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Systems modeling of Sample Transport for Liberia

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Sample Transport Modeling Overview

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- Rough roads and long distances between ETUs and diagnostic labs lead to long delays in Ebola diagnosis
- Sandia tasked by DTRA to define optimal sample transport system in Liberia
- About two weeks to develop models and perform analysis
  - Geospatial Analytics
  - Optimization-based transport routes and schedules
  - Agent-based simulation of broader Ebola treatment system
- Sandia team deployed to Liberia to verify needs and vet initial results
- Model-based transport routes and schedules used by USAID to implement new national sample transport system

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Problem: Get Samples to Labs Faster

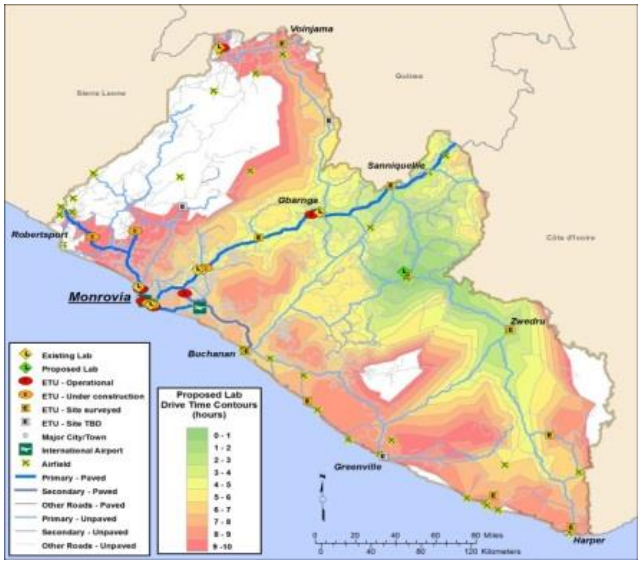
- Rapid diagnosis needed to reduce transmission of Ebola
- Rough roads, long distances
- Blood samples can take over 24 hours to reach Ebola Diagnostic Laboratories
- Can time to diagnosis be decreased?

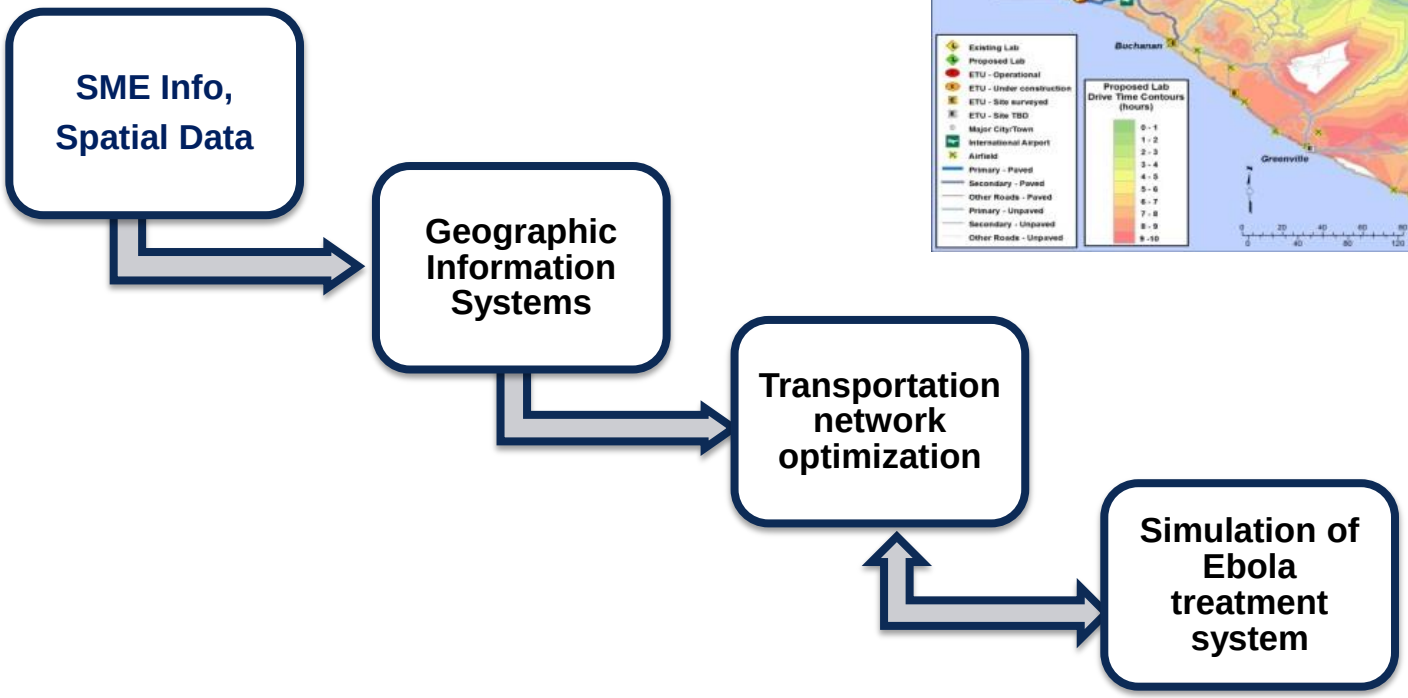
DTRA engages with Sandia

- Sandia's International Bio-threat Reduction Program (IBTR)
  - Deploys scientists to improve public and animal health in developing countries
  - Specialists in diagnostic laboratory set up, operation, safety and security
  - Active in west Africa: Mali, Cameroon, Nigeria, Ghana
  - Longstanding relationship with DTRA Cooperative Biological Engagement Program
- DTRA's Charge to Sandia
  - Assess current sample transport situation
  - Recommend improvements
  - Deploy to Liberia to engage with stakeholders
  - Deadline: Two weeks.

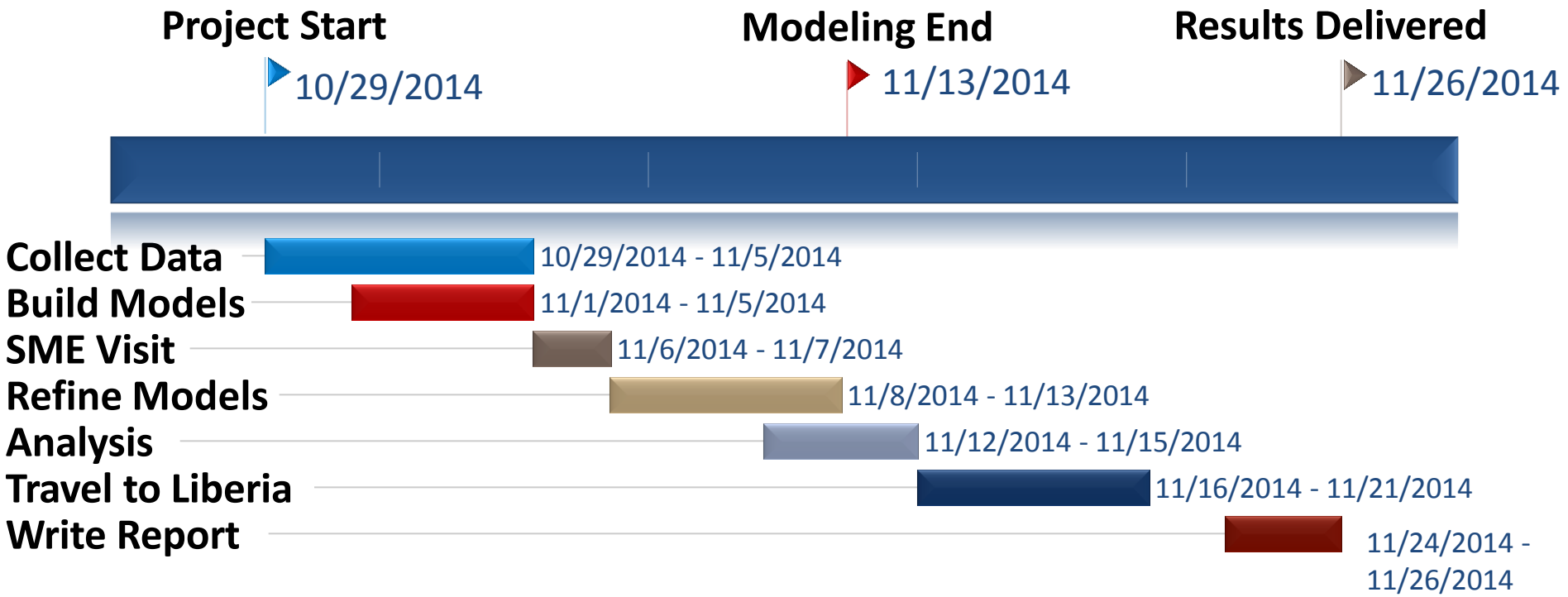
Analytical Strategy

- Small teams of scientists working in four parallel efforts
- Diagnostic Lab SMEs
- Geospatial Analysis
- Optimization Modeling
- Agent-Based Systems Modeling



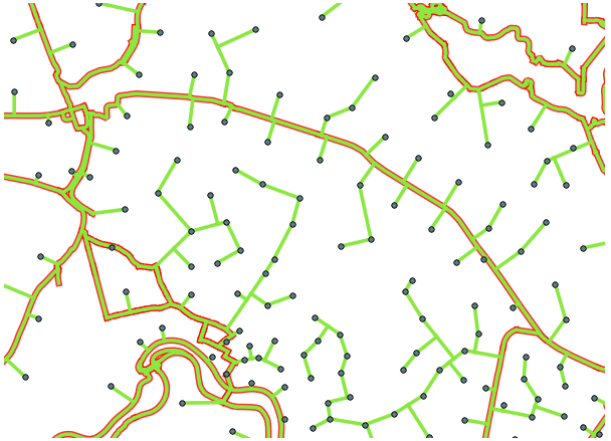


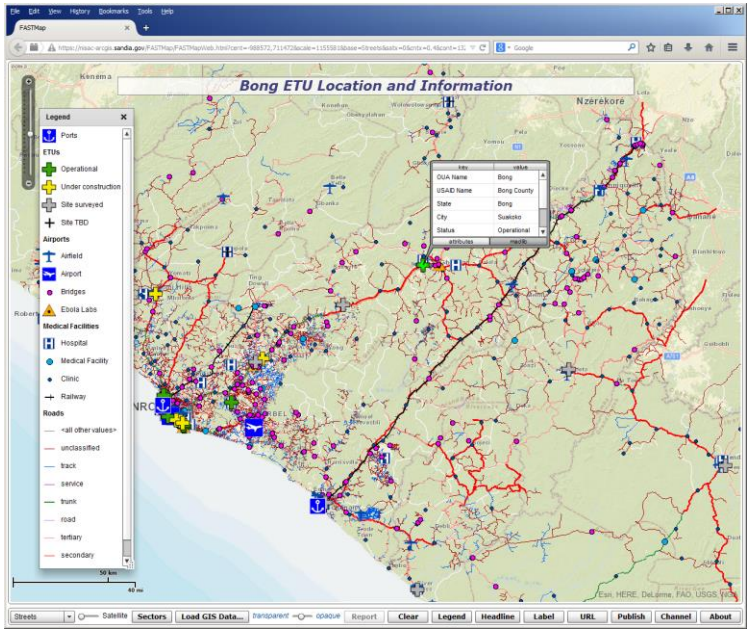
Project Timeline

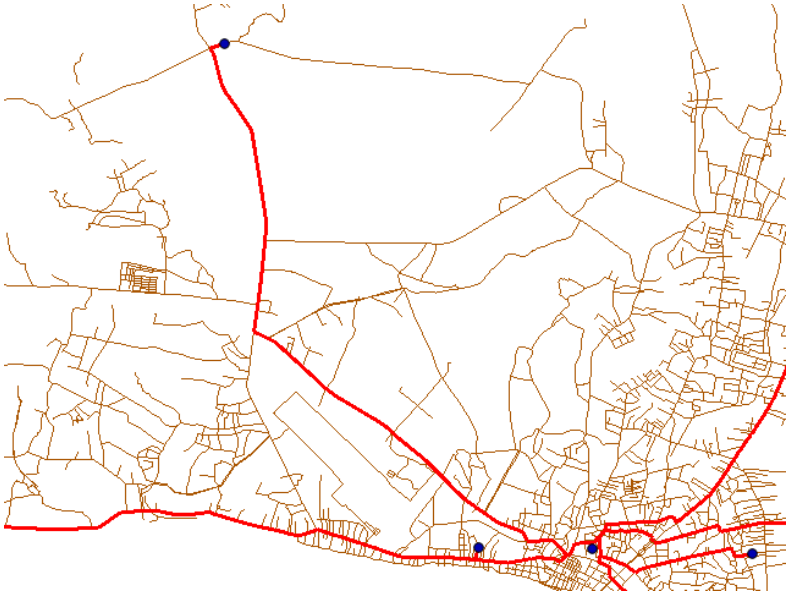


Geospatial Data Analysis

- **Provides a foundation for other elements**
  - **Location of communities, clinical and laboratory facilities, road networks**
  - **Central database repository**
- **Preliminary distance and travel time estimation**
- **Data visualization**

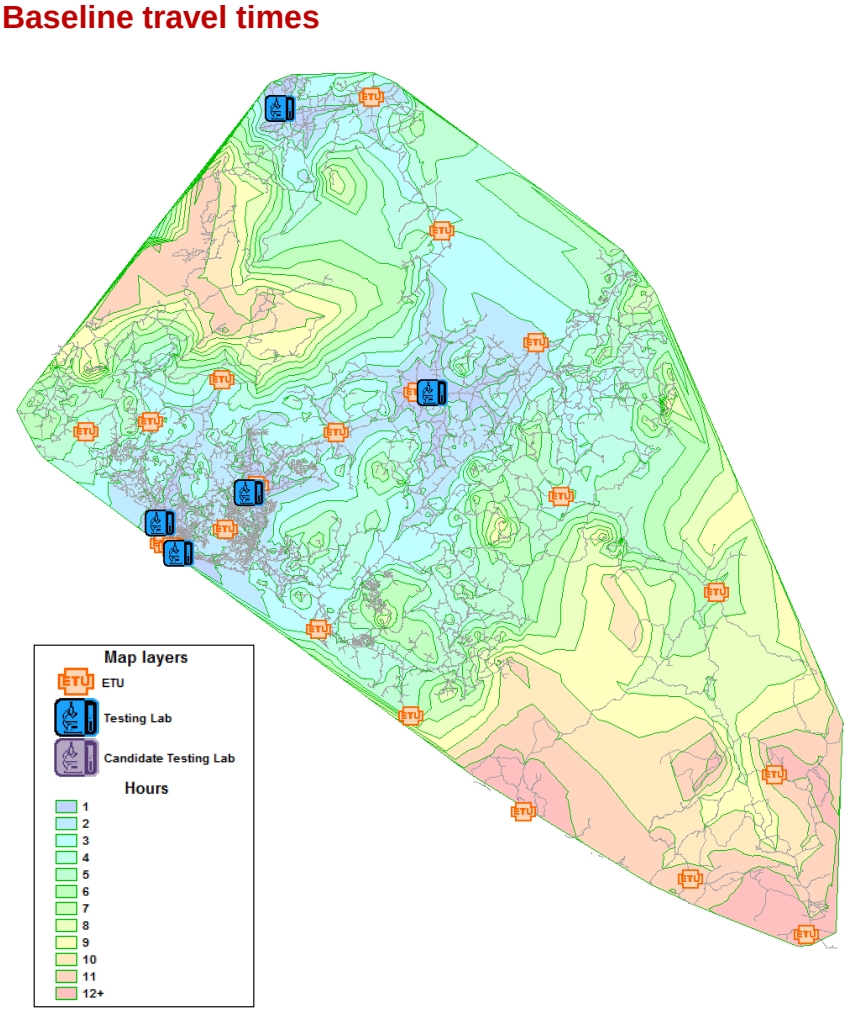






Travel time analysis gives quick answers to initial questions

- Southeast cities (Greenville, Harper, Fish Town, and Barclayville) are over 10 hours to the nearest lab
- Many cities are over 4 hours from a lab, which makes a round trip difficult in a single day



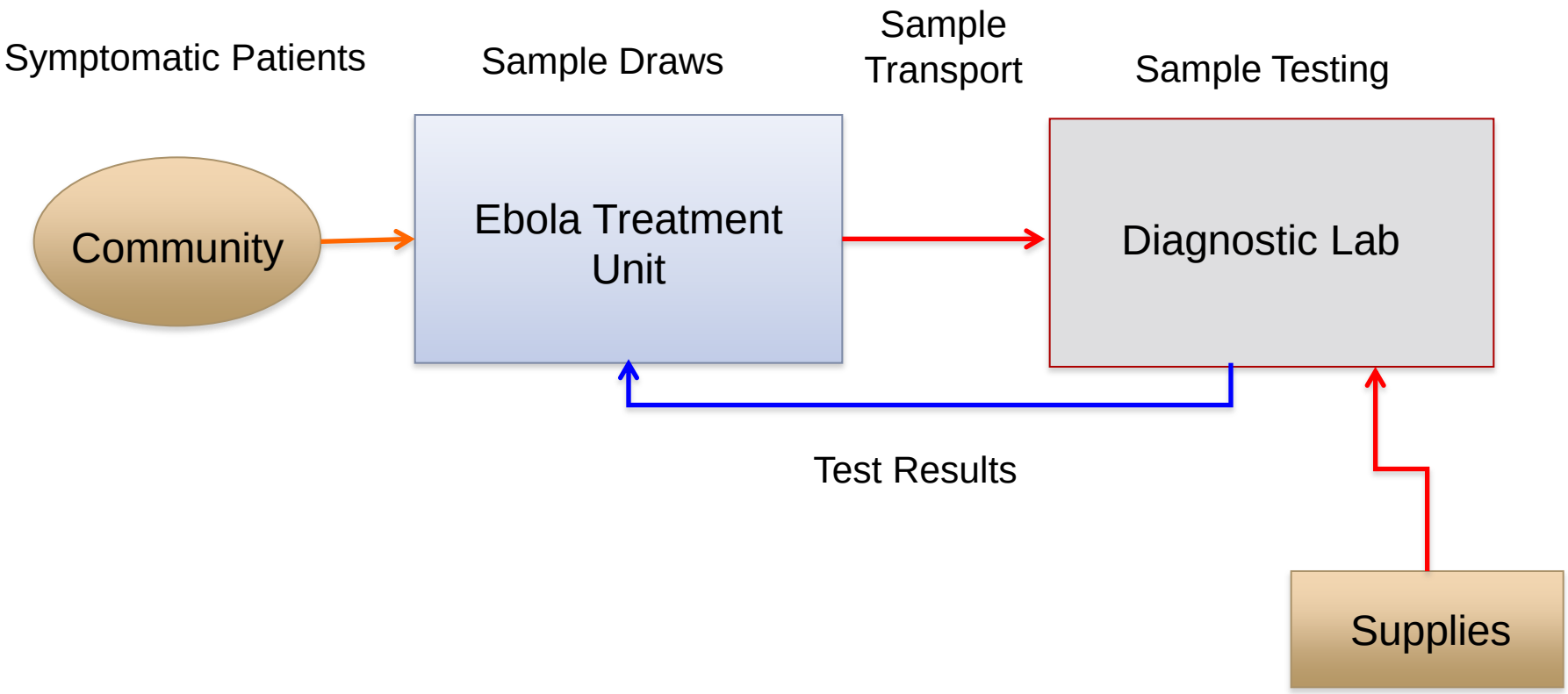
Rout Optimization Finds Actionable Solutions

- Extends shortest time analysis to include alternative routes to planned facilities
- Applies system constraints such as vehicle type, national curfew, driver breaks, etc.
- Create detailed pick up schedules for required level of service

Note: Adding a third vehicle could allow this lab to service Tapita or split the Ganta-Bong, Bong II routes in half

Agent Based Simulation of Treatment Process

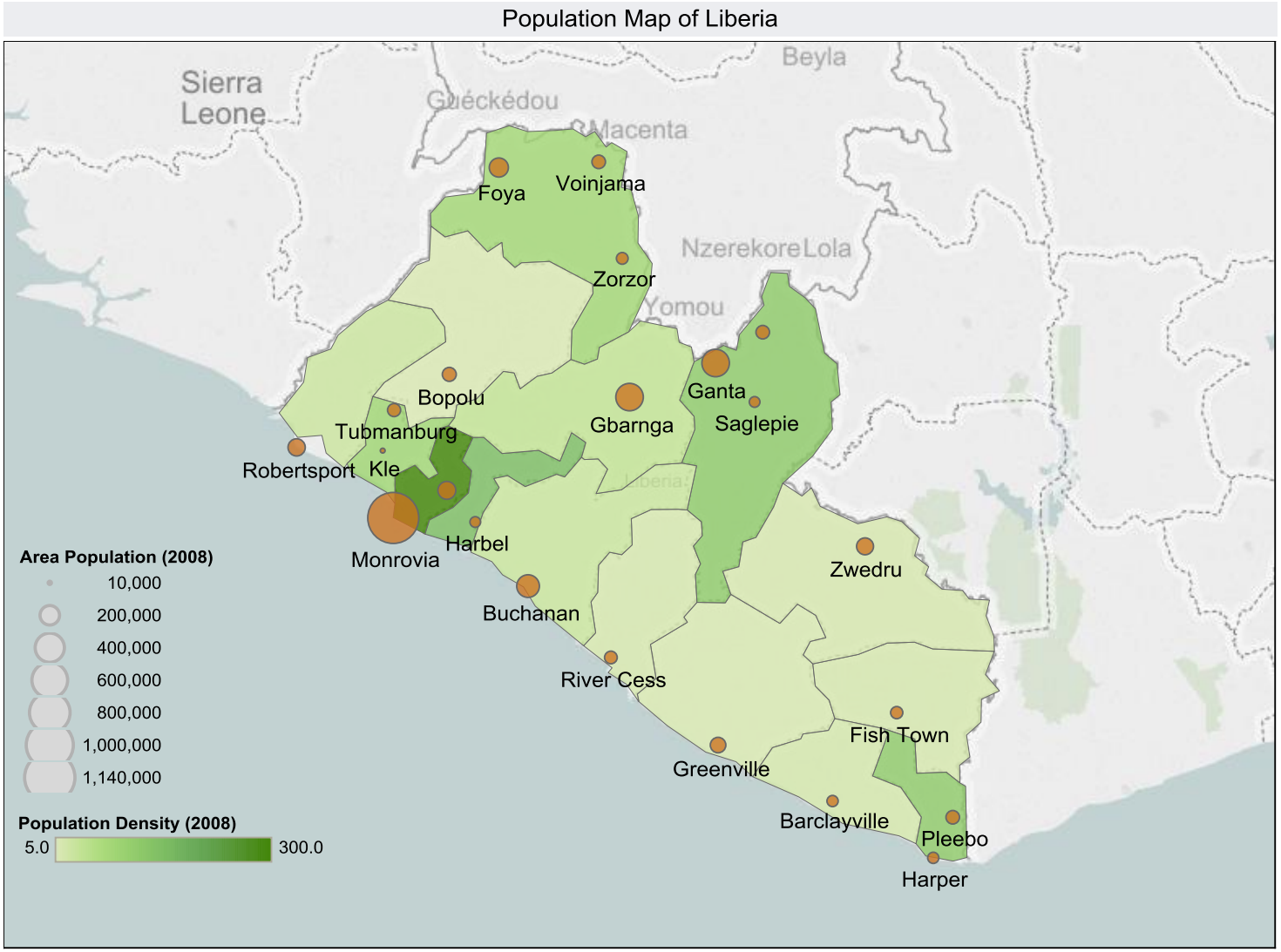


Example Simulation Components

- People
  - Patients
  - Couriers
  - Clinical and Lab Workers
- Facilities and Locations
  - Clinical
  - Laboratory
  - Communities
- Resources
  - Beds
  - Vehicles
  - Lab Equipment and Turnaround Time
- Processes
  - Generation of symptomatic people from communities
  - Travel of symptomatic to ETU
  - Blood Draw at ETU
  - Holding symptomatic awaiting results
  - Transport of Samples
  - Processing of Samples
  - Reporting of Results
  - Segregating infected and non-infected
  - Supplying ETU's and Labs

Simulation input: Liberia Population



Simulation Input: Epi Projections

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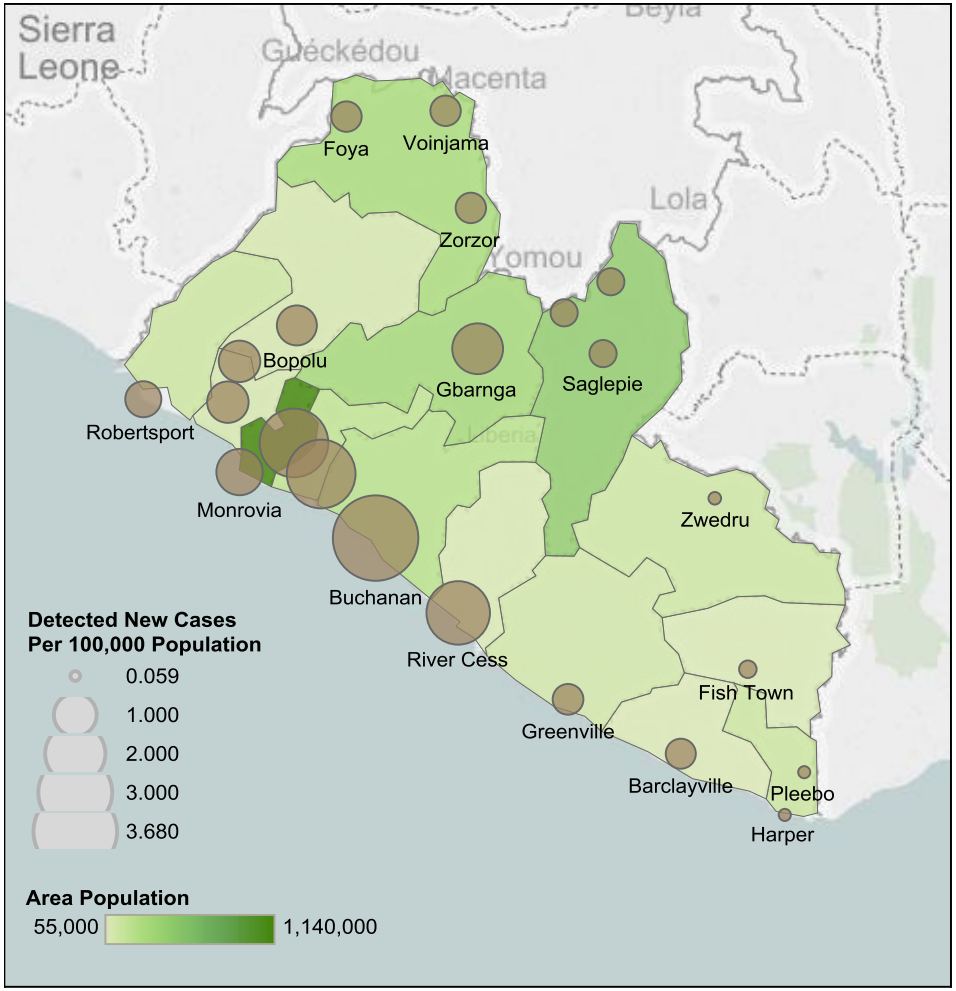
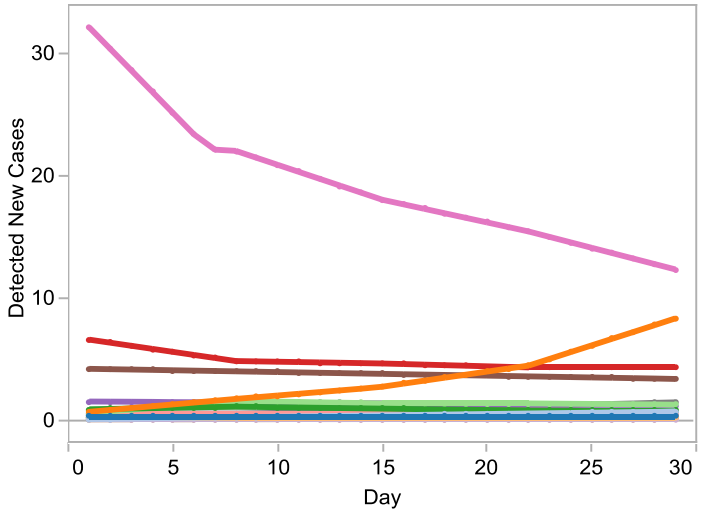
Epi Assumption Map - 29

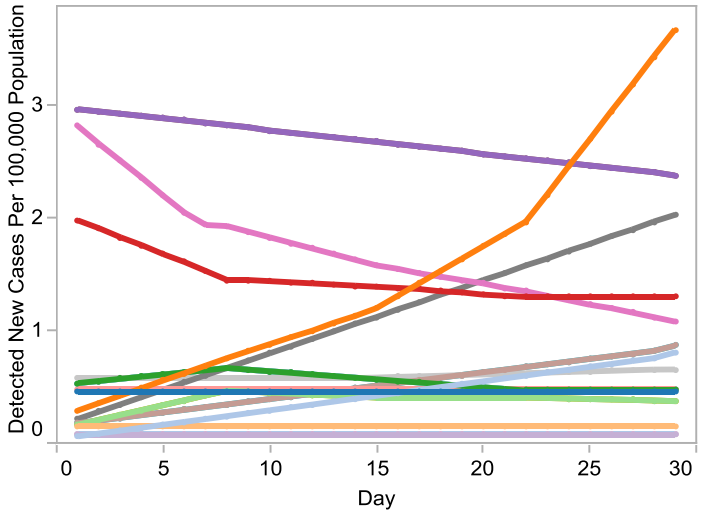


Day
29
☐ Show History

Ebola Case Projections (From Nov. 2, 2014)



Ebola Case Projections, Normalized by Population



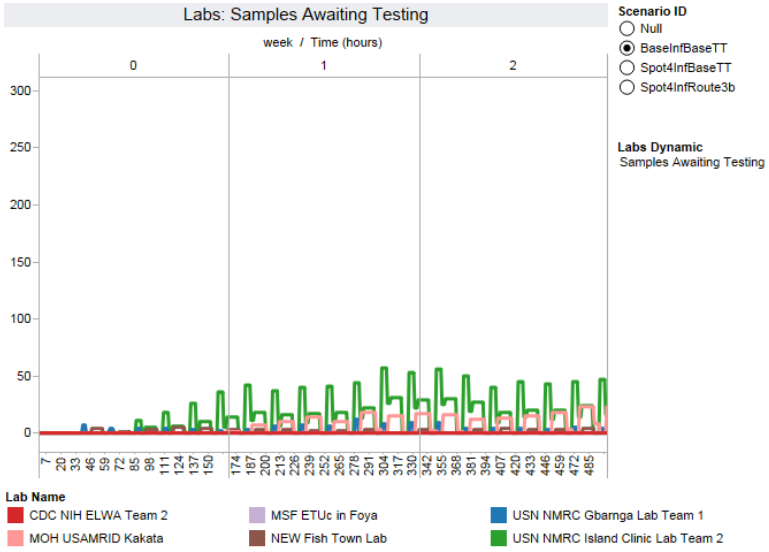
Place Name1

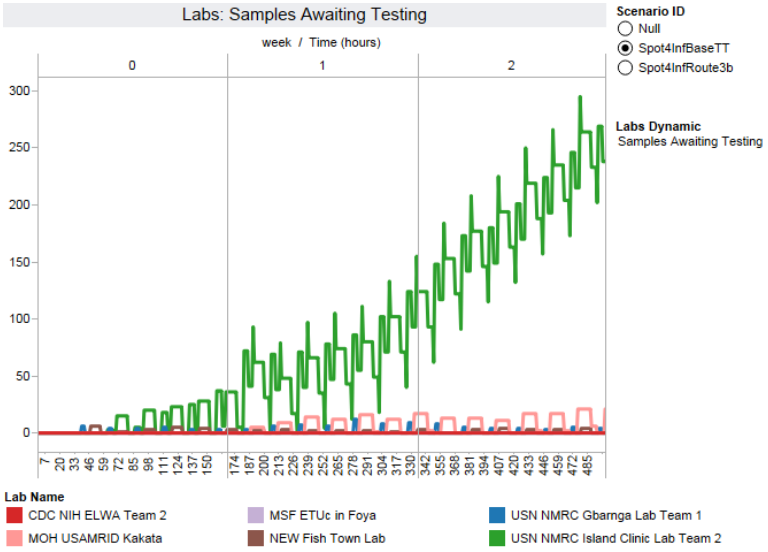
- Barclayville
- Bopolu
- Buchanan
- Fish Town
- Foya
- Ganta
- Gbarnga
- Greenville
- Harbel
- Harper
- Kingsville
- Kle
- Monrovia
- Pleebo
- River Cess
- Robertsport
- Saglepie
- Sanniquellie
- Tubmanburg
- Voinjama
- Zorzor
- Zwedru

Data: Epi projections for select counties courtesy of Jeff Shaman, http://cpid.iri.columbia.edu/ebola_p..

Test Scenario: Outbreak Hotspot

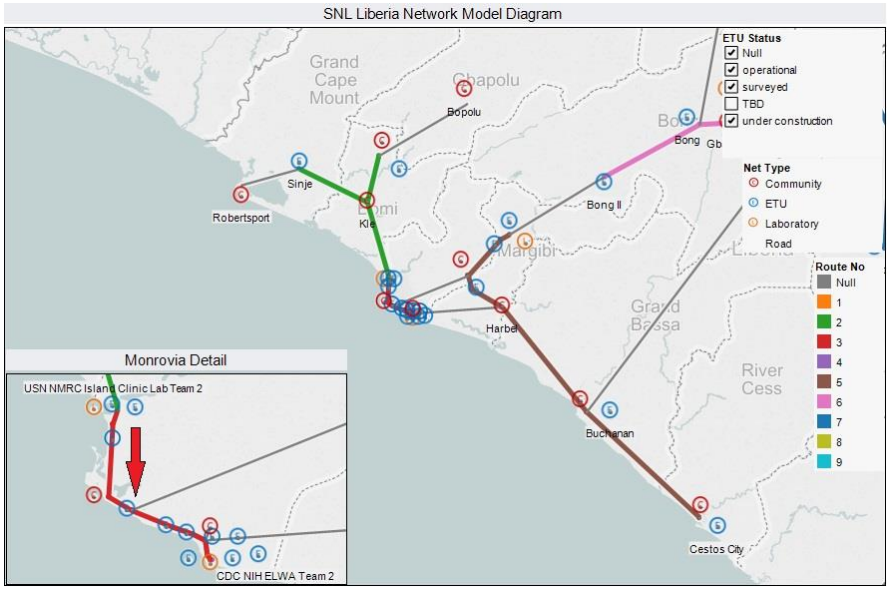
- Scenario: Outbreak in rural communities north of Monrovia – Robertsport, Tubmanburg, Klu area patients presenting at Sinje and Tubmanburg clinical facilities
- Induces overloading on Island Clinic laboratory
  - Island Clinic currently receiving samples from northern communities and from within Monrovia

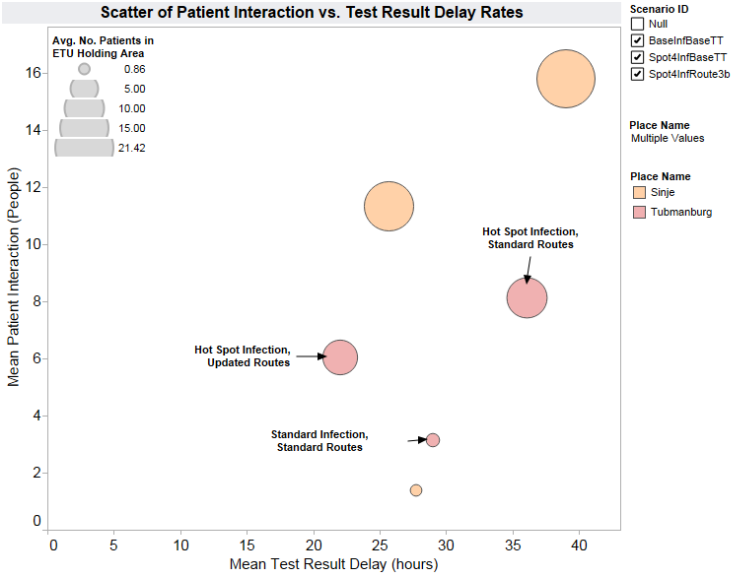




Addressing hotspot by rerouting

- Address overload by rerouting samples taken within Monrovia to ELWA lab
- Rerouting reduces load on Island Clinic, which in turn reduces patient-patient contact in holding units





Summary

- Sandia team integrated multiple methods to address transport problem.
- Designed robust solution based on complementary model results and realistic understanding of public health systems in country
- Results being used now to implement new system in-country
- Lessons Learned
  - Multiple simple methods often better than large comprehensive model
  - Close interaction with in-country people essential
  - Dynamic solutions required for fast-moving situation

Next Steps: Applying systems methods to the wider Ebola crisis

- Continue supporting Liberia response agencies as outbreak evolves
- Apply methods to sample transport problems of other West African countries
- Extend ETU and Lab logistics modeling to analyze national supply chain issues
- Adapt methods to other transport problems, e.g. medications or vaccines, sample transport in non-outbreak situations

Acknowledgements

- Liberia Partners
  - CDC
  - USAID
  - DOD
  - NGOs
  - Ministry of Health

- Sandia Crew:
  - Ben Brodsky, Lisa Gribble, Jared Gearhart, Chris Frazier, Katherine Jones, Tom Moore, Walt Beyer, Robert Jeffers, Leo Bynum, Bill Fogleman

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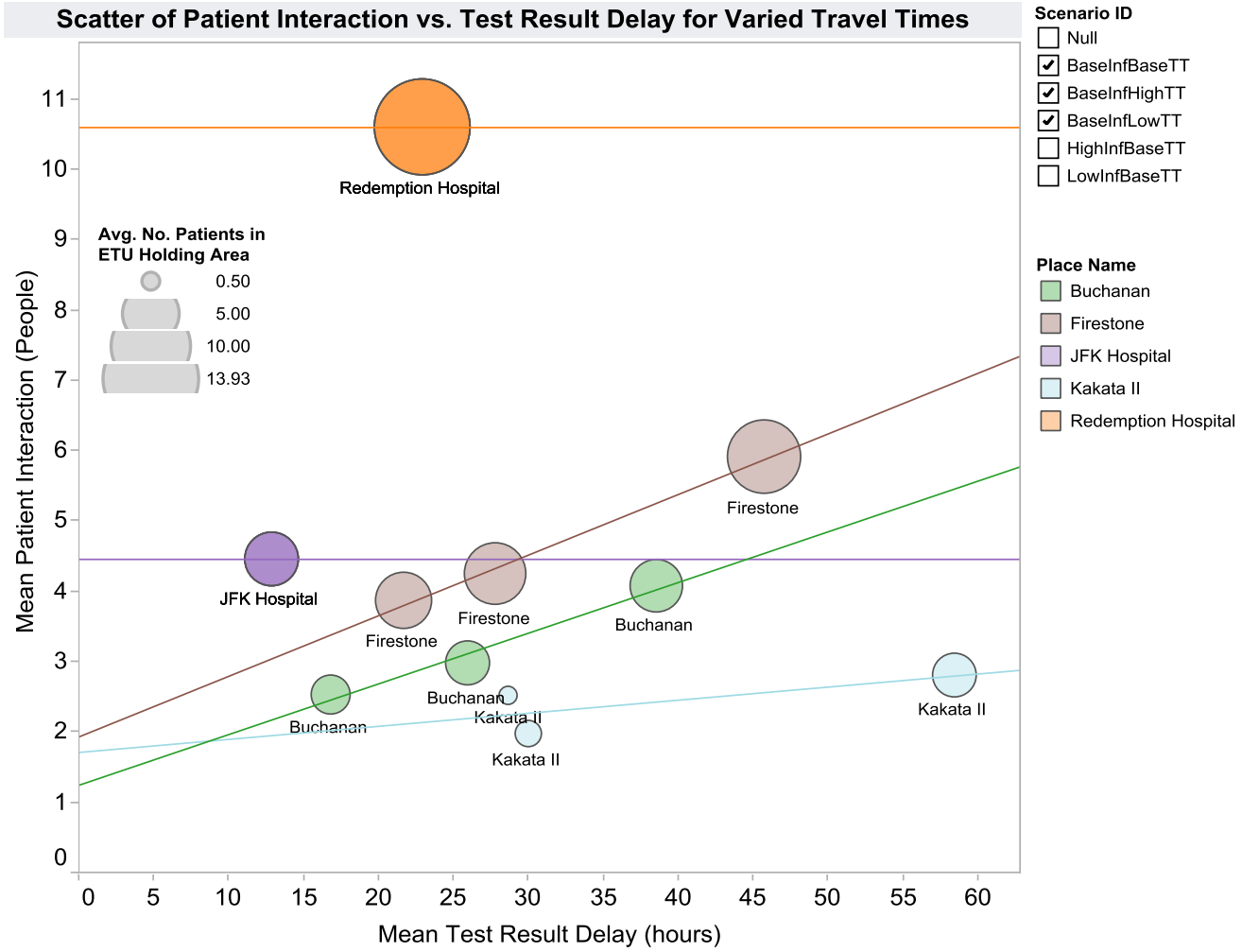
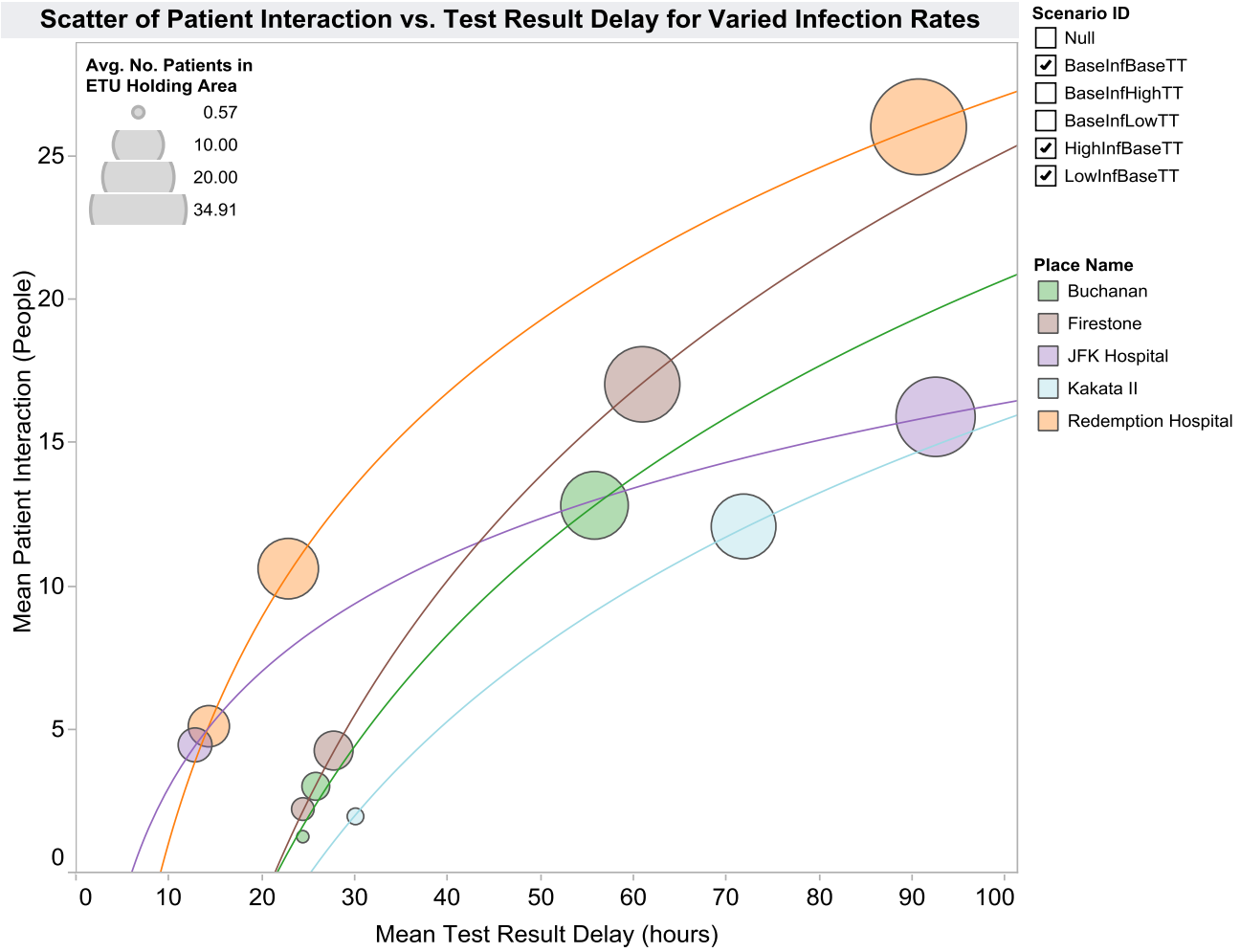
Backup Slides

Sensitivity of Patient Interactions to Delay in Diagnosis



Sensitivity of EHU Patient Interactions to Community Infection Rate



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