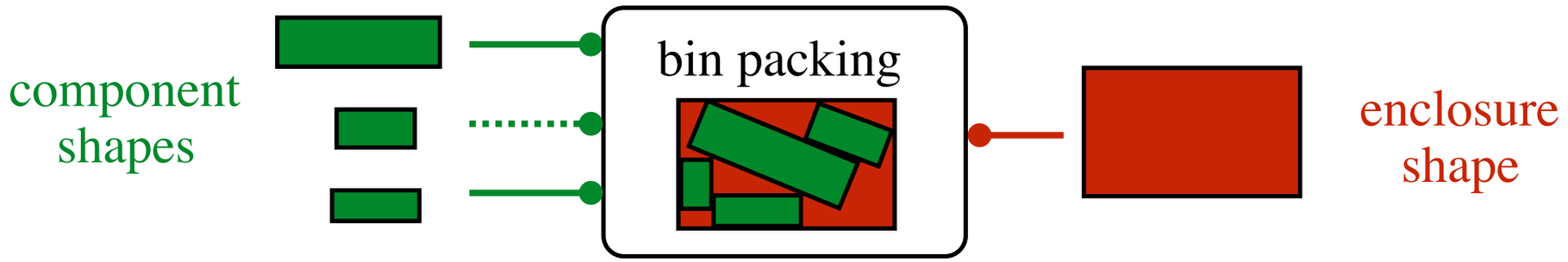
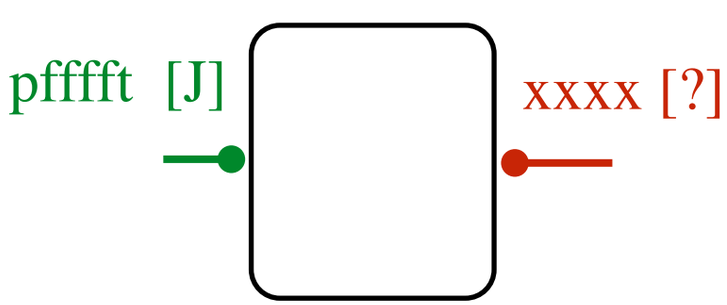
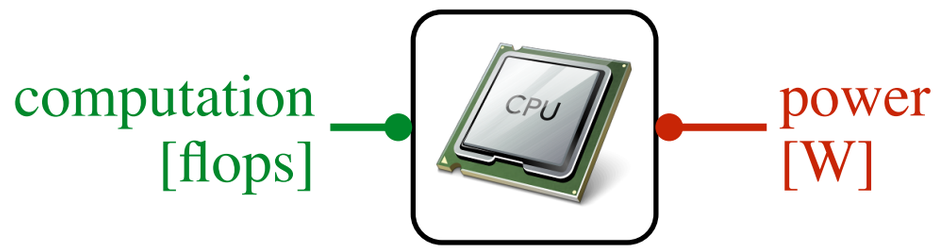
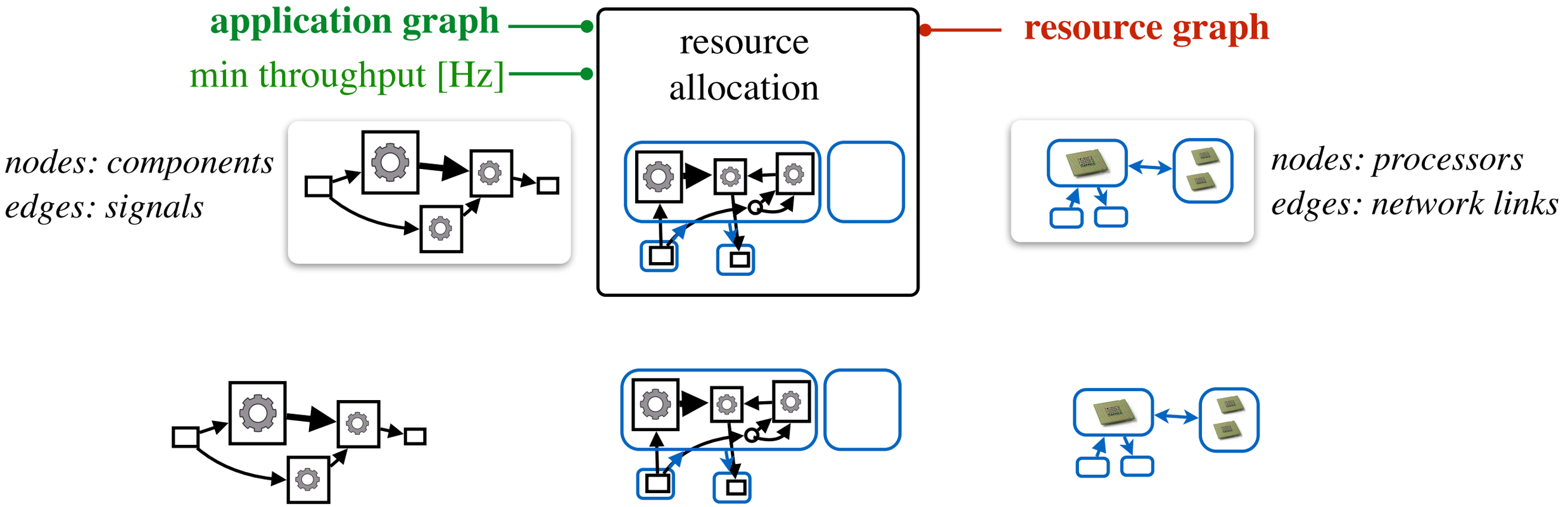
$(\mathbb{R}^3_+)^n$ $\mathbb{R}^3_+$



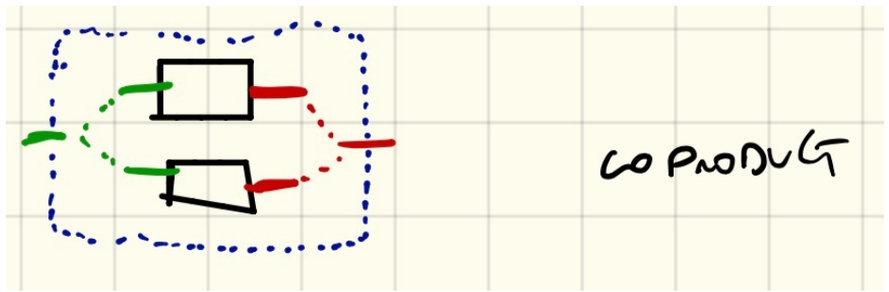


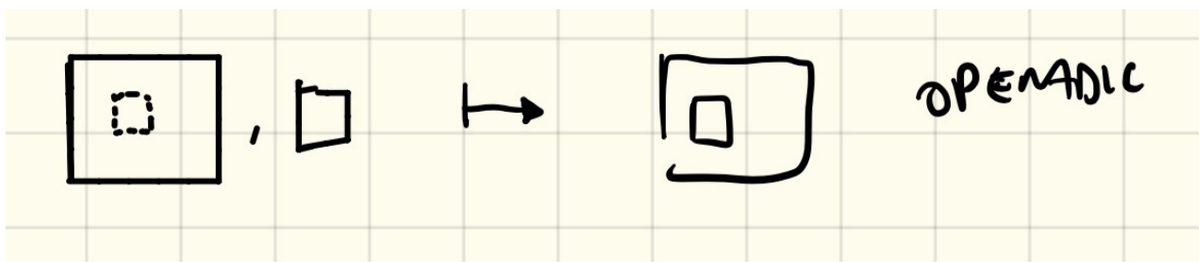


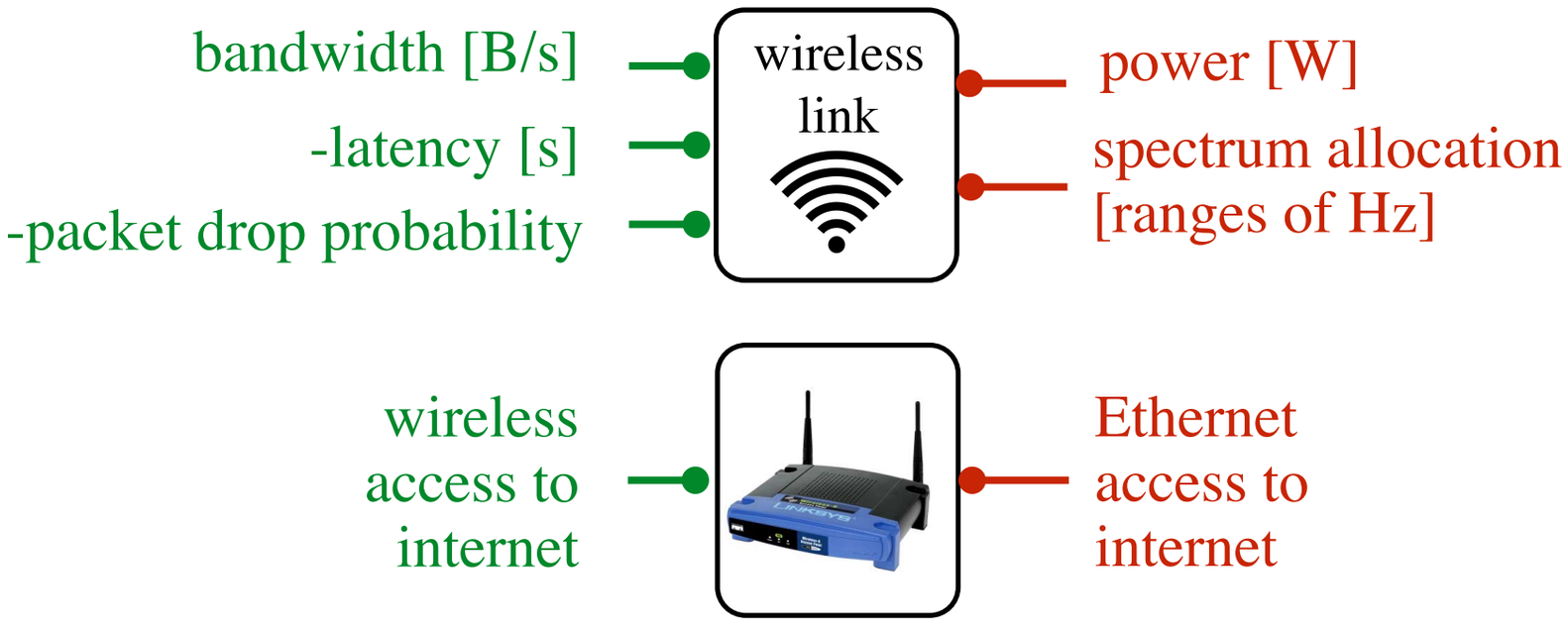



PAIRING

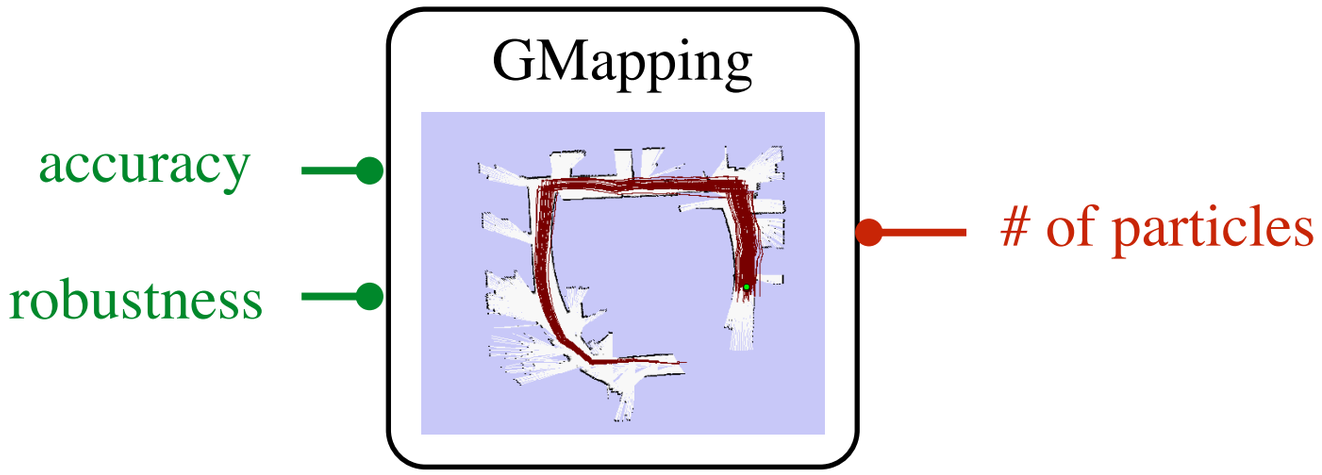

SERRES

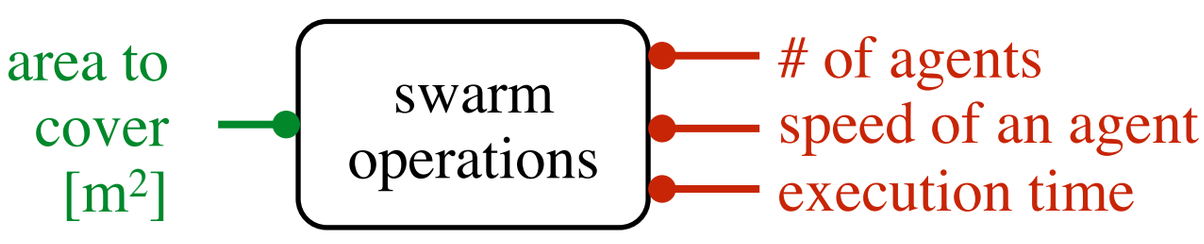

COPRODUCT

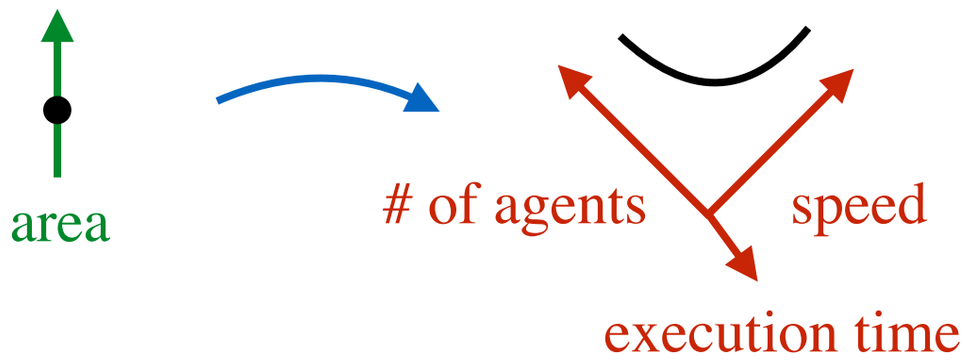

OPERADIC

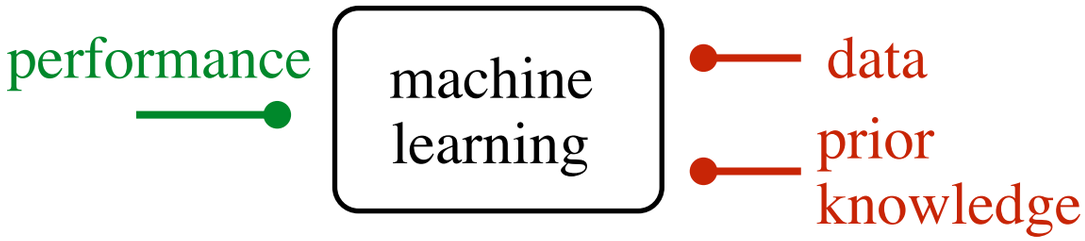

bandwidth [B/s]
-latency [s]
-packet drop probability
wireless link
power [W]
spectrum allocation [ranges of Hz]
wireless access to internet
Ethernet access to internet

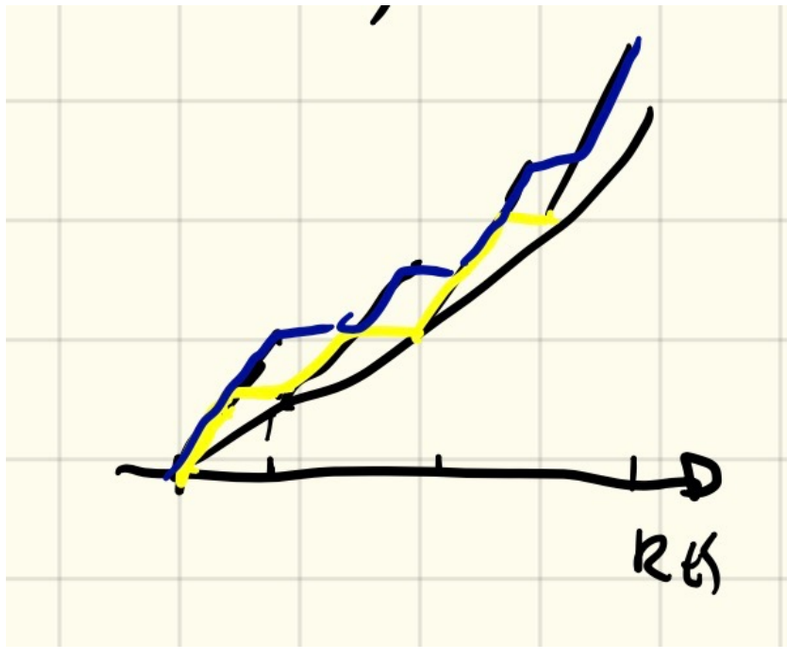
- failure probability

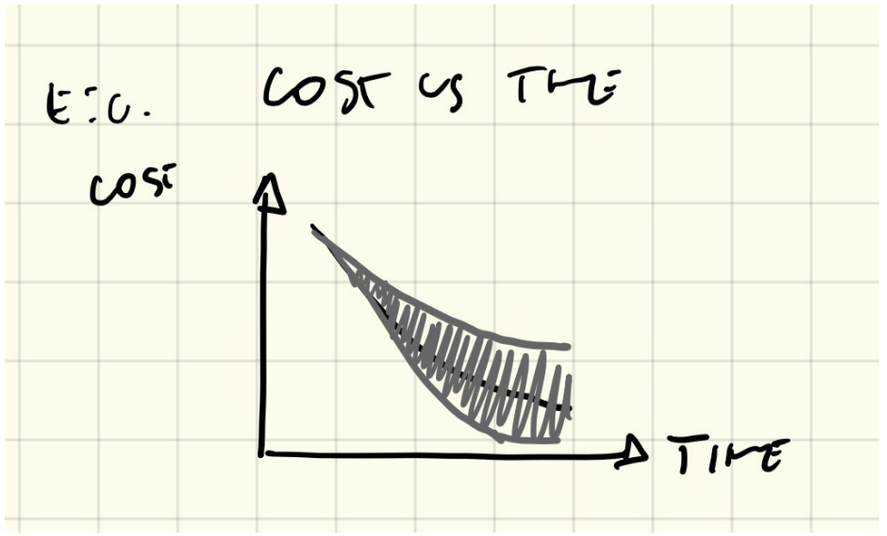










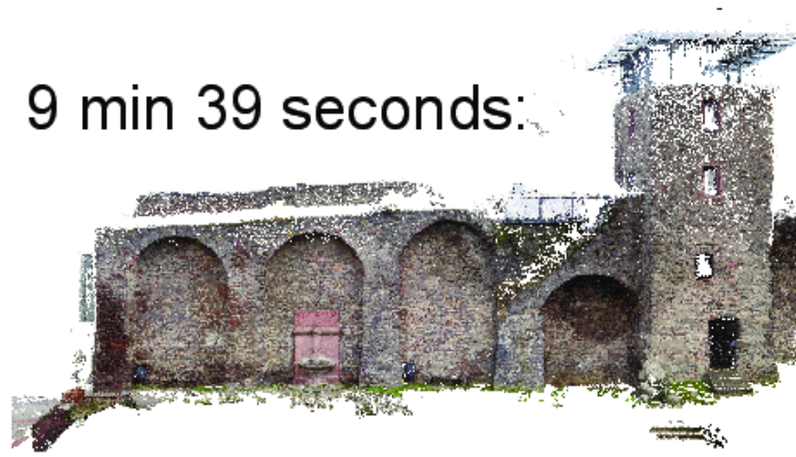


REALITY	REAL EXPERIMENTS	SIMULATION	SIMULATION LOW-FI	MODEL

2 seconds:

56 seconds:

9 min 39 seconds:



resolution

progressive stereo

latency [s]

[1] Alex Locher, Michal Perdoch and Luc Van Gool. Progressive prioritized multi-view stereo. CVPR 2016.

voxel size

```
@article{locher16,
title={Progressive Prioritized Multi-view Stereo},
author={Locher, Alex and Perdoch, Michal and Van Gool, Luc},
journal={CVPR},
year={2016}
}
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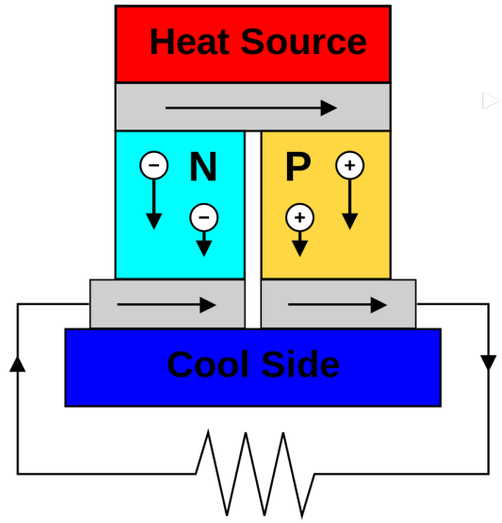
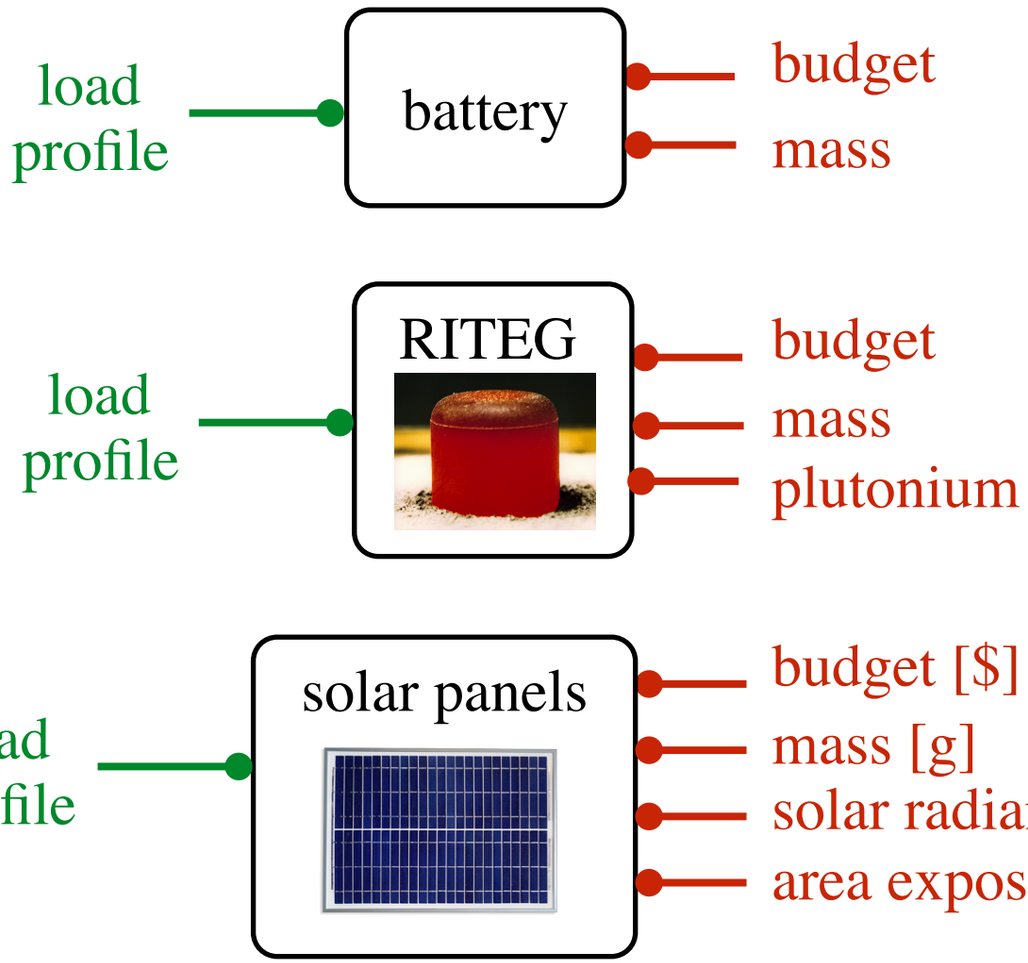
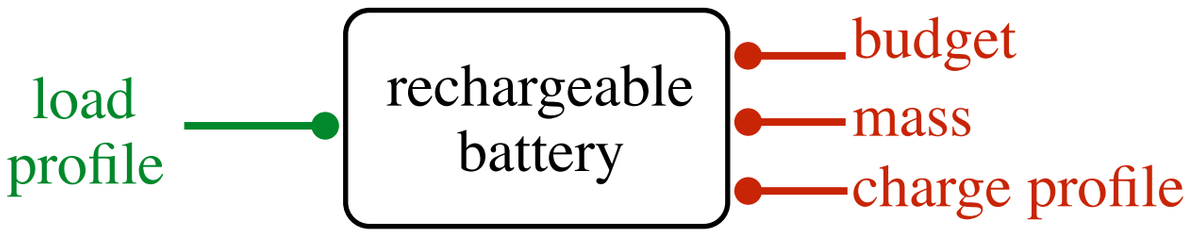
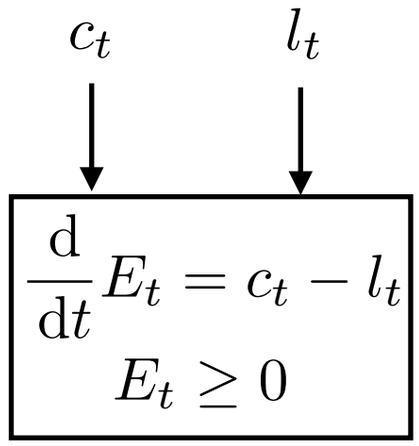
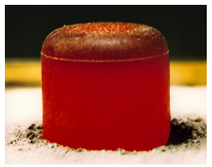

Heat Source
N
P
Cool Side


load profile
battery
budget
mass
load profile
RITEG
budget
mass
plutonium
load profile
solar panels
budget [$]
mass [g]
solar radiance [lux]
area exposed [m^2]


load profile
rechargeable battery
budget
mass
charge profile


c_t
l_t
$\frac{\mathrm{d}}{\mathrm{d}t} E_t = c_t - l_t$
$E_t \geq 0$

heating



plutonium

power

thermocouple

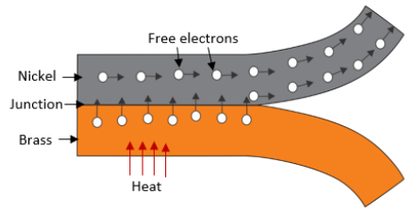
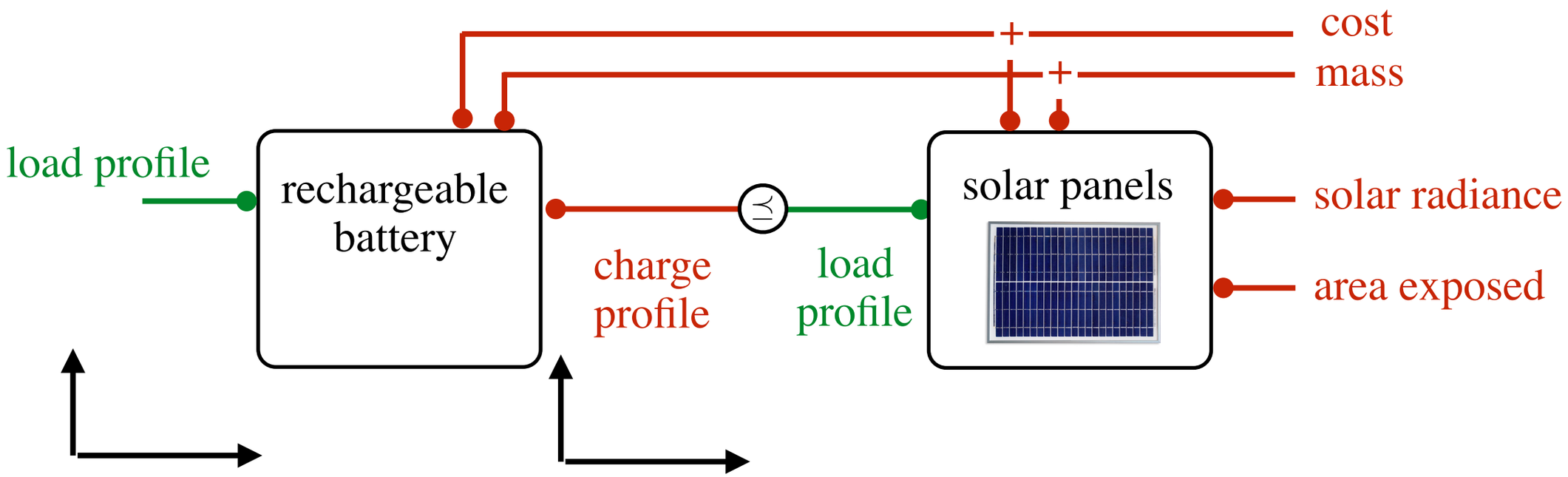
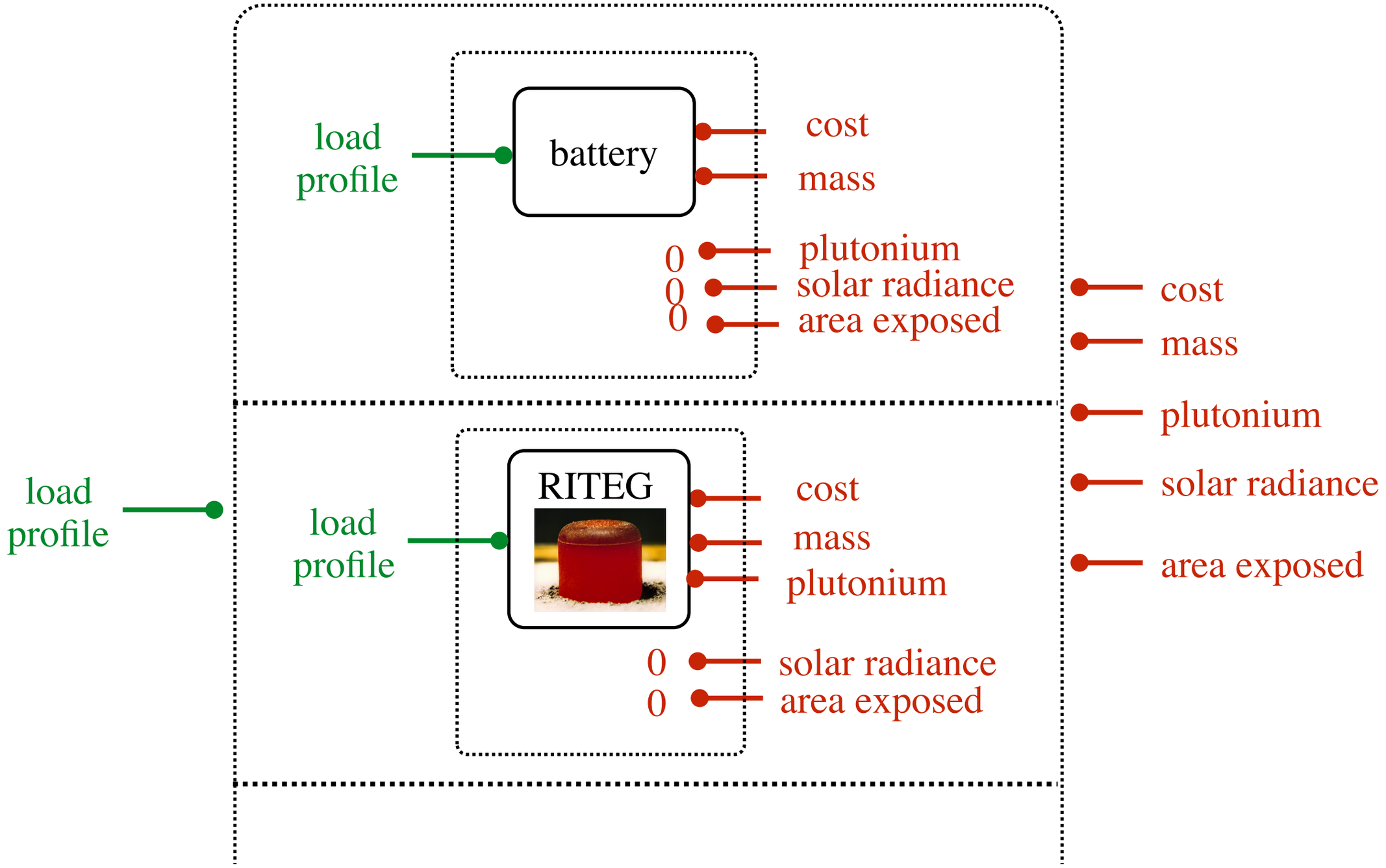


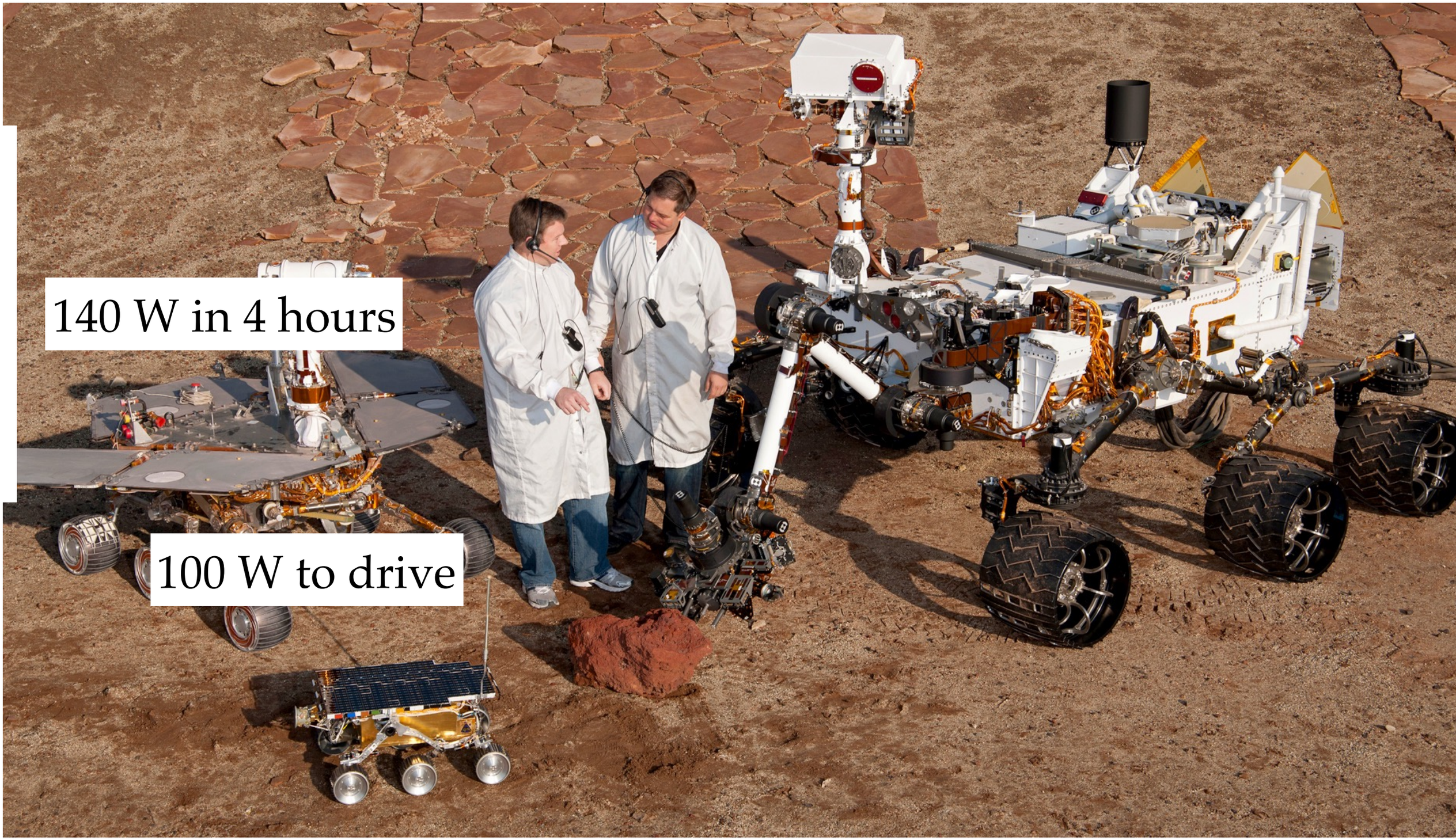
Fig 5.6.1

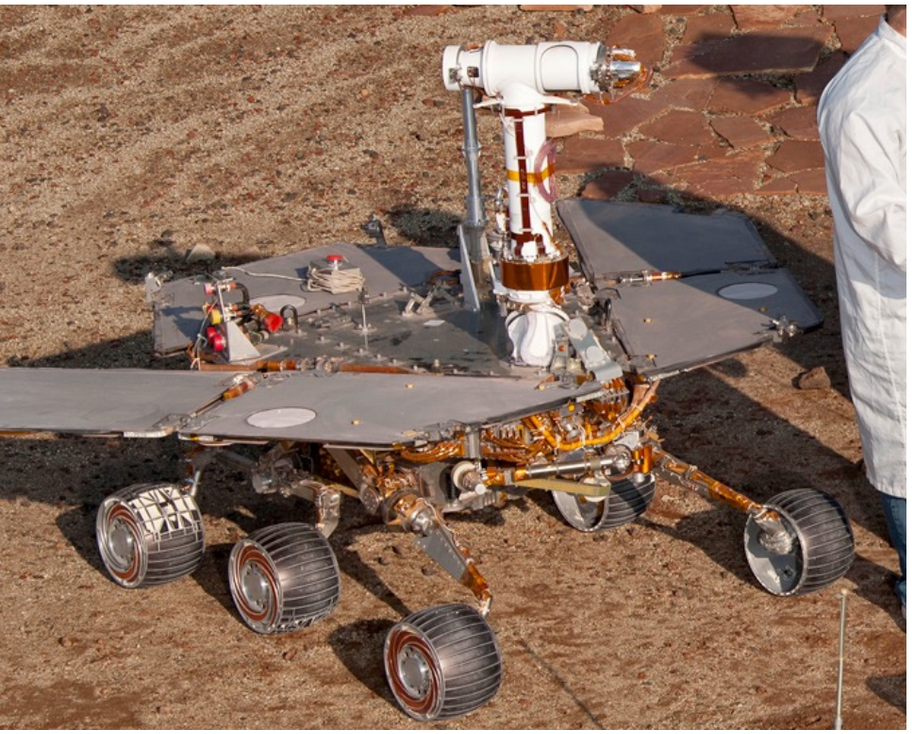
heat

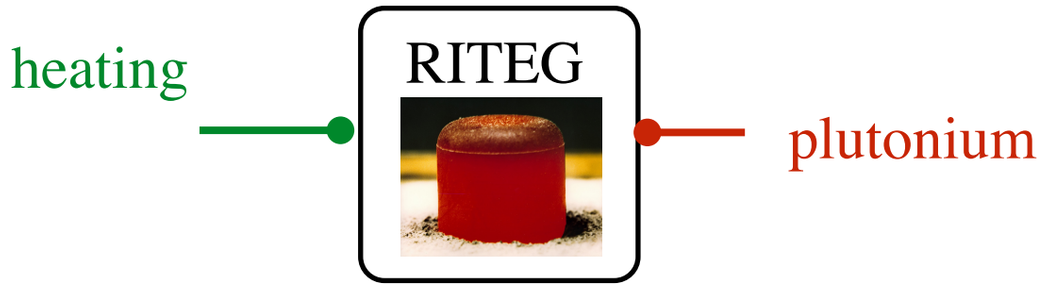

cost
mass
load profile
rechargeable battery
charge profile
load profile
solar panels
solar radiance
area exposed


load profile
battery
cost
mass
0
plutonium
0
solar radiance
0
area exposed
cost
mass
plutonium
solar radiance
area exposed
load profile
load profile
RITEG
cost
mass
plutonium
0
solar radiance
0
area exposed

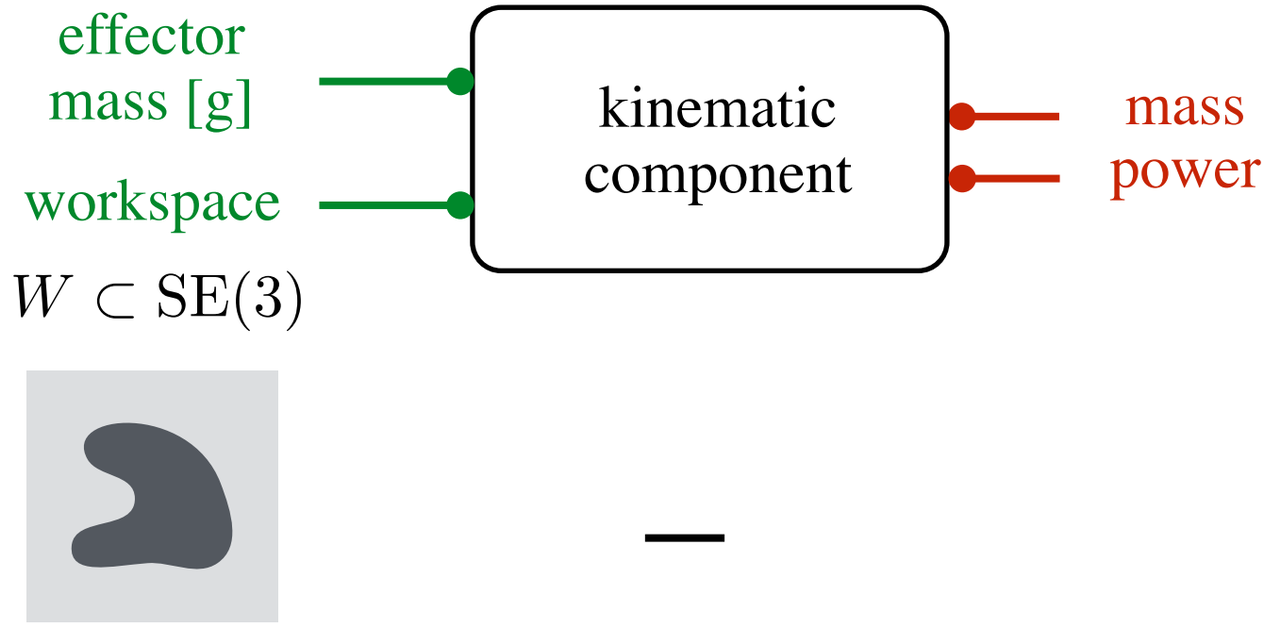
er

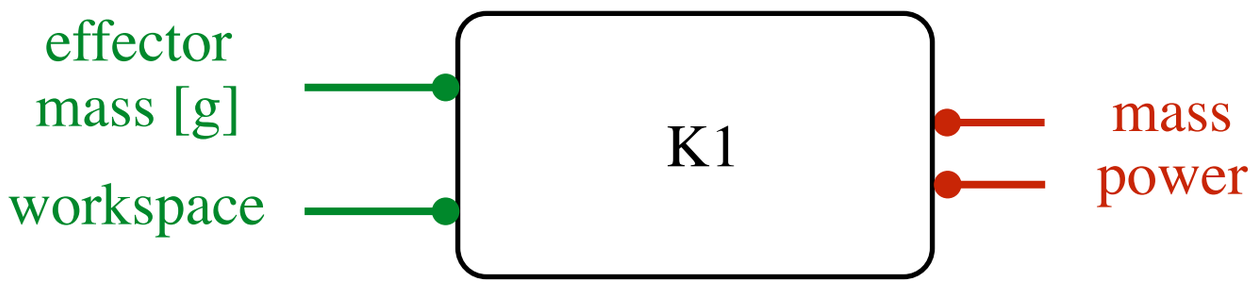


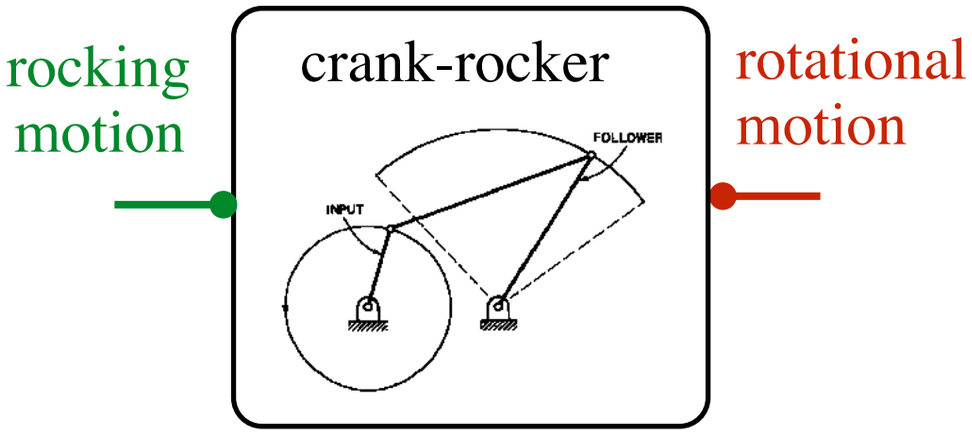


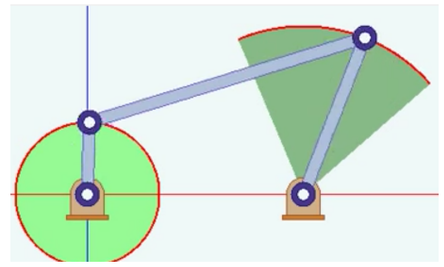

heating
RITEG
plutonium

When fully illuminated, the rover triplejunction[46] solar arrays generate about 140 watts for up to four hours per Martian day (sol). The rover needs about 100 watts to drive. Its power system includes two rechargeable lithium ion batteries weighing 7.15 kg (16 pounds) each, that provide energy when the sun is not shining, especially at night. Over time, the batteries will degrade and will not be able to recharge to full capacity.
For comparison, the Mars Science Laboratory's power system is composed of a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) produced by Boeing.[47] The MMRTG is designed to provide 125W of electrical power at the start of the mission, falling to 100W after 14 years of service.[48] It is used to power the MSL's many systems and instruments. Solar panels were also considered for the MSL, but RTGs provide constant power, regardless of the time of day, and thus the versatility to work in dark environments and high latitudes where solar energy is not readily available. The MSL generates 2.5 kilowatt hours per day, compared to the Mars Exploration Rovers, which can generate about 0.6 kilowatt hours per day.[49]

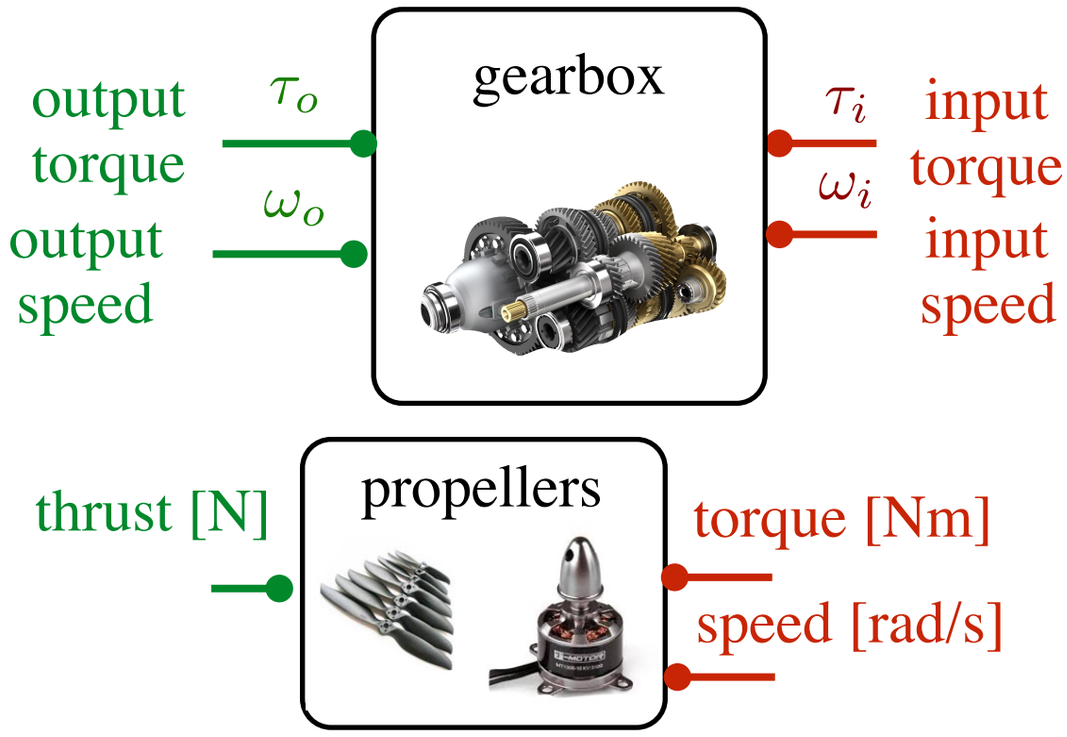

effector
mass [g]
workspace
$W \subset \mathrm{SE}(3)$
kinematic
component
mass
power


effector
mass [g]
workspace
K1
mass
power

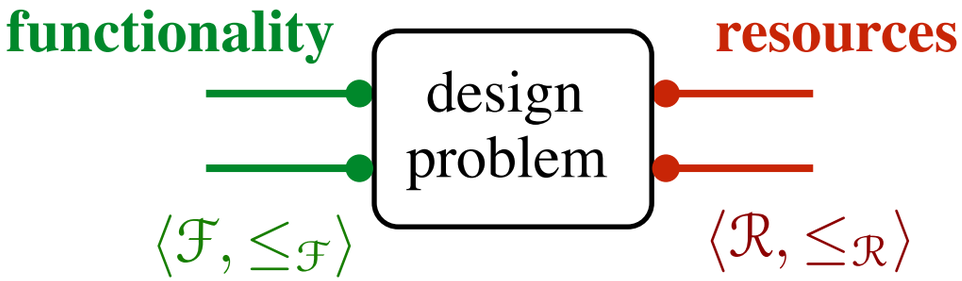


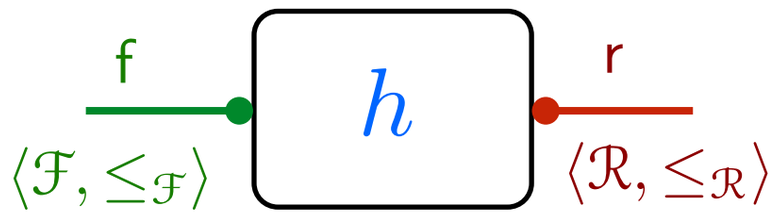


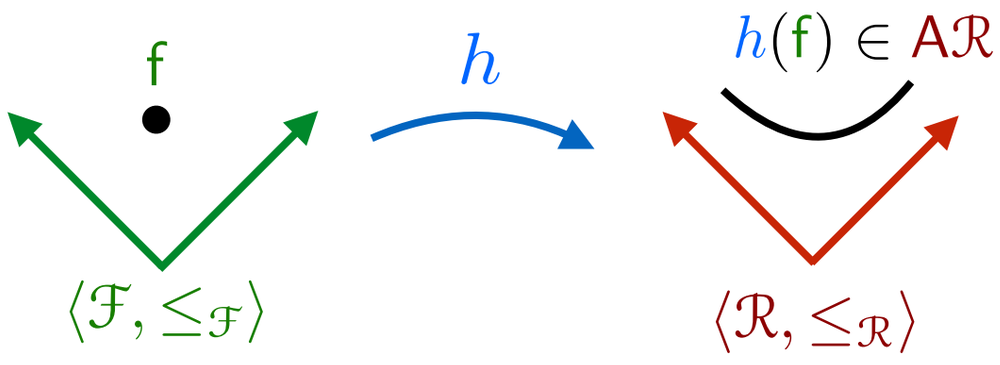
Ham et al. 58) Ham, C. W., Crank E. J. and Rogers W. L., Mechanics of Machinery, McGraw-Hill, 1958.



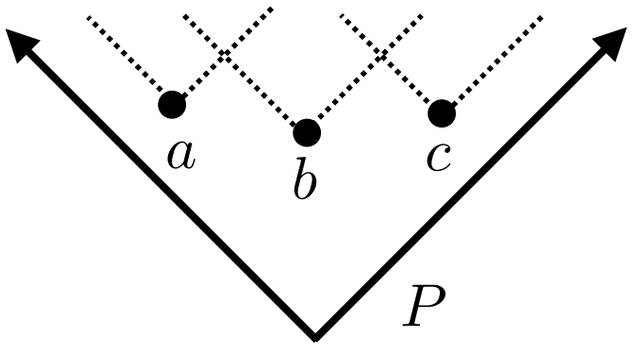
$h(\mathsf{f}_2) \succeq_{\mathsf{AR}} h(\mathsf{f}_1)$

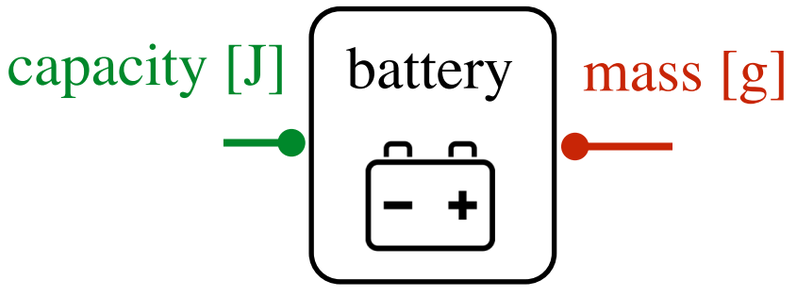

functionality
resources
design problem
$\langle \mathcal{F}, \leq_{\mathcal{F}} \rangle$
$\langle \mathcal{R}, \leq_{\mathcal{R}} \rangle$

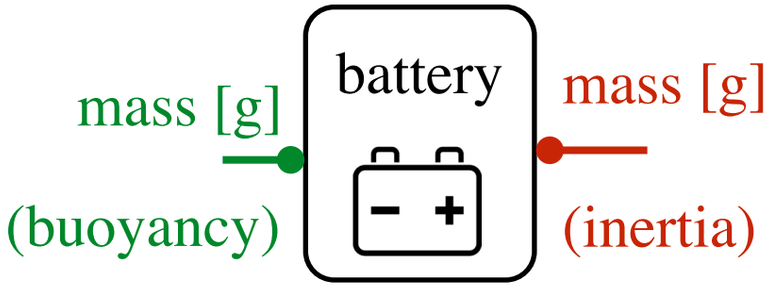

f
h
r
$\langle \mathcal{F}, \leq_{\mathcal{F}} \rangle$
$\langle \mathcal{R}, \leq_{\mathcal{R}} \rangle$

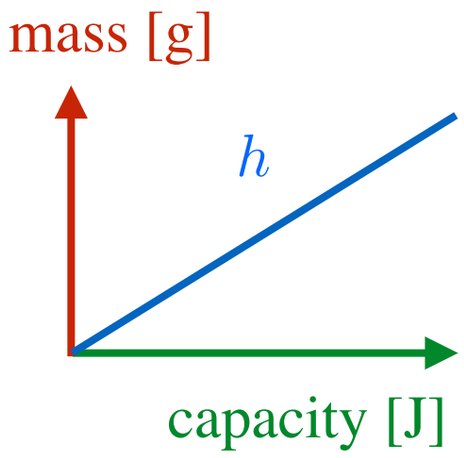

f
h
$h(\mathsf{f}) \in \mathsf{A}\mathcal{R}$
$\langle \mathcal{F}, \leq_{\mathcal{F}} \rangle$
$\langle \mathcal{R}, \leq_{\mathcal{R}} \rangle$

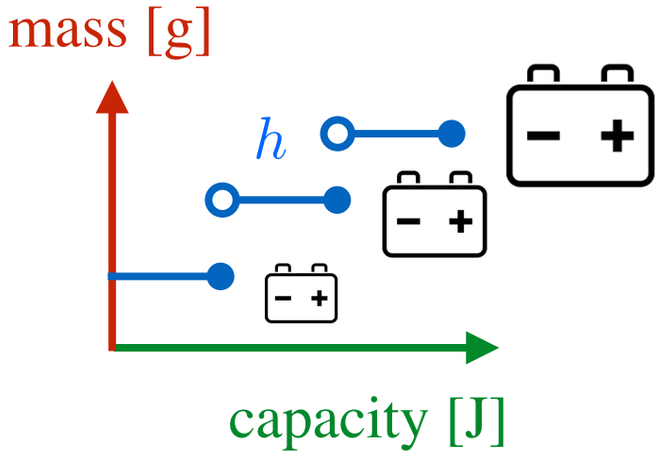

$\mathsf{f}_2 \succeq \mathsf{f}_1$
f_1

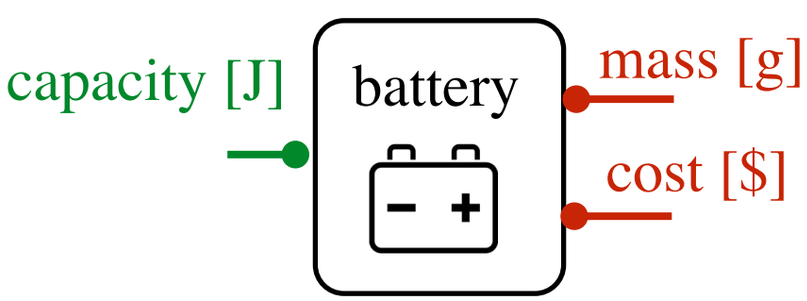

a
b
c
P

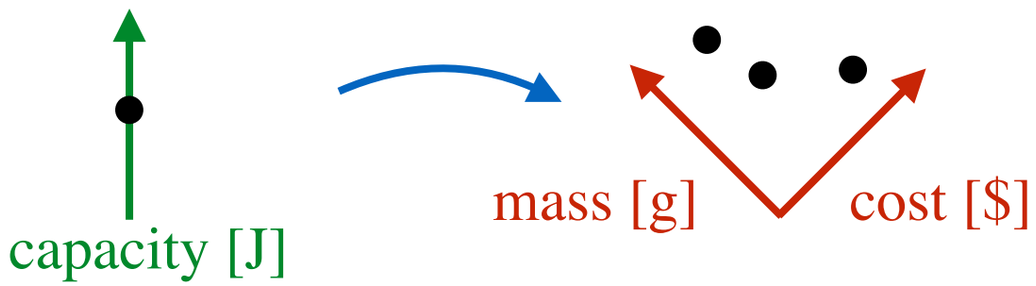

capacity [J]
battery
mass [g]

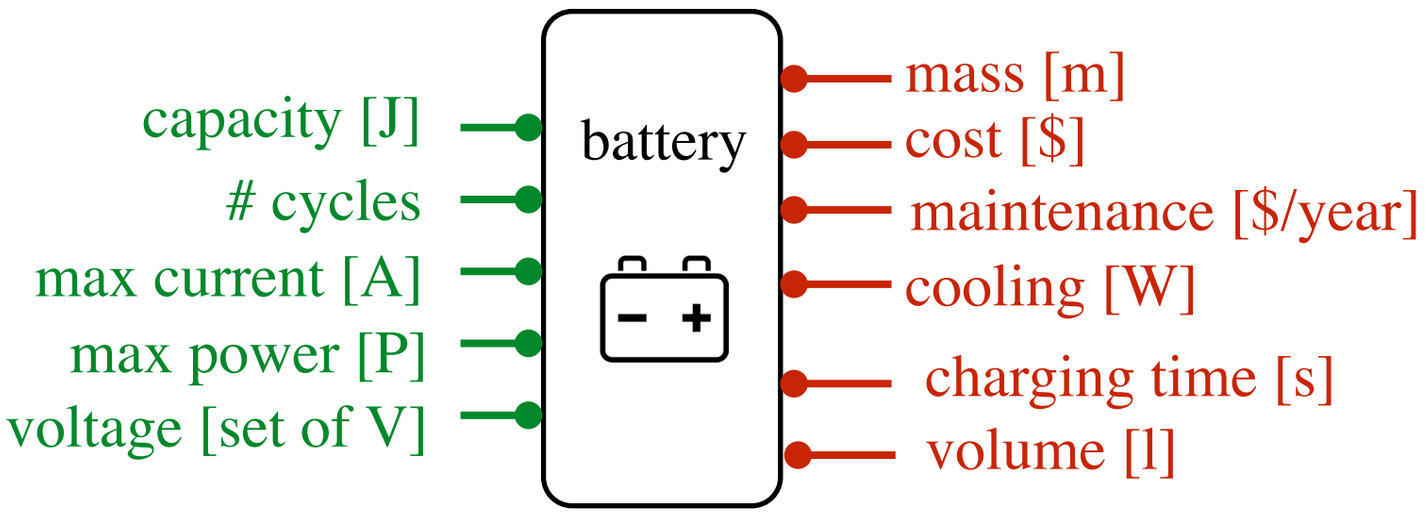

mass [g]
(buoyancy)
battery
mass [g]
(inertia)


mass [g]
h
capacity [J]


mass [g]
h
capacity [J]


capacity [J]
battery
mass [g]
cost [$]


capacity [J]
mass [g]
cost [$]


capacity [J]
cycles
max current [A]
max power [P]
voltage [set of V]
battery
mass [m]
cost [$]
maintenance [$/year]
cooling [W]
charging time [s]
volume [l]

As an engineer, would it make your life easier if *X* was larger?

no → *X* can be considered a **functionality**

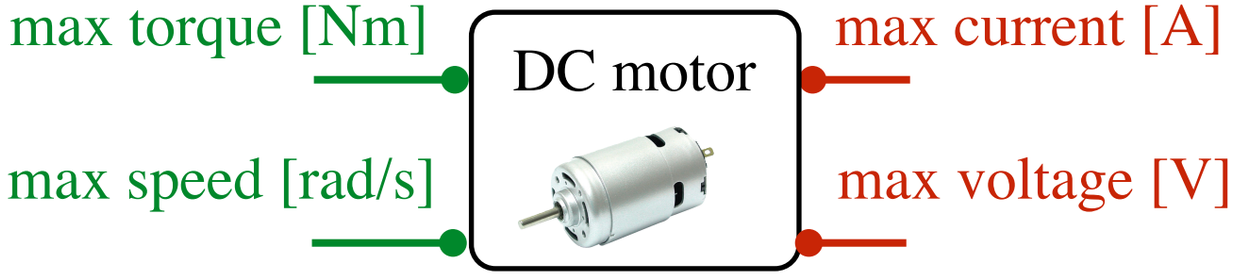
yes → If *X* increases, is there a resource that can decrease?

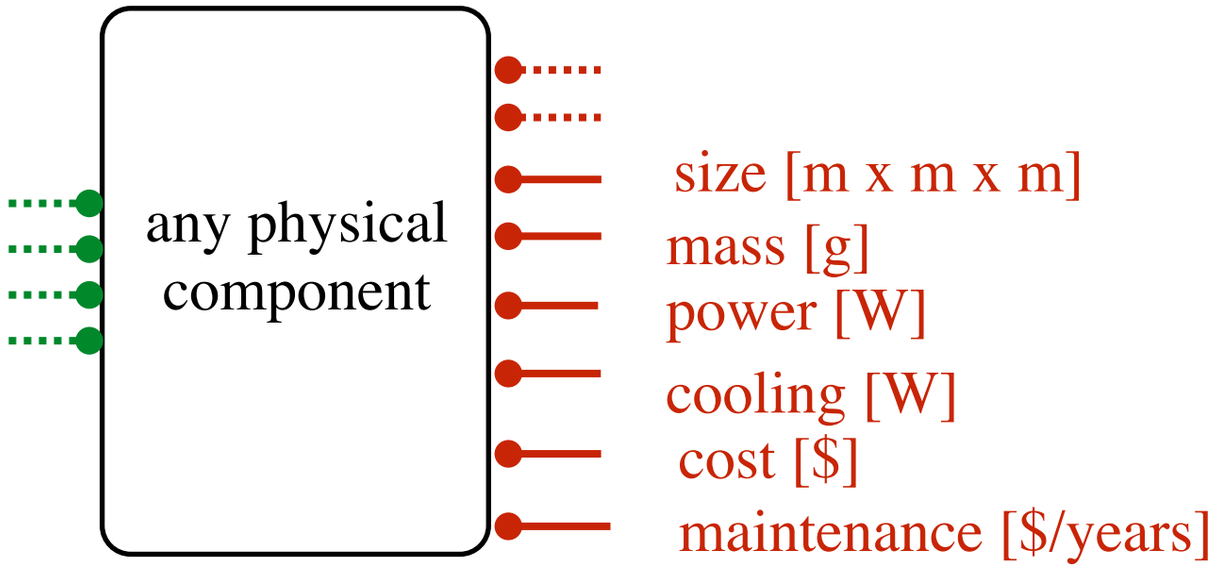
no → *X* can be considered a **functionality**

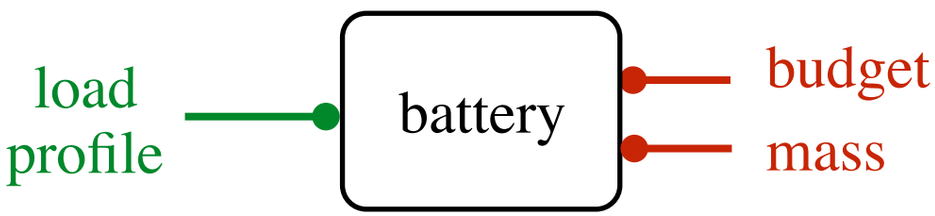
yes → If *X* increases, is there a functionality that can increase?

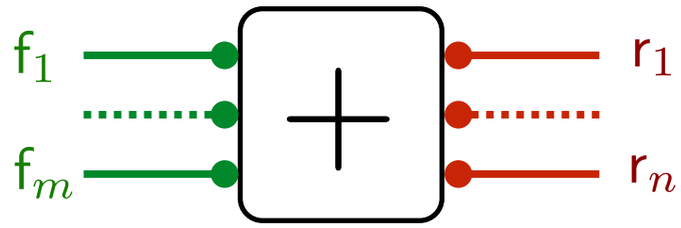
no → *X* can be considered a **functionality**

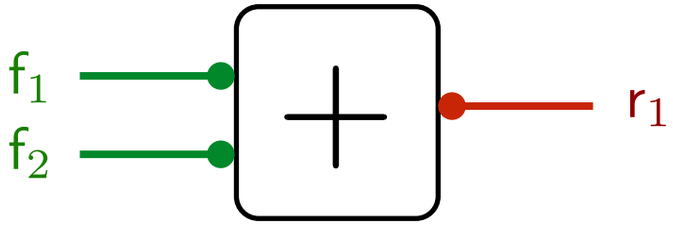
yes → *X* can be considered a **resource**

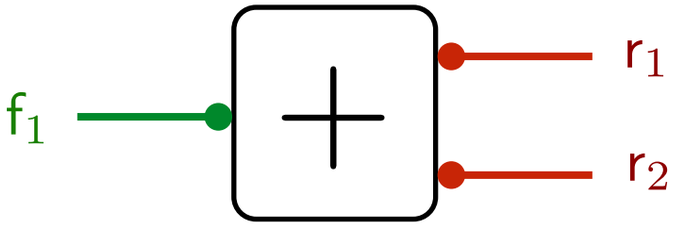

max torque [Nm]
max speed [rad/s]
DC motor
max current [A]
max voltage [V]

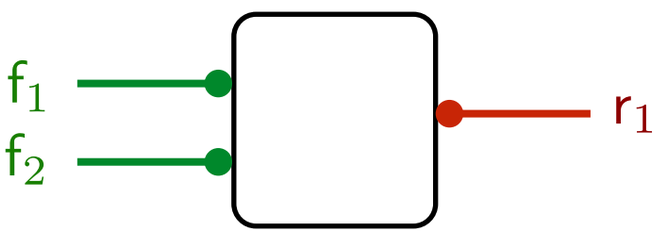

any physical component
size [m x m x m]
mass [g]
power [W]
cooling [W]
cost [$]
maintenance [$/years]

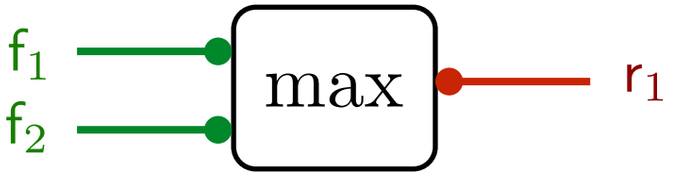

load profile
battery
budget
mass

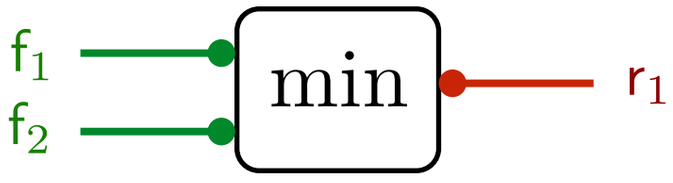

f1
fm
r1
rn

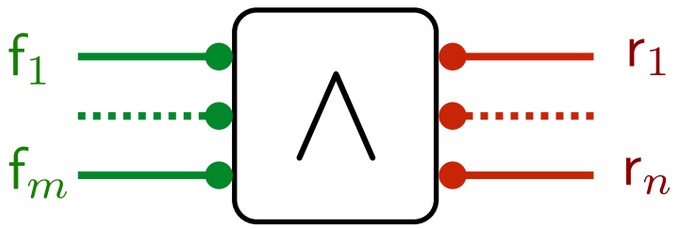

f1
f2
r1

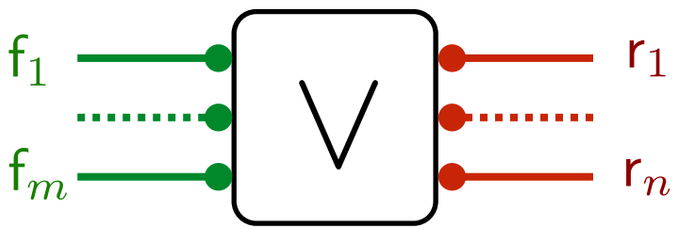

f1
r1
r2

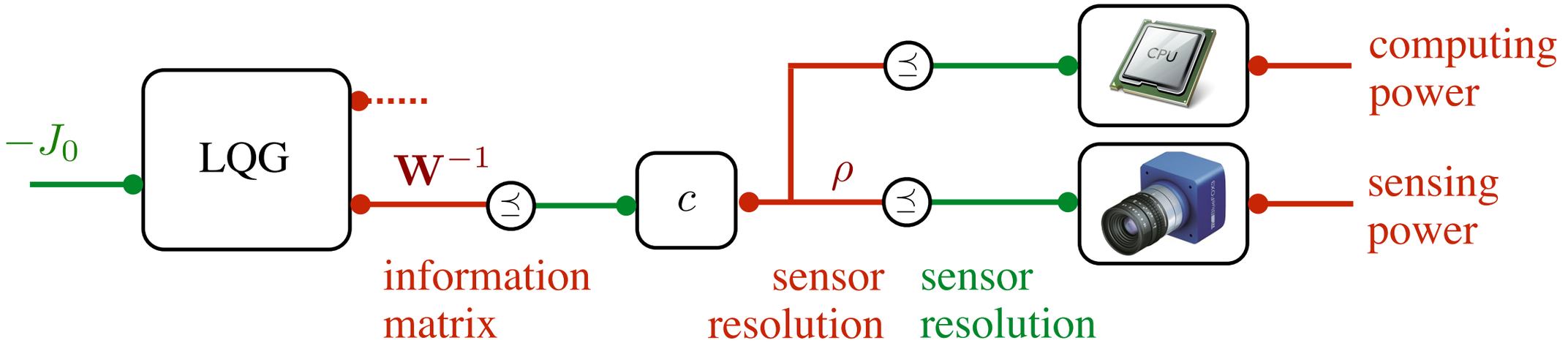

f1
f2
r1


f1
f2
max
r1

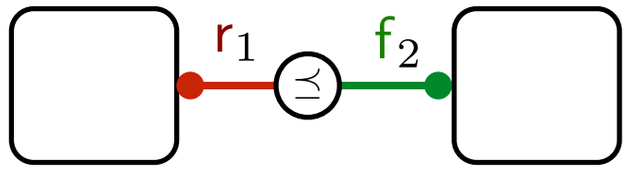

f1
f2
min
r1

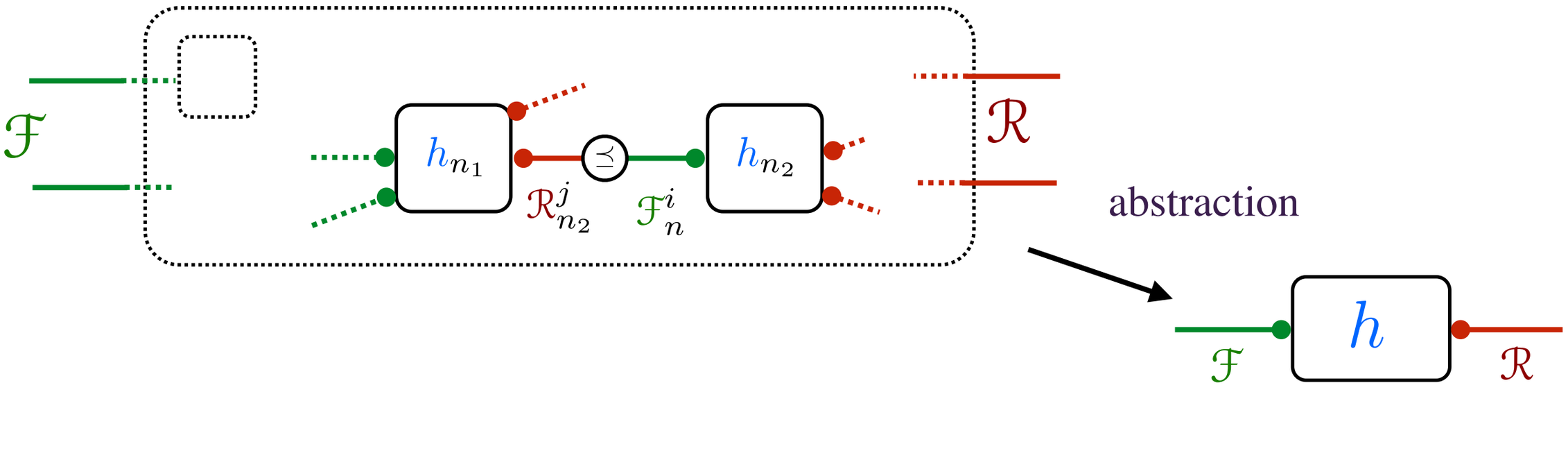

f1
fm
r1
rn

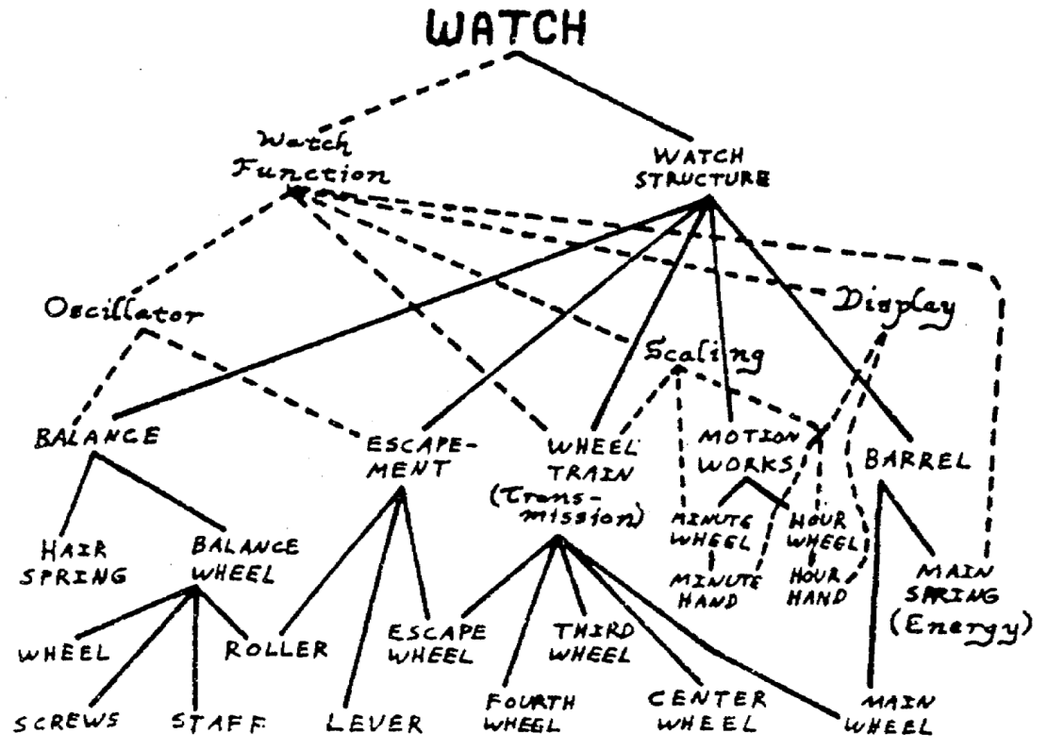

f1
fm
r1
rn

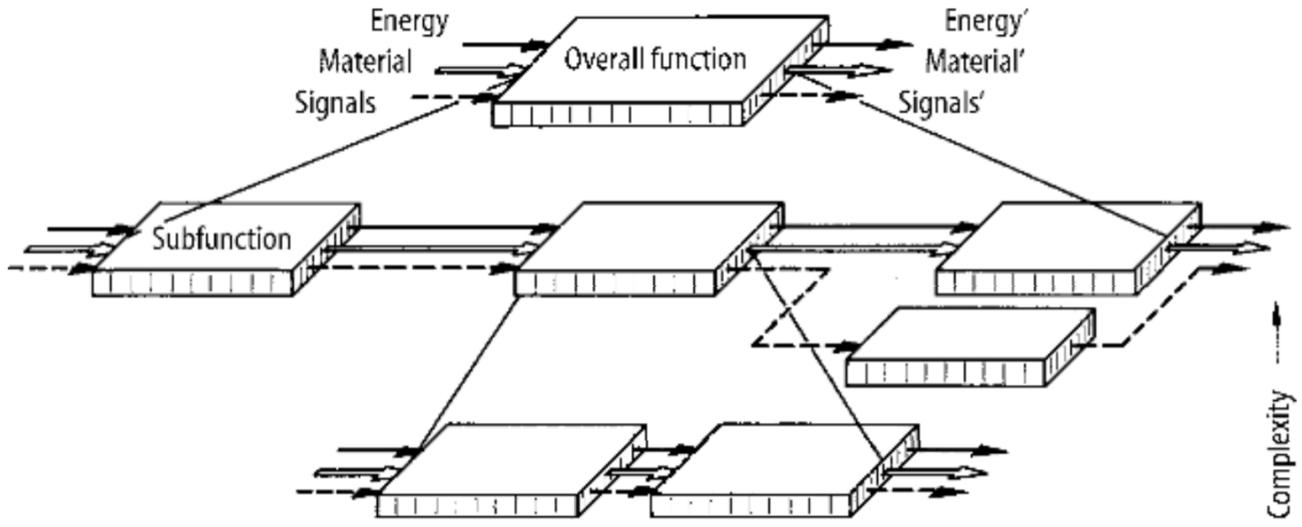

$-J_0$
LQG
$\mathbf{W}^{-1}$
c
ρ
CPU
computing power
sensing power
information matrix
sensor resolution
sensor resolution


$-J_0$
LQG
$\mathbf{V}^{-1}$
$\mathbf{W}^{-1}$

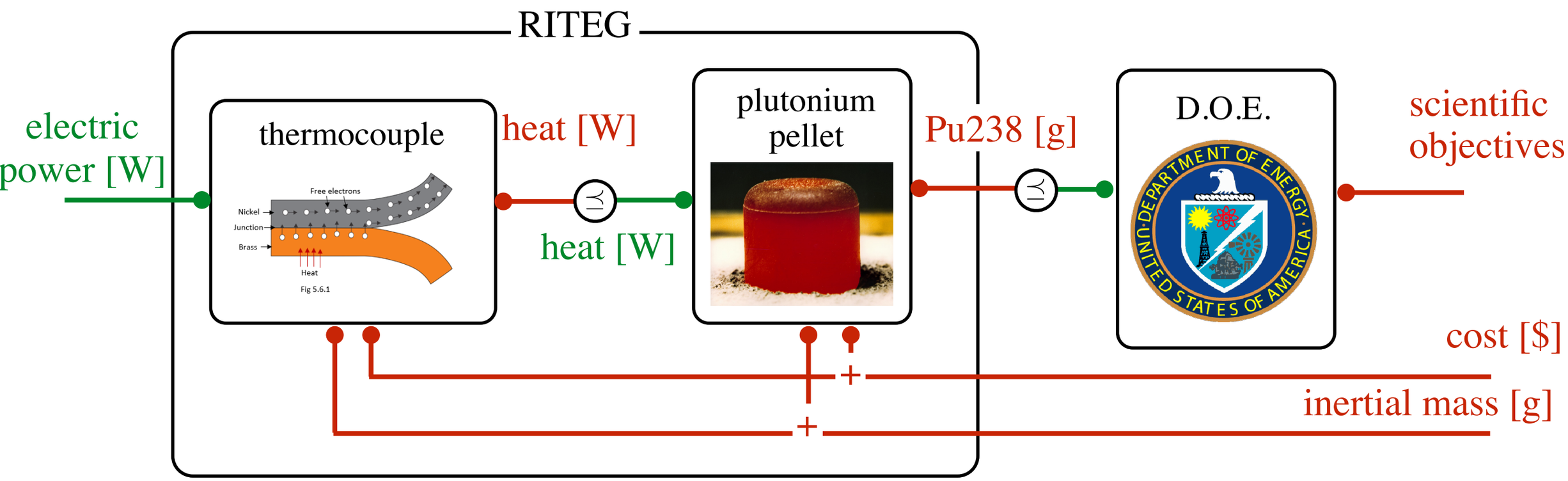

r_1
f_2

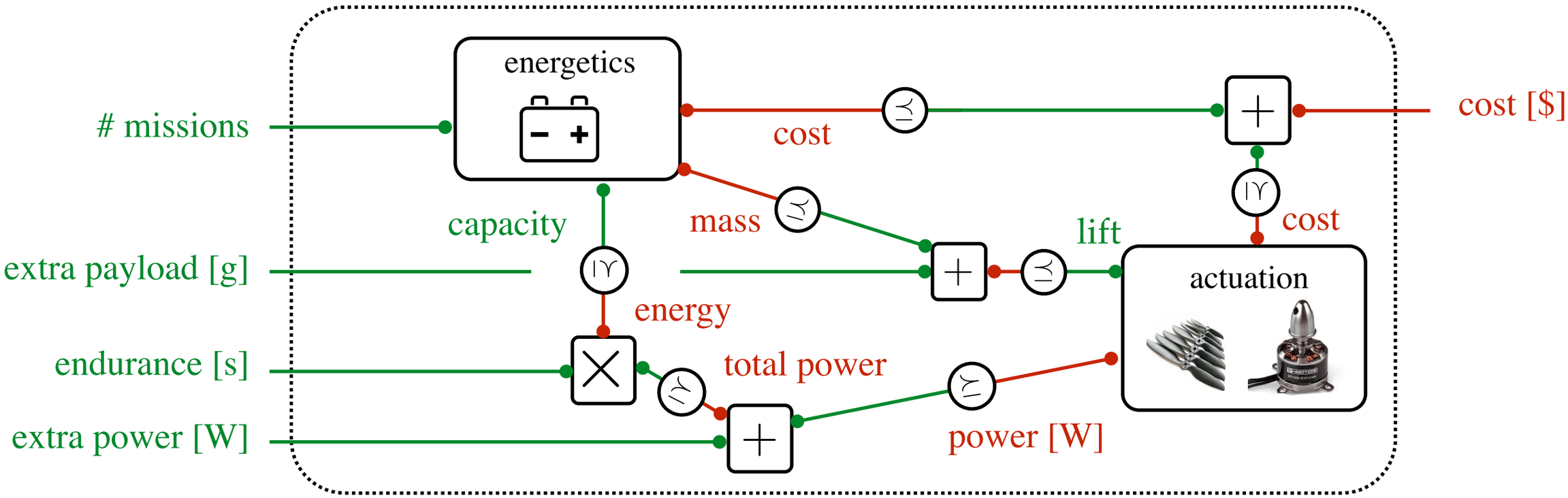

$\mathcal{F}$
h_{n_1}
h_{n_2}
$\mathcal{R}^j_{n_2}$
$\mathcal{F}^i_n$
$\mathcal{R}$
abstraction
$\mathcal{F}$
h
$\mathcal{R}$





{CONSTRAINTS} - {A}
Language for Expressing Almost-
Hierarchical Descriptions},
Author = {Gerald J.
Sussman and
Guy L. Steele Jr.},


RITEG
electric
power [W]
thermocouple
Free electrons
Nickel
Junction
Brass
Heat
Fig 5.6.1
heat [W]
heat [W]
plutonium
pellet
Pu238 [g]
D.O.E.
DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA
scientific
objectives
cost [$]
+
inertial mass [g]
+

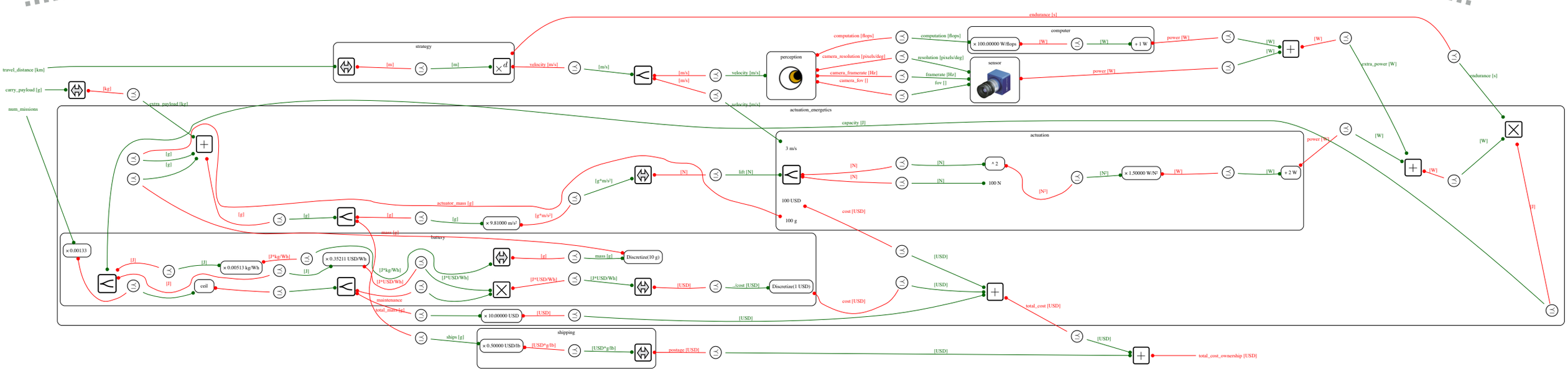

energetics
missions
cost
cost [$]
capacity
mass
lift
cost
extra payload [g]
actuation
energy
endurance [s]
total power
extra power [W]
power [W]

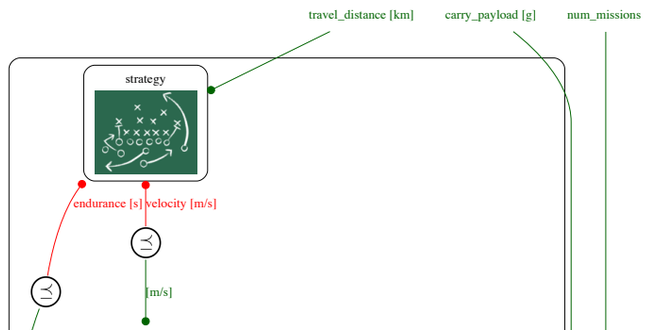
travel distance [m]

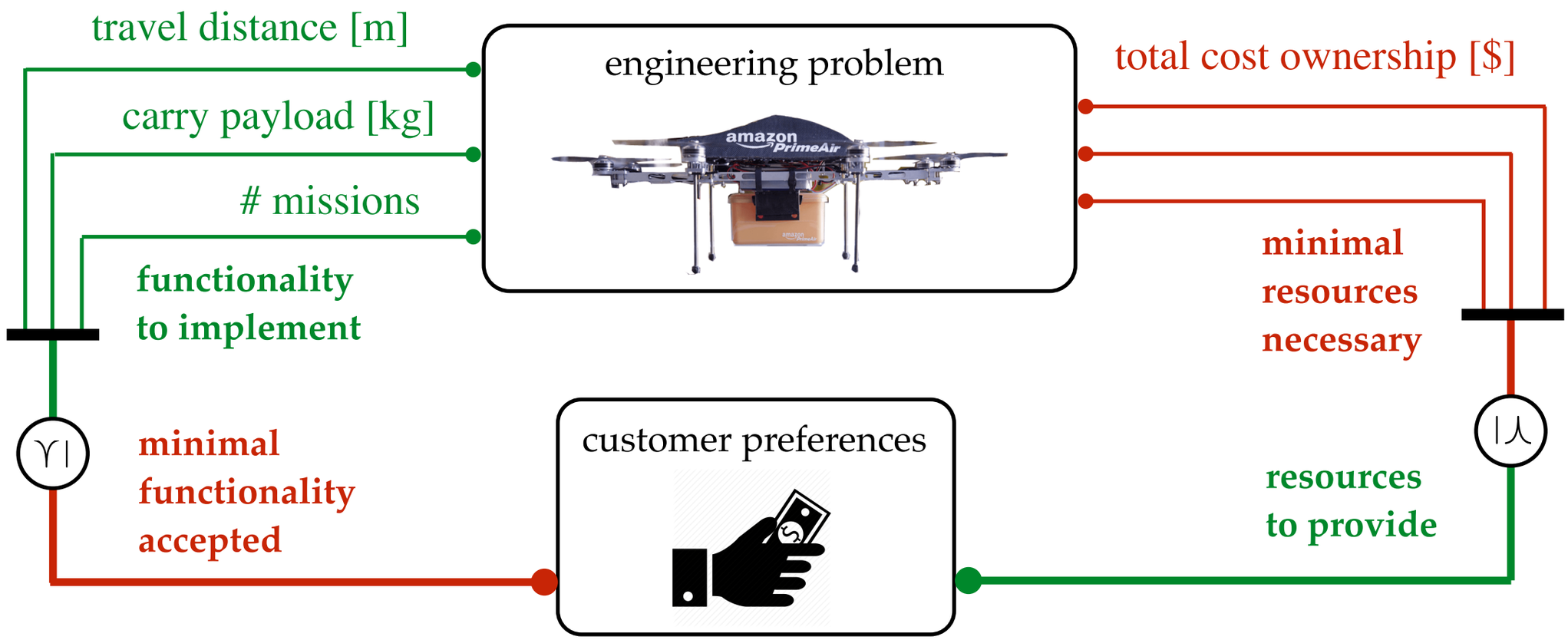
carry payload [kg]

# of missions

total cost ownership [$]






travel distance [m]
carry payload [kg]
missions
functionality
to implement
engineering problem
amazon PrimeAir
total cost ownership [$]
minimal
resources
necessary
٢١
minimal
functionality
accepted
customer preferences
١٨
resources
to provide