# Nordic probabilistic AI school

## Introduction to probabilistic programming languages (PPLs)

Helge Langseth, Andrés Masegosa, and Thomas Dyhre Nielsen

June 14, 2022

# Plan for this week

**Day 1:** Probabilistic programming

- Introduction to probabilistic programming
- Probabilistic programming in Pyro

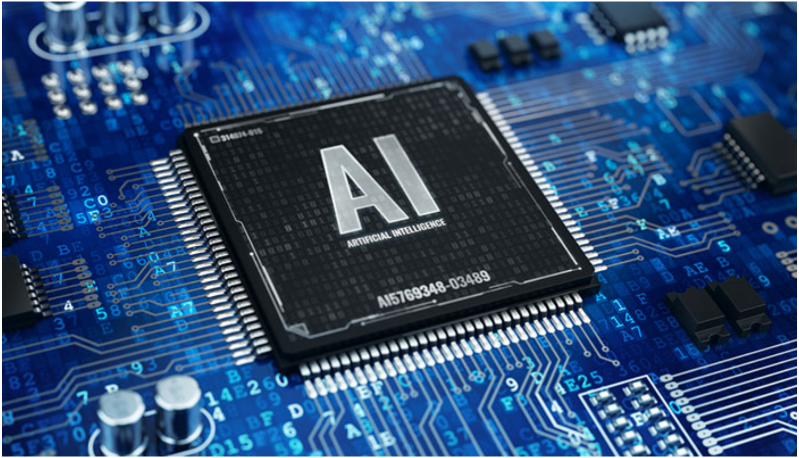
**Day 2:** Variational inference

- Recap of variational inference (variational inference as optimization)
- Derivation and implementation of selected examples
  - Bayesian linear regression
  - Factor analysis
  - . . .

**Day 3:** Variational inference – cont'd

- Black box variational inference
- Variational inference in Pyro
- Variational auto-encoders

# Machine Learning Systems



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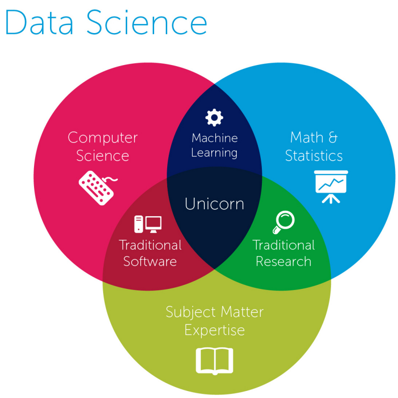
# Machine Learning Systems



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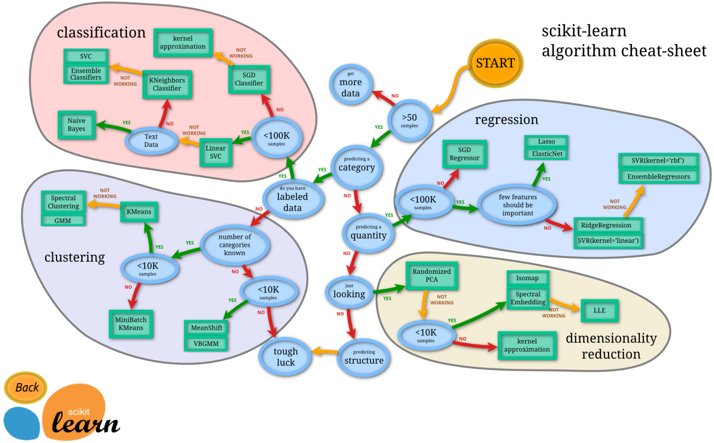
The development of **machine learning systems** requires enormous efforts.

- **It requires of highly qualified experts.**

# Machine Learning Systems



## The development of machine learning systems requires enormous effort.

- It is necessary to have highly qualified experts.
- **It is difficult to find the ML model most suitable for an application.**

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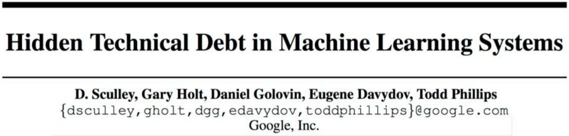
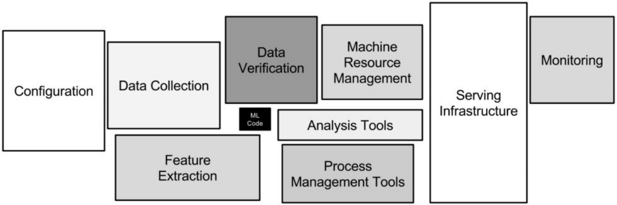


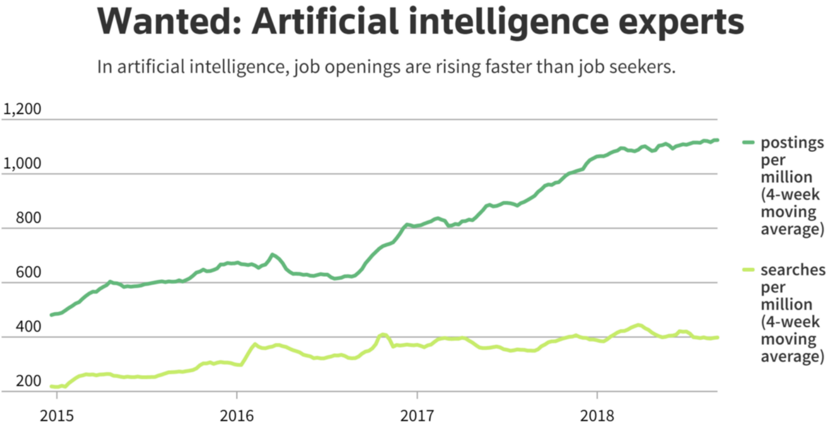
## Hidden Technical Debt in Machine Learning Systems

D. Sculley, Gary Holt, Daniel Golovin, Eugene Davydov, Todd Phillips
{dsculley,gholt,dgg,edavydov,toddphillips}@google.com
Google, Inc.



### The development of machine learning applications requires enormous effort.

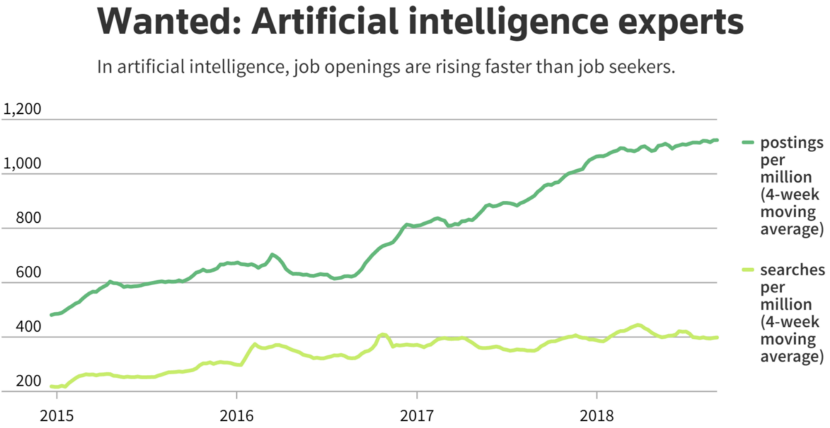
- It is necessary to have highly qualified experts.
- It is difficult to find the ML model most suitable for an application.
- **Programming a ML model is a complex task where many problems are intermingled**.



## Consequences:

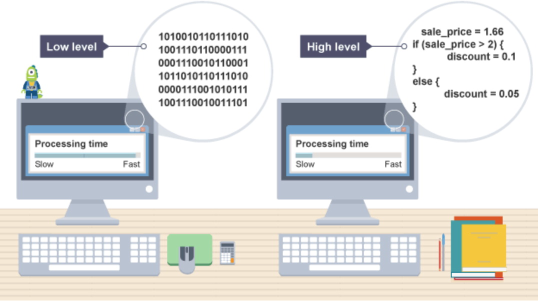
- Shortage of AI experts (and high salaries).

# Developing Machine Learning Systems



## Consequences:

- Shortage of AI experts (and high salaries).
- Only big corporations have the resources for developing ML systems.



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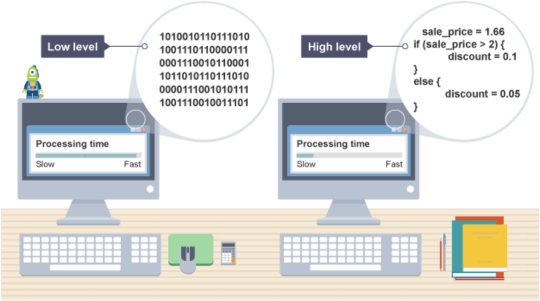
## Similar situation than 50 years ago:

# Programming Languages



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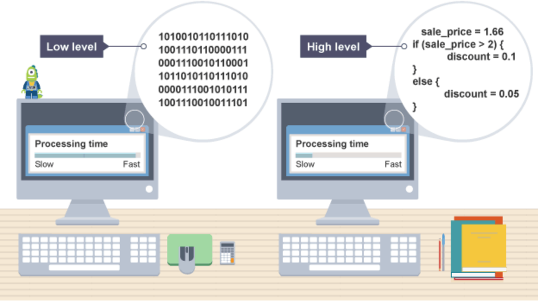

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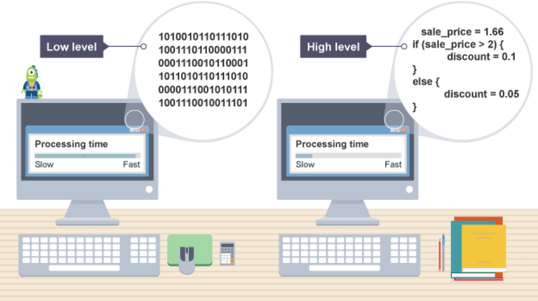

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- Programming was complex and demand high-expertise.
- Focus on application and low-level hardware details.

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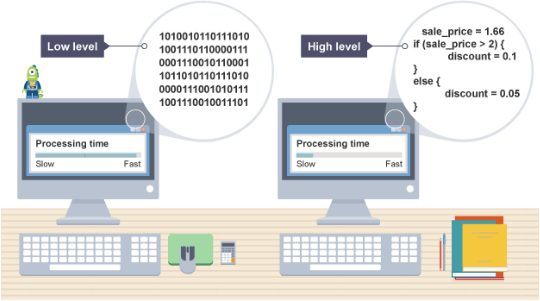

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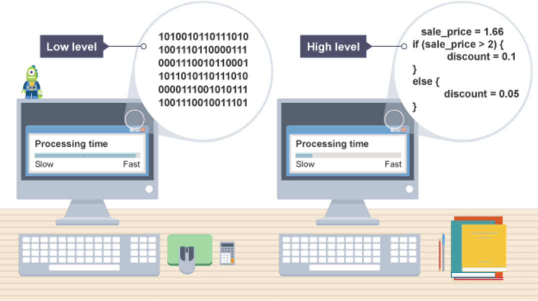

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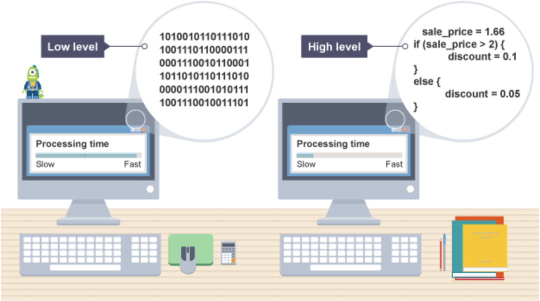

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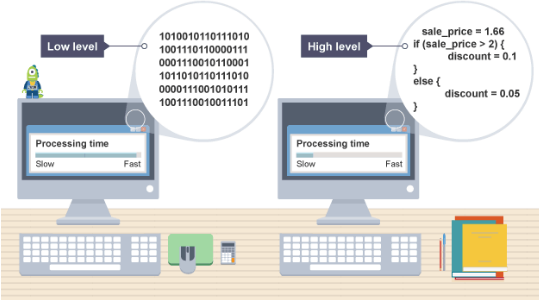

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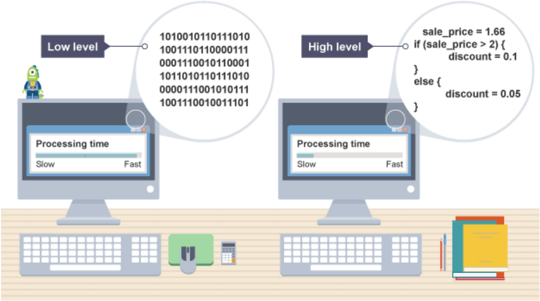

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- Programmers focused on the applications.
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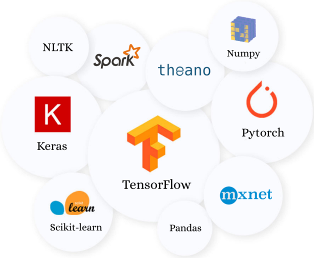
- High gains in productivity.
- “Democratization” of the software development.

# Big Data and Machine Learning Ecosystem



Claire D. Costa. Best Python Libraries for Machine Learning and Deep Learning.
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## Big Data and Machine Learning Libraries:

- **High-quality**, well-maintained and open-source libraries

# Big Data and Machine Learning Ecosystem

NLTK
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theano
Numpy
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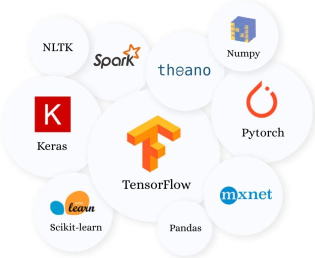

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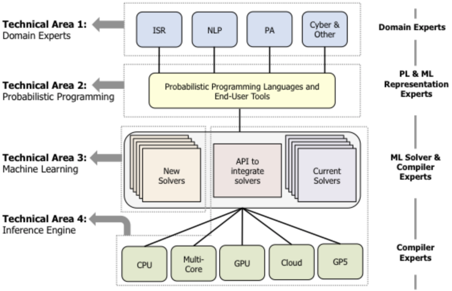
- **High-quality**, well-maintained and open-source libraries
- They try to provide **high-level abstractions**.
- Hiding under the hood **low level details**.
- Increase the **adoption** of these technologies.

# What about in Probabilistic AI?

Which are the "high-level libraries" in Probabilistic AI?

# Why PPLs?



PPLs as high-level programming languages for **probabilistic machine learning systems**:

- Stacked architecture

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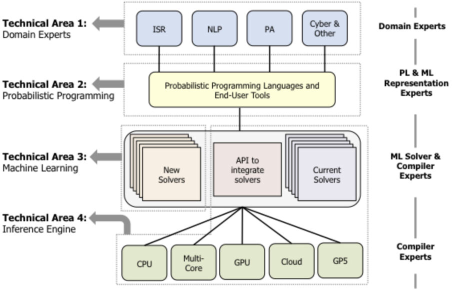

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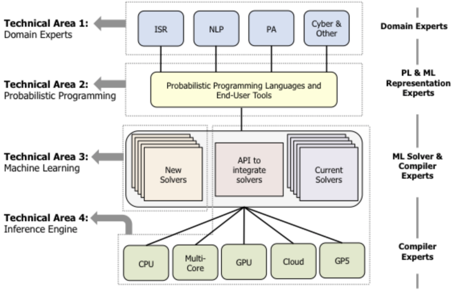

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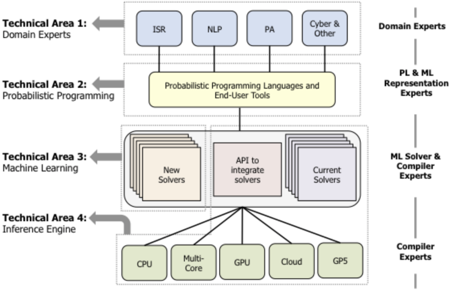
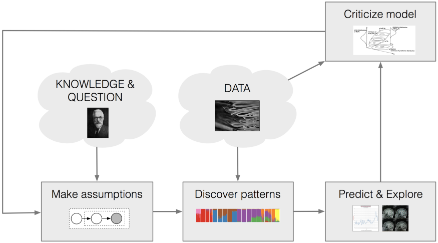


PPLs as high-level programming languages for **probabilistic machine learning systems**:

- Stacked architecture
- Different Domain Experts will code their models using the same language.
- ML experts will focus on the development of new ML solvers.
- Compile experts will focus on running these ML solvers on specialized hardware.

# Box’s Loop



[Box, 1980; Rubin, 1984; Gelman+ 1996; Blei, 2014]

## Benefits of PPLs for developing probabilistic machine learning systems:

- Simplify probabilistic machine learning model code.

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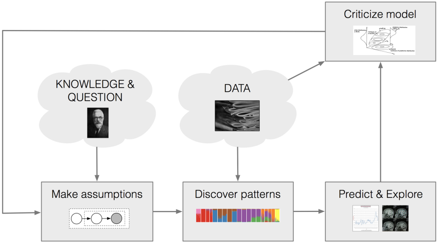

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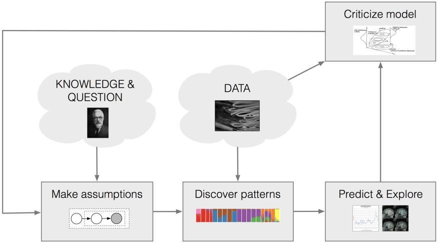

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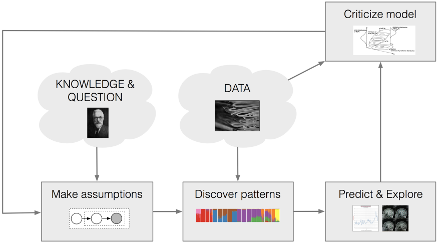

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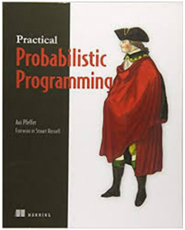
- "Democratization" of the development of probabilistic ML systems.

# PPLs



## 1st Generation of PPLs :

- Bugs, WinBugs, Jags, Figaro, etc.

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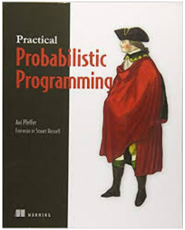

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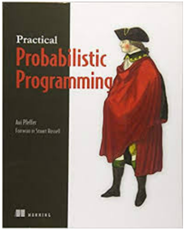

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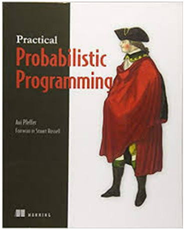

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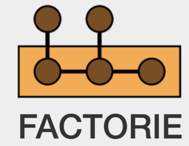

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# PPLs

infer.net

FACTORIE

AMiDST TOOLBOX

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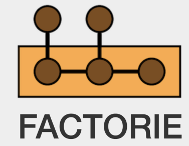

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- Infer.net, Factorie, Amidst, etc.
- Inference engine based on message passage algorithms and/or variational inference methods.
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- Restricted probabilistic model family (i.e. factor graphs, conjuage exponential family, etc.)

# PPLs

## 3rd Generation of PPLs :

- TensorFlow Probability, Pyro, PyMC3, InferPy, etc.

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    - Automatic differentiation methods.

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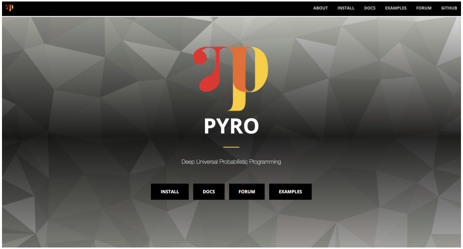

Deep Universal Probabilistic Programming

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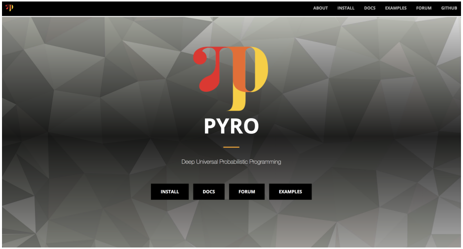

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- Initially developed by UBER (the car riding company).
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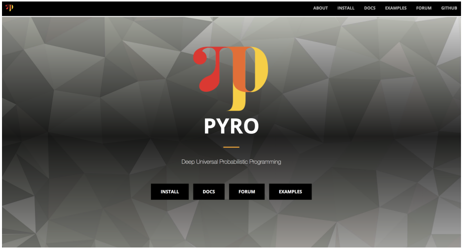

PYRO

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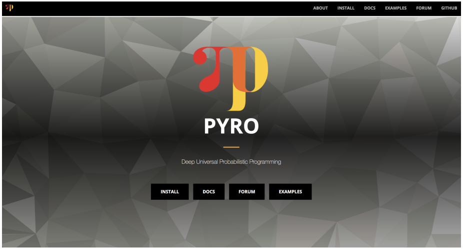

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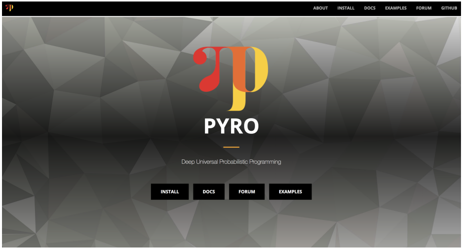

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