Trustworthy AI for Indonesia's Minerals and Geothermal Resources: Grand Opportunities and Major Challenges

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The 2nd International Conference on Research in Engineering and Science Technology 2024 (IC-REST 2024) in Gowa - Makassar, Indonesia

A bit about me

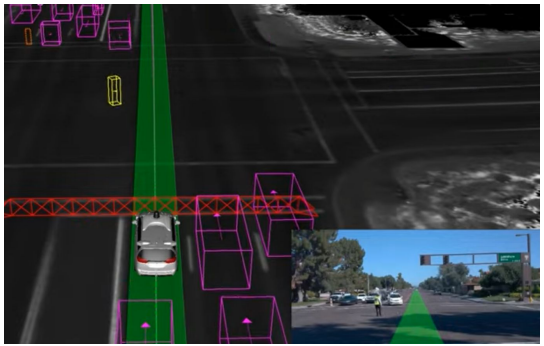
- **Research Scientist/Engineer,** Stanford, (October, 2024)
- **Postdoc, SISL and Mineral-X,** Stanford, 2023-present
- **PhD** in **Mechanical Engineering**, Carnegie Mellon, 2023
- **MSE, Industrial & Operations Engineering**, University of Michigan, Ann Arbor, 2018
- **BE, Industrial and Systems Engineering,** Sepuluh Nopember Institute of Technology, Surabaya, 2014
- Native and born in Gowa, South Sulawesi (**< 10 km from Kampus Teknik)**

Acknowledgment

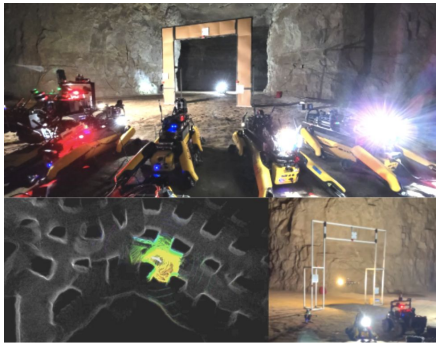
- **Special lifetime gratitude to these people:**
  - **Kak Ilham Aminuddin**
    (Geology, Unhas – Bina Antarbudaya,
    AFS Ch. Makassar)
  - **Kak Irwan Setiawan**
    (TI, Unhas – Bina Antarbudaya, AFS Ch. Makassar)
  - **Pak Syarifuddin Mabe Parenreng**
    (TI, Unhas — LSCM, ITS Surabaya)
- **Special thanks also to:**
  - **Kakanda Armin Darmawan**
    (TI, Unhas – IAPIM ‘97)
  - **Ust. Muh. Zubair Baso,**
    Physics Teacher in IMMIM (‘04-’09)

MINERAL-X SISL Stanford Intelligent Systems Laboratory

AIs are everywhere



Autonomous vehicles

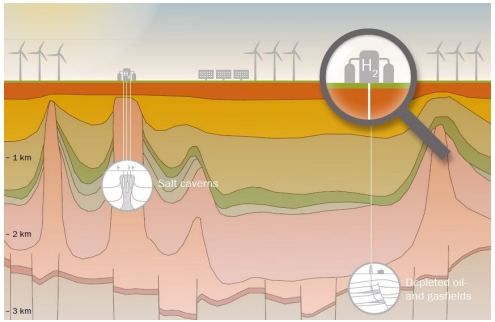


Exploratory robots

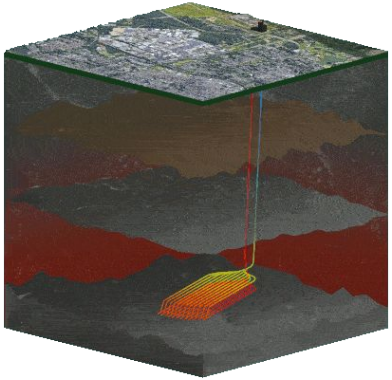
Aircraft collision avoidance systems

- Interacting with humans more intensively and collaboratively
- Making more important, even safety-critical, decisions

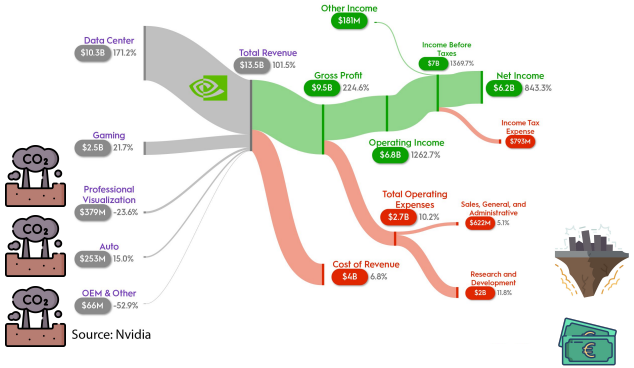
AIs are everywhere



Subsurface resources



Geothermal energy



Project portfolio management

MINERAL-X SISL Stanford Intelligent Systems Laboratory

Geosci. Model Dev., 16, 289–313, 2023
https://doi.org/10.5194/gmd-16-289-2023

Geoscientific Model Development

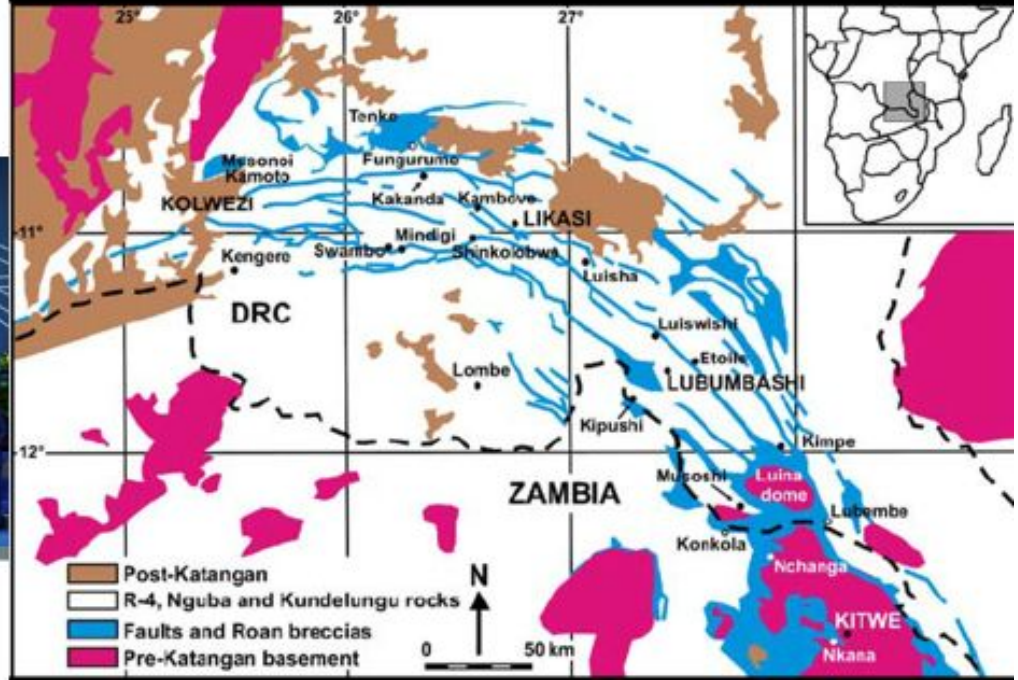
The Intelligent Prospector v1.0: geoscientific model development and prediction by sequential data acquisition planning with application to mineral exploration

John Mern[1] * and Jef Caers[2] *
[1]Kobold Metals, Berkeley, USA
[2]Department of Earth and Planetary Sciences, Stanford University, Stanford, USA
*These authors contributed equally to this work.

Bloomberg: Mining Startup KoBold Metals Seeks Zambia Copper for Green-Energy Shift

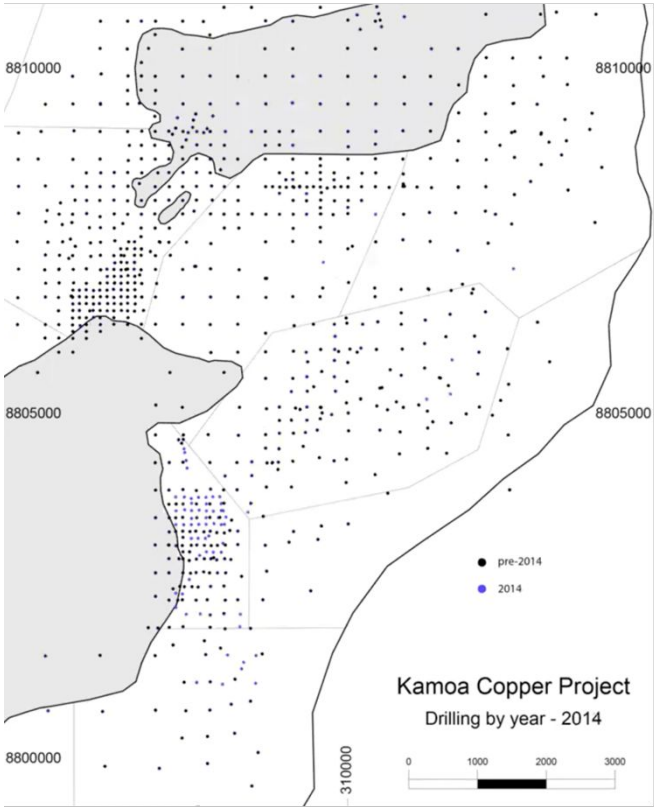
Zambia produced ~800.000 tons of copper in 2021

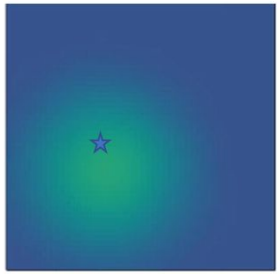
World needs to increase from 20 to 30 Million tons by 2030

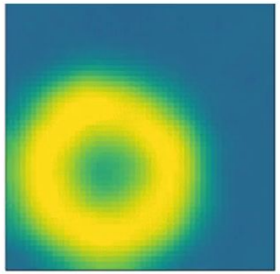


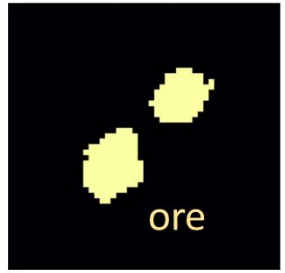
Wesley Scott Hall, 2017

Somewhere in the copperbelt

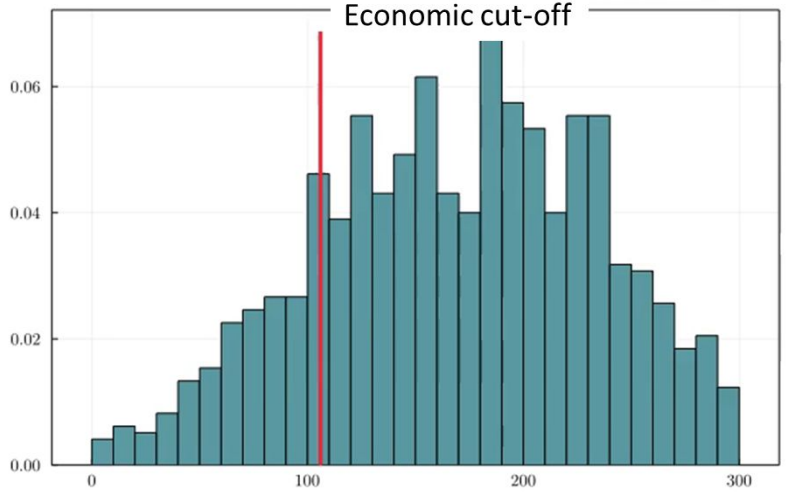




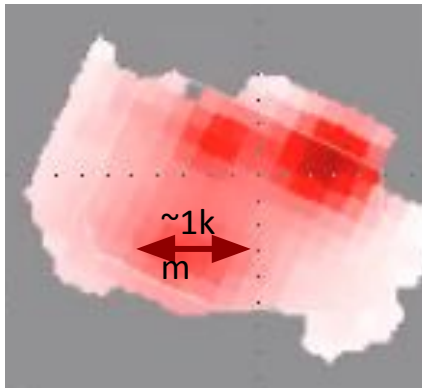




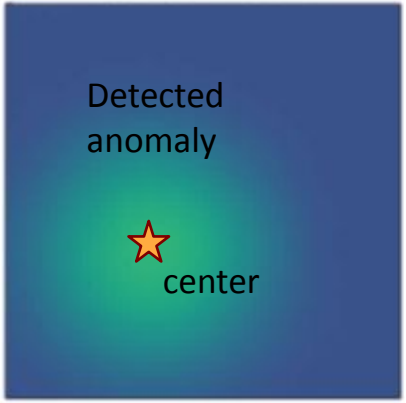
Uncertainty on mineable volume



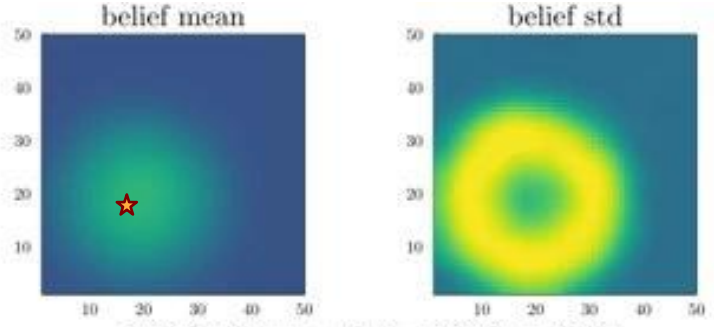
Sequential planning under uncertainty



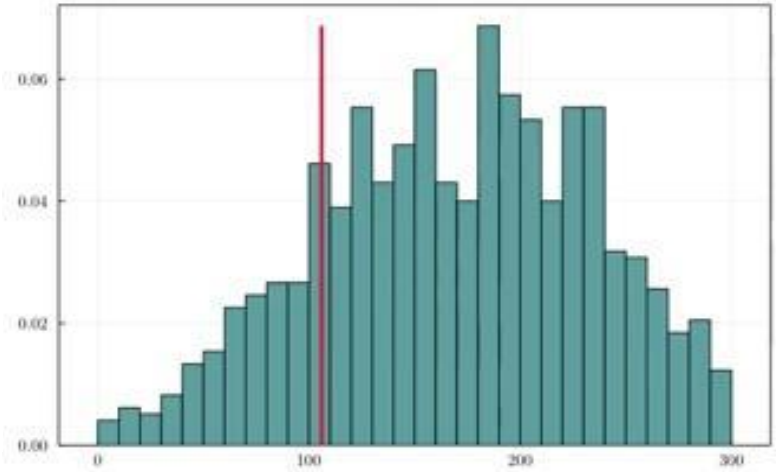
How many measurements and where?



prediction **uncertainty**



Uncertainty on mineable volume

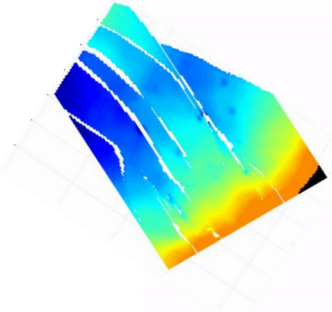


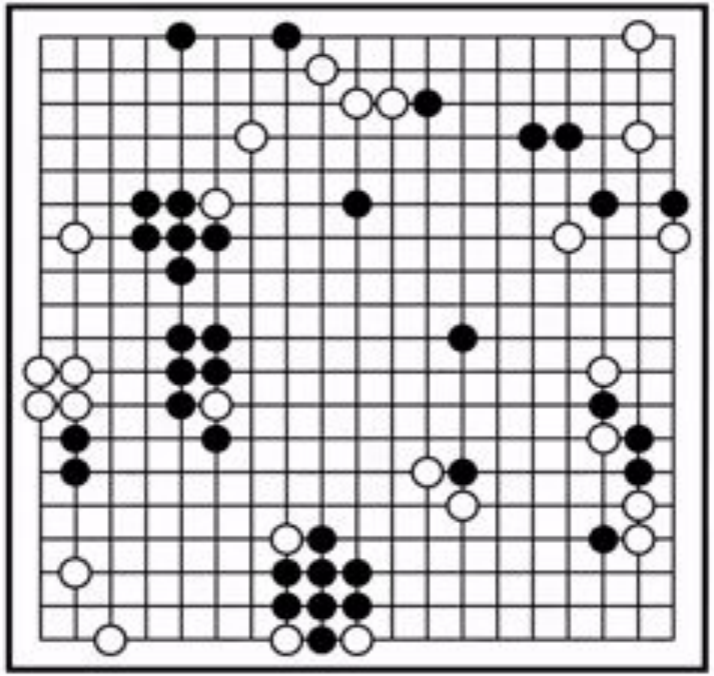
Economic cut-off

Planning with simulations

Autonomous cars

Well placements

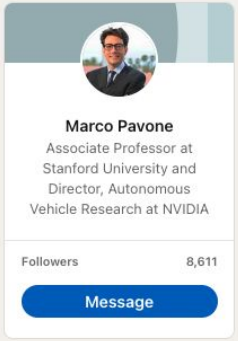


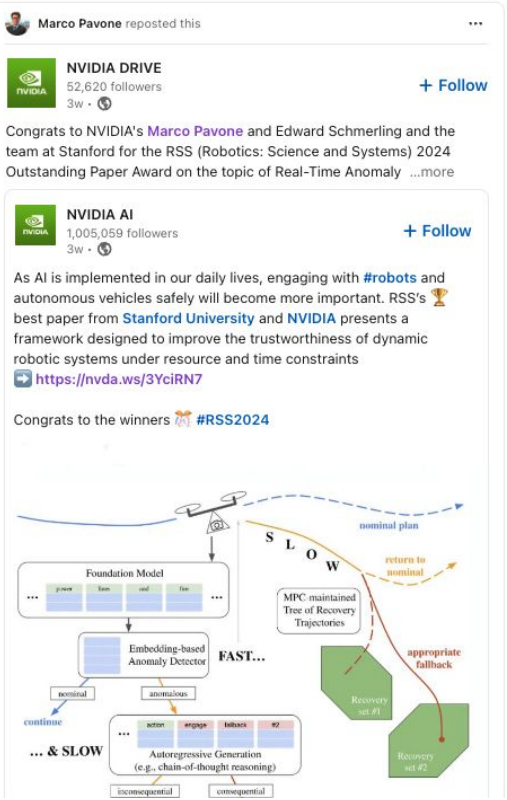


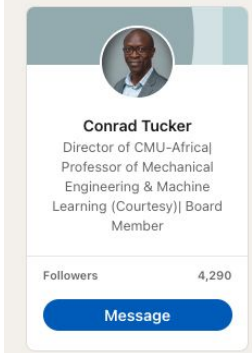
AIs is repeatedly mentioned at the Indonesia Sustainability Forum (ISF) 2024

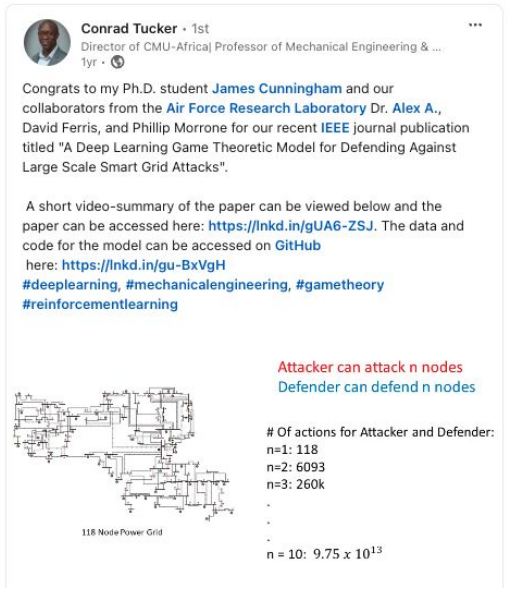

The New York Times
A.I. Needs Copper. It Just Helped to Find Millions of Tons of It.
The deposit, in Zambia, could make billions for Silicon Valley, provide minerals for the energy transition and help the United States in its rivalry with China.

This is just the beginning…

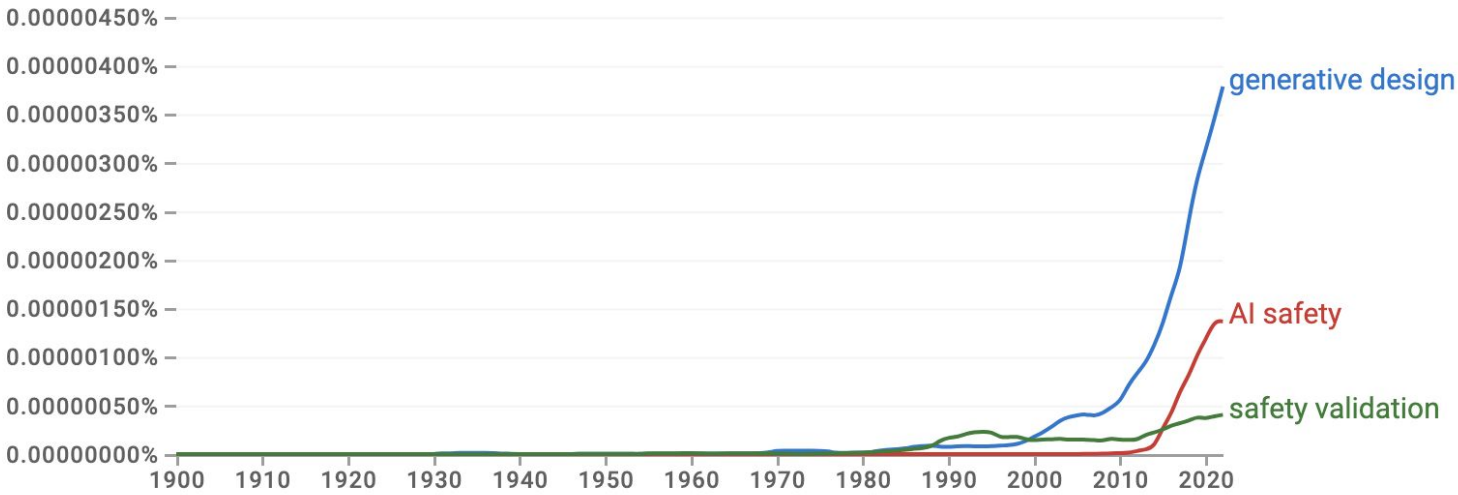








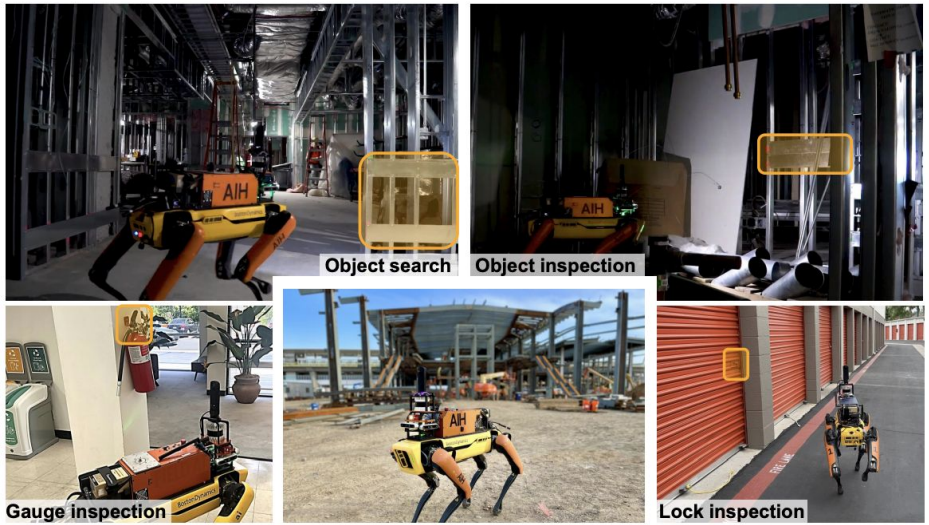
This is just the beginning…



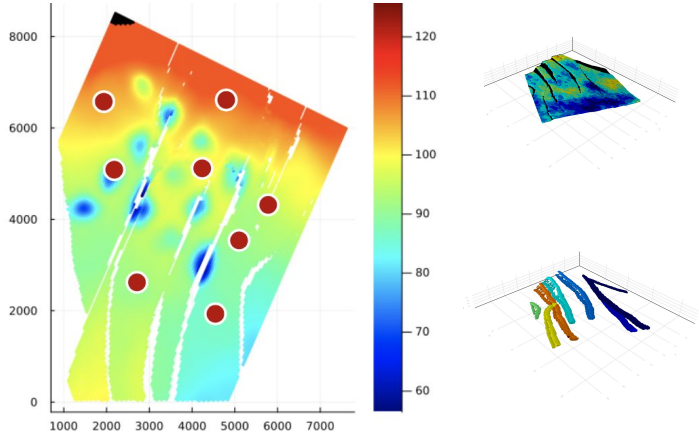
Source: https://books.google.com/ngrams/graph?content=generative+design%2C+AI+safety%2C+safety+validation

but, safety engineering should catch up quickly!

My Vision: Bring airplane-level safety to AI sustainability



Efficient inspection robots for post-mining, warehouse, and large outdoor area



Geothermal exploration and operations under uncertainty

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Wisdom from SISL's Aviation and Robot Safety

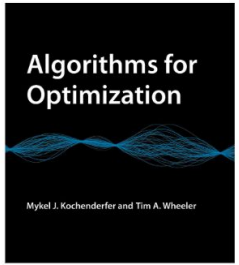
Mykel J. Kochenderfer

Stanford University, Department of Aeronautics and Astronautics

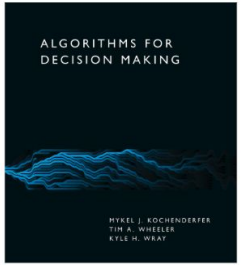
PUBLICATIONS RESEARCH MEDIA TEXTBOOKS TEACHING FAQ VISIT CALENDAR CONTACT

Mykel Kochenderfer is Associate Professor of Aeronautics and Astronautics and Associate Professor, by courtesy, of Computer Science at Stanford University. He is the director of the Stanford Intelligent Systems Laboratory (SISL), conducting research on advanced algorithms and analytical methods for the design of robust decision making systems. Of particular interest are systems for air traffic control, unmanned aircraft, and automated driving where decisions must be made in uncertain, dynamic environments while maintaining safety and efficiency. Research at SISL focuses on efficient computational methods for deriving optimal decision strategies from high-dimensional, probabilistic problem representations.

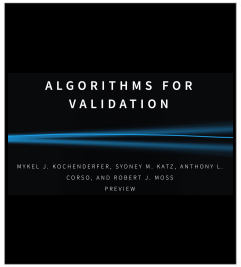
Prior to joining the faculty in 2013, he was at MIT Lincoln Laboratory where he worked on airspace modeling



2019



2022



Coming soon!

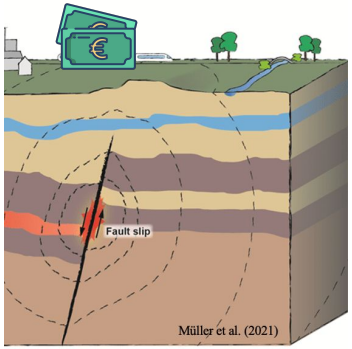
Key lesson: The framework is general, but data and context is local

Collaboration opportunities

- How do we integrate airplane-level safety culture into the industry?

Runtime monitoring and rigorous validation

Localized data and context learning

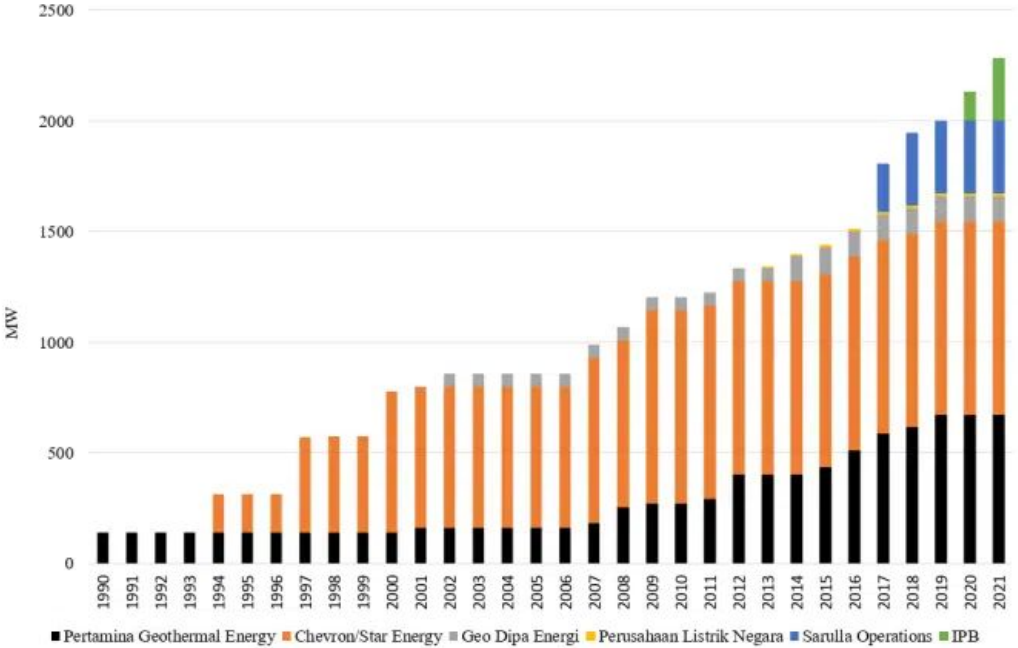


Risk-aware planning

Optimized Geothermal Exploration & Operations with AI

Geothermal landscape in Indonesia context

Source: Husin Nugraha, *Researchgate*

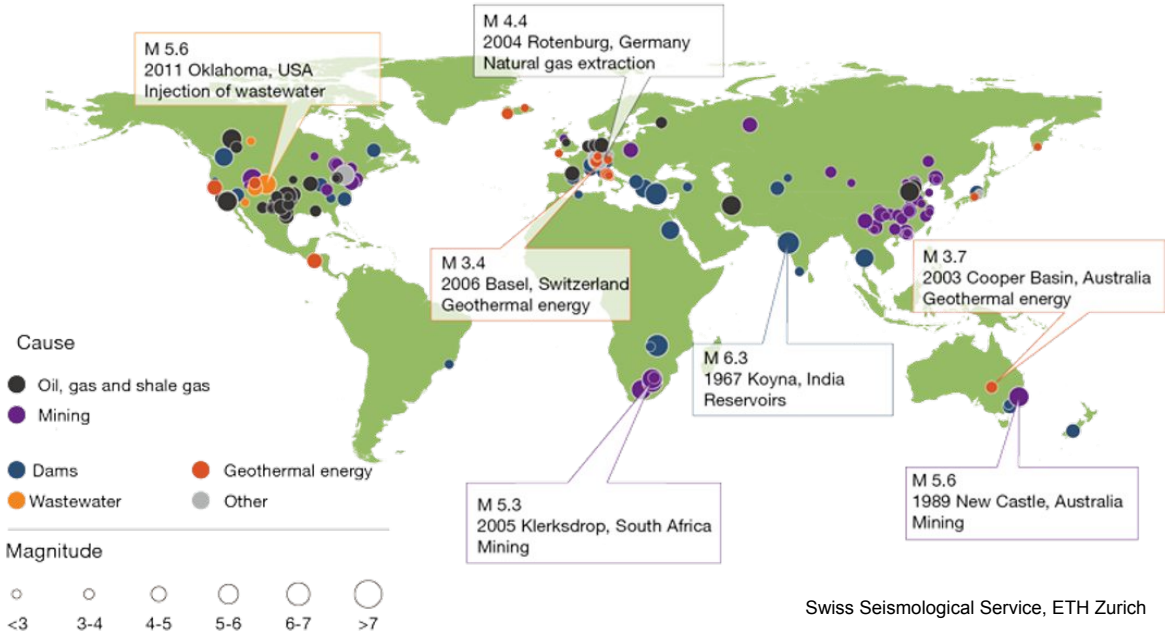


Source: *EnergyTracker*

Unleashing the potential, managing the risk

Published data from 1930 to 2014

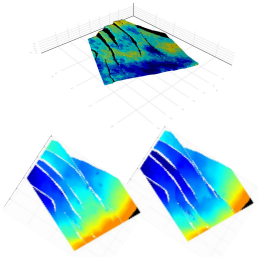
Major Human-induced Seismic Events



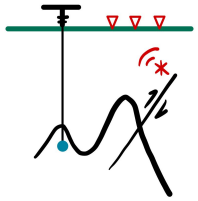
Swiss Seismological Service, ETH Zurich

Geothermal AI (POMDP model)

Reservoir model

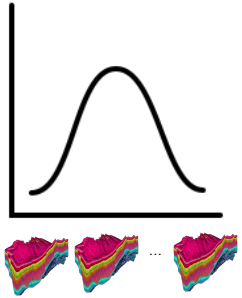


Well measurements



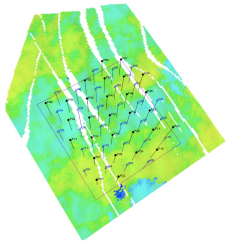
- Well temp
- Well pressure

Uncertainty



- Well temp
- Well pressure

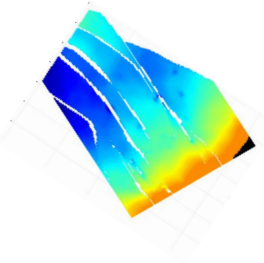
Decisions to make



- Where to place wells?
- What rate of injection?

Goal: Max NPV, safety

Reservoir simulator



- Our AI model ties together Earth and energy sciences, AI/data science, risk & safety, economics & business analysis

Geothermal AI (POMDP model)

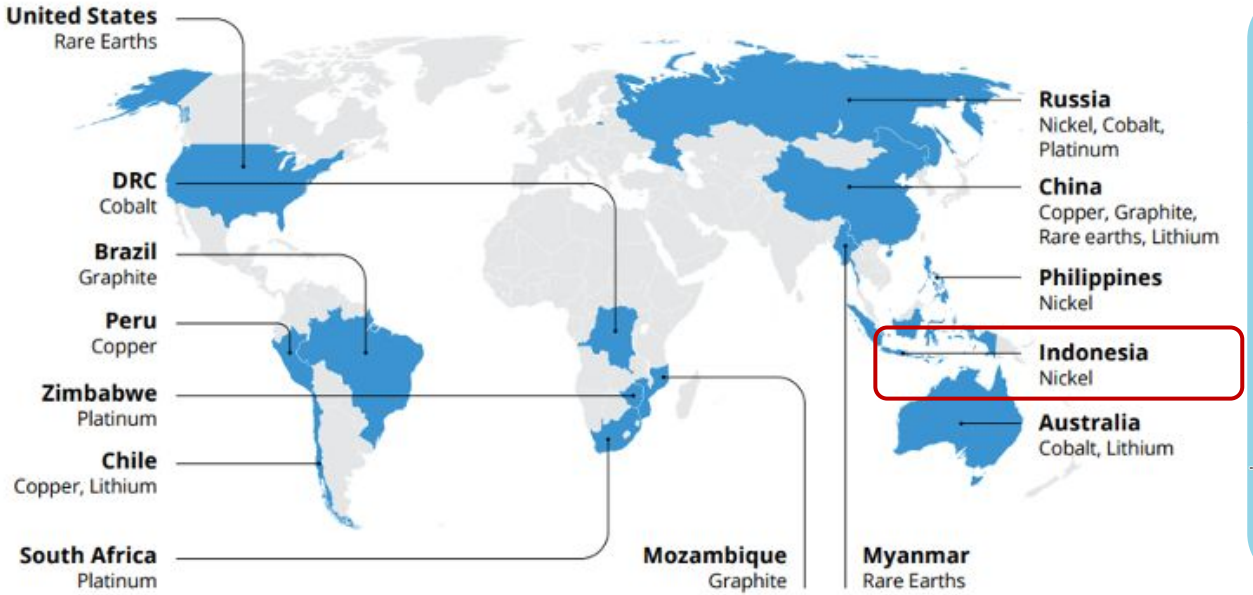
- We are interested in collaborations:
  - building geological models for Indonesia's geothermal reservoirs
  - lifetime learners with mining engineering, geology, geophysics, etc. with deep knowledge, local context, and wisdom on Sulawesi's geologies
  - interests in energy transition applications (critical minerals supply chains, geothermals, natural hydrogen, or carbon capture and storage)

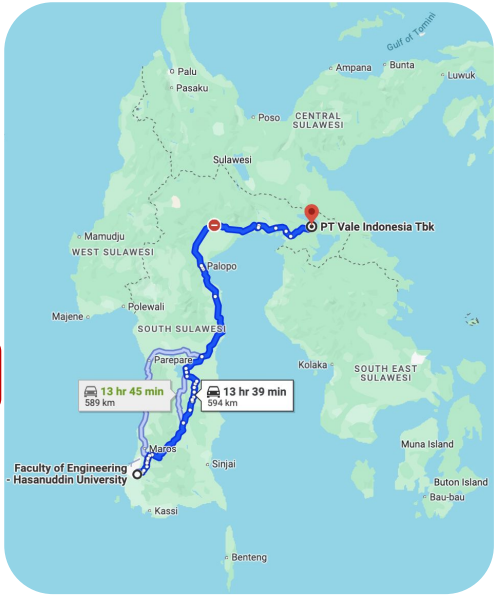
- We visited institutions: **ITS** Industrial and Systems Engineering, **ITB** Mining Engineering, **UI** Industrial Engineering, and **IPB** BRAIN Research Group (+ hopefully **Unhas**, soon)

Critical Mineral Exploration Around Us!

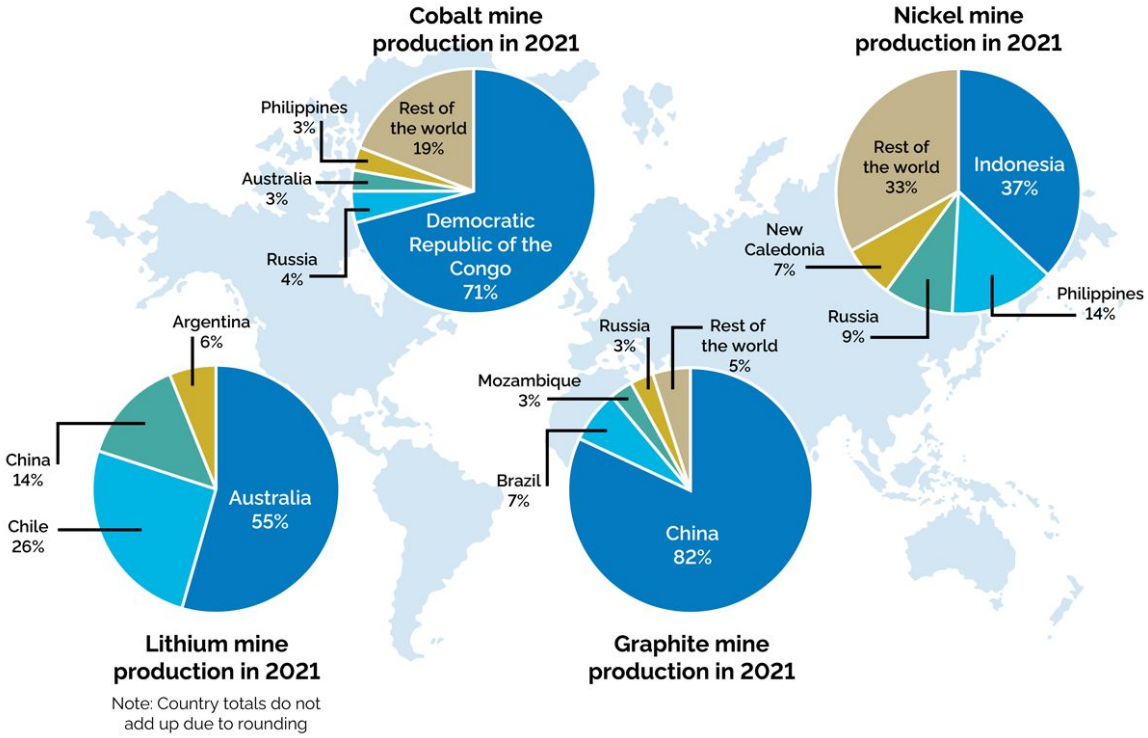
MINERAL-X SISL Stanford Intelligent Systems Laboratory

Top producer countries of energy transition minerals

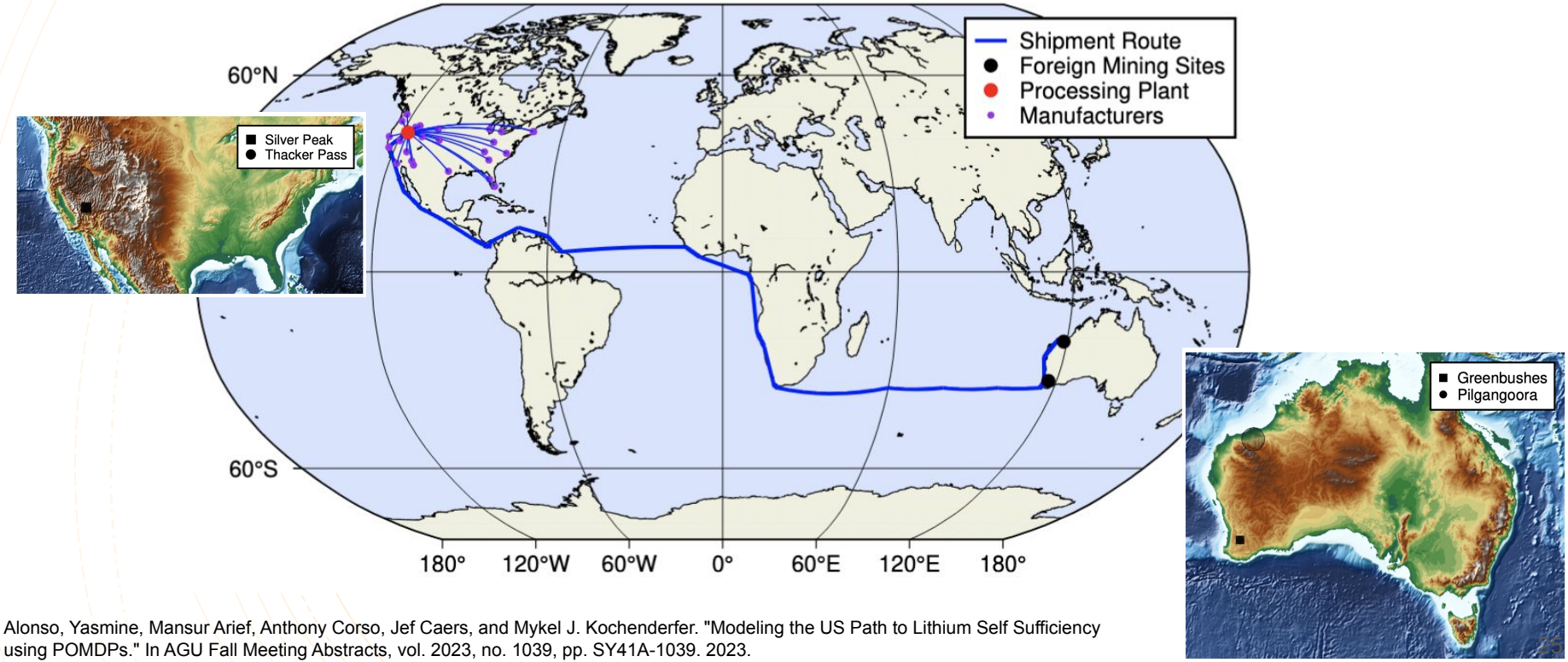




The mines are literally in our backyard


Cobalt mine production in 2021
Philippines 3%
Rest of the world 19%
Australia 3%
Democratic Republic of the Congo 71%
Russia 4%
Nickel mine production in 2021
Rest of the world 33%
Indonesia 37%
New Caledonia 7%
Philippines 14%
Russia 9%
Argentina 6%
China 14%
Australia 55%
Chile 26%
Lithium mine production in 2021
Note: Country totals do not add up due to rounding
Russia 3%
Rest of the world 5%
Mozambique 3%
Brazil 7%
China 82%
Graphite mine production in 2021

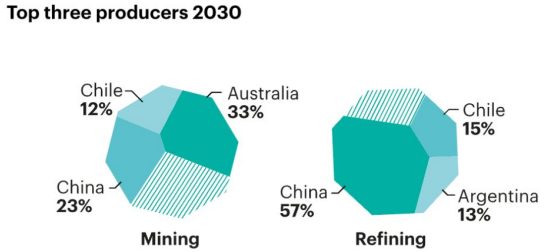
The geopolitics is complex

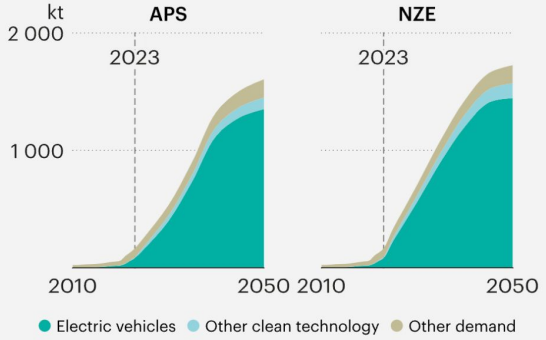


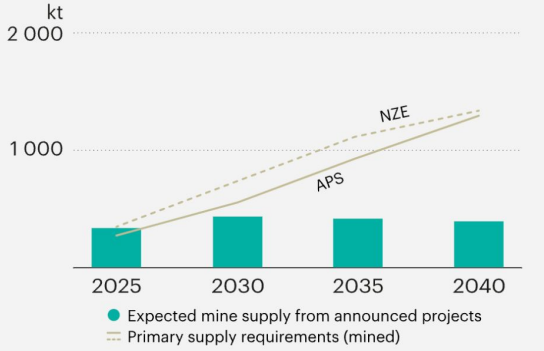
Alonso, Yasmine, Mansur Arief, Anthony Corso, Jef Caers, and Mykel J. Kochenderfer. "Modeling the US Path to Lithium Self Sufficiency using POMDPs." In AGU Fall Meeting Abstracts, vol. 2023, no. 1039, pp. SY41A-1039. 2023.

Background

Li
Lithium







The U.S. wants to become self-sufficient in lithium production

- National Security
- Sustainability

Bloomberg.com

US Aims to Boost Trade With Africa to Challenge China on Key Minerals

It's unclear whether Donald Trump or Kamala Harris will triumph in the Nov. 5 presidential election, but one thing's for sure: America's...

3 days ago

Council on Foreign Relations

The US Needs More than a Critical Minerals Stockpile, It Needs Market Infrastructure

Last month, Ganfeng Lithium, China's largest lithium producer and refiner, announced plans to establish a $1.1 billion trading desk "to...

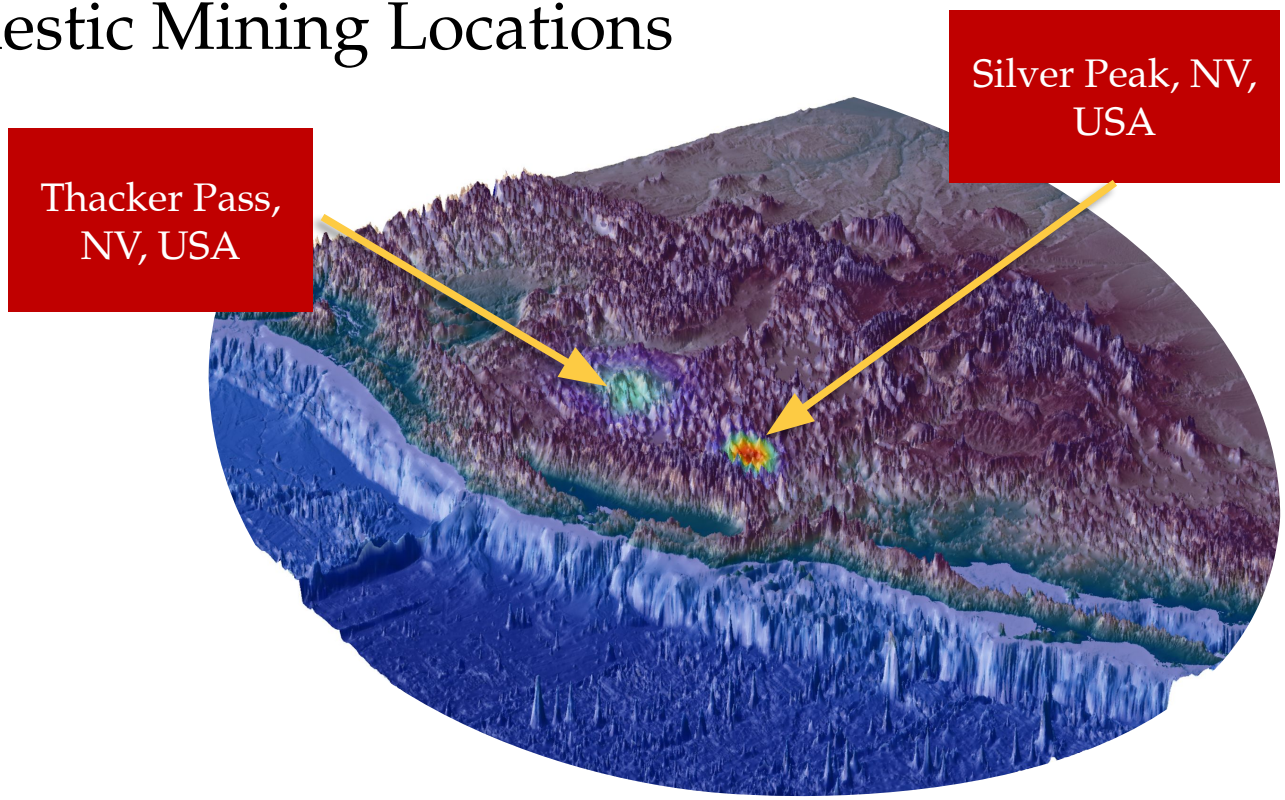
Motivations

- The desire for lithium self-sufficiency infrastructure is motivated by various factors:
- The adoption of **clean energy storage technologies**
  - Clean energy storage technologies
  - EVs
- The volume of domestic lithium deposits is **uncertain**
- Acquiring **social licenses** to mine domestically is difficult
  - Therefore we need to partially rely on international mines

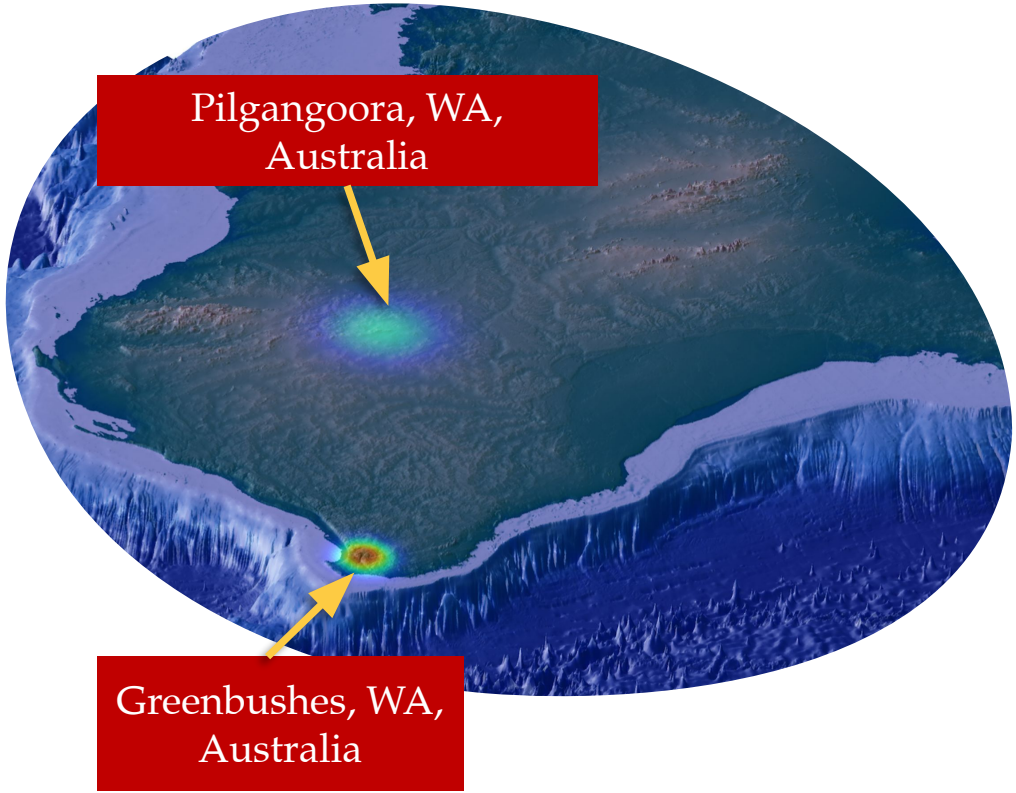
Our Research Question

- *How can the U.S. optimize its lithium supply chain to achieve partial self-sufficiency while balancing economic, environmental, and security goals?*

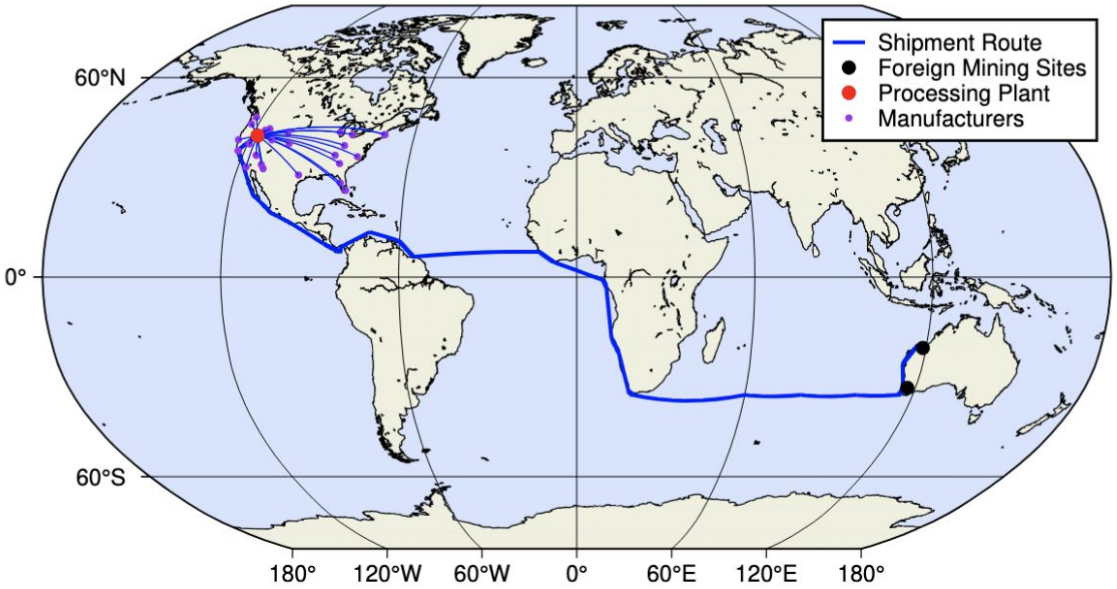
US Domestic Mining Locations



Australia Mining Locations

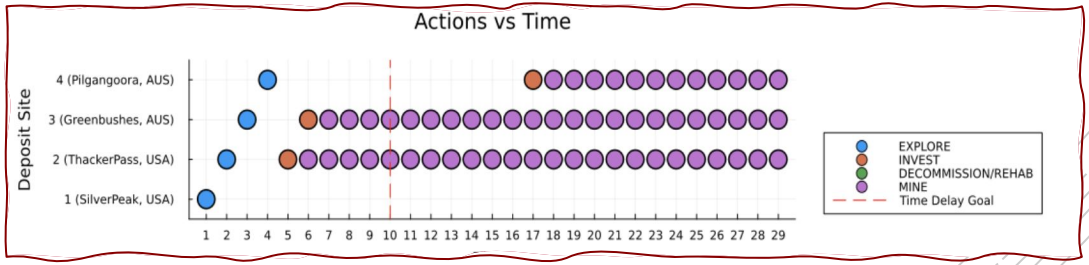


Indonesia?


Shipment Route
Foreign Mining Sites
Processing Plant
Manufacturers
60°N
0°
60°S
180°
120°W
60°W
0°
60°E
120°E
180°

Our Approach

- Formulate a POMDP
- Build an optimal policy that
  - Delays mining in the U.S
  - Satisfies lithium at each time step
  - Maximizes volume mined
  - Minimizes CO2 emissions
  - Minimize cost



POMDPs

- A method to formulate sequential decision-making problems

Kochenderfer, M. J. 2015. Decision Making Under Uncertainty: Theory and Application. MIT Press

Lithium POMDP Formulation

States

- Mining Deposits
- Volume mined domestically
- Volume imported
- A list to keep track of where we have or not have mined

Observation

- How much lithium does each deposit contain?

Belief

- How much lithium we believe each mine to contain

Action

- MINE: update time, increment volumes
- EXPLORE: update time

Reward

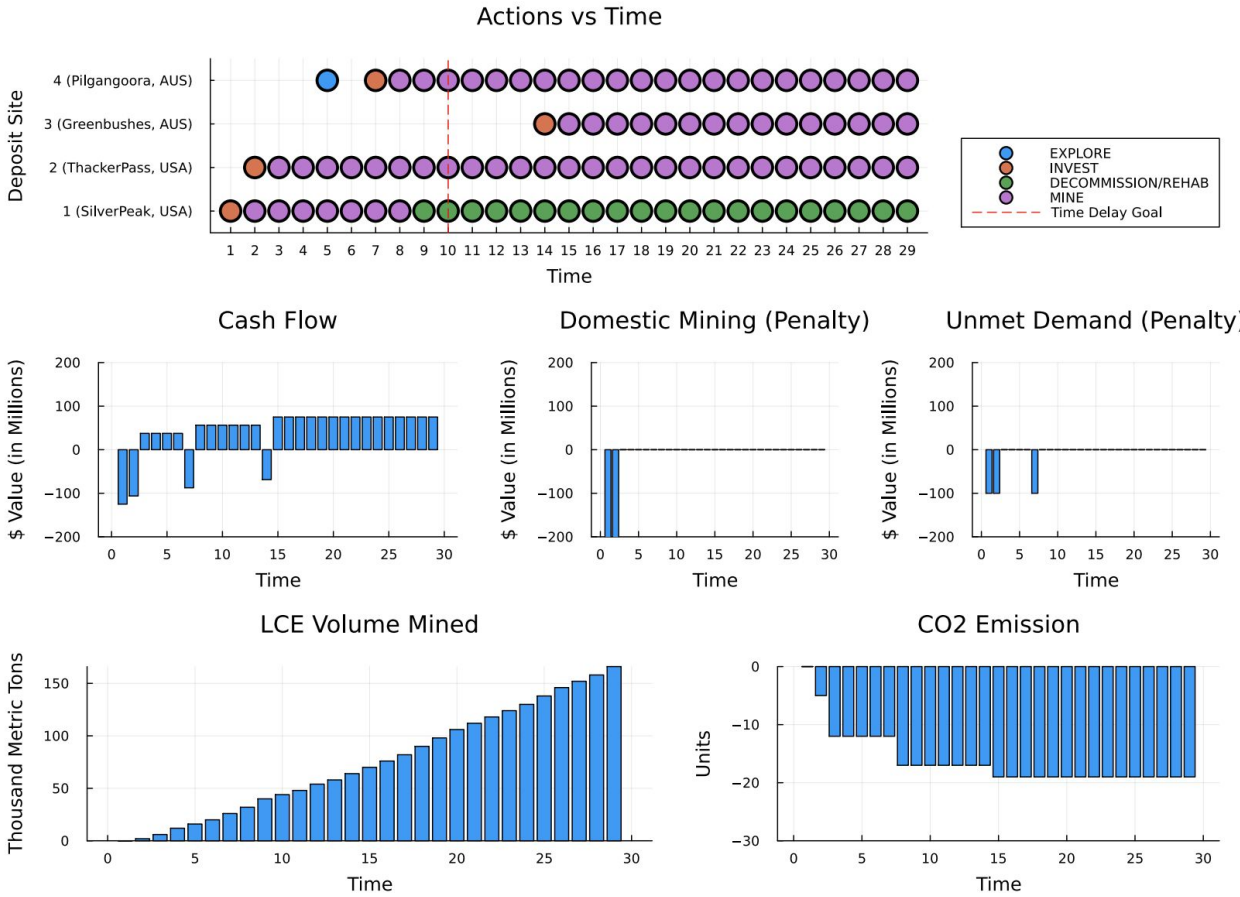
- encourages time delay for domestic mining
- maximizes lithium volume
- discourages CO_2 emissions
- Fulfills annual lithium demand
- Maximizes npv

Next State

- Mining deposits
- Volume mined domestically
- Volume imported
- A list to keep track of where we have or not have mined

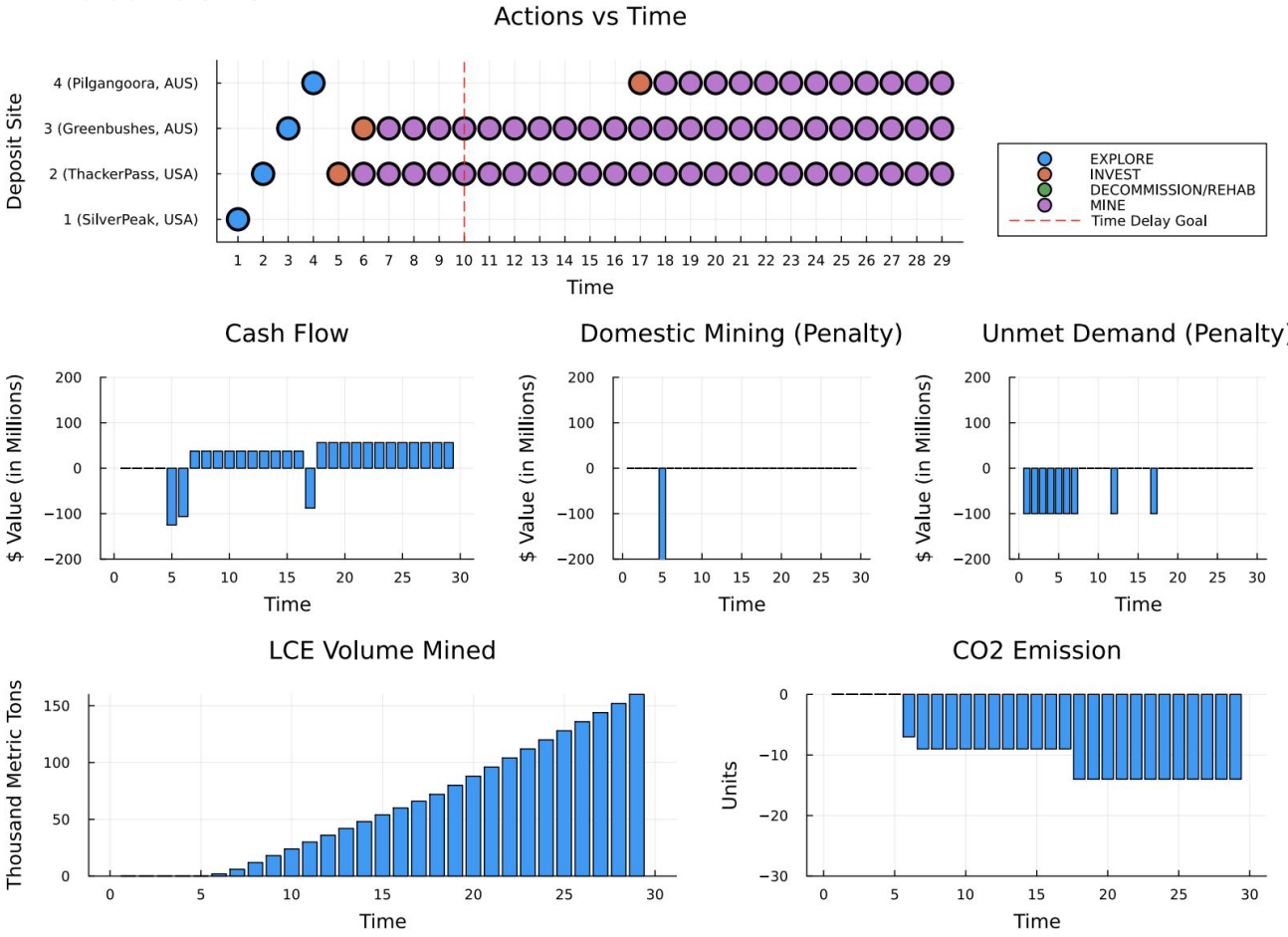
Results

(Random Policy)



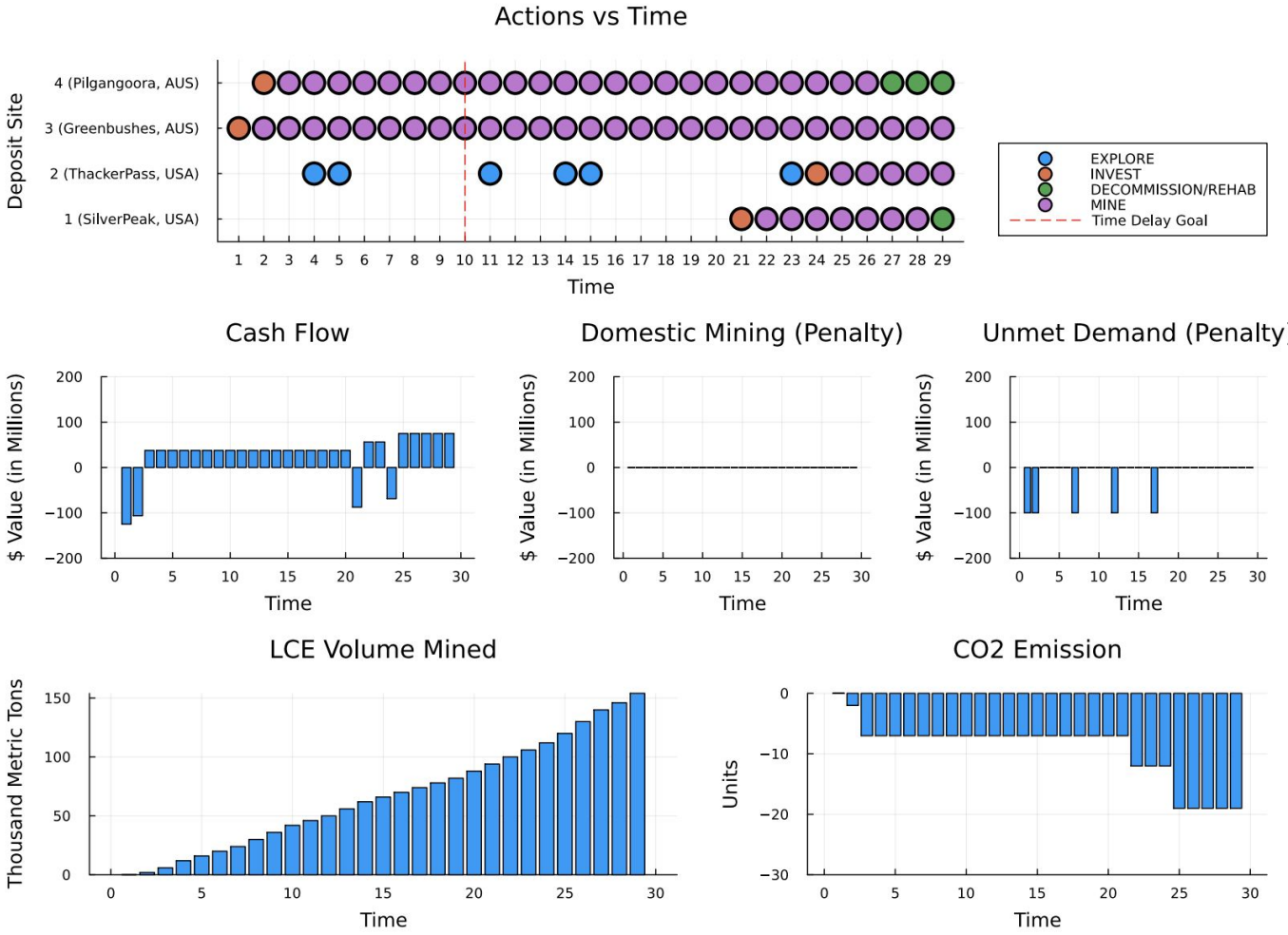
Results

(Greedy Policy)



Results

(AI Policy)



ICREST 2024 community's role

The climate case for a career in mining

The clean energy transition requires minerals mining, but young workers are reluctant to join an industry known for exploitation.

Carolyn Cole / Los Angeles Times via Getty Images

Maddie Stone

Published	Jan 31, 2024
Topic	Climate + Labor
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ADAURIS *Great journalism deserves to be heard*

Mansur Arief never imagined himself working in mining. As an artificial intelligence researcher finishing a PhD at Carnegie Mellon University, he developed safety algorithms for self-driving

bitly

What can we do?

With Pak Rachmat Kaimuddin
(Kemenko Marves)

With Pak Anindya Bakrie
(Ketua Kadin, CEO BNBR)

With Pak Pandu Sjahrir
(Ex Commissioner Bursa Efek Indonesia, CEO TBS)

At Berkeley Indonesia Club Dinner

With Pak Gita Wirjawan
(Ex Ministry of Trade, Stanford Fellow)

Let's collaborate to turn the potentials into actual benefits!

Summary

- Indonesia has potentials, but it needs us to take advantage of it.

- No matter how advanced the AI, to be trustworthy, it needs human-teaming and local context.

- Think about minerals and mining in a new paradigm:
  energy transition, sustainability, and community development.

Related research and publications

https://mansurarief.github.io/publications/

Thank you!

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Stanford Intelligent Systems Lab (SISL) and MineralX