Taxonomy of Machine Learning, and its Role in Developing AI Systems

Trung T. Pham, Ph.D.

`trung.t.pham@faa.gov`

05/13/2025

Federal Aviation Administration

Disclaimer

- **The objective of this technical presentation is only to provide an engineering perspective of the AI/ML technology in the effort to clarify what it can and cannot do, with examples in aviation that can foster conversation of the safe use of the technology.**

Agenda

- Introduction
- Taxonomy of Machine Learning
- Data Analytics with Unsupervised Machine Learning
- Developing AI Applications Through Supervised Machine Learning
- FAA’s Roadmap for AI Safety
- Data in the Context of Machine Learning
- Discussion

Introduction

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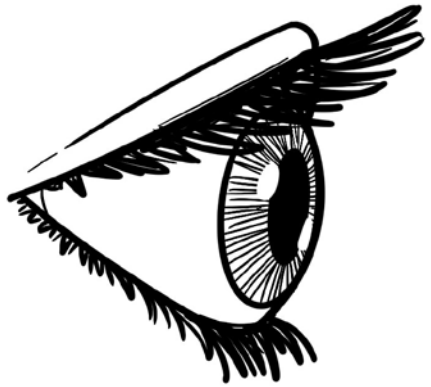
  - Machine Learning promises to shorten the development cycle
  - **Machine Learning alleviates the need of engineering expertise for the developers (lowering the cost of development)**

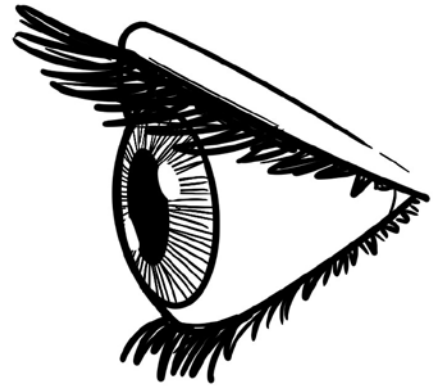
Introduction

ARTIFICIAL INTELLIGENCE



Public view of AI

AI Products	AI Related Technologies	SciFi AI Movies
• ChatGPT • Copilot • Alexa • Siri • Gemini • Deep Seek • Grammarly • etc.	• Large Language Model • Generative AI • Symbolic AI • Deep Learning • Reinforcement Learning • Artificial Neural Network • Computer Vision • etc.	• 2001: A Space Odyssey (1968) • Star Wars (1977) • Terminator (1984) • The Matrix (1999) • A.I. (2001) • I, Robot (2004) • Captain Marvel (2019) • etc.



Public view of AI

Taxonomy of Machine Learning

- **Machine Learning (ML) is a field of study in artificial intelligence concerned with the development and study of statistical algorithms that can learn from data and generalise to unseen data, and thus perform tasks without explicit instructions.**

https://en.wikipedia.org/wiki/Machine_learning

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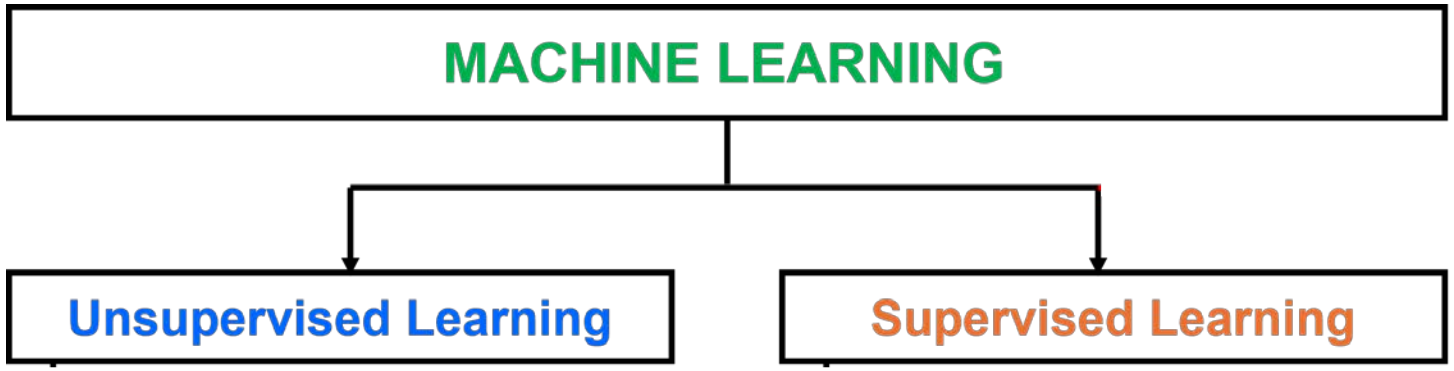
- **Important Note: Machine Learning might appear to be similar to part of human learning, but the mechanism of doing it is completely different**

Taxonomy of Machine Learning



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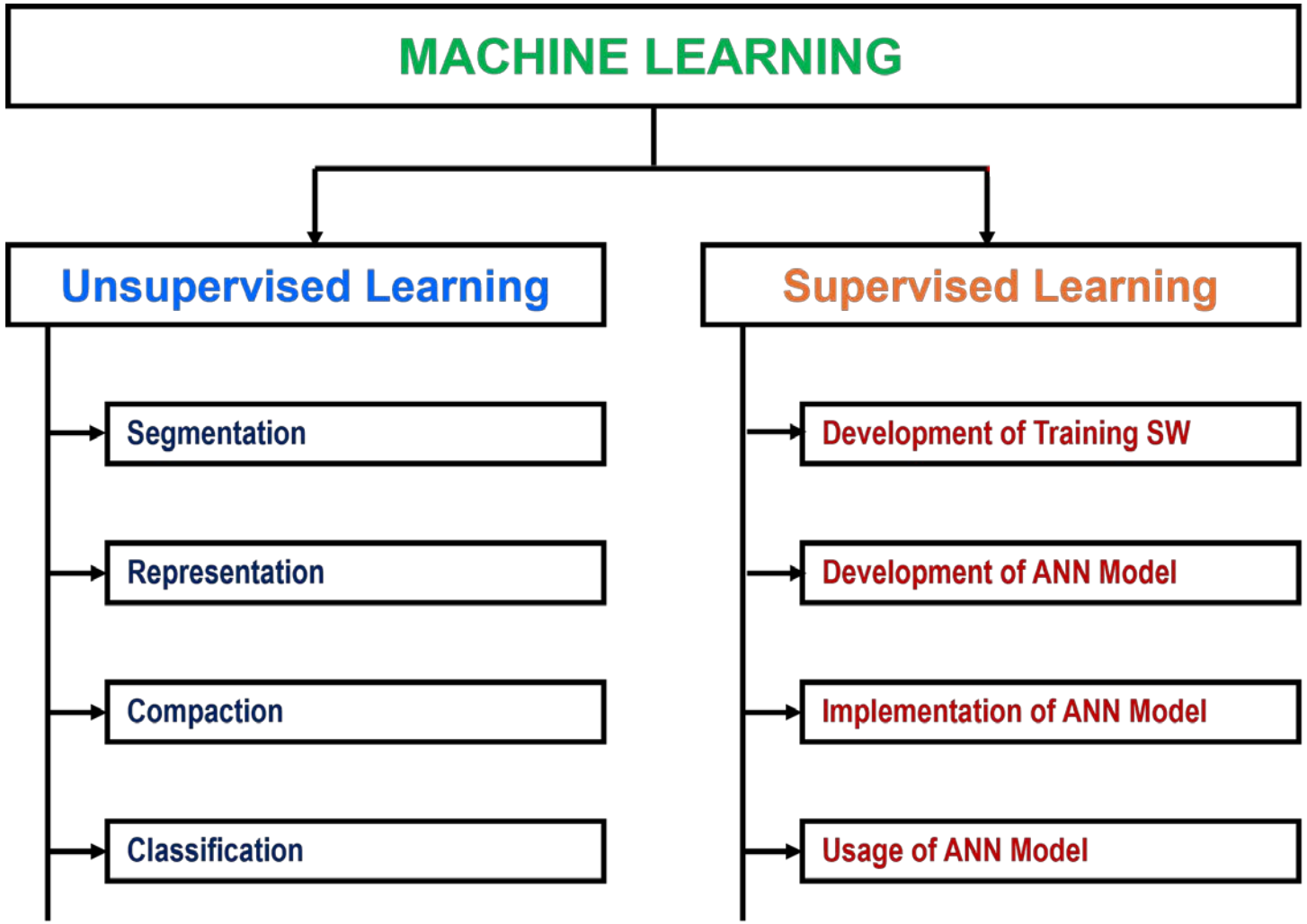

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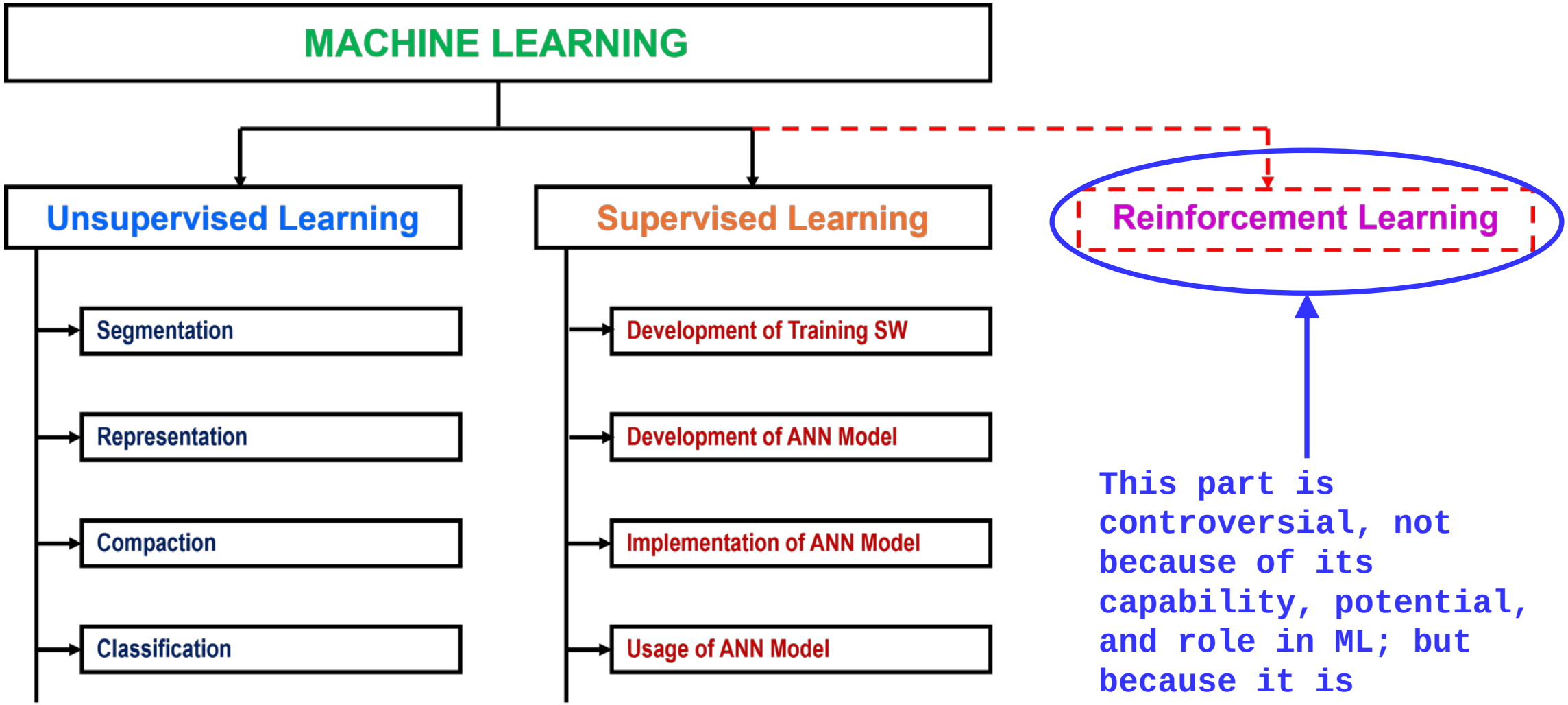

This part is controversial, not because of its capability, potential, and role in ML; but because it is incorrectly assumed to be one independent category of ML

Data Analytics with Unsupervised Machine Learning

- ***Data analytics*** **is the process of examining data to identify patterns, trends, and insights to support decision-making.**

Google AI Search

Data Analytics with Unsupervised Machine Learning

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  - **aviation example: to use Unsupervised Machine Learning to extract causal and situational data from various safety event reports (NTSB, ASRS, etc.)**

Will discuss this example later to illustrate the concept of Unsupervised Learning outlined earlier

Data Analytics with Unsupervised Machine Learning

1979 ORACLE DBMS™	1996 Google Search Engine™	2022 ChatGPT™
• organize data in a *structure* in a local file system	• data (in HTML format) are scattered across the Web	• data are scattered across the Web
• find data through *query* (SQL)	• find information on the Web based on *keyword*	• find information on the Web based on *humanlike conversations*
• generate *reports* in the form of charts and plots	• users must manually prepare *reports*	• generate *reports* in the form of comprehensive discussion

Key technologies that revolutionized how data are handled

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Large Language Model (LLM)

Data Analytics with Unsupervised Machine Learning

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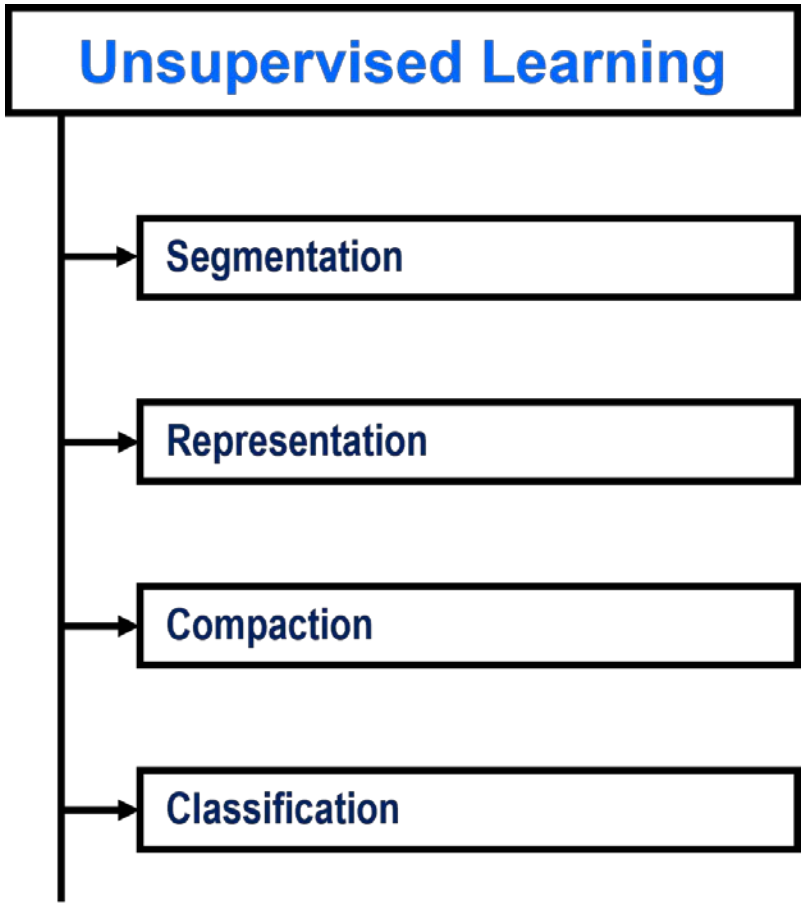

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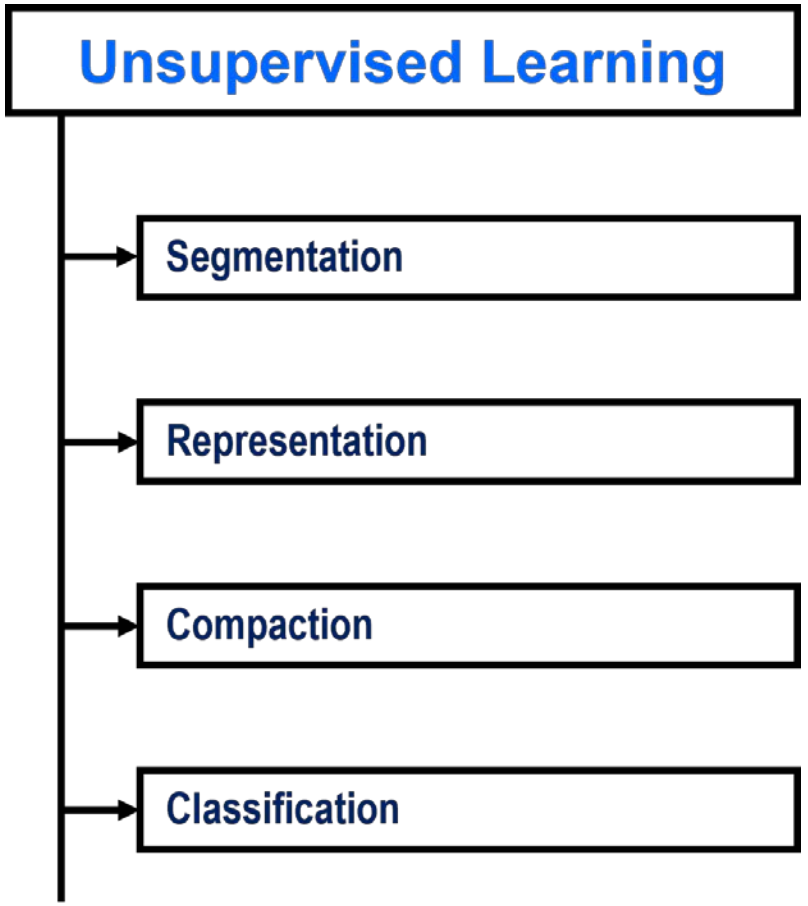

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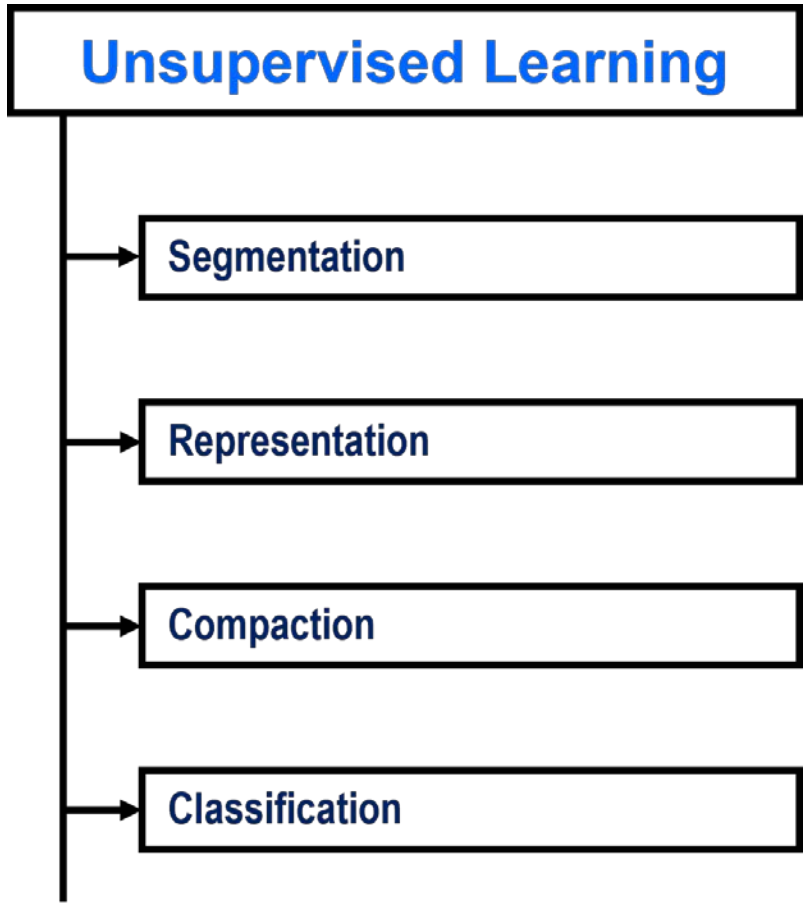

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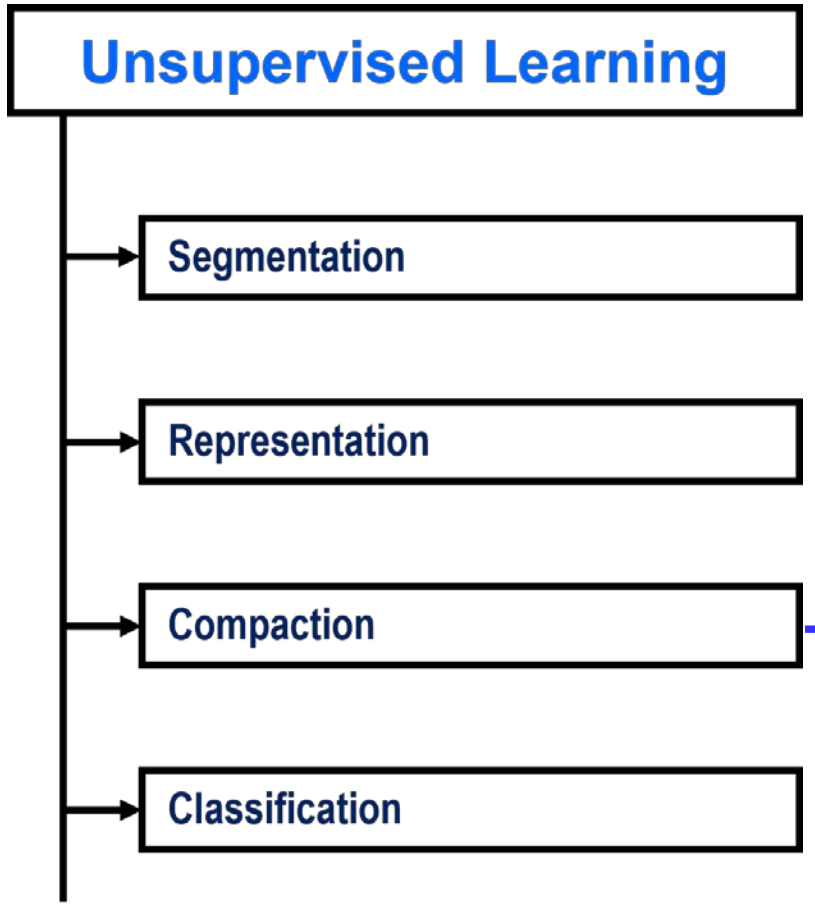

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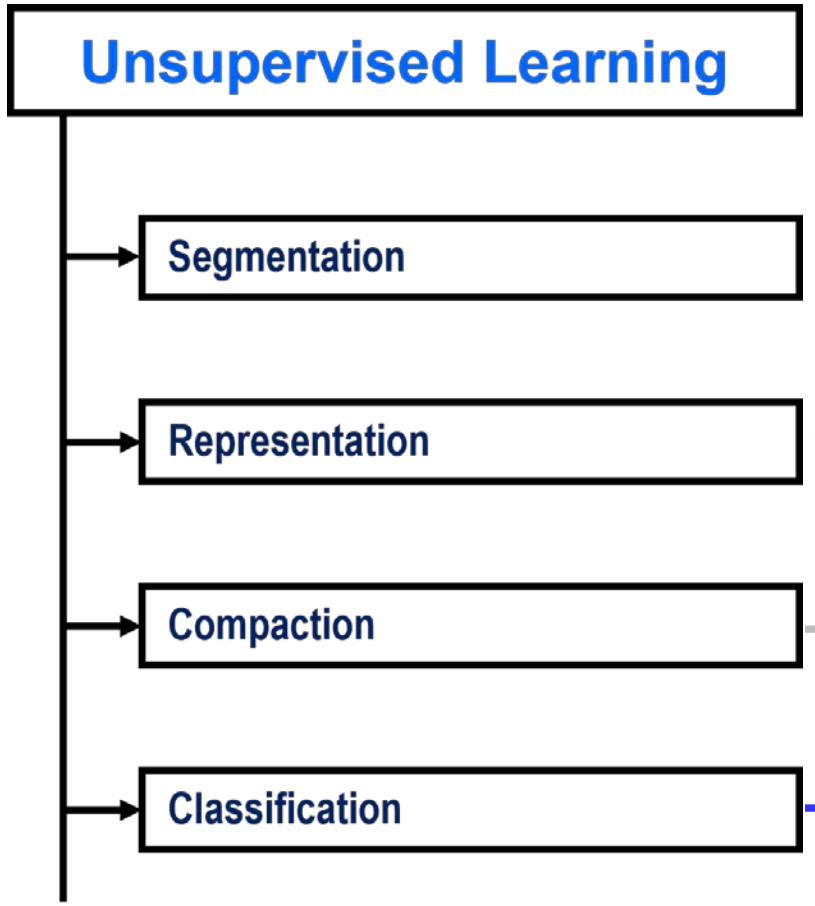

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Organizing the compact information so that it is reusable in recognizing similar situation when new data is encountered

Data Analytics with Unsupervised Machine Learning

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  - fault tree is built to represent various scenarios leading to each type of safety events
  - **fault tree is used to provide early warning (precursors to safety events)**

Developing AI Applications Through Supervised Machine Learning

- **Modeling is the process of using data to train a model to do a task**

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- **For Artificial Neural Net (ANN) models used in Supervised Machine Learning, there are two different categories**

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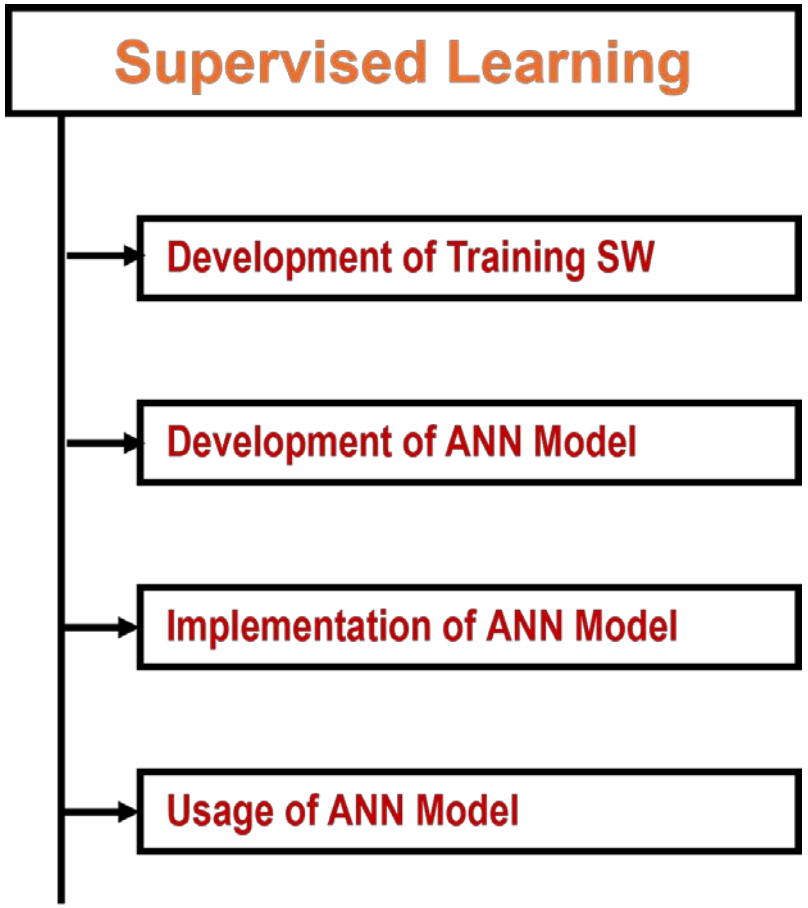
  - ANN with discrete output (zero or one) commonly used in classification problem (learning to identify if a new data that was never seen before belongs to one of the classes whose characteristics were extracted during training)
  - **ANN with continuous output commonly used in regression problem (learning to mimic a system or process in order to predict its behavior)**

Developing AI Applications Through Supervised Machine Learning

- **Supervised Learning consists of 4 groups of who is doing what**



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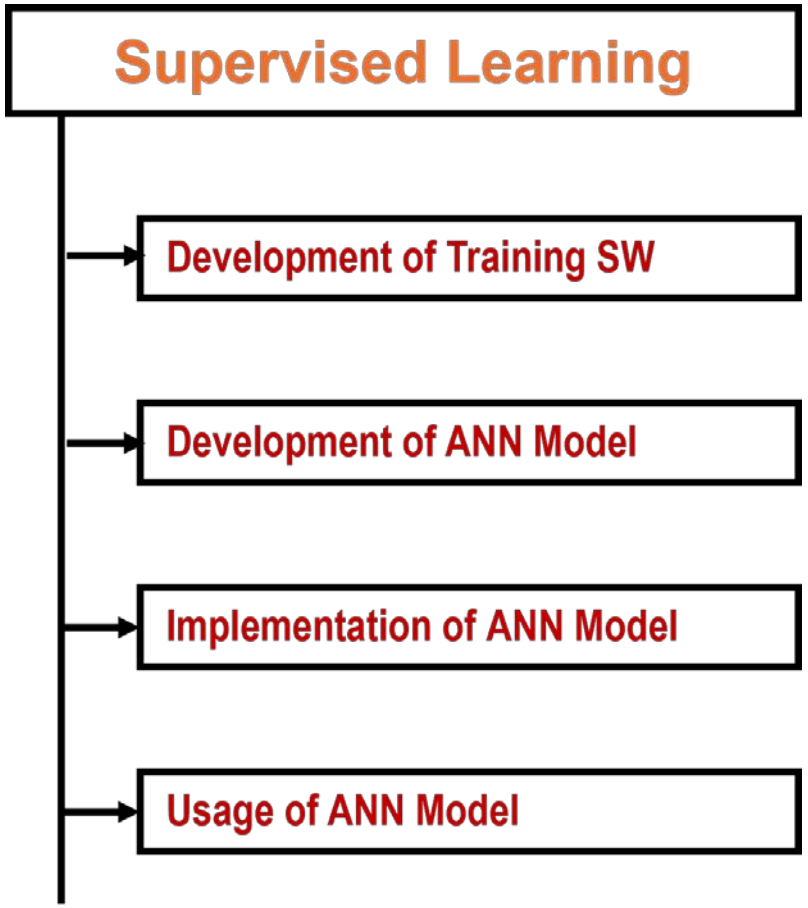

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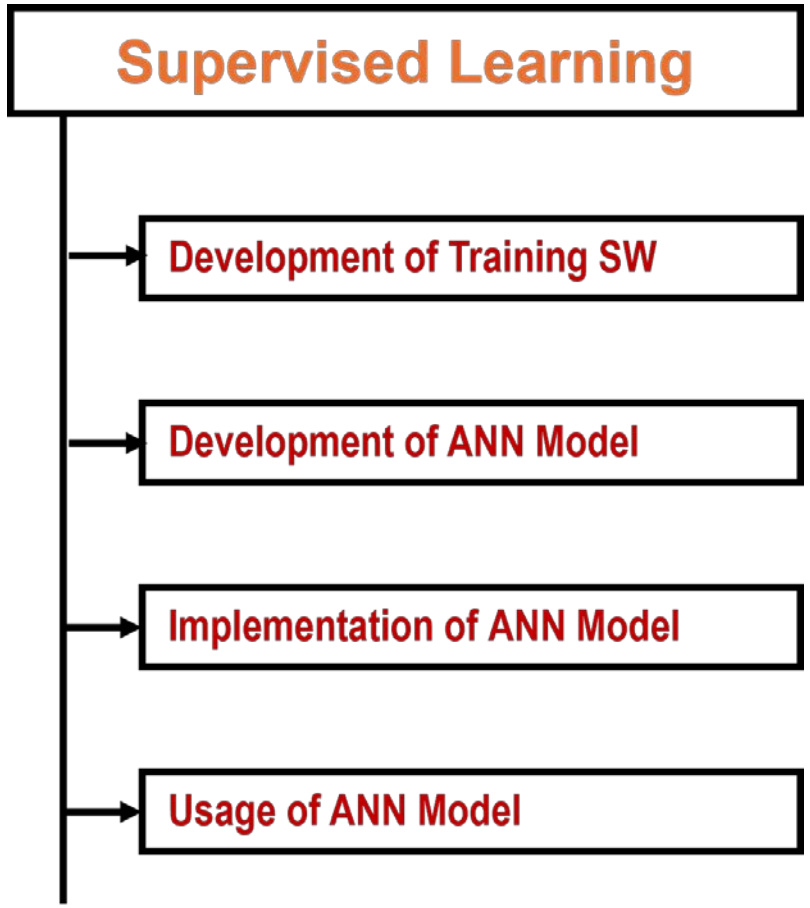

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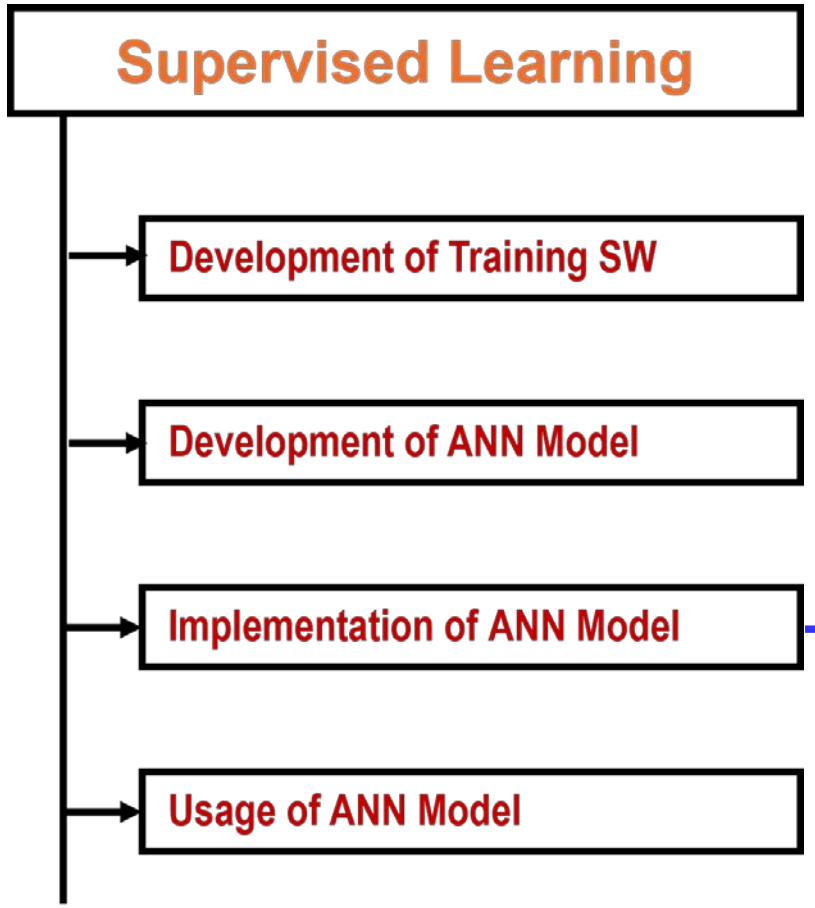

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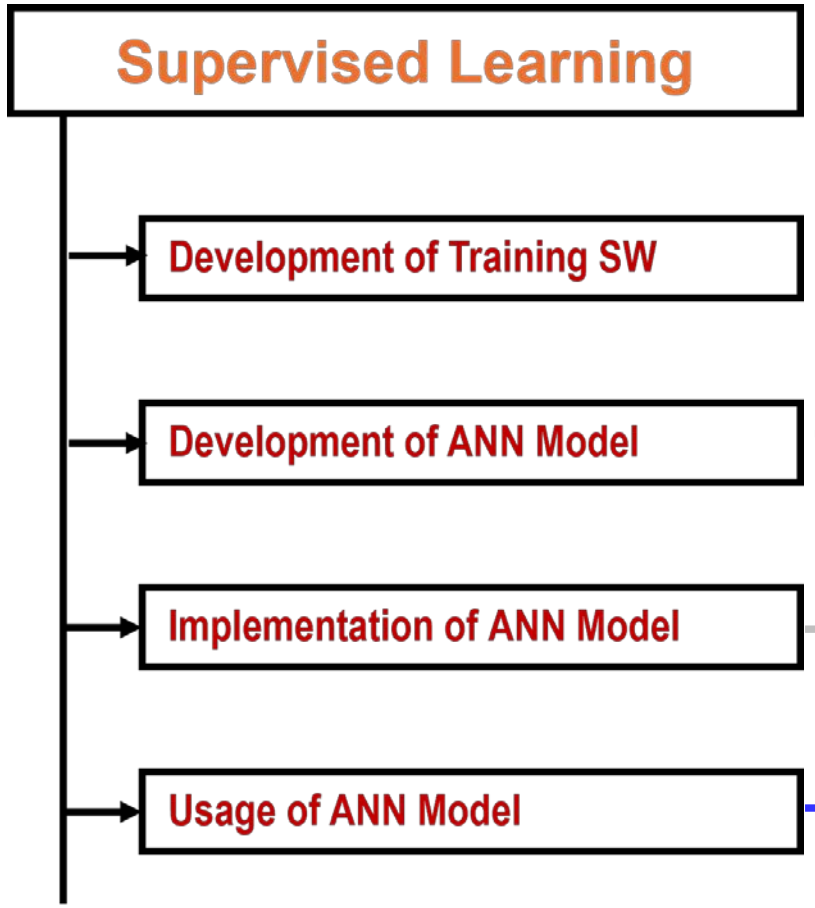

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Applicants are responsible for the safety of an aircraft with AI systems in it

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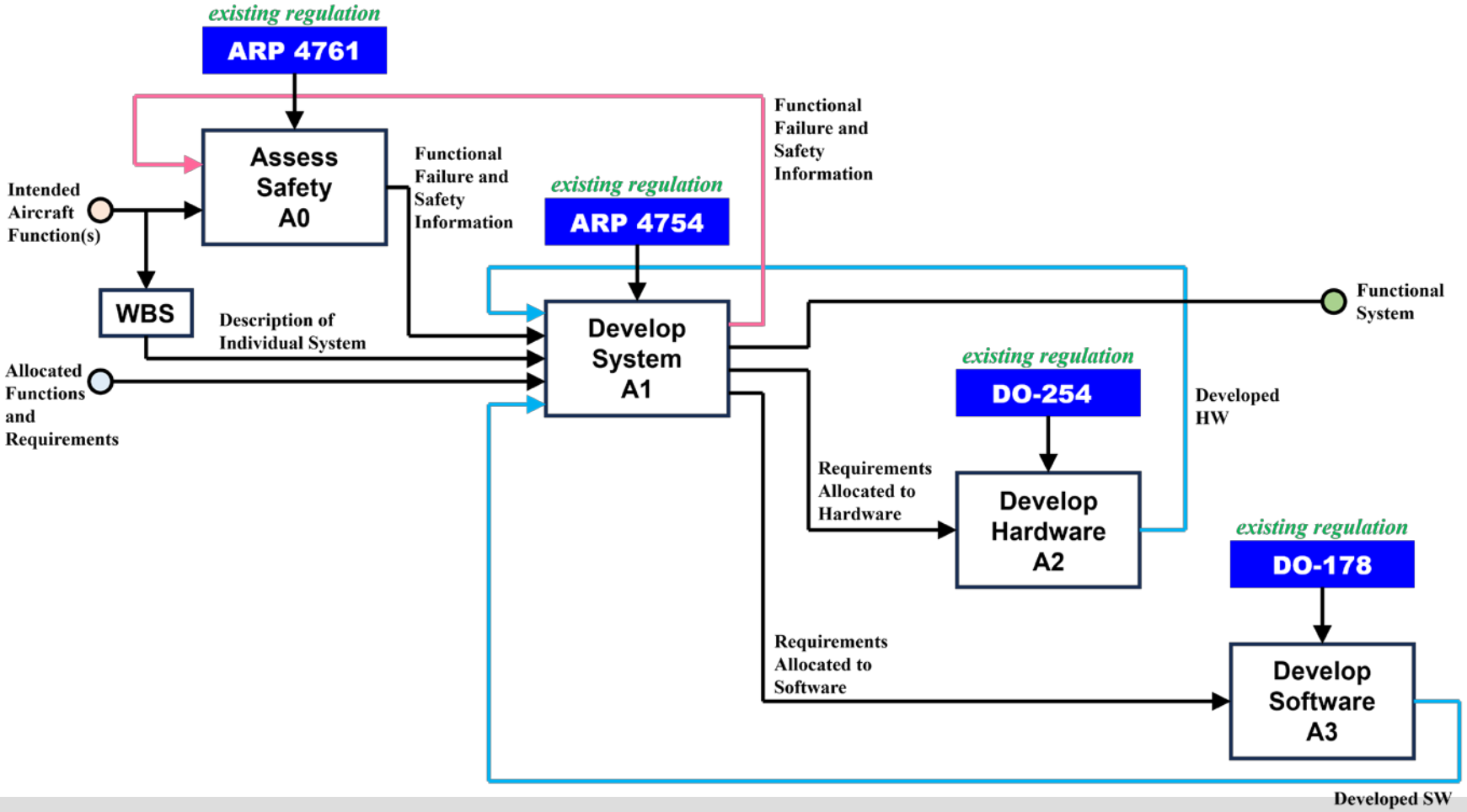
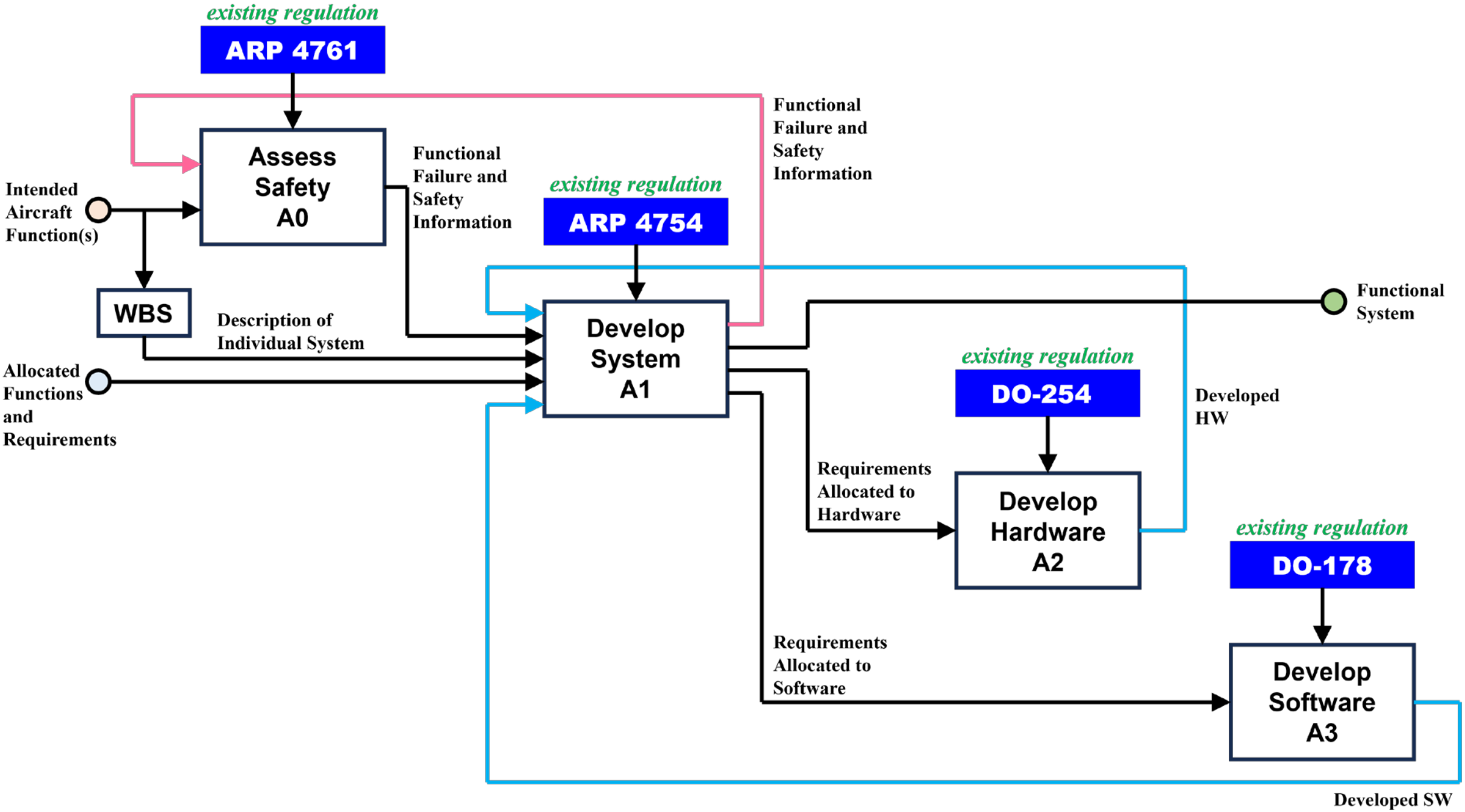
  - **monitor pilot's face to identify fatigue**

Developing AI Applications Through Supervised Machine Learning

- **Regulation side reviewing aviation examples**




existing regulation
ARP 4761
Assess Safety A0
Intended Aircraft Function(s)
WBS
Description of Individual System
Allocated Functions and Requirements
Functional Failure and Safety Information
existing regulation
ARP 4754
Functional Failure and Safety Information
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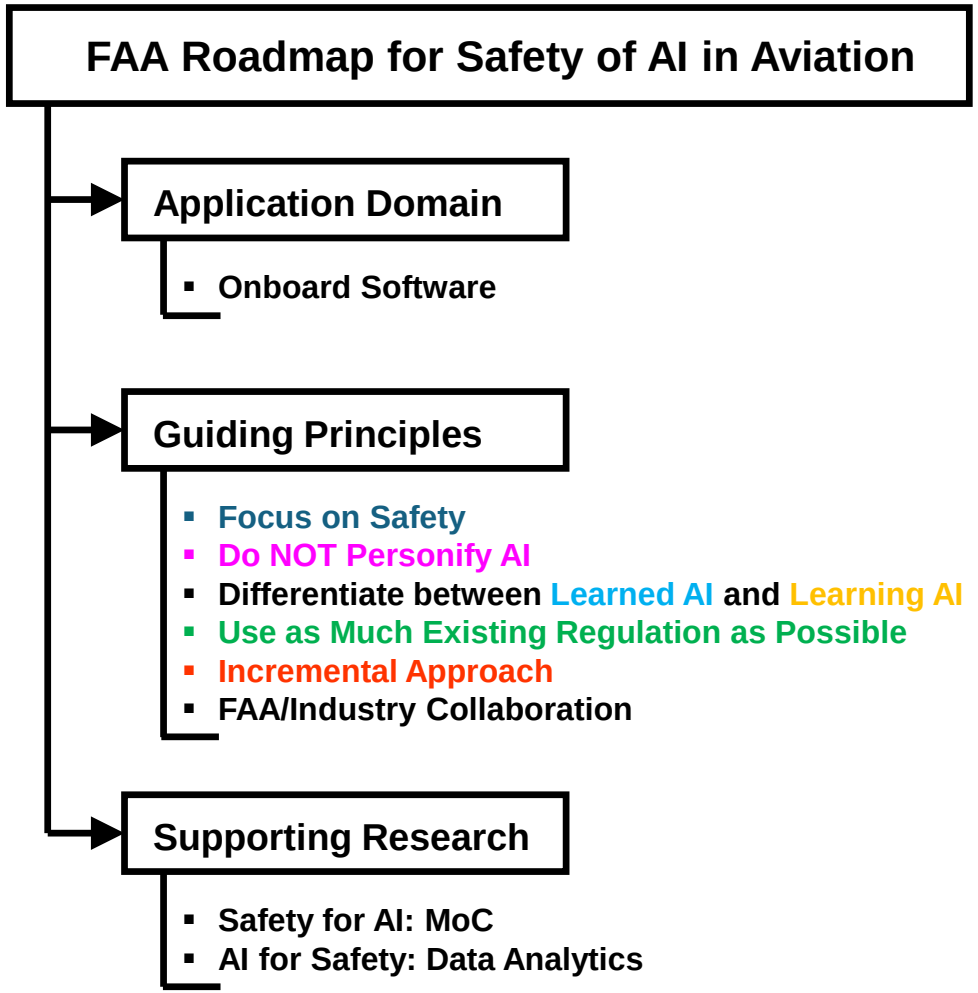
Functional System
existing regulation
DO-254
Requirements Allocated to Hardware
Develop Hardware A2
Developed HW
existing regulation
DO-178
Requirements Allocated to Software
Develop Software A3
Developed SW

FAA’s Roadmap for AI Safety



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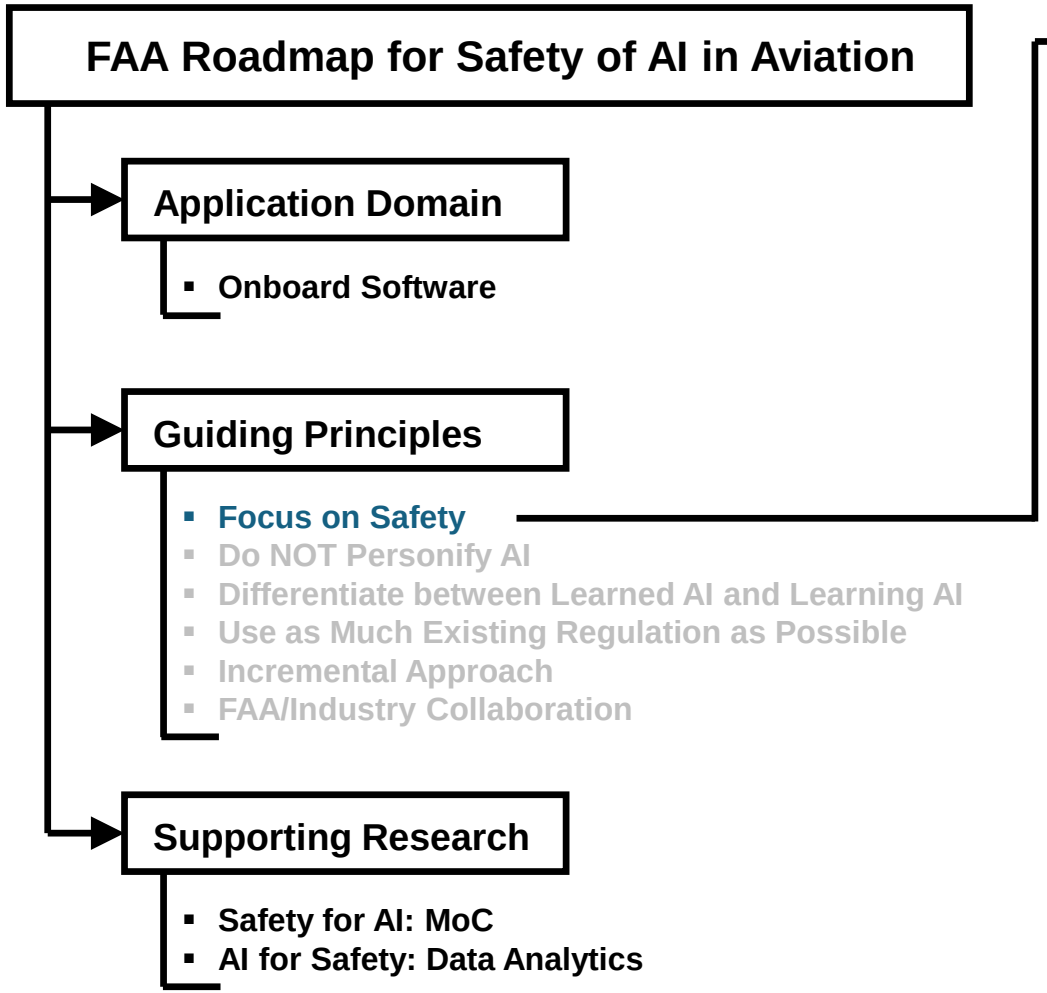

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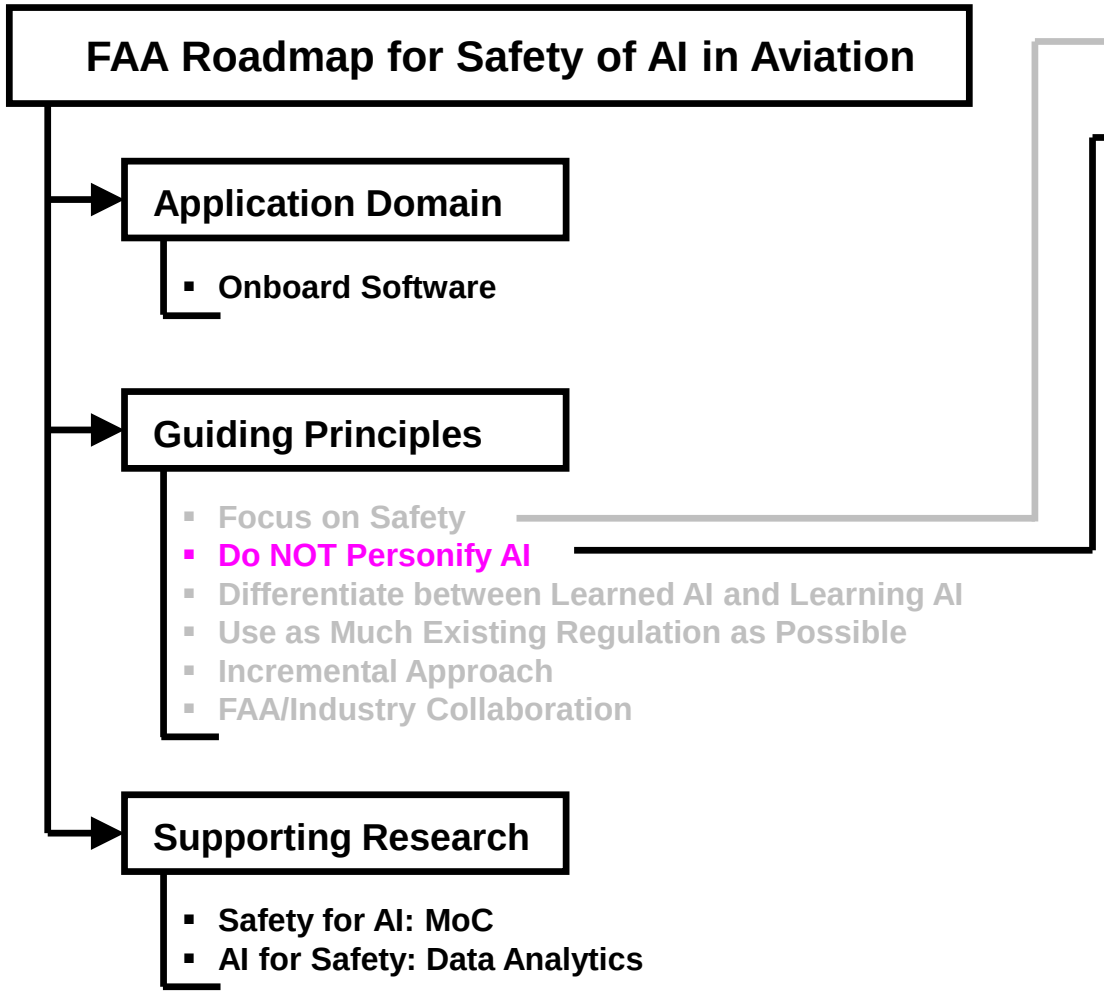

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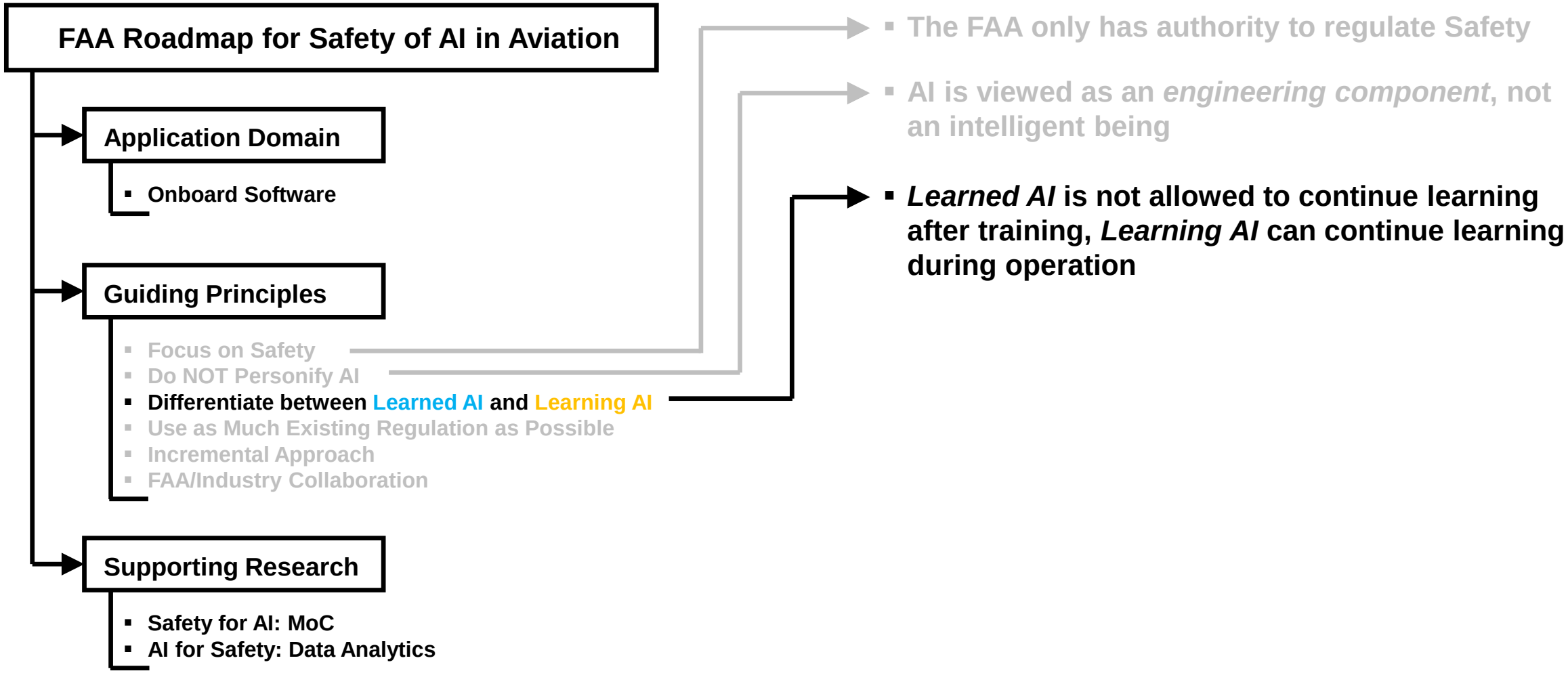

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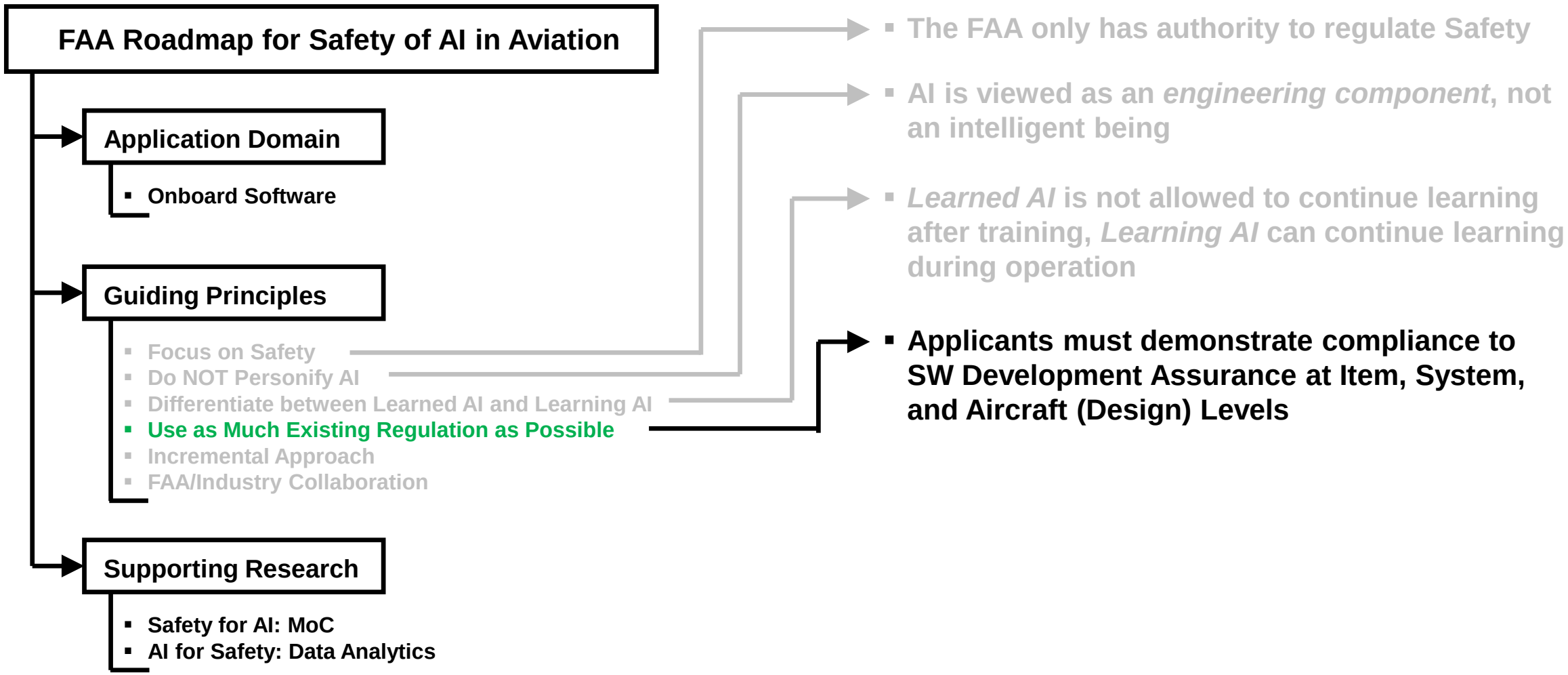

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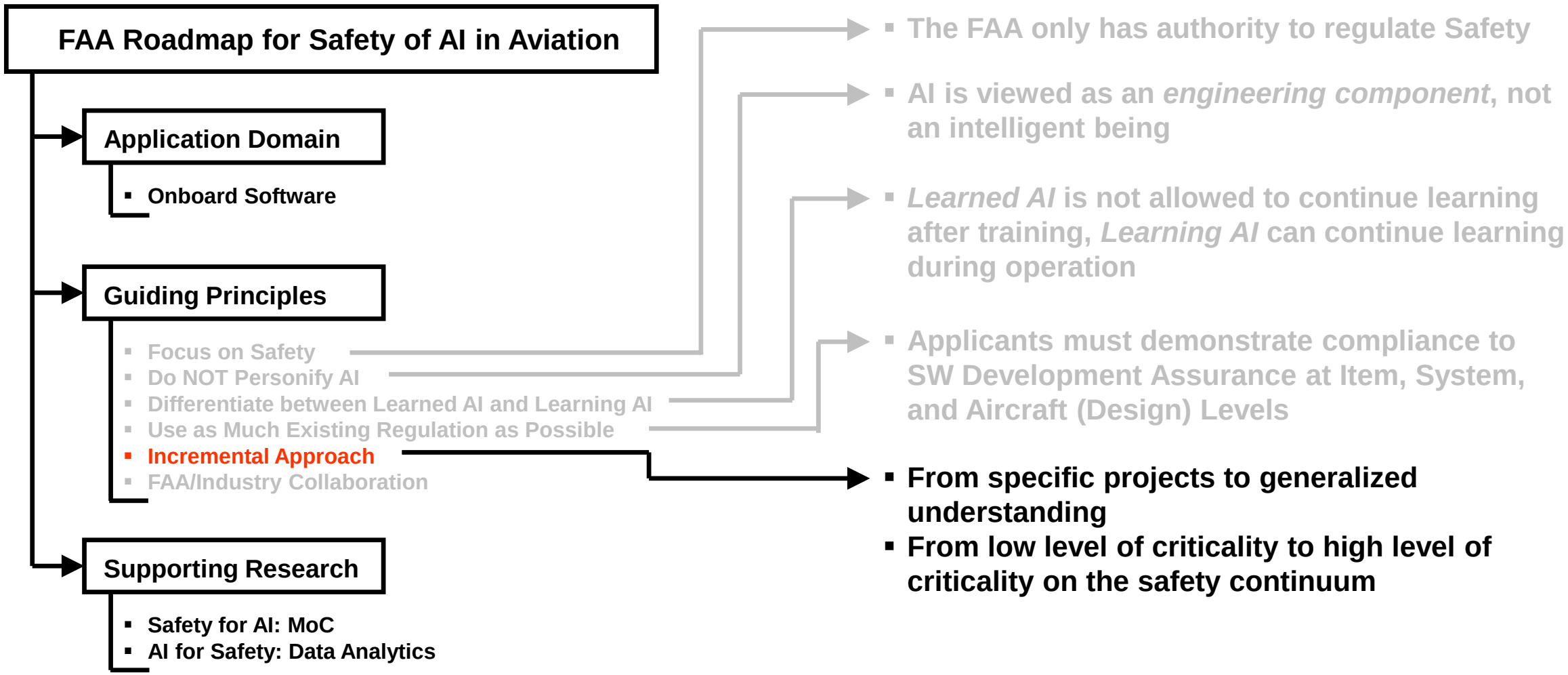

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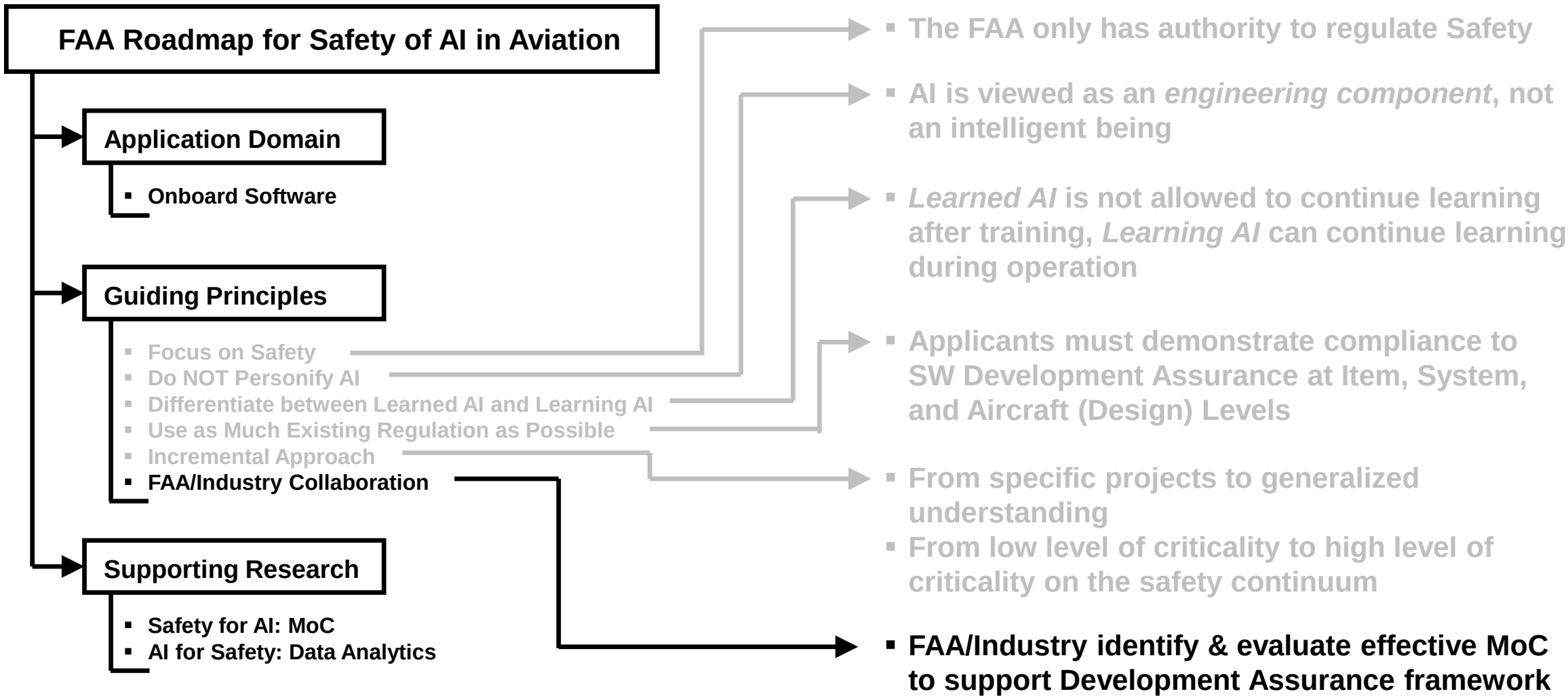

Data in the Context of Machine Learning

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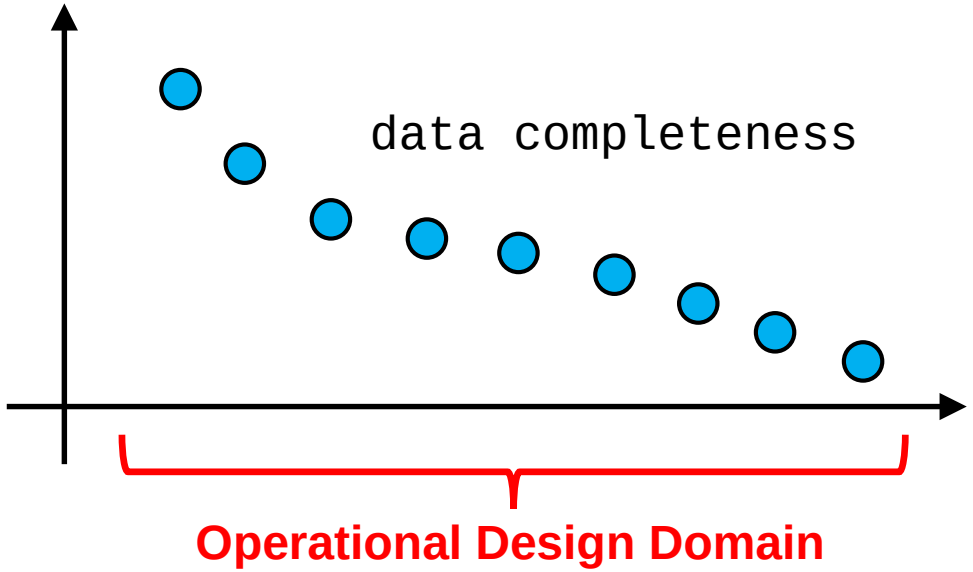

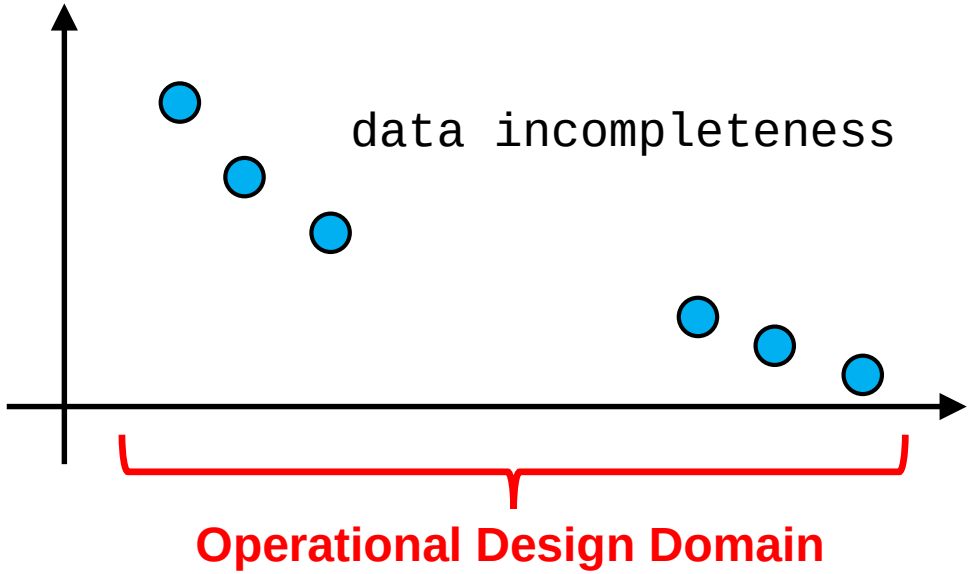

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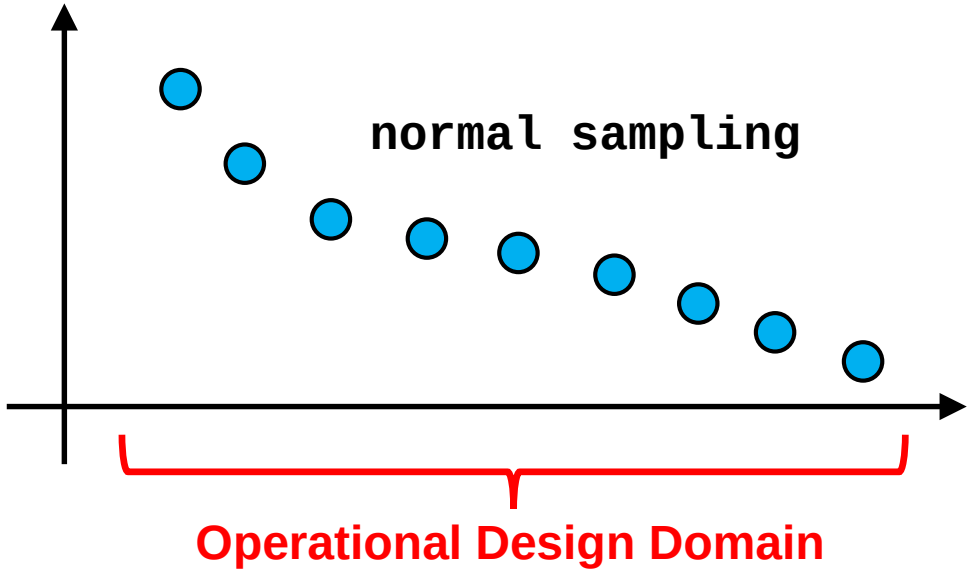
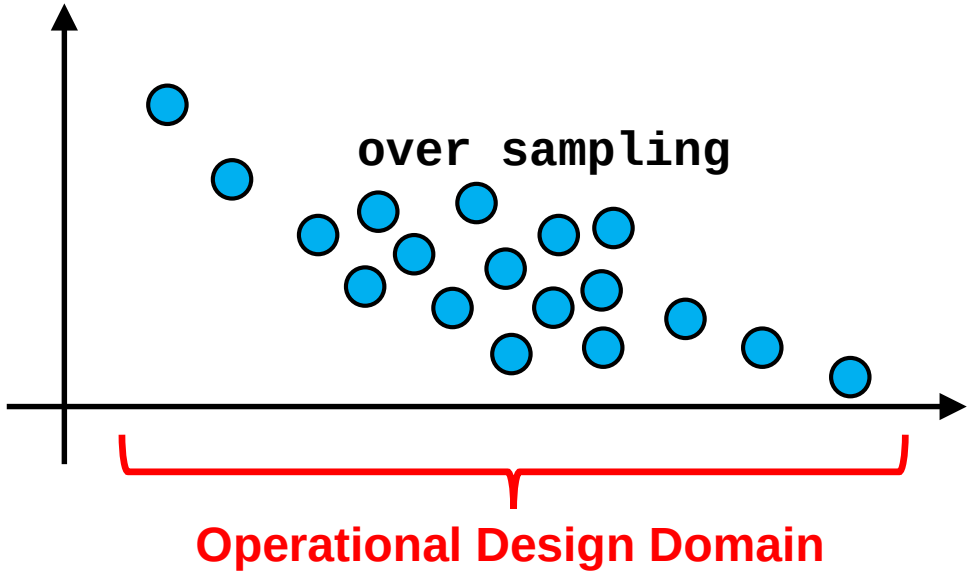
    - **data distribution in an operational design domain will shift a model or add bias to an analysis**





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  - **cybersecurity concerning for data**
    - **data integrity must be protected for future audit**

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  - Machine Learning is often applied in various disciplines, solving various types of problems (classification, regression modeling, etc.)
  - **A major issue that needs to be addressed is: the final form (an AI system or the analytical results) still need to be verified according to regulation and to comply with new consideration (safety, trustworthiness, ethics, etc.) according to how it is used**

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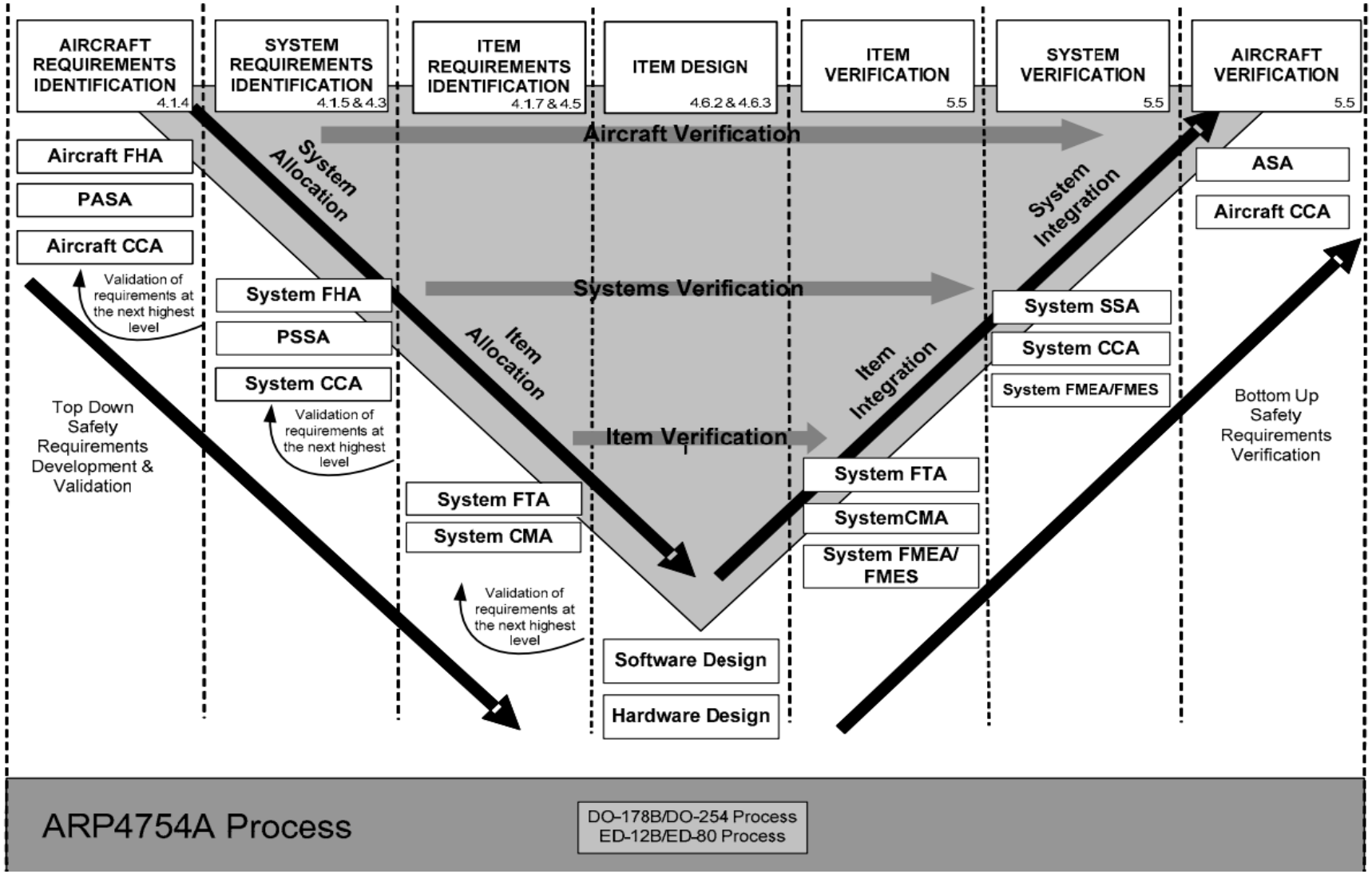
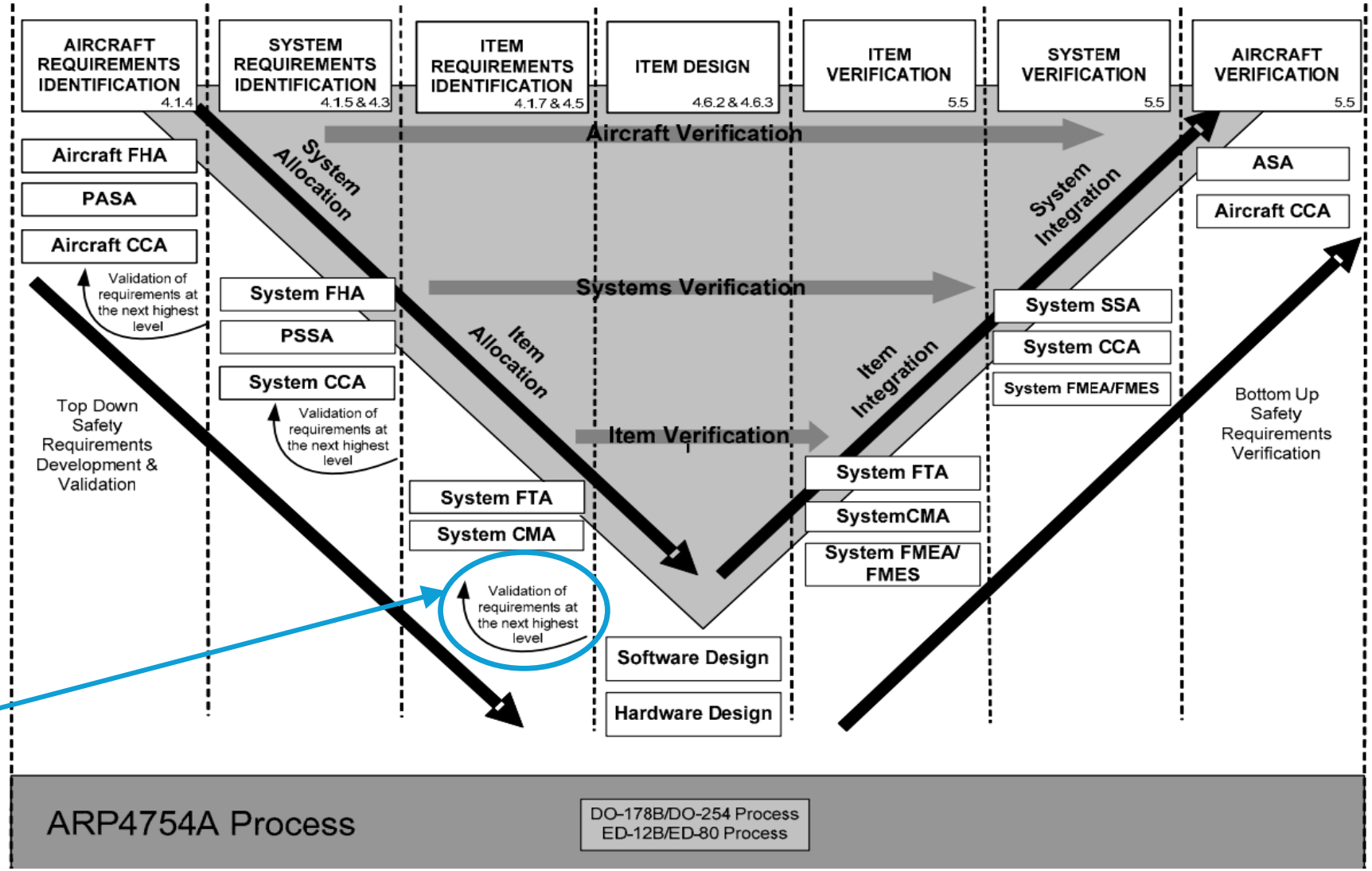
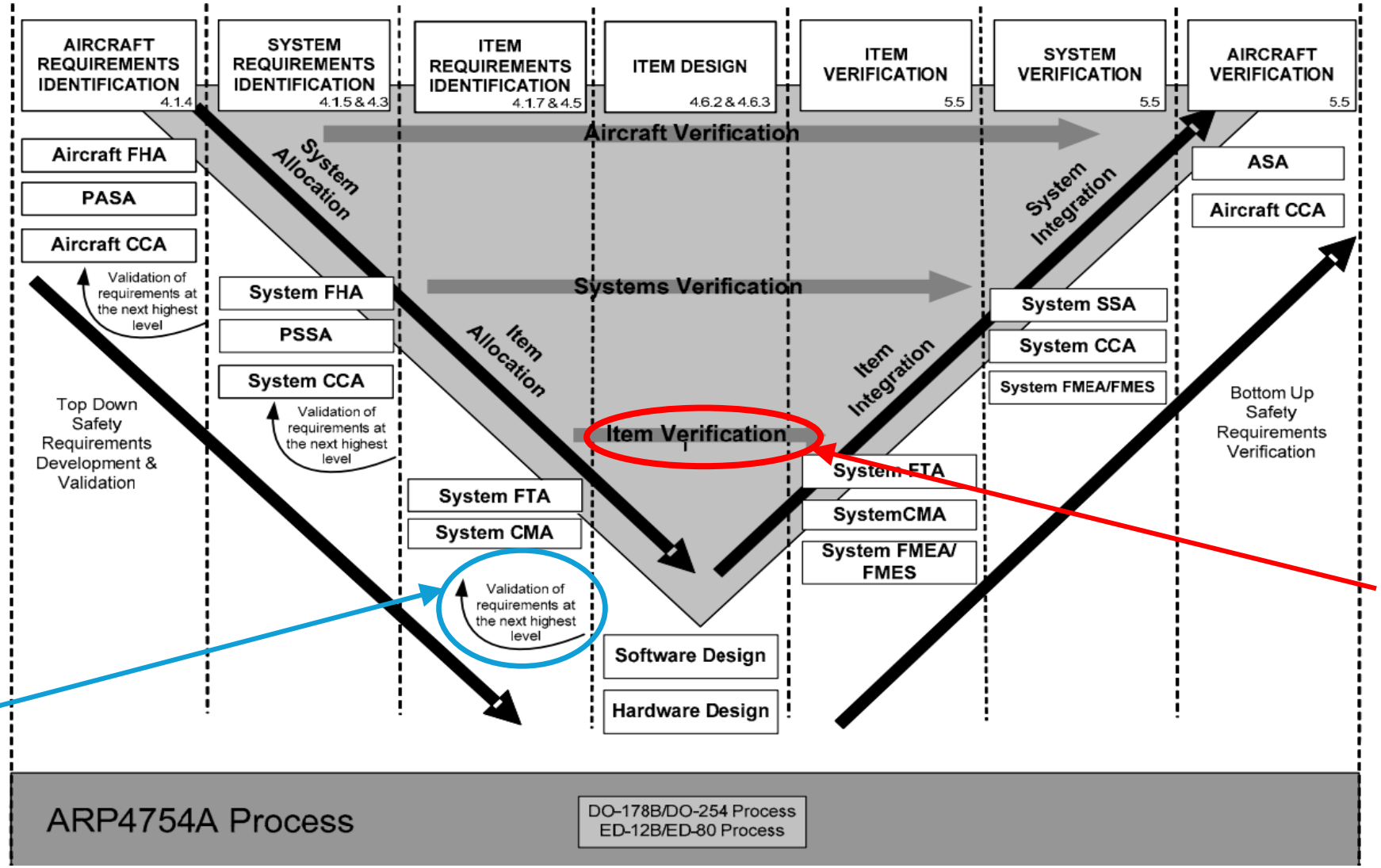

AIRCRAFT REQUIREMENTS IDENTIFICATION 4.1.4
SYSTEM REQUIREMENTS IDENTIFICATION 4.1.5 & 4.3
ITEM REQUIREMENTS IDENTIFICATION 4.1.7 & 4.5
ITEM DESIGN 4.6.2 & 4.6.3
ITEM VERIFICATION 5.5
SYSTEM VERIFICATION 5.5
AIRCRAFT VERIFICATION 5.5
Aircraft Verification
Aircraft FHA
PASA
Aircraft CCA
System Allocation
Validation of requirements at the next highest level
System FHA
PSSA
System CCA
Systems Verification
Item Allocation
Item Verification
Item Integration
System Integration
System SSA
System CCA
System FMEA/FMES
ASA
Aircraft CCA
Top Down Safety Requirements Development & Validation
Validation of requirements at the next highest level
System FTA
System CMA
Validation of requirements at the next highest level
System FTA
SystemCMA
System FMEA/ FMES
Bottom Up Safety Requirements Verification
Software Design
Hardware Design
ARP4754A Process
DO-178B/DO-254 Process
ED-12B/ED-80 Process

Discussion



Item requirements are allocated from system level, independent of the developer's choice of how to develop it

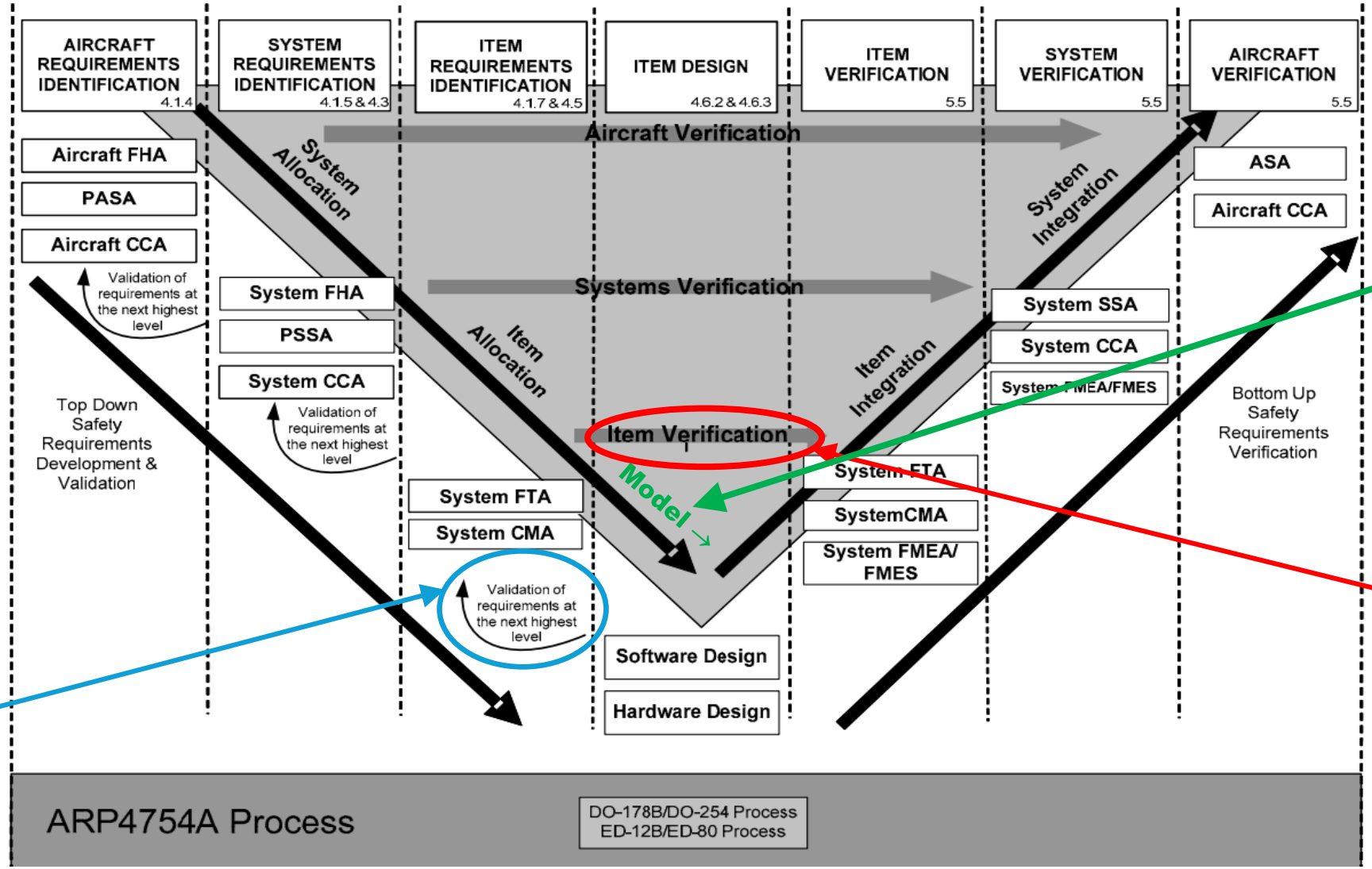
Discussion



Item requirements are allocated from system level, independent of the developer's choice of how to develop it

Verification of item's requirements should also be independent of the developer's choice of how to develop it

Discussion

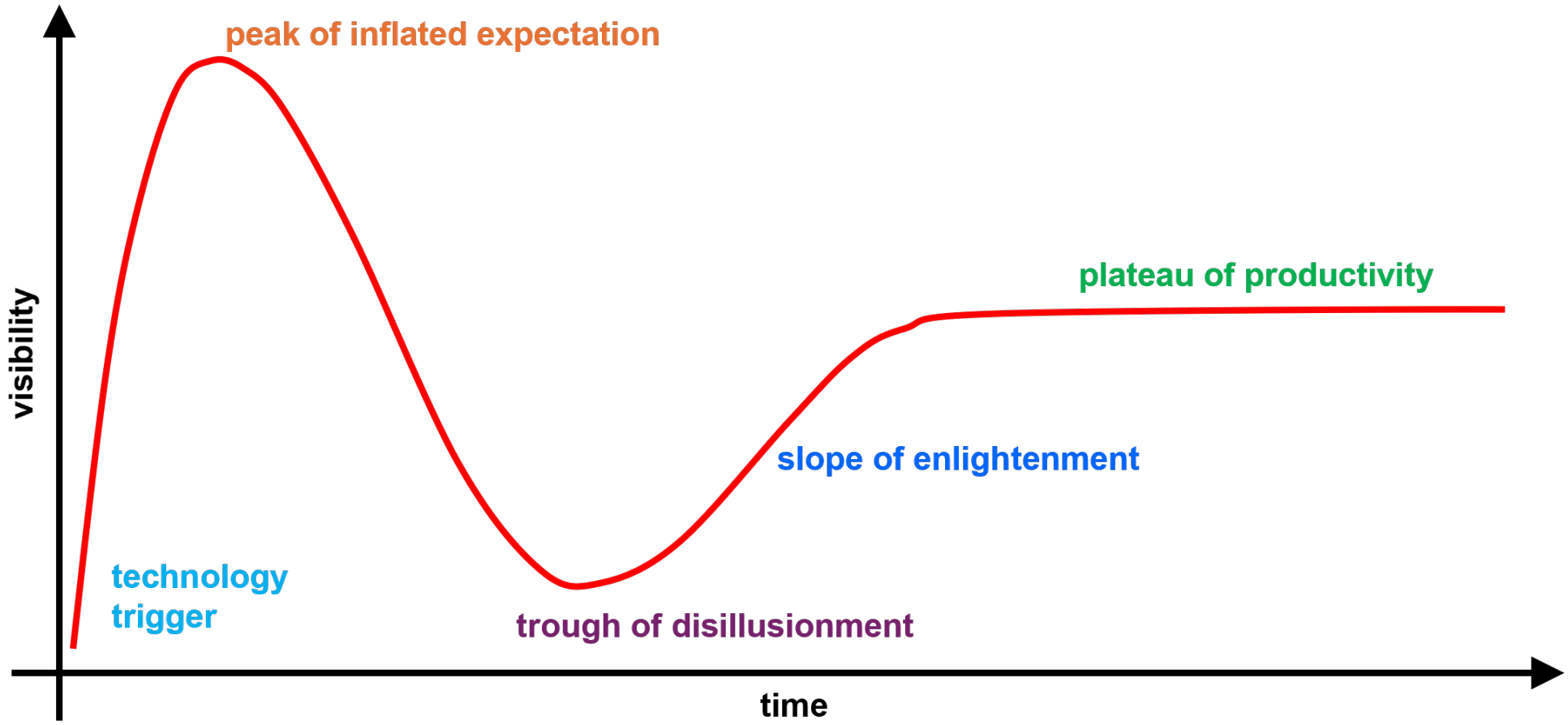


Item requirements are allocated from system level, independent of the developer's choice of how to develop it

Verification of model's specifications has been the FAA's effort to use as much existing regulation and guidance as possible

Verification of item's requirements should also be independent of the developer's choice of how to develop it

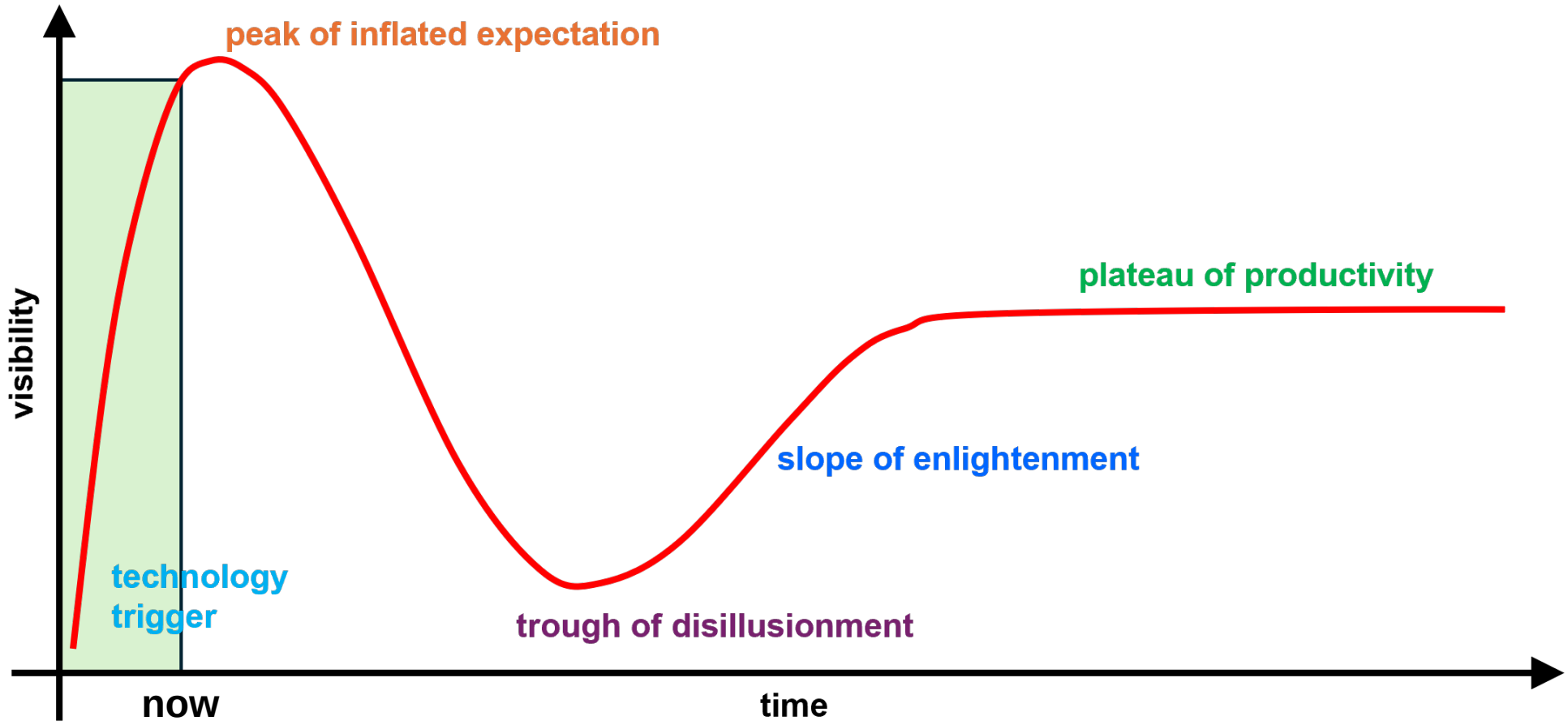
Discussion



*Source: https://en.wikipedia.org/wiki/Gartner_hype_cycle

Gartner Hype Cycle of a New Technology

Discussion



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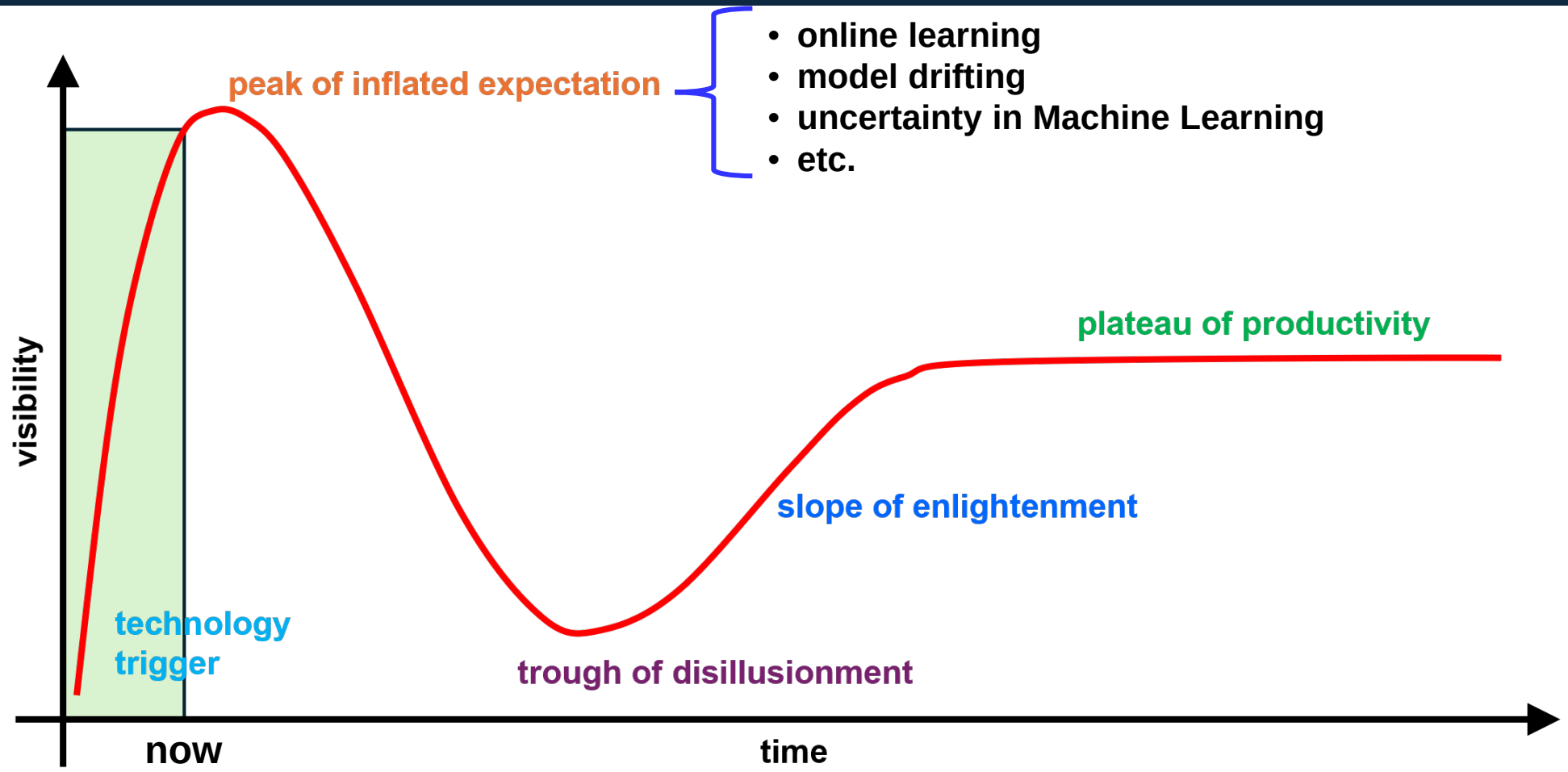
Gartner Hype Cycle of a New Technology

Discussion



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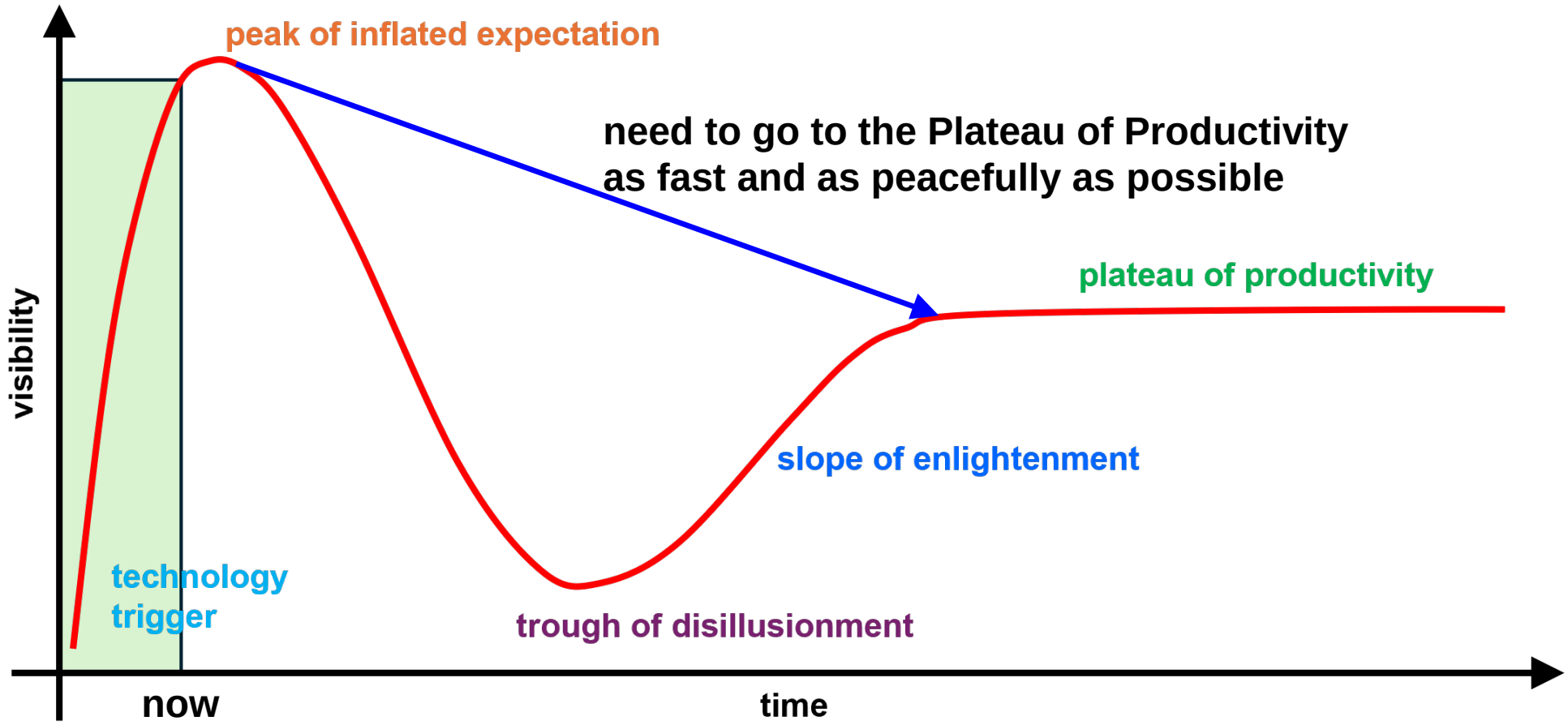
Gartner Hype Cycle of a New Technology

Discussion



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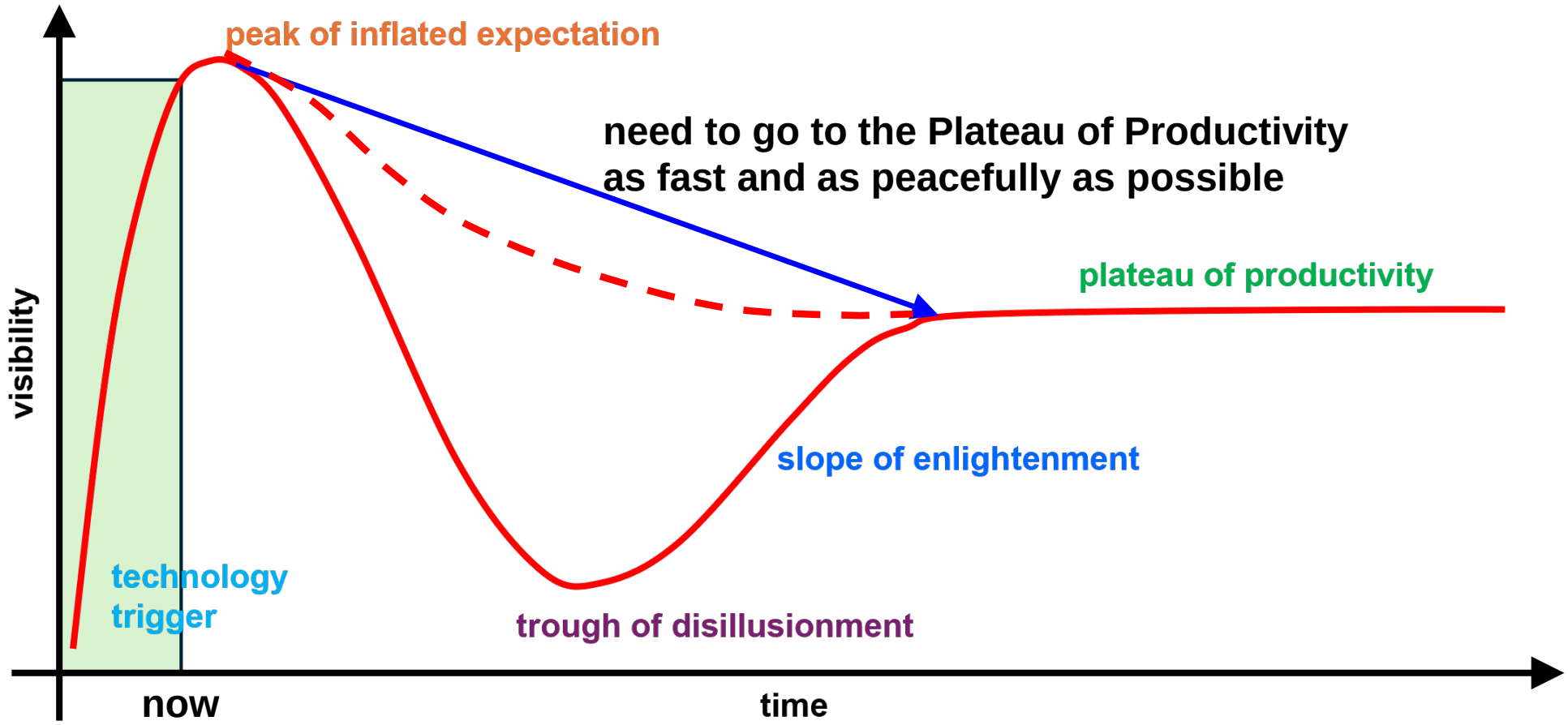
Gartner Hype Cycle of a New Technology

Discussion



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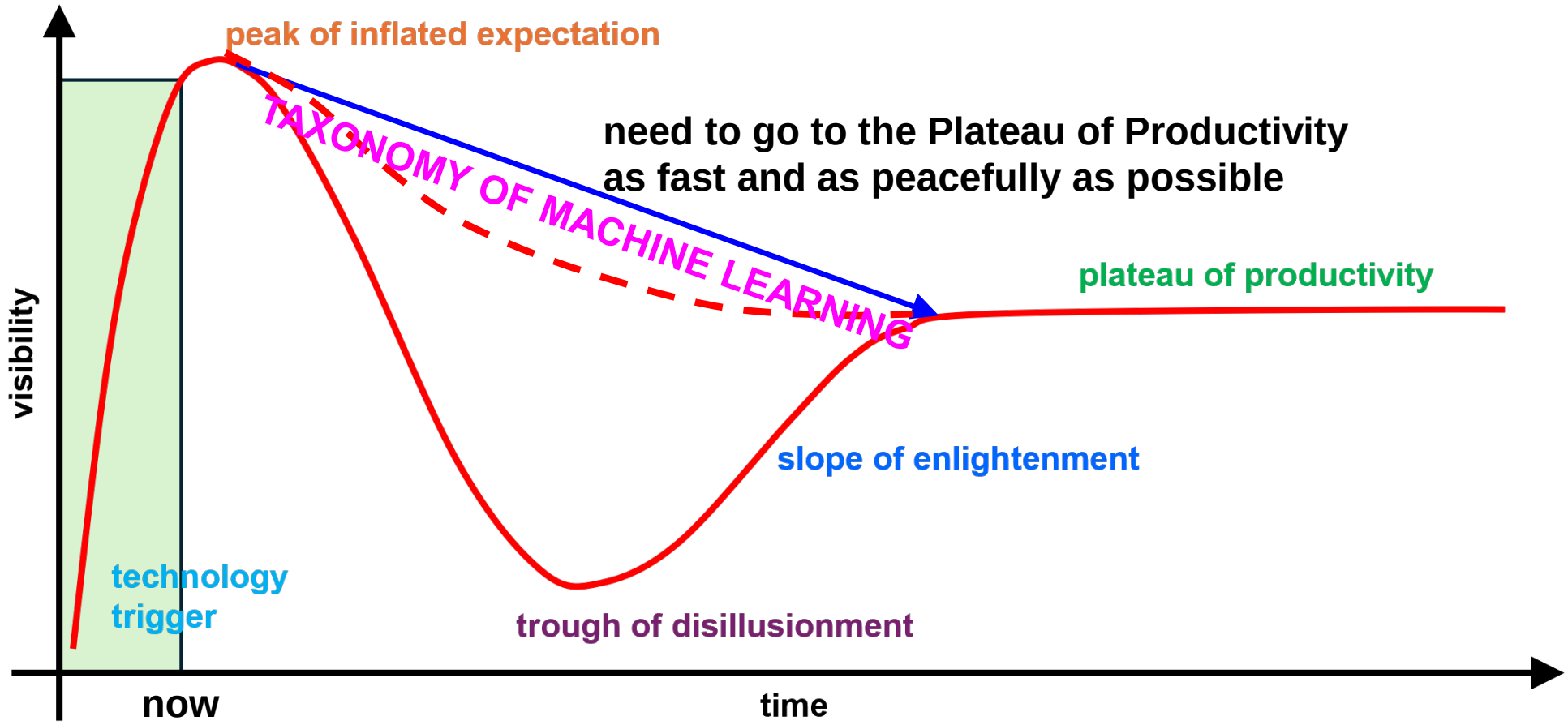
Gartner Hype Cycle of a New Technology

Discussion



*Source: https://en.wikipedia.org/wiki/Gartner_hype_cycle

Gartner Hype Cycle of a New Technology

Thank you very much

Merci beaucoup

Muchas gracias

Cám ơn rất nhiều

非常感謝

Grazie mille

Muito obrigado

Moltes gràcies

आपका बहुत बहुत धन्यवाद

Taxonomy of Machine Learning, and its Role in Developing AI Systems

Trung T. Pham, Ph.D.

`trung.t.pham@faa.gov`

05/13/2025

Federal Aviation Administration