COMPUTER SCIENCE
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# ANGEL: A Hierarchical Approach to Online Auto-Tuning

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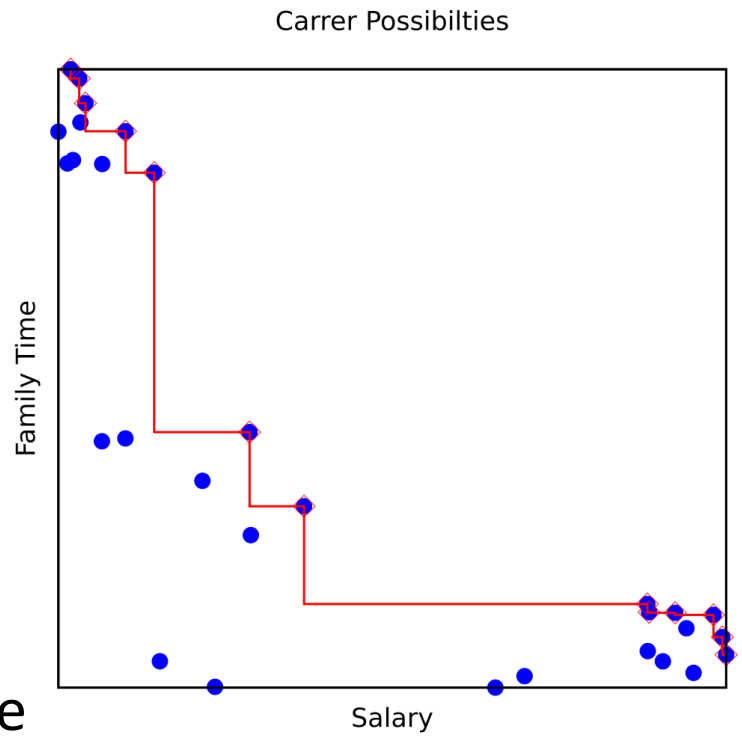
# Motivation

- HPC systems will require online auto-tuning
  - Managing billion-way parallelism is non-trivial
- Cannot myopically focus on wall-time
  - 20MW power goal represents additional hurdle
- Need an auto-tuner that is:
  - Coordinated (Managed by the runtime OS)
  - Online (Optimization occurs without training runs)
  - Multi-objective (Handle power as well as wall-time)

# Dealing with Multiple Objectives

- Multi-objective problems have a set of solutions
  - Each solution in set is equivalent
- Optimal solution is subjective
  - Tuner cannot choose for the user
- Online tuning even harder
  - Cannot pause for user input
  - Must limit overhead of testing
  - Use as few evaluations as possible



# ANGEL Inputs

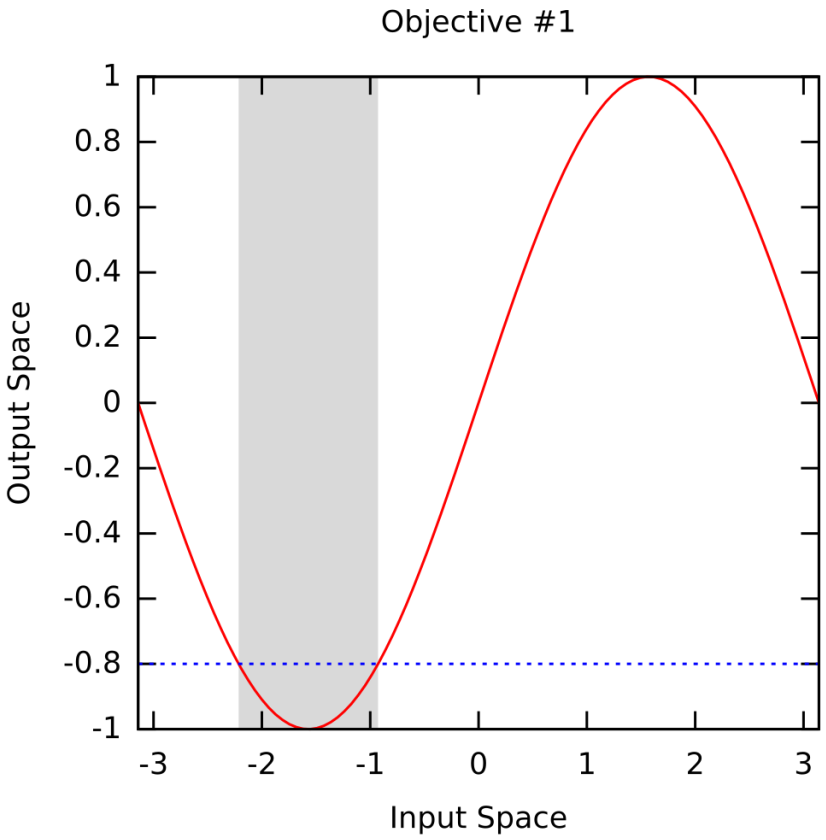
- Two values per objective collected from user apriori
  - Priority Rank
    - Orders each objective from highest to lowest
    - Each rank must be unique
  - Leeway Percentage
    - Amount ANGEL may stray from this objective's best
    - Used to find improvements in other objectives

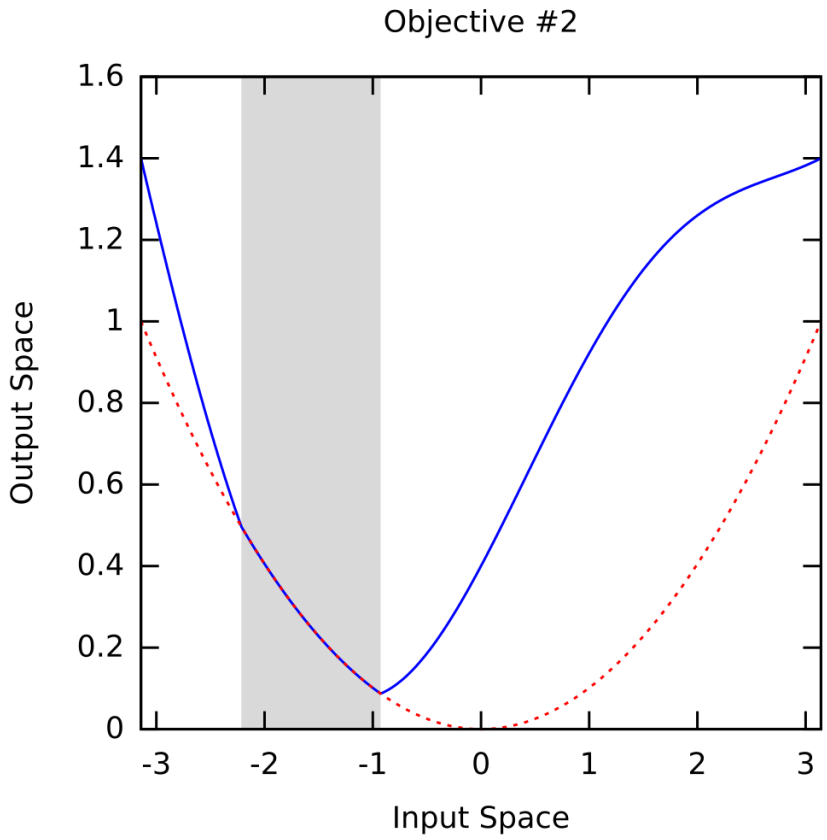
# ANGEL Algorithm

- Begin with highest priority objective
  - Use single-objective algorithm for this objective alone
  - Record all value ranges (min, max) during sub-search
  - Repeat with next highest objective until all are searched
- Penalize sub-searches to maintain leeway preference
  - Applied when higher priority objective exceeds leeway
  - Allows upper level sub-searches to guide lower levels
- Result of final sub-search is the overall solution

# ANGEL Penalty Function

- One-dimensional example with two objectives



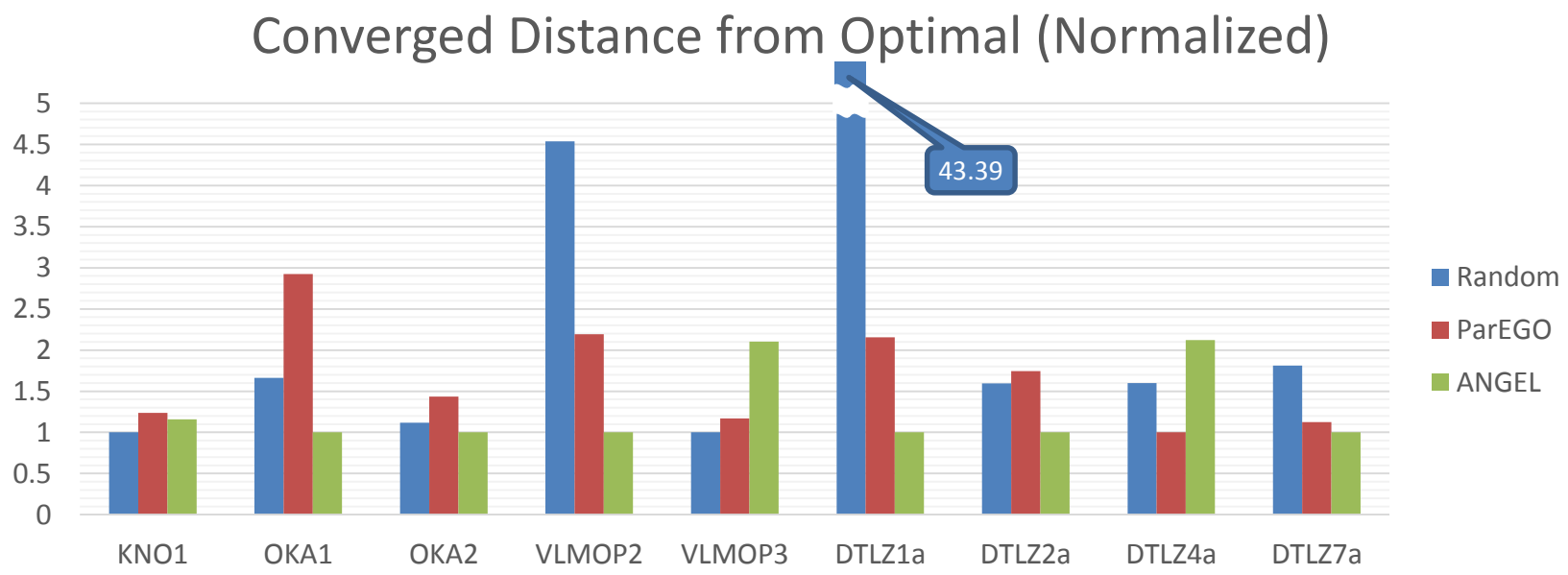



# Numerical Testsuite Experiments

- Tests from multi-objective optimization literature
  - Designed to be difficult, but not pathological
- Compared against ParEGO
  - Represents best evolutionary algorithm for our case
  - Strives to use very few function evaluations
  - Geared towards (relatively) low-dimensional objectives
- Compared against random
  - Must ensure our algorithm does something intelligent

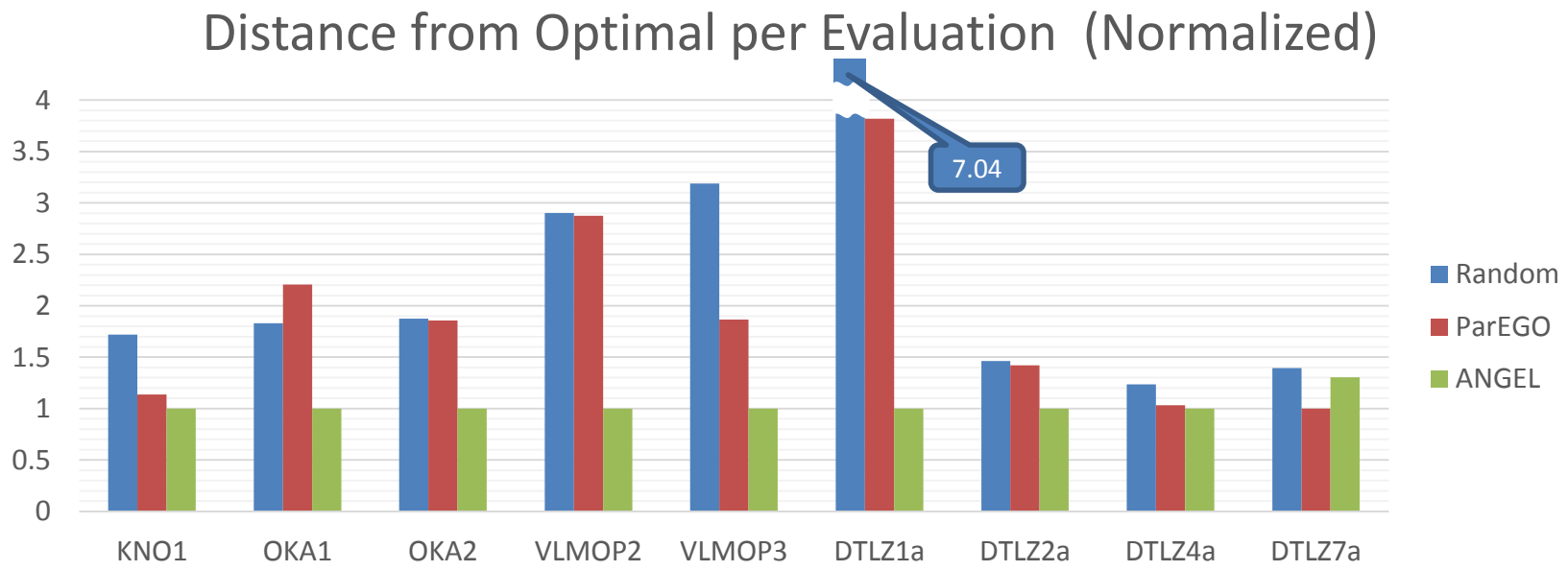
# Testsuite Results – Quality

- Quality is a measure of the converged solution.
  - Distance from the best solution discovered by hand.
- ANGEL wins on two-thirds of testsuite.



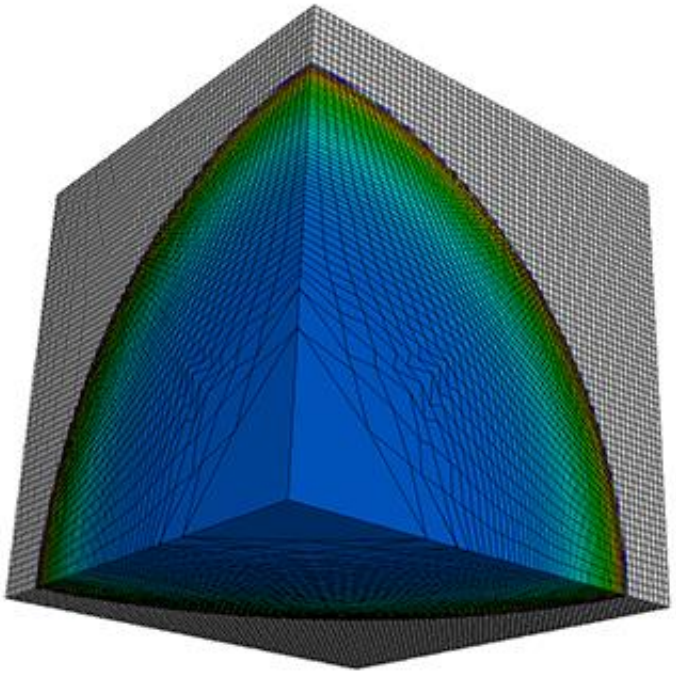
# Testsuite Results – Efficiency

- Efficiency is a measure of search overhead.
  - Critically important to keep low for online auto-tuning.
- ANGEL wins on all but one test.



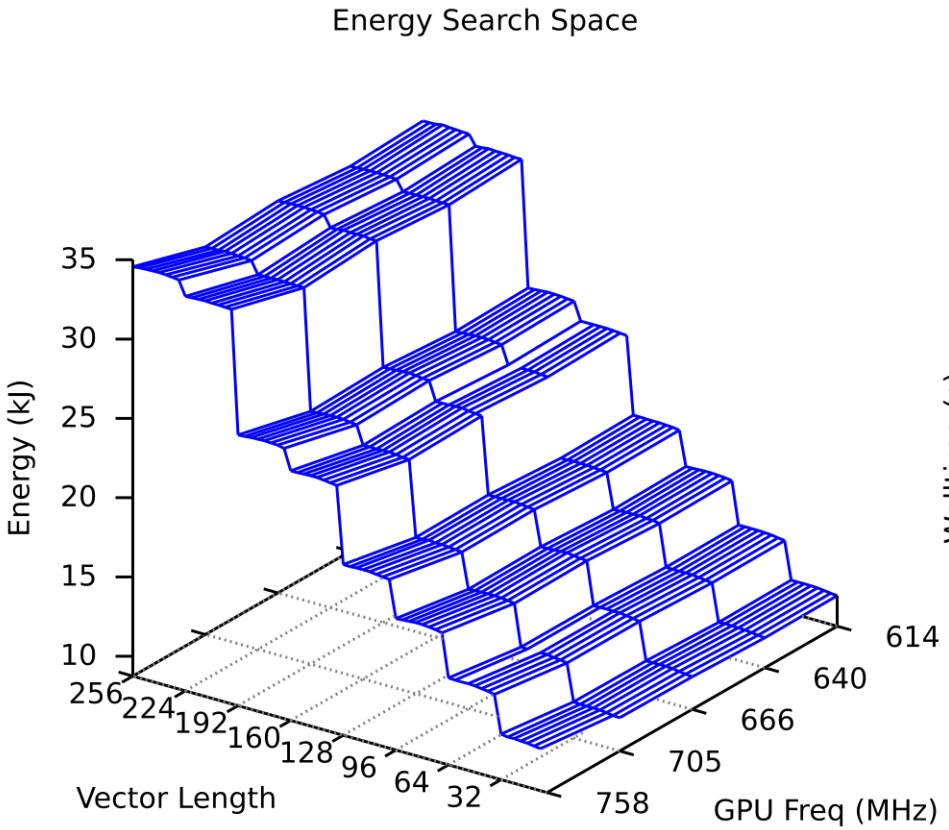
# LULESH Experiments

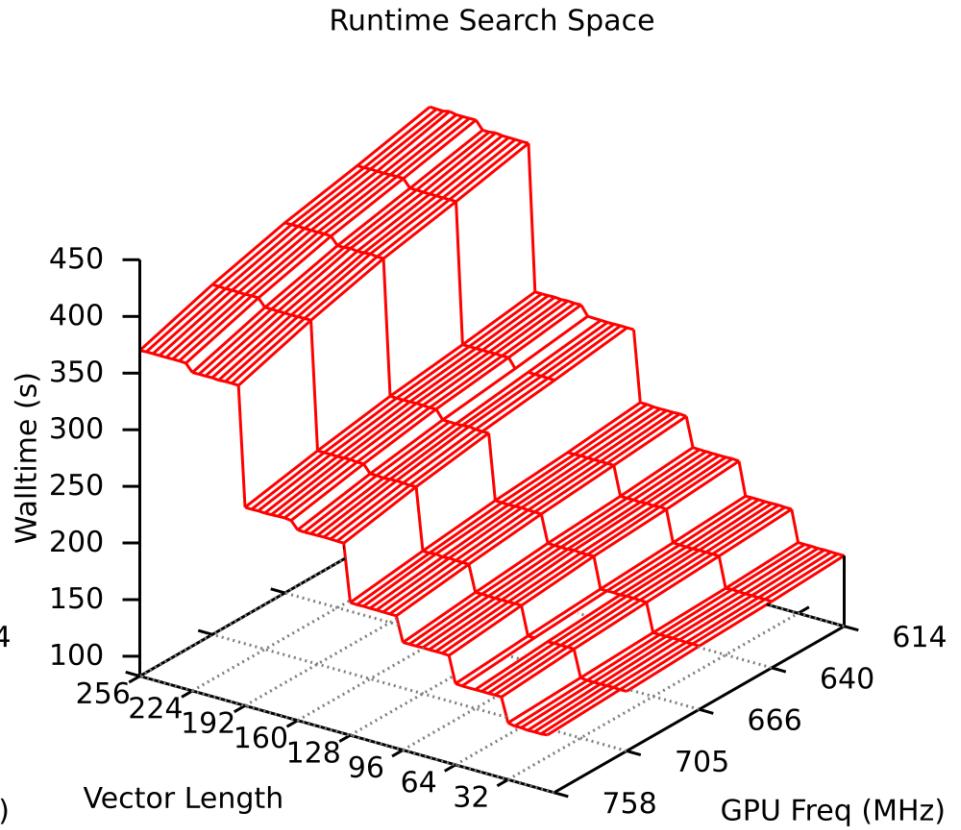
- Lawrence Livermore's LULESH proxy application
  - Unstructured hex mesh problem



- Tuning two input variables:
  - OpenACC loop vector length
  - GPU clock frequency
- Two objectives:
  - Minimize running time
  - Minimize energy consumption

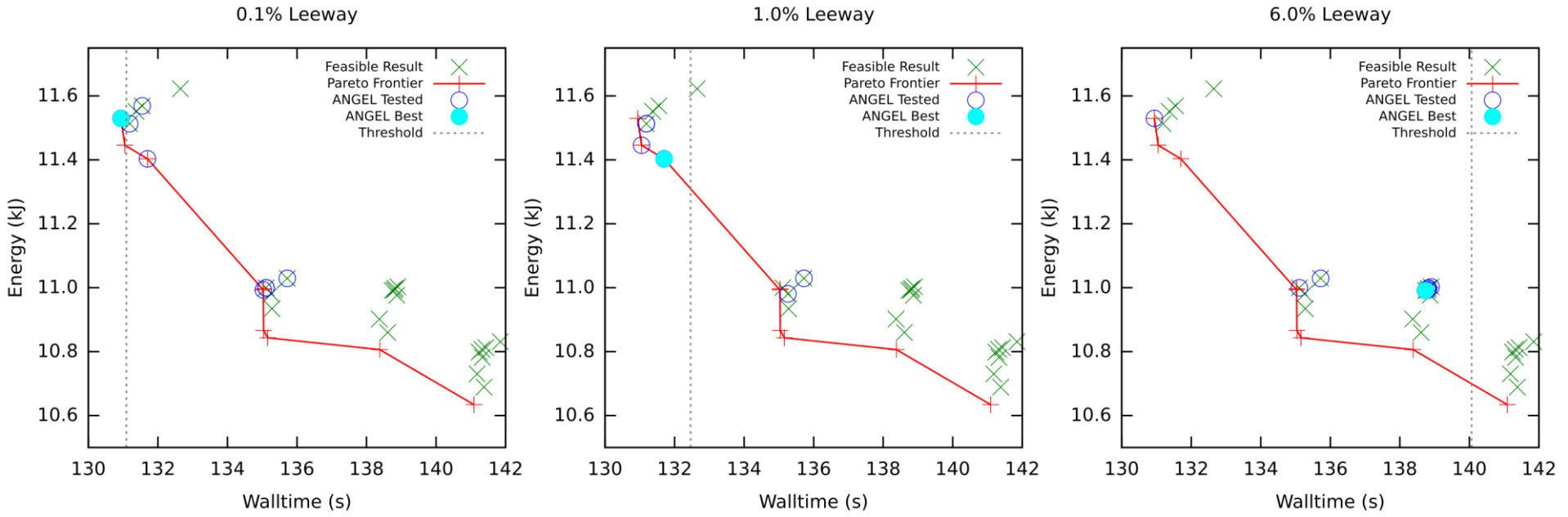
# LULESH Objective Landscapes



# Changing the Threshold

- ANGEL behaves properly for changing leeways
  - Energy usage declines along with leeway
  - Shows proper behavior for real HPC data



# Conclusion and Future Work

- ANGEL is a step towards runtime system auto-tuning
  - Uses an iterative and hierarchical approach
  - Controlled by simple user inputs provided aprioi
  - Performs well on numerical testsuite
  - Shown to work correctly on real HPC data
- Future work
  - Power (rather than energy) studies
  - Alternate underlying single-objective algorithms
  - Explore avenues for parallelism