

## The Bottom Line

- ▶ Problem
  - ▶ With BayesOpt: small data  $\implies$  instability
  - ▶ Especially in high noise environments
- ▶ Proposed Solution
  - ▶ Repeat samples to gather statistical information
- ▶ Results
  - ▶ Better Repeatability
  - ▶ Better quality surrogate
  - ▶ No more function evaluations than standard approach

## Application Overview

- ▶ Human fighter pilots need recurring training
- ▶ Physical training is expensive
- ▶ Simulations provide many benefits, and are less expensive
- ▶ Simulated agents need to be adaptive[1]



Figure 1: Pilot in Simulator

## Problem Description

- ▶ Simulate an engagement between two agents
- ▶ Use 2 AIs instead of Human/AI pair
- ▶ Give opportunities for multiple encounters
- ▶ Provide multiple metrics for performance
- ▶ High-fidelity simulation engine
- ▶ AI agents with tunable behavior parameters

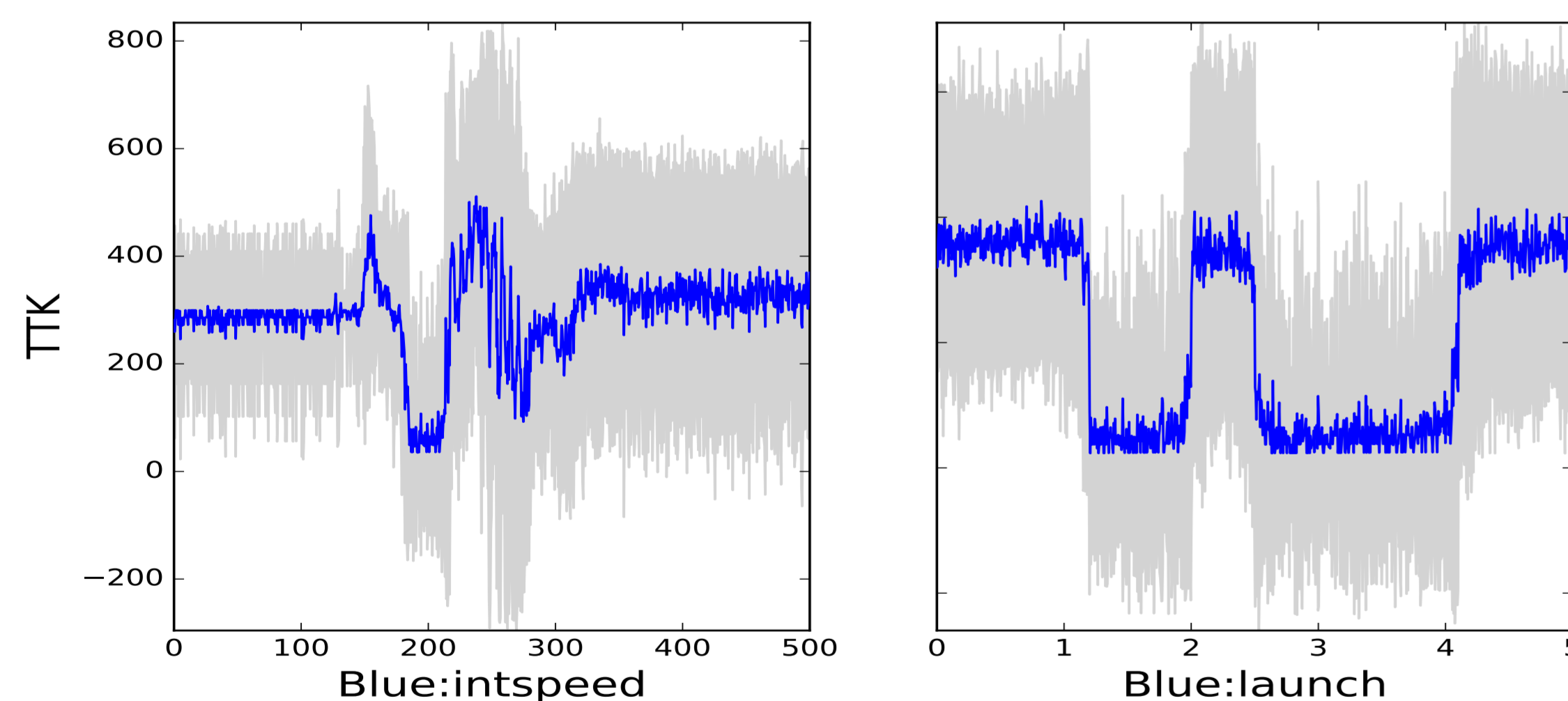


Figure 2: Examples Of 1D Objective Functions

## Methodology

- ▶ Parallel simulations are desirable
- ▶ Traditional Single Sampling (SS) fails
- ▶ Hybrid mixture of Repeat Sampling (RS) and Multi-point Sampling (MS) (HRMS)

## Methodology (continued)

- ▶ Intuition of RS: simultaneous variance information
- ▶ RS is analogous to experiment replication [3]
- ▶ Example on Forrester [2] function
- ▶ We evaluate  $q$ -EI, GP-UCB-PE, and TS (UCB plots shown here)

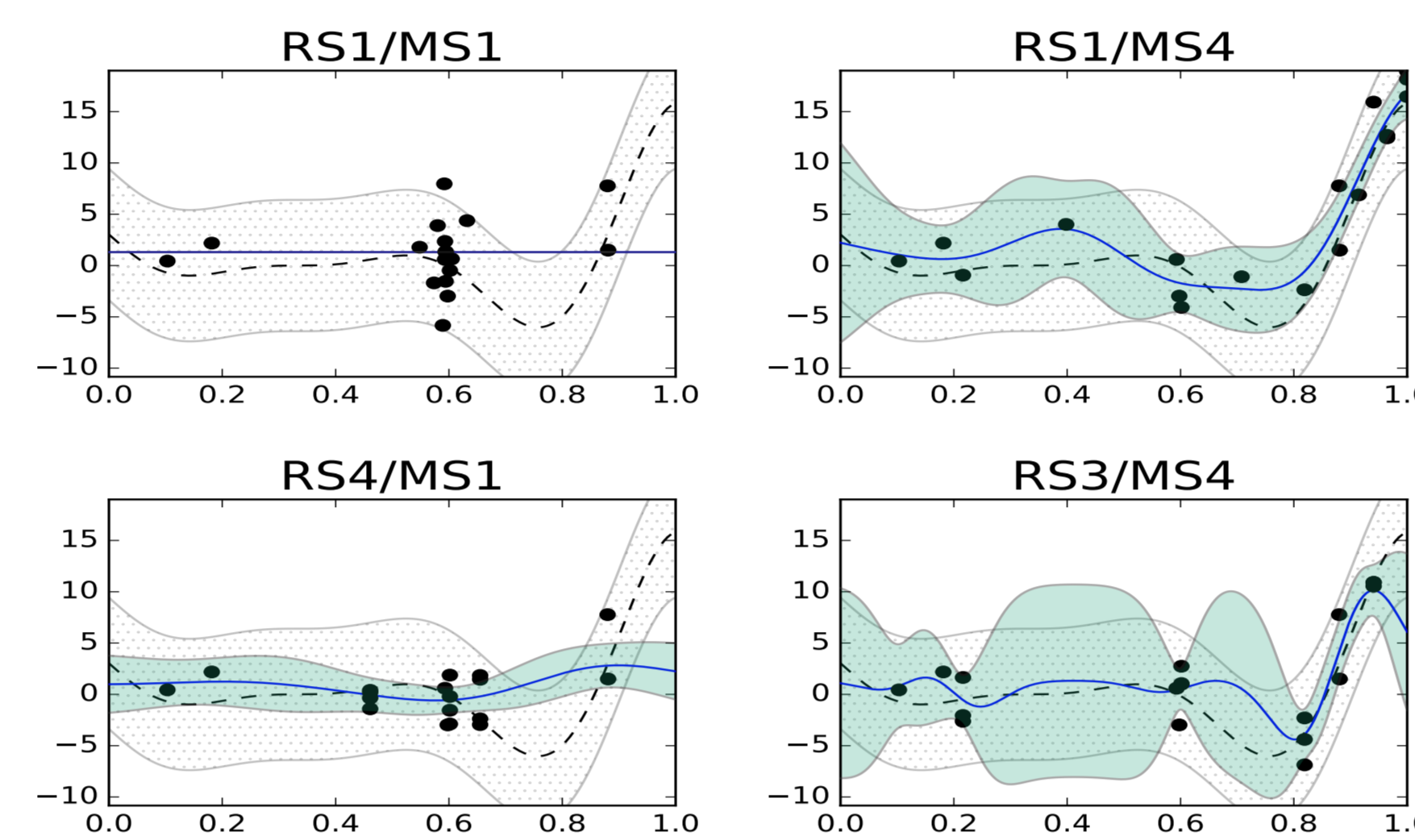


Figure 3: 1d Examples using Forrester Function

## Results: Summary

- ▶ Improves Surrogate Quality
- ▶ Improves Repeatability
- ▶ Better surrogate  $\implies$  Better Optimization
- ▶ How does RSMS help?

$$\log p(y|X, \theta) = -\frac{1}{2}y^T(K_t + \sigma_n^2 I)^{-1}y - \frac{1}{2} \log |(K_t + \sigma_n^2 I)| - \frac{n}{2} \log 2\pi$$

## Results: Surrogate Quality

- ▶ Surrogate quality is better (Figure 4)
  - ▶ Better hyperparameter estimates
  - ▶  $\sigma_n$  increases to compensate for poorly conditioned  $K_t$
  - ▶ Effectively lowers DOF when optimizing  $p(y|X, \theta)$

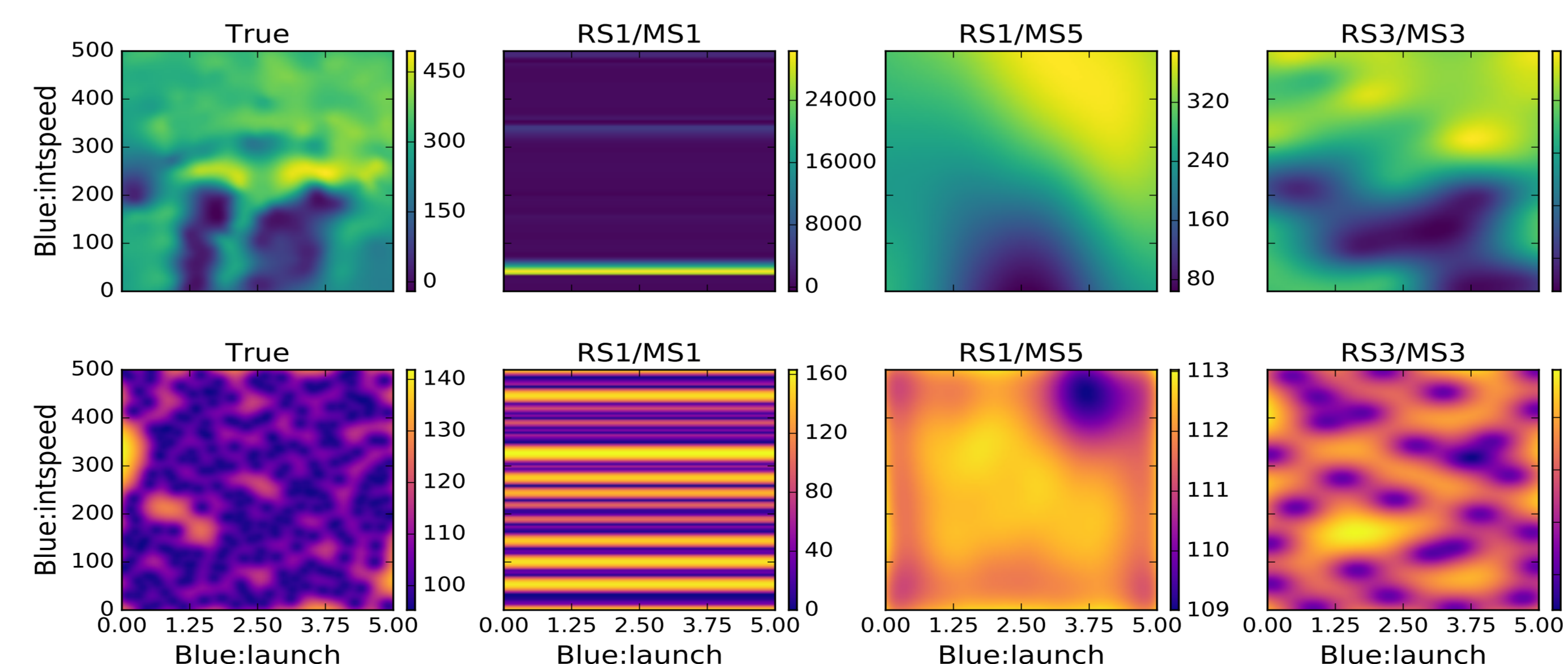


Figure 4: Example of optimization results with different HRMS configurations

## Results: Repeatability

- ▶ The “right” HRMS configuration outperforms either SS, RS, or MS alone (Figure 5)
- ▶ Total function evaluations not more than SS (Figure 6)

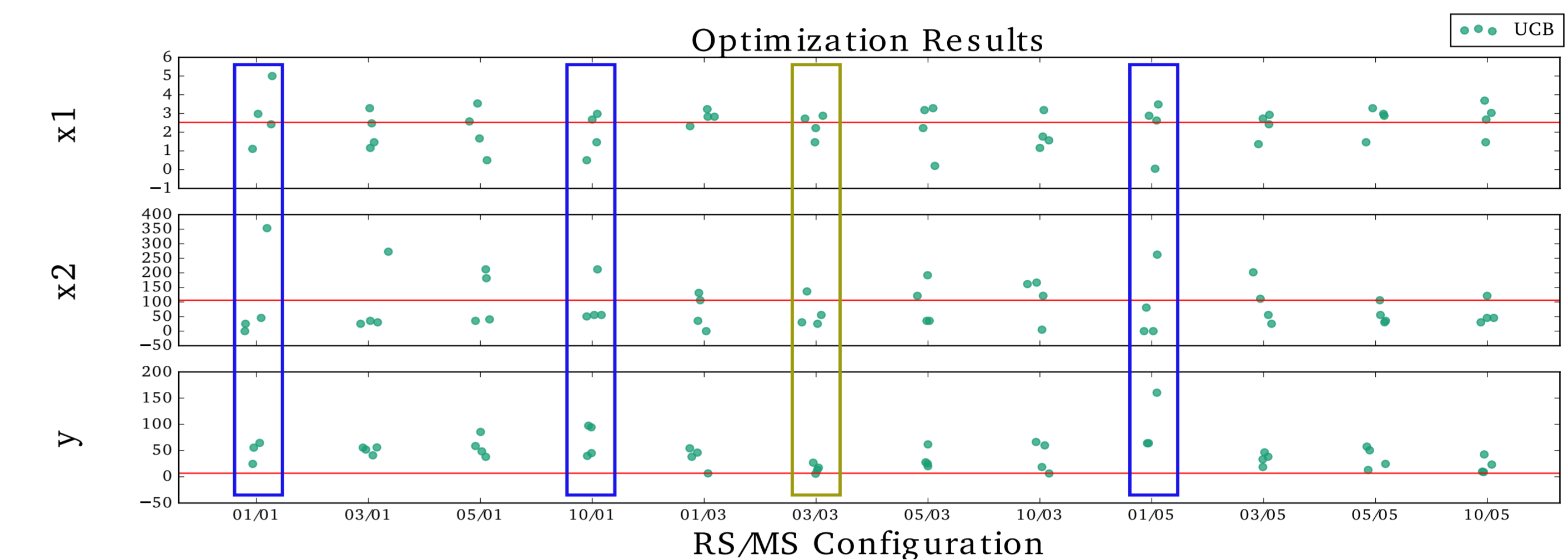


Figure 5: Optimization Repeatability by HRMS configuration

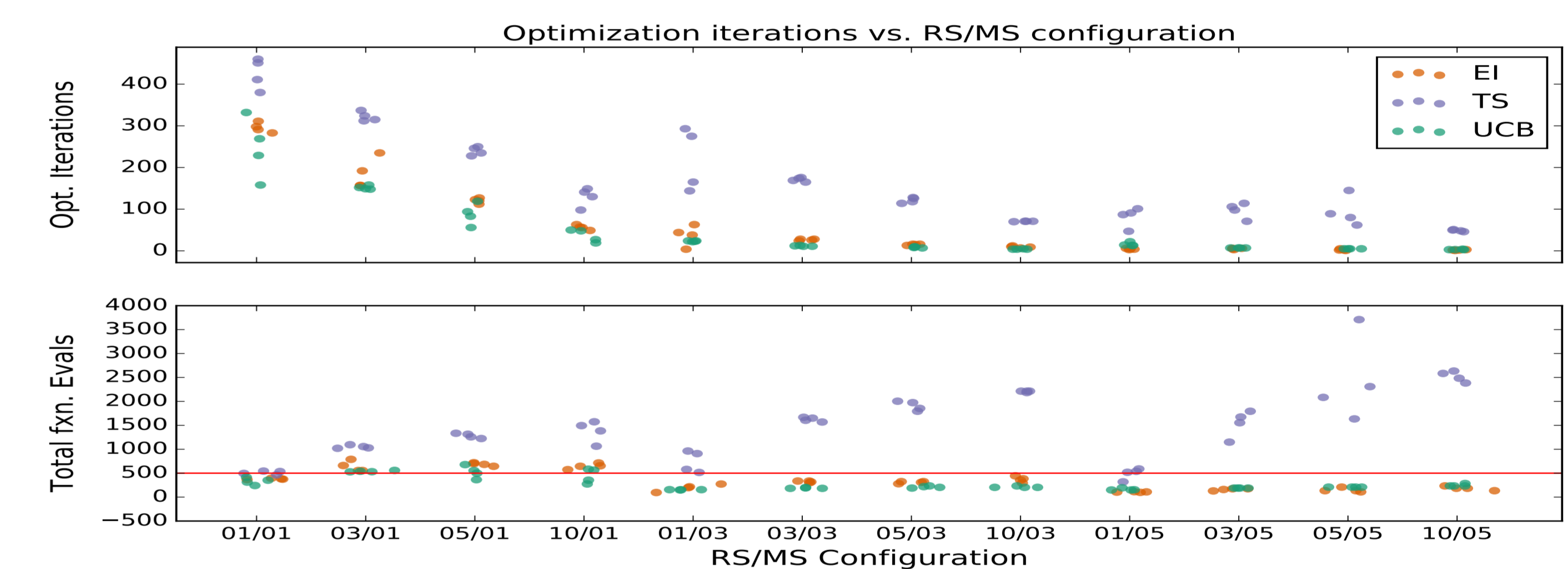


Figure 6: Iterations and Total Function Evaluations by HRMS configuration

## Future Work

- ▶ Paper for the Journal of Aerospace Information Systems (JAIS)
- ▶ How to select RS and MS?
- ▶ How to measure regression quality?

## Acknowledgements

- ▶ We would like to thank Kenneth Center and Rodney Green for their assistance in running the high fidelity combat simulations

## References

- [1] Margery J Doyle and Antoinette M Portrey. “Rapid Adaptive Realistic Behavior Modeling is Viable for Use in Training”. In: *Proceedings of the 23rd Conference on Behavior Representation in Modeling and Simulation (BRIMS)*. 2014.
- [2] Alexander Forrester, Andras Sobester, and Andy Keane. *Engineering design via surrogate modelling: a practical guide*. John Wiley & Sons, 2008.
- [3] Thomas Pyzdek and Paul A Keller. *Quality engineering handbook*. CRC Press, 2003.