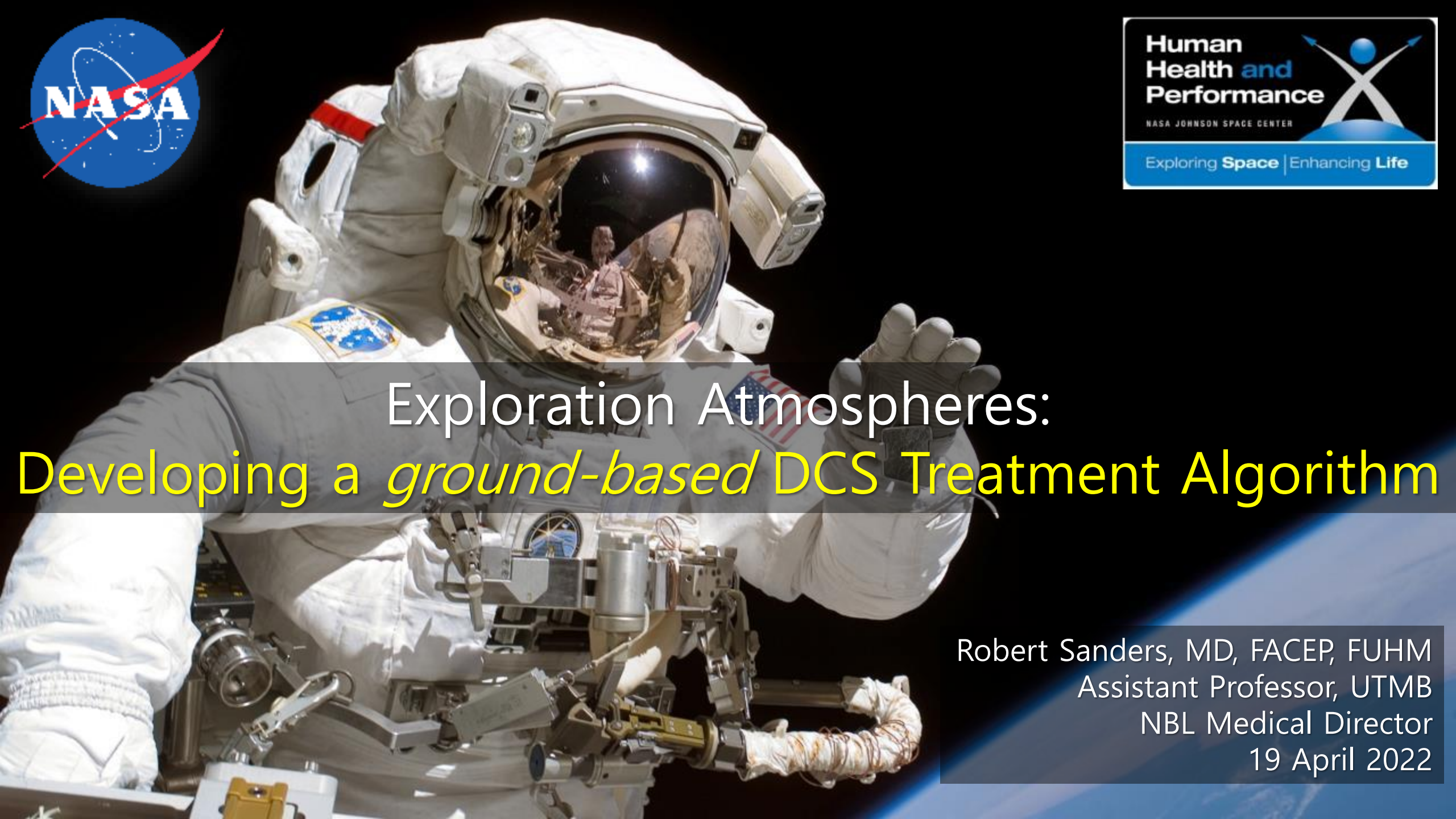


Exploration Atmospheres:
Developing a *ground-based* DCS Treatment Algorithm

Robert Sanders, MD, FACEP, FUHM
Assistant Professor, UTMB
NBL Medical Director
19 April 2022

Purpose and Outline

- Outline
  1. Review EA Trial
  2. State of Knowledge
  3. Expected Results (DCS & VGE)
  4. Critical Questions/Decision Making
  5. Decompression Sickness Review
  6. Atmospheric Impacts
  7. Planned Treatment Flow

What is “exploration atmospheres”?

- Study to validate lunar prebreathe (denitrogenation) options
- 12-day study with subjects “living” in a 3-story 20’ diameter chamber at about 15,000’ altitude
- 5 simulated EVAs

State of Knowledge – DCS and Ambulation

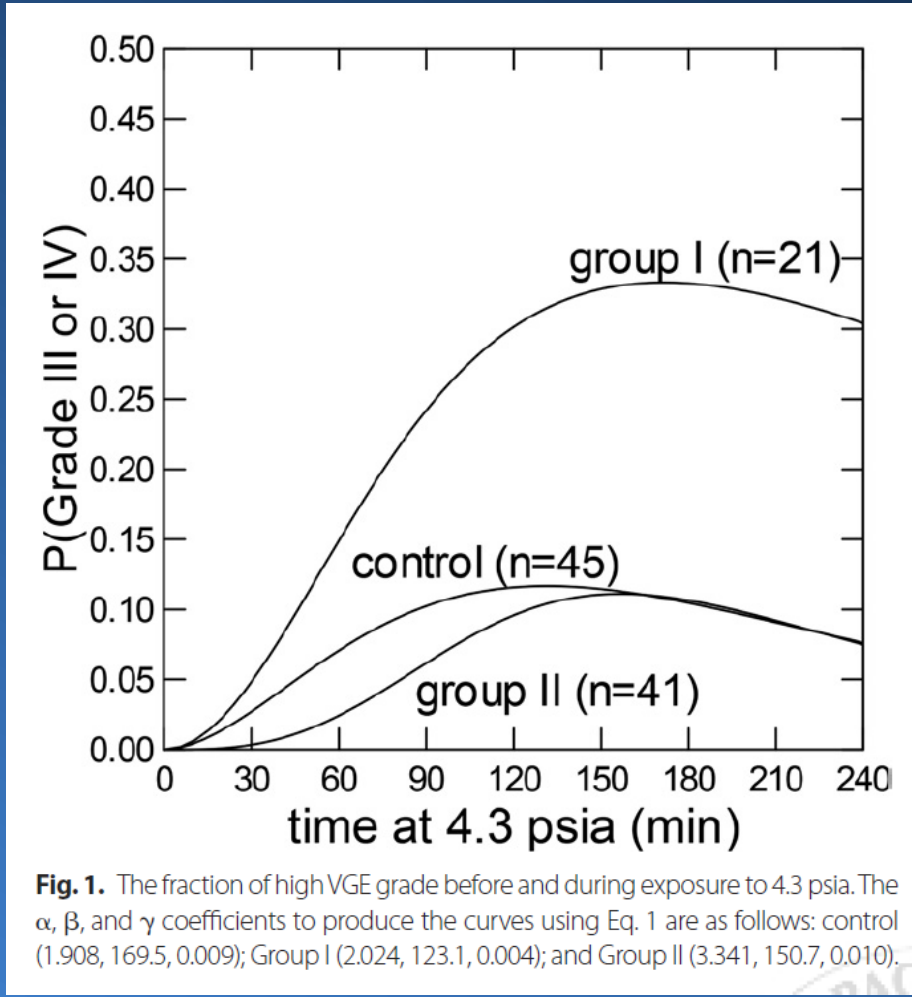
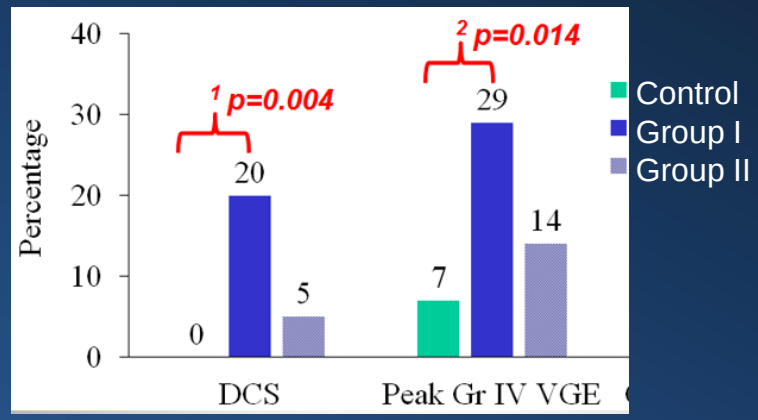


Fig. 1. The fraction of high VGE grade before and during exposure to 4.3 psia. The α, β, and γ coefficients to produce the curves using Eq. 1 are as follows: control (1.908, 169.5, 0.009); Group I (2.024, 123.1, 0.004); and Group II (3.341, 150.7, 0.010).

- Ambulation at 4.3 psia increases risk of DCS and Grade IV VGE.
- Group I ambulated at 4.3 psia, Group II ambulated before ascent, Control did not ambulate at all.



Conkin J, Pollock NW, Natoli MJ, Martina SD, Wessel JH, III, Gernhardt ML. Venous gas emboli and ambulation at 4.3 psia. Aerosp Med Hum Perform 2017; 88:370-76.

Pollock NW, Natoli MJ, Martina SD, Conkin J, Wessel JH, III, Gernhardt ML. Decompression sickness during simulated low pressure exposure is increased with mild ambulation exercise. 2016 (87th) Annual Scientific Meeting of the Aerospace Medical Association, Atlantic City, New Jersey, Abstract No. 80, pp. 188, April 24-28.

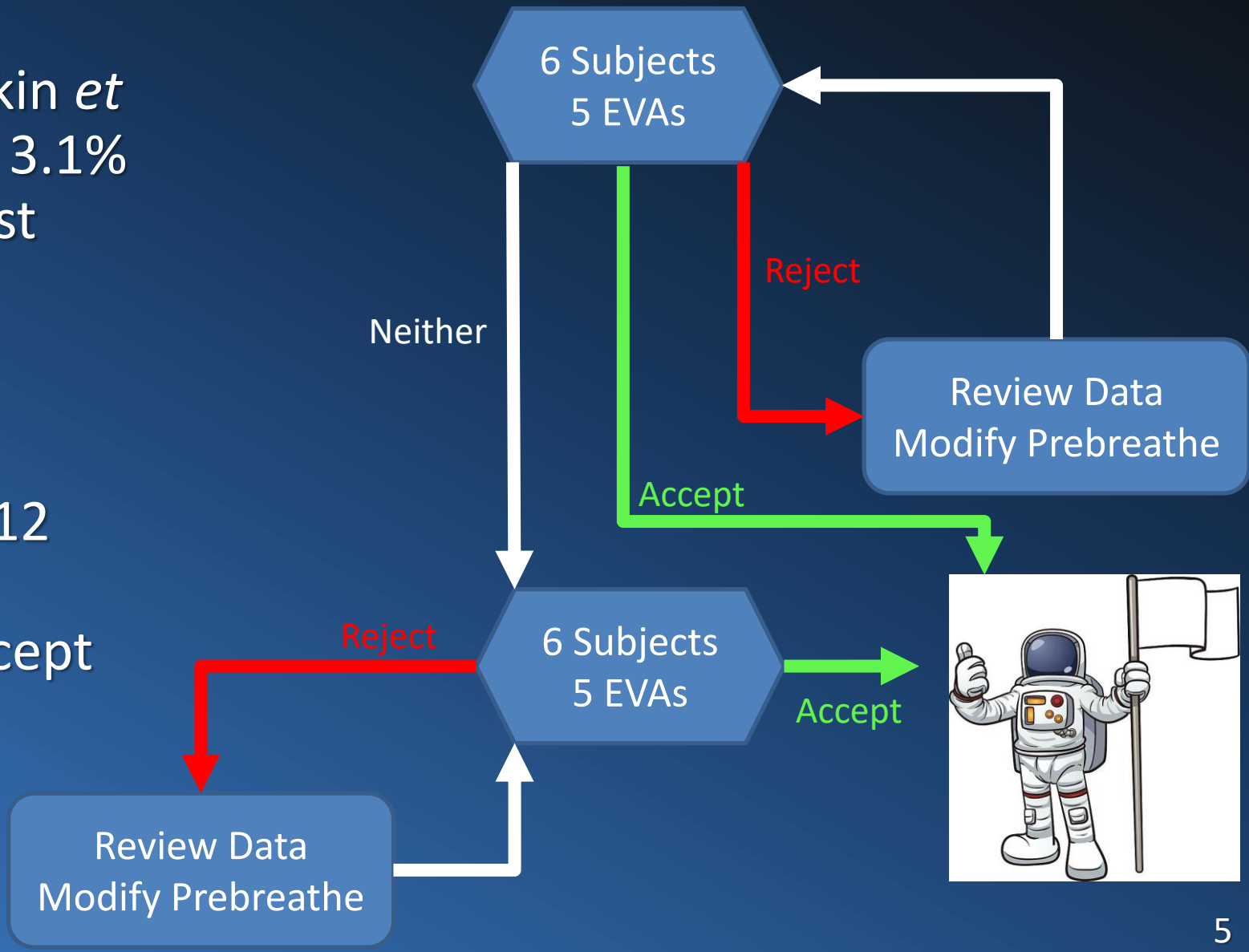
Expected Results

Model Data:

- The DCS survival model (Conkin *et al.*, 2014) calculates P(DCS) = 3.1% (1.8 to 5.4%) for planetary test subjects.

Power Analysis:

- If $P(DCS_{planetary})$ = 3.1%, then 12 subjects x 5 EVAs has an 88% probability of meeting the accept condition.



Initial Questions

- Is the plan to test & vet a treatment protocol (2-hr “GLO ± suit”)
  - or
- Strive for successful treatment (overtreat) and keep in the study if possible
  - or
- DCS patient is out of the study, so treat fully, get back to baseline (straight to chamber, gold-standard treatment).

Caveats

- If the patient comes out of the chamber BUT STAYS ON O2, may go back into study (but sit out next EVA*)
- If the patient exits the chamber but breathes ambient air, then lost to the study can't give "air breaks" (required for "gold standard" terrestrial DCS treatment)
- A Type 2 case ends the study
- Need a Treatment Chamber On-Site

Operational Classification of DCS at JSC
JPR 1800.3 DCS Manual

- Type I – pain-only
  - "Pain" can be an awareness or even impair performance
  - Will stop a research exposure regardless of intensity
- Type II – serious DCS
  - Can result in long-term injury
  - Will invalidate the research protocol

Type II, or “Serious” DCS

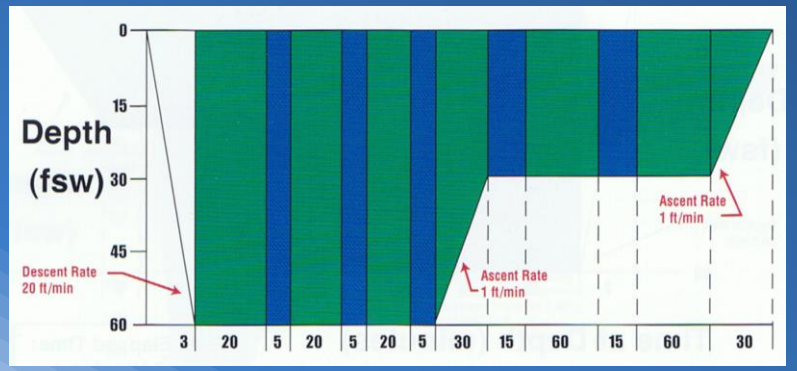
- Seven Type II cases in 1,031 NASA exposures (1982 – 2016):
  - Four of the seven had no O_2 prebreathe
  - We will provide > 6.5 hours of effective prebreathe for Exploration Atmosphere

Basic DCS Treatment

- Diver and aviator DCS is treated with:
  - pressure
  - oxygen
  - time
  - emergency care interventions
  - US Navy TT6 is the “standard”

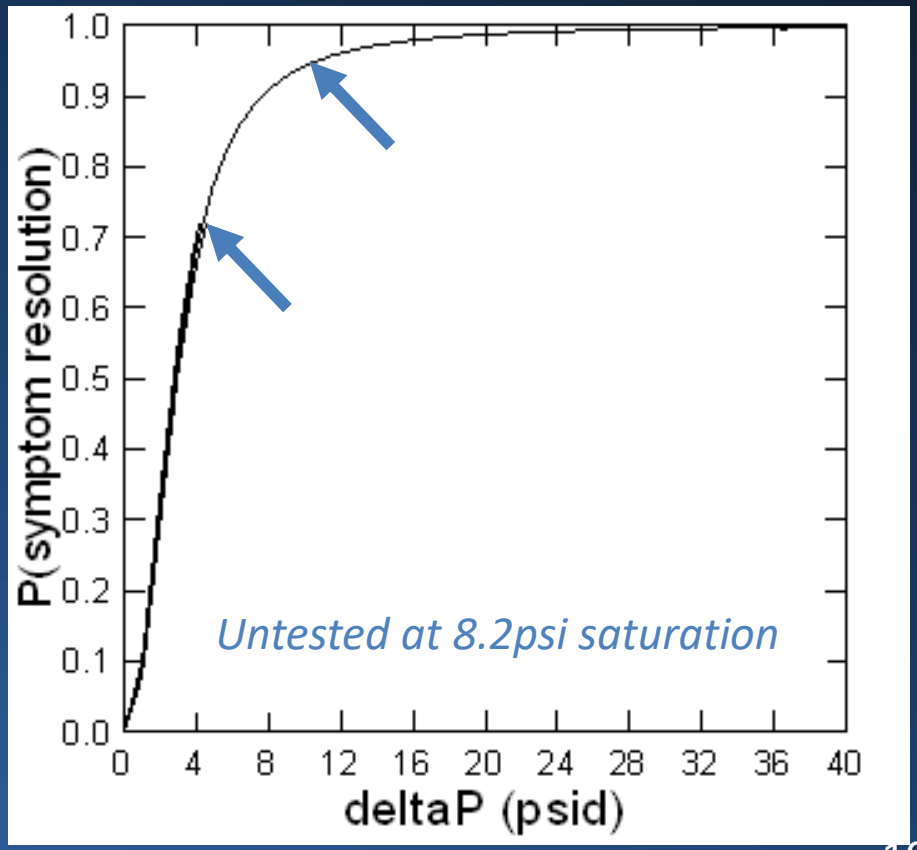
- Hypobaric DCS has built-in pressure treatment since you eventually return to saturation pressure of 14.7 psia.

- Returning to saturation pressure of 8.2 psia may be as effective, but empirical data are needed.

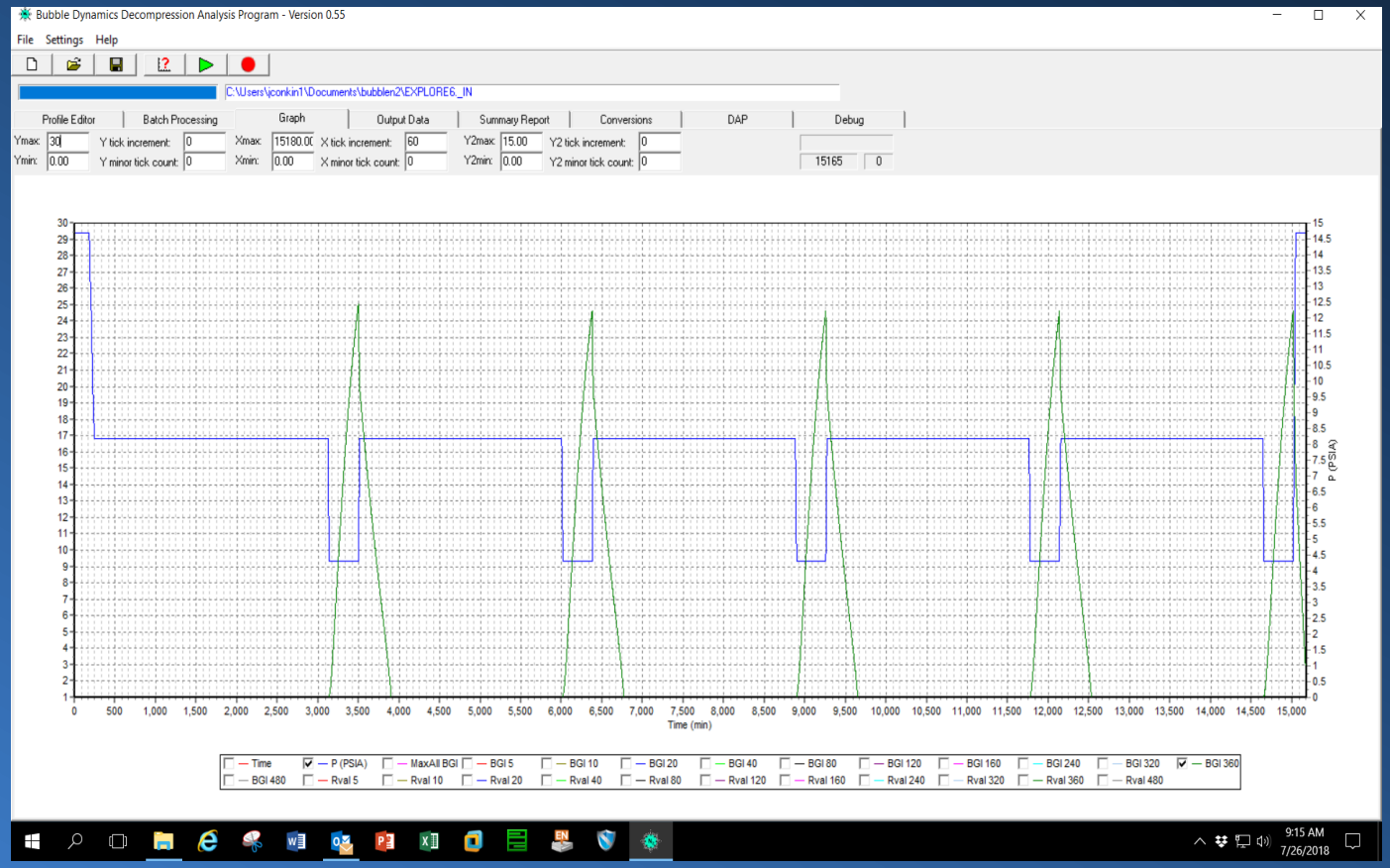


ΔP = 14.7 psia – 4.3 psia = 10.4 psid ≈ 95%

ΔP = 8.2 psia – 4.3 psia = 3.9 psid ≈ 72% (?)



State of Knowledge – DCS Risk in Exploration Atmosphere



- **Model Estimated Risk of DCS is 3% (2 - 5)**
- **Model Estimated Risk of Grade IV VGE is 8% (5 – 15)**

Conkin J. Probability of decompression sickness and venous gas emboli from 49 NASA hypobaric chamber tests with reference to Exploration Atmosphere. Houston, TX: NASA Johnson Space Center; March 2020. NASA Technical Publication NASA/TP-2020-***** (in review).

Answers to questions:

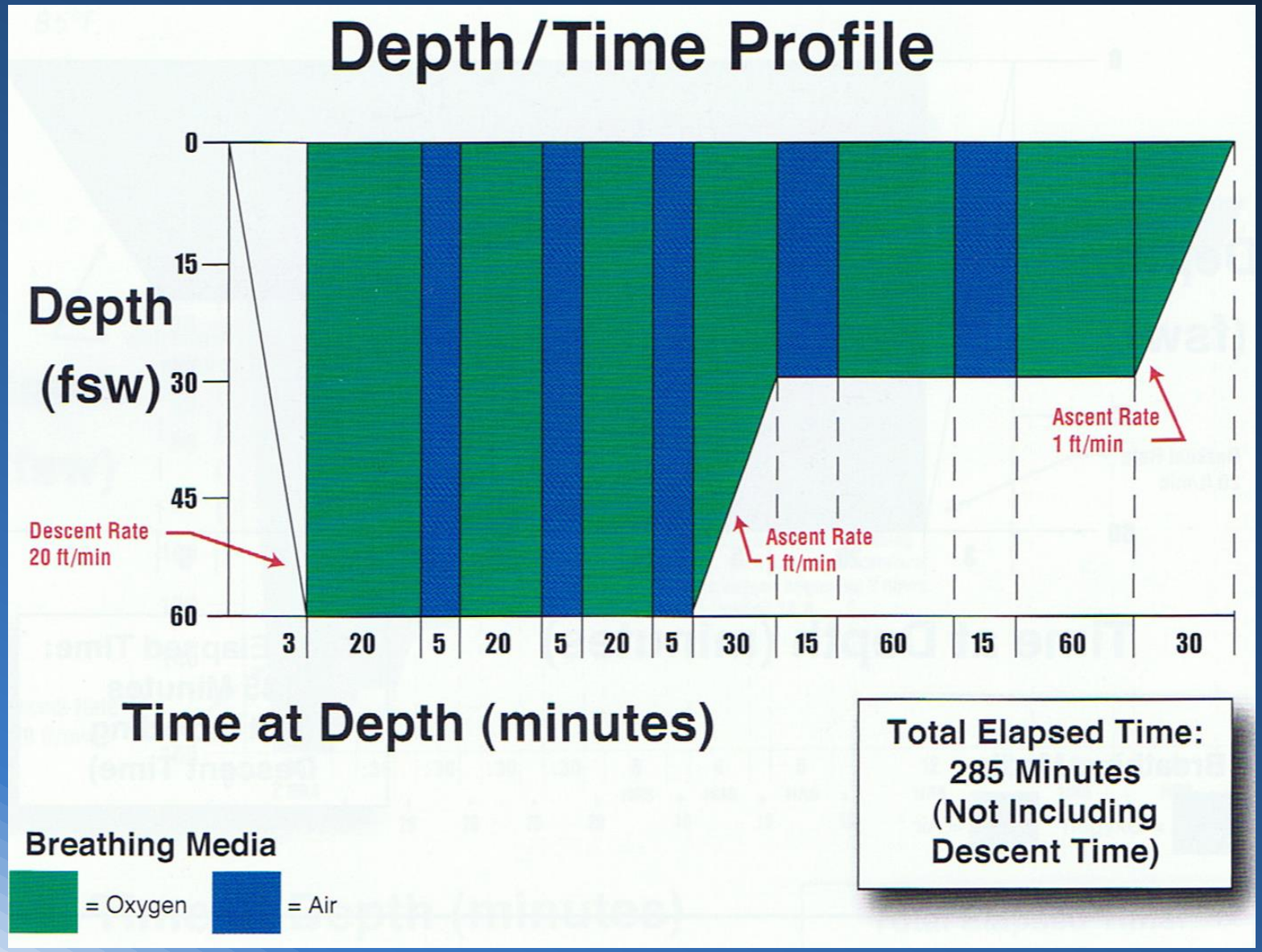
- DCS type 1 does not DQ a test subject from the study
- We are NOT vetting a Lunar Treatment plan
- Want the best chance for the subject to return to the study without recurrent DCS (new case OK)

The Math:

- Subjects live at 8.2 psi
- EVA (and DCS) happens at 4.3 psi
- Can treat at 14.7 psi

- 14.7 / 4.3 = 3.4186 (terrestrial equivalent: 79.81 fsw)
- US “Gold Standard” is 60 fsw when DCS occurs at 1ata (surface)

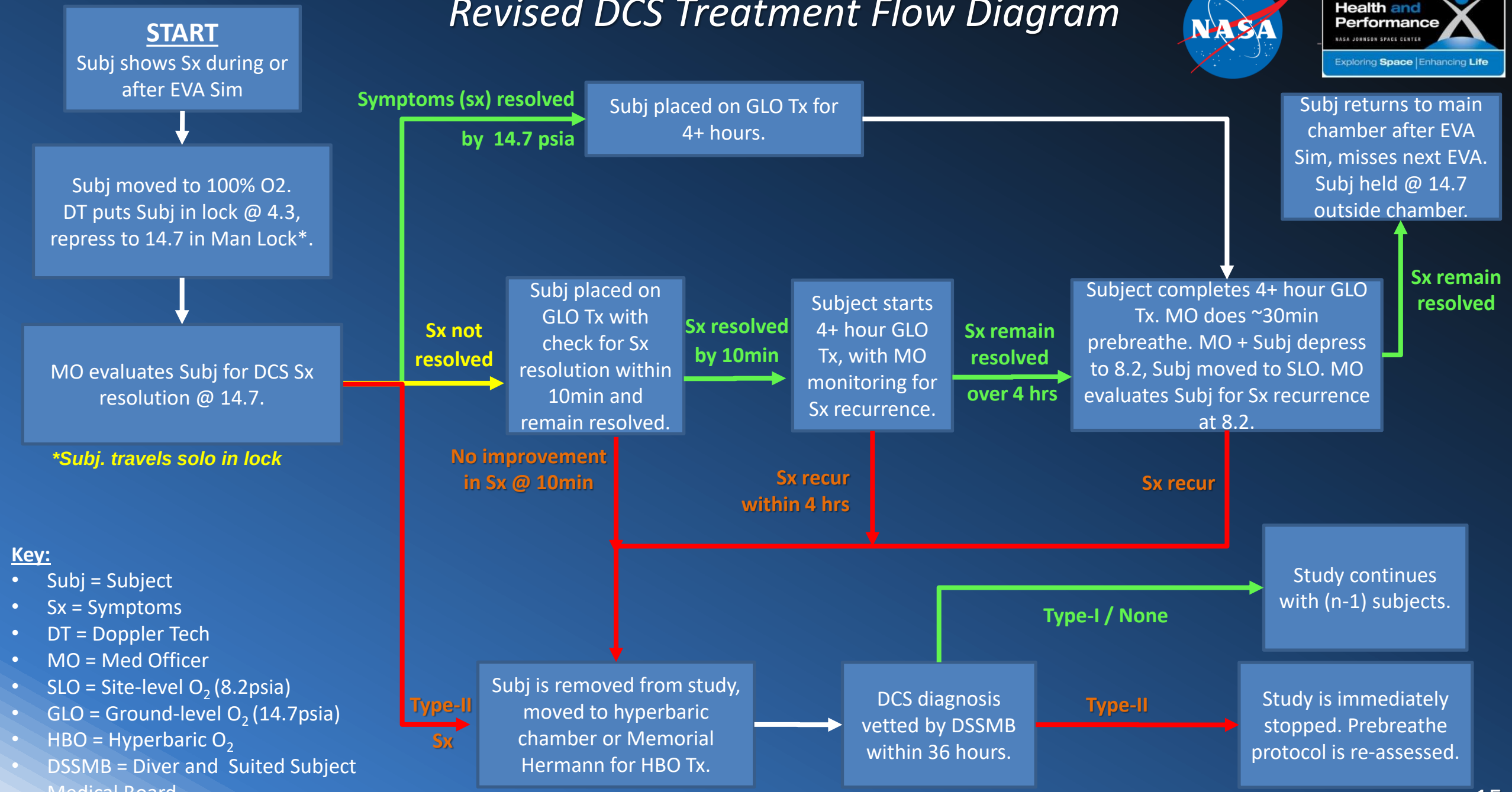
Treatment Table 6



- O2 @ 60 fsw: 60 mins
- O2 @ 30 fsw: 120 mins
- O2 from 60-30: 30 mins
- O2 from 30-0': 30 mins

- Total O2: 4 hours

Revised DCS Treatment Flow Diagram



Key:

- Subj = Subject
- Sx = Symptoms
- DT = Doppler Tech
- MO = Med Officer
- SLO = Site-level O_2 (8.2psia)
- GLO = Ground-level O_2 (14.7psia)
- HBO = Hyperbaric O_2
- DSSMB = Diver and Suited Subject Medical Board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Questions?