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Silvia D. Ferraris

Habitability in space:
design for microgravity



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Table of Contents

Preface	9
Spece design? We hope so!	11
Introduction	13
RESEARCH ARCHITECTURE	
Objectives	19
Research area	21
Research context	25
Nature of the research	31
Methodological approach	33
Limit of the research	35
DESIGN FOR MICROGRAVITY	
State of the art	39
Context	40
Habitability	49
<i>Primary needs</i>	57
<i>Daily tasks</i>	63
<i>Mobility supports</i>	71
<i>Environment</i>	76
Project results	81
Critical issues	81
Design process	89
New tools for space design	93
<i>Analysis of operational scenarios - data</i>	94
<i>Analysis of operational scenarios – storyboards</i>	99
<i>Analysis of operational scenarios – drawings</i>	105
<i>Synessay of information - logos drawing</i>	111
<i>Operational scenarios building</i>	115
Design concepts	118
Conclusions	125
References	130

Preface

The International Space Station (ISS) is the most ambitious space project ever undertaken, with 16 nations collaborating to create a world-class orbital laboratory that will conduct research for the benefit of everyone on Earth. Europe is one of the main contributors to this challenging programme with infrastructure elements (e.g. Columbus Laboratory, Automated Transfer Vehicle) as well with utilisation elements (eg. Microgravity facilities for Columbus and external payloads). This participation is the logical continuation of European involvement in human space flight that dates back to the construction of Spacelab laboratory in the 1970s.

The time spent in orbit by each crew of the ISS has been increased in the last few years and it is now up to 6 months. Looking beyond the ISS, human exploration missions to the Moon and, in a distant future, to Mars will require even longer period in micro gravity.

With such important objectives, it is important to understand all aspects of the design in micro gravity to improve the physical and psychological conditions of the astronauts in space and this book provides an important contribution towards this end.

Giuseppe Reibaldi

*Head of Micro gravity Facilities
for Columbus and External Payloads Division*

Spece design? We hope so!

Silvia's book traces and witnesses three years of her doctoral experience, and of at least five years of activity in the research group called "SpaceLab."

I cannot add anything to what Silvia writes and so much less I can comment it, because it belongs to the work of all us. I would say, instead, that five years are perhaps few if compared to the times of space programmes, but they are a lot if I think that together we have got through the great hope that the ISS could become the place of the scientific experimentation on the quality of the life of the astronauts, the Nine Eleven and the new priorities of the American politics, the tragedy of the Shuttle, the China's new interest to space, the new private enterprises and aircrafts as **SpaceShipOne**, the new hope of the scientific investment on Mars and today, perhaps cautiously, again on the Moon. It is not bad. Indeed several people think that space is not a proper place for men and that it is more reasonable and economic to send robot as explorers, scientists, workers. Perhaps it is true, but we also believe that the conquest of new unexplored territories is a drive so deeply rooted in the human DNA to be indefeasible. So, then, we keep on designing equipments, items and furnishings finalized to improve the conditions of astronauts' life.

In short, among changing stories, these have been years of great involvement, rich in several satisfactions; in which however, many disappointments have never succeeded to diminish our wish to think that when astronauts will eventually depart from the Earth to conquer other lands, they will certainly have with them a lot of things designed by a designer.

Francesco Trabucco

*Full Professor in Industrial Design
SpaceLab Scientific Director*

Introduction

Manned missions to the space represent a very challenging field of research for the Industrial Design discipline. Spacecrafts are masterpieces of engineering solutions that enable life in the most hostile environment for human beings, the extraterrestrial environment.

Where there is no air to breathe, no atmosphere to protect us from dangerous radiations, where temperatures are extreme and gravity is absent it is very hard to guarantee survival to the living beings. Nevertheless, world space agencies have reached in the past half century the skill to produce a permanent orbiting base, the International Space Station, for a crew of scientists-astronauts who spend up to three months aloft.

Still, if life is made possible, it is yet very tough. The level of comfort is very far from what we usually consider a standard in our everyday life on Earth. From sleeping to eating, to simply going to the bathroom, living in microgravity in a confined environment is indeed very hard.

The aim of this essays to highlight which main problems occur when living aloft and demonstrate how the industrial design discipline might concur into the projects of space missions in order to improve the astronauts wellbeing.

The contents of this essay were developed by the author while working as a member of SpaceLab, centre for space design of the Politecnico di Milano, Italy, where the first studies and results where achieved, since 1998, by dr. Annalisa Dominoni and dr. Mario Faicchia under the supervision of Professor Trabucco.

In particular the results presented in the book “Industrial design for space” by dr. Annalisa Dominoni represent a unavoidable base for the researches reported by the author. Indeed, by entering the Course in Industrial Design the author joined the ongoing *SpaceLab* researches, and enjoyed the advantage of becoming part of an existing and active research group. This provided the author with the chance to start off with clear goals and a scientific basis from the very outset.

abitabilità ISS This essay has been developed along two main lines. The first one is based on the results achieved by a detailed study “Abitabilità ISS” on the habitability conditions of the International Space Station - the most recent and advanced orbital aircraft available. This study, conducted by SpaceLab for the Italian Space Agency (ASI) in 2001, has approached problems relating to habitat and equipment design, highlighting possible solutions for better living conditions for the astronauts attainable by new design concepts.

qualifying period at the ESTEC/ESA The second phase of this essay is based on a research conducted by the author during a qualifying period at the Microgravity Facilities for Columbus Division of the Microgravity and Space Station Utilization Department (MSM-GF) of the European Space Research Center ESTEC, Noordwijk, NL, in 2002.

On this occasion the author conducted the research “Operational Scenario for the Columbus European Facilities” focusing on the working conditions of the Columbus Laboratory - an orbital Module planned to be added to the International Space Station in 2004 - with particular regard to the utilization of the European Microgravity Facilities (support facilities for scientific experiments).

The principal purpose of this study was to optimize the astronauts’ operations while running the scientific experiments involved. This aim was pursued through the definition of operational scenarios and through the design of innovative concepts for the improvement of facility usability and crew comfort.

MEEMM operational Study” These studies concurred to show how the Industrial Design approach could be integrated in an engineer field of action through the introduction of typical design tools such as visualization and representation of data and scenarios. These methodological results were later reused and studied more in-depth while carrying out the “MEEMM operational

Study” conducted by SpaceLab for the ESETC in 2003. The Operations Study of the MEEMM (Multi-Electrode Electroencephalogram Mapping Module) experiment defined the best configuration for the Operator’s activity and the Test Subject’s comfort during the preparation and performance of the experiment. It also proposed a concept design solution for the optimal layout of the operational scenario.

The contents of these three studies are mentioned in this work in order to describe the development, aim, path and results of this essay.

This document is structured in two main parts. The first, “research architecture”, contains the information for understanding the development and scientific approach of this essay; the second, “design for microgravity”, contains: the “state of the art” of the habitat and equipment for astronauts’ intravehicular activities on the ISS; the third “projects results” meaning both the design concepts and the design tools identified for the design process applied to the study.

**document
structure**

Research architecture

Objectives

The objectives of this essay may be described at three different levels: a general level, a theoretical level and a practical level.

At the general level, this essay aims at advancing the research area regarding “Industrial Design for the aerospace” following the path laid down by Dr A. Dominoni in her essay at the Politecnico di Milano. **general level**

That meant verifying the actual opportunity of introducing and integrating the Industrial Design discipline with the aerospace field demonstrating the valid contribution that can be given by designers to the process of realizing manned space missions. In this regard this essay was oriented at implementing researches that would offer opportunities for pursuing this goal.

Furthermore, while studying the particular case of ISS habitability, the author found food for thought in different areas of interest from arts to politics, and discovered a fundamental base of knowledge from which to draw sources of inspiration and reference points.

This phase of the research led to a widening of the horizons and allowed the essay greater breath. The author considered this aspect of the research a very important intellectual stimulus to the study.

At the practical level, the essay aims at improving life conditions on the International Space Station by suggesting design solutions to increase the comfort of astronauts living in orbit. **practical level**

The objectives are real and verifiable because the study is focused on the ISS - the only orbital aircraft in use today - and on the comments expressed by the final users, the astronauts.

Among all the living activities and discomforts of the Station, particular importance is attributed to the centrality of working activities because they are certainly the most

important and demanding.

Work tasks are those relating to maintaining and implementing the ISS, to realizing the mission (flight, boarding etc.) and to running scientific experiments.

From among these work activities, this study focuses on the experiment performance, particular attention being given to the human physiological experiments because of their complexity and not yet completely solved operational problems.

theoretical level At the theoretical level, the essay aims at finding, drawing, developing and verifying the best way of integrating the designer's approach to aerospace activity. In particular, the goal is to identify and apply some typical design tools in order to improve project methodology for space. This goal was set during the experience at the ESTEC Unit and pursued through the studies above-mentioned.