

Staying Profitable with AI

Virtual Test and Process Redesign

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Seminar Outline

- Context of Data Storage Industry
- Framing AI
- Use Case & Pain Points
- Replacing Job Task with Machine Learning
- Handling Uncertainty
- Process Redesign & ROI

Setting the Context: Data Storage

Market: Hard Disk Drive (HDD)

Key Players: Highly Concentrated. Seagate, Toshiba & Western Digital are only the three makers today.

Hard Disk Drive (HDD): Low Cost, Low Performance, (Very Very) Complicated Technology

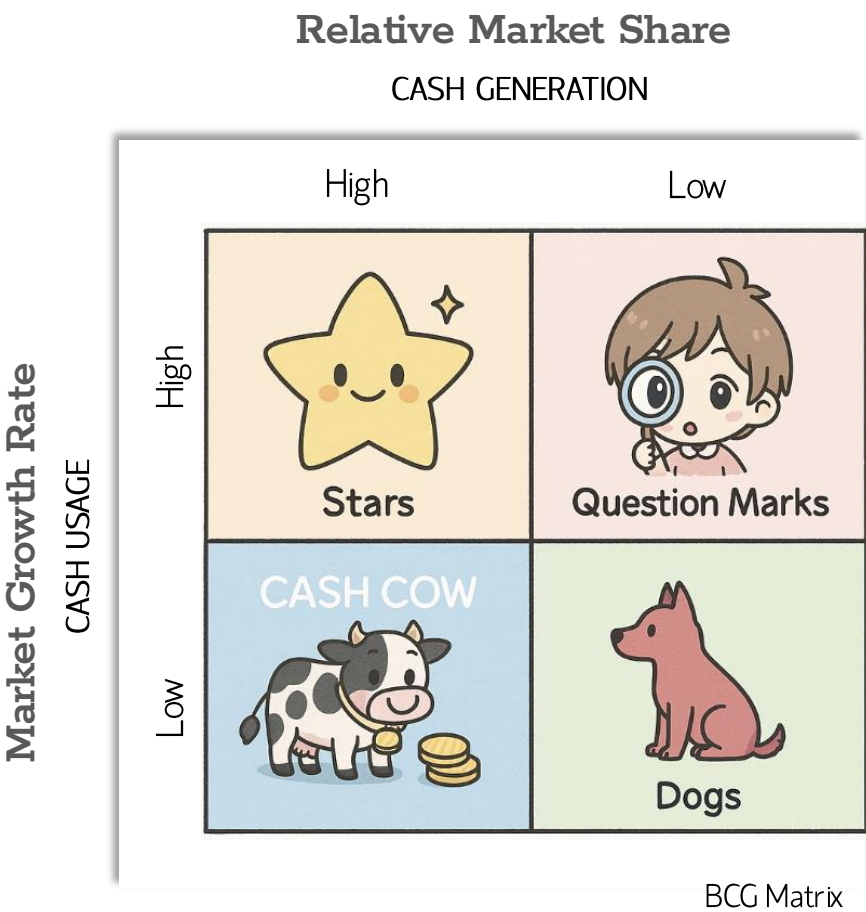
Threat: Solid State Drive (SSD), High Performance, Expensive (but getting cheaper), Simple Technology

Sunsetting Technology

Near Term: Cloud Expansion → High Demand in Data Storage

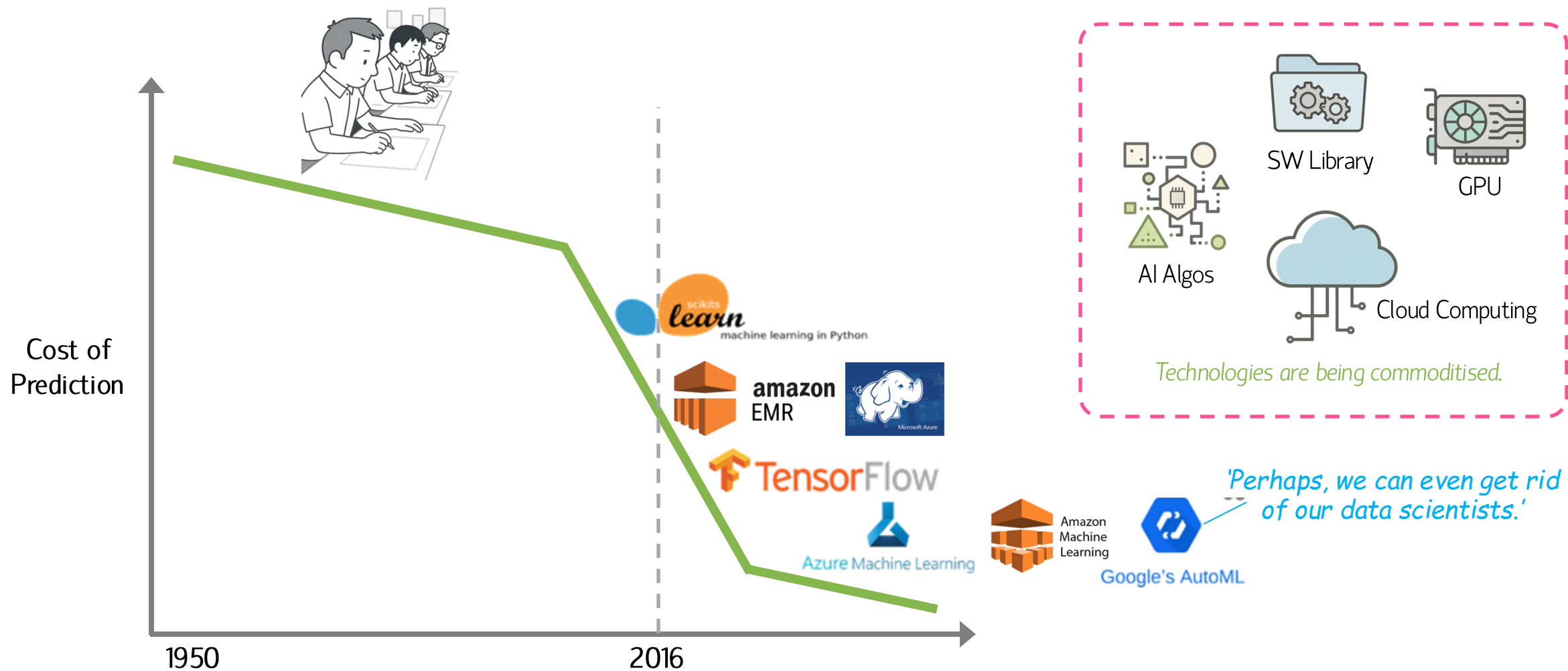
Outlook: Sunsetting Technology (being replaced by SSD)

Firms often hesitate to invest heavily in sunseting tech even amid short-term demand.



Context: We have orders. → We are struggling to fulfill the orders. → But yet, we don't want to invest.

Artificial Intelligence (AI)



(Agrawal, Gans and Goldfarb 2018)

Composite Teaching Case; Synthetic Figures; No Confidential Info.

What Is AI?

AI lowers cost of prediction. It's a cheap prediction.

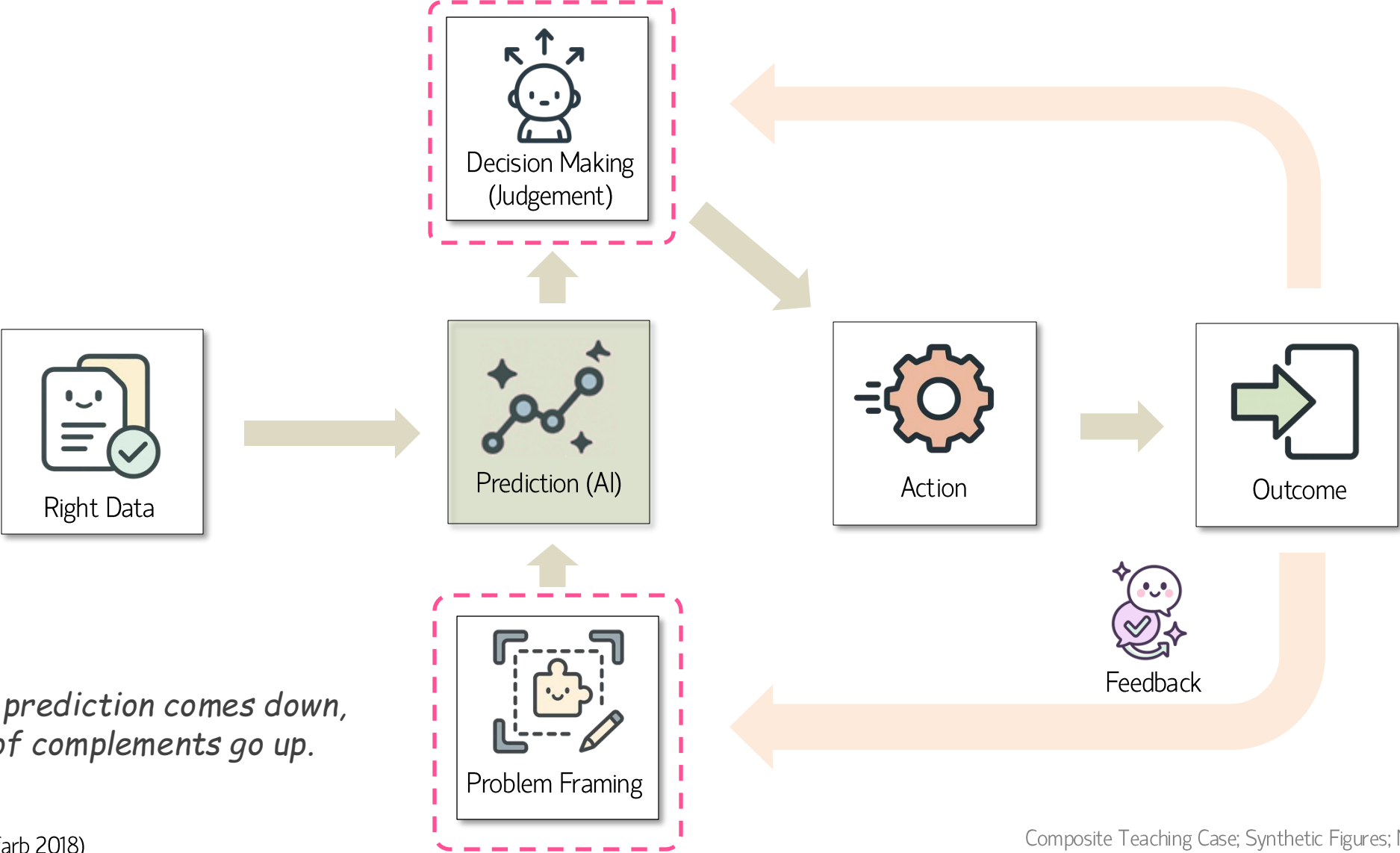
Business Meaning of AI

Think of It This Way: Things will become less magical.

What will happen when prediction becomes cheap?

Surely, we will use more of it.

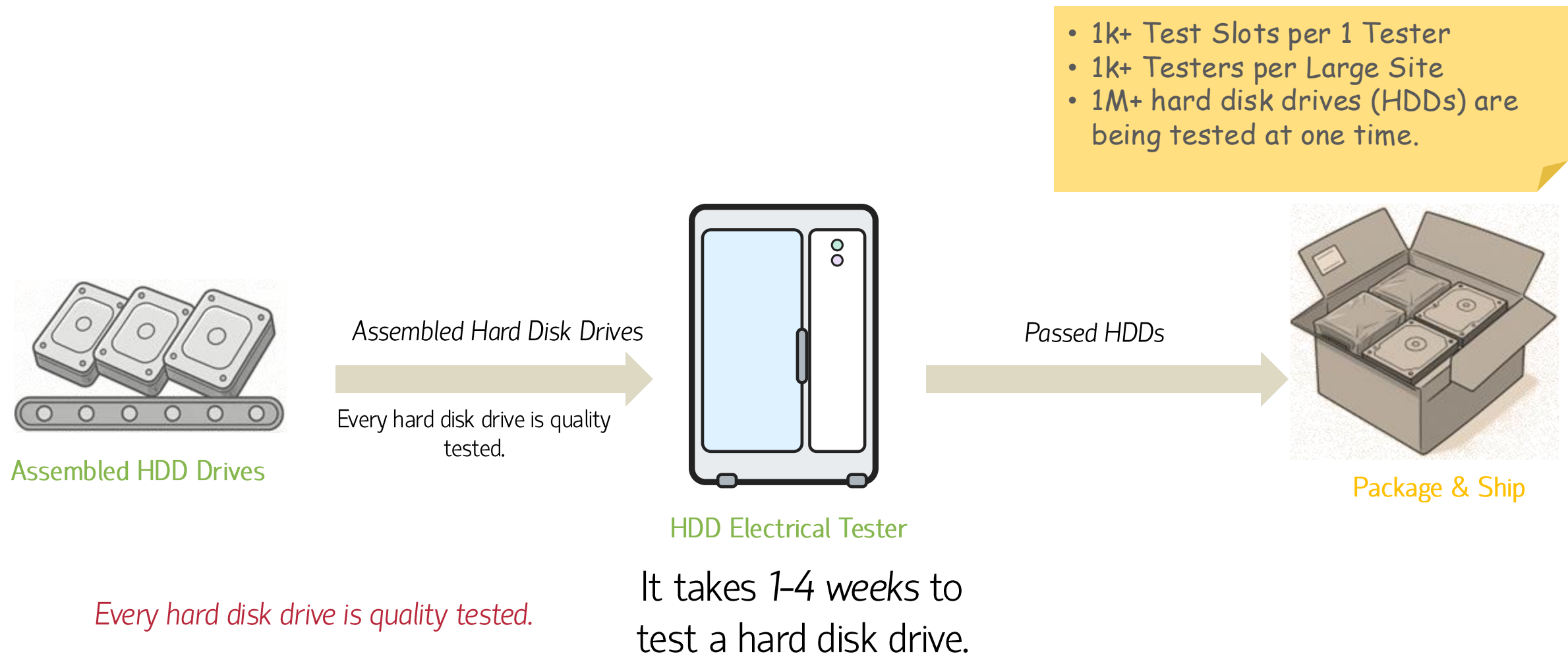
AI's Complements



(Agrawal, Gans and Goldfarb 2018)

Composite Teaching Case; Synthetic Figures; No Confidential Info.

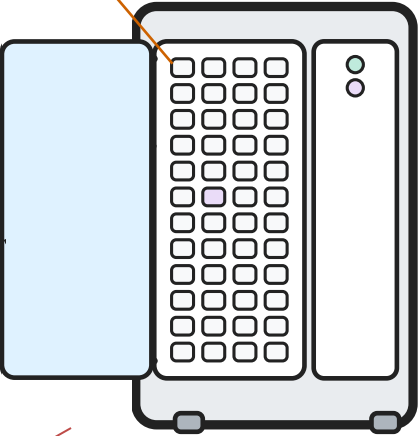
HDD Test Process: Operation Bottleneck



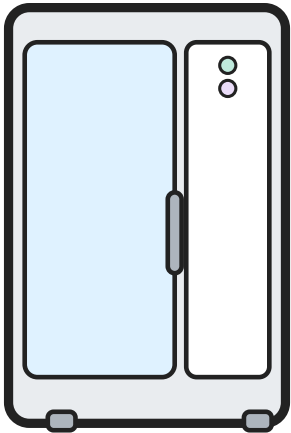
Who Test the The Tester?

1k+ Test Slots per 1 Tester

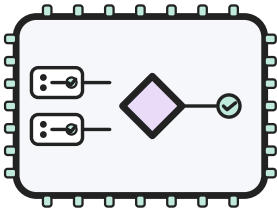
Slot: #537



HDD Test Slots



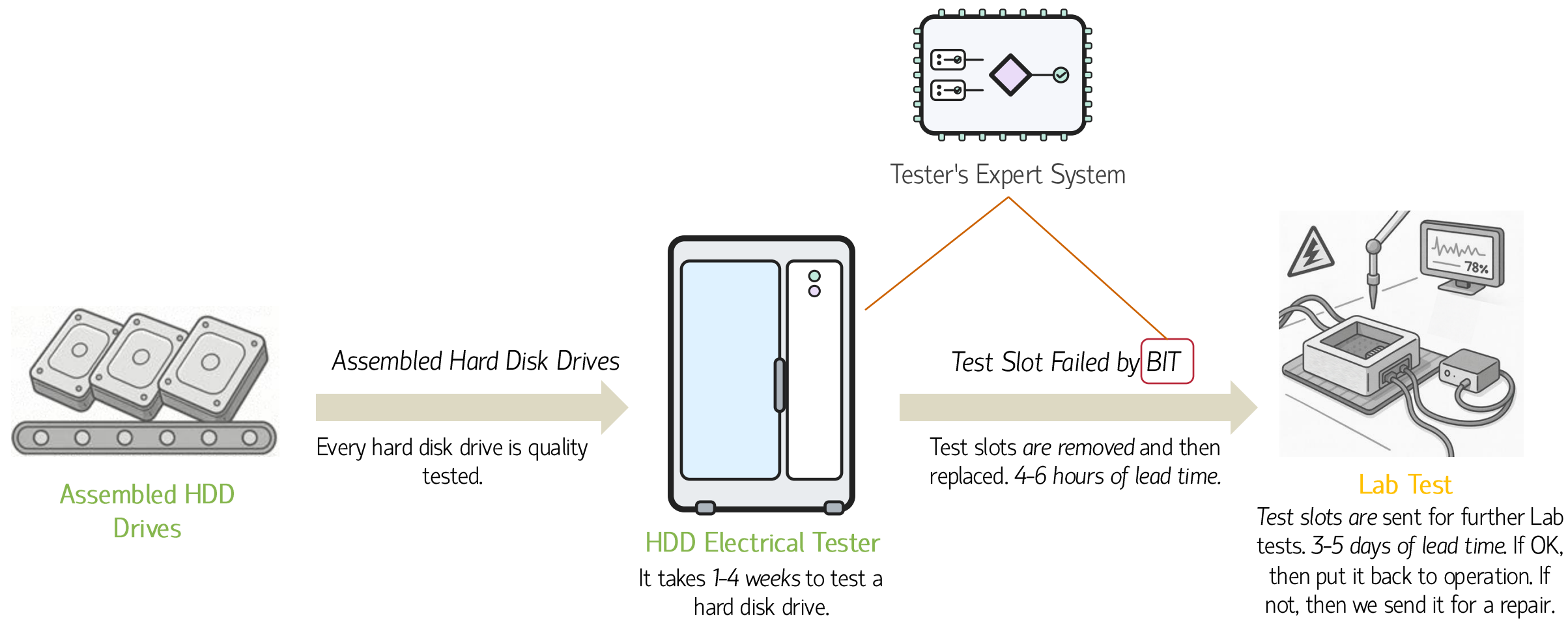
HDD Electrical Tester



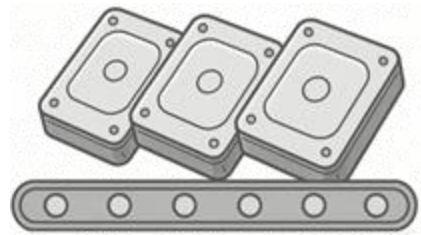
Tester's Expert System

The expert system monitors each test slot and makes use of its operational data to decide if the test slot is in good condition or not.

Test Slots Do Fail



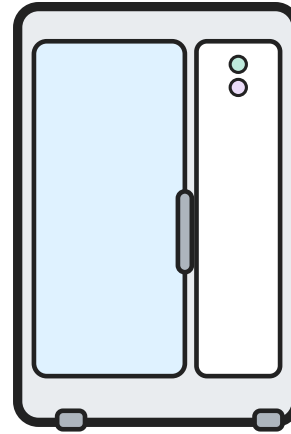
Pain Point



Assembled HDD Drives

Assembled Hard Disk Drives

Every hard disk drive is quality tested.

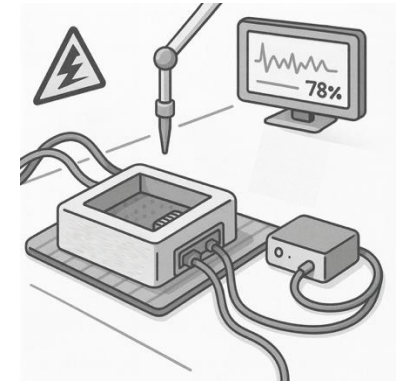


HDD Electrical Tester

It takes 1-4 weeks to test a hard disk drive.

Test Slot Failed by BIT

Test slots are removed and the replaced.
4-6 hours of lead time.



Lab Test

Test slots are sent for further Lab tests. 3-5 days of lead time. If OK, then put it back to operation. If not, then we send it for a repair.

80% of 'FAULT' are in fact 'OK' → ~1% loss in OEE.

A high false-positive rate in legacy screening can materially reduce OEE.

OEE: Overall Equipment Effectiveness

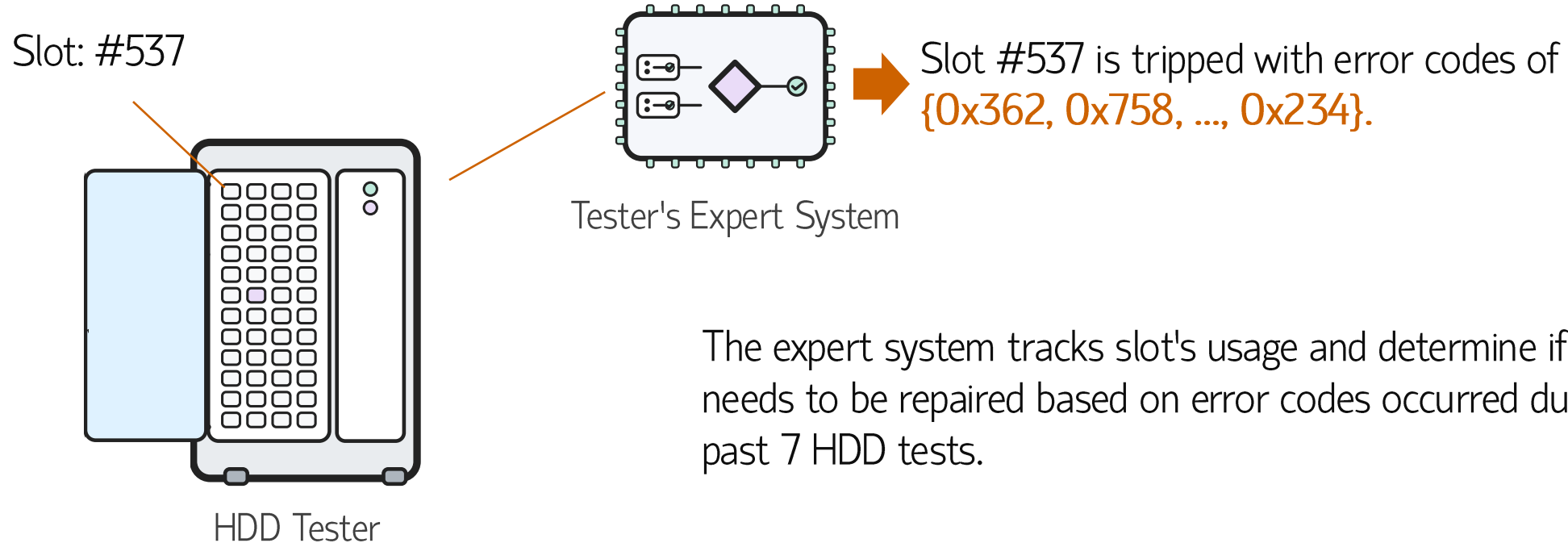
Composite Teaching Case; Synthetic Figures; No Confidential Info.

WHAT-IF Seconds vs Days

WHAT-IF: We can do the test verification in seconds, instead of 3-5 days.

THEN: 1% OEE can be re-gained, which is an additional test capacity of ~5 more testers.

Measurements



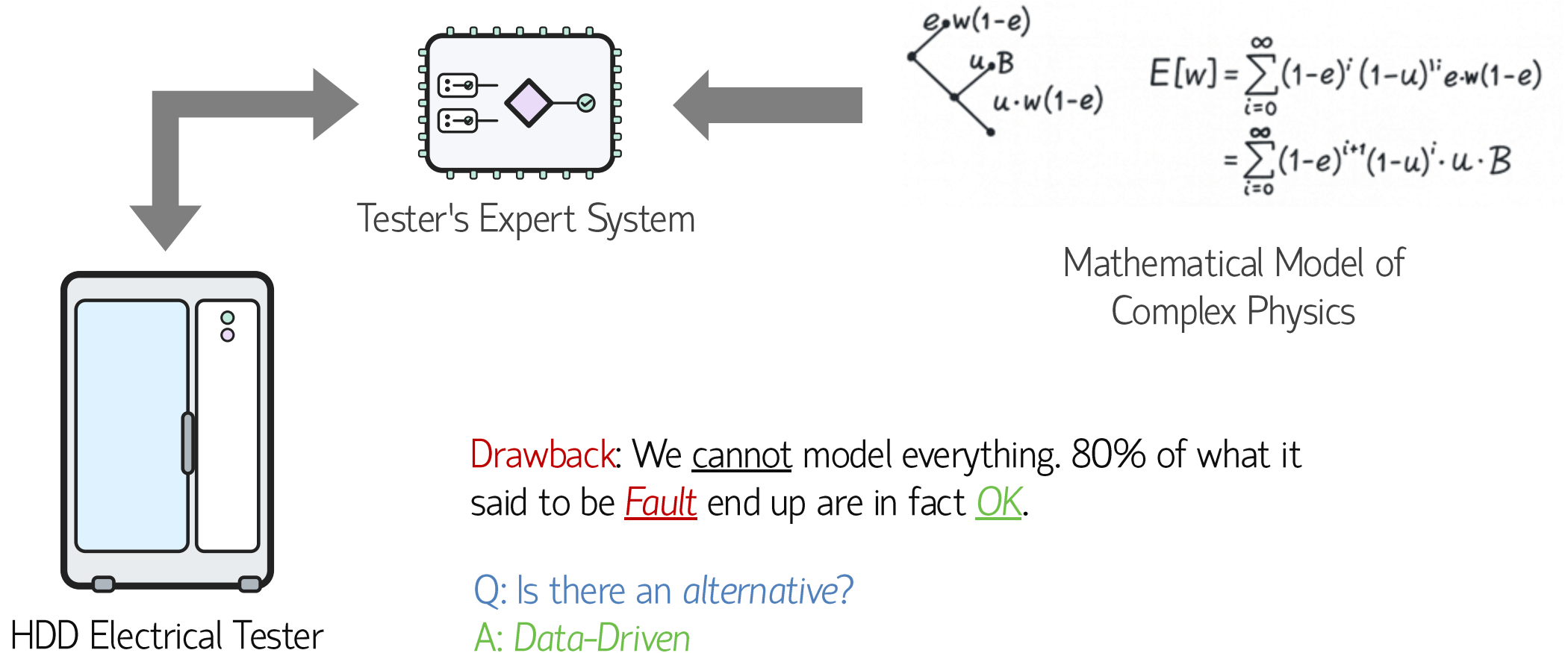
>1k Test Slots per 1 Tester

80% of slots identified as faults are *infact* 'OK' after lab re-verifications and put back online.

Isn't that a definition of 'Recall'?

Our expert system has a very High Recall (and hence very Low Precision).

Recap: Who Is Testing the Testers?



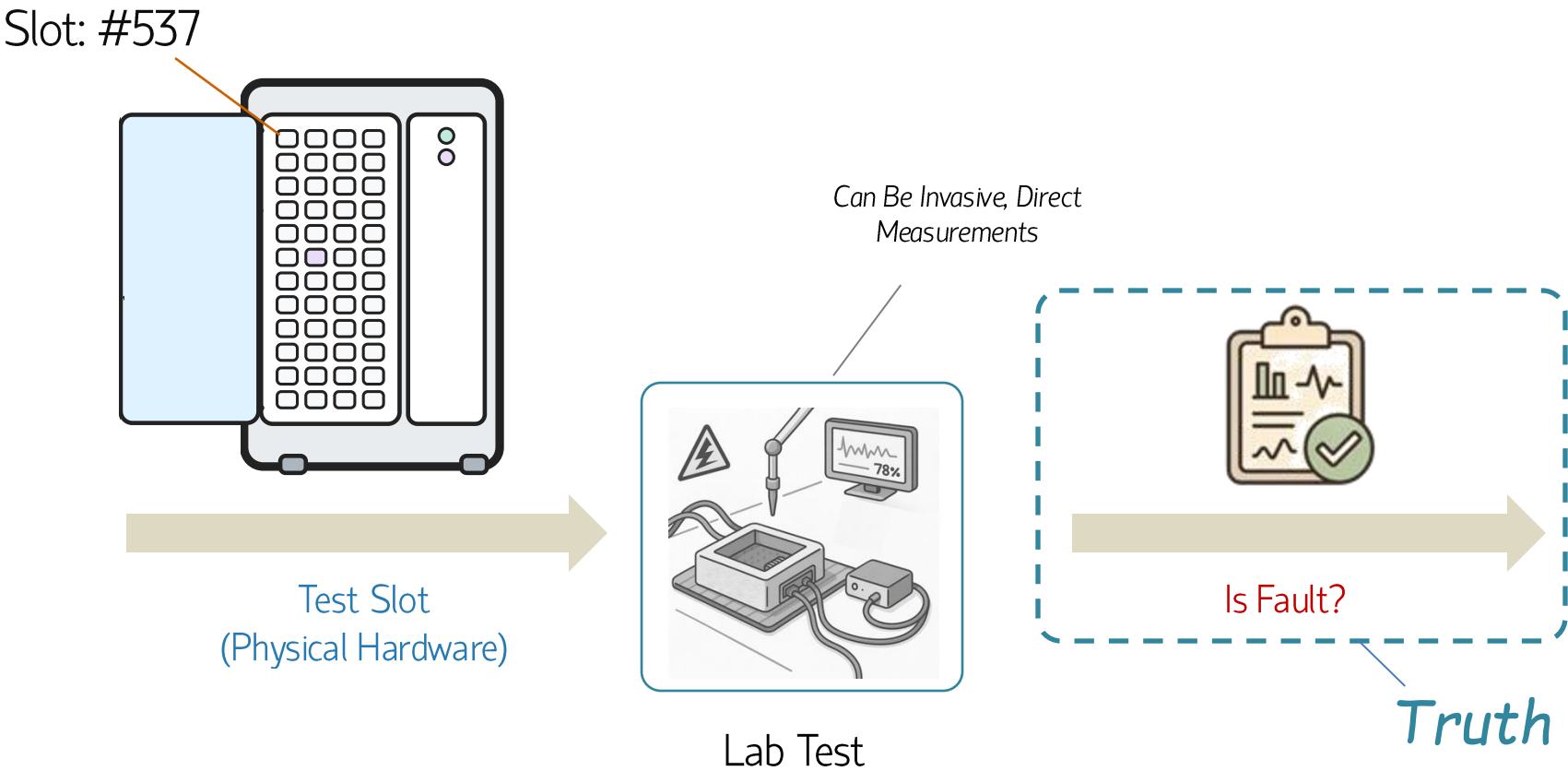
Composite Teaching Case; Synthetic Figures; No Confidential Info.

What Is Prediction?

***PREDICTION** is the process of filling in missing information.*

Prediction takes **information you have**, often called 'data', and uses it to generate **information you don't have**.

Lab Test



Analogy:



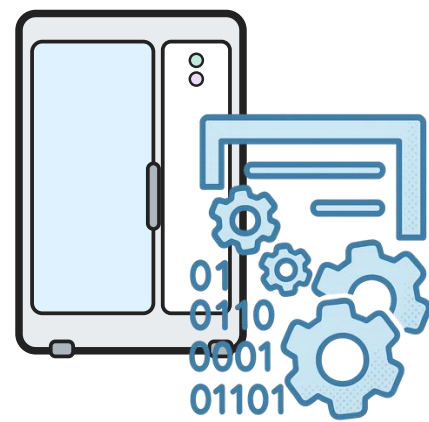
Biopsy in Medicine



GCSE/A-Level Exam

Composite Teaching Case; Synthetic Figures; No Confidential Info.

(AI-Enabled) Virtual Test



Log Data from
Operation

Info We Have



Failure Re-Verifier

*Cheap, non-invasive virtual test triages
cases before expensive steps.*

*However, we will always have uncertainty
in the predictions with the virtual test.*



Is Fault?

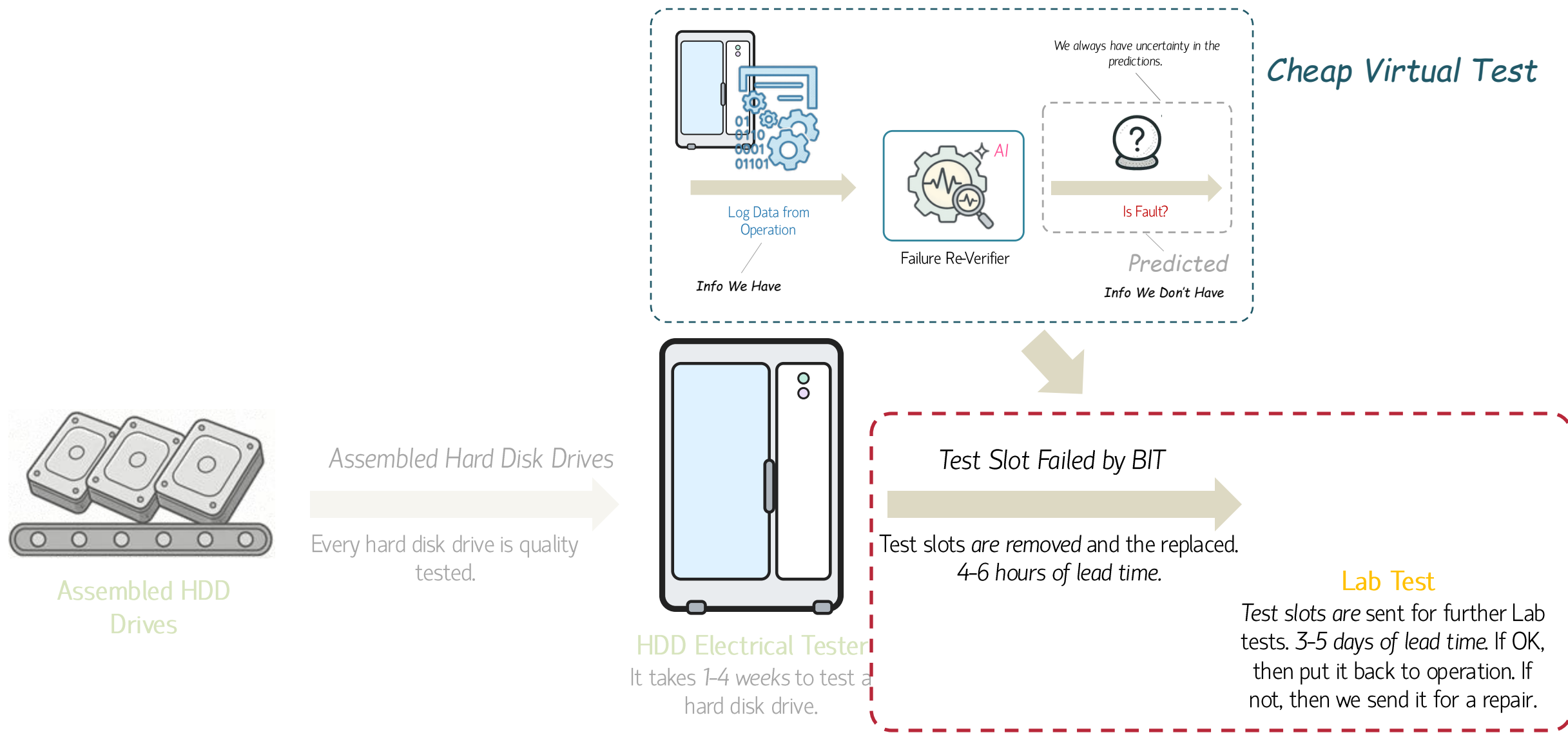
Predicted

Info We Don't Have

*We don't know the physical conditions of the
electronic components inside the test slots.*

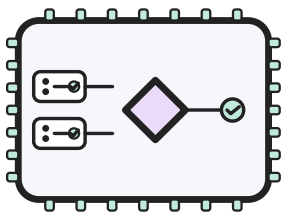
Composite Teaching Case; Synthetic Figures; No Confidential Info.

Expensive Job Task



Composite Teaching Case; Synthetic Figures; No Confidential Info.

Problem Formulation



Tester's Expert System



Slot #537 is tripped with error codes of {0x362, 0x758, ..., 0x234}.

It's sound a bit like...



My friend tried their ramen, and it was pretty forgettable.



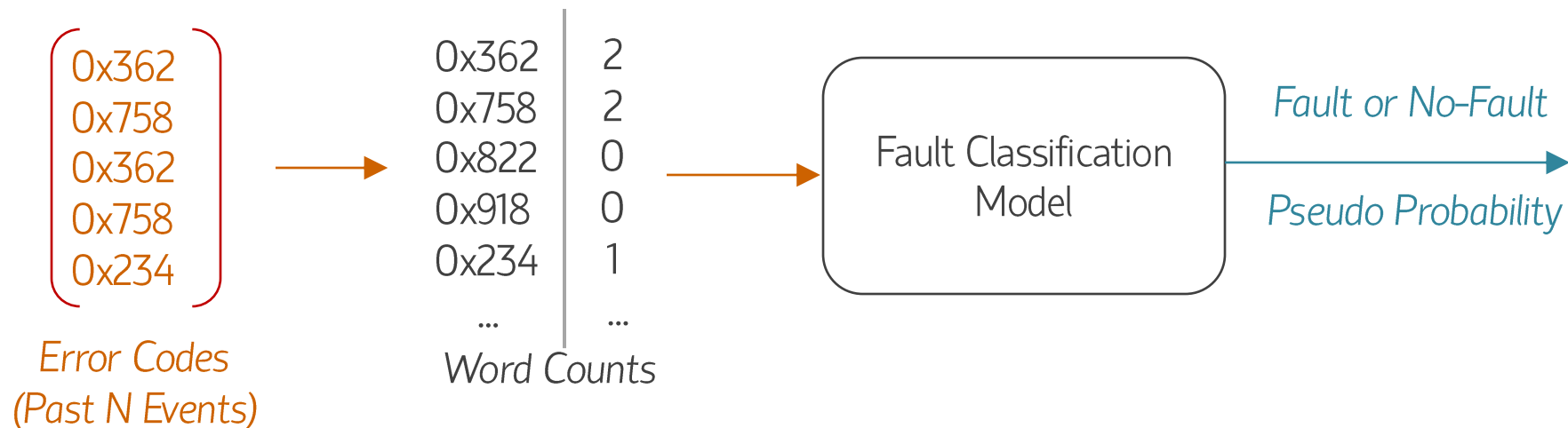
All the sushi was delicious. Easily best sushi in Bangkok.



You know what, how about we do Sentiment Analysis?

Machine Learning Model

Our Bag of Word: *Error Codes*



There are 7 words in a (review) sentence.

Q: What's Temporal?

A: Which word comes first matters.

- + Deep Learning GRN model, if *temporal* events are to be captured.
- + Logistic Regression, Naïve models, if we are to *ignore* possible *temporal* effects.

Imperfect Predictions



Known Knowns:



Known Unknowns:



D. Rumsfeld's Known & Unknown



Where Can We Know For Sure?

Classification Performance: 82% (says) Accuracy on the Balanced Classes



**Operation
Manager**

There'll be too many re-work with 82% accuracy. >98% would be ideal.

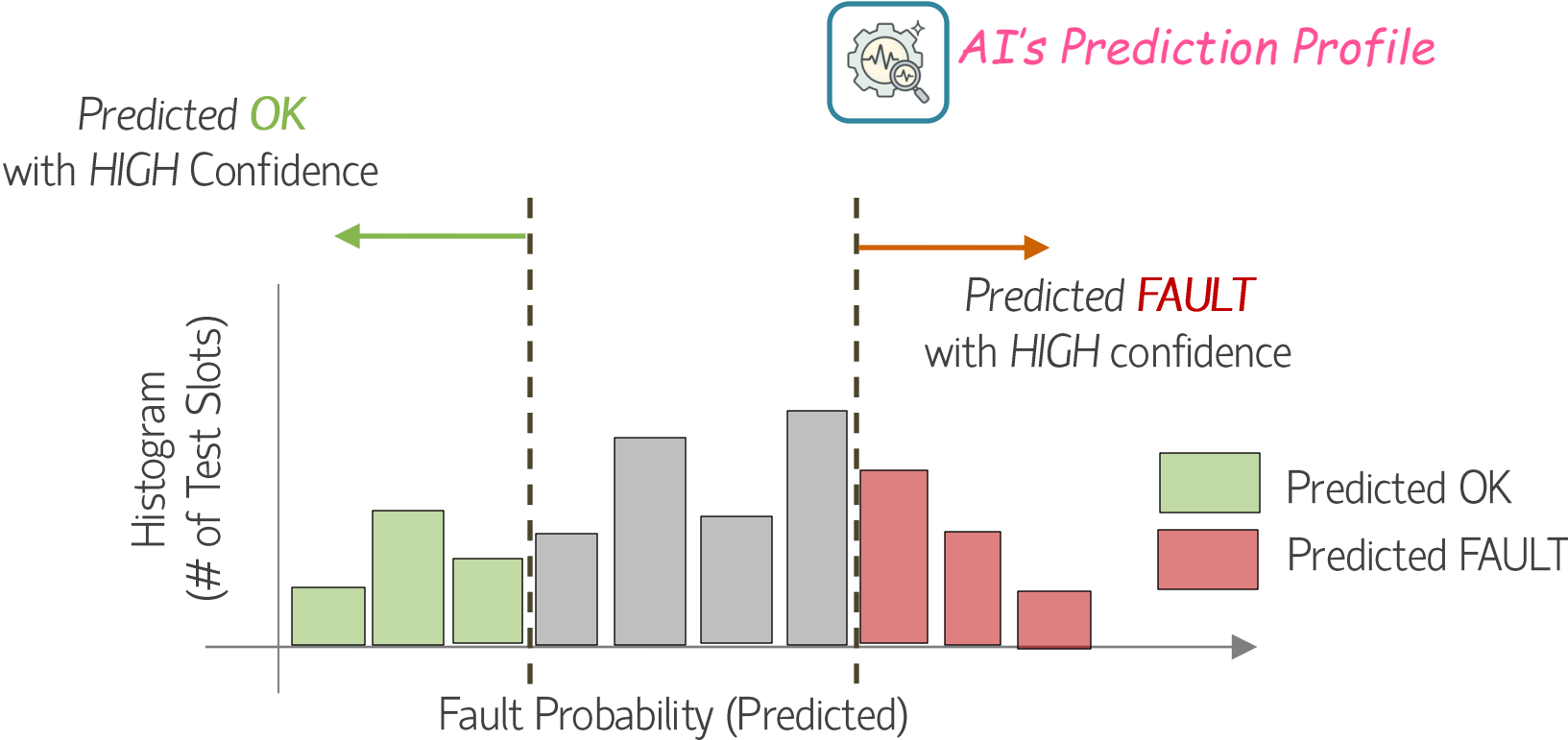
Not really. We can focus on those cases that we're sure if they're fault or no fault.

... focus on 'Known Knowns' ...



**Equipment
Engineering Manager**

Imperfect Predictions



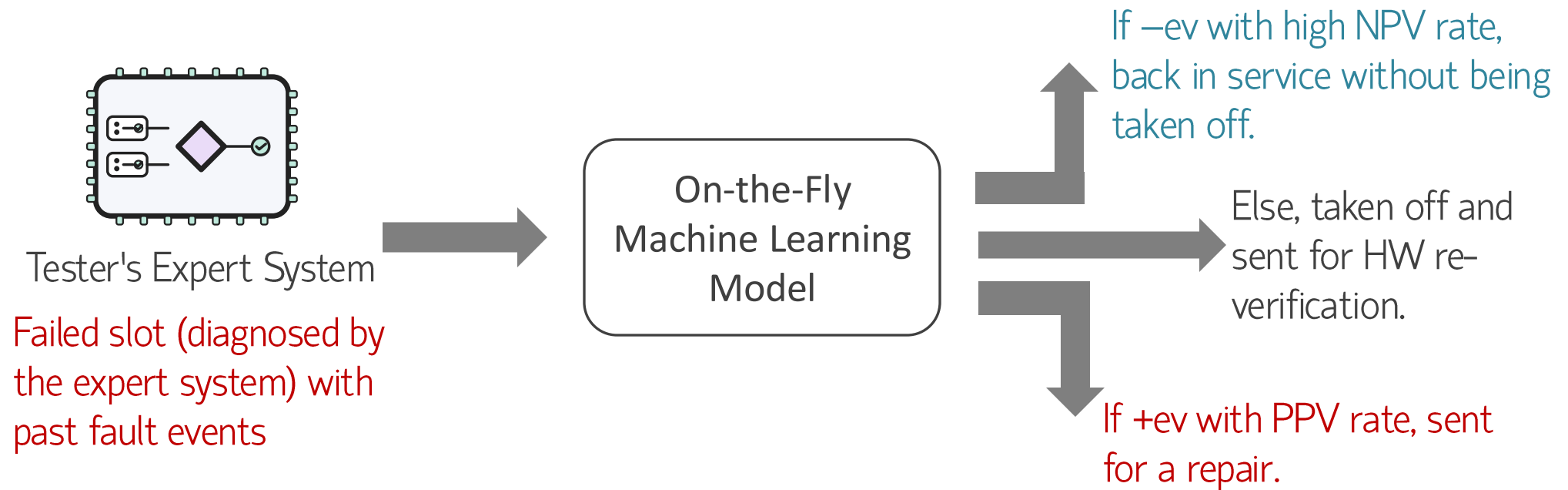
Recall: $P(Y = +1|x, \hat{w})$

Operational Constraints

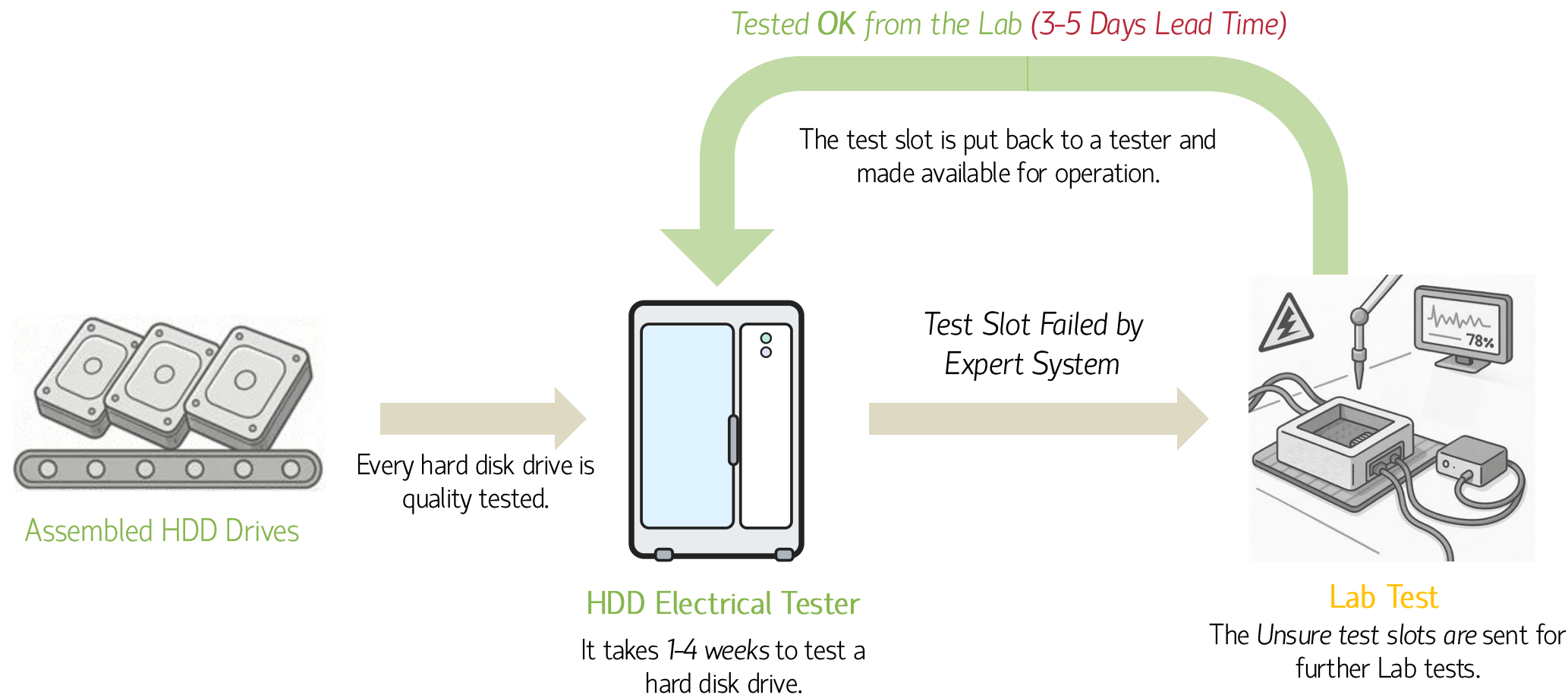
Constraint: Testers are 3rd-Party HW equipment. We cannot easily make changes to the expert system, but we can still consume machine (log) data generated by the equipment.

We cannot just replace the expert system with our machine learning model.

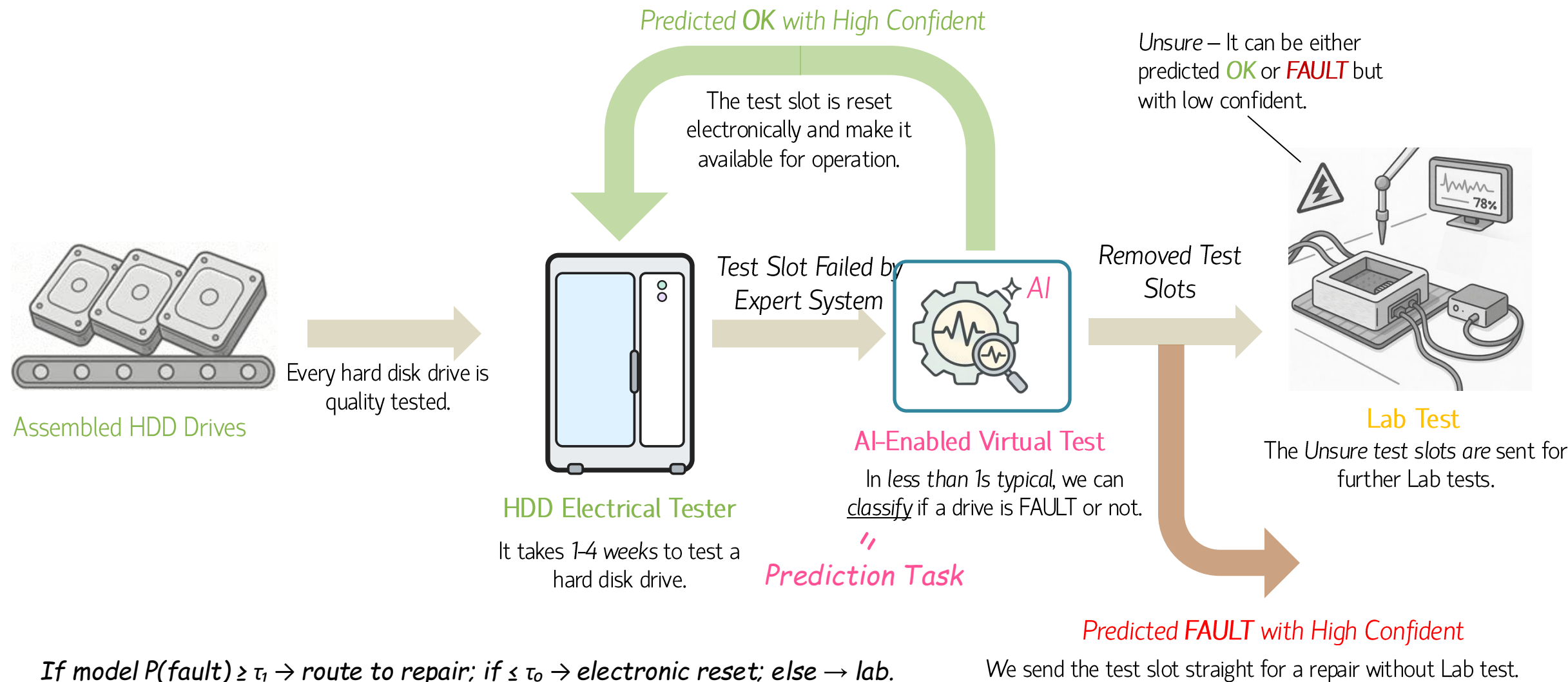
How Do We Utilise Our Predictions?



Before



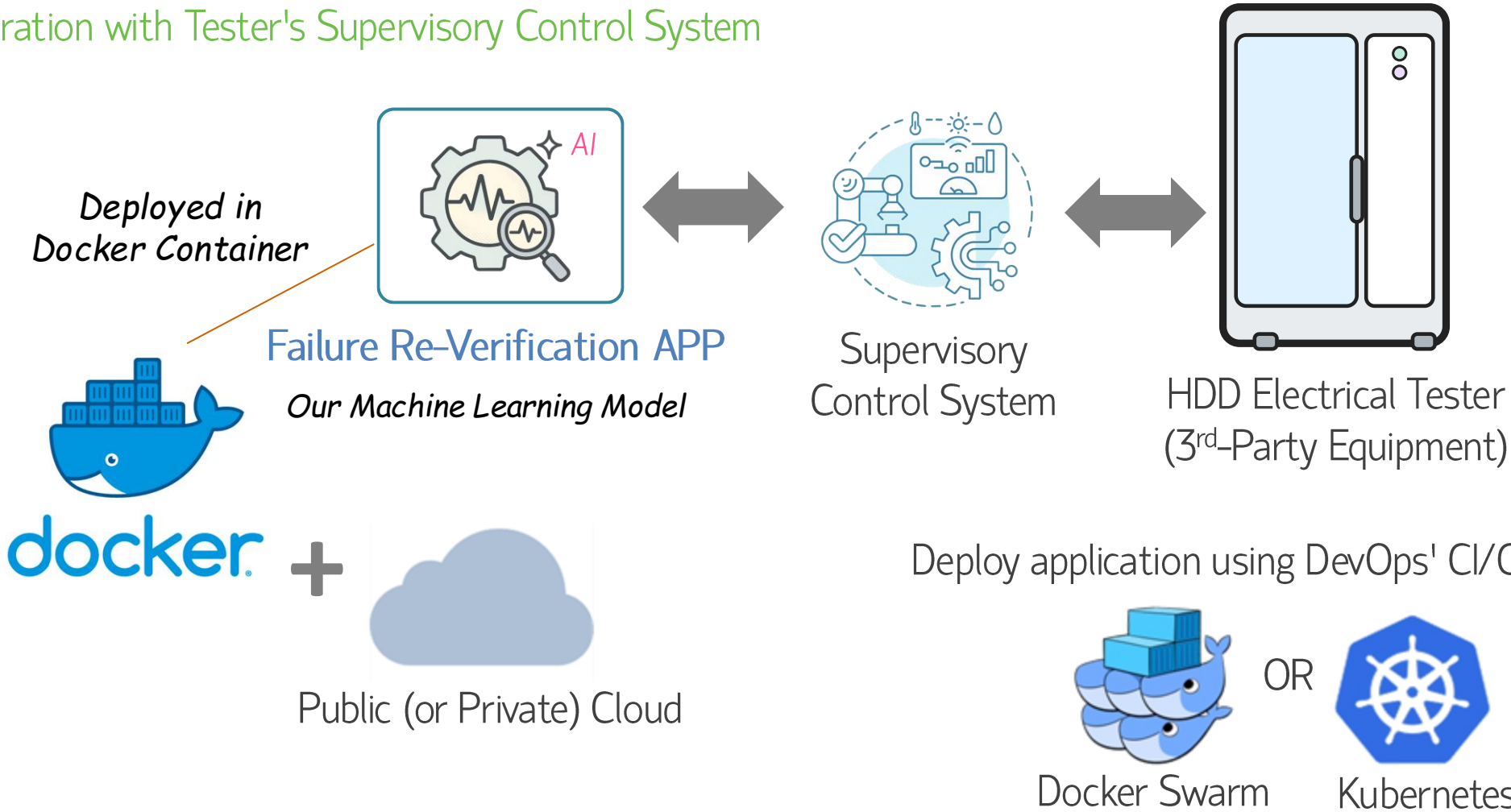
Process Re-Design



Composite Teaching Case; Synthetic Figures; No Confidential Info.

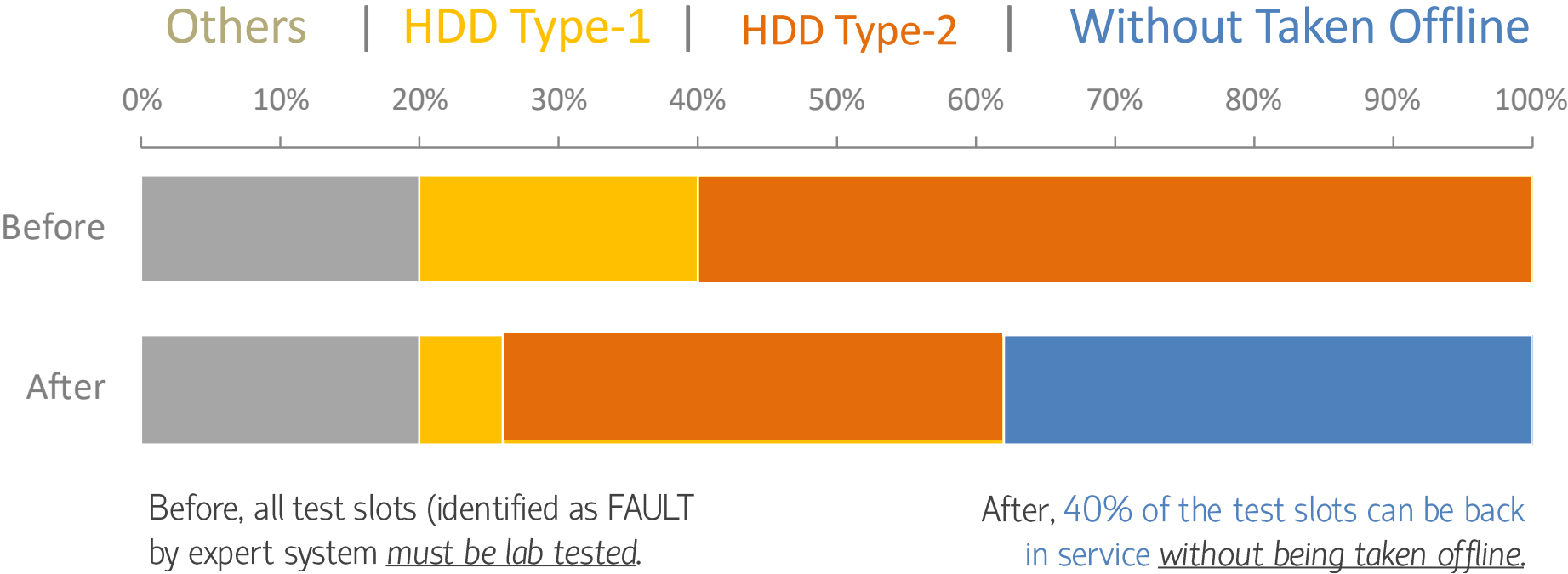
AI-as-a-Service

Integration with Tester's Supervisory Control System



Composite Teaching Case; Synthetic Figures; No Confidential Info.

Productivity Gained From Re-Designed Process



Illustrated Return on Investment (ROI)

...let put in figures...

~1200 Testers (>2M test slots, *that's a lot*), each Tester cost ~700k USD.

~0 marginal cost if to scale from 1 test slot to 1M slots.

We gain additional equipment capacities of ~2 testers without having to buy them.

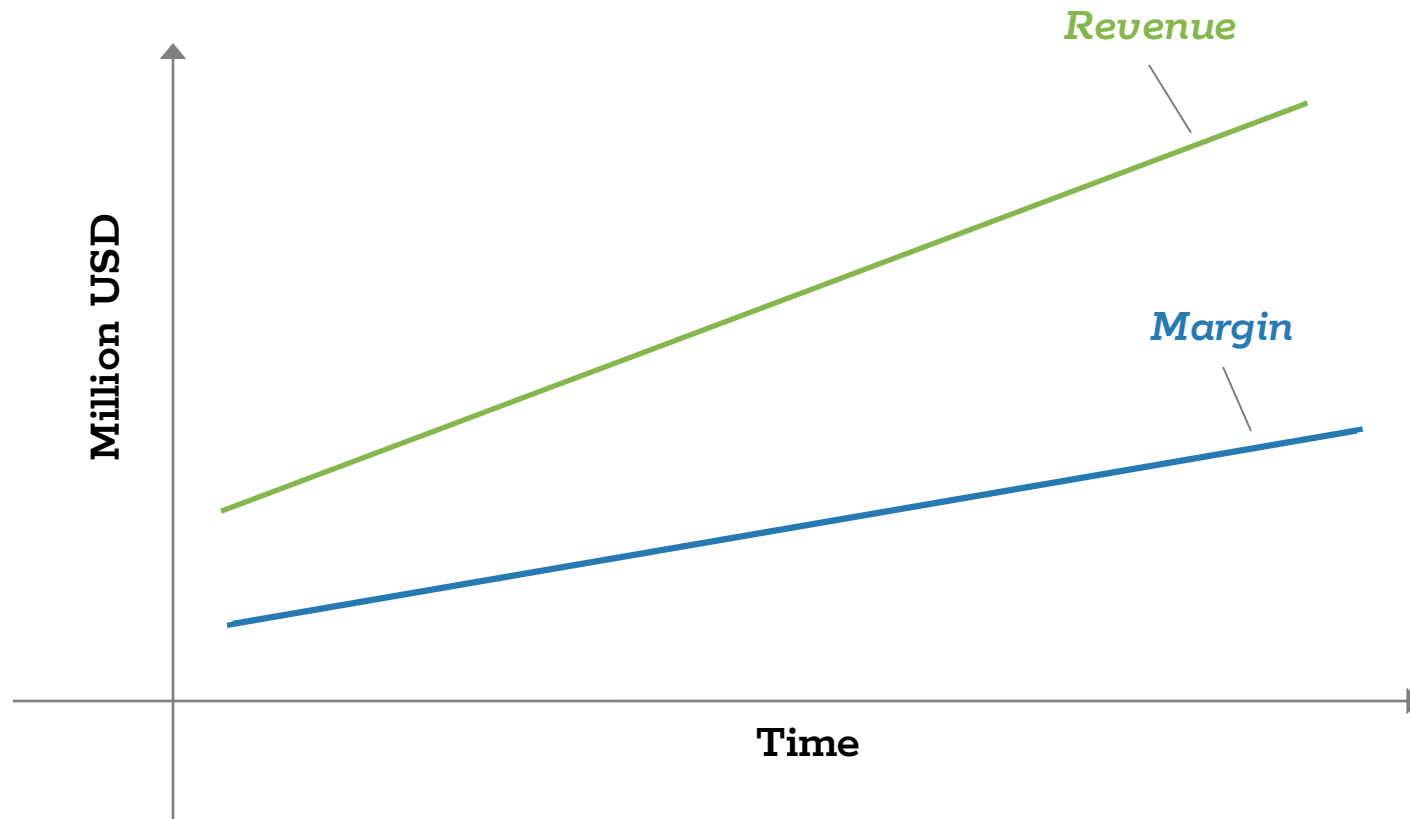
... that's about 2 testers ...

0.4% (1.4M USD)

gain in OEE enabled by our *AI-enabled process*.

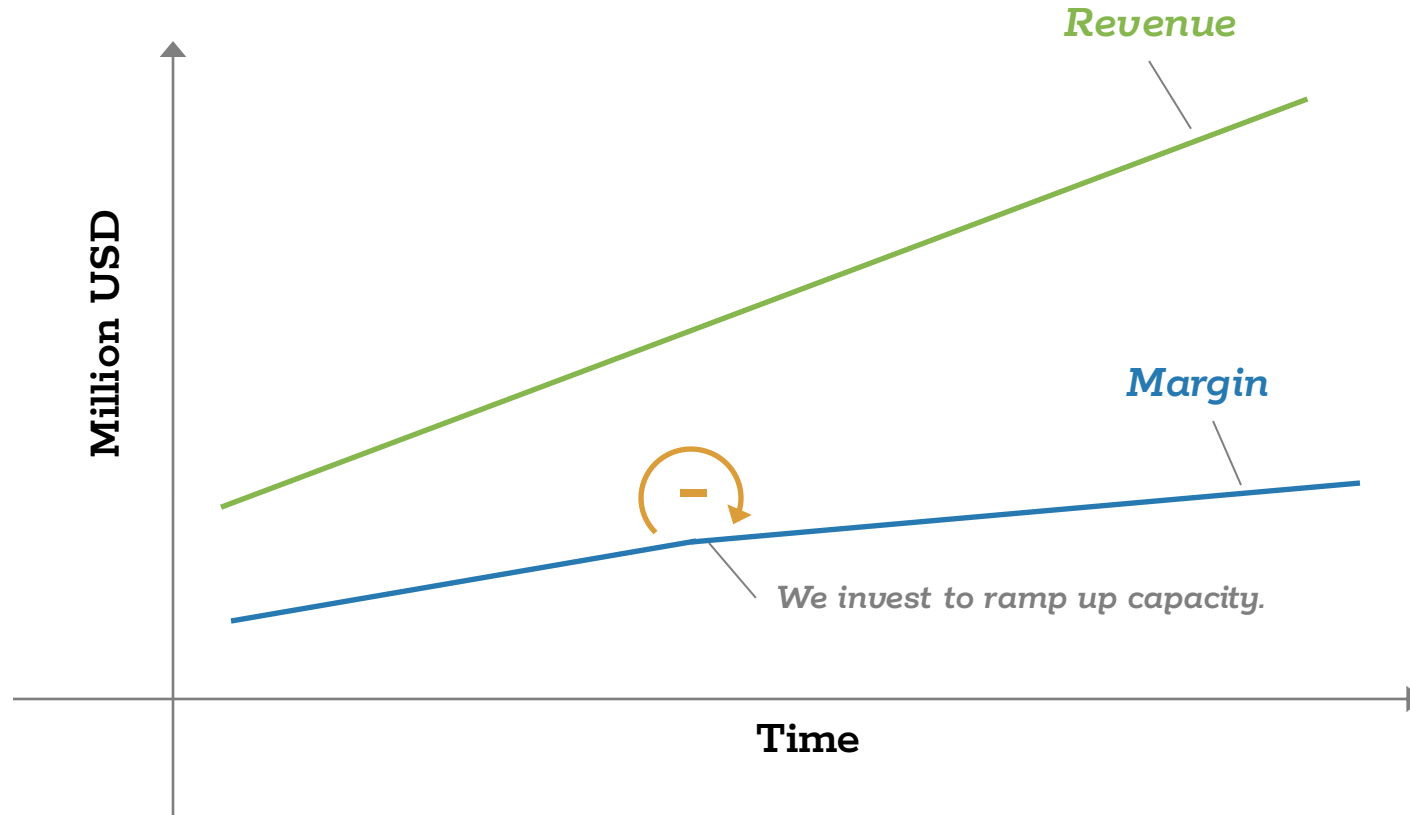
Composite Teaching Case; Synthetic Figures; No Confidential Info.

Closing Thought (1 of 3)

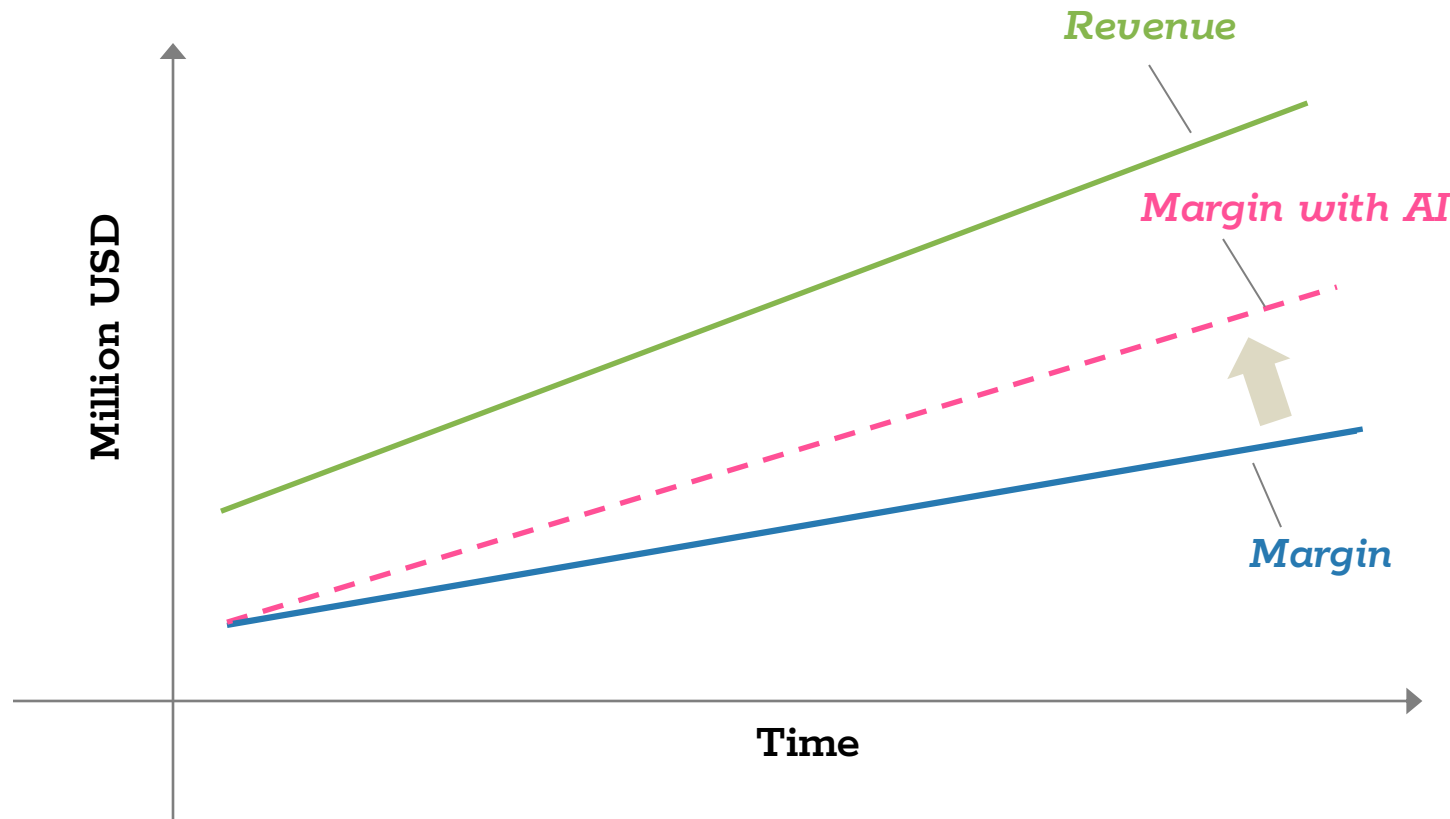


Composite Teaching Case; Synthetic Figures; No Confidential Info.

Closing Thought (2 of 3)



Closing Thought (3 of 3)



Cheap Prediction (our AI) is to replace expensive tasks.

Summary

- AI is framed as '*Cheap Prediction*', things become less magical. This gives us a focus on its economic (or practical) values which is most matter at the *management, strategic level*.
- AI's complements are becoming more critical if we are to succeed in applying AI. Implementing AI algorithms or models are more straightforward in comparison to *problem framing* and *judgment in using prediction*.
- AI is to replace tasks, not the job. We use *cheap prediction* to replace (or re-design) tasks which are as-is inefficient or expensive. Hence, this enables us to gain back the profit margin.
- Prediction uncertainty is unavoidable. Operation wise, there are cases where high accuracy is a must. We can focus on those predictions with high confident level. Hence, part of in-efficiencies can be off-loaded by our AI.

References

- Agrawal, Ajay, Joshua Gans, and Avi Goldfarb. 2018. **Prediction Machines: The Simple Economics of Artificial Intelligence**. Boston, MA: Harvard Business Review Press.
- McKinsey Global Institute. 2018. "The Economics of Artificial Intelligence." *McKinsey Quarterly*.
- Fox, E. & Guestrin, C., 2016. *Machine Learning: Classification*. Coursera — University of Washington. Available at: <https://www.coursera.org/learn/machine-learning-classification> (Accessed 20 Aug. 2025).