Mastering AVI

Part9: Future trends in AVI

Instructor Lead: Romain Veillon / Fernand Koert / Sébastien Koch

CONNECTING
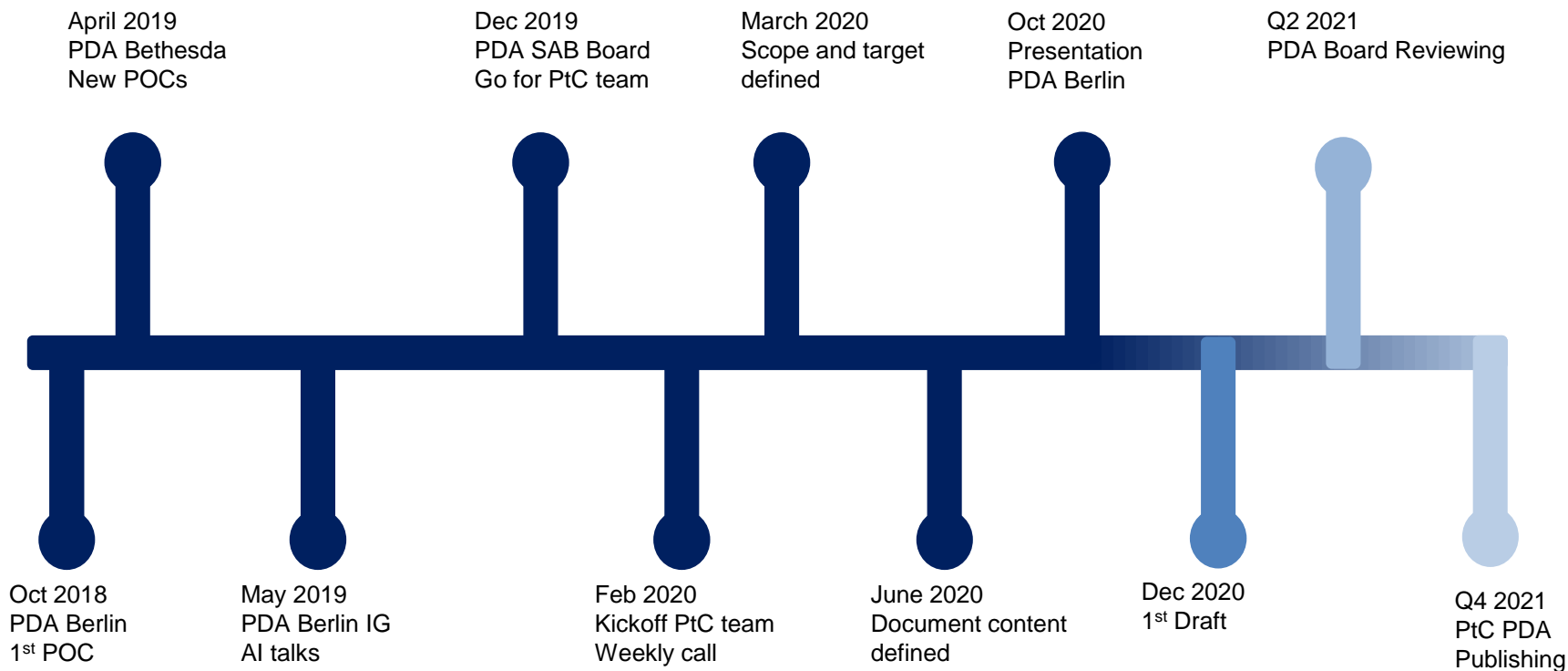PEOPLE
SCIENCE AND
REGULATION®

The Team

PTC task Force Lead:

o Romain Veillon, GSK Vaccines
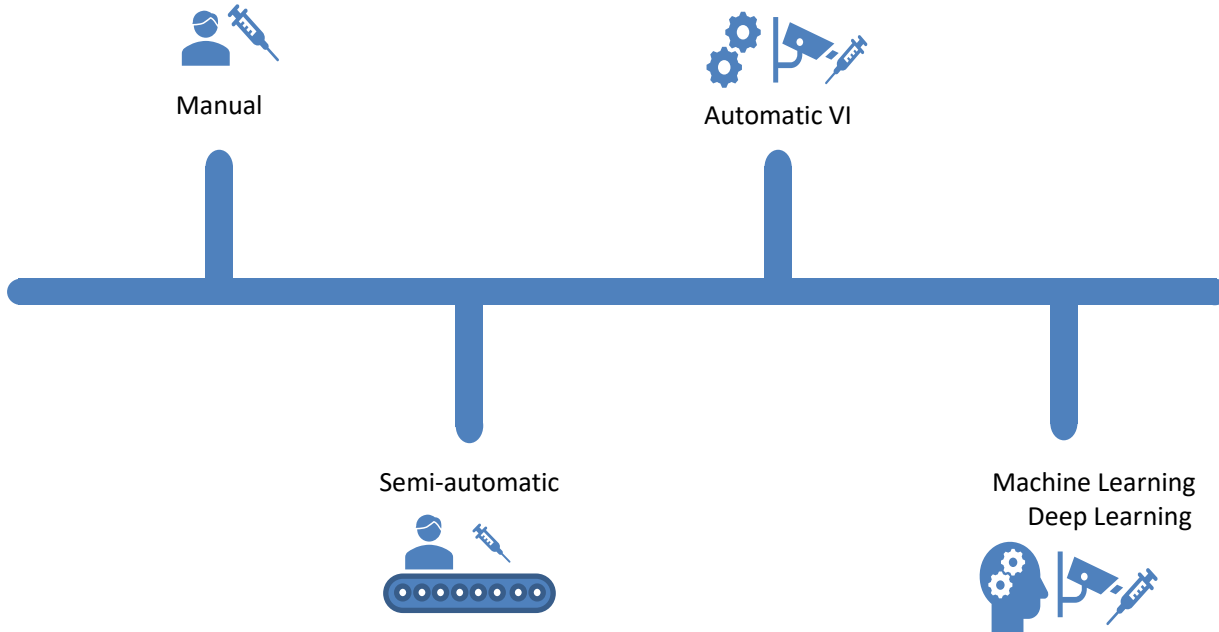o John Shabushnig, Insight Pharma Consulting

PTC Team Members

o Janie Miller, PDA
o Matthieu Duvinage, Data scientist GSK
o Soto, Manuel, Data Scientist Amgen
o Brian Turnquist, Data scientist Boon Logic
o Christian Eckstein, Data scientist MVTec
o Andrea Sardella, Stevanato Group
o Lars Aabye-Hansen, Novo Nordisk A/S
o Zheng Li, Genentech
o Jorge Delgado Torres, Amgen
o Chady Elahmad, MVTec

Timeline

April 2019
PDA Bethesda
New POCs

Dec 2019
PDA SAB Board
Go for PtC team

March 2020
Scope and target
defined

Oct 2020
Presentation
PDA Berlin

Q2 2021
PDA Board Reviewing

Oct 2018
PDA Berlin
1st POC

May 2019
PDA Berlin IG
AI talks

Feb 2020
Kickoff PtC team
Weekly call

June 2020
Document content
defined

Dec 2020
1st Draft

Q4 2021
PtC PDA
Publishing

Where do we come from ?

Manual

Automatic VI

Semi-automatic

Machine Learning
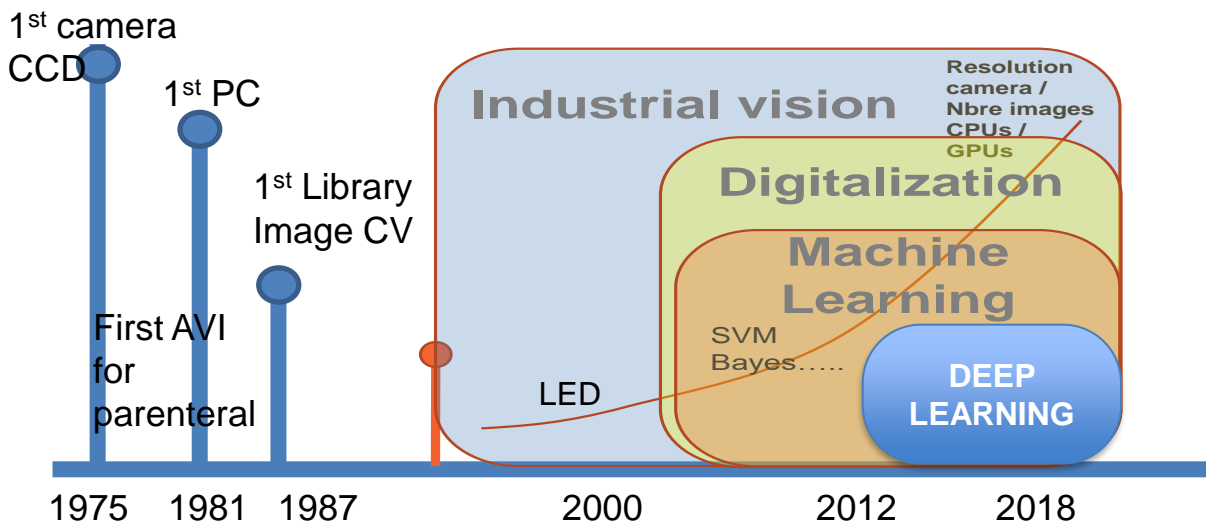Deep Learning

- **AVI is a young, but maturing technology**
- **Many step changes over the last 30 years,**
- **next step change is AI**

AVI is a fast evolving technology
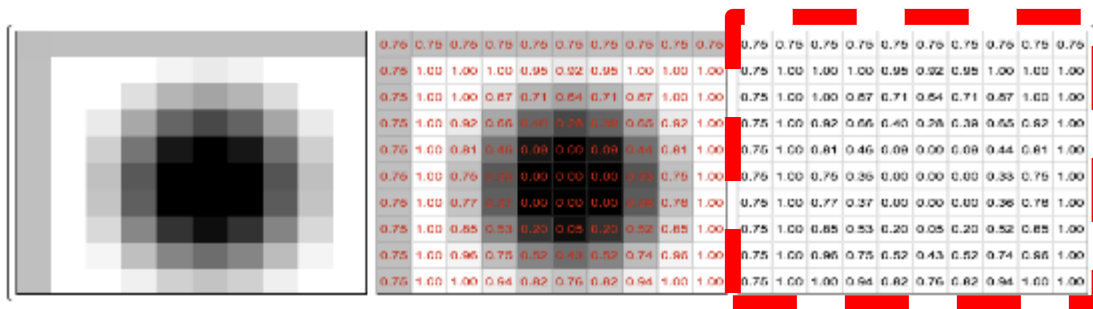

1st camera CCD

1st PC

1st Library Image CV

First AVI for parenteral

Industrial vision

Digitalization

Machine Learning

Resolution camera / Nbre images CPUs / GPUs

SVM Bayes…..

DEEP LEARNING

LED

1975   1981   1987   2000   2012   2018

Key Take Away:
- **AVI is a young, maturing technology**
- **Many changes over the last 30 years, next one is deep learning**

• What is a digital image ?
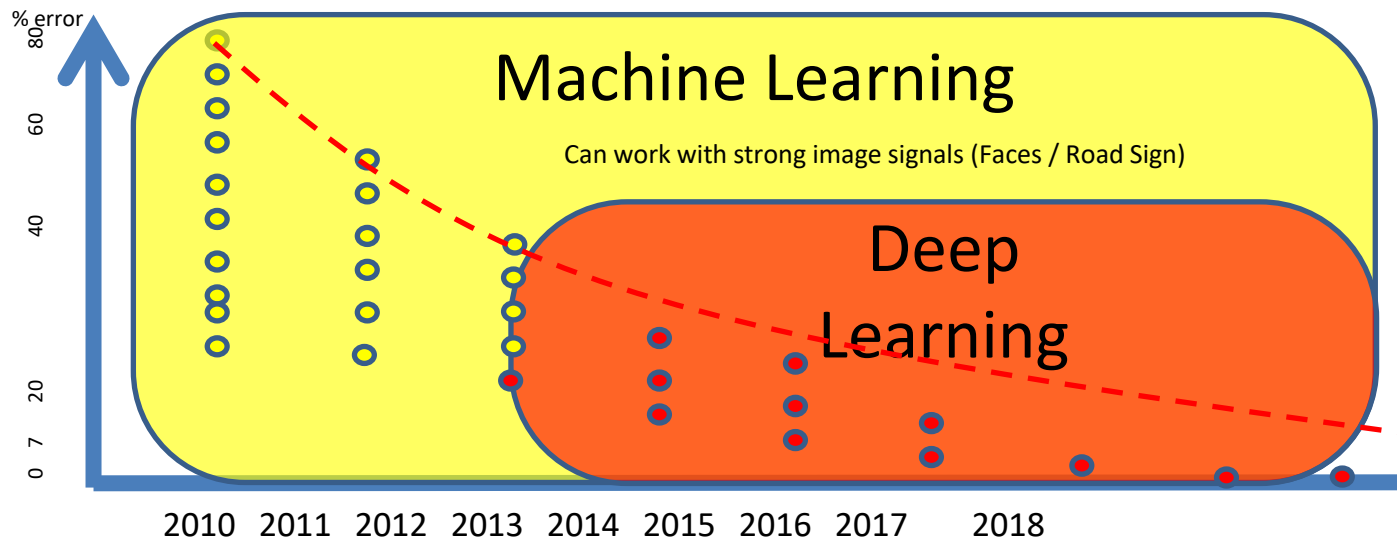

1 particle image　　**Image with grey levels…Digital Image = matrix grid of figures in X and Y**

Key Take Away:
- Computer vision see only a matrix
- That represent spatial distribution of grey levels
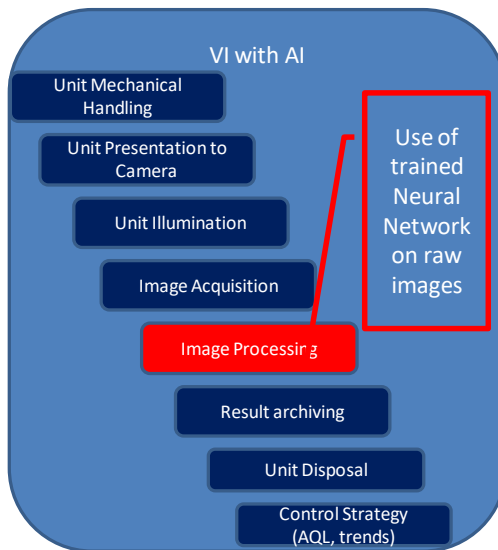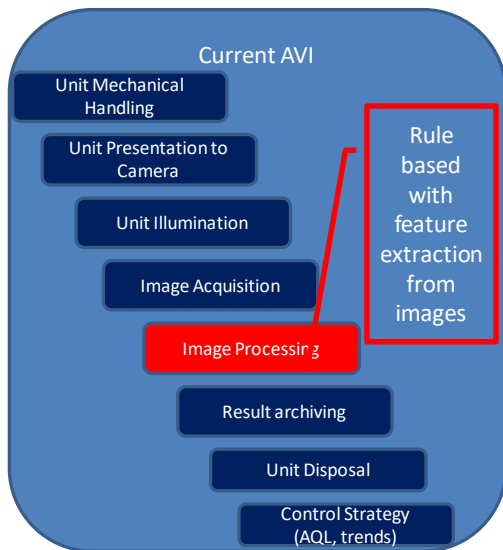- Neural Network will work with image matrix

In computer vision language (python/C++) it is a matrix object:
np.zeros(img.shape, dtype=img.dtype)

Machine Learning versus Deep Learning ?

% error

Machine Learning

Can work with strong image signals (Faces / Road Sign)

Deep Learning

2010 2011 2012 2013 2014 2015 2016 2017 2018

Key Take Away: Machine Learning (SVM) never achieved promising results with parenteral

Current AVI   versus   machine Learning

Current AVI
- Unit Mechanical Handling
- Unit Presentation to Camera
- Unit Illumination
- Image Acquisition
- Image Processing
- Result archiving
- Unit Disposal
- Control Strategy (AQL, trends)

Rule based with feature extraction from images

VI with AI
- Unit Mechanical Handling
- Unit Presentation to Camera
- Unit Illumination
- Image Acquisition
- Image Processing
- Result archiving
- Unit Disposal
- Control Strategy (AQL, trends)

Use of trained Neural Network on raw images
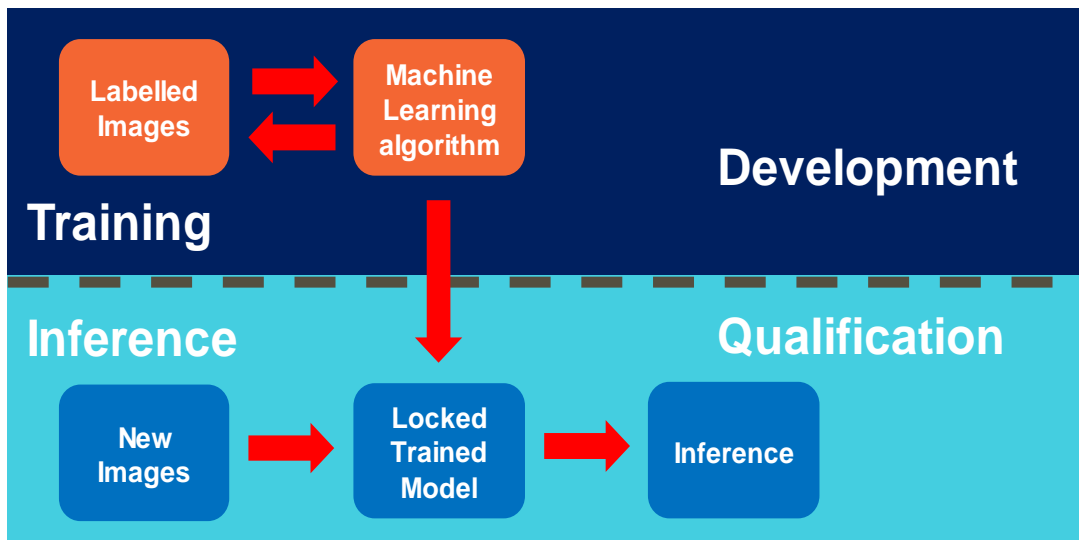
Point to consider:
- ☐ Scope of change with AI deployment is limited to image processing, all other crucial element remain the same

Principle of Deep Learning

Point to consider:
- ❑ with Supervised Deep Learning the vision set-up can be frozen and versioned before qualification and later use, it will not evolve, need for versioning control and audit trails

What is a Convolution Neural Network (DNN) ?

Key Take Away:
it is a NN dedicated to image treatment using convolution kernel filters Pitfall with Neural Network is risk of overfitting on training images
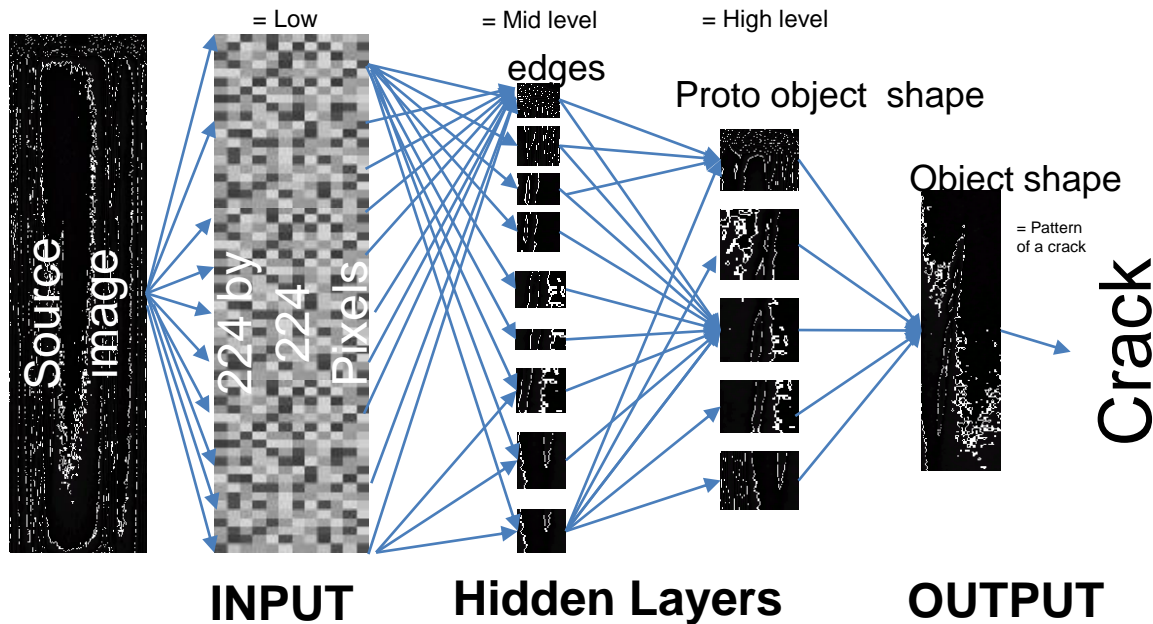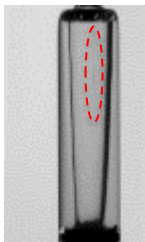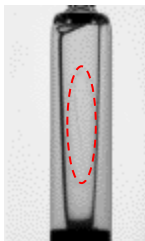
= Low   = Mid level   = High level

edges

Proto object shape

Object shape

= Pattern of a crack

Source Image

224 by 224 Pixels

Crack

INPUT   **Hidden Layers**   **OUTPUT**

Image Labelling

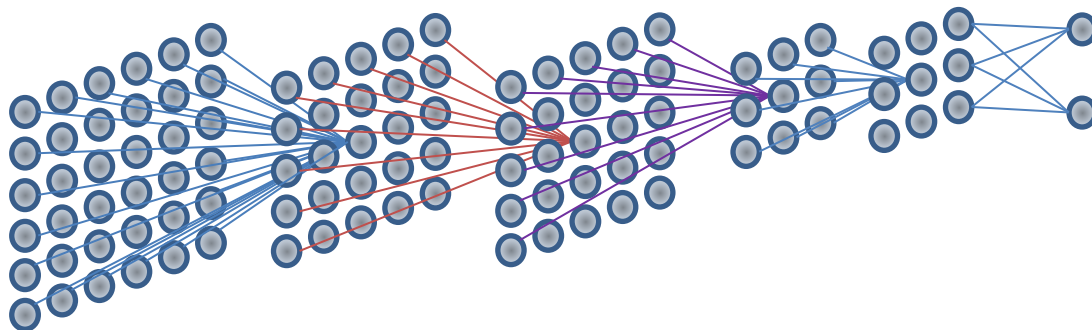Example of a binary detection between 2 classes: conform and crack
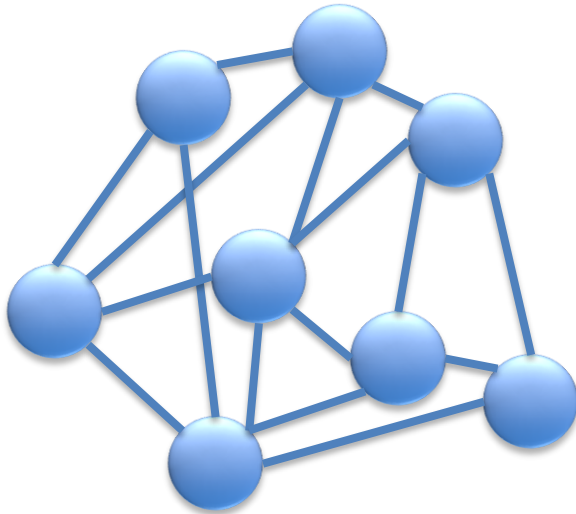
<u>**Point to consider:**</u>

☐ **Labelling defect per class is also very critical.**

☐ **Who can label an image ?**

☐ **How to document labelling ?**

☐ **What are boundaries of conforming class?**

Conform
(is a scratch conform?)

Crack

Conform

Crack
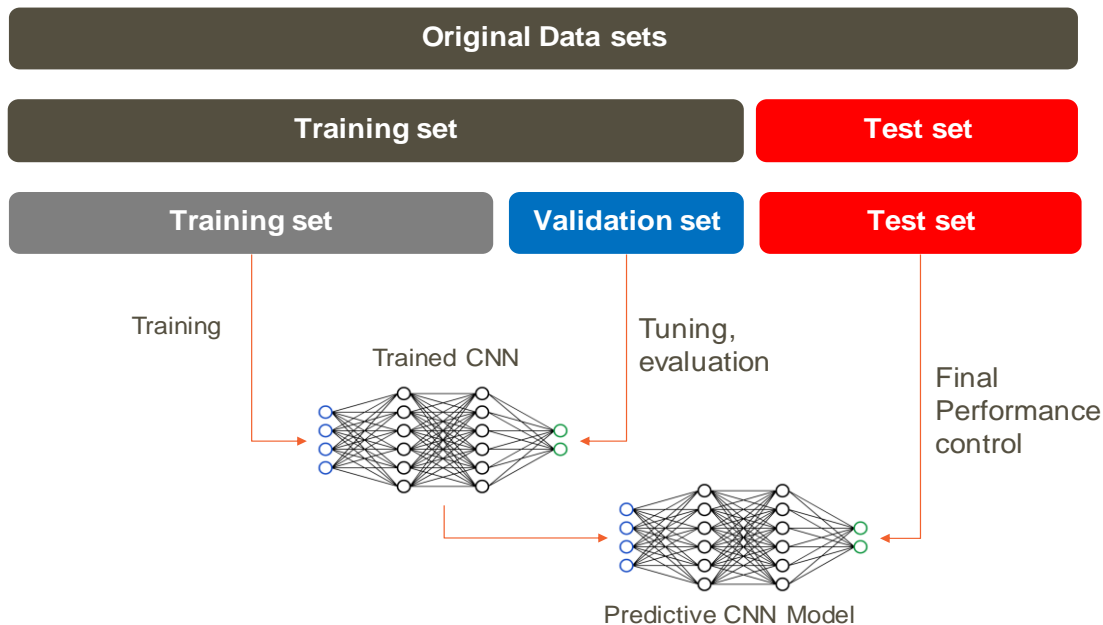
What are main points to consider to explore when moving to AI?

AVI with AI:

- ❑ Defect kit design space, explore grey zone

- ❑ Design space to the limit of unknown

- ❑ Image libraries for conforming unit class

- ❑ Defect labelling is a critical steps

- ❑ Vision engineers skills will remain

- ❑ Data science is new capabilities to develop

- ❑ Solid backend GMP IT infrastructure

Image test sets

Original Data sets

Training set	Test set

Training set	Validation set	Test set

Training

Tuning, evaluation

Final Performance control

Trained CNN

Predictive CNN Model

Point to Consider:
- [ ] **Number of image per class is critical,**
- [ ] **the independence of training, validation and test set is critical,**
- [ ] **audit trail could prevent data leakage**
- [ ] **Proportion of each**
- [ ] **Number of images per class**
- [ ] **Augment image conditions**
- [ ] **Try to generalize from input images**

Defect Design space

Day to Day defect Unknown

Design space

Daily kits

Validation kits
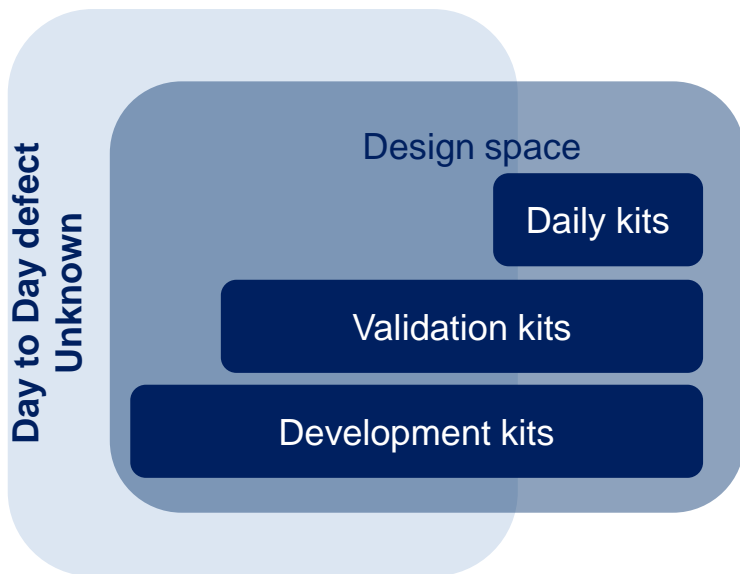
Development kits
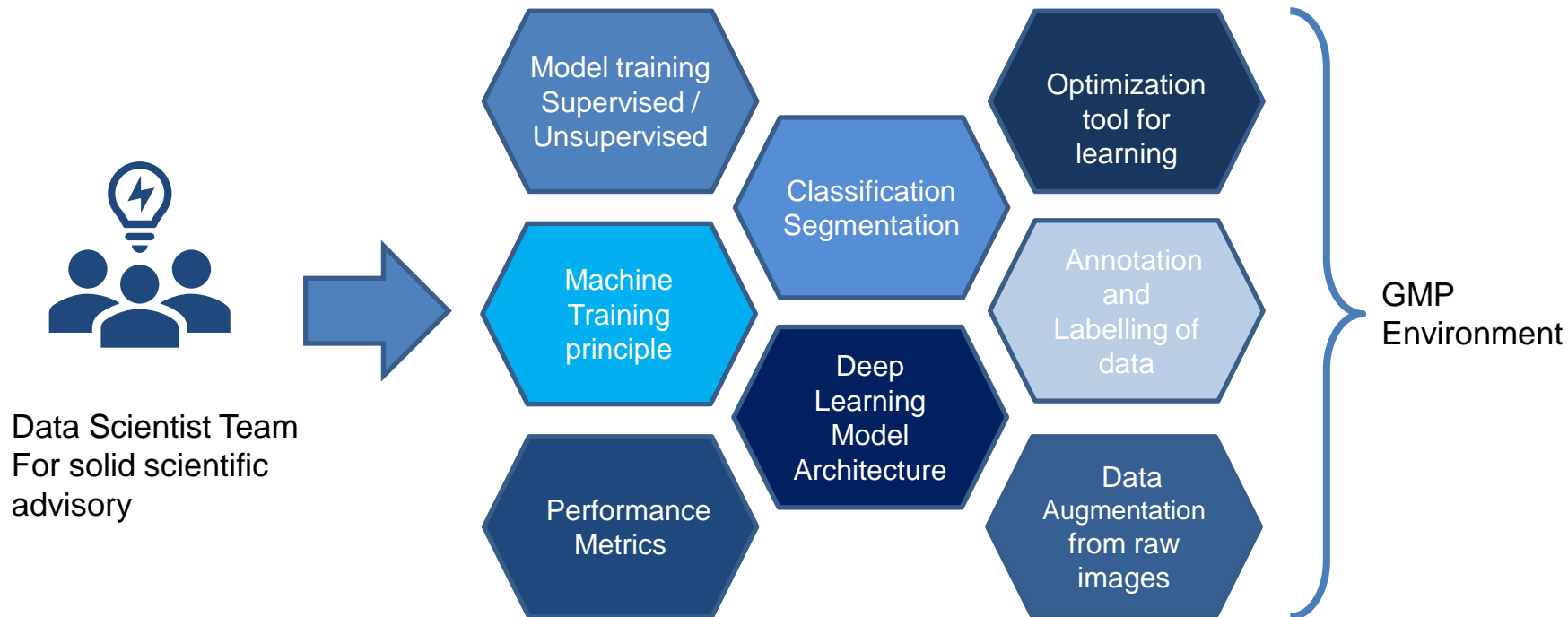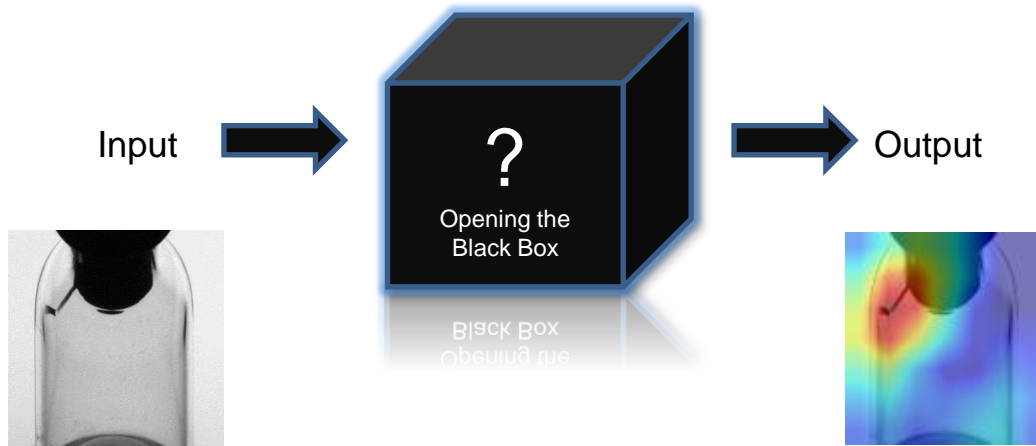
Point to Consider:

☐ **Risk to overfit on specific defect types and to have poor ability to the unknown**

☐ **The Design space should be extended to the maximal polymorphism of defect,**

☐ **The true defect zone may be too restrictive for AI development and training**

☐ **Need to explore to limit of the unknown, need more development kits to feed digital libraries**

Key Data Science element to cover

Data Scientist Team
For solid scientific
advisory

- Model training Supervised / Unsupervised
- Classification Segmentation
- Optimization tool for learning
- Machine Training principle
- Annotation and Labelling of data
- Deep Learning Model Architecture
- Performance Metrics
- Data Augmentation from raw images

GMP Environment

Why Visualization of results is so critical ?

Input → **Opening the Black Box ?** → Output

Point to consider:

- ❑ **it is key to report the results of AI with some visualization tools like heatmap, bounding box or segmentation to well document and give transparency**

- ❑ **Segmentation (SSD) can show where Deep Learning found a defects**

Validation of AI applied to VI

Desktop Qualification of ML
- Desktop performance qualification
- Strong metrics documentation

On line performance Qualification
- Digital Image testing
- Real defect kit testing

Life cycle Continuous improvement
- Data gathering for improvement
- Continuous improvement with new validation of performance