# InstaBeam: Instant Beaming into Immersive Viewing Environments

This projected is situated in the VENISE team [7] within the LISN laboratory. (Laboratoire Interdisciplinaire des Sciences du Numérique [8]). **LISN owns several immersive viewing environment**s that are part of the CONTINUUM Equipex+ network [9], including VENISE's EVE platforms (large EVE-Room CAVE and the EVE-XR network of personal head-mounted displays), as well as EX-SITU's WILD & WILDER very large high-resolution wall-sized displays. LISN is also a key player of the huge French PEPR eNSEMBLE [10] project, whose goal is to explore the future of collaboration. The VENISE team has been conducting research on remote collaboration across such platforms and beyond for close to two decades. Within eNSEMBLE this project falls into: **PC1: CATS - Collaboration spaces, 3. Infrastructure for rapid creation of hybrid collaboration environments.**

The **goal of this project** is to develop a mobile system that can be used to instantly "beam" (or "teleport") oneself from anywhere on the Université Paris-Saclay campus into the above immersive viewing environments in order to support remote collaboration between the user in the field and those in the immersive platforms. This includes the real-time 3D capture of users, artifacts, and even complete and complex environments.

Such a **mobile capture system** will consist of a strong laptop, combined with a spherical camera and a depth camera. This allows us to capture high-dynamic range video streams of the environment (to reconstruct lighting, see [1]) together with precise localization based on a SLAM system utilizing the depth camera. In order to rapidly create high-quality reconstructions of artifacts (e.g. workpieces for remote advice by an expert) or humans, we will use neural radiance fields (NeRFS).

Figure 1 depicts several **usage scenarios** that beam people, their current work pieces, and possibly their real whole environment into our immersive viewing environments: An optics researcher can beam himself and his experiment to colleagues for discussion; A bomb expert in the field facing a difficult mine that he needs to disarm can beam himself and the mine to an immersive environment for getting advice from experts; First aid responders can beam an injured person and themselves to an immersive viewing environment to discuss the next steps with experts.

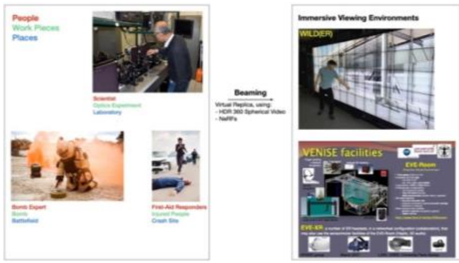

*Figure 1 - Usage scenarios of the proposed beaming system.*

Today, **such beaming systems** are still prototypes and **need a considerable amount of hardware and software integration**. For instance HDR (High-Dynamic Range) spherical cameras are very recent and expertise needs to be gained for streaming and exploiting such complex images into an immersive rendering environment. NeRFs are also a recent addition to the process of reconstructing artifacts: many competing implementations are emerging and need thorough evaluation.

**Methodology:** We envision 3 stages for this project:

1. Enable beaming inside the Université Paris-Saclay campus
2. Extend the system to enable bi-directional beaming
3. Extend the system for long-distance beaming

**1. Enabling beaming inside the Université Paris-Saclay campus:** in order to make the given scenarios possible, it will be necessary to

a) Develop the mobile capturing system;
b) Develop initial software adapters for the WILD(ER) and EVE platforms to display the captured data;
c) Develop further software adapters for other immersive displays of other teams in LISN (e.g. AMI, CPU, ILDA, and AVIZ).

**Task 1.a) is the most challenging** and will take most time. The mobile capturing system must acquire and transmit:

- *360 degree video of the environment*: this is comparatively the easiest part, as this format is well understood and supported by common standards such as MPEG. There also exist robust evaluation methods for it [3].
- *NeRFs of work pieces*: Neural Radiance Fields, introduced in 2020 [4], can be used to create high-quality volumetric models of physical objects. Compared to photogrammetry methods,

NeRFs excel at reconstructing transparent and reflective objects. The main downside is the slow reconstruction speed: an everyday item would take several hours to reconstruct. In August 2022, NVIDIA presented a breakthrough paper [2] at ACM SIGGRAPH, that speeds up the reconstruction process by several orders of magnitude, down to a few seconds. Still, NeRFs are highly experimental and require serious engineering in order to make them usable by untrained operators.

- *HDR lighting information*: it is desirable to transmit high dynamic range (HDR) environment light information to the immersive viewing environment, as only this enables the correct lighting of virtual objects. The low-dynamic range 360 degree video stream is not sufficient [5]. We plan to capture the HDR information with an algorithm in the spirit of Paul Debevec's recent work [6].

2. **Extend the system to enable bi-directional beaming:** in addition to the given scenarios, it would be extremely useful if the experts in the immersive viewing environment could also beam back artefacts to the mobile user; the mobile user must wear Augmented Reality (AR) glasses in order to view those beamed artefacts. One challenge will be to address the limited rendering capabilities of the mobile platform. Additionally, as AR glasses still have a much lower display fidelity than large immersive viewing environments, content must be adapted for the fundamentally different display.
3. **Extend the system for long-distance beaming:** In the context of the large CONTINUUM/eNSEMBLE networks, it would be extremely desirable to expand the area of use from only the Université Paris-Saclay campus to the project partners located all over France. The major challenge here will be to make the system adaptable to different network connection qualities; for example, by adapting the quality of beamed content or using progressive streaming.

**Supervisor Commitment and Team:** Dr. Sandor has only very recently moved to France (19 December 2021) and currently does only supervises 1 PhD student in France; but, he previously graduated three PhD students in Australia and Japan. The student will work closely with the other members of the VENISE team, which currently includes 5 faculty members, 2 research engineers, 5 PhD students, and several internship students. VENISE has a proven track record of designing original immersive systems, as well as experiments for a large range of AR and VR systems.

**Desired skill profile:** the proposed project requires skills from several different domains, which are listed below. We understand that no candidate will be able to have all these skills; we hope to find a candidate that possesses as many skills as possible and we will teach him the rest during the PhD project: Augmented Reality, Deep Learning, Real-time Computer Vision, Real-time Computer Graphics, Real-time Streaming, Distributed Software Architectures

**Collaborations:** In stages 1 & 2, the main collaboration partners will be other teams in LISN. Stage 3 will require the candidate to collaborate with other teams all over France, who are part of the ENSEMBLE & CONTINUUM networks. Besides that, we encourage the student to spend some time with Dr. Sandor's world-wide collaborators, especially in the USA and Asia (China, Japan, and Hong Kong).

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