Estimating Bird Strike Risk for Space Launch Vehicles

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Overview

- Explain historical concerns for bird strikes to planes and space launch vehicles
- Describe the bird strike risk assessment process
  - Explain the major factors affecting bird strike risk
  - Outline the problem solving philosophy
  - Discuss strengths and limitations of the analysis

Airplane Bird Strikes

- The dangers of bird strikes in aviation are well-established
  - 1905: First recorded bird strike, pilot Orville Wright[1]
  - 1912: First recorded fatality due to bird strike, pilot Calbraith Perry Rodgers hit a flock of seagulls[2]
  - 1960: Eastern Air Lines Flight 375 struck a flock of European starlings and crashed into Boston harbor, killing 62 people[1]
- The FAA reports from 1990-2013[1]:
  - 142,000 wildlife strikes with civil aircraft in the USA
  - 62 civil aircraft in the USA destroyed due to wildlife strikes
  - 279 human injuries due to wildlife strikes with US civil aircraft
  - 25 human fatalities attributed to wildlife strikes with US civil aircraft

NTSB Animation: US Airways Flight 1549

Airplane Bird Strikes

- Bird strikes to aircraft are increasing over time[3]
  - Populations of large birds are increasing
  - Air traffic is increasing
  - Aircraft are becoming quieter as technology progresses
- Bird strike likelihood varies by altitude and time of year[3]
  - More than 70% of bird strikes occur at or below 500 feet above ground level (but strikes above 500 feet are more likely to cause catastrophic damage)
  - About 50% of bird strikes occur between July and October

Space Craft Bird Strikes

- Only one documented bird strike to a launch vehicle at Kennedy Space Center (STS-114, July 26 2005)
- No evidence of any known strikes to other manned or unmanned space craft

Mitigation Techniques

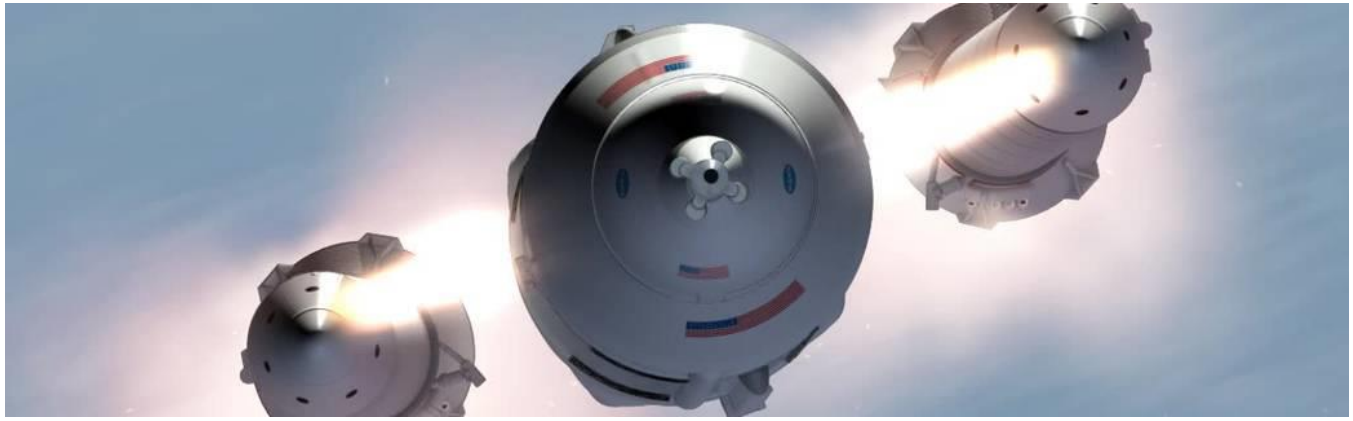
- Prior to STS-114 NASA did not devote resources to bird strikes
- After STS-114 NASA instituted a bird abatement program designed to decrease the likelihood of a bird strike[4]
  - Roadkill removal
  - Avian radar
  - Noise deterrents (discontinued due to ineffectiveness)

Bird Strike after Shuttle

- An Ares I study used a physics-based Monte Carlo analysis to estimate the risk of bird strike damaging the separation system
  - Ares I program was cancelled prior to the completion of the study
  - Left bird strike risk to other systems as forward work
  - Found that the crucial factors were the number of birds in the air and the speed of the rocket at the time of impact
  - Listed fidelity of model at one significant figure due to limited bird data availability, assumptions required, and use of engineering judgment
- Bird strike risk for space launch vehicles is primarily a function of the size of the rocket, the avian environment at the launch site, the speed of the rocket at low altitudes, and the capability of the vehicle to withstand an impact

Risk Assessment Philosophy

- Built upon the Ares I risk assessment, using improved bird population data
- Uses a simplified model to estimate loss of mission with the following inputs
  - Trajectory
    - Specific trajectory #1
    - Specific trajectory #2
    - Average
  - Vulnerable area
    - Entire vehicle
    - Specific areas of concern
  - Velocity Threshold
    - 0 ft/s
    - 100 ft/s
    - 200 ft/s
    - 300 ft/s
    - 600 ft/s



Challenges for Assessing Bird Strike Risk

- Determining the launch site avian environment
  - Native birds
    - Sizes
    - Altitudes
    - Time spent aloft
  - Migrating birds
    - Sizes
    - Altitudes
    - Migration patterns
- Changes in bird population over time
  - Time of year
  - Time of day
- Evaluating the capability of a rocket to survive a bird strike
  - Coordination between programs and elements
  - Cost impacts from testing or analysis

Lessons Learned

- Bird populations vary dramatically based on the time of day and time of year
  - Risk due to bird strike is dependent upon launch windows
  - Considering only the average annual risk obscures the high variability
- Loss of mission due to a bird strike is dependent upon the density of birds in a particular altitude band dependent upon both trajectory coupled with the launch vehicle trajectory
- Any bird strike risk assessment will have high uncertainty

References

1. Federal Aviation Administration Wildlife Strike Frequently Asked Questions (accessed 7/30/17) https://www.faa.gov/airports/airport_safety/wildlife/faq/
2. “First Across the Continent” by Charles Wiggin, Smithsonian *Air and Space Magazine*, Sept. 2011 (accessed 7/30/17) http://www.airspacemag.com/history-of-flight/the-first-across-the-continent-41006907/
3. “Wildlife Strikes to Civil Aircraft in the United States 1990-2015” by the FAA and USDA, Nov. 2016 (accessed 7/31/17) https://www.faa.gov/airports/airport_safety/wildlife/media/Wildlife-Strike-Report-1990-2015.pdf
4. “Bye Bye, Birdies” by Cheryl Mansfield, KSC, June 30, 2006 (accessed 8/6/17) https://www.nasa.gov/mission_pages/shuttle/behindscenes/avian_radar.html