The Causal Future

Intelligent Strategies for Managing Space Debris

esa | epistemology

James Ward

Founder and CEO of Epistemology
(Artificial Intelligence startup - Causal Science)

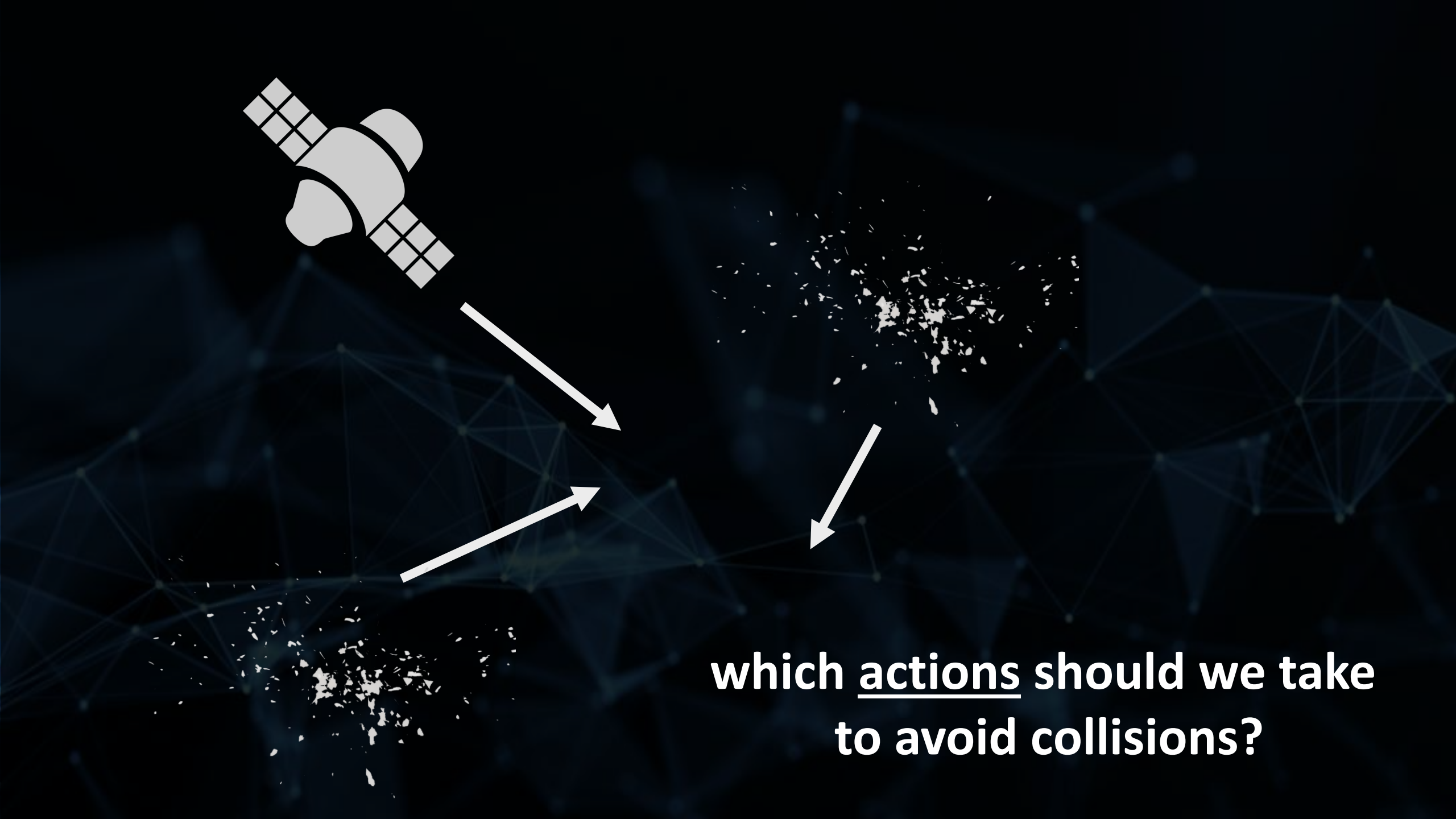
Find James on LinkedIn:

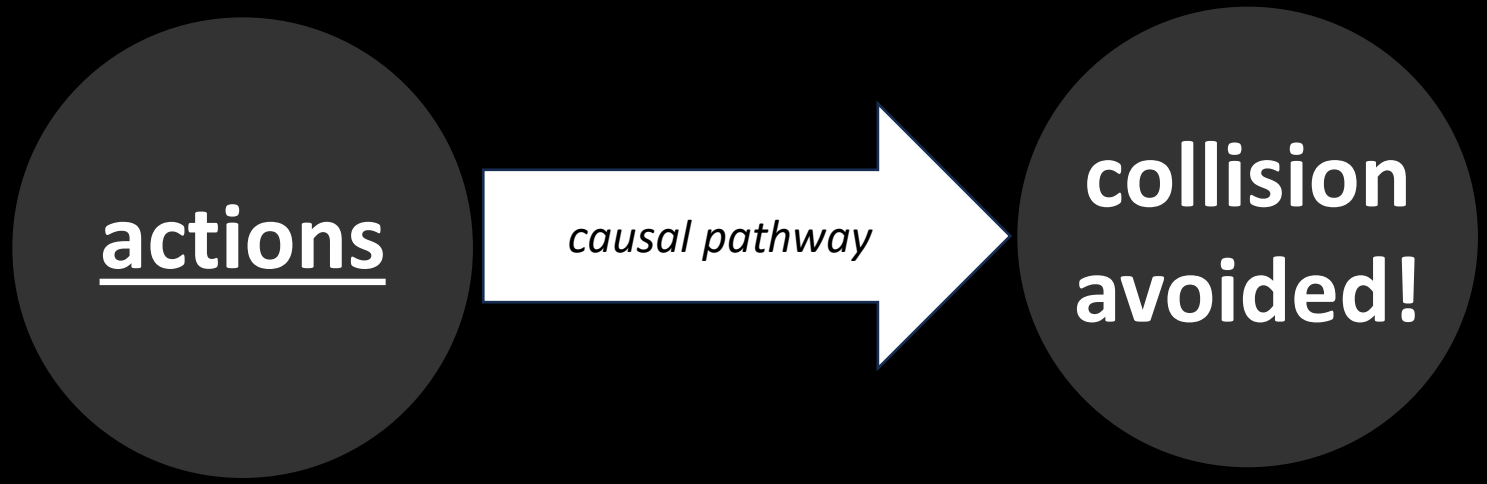
https://www.linkedin.com/in/jamesward4/

- Advisor to Private Equity
- Ex McKinsey
- BRW Fast-100
- Forbes Top 100 Global Consulting Company
- B.Appl.Sc (Comp Sci), M.Sc.(AI)

- Fascinated by the topic of Intelligence

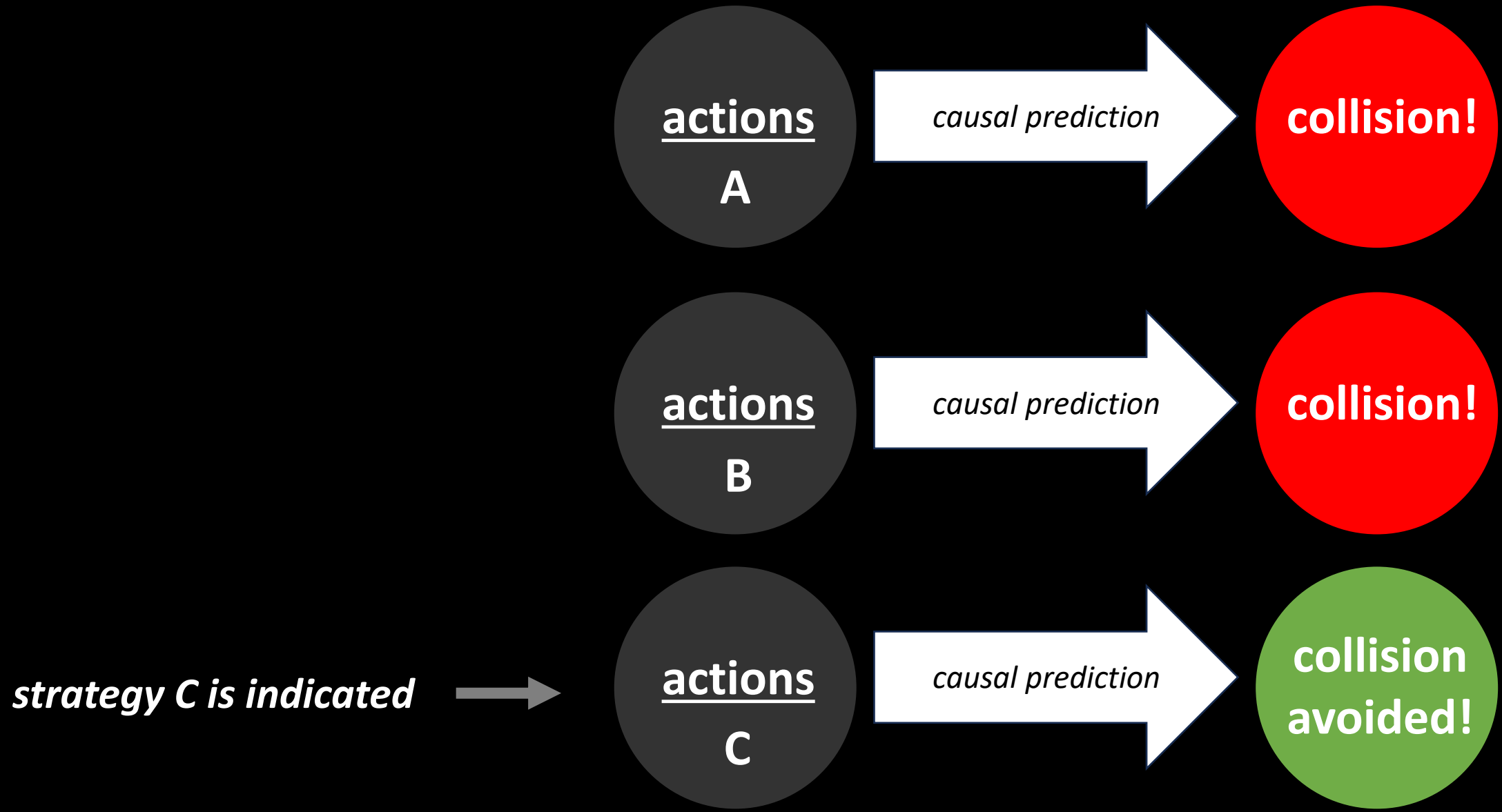
esa epistemology


which actions should we take
to avoid collisions?



Cause **Effect**

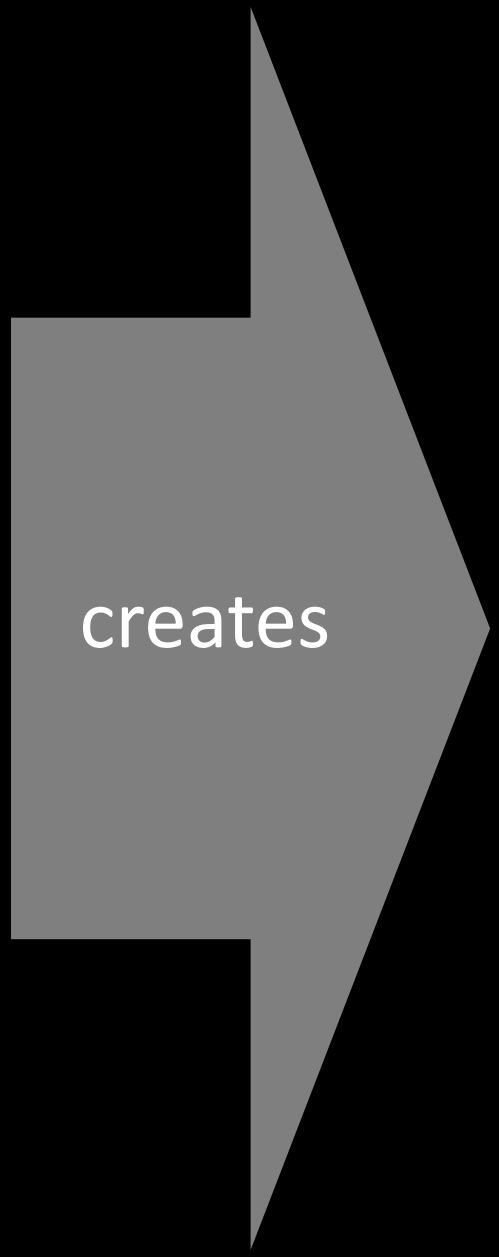
the essence of intelligent strategy is causal


actions
A
causal prediction
collision!
actions
B
causal prediction
collision!
strategy C is indicated
actions
C
causal prediction
collision avoided!


But our environment is complex!
There are many uncertainties!

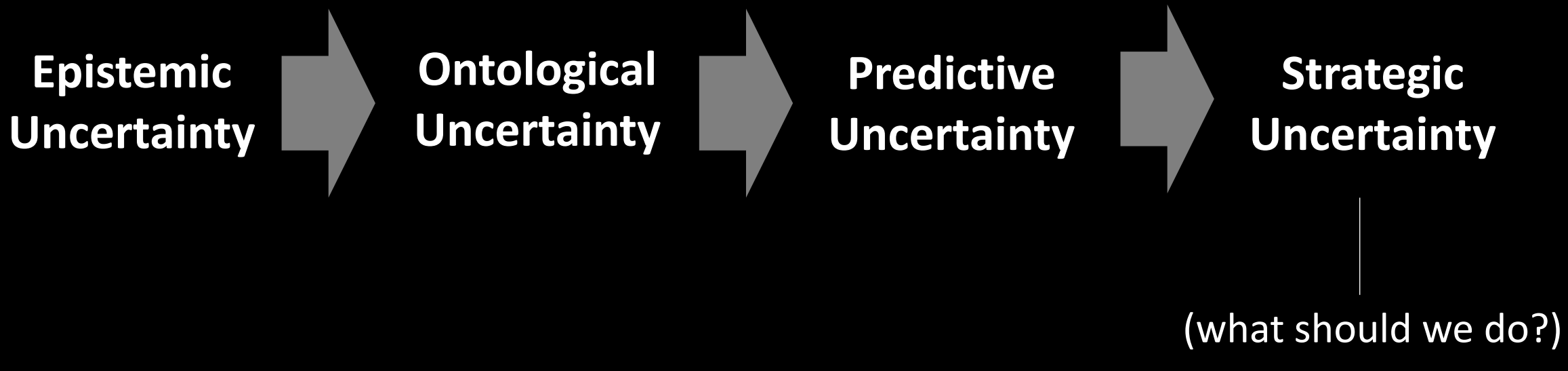
Epistemology

- our method of reasoning
- the way we sensemake
- the way we arrive at new beliefs or discard old beliefs



Ontology

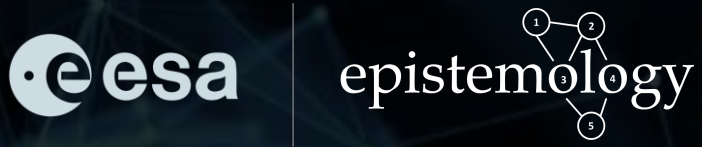
- beliefs
- hypotheses
- knowledge


Epistemic Uncertainty
Ontological Uncertainty
Predictive Uncertainty
Strategic Uncertainty
(what should we do?)

sound epistemology

is the key to intelligent strategy

The Innovator’s Mindset



Anti-Innovation Mindset

We are already doing great with existing methods, there is no need to change

We are already handling the problem as well as it can be handled

There are no serious limitations to existing approaches (physics models, statistical models)

Even if there are serious limitations to existing approaches, then these limitations are inevitable, unavoidable, and we just have to accept them

Innovation Mindset

No matter how well we are doing, how much progress we have made, we can always do better

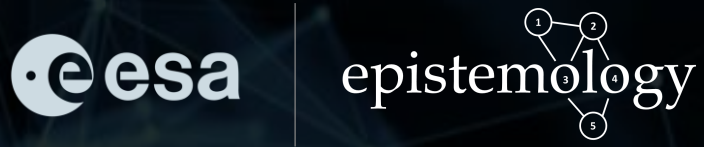
We are candid about acknowledging the limitations of existing approaches (physics models, statistical models)

We are practical and ambitious enough to highlight the cost and source of these limitations

We are confident that these limitations can be overcome by applying superior intelligence – by applying sound epistemology

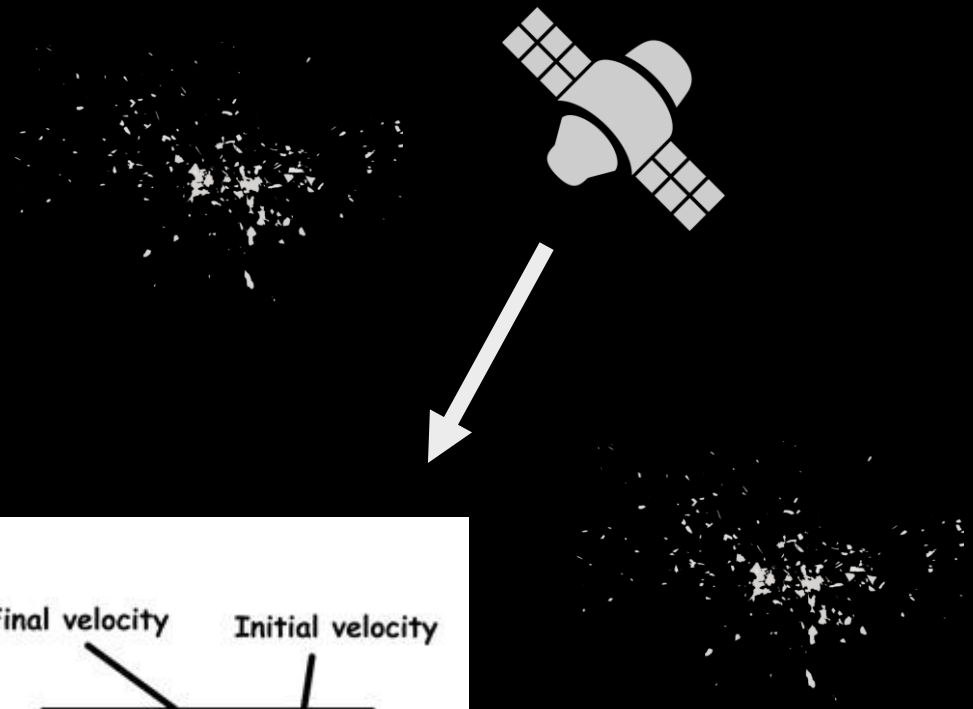
We love to help people achieve better results!

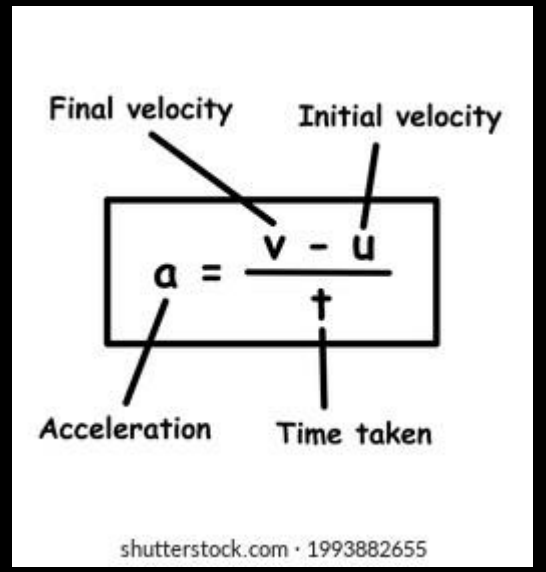
The Epistemology of Physics Models



Physics Model Assumptions

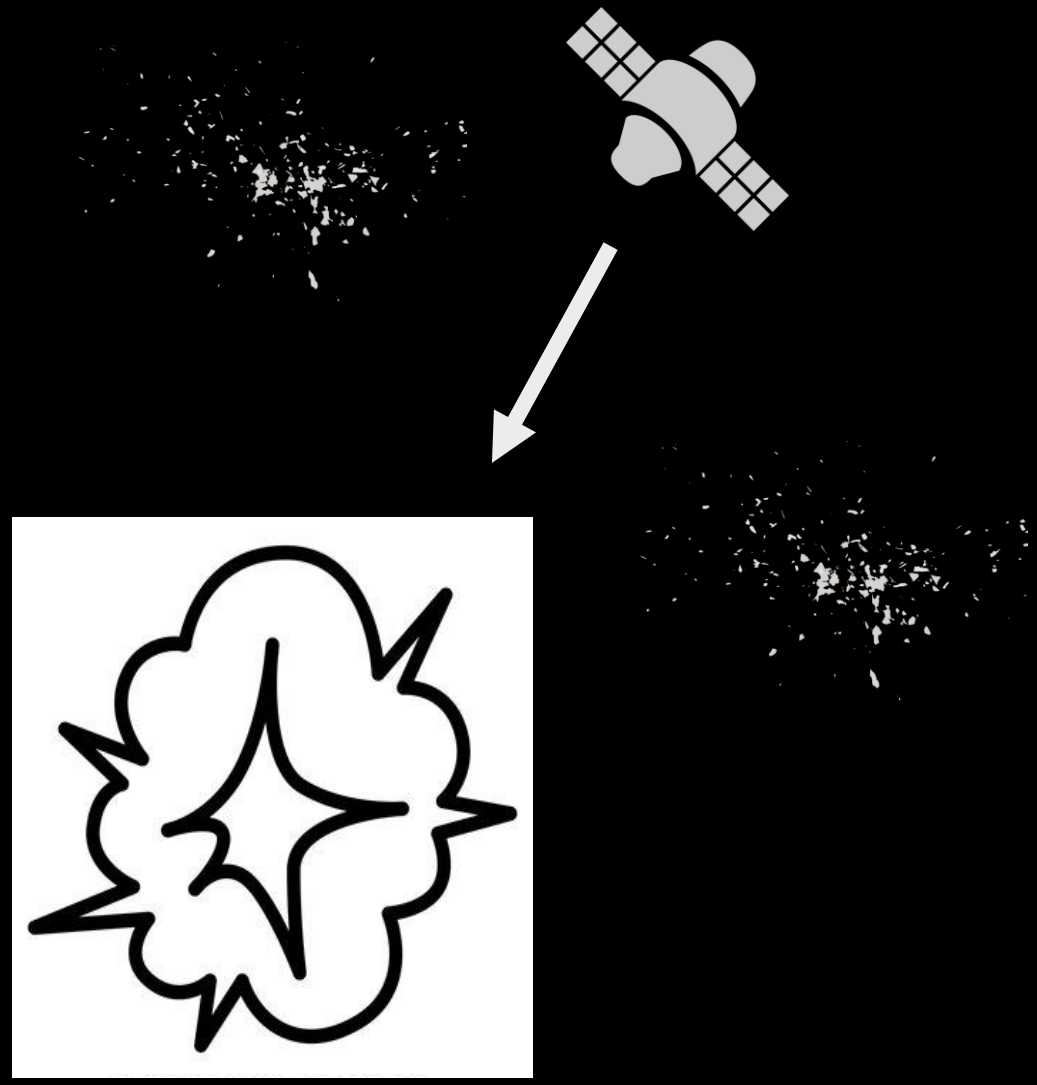
- **we know the start conditions** – we know where all the objects are (or were) at some point on the past, including their trajectories and velocities and angular momentum
- **we know the equations of motion** – we know how physical objects travel through space and time
- **we know all the future forces that will modify these trajectories**
- **so we can calculate where all the objects will be at time X, deterministically**



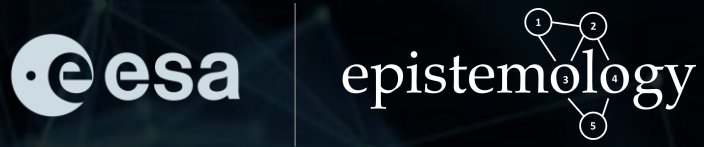


Physics Model Limitations

- **we don’t know the start conditions** - there are natural and man-made objects that we don’t know about, and these keep changing
- **because of chaos effects** - our models only calculate theoretical trajectories, in practice there is divergence – some rocket stages explode, and some don’t, and we can’t reliably calculate which
- **we don’t know all the future forces that will modify these trajectories** – this depends on things like politics and economics and potential future star wars – who will launch new satellites next year? Who will shoot at ours?
- **so we can’t calculate** where all the objects will be at time X, deterministically

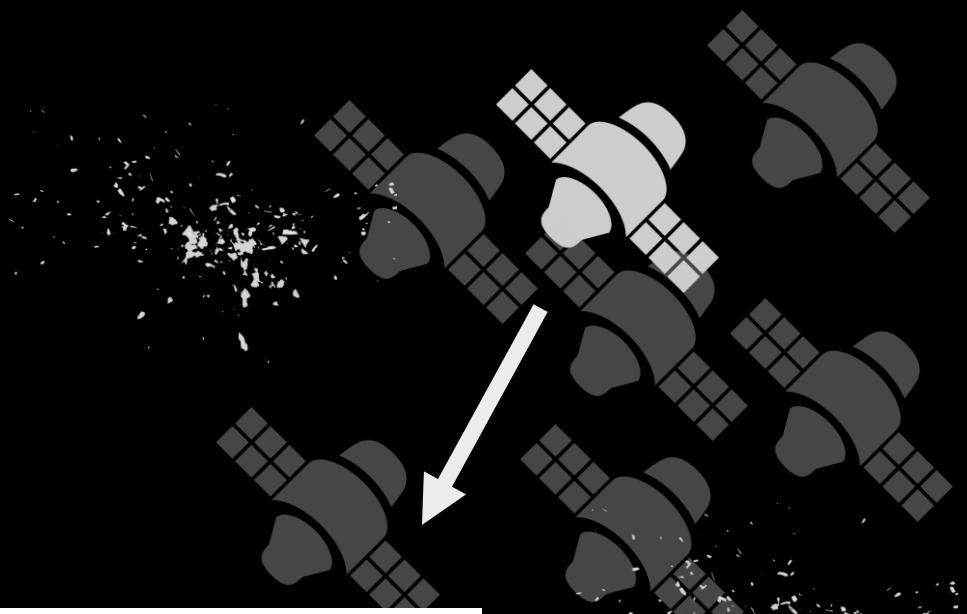


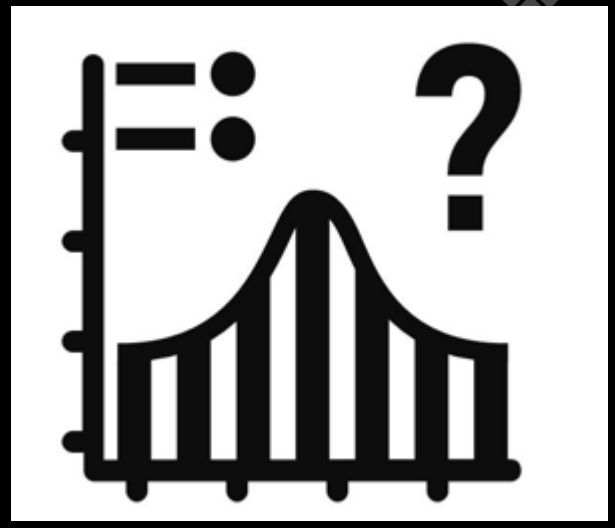
The Epistemology of Statistical Models



Statistical Model Assumptions

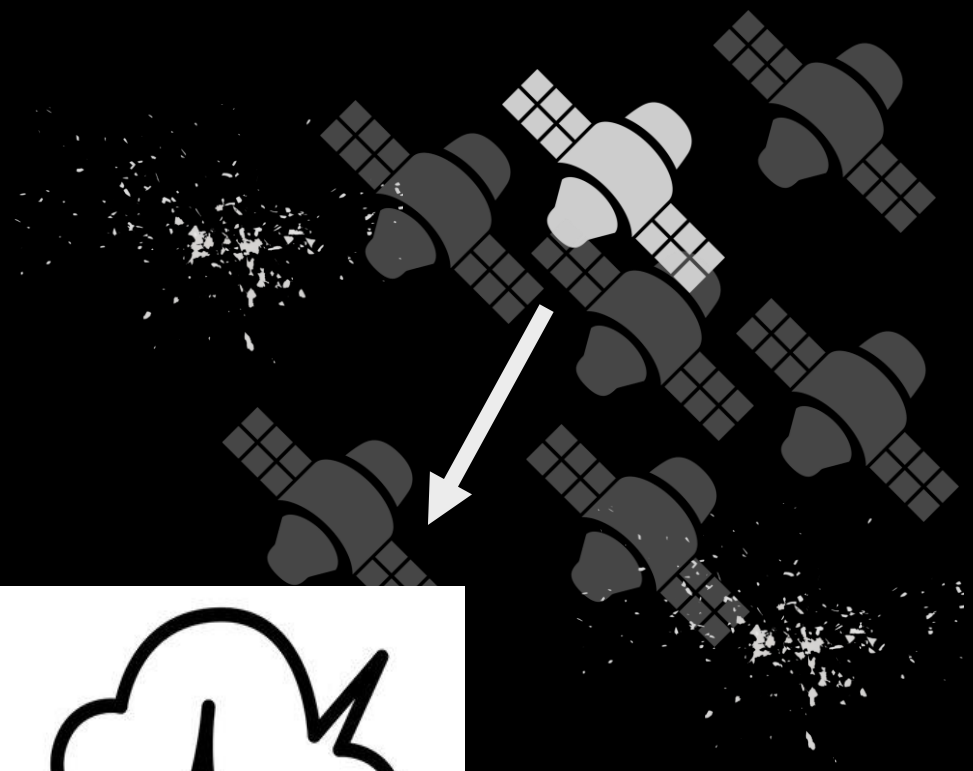
- we don’t know why things happen – things just happen randomly and there’s no point trying to figure out what caused them, because that’s impossible
- however, we assume that when things happen randomly in future, they will at least follow the same random patterns as they did in the past
- therefore collecting data – a LOT of data – about the past is an incredibly valuable thing to do

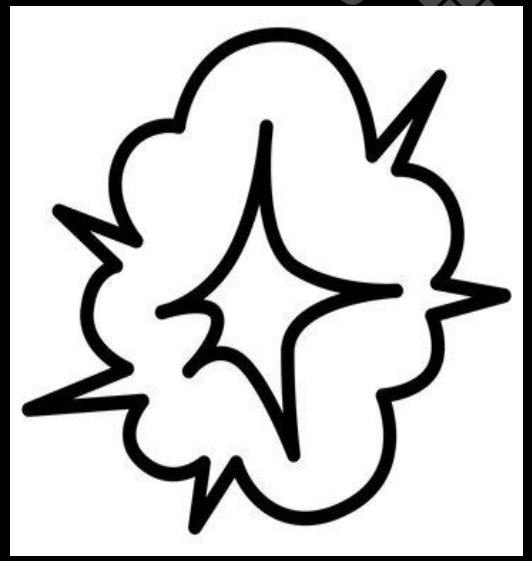




Statistical Model Limitations

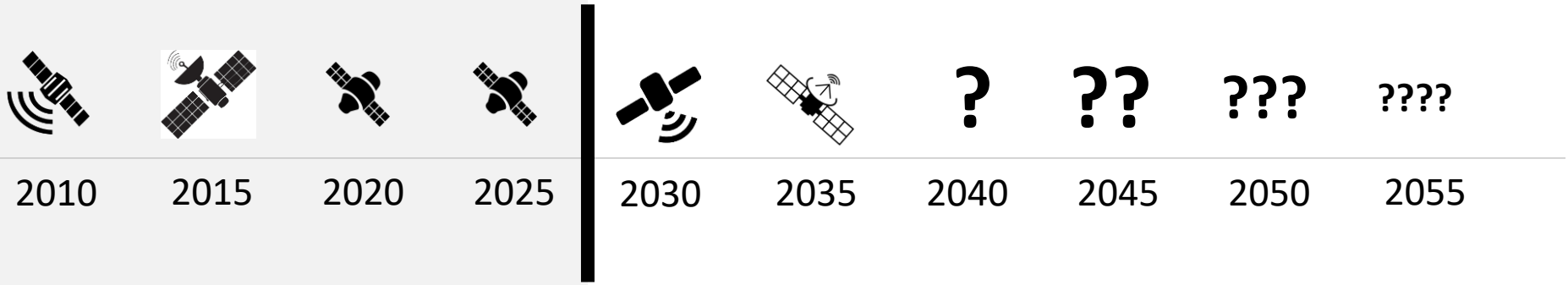
- because we don’t know what causes things, we can’t predict how our actions will affect things – for better or for worse
- so we can’t use statistical models as the basis for intelligent strategy, because strategy is inherently causal
- collecting a lot of historical data is not going to help as much as commonly assumed





CASE IN POINT:

How can we predict what satellites will be launched in future?



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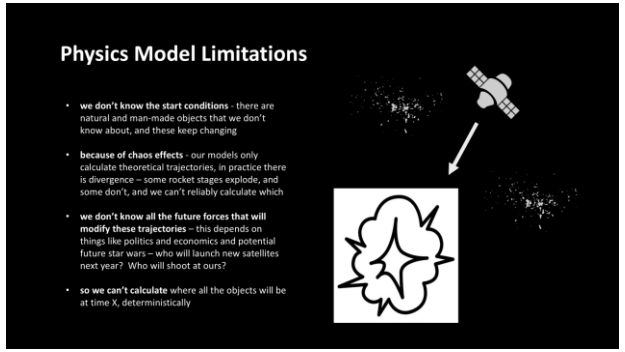
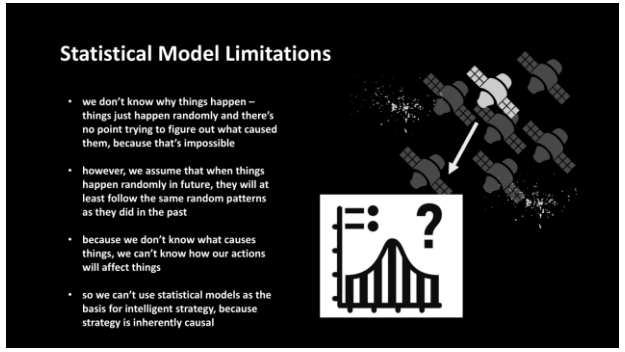


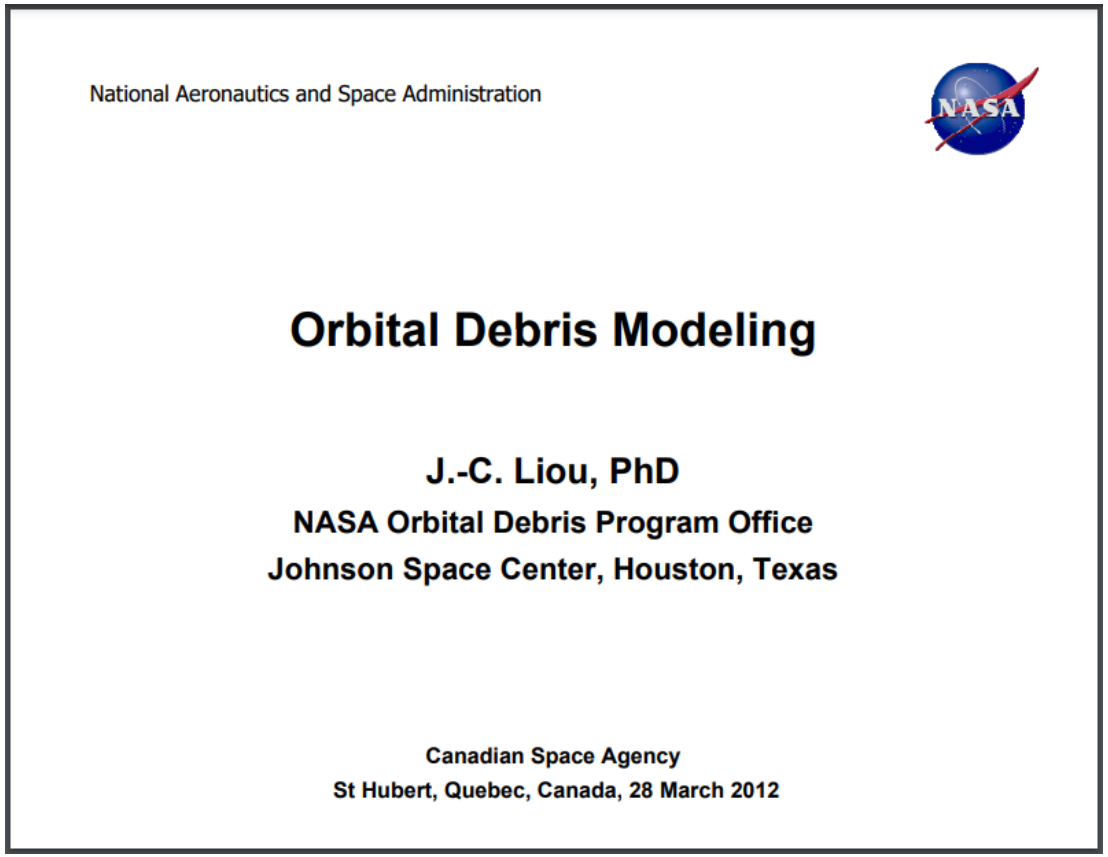
Physics Models can only work with satellites which are already in orbit, or already registered in a database.

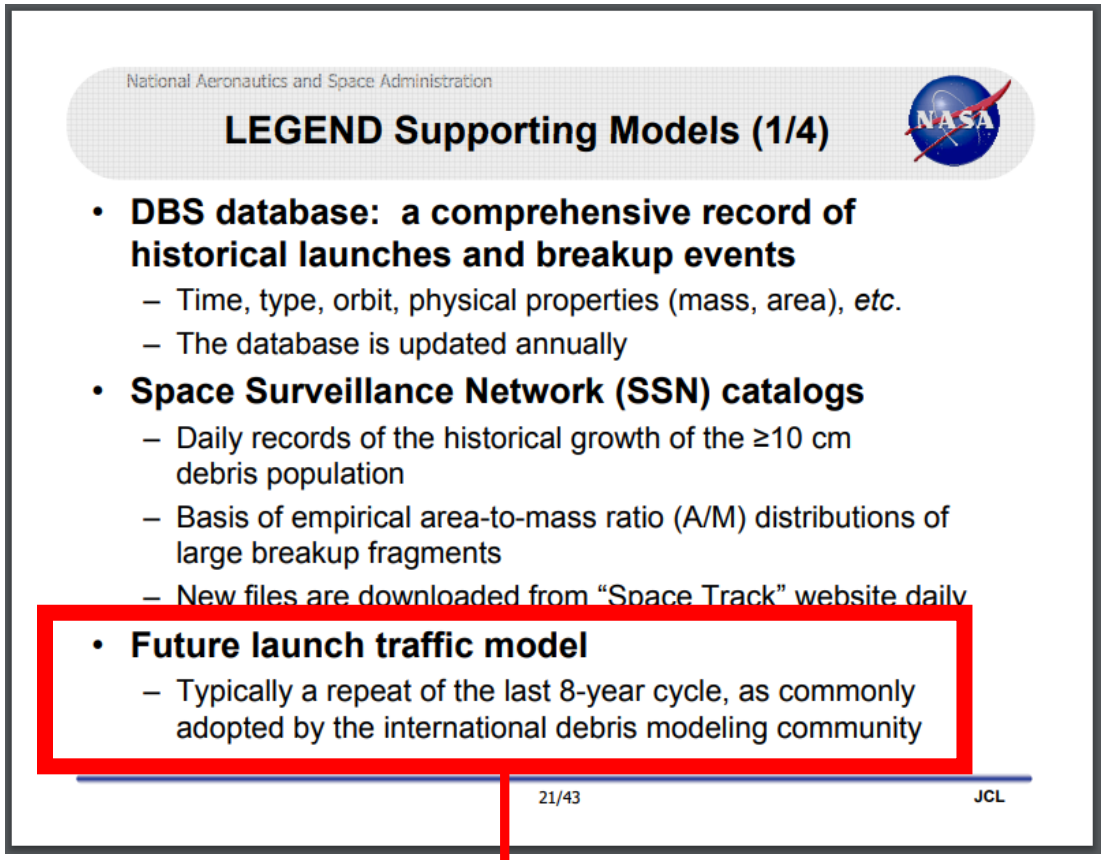
They can't be used to predict how economics, politics, and the progress of green energy policy might drive the demand and use of solar energy farms in space.



Statistics Models can be built only when there is an existing historical dataset to sample from – with the assumption that the future will essentially repeat the past, at least statistically.

Is the past a sensible guide to the (statistical) future?





What will be the pattern of future launches?

Is the past a sensible guide to the (statistical) future?

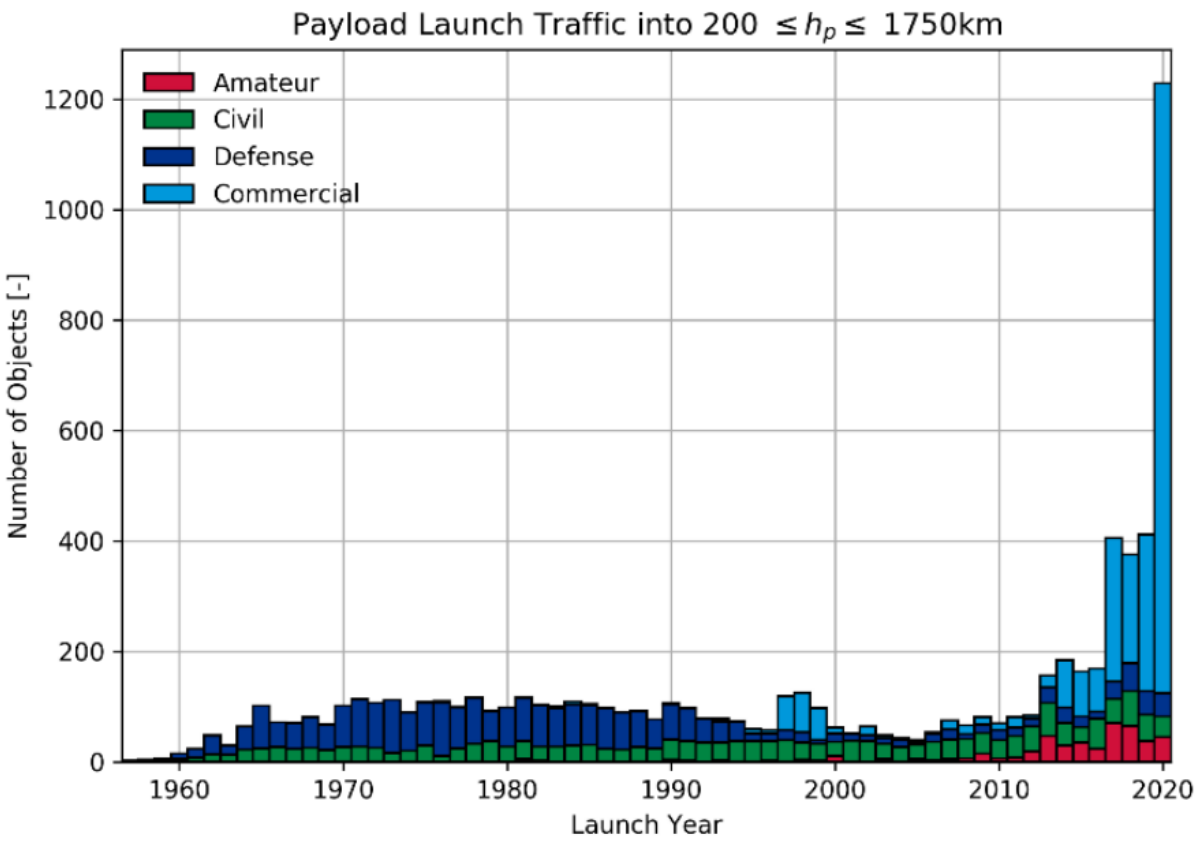
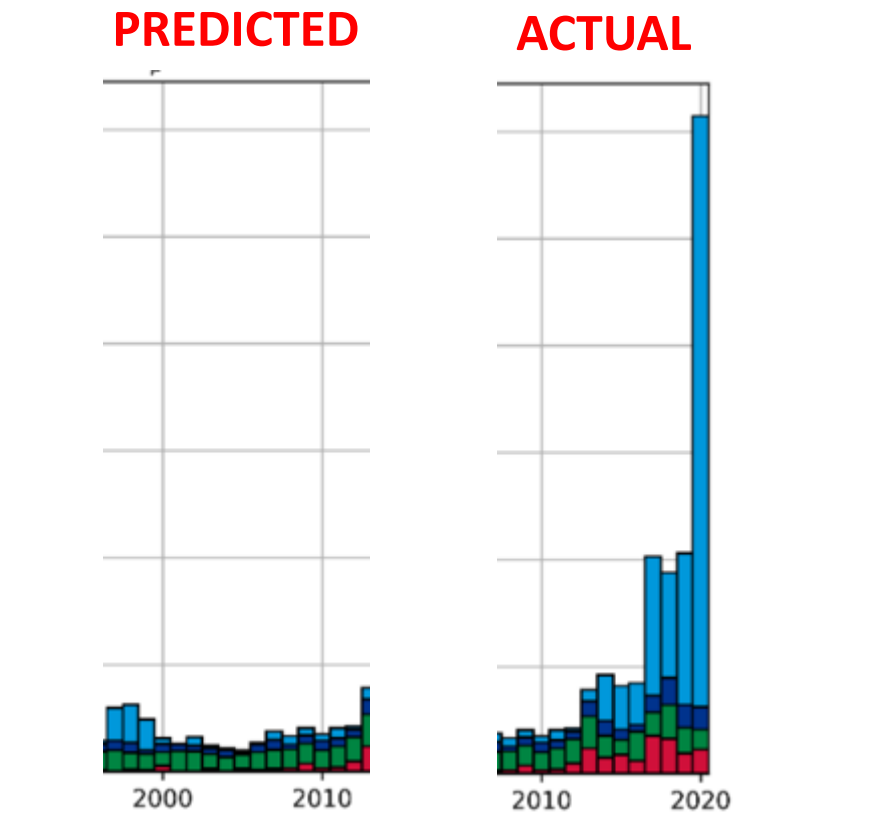


Figure 1. Payloads to LEO[2]



- **Future launch traffic model**
  - Typically a repeat of the last 8-year cycle, as commonly adopted by the international debris modeling community

CASE IN POINT:

Can we predict which rocket stages will explode and whether we can do anything to stop that?

Chinese rocket's breakup puts over 1,000 satellites and other objects at risk

By Joey Roulette

August 10, 2024 8:02 AM GMT+10 · Updated 5 months ago

WASHINGTON, Aug 9 (Reuters) - A Chinese rocket stage that broke apart in space this week created more than 700 pieces of debris, putting over 1,000 satellites and other objects in a high-traffic region of Earth's orbit at risk of hazardous collisions, analysts said on Friday.

China's state-owned Shanghai Spacecom Satellite Technology (SSST) launched 18 internet satellites into orbit on Tuesday as the inaugural batch of a communications network that will challenge SpaceX's vast Starlink constellation.

The upper rocket stage that carried those satellites into orbit appeared to explode soon after deploying its payloads, creating a growing field of debris that U.S. space-tracking firms estimate to be at least 700 pieces so far.

SSST did not respond to a request for comment.

U.S. space-tracking firm LeoLabs said it was likely the number of debris pieces exceeds 900, making the event one of the largest ever. The debris cloud, created at roughly 800 kilometres (497 miles) in altitude, will last several years, several analysts said.

It was unclear whether the latest rocket body's break-up was caused by a collision with another object or an onboard explosion of unused rocket fuel. U.S. Space Command initially said the event created 300 pieces of debris, a number that was seen as likely to increase as the debris cloud disperses.

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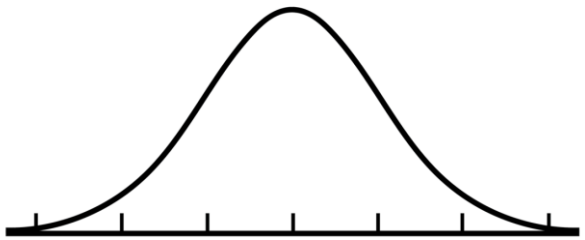


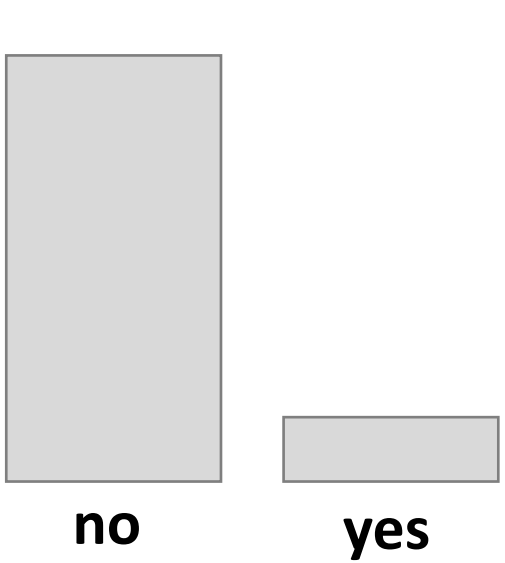
will the rocket stage explode?

The cause of failure is uncertain,
so failures are modelled as random statistical events
mirroring the pattern of historical failure

Can we predict which rocket stages will explode and whether we can do anything to stop that?

Prior Distribution

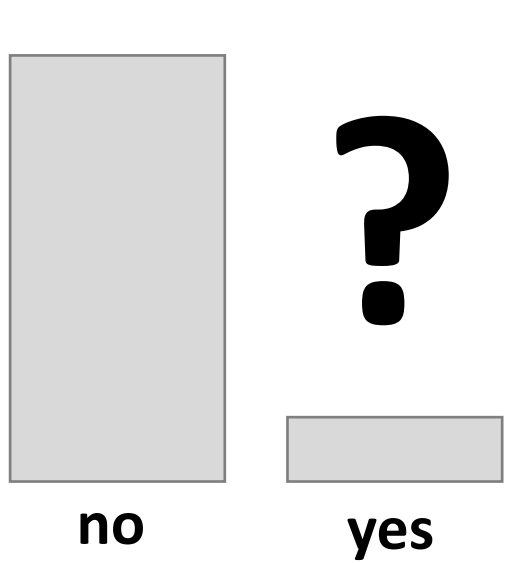
(*before* safety measures)
(mirroring historical averages)



candidate intervention

Posterior Distribution

(*after* safety measures)

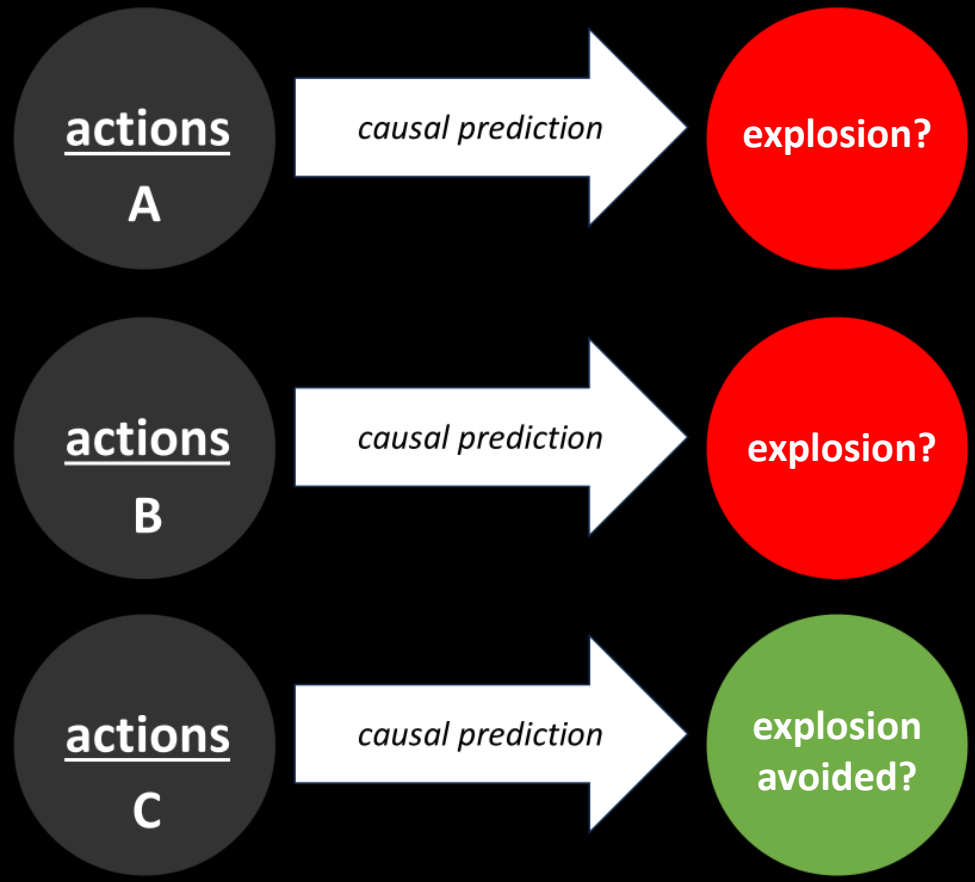


will the rocket stage explode?

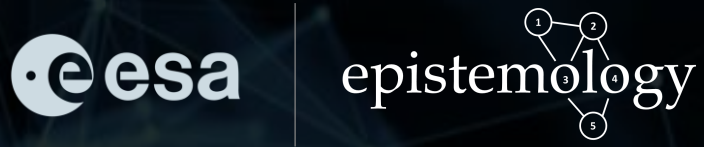
Statistical Models provide no basis for calculating strategy

candidate interventions

- A - more sophisticated collision detection
- B – jettison fuel
- C – additional shielding for fuel cells

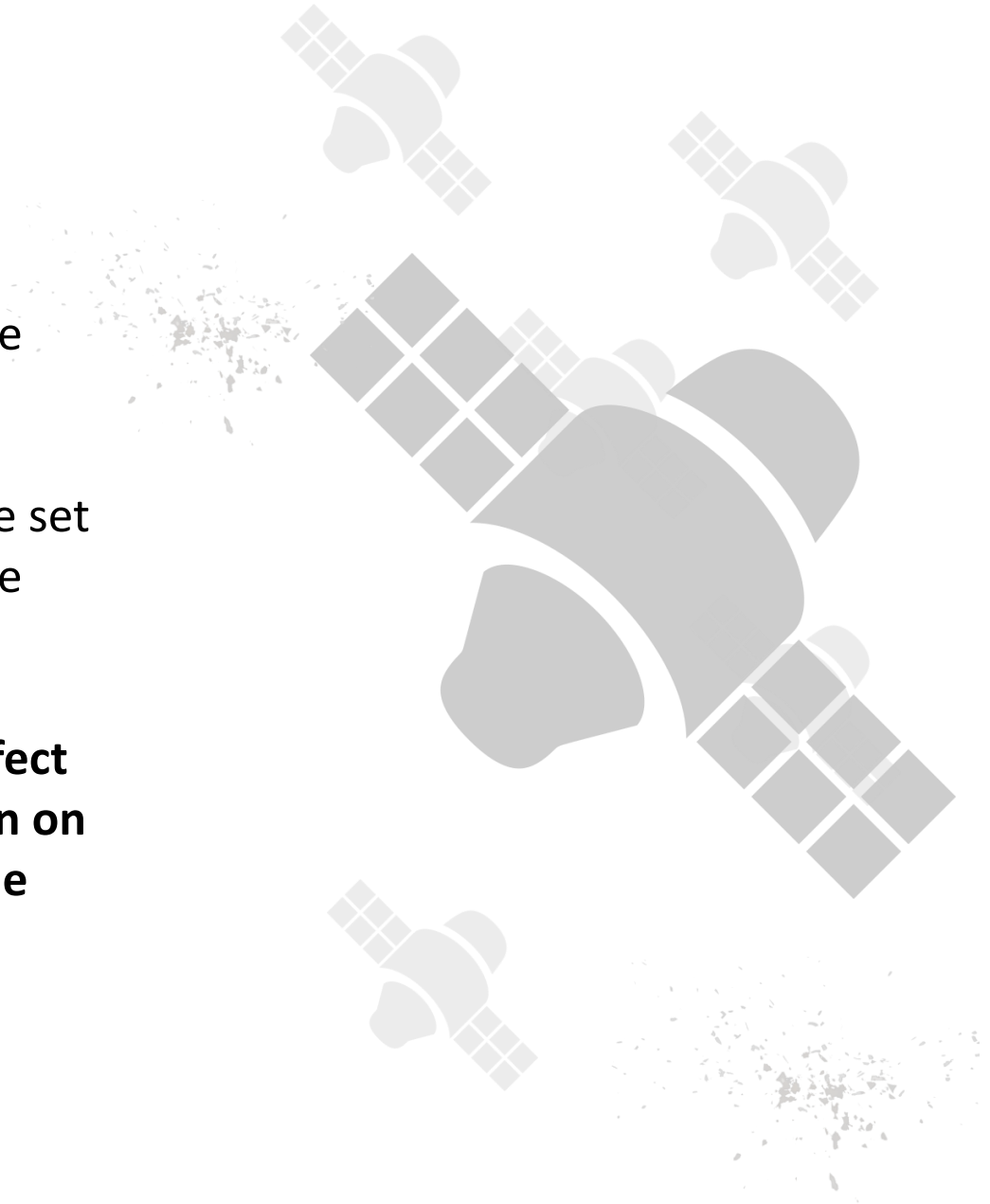


The Epistemology of Causal Models



Causal Modelling:

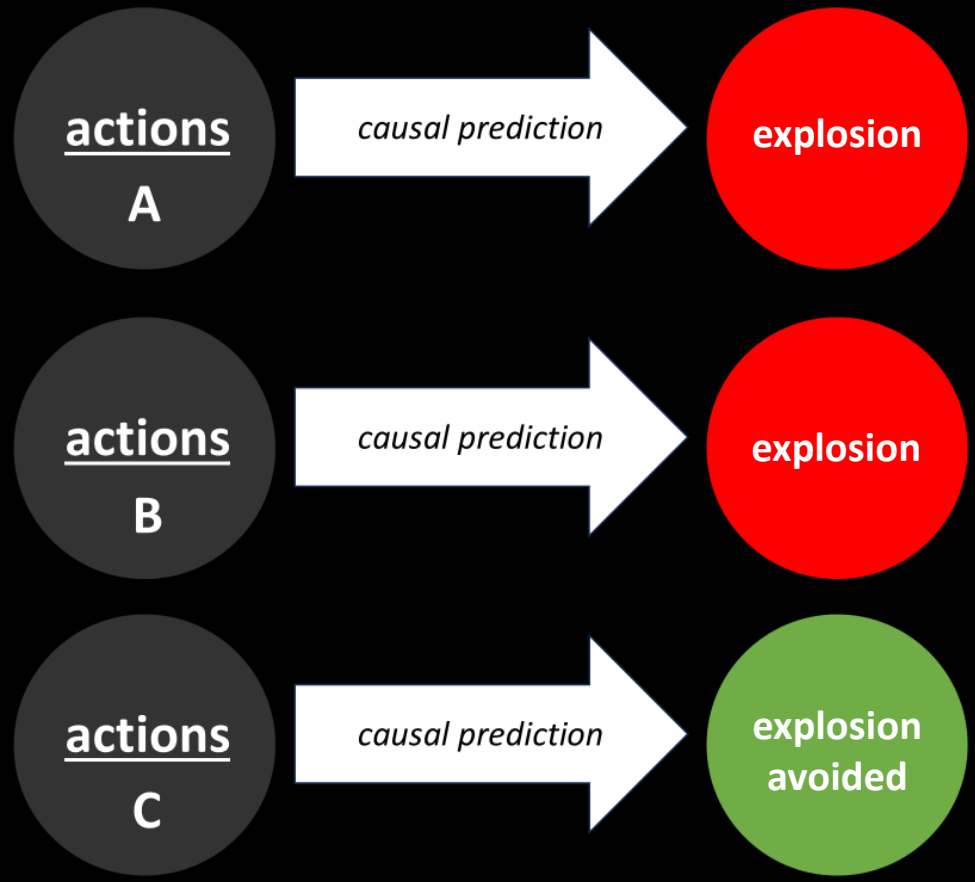
- we enumerate the set (superposition) of all plausible deterministic causes
- from this we can calculate the set (superposition) of all plausible deterministic futures
- **we can then calculate the effect of any candidate intervention on the superposition of plausible futures**



Causal Models provide a scientific basis for calculating strategy

candidate interventions

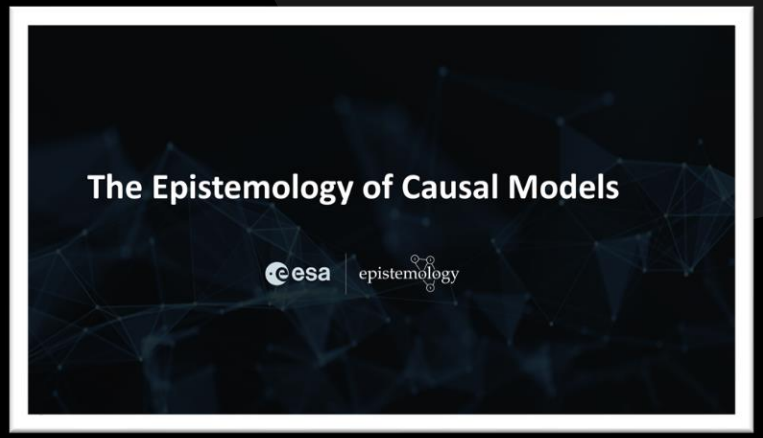
- A - more sophisticated collision detection
- B – jettison fuel
- C – additional shielding for fuel cells



Causal Epistemology focuses on the plausible ontological space - the blind spot of statistical modelling

Epistemic Uncertainty → **Ontological Uncertainty** → **Predictive Uncertainty** → **Strategic Uncertainty**

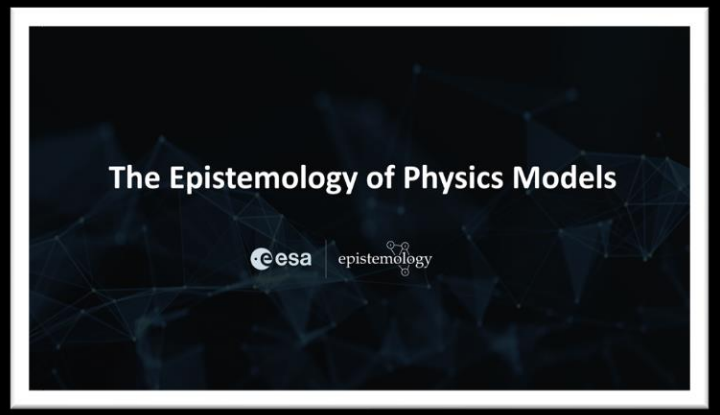
(what should we do?)



The causality is...

Assumed

false certainty



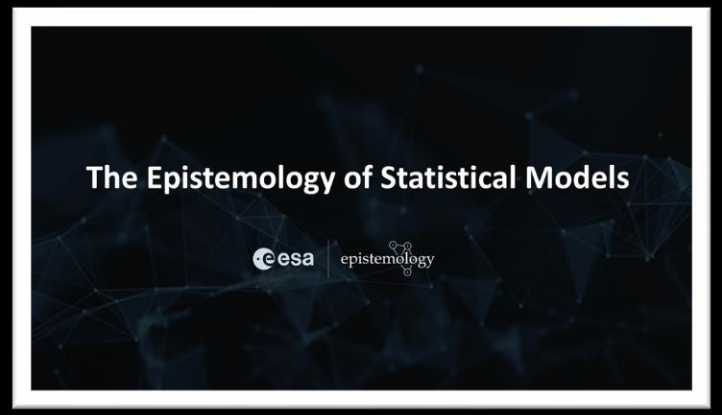
"we are sure the rocket won't explode"

Physics Models

The causality is...

Unknown

uncertain and unexplainable



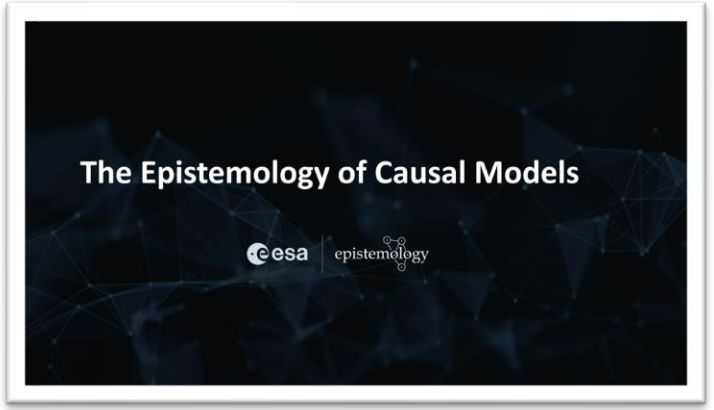
"we dont know why the rocket exploded"

Statistical Models

The causality is...

Plausible

uncertain yet explainable



"we dont know why the rocket exploded, but:

- its plausible that there was a collision
- its plausible that remaining fuel exploded"

Causal Models

AI tech-startup Epistemology offers methodologies and software platforms for solving the challenges of scale and complexity when working with causal models

Please do reach out for more information about how to get started!

causal
artificial intelligence

FIVE RINGS

SKAI

esa | epistemology

Thank You!

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QUESTION TIME

Limited time for questions today, so please reach out!

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Synopsis

The current suite of software tools for managing space debris at ESA (MASTER, DRAMA) were conceived some decades ago, when the statistical approach to uncertainty in science dominated.

Since that time, the discipline of causal science has made great strides as a tool for uncertainty management and policy optimisation. Causal science is often preferred over statistical approaches in the domain of strategy making and policy creation, since the work of strategy formulation is inherently causal. That is to say, in strategy work we seek to calculate which events we should cause to produce optimal effects (beneficial effects such as safety and profitability).

In this workshop, we explore an exciting future where the existing suite of management tools are augmented by, or replaced by, software that uses causal approaches and causal Agent-Based Artificial Intelligence.

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