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

Kayser Italia S.r.l.
Via di Popogna 501
57128 – Livorno (Italy)
www.kayser.it
kayser@kayser.it
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.
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:

- Experiment Hardware
- Facilities
- Bioanalysers
- EUs & ECs

15/17-Sep-2015 KI-MARK-HO-278
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:

Scientific investigator

Input

Scientific idea

Scientific requirements

Experiment

Space agency

Industrial partner

Output

Experiment Hardware development

15/17-Sep-2015
Introduction to a “space experiment”

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

EUs & ECs

Facilities

Bioanalysers

Bioanalysers

Facilities
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
Experiment Hardware for Life Sciences

Experiment Life Cycle

1- Scientific idea
2- Experiment Integration (EST)
3- Experiment upload
4- Experiment execution, incubation, and storage
5- Experiment download
6- Experiment analyses

19/17-Sep-2015 KI-MARK-HO-278
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 to 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, Kazakhstan
- ...
# Experiment Hardware for Life Sciences

<table>
<thead>
<tr>
<th>EXPERIMENT UNIT</th>
<th>NAME</th>
<th>SAMPLE</th>
<th>EXPERIMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OCLAST</td>
<td>2D Osteoclast</td>
<td>Oclast 2003, Oclast 2007</td>
</tr>
</tbody>
</table>

Kayser Italia Experiment Units
## Experiment Hardware for Life Sciences

<table>
<thead>
<tr>
<th>Experiment Unit</th>
<th>Description</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOKIN-4</td>
<td>Aerobic 3D bacteria Cell culture</td>
<td>BIOKIN-4 2007</td>
</tr>
<tr>
<td>P-Kinase</td>
<td>3D Monocytes Cell culture</td>
<td>P-Kinase 2007</td>
</tr>
<tr>
<td>BASE-B</td>
<td>3D Anaerobic Bacteria Cell culture</td>
<td>BioS-SPORE 2011</td>
</tr>
<tr>
<td>BASE-C</td>
<td>3D Aerobic Bacteria Cell culture</td>
<td>NIH-1a 2014</td>
</tr>
<tr>
<td>ROALD</td>
<td>3D T-lymphocytes Cell culture</td>
<td>BASE-C 2008</td>
</tr>
<tr>
<td>XENOPUS</td>
<td>Xenopus laevis aquaria</td>
<td>ROALD 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RESLEM 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XENOPUS 2008</td>
</tr>
</tbody>
</table>

**Kayser Italia Experiment Units**
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

Review on Kayser Italia HW
DOI 10.1007/s12210-013-0261-1

Example of multidisciplinary mission on-board 2011 Endeavour Shuttle
DOI 10.1007/s12217-012-9309-6
Experiment Hardware for Life Sciences

Kayser Italia experiments tree

2015 experiments
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.
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
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;
- Repeatable;
- 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…
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.

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.
BIOBOX Facility (ESA)

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.
KI main activities in the field of Space Life Sciences:

- Experiment Hardware
- Facilities
- EUs & ECs
- Facilities
- Bioanalysers
- Bioanalysers
Bioanalysers: since 2009 KI was involved in three different ESA programs on bioanalysers for space activities.

- **MIDASS**: Microorganism 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.
Contacts

• Marco Vukich, Head of Life Science  
  m.vukich@kayser.it  
  ++39 0586 562314

• Alessandro Donati, General Manager  
  a.donati@kayser.it  
  ++39 0586 562262

• Valfredo Zolesi, President  
  v.zolesi@kayser.it  
  ++39 0586 5621