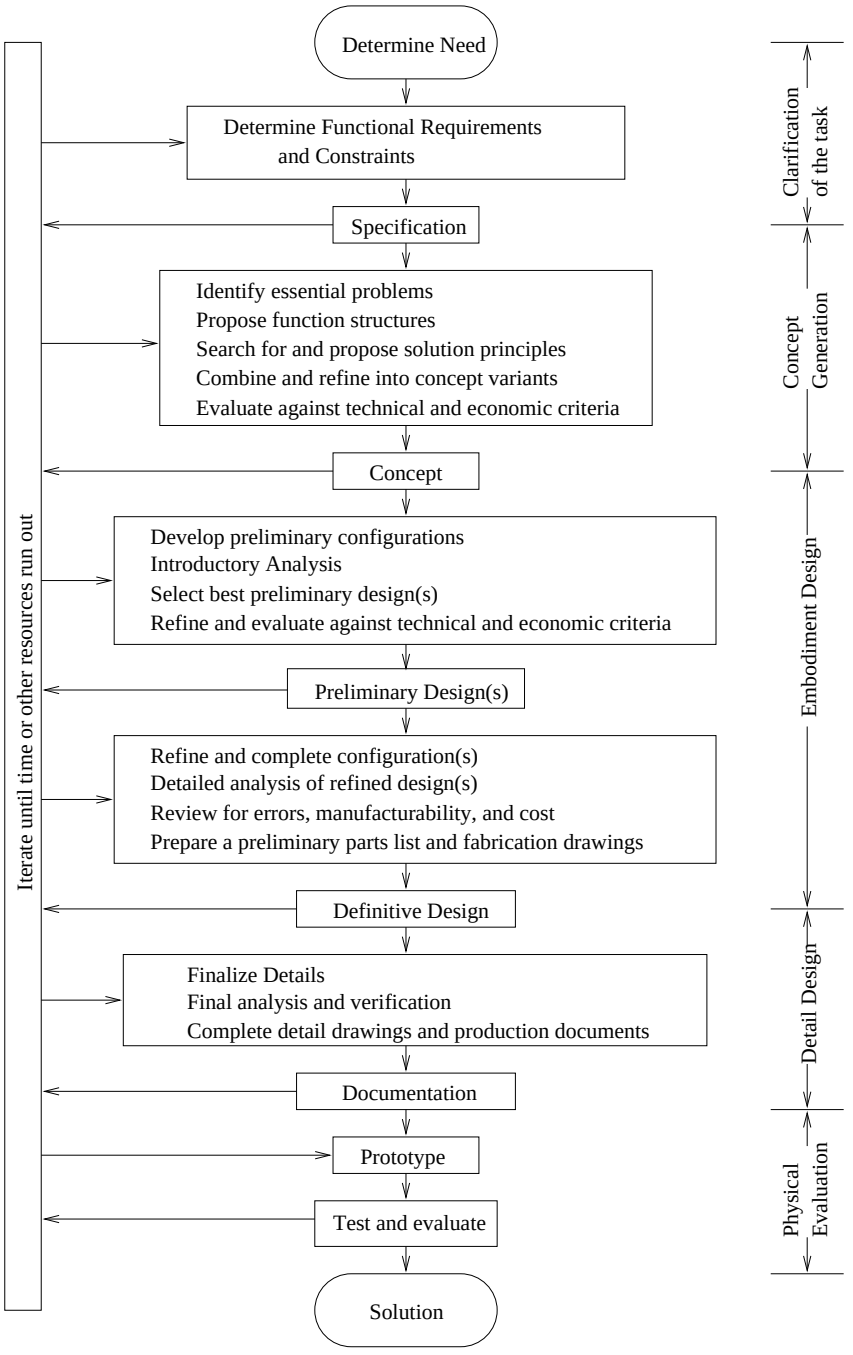
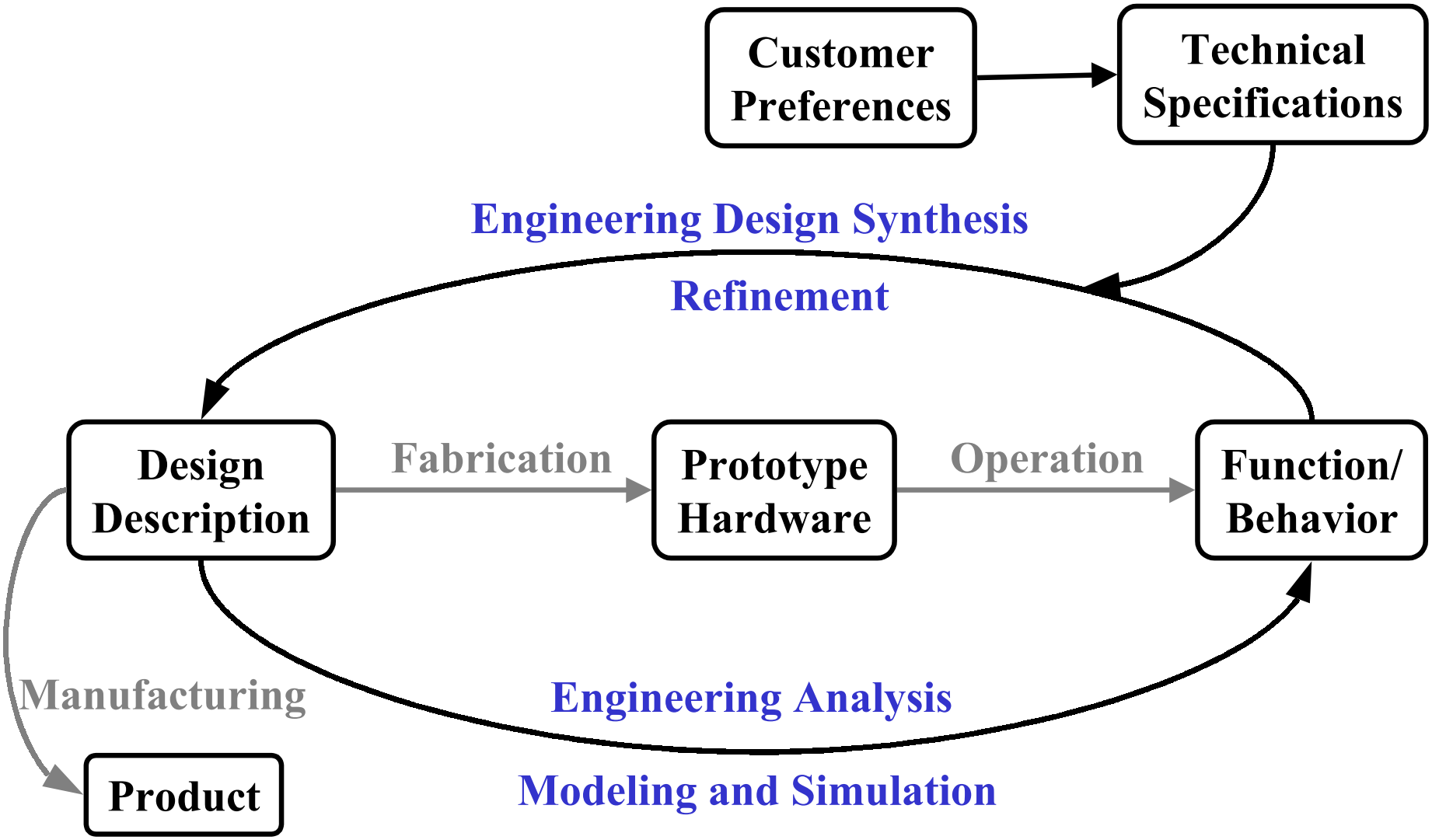
Traditional Engineering Design



[G. Pahl and W. Beitz, *Engineering Design*, The Design Council, Springer-Verlag, New York, 1984, page 41.]

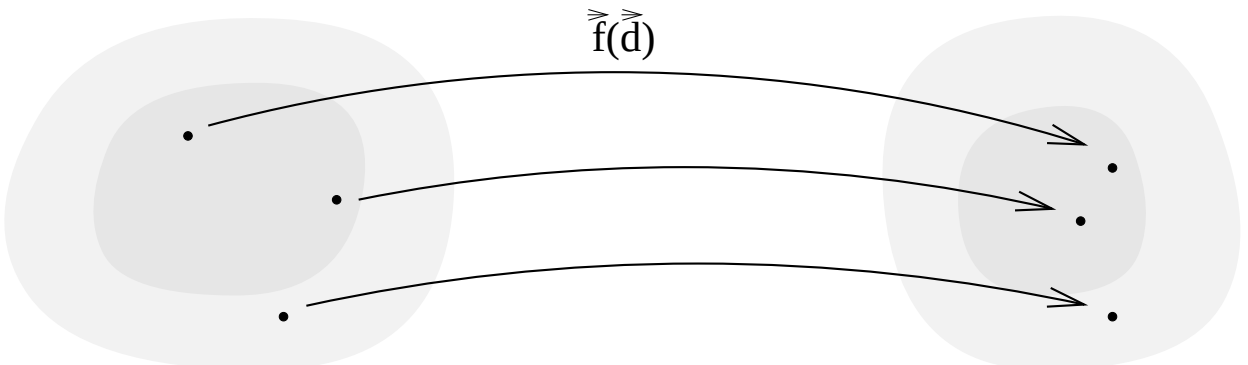

Customer Preferences
Technical Specifications
Engineering Design Synthesis
Refinement
Design Description
Fabrication
Prototype Hardware
Operation
Function/ Behavior
Manufacturing
Engineering Analysis
Product
Modeling and Simulation

DVS

(Design Variable Space)

PVS

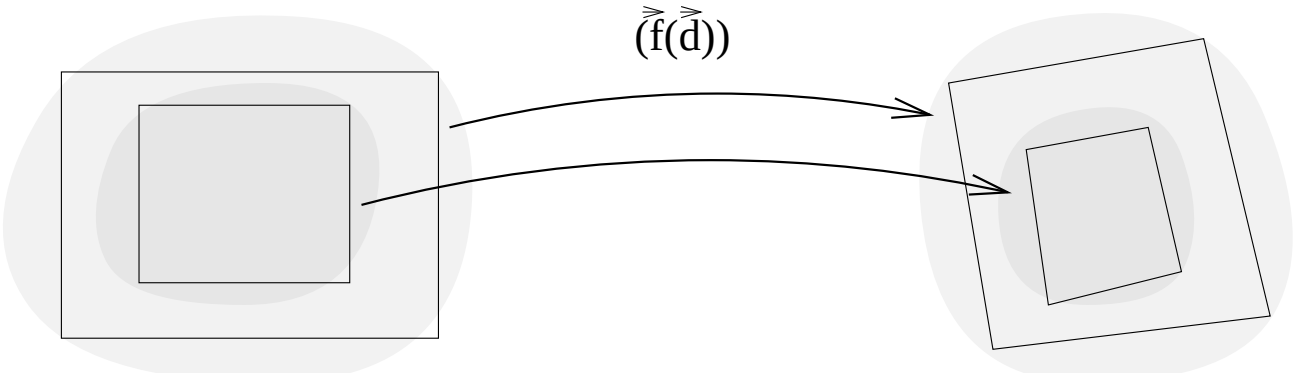
(Performance Variable Space)



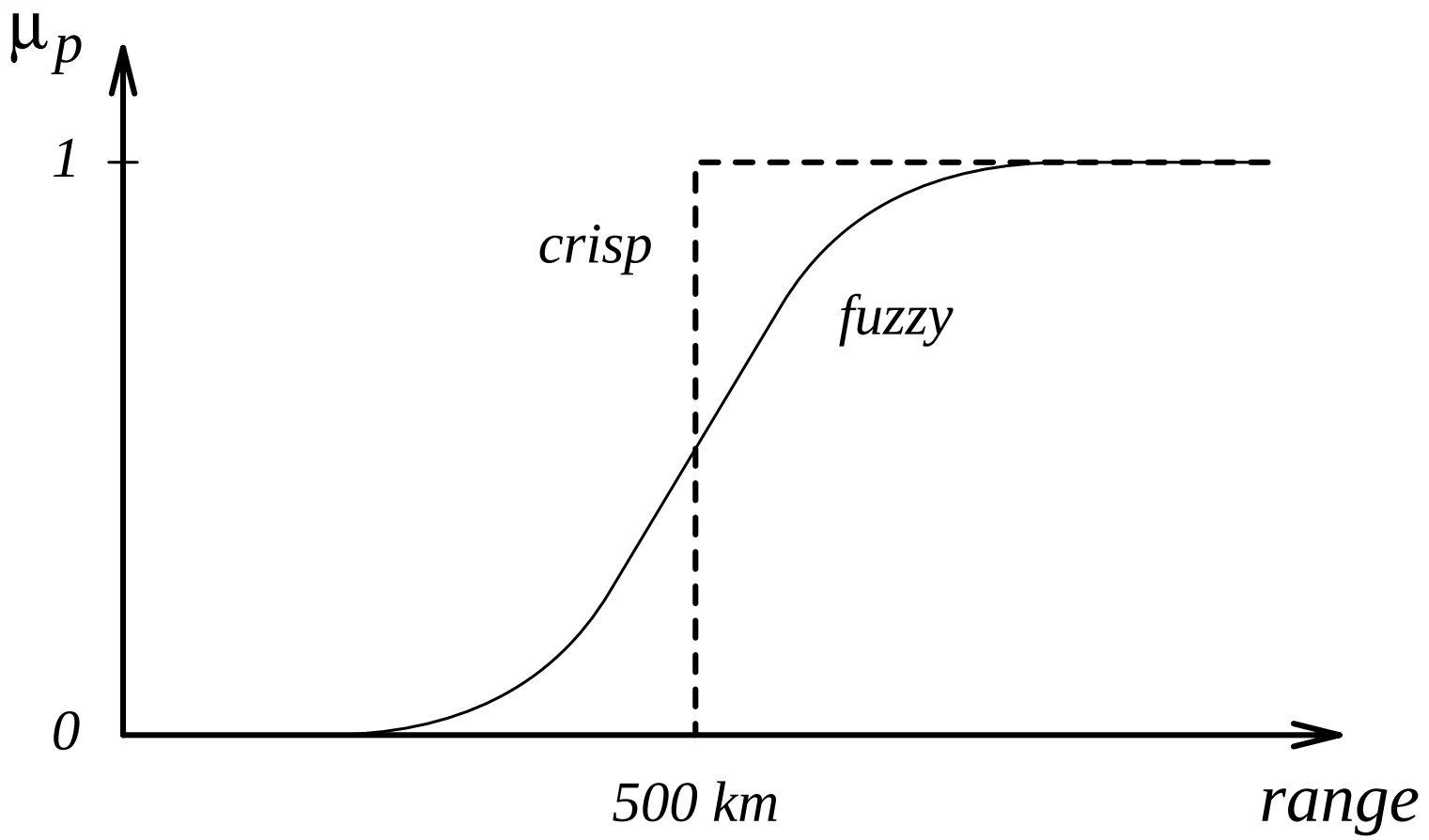
Design Exploration Point by Point

DVS

PVS



Design Exploration Sets at a Time


μp
1
0
crisp
fuzzy
500 km
range

Aggregation Operator Axioms

At each point $\vec{x}$ the following hold:

1. **Monotonicity:**
   $\mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2)(\vec{x}) \leq \mathcal{P}(\mu_1, \mu_2'; \omega_1, \omega_2)(\vec{x}) \quad \forall\, \mu_2(\vec{x}) \leq \mu_2'(\vec{x})$
   $\mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2)(\vec{x}) \leq \mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2')(\vec{x}) \quad \forall\, \omega_2 \leq \omega_2';\ \ \mu_1(\vec{x}) < \mu_2(\vec{x})$

2. **Symmetry:**
   $\mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2)(\vec{x}) = \mathcal{P}(\mu_2, \mu_1; \omega_2, \omega_1)(\vec{x})$

3. **Continuity:**
   $\mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2)(\vec{x}) = \lim_{\mu_2'(\vec{x}) \to \mu_2(\vec{x})} \mathcal{P}(\mu_1, \mu_2'; \omega_1, \omega_2)(\vec{x})$
   $\mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2)(\vec{x}) = \lim_{\omega_2' \to \omega_2} \mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2')(\vec{x})$

4. **Idempotency:**
   $\mathcal{P}(\mu, \mu; \omega_1, \omega_2)(\vec{x}) = \mu(\vec{x}) \ \ \forall\, \omega_1 + \omega_2 > 0$

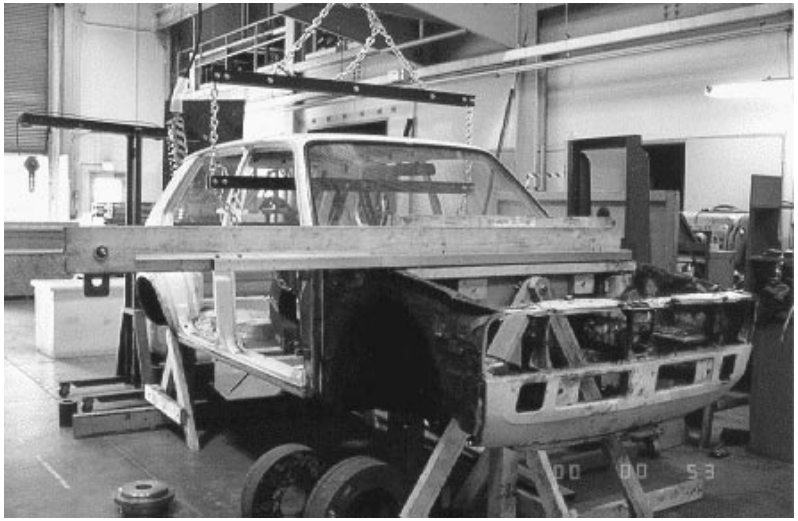
5. **Annihilation:**
   $\mathcal{P}(\mu, 0; \omega_1, \omega_2)(\vec{x}) = 0 \ \ \forall\, \omega_2 \neq 0$

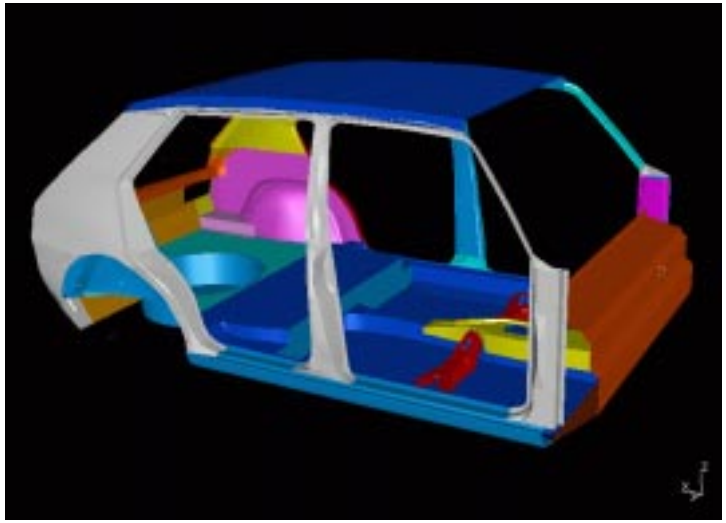
6. **Self-scaling weights:**
   $\mathcal{P}(\mu_1, \mu_2; \omega_1 t, \omega_2 t)(\vec{x}) = \mathcal{P}(\mu_1, \mu_2; \omega_1, \omega_2)(\vec{x}) \quad \forall\, \omega_1 + \omega_2, t > 0$

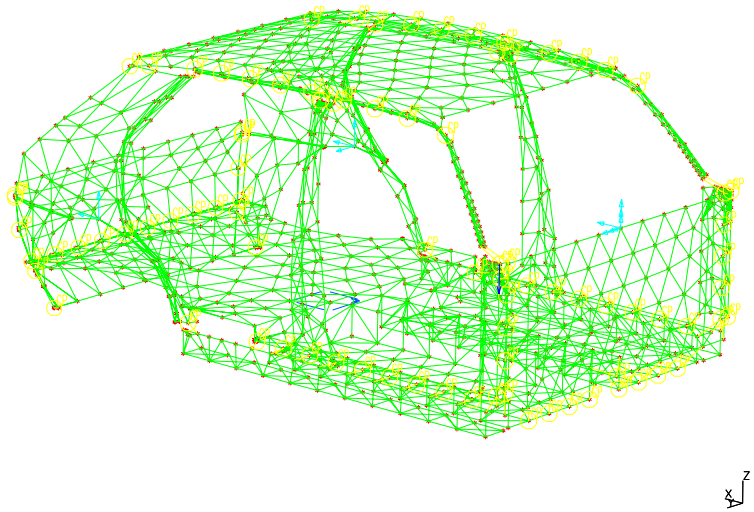
7. **Zero weights:**
   $\mathcal{P}(\mu_1, \mu_2; \omega_1, 0)(\vec{x}) = \mu_1(\vec{x}) \ \ \forall\, \omega_1 \neq 0$

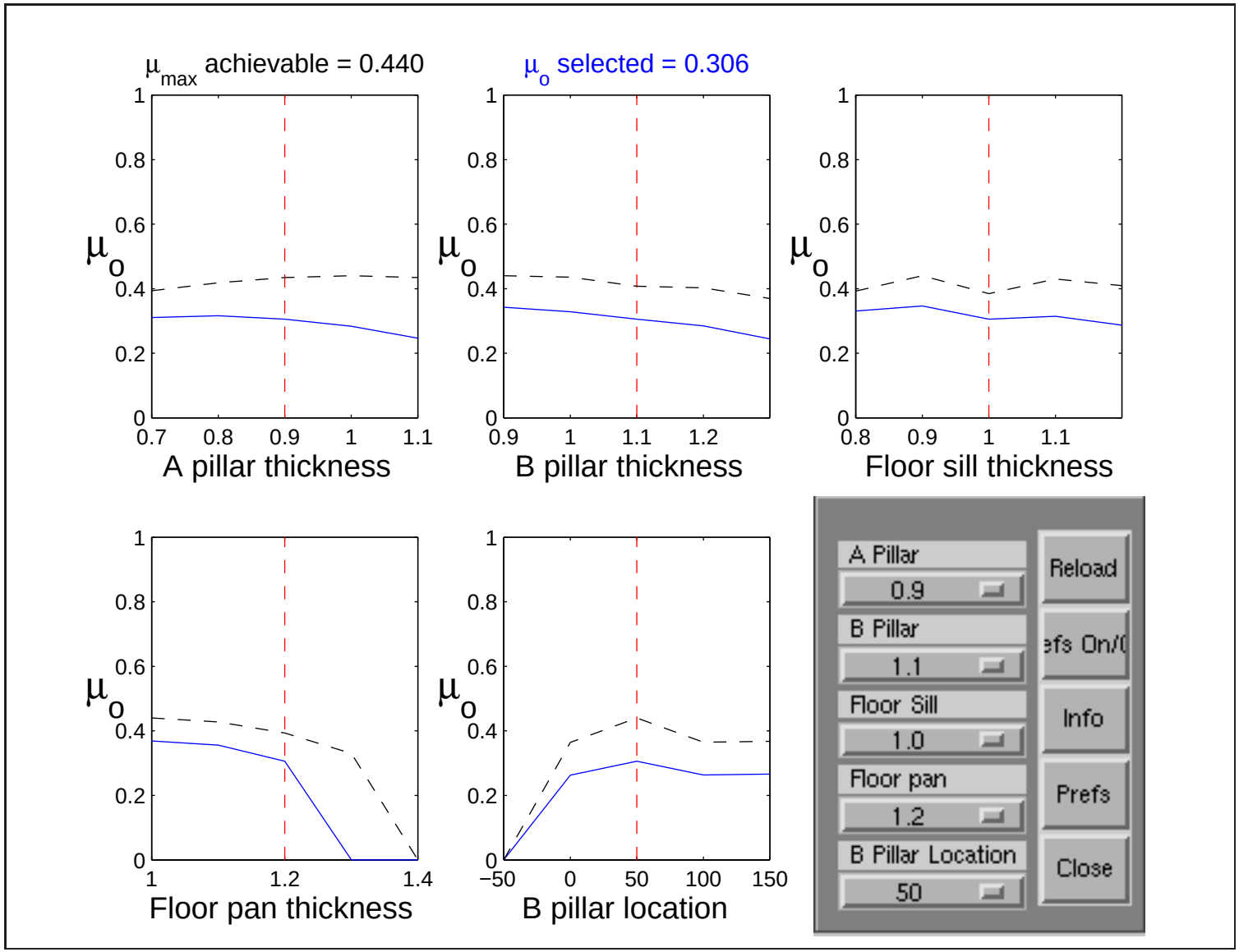
Current Related Work at Caltech

Rapid Exploration of a Large Design Space





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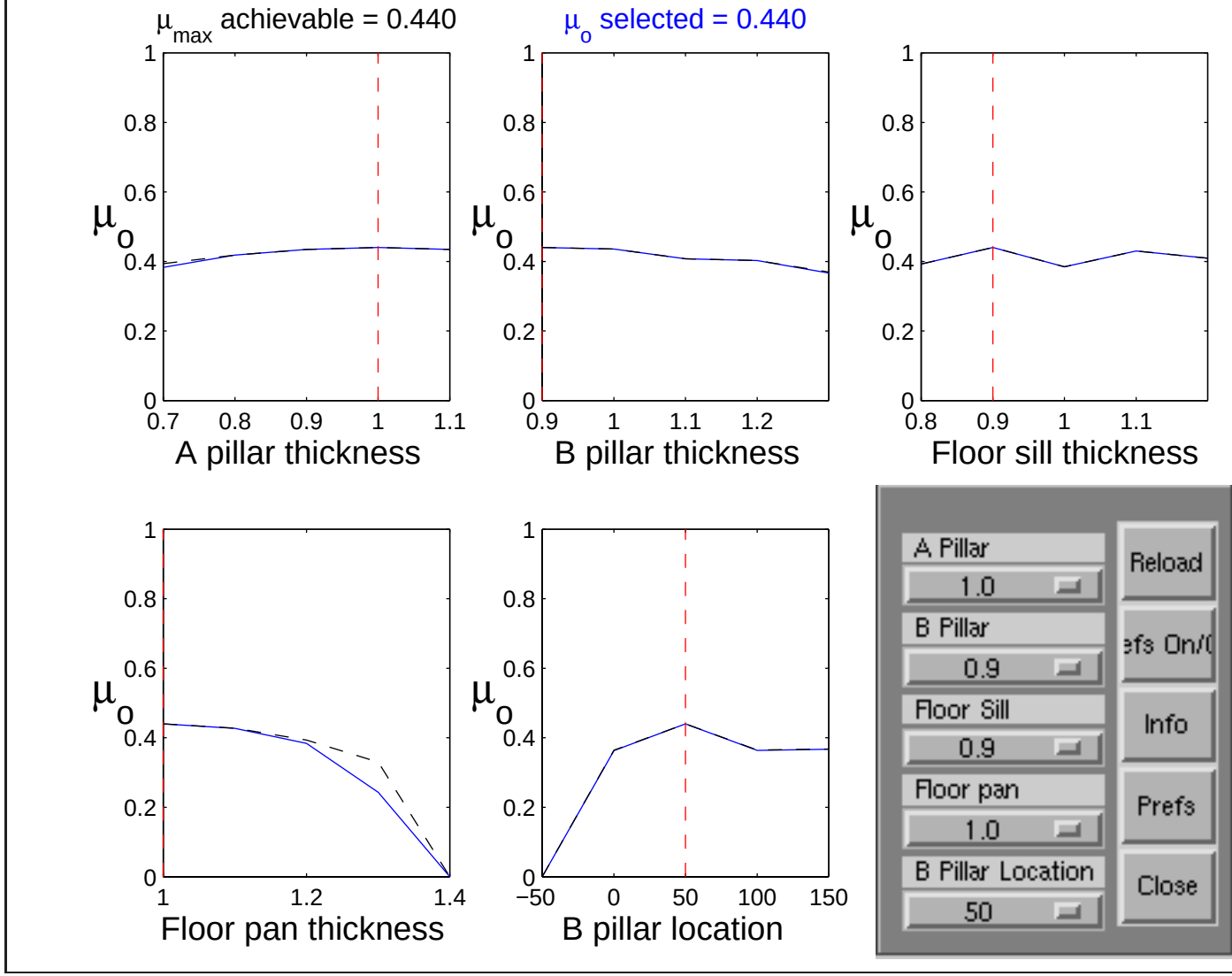
μo selected = 0.306
μo
A pillar thickness
B pillar thickness
Floor sill thickness
Floor pan thickness
B pillar location
A Pillar
0.9
B Pillar
1.1
Floor Sill
1.0
Floor pan
1.2
B Pillar Location
50
Reload
Info
Prefs
Close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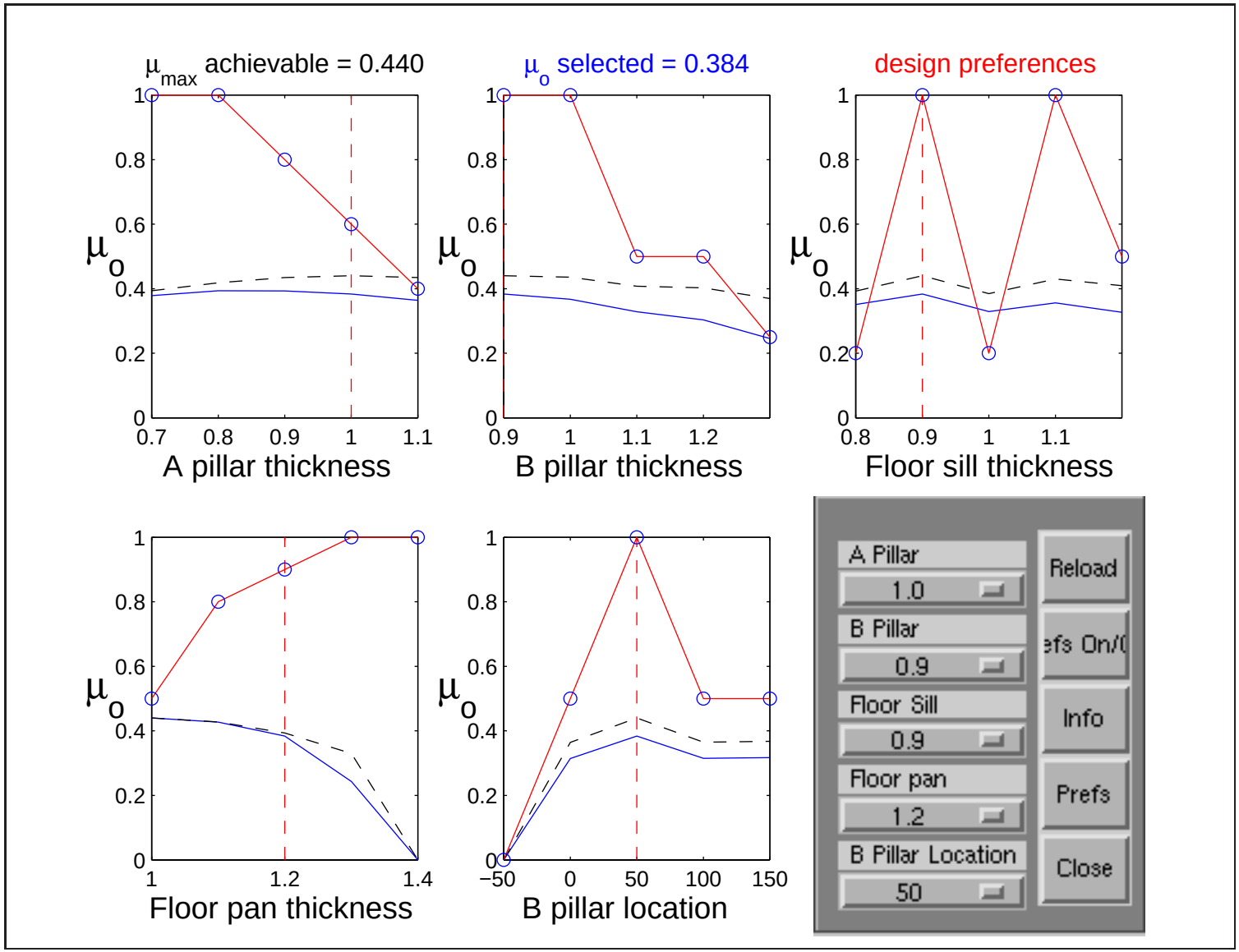
μo selected = 0.440
μo
A pillar thickness
B pillar thickness
Floor sill thickness
Floor pan thickness
B pillar location
A Pillar
1.0
B Pillar
0.9
Floor Sill
0.9
Floor pan
1.0
B Pillar Location
50
Reload
Info
Prefs
Close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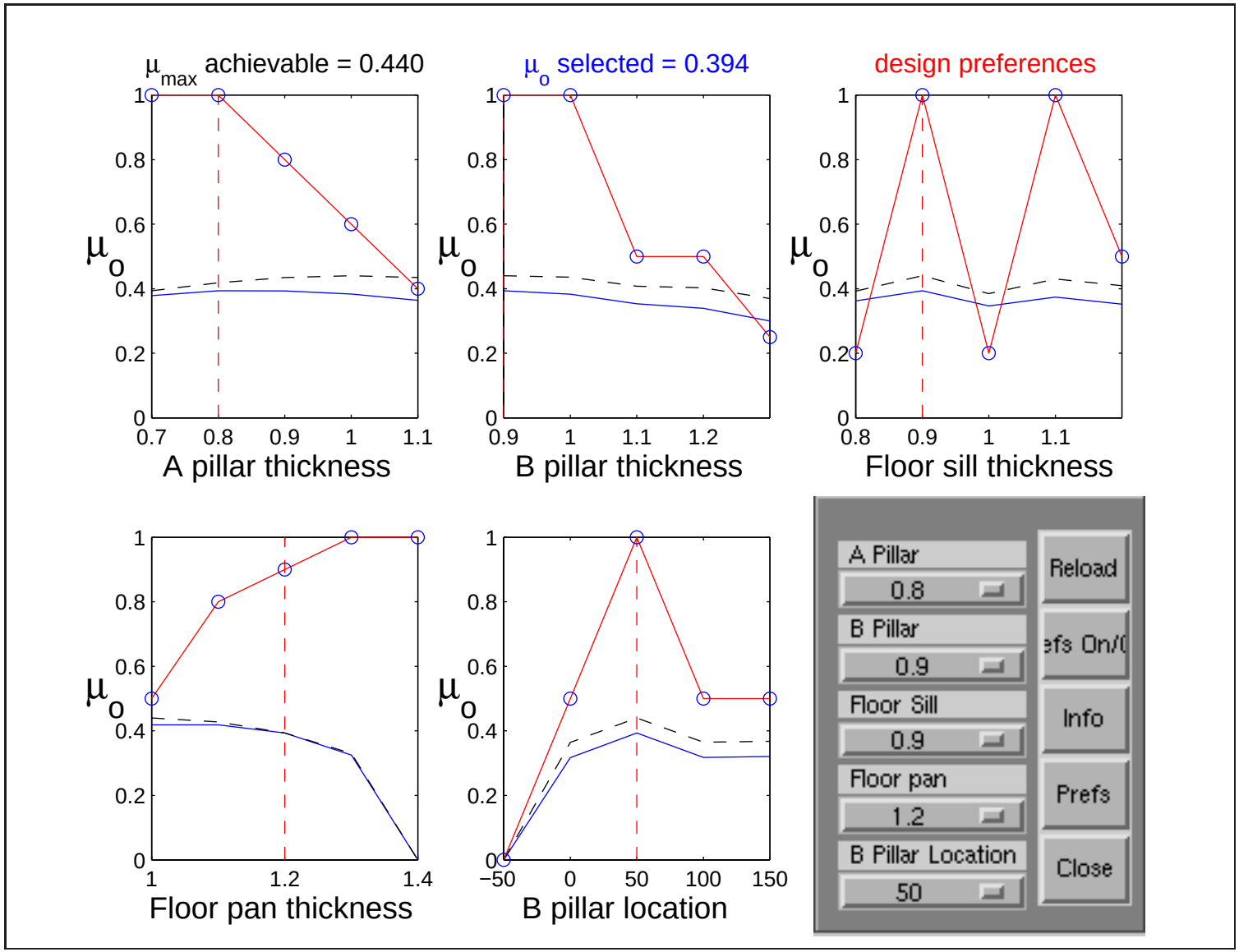
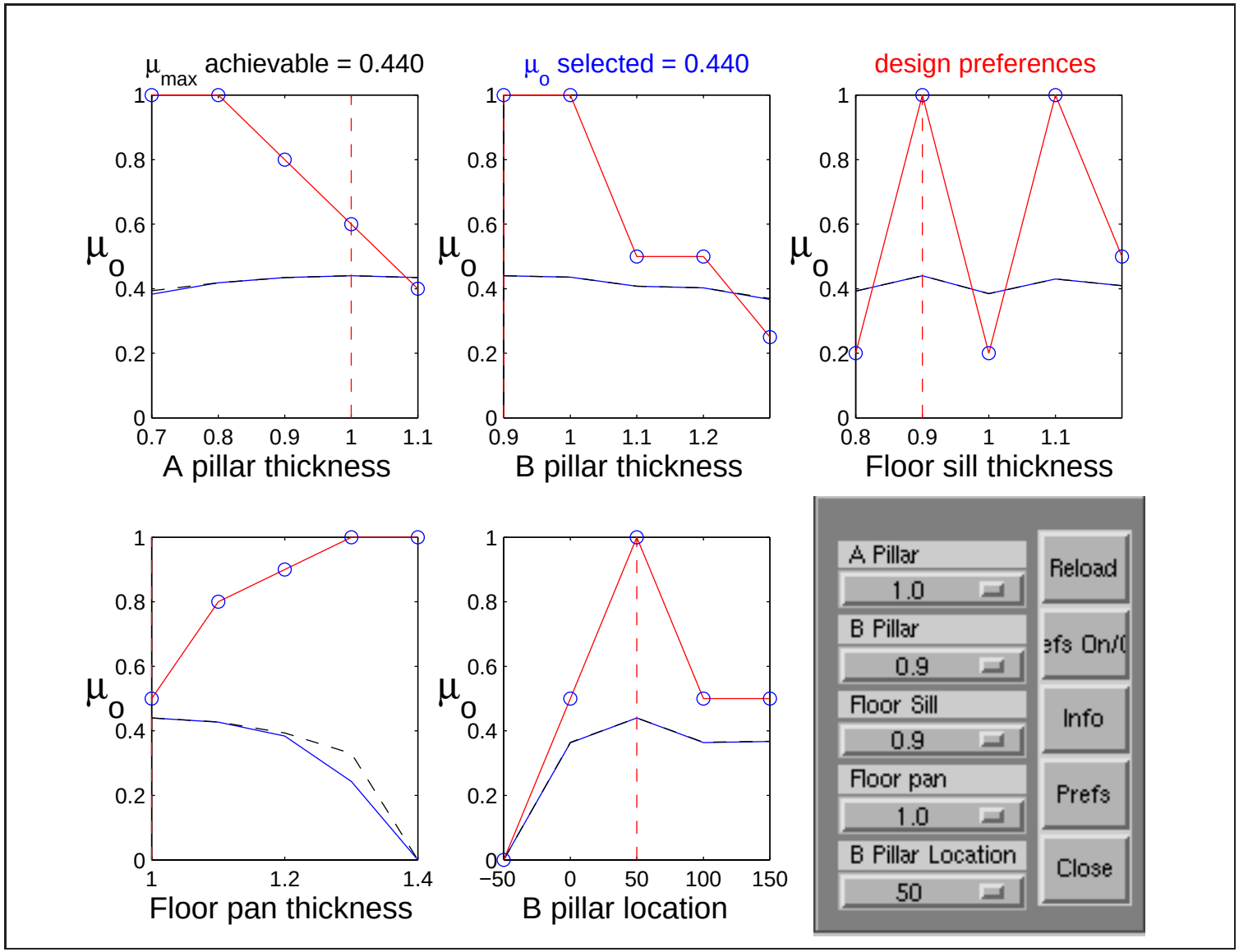
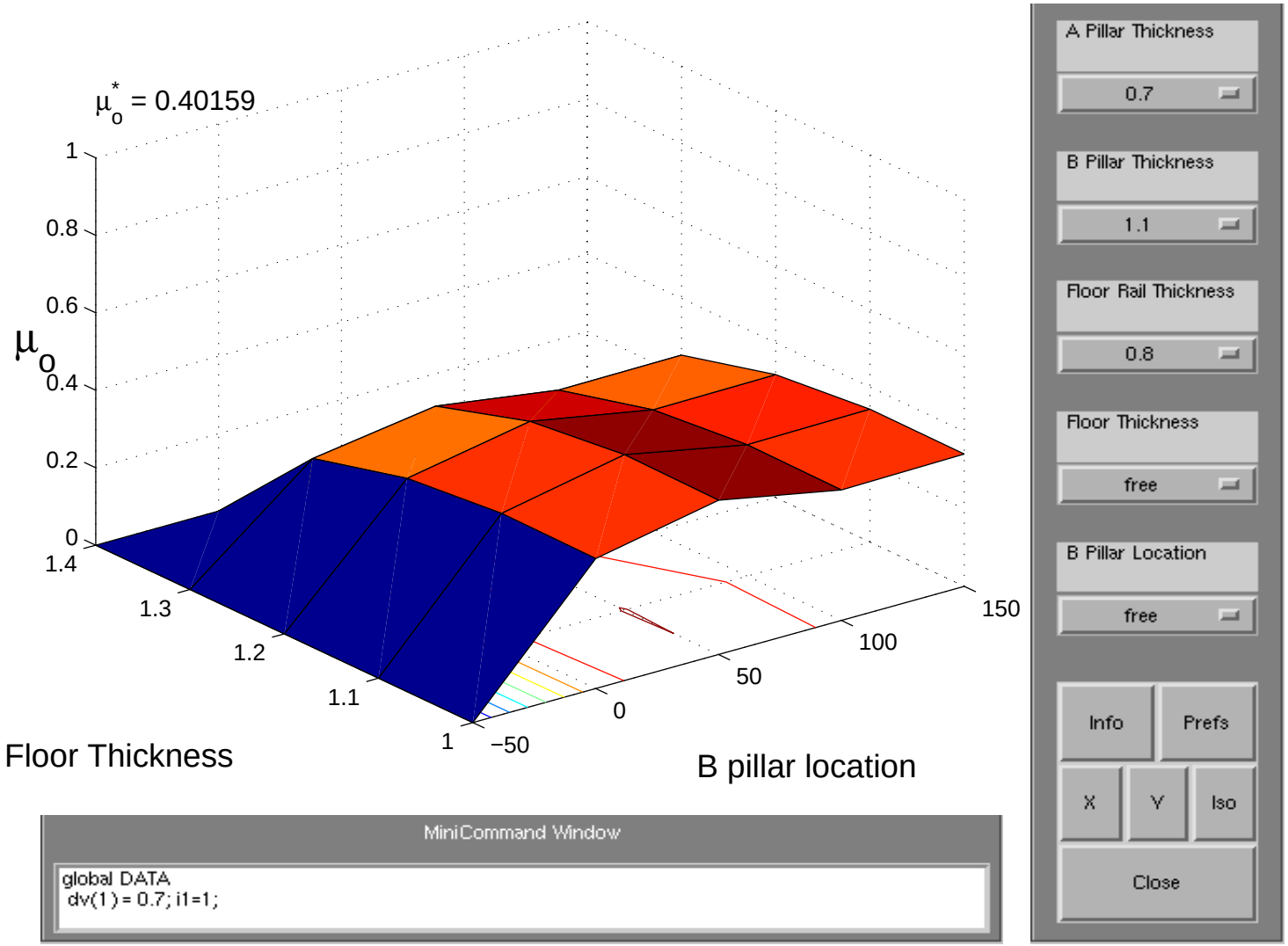
μo selected = 0.384
design preferences
μo
A pillar thickness
B pillar thickness
Floor sill thickness
Floor pan thickness
B pillar location
A Pillar
1.0
B Pillar
0.9
Floor Sill
0.9
Floor pan
1.2
B Pillar Location
50
Reload
Info
Prefs
Close


μmax achievable = 0.440
μo selected = 0.394
design preferences
μo
A pillar thickness
B pillar thickness
Floor sill thickness
Floor pan thickness
B pillar location
A Pillar
0.8
B Pillar
0.9
Floor Sill
0.9
Floor pan
1.2
B Pillar Location
50
Reload
Info
Prefs
Close

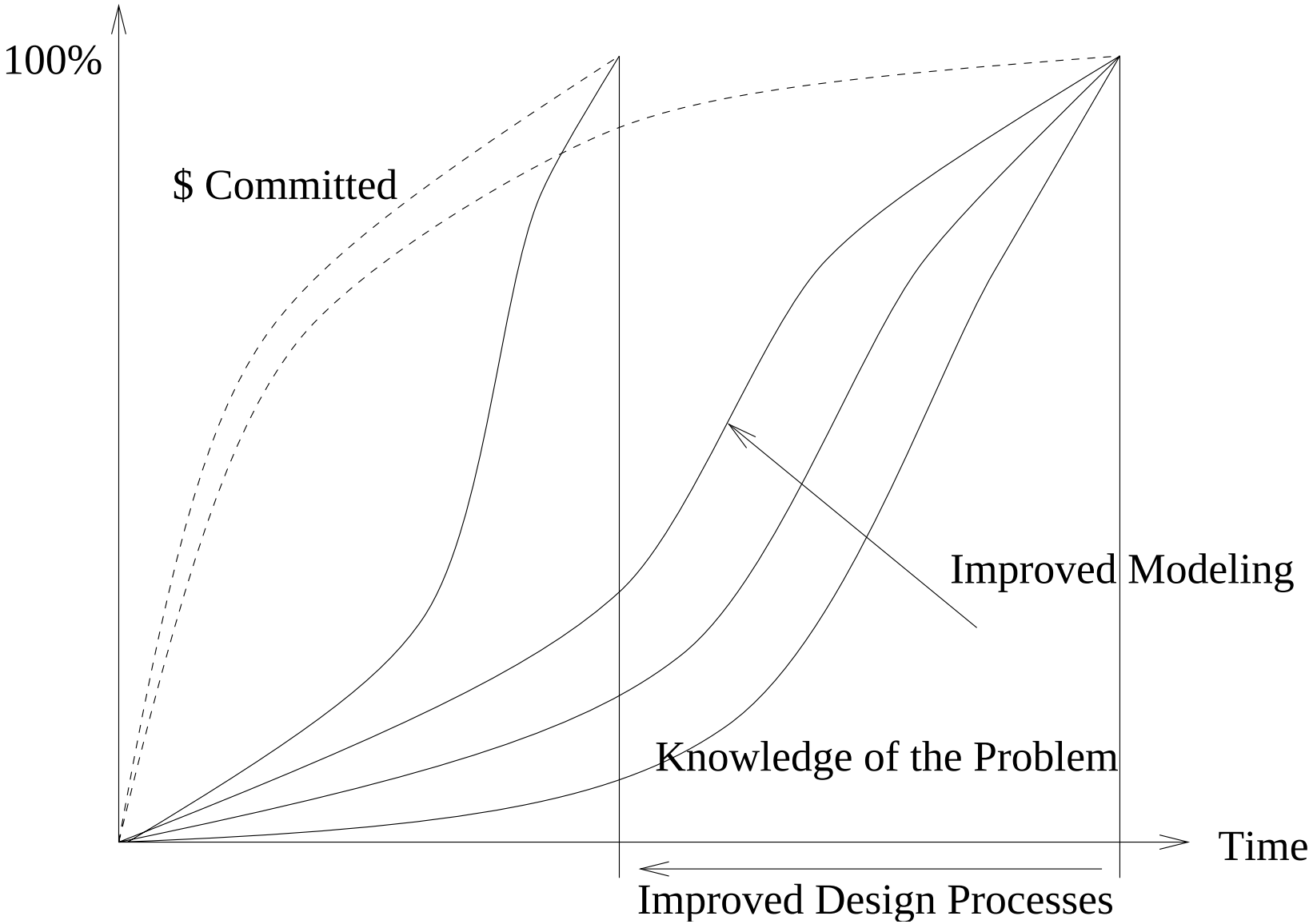

μmax achievable = 0.440
μo selected = 0.440
design preferences
μo
A pillar thickness
B pillar thickness
Floor sill thickness
Floor pan thickness
B pillar location
A Pillar
1.0
B Pillar
0.9
Floor Sill
0.9
Floor pan
1.0
B Pillar Location
50
Reload
Info
Prefs
Close

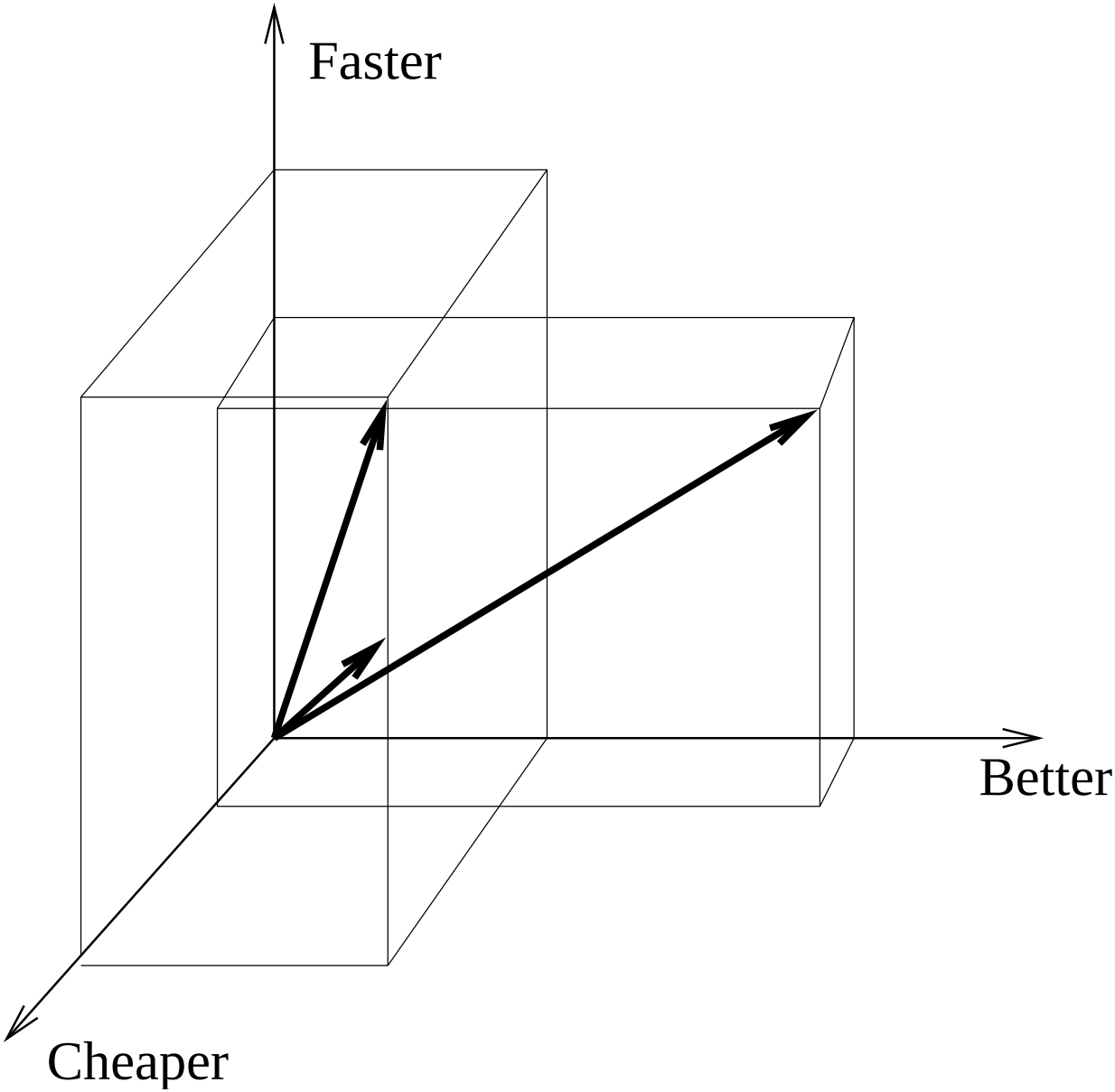
Current Related Work at Caltech

Rapid Exploration of a Large Design Space



Sobieski Paradox (1988)




Faster
Better
Cheaper