The ISS crew onboard safety actions - analysis of the acquired experience

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This article gives the information about preparation of International Space Station crew onboard training and safety briefing. The events of crew onboard training and safety briefing, the time intervals and list of the participants were reviewed. Was reviewed also experience of realization on safety briefings and onboard training of crew during flight of International Space Station.

Nomenclature

FCT = Flight Control Team
ISS = International Space Station
MCC = Mission Control Center
OCA message = message for the ISS crew
RS = Russian segment of ISS
USOS = US orbital segment of ISS

I. Introduction

Safety provision for the ISS crew is one of the main principles on which the whole International Space Station mission control organization is based. The experience gained in Russia and the USA shows that the task of safety provision for the crews of orbital space stations becomes even more important and hard-to-implement due to the growing sophistication of flight programs. This problem falls under most serious space flight problems since safety is determined not only by reliability of space station systems, but by the quality of crew preparedness, health status, flight preparation level and mission control. It was revealed that emergency situations related to ISS rapid depress, fire on board the ISS and toxic contamination in the ISS volume pose the biggest threat for the crew.

II. The crew on-board preparation

Crew preparation for safety provision starts on the ground and incorporates classes on on-board systems, trainings on actions in emergency situations and actions for implementation of flight operations, pre-flight briefings. When at the ISS, crew preparedness, knowledge and habits are maintained at the required level with the help of on-board trainings.

On-board trainings take about 5% of crew time. Figure 1 shows average distribution of crew work time.

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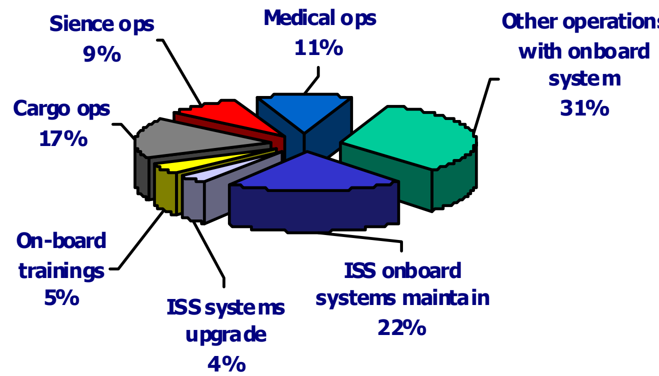

Figure 1. Average distribution of crew work time

Crew preparation on board the International Space Station is undertaken for raising crew efficiency and safety provision.

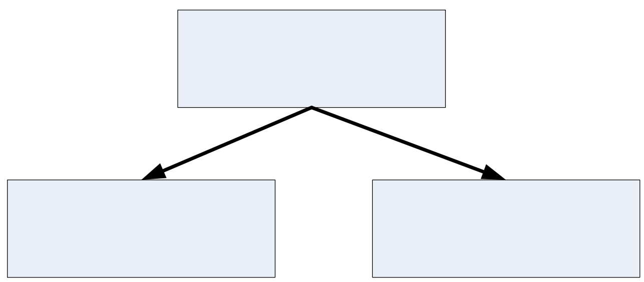

Figure 2. Parts of on-board training

The tasks of the crew on-board preparation are the following:

– Recover and maintain professional habits in implementation of the most important flight operations during the adaptation to zero gravity and in case of long intervals between specific types of operations;
– Refine professional habits under conditions of operation implementation at the space station;
– Recover and maintain professional habits in implementation of operations in case of emergency situations;
– Training of the crew for new tasks that appear in the course of the flight.

III. Safety briefings.

Final session on safety rules on board the ISS concludes ground preparation of any crew. This final shop is held at Baikonur launch site prior to Soyuz transportation vehicle start. During the shop a crew instructor reviews potentially hazardous equipment grouped by specific types of hazards.

— Toxic substances;
— Electric shocks;
— Explosion;
— Extreme temperatures;
— Emissions;
— Traumas or diseases;
— Fire hazardous elements;

— Rapid depress;
— Acoustic noise.

Besides, the crew is acquainted with the briefing procedure after they arrive at the ISS.

Two types of briefings are held on board the ISS:

1. Safety briefing.
2. Safety handover briefing.

Briefing	Time	Duration	Participants
Safety briefing	Soyuz docking day, immediately after ISS hatch open.	25 minutes	All cosmonauts and astronauts on board the ISS
Safety handover briefing	2-4 days after Soyuz docking	2 hours	All cosmonauts and astronauts on board the ISS

Table 1. Rate and duration of briefings for crew members.

Safety briefing is held on the Soyuz docking or orbiter docking day immediately after ISS hatch open. All ISS crew participate in the briefing. ISS commander is in charge of the briefing.

Soyuz post-docking briefing consists of two parts. The first part is for all crew members and the second part is for new-comers only.

The first part (for all cosmonauts and astronauts) comprises:

! Review of action plans in emergency situations, functions and responsibilities in case of rapid depress, fire and toxic emission.

! Translation along the route of emergency escape from the station for each crew member and inspection of hatches for items which would preclude hatch close, for example, drag-through cables and air ducts.

! Inspect emergency equipment location for each crew in their Soyuz vehicle.

! Analysis of gained flight experience on escape from an emergency situation (in case of emergency situation) at the Russian segment (RS) or US orbital segment (USOS).

The second part (for the new Soyuz crew) comprises:

! Briefing on prevention of traumas when moving around the station, with particular attention to:

— Potentially dangerous places associated with hatches, including sharp edges at the hatches in RS;
— Any protruding structures along the route, places where sticking is possible or sharp edges;
— Neurovestibular (sensomotor) changes in the human body which can cause orientation disturbances and vertigo of cosmonauts/astronauts until they are adapted to space flight conditions.

! Inspection of emergency equipment location at RS and USOS.

Briefing after orbiter docking is similar to the briefing after Soyuz docking. The only difference is that information about Soyuz is not included into this briefing.

ISS safety handover briefing is planned between the second and the fourth day after the new crew arrives at the ISS. During the handover members of the current expedition pass through the list of control issues to discuss them with the members of the new crew. Safety problems of the flight, equipment and operational experience are discussed but not the immediate response actions. Distribution of responsibilities for emergency situations among ISS crew members is discussed.

IV. Crew and FCT trainings for actions in emergency situations.

Trainings performed for raising the efficiency of crew operations in flight and for provision of guaranteed escape from off-nominal situations are given in Figure3 and Table 2.

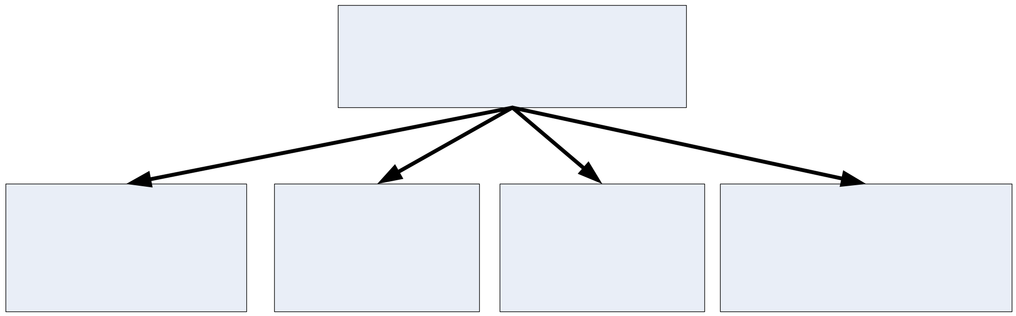

Figure 3. Parts of emergency on-board training

Table 2 shows the rate and duration of trainings on actions in emergency situations.

Type of training	*Day of flight*	*Duration*	*Participants*
Check the status and location of ISS equipment used for emergency escape	3-7	2 hours	ISS commander and the new crew-onboard ISS and FCT of MCC-H and MCC-M
Training of Fire emergency procedure	7-14	1 hour	All cosmonauts and astronauts on board the ISS and FCT of MCC-H and MCC-M
Training of Rapid depress emergency procedure	14-25	1.5 hour	All cosmonauts and astronauts on board the ISS and FCT of MCC-H and MCC-M
Training of Emergency procedures after docking of a new module	7th -10th day after arrival of a new module	2 hours	All cosmonauts and astronauts on board the ISS and FCT of MCC-H and MCC-M

Table 2. Rate and duration of crew trainings for actions in emergency situations

On-board trainings are undertaken with participation of International Partners' specialists (NASA, JAXA, ESA). On the Russian side the following specialists take part in the trainings:

- On-board training instructor;
- FCT specialists;
- Crew instructor.

The below mentioned Table 3 shows responsibilities of participants in the training.

Status and location of ISS emergency equipment

Specialist	*Responsibility*
On-board training specialist – responsible for preparation and implementation of trainings	Develop proposals on composition, periodicity, duration of the trainings and submit proposals for incorporation of required trainings into the flight program of the expedition; Develop training scenario; Prepare for training implementation (prepare and coordinate the radiogram, develop initial data for MCC, advise Real-time Operation Management Team on-console specialists); Carry out the on-board training according to the coordinated radiogram; Prepare minutes/conclusion according to the results of the training.
Real-time Operation Management Team specialists	Coordinate radiograms on on-board trainings; Provide transmission of radiograms on board the station Simulate operations to be fulfilled in emergency situations according to the training scenario; Provide communication for the tagup during the training; Tag up during the training;

Specialist	Responsibility
	Advise on life support system functioning during on-board trainings; Support communications reconfiguration during on-board trainings; Interact with MCCs participating in the training; Interact with the crew and provide real-time response to crew questions, comments and proposals.
Crew instructor	Participate in preparation of training scenario; Provide methodological support for training implementation.

Table 3. Responsibilities of participants in the training

The following procedures are used during the training:

1) Crew procedures:

EMER-1-“red book” (this procedure describes crew actions in case of an emergency situations);

EMER-2 – “orange book” (this procedure describes crew actions for elimination of consequences of an emergency situation).

2) Radiogram (r/g) for the crew, prepared by Russian specialists, if the simulated emergency situation takes place at RS.

Radiogram for the crew includes the following data:

- Tasks of the particular training;
- Initial data;
- Data on caution and warning system triggering;
- Updates on implementation of certain steps from EMER-1crew procedure;
- Questions for training debrief.

3) OCA message for the crew prepared by US specialists, if the simulated emergency situation takes place at USOS. OCA message content is similar to that of r/g.

4) Initial data for MCC specialists developed for each training.

Initial data for MCC specialists contain:

- Tasks of the particular training;
- Recommendations to FCT;
- Initial data for the training;
- Input information simulating emergency situation.

Training for checking the status and location of ISS equipment used for emergency escape is held within the first week of new crew member stay on the ISS. All crew participates in the training. If one crew member arrives later (on orbiter or Soyuz), a second training with participation of the ISS commander and the new crew member is held.

During the training the crew:

– Familiarizes with the location of equipment used in emergency situations;
– Checks presence and readiness of equipment for operation;
– Assesses equipment availability;
– Reviews RS/USOS equipment deactivation procedure and trains interaction between crew members.

Radiogram/OCA message contains updated data on location of equipment (module name, panel number) and methodological comments from the specialists.

The crew translates along the route of emergency escape following the below mentioned recommendations:

- Inspect all routes of translation to Soyuz and see that there are no obstacles to emergency escape;
- Inspect all hatch openings and check the possibility of quick removal of drag-through cables and air ducts in case of an emergency situation;
- Check accessibility to all communication panels and equipment;
- Check ISS RS valve configuration.

In case of discrepancies between current equipment status and location and those given in the radiogram or crew procedure, the crew shall report to MCC and eliminate the discrepancies, following recommendations from the ground.

Training for actions in emergency situations in case of a new model arrival shall be held not later than 7-10 days after the new module docking.

During the training the crew:

- Familiarizes with equipment and valve location at the new module;
- Checks availability and readiness of equipment for operation;
- Trains the sequence of crew actions in accordance with emergency procedure which is updated because of the new model arrival;
- Trains interaction between crew members during emergency escape.

Assets and methodology used for this type training are similar to the training for familiarization with the status and location of ISS equipment used for emergency escape.

Complex trainings for fire and rapid depress emergency procedures are the most complicated.

These trainings have a general pattern of implementation:

1. Consultation by MCC specialists. This is done on the day of the training by specialists supporting the training. On-board training specialist holds the consultation using initial data for MCC.
2. Introductory part for the crew prior to the beginning of the training.
3. Training.

The crew and FCTs start all messages with words “For training purpose…”.

Interactions required for this emergency situation are trained between crew members.

Interaction between the crew and FCTs is also trained.

The crew reports to MCC about its actions if communication is available.

FCTs responsible for a particular training interact with the crew and uplink in real time all instructions required for simulation of a real situation. FCT of MCC-Moscow interact with FCT of MCC-Houston in the course of the training by imitating its actions in a real situation.

4. Training debrief

Training debrief is held after the crew reports about completion of actions provided for by the training scenario.

Training debrief consists of two stages:

4.1. Debrief with participation of FCTs personnel which participated in the training. Personnel of the MCC responsible for the training undertake a short debrief of the training with the personnel of International Partners’ MCCs with the objective to assess the results of interaction of the parties in the simulated conditions. The crew uses this time to prepare responses to questions given in the radiogram, to reconfigure equipment and crew procedure back to nominal, to prepare questions and comments that appeared in the course of the training.

4.2. Debrief with participation of the crew and FCTs. MCC personnel analyze the training with the crew. Results of the training, drawbacks revealed in the course of the training and questions are discussed at this stage of debrief.

The tasks of the complex fire emergency training are as follows:

- Train counter fire actions and all related actions which are undertaken in case the crew detects smell of burn/smoke or open fire.
- Train methods of radio communication setup and interaction between the crew and MCC required for implementation of actions in case of fire emergency.
- Familiarize with auxiliary equipment (gas analyzer, gas masks and fire extinguishers) which is used for implementation of actions in case of fire emergency.
- Familiarize with formats used to depict fire emergency data in portable computers (“laptops”).

The tasks of the complex rapid depress emergency training are as follows:

- Train crew actions in case of rapid depress: actions in case pressure drop is registered by on-board automatic devices and software, search and identification of the non-pressurized module with the help of manovacuum meter (if on-board automatic devices does not operate) and isolation of the leaking module.
- Train methods of radio communication setup and interaction between the crew and MCC required for implementation of actions in case of rapid depress emergency.

After the termination of each type training a protocol is worked out where all questions and proposals by the crew and MCCs specialists are marked.

V. Open issue in crew on-board training for present time.

There is an open issue, which is crew training for toxic substance emission. Unfortunately, due to the long coordination of response action issues for this emergency situation between Russian and US parties, one of urgent safety problems, crew training for toxic substance emission emergency, was not solved. This type training was not held a single time throughout the whole flight of the ISS. The dander of ammonia emission increases with the growing number of USOS modules. Ammonia is used in US module thermal control system and its quantity increases. Ammonia is a highly volatile, soluble in water gas which causes irritation of upper respiratory tracts and eye mucosa and can cause unprompted lung paroxysm (if the concentration is high). In case of ammonia loop leak in any module inside ISS volume there emerges a threat to the crew life. During ground trainings the crews learn ammonia emergency actions by heart. Currently joint on-board training team is developing a training procedure for ammonia leak at the USOS and is planning its implementation.

VI. Conclusion.

In general, in spite of open issues, it should be noted that existing system of on-board training for the crews provides for the level of crew preparedness required for safe ISS mission control. This fact is confirmed by experience gained during 10 years of ISS mission control and by accomplishment of sufficiently complicated flight operations by the ISS crew.