Mem. S.A.It. Vol. 82, 430

Memorie della

Technologies for Human Space Exploration: ASI PROGRAMS

F. Svelto

Agenzia Spaziale Italiana ASI – Via di Villa Grazioli 23, 00198 ROMA, Italy
email: Francesco.Svelto@asi.it

Abstract. As part of National Space Plan, the Italian Space Agency (ASI) has defined, on the basis of its deep involvement in the International Space Station (ISS) a road map on the enabling technologies for Human Space Exploration. This strategy is in line with NASA strategy for Critical Technologies Demonstration that includes possible international partnership such as inflatable modules and advanced life support. In this respect ASI has been developing for years two projects oriented to these technologies, namely FLECS and CAB and is working in technologies for astronaut wellness as well. The paper describes in the details the ASI programs and their current results, together with the role that is playing in the international cooperation in line with the relevant future national strategies.

1. Introduction

What is the meaning of "Technologies for Human Space Exploration"? The NASA report on Fiscal Year 2011 budget estimates includes, into Critical Technologies Demonstration chapter, the Flagship demonstration program that pursues projects generally funded at $0.4-$1.0 billion over lifetimes of less than 5-years, and that can include partnerships with international, commercial and other government entities. These projects are aimed at demonstrating critical technologies such as:

- Advanced in-space propulsion (ion/plasma, etc)
- In-orbit propellant transfer and storage
- Lightweight/inflatable modules
- Aero-capture/entry, descent and landing
- Advanced life support
- Automated/autonomous rendezvous and docking (AR&D)

Some of these technologies are inspiring also the ASI strategies as detailed herein in terms of dedicated programs.

2. Lightweight/Inflatable Modules ASI Program FLECS

NASA indicated as their goals and objectives in this flagship project: advance, demonstrate and integrate technologies needed for lightweight/inflatable modules, and AR&D delivery capabilities.

Inflatable Systems are characterised by the following peculiarities:

- Large Operational Volumes, not achievable with conventional structures
- High Operational Volume/Launch Volume ratio
- Strong Mass Reduction and, consequently, Strong Reduction of Launch Costs
- Reduced Cost and Schedule for Development

Therefore, by increasing the needs of thinking and planning manned Space Exploration Missions that require:

– Minimum Mass and Inertia for supporting Long Navigation Periods
– Low Development and Production Costs
– Reduced Launch Cost

The Inflatable Structures can be a relevant asset for many of these scenarios. The ASI program FLECS was conceived exactly in line with above medium-long term objectives. In 2001 ASI, with an original approach, committed a study, named SPES, aimed at the definition of the Italian State-of-the-Art on the Inflatable Structures and of their potential Space Applications. Two years later, ASI started the B Phase of FLECS Program, recently completed. With that Program, Italy has matured the autonomous capability to reach the end of that technological Roadmap, by realising a Ground-based Prototype, and analysing possible scenarios of a Space Based Demonstration Mission. Developments concerning new Materials, new manufacturing Processes, new Bonding Techniques and new I/Fs between materials not similar at all will surely imply discovery of new Application Areas even outside the Aerospace Field. A very extensive activity for Materials Selection, Characterization and Testing has been carried out at the beginning of Phase B1, as shown in the following pictures of Figure 1.

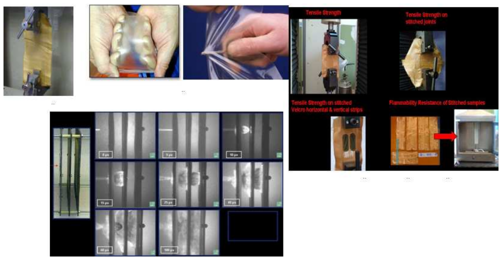

Fig. 1. FLECS material selection

Similar activities have been carried-out in terms of material qualification tests (for example against meteoroid and debris impact) and also with a Thermal Vacuum Test on the developed Breadboard as shown respectively in Figure 2 and 3.

Fig. 2. FLECS impact testing

Fig. 3. FLECS TV testing

Following the Materials selection activity, FLECS Phase B2 has been dedicated to the design and manufacturing of the Habitable B/B Module, fully assembled and completed with the following elements as shown in Figure 4:

– Bladder: constituted by a number of different layers in order to keep air inside the Module
– Restraint: that is the real structural element of the Module
– MDPS: that is the antimeteoritic protection system
– MLI: that is the thermal protection system
– I/F Flange

Fig. 4. FLECS Elements

To better support and demonstrate the high maturity level reached with FLECS Program, additional breadboards of the following representative subsystems have also been manufactured and tested:

- the B/B of a typical Internal Stowage Element (rack shape)
- the B/B of a possible Deployment/Release Mechanism
- the B/B of thin Power Cells

The breadboards are shown in the Figure 5.

FLECS B Phase has been completed by performing the TV Test of the fully integrated FLECS B/B Module (assembled with all system level elements, but without both internal furnitures and P/L), and its deployment capability in typical Space environment has been fully demonstrated.

3. Advanced Life Support ASI Program CAB

It is NASA opinion that in order to enable human space missions beyond low Earth orbit, it becomes imperative to maximize self-sufficiency and minimize the resupply of vital consumables. For considerations of crew safety, health, and mission cost, life support technologies must be developed to recycle air, water, and waste in a closed loop fashion and

Fig. 5. FLECS subsystems breadboard

to utilize in situ resources wherever possible. The knowledge gained and the technologies developed to accomplish these objectives have a direct application to addressing environmental issues on Earth. Improved water reclamation techniques, new solid waste management technologies, advanced environmental sensors, better contamination control methods and increased crop productivity are a few potential consequential benefits on Earth.

In this respect the areas of focus for the Flagship advanced ECLS (Environmental Controls and Life Support) mission are:

- Atmospheric Revitalization
- Water Recovery
- Waste Management
- Habitation System
- Environmental Monitoring
- Pressure Control
- Fire Protection
- Thermal Control
- Bio-regenerative

In line with these NASA objectives, ASI has had in progress for years a program CAB (Controllo Ambientale Biorigenerativo). In 2007 ASI committed a feasibility study, aimed to a subsequent technology development

Fig. 6. CAB Functional Blocks

program, for a controlled biological life support system, allowing food production and regeneration of resources in long duration missions. The designed system can be compared to a closed ecosystem, with various subsystems that must be properly balanced and controlled to minimize the external needed contribution of mass and energy and promote self-sufficiency.

As shown in Figure 6 the CAB functional blocks are the following:

- Structure
- Life Support System:
  - Atmosphere Revitalization & Sampling
  - Water recovery and management
  - Waste management
  - Temperature & Humidity Control
  - Atmosphere Control & Supply
  - Fire Detection & Supp.
- Higher plants growth facility:
  - Illumination
  - Nutrient delivery
  - Robotics
  - ...
- Food management
- Integrated monitoring & control, data handling
- Storage of resources

The CAB program planning is conceived in applicative stages as follows:

- 1st year: State of art review, system level trade offs, consolidation of requirements, architecture and development plan, start of S/S, scientific and technological studies, Plants Production Chamber for crop research realisation
- 2nd year: Critical technological and scientific developments, start of local demonstrators and design of the overall CAB demonstrator
- 3rd year: Execution of critical scientific and technological demonstrations, realisation of key elements of the overall CAB demonstrator, including the integration of selected technologies, system model and architecture finalization.

The program includes incremental development of technological demonstrators where "local"breadboards for critical technologies are part of as shown in Figure 7.

Fig. 7. CAB technological breadboard

4. Technologies for astronaut wellness

In addition to the list of NASA Flagship topics, ASI has a comprehensive Biomedicine Programme which goals are:

- to understand life processes and adaptation mechanisms in space environment in the long term;
- to find countermeasures to long term permanence in space
- to boost medical research on ground with the results of medical investigations in space;
- to foster the integration of multi-disciplinary expertise, both scientific and industrial, for programmes of high-level technology transfer.

Then ASI committed the realisation of some biomedical facilities and utilities to monitor different aspects of astronauts physiology and in particular selected four activities after an AO on "Biotechnology for human space exploration". They are briefly introduced in the following sections.

5. HPA - Hand Posture Analyser

It is Onboard of the ISS since August 2003 and is being utilized for the DCMC programme. Description: instrument developed to evaluate the ability of the human brain to mentally represent the presence or absence of gravity effects on object motion; to study the effects of microgravity on motor planning and movement; to determine how control of grip force is affected by exposure to weightlessness; to quantify adaptive normalization later during mission. Operations: For operation of HPA, the subject wears the sensorized glove, and then is asked to perform specific moves according to scientific protocol. The software embedded in the system measures hand posture and wrist motion. Its utilization by the Italian astronaut Roberto Vittori is shown in Figure 8.

6. ALTEA - Anomalous Long Term Effects on Astronauts

It is on board of the ISS since July 2006 and is being utilized for the MoMa project. Description: facility to study the interaction of cosmic radiation with brain functionality and

Fig. 8. HTA operated on ISS

the visual system and to detect the radiation environment on board the ISS. Operations: Two different way to utilize the instrument, with the man (CNSM) for study of light flashes and without (DOSI) as radiation dosimeter. Next utilization will verify the shielding effects of certain materials. Its operative set-up is shown in Figure 9.

Fig. 9. ALTEA operative set-up

7. ELITE-S2 (Elaborator of televised images)

It is on board of the ISS since August 2007 and is being utilised for the DCMC project. Description: instrument for gathering and analysing data on man's movement in space; its objective is to study the strategies and adaptive mechanisms of central nervous system for motor control in space environment. Located in the US Labs Express Rack, it consists of an ISIS Drawer module and four infrared video cameras that take 250 images a second, installed in the upper parts of the laboratory. Operations: Reflective markers are applied to landmarks on an astronaut which movements are captured by cameras and the data elaborated for a quantitative assessment of the motion. Its operative set-up is shown in Figure 10.

Fig. 10. ELITE operative set-up

8. Biotechnology for HSE

In complement to the above described facilities, the behaviour of the human body during long duration space mission is one of key points of ASI Biomedicine Program. The related Call for Ideas has led to the selection of four proposals:

- Molecular control of circadian rhythms during space flight
- RA (Radiation, microgravity, Apoptosis): countermeasures against eye lesions endured during space flights of long duration
- CRUSOE (CRUising in Space with Out-of-body Experiences)
- Non invasive monitoring by ultra wide band (UWB) radar of respiratory activity of people inside a spatial environment

The results of the studies will be available to by the end of 2011.

9. International cooperation

ASI, starting from the relevant role played for ISS, is deeply involved in a network of bilateral and multilateral (ESA, EC) contacts concerning the perspectives of future missions. In particular ASI is active member of ISECG (International Space Exploration Coordination Group) that has the purpose to work collectively towards the development and implementation of a global exploration strategy. In particular the following are the main objectives of the ISECG:

- providing a forum for participants to discuss their interests, objectives and plans in space exploration;
- promoting interest and engagement in space exploration activities throughout society worldwide.

The areas for initial consideration for the ISECG activities include:

- identification of standards to promote interoperability;
- methods for sharing scientific data and related analyses;
- identification of common services, allowing for the development of shared infrastructures;
- mechanism(s) to allow the provision of payload opportunities;
- ways and means to include broader future participation in the planning and coordination process;
- assessment of the requirement for any relevant international legal agreements;
- development of a common international exploration coordination tool to enhance the implementation of the coordination process.

10. Future strategies

In synthesis the ASI future strategies in Space Exploration are the following:

- ASI wants to play a role in Human Space Exploration future mission fostering Italian technology excellences
- Through the national programs ASI plan to commit technology feasibility projects (not beyond ground demonstration breadboards)
- The contribution to demonstrative and/or operative international missions must be visible and clearly identifiable
- The ISS could be an important test-bed for exploration technologies,
- An important chapter of biomedicine program will be the development of new sensors and tools for monitoring health parameters, producing early and easy diagnosis of problems and putting in place countermeasures against the extreme environment.