OASIS AI

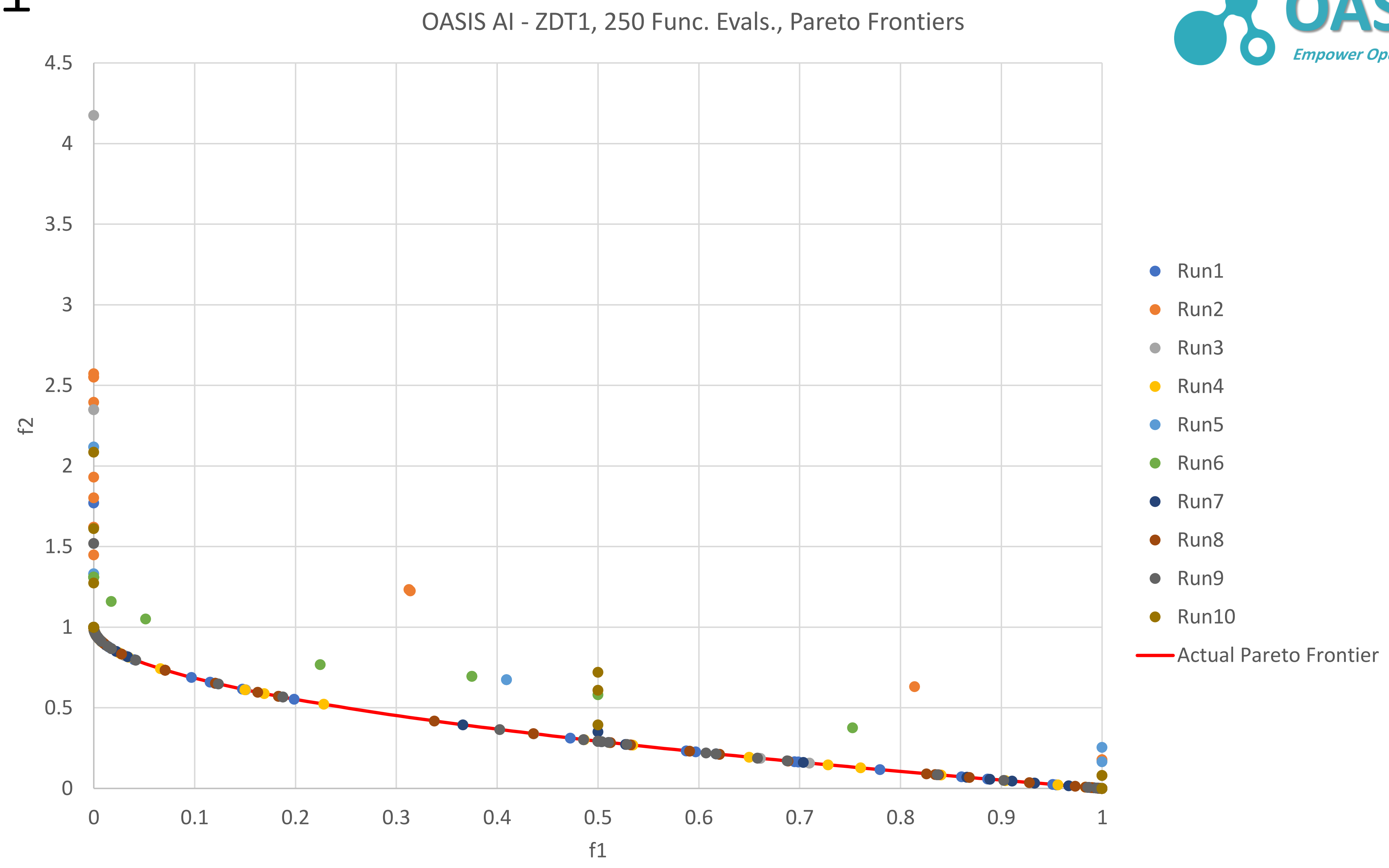
Empower Operations

Technical Assessment
November 2023

Test Cases

No	Problem Type	Benchmark	No. of Inputs	No. of Objectives	No. of Constraints	Budget (Func. Eval)
1	Multi-Objective, unconstrained	ZDT 1	30	2	0	250
2	Multi-Objective, unconstrained	ZDT 2	30	2	0	250
3	Multi-Objective, unconstrained	ZDT 3	30	2	0	250
4	Multi-Objective, unconstrained	ZDT 6	10	2	0	250
5	Multi-Objective, expensive constraints	OSY Exp. Cons.	6	2	6	500
6	Multi-Objective, cheap constraints	OSY Cheap Cons.	6	2	6	500
7	Multi-Objective, unconstrained	Geartrain	4 - Discrete	2	0	1000
8	Single Objective, expensive constraints	G7	10	1	8	500
9	Unimodal, unconstrained	Rosenbrock d10	10	1	0	1000
10	Unimodal, unconstrained	Rosenbrock d50	50	1	0	1000
11	Multimodal, unconstrained	Shubert d10	10	1	0	1000
12	Multimodal, unconstrained	Shubert d30	30	1	0	1000
13	Multimodal, unconstrained	Shubert d60	60	1	0	1000
14	Ill-shaped, unconstrained	Michalewicz d10	10	1	0	1000
15	Ill-shaped, unconstrained	Michalewicz d30	30	1	0	1000
16	Ill-shaped, unconstrained	Michalewicz d60	60	1	0	1000
17	Multimodal, high dimensional, highly constrained	Mopta08 - in progress	124	1	68	2000

ZDT1



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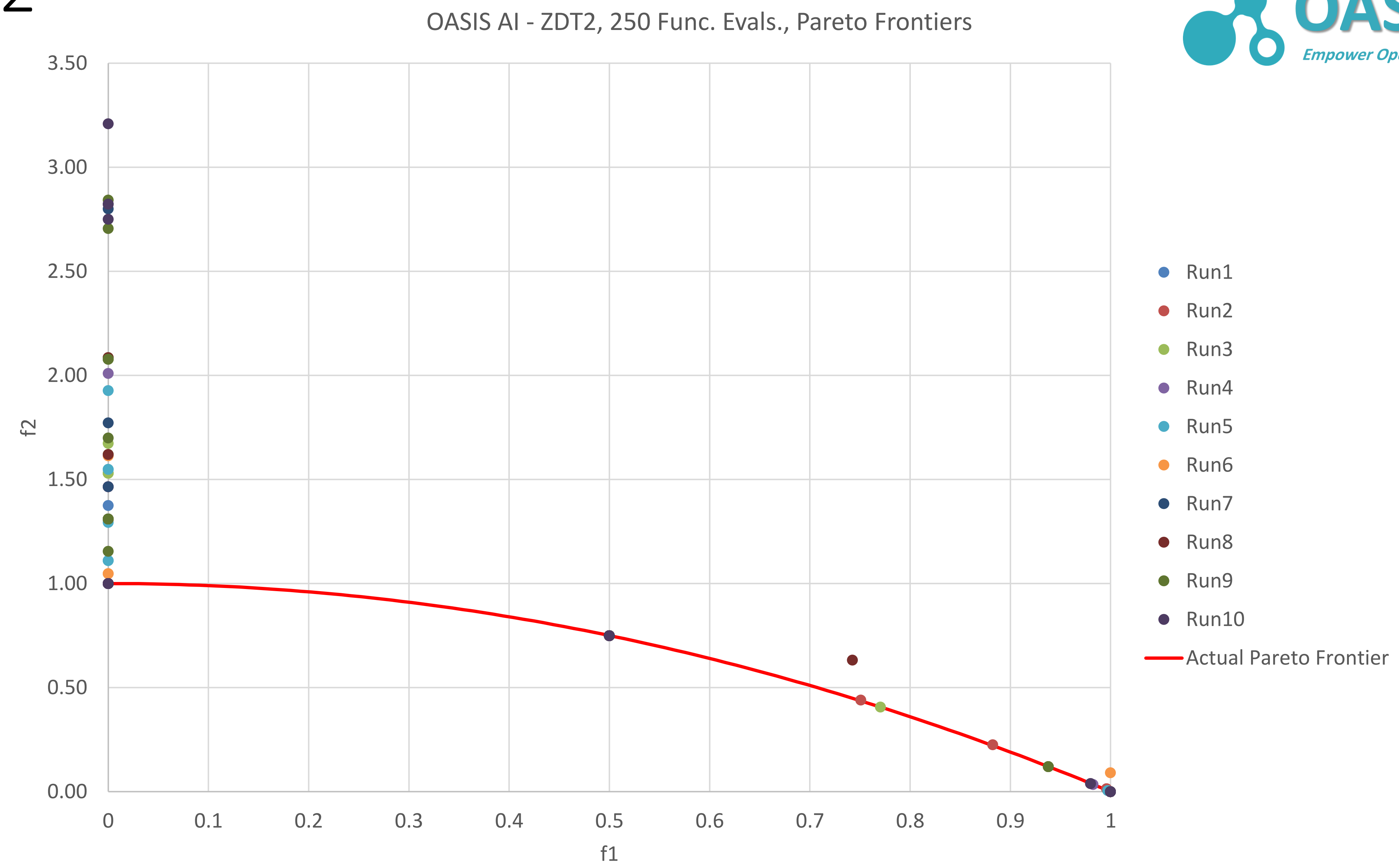
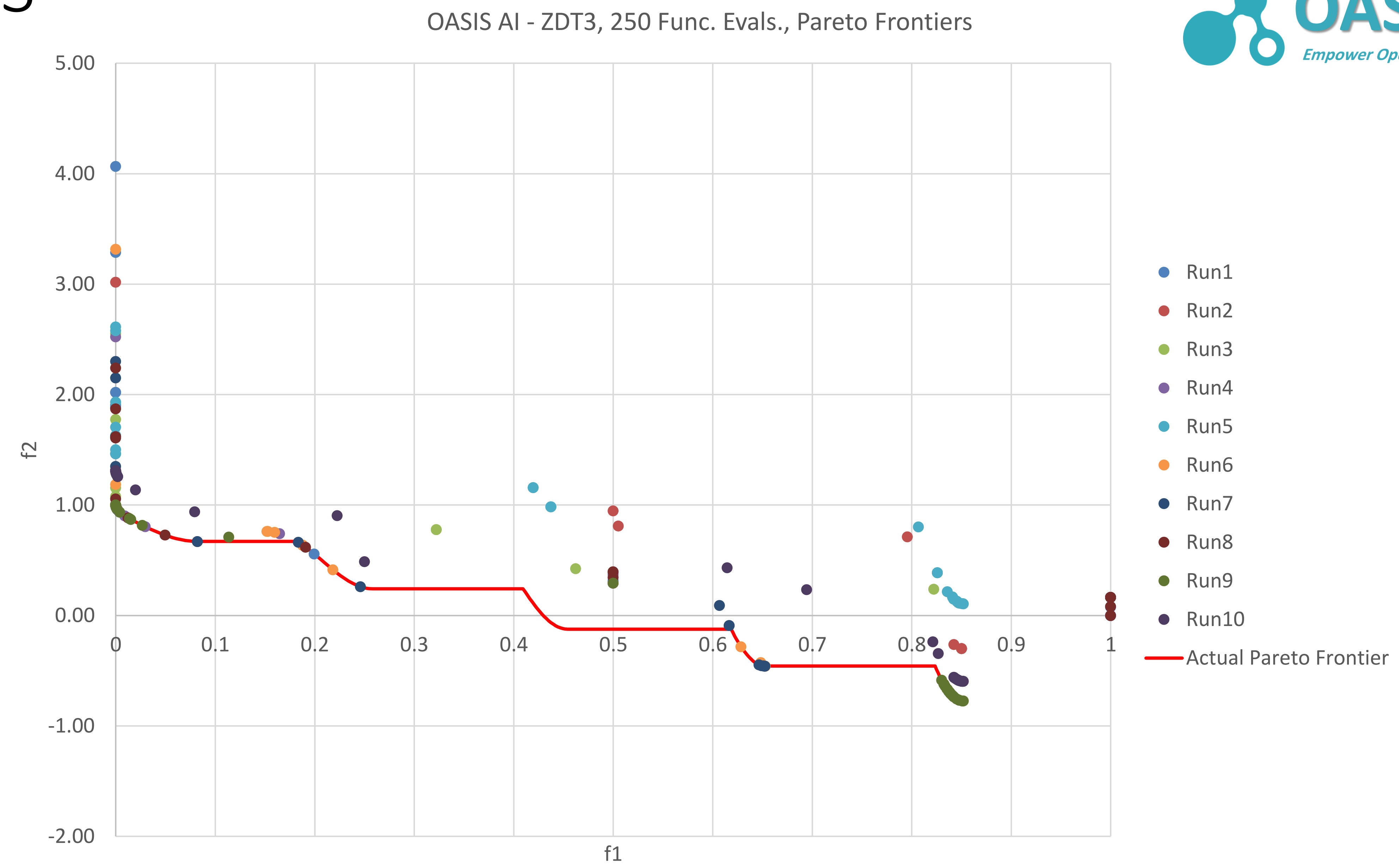
ZDT2


OASIS AI - ZDT2, 250 Func. Evals., Pareto Frontiers
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
f2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
f1
Run1
Run2
Run3
Run4
Run5
Run6
Run7
Run8
Run9
Run10
Actual Pareto Frontier

ZDT3



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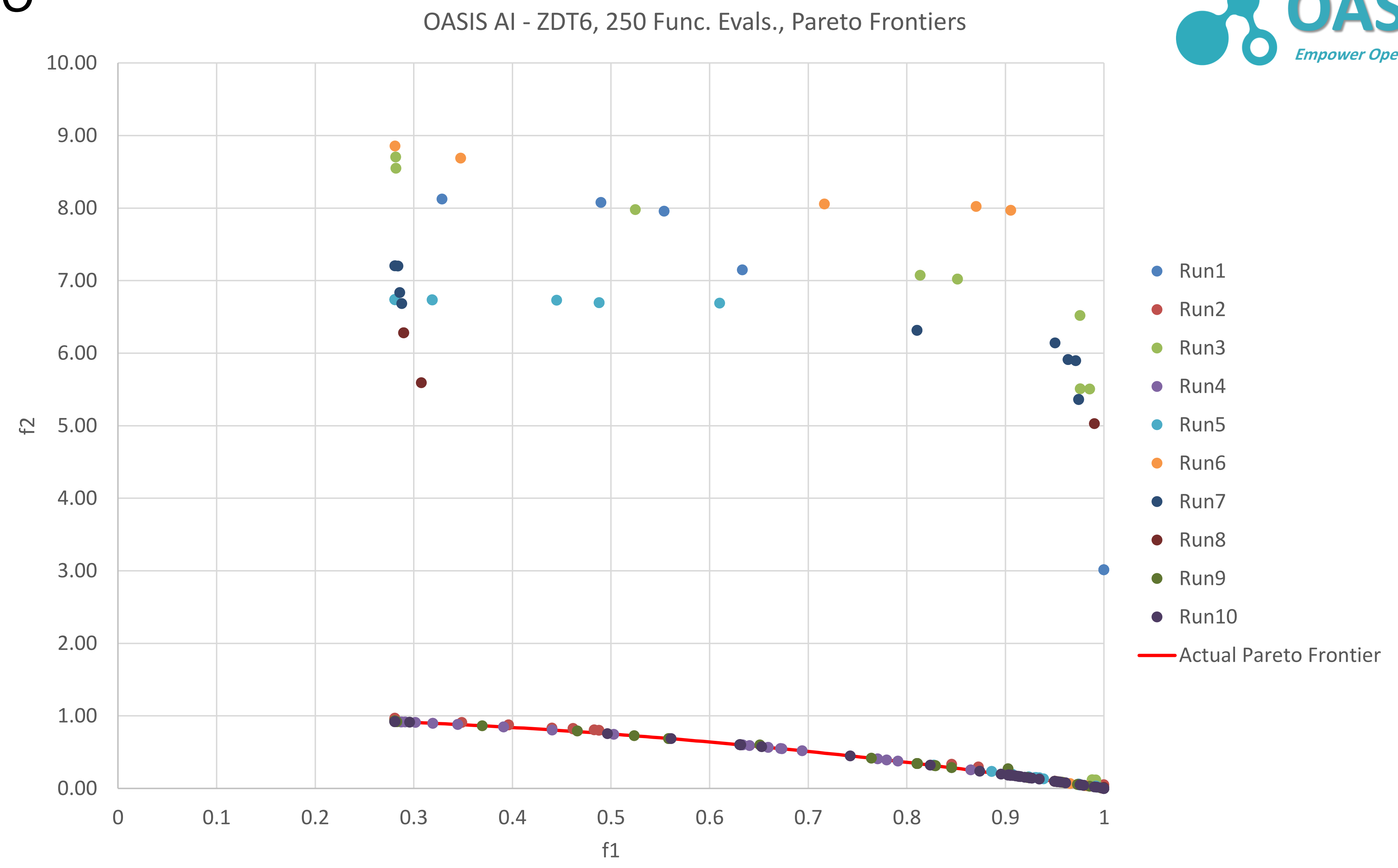
ZDT6



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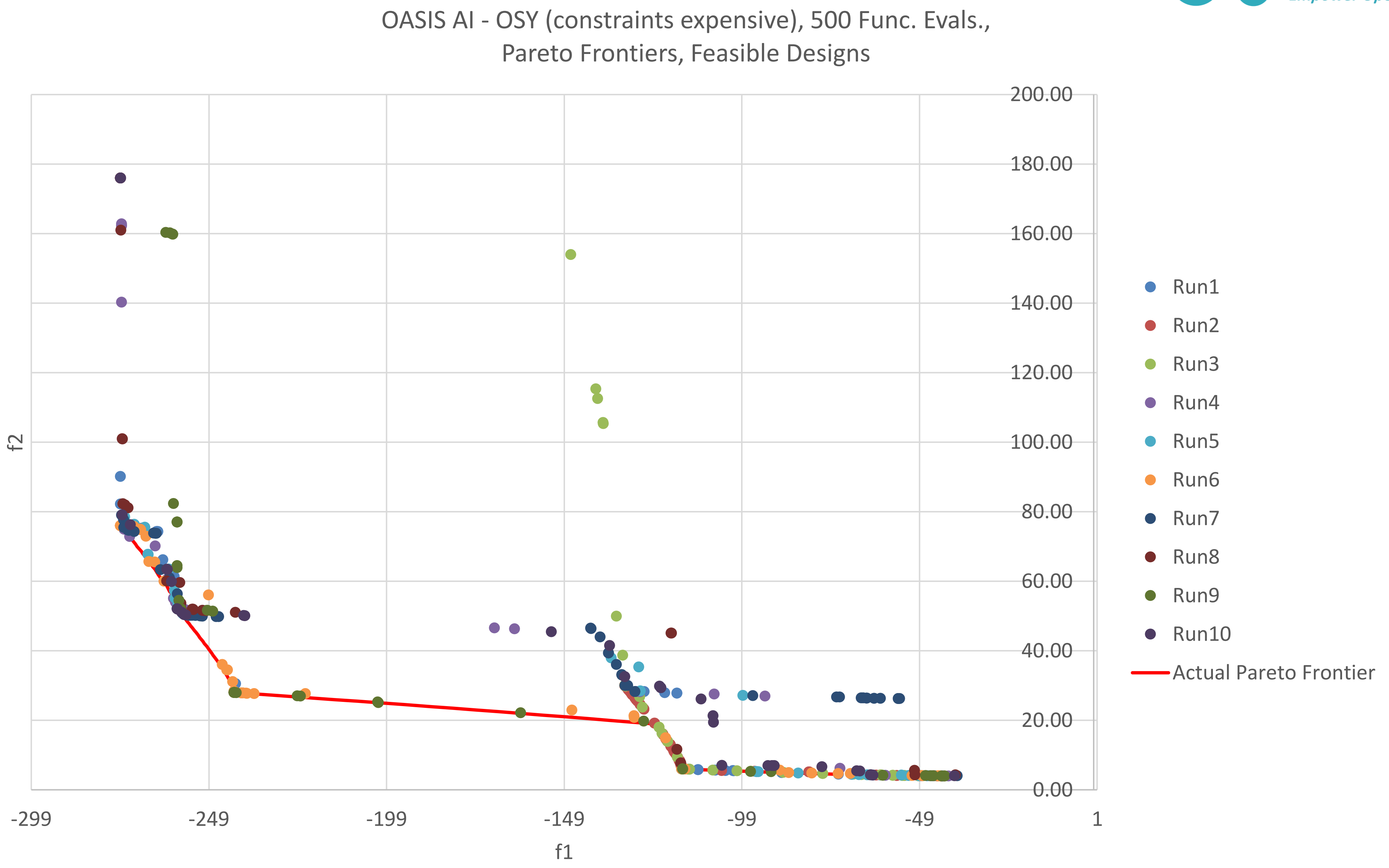
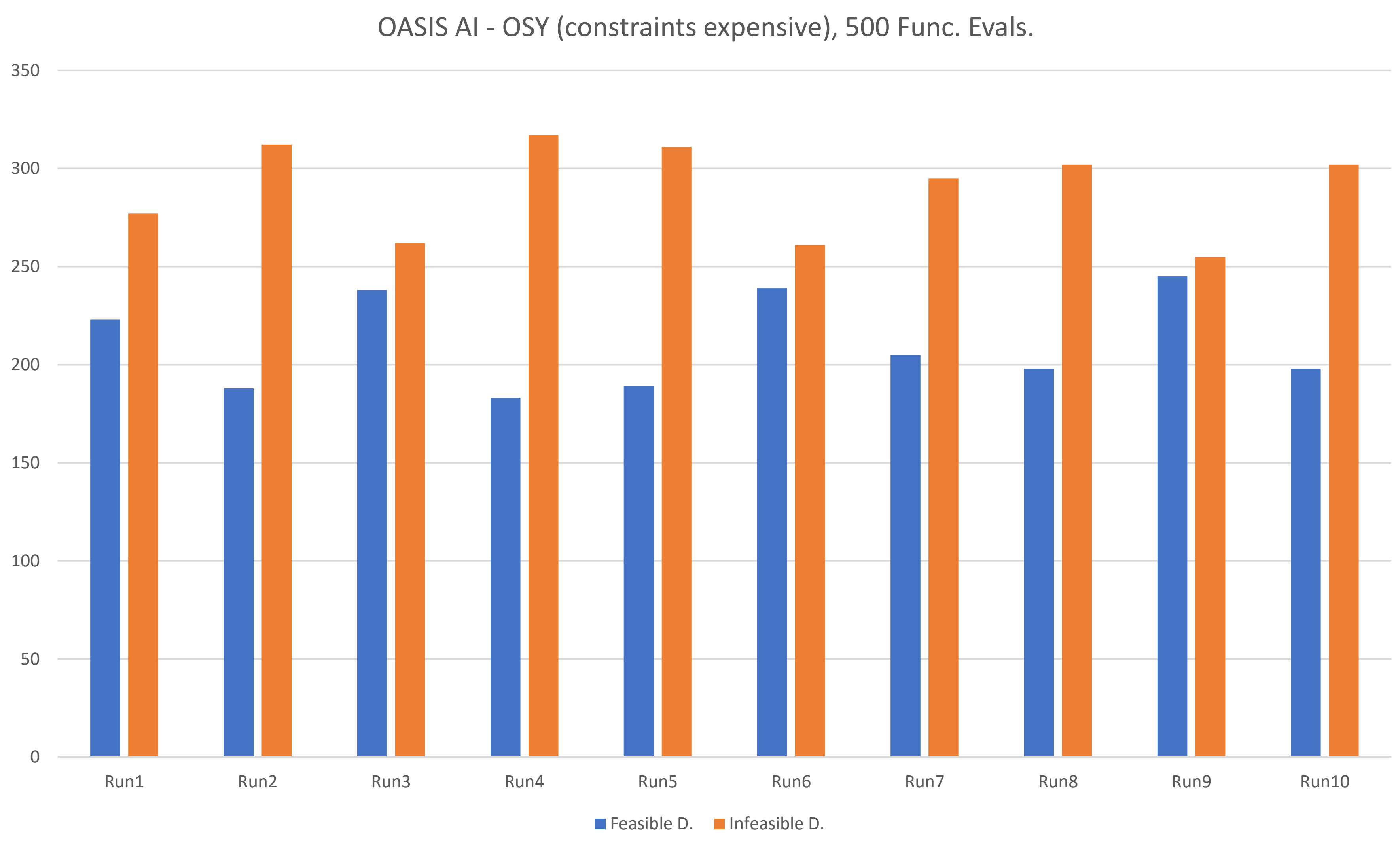
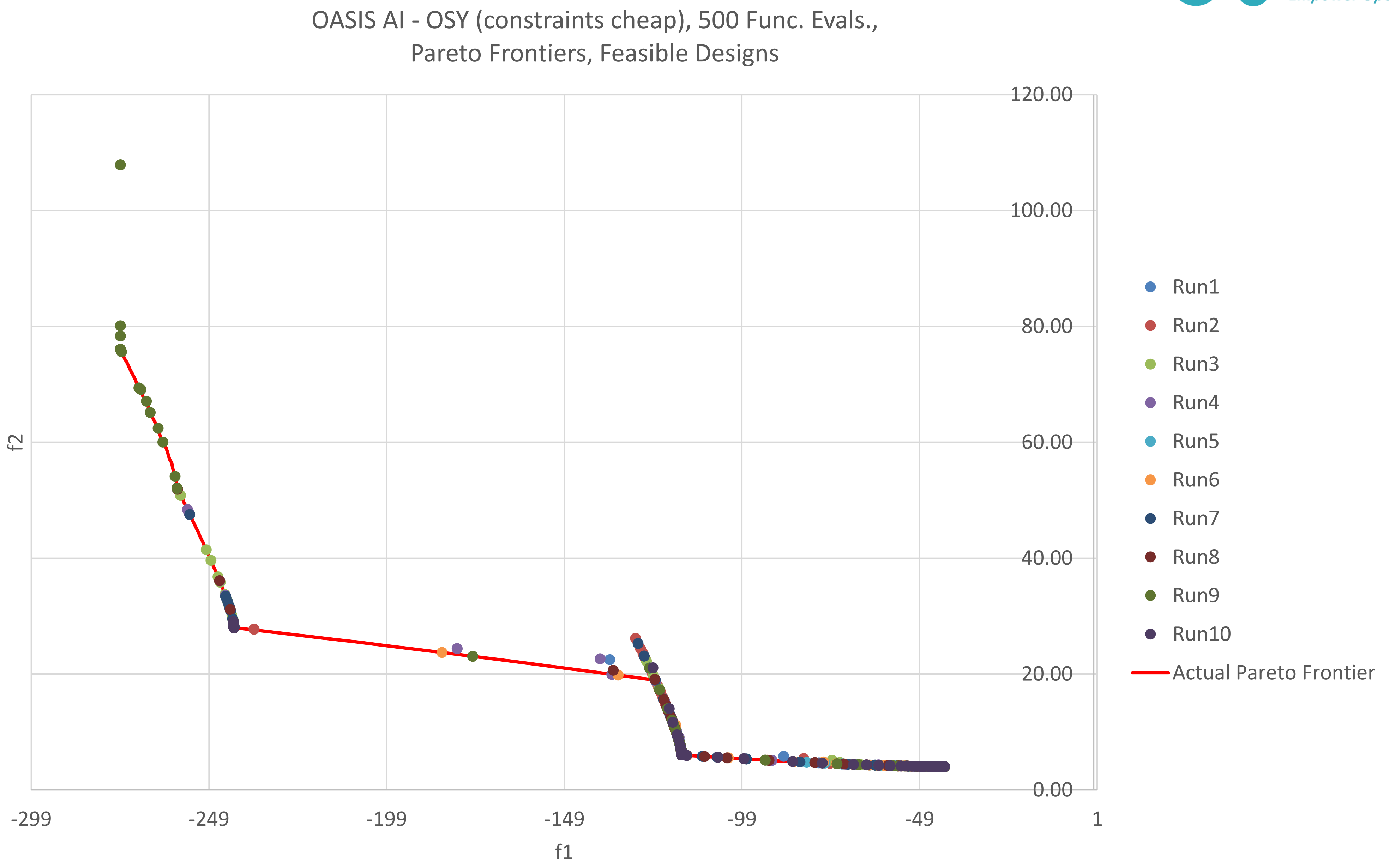
OSY – (constraints expensive)



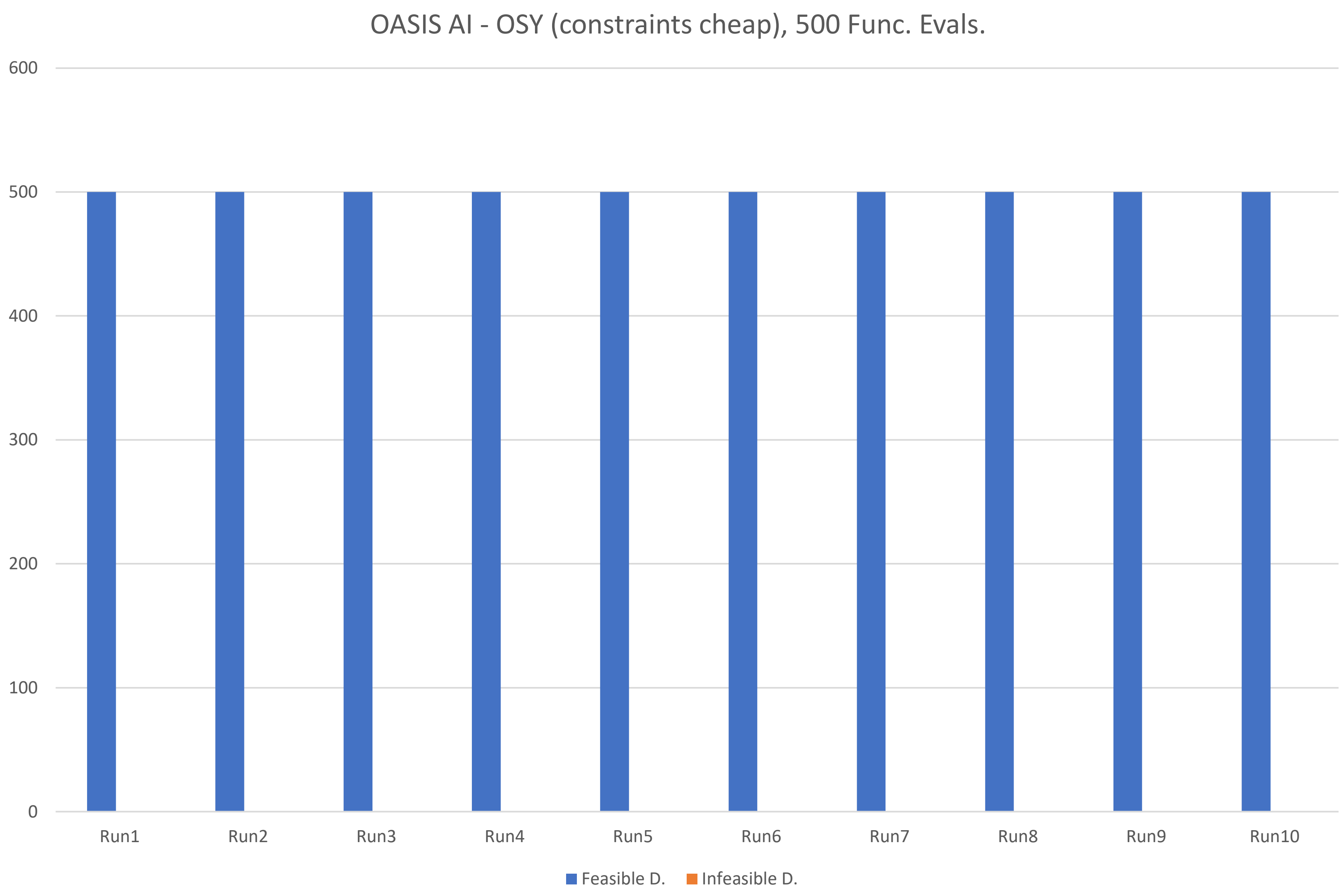
OSY – (constraints expensive) continued



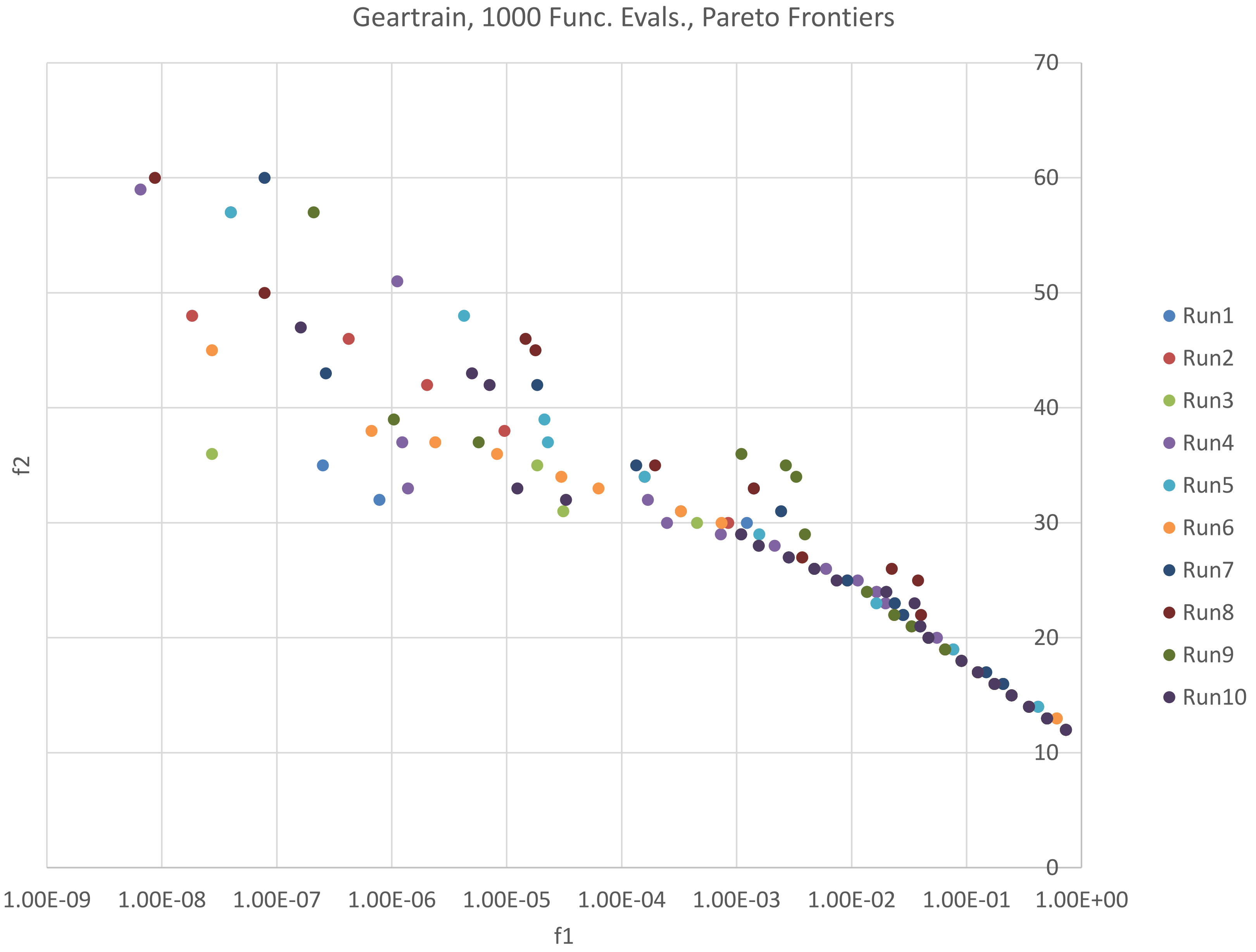
OSY – (constraints cheap)



OSY – (constraints cheap) continued



Geartrain – Inputs discrete



G7 – Single objective, expensive constraints

Inputs

Design Variables – x1 .. x10

Ranges

x1 [-10,10]

…

x10 [-10,10]

Python Script

$$
\begin{aligned}
f(\boldsymbol{x}) = {} & x_1^2 + x_2^2 + x_1x_2 - 14x_1 - 16x_2 + (x_3 - 10)^2 \\
& + 4(x_4 - 5)^2 + (x_5 - 3)^2 + 2(x_6 - 1)^2 + 5x_7^2 \\
& + 7(x_8 - 11)^2 + 2(x_9 - 10)^2 + (x_{10} - 7)^2 + 45 \\
g_1(\boldsymbol{x}) = {} & -105 + 4x_1 + 5x_2 - 3x_7 + 9x_8 \leq 0 \\
g_2(\boldsymbol{x}) = {} & 10x_1 - 8x_2 - 17x_7 + 2x_8 \leq 0 \\
g_3(\boldsymbol{x}) = {} & -8x_1 + 2x_2 + 5x_9 - 2x_{10} - 12 \leq 0 \\
g_4(\boldsymbol{x}) = {} & 3(x_1 - 2)^2 + 4(x_2 - 3)^2 + 2x_3^2 - 7x_4 - 120 \leq 0 \\
g_5(\boldsymbol{x}) = {} & 5x_1^2 + 8x_2 + (x_3 - 6)^2 - 2x_4 - 40 \leq 0 \\
g_6(\boldsymbol{x}) = {} & x_1^2 + 2(x_2 - 2)^2 - 2x_1x_2 + 14x_5 - 6x_6 \leq 0 \\
g_7(\boldsymbol{x}) = {} & 0.5(x_1 - 8)^2 + 2(x_2 - 4)^2 + 3x_5^2 - x_6 - 30 \leq 0 \\
g_8(\boldsymbol{x}) = {} & -3x_1 + 6x_2 + 12(x_9 - 8)^2 - 7x_{10} \leq 0
\end{aligned}
$$

Outputs

Objectives – minimize f(x)

Expensive Constraints

g1(x) < 0

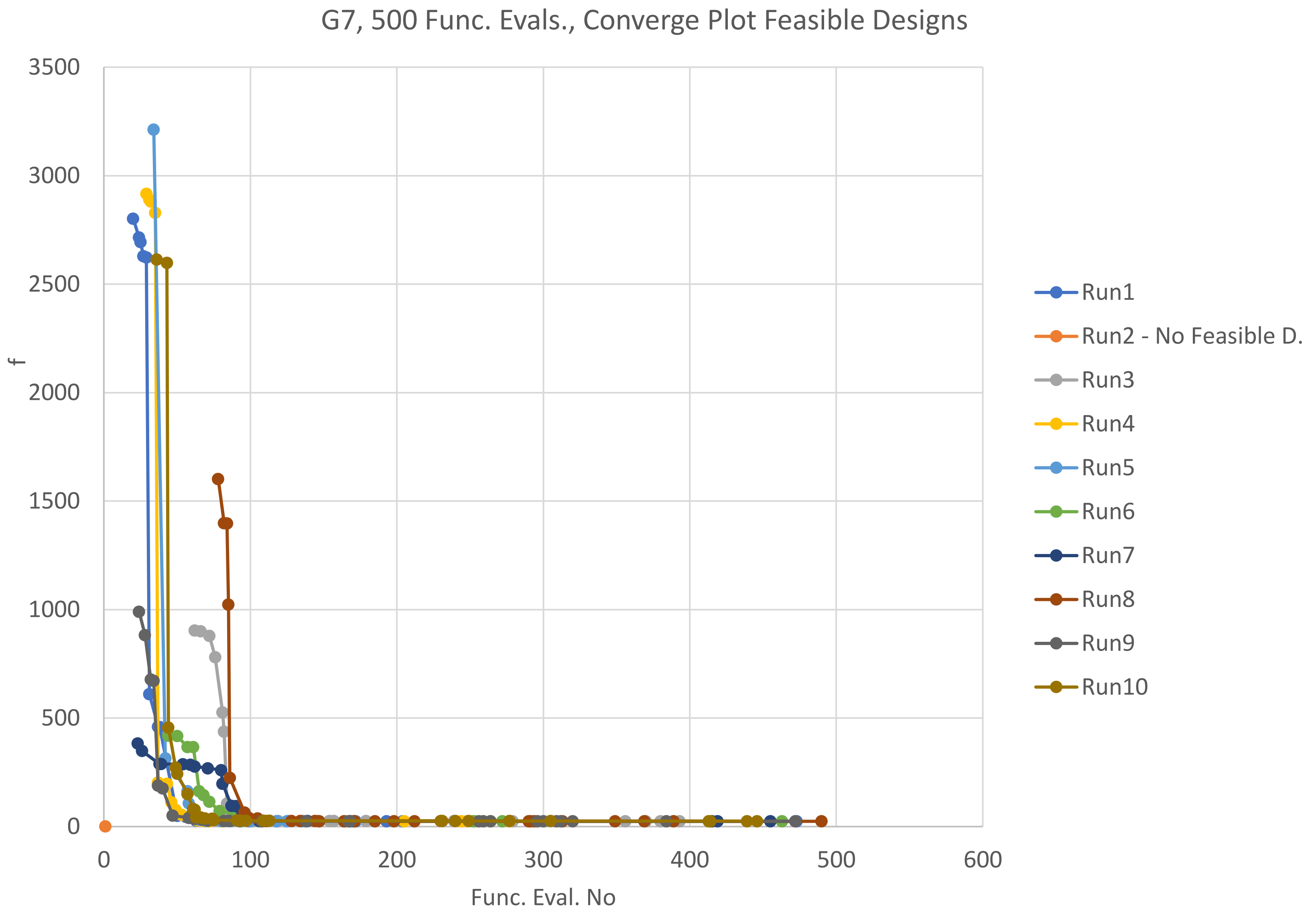
..

g8 (x) < 0

Hock, W., and Schittkowski, K., 1981, Test Examples for Nonlinear Programming Codes, Springer-Verlag, Secaucus, NJ.

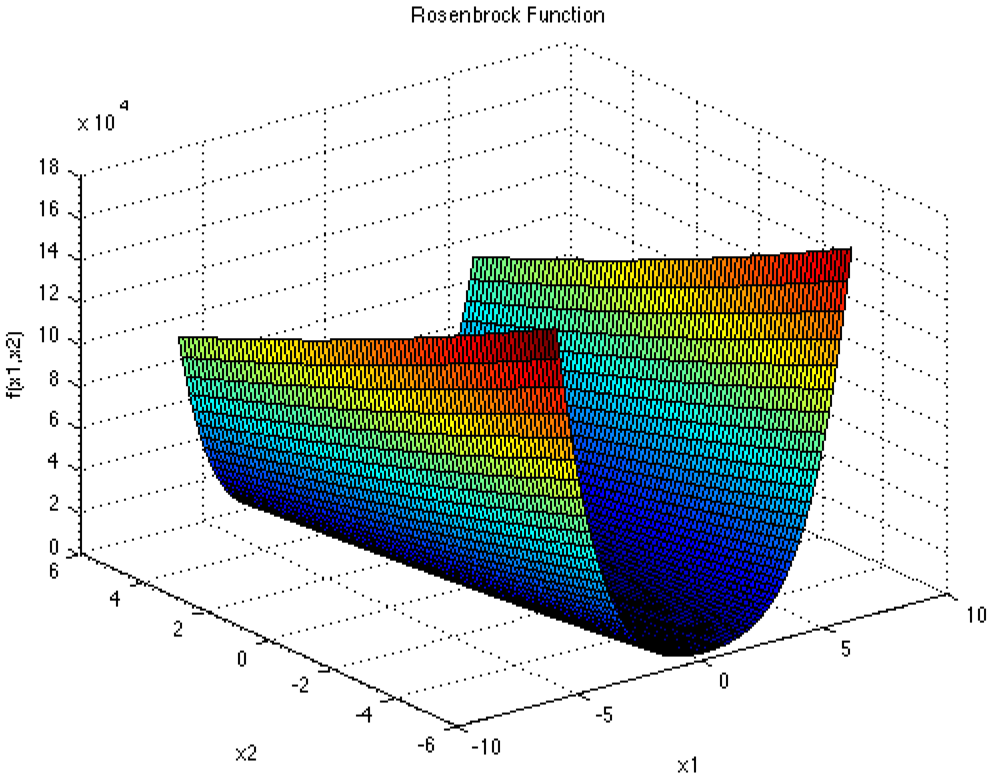
G7 – No initial designs provided

Run No	First Feasible D. at Func. Eval.
Run1	20
Run2	N/A
Run3	62
Run4	29
Run5	34
Run6	44
Run7	23
Run8	78
Run9	24
Run10	36



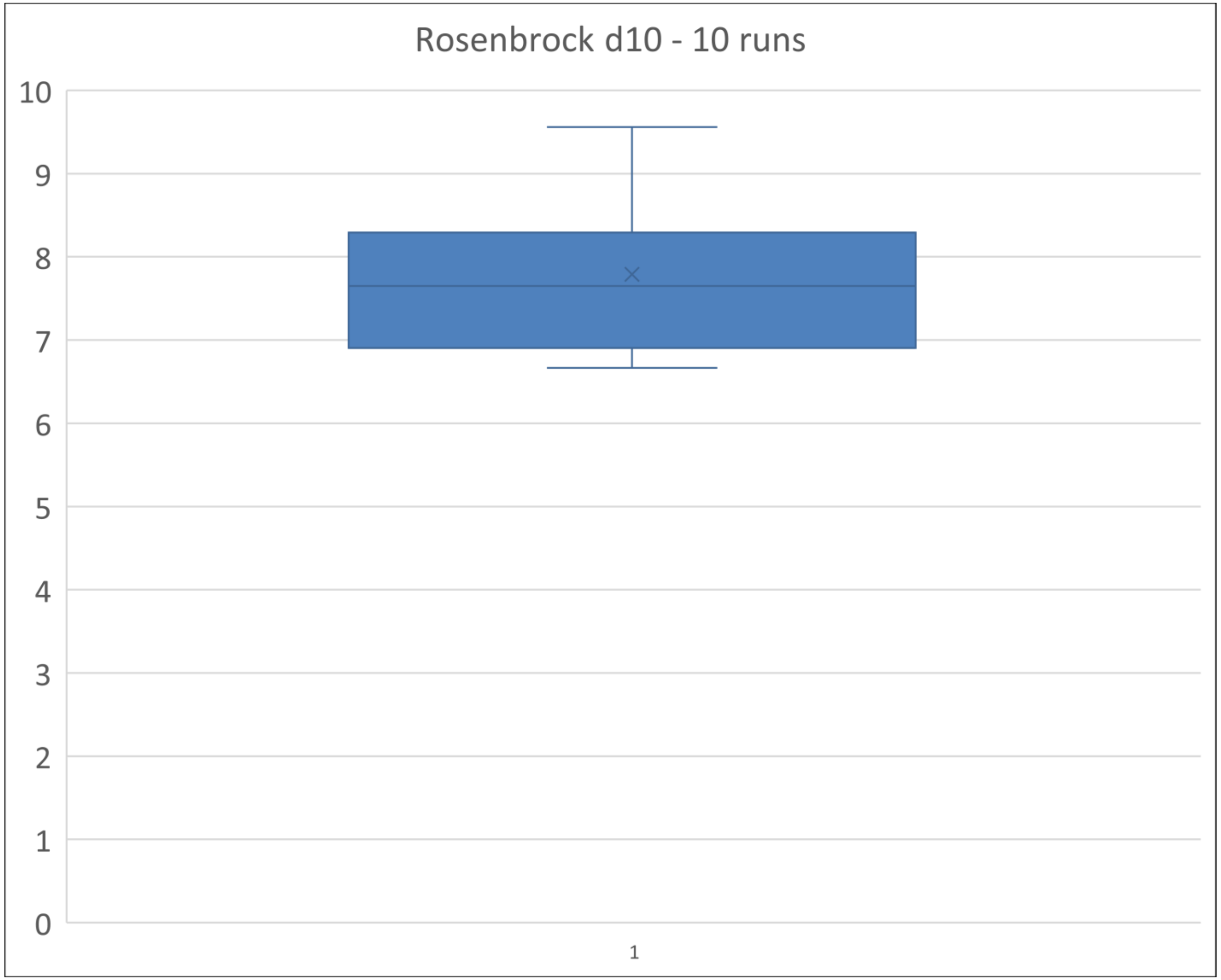
Rosenbrock – Unimodal, unconstrained

$$f(x) = \sum_{i=1}^{d} [100(x_i^2 - x_{i+1})^2 + (x_i - 1)^2]$$
$$-10 \le x_i \le 10, d = \#\ of\ variables$$



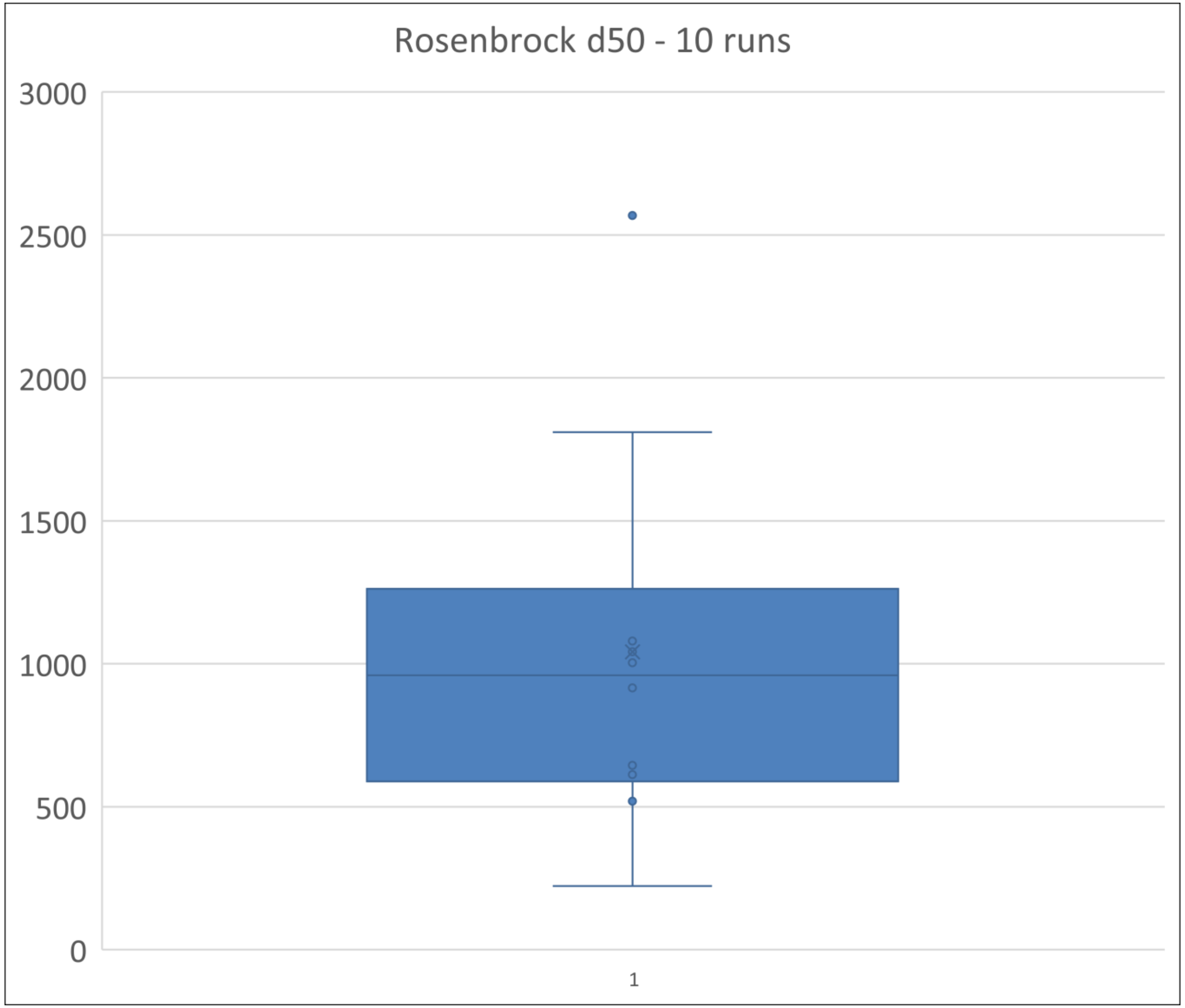
Rosenbrock d10

	f
Run1	6.919334
Run2	7.398033
Run3	6.864139
Run4	9.559364
Run5	7.855866
Run6	7.954235
Run7	9.264648
Run8	7.446289
Run9	7.967622
Run10	6.666425
Average	7.789595
Std.	0.922907
Median	7.651078



Rosenbrock d50

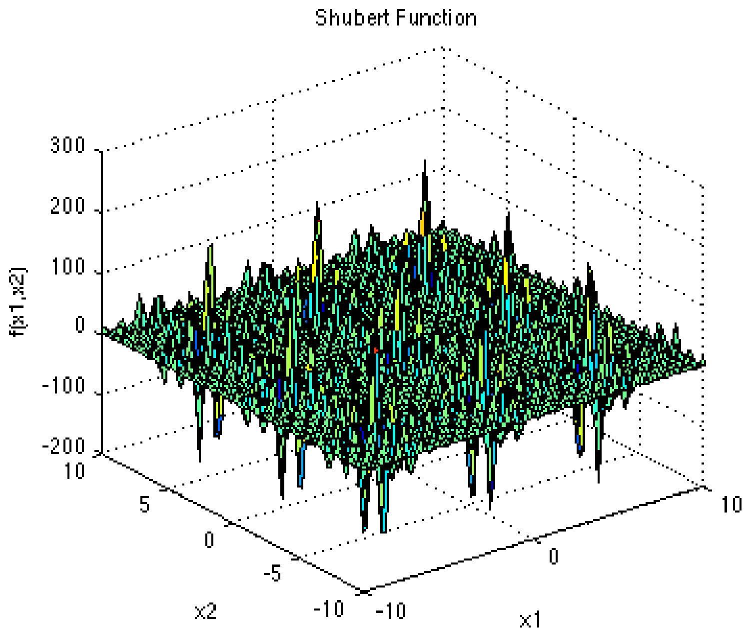
	f
Run1	222.6451
Run2	1079.161
Run3	1003.654
Run4	519.3808
Run5	916.0565
Run6	611.9465
Run7	644.763
Run8	1810.185
Run9	1041.664
Run10	2567.793
Average	1041.725
Std.	649.9294
Median	959.8552

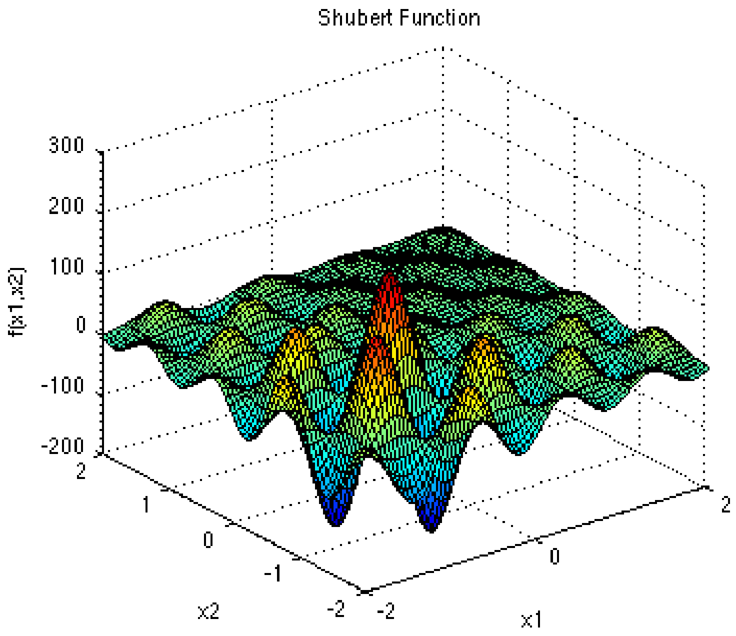


Shubert – Multimodal, unconstrained

$$f(\boldsymbol{x}) = \prod_{i=1}^{d} \sum_{j=1}^{5} j \cos\big((j+1)x_i + j\big)$$

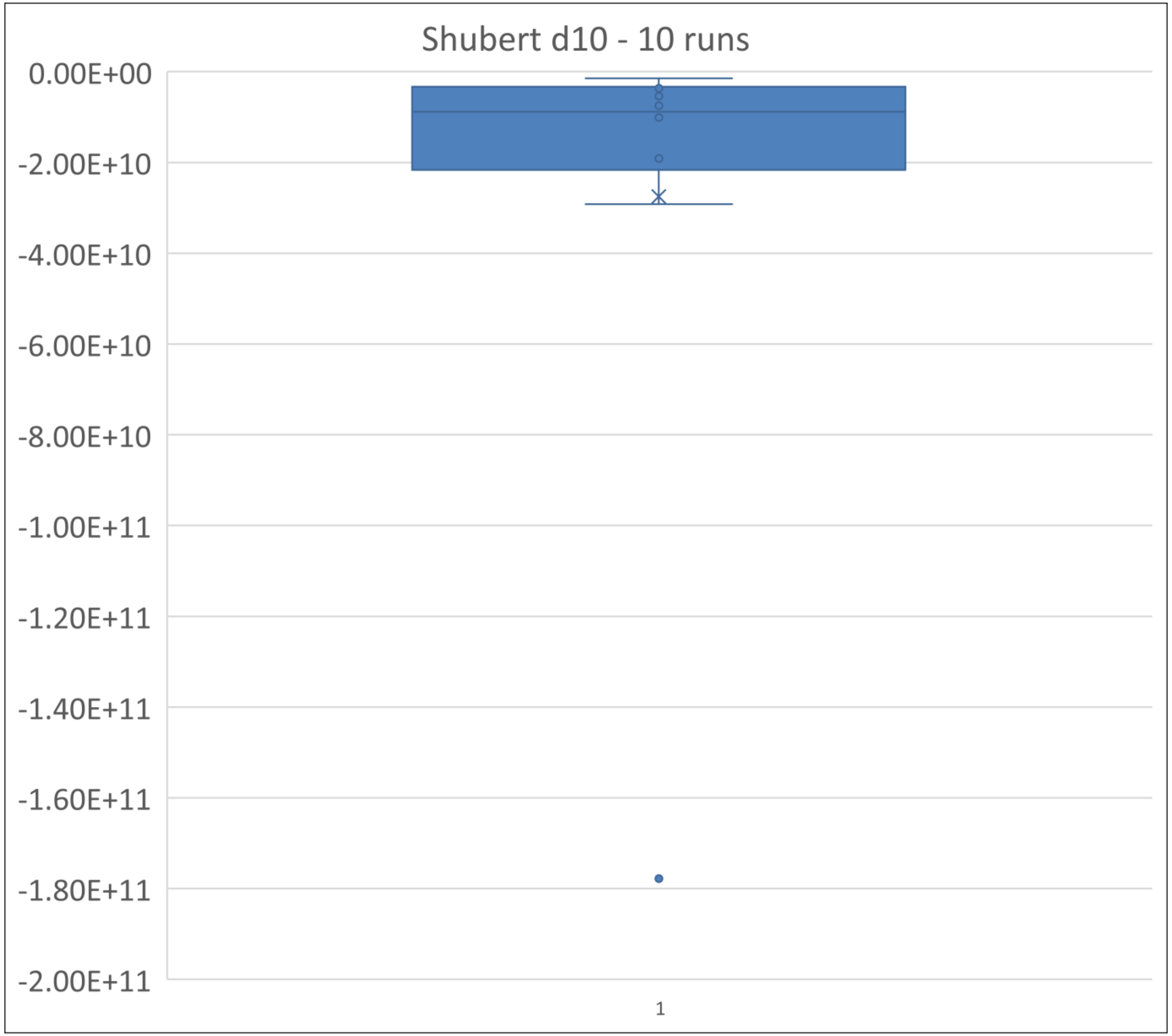
$$x \in [-5.12, 5.12]; d = \#\ variables$$





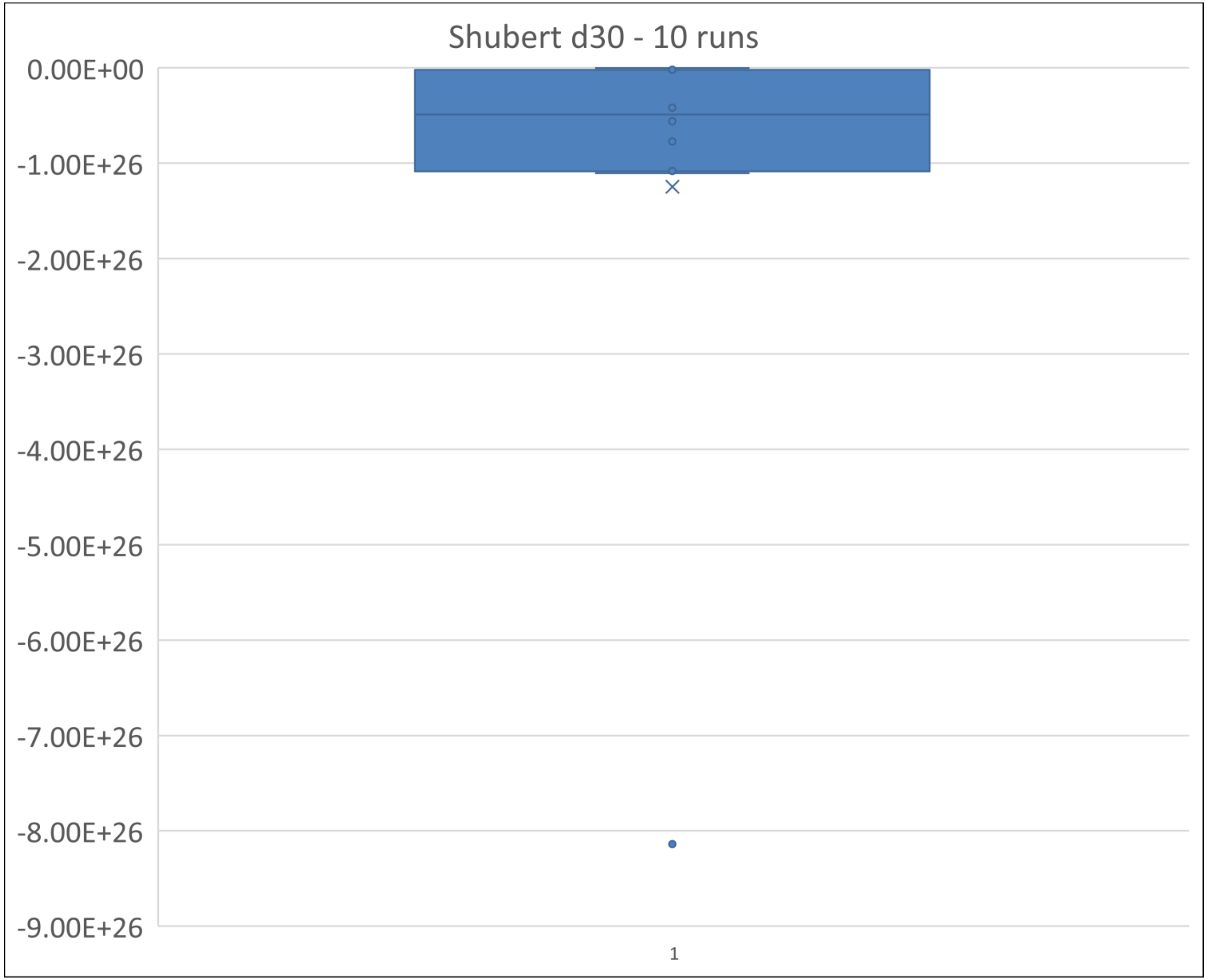
Shubert d10

	f
Run1	-1.78E+11
Run2	-1.91E+10
Run3	-7.51E+09
Run4	-5.38E+09
Run5	-1.86E+10
Run6	-1.01E+10
Run7	-3.66E+09
Run8	-2.92E+10
Run9	-1.47E+09
Run10	-2.17E+09
Average	-2.75E+10
Std.	5.08E+10
Median	-8.81E+09



Shubert d30

	f
Run1	-7.72E+25
Run2	-4.18E+25
Run3	-5.61E+25
Run4	-1.08E+26
Run5	-2.08E+24
Run6	-1.59E+23
Run7	-1.64E+24
Run8	-8.14E+26
Run9	-3.59E+25
Run10	-1.10E+26
Average	-1.25E+26
Std.	2.33E+26
Median	-4.89E+25



Shubert d60

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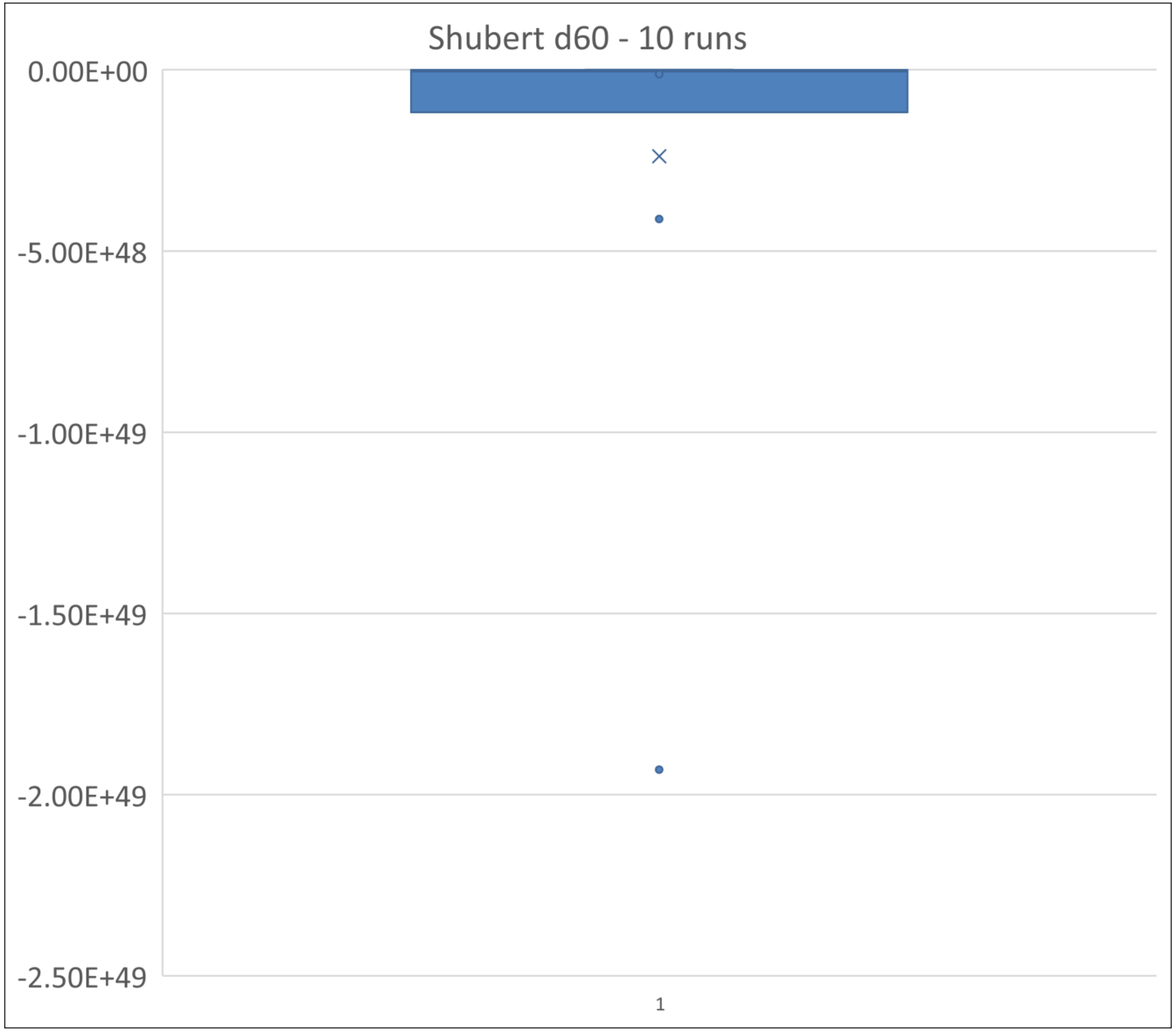
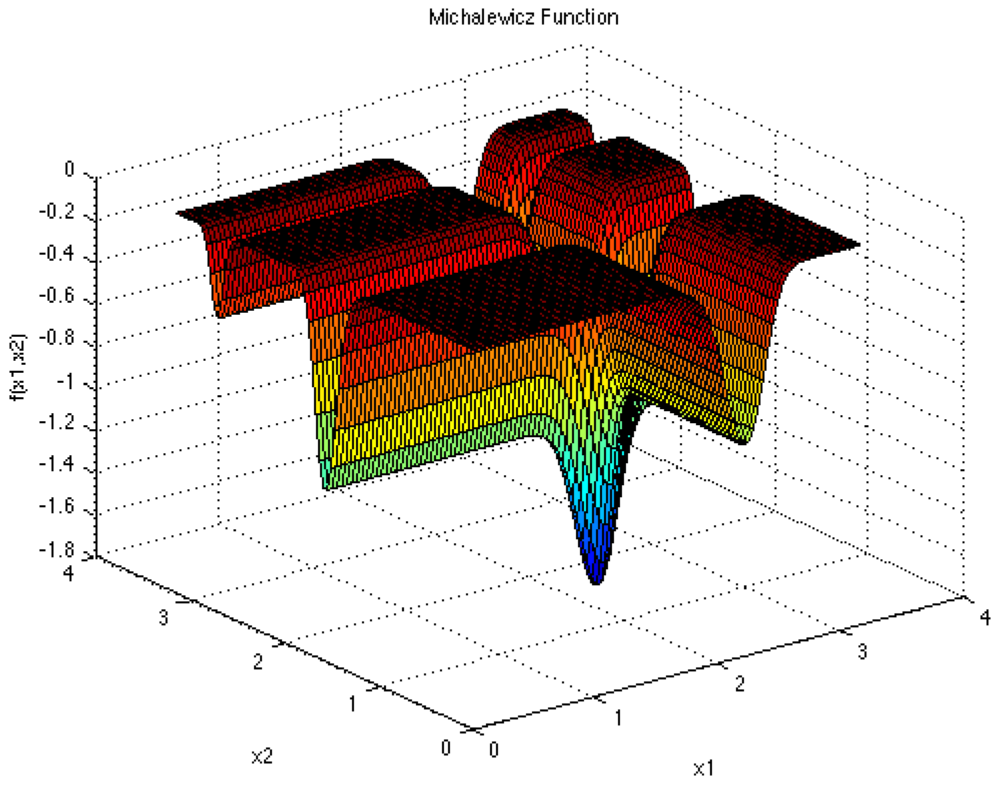
	f
Run1	-4.12E+48
Run2	-1.89E+47
Run3	-3.19E+45
Run4	-7.48E+46
Run5	-8.24E+43
Run6	-3.85E+45
Run7	-1.93E+49
Run8	-1.18E+47
Run9	-2.45E+46
Run10	-1.02E+45
Average	-2.38457E+48
Std.	5.77208E+48
Median	-4.96167E+46



Michalewicz – Ill-Shaped, unconstrained

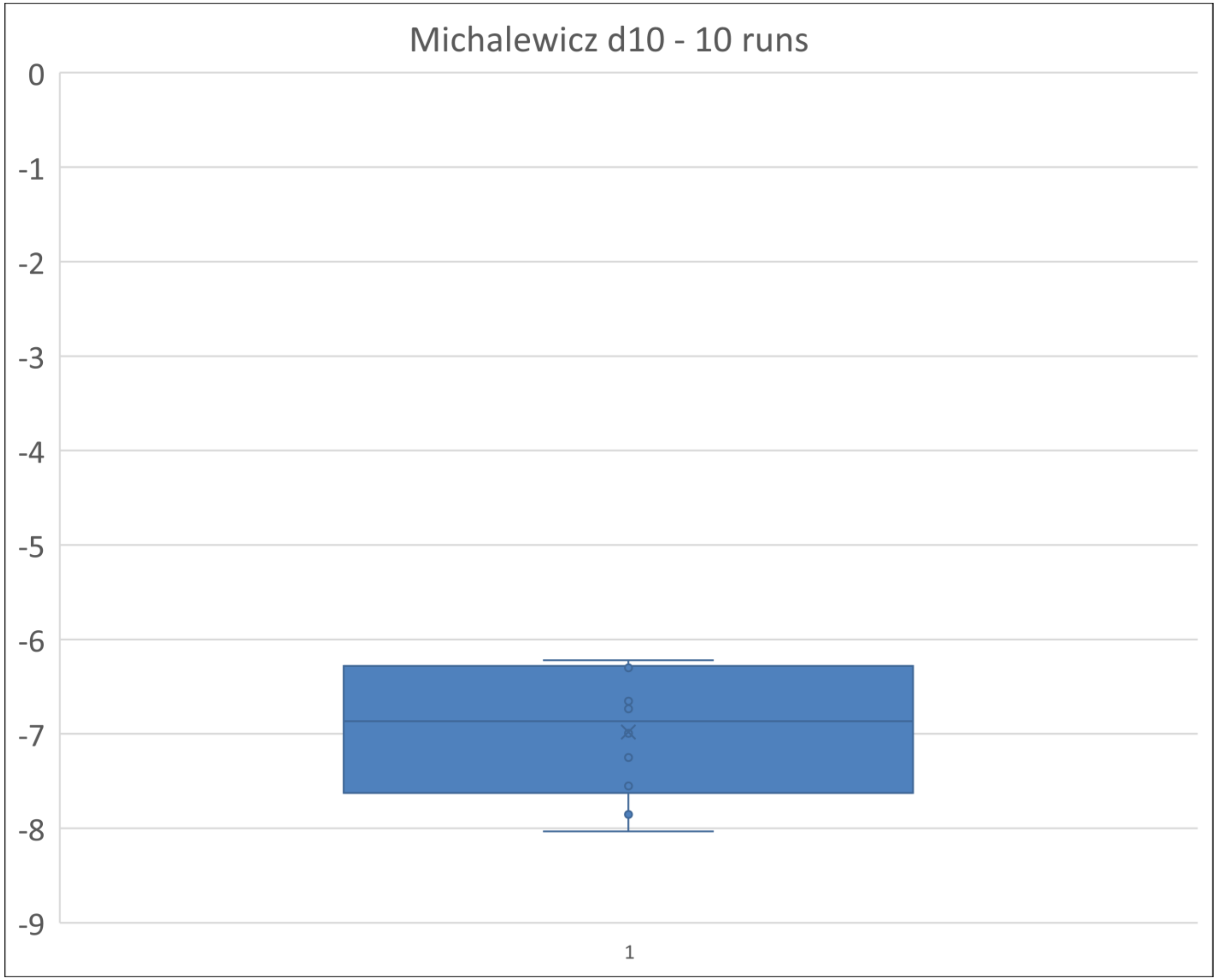
$$f(x) = -\sum_{i=1}^{d} \sin(x_i)\, sin^{2m}(\frac{ix_i^2}{\pi})$$

$$m = 10; x \in [0, \pi]; d = \#\ of\ variables$$



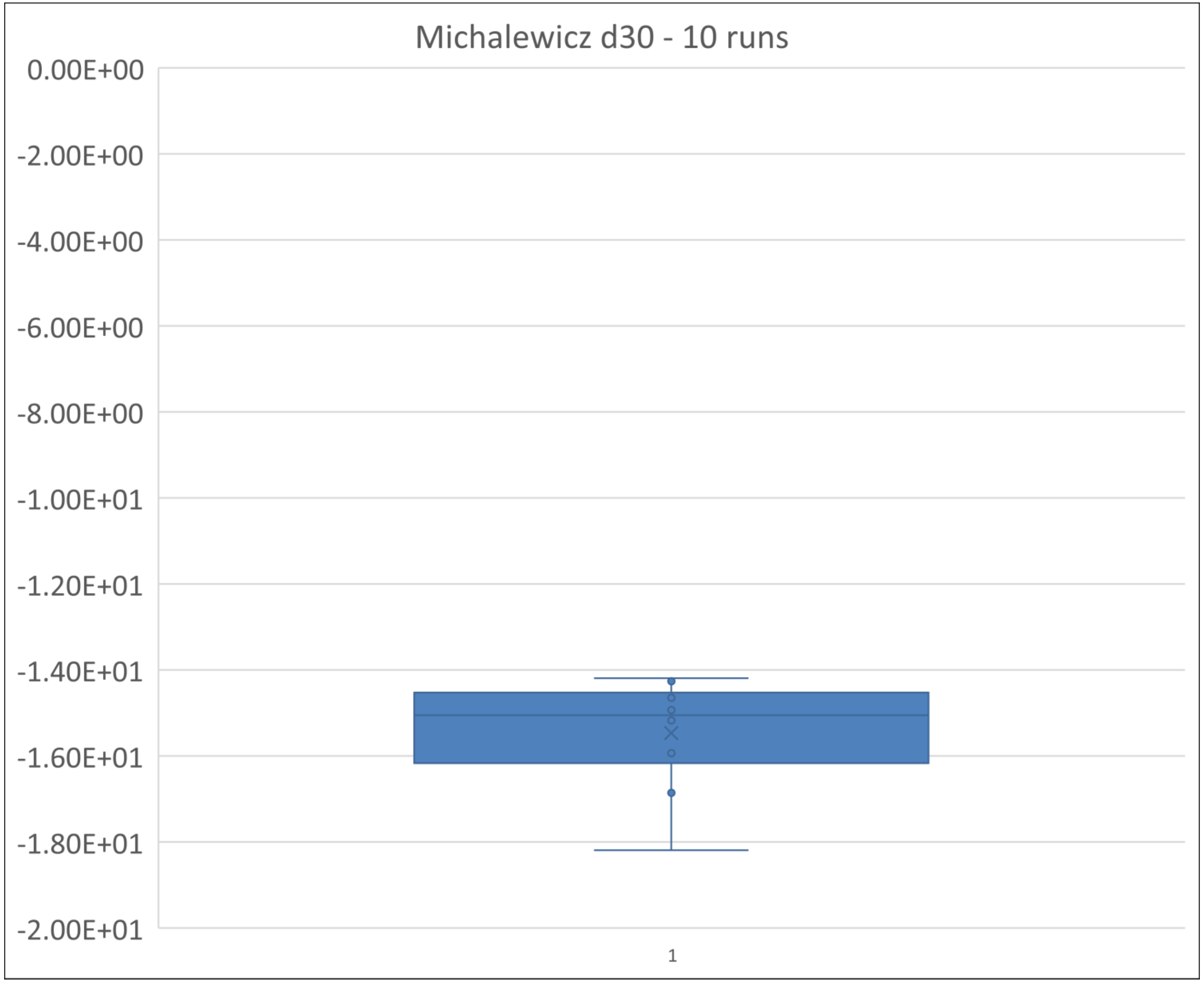
Michalewicz d10

	f
Run1	-7.852177076
Run2	-6.228031066
Run3	-6.734286674
Run4	-6.995044189
Run5	-8.032482593
Run6	-7.249619292
Run7	-6.654006129
Run8	-6.221074724
Run9	-7.551919436
Run10	-6.300118156
Average	-6.98E+00
Std.	6.36E-01
Median	-6.86E+00



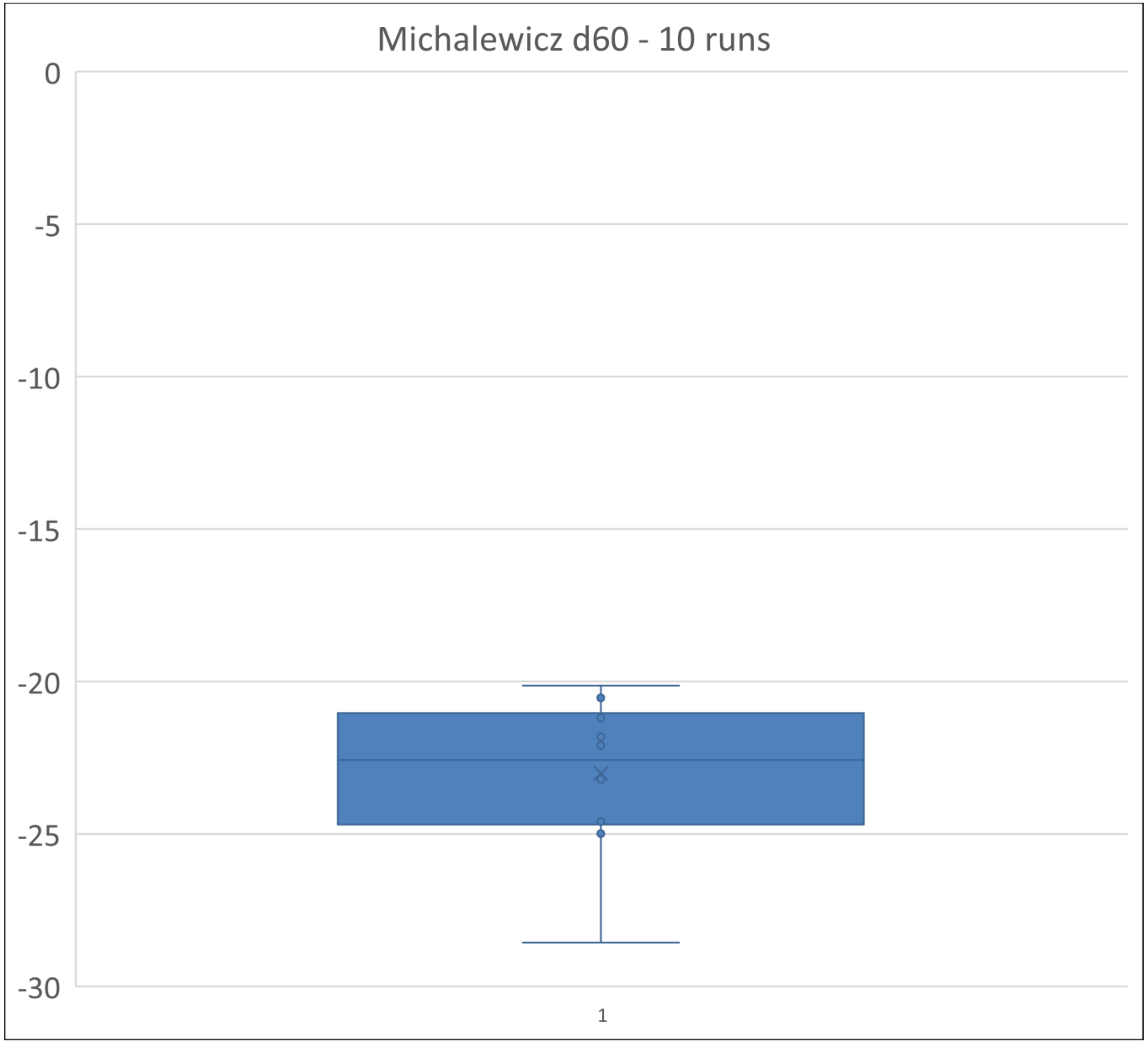
Michalewicz d30

	f
Run1	-15.88286757
Run2	-14.93024264
Run3	-15.93429641
Run4	-18.19228998
Run5	-14.26062751
Run6	-15.17177898
Run7	-14.6420262
Run8	-14.19045725
Run9	-16.85251075
Run10	-14.61121646
Average	-1.55E+01
Std.	1.21E+00
Median	-1.51E+01



Michalewicz d60

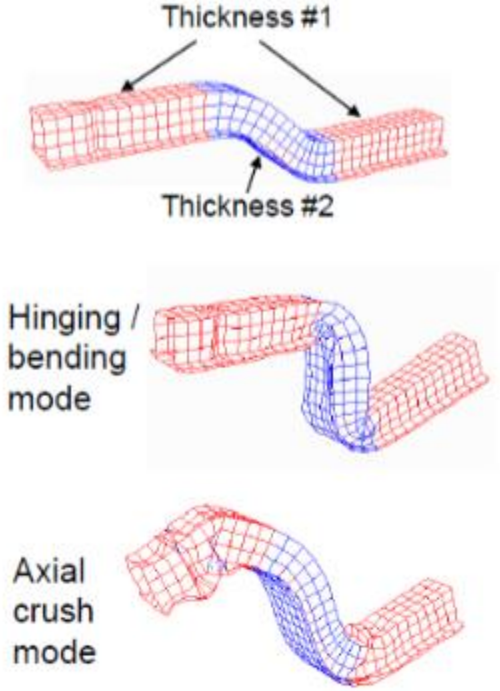
	f
Run1	-23.04826589
Run2	-20.53611678
Run3	-24.985752
Run4	-21.20113662
Run5	-22.10367199
Run6	-20.13743591
Run7	-28.56081134
Run8	-24.59575895
Run9	-23.20783415
Run10	-21.81380351
Average	-23.01905872
Std.	2.390931657
Median	-22.57596894



Mopta08 – High dimensional, highly constrained

MOPTA08, a multi disciplinary mass minimization problem from GM*

- 124 variables and 68 expensive constraints
- Variables – various thicknesses from car body
- Expensive Constraints – Outputs from Vehicle Simulations
    - Front – side - rear crash,
    - Noise vibration,
    - Durability.
- Based on a real automotive problem
- A challenging, tightly constrained problem



**Large-Scale Multi-Disciplinary Mass Optimization in the Auto Industry, Don Jones, MOPTA 2008 Conference, 2008*

Mopta08 - OASIS AI Accelerator Results

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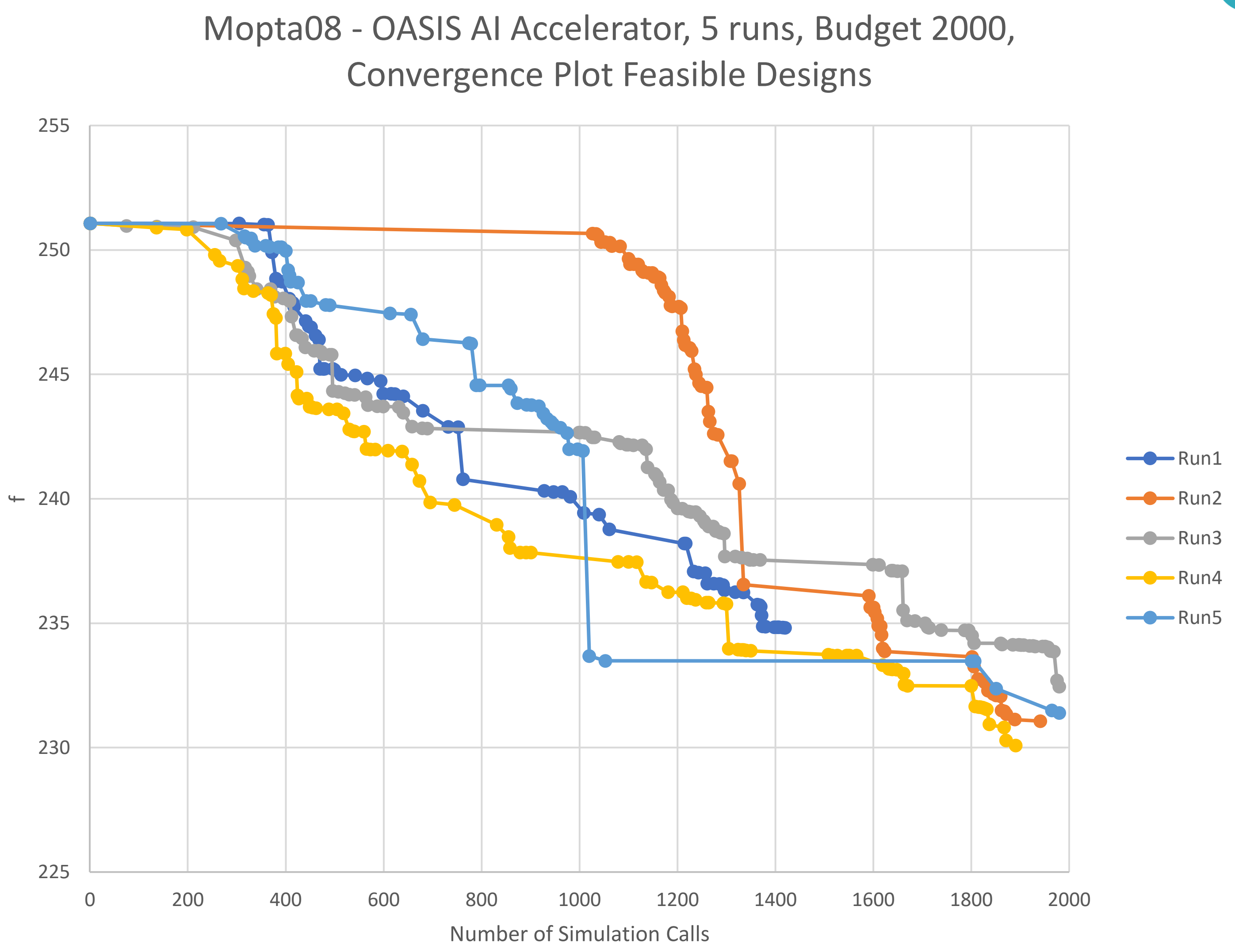

- WIP results by OASIS AI Accelerator, a R&D project to enhance OASIS AI robustness.

Thank You!

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