
2011 Decompression Sickness Risk Standing Review Panel

Research Plan Review

Final Report

I. Executive Summary and Overall Evaluation

The Decompression Sickness (DCS) Standing Review Panel (SRP) would first like to compliment the Human Research Program (HRP) DCS team on a well thought out program that addresses the inherent uncertainties of DCS in space exploration. The work performed to date on this issue is well crafted and takes advantages of an experienced team.

The SRP recognizes that decompression from a saturation level lower than 14.7 psi has not been tested in any context. Adequate ground-based human testing of such saturation levels and decompression from these levels anticipated in space exploration is critical. Since all other aspects of the program are based on the results of the testing of the 8 psi to 4.3 psi extravehicular activity (EVA) proposed profile, it is strongly suggested that this study have the highest priority and be the first to be initiated.

As the current acceptable risk of DCS assessment may well be predicated on the mitigation and treatment of “anticipated” and unanticipated DCS, we believe that there is a lack of emphasis on well-validated and operationally relevant treatment options. Possible options would include compressive and evolving non-recompressive therapies. The anticipated isolation of these space missions increases the importance of on-site treatment options. The SRP believes this is best addressed in a new “gap” dedicated to DCS therapy.

Additionally, the cumulative risk of DCS to end-organs such as the central nervous system also seems to be lacking and a well formulated evidence based “gap” on the long-term and permanent consequences of DCS should be incorporated into the program. The SRP realizes the inherent difficulty of studying the long-term effects of DCS, but nevertheless believes addressing this issue is of significant importance. Target organ systems of concern certainly encompass the central nervous system, but may also include other systems. This gap may, in part, be answered under the suggested research plan.

Overall, all offered gaps and tasks appear relevant and are supported. Some suggestions are listed under each relevant gap and task.

Suggested New Gaps:

- Treatment of DCS for exploration
 - Lifetime effects of DCS on other systems (for example, structural damage to the brain)
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II. Critique of Gaps and Tasks for the Risk of Decompression Sickness (DCS) in Micro- and Partial-Gravity Environments

Gaps and Tasks:

DCS1: We do not know the acceptable DCS risk with respect to the work efficiency index (WEI) for exploration scenarios.

- The SRP thinks that this gap is very relevant and the crux of the whole DCS program
- Lack of clearly defined treatment options makes it difficult to define what is an acceptable risk
- This acceptable DCS risk should also consider the impact to crew and disposition of a impaired crew member(s) who does not respond to the DCS treatment

Task:

- Definition of Acceptable DCS Risk - Unfunded
 - Recognition that acceptable DCS risk is predicated on limited treatment options in the space exploration environment in a saturation state (8psi) that has not been previously studied. Accept/Reject criteria for studies and DCS risk acceptable limits will be a challenge to define prospectively. The SRP agrees with the concept of rejecting any profiles that manifest central nervous system or cardiopulmonary DCS.

DCS2: We do not know the contribution of specific DCS risk factors to the development of DCS in the Space Flight Exploration Environment.

- The SRP thinks that this is a very relevant gap.

Tasks:

- DCS Nucleation Mechanisms – PI: Michael Gernhardt, Ph.D. and Neal Pollack, Ph.D., NASA JSC
 - The SRP thinks that this task is appropriate.
 - Though this is more developmental research, its translation potential is high.
- Prevalence of Venous Gas Emboli after Depressurization in Microgravity - Unfunded
 - The SRP thinks that this task would be appropriate and will contribute to DCS1 (acceptable risk) ground based studies.
- N₂ Elimination in Microgravity – PI: Kim Prisk, Ph.D., University of California, San Diego
 - The SRP thinks that this task is appropriate.
- Abbreviated Purge - Unfunded
 - The SRP thinks that this task would be appropriate.
- Intermittent Recompression - Unfunded
 - The SRP thinks that this task would be appropriate.

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- Animal Models to Evaluate DCS - Unfunded
 - An animal model can permit studies that are not ethical or feasible in humans. This task complements the overall research design but may yield the least valuable data. Be that as it may animal models to most closely mimic human physiology should be sought but are yet to be validated.
 - In addition to the suggested studies in animals, a well validated model may serve as a platform for testing interactions of drugs on DCS (such as stimulants) or potential treatment modalities, as well as environmental aspects such as relation of hypoxia to DCS.

Suggested New Tasks for DCS2:

- Individual susceptibility to DCS/bubble formation is an accepted concept in the field and should be explored within the context of the suggested research plan.
- There was some concern that the proposed age/gender group size will make sub-group comparison difficult. A more balanced subject inclusion criterion may serve as a more enduring result.
- It had been shown that body temperatures can have a profound effect on DCS risk (Balldin, UI. The preventive effect of denitrogenation during warm water immersion on decompression sickness in man. *Försvarsmedicin (Stockholm)*. 1973; 9:239-43.); temperature issues on bubble formation and DCS in space exploration should be investigated and the results incorporated in the development of protective equipment and procedures.

DCS3: We do not know the mission related factors that contribute to DCS risk.

- The SRP thinks that this is a relevant gap.
- The SRP is also impressed with the well thought out tasks being done with anticipating the mission requirements utilizing ground, ground based simulators and underwater simulations.

Tasks:

- Exploration EVA Environment Characterization - Unfunded
 - The SRP thinks that this task would be appropriate.
- EVA Simulator Development – Unfunded
 - The SRP thinks that this task would be appropriate.
 - This is a well developed aspect of the research plan.
 - As the final mission/missions are continuing to evolve, robust simulator development should be continually reviewed and improved.

DCS4: We do not know to what extent physiological and environmental factors can be incorporated and validated in a model of DCS for micro and reduced gravity.

- The SRP thinks that this is a relevant gap.

Tasks:

- Develop and Validate Risk Model for DCS – Unfunded
- Develop and Validate Treatment Model for DCS – Unfunded

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- Exercise Saturation Equivalent Testing – Unfunded

Modeling is quite important in designing experiments and developing contingency plans for unanticipated situations. However, the SRP emphasizes that only actual testing of the exposure profile will suffice. The application of predictive DCS results from models is only acceptable if the model has been validated with prospective human trials.

- The SRP thinks that all three of these tasks would be appropriate.
- The SRP agrees with proposed model testing strategy, but additional, individual testing would be the gold standard instead of modeling.
- In addition to the Tissue Bubble Dynamic Model (TBDM), other competing models (e.g., the United States Air Force Altitude DCS Risk Assessment Computer (USAF ADRAC), (<https://biodyn1.wpafb.af.mil>) should also be evaluated and incorporated into the proposed design.

DCS5: We do not know what validated procedures will adequately prevent DCS and treat it should it occur.

- The SRP thinks that this is the **most important and relevant gap; and that the tasks addressing this gap should be the first to be initiated.**
- This gap has the chance to answer the most pressing issues and is directly related to DCS1.
- If you do not answer this gap, you cannot address the other gaps.
- Suggest the word “treat” be removed here and moved to the new suggested gap on treatment. If the word “treat” is in this gap, there should be some tasks dedicated to treatment (compressive and non-compressive).

Tasks:

- Prebreathe Accept/Reject Limits for Exploration Atmosphere and PB Validation – Unfunded
 - The SRP thinks that this task would be appropriate.
- Exploration Atmosphere Prebreathe Validation - Unfunded
 - The SRP thinks that this task would be appropriate.
- ISS Airlock Exploration Atmosphere and PB Verification - Unfunded
 - The SRP thinks that this task would be appropriate.
- MMSEV on ISS Exploration Atmosphere and PB Verification - Unfunded
 - The SRP thinks that this task would be appropriate.

Suggested New Task for DCS5 (or acceptance of a new gap):

“Treatment” is underemphasized within this gap. Tested/validated options for treating DCS need to be further explored. The proper emphasis is best addressed with a stand-alone gap. Additionally the cumulative effect of DCS on end organ systems is unknown but would have relevance in consideration of prevention and treatment modalities.

DCS6 – We do not know what new developments related to DCS will come from other investigators.

- The SRP thinks that is a relevant gap.

Task:

- Technology Watch for DCS Information and Technology Development – Unfunded
 - As many of the tasks, especially in DCS2 are a direct result of recent basic research, the value of this gap is obvious. How best to integrate a very diverse body of research is a challenge, but appears well addressed by the research team.

III. Discussion on the strengths and weaknesses of the IRP

Is the Risk addressed in a comprehensive manner?

- Yes

Are there obvious areas of potential integration across disciplines that are not addressed?

- Although addressed, engineering and atmospheric issues need integration
- Need to continue coordination with engineers on parameters
- Impressed with how many disciplines the DCS group is already working with

IV. Additional Comments

Though controversy exists regarding the best mode of bubble detection and its relevance to DCS, we encourage the team to further consider collection/analysis of echocardiographic and ultrasound tissue bubble detection modalities including extravascular bubble detection within their research plan. Additionally, robust databases exist and are accessible within the Department of Defense (Air Force) and may serve to enhance aspects of this program (<https://biodyn1.wpafb.af.mil>).

V. Decompression Sickness Risk SRP Research Plan Review Statement of Task

The 2011 Decompression Sickness (DCS) Standing Review Panel (SRP) is chartered by the Human Research Program (HRP) Program Scientist at the NASA Johnson Space Center (JSC). The purpose of the SRP is to review the DCS section of the HRP's Integrated Research Plan (IRP). Your report will be provided to the HRP Program Scientist.

The 2011 DCS SRP is charged (to the fullest extent practicable) to:

1. Evaluate the ability of the IRP to satisfactorily address the risk by answering the following questions:
 - A. Have the proper Gaps been identified to address the Risk?
 - i) Are all the Gaps relevant?
 - ii) Are any Gaps missing?
 - B. Have the proper Tasks been identified to fill the Gaps?
 - i) Are the Tasks relevant?
 - ii) Are any Tasks missing?
2. Identify the strengths and weaknesses of the IRP, *and* identify remedies for the weaknesses, including answering these questions:
 - A. Is the risk addressed in a comprehensive manner?
 - B. Are there obvious areas of potential integration across disciplines that are not addressed?
3. Address (as fully as possible) the questions provided in the charge addendum and to provide comments on any important issues that are not covered in #1 or #2 above.

Additional Information Regarding This Review:

1. Expect to receive review materials at least four weeks prior to the site visit.
2. Participate in a 2011 DCS SRP teleconference to discuss any issues, concerns, and expectations of the review process approximately three weeks prior to the face-to-face meeting.
 - A. Discuss the 2011 DCS SRP Statement of Task and address questions about the SRP process.
 - B. Identify any issues the 2011 DCS SRP would like to have answered prior to the site visit.
3. Attend the 2011 DCS SRP at NASA JSC in January 2012.
 - A. Attend Element presentations, question and answer session, and briefing.
 - B. Prepare a draft report, including any recommendations. Debrief the HRP Program Scientist on what will be included in final report and should address #1, #2, and #3 above.

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4. Prepare a final report (within one month of the site visit) that contains a detailed evaluation of the risks organized by Items #1, #2, and #3 above and provides specific recommendations that will optimize the scientific return to the HRP. The report will be sent to the HRP Program Scientist. A copy of the report will be provided to the Human Health Countermeasures Element at NASA JSC that sponsors the DCS discipline. Once the report is finalized it will be made available to the public.
 5. Consider the possibility of serving on a non-advocate review panel of a directed research proposal or on a solicited research peer review panel; or otherwise advise the Program Scientist.

VI. Decompression Sickness Risk Standing Review Panel Roster

Panel Chair:

Captain Richard Mahon, M.D.

Naval Medical Research Center

503 Robert Grant Avenue

Silver Spring, MD 20910

Ph: 301-319-7317

Email: richard.mahon@med.navy.mil

Panel Members:

Stephen McGuire, M.D.

59MDW – USAFSAM/FECN

DCS Study

2200 Bergquist Drive

Suite 1, Room 6B27

Lackland AFB, TX 78236

Ph: 210-260-2153

Email: smcguire@satx.rr.com

Andrew Pilmanis, Ph.D.

5281 Hawk Eye Drive

Bulverde, TX 78163

Ph: 210-859-1303

Email: apilmanis@aol.com