esa

Lufthansa Flight Training

Complex operations on the International Space Station

training and execution in manned and unmanned situations

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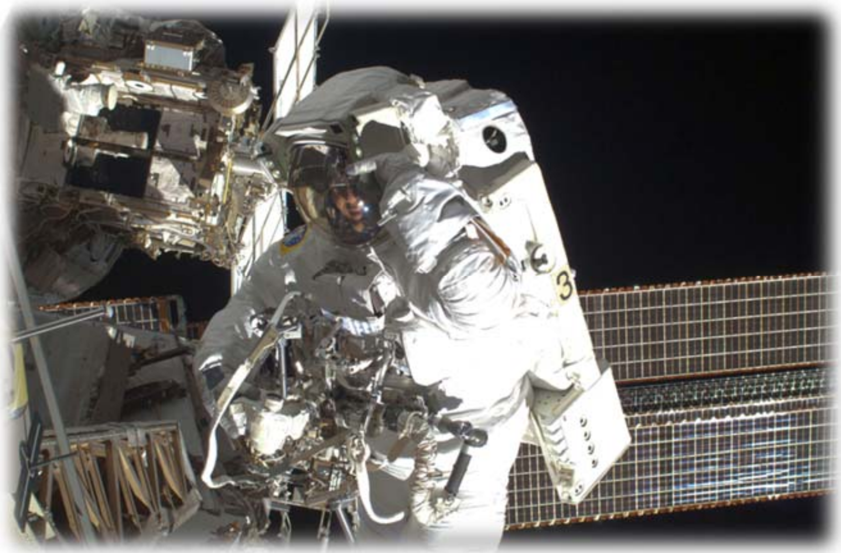
Outline

- What makes ISS operations ‘complex’
- Operations based on procedures
- Astronaut training and challenges
- Ground personnel training and challenges
- How is feedback used to improve operations



What makes ISS operations 'complex'

- Hostile/unfamiliar environment for astronauts on ISS
  (weightlessness, constricted room, high workload/stress, vacuum outside, permanent risk of emergencies: fire, depress, toxic atmosphere)
- Relatively short stay (≈ 6 month) of astronauts on the ISS
- Interaction of multiple teams (crew ⇔ multiple Control-Centres)
- Synchronous and asyncronous communication
- Parallel activities/schedules
  (e.g. about 100 to 140 experiments are running on ISS at the same time)
- A lot of complicated 'hi-tech' equipment and activities . . .

Main goal is to successfully perform operations and to bring our astronauts back home safely!

What makes ISS operations 'complex'

- To continuously operate the ISS a lot of tasks have to be accomplished.
- But crew time on the ISS is rare and precious. Crew time is usually 'over-booked' and still there are 'reserve activities' waiting.
- Therefore the astronauts perform primarily tasks which cannot remotely be done from ground and where physical presence is needed.
- Most of the 'monitoring & commanding' tasks are performed from ground without any crew interaction.

↳ Therefore we have basically three modes of operation:

- Crew only (independent from ground)
- Ground only (no crew required)
  the ISS could be considered "unmanned"
- Interactive Crew & Ground (working as one team)

'Complex' ops: Short stay – frequent crew change

- Relatively short stay (≈ 6 month) of astronauts on the ISS
  - 'inexperienced' at increment start
  - learning curve
  - when experienced at the end of 6 month stay: leaving
  - new crew member ☞ new learning curve
  - ↳ also challenging for the support teams

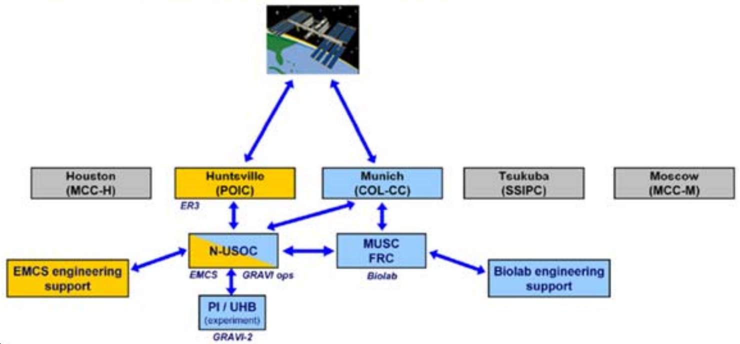
‘Complex’ ops: Interaction between different teams

- The ISS is run in ‘segregated’ operations for:
  - Russian Orbital Segment (ROS)
  - US Orbital Segment (USOS)
    incl. Canadian, European and Japanese elements
  - The US furthermore distinguish between:
    - Mission-Control: Houston
    - Payload/Science operations: Huntsville
- The astronauts are in direct contact with five Control-Centres
- But there are numerous additional support centres
  (e.g. eight additional USOCs only in Europe)

Example: GRAVI-2 experiment

GRAVI-2 is a collaborative IP effort.

In general:
All questions related to **Biolab / GRAVI-2** specific hardware notify **Munich**
All questions related to **ER3 / EMCS** notify **Huntsville**

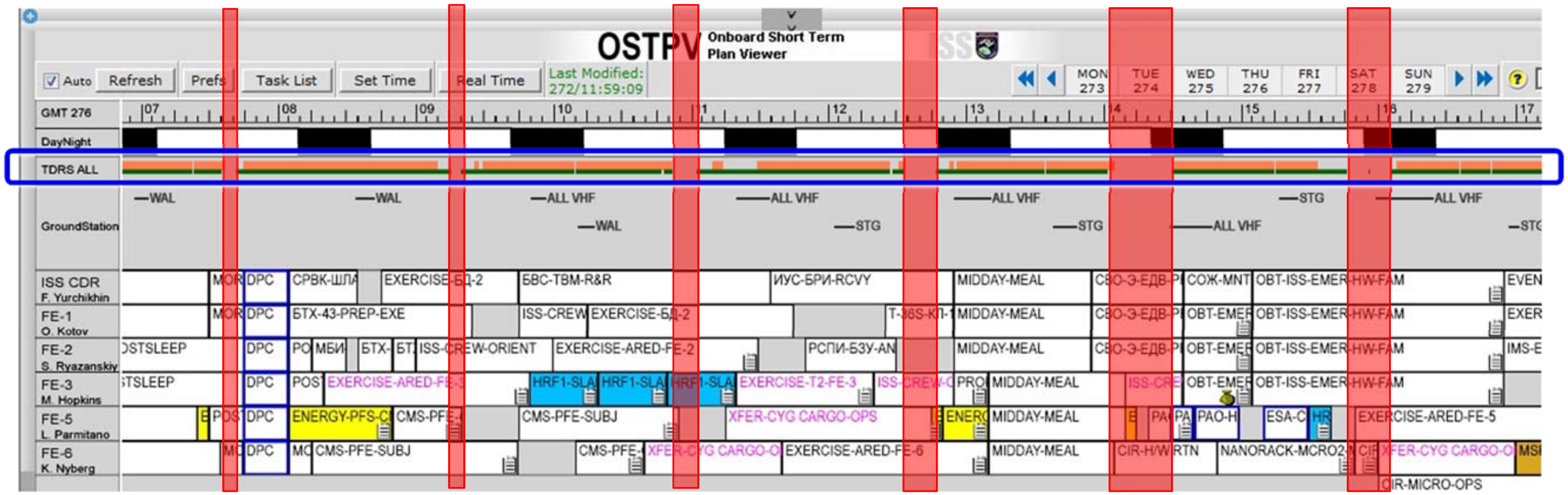


‘Complex’ ops: Synchronous / asyncronous communication

- Communication, telemetry (monitoring) and commanding of the ISS is based on satellite connections (in S-band and Ku-Band)
- During Acquisition Of Signal (AOS) ground is “live on board”
- During Loss Of Signal (LOS) ground is “blind” and the crew is on its own

➭ There might be quite significant times where we are in LOS

➭ *“to be on the safe side”* this needs to be considered for operations



‘Complex’ ops: resilience in AOS and LOS (“unmanned”)

- in AOS:
  - for operations where Ground is nominally “prime”, we might use the crew as back-up and for recovery in case of failures or technical problems
  - therefore most of the procedures have “alternate” crew blocks and ground blocks, which are identical in result

- in LOS (“unmanned”) or when crew cannot take over for recovery:
  - general design principle of our hardware/systems is: ***“safe without services”***
  - meaning each system has an (independent) internal control loop that allows for safe operations (at least temporarily) without need for interaction
  - if safe operation cannot be assured, there must be an automatism to bring the system back into a safe configuration or shut it down completely

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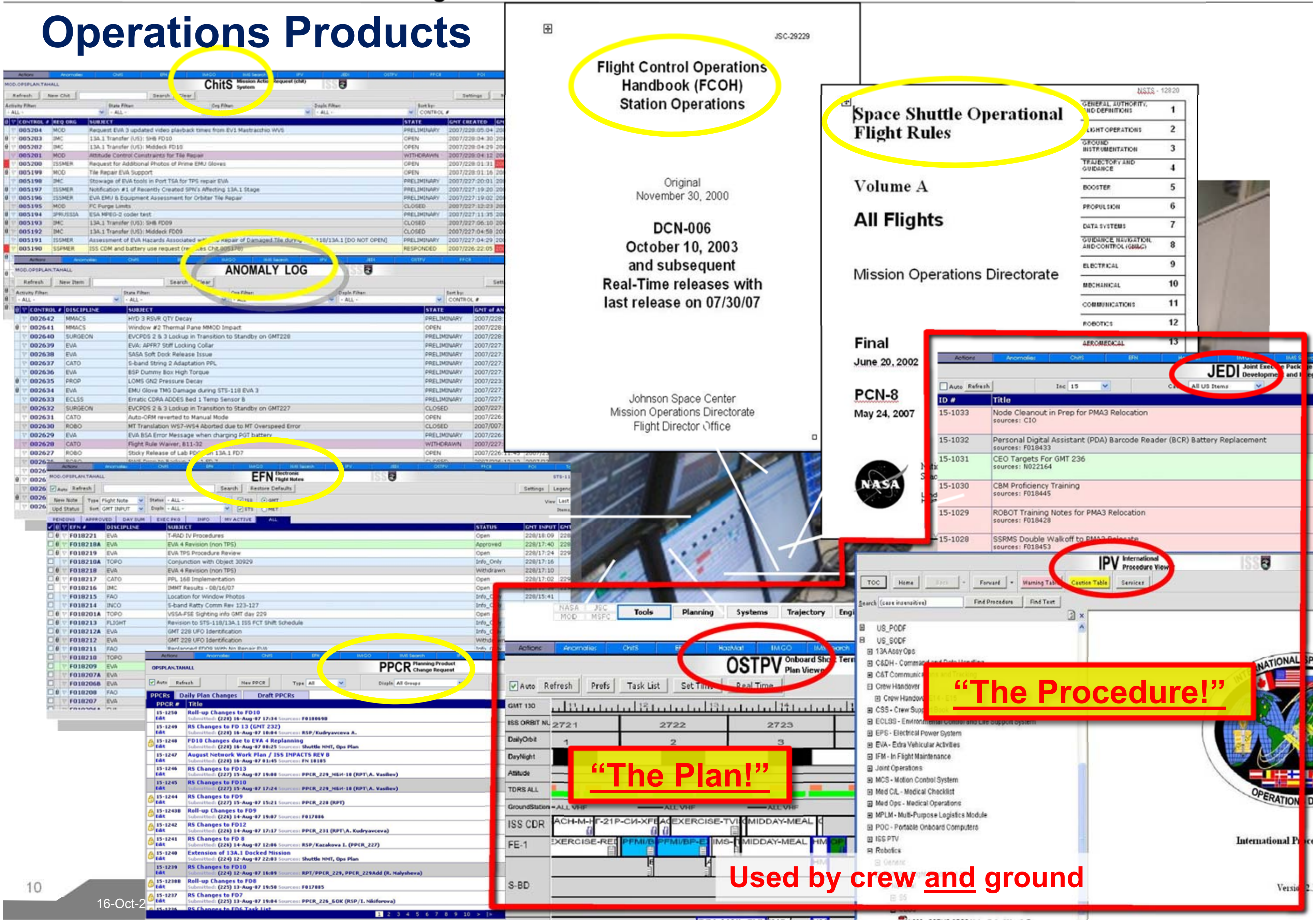
Operations Products



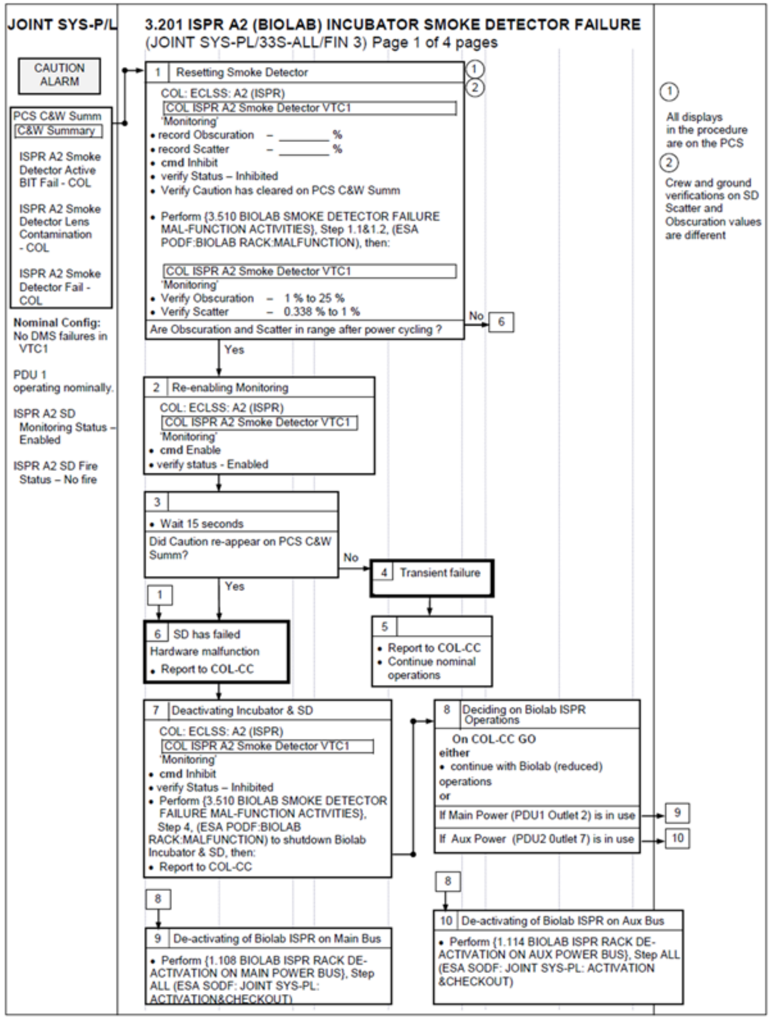
Operations based on procedures

- "The Plan": Detailed schedule of all activities
  - Showing all crew and all ground activities
  - Displayed electronically in the Onboard Short Term Plan Viewer (OSTPV)

- "The Procedure": Detailed instructions for all tasks
  - Covering all crew and all ground activities
  - Displayed electronically in the International Procedure Viewer (IPV)
  - Procedures are linked directly from activities in OSTPV

How do ISS procedures look

Logic Flow Procedures Format



Mainly used:

Checklist Procedures Format

2.305 BIOLAB TRIPLELUX EC PREPARATION
(Biolab Triplelux/ULF6 - ALL/BAS-1/HC/IMPACT US PODF) Page 10 of 13 pages

6.26 Remove Culture Tube B from Bag

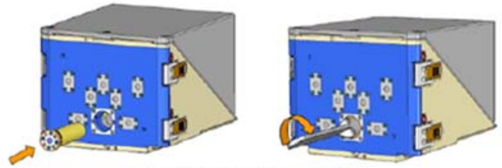


Figure 12. Culture Tube B Installation

6.27 Install Culture Tube B on EC HM Interface (Triplelux Multi Tool, rotate ↷ to lock, Figure 12)

Glovebox CMP — 6.28 sw AIR CIRC. → OFF/SEALED

6.29 Remove Glovebox Main Door

6.30 Remove Triplelux EC#1(#2) and EC HM Interface Foam (containing Dummy Cover) from Glovebox

6.31 Repeat from step 6.7 for Triplelux EC#2

7. OPENING INCUBATOR EC EXCHANGE DOOR

7.1 Doff Biolab TCU Low Temperature Gloves
ISS⇓ COL-CC to disable Smoke Detector Monitoring

COL-CC to disable Smoke Detector Monitoring {2.201 BIOLAB SMOKE DETECTION MONITORING CONTROL}, Step 3 (ESA_SODF: JOINT SYS-PL: NOMINAL)

On COL-CC GO

COL1A2_E1 (Incubator) — 7.2 Remove Inc Inspection Window Lid

7.3 Verify Incubation Rotors (two) – stopped (visually, through Inc Inspection Window)

7.4 Re-install Inc Inspection Window Lid

NOTE
The following instructions of this step are time critical. Please read before executing.

08 APR 10 — 2.305_E_BLB_TPLX_2306.xml

According to SSP 50253 Operations Data File Standards

How do ISS procedures look

Procedures also contain 'Operations Hazard Controls' in a standardised format (= safety information)

CAUTIONs shall be used for events that cause loss or damage to hardware that supports on-orbit life sustaining functions, critical mission support capabilities, and emergency systems.

CAUTION
Keep temperature sensor probes centered in duct opening to avoid damage to probes.

WARNINGs shall provide information necessary to ensure crew safety.

WARNING
CO2 discharge from US PFE is an asphyxiation hazard. Breathing Mask must be worn during and after discharge.

According to SSP 50253 Operations Data File Standards

Operational use of procedures

- Crew and ground **strictly** follow procedures
- Procedures are reviewed, verified and validated on ground (also during training) prior to final release
- Depending on the procedure purpose/topic there are several mandatory and/or optional reviewers
  (e.g. crew representatives, engineering, scientists, flight controllers, trainers)
- The safety organisation is mandatory reviewer of all procedures

Operational use of procedures

Why using detailed procedures:

- It's a help for the operator
  - no need to remember details by heart, concentrate on skills instead
  - give confidence that all necessary information is available to successfully perform the activity in time
  - "single source" of information (no need to verify or look-up in other documents)
- the validation process of the procedure should guarantee that the activity works as expected and will be successful
- review by safety organisation makes sure all (known) hazard controls are implemented
- **"situational awareness":** everyone is "on the same page" and knows what comes next (" *tell us in which step you are* ")
- Mandatory call-outs in the procedure are used to sync crew and ground

ISS⇓ **COL-CC** to disable Smoke Detector Monitoring

COL-CC to disable Smoke Detector Monitoring {2.201 BIOLAB SMOKE DETECTION MONITORING CONTROL}, Step 3 (ESA_SODF: JOINT SYS-PL: NOMINAL)

On COL-CC GO

Operational use of procedures

Procedures are **not** there to:

- **evaluate the operator** (good / bad execution).
  Procedures are not rating forms!
- **replace training**
  Anyway a procedure cannot replace skills.
- **replace highly qualified operators by "switch monkeys"**
  " you don't need to know, just do what's written in the procedure!"
- **eliminate other ways of solving a problem**
  There are also "alternate nominal" procedures.
- **restrict or limit the freedom to think on your own**
  If you think you have a better way to execute an activity, make a change request to the procedure.

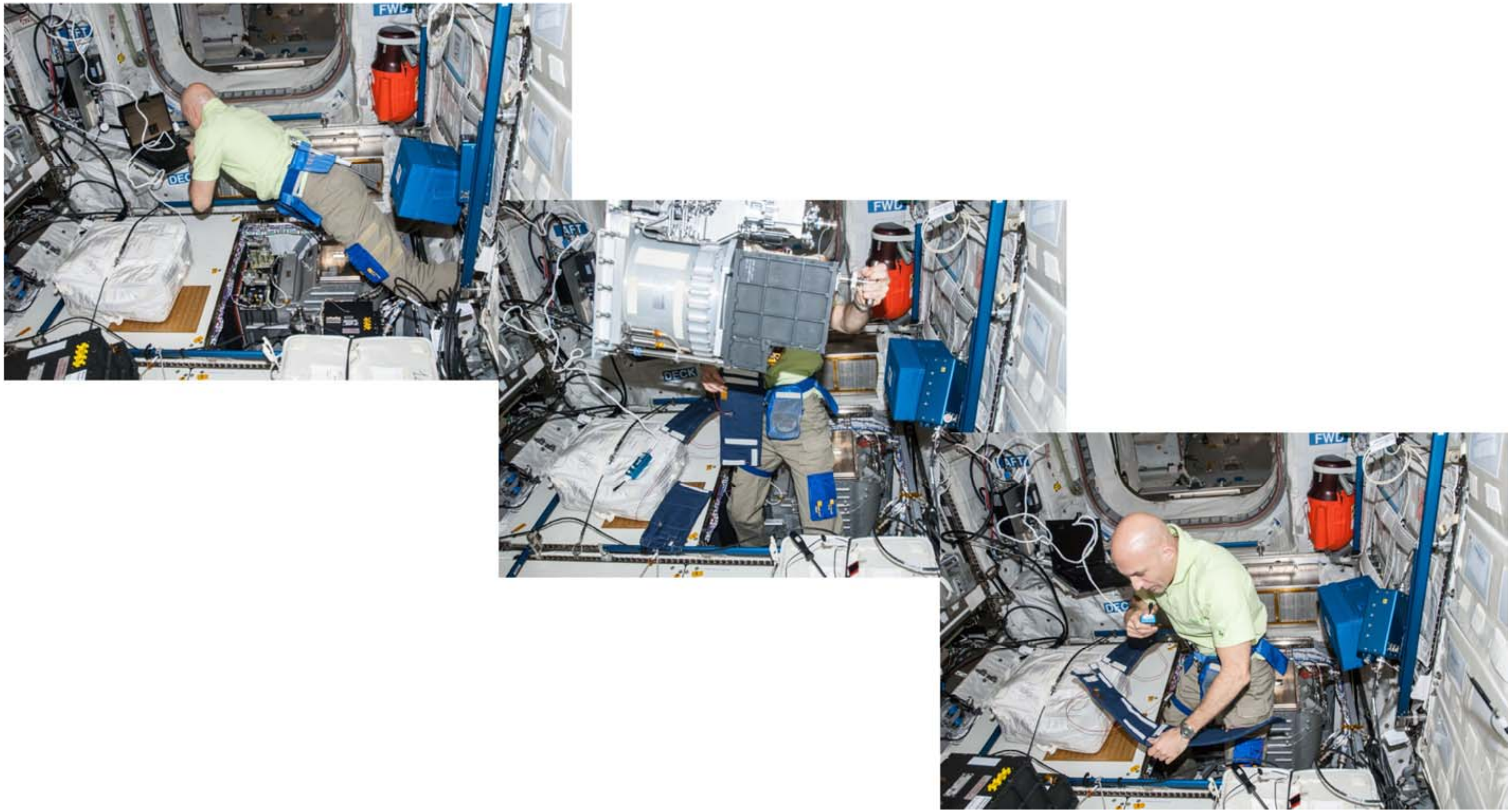
Operational use of procedures: Example 1

Extra Vehicular Activity: Luca EVA#23 critical situation, 16-Jul-2013

(video ≈3 minutes)

Operational use of procedures: Example 2

During exchange of Water Pump Assembly the noise insulation blanket did not fit . . .



Operational use of procedures

"Basics" for ISS operations:

- Strictly follow procedures
  (don't try to be "creative" on your own ☞ there's a high risk to leave the operational agreed envelope and you will "surprise" others)
- If in doubt, check with ground
- **No operations without procedure!**
- If the situation develops to go outside of an agreed procedure:
  - stop all activities
  - bring the situation/system back into a known safe configuration
  - if this is not possible, start contingency/emergency procedure
  - a new procedure will be developed and validated before continuation of the task
  - **Safety is more important than success!** (requires specific attitude)
- continue with the regular plan

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Astronaut training and challenges

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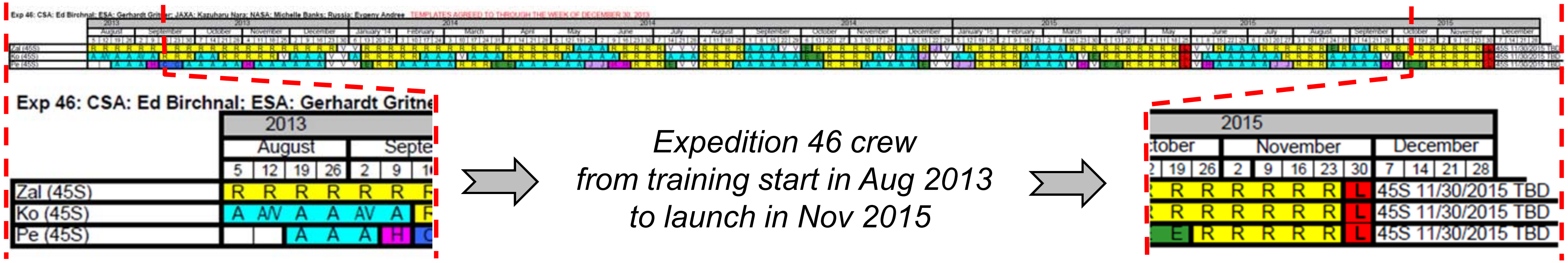

- Long training flow
  two years 'basic training'; waiting for assignment; 28 month flight specific flow
- Training based on skills and procedures
- Huge amount of training content
- From training level/time the crew members are rather 'alrounders'
  (than really specialists in a specific domain)
- Not everything can be trained close to launch
  (but everyone requests most recent training, e.g. all scientists want to get their experiment trained as late as possible)
- Simulations (nominal ops / emergency) are also used in crew training
- Simulation scenarios 'mimic' interaction with Flight Control Teams

Astronaut training and challenges

Main challenges are:

- Balanced information between ‘need to know’ and what is covered by procedure
- Main target is ‘skills training’ supported by procedures
- Procedures need to be ready in time for training
  (sometimes difficult due to late hardware development or certification process)
- If the concept of a procedure or important content has changed after training implementation, a “refresher training” or on-board-training (OBT) might be necessary

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Ground personnel training and challenges

Mission Control Centre, Houston (MCC-H)

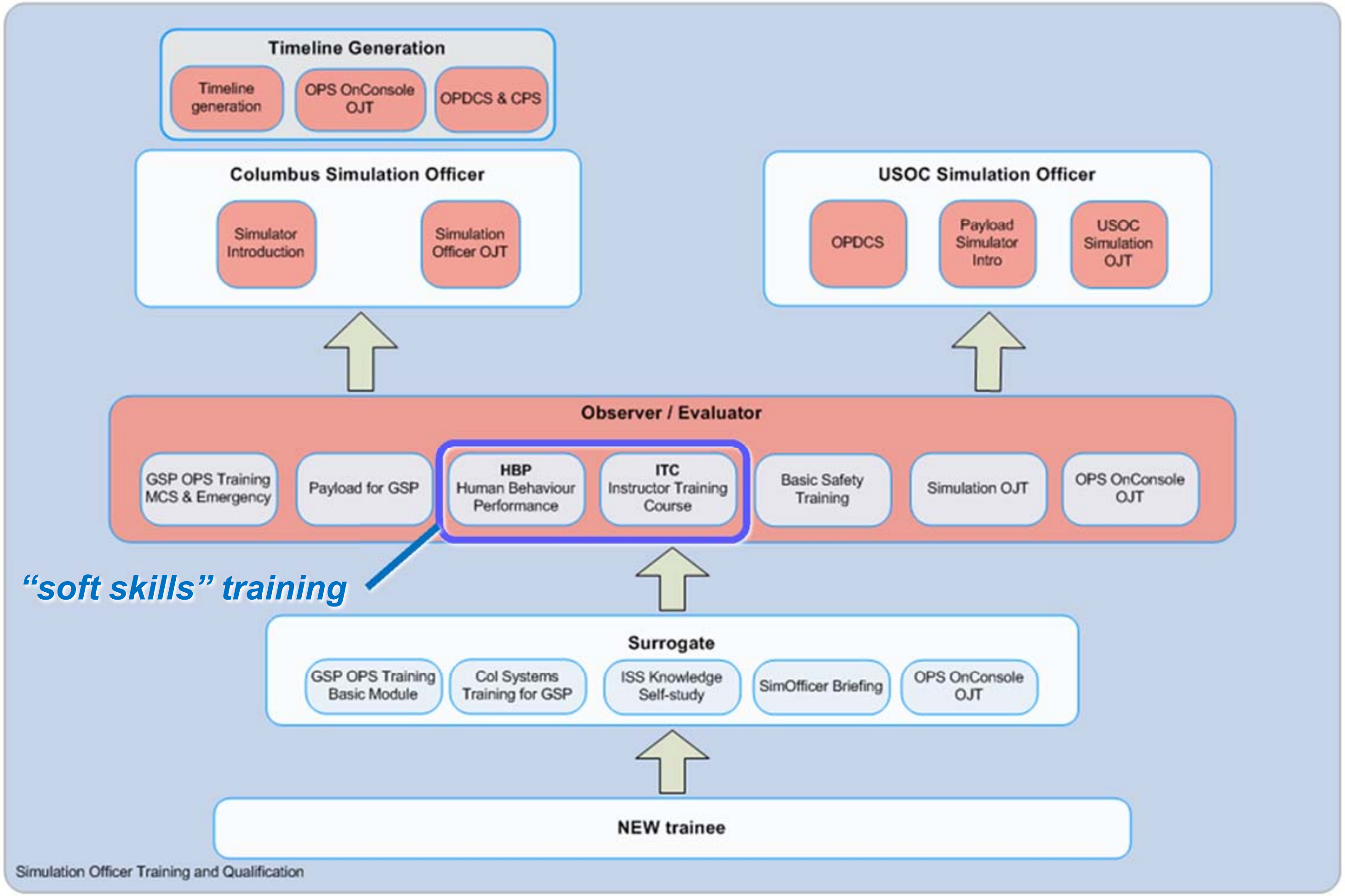
Columbus Control Centre, Munich (Col-CC)

Ground personnel training and challenges

- Controllers on ground are mainly highly qualified specialists for their system or experiment
- Besides their special field they get also general training courses for topics like ISS Program Overview, Daily Operations, Electronic Tools & Planning
- That includes a Human Behaviour and Performance (HBP) course:
  - Communication
  - Teamwork
  - Situational Awareness
  - Decision Making
  - Behavioural Observations
  - Behavioural Debriefings
- The certification of a Flight Controller is based on the performance during simulations

Ground personnel training and challenges

To prepare and implement the simulations for Flight Controller and crew specialised 'simulation officers' are trained and certified



Ground personnel training and challenges

Main challenges are:

- In remote ‘ground only’ operations the ground controller is the ‘owner’ of the activity. He is supposed to be the specialist and ‘master’.
  But when it comes to interactive operations, the controller has to step back and support the crew.
- Develop an attitude towards working together in a team to support the crew on orbit
  ☞ basically the astronauts on the ISS are our remote ‘eyes and hands’ to accomplish a common goal
- Being subject matter experts in their domain, sometimes the understanding is missing what a “non specialist” might need as support
- Especially in the beginning of training: Focused rather on technical details (in their own field) than on the situational awareness for the whole Flight Control Team

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How is feedback used to improve operations

As ISS operations is mainly procedure driven there are basically five focal points for feedback:

1. Ops products / procedures (including stowage information)
2. Optimisation of crew-time and planning
3. Hardware
4. Interaction with ground
5. Training (compared to experience on-orbit)

How is feedback used to improve operations

Feedback is collected throughout the whole process:

- Before mission/operations (e.g. as crew review / feasibility assessment during hardware development)
- During preparation of ops products and procedures (by defined review processes)
- During simulations (e.g. for interaction between crew and ground)
- During training (while a crew member uses a procedure or hardware)
- During real-time operations (direct verbal feedback or crew note)
- During post-flight crew debriefs (scheduled sessions for every crew)

Feedback to improve operations: A few examples

1.) Immediate actions to Luca's EVA #23 critical situation (excerpt):

- all further EVAs currently on hold
- Four independent teams established to investigate "Contingency EVA Capability"
- technical investigations on going on how to improve reliability of the suit cooling system
- developing "Water in Helmet: Response Sequence" (including training)
- Proposal for risk mitigation: considering snorkel as additional equipment (favorable trade when considering water inhalation risk)

Product/Analysis	Type
FN 58998: Water in EMU	Procedure
FN 58999: Expedited Repress	Procedure
FN 59001: Expedited Suit Doffing	Procedure
FN 59003: CO2 Sensor Bad	Procedure
FN 59000: Airflow Contamination	Procedure
EMU Go/No-Go (Pre and During EVA)	Flight Rule
Snorkel Build Procedure	Procedure
Snorkel Build On-Board	On-Board
Snorkel Certification (EMU Safety Only)	Analysis
CAM Buckle Inspection - SODF	Procedure
Crew CAM Buckle Inspection	On-Board
Crew and FCT Training Package Development	Training
Crew Training: Implementation	On-Board
FCT Training: Implementation	Training
Loss of Comm During EVA Protocol	Training

Feedback to improve operations: A few examples

2.) OSTPV (plan viewer) allows for direct entries of crew notes for each activity.

Example for a crew note requesting a procedure update:

"procedure X.XXX needs to be rewritten. I have never seen a procedure where a step is explained as a table. I may have done it in training, but I don't recall it at all.

. . .

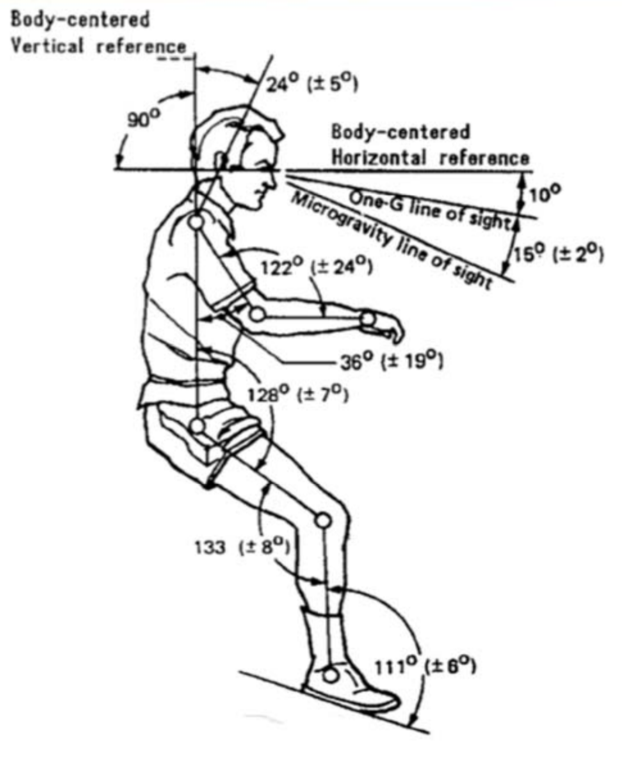
My strong recommendation is to make a video of it, going through the procedure step by step, showing each individual item (so it's easily recognisable), how and where it's connected, and the final general view."

Feedback to improve operations: A few examples

3.) Feedback for hardware usability from crew review or training

There are quite a number of technical reviews before hardware is delivered for operations or training, e.g.: SSP 57000, Pressurized Payloads Interface Requirements Document (including annex F “Human Factors Implementation Team (HFIT) Verification/ Certification”)

Microgravity Neutral Body Posture



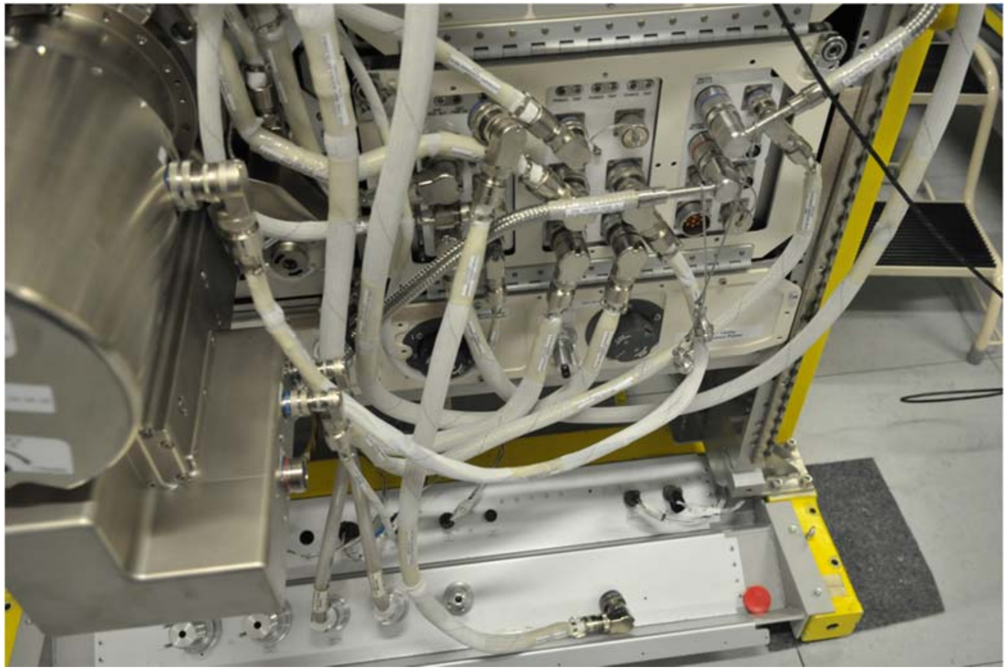
Ref: David L. Akin (2013), Spacecraft Habitability, ENAE 697 – Space Human Factors and Life Support

Feedback to improve operations: A few examples

3.) Feedback for hardware usability from crew review or training

As this comes quite late in the development process, not all requests can be implemented. Nevertheless frequent updates are:

- Clear, consistent, non-ambiguous labels (text on labels)
- Use of colour codes (e.g. for connector mating to ease identification)
- Removal of temporary obstructions to ease access (e.g. remove tethered connector caps)
- Define "optimal" installation sequence (to be included in procedure)



H/W installation check using a training model

Summary

- Multiple factors are contributing to 'complex' operations.
- One major driver of complexity is interaction between different teams, regarding situational awareness and communication.
- Strict use of procedures is one key factor to 'streamline' complex ISS operations.
- Procedures are also used to define operational envelops with respect to hazard controls and safety implementation.
- This strict use of procedures usually require a change in attitude and working style for all players (on ISS and on ground).
- Simulation scenarios are used for training and to practise 'complex' operations. Results from simulations are fed back into operations.
- Technical validation and feedback is used throughout training and operations. The attitude to consider feedback as positive trigger for improvement must be established.

Thanks for your attention!

Please feel free to ask questions.

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