How good is your embedded design, if at all?

Holger Hermanns

dependable systems and software

Saarland University

Saarbrücken, Germany


ANKER


GTI
WOB-ED 42


WINORA


Husqvarna
VIKING
01


PHILIPS
Saeco


Golf

The German Energy Turn-Around

Renewables are on the rise!

- In Germany … and elsewhere
- On residential rooftops.

1999: 0.07 GW **2009: 10.6 GW** **2019: 49.0 GW**

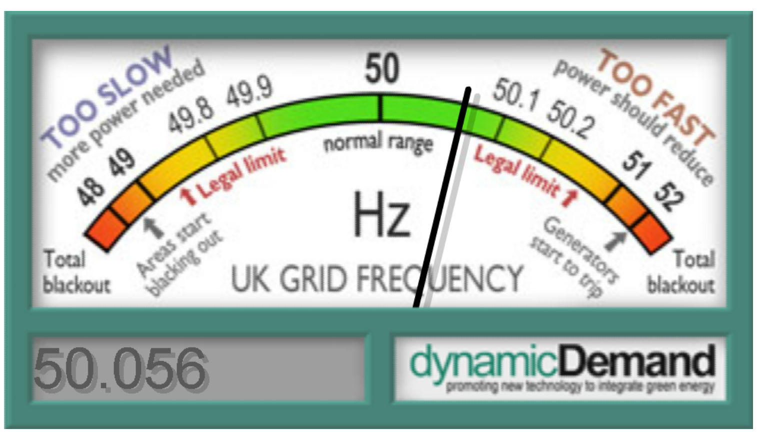
The German Energy Turn-Around

Renewables are on the rise!

- In Germany … and elsewhere
- On residential rooftops.

1999: 0.07 GW **2009: 10.6 GW** **2019: 49.0 GW**

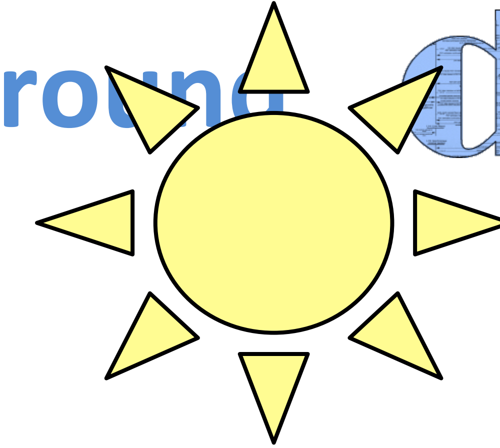
That is so great! Is it?



European Grid:
15 GW ≈ **1 Hz**

Target:
[49.8, 50.2] Hz

The German Energy Turn-Around



Renewables are on the rise!

- In Germany … and elsewhere
- On residential rooftops.

They jointly influence the stability of the European grid.

Current state of control:

"on-off" controller

EN 50438:2007, in force since 2007:

Switch off when frequency > 50.2 Hz

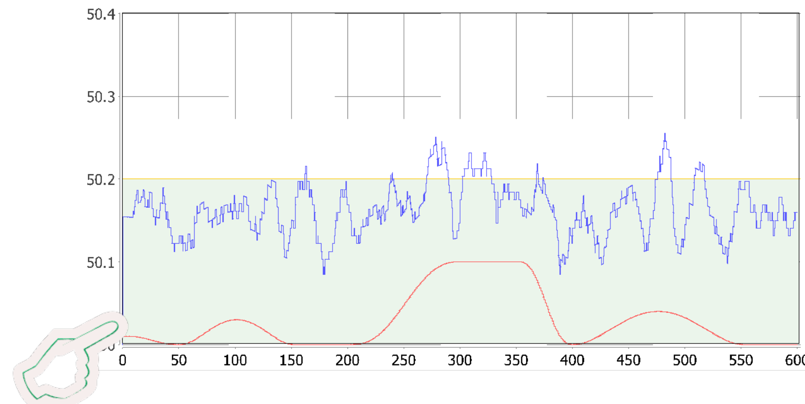
VDE-AR-N 4105, required today:

Output linear function of frequency in [50.2, 51.5] Hz
Emergency switchoff above 51.5 Hz
Switch on again when < 50.05 Hz for 1 minute

"linear" controller

The Distributed Turn-Around

Each controller is a gambler.



Let a die decide whether you must leave the grid.

Size of dice depends on grid frequency.

... as in 802.11e

(linearly)

Let another die decide when you can resume.

Size of dice depends on length of overload.

... as in Ethernet

(exponentially)

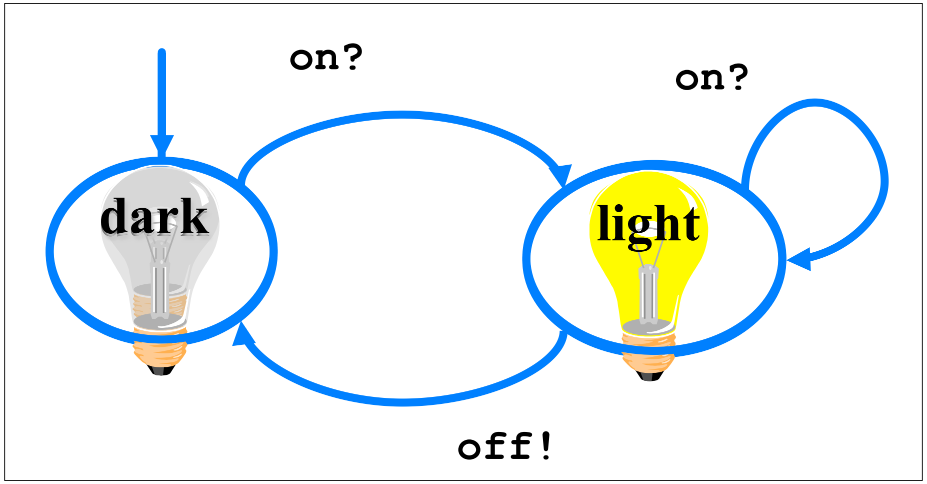
Quantitative Models

All models are wrong, but some are useful

George E. P. Box

Useful Quantitative Models

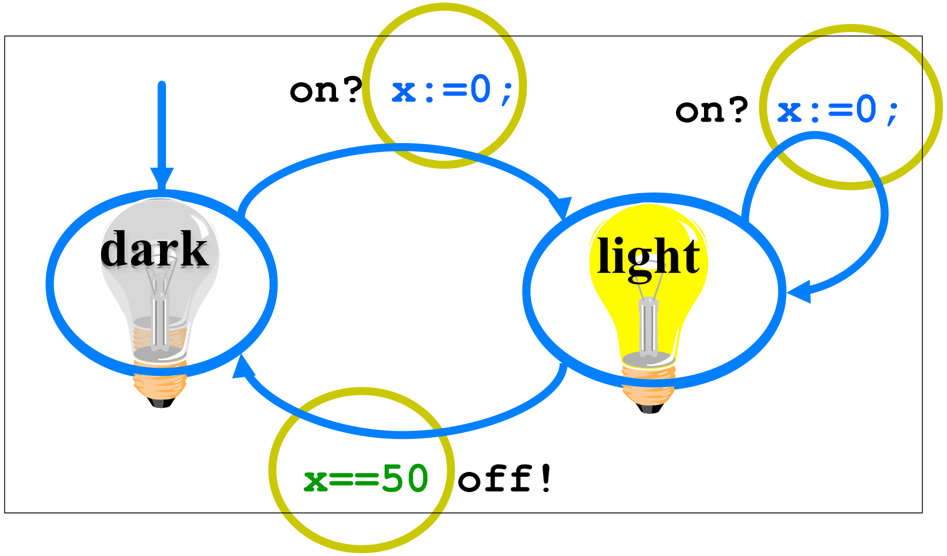
- finite automata



Useful Quantitative Models

- finite automata
- with clocks

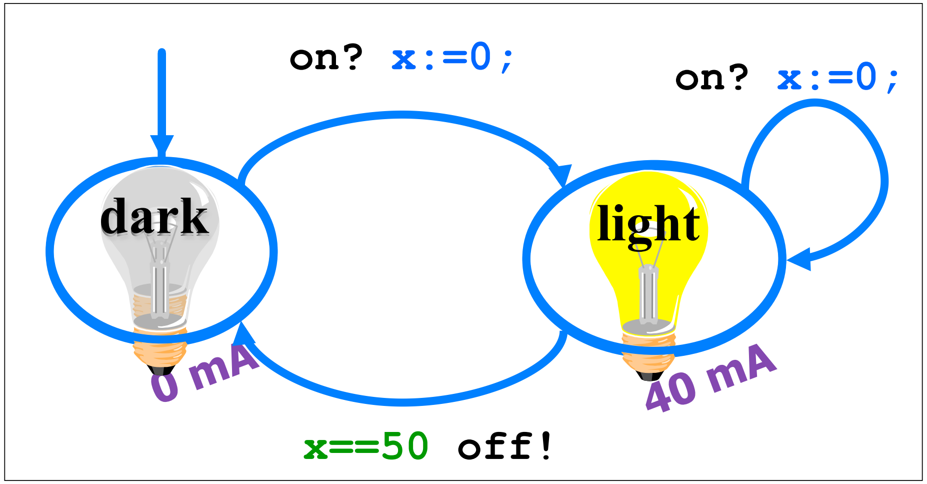
all running at the same speed



Timed Automata

Useful Quantitative Models

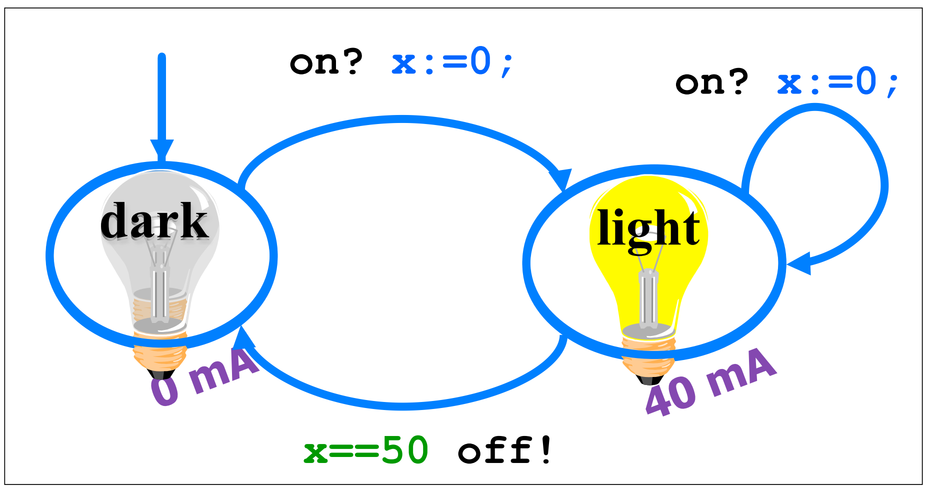
- finite automata
- with clocks
- and with costs *incurred as time advances*

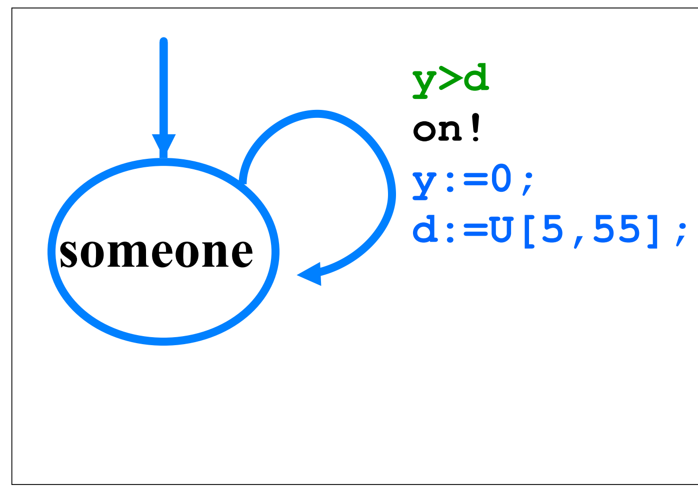


Priced Timed Automata

Useful Quantitative Models

- finite automata
- with clocks
- and with costs
- modular: composition of automata

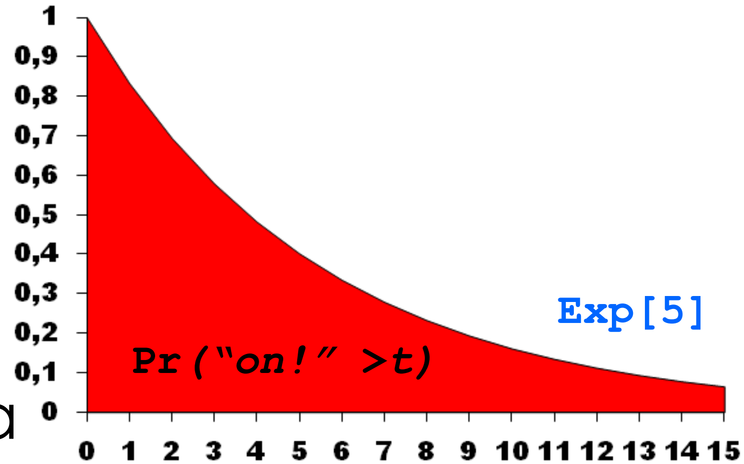


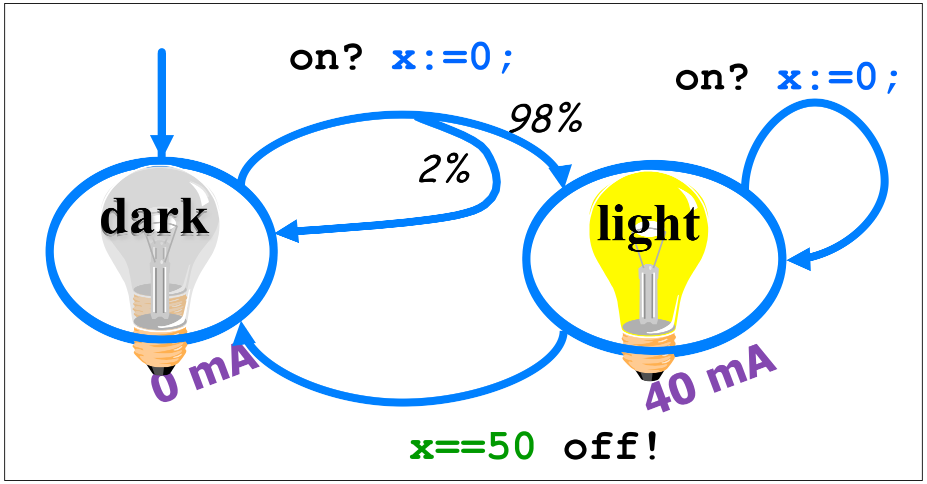


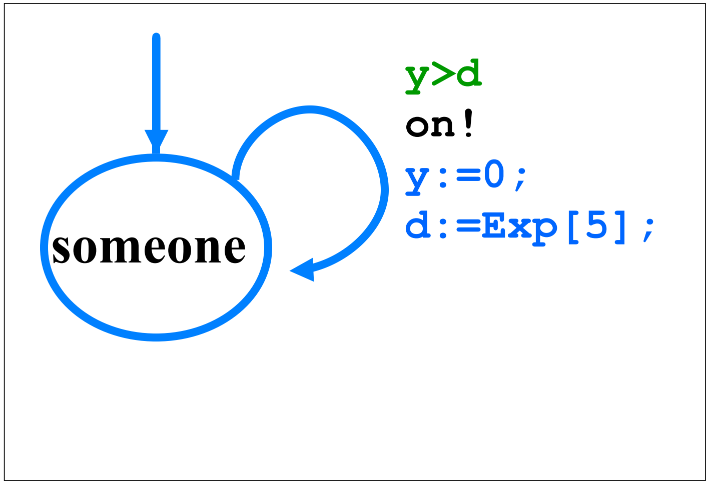
Automata Networks

Useful Quantitative Models

- finite automata
- with clocks
- and with costs
- modular: composition of automata



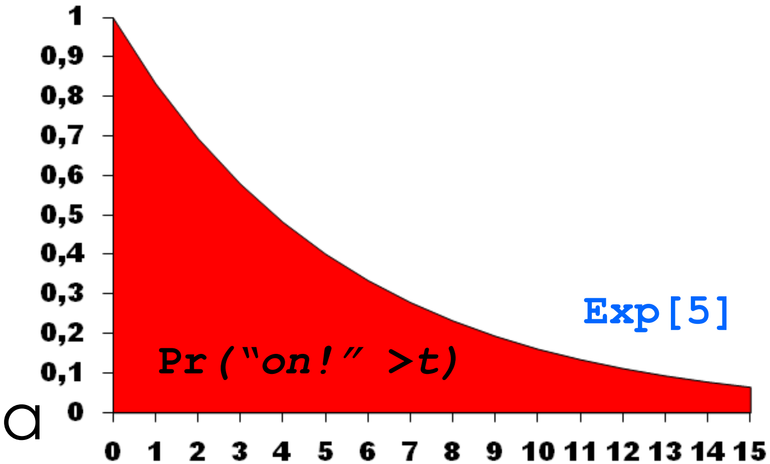




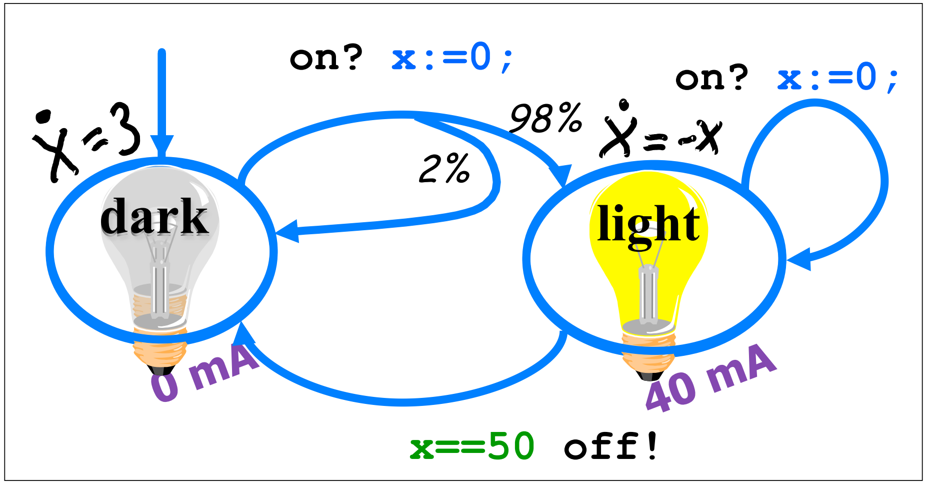
- with probability distributions

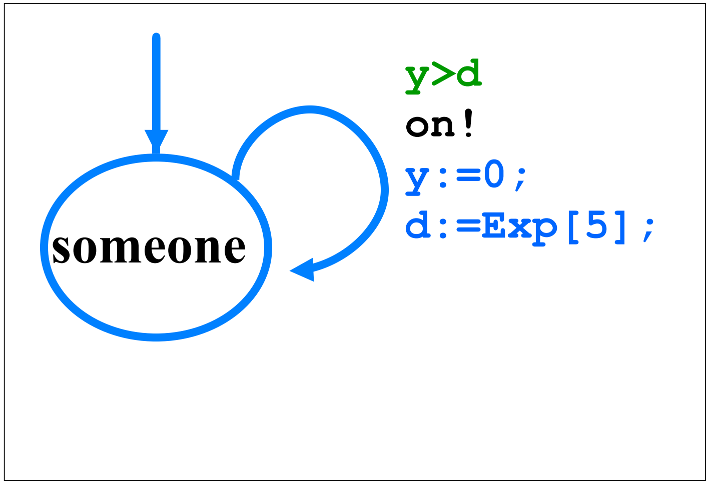
Stochastic Timed Automata

Useful Quantitative Models



- finite automata
- with clocks
- and with costs
- modular: composition of automata



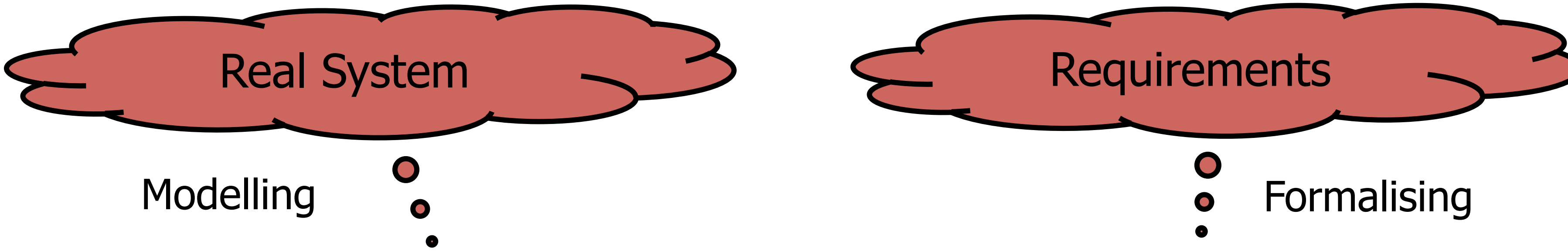


- with probability distributions
- and continuous dynamics

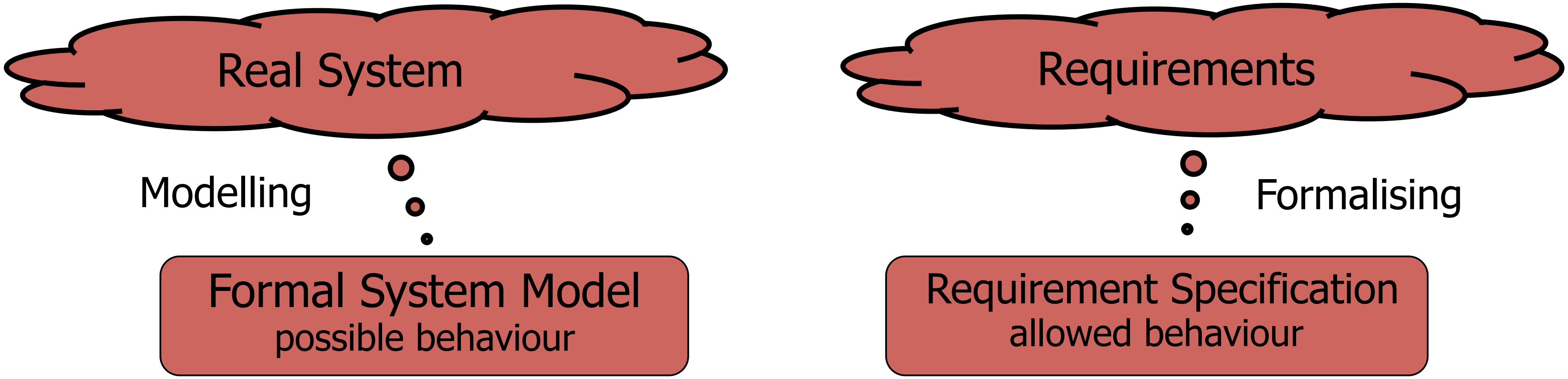
Stochastic Hybrid Automata

Model Checking

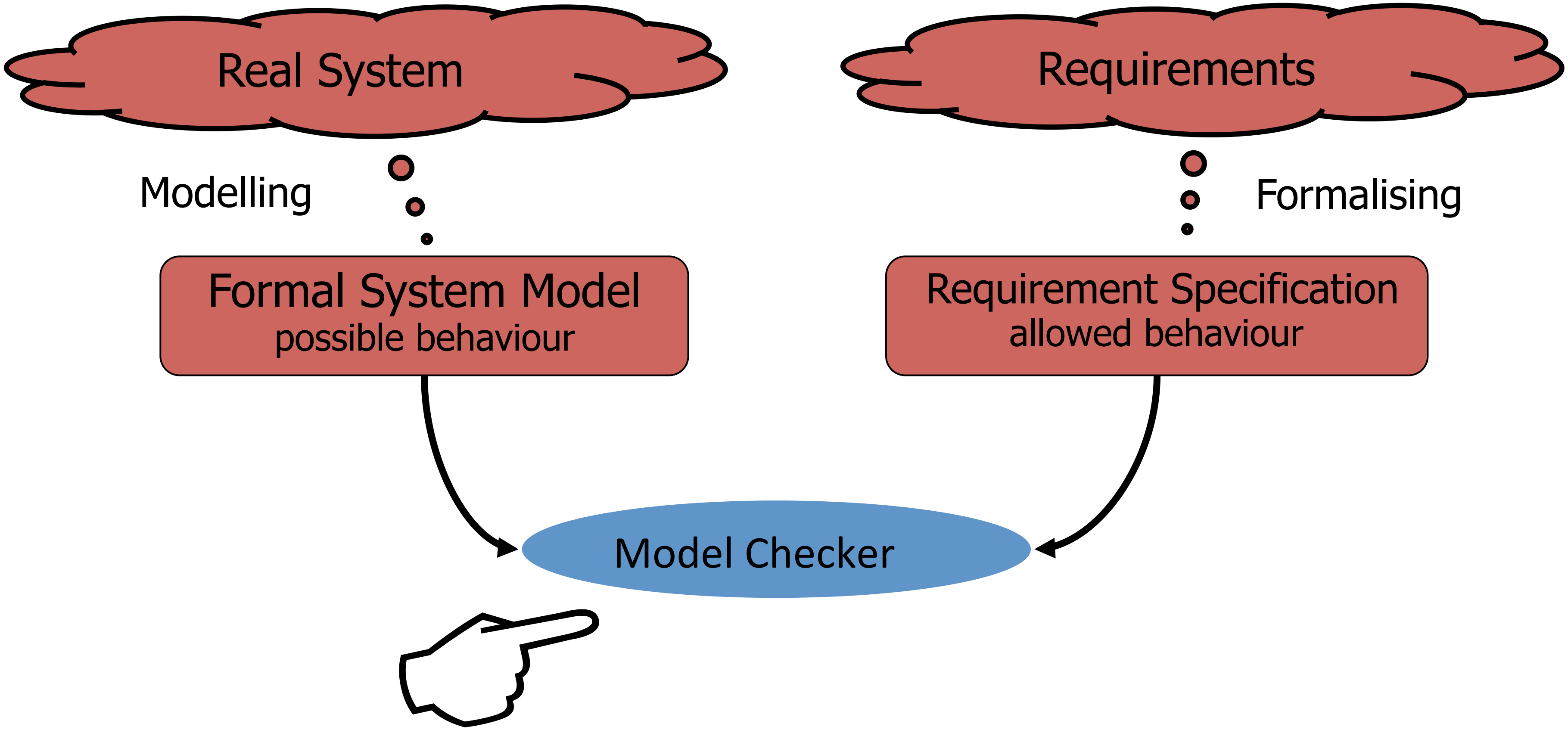
Model Checking



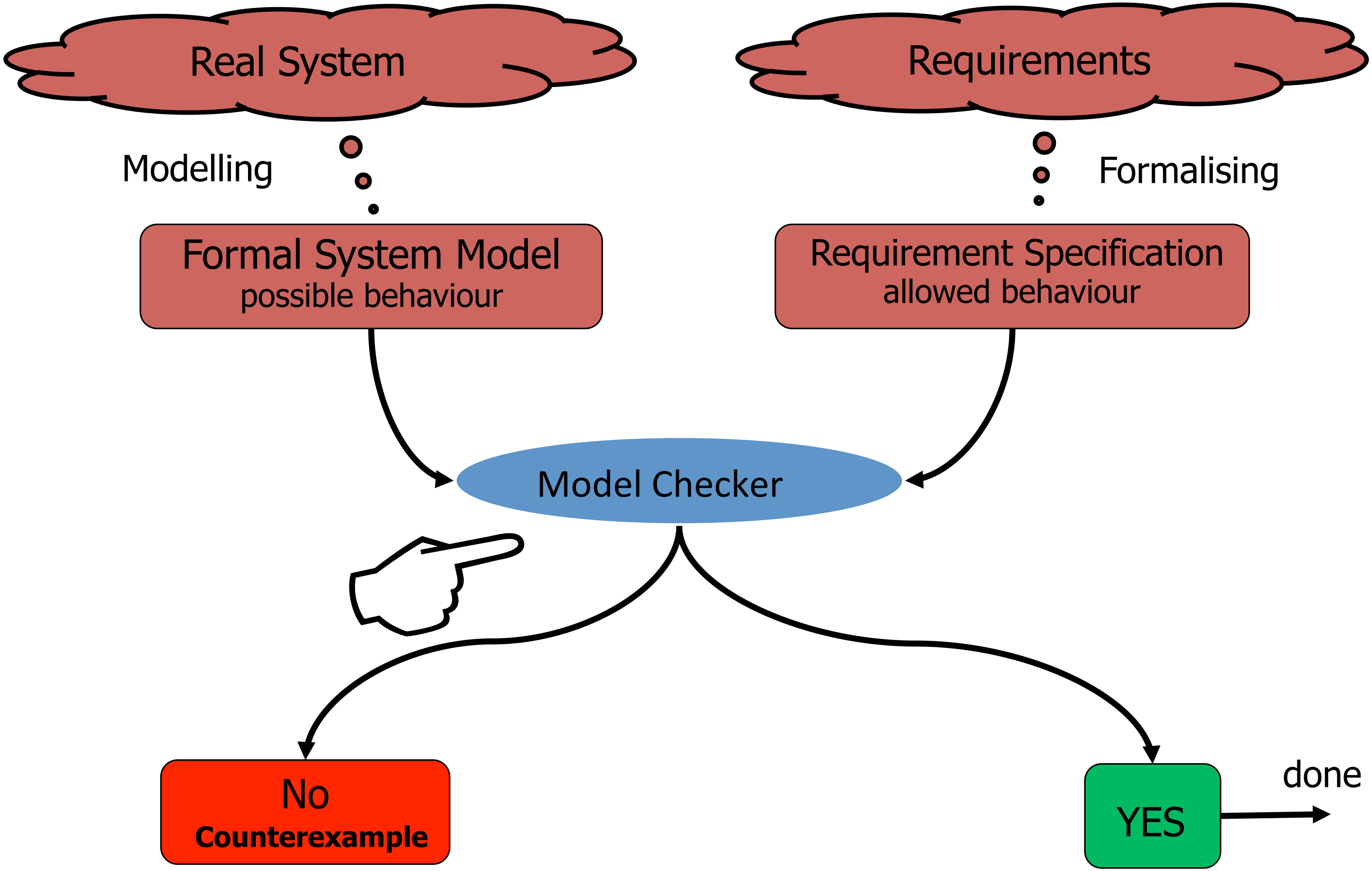
Model Checking



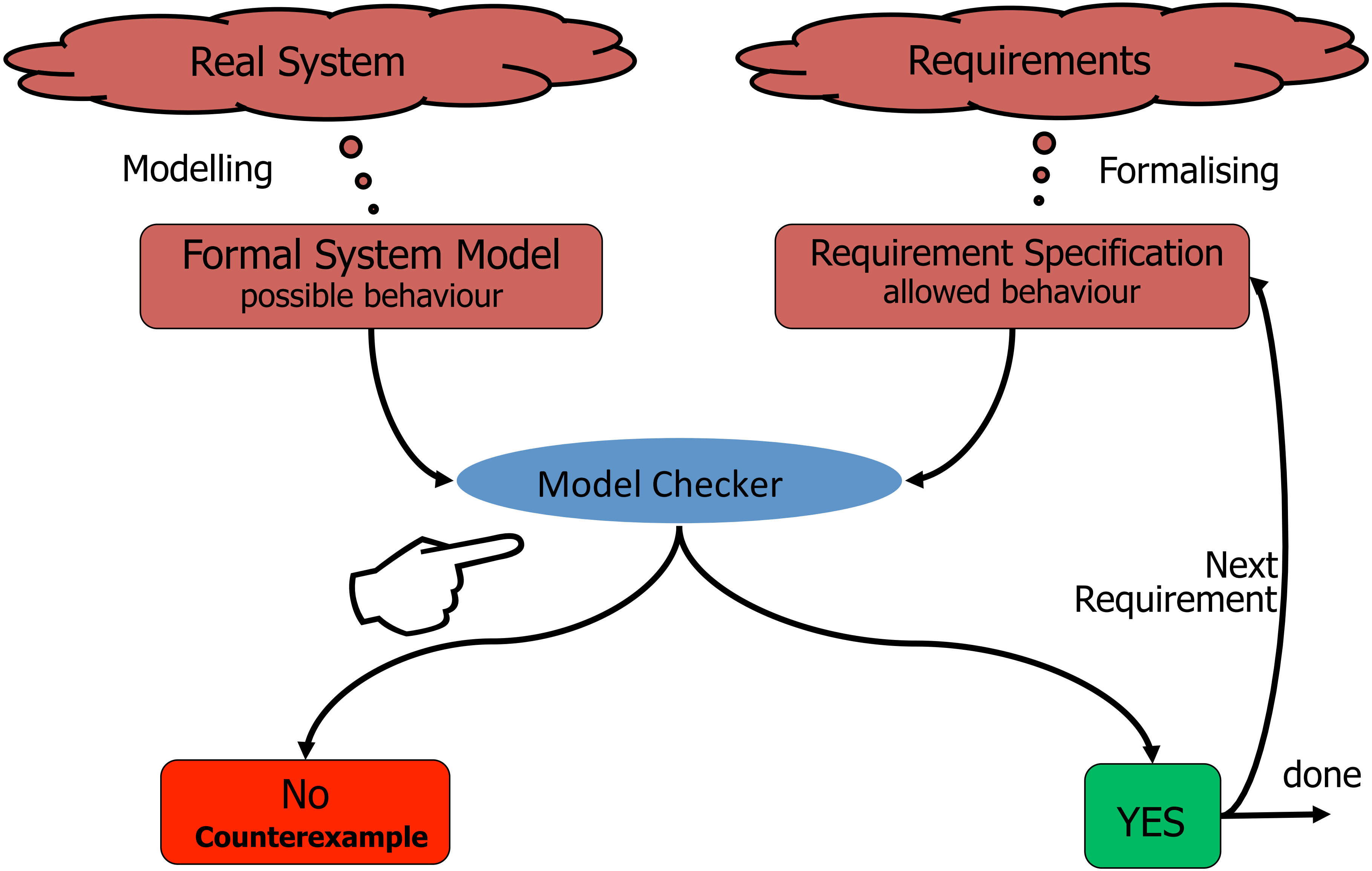
Model Checking

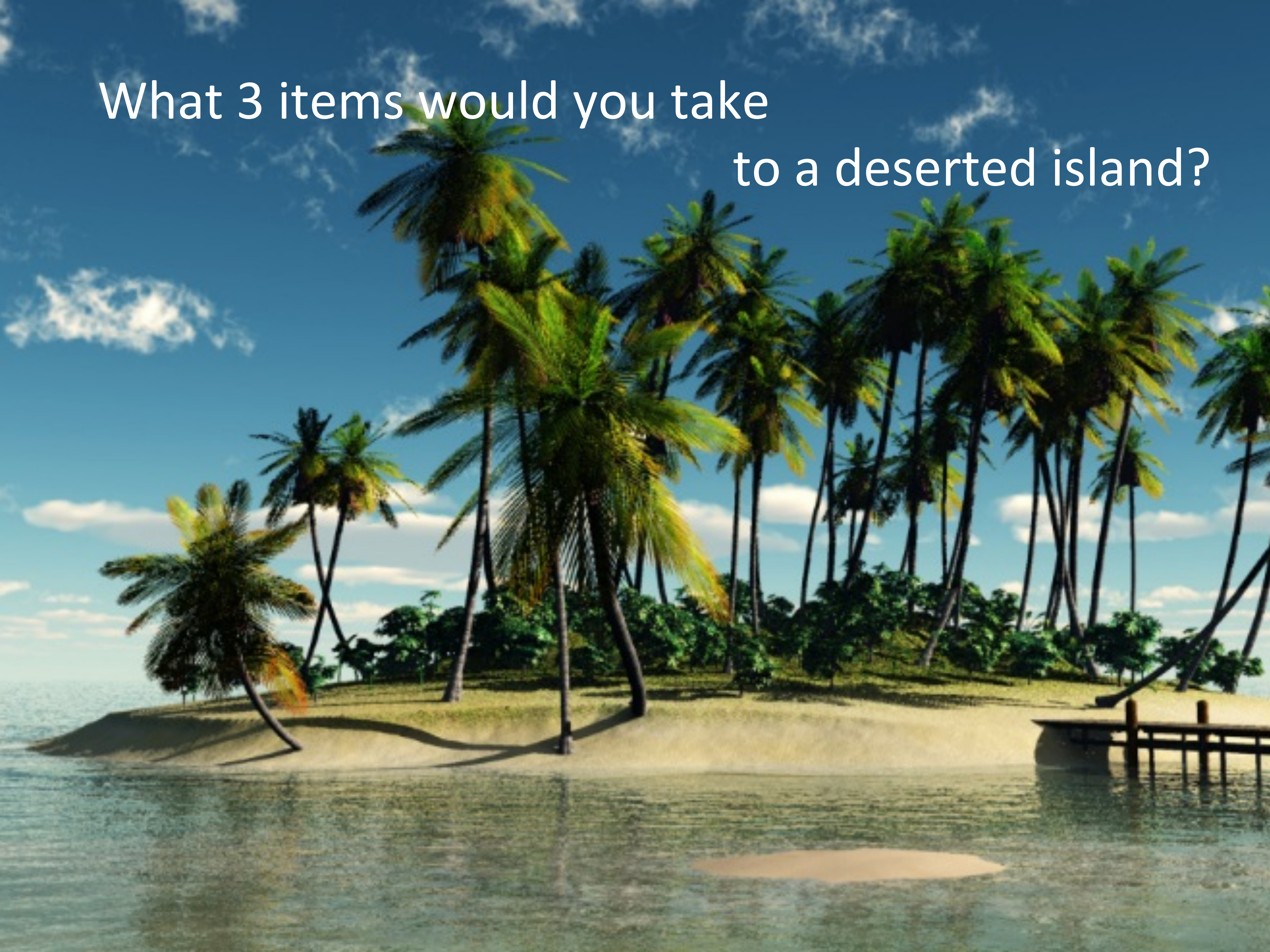


Model Checking

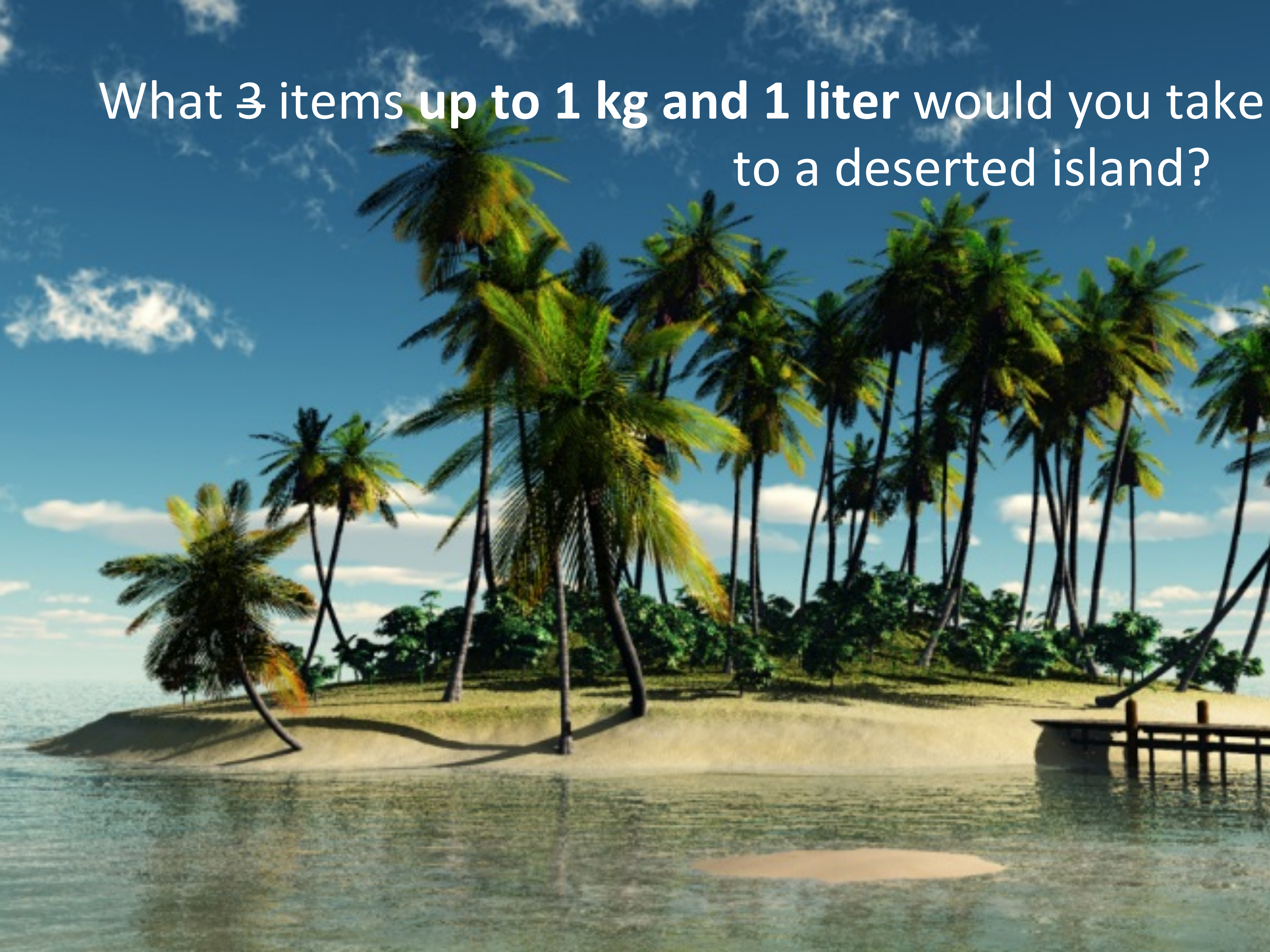


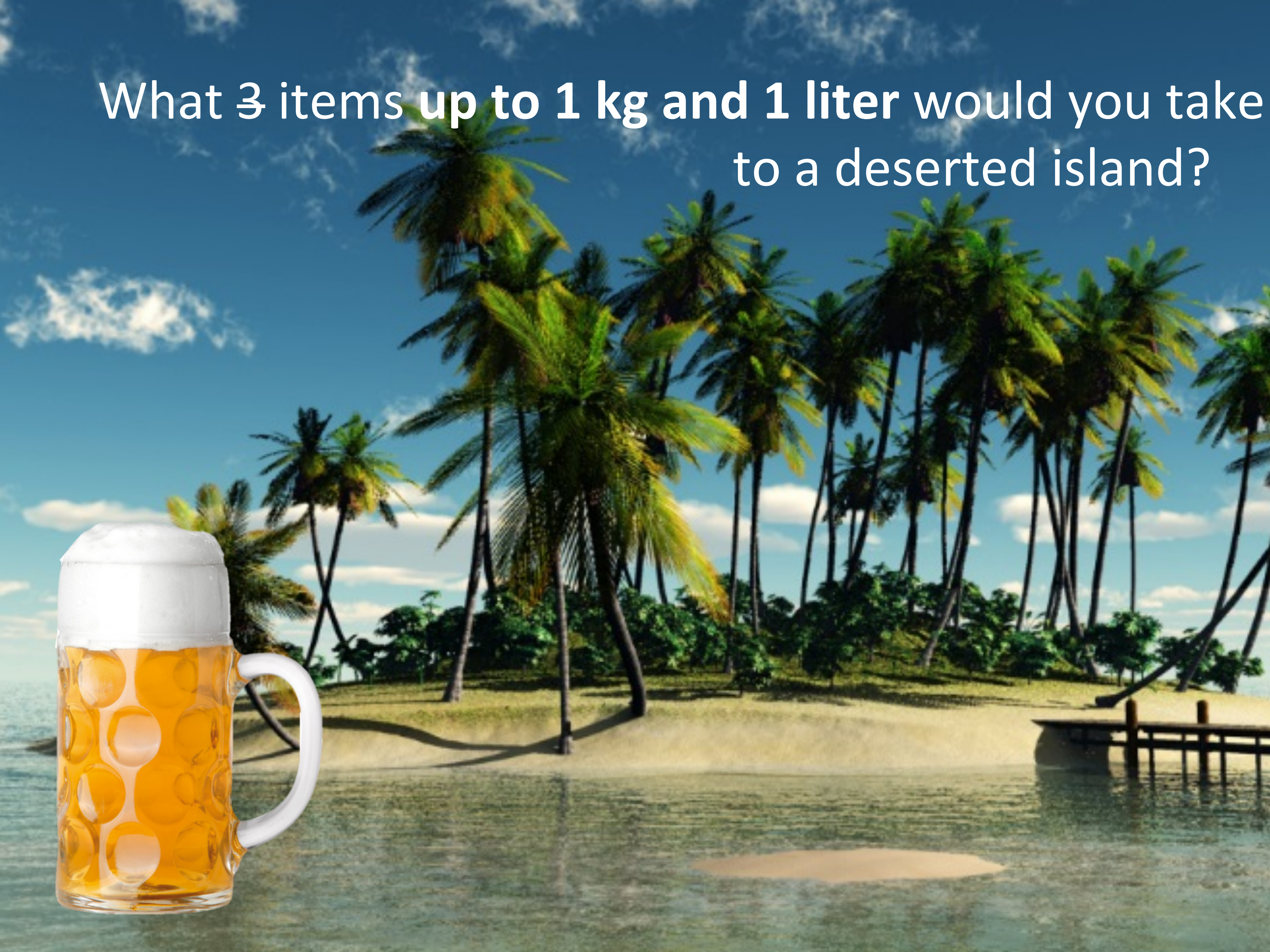
Model Checking




What 3 items would you take
to a deserted island?

What ~~3~~ items **up to 1 kg and 1 liter** would you take to a deserted island?




What ~~3~~ items **up to 1 kg and 1 liter** would you take
to a deserted island?

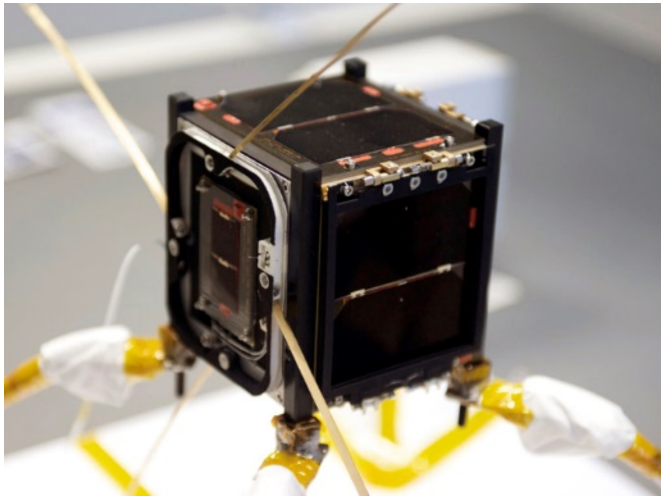
ESA 'Fly Your Satellite!' program

What ~~3~~ items **up to 1 kg and 1 liter** would you take **into space**?

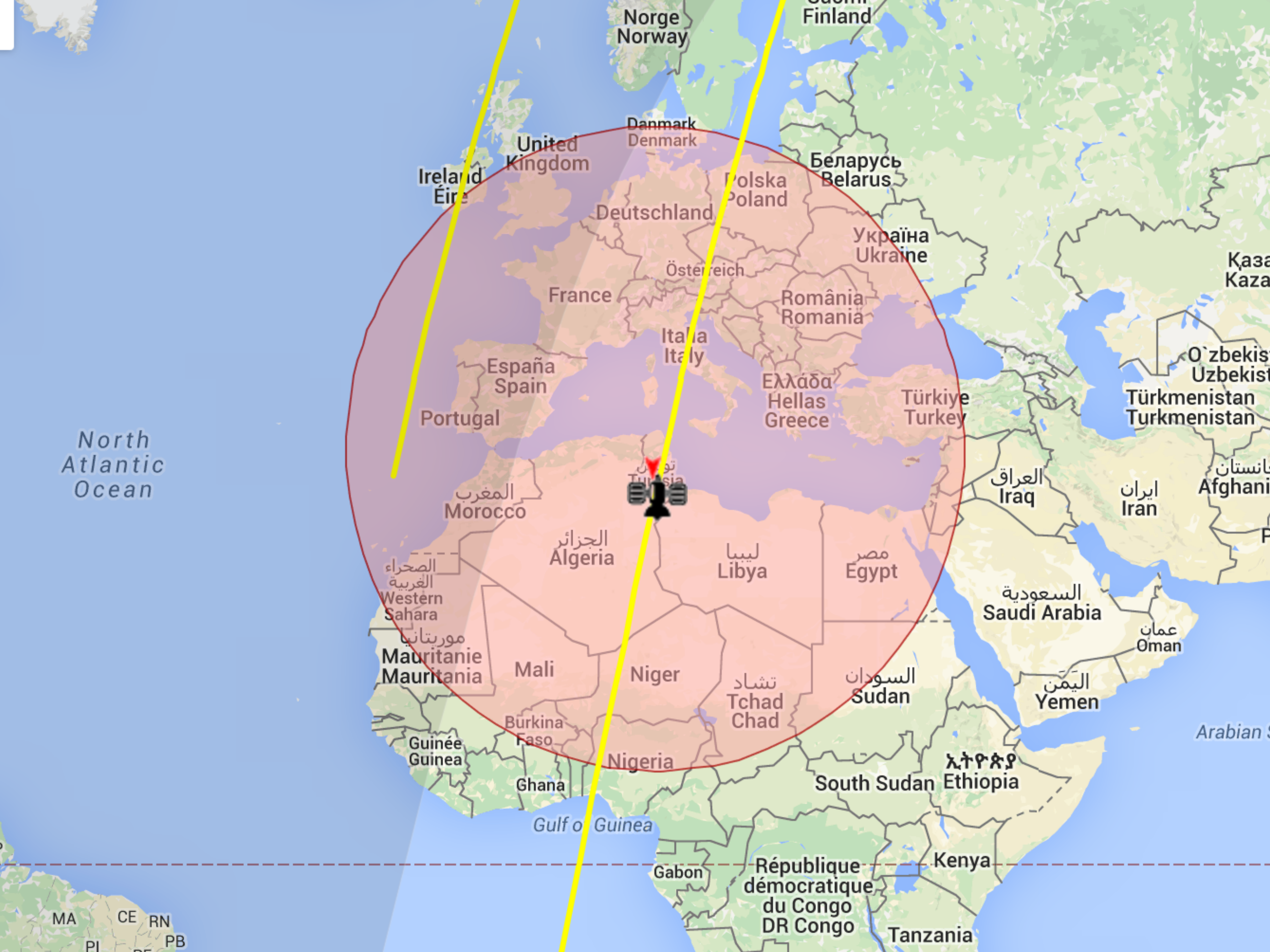
Cube Satellites, educational / scientific use

Limits: Up to 1 kg & 1 liter

Mission time: up to 4 years



esa
European Space Agency



Norge
Norway
Finland
Danmark
Denmark
United
Kingdom
Ireland
Éire
Polska
Poland
Беларусь
Belarus
Deutschland
Україна
Ukraine
Österreich
France
România
Romania
Italia
Italy
España
Spain
Portugal
Ελλάδα
Hellas
Greece
Türkiye
Turkey
Türkmenistan
Turkmenistan
North
Atlantic
Ocean
المغرب
Morocco
العراق
Iraq
ايران
Iran
الجزائر
Algeria
ليبيا
Libya
مصر
Egypt
الصحراء
الغربية
Western
Sahara
السعودية
Saudi Arabia
عمان
Oman
موريتانيا
Mauritanie
Mauritania
Mali
Niger
تشاد
Tchad
Chad
السودان
Sudan
اليمن
Yemen
Burkina
Faso
Guinée
Guinea
Ghana
Nigeria
South Sudan
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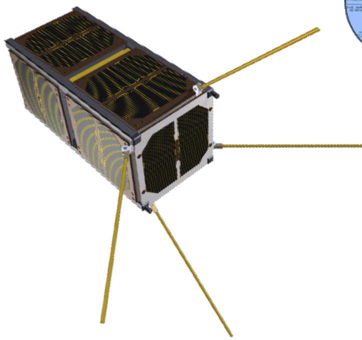
Ethiopia
Gulf of Guinea
Kenya
Gabon
République
démocratique
du Congo
DR Congo
Tanzania
MA
CE
RN
PB

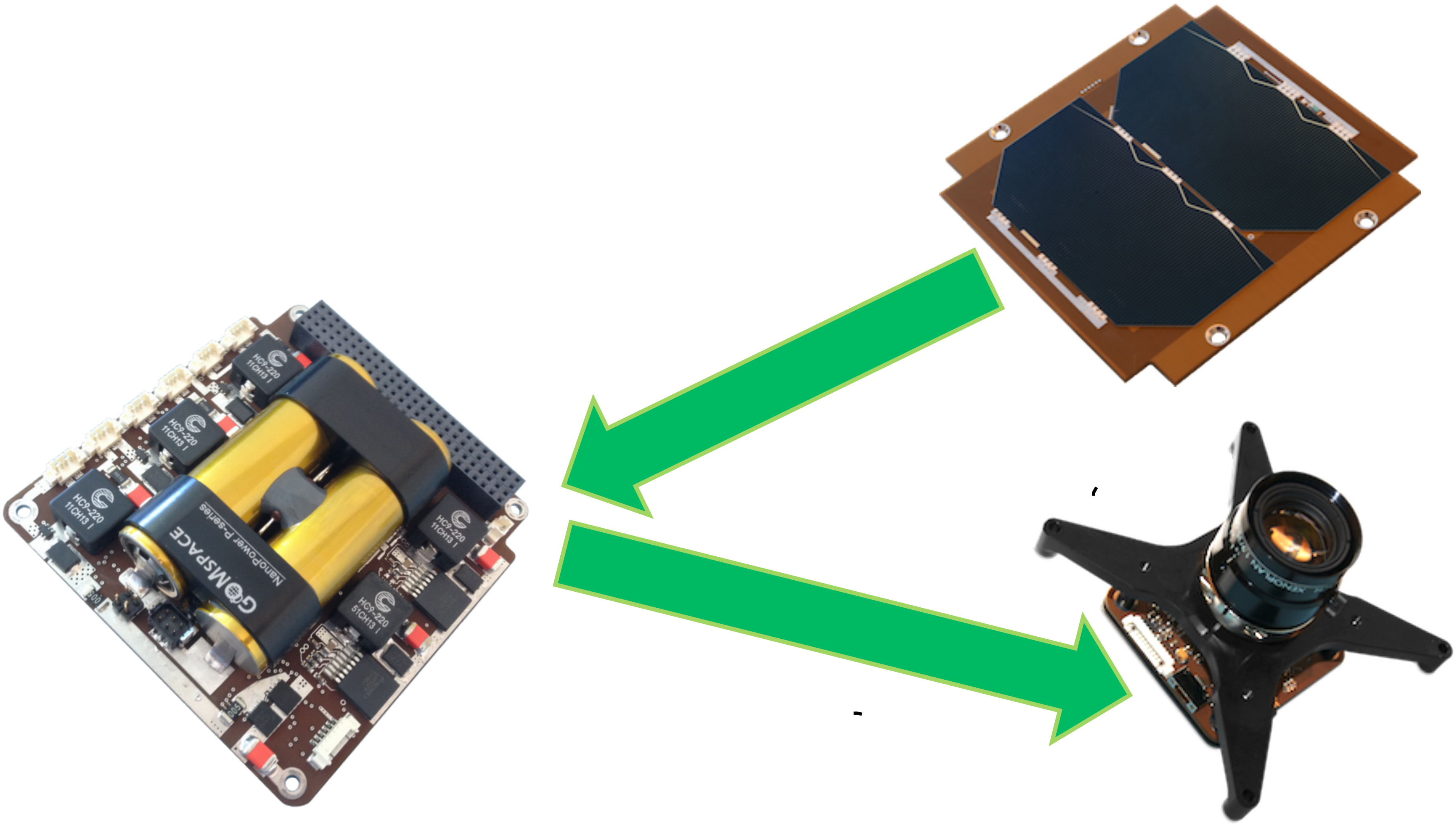
GOMX-1



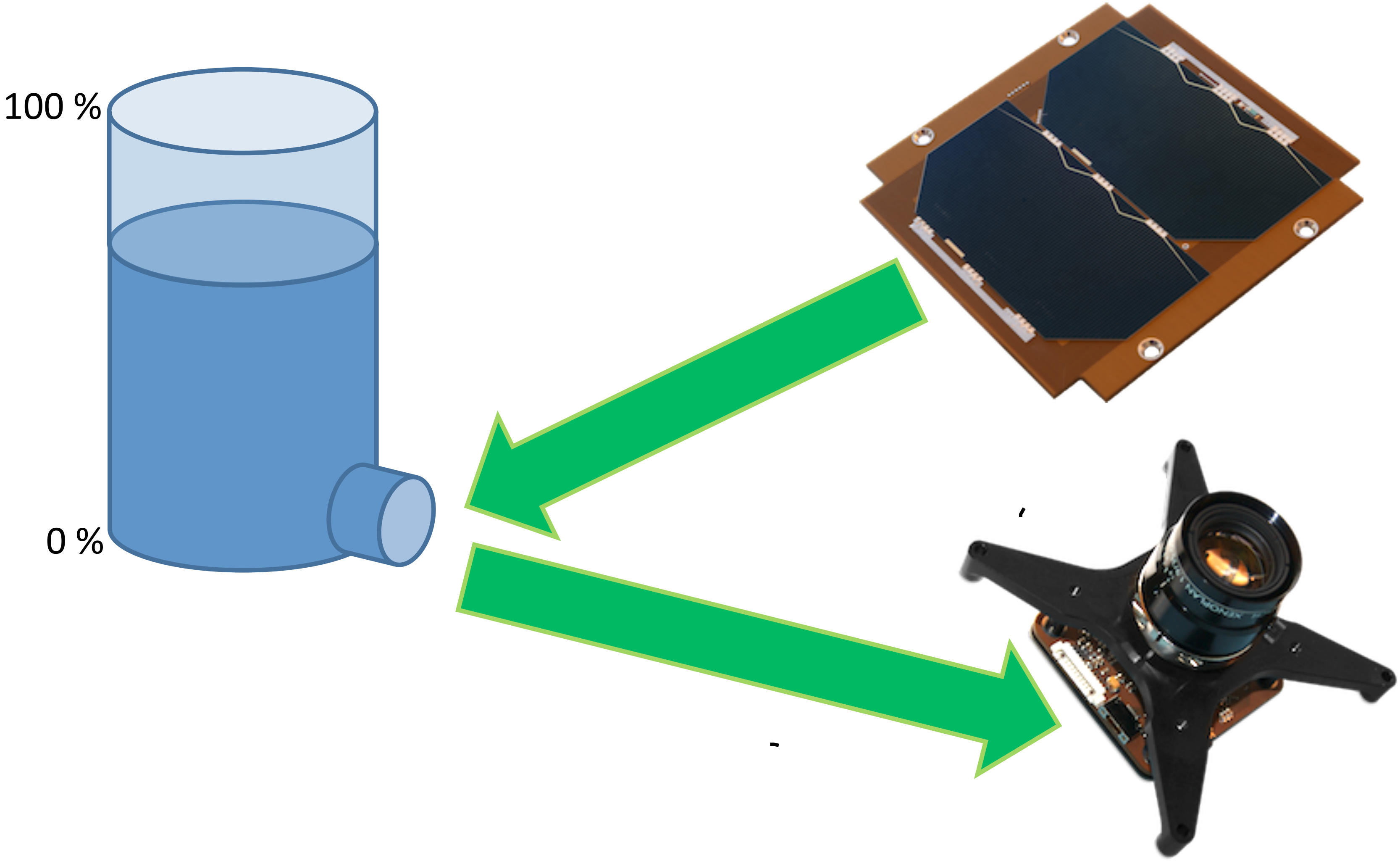
- 2U CubeSat (2 liter)
- Launched in November 2013
- Payloads:
  - software defined receiver for aircraft signals
  - color camera for earth observation
- Telemetry transmitted on amateur radio frequency
- Massive amounts of data collected
  - battery voltage, temperature, solar infeed, …

Runs our calibration experiments.

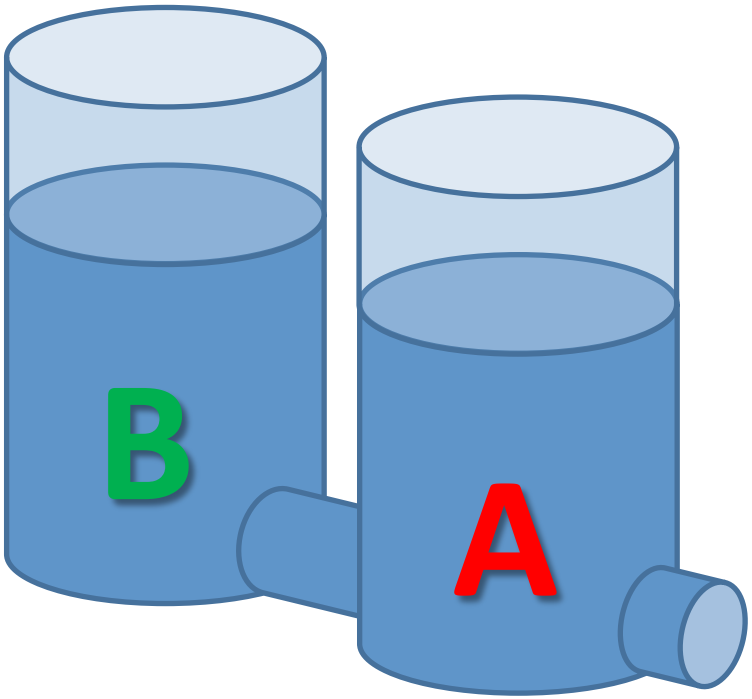
Battery Kinetics

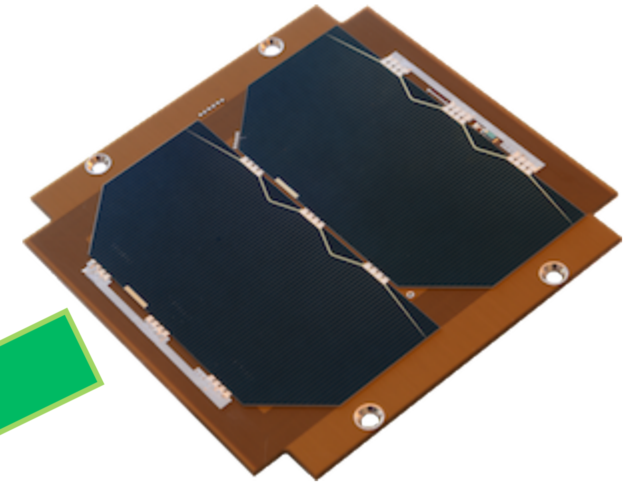


Battery Kinetics



Battery Kinetics



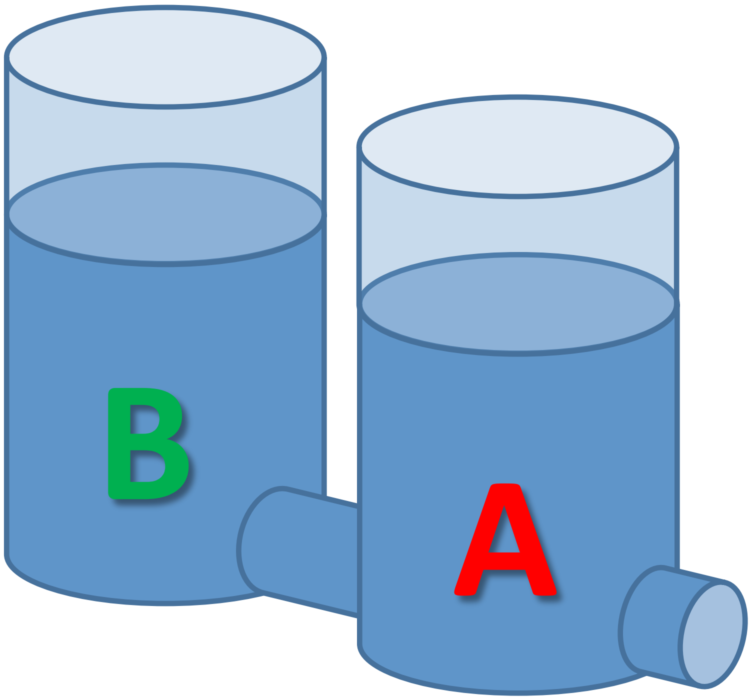


$$\dot{a}(t) = -I + p\left(\frac{b(t)}{1-c} - \frac{a(t)}{c}\right)$$

$$\dot{b}(t) = p\left(\frac{a(t)}{c} - \frac{b(t)}{1-c}\right)$$

“Kinetic Battery Model”, or KiBaM

Battery Kinetics



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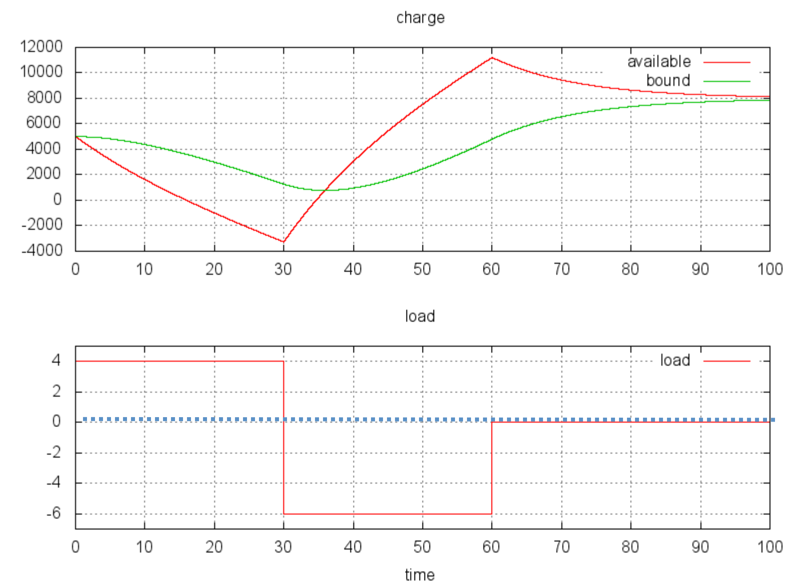
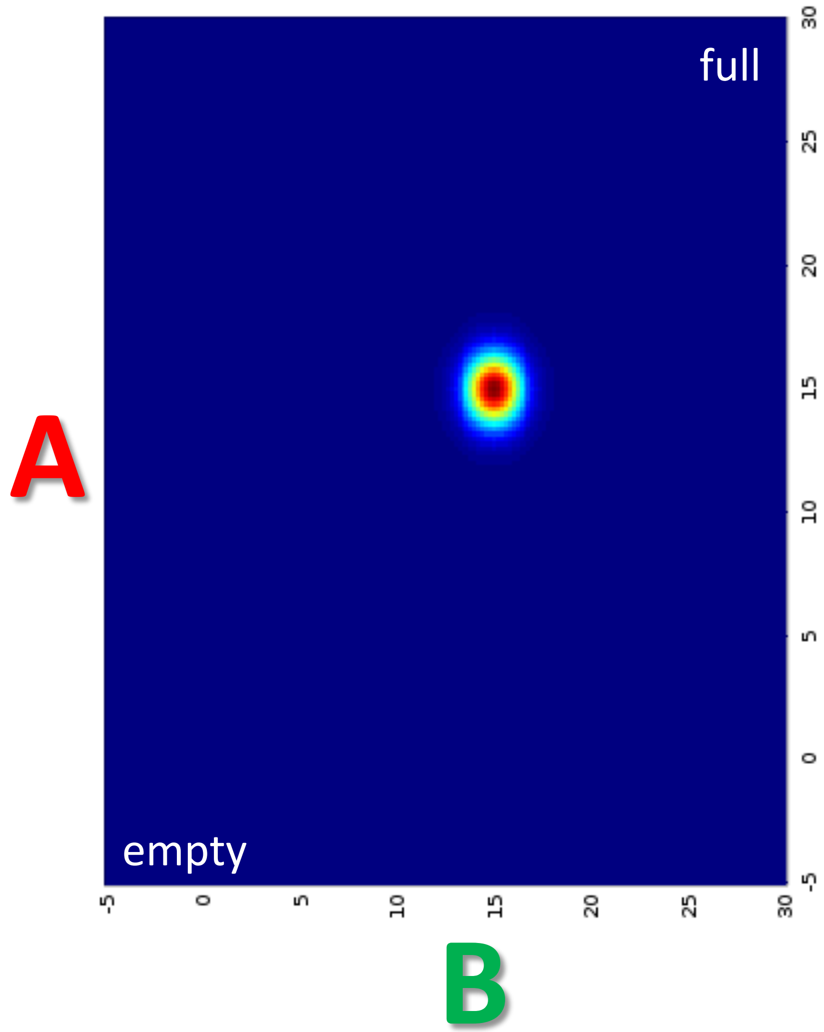
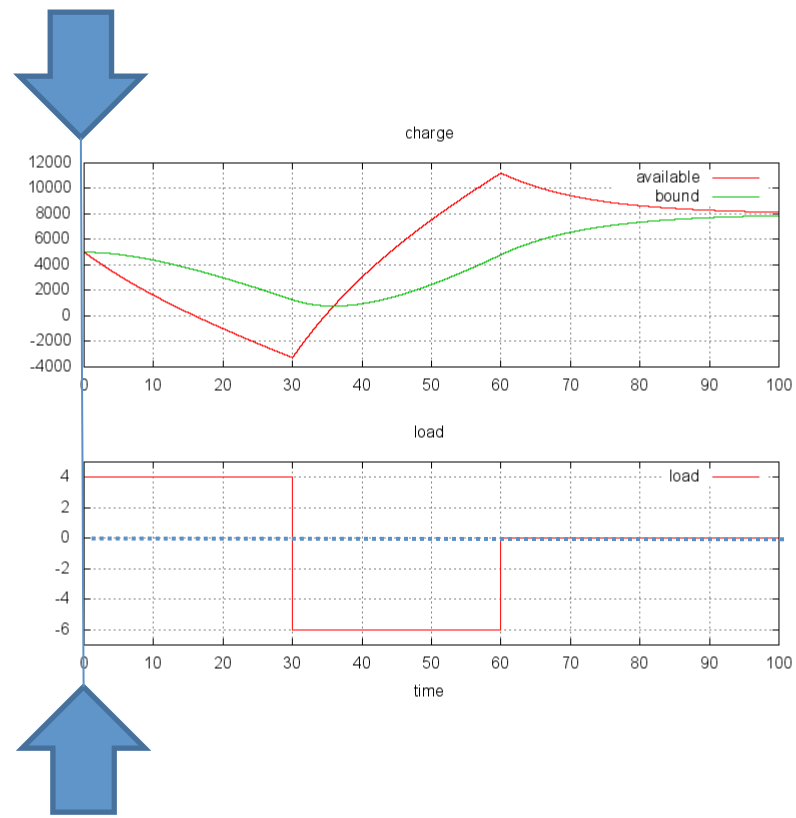


"Kinetic Battery Model", or KiBaM

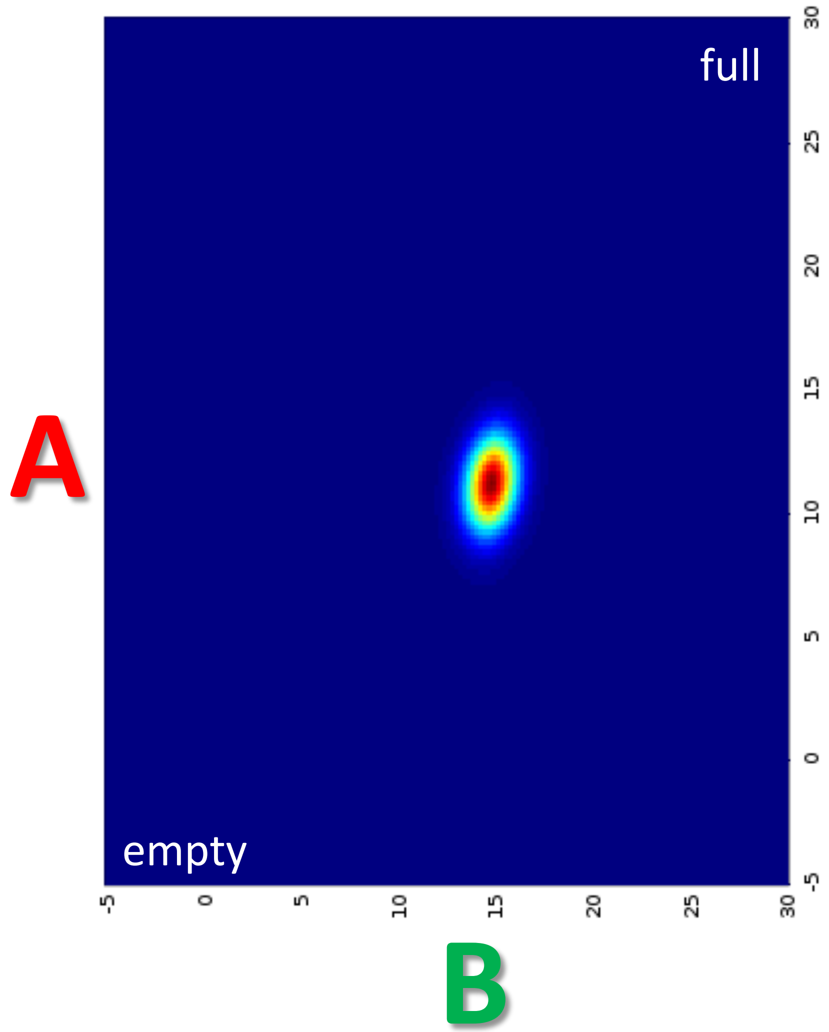
Battery Kinetics

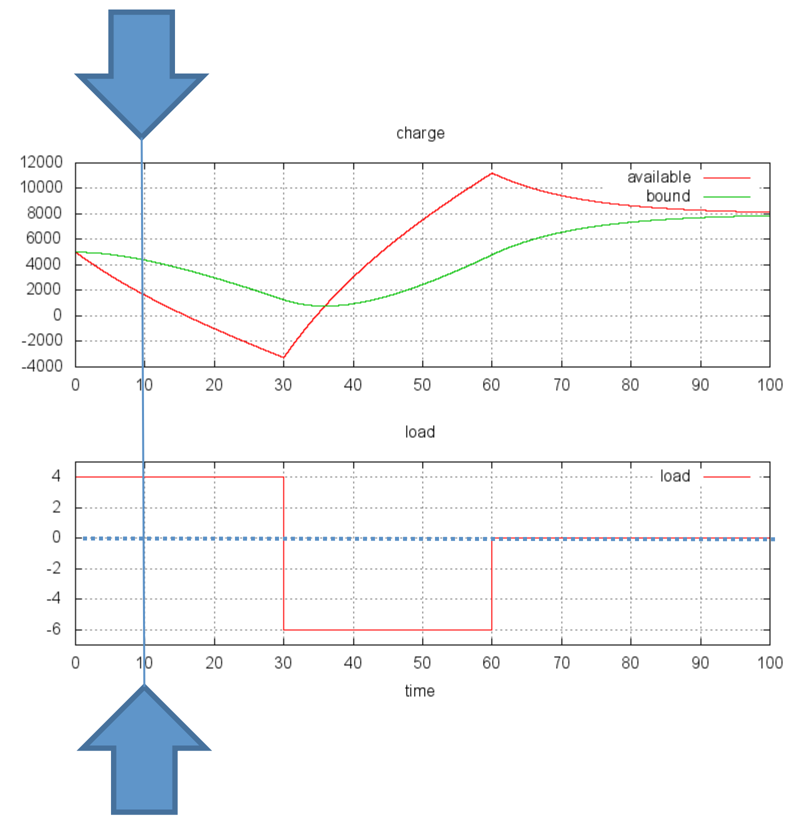




“Stochastic” KiBaM

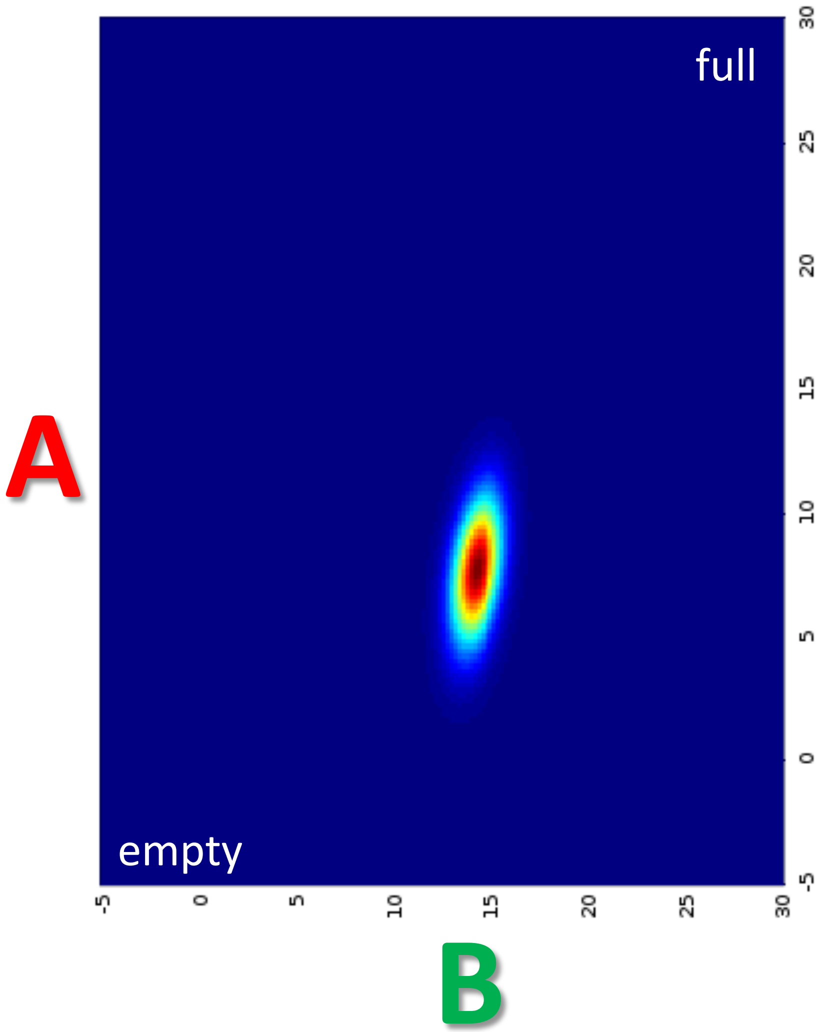
Battery Kinetics

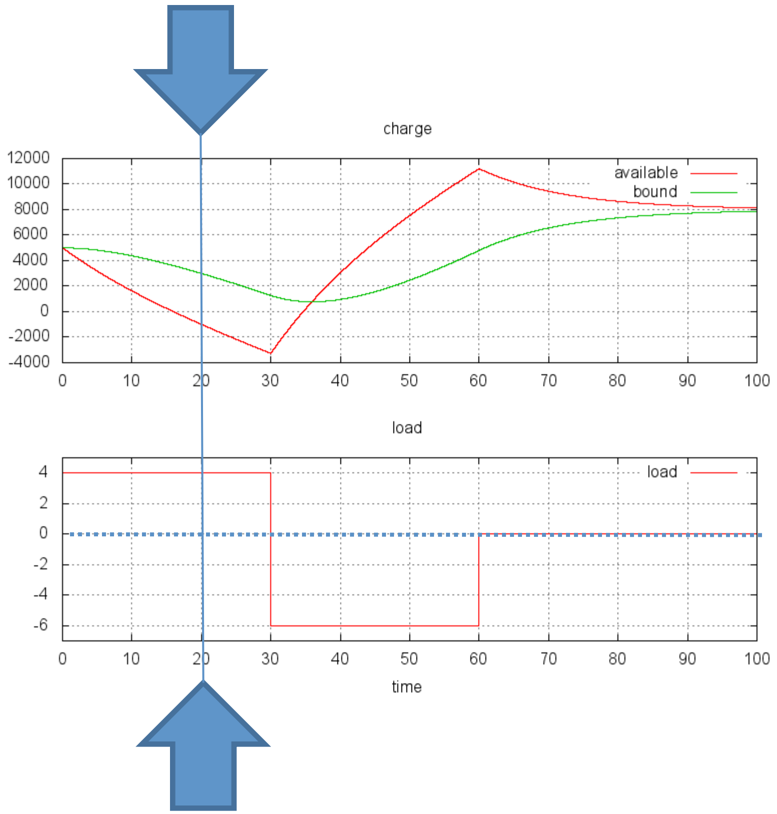




“Stochastic” KiBaM

Battery Kinetics

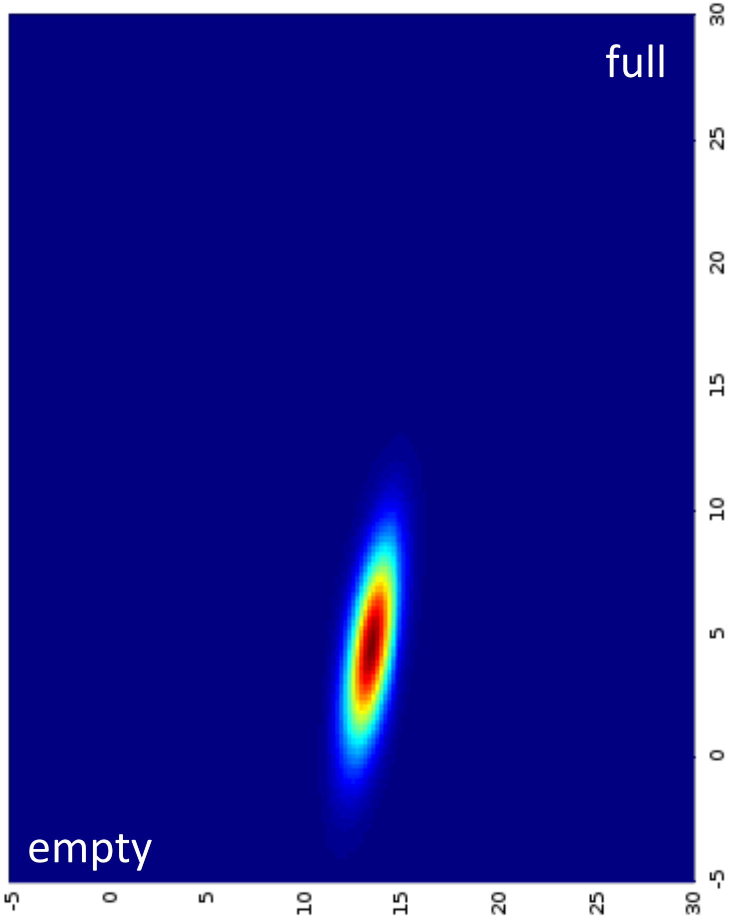




"Stochastic" KiBaM

Battery Kinetics

A



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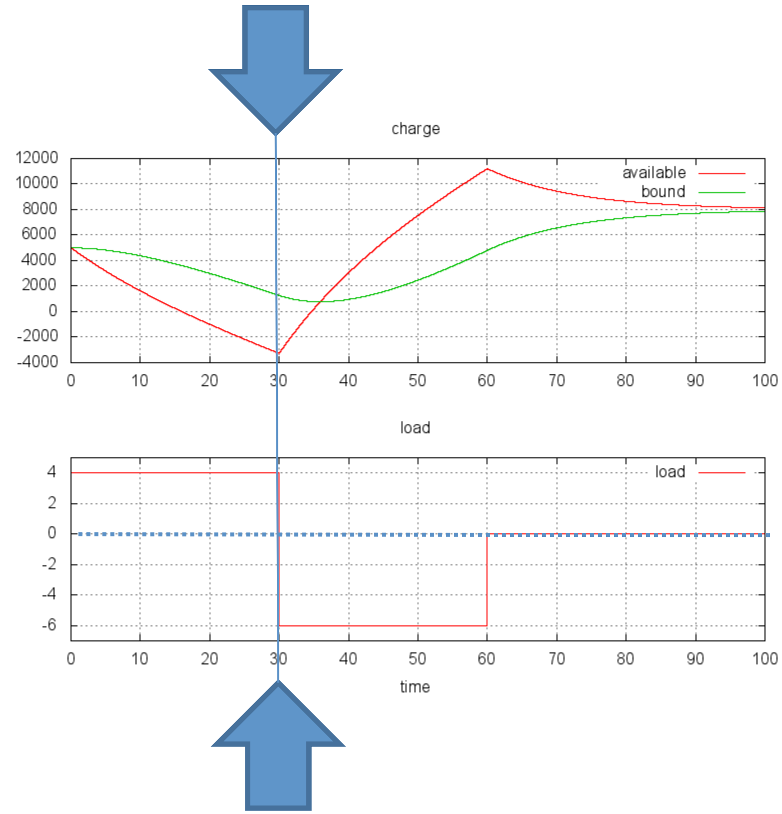
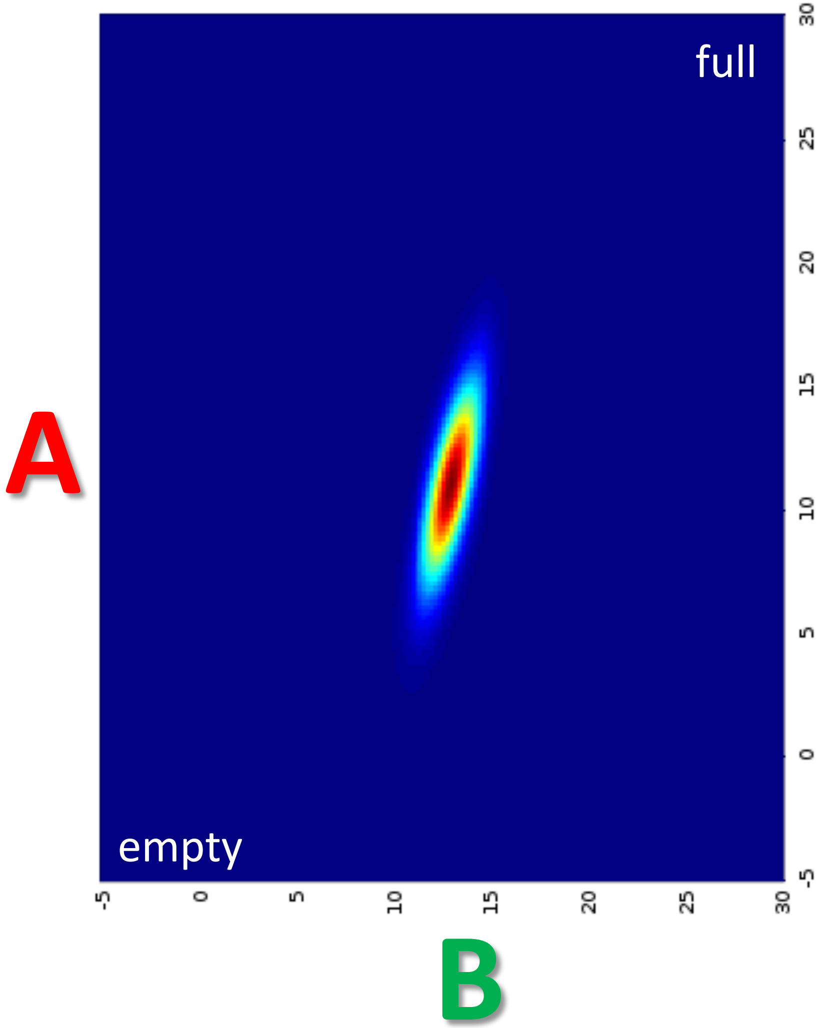
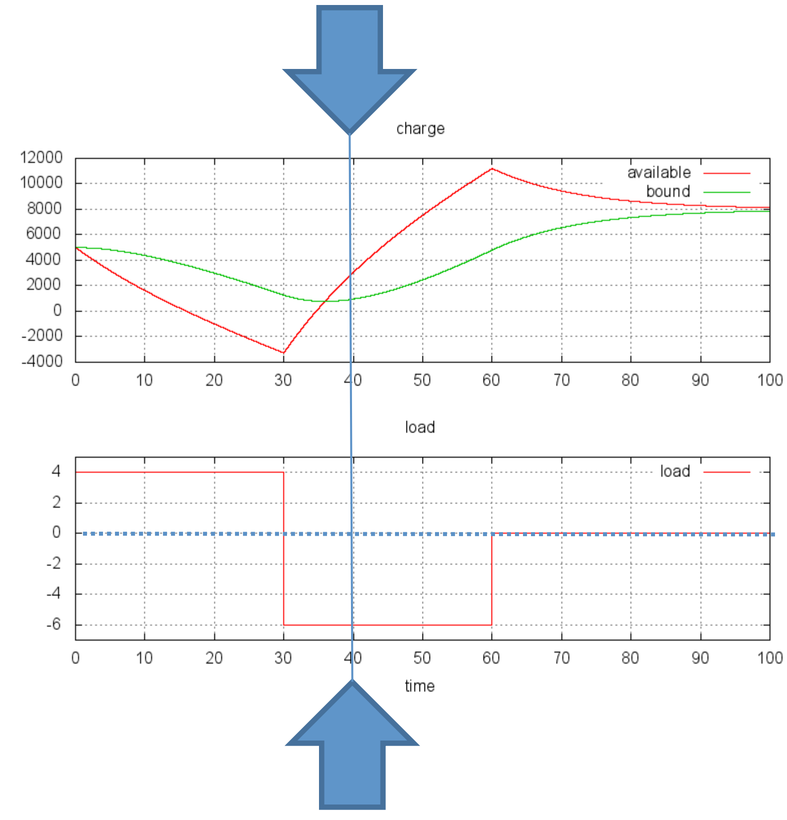


"Stochastic" KiBaM

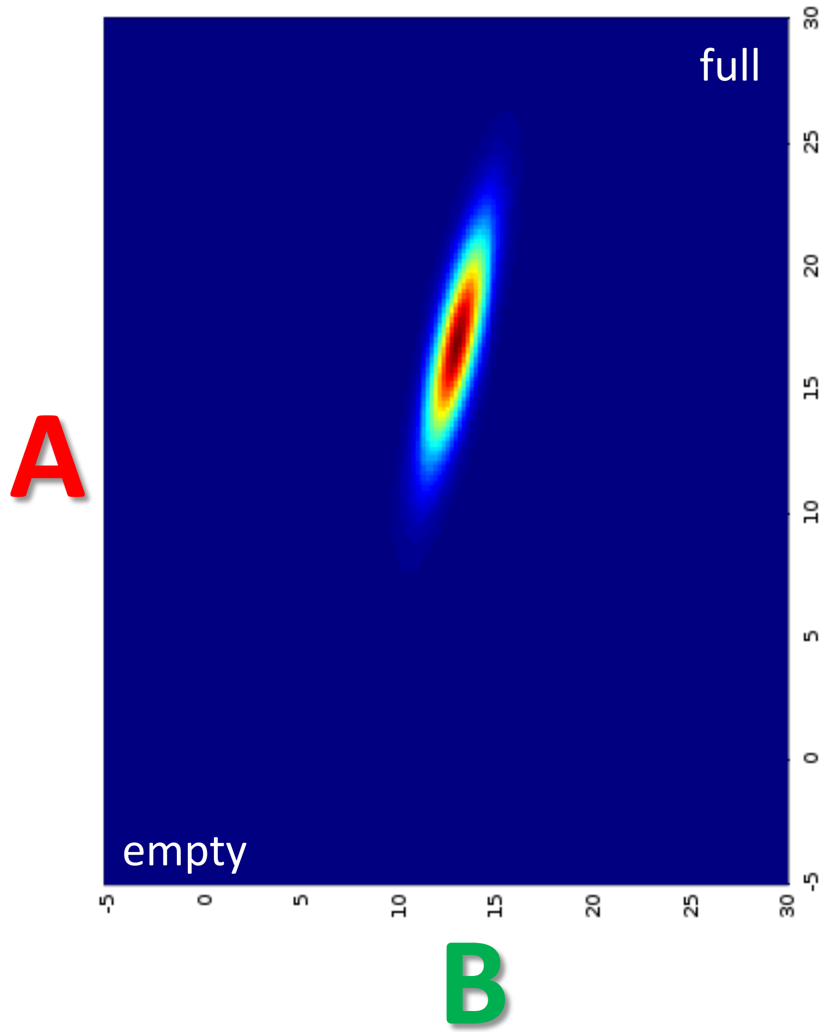
Battery Kinetics

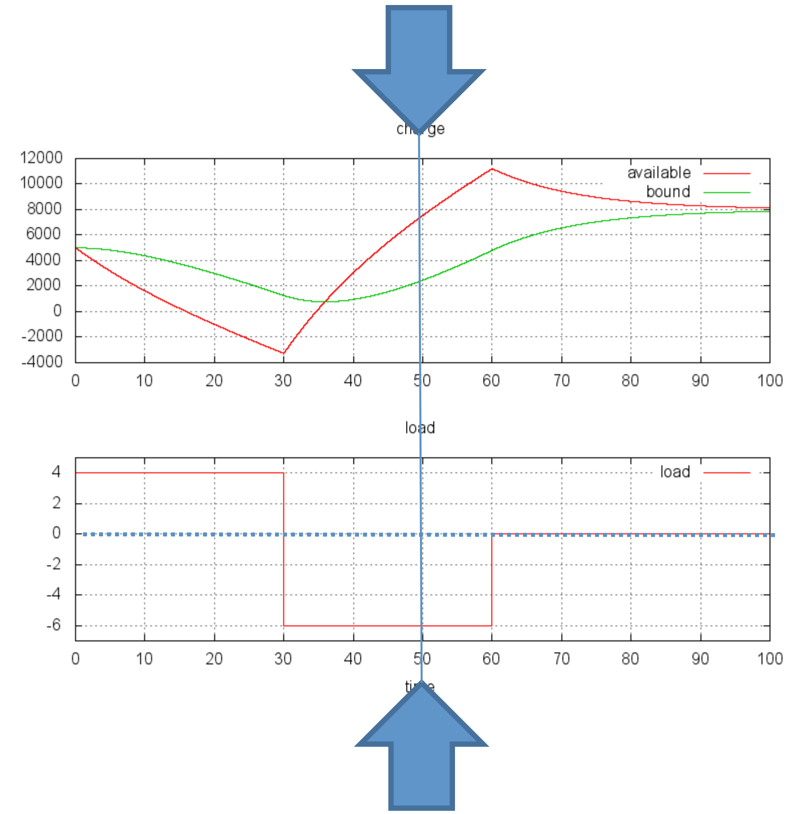




"Stochastic" KiBaM

Battery Kinetics

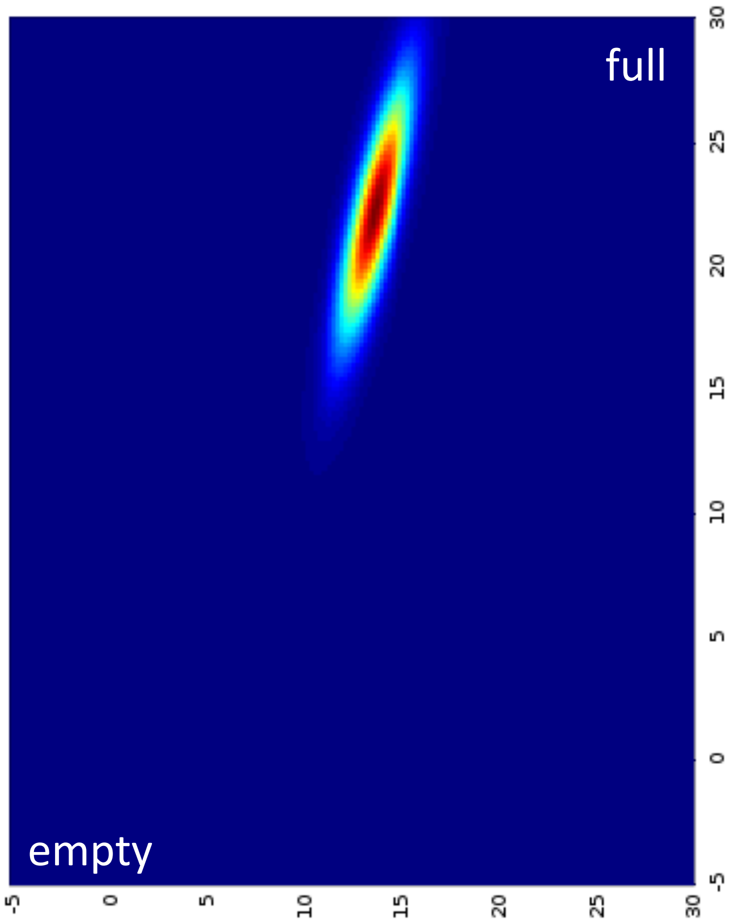




"Stochastic" KiBaM

Battery Kinetics

A



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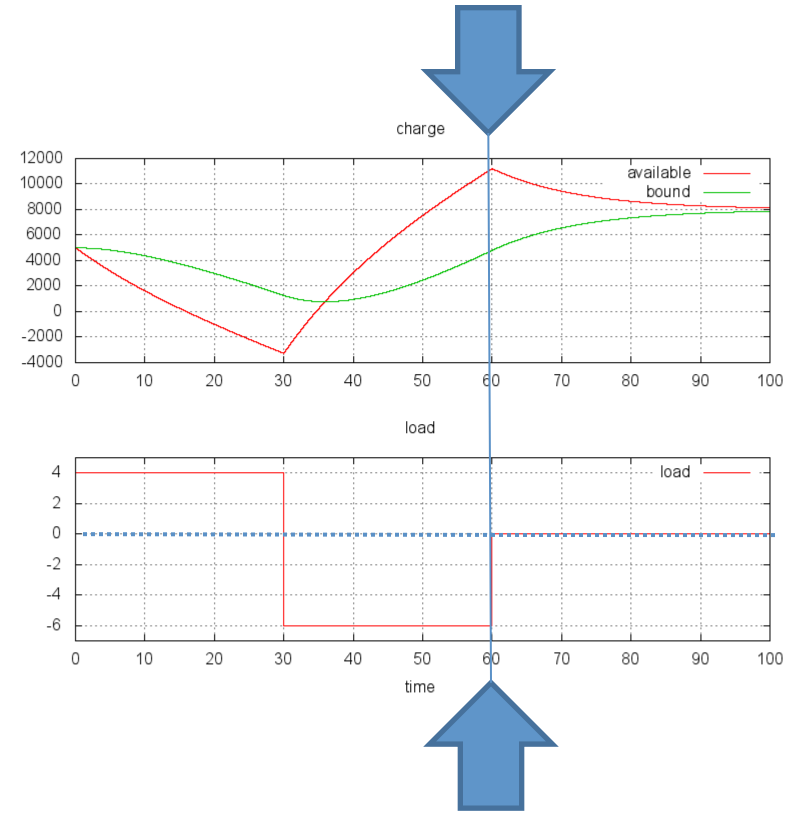
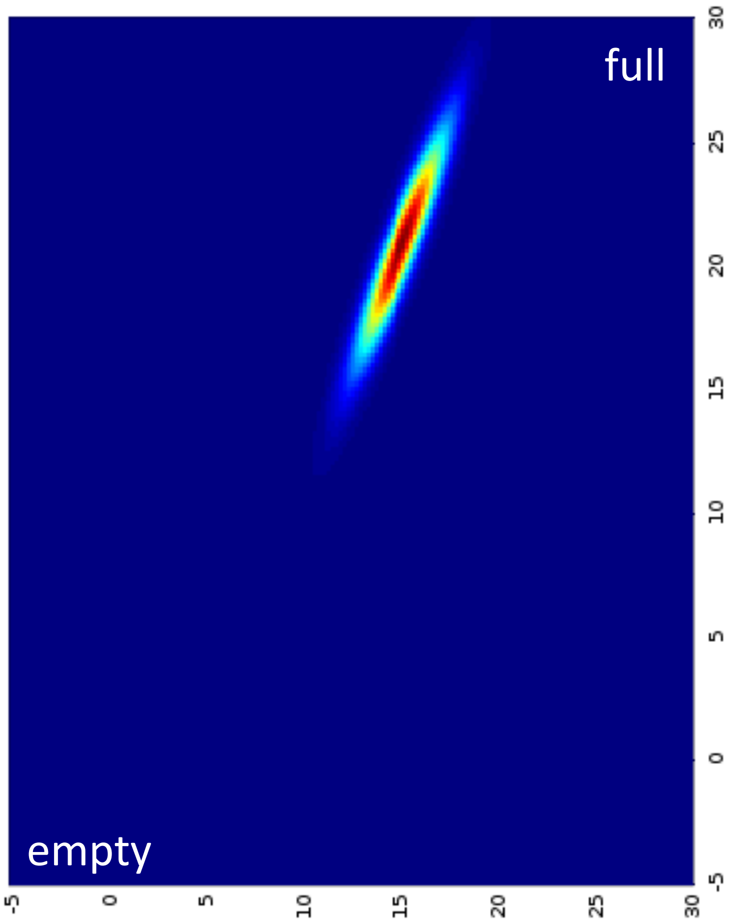


"Stochastic" KiBaM

Battery Kinetics

A



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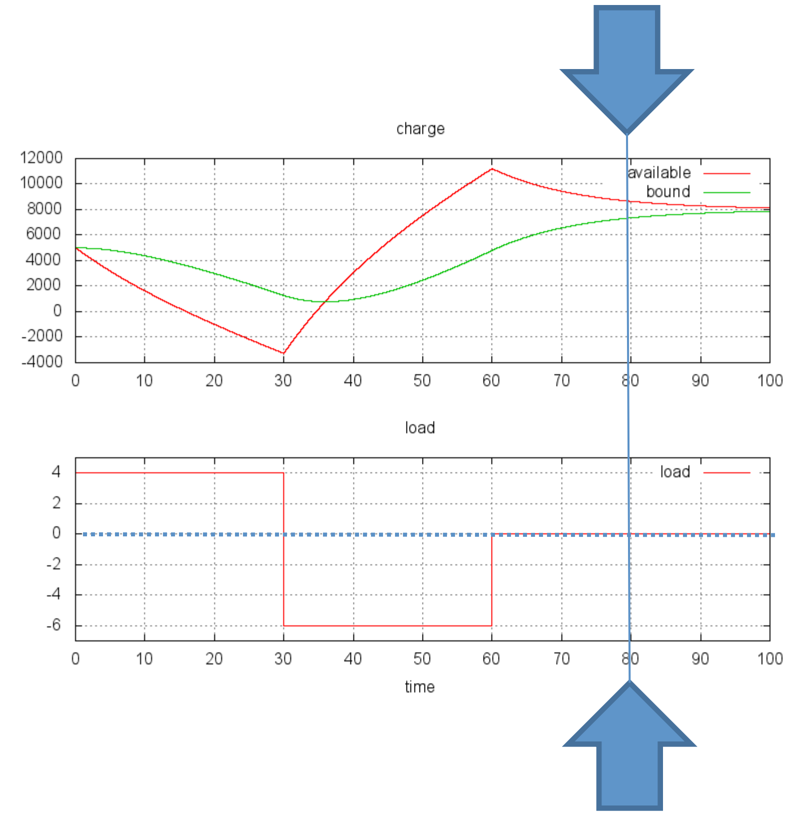
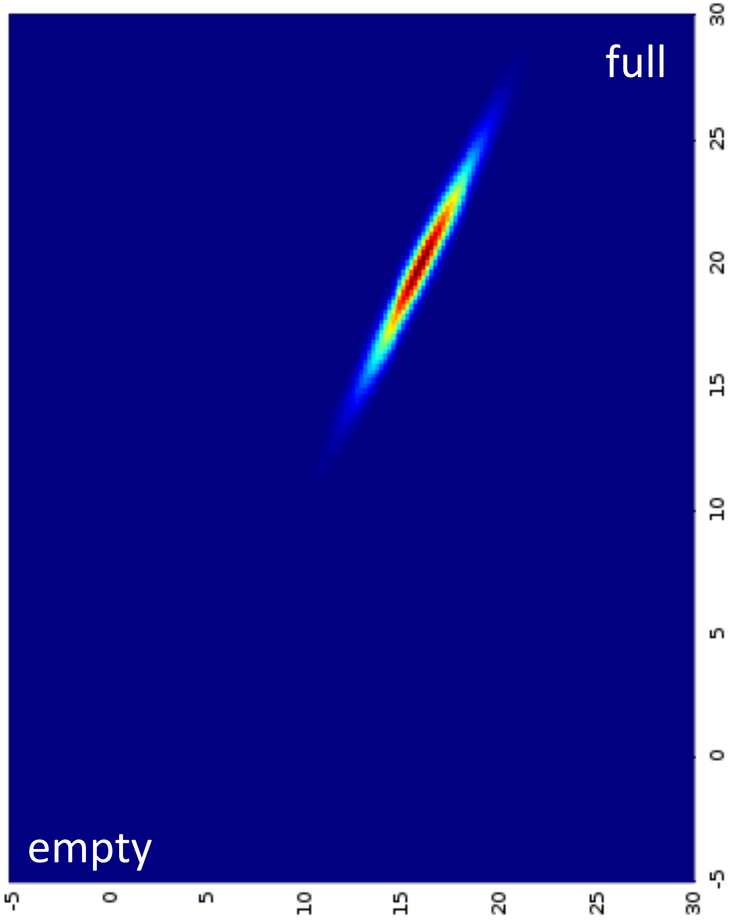


"Stochastic" KiBaM

Battery Kinetics

A



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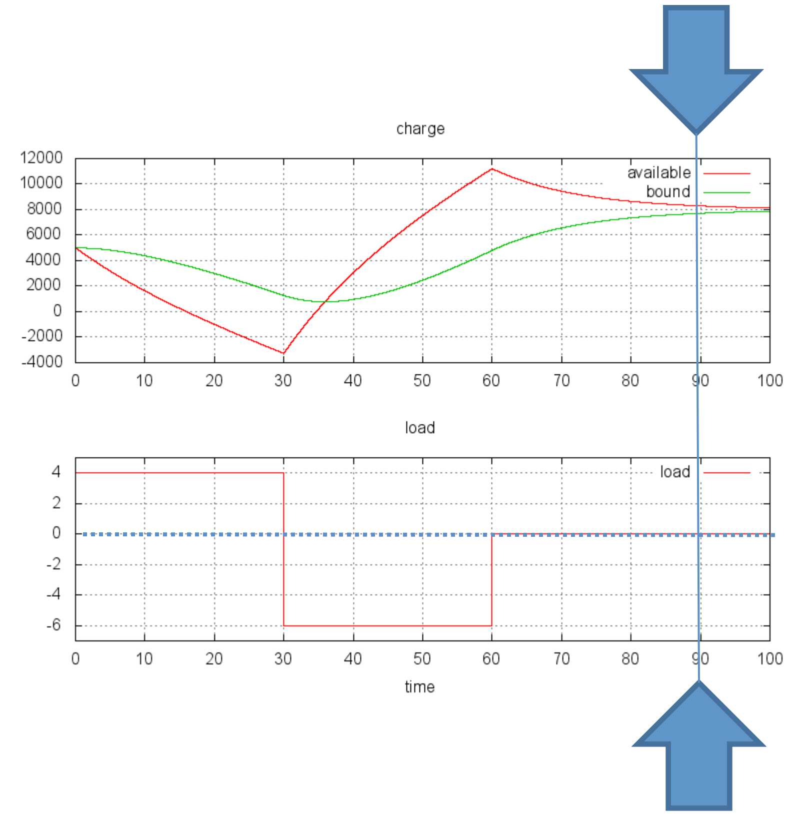


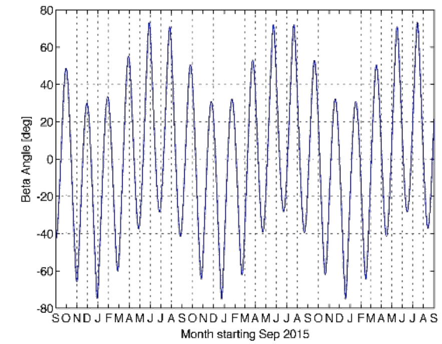
"Stochastic" KiBaM

- 2U CubeS
- Shipped i

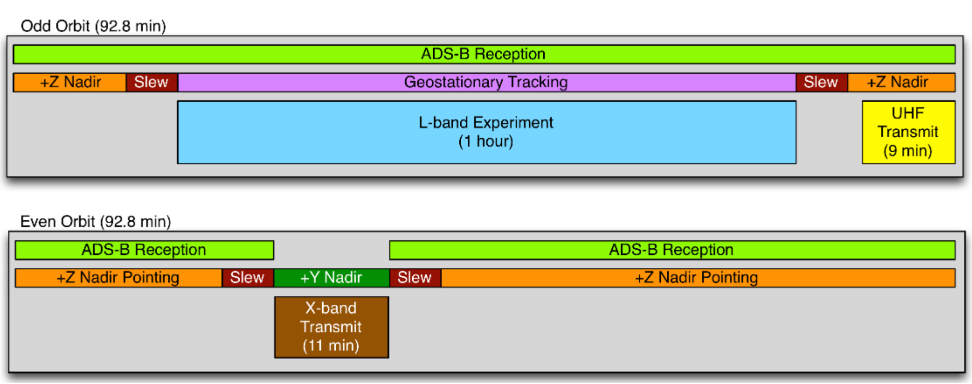
- Payloads:
  - Optical c
  - Highspeed UHF and SDR receiver
- Shipping failed after liftoff
- Satellite was recovered from wreckage and returned to manufacturer

SENSATION

GOMX-3 mission planning



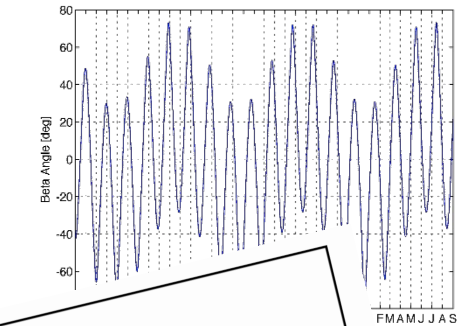
- Very tight power budget
- Needs dynamic and battery aware scheduling
- What we do:
  - Priced Timed Automata modelling with linear battery
  - Generate optimal schedules for 1 week or 1 day horizon
  - Evaluate schedules on "stochastic" KiBaM for robustness
  - Send to orbit, observe behaviour, update model

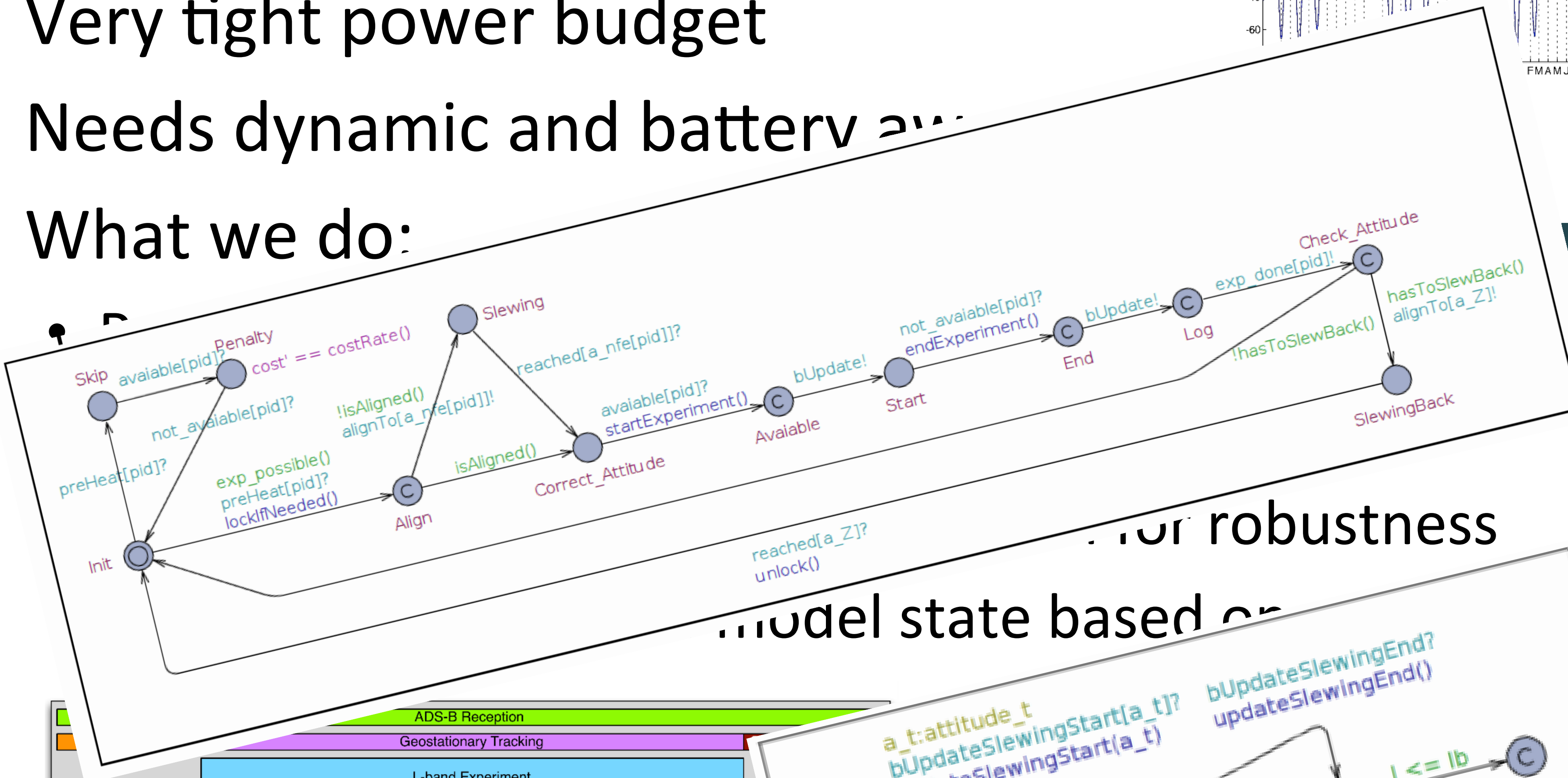


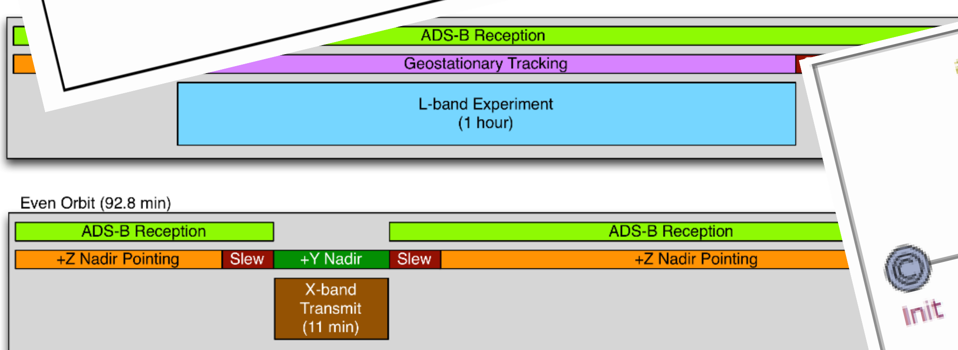
SENSATION

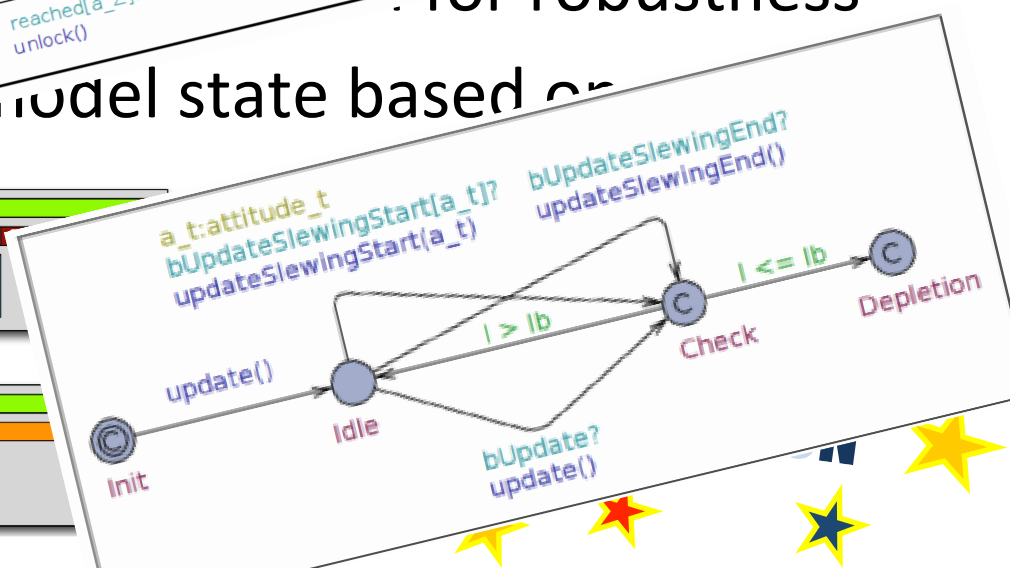
GOMX-3 mission planning

- Very tight power budget
- Needs dynamic and battery aw
- What we do:
  - ...for robustness
  - ...model state based on

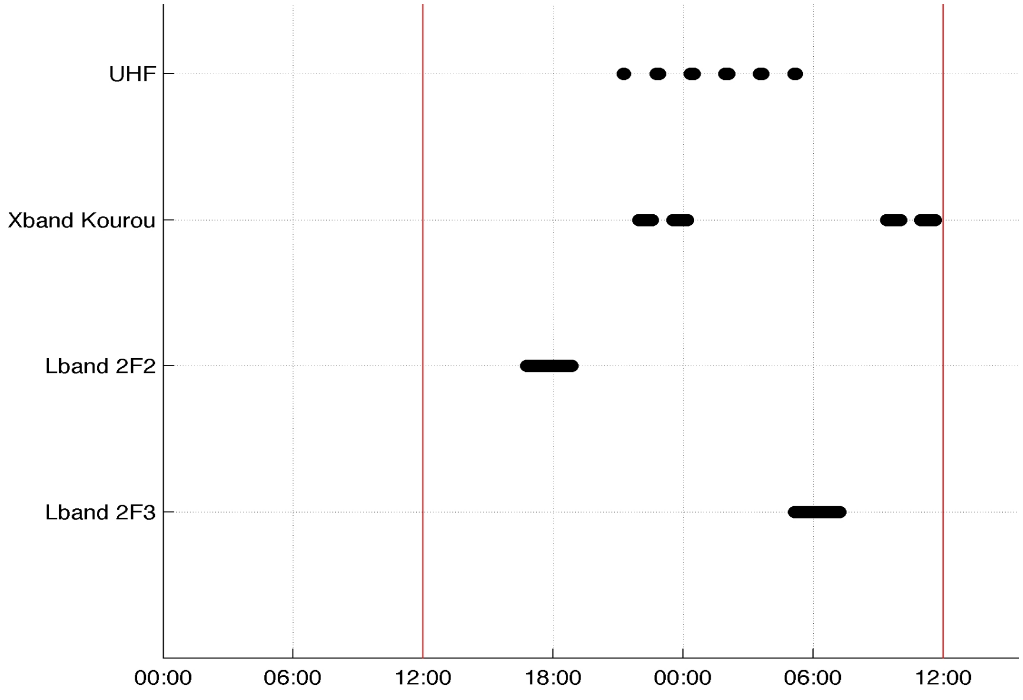


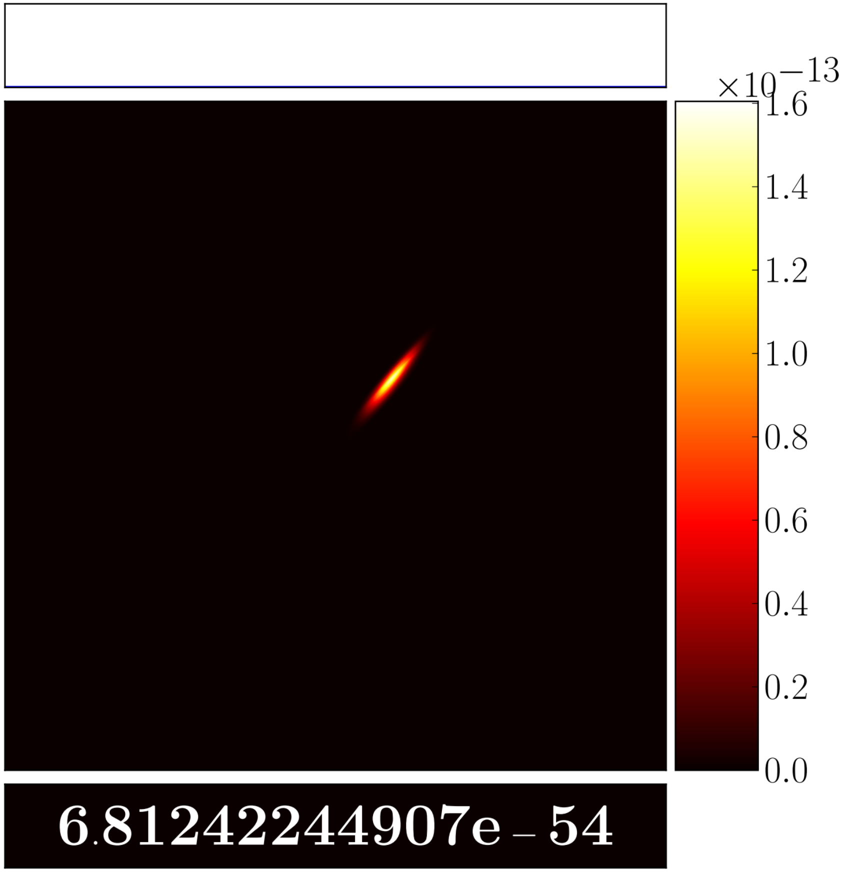






A one-day schedule

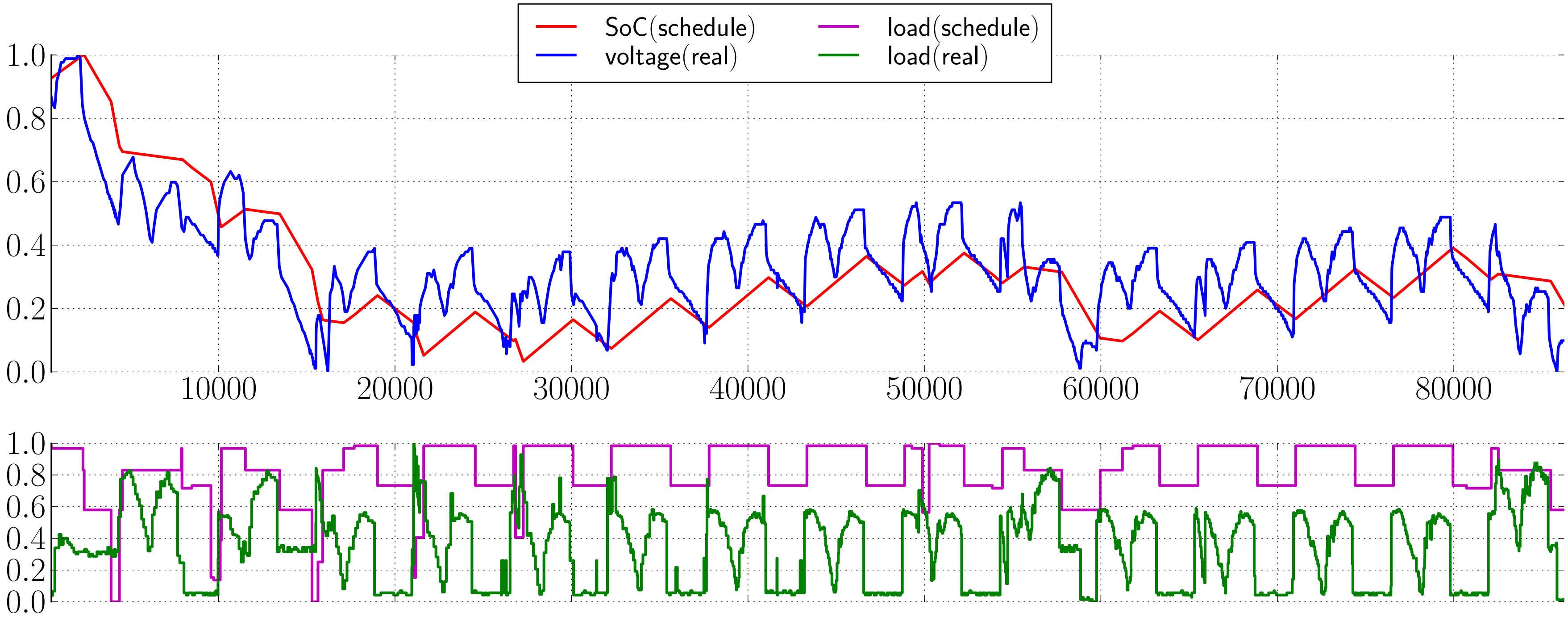




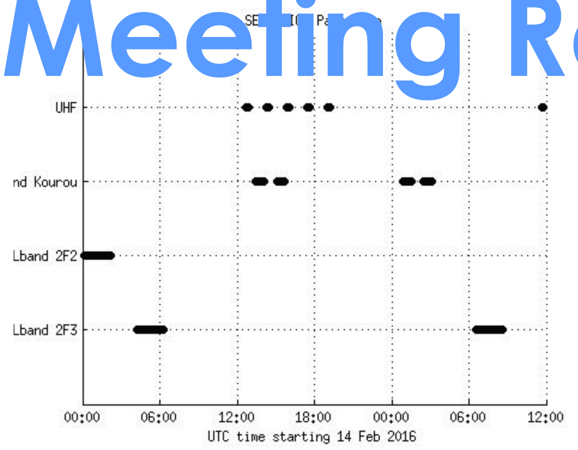
and its depletion risk

SENSATION

Meeting Reality, Safely



Meeting Reality



On-line and Compositional Learning of Controllers

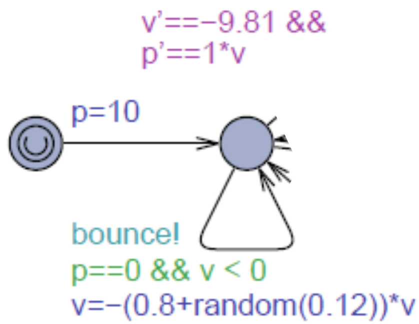
with Application to Floor Heating

Kim G. Larsen, Marius Mikucionis, Marco Muniz, Jiri Srba, Jakob H. Taankvist

Aalborg University, DK

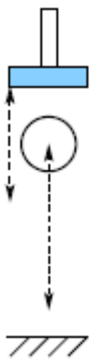
Stochastic Hybrid Systems

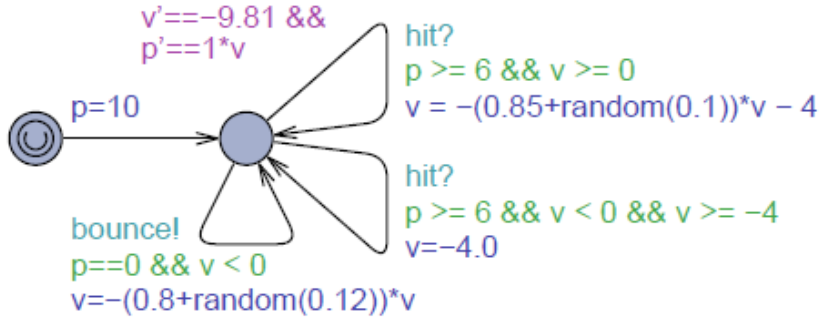
- A Bouncing Ball



Stochastic Hybrid Systems

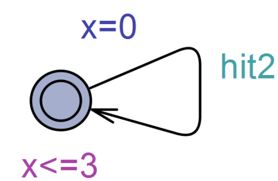
- A Bouncing Ball





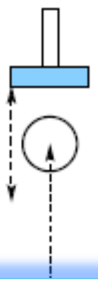
Player 1

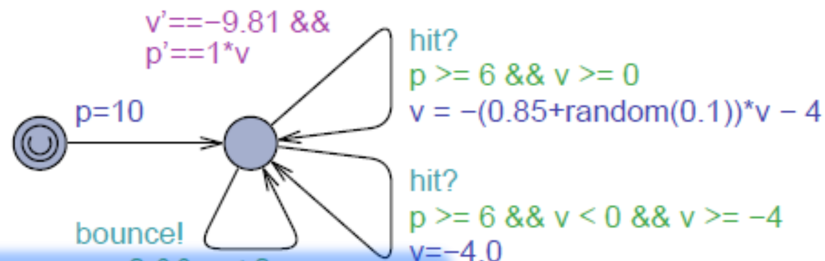
Player 2



Stochastic Hybrid Systems

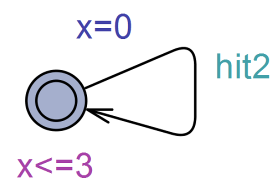
- A Bouncing Ball

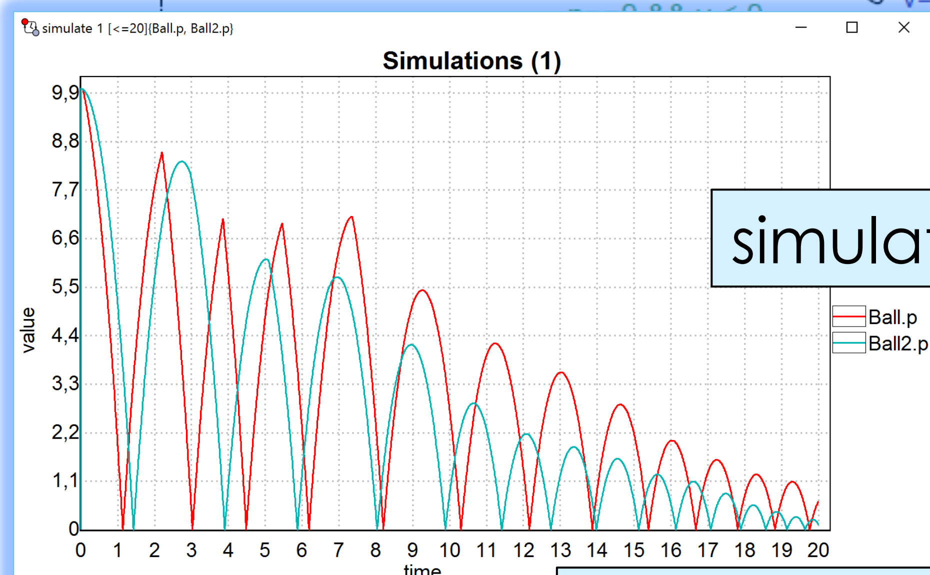




Player 1

Player 2

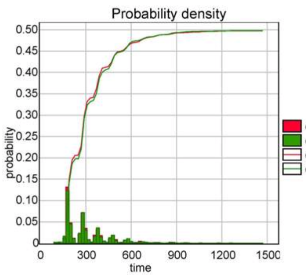


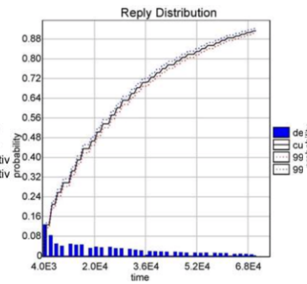


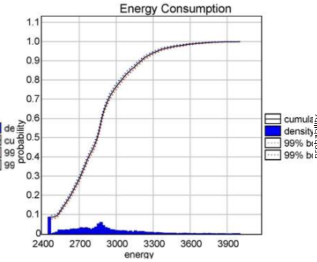
simulate 1 [<=20]{Ball1.p, Ball2.p}

Pr[<=20](<>(time>=12 && Ball1.p>4))

Other Applications

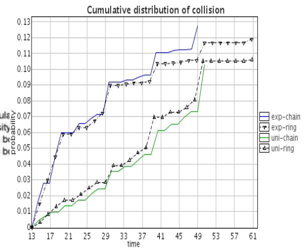


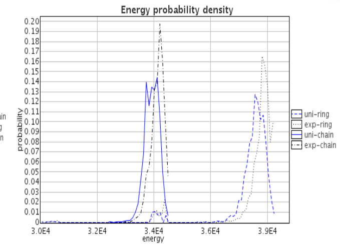




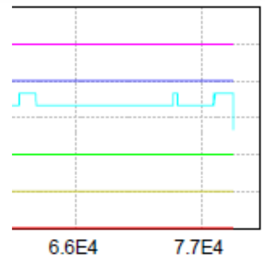
FIREWIRE

BLUETOOTH

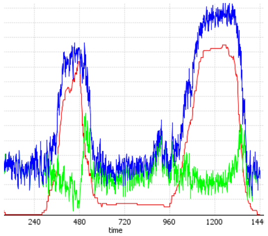




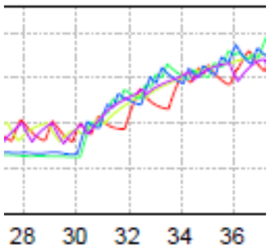
10 node LMAC



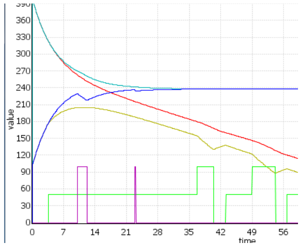
Schedulability Analysis for Mix Cr Sys



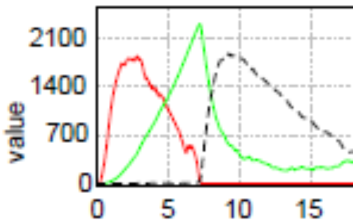
Smart Grid Demand / Response



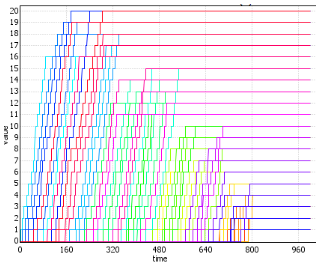
Energy Aware Buildings



Battery Scheduling



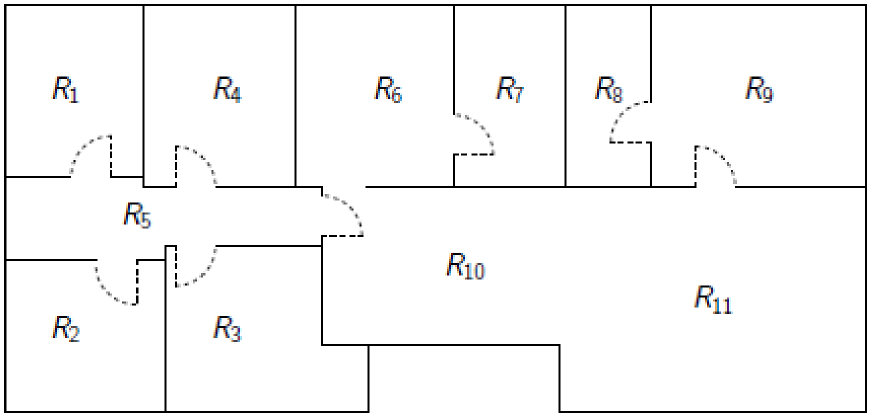
Genetic Oscilator (HBS)



Passenger Seating in Aircraft

Floor Heating Scenario

- Each room has a hot water loop that can be opened/closed
- Loops are controlled via activating / deactivating valves.
- Rooms equipped with wireless temperature sensors (report every 15 minutes).
- Each room has its user-defined target temperature.

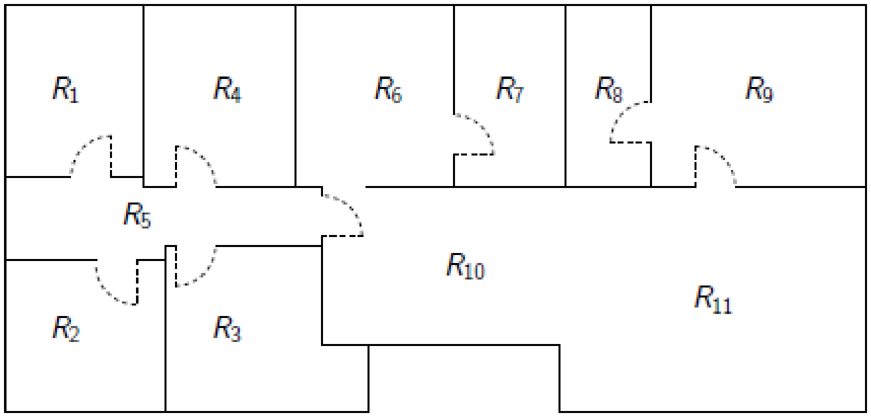


Control Task:

maintain room temperatures as close as possible to target temperatures

Additional Factors and Restrictions

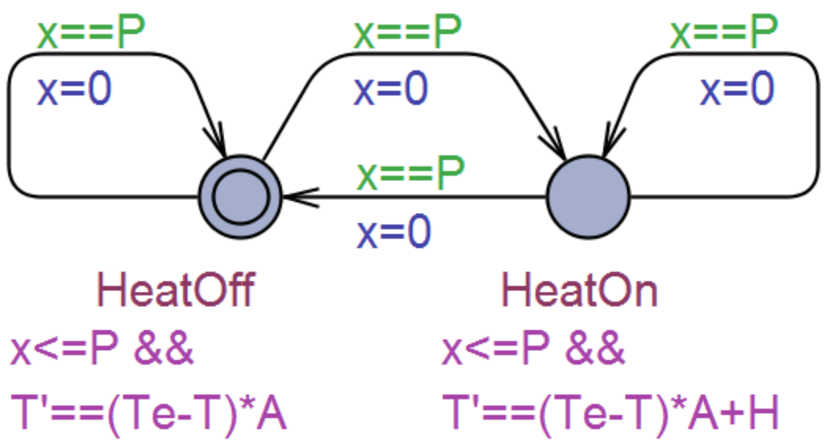
- Heat exchange among the rooms (influenced by the door positions).
- Pipes are traversing under several rooms.
- Outside temperature and weather forecast.
- Capacity of the heating system.
- Temperature user-profiles for the different (groups of) rooms.



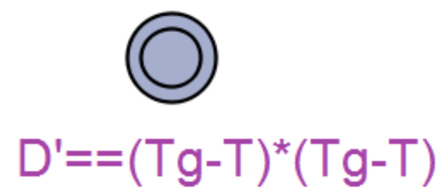
Control Task:
maintain room temperatures
as close as possible to target temperatures

1-Room / 1-Window Game

Room

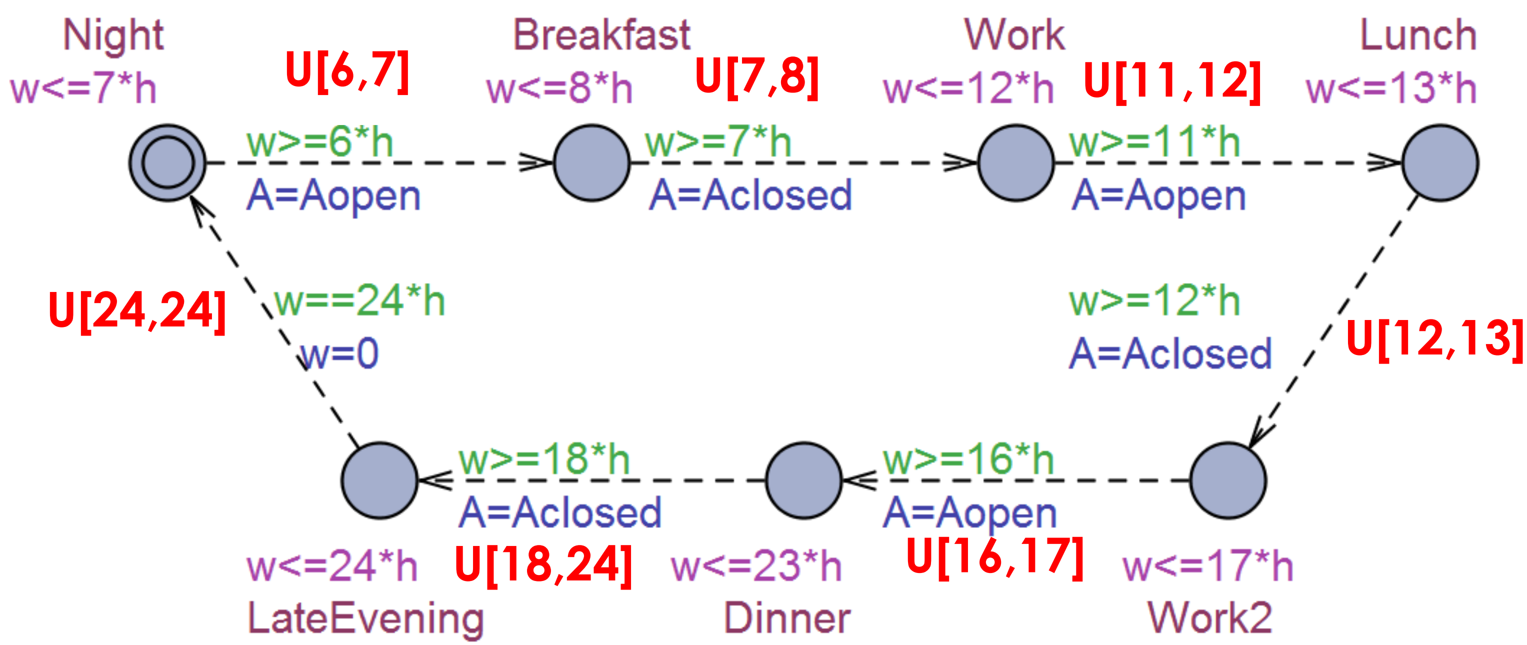


Monitor




```
const double Tg = 21.0; // room temp. goal
const double Te = 15.0; // environment temp.
const double H = 0.04;  // power of heater
const double Aclosed = 0.002; // heat loss when window closed
const double Aopen = 0.004;   // heat loss when window open
const int P = 15; // heater switching period
const int h = 60; // 1 hour = 60 time units
```

1-Room / 1-Window Game

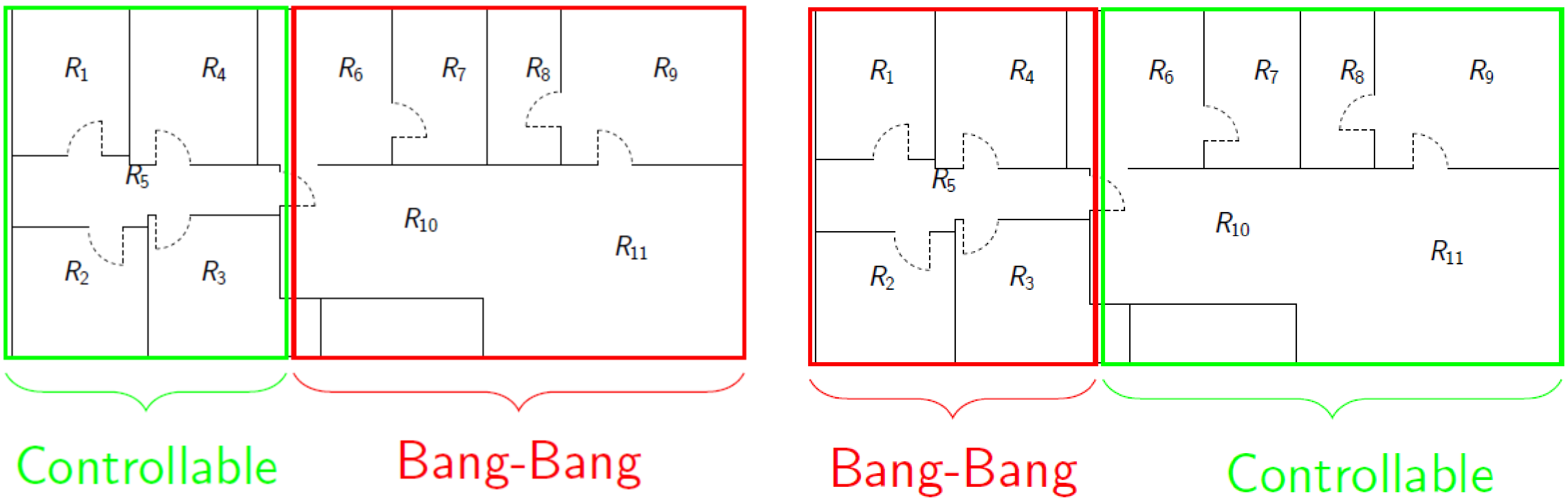


Window

Find strategy σ that minimizes **expectation** of

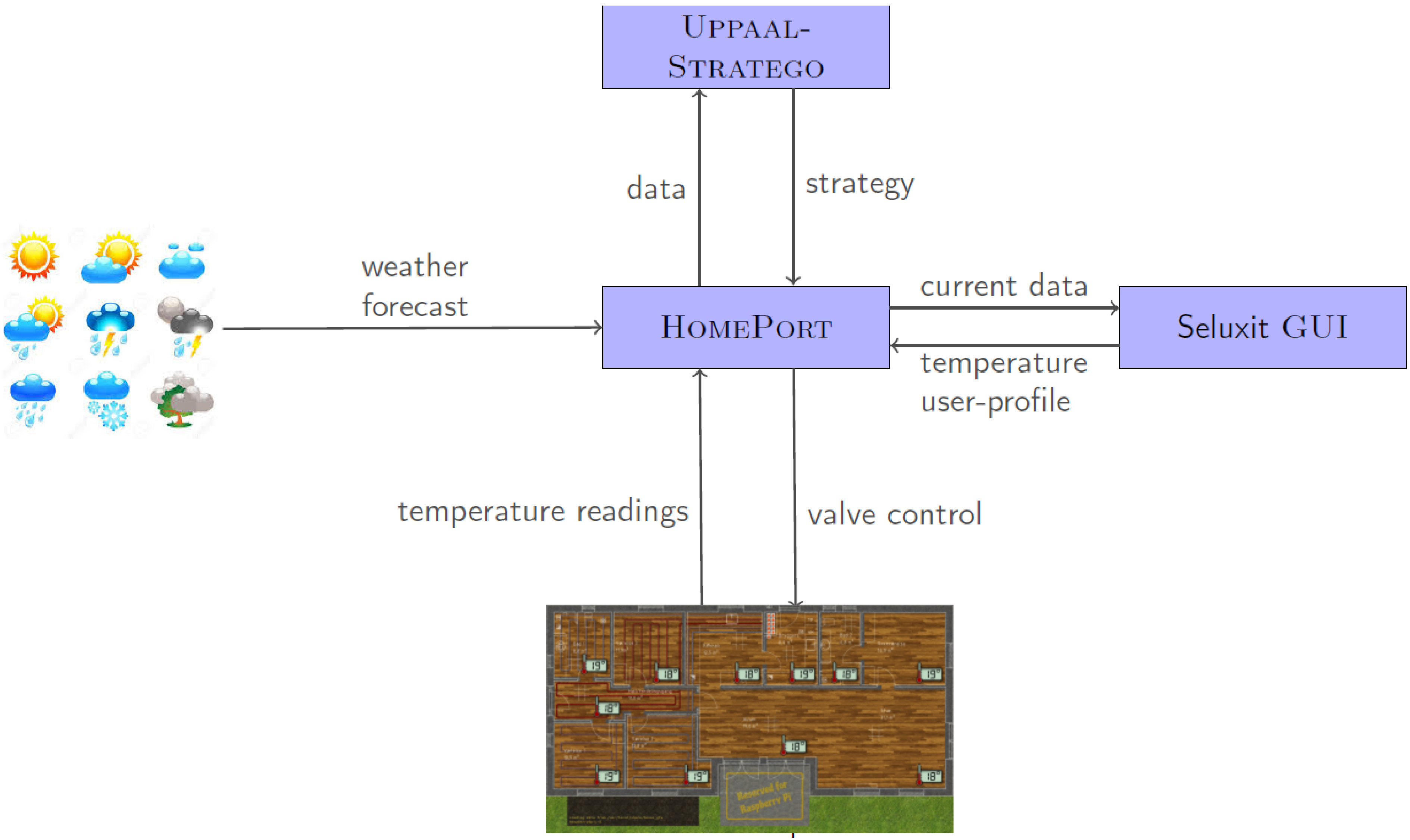
Compositional Synthesis

- Split the valves into controllable and fixed (controlled via Bang-Bang)
- Synthesize a strategy for controllable valves
- Swap the controllable and fixed valves and synthesise another strategy
- Merge strategies.



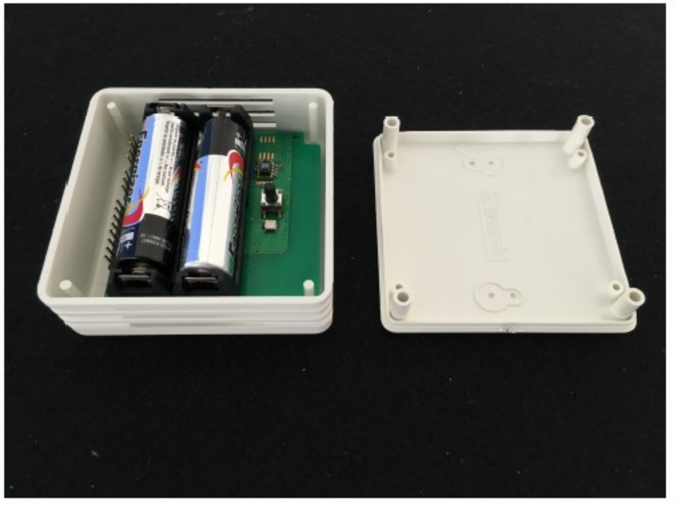
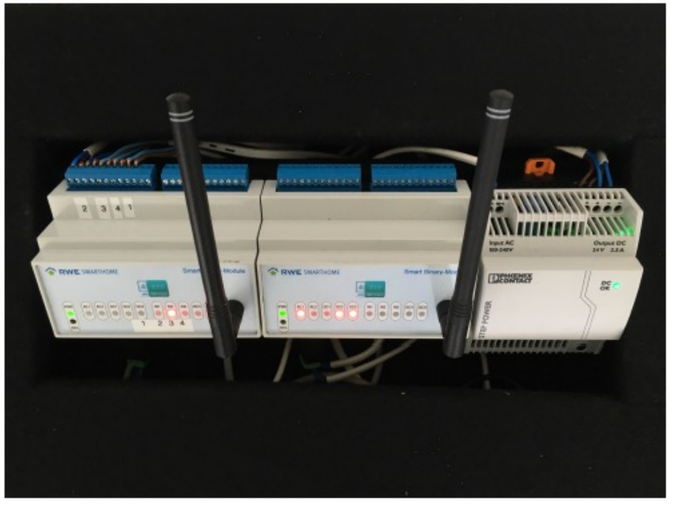
$(2^{5h} + 2^{6h})$ instead of 2^{11h} decision choices
(in our case h=3)

Latest News



UPPAAL-STRATEGO
data
strategy
weather forecast
HOMEPORT
current data
Seluxit GUI
temperature user-profile
temperature readings
valve control

Latest News


Hall/fordelingsgang
11,0 m²
19°
20.8°
Værelse 2
12,8 m²
Værelse 1
10,9 m²
22°
17.8°
22°
22.1°


RWE SMARTHOME
RWE SMARTHOME

1
2
3
4

Latest News

3 day scenario

Weather	Distance			Energy		
	Bang-Bang	Stratego	imp.	Bang-Bang	Stratego	imp.
Aalborg	14583	8342	**43%**	14180	12626	**10%**
Anadyr	2385515	1483272	**37%**	23040	22475	**2%**
Ankara	17985	10464	**41%**	17468	15684	**10%**
Minneapolis	22052	12175	**44%**	18165	15882	**12%**
Murmansk	399421	187941	**52%**	22355	21011	**6%**

Weather	Distance			Energy		
	Bang-Bang	Stratego	imp.	Bang-Bang	Stratego	imp.
Aalborg	14583	8552	**41%**	14180	12590	**11%**
Anadyr	2385515	1503448	**36%**	23040	22371	**2%**
Ankara	17985	10511	**41%**	17468	15697	**10%**
Minneapolis	22052	12725	**42%**	18165	15837	**12%**
Murmansk	399421	191441	**52%**	22355	20923	**6%**

Evaluation of under modified parameters (0-20%)