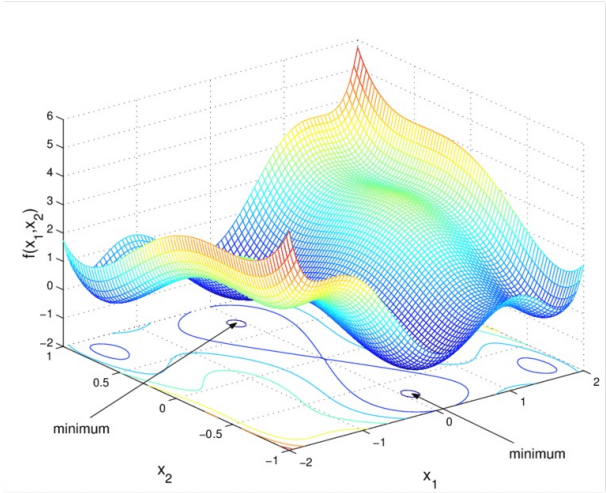
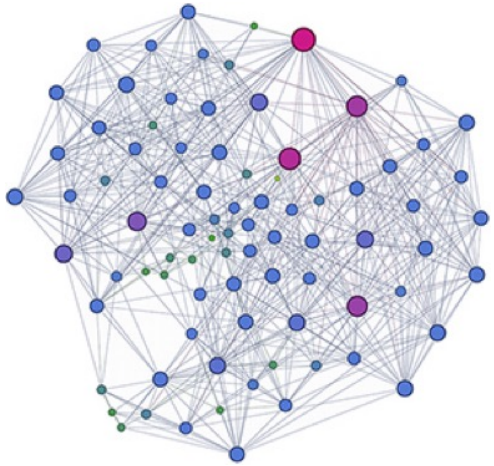
Convex Relaxations and Integer Rounding Heuristics for the Grid Optimization Competition

Hassan Hijazi - GravityX

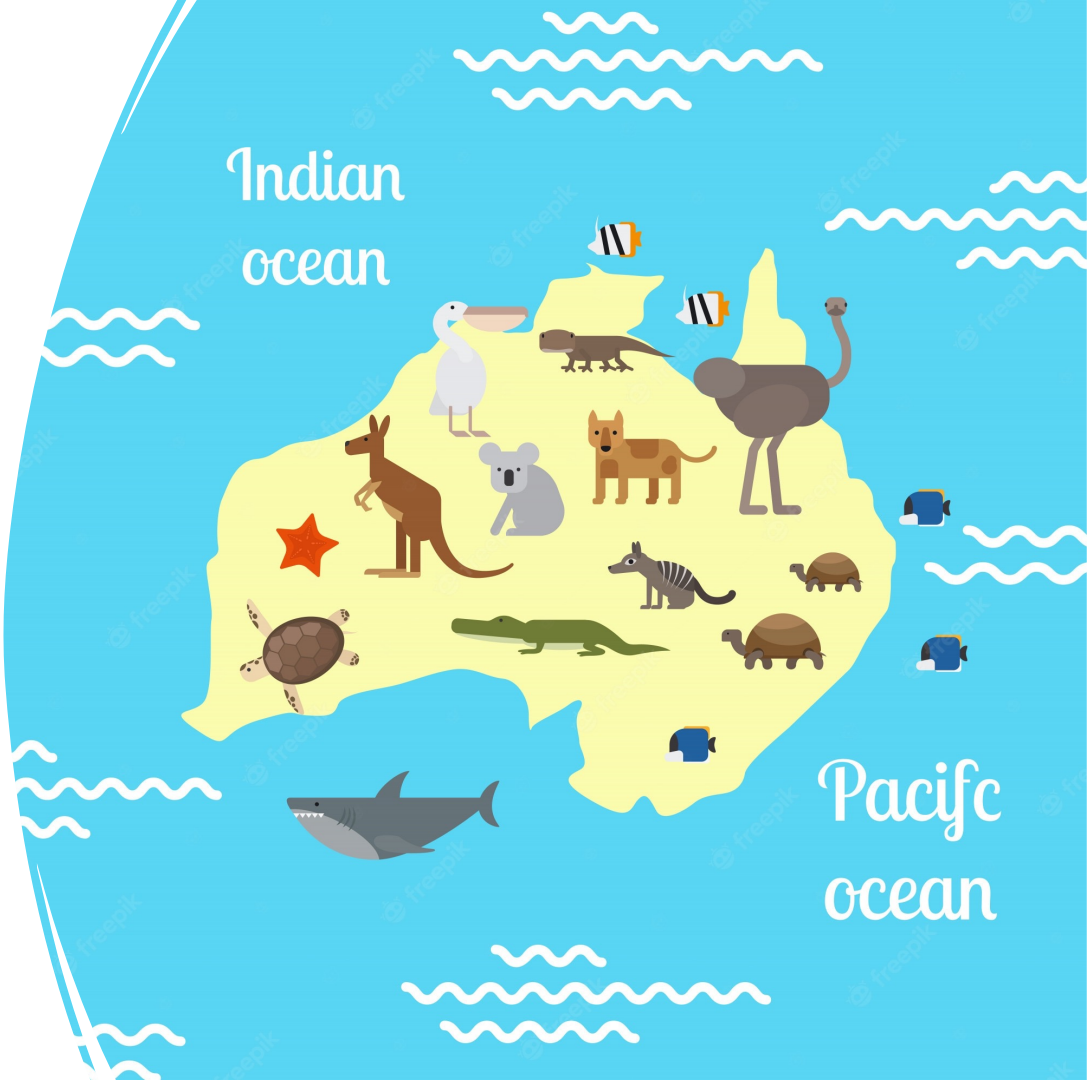
INFORMS 2022





How it all started

Ten years ago..



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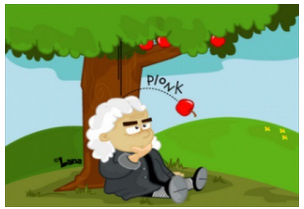
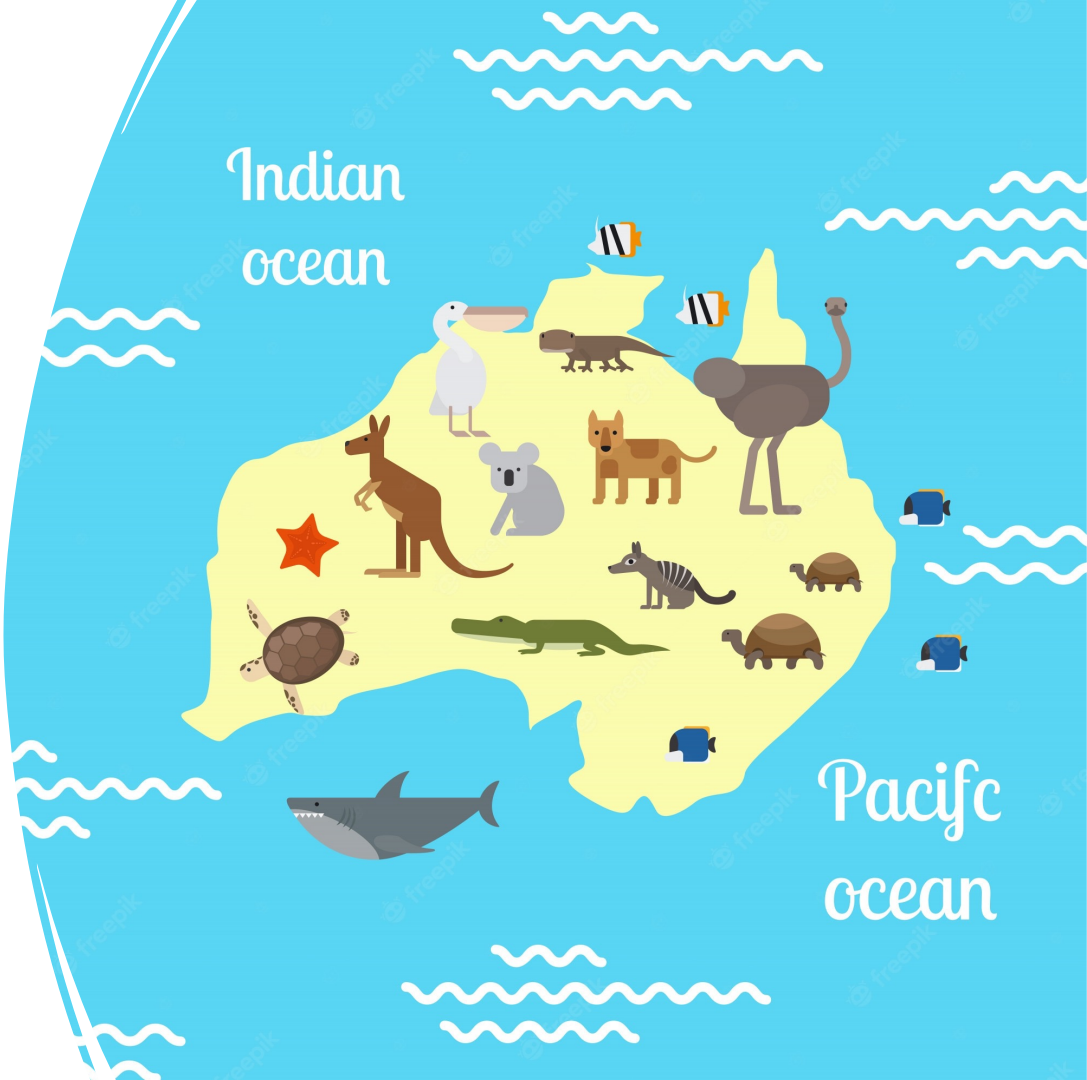


GRAVITY

Ten years ago..



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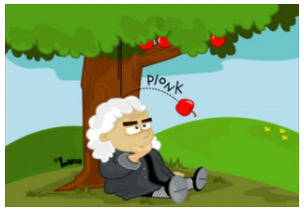
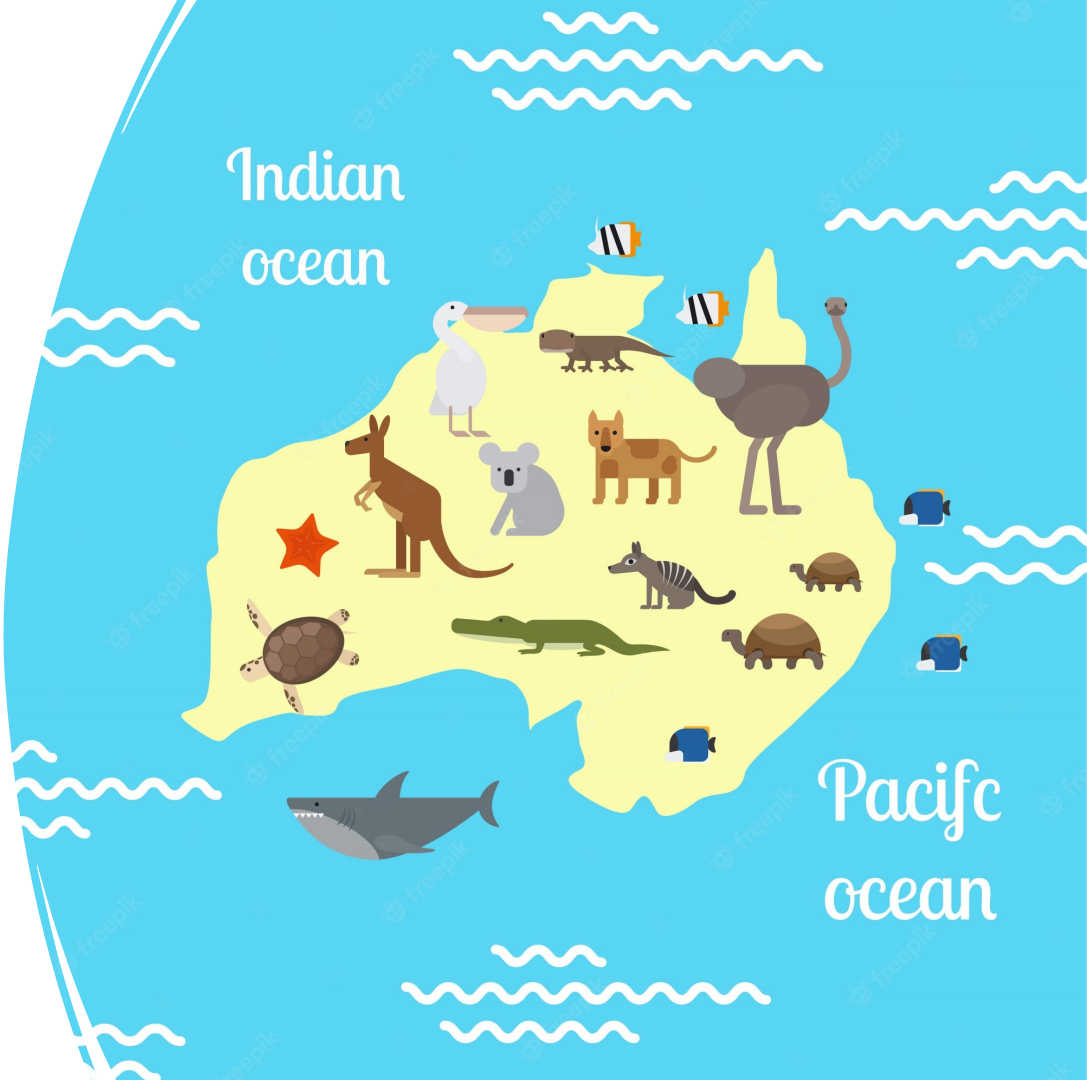


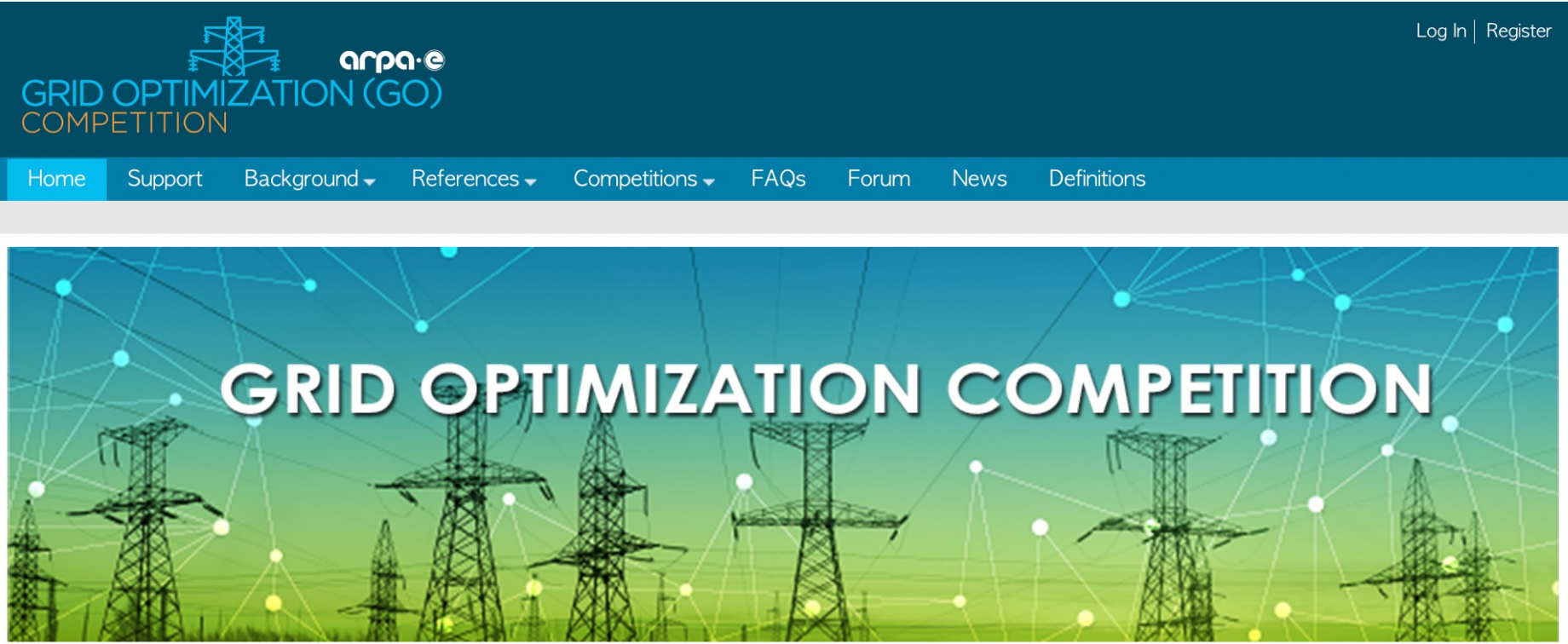
GRAVITY

Ten years ago..
If you had walked up to me



Thanks to ARPA-E, LANL, and PNNL

esp. Steve Elbert, Arun Veeramany and Jesse Holzer



Monarch of the Mountain

CHALLENGE 2: MONARCH OF THE MOUNTAIN

The Grid Optimization (GO) Competition Post Challenge 2 Event named **Challenge 2: Monarch of the Mountain** or **Ch2-MoM**, will focus on finding improved solutions to the security-constrained optimal power flow (SCOPF) problem introduced in Challenge 2.

Challenge 2 required competitors to solve SCOPF problems in a limited amount of time on a uniform High Performance Computing (HPC) system maintained and operated by the GO Administrator, Pacific Northwest National Laborabory.

Public datasets – No time limits – No hardware limits

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84 instances:

$5,000 if solution improves CH2 objective by 1%

$5,000 if solution has been on the leaderboard the longest

Challenge 2 vs Monarch of the Mountain

Algorithm 1 Iterative Batch Rounding (IBR)

1: Group discrete variables into predefined batches $\mathcal{B}_1$ to $\mathcal{B}_n$.
2: Solve continuous relaxation of MINLP (1).
3: **for** $i \in \{1, \ldots, n\}$ **do**
4: Call the custom ROUND function on batch $\mathcal{B}_i$
5: Fix all rounded variables in batch $\mathcal{B}_i$
6: Solve the continuous relaxation of reduced MINLP (1).
7: **end for**

- One hour time limit vs unlimited
- n = 3 vs n = 8
- No contingencies added to the base case model vs one line contingency added.

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Not enough!
Beaten by VATech

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Challenge 2 vs Monarch of the Mountain

IBR heuristic vs IBR + a Mixed-Integer Second-Order Cone Relaxation

Challenge 2 vs Monarch of the Mountain

IBR heuristic vs IBR + a Mixed-Integer Second-Order Cone Relaxation

Run IBR with one batch including binaries affecting line properties

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Relax the power flow equations using second-order cone constraints

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Solve the MISOC (includes unit commitment binaries) using Gurobi

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Fix the UC binaries and rerun IBR on the original MINLP

Challenge 2 vs Monarch of the Mountain

Solve the MISOC (includes unit commitment binaries) using Gurobi

```
Barrier solved model in 49 iterations and 6.52 seconds (6.52 work units)
Optimal objective 4.14182236e+06


Root relaxation: objective 4.141822e+06, 0 iterations, 5.80 seconds (6.03 work units)
Another try with MIP start

    Nodes    |    Current Node    |     Objective Bounds      |     Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time

     0     0 4141822.36    0  111          - 4141822.36      -     -    6s
     0     0 4141456.14    0   26          - 4141456.14      -     -   16s
     0     0 4141455.80    0   20          - 4141455.80      -     -   32s
     0     0 4141446.14    0   12          - 4141446.14      -     -   40s
     0     0 4141445.04    0   18          - 4141445.04      -     -   49s
     0     0 4141442.17    0   78          - 4141442.17      -     -   57s
     0     0 4141442.17    0   10          - 4141442.17      -     -   65s
     0     0 4141442.17    0   18          - 4141442.17      -     -   72s
     0     2 4141442.17    0   16          - 4141442.17      -     -  114s
     1     4 4141442.17    1   18          - 4141442.17      -   0.0  123s
     3     8 4141442.17    2   16          - 4141442.17      -   0.0  137s
     7    16 4141442.17    3    8          - 4141442.17      -   0.0  163s
```

Challenge 2 vs Monarch of the Mountain

IBR heuristic vs IBR + a Mixed-Integer Second-Order Cone Relaxation

Run IBR with one batch including binaries affecting line properties

Relax the power flow equations using second-order cone constraints

Run IBR on MISOC!

Solve the MISOC (includes unit commitment binaries) using Gurobi

Fix the UC binaries and rerun IBR on the original MINLP

Challenge 2 vs Monarch of the Mountain

Solve the MISOC (includes unit commitment binaries) using Gurobi

```
Barrier solved model in 49 iterations and 6.46 seconds (6.52 work units)
Optimal objective 4.14182236e+06


Root relaxation: objective 4.141822e+06, 0 iterations, 5.82 seconds (6.03 work units)

    Nodes    |    Current Node    |     Objective Bounds      |     Work
 Expl Unexpl |  Obj  Depth IntInf | Incumbent    BestBd   Gap | It/Node Time

     0     0 4141822.36    0  111 4141167.81 4141822.36  0.02%     -    6s
```

Challenge 2 vs Monarch of the Mountain

Date	model	scenario	Best MSgain	Best Objective	Team, Source	% MSgain Improvement	Previous Best MSgain	Previous Best Team	Best Ch2 MSgain
8/9/2022	C2FEN02020	134	170,552	4,909,025	GOT-BSI-OPF, MoM	0.3790%	170,548	GravityX, MoM	169,908
8/2/2022	C2FEN02020	260	201,713	6,057,441	GOT-BSI-OPF, MoM	0.0536%	201,654	GravityX, MoM	201,605
8/9/2022	C2FEN02020	262	211,858	5,895,315	GOT-BSI-OPF, MoM	0.0345%	211,830	GravityX, MoM	211,785
8/7/2022	C2FEN02312	3	175,061	5,645,630	GravityX, MoM	**1.0027%**	174,993	GravityX, MoM	173,323
4/21/2022	C2FEN02312	18	168,358	5,101,496	GravityX, MoM	0.4786%	*168,253*	*Gordian Knot, MoM*	167,556
4/21/2022	C2FEN02312	21	203,245	4,720,343	GravityX, MoM	0.5755%	*203,034*	*Gordian Knot, MoM*	202,082
2/28/2022	C2FEN02312	40	237,659	7,545,722	Gordian Knot, MoM	0.6624%	*237,546*	*Gordian Knot, MoM*	236,095
2/28/2022	C2FEN02312	44	206,690	6,185,958	Gordian Knot, MoM	*0.9146%*	204,817	GravityX Div. 1-4	204,817
9/6/2022	C2FEN03288	9	258,547	16,793,530	GOT-BSI-OPF, MoM	0.0786%	258,457	GravityX, MoM	258,344
3/5/2022	C2FEN03288	29	232,432	9,430,817	GravityX, MoM	0.0400%	232,393	GravityX, MoM	232,339
9/6/2022	C2FEN03288	35	245,252	9,619,315	GOT-BSI-OPF, MoM	0.1016%	245,093	GravityX, MoM	245,003
3/6/2022	C2FEN03288	41	299,817	10,361,584	GravityX, MoM	0.0298%	299,806	GravityX, MoM	299,728
8/24/2022	C2FEN03288	43	248,528	9,203,026	GravityX, MoM	0.0568%	248,430	GravityX, MoM	248,387
5/4/2022	C2FEN03970	22	169,059	222,904	GravityX, MoM	0.1502%	168,805	NU_Columbia_Artelys Div. 3,4	168,805
9/6/2022	C2FEN03970	23	163,914	257,435	GOT-BSI-OPF, MoM	0.0623%	163,842	GravityX, MoM	163,812
8/25/2022	C2FEN04200	9	1,498,655	5,836,295	GravityX, MoM	0.1231%	1,497,031	GravityX, MoM	1,496,812
3/15/2022	C2FEN04200	10	1,503,282	6,098,130	GravityX, MoM	0.0229%	1,502,939	GravityX Div. 1-4	1,502,939

Thank you!