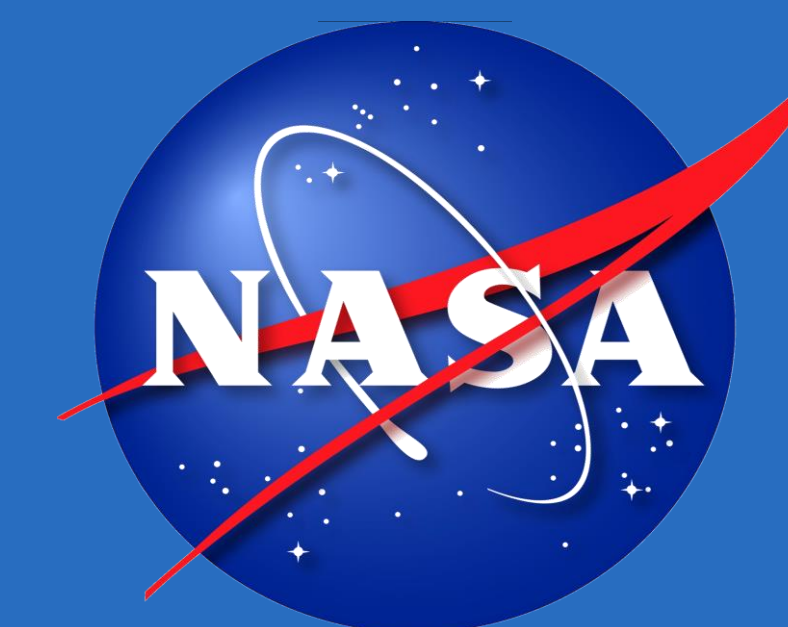




Planetary Defense
Goddard Space Flight Center

Comprehensive Mission Design Architecture Trade Study for Planetary Defense Missions

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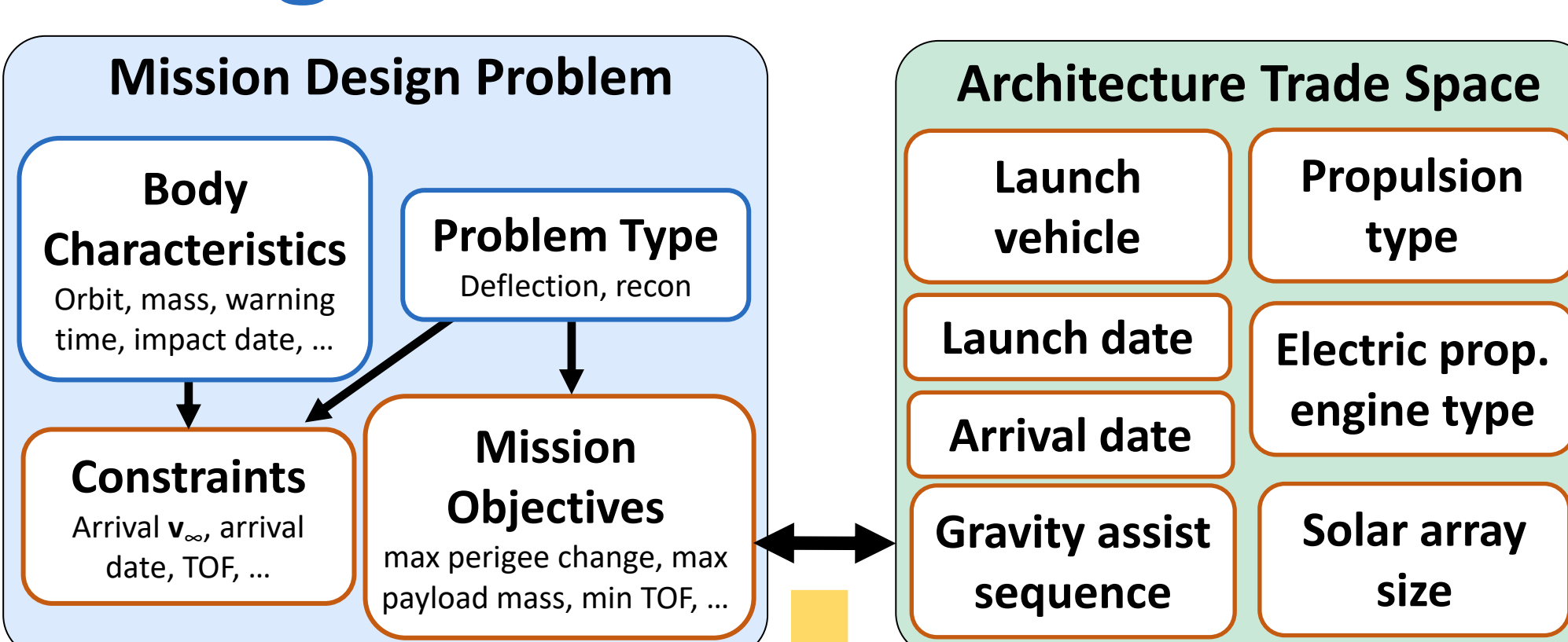
Introduction

- Mission architectures are traditionally designed on a mission-by-mission basis due to problem complexity
- However, a comprehensive understanding of mission architectures best-suited for PD problems would:
 - Allow for advance development of ready-to-build HW designs for most PD problems
 - Catalyze development of new enabling technologies (e.g., electric/thermal prop.)
 - Inform cost decisions for different mission types
 - Reduce (or eliminate) Phase A design work

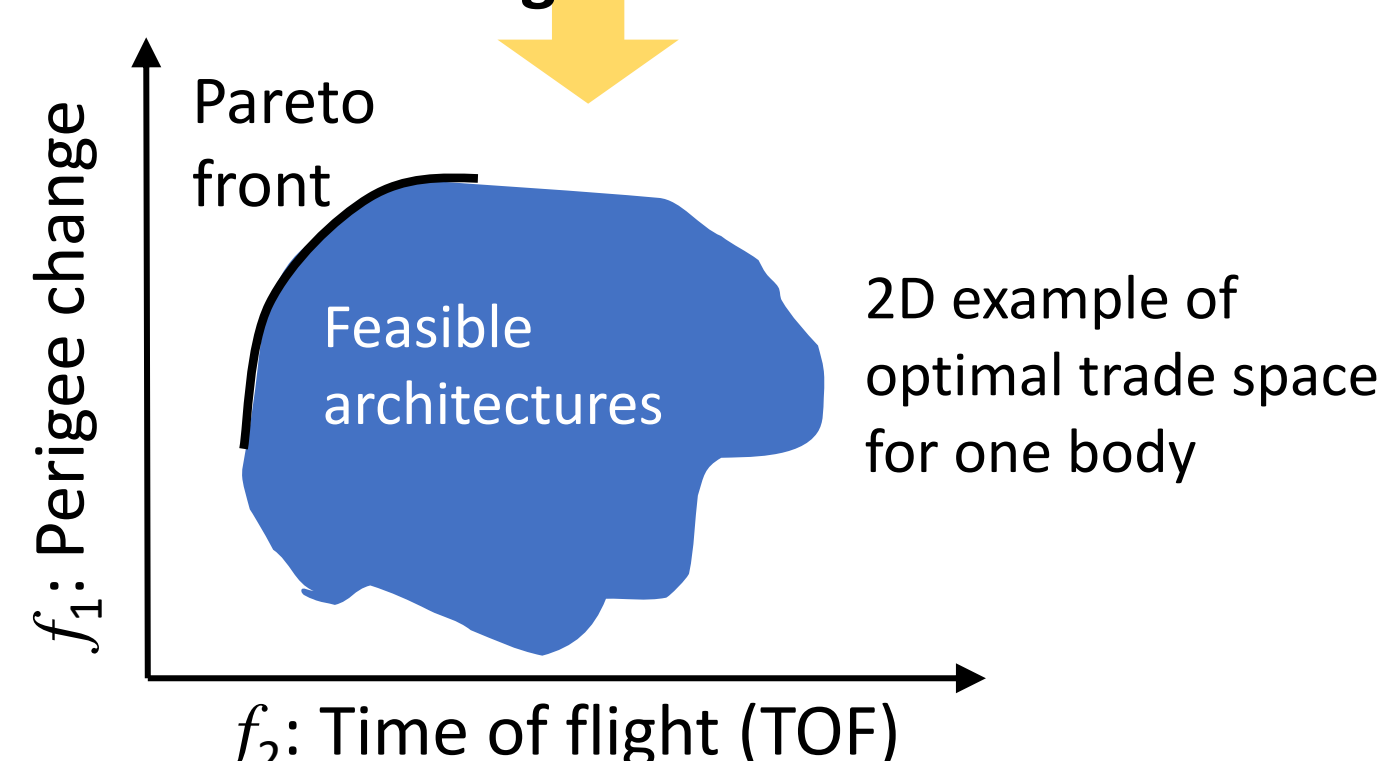
Objective

Map the full PD architecture trade space to identify missions/spacecraft that are applicable to many PD scenarios & inform how to best invest in future technology

Background



Mapping of objectives to design variables



Grid search is intractable:

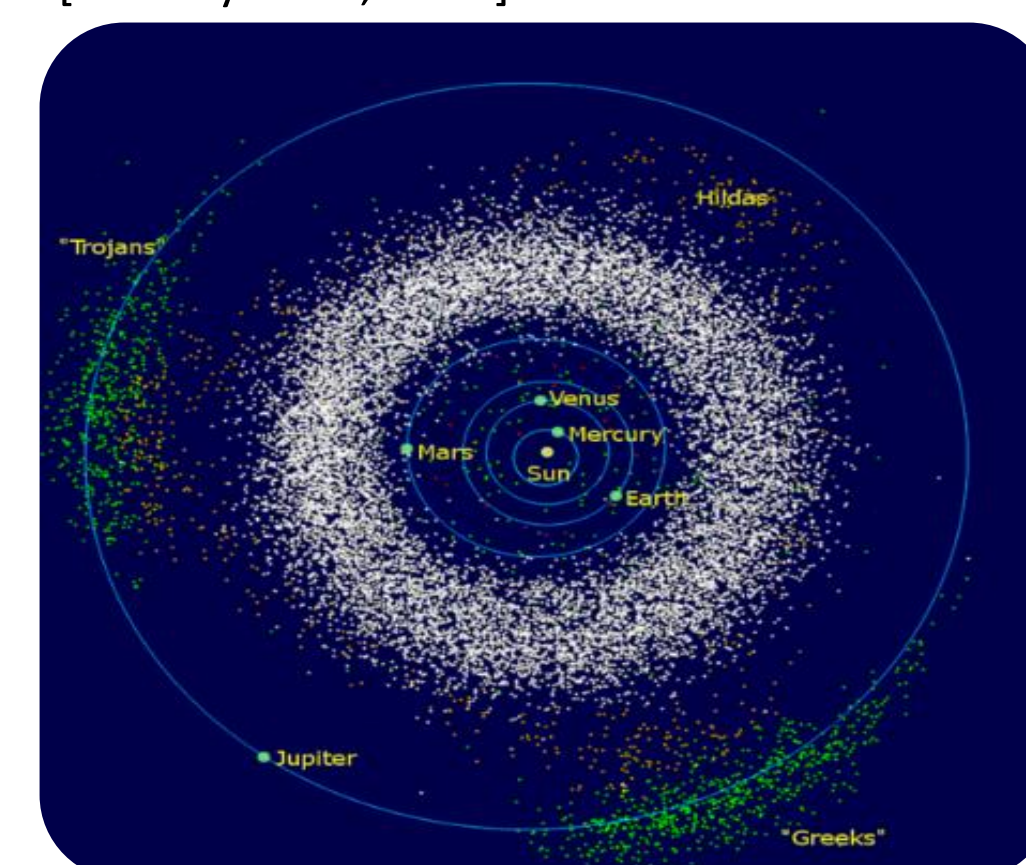
2.7×10^{13}
optimization problems given simulated pool of 27,000 impacting bodies & all trade space combinations
If each problem took only 2 minutes to optimize, it would take the age of the universe to complete the trade

Methodology

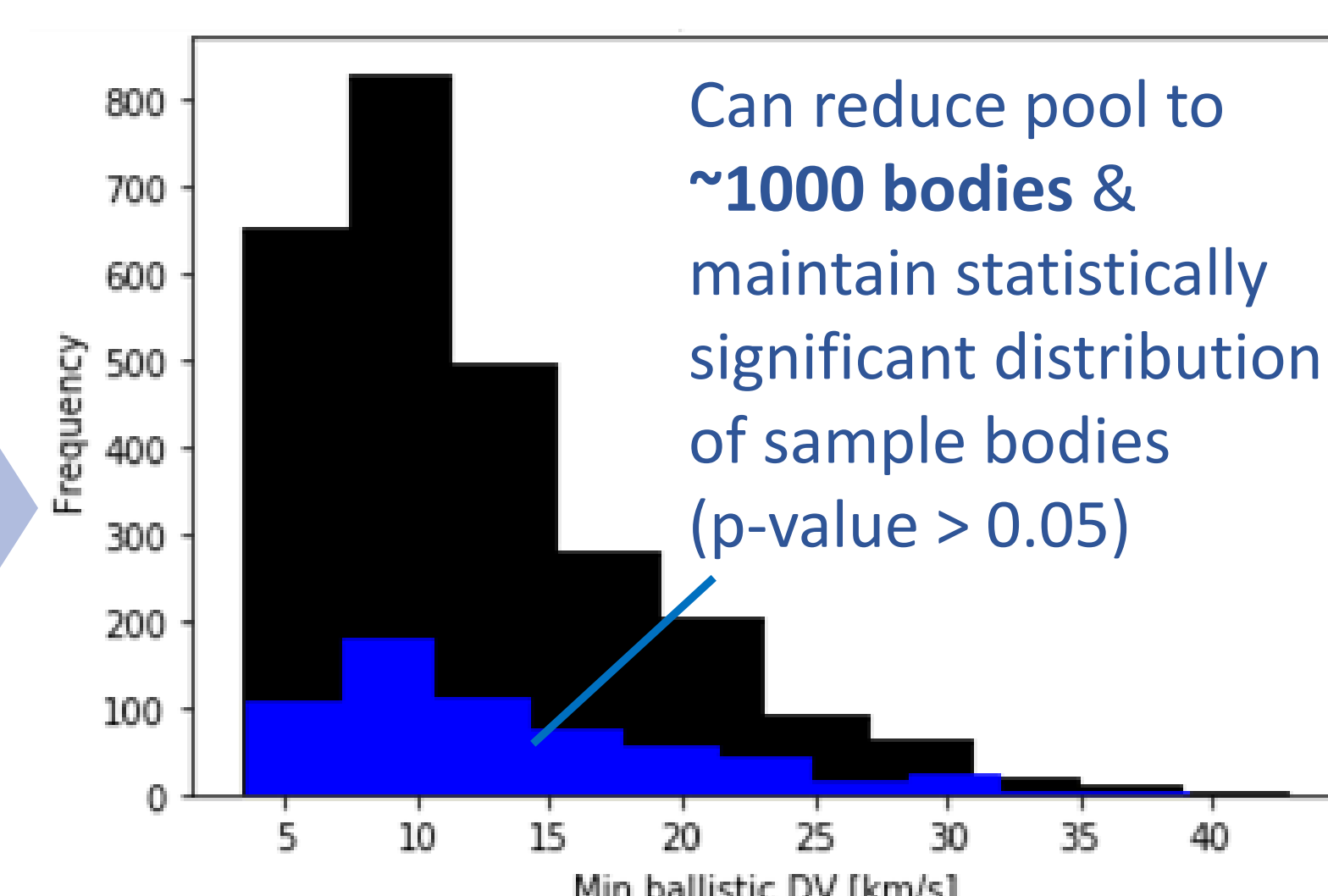
1. Body Down Selection

Select representative subset of bodies from full library of 27,000 simulated impactors

Full set of simulated impactors
[Chesley et al., 2019]



k-means clustering based on a , e , i , p , TOF, energy & Hohmann ΔV



2. Mission Design Problem Categorization

Define mission design categories & formulate tractable mission design optimization problems

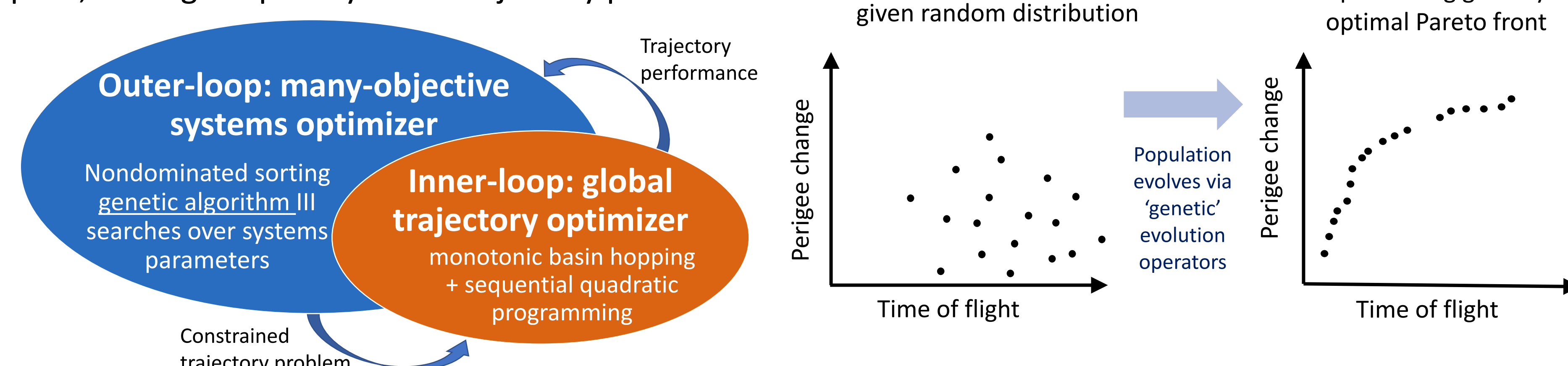
PD Objective	Propulsion Type	Optimization Objectives
1 Reconnaissance	chemical	Delivered mass, TOF, arrival date, arrival V-inf, launch vehicle (LV) class
2 Reconnaissance	SEP	Delivered mass, TOF, arrival date, arrival V-inf, LV class, solar array size, # of thrusters
3 Intercept NED deflection	chemical	Delivered mass, TOF, arrival date, arrival V-inf, LV class
4 Intercept NED deflection	SEP	Delivered mass, TOF, arrival V-inf, LV class, solar array size, # of thrusters
5 Rendezvous NED deflection	chemical	Deflection perigee change, delivered mass, TOF, LV class
6 Rendezvous NED deflection	SEP	Deflection perigee change, delivered mass, TOF, LV class, solar array size, # of thrusters
7 Kinetic impactor	chemical	Deflection perigee change, delivered mass, TOF, LV class
8 Kinetic impactor	SEP	Deflection perigee change, delivered mass, TOF, LV class, solar array size, # of thrusters

Each category is a coupled systems & trajectory optimization problem with many objectives

3. Mission Optimization

Efficiently trade mission architectures for each down-selected body & each mission design category with stochastic, many-objective optimizer

Stochastic, hybrid algorithm strategically samples trade space, solving coupled systems-trajectory problem

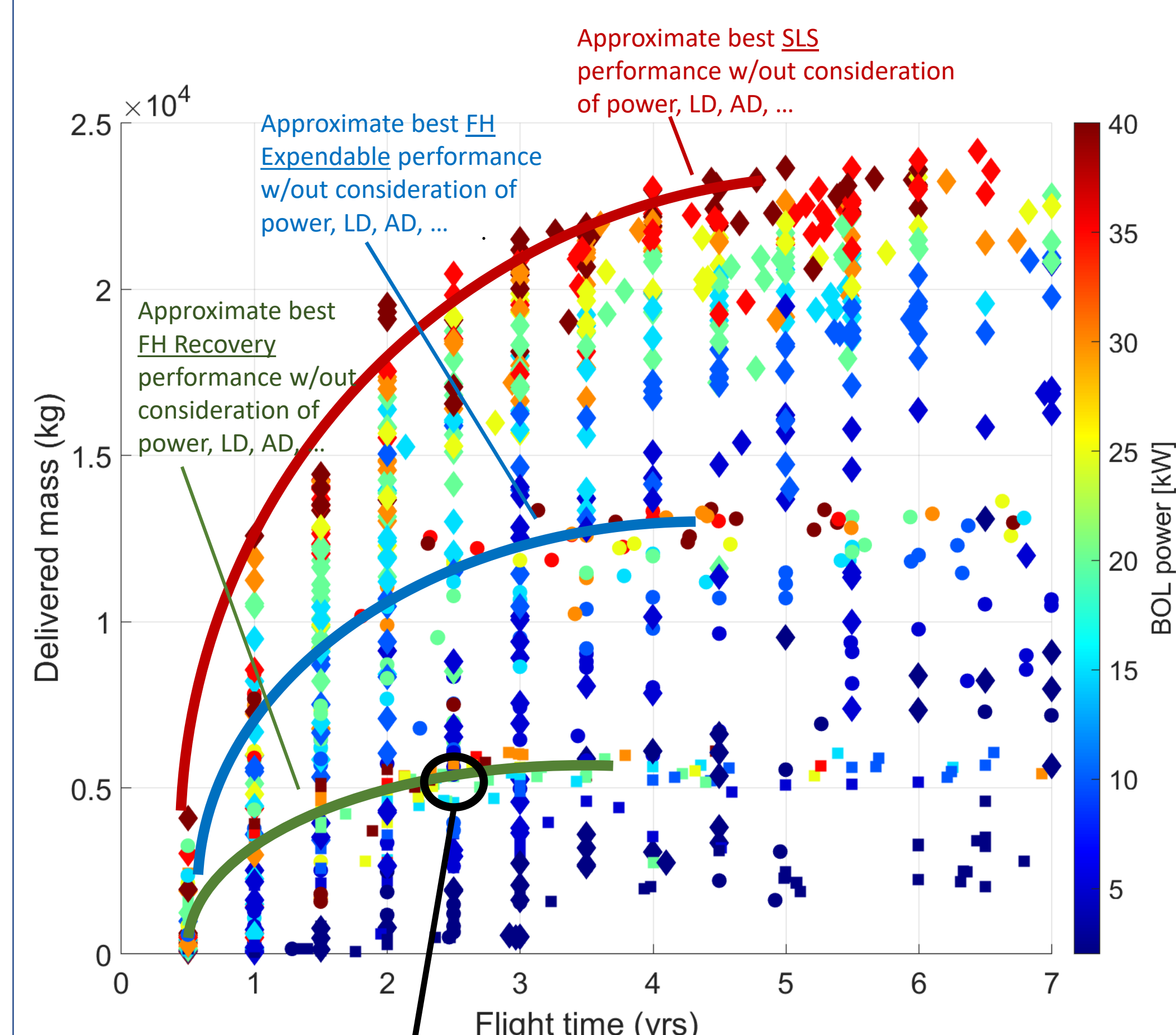


4. Catalog Solution Space

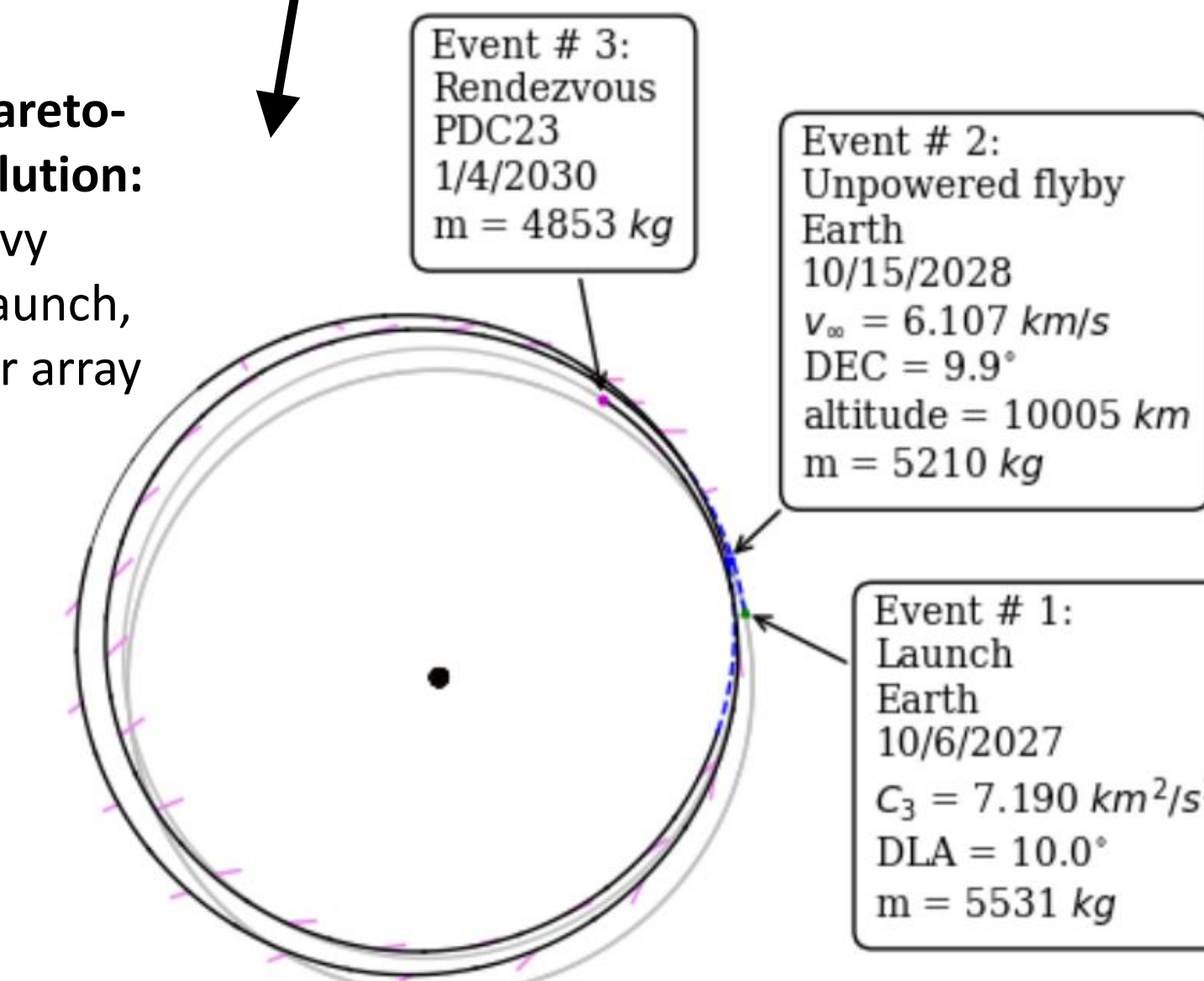
Classify & synthesize design space to solution space mapping for easy look up of optimal trade space given a specified PD problem

Example Results

Projection of LV-mass-TOF-power Pareto front representation for a SEP rendezvous deflection mission



Example Pareto-optimal solution:
Falcon Heavy
Recovery launch,
15 kW solar array



- Pareto front representation generated for each down-selected body in each problem category to generate full data set
- Strategic & automated sampling of design space via stochastic optimization enables efficient & comprehensive mapping

Next Steps

- Finalize outer-loop wrapper development for many-objective optimization
- Run full trade on NASA Advanced Supercomputing processors
- Develop cataloging approach of solution space mapping
- Analyze results to identify top-performing architectures