Safe Motion Planning under Partial Observability with an Optimal Deterministic Planner

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What is this about?

- **Safe motion planning:**
  Collision free

- **Partial observability:**
  Physical state is fully observable, agent intents are not

- **Optimal deterministic planner:**
  Time optimal plans that ignore partial observability

What is the motivation?

Properties	DP Solutions	ML Solutions	Physics Solutions	
Computational Tractability	✗	✓	✓	⎫
Model uncertainty	✗	✓	✗	⎬ Required
Hard safety constraints	✓	✗	✓	⎭
Completeness constraints	✓	✗	✗	
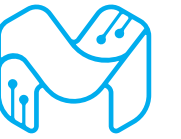
What is the motivation?

- **ML + Physics**
  Could satisfy all
  requirements

ML Solutions	Physics Solutions
✔	✔
✔	✘
✘	✔
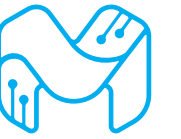
Required

What is the motivation?

- **ML + Physics** Could satisfy all requirements

- We show how to combine solutions while preserving safety

ML Solutions	Physics Solutions
✔	✔
✔	✖
✖	✔

Required

How does it work?

Axiom: If all agents, at all times, possess at least one contingency plan, collision can always be avoided.

How does it work?

Assumption: All agents will invoke a contingency plan rather than enter a state where one is not available
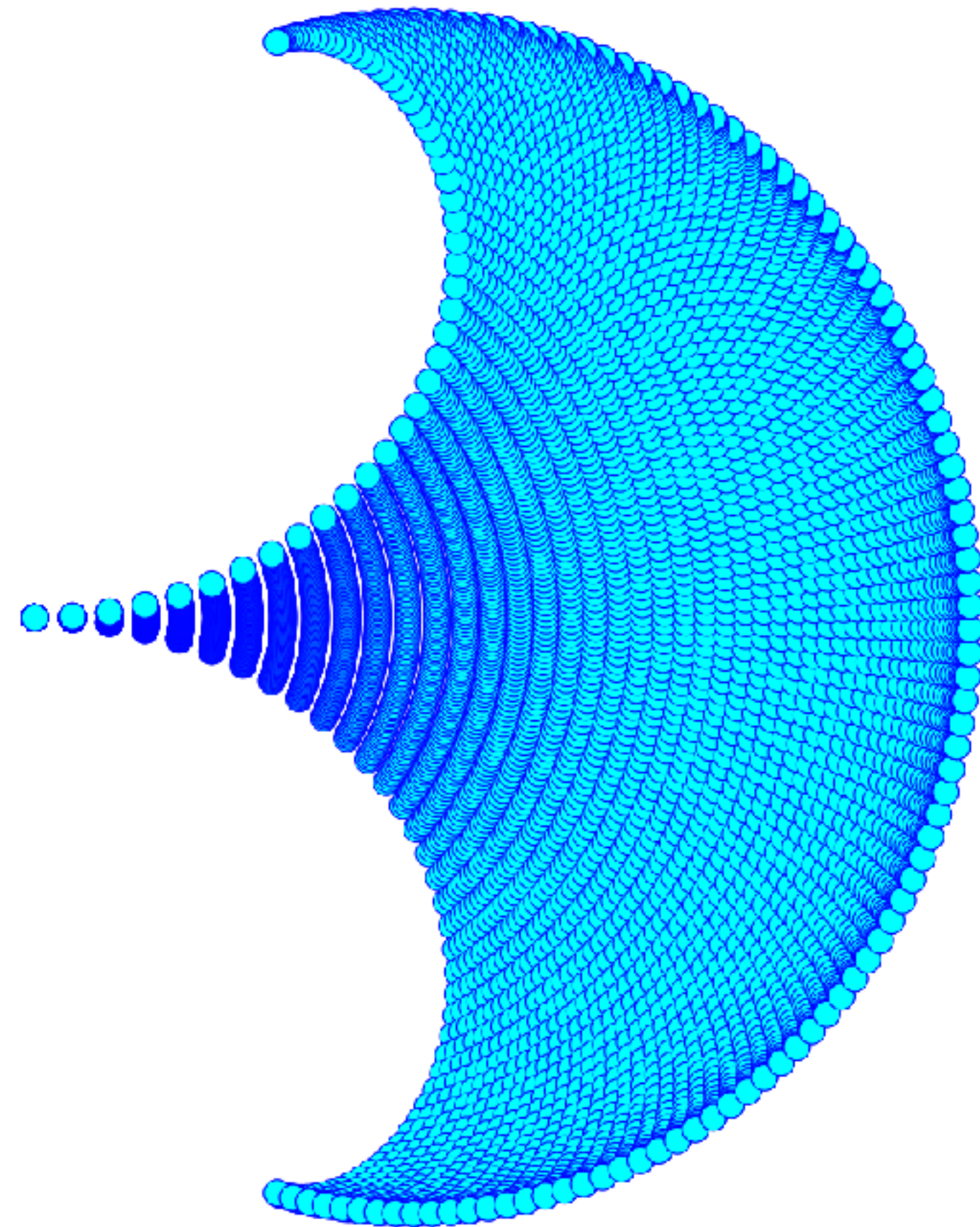
How does it work?

Axiom + Assumption =
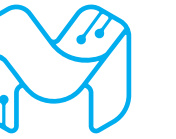No collisions, guaranteed*

*Guarantee not valid outside a lab environment, some restrictions may apply
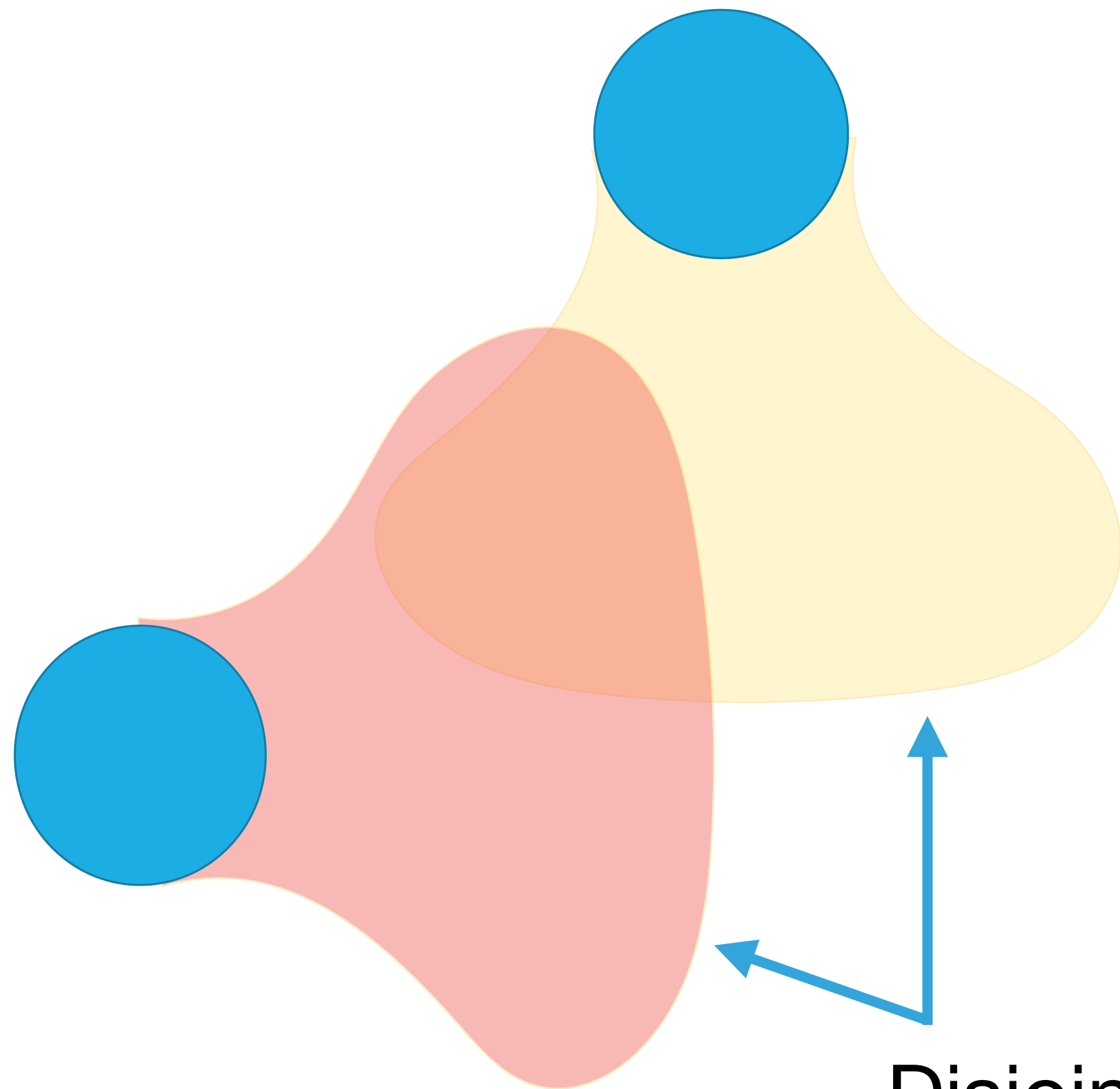
The 'Stopping Region' concept

- Set of min-time stopping paths

- Independent of action choice

- Independent of agent interactions
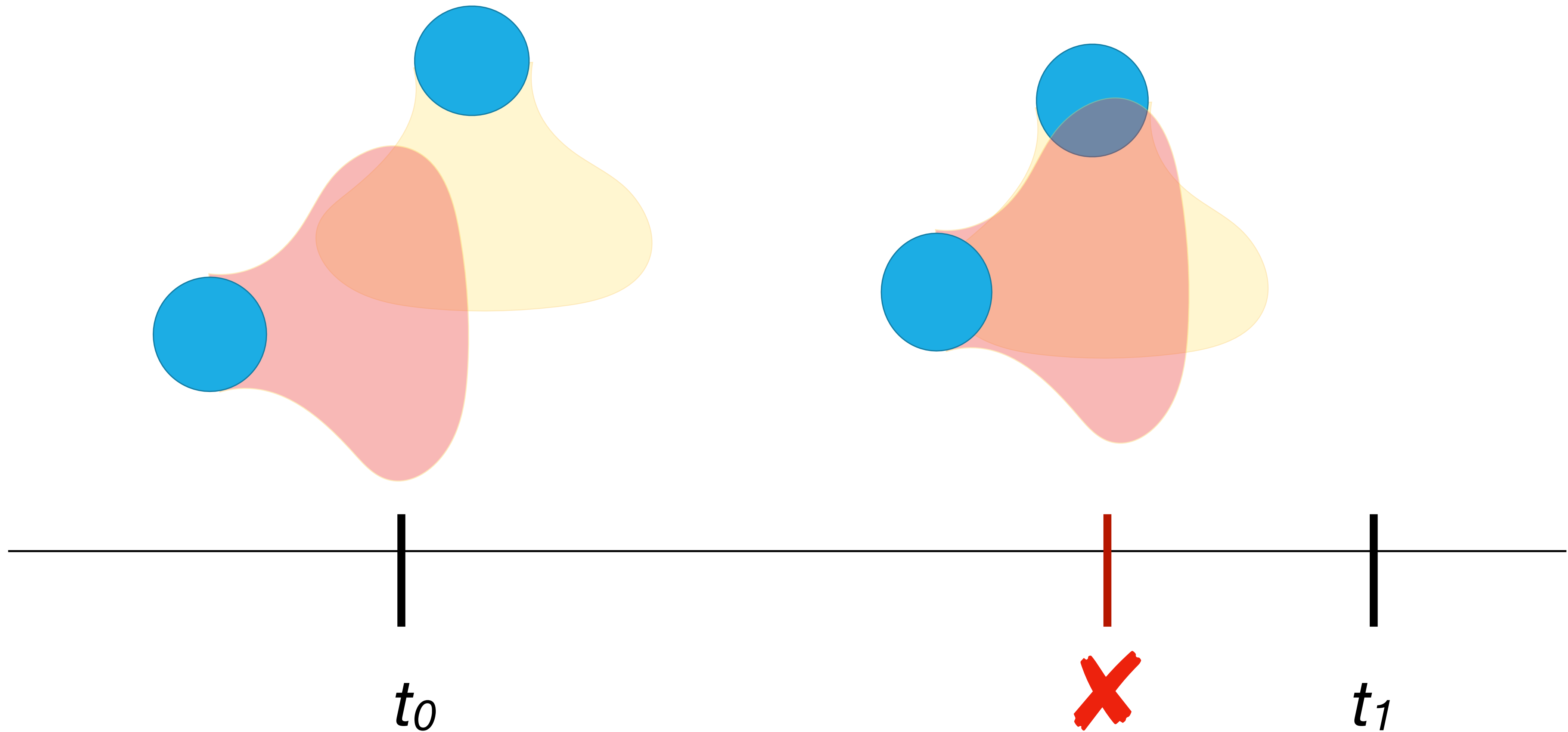
- Independently computable

Stopping regions as contingency sets

- Compute intersection

- If non-empty, contingency available
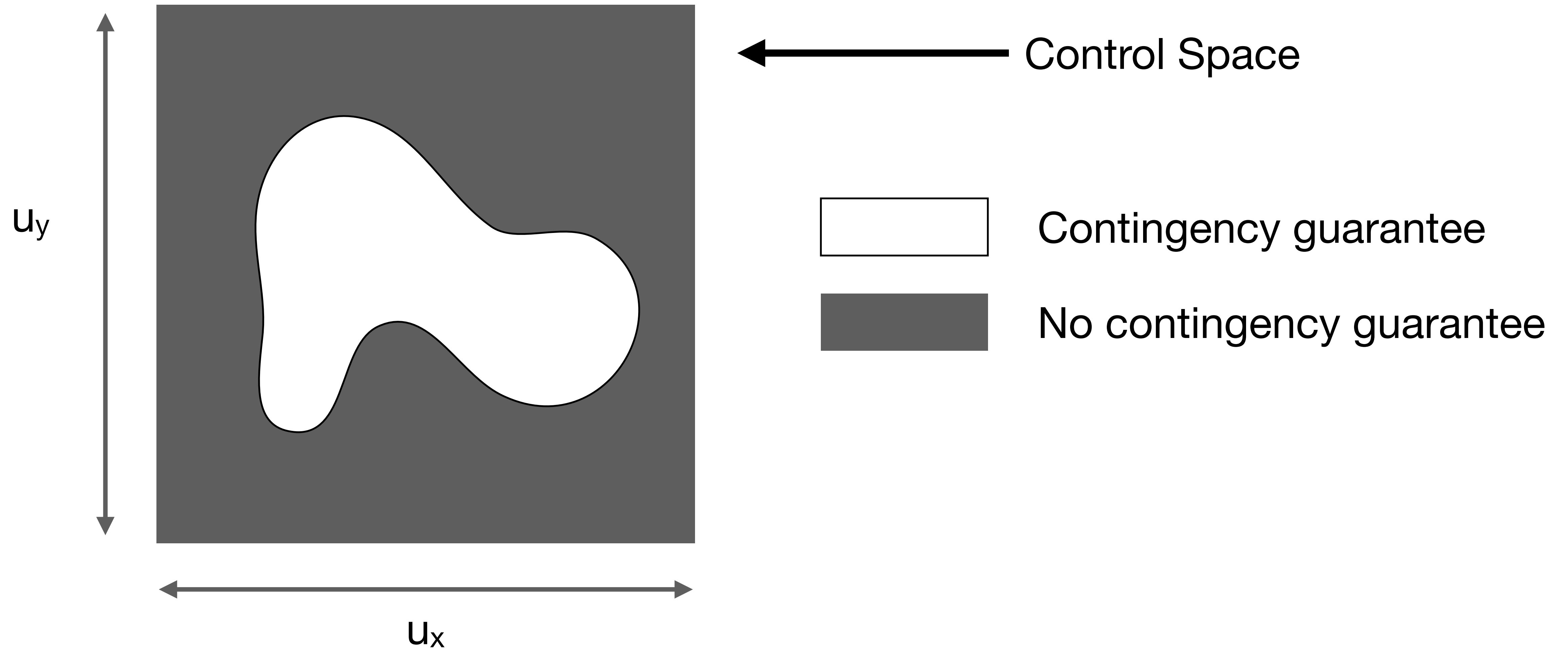
- Collision can be avoided

Disjoint paths exist

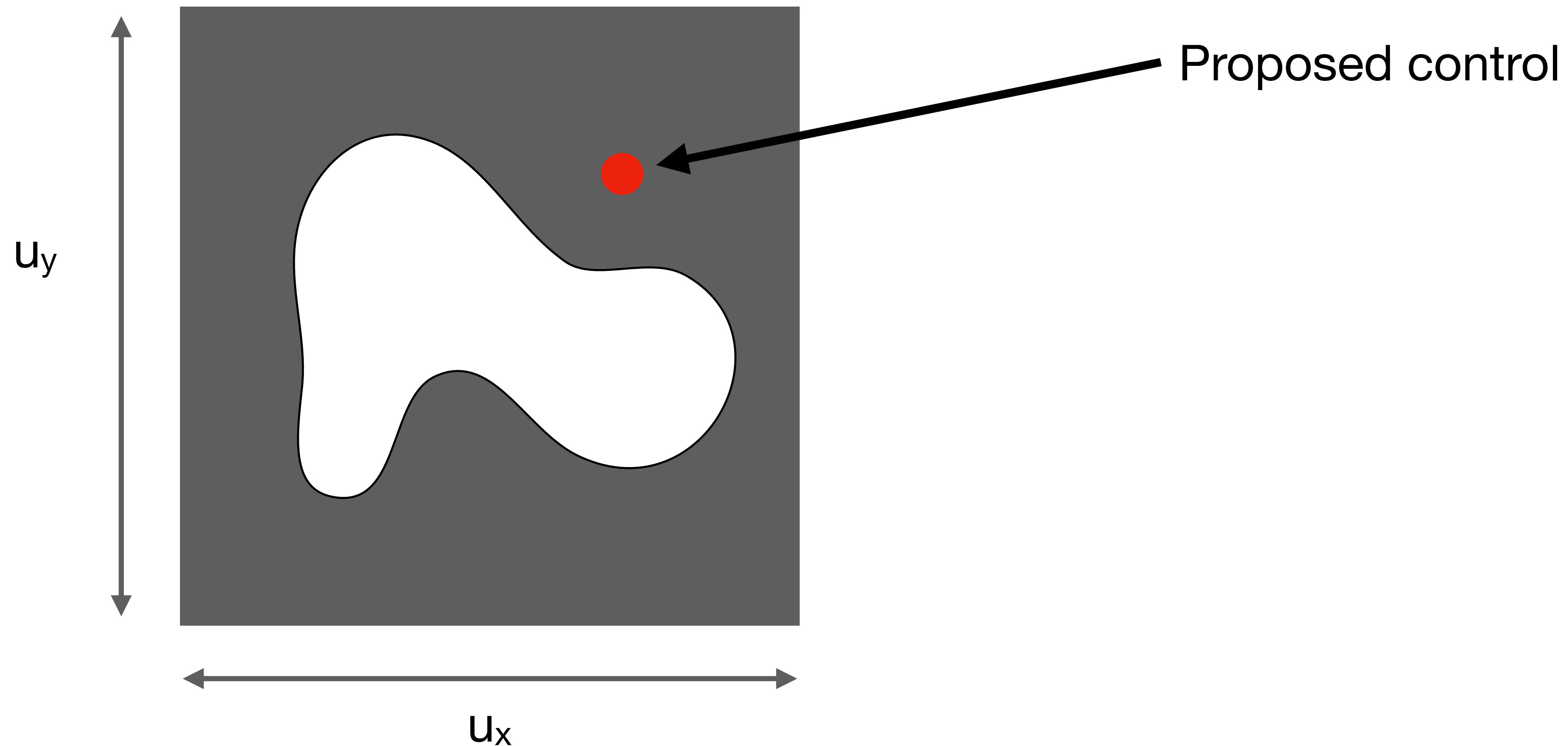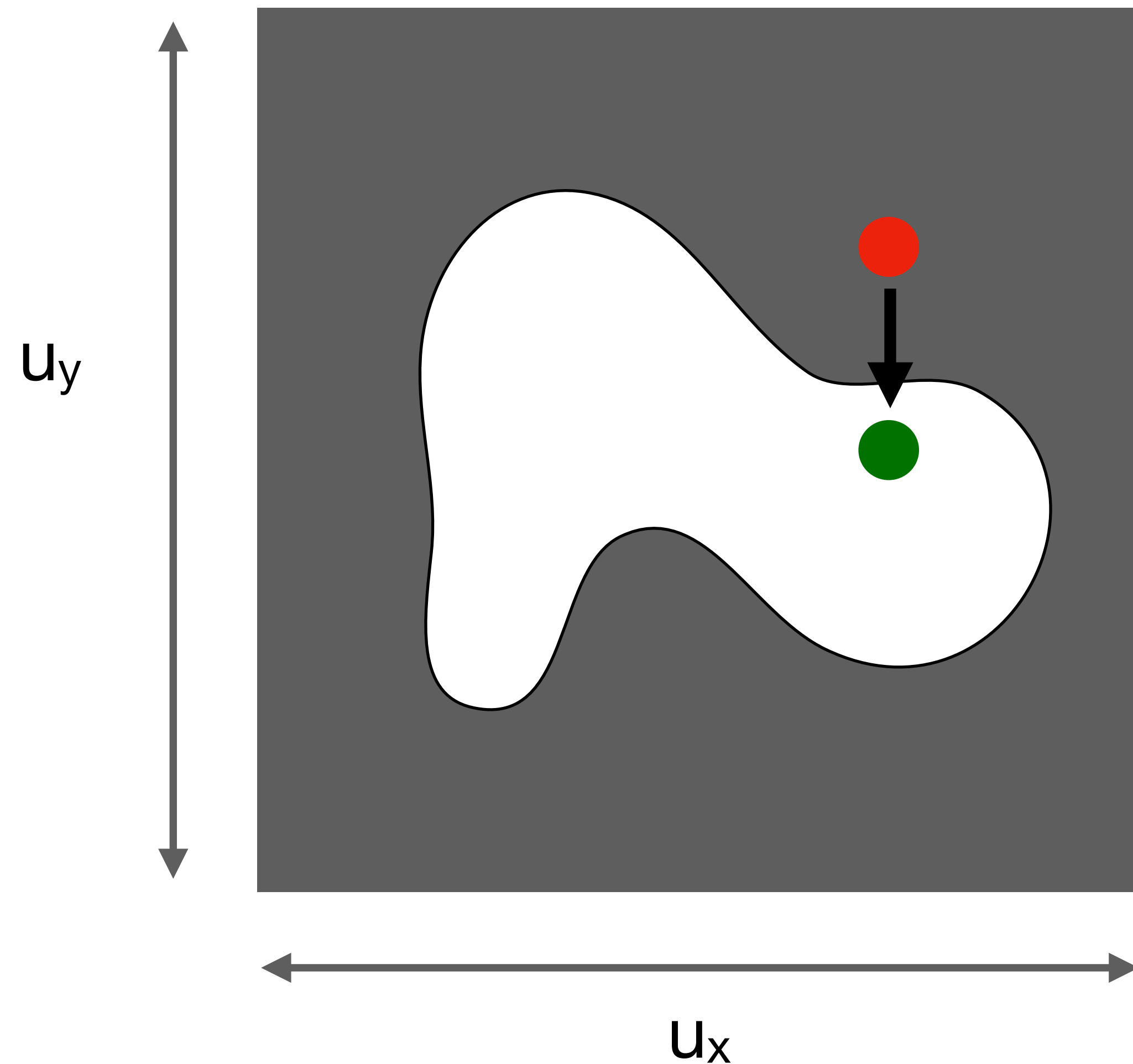# How to deal with discrete time control?

Contingency-preserving control sets

u_y

u_x

Control Space

Contingency guarantee

No contingency guarantee

We have contingencies, now what?

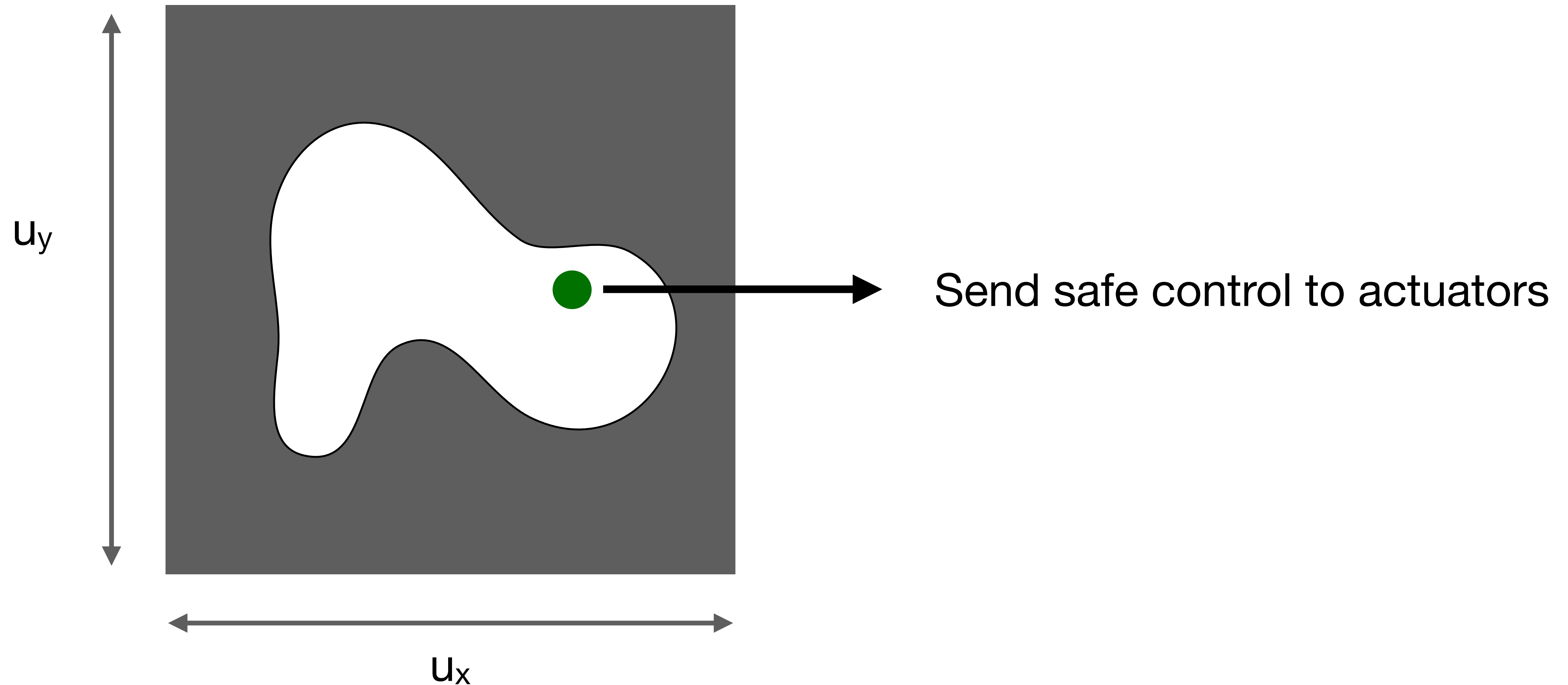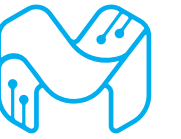Proposed control

u_y

u_x

We have contingencies, now what?

Project proposal into safe set
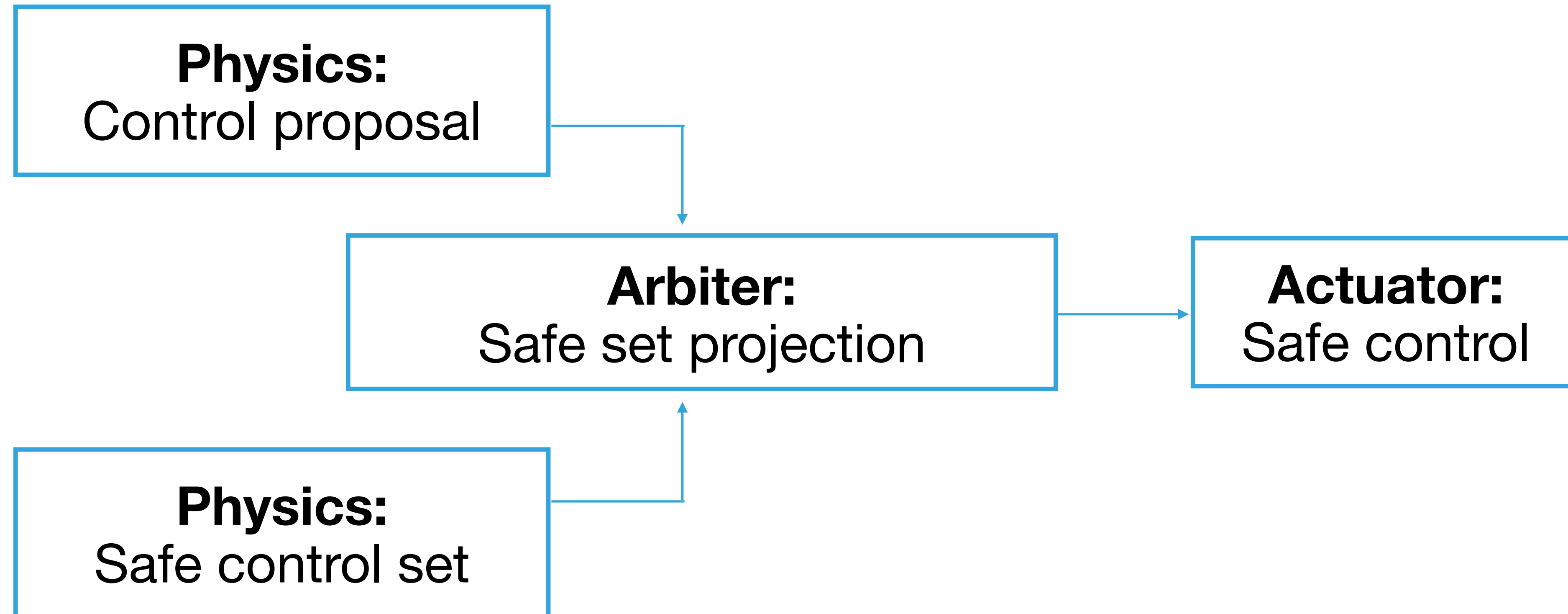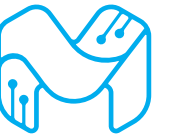
We have contingencies, now what?

u_y

u_x

Send safe control to actuators

Where does the proposal come from?

?:
Control proposal

Arbiter:
Safe set projection

Actuator:
Safe control

Physics:
Safe control set
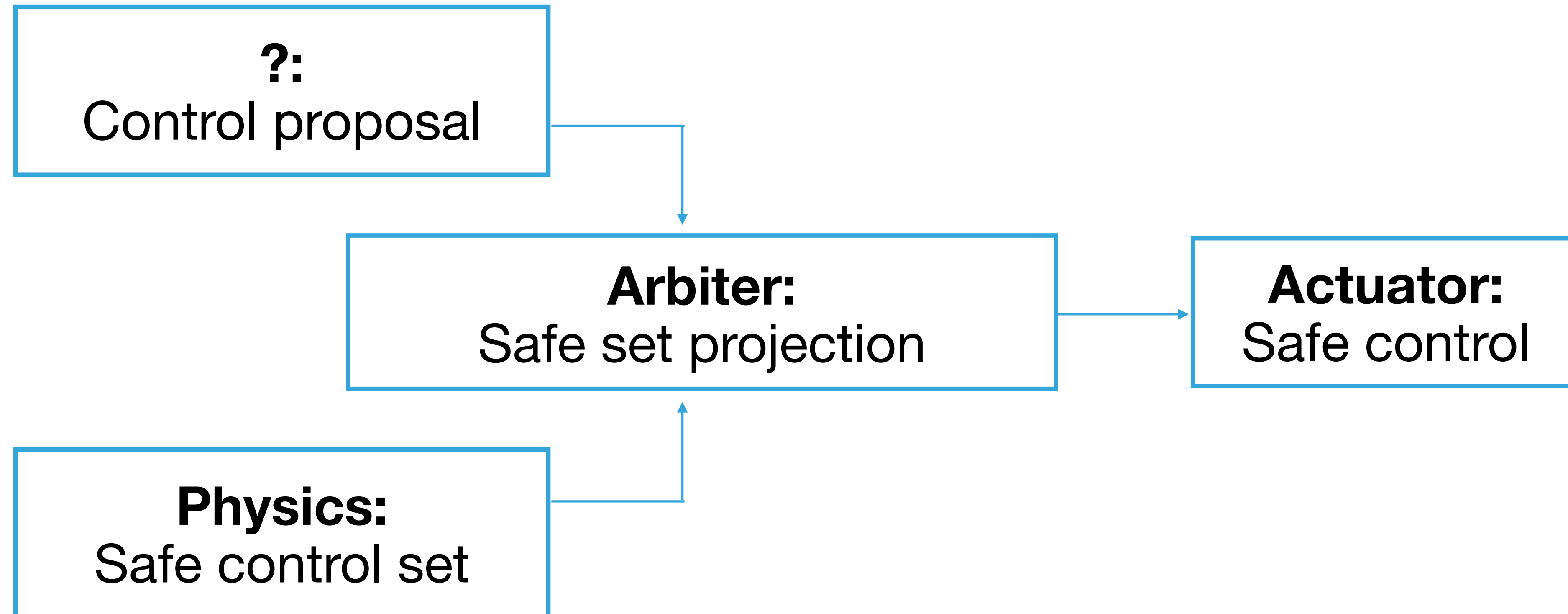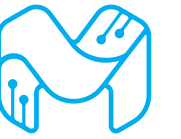
Where does the proposal come from?

Where does the proposal come from?

Machine Learning:
Control proposal

Arbiter:
Safe set projection

Actuator:
Safe control

Physics:
Safe control set
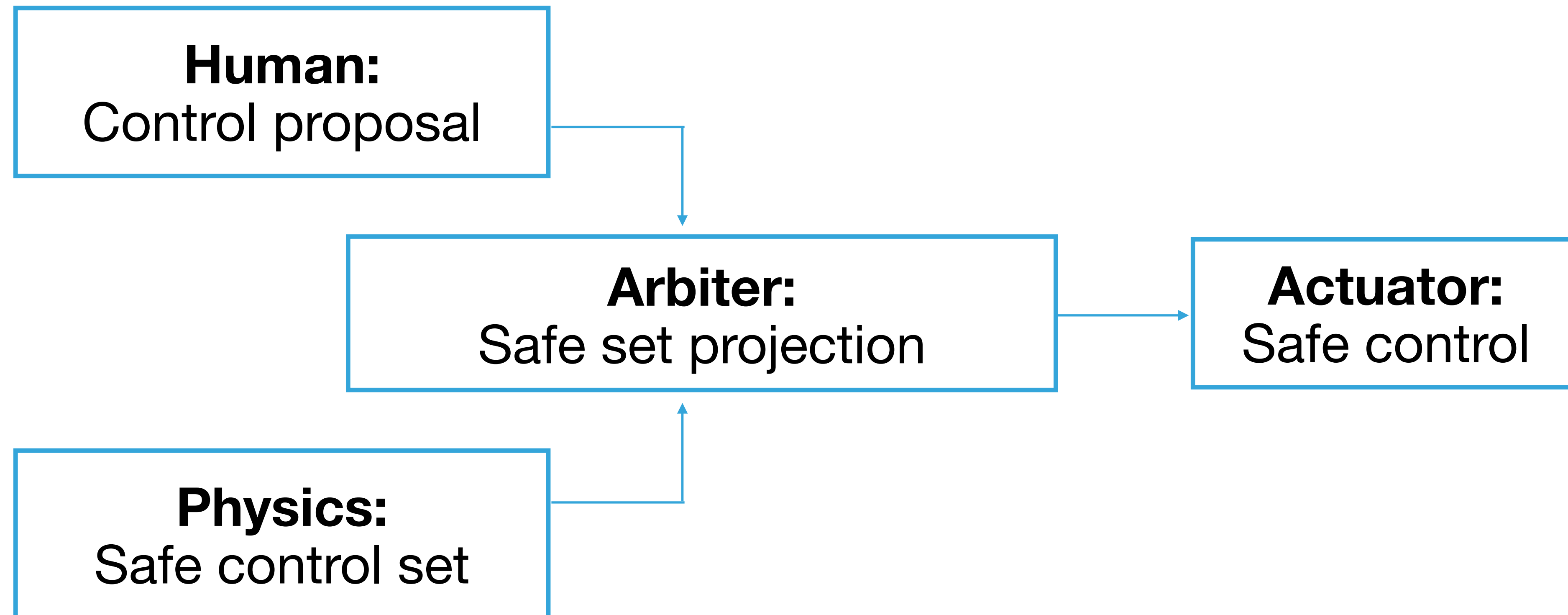
Where does the proposal come from?

Human:
Control proposal

Arbiter:
Safe set projection

Actuator:
Safe control
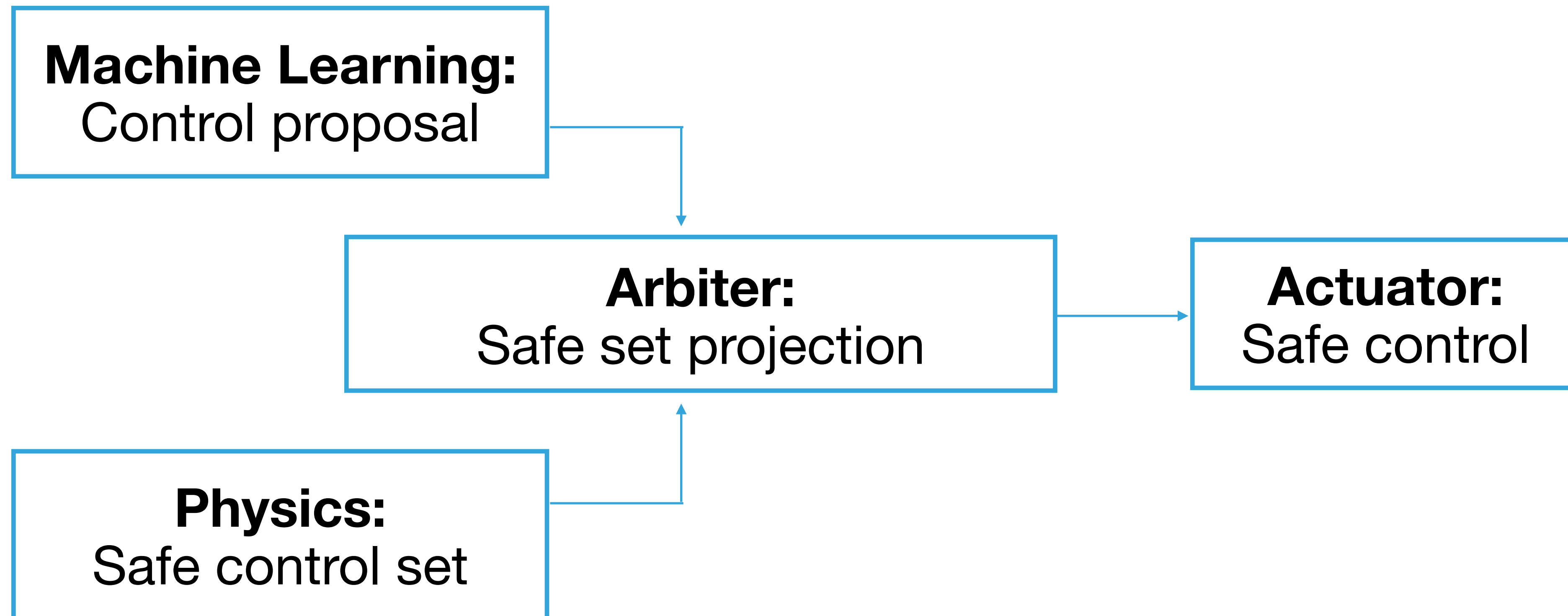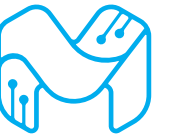
Physics:
Safe control set

The best of both worlds

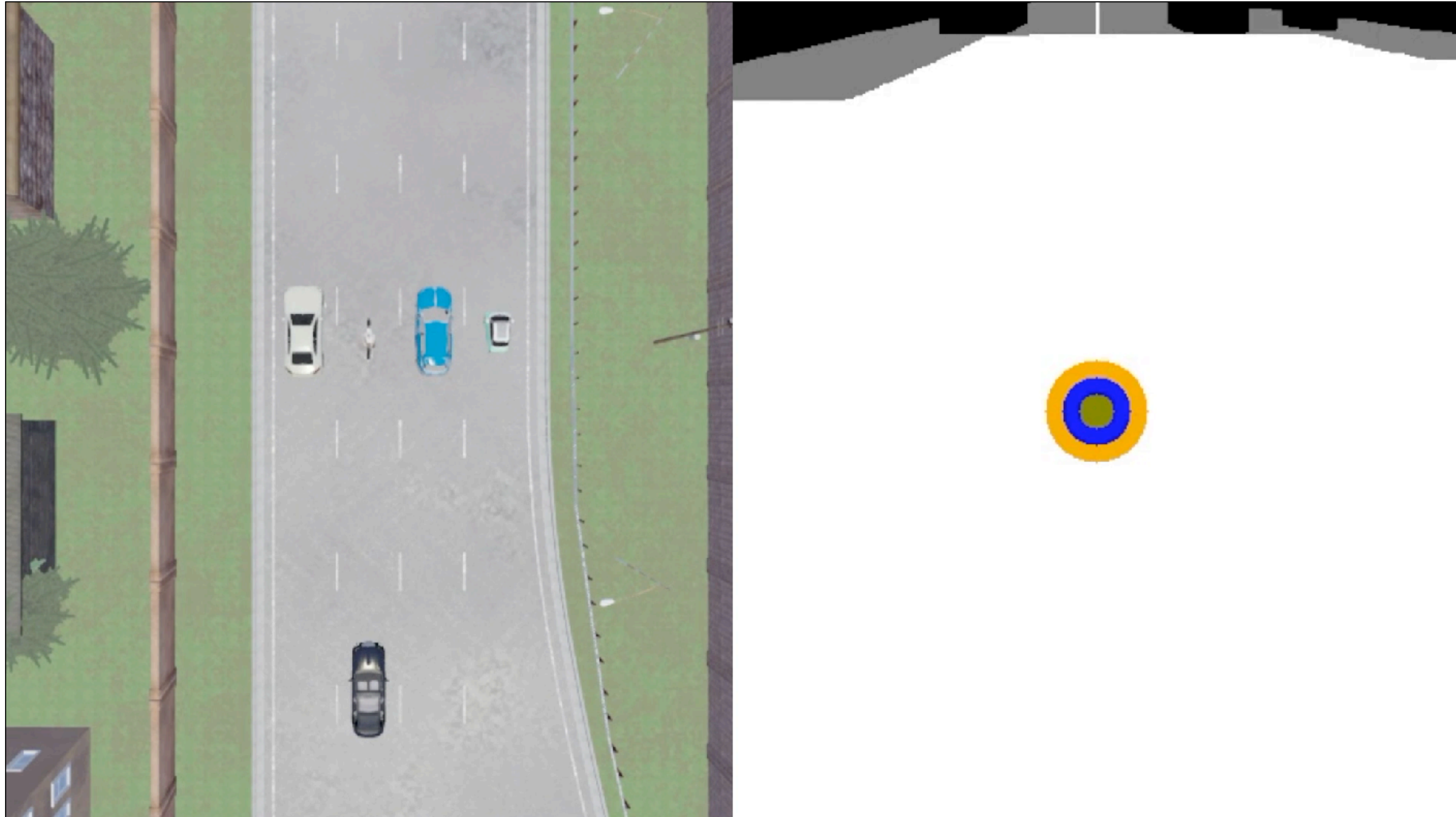| Properties	Physics Solution + Other
Computational Tractability	✔️
Model uncertainty	✔️
Hard safety constraints	✔️
Hard process constraints	❌

} Required

What does this look like?
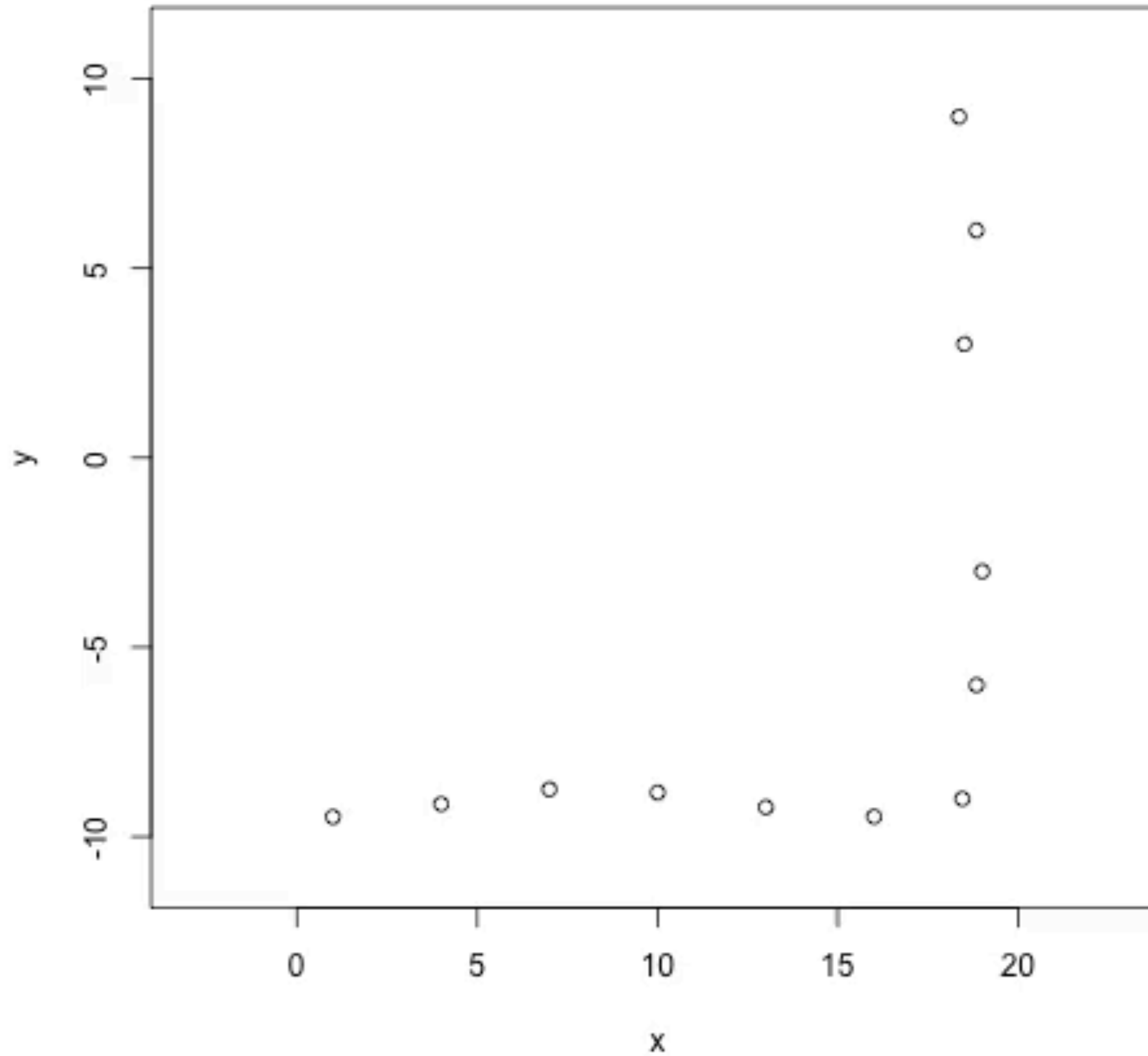
What does this look like?

About that asterisk...

- **Observable physical state is strong assumption**

- **Real concern is shared contingency strategy**

- **Our work is not quite done.**

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