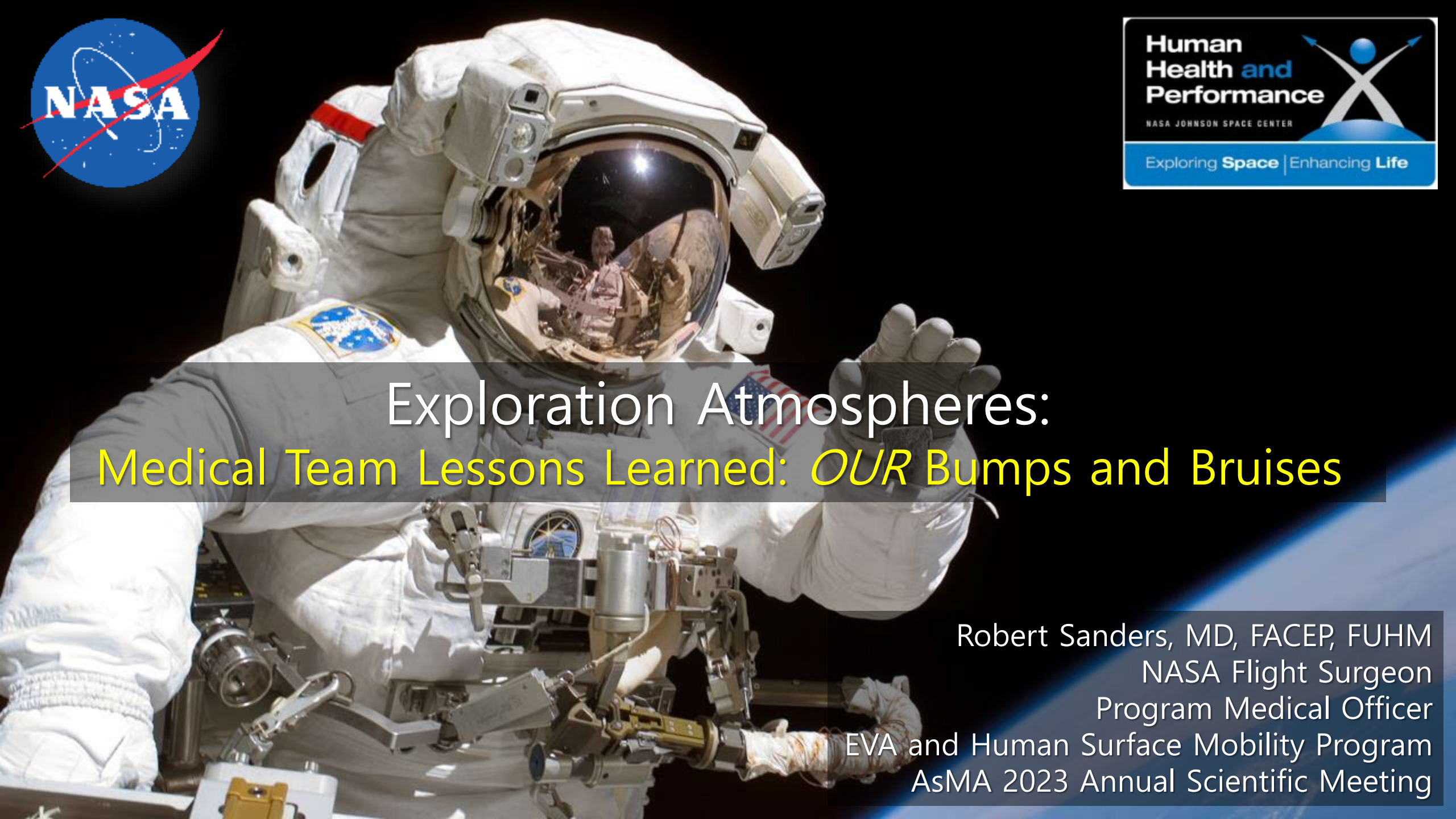


Exploration Atmospheres:
Medical Team Lessons Learned: *OUR* Bumps and Bruises

Robert Sanders, MD, FACEP, FUHM
NASA Flight Surgeon
Program Medical Officer
EVA and Human Surface Mobility Program
AsMA 2023 Annual Scientific Meeting

Disclosure Information

92nd Annual Scientific Meeting

Bob Sanders, M.D.

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation.

The opinions discussed are mine and mine alone, they do not necessarily represent those of NASA or the federal government

I would like to thank Dr. Kristi Ray for her help in preparing this presentation

Purpose and Outline

- Outline
  1. Review EA Trial
  2. Hurdles
  3. Solutions
  4. Lessons Learned:
     1. food obstacles,
     2. sleeping issues,
     3. medications,
     4. joint injury,
     5. equipment limitations,
     6. medical privacy,
     7. cases of decompression sickness,
     8. and even a COVID outbreak

What is “exploration atmospheres”?

- Study to validate lunar prebreathe (denitrogenation) options
- 11-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

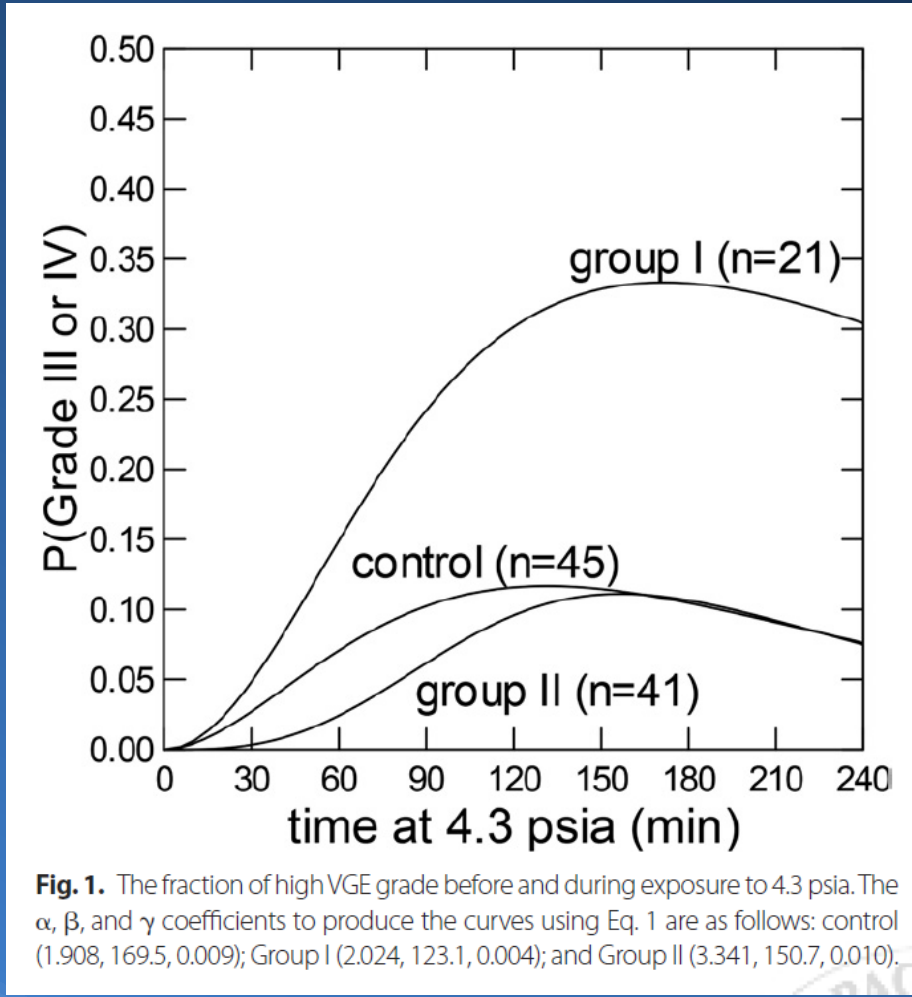
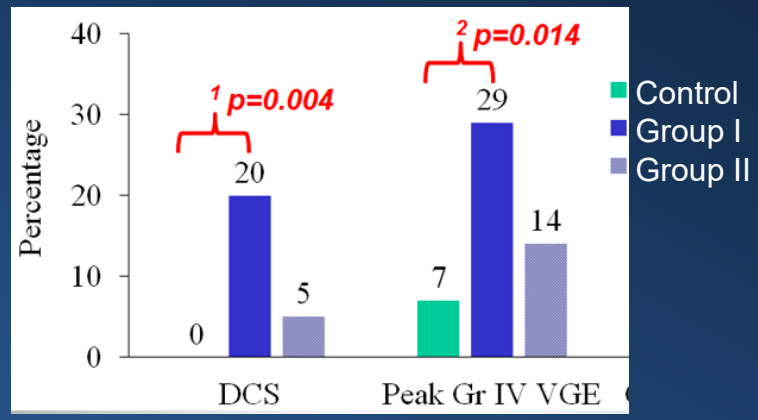


Fig. 1. The fraction of high VGE grade before and during exposure to 4.3 psia. The α, β, and γ coefficients to produce the curves using Eq. 1 are as follows: control (1.908, 169.5, 0.009); Group I (2.024, 123.1, 0.004); and Group II (3.341, 150.7, 0.010).

- 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.

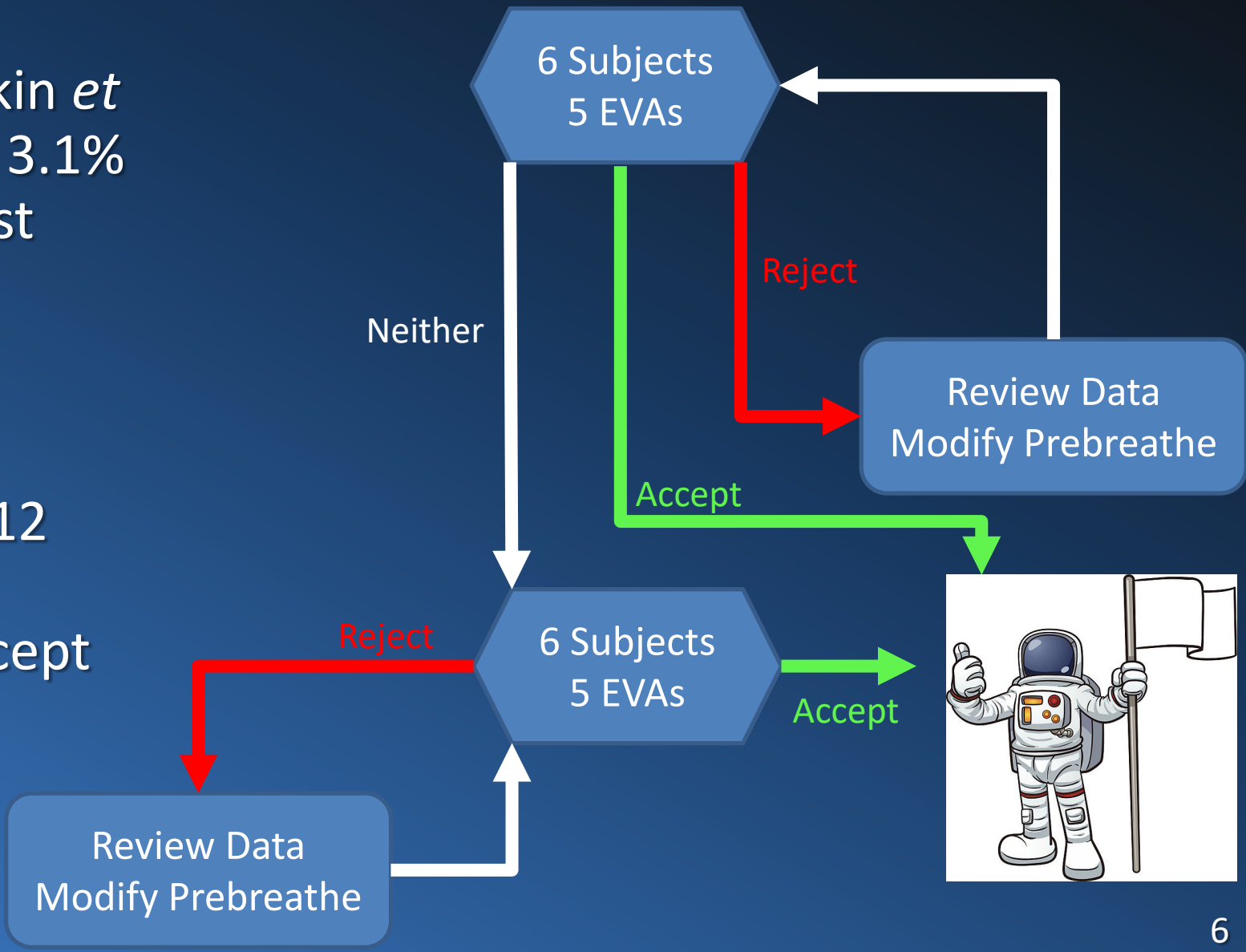
Expected Results

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 Expectations

- **So I expected the challenge to be the diagnosis of DCS, and it was…**

- Six possible cases of DCS,
  - 3 with delayed presentations,
  - 1 in real time
  - 2 cases in the Doppler/ultrasound techs,
    - (two cases were adjudicated out by expert panel)

- **But it did not stop there**

Private Medical Conferences (PMC)

- PMC's for eight persons, had to be extremely efficient
- Not around the staffing schedule *I planned*

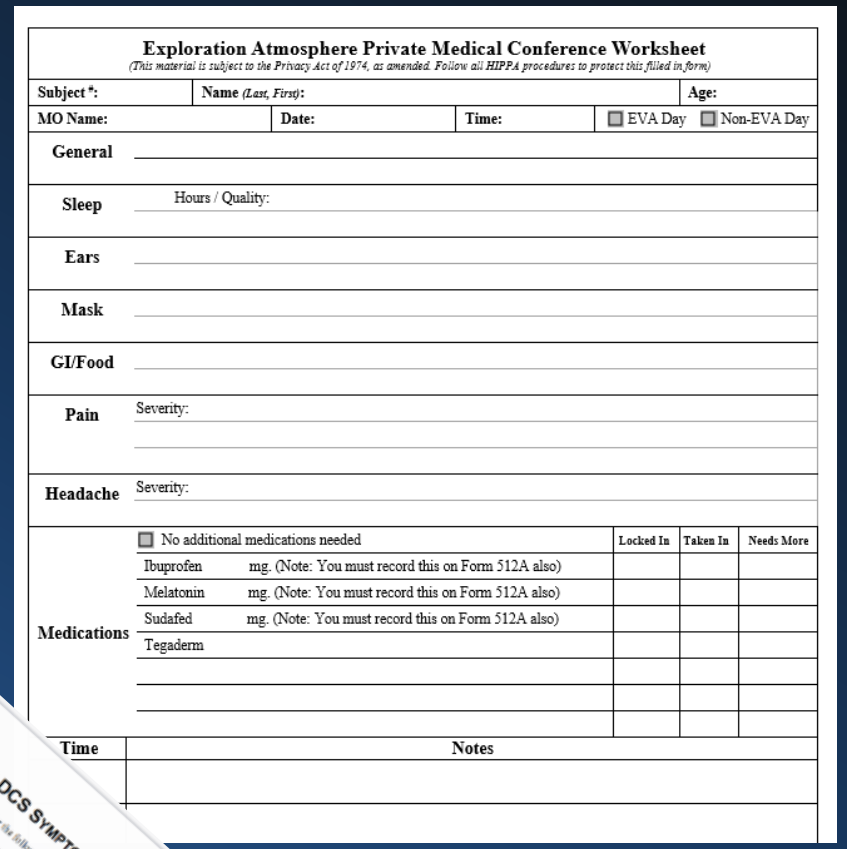
BLUF

- Training was essential!
  - EVA shift VERY different from anything a doctor has done before at NASA (& beyond)

- Because of the 24/7 nature of it
  - Teamwork essential
  - All need to be on the same page
  - Pre-event training &
  - Just-in-time training products essential
    - PMC scripts
    - Record forms

The heck with trees

- Forms (and lots of them) were critical
  - PMCs for 8 persons must be efficient
  - Paper charts have a personality, easier to navigate
  - Separate form for each phase
    - PMC
    - EVA simulation
  - New forms for each day
    - Keep all charts in the same place for quick access
    - Aids in end of shift sign out
      - See & Hear



Exploration Atmosphere Private Medical Conference Worksheet

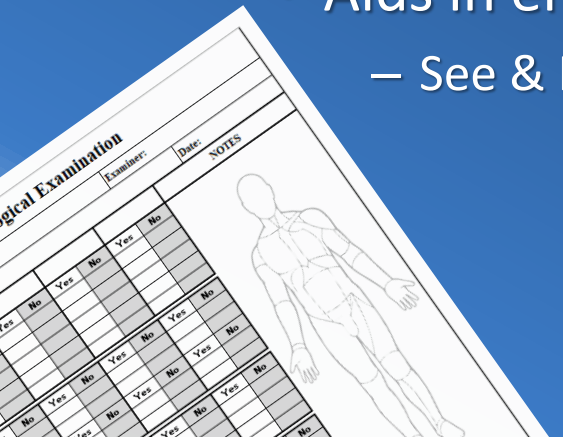
(This material is subject to the Privacy Act of 1974, as amended. Follow all HIPPA procedures to protect this filled in form)

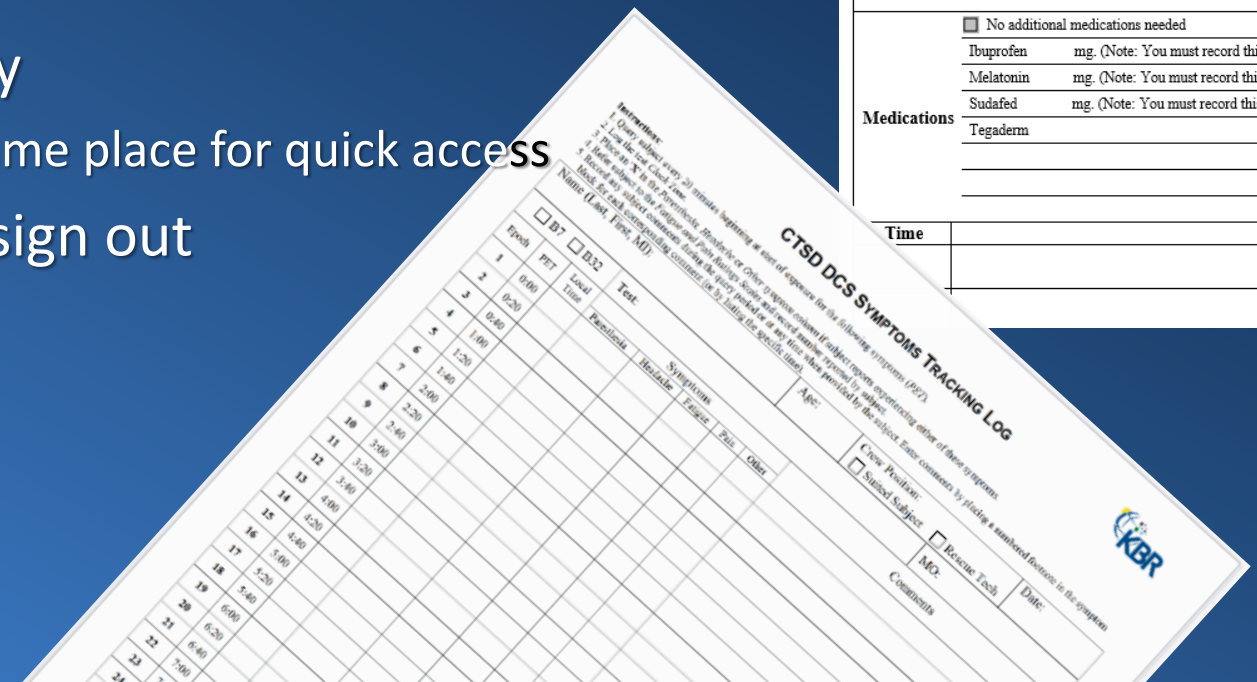
Subject *:	**Name** *(Last, First)*:		**Age:**
MO Name:	**Date:**	**Time:**	☐ EVA Day ☐ Non-EVA Day

General	
Sleep	Hours / Quality:
Ears	
Mask	
GI/Food	
Pain	Severity:
Headache	Severity:

Medications	☐ No additional medications needed	**Locked In**	**Taken In**	**Needs More**
	Ibuprofen mg. (Note: You must record this on Form 512A also)			
	Melatonin mg. (Note: You must record this on Form 512A also)			
	Sudafed mg. (Note: You must record this on Form 512A also)			
	Tegaderm			

Time	**Notes**





Mask Fit

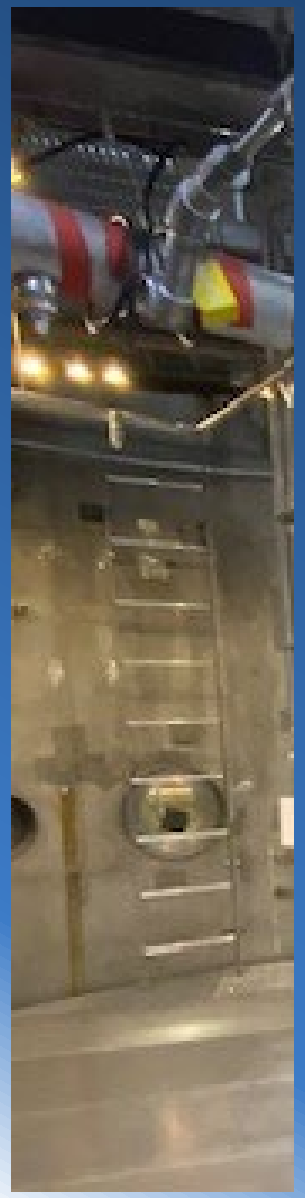
- This was one of the biggest challenges
  - Cost and Lead time
  - Fit especially bridge to chin length
  - Numbers vs. crew members
  - Tanks and fill procedures

- **For 2023
  - We are allowing phlebotomists and “visitors” to enter the chamber unmasked

Mask Fit Issues

- The activity during EVA has led to multiple subjects suffering injury
  - The need for a good seal and the 100% O2 environment limit tools for padding
  - Tegaderm is approved for use in the space suit (100% O2)
  - Definitely reduced the severity of nasal bridge trauma

Ladders



- Complaints of knee/ankle/shoulder pain and trauma (bangs) from climbing up and down ladders
- Differentiate trauma from DCS

Extravehicular Activity (EVA)

- EVA is a dynamic time in flight with 2 crew
- With research there is an ethical obligation to be hyper vigilant on tracking pain, injury and DCS
- With 8… insane and during a very busy EVA…. On multiple loops (DT/us separate) Hand signals critical to coms
- Visual Access to the whole EVA area
- In flight we are used to visual/auditory coms, cannot expect in lunar (line of sight) so will need to rely on crew reporting (need to know risk)

Food Issues

- The dietary constraints in space (weight, mass, nutrition) are such that food will likely be quite different from terrestrial equivalents
  - Multiple GI issues early in the trial
    - Bloating
    - Gas
    - Stooling differences

- For space flight: recommend allowing teams to *adjust* to the food *before* flight (not just a tasting weeks prior)

Medication Handling

- The PharmD *is* a specialist
  - Don't assume all medical professionals understand drug handling
    - Pill Counter
    - Labels
    - Masking envelope
    - Dummy envelopes

Medications

- Agreed that we were not going to leave a pharmacy or even personal medications inside (other than certain topicals)
  - Lock in personal meds daily
  - Motrin, Sudafed, antihistamines, **Melatonin**
  - Avoid masking sx with ibuprofen/Tylenol
  - Avoid forgetting to report
  - Encourage “ground testing” of melatonin

The Comfort things…

Call Room (envisioned)

Call Room (Reality)

The Comfort things…

- Chamber safe clothing, pillows and sheets
- Call room
- DVDs and video Player (treatment/holding)
- Bedside Commode (treatment/holding)
- Sleep protection / Assistance
- Doors vs. curtains

COVID Outbreak

- AsMA 22!!

- Significant impact on crew
  - Cannot socially distance in the control room

- Allow masking with N95 like we do for healthcare workers
  - Prophylactically wear masks
  - Exposure ≠ Quarantine

Phlebotomy

- Institutional challenges made phlebotomy and altitude a tremendous challenge for staffing such that only two physicians, including myself, met all the criteria to act as phlebotomists inside the chamber

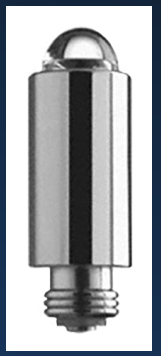
Phlebotomy

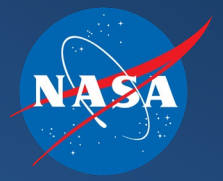
- Challenge at baseline
  - Dehydration
  - Pressure changes
  - Hypoxia
  - Locking all supplies in and out
  - Fasting in AM
  - Pre & Post EVA (long day)
  - Some need to be iced

- Does give access to crew for exams

A few final notes…

- LED lights on otoscope

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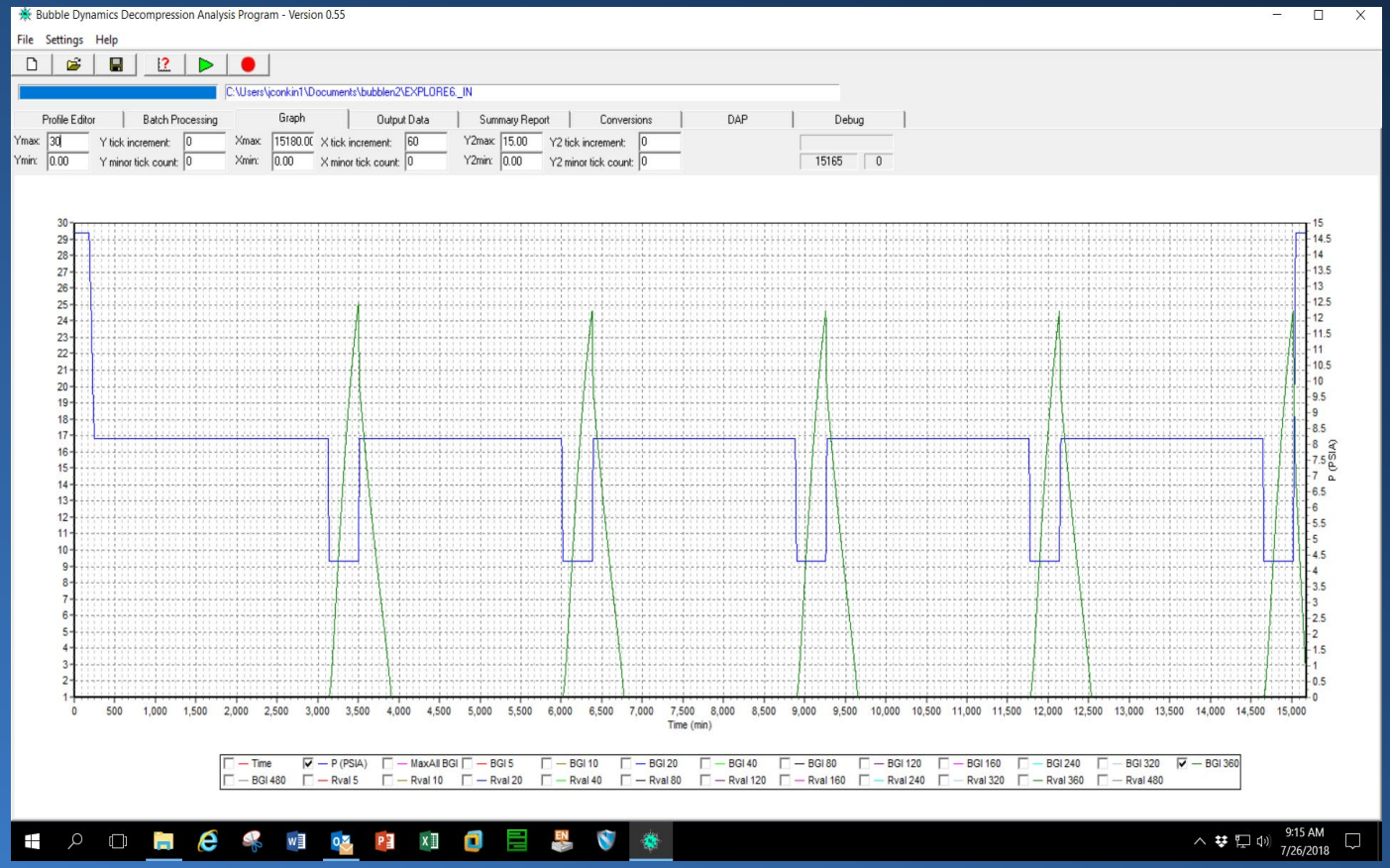
Questions?

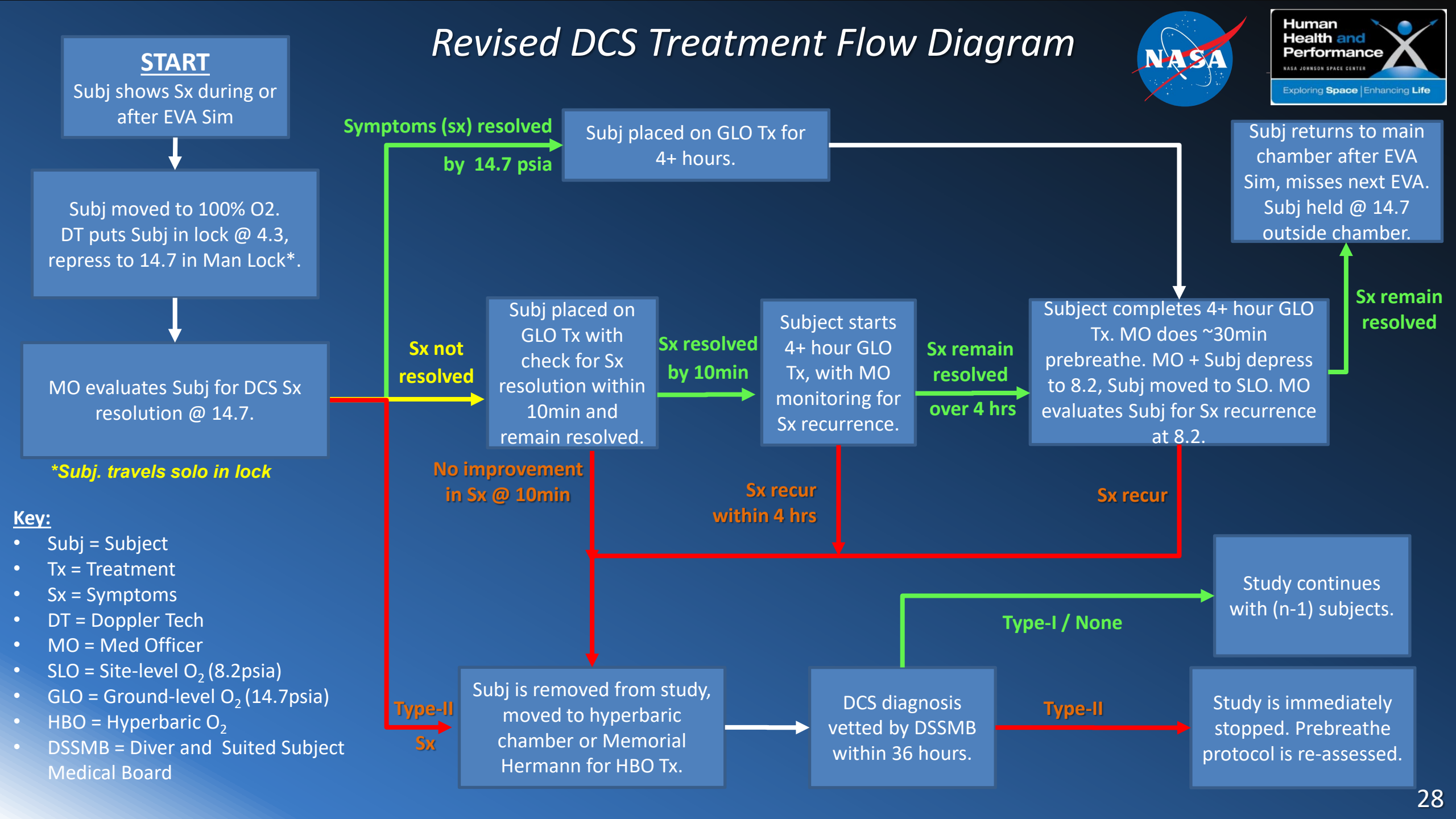
State of Knowledge – DCS Risk in Exploration Atmosphere



- **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).

Revised DCS Treatment Flow Diagram



Key:

- Subj = Subject
- Tx = Treatment
- 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