Spacecraft Occupant Risk

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Background

- More minor/moderate injuries are occurring from Soyuz landings than what is expected
  - Does spaceflight deconditioning render crewmembers more susceptible to impact injuries?
  - Are the landing loads higher than current estimates?
  - Are injury risk tools accurately capturing the risk?
- The same tools that underpredict Soyuz injuries are used for certification of other vehicles
- Study was expanded to include all current vehicles

Credit: NASA/Bill Ingalls

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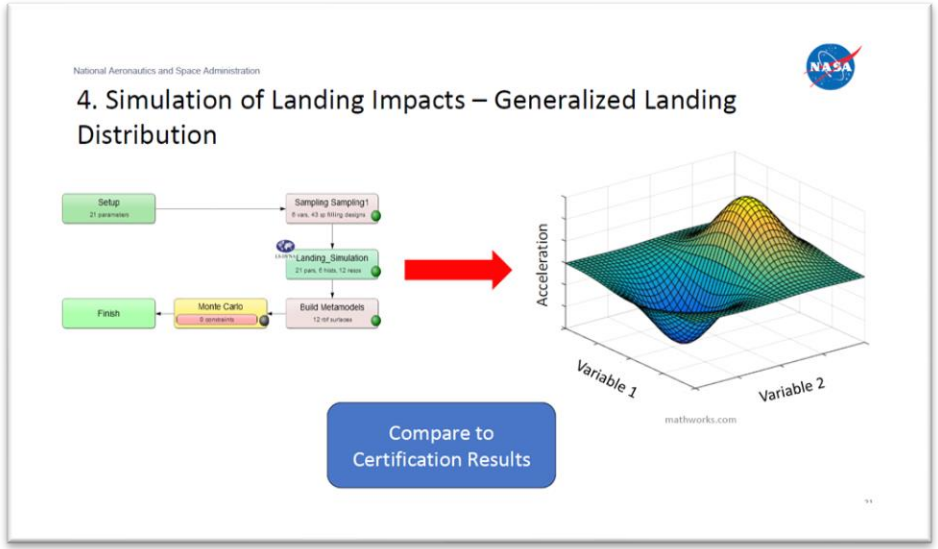
Objectives

- **Current**: Collect post-landing debrief and injury data to develop an injury database
  - Provides data to analyze vehicle injury rates and whether vehicles are meeting certification requirements
- **Previous**: Combined with additional HRP and NESC studies, previous work included reconstructing Soyuz landings using finite element analysis to evaluate whether injury rates were consistent with models



Interview → Injury Scoring → Database

Landing Debrief Questions

Vehicle:	
Mission/Exp #:	Seat Position/#:
Crewmember:	Crew Surgeon:

RE-ENTRY AND DESCENT CONDITIONS

Describe the vehicle dynamics prior to parachute deployment and while under parachutes (e.g., swinging, rotations, vibrations). Also describe if any motions or dynamics caused vision issues, motion sickness, or limb flail and if there were any anomalies, failures, or issues that impacted or could have impacted crew health.

LANDING CONDITIONS

Describe the vehicle dynamics during landing including any horizontal, vertical, or rotational dynamics. Also describe how you were positioned and braced at touchdown; if the landing felt softer or harder than expected; if there was any limb flail; and if there were any anomalies, failures, or issues that impacted or could have impacted crew health.

Type of re-entry	☐ Nominal	☐ Ballistic		
Capsule orientation in water	☐ N/A	☐ Stable 1	☐ Stable 2	Upright Time: _____
Amount of time in the water	☐ N/A	☐ <10 min	☐ 10 < t < 30 min	☐ > 30 min
Parachute operation	☐ Nominal	☐ Other _____		
Pendulum	☐ N/A	☐ Yes	☐ No	
Seat-articulation	☐ N/A	☐ Nominal	☐ Off-nominal	
Seat-stroking	☐ N/A	☐ Nominal	☐ Off-nominal	
Capsule dynamics in the water	☐ N/A	☐ Mild ±5°	☐ Moderate ± 15°	☐ > 15°
Landing Airbag Operation	☐ N/A	☐ Nominal	☐ Off Nominal _____	
Capsule dynamics after initial ground impact (check all that apply)	☐ N/A ☐ Tip	☐ Slide ☐ Bounce	☐ No dynamic motion ☐ Rollover	

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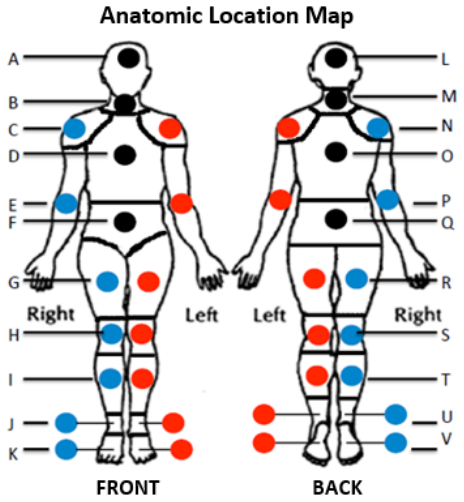

Severity / Discomfort Score	
0	No symptom awareness / discomfort
1-3	Symptom awareness / mild discomfort without performance impact
4-5	Symptom present / moderate discomfort without performance impact
6-7	Symptom present / moderate discomfort and interferes with performance
8-10	Symptom present / severe discomfort and interferes with performance

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Interview → Injury Scoring → Database

- Injuries are typically due to either inertial loading or from body parts contacting vehicular surfaces or other objects ("flail" injuries)
  - Pre-existing injuries or any non-dynamic injuries are excluded (e.g., ISS exercise, suit ingress)
- Each injury is scored based on severity (IS), ability to self-egress (SE), and return to flight status (RFS)

$$Score = \sqrt{0.25 \cdot (IS)^2 + 0.5 \cdot (SE)^2 + 0.25 \cdot (RFS)^2}$$

Table 1. Operationally Relevant Injury Scale Inputs

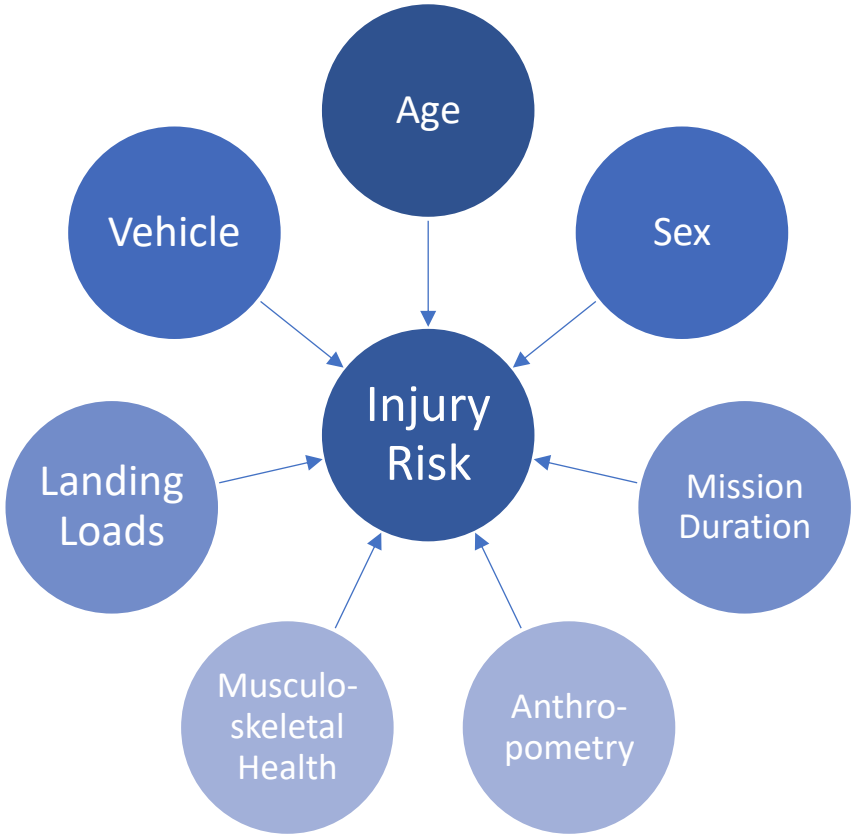
Score	AIS Description	Self-Egress Capability	Return to Flight Status
0	None*	No Impact	No Delay in Return
1	Minor	Able with minor impact (within required time)	Short Delay in Return (< 3 mo)
2	Moderate	Able with Major impact (not within required time)	Intermediate Delay in Return (<1 yr)
3	Serious	Unable without assistance	Long Delay in Return (>1 yr)
4	Severe	Unable, requires rescue and/or stabilization	Ended Flight Status/DQ'd
5	Critical		
6	Maximal		

*Not included in the AIS definition

NASA-TM-2014-217383 *Defining NASA Risk Guidelines for Capsule-based Spacecraft Occupant Injuries Resulting from Launch, Abort, and Landing*.

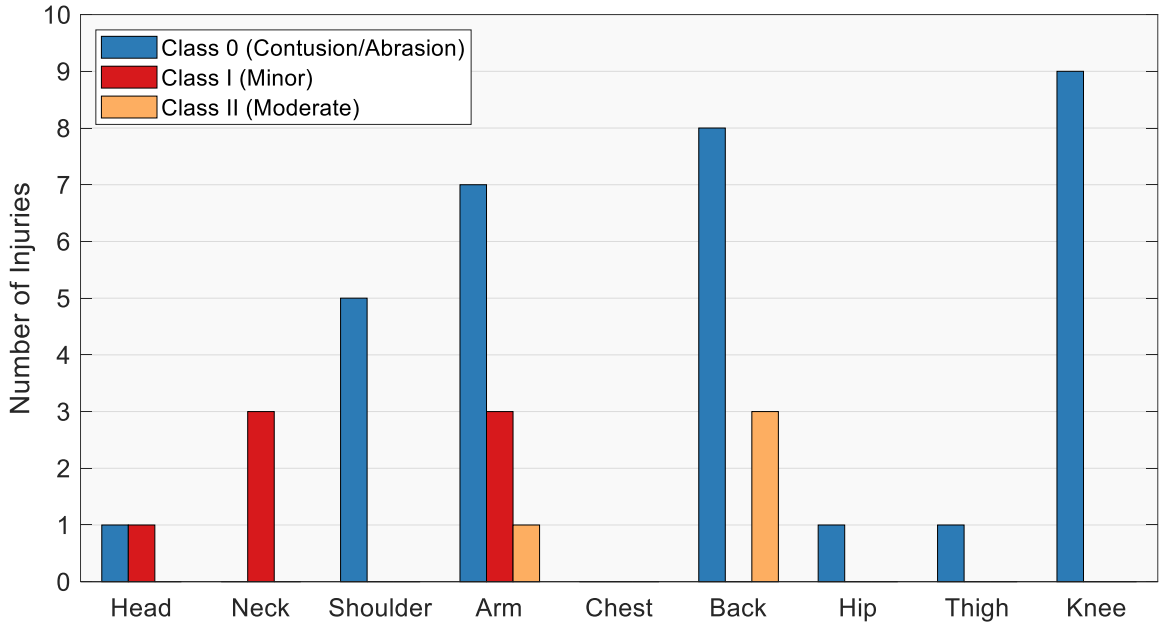
Interview → Injury Scoring → Database

- All data collections are stored in a database with relevant subject and vehicle information that relates to injury risk
- Musculoskeletal data sharing (e.g., DEXA, Isokinetic Exercise) used as indicator of spaceflight deconditioning
- For vehicles with available landing seat accelerations, landing simulations can be reconstructed



Soyuz

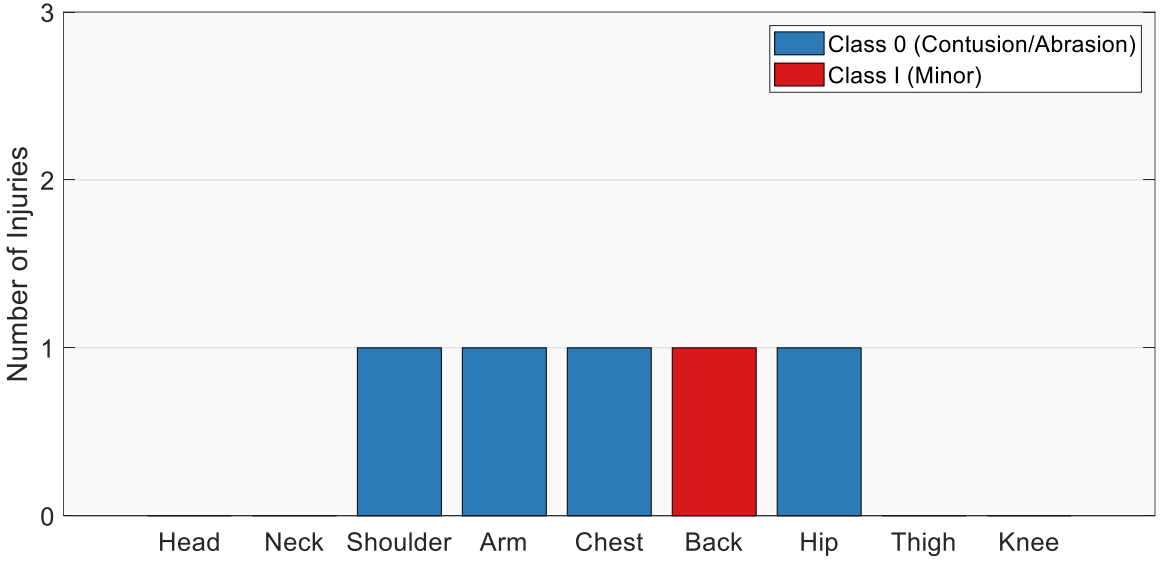
- 84 data collections
- Data spread across 4 iterations of Soyuz vehicle
- Class I and II injuries concentrated around spine and arms
  - Confined cabin a contributor to a number of blunt force/flail injuries to the arms



Injury Classification	Number of Crew Injured	Injury Rate [%]
0 (Contusion/Abrasion)	17	20
I (Minor)	5	6.0
II (Moderate)	3	3.6
III (Significant)	0	0
IV (Severe)	0	0

Dragon

- 46 data collections
- Relative to Soyuz, Dragon dataset contains more short duration missions and non-career astronauts
- Data suggest much lower injury risk than Soyuz for all injury classes

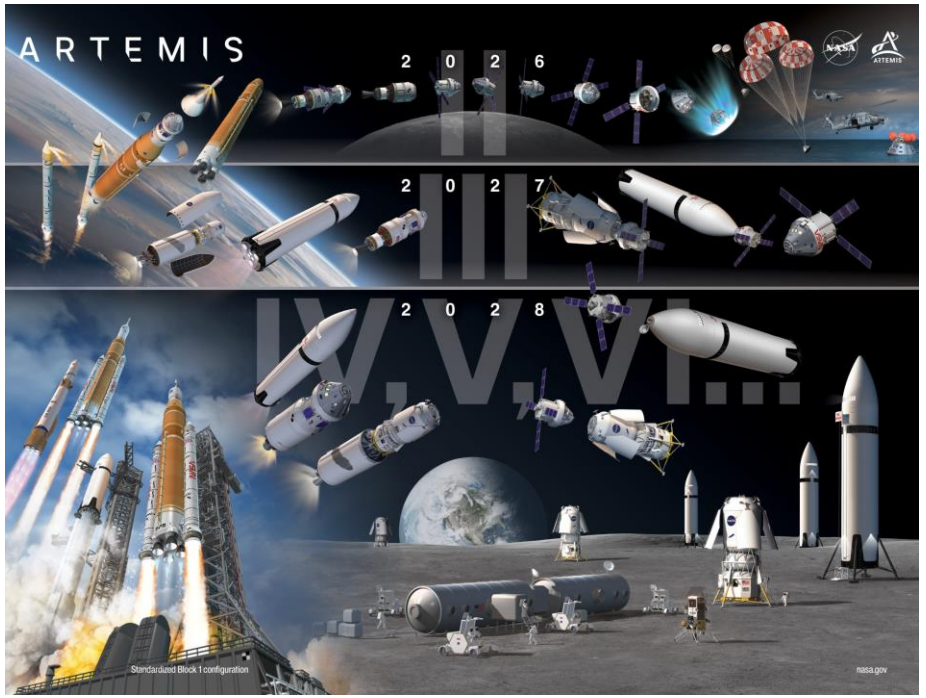


Injury Classification	Number of Crew Injured	Injury Rate [%]
0 (Contusion/Abrasion)	4	8.7
I (Minor)	1	2.2
II (Moderate)	0	0
III (Significant)	0	0
IV (Severe)	0	0

Future

- Future crewed vehicles will provide unique data to database
  - Orion
  - Lunar landers
- Statistical modeling
- Occupational health surveillance

Credit: NASA/Kim Shiflett



Credit: NASA

Questions?

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