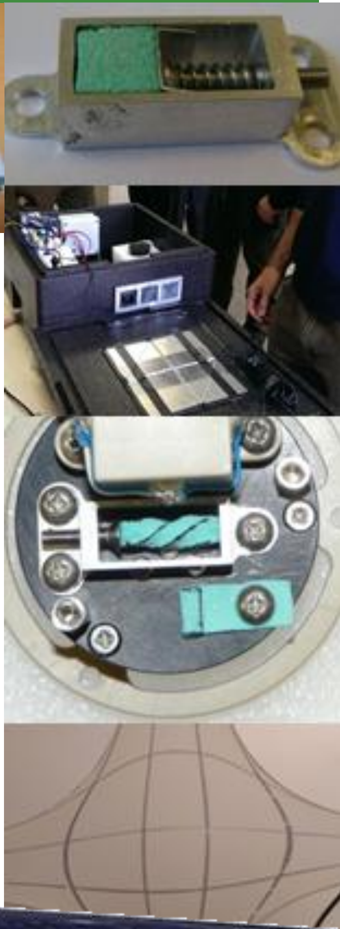


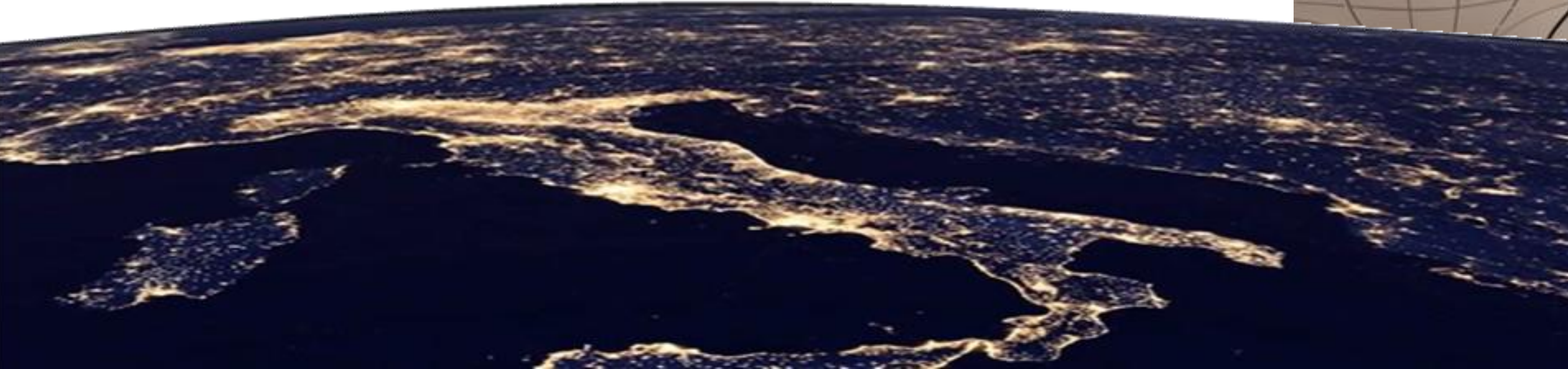
Workshop Human Capacity-Building in Space Science and Technology for Sustainable Social and Economic Development
Samara, November 2, 2017

Sustainability of in-Space Manufacturing

Loredana Santo, PhD

Department of Industrial Engineering
University of Rome Tor Vergata
Via del Politecnico, 1
00133 Roma, Italia

Technology and Manufacturing



Outline

- ✓ The concept of Sustainability for and in Space
- ✓ Research overview of my group
- ✓ Previous and future experiments on ISS about SMC
- ✓ Introduction on Shape Memory Polymer Foam and Composites (SMP and SMC) and application for debris capture
- ✓ The challenging idea of in-space manufacturing
- ✓ Conclusions

Capacity of building in Space in the 21st Century happens through connecting Human needs to Space solutions in order to meet sustainability

What is **Sustainability** in and for **Space?**

To make good educational courses in order to disseminate the concept of sustainable development in/for Space?

To have the possibility to colonize Moon, Mars for future scenario?

To find solutions for the survival of Human in Space?

To make researches in space for better life on Earth?

To enhance telecommunication?

To mantain the Space clean and save energy?

………….

Sustainability therefore can be examined by different points of view.

Sustainable development in/for Space

Space as enviroment to ensure the future of Humanity.

The experimental activity on ISS and with satellites is sufficient for these purposes?

My challenging proposal is a new **small laboratory for in-space manufacturing**

How?

Where?

Why?

Research overview

New Activities for Space — Time →

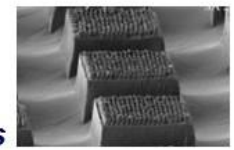
Complexity ↓

Consolidating Knowledge

Shape memory devices for self-deployable structures

Feasible innovation

Hierarchical surfaces for bio-medical applications and functional coatings

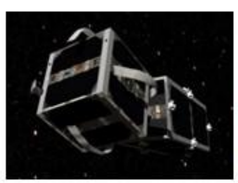


Challenge

New materials and structures for cosmic ray shielding

Satellite

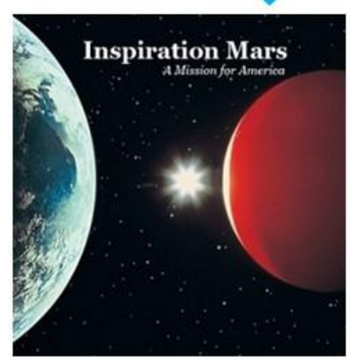
Solar sails

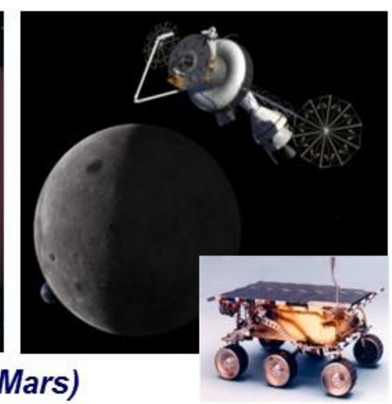


Space cleaning

Super hydrophobicity

Super hydrophilicity

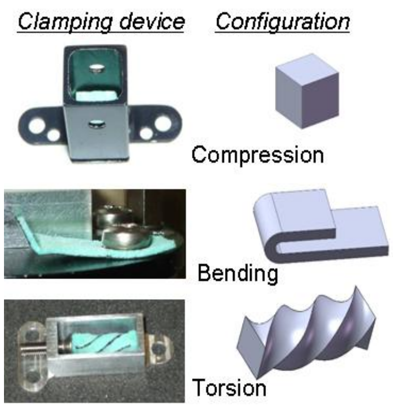


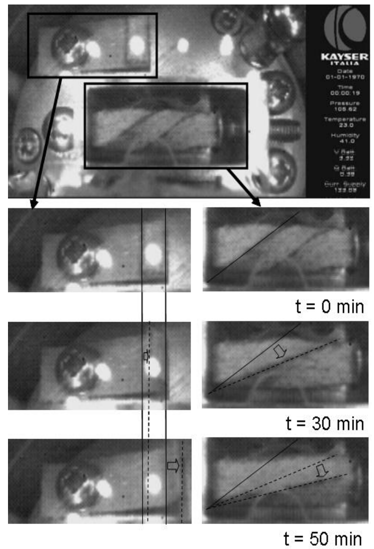


Long term missions (Mars)

Microgravity experiments

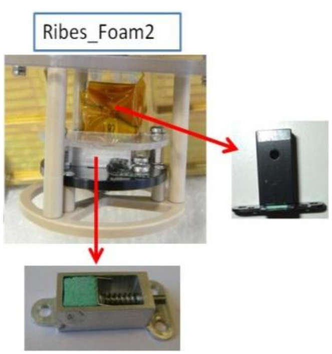
I-FOAM (Shuttle Mission STS 134, May 22, 2011)

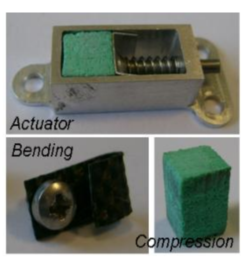


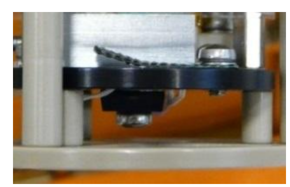


L. Santo, F. Quadrini, E.A. Squeo, F. Dolce, G. Mascetti, D. Bertolotto, W. Villadei, P-L. Ganga, V. Zolesi, “*Behavior of Shape Memory Epoxy Foams in Microgravity: Experimental Results of STS-134 Mission*”, Microgravity Science and Technology, 24 (2012) 287-296.

Ribes_Foam2 (BION-M1 Russian Mission, April 20, 2013)







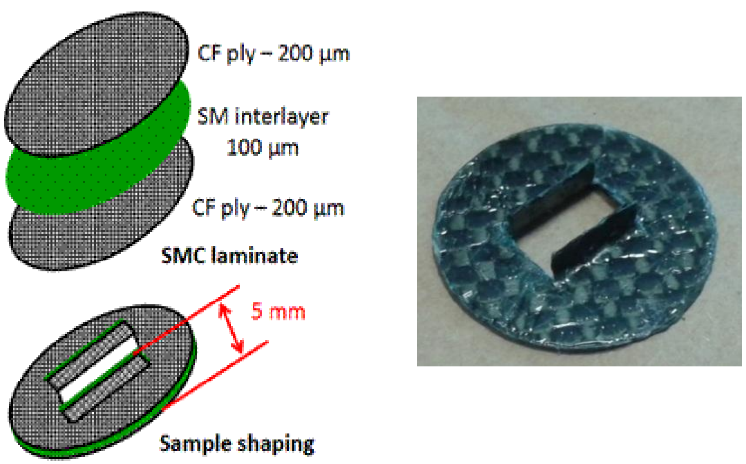
L. Santo , F. Quadrini , W. Villadei , G. Mascetti , V. Zolesi,, *Shape memory epoxy foams and composites: ribes_foam2 experiment on spacecraft “bion-m1” and future perspective*, Procedia Engineering 104 (2015) 50 – 56 .

Future experiments

Exposure to Space environment (ISS) for 1 year:

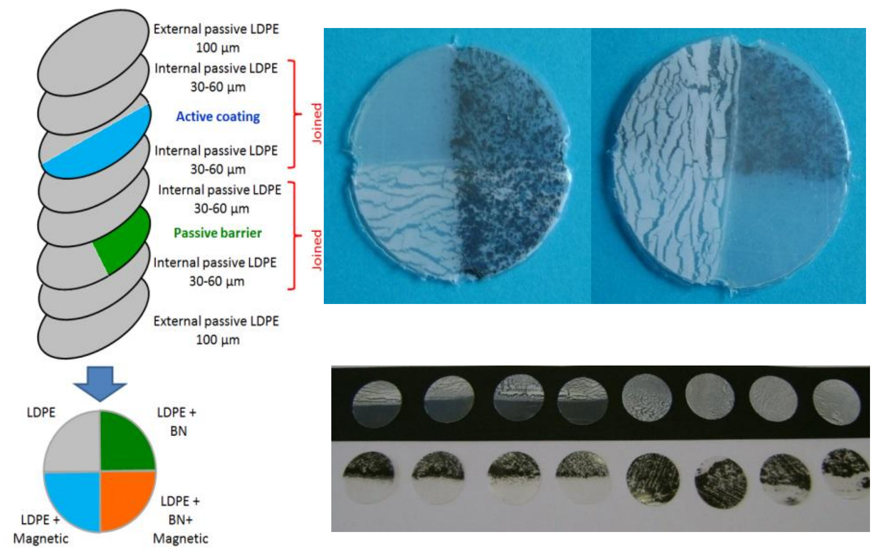
- **NASA MISSE-9 Mission , November 2017**
- **NASA MISSE-10 Mission, May 2018**

Shape memory composite (SMC)



SMC sample for MISSE-9

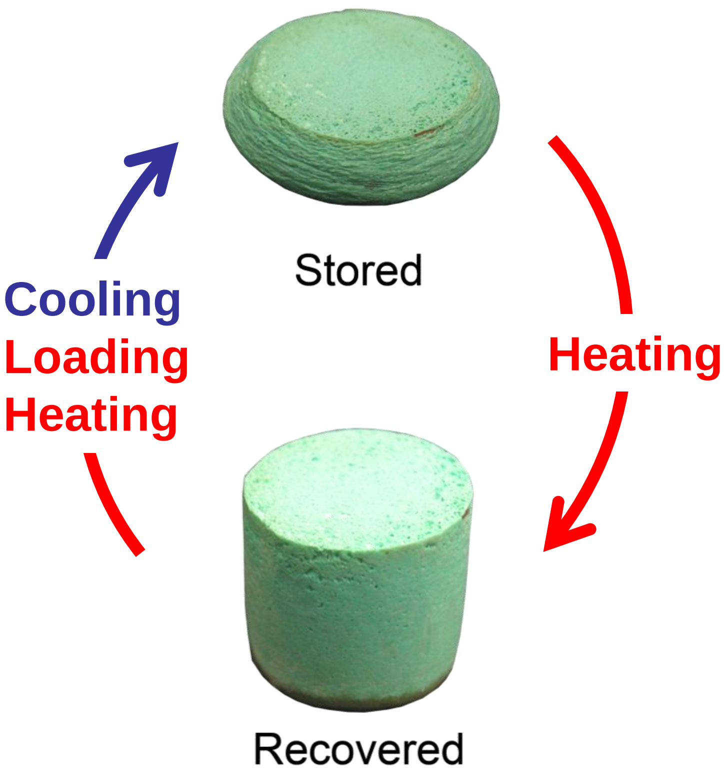
Shielding materials (CRS)

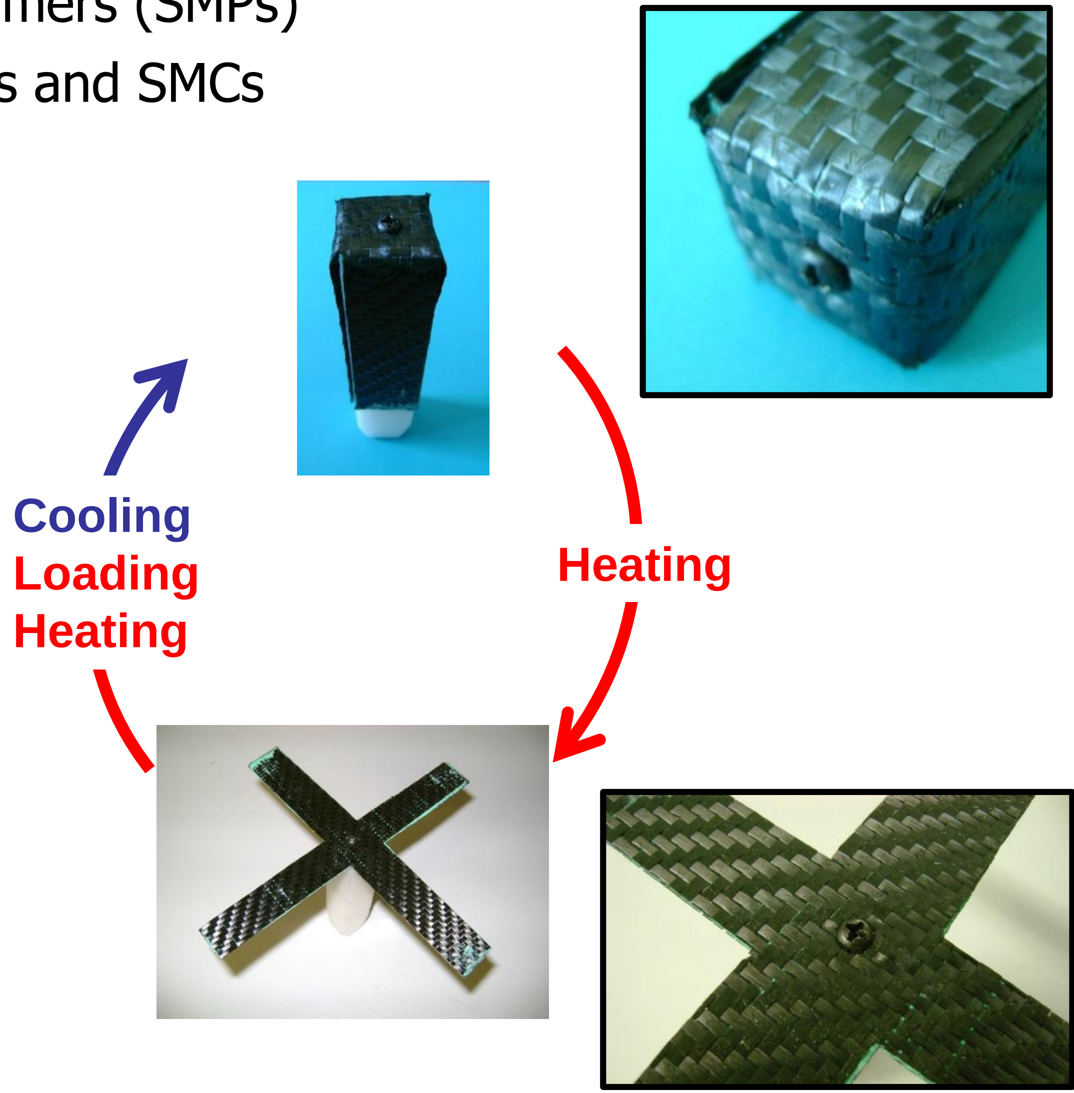


CRS sample for MISSE-9

SMP foams and SMP composites by Tor Vergata

- PMCs with shape memory polymers (SMPs)
- Thermo-mechanical cycle SMPs and SMCs





Applications for SMPC

- Self-deploying systems
- Space debris grabbing

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Text Size 245 55

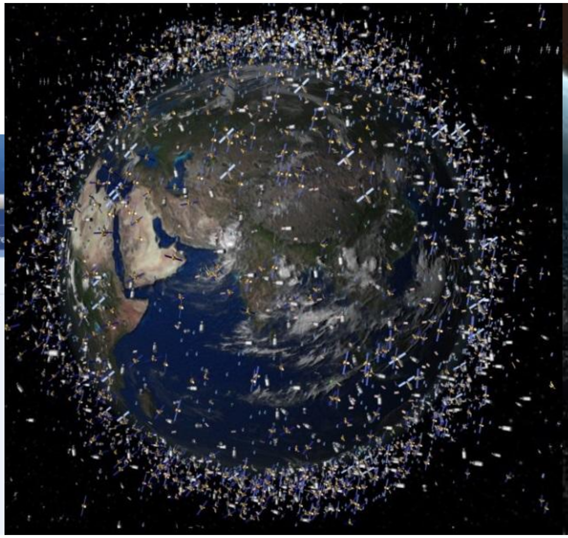
Space Debris and Human Spacecraft Sept 27, 2013

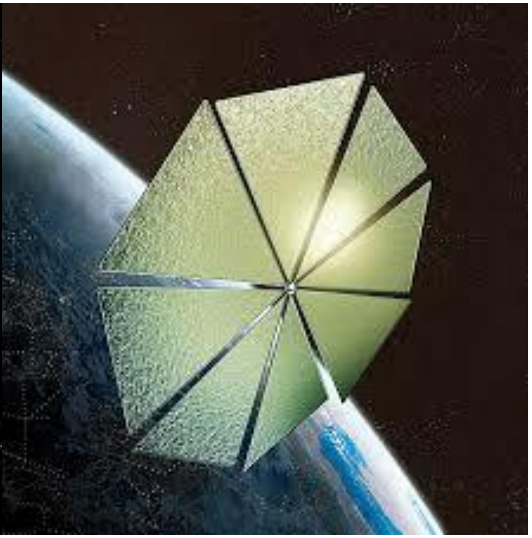
More than 500,000 pieces of debris, or "space junk," are tracked as they orbit the Earth. They all travel at speeds up to 17,500 mph, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft.

The rising population of space debris increases the potential danger to all space vehicles, but especially to the International Space Station, space shuttles and other spacecraft with humans aboard.

NASA takes the threat of collisions with space debris seriously and has a long-standing set of guidelines on how to deal with each potential collision threat. These guidelines, part of a larger body of decision-making aids known as flight rules, specify when the expected proximity of a piece of debris increases the probability of a collision enough that evasive action or other precautions to ensure the safety of the crew are needed.

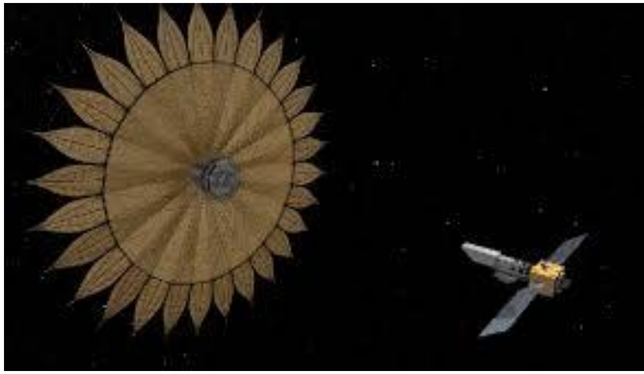
Space debris is tracked as it orbits Earth.
Image Credit: NASA

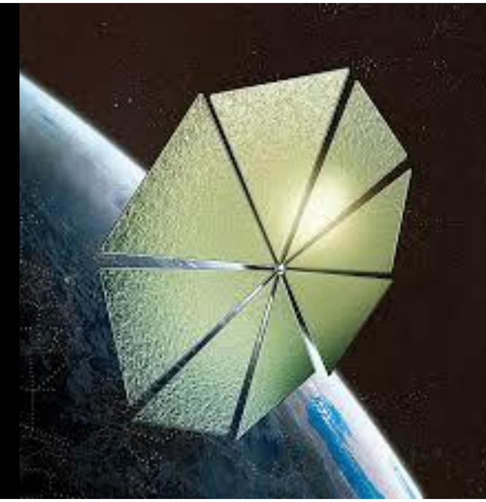


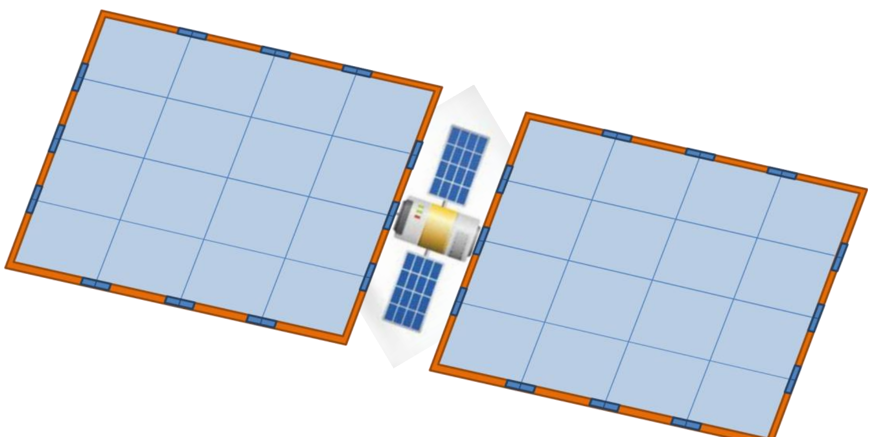


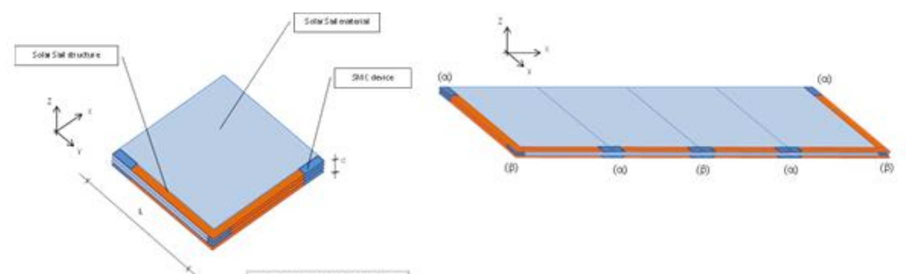
SMC structures deployment

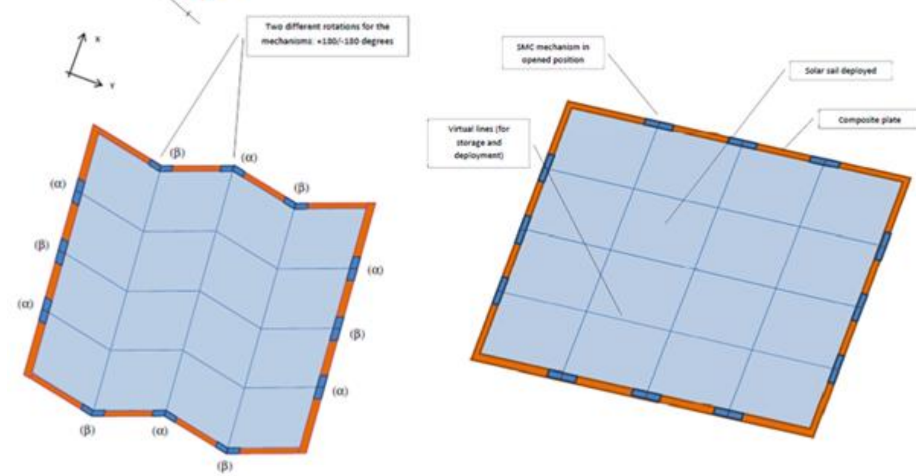
Deploying systems



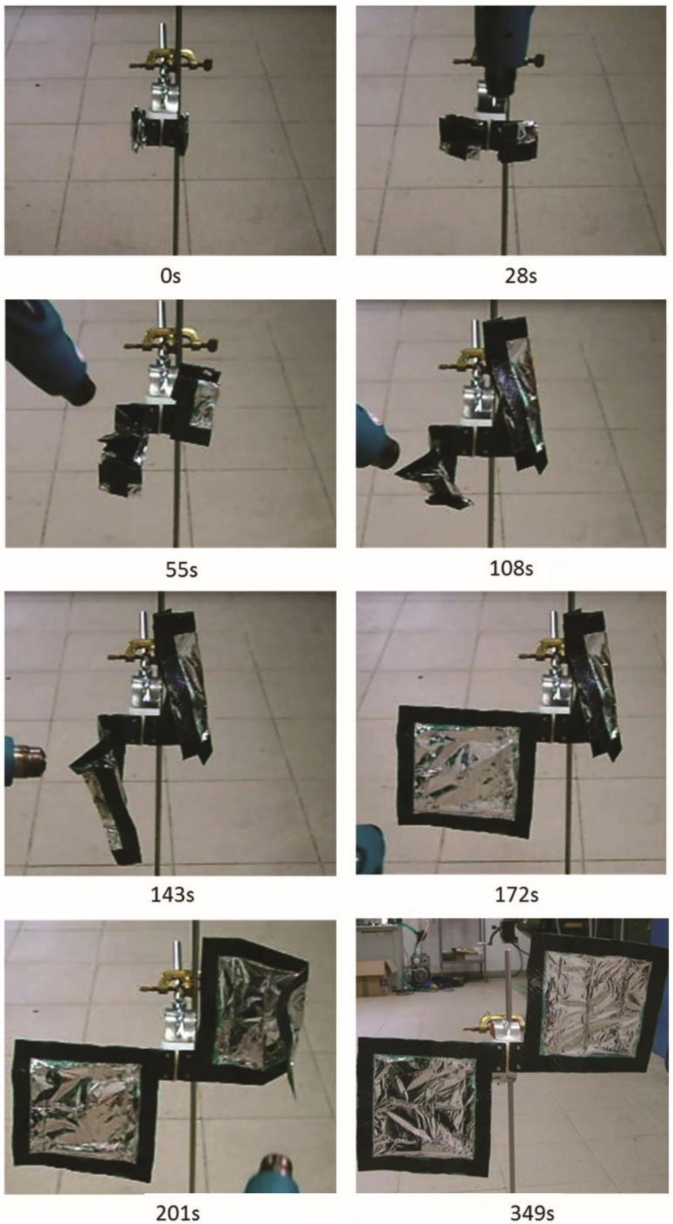


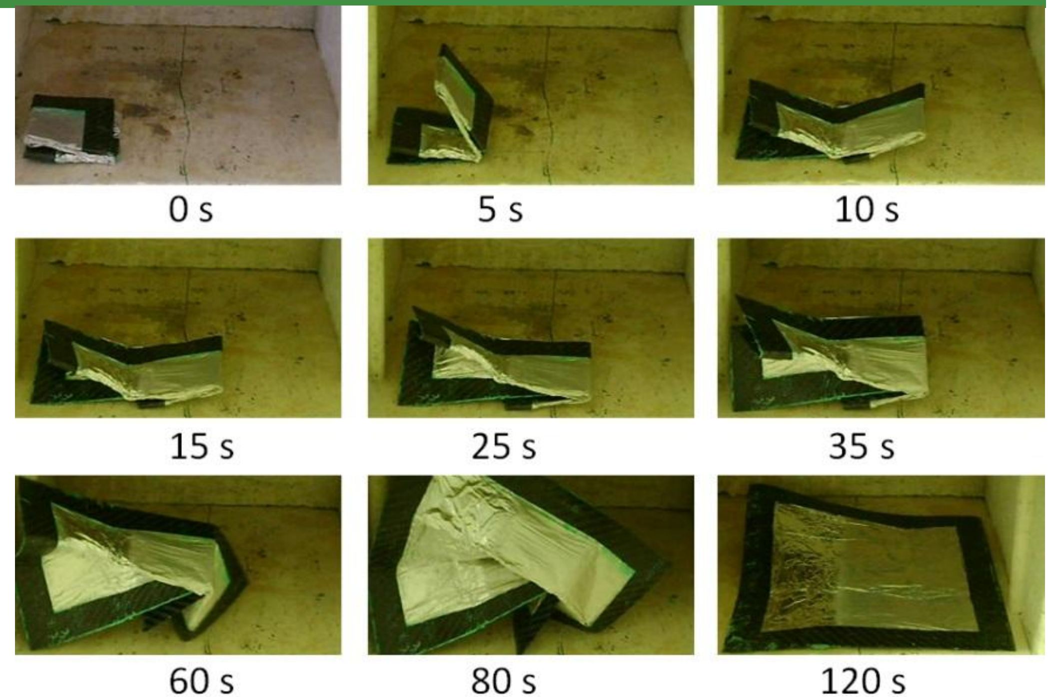


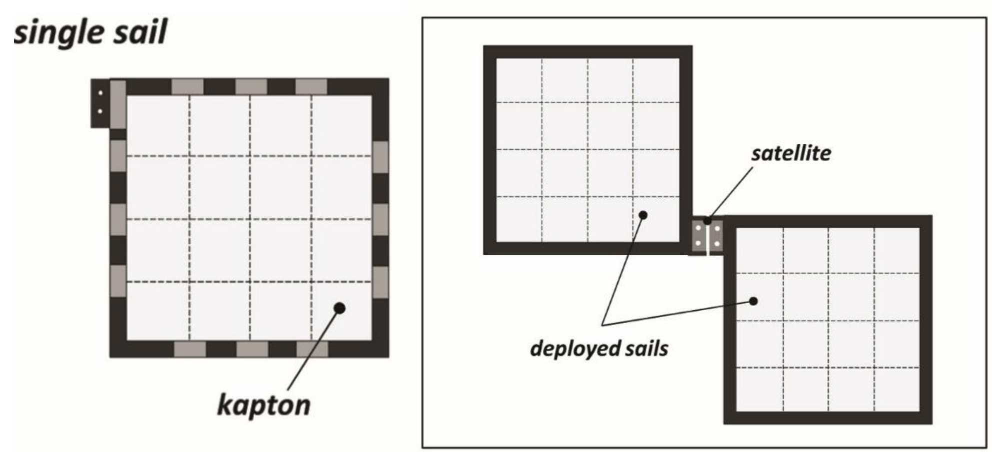




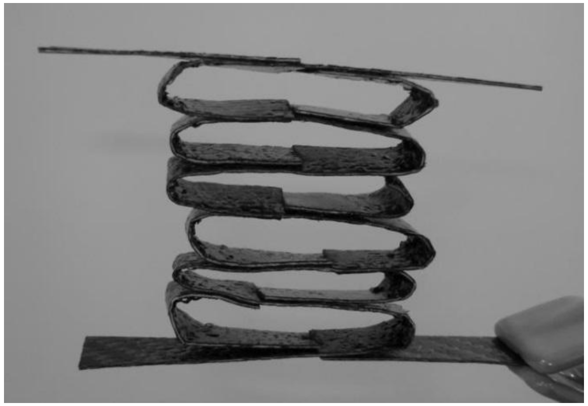
Deploying systems

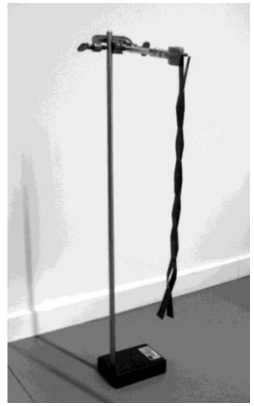


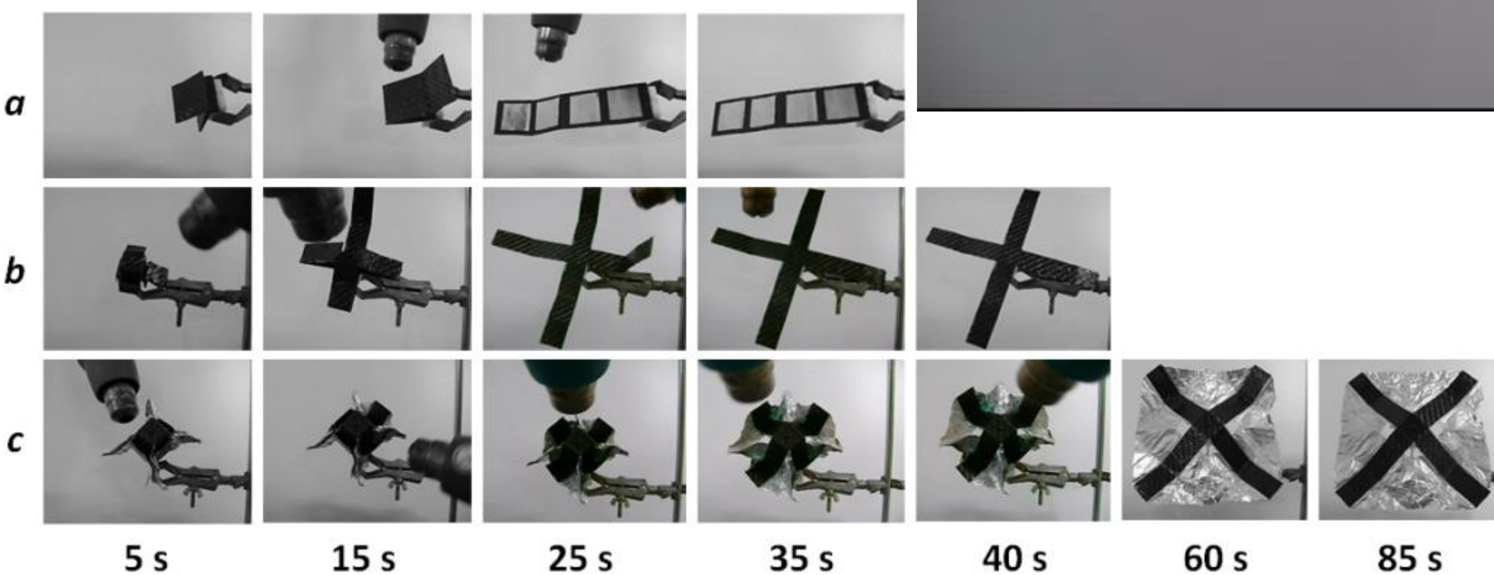




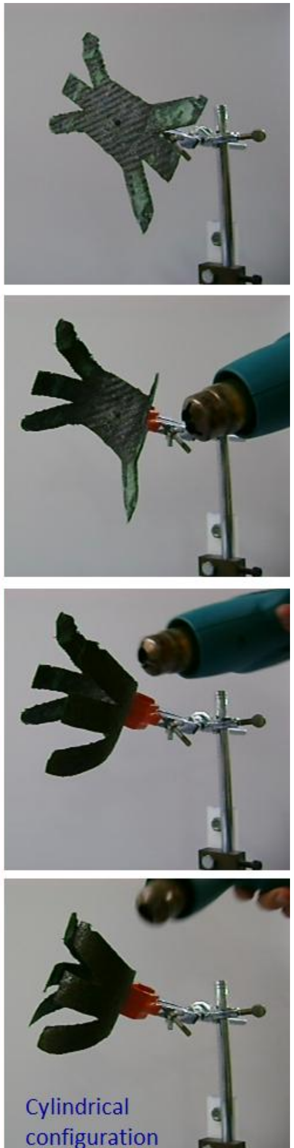
Deploying systems

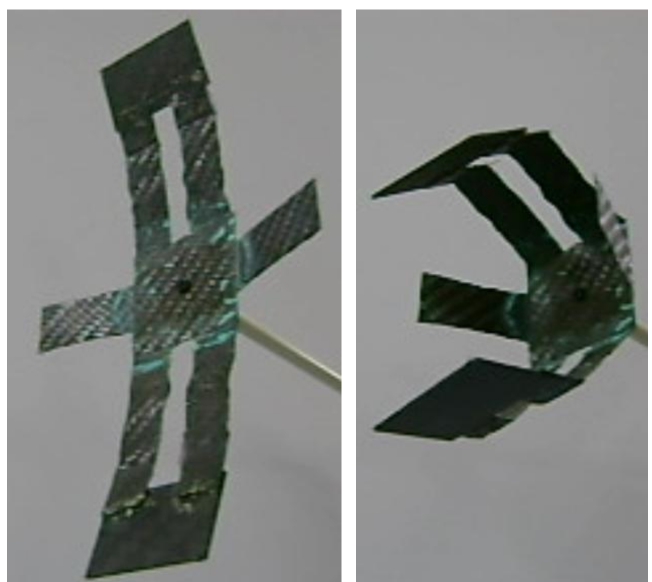






Grabbing systems





Space debris

More than 500,000 pieces of debris, or "space junk," are tracked as they orbit the Earth. There are more than 20,000 pieces of debris larger than a softball orbiting the Earth. They travel at speeds up to 17,500 mph, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft. There are 500,000 pieces of debris the size of a marble or larger.

www.nasa.gov

Kessler's sindrome (1991)

Space Debris and Human Spacecraft

Sept 27, 2013

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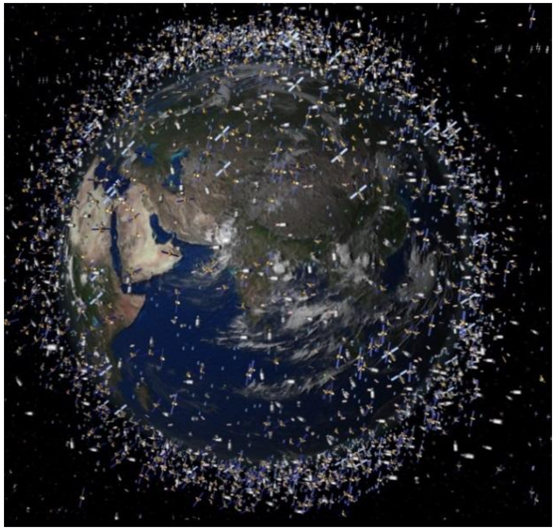
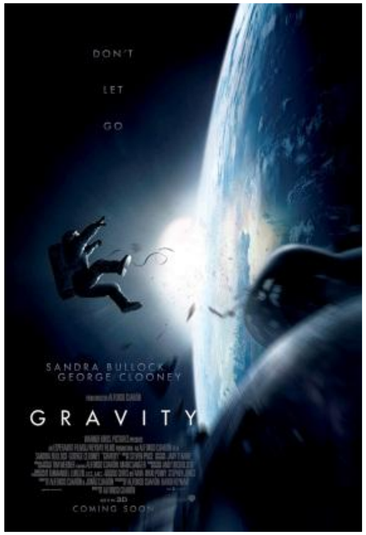
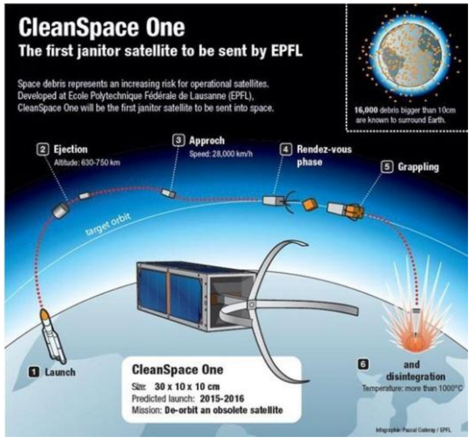
Space debris is tracked as it orbits Earth.
Image Credit: NASA

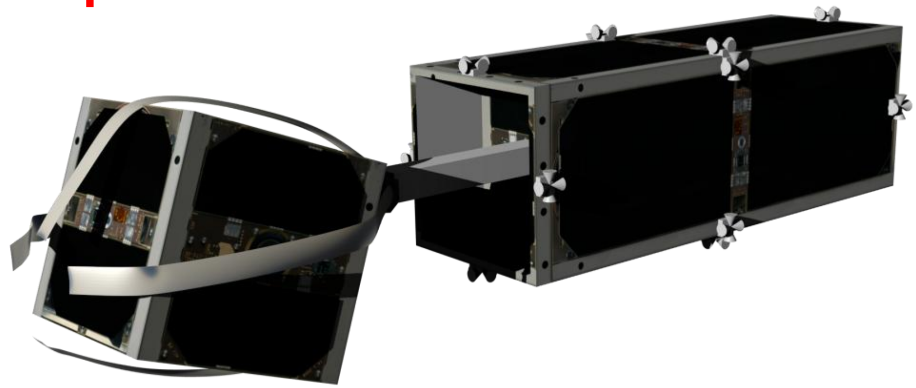


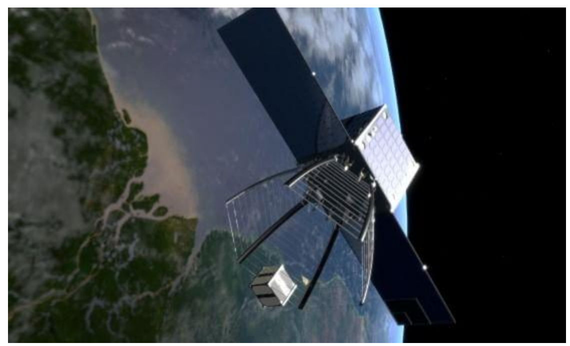


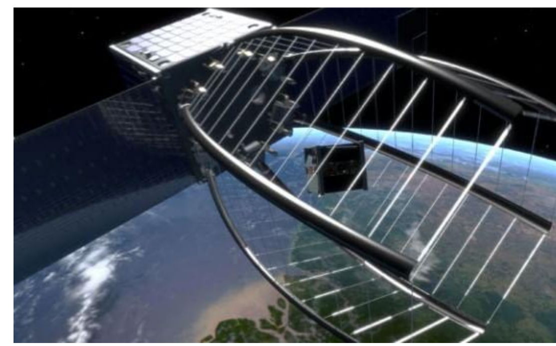
Clean Space One

Is it possible to remove Space debris?

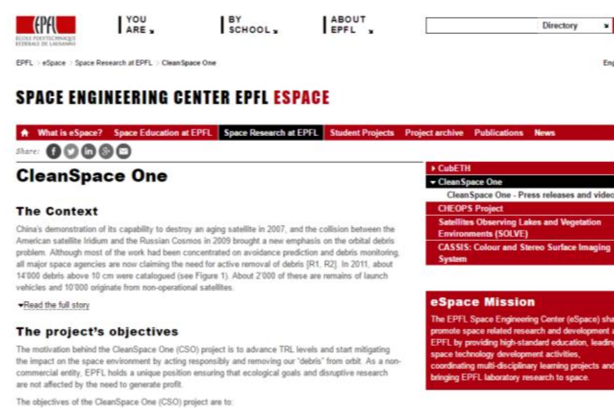








*By 2016 **(now 2018)**, Switzerland plans to launch a "janitor satellite" to start fighting the space junk problem directly while the rest of us keep twiddling our thumbs. CleanSpace One is, as far as we know, the first purpose-built spacecraft designed from the ground up to tackle the space junk **(size?)** problem directly.*
Costing just under $11 million, it's simple, cheap, and hopefully, it'll be effective.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CleanSpace One

The Context

China's demonstration of its capability to destroy an aging satellite in 2007, and the collision between the American satellite Iridium and the Russian Cosmos in 2009 brought a new emphasis on the orbital debris problem. Although most of the work had been concentrated on avoidance prediction and debris monitoring, all major space agencies are now claiming the need for active removal of debris [R1, R2]. In 2011, about 14'000 debris above 10 cm were catalogued (see Figure 1). About 2'000 of these are remains of launch vehicles and 10'000 originate from non-operational satellites.

Read the full story

The project's objectives

The motivation behind the CleanSpace One (CSO) project is to advance TRL levels and start mitigating the impact on the space environment by acting responsibly and removing our "debris" from orbit. As a non-commercial entity, EPFL holds a unique position ensuring that ecological goals and disruptive research are not affected by the need to generate profit.

The objectives of the CleanSpace One (CSO) project are to:

CubETH
CleanSpace One
CleanSpace One - Press releases and videos
CHEOPS Project
Satellites Observing Lakes and Vegetation Environments (SOLVE)
CASSIS: Colour and Stereo Surface Imaging System

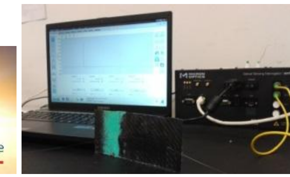
eSpace Mission

The EPFL Space Engineering Center (eSpace) shall promote space related research and development at EPFL by providing high-standard education, leading space technology development activities, coordinating multi-disciplinary learning projects and bringing EPFL laboratory research to space.

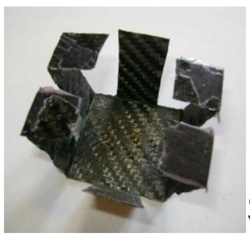
New scenario

- Is it possible to clean or to make safe a single orbit?
- Is it feasible launching rockets for grabbing small debris?
- From the manufacturing point of view…
- … integrated processes, raw materials, tolerances, costs

CIRA Italian Aerospace Research Centre



SMPC LIPI



SMP actuator

Foaming

esa space solutions

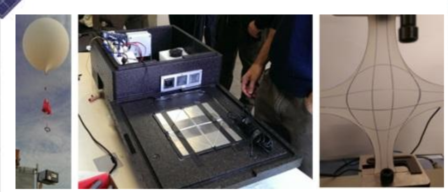
asi agenzia spaziale italiana

KetClab **Sensoring**

Key Enabling Technology Lab - A.Ma.L.A. - Advanced Materials Laboratory for Aerospace

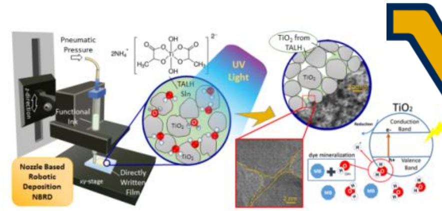
Additive manufacturing

In Space Manufacturing



Università di Roma Tor Vergata DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Shielding materials



Printed electronics

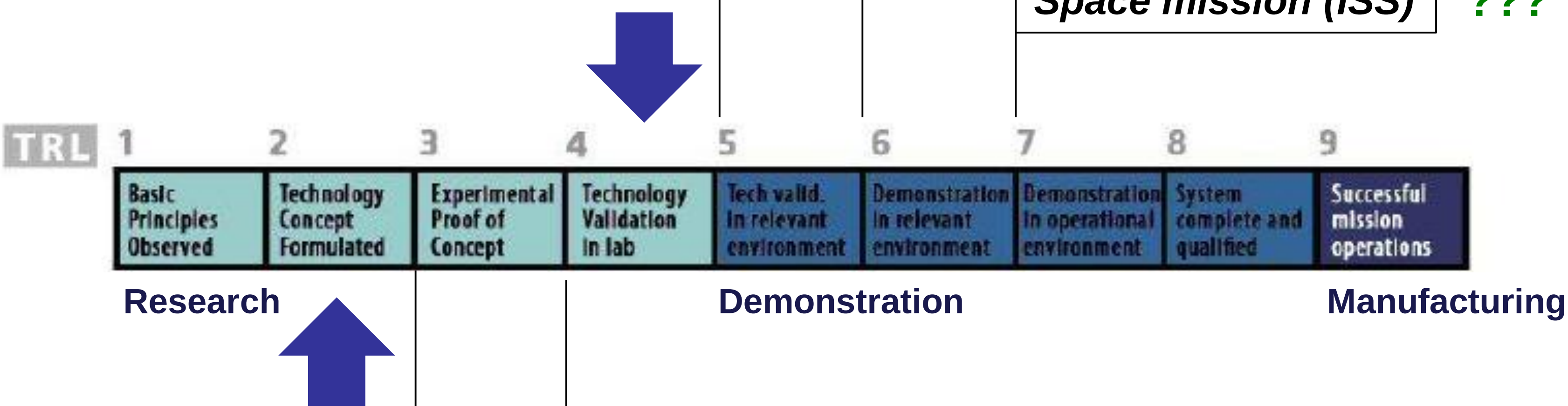
The future of the research

Grabbing systems by SMPC

Full sensor integration
Heating integration
Correct shape evolution
1 year, 250 k€

Parabolic flights
Testing chamber
1 year, 100 k€ + ???

Space mission (ISS) **???**



Small factory on the Earth **???**

Possible design of grabbing systems
Material-energy flowchart
First architecture of a Space-factory
6 months, 100 k€

***In-Space manufacturing* ????**

Conclusions

Sustainability seems a simple concept but the implementation strongly depends on the field, and economical, social, industrial aspects should be examined

I have proposed a challenging idea of the in-space manufacturing interesting for debris capture but also in the optic of planets colonization (Mars and other) for future scenarios

UN and all the Space Agencies together could promote and develop such a small but challenging laboratory as a first example of in-space manufacturing laboratory. This could be useful for all the countries involved in space activity.

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