EVA SPACESUIT INCIDENT TRACKING

Aerospace Medical Association
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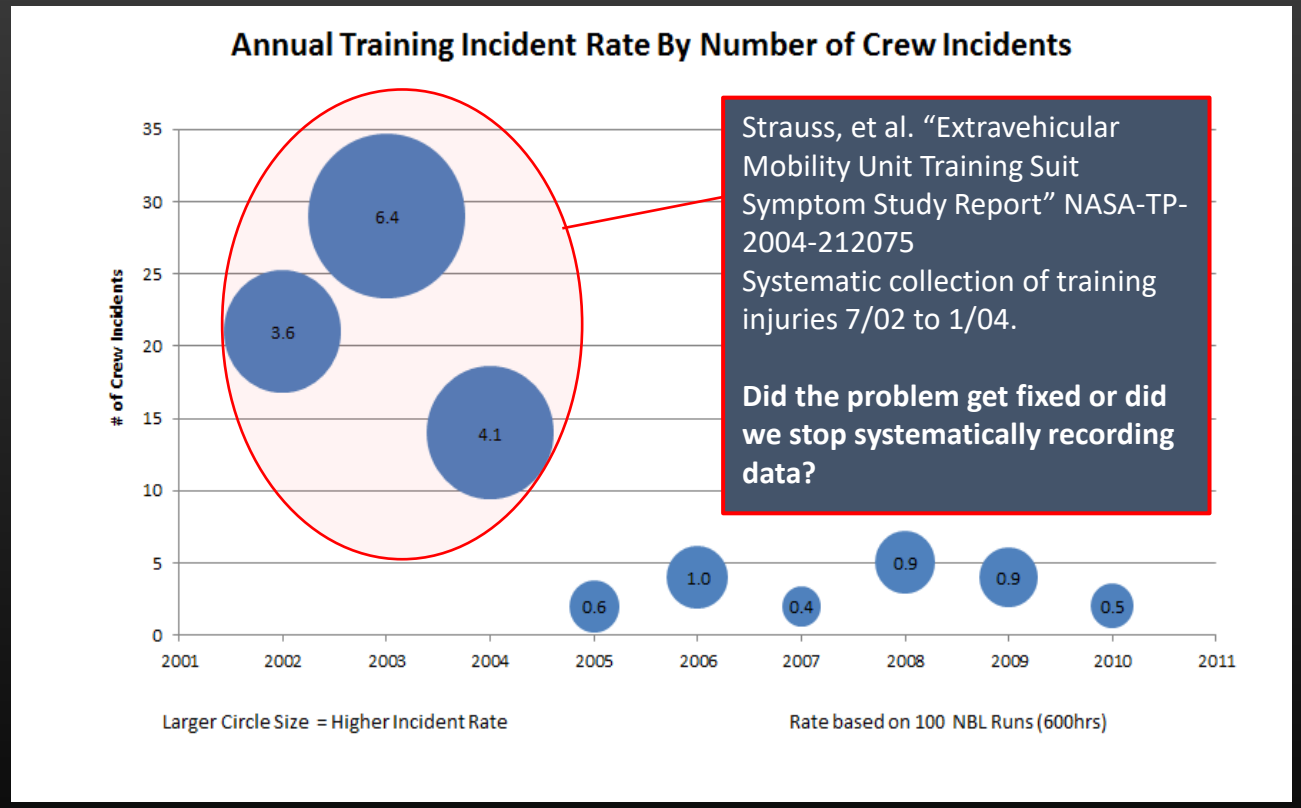
Background

- Extravehicular mobility unit (EMU) injuries have occurred both in training (190/770 sessions had injury, Strauss et al. 2005) and during operations (55 injuries/1088 hrs or 0.26/Extravehicular activity (EVA), Scheuring et al. 2009)
- Shoulder is a common site of injury, especially during training in the pool.
- Glove issues abound. Lots of bruising, soreness and nail delamination.
- Apollo EVAs (12 people, 15 EVAs across 6 crews, < 100 hours)
  - Wrist laceration from suit ring, wrist soreness, shoulder overuse injury due to compressed timeline
  - For those who did multiple EVAs, cumulative soreness made each subsequent EVA more challenging



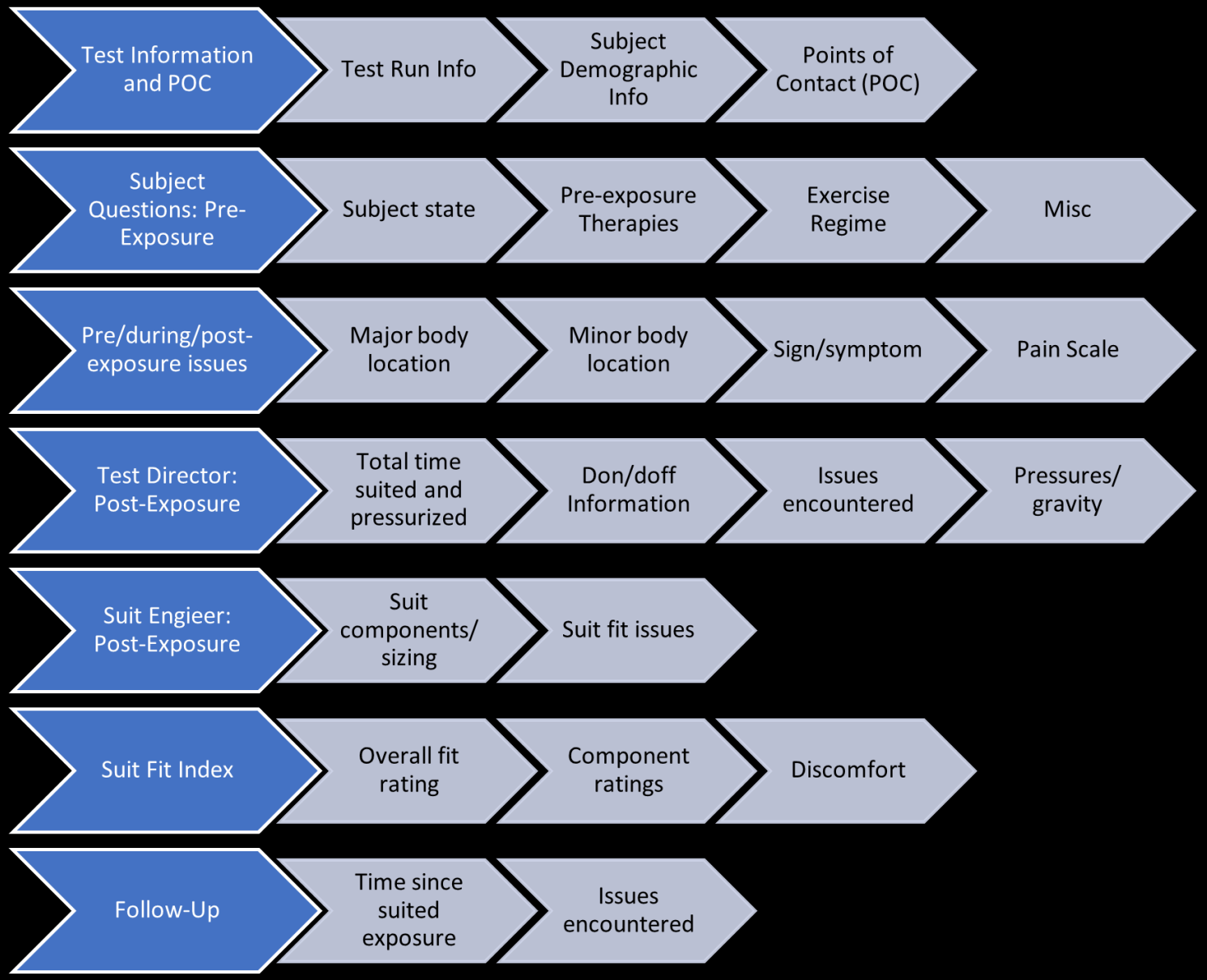
Background

- Exposure Incident System (EIS) database and survey developed to catalogue pressurized EVA suit exposures
- Began collecting data in EIS in 2017
  - Electronic version went live in 2019
    - From 2017 to 2019, the neutral buoyancy laboratory (NBL) was live, but other exposures were paper based records only
- Several rounds of improvements have been made since, & the database is now called the Suited User Incident Tracking System (SUITS)
  - So far, each time we pull and analyze data, we discover new errors and updates that need to be made
- Goals
  - Systematically collect 100% of suit exposures (1-G, in-flight EVA, and mockup suits)
  - Use SUITS for individuals (precision medicine) and across groups for trends
  - Use SUITS in an actionable way to focus work on injury prevention and mitigation
  - Use SUITS to help with new suit requirement verification

Suited Anomaly Assessment Team (SAAT)

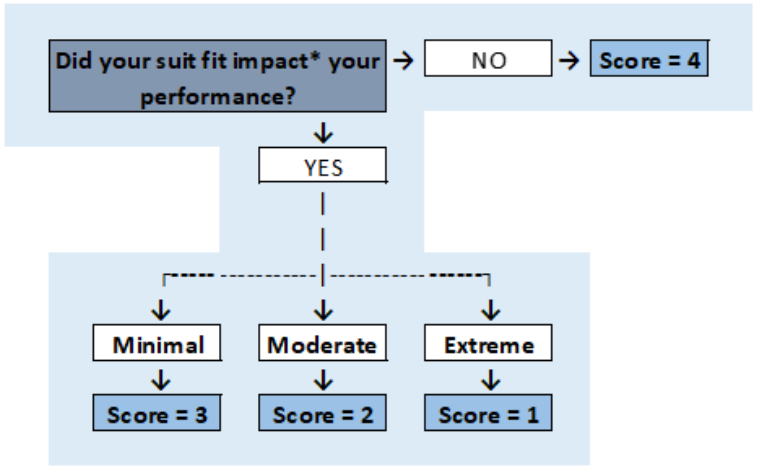
- SAAT is one of the primary consumers of SUITS
- We interviewed various EVA stakeholders (crew surgeons, flight operations directorate (FOD) trainers, suit engineers and designers, the astronaut strength, conditioning, and rehabilitation (ASCR) team, EVA office and EVA safety) in Jan 2020 to both understand the issues of the past and get a sense of anticipated issues with the exploration EMU (xEMU) and planetary EVA.
- One theme that emerged from these interviews was that suit anomalies, crew-specific issues, and injuries were not always communicated across the various stakeholder groups.
- In some cases, stakeholders had interesting potential solutions to issues had they only been aware.
  - For example, the ASCRs could institute work hardening training programs
  - Better communication amongst stakeholders may enable multi-faceted solutions involving suit design, suit fit, suit and strength training, task design, ops planning, and improved task ergonomics.
- SAAT (and other EVA stakeholders) pull SUITS data quarterly to review trends, specific suit issues, etc. in a de-identifiable manner
- SAAT also meets on an ad hoc basis to respond in a timely manner to critical suit anomalies in an identifiable manner
  - This is a critical piece of injury prevention and mitigation, and has already paid dividends

SUITS Overview



Suit Fit Rating

OVERALL Fit Rating:



No Impact: No compensation required
Minimal: Occasional compensation required
Moderate: Frequent or continuous compensation
Extreme: Task failure due to poor fit

*Impacts can include postural compensation, increased time to complete tasks, etc.

COMPONENT Ratings: did you have poor fit in any component?

	YES	NO
HUT		
HELMET		
ARMS		
GLOVES		
LTA		
BOOTS		

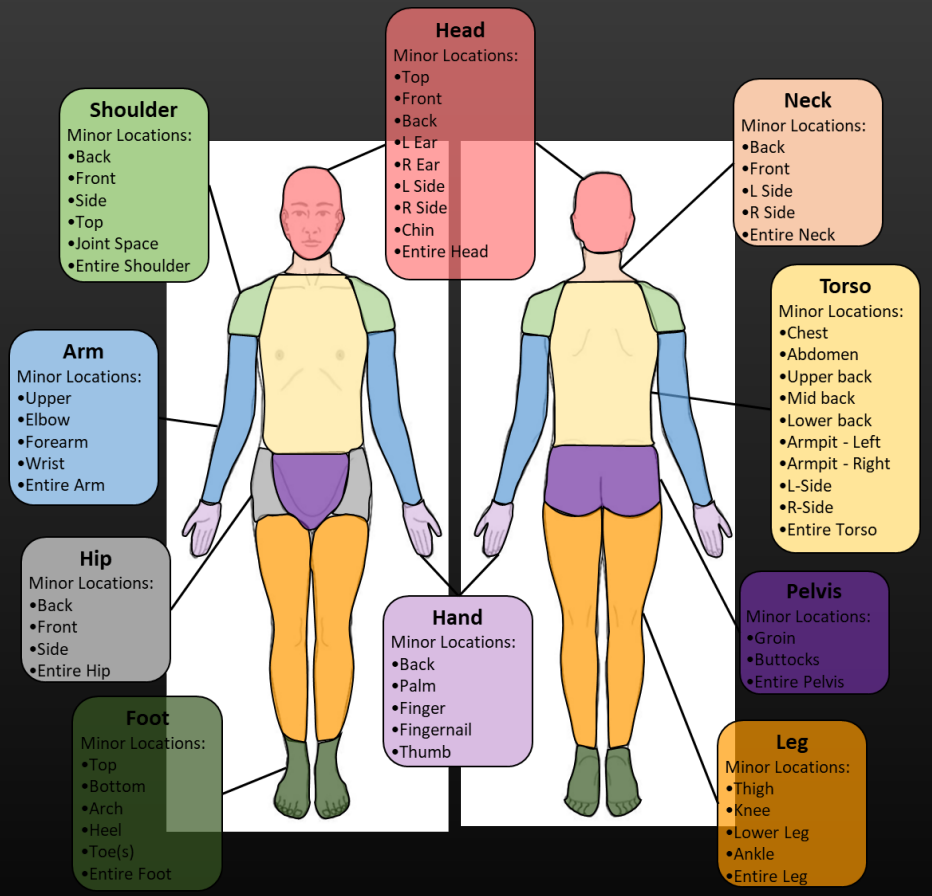
DISCOMFORT: did your suit fit contribute to any discomfort?

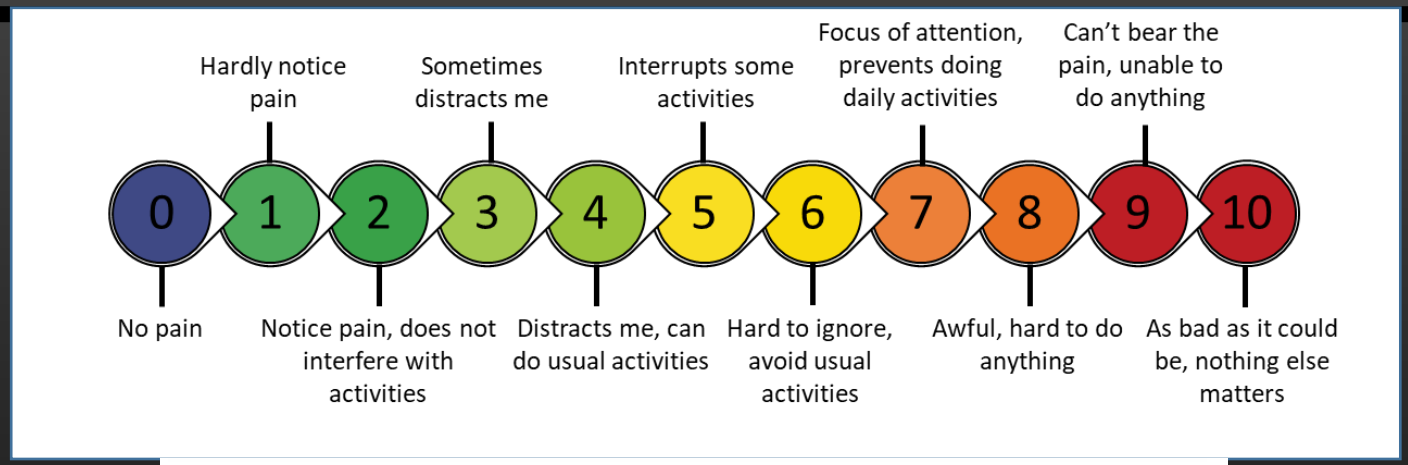
	YES	NO
DISCOMFORT		

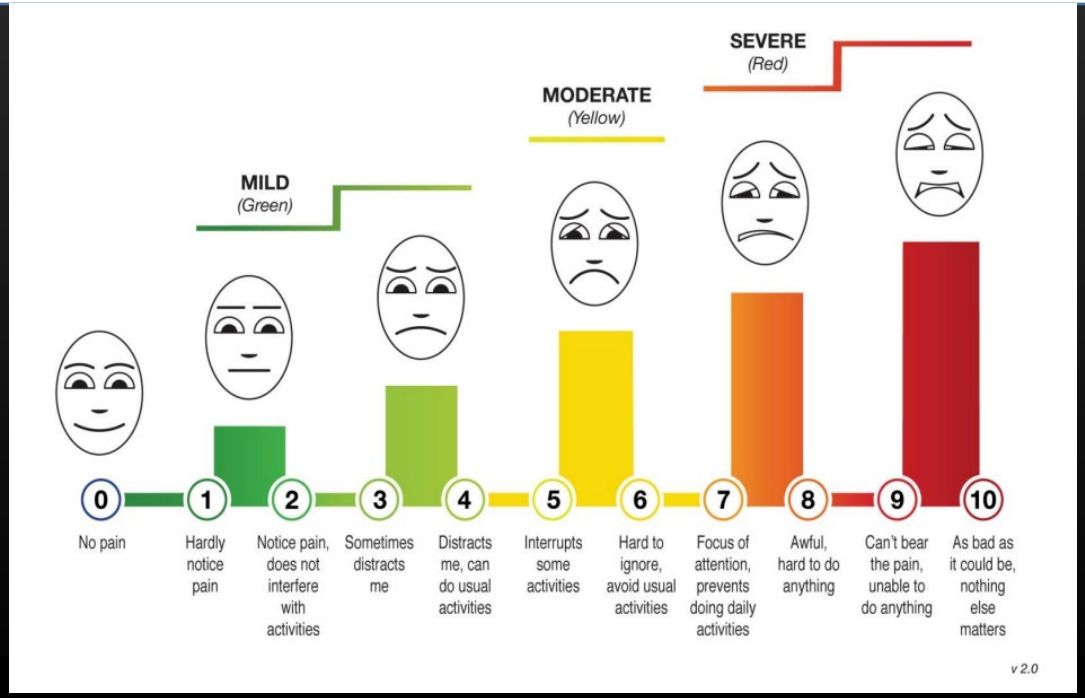
Date:	
Subject #:	
Suit type:	
Location:	

COMMENTS:

Suited Exposure Issues (Pre, During and Post)





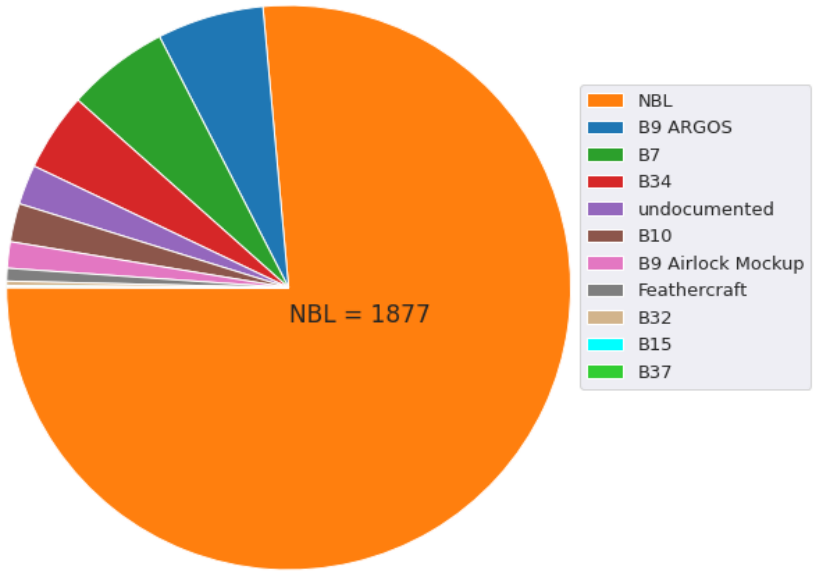


Front Matter

- A suit issue consists of the following: Anatomic location, Symptom, Sign, Pain Scale
- A medical condition or injury is noted by medical personnel in the Electronic Medical Record
- An issue can be an injury, but not all issues are injuries
- A given exposure can have more than one issue

SUITS Analysis: 2017-June 2023

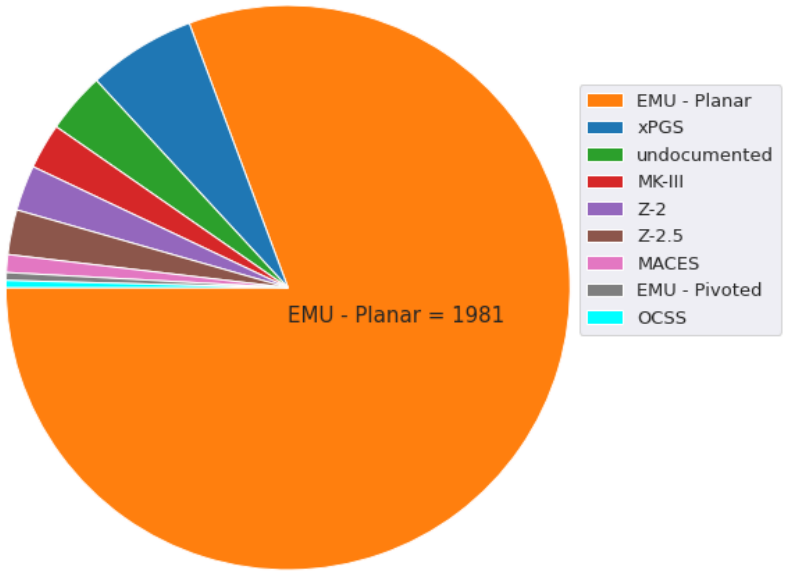
Number of Exposures by Location



Average suited time per exposure = 5.0 (Hrs)

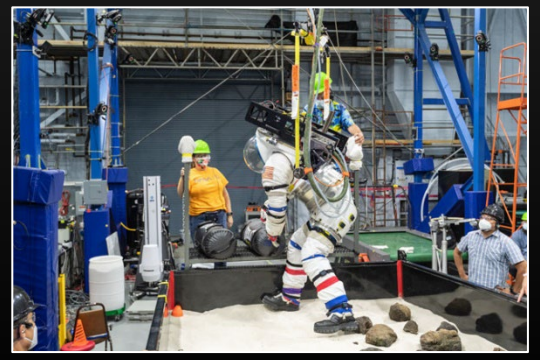
* 76.5% exposures at NBL
* 7.6% exposures at B9
* 2.3% exposures undocumented
* 13.6% exposures at other remaining locations

Number of Exposures by Suit Type



Total Exposures:2455

* 83.7% exposures in Microgravity (pressurized)
* 11.4% exposures in Planetary (pressurized)
* 1.4% exposures in Launch, Entry and Abort
* 3.5% exposures in undocumented suits



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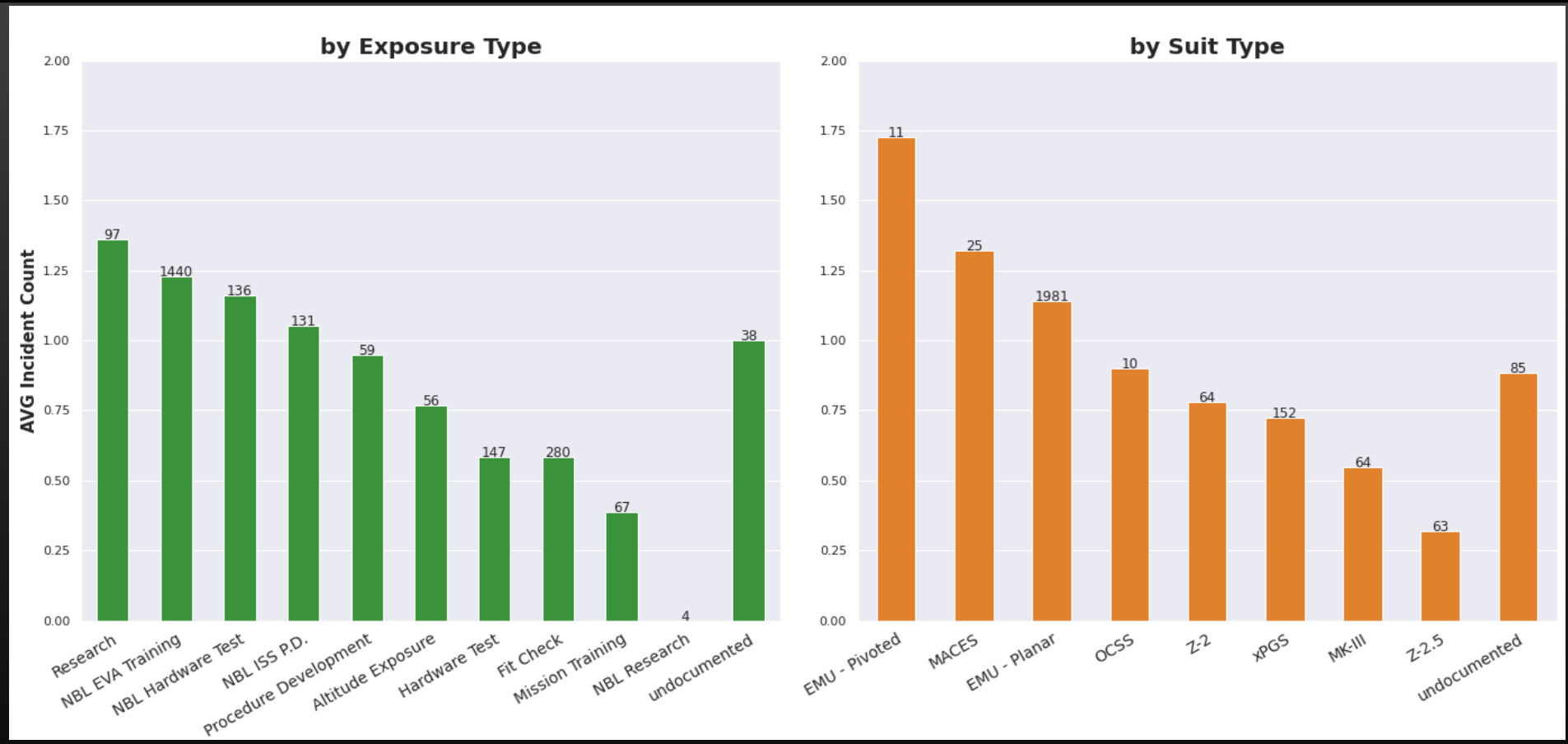
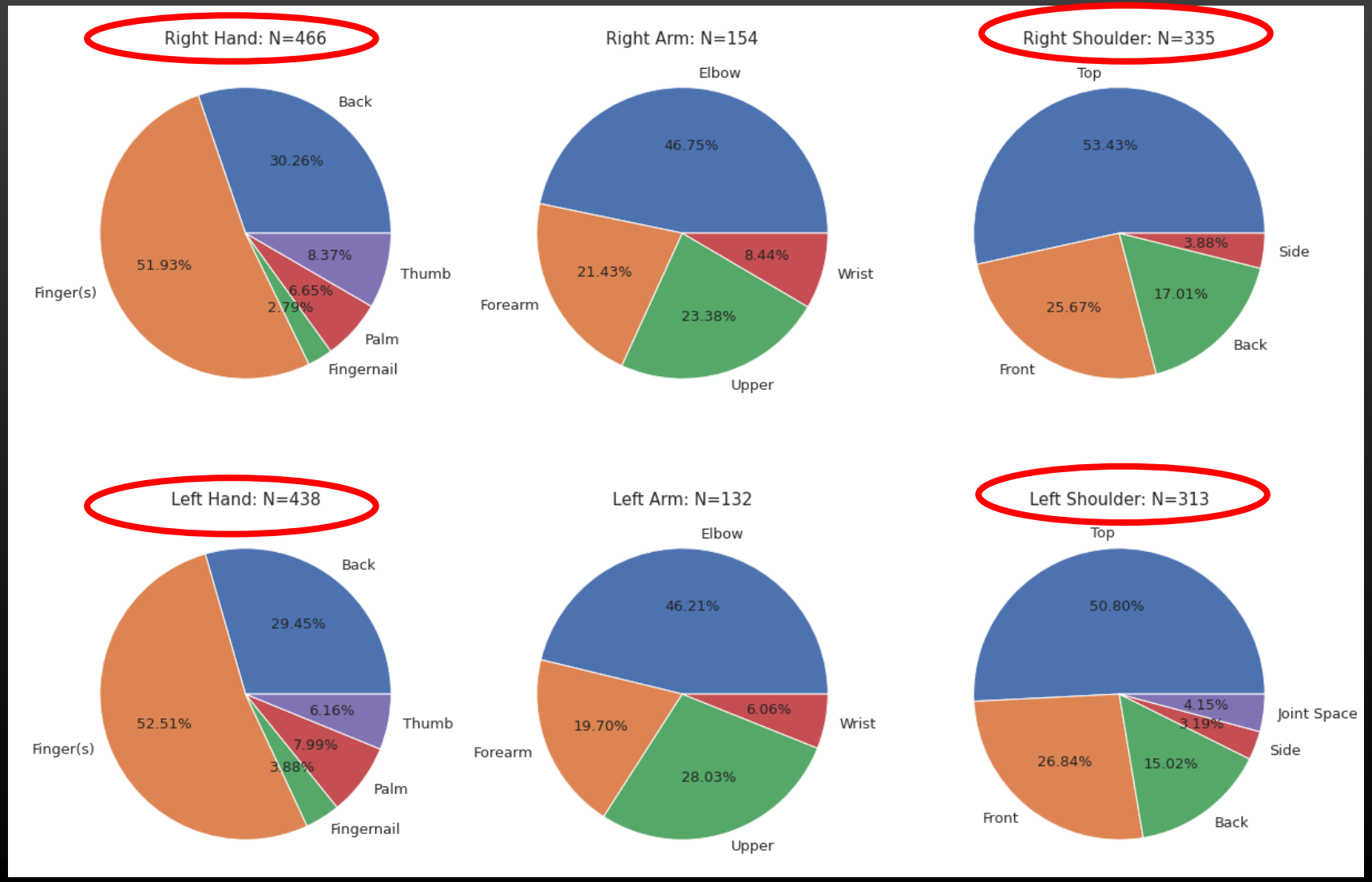


- NBL EVA Training has highest exposure count (N=1440)
- Though, Research has the highest average incident Count

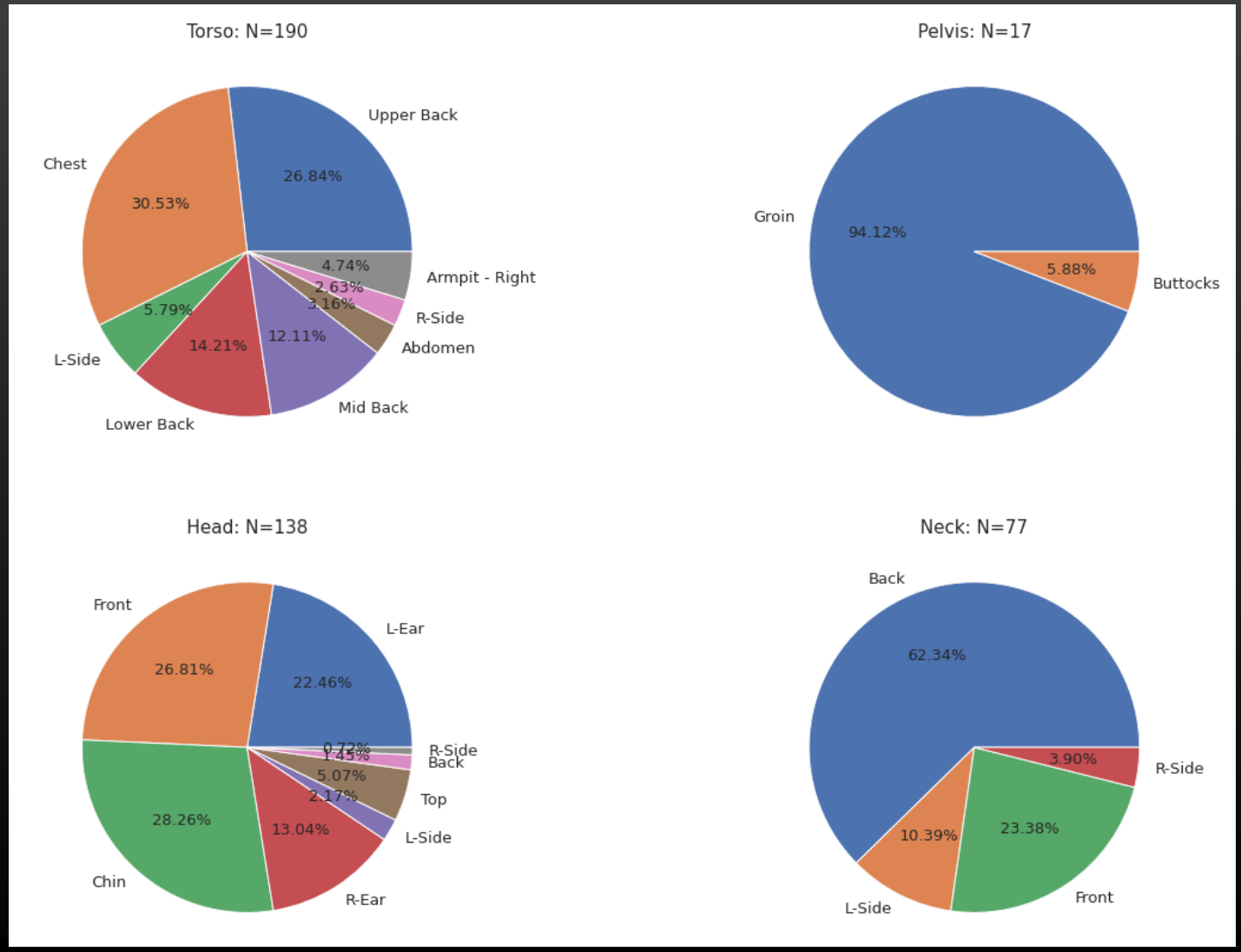
- EMU-Planar has highest exposure count (N=1981)
- Though, the EMU-Pivoted has the highest average incident Count

SUITS Analysis: 2017-June 2023



- Hands are the **highest** reported issues:
  - Right hand is N=466
  - Left hand is N= 438
- Shoulders is **second** highest reported issue:
  - Right shoulder is N=335
  - Left shoulder is N= 313

SUITS Analysis: 2017-June 2023



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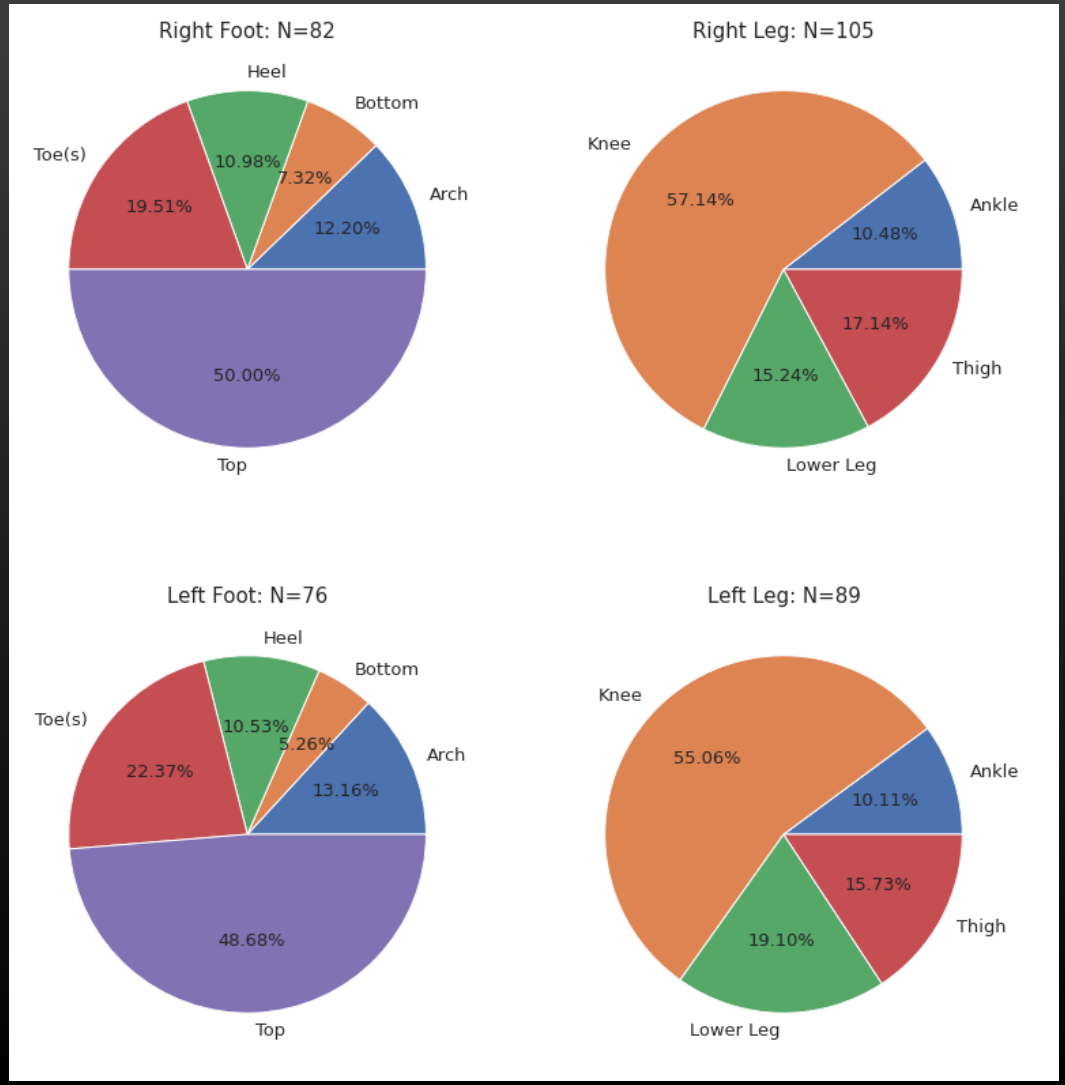
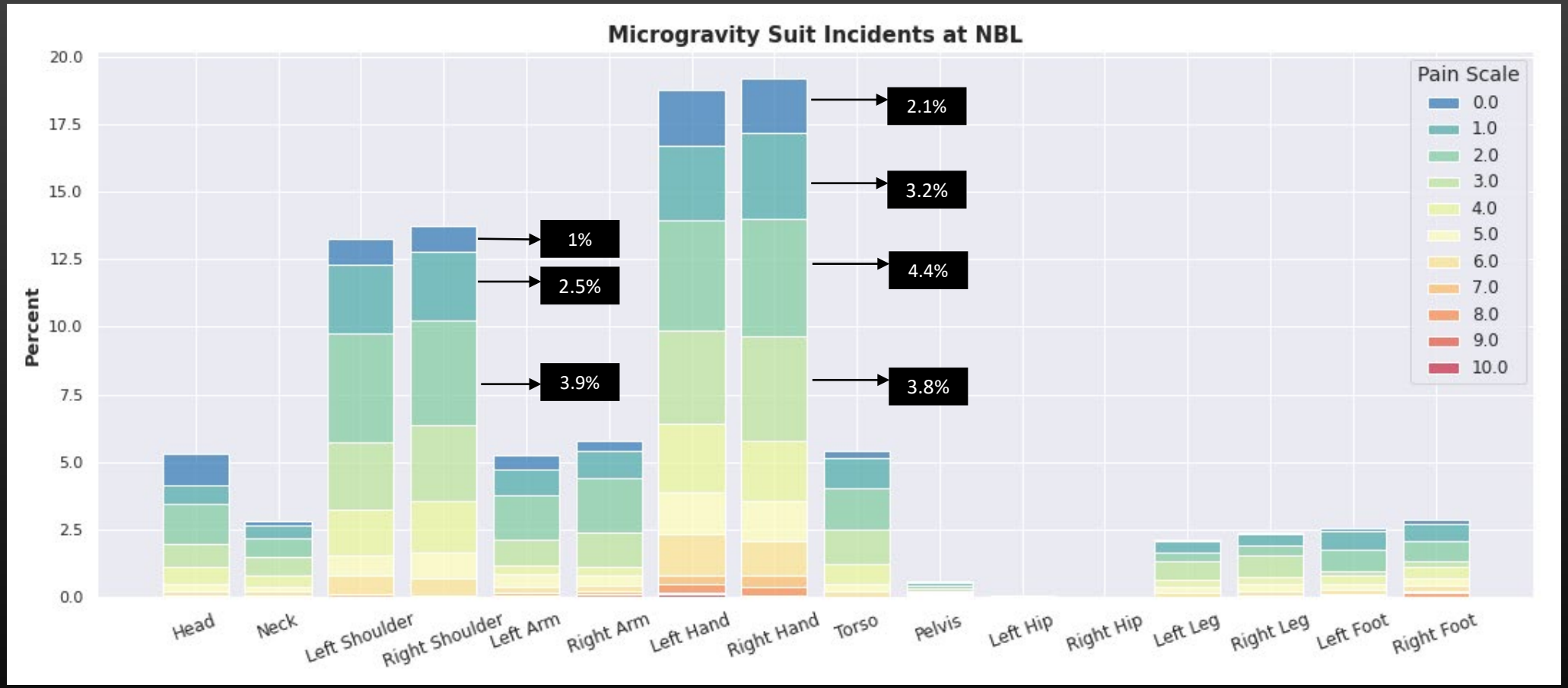


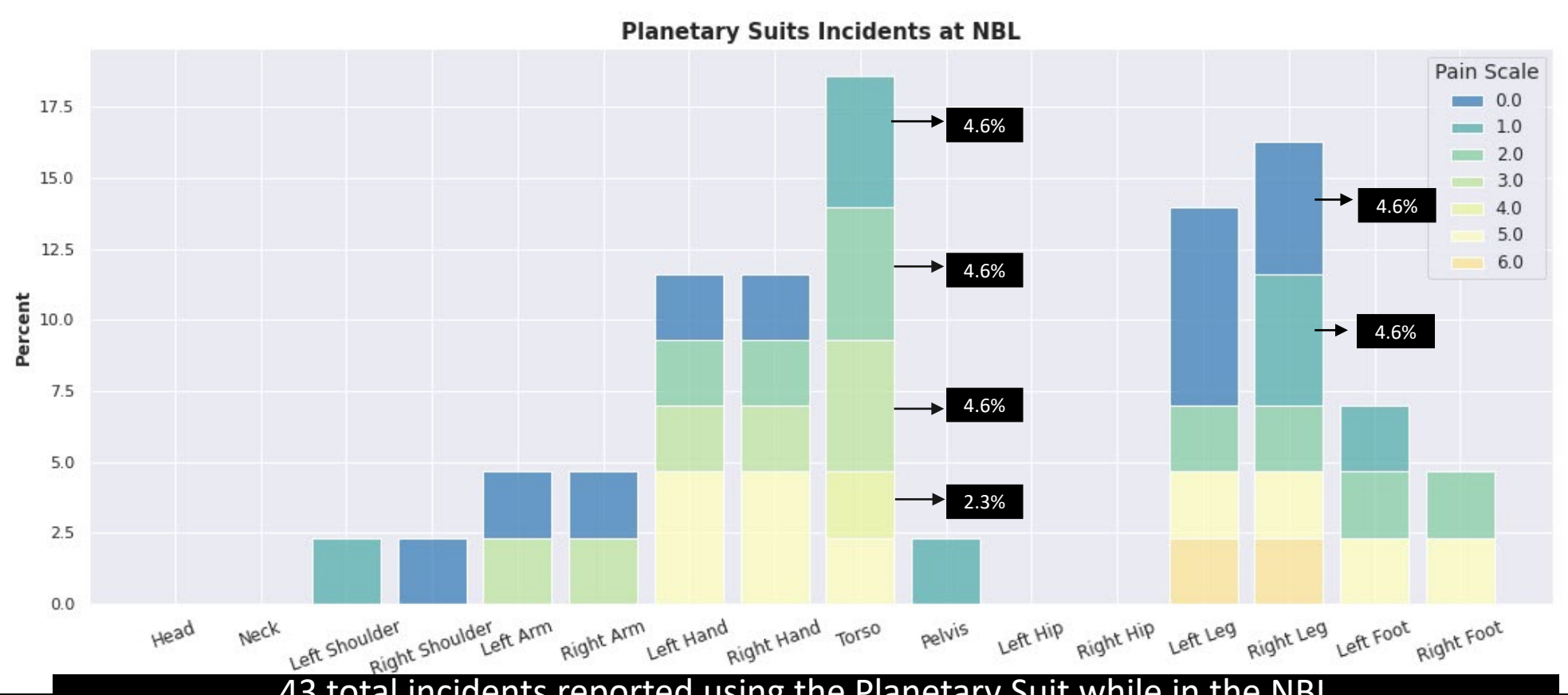
NBL Microgravity Suit Incidents



1930 total incidents reported using the Microgravity Suit in the NBL training facility

Loc.	Head	Neck	Left Should.	Right Should.	Left Arm	Right Arm	Left Hand	Right Hand	Torso	Pelvis	Left Hip	Right Hip	Left Leg	Right Leg	Left Foot	Right Foot
N	102	54	256	265	101	112	362	371	104	11	1	0	41	46	49	55
%	5.3	2.8	13.3	13.7	5.2	5.8	18.7	19.2	5.4	0.6	0.05	0	2.1	2.4	2.5	2.9

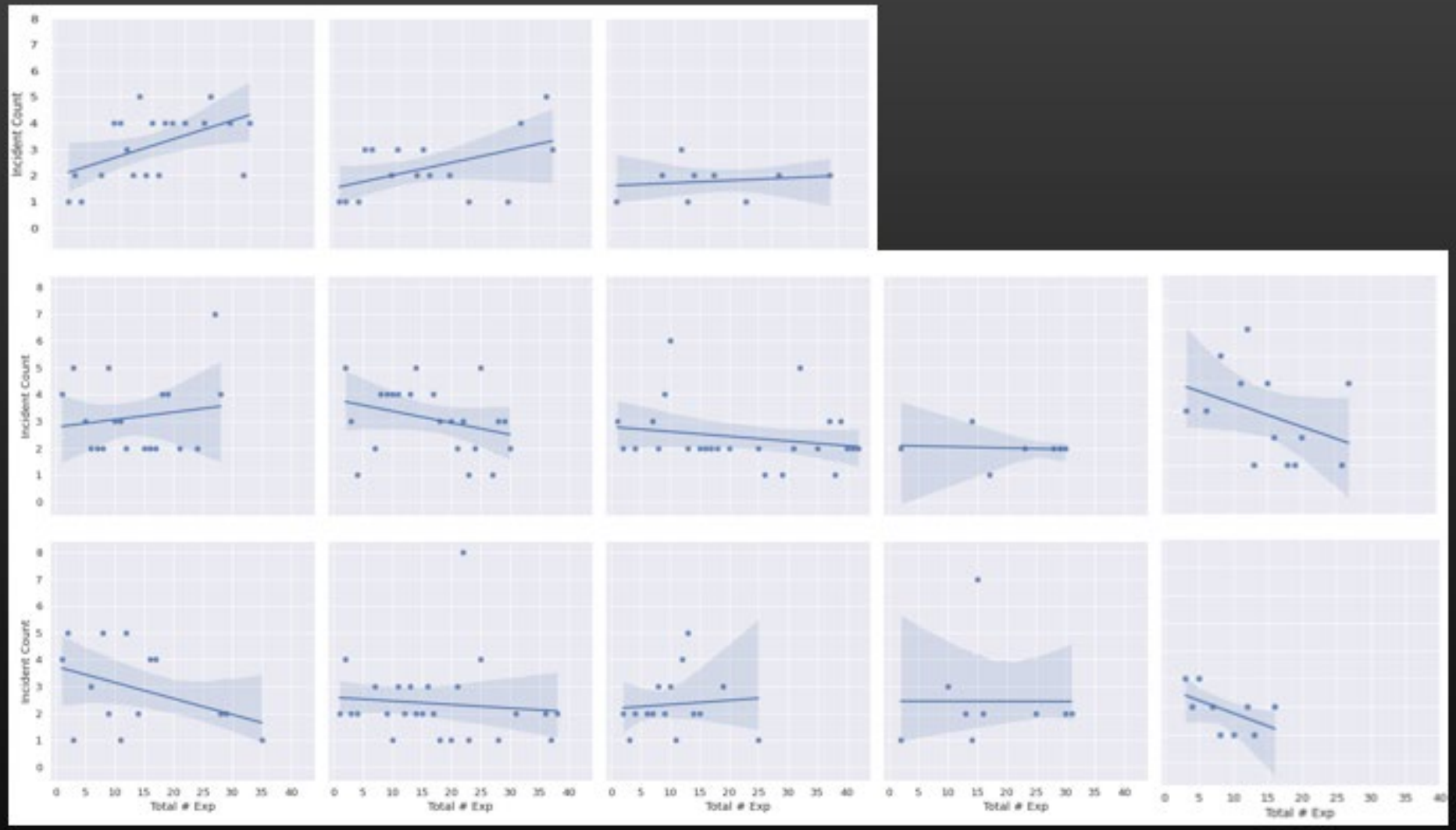
NBL Planetary Suit Incidents



43 total incidents reported using the Planetary Suit while in the NBL

Loc.	Head	Neck	Left Should.	Right Should.	Left Arm	Right Arm	Left Hand	Right Hand	Torso	Pelvis	Left Hip	Right Hip	Left Leg	Right Leg	Left Foot	Right Foot
N	0	0	1	1	2	2	5	5	8	1	0	0	6	7	3	2
%	0	0	2.3	2.3	4.6	4.6	11.6	11.6	18.6	2.3	0	0	14	16.3	7	4.6

Astronaut Class of 2017



Conclusion

- SUITS contains a large set of suited exposure data
- The SUITS repository is pulled quarterly and reviewed by EVA stakeholders
- This routine examination has led to rounds of improvement, and the expectation is that the FY25 upgrade will be quite thorough
- SUITS confirms that planetary suit exposures are leading to more lower body issues than microgravity exposures
- SUITS can be used longitudinally to track the lifecycle of suit exposures
- SUITS and it's lead to SAAT, is playing a significant role in tracking, mitigating, and preventing suit issues/injuries

Back-up Slides