How Much Autonomy Is Enough?
Applying Systems Engineering methodology to autonomy in modern systems

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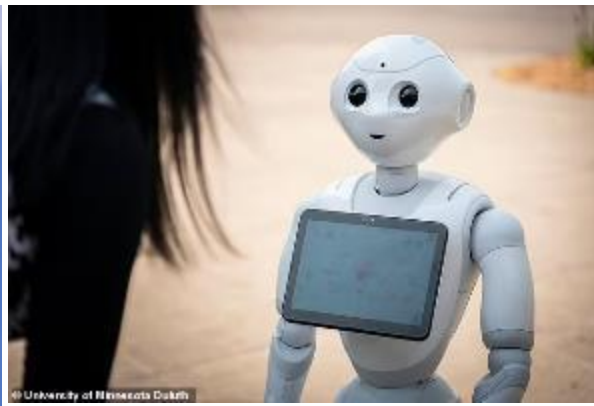https://ctme.caltech.edu

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Audience Question

Please turn to your neighbor, introduce yourself, and answer:

If the airplane (or car) that brought you here had to be guided solely by autonomy, would you be <u>in person</u>?

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Novelty? Innovation?

https://www.capradio.org/articles/2022/07/12/a-small-san-joaquin-county-town-will-be-the-guinea-pig-for-amazon-drone-delivery/
https://www.dailymail.co.uk/sciencetech/article-10991645/First-kind-humanoid-robot-deployed-nursing-home-help-patients-Alzheimers.html
https://www.restaurantdive.com/news/piestro-serve-robotics-delivery-automated-pizzeria/626789/
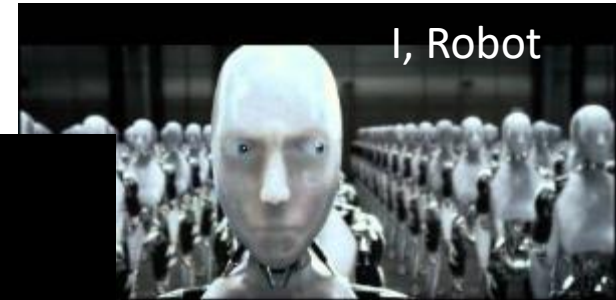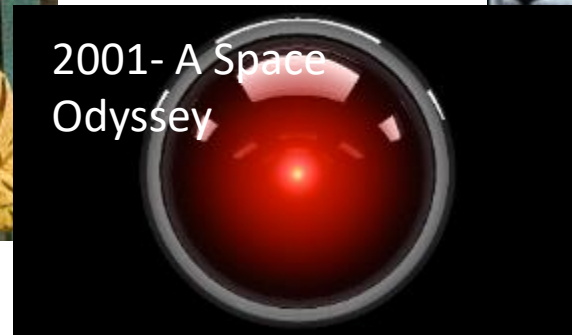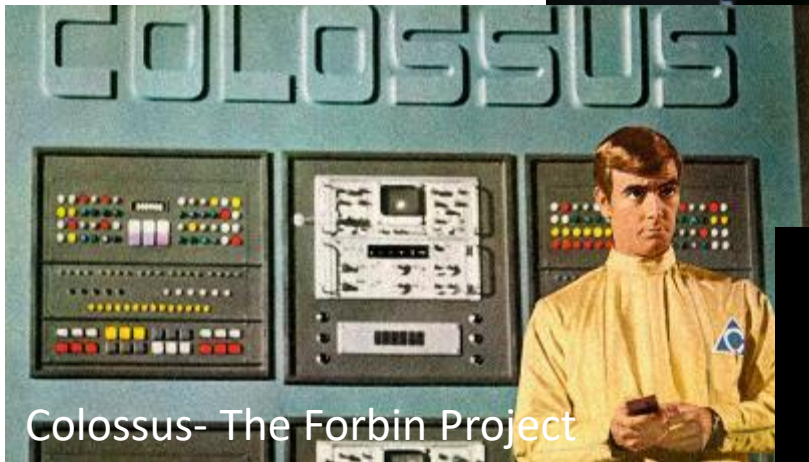
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The future?

John Deere: *The autonomous tractor serves a specific purpose: feeding the world… farmers must feed this growing population with less available land and skilled labor*

https://www.grandforksherald.com/prairie-business/is-autonomous-farming-a-trend-on-the-horizon
https://www.deere.com/en/news/all-news/autonomous-tractor-reveal/

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Or a path to Dystopia?

Star Trek

Terminator

Colossus- The Forbin Project

2001- A Space Odyssey

I, Robot

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And not just in the movies

Headline: *AI has gone wrong? Chess robot breaks child's finger at chess tournament held in Russia*

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INCOSE Vision 2035

*As society benefits from advancements in system capabilities, consumers and users continue to expect more from these systems. ...***They expect systems to be more socially acceptable by considering their impact on society*** and the environment.*

Users also expect systems to be more autonomous, enabling them to seamlessly interact, and understand and respond to their requests*.*

- Derived from Systems Engineering Vision 2035

What is the right place and right level for autonomous systems and Autonomy?

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Applying Systems Engineering to Autonomy

SEBOK Wiki: System requirements are needs… that describe functions which the system as a whole needs to fulfill

Requirements have to be NECESSARY:

- An essential capability, characteristic, constraint, and/or quality factor

https://www.sebokwiki.org/wiki/Stakeholder_Requirements_Definition

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Necessary

Where do autonomous systems fit as "necessary"?

"Dull, Dirty, and Dangerous"

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Dull

Repetitive or long tasks that humans don't have the endurance or attention for, e.g.,

- Factory assembly lines

- Aerial refueling, flying broad circles in the sky while other airplanes approach to receive fuel

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Dirty

Tasks that are particularly messy or challenging for humans to deal with, e.g., cleaning up after reactor meltdowns or toxic waste spills

- Not always successfully

https://technabob.com/blog/2016/01/19/toshiba-robot-fukushima-clean-up/
https://chernobylx.com/chernobyl-robots/?editorPath=blog-detail/153/chernobyl-robots

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Dangerous

- Homing torpedoes in WWII—certainly a dangerous mission for humans!
  - Human-guided torpedoes to autonomous homing torpedoes
- Cruise missiles, decoy airplanes, and more recently, fully autonomous combat vehicles

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Another criteria: **Appropriate**

Orderly environment: **Autonomy works well under conditions of order or "good behavior"**

- Example: robotic vacuum cleaners
- But with the occasional failure

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Disorderly conduct?

Of course things don't always work out well

https://www.independent.co.uk/news/world/americas/robot-killed-woman-wanda-holbrook-car-parts-factory-michigan-ventra-ionia-mains-federal-lawsuit-100-cell-a7630591.html
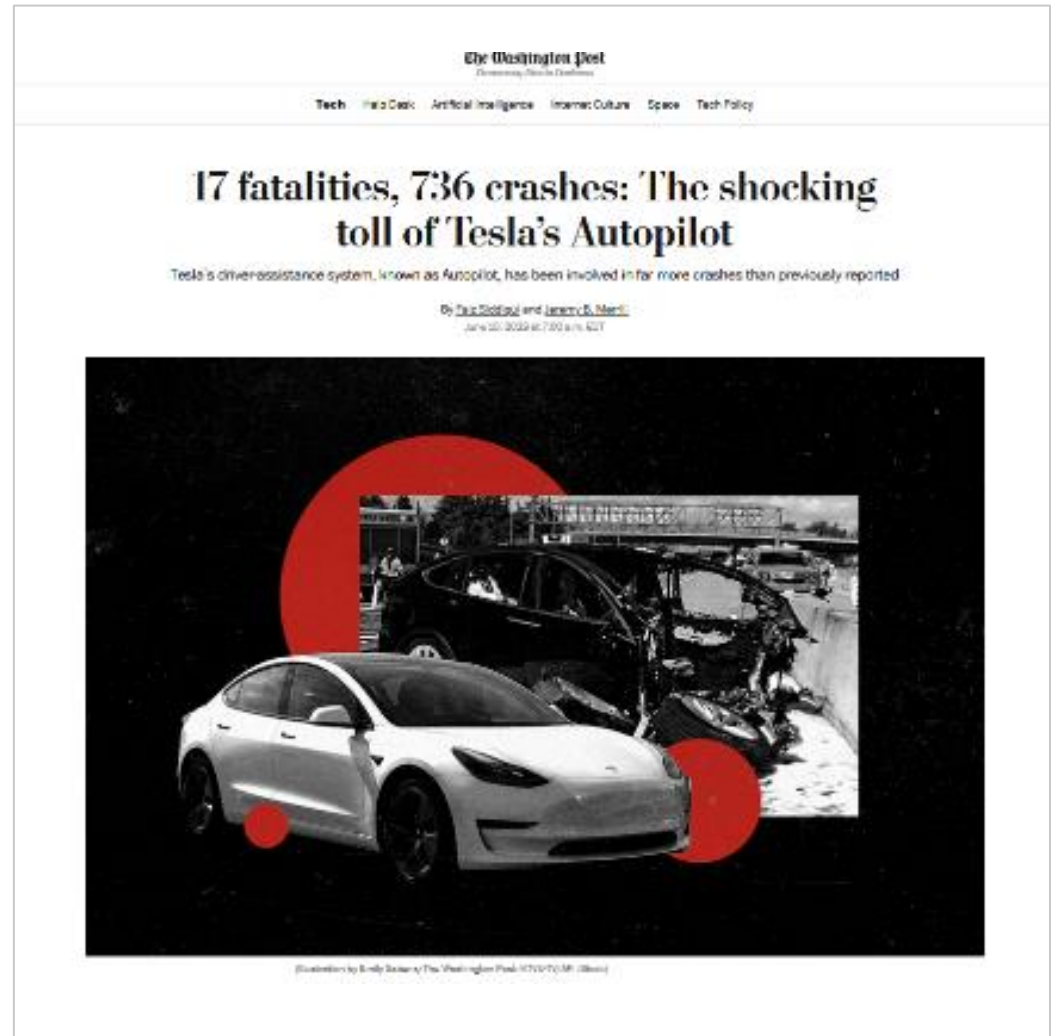https://www.thedailybeast.com/bride-to-be-crushed-to-death-by-car-factory-robot
https://www.latimes.com/business/autos/la-fi-hy-uber-self-driving-20180319-story.html
https://www.the-sun.com/motors/5837627/self-driving-car-accident-in-san-francisco/

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So what goes wrong?

Human behavior as a contributing factor – acting outside the rules

Environment as a factor: chaotic, dominated by uncertainties, "rule breakers" present

The Washington Post

Tech   Help Desk   Artificial Intelligence   Internet Culture   Space   Tech Policy

17 fatalities, 736 crashes: The shocking toll of Tesla's Autopilot

Tesla's driver-assistance system, known as Autopilot, has been involved in far more crashes than previously reported

By Faiz Siddiqui and Jeremy B. Merrill
June 10, 2023 at 7:00 a.m. EDT

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Why do autonomous systems deal badly with chaos?

- Autonomous systems run on software based on deterministic concepts: "If these conditions occur, then do X"

- Machine Learning is created by repeated exercises, which create a deterministic model of control

But life, especially among humans, is not always deterministic

Typical teenager bedroom: Deterministic or chaotic? Or both?

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Humans advantages over machines

Humans adapt to environments by ABSTRACT THINKING

- A car pulls into a parking space ahead of you. What action would you expect next? At a daycare?

- Ball rolls out from between two cars in a neighborhood—the human driver slows down. Why?
- What if the ball is thrown underhand?
- In England?

Could Machine Learning help autonomous systems? Perhaps, but most machines don't abstract

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Autonomous systems depend on valid understanding of environments

Environment input can be false—when the sensors are too limited or fail to correctly describe the environment

- Air France Flight 447

- 737MAX

Extreme disorder →
Faulty information to the autonomous system →
Wrong decisions →
Hampered ability of the aircrew to recover

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Are autonomous systems **the RIGHT solution**, even if they pass one of our Dull, Dirty, and Dangerous tests and match the environment?

"One of the misconceptions around autonomous [systems] is that, somehow, because they are autonomous, the become a jack of all trades..." -- Pete Kunz, Boeing VP of Phantom Works

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Return greater than risk

One more requirement for autonomous systems:
Return greater than the risk introduced by adding automation

Is use of an autonomous control system not just necessary and appropriate, but a good choice where the risks are outweighed by the gains?

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Cases and Discussion?

What do you think of the following test cases?

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Autonomous Trucking?

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Autonomous Trucking?

Long-haul trucking could pass the dull test, and can be dangerous – but it also exists in a world where environment can become chaotic rapidly

Do we always have perfect information about the environment?

- Author's personal experience 2015: Trucker, faced with closed roads due to winter snows, follows Google Maps advice

https://www.wsj.com/articles/truck-driver-pay-rose-almost-11-amid-strong-freight-demand-last-year-11660161041?page=1
https://www.seattletimes.com/business/robot-arms-are-replacing-shelf-stockers-in-japans-stores/
https://www.wsj.com/articles/self-driving-truck-accident-draws-attention-to-safety-at-tusimple-11659346202?page=1

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Autonomous pizza delivery?

- ❑ Dull?

- ❑ Dirty?

- ❑ Dangerous?

- ❑ Environment?

- ❑ Return vs risk?

- ❑ Appropriate?

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Autonomous pizza delivery?

- Dull?

- Dirty?

- Dangerous?

- Chaotic environment (neighborhoods)

- Return vs risk is questionable

- Big challenge is appropriate: Disorderly environment found on most streets—especially in housing areas

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Autonomous package delivery by drone?

❑Dull?

❑Dirty?

❑Dangerous?

❑Environment?

❑Return vs risk?

❑Appropriate?

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Autonomous package delivery by drone?

- All of the challenges faced by our pizza delivery robot, but replacing ground collision with risks of air collisions

- Environment of hazards: flocks of birds, kites, amateur operated drones, etc.

- Risk versus reward: crashing into someone's house, while carrying a hazardous, high-level store of hazardous energy

Appropriate?

Does reducing delivery time for household items or reducing labor costs outweigh the risks?

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Robotic crop care e.g. plowing or spraying fields

- ❏ Dull?

- ❏ Dirty?

- ❏ Dangerous?

- ❏ Environment?

- ❏ Return vs risk?

- ❏ Appropriate?

https://www.deere.com/en/publications/the-furrow/2021/summer-2021/robots-in-the-rows/
https://www.grainews.ca/machinery/john-deere-to-release-robotic-8r-tractor/

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Autonomous systems ARE a fit sometimes

Robotic crop care e.g. plowing or spraying fields

✓ Dull?

✓ Dirty?

■ Dangerous?

✓ Appropriate Environment?

✓ Reward outweighs risk

One more reason may be a growing shortage of labor with the training and skills to operate complex ag equipment on a very irregular basis

https://www.deere.com/en/publications/the-furrow/2021/summer-2021/robots-in-the-rows/
https://www.grainews.ca/machinery/john-deere-to-release-robotic-8r-tractor/

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Autonomous medical evacuation helicopters?

- ❑ Dull?
- ❑ Dirty?
- ❑ Dangerous?
- ❑ Environment?
- ❑ Return vs risk?
- ❑ Appropriate?

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Autonomous medical evacuation helicopters?

✓ Ad hoc nature, usually in poor weather and at night, unprepared landing fields=very dangerous

■ Chaotic environment

✓ Return of reducing onboard crew—potentially to zero—may outweigh the risk of operation

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Autonomous passenger airplanes?

- ❑ Dull?
- ❑ Dirty?
- ❑ Dangerous?
- ❑ Environment?
- ❑ Return vs risk?
- ❑ Appropriate?

- *Back to our original question: who would be here if you had to use autonomy?*

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Autonomous passenger airplanes?

✓ Sometimes dull, but fortunately not often dangerous or dirty

- Appropriate? Environment is mostly controlled (controlled airspace) BUT still chaotic

- While autonomy can help, it's unlikely that the flying public will accept the risk of robotic pilots—and even less so in the wake of recent crashes

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Man succeeds DESPITE automation?

January 2009: The Miracle on the Hudson

- US Airways flight 1459 struck birds and the aircrew managed to fly it to a successful water landing
- Chesley Sullenberger hailed and celebrated for his airmanship
- Sullenberger pointed out that autonomous functions of the airplane resisted his efforts near the end of flight to slow the airplane and achieve a safer landing

https://www.thedrive.com/tech/8300/can-sully-transform-the-world-of-self-driving-cars

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Robotic Airlines

Waiting for someone to invent or propose the *Autonomous Flight Attendant*—certainly this is a job that can be dull, often dirty, and sometimes dangerous!
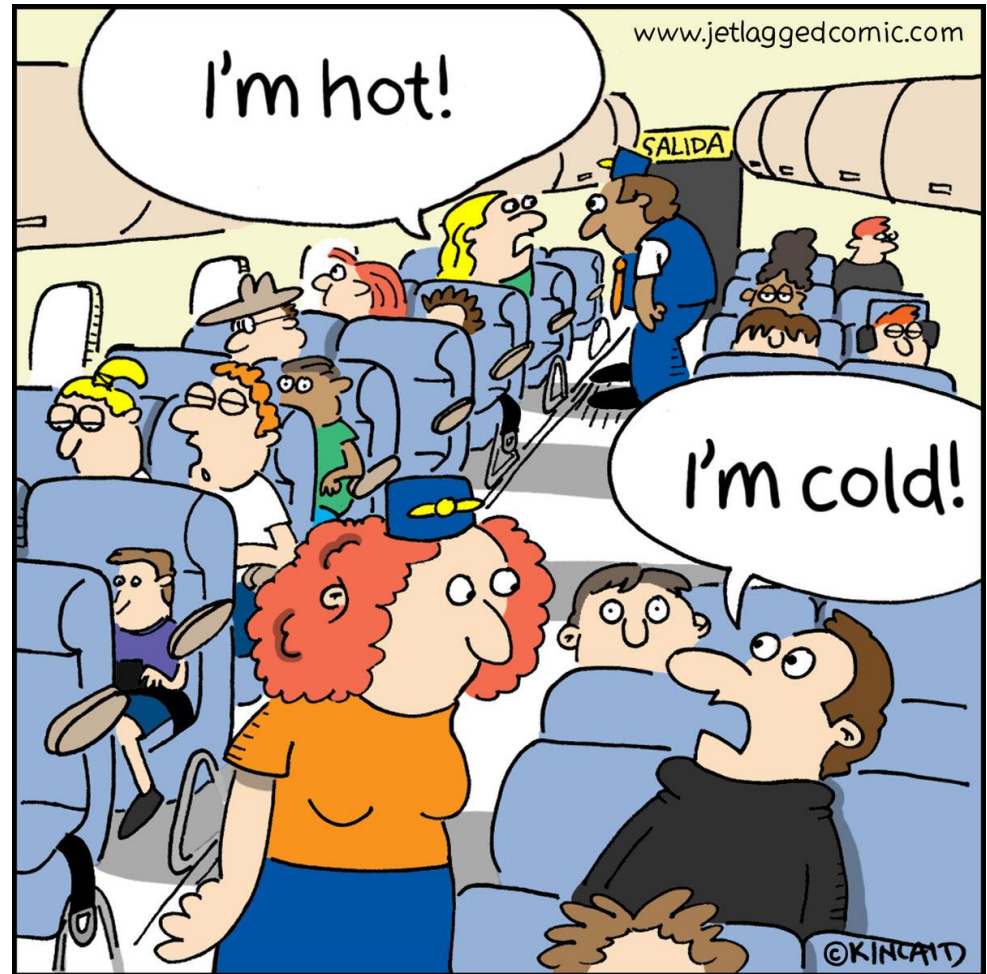
Thank you to Kelly Kincaid, author of "Jetlagged"

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Autonomous airborne firefighting

- ☐ Dull?
- ☐ Dirty?
- ☐ Dangerous?
- ☐ Environment?
- ☐ Return vs risk?
- ☐ Appropriate?

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Autonomous airborne firefighting

✓ Dull, Dirty, and Dangerous

✓ Environment can be chaotic, but can be controlled

- May not pass the risk versus return if ground fire crews are present

- But MAY if appropriate conditions established

What if we changed the operating premise to a "first response" system separated from ground fire crews??

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Autonomous child (human?) care?

- Dull?

- Dirty?

- Dangerous?

- Environment?

- Return vs risk?

- Appropriate?

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The AI Nanny in Your Baby's Future

Sophisticated artificial-intelligence helpers will relieve parents' burdens and give babies and toddlers the back-and-forth stimulation they need. But will there be a developmental cost?

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Autonomous child (human?) care?

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What about the future?

All of this is not to say that autonomous systems may not improve in years to come

Nor are they always inappropriate

BUT they remain not ready for <u>every</u> problem today….

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Conclusion

Systems Engineers need to be spearheading the move towards autonomy, but with a careful eye to *needs*, not *wants*

Autonomous solutions need to be evaluated by:

- Necessary in handling problems - Dull, Dirty, or Dangerous

- Appropriate for environments that are orderly and rules based

- Returns that are greater than the risks

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