Development of an Industry-Relevant Impact Testing Protocol for Industrial Helmets

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Background

- Traumatic Brain Injuries (TBIs) are a leading cause of death and disability
- Annually, over 3 million people in the U.S. experience a severe TBI.[1]
- Work-Related TBIs (WRTBIs) cause 17.9% of all TBI and 60% of work-related fatalities.[2]
- The construction industry has the highest incidence of WRTBI, primarily from falls.[3]
- Most falls result in oblique head impacts, with both linear and rotational acceleration.
- Current industrial helmets are designed to protect against small objects falling from above.
- Current test standards (ANSI Z89.1 and EN 12492) do not evaluate oblique impacts.[4]

*This study aimed to develop **industry-relevant** test plans to evaluate the performance of Type 2 industrial safety helmets using **real-world WRTBI fall data**.*

Methods

Industry Relevant Critical Fall Scenarios

To identify industry-relevant fall conditions, we analyzed two key datasets:
- *OSHA Severe Injury Reports (SIR)* for non-fatal, serious injuries[5]
- *Census of Fatal Occupational Injuries (CFOI)* for fatal incidents[6]

- Filtered by occupation, fall height, and fall source.
- Fall direction determined through analysis of narrative reports and available CCTV footage.
- Impact velocity, angle, and head contact location estimated based on findings from Ferro et al[7], Yu et al[8], and real-world CCTV footage[9].

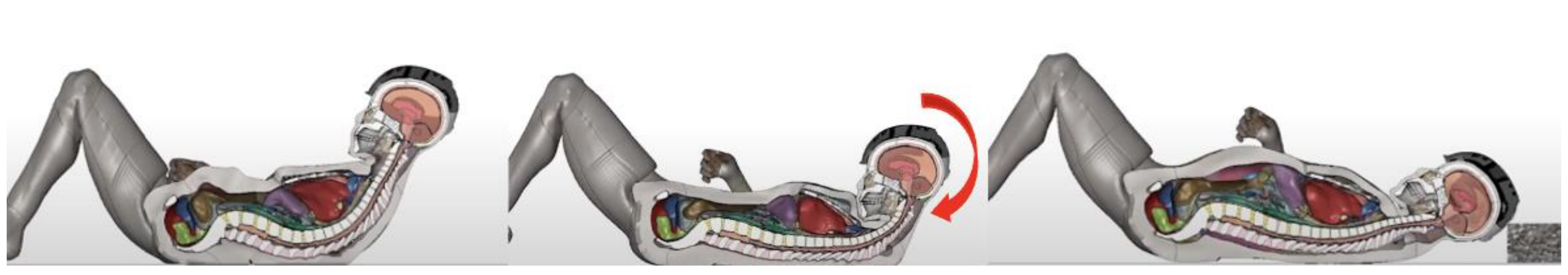
These parameters are summarized in Table 1.

To address the wide range of impact scenarios observed in real-world falls, two test methods have been developed:
1. High-velocity falls from height with high-impact angles.
2. Lower height backwards falls, involving a body first and head-secondary impact mechanism.

Table 1. Key impact parameters by occupational group, injury severity, incidence and fall source.

Occupation	Source	Incidence (% of total)	Height (m)	Speed (m/s)	Angle (°)	Head location
			Non-Fatal			
General Construction	Ladder (Backward)	37%	1.8	3.88	35	Rear
	Scaffold (Backward)	8.8%	3.5 - 5	9.7	87	Rear, Top
Roofer	Roof (Forward)	6.8%	3.5 - 5	8	80	Front
	Roof (Backward)		3.5 - 5	9.7	87	Rear, Top
			Fatal			
General Construction	Ladder (Backward)	24.2 %	3.5	9.5	87	Rear, Top
			3.5 - 5	9.7	87	Rear, Top
	Scaffold (Backward)	14.7 %	9 +	9.7 +	87 +	Rear, Top
Roofer	Roof (Forward)	32.0 %	5 - 6	8	87 +	Front, Top
	Roof (Backward)		5 - 6	9.7 +	87 +	Rear, Top

Figure 1. Mechanism of body first, head-secondary impact in backwards falls[10].



Test Design

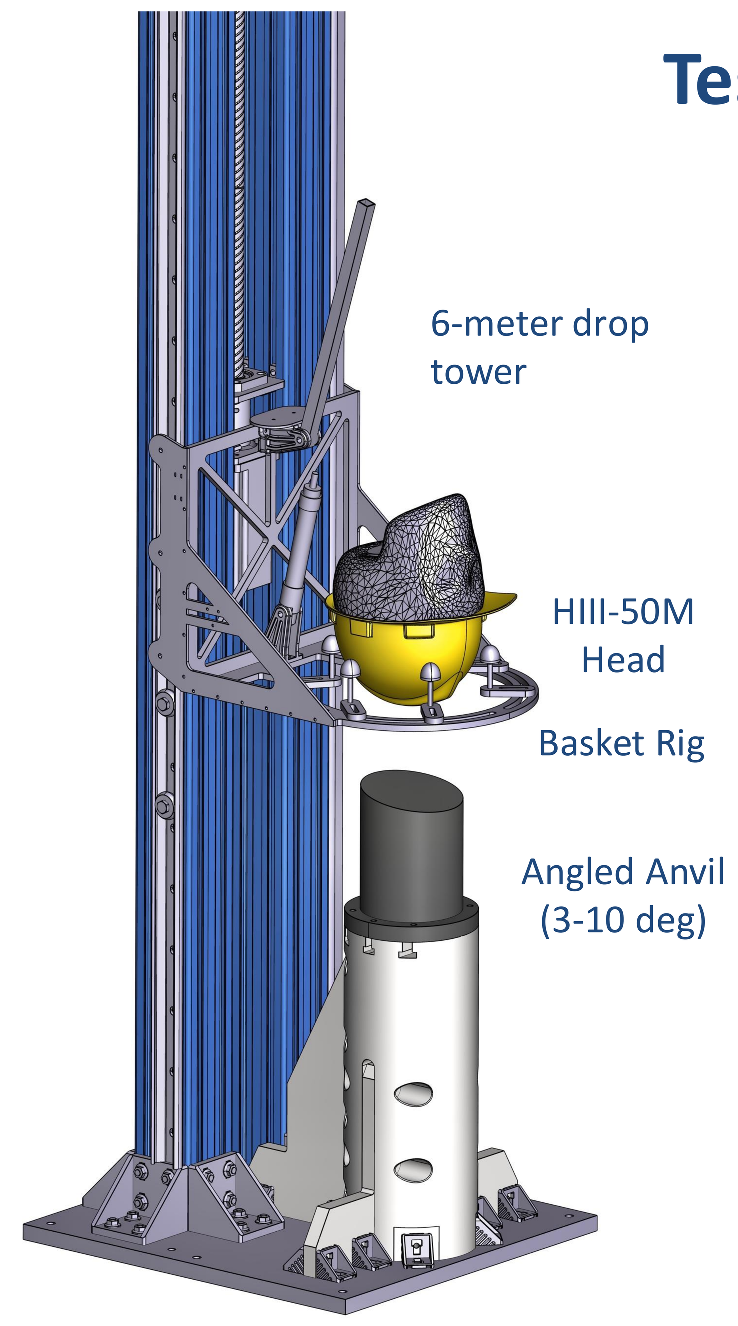


Figure 2. *Test 1 Set-Up*

Test 1 – *High Height Falls*

- Captures critical scenarios from Table 1, Rows 2-7.
- Free fall after losing contact with a platform (such as a ladder, scaffolding or roof) before directly impacting the ground.
- Result in high-speed impacts, with the primary impact occurring at high angles on the head.
- Free fall on vertically guided rail with "basket rig" for positioning of HIII head form.
- Oblique impact on an angled anvil

Test 2 – *Low Height Backwards Fall*

- Backwards falls from lower heights (primarily ladders) where the torso impacts the surface first, followed by a secondary impact of the head with high rotational acceleration (*Figure 1*).
- Captures critical scenarios from Table 1, Row 1.

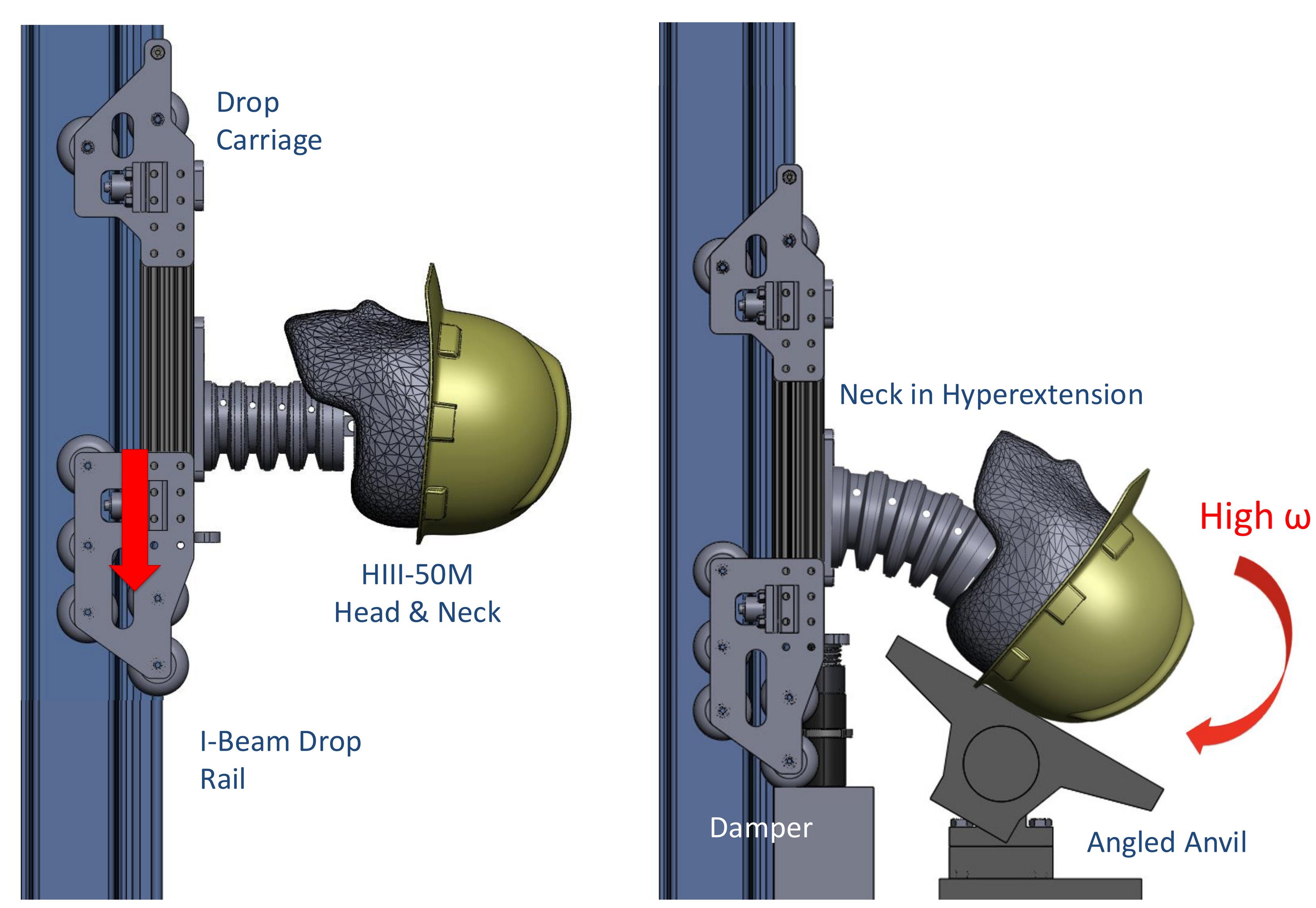


Figure 3. *Test 2 Set-Up*

- HIII head and neck mounted to a vertically guided drop carriage.
- Carriage and head/neck accelerate downward under gravity.
- Carriage impacts a hydraulic damper to simulate a torso-ground impact.
- Head continues moving due to inertia, causing neck hyperextension.
- Results in high head angular velocity prior to the head impacting the angled anvil.

Conclusion and Future Work

By incorporating industry-relevant fall conditions into helmet evaluations, we propose:
- **Testing protocols representative** of real-world injury scenarios
- That these **improved safety standards** will **enhance protection** for construction workers**.**

Future work will focus on building the physical test setup and experimentally validating key impact parameters. Results from testing will inform protocol refinement to improve accuracy, repeatability, and concordance with real-world injury scenarios.

References

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