U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Data Science & ML-Enabled Terminal Effects Optimization

Abstract #24034

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DISTRIBUTION A

ABOUT ME

Name

- John Cilli

Education

- Bachelor's in Computer Science
- East Stroudsburg University

Workplace

- Picatinny Arsenal – Systems Analysis Division

Role

- Decisions Branch - Computer Scientist

AGENDA

Current Workflow

- Issues

Prospective Workflow

- Why?
- How?
  - **Historical Data**
  - **Design of Experiments**
  - **Bayesian Optimization**

Development

- Progress
- Future Development

WHAT WE HAVE NOW? - OVERVIEW

Current Iterative Design Optimization Loop

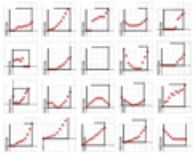
Compare Against Requirements

Generate Performance Data

Run Surrogate Model

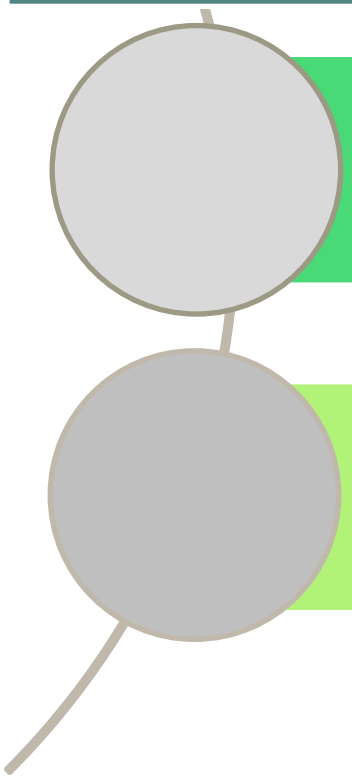
Optimize Parameters

Gather Outputs



WHAT WE HAVE NOW? - ISSUES

Findings gleaned from interviews with system analysts and from assessing past case studies



Challenges in parametrization and space exploration during early phase of system study

Surrogate modeling inaccuracies for physics simulations with sharp phase changes

WHY? – PURPOSE, PRODUCTS, & PAYOFFS

Purpose:

- Apply AI/ML to workflows
- Fully leverage the exponential growth in tech
- Decrease computational cost

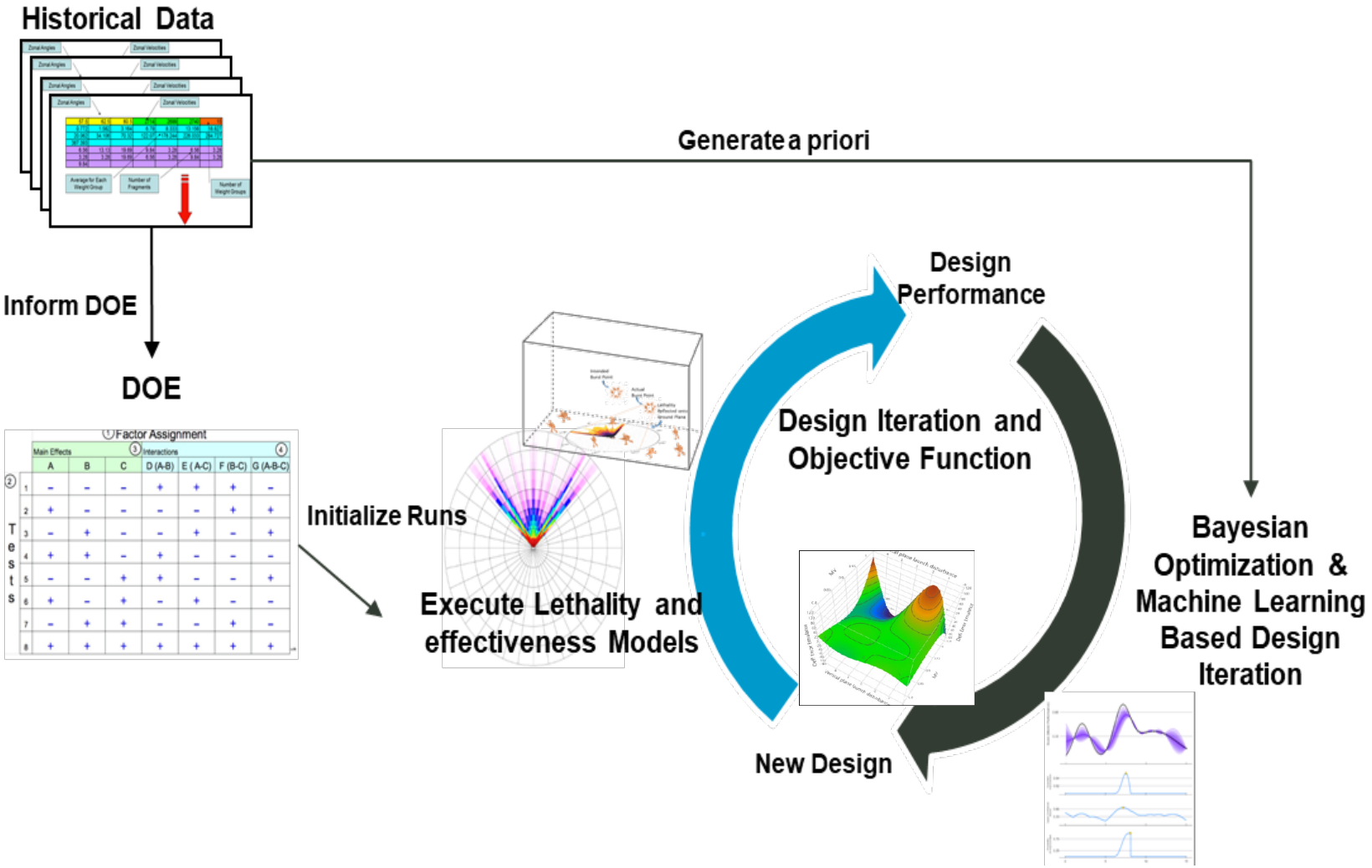
Products:

- ML and Optimization Processes
- Data driven workflow
- Data science software utilities

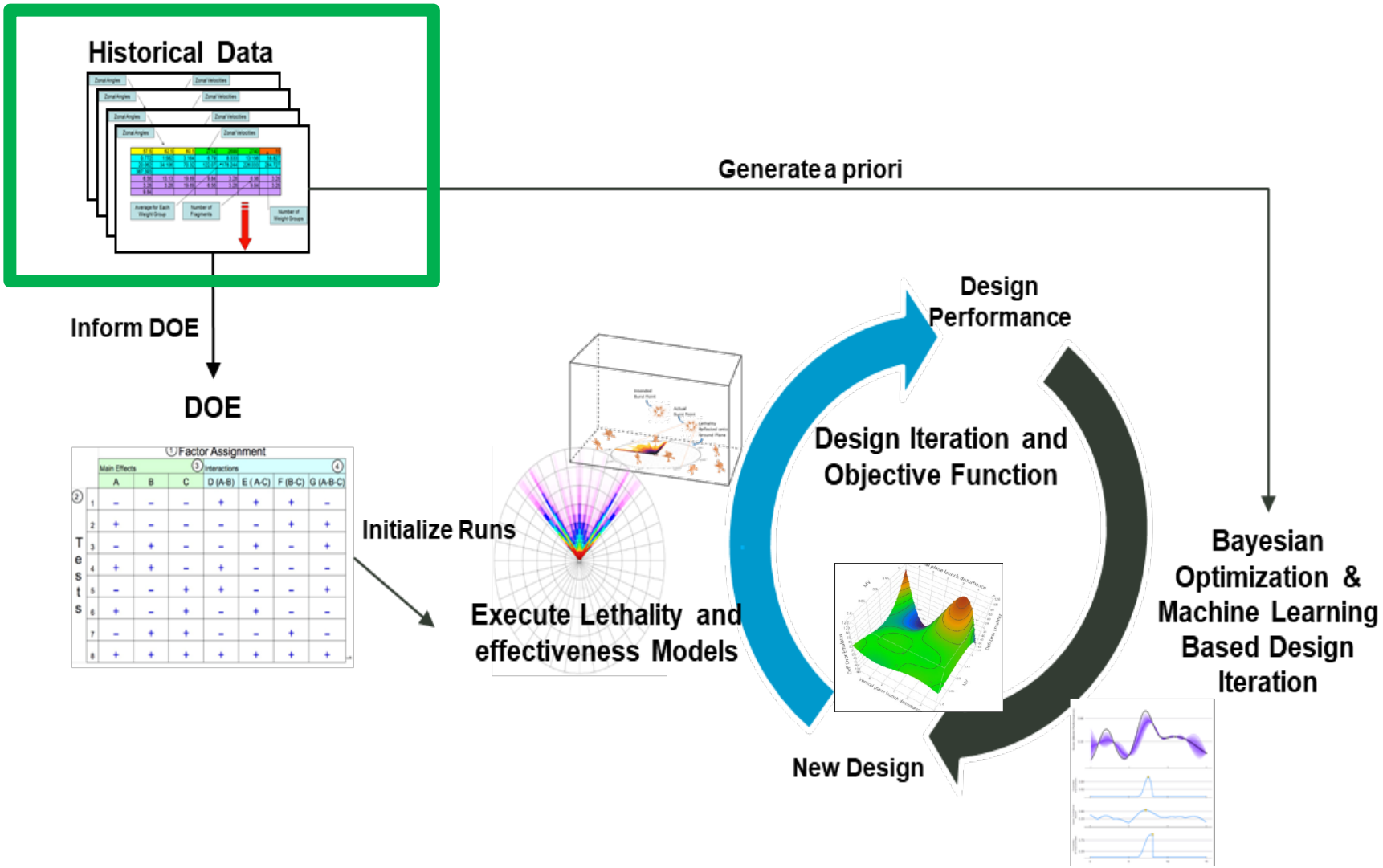
Payoffs:

- Innovative designs
- Rapid conceptualization
- Exploit past studies to better inform future developments

HOW? – ML OPTIMIZATION LOOP



HOW? – HISTORICAL DATA



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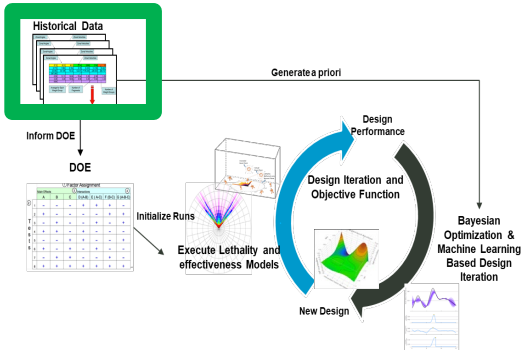


Large SQL Database

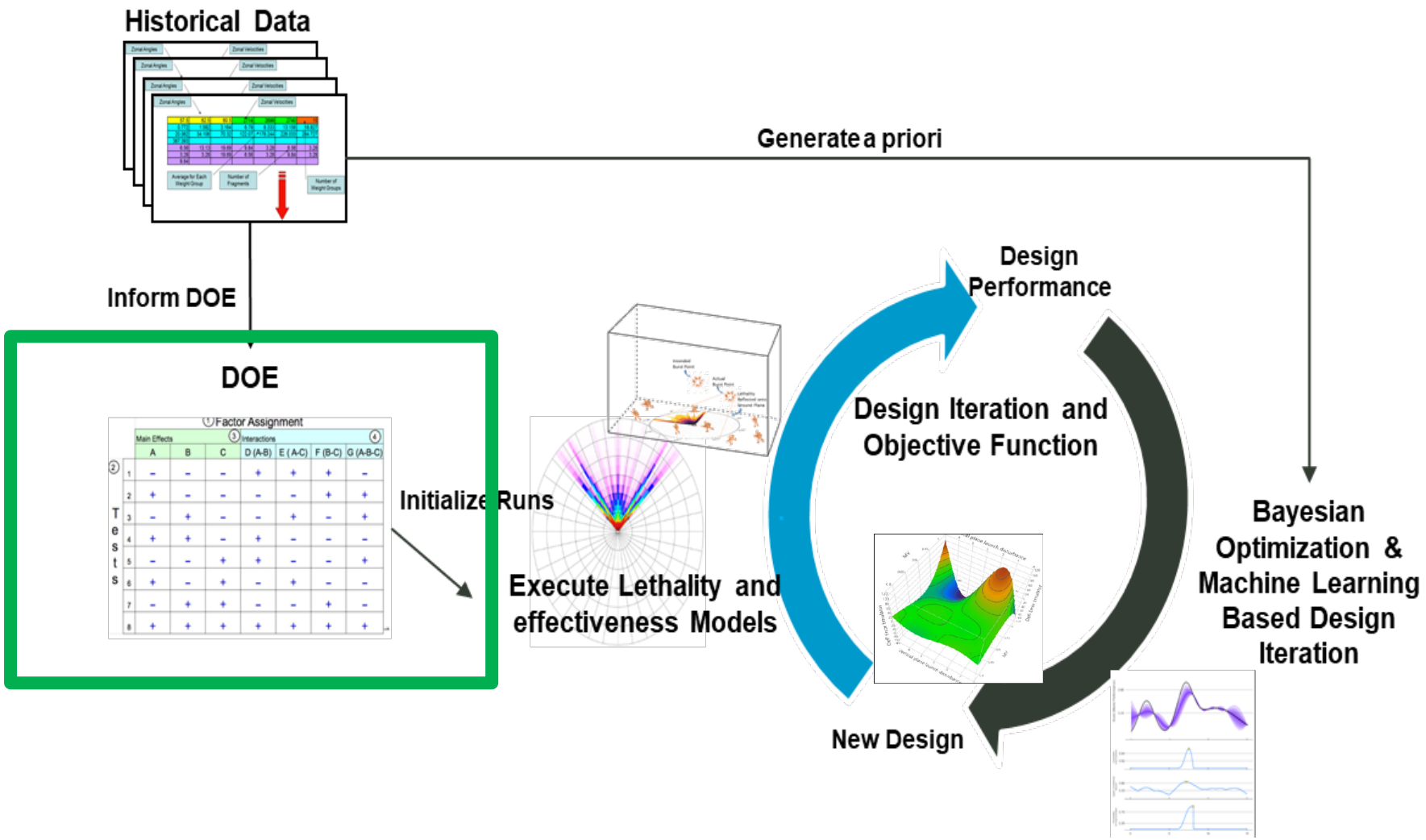
- Data-lake (raw data)
- Data-warehouse (processed data)

Ability to track between projects

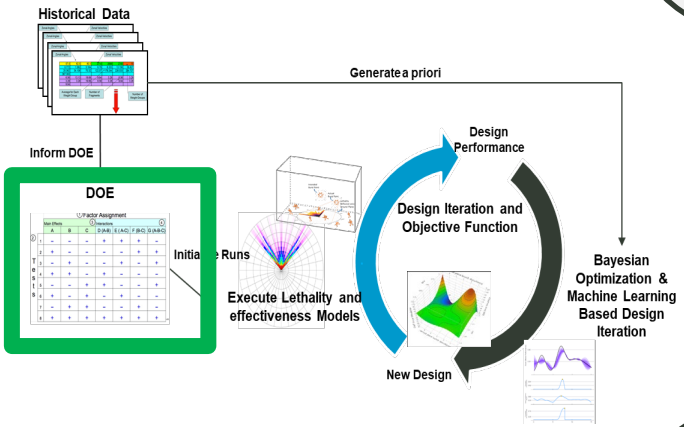
Enhance database search capabilities

Increase lifetime we can store our data

HOW? - DESIGN OF EXPERIMENTS



HOW? - DESIGN OF EXPERIMENTS

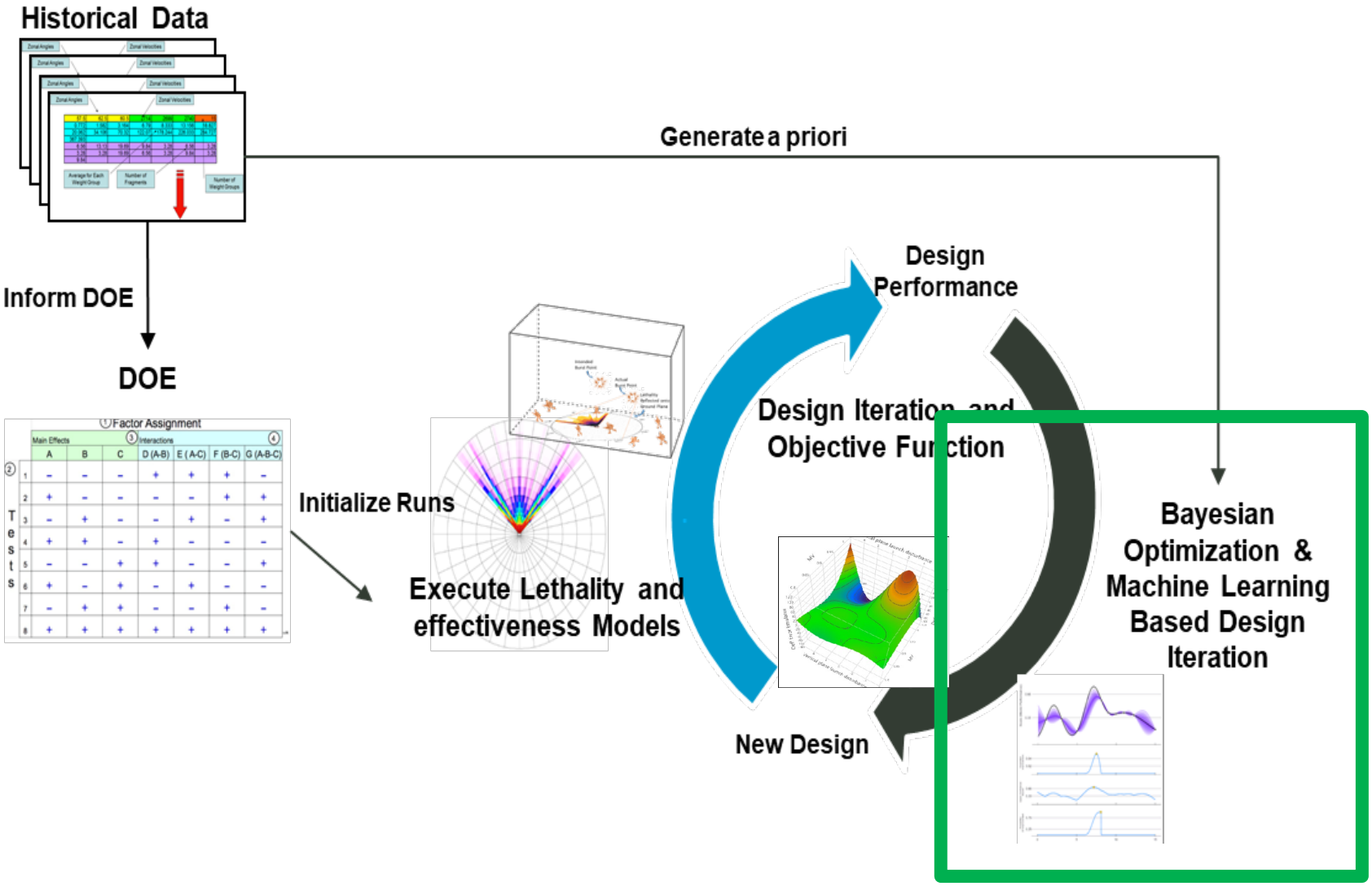


Systematic method to explore relationship between inputs and outputs

Decreased time to explore trade space

Increased understanding of trade space

HOW? – BAYESIAN OPTIMIZATION



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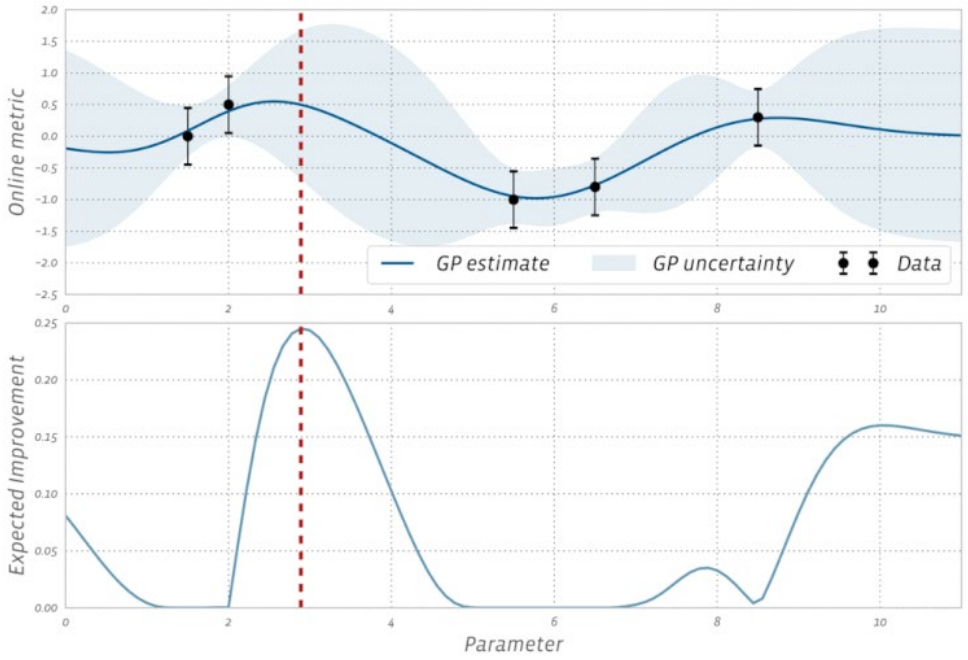


Two components:

- Surrogate model (usually Gaussian process)
- Acquisition function

Effective for optimizing functions that are:

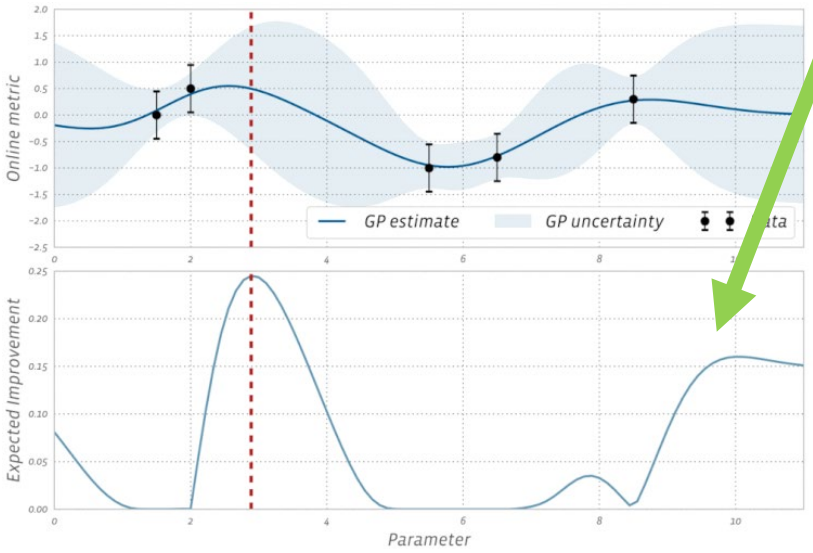
- “black box” (no analytical form, no gradients)
- noisy
- expensive to compute

Surrogate model estimates the objective function

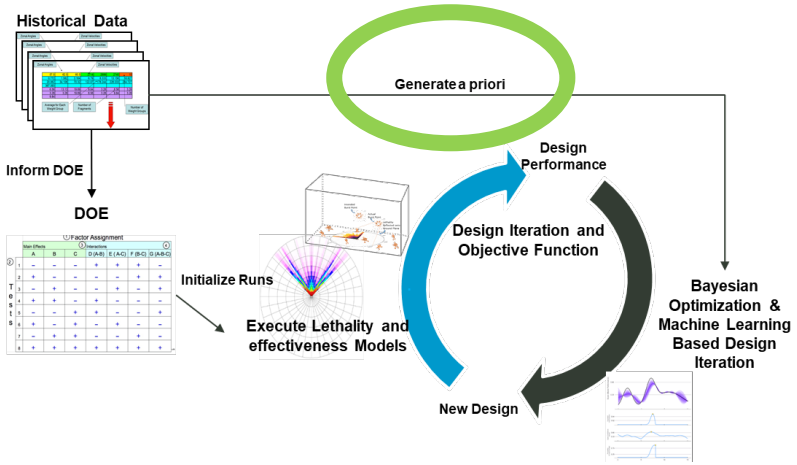
Acquisition function tells you where to probe next

Trades off exploitation and exploration

HOW? – BAYESIAN OPTIMIZATION



- **Acquisition function is heuristically designed (can be anything)**
- **Function parameters leverages:**
  - **Historical data from previous iteration runs**
  - **A priori information from domain knowledge or runs from disjoint instances**



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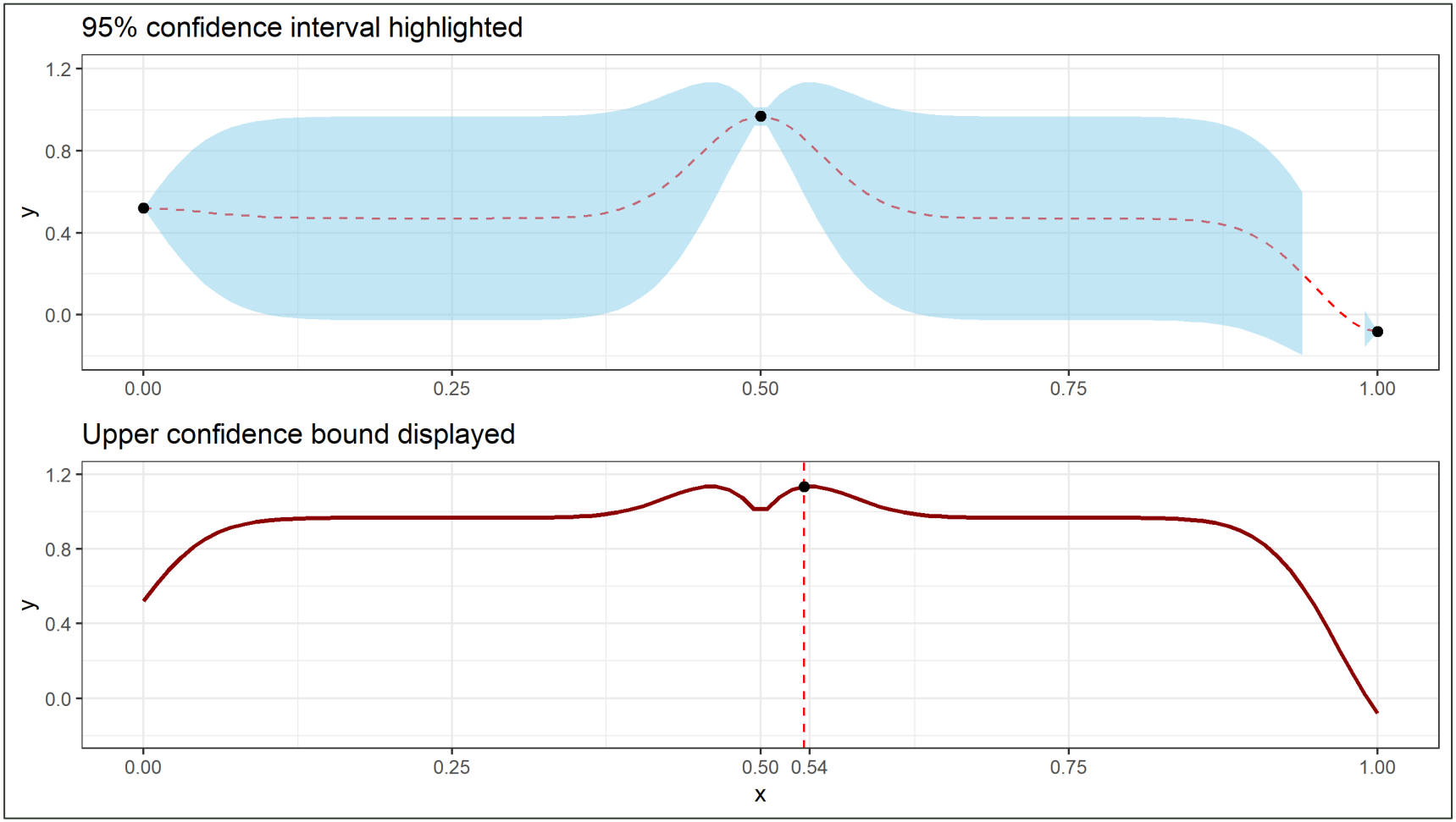

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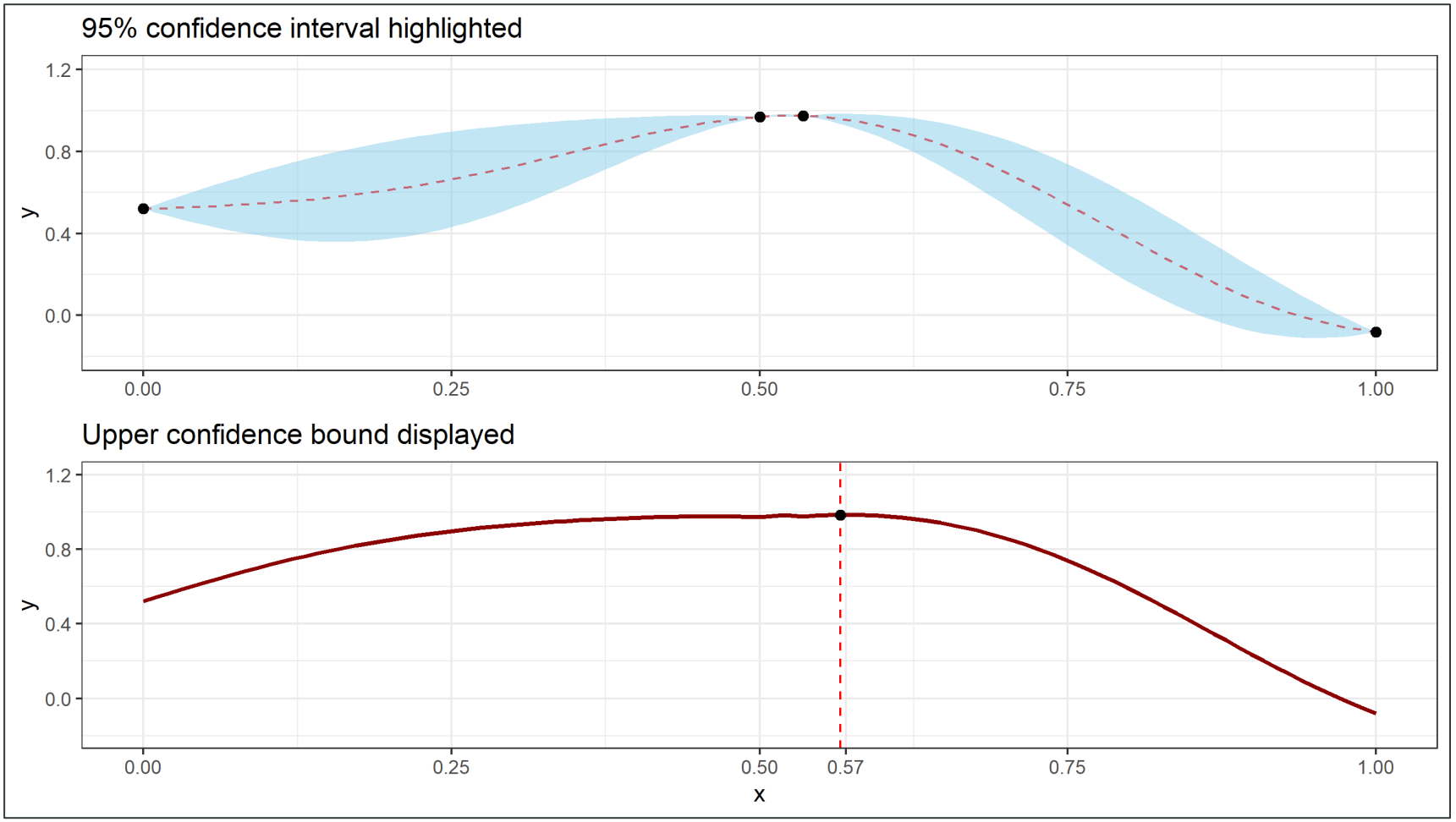

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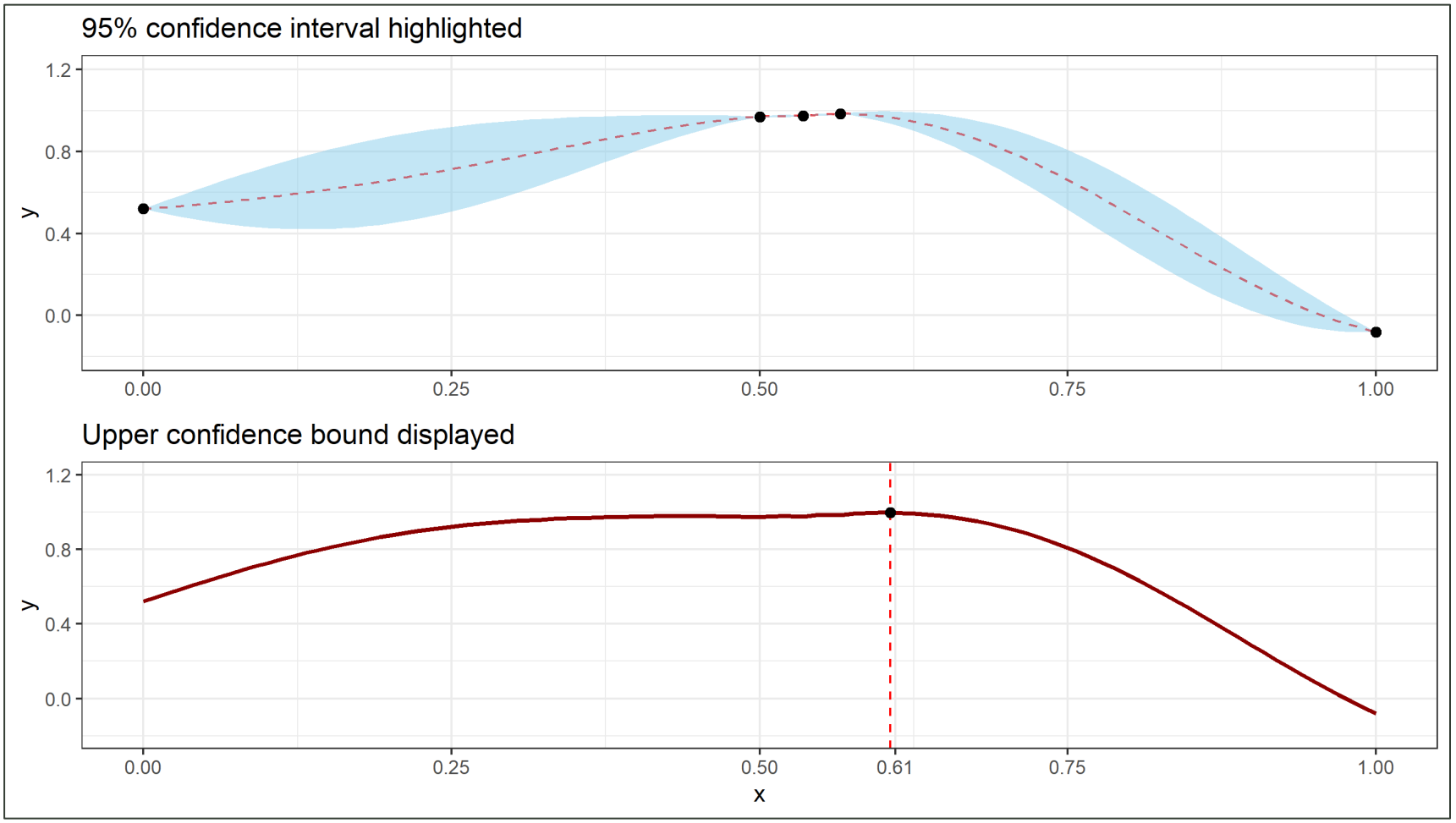

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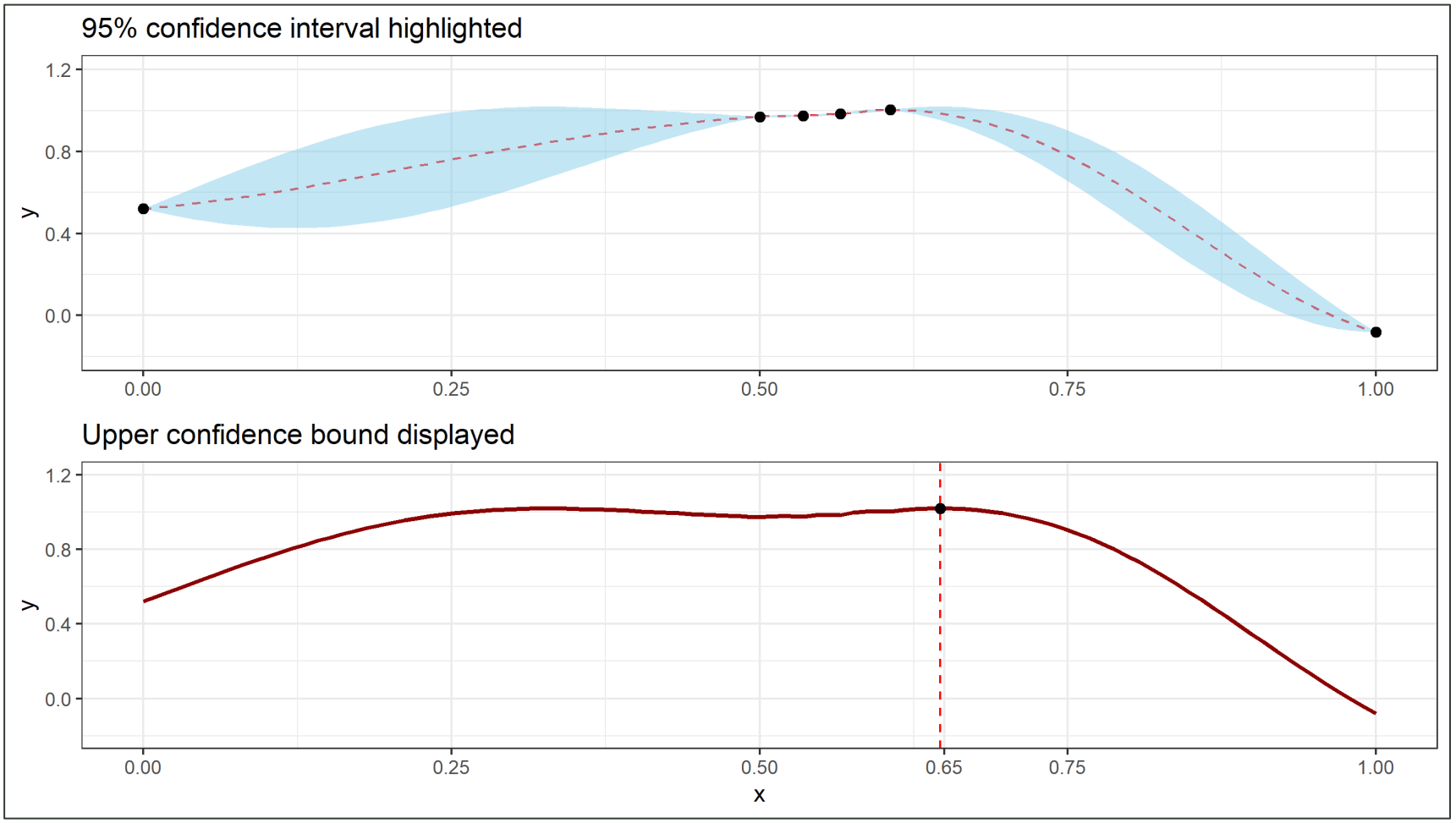

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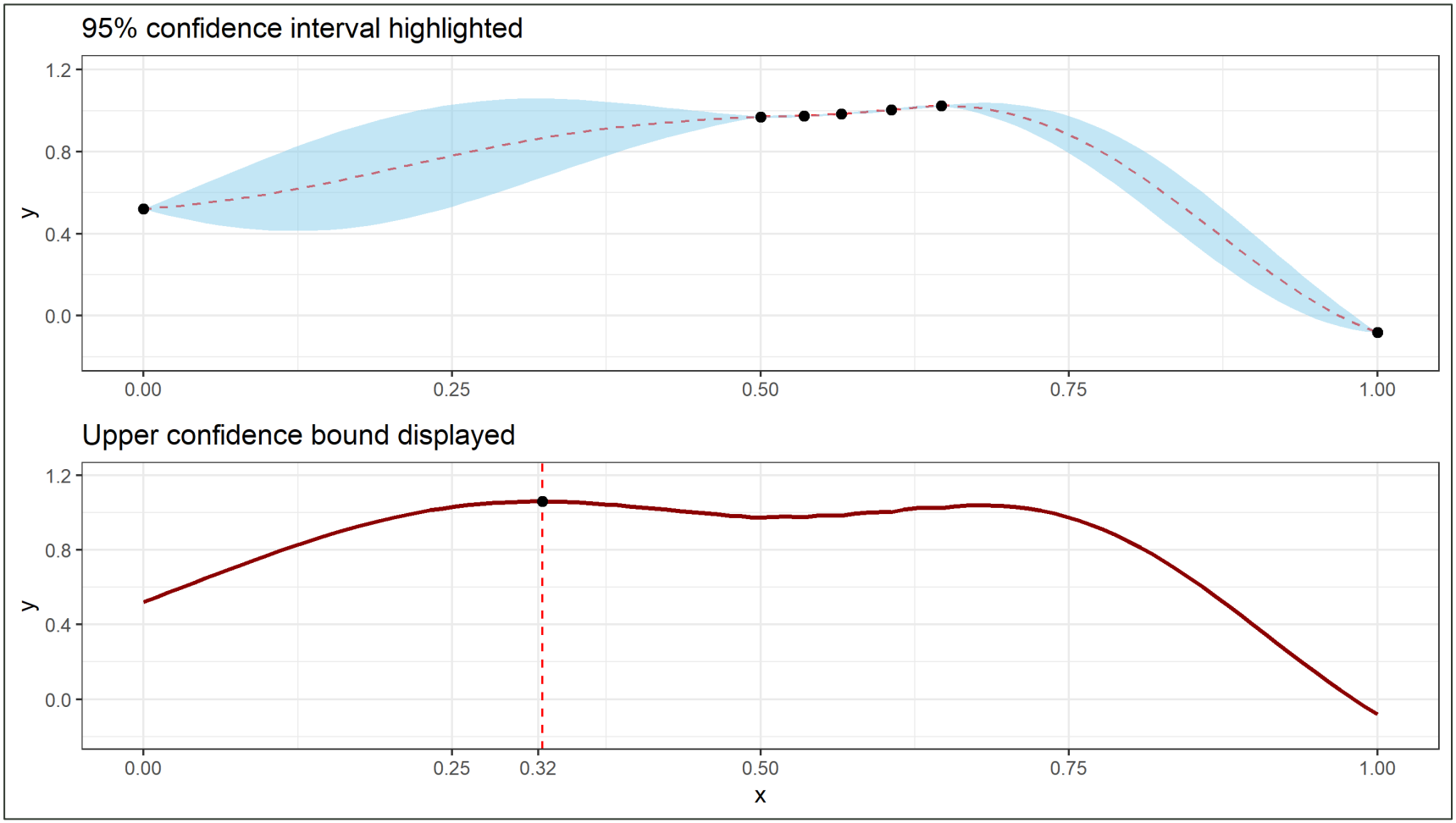

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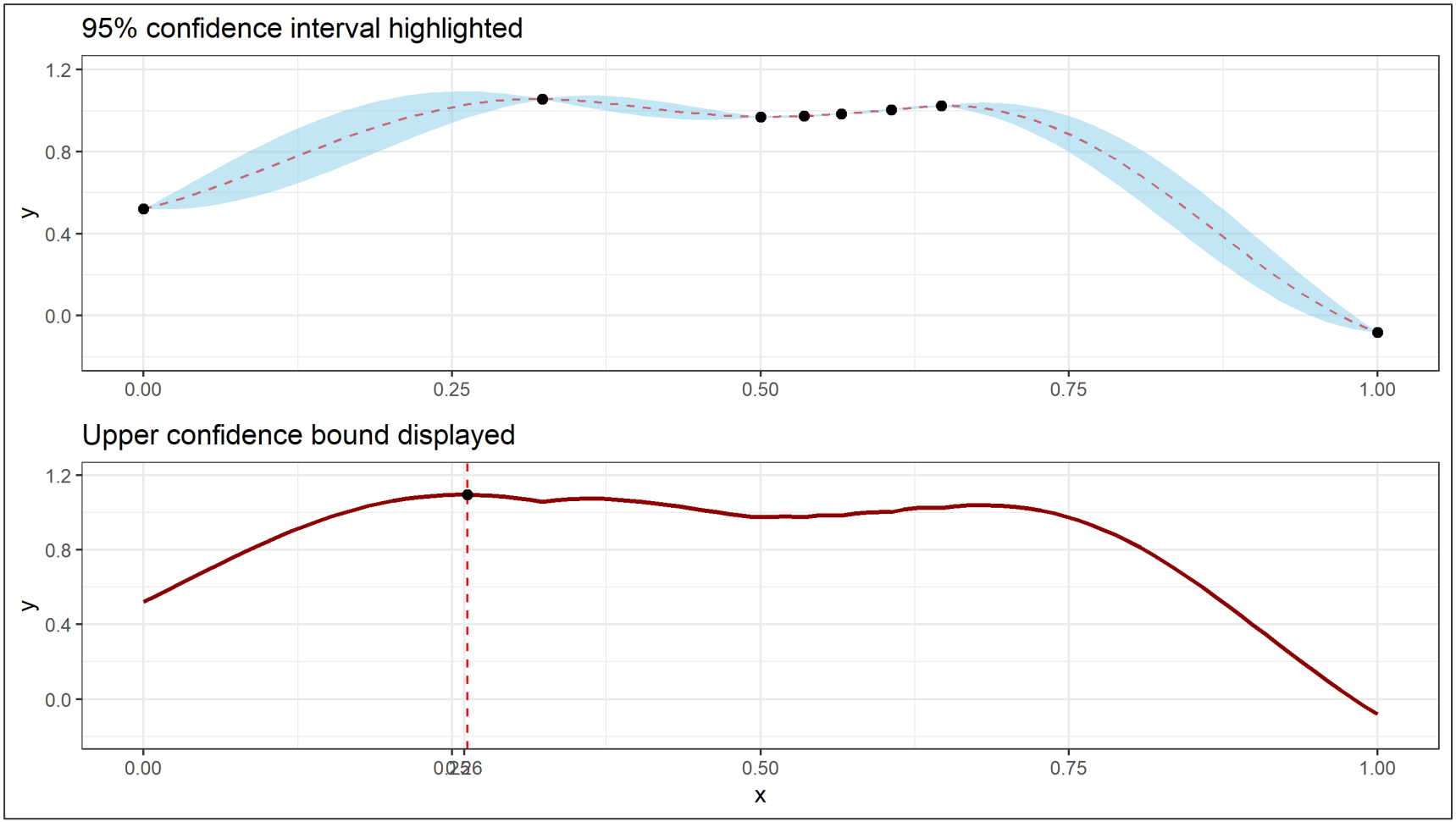

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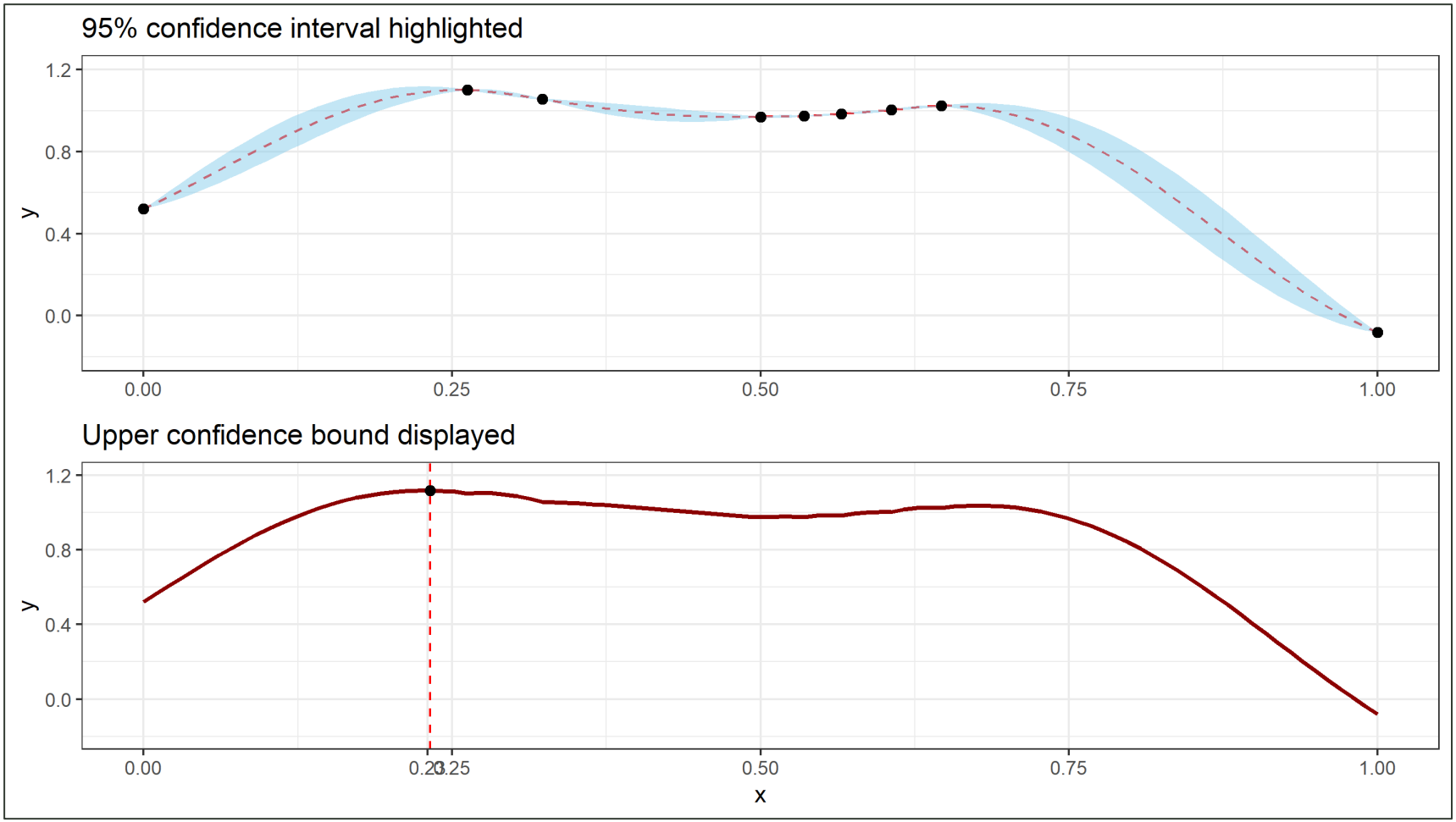

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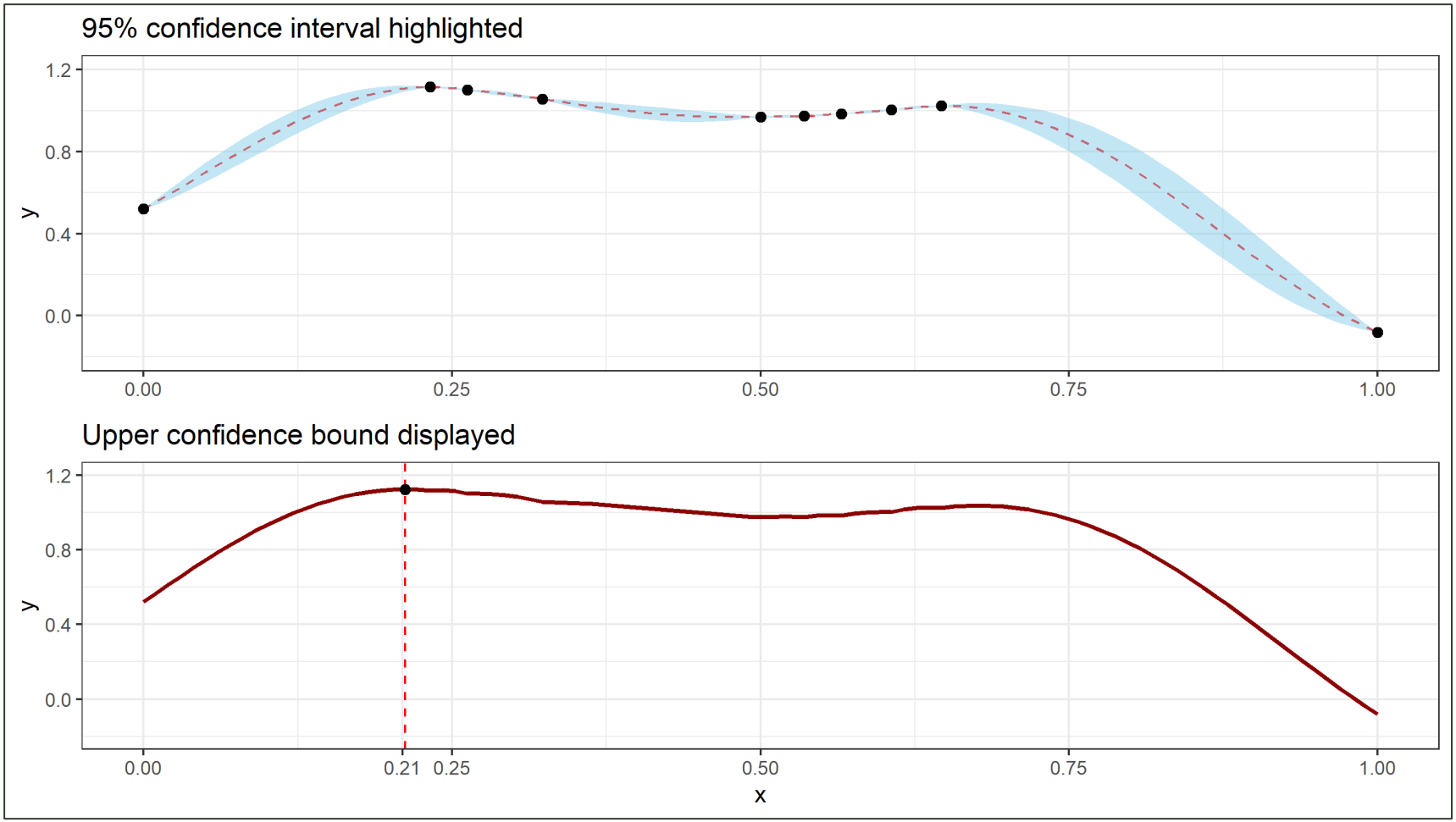

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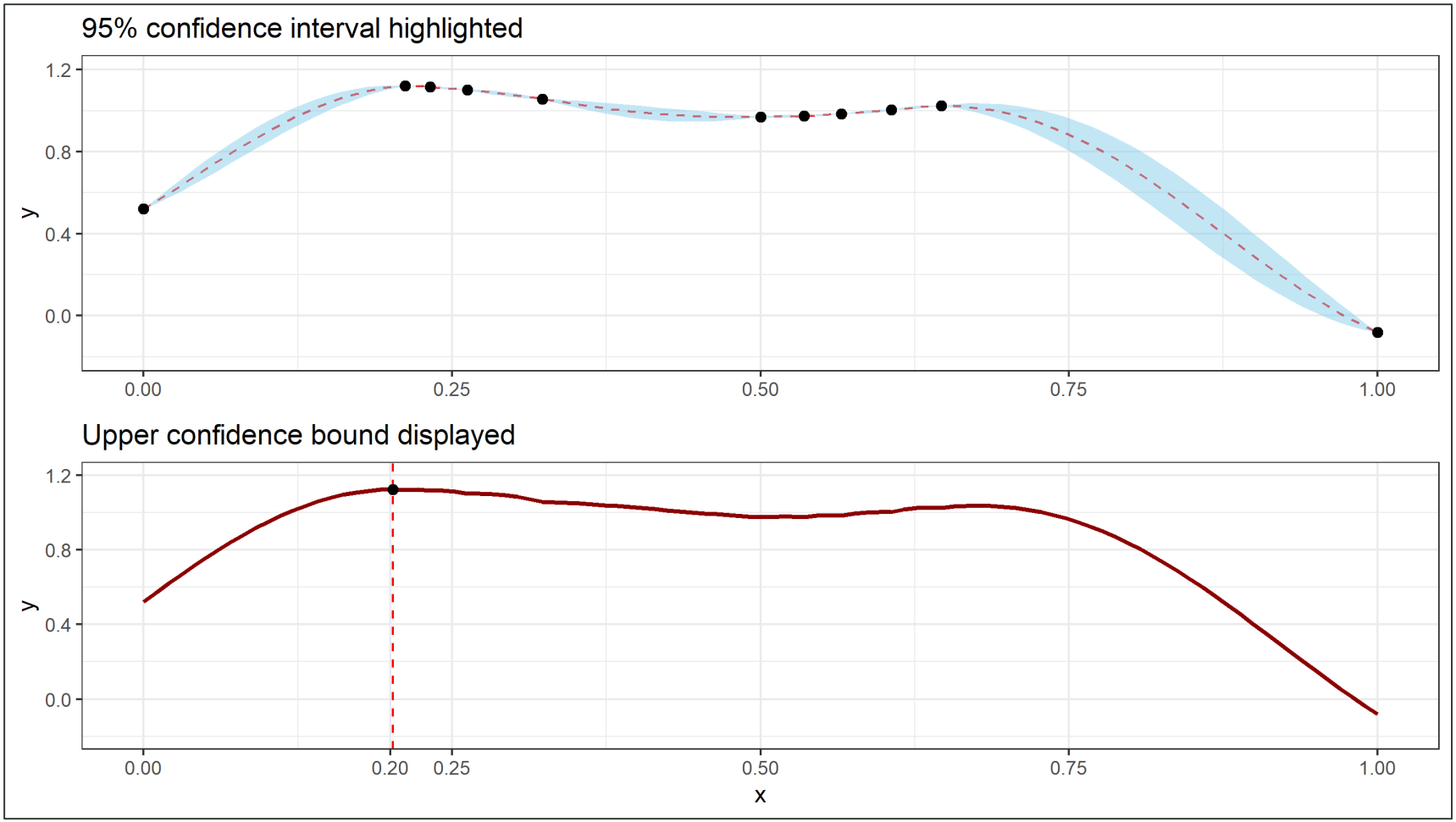

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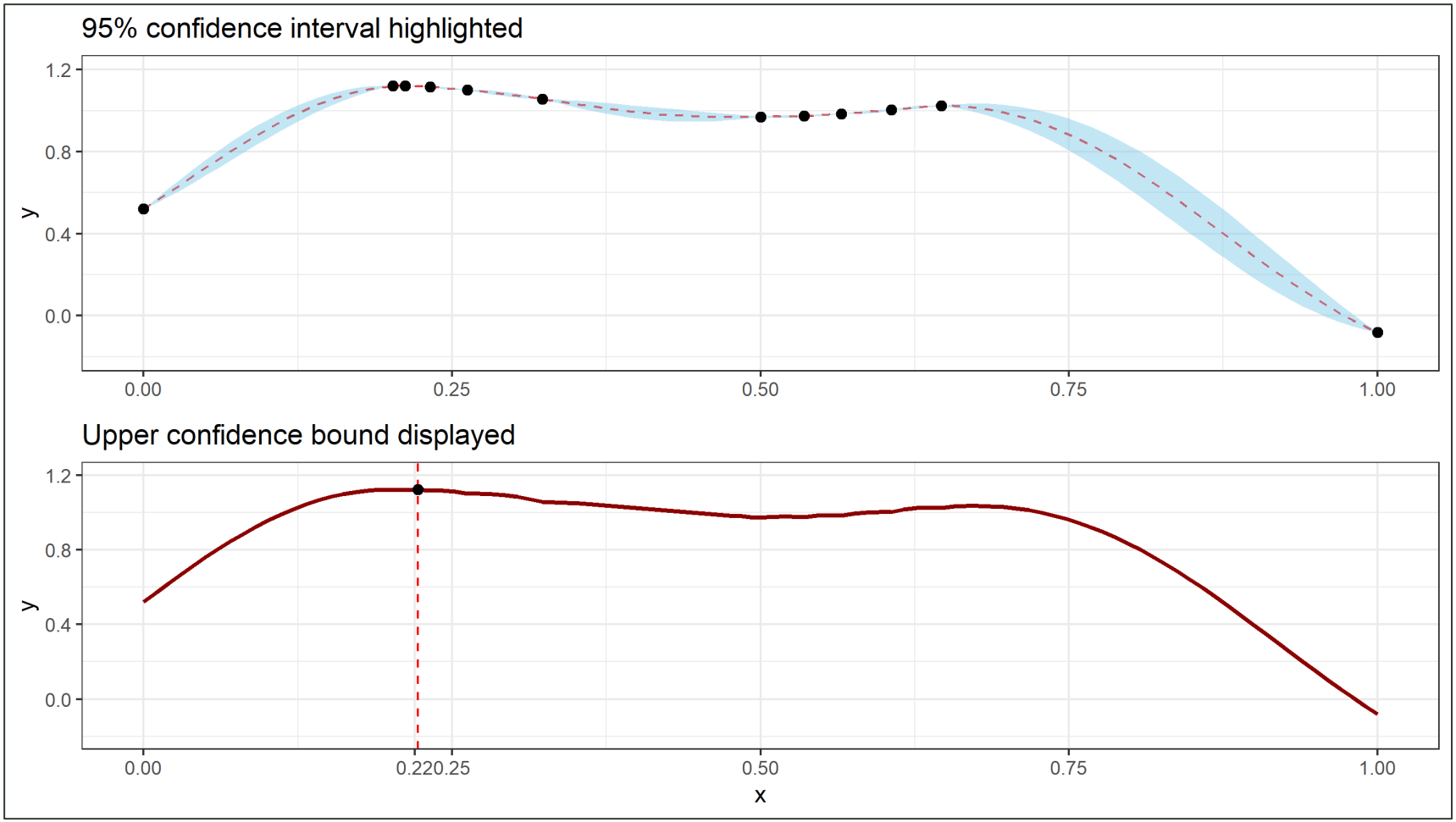
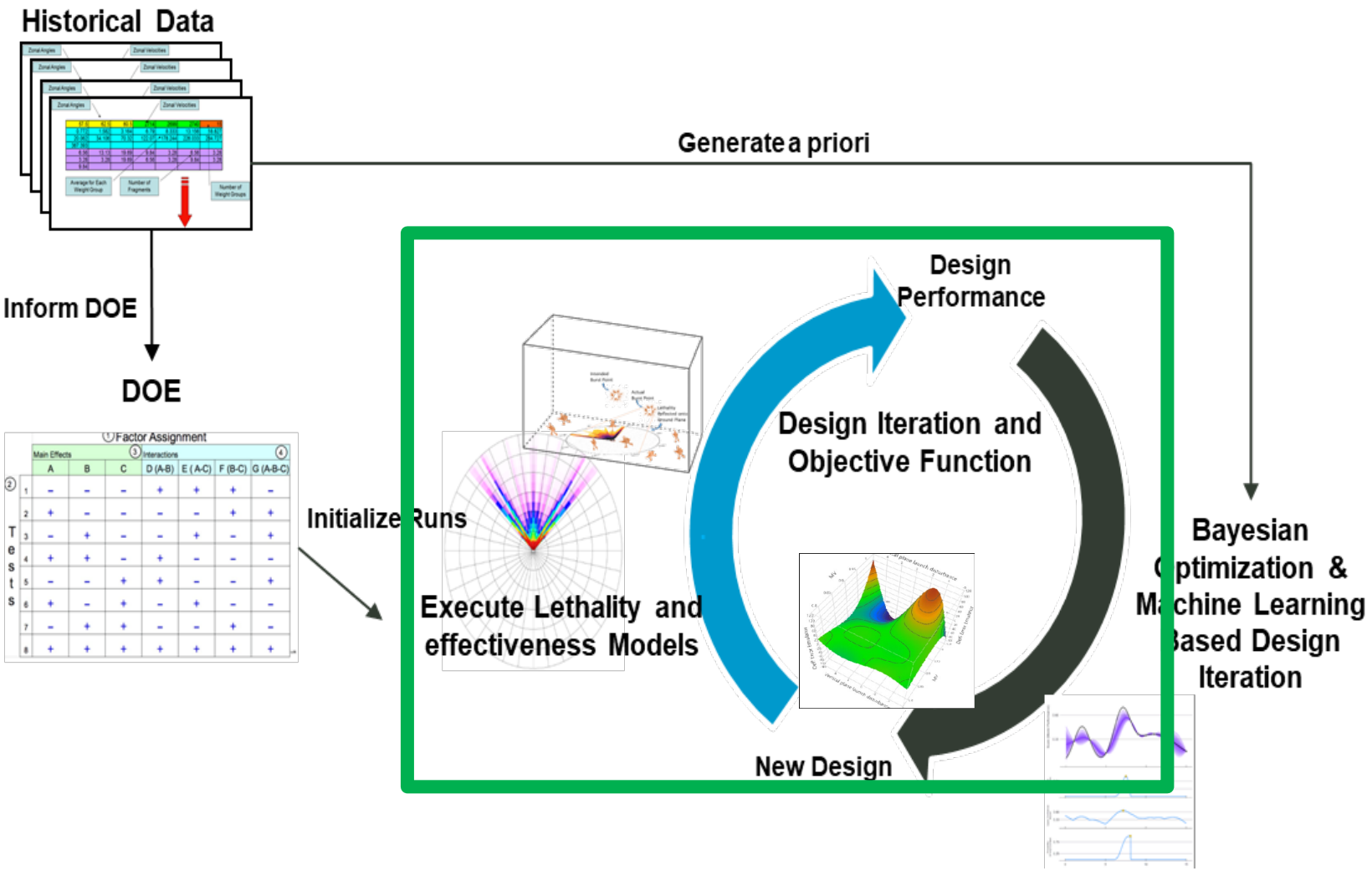


HOW? – DESIGN ITERATION PROCESS



HOW? - TOOLS

Python	High-level general purpose programming language
Jupyter	Open source web app, used to create and share documents
Dask	Open source library for distributed computing
HoloViews	Open source library for data analysis and visualization
Scikit-optimize	Simple and efficient library to minimize (very) expensive and noisy black-box functions

WHAT HAVE WE DONE?

- Prototype framework for Command Line Interface model optimization
- Improved data science capabilities in System Analysis Computer Lab
- Characterized deficiencies of warhead design loop & conceptualized potential solutions

WHAT IS PLANNED FOR THE FUTURE?

- Optimization framework support for Dask
- Use case for leveraging DOE and a priori knowledge from historical data
- Use case incorporating space-filling design into optimization framework
- Trade-space visualization
- Characterizing potential efficiencies in standardizing a data management practices
- Exploring complex surrogate modeling techniques that address phase change issues in physics simulations

Questions?