Gualtiero Fantoni[1,2]***
***1 University of Pisa, Italy; 2 Business Engineering for Data Science (B4DS) research group***

Large Language Models (LLMs) have advanced the extraction and generation of engineering design (ED) knowledge from textual data. However, assessing their accuracy in ED tasks remains challenging due to the lack of benchmark datasets specifically designed for ED applications. To address this, the study examines how theoretical concepts from Axiomatic Design Theory—such as Functional Requirements, Design Parameters, and their relationship—are expressed in natural language and develops a systematic approach for annotating ED concepts in text. It introduces a novel dataset of 6,000 patent sentences, annotated by domain experts. Annotation performance is assessed using inter-annotator agreement metrics, providing insights into the challenges of identifying ED concepts in text. The findings aim to support designers in better integrating design theories within LLMs for extracting ED knowledge.

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Design Logic Visualizations as boundary objects in design

***RAriella Knight[1], Lauren M. White[2], Jon Rask[1], Kathleen Bond[1], Erik Frankforter[2], Angela Bowes[2], Annie Miller[2], Meghan Stancliff[2], David Fuller[3], Michael Logan[2], Eric Reynolds Brubaker[2]***
***1 NASA Ames Research Center; 2 NASA Langley Research Center; 3 NASA Glenn Research Center***

Design teams commonly need to explain the rationale or logic behind how they frame design challenges and develop a particular design concept and not others. This paper explores the use of Design Logic Visualizations (DLV) as a boundary object to enhance understanding and communication in convergent interdisciplinary engineering design environments. We developed the DLV as a new design tool, building upon existing design process visualizations like design signatures, and provide a case study from our NASA team. We then use a reflection-based autoethnographic and collaborative inquiry approach to reflect on how the DLVs influenced our team, our process, and our decision-making. The findings suggest DLVs can serve as a succinct storytelling tool, support shared understanding across disciplines and levels of leadership, and, ultimately, influence design outcomes.

## Session Chair: Eswaran Subrahmanian, Carnegie Mellon University, United States of America

## Location: ECSS 2.412

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Creating design catalog from patent documents with large language model for design concept Generation

***Yutaka Nomaguchi[1], Kei Kuroishi[1], Aiza Syamimi[2], Daichi Tanaka[1], Kazuya Okamoto[2,3], Kikuo Fujita[1]***
***1 Osaka University, Japan; 2 Yamaguchi University, Japan; 3 Nippon Institute of Technology, Japan***

A design catalog is a repository of design problems and their solutions, enabling designers to explore and discover applicable solutions for their specific design challenges. Creating such catalogs has depended on human knowledge and implicit judgment, with no systematic approach established. This study aims to develop a systematic method to create a design catalog from patent documents. We utilize a large language model (LLM) to extract problem-solution pairs described in the documents, presenting them as general purpose-means pairs. Subsequently, we create a design catalog by classifying the problems using similarity-based clustering, enhanced by the LLM's semantic text similarity capabilities. We demonstrate a case study of creating a design catalog for martial arts devices and generating new design concepts based on the catalog to verify the effectiveness of the proposed method.

### The role of design problem presentation in shaping neural activity and learning in engineering students

***Corey James Kado, Elisabeth M. Kames***
***Florida Polytechnic University***

Over the last decade, engineering institutions have implemented changes in engineering education curriculum to address evolving industry needs. This includes the integration of design-focused curricula at various instances throughout engineering programs. This study investigates the relationship between design problem modality and neural activity. Participants in this study were engineering students enrolled in cornerstone design. Neural activity was measured using electroencephalography (EEG) during a single session where students were presented with two design problem modalities. This data was compared with motivational factors and learning preferences. The findings reveal correlations between neural activation, student motivation, and learning preferences. This suggests that problem modality influences cognition and motivation, offering valuable insight into individual student needs.

## Location: ECSS 2.412

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### The influence of aesthetic taste on product choice: does mode of evaluation impact decision making?

***Chukwuma M Asuzu, Alison Olechowski***
***University of Toronto***

The study investigates the cognitive aspects of aesthetic taste, which is a subjective quality linked to individuals' ability to make superior aesthetic judgments. It explores how evaluation modes during product choice decision-making relate to aesthetic taste. We defined taste through two dimensions: expertise (professional experience) and acumen (consumption experiences). By comparing research participants in a consumer study across these dimensions, we analyzed decision-making patterns using both quantitative and qualitative methods. Our results show that participants with low aesthetic taste (across both dimensions) express their product choice in terms of product attributes they dislike. We also find that the expression of personal preferences is associated with low aesthetic taste for the expertise dimension but is associated with high aesthetic taste for the acumen dimension.

### Standards as discourse

***Jacob Collard[1], Eswaran Subramnanian[1,2], Spencer Breinner[1], Ram Sriram[1]***
***1 National Institute of Standards and Technology; 2 Carnegie Mellon University***

Technical standards provide order and consistency in application domains; however, standards development organizations produce large families of related documents containing significant amounts of information that can be difficult to access, evaluate, and produce consistently. We describe standards as linguistically, socially, and conceptually dynamic constructs using theory drawn from systems engineering and linguistics to create a model of standards documents that can be updated, evaluated, and queried to retrieve information reliably. We describe the theoretical basis for this model from multiple perspectives and explain broadly how it can be used to retrieve relevant information from standards.

# P 11-2: Digitalisation and Digital Twins

## Session Chair: Rainer Stark, Technische Universität Berlin, Germany

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Quantitative metrics for validation and decision-making in Digital Twins: a comparative study on a railway braking system

***Dmitrii Ershenko, Glafira Derbysheva, Andreas Panayi, Clement Fortin***
***Skolkovo Institute of Science and Technology (Skoltech)***

The overall quality of final Digital Twin (DT) solutions and their ability to produce useful insights are key considerations for researchers and for the industry to readily adopt them. However, validation of DTs is often neglected in existing research dedicated to their development. Further, there is a lack of methodologies for building bi-directional information exchanges between virtual and real spaces, potentially hindering effective decision-making. This work presents a comparative analysis of several quantitative metrics by implementing them on the Digital Twin of a railway braking system as a use case. Their suitability as performance measures for validation and as thresholds to support decision-making is assessed. Their integration into a novel DT structure is shown to contribute to a well-rounded validation procedure and a practical decision-making framework.

### A systematic description of twinning levels of measured data and models in Digital Twins

***Svenja Nicole Schulte, Carl-Philipp Grunenwald, Philipp Schulze, Tobias Breiten, Rainer Stark***
***Technische Universität Berlin, Germany***

Digital Twins are digital representations of products or product-service systems comprising a Digital Master, which consists of product description models, and a Digital Shadow, which encompasses data collected throughout the product's life cycle. To create a Digital Twin, the Digital Master and Digital Shadow must be interlinked. The Digital Master, Digital Shadow, and thus their twinning can vary in complexity and analytical capabilities. This paper introduces a systematic description of six twinning levels ranging from simple data exchange based on generic models to more complex forms targeting model parameter and Digital Twin goal optimization. The example of a valve is used for illustration. The presented description aids in understanding the potential of Digital Twins and serves as a guide to select appropriate twinning levels based on specific product requirements and use cases.

## Location: ECSS 2.410

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Customer engagement, digitalization, and business performance: a model for digital startupsing system

***Isabela Simões Zacharias[1], Glauco Henrique de Sousa Mendes[2], Sânia da Costa Fernandes[2], Bruno Michel Roman Pais Seles[1,3], Fabiane Letícia Lizarelli[2], Marly Monteiro Carvalho[1], Janaina Mascarenhas[1]***
***1 University of São Paulo; 2 Federal University of São Carlos; 3 Marília University***

Customer engagement is crucial for success and innovation in digital businesses, but its impact on digital startups, particularly on business performance, is underexplored. This study investigates the relationship between customer-related digitalization factors, engagement, and business performance. Using a cross-sectional survey and Partial Least Squares Structural Equation Modeling, data from 125 startups were analyzed. The findings reveal that digitalization factors, encompassing Data Security, Transparency, Consumer Reviews, and Effective Communication, significantly impact customer engagement and digital business performance. Additionally, customer engagement mediates the relationship between digitalization factors and digital business performance, highlighting its critical role in fostering customer loyalty, communication, and co-creation.

### Towards an integrative approach for designing for cybersecurity in systems engineering

***Megan A. Harris, Matthew L. Hale, Christine A. Toh***
***University of Nebraska at Omaha***

Secure development is an ever-evolving field that has advanced quickly in recent years with initiatives like Secure Development Lifecycle (SDLC), Development Security Operations (DevSecOps), and Model-Based Security Engineering (MBSE). Despite the persistence of the security and design communities to include security in the design process, significant security breaches continue to occur. Our work reviews existing literature to determine the current state of the research at the intersection of these design and cybersecurity fields and ultimately proposes an integrative and systematic approach for developers to generate design principles that incorporate traceable security. This approach integrates security regulations and design principles and activities, encouraging compliance and security considerations at the earliest stages of the design thinking process.

# P 11-3: Sustainable Design and Circular Economy 3

## Session Chair: Yong Se Kim, Tongji University, China, People's Republic of

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Modeling stochastic yield rates in disassembly processes for green profit maximization

***Yilan Jiang, Harrison Kim***
***University of Illinois at Urbana-Champaign, USA***

Many optimization models have been proposed to assist original equipment manufacturers (OEMs) in pric- ing and production planning for remanufactured product; however, most assume deterministic yield rates for takeback products during disassembly. In practice, yield rates are influenced by interdependencies among subparts and disassembly operations. To address this limitation, this study enhances a previously established optimization approach by incorporating yield uncertainty into the disassembly process using a diffusion pro- cess framework. The effectiveness of this approach is validated through case studies on two distinct products: a smartphone and a recreational boat engine. The results demonstrate that integrating stochastic yield model- ing allows stakeholders to make more informed decisions, ultimately improving both economic performance and environmental sustainability.

### Key elements to navigate sustainable product development in Aerospace

***Pauline L. Y. Léonard[1,2], Sophie I. Hallstedt[2], Ola Isaksson[2], Timos Kipouros[3], Adam Mallalieu[2]***
***1 GKN Aerospace Sweden; 2 Chalmers University of Technology, Sweden; 3 Cranfield University, UK***

Product development is critical for sustainable development, yet sustainable design practices remain under-implemented in the industry. This paper explores the aerospace sector, addressing its specific barriers and enablers to sustainable design. Through a comprehensive literature review, group discussions, and expert group interviews, this study introduces an impact model with essential elements for enabling sustainable product development in aerospace and explains their causal relations. Five key elements were identified: business drive, sustainability implementation, knowledge, ownership, and collaboration. In addition to the impact model, the paper discusses aerospace-specific challenges and opportunities for sustainable product development. Findings from this study offer a practical framework for practitioners and researchers to plan and implement interventions in organizations.

# P 11-3: Sustainable Design and Circular Economy 3

## Location: ECSS 2.312

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Sustainability in product engineering – a guide to initiate targeted sustainability action

***Michael Jäckle, Elisabeth Does, Leonard Tusch, Albert Albers***
***Karlsruhe Institute of Technology (KIT)***

Uncertainty in coping with sustainability demands poses a challenge to decision makers concerned with manufacturing companies' product engineering. Therefore, our paper reports on a newly developed guide to address their uncertainty and support them in initiating targeted sustainability action. The guide, based on an interview study (n = 25; 4 company cases and 1 consultancy) and a systematic literature review, addresses decision makers in product engineering and beyond. It was initially applied and evaluated in company workshops. The guide provides success criteria and reflection questions for each step toward targeted sustainability action: understanding, operationalizing, and implementing. This paper outlines the main concepts behind the guide and contributes to the literature by suggesting a novel approach to sustainability action in product engineering by addressing uncertainty.

### Challenges in addressing sustainability within product development

***Katharina Zumach, Sven Wehrend, Dieter Krause***
***Hamburg University of Technology***

Due to climate change, sustainability has become a crucial topic in product development, while addressing it is associated with many challenges. Based on a literature review, those challenges are collected and clustered into nine categories and sub-categories defined for this purpose. Additionally, a research project is analysed. The exhibited challenges such as data availability versus influenceability, a lack of unified sustainability criteria, and decision-making trade-offs underscore the need for refined methodologies and collaboration in sustainability-oriented design. The differently sourced challenges are compared and the new challenges arising from the research project are sorted into the categories. Finally, possible reasons are discussed for why within the project only challenges from four out of nine categories are encountered.

# P 11-4: Creativity and Collaboration

## Session Chair: Vishal Singh, Indian Institute of Science, India

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### ★ Evaluating ChatGPT's role in collaborative CAD task completeness

***Jelena Šklebar, Tomislav Martinec, Stanko Škec, Mario Štorga***
***University of Zagreb, Croatia***

This study explores the role of ChatGPT in the completeness of collaborative computer-aided design (CAD) tasks requiring varying types of engineering knowledge. In the experiment involving 22 pairs of mechanical engineering students, three different collaborative CAD tasks were undertaken with and without ChatGPT support. The findings indicate that ChatGPT support hinders completeness in collaborative CAD-specific tasks reliant on CAD knowledge but demonstrates limited potential in assisting open-ended tasks requiring domain-specific engineering expertise. While ChatGPT mitigates task-specific challenges by providing general engineering knowledge, it fails to improve overall task completeness. The results underscore the complementary role of AI and human knowledge.

### AI-powered inventive design: idea funnelling, concept creation, and hybrid problem-solving teams

***Pavel Livotov, Mas'udah Mas'udah***
***Offenburg University of Applied Sciences, Germany***

Generative AI, guided by inventive heuristics, can systematically and rapidly generate hundreds of ideas for engineering inventive design problems. This paper examines the reliability and effectiveness of AI-powered "idea funnelling," a process that generates, evaluates, filters, and synthesizes raw ideas into feasible solution concepts. Key challenges include the consistency and objectivity of AI-driven evaluations, the robustness of concept generation, and the collaboration of multiple AI chatbots such as ChatGPT and Gemini. The study explores the integration of human expertise in hybrid problem-solving teams to improve feasibility, contextual relevance, and innovation quality. Through comparative experiments, it provides insights to improve the reliability of AI-driven concept creation and the performance of hybrid AI-human teams in solving complex engineering design problems.

## Location: ECSS 2.311

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Leveraging large language models for enabling design by analogy: A computational framework

***Rohin Joshi[1], Ruhi Mitra[1], Vijayalaxmi Sahadevan[1], Kane Borg[2], Vishal Singh[1], Bilal Muhammed[3], Soban Babu Beemaraj[3], Amol Joshi[3]***

***1 Indian Institute of Science Bangalore, India; 2 Aalto University, Finland; 3 TCS Research & Innovation, Tata Consultancy Services, Pune, Maharashtra, India***

Design by Analogy (DbA) is a powerful method for fostering innovation by transferring knowledge from a source domain to solve problems in a target domain. However, traditional DbA approaches face significant challenges, including resource-intensive database management, linguistic and representational differences across domains, and the complexity of access and mapping processes. These limitations hinder scalability and efficiency, particularly for cross-domain analogies. Recent advancements in Artificial Intelligence (AI), especially Large Language Models (LLMs), offer promising solutions by facilitating efficient knowledge retrieval, bridging linguistic gaps, and enhancing semantic reasoning. This paper explores the potential of AI technologies to address these challenges, proposing a framework for analogical reasoning.

### A practical use case and IRR based validation of concept maps coding scheme

***Pavan Kumar, Joshua Summers***
***University of Texas at Dallas***

Concept maps have been used to measure student learning and performance comparisons before and after interventions. However, these concept maps may vary in structure and content. The complexity of the maps are difficult to measure when multiple concepts are embedded within individuals nodes. A systematic coding scheme is evaluated for objectivity and reliability using 22 undergraduate researchers. The findings suggest that the coding scheme is suitable and will allow multiple different researchers to generate similar bi-partite graphs from the notional concept maps generated. Additional work is needed to ensure that the semantic content is not invalidated through the coding scheme.

## Session Chair: Gordon Krauss, Harvey Mudd College, United States of America

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Flexibility evaluation of modules with a focus on interfaces

***Julia Beibl, Jan Küchenhof, Markus Christian Berschik, Dieter Krause***
***Hamburg University of Technology (TUHH), Germany***

In the context of volatile markets, characterised by a need for continuous product development involving module-wise product modifications, the importance of flexibility as an attribute of products and their production system has been increasing.
This paper presents a methodological approach focusing on the flexibility evaluation of modules regarding their interfaces. The subject encourages engineers and researchers to analyse and rethink the interface design and the location of module boundaries regarding change propagation. The method was validated using the Design Method Validation System (DMVS) to determine its usefulness, applicability and acceptability. The design workshop for validation was applied to a product family of trunk lids by employees of a German car manufacturer.

### Development of an intelligent tutoring system for design education: Personalised learning support in engineering

***Christian Becker, Lukas Valentin Hoppe, Stefan Plappert, Kevin Herrmann, Paul Christoph Gembarski, Roland Lachmayer***
***Leibniz University Hanover***

The diverse knowledge levels among first-year mechanical engineering students lead to significant disparities in individual learning. Intelligent tutoring systems (ITS) offer a solution by providing tailored digital one-to-one instruction, bridging knowledge gaps, and equalizing learning outcomes. This thesis develops an ITS for design theory based on a knowledge-based engineering system, presenting an innovative model that integrates key features of ITS and knowledge-based systems. Implemented in a specialized environment, the system's application and validation demonstrate its ability to meet context-sensitive design teaching requirements and provide adaptive tutoring.

## Session Chair: Gordon Krauss, Harvey Mudd College, United States of America

## Location: ECSS 2.306

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### ★ Investigating engineering design tasks - iterative testing in large-scale engineering courses

***Mona Batora[1], Oliver Liewerenz[2], Patric Grauberger[2], Noreen Enseroth[1], Mathis Wolter[1], Sven Matthiesen[2], Nikola Bursac[1]***
***1 ISEM – Institute for Smart Engineering and Machine Elements, Hamburg University of Technology (TUHH); 2 IPEK – Institute of Product Engineering, Karlsruhe Institute of Technology (KIT)***

In this research a study environment is presented that enables iterative design in large engineering lectures and show possibilities for investigations at two example lectures from German universities. The initial results show that it is possible for large lecture-hall-based courses to engage in in-depth tasks of engineering design. Design researchers can use the generated data to measure influences, e.g. the applied methods on specific design tasks. Two key insights include the potential for large courses to serve as large-scale research wnvironments for design research and the observed effects of influences on students' decision-making processes. This approach offers a promising method to further explore the complexities of decision influences and design optimization in educational settings.

### Re-examination of design exercises in a materials engineering course

***Gordon Krauss***
***Harvey Mudd College***

Research is presented on the development of student confidence in design through the use of design exercises in a non-design (materials engineering) course. This work revisits a prior study incorporating over three times the number of subjects, substantially expanding the statistical robustness of the analysis. Four distinct design exercises, covering topics like tensile failure, creep, impact, and fatigue, are integrated into the course, each employing structured pre- and post-assessment surveys to gauge confidence levels. Results consistently show significant improvements in student confidence, with post-exercise scores rising by 2 points on a 9 point Likert scale. This work underscores the efficacy of design exercises in bridging engineering science with practical design application of the topical knowledge, with implications for optimizing engineering education strategies.

# P 11-6: Complexity and Data

## Session Chair: Matthias Kreimeyer, Universität Stuttgart, Germany

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### ★ Large language models for combinatorial optimization of design structure matrix

***Shuo Jiang, Min Xie, Jianxi Luo***
***City University of Hong Kong***

Combinatorial optimization (CO) is essential for improving efficiency and performance in engineering applications. Traditional algorithms based on pure mathematical reasoning are limited and incapable to capture the contextual nuances for optimization. This study explores the potential of Large Language Models (LLMs) in solving engineering CO problems by leveraging their reasoning power and contextual knowledge. We propose a novel LLM-based framework that integrates network topology and contextual domain knowledge to optimize the sequencing of Design Structure Matrix (DSM) —a common CO problem. Our experiments on various DSM cases demonstrate that the proposed method achieves faster convergence and higher solution quality than benchmark methods. Moreover, results show that incorporating contextual domain knowledge significantly improves performance despite the choice of LLMs.

### Investigating data-driven requirements management for smart PSS development

***Yevgeni Paliyenko, Carl Simon, Daniel Roth, Matthias Kreimeyer***
***University of Stuttgart, Germany***

The development of smart Product-Service Systems (smart PSS) introduces unique challenges for requirements management due to their dynamic, data-driven, and multidisciplinary nature. This paper investigates methods and principles for data-driven requirements management, emphasizing lifecycle alignment, data utilization, multidisciplinary collaboration, and customer-centricity. A systematic literature review forms the basis for assessing 16 existing frameworks, focusing on their suitability for the data-driven design of smart PSS. Key gaps are identified in areas such as data planning, lifecycle integration, and the handling of system-level requirements. To address these challenges, this study proposes principles for data-driven requirements management that leverage real-time data, ensure traceability, foster interdisciplinary alignment, and adapt to contextual variables.

## Location: ECSS 2.305

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Identifying the needs for a requirements authoring design enabler

***Shanae Edwards, Oredola Adebayo, Joshua Summers***
***University of Texas at Dallas, USA***

Requirements engineering is in the design process, translating stakeholder needs into actionable and well-defined specifications. While existing design enablers and tools provide partial solutions, they often fall short in addressing essential aspects such as real-time feedback, lifecycle management, and the use of controlled vocabularies. To bridge these gaps, the Requirements Authoring Design Enabler (RADE), a macro-enabled Excel tool, is presented to support requirement authoring, tracking, and management. RADE integrates features like automated feedback, a dual-mode interface, robust change tracking, and controlled vocabularies. The tool was tested with pre-service engineers with user feedback informing iterative refinements. RADE addresses key challenges in requirements engineering, demonstrating its potential to enhance design outcomes across various domains.

### Redefining interfaces: A generic interface architecture for complex system integration

***Daniel Aron, Yoram Reich***
***Tel Aviv University, Israel***

This paper proposes a redefinition of interfaces as dynamic, adaptive systems crucial for managing the increasing complexity of modern systems. Drawing on diverse domains, the paper identifies key interface properties such as adaptability, cost-efficiency, and error response. The paper introduces a novel Generic Interface (GI) architecture, utilizing a model-based systems engineering approach. The GI architecture features modular components, designed to handle integration, data management, and error resolution. A case study of smart grids demonstrates the effectiveness of the GI architecture in addressing challenges like integrating diverse energy sources, ensuring grid reliability, and enabling demand response. The proposed GI architecture provides a robust framework for integrating complex systems, emphasizing adaptability, cost optimization, and error response.

# P 11-7: Design Knowledge and Computation

## Session Chair: Zhenghui Sha, The University of Texas at Austin, United States of America

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### ★ An ontology-based framework for reusing decisions in product development processes

***Jessica Pickel, Stefan Goetz, Sandro Wartzack***
***Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany***

Decision-making in product development is a complex process that benefits from leveraging past experiences. This paper presents an ontology-based framework to facilitate decision-reuse in product development by classifying current decisions within a structured scheme. The proposed decision-reuse ontology provides similar past decisions, linking them to their classifications and offering SPARQL queries, conditions, and decision outcomes. By integrating the ontology with other domain-specific ontologies, it supports product developers in making informed decisions based on historical knowledge. The resulting decision outcomes, classifications, and metadata are fed back into the decision-reuse ontology, ensuring a continuous cycle of knowledge enrichment. This approach not only enhances decision-making but also fosters knowledge transfer throughout the development process.

### Spatial computing in design: Opportunities and challenges of a new technological paradigm

***Chris Snider, Aman Kukreja, Chris Cox***
***University of Bristol, UK***

Spatial Computing (SC), the use of technology to blur the boundaries between physical and digital into an efficient, intuitive, high performance set of tools, holds huge promise for engineering design. With dramatic and accelerating industry prominence but little research in the design field, there is a need to generalize and frame SC for design. This paper contributes an operational framework for Spatial Engineering (SE) systems highlighting the roles of physical and digital users, objects, environments, and data, and five capabilities required for implementation. It then identifies value propositions for SE evidenced from review of the design field, including design activities in which value is generated. Finally, it presents research opportunities centered on good practice, system interaction and technology, and balancing overhead with the value that these systems provide.

## Location: ECSS 2.203

Time: Thursday, 14/Aug/2025: 1:45pm - 2:45pm

### Player profile as tool for communities of practice animation

***Pierre Miroite[1], Geneviève-Anaïs Proulx[2], Mickaël Gardoni[3]***
***1 ETS Montreal, Canada; 2 Moment Factory; 3 ÉTS Montréal, INSA Strasbourg, Canada***

This paper investigates the integration of player profiles and gamification elements into knowledge management practices within communities of practice engaged in engineering design. The study proposes a framework combining the MEREX method with gamification, tailored to Marczewski's player types. The research aims to personalize knowledge sharing, promote user engagement, and structure engineering design knowledge effectively. The framework leverages MEREX sheets with a narrative format structured around phases of the engineering design process. Additionally, it features personalized knowledge maps and contributor profiles to foster collaboration, facilitate knowledge formalization, and encourage knowledge reuse. This integrated approach seeks to improve both community animation and overall knowledge management within engineering design contexts.

### Using statistical clustering of trajectory data to support analysis of subject movement in a virtual environment

***Martin Galicia Avila, Douglas Timmer, Alley Butler***
***University of Texas Rio Grande Valley, Manufacturing and Industrial Engineering***

Gracia de Luna conducted experiments with an HMD virtual environment in which human subjects were presented with surprise distractions. His collected data for head, dominant hand, and non-dominant hand included 6 DOF human subject trajectories. This paper examines this data from 57 human subject responses to those surprise virtual environment distractions using statistical trajectory clustering algorithms. The data is organized and processed with a Dynamic Time Warping (DTW) algorithm and then analyzed using the Density Based Spatial Clustering (DBSCAN) algorithm. The K-means method was used to determine the appropriate number of clusters. Chi Squared goodness of fit was used to determine statistical significance. For five of the data sets, a p value of less than 0.05 was found. These five data sets were found to have a limited relationship to the measured variables.


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