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Space4Inspiration: Survival Lab. Designing Countermeasures for Natural Disasters

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Abstract: The advances made for spaceflight have influenced almost every aspect of modern life on Earth through spin-off technologies. Looking at the Space environmental context and the crew dynamics we can gain insights and inspiration into how to manage stressful and unpredictable emergency situations. In this paper we enquire into ways that design can help generate countermeasures to enhance our resilience to terrestrial extremes and generate solutions for sustained survival to natural disasters. The extraordinary dynamics in urban populations means that growing numbers of people find themselves in an extreme environmental situation – floods, earthquakes, volcanic eruptions, tsunamis, fire or hurricane. Design for Space and extreme environments provide the transformative lens for applying lessons learned from one extreme scenario to another. What if the design of an emergency habitation module could be transformed into a Survival Lab: a mobile training centre able to recreate analogue conditions determined in natural disasters and prepare people to respond actively?

Keywords: Analogue, Resilience, Space Design, Spin-Off

1. Introduction

Looking from outer space, an environment considered too hostile for life to exist, we recognize that the conditions brought about by natural disasters result in equally harsh conditions of similar but differing constraints. What if buildings begin to tremble and collapse and the inhabitants are forced to abandon their home and the city itself (e.g. Centre of Italy 2016 – L'Aquila 2009)? What if in a few minutes the roads of a city are transformed by a flood that sweeps away all surrounding objects resulting in an unpredictable streetscape (e.g. Calgary, Canada 2013)?

Considering the many descriptions of natural disaster, we can acknowledge that the most unsolved factor is the **unpredictability** of the natural phenomena and the consequent incapacity of the human being to be prepared in advance to manage the emergency.

Although every natural disaster is followed by analysis of the causes contributing to cities flooding or building collapse, to the structural and architectural deficiencies due to the human construction

errors, in reality we know that we can do nothing against the power of nature, and we cannot manage the violence of the events with our own strength. So, together with actions to improve the quality of the constructions we should work on the human being creating skills to be used as countermeasures to enhance our resilience to terrestrial extremes and to respond better to natural disasters.

2. Designing perception and experience in Space and on Earth

As designers, with strong expertise in Space and extreme environments, we believe that crossing design experiences together with different fields of application is a good method to find new design solutions, facilitate creativity and innovation.

Designing for Space, and specifically microgravity conditions, extends the area of design research outside of the common rules and consolidate methodologies that we use to consider and apply in a design process. Looking through the transformative lens of Space, we are freed from the conventional references and potentially advantaged by different points of view and new scenarios (Fairburn and Dominoni, 2015) and at the same time we have the advantage to apply the lessons learned from one extreme scenario to another one. In this case: we draw from outer space, an environment considered too hostile for life to exist, and we recognize that the conditions brought about by natural disasters result in equally harsh conditions of similar but differing constraints.

Using the experience of design for Space to inform methodologies for design on Earth may generate a paradox, as clearly microgravity isn't a condition on Earth, but therein lies the opportunity to find analogous ways to create this state, and other states, to generate new conditions, in turn leading to design innovation.

In this context, the **designer becomes a translator of languages and experiences** able to read usages, gestures and behaviours of the people and translate them into new useful products and processes. Looking at the research in Space we have some valid examples of studies - completed during the formative Space Station Advanced Development Program for planetary exploration - on architectural design for habitable space environments that show how the full-scale simulation mockups are the most appropriate to meet specialized needs mixing with the virtual reality technologies that are becoming more precise and immersive.

As in Space, in order to collect experiences we need to design an environment that is reliable, reproducible and verifiable (Cohen, 1991), we believe it is necessary to build a traditional static simulator able to reproduce in real time the extreme conditions that could happen during a natural disaster.

For these reasons we propose a **Survival Lab** following the same approach adopted in Space - giving priority to **realism vs design research** and considering that the difference between perception and experience corresponds to the difference between virtual reality and full scale architecture simulations.

If in Space research we have the possibility to experiment new environments - reproducing as example Lunar and Martian landscapes, or orbital Space habitat, together with many operations and interactions between the human being in those new environments, thanks to the immersive virtual reality - why we couldn't apply the same methodology on Earth where we have other landscape with extreme conditions produced by natural disasters?



Figure 1. Taking inspiration from Space research experience we can transfer good practices adopted by astronauts on-board the ISS and generate countermeasures to enhance our resilience to natural disasters.

3. Alignment between Space and disasters

The scientific experience collected in exploring and living in Space has informed our understanding of how to survive the journey to Space and what it means to live in an artificial environment, such as that provided by an orbiting or a planetary space station. The environmental and contextual conditions of Space extend beyond gravity, to the atmospheric conditions of temperature, pressure and radiation, the psychosocial conditions of isolation, infinite space and most importantly, the need to anticipate and mitigate life-threatening challenges (Connors et al, 1999).

It is in our transition from surviving in Space to living in Space that we have developed our capacity to be resilient, to design countermeasures for our continued existence, hence our capacity for survival.

"I've often been asked about fear: when you're that far from home and a million things could go wrong, aren't you afraid? ... True fear is fear of the unknown, and all our training has been geared towards eliminating the unknown as much as possible. For a month before the flight we'd worked 12 hours a day, at times on a simulated Lunar surface, tromping around in a sand-filled 'litter box' that took up slightly less room than a tennis court, with heavy equipment on our backs." (Aldrin, 2000).

Acknowledging the words of an early Astronaut, we propose to draw from the experience of Astronauts and their training to mitigate fear of the unknown by anticipating risks and exposure to experiences. The keywords that we suggest to resume the characteristics of the natural disasters on the human being are **unexpected and unprepared**: two conditions that bring our society system to unsustainable responses, unable to give us convincing knowledge and tools pertinent to survive.

How extreme scenarios based in design for space can inform design methodologies as a creativity tool, for generating in this case new systems and artefacts useful for the familiar environments we

inhabit that can be transformed completely and immediately into a terrible experience by a flood or a earthquake?

Our proposal is focussing on the experience of Space as a training environment for coming out of a constrained dangerous environment when natural disaster happen. In Space we have an experience of disorientation similar to the conditions that can endure people during natural disasters involving water, but also that can be translated to the dynamics of human's movement through different mediums: water, avalanche, turbulent air, dust cloud, etc. In microgravity, humans experience disorientation and a cephalic fluid shift that sets up a number of subsequent adaptive physiological responses.

Research from living in Space has characterised the environmental factors and developed countermeasures to counteract the effects, so we believe there is an interesting opportunity to transfer countermeasures to many effects of natural disasters.

Despite the strong training that make astronauts bloods resilient to danger, they remain human beings with the same needs of people on Earth; physiological (need to breathe, eat, sleep etc), physical (strength, agility, speed etc) and emotional (stress, fear, despair etc) parameters. The majority of the training programs of NASA manuals are focussed to increase all these parameters of the astronauts according to the unpredictable situations that could happen in Space to allow them to be able to manage all the problems that may arise.

The goal is to pursue a mental form similar to the astronaut, who is used to working with codified procedures and follow them according to the events, and is prepared to live with the unfamiliar and the unexpected all the time. We have to consider that the biggest obstacle for common people instead is to see changing completely the environment **from a comfortable to a dangerous condition in a few seconds**. And this situation encloses the sense of the title of this conference: Design for Next, could not be more appropriate.

4. The context of disasters and the challenges of disaster response

4.1 Situation Management

The United Nations Office for Outerspace Affair's Knowledge Portal defines a disaster as: "A serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of the affected society to cope using only its own resources" (UN-Spider, 2014). They clarify that a disaster is triggered by a natural or a technological hazard and they differentiate between a disaster and an emergency as; a disaster involves losses that exceeds the ability of the affected society to cope using its own resources, while in an emergency the society has enough resources to cope with those losses (ibid).

Natural disasters arrive with little if any warning. Be it a hurricane, a flood or other, hundreds of thousands of people can be displaced from their homes. Structures are submerged or swept away, public utilities fail and many modes of communication are compromised. Survivors find themselves trapped without water, power, and seeking contact with emergency support or family.

In the aftermath of a disaster, the first 36 hours are critical and managing disaster responses and their ensuing personnel is essential. For example, the Galveston Hurricane of 2008 saw 65.000 responders assemble across a wide area, and act, at the peak of the response effort



Figure 2. Basilica of St. Benedict collapsed after the earthquake, Norcia, 2016.

(George et al, 2010). But central to understanding situation management is the identification of some of the key defining challenges: the infrequent and unpredictable nature of disasters, the variation in scale and lack of standardisation, lack of communications infrastructure, and lastly, the dispersed and sometimes disconnected nature of the activities of disaster responders (ibid).

While the first 36 hours are clearly of importance for the coordination of disaster response and the management of the situation, it raises the following questions: What is possible in the way of individual or **societal countermeasures**? How might communities prepare themselves? How might designers familiar with analogue situations draw from precedents and experience elsewhere and offer an approach to address disaster preparedness: Design for Next environments.

4.2 Disaster Design Case Studies: Centre of Italy 2016 - 2009

The first case study is the earthquake that occurred in central Italy involving a number of seismic episodes that began in August 2016 with epicenters located between the Tronto Valley and the Sibillini Mountains. Being in a very active seismological area, that includes also L'Aquila (2009) and involving many old towns like Accumoli, Amatrice and Norcia, we have chosen this case study for the complexity of the reconstruction's programs including historical buildings.

The first emergency aid arrived on the earthquake places already a few hours after the quake of August 24, albeit with some delay in reaching the most isolated villages because of the many bridges collapsed and roads blocked by rubble. The following day the total number of rescuers put in place amounted to 5.400 units. The Civil Protection counted 299 victims, and pulled 238 survivors from the rubble (some of whom have subsequently died as a result of injuries sustained), 215 by the Fire Department and 23 from Mountain Rescue. The injured



Figure 3. Basilica di Santa Maria di Collemaggio, L'Aquila, 2009.

taken to hospital were 388. In Norcia the Basilica of St. Benedict and the Cathedral of Santa Maria Argentea collapsed, and the hamlet of Castelluccio was almost completely destroyed, with about 60% of the houses collapsed.

The strongest earthquake occurred in 2009 at L'Aquila, the capital of Abruzzo, which together with surrounding villages suffered most damage, have been several thousand foreshocks and aftershocks since December 2008 and not yet completed. The earthquake caused damage to between 3.000 and 11.000 buildings in the medieval city, several buildings also collapsed. More than 300 people died and approximately 1.600 people were injured. Around 65.000 people were rendered homeless and housed temporarily in tents, cars, hotels along the Adriatic coast.

Aftershocks caused safety problems for rescue crews searching for injured victims trapped in precarious structures in the historic center of L'Aquila. Using cranes and backhoes to remove loose bricks and broken timbers, rescuers were aware that even a small aftershock could have triggered the collapse of seriously damaged walls or parapets.

The event immediately led to a significant deployment of police forces, air and ground's emergency vehicles by Fire Brigade, Civil Protection and Army. Stages of the emergency have been divided into: a first phase consisting of the immediate and subsequent rescue to the involved; a second phase constituted by the realization and management of the tent city; a third phase focussed on the realization of containers as temporary houses regarding the emergency housing; a last one for the commissioning securing of damaged buildings and their subsequent reconstruction.

Immediately after the first and second phases of the emergency the Civil Protection inhibits the pedestrian traffic, for safety reasons, different areas affected by the earthquake: from the old town of L'Aquila to neighboring centers more involved, labelling them as "red zone".

4.3 Disaster Design Case Studies: Calgary, Canada, 2013

The second case study was selected for the setting (dense, urban population and modern financial centre), the scale of the flood, and for the unique way it was first captured and documented; an approach drawing from Space technologies.

On June 22, 2013, the City of Calgary, Canada's fourth largest city was inundated by floodwaters. Flooding extended from the Rocky Mountains to the prairies, across one quarter of the province's landmass, devastating the city centre, and forcing the evaluation of more than 100,000 citizens. The area received a "water bomb" when over 68 mm of precipitation fell in 48 hours, combined with exceptionally heavy and torrential rainfall west of the city – more typical of a tropical storm in quantity and intensity.

Six months prior, in January 2013, a new camera system was installed in the window of the Destiny Module of the International Space Station to serve the Environmental Research and Visualization System called ISERV (ISS SERVIR), which has more recently become known as the "Disastercam". Orbiting at an altitude of 400 km, the device offers a particular perspective on natural disasters, with a scale of capture much greater than a "birds-eye" view. On this occasion, the ISERV captured more than 20 images of the flooding in Calgary over the 3 day period and sent the images to Environment Canada who distributed them to other federal departments to aid emergency responses, assessment of the damage, and rebuilding efforts (SERVIR Global, 2013).

The most significant aspects of the impact were at street-level and across communities, where the damage was extensive and yet, still somewhat unpredictable as water levels continued to rise, furthering the effect and contributing to an unfamiliar streetscape.

In terms of the likelihood that this level of flooding will happen again, new research suggests that during the course of the next several decades, due to global warming, the risk of river flooding events is likely to increase, around the world (Hirabayashi, et al, 2013).

Calgary Pre-Flood/Post-Flood Comparison



Before flood: Google Earth Image
September 2008



After flood: NASA/ISERV Image
June 22, 2013

Figure 4. Calgary Pre-Flood and Post-Flood Comparison - as captured by NASA's ISERV camera onboard the International Space Station.

5. Survival Lab as a means to achieve a sustainable response

The need to have an habitation module for first aid and restoring living conditions in urban contexts devastated by natural disasters as floods, earthquakes, fires, tsunamis etc. is increasing according to the climate changes that today provoke much more tragic transformations of the territory than in the past, with tremendous implications for people involved with different levels of gravity.

Our proposal is to use a shipping container as a base to start thinking around this theme, because it is considered an international standard in terms of dimensions, volumes and transportation. The container in many cases is seen in the middle between temporary shelter and building, an “ideal tool” for devastated areas with a light way in first aid care and restoring urban life. At the moment there are already examples of containers used with survival purpose by Civil Protection on site, to provide first aid in terms of medical care and life support for food and accommodation. Our design intent deviates from the temporary shelter: we imagine the container for innovative uses, imagining our ideal tool more as a service provider instead of an habitation module for emergency situations that has been utilized many times until now, with the effect to impoverish the living conditions of people (forced to stay also for long periods in precarious conditions) as after L’Aquila earthquake in Italy in 2009.

5.1 A Research Methodology by Space

Survival Lab is proposed as a new tool that could be used as a service provider to design the extreme experiences able to stage, as a theatre performance offering different scenarios of natural disasters, a set of experiences simulating their effects on cities, buildings, objects and the interaction with people involved. The focus of the project is a survival container that suggests a **new method of “training for the unfamiliar and the unexpected”** to counteract the immediate effects of natural disaster on people and achieve methods and models for preparation and sustained responses: a Lab for designing survival.

Our idea strengthens the active inclusion of people in order to empower them and offer them the correct answers and actions to respond to unexpected events. This approach assumes that people could see the value in being prepared in the immediate, and are conscious that exposure to scenarios is a key aspect of learning to respond, to combating fear, and to surviving.

A container is very useful to experiment different cases in which we could find ourselves involved in a natural disaster while living inside a building - sleeping in a room, working in an office, doing all the daily activities – or moving around the city by car, public transport or by foot. The Survival Lab should ideally recreate all the possible familiar environments - as towns, villages, buildings, interior, passages, paths, underpasses, subway - disrupted by disaster events, and in which we are forced in a confined situation determined by a physical structure, inside or outside the buildings.

We think that the training experience of a confined environment, that can be flexible and transformable according to different scenarios and “effects” provoked by natural disaster, will test our limits and teach us the best ways and “reactions” to survive the first minutes/hours/days of the tragedy.

In this paper we are at the preliminary phase of this project and there are many directions and opportunities to develop in order to define the principal needs that could drive our “physical” design research:

- the requirements for the design solutions of an emergency habitation module, the Survival Lab as a mobile training centre with augmented reality systems able to recreate the conditions involved in natural disasters and prepare people to respond actively;
- the different scenarios which could be recreated looking at natural disasters and their effects on human being foreseeing the first boundaries according to design feasibility and taking inspiration from Space conditions.

The principal aim is to provide a “tool” that could educate people to the right actions and behaviour for their personal prevention of severe harm, when natural disaster occur.

We imagine a multifunctional environment working with a learning model, similar to that offered by the videogames, to training people to react with different behaviours according to different disaster scenarios. The Survival Lab will act as a simulator mixing what is real, what is perceived, what is experienced, with the aim to give the most effective immersive experience that could prepare people for extreme situations.

This project requires the involvement and collaboration of authority and agency bodies responsible of the Civil Protection, such as the Red Cross, to have scenario data of the disasters, analyze them and develop behavioural procedures together with consequent software.

5.2 Focus on Design

We believe the Survival Lab could be a good and effective response to many different social environmental contexts as well as the design has a central role to analyse the impacts of the extreme conditions of the people involved into disasters and to find new methods and tools to increase the ability to answer properly to the emergencies and survive.

It is important focussing the attention on the central role of the designer in this project as a mediator of languages and experiences able to interpret the needs of the actors involved, the requirements of each emergency related to natural disasters and the possible scenarios according to the specific context and considering the social effects on different territories.

A design approach can help generate countermeasures to enhance our resilience to terrestrial extremes and generate solutions for natural disasters. The concept of the Survival Lab implies different levels of design regarding the structure, the contents, the outfitting, etc. but overall allows to **forecast scenarios and extreme conditions** experimenting through virtual reality environments, actions and procedures that could become instruction and training opportunities for people living in dangerous areas and for rescue workers.

The first step we will undertake is to identify those particular conditions related to a specific case study, for example Amatrice earthquake in the centre of Italy occurred on 2016, and use those requirements as a starting point for the Survival Lab, matching the needs of “terrestrial” people and their behaviours with the Space experience of the astronauts who are prepared for living in the range of analogue environments and in Space.

The spin-off of behaviours, experiences, procedures that we propose in this paper shows that Space can be an inspiration not only for technology. Design for Space extends the fields of applications to many extreme environments and conditions on Earth in which we do not have enough instruments to face unpredictable disasters. Design means starting from scratch, thinking along different lines and for a different kind of environment, envisaging new tools for uses and activities that it is hard for

us living down here on Earth to imagine, but which, in most cases, assume a different kind of relationship between our body, objects and surrounding space (Dominoni, 2015).

6. Conclusions

Presenting this paper we would like to introduce a new methodology taking inspiration by Space research experience with the aim to transfer effective practices adopted by astronauts on-board the International Space Station to people on Earth with increased risk to natural disasters, and to generate countermeasures to enhance our resilience to terrestrial extremes.

Our aim is to show that spin-off could not concern only transfer of technology, but as in this proposal, physical and emotional attitudes of the human being in extreme context in Space, attitudes that we could replicate to apply the right reaction to the emergency of natural disasters.

The situation management within the case studies described demonstrates that unpredictability of the natural phenomena drives us towards the possibility to increase the capacity of the human being to be prepared and react efficiently and promptly to the unexpected emergencies that transform the daily life environment in something unfamiliar and very close to the extreme environment in which astronauts “live”.

In our opinion the Survival Lab could be one response to this need, if we think to a new use of a container – usually offered to displaced people as a temporary shelter – more close to a “tool” able to stage as a theatre performance different scenarios of natural disasters simulating their effects on cities, buildings, objects and the interaction with people involved.

During the process of development of this idea we will cross design experiences using the transformative lens of Space to mediate languages, uses and gestures useful to achieve sustainable responses and evolve our capacity of learning to respond, to combating fear, to surviving.

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