Automated design rationalization of robot component configuration for in-vessel task of ITER Blanket Remote Handling System

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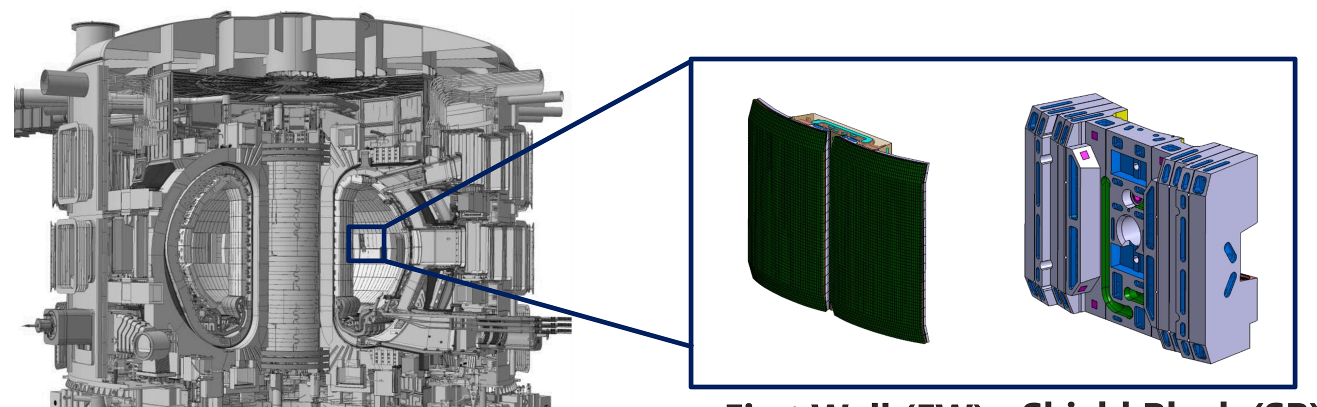
Conclusion

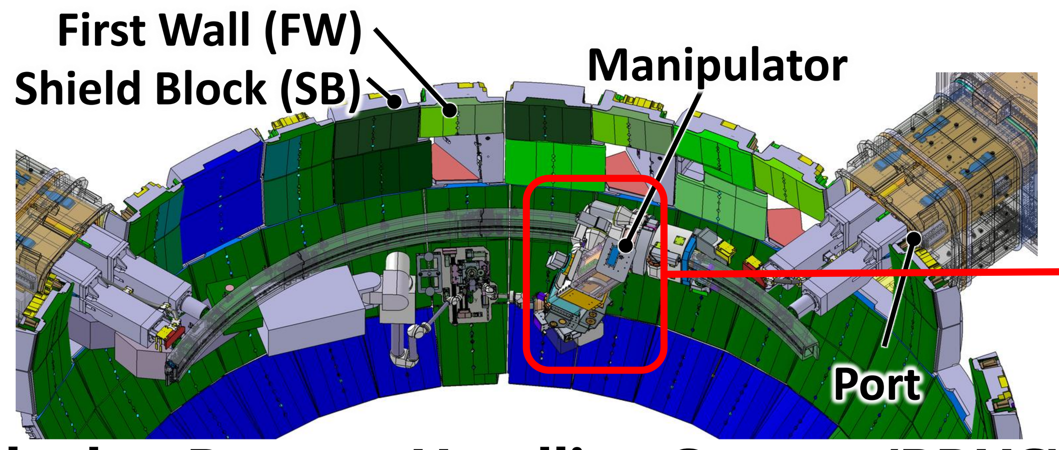
- **Developed an automated design process to optimize robotic component for ITER Blanket Remote Handling System (BRHS).**
- **Integrated automated re-configuration of component geometry, load reduced path-planning, and Bayesian optimization for efficient design iteration.**
- **Optimized the design of the BRHS components with approximately one-tenth the number of iterations compared to the conventional process.**

Component Overview

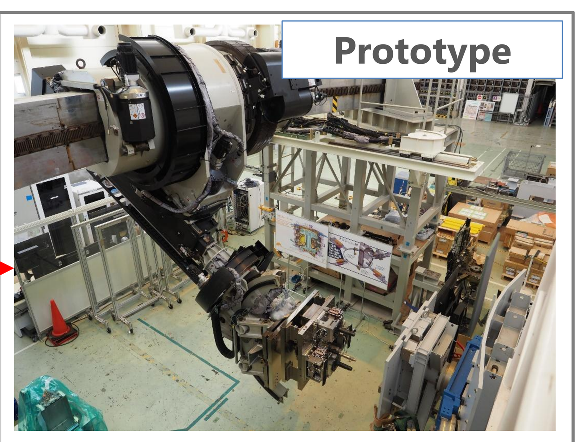
BRHS and Shield Block Gripper (SBG)



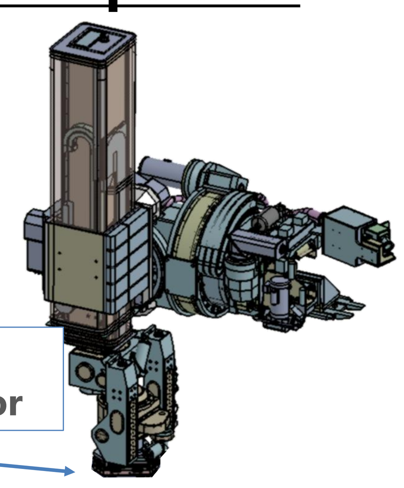
Target modules

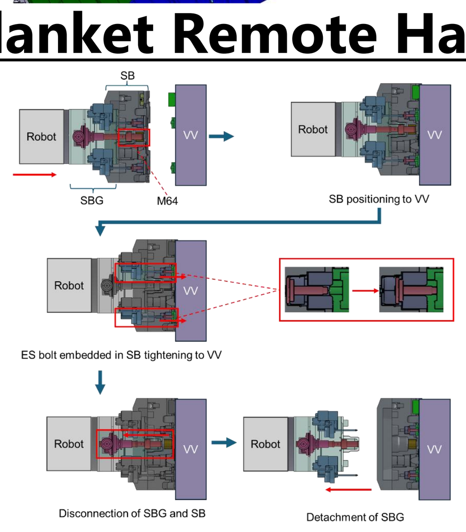


Blanket Remote Handling System (BRHS)

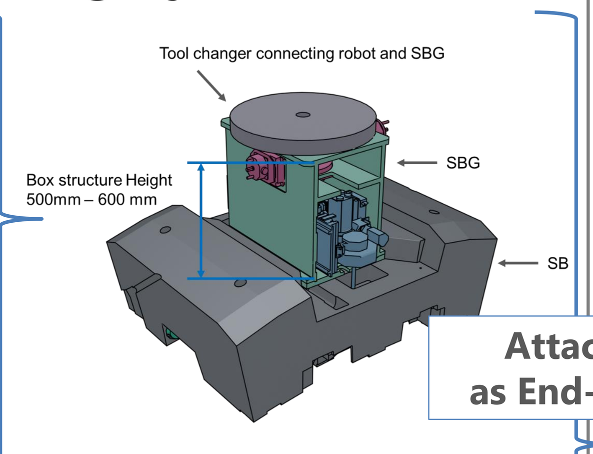


Manipulator





SB installation

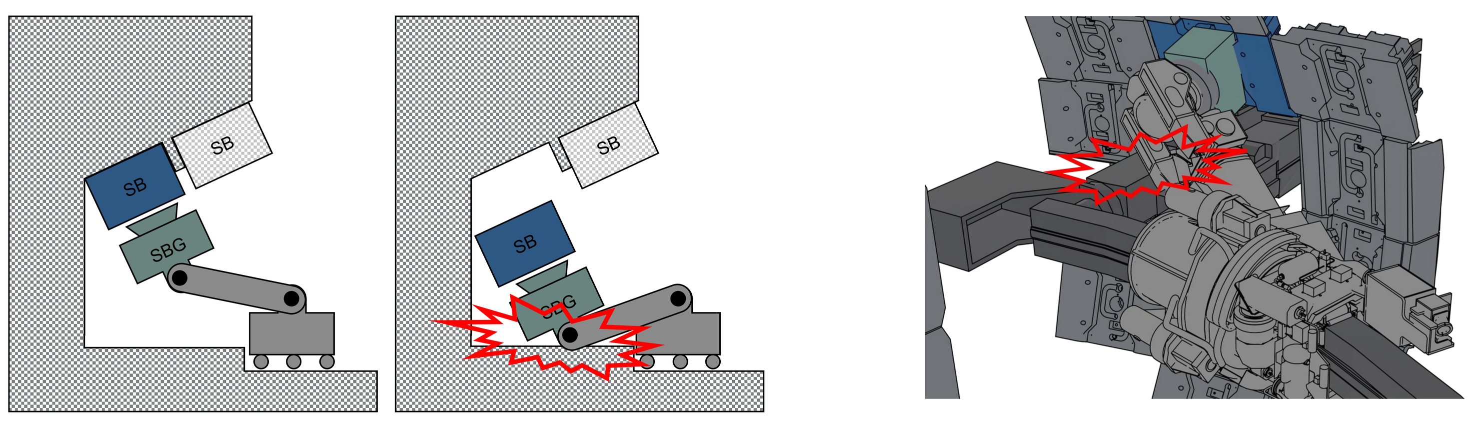


SBG for normal SB

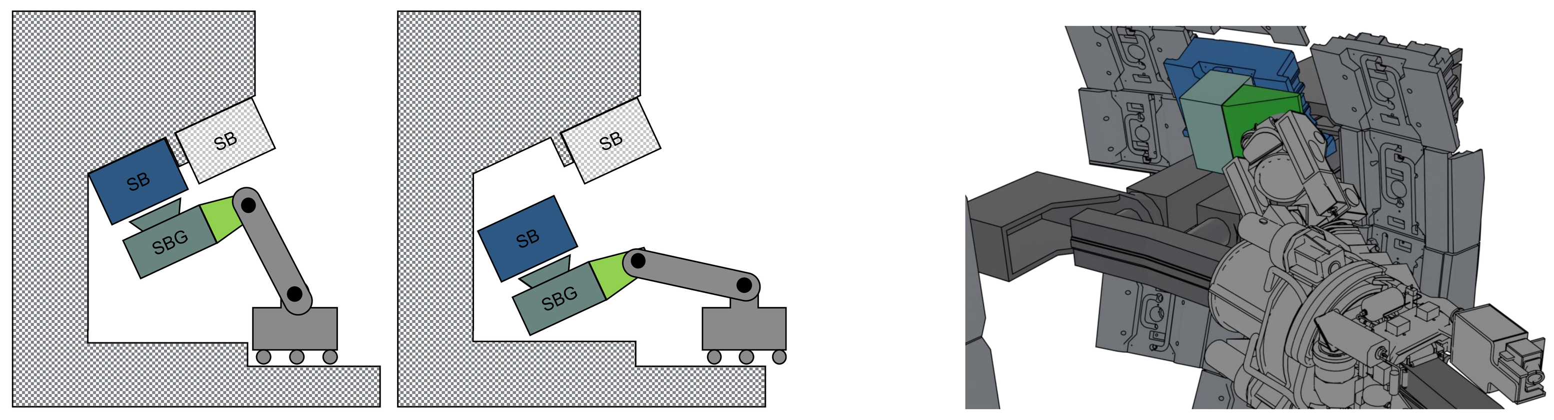
Several Types of SBG are required for the BRHS task

Kinematic difficulty in SB handling

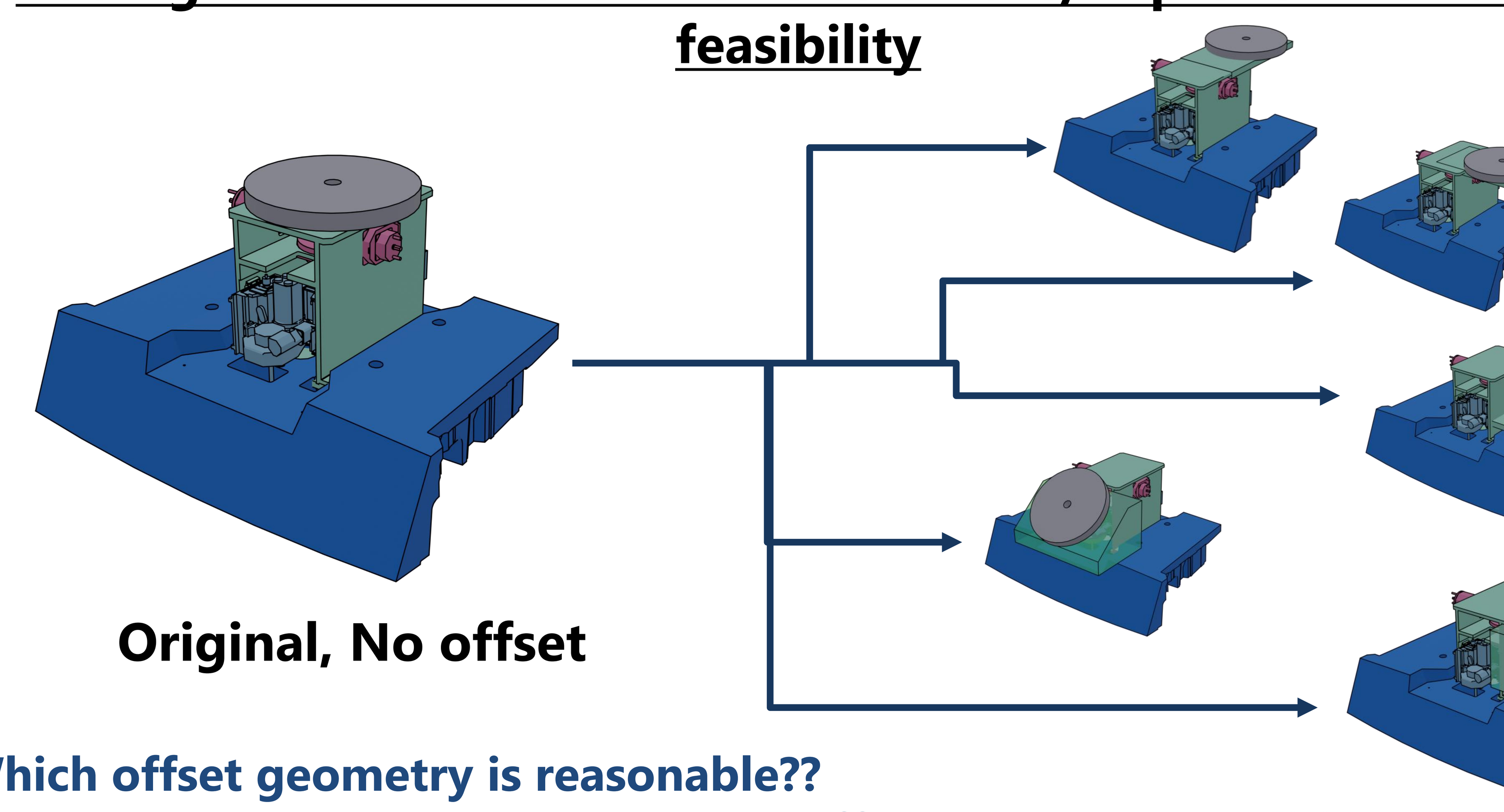
Several design changes caused kinematic challenging areas in SB handling.



Adding "Offset" structure to SBG



Adding Offset structure on SBG to ensure/improve kinematics feasibility

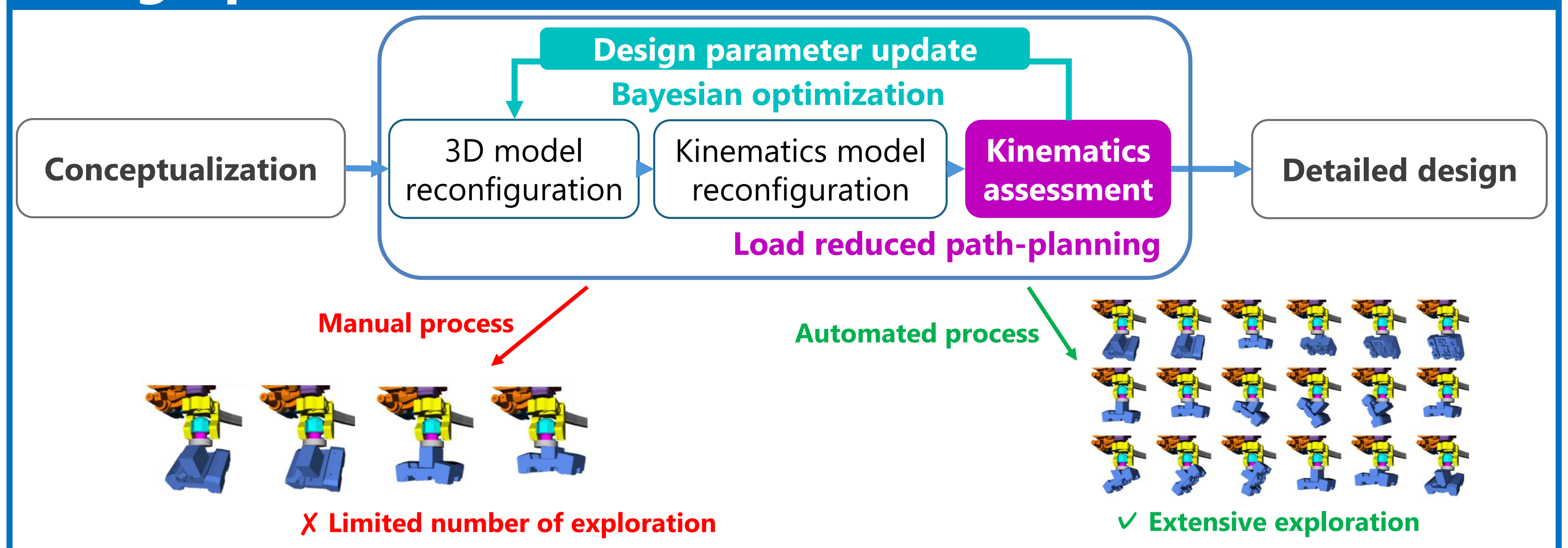


Original, No offset

Which offset geometry is reasonable??
⇒ Parameter survey under numerous offset geometry conditions is needed

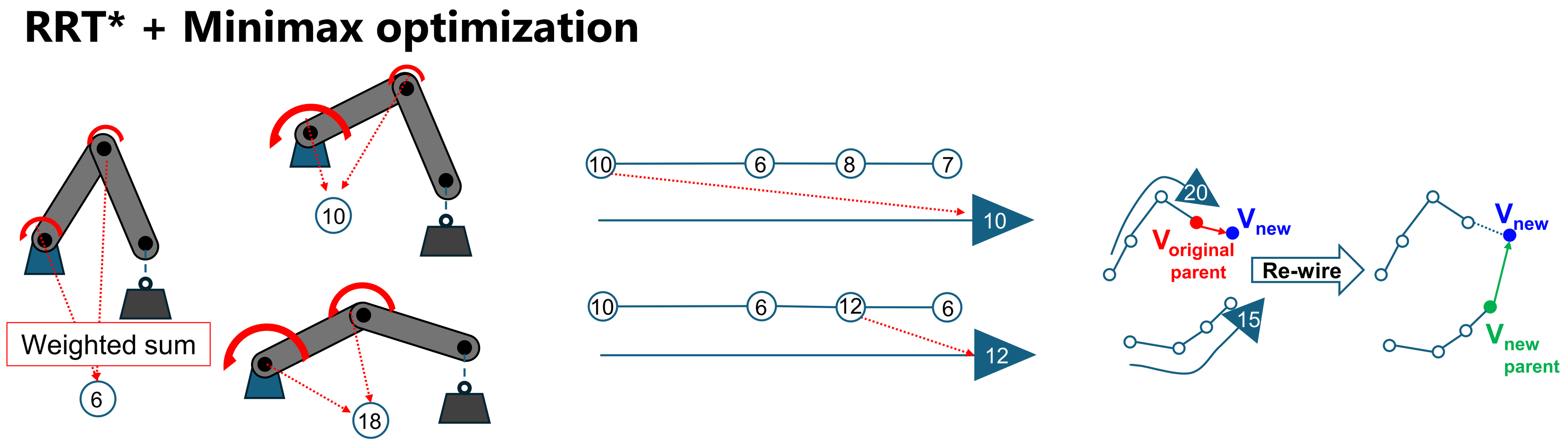
Developed Method

Design process Automation



Load reduced path-planning

RRT* + Minimax optimization



Sampled node cost — Edge/Path cost — Re-wire

Objective function / Bayesian optimization

$$\textbf{Objective function: } f(x) = \begin{cases} 4 & \text{if path planning failed} \\ S(x) + L(x) & \text{if path exists} \end{cases}$$

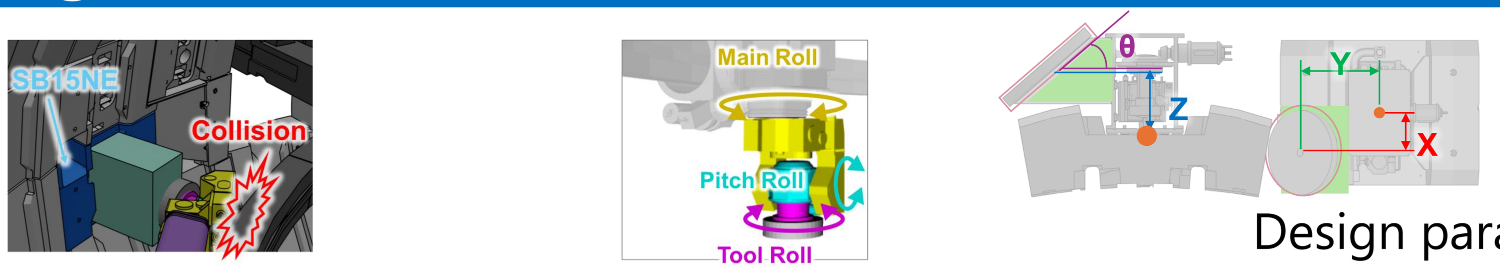
Term for compactness: $S = s/\max(s)$, $s = \sqrt{X^2+Y^2+Z^2}$

Term for joint load: $L = \sum_i w_i \max\left(\tau_i(q_1), \tau_i(q_2), \ldots, \tau_i(q_n)\right)$

Design parameters x minimizing this function:
Desirable parameters that achieve both compactness and reduced load.

Demonstration and Result

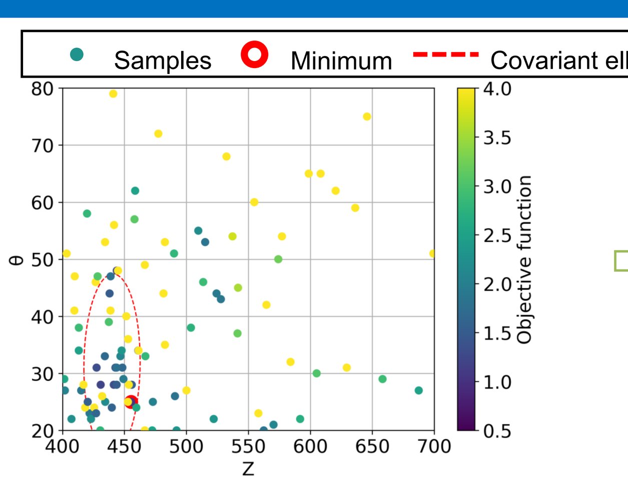
Target



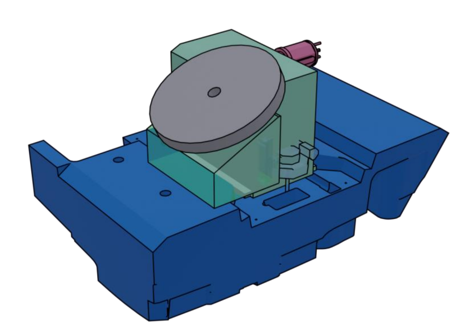
Target SB — Torque Evaluated joint — Design parameter $\boldsymbol{x} = (X, Y, Z, \theta)$

$0 \le X \le 500$
$0 \le Y \le 500$
$400 \le Z \le 700$
$20 \le \theta \le 80$

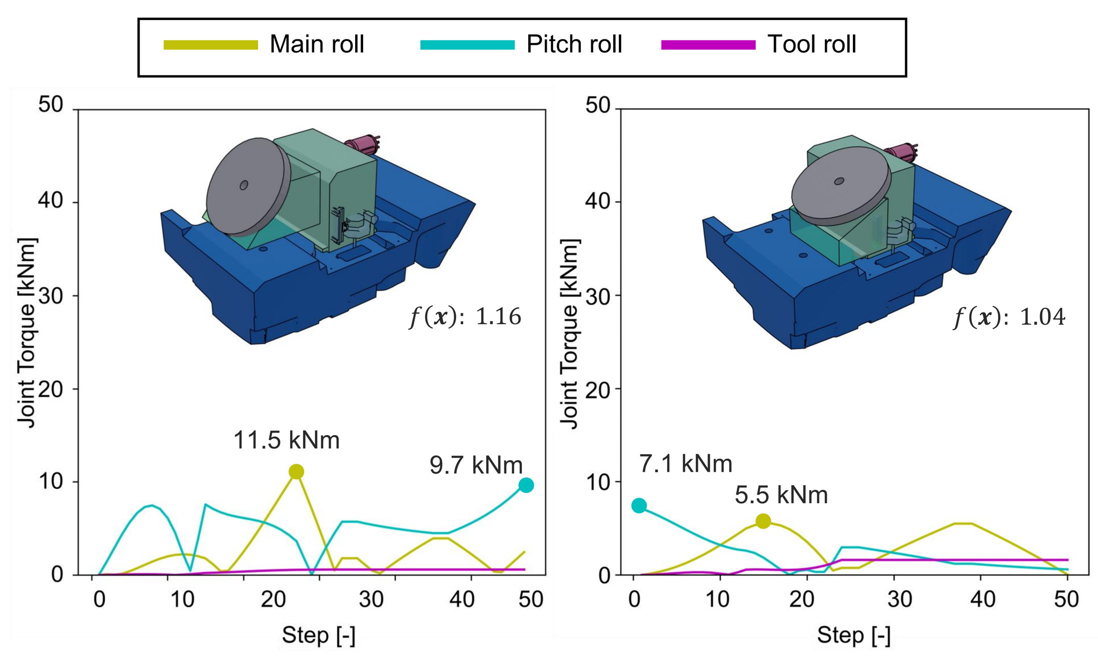
Result



Samples Projection to (Z, θ) Plane



Obtained Solution



Conventional design optimization method
- **1008** conditions of grid-search
- **w/o load reduced path-planning**

Developed design optimization method
- **100** sampling
- **w/ load reduced path-planning**

Required torque comparison

⇒Achieves better optimality with fewer iterations.

18th October 2025 08:30 – 14:20
Presented by IWAMOTO Takuya (iwamoto.takuya@qst.go.jp)

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