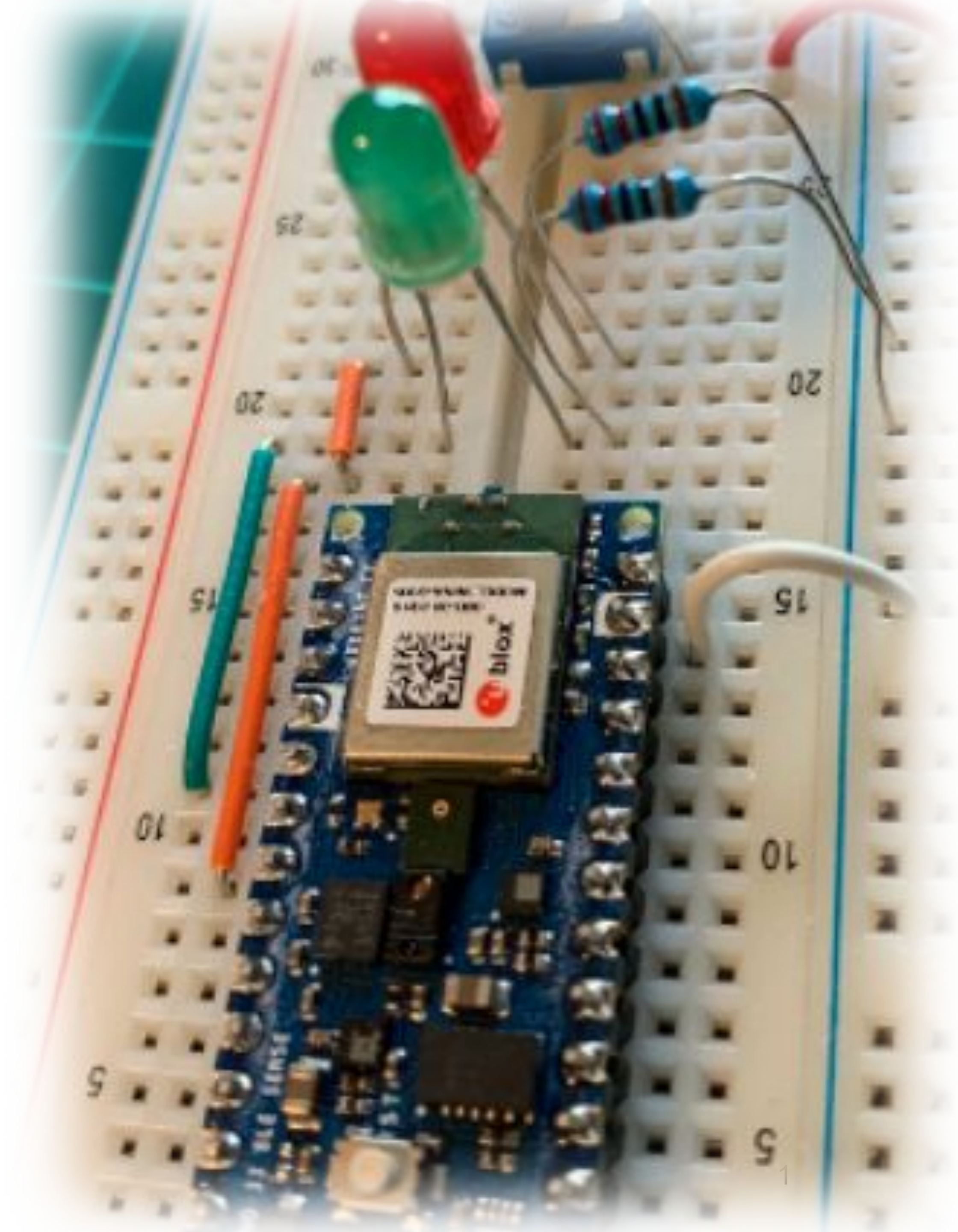
IESTI01 – TinyML

Embedded Machine Learning

15. ML Applications Overview
AI Lifecycle and ML Workflow



Prof. Marcelo Rovai
UNIFEI

TinyML Application

Examples (Classification)

Predictive Maintenance

Motion, current, audio and camera

- ➔ **Industrial**
- ➔ White goods
- ➔ Infrastructure
- ➔ Automotive

Asset Tracking & Monitoring

Motion, temp, humidity, position, audio and camera

- ➔ Logistics
- ➔ Infrastructure
- ➔ Buildings
- ➔ Agriculture

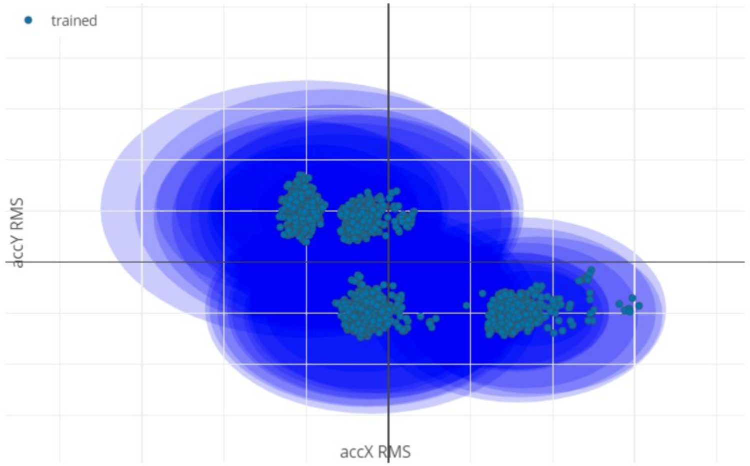
Human & Animal Sensing

Motion, radar, audio, PPG, ECG

- ➔ Health
- ➔ Consumer
- ➔ Industrial

EDGE IMPULSE

Industrial – Anomaly Detection



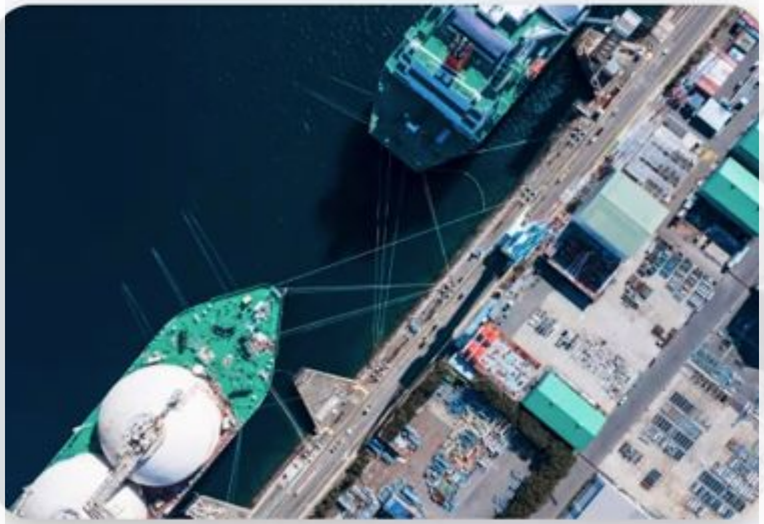
[IESTI01 2021.2 - Final Group Project: Bearing Failure Detection]

Predictive Maintenance

Motion, current, audio and camera

- → Industrial
- → White goods
- → Infrastructure
- → Automotive

Asset Tracking & Monitoring



Motion, temp, humidity, position, audio and camera

- → Logistics
- → Infrastructure
- → Buildings
- → **Agriculture**

Human & Animal Sensing

Motion, radar, audio, PPG, ECG

- → Health
- → Consumer
- → Industrial

EDGE IMPULSE

Agriculture - Cow Monitoring

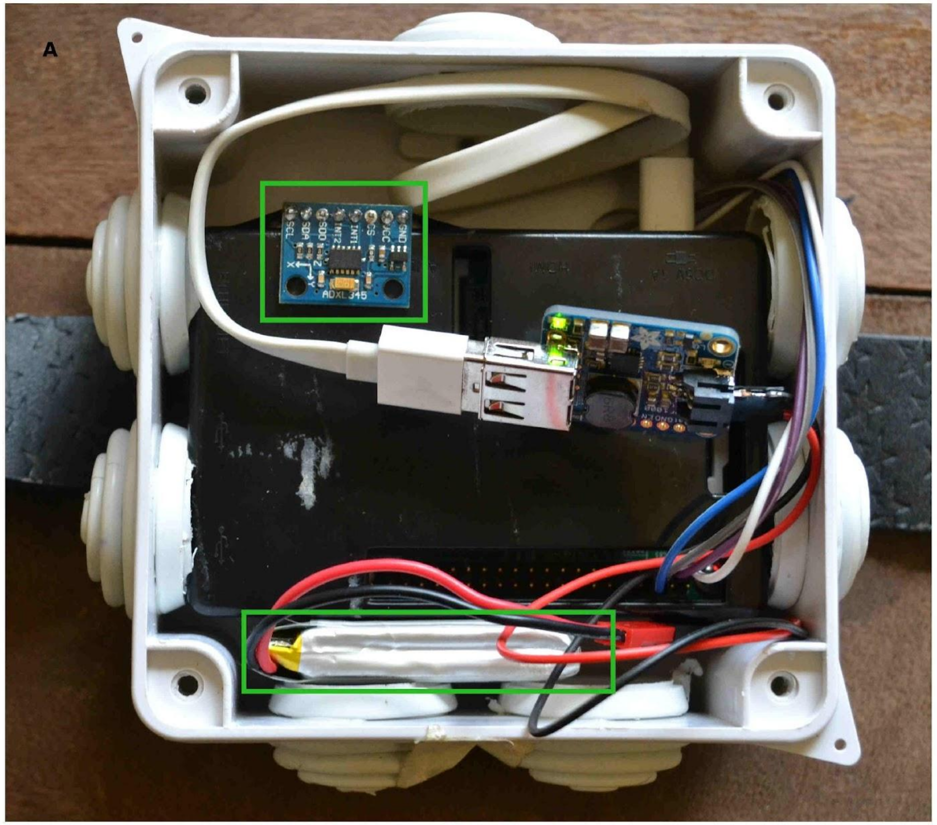
Using the Internet of Things for Agricultural Monitoring

“We aim to deploy a variety of sensors for agricultural monitoring. One of the projects involves using accelerometer sensors to monitor activity levels in dairy cows with a view to determining when the cows are on heat or when they are sick.”

Ciira wa Maina, Ph.D.

Senior Lecturer
Department of Electrical and Electronic Engineering
Dedan Kimathi University of Technology
Nyeri Kenya
Email: ciira.maina@dkut.ac.ke

Kenia



https://sites.google.com/site/cwamainadekut/research

Predictive Maintenance

Motion, current, audio and camera

- → Industrial
- → White goods
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Asset Tracking & Monitoring

Motion, temp, humidity, position, audio and camera

- → Logistics
- → Infrastructure
- → Buildings
- → Agriculture

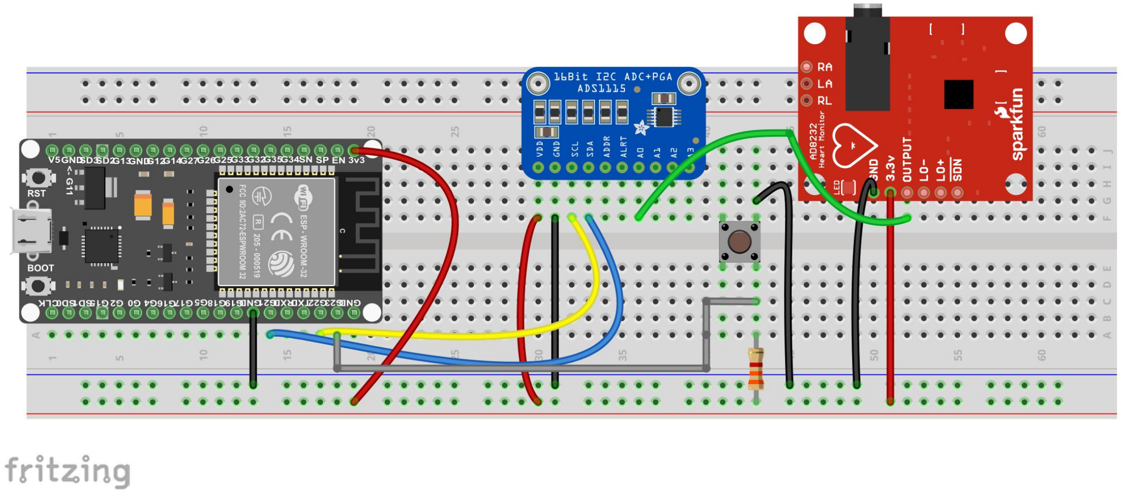
Human & Animal Sensing

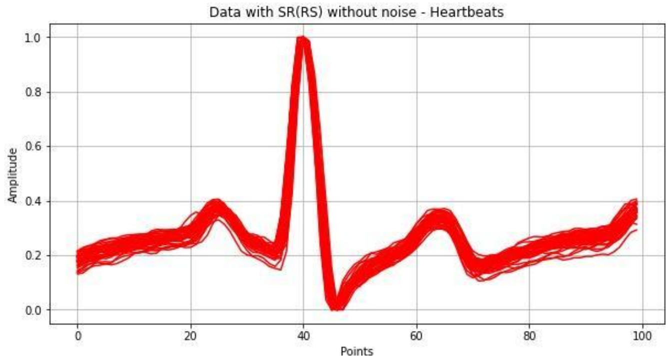
Motion, radar, audio, PPG, ECG

- → **Health**
- → Consumer
- → Industrial

EDGE IMPULSE

Health - Human Sensing





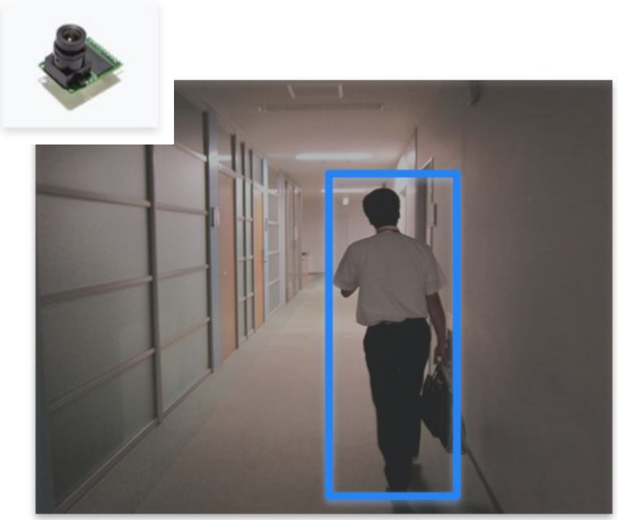
Guilherme Silva
Engenheiro - UNIFEI

[Atrial Fibrillation Detection on ECG using TinyML](#)
[Silva et al. UNIFEI 2021](#)

Sound

Vibration

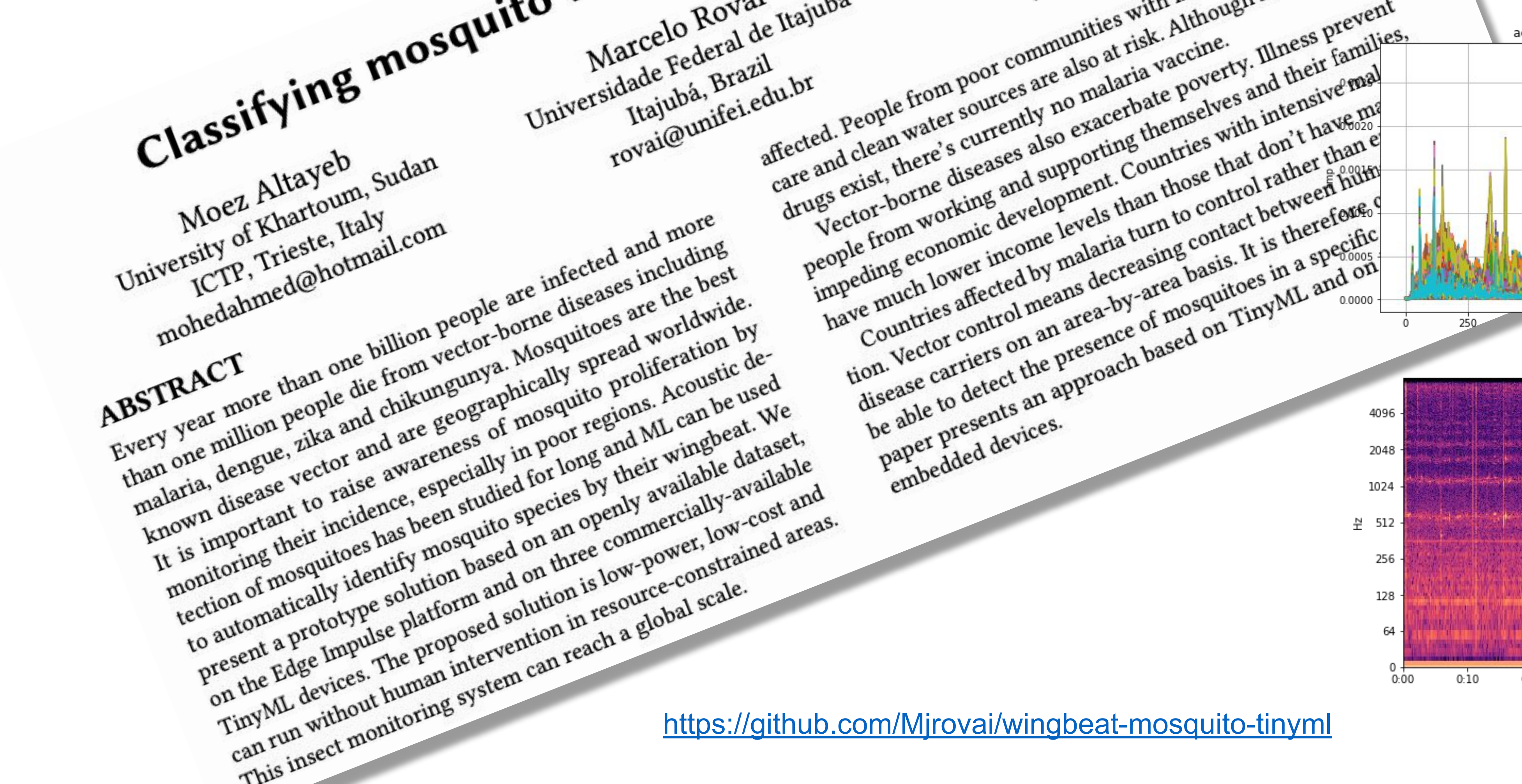
Vision



Sound

Vibration

Vision



Classifying mosquito wingbeat sound using TinyML

Moez Altayeb
University of Khartoum, Sudan
ICTP, Trieste, Italy
mohedahmed@hotmail.com

Marcelo Rovai
Universidade Federal de Itajubá
Itajubá, Brazil
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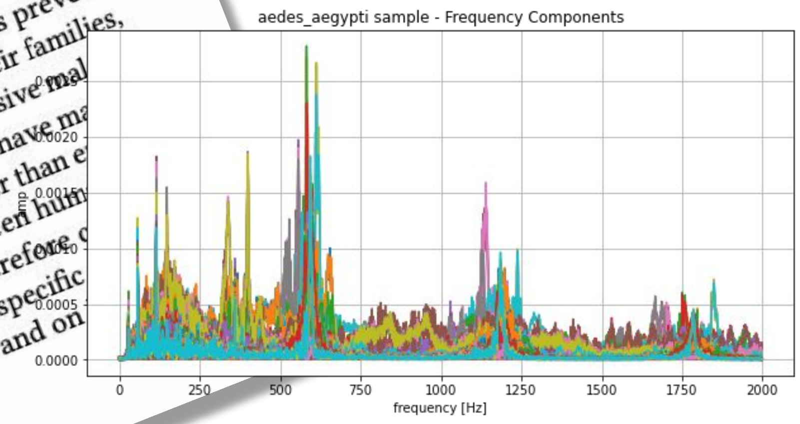
Marco Zennaro
ICTP
Trieste, Italy
mzennaro@ictp.it

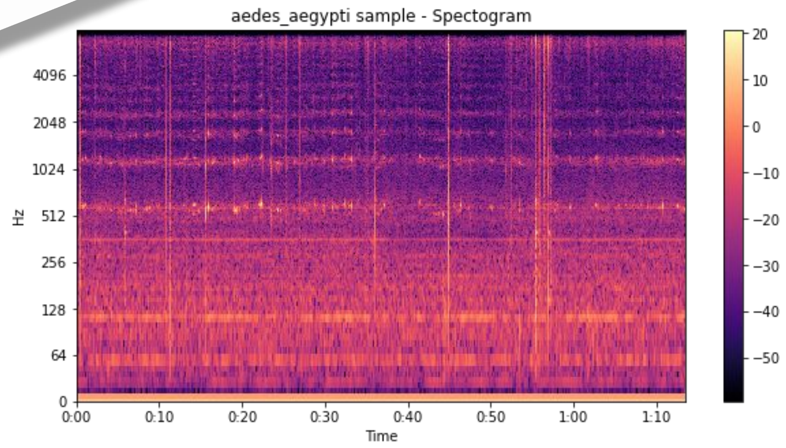
ABSTRACT

Every year more than one billion people are infected and more than one million people die from vector-borne diseases including malaria, dengue, zika and chikungunya. Mosquitoes are the best known disease vector and are geographically spread worldwide. It is important to raise awareness of mosquito proliferation by monitoring their incidence, especially in poor regions. Acoustic detection of mosquitoes has been studied for long and ML can be used to automatically identify mosquito species by their wingbeat. We present a prototype solution based on an openly available dataset, on the Edge Impulse platform and on three commercially-available TinyML devices. The proposed solution is low-power, low-cost and can run without human intervention in resource-constrained areas. This insect monitoring system can reach a global scale.

affected. People from poor communities with little access to health care and clean water sources are also at risk. Although anti-malarial drugs exist, there's currently no malaria vaccine.

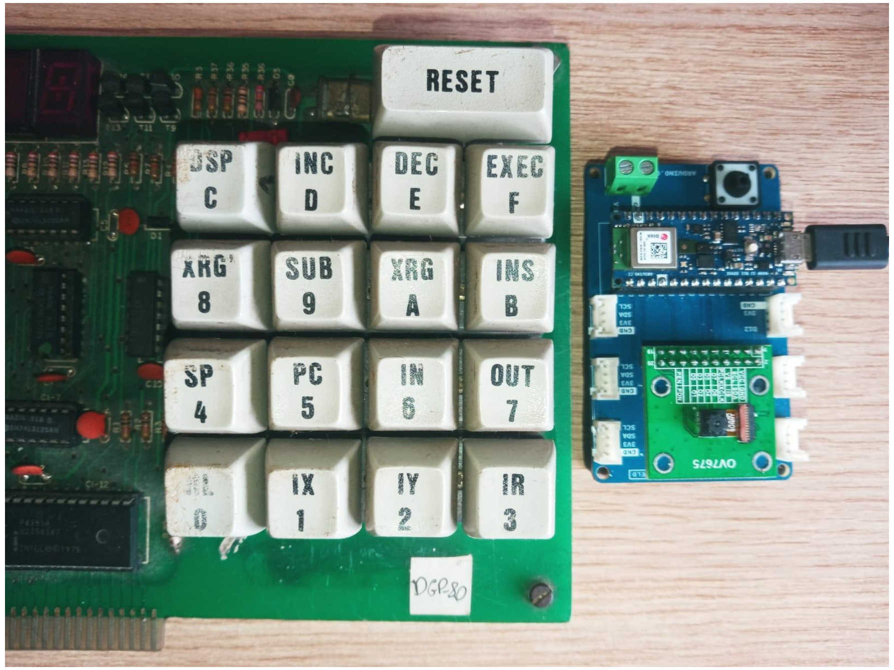
Vector-borne diseases also exacerbate poverty. Illness prevent people from working and supporting themselves and their families, impeding economic development. Countries with intensive mal have much lower income levels than those that don't have ma Countries affected by malaria turn to control rather than e tion. Vector control means decreasing contact between hum disease carriers on an area-by-area basis. It is therefore c be able to detect the presence of mosquitoes in a specific paper presents an approach based on TinyML and on embedded devices.

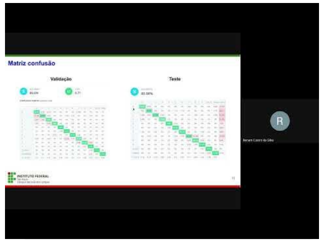




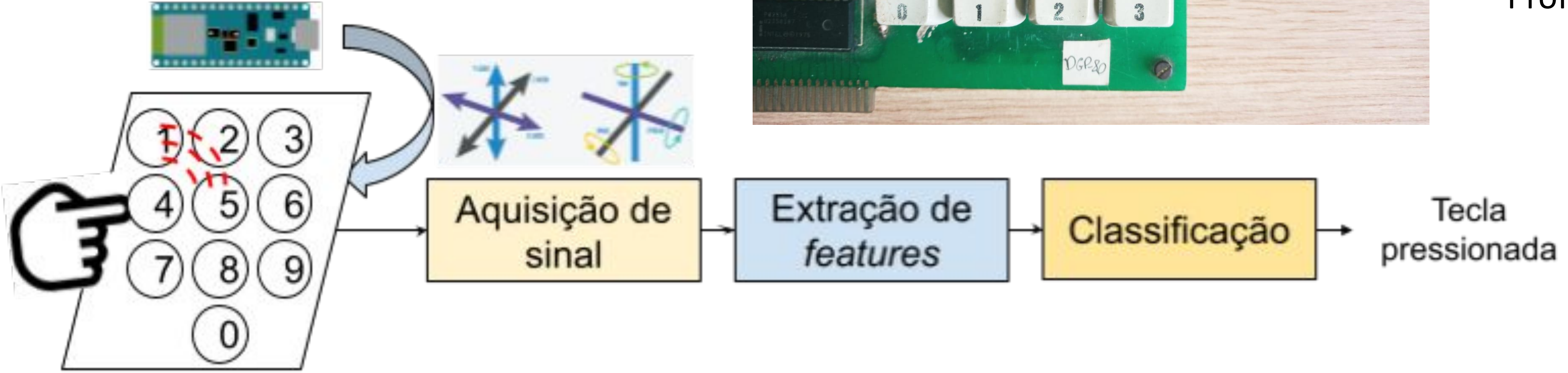
https://github.com/Mjrovai/wingbeat-mosquito-tinyml

Key Stroke Detection





Renam Castro
Professor IFESP



[IESTI01 2021.2 – Final Group Project Key Stroke Detection]()

Sound

Vibration

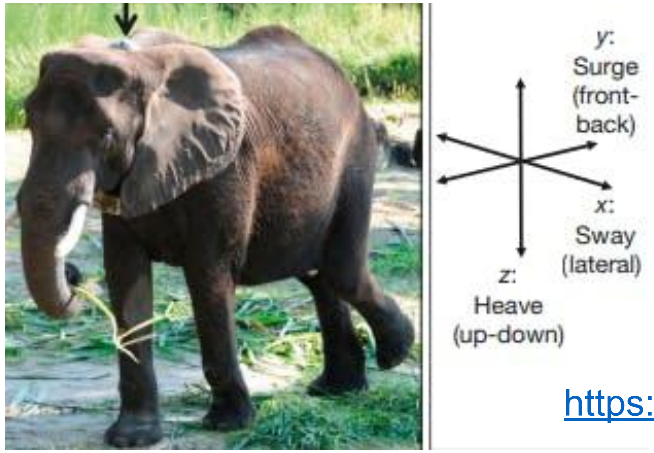
Vision

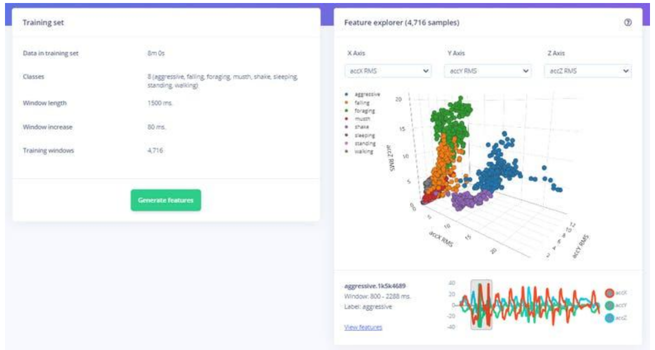
Predict and classify common Elephant behavior

Aggressive

Standing

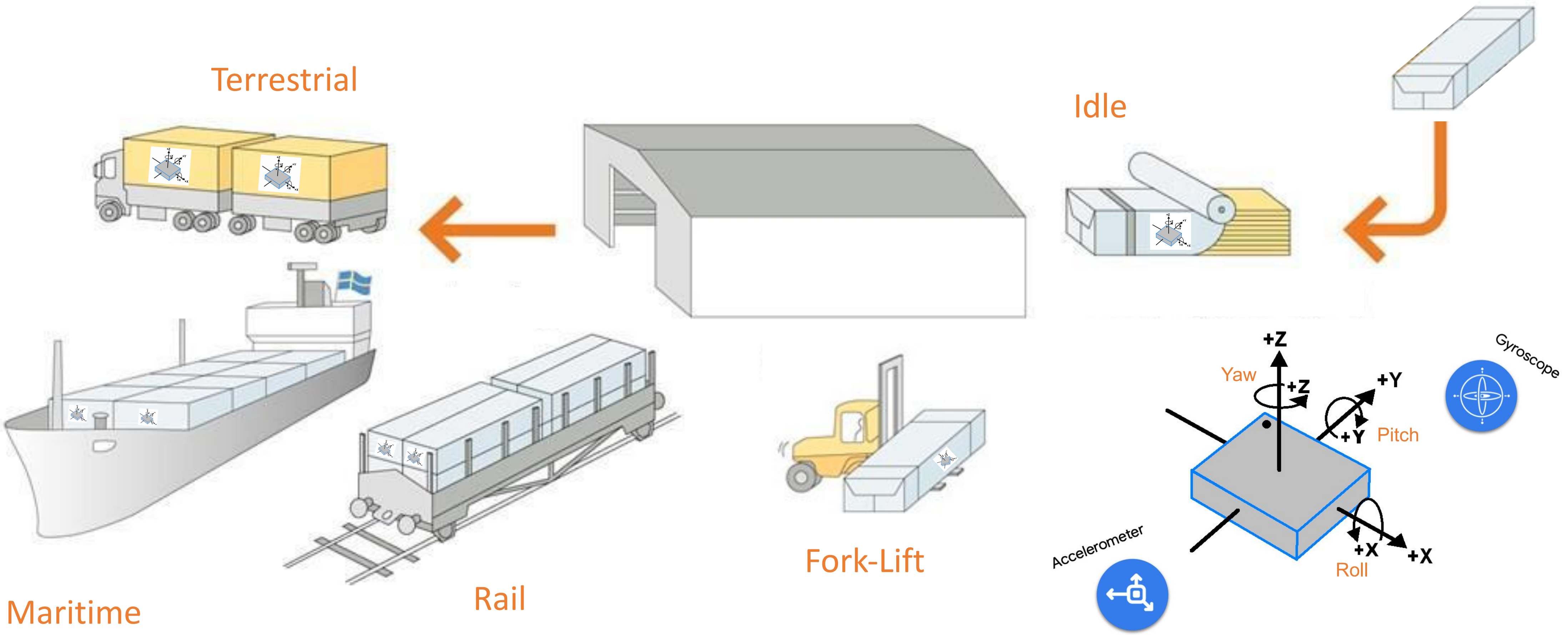
Sleeping





https://www.hackster.io/dhruvsheth_/eletect-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a

Mechanical Stresses in Transport

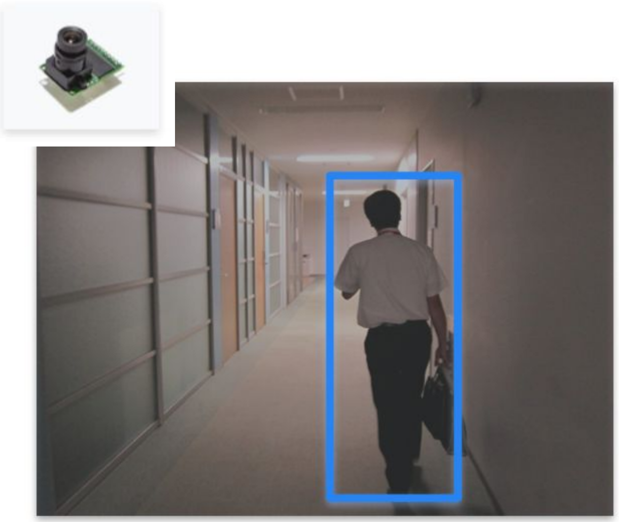


[ICTP SciTyniML 21 - Hands on Embedded ML - Motion/Anomaly Detection and Scientific Applications]

Sound

Vibration

Vision



Person Detection

✔

✘

Forest Fire Detection

[TinyML Aerial Forest Fire Detection]

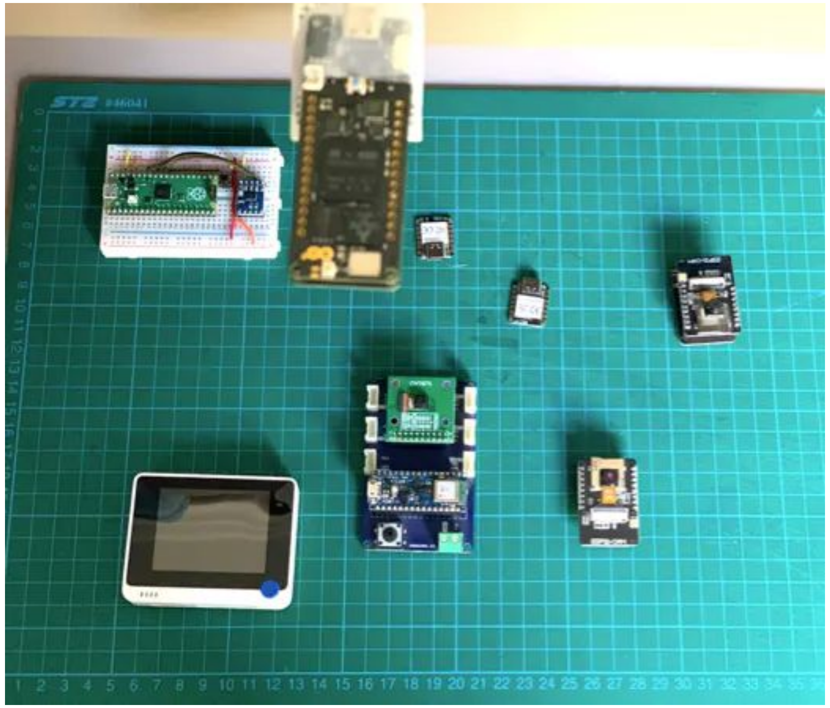
[IESTI01 - Forest Fire Detection – Proof of Concept]

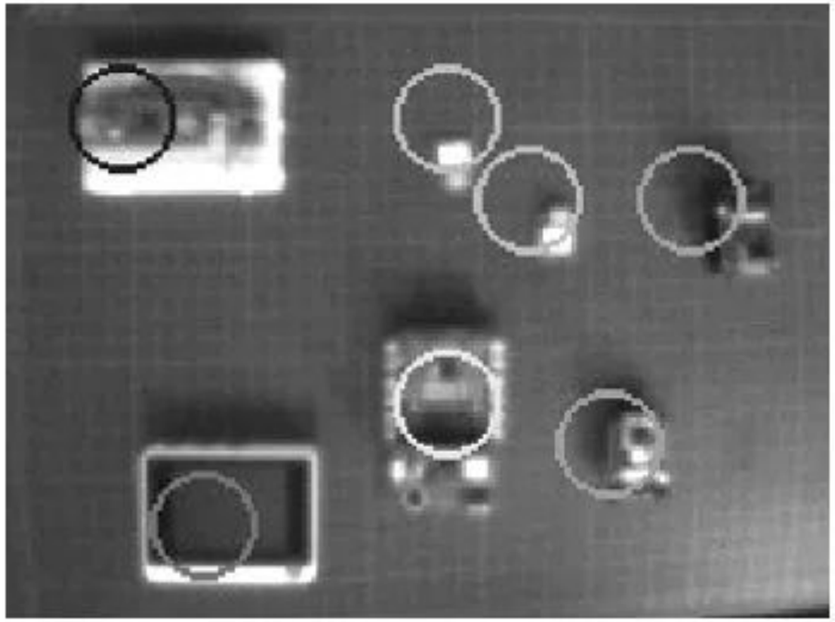
Coffee Disease Classification

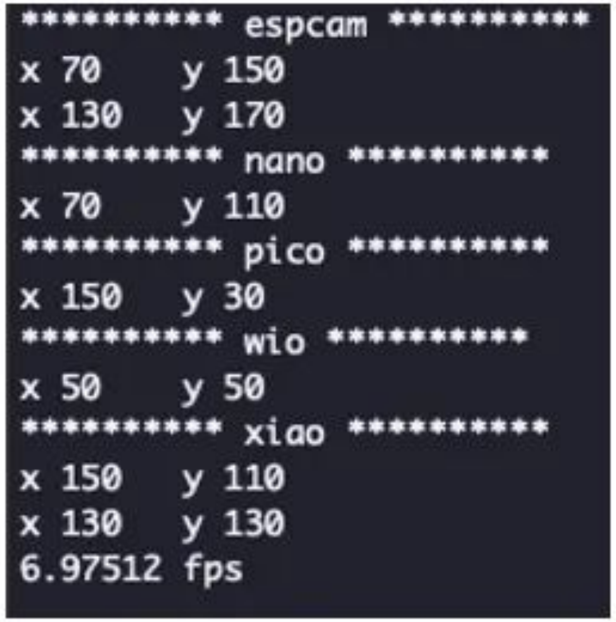
https://www.hackster.io/Yukio/coffee-disease-classification-with-ml-b0a3fc

João Vitor Yukio Bordin Yamashita
Graduando em Engenharia Eletrônica pela UNIFEI

Detecting Objects using TinyML (FOMO)







[EdgeAI made simple - Exploring Image Processing (Object Detection) on microcontrollers with Arduino Portenta, Edge Impulse FOMO, and OpenMV]

Other TinyML / MCUs Project Examples

Vision

- Image Classification with ESP32-CAM [Doc]
- Image Classification with Portenta H7 [Doc]

Sound

- Listening Temperature with Nano 33 [Doc]

Vibration

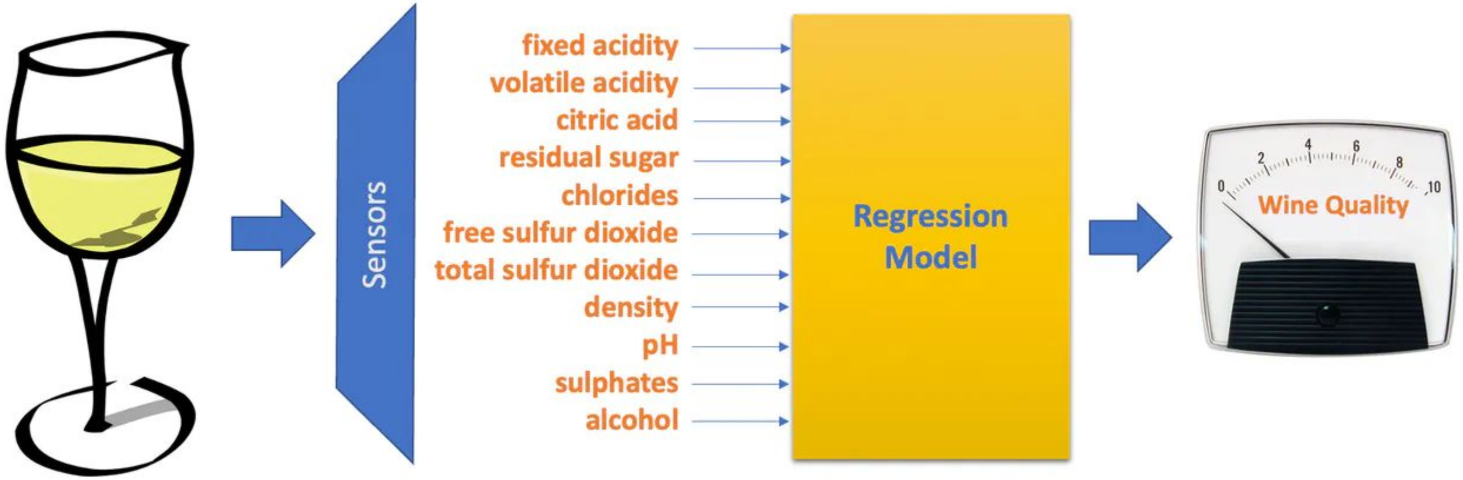
- Motion Recognition with RPi Pico [Doc]
- Gesture Recognition with Wio Terminal [Doc]

TinyML Application

Examples (Regression)

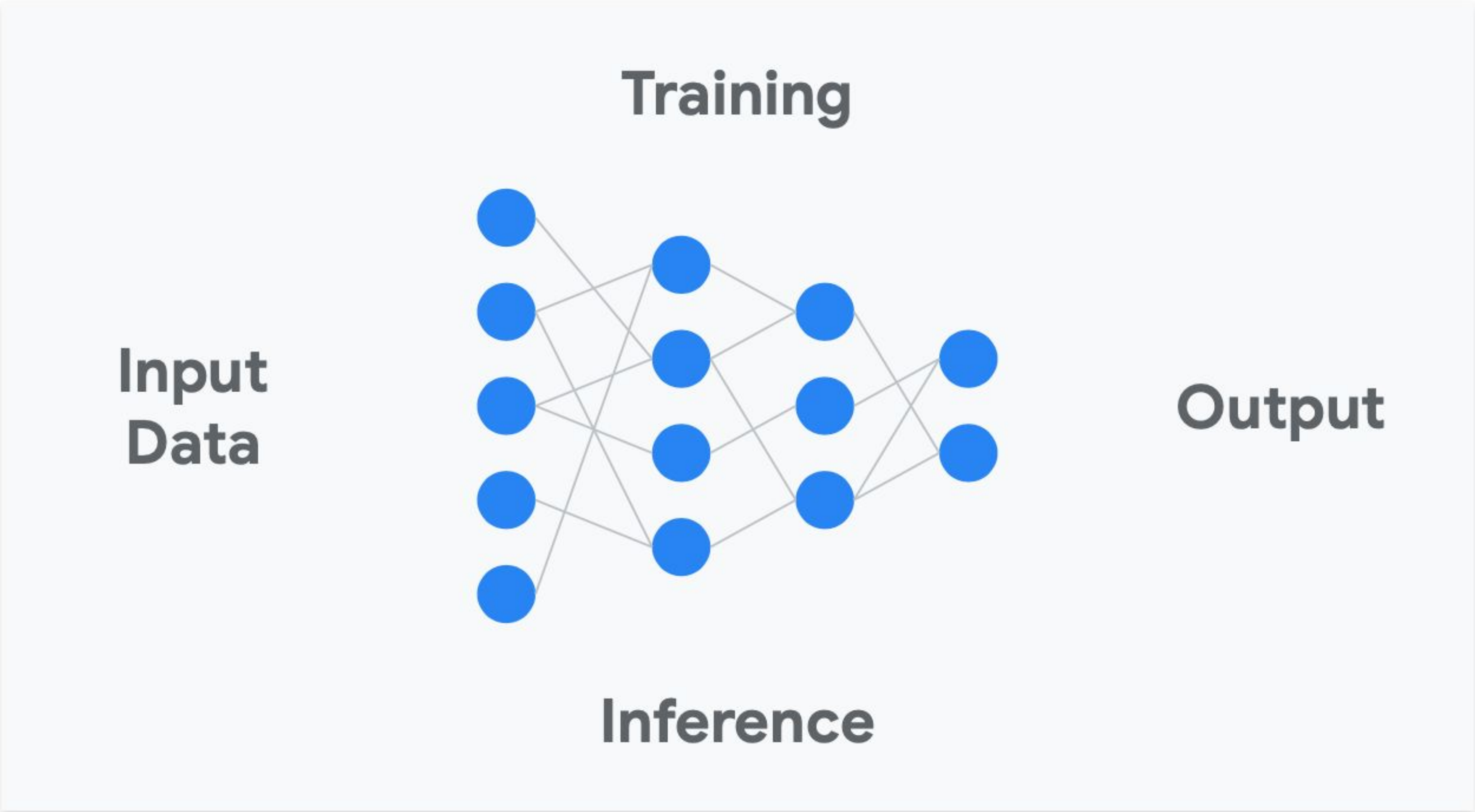
Regression on TinyML

Estimate Weight From a Photo Using Visual Regression in Edge Impulse



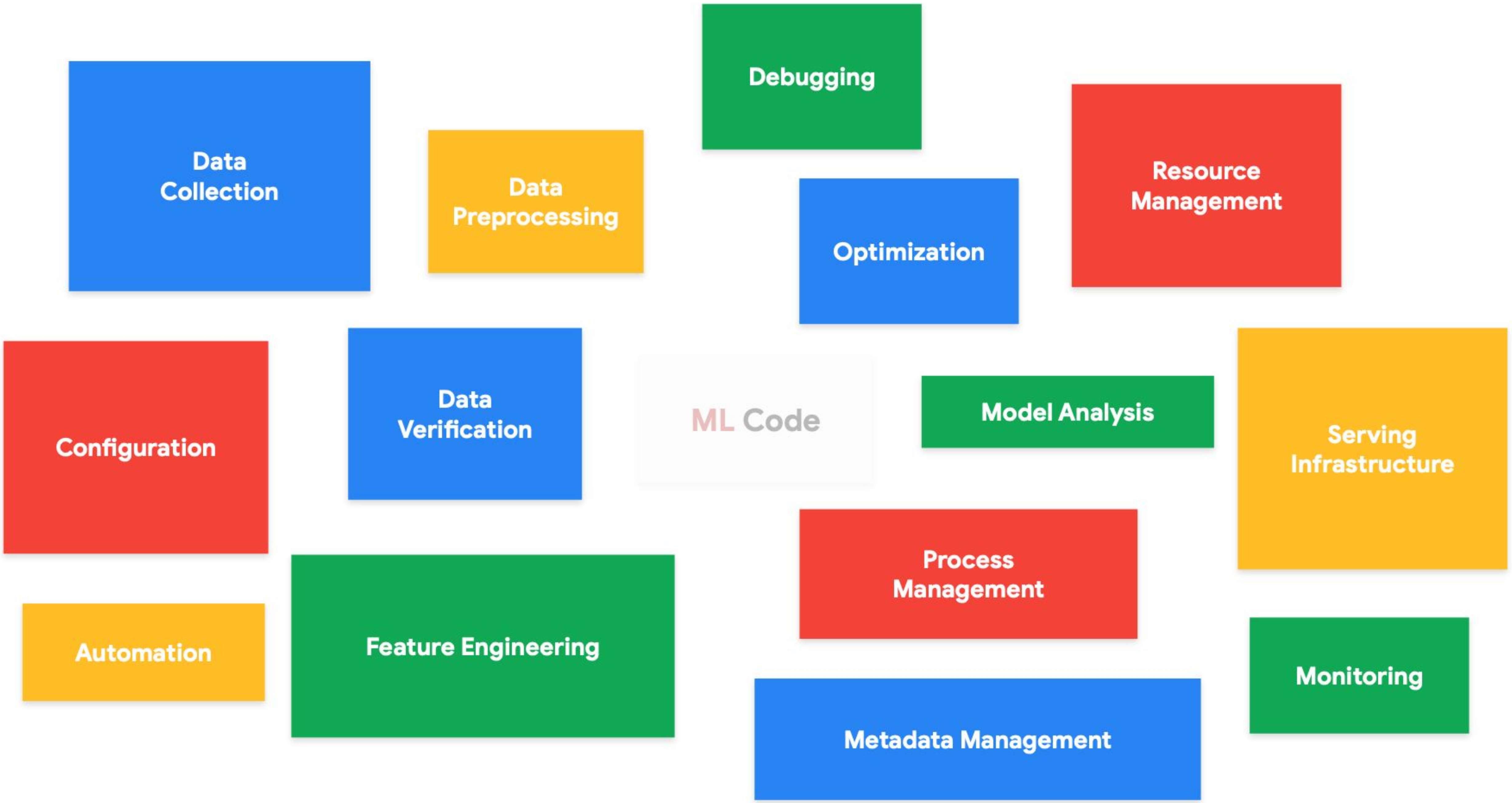
TinyML Made Easy: Exploring Regression - White Wine Quality

ML Lifecycle


Training
Input
Data
Output
Inference


Training
Input
Data
Output
Inference

ML Code


Data Collection
Data Preprocessing
Debugging
Resource Management
Optimization
Configuration
Data Verification
ML Code
Model Analysis
Serving Infrastructure
Process Management
Automation
Feature Engineering
Monitoring
Metadata Management


AI Infrastructure
Data Engineering
Model Engineering
Model Deployment
Product Analytics

Data Engineering

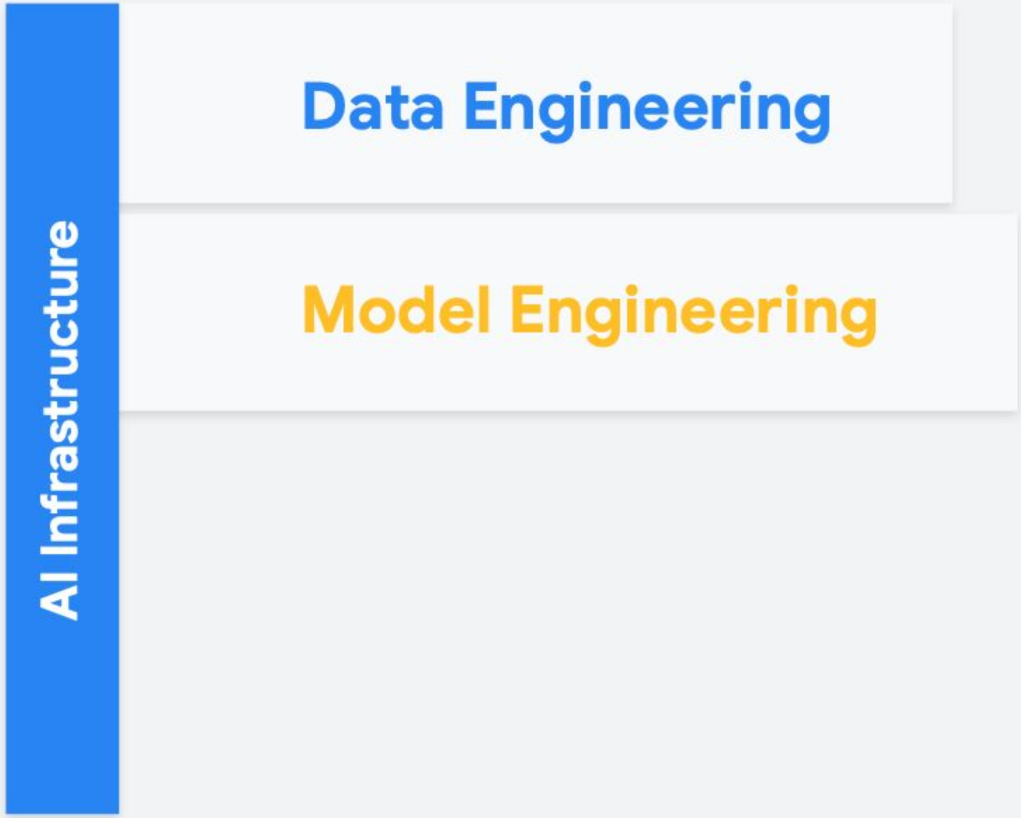
- Defining data **requirements**
- **Collecting** data
- **Labelling** the data
- Inspect and **clean** the data
- Prepare data for **training**
- **Augment** the data
- Add **more data**

Data Engineering

- Defining data **requirements**
- **Collecting** data
- **Labelling** the data
- Inspect and **clean** the data
- Prepare data for **training**
- **Augment** the data
- **Add more data**

Model Engineering

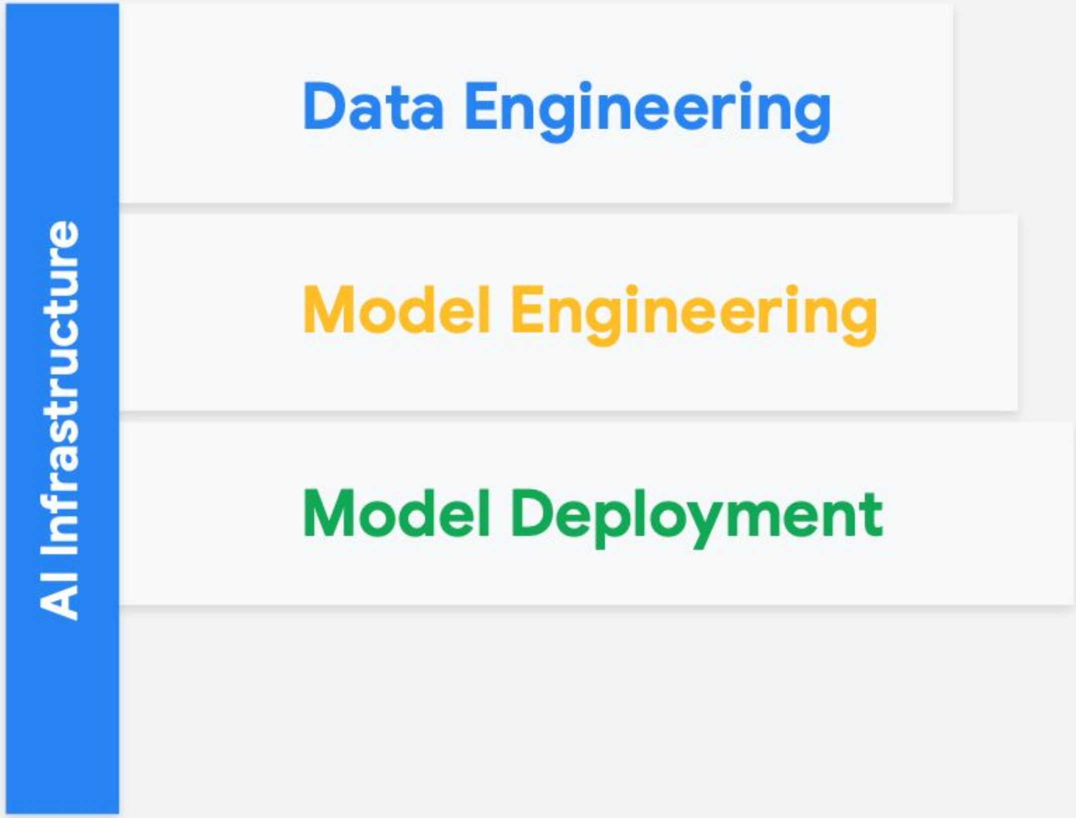
- **Training** ML models
- Improving training **speed**
- Setting **target** metrics
- **Evaluating** against metrics
- **Optimizing** model training
- Keeping up with **SOTA***



* “State of the Art”

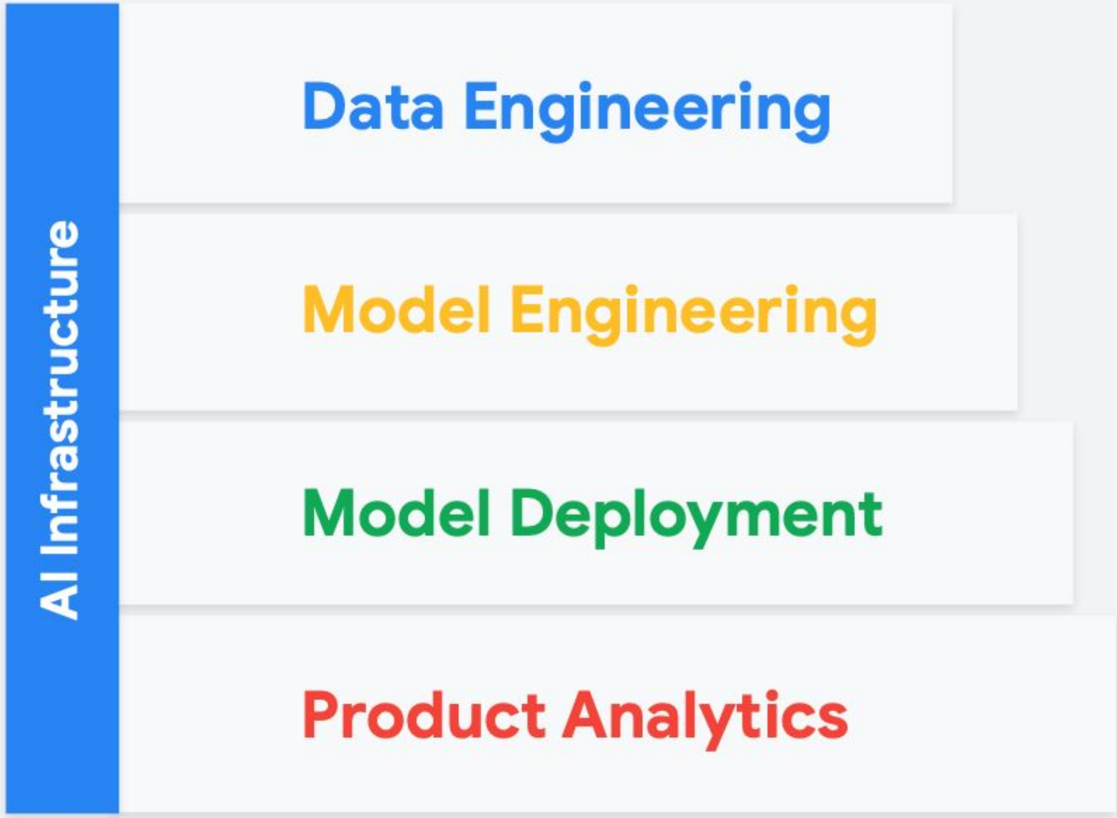
Model Deployment

- Model **conversion**
- **Performance** optimization
- **Energy-aware** optimizations
- **Security** and **privacy**
- **Inference** serving APIs
- **On-device** fine-tuning



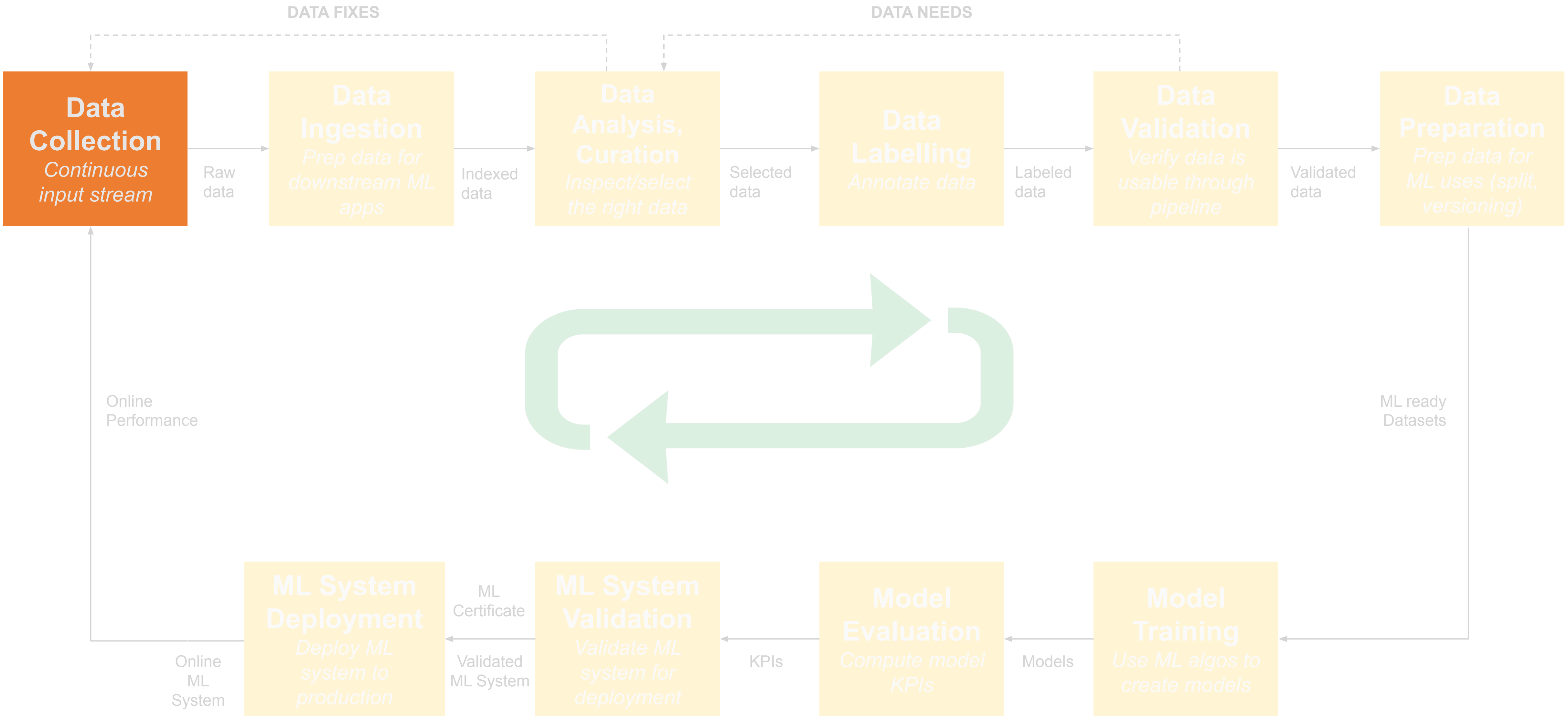
Product Analysis

- **Dashboards**
- Field data **evaluation**
- **Value-added** for business
- Opportunities for **advancement** and **improvements**

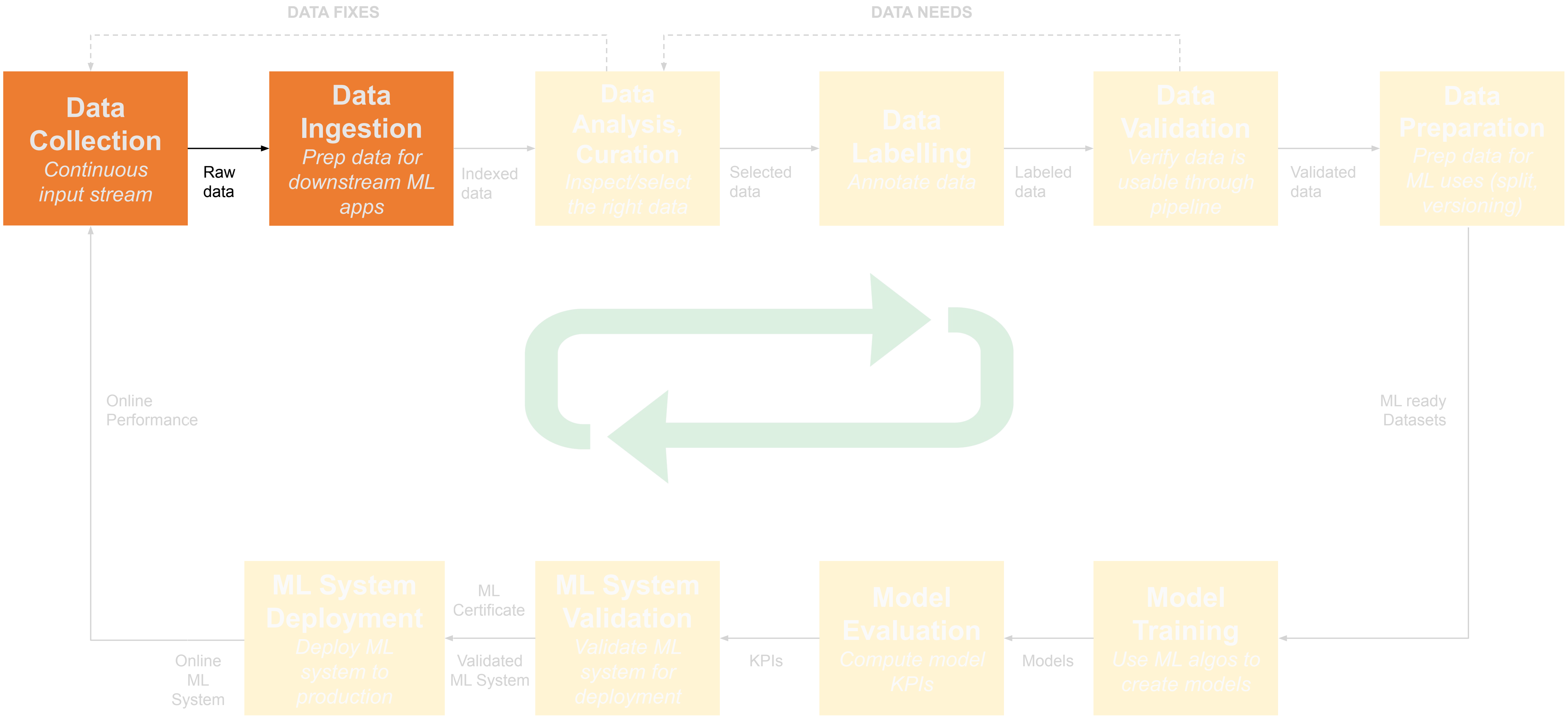


Focus in TinyML

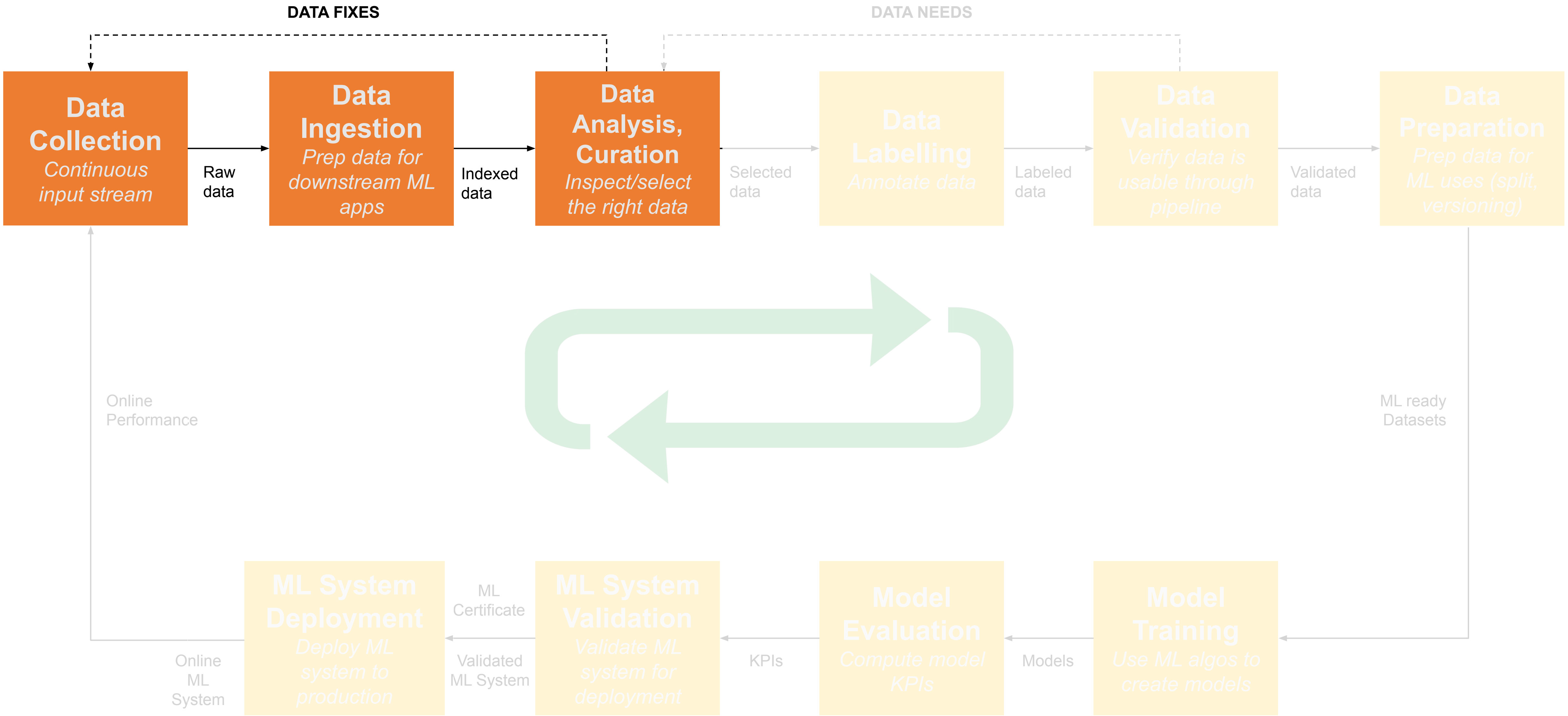
Life cycle of ML



Life cycle of ML



Life cycle of ML



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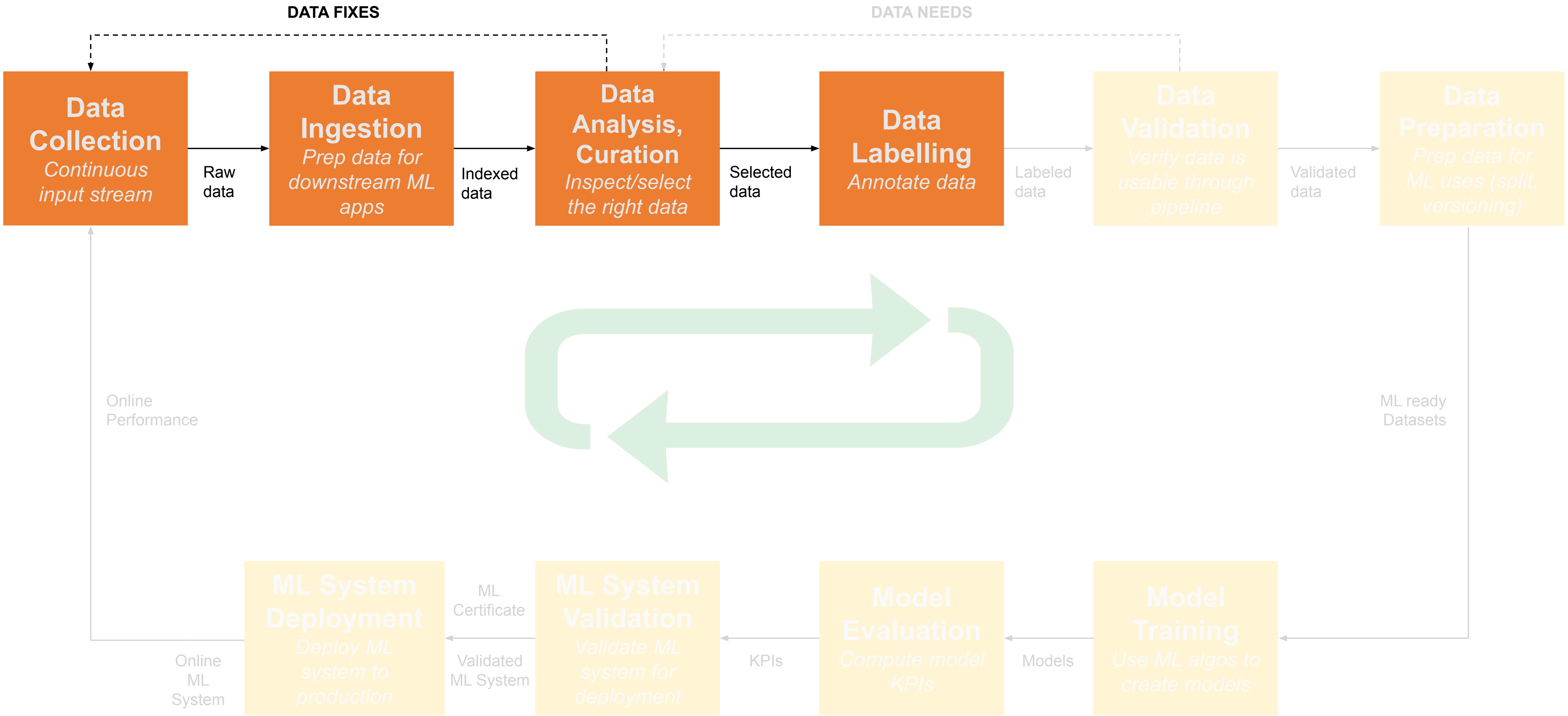
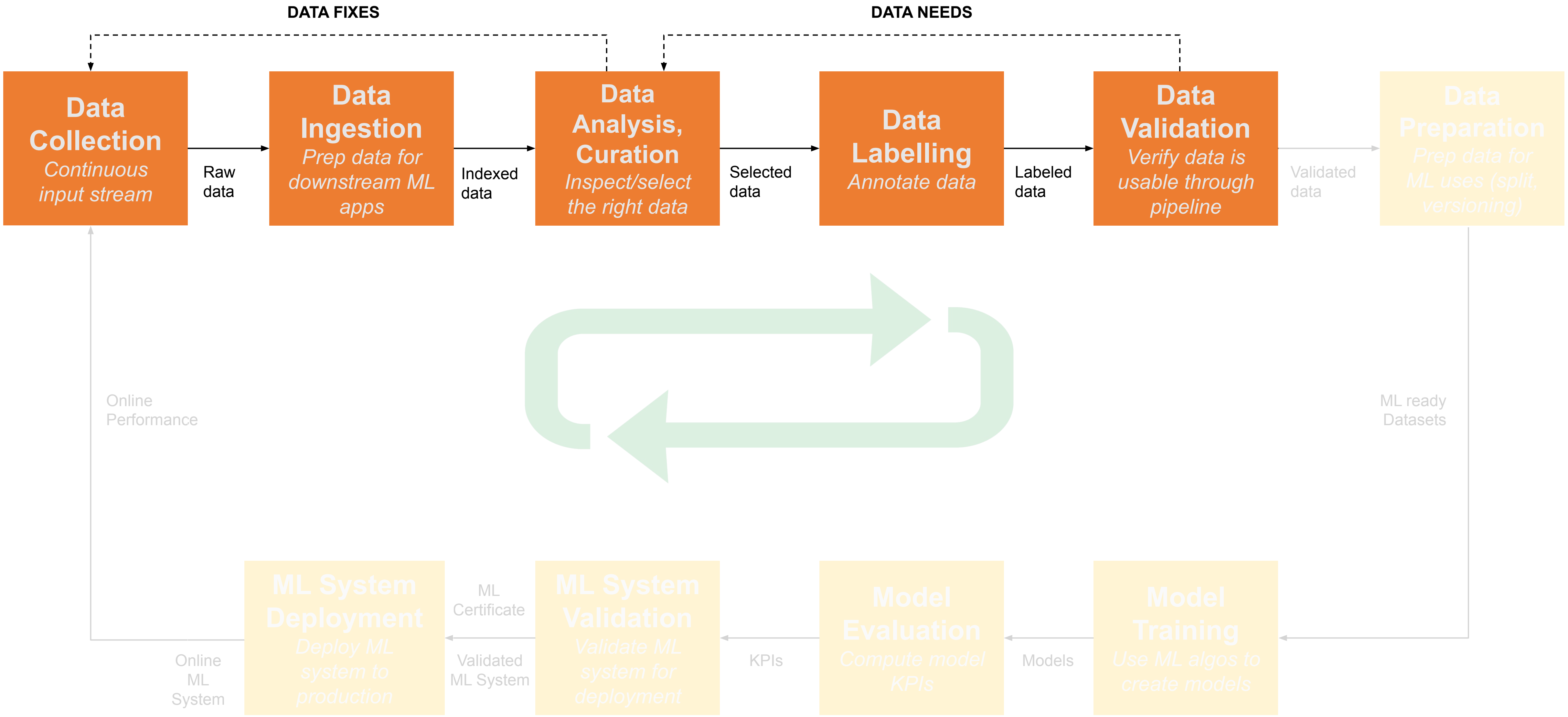


Life cycle of ML



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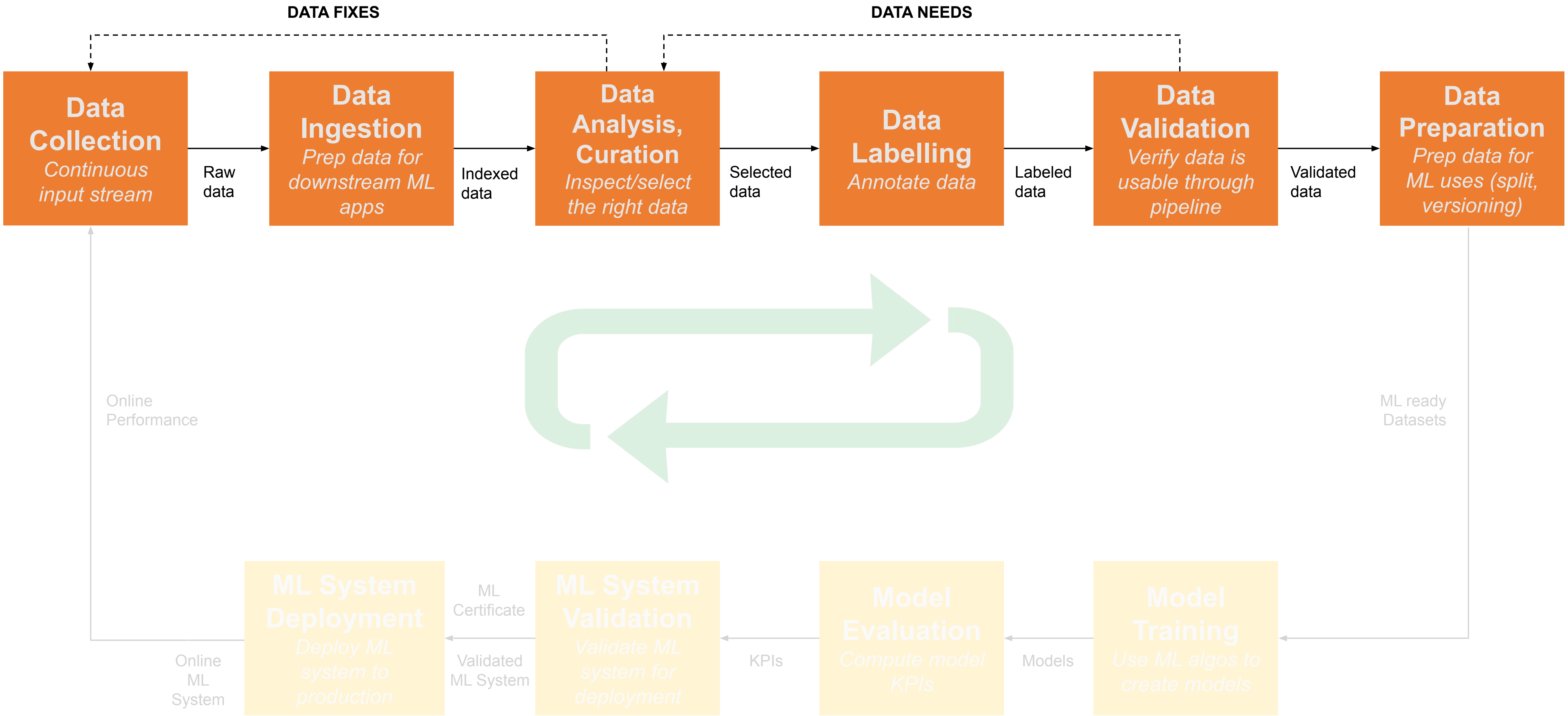
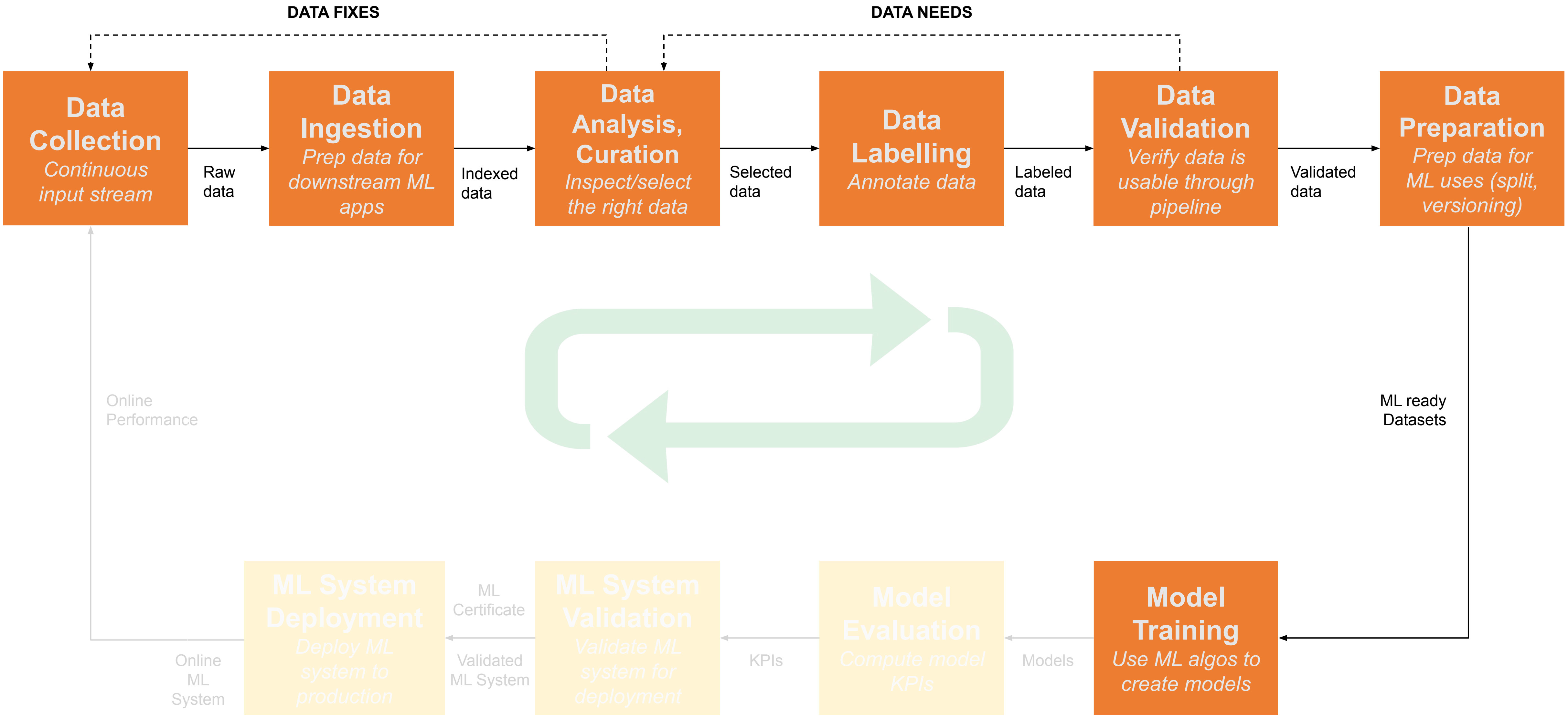
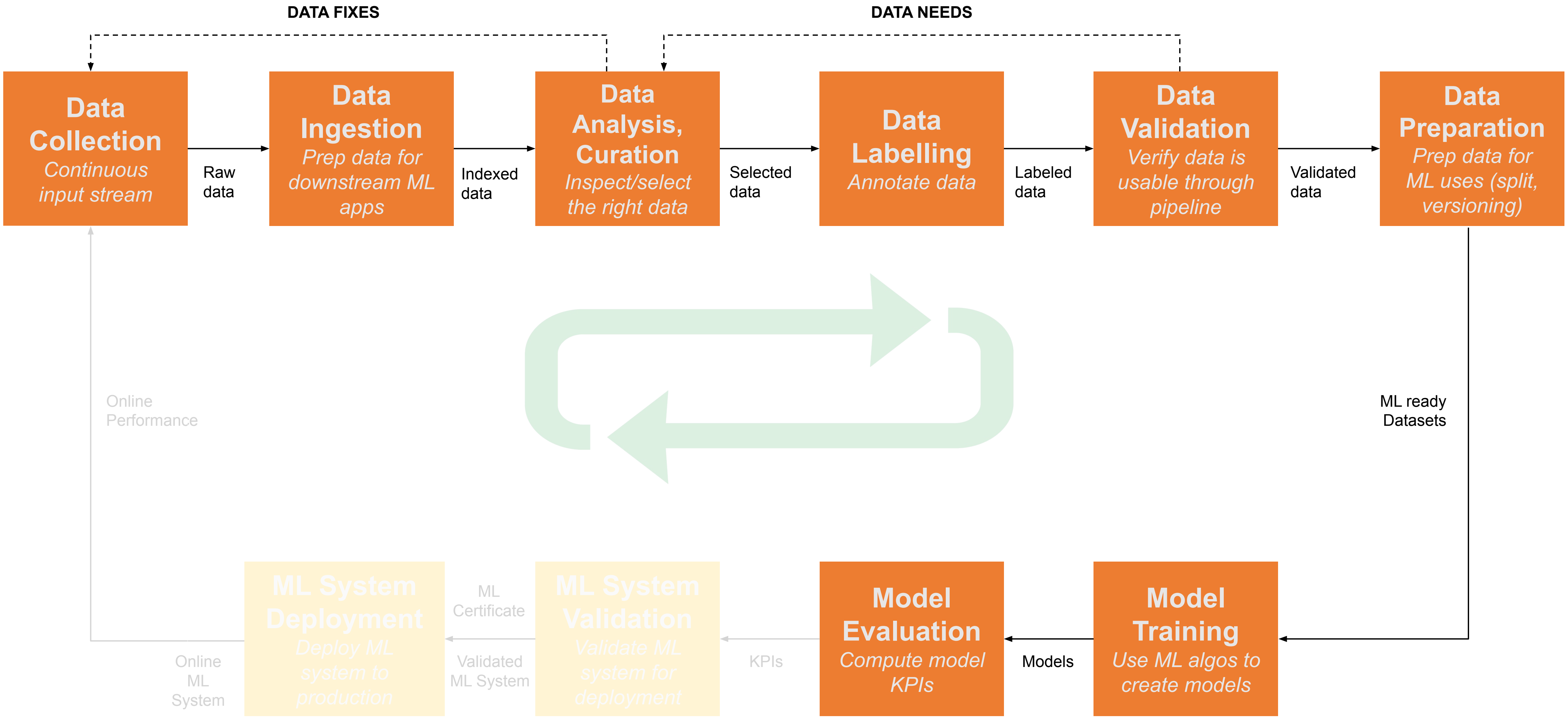


Life cycle of ML



Life cycle of ML



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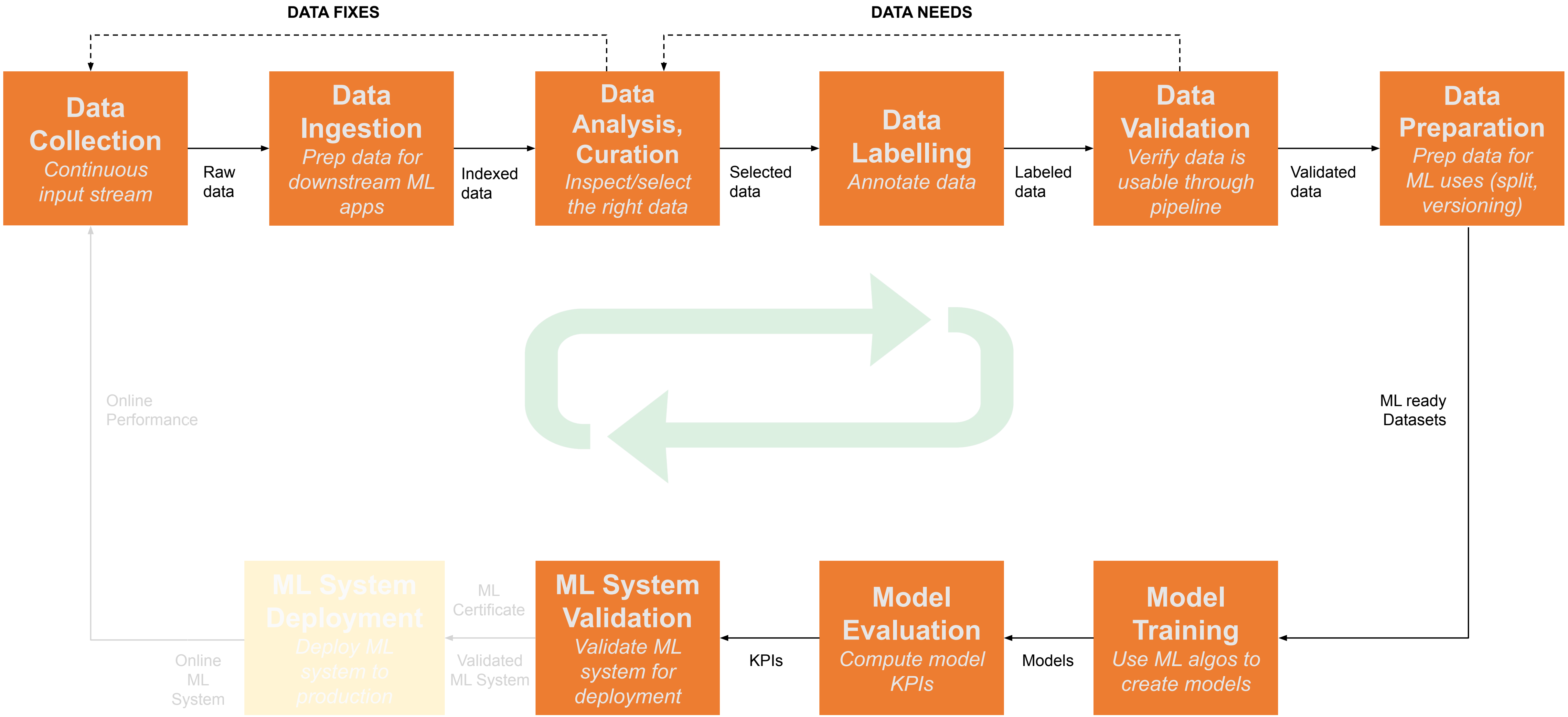

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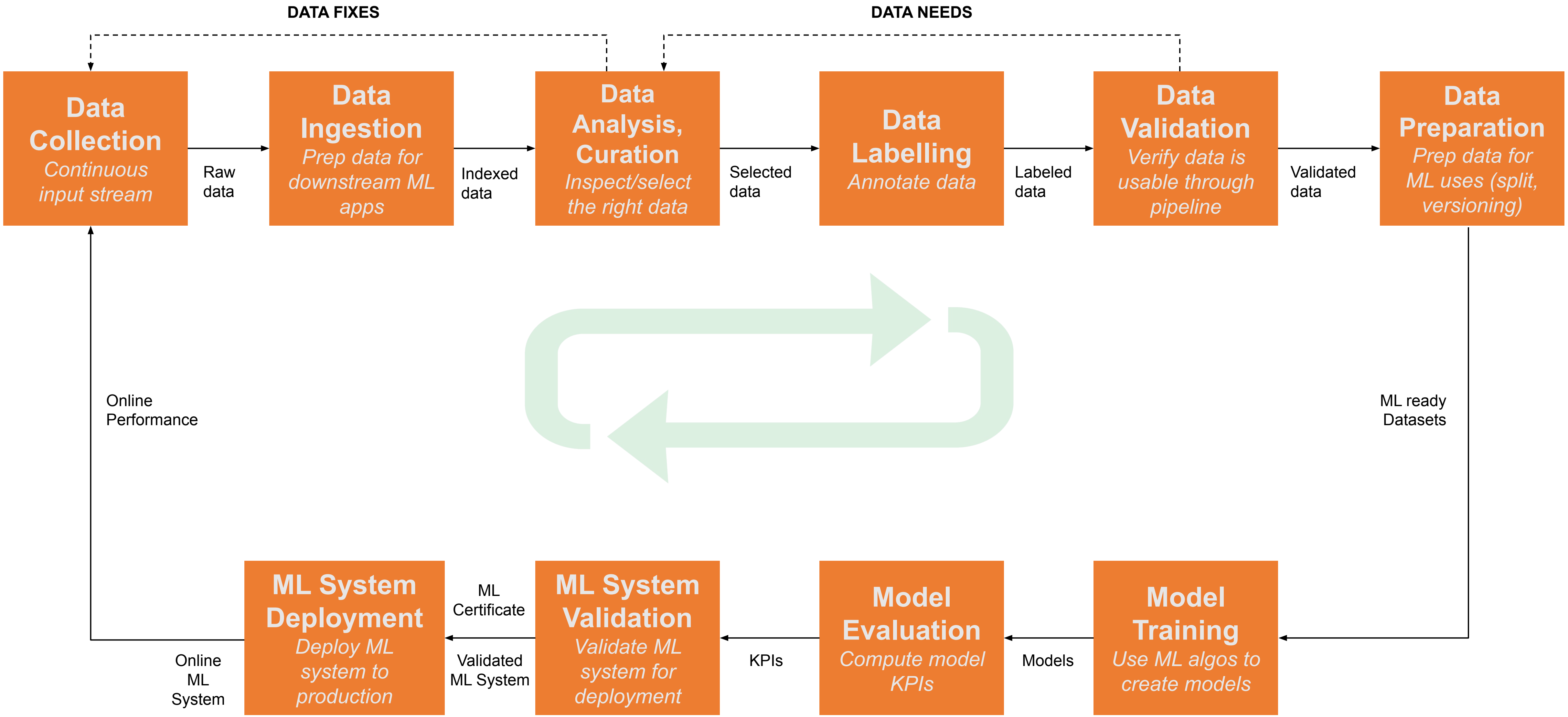

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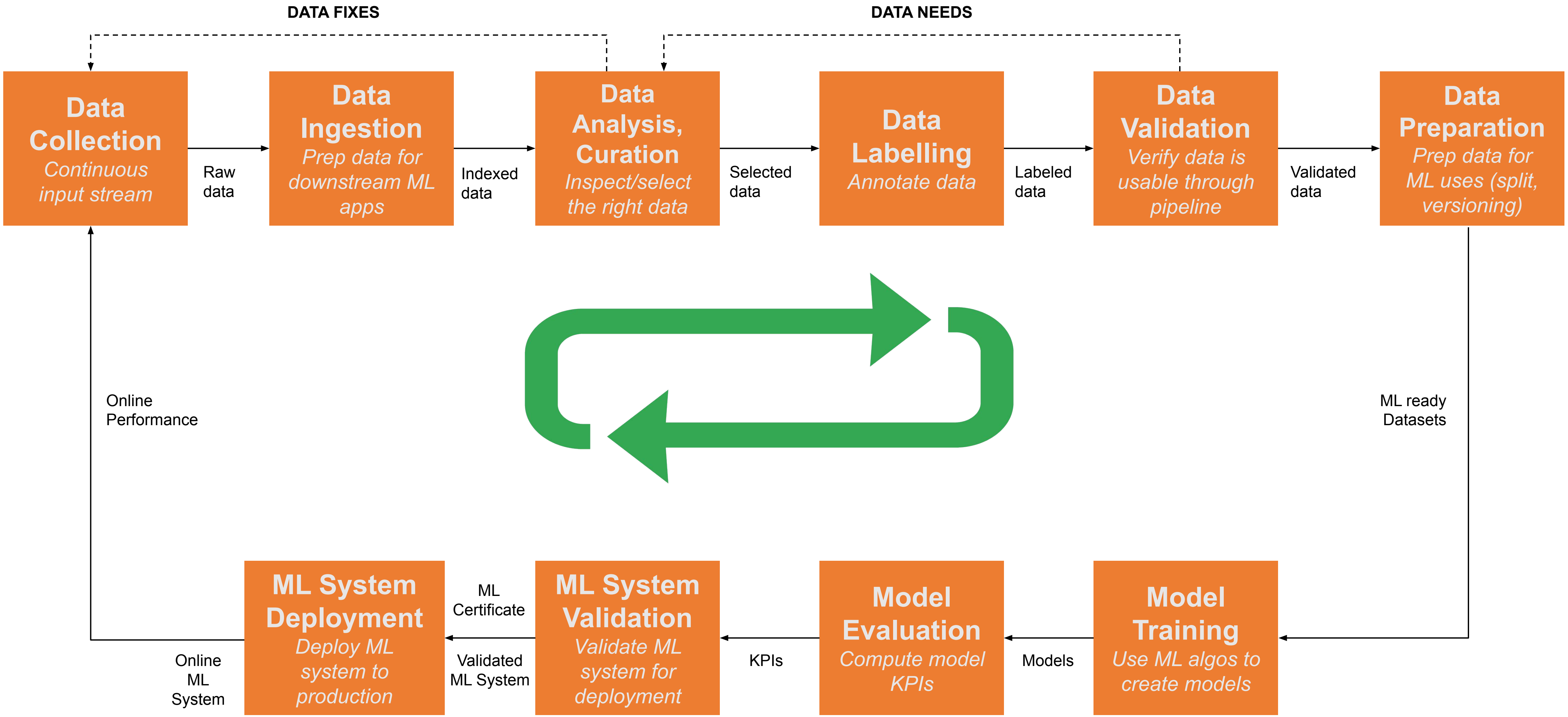


ML Workflow

AI Infrastructure
Data Engineering
Model Engineering
Model Deployment
Product Analytics

Acoustic Sensors
Ultrasonic, **Microphones**, Geophones, Vibrometers

Image Sensors
Thermal, **Image**

Motion Sensors
Gyroscope, Radar, **Accelerometer**

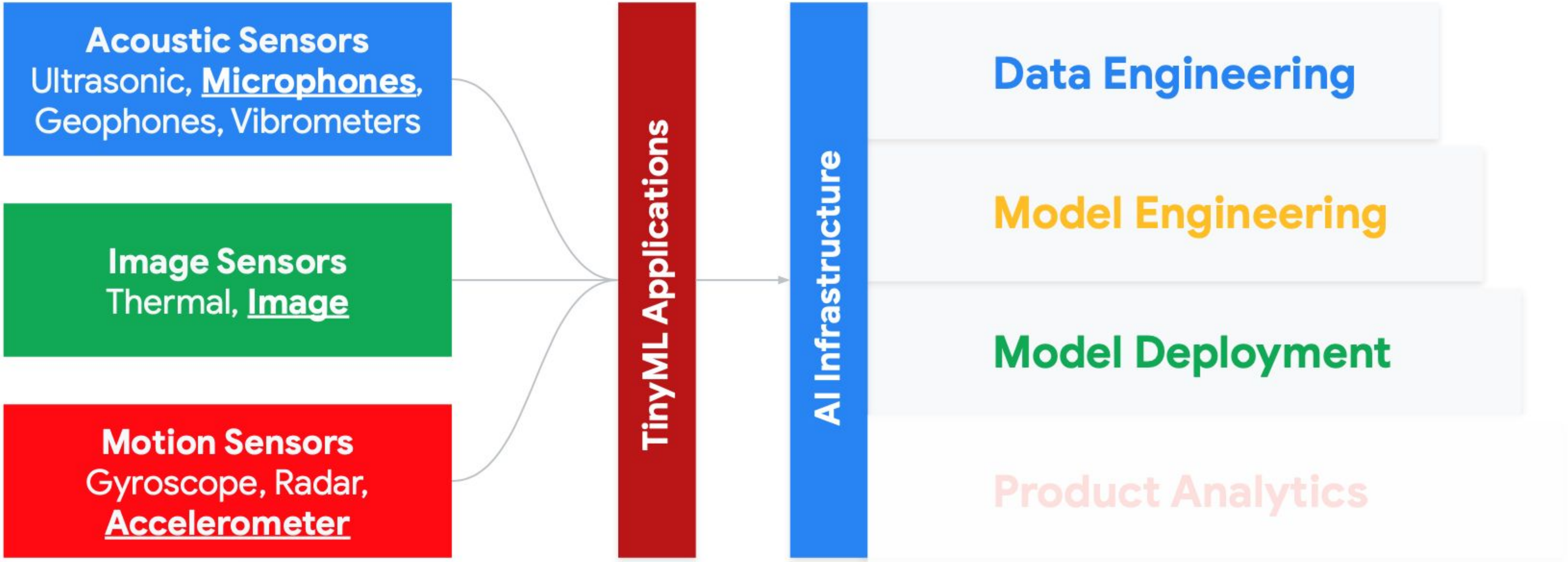
AI Infrastructure

Data Engineering

Model Engineering

Model Deployment

Product Analytics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Ultrasonic, Microphones, Geophones, Vibrometers
Image Sensors
Thermal, Image
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TinyML Applications
AI Infrastructure
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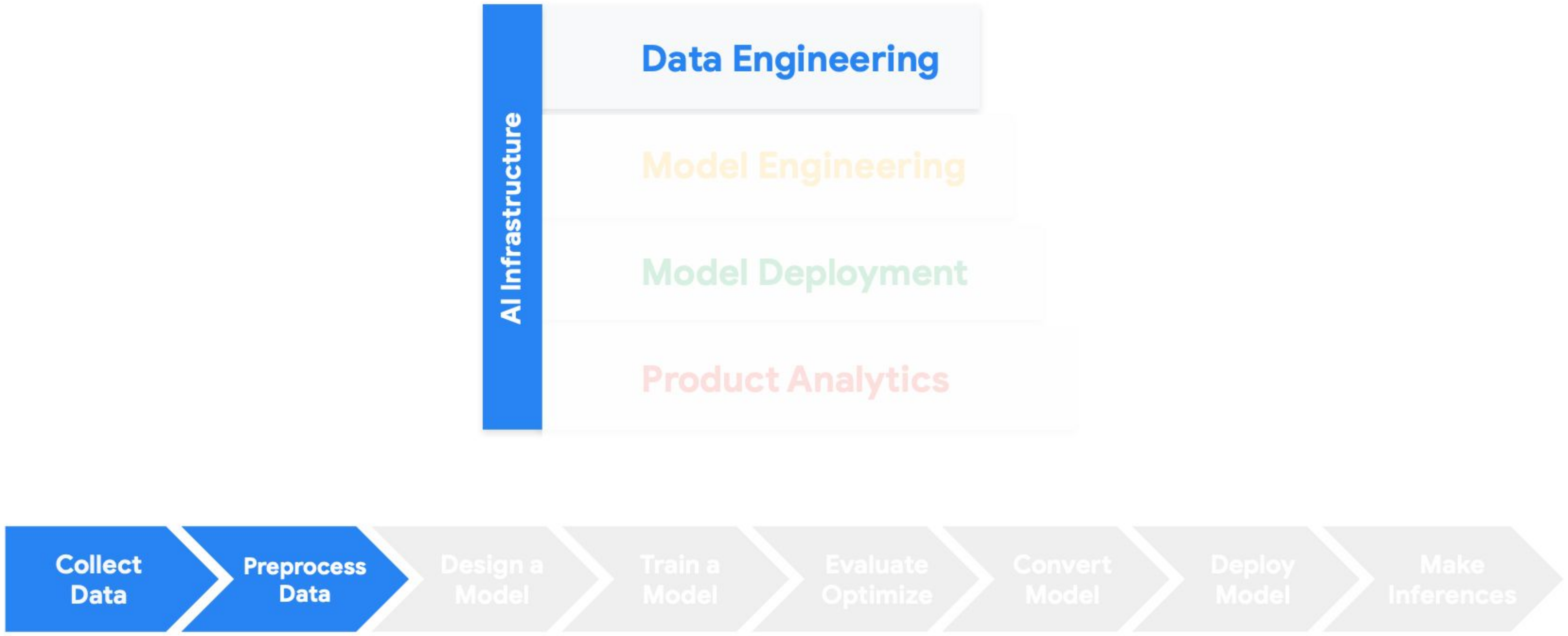
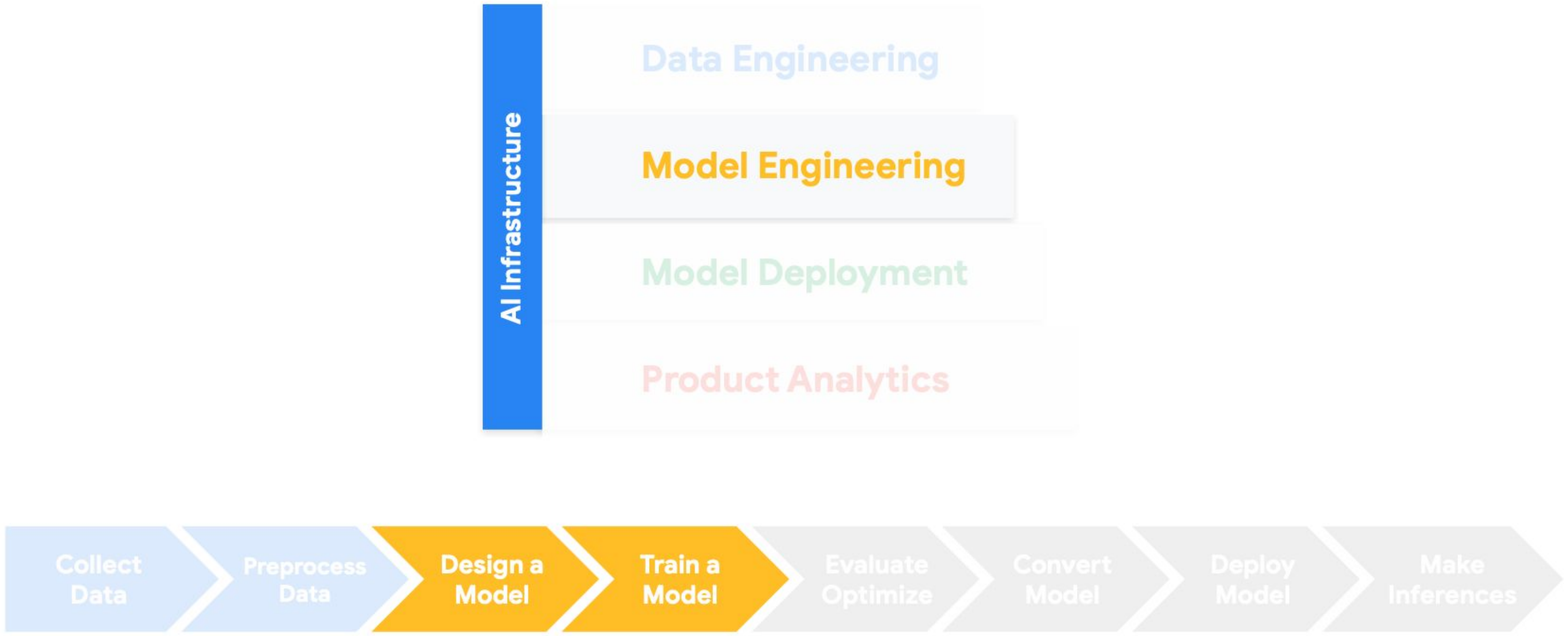

AI Infrastructure
Data Engineering
Model Engineering
Model Deployment
Product Analytics
Collect Data
Preprocess Data
Design a Model
Train a Model
Evaluate Optimize
Convert Model
Deploy Model
Make Inferences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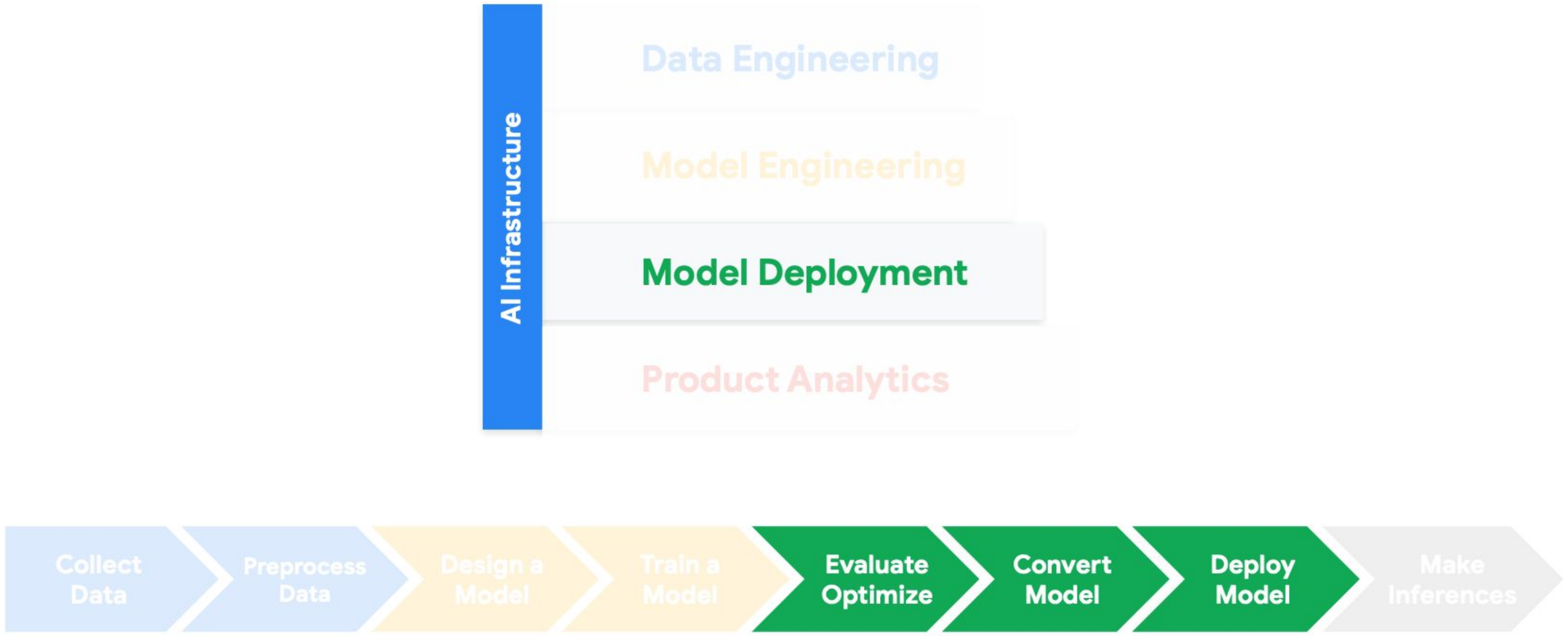
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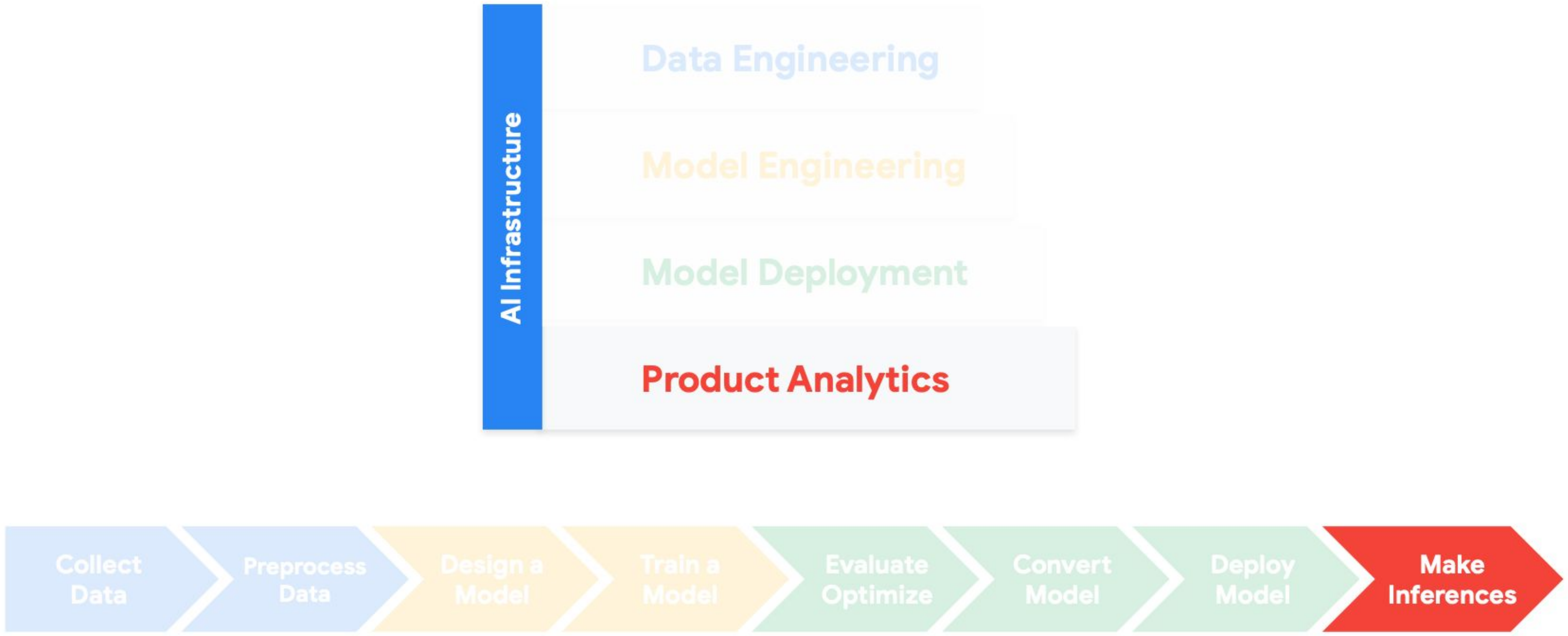
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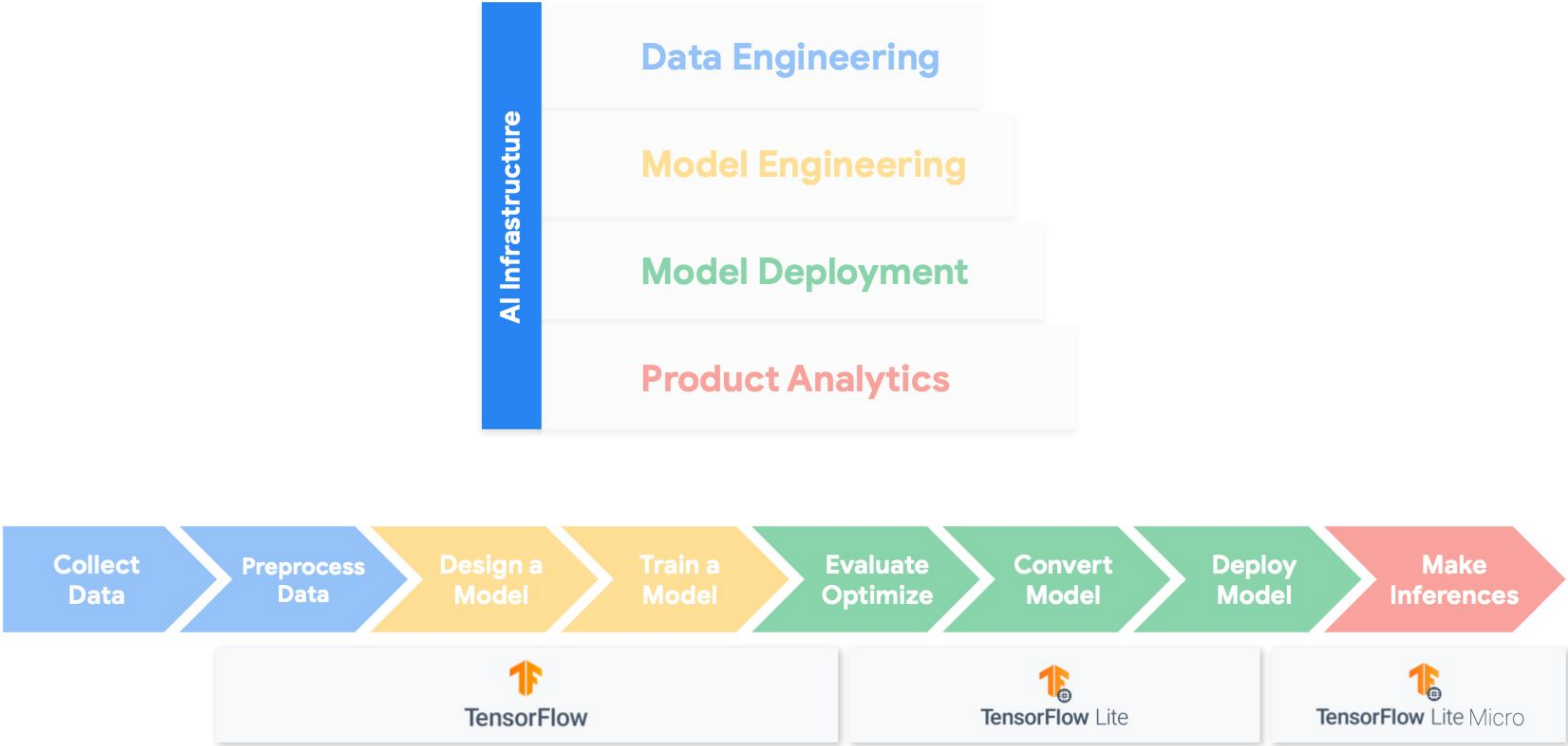
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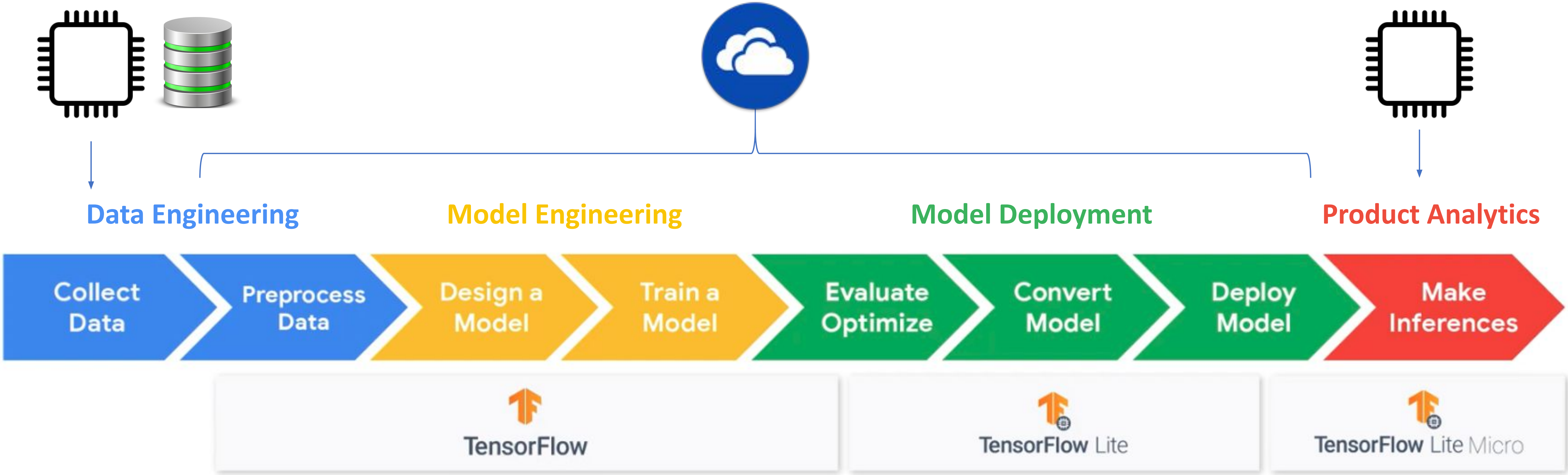
TensorFlow
TensorFlow Lite
TensorFlow Lite Micro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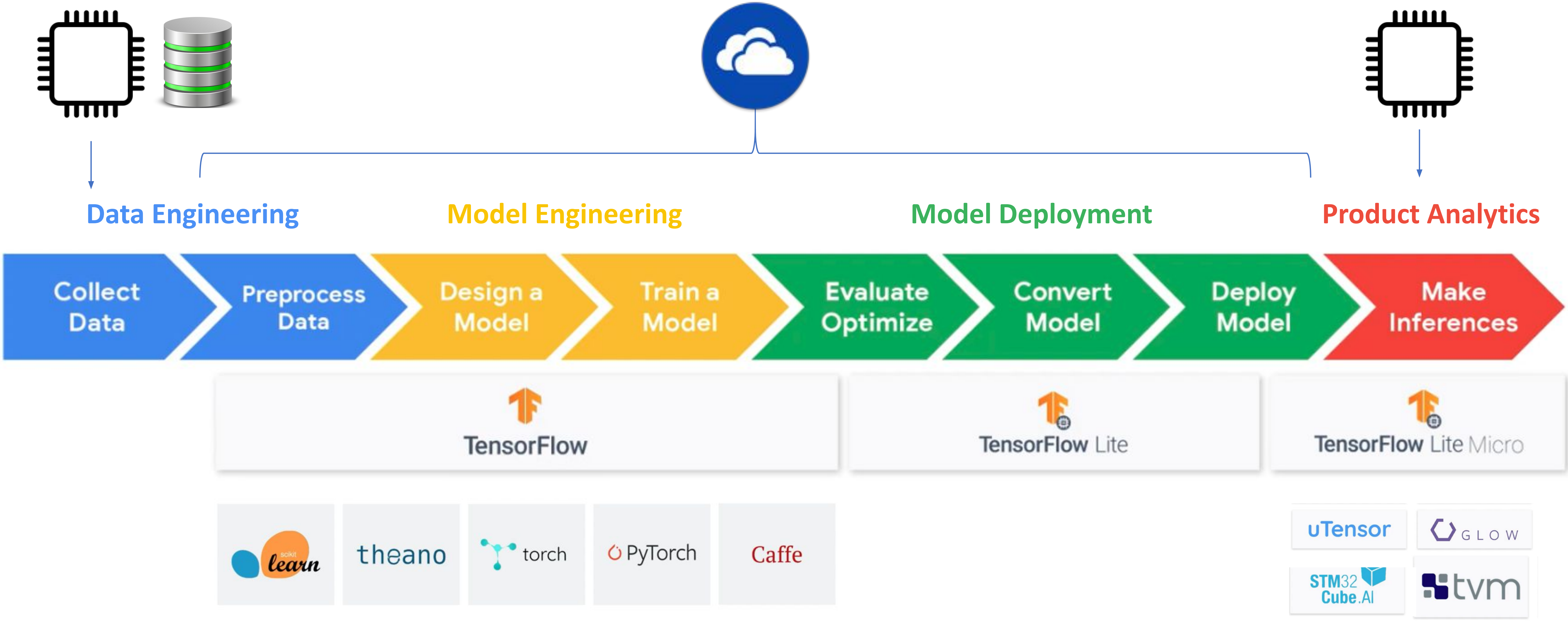
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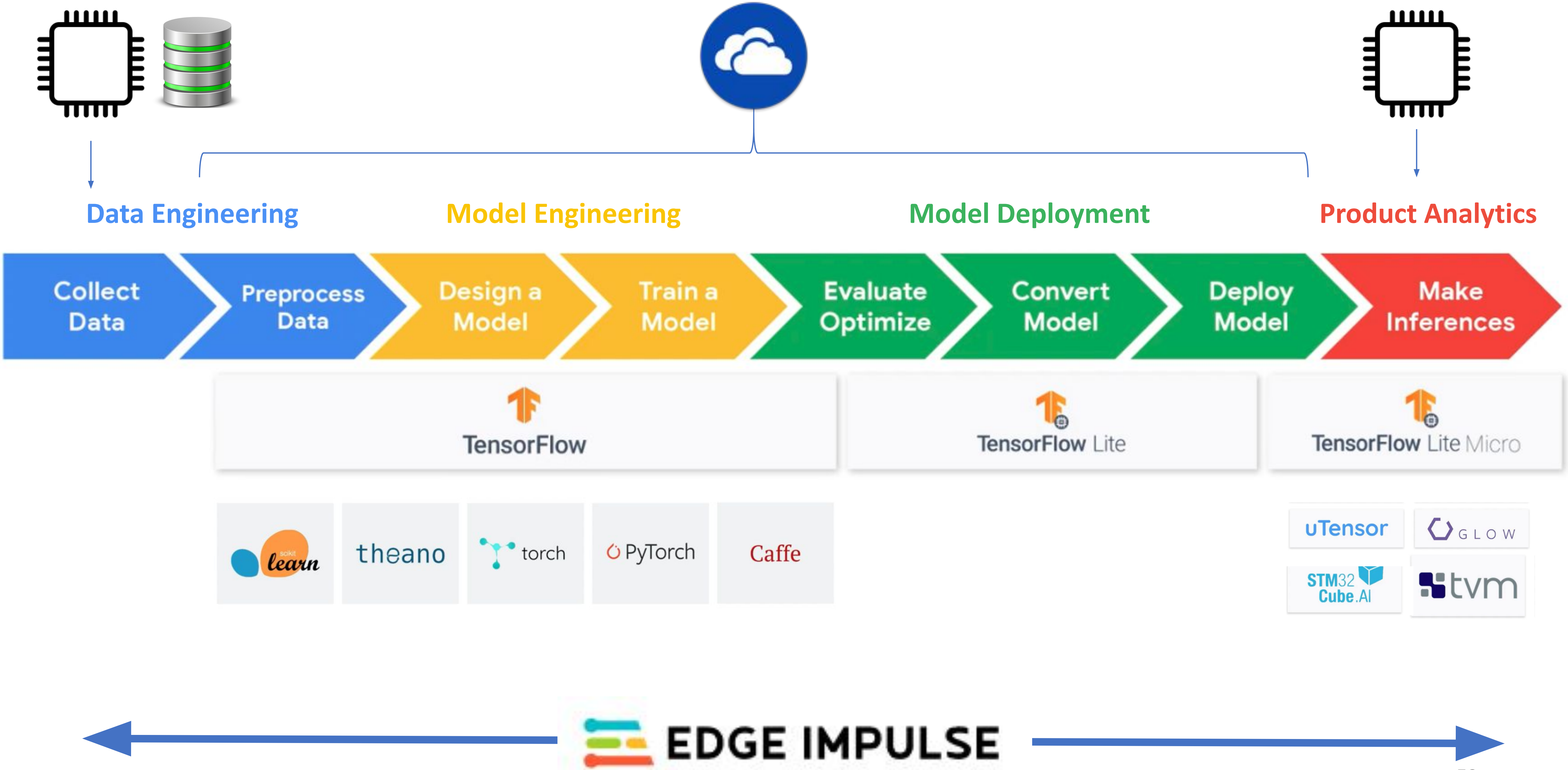
Make Inferences
TensorFlow
TensorFlow Lite
TensorFlow Lite Micro
learn
theano
torch
PyTorch
Caffe
uTensor
GLOW
STM32 Cube.AI
tvm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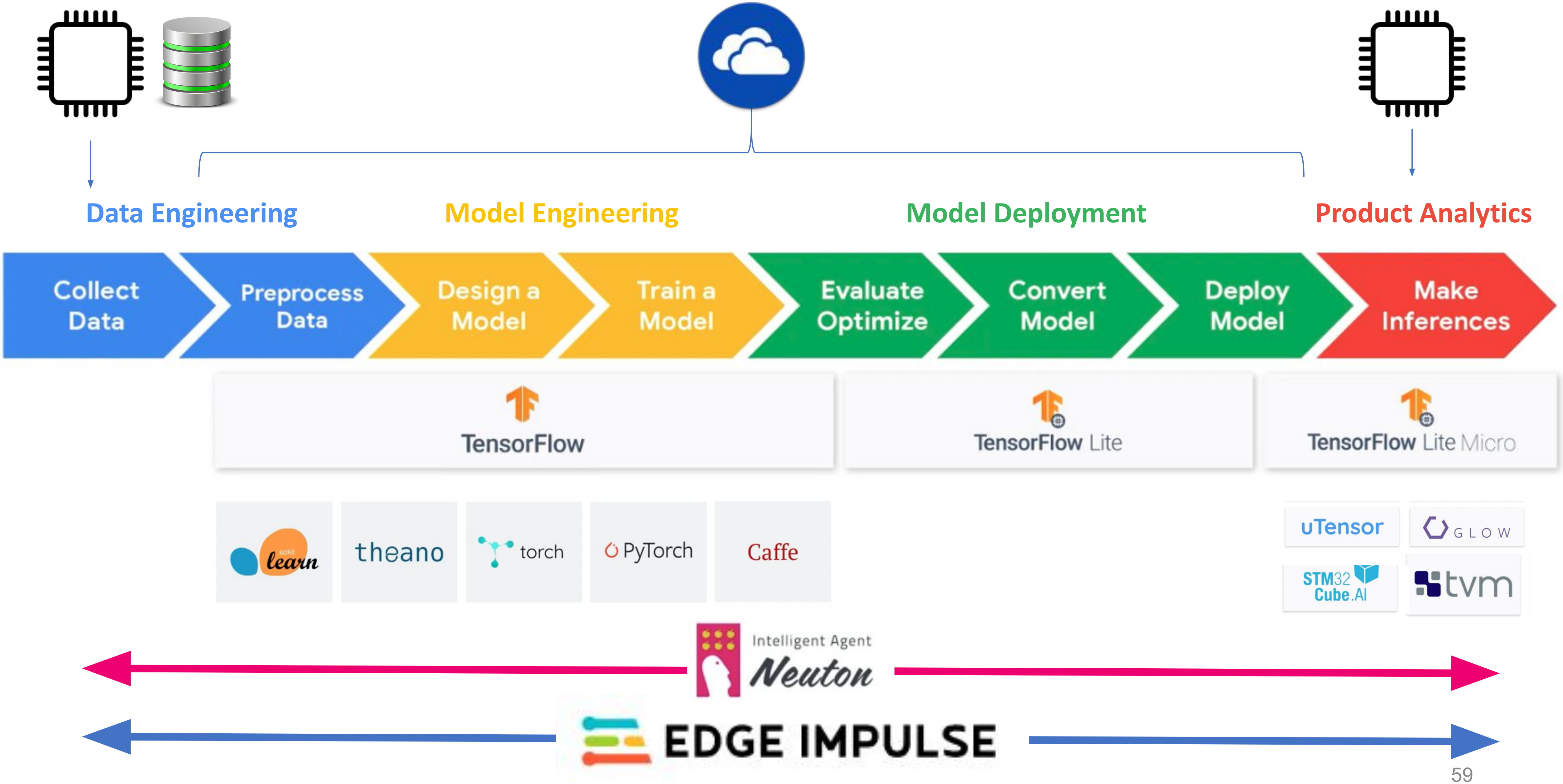
TensorFlow Lite
TensorFlow Lite Micro
scikit learn
theano
torch
PyTorch
Caffe
uTensor
GLOW
STM32 Cube.AI
tvm
EDGE IMPULSE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learn
theano
torch
PyTorch
Caffe
uTensor
GLOW
STM32 Cube.AI
tvm
Intelligent Agent
Neuton
EDGE IMPULSE

Reading Material

Main references

- Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- Fundamentals textbook: "Deep Learning with Python" by François Chollet
- Applications & Deploy textbook: "TinyML" by Pete Warden, Daniel Situnayake
- Deploy textbook "TinyML Cookbook" by Gian Marco Iodice

I want to thank Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google, Professor Vijay Janapa Reddi and Brian Plancher from Harvard, and the rest of the TinyMLedu team for preparing the excellent material on TinyML that is the basis of this course at UNIFEI.

The IESTI01 course is part of the **TinyML4D**, an initiative to make TinyML education available to everyone globally.

Thanks

UNIFEI