GUROBI
OPTIMIZATION

Boost Profitability and Efficiency with Mathematical Optimization

Insights from the Forrester Mathematical Optimization Financial Services Study.

Presenters

Ed Rothberg, CEO and Co-founder, Gurobi Optimization

Special Guest - Mike Gualtieri, VP, Principal Analyst, Forrester

FORRESTER®

AI: The Fastest Growing Technology On The Planet

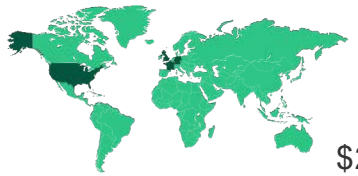
AI = Machine Learning + Mathematical Optimization

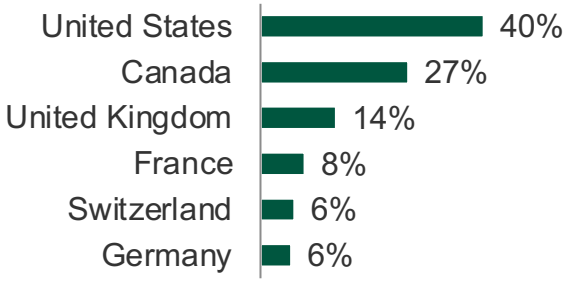
Mike Gualtieri
Vice President, Principal Analyst

BOLD AT WORK

Respondent demographics

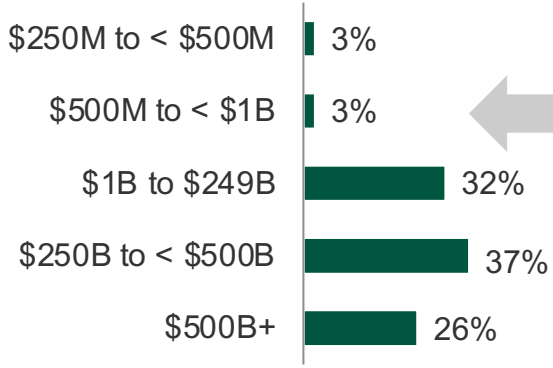
Countries



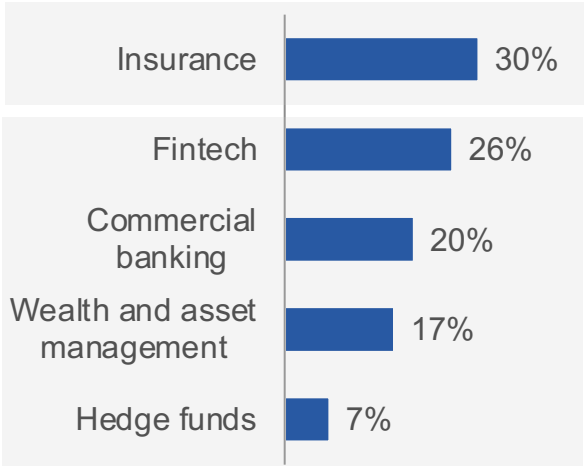


NA: 67%; EMEA: 33%

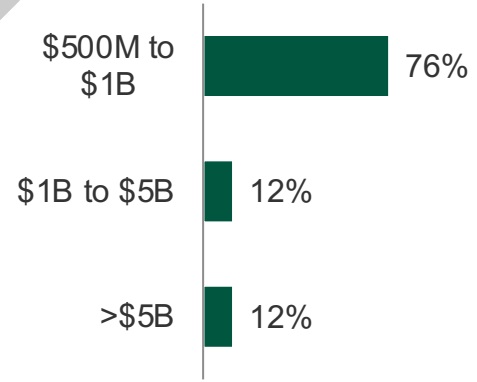
Value of Assets Under Management (USD)*



Role in Financial Services



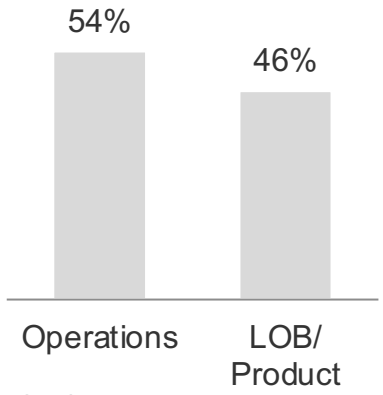
Annual Revenue (USD)**



Position

40% C-level
26% VP
25% Director
9% Manager

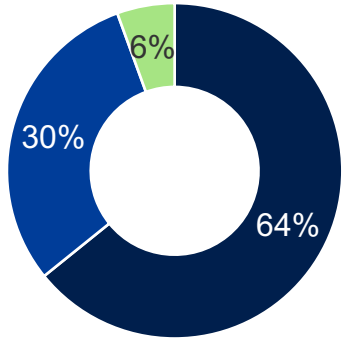
Job Function



Areas of Involvement

59% Asset management
42% Operations management
17% Portfolio risk management

Responsibility Level

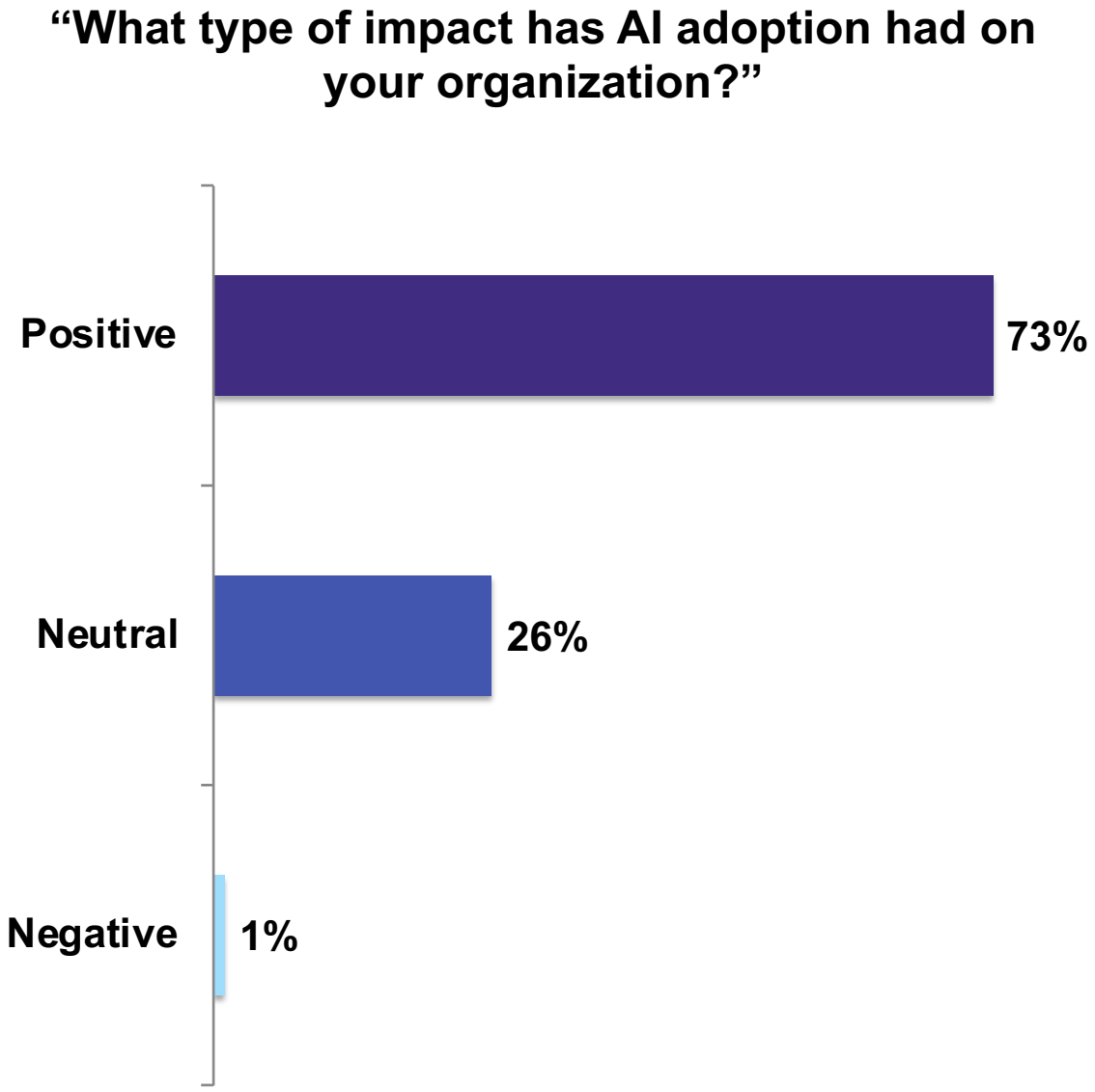


- Final decision-maker
- Part of a team
- Influence decisions

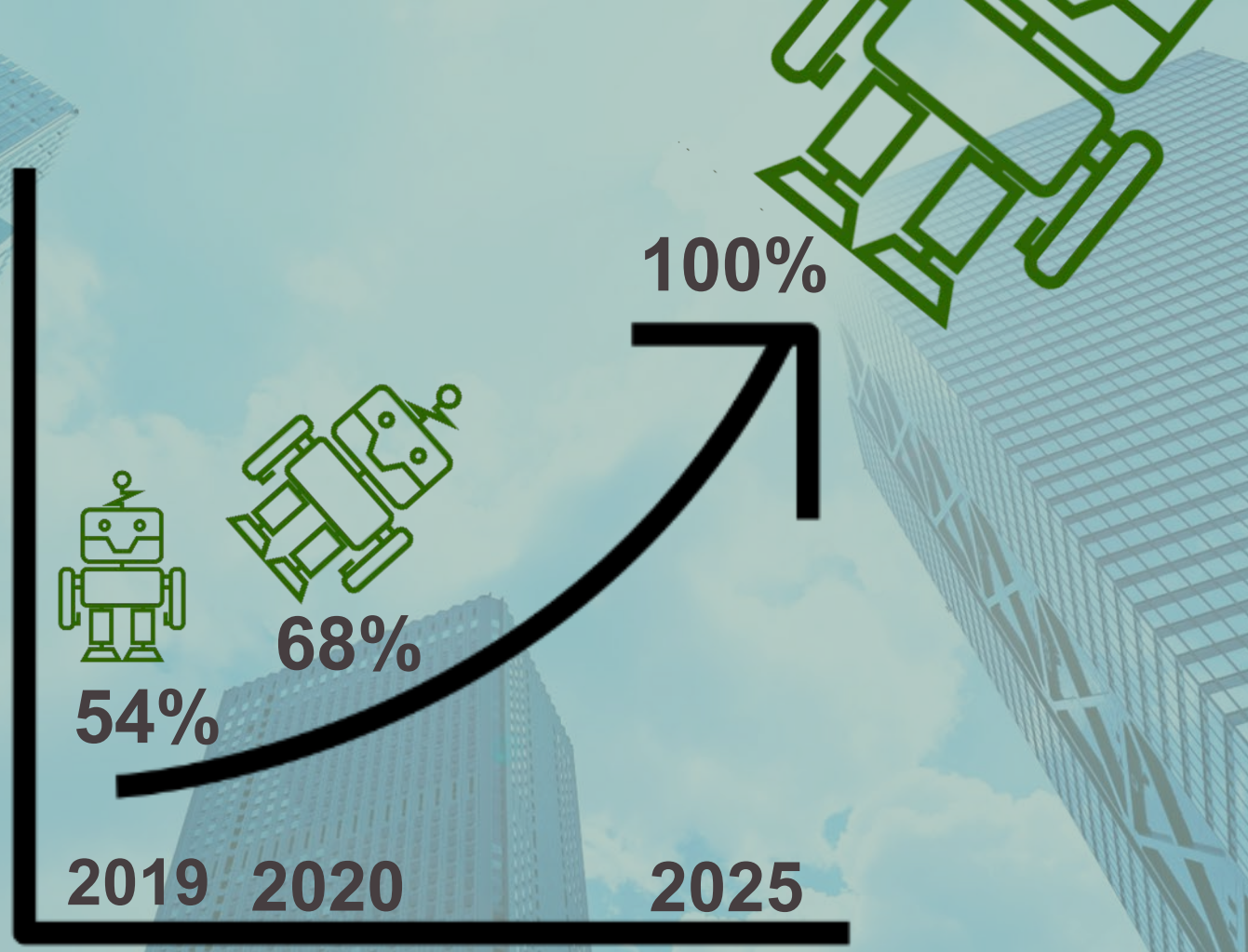
Base: 162 global decision makers of optimization technology
*Base: 113 global decision makers of optimization technology in financial services, excluding insurance
**Base: 49 global decision makers of optimization technology in insurance
Source: A commissioned study conducted by Forrester Consulting on behalf of Gurobi, August 2021

AI

Organizations that implement AI get results



Base: 1,466 data and analytics decision-makers whose firm is implementing or expanding use of AI
Source: Forrester Analytics Business Technographics® Data And Analytics Survey, 2020



We estimate that nearly 100% of enterprises will use AI by 2025.

. . . there are 5, 50, 500, and 5,000 enterprise use cases yet to be implemented with AI.

?AI

FORRESTER

AI is software that can mimic or exceed human intelligence to identify patterns, make decisions, and/or formulate new knowledge.

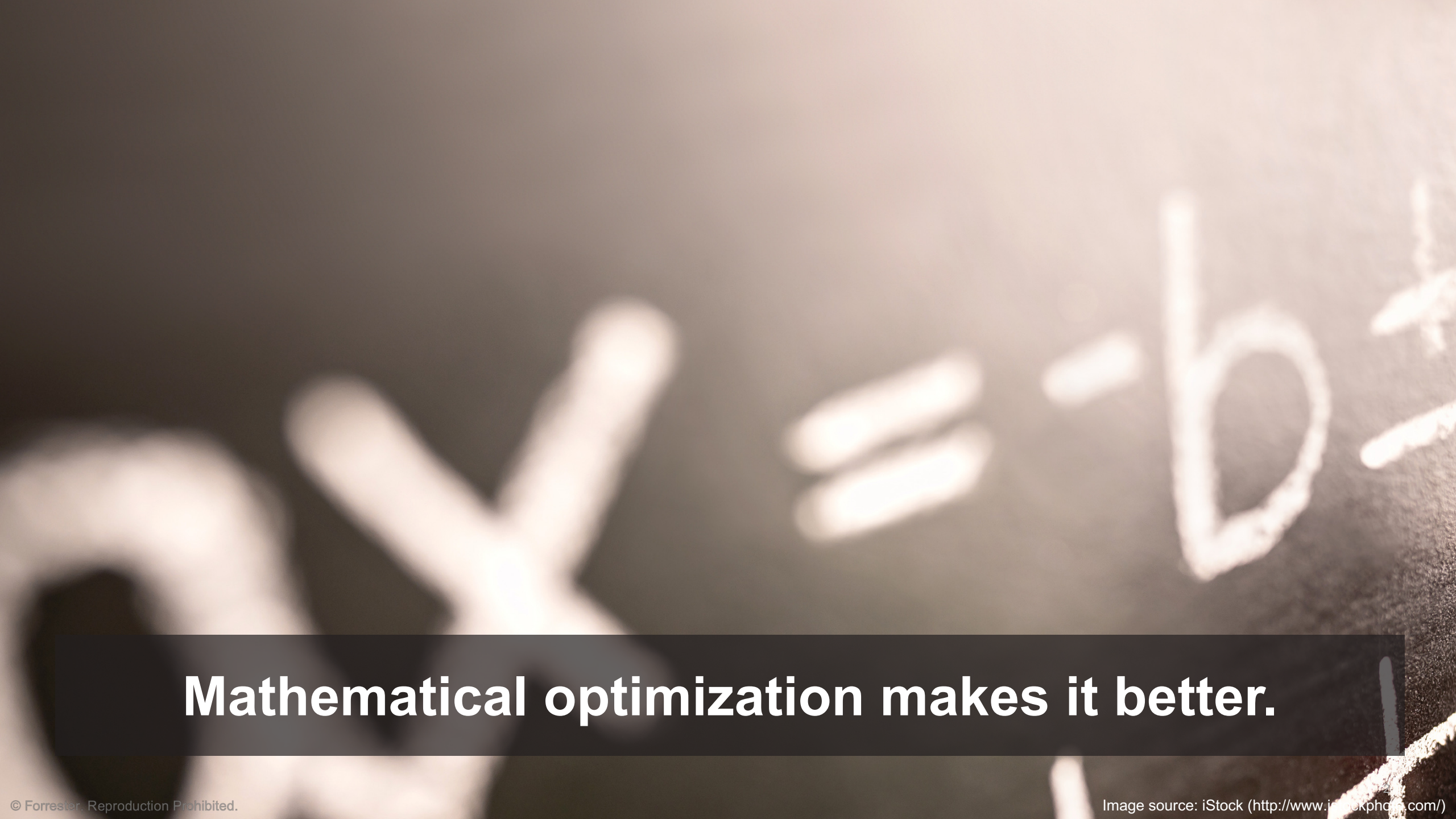
DEFINITION

AI solutions are free to use any or all technologies and techniques to mimic or exceed human intelligence.

Image source: iStock (http://www.istockphoto.com/)

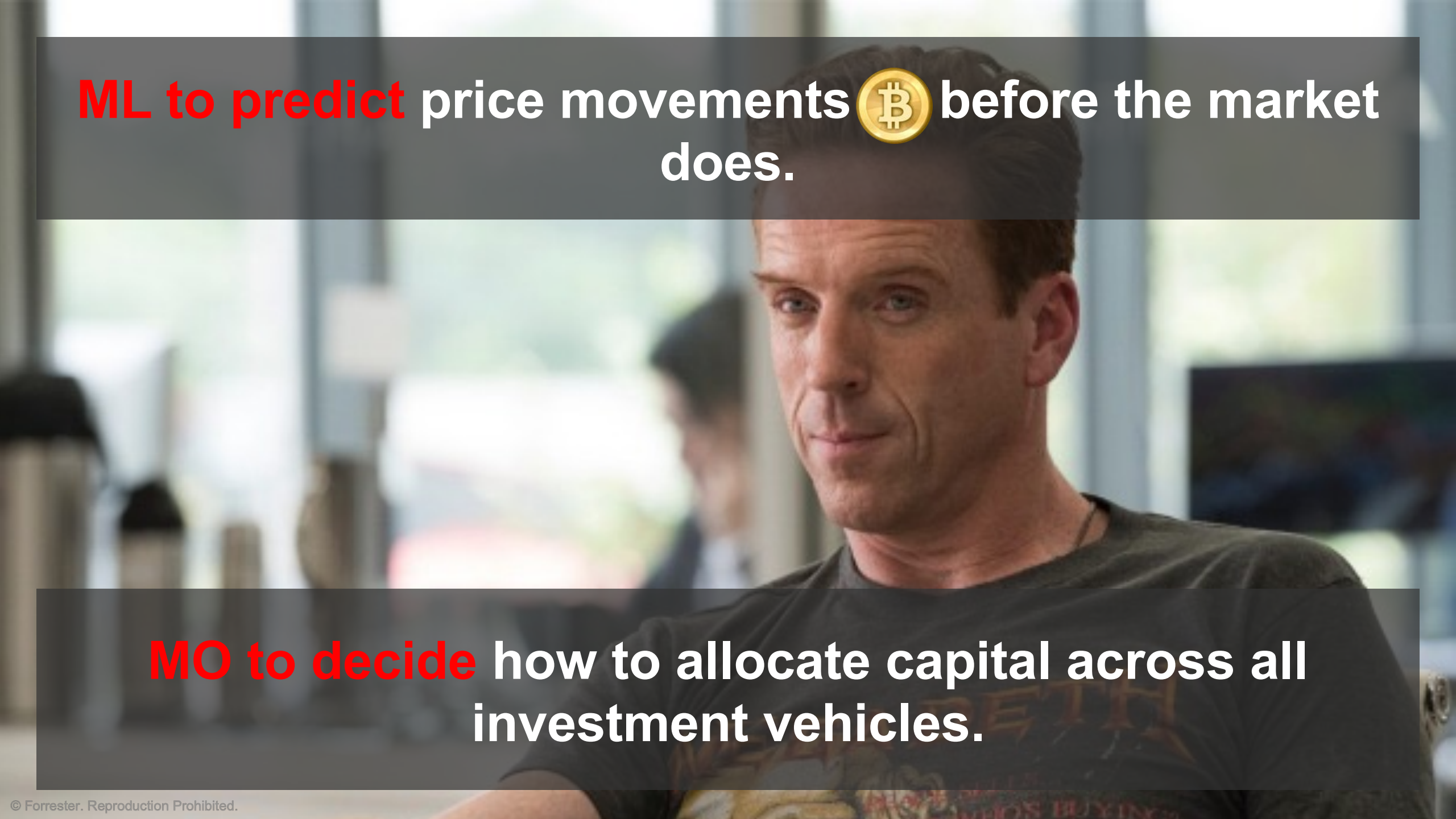
Machine learning is a popular approach.

Image source: iStock (http://www.istockphoto.com/)



Mathematical optimization makes it better.

Image source: iStock (http://www.istockphoto.com/)



ML to predict customer propensity to buy more with targeted offers.

MO to decide how many discount coupons to offer to maximize revenue or to maximize profit.

Image source: iStockphoto

ML to predict imminent machine failure.

MO to decide when to shut the production line down to perform maintenance to minimize cost and customer complaints.

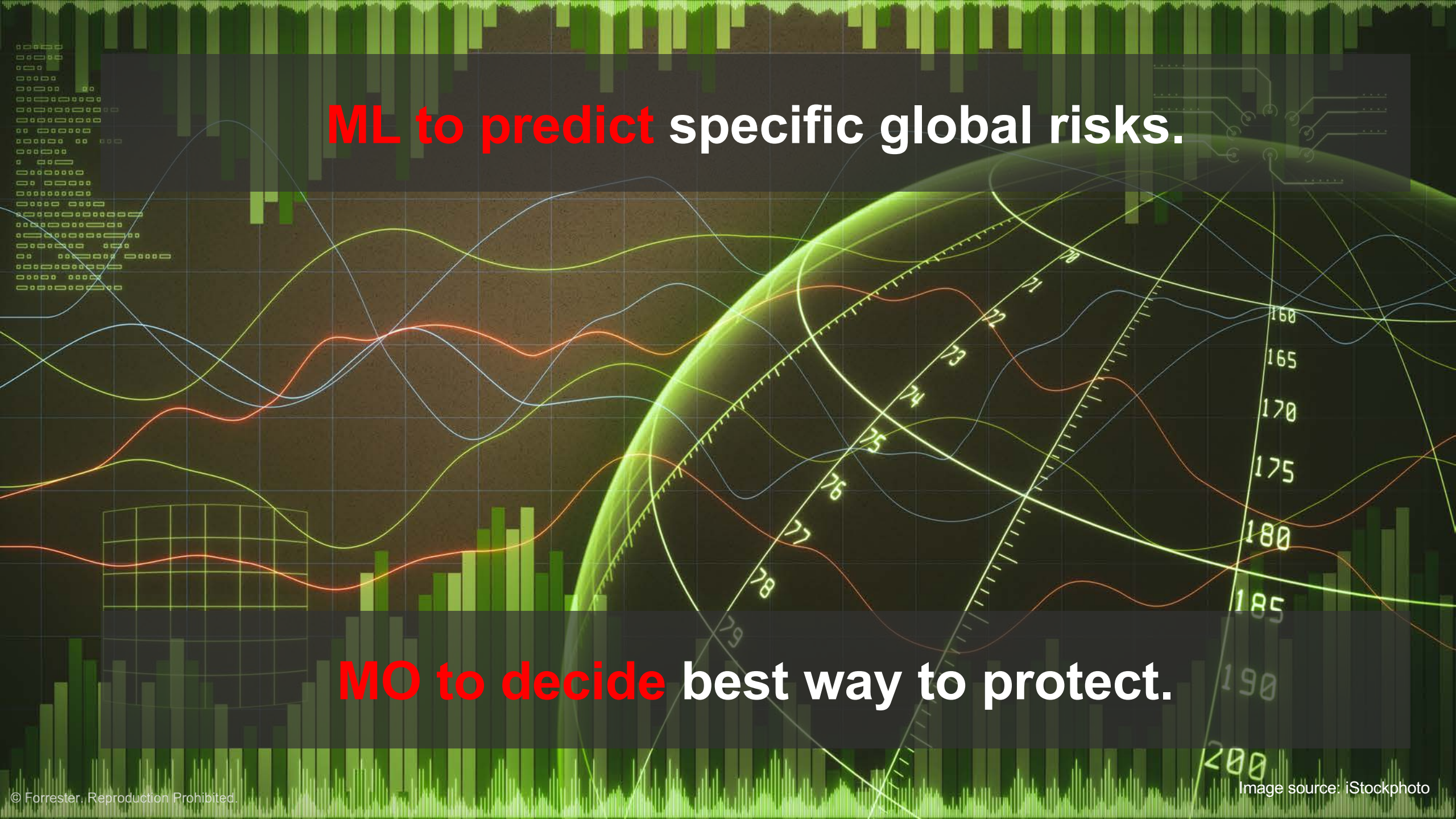


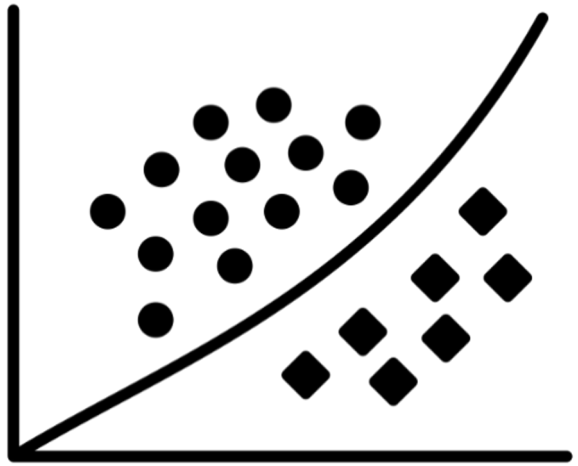
Image source: iStockphoto

Decisions

AI ❤ decision optimization because…

…that’s how to maximize the value of AI.

?How



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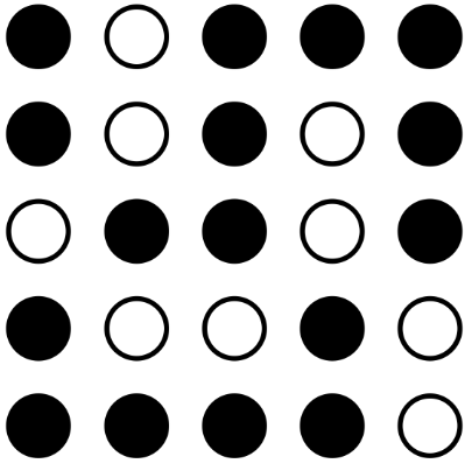

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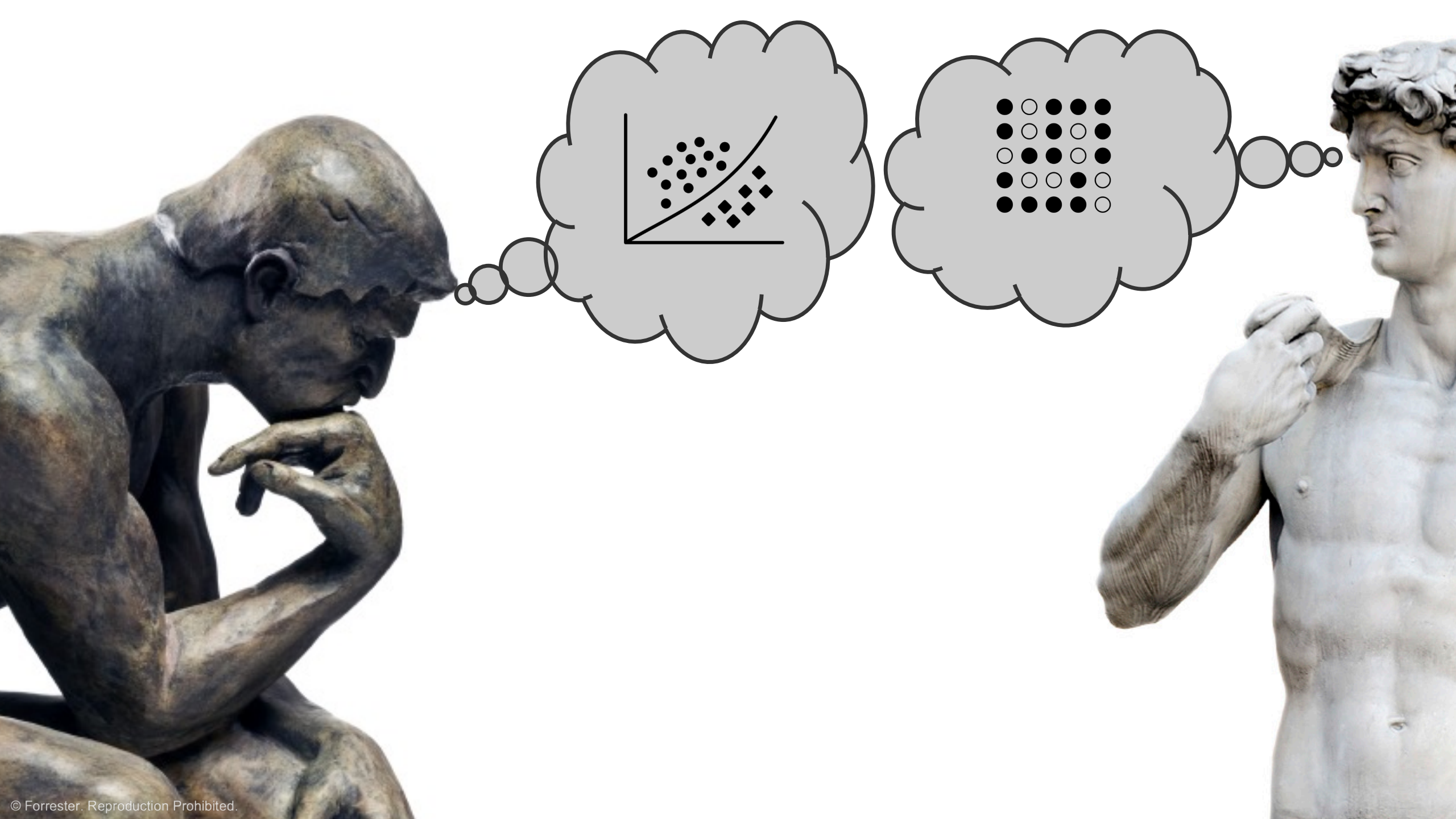


It’s common for a single enterprise use case to yield millions of dollars in top- and/or bottom-line outcomes.

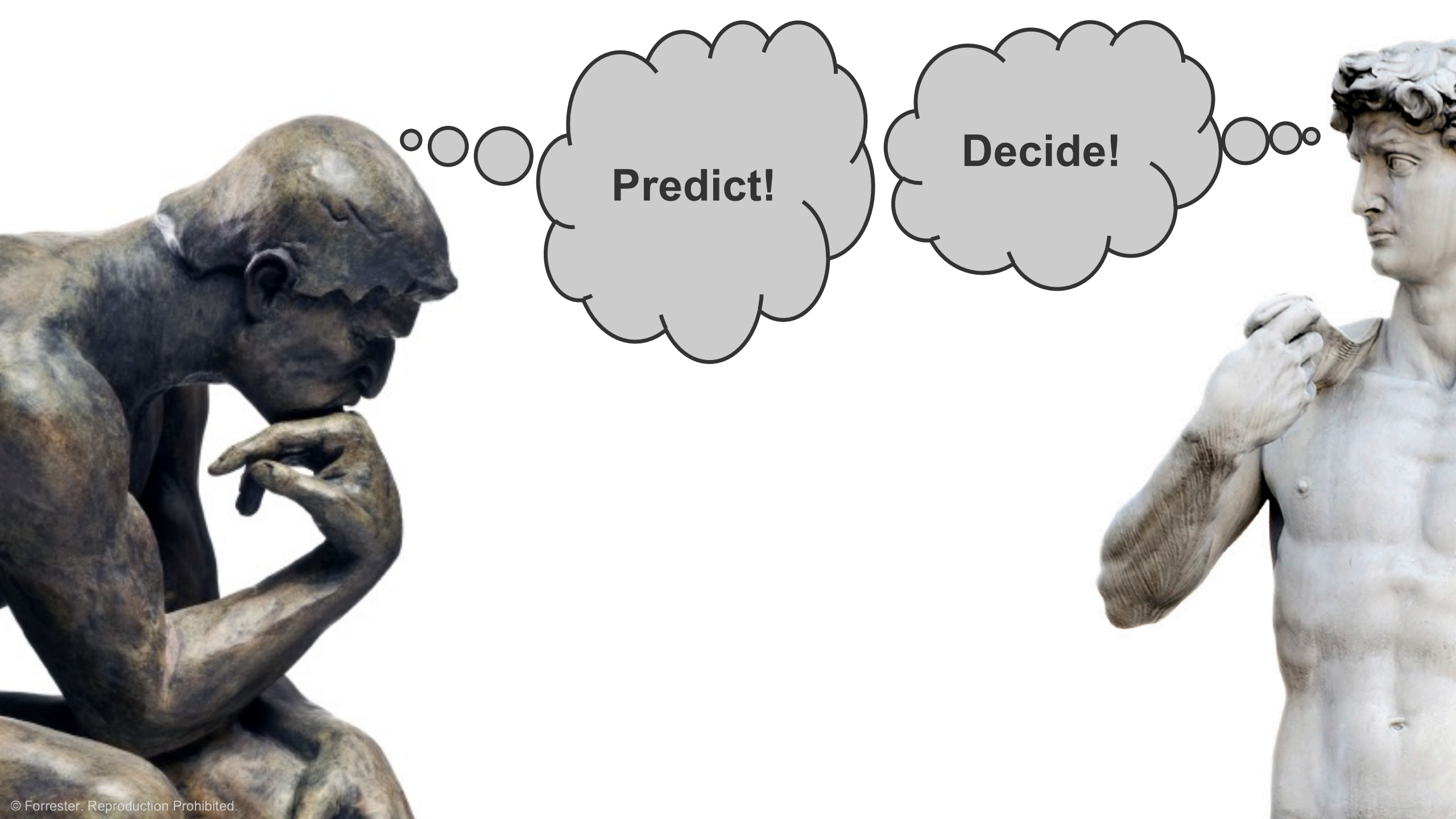
Image source: iStock (http://www.istockphoto.com/)

ML predictions can determine the need to make a MO decision.

ML predictions can be used as MO decision constraints.

MO decisions can be used as ML model training features.

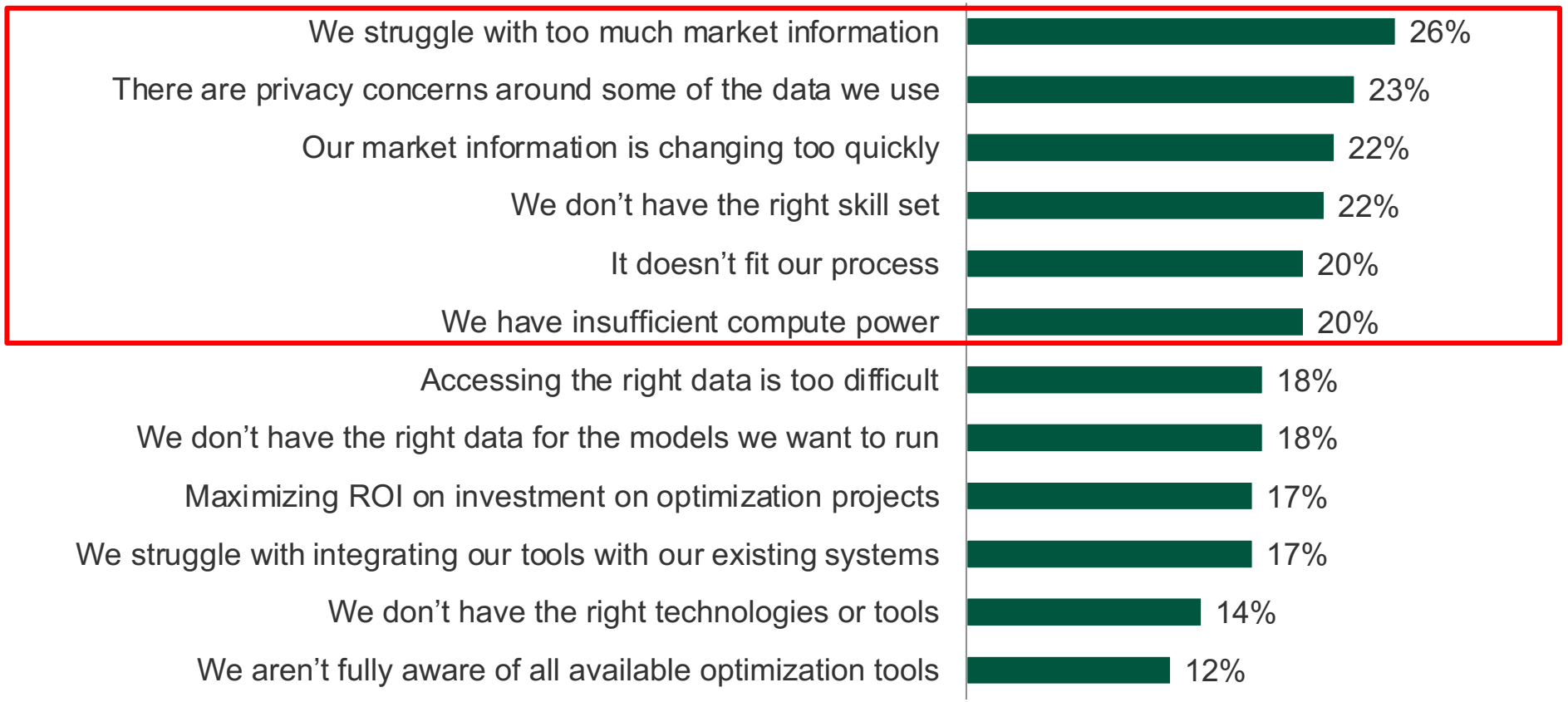
MO decisions can be used as ML model scoring/inferencing inputs.



Virtually all face challenges with combining MO with other technologies

46% want to be able to combine mathematical optimization together with other advanced analytical technologies, but **98% face challenges doing so**

Q6-What are the challenges that your organization faces with combining mathematical optimization with other advanced analytics technologies for optimization projects?



Base: 162 global decision makers of optimization technology

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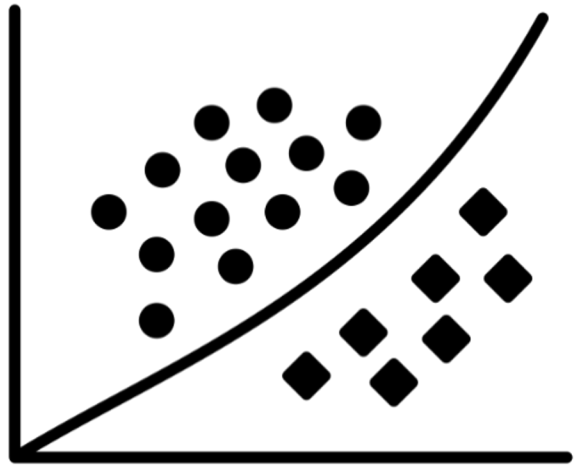

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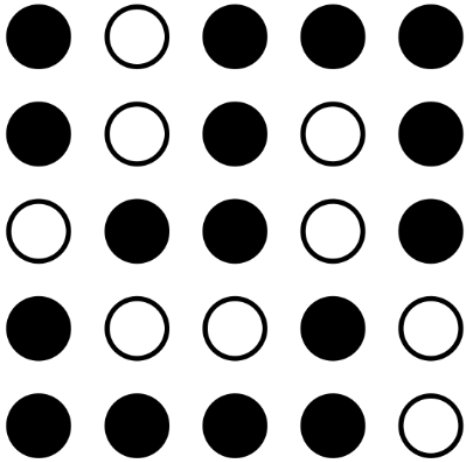

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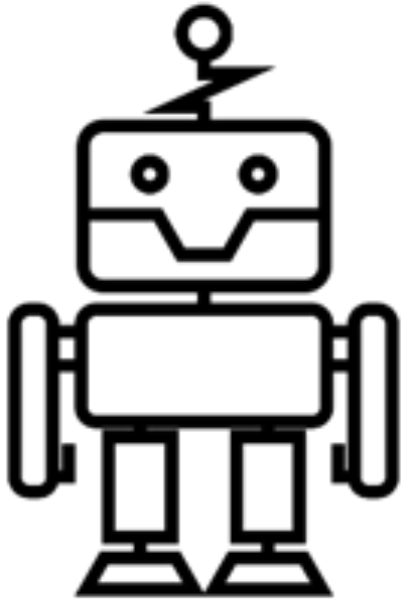


ML + MO = AI

Why is AI the fastest growing technology on the planet?

#1

FORRESTER

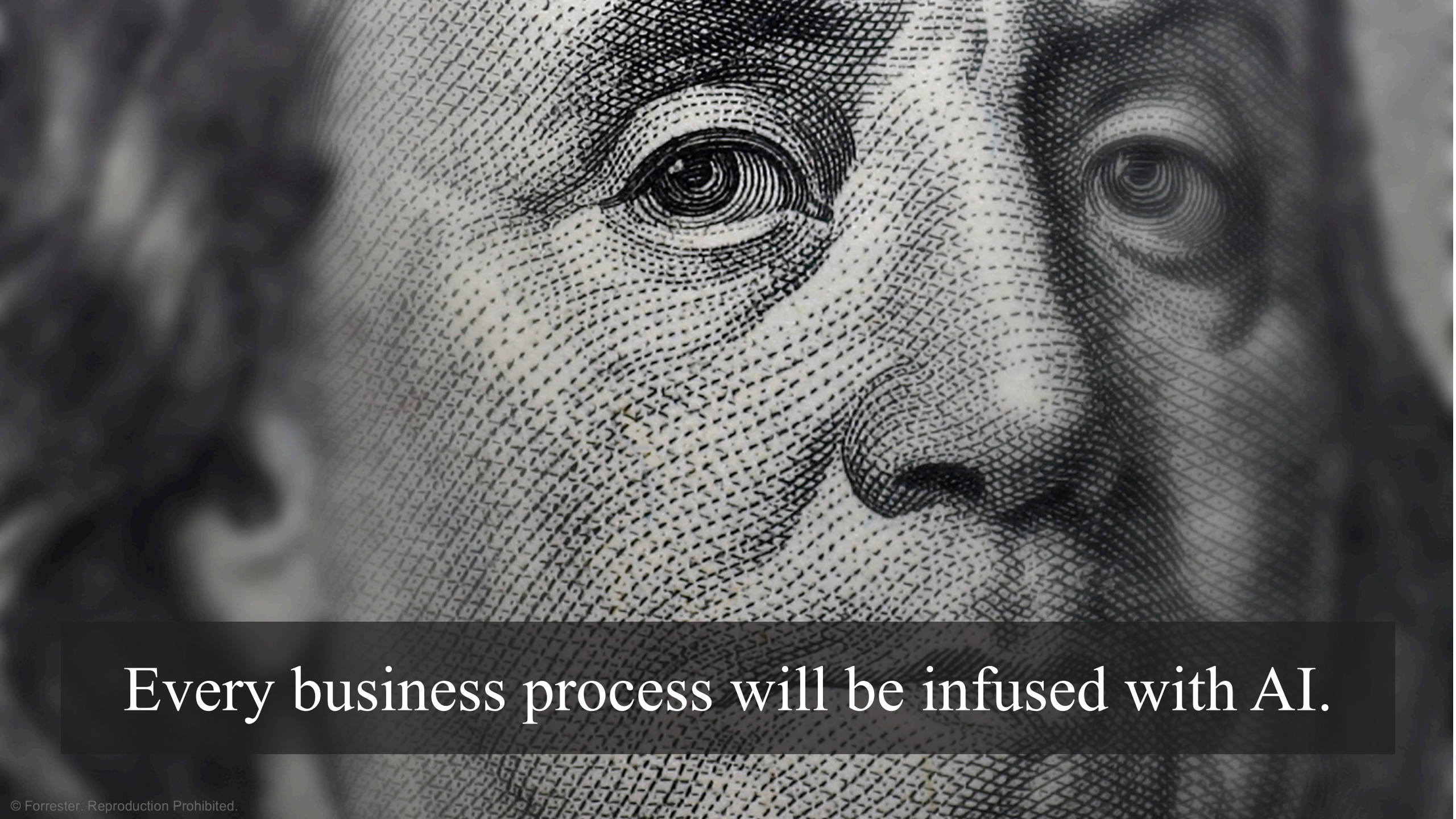
AI use cases number in the thousands for global enterprises.

TRENDS

There are thousands of enterprise AI use cases in business processes and customer-facing applications.

Most enterprise AI use cases remain unimplemented.

The more models the merrier.



#2

FORRESTER

AI requires data – lots of rich data and more data.

TRENDS

Data represents physical events.

Data represents digital events.

Data represents customer events.

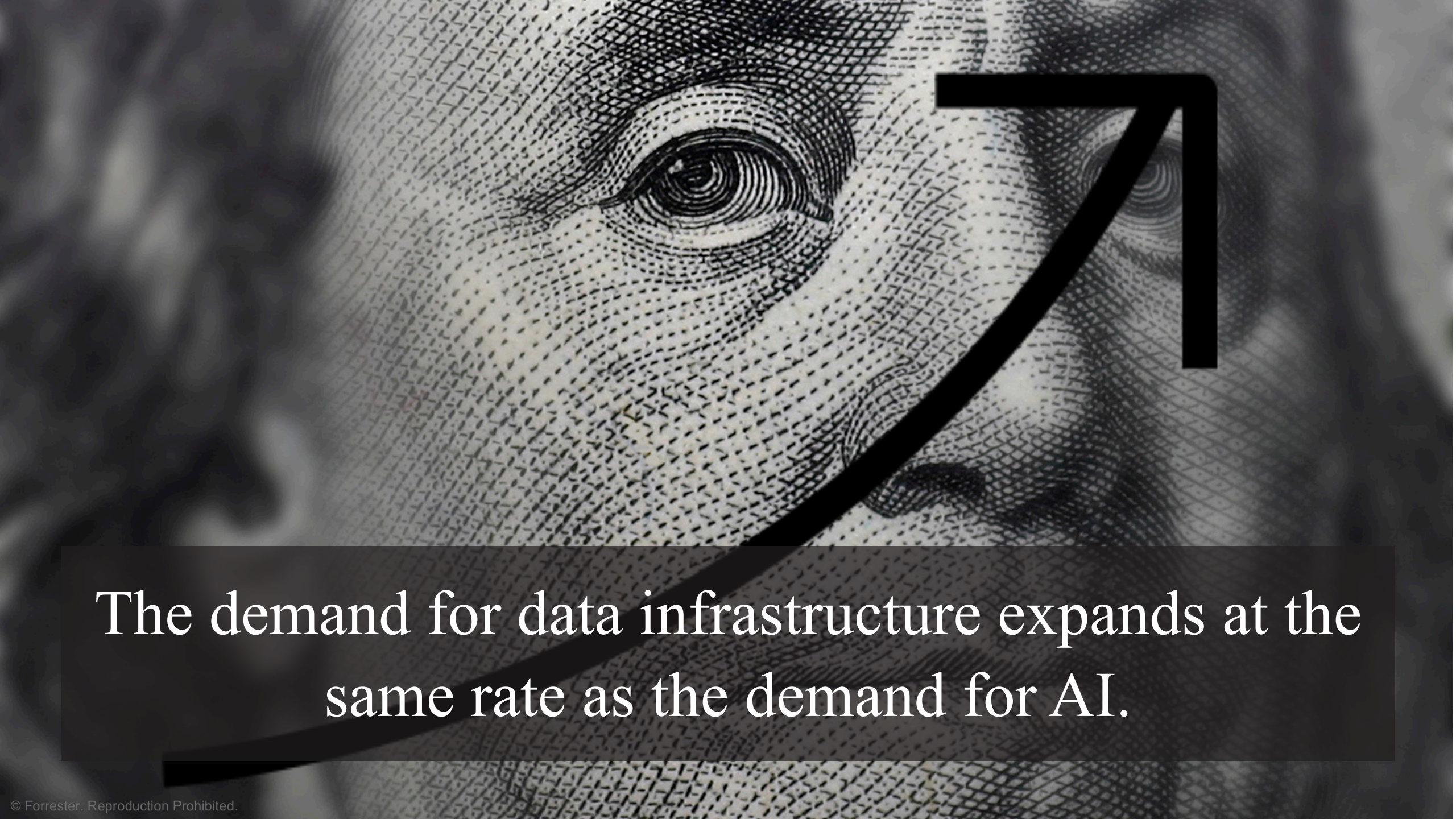
Enterprises are flush industry-specific operational and customer data.

Enterprise data is super rich, as is needed for successful, pervasive AI

- Customer transaction data
- Point-of-sale data
- Customer and supplier contract data
- Inventory data
- Supply chain data
- Product/service data
- ERP and manufacturing data
- Supplier transactions
- R&D data
- Sales and CRM data
- Marketing/advertising data
- Human resources data
- Finance/accounting data

Siloed data must be connected, transformed, and enriched for AI to analyze it.

Algorithms get all the press, but it's data that leads to success.



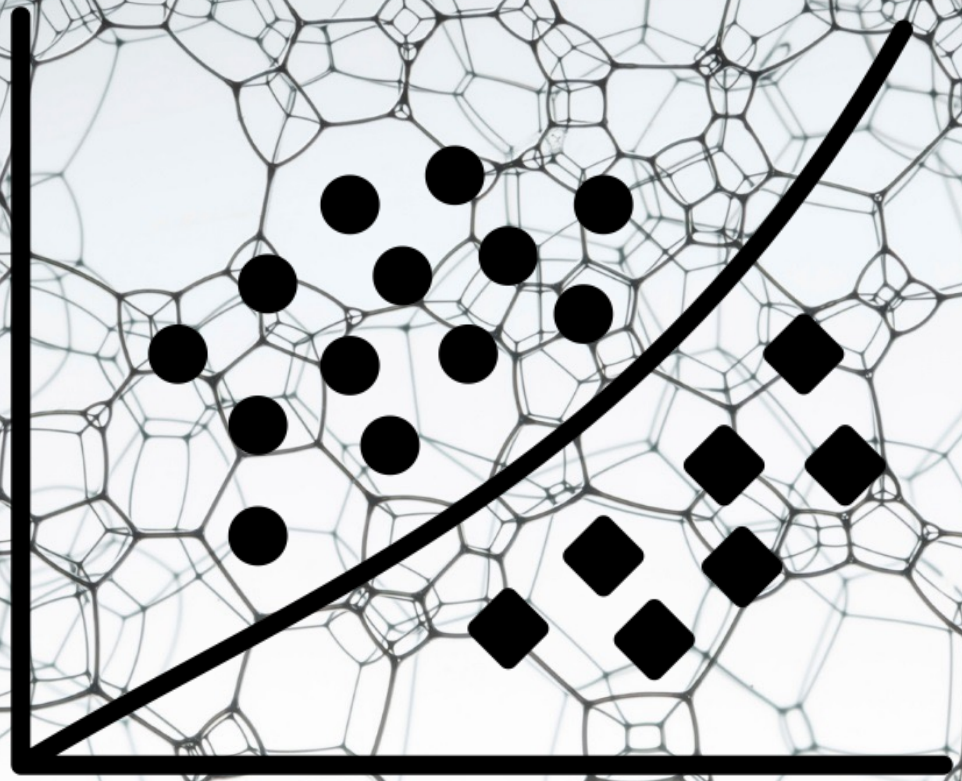
The demand for data infrastructure expands at the same rate as the demand for AI.

#3

FORRESTER

AutoML is mainstream.

TRENDS

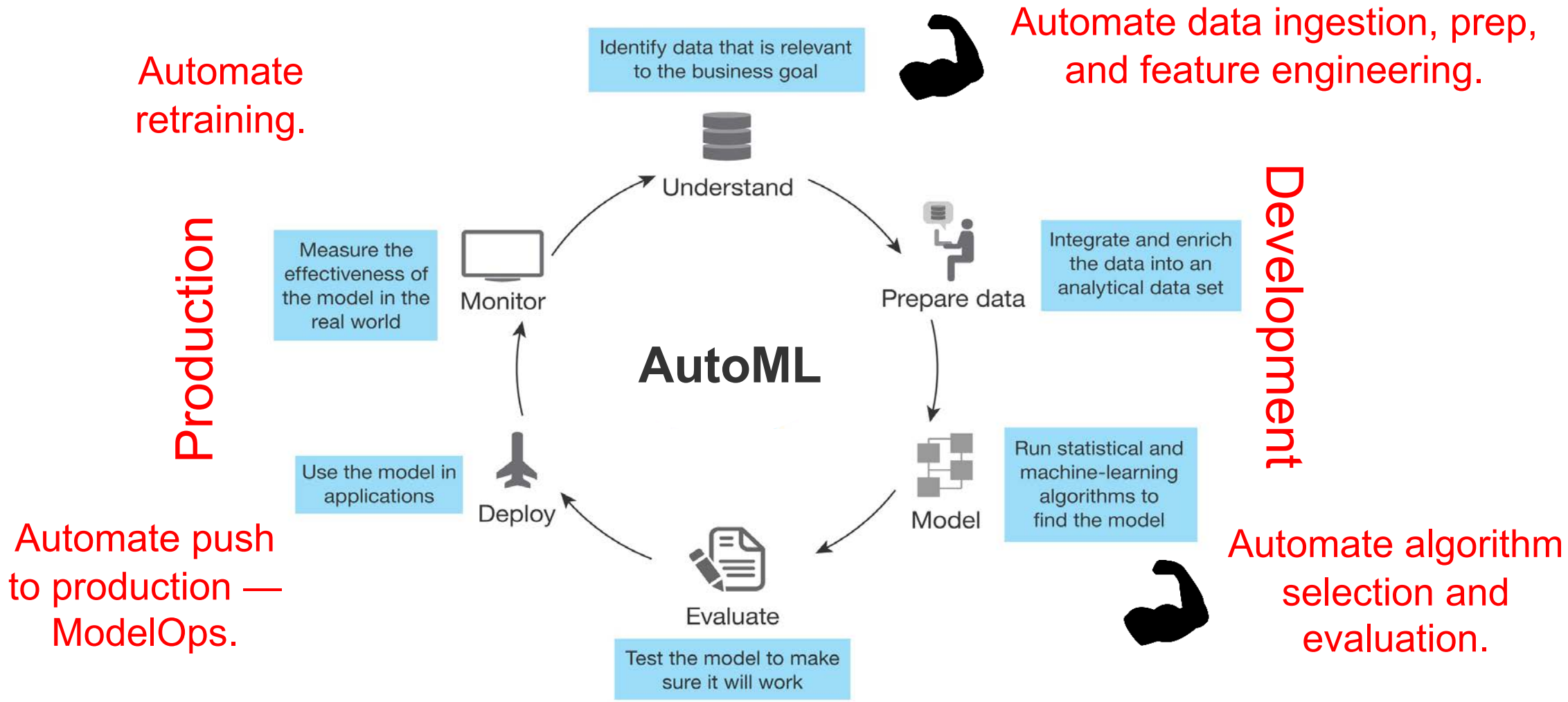


Machine learning models are the fundamental building blocks of AI applications.

Machine learning algorithms analyze data to create models used in AI solutions.

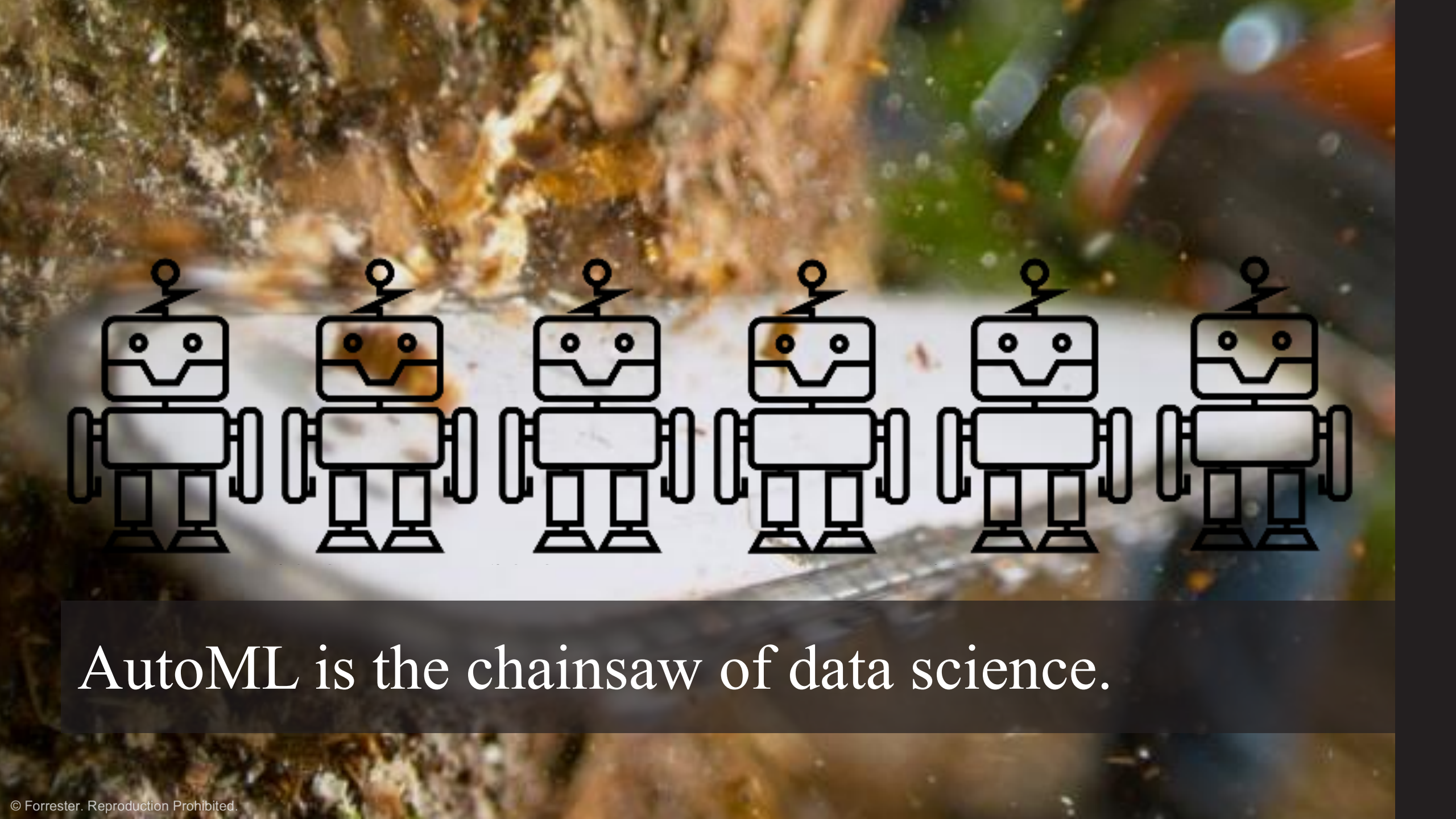
- Support vector machines (SVM)
- Convolution networks
- Last takeaway
- Gradient boosting (GBM)
- K-means
- Feature selection
- PCA
- Kohonen Networks (SOFM)
- Random forests
- Mars regression splines
- Linear and logistic regression
- Naïve Bayes
- Recurrent networks

The ML model building lifecycle is tumultuously iterative and continuous



Lumberjacks can fell about 15 trees per day with an axe . . .

. . . and with a chainsaw, 400 to 600 per day.

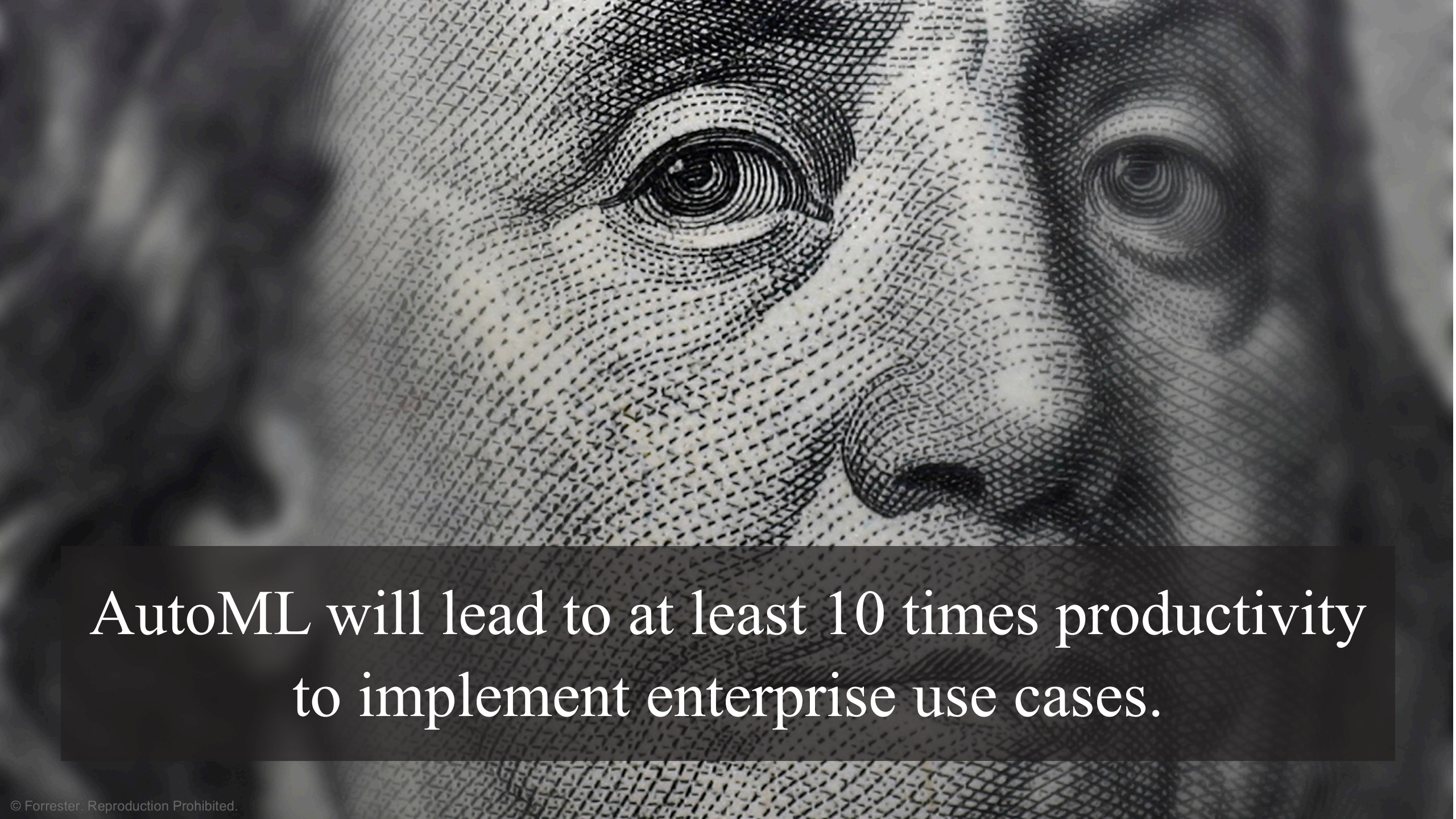


AutoML is the chainsaw of data science.

Using infrastructure is orders of magnitude less expensive than data manually iterating through ML experiments.

Some AutoML solutions enable data-savvy business people (aka citizen data scientists) to build models.

Ring your bell with autoML.



AutoML will lead to at least 10 times productivity to implement enterprise use cases.

#4

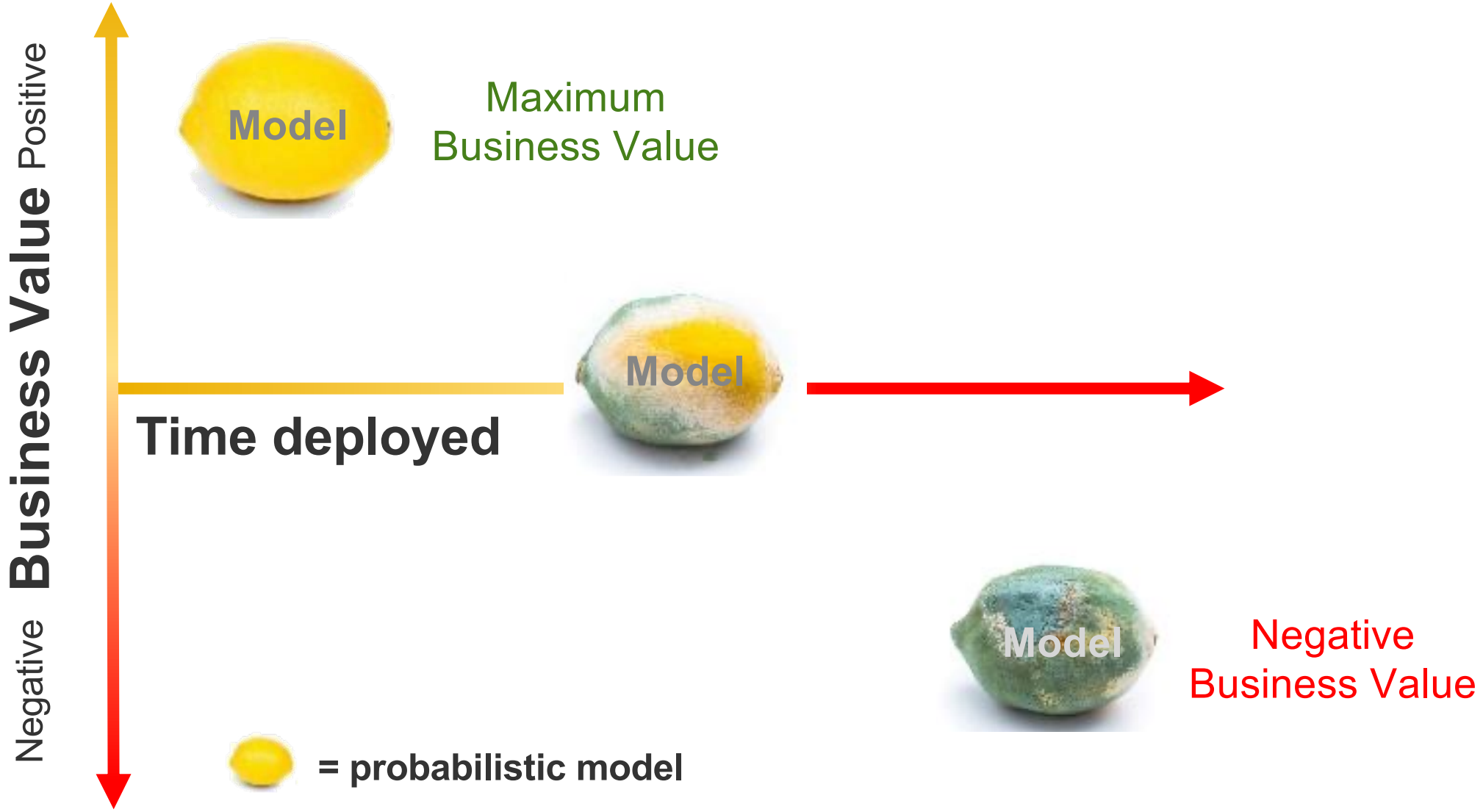
FORRESTER

AI must learn in perpetuity.

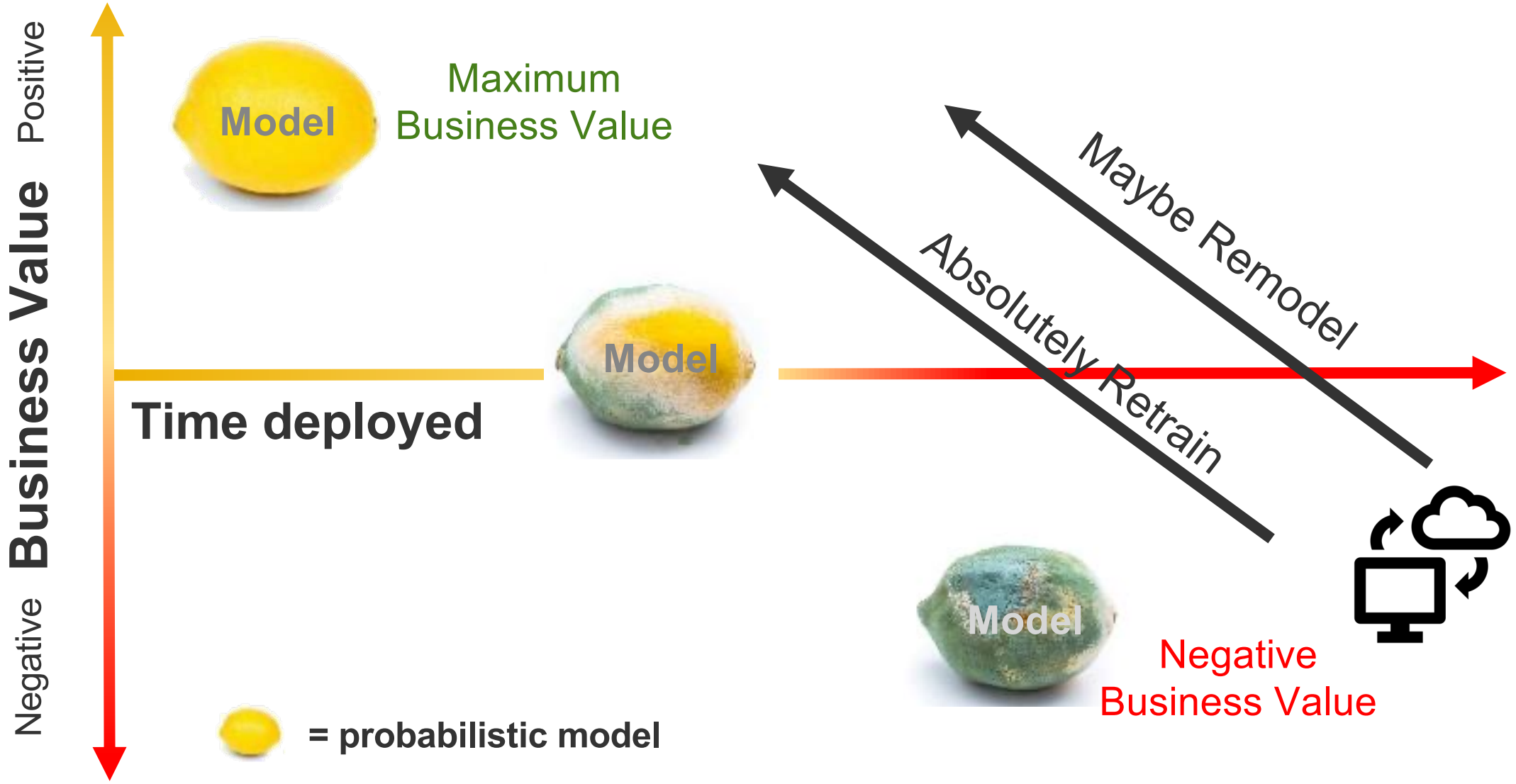
DRIVERS

…and so too must machine models.

ML model performance can decay over time

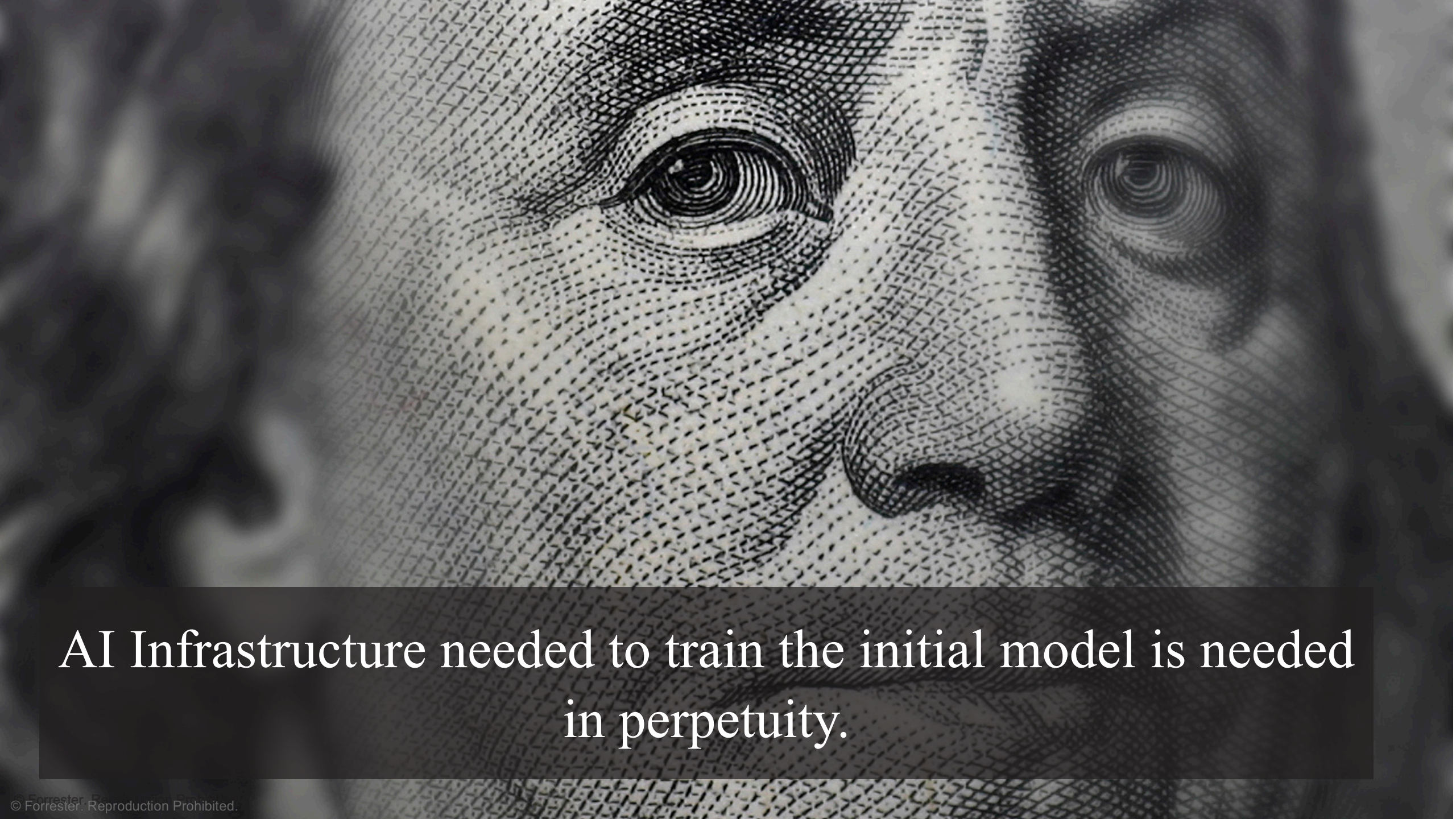


ML models must be monitored, retrained, and often remodeled



Many models may be retrained as frequently as daily.

AI models must stay in school to remain cool.



AI Infrastructure needed to train the initial model is needed in perpetuity.

#5

FORRESTER

AI nestles nicely in automation.

DRIVERS

"Inferencing" is using AI in the real world – digital and physical.

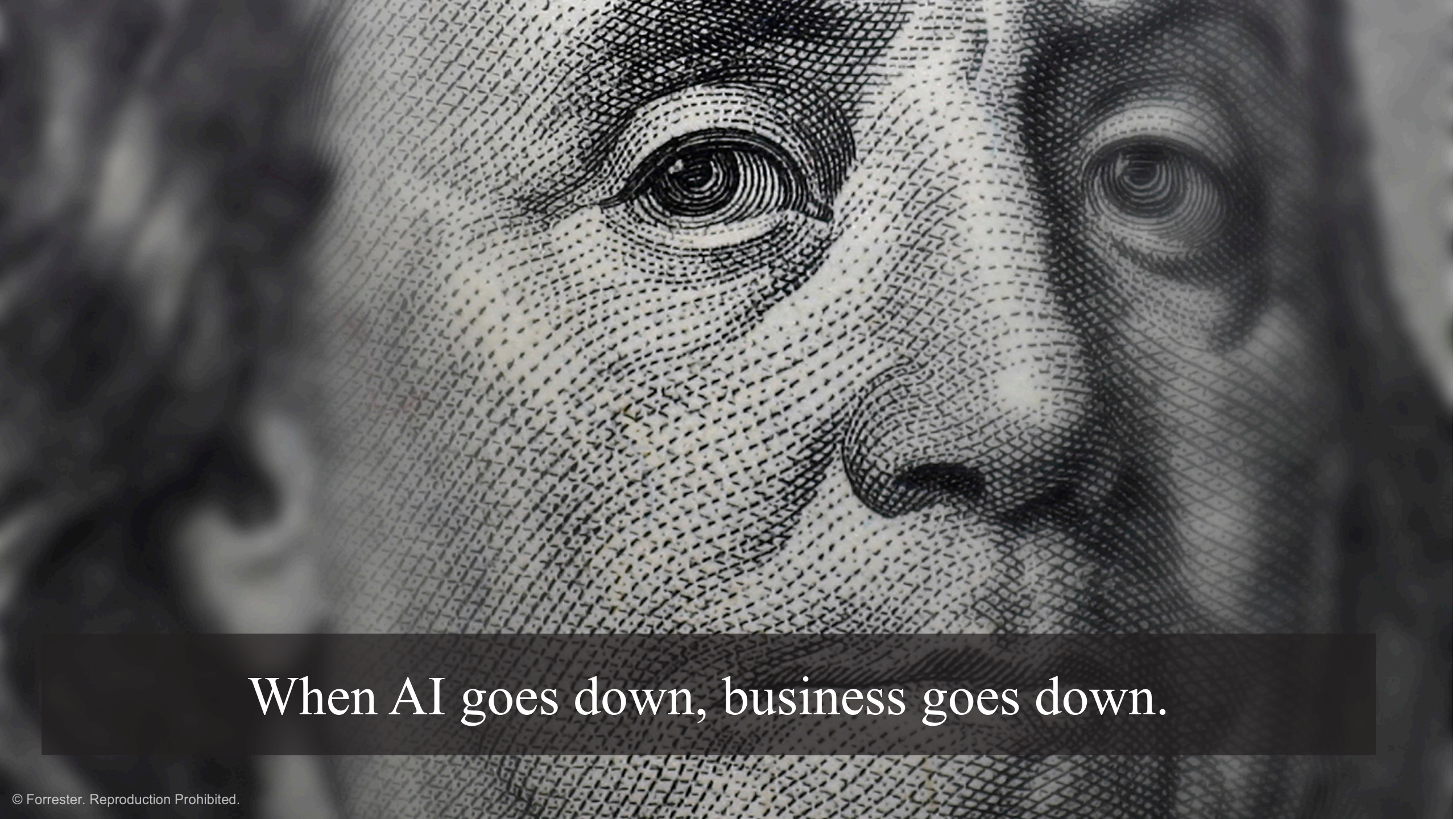
…every aspect of roboto control.

…every aspect of customer engagement.

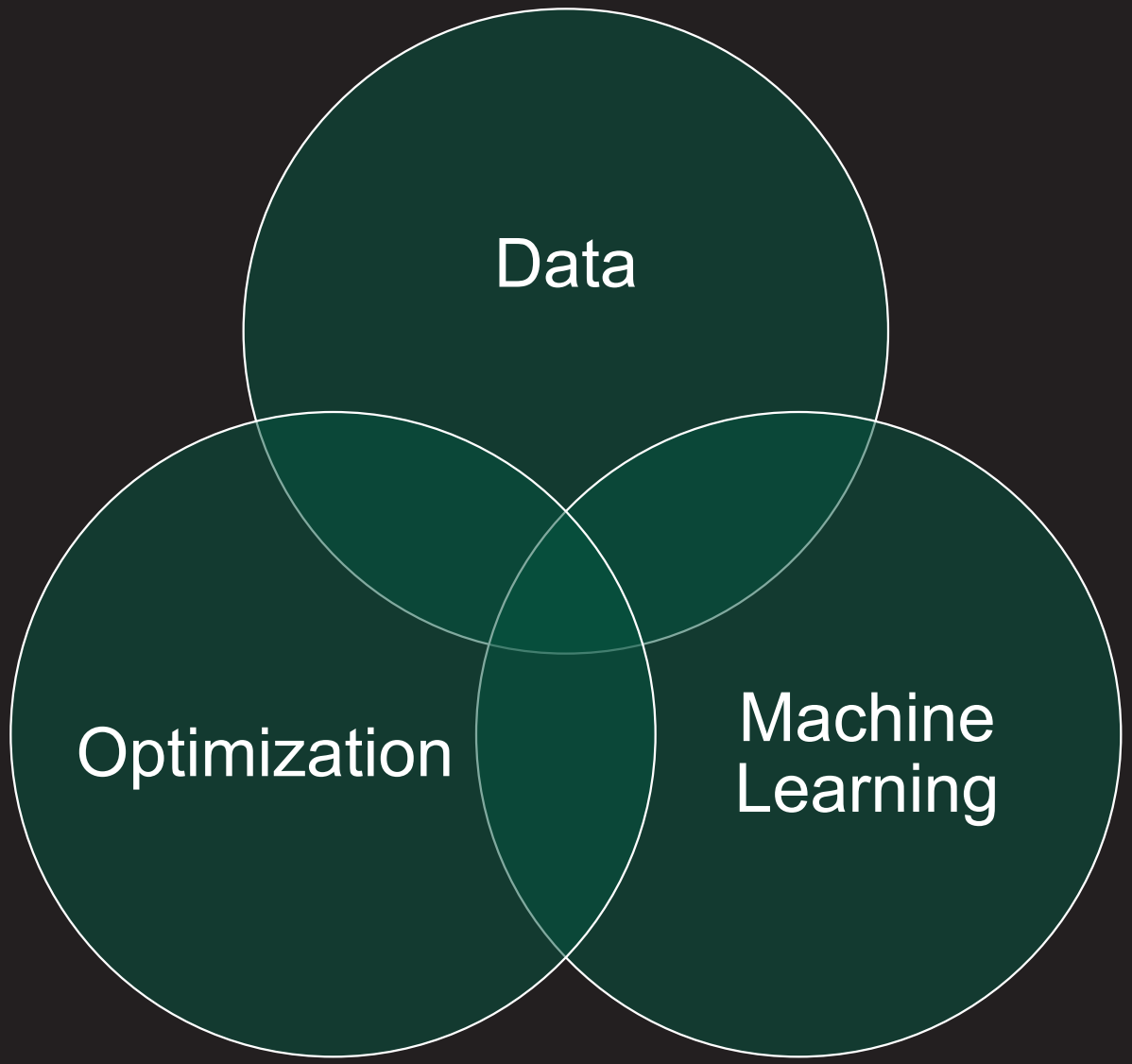
…every aspect of transportation.

AI is infused in existing as well as new enterprise operational and customer applications.

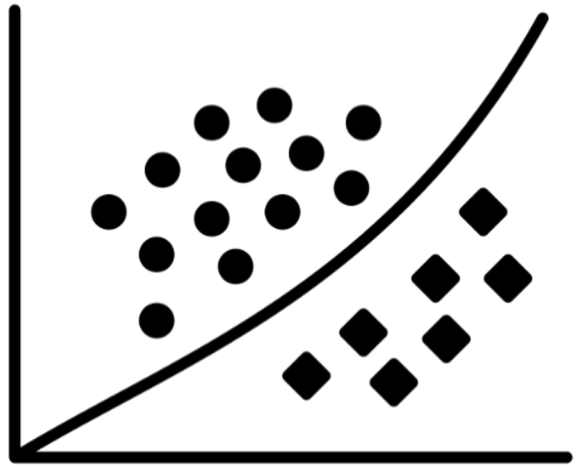
It ain’t fun,
if it don’t run.



AI



That’s why AI is the fastest growing technology on the planet.



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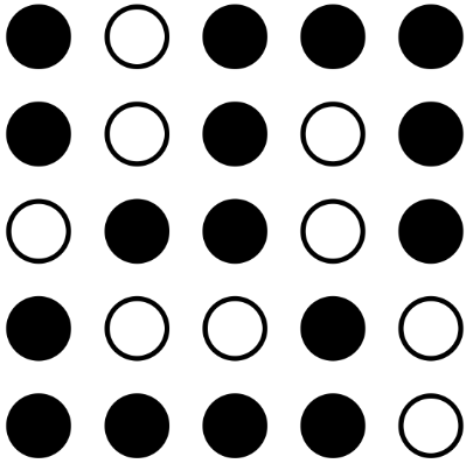

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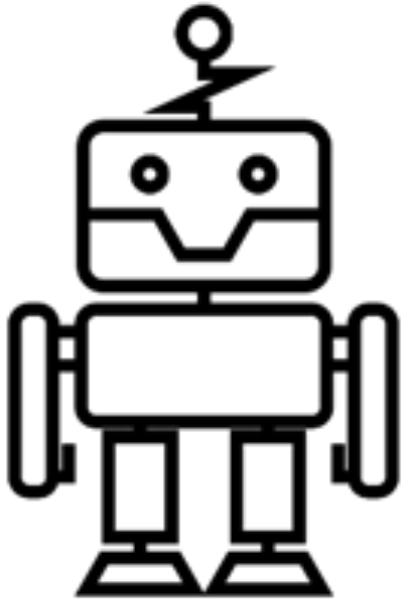


ML + MO = AI

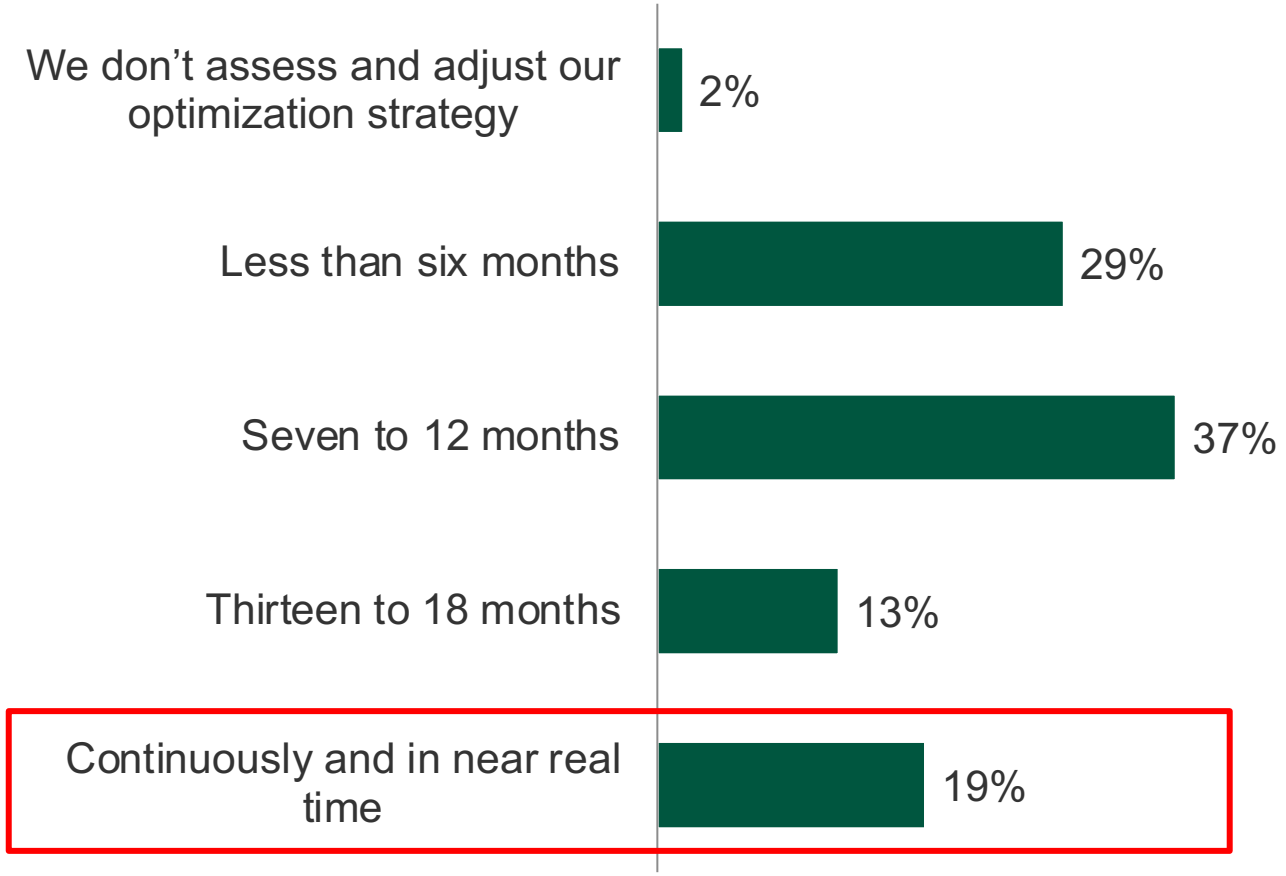
Firms want to adjust their optimization strategy more frequently

All respondents agree that there are benefits to adjusting their optimization strategy frequently

Only **19%** of respondents assess their optimization strategy **continuously and in near real time**.

45% want to assess and adjust their optimization strategy **more frequently**.

Q8-How frequently does your organization assess and adjust its optimization strategy?



Base: 162 global decision makers of optimization technology

Source: A commissioned study conducted by Forrester Consulting on behalf of Gurobi, August 2021

Thank You.

Mike Gualtieri
Vice President, Principal Analyst

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BOLD AT WORK

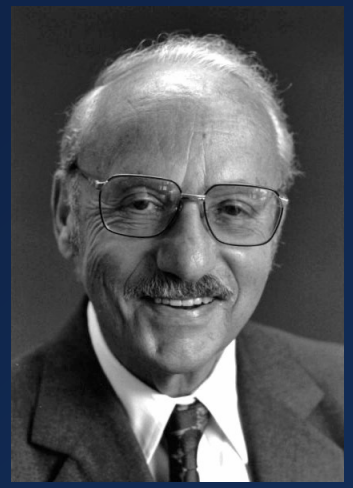
Overview

Mathematical Optimization in Finance

Ed Rothberg
CEO, Gurobi Optimization

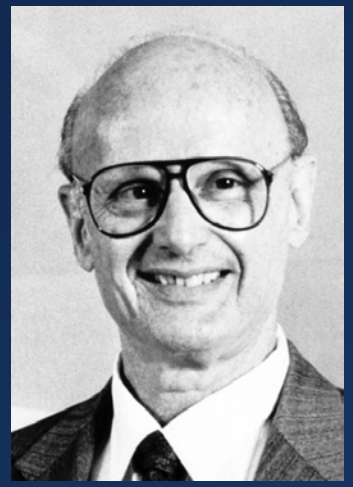
GUROBI OPTIMIZATION

Mathematical optimization and computational finance developed in parallel. Worked together at the RAND Corporation in early 1950's.



George Dantzig

- Simplex method: 1947
- Fundamental building block for modern mathematical optimization



Harry Markowitz

- "Portfolio selection": 1952
- "A Simplex Method for the Portfolio Selection Problem": 1957
- Nobel prize in Economics in 1990

Portfolio optimization a fundamental building block for modern finance

GUROBI OPTIMIZATION

Diversity of Applications

Mathematical Optimization + Finance = Portfolio Optimization?

Applications Areas for MO

Accounting
Advertising
Agriculture
Airlines
ATM provisioning
Compilers
Defense
Electrical power
Energy
Facility location
Finance
Food service
Forestry
Gas distribution
Government
Internet applications
Logistics/supply chain
Medical
Mining
National research labs
Online dating
Petroleum
Portfolio management
Railways
Recycling
Revenue management
Semiconductor
Shipping
Social networking
Sourcing
Sports betting
Sports scheduling
Statistics
Steel Manufacturing
Telecommunications
Transportation
Utilities
Workforce Mgmt.

Applications Areas for MO

Accounting
Advertising
Agriculture
Airlines
ATM provisioning
Compilers
Defense
Electrical power
Energy
Facility location
Finance
Food service
Forestry
Gas distribution
Government
Internet applications
Logistics/supply chain
Medical
Mining
National research labs
Online dating
Petroleum
Portfolio management
Railways
Recycling
Revenue management
Semiconductor
Shipping
Social networking
Sourcing
Sports betting
Sports scheduling
Statistics
Steel Manufacturing
Telecommunications
Transportation
Utilities
Workforce Mgmt.

Relevance to Finance

Financial firms are multi-faceted enterprises and MO touches lots of different corporate functions

Optimizing credit card offerings
Marketing campaign optimization

Optimizing a branch network
Network design optimization

Optimizing appt scheduling
Manpower scheduling

Optimizing field service scheduling
Transportation optimization

Securitization
Blending optimization

Plus…
- Portfolio optimization
- Portfolio replication
- Trade settlement
- Risk management
- Credit swap management
- Asset-liability management
- Payment netting
- …

GUROBI OPTIMIZATION

The Virtues of Declarative Modeling

Mathematical Optimization is Declarative Modeling

Declarative

Mathematical optimization is Declarative Modeling

- You declare a set of facts about your desired solution
  - A set of constraints
  - An objective function
- An optimization solver performs a systematic search for solution that adhere to these facts
  - Satisfy constraints
  - Maximize objective

In contrast to a *procedural* approach

- Where you specify a process for finding a solution

$$\begin{aligned} &Minimize && c^T x \\ &Subject\ to && Ax = b \\ & && l \le x \le u \\ &\text{some or all } x_j && \text{integer} \end{aligned}$$

Modeling

Mathematical optimization is Declarative Modeling

- You build a model of how your system behaves

As opposed to a data-based approach

- Where you draw conclusions about how the system functions from data

Digital Twin

Optimization model acts as a “digital twin” for your business process

- Captures the behavior of the system for all inputs

Explores the entire solution space to find the best solution

- Also provides a “lower bound” on the best possible solution
- Provides a worst-case guarantee on the quality of the computed solution

Tradeoffs Versus Machine Learning

Model-based versus data-based approach

Model-based does not rely on historical data

- No need to gather massive amounts of training data (which may not be available)
- No need to worry about potential input data that isn't captured in training data
- No need to worry about model drift (when important characteristics of input data change)

Model must be built

- Data-based approach can recognize patterns without significant user input

Tradeoffs Versus Heuristics

Declarative versus procedural approach

Declarative approach

- General solution approach - not built to solve just your specific problem
  - May not be robust with respect to changes in the problem
- Easier to understand
  - Much easier to understand declarative statements about the solution than thousands of lines of code
- Passive improvements
  - Improvements in the underlying solver produce improvements for your problem
- Systematic
  - Will find the best solution eventually
- Bound information
  - Guarantees about the quality of the solution

Procedural approach

- Can be quicker to find reasonable quality solutions
- Only ‘skill’ required to build a heuristic is coding

Ingredients for Optimization Success

- A problem that involves multiple activities competing for scarce resources
- Available data that captures the current state and upcoming demands of these activities
- A well-formed objective function
- A data scientist that has the ability to systematically state the objective and constraints in a mathematical form
- Process of formulating an optimization model often as valuable as the model itself

GUROBI OPTIMIZATION

ROBECO

Optimizing fixed-income investment portfolios for private and institutional investors

swissQuant

Portfolio optimization for private banking customers

WINCOR NIXDORF

"Cash logistics"

Restocking ATM machines

Available on our website: www.gurobi.com/customers/case-studies

To Learn More

Get Started with Mathematical Optimization

- Visit www.gurobi.com
- Browse through our ”Resources”

Get a free 30-day trial of the Gurobi Optimizer

- www.gurobi.com/eval

Need help leveraging optimization for your business?

- Contact us at info@gurobi.com

Thank You

Questions?