Workshop

FAA UAS SYMPOSIUM

UAS Research – Who's Doing What to Support Integration

Federal Aviation Administration

AUVSI

#UAS2018

UAS Research – Who's Doing What

Sabrina Saunders-Hodge, FAA

Nick Lento, FAA

Mark Blanks, Mid-Atlantic Aviation Partnership

Steve Luxion, ASSURE

Davis Hackenberg, NASA

FAA UAS SYMPOSIUM

#UAS2018

ASSURE Research

Collision Studies' Results & Path Forward

ASSURE Completed Projects

- A1 - Certification Test Case to Validate sUAS Industry Consensus Standards
- ***A2 - Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations***
- **A3 - UAS Airborne Collision Severity Evaluation (Peer Reviewed)**
- **A4 - UAS Ground Collision Severity Evaluation (Peer Reviewed)**
- A5 - UAS Maintenance, Modification, Repair, Inspection, Training, and Certification Considerations*
- ***A6 - Surveillance Criticality for Sense and Avoid (SAA)***
- A7 - Human Factors Control Station Design Standards
- A8 - Unmanned Aircraft Systems (UAS) Noise Certification
- A10 - Human Factors Considerations of UAS Procedures, & Control Stations *
- A11 - Part 107 Waiver Request Case Study

ASSURE Active Projects

- A9 - Secure Command and Control Link with Interference Mitigation
- A12 - Performance Analysis of UAS Detection Technologies Operating in Airport Environments
- **A13 – UAS Ground Collision Research Plan (Peer Review)**
- **A14 – UAS Ground Collision Severity Studies**
- A15 – STEM II
- ***TBD - Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations***
- **TBD - Airborne Collision Engine Impacts**
- **TBD - Airborne Collision Structural Impacts**
- TBD - e-commerce, Emerging UAS Network and Implications on NAS Integrations
- TBD - Safety Research Facility

A4: sUAS Air-to-Ground Collision Severity Study

Lead Principal Investigator:

Dave Arterburn, Univ. Alabama at Huntsville

Collision Dynamics (UAS v. Wood/Steel)

Comparison of Steel & Wood with Phantom 3

UAS

Test Weight: 2.69 lbs.
Impact Velocity: 49-50 fps
Impact Energy: 100-103 ft-lbs.

Motor Vehicle Standards

- Prob. of neck injury: 11-13%
- Prob. of head injury: 0.01-0.03%

Range Commanders Council Standards

- Probability of fatality from…
  - Head impact: 98-99%
  - Chest impact: 98-99%
  - Body/limb impact: 54-57%

Wood

Test Weight: 2.69 lbs.
Impact Velocity: 52-54 fps
Impact Energy: 116-120 ft-lbs.

Motor Vehicle Standards

- Prob. of neck injury: 63-69%
- Prob. of head injury: 99-100%

Range Commanders Council Standards

- Probability of fatality from…
  - Head impact: 99-100%
  - Chest impact: 99-100%
  - Body/limb impact: 67-70%

Steel

Test Weight: 2.7 lbs.
Impact Velocity: 52-53 fps
Impact Energy: 114-121 ft-lbs.

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: 99-100%
  - Chest impact: 99-100%
  - Body/limb impact: 65-71%

Key Findings:
Ground Collision Severity Report

FAA UAS SYMPOSIUM

- 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
  - sUAS are flexible during collision and retain significant energy during impact
  - Wood and metal debris do not deform and transfer most of their energy
- 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
- Payloads can be more hazardous due to reduced drag and stiffer materials
- Lithium Polymer Batteries need a unique standard suitable for sUAS to ensure safety

Ground Collision Severity Follow-on

FAA UAS SYMPOSIUM

- Research results and plan peer reviewed & work has begun
- Expand the number of UAS evaluated
- Validate previous results (head, neck, thorax)
  - Models
  - Test Dummies
  - Post Mortem Human Subjects
- Develop a simplified test to categorize UA and its risk-level
  - Informed/Validated with all the above
  - For UAS manufactures
  - Potential use in regulation for operations over people

A3: sUAS Air-to-Air Collision Severity Study

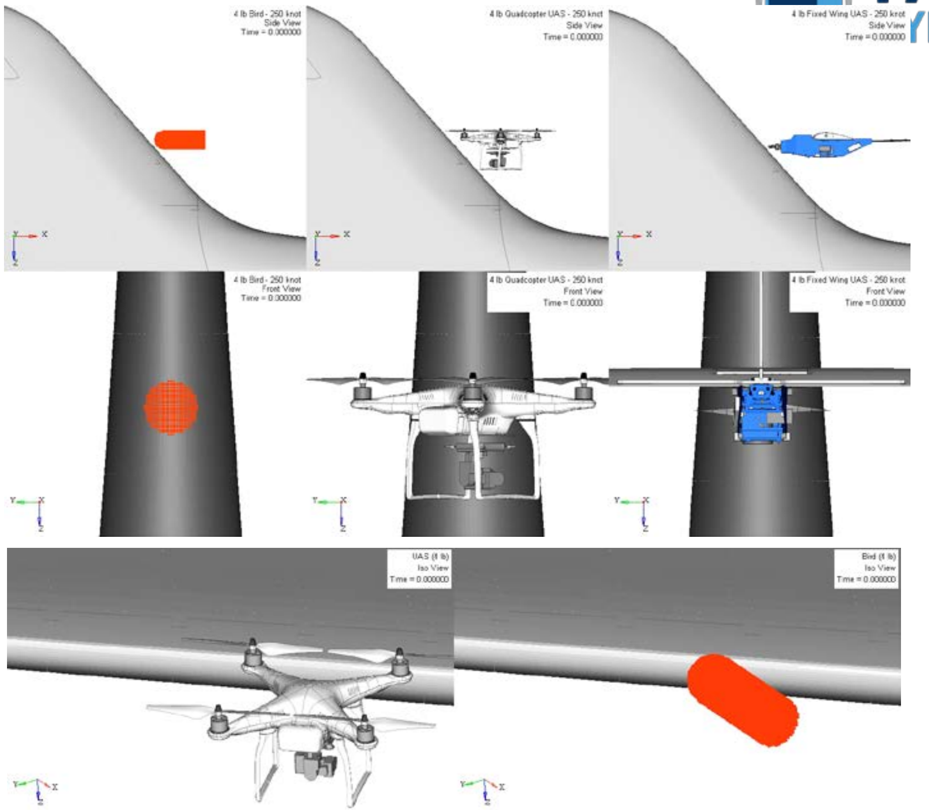
Lead Principal Investigator:

Gerardo Olivares, Ph.D., Wichita State Univ.

Air-to-Air Collision Severity Study: Scope

- Study of Severity of perfect strike (Physical Damage & Fire Risk)
  - Targets:
    - Narrow-body commercial transport (B737 / A320 Class)
    - Business Jet (Learjet 31A Class)
  - Projectile (UAs)
    - Quadcopter (DJI Phantom III)
    - Fixed-Wing (Precision Hawk Lancaster)

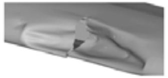
Can a sUAS Impact be Classified Similar to a Bird Strike?

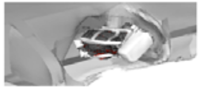
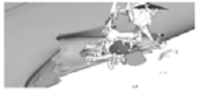
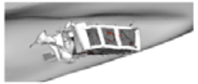
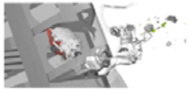
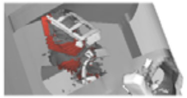


FAA UAS SYMPOSIUM

Severity Level and Risk of Post Impact Battery Fire Classification

FAA UAS SYMPOSIUM

Severity Level	Description	Example
Level 1	• Undamaged. • Small deformation.	
Level 2	• Extensive permanent deformation on external surfaces. • Some internal structure deformed. • No failure of skin.	
Level 3	• Skin fracture. • Penetration of at least one component.	
Level 4	• Penetration of UAS into airframe. • Failure of primary structure.	

Fire Risk	Description	Example (UAS Visible)	Example (UAS Hidden)
Yes	• UAS (including the battery) penetrates the airframe. • Battery deforms but stays undamaged. • Validation tests showed that partly damaged batteries created heat and sparks.		
No	• The UAS does not penetrate the airframe.		
No	• UAS (including the battery) penetrates the airframe. • The battery sustains great damage, destroying its cells. • Validation tests showed that completely damaged batteries did not create heat or sparks.		

What is the Severity of a sUAS Midair Collision with a Jet Aircraft?

FAA UAS SYMPOSIUM

2.7 lb. Quadcopter

4 lb. Fixed Wing

Level 1	(green)
Level 2	(yellow)
Level 3	(orange)
Level 4	(red)

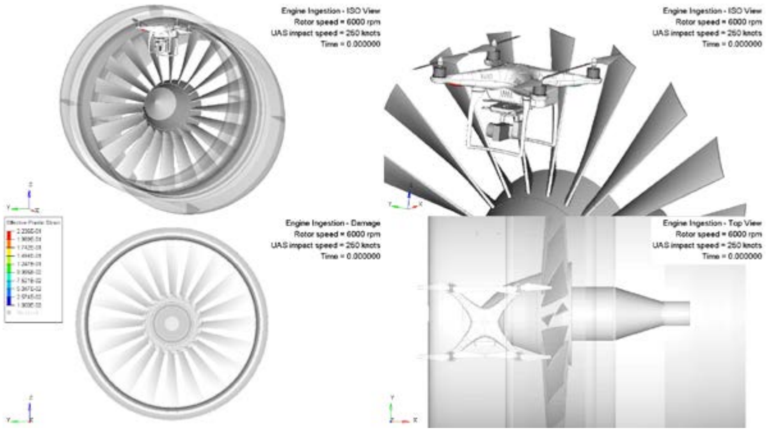
#UAS2018

Conclusions Airframe – sUAS Impact R&D

- **Comparison to Bird Strikes**
  - sUAS collisions caused greater structural damage than bird strikes for equivalent impact energy levels
- **Velocity and Mass (kinetic energy)**
  - Physical damage noted for velocities above landing speeds for masses equal to or above 2.6lbs (1.2 kg)
  - Damage severity increases with increased mass and velocity
- **Stiffness of Components**
  - Component level testing demonstrated that stiff components such as motors can produce severe damage.
  - Full-scale sUAS simulations confirm: most damage produced by stiffer components (battery, motor, payload)
- **Distribution and Connection of Masses**
  - Distribution of mass and stiffness in the design of the sUAS is critical to the energy transfer
  - With concentrated or aligned masses the probability of critical damage increases.
- **Energy Absorption Capability**
  - sUAS designs which incorporate energy absorbing components (materials and/or structural features) could reduce the damage to the target aircraft

Engine Ingestion – Summary Results

- Quick look study using FAA Fan-Blade-Out Model
- Simulations focus on damage to fan, nacelle, and nosecone only
- Similar findings as structural research
- Fixed wing introduced more damage than the quadcopter.



- Stiffer components such as motors, cameras and batteries do the most damage to the fan.
- Location of impact along fan is a key parameter--More damage as the impact occurs closer to the blade tip.
- Takeoff scenario is the worst case because of high fan speeds.

Air-to-Air Collision Study Follow-on

- Other research to keep aircraft apart (Detect-and-Avoid)
- Rotorcraft and General Aviation Aircraft
- Boundary-layer influences to probabilities of direct impact
- Engine
  - Engine OEMs working with ASSURE to develop a generic high-bypass turbofan
  - Used to analyze threat to modern engines
  - Study UA designs to mitigate damage/risk to engines

Thank You

FAA UAS SYMPOSIUM

ASSUREuas

ASSUREuas

ASSURE UAS

www.ASSUREuas.org

SLuxion@ASSURE.msstate.edu