J. Biol. Res. 2003 n. 1 - Vol. LXXIX - Rubbettino - Soveria Mannelli

How to Organise Life Sciences Experiments Taking into Account Ergonomic and Functional Requirements in Microgravity

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Experimental science is already a challenge on ground, and usually the Life Science experiments are more complex and time demanding than others. In general for all experiments the results are dependent from the quality, i.e. knowledge and skill of the operator and quantity of resources both in time and in number of people involved. Additionally quite often Life Science experiments have heavy safety constraints requiring dedicated insulation or they require high grade of dexterity from the operator.
For the above reasons Life Science experiments carried out on board a spacecraft represent a particular challenge to the designer. It is possible to identify three main factors affecting the capability to perform experiments and especially Life Science on board:
1) 0-g environment
2) Limited Resources environment
3) Crew limitation (crew operating in an extreme environment)

1) 0-G Environment

One part of the first factor is well known and it is the main reason to perform experiment on board i.e. to analyse effect of gravity (or absence of it) on a biological or human sample. The second part, that is not always taken correctly into account, is the absence of gravitational effect on the experiment instrumentation. Due to the lack of gravity, experiment equipment need to be at best adapted if not completely redesigned from the nominal laboratory equipment.

2) Limited resources environment

The International Space Station (ISS) is what we have available now to perform experiments on board when the support from an operator is needed that is mostly the case for Life Science experiments. The ISS is an environment with extremely limited resources both in terms of power and communication as well as human resources.
The manned part of the ISS is composed by pressurised modules interconnected one to the other. Each module up to now is a laboratory or a resource module (the habitation is foreseen much later in the assembly phases of the ISS). A typical laboratory module is able to provide up to 20 m3 of habitable volume (i.e. a sort of squared 2x2 meter corridor 5 meter long) surrounded by equipments.
Experiment equipment is normally accommodated and operates in racks (19" standard) they receive all the utilities from the rack that provides also to the mechanical integrity. The already in orbit laboratories as well as the foreseen ones are fitted with various experimental support facilities dedicated to various disciplines and providing a set of standard equipment this to reduce cost for the singular experiment and limit the request for up-load.

3) Crew limitation

The presence of the crew on-board provides the most flexible and intelligent tool in support to the experiments but it is subject to much limitation especially concerning the available time for experimentation.
The crew on board experiences various problems related to the microgravity environment. Some are modification in the body behaviour (for example body fluids concentrates in the torso, muscles and bones deteriorate) and other are more related to the capability to perform activities (the body posture changes, movements that are normal on ground become difficult in-orbits and vice versa) and then the specific extreme environment produces cognitive and physical fatigue.
To counteract some of these affecting factors is the task of the human factors experts in Alenia. Our task is to provide for a design that promotes efficient and effective utilisation of the on-board crew as well as their well being. More specifically we work on improving experiment usability by taking care of all aspects that impacts on it, for example the following:
– Provision of body and equipment restraints
– Provision of mobility aids
– Development of efficient HCI
– Correct identification and provision of all needed tools and equipment
– Development and delivery of training
– Preparation of procedures and support materials
– Definition and test of timelines that take into consideration "on-board" constraints
– Development of proper tools to allow expert support from ground, etc.
Another peculiarity of the Space environment is the limited or sometime not existing capability to provide for post delivery resolution of discovered problems. So not simply we have to design for an extreme environment but we have to provide for proper verification of this design in order to avoid as much as possible to have post delivery problem. Clearly to achieve

this to be a good designer is not enough but we have to follow a structured methodology that is capable to guarantee as much as possible to us to have correctly taken into consideration all affecting factors. The following gives an ideas on our way to proceed:

– Analyse Client and pertinent Standard requirements
– Prepare a detailed task analysis of the activity in which crew tasks are identified
– Assign each task to the various system components (either H/W – S/W or Human)
– Once the task are correctly assigned in the mean time the equipment are developed our tasks are on one side to keep control on this development in order to keep updated the task and on the other to identify the characteristics and design/procure:
– The work places
– The support tools and equipment
– The required procedures
– The required support materials
– The required labels
– The training materials including mock-ups if needed
– The verification approach and methodologies for all crew related requirements.

In support of this development tests are performed using both digital and physical simulation environments (Digital Human Models, or Neutral Buoyancy Facilities or Parabolic flights).

Once the design has reached its implementing phase a functioning equipment for ground purposes is produced this is used to perform the following activities:

– Support the training
– Perform development and validation tests for procedures, timelines, supports etc.
– Following the test perform the required updates.

This methodology was deviced when two Technological experiments T2 and T4 (ASI program MIRIAM, Euromir'95 mission) have been design and developed, despite some problems they have performed successfully in orbit.
Beside their primary scopes, the activities have permitted to define an efficient and ergonomic approach to design, realization and verification of the experiment apparatus.
Particular attention was given – for example – to stowage of items, their temporary fixation in safe and functional positions, labelling, equipment interface with the astronaut etc. the following figures are taken from experiment T4 that was dedicated to the analysis of human postural behaviour and movements, it was performed in collaboration with the Centro di Bioingegneria of the Politecnico of Milan (Prof. A. Pedotti and Prof. G.C. Ferrigno).

References

[1] I.V. Guarnieri. The microbiological control problem on board manned spacecraft.

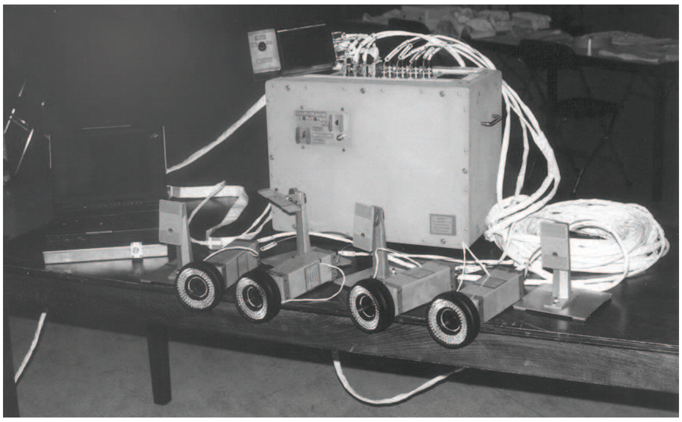

Fig. 1

Fig. 2

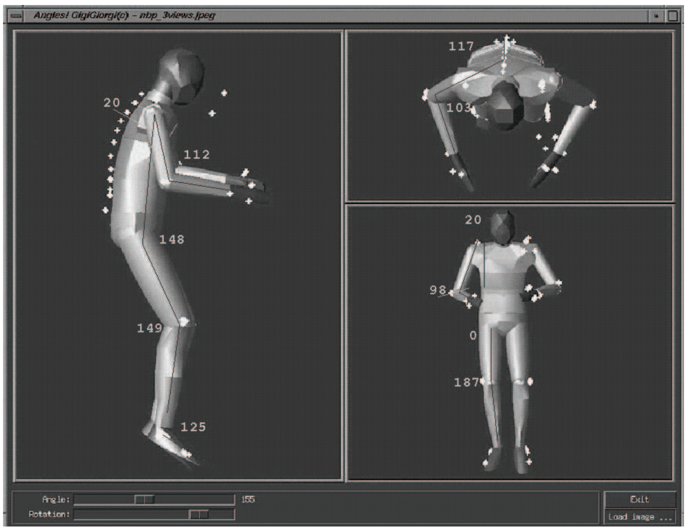

Fig. 3

Fig. 1. ELITE-S
Fig. 2. ELITE-S
Fig. 3. Elaboration in ROBCAD of orbital acquired data with ELITE-S