MODELING ROCKET LAUNCH NOISE
FOR COMMERCIAL SPACEPORTS

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OUTLINE

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BACKGROUND

- Federal Spaceport Licensing
  - FAA Office of Commercial Space Transportation (AST)
  - Multiple non-Federal sites established or proposed

- Spaceport Colorado
  - Front Range Airport, east of Denver
  - NEPA Environmental Assessment required
  - Includes noise modeling & analysis
  - FAA-approved Integrated Noise Model (INM) not designed for spaceports
BACKGROUND

- Reusable Launch Vehicle (RLV) Industry
  - Private, for-profit operations
  - Multiple vehicles in development

- Typical Operations
  - Suborbital flights
    - Air launch or horizontal launch from runway
    - Into space (100 km), but not into orbit
    - Similar suborbital flight profiles
  - Recovery (landing) of orbital vehicles
BACKGROUND

- FAA Noise Requirements
  - Space flights must comply with FAA's 65 db day-night average sound level (DNL) standard
  - "...the FAA has determined that the cumulative noise energy exposure of individuals to noise resulting from aviation activities must be established in terms of the day-night average sound level (DNL) in decibels (dB). The 65 DNL is the Federal significance threshold for aircraft noise exposure.

- Why a GIS-based 3D noise model?
  - Legacy approach (XLS + NM-Plot) clumsy
  - FAA's Airport GIS initiatives favor delivery of airport data in GIS format

Source: [http://www.faa.gov/airports/airport_development/omp/FAQ/Noise_Monitoring/?print=go#q4](http://www.faa.gov/airports/airport_development/omp/FAQ/Noise_Monitoring/?print=go#q4)
OBJECTIVES

- Create GIS-based model
  - Obtain RLV’s time series, trajectory data
  - Create GIS-based time series model
  - Perform testing & verification

- Spaceport Colorado noise analysis
  - Run scenarios
  - Generate noise contours
  - Show compliance with FAA’s 65 DNL standard
METHODOLOGY: FLIGHT PATH DATA

- Assumes Horizontal Launch
- Flight profile in Excel spreadsheet
  - Time series (1 second time step)
  - 1,105 time steps
  - ~20 minutes round trip
- Key parameters for noise modeling:
  - Longitude/Latitude/Altitude (x,y,z)
  - Velocity (meters per second)
  - Heading (2D and 3D vector components)
METHODOLOGY: NOISE PROPAGATION

- Source-Path-Receiver Model
- Launch site + Runway + Trajectory
- Rocket noise source
- Receptor grid on Cartesian coordinates
- Receptor distance, angle from source
- Propagation & sound power level
- Combined sound of several sources

\[
L_{eq,b} = 10 \log \left[ \frac{1}{T} \sum_{i=1}^{n} t_i 10^{0.1L_{P,b,i}} \right]
\]

The directivity index

\[
DI(\beta) = 21.4 + 10 \log \left[ \frac{1 + \cos^4 \beta}{(1 - M \cos \beta)^2 + (\alpha M)^2} \right]
\]

\[
S_t = \frac{f_0 \alpha_{exit}}{U_{exit}}
\]

\[
L_{WB} = L_W + K_b
\]

\[
K_b = -12.8 - 10 \log \left[ S_t^{0.9} + (0.00268) S_t^{-1.5} \right]
\]

\[
F \ (F_x, F_y, F_z) \quad RA \ (RA_x, RA_y, RA_z) \quad R \ (R_x, R_y, R_z)
\]

RD, RD_x, RD_y, RD_z, RD_z
METHODOLOGY: RECEPTOR GRID

- Raster cells represent receptor locations
- Varying raster resolution
  - High density at or near runway
  - Low density away from areas of high noise
METHODOLOGY: THE “TOOL”

- ArcGIS Spatial ModelBuilder
  - Combination of Python, Iterators and ArcToolbox tools
  - “Custom” tools for frequently requested additional analyses

- Automated Analysis for Multiple Scenarios
  - Variable # flights (1 per week, 1 per month, etc.)
  - Variable # of Static Hot Fire Tests per year
  - Combination of # flights & hot fire tests
METHODOLOGY: NOISE LEVEL ANALYSIS

- Noise impact calculation
  - Baseline = General aviation activity (GA)
  - Spaceport noise effects
    - Static Hot Fire Test (SHFT)
    - Launch event
  - Total noise = GA + SHFT + Launch
  - Increased noise = Total Noise – GA
  - Sonic booms not included
SUMMARY

- FAA approved the GIS-based spacecraft noise model on October 21, 2014
- First ever FAA-approved 3D-GIS launch noise model!
- National Academy of Sciences Airport Cooperative Research Program issued research RFP for new launch & sonic boom noise model compatible with FAA's GIS-based Aviation Environmental Design Tool
- Future for GIS: The sky's the limit!

Stacey Zee
Office of Commercial Space Transport
Federal Aviation Administration
800 Independence Ave. SW
Washington, DC 20591

Dear Ms. Zee,

The Office of Environment and Energy (OEE) has reviewed the proposed non-standard noise modeling method for the Draft Environmental Assessment for Front Range Airport Launch Site Operator License, Spaceport Colorado. This is in support of the noise impact analysis for the National Environmental Policy Act (NEPA) Environmental Assessment. In accordance with FAA Order 1050.1e, all non-standard noise analysis must be approved by OEE. This letter serves as OEE’s response to the proposed noise method for the NEPA document.

The methodology is a quantitative analysis based on the latest available methods for launch noise. The FAA does not currently have an approved model for launch vehicles and the document includes a proposed noise modeling methodology for a proposed launch vehicle as a vehicle has not been determined for the site. The proposed noise modeling method is based on the best available research and understanding at this time. Given that a vehicle type has not been determined, an updated analysis may need to be performed once additional information regarding vehicle characteristics is available.

Given the proposed launch noise method is based on the best available knowledge on the vehicles that will be using the facility and research on vehicle launches, this approach is appropriate for the NEPA document for the Front Range Airport Launch Site Operator License, Spaceport Colorado. AEE concurs with the launch noise methodology used for this project. Please understand that this approval is limited to this particular project. Any additional projects using this or other launch noise methodologies not mentioned here will require separate approval. In addition, a review and potential updated analysis may need to be performed when the vehicle is identified.

Sincerely,

Rebecca Cointin, Manager
AEE/Noise Division
QUESTIONS
TO LEARN MORE…

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