

Spaceflight Decompression Sickness Contingency Plan

Joe Dervay, M.D.



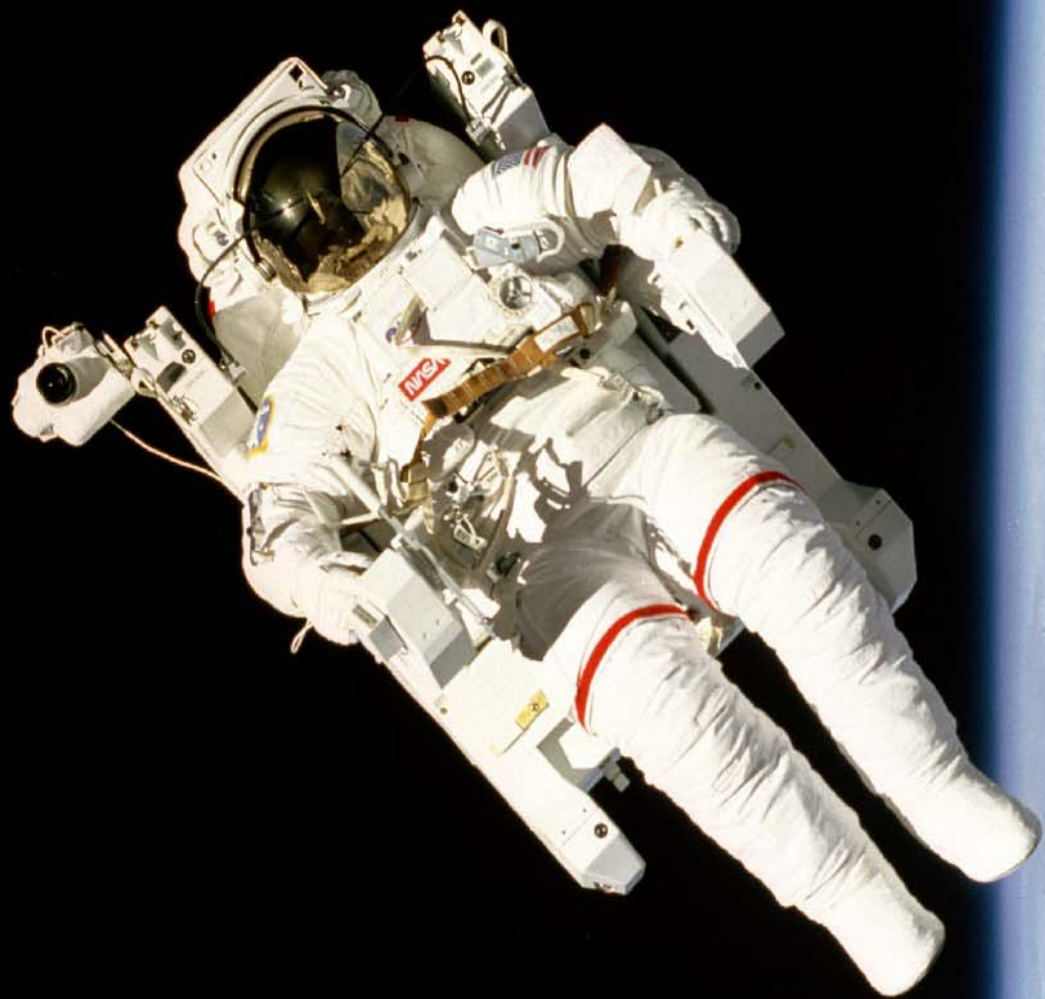


Spaceflight Decompression Sickness Contingency Plan

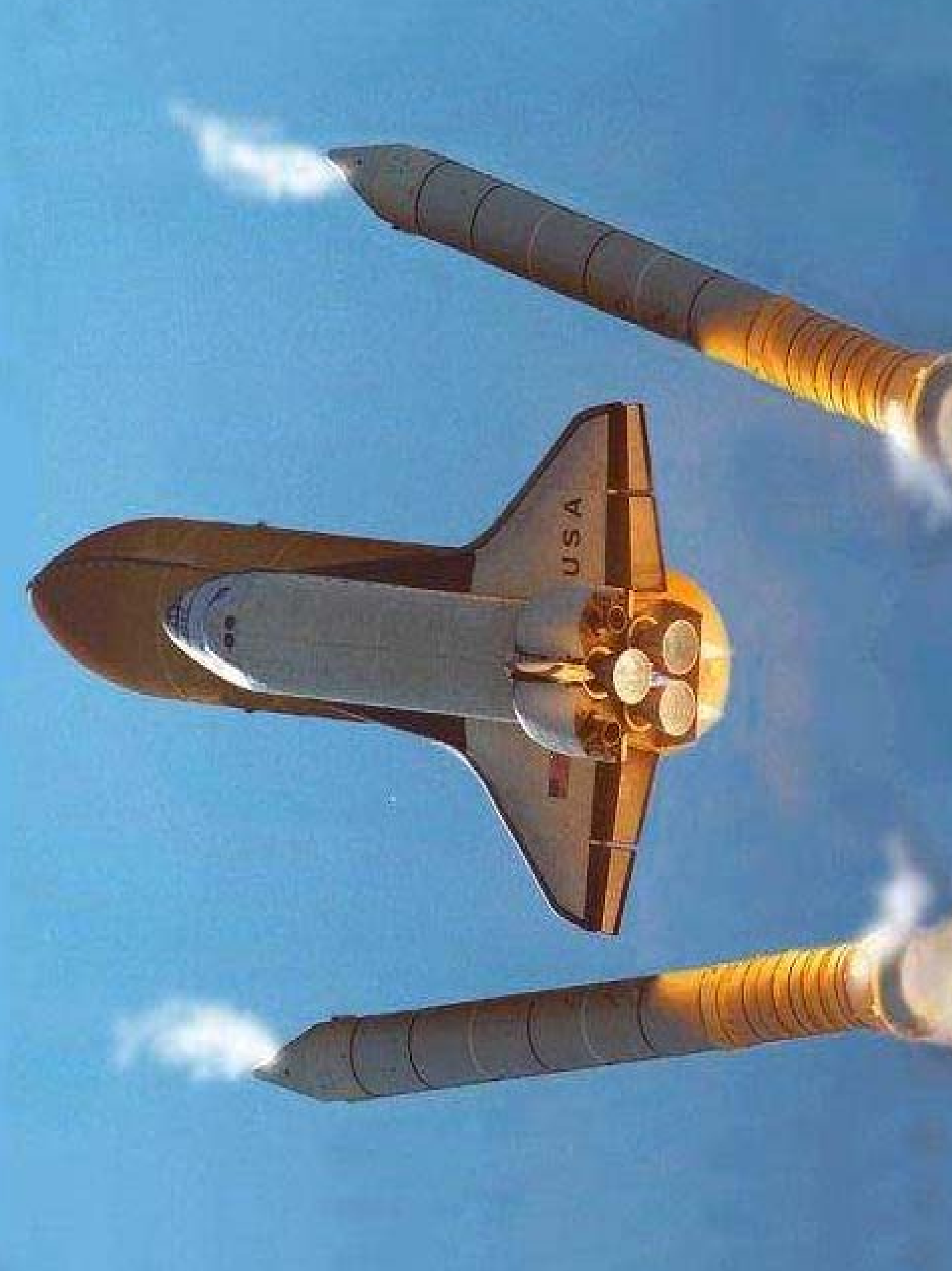
Medical Operations

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- **Approach**
- **DCS Contingency Plan Overview**
- **Extravehicular Activity (EVA) Cuff Classifications**
- **On-orbit Treatment Philosophy**
- **Long Form Malfunction Procedure (MAL)**
- **Medical Checklist**
- **Flight Rules**
- **Crew Training**
- **Flight Surgeon / Biomedical Engineer (BME) Training**
- **DCS Emergency Landing Site**





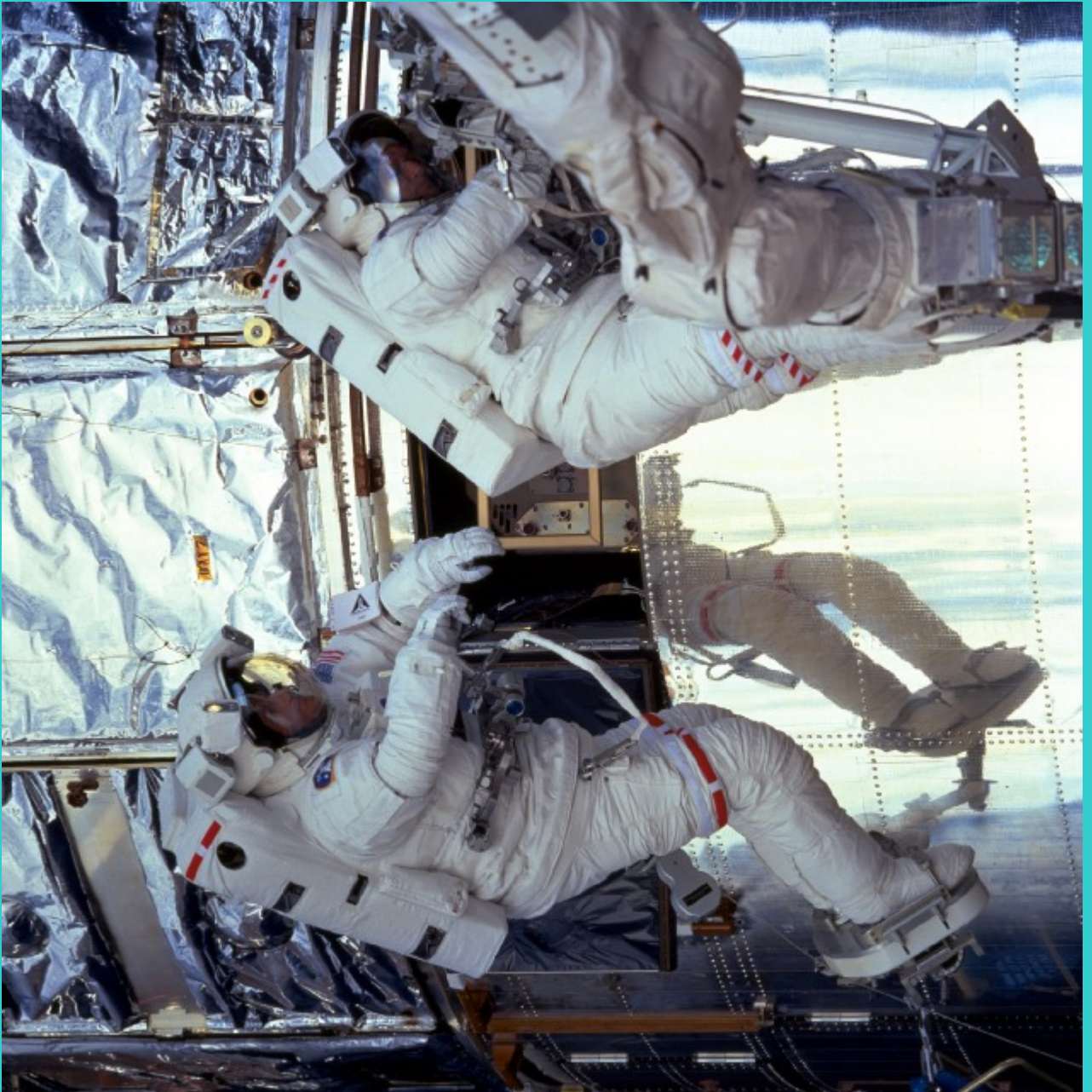






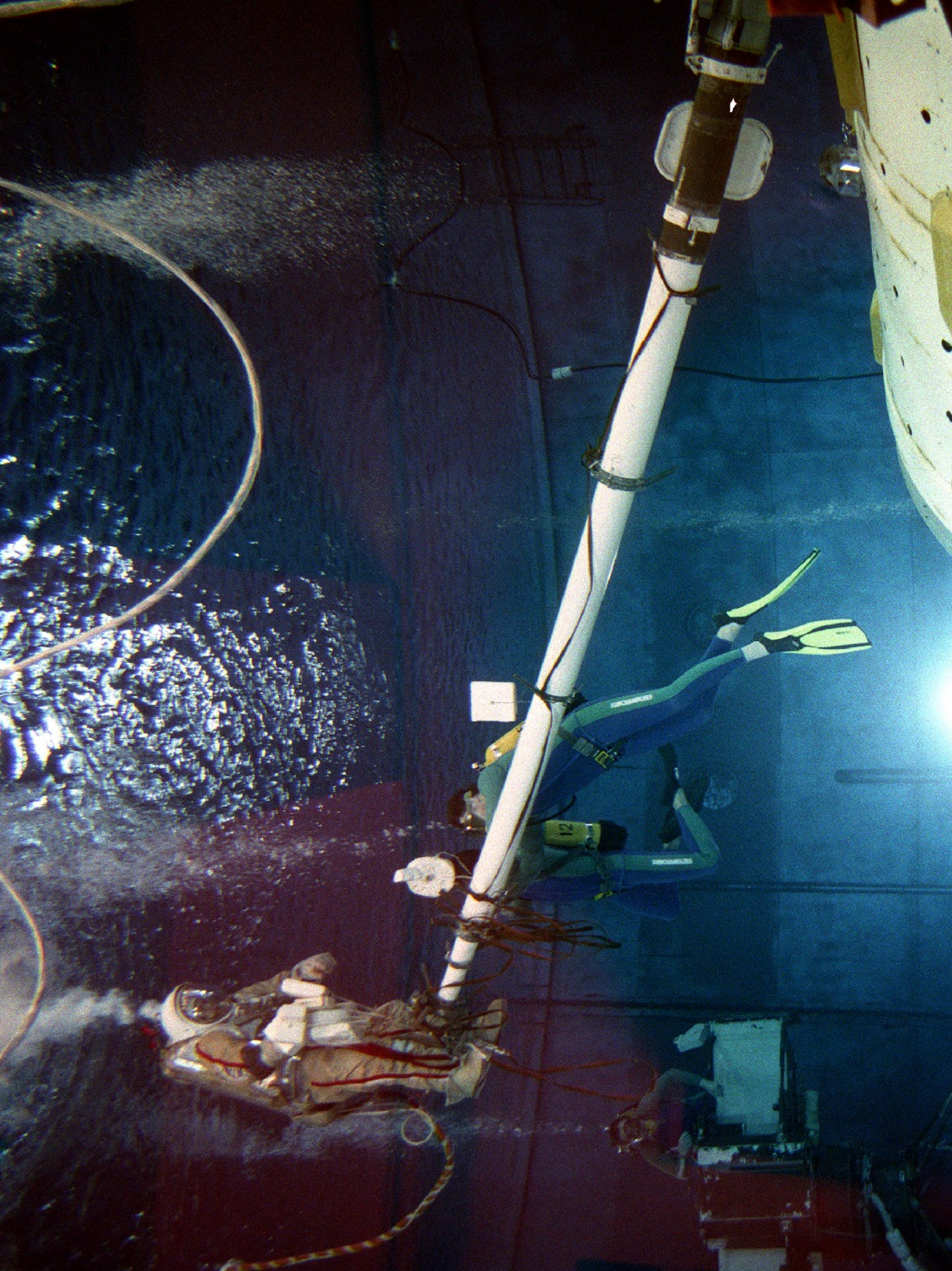
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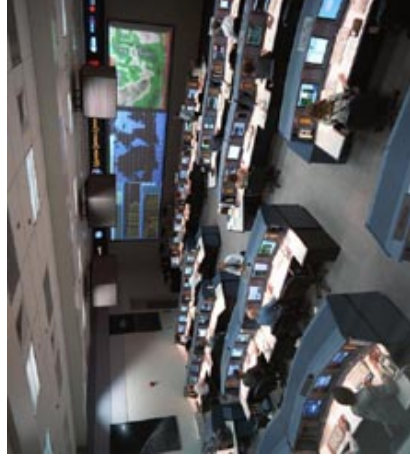


Mission Support

On-orbit Flight Control Room (FCR) Staffing



Surgeon Console - FCR





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- **Current ISS Prebreathe Protocols**
 - Four hour In-suit (Originally accepted by testing. Currently acceptable by analysis)
 - Campout (Accepted by analysis of related data/similarity to shuttle 10.2 psi staged protocol)
 - Exercise Prebreathe (Accepted by testing utilizing the criteria below)
- **Accept Criteria for ISS EVA Prebreathe Protocols***
 - One-year “DCS Risk Definition & Contingency Plan” effort designated accept criteria of research protocol
 - » Decompression Sickness (DCS) $\leq 15\%$ at 95% CL
 - » Grade 4 Venous Gas Emboli (VGE) $\leq 20\%$ at 95% CL
 - » No Type II (serious) DCS

* This criteria was not applied to the shuttle protocols



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- **Operational Experience**

- To date, there have been 141 person-EVAs conducted with 10.2 psi Staged PB Protocol
 - » 12-16 hr stay at 10.2 --- 20
 - » 16-20 hr stay at 10.2 --- 4
 - » 20-24 hr stay at 10.2 --- 12
 - » 24 hr > stay at 10.2 ---- 105
- Final PB**
- 75 min
 - 60 min
 - 50 min
 - 40 min
- In no case has there been any reported symptoms or signs of DCS



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OBJECTIVE:

- Develop enhanced plan to diagnose, treat, and manage on-orbit DCS
 - Achieve new level of DCS awareness among flight controllers, astronauts, and the medical community
- Historically, few drivers to modify existing plan
- Significant upcoming increase in EVA activity to build and maintain ISS - “Wall of EVA’s”
- Important to involve International Partners with plan



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APPROACH:

- Johnson Space Center multi-disciplinary team: Medical Operations, Astronaut Office, EVA Office, Mission Operations Directorate
- Consultation with military, civilian, and commercial experts
- Review of literature and databases
- Analysis of past Mission Control “Simulation” scenarios
- Overall plan reviewed by expert committee chaired by Dr. Lambertson (1998)

DCS Contingency Plan

EVA Checklist Development

Shuttle / EMU

ISS / EMU

Russian / ORLAN

Improved On-Orbit DCS Treatment

Insuit Treatment

BTA Mods

Hyperbaric Chamber

Technology Dev.

Adjunctive Drug Therapy

DCS Flight Rules Development

Mission Control DCS Simulation Program

Crew Flight Surgeon Training

Ground Support Infrastructure

Primary Hyperbaric Landing Sites

Cooperative USAF/NASA Programs

Russian EMS Plan

DCS Disposition Policy



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EVA “CUFF CLASSIFICATION” SYSTEM :

- Simple operational classification of DCS symptoms relevant to EVA crewmember
- Provides clear communication of symptoms and associated operational response.
- Defines actions required to place payload in safe configuration and repress affected crewmember
- Sensible system to encourage symptom reporting



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EVA CUFF CLASSIFICATIONS

<u>Cuff Class</u>	<u>Symptoms</u>	<u>Response</u>	<u>Rationale</u>
1	Mild pain, at single or multiple sites <u>and/or</u> single extremity paresthesia. Difficult to distinguish from suit pressure points. -Symptoms do not interfere with performance.	Report in post EVA PMC. No future EVA impact.	1-8
2	Moderate cuff 1 symptoms that interfere with performance.	Terminate EVA for both crew members, perform worksite clean-up only, minimize activity of affected crew member. Perform repress.	3,6 9-10
			Set up PMC post repress.



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EVA CUFF CLASSIFICATIONS (cont.)

<u>Cuff Class</u>	<u>Symptoms</u>	<u>Response</u>	<u>Rationale</u>
3	Severe cuff 1 symptoms or migratory, trunkal or multiple site paresthesia, unusual headache.	Terminate EVA. Assisted return of affected crew member to airlock, buddy perform worksite safing, then airlock repress. Set up PMC.	12,13
4	Serious symptoms – Central neurological, cardiopulmonary.	Abort EVA. Crew assisted return to airlock. Repress affected crew member. Buddy perform worksite safing, then airlock depress, repress. Set up PMC.	14-19



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RATIONALE:

- Spacesuit itself creates pressure points, joint pains, and local paresthesias
- Majority of pain symptoms (86%) in historic database improved or remained the same with time
- Low risk of mild or moderate symptoms progressing to serious
- Worksite safing important for potential Shuttle de-orbit as well as Station operations
- May require 30-45 min. transit to airlock from worksite location
- With serious symptoms, may need to repress affected crewmember ASAP while solo crewmember completes clean-up tasks



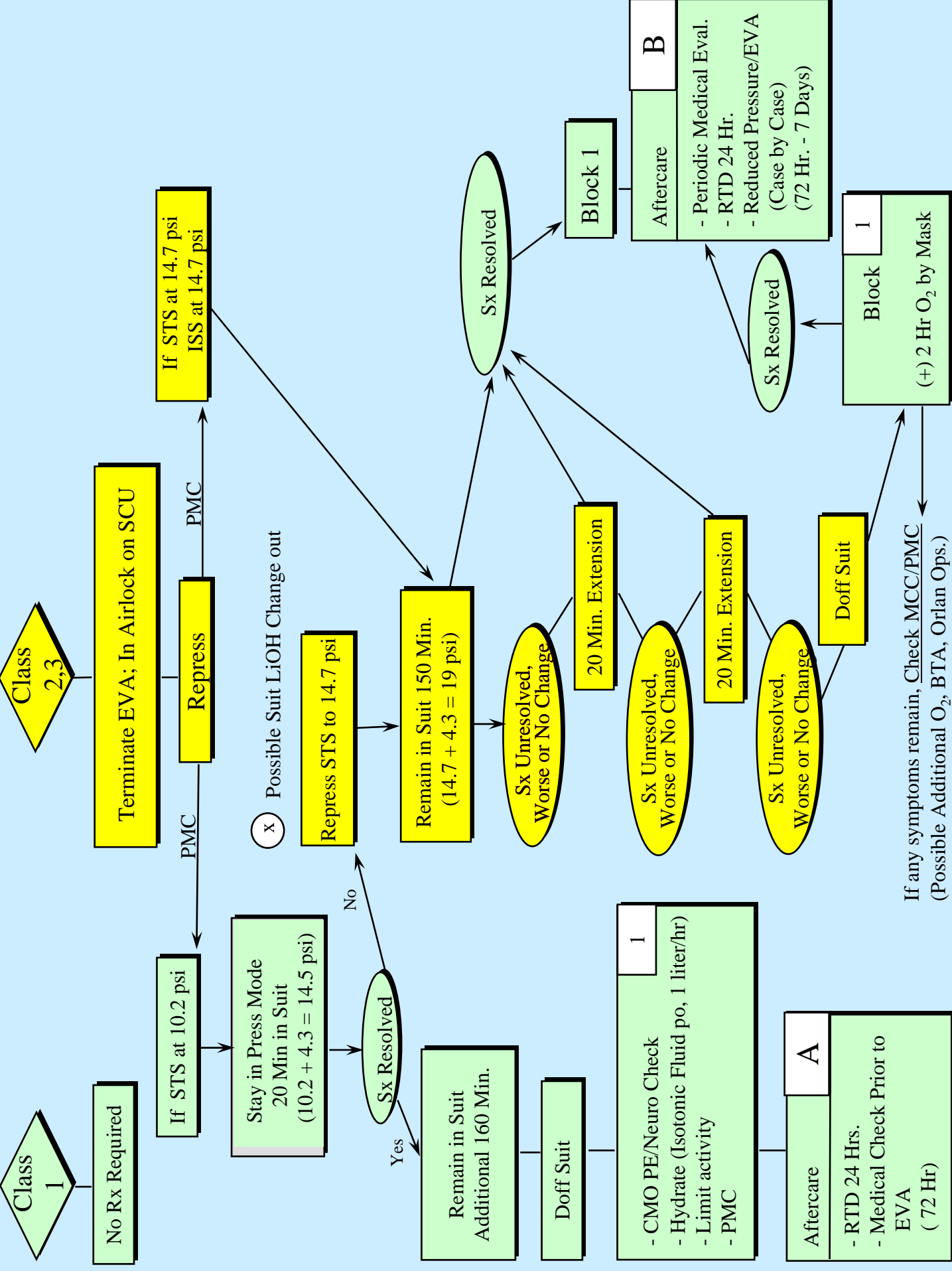
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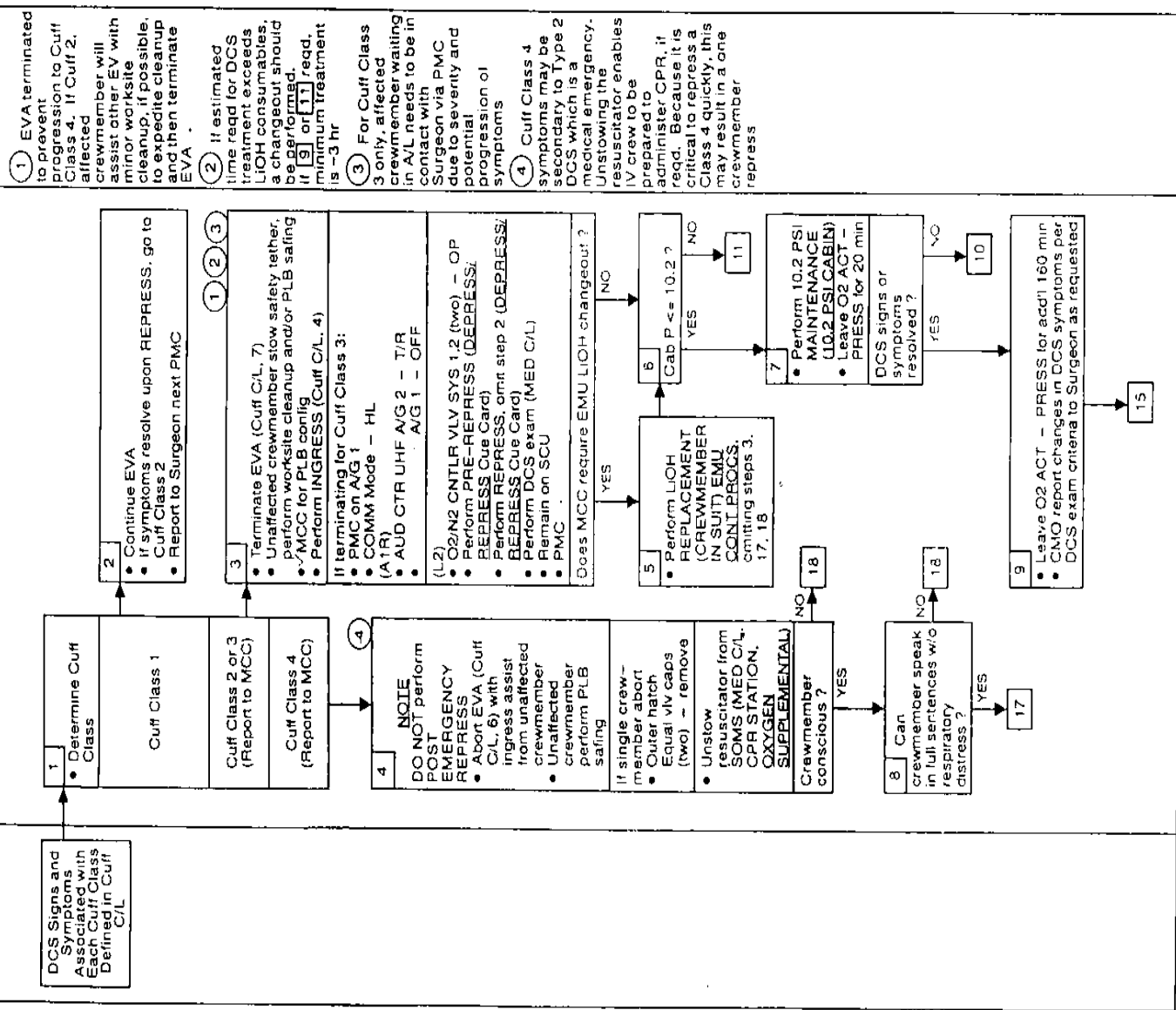
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TREATMENT PHILOSOPHY:

- Oxygen, pressure, and time are definitive measures
 - Fluids and medications are adjunctive
- Provide higher pressures and longer times than proven 2-hr. Ground Level Oxygen (GLO) – treat gas phase, not just symptoms
- Avoid breaking suit integrity for 20-30 min. for installation of Bends Treatment Apparatus (BTA) [increases suit pressure to 8 psij]
- Development of treatment flows, extensions
- Conversion into Malfunction (MAL) Procedures
- Enhanced Medical Checklist
 - Aftercare
 - Addresses late and recurrent “hit”



20.1 DCS TREATMENT



1 EVA terminated to prevent progression to Cuff Class 4. If Cuff 2, crewmember will assist other EV with minor worksite cleanup, if possible, to expedite cleanup and then terminate EVA.

2 If estimated time reqd for DCS treatment exceeds LiOH consumables, a changeout should be performed. If 9 or 11 reqd, minimum treatment is -3 hr

3 For Cuff Class 3 only, affected crewmember waiting in A/L needs to be in contact with Surgeon via PMC due to severity and potential progression of symptoms

4 Cuff Class 4 symptoms may be secondary to Type 2 DCS which is a medical emergency. Unstowing the resuscitator enables IV crew to be prepared to administer CPR, if reqd. Because it is critical to repress a Class 4 quickly, this may result in a one crewmember repress



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MEDICAL KITS

- **IV Fluids**
 - Shuttle: 3.1 liters normal saline
 - ISS: 12.1 liters normal saline

- **Medication**
 - Compiled to cover broad range of potential conditions
 - » Includes limited quantities of Dexamethasone and Lidocaine

- **ISS Respirator – Autovent 2000 (Allied Health)**

- **ISS Defibrillator – PD 2000 (Zoll Medical)**



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FLIGHT RULES:

- Pre-established rules for Flight Control Team to respond in coordinated manner
- Avoid miscommunication across multiple disciplines
- Documents Cuff Classes, deorbit requirements to Primary Hyperbaric Care site (3 CONUS, Hickam, Guam), deorbit within 10 hrs. for unresolved Type II symptoms



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TRAINING:

- Astronauts
 - MAL checklists
 - New class on Medical Evaluation of DCS
 - » Physiology, symptoms, treatment, neuro exam
 - » Video of DCS Neurological exam

- Flight Surgeon/Biomedical Engineer
 - DCS syllabus, console requirements, CME courses

- Mission Control Simulations



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DCS EMERGENCY LANDING SITES

- **Primary Hyperbaric Care Landing Sites**
 - Chamber capabilities, proximity to trauma center, points of contact being coordinated with DDMS medical personnel
- **Russian Landing Site Capability and Response**
 - Work in progress to further document plan

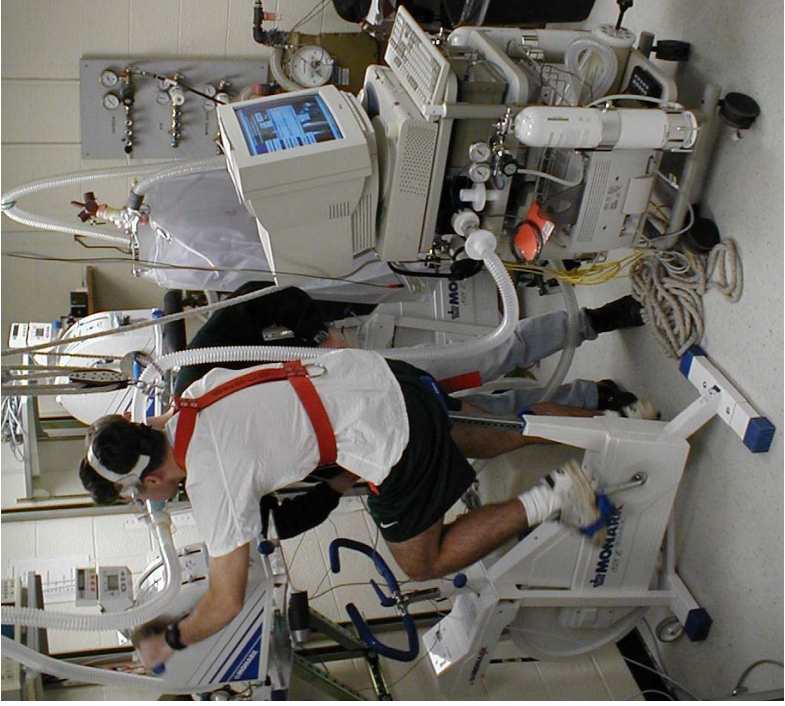




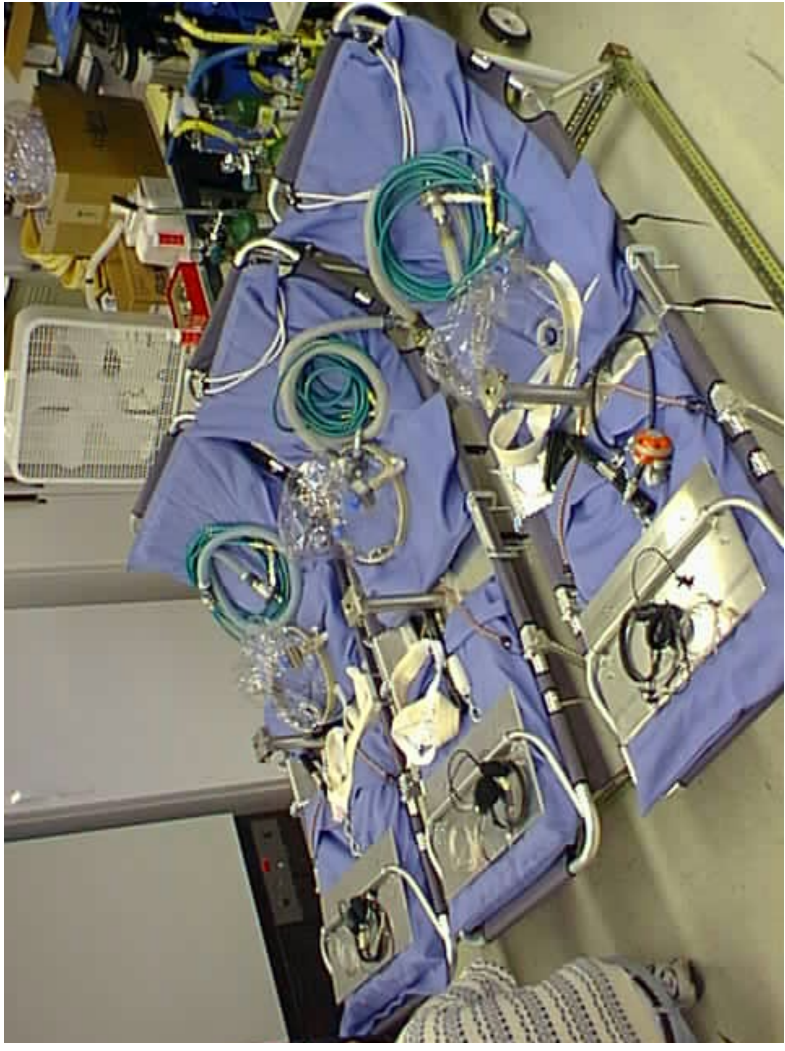




PRP EXERCISE STRATEGIES



**Upright dual arm
and leg cycle
exercise
(ALE)**

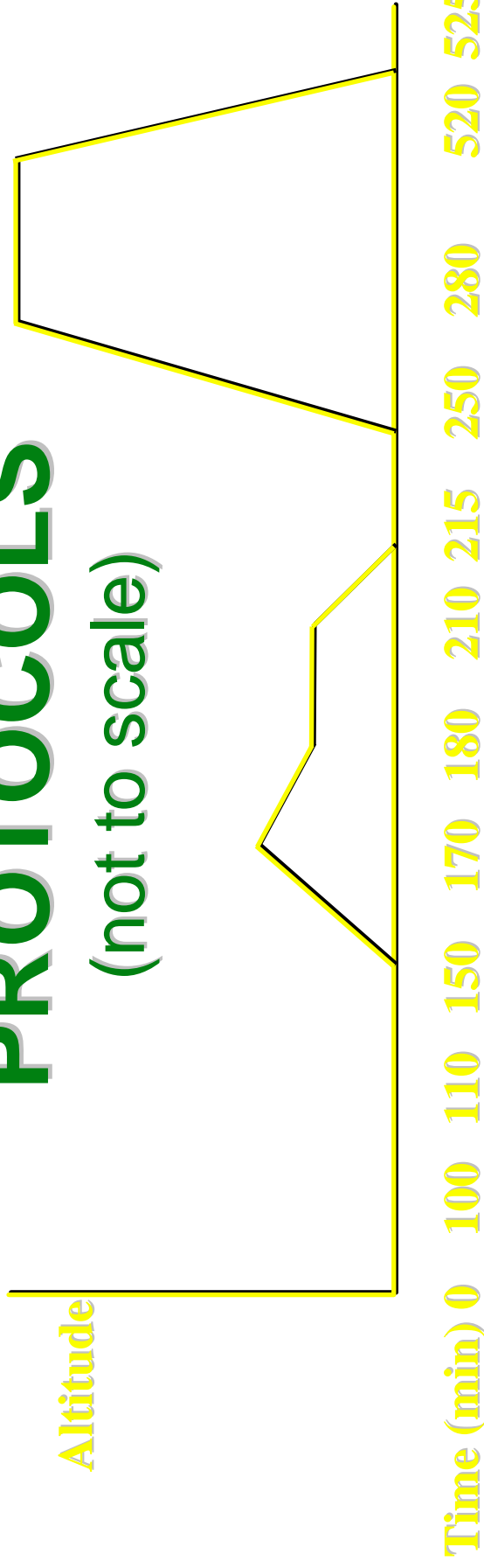


**Semi-recumbent intermittent
light exercise simulating
astronaut tasks
(ILE)**

RESULTS: 2 HOUR

PROTOCOLS

(not to scale)



Phase I	Rest	10 min	9 DCS/47 trials = 19%	4 hr
Phase II	Rest	75% $\dot{V}O_{2\text{ peak}}$	40 min	EVA
Phase III	Rest	Light Work	2/10 = 20% (1 cerebral DCS)	Simu-lation
Phase IV	Rest	95 min Light Work	8/57 = 14%	



Mission Support

- Extravehicular Activity (EVA) Monitoring



DCS Contingency Plan

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Russian / ORLAN

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DCS Disposition Policy

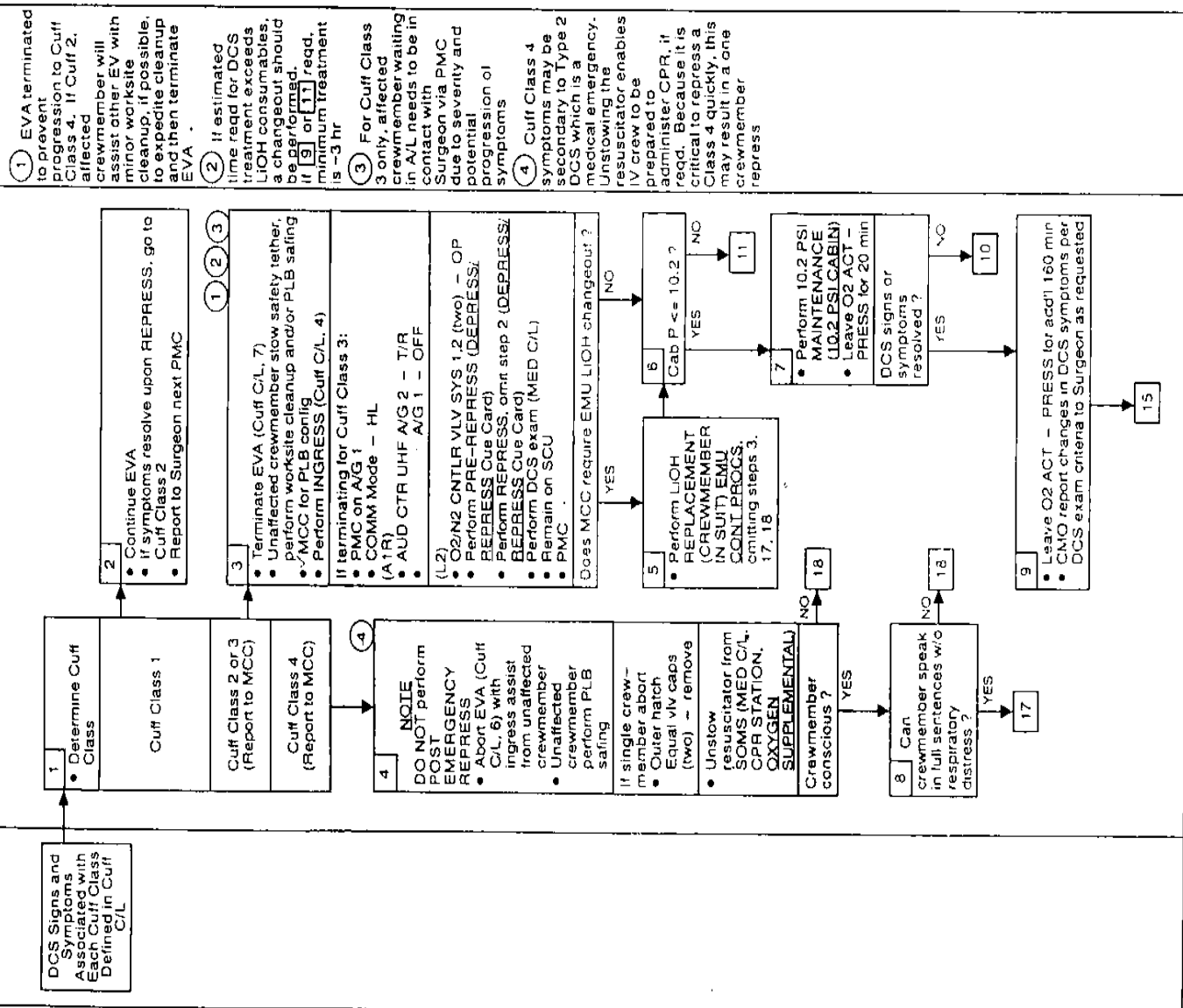
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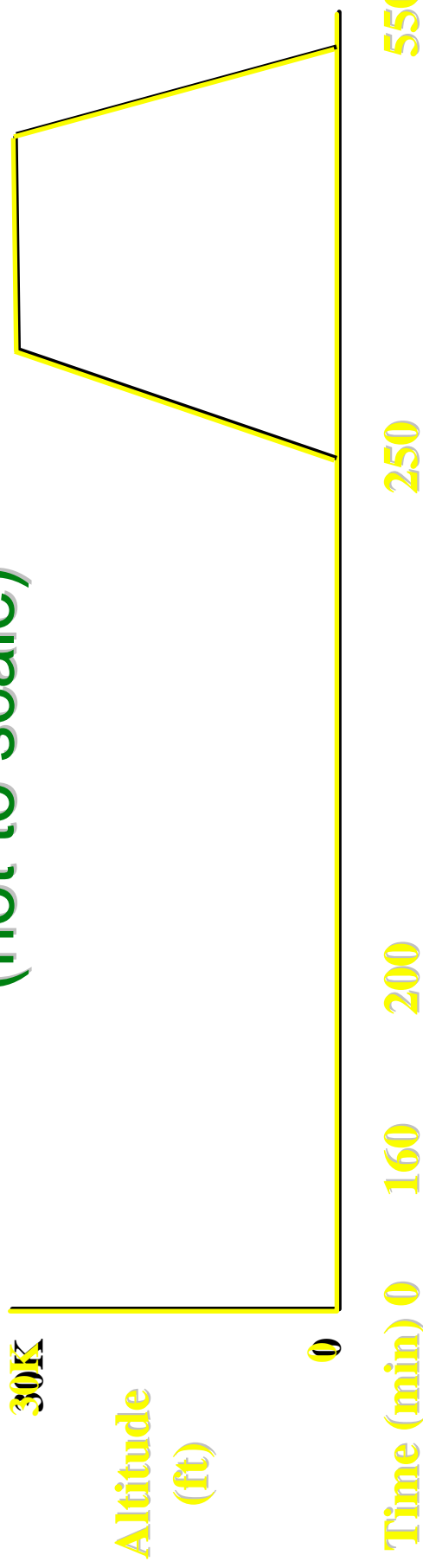
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RESULTS: 90 MIN PROTOCOLS

(not to scale)



V-1	Rest	44 min 2/2: 60%	3 DCS/10 trials = 30%	4 hr EVA
V-2	Rest	34 min 3/2: 60%	0/2 = 0%	Simulation



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4 hr In-suit Protocol Timeline

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1:15	2:45	2:57	6:5
POST SLEEP 75 min	EVA PREP 90 min	Purge	EMU PREBREATHE 4 hours
	EMU Donning 55 min	Ck	* Metox C/O
7:27		13:57	15:17
C/L Depress (30 min)		*EVA PET = 6:30	Rep POST EVA w/o H2O

* It is possible to perform METOX Change-Out (manned) to allow for maximum EVA PET capability. Provided that Crew Day Length violations can be approved, we could support a 6:30 EVA PET.

Note: Assume depress pump and EMERG MPEV & AL VAI; 30 min C-Lk depress without built in hold at 5psi. With 2 hours of Pre-sleep, **STS Crew Day length = 17:17.**

EVA DAY SUMMARY

- Post Sleep (1 hour 15 mins total)
- EVA Prep (1 hour 30 mins)
 - EVA Prep for Donning (30 mins)
 - Suit Donning at 10.2 (1 hour)
- Suit Purge (12 mins)
 - Airlock Repress to 14.7
- In-suit Prebreathe (4 hours)
- Crewlock Depress to vacuum (30 mins)
- EVA tasks (6 hours 30 mins)
- Airlock Repress (20 mins)
- Post EVA without EMU H2O Recharge or METOX Regeneration (1 hour)
- Pre Sleep (2 hours)



CEVIS Exercise Protocol Timeline Spaceflight Decompression Sickness Contingency Plan

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1:15	POST SLEEP 75 min	4:05	4:17	5:17	5:52
	EVA PREP 170 min	Purge	EMU Prebreathe (60 min)	C/L Dep (35 min)	
	Exercise PB/Prep for Donning - 80 min on mask total	Rep			
	50 min on mask prior to start of 10.2 depress	EMU Donning 55 min			
	EV1 ex* EV2 ex* Req'd 45 min mask P/B after exer				
	45 min req'd before below 11.8 psi				
	EVA PET = 6:30	12:22			13:42
		Rep	POST EVA w/o H2O		

* EV1 must start exercise within 10 min after PB initiate, EV2 must start exercise within 25 min after PB initiate to maintain 45 minute of mask time after exercise per FR

Note: Assume depress pump and EMERG MPEV & AL VAJ; 40 min C-Lk depress with built in hold at 5psi PET = 25. With 2 hours of Pre-sleep, **STS Crew Day length = 15:42.**

EVA DAY SUMMARY

- **Post Sleep (1 hour 15 mins)**
- **EVA Prep (Total of 2 hours 50 mins)**
 - Mask Prebreathe (1 hour 20 mins)
 - 10 mins exercise for EV1
 - 10 mins exercise for EV2
 - 10.2 psi Airlock Depress (20 mins)
 - Mask Prebreathe Termination
 - Suit Donning at 10.2 (1 hour)
- **Suit Purge (12 mins)**
 - Airlock Repress to 14.7
- **In-suit Prebreathe (60 mins)**
- **Crewlock Depress to vacuum (35 mins)**
- **EVA tasks (6 hours 30 mins)**
- **Airlock Repress (20 mins)**
- **Post EVA without EMU H2O Recharge or METOX Regeneration (1 hour)**
- **Pre Sleep (2 hours)**



Shuttle 10.2 PSI Staged Protocol Timed Medical Operations Spaceflight Decompression (not shown) Sickness Contingency Plan

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	1:15	2:45	2:53	4:0
60 min Mask PB	*12 HOURS AT 10.2 psi	POST SLEEP 75 min	EVA PREP 90 min	EMU PREBBREATHE 75 min**
45 min before 12.5	EMU Donning 55 min Ck			
A/L Dep (15 min)	EVA PET = 6:30			10:53
			Rep	POST EVA w/o H2O
				12:13

* If the EVA is scheduled within 36 hours of 10.2 Dep, this table may be used to calculate the Final EMU PB time.

** The less time spent at 10.2, the longer the Final EMU Prebreathe time will be; thus, resulting in an overall longer crew day length. See chart.

*** If the EVA is scheduled later than 36 hours from 10.2 Dep, the initial PB may be eliminated and the final in-suit PB is 40 mins.

Note: Assume depress with AIRLCK DEPRESS vlv; 15 min. With 2 hours of Pre-sleep, **STS Crew Day length = 14:17.**

1 OR MORE DAYS PRIOR TO EVA DAY

- Mask Prebreathe (1 hour)
- Depress Shuttle Crew Cabin to 10.2 psi (12 hours minimum)

EVA DAY SUMMARY

- Post Sleep (1 hour 15 mins total)
- EVA Prep (1 hour 30 mins)
 - EVA Prep for Donning (30 mins)
 - Suit Donning at 10.2 (1 hour)
- Suit Purge (8 mins)

EVA DAY SUMMARY (continued)

- In-suit Prebreathe (40 to 75 mins depending on the time at 10.2 psi)
- Crewlock Depress to vacuum (15 mins)
- EVA tasks (6 hours 30 mins)
- Airlock Repress (20 mins)
- Post EVA without EMU H2O Recharge or METOX Regeneration (1 hour)
- Pre Sleep (2 hours)

INITIAL PREBBREATHE	TIME AT 10.2 PSI	FINAL PREBBREATHE
60 MINUTES	24 HOURS	40 MINUTES
60 MINUTES	20 HOURS	50 MINUTES
60 MINUTES	16 HOURS	60 MINUTES
60 MINUTES	12 HOURS	75 MINUTES

Table 1

Prebreathe Protocols- Observed and Estimated Risks

Prebreathe Protocol	Observed Risk (total DCS) Ground Trials	Flight Experience	Predicted Risk Accounting for Flight Factors* (microgravity, purge, leak check, depressurization rate, etc.)	Predicted Risk (serious Type II DCS) Accounting for Flight Factors*
EXERCISE (CEVIS)				
N	45	0 / 34		
DCS	0% ($\leq 6.5\%$ @ 95% ci)**		1.7% ($\leq 4.0\%$ @ 95% ci) ***	1 / 4972 (1/3447 – 1/8928 ci)
Grade IV VGE	6.6% ($\leq 16.3\%$ @ 95% ci)		3.8% ($\leq 12.4\%$ @ 95% ci)	
4.0 HOUR (In-suit)				
N	28	0 / 4		
DCS	21% ($\leq 38.0\%$ @ 95% ci)		4.6% ($\leq 9.4\%$ @ 95% ci)	1 / 1372 (1/960 – 1/2402 ci)
Grade IV VGE	39% ($\leq 56.6\%$ @ 95% ci)		9.9% ($\leq 32.2\%$ @ 95% ci)	
CAMPOUT (ISS)				
N	No direct ground tests	N/A		
DCS			2.8% ($\leq 5.9\%$ @ 95% ci)#	1 / 936 (1/656 – 1/1635 ci)#
Grade IV VGE			5.8% ($\leq 19.0\%$ @ 95% ci)#	
10.2 PSIA STAGED				
N	35	0 / 141		
DCS	23% ($\leq 37.5\%$ @ 95% ci)		3.8% ($\leq 7.6\%$ @ 95% ci)	1 / 311 (1/217 – 1/549 ci)
Grade IV VGE	23% ($\leq 37.5\%$ @ 95% ci)		8.0% ($\leq 26.0\%$ @ 95% ci)	

*Includes operational margin, microgravity simulation (non ambulation), accounts for exercise with CEVIS protocol. Published/peer-reviewed models.

**ci is upper 95% binomial confidence limit, based on observation of test result.

***ci is the upper part of the 95% confidence interval, based on a statistical regression.