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Title: Experimental Investigation of 'Falling Man' Scenarios: Technical Approach

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LANL routinely supports hazards analysis studies for the NNSA/DOE (National Nuclear Security Administration/Department of Energy). Slips, trips, and falls ("falling man") are plausible scenarios for these processes. The forces from a "falling man" scenario can adversely affect nearby energetic materials with energy levels sufficient to cause a violent response. These phenomena are not well understood by the safety analysis community.

To extend the current state of knowledge on this topic, a series of experiments will be performed and mathematical models will be developed to better understand the biomechanical mechanisms related to a "falling man" scenario.

The presentation describes how a study devoted to a "falling man" research and development effort will be accomplished.

Experimental Investigation of 'Falling Man' Scenarios

Technical Approach

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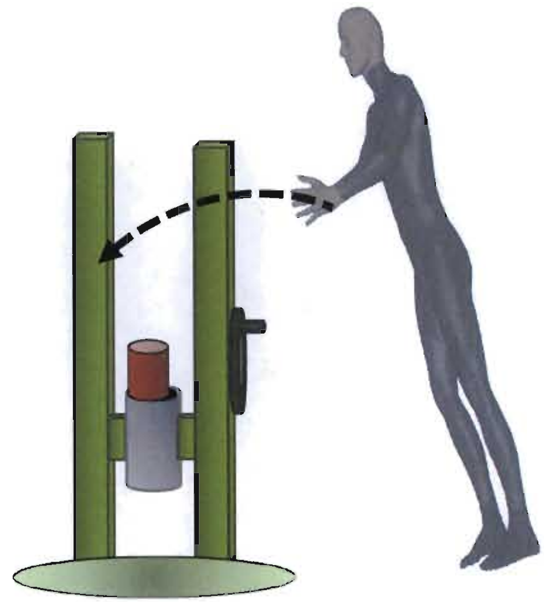
Background

- Hazards analysis – assembly and disassembly of energetic components.
- Analyze scenarios involving slips, trips, and falls ("falling man").
- Risk of violent response if the worker falls onto the energetic material.
- Models for a "falling man" scenario are overly conservative.
- Biomechanical properties not well understood.



Scope

- To understand these mechanisms – Conduct an in depth investigation of the "falling man" scenario.
- Results provide a rationale for reviewing the conservatisms.
- Determine if a less conservative model can be empirically substantiated.

"…multiple mechanisms are involved in slip and fall accidents. "

Lockhart, T. E., Woldstad, J. C., and Smith, J. L., "Assessment of slip severity among different age groups," ASTM STP 1424, Metrology of Pedestrian Locomotion and Slip Resistance. M. Marpet and M. A. Sapienza, Eds., American Society for Testing and Materials, West Conshohocken, PA, 2002.

Collaboration

Los Alamos National Laboratory • Arlan Swihart • Paul Peterson • Mark Mundt • Gary Parker • Bob Matavosian • Walt Gilmore	**B& W Pantex** • Steve Young • Doug Kaczmarek • Richard Ray • Scott Weaver • Natalie Waters
Virginia Polytechnic Institute and State University • Thurmon Lockhart	**Sandia National Laboratories** • Caren Wenner • Courtney Dornburg • Jason Morris • Nathan Brannon

Project Plan

Phase I: Fall Experiments: Human Subjects

- PT trips and impacts the HE (No Tool)
- PT trips and impacts the HE (Probe – Hand Tool)
- PT trips and impacts the HE (Blunt – 40 lb. Tool)

Phase II: Fall Experiments: Cadavers

PT trips and impacts the HE – "Worst Case"
(Probe – Hand Tool)
[Tool trapped between the target and upper torso]

LANL Rigid-Arm Pendulum / Impactor tests
[Test human induced potential for penetration into HE]

Phase I: Fall Experiments: Human Subjects

Two Stage Experiment – Empirical and Modeling and Simulation

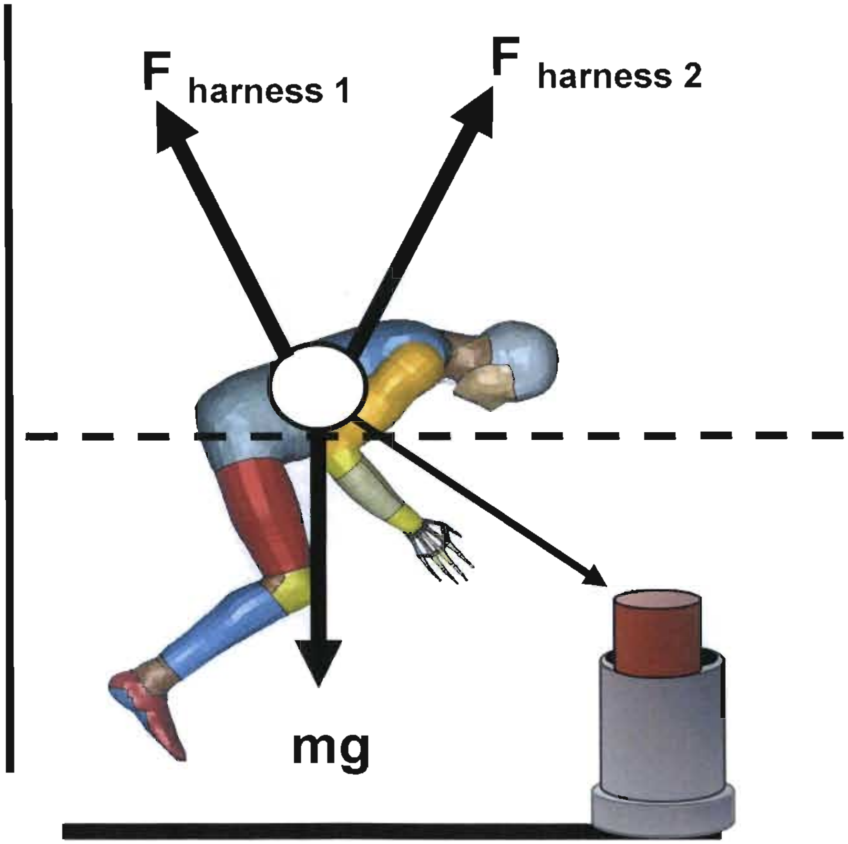
- Traverse a test track and induce a fall event.

- Measure reactive control motions – Kinematic and kinetic properties as the fall progresses to termination.

Model and simulation Stage:

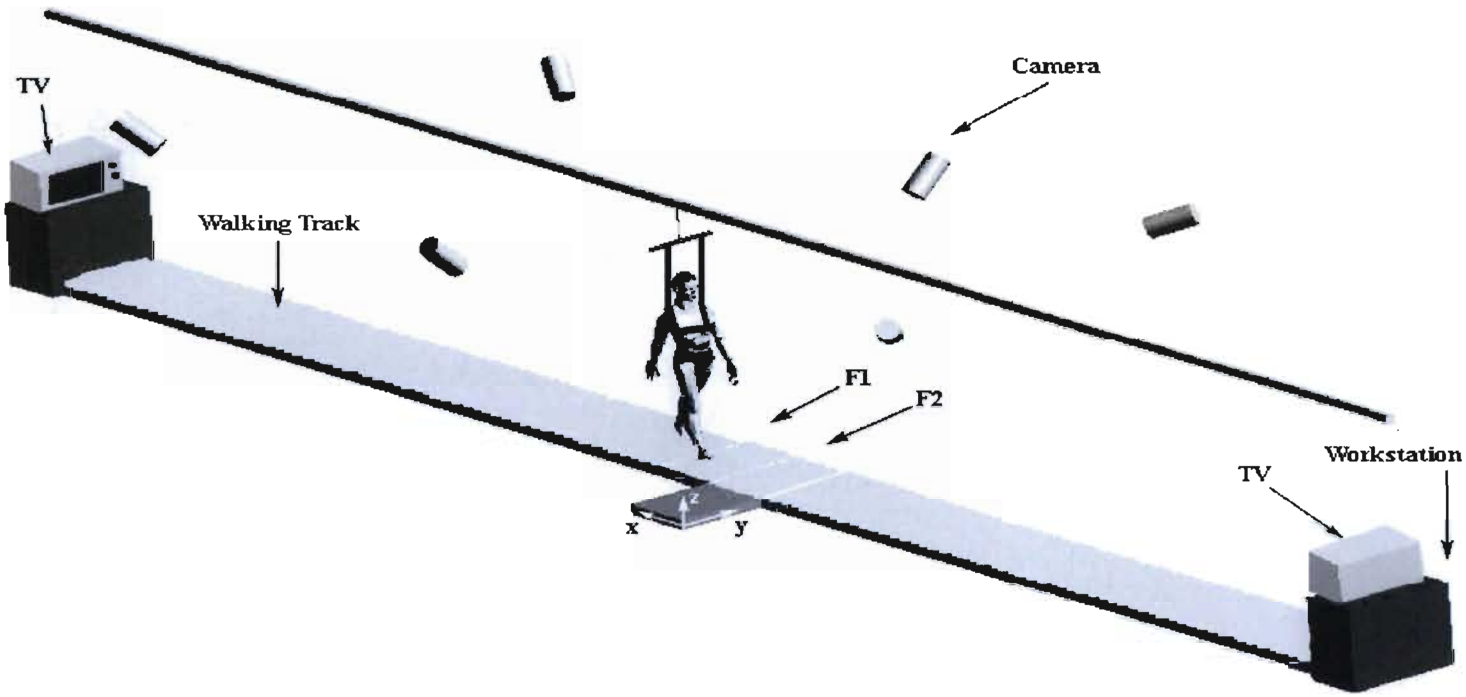
- Estimate the impact forces.

Lockhart, T. E., Research Design and Methods, *Personal Communication*, May 25, 2011.



Phase I: Fall Experiments: Human Subjects

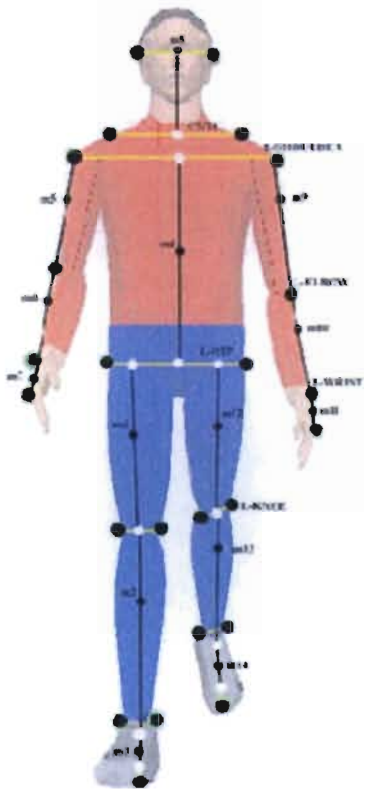
Perform experiments and collect biomechanical data - predict the bounding force profile associated with a "falling man" scenario.

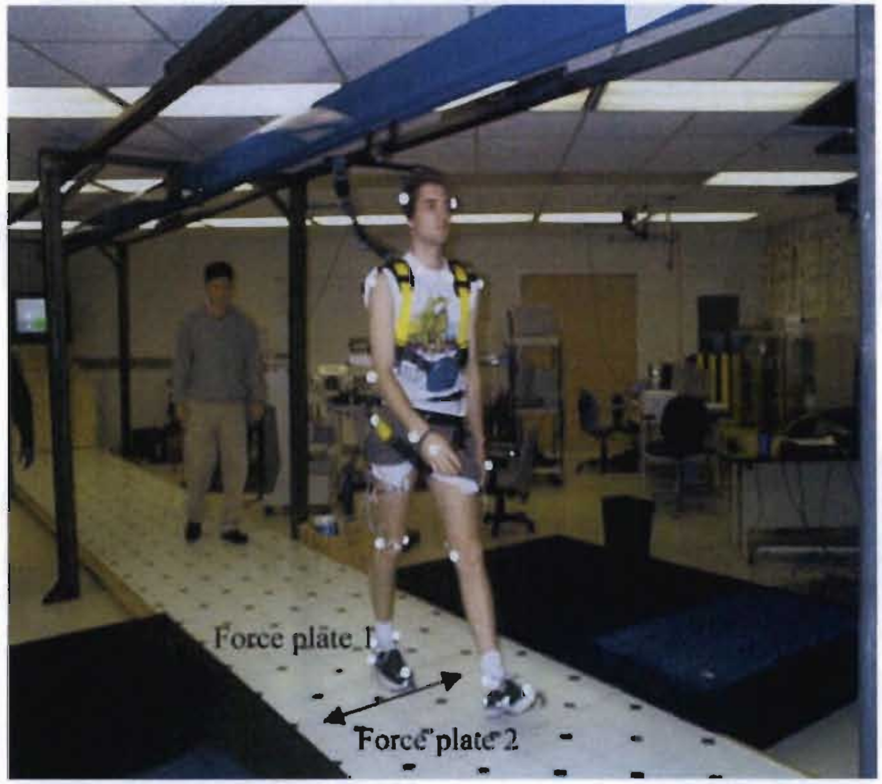


Source: Assist Technol. Author manuscript; available in PMC 2010 June 30. NIH-PA

Phase I: Fall Experiments: Human Subjects

Markers Collect 3D Posture Data

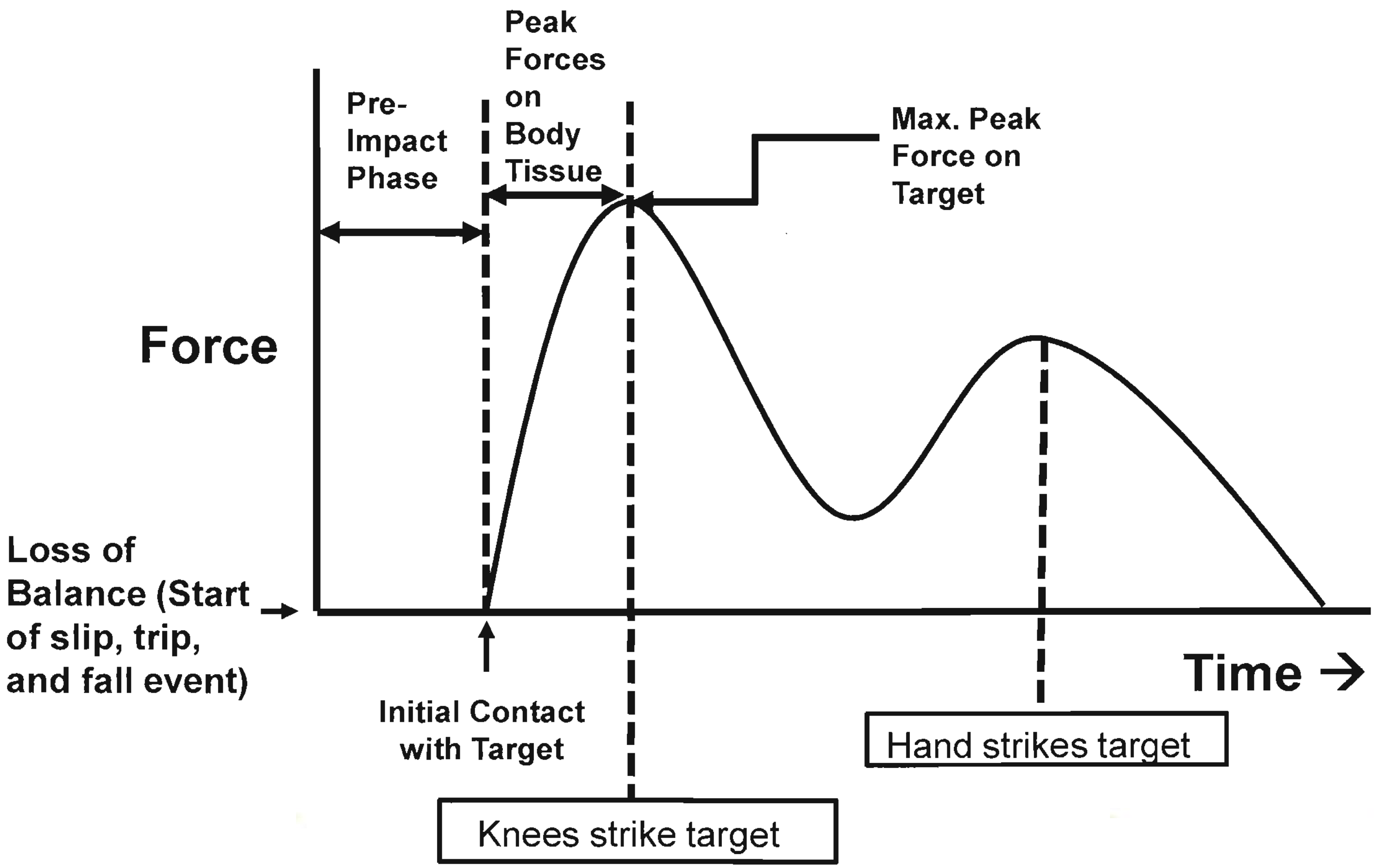




Source: Lockhart, T. E. & Kim, S. (2006). Relationship between hamstring activation rate and heel contact velocity: factors influencing age-related slip-induced falls. *Gait Posture*, Aug;24(1):23-34. Epub 2005 Aug 19.

Phase I: Fall Experiments: Human Subjects

Predict the bounding force profile – body and the target.



Phase II: Fall Experiments: Cadavers

- Identify "worst case" bounding force profile. A benchmark for comparison with human subjects experiments.
- Evaluate an event at the injury producing thresholds (e.g., fall while holding a screwdriver, trapped between sternum and impacted target).
- Assess extent of compliance in soft tissues and skeletal structures.

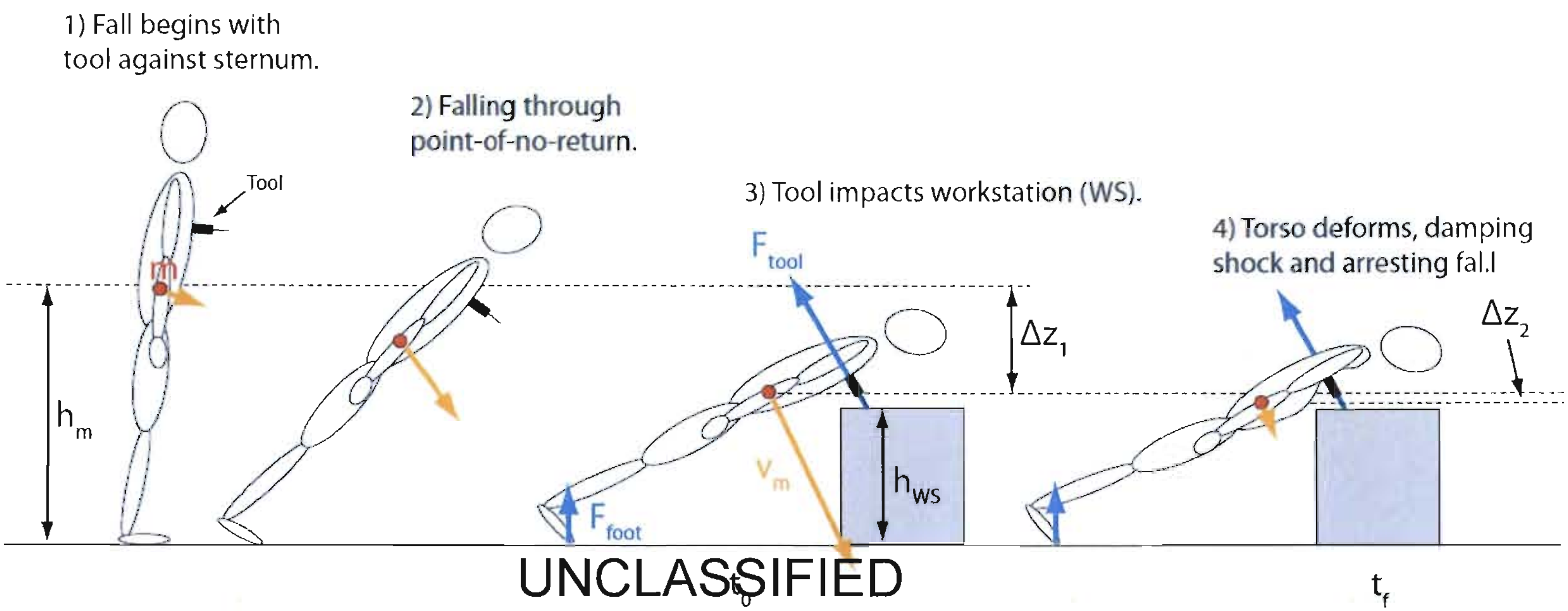
Distal Radial Mean Fracture Force = 2.27 kN [1]
Hip Fracture Force = 6.0 kN [2]

[1] Chiu, J., Robinovitch, S. N. (1998). Prediction of upper extremity impact forces during falls on the outstretched hand. *Journal of Biomechanics,* 31, 1169 – *1176.*

[2] Lockhart, T. *Personal Communication* [Verbal] (06/14/2011).

Phase II: Fall Experiments: Cadavers

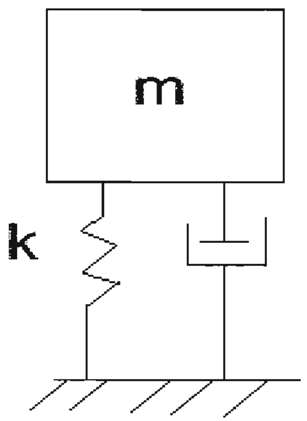
Pointed tool pinned between upper torso and target



Parameterization of the "Falling Man" Scenario

LANL Rigid-Arm Pendulum / Impactor test apparatus

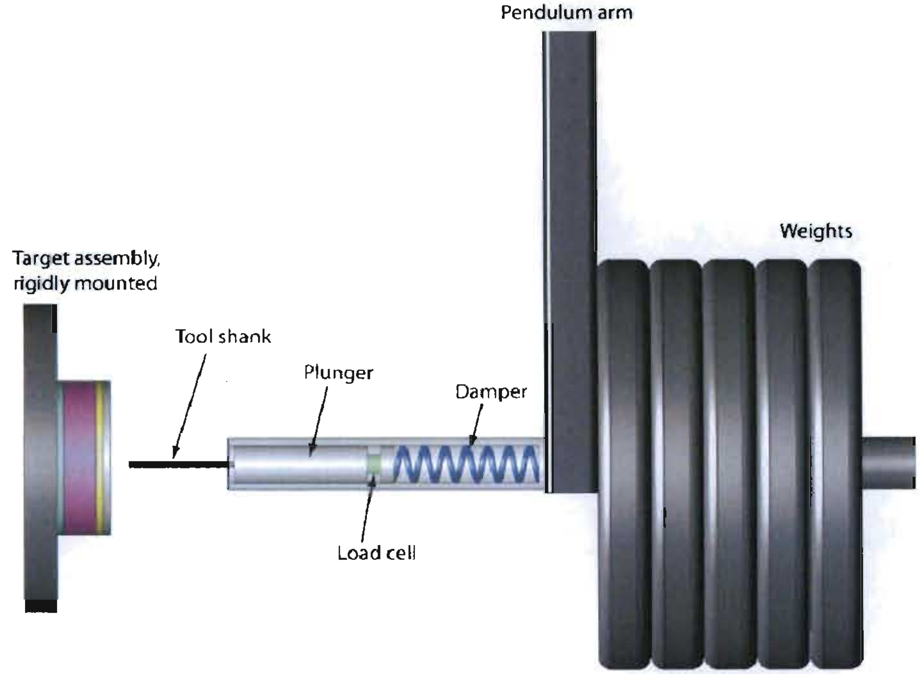
Parameters derived from the Human subjects/cadaver experiments



K = stiffness

b = damping coefficient

Lockhart, T. E., Research Design and Methods, *Personal Communication*, May 25, 2011.



Parker, G., Dickson, P., Rae, P. and Novak, A. *Proposal to Study Low-Velocity Impact of U6Nb-Clad HE Mock: Addressing the Worst-Case "Falling Man" Insult Scenario*, LANL/WX-6, High Explosives Physics Team, 2011.

Future Plans

FY-2011	
Task Description of a "Falling Man" Scenario	September 2011
FY-2012	
Fall Experiment: Human Subjects	October, 2012
Fall Experiment: Cadavers	November, 2012

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