IAA

Position Paper
on

EVA SAFETY

SPACE SUIT SYSTEMS INTEROPERABILITY

July 14, 1996

The International Academy of Astronautics (IAA) a non governmental organization recognized by the United Nations was founded in 1960. Since that time, IAA has brought together the world's foremost experts (1216) in the disciplines of astronautics on a regular basis to recognize the accomplishments of their peers, to explore and discuss cutting-edge issues in space research and technology, and to provide direction and guidance in the non-military uses of space and the ongoing exploration of the solar system. The purposes of the IAA, as stated in the Academy's statutes are to foster the development of astronautics for peaceful purposes, to recognize individuals who have distinguished themselves in a branch of science or technology related to astronautics, to provide a program through which the membership can contribute to international endeavors and cooperation in the advancement of aerospace science, in cooperation with national science or engineering academies. Prof. Ed. Stone is president of the International Academy of Astronautics.

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1. Purpose

Assembly and maintenance of the International Space Station (ISS) will, by the end of this century require some 25-40 extravehicular activity (EVA) sorties of 300-500 EVA-hrs per year. This annual effort is equivalent to the total Russian Salyut-MIR or the US STS accomplishments till today.

Anomalies in EVA hardware and crew performance have occurred, fortunate enough without any serious consequences for the crew. With the tremendous increase in EVA activities in the near future, the significant potential risk in these operations must be minimized to what ever extent possible to prevent disastrous events from happening. Future scenarios include EVA space suit systems, transport vehicles and orbital space bases of different national origins to cooperate very closely together. As the purpose of an EVA space suit system, in addition to permitting routine operations outside of a spacecraft, includes emergency support between EVA crew members and emergency back-up for some automated spacecraft systems, the desired future scenario must permit an EVA space suit system of any national origin to support any other space suit system or spacecraft regardless of its origin, i.e. space suit interoperability is mandatory.

However todays existing and planned US and Russian EVA space suit systems (Fig. 1) can not provide a bare minimum of emergency support to systems of another nationality, nor can they presently be used in routine operations from a spacecraft of another nationality as a base.

Even the joint airlock configuration planned for the International Space Station only partially addresses the incompatibility. The use of multiple umbilical configurations and interface adapters are necessary in the joint airlock to provide for pre- and post-EVA life Support functions, including EVA systems servicing and expendables replacement.

The purpose of this position paper of the International Academy of Astronautics is to draw the attention to the lack of space suit systems interoperability and to make recommendations, both system specific and generic, on how to improve the situation based on identified EVA space suit system interoperability deficiencies. This will support decision makers and engineers in providing a maximum of safety and operational flexibility of future EVA space suit systems expected to be necessary for the operation of space transportation vehicles and orbital bases.

2. Executive Summary

2.1 Background

In the past decade and a half some very ambitious and spectacular Extravehicular Activities have been performed in LEO from the Salyut/MIR orbital complexes and from the Space Shuttle like satellite retrievals, external space complete maintenance and repair, welding, structure's assembly, and repair and refurbishment of the Hubble Space Telescope.
The total Soviet/Russian EVA activities from Salyut/MIR (1977 - February 1995) represents 112 cosmonaut-sorties at 452 hrs, and the US STS EVA activities (1983 - February 1995) 59 astronaut-sorties at 348 hrs.

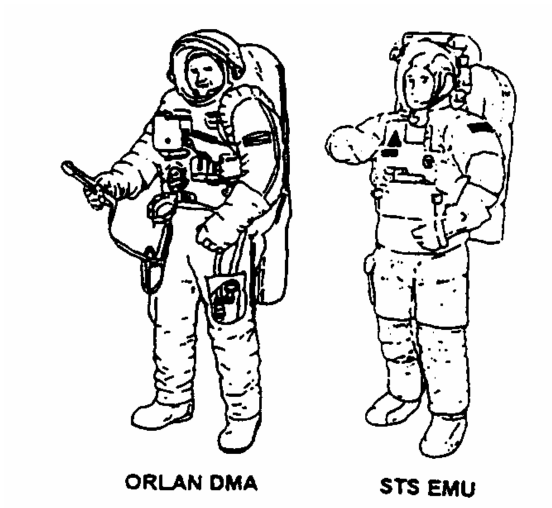


Fig. 1: EVA Space Suit Systems

The assembly and maintenance of the International Space Station will, at the end of this century, typically require some 25 40 EVA's (50-80 cosmonaut/astronaut-sorties) of 300 500 hrs annually.
This represents a yearly effort, when compared with the total Soviet/Russian effort in 18 years or the US effort in 12 years, of more than one order of magnitude increase in EVA activities (Fig. 2)!
This significant increase in the number of EVA's requires space suit systems that provide a maximum of interoperable capability for safe, efficient, and flexible operations. Ideally, different systems used should be operable from all of the station complex airlocks, by other countries crewmembers, and with mothercrafts being fully supportive of all systems in case of an emergency. At a minimum, different space suit systems must be operationally compatible with exterior translation, worksite restraint, and free-float safety tethering and/or rescue provisions; communication systems; and with equipment interfaces and tools necessary for station assembly, repair, and maintenance.

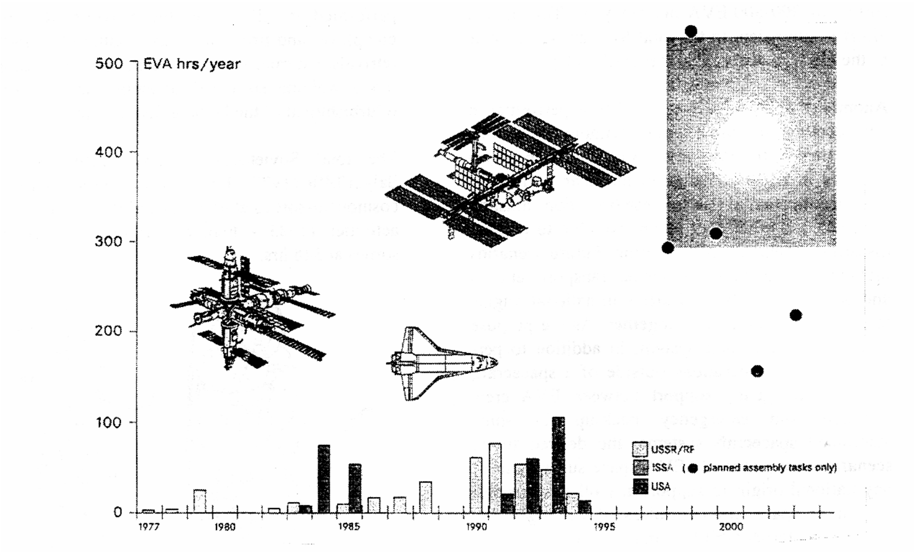


Fig. 2: Annual EVA Effort

2.2 Interoperability Incompatibilities

Existing and enhanced design space suit systems (US STS EMU and Russian Orlan DMA/M) and their respective mothercraft systems (MIR, STS, ISS) have been assessed with respect to essential and critical parameters for nominal and emergency EVA interoperability (Table 1).

TABLE 1: Interoperability Criticality

	Nominal EVA	Emergency EVA
Prebreathing	Not Critical[1)]	Critical
Hatch diameter	Critical	Critical
Airlock pressure profile	Not Critical[1)]	?
Communications	Critical	Critical
Life Support during airlocking	Critical	Critical
Foot restraints	Critical	Critical
Safety tethers	Critical	Critical

Handholds	Critical	Not Critical
Tools	Critical	Critical
Logistics	Critical	Not Critical

Note 1: Two different protocols of prebreathing do not require suit modifications, but make it difficult to perform simultaneous sorties with two different suits from the same airlock

When comparing the various existing EVA systems for interoperability of critical parameters for nominal operations and/or emergency operations following critical incompatibilities (No Inter-operability) can be identified:

Nominal EVA	**Emergency EVA**
	- Prebreathing
- Hatch Diameter	- Hatch Diameter (TBC)
- Communication	- Communication
- Life Support	- Oxygen Supply
- Safety Tethers	- Safety Tethers
- Tools	- Tools
- Handholds	- Handholds
- Foot Restraints	
- Logistics	

Thus in all cases presently no interoperability exists between the STS EMU and the Orlan DMA/M due to incompatibility of communication systems and the Airlock Interface Control Panel/Umbilicals. As for the hatch dimensions, the largest STS EMU size is critical for use in the MIR emergency airlock and needs further investigation.

Oxygen prebreathing is required before decompressing the airlock to vacuum due to reduced suit pressure to avoid decompression sickness symptoms. Different prebreathing protocols are used due to different R-factors and suit pressure requirements and are an operational inconvenience for nominal operations which ought to the further analysed. For emergency situations a harmonization of prebreathing protocols is mandatory to ensure immediate response actions.

Other critical incompatibilities are associated with auxiliary EVA equipment like safety tethers, handholds, tools and foot restraints.

Future space suit systems can be envisaged to rely more on the use of modular replacement or exchange units for resupply of consumable resources and for exchange of life limited items: one key to commonality and an interoperability issue for such systems will be the standardisation of selected modular units. Such standardisation would permit for example, the interoperability of space suit systems having a common interchangeable oxygen tank or CO_2 removal cartridge.

2.3 EVA Safety Recommendations

The necessity to remove critical incompatibilities to enhance mission flexibility and in particular to increase the level of safety for EVA operations can be summarized into following recommendations:

- Airlock hatch dimensions for suited transfer is a necessary standardisation effort to provide for the full access required for international interoperability.
- RF communications capability between EVA crewnumbers, mothercraft, and ground flight controllers is a time-issue pending results of planned STS-MIR mission evaluation of RF communications between both nations EVA crewmembers through a common spacecraft to spacecraft communications link. Should this RF communications approach prove unsatisfactory, future standardization of all EVA crewmembers space suit RF communications systems would be required.
- Standardized prebreathe protocols and potentially suit pressures to support simultaneous EVA with different space suit systems would add significant operating redundancy and in particular safety to EVA emergency operations.
- Life support interface control panels and umbilicals interfaces must be standardised either by design or by implementing adapter technology for both critical fluids and power. An intermediate alternative to this could be to provide a separate "emergency" umbilical common to all suit configurations.
- Safety restraint tethers must be standardised for future space suits to minimize operational complexities related to tether hooks design and attachment, use, procedures and potential tether line entanglement between EVA crewmembers.
- Foot restraints and space suit boot interfaces must be standardized to permit two-handed work task performance of EVA crewmembers whenever required.

The EVA space suit system provides not only routine operations capability outside a spacecraft but also the emergency back-up for the mothercraft and other space suit systems, and thus in future international cooperation scenarios an EVA space suit system of any national origin must be able to support any other space suit system or spacecraft regardless of its origin. Therefore space suit interoperability is mandatory to warrant a maximum of safety.

3. Introduction

Presently two EVA space suit systems are operational, the Space Shuttle EMU in the United States (US) and the Orlan DMA for MIR in the Russian Federation (RF). However they are not compatible with each other or the EVA support system of the other nations mothercraft. Without modifications and adaptations these space suit systems do not even provide the possibility for basic support of each other in case of emergency operations such as rescue, except for the capability of one EVA crewmember to transport a disabled EVA crewmember

manually back to his mothercraft's airlock. Closing the EVA hatch from outside, is only possible for STS.
The modified Space Shuttle EMU and the modified Orlan M planned for the assembly and initial operation of the International Space Station (ISS) do not presently provide any significant improvements with respect to potential interoperability and enhanced safety. In the ISS Joint Airlock it will be possible to use either EMU or ORLAN M space suits simultaneously only with separate umbilicals connected to and compatible with individual airlock interface control panels.
Future space activities are being based more and more on cooperative international efforts, e.g. Shuttle flights to the MIR station and the International Space Station. No joint US-RF EVA sorties are currently planned for the ISS assembly and build-up (Ref. 1). Should difficulties arise during an EVA sortie, only the RF Orlan space suit system may be available outside within a short time to assist. The converse is not true. The (4,5-hours) prebreathe protocol of the US EMU extends its response time to beyond the nominal 6-hours duration of scheduled EVA's.
Other joint operating scenarios, such as routine EVA-support and rescue situations, can also be envisioned. During these joint scenarios, interoperability capabilities of the different space suit systems and interface compatible or common tools and EVA support equipment would greatly enhance nominal mission flexibility. A minimum quick response and interoperability of suits/mothercraft appears to be highly desirable to allow back-up support and to increase the level of safety (i.e. to reduce the probability of loss of human life).
Interoperability also adds "robustness" to EVA system operations. When unforeseen events occur during EVA, a robust EVA system has alternative operating modes that support human ingenuity in resolving problems. Inevitably, as manned space missions increase in duration and occur further from earth, task specific training prior to flight to cover all imaginable problems becomes less and less feasible. The flight crew, acting in real time, will assume more "real time" responsibility in devising solutions to problems. This in turn, will drive the requirement for a more robust EVA system. Increasing the interoperability of the current and presently planned EVA systems is a first step towards increasing safety and robustness of future EVA systems.
At the 9th IAA Man-In-Space Symposium held in Cologne, June 1991, representatives of all EVA space suit developing agencies and industries met for the first time altogether in an EVA session. During a round-table discussion with an EVA astronaut and cosmonauts, and representatives of the medical and engineering disciplines the technical and operational differences of the existing and planned space suits (STS EMU, Orlan DMA and the planned European Space Suit) were discussed (Ref. 2).
All participants of this round-table discussion shared the opinion that a strong effort should be made to implement space suit interoperability in future to provide capabilities for joint EVA operations. With the increasing number of planned international joint missions and development of an International Space Station, requirements for possible interoperability of future EVA space suits have increased considerably. Today's space suits provide little if any interoperability, especially from a safety point of view.
The members of the round-table group recommended the formation of an independent international committee, preferably within the International Academy of Astronautics (IAA), to further analyse the issue and elaborate recommendations to identify and propose solutions to the interoperability aspects of EVA space suit systems.
This proposition was adopted by the IAA, and a Committee on EVA Protocols and Operations was set up to meet for the first time in October 1991 in Montreal during the 42nd International Astronautical Congress. The committee now represents all space agencies involved in manned space activities together with the major industries involved in EVA activities (Appendix 1). Since its founding the committee has convened seven times.

This report represents the consorted results and recommendations to improve interoperability of future EVA space suit systems as elaborated by the IAA Committee on EVA Protocols and Operations.

4. Assessment of Major Issues

4.1 Review of Critical Parameters

Taking the current Russian and US space infrastructure into account, and its planned near term enhancements, the EVA elements to be considered in a time frame up to the early 21st century are:

- Space Suit Systems:
  - STS EMU
  - - Enhanced EMU
  - - Orlan DMA
  - - Orlan M

and their coexistence with:

- Mothercraft Systems:
  - MIR 1 Space Station
  - Space Shuttle (STS)
  - International Space Station (ISS)
    - US Segment Joint Airlock
    - Russian Segment Airlock
    - EVA Aids (tethers, handholds, foot restraints)

The enhanced EMU (US) and the Orlan M (Russia) are the new, modified space suit systems presently under development for use on the ISS (Ref. 3-5). The essential and critical parameters for a compatibility analysis, and thus the crucial characteristics determining a possible interoperability, have been defined for both nominal and emergency EVA's (Table 2).

TABLE 2: Critical Parameters for Compatibility Analysis

Nominal EVA
1. Prebreathing (denitrogenation)
2. Airlock hatch diameter
3. Airlock decompression/recompression pressure profile
4. Communications voice and data (radio and umbilical)
5. Life support during airlocking (airlock/vehicle Interface Control Panel and umbilical configuration) - O2 supply - H2O cooling - Feedwater resupply/condensate drain - Power - Intravehicular communication
6. Foot restraints
7. Safety tethers
8. Handholds (stand-off)

7. Safety tethers
8. Handholds (stand-off)
9. Tools
10. Logistics
Emergency EVA
1. Prebreathing
2. Airlock hatch diameter
3. Airlock decompression/recompression pressure profile
4. Communication
5. Suit interfaces (airlock/vehicle Interface Control Panel and umbilicals)
6. Safety tethers
7. Handholds
8. Tools

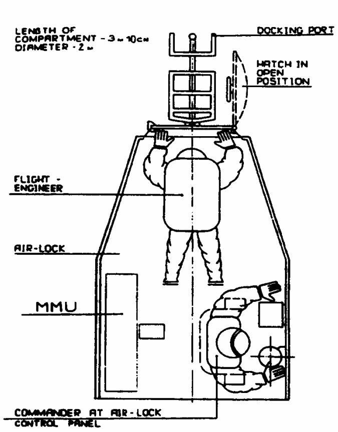
The relevant spacecraft/vehicle characteristics, space suit system parameters and EVA protocols for interoperability assessments are shown in Appendix 2.

4.1.1 Prebreathing

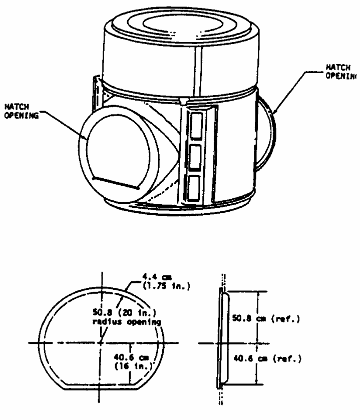
Due to the reduced suit pressure (300-400 hPa) prebreathing of pure oxygen (> 95% O2) is required for a certain length of time, before donning the space suit to reduce the pressure, in order to avoid decompression sickness symptoms.

There are two primary options for prebreathing prior to use of the Shuttle EMU (Ref. 6) in the Orbiter cabin. The first option is performance of an EVA from a 1013 hPa nominal pressure cabin. A 240 minute prebreathe is required prior to depressurisation of the airlock. The second option is performance of an EVA from a 703 hPa nominal pressure cabin. The procedure starts at the nominal cabin pressure of 1013 hPa and begins with a depress to a 703 hPa cabin with concurrent O2 enrichment. If EVA is scheduled in less than 36 hours, the depressurisation from 1013 hPa is preceded by a 1 hour prebreathe. If the stay time at 703 hPa prior to depressurisation is longer than 24 hours, the in-suit prebreathe prior to initiation of depressurisation to EVA pressure is a minimum of 40 minutes. If the stay time at 703 hPa prior to depressurisation is between 12 hours and 24 hours the minimum insuit prebreathe prior to initiation of depressurisation is between 40 minutes and 75 minutes and is an inverse function of the stay time at 703 hPa.

The Orlan DMA prebreathing protocol (Ref. 7) requires 30 minutes insuit prebreathe during check-out. The same protocol will be used for the Orlan M suit.



KVANT-2 MODULE AIRLOCK



STS AIRLOCK

Fig. 3: Airlock/Hatch Configurations

4.1.2 Hatch Diameter

The different airlock/vehicle hatch diameter requirements (EMU = 914 mm, Orlan = 800 mm) Fig. 3 means that great care is required during traverses of the largest size EMU (610 mm front to back) through the present MIR hatch, as the individual suits are designed to meet the hatch diameter of its own mothercraft only.

4.1.3 Airlock Pressure Profiles

The airlock pressure profiles are different in timelining, pressure holds, check-out duration and prebreathing protocols. The pressure equalisation during post-EVA would have to be maintained in two steps, as the operational suit pressures differ by about 120 hPa. In principle the same is true for the final leakage test, which also requires two holds.
The fact that the EMU uses differential pressure regulators and the Orlan DMA/M has absolute pressure regulators may have another impact on the proper selection of a joint airlock pressure profile. During depressurisation and repressurisation the pressure in the ORLAN DMA/M suit is controlled from the interface control panel via the umbilical for airlock pressure levels above nominal suit pressure, whereas the EMU is controlled by its own pressure regulator and the positive/negative pressure relief valves.

4.1.4 Communication

Today none of the systems are compatible. But with the planned Shuttle to MIR flights in 1995-97, which also will include joint EVA's, this interface will later be compatible for all systems.

4.1.5 On-Board/Space Suit Interface Unit

The physical oxygen and cooling water supply data of the current support systems, used in the Shuttle and in the MIR station are summarised in Tab. 3.

TABLE 3: Interface Control Unit Fluid Characteristics

	SPACE SHUTTLE	MIR
Oxygen Supply:		
Supply provided through	umbilical	nominal umbilical & emergency hose
O2 supply pressure	6.205 ± 0.345 MPa = 5.860 - 6.550 MPa	42 MPa (replacement) 0.45 MPa (via umbilical)
Nominal flow rate	2.268 kg/hr	Mode 1: 206-255 g/hr Mode 2: 2 kg/hr (3 kg/hr max.)
Pressure drop	0.3103 MPa at nominal flow rate and 5.1365 MPa	
Emergency hose	N/A	0.45 MPa
Cooling Water Supply:		

Supply provided through	umbilical	umbilical
Heat sink	STS heat-exchanger	MIR heat-exchanger
Nominal flow (equals pump performance)	113.4 +9/-22.7 kg/hr =122.4 -90.7 kg/hr	90-180 kg/hr
Temperature of chilled water (inlet)	10°C	5 - 14°C
Maximum operating pressure	1517 hPa	1463 hPa
Pressure drop at connectors	137.9 hPa at 108.8 kg/hr	no definition

Major differences mainly in oxygen supply methods and flow characteristics prevents the interchangeability of space suits and mothercraft without major modifications to the Interface Control Units, or adding different units into each mothercraft.

4.1.6 Foot Restraints

Different dimensions used stem from the space suit boot designs, and here a standardisation is needed for common restraint and work location to provide two-handed task performance for routine EVA interoperability. Note that due to different suit waist and lower torso joint designs different levels of mobility (e.g. reach) will be the result even with standardised boot designs/foot restraints.

4.1.7 Safety Tethers

Concept, suit interfaces, length and operations must be standardised in particular for crew assistance and rescue.
Presently the safety tether of the EMU is not operatable with the Orlan DMA glove/arm combination.

4.1.8 Handholds and Tools

For nominal EVA operations a standardisation of tools and handholds (Ref. 8 & 9) would be most beneficial but would then imply to use e.g. the metric system. Otherwise only a few pieces (hammer, screwdriver, pliers) could be used in both systems and e.g. wrenches with different sockets would be needed.
An impact on emergency EVA situations can be expected if differences in tools and tethers cannot be avoided.

4.1.9 Logistics

For nominal EVA interoperability spares must be planned for the different suits and airlocks in use. If an EMU would eventually enter a MIR airlock after a nominal EVA, the EMU would be deprived of its nominal EVA capability if spares are not foreseen and vice versa for other combinations of airlocks/suits.

4.2 Compatibility Assessment

Reviewing the previously defined essential and critical system parameters allows for the classification as "critical" if a compatibility is absolutely necessary to facilitate nominal and/or emergency interoperability (Tab. 4). In addition the suit systems are analysed as to compatibility existing or not, based upon the present design. If a parameter is critical but the systems are not compatible, the combination "Yes-No" signals the critical interoperability incompatibility.
The electrical interfaces like power, and communication and data must be made compatible in order to achieve interoperability but are not considered strong design drivers and can

technically be handled by the implementation of additional power converters, or frequency synthesisers.

TABLE 4: Overview of Interoperability Criticality for EVA Equipment

Functions	Nominal EVA		Emergency EVA	
	Interops	Critical	Critical	Interops
Prebreathe	No	No 2)	Yes	No
Hatch Diameter	TBC	Yes	Yes	TBC
Airlock Pressure Profile	No	No	TBD	TBC
Communication	No	Yes	Yes	No
Life Support Interfaces:				
- O2 Supply	No	Yes	Yes	No
- H2O Cooling	No	Yes	Yes	No
- Feedwater Resupply	No	Yes	No	No
- Power	No	Yes	No	No
- IV Communication	No	Yes	No	No
Foot Restraints	No	Yes 1)	Yes 1)	No
Safety Tethers	No	Yes 3)	Yes 3)	No
Handholds	No	Yes 3)	N/A	---
Tools	Partly	Yes 1)	Yes 1)	Partly
Logistics	No	Yes	N/A	---

TBD = to be defined
TBC = to be confirmed
N/A = not applicable
Notes:
1) Task dependent
2) Critical for EMU in MIR A/L as not enough oxygen for prebreathe
3) Handholds different between US and RF parts and requires different tether hocks

For thermal control feedwater, two different concepts for supply are being used. The manual refill or change-out of Orlan DMA/M feedwater tanks is independent of the interface panel, thus being no servicing problem. Furthermore the EMU feedwater purity is critical to the sublimator performance.

The cooling water supply concept is the same for both systems, except for the physical performances, i.e. pressure and flow rate, which are adaptable by pressure reducers or flow restrictors. An issue of water quality in cooling loops should be resolved.

The most important interface remains the oxygen supply, as the systems are incompatible with respect to operating pressure and control of pre-EVA modes like purging, prebreathing, leakage test etc.

When comparing the various EVA systems for critical parameters versus nominal operations and/or emergency operations (Tab. 4) following critical incompatibilities (**No Interoperability**) can be identified:

Nominal EVA
- Hatch Diameter (TBC) - Communication - Life Support (Interface Control Panel and Umbilical) all functions - Foot Restraints - Safety Tethers - Handholds

- Tools - Logistics
Emergency EVA
- Prebreathe - Hatch Diameter (TBC) - Communication - Oxygen Supply - Safety Tethers - Handholds - Tools

Thus in all cases presently only limited interoperability exists between the STS EMU and the Orlan DMA and M due to communication systems and the Airlock Interface Control Panel/Umbilical. As for the hatch dimensions the largest STS EMU size is critical for MIR emergency airlock and needs further investigation.
The different pre-breathing protocols due to different R-factors and suit pressure requirements are also an operational inconvenience for nominal operations which ought to be further analysed. But for emergency situations a harmonization of protocols are mandatory to ensure immediate response actions (Ref. 10).
As to other critical incompatibilities they are all associated with auxiliary EVA equipment like safety tethers, handholds, tools and foot restraints.
Future space suit systems can be envisaged to rely more on the use of modular exchange units (ORU like) for the resupply of resources and exchange of life limited items: hence the key commonality and interoperability issue for such systems will be the standardisation of selected ORU's. Such standardisation would permit for example, the interoperability of space suit systems having different oxygen regulations and in-suit pressures working with a common oxygen tank.

5. Recommendations

The necessity to remove the critical incompatibilities to enhance mission flexibility and to increase the level of safety for EVA has been assessed (Ref. 11).

- Airlock Hatch dimensions is a far-reaching but necessary standardisation effort to provide for the full access necessary to support international interoperability.

- RF Communication is most likely only a time-issue as planned STS-MIR and ISS activities may force a standardisation, but is a must for interoperability.

- Standardized prebreathe protocols and potentially suit pressures to support simultaneous EVA's with different space suit systems would add significant redundancy and safety to EVA operations.

- Life support interfaces must be standardised via Interface Control Panels and Umbilicals either by design or by implementing adapter technology for both critical fluids and power. Provisioning kits for projected interoperability missions are also a possibility. An intermediate alternative to this could be to provide a separate "emergency" umbilical common to all suit configurations.

- Safety tethers must be standardised for future space suits.

- Foot restraints must be standardized as well as the space suit boots to permit two-handed work task performance of EVA crewmembers whenever required.

Two other factors could influence EVA interoperability namely a potential hyperbaric use and the suits stowage position/devices. The first point would be of great use in case of a decompression problem during an EVA. The EMU has a limited hyperbaric capability afforded by a special backpack adapter component. This can be used in any airlock. It allows pressurisation of the suit to 572 hPa which in combination with an elevated cabin pressure can provide a 1600 hPa treatment pressure. The MIR airlock can in combination with the Orlan DMA/M provide a total pressure of 1400 hPa, which can be of great help in case of medical care necessity.

Suit stowage inside the airlock must also be compatible: a harmonisation or specific interface design is necessary to avoid one suit becoming a free-floating object inside an alien airlock.

Standardisation of modular on-orbit exchangeable units for resupply of resources and life limited items is strongly recommended in order to reduce in-orbit logistics and to provide a maximum of flexibility for future planned systems.

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Appendix 1
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Appendix 2
Spacecraft/Vehicle Characteristics and Space Suit System Parameters

TABLE A: COMPARISON OF SUPPORT VEHICLE CHARACTERISTICS

Spacecraft Characteristics	**USA** **STS and ISS**	**Russian** **MIR**
Normal Operations * Cabin Pressure * Atmosphere Composition	1013 ±13.8 hPa PPO2 = 221 ±17.2 hPa	1013 hPa O2 = 21 - 40 %
Pre EVA Operations * Cabin Pressure * Atmosphere Composition	0 - 703 hPa PPO2 = 176 - 193 hPa	same as above same as above
EVA Support in Airlock * Cabin Pressure * Atmosphere Composition	0 - 1013 hPa O2 = 21 - 30 %	0 - 1013 hPa O2 = 21 - 40 %
EVA Support Interfaces (ref. to Interface Control Document number) * Don/Doff Opening * IV Support & Resupply	JSC 17325 SSP 30256: 001 E Waist	Rear Door 1 umbilical fluid 1 umbilical electrical

* Foot Restraints & Workaids	1 fluid/electrical umbilical ICD + JSC 20466	
Hatch Size (Dimensioning for space suits)	914 mm (STS) 1270 mm (ISS)	800 mm 1000 mm (Kvant 2)

TABLE B: COMPARISON OF SPACE SUIT SYSTEM CHARACTERISTICS

EVA Space Suit System Characteristics	**USA STS EMU**	**Russian ORLAN DMA**
Suit Pressure * Nominal * Emergency	 296 ±6.9 hPa 229.6 - 268.9 hPa	 392 + 14/ - 42 hPa 265 + 25/ - 15 hPa
Gas Composition	O_2 > 95 %	O_2 > 95 %
O_2 Resupply Primary * Method * Pressure * Quantity	 Recharge in orbit 6.20 ±0.34 MPa 0.55 kg	 Replace in orbit 42 MPa 1.0 kg
O_2 Resupply Emergency * Method * Pressure * Quantity	 Recharge on ground 51.0 MPa 1.19 kg	 Replace in orbit 42 MPa 1.0 kg
H_2O Recharge * Method * Pressure * Flow Rate * Quantity * Purity Spec./Biocide	 via umbilical, manual valves 862 - 1724 hPa 4.54 - 13.61 kg/hr 3.76 kg main/0.38 kg second 3 - 5 ppm by weight	 on-board manual 1113 - 1463 hPa --- 3.6 kg ground purification

TABLE B (cont.): COMPARISON OF SPACE SUIT SYSTEM CHARACTERISTICS

EVA Space Suit System Characteristics	**USA STS EMU**	**Russian ORLAN DMA**
Umbilical * Type * Length	1 Fluid/electrical Pri O_2, H_2O for cooling and recharge, condensate drain, power, comms STS: 3.53 +-0.03 m	1 Fluid (O_2, ventilation, H_2O cooling), 3.0 m 1 Electrical (power, comms) 25m 1 Emergency O_2, 3.0 m (Add. electrical umbilical for emergency airlock 2.5 m)
Condensate Drain * Method * Pressure (from suit) * Flow Rate * Quantity	 via umbilical 1138 ±34.5 hPa 10 kg/hr 4.14 kg	 * to SS heatexchanger * removal/replacement of moisture collector
CO_2 Removal (non-regenerable) *Methods * Dimensions * Weight	 LiOH Flat: 280 x 76 x 205 mm 2.9 kg	 LiOH cylindrical: diameter:120 x 240 mm 2.2 kg

* Stowage Requirements	sealed	sealed
CO2 Removal (regenerable) * Methods * Status Implementation	 N/A N/A	 N/A N/A
IV Power (from umbilical) * Voltage * Current * Time	 18.5 ±0.5 VDC ~ 4.5 amps ~ 2 hrs (nominal)	 27 + 7/ -4 VDC 2.4 amps aver. 3.6 amps max. 2.5 hrs
Battery Recharge * Method * Voltage * Current * Time	 Recharge or replace in orbit 21.8 + 0.1/-0.2 VDC 1.5 - 1.6 amps ~ 16 hrs	 Replace in orbit 27 +7/ -4 VDC --- ---
Biomed. Monitoring * Parameters * Methods	 ECG3 skin electrodes	 ECG, resp. rate, body temp. skin electrodes
EVA Comm. * Transmit Frequencies * Space Suit Data Parameters * Receive Frequencies	 259.7/279.0/259.7 MHz C&W, Status suit parameters, biomedical 296.8/279.0/259.7 MHz	 100.125 MHz C&W, status, biomedical; (321 and247 MHz) 130.167 MHz
IV Comm. * Characteristics	Duplex voice/hardwire simplex (backup)	Duplex/simplex voice/hardwire

Note:
TBC = to be confirmed
TBD = to be defined

TABLE C: COMPARISON OF SPACE SUIT PROTOCOLS

EVA Space Suit Protocol	**USA** **STS/ISS with** **STS EMU**	**Russian** **MIR with** **ORLAN DMA**
Pre-EVA Protocol Summary * Don Sequence * Pre-breathe:	 Urine collection device. Biomedical, LCVG, LTA, comm. carrier. HUT/arms/helmet/LSS, Gloves/Wrist Mirror	biomedical, LCVG, headset, suit entry, connect electrical, connect fluid, close rear door. 30 min

- from 1013 hPa cabin - from 703 hPa cabin * Check-out * R-factor (with above pre-breathe): - from 1013 hPa cabin - from 703 hPa cabin Emergency:	240 min 40 min All controls/functions, leak check 1.68 1.65 2.0	All controls/functions, leak check <1.8 <2.8 (for max 15 min)
Post-EVA Protocol Summary * Doff Sequence * Post-EVA Service (e.g. suit wipe down & dry) * Consumables recharge * Maintenance Operations on-orbit	 reverse don yes Recharge: O2, H2O, battery Replace: LiOH, battery optional as required	 reverse don yes Recharge: H2O, Replace: O2, moist sep., LiOH, battery as required