



Software Center

AI Engineering A Research Agenda

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Software Center

Why Digitalization Will Kill Your Company Too

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How many companies that were on the Fortune 500 list in 2000 are still on the list in 2014?

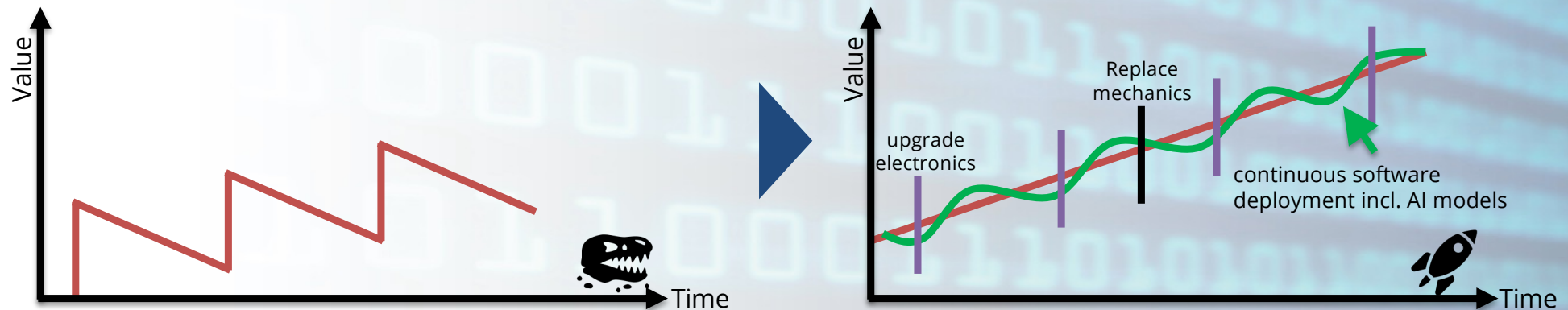


Disruption Is The New Normal

- Jim Collins (Built to last): Companies last, on average, ~~30~~ **15** **10** years on the Fortune 500 list. And that time period is decreasing
- Main cause: Companies fail to innovate and to build new core capabilities

Digitalization Is The New Disruptor!

Why digitalization?



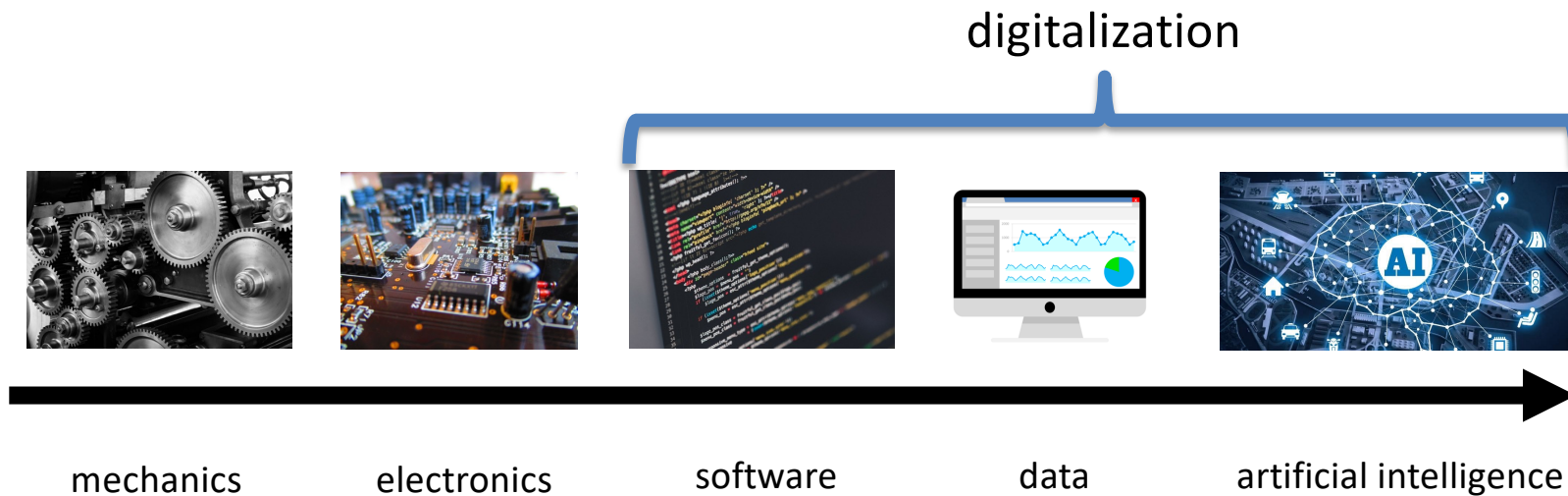
- Differentiation through mechanics and electronics is increasingly difficult
- To avoid commoditization, new solutions and services are required
- Digitalization of products, data from the field and changed business models can provide differentiation

Hypothesis: growing revenue through new, *continuous* business models based on a *digitalized* product portfolio is the most promising strategy to increase differentiation and avoid commoditization

What Makes A Digital Company?

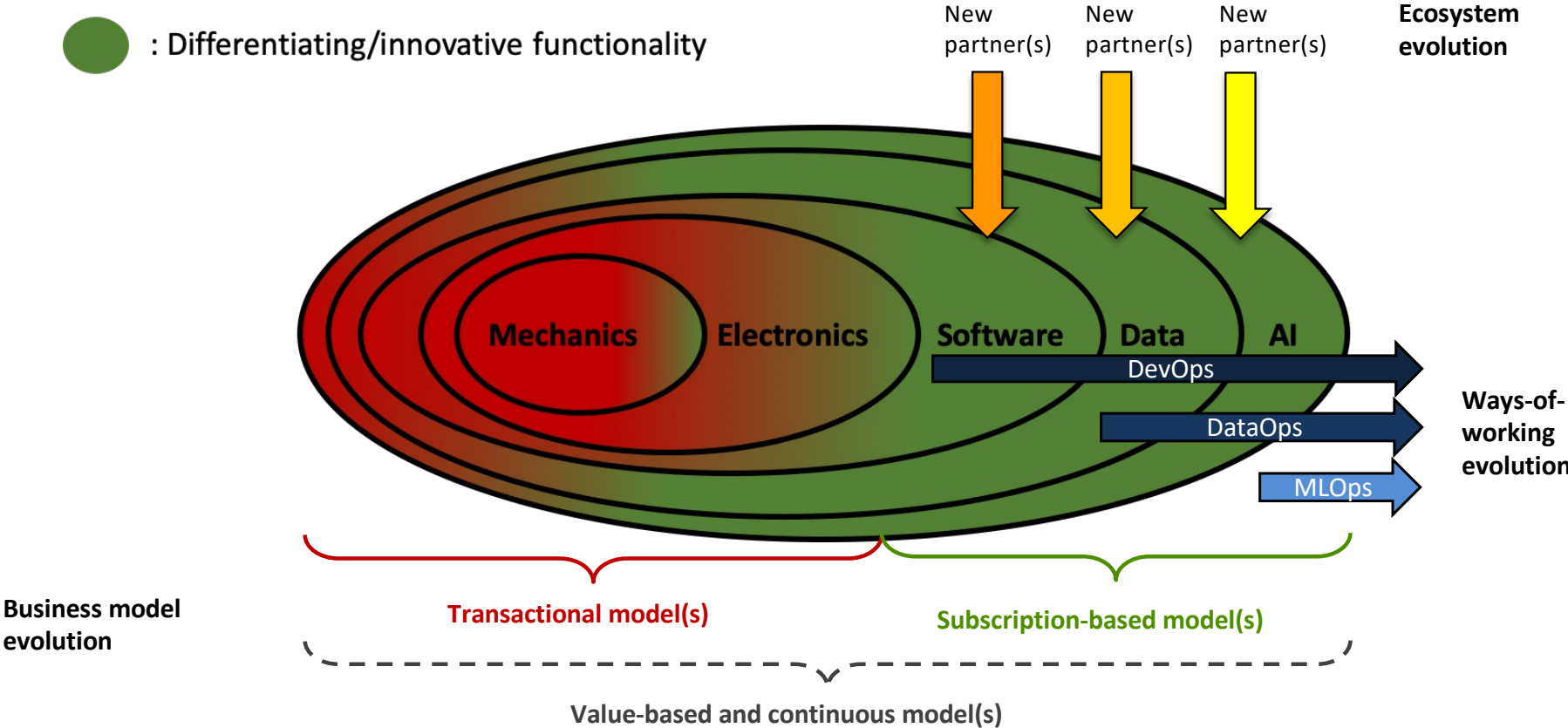
- Using email?
 - Have a website?
 - Use social media?
 - Video conferencing?
 - Chatbots?
-
- Data-driven decision making
 - Relentless experimentation (e.g. A/B testing)
 - Short feedback cycles
 - Decision making pushed down in organization
 - Strategic data collection
 - Unified data warehouse
 - Pervasive use of AI and automation
 - New job descriptions

Technology Evolution



Business Evolution

- : Commodity functionality
- : Differentiating/innovative functionality



Systems Engineering 2.0

1. Build it in **software** unless you really, really can't
2. Build it in **hardware** and keep it flexible (FPGAs instead of ASICS) unless you really, really can't
3. Build it in **mechanics** if you HAVE to and keep it modular, easily replaceable and simple

Systems Engineering 2.0

From:

- Systems built to last
- Opinions-based decision making (experience)
- Deeply integrated architectures
- Hierarchical organizational model
- Satisfying the requirements
- Static certification



To:

- Systems built to evolve
- Data-driven decision making
- Modularized architectures
- Ecosystem of partners
- Constant experimentation and innovation
- Dynamic, continuous certification

Three Key Take-Aways

- Digitalization is disrupting industry and society to an extent that we have only seen the early beginnings of
- Digital companies need to be world class in:
 - Software (continuous deployment)** to continuously deliver value
 - Data** to increase the quality of decision making
 - Artificial Intelligence** to provide superior solutions to almost everything
- Using AI requires AI Engineering and many companies fail to incorporate this

Overview

- Vem är jag? Wie ben ik? Who am I?
- Towards a Digital Business Operating System
- AI Engineering
- Some ongoing research
- Conclusion



Academic Research



TU/e



Software Center



Consultancy



Boards



Angel investing



Industry



Software Center

Mission: To significantly improve the *digitalization* capability of the European Software-Intensive industry

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GRUNDFOS

SIEMENS Gamesa
RENEWABLE ENERGY



BOSCH

JEPPESEN
A BOEING COMPANY

ERICSSON

zenseact

AXIS
COMMUNICATIONS



advenica

VOLVO
VOLVO GROUP



SIEMENS



SAAB



SCANIA

DEIF

A New Collaboration Model

- Software Center aims to develop a strategic partnership with partner companies to significantly accelerate their adoption of digitalization practices
- Research is performed in 6-month sprints
- Long term goal; short term value
- System-level, holistic perspective, including business, architecture, ways of working and organizational aspects

RESEARCH THEMES

Continuous
Delivery

Continuous
Architecture

Software

Metrics

Customer
Data- and
Ecosystems

Data

AI
Engineering

AI



How are we doing?

- Stairway to Heaven
- CIVIT model
- CAFFEA model
- HYPEX model
- Metrics-based visualization
- Etc.

Active use by the Software Center companies!

Advantages for Industry

- More consistent, integrated focus on your key change initiatives
- Holistic approach including technical, organizational and business aspects
- Value every 6 months
- Opportunity to steer projects frequently

Some Online Companies



Overview

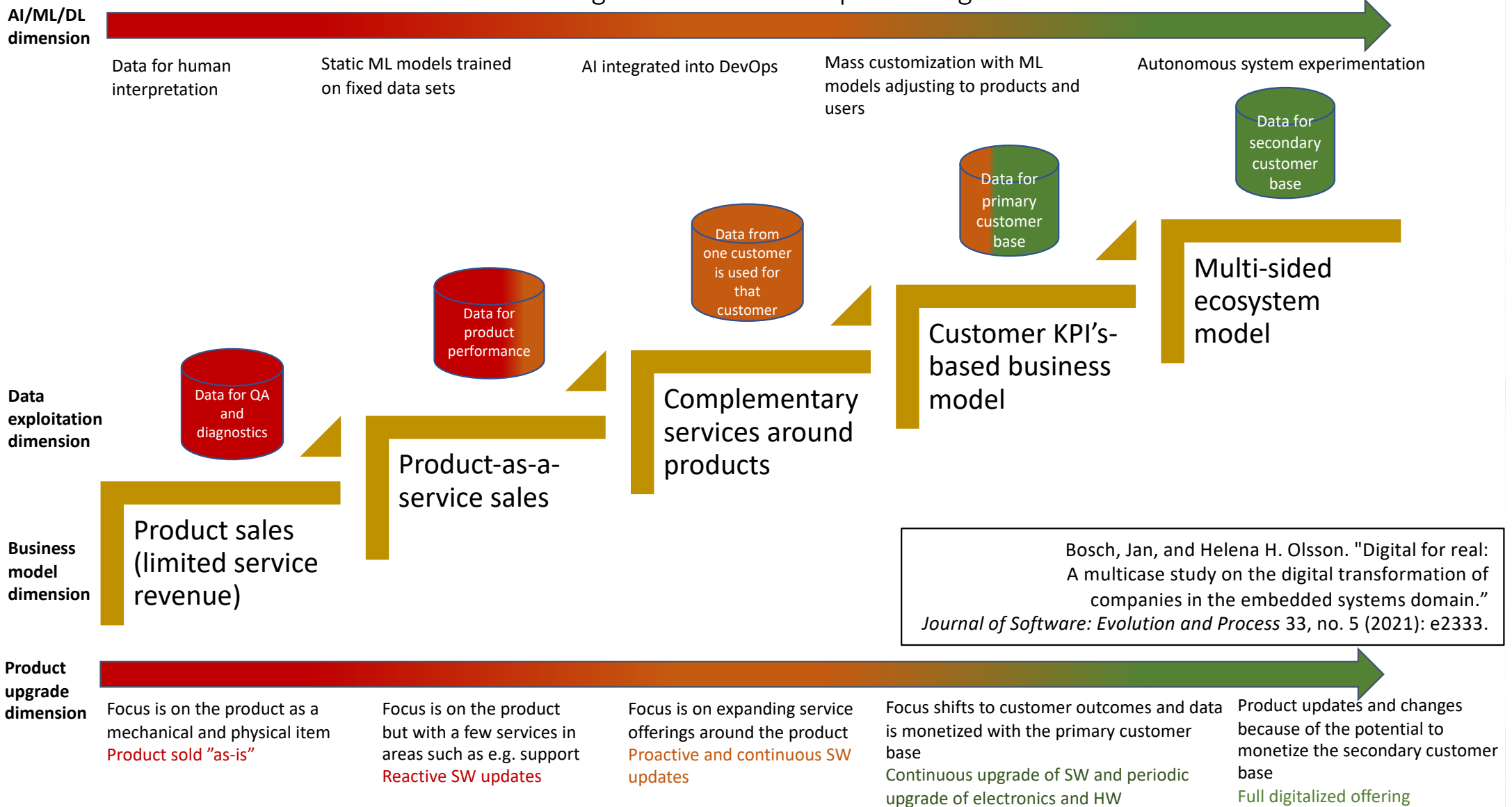
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How do we deliver value to customers?

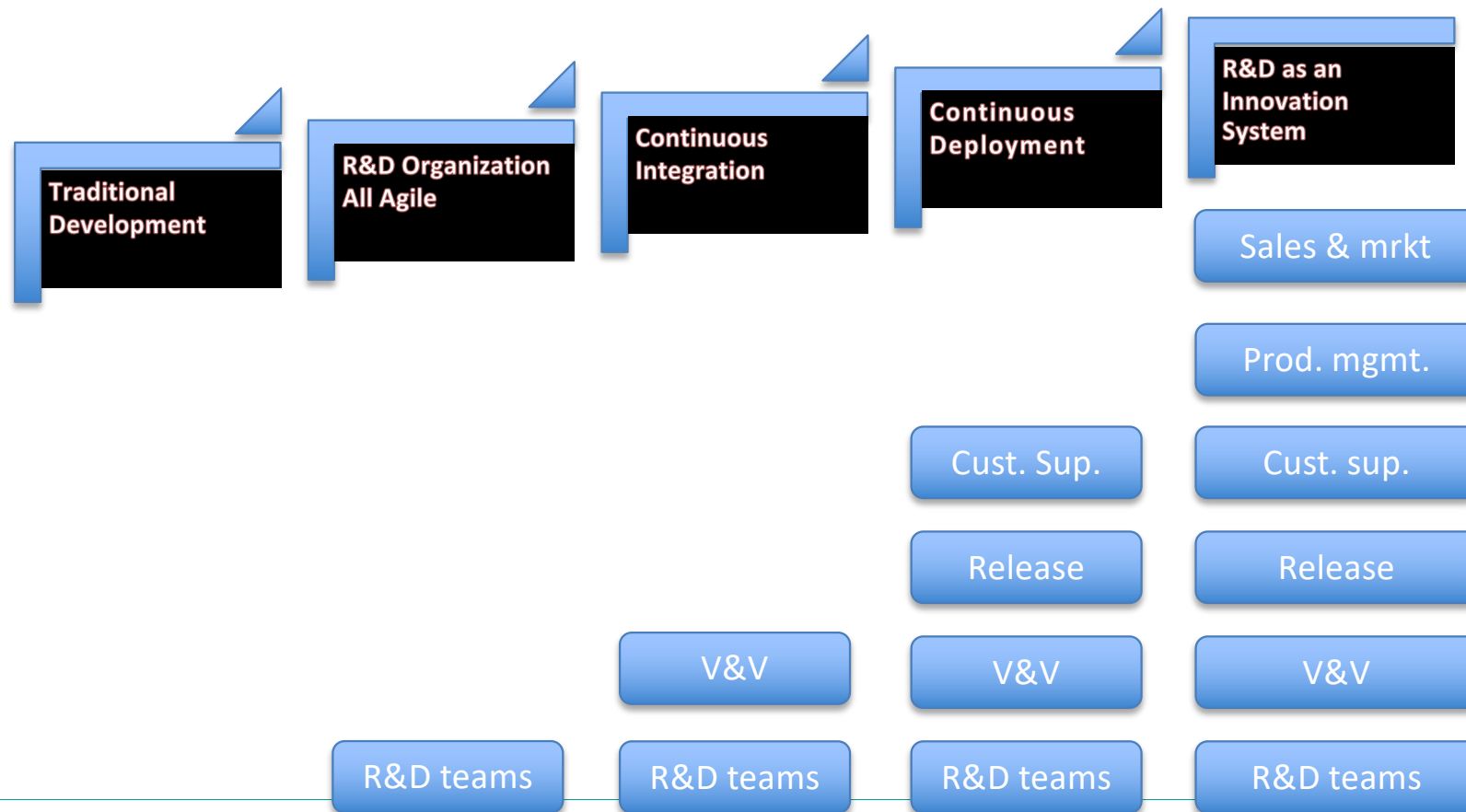
- Product generations
- Annual software updates
- DevOps, DataOps and AI/MLOps
- A/B testing
- Reinforcement learning

shortening of value delivery cycles

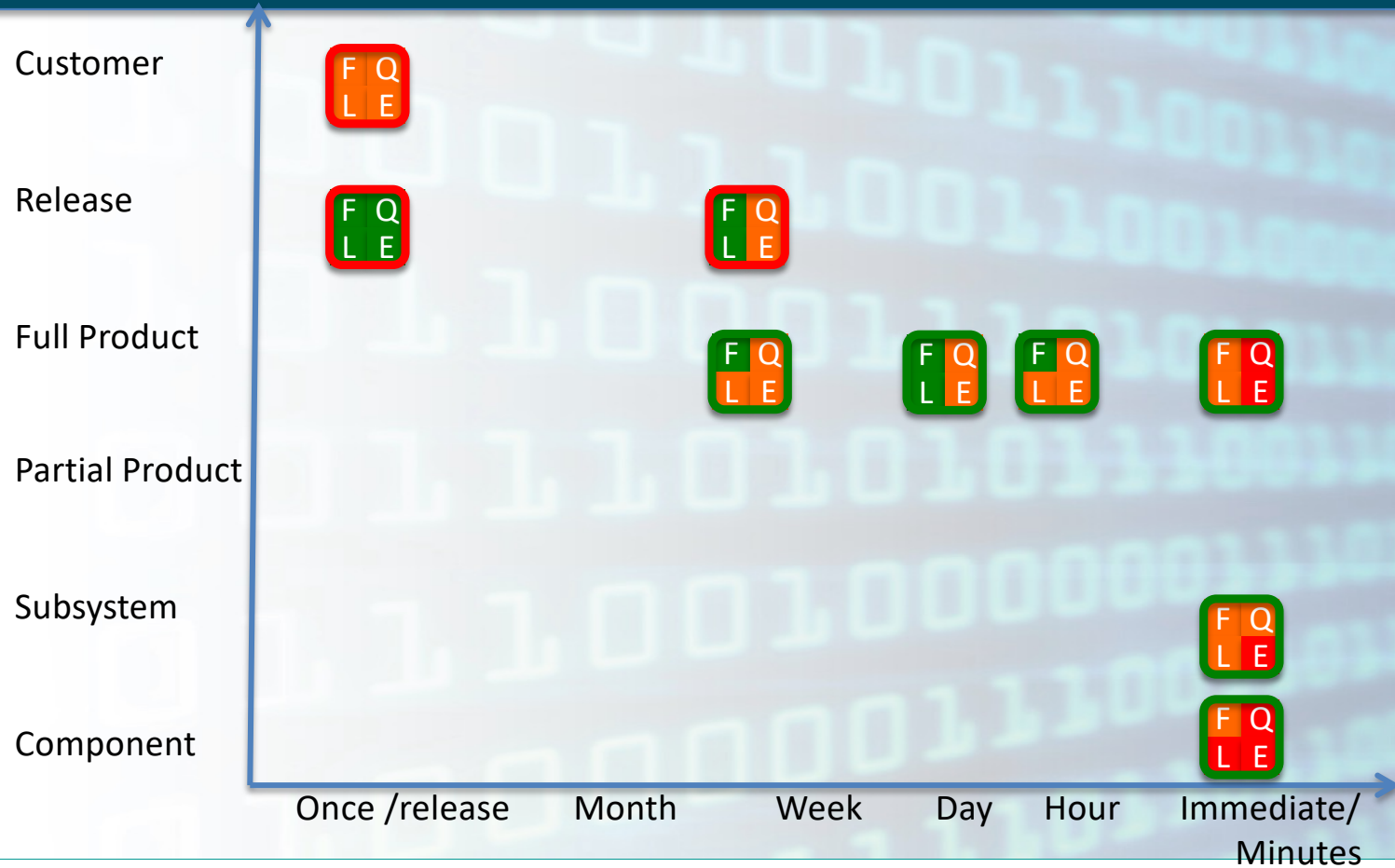
From Traditional to Digital: The evolution path along four dimensions



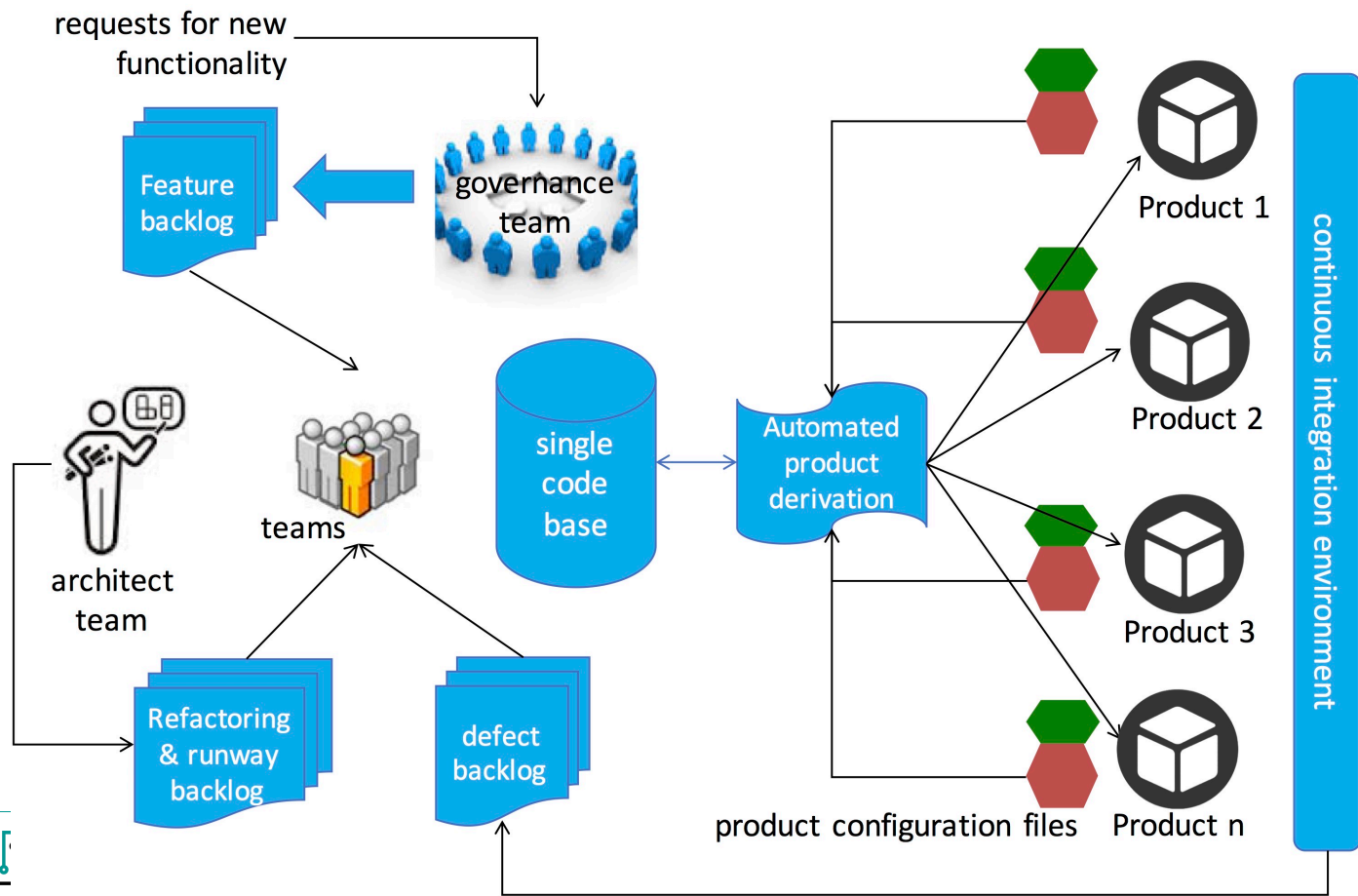
Stairway to Heaven: Speed



CIVIT: Visualizing Continuous Integration And Test



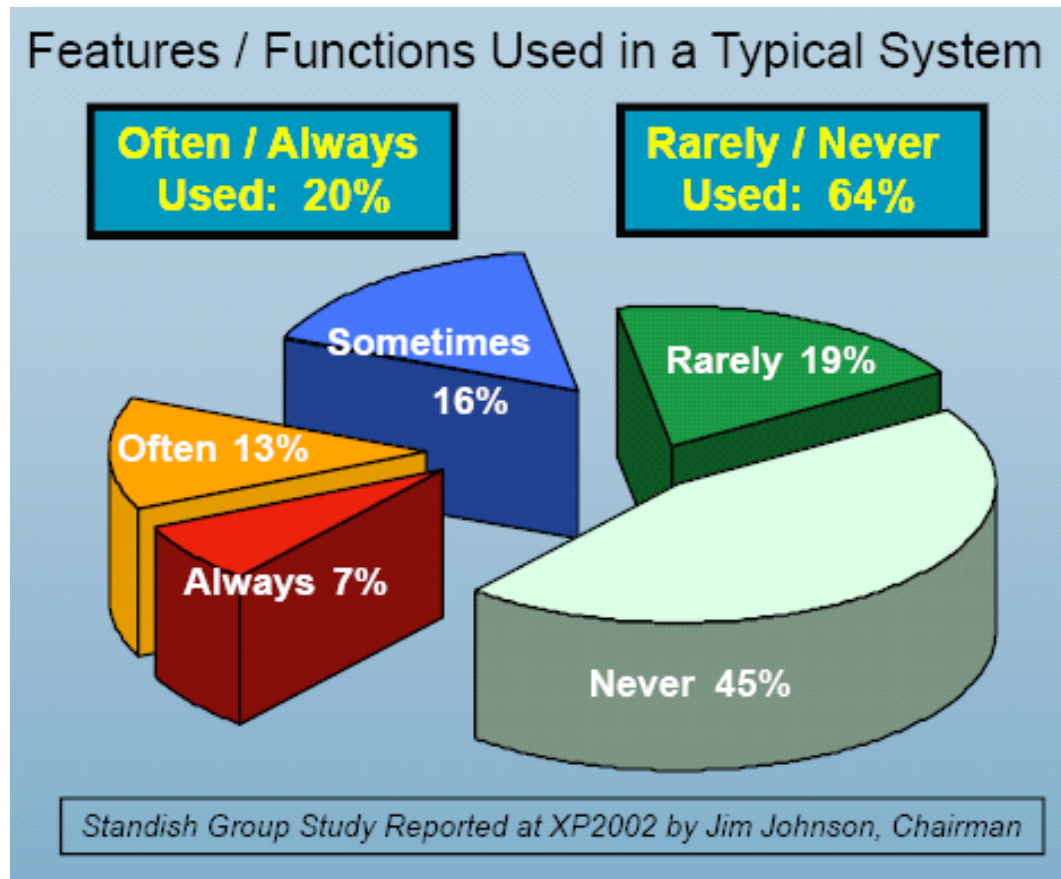
Continuous Delivery Model



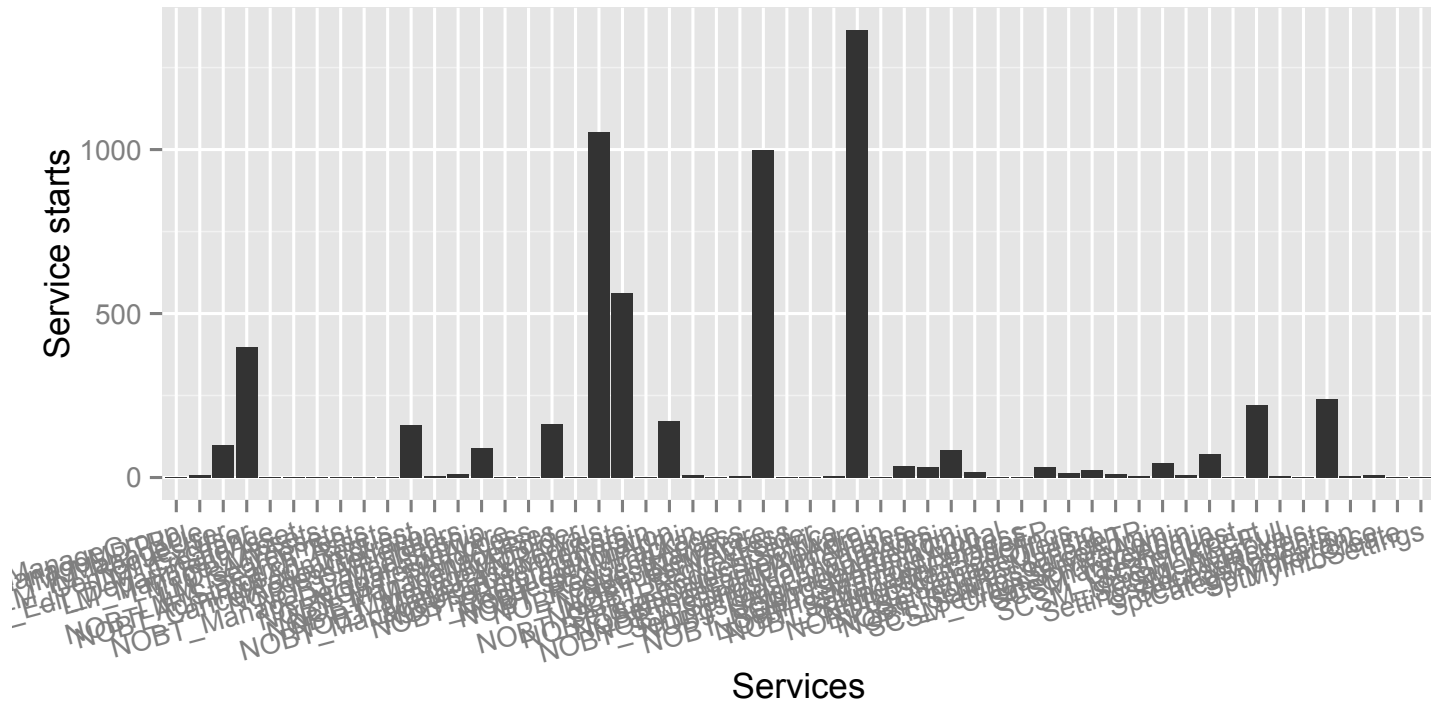


How do we know that we're actually delivering value customers care about?

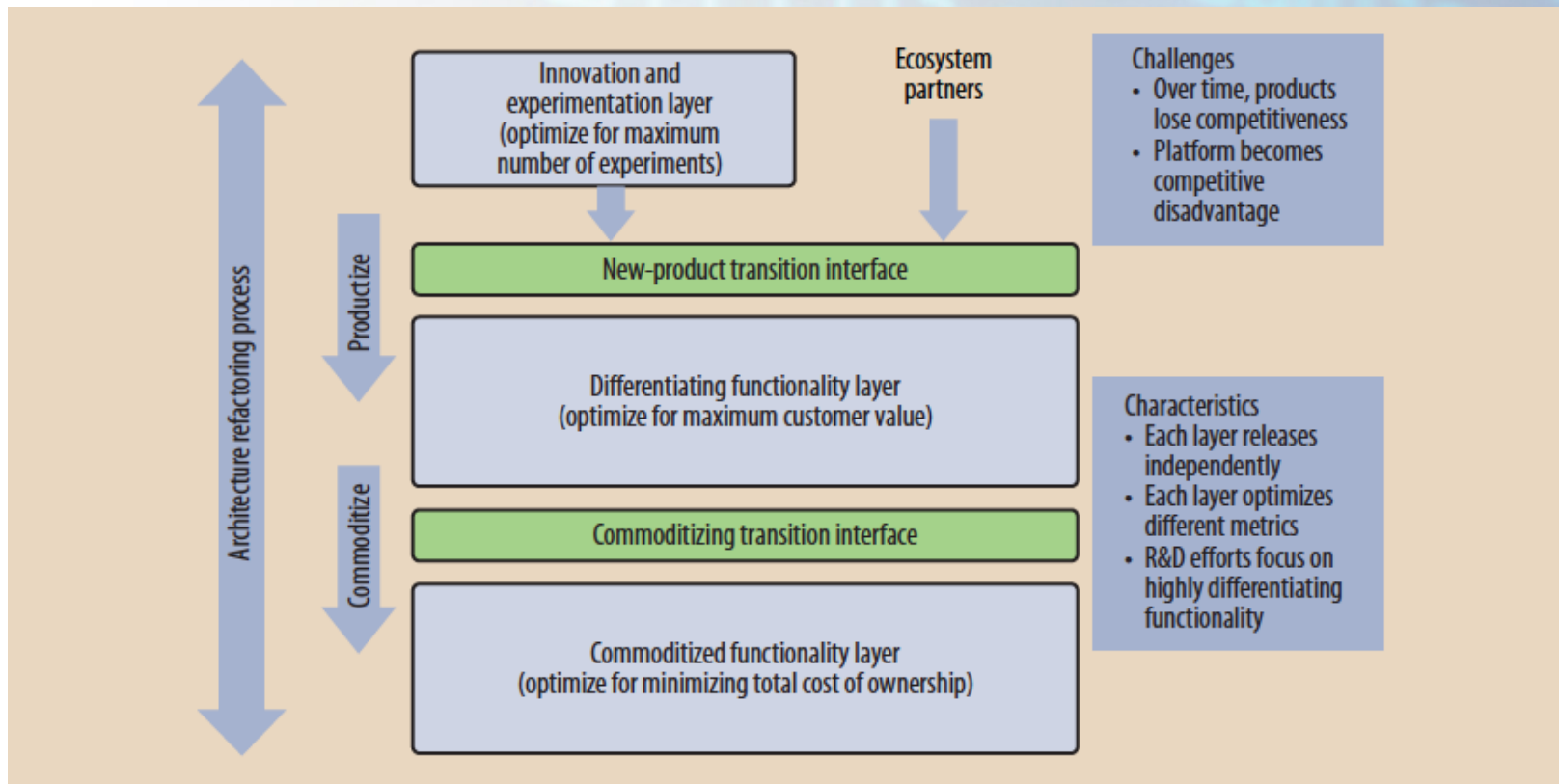
“Featuritis”



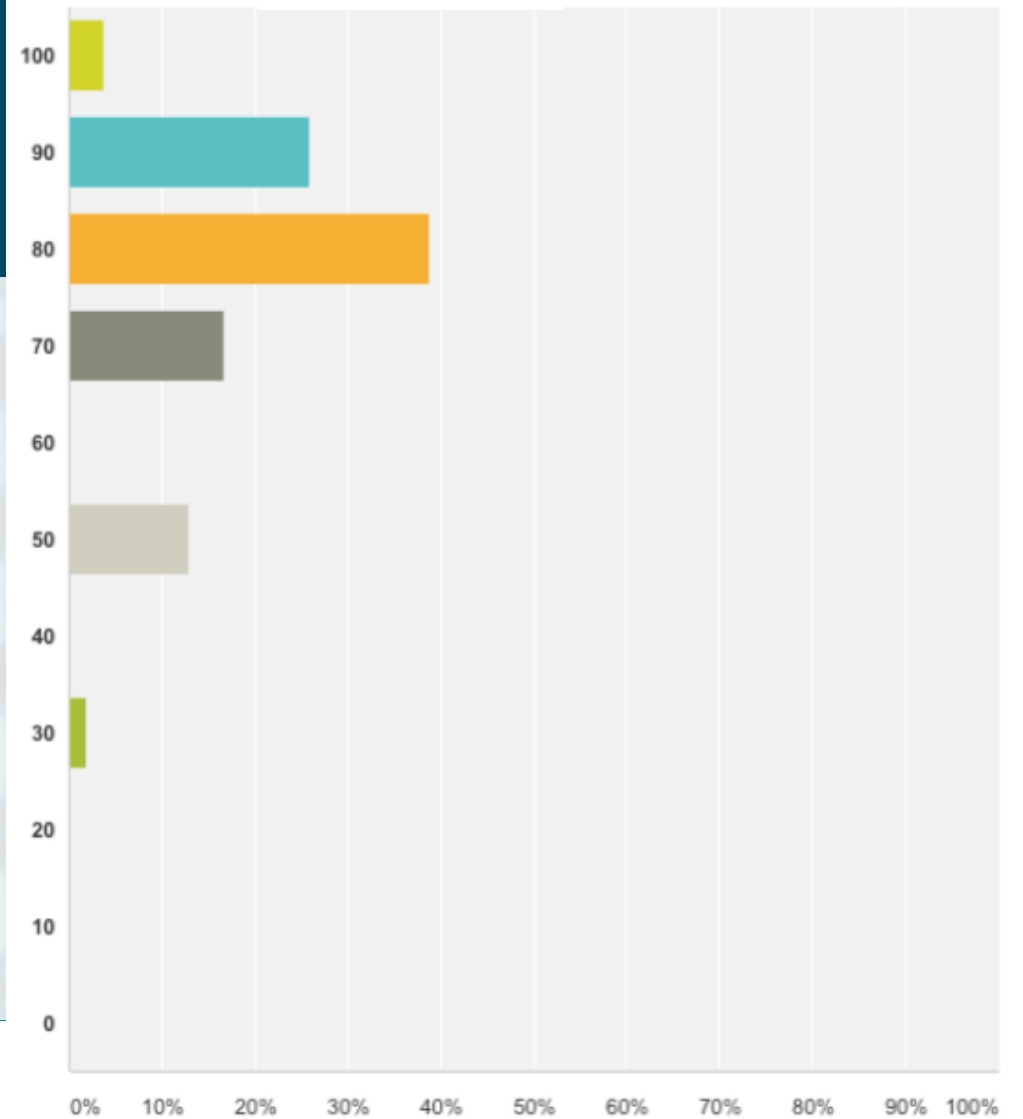
Our Research ...



Three Layer Product Model

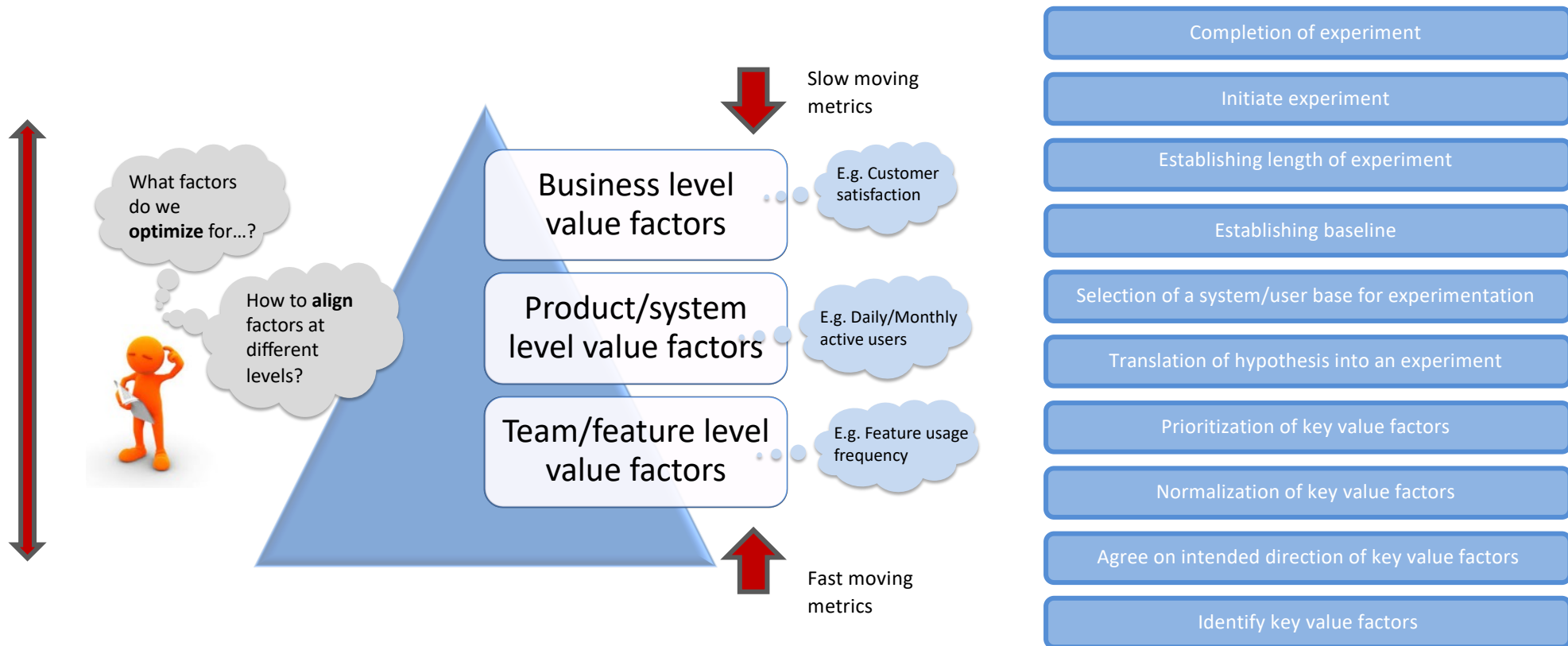


What % of R&D for Commodity?



Value Design

Value factors at different levels that need to align for an organization to benefit from data driven development practices and achieve the **outcomes** they look for.



Case company example I: Key value factors

Adaptive Cruise Control

- % of total time.
- % of low speed
- % of medium speed
- % of high speed
- # deactivation when following a car
- # daily users
- # deactivation while accelerating
- # manual activation (< 1 month)
- # sustaining users (> 1 month)

Adaptive Cruise Control

Brand	Priority	Weight
I - # deactivation (C50)		
- % of low speed (< 50)		
- % of medium speed (50 < x < 90)		
- % of high speed (> 90)		
III - # deactivation when following a car.	↓	
- # daily users	↑	
II - # deactivation while accelerating	↓	
II - # manual activation (< 1 month)	↑	
I - # sustaining users (> 1 month)		
II - # manual interactions		

Adaptive Cruise Control

Brand	Priority	Weight
I - # deactivation (C50)		
- % of low speed (< 50)		
- % of medium speed (50 < x < 90)		
- % of high speed (> 90)		
III - # deactivation when following a car.	↓ 0.2	
- # daily users	↑ 0.35	
II - # deactivation while accelerating	↓ 0.15	
II - # manual activation (< 1 month)	↑ 0.15	
I - # sustaining users (> 1 month)		
II - # manual interactions		



Identify key value factors

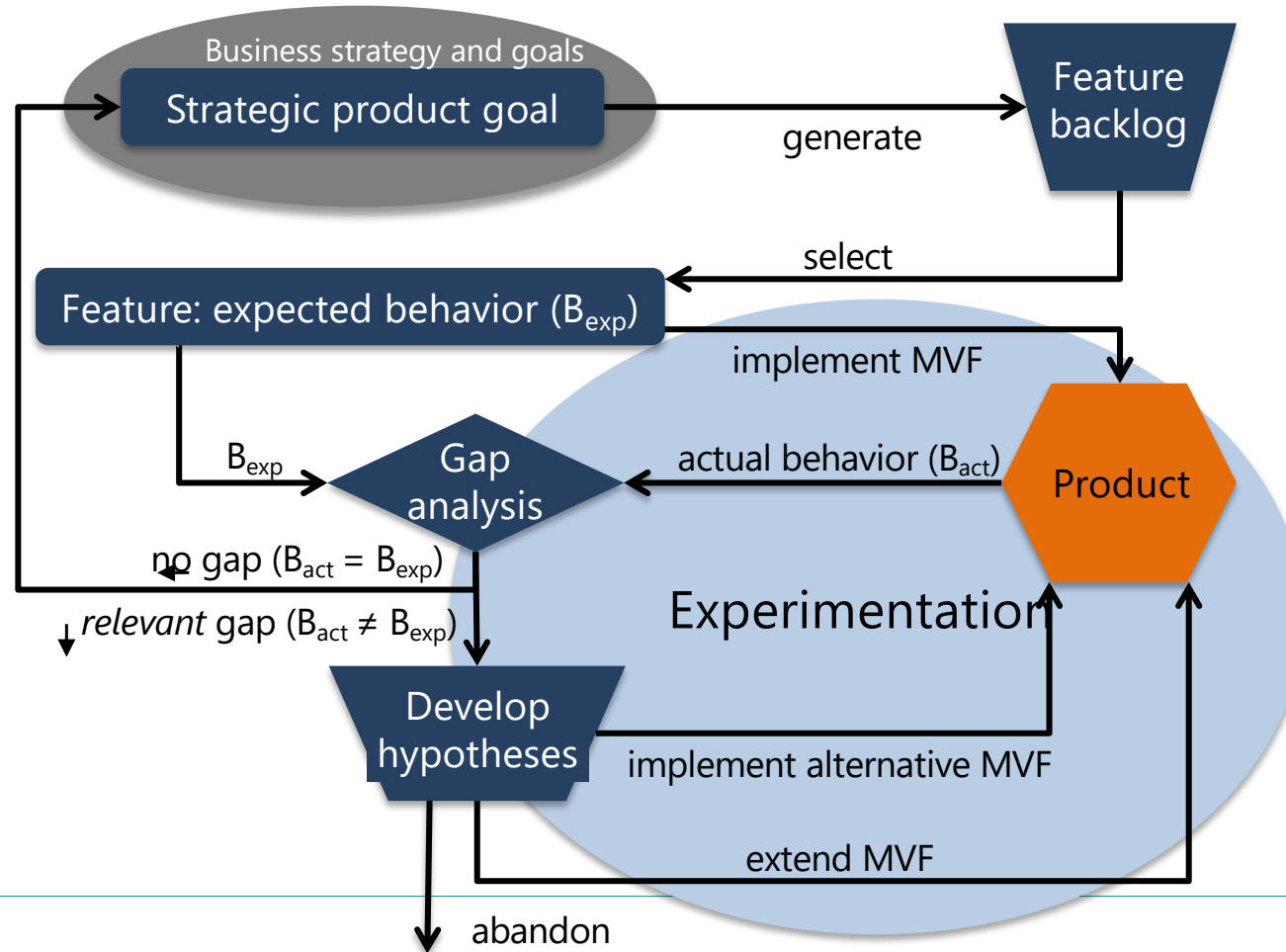


Direction of key value factors



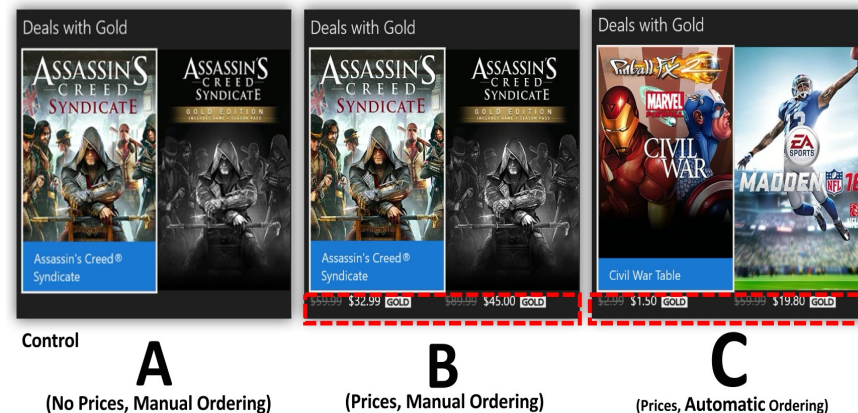
Prioritization of key value factors

The HYPEX Model



A/B testing: “Xbox deals” experiment

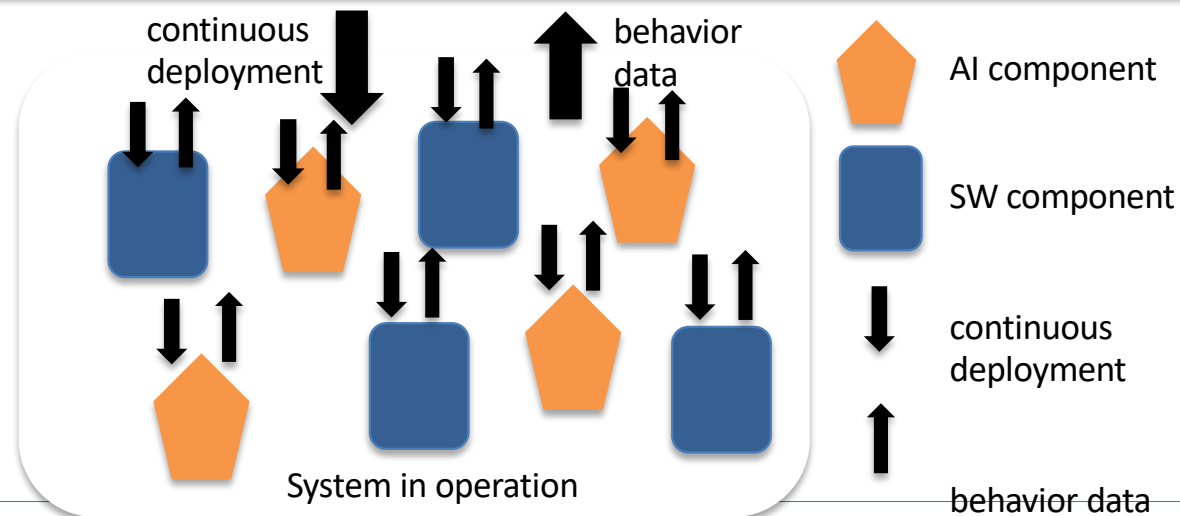
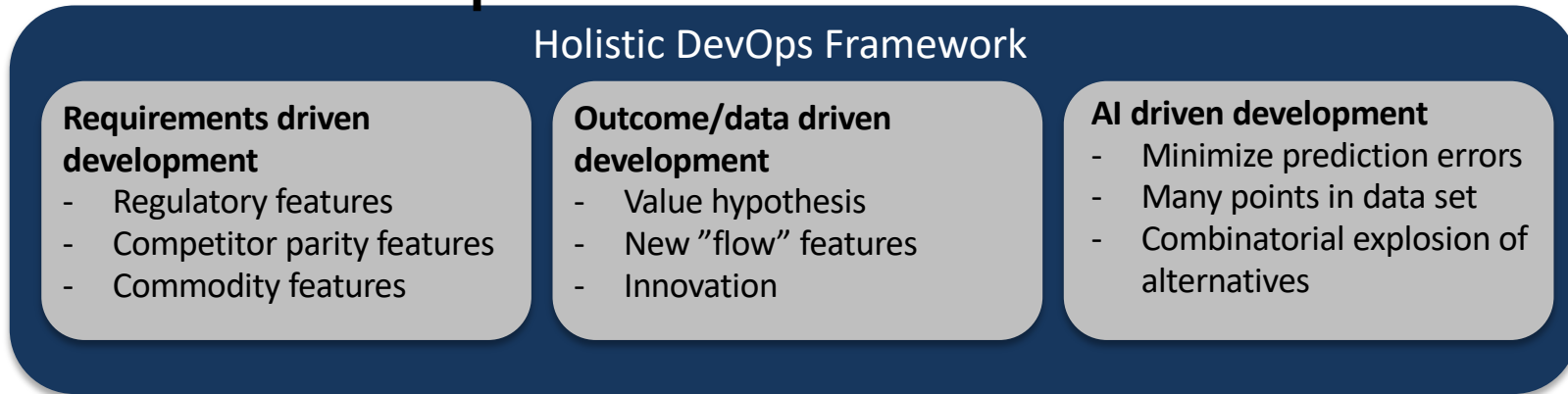
- **Experiment Goal:**
 - Identify the impact of showing the discount in the weekly deals stripe.
- **Value Hypotheses:**
 - (1) increased engagement with the stripe
 - (2) no decrease in purchases.
- **Outcome:**
 - Treatment B **decreased engagement** with the stripe **without** decreasing purchases.
 - Treatment C **increased** both **engagement** with the stripe **and purchases made**.



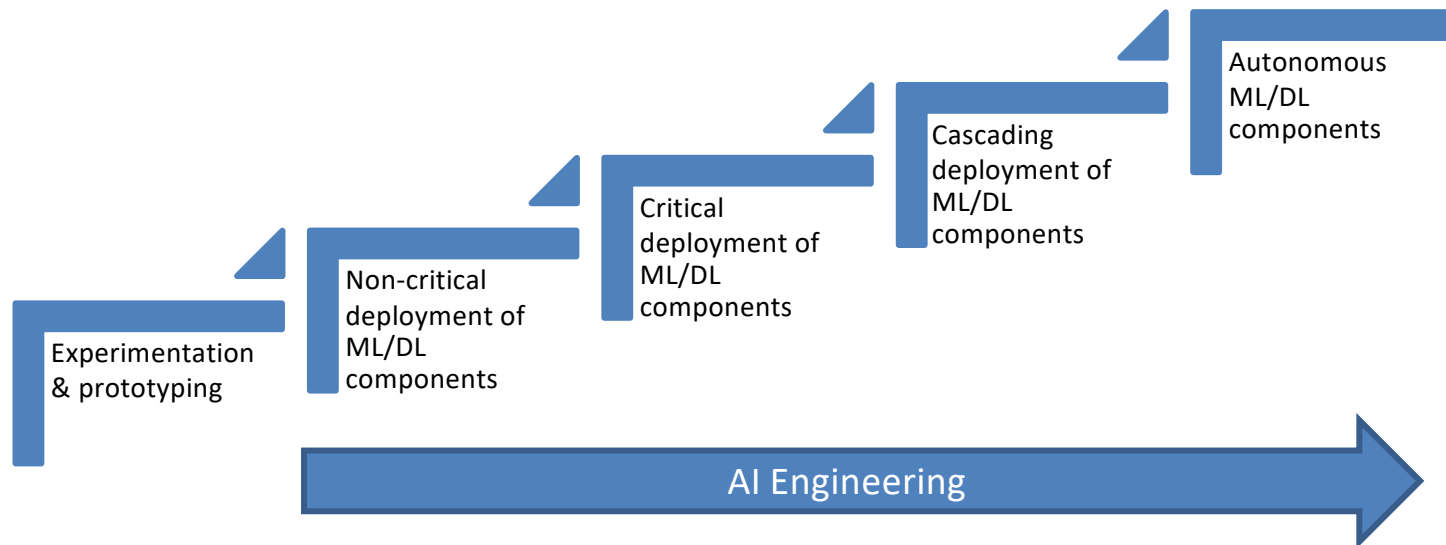
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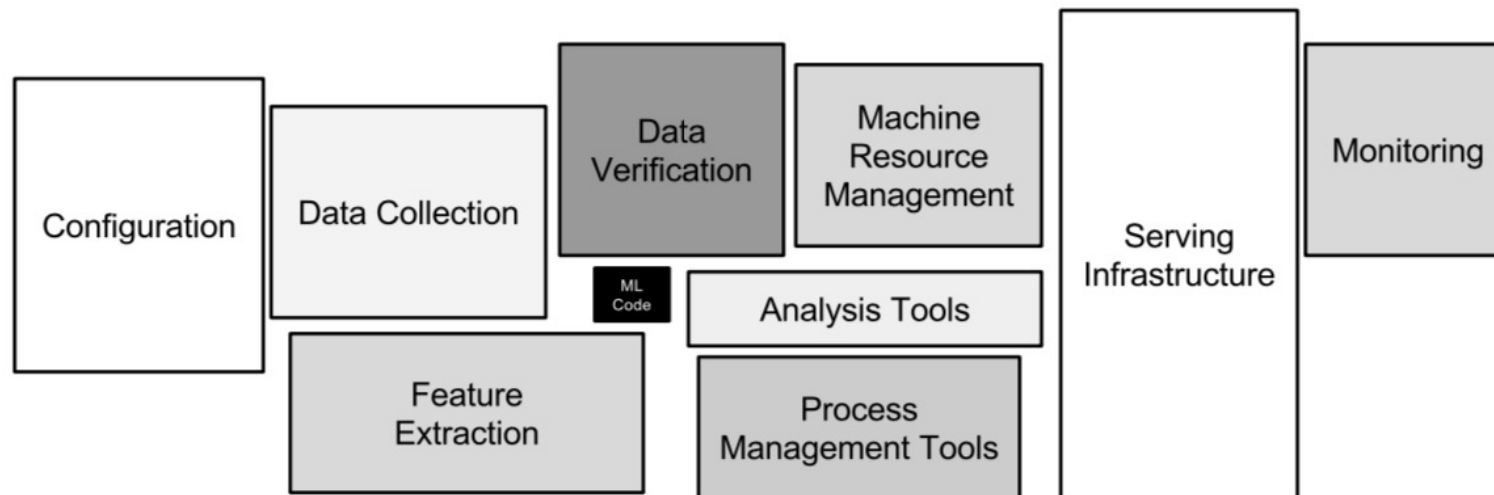
Holistic DevOps Framework



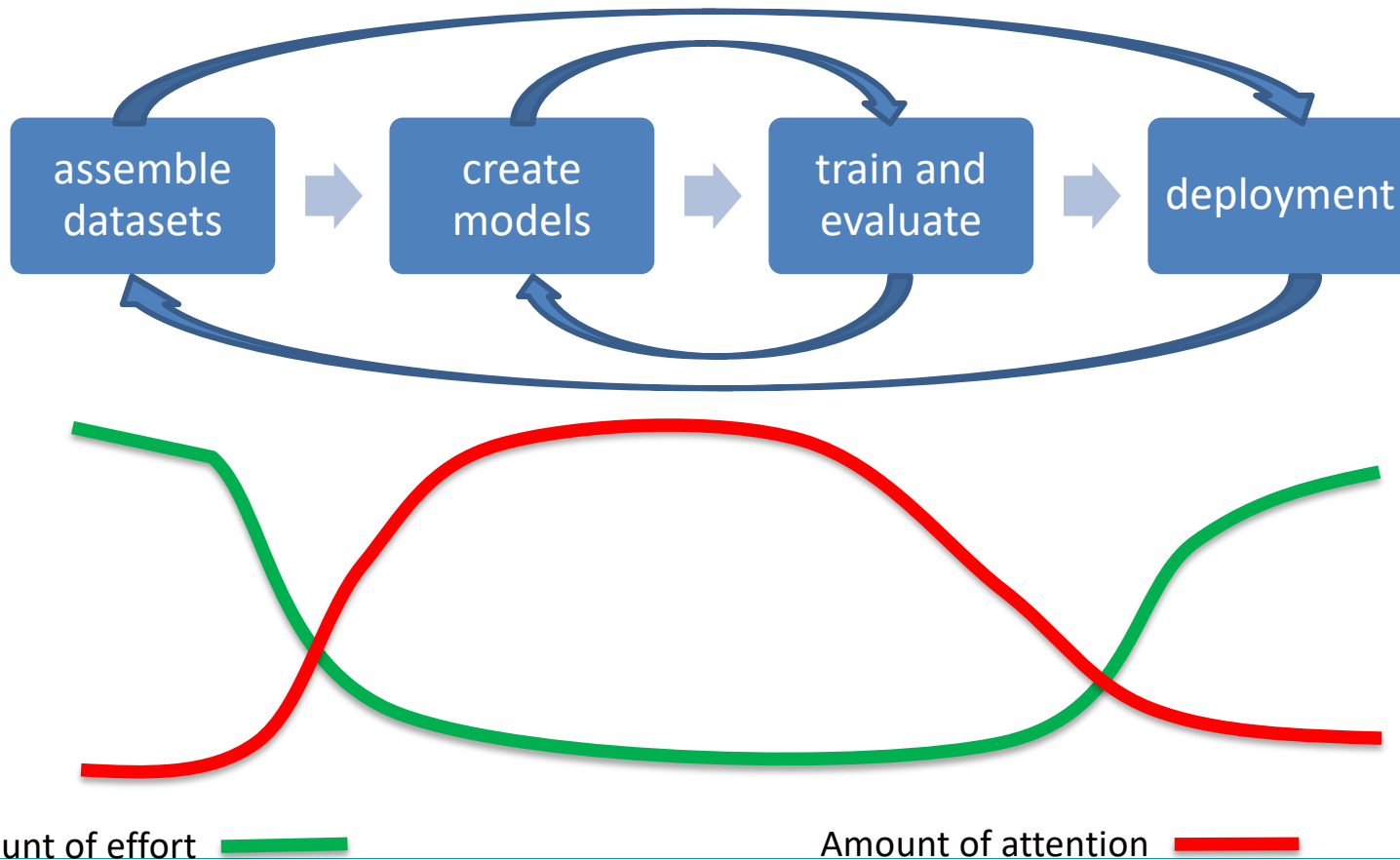
Artificial Intelligence



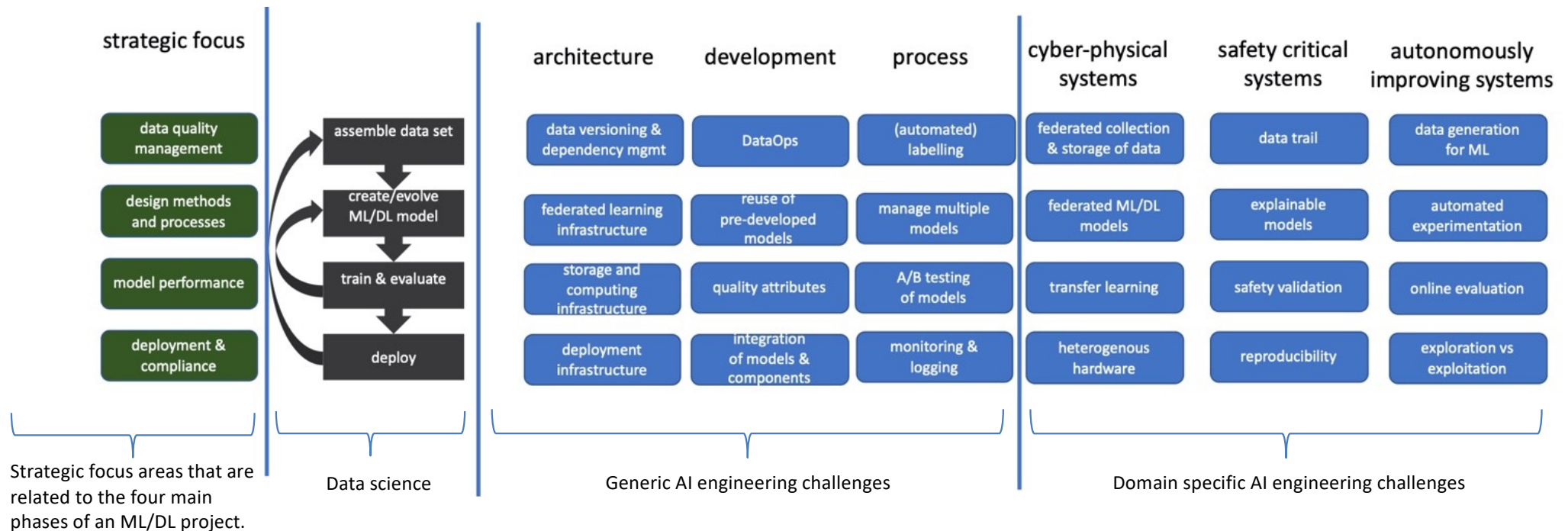
Why Software Engineering For Deep Learning?



Where The Effort Goes ...



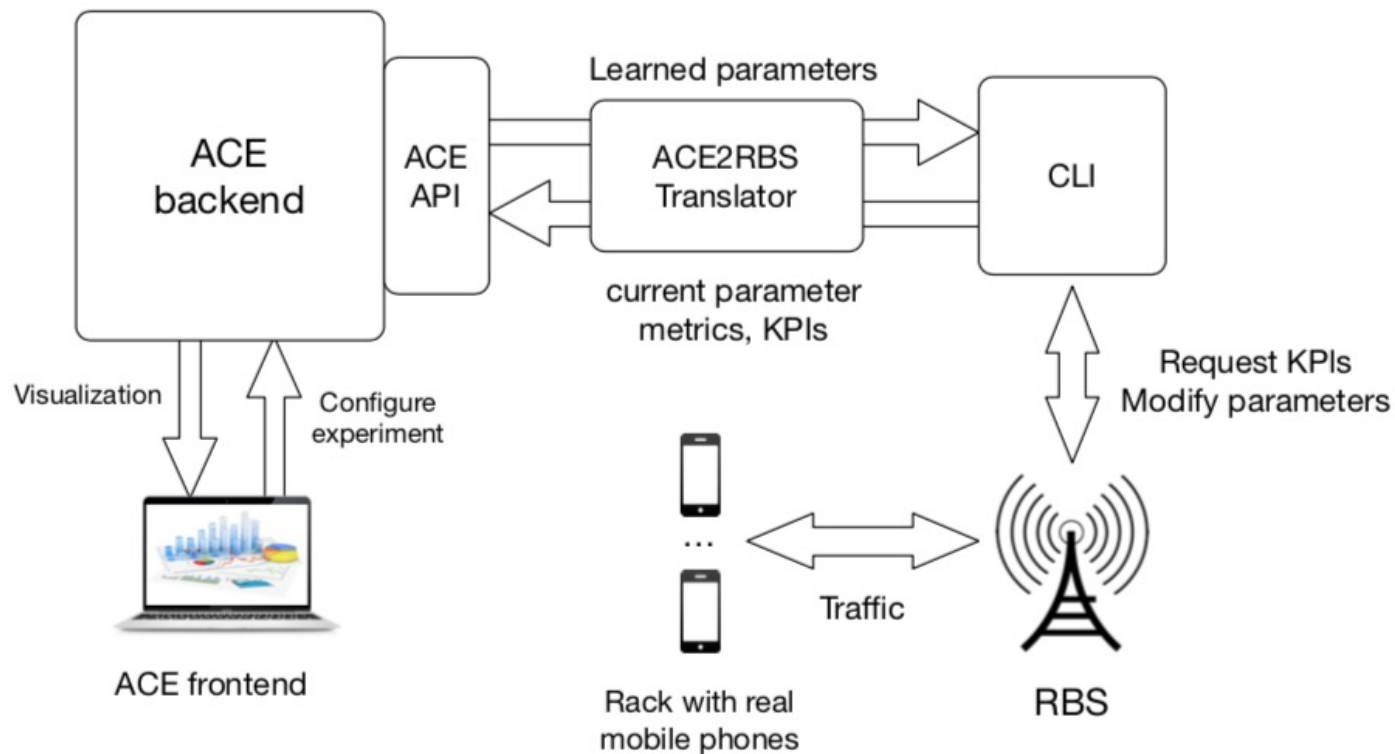
AI engineering: Research agenda*



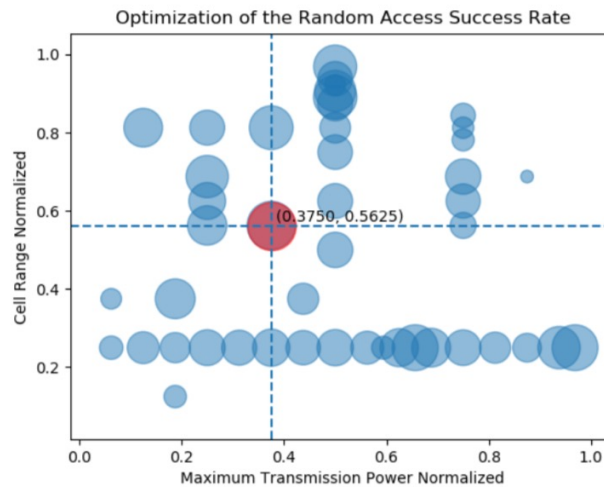
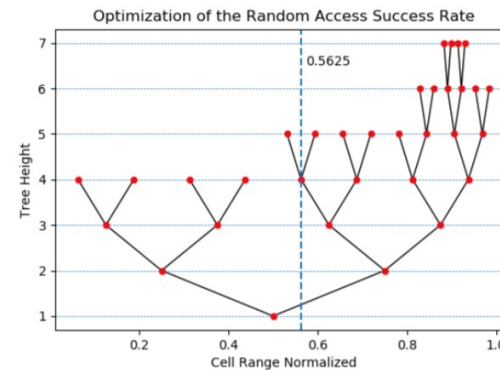
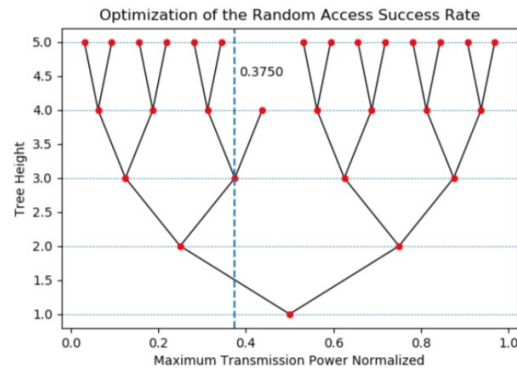
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Automated Experimentation

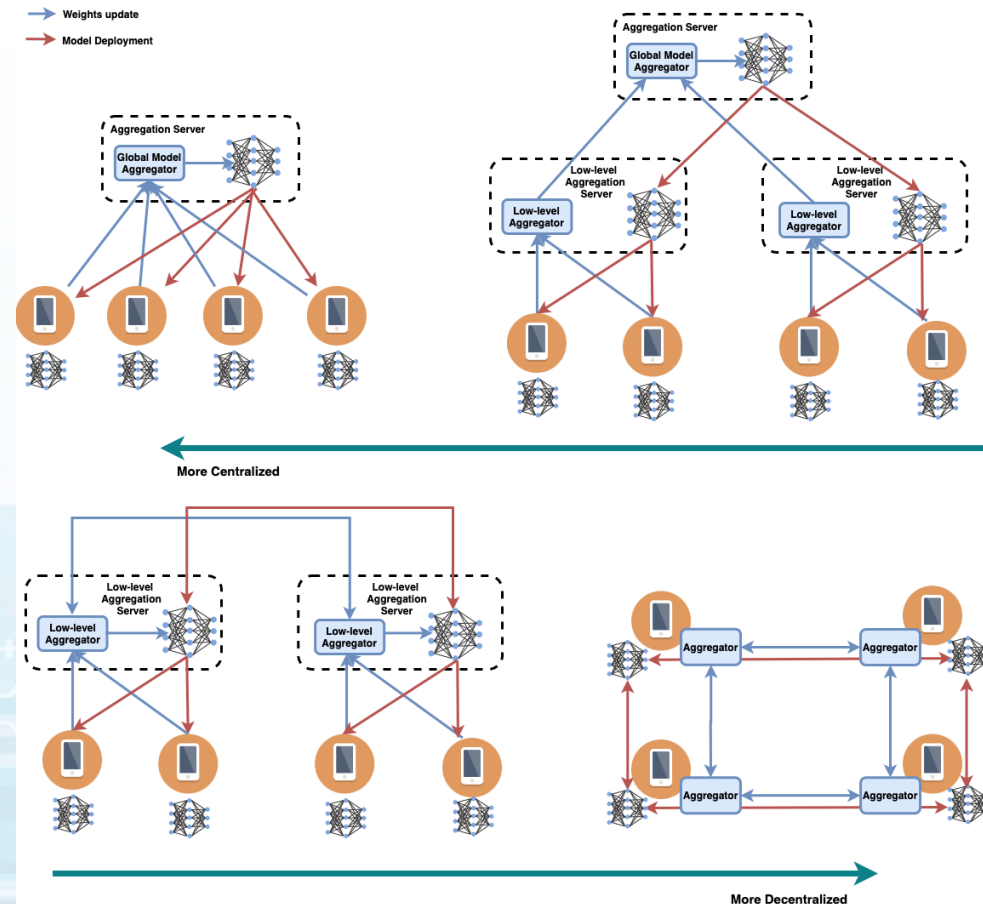


Multi-armed bandit algorithms



Federated Learning: Architectures

- We propose and compare four architecture alternatives for a Federated Learning system, i.e., centralized, hierarchical, regional and decentralized architectures.
- We conducted the study by using two well-known data sets and measuring several system performance metrics for all four alternatives. Our results suggested scenarios and use cases which are suitable for each alternative.



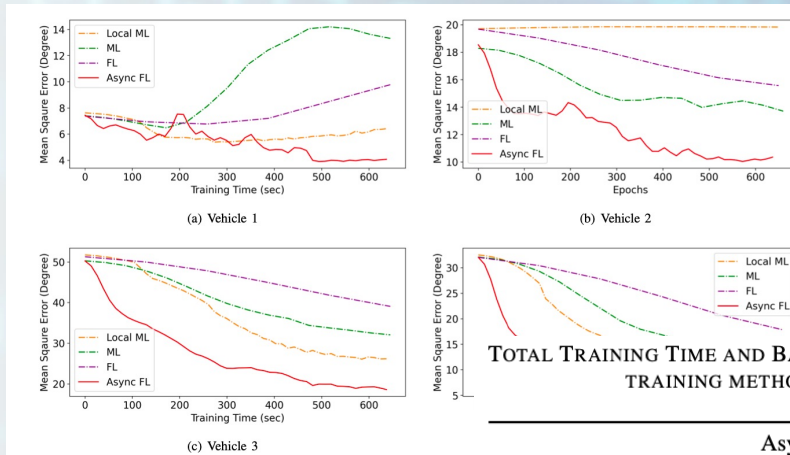
Real-time End-to-End Federated Learning

Async FL aggregation protocol:

During the training procedure, the central node performs aggregation based on the model version and don't need to wait for other nodes to complete local training.

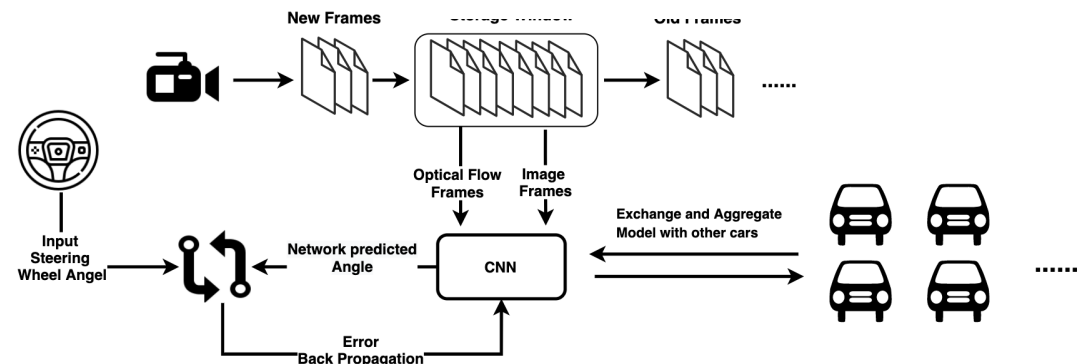
When perform aggregation:

$$w_{t+1} \leftarrow (1 - \alpha) \times w_t + \alpha \times w_{t+1}^k$$



TOTAL TRAINING TIME AND BANDWIDTH COST WITH DIFFERENT MODEL TRAINING METHODS (4 VEHICLES IN TOTAL)

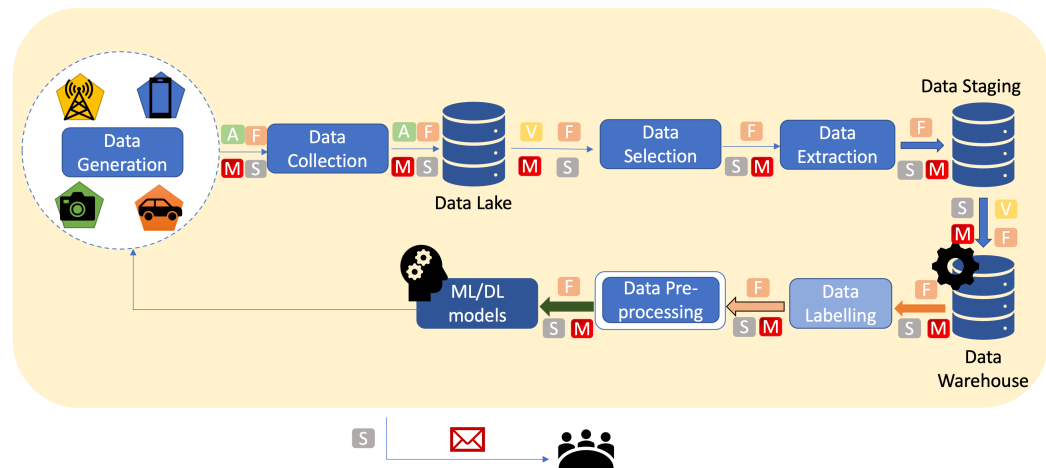
	Async FL	FL	ML	Local ML
Training Time (sec)	669.2	5,982.8	2143.7	5,903.4
Bytes Transferred (GB)	0.78	0.78	2.02	-



Data Pipelines for Machine Learning

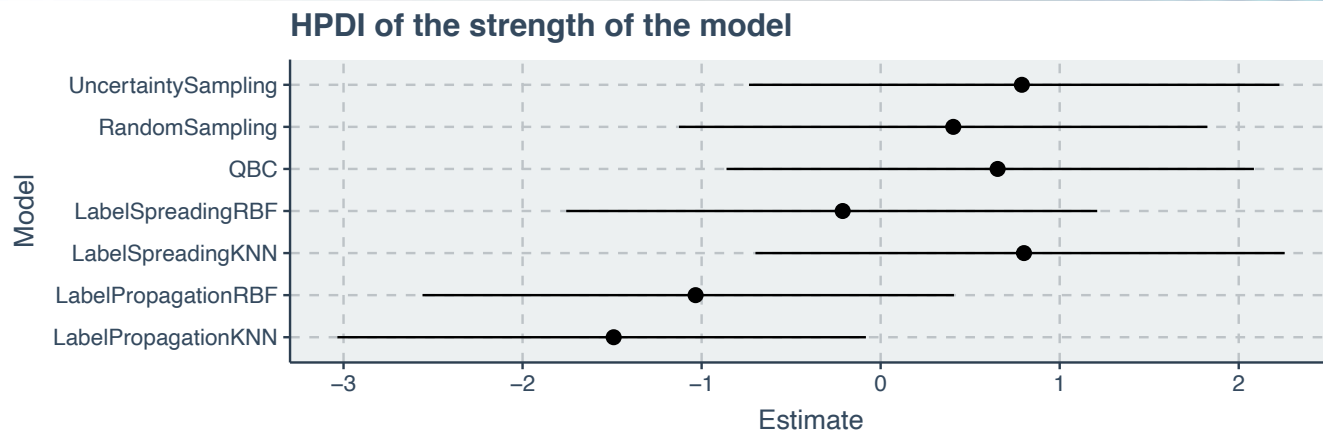
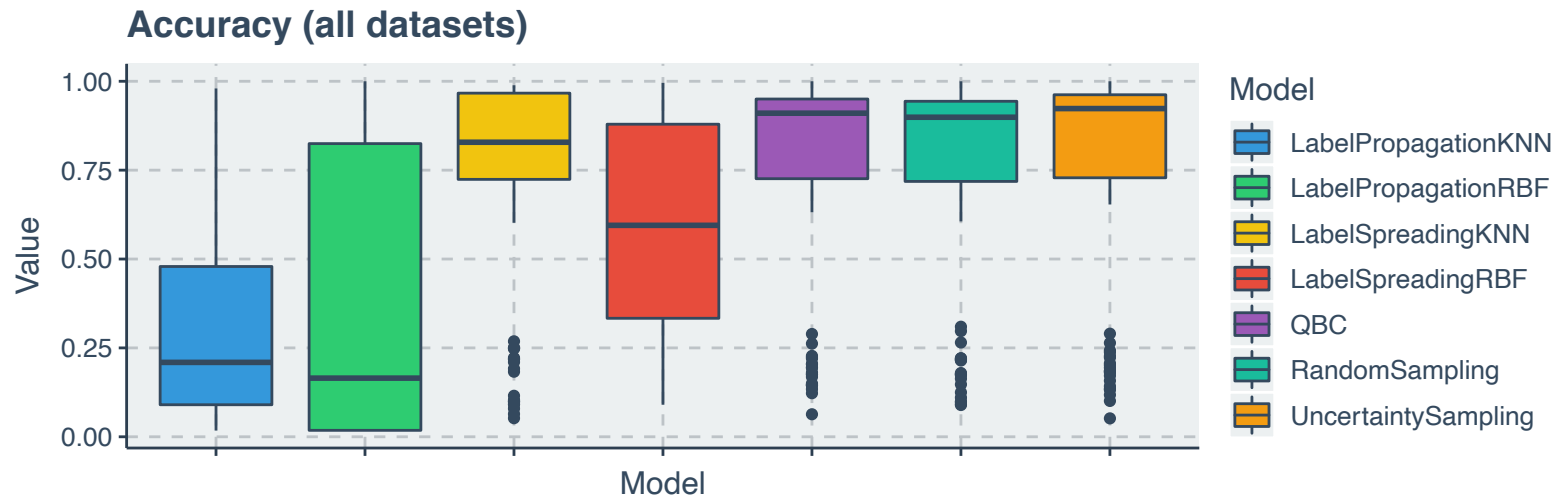
DATA PIPELINE FOR ML

- Efficient flow of data from source to destination with minimum human intervention and maximum automation
- Exploratory Study: Ericsson
- Validation Study: Grundfos, CEVT and Ericsson

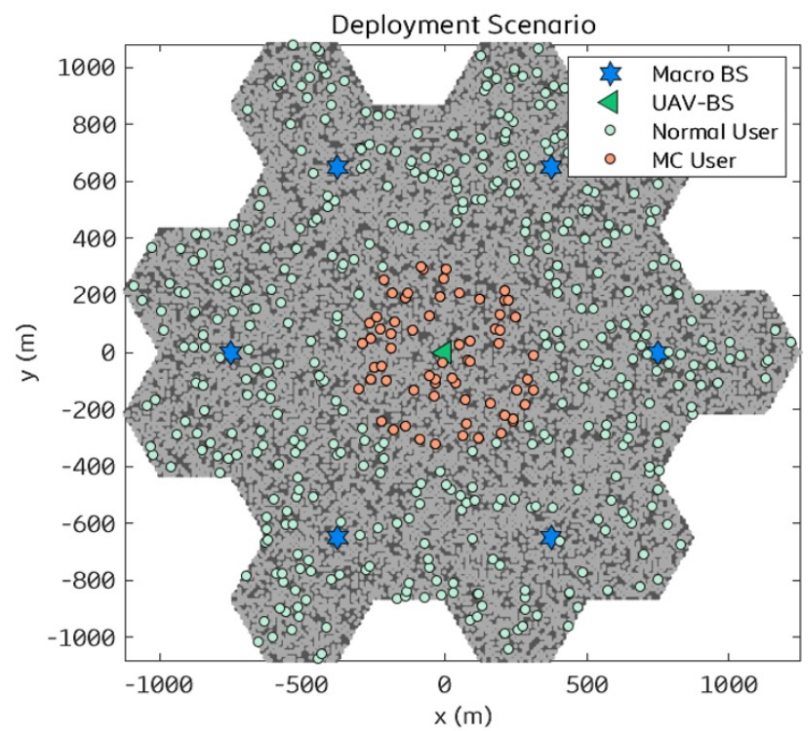
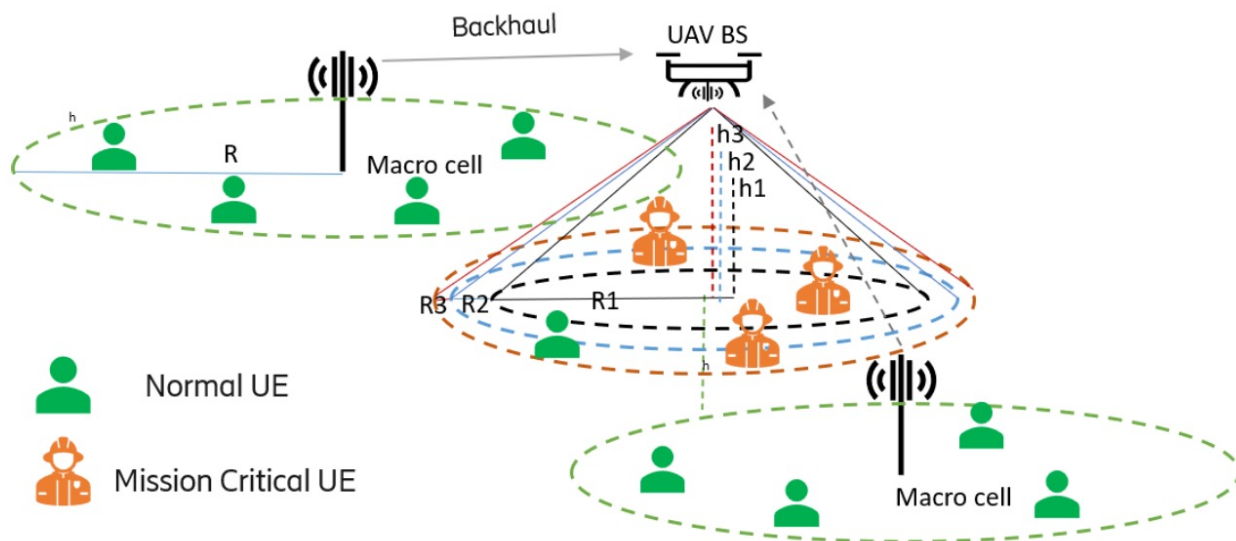


Munappy, R.A., Bosch, J., Olsson, H.H., and Wang, T.J. (2020). Modeling Data Pipelines. *In Proceedings of the Euromicro Conference on Software Engineering and Advanced Applications (SEAA), August 26-28th, Slovenia.*

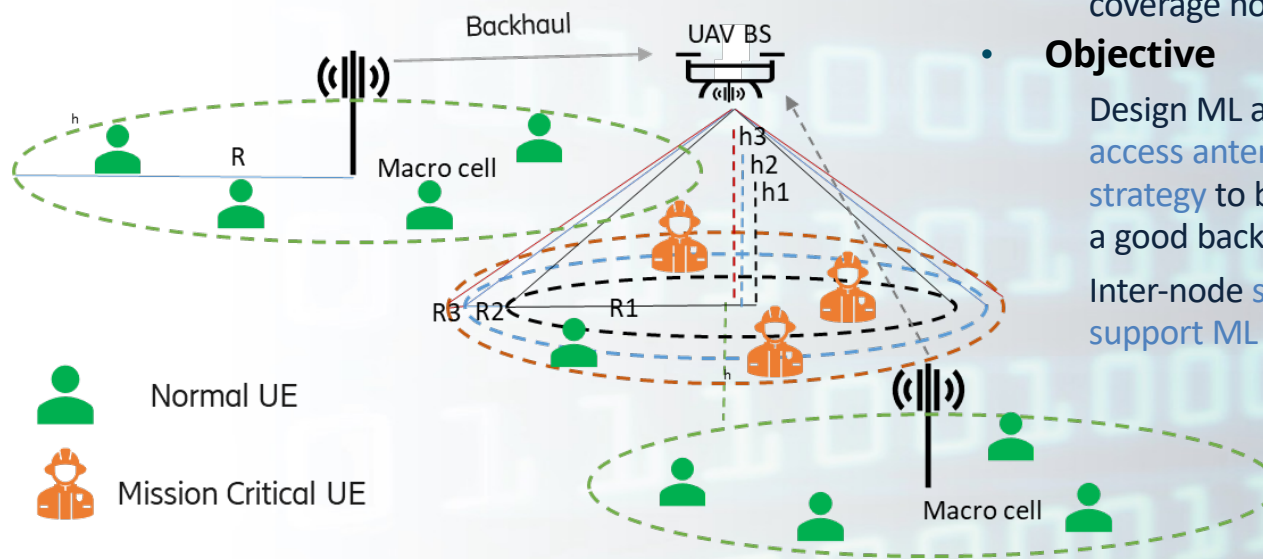
Automatic Labeling



UAV-assisted wireless network deployment



Multiple Deployable UAV-BSs



- **Scenario**

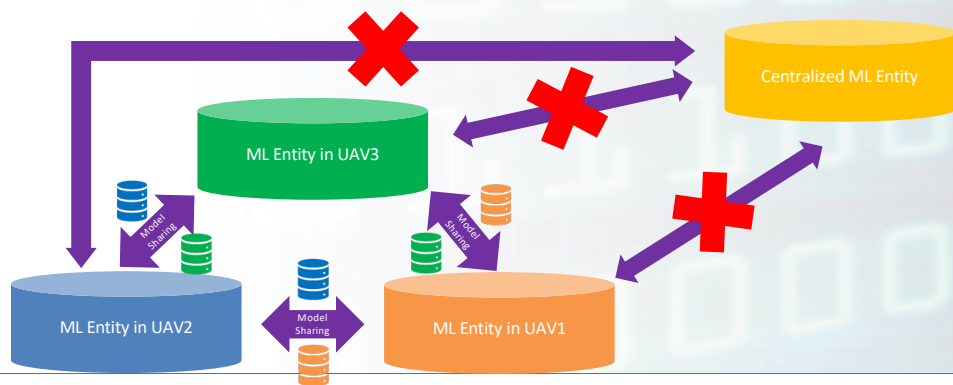
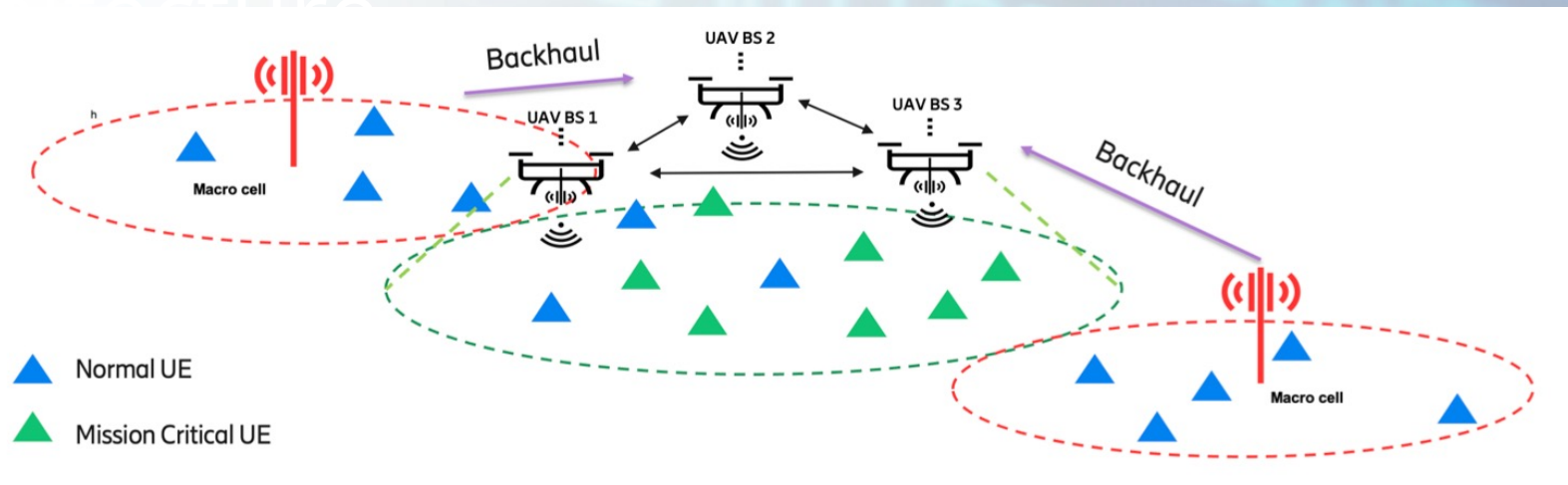
Multiple Deployable UAV-BSs are integrated into a public network using integrated access and backhaul (IAB) to fill coverage holes for mission critical communications

- **Objective**

Design ML algorithm to jointly optimize the backhaul and access antenna configurations and/or UAV-BS movement strategy to best serve on-ground users while maintaining a good backhaul

Inter-node signaling procedure and framework to support ML

Coordinated and Decentralized ML

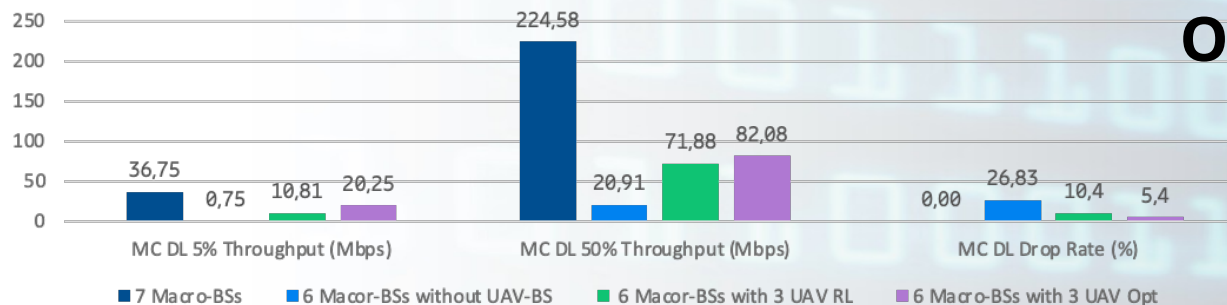


- Local Data at UAV-BS
- 2D location of the UAV-BS
 - Performance metrics of served MC users:
 - 5% throughput (DL&UL)
 - 50% throughput (DL&UL)
 - Drop rate (DL&UL)

- Data for Exchange between UAV-BSs
- 2D location of the UAV-BS
 - Reward value derived from local performance metrics

Performance Comparison (With/Without UAV-BSs)

DL Performance Comparison (With/Without UAV-BSs)

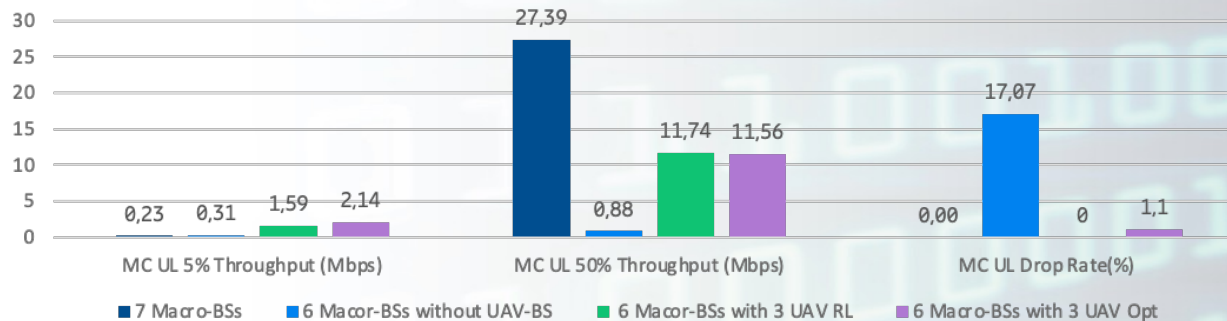


Observations:

Comparing with no-UAV case, deployable UAV-BSs improve the performance of MC users in terms of throughput (5%, 50%) and drop rate in both DL&UL

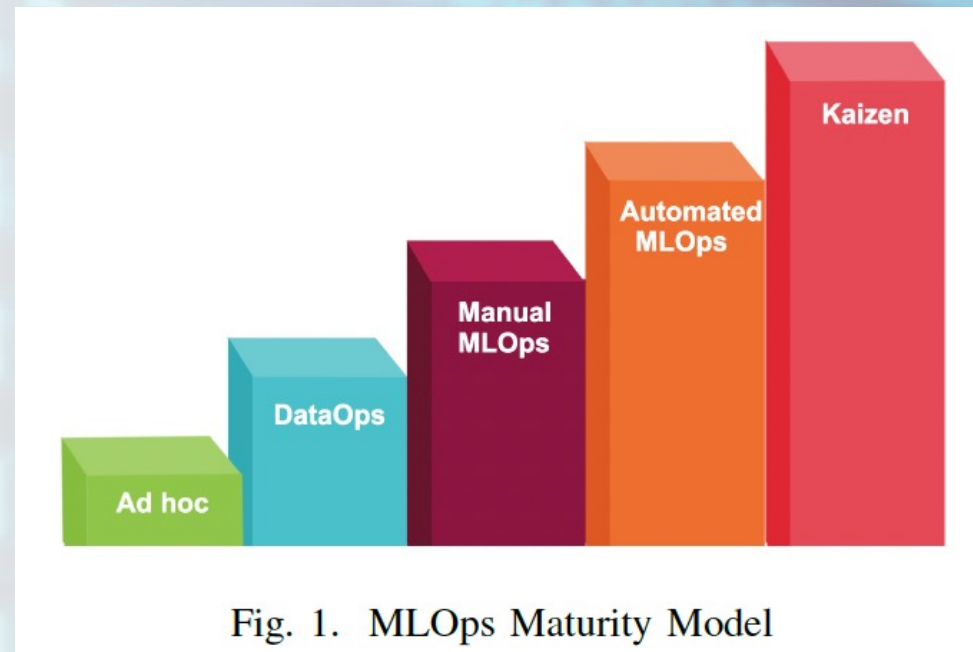
Big gap still exists if comparing with macro-BS case due to capability difference (40 dBm, 10 m height vs 46 dBm, 32m height)

UL Performance Comparison (With/Without UAV-BSs)



MLOps Maturity Model

- **Ad hoc:** A stage in which companies have ad hoc processes for the end-to-end MLOps lifecycle.
- **DataOps:** A stage in which companies have standard and automated processes for end-to-end data lifecycle.
- **Manual MLOps:** A stage in which companies manually standardise the end-to-end MLOps lifecycle.
- **Automated MLOps:** A stage that automates end-to-end MLOps workflow. At this stage, companies have fully automated tasks related to data and models.
- **Kaizen MLOps:** Kaizen is a Japanese term meaning “continuous improvement”. At this stage, companies need continuous improvement in MLOps workflow.




MLOps Framework

	Ad hoc feature store	Standardised and automated feature store	Standardised and automated feature store	Standardised and automated feature store	Continuously improved and optimised feature store
Model	Ad hoc processes for model development	Ad hoc processes for model development	Standardised and manual processes for model development	Standardised and automated processes for model development	Model development is continuously improved through an iterative processes
	Ad hoc code versioning and code review	Basic code versioning and code review	Highly structured and manual code versioning and code review	Highly structured and automated code versioning and code review	Continuously improved and optimised code versioning and review
	Ad hoc model metadata management	Ad hoc model metadata management	Standardised and manual model metadata management	Standardised and automated model metadata management	Continuously improved and optimised model metadata management
	No reproducible experimentation setup	Limited reproducible experimentation setup	Manual reproducible experimentation setup	Automated reproducible experimentation setup	Reproducible experimentation setup is continuously refined and improved
Deployment	Adhoc processes for model deployment	Ad hoc processes for model deployment	Standardised and manual processes for model deployment	Standardised and automated processes for model deployment	Model deployment is continuously improved through an iterative processes
	Infrequent model deployments	Less frequent model deployments	Frequent model deployments	Highly frequent model deployments	Continuous and iterative model deployments
	No/basic CI/CD pipeline	Well-defined CI/CD pipeline	Manual CI/CD pipeline	Highly automated CI/CD pipeline	CI/CD pipeline is continuously improved and optimised
Operations and Infrastructure	Ad hoc processes for model monitoring	Ad hoc processes for model monitoring	Standardised and manual processes for model monitoring	Standardised and automated processes for model monitoring	Model monitoring is continuously improved through an iterative processes
	Ad hoc processes for model retraining	Ad hoc processes for model retraining	Standardised and manual processes for model retraining	Standardised and automated processes for model retraining	Model retraining is continuously improved through an iterative processes
	Infrequent model retraining	Less frequent model retraining	Frequent model retraining	Highly frequent model retraining	Continuous and iterative model retraining
	Limited infrastructure and tooling	Infrastructure and tooling focus on data management and governance	Infrastructure and tooling focus on manual ways to manage ML lifecycle	Infrastructure and tooling focus on automated ways to manage ML lifecycle	Infrastructure and tooling support continuous improvement

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A photograph of George F. Colony, CEO of Forrester Research, speaking at a conference. He is wearing a dark suit, a white shirt, and a blue patterned tie. He has his hands clasped in front of him. The background is a dark blue wall with a blurred logo. A semi-transparent dark blue box is overlaid on the image, containing the quote and attribution.

**“In the future, all companies
will be **Digital** companies”**

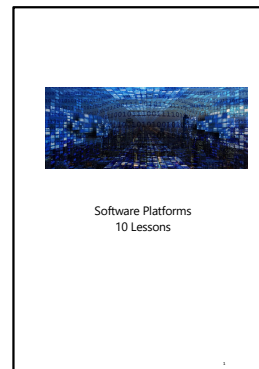
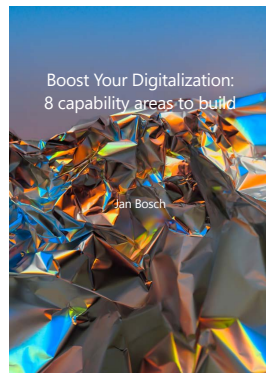
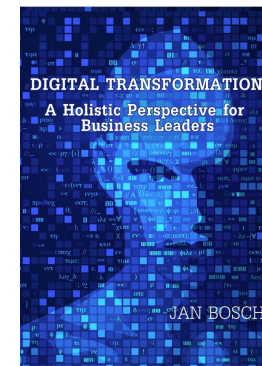
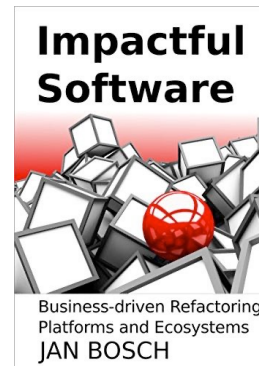
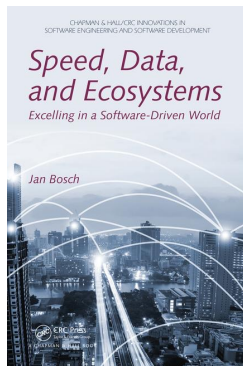
(Software, Data & AI)

George F. Colony (CEO Forrester Research)

Conclusion

- Digitalization is disrupting industry and society to an extent that we have only seen the early beginnings of
- Digital companies need to be world class in:
 - Software (continuous deployment)** to continuously deliver value
 - Data** to increase the quality of decision making
 - Artificial Intelligence** to provide superior solutions to almost everything
- Using AI requires AI Engineering and many companies fail to incorporate this

Learn More?





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