An Operational Perspective on Atmospheric Dispersion Modeling

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14th Annual GMU Conference on Atmospheric Transport and Dispersion Modeling

OFCM Session Panel

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LLNL-PRES-442474

Operational Systems Provide Timely Information to Protect the Public and the Environment Via End-to-End Capabilities

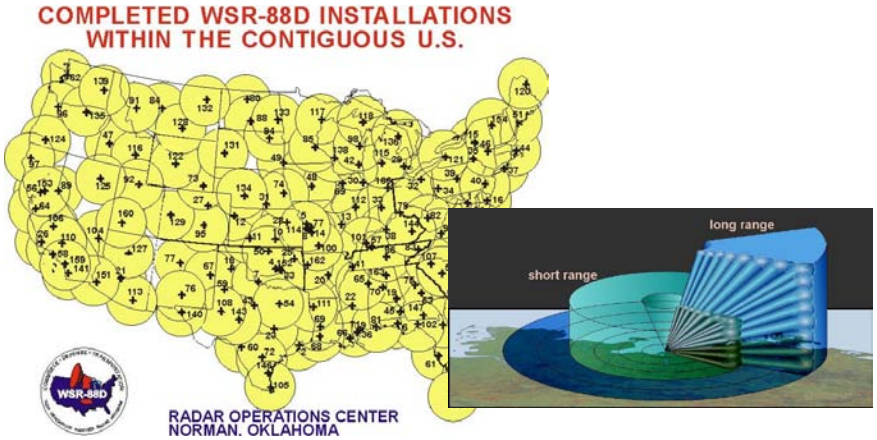


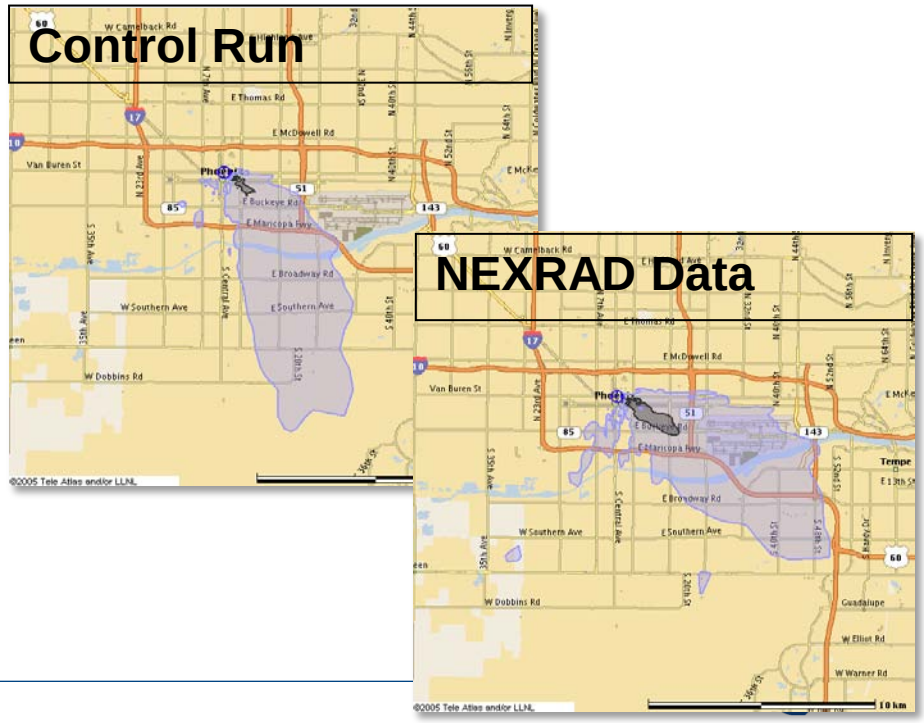



- Event information
  - Weather data
  - CBRN material and source terms
  - Geographic and population databases
  - Field data and observations
- Operational services
  - Suite of multi-scale tools
  - 24/7/365 reachback to experts
  - Product distribution
  - Interagency coordination
- Actionable information
  - Characterization of hazard areas
  - Affected populations, including casualty and fatality estimates
  - Health effect, protective action guide, worker protection levels
  - Sampling plan guidance

Higher-Resolution Data and Data Assimilation Methods are Key to Reducing Meteorological Uncertainty

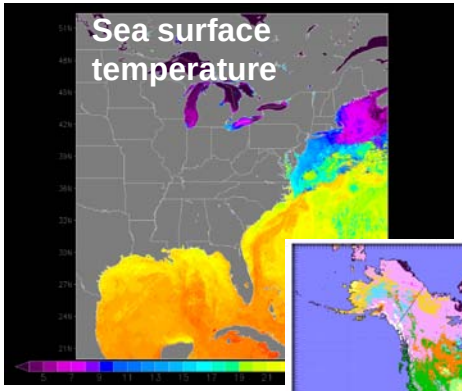
- Real-time collection and quality assurance of data from diverse observing networks (wind velocity, T, turbulence)
- Remote sensing system provide much higher resolution upper level wind observation
  - Example: NEXRAD hourly data, improved boundary layer resolution, volume coverage
  - Example: LIDAR
- Methods for using and assimilating diverse data (e.g., radar-derived winds, aircraft data, satellite)

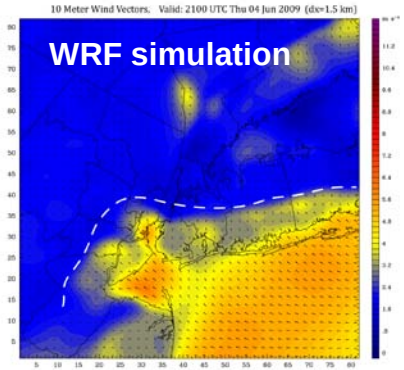


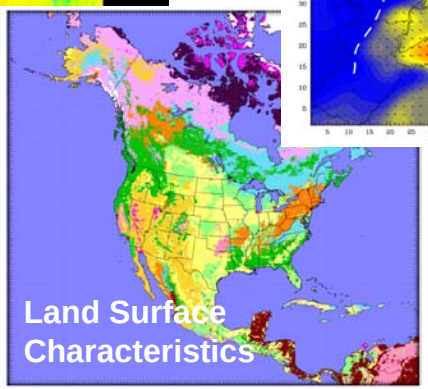


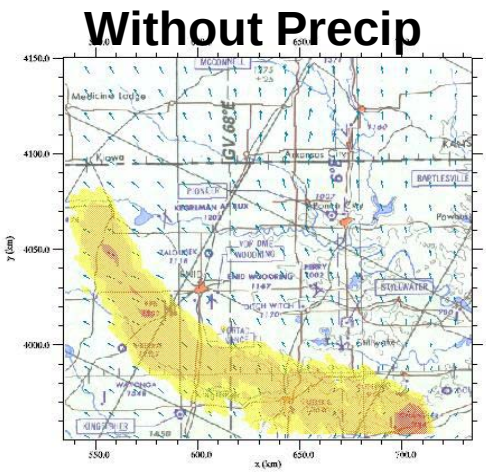
Higher-Resolution Data and New Data Assimilation Methods are Key to Reducing Uncertainty

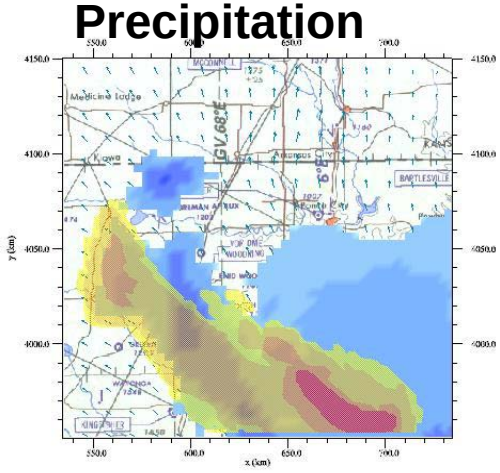
- Example: Satellite retrievals incorporated into NWP simulations provides seasonal and regional variation and improve simulations in heterogeneous environments (coastal, urban, complex terrain)
  - Surface roughness
  - Sea surface temperature
  - Land-surface characteristics
- Example: Rain rate and particle-size dependent precipitation scavenging
  - Radar precipitation data calibrated with rain gauge data





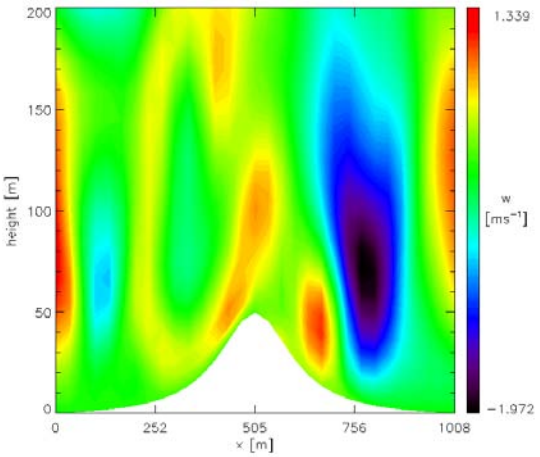


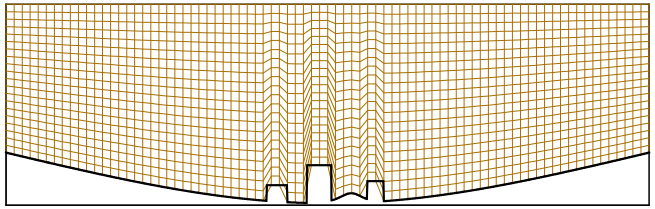


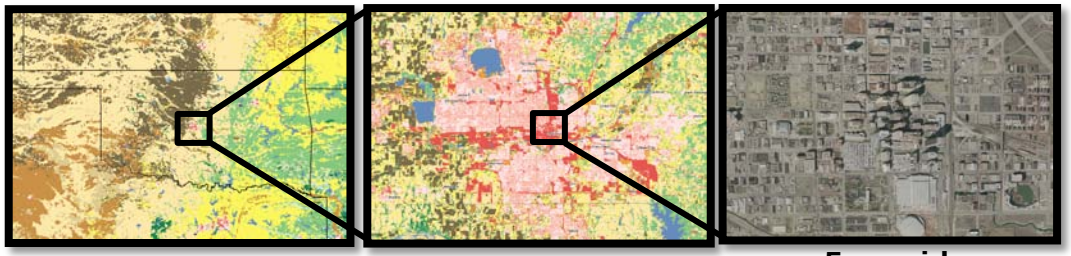


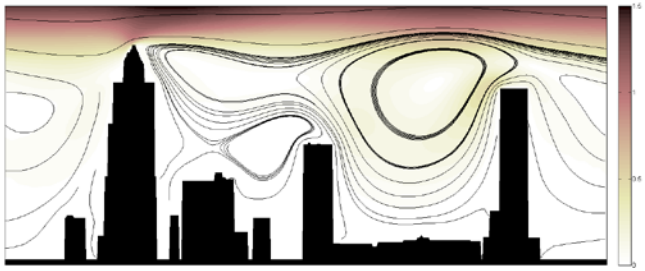
Methods are Needed that Integrate Physical Processes Across a Range of Scales (Micro-to-Mesoscale Gap)

- Development of advanced turbulence models for large-eddy simulations
- Example: Immersed boundary conditions to represent complex geometries on a structured grid
  - Standard NWP methods at mesoscale with terrain following coordinates
  - IBM on inner nest to explicitly resolve urban structures (boundary conditions) imposed inside computational domain
  - Nesting with up-and-down scale coupling



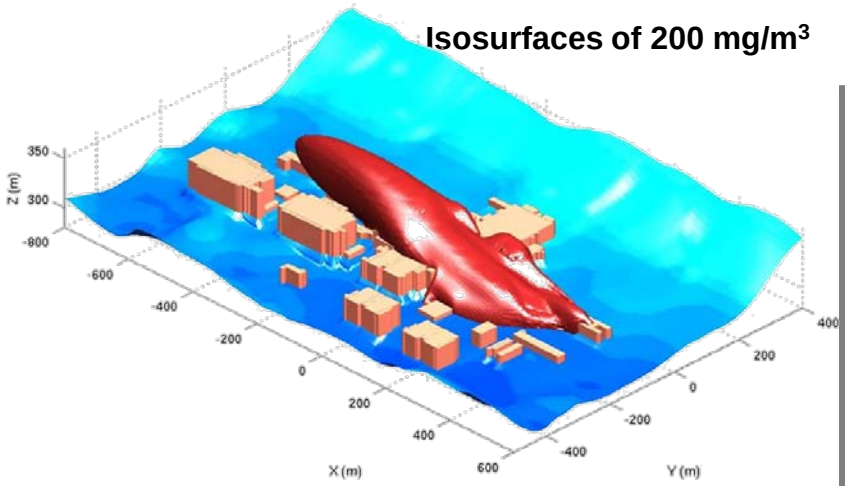






Release Source Term is Often the Greatest Unknown During a Real-World Response

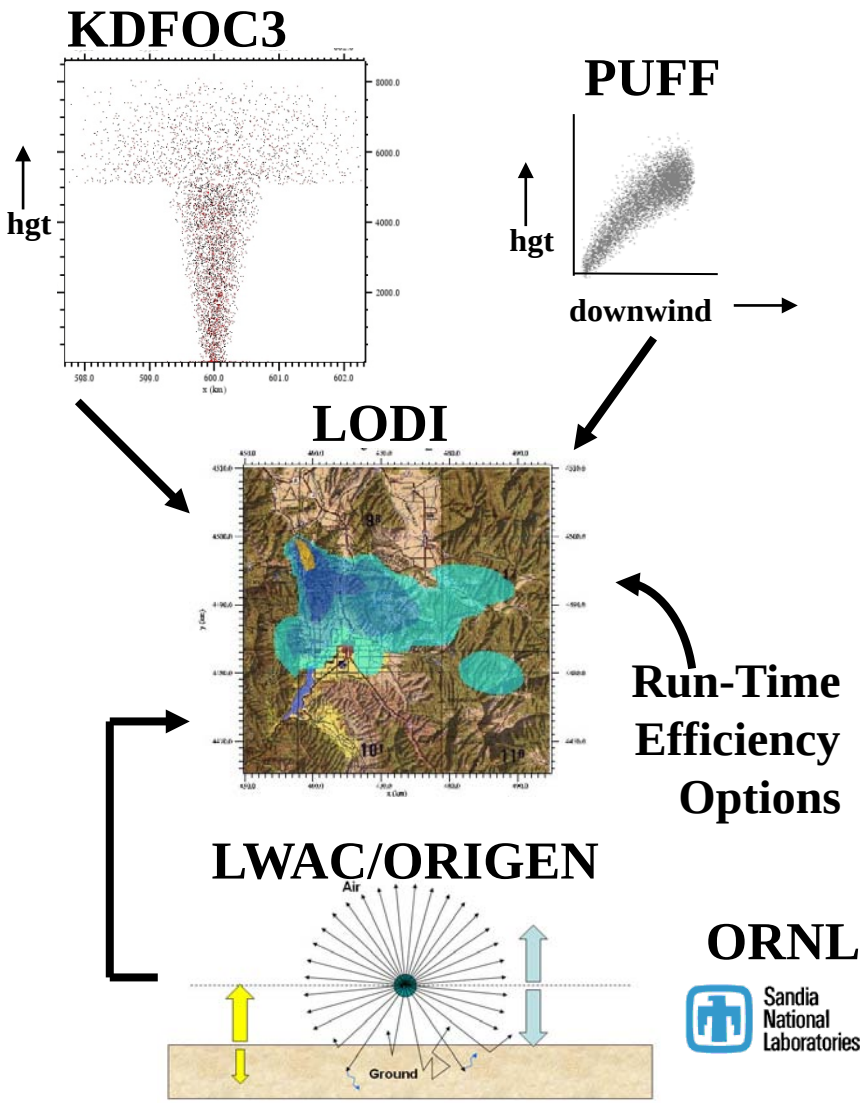
- Toxic industrial chemicals
  - Chemical mixtures and reactions
  - Multi-phase source terms
  - Dense gas effects in urban environments
  - Catastrophic releases
- Operational need: Reducing complex physics to key elements based on observables or derivable from field data
- RDD
  - Radiological mixtures
  - US/Canada/Israel cloud rise experiments
  - Deposition of ballistic-size explosively dispersed particles (SNL experiments)
  - Gap: urban effects on initial cloud rise



Example: Urban-scale dense gas release. Density reduces vertical mixing, increases lateral spreading and upwind spread, and induces downslope transport

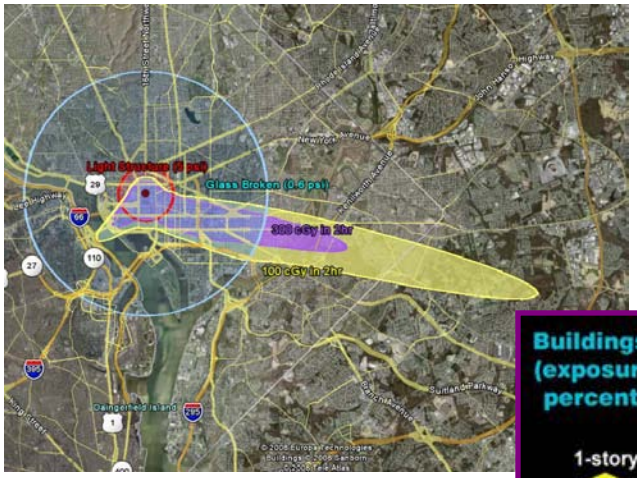
User Community is Asking Questions Requiring Higher Fidelity Integrated Models: IND Example

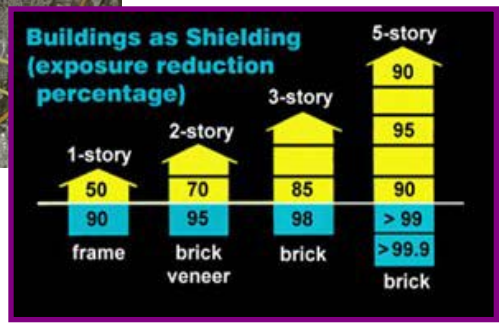
- LLNL/SNL model
  - Fission product inventory (ORNL ORIGEN)
  - Device and surface-dependent neutron-activation products plus ground-shine dose from undisturbed soil activation (LLNL LWAC)
  - Nuclear detonation source description (LLNL KDFOC)
  - Dynamic high-explosive cloud rise model (SNL PUFF)
- Improvised nuclear device (IND)
  - Fractionation
  - Gap: Impact of urban structures on nuclear detonation prompt effects and fallout
  - Gap: Activity size distribution resulting from different environments and emplacement (water, underground)
  - Gap: Validation data

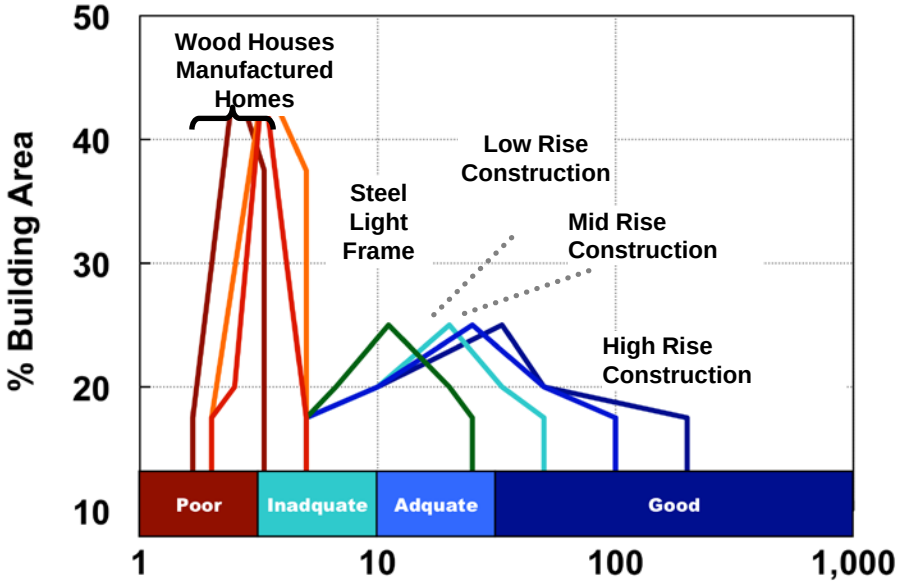


Incorporation of Building Information Improves Estimates of Casualties and Protective Action Guidance for INDs

- Building shadowing calculations of nuclear detonation prompt effects (thermal radiation)
- Building damage by structural type and related injury estimates
- Improved injury estimates from broken glass
- Building protection factors / shielding reduces fallout radiation casualties
- Data gap: Improved database of building structure details and categories building on FEMA HAZUS data







Health Effect and Detailed Population are Necessary for Realistic Casualty Projections

- CB health effects for civilian and special populations
  - Chemical toxic load models
  - Biological agent data (viability, dose-response, degradation)
  - Official federal Protective Action Guide and Worker Protection Levels for CB exposures
- Improved methods that account for compounding effects of combined injuries
  - INDs: radiation, thermal, blunt trauma, lacerations
- Continued development of higher resolution population data for improved casualty estimation
  - Demographic data
  - Indoor-outdoor fractions
  - Population movement
  - Building category occupancy data for shielding / sheltering effects

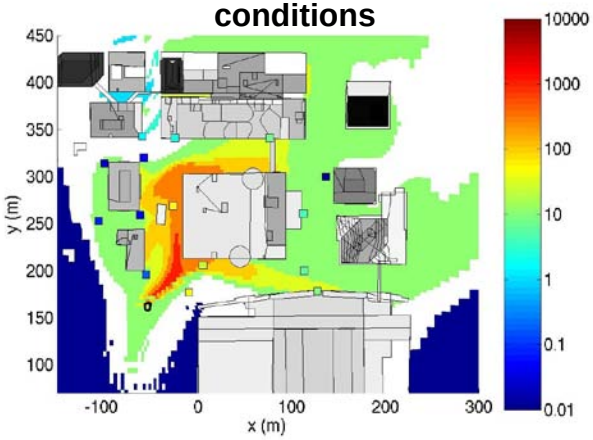
Degradation, Deposition, and Secondary Transport Information are Needed for Response and Recovery

- Chemical reactions and phases changes
  - Atmospheric chemistry
  - Gas-to-particle decay (nuclear power plants and reactors)
- Environmental effects
  - Deposition based on spatially varying land-use properties and building materials
  - Weathering (causes resuspension to decrease with time)
  - Mitigation measures
- Secondary transport (biological agents, radiological materials)
  - Wind-induced resuspension models
    - Time depending models perform better
    - Data sets typically provide long-time averages appropriate for months to years after deposition; wind tunnel show significant early resuspension
  - Mechanical abrasion (vehicle tracking, fomites)

Uncertainty Estimation Relies on a Wide Range of Methods and Sampling and Lacks Operational Robustness

- Meteorological ensembles
- Dispersion “ensembles” (range of key input parameters, Monte Carlo sampling)
- Event reconstruction tools (inversion, adjoints, statistical matching, Bayesian inferencing and stochastic methods) for rigorous treatment of a large number of correlated source and transport variables
- Operational response based on measurement data, expert judgment and statistical tools
- Gaps
  - End-to-end uncertainty estimation from source to effects
  - Data-driven operational approaches for optimizing building-scale models

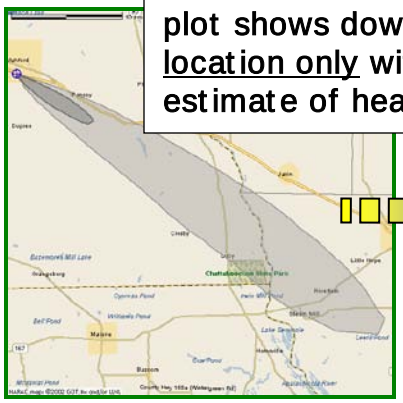
Average fallout dose pattern for a sampling of historical weather conditions



90% confidence plume derived from Bayesian inference and stochastic sampling

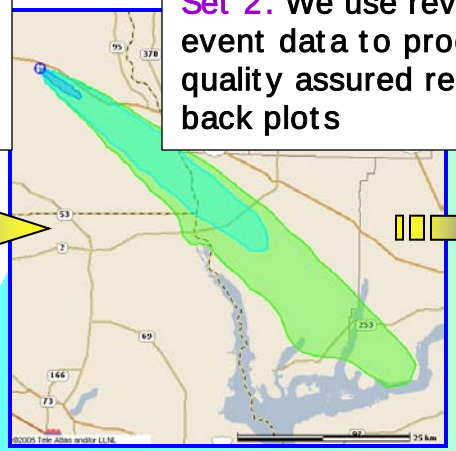
Standard Operational Procedures Couple Modeling and Monitoring in a Cyclical Process to Reduce Uncertainty

Set 1. An initial automated plot shows downwind <u>location only</u> with no estimate of health effects



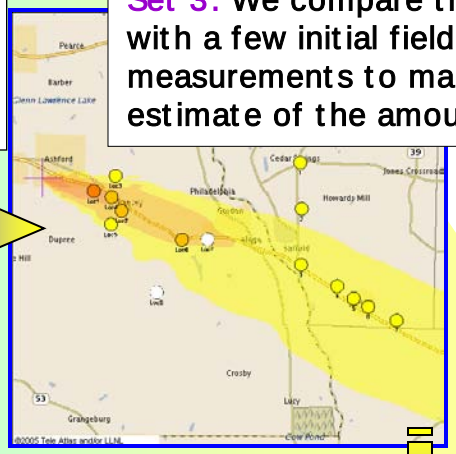
Automated Web-Initiated or via Emergency Call; Only know release time and location

Set 2. We use revised event data to produce quality assured reach-back plots



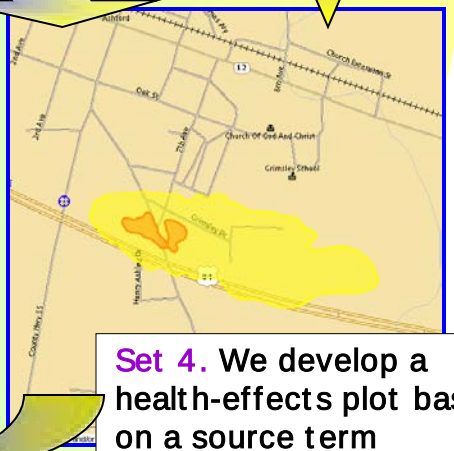
Example revised data: Updated source location, detailed weather

Set 3. We compare the model with a few initial field measurements to make an initial estimate of the amount released

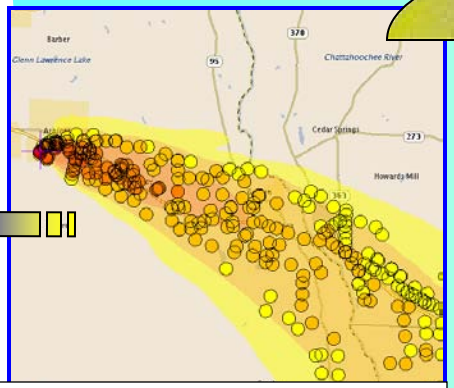


Source scaled to initial set of measurements

Cycle of new products based on updated sets of measure-ments



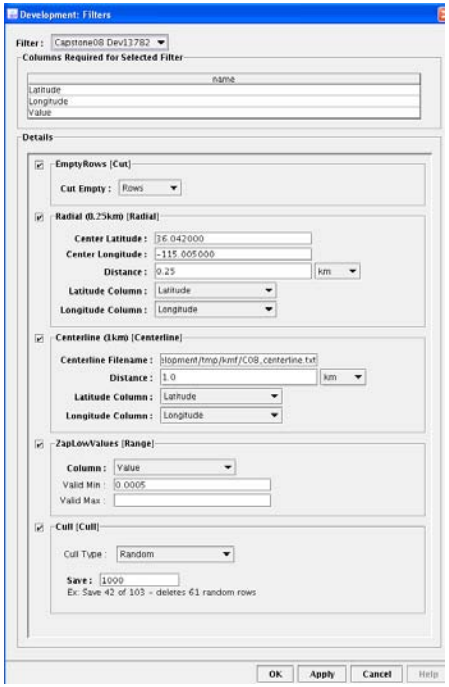
Set 4. We develop a health-effects plot based on a source term estimated from field measurements

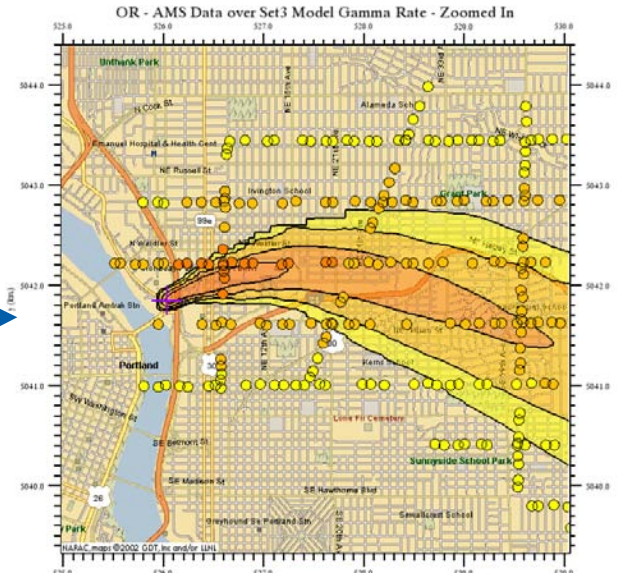


Set 5. We use more extensive sets of field measurements to improve the accuracy of the source term calculation

Later sets:
We develop Relocation and Food-Ingestion plots

Real-Time Field Data Acquisition and Processing Reduce the Delivery Time for Data-Model Products





Electronic transfer of measurement data

• DOE RAMS, EPA Scribe, CST

• XML, Excel/CSV formats)

Analysis Software

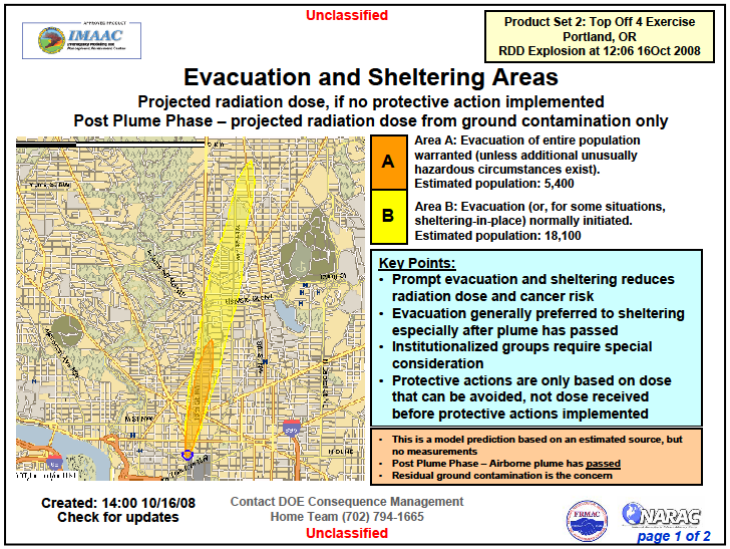
- Data filtering, selection and outlier elimination
- Graphical/statistical analysis of data-model agreement
- Determination of improved model inputs

Filtered Data and Refined Model Predictions

Processing time to use large field measurement data sets to update model predictions has been reduced by a factor of ten (from over 1 hour to under 10 minutes)

Interagency Briefing Products Were Tailored to Convey Actionable Information to Decision Makers

- Goal: Develop hazard area graphics and non-technical language to assist SMES in briefing decision makers (Homeland Security Council tasking)
  - Three slide PowerPoint format
  - Focused on possible actions (evacuation/sheltering, relocation, worker protection)
  - Standard plot suites and levels based on interagency collaboration
- Briefing versions of standard IMAAC/NARAC RDD and IND model-data products (DOE)
- Draft chemical/biological briefing product templates proposed under development (DHS S&T)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IMAAC

Product Set 2: Top Off 4 Exercise
Portland, OR
RDD Explosion at 12:06 16Oct 2008

Evacuation and Sheltering Areas

Projected radiation dose, if no protective action implemented
Post Plume Phase – projected radiation dose from ground contamination only

A — Area A: Evacuation of entire population warranted (unless additional unusually hazardous circumstances exist). Estimated population: 5,400

B — Area B: Evacuation (or, for some situations, sheltering-in-place) normally initiated. Estimated population: 18,100

Key Points:
- Prompt evacuation and sheltering reduces radiation dose and cancer risk
- Evacuation generally preferred to sheltering especially after plume has passed
- Institutionalized groups require special consideration
- Protective actions are only based on dose that can be avoided, not dose received before protective actions implemented

- This is a model prediction based on an estimated source, but no measurements
- Post Plume Phase – Airborne plume has passed
- Residual ground contamination is the concern

Created: 14:00 10/16/08
Check for updates

Contact DOE Consequence Management
Home Team (702) 794-1665

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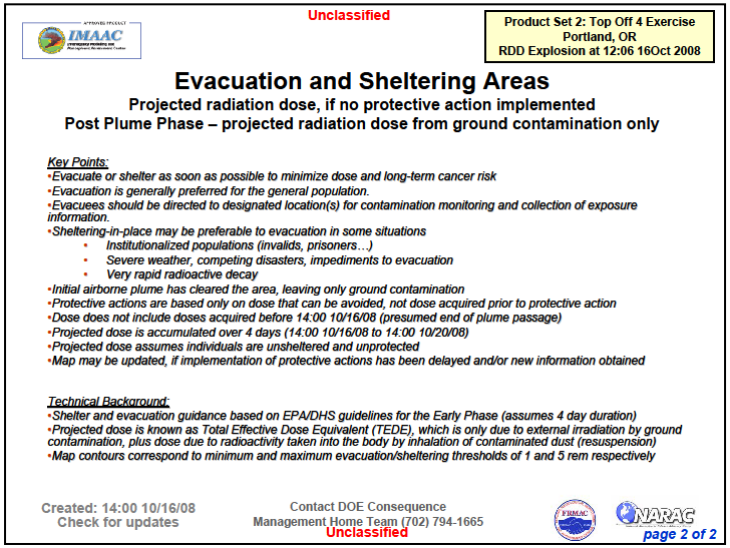
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- *Evacuation is generally preferred for the general population.*
- *Evacuees should be directed to designated location(s) for contamination monitoring and collection of exposure information.*
- *Sheltering-in-place may be preferable to evacuation in some situations*
  - *Institutionalized populations (invalids, prisoners…)*
  - *Severe weather, competing disasters, impediments to evacuation*
  - *Very rapid radioactive decay*
- *Initial airborne plume has cleared the area, leaving only ground contamination*
- *Protective actions are based only on dose that can be avoided, not dose acquired prior to protective action*
- *Dose does not include doses acquired before 14:00 10/16/08 (presumed end of plume passage)*
- *Projected dose is accumulated over 4 days (14:00 10/16/08 to 14:00 10/20/08)*
- *Projected dose assumes individuals are unsheltered and unprotected*
- *Map may be updated, if implementation of protective actions has been delayed and/or new information obtained*

Technical Background:
- *Shelter and evacuation guidance based on EPA/DHS guidelines for the Early Phase (assumes 4 day duration)*
- *Projected dose is known as Total Effective Dose Equivalent (TEDE), which is only due to external irradiation by ground contamination, plus dose due to radioactivity taken into the body by inhalation of contaminated dust (resuspension)*
- *Map contours correspond to minimum and maximum evacuation/sheltering thresholds of 1 and 5 rem respectively*

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1700 HST 8 April 2008

Backup Slides

IMAAC Provides Federal Dispersion Modeling During Events Requiring Federal Coordination Since 2004

- Created by Homeland Security Council (2004)
  - Eight agency Memorandum of Understanding (MOU)
  - 2010 MOU renewal draft recognizes NARAC as Operations hub of the IMAAC
- National deployment plan via federal operations centers and federal agency regional assets
  - Special events
  - National Exercise Program
  - Three year EPA outreach and training program
  - State and local outreach initiative

The IMAAC "provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position" during actual or potential incidents - *National Response Framework, 2009*

Component-based LLNL NARAC-IMAAC Computer Systems Support In-house and External Users

LLNL Computer Systems

Central System: Automated model set-up and execution software

- Weather Data & Forecasts
- Geographic/Terrain Data
- CBRN Material Property Data
- Dose/Risk Factor Data
- Measurement Data
- Source models
- 3-D Meteorological, Dispersion and Fallout Models
- Prompt Effects Models
- Data-driven modeling tools
- Mapping and product generation software
- Population, casualty and fatality estimation

Remote Access Computer System

User interfaces and Analysis Tools for LLNL scientists

Internet/Intranet

External User Tools

***IMAAC/CM/NARAC Web* tools**

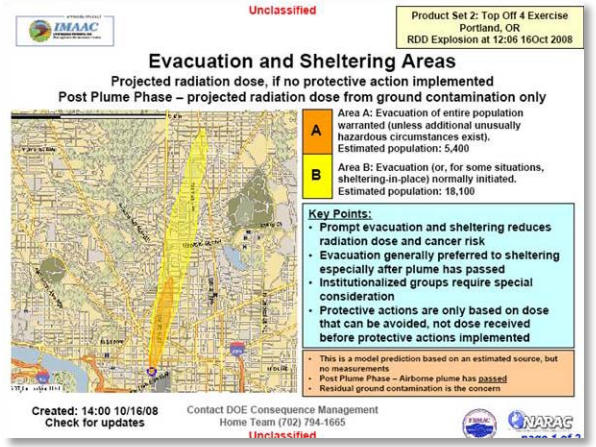
NARAC iClient

HotSpot

Standalone models and mapping

- Over 400 software applications
- 50 databases
- 3 million lines of computer code
- 28 servers
- 8 data storage systems

Interagency Briefing Products Were Tailored to Convey Information to Non-Technical Decision Makers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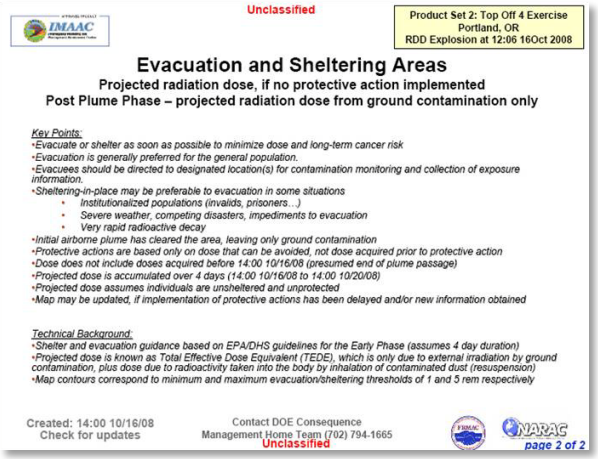
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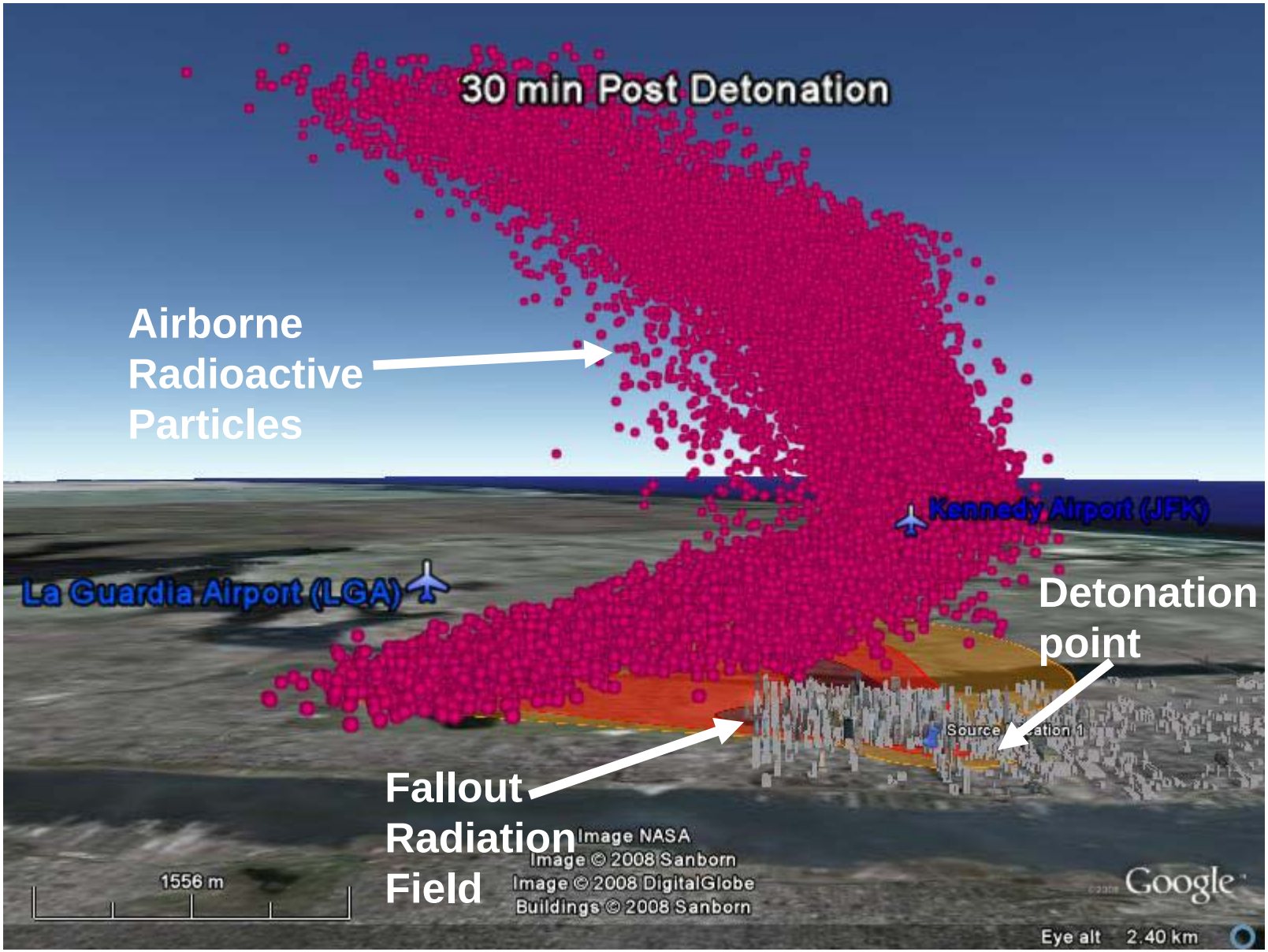
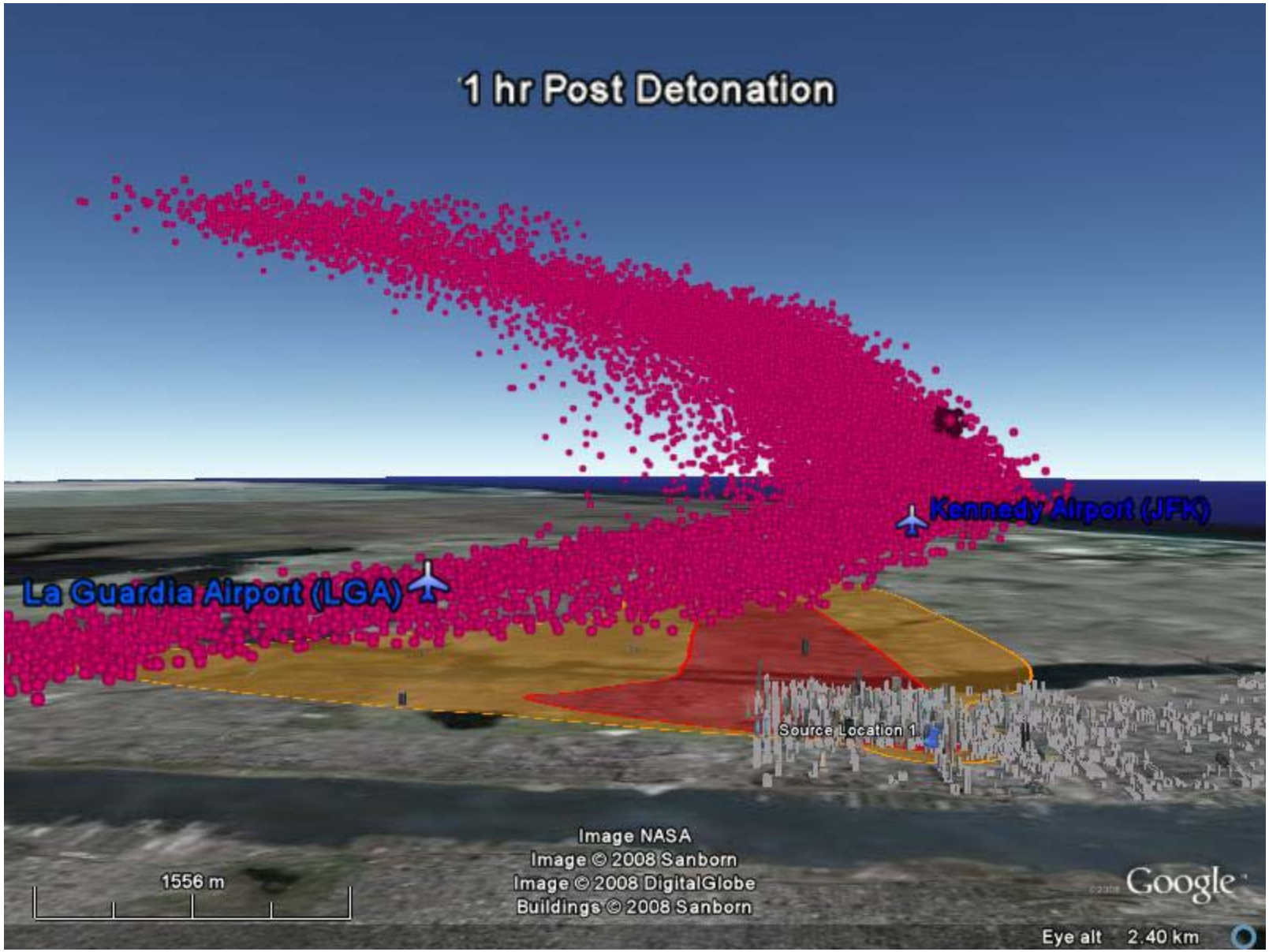
NARAC/IMAAC supports over 300 collaborating local, state, and federal agencies, 2,000 on-line users, and 10,000 requests/year, including 100 exercises and 20 real-world events requiring staff support annually

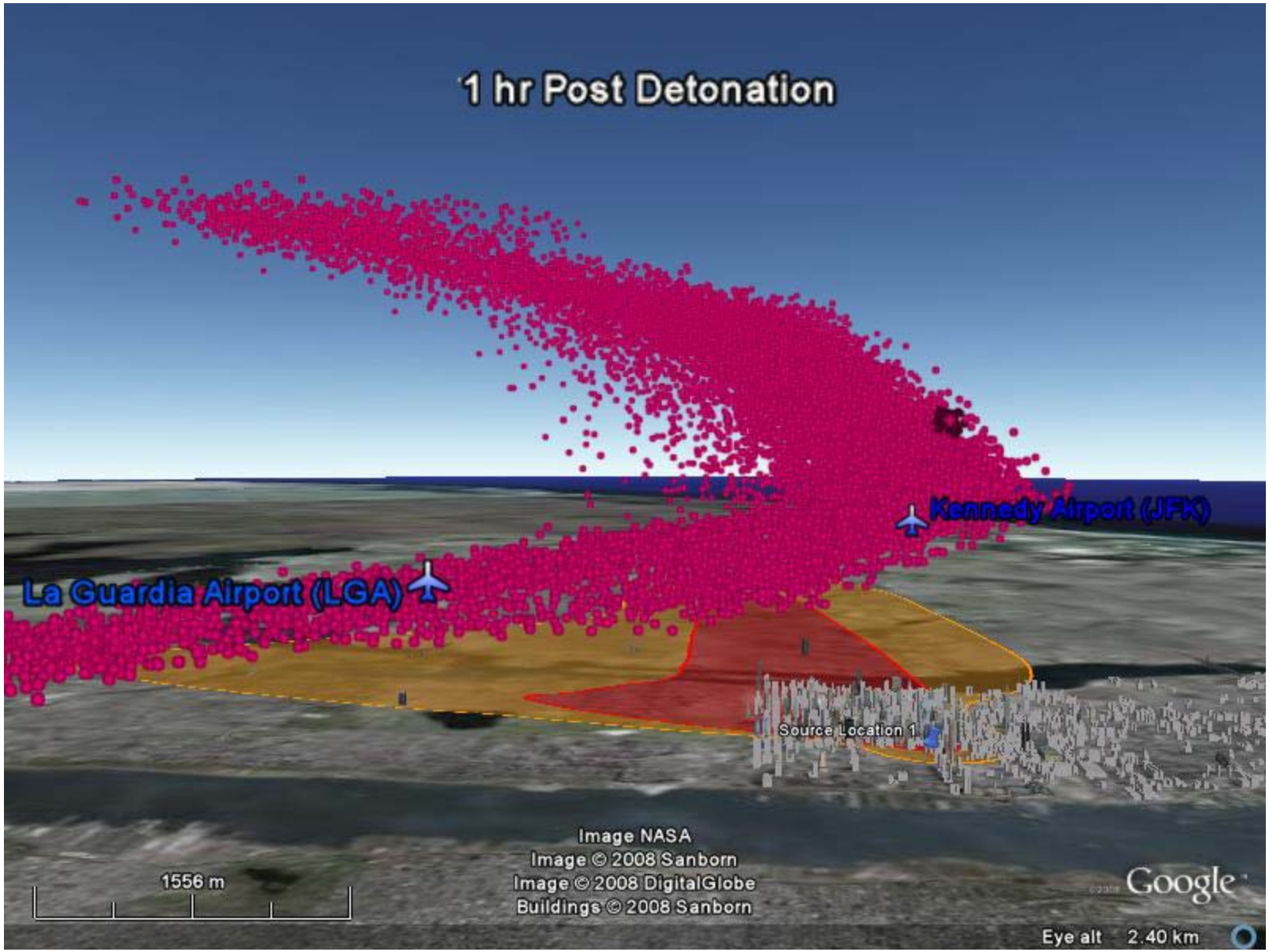
Animations are Needed to Provide Time-Dependent Situational Awareness

DHS Simulations for Planning Guidance

Airborne Nuclear Debris Cloud and Fallout Contamination Footprint


30 min Post Detonation
Airborne Radioactive Particles
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Detonation point
Fallout Radiation Field
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km


1 hr Post Detonation
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km


1 hr Post Detonation
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
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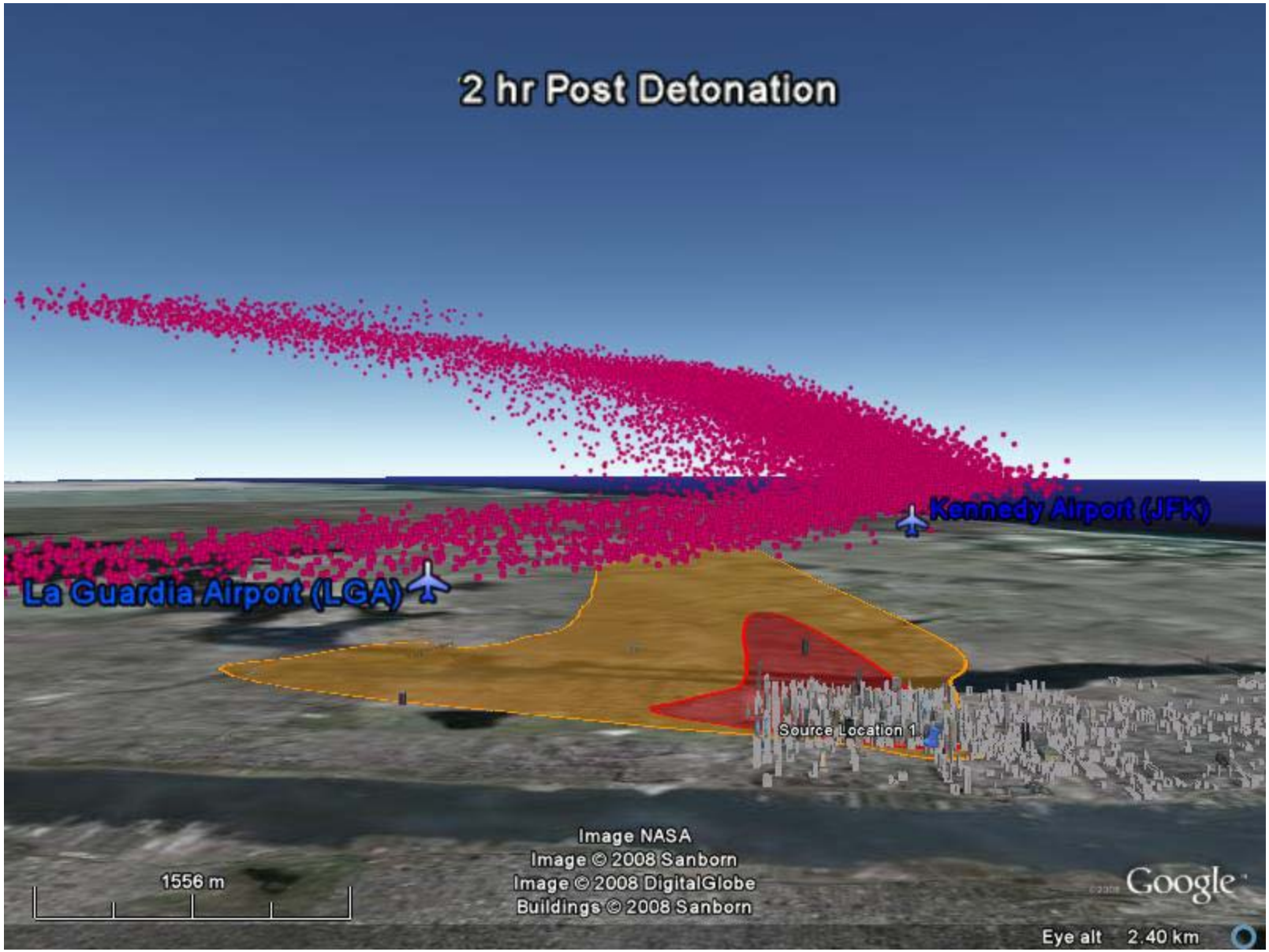
1556 m
Google
Eye alt 2.40 km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Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
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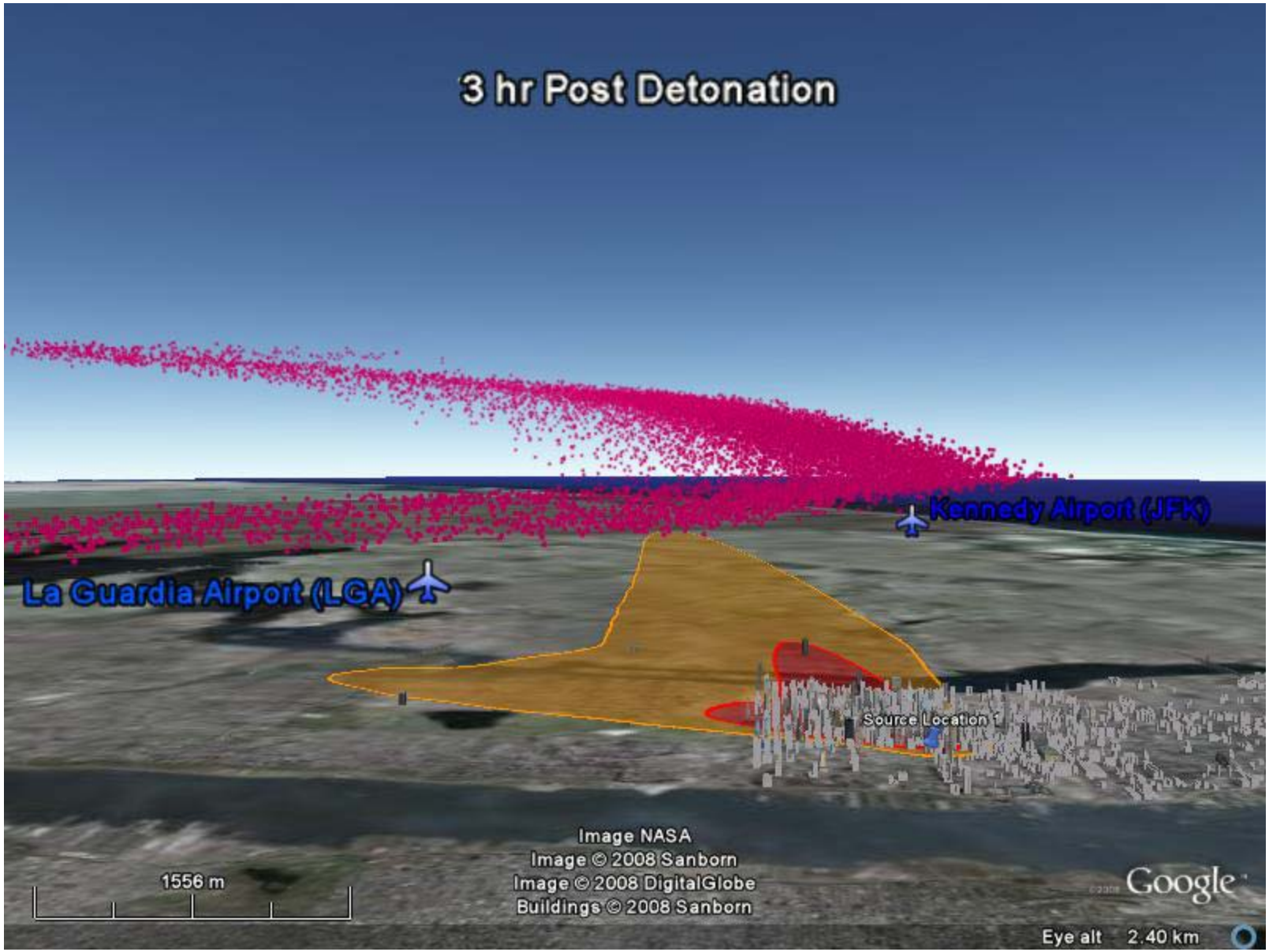
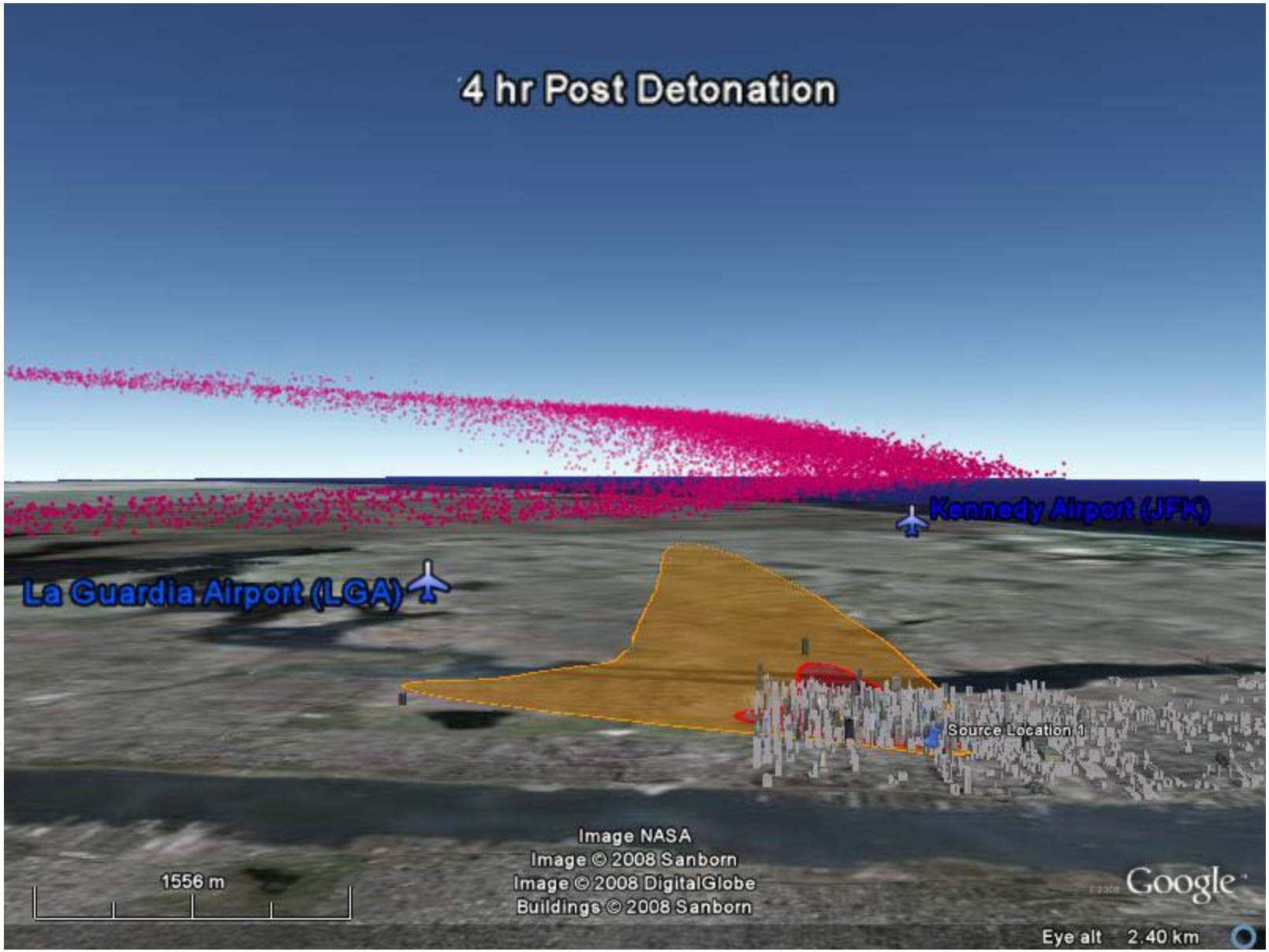
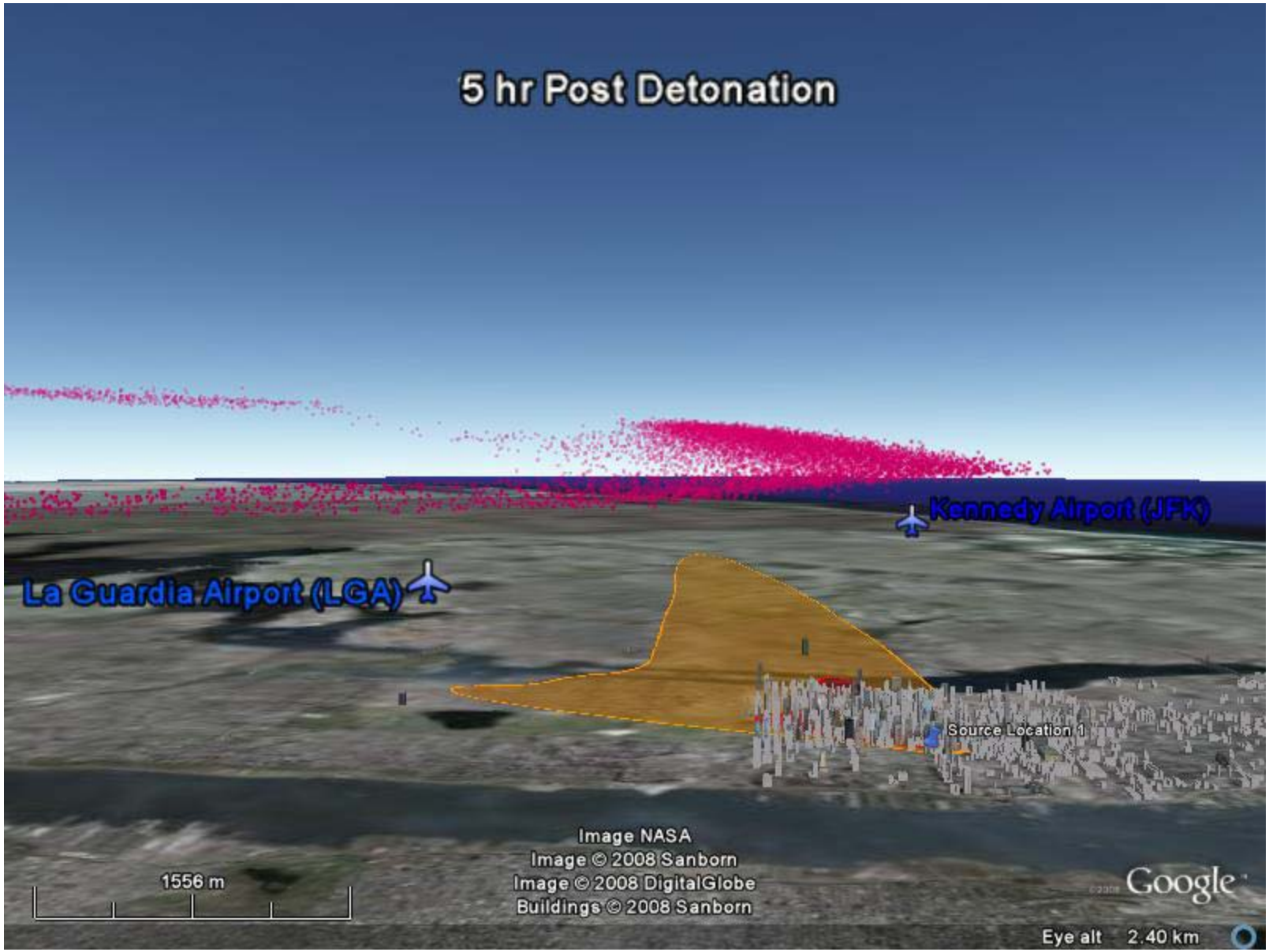
1556 m
Google
Eye alt 2.40 km


3 hr Post Detonation
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km


4 hr Post Detonation
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km


5 hr Post Detonation
Kennedy Airport (JFK)
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Source Location 1
Image NASA
Image © 2008 Sanborn
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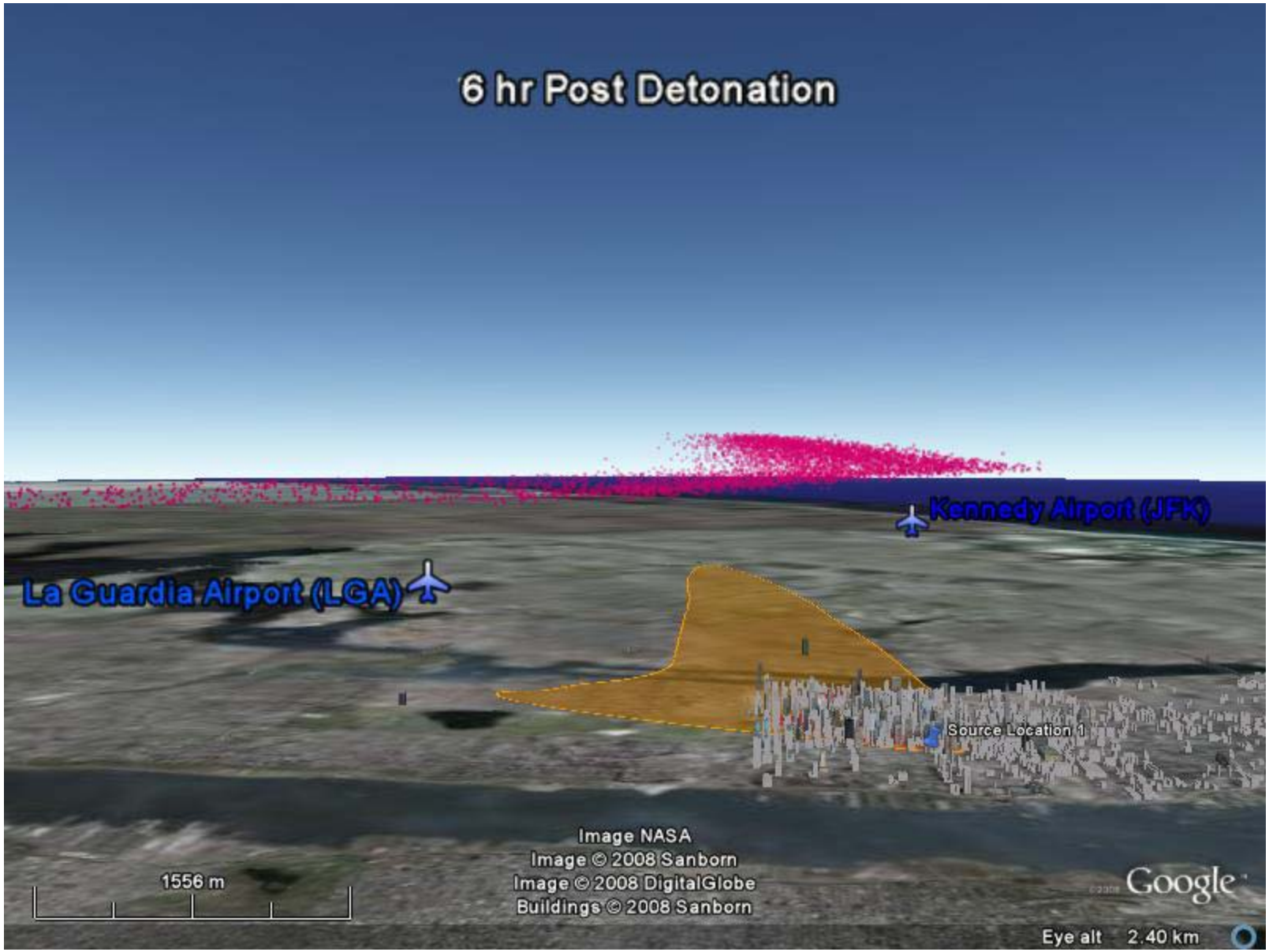
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km


6 hr Post Detonation
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
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1556 m
Google
Eye alt 2.40 km