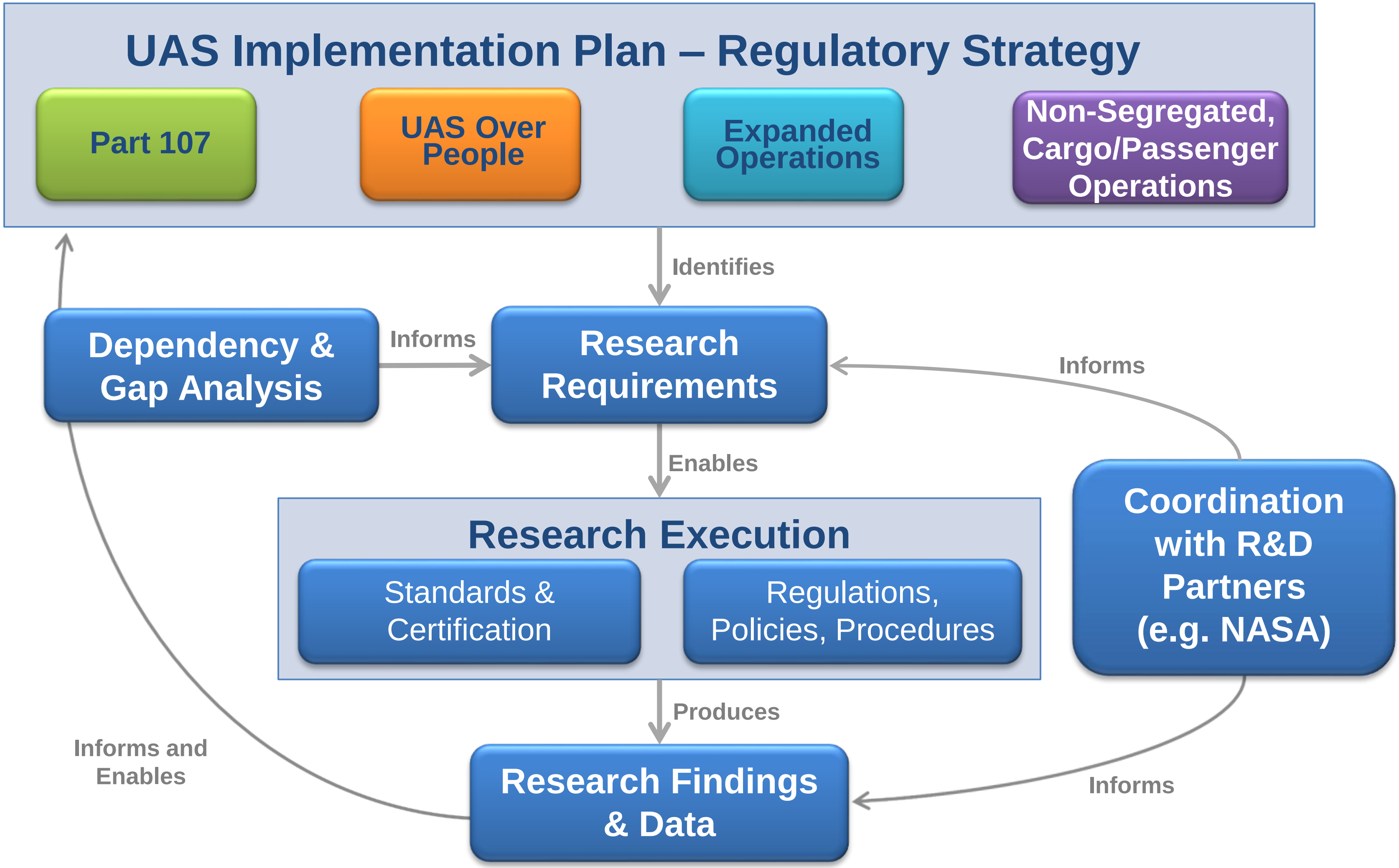
Release of ASSURE's Ground Collision Severity Research

Presented by: Earl Lawrence, Director, FAA UAS Integration Office

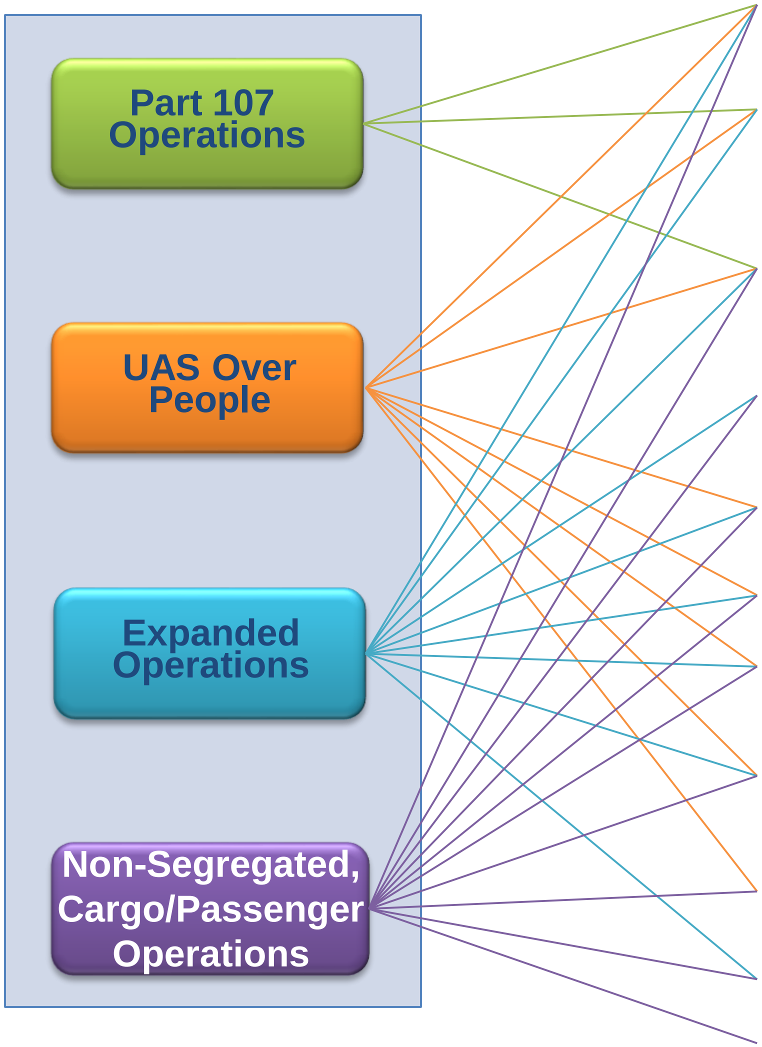
Date: April 28, 2017

UAS Center of Excellence

R&D Support for UAS Rulemaking



R&D Support for Regulatory Strategy



FAA Integrated Research (AUS, AVS, ASH, ATO, ARP, APO, ANG/Tech Center)

Focus Area Pathfinders
- ConOps
- Operational procedures and risk analysis
- Standards development
- Flight testing

UAS Center of Excellence
- Kinetic energy research
- **Ground and Airborne Collision Evaluation**
- Impact risk analysis

NASA
- UAS Traffic Management (UTM)
- UAS in the NAS

UAS ExCom SARP (FAA, DoD, NASA, DHS, DOJ, DOI, DOC, *DOE*)
- Population & airspace density risk assessment
- ‘Well Clear’ definition

UAS Test Sites
- Missions & research lessons learned

International
- Standards and procedures harmonization (ICAO, JARUS, SESAR, CAAs)

FFRDCs
- Data forecasting, airworthiness standards, risk analysis
- Small cargo delivery analysis
- Technical performance-based standards

ASTM International
- Standards development for ops over people and BVLOS
- Operational risk analysis

National Academies
- Probabilistic risk study

RTCA
- DAA and C2 standards development

Today's Announcement

- **Fundamental goal of COE research**
  - How to safely fly UAS over people, minimal risk to serious injury

- **Today's research first in a series**
  - First step to answering fundamental and complex question

Today's Announcement

- **FAA perspective**
  - Wes Ryan, Manager, Programs & Procedures (Advanced Technology), ACE-114, Small Airplane Directorate
- **Results**
  - FAA UAS Center of Excellence – ASSURE
- **Questions and Answers**
- **Closing**

FAA Perspective

- **Why the Research Was Done**
  – Understand risks to public for ops over people
- **Who Performed the Research**
  – FAA UAS Center of Excellence – ASSURE
- **FAA Sponsored Peer Review**
  – NASA, DoD, FAA subject matter experts, chief scientists
- **Results & Future**
  – Identified the complexity of problem and future R&D

ASSURE

Alliance for System Safety of UAS through Research Excellence

FAA UAS COE Task A4 and A11
Ground Collision Severity Brief to Stakeholders
28 April 2017

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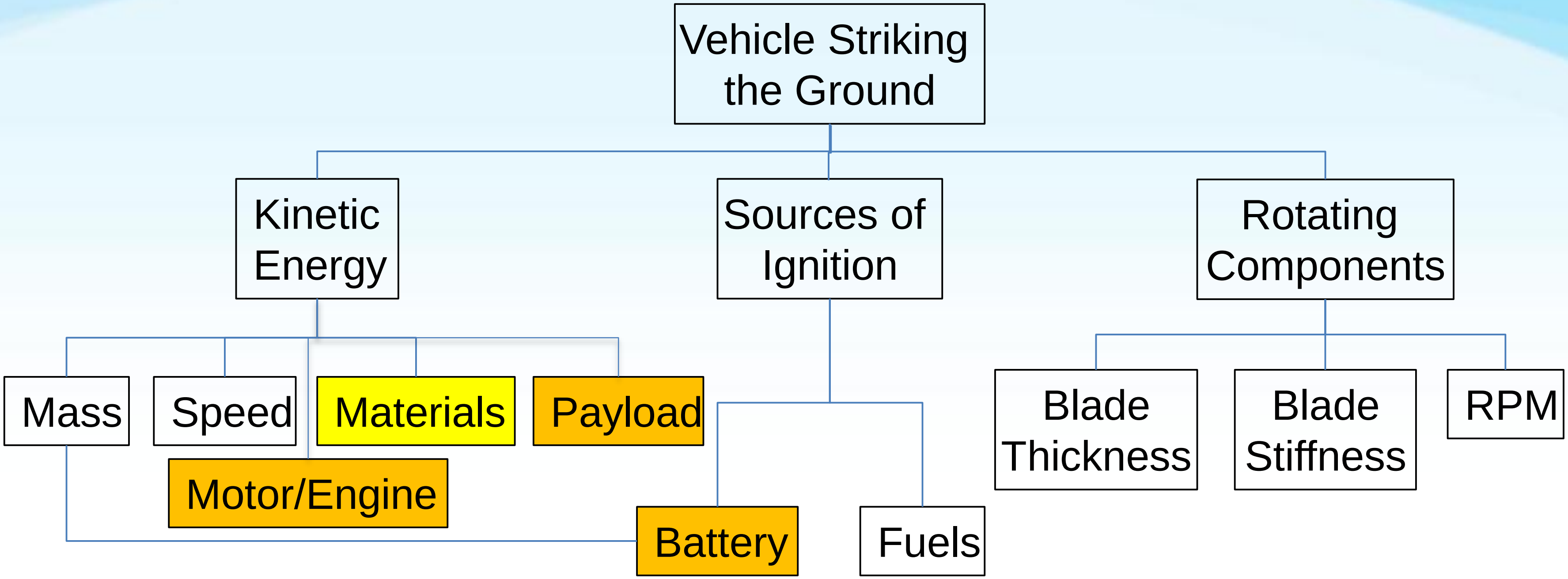
Approach

- Development of a Taxonomy for Ground Collision Severity
  - Identify hazardous vehicle attributes and associated physical properties
- Conduct Literature Search
  - Document characteristics of various classes of UAS (materials, construction, etc.)
  - Identify documented injury and damage mechanisms
  - Identify injury and damage events documented among RC modelers
  - Identify casualty and injury models/analysis, from various disciplines, used to evaluate injury probability and severity
- Conduct modeling/analysis/testing of sUAS collisions with humans
  - Evaluate existing casualty and injury models/analysis methods for applicability to sUAS
  - Evaluate mitigations to injury mechanisms

Collision Severity Taxonomy



Payloads, batteries, and motors present unique challenges in that they are dense, and not likely to be made to come apart to dissipate impact energy.

Material properties must be evaluated to determine risk of injury and damage for different types and constructions.

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Initial Framework for Injury Metrics

- Mirco-UAS Advisory Rulemaking Committee made recommendations on impact and injury metrics
- Recommended energy density (KE per unit of contact area) as the metric for evaluating small UAS
- Energy density thresholds determined by industry consensus standard
- Consensus standards should not result in the probability of an AIS 3 or greater injury when hit by a UAS as defined by each performance category
  - AIS – Abbreviated Injury Scale developed by the Association for the Advancement of Automotive Medicine (AAAM)

Table 7 – Micro-UAS ARC Recommended FAA Allowable Rates of Serious (or worse) Injury Due to an Impact with a Person on the Ground [41]

Category	Flight scenario in which an impact with a person the ground occurs	Acceptable rate of AIS 3 or greater injury
2	No less than 20' above, 10' laterally from people	1%
3	In a specified region not over people except ground crew	30%
4	Over crowds, but with operational/other mitigation	30%

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Key Findings from the Ground Collision Severity Report

- 300 publications reviewed to evaluate existing injury metrics, battery standards, toy standards, and casualty models to determine applicability to small UAS
- Three dominant injury metrics applicable to sUAS
  - Blunt force trauma injury – Most significant contributor to fatalities
  - Lacerations – Blade guards required for flight over people
  - Penetration injury – Hard to apply consistently as a standard
- Collision Dynamics of sUAS is not the same as being hit by a rock
  - Multi-rotor UAS fall slower than metal debris of the same mass due to higher drag on the drone
  - UAS are flexible during collision and retain significant energy during impact
  - Wood and metal debris do not deform and transfer most of their energy
- Payloads can be more hazardous due to reduced drag and stiffer materials
- Blade guards are critical to safe flight over people
- Lithium Polymer Batteries need a unique standard suitable for sUAS to ensure safety

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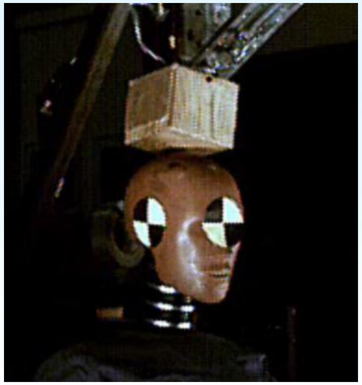
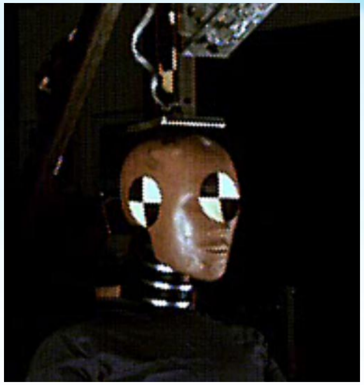
Comparison of Steel and Wood with Phantom 3

UAS	Wood	Steel
		
Test Weight: 2.69 lbs. *Impact Velocity: 49-50 fps* *Impact Energy: 100-103 ft-lbs.*	*Test Weight: 2.69 lbs.* *Impact Velocity: 52-54 fps* *Impact Energy: 116-120 ft-lbs.*	*Test Weight: 2.7 lbs.* *Impact Velocity: 52-53 fps* *Impact Energy: 114-121 ft-lbs.*
Motor Vehicle Standards • Prob. of neck injury: 11-13% • Prob. of head injury: 0.01-0.03%	**Motor Vehicle Standards** • Prob. of neck injury: 63-69% • Prob. of head injury: 99-100%	**Motor Vehicle Standards** • Prob. of neck injury: 61-72% • Prob. of head injury: 99-100%
Range Commanders Council Standards • Probability of fatality from… - Head impact: 98-99% - Chest impact: 98-99% - Body/limb impact: 54-57%	**Range Commanders Council Standards** • Probability of fatality from… - Head impact: 99-100% - Chest impact: 99-100% - Body/limb impact: 67-70%	**Range Commanders Council Standards** • Probability of fatality from… - Head impact: 99-100% - Chest impact: 99-100% - Body/limb impact: 65-71%

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What's Next?

- Continue research to refine metrics developed in Task A4
  - Assess injury potential of a broader range of vehicles
  - Refine modeling effort to address more scenarios
- Develop a simplified test method for characterizing injury potential of sUAS
- Validate proposed standard and models using potential injury test data

Questions

Closing

- **Ground collision research first in a series**
  - Airborne collision severity in Summer 2017
- **What's next**
- **Ground collision research contact:**
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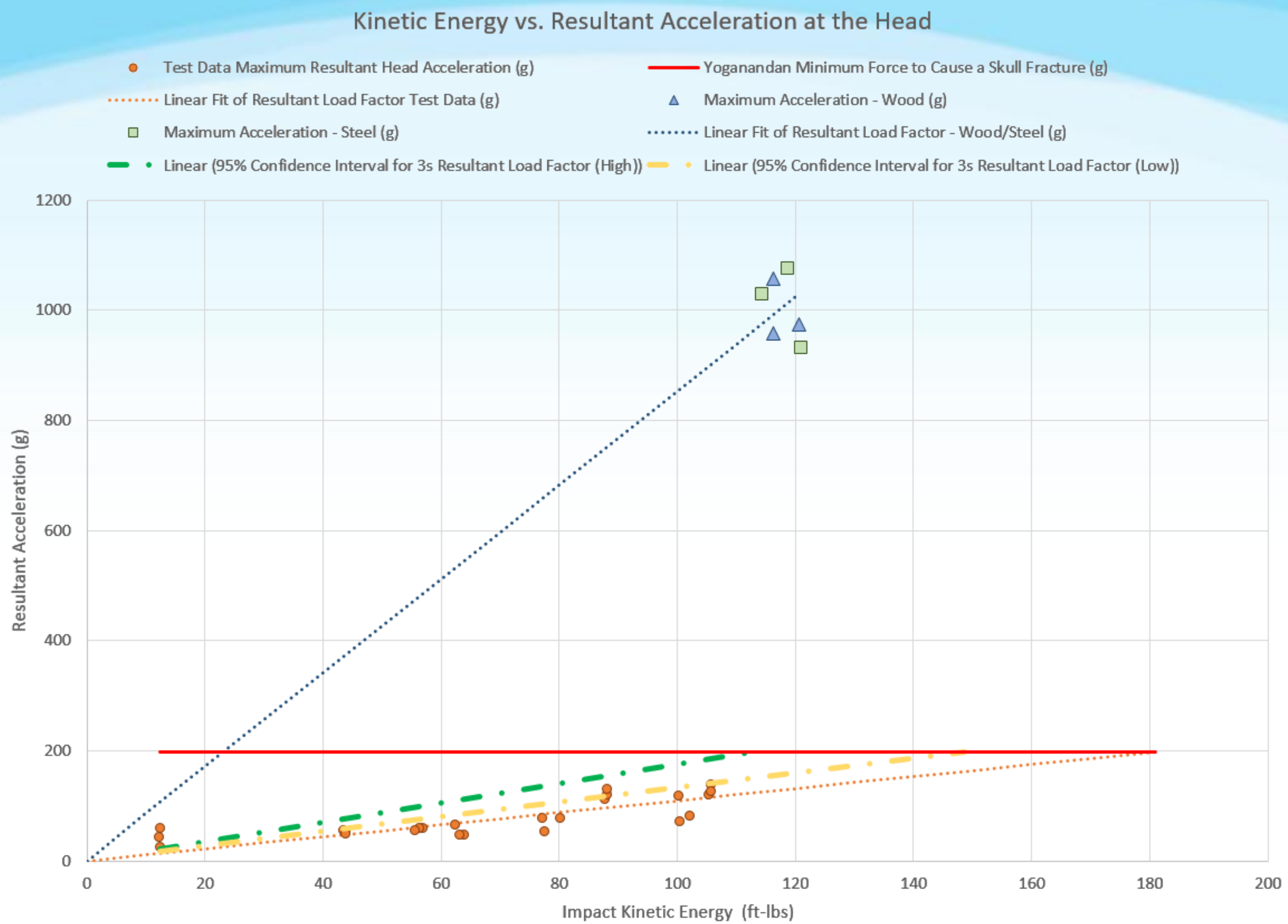
Back-up



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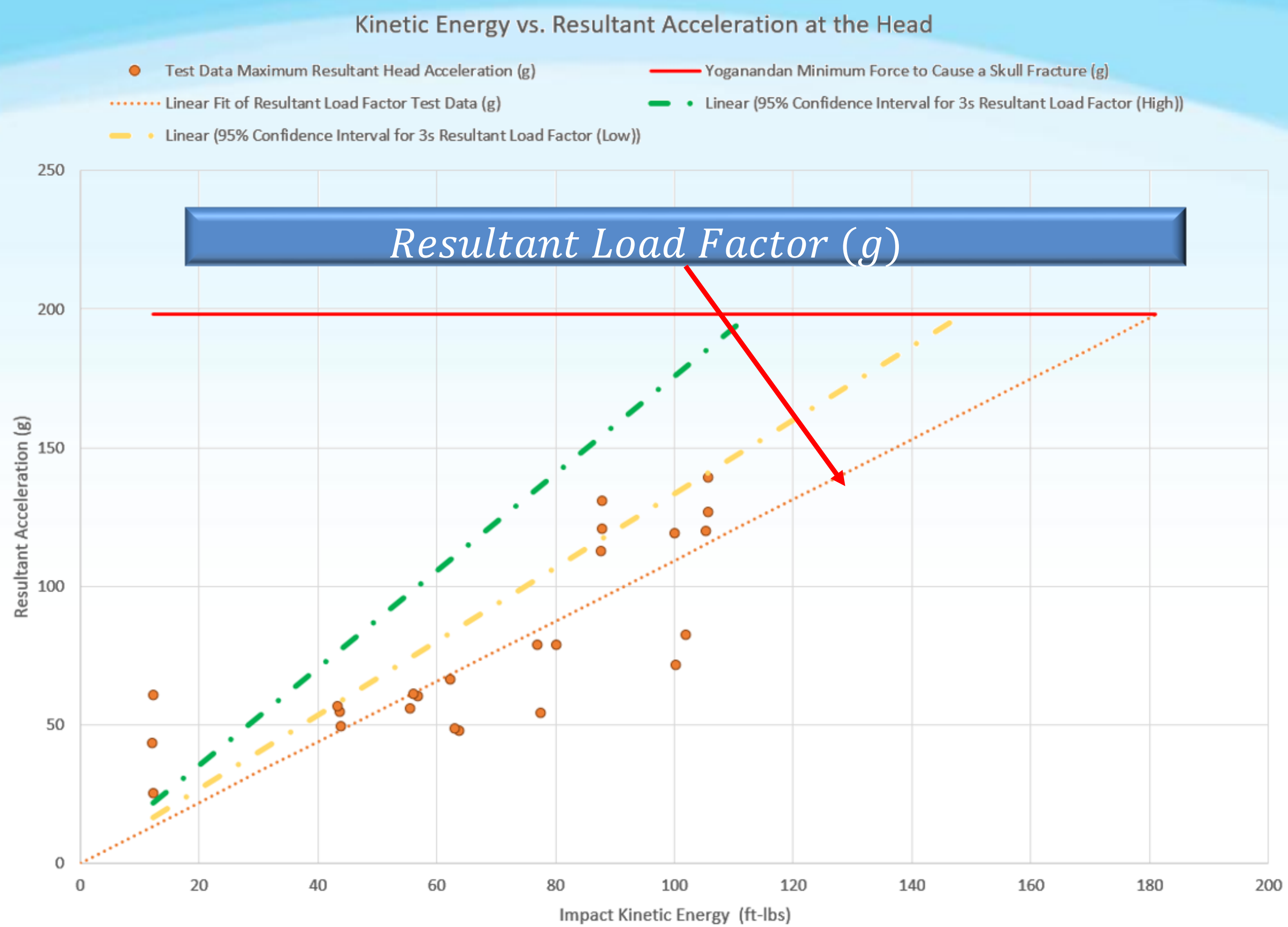

Figure 21 - Analysis of Resultant Impact for Skull Fractures versus Impact KE

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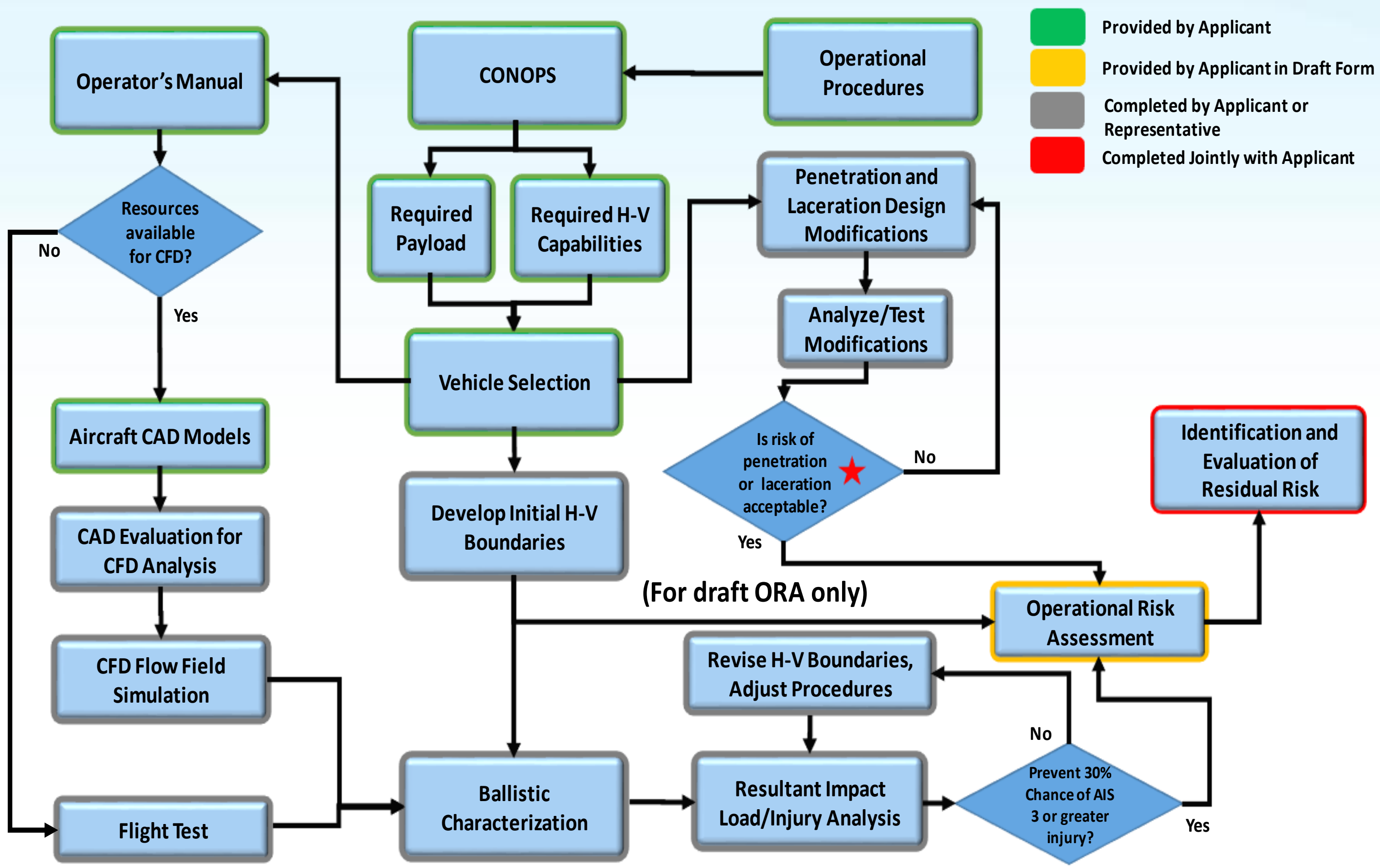
Proposed Standard with Evaluation of Potential Injury Severity



★ Sharp points, edges, and small contact areas will be evaluated against the impact energy density threshold of 12J/cm². Exceeding this threshold may be permissible based on a low likelihood of contact during impact.

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