



DEEPLARNING@SICK

**SICK**  
Sensor Intelligence.

Dr. Dominic Mai

Uwe Schöpflin

Summer School HS Offenburg



- Uwe Schöpflin
  - ▶ Software Development
  - ▶ Project Lead Vision@Systems
  - ▶ Technical Computerscience FH Furtwangen
  - ▶ 17years@Sick



- Dominic Mai
  - ▶ 2010: Diploma in Computerscience Uni Freiburg
  - ▶ 2017: PhD in Computervision Uni Freiburg
  - ▶ Since 2018: Deep Learning Initiative@SICK

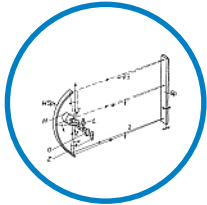
- **SICK AG Company Presentation**
- Deep Learning Initiative
- Logistics Applications
- Deep learning to go
- Master / Bachelor Theses @SICK



SICK – worldwide one of the leading manufacturers of sensors and sensor solutions for industrial applications

# CONTINUITY

## USING INNOVATIVE SENSORS BRINGS YOU COMPETITIVE ADVANTAGE



**1950**

First photoelectric switch based on autocollimation principle



**1952**

First light curtain for accident prevention



**1956**

First flue gas monitor



**1978**

First in-situ gas measurement device



**1989**

First distance determination with laser light on the pulse time-of-flight principle



**1993**

First safety laser scanner based on pulse time-of-flight principle



**2001**

High-speed 2D code reader



**2009**

Navigation based on natural landmarks



**2014**

MultiTask photoelectric sensor DeltaPac counts products without gaps



**2016**

SICK AppSpace for creating tailor-made solutions



**2017**

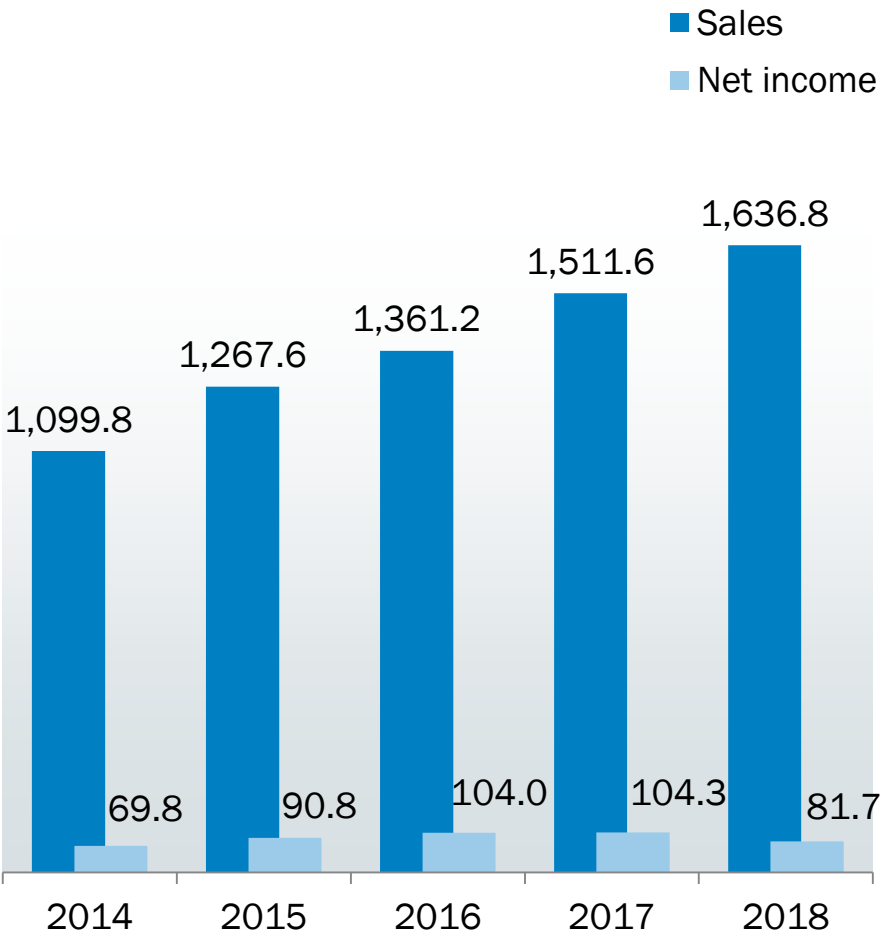
Ranger3 High-resolution and high-speed 3D camera



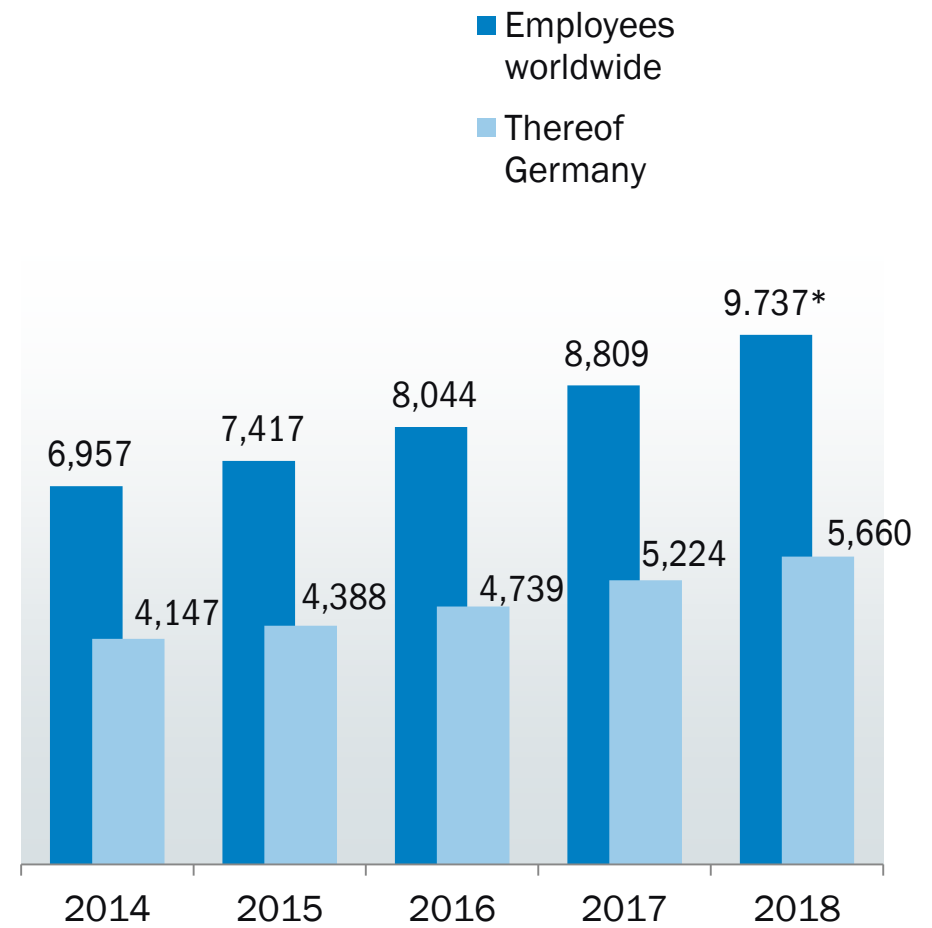
**2018**

outdoorScan3 Outdoor safety laser scanner

### SALES AND NET INCOME IN EUR MILLION



### EMPLOYEES PER DECEMBER 31



\* Thereof trainees 364 (annual average)



# INCREASED PERFORMANCE THROUGH CUSTOMIZED SOLUTIONS



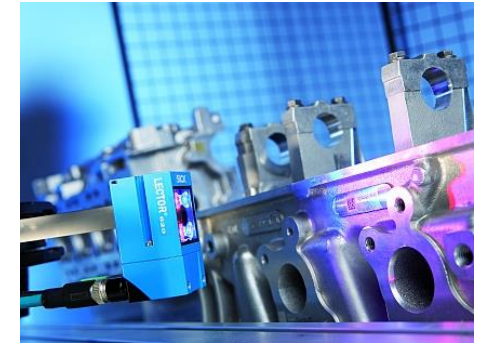
DETECTING



MEASURING



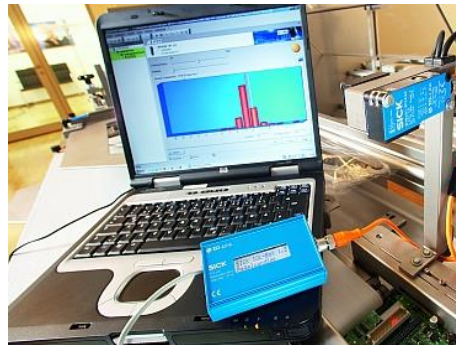
PROTECTING



IDENTIFICATION



POSITION  
DETERMINATION



NETWORKING  
AND INTEGRATION



MONITORING AND  
CONTROLLING



SERVICES

# WE ARE CLOSE TO YOUR INDUSTRY

## YOUR BENEFIT: EASY COMMUNICATION + EASY-TO-USE SOLUTIONS



FACTORY AUTOMATION

LOGISTICS AUTOMATION

PROCESS AUTOMATION



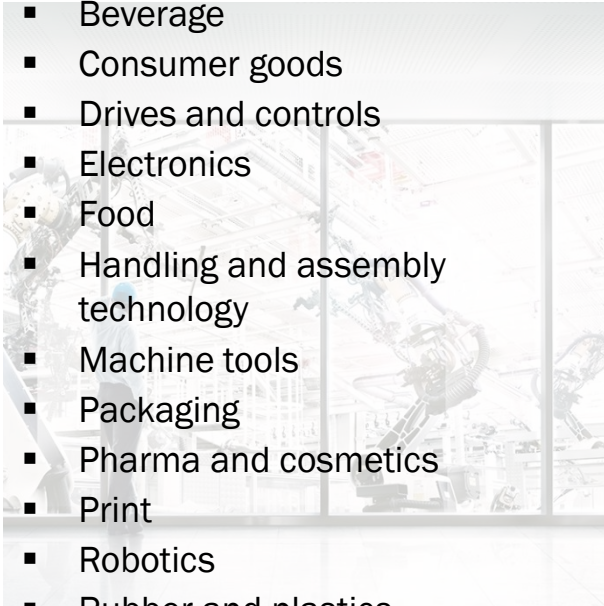


# WE ARE CLOSE TO YOUR INDUSTRY

YOUR BENEFIT: EASY COMMUNICATION + EASY-TO-USE SOLUTIONS

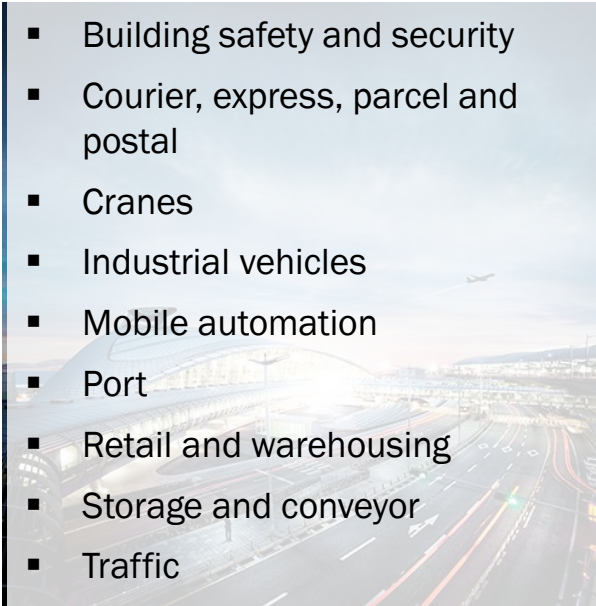
## FACTORY AUTOMATION

- Automotive and parts supplier
- Battery
- Beverage
- Consumer goods
- Drives and controls
- Electronics
- Food
- Handling and assembly technology
- Machine tools
- Packaging
- Pharma and cosmetics
- Print
- Robotics
- Rubber and plastics
- Semiconductor
- Solar
- Wind energy
- Wood



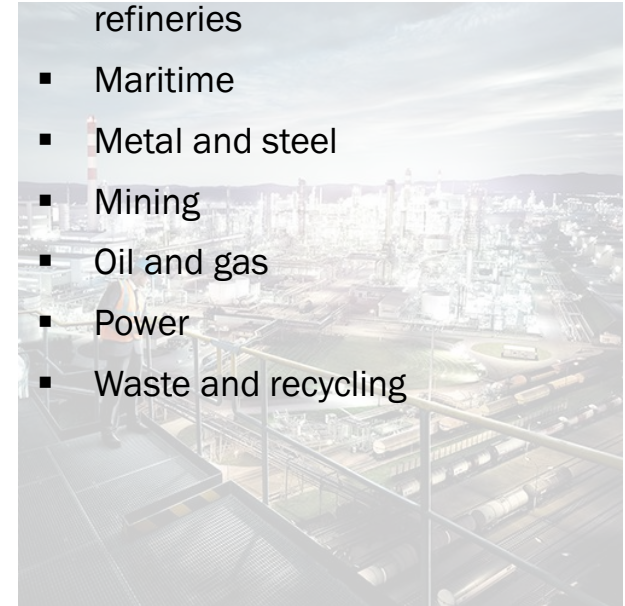
## LOGISTICS AUTOMATION

- Airport
- Building management
- Building safety and security
- Courier, express, parcel and postal
- Cranes
- Industrial vehicles
- Mobile automation
- Port
- Retail and warehousing
- Storage and conveyor
- Traffic



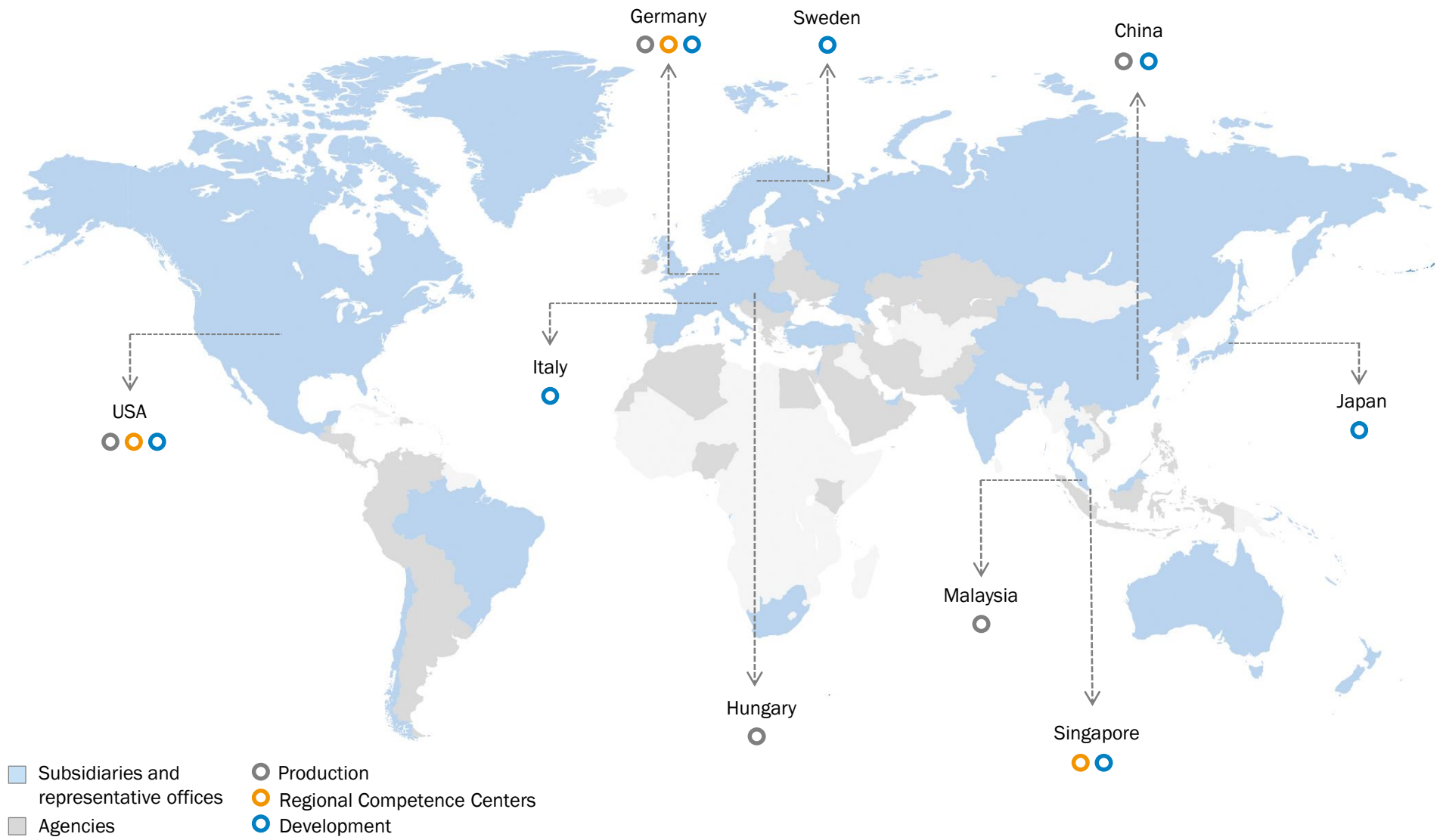
## PROCESS AUTOMATION

- Cement
- Chemicals, petrochemicals and refineries
- Maritime
- Metal and steel
- Mining
- Oil and gas
- Power
- Waste and recycling



# ALWAYS CLOSE TO YOU

## SHORT DISTANCES SAVE YOU TIME AND MONEY



THANKS FOR THE ATTENTION.

**SICK**  
Sensor Intelligence.

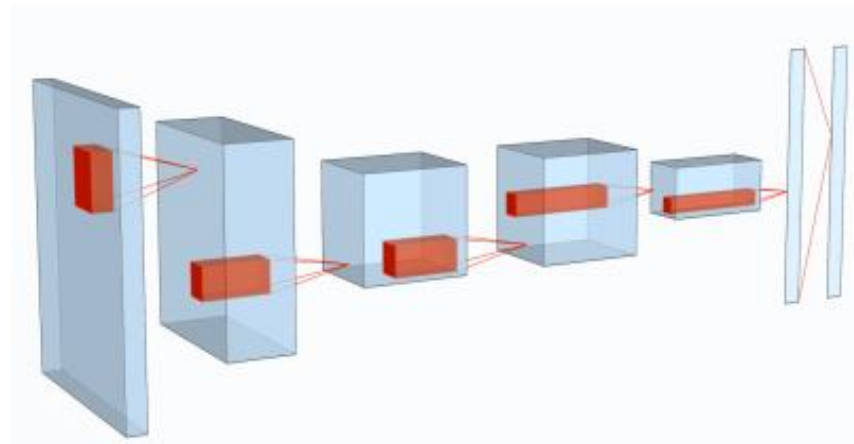
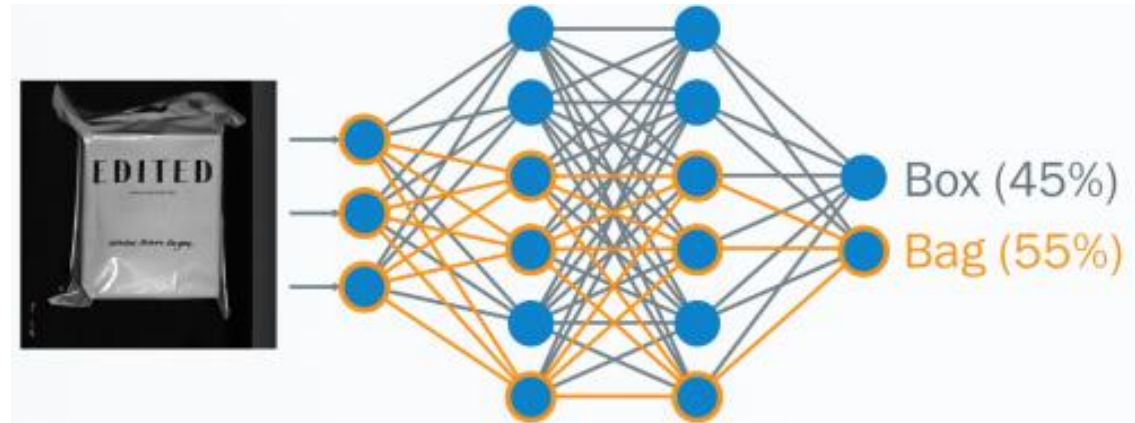
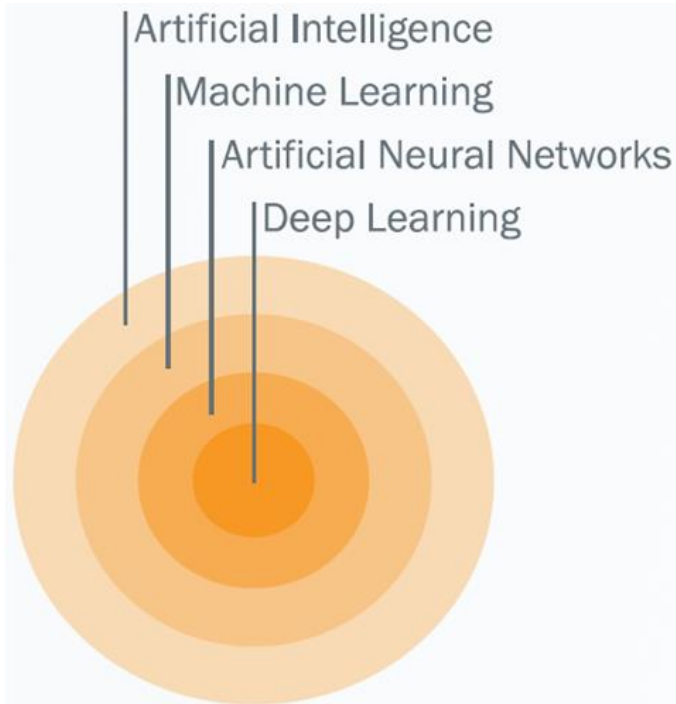
Questions?



- SICK AG Company Presentation
- **Deep Learning Initiative**
  - ▶ **Intro**
  - ▶ Tooling
- Logistics Applications
- Deep learning to go
- Master / Bachelor Theses @SICK

# DEEP LEARNING

## AN ARTIFICIAL INTELLIGENCE TECHNOLOGY



<https://leonardoaraujosantos.gitbooks.io/artificial-intelligence/content/>



# DEEP LEARNING THE HYPE



[http://static.euronews.com/articles/32/68/326842/580x378\\_bonus-kasparov-deep-blue.jpg](http://static.euronews.com/articles/32/68/326842/580x378_bonus-kasparov-deep-blue.jpg)

1997



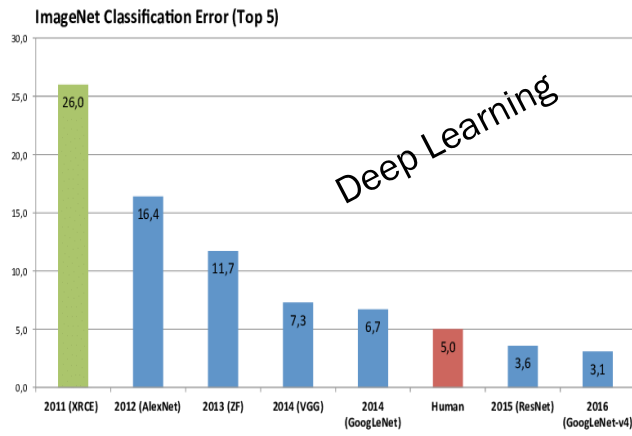
[http://cdn1.alphr.com/sites/alphr/files/2016/03/deepmind\\_alpha\\_go\\_beats\\_lee.png](http://cdn1.alphr.com/sites/alphr/files/2016/03/deepmind_alpha_go_beats_lee.png)

2016

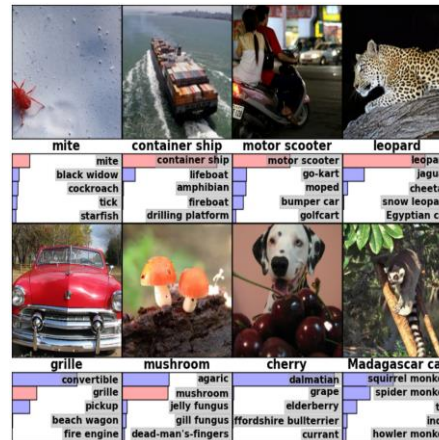


2012

soon



<http://www.videantis.com/wp-content/uploads/2018/07/LSVRC-winners-over-time.png>



"ImageNet Classification with Deep Convolutional Neural Networks" A. Krizhevsky et al.



Photo: metamorworks / Getty Images

- 2000: Shift away from knowledge (rule based) systems to machine learning (data driven)
- 2010: Rise of popularity of neural networks
- 2015: More and more reinforcement learning

## The number of papers we downloaded from the arXiv

All of the papers available in the "artificial intelligence" section through November 18, 2018

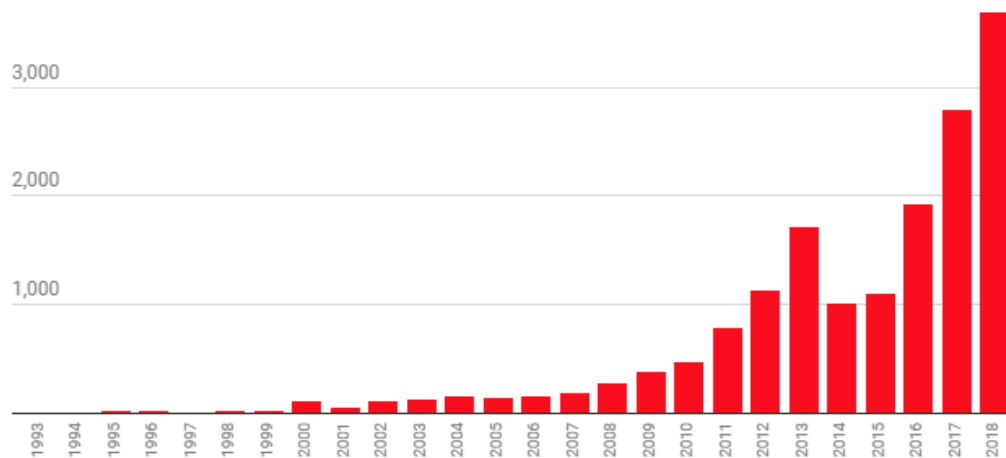
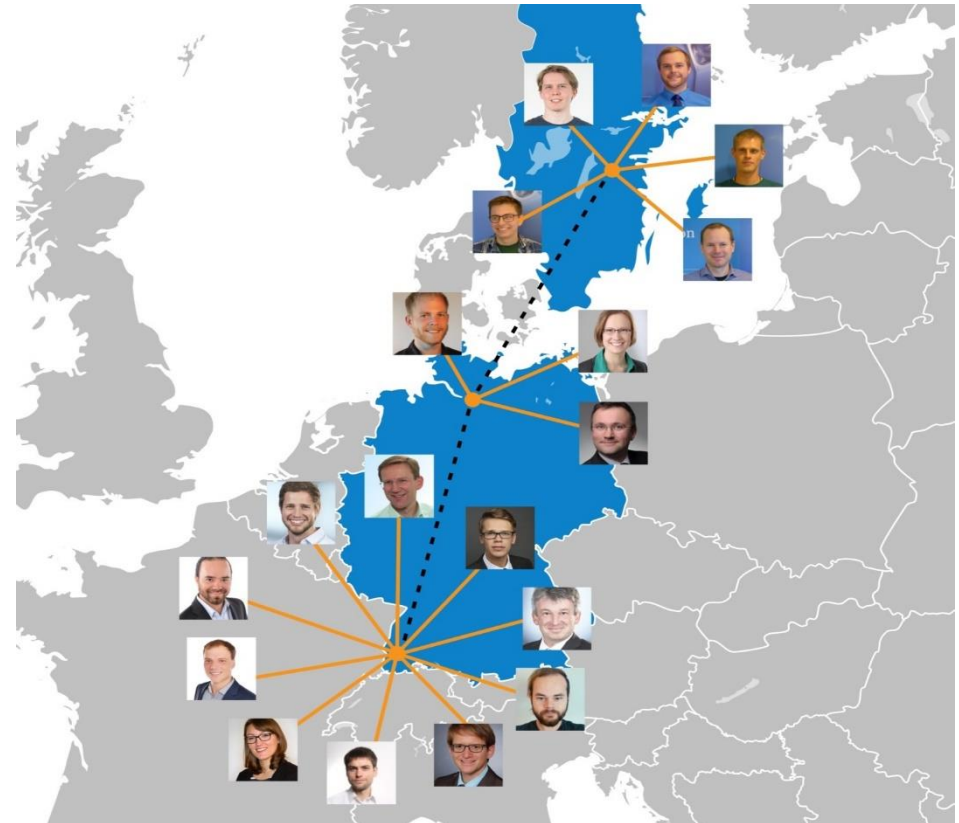


Chart: MIT Technology Review • Source: [arXiv.org](https://arxiv.org) • Created with Datawrapper

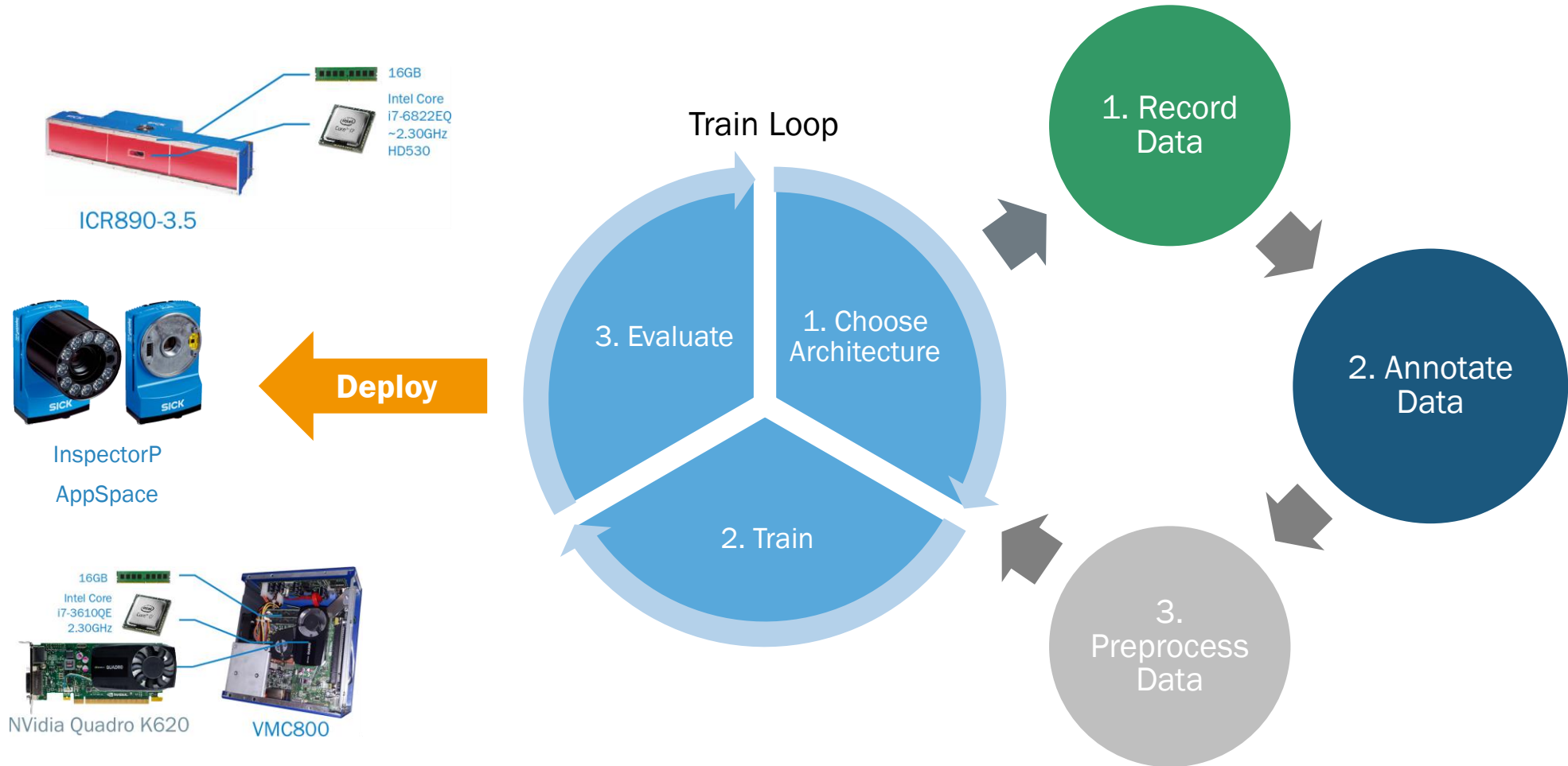
<https://www.technologyreview.com/s/612768/we-analyzed-16625-papers-to-figure-out-where-ai-is-headed-next/>



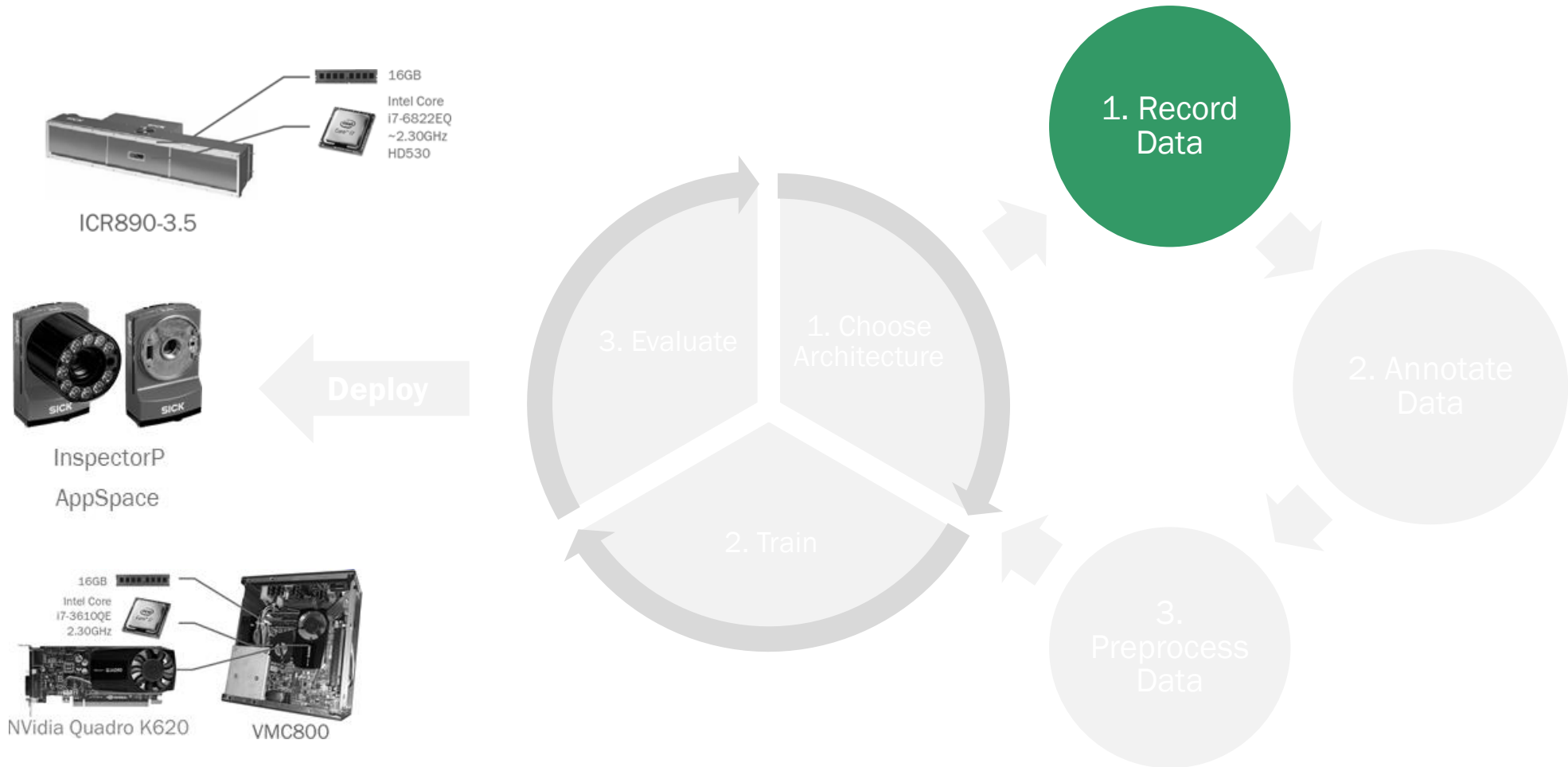
- Expert cluster within SICK for Machine Learning Topics
  - ▶ 20 Persons @3 locations – mostly R&D
  - ▶ Consulting
  - ▶ Pilot studies
  - ▶ Tooling
  - ▶ Student Theses
  - ▶ Marketing



- SICK AG Company Presentation
- **Deep Learning Initiative**
  - ▶ Intro
  - ▶ **Tooling**
- Logistics Applications
- Movidius compute stick
- Master / Bachelor Theses

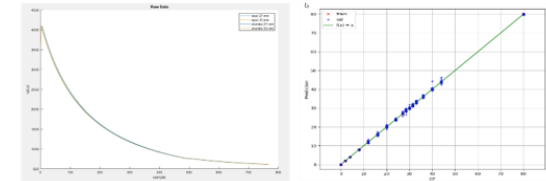




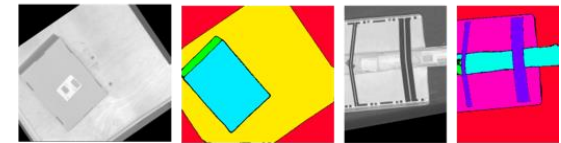


- Deep learning models
  - ▶ Arbitrary data
  - ▶ Multiple data sources
- **Your task:** Record the data!

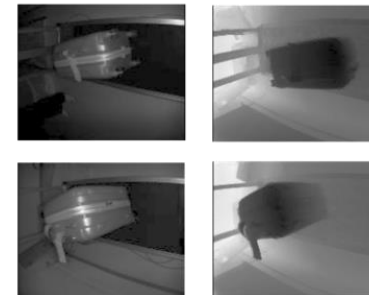
## 1D Data

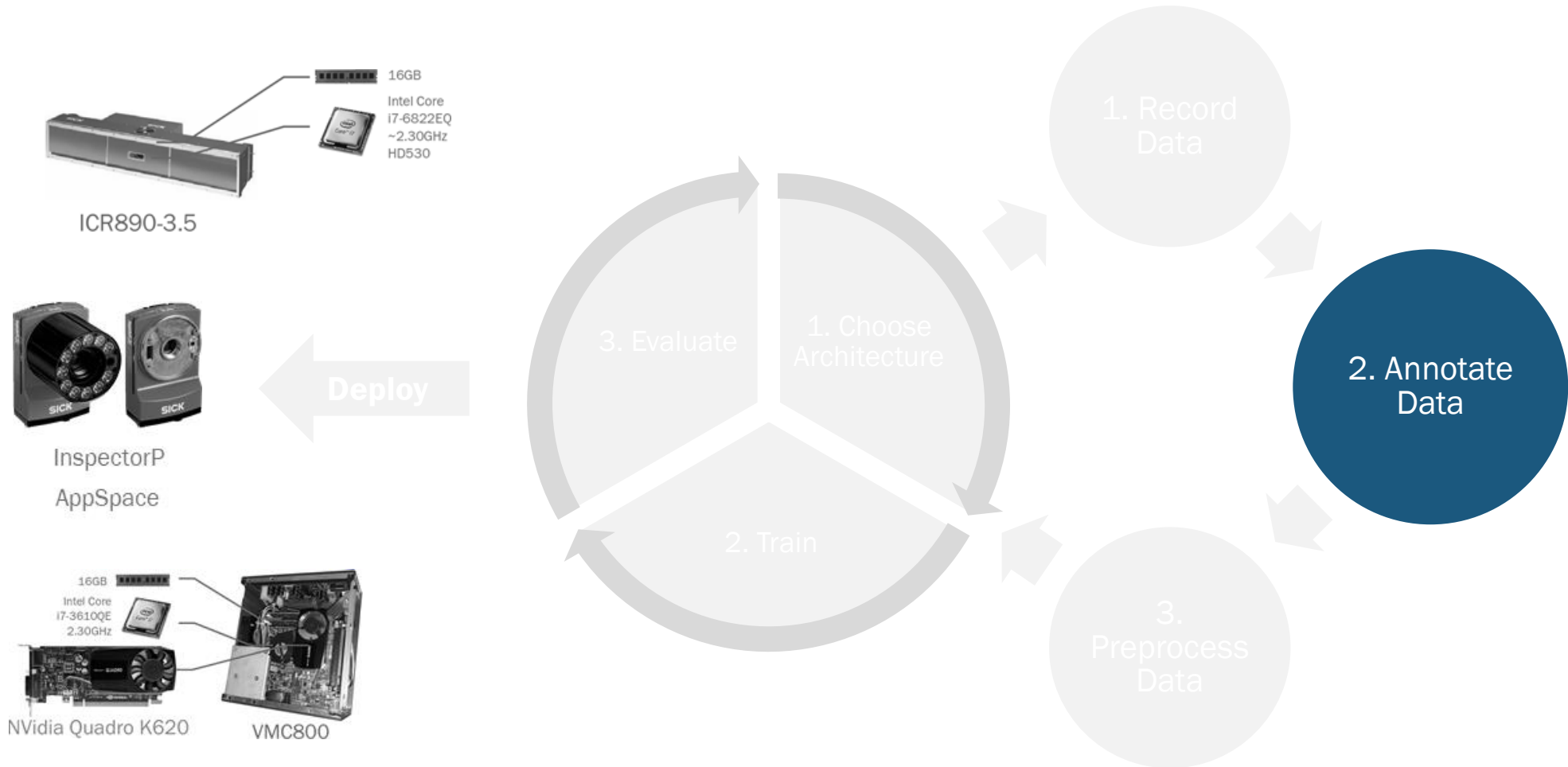


## 2D Data



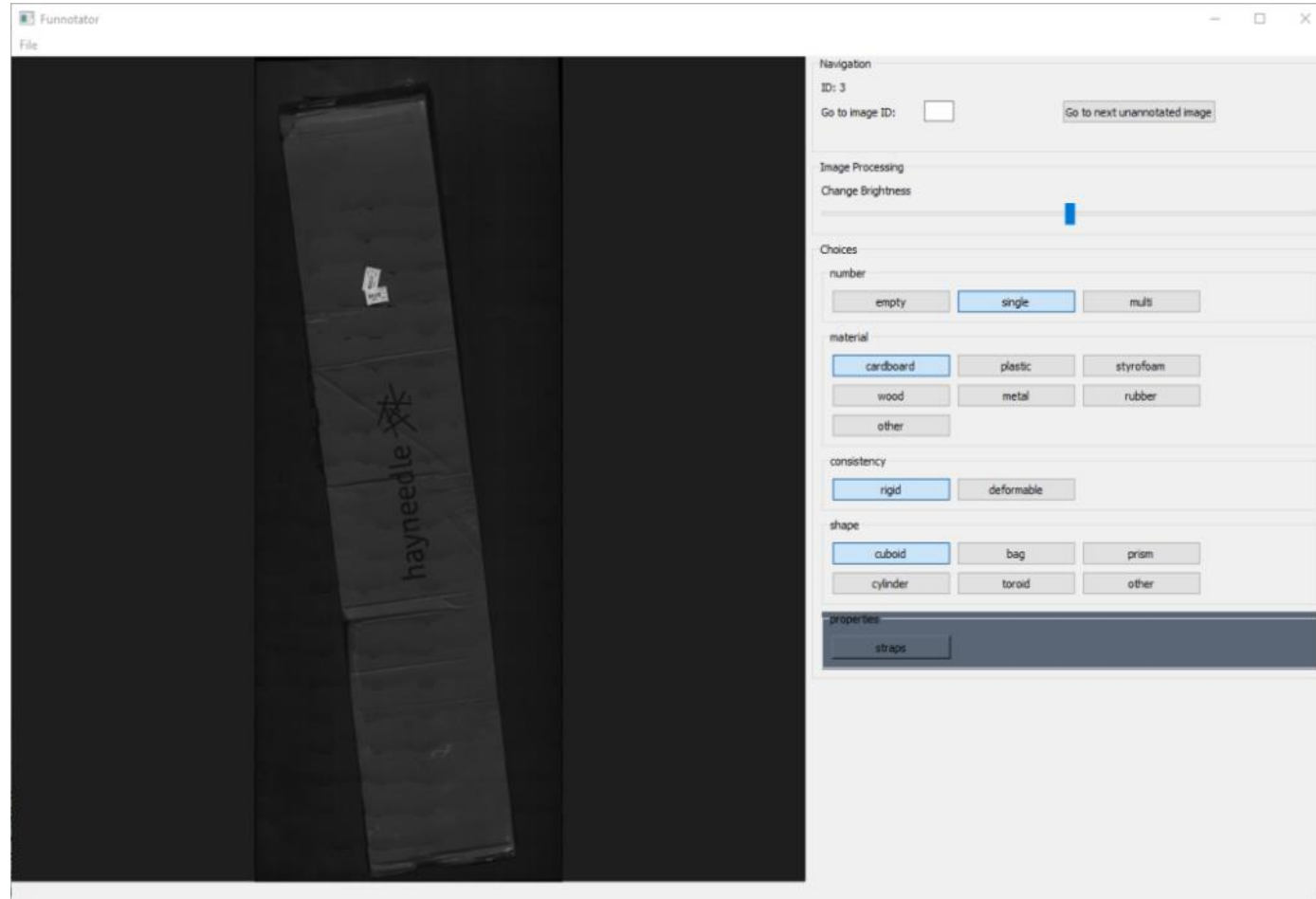
## 2.5D/3D Data







- Label – Annotations
- Minimize Errors
  - ▶ Categories
  - ▶ Image enhancement
- Usability
  - ▶ Custom shortcuts
  - ▶ Concurrent Annotation
  - ▶ Pre-loading of data

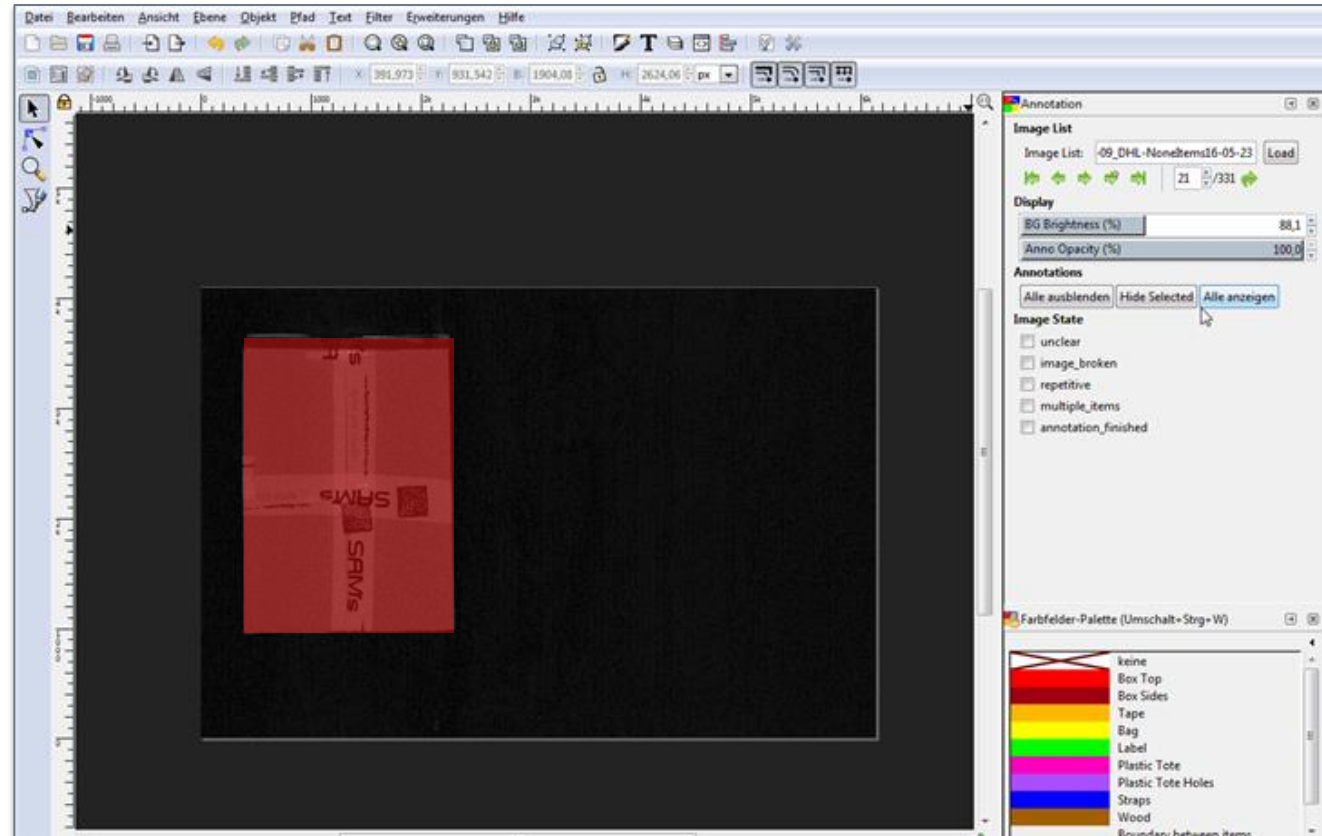


# ANNOTATION

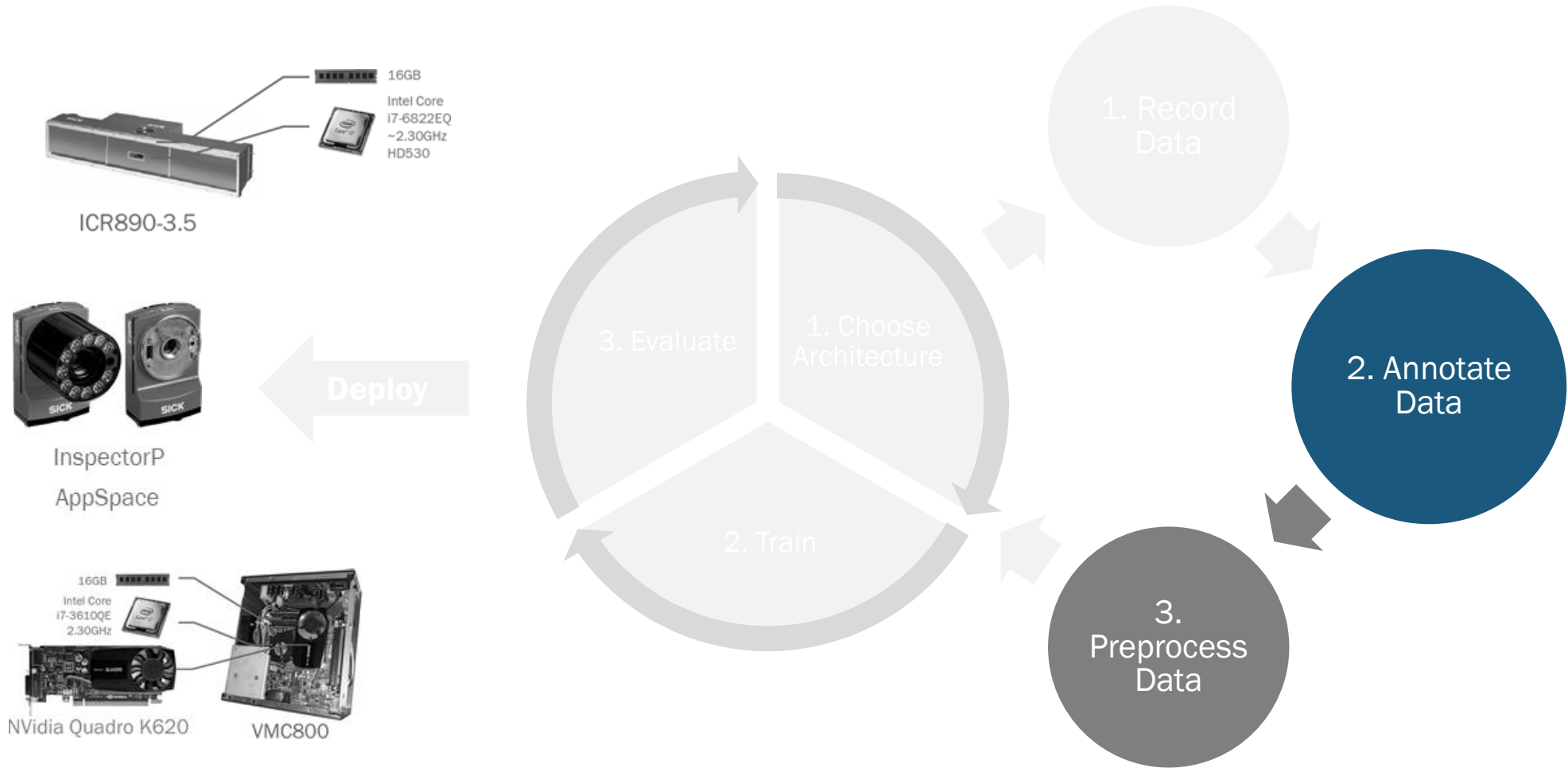
## INKSCAPE ANNOTATOR

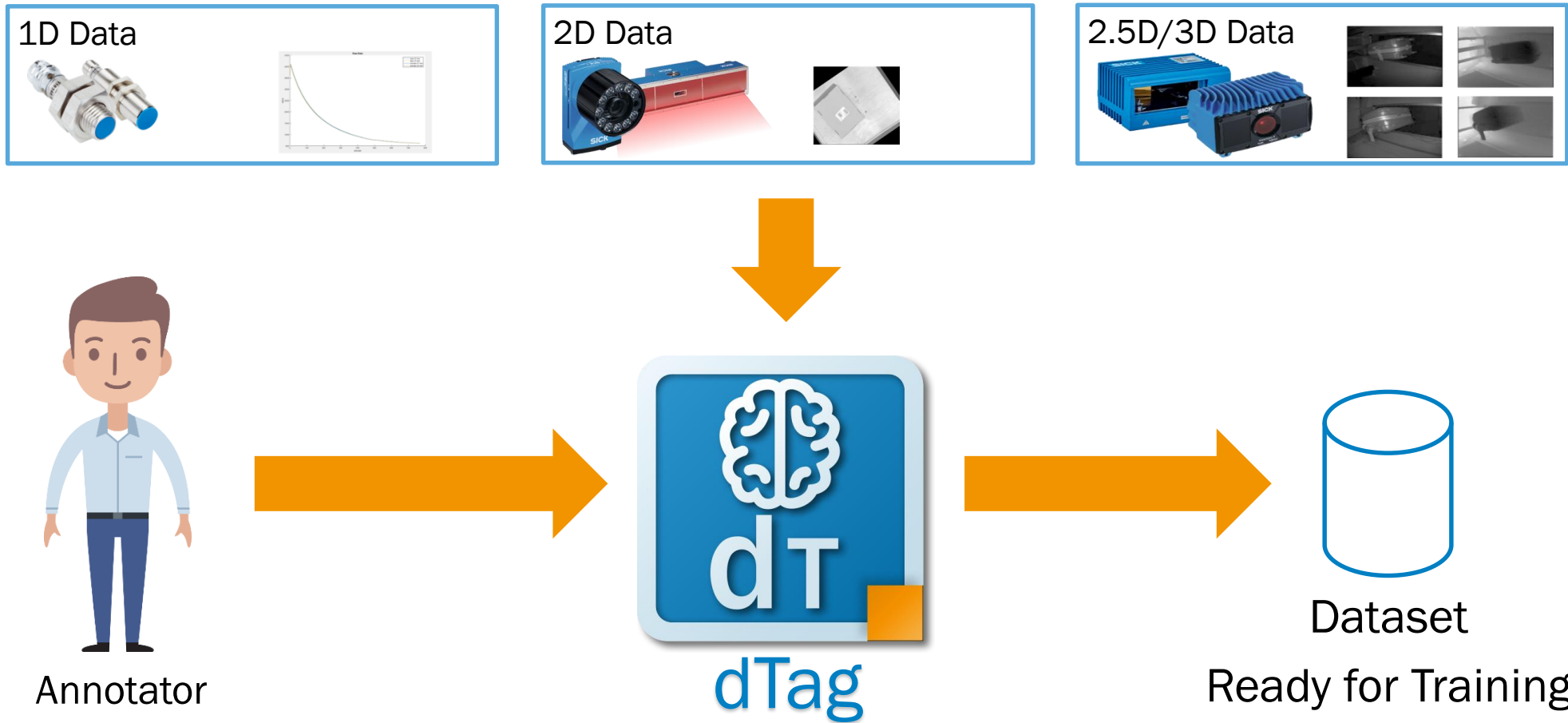


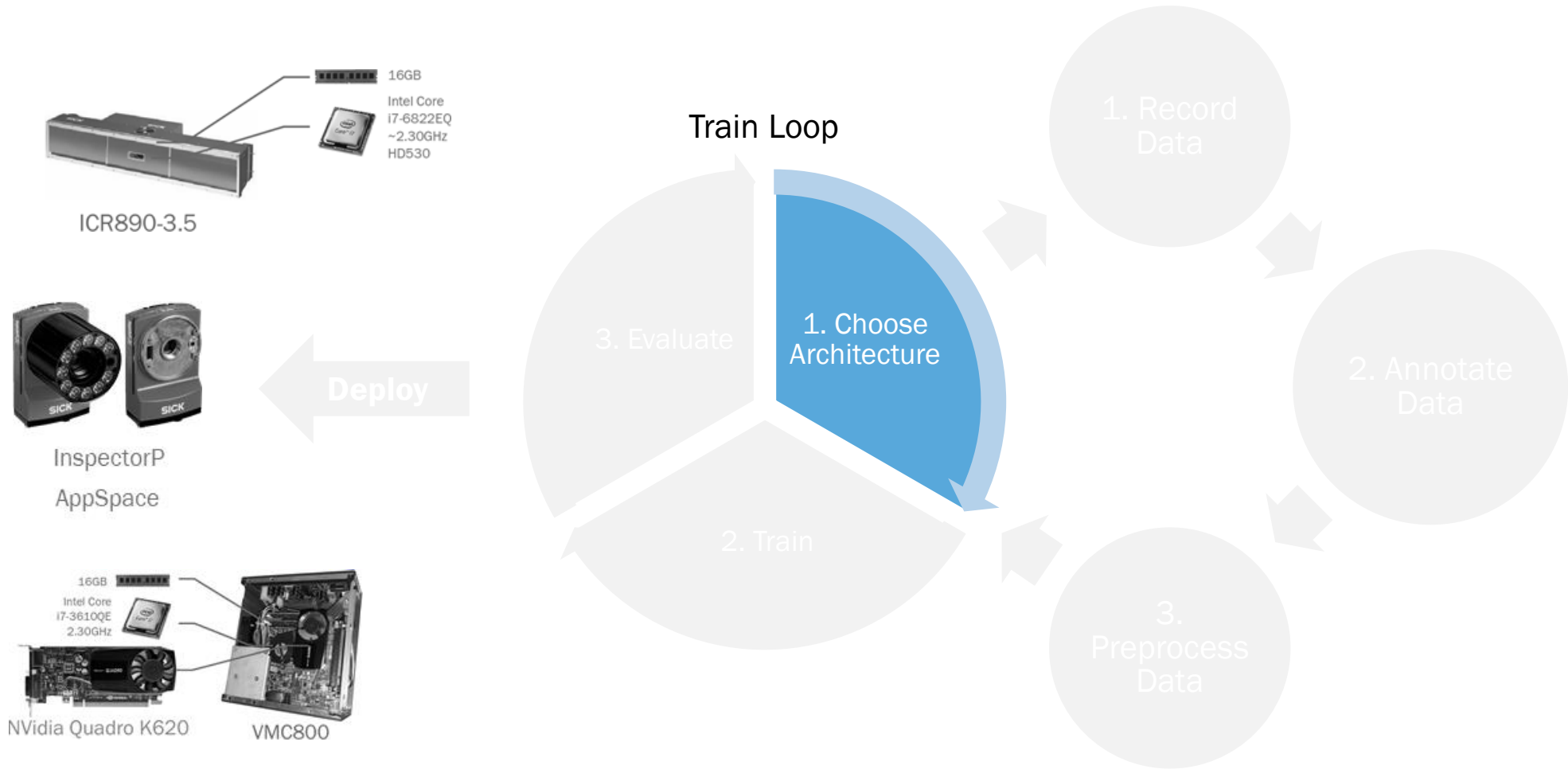
- Segmentation – Annotations
- Minimize Errors
  - ▶ Mark broken images
- Usability
  - ▶ Custom classes
  - ▶ Zooming & Transparency

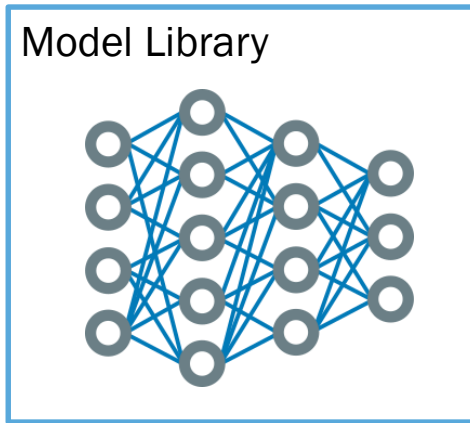












### Classification

95% <b>Single</b>	1% <b>Single</b>
5% <b>Multi</b>	99% <b>Multi</b>

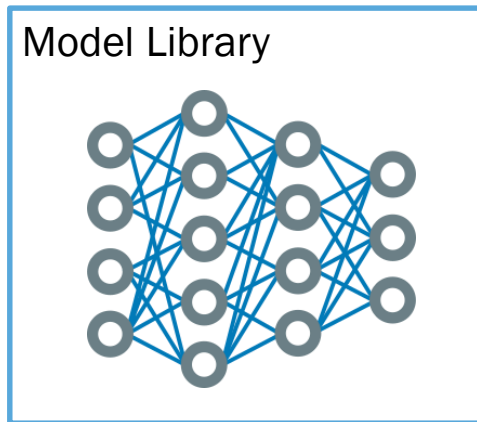
### Detection

### Segmentation

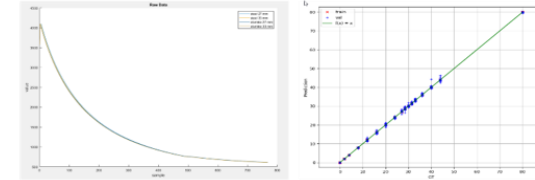
### Anomaly Detection

# MODEL LIBRARY

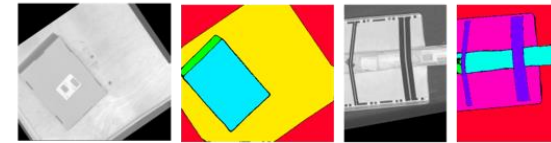
## INPUT MODALITY



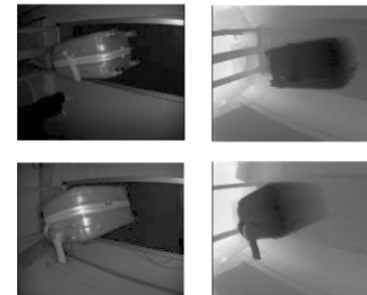
### 1D Data



### 2D Data

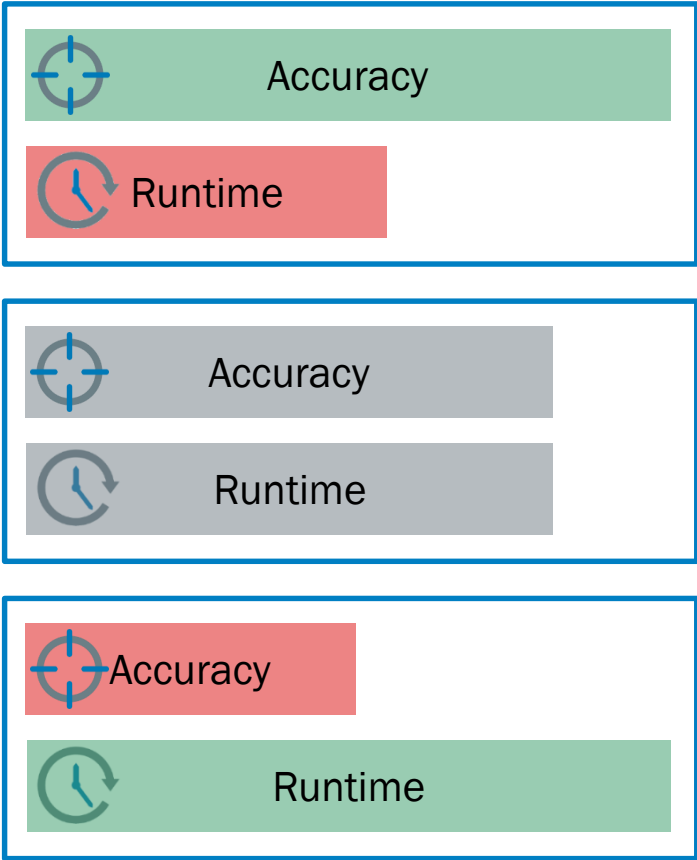
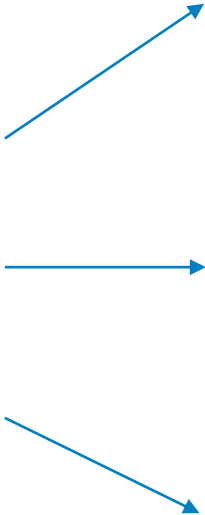
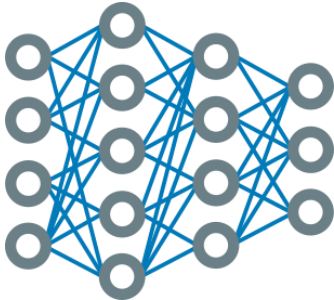


### 2.5D/3D Data

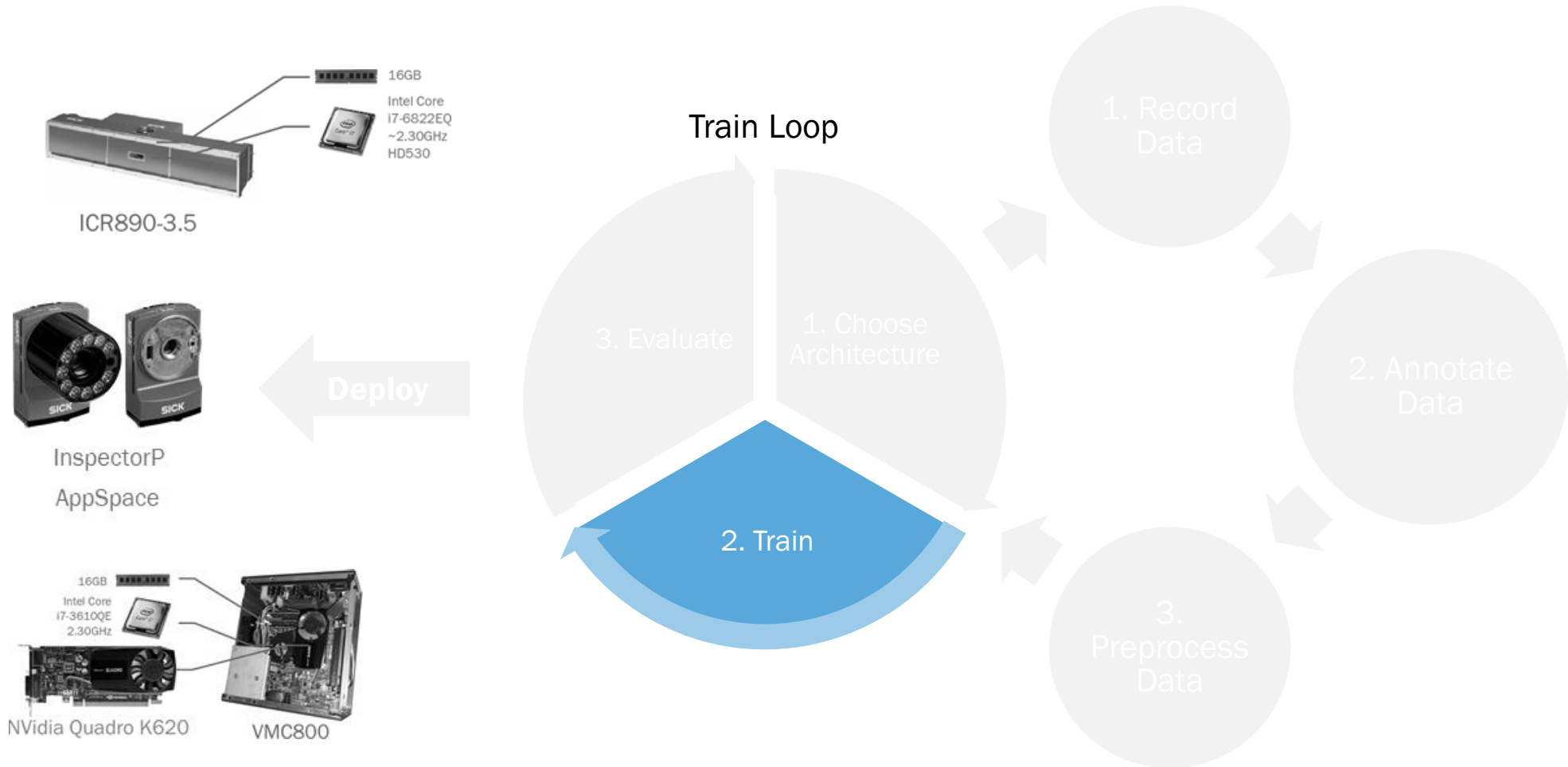


# MODEL LIBRARY BENCHMARKING

Model Library









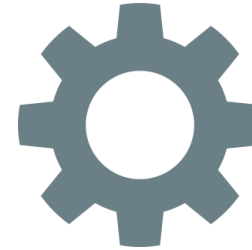
dLearner



Using TensorFlow



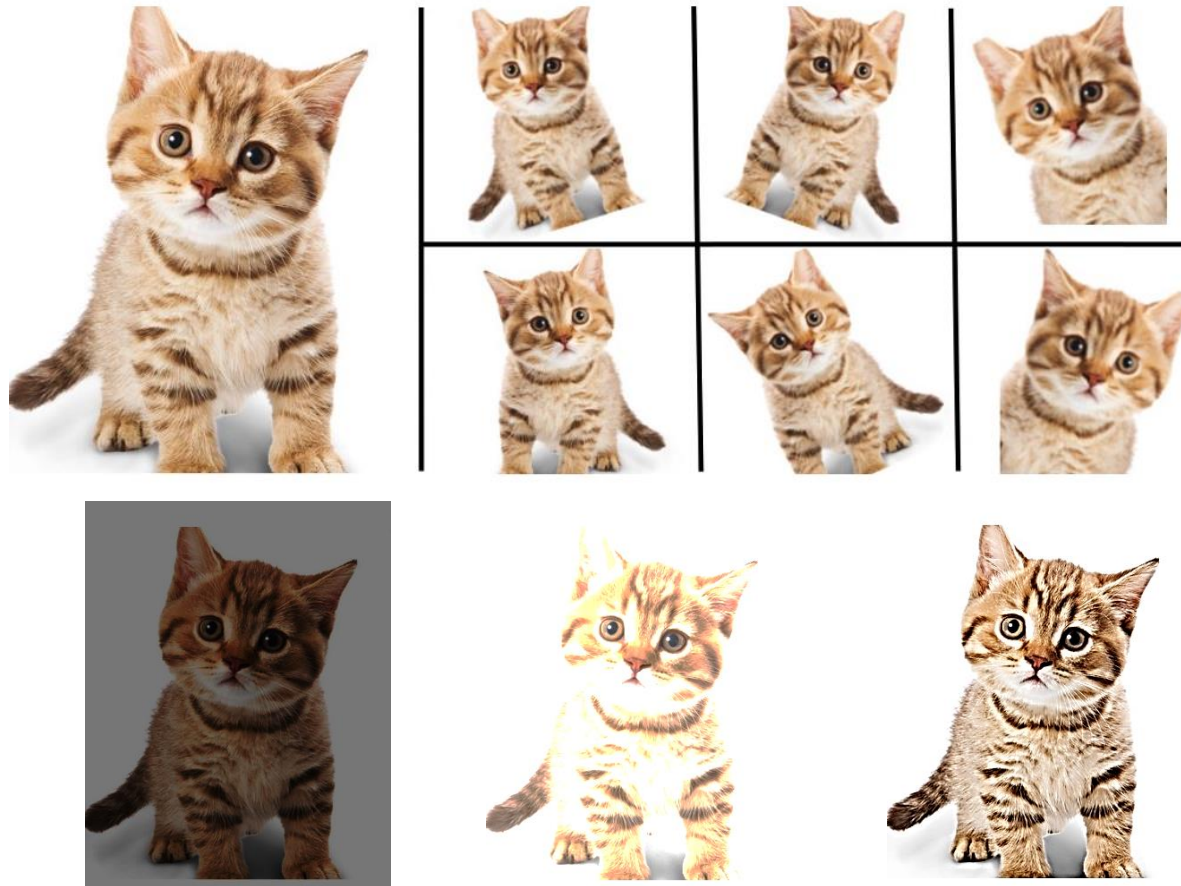
- `dlearner train`
- Interrupt/resume training
- Finetuning of models
  - ▶ Save time on training

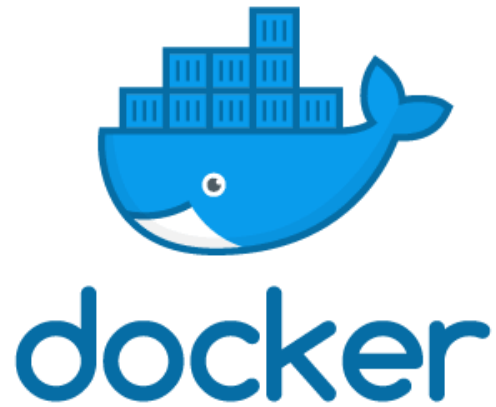


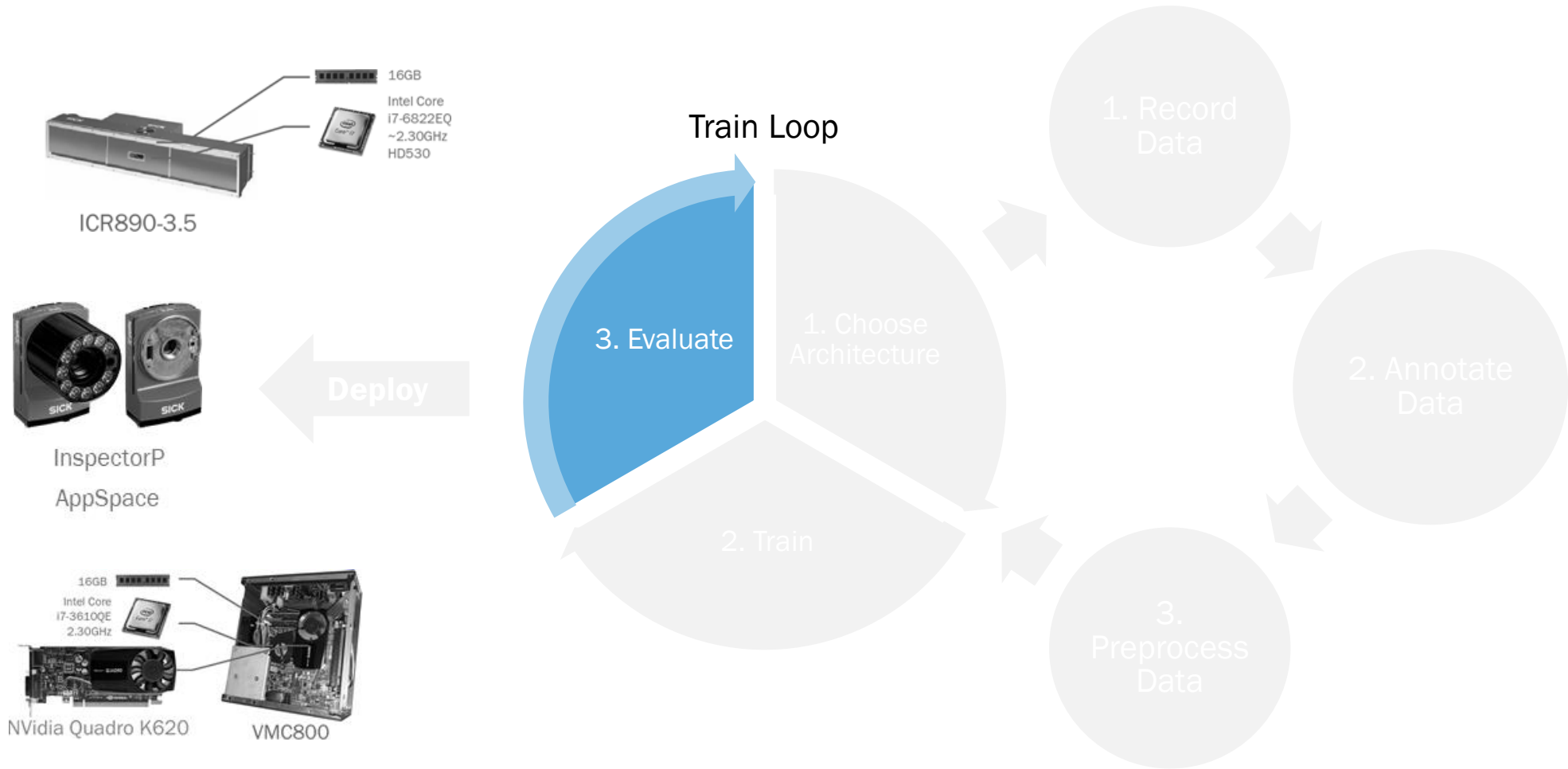
- Advanced configuration
- Advanced dataset combinations
- Custom models
- Custom input or output modality
- Augmentations

# TRAINING

## 2D ONLINE AUGMENTATIONS

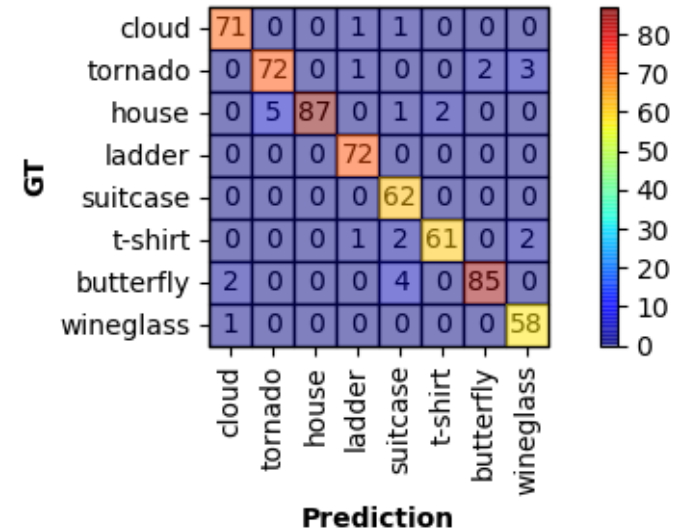
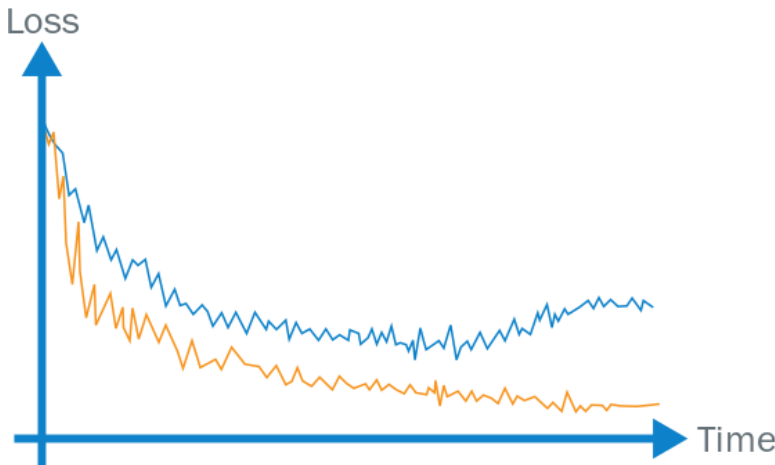




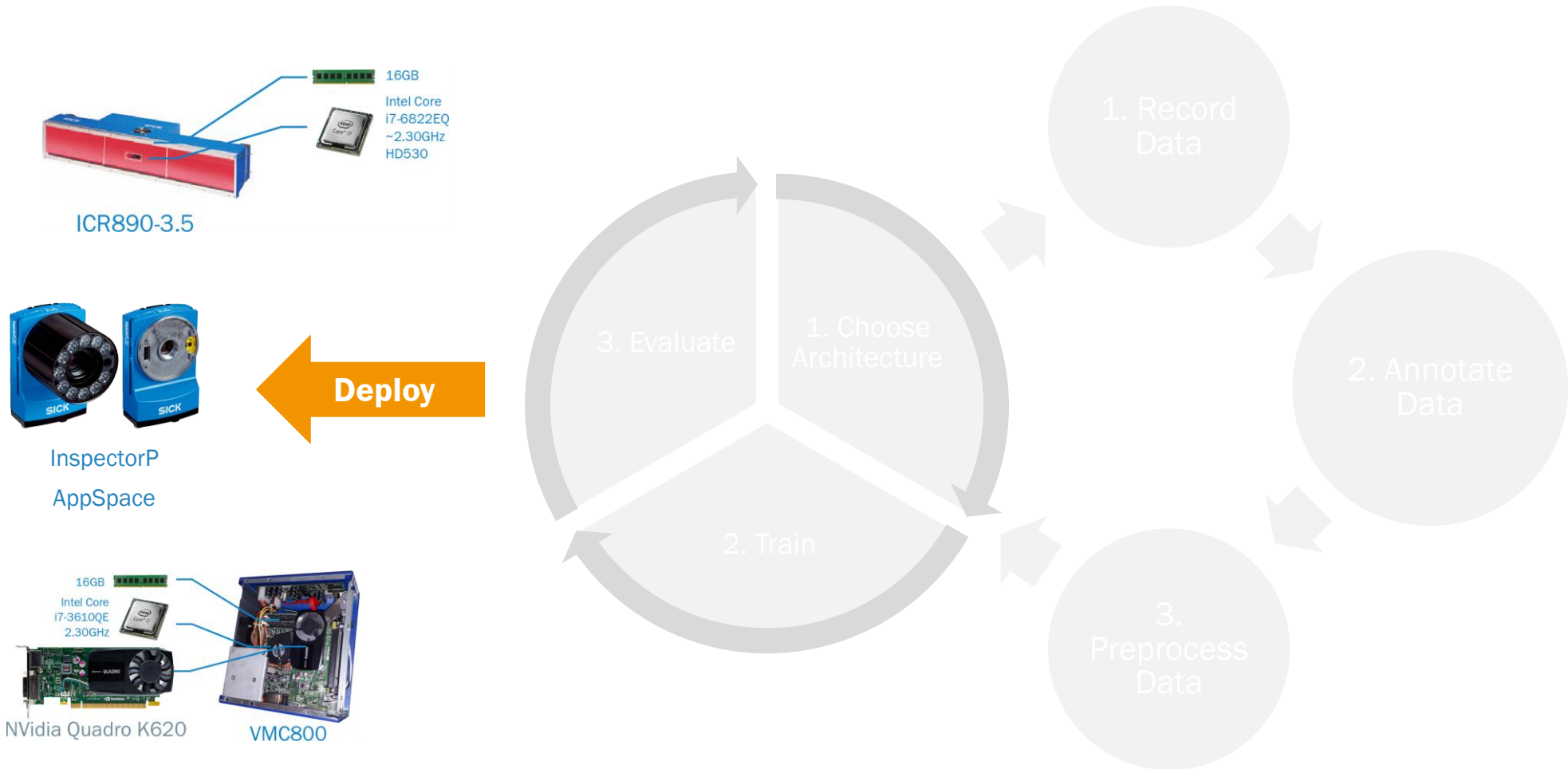


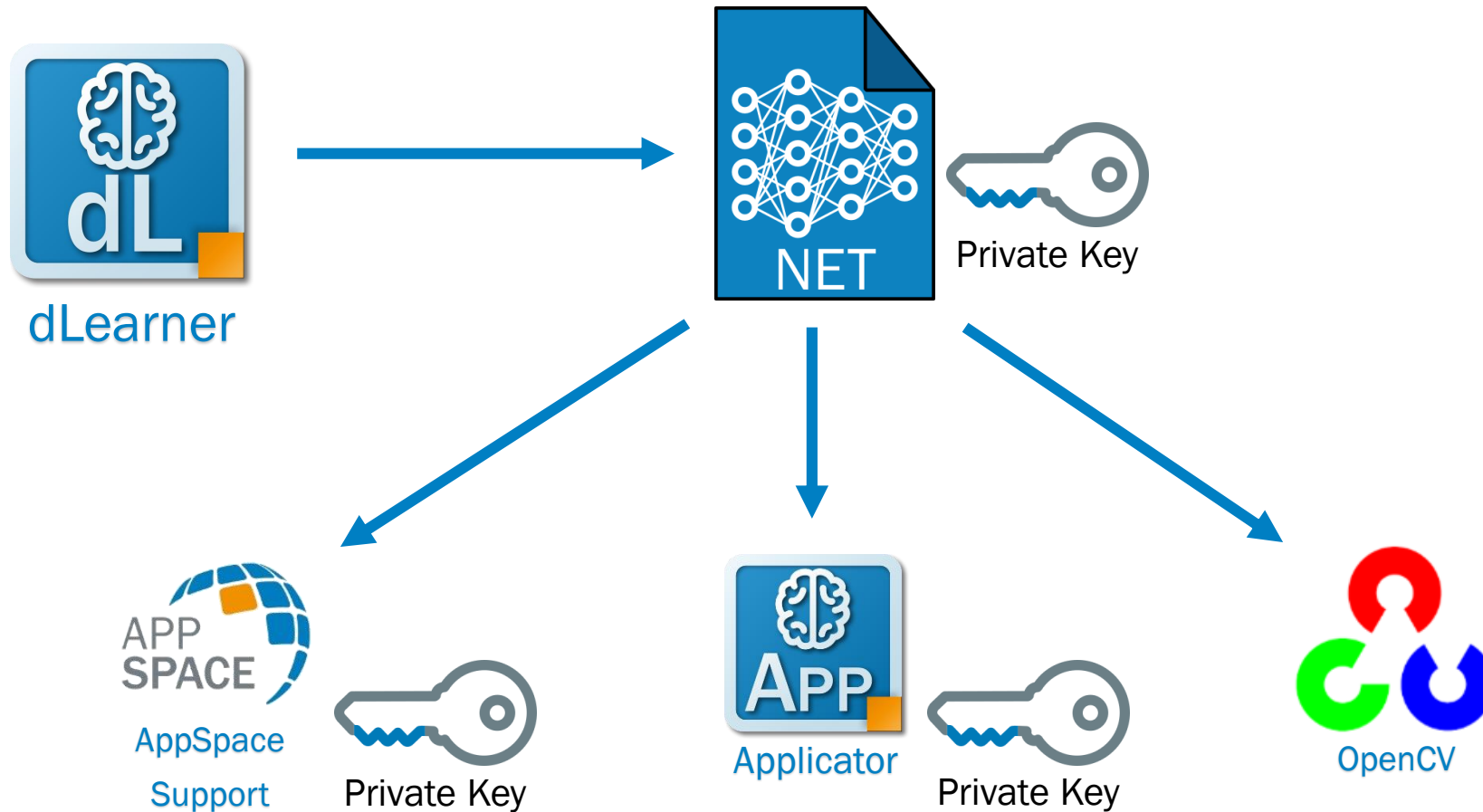
- Monitor training
  - Performance analysis on validation data
    - ▶ Runtime
    - ▶ Accuracy
- Test on samples

Accuracy overall = 95.3%  
 cloud = 97.3%  
 tornado = 92.3%  
 house = 91.6%  
 ladder = 100.0%  
 suitcase = 100.0%  
 t-shirt = 92.4%  
 butterfly = 93.4%  
 wineglass = 98.3%









ICR8903  
OpenCV

16GB  
Intel Core  
i7-6822EQ  
~2.30GHz  
HD530

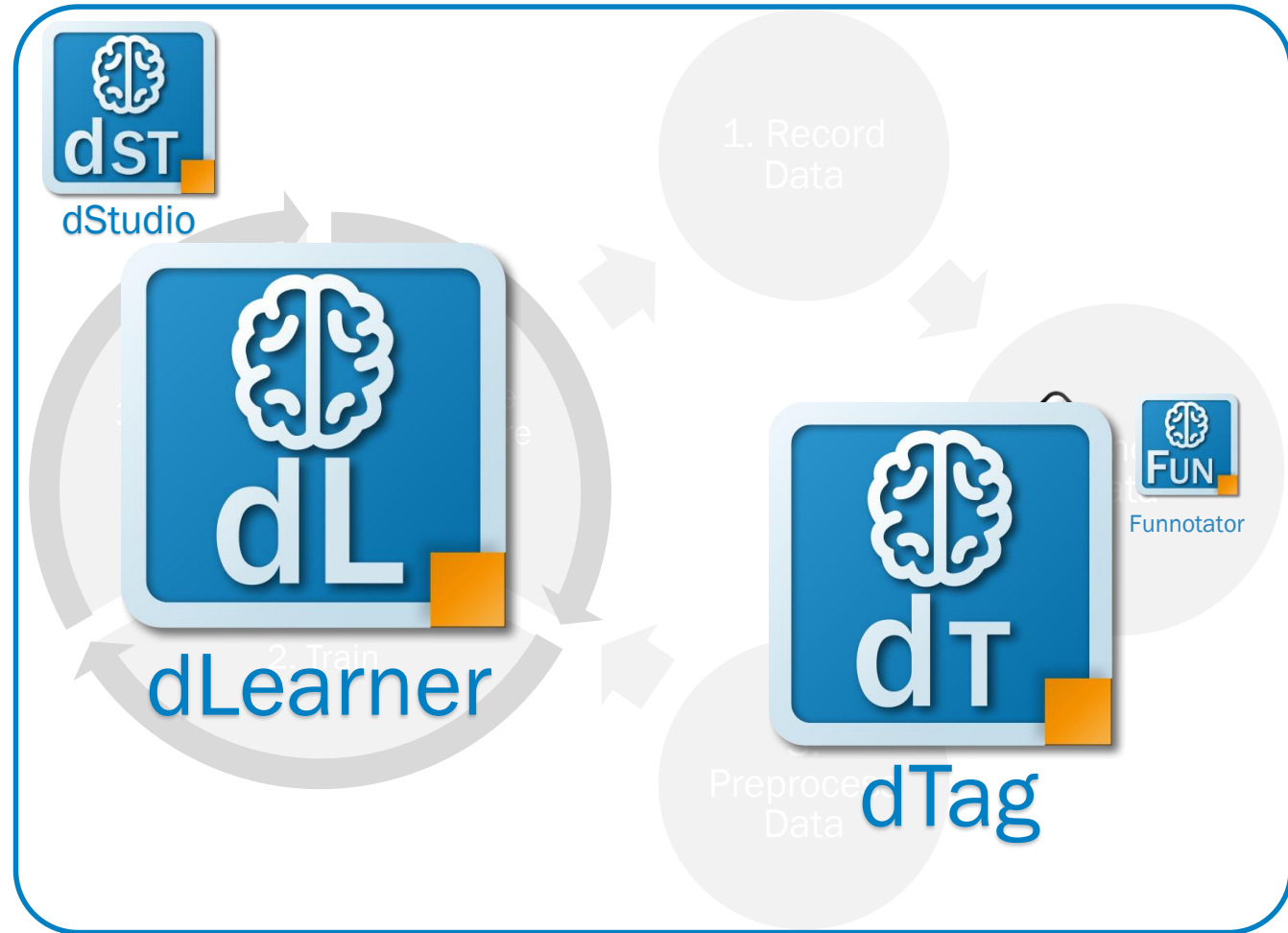
InspectorP  
AppSpace

APP SPACE  
AppSpace  
Support

16GB  
Intel Co  
i7-3610Q  
2.30GHz

APP  
Applicator

NVidia Quadro K620  
VMC800



THANKS FOR THE ATTENTION.

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# INTRODUCTION LOGISTIC AUTOMATION

## PARCEL SORTING TUNNEL

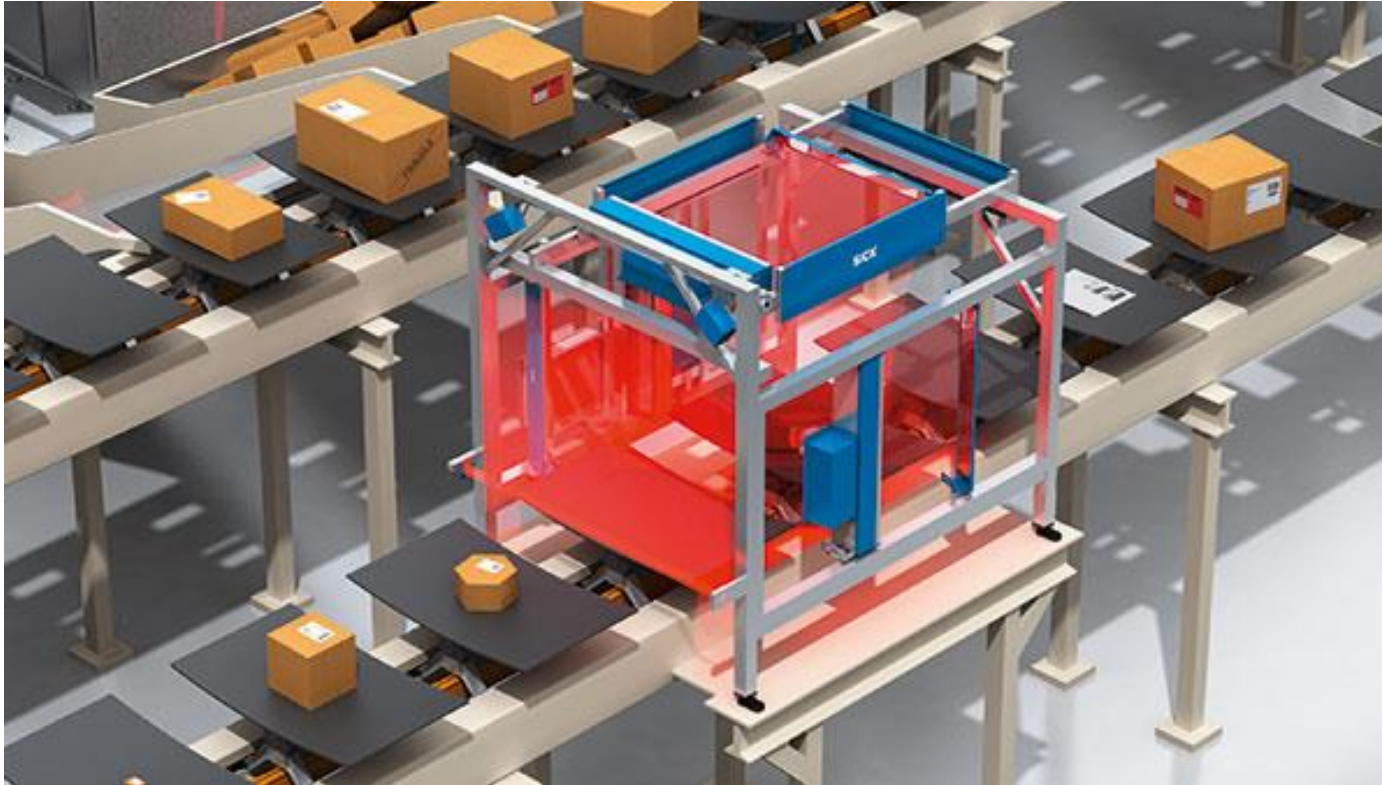
DHL Germany sorts 12 Mio parcels per day





# INTRODUCTION LOGISTIC AUTOMATION

## PARCEL SORTING TUNNEL



- Barcode reading
- Image lift for OCR/VC and archiving
- Dimensioning
- Weighing
- Additional image processing functions

# INTRODUCTION LOGISTIC AUTOMATION

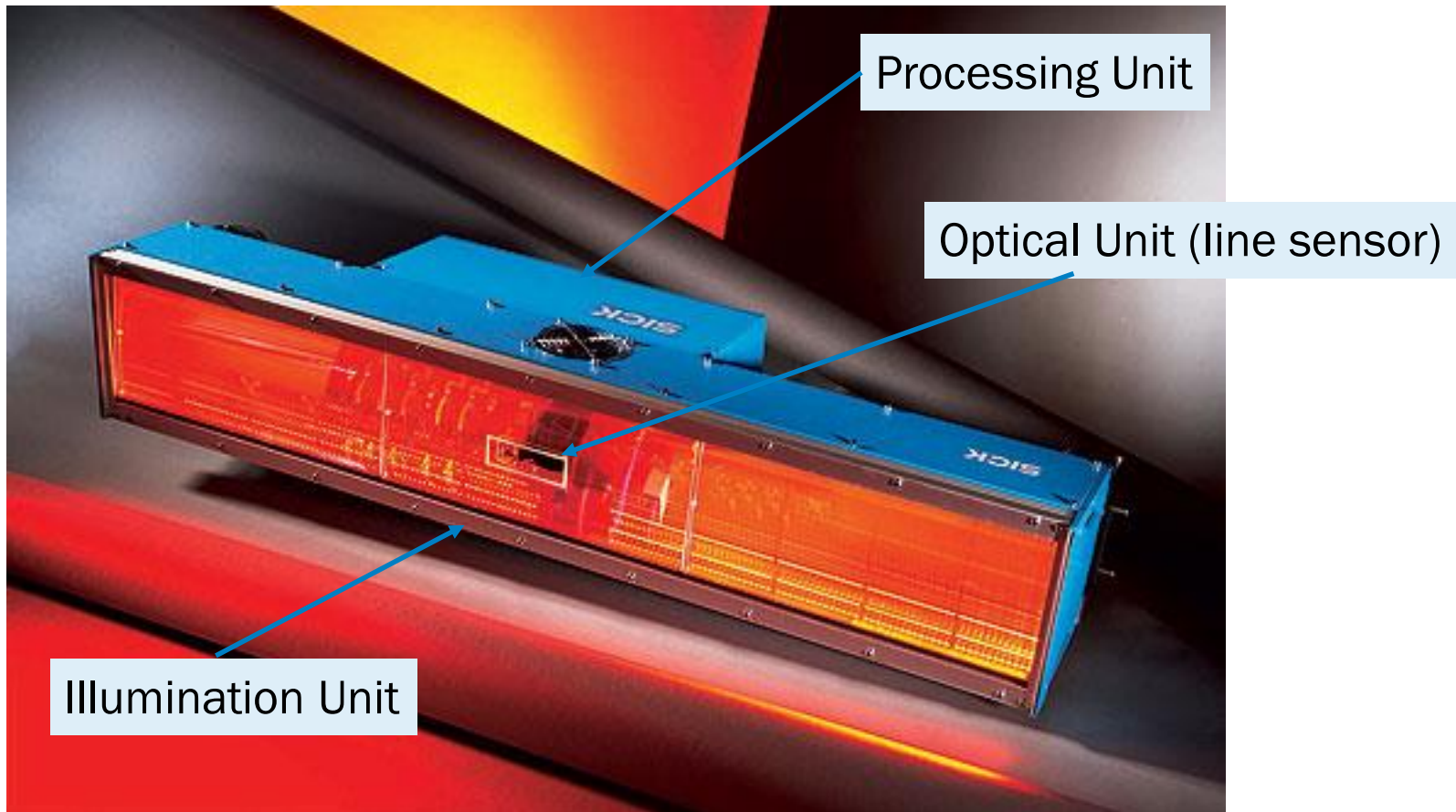
## PARCEL SORTING CAMERA



# INTRODUCTION LOGISTIC AUTOMATION

## PARCEL SORTING CAMERA

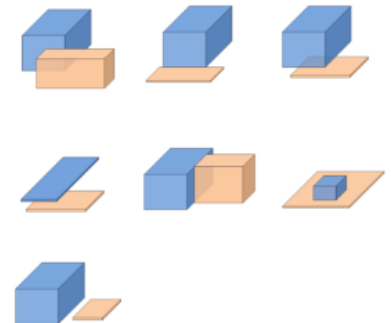
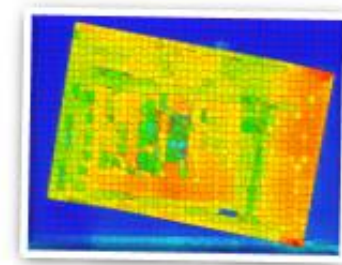
- ICR890 has a 8k/12k line sensor
- ICR890 has an autofocus unit
- ICR890 weight 35Kg
- ICR890 has length of 110cm



# INTRODUCTION LOGISTIC AUTOMATION

## AGENDA

- Dangerous Goods Detection
- Flat Object Profiling
- Single Item Verification
- Object Classification





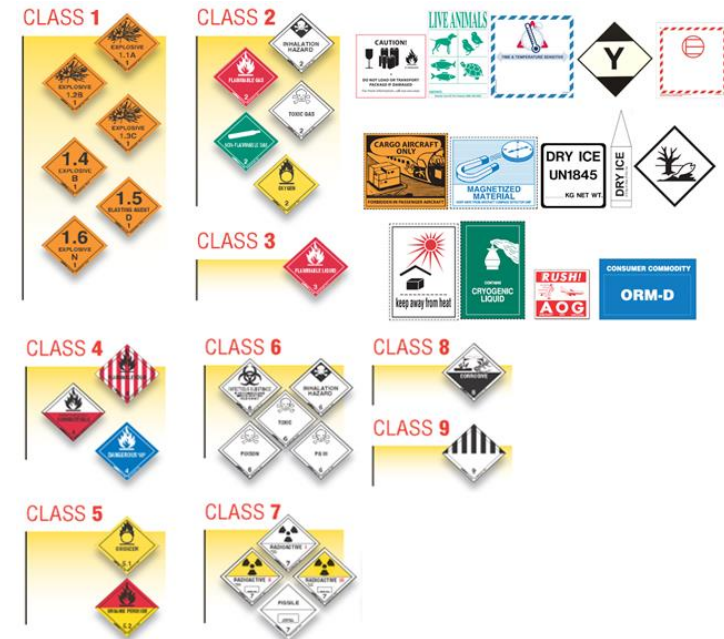
# INTRODUCTION LOGISTIC AUTOMATION

## DANGEROUS GOODS DETECTION



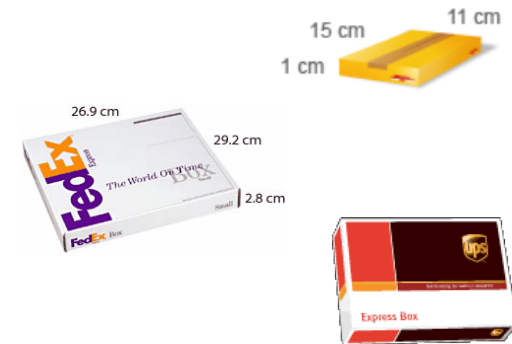
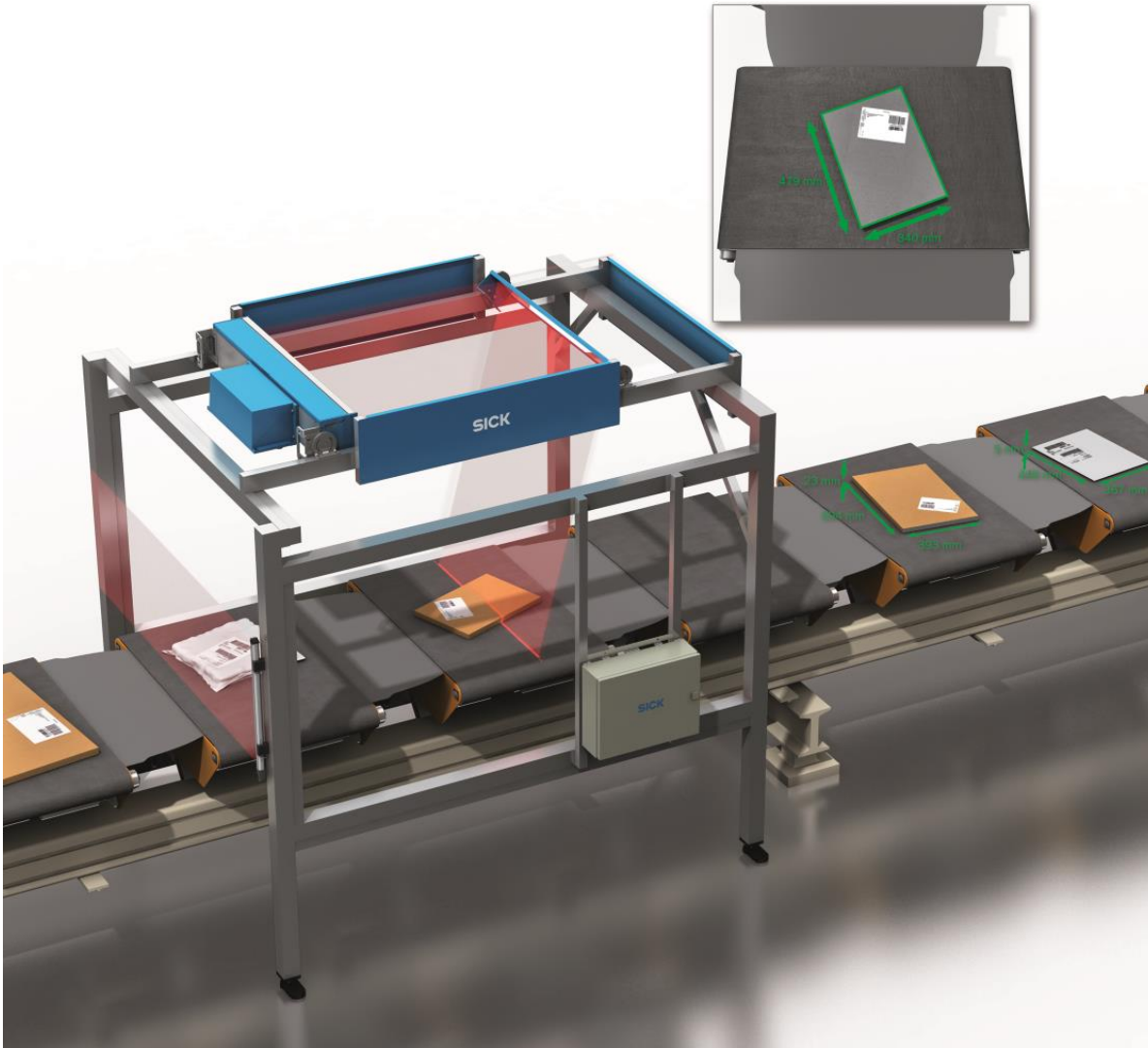
### Trends:

- **Automatic unloading**
- **Stronger Regulations for Dangerous Goods**
- **Audits at retailers and CEP service providers**



# INTRODUCTION LOGISTIC AUTOMATION

## FLAT OBJECT PROFILING



### Dimensioning:

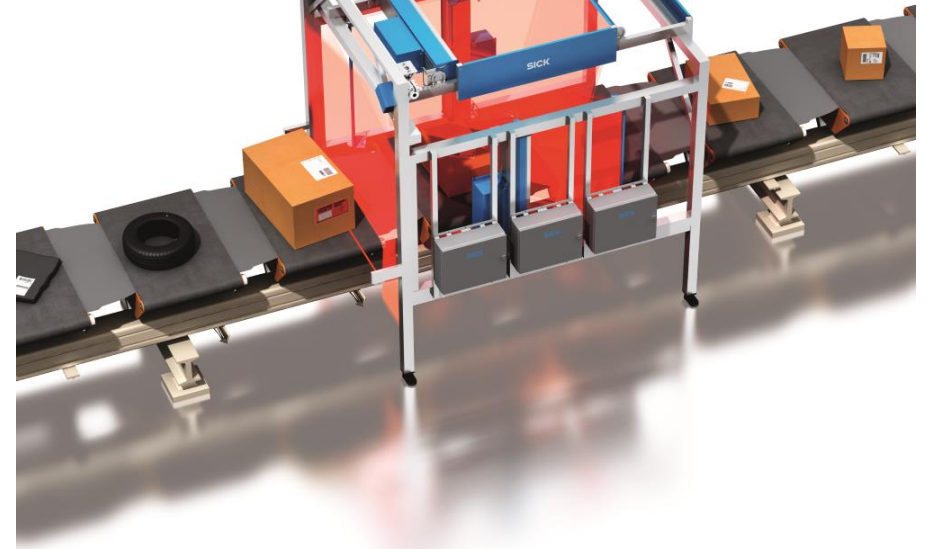
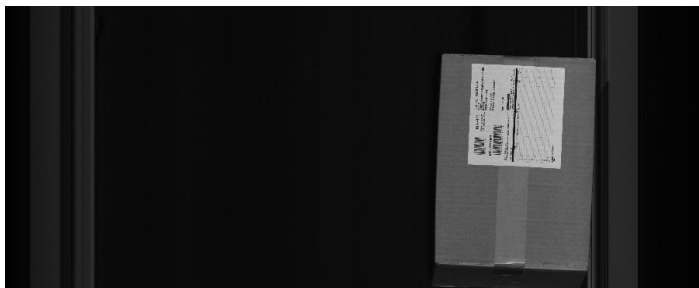
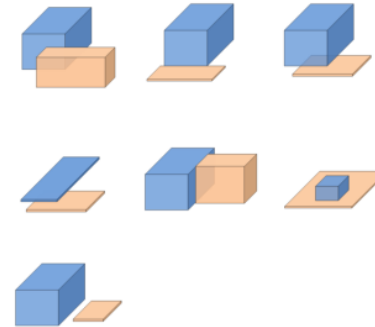
- **On cross-belt sorters and belts**
- **MLG + special ICR890 firmware**
- **Minimal objects: 100 x 50 x 5 mm**
- **Accuracy 5/5/5**
- **Around 50 systems installed**



# INTRODUCTION LOGISTIC AUTOMATION

## SINGLE ITEM VERIFICATION

- Classify single or multiple objects in CEP for sorting
- Directly in ICR890-3,5 camera
- Customer benefit:
  - ▶ Verification of singulation process
  - ▶ Delete LFT-dimensioning for multi



# INTRODUCTION LOGISTIC AUTOMATION

## OBJECT CLASSIFICATION

### Measureable characteristics:

- Object materials (cardboard, plastic, styrofoam etc.)
- Bag / Box
- Packaging straps
- Single / Multi
- Totes / Trays
- Missing parts (components, packaging)



### Customer benefits:

- Portfolio analytics (process optimization)
- Quality inspection
- Revenue recovery
- Process verification



Bag

Box

Singl

Mult

Packaging strap

Tote

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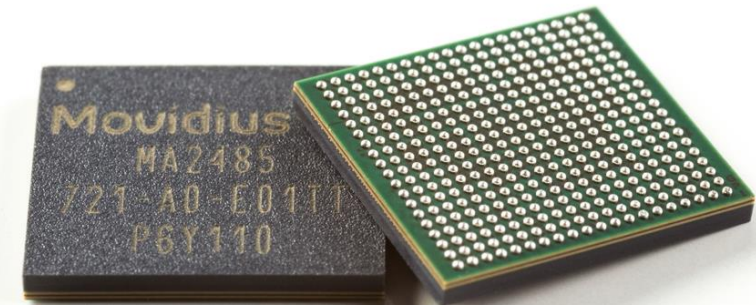
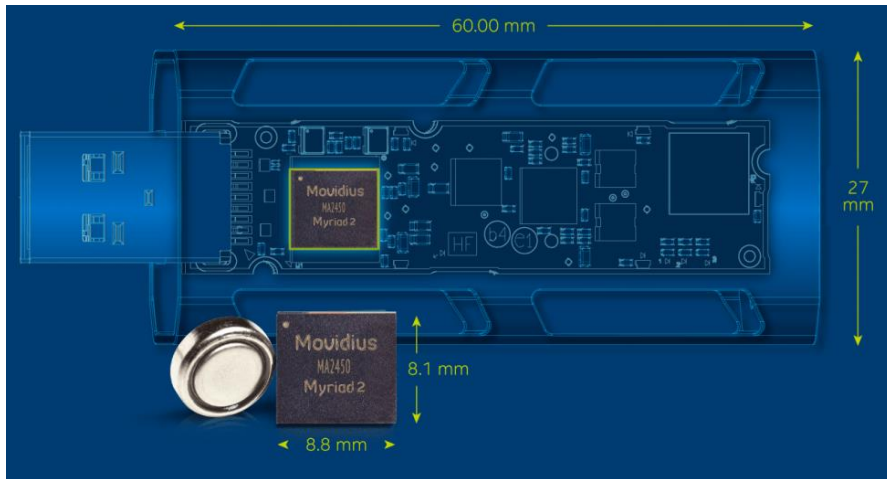
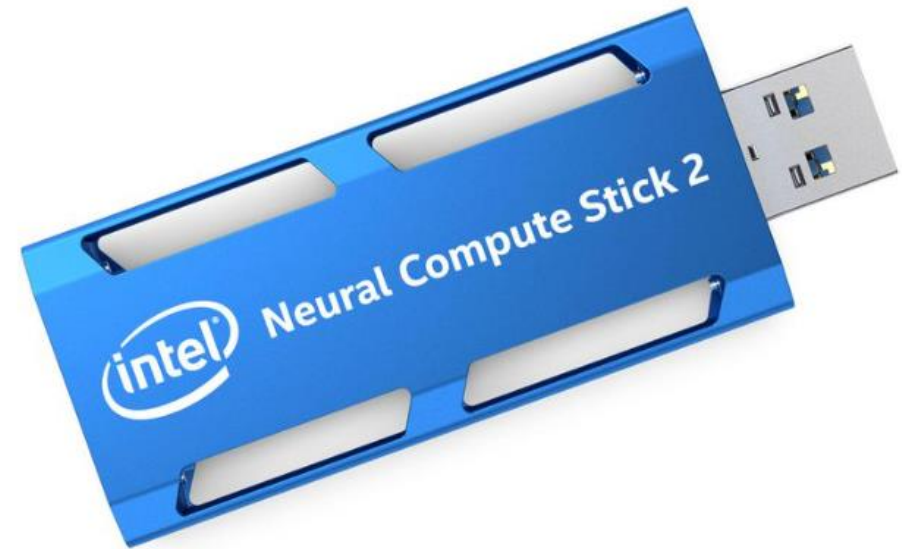
## The Hardware

## The Intel® Neural Compute Stick 2 (NCS2)

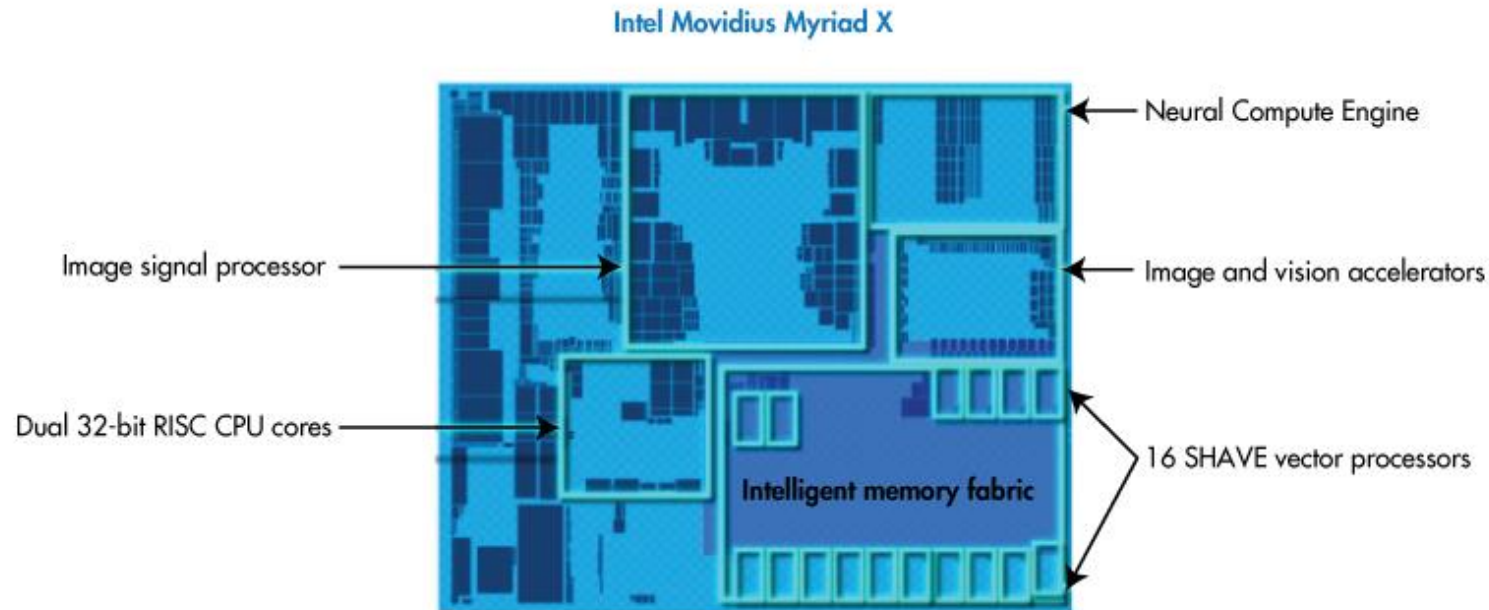
Interfaces: USB 3.1

Power: 1,5W

Price Stick: 95€



Intel® Movidius™ Myriad™ X VPU 2485,  
(VPU) *Vision Processing Unit*



Intel® Movidius™ Myriad™ X VPU 2485

16 VLIW-128-Bit-Units (*Verry Long Instruction Word*)

2,5 MB Cache

Integrated 4 GBit LPDDR Ram

Bandwidth 450MB

Interfaces: USB 3.1, PCIe gen3

Power: 1,5W

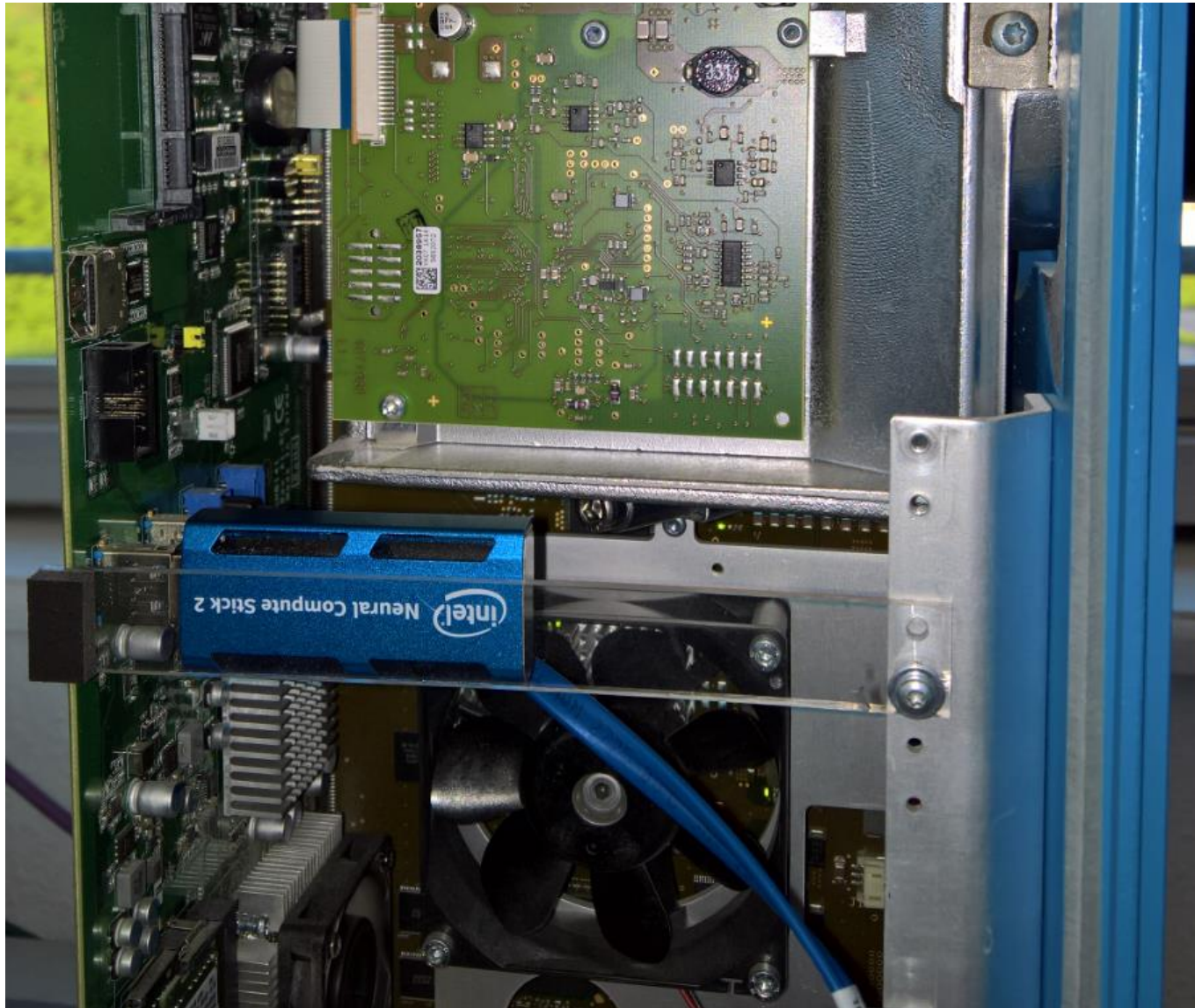
Operating temperature: 0°C – 40°C

Price: >10\$



# DEEP LEARNING TO GO

## INTRODUCING VPU



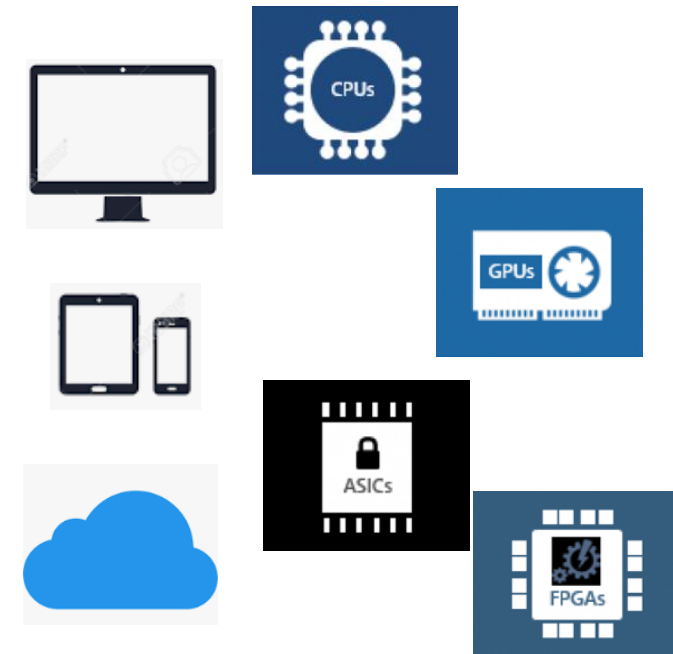


## **The Inference Framework**

# How to reuse pre-trained models on an application?



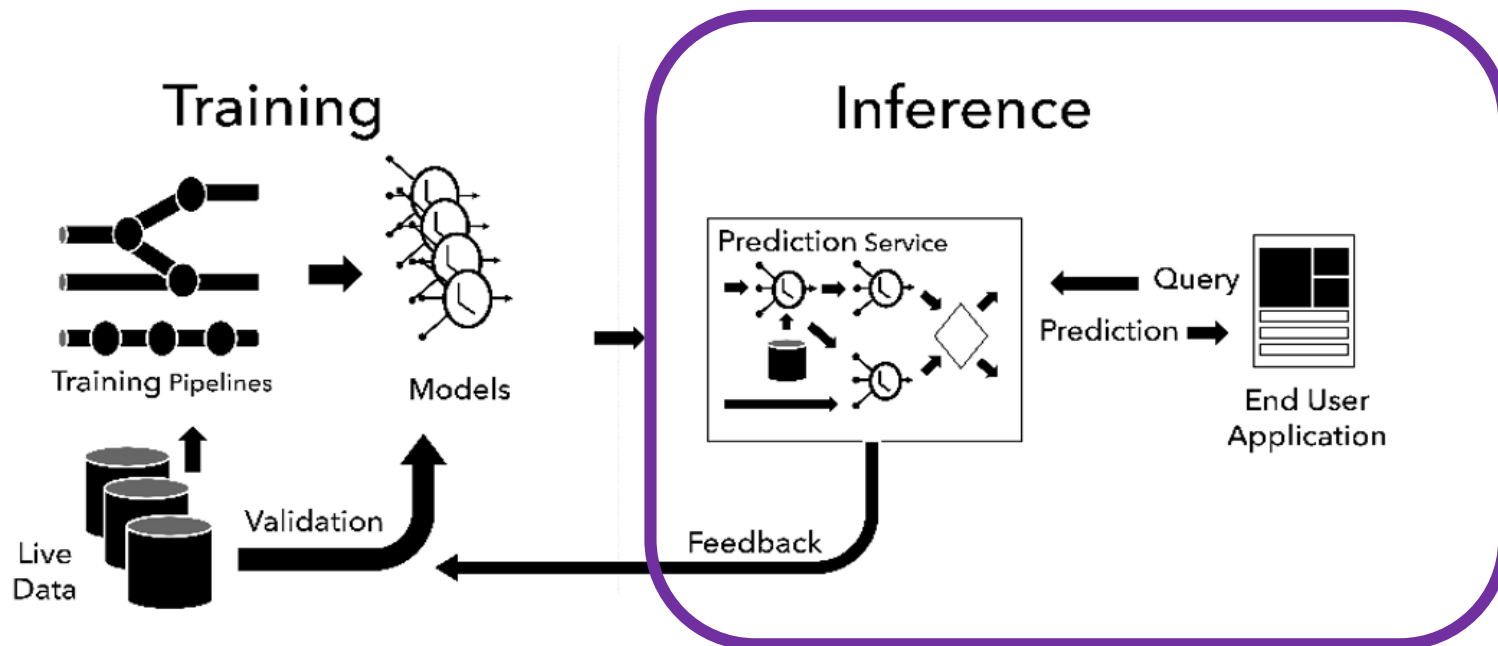
Pre-trained Models



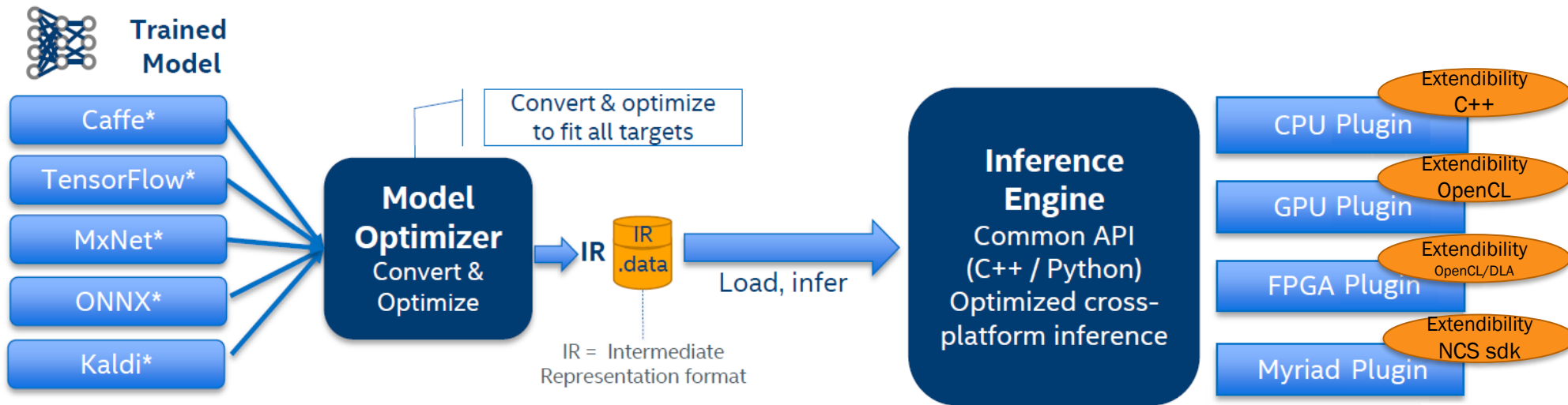
Our application?

# OpenVINO™

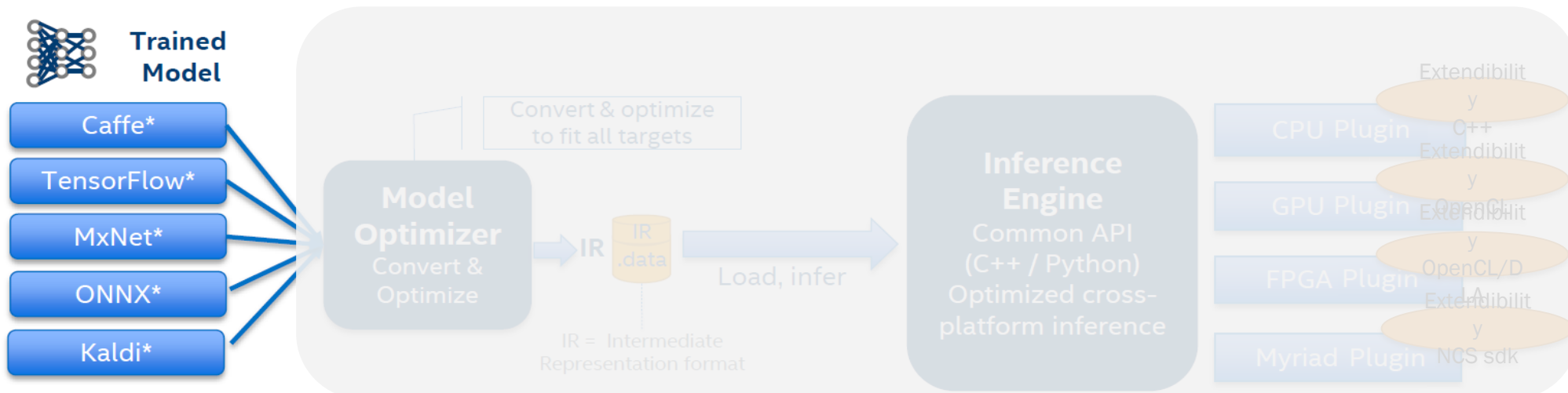
Intel **OpenVINO** Toolkit = **Open** Visual Inference & **Neural** network **O**ptimization



It is not a training toolkit - it is an inference toolkit



- Enables CNN-based deep learning inference on the edge
- Supports heterogeneous execution across an Intel® CPU, Intel® Integrated Graphics, Intel® FPGA, Intel® Movidius™ Neural Compute Stick, Intel® Neural Compute Stick 2 and Intel® Vision Accelerator Design with Intel® Movidius™ VPUs
- Speeds time-to-market via an easy-to-use library of computer vision functions and pre-optimized kernels
- Includes optimized calls for computer vision standards, including OpenCV\*, OpenCL™, and OpenVX\*

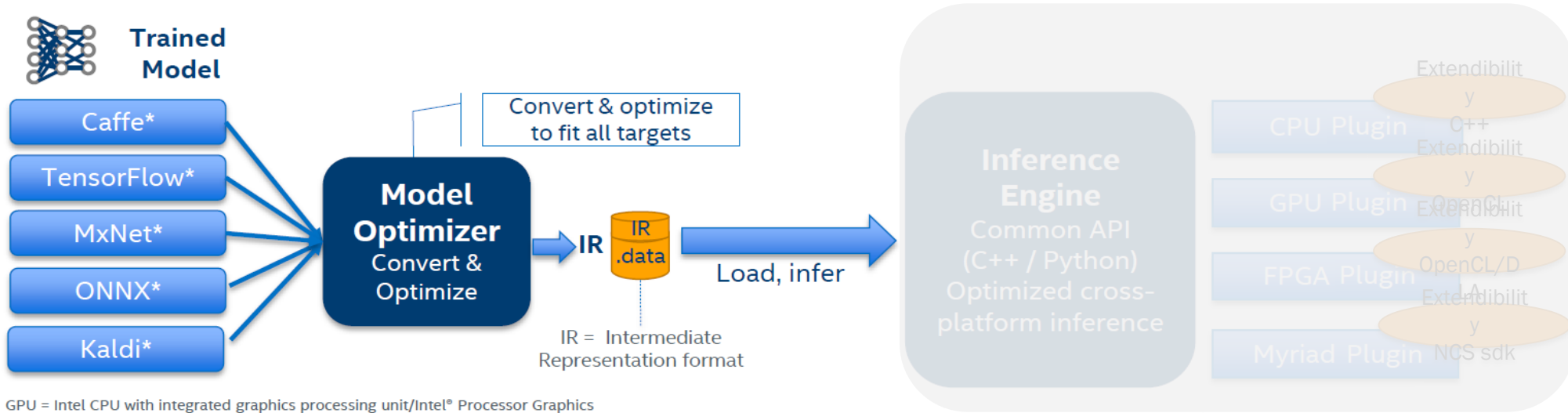


GPU = Intel CPU with integrated graphics processing unit/Intel® Processor Graphics

- Object Detection Models
- Object Recognition Models
- Reidentification Models
- Semantic Segmentation Models
- Instance Segmentation Models
- Human Pose Estimation Models
- Image Processing
- Text Detection
- Text Recognition
- Action Recognition Models
- Compressed Models

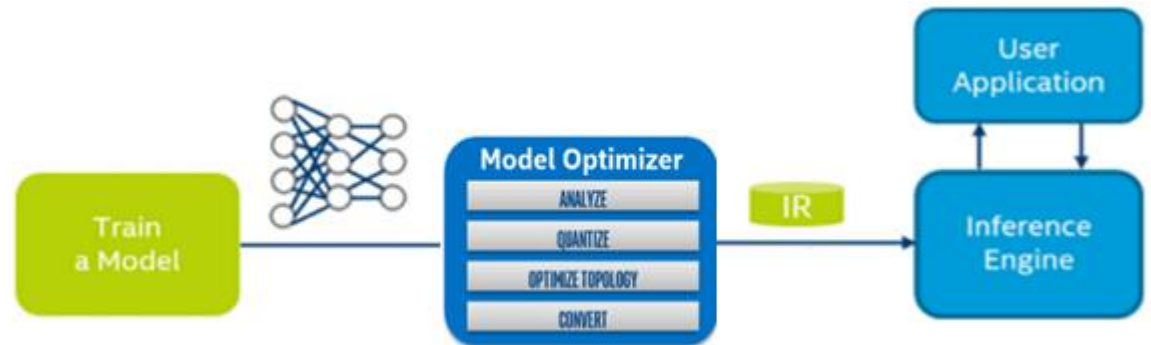
Open Model Zoo  
(42)





GPU = Intel CPU with integrated graphics processing unit/Intel® Processor Graphics

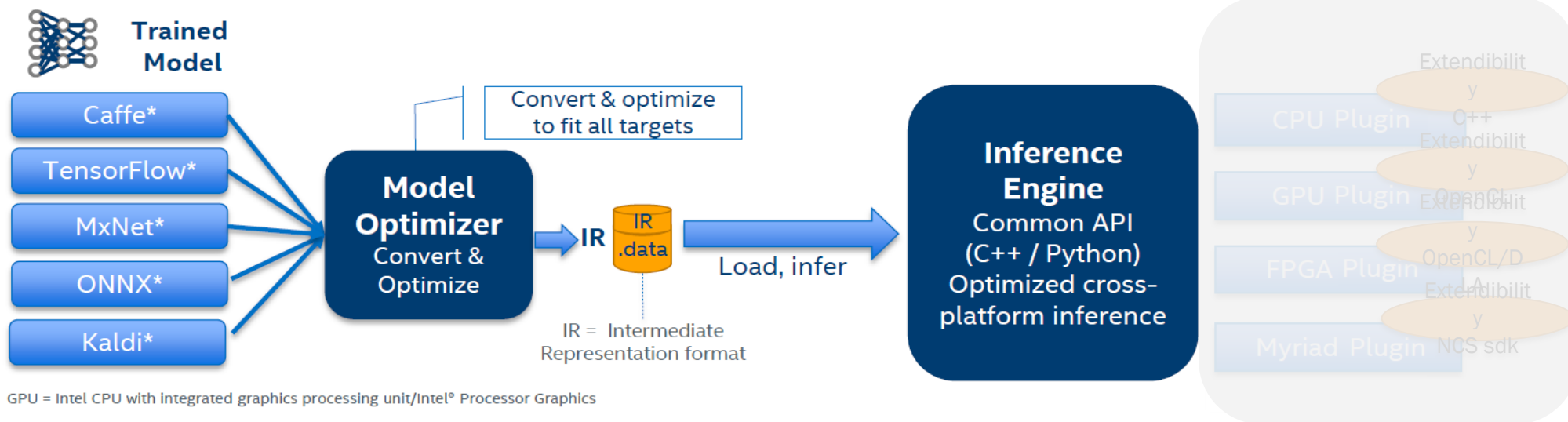
- Model Optimizer Tool
- Accuracy Checker Tool
- Benchmark Tool
- Calibration Tool
- Statistics Tool



Caffe: .caffemodel, .prototxt  
Tensorflow: .pb, .pbtxt

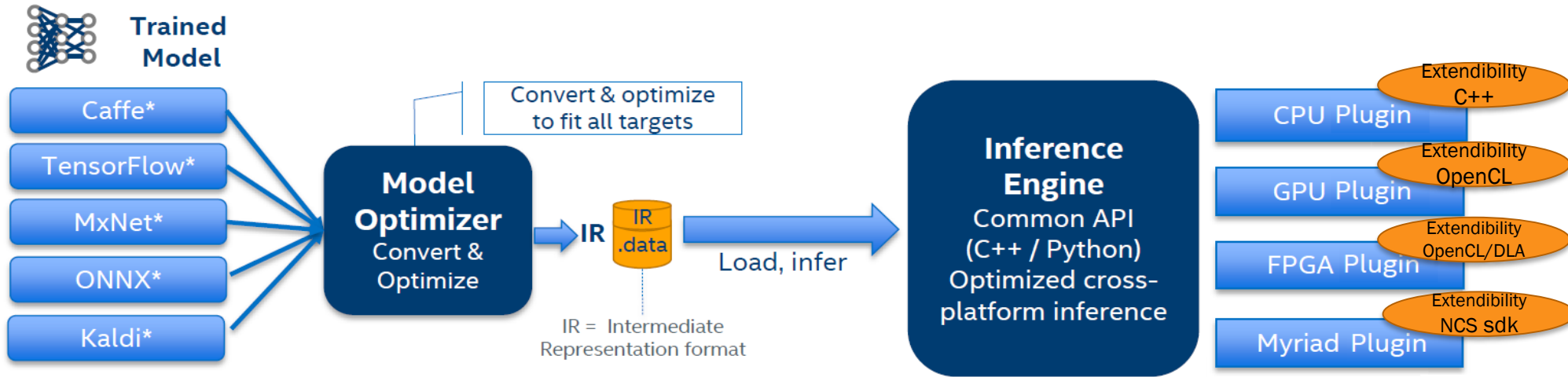
→ .bin, .xml

IR: Intermediate Representation

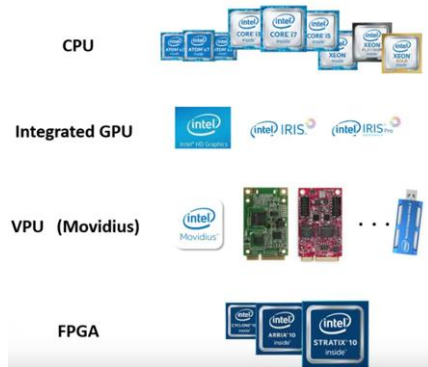


- Inference engine with unified API
- Plugin architecture
- Windows OS, Linux OS

# DEEP LEARNING TO GO INTRODUCING OPENVINO



GPU = Intel CPU with integrated graphics processing unit/Intel® Processor Graphics

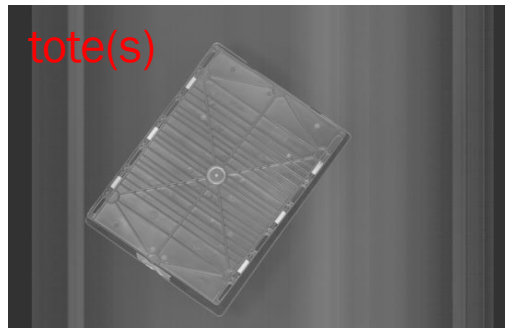


- OpenCV - Compiled for Intel® hardware.
- OpenCL - Drivers and runtimes for version 2.1
- Intel® Media SDK
- OpenVX - Intel's implementation of OpenVX

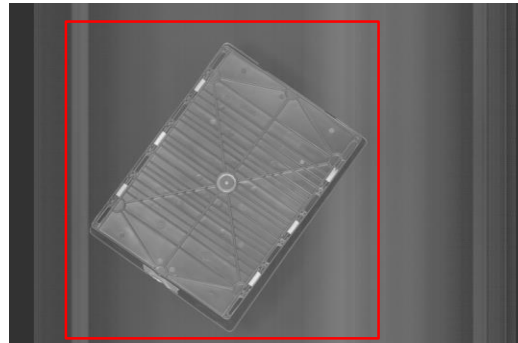


## **Applications**

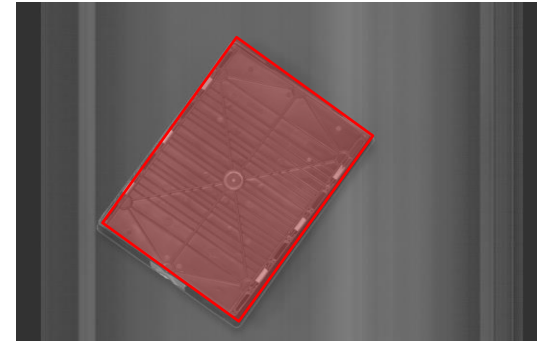
## Example Application: Tote Detection



(a) Classification - presence



(b) Detection - region



(c) Instance Segmentation - pixel

*Complexity*

The complexity of the problem (data set) dictates the network structure. The more complex the problem, the more 'features' required, the deeper the network.

Network	Depth	Size	Parameters (Millions)	Image Input Size	Image Format	Complexity (GFLOPs)
alexnet	8	227 MB	61.0	227 x 227	RGB	0.7
vgg16	16	515 MB	138	224 x 224	RGB	15.5
squeezenet	18	4.6 MB	1.24	227 x 227	RGB	1.0
googlenet	22	27 MB	7.0	224 x 224	RGB	1.6
<b>totenet</b>	<b>6</b>	<b>0.7 MB</b>	<b>0.09</b>	<b>64 x 64</b>	<b>GRAY</b>	<b>0.13</b>

1. Frame/sec of Inference/sec (throughput)
2. Respond time (Latency)
3. Data format (FP32, FP16, INT8,...)
4. Which device (CPU/GPU/VPU/FPGA)

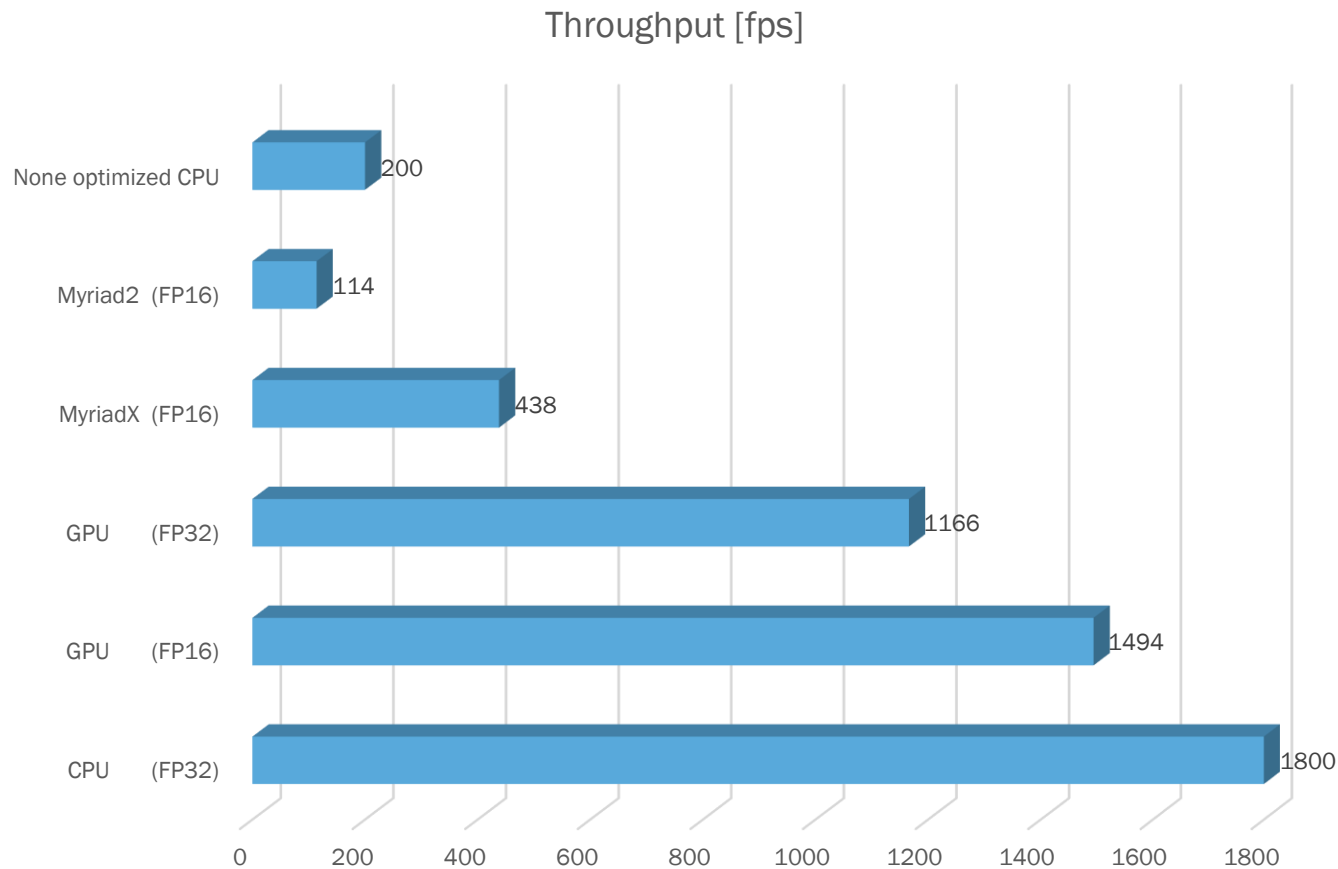
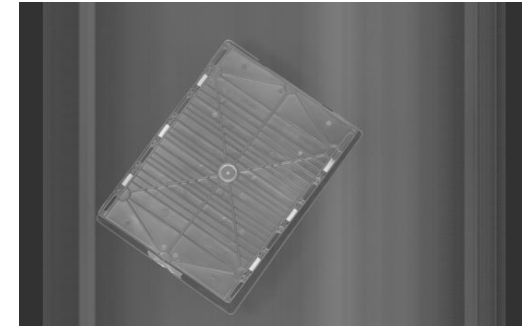


# DEEP LEARNING TO GO BENCHMARKING

Model: totenet 1.0

CPU: Intel i7-6822EQ

GPU: HD530 (ICR890-35)



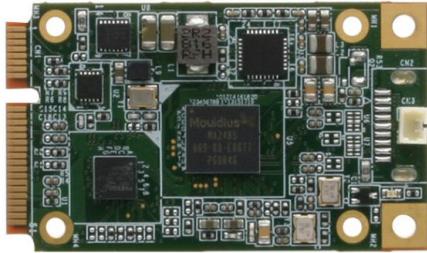
## Device Metrics:

Device	Performance	P	Price	Area
CPU (i7-6822EQ) <sup>1)</sup>	128 GFLOPS	25 W	303 \$	42 x 42
GPU (HD530) <sup>2)</sup>	441 GFLOPS	15 W	(303 \$)	42 x 42
MYRIAD-X	800 GFLOPS	1,5 W	10 \$	8.0 x 8.1
MYRIAD-2	100 GFLOPS	1,0 W	10 \$	8.0 x 8.1
Tesla V100 PCI-E 16GB	112 TFLOPS	250 W	10.000 \$	140 x 78

- Estimate how fast a net will be.
- Select best hardware for your application.



## **Outlook**



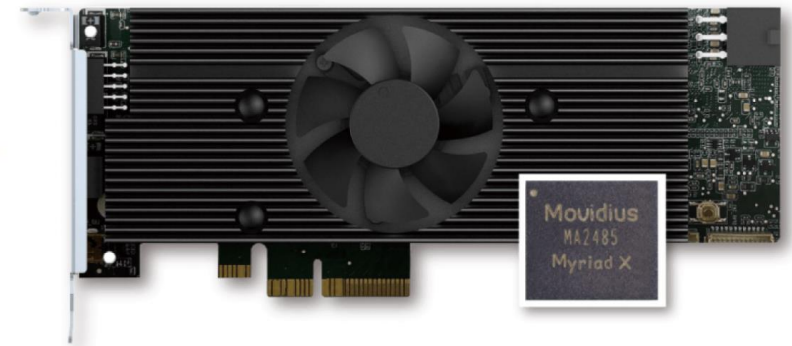
## AI Core X

- 1x Myriad™ X VPU
- mPCIe



## AI Core XM 2280

- 2x Myriad™ X VPU
- M.2



## Mustang V100-MX8

- 8x Myriad™ X VPU
- PCIe 2.0 x4

## • Conclusion:

- USB stick not for industrial applications.
- Most of pre-trained nets are trained with color images.
- Fast moving technology trend to VPU visible, but with short term availability.

THANKS FOR THE ATTENTION.

**SICK**  
Sensor Intelligence.

Questions?



- Company Presentation SICK AG
- Deep Learning Initiative
- Logistics Applications
- Deep learning to go
- **Master / Bachelor Theses @SICK**



- SICK offers paid Bachelor / Master - theses
- Get to know SICK / the DeepLearning Initiative
- Try out modern/experimental approaches to relevant problems
  - ▶ However: Focus lies on scientific part of the work
  - ▶ But: Work on industry data / Industry relevant applications

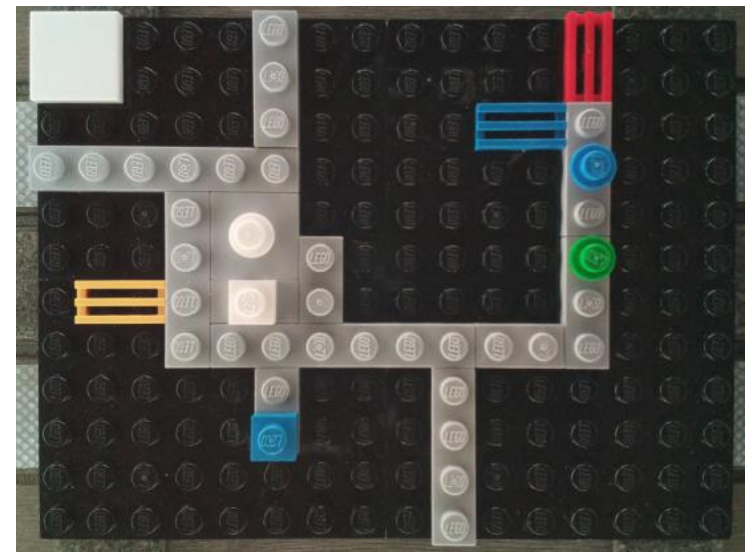
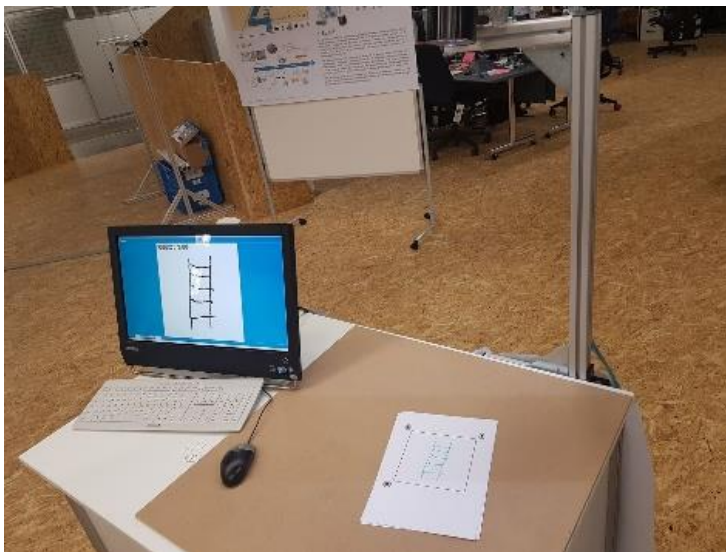
- ATM we use linear transformations (shift, rotation, shear) for online augmenting data
- Task: Use more sophisticated models
  - ▶ Generative networks
  - ▶ More realistic deformations
  - ▶ Base image generation on a 3d model with physics engine, probably also simulate recording process of (line-) camera



# CURRENTLY OPEN TOPICS

## DL APPS FOR DEMONSTRATOR (INTERNSHIP / BACHELOR)

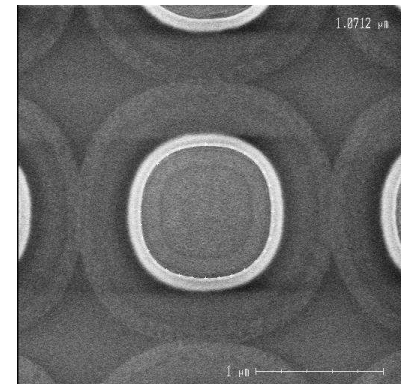
- Implement Apps for our DL demonstrator
  - ▶ Detection of e.g. barcodes
  - ▶ Image enhancement (probably also barcodes)
  - ▶ Quality control for lego - PCBs



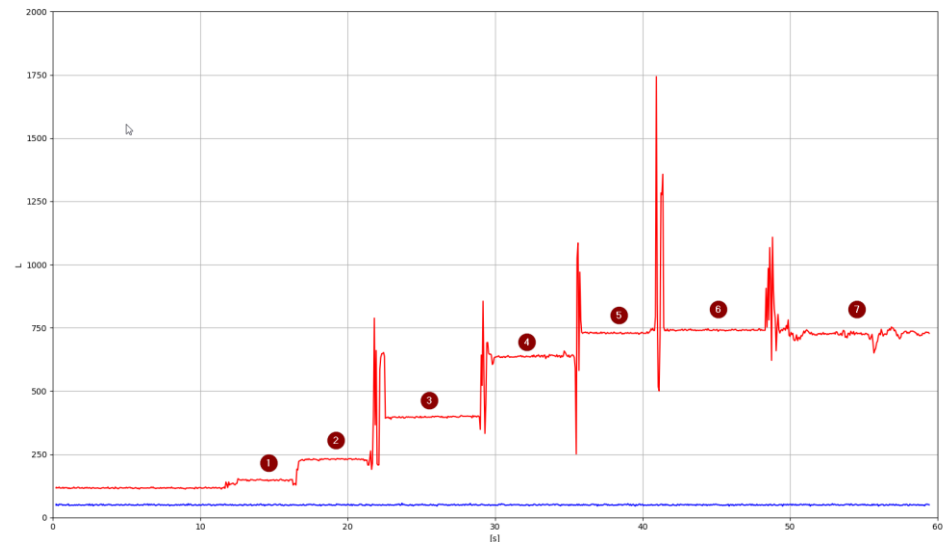
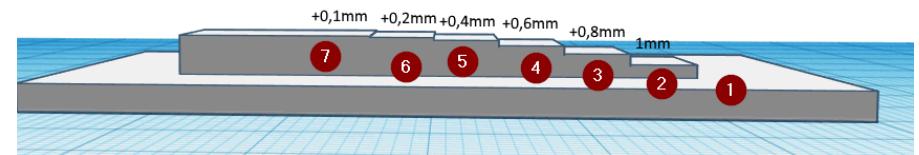
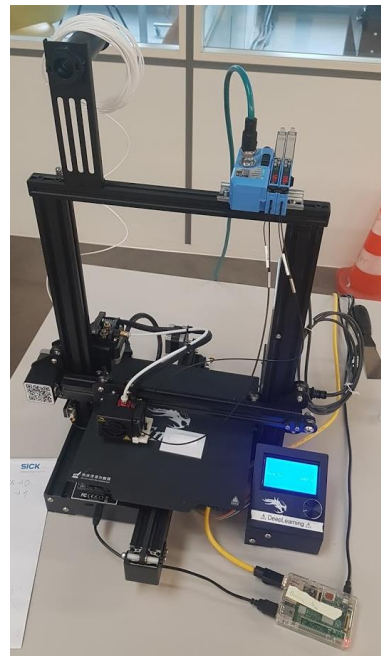
# CURRENTLY OPEN TOPICS

## ANOMALY DETECTION (BACHELOR / MASTER)

- Implement and evaluate reconstruction based and/or discriminative approaches for anomaly detection
  - ▶ Class imbalance: Usually mostly good samples
  - ▶ Unknown Failure cases
- Approchaes
  - ▶ Reconstruction: Auto-Encoders
  - ▶ Discriminative: Supervised Training on labelled data – segmentation, classification
- Probably in cooperation with micronas



- Goal: reconstruct distance measurements from „1 Pixel – fibre optic sensor“
  - ▶ Train model that uses multiple sensors as input
  - ▶ Examine different sensor configurations
  - ▶ Automatic calibration of sensors
  - ▶ Design Experiments



- We offer Project/Bachelor/Master Topics with scientific focus in the following areas:
  - ▶ Network Generalization / Domain Adaptation
  - ▶ Object Detection / Instance Segmentation
  - ▶ Network Compression
  - ▶ Anomaly Detection
- Benefits for you
  - ▶ Expense allowance (~1000€/month)
  - ▶ PhD / Postdoc level of supervision
  - ▶ Get to know one of the world's leading sensor manufacturers from the inside
  - ▶ Work on real world problems
- Requirements
  - ▶ Strong interest in DeepLearning / Image Processing
  - ▶ Good knowledge of python / Tensorflow

Interested? → your application to:

**[deeplearning@sick.de](mailto:deeplearning@sick.de)**

(Also have a look at the SICK JOB portal: [jobs.sick.com](http://jobs.sick.com))

**THANKS FOR THE ATTENTION.**

**SICK**  
Sensor Intelligence.

Questions?

