Habitability Assessments & Lessons Learned from 3-Day and 11-Day Enriched Oxygen Hypobaric Chamber Tests at NASA Johnson Space Center

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Aerospace Medical Association

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Disclosure Information

93rd Annual Scientific Meeting

Andrew Abercromby, Ph.D.

I have no financial relationships to disclose.

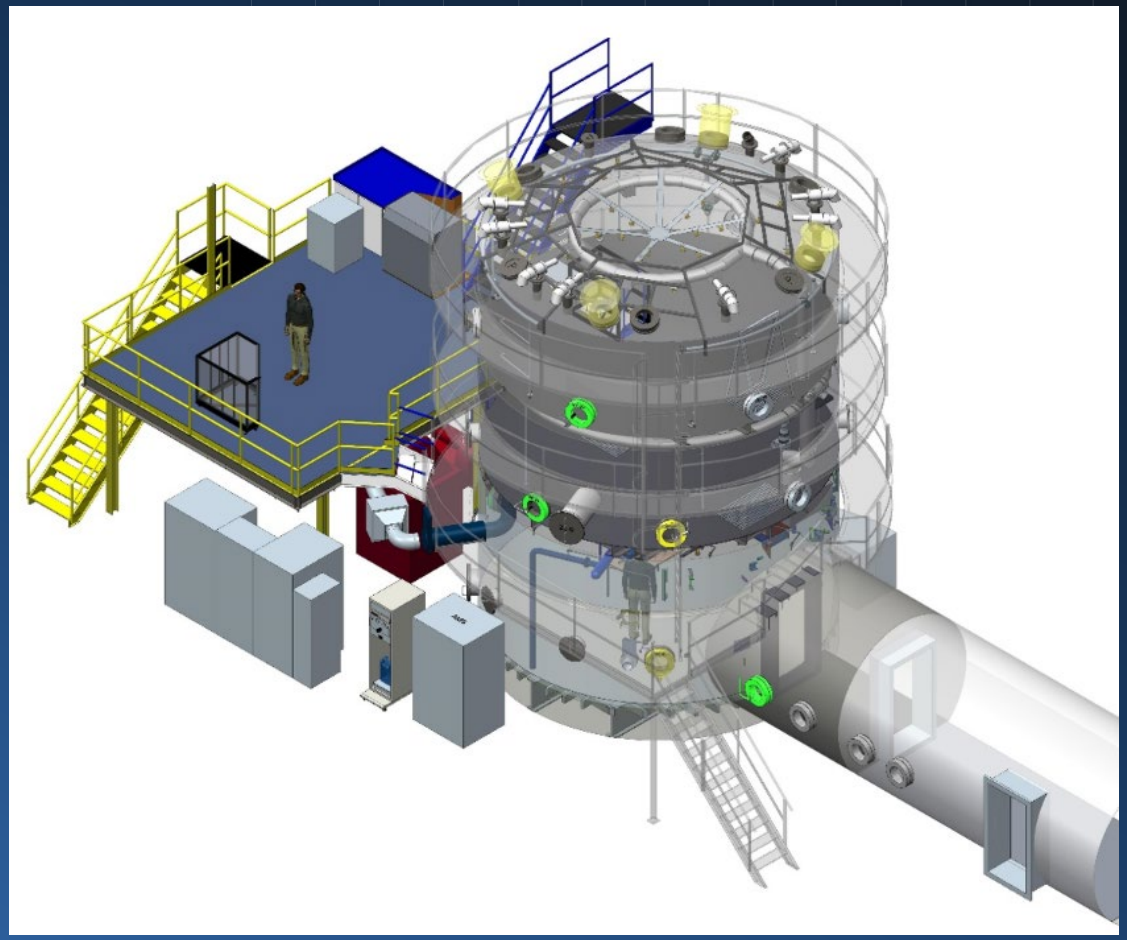
I will not discuss off-label use and/or investigational use in my presentation.

Objectives

- Briefly describe the purpose and capabilities of the enriched oxygen hypobaric chamber facility at NASA Johnson Space Center
- Review habitability data and other lessons learned following recent 3-day and 11-day tests with 8 human subjects

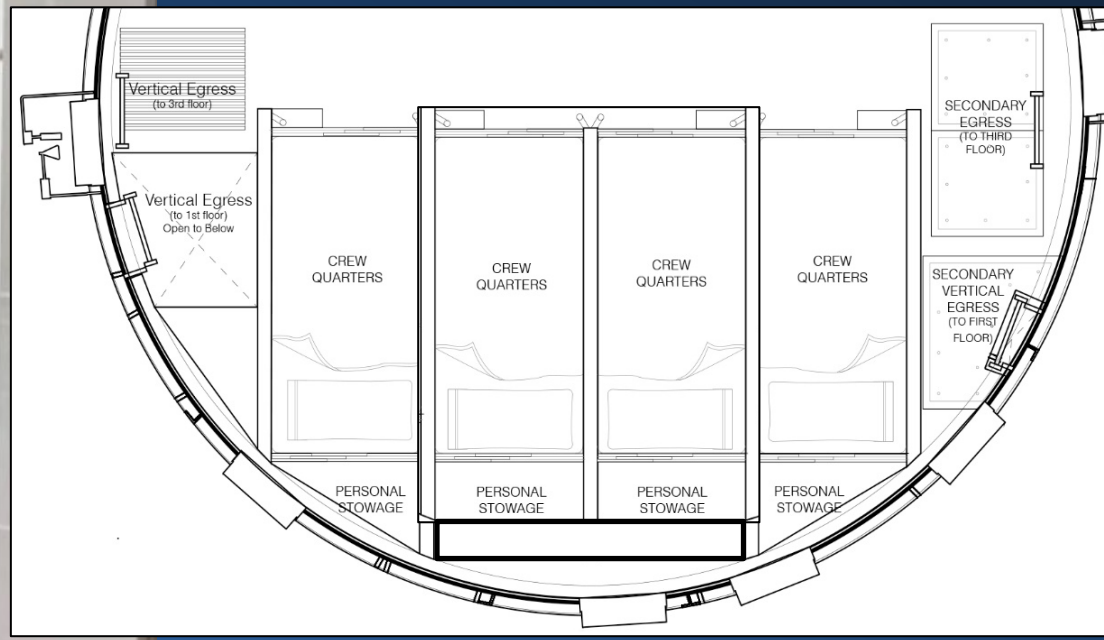
Background

- Completed outfitting of dedicated facility at Johnson Space Center to support testing of up to eight human subjects for multiple days in hypobaric and enriched oxygen atmospheres.
- Primary purpose of testing capability is validation of DCS risk mitigation protocols for Artemis missions to the Moon; however, will also support development and validation of a generalizable altitude DCS risk estimation tool.
- Enriched oxygen (up to 36% O2) requires strict control of ignition sources and flammable materials, which limits options for habitability



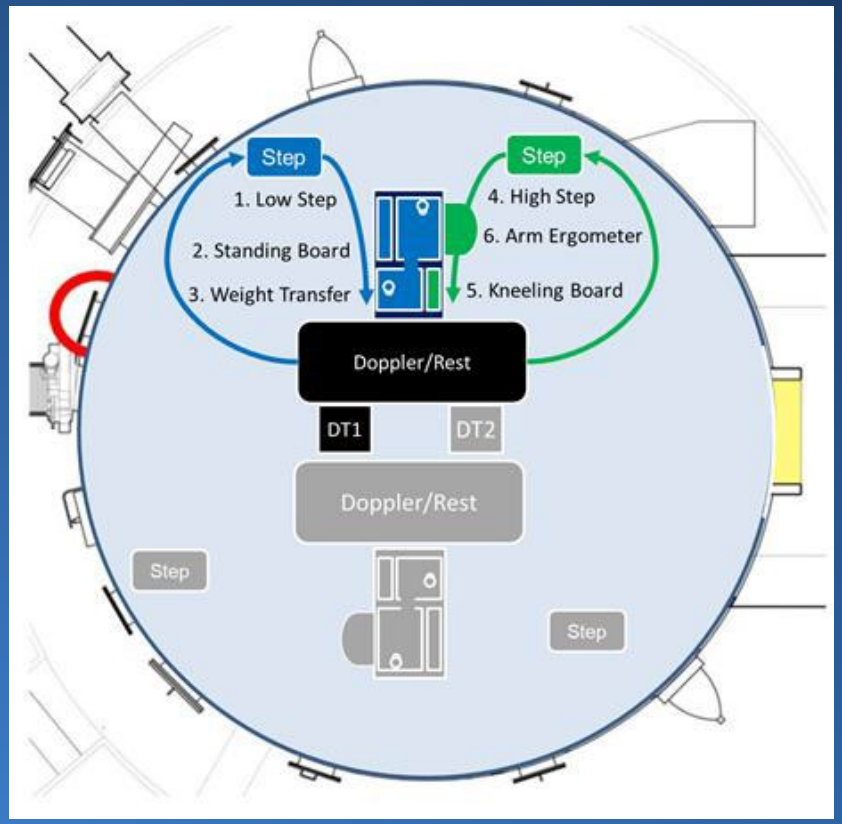
3rd Floor Configuration

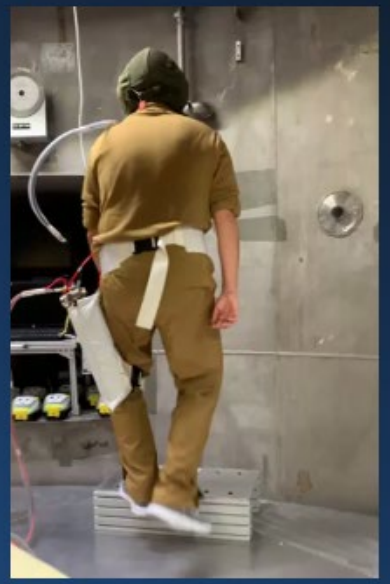
2nd Floor – Crew Quarter Layout

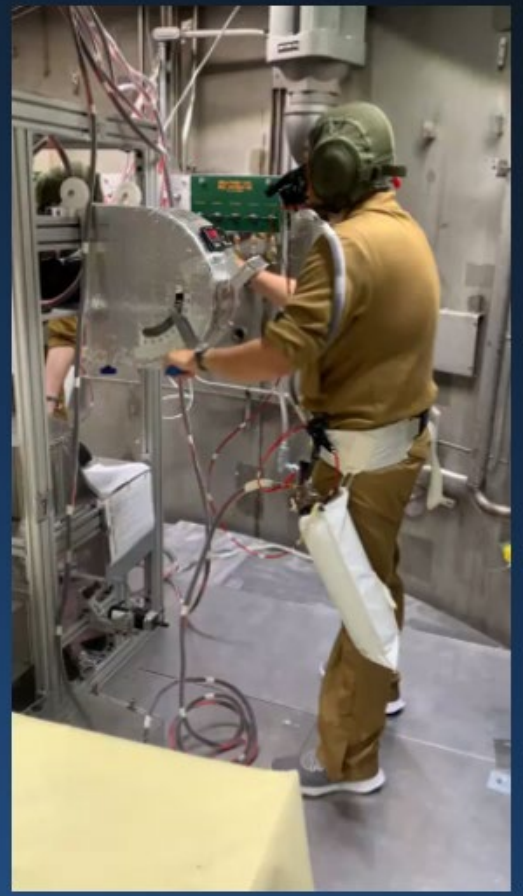


EVA Sim Stations

EVA Simulation







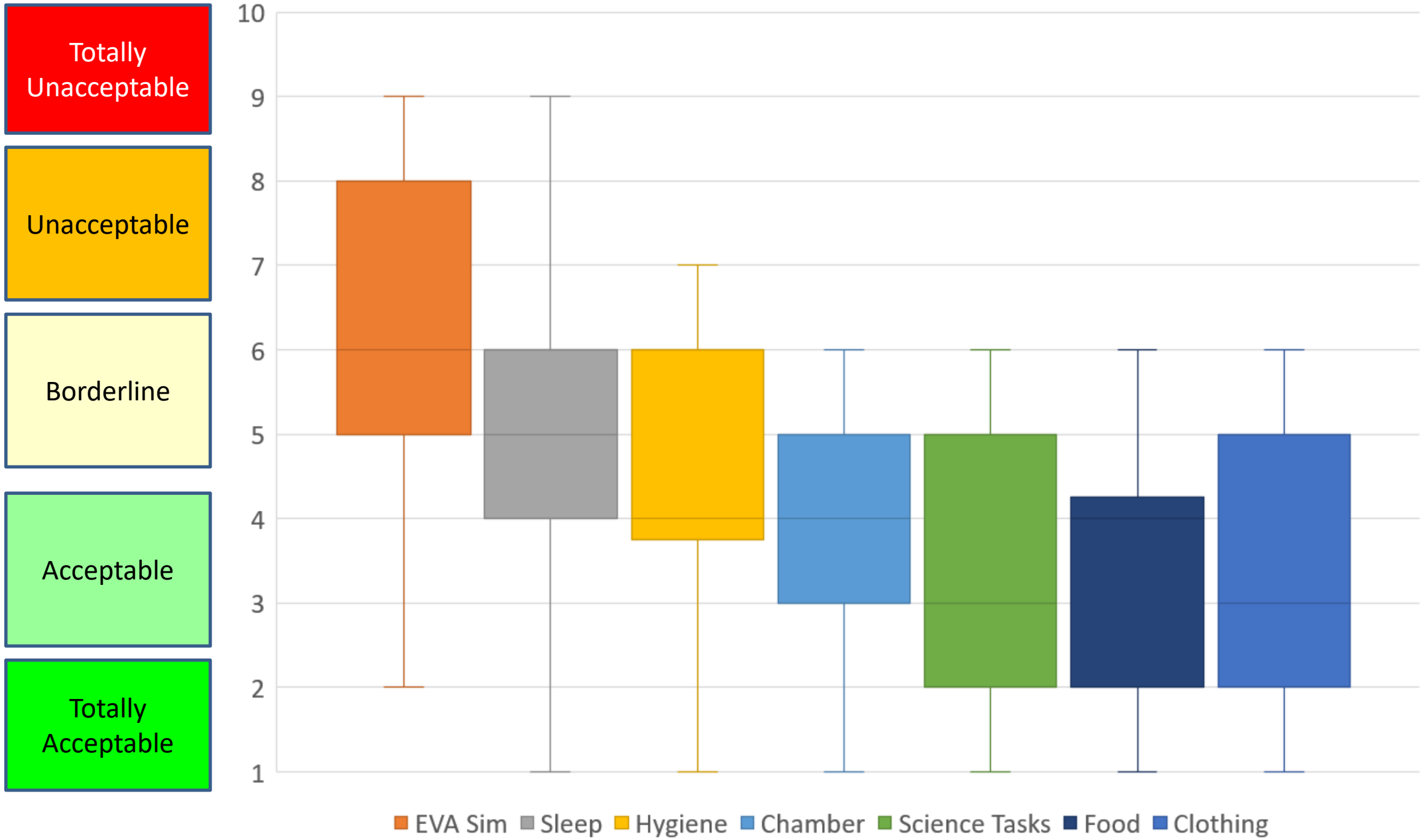
Methods

- 3-day and 11-day prebreathe validation tests completed in 2022
- 8 human subjects per test living at 56.5 kPa (8.2 psia), 34% O_2, 66% N_2, with 6 simulated EVAs performed on masks at 29.6 kPa (4.3 psi), 85% O_2, 15% N_2
- Subjective habitability ratings recorded daily during the 11-day test in 7 different categories:

EVA Simulation	Sleep	Hygiene	Chamber	Science Tasks	Food	Clothing
e.g., mask fit, prebreathe, exercises, discomfort	e.g., timing, interruptions, lighting, comfort, temperature	e.g., toilets, personal care items, etc	e.g., comms, noise, transfer ops, etc	e.g., duration, level of effort, timing	e.g., quantity, type, quality	e.g., comfort, fit, hygiene

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable		No Rating
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies		Unable to assess capability
1	2	3	4	5	6	7	8	9	10	NR

- Hypoxia and DCS-related physiological and cognitive outcome measures reported in companion presentations


Totally Unacceptable
Unacceptable
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Totally Acceptable
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EVA Sim
Sleep
Hygiene
Chamber
Science Tasks
Food
Clothing

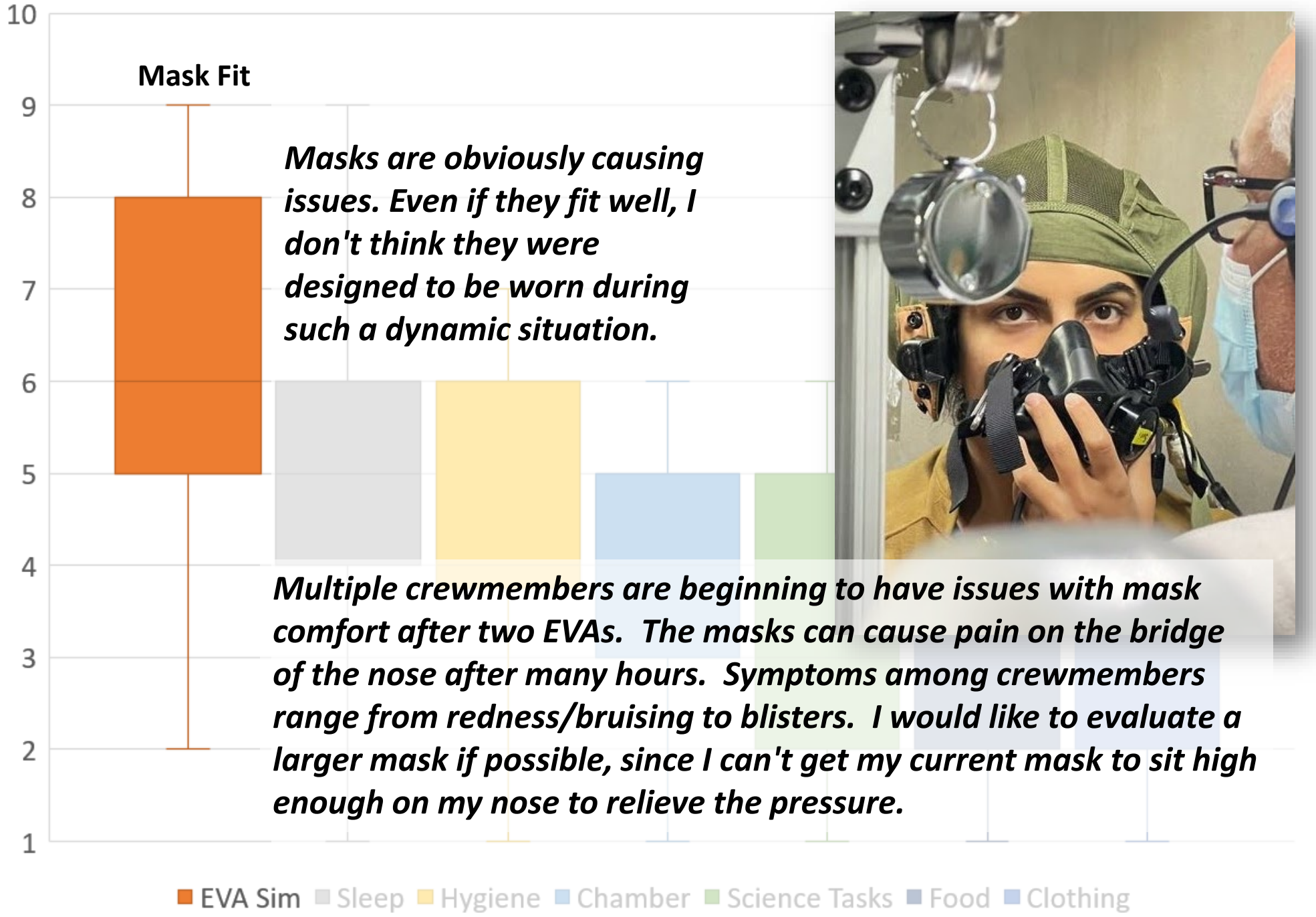
Totally Unacceptable

Unacceptable

Borderline

Acceptable

Totally Acceptable



Masks are obviously causing issues. Even if they fit well, I don't think they were designed to be worn during such a dynamic situation.

Multiple crewmembers are beginning to have issues with mask comfort after two EVAs. The masks can cause pain on the bridge of the nose after many hours. Symptoms among crewmembers range from redness/bruising to blisters. I would like to evaluate a larger mask if possible, since I can't get my current mask to sit high enough on my nose to relieve the pressure.

Totally Unacceptable

Unacceptable

Borderline

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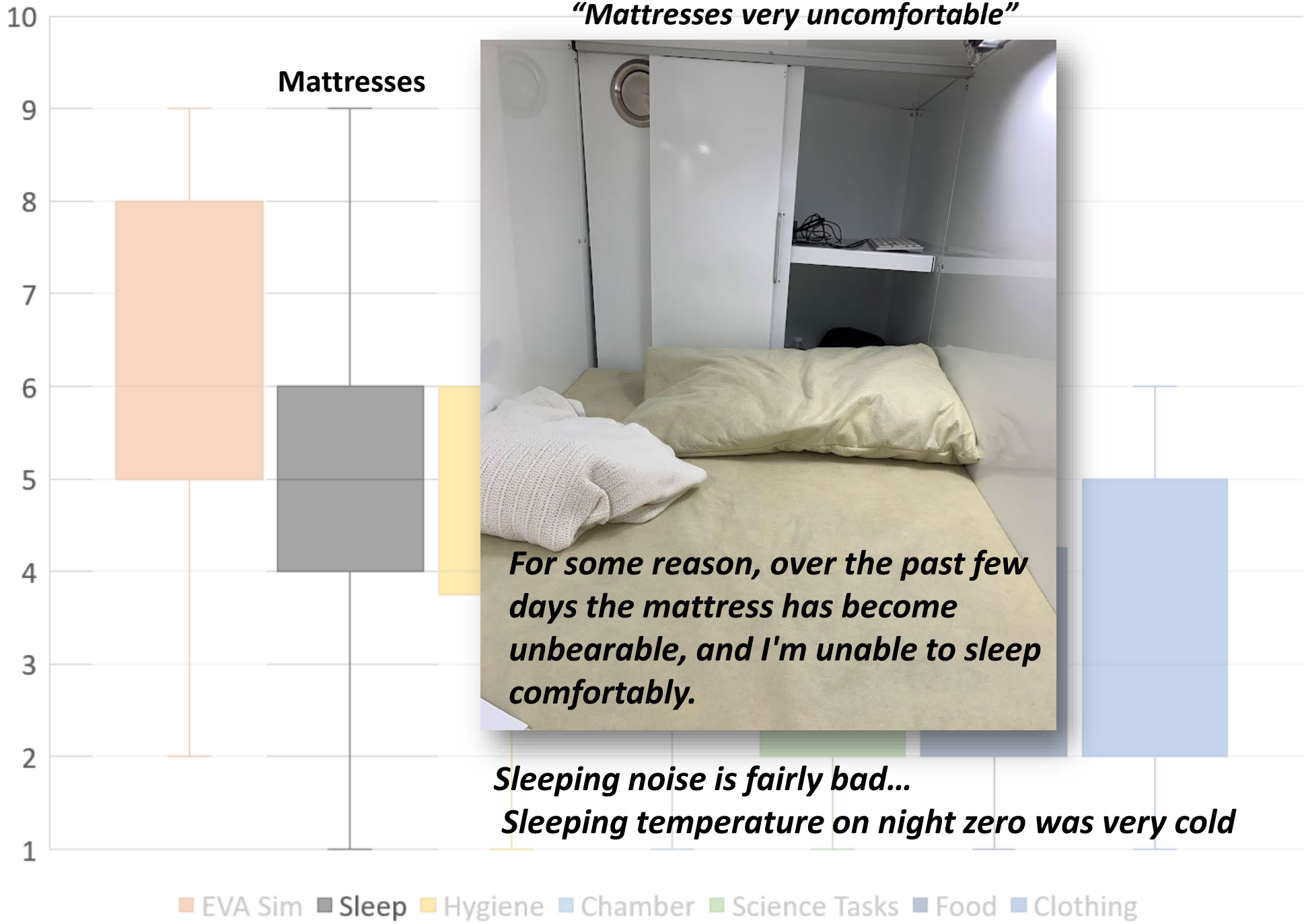
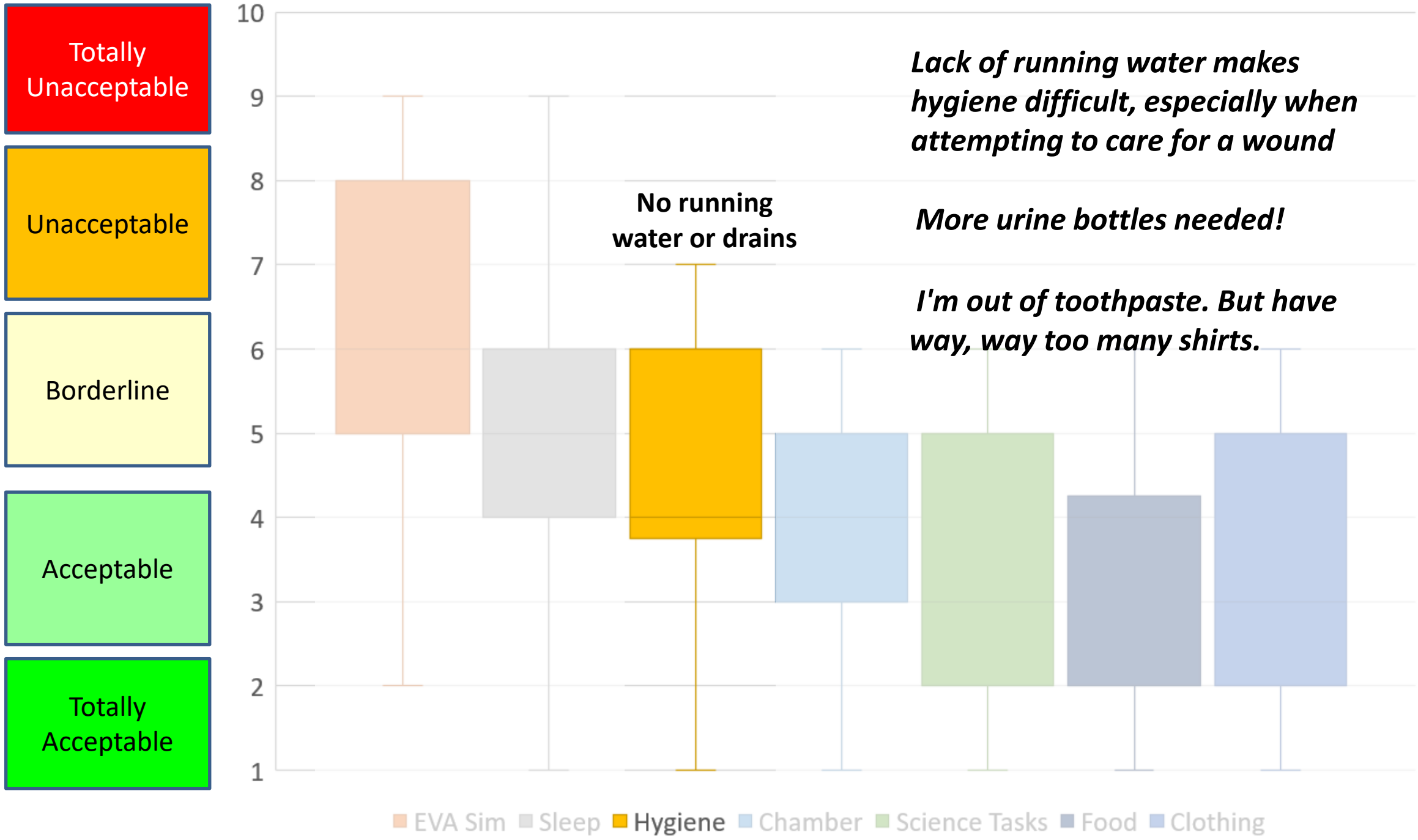
Totally Acceptable



"Mattresses very uncomfortable"

Sleeping noise is fairly bad…

Sleeping temperature on night zero was very cold


Totally Unacceptable
Unacceptable
Borderline
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Totally Acceptable
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No running water or drains
Lack of running water makes hygiene difficult, especially when attempting to care for a wound
More urine bottles needed!
I'm out of toothpaste. But have way, way too many shirts.
EVA Sim
Sleep
Hygiene
Chamber
Science Tasks
Food
Clothing

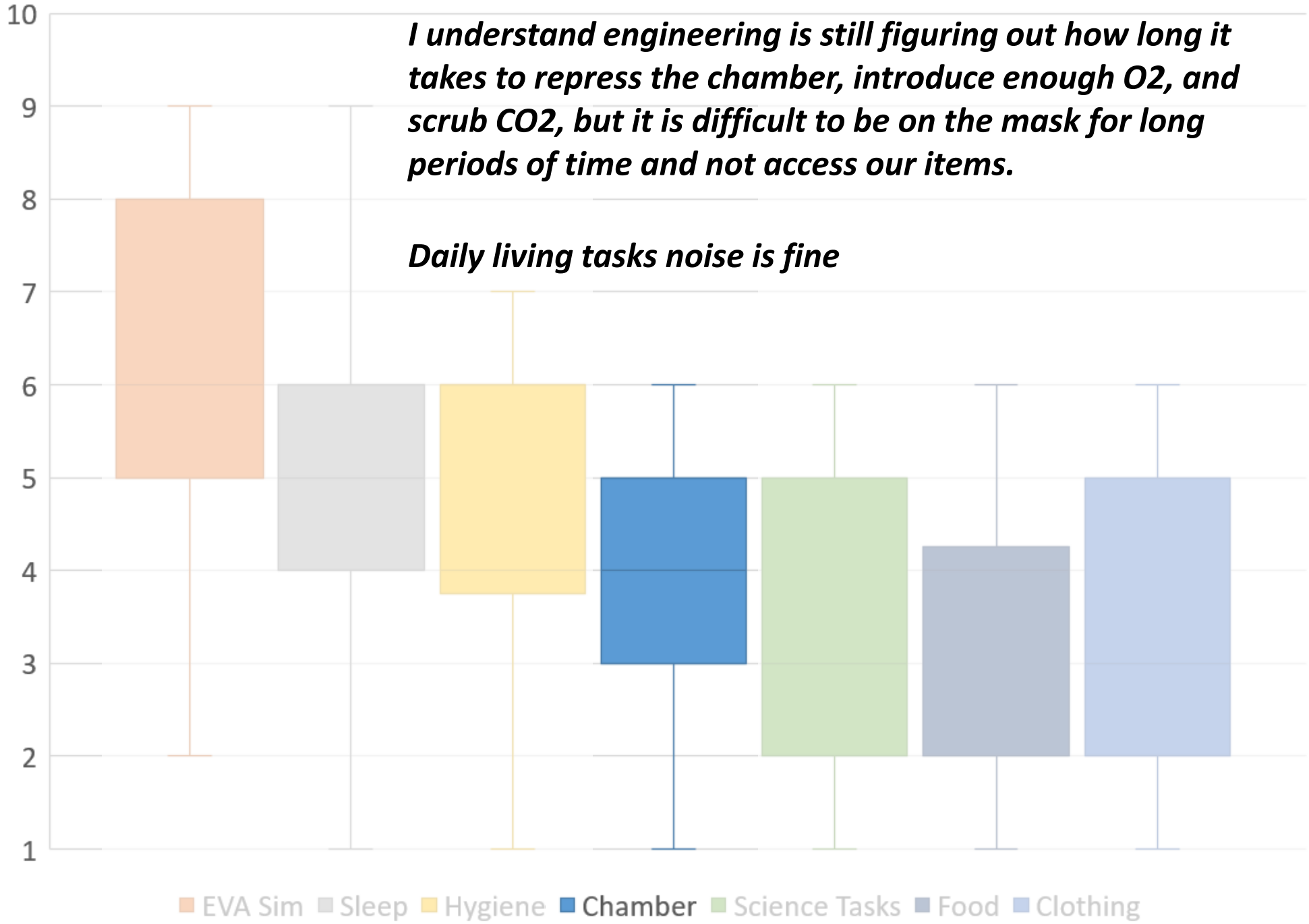
Totally Unacceptable

Unacceptable

Borderline

Acceptable

Totally Acceptable



I understand engineering is still figuring out how long it takes to repress the chamber, introduce enough O2, and scrub CO2, but it is difficult to be on the mask for long periods of time and not access our items.

Daily living tasks noise is fine

Totally Unacceptable

Unacceptable

Borderline

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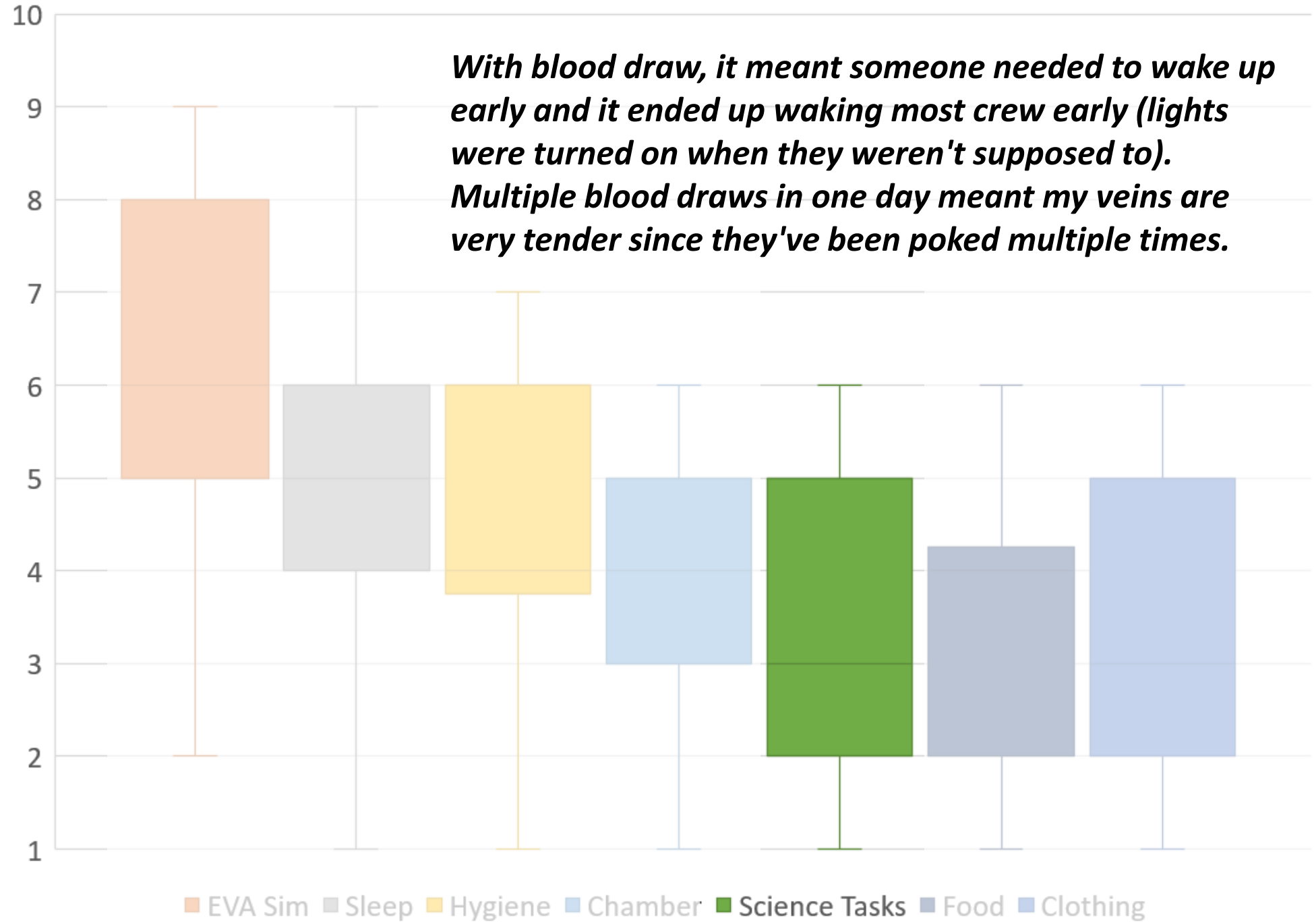
Totally Acceptable



With blood draw, it meant someone needed to wake up early and it ended up waking most crew early (lights were turned on when they weren't supposed to). Multiple blood draws in one day meant my veins are very tender since they've been poked multiple times.

Totally Unacceptable

Unacceptable

Borderline

Acceptable

Totally Acceptable

There is plenty of food, but it's a little difficult to eat cold.

Individual input on menu would go a long way

The food isn't bad but hard to get enough kcals in to maintain weight when eating cold.

Totally Unacceptable

Unacceptable

Borderline

Acceptable

Totally Acceptable

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My PBI bottoms are very tight through the hips. Makes it hard to go to the bathroom. Past that I think I'm mostly fine on clothes.

The clothes don't fit 100%, most subject's pants waist bands dont give and it is hard to pull down.

The buttons on the sleeves of the shirt and pants are sewn in the wrong place to fasten when rolled up. Non-functional.

EVA Sim Sleep Hygiene Chamber Science Tasks Food Clothing

Conclusions

1. The hypobaric chamber facility at NASA Johnson Space Center has successfully supported 2x 3-day tests, an 11-day test, and a multi-day test with a commercial company with no test subject withdrawals
2. Mask-related issues resulted in unacceptable levels of discomfort and loss of some objectives due to minor mask-induced injury; work is ongoing with vendor to mitigate issues
3. Thin mattresses due to materials flammability constraints were unacceptable to two out of eight subjects during the 11-day test; currently unresolved
4. Other lower-priority recommendations for habitability improvements were identified and implemented as possible during and following the multi-day tests
5. Additional hypobaric testing planned in support of an open-source Aerospace Estimation Tool for Hypobaric Exposure Risk (AETHER)

National Aeronautics and Space Administration

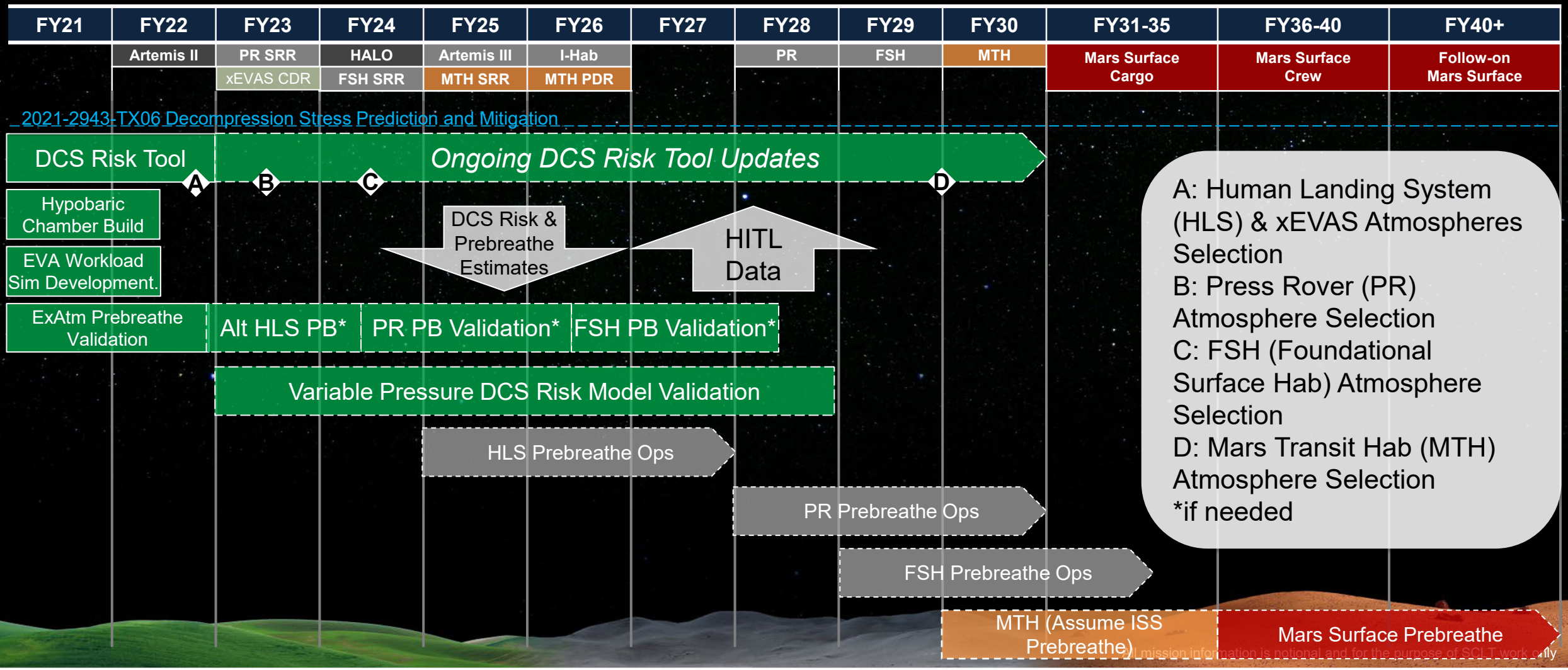
Questions?

www.nasa.gov


NASA


VSVN

DCS Prediction & Mitigation Roadmap (all dates estimated)



Ground
ISS / LEO
Lunar orbit
Lunar surface
Mars transit
Mars surface
Events/milestones
Decision point

See acronyms list at front of document

Assumed that Shuttle/ISS prebreathe protocols will be applicable to Gateway and MTH; these protocols are already validated for microgravity but not for planetary EVA

DCS Prediction & Mitigation Roadmap (all dates estimated)

FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31-35	FY36-40	FY40+
	Artemis II	PR SRR										
		xEVAS CDR										

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DCS Risk Tool

A

B

Hypobaric Chamber Build

EVA Workload Sim Development.

ExAtm Prebreathe Validation

Alt HLS P

Va

Atmosphere Selection
*if needed

PR Prebreathe Ops

FSH Prebreathe Ops

MTH (Assume ISS Prebreathe)

Mars Surface Prebreathe

All mission information is notional and for the purpose of SCLT work only

Ground
ISS / LEO
Lunar orbit
Lunar surface
Mars transit
Mars surface
Events/milestones
Decision point

See acronyms list at front of document

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