TECHNISCHE UNIVERSITÄT DARMSTADT

Parallel Programming

Software Technology for Performance and Scalability

Prof. Dr. Felix Wolf

Avoiding satellite collisions

esa
European Space Agency

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The evolution of objects in space

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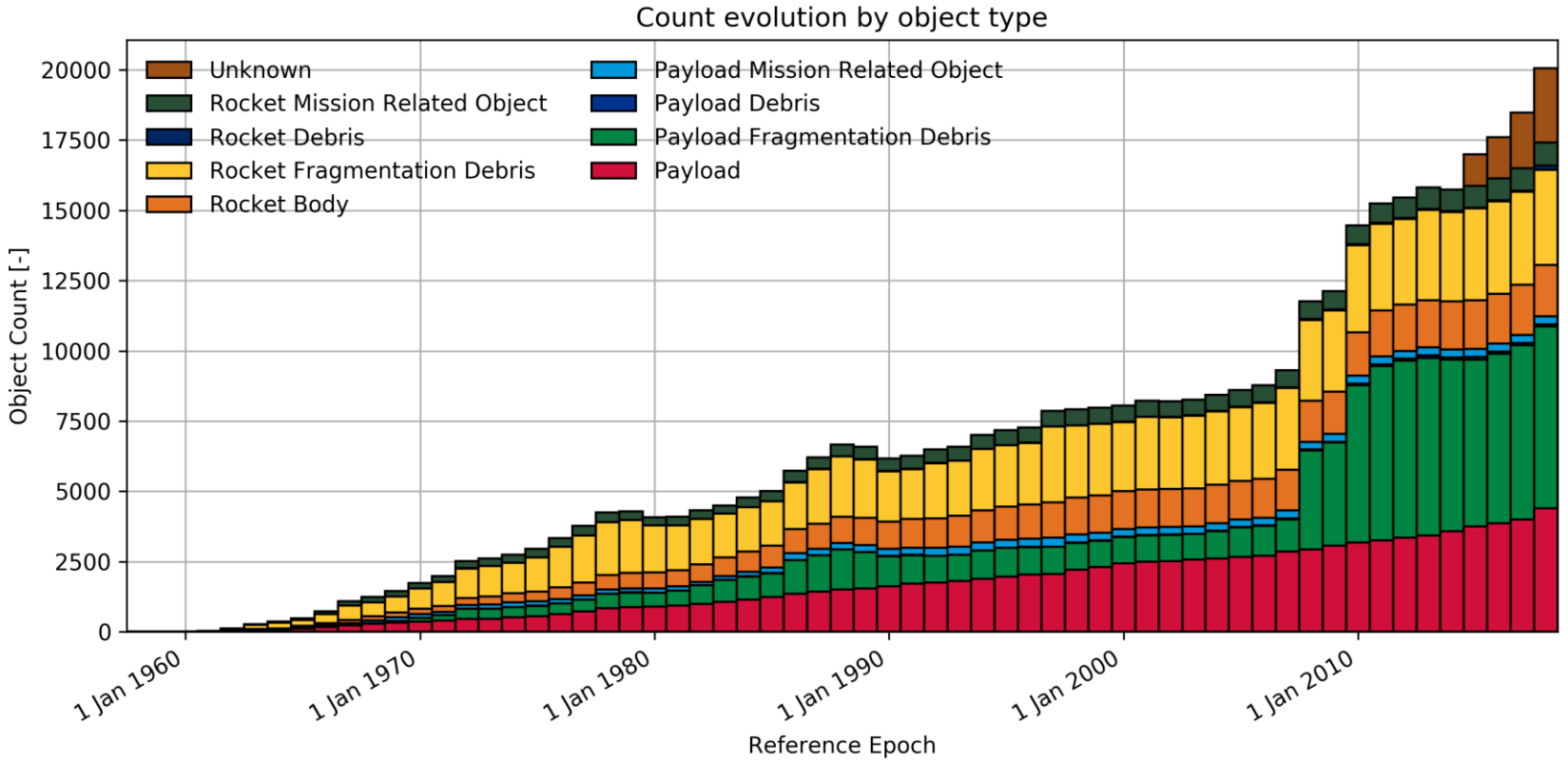
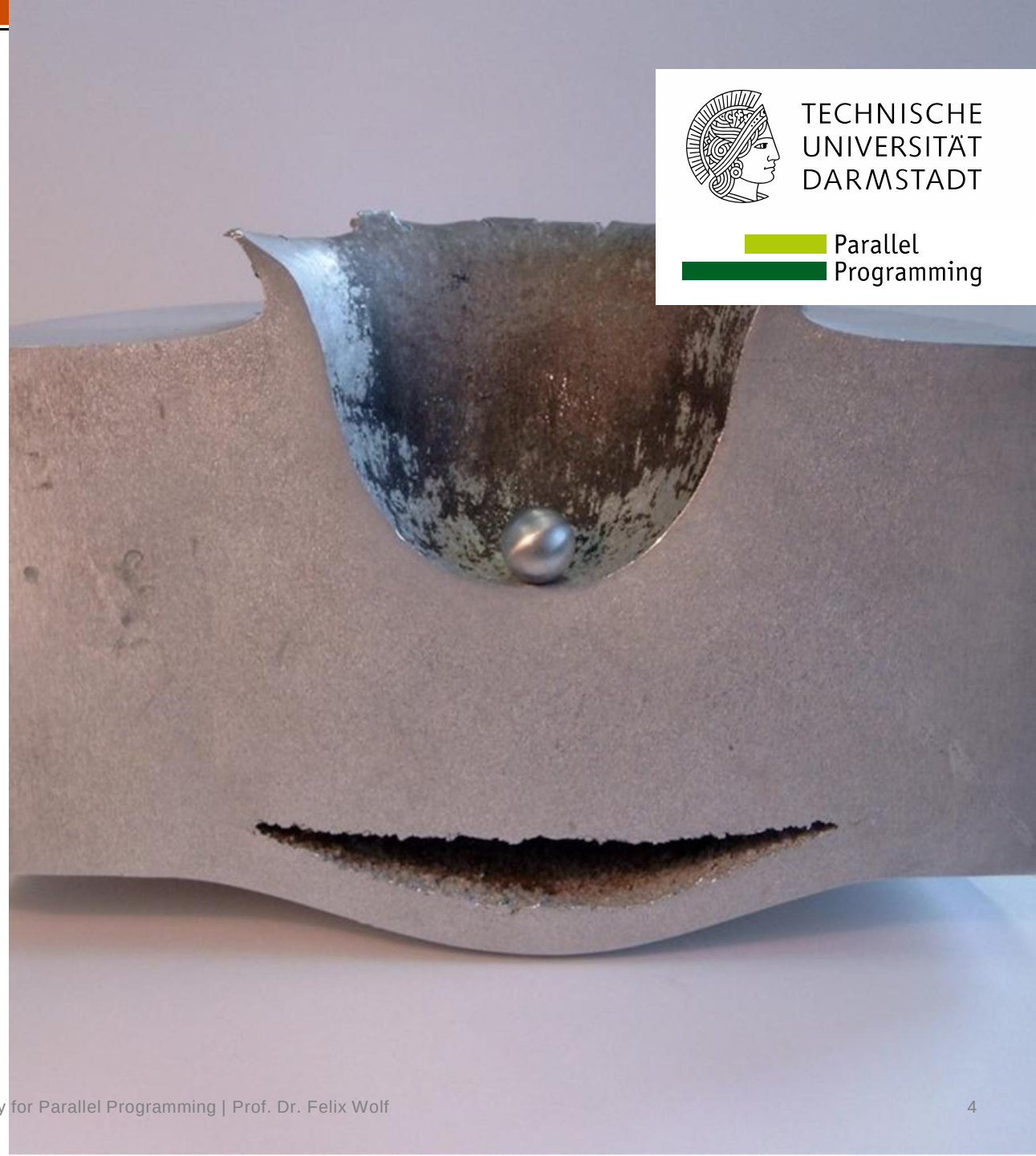
- Currently, there are ~28 k tracked objects in space



High-velocity impact

- 900,000 objects larger than 1 cm
- 130,000,000 objects between 1 mm and 1 cm
- Parts travel at **high speed (7.5 km/s)**
  - Muzzle speed of high-velocity rifle up to 1.2 km/s



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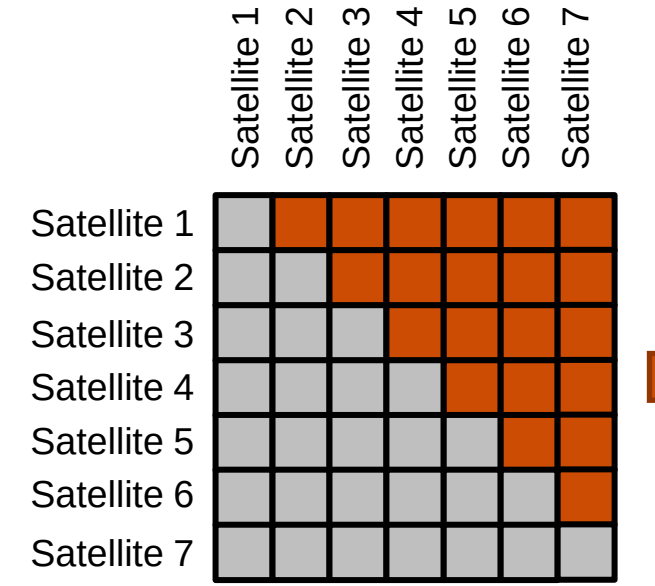
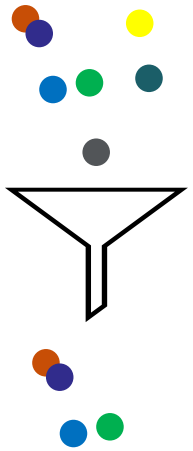
Traditional collision detection



Number of comparisons:

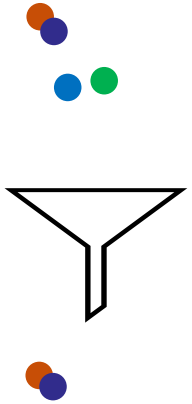
$$\frac{n(n-1)}{2} \in O(n^2)$$

- Apogee/Perigee-filter
- Orbit path filter
- Time filter



Broad phase
(Fast but inaccurate)

- Optimization algorithm
- TCA/PCA



Narrow phase
(Slow but detailed)

Acceleration with geometric decomposition

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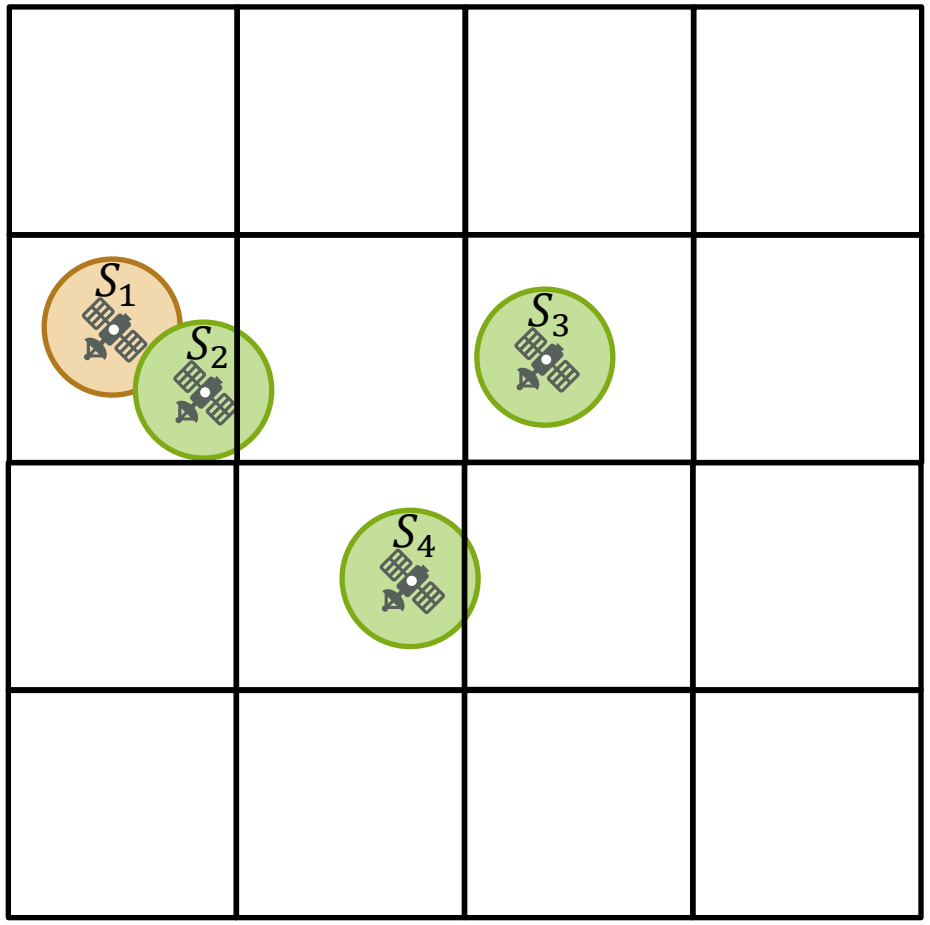
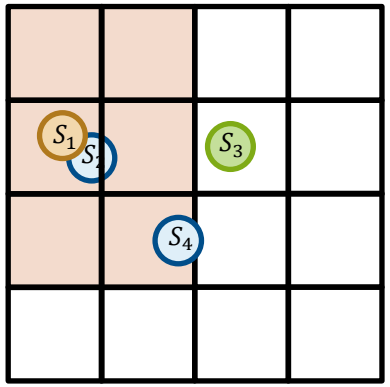
- Decompose simulation domain into small cells
  - Save cells in a hash map to reduce memory consumption
- Sample satellite positions during the simulation
- Insert satellites into cells based on their position
  - Has a small error
- Check for collisions within the box and neighboring boxes

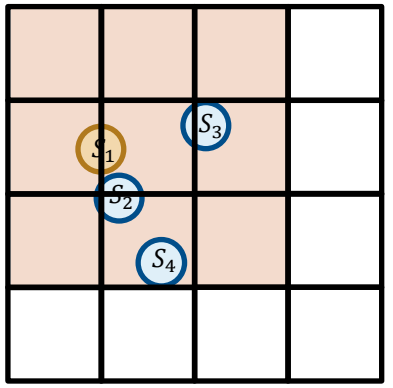
Christian Hellwig, Fabian Czappa, Martin Michel, Reinhold Bertrand, Felix Wolf: Satellite Collision Detection using Spatial Data Structures. In *Proc. of the 37th IEEE International Parallel and Distributed Processing Symposium (IPDPS), St. Petersburg, Florida, USA*, pages 1–11, May 2023.

Example with motion

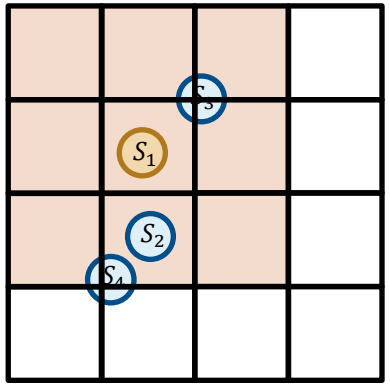




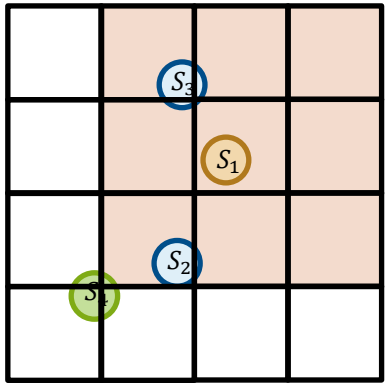
t_0



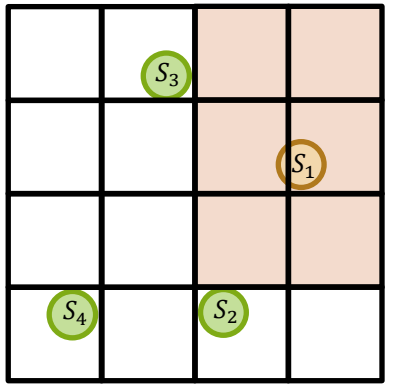
t_1



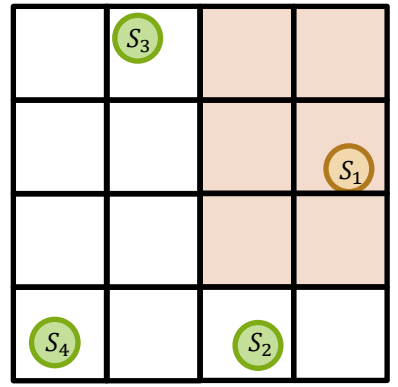
t_2



t_3



t_4



t_5

Speed-up

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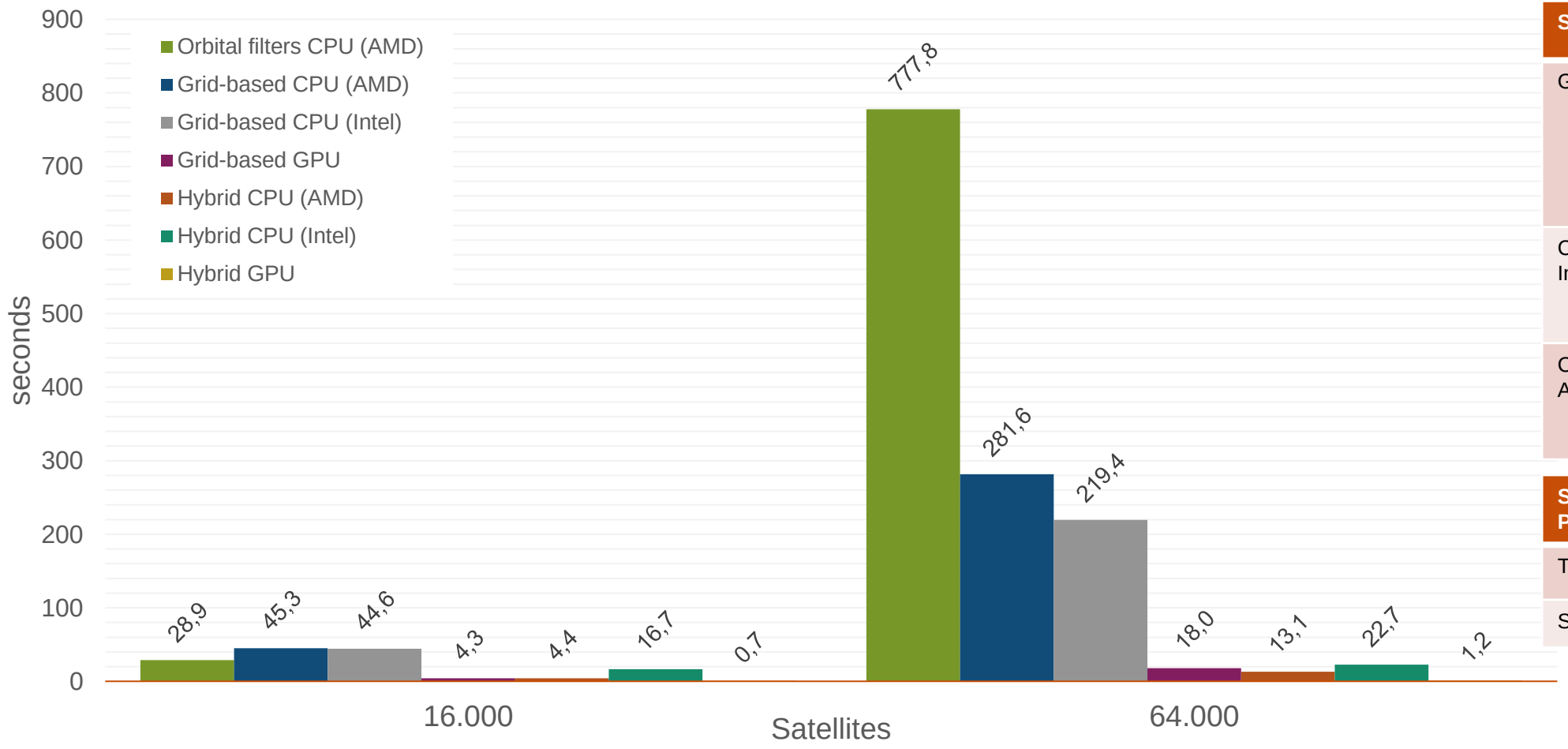
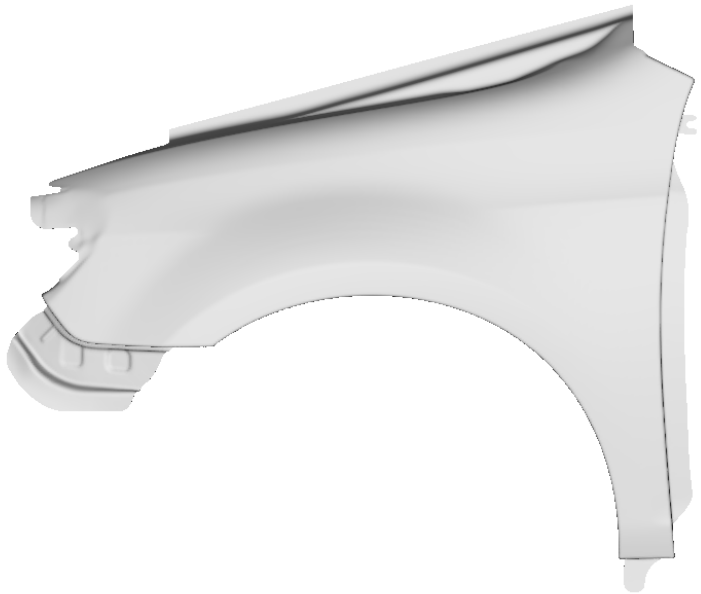


Systems	Value
GPU	• AMD Ryzen 9 5950X (3.4GHz, 16 cores) • NVIDIA RTX 3090 (24 GB GDDR6) • Max 55 GB DDR4
CPU Intel	• Intel Xeon Platinum 9242 (2.3GHz, 2x48 Cores) • Max 55 GB DDR4
CPU AMD	• AMD Ryzen 9 5950X (3.4GHz, 16 Cores) • Max 55 GB DDR4

Simulation Property	Value
Threshold	2 km
Simulation Time	5 h

ENSIMA

Optimization of simulation-driven design processes – deep drawing of sheet metal



Kotfluegel_OFSolv-2.15: 100% (Time: 200.6 Inc: 578)
OP40: 100%
Schliessen 40_formbacke bis UT: 100%

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RWTH AACHEN UNIVERSITY

JÜLICH Forschungszentrum

GESELLSCHAFT FÜR NUMERISCHE SIMULATION gns

GNS Systems
IT Services for Engineering

SIMCON GmbH
TH Würzburg-Schweinfurt

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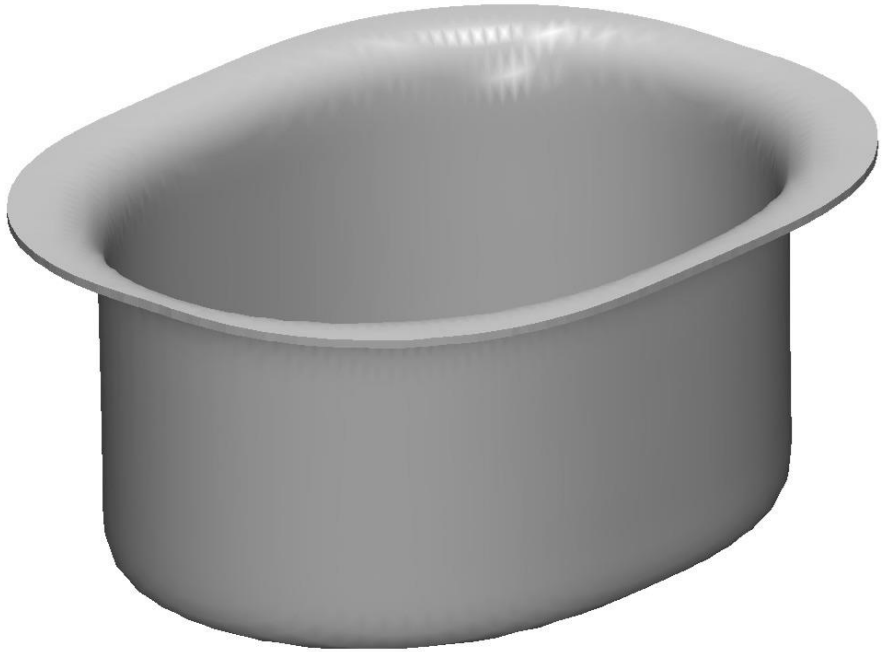
Elliptical cup



Deep drawing process

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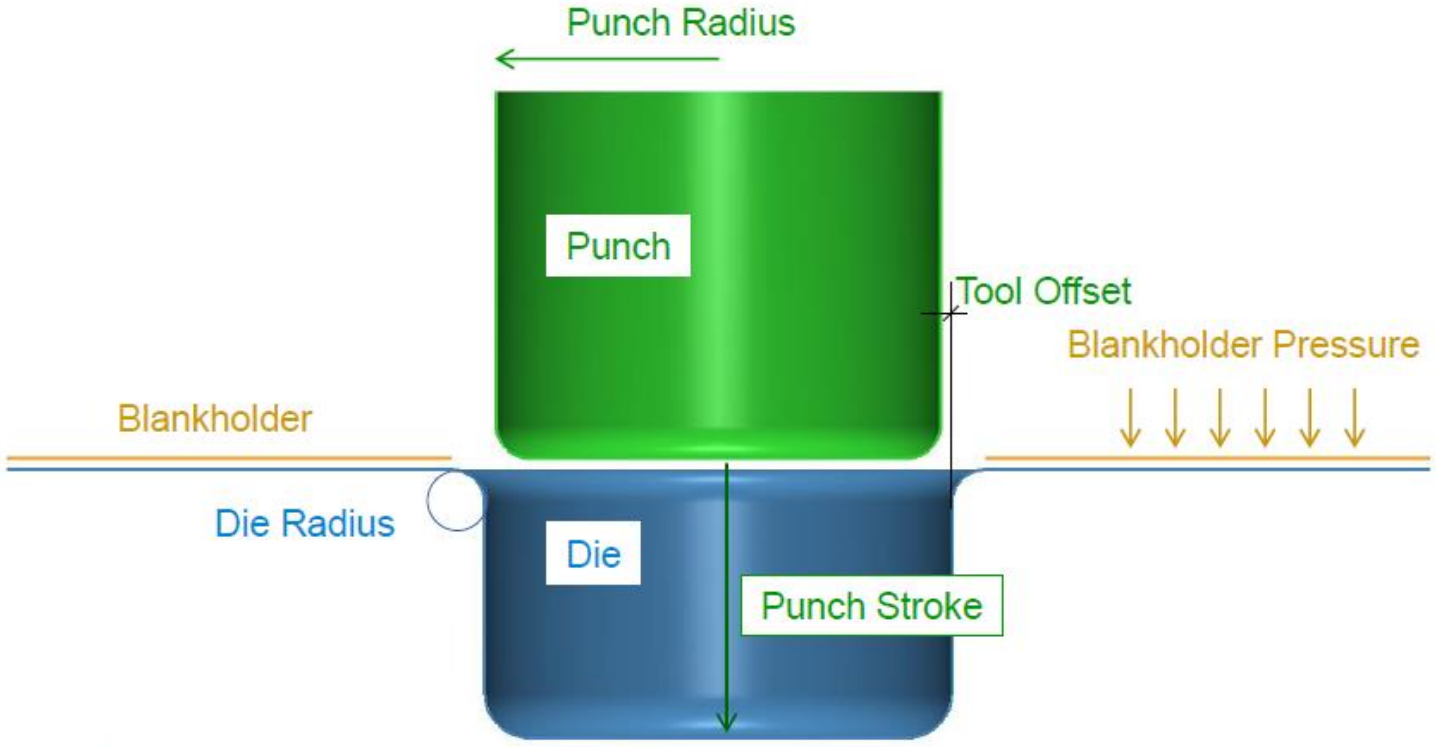

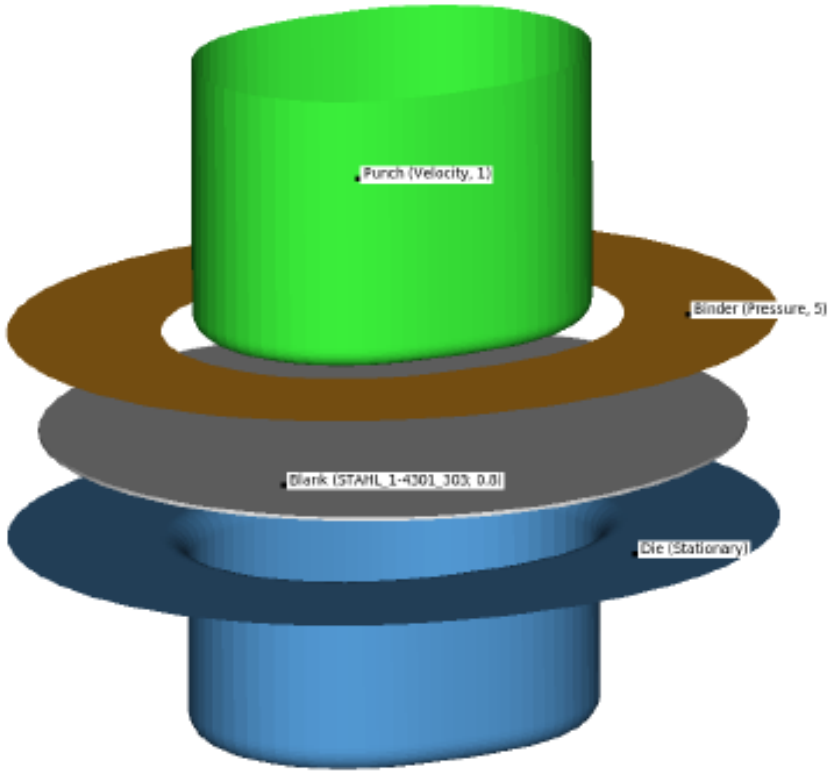

OpenForm – Numerical simulation of deep drawing for design optimization

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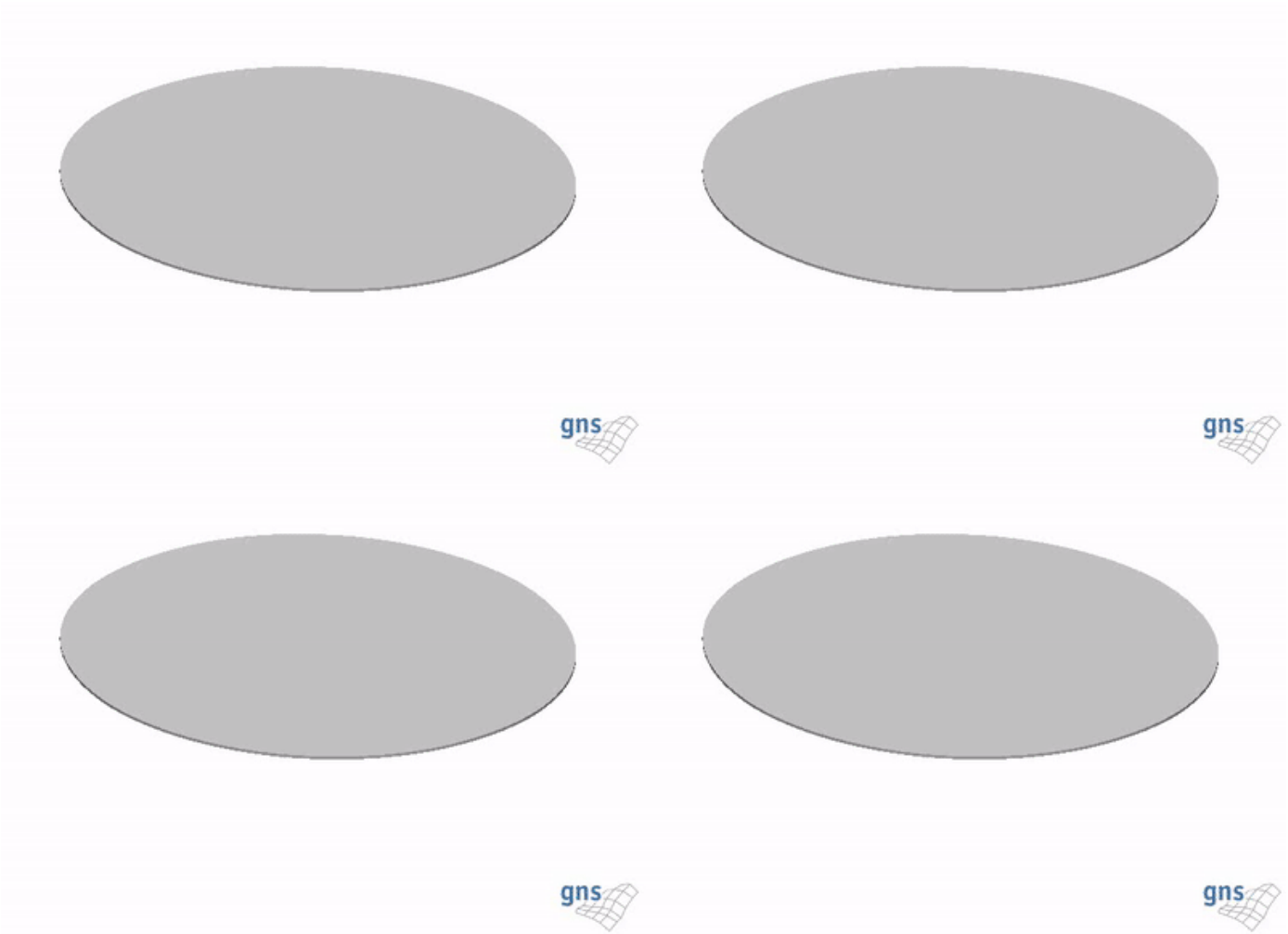
GESELLSCHAFT FÜR NUMERISCHE SIMULATION gns



Influence of the blank's initial shape

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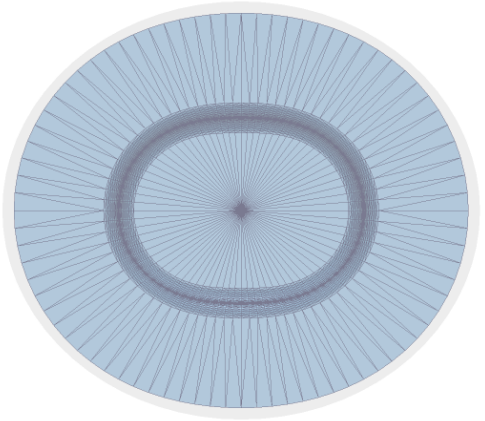
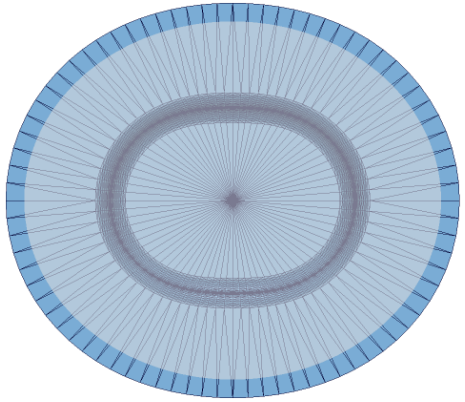
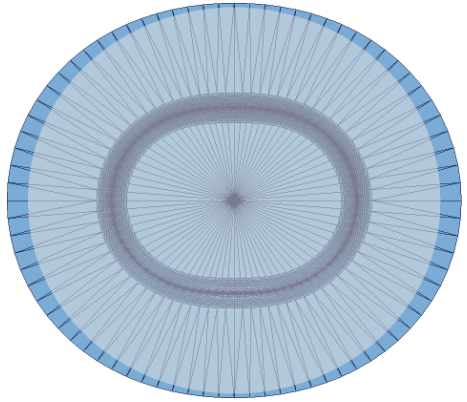


A = 80mm, B = 70mm



A = 70mm, B = 60mm



A = 69mm, B = 65mm

Simulation input

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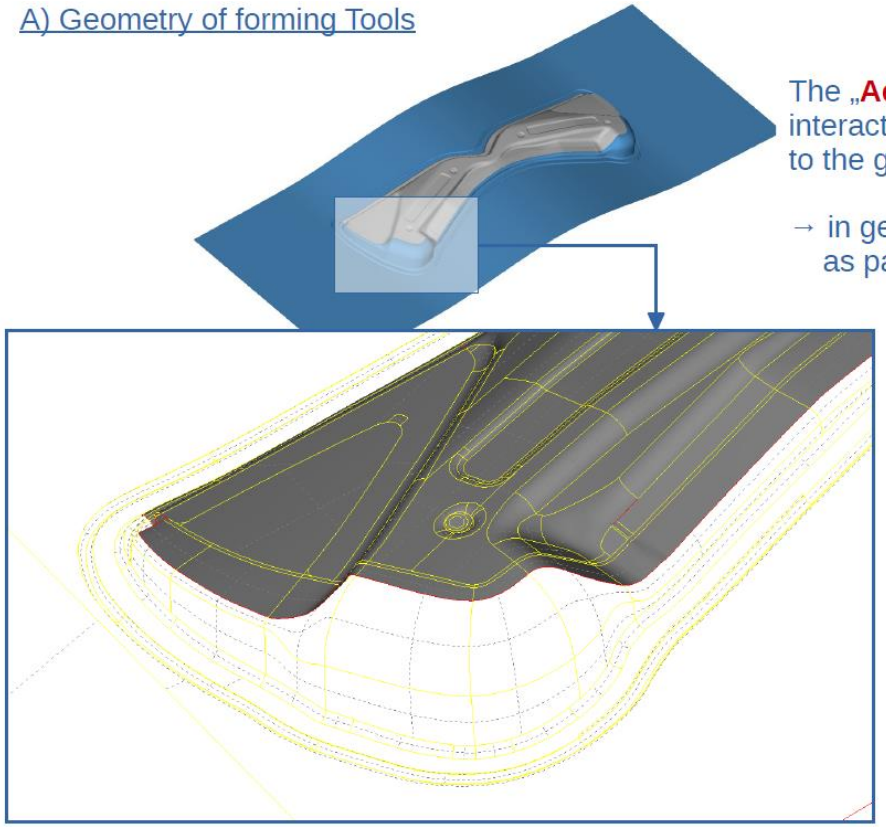
A) Geometry of forming Tools



The „**Addendum**“ surfaces are interactively created and added to the given Part geometry

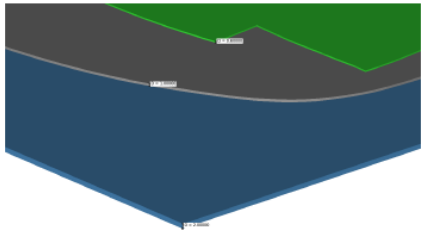
→ in general cannot be considered as part of the design parameters.

B) Initial Geometry and Properties of Blank

Blank **Outline**

Parameter type: polygon (x,y,z)
Lower bound: Part outline
Upper bound: Bounding Box

Blank **Thickness**



Parameter type: scalar (t)
Lower bound: 0.60 [mm]
Upper bound: 2.00 [mm]

Simulation output

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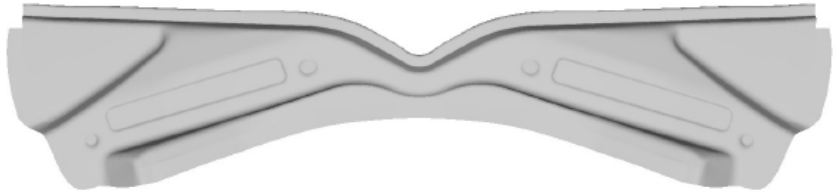

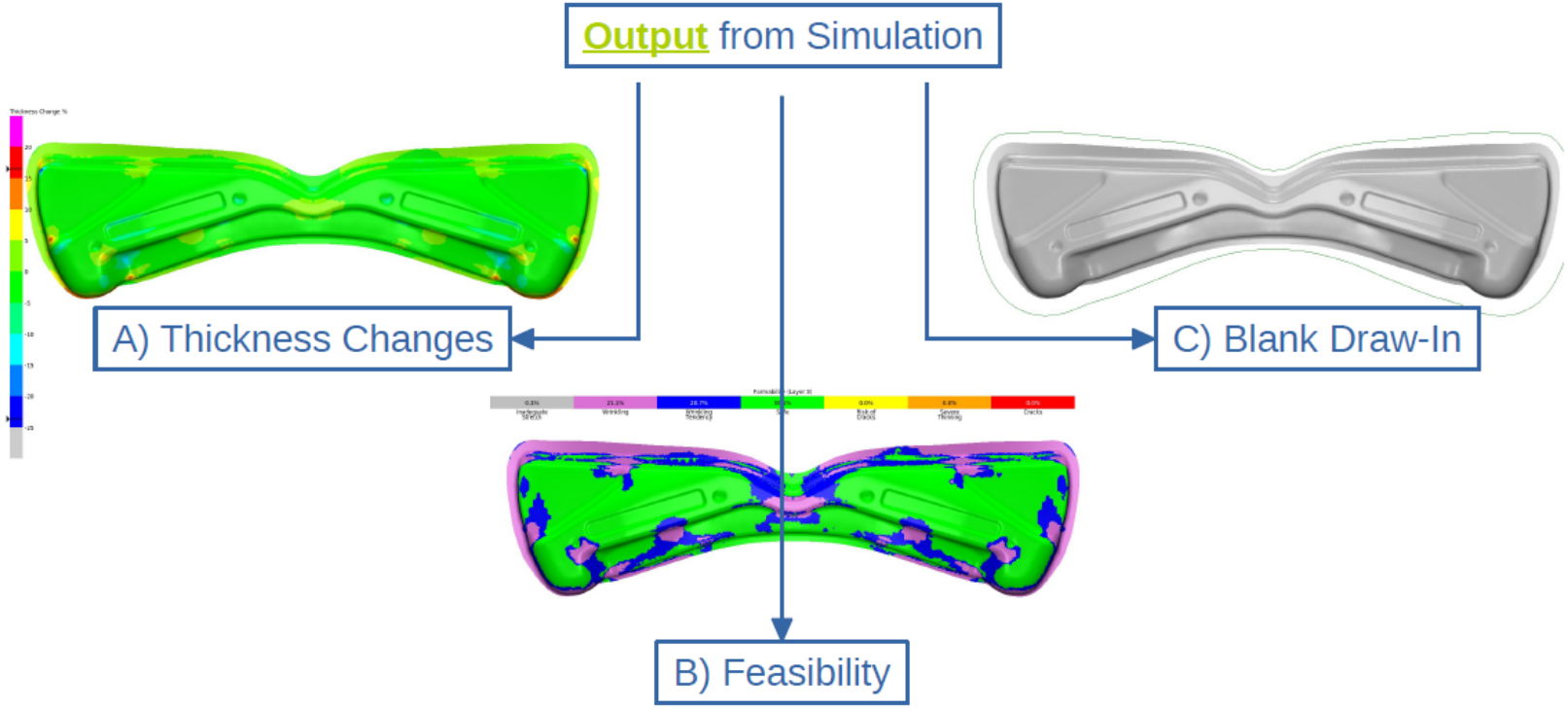

Trial and error- time and resource consuming

Objectives

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- **Acceleration of the workflow and its components** – reduces energy and compute time for simulation
- **Increased quality of the solution** –reduces resource consumption in later steps of the industrial production

- Methods
  - Artificial intelligence/machine learning
  - Approximate computing
  - Efficient use of accelerators
  - Performance tools

- Deep learning
- Reinforcement learning
- Active learning
- Gaussian process regression

Opportunities & challenges

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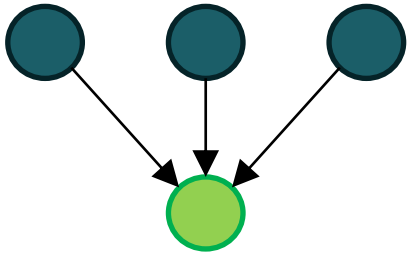
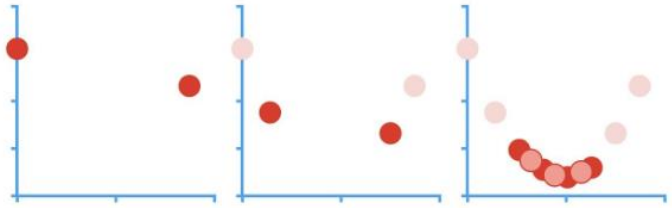
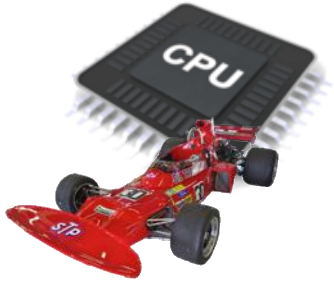
Order



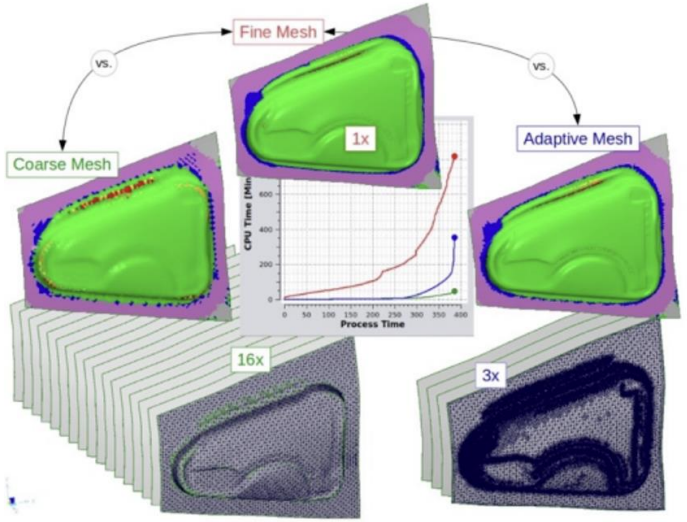


Resources



vs

Accuracy



Geometry-specific surrogate model?

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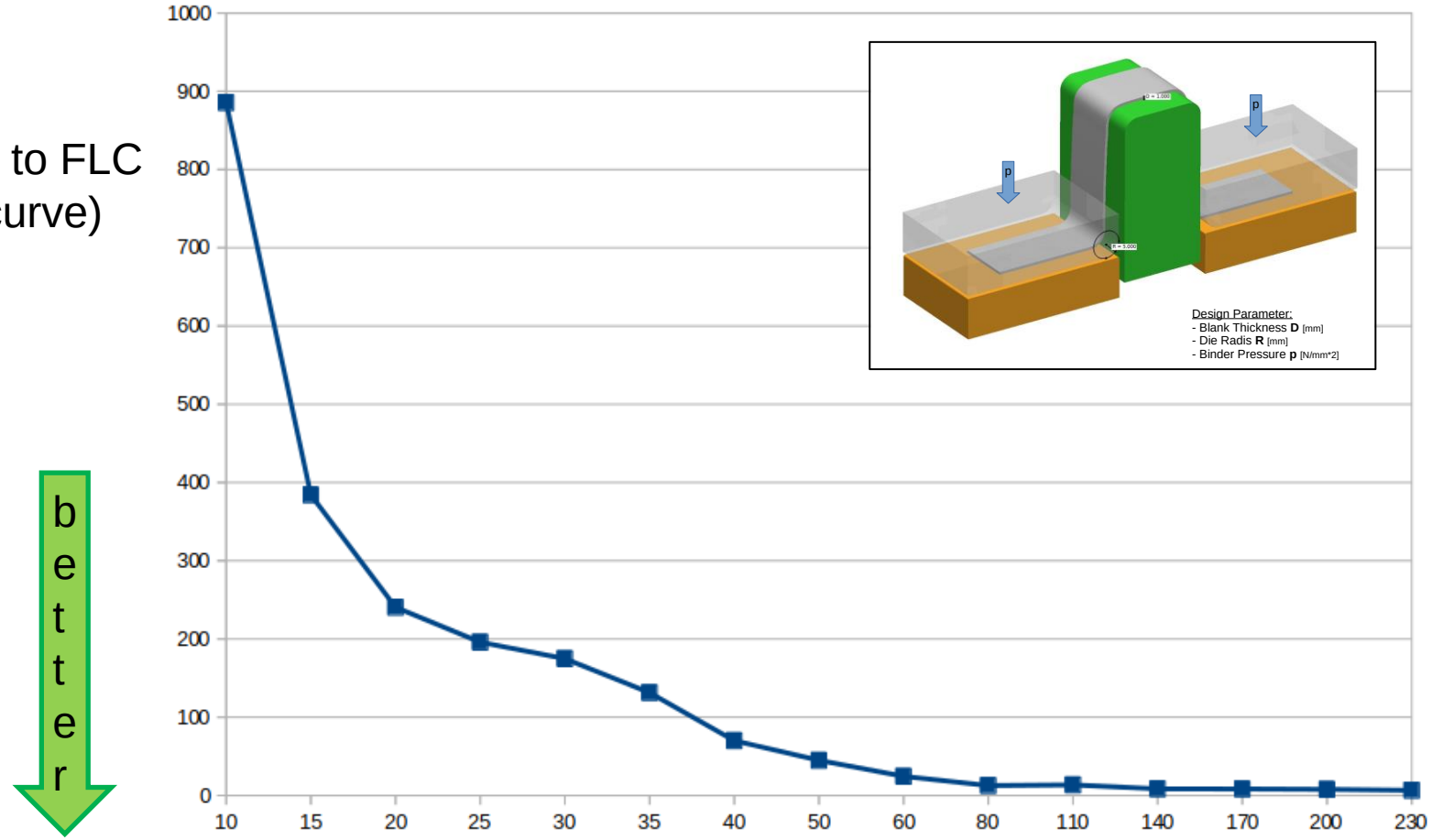
MSE of distance to FLC
(= forming limit curve)



better

Acceptance threshold

Adding results from similar geometries to the training set

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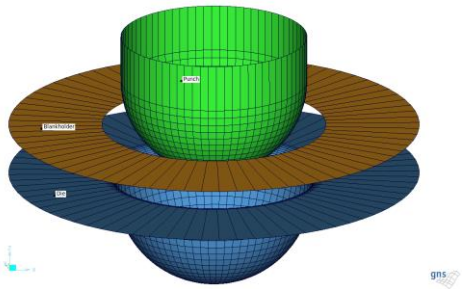
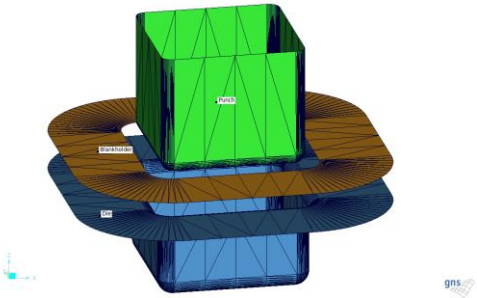
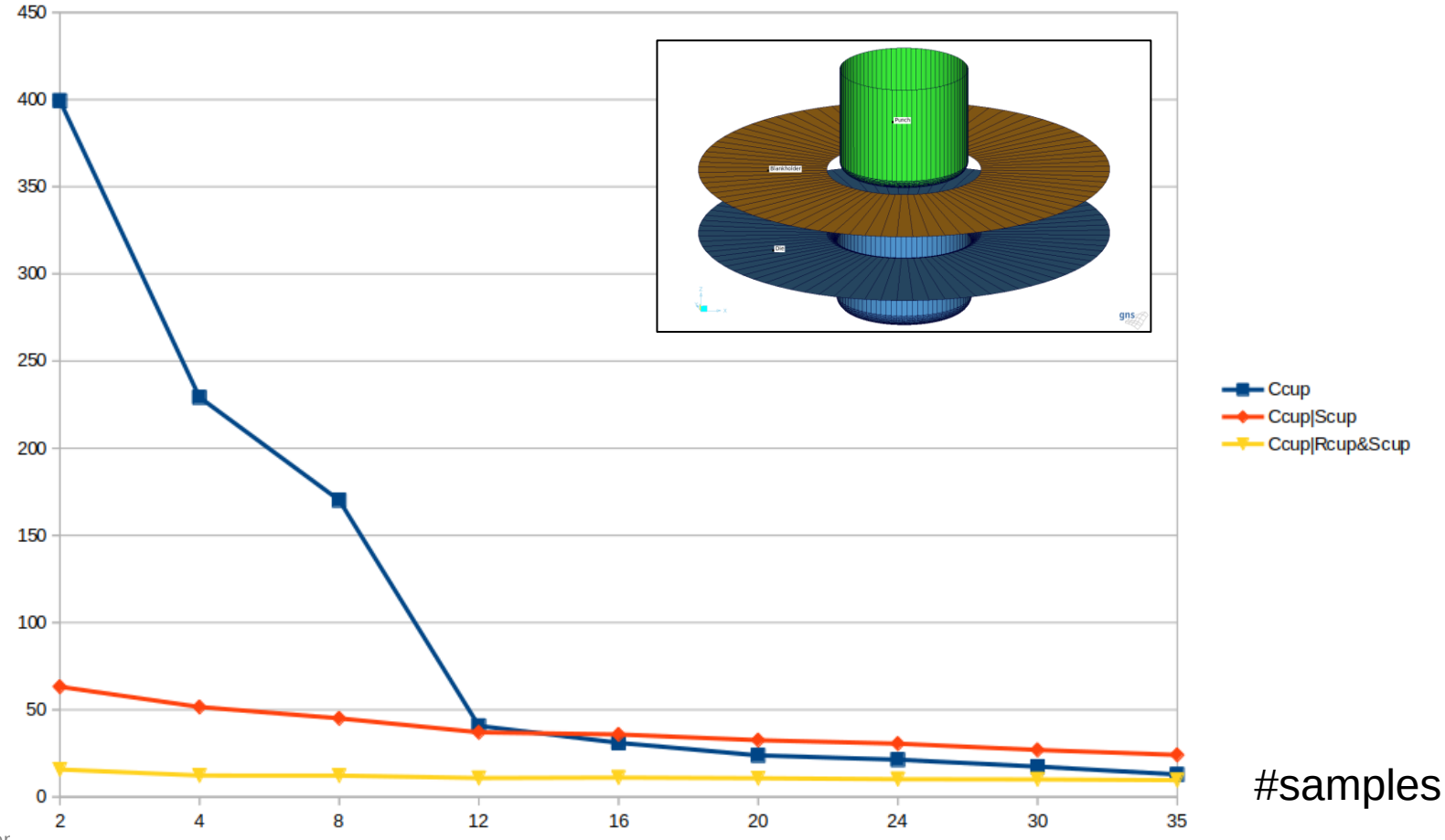




Feasibility error

better



#samples

Optimized workflow

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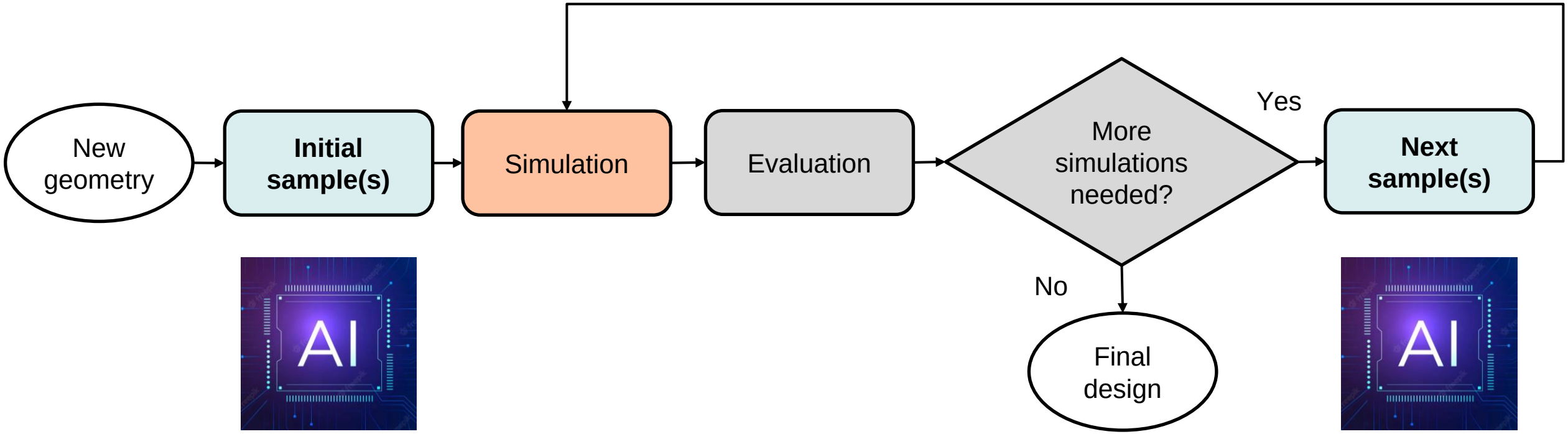

Effect of different numbers of initial samples

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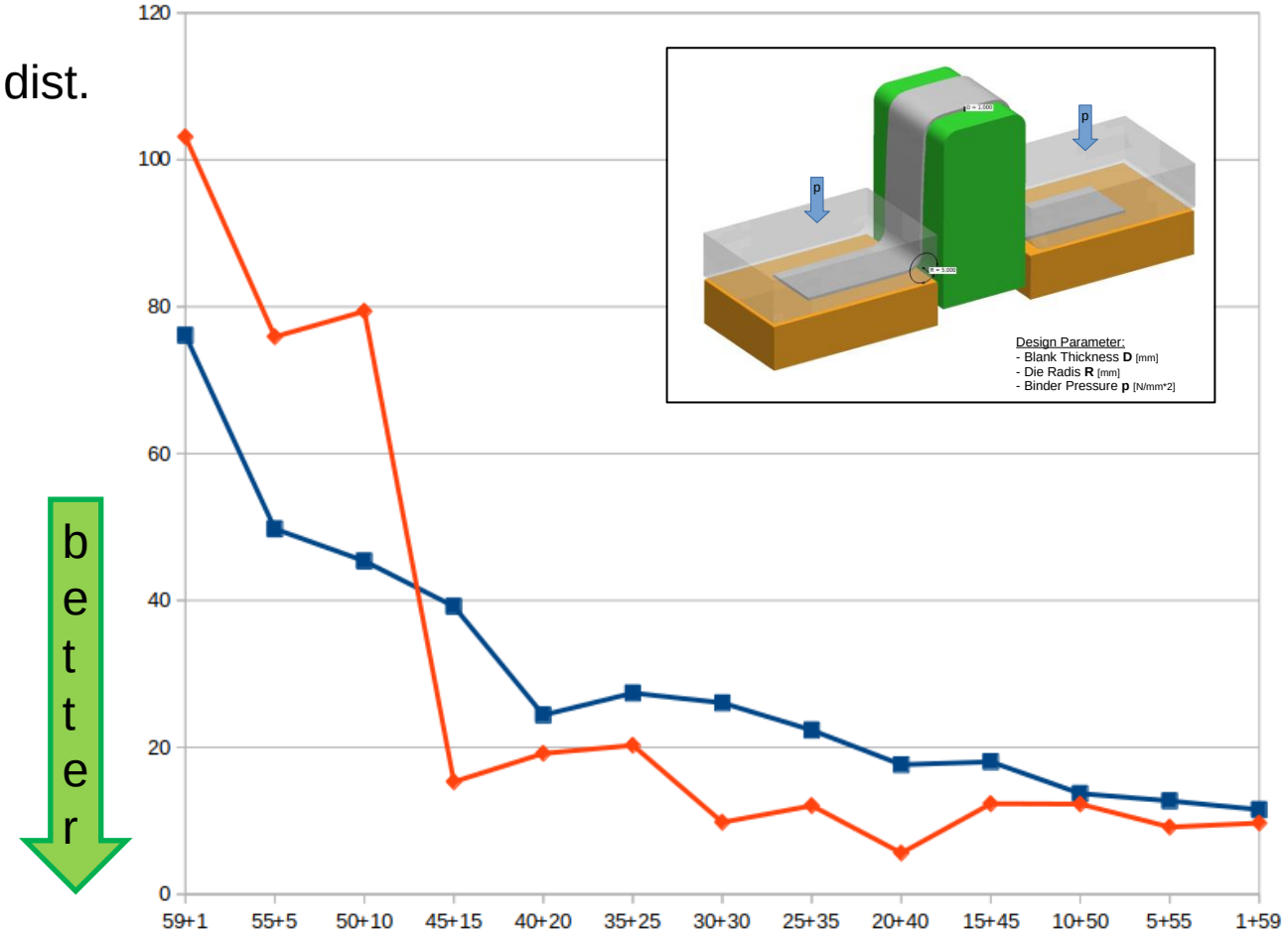
MSE of dist. to FLC



#samples:
initial random samples + GP+AL samples

Acknowledgment

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Avoiding satellite collisions

- Reinhold Bertrand
- Fabian Czappa
- Christian Hellwig
- Martin Michel

esa

European Space Agency

Deep drawing

- Semih Burak
- Kassem Koutaiba
- Ali Mohammadi
- Lukas Moj
- […]

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Thank you!

Picture credits

- https://www.esa.int/Space_Safety/Space_Debris/ESA_s_Space_Environment_Report_2022
- https://www.esa.int/Space_Safety/Space_Debris/About_space_debris
- https://www.esa.int/Space_Safety/Space_Debris/Hypervelocity_impacts_and_protecting_spacecraft
- Deep drawing illustrations: Courtesy of GNS mbH