

# IESTI01 – TinyML

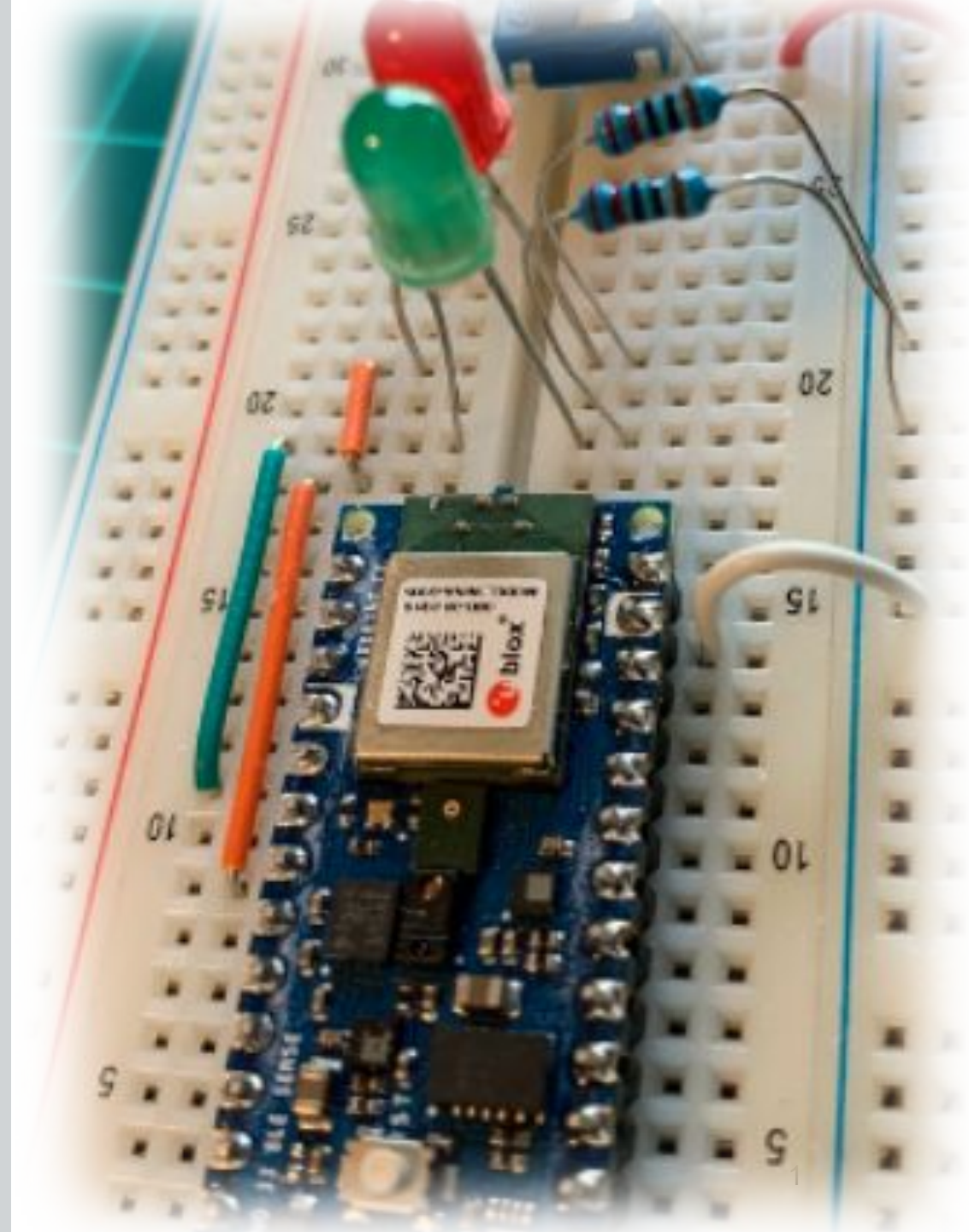
## Embedded Machine Learning

### 15. ML Applications Overview AI Lifecycle and ML Workflow



Prof. Marcelo Rovai

UNIFEI



# TinyML Applications

Examples

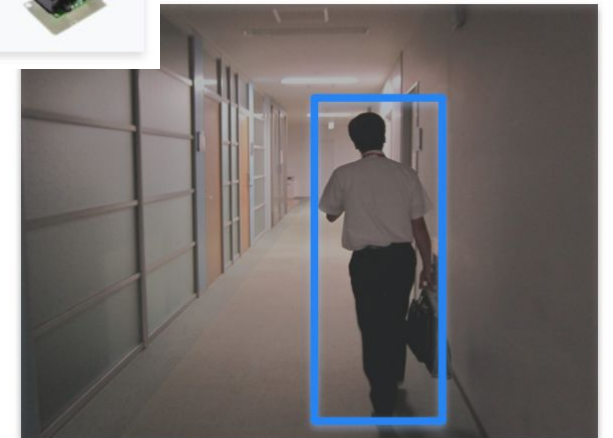
# Sound



# Vibration



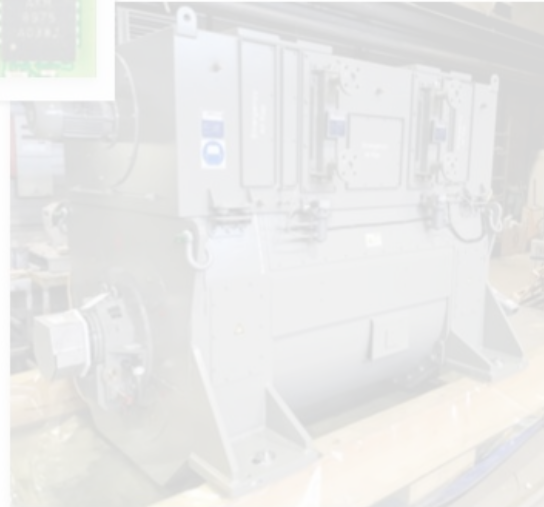
# Vision



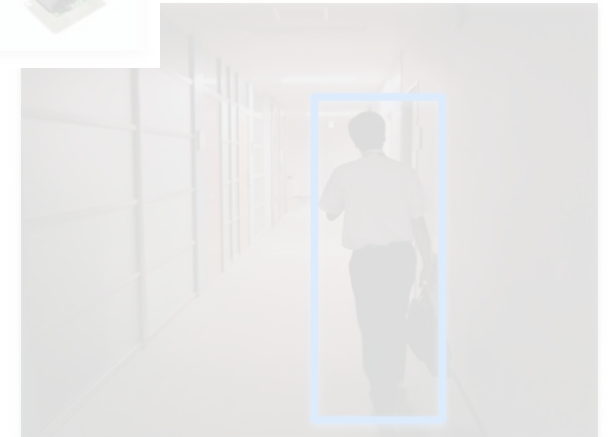
# Sound



# Vibration



# Vision

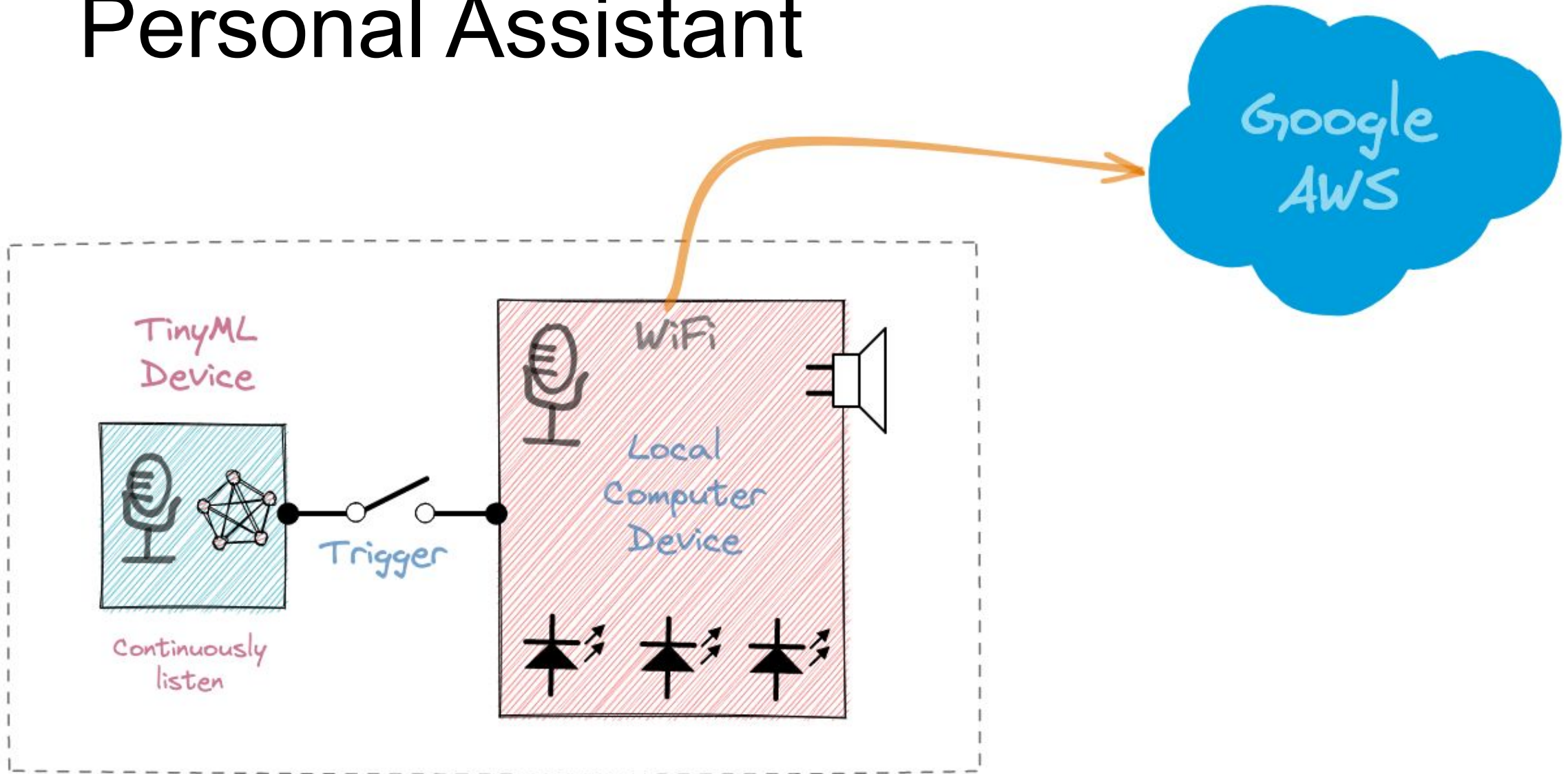


# Personal Assistant

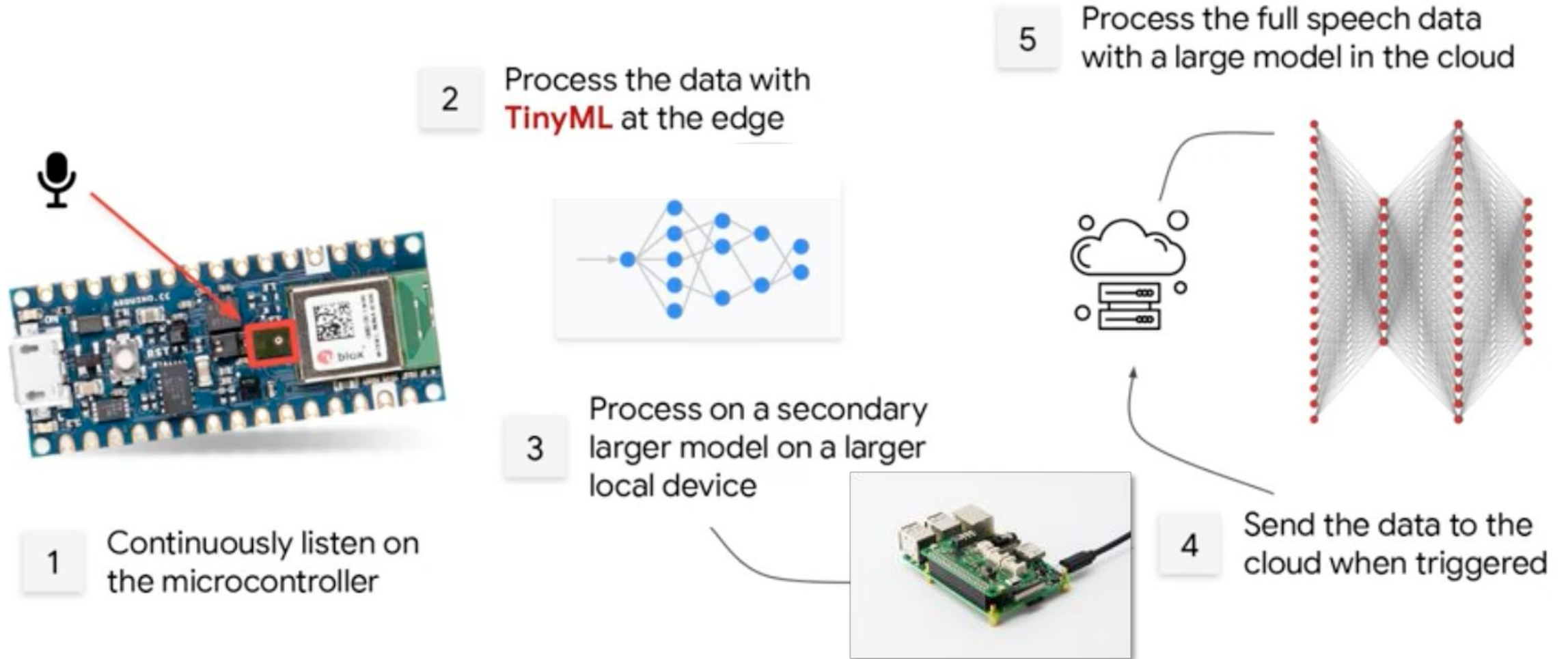




# Personal Assistant

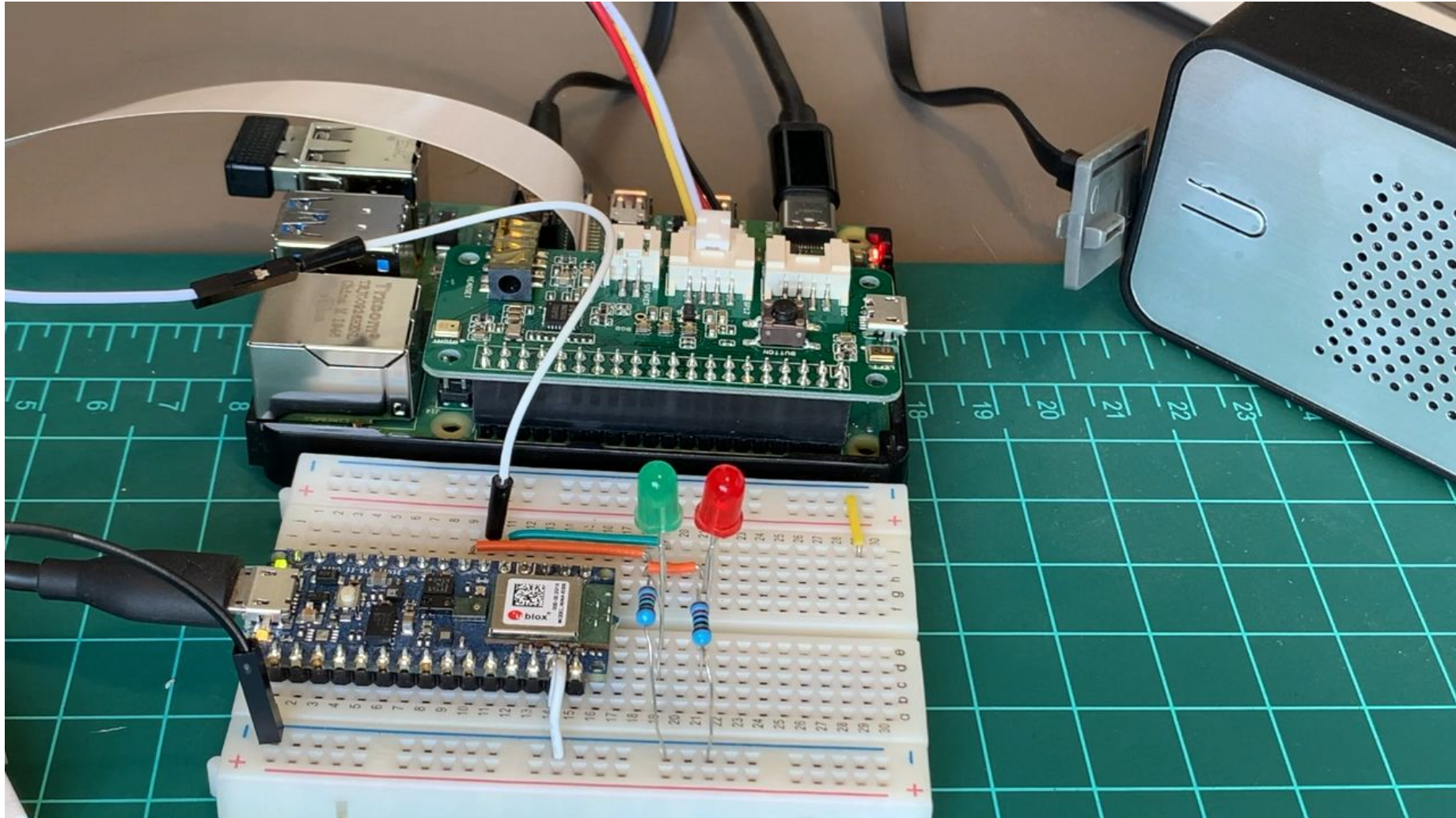


# “Cascade” Detection: multi-stage model





# KeyWord Spotting (KWS)

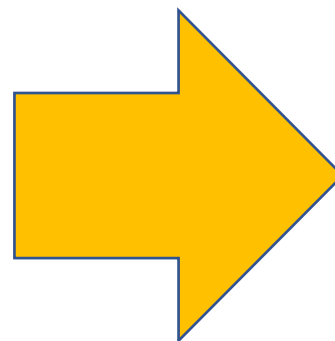


<https://mrobot.org/2021/01/27/building-an-intelligent-voice-assistant-from-scratch/>





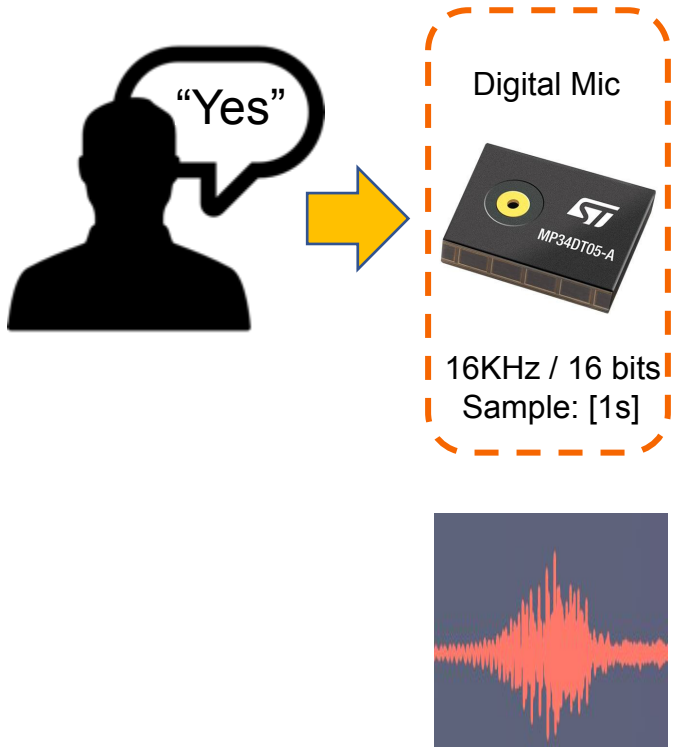
Sound



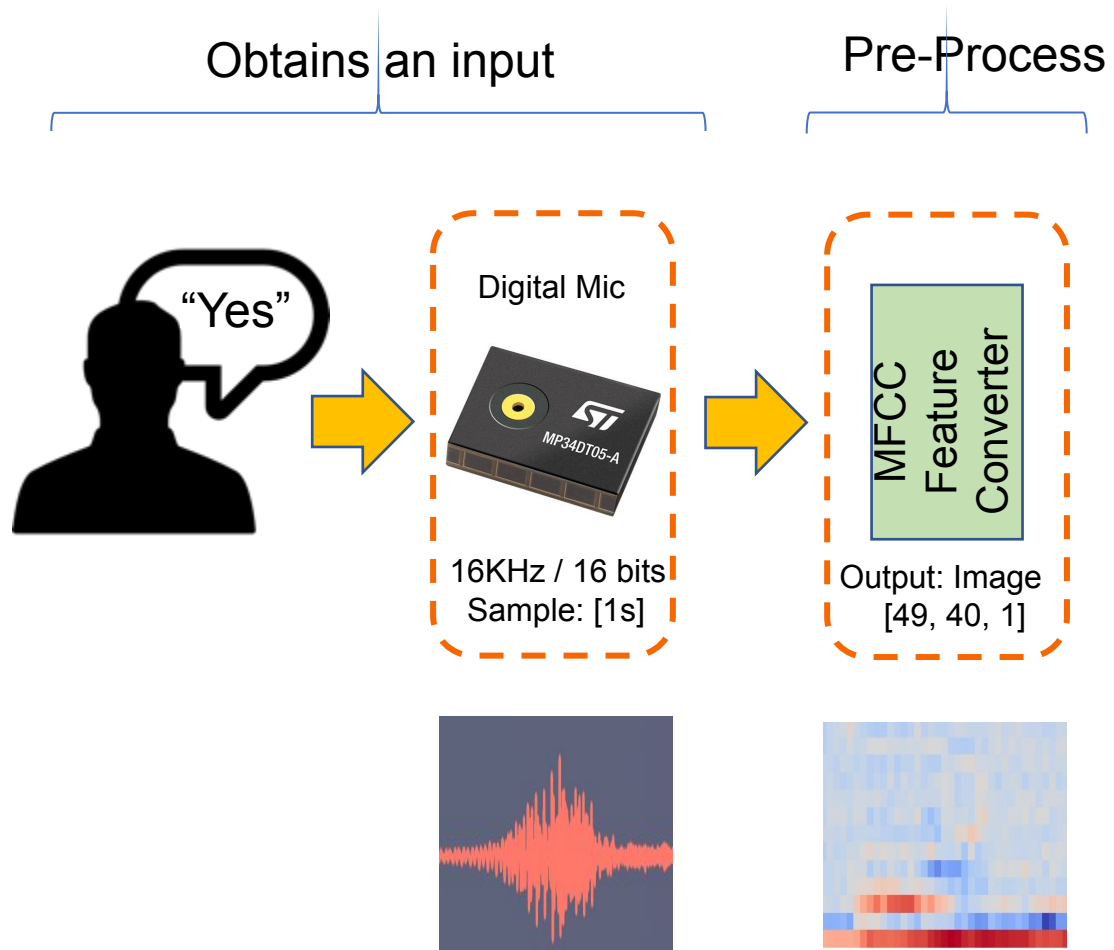
Image

# KeyWord Spotting (KWS) - Inference

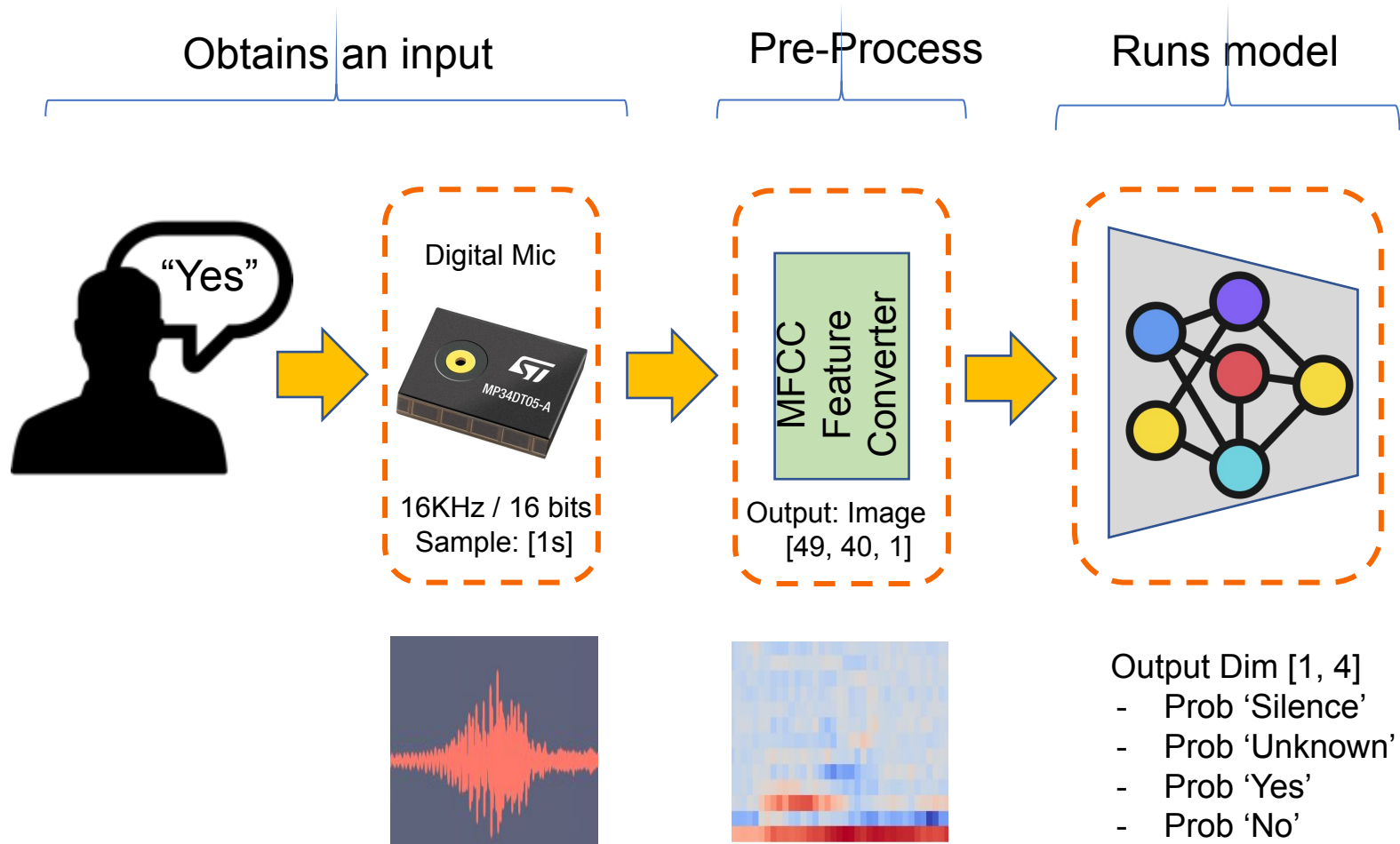
Obtains an input



# KeyWord Spotting (KWS) - Inference

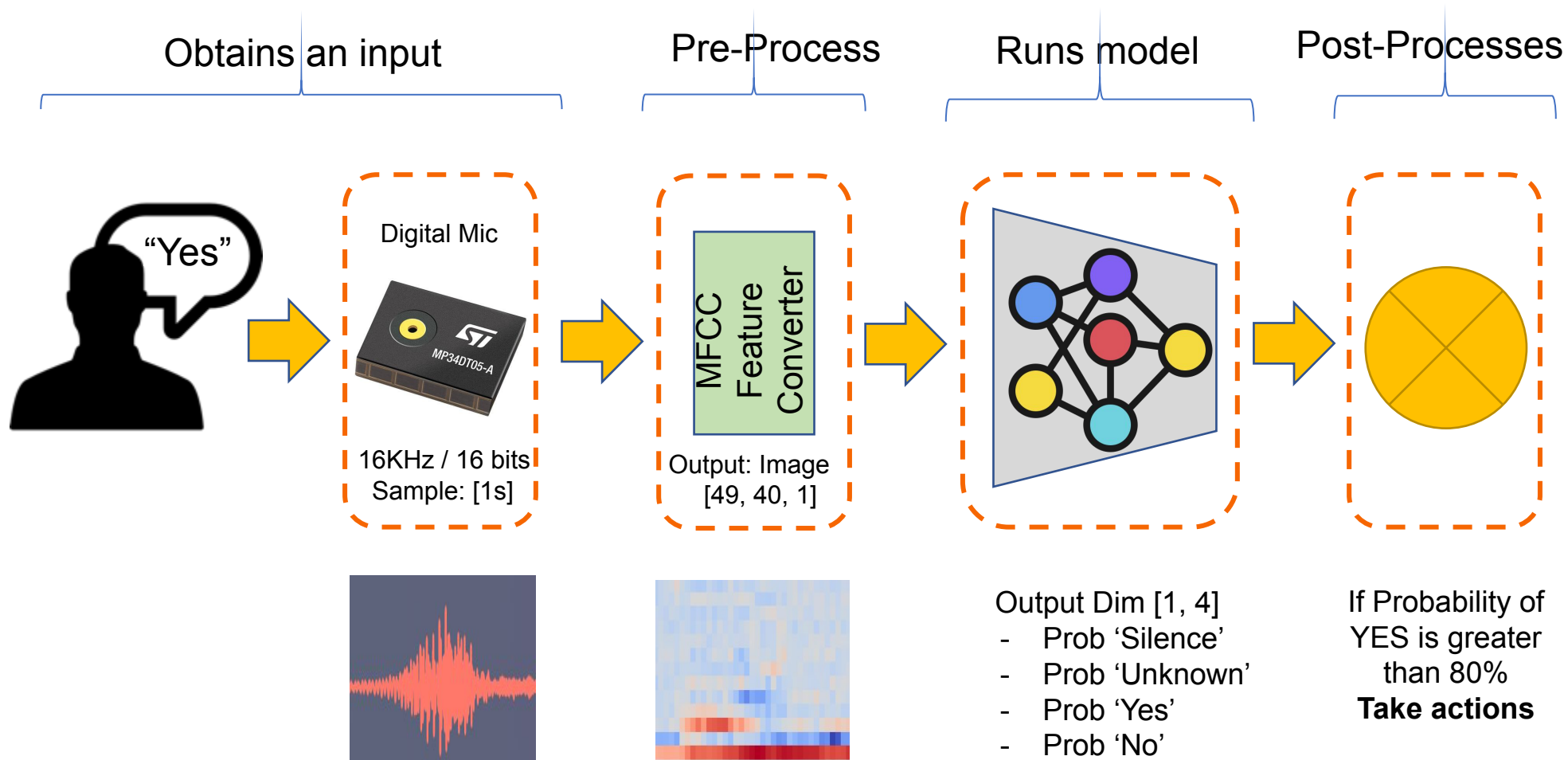


# KeyWord Spotting (KWS) - Inference

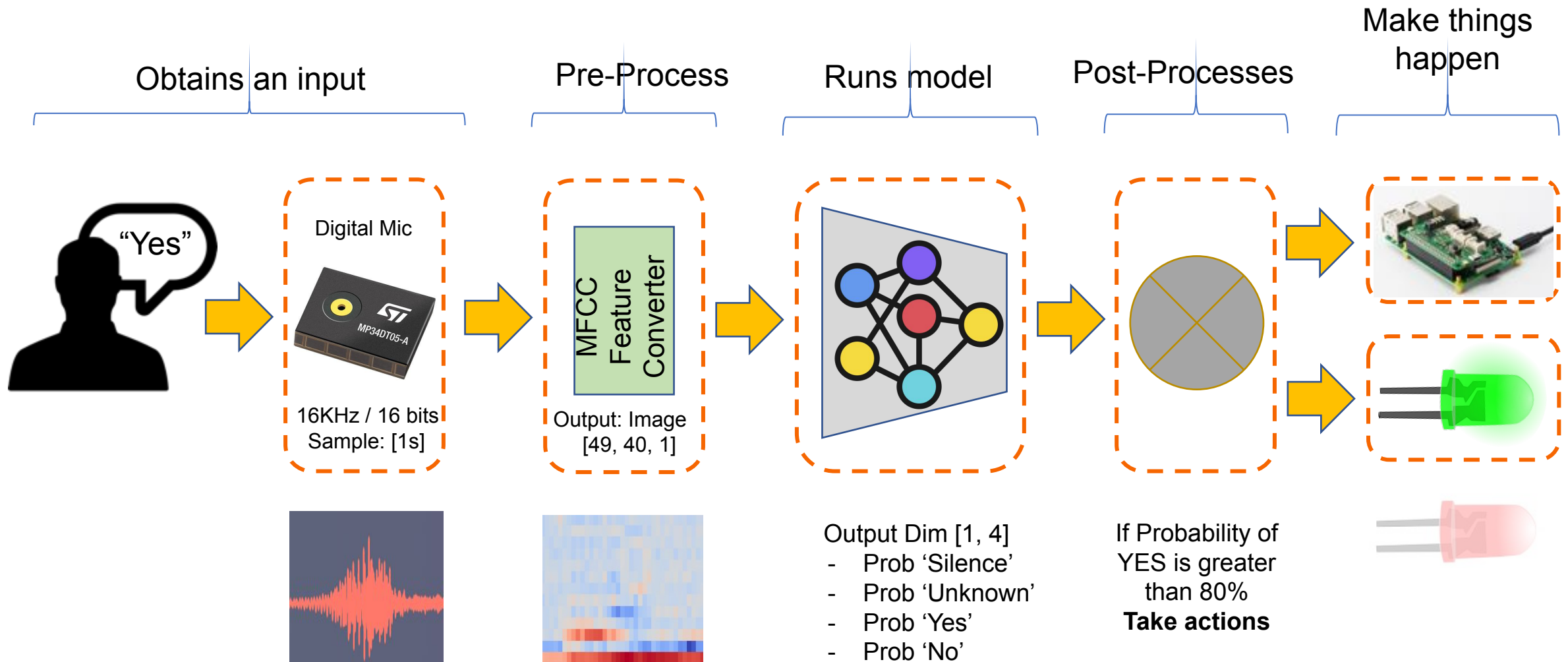




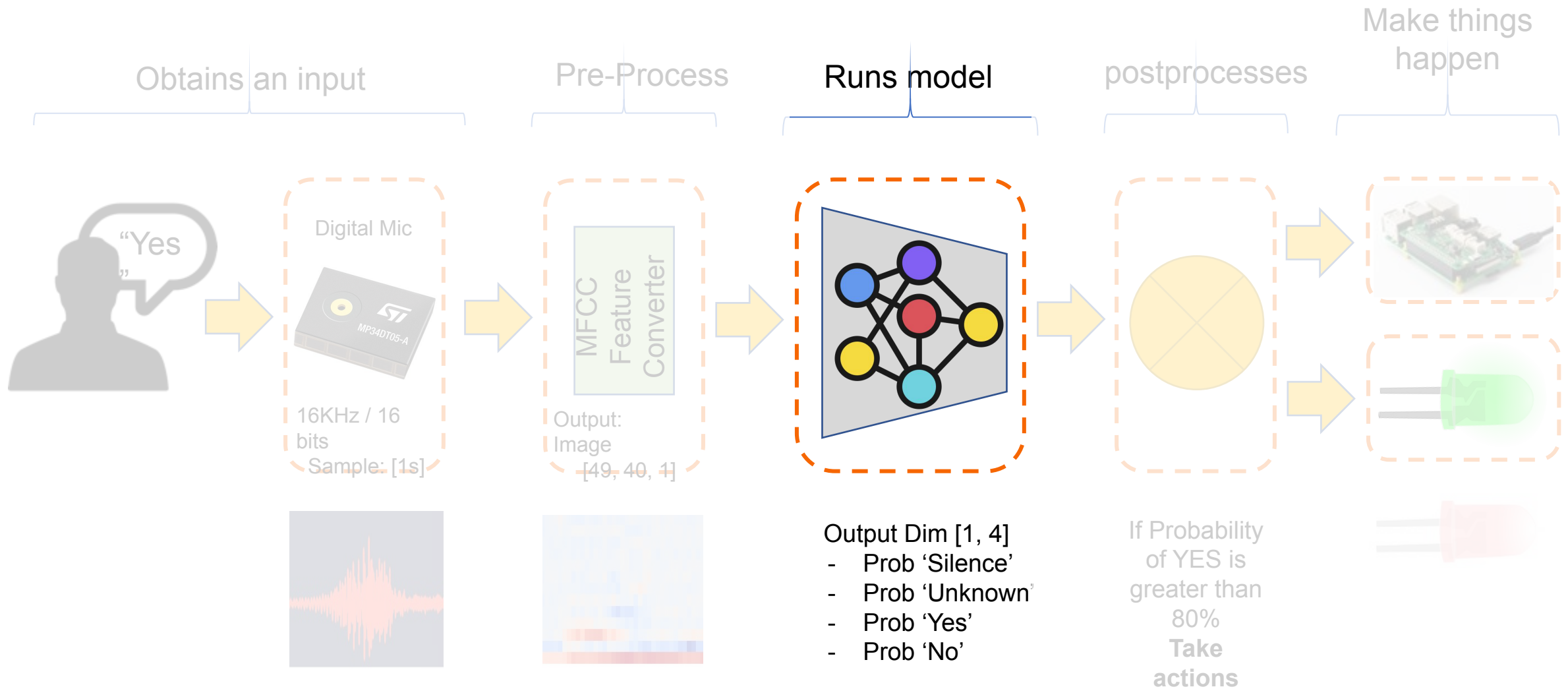
# KeyWord Spotting (KWS) - Inference



# KeyWord Spotting (KWS) - Inference



# KeyWord Spotting (KWS) - Model



# KeyWord Spotting (KWS) – Create Model (Training)

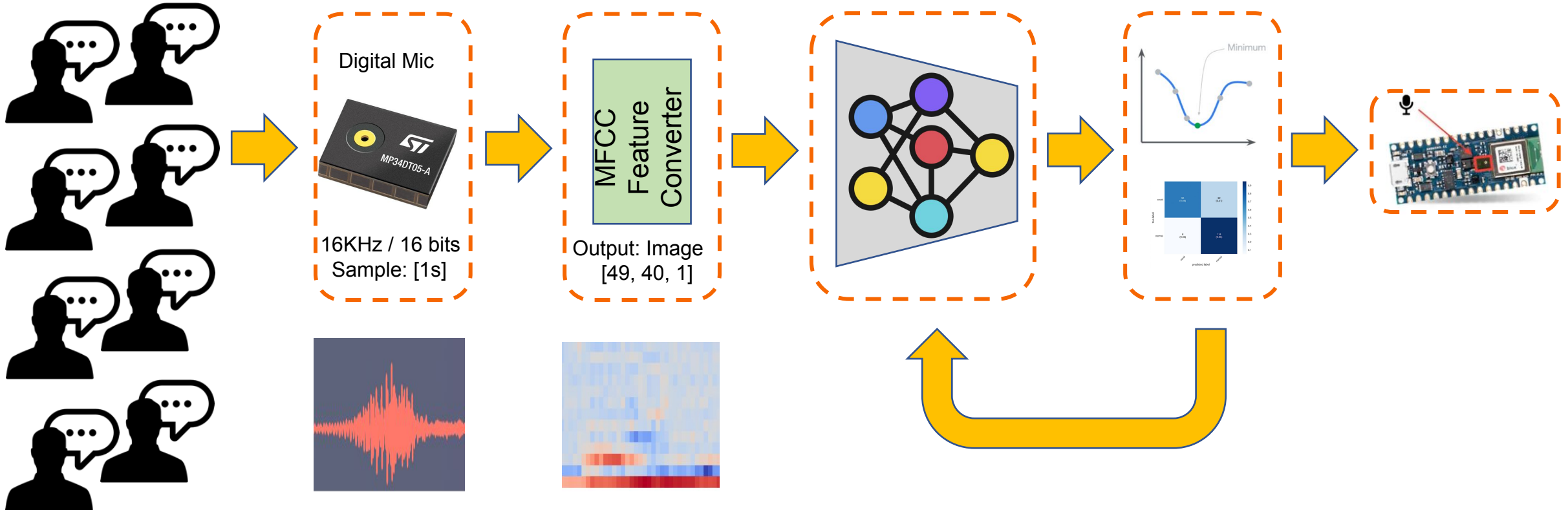
Obtains data

Pre-Process

Train model

Evaluate Model

Deploy

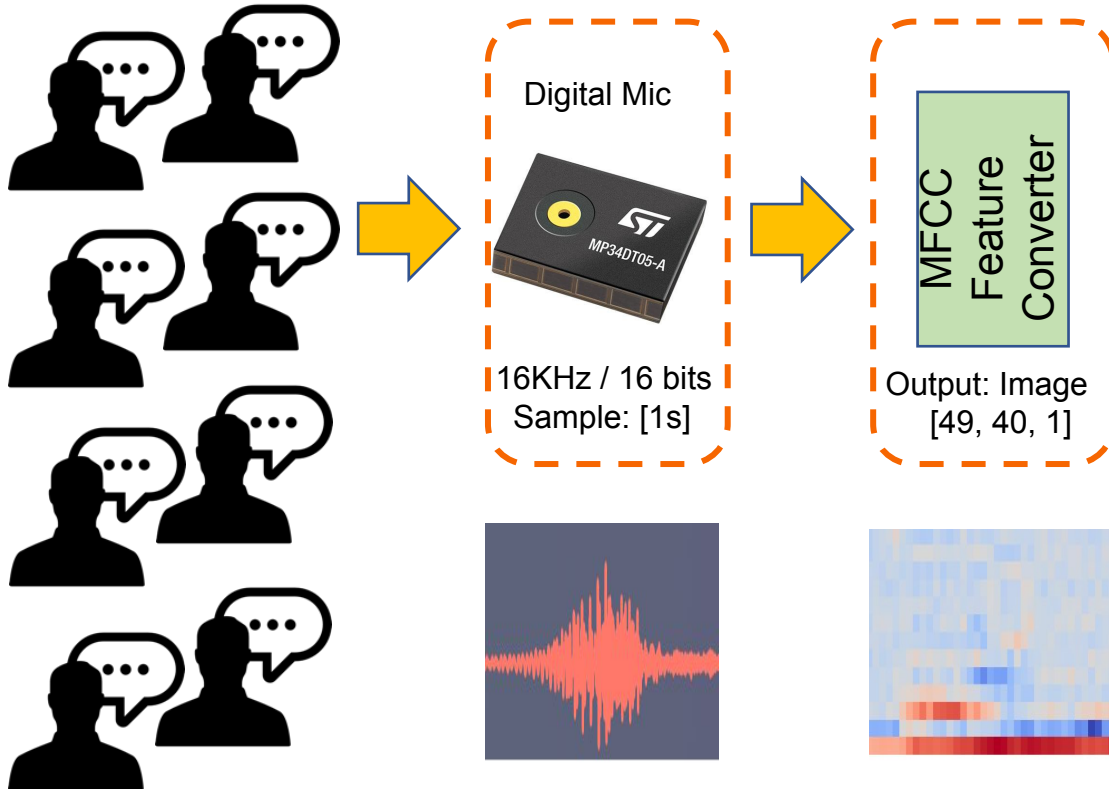




# KeyWord Spotting (KWS) – Create Model (Training)

Obtains data

Pre-Process



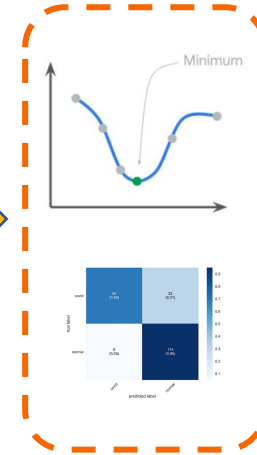
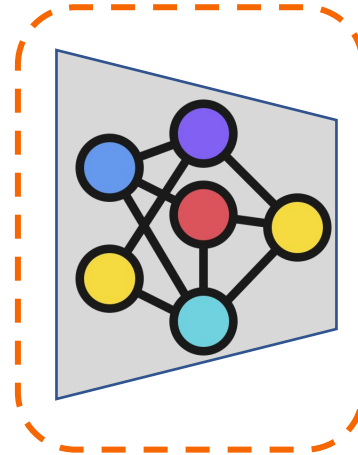
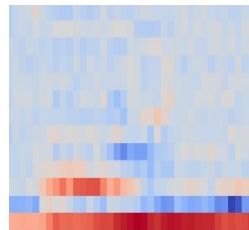
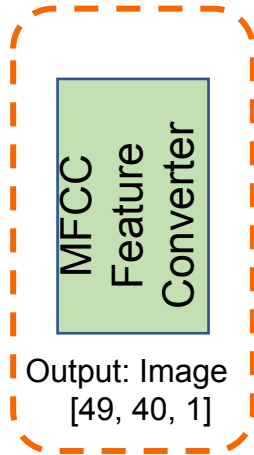
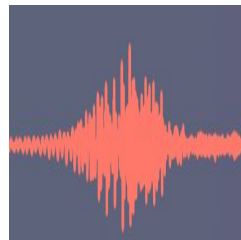
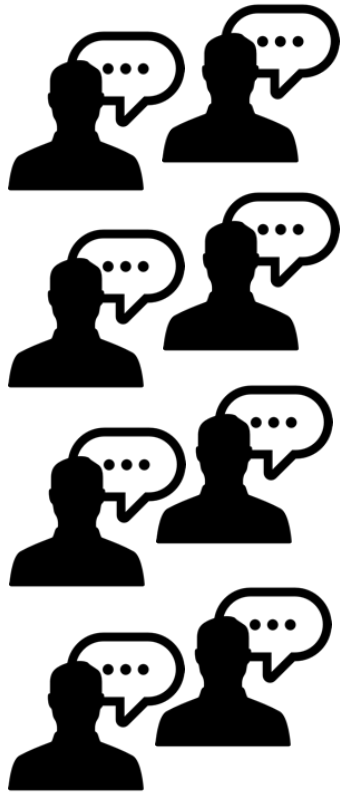
# KeyWord Spotting (KWS) – Create Model (Training)

Obtains data

Pre-Process

Train model

Evaluate Model



# KeyWord Spotting (KWS) – Create Model (Training)

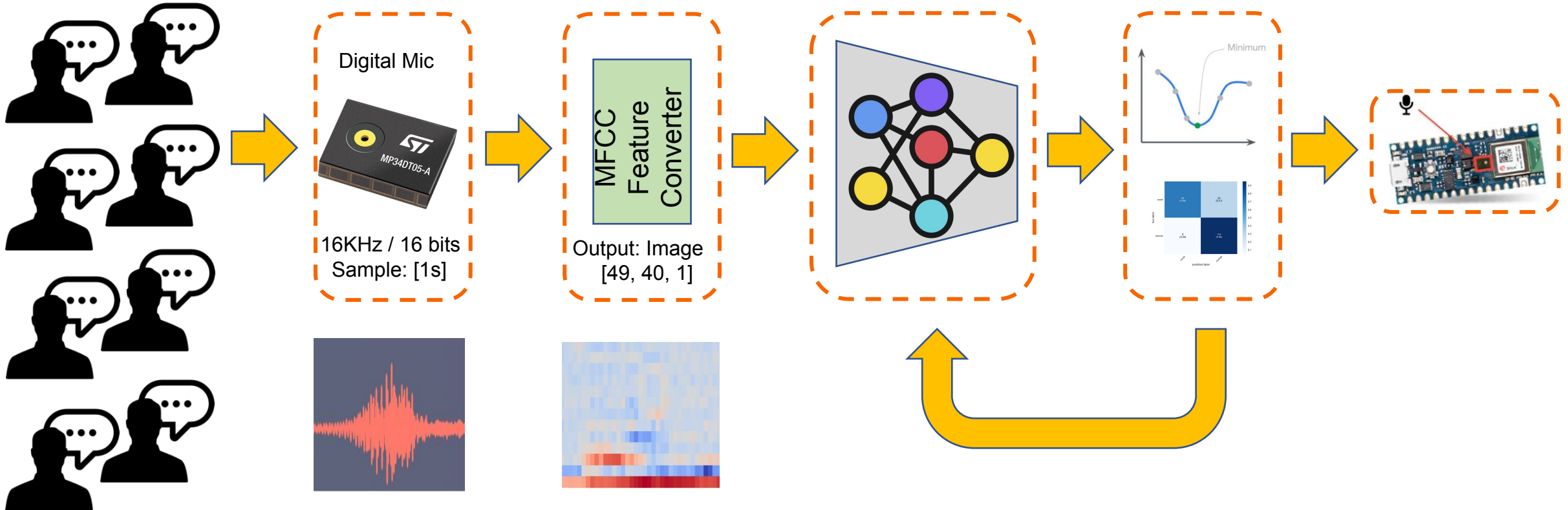
Obtains data

Pre-Process

Train model

Evaluate Model

Deploy



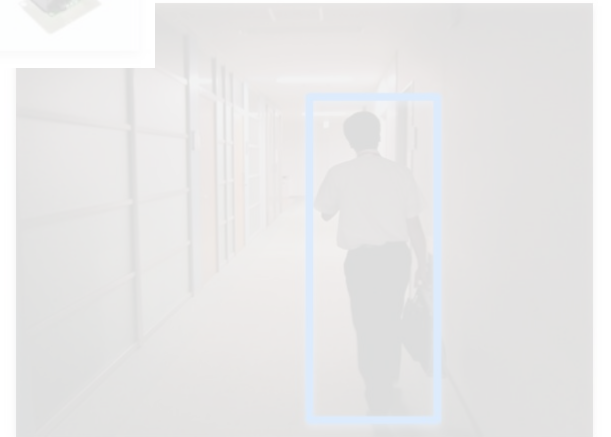
# Sound



# Vibration

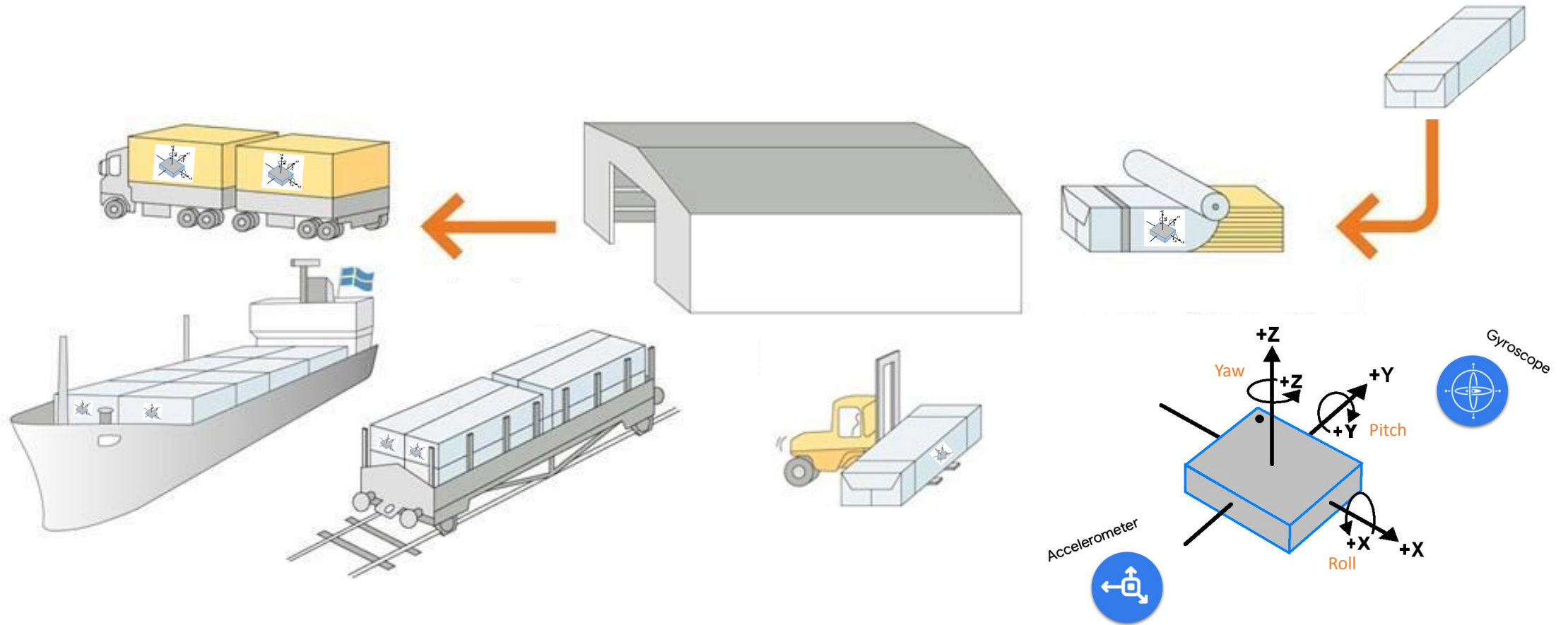


# Vision





# Mechanical Stresses in Transport



# Anomaly Detection



Ball Bearings

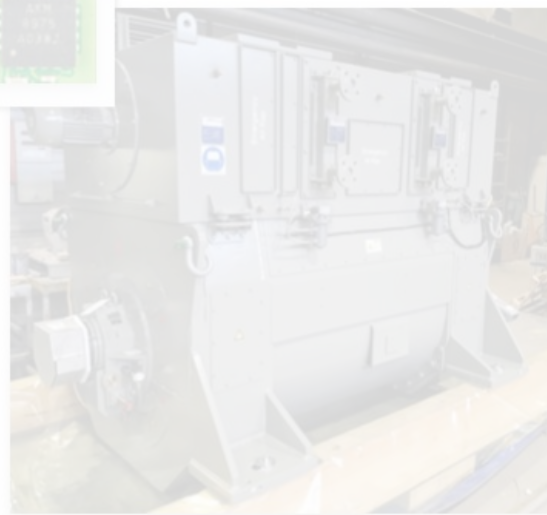


Accelerometer

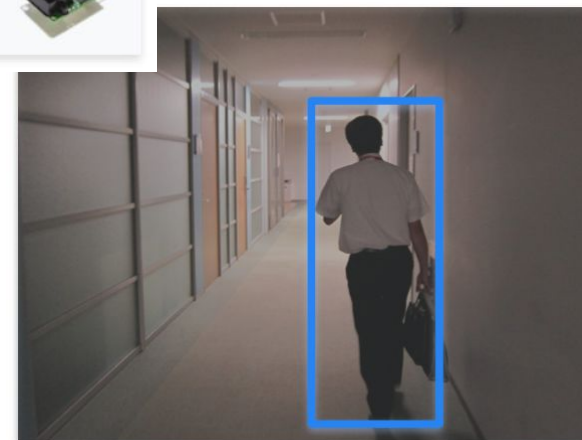
# Sound



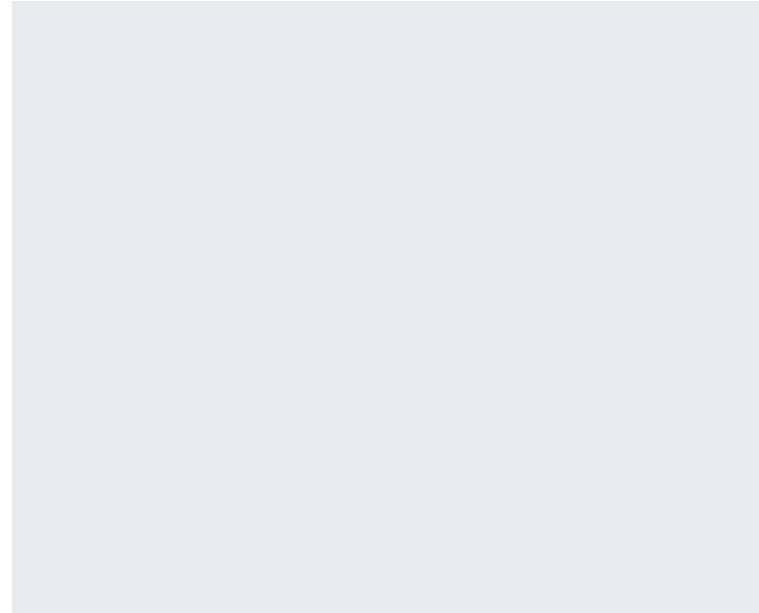
# Vibration



# Vision



# Person Detection





# TinyML Projects – UNIFEI / IESTI01 2021.1

## Vision

- Mask Detection [\[Docs\]](#) [\[Video\]](#)
- Forest Fire Detection [\[Docs\]](#) [\[Video\]](#)

## Sound

- Covid Detection (cough) [\[Docs\]](#) [\[Video\]](#)
- Seismic Detection [\[Docs\]](#) [\[Video\]](#)

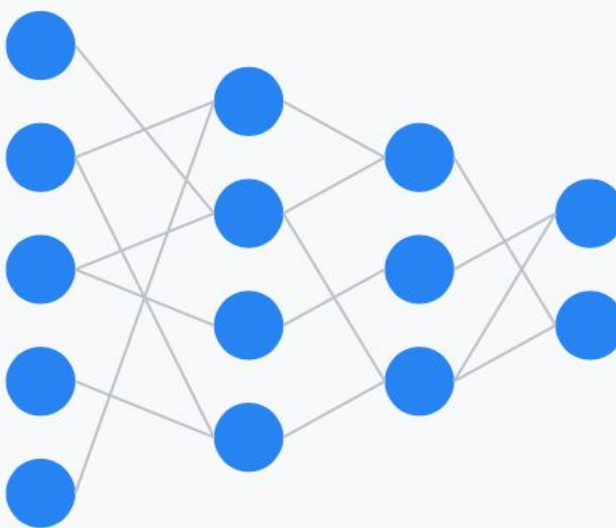
## Vibration

- Personal Trainer [\[Docs\]](#) [\[Video\]](#)

# ML Lifecycle

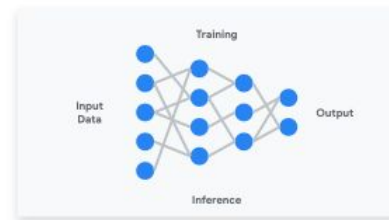
**Training**

**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**

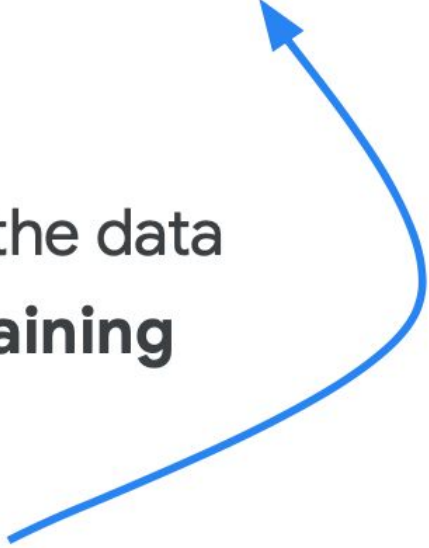
# Data Engineering

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

AI Infrastructure

Data Engineering

# 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**
- 

AI Infrastructure

Data Engineering

# Model Engineering

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

\* “**S**tate **o**f **t**he **A**rt”

AI Infrastructure

Data Engineering

Model Engineering

# Model Deployment

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

AI Infrastructure

Data Engineering

Model Engineering

Model Deployment

# Product Analysis

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

AI Infrastructure

**Data Engineering**

**Model Engineering**

**Model Deployment**

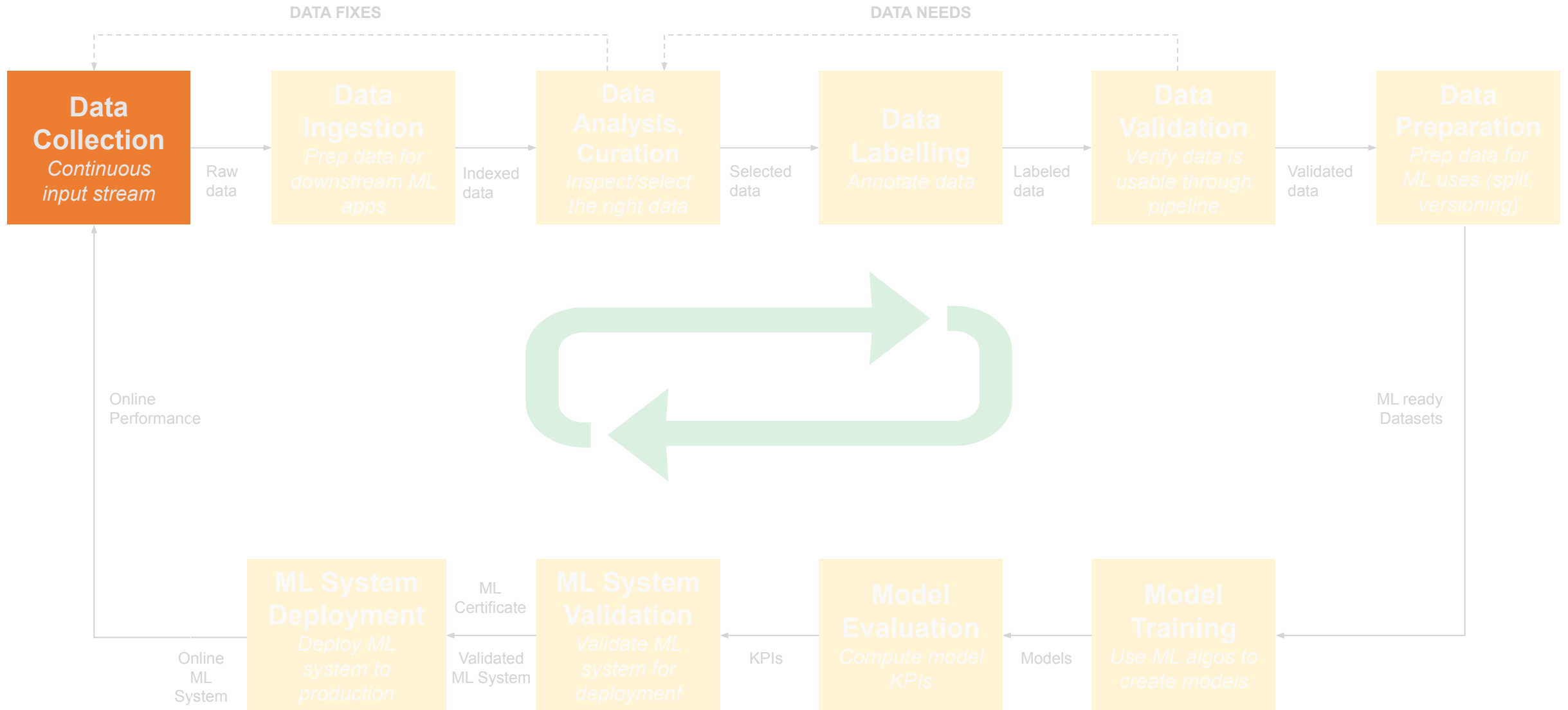
**Product Analytics**



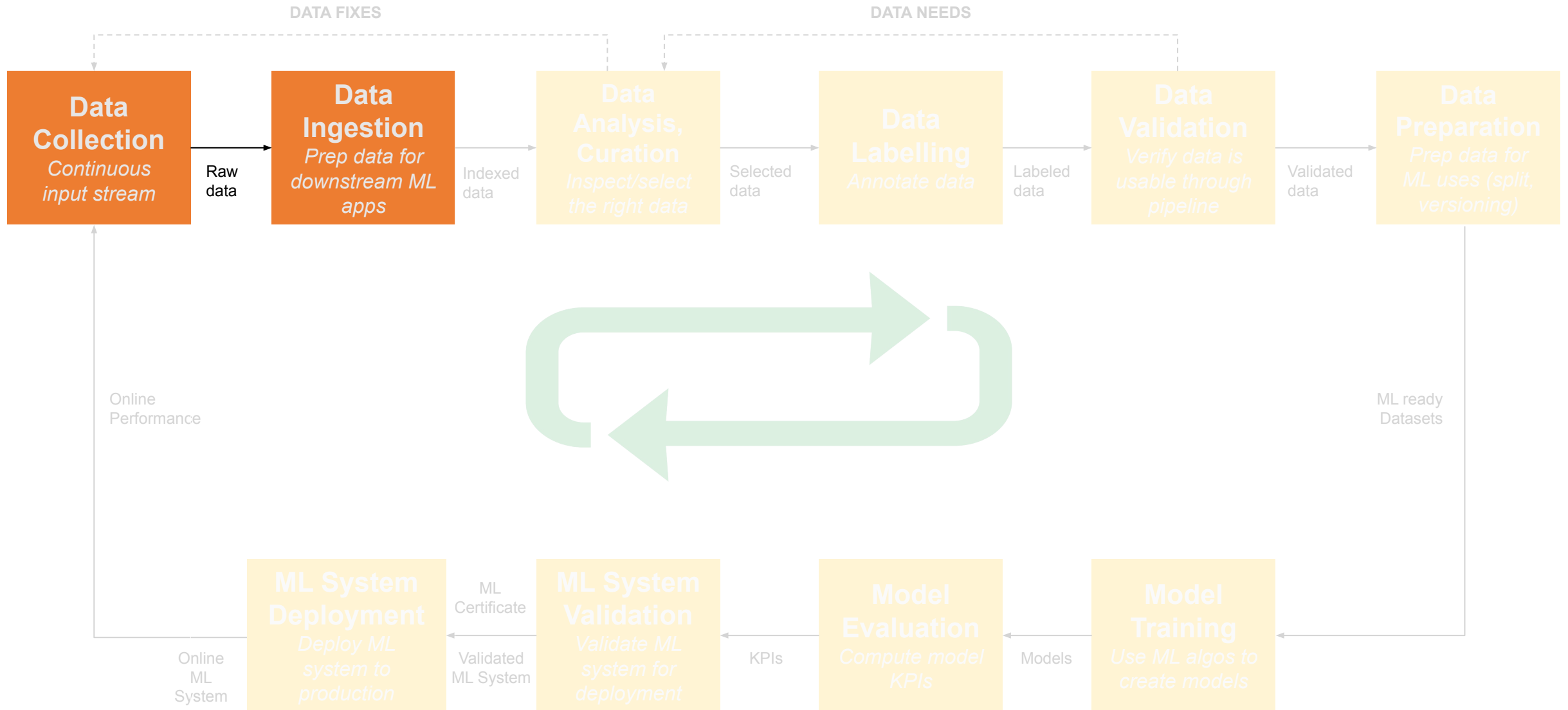
# Focus in **TinyML**



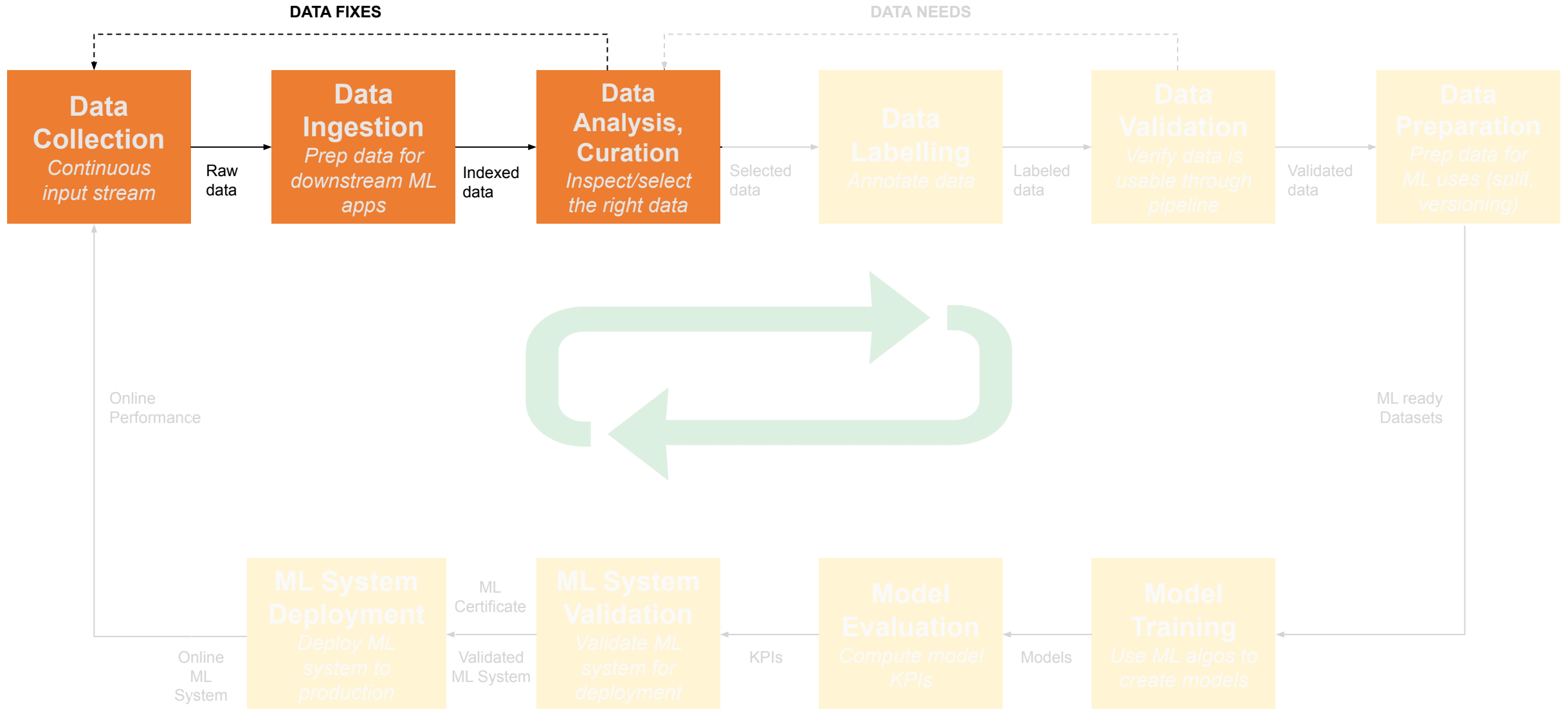
# Life cycle of ML



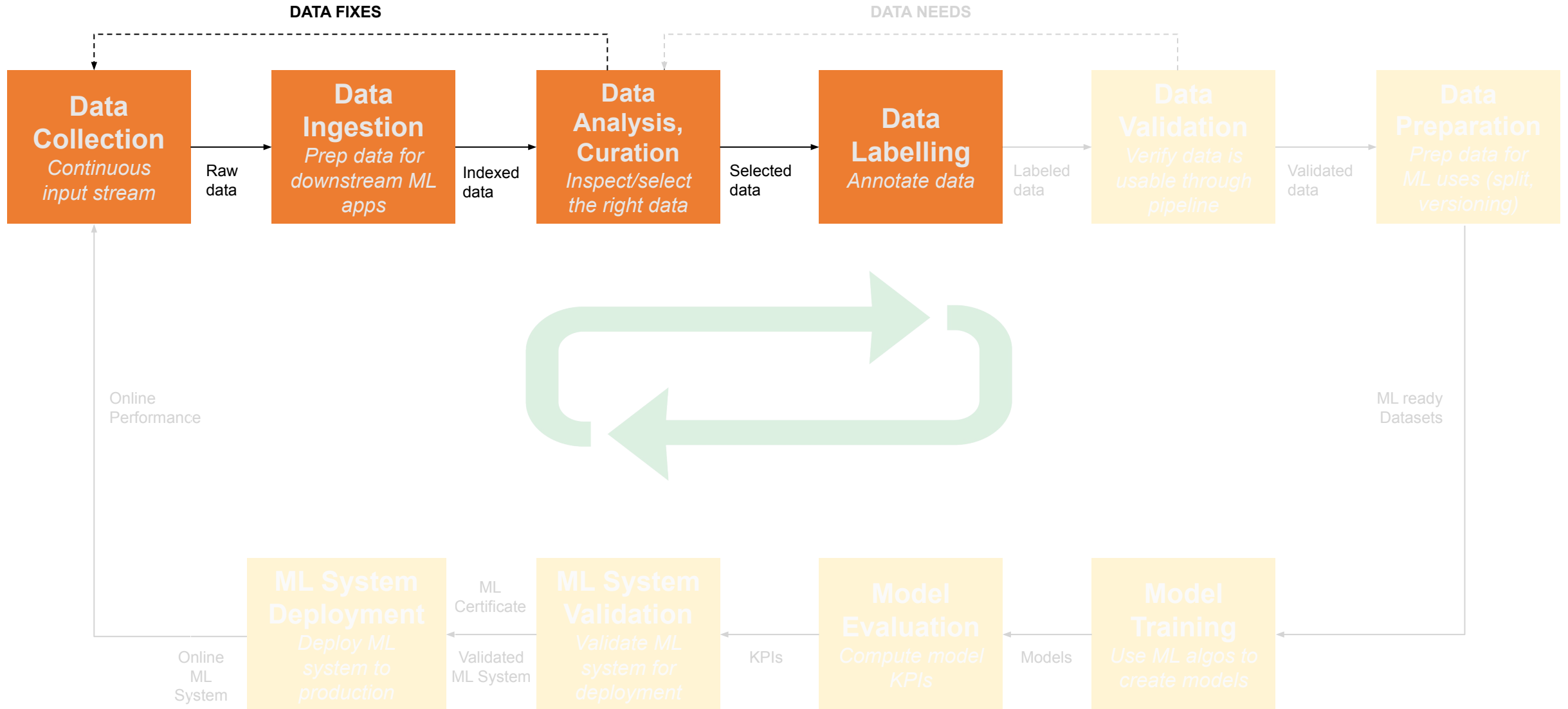
# Life cycle of ML



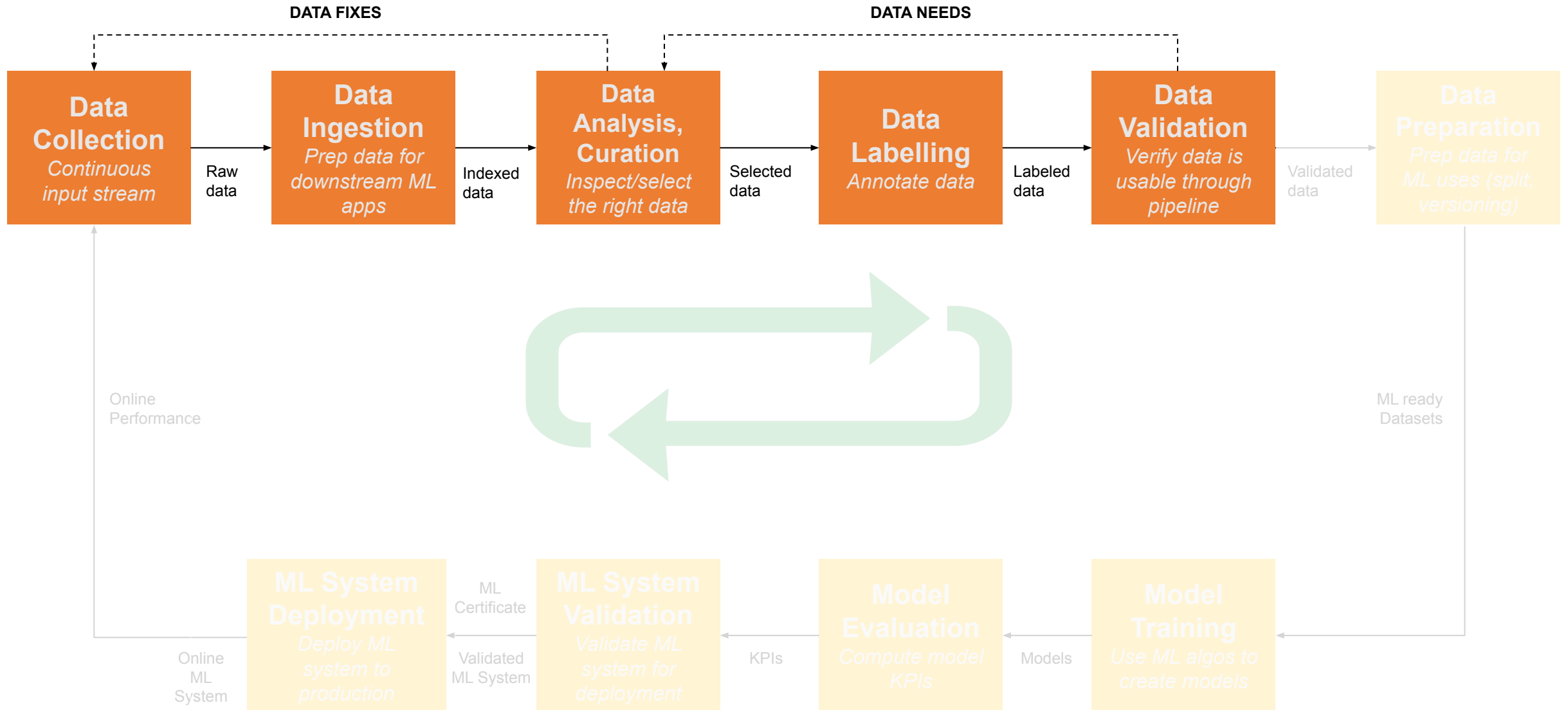
# Life cycle of ML



# Life cycle of ML

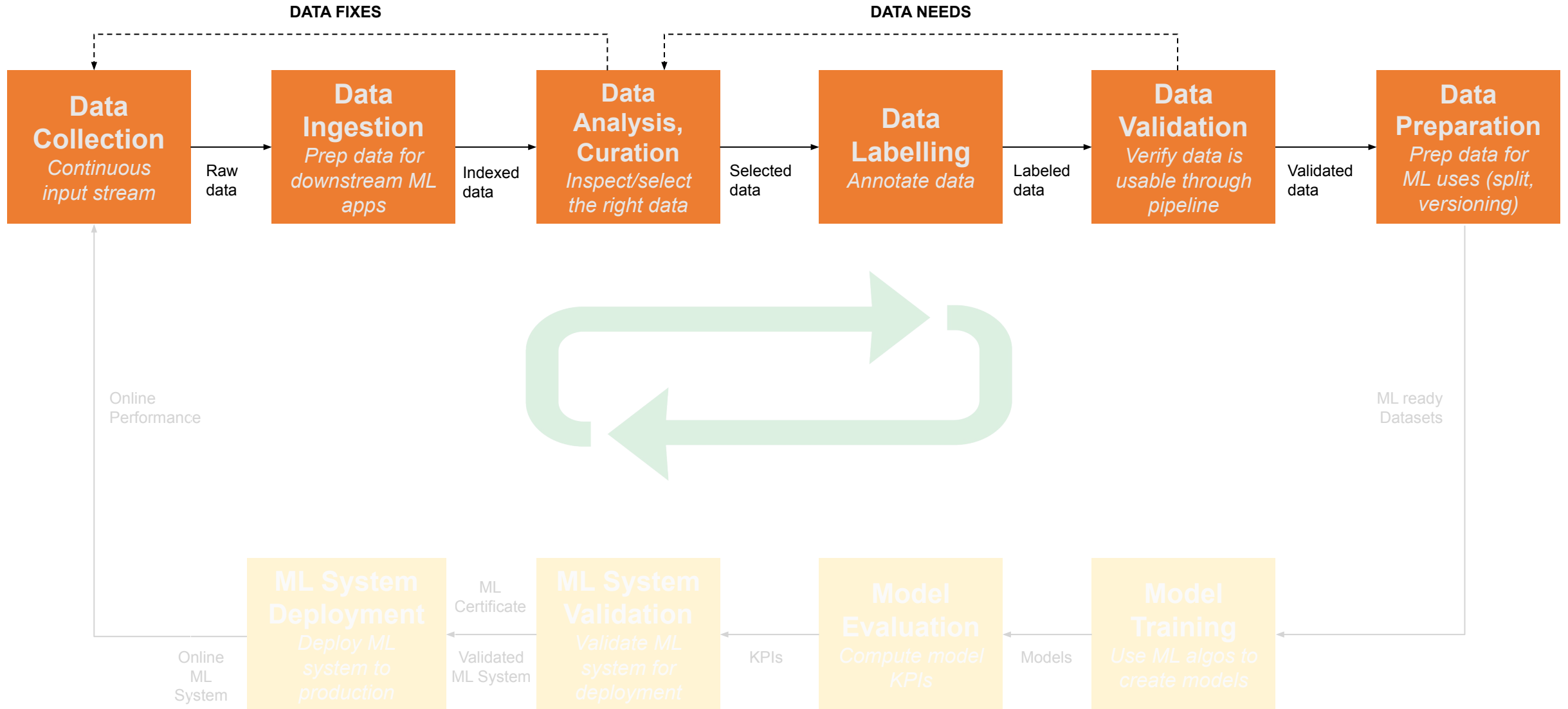


# Life cycle of ML

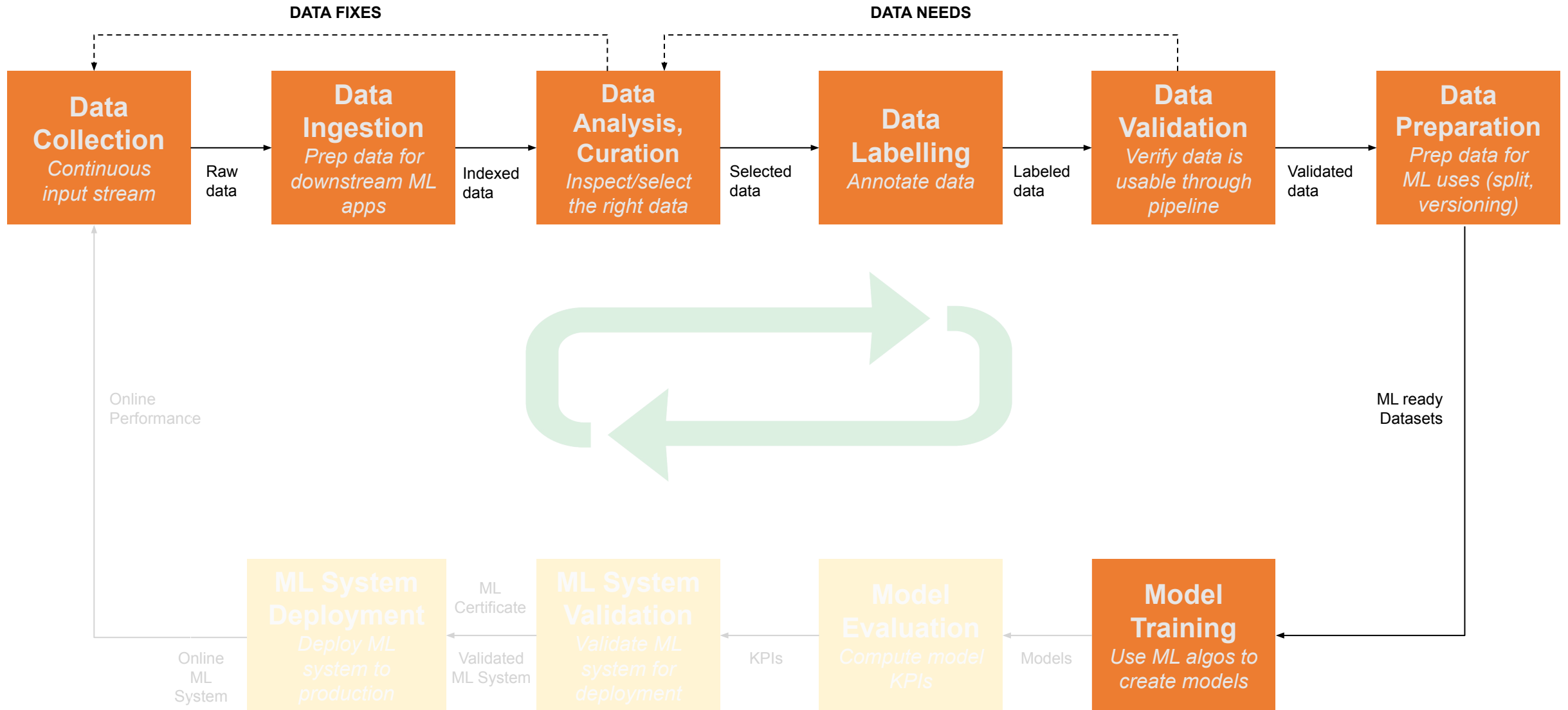




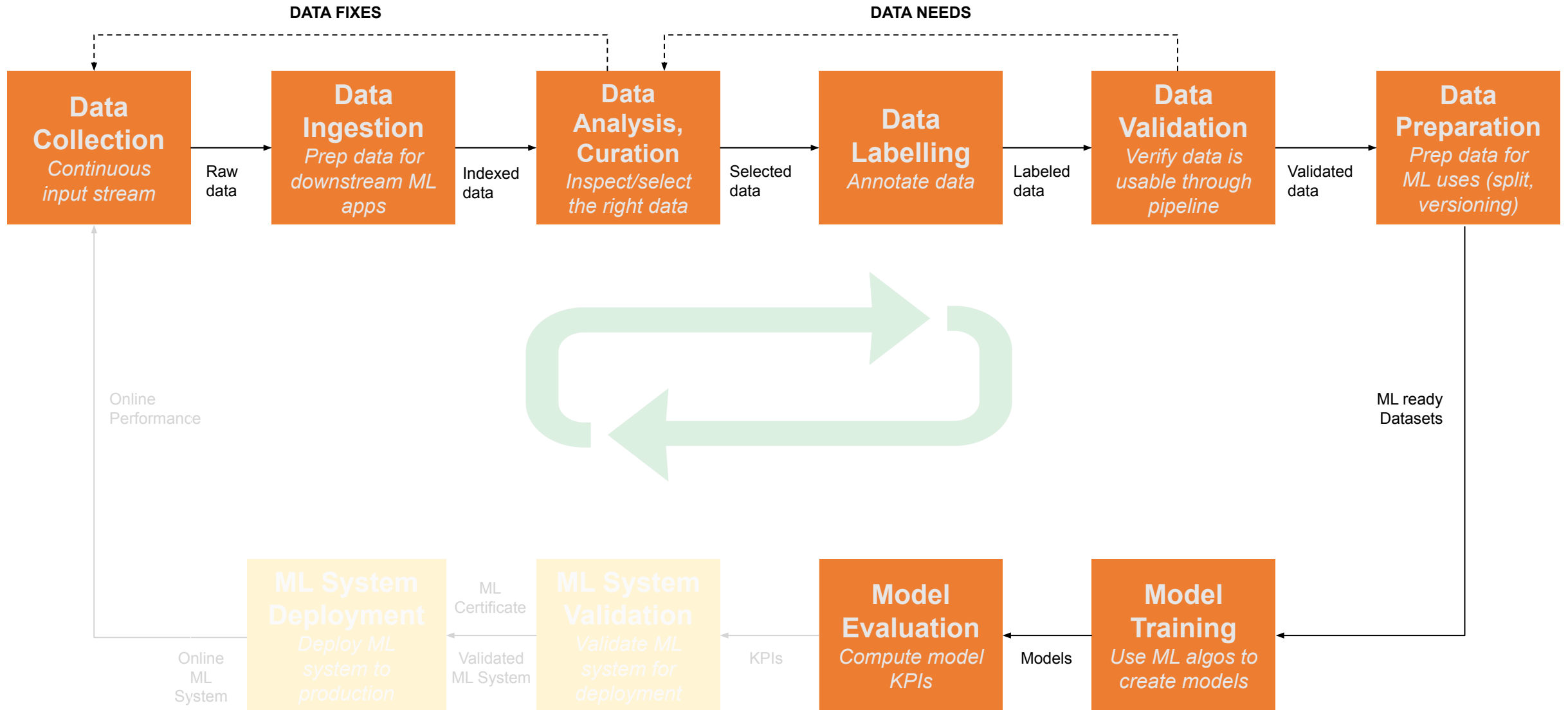
# Life cycle of ML



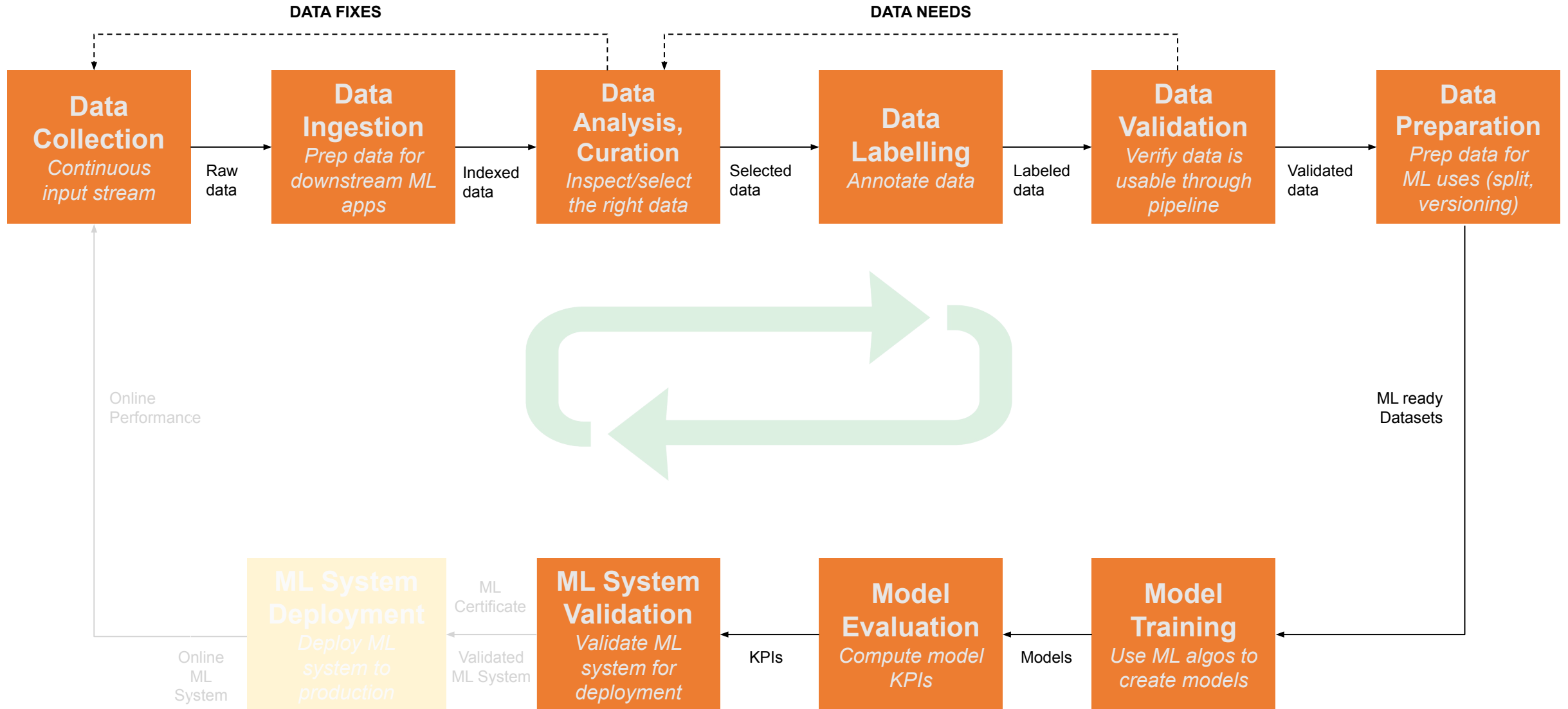
# Life cycle of ML



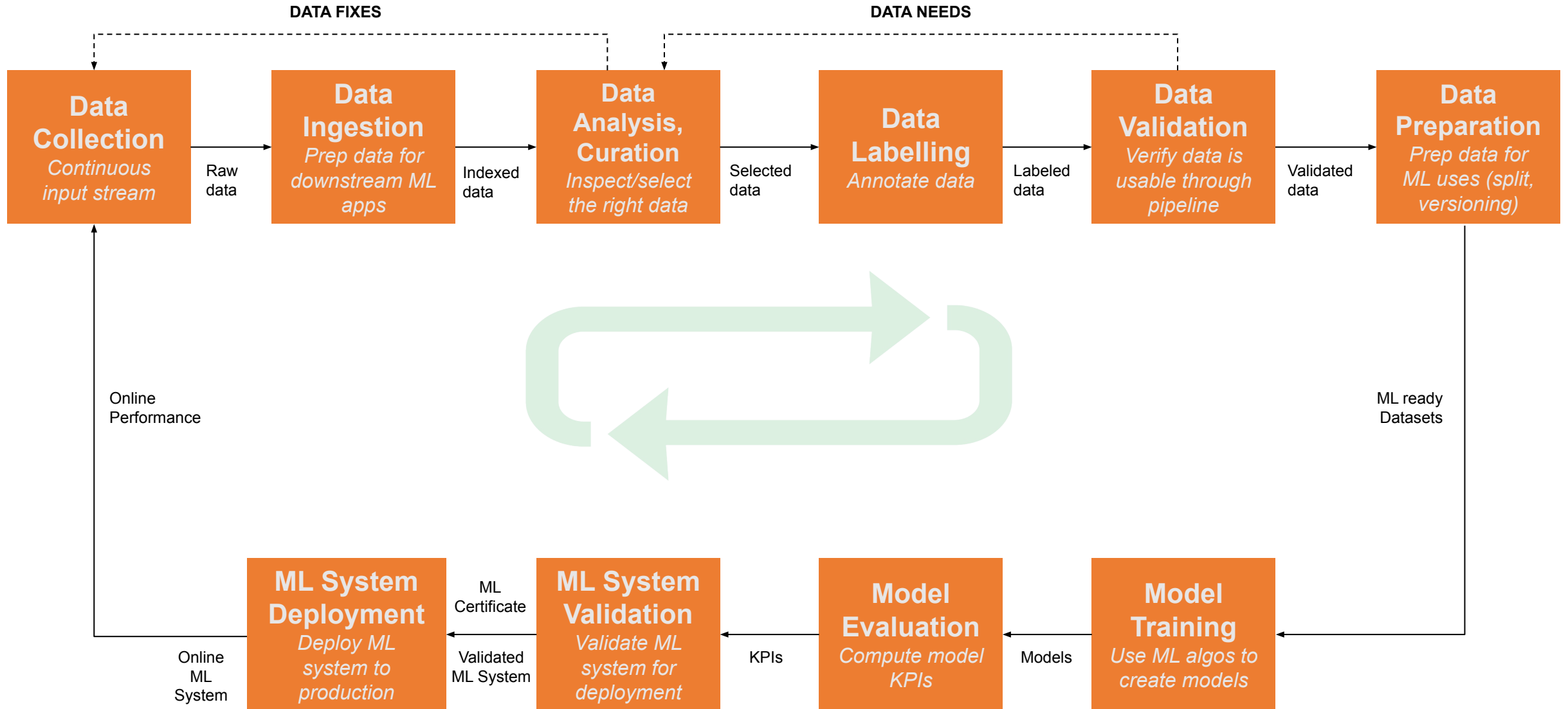
# Life cycle of ML



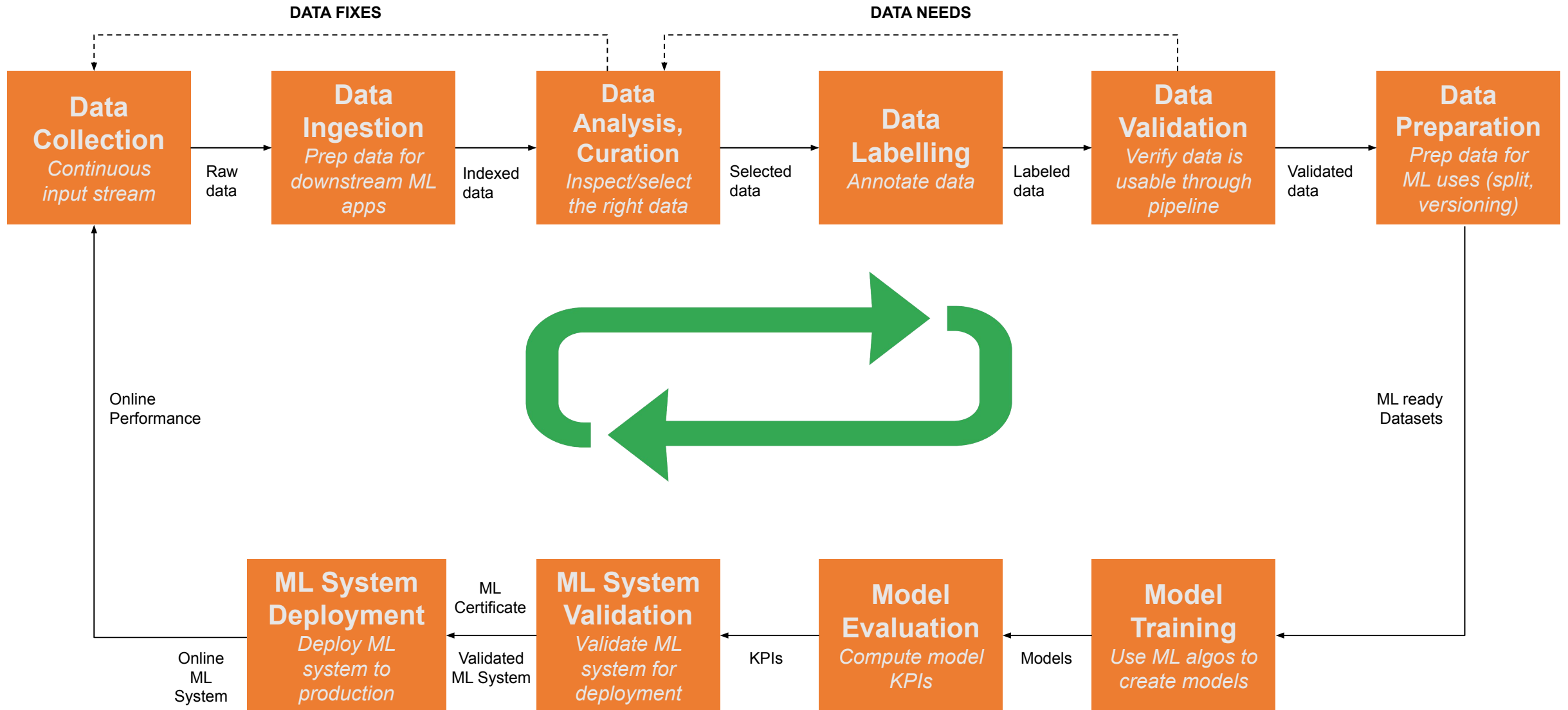
# Life cycle of ML



# Life cycle of ML



# Life cycle of ML





# 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



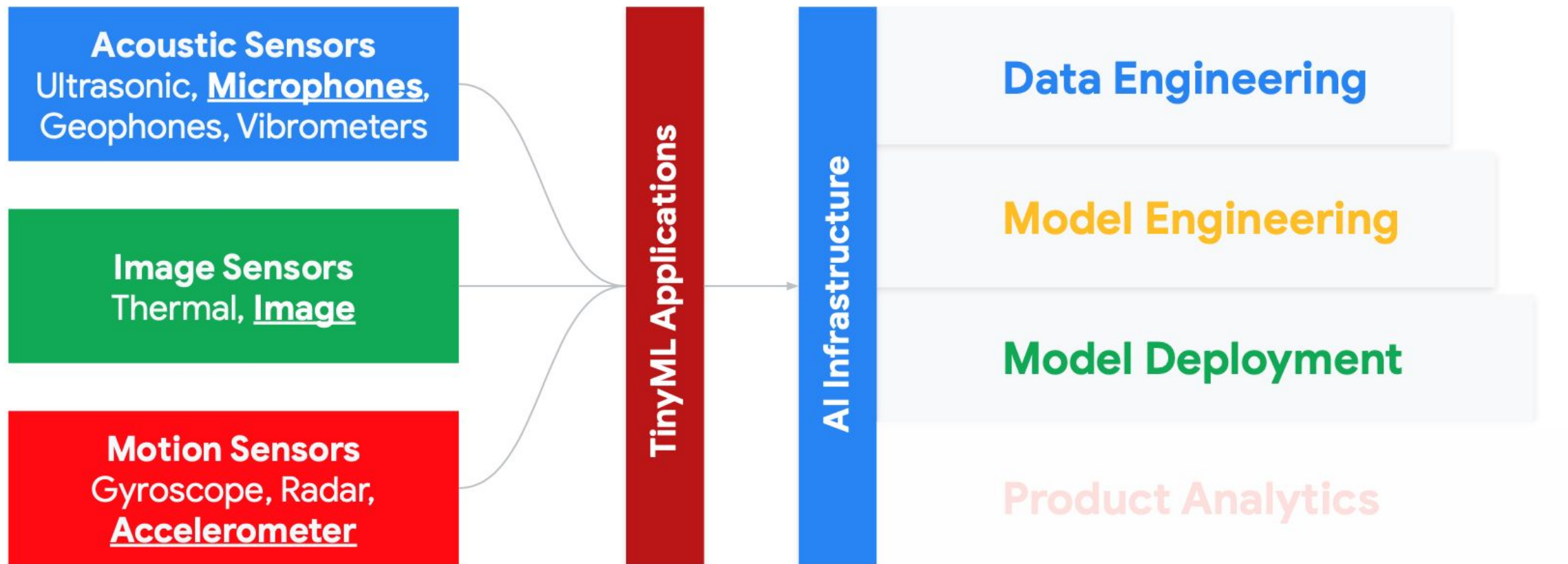
**AI Infrastructure**

**Data Engineering**

**Model Engineering**

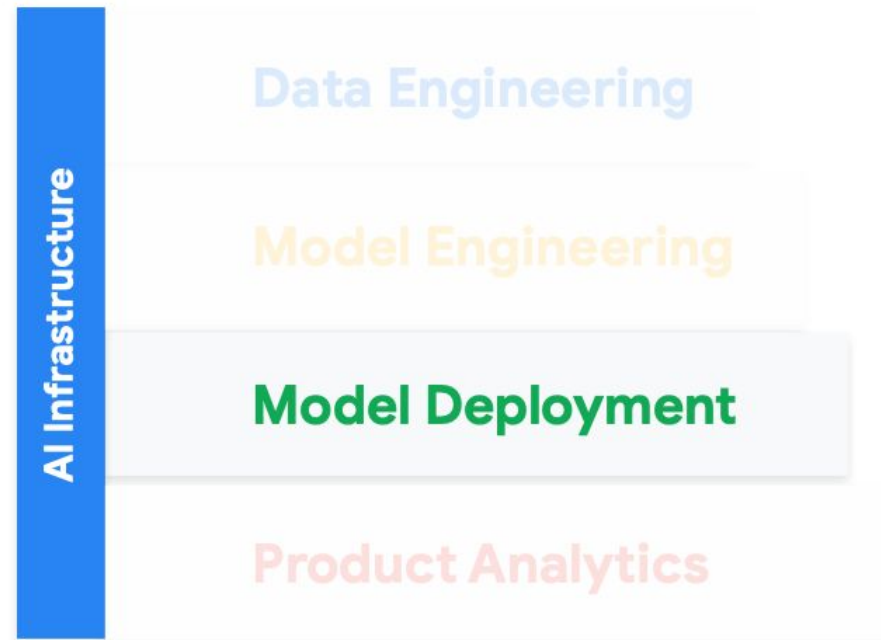
**Model Deployment**

**Product Analytics**



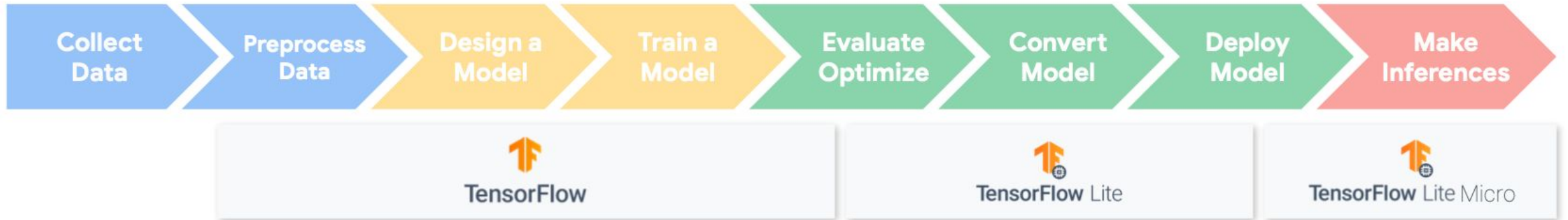


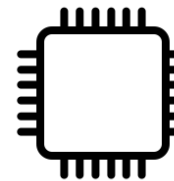
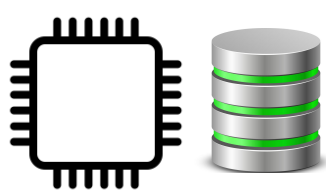












## Data Engineering

## Model Engineering

## Model Deployment

## Product Analytics

Collect  
Data

Preprocess  
Data

Design a  
Model

Train a  
Model

Evaluate  
Optimize

Convert  
Model

Deploy  
Model

Make  
Inferences



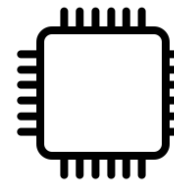
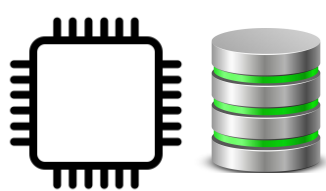
TensorFlow



TensorFlow Lite



TensorFlow Lite Micro



## 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



TensorFlow



TensorFlow Lite



TensorFlow Lite Micro



theano



PyTorch

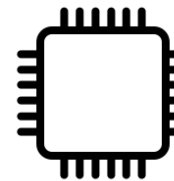
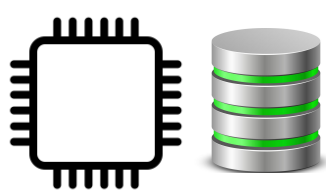
Caffe

uTensor



STM32  
Cube.AI

tvm



## 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



TensorFlow



TensorFlow Lite



TensorFlow Lite Micro



theano



PyTorch

Caffe

uTensor

GLOW

STM32  
Cube.AI

tvm



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 \(Coursera\)](#)
- [Text Book: "TinyML" by Pete Warden, Daniel Situnayake](#)

**I want to thank Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google, and especially Harvard professor Vijay Janapa Reddi, Ph.D. student Brian Plancher and their staff 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**  
**And stay safe!**



**UNIFEI**