DCS Disposition Policy Strategy Analysis for Short Duration Missions

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Analysis of Mild Type I Decompression Sickness and Return to Alternobaric Operations for Short Duration Lunar Missions

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Disclosures

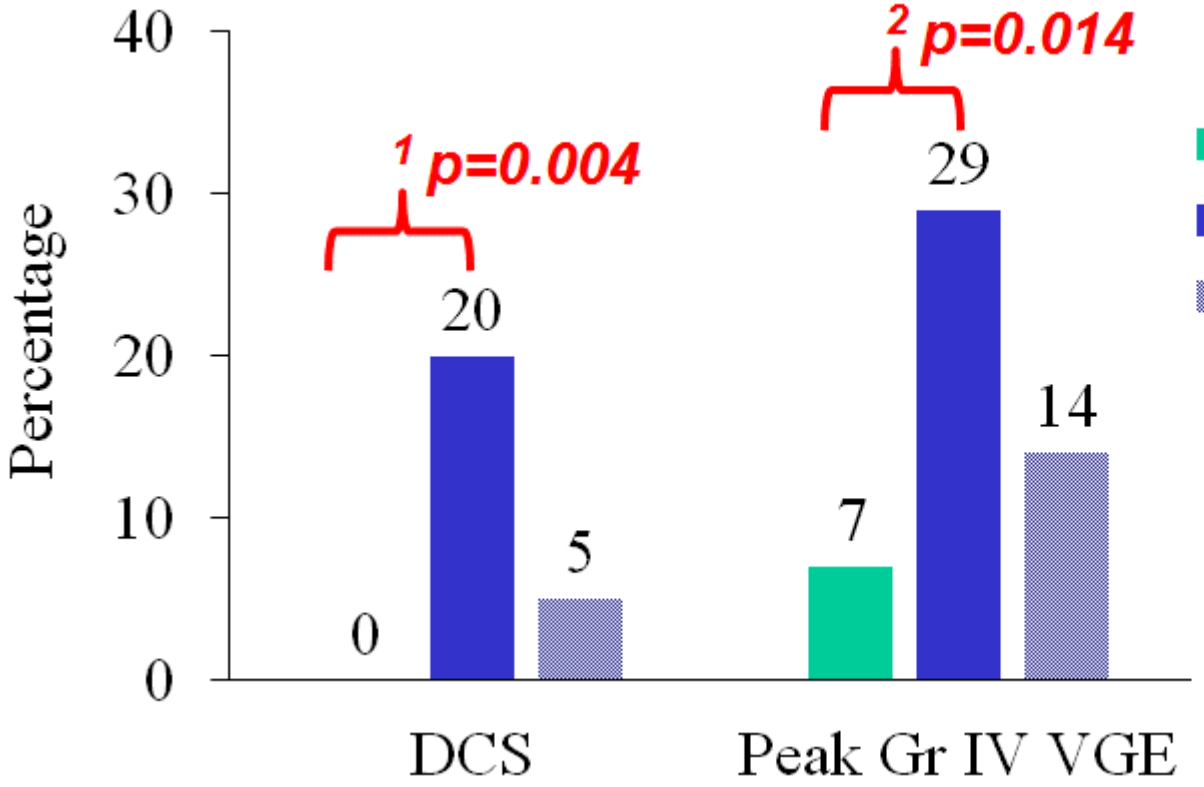
- No conflicts of interest/disclosures

Background: Difference Between Artemis and ISS EVAs

- Early Artemis mission profiles are expected to have up to 24 EVA (Extravehicular Activity) hours/week.
  - This is a significant increase compared to current operations on the ISS.
- The current downtime policy due to mild type 1 decompression sickness (DCS) with an uncomplicated recovery is 72 hours if symptoms resolve upon repress.
  - Otherwise, return to duty is 7 days after treatment and symptom resolution
- To understand future mission impacts due to DCS, the goal is to quantify how different downtime policies affect the timeline and success of various mission profiles

Planetary vs. Microgravity

- The current risk of DCS for microgravity EVAs is low, but is expected to increase for equivalent ambulatory EVAs.
- DCS risk is increased by ambulation and physical activity during altitude exposure [1]



No Ambulation (CEVIS)

Ambulation Before and During Exposure (Expt 1)

Ambulation Before Exposure Only (Expt 3)

	CEVIS	Expt 1	Expt 3
Age (y); Sex (m/f)	32±9 (35/10)	37±9 (15/5)	36±9 (17/4)
DCS	0/45 (0%)[1]	4/20 (20%)[1]	1/21 (5%)
Peak Gr IV VGE	3/45 (7%)[2]	6/21 (29%)[2]	3/21 (14%)
Cum Gr IV VGE	26/630 (4%)	12/262 (5%)	11/286 (4%)

VGE: Venous Gas Emboli

[1]Conkin J, Pollock NW, Natoli MJ, Martina SD, Wessell JH III, Gernhardt ML. Venous gas emboli and ambulation at 4.3 psia. Aerosp Med Hum Perform. 2017; 88(4):370–376.

Methods: Parameters

- Crew Size: 2
- Mission Duration: 1 week
  - Based off the Artemis III mission profile
- DCS Disposition Downtime: 24 and 72 hours from end of treatment

EVA Schedule

- Proposed scheduling:

EVAs per Week	Duration (hrs/EVA)
4	6

Number of EVAs/week	Initial Lunar Mission EVA Week						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
4	E	E		E	E		

Methods: Assumptions

- No more than 2 consecutive daily EVAs
- Cabin saturation pressure is 8.2 psia
- **Only 1 *uncomplicated* Type I DCS occurrence over a given mission** on one crew member
- **2 crew necessary** to perform EVA
- DCS event results in EVA terminate and the **DCS disposition policy** results in missing subsequent EVA(s)
- The EVA in which the DCS event occurs could be marked as completed, depending on objectives met when symptoms present
- Crew duty day requires that the EVA be initiated early in crew duty day (Final day of downtime operationally becomes closer to 36 hours)
- All EVAs are of equal importance and criticality

Future Minimum Mission Success Criteria

- *Planned* **4 EVAs in 5 days during 1st lunar mission**

- Minimum criteria: **2 Lunar Surface EVAs** lasting 4 hours each +/- 2 hours
  - (4 hour nominal + 1 hour contingency)

Calendar Analysis with Current Disposition Policy

Initial Lunar Mission EVA Week							EVAs Completed
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
E^{DCS}	E		E	E			1
E	E^{DCS}		E	E			1
E	E		E^{DCS}	E			2*
E	E		E	E^{DCS}			3*

* Meets minimum criteria

Calendar Analysis with a 24 Hour Disposition Policy

Initial Lunar Mission EVA Week							EVAs Completed
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
E^{DCS}	E		E	E			2-3*
E	E^{DCS}		E	E			3-4*
E	E		E^{DCS}	E			2-3*
E	E		E	E^{DCS}			3-4*

* Meets minimum criteria

Comparison for 4 EVAs/Week

Downtime	Initial Lunar Mission EVA Week							EVAs Completed
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
72 Hours (Current Policy)	E^{DCS}	E		E	E			1
	E	E^{DCS}		E	E			1
	E	E		E^{DCS}	E			2*
	E	E		E	E^{DCS}			3*
24 Hours (Alternate)	E^{DCS}	E		E	E			2*
	E	E^{DCS}		E	E			3*
	E	E		E^{DCS}	E			2*
	E	E		E	E^{DCS}			3*

* Meets minimum criteria

Results: One Week Missions

- DCS events that occur on EVAs earlier in the week have a much more significant impact than later in the week.
  - A shorter disposition policy allows for less significant operational impacts
- For more EVAs in a week, rescheduling has a smaller potential to makeup for missed EVAs.

Summary and Results

- 3 or 4 EVAs/week are realistic operational expectations for Artemis III
- The selected disposition policy will have a real effect on EVA operations if a crew member experiences a DCS event.
  - A 72 hour disposition policy can have a significant impact on mission success. Each disposition policy will impact mission timelines in different ways
- Rescheduling may allow for a longer downtime – currently, rescheduling a missed EVA is difficult.
  - For early Artemis missions, rescheduling would be even harder.
- Functionally, a 24 hour DCS downtime policy will result in more downtime due to scheduling gaps.
- EVAs earlier in the week and mission will have more of an operational impact

Policy Review

- Along with a review of DCS Policies from different organizations - military, diving, etc. – show the mission impacts of using different downtime policies [Abstract 154]
- There may be an increase in mission success probabilities after a Type 1 DCS event if a policy change is implemented
  - No anticipated change in risk posture for Artemis Missions.
  - ISS/Current operations: No mission impact
    - Low EVA frequency + alternate crew availability
  - This return to duty timeframe decreases is driven by the research/medical community and data.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Thank you!
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Purpose

- Analyze the effects of different DCS Disposition Strategies for 2 crew member, short duration missions
- Combine this with other DCS Policy and Disposition Analysis work
  - Action 1800.3

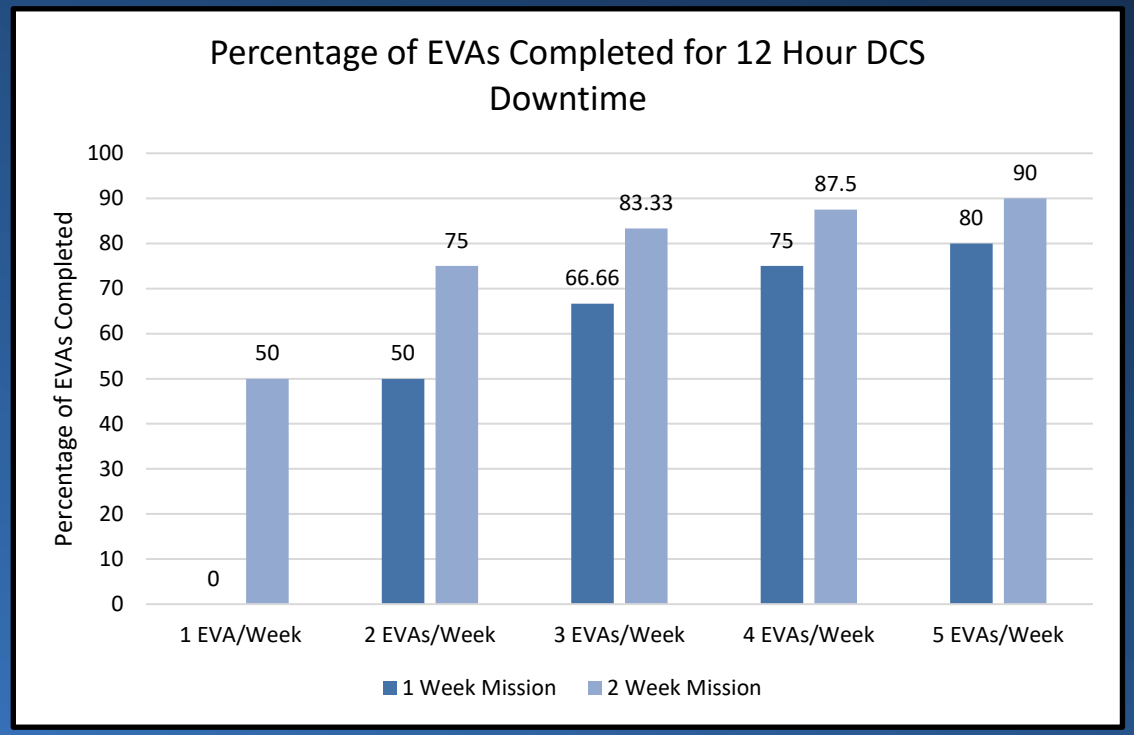
Results: 72 Hour DCS Downtime, 2 Week Mission, 4 EVAs/week

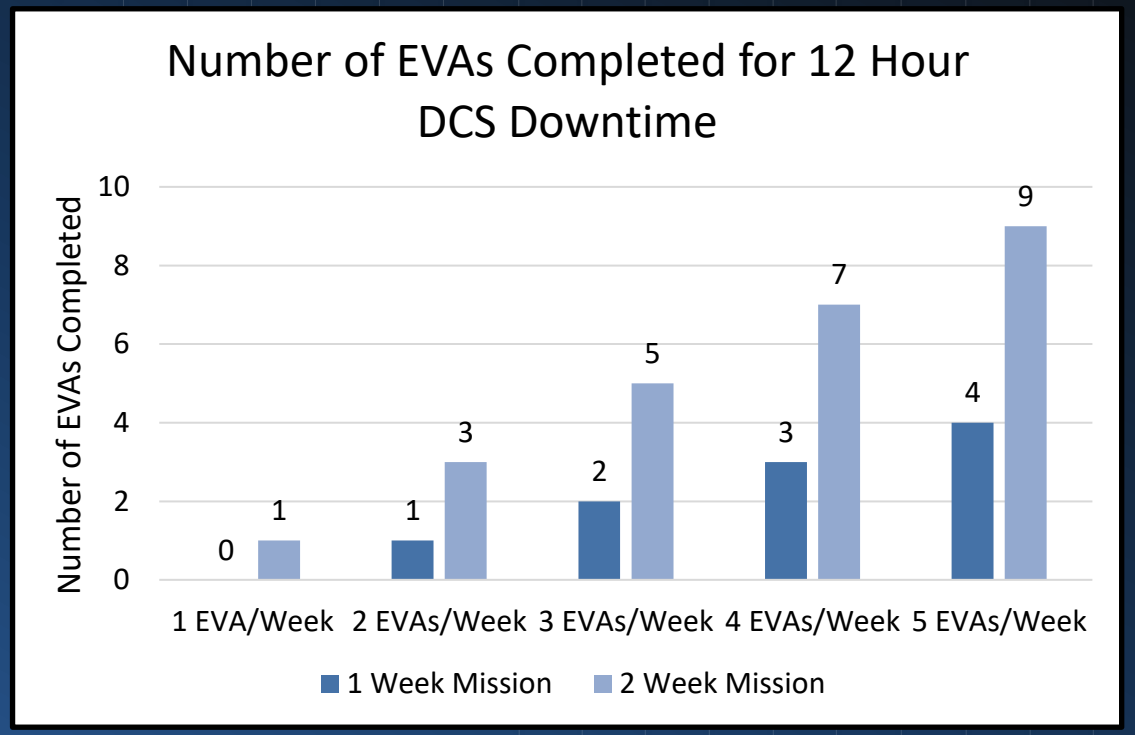
EVAs/wk	EVA Duration	EVA Number Missed	Number of EVAs Missed	Number of EVAs Completed	Percentage of EVAs Complete	Notes
4	6	1	2.5	5.00	62.5 %	Assumes 72 Hour gap between EVA 1 and 2
4	6	2	2.5	5.00	62.5 %	
4	6	3	1.5	6.00	75 %	Assumes 72 Hour gap between EVA 2 and 3
4	6	4	1.5	6.00	75 %	
4	6	5	2.5	5.00	62.5 %	Assumes 72 Hour gap between EVA 3 and 4
4	6	6	2.5	5.00	62.5 %	
4	6	7	1.5	6.00	75 %	Assumes 72 Hour gap between EVA 4 and 5
4	6	8	0.5	7.00	87.5 %	

Major Takeaways for 4 and 5 EVAs/week

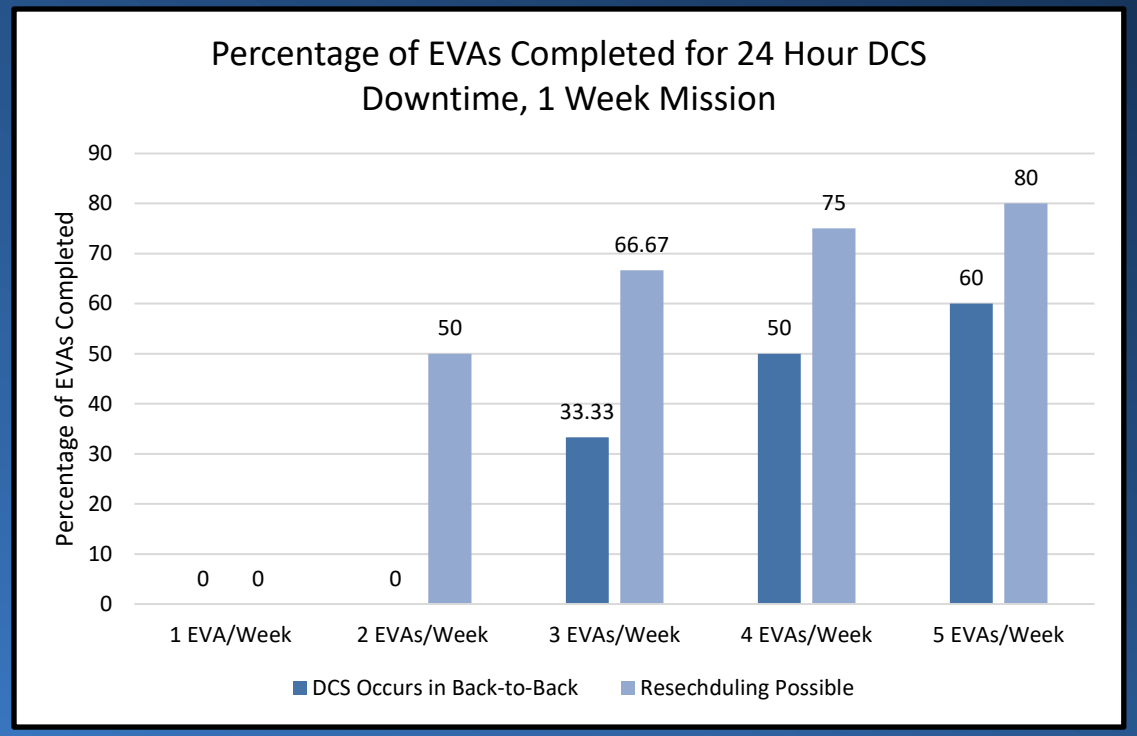
- There is little difference between 12 and 24 hour downtime policies for both 1 and 2 week missions.
  - For less than 3 EVAs/week there is no difference in percentage of EVAs completed.
- 3 or 4 EVAs/week are realistic operational expectations for Artemis III
  - The selected disposition policy will have a real effect on EVA operations if a crew member experiences a DCS event.
  - Rescheduling may allow for a longer downtime – currently, rescheduling a missed EVA is difficult.
- EVAs earlier in the week and mission will have more of an operational impact

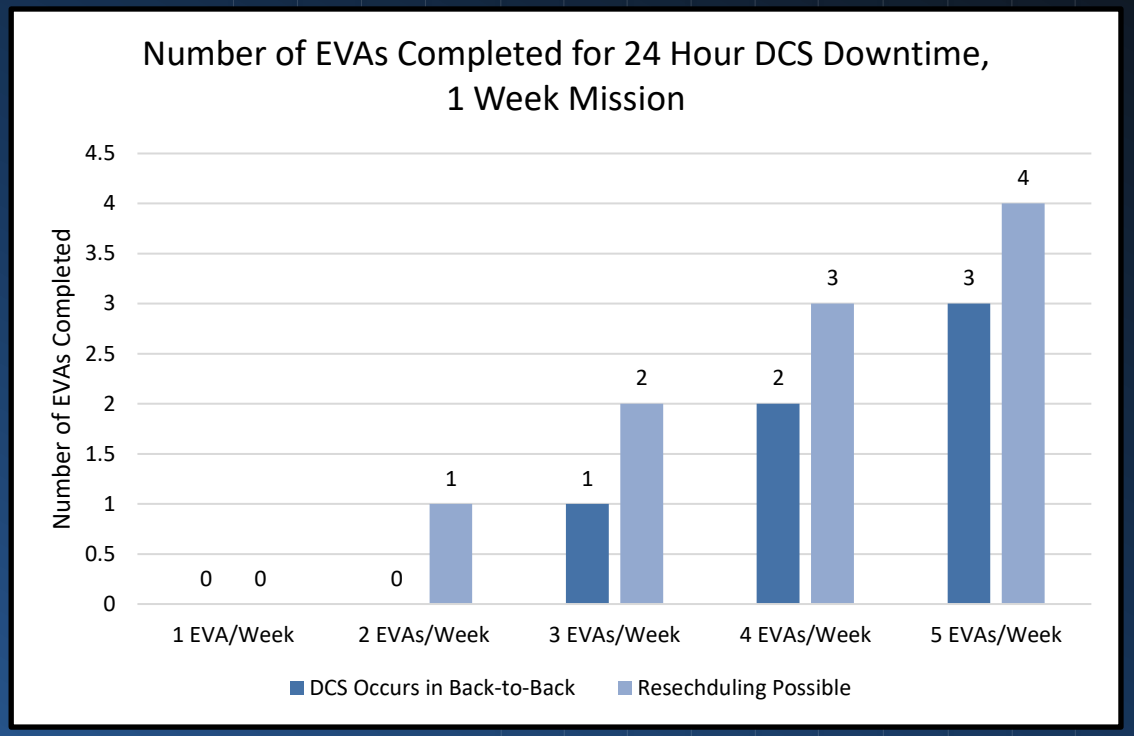
Results: 12 Hour DCS Downtime





Results: 24 Hour DCS Downtime, 1 Week Mission





Results: 24 Hour DCS Downtime, 2 Week Mission