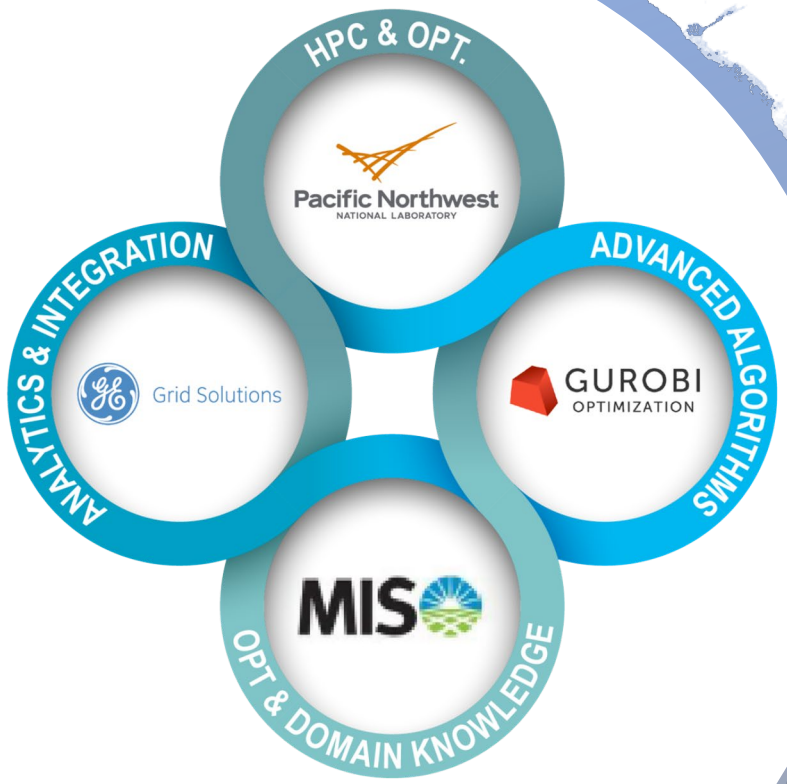
HIPPO – A Concurrent Optimizer for Solving Day-ahead Security Constrained Unit Commitment Problem

FERC Technical Conference

June 26, 2019



HIPPO Background

Funded by ARPA-E, 11/2016 – 1/2020.

Problem – Day-ahead security constrained unit commitment problem

Challenge - Slow solution times lead to inefficient cost, reduced reliability and slow adaptation of new market designs.

Solution – A solution framework based on parallel and concurrent optimization.

Goal – 10+ speedup.

Day-ahead Security Constrained Unit Commitment (SCUC) + SFT

- Load-generation balance
- Generator/resource operational requirements
- Reserve requirements.
- Security constraints
- Simultaneous feasibility test.

Challenges of Solving SCUC

Solving MIP is Hard

Size of problem – number of resources, time resolution, cost details.

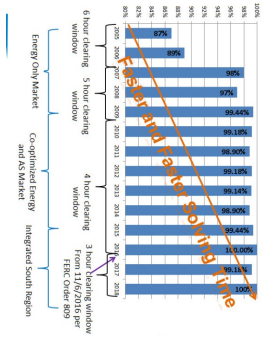
Security constraints - dense, linking resources across the power system.

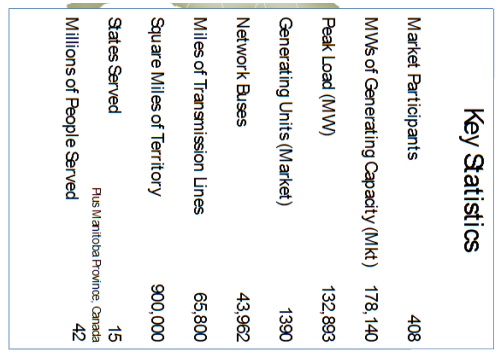
Feasibility test - solving SCUC multiple times

Reserve requirements- another set of system-wide constraints.

Combinatorial nature - several conditions in combination, sensitive to input.

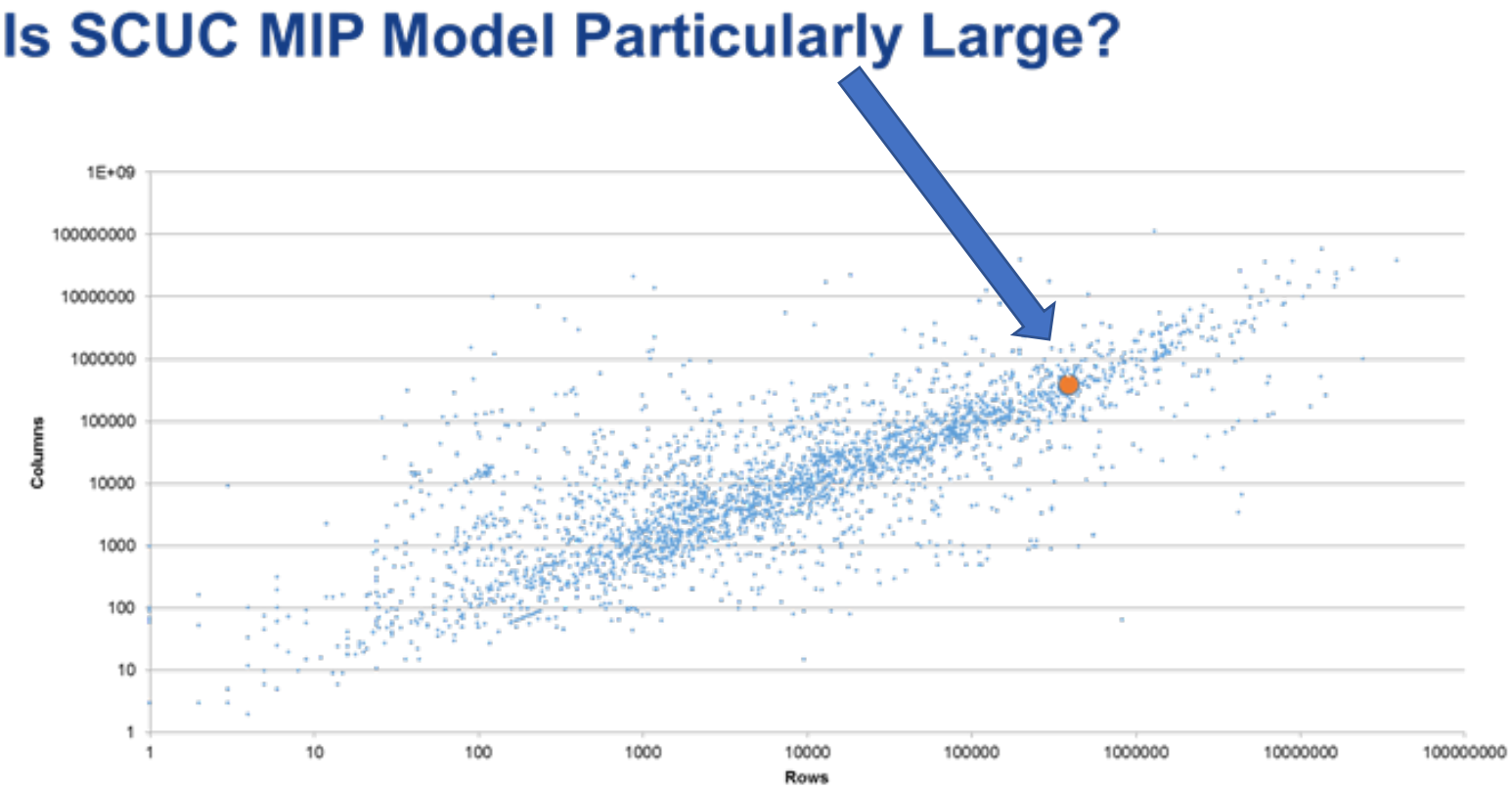
High-quality solutions -cost efficiency, reliability and fairness.



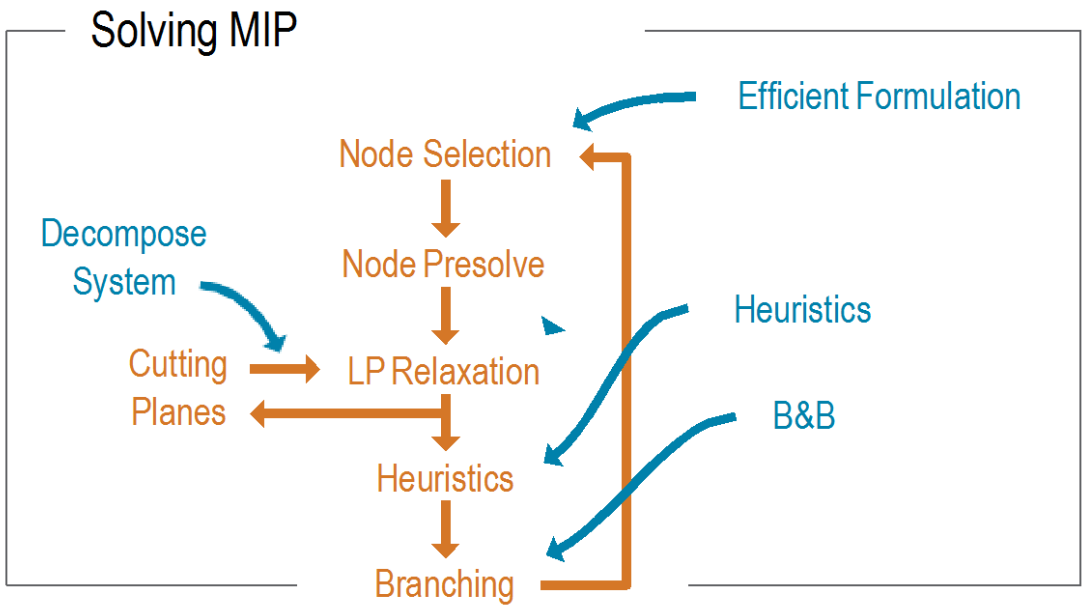


Large size with limited time and high accuracy requirement

- MISO: 20 minute and 0.1% MIP gap for each DA SCUC run
- 2-3 runs

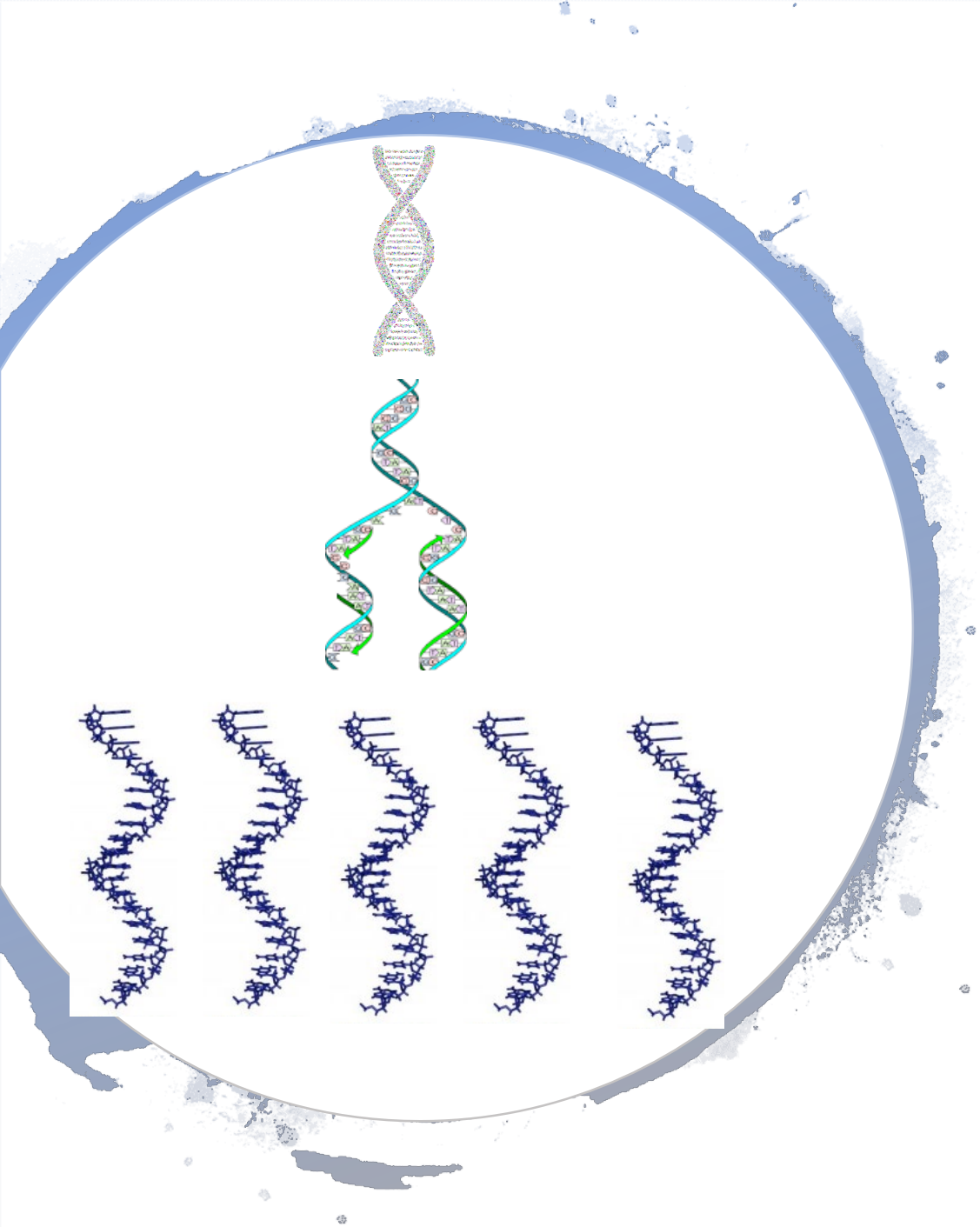


Solving SCUC – Traditional Approach



A single process of searching for incumbent solution and certifying incumbent solution.

Focus on a single formulation and single solution process.
Improve formulation. ✓
Cutting planes. ✓
Decomposition methods.
Feasibility check after solving a single SCUC.
Searching for incumbent solution and certifying incumbent solution in a single process.



Solving SCUC – HIPPO Approach

Organic solution framework

Parallel algorithmic steps.

Concurrent execution of multiple algorithms.

Communication among algorithms during execution.

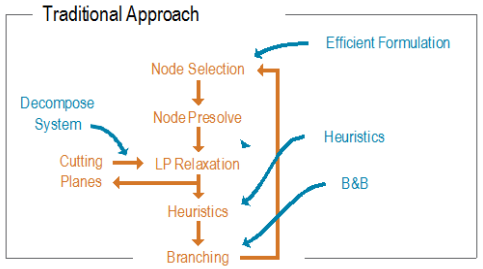
Separated procedures for search and certification.

Callback - accessing intermediate state of solution process.

HIPPO Technology

MANAGE ALGORITHMS, SHARE SOLUTIONS, COMMUNICATE INFORMATION

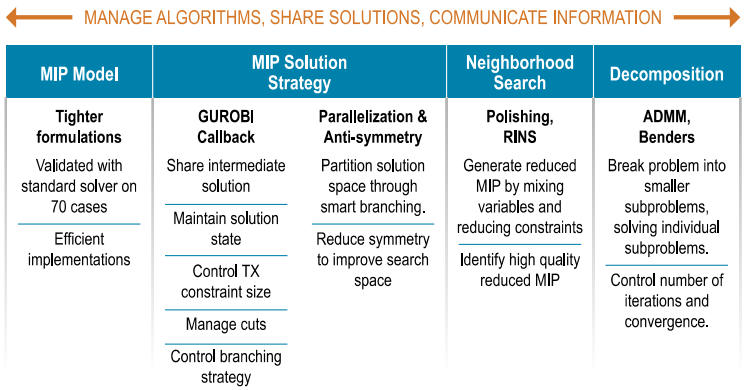
MIP Model	MIP Solution Strategy		Neighborhood Search	Decomposition
Tighter formulations	**GUROBI Callback**	**Parallelization & Anti-symmetry**	**Polishing, RINS**	**ADMM, Benders**
Validated with standard solver on 70 cases	Share intermediate solution	Partition solution space through smart branching.	Generate reduced MIP by mixing variables and reducing constraints	Break problem into smaller subproblems, solving individual subproblems.
Efficient implementations	Maintain solution state	Reduce symmetry to improve search space	Identify high quality reduced MIP	Control number of iterations and convergence.
	Control TX constraint size			
	Manage cuts			
	Control branching strategy			

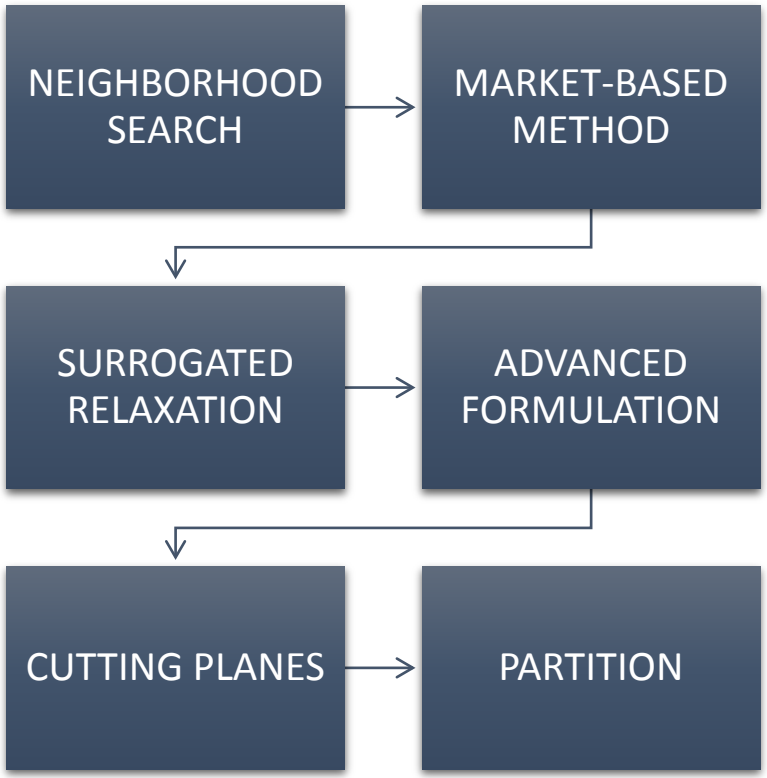


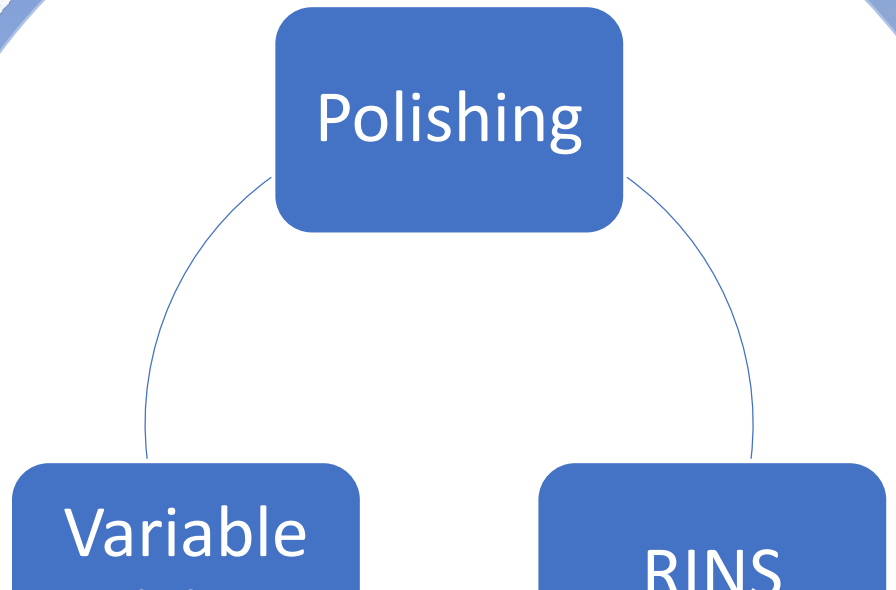
METHODOLOGY

SOFTWARE

HIPPO Methodology





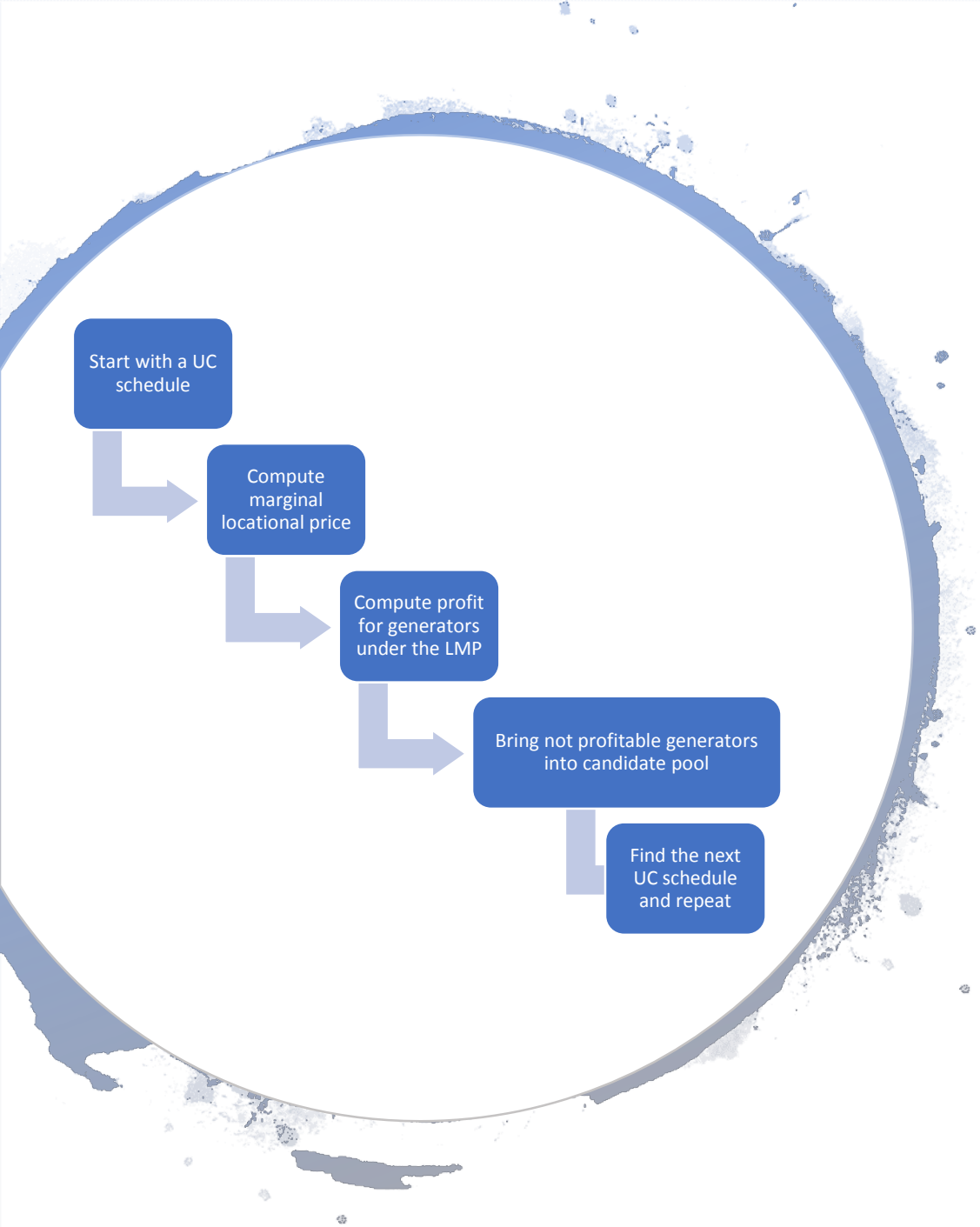


Neighborhood Search – Some Details

Variable Fixing - select center based on LP relaxation solution enhanced by machine learning.

Polishing – iterative improve center based on market-based strategy

RINS - select center based on consensus between known solution and LP relaxation.



Market Based Methods – Profit Maximization

Use market efficiency to identify “out-of money” generators which can potentially reduce objective cost.

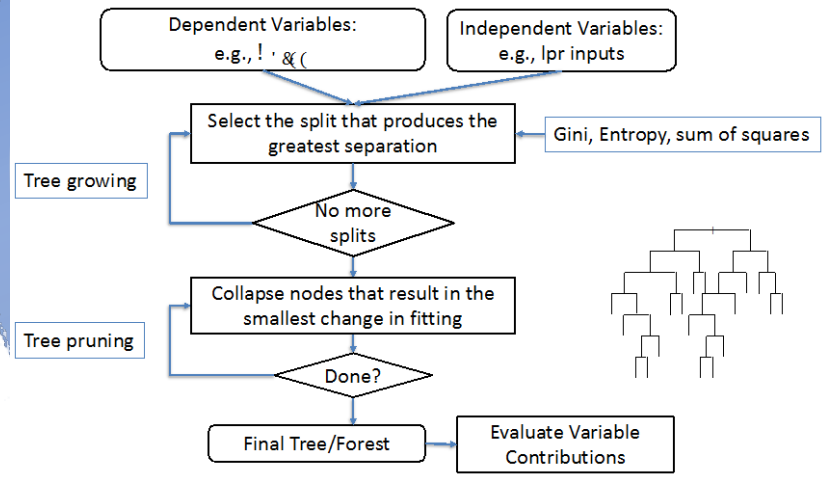
Robust – generate multiple directions for improvement and parallelizable.

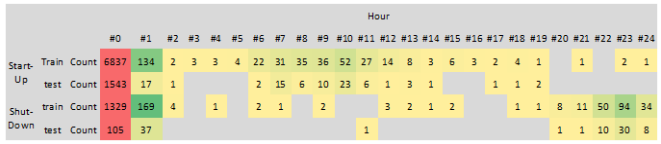
Explore Machine Learning

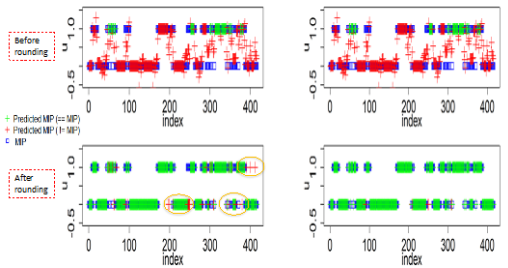
Used as an accelerator to close distance to optimal solution

Used as predictor to narrow the start and shut-down windows.

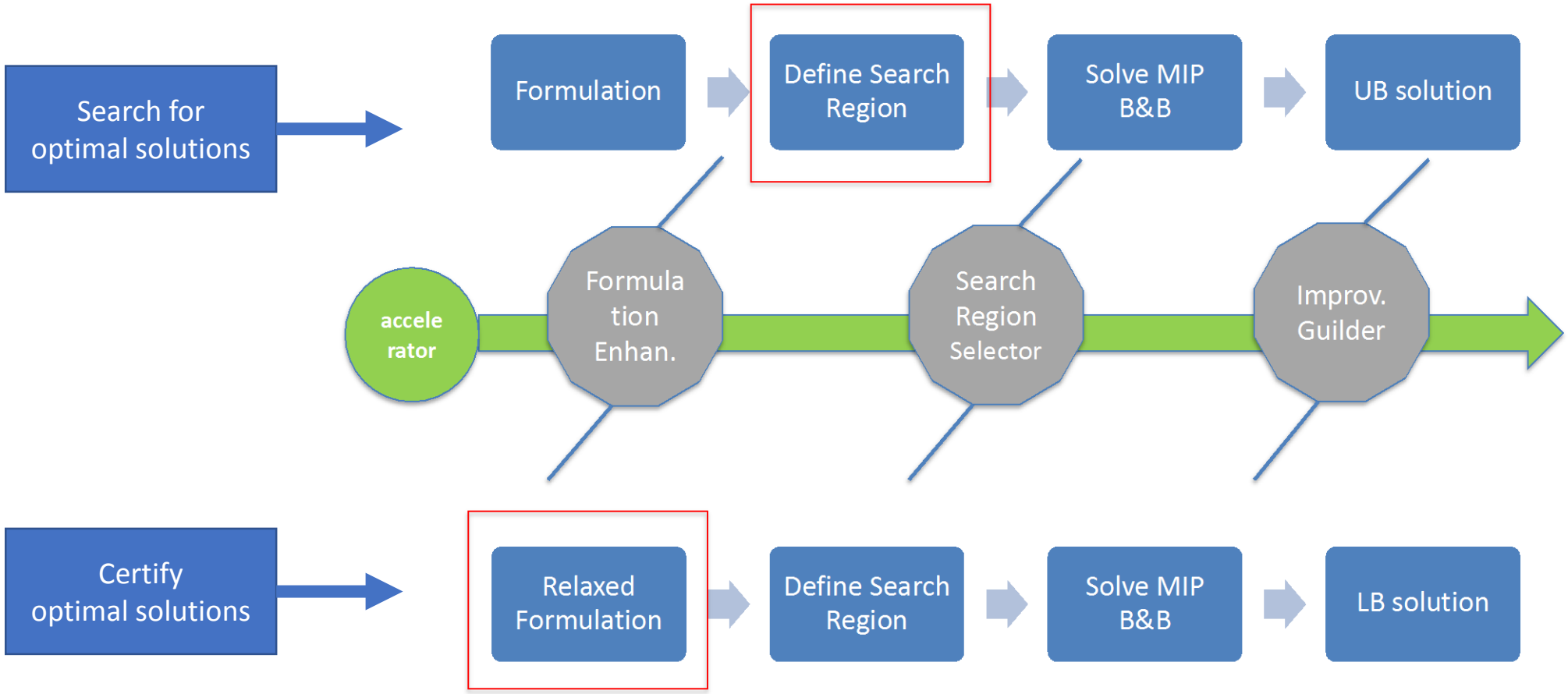
Combining regression and classification models.



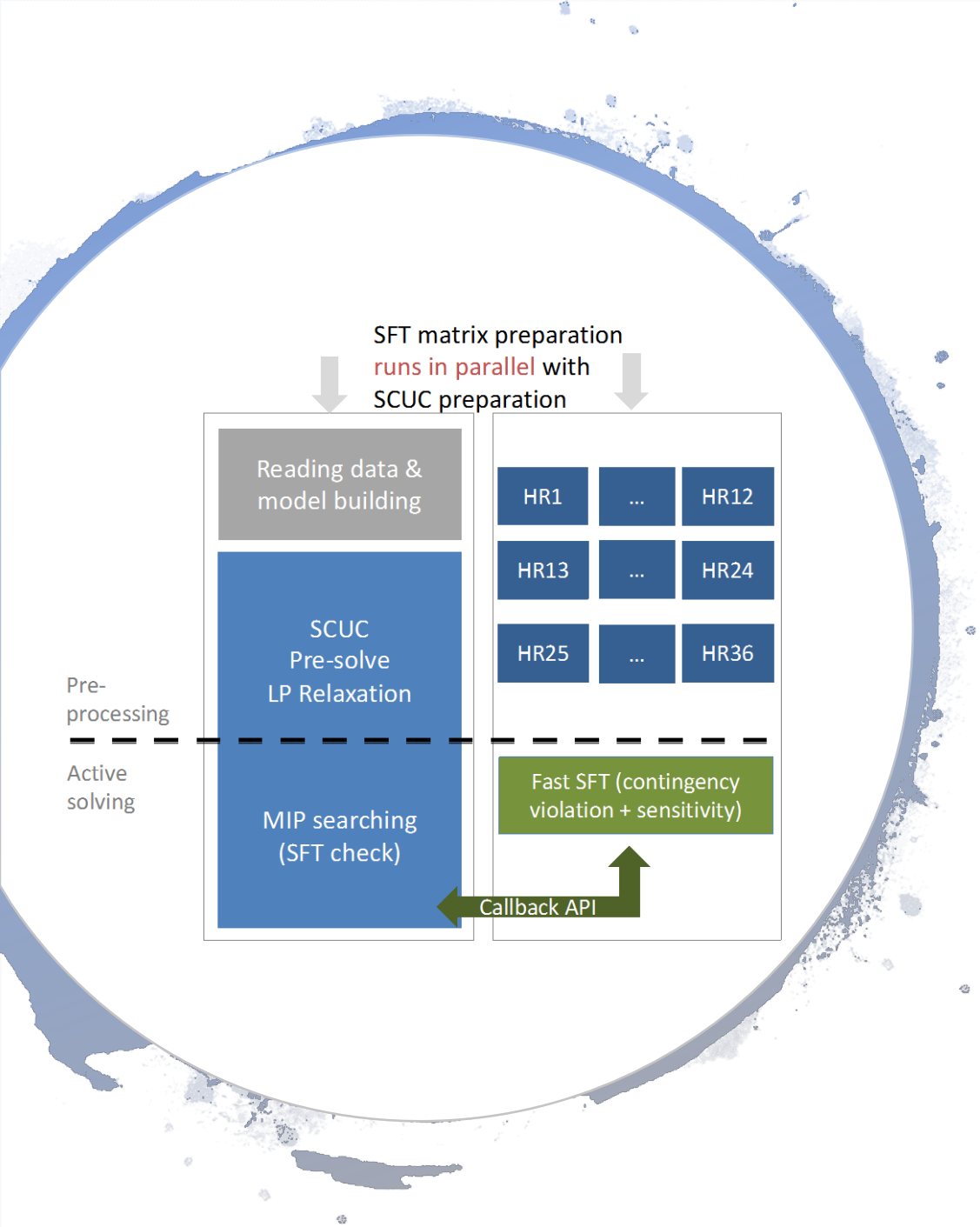




A view of Overall Solution Process



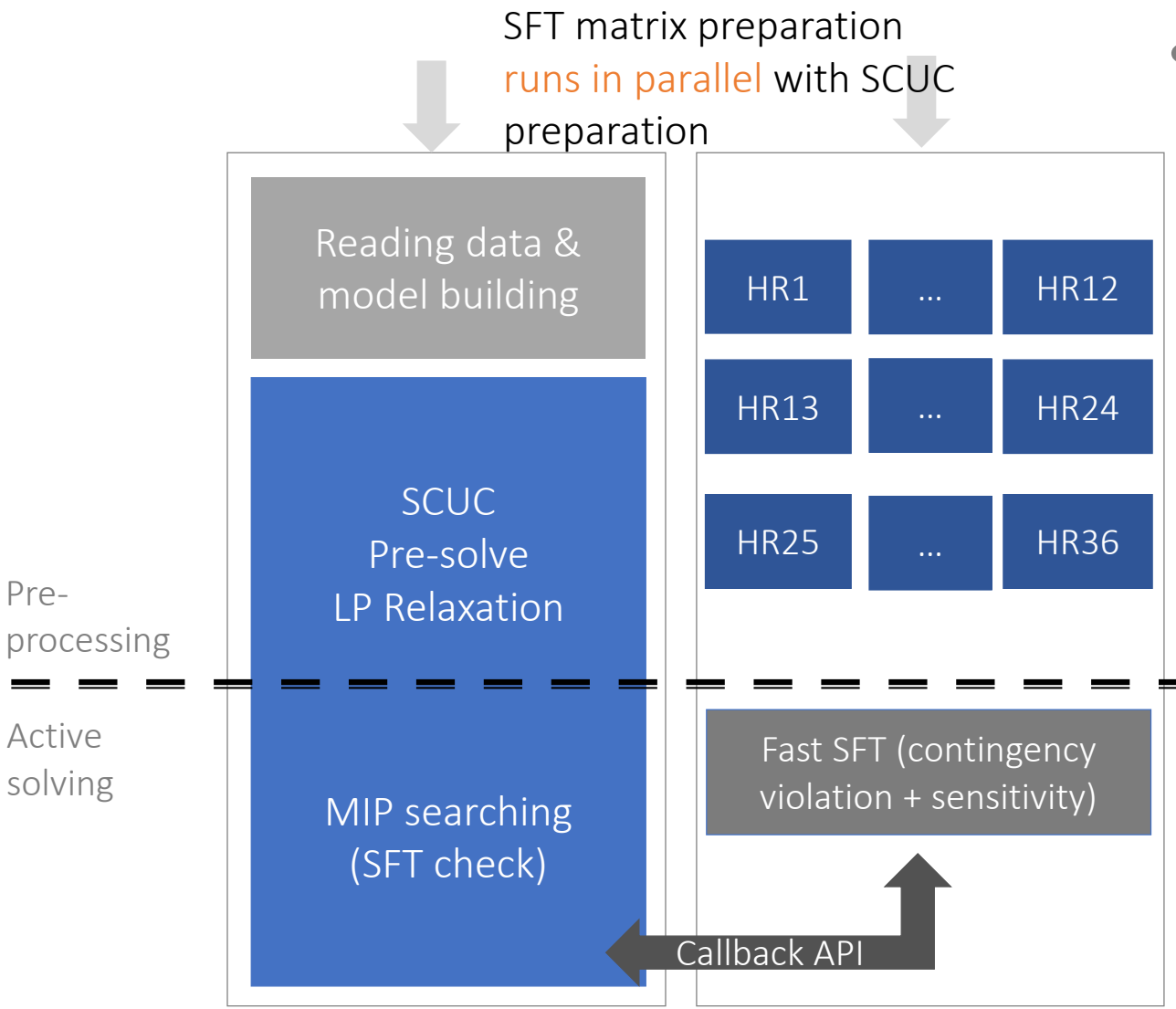
HIPPO - Simultaneous Feasibility Test (SFT)



Check feasibility of a given configuration of resource dispatch and load distribution.

Extremely fast SFT allows iteration with HIPPO SCUC through callback

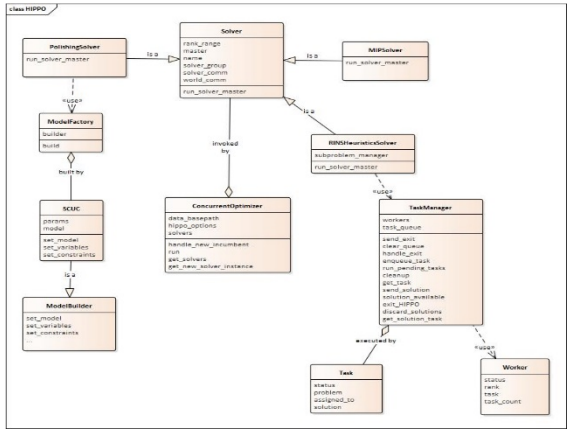
New SFT design uses parallel processing, is easily configurable across server nodes & uses efficient communication between SFT & MIP.

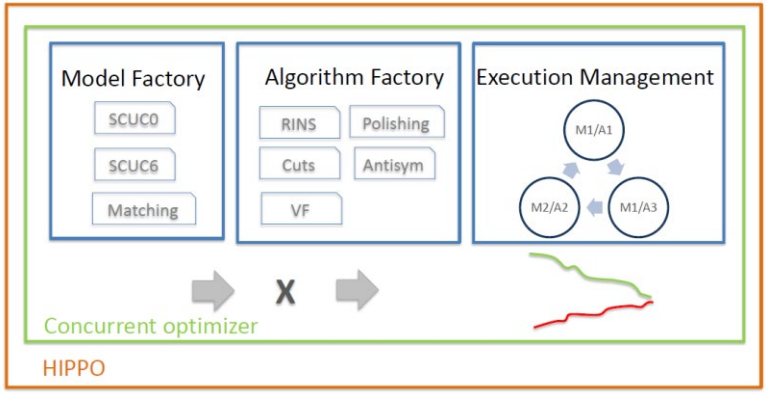


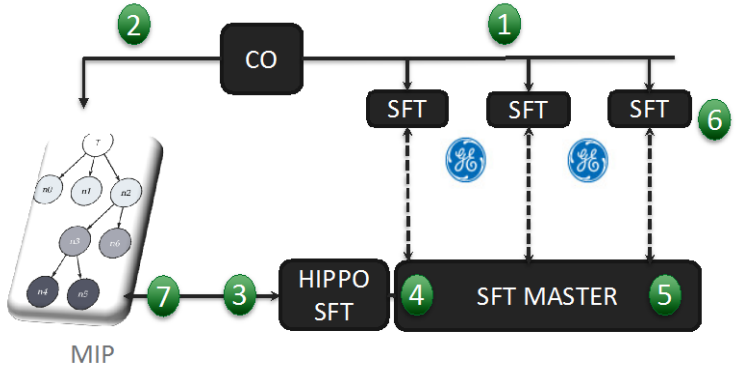
- SFT preparation for 36 intervals can be a bottleneck and require 3 nodes. (1interval1node and 36interval3node are similar)
- 1,000 contingencies are embedded in one matrix: all solved at once
- MIP callback API checks SFT and adds new constraints for each new incumbent solution

- 1000 contingency * 36 interval SFT can finish in 5 second!
- Can be integrated with MIP callback and solve SCUC-SFT in one pass.

MIP_MSS_109012019011102309_0X_run1_um1_CONCURRENT.log				
SFT configuration	3node*12processor	1node *12 processor	1node*36processor	6node*6processor
Pre-processing #Matrix/Node	12	12	36	6
#nodes	3	1	1	6
#Matrix	36	12	36	36
SFT run time | end time | #violation	40.22 | **195.70** | 252	39.85 | **197.47** | 252	418.73 | **572.77** | 252	5.82| 161.28 | 252
	4.46 | 203.47 | 7	8.82 | 209.61 | 7	7.88 | 583.93 | 7	3.88 | 168.44 | 7
	4.34 | 237.23 | 1	8.73 | 248.44 | 1	7.84 | 620.60 | 1	3.84 | 201.45 | 1
	4.35 | 260.45 | 0	8.70 | 276.21 | 0	7.73 | 646.93 | 0	3.83 | 224.04 | 0
	4.40 | 276.81 | 0	8.23 | 296.49 | 0	7.42 | 666.12 | 0	3.80 | 239.68 | 0
	4.36 | 294.97 | 1	8.60 | 319.35 | 1	7.85 | 687.60 | 1	3.75 | 257.12 | 1
	4.35 | 312.84 | 1	8.70 | 341.97 | 1	7.65 | 708.68 | 1	3.77 | 274.27 | 1
	4.36 | 328.24 | 0	8.29 | 361.73 | 0	7.74 | 727.39 | 0	3.85 | 289.09 | 0
Total Time	419	452	816	378
	H 0 0 1.640910e+07 1.6355e+07 0.33% - 115s	H 0 0 1.640910e+07 1.6355e+07 0.33% - 116s	H 0 0 1.640910e+07 1.6355e+07 0.33% - 492s	H 0 0 1.640910e+07 1.6355e+07 0.33% - 80s







HIPPO Software

PYTHON PROGRAMMING LANGUAGE.

EXECUTABLE IN DESKTOP AND HPC.

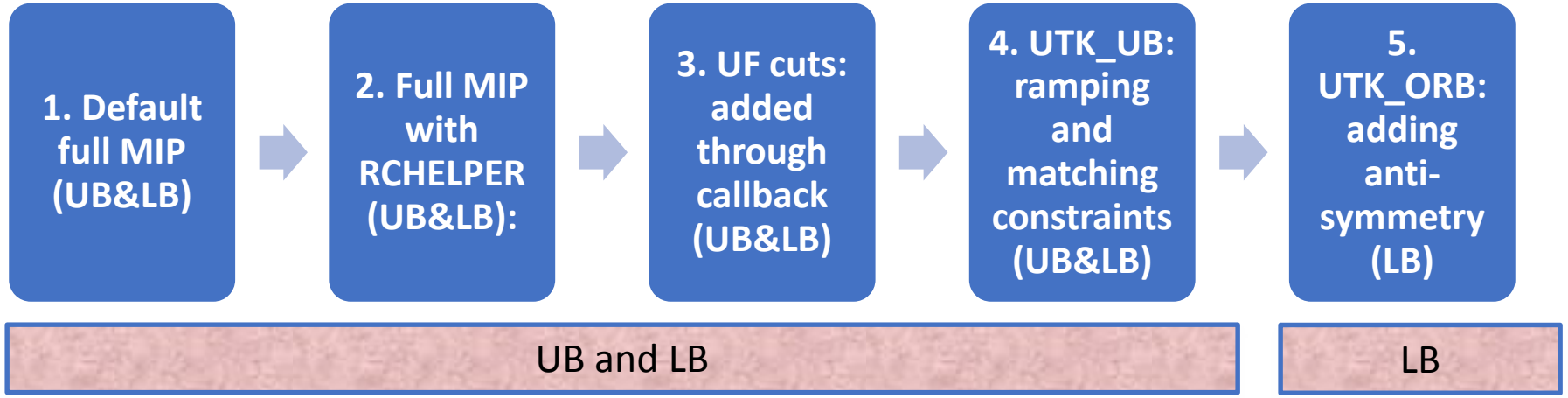
DATA MODULE, FORMULATION FACTORY, ALGORITHM FACTORY, CONFIGURATION SCRIPTS.

CONFIGURABLE CONCURRENT OPTIMIZER.

CONTINUING DEVELOPMENT.

HIPPO Concurrent Optimizer Configuration I

Gurobi full MIP with different settings
Using customized **Gurobi8.1.0** with variable fixing fork-off



May also be valid for UB. Need to add a validation step

HIPPO Technology

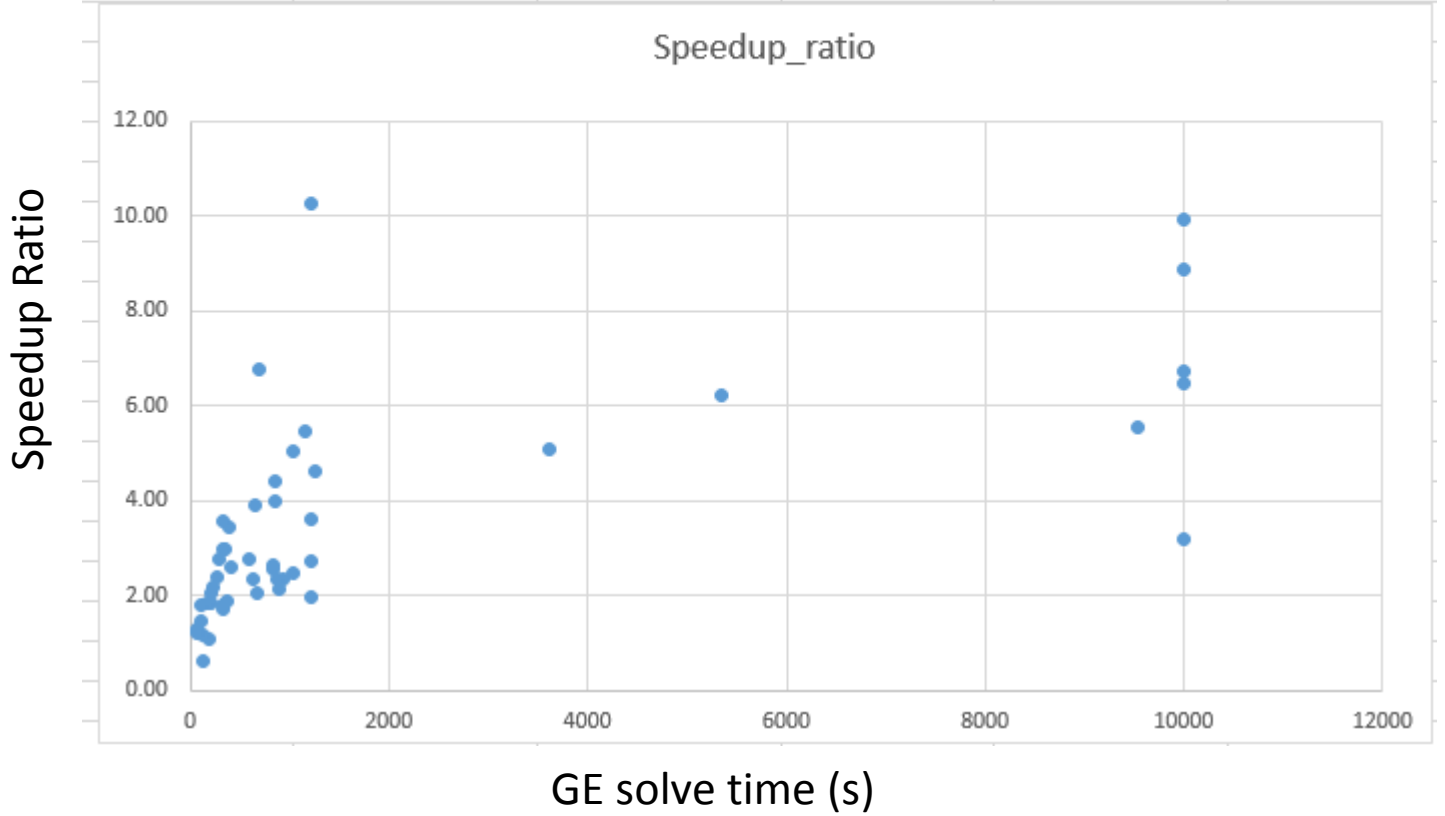
- Market data handler
- Formulation module
- Algorithm
- Security constraints
- Simultaneous feasibility test.

HIPPO Performance

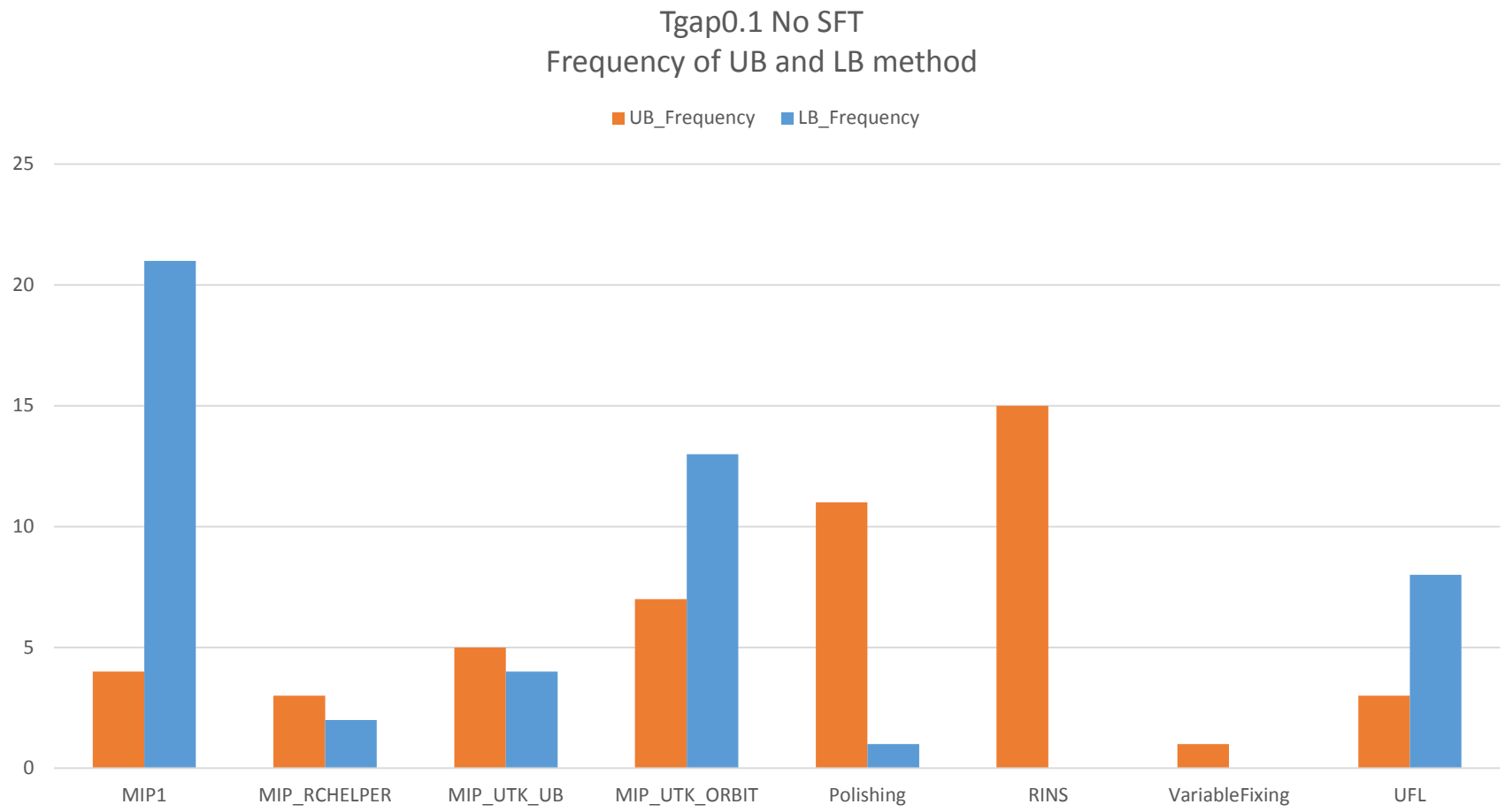
- 3-10X for SCUC without SFT
- 4-24X for SCUC with SFT

HIPPO_Concurrent versus GE (no SFT)

	HIPPO_tgap0.1	GE_tgap0.1	Speedup_ratio
Max	3113	10000	10
Median	205	677	3
Min	56	74	1

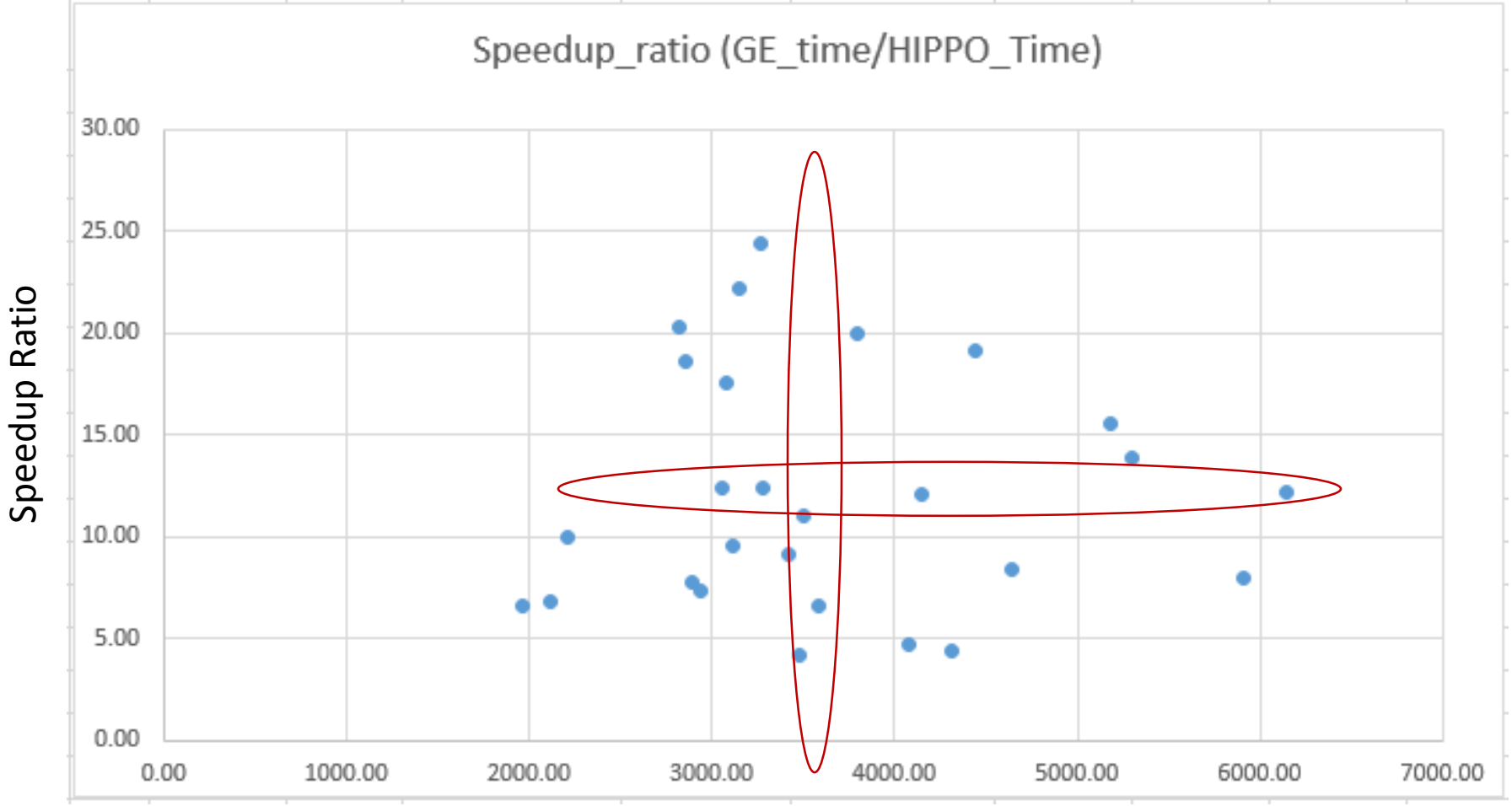


Tgap0.1 No-SFT: Frequency of UB and LB methods



HIPPO_Concurrent versus GE (with SFT)

	HIPPO_time (s)	GE_time (s)	SpeedupRatio
max	972.64	6146.93	24.41
min	133.68	1961.14	4.17
median	326.01	3417.93	11.04



Comparison by case

case	HIPPO tgap0.1 run	Gap	GE_time	Speedup_ratio (GE_time/HIPPO_Tim
MSS_20401201902102484_0X	502.10	0.09	6146.93	12.24
MSS_12401201901102815_0X	736.99	0.09	5908.18	8.02
MSS_21101201902103798_0X	382.21	0.08	5304.97	13.88
MSS_10901201901102309_0X	332.32	0.10	5185.01	15.60
MSS_21401201902102345_0X	554.34	0.07	4646.35	8.38
MSS_21201201902102208_0X	231.94	0.10	4447.27	19.17
MSS_12801201901103679_0X	972.64	0.10	4310.16	4.43
MSS_12901201901102058_0X	344.32	0.10	4149.80	12.05
MSS_31501201903091896_0X	869.88	0.08	4075.27	4.68
MSS_12201201901102121_0X	189.59	0.09	3791.59	20.00
MSS_12101201901103726_0X	545.02	0.10	3587.83	6.58
MSS_31101201903092243_0X	317.02	0.09	3500.83	11.04
MSS_21501201902102935_0X	835.62	0.10	3482.29	4.17
MSS_31401201903091482_0X	373.79	0.10	3417.93	9.14
MSS_31201201903092764_0X	263.53	0.09	3277.54	12.44
MSS_20601201902101872_0X	133.68	0.10	3263.62	24.41
MSS_31801201903091613_0X	141.80	0.10	3149.88	22.21
MSS_10801201901101208_0X	326.01	0.09	3118.49	9.57
MSS_22201201902102387_0X	175.76	0.10	3078.86	17.52
MSS_31301201903091864_0X	246.38	0.07	3060.54	12.42
MSS_30801201903101344_0X	399.97	0.09	2940.59	7.35
MSS_20501201902101976_0X	370.18	0.10	2888.79	7.80
MSS_20701201902102380_0X	153.53	0.07	2855.89	18.60
MSS_21601201902101713_0X	138.79	0.09	2823.06	20.34
MSS_12301201901101610_0X	222.01	0.10	2213.88	9.97
MSS_12601201901101230_0X	310.38	0.10	2111.20	6.80
MSS_12501201901101807_0X	296.88	0.10	1961.14	6.61

HIPPO_Concurrent versus GE (with SFT)

HIPPO Status

- Current status
- Future plan and opportunities

HIPPO – Current Status

Validated with MISO-GE production models.

Good performance results.

Remove computation hurdles and technology transfer.

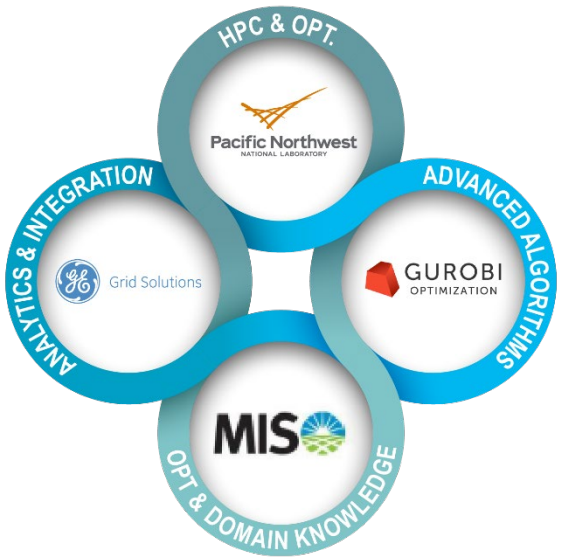
Test for future cases -15-min interval, increasing virtuals and dispatchable demands

Improve HIPPO for usability and to handle the next generation challenges.

HIPPO at MISO

Future resource project	Future DER scenarios and evaluation of market rules and software performance	DER aggregation T&D integration
Renewable study - 15-min DA case	Watchlist constraint pre-screening	Enhanced combined cycle and pumped storage optimization
Pricing study	Historical data / ML	Case library with over 120 historical cases can be used for future studies

Evaluate path for production implementation



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Thank you!