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SIMCENTER
GUIDELINES TO DEVELOP A MEDICAL SIMULATION CENTER

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DESIGN

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ABSTRACT
Simulation techniques are an essential tool, to allow learners and operators to develop hard and soft skills simultaneously. Emerging technologies in the field of sensory perception will improve training and emergency management. The combination with virtual reality technologies will allow the development of complex systems, more realistic, allowing an effective and targeted training. They will allow the monitoring of training sessions and the collection of useful data for the generation of a standardized, efficient and unambiguous practice of action. The Design takes on the role of facilitator and manager of the system constituted by the different actors, with the mission to design and indicate the guidelines for setting up an innovative simulation center.

KEYWORDS
medical simulation, training, design guidelines, simulation center, simulation network

Simulate, simulate, simulate! This seems to be the slogan that the medical world has given itself as a mission and as one of the founding values for the professional training of health subjects. This trend is the result of a multiplicity of technological, but also ethical and social factors, which have pervaded the world of medicine in recent decades. First of all, it can be said that simulation is becoming a pervasive phenomenon. Secondly, the widespread use of simulation in medicine is meant to be a necessity, hence the idea that simulation is not only a pervasive phenomenon, but it is also a necessary phenomenon. Thirdly, the diffusion of simulation's techniques and the need for their use, open the door to another aspect of the phenomenon, namely its organizational dimension.

This research is based on the integration between medical knowledge and the know-how of the SIMNOVA simulation center system, the technological means offered by LogosNet and the design and management skills of the Design Department of the Politecnico di Milano. The mingling of these three entities has led to the creation of an open-source, cooperative Co-Design network (Fig. 1), strongly committed to creating guidelines for the development of a Simulation Center. The objective of the contribution is to draw up guidelines, from a technical-technological, managerial, ergonomic and proxemic point of view, which allow the development of a Center for medical simulation, which can become an example of excellence and the first node of over-state network constituted by the different Centers activated after the first one.

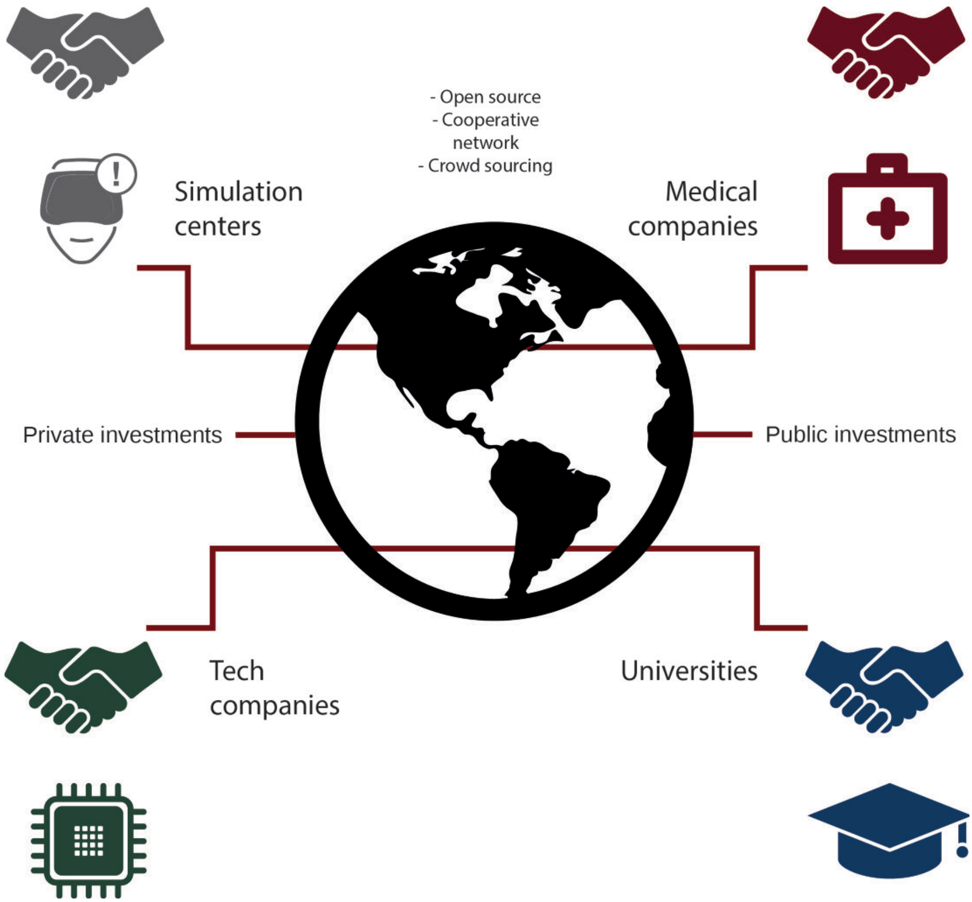


Fig. 1 - Co-Design network scheme.

Medical simulation's state of art – Simulation as a didactic tool knows its origin in the aeronautical and military field, to arrive in the medical sector during the 70s, with a full diffusion only twenty years later (Aggarwal et alii, 2010). The use of human mannequins, known as simulators, actors who play the part of the sick, was spreading in the field, but also the use of 3D virtual reality systems which reproduce various types of interventions on computers or in dedicated environments, had become to spread. Every doctor needs to practice to learn and/or maintain patient-centered skills (care, communication, information gathering), process skills (group management, information) and environmental skills (cultural skills, administrative and leadership matters). It also must be added the cyclical updating of health procedures, the increase in medical knowledge and the widespread use of minimally invasive surgical techniques.

Until now, attention has been given to the ability that the dummy has to transmit feedback to the student, related to the behavior of the simulated patient and the interaction that occurs between the student and the dummy. The first human simulator appeared in the 1960s: it was Resusci-Anne and marked the beginning of the era of simulations in the health sector (Good, 2003). The dummy had to guarantee the simulation of the ABC (Airway, Breathing, Circulation) of cardiopulmonary resuscitation (CPR). Today the evolution has led to several high-fidelity simulation mannequins that, through the interaction with the control room, allow a dynamic simulation experience. Maneuvers, procedures and interventions have almost immediate answers that the mannequin sends back to the student. Simultaneously with the development of mannequins, PC simulators appeared at the beginning of 2000.

Modern simulators are programmed to interact with the user, responding to his actions and combining both visual and tactile stimuli, as the aim is to obtain increasingly realistic simulated experiences. The simulation would require three fundamental elements: ‘realism, realism and realism’ (Ingrassia et alii, 2014, 2014a). Health professionals need to interact with an anatomically realistic scenario, but at the same time the environment must adapt in response to it. Giving importance to ergonomics means problematizing, for example, the professional needs of the organizational subjects and then the translation of them into satisfactory environments and experiences. This does not mean, however, only to provide comfortable environments that are compatible with the physiological characteristics of people, but also to promote the communicative exchange between these (Shams and Seitz, 2008). The surrounding work environment is also recreated in detail to make the experience more real. The reproduction of the environment must not be seen as a static representation, but the environment itself must stimulate the student and it must also change according to the choices made by the learner (McGaghie et alii, 2010). The more senses are activated during the execution of the action, the greater the storage of the experience that results from the action itself.

Technology’s state of art – With the advent of new technologies the possibility of accessing a patient’s and environment’s simulation much more realistic and usable by a large number of people, assigned to the services, has opened up. Currently we can talk about three different types of ‘parallel’ realities: virtual reality, augmented reality and mixed reality. Virtual reality is an environment simulated through a series of technologies, which, combined with other techniques, such as the projection of a scene, generate a context in which the user is able to perform different actions, receiving an answer from it. A person who experiences this type of experience will be able to look around, move and interact with the features or objects present within the scene. Looking at the existing, both in terms of research and product development, it is clear that the technologies related to virtual reality, allow at this time to reach a level of immersion unthinkable until a few years ago. It is also true that, compared to the two ‘realities’ described below, it also has disadvantages, linked to the complexity of the system and consequently to the higher costs.

Augmented reality consists of a vision, direct or indirect, of a real environment, whose elements are increased or modified, by sensory input, such as audio-visual stimuli, graphics or GPS data, generated by a computer[1]. Unlike virtual reality, its use turns out to be simpler and requiring a less complex system, relying on the real environment, on which digital increments are represented; however, this implies an adherence to reality and an immersive experience of lower quality, having to rely on what really surrounds the user and therefore not being able to completely simulate the scenario. On the other hand, with current developments, it allows the necessary system to be leaner and exportable in different contexts of use.

Mixed reality is the fusion of the real and virtual worlds to produce a new environment and a new visualization, where physical and digital objects coexist and interact in real time. Among the presented realities, the latter is, without a doubt, the most recent and innovative: it is possible to have images at better resolution, compared to virtual ones, and of considerably higher dimensions; it can be used with different types of devices. The presence of several people in the same co-environment, real and virtual, and the interaction between them and the virtual elements present on the scene, is possible, even allowing the presence in the virtual world without having the need of physical presence in the place. Being comparable to an evolution of augmented reality, it is endowed with more performing characteristics, eliminating that aura of immobility, thanks to the interaction in real time, between virtual and real components[2]. It has the same advantages of augmented reality with respect to virtual reality, even if its development is further behind the other two technologies, and therefore it has lower reliability. Looking in the future, however, it could be the technology to focus on. Given the design requirements, among the three technologies presented, two are convincing and valid to use, even if the choice of one instead of the other will lead to significant design and use changes. They appear to be virtual reality and mixed reality. Currently the best choice, especially for the degree of development achieved, is virtual reality, but, looking at a development in the next decade, the reality to focus on will be the mixed one.

The Internet of Things represents an extension of the Network (Jayavardhana et alii, 2013): objects become recognizable and acquire intelligence, managing to communicate data about themselves and to access aggregated information from others. The goal of the Internet of things is to make an electronic map of the real world, giving an electronic identity to things and places in the physical environment. MEMS (Micro Electro-Mechanical Systems) are a set of devices of various kinds (mechanical, electrical and electronic) that constitute intelligent systems capable of combining electronic, fluid, optical, biological, chemical and mechanical functions in a very small space, integrating sensor and actuator technology and process management functions. The integration of this type of technology within the simulated training tools system, can be useful to achieve the before mentioned objective, which is to map and regulate the behaviors and actions to be performed during the actual aid, to succeed in creating a univocal practice of intervention (Fig. 2).

SIMNOVA – The Interdepartmental Center for Innovative Education and Simulation in Medicine and Health Professions (SIMNOVA)[3] is established with the aim of carrying out higher education, research and service activities in the health field, with particular attention to the use of simulation as a tool to innovate programs training, to improve the quality of care, to reduce clinical risk and increasing patient safety. It was created to make the spaces welcoming and functional in order to reproduce highly realistic scenarios, which recreate the natural environments of health care in different phases of the hospital and extra-hospital process and where students, doctors and health personnel can face the diagnostic-therapeutic and interventional routes on patient-simulators. The latter are the tools used by teams to simulate the human patient. During the activities the unit can use different types of dummies, depending on the course and the procedures that must be implemented. The simulator can faithfully reproduce the human body from a physical and physiological point of view, responding to different types of stimuli and being able to undergo surgical or administration operations, thanks to the use of dedicated software.

Inside the Center there are a series of equipment for training in maxi-emergency scenarios, such as the XVR© simulator, the ISEE© simulator and the Disaster Simulation Suite (DSS©). Thanks to the collaboration with LogosNet[4], an Italian company that deals with the design and the use of virtual and augmented reality systems, an immersive simulation environment has recently been set up, consisting of three spaces (simulation room, debriefing room and control room), within which it is possible, through the video projection on white walls, to reproduce high-fidelity environments, within which to carry out the practices. Another feature of this space is being equipped, thanks to technologies provided by LogosNet, of capacitive walls, with which it is therefore possible to have a tactile dialogue, useful during the debriefing phase or for certain types of scenario.

The role of Design – The complexity and the interconnected nature of today's projects necessarily require a deep and multipolar exploration, rather than an approach devoted to the immediate search for a solution (Cross and Dorst, 2001). In addition, Mozota (2006), while stating the four strengths of Design (Design as a differentiator, Design as an integrator, Design as a transformer and Design as a business model) concludes that each of these four elements contributes to creating value, while problems and solutions

2018	Complexity	Costs	Development	Realism
VR	● ● ○	● ● ●	● ● ●	● ● ●
AR	● ○ ○	● ○ ○	● ● ○	● ○ ○
MR	● ● ●	● ● ○	● ○ ○	● ● ○

Fig. 2 - Comparison scheme of the three realities.

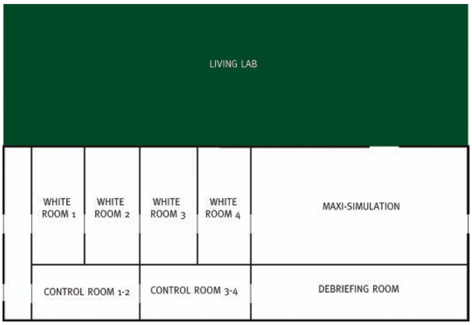
are fragmented. In the literature concerning Design-driven innovation, the importance of the involvement of different stakeholders within the project, is repeatedly emphasized. Some conclude that the major discriminant for the success of this methodology lies in the co-development model, facilitated by Designers, which involves various stakeholders during all the project phases (Bailey et alii, 2018).

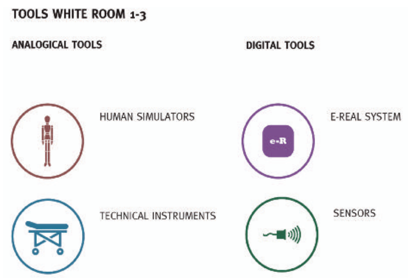
Some authors promote the involvement of external stakeholders, who nominate 'performers', in order to feed disruptive innovation (Norman and Verganti, 2014). Manzini states that Design can take on different roles in a context of co-planning, both as an activator of the innovation process and as a facilitator of co-creation activities. He also denotes the great importance of the involvement of different actors, affirming that the designer's role is to 'make things happen' (Manzini, 2015). In the literature of the sector it is repeatedly emphasized that the value of Design is fundamental to innovate sectors other than the reference one: Martin, Yee and other authors present cases of companies and organizations that have been able and far-sighted enough to use typical Design methodologies to innovate their business sectors (Martin, 2009; Yee et alii, 2017). Design, therefore, in such a context, where actors with different competences, from different sectors coexist, must be able to act as a catalyst for innovative design processes, continuously stimulating the various stakeholders, and as a facilitator of the design practice, allowing the best exchange of information possible within the co-planning network established.

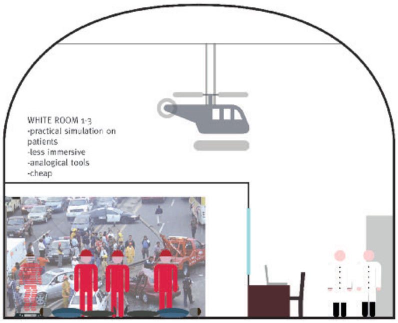
Design guidelines – The objective is to develop a set of toolkits to set up a highly performative simulation center, given the technological development of certain sectors. In this section the simulation environments will be described in detail, the guidelines to set up the environments will be defined and a series of hardware, software and tools necessary for the correct functioning of the Center will be listed, in relation to the objectives to achieve, always trying to provide more viable solutions (Figg. 3-13). The proposed set-up model must be open, exportable and replicable, in order to create an accessible and democratic network, based on principles that determine the standard of admission to the network itself. There will be four main simulating environments in the Center. The number of environments was chosen, basing it on the various simulated experiences that want to be proposed, which can be grouped into four sets: medium-level simulation of realism, with few users; high level simulation of realism, with few users; maxi-simulation in the interior and maxi-simulation in the exterior.

The first two environments will consist of three spaces, interdependent with each other: the simulation room, where the team training takes place, the control room, where the instructors and managers will assist the practice and will actively intervene in modifying the parameters of the simulated scenario and the debriefing room, where the teams and the instructors will discuss what happened during the training session, reporting impressions and feelings and highlighting the strengths and weaknesses of the team members, in order to conclude the training activities in a profitable and constructive manner.

The proposals of setting up for each of the three rooms can vary according to the







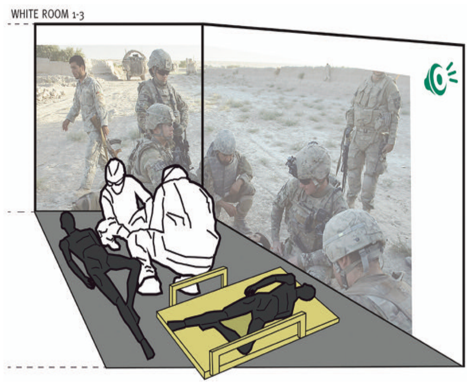
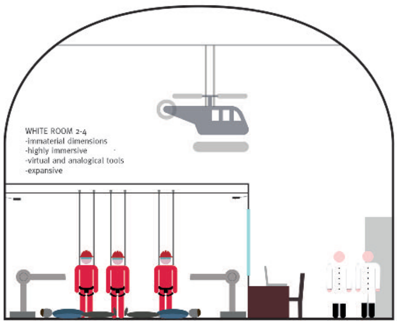


Fig. 3 - Top view of the Center.

Figg. 4-6 - Tools, prospectus and axonometry of white room 1.

simulation needs of the activators and the managers of the Center. Each room can be set up with independent packages, which, installed in their entirety, will make it possible to satisfy a wide range of needs and to achieve important objectives, both for the single Center and for the network. The simulation room is the environment where students carry out practical training activities, according to the learning by doing methodology, through simulation techniques.

By combining different types of technologies, hardware and tools, and using software to allow the system to function, highly immersive scenarios, which allow learning and the development of hard and soft skills, are recreated. The space must meet certain requirements, so that the training can be really effective and formative, it must: allow to adhere to the standards of real practice; allow the simulation of numerous types of scenarios, from the simplest to the most complex, combining virtual-digital and physical-environmental elements; be an easily reconfigurable environment based on the simulation that is carried out; the activities and practices carried out within it must be able to be monitored and analysed, in order to generate an important amount of data which will lead to the identification of best practices; be connected to other space envi-



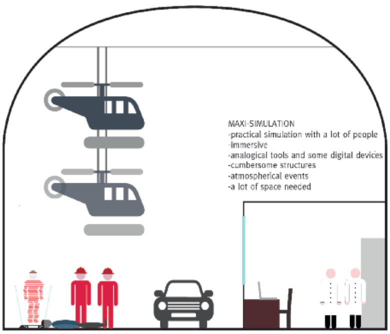
Figg. 7-9 - Prospectus, axonometry and tools of white room 2.

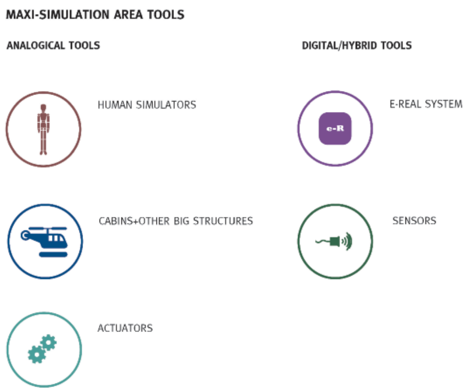
ronments, through an IoT system, so that it is possible to remotely manage some elements of the room and get feedback in real time.

The high and medium immersion simulation room has three walls painted in white and it is connected to the control room by an environmental division glass, which allows the supervision of the practice by the instructors. Activities are carried out by teams of 3-5 people. There are four solutions packages that can be installed inside. Each of these packages consists of different hardware that allow to achieve the different features mentioned before: the first one allows a generical kind of simulation, which is useful to train managerial skills. The second one is designed to train the hard and soft skills in the clinical field. The third one allows to recreate atmospherical events in order to train the extra-clinical skills of the students; and the last one is the one that make possible the tracking of the movements done by the learners, inside the simulation room in order to obtain a high number of useful data.

The control room, which is used by the instructors and supervisors of the teams involved in simulation sessions, has a fundamental importance due to allowing them to have clear, objective, methodical feedback focused on checkpoints and training objectives. The space must, like the previous one, comply with some requirements, so that the transmission of concepts is effective. It must: allow to observe what happens in the simulation room, without influencing the learners; allow video and audio recording of simulation sessions and other forms of data collection; allow the insertion and management of variables in the scenario, in real time; allow the observation and monitoring of the status of the simulation room; being able to communicate directly with the simulation room; allow the supervision of action checklists and scenario objectives; be connected to other space environments, through an IoT system.

To create a protected environment that does not influence learners in practice, it is necessary that the instructors can observe the practice without being noticed: for this reason the two rooms, the simulation and the control rooms, are adjacent and connected by a glass of environmental division. Based on the packages installed in the simulation room, the control room will present several elements within it. The debriefing room is the environment dedicated to the last moment of a simulated training session, where teams and instructors will discuss the ended practice, covering the recordings and trying to share impressions and feelings, points of strength and weakness demonstrated, good deeds and errors, so as to conclude the activities with profit. The requirements that the room must satisfy, so that the practice has really educational effect are: to be a comfortable environment that facilitates sharing and constructive discussion; to allow another/two other non-practicing teams to attend the current simulation session; to allow the review of the session just ended; to provide interactive tools for the activities performed within it; to provide educational tutorials related to the mistakes made to be connected to other space environments, through an IoT system. The room is designed to accommodate up to two teams of learners (6-10 people) and the team of instructors (2-4 people). It can also be configured as a white room, having three walls painted in white. The hardware and tools that can be installed inside it are not dependent on those of the simulation and control room.



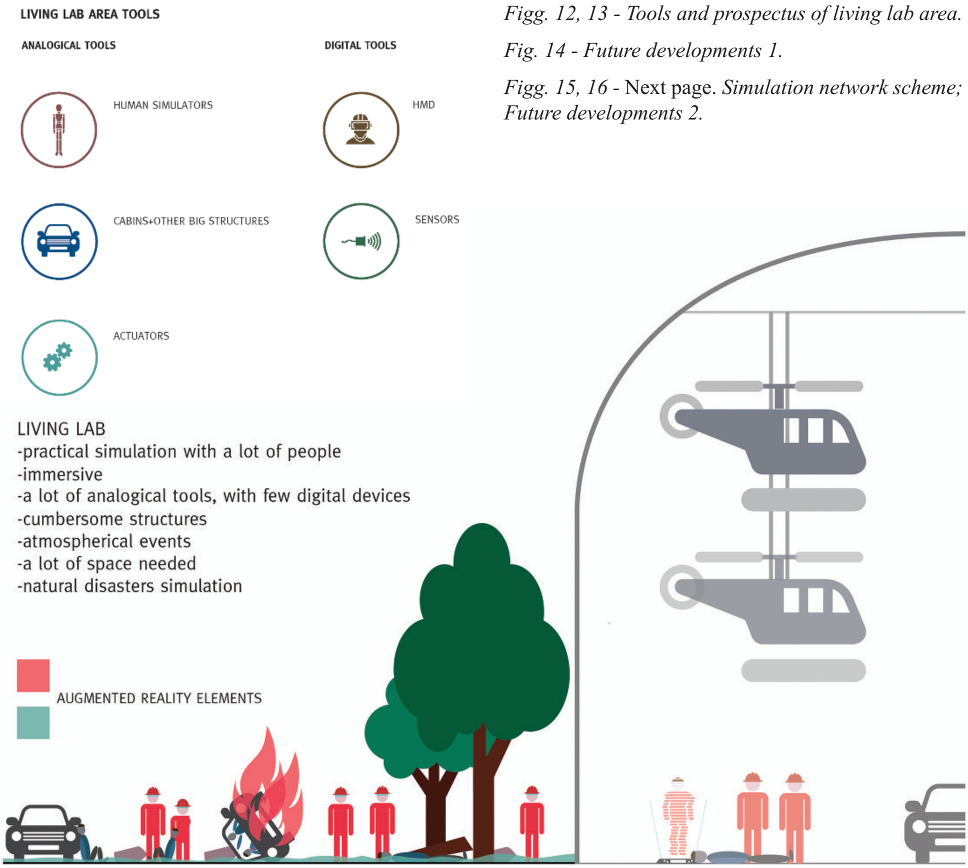


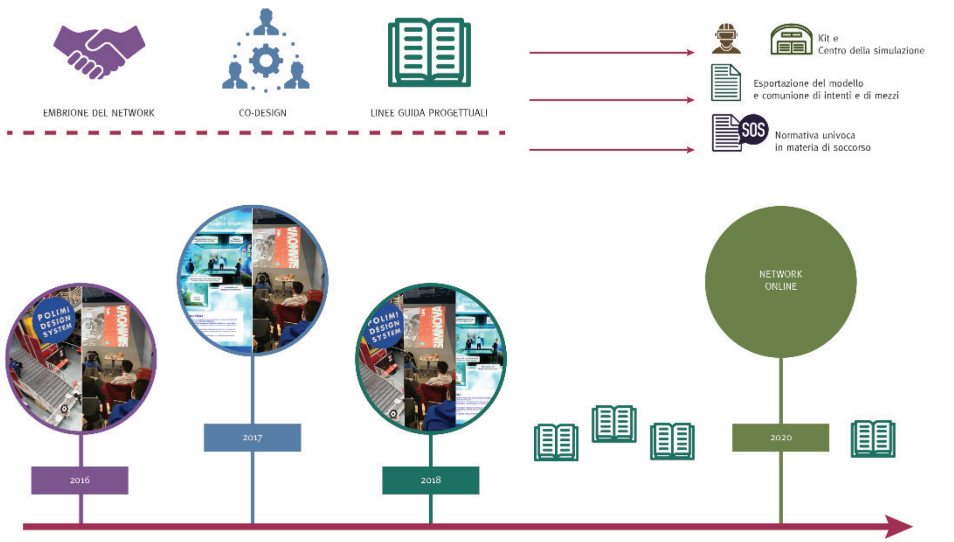
Figg. 10, 11 - Prospectus and tools of emergency area.

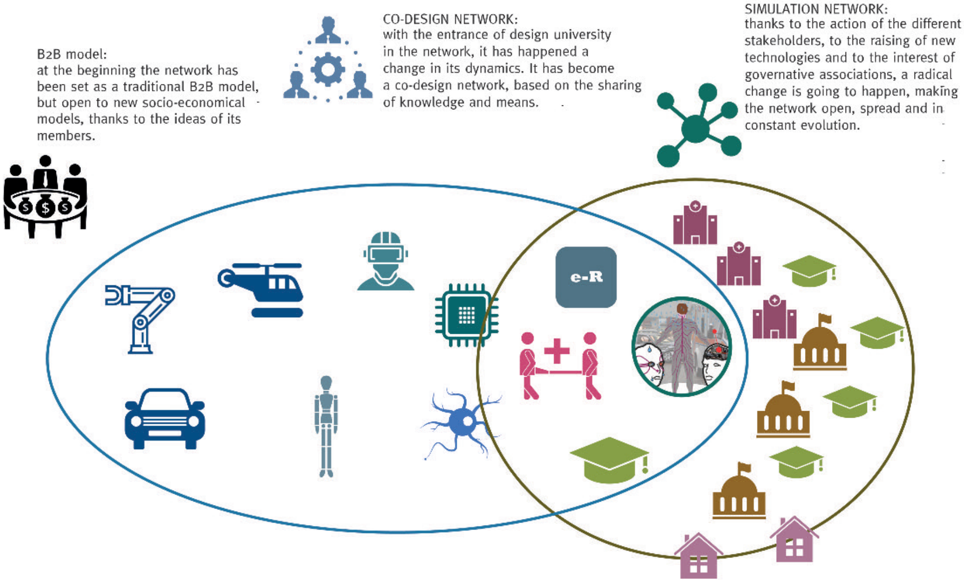
Figg. 12, 13 - Tools and prospectus of living lab area.

Fig. 14 - Future developments 1.

Figg. 15, 16 - Next page. *Simulation network scheme; Future developments 2.*






B2B model:
at the beginning the network has been set as a traditional B2B model, but open to new socio-economical models, thanks to the ideas of its members.
CO-DESIGN NETWORK:
with the entrance of design university in the network, it has happened a change in its dynamics. It has become a co-design network, based on the sharing of knowledge and means.
SIMULATION NETWORK:
thanks to the action of the different stakeholders, to the raising of new technologies and to the interest of governative associations, a radical change is going to happen, making the network open, spread and in constant evolution.
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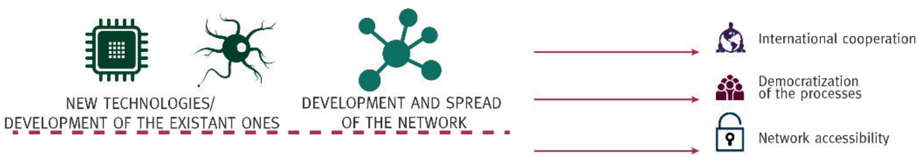
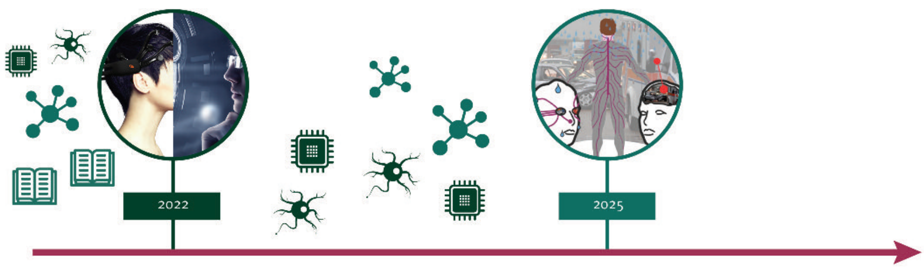

NEW TECHNOLOGIES/
DEVELOPMENT OF THE EXISTANT ONES
DEVELOPMENT AND SPREAD
OF THE NETWORK
International cooperation
Democratization
of the processes
Network accessibility


2022
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The other two environments inside the Center are the internal area for maxi-simulations and the living lab in the external area: the first is equipped with mannequins, nacelles or other large structures, actuators for different atmospheric or extraordinary events; as regards the digital pull, various types of sensors are found and the system offered by LogosNet that relies on e-Real software. Finally, the living lab must be equipped with dummies, cockpits or other large structures and actuators to simulate atmospheric events, as well as visors for augmented reality and a sensor system.

Through the kits and guidelines, the goal is to set up a simulation Center that can become an example of excellence, exportable and replicable in as many places and countries as possible. Medium-immersion white rooms are used for direct patient training, involving few people; given the high level of immersion of the other two rooms, they will be used for the training of emotions and operational stress. The environment dedicated to maxi-simulations is used for a practical training that involves a large number of people, also allowing a good level of immersion, although it requires a large space. Finally, the outdoor space is used to train practical situations that, like for the internal area, will involve a large number of people, managing to guarantee a high level of immersion, using the surrounding environment. It must be used often for the reproduction of catastrophic atmospheric events.

The commissioning of the Center will enable the network, which will be much more devoted to horizontal collaboration between the different actors, mainly the various Centers that will be built after the first one, to be activated. Once online, the network will allow the supervision and sharing of data and scenarios, produced by the high number of simulations carried out, practiced identically in different areas of the globe, in order to generate innovative, but unambiguous, rules and practices. in the matter of rescue. A first embryo of the simulation network was born during 2018, with the activation of an Interdepartmental Center within the Politecnico di Milano, established by the Department of Design, by the Department of Chemical Engineering and Materials, by the Department of Electronics Engineering and the Department of Mechanical Engineering, to which SIMNOVA and LogosNet have been added. It consists of two environments, within which it is possible to live experiences of virtual reality, in the context of white rooms, where virtual environments are projected to encourage immersive practice. Simultaneously with the creation of the space within the Polytechnic, a similar environment for conformation and application possibilities, was created at the SIMNOVA site, in communication with the Center at the Politecnico, establishing a first form of simulation network, capable of sharing the scenarios created and the experiences lived within them.

Conclusions – The presented project constitutes the first step for the realization of what has been conceptualized and designed, providing specific guidelines that indicate how to set up the spaces and which hardware must be used to activate a Center. Software development will be the second milestone to be reached, to ensure that the model becomes operative and sharable. Simultaneously with the development of the software part, the network's activation processes must also be stimulated, acquiring a cloud platform, a website and other necessary digital applications, so that the network can be online in a short time. When these two steps are going to complete, it will be possible to make the replicable and exportable model available to the public and to activate the network, to achieve the goals set (Figg. 14-16).

Defined the design guidelines for development in the near future, it is also interesting to define a visioning operation for the year 2025. Medical simulation in 2025 will allow total experiential and sensorial immersion, facilitating and making training absolutely true and effective for the teams; this will be possible thanks to a series of studies and technologies being developed today, such as haptic and neuro-device technologies that will allow to actively interact with intelligent interfaces and machines, generating dynamic simulations, modifiable at will in real time and therefore highly formative especially as far as concerns problem solving skills. A fundamental point will be the accessibility to the simulation, which will become the fundamental tool for training in all medical fields. Another main objective is the creation of a norm of behavior that doctors and all operators will have to follow in order to be highly efficient; this will be possible by mapping those who simulate and crossing the data obtained, so as to go to identify the correct positions, movements and actions to perform, depending on the situation in which one will find oneself.

NOTES

1) Pokemon Go, a famous game for mobile phone, is an example of augmented reality. [Online] Available at: https://www.pokemongo.com/en-us/ [Accessed 28 January 2019].
2) The start-up Magic Leap, purchased by Google in 2016, is one of the companies promoting mixed reality technology. [Online] Available at: https://www.magicleap.com [Accessed 25 February 2019].
3) For further information cfr. web-site: https://www.simnova.unipo.it [Accessed 12 January 2019].
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