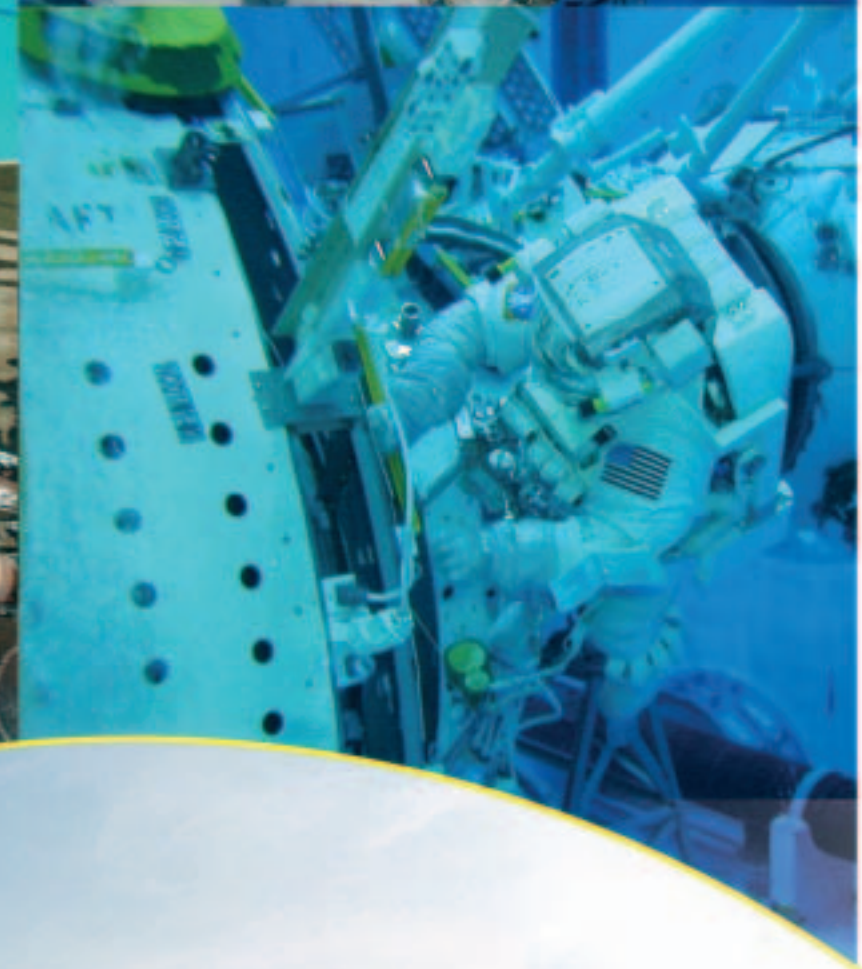
Preparing for Space

EVA Training at the European Astronaut Centre



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The European Astronaut Centre has developed an Extra Vehicular Activity (EVA) training course for ESA astronauts to bridge the gap between their scuba diving certification and the spacesuit qualification provided by NASA. ESA astronauts André Kuipers and Frank De Winne have already completed this 'EVA Pre-Familiarisation Training Programme' before their training at NASA. In June 2006, an international crew of experienced EVA astronauts approved the course as good preparation for suited EVA training; they recommended that portions of it be used to help maintain EVA proficiency for astronauts.

Introduction

During Extra Vehicular Activities (EVAs – spacewalks), astronauts venture from their protective spacecraft in autonomous spacesuits to work on, for example, the International Space Station (ISS) or the Hubble Space Telescope.

EVAs are among the most challenging tasks of an astronaut's career. They are complex and demanding, placing the astronauts in a singular, highly stressful environment, requiring a high level of

situational awareness and coordination while working at peak performance.

Careful and intensive preparation of the astronaut is key to safe, smooth and successful EVAs. Water is the best environment for EVA training on Earth, substituting neutral buoyancy for microgravity. Preparation is therefore centred on special facilities such as the Neutral Buoyancy Laboratory (NBL) at NASA's Johnson Space Center (JSC, Houston), the Hydrolab at the Gagarin Cosmonaut Training Centre (GCTC, Moscow) and now also at the Neutral Buoyancy Facility (NBF) of ESA's European Astronaut Centre (EAC, Cologne).

During their Basic Training, all astronauts undergo a scuba diving course as a prerequisite to EVA training. For NASA and ISS partner astronauts undergoing Shuttle Mission Specialist training, this is followed by a general EVA skills programme at JSC that also helps to identify the most suitable EVA crewmembers.

Unfortunately, it is becoming increasingly difficult for ESA astronauts to undergo this NASA training. With the last Shuttle launch in 2010, the agreement for ESA Shuttle Mission Specialist training will come to an end. Moreover, the intense period of Station assembly flights means that NASA's NBL is significantly overbooked for operational testing and mission-related EVA training. And work for future exploration missions will only add to the burden.

So EVA skills training will not be fully available to international astronauts. Yet assignment to an EVA depends on evaluating astronauts' skills early in their training, and it is important for assigning Station crews and tasks.

EAC therefore took the initiative to develop the 'EVA Pre-Familiarisation Training Programme' to bridge the gap between scuba training and NASA's EVA skills training. It better prepares ESA astronauts in their initial qualification for using the Shuttle/ISS spacesuit (the Extravehicular Mobility Unit, or EMU), and to provide cognitive, psychomotor and behavioural skills ahead of the NASA training.

ESA Astronaut Claude Nicollier takes a photograph during a break from servicing the Hubble Space Telescope

"Together with NASA astronaut Mike Foale, I was privileged to perform EVA-2 during the Hubble Space Telescope Servicing Mission 3A in December 1999. As an ESA astronaut assigned to JSC for 20 years by then, my situation was not common: EVA training and discussions had almost become part of daily life as one of the major disciplines that had to be mastered for assembly of the ISS, in addition to a couple of anticipated Hubble visits.

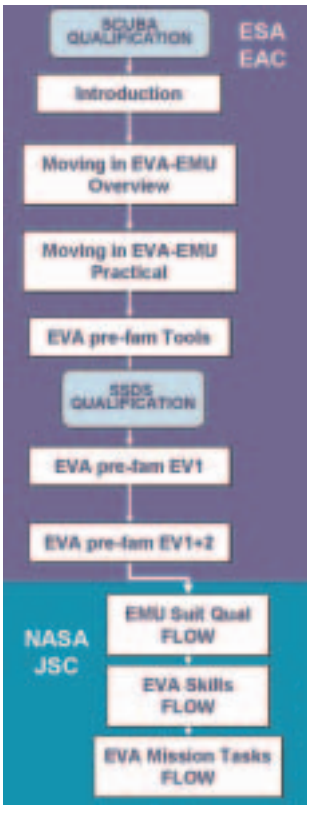
"In the future, European crewmembers will be less exposed to JSC's EVA culture than we were. Training in the Neutral Buoyancy Laboratory will not always be as extensive as it was, so preparation and preconditioning of astronauts from partner nations beyond the US and Russia are going to be a must for effective transition to the demands of training in the NBL.

"The preparation training provided at EAC's Neutral Buoyancy Facility will nicely fill that gap. Although without a spacesuit, it exposes the trainees to enough of the EVA challenges to be excellent preparation for NBL runs. Translation techniques, tether protocols, working under limited visibility and properly communicating with other crewmembers or the capcom/instructor can be exercised. It will give our astronauts a flying start in subsequent phases of EVA training, whether using the US Extravehicular Mobility Unit or the Russian Orlan spacesuit."

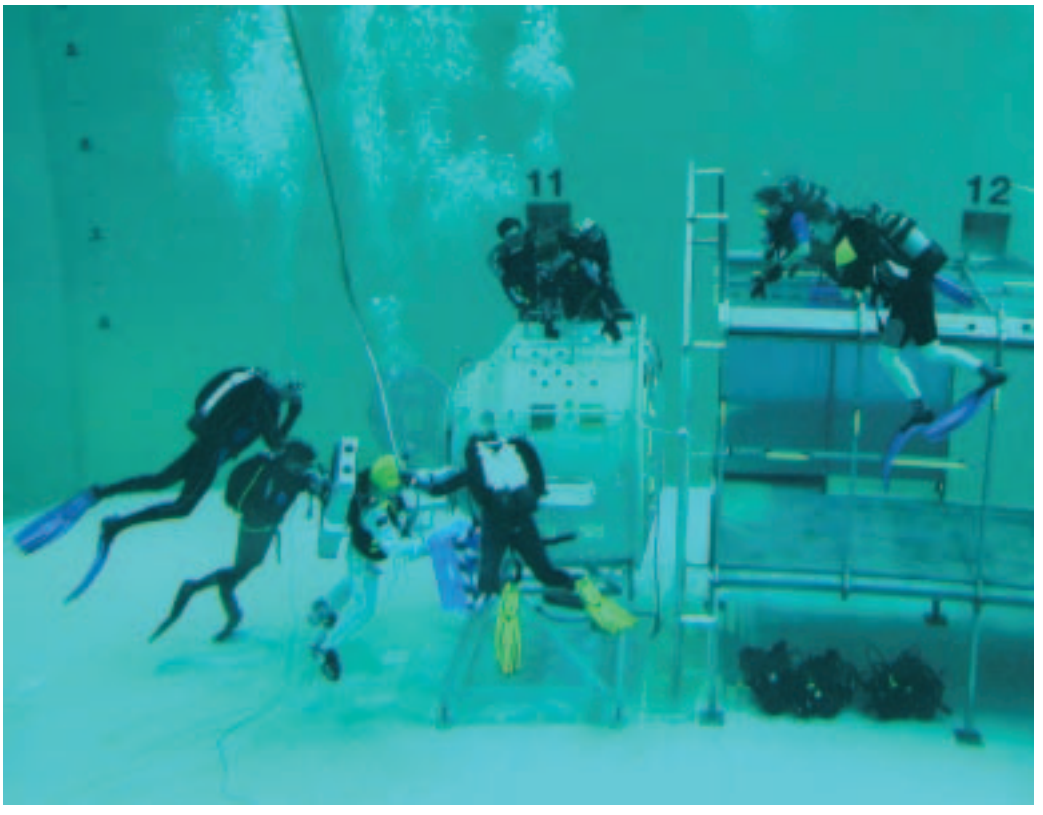
Claude Nicollier

EVA Pre-Familiarisation Training

A successful EVA requires psychomotor, cognitive and behavioural skills. Psychomotor skills range from the ability to move in the suit, move along the Station using handrails (translation) and pass obstacles, to operating equipment and tools. Cognitive skills are as important, and range from navigating around the Station despite the very limited field of view, to applying tethering and operational rules. Behavioural skills include situation and spatial awareness, decision-making and problem-solving, workload management and efficiency, teamwork and communication.



The training flow of ESA's EVA Pre-Familiarisation course at EAC



An ESA astronaut (white suit) performing the EV1 dive in EAC's tank. He is equipped with SSDS and a mockup of the life-support backpack

The objectives of the course are for the trainees to become able to:

- explain and demonstrate the correct use of a set of tools and equipment, including the transportation and installation of Orbital Replaceable Units (ORUs) and the manipulation of connectors;
- perform translation, rotation, passing of obstacles in a typical EVA translation path, while wearing EVA-like equipment, using safety tethers or waist tether protocol (Russian-like);
- perform a worksite assessment, secure oneself at the worksite and perform, alone or with a partner, a defined task including ORU exchange;
- handle tether operations, as in exiting from an airlock;
- plan a typical EVA as a 'buddy' team, and carry it out in cooperation with a crewmember inside the craft.

The course is spread over 1–2 weeks, consisting of a series of classroom courses, briefings and in-water exercises, scripted to challenge the trainees to think and perform as if they were conducting actual EVAs.

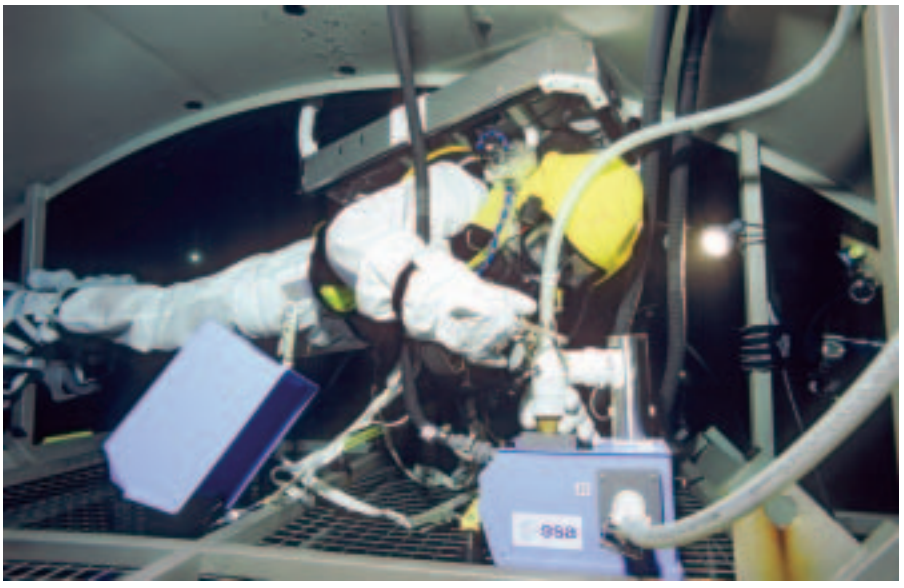
The main elements of the programme are:

- a description of the EVA course leading up to the EMU Suit Qualification in the NBL, to give an overview of the programme and general expectations during the training exercises to follow;
- an overview of the EMU suit, describing its biomechanics and constraints in water and space;
- a briefing on 'moving in space', providing recommendations on the best strategies for moving in the suit without fighting it, for moving along and around the Station structure while allowing for suit limitations and the Station constraints (obstacles, keep-out zones);
- a practical session of underwater exercises to apply the movement strategies. This training is in the NBF tank led by an instructor to demonstrate various methods of performing translations in different body postures, changing attitude and adjusting body orientations around confining structures;
- a briefing and hands-on training on deck describing the EVA tool operations and interfaces to specific wet equipment that will be used in the underwater exercises;
- the Surface Supplied Diving System (SSDS) qualification, required for voice communications between the trainee and the instructor in the Control Room (for details see the 'NBF Characteristics' box);
- a second session underwater, the 'EV1 Run', to highlight the fundamental skills of a typical EVA. It is performed fully equipped for SSDS and wearing a low-fidelity mini-work station strapped to the chest to carry EVA tools, a backpack representing the EMU's Primary Life Support System,

a representative helmet, a pair of unpressurised EMU gloves and boots suitable for foot restraints. There is a very limited set of tethers, along with dummy tethers deliberately to increase the likelihood of tethers snagging during translation. The trainee has to perform an end-to-end EVA including airlock egress/ ingress, ORU payload transportation to/from a worksite, translation using waist tethers (Russian protocol) and operation of ISS connectors. The trainee must always comply with the EVA rules: items and body must be tethered at all times, touch handrails only for translation, use only D-rings or handrails for attaching safety tethers, and avoid keep-out zones. Disturbances are introduced during the scripted run to exercise situational awareness, communication skills and decision-making;

– the third and final 'EV1+2 Run' underwater consists of a two-member EVA designed to emphasise teamwork and team situational awareness, crew communication and workload management, in an even more realistic and challenging scenario. The trainees are paired and encouraged to develop their own timeline and to define the sharing of their EVA tools. The equipment is the same as for the EV1 Run, except that the US safety tether protocol is used and the life-support backpack cannot be used owing to space limitations in the airlock. More tethers are also worn. The rules of engagement include all those of the EV1 Run plus additional constraints for an ORU change-out requiring specific tools from a toolbox at a second work site. The Test Conductor/instructor, who also plays the onboard crew role, inserts unexpected equipment failures and unplanned activities, adjusting the script's intensity to the crewmembers' performance.

These last two activities are controlled by a Test Director, responsible for leading the EVA operations and supervised by the Test Conductor. Both are in the Control Room, with a Medical Doctor and a Safety Officer, responsible for the well-being of the crew and the safety of the operations, and an Audio/Video Operator to ensure the distribution and recording of all required signals. The Dive Supervisor directs and monitors on-deck the pre- and post-dive activities of the Trainees, Safety, Utility and Camera Divers, SSDS operator and deck support personnel.



An ESA astronaut works with ISS connectors while standing in a portable foot restraint

A study guide and DVD package with the course material, videos of the EVA runs at EAC and additional reference documentation and EVA skill demonstration videos, as well as computer-based training material, is given to the trainees upon course completion.

During the past 2 years the Neutral Buoyancy Facility and its operations have been constantly upgraded and adapted for the programme. Around 20 certified staff are available for NBF and EVA operations, many with cross-certification for multiple operational functions. Operations documents, processes, checklists and dive plans have been developed to support smooth and safe diving operations. Safety processes have been defined and conducted to evaluate and (re-)certify the NBF and EVA infrastructure and equipment.

A Test Readiness Review process has been developed to ensure safety and readiness of the test operations, facility, equipment and personnel. It is called on for each diving campaign, for new or modified equipment and for changes in procedures, rules or operations.

An end-to-end test of the emergency rescue chain was run in June 2006, including external support from medical operations, onsite security, the water rescue team of the fire brigade, and rescue helicopter teams.

Training Runs for ESA Astronauts

Two ESA astronauts with no EMU experience were scheduled to start their EVA training in Houston in late 2005, as part of their ISS crewmember training programme: Frank De Winne and André Kuipers. Both had done scuba training at EAC, and André had already undergone Russian Orlan suit training in the Hydrolab at the Gagarin Cosmonaut Training Centre.

To help them, development of the training programme was accelerated in early 2005, and tested by experienced spacewalkers Claude Nicollier and Gerhard Thiele.

Neutral Buoyancy Facility Characteristics

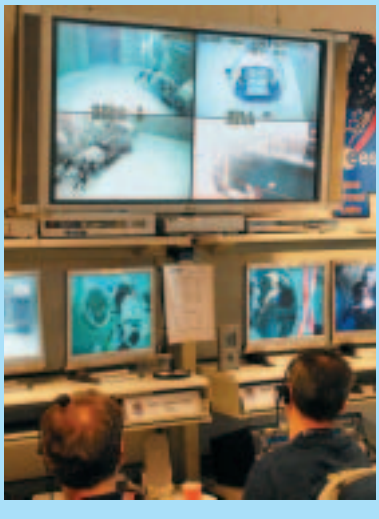
NBF Hall, Rooms and Equipment
- 48 m long, 24 m wide and 14.4 m high
- NBF control room, scuba equipment room, EVA equipment room, electrical and mechanical repair shop, scuba filling station, technical rooms for pool maintenance, water filtration/purification, control and heating, showers/dressing rooms and sauna
- Remote air compressor with storage tank assembly including high-pressure feedline connection to multiple filling station in NBF hall
- Overhead girder crane with 5 t capacity

Water Tank
- 22 m long, 17 m wide and 10 m deep, volume 3747 m^3, temperature range 27–29°C
- Submersible platform 5x3.5 m for 0–9.5 m depths, 250 kg loading capacity at 0 m
- Continuous monitoring of water quality (e.g. pH value, chlorine, temperature)

Mockups
- Modified Columbus wet mockup with ISS handrails and EVA workstations
- Russian airlock mockup
- deployable solar panel mockup

Scuba and SSDS Diving Equipment
- 20 complete sets of scuba equipment (tanks, regulators, suits etc)
- 3 SSDS sets composed of:
  - full-face mask with microphone and earphones for 2-way communications between SSDS divers and on-deck personnel;
  - buoyancy jacket including inflator, with 6 litre/300 bar reserve air tank, pressure gauge and dive computer;
  - 60 m umbilical hose connected to deck air supply and for communication cables.
- SSDS cart on-deck hosting umbilicals, air tanks, pressure-monitoring devices and video and audio monitoring

EVA Tools
- ISS handrails mounted on airlock and Columbus mockups
- Portable Foot Restraints (PFRs) mounted on EVA worksites on Columbus mockup
- EMU-like boots for use with PFR
- EMU Primary Life Support System backpack, helmet and gloves (unpressurised)
- Mini Work Stations
- limited sets of EVA and dummy tethers
- EVA connectors (electrical and fluid)
- ORU box and EVA tool box



NBF Control Room
- Video: 8 channels, including switching matrix for observation and multiple recording of underwater and deck operations
- Additional monitor with switching matrix for deck personnel in NBF hall
- Audio: 2 audio loops for bi-directional communications between deck personnel and between deck personnel and divers (including private loops with SSDS divers)
- Underwater loudspeakers for unidirectional communication with all divers
- Wireless headsets for deck personnel

Frank and André completed the course in three slots. The first two, in June and September 2005, covered everything up to the EV1 Run so that they could gain their EMU Suit Qualification at JSC. Feedback from them and their NASA instructors confirmed that the ESA programme had significantly contributed to their performances during the first training run in Houston. They also provided valuable suggestions for improvement.

The training concluded in March 2006 before Frank and André resumed their EVA training at JSC, and focused on the EV1+2 Run. Both asked to perform it again some time as a refresher, because it appeared to be useful for proficiency training.

Frank and André's EVA Pre-Familiarisation Training was fully coordinated with NASA's chief EVA instructor. Following this success, the NASA EVA office decided to have international and experienced EVA crewmembers perform an official review to validate the training.

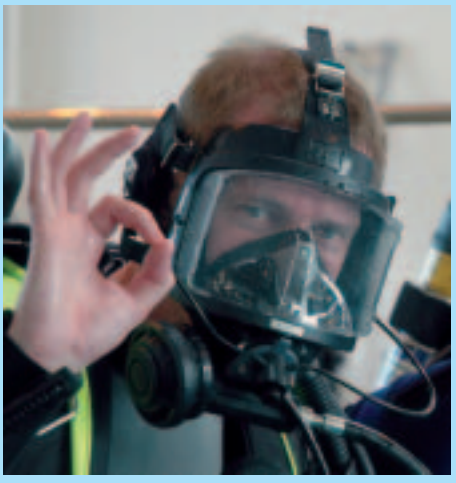
Cooperation with NASA

This programme was developed through very fruitful cooperation, first proposed in 2002, between EAC and the EVA training experts at JSC.

As a first step, NASA-NBL and ESA-NBF in 2004 jointly agreed on a *Diving Certification Protocol for ISS Crew Members and Training Specialists* to harmonise the requirements for scuba diving proficiency training and certification. The logical next step was to extend the cooperation to the NASA EVA Office to identify jointly how EAC could improve the preparation of European astronauts for future EVA training at the NBL. This led to the signature of a *Framework of Cooperation between the NASA EVA Office, NASA Neutral Buoyancy Laboratory (NBL), NASA EVA Operations and the ESA Neutral Buoyancy Facility (NBF) for the preparation of European Astronauts to EVA Pre-Familiarisation*.

As a result of this agreement, NASA provided 40 hours of EVA training to ESA instructors Loredana Bessone and Hervé Stevenin, including a 4-hour EMU Suit Qualification at NBL. It was the first time that non-astronaut Europeans had received such training at JSC. In cooperation with the NASA instructors, objectives were identified, requirements defined and the new course developed, tested and in place at EAC in less than a year.

In December 2005 an *ESA-NASA EVA Pre-Familiarisation Workshop* took place at EAC over a week to demonstrate the ESA course to NASA EVA experts, including the supporting NBF operations and EAC's safety set-up. NASA feedback and recommendations were integrated and ESA and NASA jointly developed the EV1+2 Run.



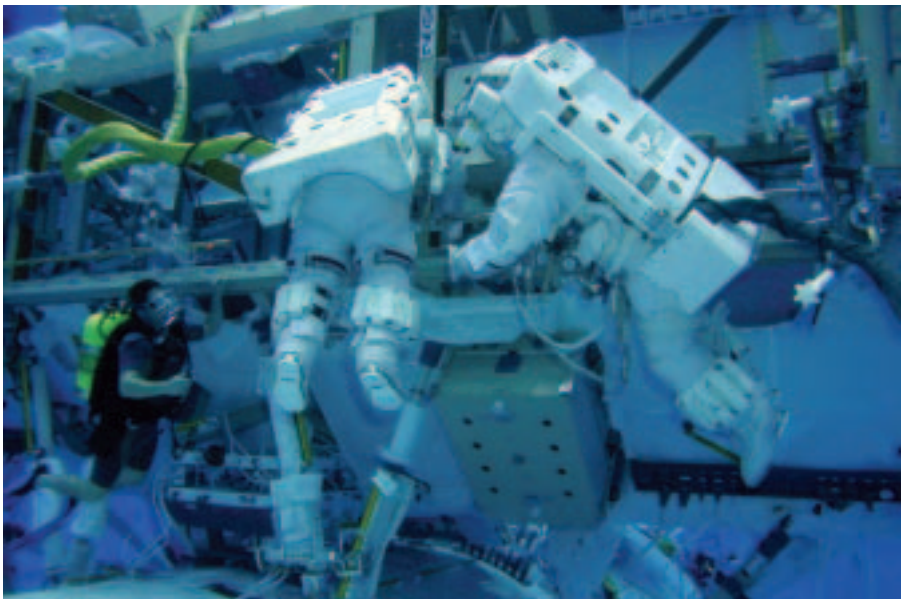
Frank De Winne in the SSDS mask at EAC

"This training really helped me in preparing for the first EVA runs I had to do at JSC. During my first runs in the NBL, I was really amazed to see how much I had learned from these first simulations. This EVA precursor training is, for me, the first step in acquiring European expertise in operational training, beyond the normal system training that is already performed at EAC."

Frank De Winne

Claude Nicollier undertakes the pre-familiarisation training at EAC

ESA instructors Loredana Bessone and Hervé Stevenin work in JSC's Neutral Buoyancy Laboratory to gain their NASA Suit Qualification



ESA-NASA-JAXA Crew Review

The success of the workshop raised the interest of the NASA Crew Office, who decided to perform an official Crew Review, to assess the suitability of ESA's course for inexperienced EVA crewmembers, and the suitability of the EV1+2 run for maintaining the proficiency of experienced EVA crew during long periods of non-EVA training.

The following astronauts took part as trainees to evaluate the course:

- Scott Parazynski, NASA (former Chief of the NASA Astronaut Office EVA Branch, has logged 20 hours of EVA);
- Koichi Wakata, Japan Aerospace Exploration Agency (JAXA; two spacewalks);
- Paolo Nespoli, ESA (working for the NASA Astronaut Office EVA Branch).

They were supported by a NASA delegation that included representatives from the EVA office, the NBL and NASA Safety. Stephen Doering, Head of the NASA EVA Office, also attended the training at EAC. The first week consisted of a thorough safety inspection, and the preparation and execution at EAC of a joint NASA-ESA Test Readiness Review to ensure that both parties had a common agreement on the safety and operational readiness of the programme before the the crew arrived.

The participants in the ESA-NASA-JAXA Crew Review, June 2006

This event was followed by an intense week of training for the three astronauts, who went through the complete course. They provided outstanding feedback, including detailed recommendations to improve the quality even further. As a close-out of this Crew Review, all of them delivered reports to a NASA *EVA Crew Consensus Memorandum for Validation of the European Astronaut Centre EVA Pre-Familiarisation Training Program* issued by Dave Wolf, Head of the EVA Branch in the NASA Crew Office.

ESA Astronaut Paolo Nespoli (left) and NASA Astronaut Scott Parazynski prepare for a dive

Conclusion

The ESA EVA Pre-Familiarisation Training Programme has proved to benefit ESA astronauts who have not yet been through EVA training at JSC or GCTC ("*EAC personnel are to be commended for their innovation and hard work preparing this excellent course*" said Dave Wolf). It will also be of great value to the new ESA astronaut candidates, who will begin Basic Training at EAC within the next 2–3 years.

The programme not only prepares ESA astronauts for assignment to ISS EVA crews. As reported in the Crew Consensus Memorandum, "*it has also considerable potential to aid current ESA astronauts in general proficiency maintenance of EVA operations and situational awareness while not assigned to training at JSC or GCTC*".

The memorandum also states "*other*

Thomas Reiter during his ISS spacewalk on 3 August 2006

International Partner astronauts not in full time training at JSC or GCTC might find this program beneficial prior to commencing suited EVA training". This innovative ESA programme is an open door to extend current EVA cooperation to the other ISS partners.

Besides crew training, the NBF infrastructure (including the EVA expertise available at EAC) can also test space hardware underwater. The first underwater test of Eurobot is scheduled before the end of 2006.

Last but not least, this programme has provided ESA with valuable expertise in developing and performing spacewalk training. Combined with the EVA experience acquired by the ESA astronauts through their space missions, it is helping to build operational knowledge at EAC for Europe on the challenges of EVAs, which can only be beneficial for future human spaceflight exploration.

Acknowledgements

Numerous individuals and organisations made this course possible through their expertise, support and dedication. Our gratitude goes to all of them, but since it is impossible to name them all, the authors thank the organisations they represent: NASA-NBL, NASA EVA Office and EVA Operations, NASA JAXA and ESA Astronaut Offices, NASA and EAC Safety. The diving team from SDT&S, DLR Technische Dienste, DLR Institut für Luft- und Raumfahrtmedizin and EAC Medical Support Office, Berufsfeuerwehr Koeln and Taucherrettungsgruppe der Berufsfeuerwehr Koeln, ADAC Luftrettung 'Christoph-Rheinland', Polizeifliegerstaffel West. A special mention goes to the divers and EAC team members involved in the NBF/EVA operations.

Further information on the European Astronaut Centre and its activities can be found at www.esa.int/eac