Human-Cyber-Physical Systems: Challenges and Innovations
Focus: Science Communication “Demo or Die - Publish or Perish”

1) Project Suggestions

	category	short description
1	network / communication	Ultra-Low-Latency 5G with DECT NR+: Exploring Access Strategies for the Tactile Internet **Background:** The Tactile Internet aims to enable real-time interaction with remote systems, requiring extremely low latency and high reliability. A central challenge is how multiple devices efficiently share the same wireless medium. DECT NR+ is a modern, ETSI-standardized wireless technology designed for private, scalable, and low-latency communication, making it well-suited for such use cases. Understanding and optimizing how devices access the channel is key to achieving responsive system behavior. **Description:** Participants will design and implement a simple strategy that determines how multiple devices take turns using a shared wireless channel (e.g., round robin or random access). Using provided development kits, they will explore how different approaches affect responsiveness and reliability in a simplified Tactile Internet scenario. The task is accessible to participants with general networking knowledge, while optional extensions (e.g., adaptive or priority-based access) are available for more advanced students. **Possible Outcomes:** - Comparison of different access strategies in terms of latency and fairness - Identification of trade-offs between simplicity and performance - Basic prototype demonstrating wireless communication behavior **Material needed:** - PC/laptop with nrf-SDK (development environment) - Nordic Semiconductor nRF9151/9161 DK + USB cable - Example Tactile Internet application (will be provided by us, t.b.d.)
2		**Analog computing hands on** Analog computing is nothing new: analog computers flew rockets to the moon! Today, we witness a new advent of analog computing since we are

		hitting physical walls with digital platforms. To perform complex computing tasks in short time and with low energy, new computing platforms have to evolve, including quantum, biological and analog computing. This is a hands-on workshop with a real analog computer! We will start with exploring what can be done with it and then we will think of and realize a project! potential material needed: analog computer (500€); we can borrow one or maybe two from anabrid, but it would be cool to buy one earlier to prepare the workshop
3		Virtual social touch and thermal actuators Explore dual-person VR and interpersonal touch using different audio-visual cues to contact and different types of thermal actuators
4	Machines	Orientation for Astronauts - Hands-on Prototyping of Haptic Peripherals **Background:** In space, the concept of 'gravitational down' becomes irrelevant for free-floating astronauts due to the lack of vestibular input and physical haptic cues. Instead, they depend on 'visual down'—their orientation relative to the spacecraft's surfaces. Visual references, like floors or walls, help astronauts perceive what feels like 'down' and maintain their spatial awareness. However, in the unique environment of space, where familiar gravitational cues are nearly nonexistent, astronauts often face challenges with spatial orientation and navigation. To address this, a sensory augmentation device, such as a vibrotactile belt, could assist in improving orientation during microgravity, extravehicular activities (EVAs), and even while reacclimating to Earth's gravity in the first days after their return. **Description**: This hands-on workshop focuses on designing and building custom haptic peripherals or working with a pre-built CeTI prototype. Participants will develop a comprehensive concept that considers requirements, functionality, utility, and testing. This concept will guide the coding, control, and programming of the haptic devices. **Possible Outcomes:** ● A sensory augmentation device that enhances astronaut orientation and navigation in microgravity. ● Study designs or experiments to evaluate the functionality and utility of the device. **Material needed:** ● Textile basis (~20€) ● Vibration actuators (~100€) ● Wearable electronics (~250€) ● Flipchart, paper, pens

5	Machines	With the development of humanoid robots, interactions between humans and robots are becoming increasingly close in daily life. However, due to the rigid robotic bodies made of metallic materials, the potential risk during intimate contact with humans is unavoidable. Skin, the largest organ of the human body, functions not only as a sensory interface but also as a buffering layer when interacting with surfaces of varying textures and moduli. Inspired by these functions, electronic skin with tissue-like mechanical properties and sensing capabilities can enable robots to interact with target objects more gently and control their movements more precisely. **Description:** This application-oriented workshop focuses on the design and fabrication of electronic skin for robotic joints, such as robotic hands or robotic dogs. The working principles, characterization methods, and functionalities of general electronic skin will be introduced, along with their potential applications in combination with other technologies (e.g., 3D printing, closed-loop systems) and sensors. **Possible Outcomes:** ● Understanding the design principles and characterization methods of electronic skin ● Development of sensors with unique 3D structures for diverse applications ● Construction of sensory systems enabling remote control of robots **Materials Needed:** ● TPU filament for 3D printing (~50 Euro) ● Conductive materials (~100 Euro) ● Electrical wires (~30 Euro)
6	Machines	**Tactile Sensing With Haptic Feedback** We are currently witnessing a dynamic development in robotics with humanoid robots and robotic hands being released every other week. This makes complex remote operation and autonomous robotic tasks with unprecedented complexity a realistic vision. However, to make this come true, novel human-machine interfaces are needed. Based on the CeTI sensor glove, we want to combine it with Haptic Feedback to allow for complex tasks to be performed remotely, allowing the user to experience the environment of the remote robot. This will also enable new possibilities in VR environments.
7	Medicine	**Mixed Reality Telepresence in the Walkable OR** Telesurgery offers the potential to democratize access to surgical

		expertise on a global scale. However, as of now that telepresence for minimally invasive surgery is mainly focusing on the view inside the patient. The complex, high-stake environment of the whole operating room is poorly reflected. Based on our previous work in t hirst phase of CeTI and results of a randomized controlled user trial we want to push our current prototype by incorporating new technologies and methods from CeTI phase 2 including peripherals, robotics, metaverse and network of network components.
8	Medicine	**Multi-Human Multi-Robot-Interaction in Surgery** Robotic surgery can be considered an ultimate benchmark for autonomous robotics, because of the delicate manipulation of tissue as well as the high-stake environment of operation on a human in a multi-stakeholder operating room. Thus, we believe that surgical robots should not be autonomous, but keep the human-in-the-loop in order to achieve best outcome for the patients. To challenge the current state of the art, we are working towards a seemless co-operation of multiple humans and multiple robots in a seemless interface of flexible autonomy and welcome all ideas and technologies that want to contribute to this use-case.
9	Work	**Rethink Human-Robot Collaboration for Assembly and Disassembly** **Background:** Robots are becoming increasingly prevalent in industrial environments as advances in AI, sensing, and automation make robotic systems more capable, flexible, and accessible. This creates new opportunities for close human-robot collaboration in assembly and disassembly scenarios. Emerging interaction methods such as XR-based teaching, multi-user interfaces, intention visualization, and AI-assisted skill generation can make robots easier to instruct, adapt, and supervise. These approaches are especially promising for small-scale production, where tasks change frequently, and for disassembly in circular-economy settings, where products must be recognized, handled, and taken apart efficiently. **Description:** Develop a prototype robotic application for an industrial assembly or disassembly use case. You are free to choose your focus: develop a concrete (dis-)assembly skill, implement a multi-user XR interface, or explore the use of LLMs and agentic AI for robotics and human-robot interaction. The hardware is provided — your task is to turn it into an award-winning concept or prototype. Possible directions include teaching or adapting robot skills for small-scale assembly tasks, using XR to support intuitive interaction; developing a prototype for disassembly in recycling contexts, for example by recognizing screws and performing automated unscrewing; integrating intention visualization; or creating a multi-user XR setup for teaching,

		interaction, and coordination between multiple humans and robots. Another possible focus is to investigate how LLMs and agentic AI can support robotic skill development, interaction design, or adaptive assistance. **Possible Outcomes:** ● A clearly developed and well-communicated concept for human-robot collaboration in assembly or disassembly. ● A prototype for XR-based robot skill teaching, for example for screwing or pick-and-place tasks. ● A prototype for automated product disassembly for recycling. ● A multi-user XR interface for robot teaching, interaction, or intention visualization. ● A concept or demonstrator exploring the use of LLMs or agentic AI in robotics and human-robot interaction. **Material needed:** ● Robot(s) on a cobot table, including required networking and computer hardware ● End-effectors (grippers and screwdriver) ● XR headsets ● Objects or products for assembly / disassembly
10	Space	Reimagine Human Control in Space - Push the Boundaries of Six Degrees of Freedom **Background:** Controlling vehicles and complex systems in space is challenging due to altered perception in microgravity and the absence of familiar landmarks. Astronauts must perform high-risk manual control tasks under extreme conditions, where small errors can have significant consequences. These tasks require advanced sensorimotor and cognitive skills, which are sensitive to the stressors of spaceflight. The 6 Degrees of Freedom Docking Simulation Research Tool (6df) is currently used to train and evaluate these skills. However, an ideal 6 DoF control system would enable intuitive and adaptive control, account for operator states like cognitive overload or loss of situational awareness, and provide targeted support to enhance performance and safety. **Description:** Participants will explore and test the standard 6df simulation, develop new approaches to 6 DoF control, or augment the existing system. They can also create immersive training environments including technologies like XR, motion platforms, or simulators. The goal is to design innovative solutions that improve control precision, adaptability, and usability in space applications. Hands-on prototyping is encouraged to bring concepts to life.

		[Is there hands-on prototyping possible?] **Possible Outcomes:** ● A thoroughly developed and clearly communicated concept, which may include an augmentation of the existing 6df control system, a novel 6 DoF control device concept, an XR-based learning and/or test environment concept. ● A functional or demonstrable 6df / 6 DoF control prototype. **Material needed:** ● 6df controller and simulation ● Laptop ● Flipchart, paper, pens ● electronics/ actuators/ etc. ...?
11	Space	Immersive Space Training: Creating XR Environments to Enhance Human Skill Performance **Background:** Human space exploration challenges individuals to perform complex tasks in Isolated, Confined, Extreme (ICE) environments. Microgravity, limited movement, social isolation, and dependence on technology create physical, emotional, and cognitive challenges for astronauts, often reducing their performance. Additionally, communication delays with Earth and remote support exacerbate these difficulties. To address these challenges, advanced tools like Extended Reality (XR) can simulate space environments, train essential skills, and explore ways to enhance astronaut performance through innovative technologies. **Description:** Participants will explore and adapt existing XR environments to simulate human skill performance in space. Participants will identify requirements for XR environments, improve or augment them with multisensory feedback, and integrate CeTI technologies to enhance human performance in ICE conditions. The hackathon will focus on developing tasks and concepts to investigate and support astronaut orientation, navigation, and docking in microgravity. **Possible Outcomes:** ● Participants may develop a concept that includes new tasks for XR environments, the expansion of existing XR environments, or the creation of entirely new XR environments. They may also augment these environments with multisensory feedback and integrate CeTI technologies to enhance the realism and effectiveness of the simulations. ● Participants could propose study ideas to examine astronaut navigation, orientation, and 6 Degrees of Freedom (6DoF) control in space-like conditions.

		Material needed: ● XR setup (HMDs, PCs/ Laptops) ● Flipchart, paper, pens