NASA Training Techniques for Safety Critical Operations

1. Defining Safety Critical Operations

From a NASA perspective, safety critical operations include any nominal or off-nominal situation that could threaten the safety of the crew or the vehicle. Foremost among these are potential spacecraft emergencies such as fire, rapid depressurization, or a toxic atmosphere. Nominal operations that also receive a similar training approach include extravehicular activities and visiting vehicle rendezvous among other things. The information in this document will focus on training techniques for fire response.

2. Participants

Successfully responding to a fire on-board the International Space Station (ISS) requires coordination between the 6-person crew on-board ISS and Mission Control Centers (MCC) in Houston, Texas, Huntsville, Alabama, Moscow, Russia, Montreal, Canada, Tsukuba, Japan, and Munich, Germany. Depending on which segment of the vehicle the fire is on, either Houston or Moscow will take the lead for coordinating the response. Each control center will coordinate with the crew or the lead control center to execute corrective or preventative actions that need to be taken in their module of concern.

3. Multi-National Training Approach

Each partner in the ISS program has the responsibility of training hardware and operations executed within the module that partner owns. Since emergency response is an integrated operation, NASA has the responsibility of providing integrated end-to-end training for these scenarios. To eliminate unnecessary duplication of content, a training needs analysis was conducted on emergency response. The resultant skills and knowledge to be covered in training were concurred upon by all involved ISS partners. Due to the nature of the teamwork and coordination skills required to successfully respond to an emergency, the training needs analysis process took quite a bit of effort to overcome vocabulary and cultural differences among all the partners.

4. Crew Expectations

ISS crews must be able to execute emergency response actions without the assistance of mission control. If the emergency leaves the crew without communications with MCC-Houston or Moscow, then the crew will have to execute the procedures on their own. The crew training flow is built around this expectation.

5. Common Emergency Response

ISS crews are trained on a set of actions that should be executed in any emergency scenario. These actions are intended to ensure a safe, coordinated, and methodical response by the crew. These actions include gathering all crewmembers in a safe haven, making sure all crewmembers are accounted for, clarifying the current situation and determining the appropriate response, and coordinating the actions of the team. A safe haven is anyplace on board the ISS with appropriate communication and computing resources, access to protective equipment, and has a clear path to the escape vehicle, currently the Soyuz.

6. Crew Roles & Responsibilities

Since there are different types and degrees of emergency situations, it is imperative that all participants are executing the same response procedures. Within these procedures, there are different actions for different crewmembers. Some crewmembers will enter the module with the fire and start taking action to extinguish the fire. Some crewmembers will stay in the safe haven and act as a communications conduit between the crewmembers in the affected module and Mission Control. Some crewmembers may be required to wait in their escape vehicle. It is critical that everyone understands who is doing what and where they will be.

Jason T. Hutt
Spaceflight Training Management Office

7. Individual Crewmember Training

With the different roles to be completed during emergency response, each individual crewmember must have a firm understanding of what all the roles require. While a given crewmember may have a preference for which role they fulfill, they may be asked to perform different actions depending on the actual scenario. For this reason, individual crewmembers are trained to complete the response to an emergency on their own from end-to-end. Each crewmember's performance is evaluated in a capstone lesson called 'Emergency Mastery.' Once a crewmember demonstrates that he/she can complete all necessary actions on his/her own, the crewmember will progress to team-based training.

8. Team-Based Training

ISS crews receive a series of scenario-based training in the Space Vehicle Mockup Facility (SVMF) to practice a coordinated response to emergency situations. Crews will receive training as both a team of 3 crewmembers and a team of 6 crewmembers. The crew complement in the scenarios will match the expected on-orbit crew complement. The scenarios will test the crews ability to respond to varying degrees of emergency events that occur in different operational scenarios. Additionally, scenarios will introduce complications such as an incapacitated crewmember or failed hardware that impact the crew's ability to respond to the emergency. The lead Flight Director and other members of the mission control team will also participate in this team-based training in order to prepare the crewmembers for the type of interaction they will have with the mission control centers during emergency response.

9. Simulation Environment

The SVMF is the primary facility for conducting full crew emergency scenarios training. It is the only facility in the world with mockups for almost every ISS module. The biggest challenges in implementing a realistic training environment are cost and safety. Flight-like hardware is expensive; every new component is evaluated to determine the level of mockup fidelity needed for training. MOD borrowed an approach from the airline industry and incorporated a smoke machine into the facility that generates non-toxic smoke. This smoke is an excellent visual cue that helps increase the stress and urgency of the training scenario. In addition, some hardware modifications are made for safety reasons. For example, gas masks have been adapted so that astronauts did not carry small high pressure gas tanks on their hips.

10. On-Board Training

To maintain proficiency in executing emergency response, crews are required to complete a series of training events while on-board ISS. These training events include participation from the crew and the mission control center. When a crew first arrives, they conduct a survey of the entire vehicle to verify that hardware is configured to appropriately respond to an emergency as well as to orient them on the location of emergency response hardware. Then, the crew will complete an emergency drill roughly once per month. Currently, these are planned events; unplanned events are not currently feasible for a variety of reasons. If there is a significant vehicle change, crews will be required to complete a training session to familiarize them with any emergency response steps resulting from that change.

11. Mission Control Expectations

The mission control team must be able to assist the crew with emergency response. The mission control team has access to much more data than the crew has available to them. The team can provide context information that can greatly assist the crew with locating the source of the emergency event. To sufficiently do this, the team must maintain awareness of the crew's actions at all times. Clear communication is key to facilitating this coordination.

12. Mission Controller Training

Mission controllers take a suite of training to prepare them for emergency response, this includes lessons, mini-simulations, and generic simulations. Individual mission controllers must demonstrate their ability to respond to every different type of emergency as a milestone in their certification flow. Once certification is achieved, mission controllers are required to complete periodic training to maintain emergency response skills. For certain types of missions, the mission control team will conduct emergency simulations to ensure that all participants are ready to respond to an emergency when the spacecraft is in a mission-specific configuration.

Mission Operations Directorate

Spaceflight Training Management Office

NASA Training Techniques for Safety Critical Operations

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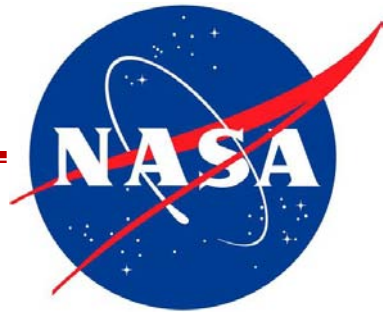


Overview

- **Introduction to Mission Operations**
- Introduction to the International Space Station (ISS)
- Multi-National Approach to Emergency Training
- Crew Training
- Mission Control Team Training

Scope of “Mission Operations”

Plan

Mission Concept Definition

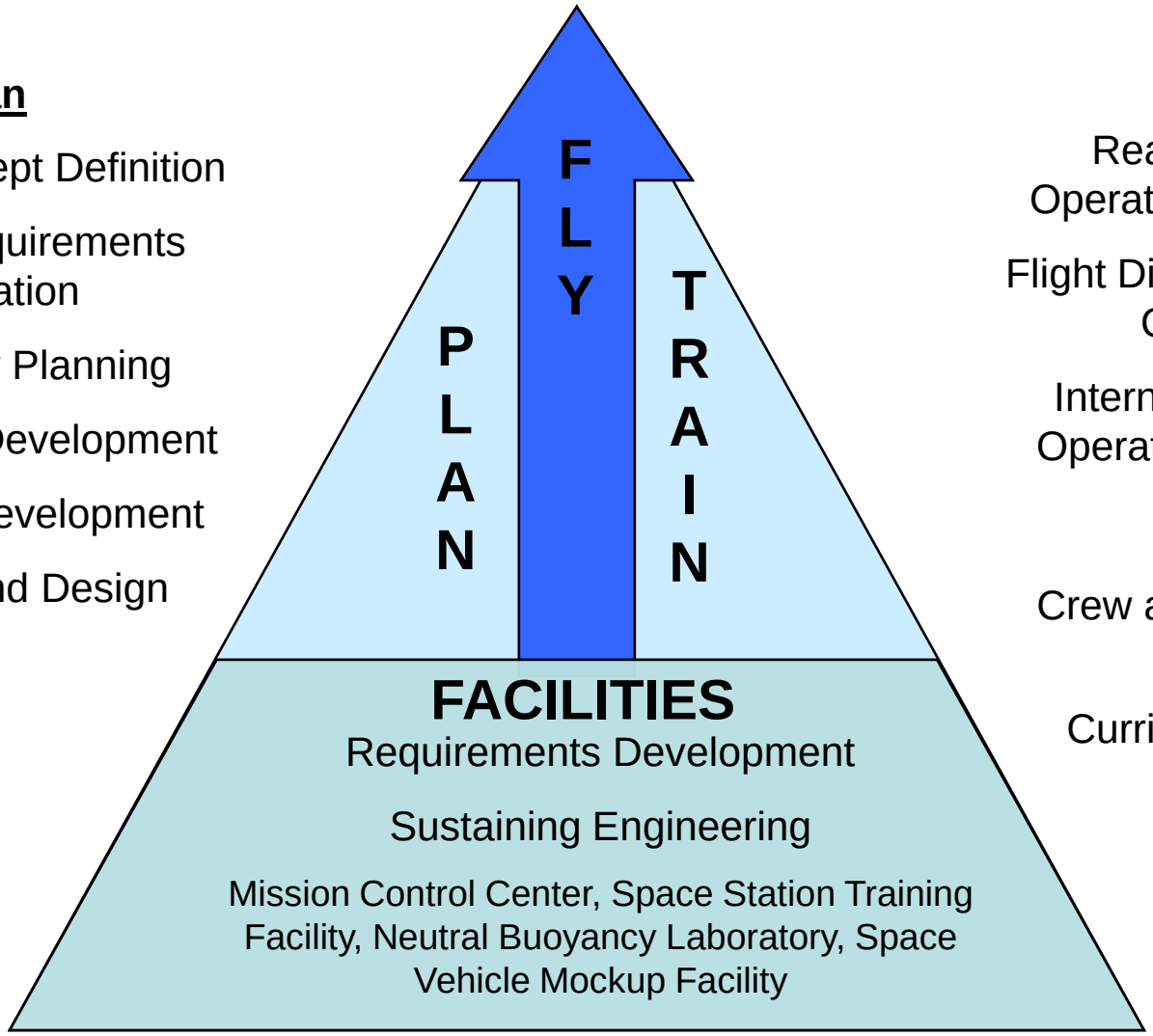
Mission Requirements Integration

Flight Crew Planning

Flight Rules Development

Procedure Development

Analysis and Design



Fly

Real Time Flight Operations (Execution)

Flight Directors and Flight Controllers

International Partner Operations Integration

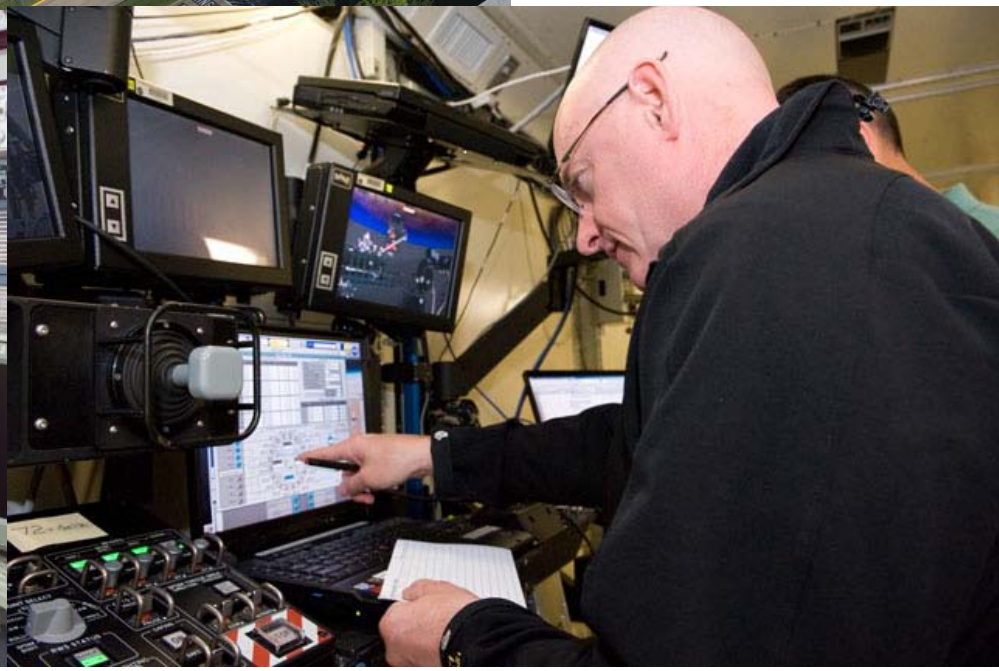
Train

Crew and Flight Controller Training

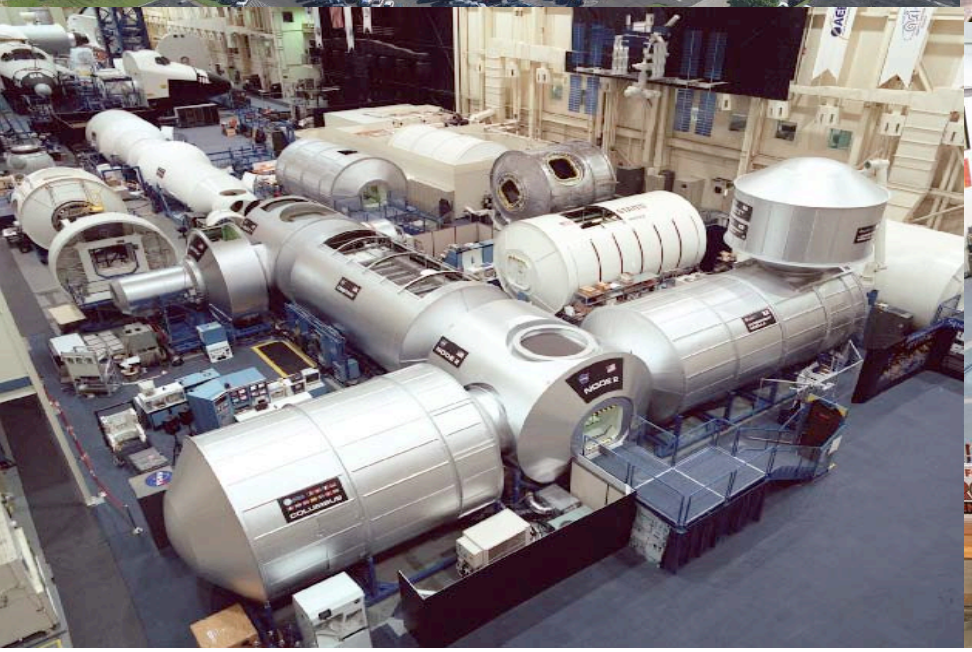
Curriculum Design and Development

Mission Control Center (MCC)

Space Station Training Facility (SSTF)



Space Vehicle Mockup Facility (SVMF) & Neutral Buoyancy Lab (NBL)



Mission Operations ‘Culture’

1. **To instill within ourselves these qualities essential to professional excellence: Discipline, Competence, Confidence, Responsibility, Toughness, Teamwork, and Vigilance.**

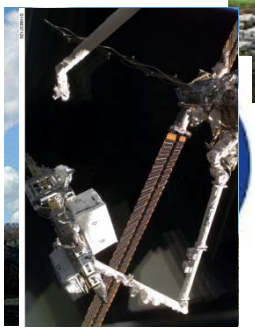
2. **To always be aware that suddenly and unexpectedly we may find ourselves in a role where our performance has ultimate consequences.**

3. **To recognize that the greatest error is not to have tried and failed, but that in the trying we do not give it our best effort.**

Overview

- Introduction to Mission Operations
- **Introduction to the International Space Station (ISS)**
- Multi-National Approach to Emergency Training
- Crew Training
- Mission Control Team Training

ISS: A New Training Challenge

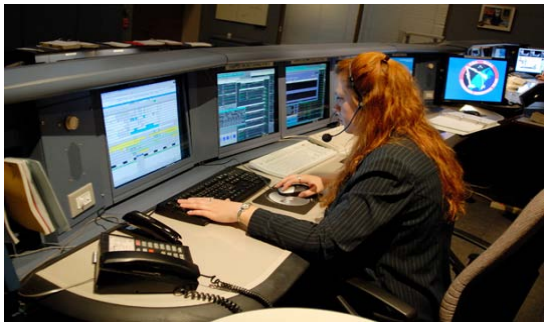


Operating ISS

MCC-Houston

MCC-Moscow

POIC-Huntsville

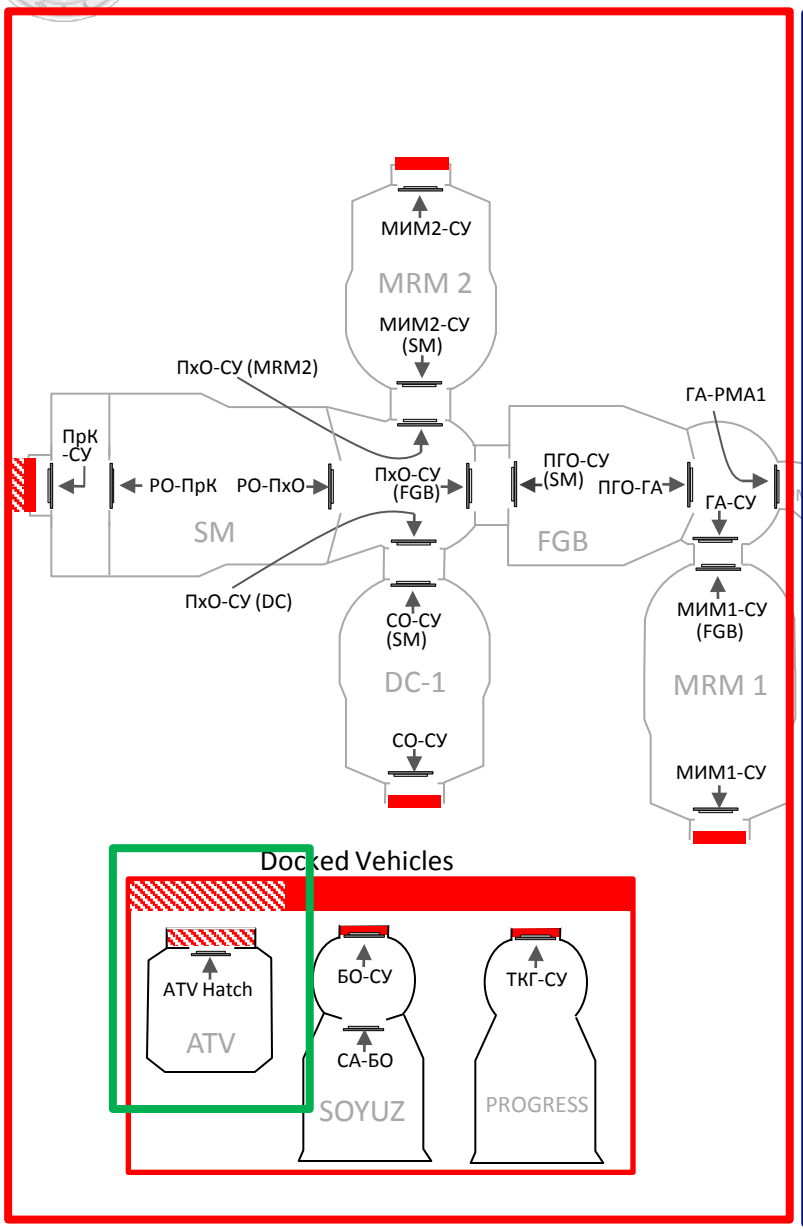


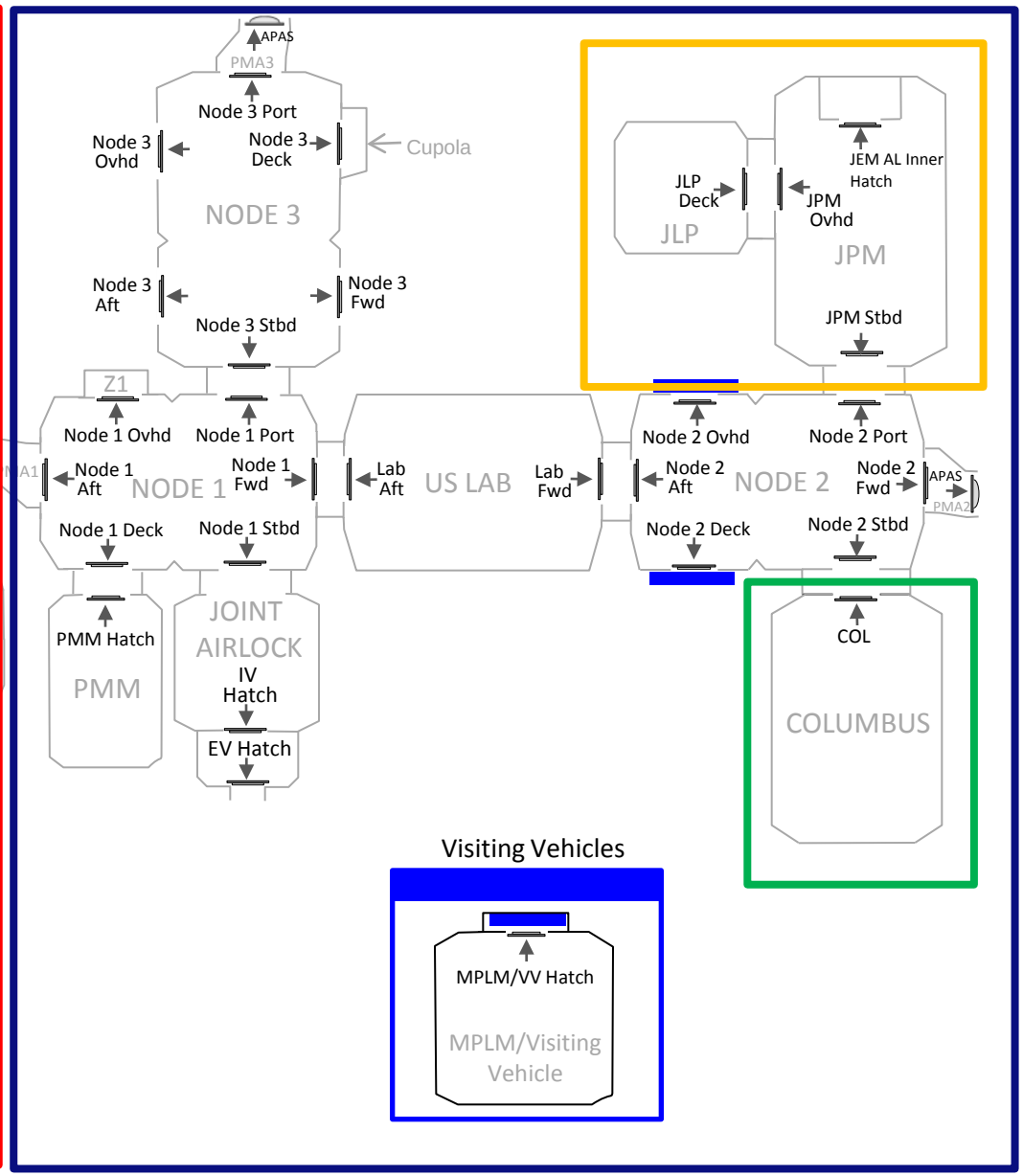
CSA-MCC

SSIPC(JAXA)

Columbus-CC
(ESA)

ISS Overview





ISS Operations Overview

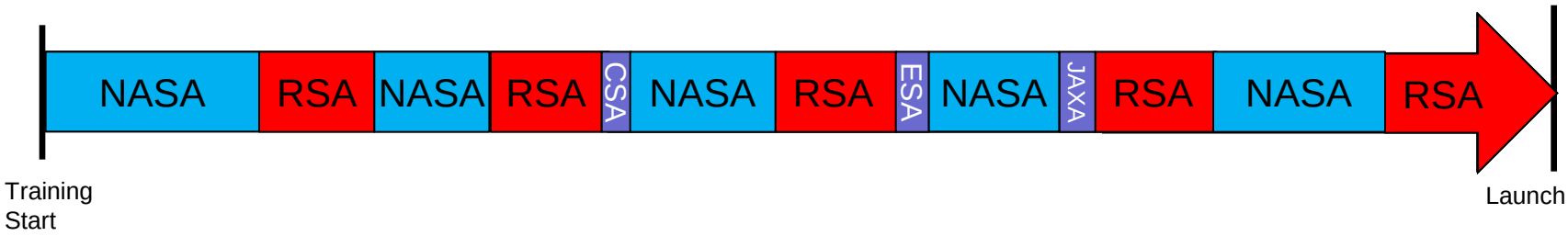
Long duration mission (6 months).

Mixed international crews.

Primarily controlled remotely by MCC.

Crew focused on utilization.

Long Duration Crew Training



- Currently a 2.5 year training flow for an inexperienced crewmember.

- First 2 years of training are focused on generic skills training. Final 6 months of training focuses on mission specific skills.

- Crewmembers may spend up to 55-65% of the 2.5 year training period in Russia, Germany, Japan and Canada.

Training Governance

- Multi-National Control Board
  - Co-chaired by NASA & Roskosmos

- Spaceflight Training Management Office

Safety Critical Operations

- Operations that could jeopardize the health and safety of the ISS crew and vehicle.

- Contingency operations include:
  - Fire
  - Rapid Depressurization
  - Toxic Atmosphere

- Nominal operations include:
  - Extravehicular Activities (EVAs)
  - Visiting Vehicle Rendezvous

Overview

- Introduction to Mission Operations
- Introduction to the International Space Station (ISS)
- **Multi-National Approach to Emergency Training**
- Crew Training
- Mission Control Team Training

Multi-National Approach

- Each partner is responsible for training emergency response hardware and operations for its modules.
- NASA is responsible for providing integrated training.

Integrated Curriculum

- Training Needs Analysis defined required skills & knowledge.
- All international partners concurred with TNA results.

Overview

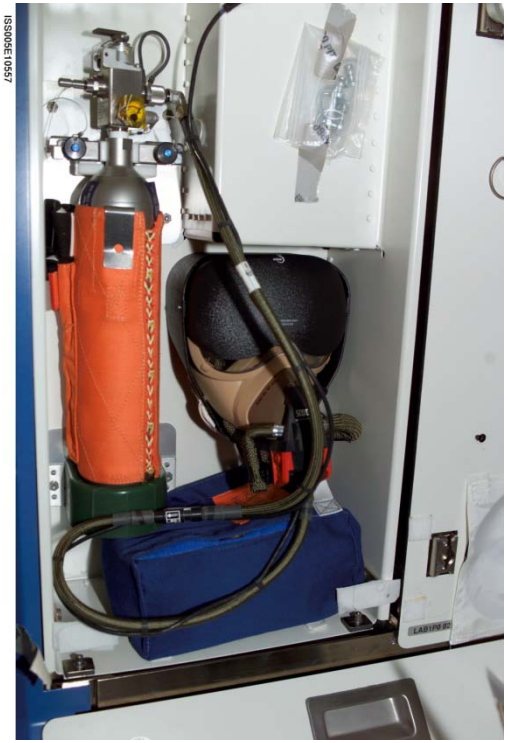
- Intro to International Space Station (ISS)
- Multi-National Approach to Emergency Training
- **Crew Training**
- Mission Control Team Training

Crew Training

ISS Crews must be able to execute emergency response actions without assistance from mission control.

Initial Hardware Training

- Crewmembers receive hardware training at each partner site.



Common Response Strategy

- Warn everyone
- Get to a safe haven
- Is everyone accounted for?
- What response are we executing?
- Who is doing what?

Crew Roles & Responsibilities

- Crewmembers will be in multiple locations on ISS during emergency response.

Individual Response Training

- Individual crewmembers must know the entirety of emergency response.
  - Must pass a capstone evaluation called ‘Emergency Mastery’

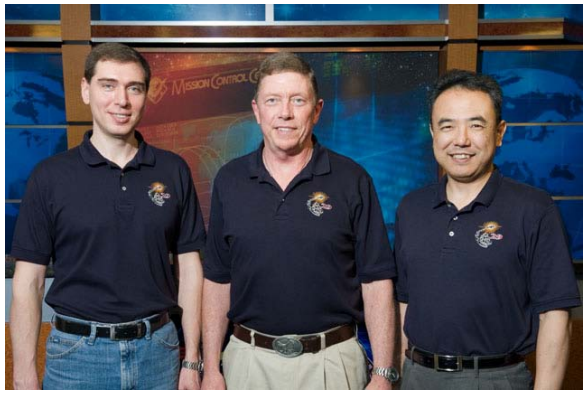
Team-based Training

- Emergency Scenarios Training
  - Mix of cases designed to test strengths & weaknesses of the team

Simulation Environment

- Borrowed technique from airline industry to use non-toxic smoke for more realistic simulations.

Changing Crew Complements



Expedition 28

- Each crew trained to perform emergency response as a 3-person crew and with both 6-person variants.

Expedition 29

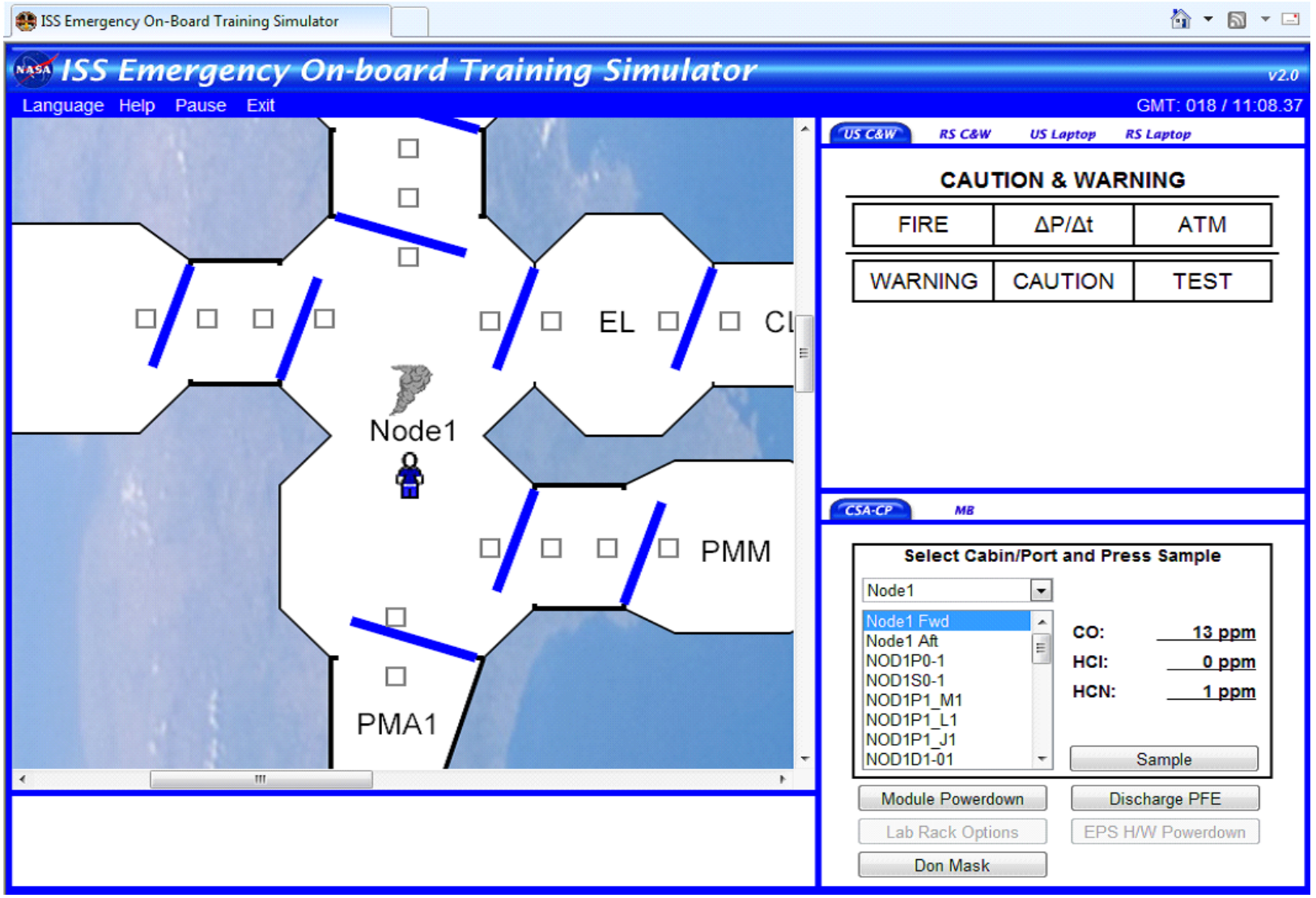
Expedition 30

On-Board Training (OBT)

- Vehicle familiarization and readiness check
- Monthly drills focused on different emergency cases
- Events include mission control center coordination

ISS021E007175

OBT Simulator



Evaluation

- Team performance
- Individual performance
- Communication
- Decision-making
- Technical knowledge
- Resource Management

Feedback

Overview

- Intro to International Space Station (ISS)
- Multi-National Approach to Emergency Training
- Crew Training
- **Mission Control Team Training**

The Mission Control Team must be able to assist the crew with emergency response actions.

Mission Controller Training

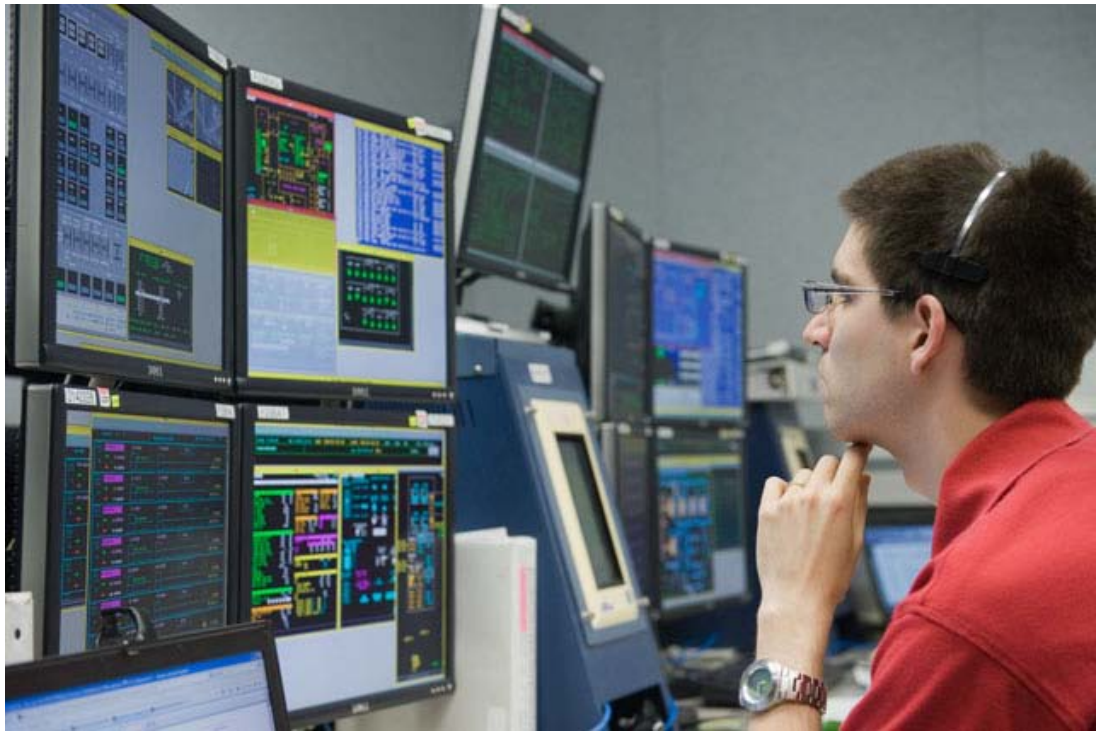
Lessons

Mini-sims

Qualifications Exercises

Generic simulations

Mission-specific simulations



Facility Availability

ISS Emergency Training (00:51 / 16:16) | ECG Glossary and Acronyms | Resources | Bookmark This Page | Exit

E-LESSONS

Index

1. Intoduction
2. Warn Others
3. Gather in Safe Haven
4. Work Procedures
6. How to calculate T.Res
7. Nomograph Interaction
8. Soyuz Leak Check
9. 1.7 Leak Isolation
12. 1.8 Leak Pinpoint
15. 1.9 US Segment Leak Check
18. Nomograhp Interaction
19. 1.9 US Segment Leak Check
20. Check your understanding
21. 1.9 US Segment Leak Check

COMMON EMERGENCY RESPONSE
WARN OTHERS

Crew presses dp/dt alarm

SM AFT(MRM2)

1.3 RESPONSE TO DEPRESS ALARM SIGNALS

(EMER/SOYUZ AT SM AFT/FIN 12/MULTI E, J, R/Paper on ISS) Page 1 of 1 page

ПСС or PCS	☐ ΔP/ Δt, **ЗВУК** (high-pitch intermittent tone) (ΔP/Δt ≥ 0.87 mm/min and ΔP > 15 mm, T.res ≤ 06:11:00)	☐ ΔP/ Δt, ☐ USOS, **ЗВУК** (high-pitch intermittent tone) (ΔP/Δt > 0.78 mm/min and ΔP > 20 mm)	☐ ATM PRESS, **ЗВУК** (high and low-pitch warble) (P = Low or P = ДСД or P < 719)	☐ OTHER, **ЗВУК** (high and low-pitch warble) (0.4 ≤ ΔP/Δt < 0.8 mm/min 06:11:00 < T.res ≤ 13:17:00)

P[MB]_____ GMT_____

Continuously monitor P[MB], if P[MB] is stable report to **MCC**. >>

ПСС If ■ ΔP/Δt

⭳ MANUAL ALARM ΔP/Δt ☐ MANUAL, **ЗВУК** (low-pitch warble), ☐ ΔP/Δt, ☐ SM

Crew without ISS CDR GO TO 1.11 CREW WITHOUT ISS CDR SOYUZ LEAK CHECK, p. 1-114E.

If there is gas introduction from Progress or ATV, close manual valves.

MCC **MCC-H/MCC-M** performs 7.9 EMERGENCY MULTI-ELEMENT COMMUNICATIONS SETUP.

SLIDE 2 OF 21 | PAUSED | 00:22 / 00:45

Supplementary Notes

Mission Operations Directorate

Spaceflight Training Management Office

Thank You!