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# SPACE LAUNCH SYSTEM

2022 AIAA SciTech Forum

## Informing the Space Launch System Booster Separation Initial CFD Run Matrix with Observed Parametric Sensitivity

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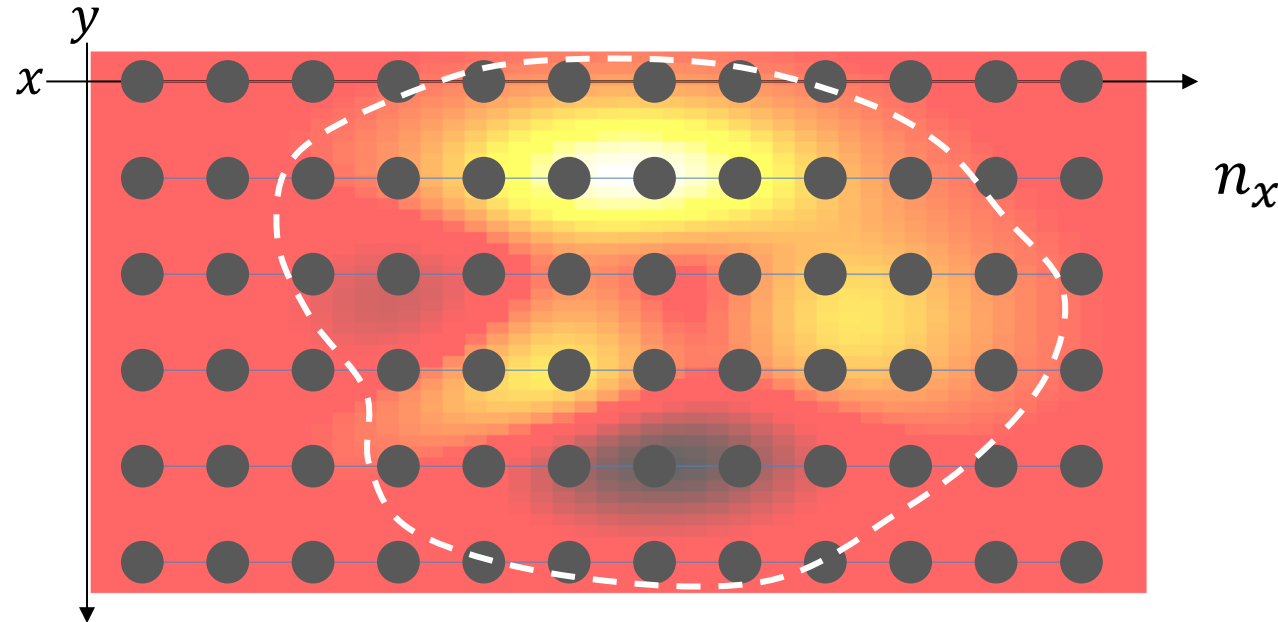
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# OUTLINE

- **Problem description**
- **Booster separation CFD run matrix**
  - Old construction method
  - New construction method
- **Validation of new method's improvement**
- **Summary**

# HIGH-DIMENSION PARAMETER SPACES

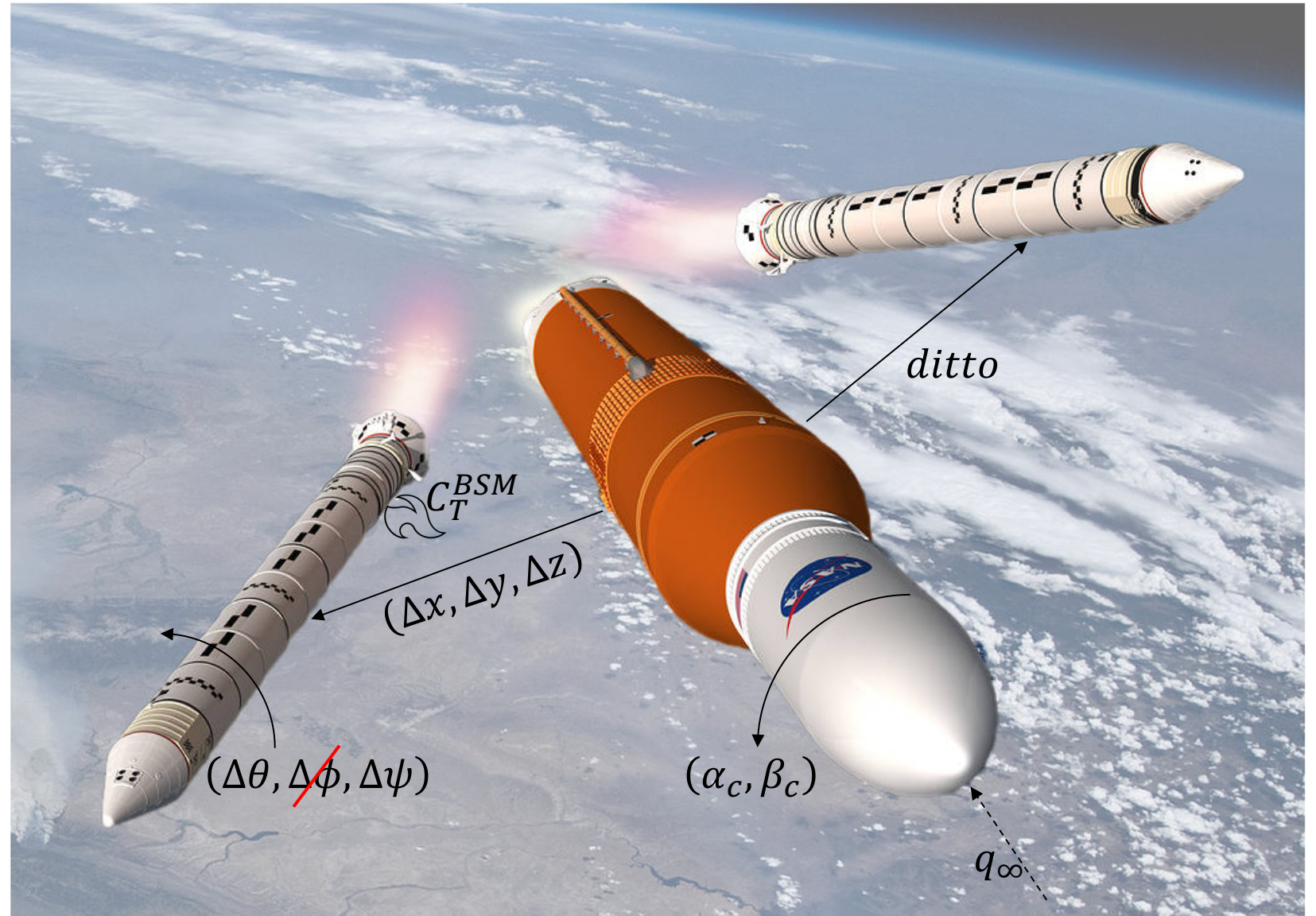
- Parametric independence → Computational cost



- **How to best populate?**
  - How many points can we afford?
  - Where do they belong?

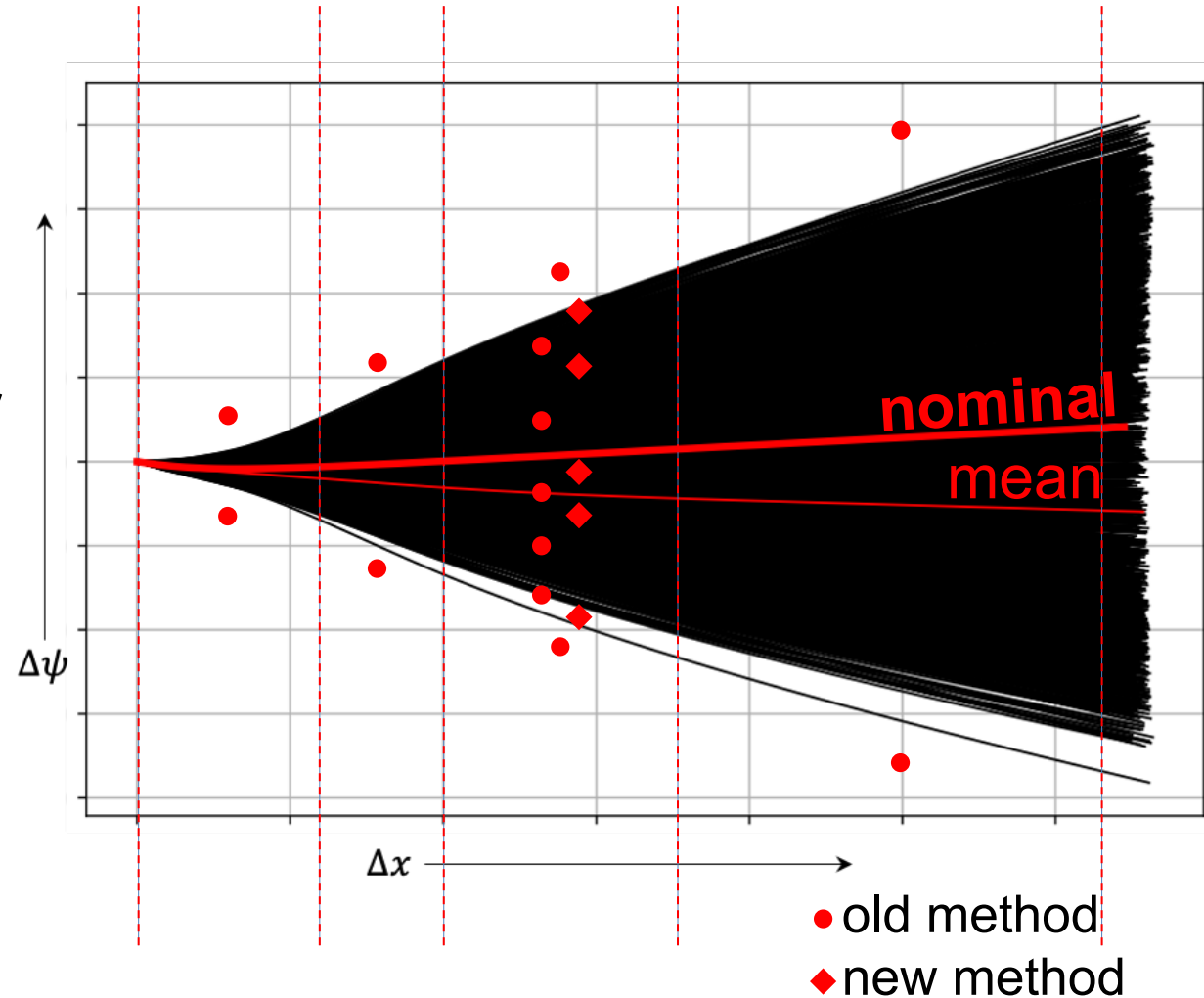
# BOOSTER SEPARATION ON THE SPACE LAUNCH SYSTEM

- Nine parameters
- Points are expensive
- System is complicated
- Need low errors
- High technology readiness level



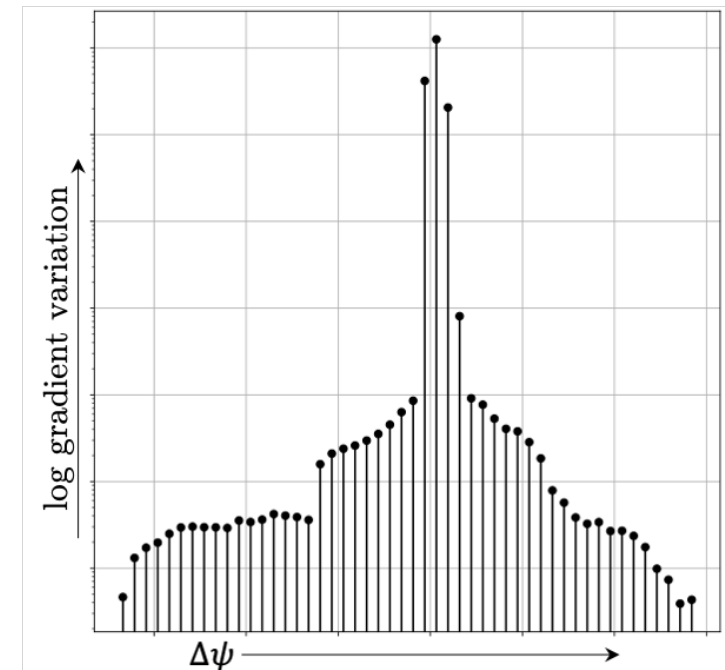
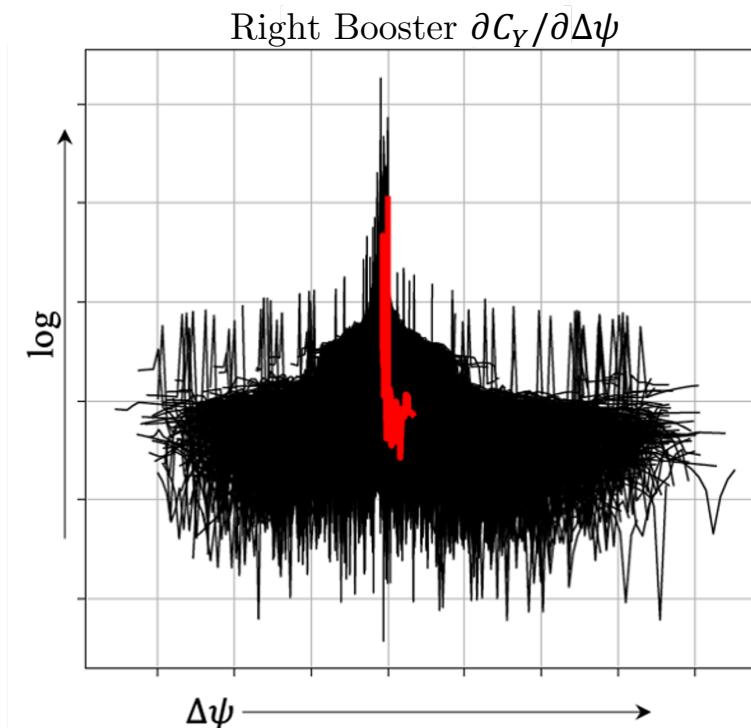
# BREAKPOINT SELECTION PROCESS

1. High uncertainty trajectory Monte Carlo simulation from similar database
2. Pick breakpoints in  $\Delta x$ 
  - Was rigorous engineering judgment
  - Now data-driven, engineer-adjusted
3. In each  $\Delta x$  block, find extrema of other parameters
4. In each  $\Delta x$  block, find breakpoints of other parameters
  - Was uniform distribution centered on trajectory means
  - Now data-driven, algorithmic
5. Low uncertainty trajectory Monte Carlo simulation



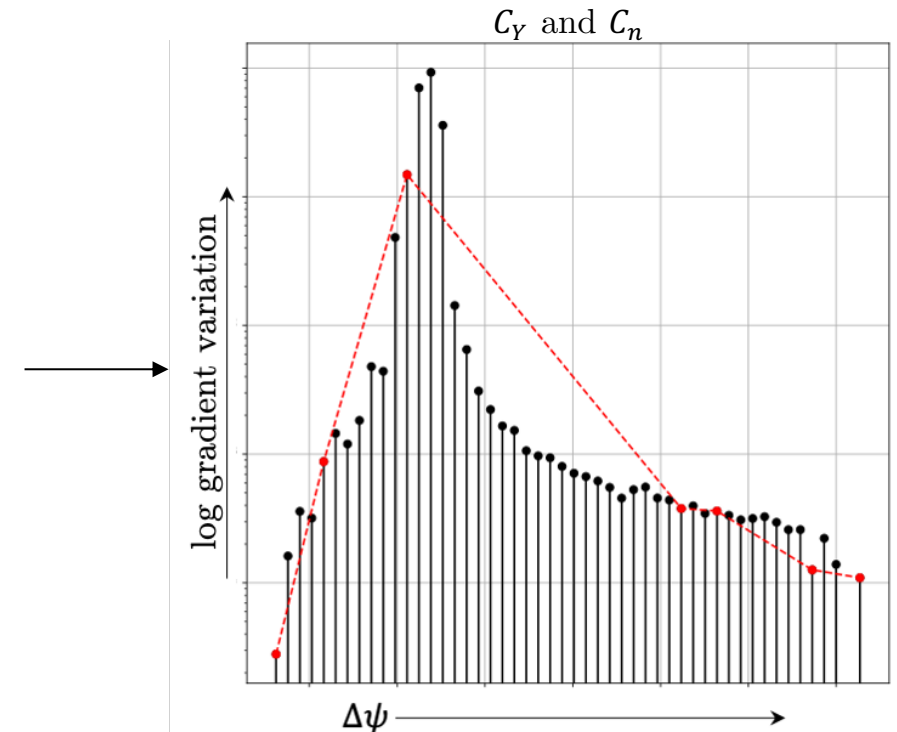
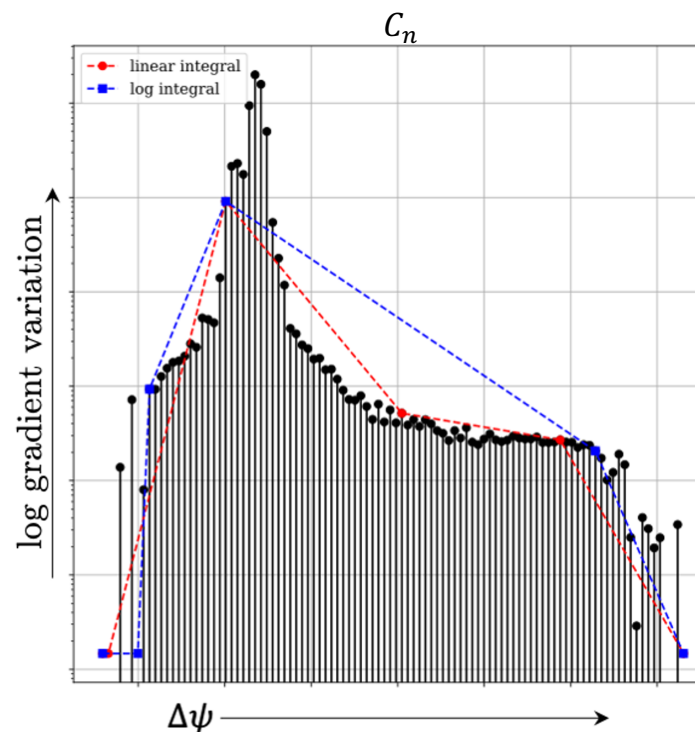
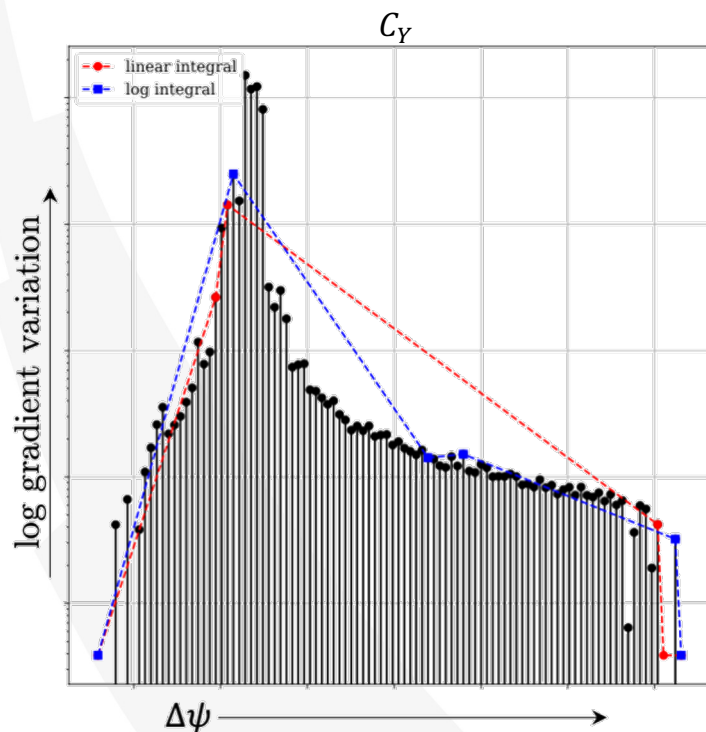
# DATA-DRIVEN BREAKPOINT SELECTION

- **Steeper gradients** of aerodynamic forces/moments relative to database parameters necessitates **higher breakpoint resolution**
- **Higher variation** in statistical distribution of trajectory set gradients characterizes **simulation uncertainty**



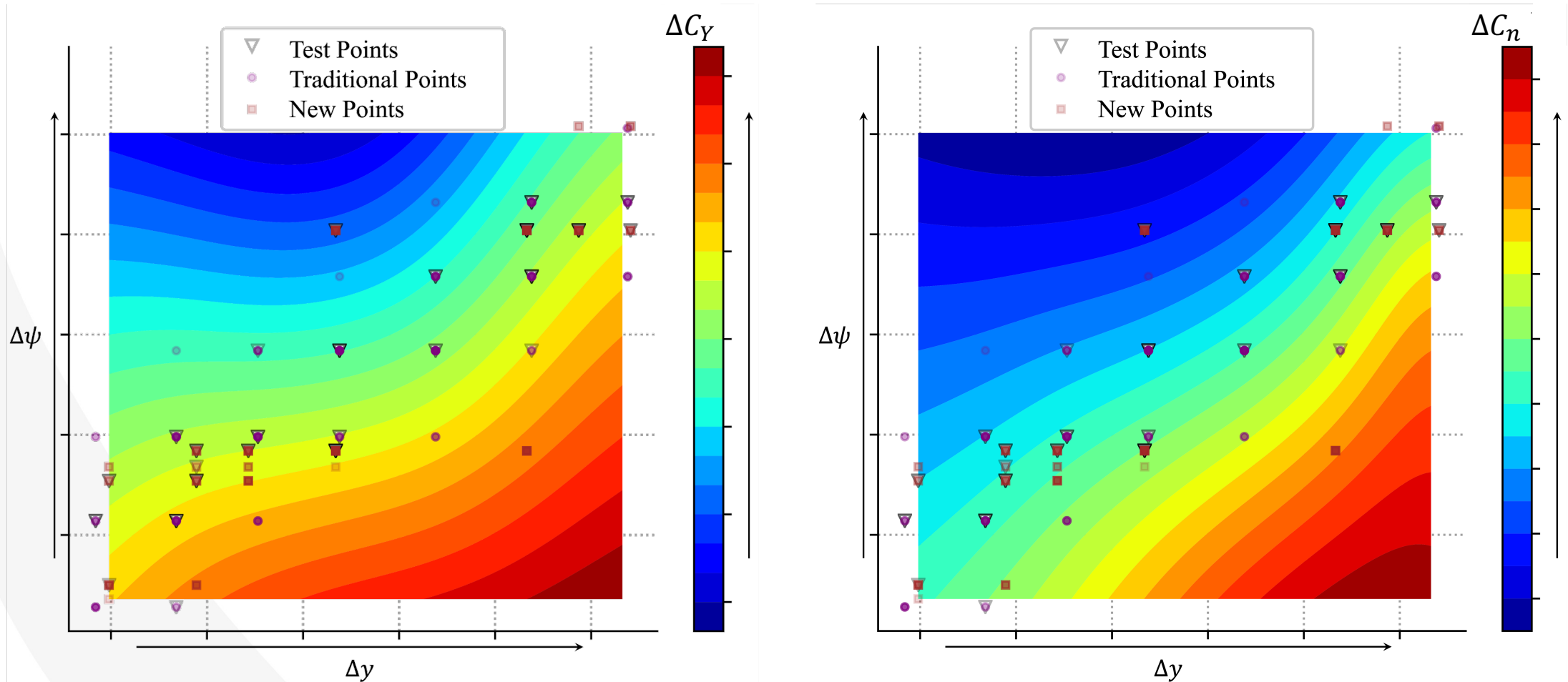
# DATA-DRIVEN BREAKPOINT SELECTION

- **Select breakpoints in each parameter** to best capture the max gradient variation
  - Minimize the error in the integrated max gradient variation function
- **Account for all force/moment** values of interest at once



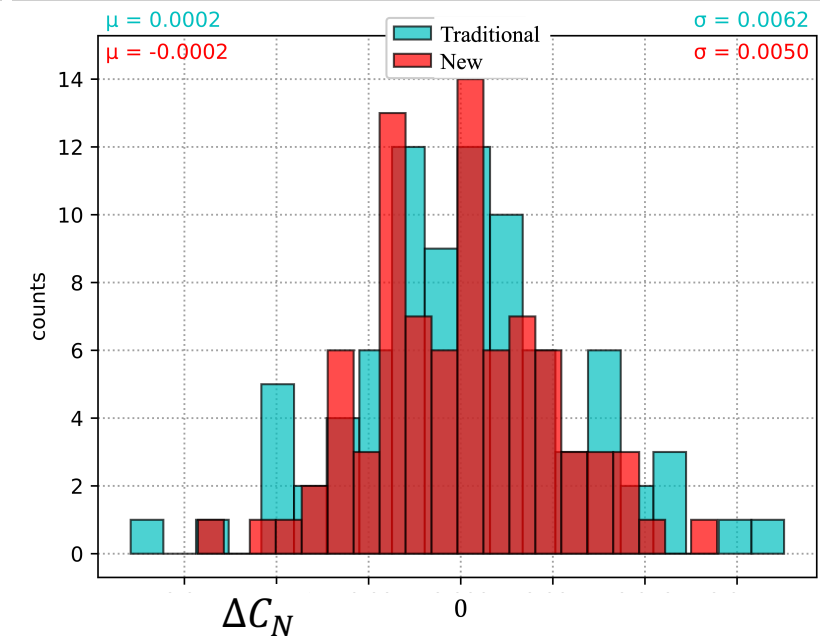
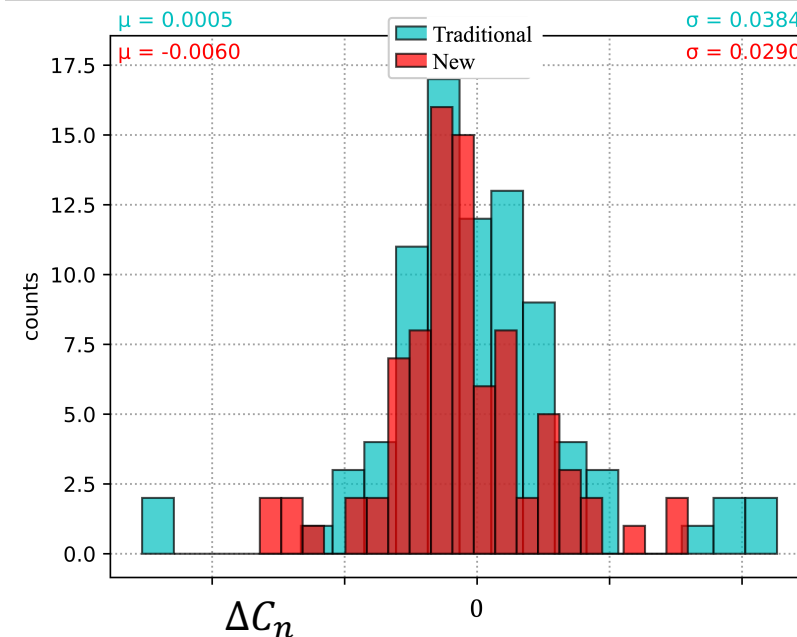
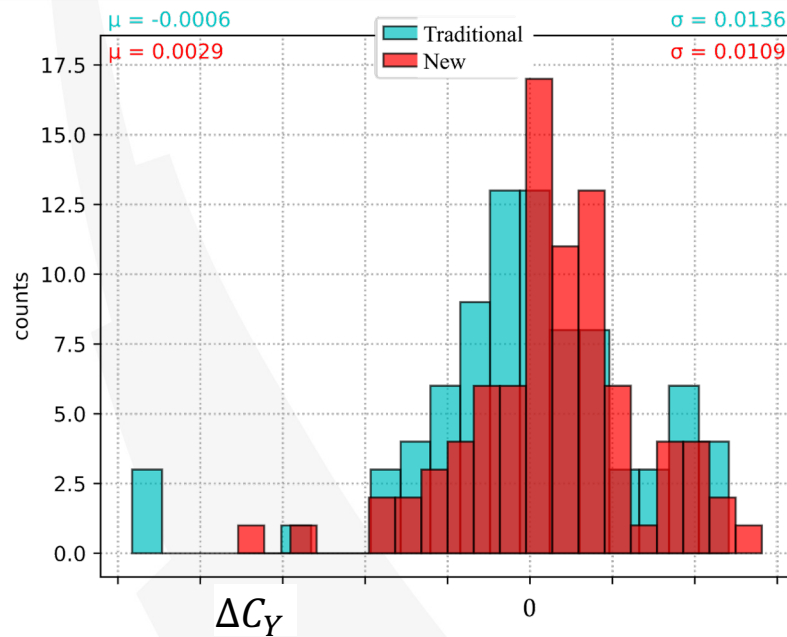
# DATA-DRIVEN BREAKPOINT SELECTION

- **Select subset of all breakpoint combinations to populate run matrix**
  - Equate high-resolution and low-resolution covariance matrices using Latin hypercube sampling



# REDUCTION OF INTERPOLATION ERROR

- Trajectory simulation interpolates database values as necessary
- New breakpoints reduce error even in force/moment values not considered during selection



# SUMMARY

- **This new breakpoint method**
  - is more data-driven;
  - yields lower interpolation error in resulting database;
  - gives database designers more cost control.
- **However, it**
  - remains one-dimensional;
  - is not physics-based.

