Automation and Crew Time Saving in the Space Experiment

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ABSTRACT

In this paper, we will describe the preliminary results of the feasibility study of the automation and crew workload saving in the space experiments. Four apparatuses have been selected as the study case. In this paper, three results will be summarized. The fourth result will be described in other paper.[1]

1. INTRODUCTION

During the restructuring and the re-design efforts and during the user integration work for the JEM, it has been revealed that crew work might be too short on the space station.

The common experiment apparatuses for the initial utilization of the JEM have been under development already. Some automation functions have been studied for the devices, that can be automated within a single rack and without major impacts for the development process and costs.

In addition to such automation, in our study, we assume the following premises to develop new concepts;
(1) Applicable as the second generation apparatuses.
(2) Maximum reduction of the crew workload.
(3) Automation between racks including the storage.

2. CONCEPTS FOR THE AUTOMATION AND CREW TIME SAVING (A&C)

In this chapter, three A&C concepts will be described for the material processing furnace, the life sciences experiment apparatus, and the cleanbench. During the study, most of the effort were devoted to keep the rationality of the experiment itself with the minimum non-scientific degradation by the automation and/or robotics concepts.

2.1 A&C FOR THE MATERIAL PROCESSING EXPERIMENT FURNACES

(1) Tasks for A&C

The current design for the furnaces closes to its automation inside the experiment module itself. The effort for A&C focuses on the exchange of the sample holders for the logistic operation.

In the JEM, most of the logistic materials will be stored in the pressurized logistic module, that will be connected vertically to the JEM through the connecting hatch. The A&C system transfers and or hand-overs the sample holders through the hatch.

Specimen cartridges are covered with the packing or shock-absorbing materials. Unpacking and attaching cartridges to the sample holder will be the most time consuming crew works. The A&C system saves the crew workload by automating these tasks.

(2) Major elements of the automatic re-supply device for the furnaces

Fig. 1 shows the system structure and its hand-over operation through the hatch. Proposed A&C system consists of apparatuses explained below.

(a)Sample holder for launch environment: Multiple specimen cartridges are held in a holder. Each holder is designed to simplify unpackage and package tasks and hand-over tasks.
(b)Carrier mechanism: Wire driven planar carrier mechanism is used both in the logistic module and in the pressurized module. When no logistic module is used, storages are placed in the pressurized module.

The proposed design improves safety of the crew-carrier co-working. The wire driven mechanism

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enables driving actuators to be placed in a fixed and remote area from crews. Because moving part weight is reduced, safety against the possible collision with crews improves. Also the planar implementation reduces the interference volume between crews and carrier mechanisms.

(c)Handover mechanism through the hatch Two hand-over mechanisms are installed close to the hatch. One is in the pressurized module and the other is in the logistic module. Each mechanism hand-overs one sample holder between the carrier and the another hand over mechanism. These mechanisms are folded and placed outside the hatch to keep the hatch clear when not used.

(d)Sensors, cameras: Proximity sensors are installed to detect crews and unexpected obstacles on the carrier's moving path. System cameras in the JEM or a new inspection camera are used to supervise carrier motion and to check sample cartridge defects.

(3) Merits and Problems

Proposed A&C system significantly reduces the crew workload. Though visual inspection by the crew or by the operator on the ground is still needed when new sample holder is unpacked, time for inspection is small compared with the whole time to complete sample exchange.

To keep the safety level high, carrier mechanism motion is restricted to relatively slow. This inefficiency can be improved by operating in more large velocity, when the crew is absent from JEM.

(4) Safety Investigation

There are two safety issues to be considered. One is the crew safety when carriers are moving. Another is the system safety against unexpected environment changes.

To assure the crew safety, A&C system is designed with the safety guideline shown in Table1. The carrier design fits this guideline as stated above.

The system safety is improved with sensors installed on the moving part. Even if the crew leaves something on the carrier path, sensors detects it and stops the motion. Obstacles can be removed afterwards by crew or by the teleoperation from the ground.

Before the full co-working operation, several development steps shall be considered to assure the safety functions completeness. Table 2 shows the possible development steps.

(5) Future Subjects

Items listed below should be investigated further.
- -Detailed interfaces with JEM system:
  electrical and mechanical
- -Carrier mechanism performance:
  accuracy, compliance, driving power, etc.
- -System control method:
  autonomous control and/or manual control.
- -Testbed experiment of proposed design:
  feasibility test and reliability test through on Telescience testbed experiments on the ground.

2.2 A&C FOR JEM LIFE SCIENCE EXPERIMENT

(1) Tasks for A&C

The current design for JEM incubator and cell culture devices covers only the crew operation. The A&C concepts will be required in accordance with growing needs of experiments and much less availability of crew works. For JEM incubator and cell culture devices, following factors shall be considered:
(a) Automation of experiment devices
(b) Automation of observation devices
(c) Implementation of inter rack/device operation support system (IRDOSS)

(2) Automation scheme for JEM life Science

(a)Experiment devices: In the current design, number of devices have been modified from the Spacelab's devices to improve operability, instead to enable the automation, because the automation of each devices would result in so bulky design of them. For example, the elastic bungee to fix samples in the incubator, and polyethylene soft bag to securely contain samples, both adopted on Spacelab's incubator, required much crew involvement. So, the rail sliding tray that can securely load samples, and hard cases with transparent window are adopted on JEM incubator to replace bungees and soft bags.

(b)Observation devices: On Spacelab, high quality observation devices, such as camcorder, camera, and microscope were used to adapt to the variety of experiments. The problem was that they are originally designed for commercial use and required much crew involvement during the observation.

On JEM experiment, standardization of sample size and remote command to the observation devices (commanding of zoom, focus, exposure, and so on) are considered to reduce crew involvement. The automation of exchanging lenses and films remain critical to achieve unmanned observation.

(c)Implementation of IRDOSS : In order to achieve unmanned sample exchange across the racks, automated handling system should be implemented into the existing devices. We call this system inter-rack /device operation support system (IRDOSS). Conceptual design of IRDOSS is shown in Fig.2. The system is composed of sets of articulated manipulators and planar positioning mechanism. The positioning mechanism can be attached to the seat tracks on each experiment rack, and the manipulator on it can reach every experiment equipment on the rack, open the door, and fetch bio-sample from the incubator or the stowage container.

(3) Merit and Problems

Those devices designed for unmanned operation would contribute to reduce crew involvement during manned operation. However, some of the devices such as hard cases, are likely to be too bulky or massive to be handled and stowed.

(4) Crew Safety in IRDOSS

For IRDOSS, safety is most important, because IRDOSS cannot avoid working with crew. For this matter, the smooth surface of the manipulator, or the proximity sensor to detect the crew shall be considered .

(5) Future subject

Ground test for IRDOSS will be demonstrated.

2.3 A&C FOR THE TELEOPERATION OF THE CLEANBENCH

(1) Tasks for A&C

Tasks inside the cleanbench are those such as exchange the medium of the culture cell, procedure to preserve samples, micro-manipulation, observation using the phase-contrast microscope. In this study, those typical task for the life science experiment are subjected to A&C.

(2) Concepts for A&C

The cleanbench A&C is achieved by automation and teleoperation of the following tasks listed below.
(a)Preparation of the Cleanbench: Uplink Experiment Process Managing Program (EPMP). Temperature, cleanliness and other condition of the cleanbench is controlled by the execution of EPMP.
(b)Transfer of samples : For the handling operation, two types of handling manipulators will be utilized. One will serve for the handling between the cleanbench and the other devices such as incubators and refrigerators. Another tiny manipulators will serve handling within the cleanbench. (Fig.3)
(c)Sterilization in the Airlock : In the airlock, equipment that goes through will be sterilized by 70% ethanol. Spray the ethanol, removal of the ethanol, monitor the concentration of the remaining alcohol shall be automated or teleoperated.
(d)Task performed in the cleanbench's working chamber : The culture cell is handled by the tiny manipulators. The cell is positioned to the Automated Sample Manipulation System (ASMS) and exchanging the medium of the culture cell and preservation of the samples are executed. Mircomanipulators and the phase-contrast microscope is able to be controlled by joystick and keyboard from the ground.

(3) Merit and Problems
(a)Merit
(i)Saves Crew time.
(ii)On certain task, PS participation will not be needed. Automated task may be able to perform more precise work than the PS.
(b)Demerit
(i)Total weight of the cleanbench increase.
(ii)On board computer is preferred to be multitask and high-performance.
(iii)Automated cleanbench may need major remodeling when the crew stays on orbit permanently and some automated part of cleanbench becomes obstacle.
(iv)Consumption of electrical power may increase.

(4) Crew Safety Assurance

(a)When equipment are teleoperated or operated automatically, crew are prohibited to enter the working area.
(b)The sensor shall be attached to the equipment. The sensor system avoids collision of crew and equipment.

(5) Future Subject

(a)To ensure crew's safety, when equipment are teleoperated or operated automatically.
(b)Recovery strategy from the handling error, such as release anomaly.

3. CONCLUDING REMARK

At present, the first steps were taken to the A&C evaluation. Those three results described here have each depth of its concepts and also have variety of positions to the A&C implementation. The integrated concept will be needed in the next step of A&C evaluation.

Also for the next step of A&C feasibility study, in addition to the follow on study of the above subjects, a couple of demonstration experiments using Telescience testbed will be investigated in this year.

REFERENCES

[1]Yamawaki, T., Shimoji, H., Abe, T., 1994. Robotic Servicing System for Space Material Experiment. In Proceedings of i-SAIRAS'94.

Table 1 Safety Guideline of Co-working System

1. Low mass property of the movable part.
2. Smooth shape without protuberance.
3. Manual operability in anomaly situation.
4. Monitoring of non-safety action.

Table 2 Possible Development Step of the A&C Safety

1. Ground test:
   Functional Test of mechanics & software.
   Long term validation operation using test devices.
   Exhaustive test of obstacle sensors.
   Emergency shutdown test for various situation.
2. On-orbit test:
   With Crew : Functional test monitored by crew.
   Emergency stop by crew.
   Without Crew: Programmed and teleoperated test.
3. Unmanned Operation:
   Ground Checkout against the damage of specimens.
   Autonomous recovery for partial emergency.
   Recovery operation by the ground teleoperation.
   Recovery by crew for serious anomaly.
4. Manned Operation
   Crew checkout against the damage of specimens.
   Ground monitoring for safety operation.
   Effective recover operation by crew.
   Consideration of the anomaly induced by crew.

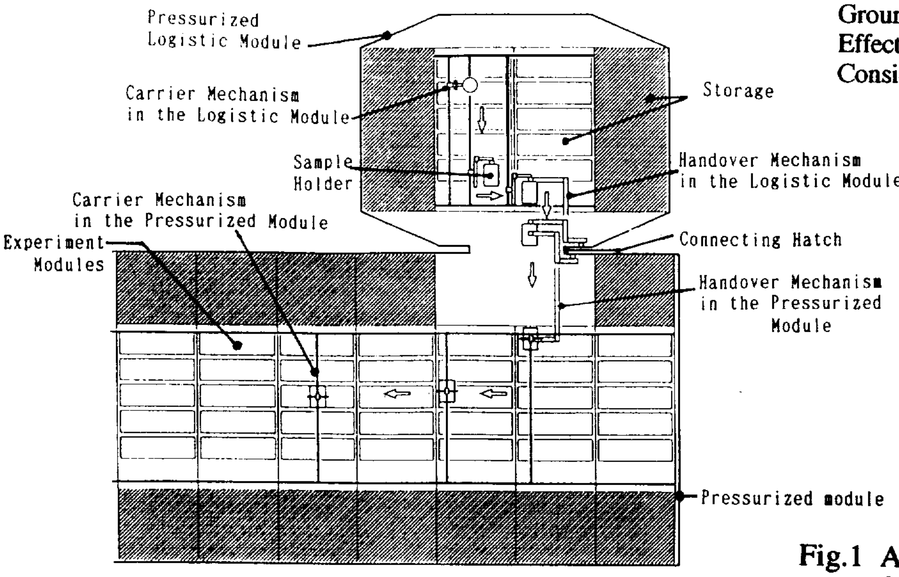

Fig.1 Automatic Re-Supply System between Modules.

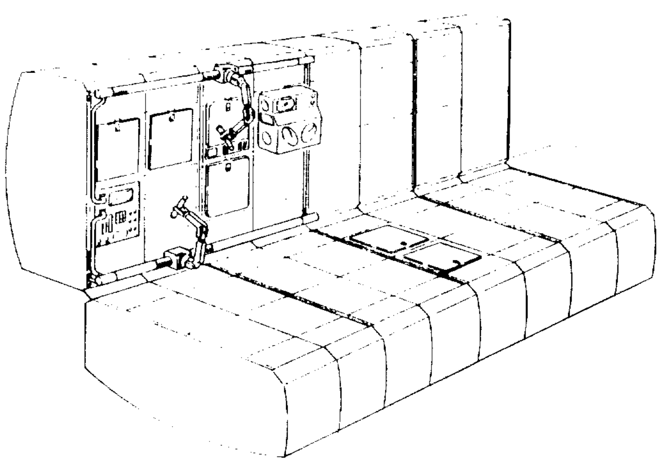

Fig.2 Inter-Rack/Device Operation Support System (IRDOSS)

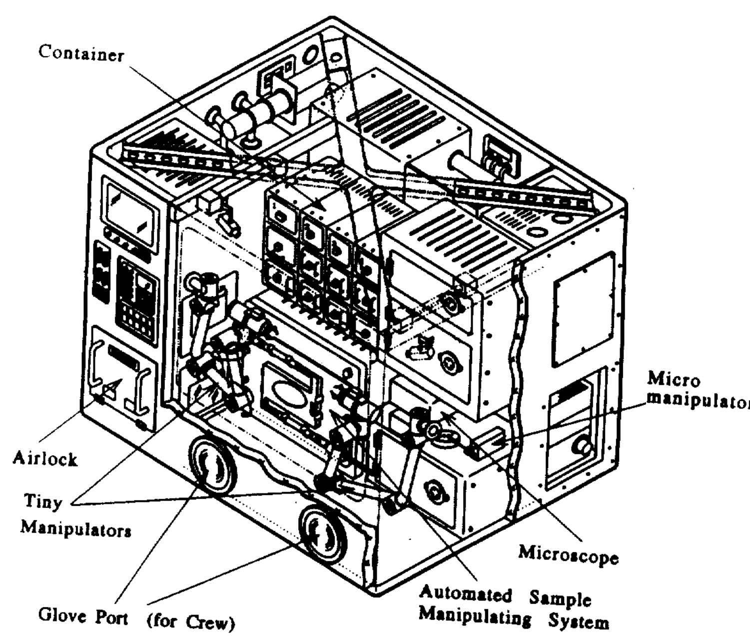

Fig.3 Automated and Tele-Operable Cleanbench