RÉPUBLIQUE FRANÇAISE
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agence nationale de la recherche

2021-2022 vague 2
Appel à programmes
PEPR EXPLORATOIRES

Document de soumission / *Submission form*

eNSEMBLE

Acronyme du programme/ *Program acronym*	eNSEMBLE	
Titre du programme en français	Futur de la collaboration numérique	
Program title (in English)	*Future of digital collaboration*	
Mots clés/*Keywords (min 10 – max 15)*	Collaborative environments, User experience, Community management, Social computing, Human-Computer Interaction, Virtual/Augmented Reality, Artificial Intelligence, Distributed platforms, Interoperability, Sovereignty. Environnements numériques collaboratifs, Expérience Utilisateur, Gestion de communauté en ligne, Interaction sociale, Interaction Humain-Machine, Réalité Virtuelle/Augmentée, Intelligence Artificielle, Plateformes distribuées, Interopérabilité, Souveraineté.	
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Etablissement(s) pilote(s) / *Pilote(s) institution(s)*	CNRS, EPST Inria, EPST Université Grenoble Alpes, EPSCP Université Paris-Saclay, EPSCP	
Partenaires(s) / *Partner (s)*	Institut Mines-Télécom, EPSCP Sorbonne Université, EPSCP Université Claude-Bernard-Lyon 1, EPSCP Université de Lille, EPSCP Université Toulouse III, EPSCP	
Durée envisagée du programme / *Estimated duration of the programme*	84 Mois /*Months*	
Montant demandé /*Requested funding*	45 000 k€	

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RÉSUMÉ

Le projet eNSEMBLE (Futur de la collaboration numérique) a pour objectif de redéfinir en profondeur les outils numériques pour la collaboration. La pandémie a donné un aperçu à la fois des possibilités et des limites des outils actuels pour la collaboration médiée par le numérique. Que ce soit pour réduire nos déplacements, pour mieux mailler le territoire, ou pour affronter les problèmes et transformations des prochaines décennies, les défis du XXIe siècle vont nous demander de collaborer à une vitesse et à une échelle sans précédent.

Pour ce faire, un changement de paradigme dans la conception des systèmes collaboratifs est nécessaire, comparable à celui qui a vu l'avènement de l'informatique personnelle. Pour collaborer de manière fluide et naturelle tout en tirant parti des capacités du numérique, il faut faire de la collaboration et du partage des fonctionnalités natives des systèmes numériques, au même titre que le sont les fichiers ou les applications aujourd'hui. Pour cela il faut inventer des espaces numériques partagés qui ne se limitent pas à répliquer le monde physique dans des environnements virtuels, permettant à des équipes co-localisées et/ou distribuées géographiquement de travailler ensemble de manière fluide et efficace.

Au-delà de cet enjeu technologique, le projet ENSEMBLE porte aussi un enjeu de souveraineté et un enjeu sociétal : en créant les conditions d'interopérabilité entre services de communication et de partage pour ouvrir les «jardins privés» (walled gardens) qui imposent à tous les participants d'utiliser les mêmes services, l'objectif est de permettre à de nouveaux acteurs de proposer des solutions adaptées aux besoins et aux contextes d'usage. Les utilisateurs pourront ainsi choisir les combinaisons d'outils et de services, potentiellement « intelligents », pour définir des espaces de collaboration mixte, physique et numérique, qui répondent à leurs besoins, sans obérer leur capacité à échanger avec le reste du monde. En rendant ces services plus accessibles à une plus large population, on pourra contribuer à réduire la fracture numérique.

Ces enjeux nécessitent un investissement important pour développer des travaux pluridisciplinaires (Informatique, Ergonomie, Psychologie cognitive, Sociologie, Design, Droit, Économie) de nature théorique et empirique. Les verrous scientifiques sont les suivants : 1) Concevoir des environnements collaboratifs et des modèles conceptuels novateurs ; 2) Combiner l'intelligence humaine et artificielle dans des configurations collaboratives ; 3) Permettre des expériences collaboratives fluides qui favorisent l'interopérabilité ; 4) Soutenir la création de collectifs sains et durables ; et 5) Spécifier des normes socio-techniques avec des cadres juridiques/réglementaires.

Les avancées sur les activités collaboratives médiées par le numérique auront un impact dans de nombreux secteurs de la société - éducation, santé, industrie, science, services, vie publique, loisirs - en améliorant la productivité, l'apprentissage, le soin et le bien-être, ou la démocratie participative. De plus, un bond qualitatif majeur dans l'expérience d'activités sociales à distance permettra de réduire nos mobilités et l'empreinte environnementale qu'elles engendrent. Un tel programme permettra aussi de positionner les acteurs français des secteurs des Télécoms, du Cloud et des services du numérique sur un marché voué à croître fortement, en capitalisant sur la vision et les avancées techniques du programme de recherche, mais aussi en accompagnant en amont la régulation du secteur pour s'assurer que nos valeurs et notre souveraineté soient préservées. C'est cet objectif d'impact qui a conduit au pilotage de ce programme par Inria et le CNRS en partenariat avec deux grandes universités, afin de garantir une couverture optimale des domaines scientifiques, mais aussi pour s'appuyer sur les projets et partenariats que mènent ces institutions avec les acteurs français majeurs du domaine.

ABSTRACT

The purpose of eNSEMBLE (Future of Digital Collaboration) is to fundamentally redefine digital tools for collaboration. The pandemic has demonstrated both the possibilities and limitations of current tools for computer-mediated collaboration. Whether it is to reduce our travel, to better mesh the territory and society, or to face the forthcoming problems and transformations of the next decades, the challenges of the 21st century will require us to collaborate at an unprecedented speed and scale.

To address this challenge, a paradigm shift in the design of collaborative systems is needed, comparable to the one that saw the advent of personal computing. To collaborate in a fluid and natural way while taking advantage of computer capabilities, collaboration and sharing must become native features of computer systems, in the same way that files or applications are today. To achieve this goal, we need to invent mixed (i.e. physical and digital) collaboration spaces that do not simply replicate the physical world in virtual environments, enabling co-located and/or geographically distributed teams to work together smoothly and efficiently.

Beyond this technological challenge, the ENSEMBLE project also addresses sovereignty and societal challenges: by creating the conditions for interoperability between communication and sharing services in order to open up the "private walled gardens" that currently require all participants to use the same services, we will enable new players to offer solutions adapted to the needs and contexts of use. Users will thus be able to choose combinations of potentially "intelligent" tools and services for defining mixed collaboration spaces that meet their needs without compromising their ability to exchange with the rest of the world. By making these services more accessible to a wider population, we will also help reduce the digital divide.

These challenges require a major long-term investment in multidisciplinary work (Computer Science, Ergonomics, Cognitive Psychology, Sociology, Design, Law, Economics) of both theoretical and empirical nature. The scientific challenges addressed by eNSEMBLE are: 1) Designing novel collaborative environments and conceptual models; 2) Combining human and artificial agency in collaborative set-ups; 3) Enabling fluid collaborative experiences that support interoperability; 4) Supporting the creation of healthy and sustainable collectives; and 5) Specifying socio-technical norms with legal/regulatory frameworks.

eNSEMBLE can impact many sectors of society - education, health, industry, science, services, public life, leisure - by improving productivity, learning, care and well-being, as well as participatory democracy. In addition, a major qualitative leap in the user experience of remote social activities will reduce mobility and its environmental footprint. eNSEMBLE will also enable French players in the telecoms, cloud and digital services sectors to position themselves in a growing market by capitalizing on the vision and technical advances of the research program and by accompanying the regulation of the sector upstream to ensure that our values and sovereignty are preserved. This ambitious objective has led Inria and CNRS to manage the project in partnership with two major universities, therefore guaranteeing optimal coverage of the scientific fields and leveraging the projects and partnerships that these institutions are conducting with the major French players in the field.

1 SCIENTIFIC AND STRATEGIC FRAMEWORK OF THE PROGRAMME

1.1 MOTIVATION AND IMPACT

As the physical and digital worlds become more and more intertwined, addressing the complex challenges that we face, including the green transition, participatory democracy and life-long learning and well-being all require unprecedented efforts by human and machine collectives. Computer-mediated collaboration has become part of the fabric of both our professional and private lives, from email to videoconferencing, from document sharing to social networking. The COVID-19 pandemic has drastically increased our reliance on such collaborative tools for work, education and entertainment (+44% according to Gartner 2021). The need to connect with others across time and space will keep expanding due to the continuing digitalization of activities, the advent of 5G technologies that make us reachable wherever we are, and the environmental crisis that requires cutting down on travel.

While current collaboration tools seem to cover users' needs, they are in fact heavily limited in terms of capability, openness and level of integration[1,2]. Unlike the telephone and email where anybody can communicate with anybody else irrespective of their choice of provider and client application, most of these tools trap their users in « private walled gardens » and information silos, creating de facto monopolies and stifling innovation. Sharing a document or joining a video-call requires *all* users to use the same application and centralized service. Setting a collaborative session requires using several independent applications and platforms to schedule the event, make a video call, share a document, record the minutes, etc. This lack of interoperability and integration of current tools is a major hurdle for developing and deploying novel collaboration technology in an open competitive market.

It is therefore of critical importance to provide users at large with robust, easy-to-use yet powerful and safe tools for collaborating efficiently at several levels of scale, from small groups to large crowds, from collocated activities to remote ones, from short impromptu sessions to long-term projects and relationships, from simple chats to real-time sharing of complex objects.

This requires **a paradigm shift from personal computing to collaborative computing**, whereby collaborative capabilities are deeply integrated into the operating systems, user interfaces and digital services that we use every day rather than available as independent apps. By creating the conditions for openness and interoperability among these collaboration services, we will enable new players, other than GAFAM, to offer innovative interactive solutions; we will enable users to choose the tools and services for defining mixed physical and digital collaboration spaces that meet their needs; and we will reduce the digital divide by making these services more accessible to a wider population.

eNSEMBLE will allow France and Europe to leap-frog the current generation of locked, proprietary enterprise systems and help recover national and European sovereignty over a key aspect

[1] A study of the practices of 61182 US Microsoft employees during the COVID-19 pandemic (Dec. 2019-June 2020) identified the effects of current collaboration tools that have a negative impact on the performance making harder for employees to acquire and share new information. Journal Nature Human Behaviour 2022.
[2] An industrial online survey (Sept. 2020) on collaboration and creativity of 1000 employees in U.S. found that 52% of remote workers reported lower productivity and 25% lower creativity.

of the digital services infrastructure. France is well placed to capitalize on the results of this project: it features European and global champions in the telecom, cloud and digital services sectors (ESN). eNSEMBLE can lead to a "national strategy" effort to spearhead an ecosystem of start-ups and larger companies providing novel collaborative services in a variety of areas: education, health, industry, science, services, public life, leisure, …

1.2 Vision and Scientific Strategy

The challenges of the 21st century require us to collaborate at a speed and scale unique in human history. A paradigm shift, comparable to the one that saw the advent of personal computing in the 80's, is needed to enable fluid and natural collaboration while leveraging digital capabilities. **The vision of eNSEMBLE is to enact the shift from personal to collaborative computing**. This change will allow co-located and/or geographically distributed teams to work together efficiently, to assemble "task forces" of thousands of people in an emergency situation, but also to entertain or take care of our loved ones, while reducing our travel and environmental footprint.

The current collaboration tools (video conferencing, shared documents, private or corporate social networks) were designed within the framework of personal computing and by reproducing our physical exchanges and means of organization, without taking full advantage of the extended capabilities offered by the digital medium. The goal of eNSEMBLE is to **fundamentally revisit the entire stack of digital services**, from conceptual model to user interface to underlying infrastructure in order to make collaboration and sharing native functionalities of these systems, just like files, applications and graphical user interfaces have enabled the advent of personal computing.

To realize this vision, we will advance our understanding of digitally mediated collaborative practices and develop theories of collaboration that account for the wealth of digital tools and devices that mediate interactions among individuals and redefine our notions of space and time. We will build upon this knowledge to develop a new generation of infrastructure and tools that support efficient, sustainable and inclusive collaboration across a variety of areas from knowledge work to education, from play to factory work, and more. We will also identify effective models of organization that enable society to invent new modes of collaboration suited to their needs.

A concrete outcome of the project would be the ability to create a hybrid collaborative interaction space that can be accessed through virtual or augmented reality, but also simple video conferencing or even a voice-only or text-only interface, using the participant's preferred tool (Figure 1). Other examples include (1) safely sharing a document in a peer-to-peer manner without moving it to a proprietary cloud service so that any of the participants can use their preferred editing tool when writing collaboratively in real-time; (2) representing an entire collaborative project as a full-fledged shareable digital object (a super-charged shared folder) that can be enriched over time, record its history, and serve as shared context when creating on-the-spot collaborative sessions; (3) enabling community members to reconfigure the platforms they use to match their organizational structures and practices as they evolve over time, handle toxic behavior and foster participation; and (4) letting users include the AI agents of their choice as participants in any of the above collaborative activities, such as an agent taking notes during a meeting or suggesting decisions based on the project history.

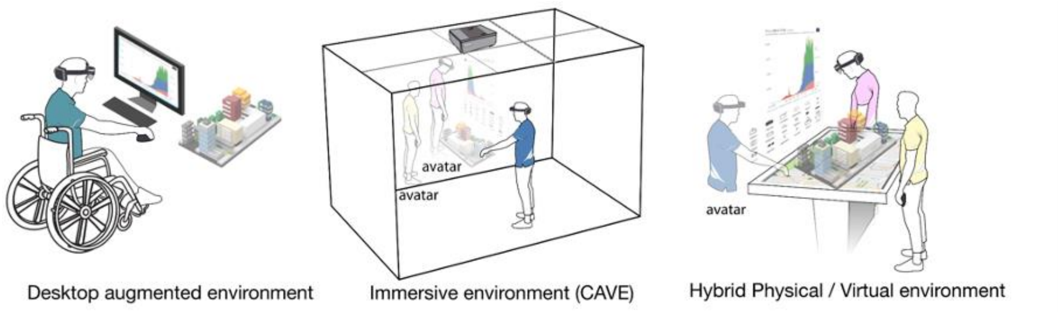


Figure 1 – Example of a collaboration space with four participants, two being co-located

A current corporate effort in collaborative interaction is shaping up around the so-called « metaverse ». This effort covers hardware and software, but also the social design and economics of these spaces. In 2021 alone, Meta (Facebook) invested over 10 billion dollars in Reality Labs. Big Tech efforts in the metaverses are not about land grab in a virtual space, but technical mastery and control over the design of the socio-technical stack, so that they can define its contours. Yet in many ways metaverses are “obsolete futures”: they have been proposed since the 1970s, and have existed under various forms since the 1990s. The main critiques of such virtual spaces were made in the 90s and still stand today: mimicking a persistent physical space in the digital domain is too literal. It misses that social activities turn spaces into places[3] that are inhabited and lived in. In practice these places rarely replicate the forms of sociality and organization we are used to, and focusing on hyper-realism, e.g. digital twins, can only lead to disappointment[4]. The most successful alternate realities are games, which can be immersive 3D, but also low-fidelity 2d, or even text-based.

Online and hybrid sociality should not literally replicate the “real world” but leverage the potential of technology to empower people. New forms of interaction and organization aligned with European values are yet to be invented that foster dignity, freedom, democracy, equality, rule of law and human rights, rather than extractive platforms and walled gardens enclosing public life and data. As an increasing amount of our collaborative activities will move to environments blending digital and physical, we need to reassert sovereignty in an integrative manner.

1.3 Scientific Challenges

The overarching challenge of eNSEMBLE is to address the design of collaborative platforms by engaging at once with engineering, design, organizational, educational, and regulatory concerns. To properly address this challenge and enact the paradigm shift from personal to collaborative computing, **we must consider the entire collaborative stack** (in the sense of B. Bratton[5]), from infrastructure to users and their social relations, in an integrative manner. Solving one facet of the problem at a time will be much less effective or even counter-productive. The project therefore requires a strong and

[3] Harrison, S., & Dourish, P. Re-place-ing space: the roles of place and space in collaborative systems. In *Proc. ACM conference on Computer-supported cooperative work*, pp. 67-76. ACM, 1996.
[4] Borges, J.L.. On Exactitude in Science. *Collected Fictions*. p. 325. Penguin Books, 1998.
[5] Bratton, Benjamin H. *The stack: On software and sovereignty*. MIT press, 2016.

long-term investment in multidisciplinary work combining Computer Science, Cognitive Psychology, Sociology, Design, Law, Economics and Organizational Science.

The design and engineering of collaborative platforms developed in the project will build upon regulatory challenges, organizational theories and thick description from the field, while at the same time challenge these approaches by demonstrating alternative digital futures in order to anticipate rather than react to technological changes. Anticipating changes and regulations should also assert sovereignty while enabling a “French (or European) exception” on digital platforms that guarantees autonomy of individual actors, but also foster care, trust and digital well-being in a time of increasing fracture and tension.

The key challenges of the project stem from the different aspects of the socio-technical stack that the project is revisiting: the underlying conceptual models of the new digital artifacts we seek to create (Key challenge 1), the role of AI and computer agency in collaborative systems (Key challenge 2), the necessary infrastructure to enact these interactions (Key challenge 3), the measures of success at the individual and social levels (Key challenge 4) and the required regulatory and economic framework to sustain the transition to collaborative computing (Key challenge 5).

Key challenge 1: Design novel collaborative environments and conceptual models

Transitioning from personal to collaborative computing requires inventing new forms of digital environments that support sharing, communication and coordination in heterogeneous environments where different users may have different interaction capabilities at their disposal.

Key challenge 2: Combine human and artificial agency in collaborative set-ups

Combining human and artificial intelligence requires the creation of novel human-computer partnerships where the whole is more than the sum of the parts. Human-centered AI promotes upskilling rather than deskilling, as well as intelligibility and control by the human actors.

Key challenge 3: Enable fluid collaborative experiences that support interoperability

The current approach to digital services, based on information silos and walled gardens, creates unneeded barriers to fluid forms of collaboration. Users need to be able to create their own secure collaborative environments that exist over time. This requires embracing interoperability at every level of the socio-technical stack. It is also key to enabling accessibility by diverse collectives of users.

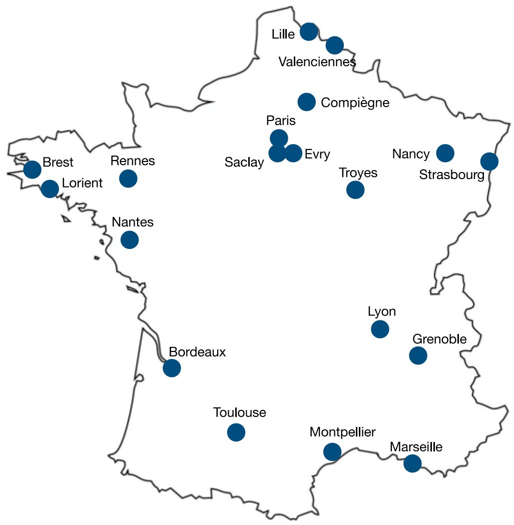
Key challenge 4: Support the creation of healthy and sustainable collectives

As collectives grow to larger scales, they must be able to dynamically create organizational structures that are adapted to the situation at hand while handling trust and supporting care (e.g., limit over-connection, discourage harassment, etc.). This requires new measures and metrics that make sense for the actors to manage these structures.

Key challenge 5: Specify socio-technical norms with legal/regulatory frameworks

For the proposed approach to work in the real world, technological advances alone are not enough. Interoperability requires regulatory and possibly legal frameworks as well as business models to ensure a level playing field while ensuring healthy economical growth.

1.4 POSITIONING



The topic of digitally mediated collaboration is addressed across a variety of disciplines and subdomains within Computer Science (CS) on the one hand, Social Sciences Humanities (SSH) on the other. This project was spearheaded by a group of researchers in Human-Computer Interaction (HCI) and very quickly gathered a critical mass of interested parties in CS and SSH, with 80 research teams directly involved at the time of this writing from HCI, Virtual and Augmented Reality (VR/AR), artificial intelligence (AI), distributed systems, as well as psychology, ergonomics, sociology, anthropology, law, economics, management and more (see Appendix for a detailed list).

At the national level, these communities are organized through learned societies such as AFIHM for HCI, AFIA for AI, AFXR for VR/AR, AFIG for Computer Graphics, ARPEGE for human factors and cognitive ergonomics as well as national networks funded by CNRS ("GdR" research networks) such as IG-RV for VR/AR/Computer Graphics/Visualization or Internet, AI and Society for multidisciplinary research on digital technology and its impact on society. At the European level, they are active in organizations such as EUSSET for socially-embedded technologies. They have been active and highly successful in garnering public funding and participating in joint projects related to mediated collaboration: as shown in the attached spreadsheet, eNSEMBLE teams have been involved in projects at least partially related to mediated collaboration that have collected over 150M€ in public funding over the past few years at the national and European levels. However, we estimate at about 10% the part of this funding that is directly related to computer-mediated collaboration.

Many of the research groups involved in the project have already collaborated with each other in multidisciplinary projects or within interdisciplinary research networks. The HCI community, in particular, has a long history of working in multidisciplinary teams and using methods from different disciplines. eNSEMBLE is therefore a unique opportunity to crystallize a rich transdisciplinary community around computer-mediated collaboration and put France ahead of the pack on this important topic.

We are not aware of any similar initiative elsewhere. In France, the French Defense and Research Agencies launched a call about Man-Machine Teaming in the limited domain of Defense and with a TRL level such that it did not address as broad and generic a perspective as eNSEMBLE. At the European level, Cluster 4 of the Horizon Europe framework addresses digital social mediation in one of its objectives but only applied to industry and innovation. In the United States, NSF has identified the “Future of Work at the Human-Technology Frontier” as one of 10 big ideas and is the closest to eNSEMBLE. Japan recently launched a national initiative around Society 5.0 on a similar theme, but with far less involvement of Human Sciences and a focus on the use of AI in society. Scandinavian countries have a long history of focusing research on both supporting group activities with technology and studying its impact on society. Whereas topics such as computer-supported cooperative work (CSCW) or Internet and Society have their own conferences, journals and established communities, they do not cover the entire spectrum targeted by eNSEMBLE. The time is therefore ripe for such community building as demonstrated by the strong level of engagement triggered by the project.

1.5 Training and Education

Studying collaboration is inherently transdisciplinary. Although there are educational programs dedicated to digital transformation, community management, interaction design, human-computer interaction (HCI), Virtual and Augmented Reality, there are no masters dedicated to collaborative technologies in France. Traditionally these masters have been anchored in disciplinary programs in business, engineering, design schools, or universities. France is lacking interdisciplinary training programs tackling at once the technical, social, and design-oriented facets of the digital transformation. It lags far behind the 50 US iSchools that graduate 6.000 to 8.000 students annually and the 120 iSchools worldwide. In France, only Institut Mines Télécom belongs to the iSchool network with one Master program. The recent university mergers in France have created the conditions for more interdisciplinary programs within the same institutions. For instance, the two pilot Universities, UGA and UPSaclay, have recently developed transdisciplinary courses and programs. At UGA, HCI (Human-Computer Interaction) courses are open to software engineering students as well as graphic designers and artists from the ESAD School of Art and Design. UPSaclay is part of the EIT Digital Master School with the Human-Computer Interaction and Design (HCID) Masters that combines computer science, HCI and business and features strong links with the art-science and design communities of the University. The university of Nantes has also recently created a Master program bringing together Design, Information Science and Computer Science.

These efforts need to be scaled up and provide more visibility and attractiveness for students as well as better legibility for employers. The skills developed in iSchools are highly valued in the marketplace given the increasing shortage not only of CS engineers, but also of UX (User Experience) designers, user researchers, information architects and other professions capable of understanding the social and technical facets of the digital economy. To bootstrap this effort, eNSEMBLE will develop education and training programs at several levels, as detailed in section 2.4.3 Dissemination.

2 Programme implementation detailed plan

2.1 Program

The scientific program of eNSEMBLE is organized into four scientific axes and a transversal one. These axes address the challenges identified above (section 1.3) in a cross-cutting manner, i.e., the five key challenges do not map one-to-one to the five axes. Instead, the five axes stem from an analysis of computer-mediated collaborative activities along the three (classic) dimensions of space, time and users. **Axis 1** focuses on **the dimension of space to create new collaborative environments**; **Axis 2** focuses on **time to sustain long-term collaborative activities**; **Axis 3** focuses on **the role of AI as participant or mediator in collaborative activities**; and **Axis 4** addresses **collectives at larger scales**.

Axis 5 is a **transversal axis** that addresses cross-cutting concerns on methodology (including measurements), ethics, and legal and economic frameworks. This organization results in axes that are complementary but feature well-identified overlapping topics that will foster inter-axis collaborations.

Each axis will be coordinated by two or three leading experts from different disciplines representing the major fields involved in the project. For example, axis 1 is coordinated by an expert in Virtual Reality, an expert in Psychology and Ergonomics, chair of the French Ergonomics association ARPEGE, and an expert in HCI. For each axis we assembled a consortium of research groups from diverse research fields all concerned by the question of collaboration, ranging from social sciences, cognitive psychology, economics and management sciences, and computer science. These groups are nationally and internationally recognized as key actors in their respective areas.

The research program will be conducted in close connection with major equipment programs, in particular the CONTINUUM national network of collaborative platforms and the Huma-Num national infrastructure for social sciences, as well as other related research programs such as the Acceleration PEPRs on Digital Education, Digital Health and Cybersecurity.

2.2 DETAILED PLAN

2.2.1 Axis 1: Collaboration spaces

Axis id and Name	**Pilot**	**Coordinators**	**Affiliation**
1 **Collaboration spaces**	UPSaclay	Christian Sandor	Université Paris-Saclay
		Marcos Serrano	Université Toulouse 3
		Jean-Marie Burkhardt	Université Gustave Eiffel
Institutions: CNRS; Inria; Université Grenoble Alpes; Université Paris-Saclay; Institut Mines Télécom; Sorbonne Université; Université Lyon 1; Université de Lille; Université Toulouse 3 Université de Strasbourg; Université Bretagne Sud; Université d'Evry; Université Gustave Eiffel; CESI-Paris Nanterre; INSA Rennes; Université Rennes 2; ENS Rennes; Université de Bordeaux; Université Polytechnique Hauts de France			

The situations in which several participants communicate and collaborate at the same time, remotely or face-to-face, are many and varied: project review, hybrid teaching, telesurgery, crisis management, family reunion in a pandemic situation, etc. Such collaboration among participants engaged in various forms of activity and work takes place in a *collaboration space*. The unprecedented, extensive and sometimes unexpected use of collaboration spaces during the COVID-19 pandemic is the result of three decades of research on computer-mediated collaboration. For example, keeping a Zoom or Skype video call continuously open to maintain a sense of shared presence mimics the research prototype of Portholes[6], a media space created back in 1992.

[6] Harrison, S. (Ed.). (2009). *Media space 20+ years of mediated life*. Springer Science & Business Media.

We are however at a turning point due to a change of scale. The recent technological developments in sensing technologies, displays (large, immersive, mobile, wearable), networking and visualizations tools has led to increasingly heterogeneous physical and digital collaboration spaces where participants with different interaction devices and modalities must be able to collaborate efficiently, raising the critical issue of interoperability between these devices and modalities. What was once confined to industrial and academic laboratories is now becoming increasingly available to a wider audience. It is paramount that these collaboration spaces are accessible to the widest diversity of users to ensure equal access to collaborative activities, education and jobs. Moreover, the wider availability of these technologies is accompanied by an increase in the diversity but also complexity of activities that require collaboration, such as the analysis of large heterogeneous data sets that cannot be thoroughly explored and understood by any single person. **The scientific challenges addressed by this axis** come from a change of scale along the following 3 dimensions of collaboration spaces: **1) diversity of users, 2) diversity of interaction devices/modalities, and 3) complexity of datasets, tasks and environments**. A fourth challenge is to handle the **dynamic transitions between collaboration spaces.** This challenge requires an integrative approach with the 3 dimensions of a collaboration space. Indeed, the fundamental research question is to design collaboration spaces that allow for continuous and seamless collaboration in order to unify remote and face-to-face collaborations, tightly coupled and loose collaborations, as well as group collaborations, in spontaneous subgroups or asides.

The expected breakthrough is the definition of mixed collaboration spaces where users are in full control and that provide rich and flexible multi-user experiences. These spaces must adapt to the diversity and dynamicity of the interaction capabilities of each participant, to their physical and digital environments, and to the different modes of collaboration. These collaboration spaces will support more and more of our activities as well as change them. We need to better understand these phenomena, some of which are general while others are domain-specific, in order to create appropriate solutions. The design of these new mixed collaboration spaces, seamlessly integrated into our private and professional lives and into the social fabric as well as the study of their impact on changes in collaboration patterns require interdisciplinary work involving social, management scientists, psychologists, ergonomists, domain tasks experts (e.g. mechanical engineering), and computer scientists (human-computer interaction, software engineering, computer graphics, network and multimedia, virtual/augmented reality), all engaged in this axis.

Sub-axis 1.1 – Change of scale in the diversity of interaction devices and modalities

The advent of fabrication techniques such as additive manufacturing and printed electronics (e.g., smart materials, ultrasound mid-air haptic) as well as the emergence of a variety of commercially available[7] multi-sensory devices pave the way for a very large space of possibilities in terms of input and output interaction devices. For example, output devices range from smartwatches and hand-held screens to tabletop, head-mounted displays, wall-sized displays and CAVEs. A large set of technological possibilities are available in the CONTINUUM Equipex+ project, a collaborative research infrastructure

[7] Conseil supérieur de la propriété littéraire et artistique. [Sept. 2020 report on VR and AR in France.]()

of 30 platforms distributed throughout France. By creating the conditions for interoperability among these technologies, **we will open up new design solutions for heterogeneous collaboration spaces**.

The scientific challenges involve understanding the impact of these heterogeneous multimodalities on the users of these collaboration spaces. For collaboration spaces that replicate human behavior/interaction found in our daily actions in the physical world, the key issue is to ensure the transfer of skills from real to virtual and from virtual to real, blurring the boundary between the two. The heterogeneity of devices will require revisiting the concepts of presence, common ground and group awareness. This includes investigations of interaction modalities (e.g., brain-computing, sound or haptic) and interaction latency in fragmented physical, 2D and 3D virtual environments. This will lead to the creation of **new collaboration spaces supporting very different types of experiences than in the real world**.

Sub-axis 1.2 – Change of scale in the diversity of users: collaboration spaces for all

Despite huge progress in communication technology, remote collaboration remains often hard and less satisfactory than face-to-face, resulting in less engagement, motivation or perceived support, and more collaboration failures. Apart from geographic distance, other factors come into play such as the diversity of collaborators' sensory, motor and cognitive capabilities, the diversity of the team members' roles, and the diversity of the stakeholders' cultural background and familiarity with technology. A solution is to adopt personalized representations (e.g., avatars) controlled by the users and employing part or whole of the users' body to interact with digital content and to support collaboration. However, this approach is also likely to create barriers to accessibility. Finally, there is no satisfying approach to assess the resulting quality of participants' experience as the collective collaborative processes scales up.

Since the diversity of users has been largely ignored until now, **we will develop inclusive methods and design solutions for collaborative tools** so that the resulting technology is accessible and useful to all members of society and consistent with human diversity (cf. Universal Design / Design for All). Moreover, to foster engagement in remote collaborative interaction, we will provide measures of the impact of embodiment on users and innovative techniques for controlling an avatar. Finally, based on an interdisciplinary approach, **we will create a framework for describing and measuring the quality of collaborative experiences**.

Sub-axis 1.3 – Change of scale in the complexity of datasets, tasks and environments

Collaborative activities are increasingly dealing with complex datasets, tasks and environments. The ever growing distribution of sensors in our surroundings generates large amounts of *data* (e.g. energy consumption), which are crucial to help stakeholders in collaborative decision-making processes. Real-world collaborative scenarios, such as crisis management, involve several actors, operators, analysts and decision makers in very complex *collaborative tasks*. These tasks require the orchestration and management of collaborative actions (e.g., crisis responses) with actors spread over various physical locations (e.g. fireman in the field). Finally, *collaboration environments* can take a myriad of forms: from completely virtual such as a metaverse, to physical such as a control room, with all sorts of hybrid combinations.

These evolutions raise tremendous challenges for the design and development of the collaboration spaces of tomorrow. **We will create new conceptual models, procedures, certifications and software tools to support complex collaborative tasks**. In particular we will develop coherent and broadly applicable visualization and interaction approaches to make collaborative data analytics systems productive in real world scenarios. Finally, to support real-time and realistic collaboration, we will invent adaptive interfaces, beyond the desktop metaphor, that take into account the available display space, context, and users' cognitive state and we will study their impact on group dynamics.

Sub-axis 1.4 – Transitions between collaboration spaces: dynamic collaboration space

Given the diversity of users, the heterogeneity of collaboration spaces and the increasing complexity of tasks, environments and datasets, the design of *transitions* between these components is crucial to support effective and efficient collaboration.

This sub-axis takes a holistic approach to managing the dynamicity of collaborative spaces by addressing the three dimensions of users, interaction devices/modalities, and environments/tasks. For example, how to welcome a new user with specific sensory, motor and cognitive abilities into a collaboration session without disrupting the collaborative experience? How to smoothly transition from AR to VR during a collaborative session? This holistic approach will allow us to **identify and categorise the design issues in transitioning between collaboration spaces**, as well as to **design and develop new techniques to support continuous and seamless collaboration**.

2.2.2 Axis 2: Long-term collaboration

Axis id and Name	**Pilot**	**Coordinators**	**Affiliation**
2 **Long-term Collaboration**	INRIA	François Charoy	Inria Nancy
		Myriam Lewkowicz	Université de Technologie de Troyes
Institutions: CNRS; Inria; Université Grenoble Alpes; Université Paris-Saclay; Institut Mines Télécom; Sorbonne Université; Université de Lille; Université Lyon 1; Université Toulouse 3 École Centrale Lyon; ENS Rennes; École Nationale Supérieure des Arts et Métiers; INSA Rennes; Université de Lorraine; Université Rennes 1; Université de Strasbourg; Université de Technologie de Troyes			

The last 20 years have seen the rise of a large collection of tools and platforms that provide services to support group collaboration, communication and coordination. The acculturation of people to these services has grown at the same pace, with an acceleration during the last two years due to the pandemic. Indeed it has become fairly easy to share and work on data and documents, to organize communication through different channels, workspaces and platforms that can be integrated into all kinds of business applications, and to coordinate actions through boards or workflows that mimic the office environment.

Despite these advances, setting up a collaborative environment for a project that may last weeks or months with participants belonging to different organizations requires many decisions based on contradictory requirements, including interoperability, security, trust, organization policies, ease of use, previous knowledge, and cost. We always face the double binding injonction between organizations' policies and ease of collaboration: should we use this public centralized platform offered by a global, private third party or rely on the internal solution that we will have to impose to the group? How is organized the governance of the collaboration for group management, data ownership, and the definition of the collective process? Wrong decisions lead to inefficient collaboration. People do not adopt the offered technical solutions and fall back to inadapted ones such as email attachments. They prefer to use their own devices and usual applications to collaborate. They want to be able to work seamlessly from their office, from home, or on the go. They also want to be able to adapt their environment to new needs that may arise during their activities.

The implementation strategy of this axis is organized around four related scientific challenges. First, we need to **better understand current and future forms of long-term collaboration**. We will investigate the current forms of collaboration disseminated around multiple technology artifacts, especially in domains that are currently inventing new ways of working together with technology (Industry 4.0, software engineering, digital learning, crisis management, and healthcare), while taking into account the evolution of legal and regulatory frameworks for digital technology (addressed in Axis 5). Second, at a technology level, we will develop **new interoperable capabilities for software and networking that will be key for the future of long-term collaboration**. We will share these advanced components within the program for identifying use cases. Third, we will develop **new conceptual and analysis tools for articulating social needs and technology capabilities in a sociotechnical perspective**. Finally, we will develop **frameworks for translating these analyses into actionable visions and propositions** that will guide research and industry for the future of long-term collaboration.

Sub-axis 2.1 – Understanding current and future forms of long-term collaboration

Long-term collaboration typically involves multiple technological artifacts, especially in domains that are inventing new ways of working with technology. This sub-axis will investigate existing innovative research projects in order to highlight the forms, stakes and limits of these new forms of collaboration. The legal landscape is also changing with new frameworks emerging at the EU and states' scales that require better account for the location, privacy, ownership, and transferability of data that is not yet dealt with by existing digital tools and platforms, and could even prevent current services from continuing to exist.

This sub-axis will study emerging forms of collaboration in particular in the following areas: industry, software engineering and architecture, hybrid and distance learning, crisis management, and healthcare. These domains have been key in the emergence of technology-based collaborative practices. In connection with Axis 5, we will also study the evolution of legal and regulatory frameworks for digital technology that affect long-term collaboration. All these elements will allow us to **collect, build and organize a repository of up-to-date analyses, use cases and reports about future forms of long-term collaboration, their challenges and their limits**.

Sub-axis 2.2 – Open technical frameworks and protocols for long-term collaboration

The next generation of long-term collaboration technology will require fluid distributed infrastructure that can be partly owned and shared among participants. Interoperability, sustainability, trust, reliability, and security will be at the heart of the capabilities of this new infrastructure. We will investigate new algorithms and infrastructure to manage shared and replicated data while keeping track of user intention, dependencies and change histories between shared artifacts and across organizational barriers. We will also develop an interoperability framework that can be used as the basis for collaborative services integration in an heterogeneous environment. In the area of heterogeneous multimedia-based asynchronous collaborative applications, we will use service virtualization to support interoperability and portability while enabling continuous control over service parameters based on the users' quality of experience, thereby supporting a modular yet unified multimedia experience. Finally we will develop, in cooperation with PEPR Cybersecurity (and sub-axis 4.1), security models and protocols adapted to long-term collaboration that do not require a central authority. All these capabilities will **create the foundations for the future infrastructure for long-term collaboration by providing new technology components that can be at the heart of safe,** sustainable **and secure collaborative services**.

Sub-axis 2.3 – Matching collaborative software bricks with future collaborative practices

As collaborative activities spread across multiple software and devices, breakdowns in the way information is shared, and group coordinated become increasingly frequent and problematic. New conceptual frameworks are needed to account for the organizational evolutions (e.g. people increasingly collaborating across teams and organizations), the constant evolution of software (e.g. constant updates, or switch from one platform to another), and emerging collaborative practices.

We will develop new conceptual and analysis tools for articulating social needs and technology capabilities in a sociotechnical perspective, therefore developing new practices for software engineering and design. These frameworks will account for the asymmetries of roles, goals and preferences when collaborating on a shared artifact, and for the recording and browsing of collaborative interaction histories. Such conceptual frameworks for long-term collaboration will allow an appropriate modelling of coordination mechanisms to ensure the appropriation of technology by end-users, which is challenged by the complexity of the ecologies of artifacts at stake. This sub-axis will produce **theoretical constructs for analysis, modelling and design that match new forms of long-term collaboration** (as identified in sub-axis 2.1) **with technology capabilities** (in particular those developed in sub-axis 2.2).

Sub-axis 2.4 – Actionable guidelines and demonstrators for long-term collaboration

More than 50 years ago, in his seminal conference "*a research center for augmenting human intellect*"[8], Douglas Engelbart articulated a vision for creating collectives of humans and machines working together in a complementary way on "big problems". While this vision is often cited, it is far

[8] Engelbart D. & English W. (1968) *A Research Center for Augmenting Human Intellect*. SRI.

from being realized. Our approach will be to translate the knowledge gathered about new forms of long-term collaboration into actionable guidelines to inspire research and industry in creating future forms of long-term collaboration. We will focus on work domains where long-term collaboration is complex and challenging and require collaboration beyond the desktop, hybrid collaboration in real and virtual worlds (in collaboration with Axis 1), or collaboration that involves intelligent agents (in collaboration with Axis 3).

Beyond actionable guidelines for the design of tools for long-term collaboration, the main outcome of this sub-axis will be **prototypes and demonstrators** in the application domains identified in sub-axis 2.1 (industry, software engineering, digital learning, crisis management, healthcare).

2.2.3 Axis 3: Collaboration with intelligent systems

Axis id and Name	Pilot	Coordinators	Affiliation
3 Collaboration with intelligent systems	CNRS	Catherine Pelachaud	CNRS
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		Gilles Coppin	Institut Mines Télécom
Institutions: CNRS; Inria; Université Grenoble Alpes; Université Paris-Saclay; Institut Mines Télécom; Sorbonne Université; Université de Lille; Université Lyon 1; Université Toulouse 3 École Nationale d'Ingénieurs de Brest; Université de Montpellier; INSA Lyon; Université de Technologie de Troyes; Université Lyon 3; Université de Lille; SciencesPo; Université d'Evry; Université Aix-Marseille; Université de Nantes			

Intelligent systems (or agents) are becoming an integral part of nearly all areas of our daily lives. They can be a recommendation system on our smartphone, a conversational agent (e.g. Siri) or a robotic system at home or in industry. Their introduction raises new questions about how humans and machines collaborate and the impact of these technologies on human activity. These systems can empower our ability to make decisions but can also reduce human autonomy. They can provide services tailored to each individual or can be used to increase surveillance. They can create new forms of human activity or make some jobs redundant. Intelligent systems impact habits, abilities and social behaviours from individuals to large organizations.

Despite efforts in HCI and SSH to address these questions, we still do not know, *today*, how to design and evaluate intelligent systems. *Tomorrow*, this will be even more challenging as these systems will be more diffuse in the environment. This requires novel theoretical models of interaction to support collaboration between human users and intelligent systems along the following dimensions:

1. **Actors**. Interaction in everyday life or work situations happens often in groups. Injecting intelligent systems changes how a group of humans collaborates on a joint action, how tasks distribution happens, how roles are defined, etc. How to ensure that group dynamics with intelligent systems serve the purpose of the collaboration?

2. **Space**. With the ubiquitous nature of collaboration, interaction with these systems goes beyond a single location. This raises the issue of interoperability between heterogeneous devices and modalities. Users can perform direct interaction with a physical robot in a workshop, then continue to interact remotely over their smartphone or in an immersive environment. How to ensure the continuity of the collaboration through spaces, devices and modalities?

3. **Complexity**. While assisting users to achieve complex tasks, intelligent systems are also more and more difficult to configure. Before and during the use of a system, users should be able to define their goals, maintain privacy or train the algorithms to drive the system. In other words, the complexity of the task is translated into the complexity of the control of the system. How to ensure that users maintain understanding and control with increasing system complexity?

4. **Time**. Intelligent systems are generally designed and evaluated regarding the quality of the collaboration during the interaction, e.g., effectiveness to achieve a task. However, interacting with these systems can have long-term impacts outside the interaction by adversely modifying users' behaviors. How to adapt collaboration with intelligent systems to augment users' capabilities over the long-term?

The expected breakthrough in this axis is to develop multi-scale collaboration in actors, space, complexity and time, between human collectives and intelligent systems. The ultimate goal is to create new forms of interactions between human users and intelligent systems that take advantage of differences in human's and system's skills, while reducing reliance on their respective weaknesses, to create an overall partnership where the combination of the human and the system is better than either one alone. Addressing these challenges requires collaboration with specialists in HCI, AI, ethics, sociology, anthropology and management science.

Sub-axis 3.1 – Collaboration between groups of people and intelligent systems

Interaction in everyday life or work situations happens often in groups. Here, a group may be composed of up to twenty people (see axis 4 for larger-scale collaborations) and include one or several intelligent systems. Group interactions involve complex human behaviors with turn-taking, embodied synchronization, imitation, etc. However, they cannot be viewed as a dyad or even as a set of dyads. Moreover, interactions in groups involve dynamics that tend to accentuate polarization among group members. Introducing intelligent systems for supporting group interaction should consider these complex configurations and capture these group dynamics to enhance cohesion, ensure collaboration on a joint action and manage conflicts.

The challenge is to ensure that the introduction of intelligent systems in a group of human users serves the purpose of the collaboration. We will develop **measures and metrics to understand how collaboration happens and evolves in a group of human users and intelligent systems**, taking into account the complexity of individual behaviour in the context of collaboration. We will also **define mechanisms so that a group of intelligent systems do not manipulate the leadership at the expense of the human users**. This requires complex moderation principles to de-escalate conflicts, enhance the creativity process and drive the group to a common performance/goal as well as ethical considerations regarding the role and limits of the actions of an intelligent system and to which extent it should report its action to a human expert.

Sub-axis 3.2 – Continuity of collaboration through space, devices and modalities

Because of the ubiquitous nature of interaction, collaboration between humans and intelligent systems will occur across different locations: An operator may train a physical robot to execute a manipulation task in a workshop, monitor and refine its behavior using her tablet at home, uses a VR environment at her lab to remotely teach a new task to the robot through its digital twin. Beyond location, this scenario also illustrates the interoperability issues that occur when the collaboration between human and machine involves different combinations of modalities: natural language and physical interaction in the workshop, GUIs at home and mixed reality in the lab.

The challenge is to ensure the continuity of the collaboration through spaces, devices and modalities. We will **create interoperable conditions so that human users can perceive and interpret the different representations of a single system** (physical, iconic, virtual) and to **control it from heterogeneous devices**. We will also **develop models to ensure that the intelligent systems are robust to context change**: These systems will maintain human representation consistency when switching devices and modalities and support data from heterogeneous sensors, modalities and qualities (e.g. voice recognition, action/motion tracking) related to the same human user, but in different contexts.

Sub-axis 3.3 – Maintaining understanding and control with complex intelligent systems

With the increasing complexity of intelligent systems comes the complexity of understanding them. Indeed, a common observation when interacting with intelligent systems is the lack of understanding of the human users upon the elements that drive the system's decisions which are necessary to empower individuals and maintain a sense of control. The goal of Explainable AI (XAI) is generally couched in terms of explaining to users how the algorithm works (e.g. criteria). However users also seek to understand what aspects of their own behavior the intelligent system understands. More importantly, they want to know what the system will allow them to do next and what are the consequences on the different stakeholders. Moreover, human users need to stay in control of these intelligent systems. But as a system achieves more and more complex tasks, it also becomes more and more difficult to control, whether through off-line configuration (e.g. recommender systems) or online dialog (e.g. conversational agents), especially when the control depends on proprietary applications.

The challenge is to ensure that users maintain understanding and control despite increasing system complexity. We will **develop practical approaches and interactive visualization** that allow users to both **understand and trust** interaction with intelligent systems. We will also conceive **theoretical models and frameworks to design interactions with intelligent systems and allow users to efficiently control** the whole pipeline of data processing of intelligent systems. Despite the complexity of controlling intelligent systems, users will be able to define goals (e.g. making a manipulation task), select which data types are captured and how they are interpreted to maintain privacy and agency over which models to use, the best methods to train them, and their optimization criteria as well as how to deal with interoperability issues related to using an agent in multiple applications.

Sub-axis 3.4 – Long-term collaboration with intelligent systems

Human users can engage month- or even year-long interactions with intelligent systems for their services. By adapting to the users, intelligent systems may change the behaviors of human users. For example, humans who search for recommendations (e.g., movies, diagnosis) may get used to following them rather than exploring alternatives or questioning them; they may also decide to systematically go against them due to new algorithm aversion; finally they may try to develop intuitions on how the system works (such intuitions are rarely "correct", since humans and machine learning algorithms reason in completely different ways). These long-term interaction mechanisms can lead to incorrect assumptions, expectations and potentially deception.

Collaboration between humans and intelligent systems can also modify users' behavior outside of the interaction, potentially at a much longer time scale. Indeed, users, especially expert users, come to rely on these systems, and begin to lose expertise. This form of deskilling may be benign or devastating in safety critical systems (e.g., assistive robotic surgery) when users no longer fully recall how to utilize their skills in an emergency. While some railings are available in specific contexts (e.g., continuous training of airline pilots), many users and institutions do not consider this form of deskilling which can lead to the reduction in the quality of users' work.

The challenge is to adapt collaboration with intelligent systems to augment users' capabilities over the long-term. We will **develop effective measures of the quality of the collaboration during interaction**, with the goal of understanding how users' behavior evolves over time and improve how humans and intelligent systems collaborate. We will also **develop measures of the quality of the collaboration outside collaboration**. We will create **intelligent systems that effectively and continuously develop users' expertise** and avoid deskilling.

2.2.4 Axis 4: Managing communities at different scales

Axis id and Name	Pilot	Coordinators	Affiliation
4 Managing communities at different scale	UGA	Anne Bartel-Radic	Université Grenoble Alpes
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Digital platforms have enabled collaboration at a scale that was not possible before. They afford both opportunistic and structured forms of association, engagement, work, in voluntary-based or more traditional organizations. However, they can also drift toward inefficiency, misinformation, loss of skills, dehumanization of collaboration, and lack of respect for privacy and control over personal data.

These platforms have been accused of reinforcing an unbalanced control of power of some participants over the many others, which may lead to an unfair distribution of the benefits.

The goal of this axis is to offer a new generation of digital tools and guidelines enabling communities to collaborate in a secure, inclusive, empowering, and efficient manner. We use the term "community" knowing its polysemic sense to stress that we are studying the interaction of several people, considering the variety of organizational structures, sizes, and layers. Our main scientific challenge is understanding and supporting community management in their organizational diversity. We will tackle this challenge in a transdisciplinary manner from low-level technical challenges to organizational ones: 1) ensuring that technical infrastructures are reliable, secure and scalable; 2) understanding the dynamics and functioning of communities, at different scales, and providing organizational guidelines to improve the performance, health and longevity of communities; 3) enabling stakeholders to coordinate communities by themselves, to define organizational structures and to recruit and mobilize participants. Finally we will contribute an open observatory of collaboration to collect qualitative and quantitative open data and to produce and maintain analytics (e.g. on open-source software) about and for specific communities.

The expected breakthrough lies in enabling communities to effectively manage their dynamic (re-)organization, handling the individual and collective goals, their various layers (roles, and hierarchies, participants), in a sustainable and equitable way. As stressed by Nobel laureate E. Ostrom in her study of digital commons[9], we have to address the co-constitutive entanglement of technology with tasks, structures and forms of organizing[10]. This means considering in our research the co-evolution of platform design and the collectives that leverage them. While existing works either analyze social interactions ("community organization") or address technical challenges related to platform design, this axis will bring together computer scientists, designers, social and organization scholars to intervene across the whole spectrum from technical to social. To do so, we will anchor our work in specific projects: epistemic communities such as Wikipedia[11], or task-oriented groups, bringing experts together around a common goal, Open Data platforms such as OpenStreetMap or FauneFrance (Open Science), debate platforms, such as AgoraVox, crisis management, but also projects that are willing to work with us via an open call.

Sub-axis 4.1 – User-centric large-scale infrastructures for collaboration

As collaboration moves toward larger communities, distribution and interoperability become necessary, meaning that data, documents and collaborative spaces are hosted in multiple locations that must maintain consistency and that must be accessible through open protocols. A real-time, responsive and resilient infrastructure that maintains consistency at all times is mandatory. Multiple

[9] Hess, C., & Ostrom, E. (2007). *Understanding knowledge as a commons: From theory to practice* (p. 24). Cambridge, MA: MIT press.
[10] Faraj, S., & Pachidi, S. (2021). Beyond Uberization: The co-constitution of technology and organizing. *Organization Theory*, 2(1), 2631787721995205.
[11] Francesco Rullani & Stefan Haefliger. (2013) The periphery on stage : The intra-organizational dynamics in online communities of creation. *Research Policy*, 42(4) :941–953.

channels (AR/VR, video, audio, text) must behave in a coherent fashion within and across groups while maintaining security and privacy. Unlike for traditional distributed databases, special challenges and opportunities arise from working with people collaborating together: users must be made aware of the state of the system and of what their peers are doing, which enables them to avoid conflicts at the data level, coordinate their actions, manage trust, and ensure consistency at a human level rather than a technical one.

The main outcome of this sub-axis will be technical frameworks tied to user-centric principles for privacy, security and group management for large communities. The specificity of our approach is to take into account individual and social behaviors when designing the infrastructure layers, whether it relates to security issues, management of roles, tasks, and organizational policies in groups ranging from ten to hundreds of thousands of people, or privacy in collaborative contexts that require partial disclosure of information while retaining sensitive elements. We take a complementary approach to the Cybersecurity PEPR by focusing on usability, and will work with them to leverage user research and user testing to ensure that the general public can benefit from our technical contributions.

Sub-axis 4.2 – Understanding community dynamics and functioning

Successful collaboration within communities heavily depends on their dynamics. This sub-axis aims at a better understanding in order to come up with guidelines to manage communities. We will study communities ranging from large-scale collectives, such as the contributors to Wikipedia, to intermediate sizes such as members of a public or private organization, to workgroups of two to several dozen collaborators. Communities may be of different natures, e.g. top-down “prescribed” groups vs. bottom-up emergent groups, or members who interact and recognize each other as members of the same group, vs. contribute separately from each other towards a shared goal. Over time, communities evolve and change, including across these categories, which affects collaboration outcomes.

The main outcome will be the **characterization of the conditions and causes of successful collaboration, with tools for defining and measuring them.** We will consider three dimensions of community performance[12]: 1) the achievement of the goals of the community, whether they are assigned or self-determined in an emergent way, with a focus on creativity and innovation; 2) the community becoming a well-performing unit in terms of communication, knowledge-sharing and cohesion; and 3) the community members’ development of knowledge, skills and well-being, including techno-stress avoidance and impaired people inclusiveness. We expect breakthroughs to come from an interdisciplinary approach that combines computer science approaches (community detection, multi-graph analysis) with social science ones (organizational models and frameworks), instantiated into integrated models.

Sub-axis 4.3 – Community-centric management tools

The understanding of collaborative practices at scale developed in the previous sub-axis is only a first step. The richness and complexity of metrics that result from our combined organizational guidelines

[12] Hackman, J.R. & Kats, N. (2010). *Group Behavior and Performance. Handbook of Social Psychology*. Wiley.

and data mining approach may be of high scientific value, but this information must be geared toward action. The key challenge lies in identifying how to design analytics and community management tools that community stakeholders can use.

The main outcome of this sub-axis will be **generic monitoring, visualization and community management tools**. While designing effective user experiences at the individual level is now common practice, understanding how to design for communities would be a breakthrough. We will propose new design methods so that management tools answer the diversity of needs and concerns of community members. Leveraging these methods, we will develop a unique set of tools that can support the management of communities by the stakeholders themselves, enabling them to re-organize communities and groups, re-attribute roles and re-structure hierarchies, handle toxic behaviors, and other interventions related to specific case studies. Understanding the implication and trade-offs of these tools will require real-world longitudinal studies with communities.

Sub-axis 4.4 – The Open Observatory of Collaboration

Private collaboration platforms have too much control over scientific research, which strongly limits public knowledge of research results (from professionals using Microsoft 365, to communities organizing on Facebook). They tightly control which data gets shared, at which granulary, on which time-scale, and even define the questions that can be asked, by framing them in ways that are favorable to them. This sub-axis is not about developing new scientific theories or tools, but to ensure that these data, knowledge and tools are made available to broader audiences.

The main outcome of this axis will be the creation of an open observatory of computer- mediated collaboration for the scientific community and practitioners. **This observatory will gather, label, and maintain open data, open source software tools, questionnaires, white papers resulting from previous sub-axes.** This will be done in coordination with huma-num, the national digital-humanities infrastructure. We will launch open calls dedicated to bottom-up initiatives that can contribute to the observatory. We will also consider how platform participants can benefit from new collaborative tools as a key element in the selection or proposals.

2.2.5 Axis 5: Transversal challenges of the program for science and society

Axis id and Name	Pilot	Coordinators	Affiliation
5 **Transversal challenges of the program for science and society**	CNRS	Wendy Mackay	Inria
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Institutions: CNRS; Inria; Université Grenoble Alpes; Université Paris-Saclay; Institut Mines Télécom; Sorbonne Université; Université Lyon 1; Université Toulouse 3 Université Lyon 2; Université Lyon 3; Université de Technologie de Troyes; Université de Nantes; CEA-tech; Universités Rennes 1 et Rennes 2; CESI-Paris Nanterre; ENSAM			

The transversal axis addresses issues that arise from the previous four axes but require a meta perspective, primarily with respect to assessing the impact of the collaborative technologies developed by eNSEMBLE at the individual, societal and cultural levels. More specifically, Axis 5 will study **how these technologies affect *sustainability*, *impacts beyond technology* and *ethical issues***.

The key scientific challenges include 1) identifying or developing methodologies for assessing the impact of collaborative technology on individuals, groups of users, and society; 2) recommending strategies for reducing the carbon footprint of collaborative technologies, and 3) identifying the ethical and legal issues raised by technology-mediated collaboration.

Sub-axis 5.1 – Methodologies for understanding the impact of technology-mediated collaboration on users and society

Different research disciplines use different research methods with correspondingly different underlying goals and assumptions. In order to encourage an active dialogue among partners trained in the natural sciences, social sciences and the humanities, we need to develop a common framework that characterises the similarities and differences across methods, as well as strategies for assessing risk. Axis 5 extends the scope beyond measuring specific collaborative technologies developed in Axes 1-4 to **create a taxonomy of research methods and a general framework for assessing collaborative technologies**. We will borrow from existing disciplines, such as the evaluation of the positive, neutral or negative impact of inter-related populations upon each other in evolutionary biology or the analysis and understanding of addictive behavior from psychology and behavioral economics. We will examine methods for studying social dynamics, cultural frameworks, beliefs and views on technologies, and measure changes in collective imagination, as expressed through literature, the press, cinema, graphic narratives and other cultural productions.

The first challenge is to describe, compare, and extend the research methods used in the other four Axes. We will create a taxonomy that identifies both effective existing methods as well as gaps that require new methodologies. For example, the development of technological collaboration identified in Axes 1, 3 and 4 produces new forms of social spaces for work, sociability and leisure, with correspondingly new patterns of the spatial distribution of social interactions. We will consider both qualitative and quantitative methods for examining collaborative technology's impact on human relationships with other humans and intelligent agents, and assess the diverse factors and conditions that affect how people collaborate and undertake collective action. We will also consider methods that address behavior change at different time scales, from immediate impact on individuals to long-term impact on people and society.

The second key challenge is to create a roadmap that helps partners, as well as students and practitioners, to identify appropriate research methods for assessing and effectively deploying collaborative technologies. This transversal axis will facilitate communication across all the partners, and will encourage the **development of cross-disciplinary research methods specifically adapted to the unique challenges of evaluating the impact of collaborative technologies on users and society**.

Sub-axis 5.2 – Address the positive and negative ecological effects of technology-mediated collaboration

Collaborative technologies that support remote work, conferences, education and forms of care offer an effective tool for reducing unnecessary mobility and the corresponding green-house gas (GHG) emissions. Indeed, the transportation sector accounts for about 16% of GHG emissions, compared to 2-4% for the IT sector. However the footprint of the IT sector is growing, and includes, besides GHG, pollution related to rare-earth extraction, e-waste, and geo-political tensions related to control over raw materials and component manufacturing. Although the project cannot address all these issues, Axis 5 will ensure that they are considered within the context of Axes 1-4.

The key challenge is to address issues of efficiency and longevity in the design of collaborative tools. This entails both principles of ecodesign and societal changes. We will develop **methods and measures to achieve reliable life-cycle assessments of collaboration tools from networking to end-user devices**. This knowledge will enable us to minimize the footprint of the technologies developed. While analysis and optimization are necessary, broader changes within society are necessary, this requires questioning how socio-technological imaginaries are built. We will produce analyses of changes in collective imagination about collaboration and sustainability, as expressed through literature, the press, cinema, graphic narratives and other cultural productions, and how they relate to possibilities of social or ideological change.

Sub-axis 5.3 – Address legal, ethical and philosophical issues

Collaboration technologies raise important ethical issues, particularly with respect to technological control, citizen's liberty, digital democracy, free will, governance of and by digital technologies, and the control of work[13] or ordinary activities. This echoes the question of the legal framework organizing privacy, data protection, interoperability, security, and IA responsibilities, but also more classical questions such as the property of the collective intellectual productions especially in light of the EU member States of Directive 2019/790 on copyright and related rights in the Digital Single Market. Finally, philosophical debates and reflections posed by the Humanities explore how far humans can be helped, assisted, facilitated in their tasks and activities, while remaining "human"[14].

Key challenges include identifying the ethical responsibilities in human-machine collaboration, and clarifying legal issues related to the impact of both collaborative and intelligent systems on individuals and society. Finally, it is crucial to address regulatory concerns related to privacy, copyrights, and interoperability.

[13] De Vaujany, F. X., Leclercq-Vandelannoitte, A., Munro, I., Nama, Y., & Holt, R. (2021). Control and surveillance in work practice: cultivating paradox in 'new' modes of organizing. *Organization Studies*, 42(5), 675-695.
[14] Stuart Russell, *Human Compatible: Artificial Intelligence and the Problem of Control*, Viking, 2019

2.3 GOVERNANCE

The governance of the program is outlined in Figure 2. The 4 **PEPR Program Directors** are designated by the CEO of each lead institution: CNRS, Inria, University Grenoble-Alpes (UGA) and University Paris-Saclay (UPSaclay). With a strong experience in research management and an in-depth knowledge of the French research landscape, they are in charge of the strategic monitoring and operational management of the PEPR:

- they ensure effective coordination with the taskforce, validate the progress of the 5 axes, the annual reports and budget allocations;
- they define research priorities, develop the scientific program, propose and implement funding instruments (CfP, CEI, micro-projects, equipment, etc.);
- they ensure the representation and communication about the program in the various relevant ecosystems: academic, institutional, industrial, etc.;
- they meet as frequently as necessary and are supported by a project management team, including a project manager and administrative support staff.
- they regularly report to the institutional management of the PEPR, the Steering Committee. Together, they guarantee the long-term vision of the PEPR. Based on the principle of separation of roles and responsibilities, the decisions of the Program Directors are submitted for validation to the PEPR Steering committee.

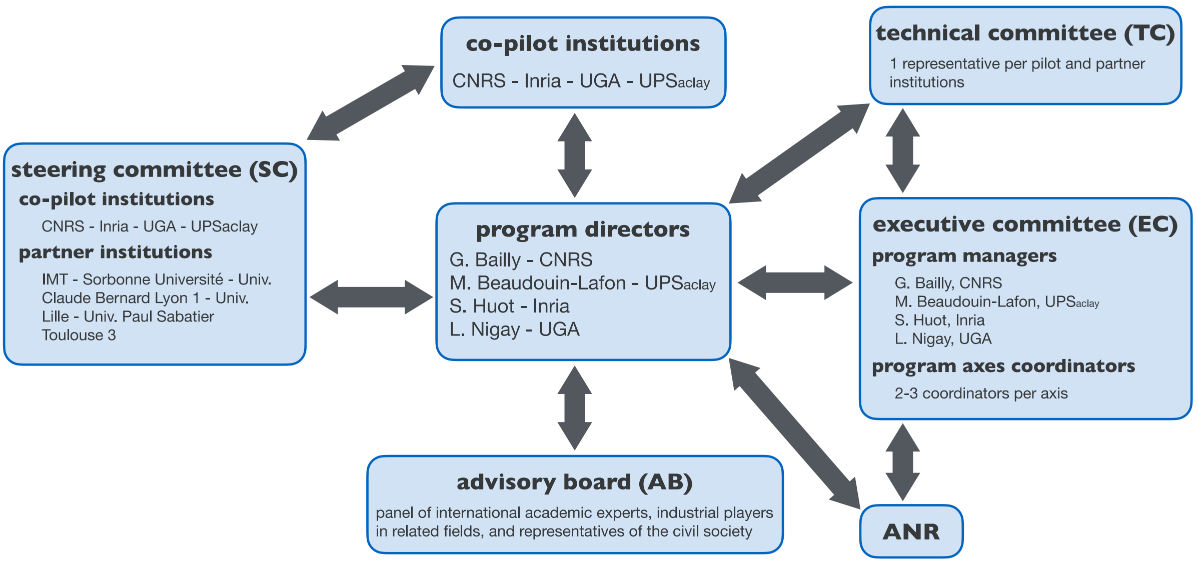

Figure 2 – governance of PEPR eNSEMBLE

The **Steering Committee** (SC) is composed of one representative of the scientific board of each pilot or partner institution (appointed by their CEO/President). The committee is chaired by one of the representatives of the pilot institutions. It meets at least once a year and issues opinions and recommendations to the PEPR Program Directors on the execution and main orientations of the program. The four program executive directors are permanent guests of the SC.

The **Executive Committee** (EC) is proposed by the Program Directors and validated by the SC. It includes the 4 Program Directors and the **Axes Coordinators**: each of the 5 axes of the program is coordinated by 2-3 scientific personalities from the PEPR community. These coordinators come from different fields of Computer Science and Social Sciences & Humanities in order to ensure a good representation and involvement of the different scientific communities in each axis. The EC assists the Program Directors in the implementation, management and monitoring of the program. Together, they ensure the supervision of the program phases in each of the axes, as detailed in section 2.4 Animation.

The Program Directors meet at least once annually with the EC in order to report to the SC on the progress of the project and to propose a possible revision of the roadmap for each axis. During these progress points and in particular at the end of its first phase (see section 2.4.1 Program Coordination), calls for expressions of intent (CEI) and calls for projects (CfP) will be prepared by the Program Directors and the EC, validated by the SC and managed by the **ANR**.

The **Technical Committee** (TC) is proposed by the Program Directors and validated by the SC. It includes one representative per pilot and partner institution. TC members are chosen for their technological and engineering expertise. The TC assists the Program Directors and the EC in the management of the technological aspects of the program. Its main missions are the coordination and animation of a network of engineers of the project and the management of an "integration platform", as detailed in section 2.4 Animation.

The Program Directors and the EC meet at least once annually with the TC in order to report to the SC on the progress of the project from the technological perspective, and to align TC's actions according to the scientific progress and possible revisions to the roadmap.

The **Advisory Board** (AB) is composed of 8 international scientists in the fields of the PEPR – Computer Science (Distributed Systems, HCI, AR/VR, AI), Social Sciences and Humanities (psychology, sociology, ergonomics, management science, design) – and of 2 to 4 representatives from the relevant industrial ecosystem and from civil society. Its role is to provide the Program Directors and the EC with independent and informed expertise on the scientific and innovation orientations of the program and its implementation. It is consulted during the definition of the roadmap of the major phases of the program. It is invited to the annual eNSEMBLE event where a meeting with the Program Directors and the EC is held. The AB is also consulted as often as necessary by the Program Directors.

2.3.1 Role of the co-pilot and partner institutions

Because of the necessary national vision to strategically coordinate the project, the joint participation of CNRS, Inria, UGA and UPSaclay as co-pilots guarantees that research, teaching and transfer to industry and society will be at the center of concerns throughout the project. The complementarity between these institutions is strong: Inria and the INS2I institute of CNRS are recognized for their scientific excellence in computer and digital sciences and already collaborate closely through numerous joint research teams and national initiatives. They will also be able to rely on strong partnerships with French players in the field (telephony/communication, cloud, software publishers and digital services). CNRS and in particular its INSHS institute (social sciences and humanities) as well as UGA and UPSaclay guarantee the required interdisciplinary approach by their wide research spectrum. Finally, UGA and UPSaclay are historical and pioneering centers of Human-Computer Interaction in France and in Europe. With more than 200 professors/researchers in the field, they also provide multidisciplinary skills through their LabEX, EquipEX+ CONTINUUM, AI institutes and scientific clusters. CNRS, Inria, UGA and UPSaclay will share the operational management of the PEPR eNSEMBLE, with Inria as administrative lead of this package.

The other partner universities (Sorbonne University, Claude Bernard University Lyon I, University of Lille, Paul Sabatier University Toulouse III) as well as Institut Mines Télécom also have important strengths in the project's fields, and have committed themselves as partners. This consortium will create a unique scientific and territorial network for the field, with the contribution of various ecosystems that will bring complementary and recognized multidisciplinary scientific skills, numerous fields of application and opportunities for transfert, and a strong link with higher education.

2.4 Animation

The 3 main objectives of the animation of the PEPR eNSEMBLE are to:

- **coordinate** the different actions of the program to ensure its success, focusing on (1) the monitoring and articulation of the phases of the program; (2) the definition and monitoring of common use cases; and (3) the monitoring and coordination of technical aspects;
- **consolidate and animate a French multidisciplinary community** around the scientific and societal issues of mediated collaboration;
- **ensure the dissemination of the results** of the program (scientific, technological, pedagogical, economic and societal).

The realization of these objectives will be under the responsibility of the 4 Program Directors and implemented as detailed below.

2.4.1 Program Coordination

In charge: Program Directors, Executive Committee and Technical Committee

The program has been designed in **two main phases** (Figure 3), "*Maturation*" (2-3 years) and "*Concretization*" (4-5 years). The maturation phase will consist of addressing the high-priority scientific issues already identified in the proposal. These initial results will lead to new scientific challenges to be addressed in the concretization phase and to a plan for the technological developments to be conducted in parallel.

The Program Directors, in collaboration with the Executive Committee, will ensure the supervision of the program phases in each of the 4 focused axes and in the transversal axis. Together they will define roadmaps and milestones (scientific challenges and demonstrators) at the beginning of each phase of the program, which will be discussed at the beginning of the phase and evaluated at mid-term together with the Advisory Board. They will also define, at the beginning of the program, relevant indicators for reporting at each phase of the projects (e.g., number of co-directed interdisciplinary Ph.Ds, number of co-authored interdisciplinary publications).

In addition to the already defined axes, parts of the program will rely on focused calls for expressions of interest (CEI) and subsequent calls for projects (CfP), especially at the end of the maturation phase and in the concretization phase, after the priority actions have been addressed and new significant challenges identified. Three rounds of CEIs and CfPs are planned and selected projects are expected to last 3 to 4 years. The first call will be dedicated to a cross-cutting topic identified from the studies of each axis. The other two calls will be dedicated to new interdisciplinary challenges identified during the first phase. The calls will be prepared by the Program Directors and the Executive Committee, validated by the Steering Committee and managed by the ANR. The emphasis will be put on interdisciplinary projects that contribute to federating the community around common problems.

From the technological perspective, several actions will be set up by the Program Directors, assisted by the Technical Committee.

A **network of engineers** involved in the different axes of the program will set up shared tools and ensure the mutualization of resources, best practices and technological development when possible and relevant. The Technical Committee will manage this network and organize exchange sessions and technological training in order to contribute to the empowerment of engineers on the technologies required by the project.

An "**integrative platform**" will be set up and managed by two dedicated engineers to facilitate the realization and mutualization of the demonstrators of the project, which are important milestones for the validation and dissemination of the results. The Technical Committee will request human and technological resources from the Program Directors and Executive Committee for finalizing the development of the demonstrators and integrating them into the platform so that the other partners can benefit from them. Such sharing and integration of technological developments will **promote the use of these tools within the project**, in a logic of iterative design. It will also promote their use by external partners (organizations, companies), e.g., for evaluation and validation on real use cases.

Finally, the Technical Committee will support **open specifications and standards** to promote interoperability and ensure the long-term impact of the program's technological contributions.

2.4.2 Animation of the scientific community

In charge: Program Directors and 2 designated members of the Executive Committee

A major objective of eNSEMBLE is the **emergence and sustainability of a strong and interdisciplinary community** on mediated collaboration. The process of putting the project together has highlighted the fact that many French laboratories and research teams were addressing this topic in isolation and through different perspectives/fields. The proposal itself is therefore already a success showing their determination to work together. The animation of the project thus consists of consolidating this new community and ensuring its long-term success.

First, each axis will be coordinated by two or three coordinators from different fields (mainly Computer Science and Social Sciences & Humanities) in order to ensure a good representation and involvement of the different scientific communities (see section 2.2). Similarly, we will also ensure a balanced representation of the disciplines involved in governance, in particular the Advisory Board composed of independent international experts (see section 2.3).

Four waves of **doctoral and post-doctoral programs** will be set up during the program. In the first phase, they will be focused on specific topics and challenges, typically within each of the axes; In the second phase, they will be opened to more general topics, to foster the synergy across axes. In both cases, we will favor collaborative interdisciplinary projects by implementing "twin" doctoral programs (to address a research question from different disciplinary perspectives), and provide support for students to visit different partners of the program in order to enrich their research experience during their PhD or after (with the possibility of pursuing a post-doc in another partner institution or with major international partners).

Meetings and events. Axes coordinators will be in charge of organizing at least 2 general meetings per year bringing together all the participants to their program axis in order to share their results and ensure that everyone is following the established roadmap. We will encourage the **organization of events/workshops** within and between the axes, through internal calls using program funds. We will also organize a **bimonthly seminar** to present the advances of the program and where recognized speakers from the academic world or civil society will be invited to address relevant topics. Starting in year 2, we will organize the **annual eNSEMBLE days**, with 3 tracks:

- **conferences** to present and discuss the major results from the program's axes to other participants and to the governance bodies (Steering Committee and Advisory Board). Some of these conferences will be opened to a larger academic or general audience;
- a **multidisciplinary Young Researchers School/Seminar (YRS)**, dedicated to young researchers involved in the program, and favoring the opening to other scientific fields (an ad-hoc organization and program committee will be composed every year under the responsibility of the Program Directors);
- "**Innov' eNSEMBLE**", a forum and exhibition of demonstrations targeting users, companies and institutional representatives, which will foster connections with these actors and more generally with civil society (this session will take place once enough demonstrators have been developed).

One objective of this event is also, as mentioned in the Program Coordination section, to use the tools developed in the project to organize and hold it in a hybrid physical/virtual format.

We will fund "**collaborative micro-projects**". A collaborative micro-project should involve a small group of researchers from different partner institutions and address either an exploratory topic at the edges of the roadmap (e.g., a new use case, alternative methodology, etc.) or a well-defined problem with tangible results (e.g., a dataset, a toolkit, etc.). The advantages of collaborative micro-projects are (1) to require limited funding and a light and fast process complementary to the other instruments of the PEPR (e.g., CfP); (2) to create synergies and new multidisciplinary collaborations within the community; and (3) to anticipate the future of the program, by quickly bootstrapping "good small ideas". Micro-projects will be submitted as they come but selected 4 times a year.

Finally, we will create and promote **connections with major equipment programs**, e.g., Equipex+ / Research Infrastructures CONTINUUM and Huma-Num, **research programs**, e.g., Acceleration PEPRs on Digital Education, on Digital Health and on Cybersecurity, and **research networks**, e.g., CNRS GDR "Internet, IA and Society". This will open up a variety of large-scale application domains and use cases for eNSEMBLE, but also give access to the necessary technological resources for the execution of the program. We will leverage the implication of the 4 pilot institutions in these other programs to issue transversal calls for projects or to organize joint events (seminars, conferences, summer schools).

The consolidation and animation of a multidisciplinary community around this scientific program is ambitious. We are confident that we will be able to achieve it through these modalities, because of the enthusiasm that this program has sparked and the fact that many of its participants are already, by the very nature of their research fields, involved in multidisciplinary actions.

2.4.3 Dissemination

In charge: Program Directors and 2 designated members of the Executive Committee

The dissemination of results, whatever their nature (scientific, technological, societal) is a primary objective of the program. From a scientific point of view, we will ensure the publication and dissemination of results in major journals and conferences in the relevant fields (e.g., by supporting the organization of workshops associated with the main conferences in the fields).

We will follow ANR's **Open Science policy** by requiring all the funded research projects within the program to publish their data and outputs on national platforms: HAL open archive for publications, TGIR Huma-Num's Nakala for data. All the produced code will be released and maintained under open-source licenses and referenced in the Software Heritage database, with the support of the project research engineers who will be specifically trained in these practices.

To ensure the visibility of the community beyond its scientific results, we will establish connections with national (AFIHM, AFIA, AFXR, ARPEGE) and international (ACM, EUSSET) learned societies, taking advantage of the fact that several Program Directors and members of the Executive Committee are strongly involved in them.

Industrial partnerships. The program has received strong support from major French industrial players in the field (see letters of support in the appendix). We will strive to transform this support into concrete collaborations through targeted actions:

- through the strong partnerships already in place between these companies and the PEPR pilot institutions;
- by creating an industrial liaison team within the Executive Committee, which will be in charge of (1) identifying potential companies as "users" of the PEPR results; (2) identifying relevant use cases with them and ensuring that these practical cases are addressed in the different axes of the program; (3) setting up collaborative projects involving industrial partners through the program calls for projects or the "micro-projects" mentioned above;
- by organizing the annual "Innov' eNSEMBLE" event dedicated to potential users and companies;
- and more broadly by establishing and animating a "community of users" beyond these companies, e.g., taking advantage of the users of the Equipex+ CONTINUUM platforms.

For all these actions, we will rely on the experience and resources of the transfer, innovation and partnership departments of Inria and CNRS.

Education and Training. To bootstrap the education and training efforts detailed in section 1.5, eNSEMBLE will develop programs at several levels: (1) We will organize international interdisciplinary summer/winter schools in France open to European doctoral students to foster exchanges; (2) We will create a scholarship program for attracting exceptional candidates who wish to obtain a master's degree from the universities involved in eNSEMBLE and then apply to a doctoral program within one of the laboratories associated with eNSEMBLE; (3) We will develop interdisciplinary Master tracks (planned to start during the second phase of eNSEMBLE, see Figure 3), especially in the pilot universities (UGA and UPSaclay), bringing together social sciences, management and computer science, to train a generation of experts; (4) We will create short training programs for companies, Ph.D. students and high school teachers; (5) We will develop shared curricula to be integrated into existing Bachelor and Master programs in universities, business schools and engineering schools.

We will also be in contact with CLEMI, an organization in charge of Media and Information Literacy in the French Education system. Its mission is to train teachers to better understand and use new media systems, to foster critical thinking and media literacy of children.

Finally, when the software and platforms developed in the project have reached a sufficient level of maturity, we will set up training sessions for professionals within the framework of Inria Academy.

General public, civil society and institutions. We will encourage the participation and presentation of the program's activities in annual national events such as *Fête de la Science*, or in outreach initiatives in high schools such as Chiche!. We will also work closely with local initiatives of pilot and partner institutions to bring the academic world closer to society, such as contributing to funding programs for artists' or designers' residencies in research laboratories (e.g. AIRlab at University of Lille). This will feed our research, but also produce artifacts adapted to communication towards the general public (interactive artworks, serious games, performances) that will be showcased e.g., during public sessions of the eNSEMBLE days.

Finally, in order to enable institutions and decision makers to better understand how communities collaborate on digital platforms, we will build an *Open Observatory of Collaboration* (Sub-axis 4.4). This observatory will offer interactive visualization to monitor community activity and produce white papers with in-depth analyses on specific communities such as Wikipedia, Open-Science initiatives or participatory democracy platforms.

2.5 OVERALL PLANNING AND REQUESTED FINANCIAL RESOURCES

To achieve this two-phase planning, the total requested budget of 45 million is divided as follows (Figure 4): 60% for the five axes, 30% for the open calls and 10% for the animation of the whole program.

The four axes are programs of similar size in terms of objectives and involved teams. Thus, for each axis 1 to 4, which cover both phases, the provisional budget is 6000k€, while for the transversal axis the budget is 3000k€. This budget includes a doctoral and postdoctoral program. The doctoral program will be staggered over 4 years, with an estimated 8 Ph.D. grants per year and per axis (approx. half the budget). The program includes 10 post-doctoral fellows or engineers for 12 months each per axis. We expect them to be recruited mostly during the second phase.

We foresee three open calls for 4-year projects, one in the first phase and two in the second phase. We are planning for a total of 18 projects, each with a budget of 750k€, that will further expand the eNSEMBLE community.

The budget for animation (4500k€) is dedicated to the activities described in section 2.4 Animation. We plan for about 7 micro-projects per year with an average budget of 10k€ each. For technology development projects, we expect 5 projects per year with an average budget of 20k€ each. This budget can vary significantly depending on the objectives of the project and the number of corresponding engineer-months needed to develop a demonstrator or a tool.

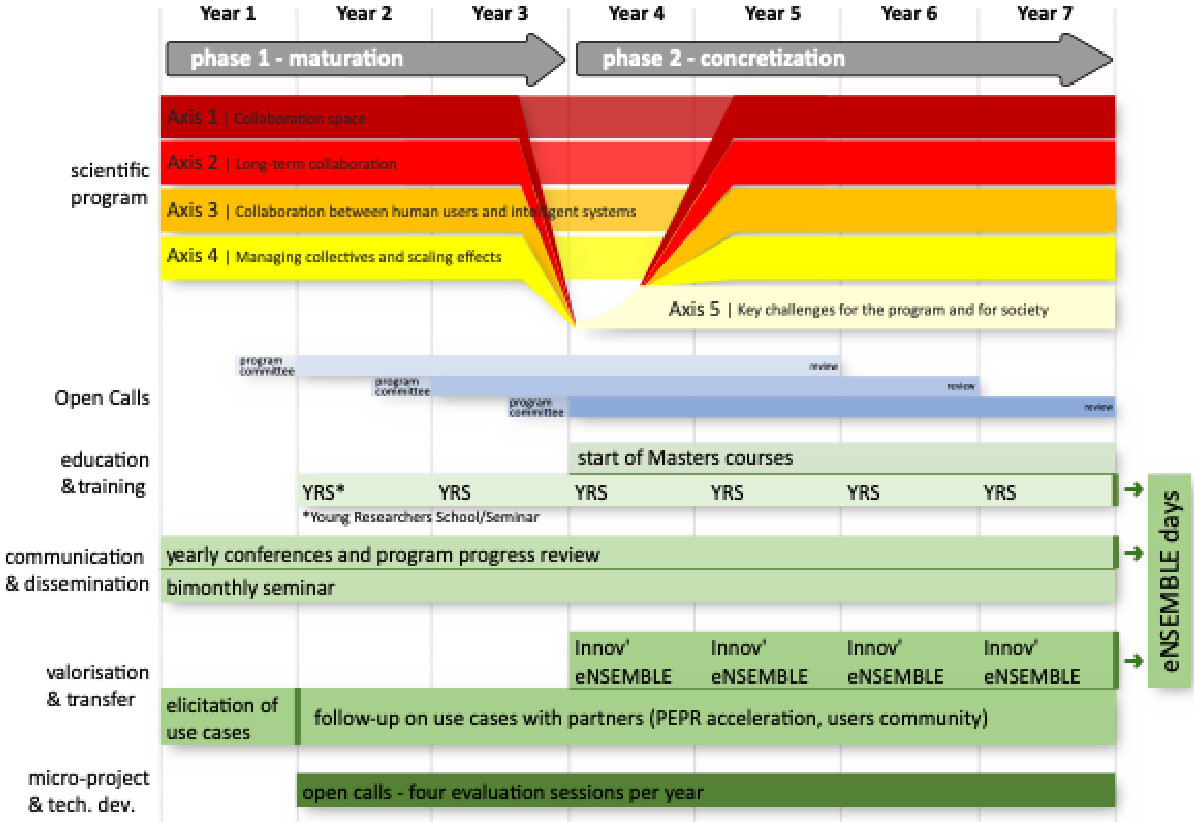

Figure 3 – Timeline of the eNSEMBLE program

Category	Types of expenses	keuros	%
Animation& Management	Education & Training	675	1,5
	Valorisation Transfer	450	1
	Communication & Dissemination	450	1
	Collaborative micro-projects	675	1,5
	Technical development projects	900	2
	International strategy (visit, invitation)	675	1,5
	Global project management	675	1,5
	Animation & Management: Total	**4500**	**10**
Open calls	**3 Calls - 6 selected projects per call: Total**	**13500**	**30**
Axes	Axes 1-4 (6000 per axis)	24000	
	Axis 5: Transversal challenges	3000	
	Axes: Total	**27000**	**60**
	Total budget with overheads	**45000**	

Types of expenses	keuros
Personnel costs including equipment and travel	
˜32 PhD Thesis	5000
˜10 Postdocs and Research engineers	700
Small equipment	150
Management	150
Per axis (1-4): Total	**6000**

Figure 4 – Estimated budget: overall (left); per axis (right)

2.6 Mini CV of Program Directors (see Appendix for longer versions)

Gilles Bailly is CNRS researcher at Sorbonne Université and heads the HCI group (~15 members including 4 permanent faculty) at ISIR (UMR 7222). He is a board member of the French Association of Human-Computer Interaction (AFIHM). He has published over 120 articles and received 11 awards. Gilles Bailly has been involved in several national collaborative projects and led the ANR GESTURE project (2016-2021).

Michel Beaudouin-Lafon is Professor of Computer Science at Université Paris-Saclay and adjunct director of LISN (UMR 9015) where he directed the HCI group (14 permanent faculty). Honorary member of the IUF, ERC laureate and scientific leader of the Equipex Digiscope and CONTINUUM, he was chair of the ICT department of Université Paris-Saclay (1300 faculty and staff). He is currently vice-president of the ACM Technology Policy Council.

Stéphane Huot is Senior Researcher at Inria Lille - Nord Europe. He is scientific officer (i.e., adjunct director for science) at Inria Lille - Nord Europe (15 teams, ~360 faculty and staff) and head of the Loki Inria project-team (6 permanent faculty) within the CRIStAL laboratory (CNRS UMR 9189, Université de Lille and Centrale Lille). He has been involved in the coordination of several collaborative research projects, in the board of the French Association of Human-Computer Interaction (AFIHM), and vice-president of evaluation committees of the French National Research Agency (ANR).

Laurence Nigay is Professor of Computer Science at Université Grenoble Alpes and a member of LIG (UMR 5217) where she directs the HCI research group (˜35 members including 12 permanent faculty) and the Interactive and Cognitive Systems axis (4 groups). Bronze medal of CNRS (2002), leader of the first national ALLISTENE programmatic group "knowledge, contents and HCI", president of evaluation committees of the French National Research Agency (ANR), she was selected as a junior member and currently as a senior member of IUF.

2.7 Content of the appendix

- Provisional structure of the axes and sub-axes, with lists of work packages and involved teams
- Letters of support from Immersion, OVHcloud, Berger-Levrault, Wikimedia France and Minalogic
- CVs of the program directors
- Short bios of the axes coordinators
- List of laboratories and teams involved in the project.