Experiment Units
to investigate biological systems
for Space Life Sciences

5th workshop of the Italian Astrobiology Society
«Life in a cosmic contest»
Trieste, 15-17 September 2015

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Agenda

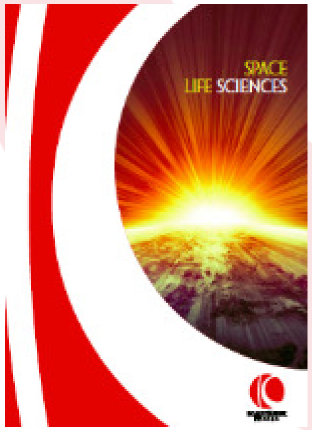
- **Kayser Italia in pills;**
- Introduction to a space experiment;
- Experiment Hardware for Life Sciences.

Kayser Italia in pills

•Kayser Italia is a private System Engineering company. KI has its core business into the space industry;

•In the last twenty-five years, Kayser Italia has participated to **63** space missions with **97** payloads developed both as prime- or sub-contractor to many ESA and ASI programs;

•A multidisciplinary staff of 50 highly specialised engineers and scientists, with expertise in electronics, aeronautics, mechanics, thermodynamics, physics, computer science, optics, chemistry, cell and molecular biology.

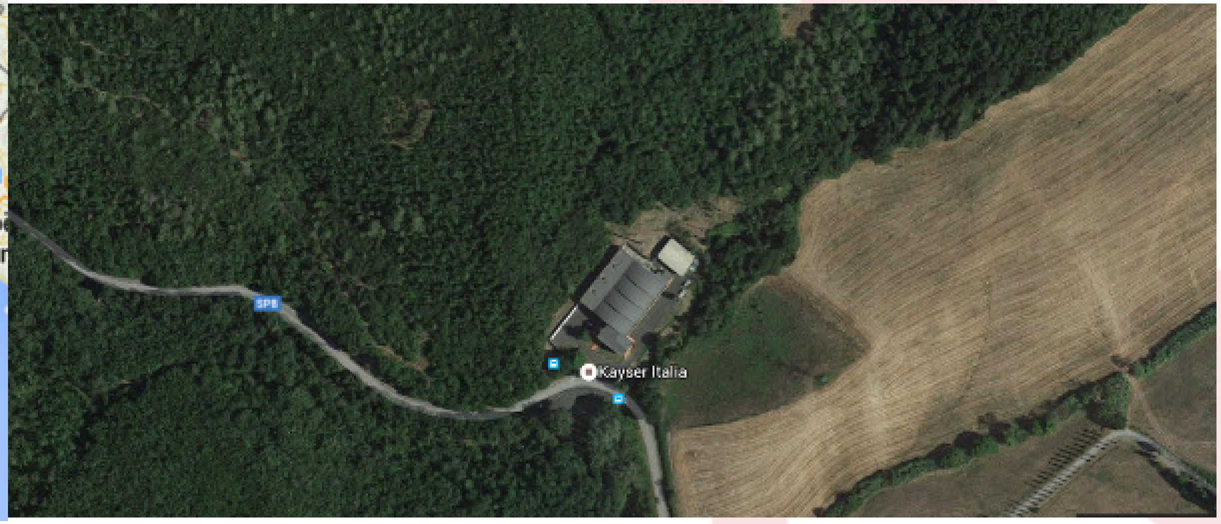


References: www.kayser.it

Download Kayser catalogue at http://www.kayser.it/index.php/catalog

Kayser Italia in pills

Located in the south area of Livorno, the company has 5,000 sq. meters of property, organized into offices, meeting rooms, conference room, laboratories, clean room, manufacturing, inspection and integration area, and an User Support Operation centre to support operation on-board ISS.



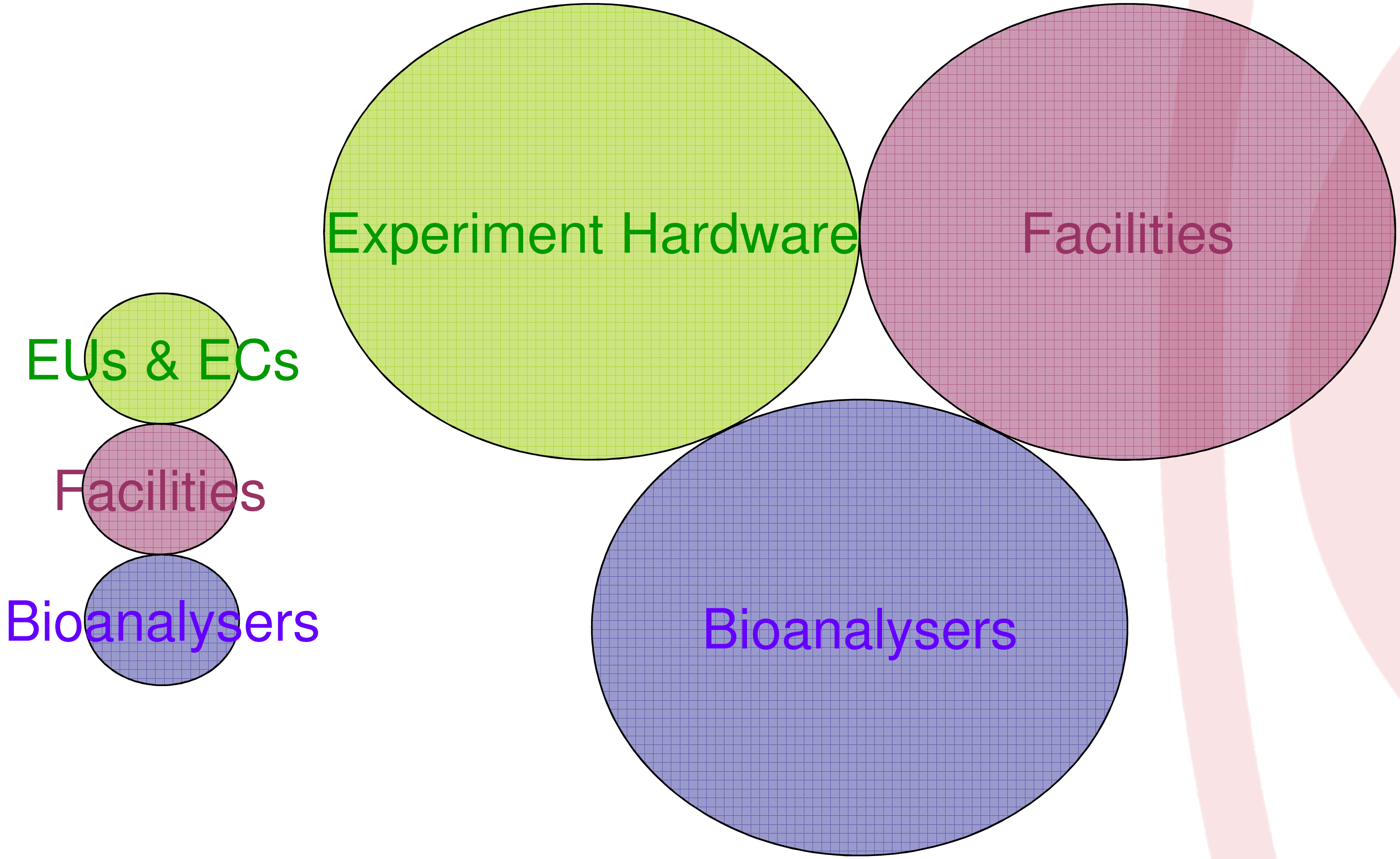
Kayser Italia in pills

The payloads developed by Kayser were flown on:

- the International Space Station (ISS);
- the Chinese Shenzhou spaceship (神舟).
- the Shuttle Transportation System (STS) and Space X Dragon capsule
- the Japanese module (HTV);
- the European module (ATV);
- the Russian capsules (Бион, Фотон, Союз, Прогресс)

Kayser Italia in pills

KI main activities in the field of Space Life Sciences:



Agenda

- Who is Kayser Italy;
- **Introduction to a space experiment;**
- Experiment Hardware for Life Sciences.

Introduction to a “space experiment”

What is new in a space experiment?
Nothing but practise

1- How **is an experiment to be conducted**
2- What **equipment to conduct that experiment**

Introduction to a "space experiment"

TEAM PLAYERS:

Space agency

Scientific investigator

Input

Scientific idea

Industrial partner

Output

Experiment Hardware development

Experiment
Scientific Requirements

Introduction to a “space experiment”

In the frame of ESA projects requirements are collected into a dedicated document: the Experiment Scientific Requirements doc, ESR.

Reference: ESA-HSF-ESR-SPHINX
Issue 2, Rev. 0
Date: 3rd May 2010

Table of contents

Introduction to a “space experiment”

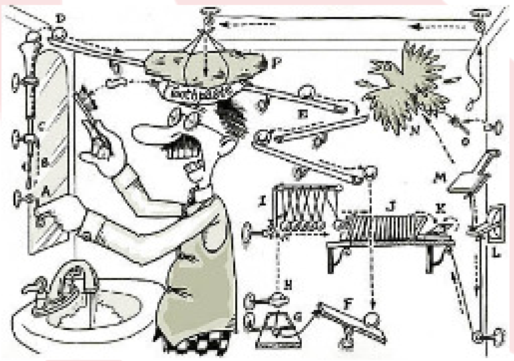
Requirements analysis (RA)

- Collection of experiment requirements
- Evaluation and impact of experiment requirements

RA is a delicate and crucial step;
RA does requires iteration;
RA has a dramatic impact on the project success;

TIP 1: PI has to present the scientific idea in the clearest way, focusing on experiment requirements rather then technological solution

TIP 2: follow the “keep it simple” approach



Introduction to a “space experiment”

Design and development of Experiment Hardware

- Basically, HW design, development and manufacturing is a responsibility of the Developer, i.e. the industrial partner;
- Requirements must be fulfilled by Design. Experiment Hardware design is driven by the Experiment Scientific Requirements (ESR);
- The Experiment Hardware will be tested by the PI during the EST campaign, namely a simulation of the experiment to be performed in space.

Agenda

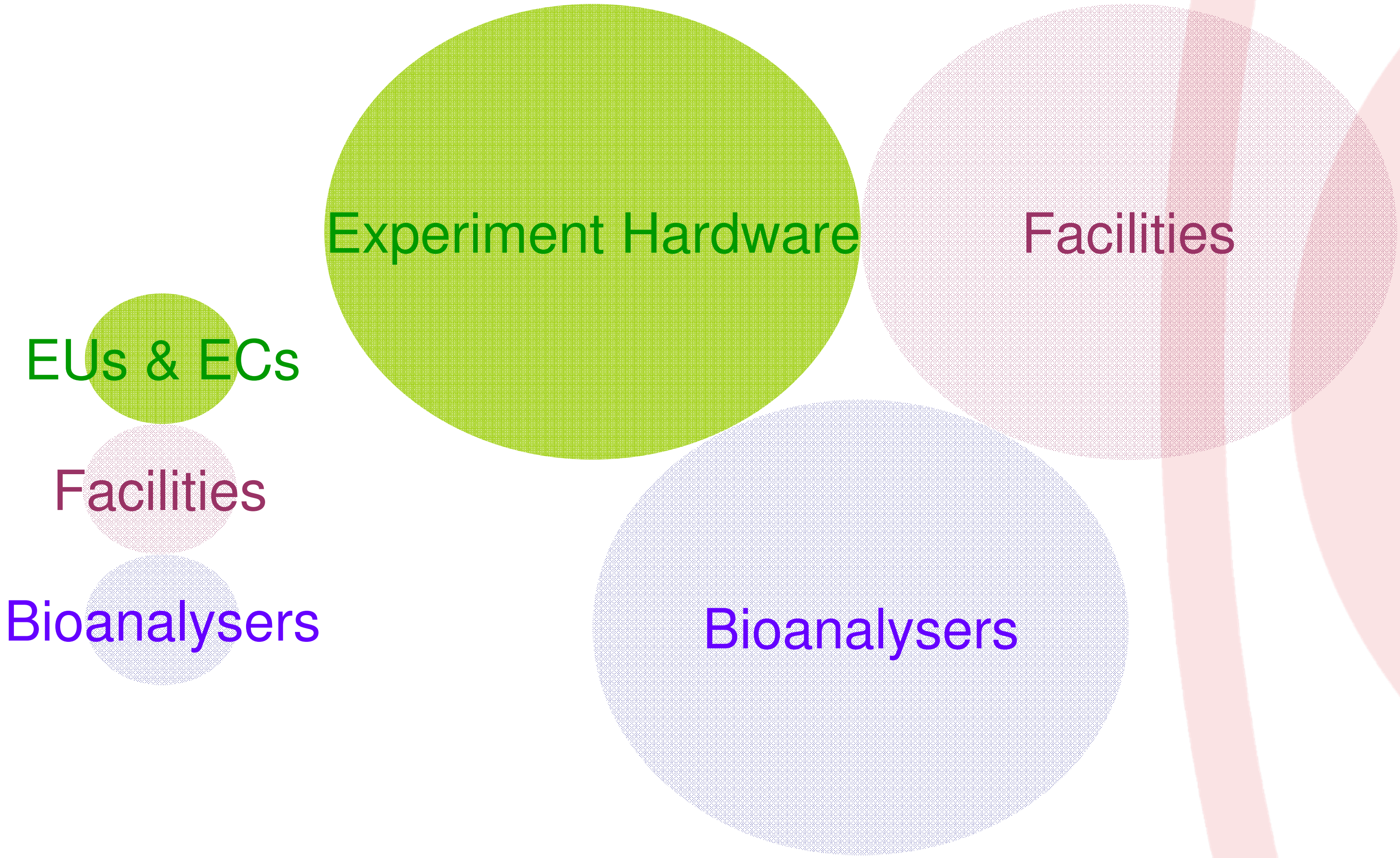
•Who is Kayser Italy;

•Introduction to a space experiment;

•**Experiment Hardware for Life Sciences.**

Experiment Hardware for Life Sciences

Experiment Units and Experiment Containers



Experiment Hardware for Life Sciences

Life science experiments in space are conducted in order to study:

- the changes induced by the Space environment on biological systems;
- the possibility of life (and precursors).

We are looking to the possibility of surviving in hostile environment and countermeasures to be adopted (calcium loss, plant growth, genetic modifications…)

Cosmic radiation, electromagnetic fields, temperature, pressure, and gravity level deeply affect the organic life.

Experiment Hardware for Life Sciences

EUs & ECs Experiment Units and Experiment Containers

The EXPERIMENT UNITS:

The EU reduces a laboratory into a hand-sized electromechanical device which allow the autonomous execution of a scientific protocol on-board;

The EU is designed to provide all the chemicals required by the experiment;

The experiment is autonomously performed and electrically controlled by a timeline on the microcontroller;

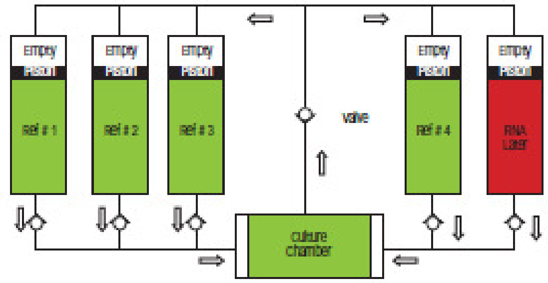
Housekeeping data are recorded during the mission and downloaded at re-entry.

The EXPERIMENT CONTAINERS:

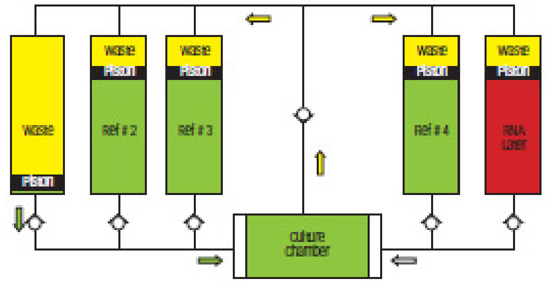
The EC complement the EUs making possible to interface them with the incubator, providing electrical power, data transfer interfaces and additional containment for the chemicals.

Experiment Units protocol execution

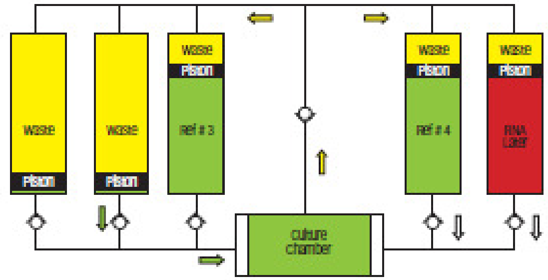
EU summary:
No. of fluidic systems: 1
• Fluidic system:
- actuators: 5
- plungers: 5
- reservoirs: 5
- culture chambers: 1
• Size: 80X39X19 mm
• Weight: 104 g



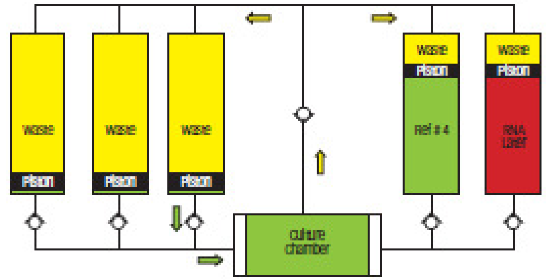
Pre-flight stand by



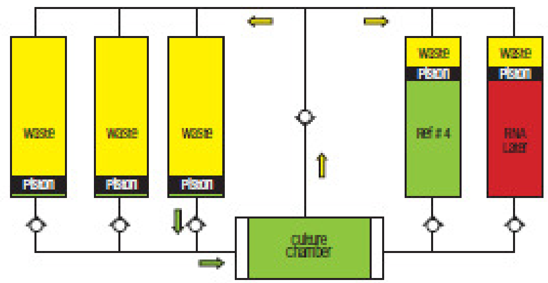
Stage 1: First Medium re-fresh



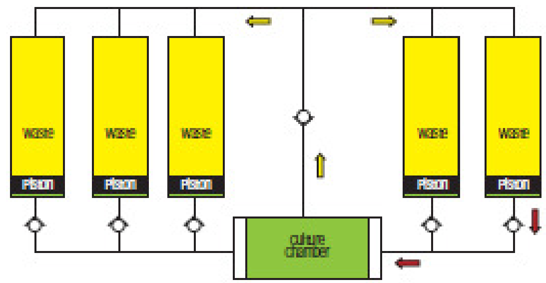
Stage 2: Second Medium re-fresh



Stage 3: Third Medium re-fresh

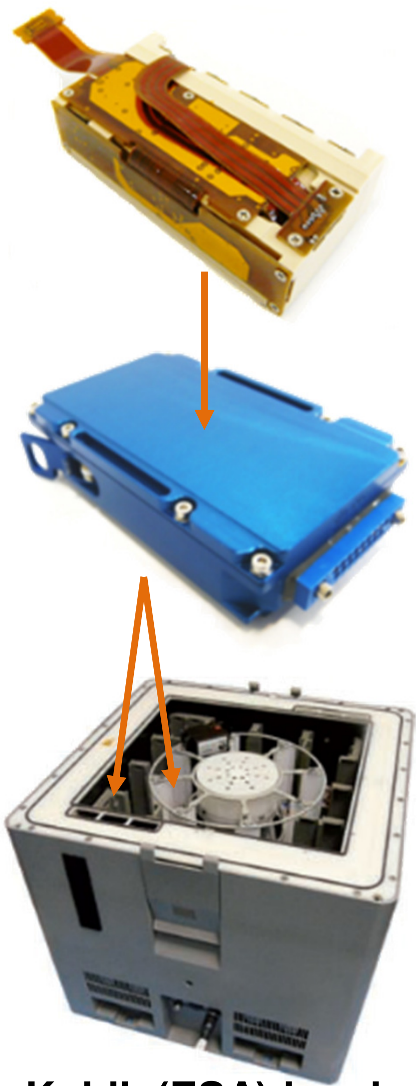


Stage 4: Fixation

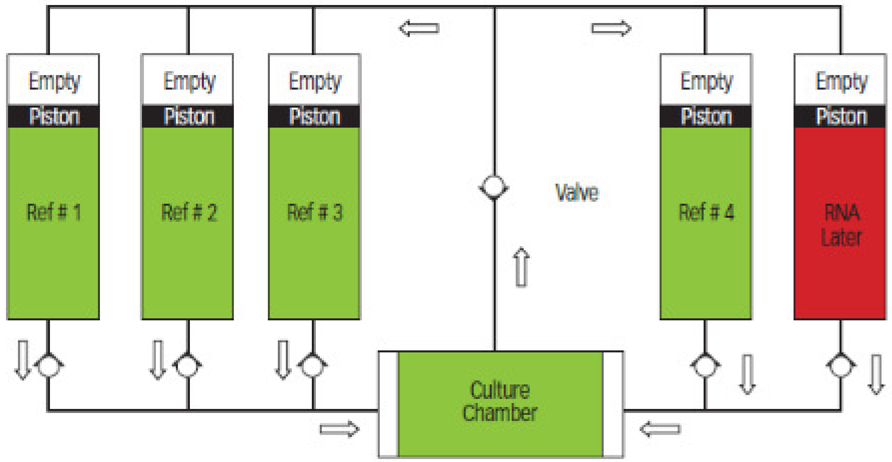


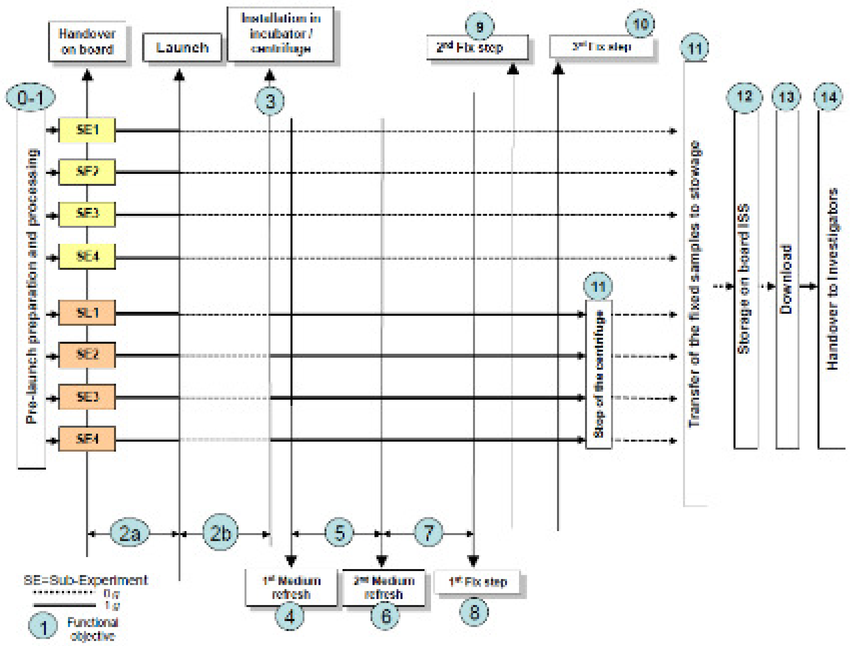
Experiment end. Stowage.

Experiment Units protocol execution



Kubik (ESA) incubator on-board ISS





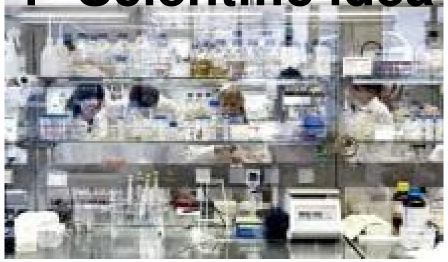
Experiment Hardware for Life Sciences

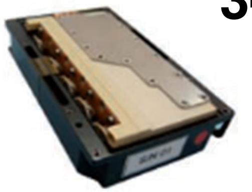
Experiment Life Cycle

1- Experiment Hardware development

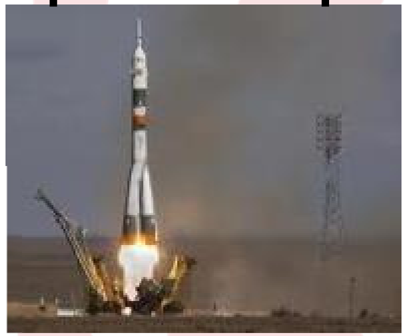
2- Experiment Integration (EST)

1- Scientific idea





3- Experiment upload



6- Experiment analyses

5- Experiment download

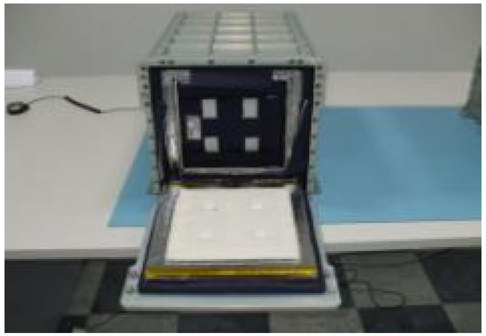
4- Experiment execution, incubation, and storage

Experiment Hardware for Life Sciences

Each step of the Experiment Cycle represents an opportunity for a space company to business

ECCO (ESA) Temperature controlled containers

Features: Set of containers for passive transportation (in the range of -25°C to + 40°C) of biological material to/from ISS at controlled temperature. Can be transported using SpaceX, Soyuz, Progress, HTV, ATV.



Typical ECCO Performances

Outer temperature 28°C

EC temperature within the range 2° .. 10°C for 5 days and 4 hours

Temperate slowly increases

10,4° after 5,5 days

11,0 after 5 days and 20 hours (end of data collection)

ECCO Transport Capabilities

ECCO: 4 Biolab EC 2 Kg each (STS)

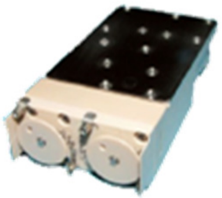
ECCO-b: 9 KIC or up to 1.5 Kg experiments (STS/Soyuz/Progress/HTV/ATV)

Experiment Hardware for Life Sciences

Mission support for experiment integration at the launch site

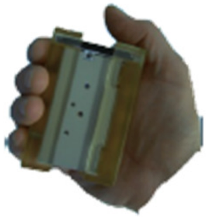
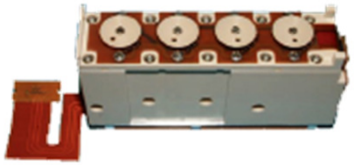
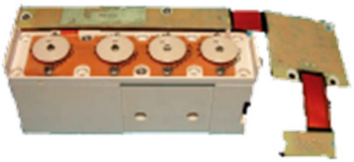
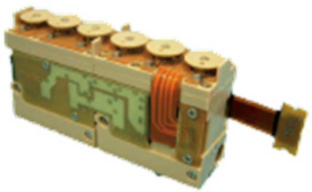
- Cape Canaveral, USA
- Bajkonur cosmodrome, Kazakistan
- …

Experiment Hardware for Life Sciences

EXPERIMENT UNIT	NAME	SAMPLE	EXPERIMENT
	STROMA	2D BMSCs Cell culture	Stroma 2003, Stroma2 2006, PITS 2007, MYO 2007, Sphinx 2010, SCD NATO, CYTO, ENDO 2015
	OCLAST	2D Osteoclast Cell culture	Oclast 2003 Oclast 2007
	PHOTO	2D Chlamnidomonas r. Cell culture	PHOTO-I 2002 PHOTO-II 2005 Photo-Evolution 2011
	AT-SPACE	Arabidopsis seeds	AT-SPACE 2007 ArabidopS-ISS 2011

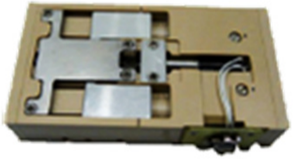
Kayser Italia Experiment Units

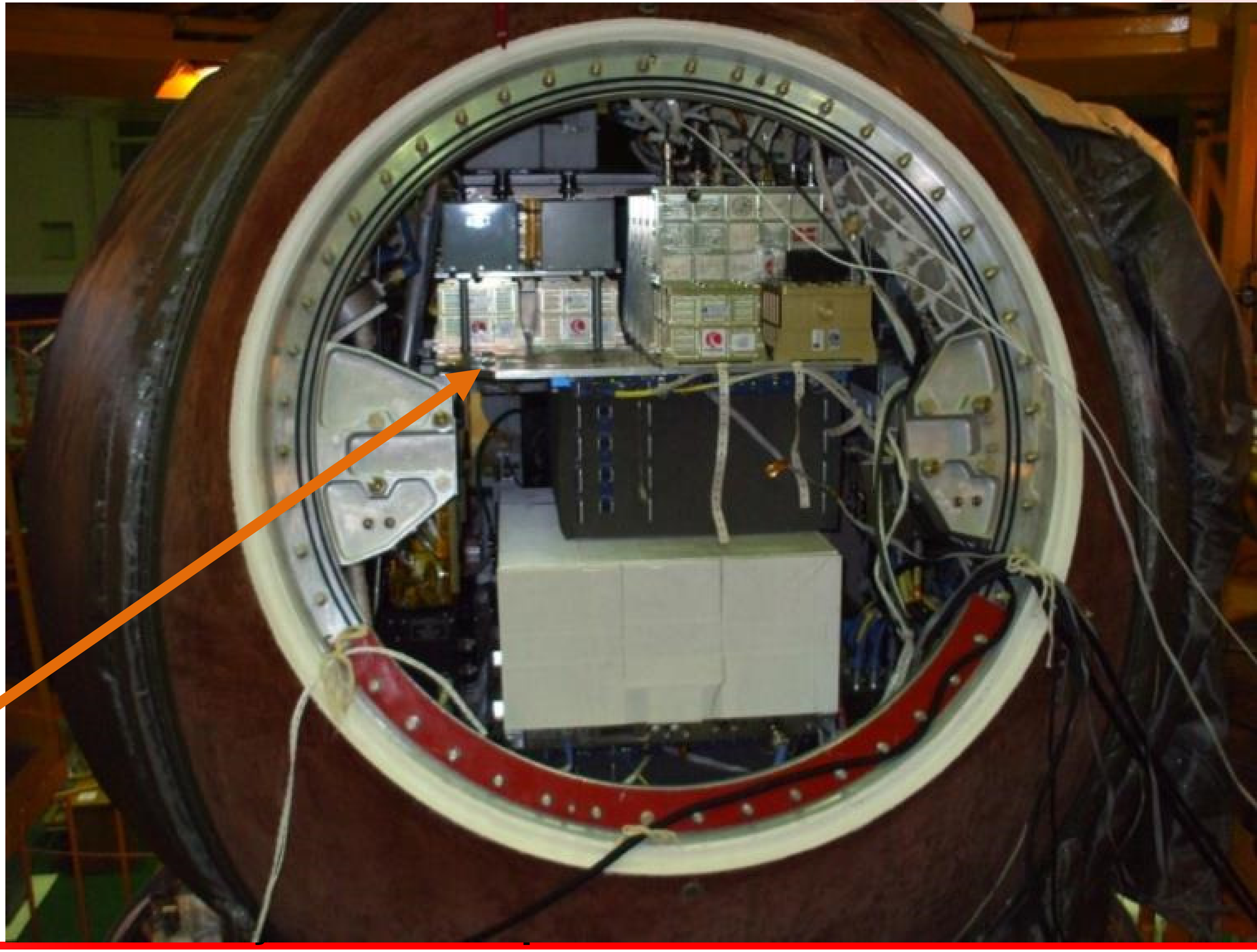
Experiment Hardware for Life Sciences

	BIOKIN-4	Aerobic 3D bacteria Cell culture	BIOKIN-4 2007
	P-Kinase	3D Monocytes Cell culture	P-Kinase 2007 BioS-SPORE 2011 NIH-1a 2014
	BASE-B	3D Anaerobic Bacteria Cell culture	BASE-B 2008
	BASE-C	3D Aerobic Bacteria Cell culture	BASE-C 2008
	ROALD	3D T-lymphocytes Cell culture	ROALD 2008 RESLEM 2011
	XENOPUS	Xenopus laevis aquaria	XENOPUS 2008

Kayser Italia Experiment Units

Experiment Hardware for Life Sciences

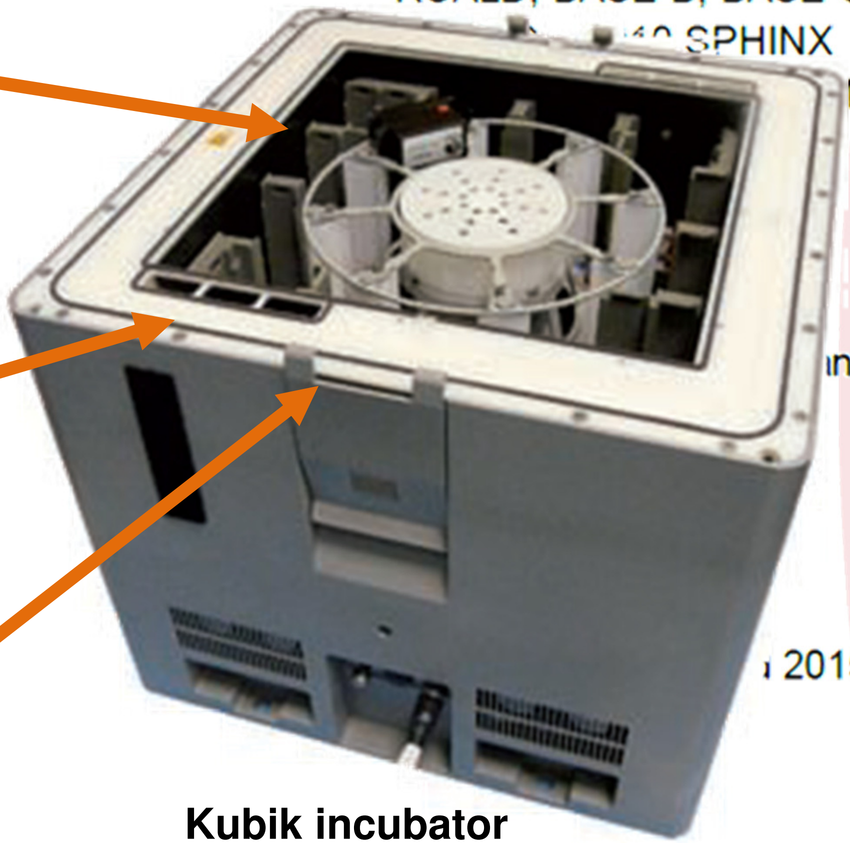




Experiment Hardware for Life Sciences

EXPERIMENT CONTAINER	NAME	EXPERIMENT

ROALD, BASE B, BASE C 2008,
SPHINX 2010,
2011,
2015



nned

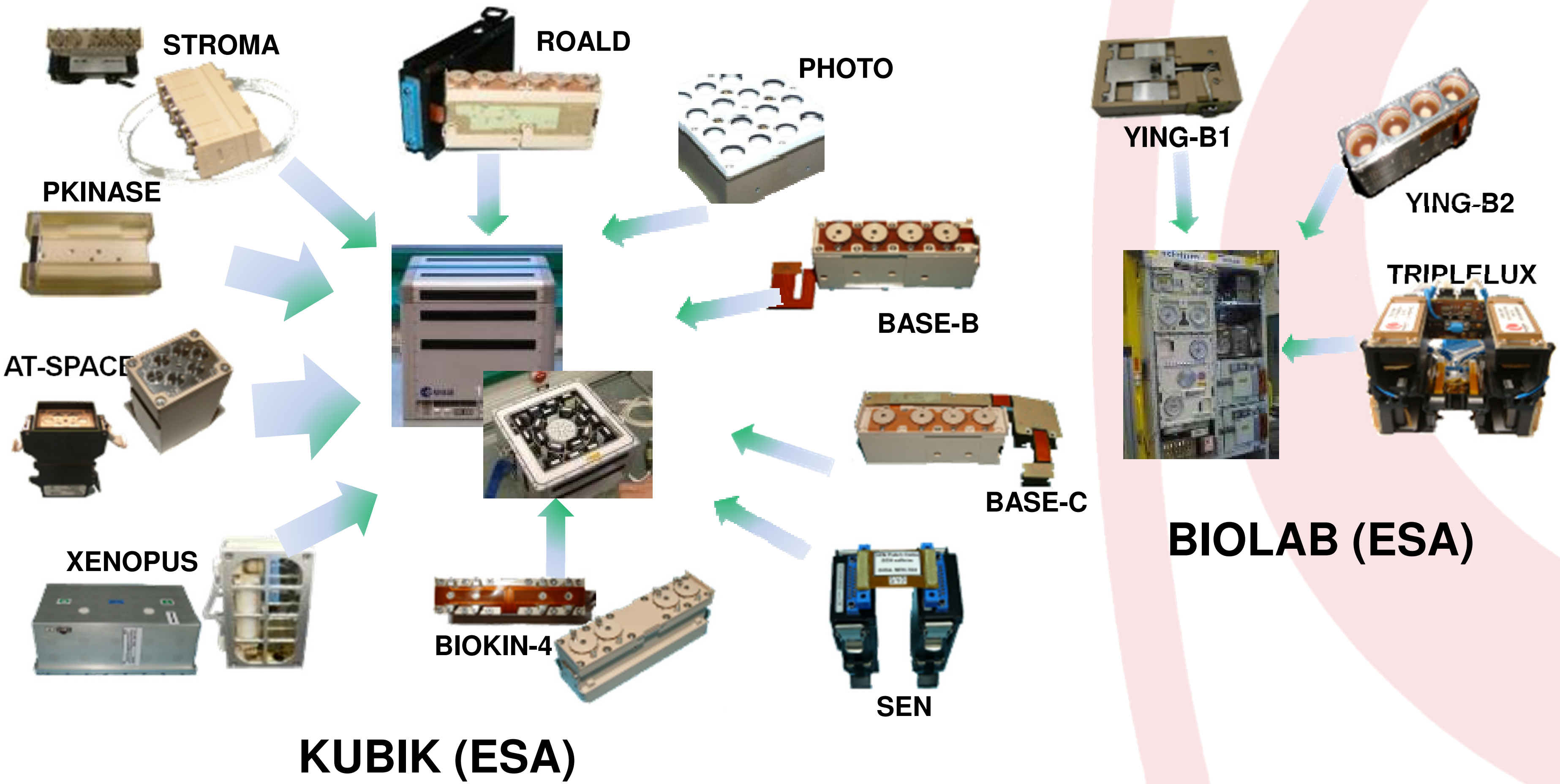
2015

Kubik incubator

Kayser Italia Experiment Containers

Experiment Hardware for Life Sciences

EUs for Kubik and Biolab incubator facilities. Thirteen different EUs were developed, all of them flown, some EUs flown a few times



Experiment Hardware for Life Sciences


Kayser Italia hardware for radiation and microgravity experiments in space

Marco Vukich, Alessandro Donati & Valfredo Zolesi

Review on Kayser Italia HW

Rend. Fis. Acc. Lincei (2014) 25 (Suppl 1):S7–S11

DOI 10.1007/s12210-013-0261-1


BIOKIS: A Model Payload for Multidisciplinary Experiments in Microgravity

Marco Vukich, Pier Luigi Ganga, Duccio Cavalieri, Lisa Rizzetto, Damariz Rivero, Susanna Pollastri, Sergio Mugnai, Stefano Mancuso, et al.

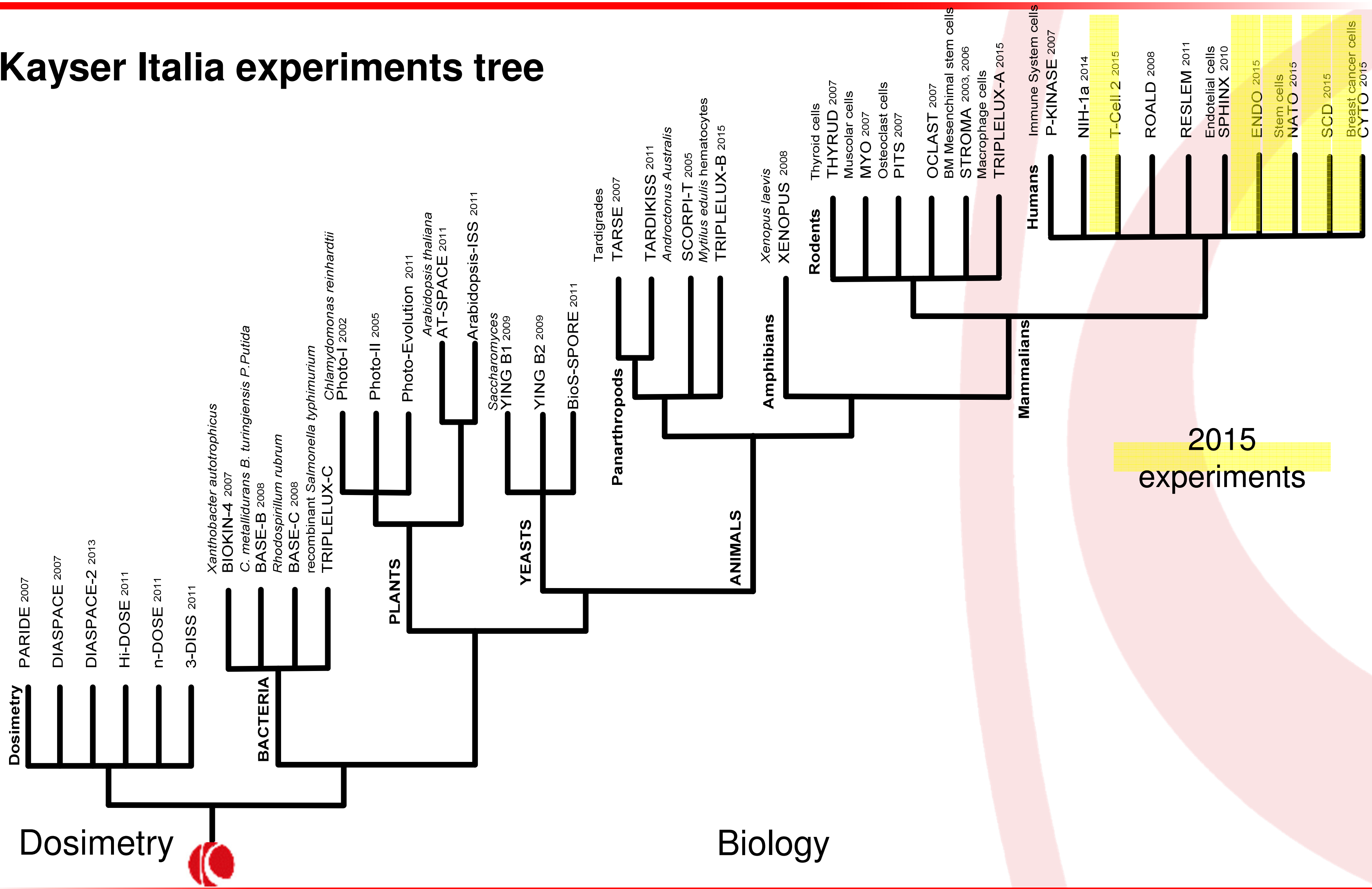
Example of multidisciplinary mission on-board 2011 Endeavour Shuttle

Microgravity Sci. Technol.

DOI 10.1007/s12217-012-9309-6

Experiment Hardware for Life Sciences

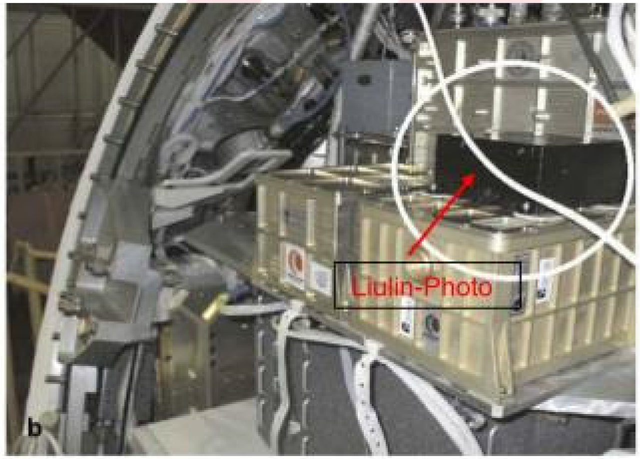
Kayser Italia experiments tree

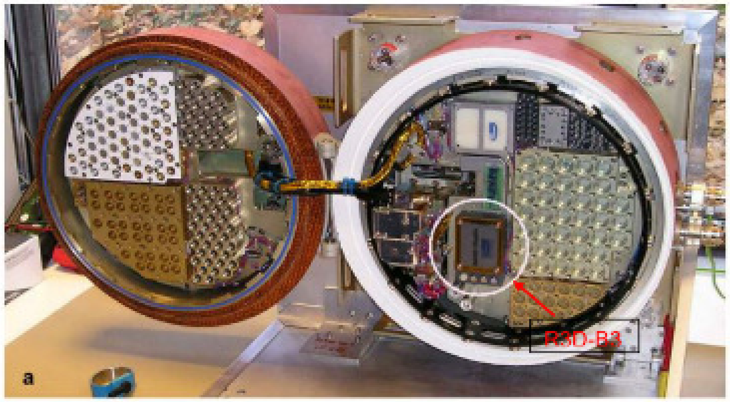


Experiment Hardware for Life Sciences

The insertion of dosimeters into the EC, could allow ground testing with irradiation facilities, adding another important experimental factor for comparison.

R3D-B2 instrument was a LIULIN-type dosimeter situated inside the ESA Biopan-5 platform to measure radiation dose and flux outside the Foton M2 capsule.





Experiment Hardware for Life Sciences

The Matroshka Facility (ESA) was installed for one year outside the ISS Russian segment.
Matroshka measures the radiation dose at different depths in a human mannequin during an exposure to the environmental conditions outside and inside the International Space Station. Sensors within the mannequin measure radiation doses at organ sites such as stomach, lungs, kidney, colon and eyes. Active sensors measure different radiation levels on a real time basis, while after exposure passive sensors can be removed from the phantom for analysis after their return to Earth.

Kayser Italia was responsible for the development of the Matroshka Facility control electronics, flight software and EGSE.

Sampling Units

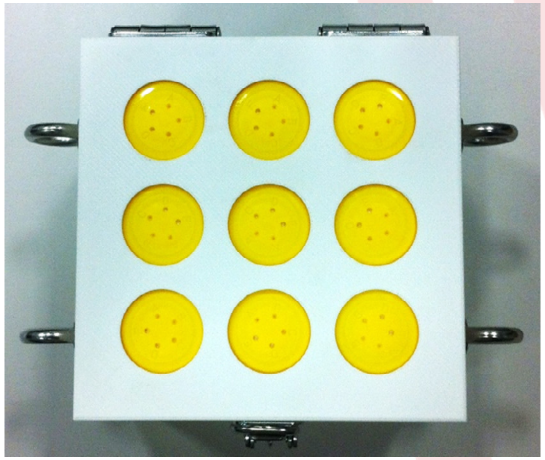
In the frame of the ECMB project (Esobiologia e ambienti estremi: dalla Chimica delle Molecole alla Biologia degli estremofili) KI designed and developed the KI-SSC (Solfatara Sampling Container) to collect the extremophile specimens from the Solfatara Pisciarelli and to make experiments on *Sulfolobus solfataricus*, an *Archea* species, ubiquitous into the «solfatara».

ECMB team:
Institute of Biosciences and Bioresources-CNR (IBBR-CNR) of Napoli

University of Tuscia

University La Sapienza

Kayser Italia



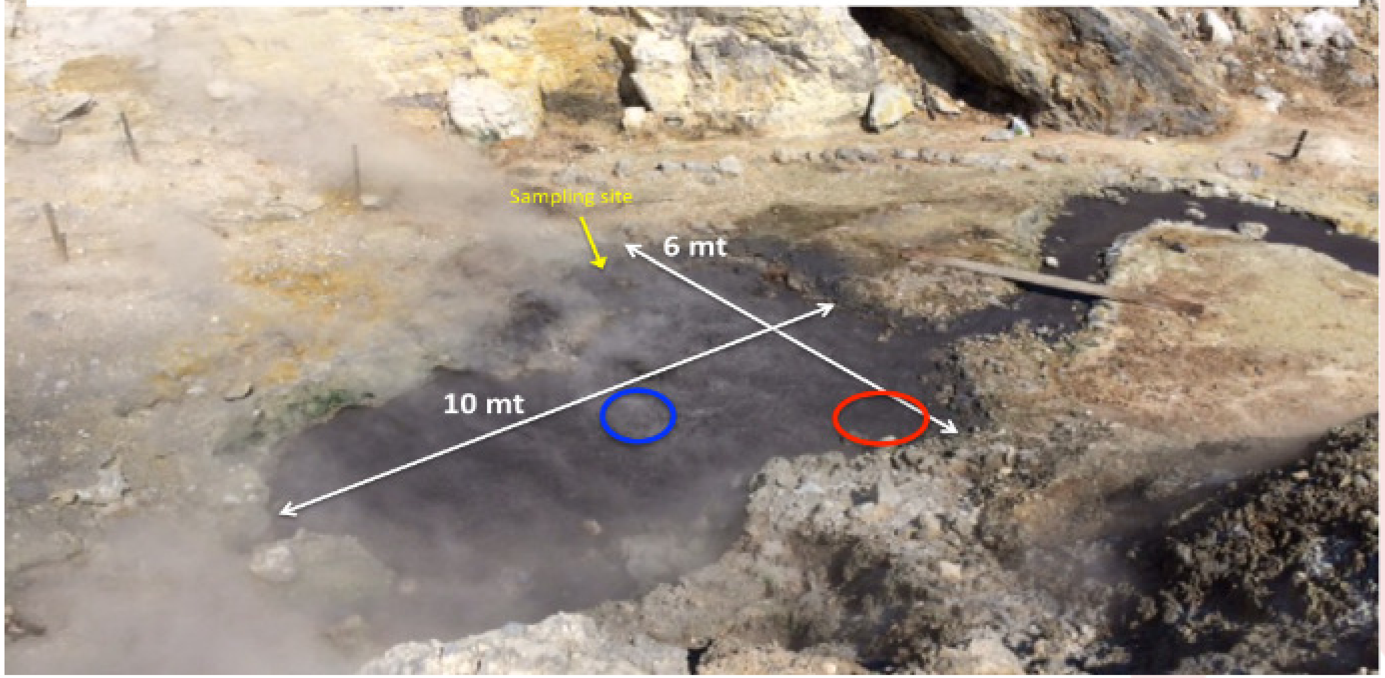
KI-SSC

Sampling Container

Solfatara Pisciarelli is a shallow volcanic crater at Pozzuoli, a dormant volcano, which still emits jets of steam with sulfurous fumes.

Pond with bubbling water, depth 70-80cm

Putative anchoring point for water sampling



Water parameters during sampling

- Temperature ~ 85°C
- pH ~ 2,5

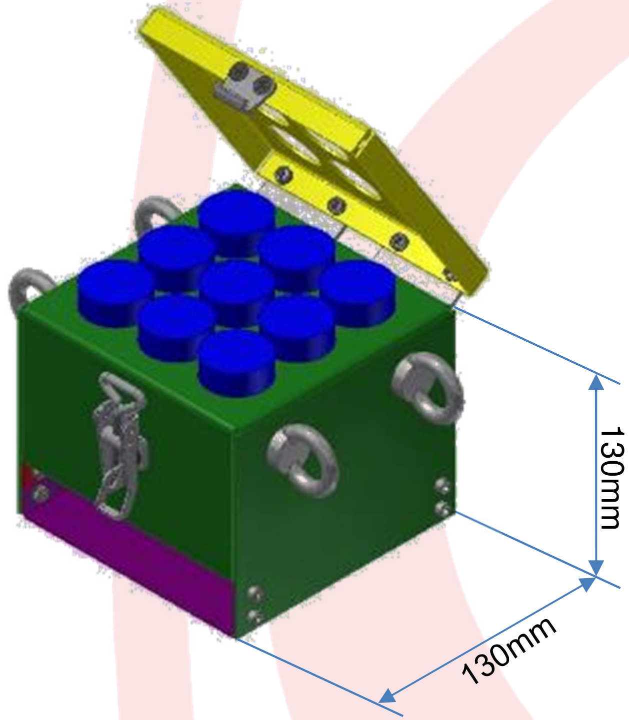
Sampling Container

KI-SSC features:

KI-SSC will be entirely manufactured by AISI 316 stainless steel

Resistance to high temperature and low pH

KI-SSC will host 9 conical centrifuge tubes



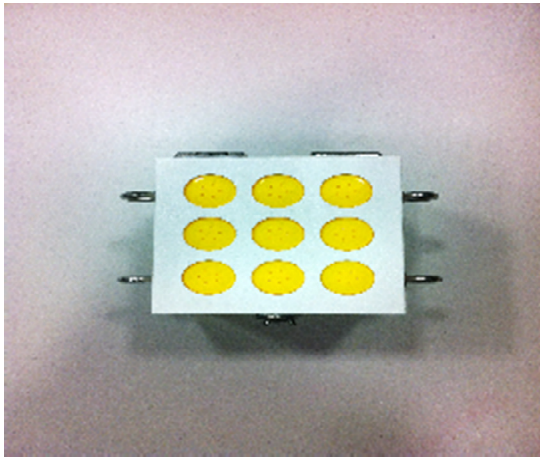
KI-SSC allows accurate sampling:

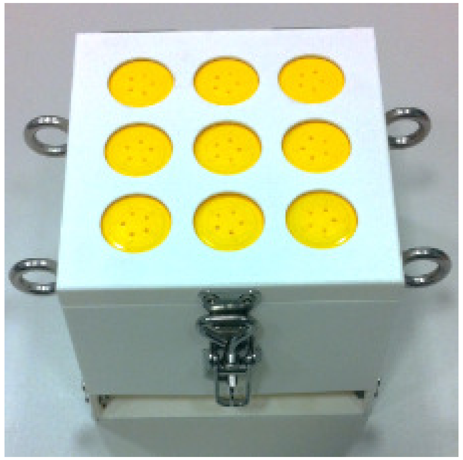
- Statistically significant amount of sampling;
- Repeatable sampling.

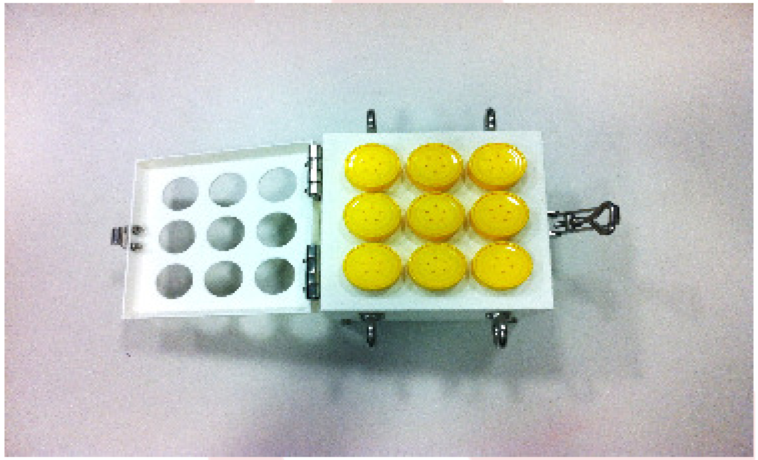
Sampling Units

50 ml vented centrifuge tubes made of polypropylene

3D printed prototype of KI-SSC







Sampling Hardware for Life Sciences

Sampling

- *Fundamental step for a scientific investigation;*
- *Reliable;*
- *Repeatible;*
- *Statistically significant;*

It requires specific equipment which is dependent by:

The specimen kind (Biological sample, Chemical sample, Geological sample);
The media/substrate where the sample is (chemical composition of the media);
The operational environment;
The geography (distance from power resources, etc…);
etc

Sampling Hardware for Life Sciences

Thus sampling campaigns (missions) can require a dedicated design, development and manufacturing of sampling equipment.

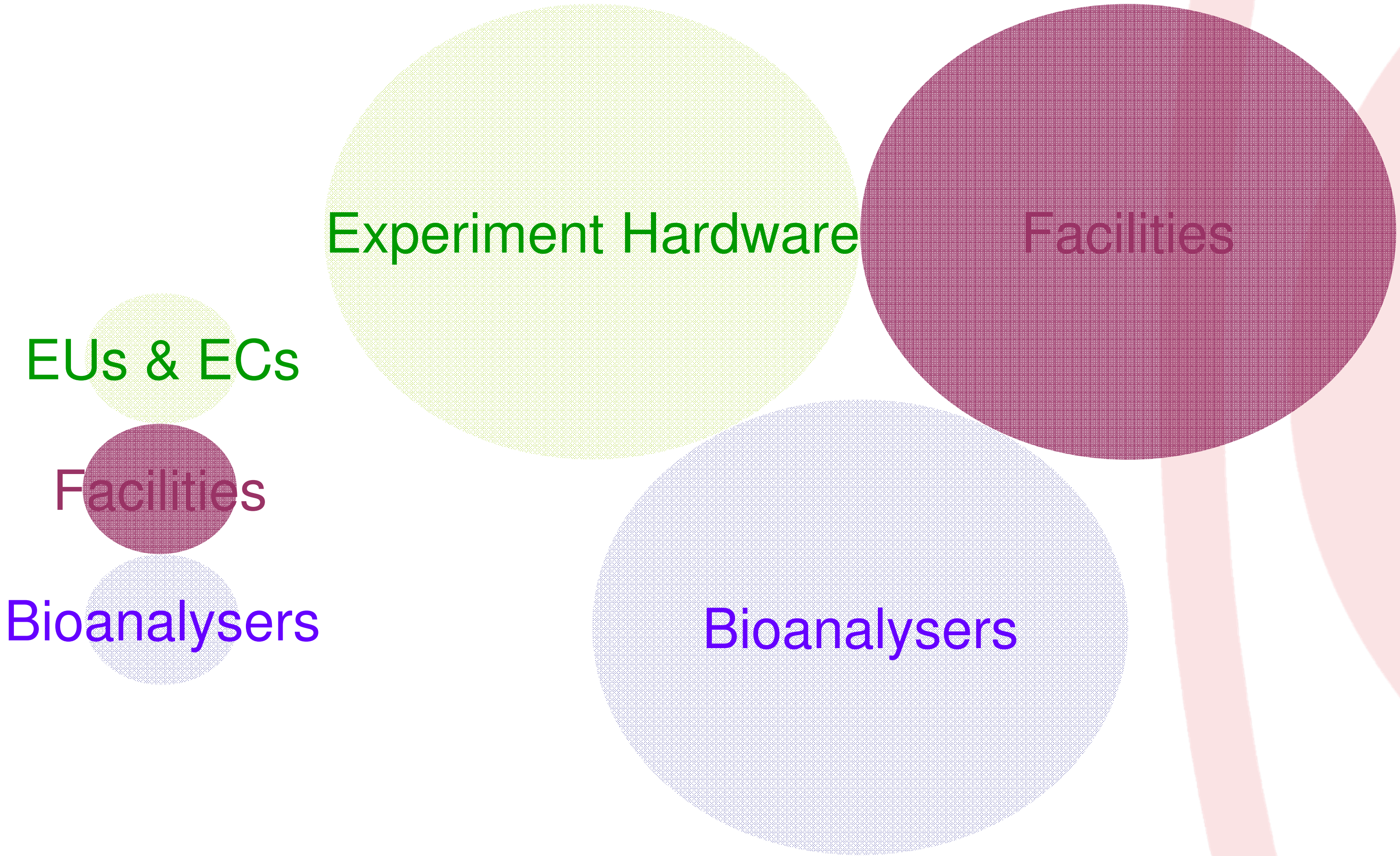
Particularly, a first engineering effort will be the selection of materials to be used into the manufacturing of the equipment:

- Resistance to environmental conditions;
- Level of containment;
- Chemically inert;

Especially for extreme environments…

Kayser Italia Space Life Sciences

KI main activities in the field of Space Life Sciences:

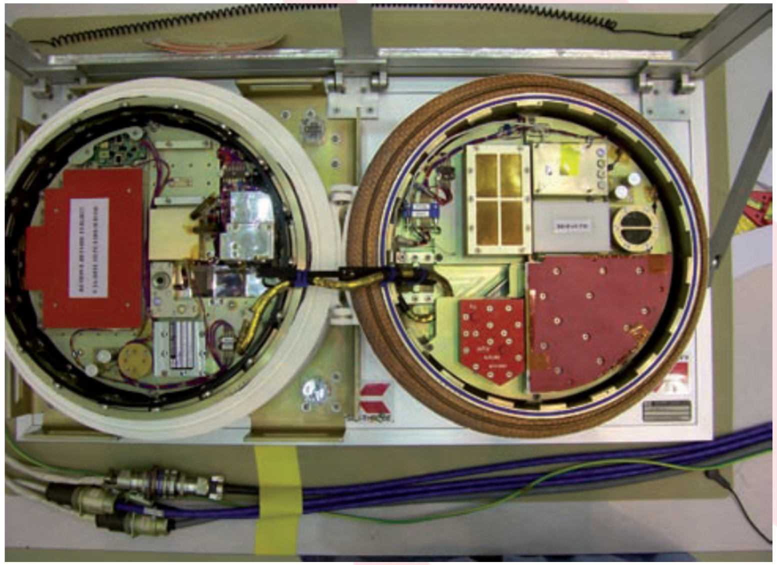


BIOPAN Facility (ESA)

BIOPAN was developed in the early nineties as a multi-user experimental facility, designed to investigate the effect of the space environment on biological material as well as for carrying out material science investigations requiring exposure to the space environment.

As such the experiments in BIOPAN are exposed to solar and space radiation, the space vacuum and weightlessness, or a selection thereof.

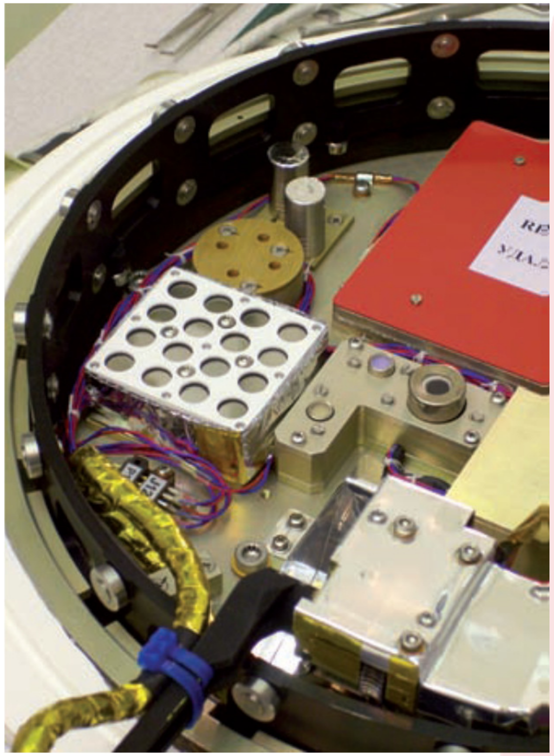
Kayser Italia was responsible for the development of Biopan electronics: signal acquisition board, microcontroller board, flight software, memory board and EGSE.



BIOPAN missions: Foton-8 in 1992 (QF); Foton-9 in 1994, Foton-11 in 1997, Foton-12 in 1999, Foton-M1 in 2002, Foton-M2 in 2005, Foton-M3 in 2007.

BIOPAN Facility (ESA)

PHOTO-I is placed in the bottom tray of the BIOPAN facility. Directly exposed to the harsh space environment conditions throughout the entire flight.
The PHOTO-I facility is a biological container provided of 16 culture chambers, where the photosynthetic organisms are located, immobilized in nutrients. The natural light to which the device is exposed on orbit is filtered (only visible and UV radiation reach the organisms) and its intensity is reduced. This is performed by optical filters



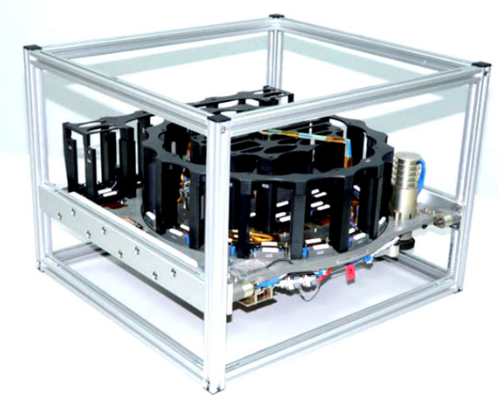
MISSIONS

FOTON-M1 PHOTO-I launched in the ESA BIOPAN facility on October 15th, 2002.

FOTON-M2 PHOTO-I launched in the ESA BIOPAN facility on May 31st, 2005, return to ground June 16th, 2005.

(5) BIOPAN is an ESA multi-user exposure facility, designed for exobiology, radiation biology, radiation dosimetry and material science investigations in space. The facility has been jointly developed by Kayser-Threde and Kayser Italia.

BIOBOX Facility (ESA)



Incubator facility for environmental control: Temperature; Atmosphere; Humidity, Stowage.

The BIOBOX incubator is a programmable space-qualified incubator for biology research in space. It offers a controlled thermal environment and it allows fully automatic execution of biological experiments, with no needs of commands during orbital flight.

All experiments are accommodated on the so called “Experiment Platform” that is a fully autonomous subsystem extractable from the incubator. That approach allows dealing with different mission scenarios, making possible a very late access to spacecraft integration a crucial aspect for biological experiments.

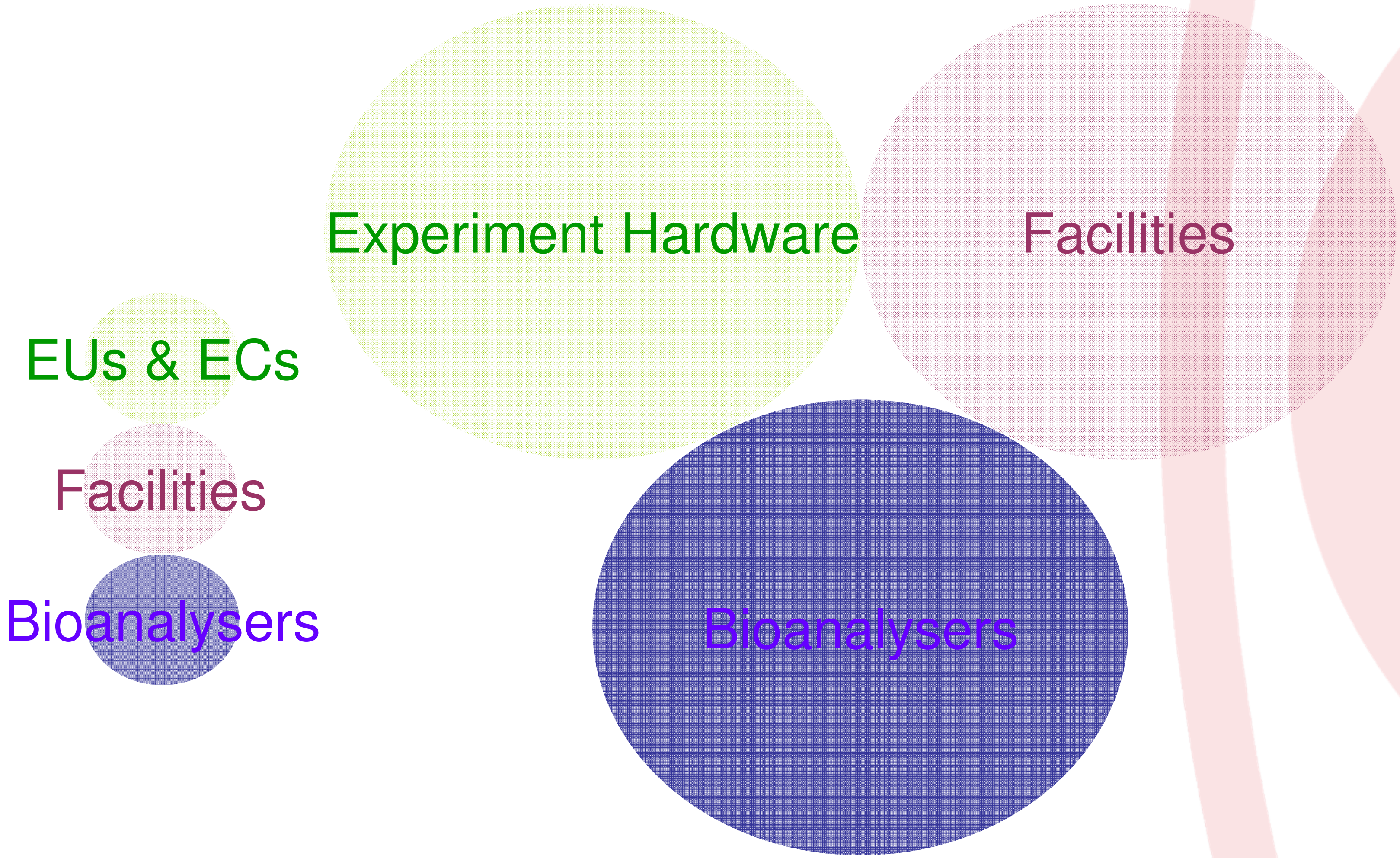
To rationalise the effects of weightlessness, an in-flight 1g centrifuge is installed into the BIOBOX, allowing for 1-g control experiments to be conducted on-board the spacecraft at the same time of samples exposed to the µ-g environment inside the incubator.

The BIOBOX was firstly developed in 1992 and since then it was flown on-board of Russian and Chinese unmanned capsules (FOTON-10 in 1995, FOTON-11 1997, FOTON-M3 2007, Shenzhou-8 2011) and the American manned shuttle (STS-95 in 1998).

Kayser Italia was responsible for the development of the Biobox electronics, between them: thermal assemblies, main control electronics with embedded display, mass memory.

Kayser Italia Space Life Sciences

KI main activities in the field of Space Life Sciences:



Bioanalysers

Bioanalysers

Bioanalysers: since 2009 KI was involved in three different ESA programs on bioanalysers for space activities .

- **MIDASS:** MIcrorganism Detection of Air Samples for Space by molecular biology. MIDASS targets nucleic acids (diagnostic) for environmental biomonitoring and planetary protection (clean room).
- **IBICA:** multipurpose platform for research and astronaut’s health monitoring. IBICA targets proteins (proteomics).
- **BioanalysISS:** multipurpose platform for research using gene expression analyses. BioanalysISS targets nucleic acids (genomics).
- **Bioanalysers concept relies on:**
  - **a disposable cartridge;**
  - **fluorescence measurement.**

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