Engineering, Operations & Technology
Boeing Research & Technology

Bird Strike Simulation for Composite Aircraft Structure

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Abstract

- There is an increasing trend of birds colliding with aircraft. Aircraft are most susceptible to bird impacts during takeoff and landing. Typical impacts occur on components such as wing leading edges, radomes, turbofan engines, and cockpit windshields. These components should be capable of withstanding the impact load without experiencing catastrophic failures or penetration that might compromise continued safe flight. The use of full scale testing to assess all possible components is time consuming and cost prohibitive.
- Significant savings can be achieved by using state of art modeling tools capable of predicting the structural damage due to impact. However, there is a large variability in modeling approaches and complexity of simulation processes to design the forward facing components of the aircraft. Available closed form solutions are over-simplistic. FEA is the tool of choice to capture the details required to accurately assess these events. LS-DYNA is one such tool and is being selected because it is widely used in the industry and has the ability to model the bird using different formulations: Lagrangian, Eulerian (ALE), SPH (meshless).
- The objective of this research is to standardize the numerical methods and develop a simplified analytical approach to evaluate compliance of aircraft structures to bird impacts during the design phase. The project is to leverage both the numerical and experimental efforts available in this field. The deliverables of the project are a standardized and simplified analysis tool with numerical guidelines to enable generating design curves and parametric studies to size structure to variables such as impact velocity, angle, bird size, structure geometry, and material at any point in the aircraft.

Outline

- **Related Accidents**
- **Motivation**
- **Objectives**
- **Existing Analysis Methods**
- **Technical Approach**
- **Validation Test**
- **Collaborators**

Bird Strike Related Accidents

Air Transport Article: 18/03/09

- **Number of strikes reported annually increased 336%, from 1,759 in 1990 to 7,666 in 2007**
- **Numbers climbed due to an increase in both the number of aircraft operations and number of 'hazardous wildlife species'**

Aviation Week & Space Technology (Feb. 23, 2009)

- **Estimated damage worldwide $1.2B**
- **Fatalities worldwide (since 1988) 219**
- **Strikes in U.S. 7,600**
- **Bird strike vulnerability altitude below 3,000 ft**
- **Strikes unreported, U.S. airports with airline service 80%**
- **In North America, the Canada geese population grew to more than 3.5 million in 2007 from 1 million in 1990**
- **More than 1,400 strikes by Canada geese were reported in the U.S. in 1990-2007 and more than 40% involved multiple birds**

Bird Strike Related Accidents

- **US Airways Flight 1549 ditched in the Hudson River after striking one or more Canada geese on departure from LaGuardia Airport. No one was killed in the accident.**
- **UTube – Ditching of a US Airways A320 on Hudson River http://www.youtube.com/watch?v=HKkCzXxu7ks**

US Airways Flight 1549 Ditching in Hudson River

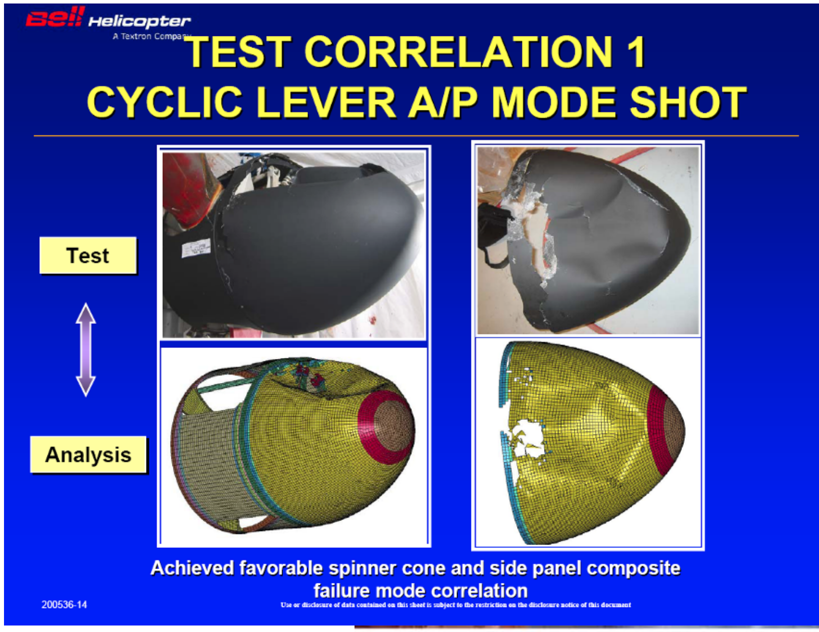
Motivation

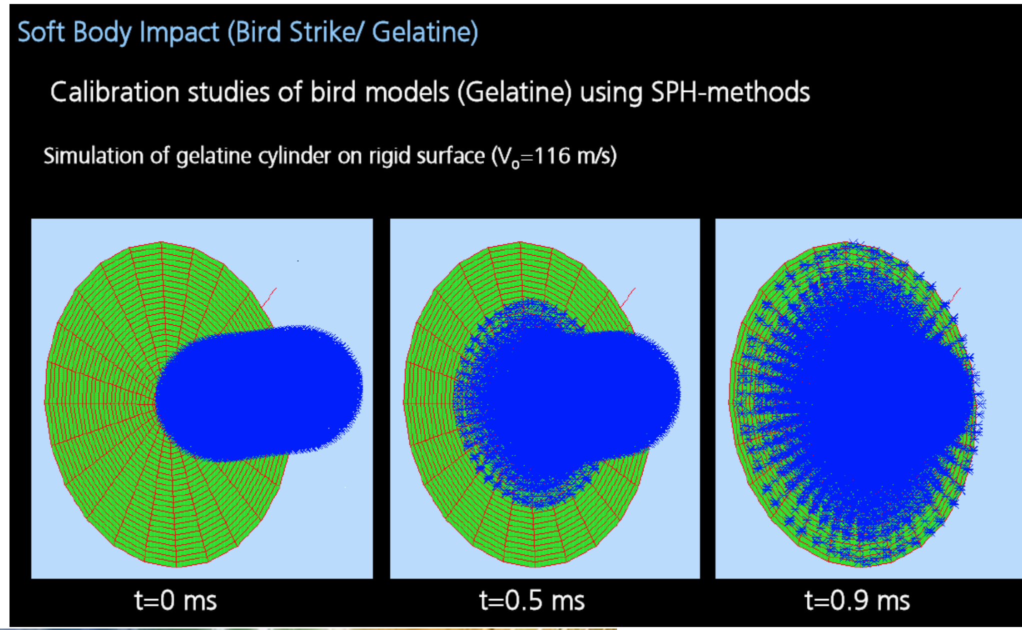
- There is limited information in the public domain on the simulation of bird impact events correlated with experimental data
- Analytical bird models are considered proprietary by their developers
- There is no rigorous closed form analysis formulation
- The bulk of historical experience is with traditional metallic structure
- There is limited field experience with bird strike on composite primary structure

Objectives

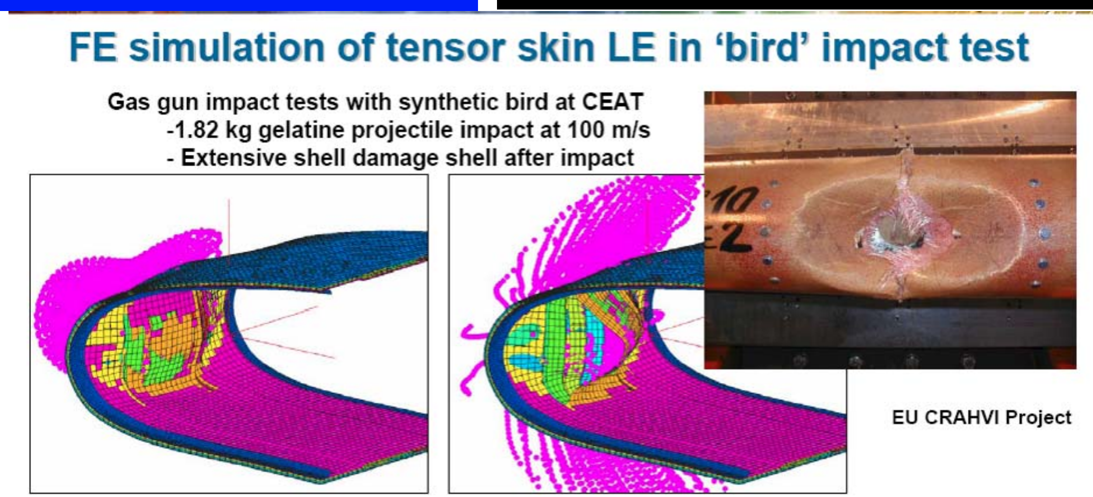
- **Develop design guidelines for composite damage resistance to bird strike**
- **Provide numerical guidelines for bird strike analysis using available commercial FE codes**
- **Develop analytical PD methods for rapid sizing/optimizing bird-strike-designed structure**

Existing Analytical Methods





Bell Helicopter, LS-DYNA



DLR PAM-Shock, SPH

Technical Background

- Primary bird threat velocity is in the range of 100 to 250 knots
- Various bird models have been proposed in the literature but limited information is actually available
  - Lagrangian Bird, Arbitrary-Lagrangian-Eulerian formulation ALE, Smooth Particle Hydrodynamics SPH
- Various FEA codes are available that can handle composite material failure and bird impactor behavior
  - LS-DYNA has been the tool of choice for these applications
- Composite prepreg materials are available that have already been characterized for other research efforts
  - BMS8-212 material characterization exist for rotor burst analysis tool
  - Toray AGATE Plain Weave material being used for CMH-17 Crashworthiness round robin
- Key variables need to be defined:
  - impactor (bird size, angle, velocity)
  - targets (shape, size, composite material system, etc.)
- Potential collaboration may exist with on-going NASA and FAA high-strain rate impact research programs

Technical Approach

- **Perform literature review (analytical methods, FEMs, failure models, existing test data) and Regulatotry Requirements (FARs)**
- **Identify any public domain bird models validated by industry**
- **Validate Lagrangian, ALE and SPH Bird model with existing literature data**
- **Identify numerical parameters for the impactor:**
  - **Fixed size 4 lbs bird**
  - **Sensitivity studies (e.g., strain rate effects, bird shape, speed, angle)**
- **Identify numerical parameters for the target:**
  - **Panel geometry (flat and curved))**
  - **Sensitivity studies (e.g., strain rate effects, composite layup, material system)**
- **Depending on success and availability of budget, extend the capability for stiffened panels representative of aircraft structure**

Technical Approach (cont'd)

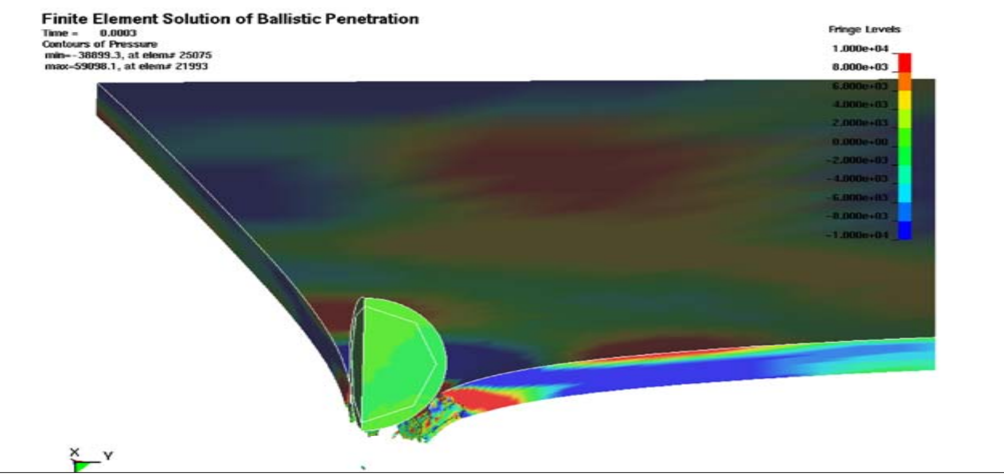
- **Perform selected validation testing**
  - **Impact rigid surface with simulated bird to validate bird model**
  - **Impact composite flat and curved panels with hard impactor to calibrate composite material**
  - **Impact composite flat and curved panels with the simulated bird**
- **Validate the FEA models with test data and expand the design space using FEA**
- **Develop FEA guidelines for bird and composite material models (link to CMH-17 and other FAA safety and certification initiatives)**
- **Adapt or develop closed-form solution analysis methods for rapid sizing, correlated with experimental and FEA results**
- **Develop design curves for composite bird impact damage resistance, for different levels of structural complexity from flat unstiffened panels up through curved stiffened panels (level of complexity will depend on project initial success and funds available)**

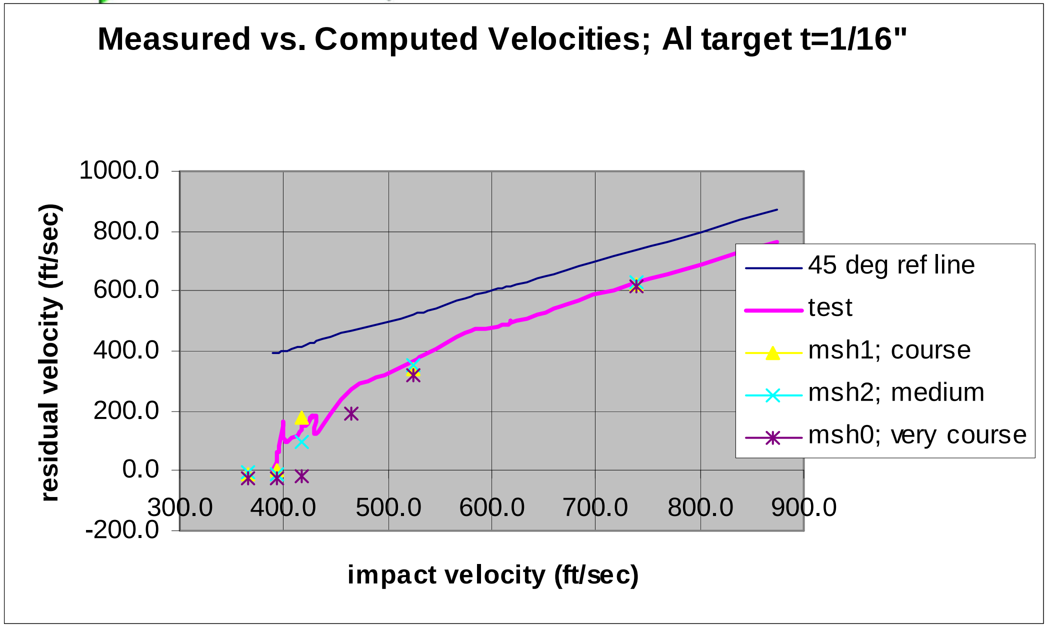
Approach:

- **Start with a flat panel target and generic bird model**
- **Validate impactor and target models**
- **Add curved test panels**
- **Develop validated general modeling strategy**

Goals:

- **Rapid modeling solution**
- **Calibrated bird model**
- **Validate material failure model**
- **Boeing-UW to negotiate composite lay-up details**
- **leverage and complement FAA-NASA high-strain rate research**





Collaborators

PI's

Mostafa Rassaian – Boeing

Paolo Feraboli – UW

FAA

Chip Queitzsch (Chief Scientist for Engine System Dynamics and Project Technical Advisor)

Larry Ilcewicz (Chief Scientist for Composites)

Curt Davies (JAMS Program Manager)

Test partners (tentative)

Kevin Housen – Boeing

Mike Pereira – NASA Glenn