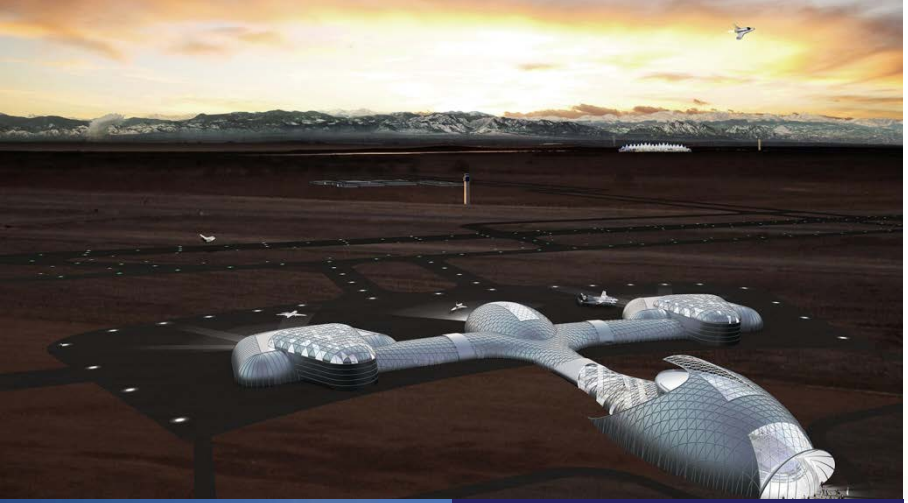
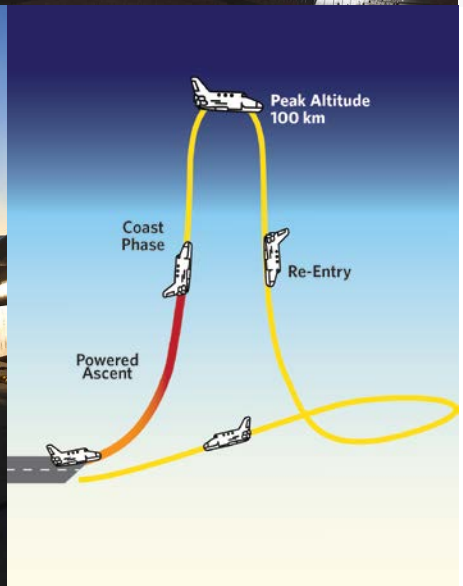




MODELING ROCKET LAUNCH NOISE FOR COMMERCIAL SPACEPORTS

Michael Gilbrook, PhD, GISP, AICP
Sumant Mallavaram, GISP
Tim Casey, Elliott Dick, John Van Kirk

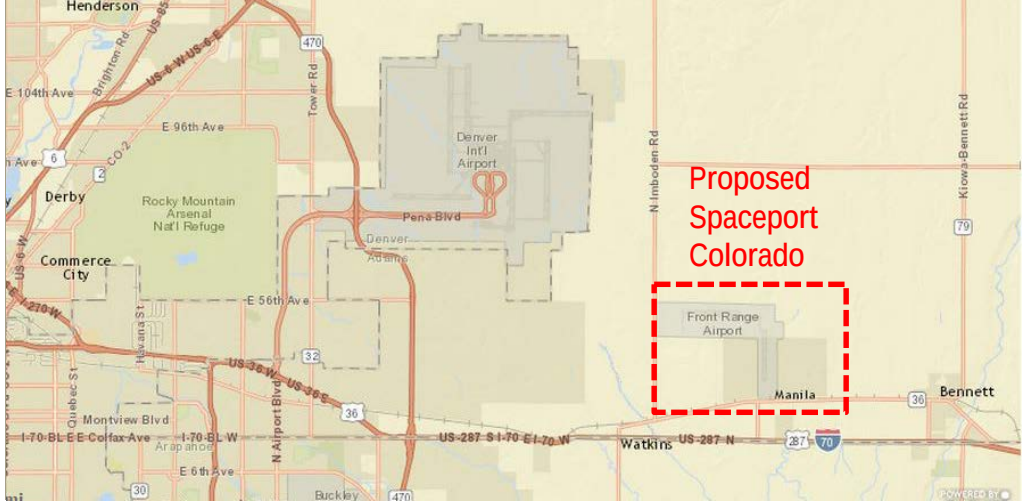
HDR

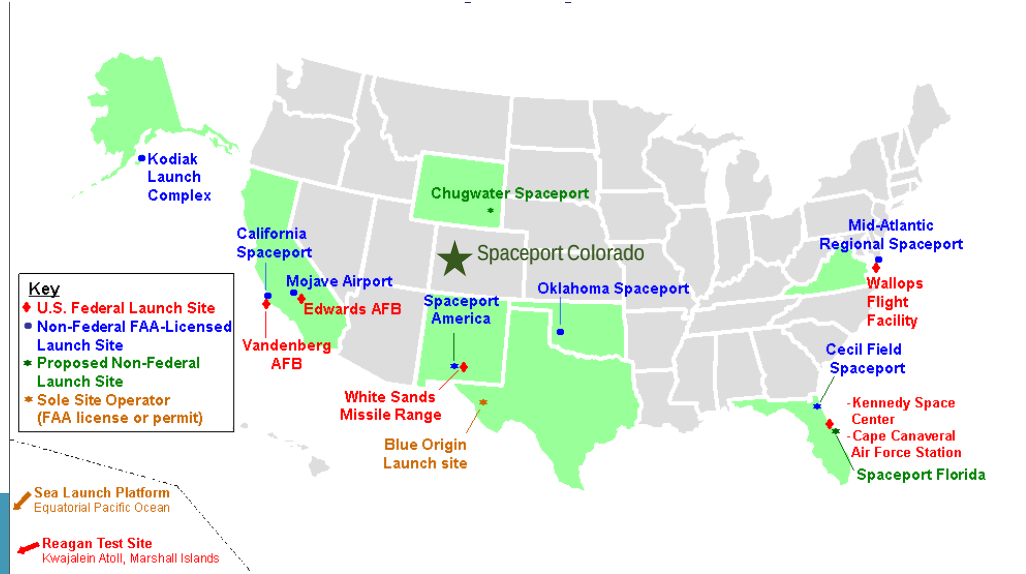
OUTLINE

- Background
- Objectives
- Methodology
- Summary
- Questions
- Contacts

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

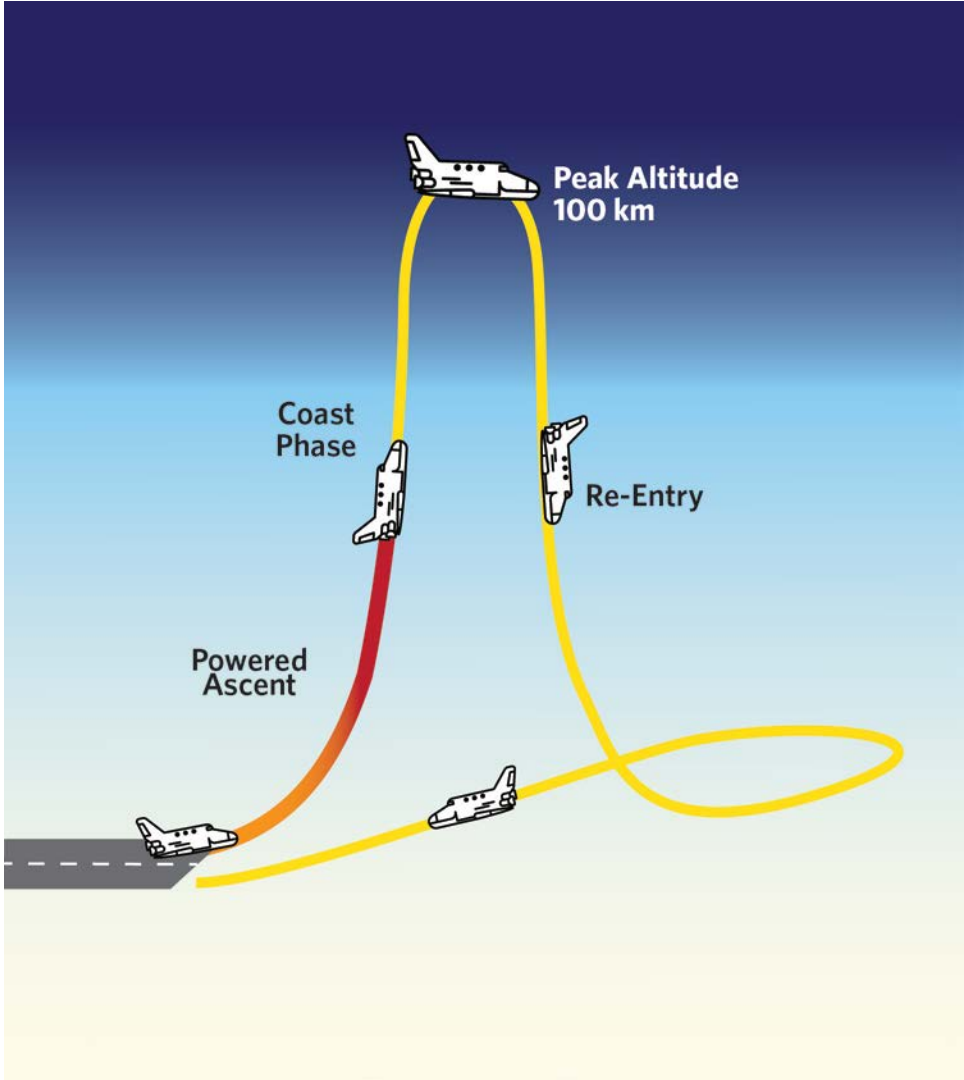





8,000 Feet
8,000 Feet
Front Range Airport
Adams County, CO
DigitalGlobe, GeoEye, Microsoft, USDA FSA, CNES/Airbus DS
POWERED BY
esri

BACKGROUND

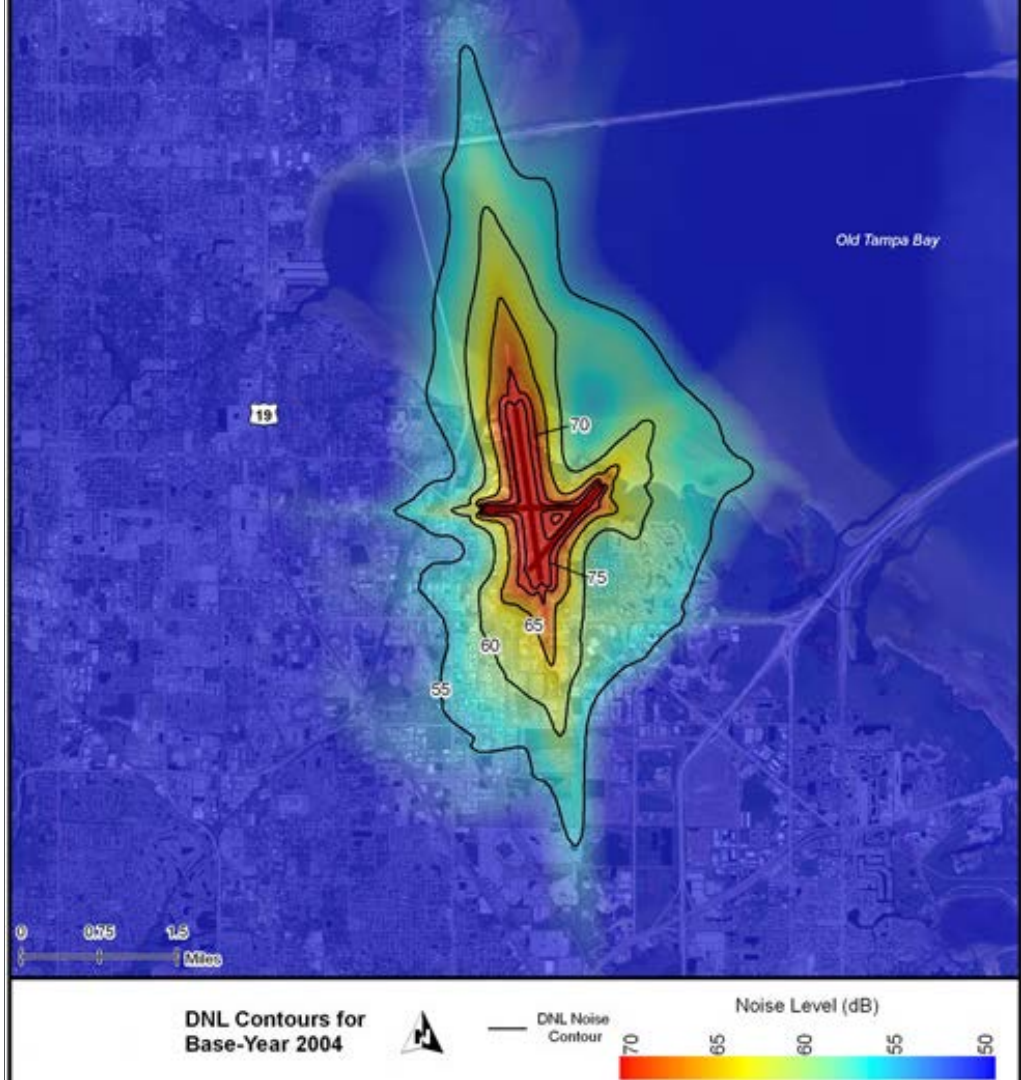
- Reusable Launch Vehicle (RLV) Industry
  - Private, for-profit operations
  - Multiple vehicles in development
- Typical Operations
  - Suborbital flights
    - Air launch or horizontal launch from runway
    - Into space (100 km), but not into orbit
    - Similar suborbital flight profiles
  - Recovery (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



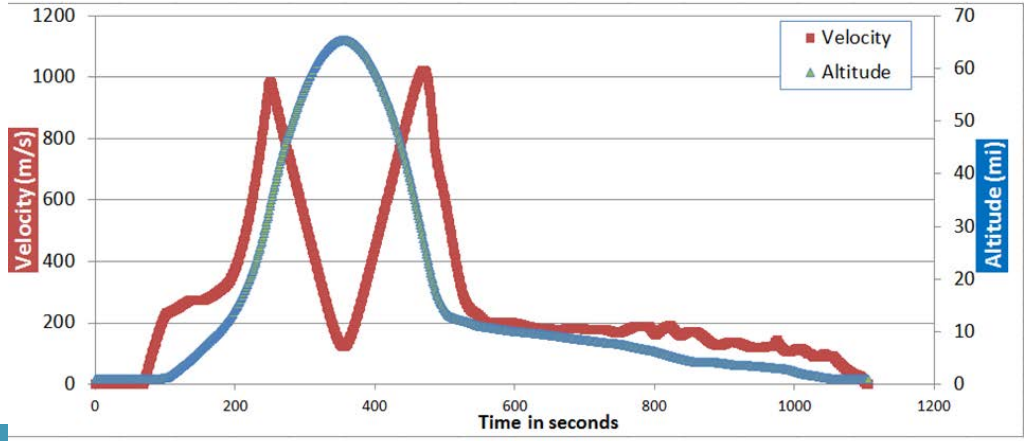
OBJECTIVES

- 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)

TimeStep	Vtrue,_ktas	Vel_ (m/s)	hpath,__deg	vpath,__deg	__lat,__deg	__lon,__deg	__alt,ftmsl
0	0	0	0	0	39.79401	-104.56509	5516.10498
1	0.20791	0.106958052	179.99998	-84.65866	39.79401	-104.56509	5516.50488
2	0.01533	0.007886427	179.99998	-38.26693	39.79401	-104.56509	5516.57178
3	0.00065	0.000334389	179.99998	-1.90404	39.79401	-104.56509	5516.5708
4	0.00006	3.08666E-05	179.99998	-0.17221	39.79401	-104.56509	5516.5708
5	0.00006	3.08666E-05	179.99998	-0.17584	39.79401	-104.56509	5516.5708
6	0.00009	4.63E-05	179.99998	0.27797	39.79401	-104.56509	5516.5708
7	0.00009	4.63E-05	179.99998	-0.26429	39.79401	-104.56509	5516.5708
8	0.00004	2.05778E-05	179.99998	-0.12945	39.79401	-104.56509	5516.5708
9	0.00004	2.05778E-05	179.99998	-0.13129	39.79401	-104.56509	5516.5708
10	0.00014	7.20222E-05	179.99998	0.40075	39.79401	-104.56509	5516.5708
11	0	0	179.99998	0.00862	39.79401	-104.56509	5516.5708
12	0.00006	3.08666E-05	179.99998	0.17631	39.79401	-104.56509	5516.5708
13	0.00004	2.05778E-05	179.99998	-0.12947	39.79401	-104.56509	5516.5708
14	0.00028	0.000144044	179.99998	0.83395	39.79401	-104.56509	5516.5708
15	0.00011	5.65888E-05	179.99998	-0.3384	39.79401	-104.56509	5516.5708
16	0.00011	5.65888E-05	179.99998	0.32919	39.79401	-104.56509	5516.5708
17	0.00006	3.08666E-05	179.99998	-0.18341	39.79401	-104.56509	5516.5708
18	0.00004	2.05778E-05	179.99998	-0.13067	39.79401	-104.56509	5516.5708
19	0.00004	2.05778E-05	179.99998	-0.10626	39.79401	-104.56509	5516.5708



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

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

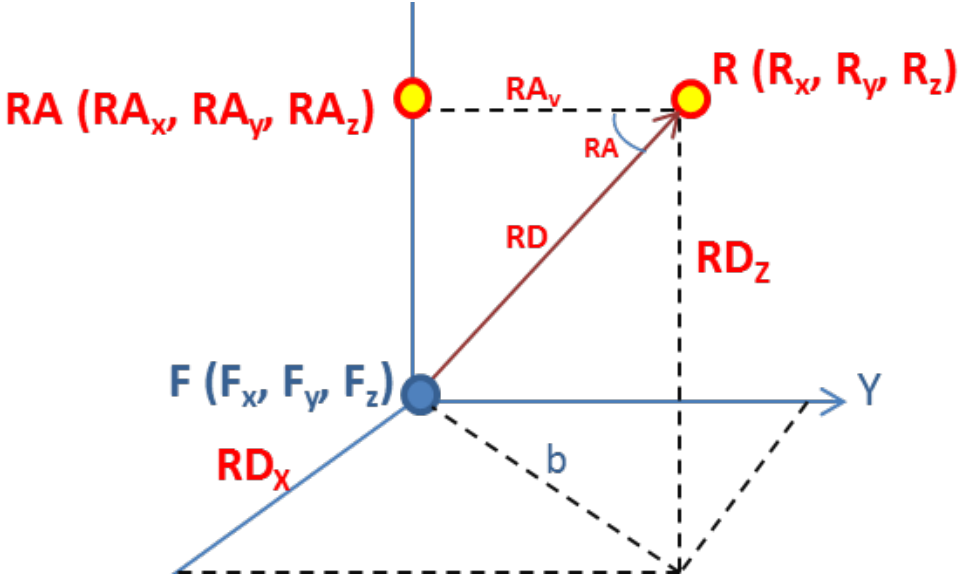
The directivity index

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

$$S_t = \frac{f_0 a_{\text{exit}}}{U_{\text{exit}}}$$

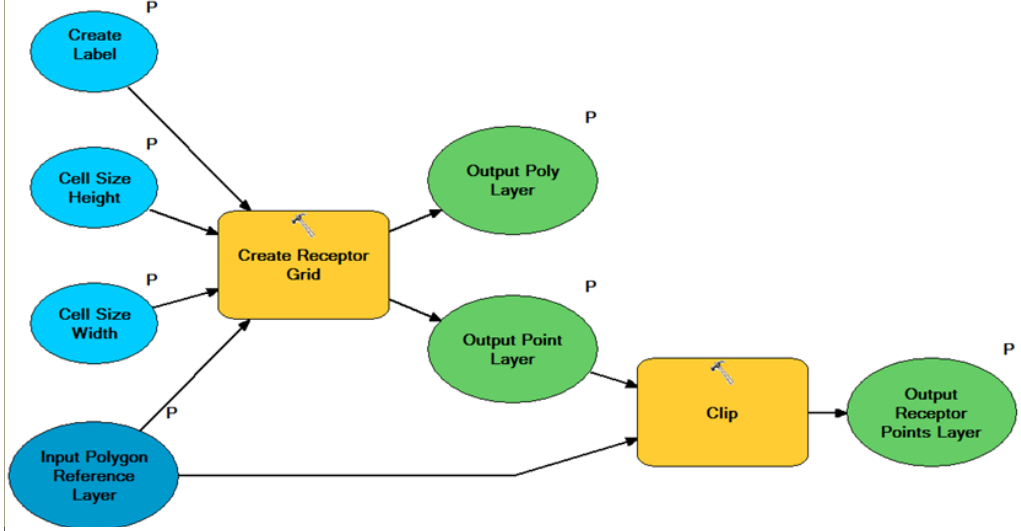
$$L_{Wb} = L_W + K_b$$

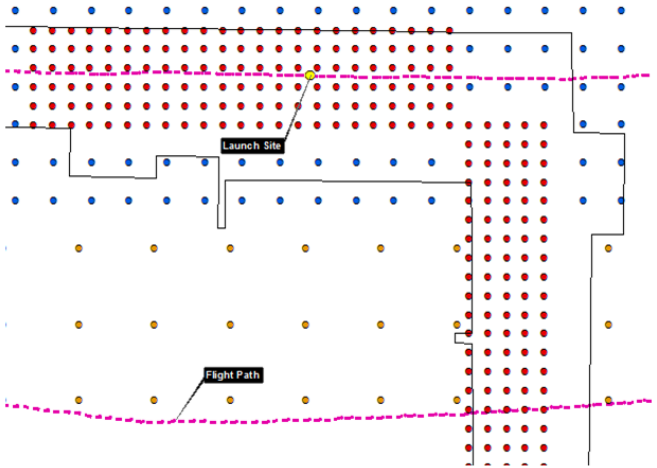
$$K_b = -12.8 - 10\log[S_t^{0.9} + (0.00268)S_t^{-1.5}]$$



METHODOLOGY: RECEPTOR GRID

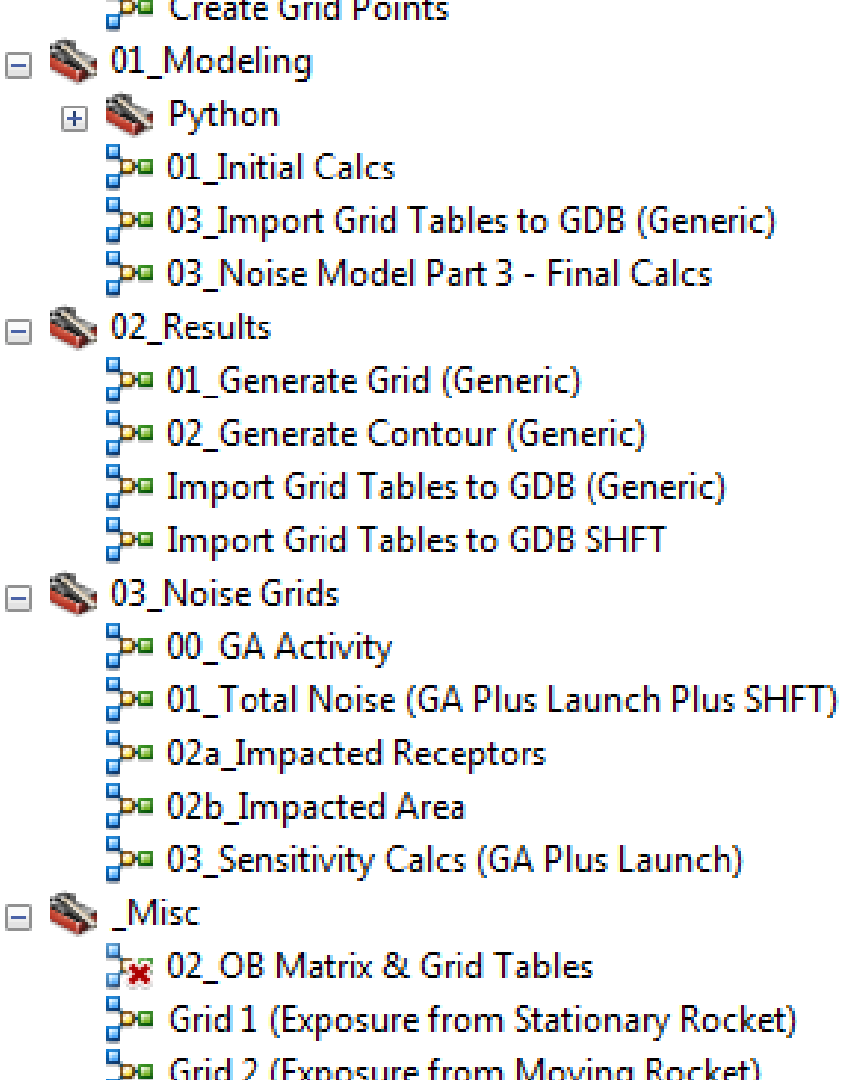
- Raster cells represent receptor locations
- Varying raster resolution
  - High density at or near runway
  - Low density away from areas of high noise





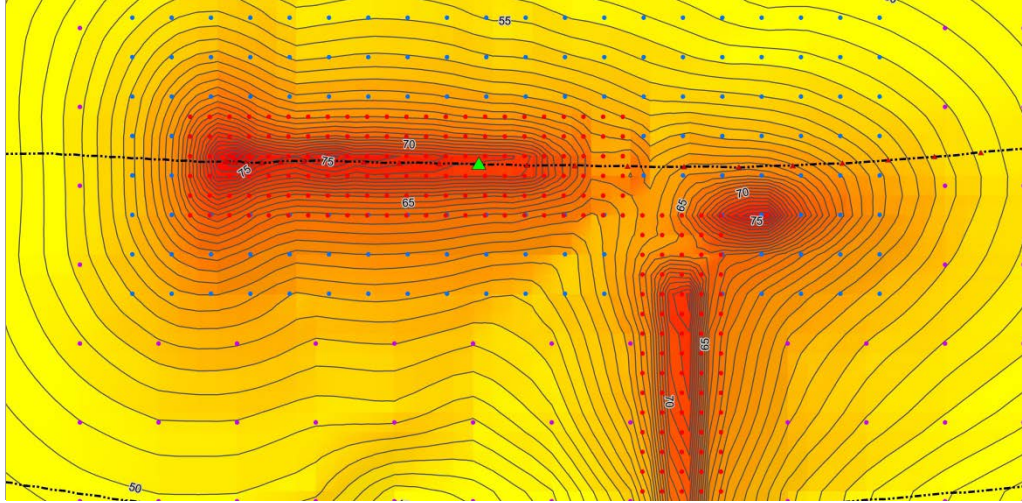
METHODOLOGY: THE “TOOL”

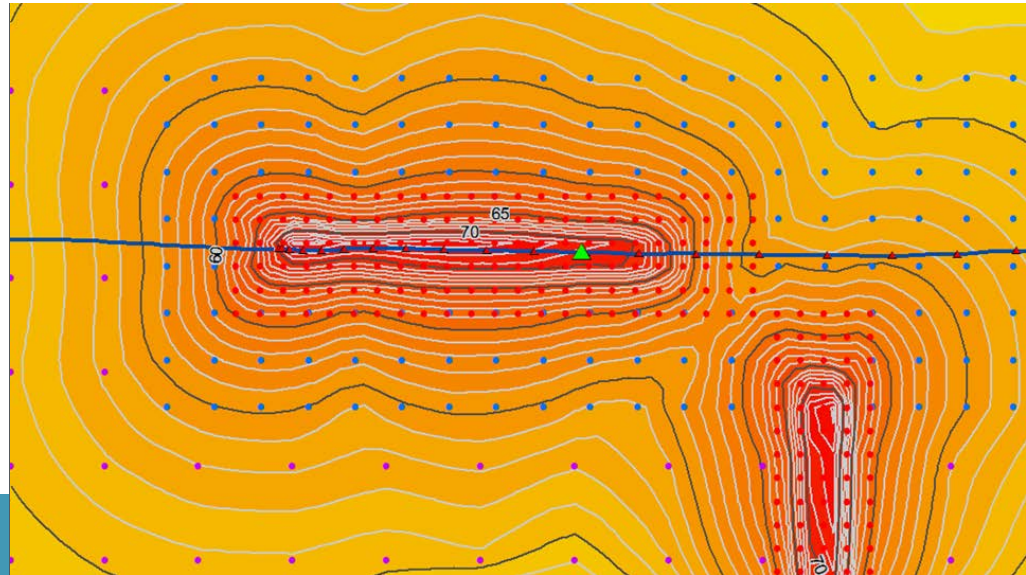
- ArcGIS Spatial ModelBuilder
  - Combination of Python, Iterators and ArcToolbox tools
  - “Custom” tools for frequently requested additional analyses
- Automated Analysis for Multiple Scenarios
  - Variable # flights (1 per week, 1 per month, etc.)
  - Variable # of Static Hot Fire Tests per year
  - 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!

U.S. Department of Transportation
Federal Aviation Administration

Office of Environment and Energy

800 Independence Ave., S.W.
Washington, D.C. 20591

October 21, 2014

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 (AEE) 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 AEE. This letter serves as AEE'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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